

Mastering PostgreSQL Administration

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POSTGRES SQL is an open-source, full-featured relational database.
This presentation covers advanced administration topics.

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<http://momjian.us/presentations>

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Outline

1. Installation
2. Configuration
3. Maintenance
4. Monitoring
5. Recovery

1. Installation

- ▶ Click-through Installers

- ▶ MS Windows
- ▶ Linux
- ▶ OS X

- ▶ Ports

- ▶ RPM
- ▶ DEB
- ▶ PKG
- ▶ other packages

- ▶ Source

- ▶ obtaining
- ▶ build options
- ▶ installing

Initialization (initdb)

```
$ initdb /u/pgsql/data
```

The files belonging to this database system will be owned by user "postgres".
This user must also own the server process.

The database cluster will be initialized with locale "en_US.UTF-8".
The default database encoding has accordingly been set to "UTF8".
The default text search configuration will be set to "english".

Data page checksums are disabled.

```
fixing permissions on existing directory /u/pgsql/data ... ok
creating subdirectories ... ok
selecting default max_connections ... 100
selecting default shared_buffers ... 128MB
selecting dynamic shared memory implementation ... posix
creating configuration files ... ok
running bootstrap script ... ok
performing post-bootstrap initialization ... ok
syncing data to disk ... ok
```

WARNING: enabling "trust" authentication for local connections
You can change this by editing pg_hba.conf or using the option -A, or
--auth-local and --auth-host, the next time you run initdb.

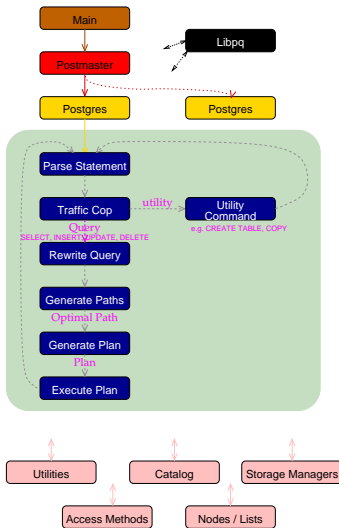
Success. You can now start the database server using:

```
pg_ctl -D /u/pgsql/data -l logfile start
```

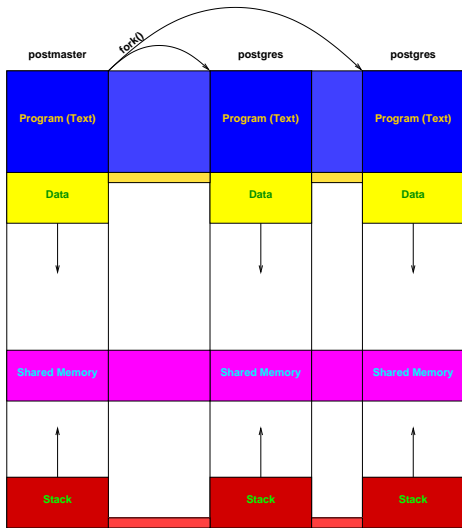
pg_controldata

```
$ pg_controldata
pg_control version number:          1002
Catalog version number:            201707211
Database system identifier:         6544633619067825437
Database cluster state:             shut down
pg_control last modified:           Sun 15 Apr 2018 07:20:58 AM EDT
Latest checkpoint location:         0/15C09E0
Prior checkpoint location:          0/15C0708
Latest checkpoint's REDO location:  0/15C09E0
Latest checkpoint's REDO WAL file:  00000001000000000000000001
Latest checkpoint's TimeLineID:     1
Latest checkpoint's PrevTimeLineID: 1
Latest checkpoint's full_page_writes: on
Latest checkpoint's NextXID:         0:555
Latest checkpoint's NextOID:         12296
Latest checkpoint's NextMultiXactId: 1
Latest checkpoint's NextMultiOffset: 0
Latest checkpoint's oldestXID:       548
Latest checkpoint's oldestXID's DB:  1
Latest checkpoint's oldestActiveXID:  0
Latest checkpoint's oldestMultiXid:  1
Latest checkpoint's oldestMulti's DB: 1
Latest checkpoint's oldestCommitTsXid:0
Latest checkpoint's newestCommitTsXid:0
Time of latest checkpoint:           Sun 15 Apr 2018 07:20:58 AM EDT
Fake LSN counter for unlogged rels:  0/1
Minimum recovery ending location:     0/0
Min recovery ending loc's timeline:    0
Backup start location:                 0/0
Backup end location:                   0/0
End-of-backup record required:         no
wal_level setting:                     replica
wal_log_hints setting:                 off
max_connections setting:               100
```

System Architecture



Session Creation



Starting Postmaster

```
2018-04-15 07:23:18.172 EDT [12055] LOG: listening on IPv4 address "127.0.0.1", port 5432
2018-04-15 07:23:18.173 EDT [12055] LOG: listening on Unix socket "/tmp/.s.PGSQL.5432"
2018-04-15 07:23:18.185 EDT [12056] LOG: database system was shut down at 2018-04-15 07:22:54 EDT
2018-04-15 07:23:18.188 EDT [12055] LOG: database system is ready to accept connections
```

- ▶ manually
- ▶ `pg_ctl start`
- ▶ on boot

Stopping Postmaster

```
2018-04-15 07:23:47.317 EDT [12055] LOG: received fast shutdown request
2018-04-15 07:23:47.318 EDT [12055] LOG: aborting any active transactions
2018-04-15 07:23:47.318 EDT [12055] LOG: worker process: logical replication launcher (PID 12062) exited with
2018-04-15 07:23:47.319 EDT [12057] LOG: shutting down
2018-04-15 07:23:47.327 EDT [12055] LOG: database system is shut down
```

- ▶ manually
- ▶ `pg_ctl stop`
- ▶ on shutdown

Connections

- ▶ local — unix domain socket
- ▶ host — TCP/IP, both SSL or non-SSL
- ▶ hostssl — only SSL
- ▶ hostnossll — never SSL

Authentication

- ▶ trust
- ▶ reject
- ▶ passwords
 - ▶ scram-sha-256
 - ▶ md5
 - ▶ password (cleartext)
- ▶ local authentication
 - ▶ socket permissions
 - ▶ 'peer' socket user name passing
 - ▶ host ident using local identd

Authentication (continued)

- ▶ remote authentication
 - ▶ host ident using pg_ident.conf
 - ▶ kerberos
 - ▶ gss
 - ▶ sspi
 - ▶ pam
 - ▶ ldap
 - ▶ radius
 - ▶ cert

Access

- ▶ hostname and network mask
- ▶ database name
- ▶ role name (user or group)
- ▶ filename or list of databases, role
- ▶ IPv6

pg_hba.conf Default

```
# TYPE DATABASE USER ADDRESS METHOD

# "local" is for Unix domain socket connections only
local all all trust
# IPv4 local connections:
host all all 127.0.0.1/32 trust
# IPv6 local connections:
host all all ::1/128 trust
# Allow replication connections from localhost, by a user with the
# replication privilege.
#local replication postgres trust
#host replication postgres 127.0.0.1/32 trust
#host replication postgres ::1/128 trust
```

pg_hba.conf Example

```
# TYPE DATABASE USER ADDRESS METHOD

# "local" is for Unix domain socket connections only
local all all trust
# IPv4 local connections:
host all all 127.0.0.1/32 trust
# IPv6 local connections:
host all all ::1/128 trust

# disable connections from the gateway machine
host all all 192.168.1.254/32 reject
# enable local network
host all all 192.168.1.0/24 scram-sha-256
# require SSL for external connections, but do not allow the superuser
hostssl all postgres 0.0.0.0/0 reject
hostssl all all 0.0.0.0/0 scram-sha-256
```

