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Implementation of IoT for temperature monitoring system on combustion furnace

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ABSTRACT

Combustion equipment requires precise and continuous temperature monitoring to ensure process safety and efficiency. Manual monitoring often causes delays and a lack of real-time feedback, which increases the risk of thermal instability. To address this issue, this study proposes an IoT-based temperature monitoring system that uses affordable and open-source components. The system uses an ESP32 microcontroller and a type K thermocouple for temperature measurement. Temperature data is transmitted via Wi-Fi to a PHP-based web server, stored in a MySQL database, and displayed in real-time through a remotely accessible web interface. The development method involved system design, sensor integration, microcontroller programming, and testing. Flowcharts and block diagrams were created to define the system's behavior. The system was evaluated through sensor accuracy testing, data verification, and latency measurements. The results showed that the sensor had an error margin of less than 5% compared to a gun thermometer. Data recorded by the ESP32 matches 100% with database and web outputs. Average data transmission delay is approximately 3 seconds, indicating responsive real-time monitoring. This system demonstrates a reliable, scalable, and cost-effective solution for industrial furnace monitoring, enhancing operational safety through IoT-based automation.

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1. INTRODUCTION

Temperature monitoring in combustion furnaces plays a vital role in maintaining operational safety, thermal process stability, and preventing damage due to overheating. In many industrial settings, continuous and accurate temperature measurement is essential to ensure optimal performance and reduce the risk of equipment failure [1]-[2]. Manual temperature checks are often inefficient and cannot provide real-time updates or remote access . Operators must be physically present, and data cannot be logged continuously, which limits the ability to monitor long-term trends or detect rapid fluctuations. This becomes a critical limitation in industrial environments that require high reliability and rapid response [3]–[4].

To address these challenges, this research implements an IoT-based system for monitoring furnace temperature using an ESP32 microcontroller, which is capable of connecting to wireless networks and transmitting data over the internet [5]-[6]. A Type-K thermocouple is used as the temperature sensor, while the MAX6675 module functions as a digital converter that interfaces with the ESP32. The measured temperature values are sent to a PHP-based web server and stored in a MySQL database [7]. The web interface allows users to remotely observe furnace temperature in real time [8]–[9]. In addition, the use of a structured database enables all temperature records to be stored chronologically for later review [10]-[11]. This facilitates historical analysis, diagnostics, and documentation of furnace performance, which are essential for preventive maintenance and operational traceability.

This research contributes to the development of a low-cost and scalable solution for real-time temperature monitoring in combustion systems. By utilizing open-source hardware, the system offers a practical alternative for industries seeking affordable automation technologies.

2. METHOD

This research was conducted using a technology engineering method, which consists of several integrated phases including system analysis, component selection, programming, and testing. The primary objective is to develop a real-time temperature monitoring system for a combustion furnace using IoT principles. The system was designed based on the functional requirements of a high-temperature furnace, where precise and continuous monitoring is critical. The microcontroller ESP32 serves as the central control unit due to its integrated Wi-Fi capabilities, enabling wireless communication with the web server[12]. A Type-K Thermocouple sensor is used for high-range temperature detection in the furnace environment [13], while the MAX6675 module functions as the signal conditioning and digitization interface, converting thermocouple analog signals into digital data that can be read by the ESP32 [14].

All sensor data is then processed and transmitted by the ESP32 to a web server, which was developed using PHP and MySQL. This allows users to access real-time temperature readings from any internet-connected device through a web browser interface. To represent the overall architecture and data flow, a system block diagram is provided in Figure 1.

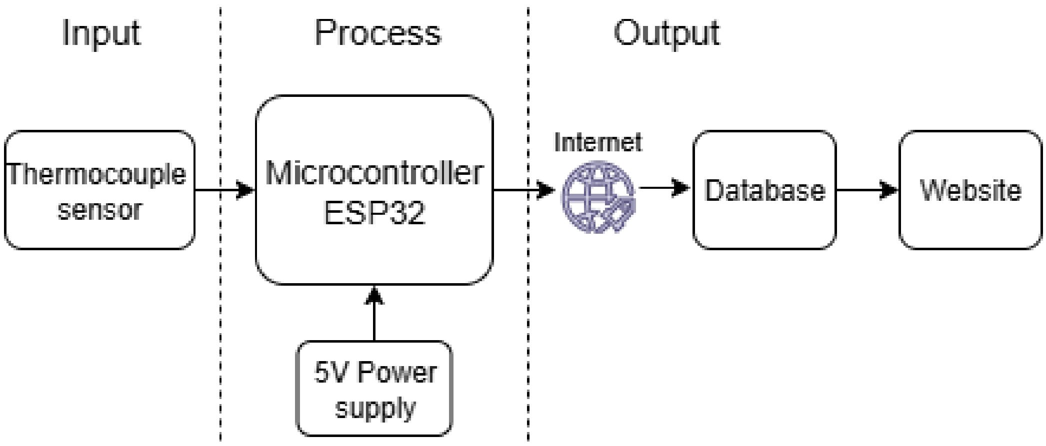

Figure 1. Block Diagram

Figure 1 shows the block diagram of the IoT-based temperature monitoring system for a combustion furnace. The system consists of three main stages: input, processing, and output. The function of each block is as follows: 1) Thermocouple Sensor: Measures high temperatures inside the furnace and generates an analog voltage signal. 2) ESP32 Microcontroller: Serves as the system's controller, processes temperature data, and sends it to the server via Wi-Fi. 3) 5V Power Supply: Provides operating voltage to the ESP32 and its connected modules. 4) Internet: Facilitates wireless communication between the ESP32 and the cloud-based server. 5) Database: Stores temperature data in MySQL format for long-term logging and access. 6) Website: Displays real-time temperature readings through a web interface accessible remotely by users.

