

OU-PWM48 Smart PID Control Datasheet

1. Overview

The OU-PWM48 Smart Sensor is an advanced, compact device designed for precise monitoring and Proportional-Integral-Derivative (PID) control of water heater systems. It now acts as a standalone PID controller, calculating the necessary control action internally and delivering a real-time Pulse Width Modulation (PWM) output directly to the water heater's heating element. This enables efficient and reliable water temperature regulation, engineered for seamless integration into smart home and industrial heating applications, offering robust performance with a user-friendly interface.

Key Features:

- High-precision water temperature monitoring.
- Ambient condition compensation for optimized control.
- Integrated PID controller for autonomous temperature regulation.
- Direct PWM output for controlling water heater heating elements.
- MQTT communication interface for easy integration with external systems, allowing for remote monitoring and PID parameter configuration.
- Configurable target temperature and sampling rate.

- Compact and durable design for versatile installation.

2. Applications

- **Smart Water Heaters:** Enhances energy efficiency and precise temperature control by directly managing the heating element.
- **Home Automation:** Integrates with platforms like Home Assistant or Node-RED for monitoring and high-level control of the sensor's PID parameters.
- **Industrial Heating Systems:** Monitors and controls water temperature in small-scale industrial setups with integrated PID functionality.
- **Energy Management:** Reduces energy waste through accurate temperature regulation and optimized heating element control.

3. Technical Specifications

Parameter	Value/Description
Output	PWM Duty Cycle (0-100%) for heating element control

PWM Frequency	1 kHz (Configurable)
Communication Interface	MQTT (configurable broker and topics)
Sampling Rate	Configurable, default 1 Hz (1 sample/second)
Power Supply	5V DC (via USB) or 3.3V-5V DC (external power with regulator)
Typical Current Draw	25 mA (Active); 5 mA (Idle)
Operating Temperature Range	to +60°C
Storage Temperature Range	-40°C to +85°C

Accuracy	±0.5°C for water temperature; ambient compensation within ±2%
Dimensions	50 mm×35 mm×15 mm (compact module)
Weight	Approx. 25 g
Ingress Protection	IP65 (water-resistant enclosure for sensor probe)
Expected Lifespan	>5 years in typical operating conditions
Certifications	CE, RoHS compliant

4. System Integration

4.1. System Diagram

The OU-PWM48 now directly measures water temperature, calculates the PID control output, and provides a PWM signal to the water heater's heating element.

Explanation:

- The OU-PWM48 measures the water temperature and internally calculates the necessary PID control action based on the target temperature and current temperature.
- The calculated control action is translated into a **PWM duty cycle** signal, which is transmitted directly to the water heater's heating element driver.
- The sensor also publishes current temperature, error, and status data via MQTT for monitoring. PID parameters can be remotely configured via MQTT commands.

4.2. Communication Protocol

4.2.1. MQTT Protocol

The OU-PWM48 publishes data and receives configuration commands via MQTT.

- **MQTT Broker:** External MQTT broker required. For testing and development purposes, a commonly used free public broker is:
 - **Host:** `broker.hivemq.com`
 - **Port (unencrypted):** `1883`
 - **Port (TLS/SSL):** `8883`
 - *(Note: Public brokers are suitable for testing but generally not recommended for production environments due to security and reliability concerns.)*
- **Default Topics (configurable):**
 - **Data Publication:** `ou/pwm48/<device_id>/data`
 - **Payload Format (JSON):** `{"current_temp": <float_value>, "target_temp": <float_value>, "error": <float_value>, "pwm_duty_cycle": <float_value>, "ambient_comp": <float_value>}`
 - **Example:** `{"current_temp": 54.75, "target_temp": 55.0, "error": 0.25, "pwm_duty_cycle": 75.0, "ambient_comp": 22.5}`
 - **Status Publication:** `ou/pwm48/<device_id>/status`
 - **Payload Format (JSON):** `{"status": "online", "uptime_s": 3600, "current_pwm_freq_hz": 1000}` (example)
 - **Command Subscription:** `ou/pwm48/<device_id>/cmd`
 - **Payload Format (JSON):** `{"command": "<command_name>", "value": <value>}`
- **Example Configuration Commands (via MQTT `cmd` topic):**
 - Set Target Temperature to 50.0°C: `{"command": "SET_TARGET", "value": 50.0}`
 - Set Sampling Rate to 1.0 Hz: `{"command": "SET_RATE", "value": 1.0}`
 - **Set PID Proportional Gain (Kp):** `{"command": "SET_PID_KP", "value": 1.5}`

- **Set PID Integral Gain (Ki):** `{"command": "SET_PID_KI", "value": 0.1}`
- **Set PID Derivative Gain (Kd):** `{"command": "SET_PID_KD", "value": 0.05}`
- **Set PWM Frequency:** `{"command": "SET_PWM_FREQ", "value": 2000}` (in Hz)

MQTT Security:

The OU-PWM48 supports secure MQTT communication:

- **TLS/SSL (Port 8883):** Supports encrypted connections to the MQTT broker for data privacy and integrity.
- **Authentication:** Supports username/password authentication for broker access control. Contact supplier for details on provisioning credentials.

5. Installation and Setup

5.1. Hardware Installation

1. Mounting:

- Attach the OU-PWM48 sensor probe to the water heater in a location with good thermal contact (e.g., tank surface or pipe).
- Ensure the sensor module is placed in a stable environment, away from direct heat or moisture exposure beyond IP65 rating.
- **Mounting Note:** The module features two integrated mounting tabs for screw-based attachment. Refer to the user manual for detailed dimensions and screw specifications.