Permissions

- ▶ Host connection permissions
- ▶ Role permissions
 - ▶ create roles
 - ▶ create databases
 - ▶ table permissions
- ▶ Database management
 - ▶ template1 customization
 - ▶ system tables
 - ▶ disk space computations

Data Directory

```
$ ls -CF
```

```
base/          pg_ident.conf  pg_serial/     pg_tblspc/     postgresql.auto.conf
global/        pg_logical/    pg_snapshots/  pg_twophase/   postgresql.conf
pg_commit_ts/  pg_multixact/  pg_stat/       PG_VERSION     postmaster.opts
pg_dynshmem/   pg_notify/     pg_stat_tmp/   pg_wal/
pg_hba.conf    pg_replslot/   pg_subtrans/   pg_xact/
```

Database Directories

```
$ ls -CF global/
```

```
1136      1214_fsm 1261_vm  2671  2846    2967    6000_vm
1136_fsm  1214_vm  1262    2672  2846_vm 3592    6001
1136_vm   1232    1262_fsm 2676  2847    3592_vm 6002
1137      1233    1262_vm  2677  2964    3593    pg_control
1213      1260    2396    2694  2964_vm 4060    pg_filenode.map
1213_fsm  1260_fsm 2396_fsm 2695  2965    4060_vm pg_internal.init
1213_vm   1260_vm  2396_vm  2697  2966    4061
1214      1261    2397    2698  2966_vm 6000
```

```
$ ls -CF base/
```

```
1/ 12406/ 12407/ 16384/
```

```
$ ls -CF base/16384
```

```
112      1249_fsm 2606_vm  2652  2699    3081    3598_vm
113      1249_vm  2607    2653  2701    3085    3599
12242    1255    2607_fsm 2654  2702    3118    3600
12242_fsm 1255_fsm 2607_vm  2655  2703    3118_vm 3600_fsm
12242_vm  1255_vm  2608    2656  2704    3119    3600_vm
12244    1259    2608_fsm 2657  2753    3164    3601
12246    1259_fsm 2608_vm  2658  2753_fsm 3256    3601_fsm
```

```
...
```

Transaction/WAL Directories

```
$ ls -CF pg_wal/  
000000010000000000000001 archive_status/
```

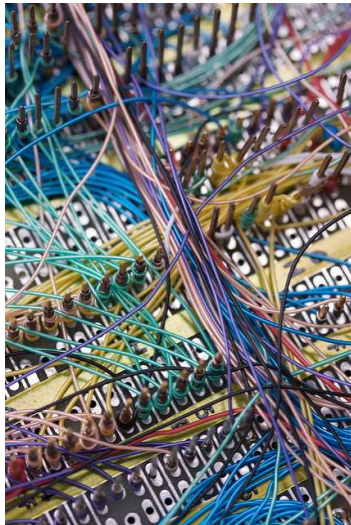
```
$ ls -CF pg_xact/  
0000
```

Configuration Directories

```
$ ls -CF share/
```

```
conversion_create.sql  postgres.bki          snowball_create.sql  
extension/             postgres.description  sql_features.txt  
information_schema.sql postgresql.conf.sample system_views.sql  
pg_hba.conf.sample    postgres.shdescription timezone/  
pg_ident.conf.sample  psqlrc.sample        timezonesets/  
pg_service.conf.sample recovery.conf.sample  tsearch_data/
```

2. Configuration



<https://www.flickr.com/photos/mwichary/>

postgresql.conf

```
# -----  
# PostgreSQL configuration file  
# -----  
#  
# This file consists of lines of the form:  
#  
#   name = value  
#  
# (The "=" is optional.)  Whitespace may be used.  Comments are introduced with  
# "#" anywhere on a line.  The complete list of parameter names and allowed  
# values can be found in the PostgreSQL documentation.  
#  
# The commented-out settings shown in this file represent the default values.  
# Re-commenting a setting is NOT sufficient to revert it to the default value;  
# you need to reload the server.
```

postgresql.conf (Continued)

```
# This file is read on server startup and when the server receives a SIGHUP
# signal.  If you edit the file on a running system, you have to SIGHUP the
# server for the changes to take effect, run "pg_ctl reload", or execute
# "SELECT pg_reload_conf()".  Some parameters, which are marked below,
# require a server shutdown and restart to take effect.
#
# Any parameter can also be given as a command-line option to the server, e.g.,
# "postgres -c log_connections=on".  Some parameters can be changed at run time
# with the "SET" SQL command.
#
# Memory units:  kB = kilobytes           Time units:  ms = milliseconds
#                MB = megabytes           s           = seconds
#                GB = gigabytes           min          = minutes
#                TB = terabytes           h           = hours
#                                           d           = days
```

Configuration File Location

```
# The default values of these variables are driven from the -D command-line  
# option or PGDATA environment variable, represented here as ConfigDir.
```

```
#data_directory = 'ConfigDir'           # use data in another directory  
                                           # (change requires restart)  
#hba_file = 'ConfigDir/pg_hba.conf'     # host-based authentication file  
                                           # (change requires restart)  
#ident_file = 'ConfigDir/pg_ident.conf' # ident configuration file  
                                           # (change requires restart)
```

```
# If external_pid_file is not explicitly set, no extra PID file is written.  
#external_pid_file = ''                 # write an extra PID file  
                                           # (change requires restart)
```


Connections and Authentication

```
#listen_addresses = 'localhost'          # what IP address(es) to listen on;
#port = 5432                               # comma-separated list of addresses;
max_connections = 100                       # defaults to 'localhost'; use '*' for all
#superuser_reserved_connections = 3        # (change requires restart)
#unix_socket_directories = '/tmp'          # (change requires restart)
#unix_socket_group = ''                   # (change requires restart)
#unix_socket_permissions = 0777           # (change requires restart)
#begin with 0 to use octal notation
#bonjour = off                             # advertise server via Bonjour
# (change requires restart)
#bonjour_name = ''                        # defaults to the computer name
# (change requires restart)
```

Security and Authentication

```
#authentication_timeout = 1min          # 1s-600s
#ssl = off
#ssl_ciphers = 'HIGH:MEDIUM:+3DES:!aNULL' # allowed SSL ciphers
#ssl_prefer_server_ciphers = on
#ssl_ecdh_curve = 'prime256v1'
#ssl_dh_params_file = ''
#ssl_cert_file = 'server.crt'
#ssl_key_file = 'server.key'
#ssl_ca_file = ''
#ssl_crl_file = ''
#password_encryption = md5              # md5 or scram-sha-256
#db_user_namespace = off
#row_security = on

# GSSAPI using Kerberos
#krb_server_keyfile = ''
#krb_caseins_users = off
```