The system architecture is designed for modularity and scalability, making it adaptable to various furnace environments. The thermocouple sensor are placed near the heat source to ensure accurate data capture, while the ESP32, positioned in a safer zone, acts as a bridge between the physical environment and the digital platform. By leveraging Wi-Fi communication, the system eliminates the need for wired data transfer, reducing installation complexity[15]. Furthermore, the use of a cloud-hosted database allows for centralized data storage, enabling future integration with analytics or alert systems [10]. This configuration ensures both real-time performance and historical data accessibility. To describe the detailed operational logic of the system, a flowchart is presented in Figure 2.

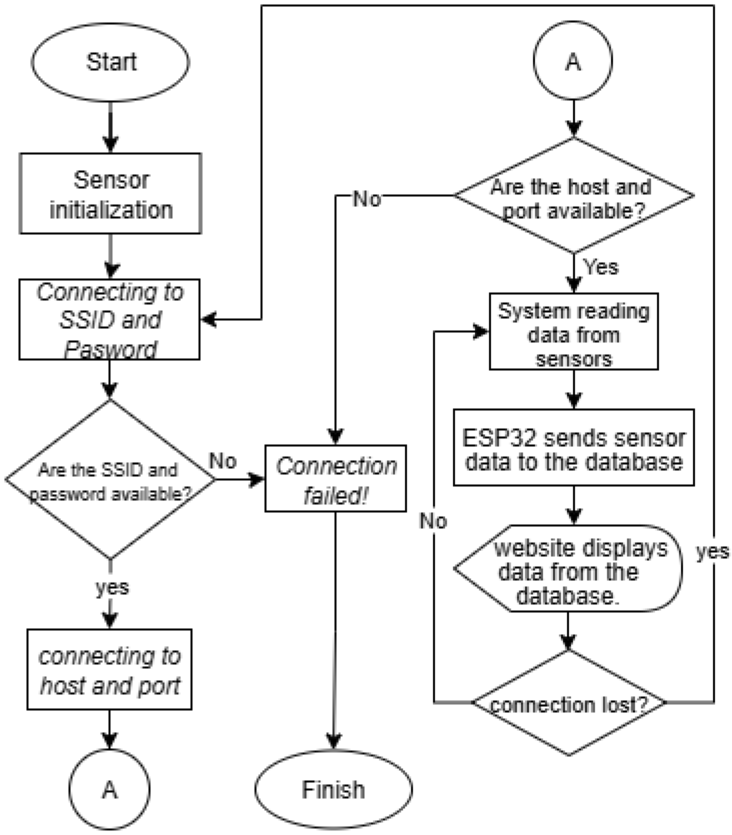

Figure 2. Flowchart System

Figure 2 illustrates the operation flow from sensor initialization, Wi-Fi connection, and host availability check, to data transmission to the database. A decision path is included to verify whether the ESP32 remains connected to the SSID and host. If successful, the ESP32 continuously sends sensor data to the web server; if not, the ESP32 displays the message "Connection failed!" and the ESP32 will attempt to reconnect to the SSID and host until the SSID and host are available again. This flowchart illustrates the automatic behavior of the system and ensures reliability through fail-safe decision-making logic. By implementing a loop based on connection availability. To visualize how the monitoring results are accessed by the user, the interface design of the IoT-based monitoring system is shown in Figure 3.

