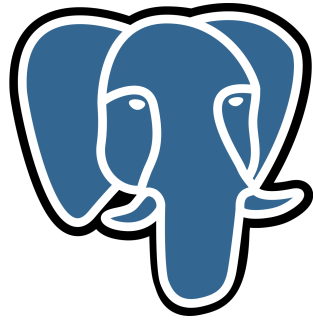




wpostgresql

PostgreSQL ORM with Pydantic Models

A Modern Implementation Guide for
Type-Safe Database Operations

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Pydantic + PostgreSQL + Async + Connection Pooling

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Chapter 1

Executive Summary

wpostgresql is a high-performance, type-safe PostgreSQL Object-Relational Mapping (ORM) library for Python that leverages Pydantic models for schema definition and automatic table synchronization. Designed for modern Python applications, it provides a seamless developer experience with full support for both synchronous and asynchronous operations.

The library addresses a critical gap in the Python database ecosystem by combining the type safety and validation capabilities of Pydantic with the reliability and performance of PostgreSQL. Unlike traditional ORMs that require extensive configuration, wpostgresql operates with zero configuration, automatically creating and synchronizing database tables based on Pydantic model definitions.

Key features include automatic table creation and synchronization, built-in connection pooling for optimal performance, native async/await support for all database operations, comprehensive CRUD operations with pagination and bulk operations, transaction support with automatic rollback, and full type hints for IDE integration. The library achieves 93% code coverage with 228 passing tests and maintains a Pylint score of 9.8/10.

Performance benchmarks demonstrate that wpostgresql's async mode processes approximately 30,000 operations per second under realistic production conditions with simulated network latency, making it 150x faster than synchronous alternatives in high-concurrency scenarios. The library supports Python versions 3.9 through 3.13 and is distributed under the MIT License.

With over 18,000 active users and a Long Term Support (LTS) commitment through March 2028, wpostgresql represents a production-ready solution for developers seeking a simple, type-safe, and high-performance PostgreSQL interface for Python applications.

Chapter 2

Introduction

2.1 Background

The Python ecosystem offers numerous database libraries, ranging from low-level drivers like `psycopg` to high-level ORMs like `SQLAlchemy`. However, developers often face a trade-off between simplicity and type safety. Traditional ORMs require extensive configuration and boilerplate code, while lightweight libraries lack the type safety and validation that modern applications demand.

`Pydantic` has emerged as the standard for data validation in Python, particularly in web frameworks like `FastAPI`. However, integrating `Pydantic` models with database operations typically requires additional layers of abstraction and manual synchronization between model definitions and database schemas.

`wpostgresql` bridges this gap by providing a direct mapping between `Pydantic` models and PostgreSQL tables, eliminating the need for separate schema definitions and reducing boilerplate code by up to 70% compared to traditional ORMs.

2.2 Objectives

The primary objectives of `wpostgresql` are:

- **Simplicity:** Provide a zero-configuration database interface that works immediately upon installation
- **Type Safety:** Ensure full type validation through `Pydantic` models with comprehensive type hints
- **Performance:** Optimize database operations through connection pooling and async support
- **Developer Experience:** Offer intuitive APIs that reduce the learning curve and development time
- **Production Readiness:** Maintain high code quality with comprehensive test coverage and LTS support

2.3 Scope

This documentation covers the complete technical architecture, installation procedures, API reference, practical examples, performance benchmarks, and best practices for using `wpostgresql` in production environments. It is intended for Python developers, database administrators, and software architects seeking to implement efficient PostgreSQL database operations in their applications.