TCP/IP Control

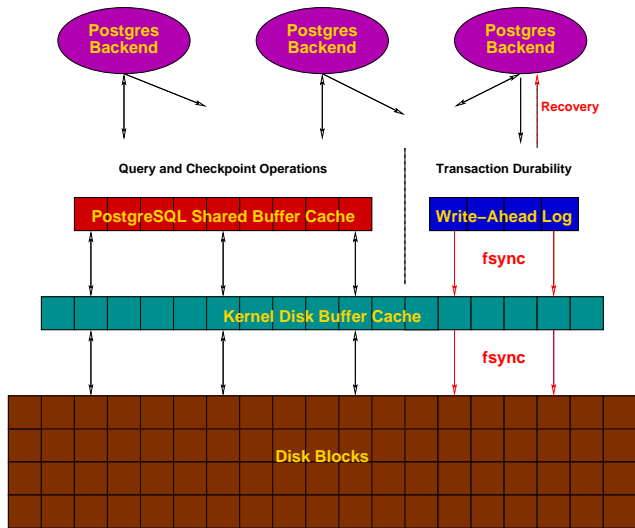
```
#tcp_keepalives_idle = 0
#tcp_keepalives_interval = 0
#tcp_keepalives_count = 0

# TCP_KEEPIDLE, in seconds;
# 0 selects the system default
# TCP_KEEPINTVL, in seconds;
# 0 selects the system default
# TCP_KEEPCNT;
```

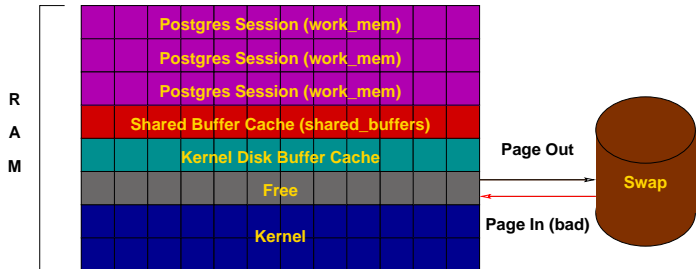
Memory Usage

```
shared_buffers = 128MB          # min 128kB
                                # (change requires restart)
#huge_pages = try               # on, off, or try
                                # (change requires restart)
#temp_buffers = 8MB            # min 800kB
#max_prepared_transactions = 0 # zero disables the feature
                                # (change requires restart)
# Caution: it is not advisable to set max_prepared_transactions nonzero unless
# you actively intend to use prepared transactions.
#work_mem = 4MB                 # min 64kB
#maintenance_work_mem = 64MB   # min 1MB
#replacement_sort_tuples = 150000 # limits use of replacement selection sort
#autovacuum_work_mem = -1      # min 1MB, or -1 to use maintenance_work_mem
#max_stack_depth = 2MB         # min 100kB
dynamic_shared_memory_type = posix # the default is the first option
                                # supported by the operating system:
                                #   posix
                                #   sysv
                                #   windows
                                #   mmap
                                # use none to disable dynamic shared memory
                                # (change requires restart)
```

Memory Usage (Continued)



Sizing Shared Memory



Disk and Kernel Resources

- Disk -

```
#temp_file_limit = -1                # limits per-process temp file space  
# in kB, or -1 for no limit
```

- Kernel Resource Usage -

```
#max_files_per_process = 1000        # min 25  
# (change requires restart)  
#shared_preload_libraries = ''      # (change requires restart)
```

Vacuum and Background Writer

- Cost-Based Vacuum Delay -

#vacuum_cost_delay = 0	# 0-100 milliseconds
#vacuum_cost_page_hit = 1	# 0-10000 credits
#vacuum_cost_page_miss = 10	# 0-10000 credits
#vacuum_cost_page_dirty = 20	# 0-10000 credits
#vacuum_cost_limit = 200	# 1-10000 credits

- Background Writer -

#bgwriter_delay = 200ms	# 10-10000ms between rounds
#bgwriter_lru_maxpages = 100	# 0-1000 max buffers written/round
#bgwriter_lru_multiplier = 2.0	# 0-10.0 multiplier on buffers scanned/round
#bgwriter_flush_after = 512kB	# measured in pages, 0 disables

- Asynchronous Behavior -

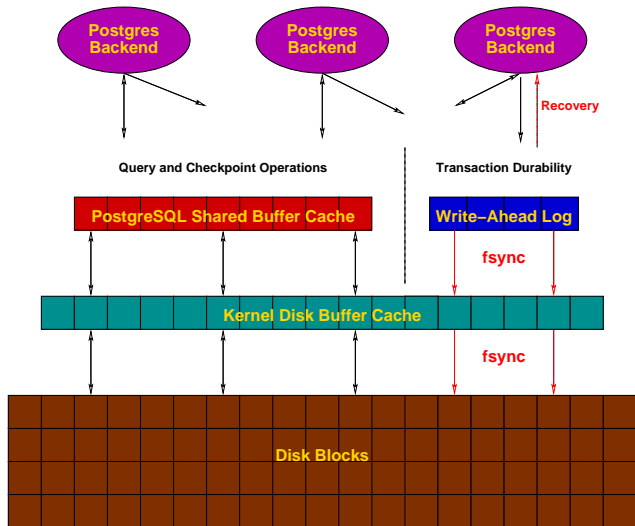
#effective_io_concurrency = 1	# 1-1000; 0 disables prefetching
#max_worker_processes = 8	# (change requires restart)
#max_parallel_workers_per_gather = 2	# taken from max_parallel_workers
#max_parallel_workers = 8	# maximum number of max_worker_processes that
	# can be used in parallel queries
#old_snapshot_threshold = -1	# 1min-60d; -1 disables; 0 is immediate

Write-Ahead Log (WAL)

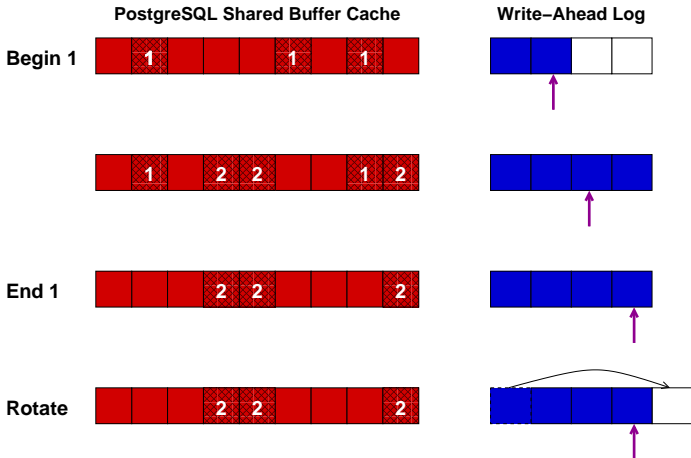
```
#wal_level = replica                # minimal, replica, or logical
                                     # (change requires restart)
#fsync = on                          # flush data to disk for crash safety
                                     # (turning this off can cause
                                     # unrecoverable data corruption)
#synchronous_commit = on            # synchronization level;
                                     # off, local, remote_write, remote_apply, c
#wal_sync_method = fsync             # the default is the first option
                                     # supported by the operating system:
                                     #   open_datasync
                                     #   fdatasync (default on Linux)
                                     #   fsync
                                     #   fsync_writethrough
                                     #   open_sync
#full_page_writes = on              # recover from partial page writes
#wal_compression = off              # enable compression of full-page writes
#wal_log_hints = off                # also do full page writes of non-critical
                                     # (change requires restart)
#wal_buffers = -1                   # min 32kB, -1 sets based on shared_buffers
                                     # (change requires restart)
#wal_writer_delay = 200ms           # 1-10000 milliseconds
#wal_writer_flush_after = 1MB       # measured in pages, 0 disables

#commit_delay = 0                   # range 0-100000, in microseconds
#commit_siblings = 5                # range 1-1000
```