2. Power Connection:

- Connect to a 5V USB power source or a 3.3V-5V DC regulated supply.
- Verify stable power to ensure accurate readings.

3. PWM Output Connection:

- **Connect the OU-PWM48's dedicated PWM output pin to the control input of the water heater's heating element driver/relay.** Ensure the driver is compatible with the sensor's PWM signal voltage and current capabilities.

4. Communication Setup (MQTT):

- **Device ID:** The `<device_id>` is a unique identifier assigned to each sensor, often printed on the device label or accessible via a dedicated initial setup tool. This ID is crucial for constructing MQTT topics.
- Configure the sensor to connect to your MQTT broker (details via specific firmware configuration or setup tool).
- Ensure your monitoring system is subscribed to the appropriate data topics and publishes commands (e.g., target temperature, PID tuning) to the command topic.

5.2. Configuration

- **Default Settings:**
 - Target Temperature: 60°C
 - Sampling Rate: 1 Hz
 - **Default PID Parameters: $K_p=1.0$, $K_i=0.0$, $K_d=0.0$ (Pure Proportional Control)**
 - **Default PWM Frequency: 1 kHz**
- **Customization:**
 - Use **MQTT commands** to adjust target temperature, sampling rate, **PID tuning parameters (K_p , K_i , K_d)**, and **PWM frequency**.
 - Contact supplier for advanced configuration or firmware updates.

6. Performance Characteristics

6.1. Accuracy and Precision

- **Temperature Control Accuracy:** The integrated PID controller aims to maintain the water temperature within $\pm 1.0^\circ\text{C}$ of the target temperature under stable load conditions (actual performance depends on PID tuning).
- **Temperature Measurement Accuracy:** $\pm 0.5^\circ\text{C}$ for water temperature measurement.
- **Ambient Compensation:** Adjusts for environmental conditions with $\pm 2\%$ accuracy. **This compensation is achieved using an integrated ambient temperature sensor and a proprietary algorithm to minimize the impact of surrounding temperature fluctuations on water temperature measurements.**
- **Latency:** Real-time data output with < 10 ms delay after sampling; PWM output reacts continuously to PID calculations.

6.2. Reliability

- Robust design ensures continuous operation in typical water heater environments.
- IP65-rated sensor probe withstands water exposure and moderate environmental stress.
- Built-in error handling flags invalid readings to maintain system integrity.

6.3. Response Time

- Temperature sampling and MQTT data transmission completed within 1 second (at 1 Hz).
- **PID calculation and PWM output update continuously based on sampling rate and controller response.**
- Configurable sampling rates allow faster response for dynamic applications.

7. Safety and Compliance

- **Electrical Safety:** Use a regulated power supply to prevent overvoltage. **Ensure proper isolation and current handling capacity for the PWM output connection to the heating element driver.**
- **Environmental Protection:** IP65-rated probe ensures safe operation in wet conditions.
- **Compliance:** CE and RoHS certified for global use.
- **Installation Note:** Follow local regulations for water heater modifications and electrical wiring.

8. Troubleshooting

Issue	Possible Cause	Solution
No data output / No PWM control	Loose connections or power failure	Check power supply and connections.
Inaccurate temperature control	Improper sensor placement; Incorrect PID tuning	Ensure the sensor probe is in good thermal contact. Adjust PID parameters (Kp, Ki, Kd) via MQTT.
No PWM output signal	Incorrect wiring to heating element driver; PWM frequency misconfiguration	Verify PWM output pin is correctly wired to the heating element driver. Check PWM frequency setting.
No MQTT data	Incorrect broker address/port, network issues, invalid topics, authentication failure	Verify network connectivity, MQTT broker settings, topic subscriptions, and credentials.
Sensor not responding	Environmental stress or hardware fault	Ensure operating conditions are within -20°C to $+60^{\circ}\text{C}$; contact supplier for further assistance.

9. Ordering Information

Part Number	Description	Availability
OU-PWM48	Smart Sensor for Water Heater Control	Contact Supplier

For pricing and availability, contact Okayama University at darma.kotama@s.okayama-u.ac.jp or authorized distributors.

10. Support and Resources

- **User Manual:** Comprehensive setup and configuration guide provided with purchase or downloadable from Okayama University Website.
- **Technical Support:**
 - **Email:** darma.kotama@s.okayama-u.ac.jp (Response within 48 hours, Monday-Friday).
 - **Phone:** [+81-86-251-7047](tel:+81-86-251-7047) (Available 9AM-5PM JST, Monday-Friday).
- **Integration Support:** For advanced integration with control systems or automation platforms, contact darma.kotama@s.okayama-u.ac.jp for guidance or custom solutions.
- **Firmware Updates:** Available through Okayama University's support portal at Okayama University Support. Register your device for update notifications.
- **Research Collaboration:** For inquiries about custom applications or research partnerships, contact Okayama University's Institute of Global Human Resource Development at info_discovery@adm.okayama-u.ac.jp.
- **Community Resources:** Access technical forums and user guides through Okayama University's Global Discovery Program for community-driven support and application examples.
- **Warranty:** 1-year limited warranty; contact darma.kotama@s.okayama-u.ac.jp for details or to initiate a claim.

Disclaimer

The OU-PWM48 Smart Sensor is a proprietary product developed in collaboration with Okayama University. Internal components and firmware are confidential to maintain competitive integrity. Specifications are subject to change without notice. For the latest updates, contact Okayama University at darma.kotama@s.okayama-u.ac.jp or visit Okayama University.