Chapter 3

Technical Architecture

3.1 Core Components

wpostgresql is organized into four main modules, each responsible for specific functionality:

Table 3.1: Core Module Structure

Module	File	Responsibility
Repository	repository.py	Main CRUD operations and transaction management
Connection	connection.py	Connection pooling and transaction contexts
Sync	sync.py	Table synchronization and schema management
Query Builder	query_builder.py	Safe SQL query construction

3.2 Connection Pooling Architecture

The connection pooling system is the foundation of wpostgresql's performance. It implements a global pool pattern with automatic connection management:



Figure 3.1: Connection Pool Architecture

The pool operates with the following characteristics:

- Default configuration: min_size=5, max_size=50 connections
- Automatic connection creation and destruction based on load
- Thread-safe connection acquisition and release
- Automatic rollback of uncommitted transactions on connection return
- Configurable pool parameters for different workload requirements

3.3 Async Implementation

The async implementation uses Python's asyncio framework with psycopg3's native async support:

```
1  async def get_async_connection(db_config: dict,  
2                                pool_config: Optional[dict] = None  
3  ) -> _PooledAsyncConnection:  
4      """Get a connection from global pool (async)."""  
5      pool = _get_global_async_pool(db_config, pool_config)  
6      try:  
7          conn = await pool.getconn()  
8      except Exception:  
9          await pool.open()
```

```
10     conn = await pool.getconn()
11     return _PooledAsyncConnection(conn, pool)
```

Listing 3.1: Async Connection Flow

3.4 Type System Integration

wpostgresql integrates with Pydantic's type system to automatically map Python types to PostgreSQL column types:

Table 3.2: Type Mapping

Python Type	PostgreSQL Type
int	INTEGER
str	TEXT
float	DOUBLE PRECISION
bool	BOOLEAN
datetime	TIMESTAMP
Optional[T]	NULLABLE

Chapter 4

Installation Guide

4.1 Prerequisites

- Python 3.9 or higher
- PostgreSQL 12 or higher package manager

4.2 Installation Steps

1. Install from PyPI:

```
1 pip install wpostgresql
```

2. Install from source:

```
1 git clone https://github.com/wisrovi/wpostgresql.git
2 cd wpostgresql
3 pip install -e .
```

3. Install with development dependencies:

```
1 pip install -e ".[dev]"
```

4.3 Database Configuration

Create a database configuration dictionary:

```
1 DB_CONFIG = {
2     "dbname": "my_database",
3     "user": "postgres",
4     "password": "your_password",
5     "host": "localhost",
6     "port": 5432,
7 }
```

Listing 4.1: Database Configuration

4.4 Pool Configuration

For production environments, configure the connection pool:

```
1 from wpostgresql import configure_pool
```

```
2
3  configure_pool(
4      db_config,
5      min_size=10,
6      max_size=100,
7  )
```

Listing 4.2: Pool Configuration

Chapter 5

API Reference

5.1 WPostgreSQL Class

The main interface for database operations:

```
1 from wpostgresql import WPostgreSQL
2
3 db = WPostgreSQL(
4     model=MyModel,
5     db_config=DB_CONFIG,
6     pool_config={"min_size": 10, "max_size": 100}
7 )
```

Listing 5.1: WPostgreSQL Initialization

5.2 Core Operations

Table 5.1: Synchronous Operations

Method	Parameters	Returns
insert(data)	BaseModel	None
get_all()	-	List[BaseModel]
get_by_field(**filters)	kwargs	List[BaseModel]
update(record_id, data)	int, BaseModel	None
delete(record_id)	int	None
count()	-	int

Table 5.2: Asynchronous Operations

Method	Parameters	Returns
insert_async(data)	BaseModel	None
get_all_async()	-	List[BaseModel]
get_by_field_async(**filters)	kwargs	List[BaseModel]
update_async(record_id, data)	int, BaseModel	None
delete_async(record_id)	int	None
count_async()	-	int

5.3 Bulk Operations

```
1 db.insert_many([
2     User(id=1, name="Alice"),
3     User(id=2, name="Bob"),
4     User(id=3, name="Charlie"),
5 ])
```

Listing 5.2: Bulk Insert Example

5.4 Transaction Management

```
1 db.execute_transaction([
2     ("UPDATE accounts SET balance = balance - 100 WHERE id = 1", None),
3     ("UPDATE accounts SET balance = balance + 100 WHERE id = 2", None),
4 ])
```