Write-Ahead Logging (Continued)



Write-Ahead Logging (Continued)



Sending Server

Set these on the master and on any standby that will send replication data.

```
#max_wal_senders = 10          # max number of walsender processes
                                # (change requires restart)
#wal_keep_segments = 0        # in logfile segments, 16MB each; 0 disables
#wal_sender_timeout = 60s     # in milliseconds; 0 disables

#max_replication_slots = 10   # max number of replication slots
                                # (change requires restart)
#track_commit_timestamp = off # collect timestamp of transaction commit
                                # (change requires restart)
```

Primary Replication Server

```
# These settings are ignored on a standby server.
```

```
#synchronous_standby_names = '' # standby servers that provide sync rep  
                                # method to choose sync standbys, number of sync st  
                                # and comma-separated list of application_name  
                                # from standby(s); '*' = all  
#vacuum_defer_cleanup_age = 0  # number of xacts by which cleanup is delayed
```

Standby Replication Server

These settings are ignored on a master server.

```
#hot_standby = on                # "off" disallows queries during recovery
                                  # (change requires restart)
#max_standby_archive_delay = 30s  # max delay before canceling queries
                                  # when reading WAL from archive;
                                  # -1 allows indefinite delay
#max_standby_streaming_delay = 30s # max delay before canceling queries
                                  # when reading streaming WAL;
                                  # -1 allows indefinite delay
#wal_receiver_status_interval = 10s # send replies at least this often
                                  # 0 disables
#hot_standby_feedback = off       # send info from standby to prevent
                                  # query conflicts
#wal_receiver_timeout = 60s      # time that receiver waits for
                                  # communication from master
                                  # in milliseconds; 0 disables
#wal_retrieve_retry_interval = 5s # time to wait before retrying to
                                  # retrieve WAL after a failed attempt
```

Subscriber Server

```
# These settings are ignored on a publisher.
```

```
#max_logical_replication_workers = 4    # taken from max_worker_processes  
                                         # (change requires restart)
```

```
#max_sync_workers_per_subscription = 2  # taken from max_logical_replication_workers
```


Planner Method Tuning

```
#enable_bitmapscan = on  
#enable_hashagg = on  
#enable_hashjoin = on  
#enable_indexscan = on  
#enable_indexonlyscan = on  
#enable_material = on  
#enable_mergejoin = on  
#enable_nestloop = on  
#enable_seqscan = on  
#enable_sort = on  
#enable_tidscan = on
```

Planner Constants

```
#seq_page_cost = 1.0           # measured on an arbitrary scale
#random_page_cost = 4.0        # same scale as above
#cpu_tuple_cost = 0.01         # same scale as above
#cpu_index_tuple_cost = 0.005  # same scale as above
#cpu_operator_cost = 0.0025    # same scale as above
#parallel_tuple_cost = 0.1     # same scale as above
#parallel_setup_cost = 1000.0  # same scale as above
#min_parallel_table_scan_size = 8MB
#min_parallel_index_scan_size = 512kB
#effective_cache_size = 4GB
```

Planner GEQO

```
#geqo = on
#geqo_threshold = 12
#geqo_effort = 5
#geqo_pool_size = 0
#geqo_generations = 0
#geqo_selection_bias = 2.0
#geqo_seed = 0.0

# range 1-10
# selects default based on effort
# selects default based on effort
# range 1.5-2.0
# range 0.0-1.0
```

Miscellaneous Planner Options

```
#default_statistics_target = 100           # range 1-10000
#constraint_exclusion = partition           # on, off, or partition
#cursor_tuple_fraction = 0.1             # range 0.0-1.0
#from_collapse_limit = 8
#join_collapse_limit = 8                 # 1 disables collapsing of explicit
                                           # JOIN clauses
#force_parallel_mode = off
```

Where To Log

```
#log_destination = 'stderr'                                # Valid values are combinations of
                                                           # stderr, csvlog, syslog, and eventlog,
                                                           # depending on platform.  csvlog
                                                           # requires logging_collector to be on.

# This is used when logging to stderr:
#logging_collector = off                                    # Enable capturing of stderr and csvlog
                                                           # into log files. Required to be on for
                                                           # csvlogs.
                                                           # (change requires restart)

# These are only used if logging_collector is on:
#log_directory = 'log'                                     # directory where log files are written,
                                                           # can be absolute or relative to PGDATA
#log_filename = 'postgresql-%Y-%m-%d_%H%M%S.log'         # log file name pattern,
                                                           # can include strftime() escapes
#log_file_mode = 0600                                     # creation mode for log files,
                                                           # begin with 0 to use octal notation
```

Where To Log (rotation)

```
#log_truncate_on_rotation = off
```

```
#log_rotation_age = 1d
```

```
#log_rotation_size = 10MB
```

```
# If on, an existing log file with the  
# same name as the new log file will be  
# truncated rather than appended to.  
# But such truncation only occurs on  
# time-driven rotation, not on restarts  
# or size-driven rotation. Default is  
# off, meaning append to existing files  
# in all cases.
```

```
# Automatic rotation of logfiles will  
# happen after that time. 0 disables.  
# Automatic rotation of logfiles will  
# happen after that much log output.  
# 0 disables.
```

Where to Log (syslog)

```
#syslog_facility = 'LOCAL0'  
#syslog_ident = 'postgres'  
#syslog_sequence_numbers = on  
#syslog_split_messages = on
```

```
# This is only relevant when logging to eventlog (win32):  
# (change requires restart)  
#event_source = 'PostgreSQL'
```

When to Log

```
#client_min_messages = notice
```

```
# values in order of decreasing detail:  
#   debug5  
#   debug4  
#   debug3  
#   debug2  
#   debug1  
#   log  
#   notice  
#   warning  
#   error
```

```
#log_min_messages = warning
```

```
# values in order of decreasing detail:  
#   debug5  
#   debug4  
#   debug3  
#   debug2  
#   debug1  
#   info  
#   notice  
#   warning  
#   error  
#   log  
#   fatal  
#   panic
```


When to Log (Continued)

```
#log_min_error_statement = error
```

```
# values in order of decreasing detail:  
#  debug5  
#  debug4  
#  debug3  
#  debug2  
#  debug1  
#  info  
#  notice  
#  warning  
#  error  
#  log  
#  fatal  
#  panic (effectively off)
```

```
#log_min_duration_statement = -1
```

```
# -1 is disabled, 0 logs all statements  
# and their durations, > 0 logs only  
# statements running at least this number  
# of milliseconds
```

What to Log

```
#debug_print_parse = off
#debug_print_rewritten = off
#debug_print_plan = off
#debug_pretty_print = on
#log_checkpoints = off
#log_connections = off
#log_disconnections = off
#log_duration = off
#log_error_verbosity = default      # terse, default, or verbose messages
#log_hostname = off
```

What To Log: Log_line_prefix

```
#log_line_prefix = '%m [%p] '
```

```
# special values:  
# %a = application name  
# %u = user name  
# %d = database name  
# %r = remote host and port  
# %h = remote host  
# %p = process ID  
# %t = timestamp without milliseconds  
# %m = timestamp with milliseconds  
# %n = timestamp with milliseconds (as a  
# %i = command tag  
# %e = SQL state  
# %C = session ID  
# %l = session line number  
# %s = session start timestamp  
# %v = virtual transaction ID  
# %X = transaction ID (0 if none)  
# %q = stop here in non-session  
# processes  
# %% = '%'  
# e.g., '<%u%%d> '
```

What to Log (Continued)

```
#log_lock_waits = off
#log_statement = 'none'
#log_replication_commands = off
#log_temp_files = -1

log_timezone = 'US/Eastern'

# - Process Title -

#cluster_name = ''
#update_process_title = on

# log lock waits >= deadlock_timeout
# none, ddl, mod, all

# log temporary files equal or larger
# than the specified size in kilobytes;
# -1 disables, 0 logs all temp files

# added to process titles if nonempty
# (change requires restart)
```

Runtime Statistics

```
# - Query/Index Statistics Collector -
```

```
#track_activities = on
#track_counts = on
#track_io_timing = off
#track_functions = none           # none, pl, all
#track_activity_query_size = 1024 # (change requires restart)
#stats_temp_directory = 'pg_stat_tmp'
```

```
# - Statistics Monitoring -
```

```
#log_parser_stats = off
#log_planner_stats = off
#log_executor_stats = off
#log_statement_stats = off
```

Autovacuum

```
#autovacuum = on
#log_autovacuum_min_duration = -1
#autovacuum_max_workers = 3
#autovacuum_naptime = 1min
#autovacuum_vacuum_threshold = 50
#autovacuum_analyze_threshold = 50
#autovacuum_vacuum_scale_factor = 0.2
#autovacuum_analyze_scale_factor = 0.1
#autovacuum_freeze_max_age = 200000000
#autovacuum_multixact_freeze_max_age = 400000000
#autovacuum_vacuum_cost_delay = 20ms
#autovacuum_vacuum_cost_limit = -1
```

Enable autovacuum subprocess? 'on'
requires track_counts to also be on.
-1 disables, 0 logs all actions and
their durations, > 0 logs only
actions running at least this number
of milliseconds.
max number of autovacuum subprocesses
(change requires restart)
time between autovacuum runs
min number of row updates before
vacuum
min number of row updates before
analyze
fraction of table size before vacuum
fraction of table size before analyze
maximum XID age before forced vacuum
(change requires restart)
maximum multixact age
before forced vacuum
(change requires restart)
default vacuum cost delay for
autovacuum, in milliseconds;
-1 means use vacuum_cost_delay
default vacuum cost limit for

Statement Behavior

```
#search_path = '$user', public'           # schema names
#default_tablespace = ''                  # a tablespace name, '' uses the default
#temp_tablespaces = ''                   # a list of tablespace names, '' uses
                                           # only default tablespace

#check_function_bodies = on
#default_transaction_isolation = 'read committed'
#default_transaction_read_only = off
#default_transaction_deferrable = off
#session_replication_role = 'origin'
#statement_timeout = 0                    # in milliseconds, 0 is disabled
#lock_timeout = 0                         # in milliseconds, 0 is disabled
#idle_in_transaction_session_timeout = 0  # in milliseconds, 0 is disabled
#vacuum_freeze_min_age = 50000000
#vacuum_freeze_table_age = 150000000
#vacuum_multixact_freeze_min_age = 5000000
#vacuum_multixact_freeze_table_age = 150000000
#bytea_output = 'hex'                     # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
#gin_fuzzy_search_limit = 0
#gin_pending_list_limit = 4MB
```

Locale, Formatting, and Full Text Search

```
datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
timezone = 'US/Eastern'
#timezone_abbreviations = 'Default' # Select the set of available time zone
# abbreviations. Currently, there are
#   Default
#   Australia (historical usage)
#   India
# You can create your own file in
# share/timezonesets/.
# min -15, max 3
#extra_float_digits = 0 # actually, defaults to database
#client_encoding = sql_ascii # encoding

# These settings are initialized by initdb, but they can be changed.
lc_messages = 'en_US.UTF-8' # locale for system error message
# strings
lc_monetary = 'en_US.UTF-8' # locale for monetary formatting
lc_numeric = 'en_US.UTF-8' # locale for number formatting
lc_time = 'en_US.UTF-8' # locale for time formatting
# default configuration for text search
default_text_search_config = 'pg_catalog.english'
```


Other Defaults

```
#dynamic_library_path = '$libdir'  
#local_preload_libraries = ''  
#session_preload_libraries = ''
```

Lock Management

```
#deadlock_timeout = 1s
#max_locks_per_transaction = 64
#max_pred_locks_per_transaction = 64
#max_pred_locks_per_relation = -2
#max_pred_locks_per_page = 2

# min 10
# (change requires restart)
# min 10
# (change requires restart)
# negative values mean
# (max_pred_locks_per_transaction
# / -max_pred_locks_per_relation) - 1
# min 0
```

Version/Platform Compatibility

- Previous PostgreSQL Versions -

```
#array_nulls = on
#backslash_quote = safe_encoding      # on, off, or safe_encoding
#default_with_oids = off
#escape_string_warning = on
#lo_compat_privileges = off
#operator_precedence_warning = off
#quote_all_identifiers = off
#standard_conforming_strings = on
#synchronize_seqscans = on
```

- Other Platforms and Clients -

```
#transform_null_equals = off
```

Error Handling

```
#exit_on_error = off  
#restart_after_crash = on
```

```
# terminate session on any error?  
# reinitialize after backend crash?
```

Config File Includes

```
#include_dir = 'conf.d'           # include files ending in '.conf' from
                                  # directory 'conf.d'
#include_if_exists = 'exists.conf' # include file only if it exists
#include = 'special.conf'         # include file
```

Interfaces

- ▶ Installing
 - ▶ Compiled Languages (C, ecpg)
 - ▶ Scripting Language (Perl, Python, PHP)
 - ▶ SPI
- ▶ Connection Pooling