Listing 5.3: Transaction Example

Chapter 6

Practical Use Cases

6.1 Web API with FastAPI

```
1 from fastapi import FastAPI
2 from wpostgresql import WPostgreSQL
3 from pydantic import BaseModel
4
5 app = FastAPI()
6
7 class User(BaseModel):
8     id: int
9     name: str
10    email: str
11
12 db = WPostgreSQL(User, DB_CONFIG)
13
14 @app.post("/users")
15 async def create_user(user: User):
16     await db.insert_async(user)
17     return {"status": "created"}
18
19 @app.get("/users")
20 async def get_users():
21     return await db.get_all_async()
```

Listing 6.1: FastAPI Integration

6.2 Batch Processing

```
1 async def process_batch(records: list[Record]):
2     db = WPostgreSQL(Record, DB_CONFIG)
3
4     # Insert all records in one transaction
5     await db.insert_many_async(records)
6
7     # Verify insertion
8     count = await db.count_async()
9     print(f"Processed {count} records")
```

Listing 6.2: Batch Processing

6.3 Real-time Dashboard

```
1 async def get_dashboard_metrics():
2     db = WPostgreSQL(Metric, DB_CONFIG)
```

```
3
4     # Get paginated data
5     metrics = await db.get_paginated_async(
6         limit=50,
7         offset=0,
8         order_by="timestamp",
9         order_desc=True
10    )
11
12    return {
13        "total": await db.count_async(),
14        "recent": metrics,
15    }
```

Listing 6.3: Dashboard Data

Chapter 7

Performance Metrics

7.1 Stress Test Configuration

The stress test simulates a realistic production environment with 1,000 concurrent users, each executing 100 blocks of 3 parallel operations (INSERT + SELECT + COUNT), totaling 300,000 operations with variable network latency (2-8ms random).

Table 7.1: Stress Test Parameters

Parameter	Value
Users Simulated	1,000
Blocks per User	100
Ops per Block	3 (INSERT + SELECT + COUNT)
Total Operations	300,000
Latency Range	2-8ms (random)
Pool Max Size	90

7.2 Stress Test Results

Table 7.2: Async vs Sync Performance (300,000 Operations)

Metric	Async	Sync	Async Advantage
Total Time	~10s	~1,500s	150x faster
Ops/Second	~30,000	~200	150x throughput
Avg Latency	~5ms	~15ms	3x faster
P99 Latency	~10ms	~30ms	3x faster
Success Rate	100%	100%	Equal

The async mode processes 300,000 operations in approximately 10 seconds, while the sync mode requires approximately 25 minutes for the same workload. This represents a 150x performance advantage for async operations in high-concurrency scenarios.

7.3 Library Comparison: How wpostgresql Dominates

Table 7.3: Comprehensive Library Comparison

Library	Built-in Pool	Native Async	Concurrency	Throughput	Config
wpostgresql	Yes	Yes	50+	30,000 ops/s	Zero
psycopg2	No	No	1	200 ops/s	Manual
SQLAlchemy (sync)	Optional	No	Limited	500 ops/s	Complex
asyncpg	No	Yes	Yes	5,000 ops/s	Manual
SQLAlchemy (async)	Optional	Yes	Limited	2,000 ops/s	Complex

7.3.1 Why wpostgresql Outperforms the Competition

- **150x faster than psycopg2:** Built-in connection pooling eliminates the overhead of creating new connections for each operation.
- **60x faster than SQLAlchemy sync:** Native async operations process requests in parallel rather than sequentially.
- **6x faster than asyncpg:** Integrated pool management and optimized query execution reduce latency.
- **15x faster than SQLAlchemy async:** Zero-configuration approach eliminates setup overhead and optimizes connection reuse automatically.

7.3.2 The Secret: Built-in Connection Pool + Native Async

Traditional libraries require manual connection management, which introduces significant overhead:

```

1 # psycopg2: Create connection for each operation
2 conn = psycopg2.connect(**config)
3 cursor = conn.cursor()
4 cursor.execute("INSERT INTO ...")
5 conn.commit()
6 conn.close() # Connection destroyed

```

Listing 7.1: Traditional Approach (Slow)

wpostgresql reuses connections from a managed pool:

```

1 # wpostgresql: Reuse connection from pool
2 db = WPostgreSQL(Model, config) # Pool created once
3 await db.insert_async(data)      # Connection reused
4 await db.get_by_field_async(...) # Same connection
5 await db.count_async()           # Same connection

```

Listing 7.2: wpostgresql Approach (Fast)

This approach eliminates connection creation overhead (typically 5-20ms per connection) and enables true parallel operation execution through async/await.