Include Files

```
$ ls -CF include/
```

```
ecpg_config.h      libpq/                pgtypes_date.h      sql3types.h
ecpgerrno.h        libpq-events.h        pgtypes_error.h     sqlca.h
ecpg_informix.h    libpq-fe.h            pgtypes_interval.h  sqlda-compat.h
ecpglib.h          pg_config_ext.h       pgtypes_numeric.h   sqlda.h
ecpgtype.h         pg_config.h           pgtypes_timestamp.h sqlda-native.h
informix/          pg_config_manual.h    postgres_ext.h
internal/          pg_config_os.h        server/
```

Library Files

```
$ ls -CF lib/
```

```
ascii_and_mic.so*      libpgcommon.a      utf8_and_ascii.so*
cyrillic_and_mic.so*  libpgfeutils.a    utf8_and_big5.so*
dict_snowball.so*     libpgport.a        utf8_and_cyrillic.so*
euc2004_sjis2004.so*  libpgtypes.a       utf8_and_euc2004.so*
euc_cn_and_mic.so*    libpgtypes.so@     utf8_and_euc_cn.so*
euc_jp_and_sjis.so*   libpgtypes.so.3@   utf8_and_euc_jp.so*
euc_kr_and_mic.so*    libpgtypes.so.3.10* utf8_and_euc_kr.so*
euc_tw_and_big5.so*   libpq.a             utf8_and_euc_tw.so*
latin2_and_win1250.so* libpq.so@           utf8_and_gb18030.so*
latin_and_mic.so*     libpq.so.5@        utf8_and_gbk.so*
libecpg.a              libpq.so.5.10*     utf8_and_iso8859_1.so*
libecpg_compat.a      libpqwalreceiver.so* utf8_and_iso8859.so*
libecpg_compat.so@    pgoutput.so*       utf8_and_johab.so*
libecpg_compat.so.3@  pgxs/               utf8_and_sjis2004.so*
libecpg_compat.so.3.10* pkgconfig/           utf8_and_sjis.so*
libecpg.so@            plperl.so*          utf8_and_uhc.so*
libecpg.so.6@          plpgsql.so*         utf8_and_win.so*
libecpg.so.6.10*      plpython2.so*
```

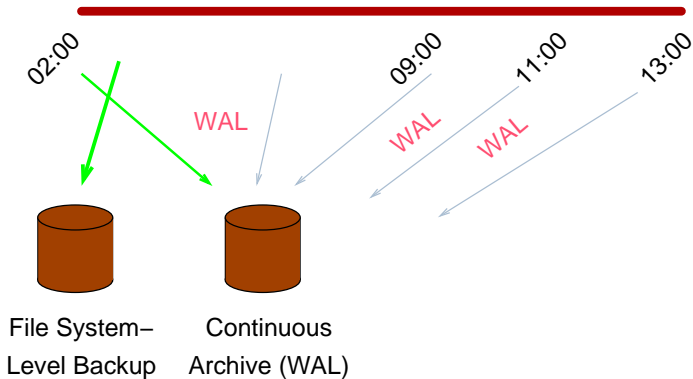

3. Maintenance



Backup

- ▶ File system-level (physical)
 - ▶ tar, cpio while shutdown
 - ▶ file system snapshot
 - ▶ rsync, shutdown, rsync, restart
- ▶ pg_dump/pg_dumpall (logical)
- ▶ Restore/pg_restore with custom format

Continuous Archiving / Point-In-Time Recovery (PITR)

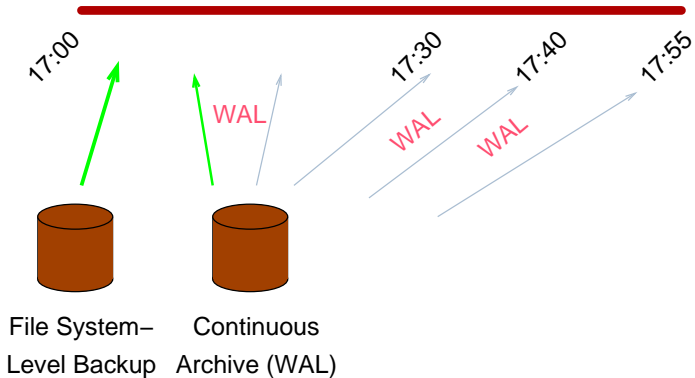


PITR Backup Procedures

1. `archive_mode = on`
2. `wal_level = archive`
3. `archive_command = 'cp -i %p /mnt/server/pgsql/%f < /dev/null'`
4. `SELECT pg_start_backup('label');`
5. Perform file system-level backup (can be inconsistent)
6. `SELECT pg_stop_backup();`

pg_basebackup does this automatically.

PITR Recovery



PITR Recovery Procedures

1. Stop postmaster
2. Restore file system-level backup
3. Make adjustments as outlined in the documentation
4. Create recovery.conf
5. `restore_command = 'cp /mnt/server/pgsql/%f %p'`
6. Start the postmaster

Continuous Archive Management

Simplify backups and WAL archive file management with:

- ▶ *pgBackRest*
- ▶ *barman*

Data Maintenance

- ▶ VACUUM (nonblocking) records free space into .fsm (free space map) files
- ▶ ANALYZE collects optimizer statistics
- ▶ VACUUM FULL (blocking) shrinks the size of database disk files

Automating Tasks

Autovacuum handles vacuum and analyze tasks automatically.

Checkpoints

- ▶ Write all dirty shared buffers
- ▶ Sync all dirty kernel buffers
- ▶ Recycle WAL files
- ▶ Controlled by *checkpoint_timeout* and *max_wal_size*

4. Monitoring



ps

```
$ ps -f -Upostgres
postgres  825    1  0 Tue12AM  ??           0:06.57 /u/pgsql/bin/postmaster -i
postgres  829    825  0 Tue12AM  ??           0:35.03 writer process      (postmaster)
postgres  830    825  0 Tue12AM  ??           0:16.07 wal writer process  (postmaster)
postgres  831    825  0 Tue12AM  ??           0:11.34 autovacuum launcher process (postmaster)
postgres  832    825  0 Tue12AM  ??           0:07.63 stats collector process (postmaster)
postgres 13003   825  0  3:44PM  ??           0:00.01 postgres test [local] idle (postmaster)
postgres 13002 12997  0  3:44PM  ttyq1       0:00.03 /u/pgsql/bin/psql test
```

top

```
$ top -c
```

```
top - 10:29:47 up 23 days, 18:53, 6 users, load average: 1.73, 1.49, 0.81
```

```
Tasks: 387 total, 2 running, 385 sleeping, 0 stopped, 0 zombie
```

```
%Cpu(s): 5.9 us, 0.5 sy, 0.0 ni, 93.7 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
```

```
KiB Mem: 24734444 total, 19187724 used, 5546720 free, 532280 buffers
```

```
KiB Swap: 6369276 total, 168292 used, 6200984 free. 16936936 cached Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
32037	postgres	20	0	190980	27940	21420	R	100.0	0.1	0:09.74	postgres: postgres test [local] INSERT
32061	root	20	0	26056	3240	2444	R	0.7	0.0	0:00.09	top -c

Query Monitoring

```
test=> SELECT * FROM pg_stat_activity;
```

```
...
```

datid		16384
datname		test
pid		16382
usesysid		10
username		postgres
application_name		psql
client_addr		
client_hostname		
client_port		-1
backend_start		2018-04-15 09:00:26.467813-04
xact_start		2018-04-15 09:00:48.028667-04
query_start		2018-04-15 09:00:48.028667-04
state_change		2018-04-15 09:00:48.028671-04
wait_event_type		
wait_event		
state		active
backend_xid		
backend_xmin		556
query		SELECT * FROM pg_stat_activity;
backend_type		client backend

Access Statistics

pg_stat_all_indexes	view	postgres
pg_stat_all_tables	view	postgres
pg_stat_database	view	postgres
pg_stat_sys_indexes	view	postgres
pg_stat_sys_tables	view	postgres
pg_stat_user_indexes	view	postgres
pg_stat_user_tables	view	postgres
pg_statio_all_indexes	view	postgres
pg_statio_all_sequences	view	postgres
pg_statio_all_tables	view	postgres
pg_statio_sys_indexes	view	postgres
pg_statio_sys_sequences	view	postgres
pg_statio_sys_tables	view	postgres
pg_statio_user_indexes	view	postgres
pg_statio_user_sequences	view	postgres
pg_statio_user_tables	view	postgres

Database Statistics

```
test=> SELECT * FROM pg_stat_database;
```

```
...
```

```
-[ RECORD 4 ]-+-----
```

datid		16384
datname		test
numbackends		1
xact_commit		188
xact_rollback		0
blks_read		95
blks_hit		11832
tup_returned		64389
tup_fetched		2938
tup_inserted		0
tup_updated		0
tup_deleted		0

Table Activity

```
test=> SELECT * FROM pg_stat_all_tables;
-[ RECORD 10 ]-----+-----
relid          | 2616
schemaname     | pg_catalog
relname        | pg_opclass
seq_scan       | 2
seq_tup_read   | 2
idx_scan       | 99
idx_tup_fetch  | 99
n_tup_ins      | 0
n_tup_upd      | 0
n_tup_del      | 0
n_tup_hot_upd  | 0
n_live_tup     | 0
n_dead_tup     | 0
last_vacuum    |
last_autovacuum |
last_analyze   |
last_autoanalyze |
```

Table Block Activity

```
test=> SELECT * FROM pg_statio_all_tables;
```

```
-[ RECORD 50 ]--+-+-----
```

relid		2602
schemaname		pg_catalog
relname		pg_amop
heap_blks_read		3
heap_blks_hit		114
idx_blks_read		5
idx_blks_hit		303
toast_blks_read		
toast_blks_hit		
tidx_blks_read		
tidx_blks_hit		

Analyzing Activity

- ▶ Heavily used tables
- ▶ Unnecessary indexes
- ▶ Additional indexes
- ▶ Index usage
- ▶ TOAST usage

CPU

\$ vmstat 5

procs			memory		page					disks		faults			cpu			
r	b	w	avm	fre	flt	re	pi	po	fr	sr	s0	s0	in	sy	cs	us	sy	id
1	0	0	501820	48520	1234	86	2	0	0	3	5	0	263	2881	599	10	4	86
3	0	0	512796	46812	1422	201	12	0	0	0	3	0	259	6483	827	4	7	88
3	0	0	542260	44356	788	137	6	0	0	0	8	0	286	5698	741	2	5	94
4	0	0	539708	41868	576	65	13	0	0	0	4	0	273	5721	819	16	4	80
4	0	0	547200	32964	454	0	0	0	0	0	5	0	253	5736	948	50	4	46
4	0	0	556140	23884	461	0	0	0	0	0	2	0	249	5917	959	52	3	44
1	0	0	535136	46280	1056	141	25	0	0	0	2	0	261	6417	890	24	6	70

I/O

```
$ iostat 5
```

tty		sd0			sd1			sd2			% cpu				
tin	tout	sps	tps	mtps	sps	tps	mtps	sps	tps	mtps	usr	nic	sys	int	idl
7	119	244	11	6.1	0	0	27.3	0	0	18.1	9	1	4	0	86
0	86	20	1	1.4	0	0	0.0	0	0	0.0	2	0	2	0	96
0	82	61	4	3.6	0	0	0.0	0	0	0.0	2	0	2	0	97
0	65	6	0	0.0	0	0	0.0	0	0	0.0	1	0	2	0	97
12	90	31	2	5.4	0	0	0.0	0	0	0.0	4	0	3	0	93
24	173	6	0	4.9	0	0	0.0	0	0	0.0	48	0	3	0	49
0	91	3594	63	4.6	0	0	0.0	0	0	0.0	11	0	4	0	85

Disk Usage

```
test=> \df *size*
```

List of functions				
Schema	Name	Result data type	Argument data types	Type
pg_catalog	pg_column_size	integer	"any"	normal
pg_catalog	pg_database_size	bigint	name	normal
pg_catalog	pg_database_size	bigint	oid	normal
pg_catalog	pg_indexes_size	bigint	regclass	normal
pg_catalog	pg_relation_size	bigint	regclass	normal
pg_catalog	pg_relation_size	bigint	regclass, text	normal
pg_catalog	pg_size_pretty	text	bigint	normal
pg_catalog	pg_table_size	bigint	regclass	normal
pg_catalog	pg_tablespace_size	bigint	name	normal
pg_catalog	pg_tablespace_size	bigint	oid	normal
pg_catalog	pg_total_relation_size	bigint	regclass	normal

Database File Mapping - oid2name

```
$ oid2name
```

```
All databases:
```

```
-----  
18720 = test1
```

```
1     = template1
```

```
18719 = template0
```

```
18721 = test
```

```
18735 = postgres
```

```
18736 = cssi
```

Table File Mapping

```
$ cd /usr/local/pgsql/data/base
```

```
$ oid2name
```

```
All databases:
```

```
-----  
16817 = test2
```

```
16578 = x
```

```
16756 = test
```

```
1      = template1
```

```
16569 = template0
```

```
16818 = test3
```

```
16811 = floattest
```

```
$ cd 16756
```

```
$ ls 1873*
```

```
18730  18731  18732  18735  18736  18737  18738  18739
```



```
$ oid2name -d test -o 18737
```

```
Tablename of oid 18737 from database "test":
```

```
-----  
18737 = ips
```

```
$ oid2name -d test -t ips
```

```
Oid of table ips from database "test":
```

```
-----  
18737 = ips
```

```
$ # show disk usage per database
```

```
$ cd /usr/local/pgsql/data/base
```

```
$ du -s * |
```

```
> while read SIZE OID
```

```
> do
```

```
>     echo "$SIZE      `oid2name -q | grep ^$OID' "`
```

```
> done |
```

```
> sort -rn
```

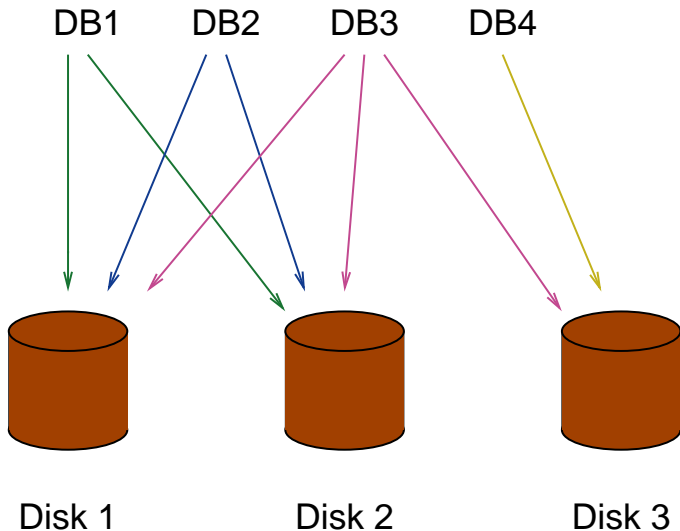
```
2256      18721 = test
```