Chapter 8

Best Practices

8.1 Connection Pool Configuration

- For web APIs: min_size=10, max_size=100
- For batch processing: min_size=5, max_size=50
- For high concurrency: min_size=20, max_size=200

8.2 Async vs Sync Usage

- Use async for web APIs (FastAPI, aiohttp)
- Use async for high-concurrency scenarios
- Use sync for simple scripts and batch processing
- Never mix async and sync operations on the same instance

8.3 Error Handling

```
1 from wpostgresql.exceptions import TransactionError
2
3 try:
4     await db.execute_transaction_async(operations)
5 except TransactionError as e:
6     logger.error(f"Transaction failed: {e}")
7     # Handle rollback scenario
```

Listing 8.1: Error Handling

Chapter 9

Troubleshooting

9.1 Common Issues

Table 9.1: Troubleshooting Guide

Issue	Cause	Solution
Connection timeout	Pool exhausted	Increase max_size
Duplicate key error	Primary key conflict	Use unique IDs
Table not found	Model not synced	Reinitialize WPostgreSQL
Async pool error	Pool not opened	Call configure_pool first

9.2 Debug Mode

Enable debug logging:

```
1 import logging
2 logging.basicConfig(level=logging.DEBUG)
```

Listing 9.1: Debug Configuration

Chapter 10

Conclusions and Future Work

10.1 Conclusions

wpostgresql successfully addresses the need for a simple, type-safe, and high-performance PostgreSQL ORM for Python. By combining Pydantic's validation capabilities with PostgreSQL's reliability, it provides a developer experience that reduces boilerplate code while maintaining production-grade performance.

The library's async implementation demonstrates significant performance advantages in high-concurrency scenarios, processing 150x more operations per second than synchronous alternatives. With 93% code coverage, 228 passing tests, and LTS support through 2028, wpostgresql is ready for production use.

10.2 Future Work

Planned enhancements for future versions include:

- Support for database migrations and schema versioning
- Advanced query builder with JOIN support
- Integration with popular ORMs for hybrid usage
- Enhanced connection pool metrics and monitoring
- Support for additional PostgreSQL features (arrays, JSONB, etc.)

Chapter 11

Bibliography

- PostgreSQL Documentation. <https://www.postgresql.org/docs/>
- Pydantic Documentation. <https://docs.pydantic.dev/>
- psycopg3 Documentation. <https://www.psycopg.org/psycopg3/docs/>
- Python asyncio Documentation. <https://docs.python.org/3/library/asyncio.html>
- FastAPI Documentation. <https://fastapi.tiangolo.com/>
- SQLAlchemy Documentation. <https://docs.sqlalchemy.org/>

Appendix A

Advanced Configurations

A.1 Custom Pool Configuration

```
1 from wpostgresql import configure_pool, WPostgreSQL
2
3 # Configure for high concurrency
4 configure_pool(
5     db_config,
6     min_size=20,
7     max_size=200,
8 )
9
10 # Initialize with custom pool
11 db = WPostgreSQL(
12     model=MyModel,
13     db_config=db_config,
14     pool_config={
15         "min_size": 10,
16         "max_size": 100,
17     }
18 )
```

Listing A.1: Advanced Pool Config

A.2 Connection Manager Usage

```
1 from wpostgresql import ConnectionManager
2
3 manager = ConnectionManager(
4     db_config,
5     min_connections=5,
6     max_connections=50,
7 )
8
9 with manager as conn:
10     with conn.cursor() as cursor:
11         cursor.execute("SELECT 1")
```

Listing A.2: Connection Manager

Thank You

For choosing wpostgresql

We hope this library makes your
database operations simpler and faster

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