```
2135      18735 = postgres
```

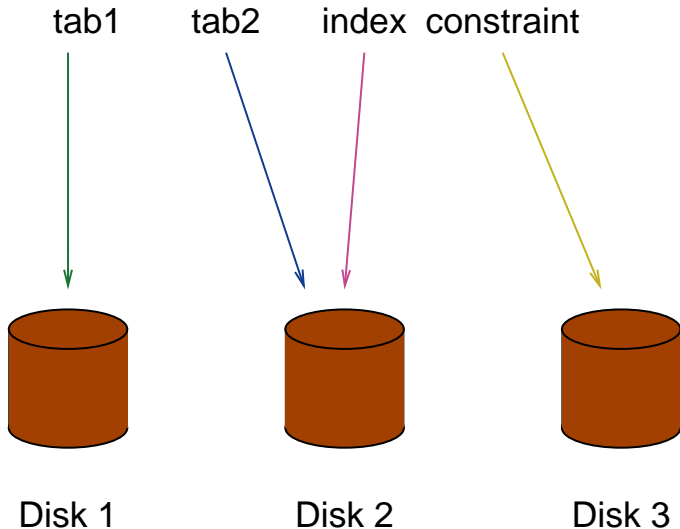
Disk Balancing

- ▶ Move pg_wal to another drive using symlinks
- ▶ Tablespaces

Per-Database Tablespaces



Per-Object Tablespaces



Analyzing Locking

```
$ ps -f -Upostgres
```

```
  PID TT  STAT      TIME COMMAND
 9874 ??  I       0:00.07 postgres test [local] idle in transaction (postmaster)
 9835 ??  S       0:00.05 postgres test [local] UPDATE waiting (postmaster)
10295 ??  S       0:00.05 postgres test [local] DELETE waiting (postmaster)
```

```
test=> SELECT * FROM pg_locks;
```

relation	database	transaction	pid	mode	granted
17143	17142		9173	AccessShareLock	t
17143	17142		9173	RowExclusiveLock	t
		472	9380	ExclusiveLock	t
		468	9338	ShareLock	f
		470	9338	ExclusiveLock	t
16759	17142		9380	AccessShareLock	t
17143	17142		9338	AccessShareLock	t
17143	17142		9338	RowExclusiveLock	t
		468	9173	ExclusiveLock	t

Miscellaneous Tasks

- ▶ Log file rotation, syslog
- ▶ Upgrading
 - ▶ pg_dump, restore
 - ▶ pg_upgrade
 - ▶ Slony
- ▶ Migration

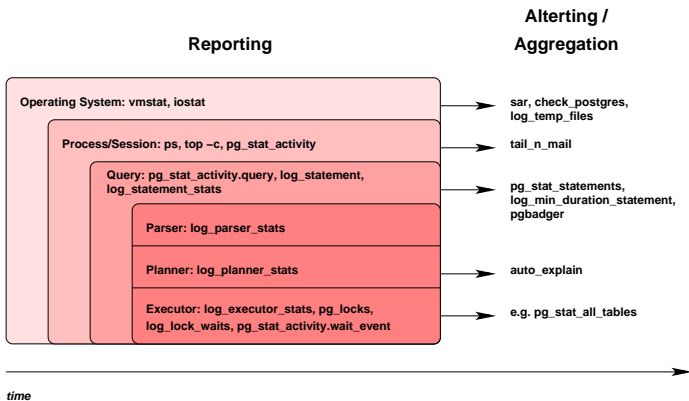
Administration Tools

- ▶ pgadmin
- ▶ phppgadmin

External Monitoring Tools

- ▶ Alerting: `check_postgres`, `tail_n_mail`, Nagios
- ▶ Server analysis: Munin, Cacti, Zabbix, Nagios, MRTG
- ▶ Queries: `pg_stat_statements`, `auto_explain`, `pgbadger`
- ▶ Commercial: Circonus (or open-source Reconnoiter), Postgres Enterprise Manager (PEM)

Monitoring Summary



5. Recovery



<https://www.flickr.com/photos/coastguardnews/>

Client Application Crash

Nothing Required. Transactions in progress are rolled back.

Graceful Postgres Server Shutdown

Nothing Required. Transactions in progress are rolled back.

Abrupt Postgres Server Crash

Nothing Required. Transactions in progress are rolled back.

Operating System Crash

Nothing Required. Transactions in progress are rolled back.
Partial page writes are repaired.

Disk Failure

Restore from previous backup or use PITR.

Accidental DELETE

Recover table from previous backup, perhaps using `pg_restore`. It is possible to modify the backend code to make deleted tuples visible, dump out the deleted table and restore the original code. All tuples in the table since the previous vacuum will be visible. It is possible to restrict that so only tuples deleted by a specific transaction are visible.

Write-Ahead Log (WAL) Corruption

See `pg_resetwal`. Review recent transactions and identify any damage, including partially committed transactions.

File Deletion

It may be necessary to create an empty file with the deleted file name so the object can be deleted, and then the object restored from backup.

Accidental DROP TABLE

Restore from previous backup.

Accidental DROP INDEX

Recreate index.

Accidental DROP DATABASE

Restore from previous backup.

Non-Starting Installation

Restart problems are usually caused by write-ahead log problems. See `pg_resetwal`. Review recent transactions and identify any damage, including partially committed transactions.

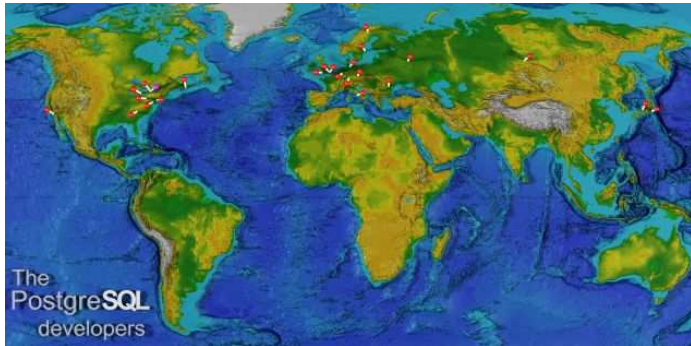
Index Corruption

Use REINDEX.

Table Corruption

Try reindexing the table. Try identifying the corrupt OID of the row and transfer the valid rows into another table using `SELECT...INTO...WHERE oid != ###`. Use `pageinspect` to analyze the internal structure of the table.

Conclusion



<http://momjian.us/presentations>