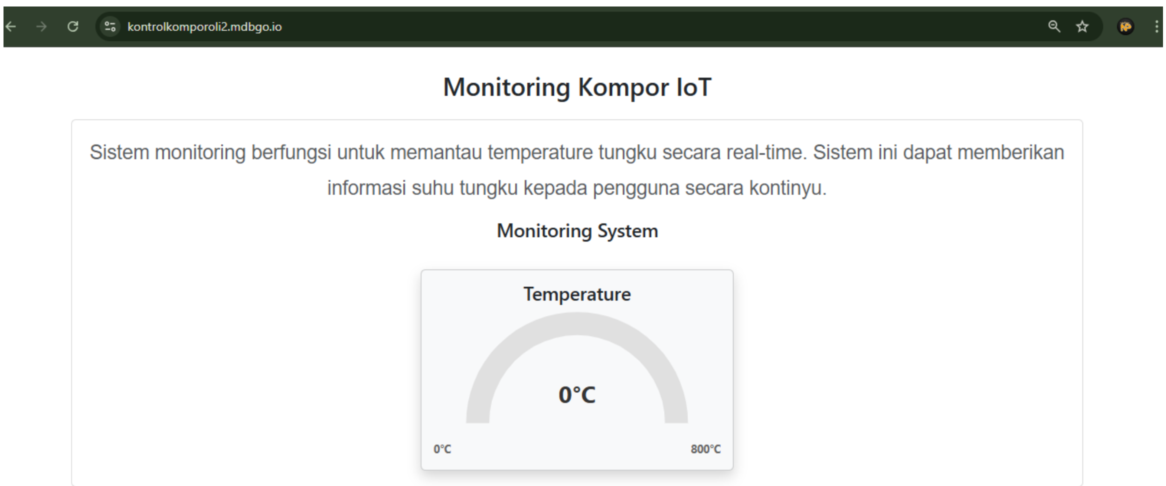

Figure 3. Website Design

Figure 3 presents the website interface built using PHP. It displays the current temperature of the combustion furnace in real time through a digital gauge. The layout is designed for clarity and mobile responsiveness. This frontend It enhances usability by enabling remote access and clear visualization. To support backend storage of sensor data, the structure of the MySQL database used in this system is depicted in Figure 4.

#	Name	Type	Collation	Attributes	Null	Default	Extra
1	**id**	int			No	*None*	AUTO_INCREMENT
2	**waktu**	timestamp			Yes	*NULL*	
3	**TEMPERATURE**	float(4,1)			Yes	*NULL*	

Figure 4. Structure Database

Figure 4 shows a three-column structure: id (auto-incremented), waktu (timestamp), and TEMPERATURE (float value). This schema design is optimized for lightweight storage, fast retrieval, and chronological data logging. The use of time-indexed records ensures accurate historical tracking, which is essential for industrial diagnostics and reporting.

3. RESULTS AND DISCUSSION

Testing the thermocouple sensor is done to determine the accuracy of the sensor in monitoring the stove temperature by comparing it with measurements using a thermogun. The results, as shown in Figure 5.

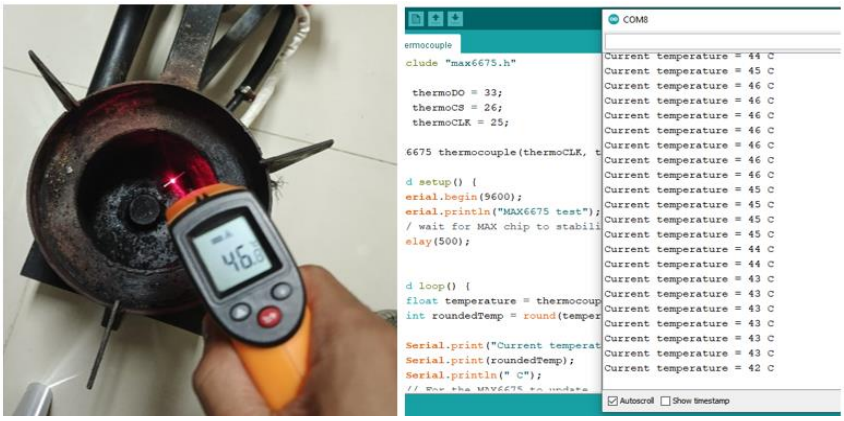

Figure 5. Measuring Temperature Between Thermocouple and Thermogun

Figure 5 shows the temperature measurement process carried out simultaneously between the thermocouple and thermogun. The results of these measurements are then compared to calculate the percentage error between the two tools. as shown in table 1.

Table 1. Thermocouple Sensor Accuracy Test Results

Test	Thermocouple temperature (°C)	Thermogun temperature(°C)	Error (%)
1	44	46	4%
2	100	103	3%
3	130	135	4%
4	154	162	5%
5	185	192	4%

The test result in table 1, demonstrate a high level of accuracy, with the error percentage remaining below 5% across all measured temperature ranges. This indicates that the thermocouple sensor is reliable for real-time temperature monitoring in the automated stove system. To ensure the reliability of the system in transmitting accurate data across all stages—ESP32, database, and web interface—the data conformity testing is presented in Table 2.

Table 2. Data Conformity Verification Testing

Test	ESP32 Data (°C)	Database	Web Display (°C)	Status
1	209.5	209.5	209.5	Matched
2	210.7	210.7	210.7	Matched
3	212.1	212.1	212.1	Matched
4	214.2	214.2	214.2	Matched
5	217	217	217	Matched

Table 2 shows the compares temperature values measured by the ESP32, stored in the MySQL database, and displayed on the web interface. All five data points show exact matches across all three stages. This outcome demonstrates that the system maintains 100% data accuracy throughout the transmission pipeline. The absence of discrepancies confirms that both the hardware (ESP32 and MAX6675) and the backend infrastructure (PHP and MySQL) are properly synchronized, ensuring data consistency. To demonstrate how the system displays temperature data in real-time, a live screenshot of the monitoring website interface is shown in Figure 6. To reinforce this validation, a comparison with temperature measurements at the site using a gun thermometer is shown in Figure 7.

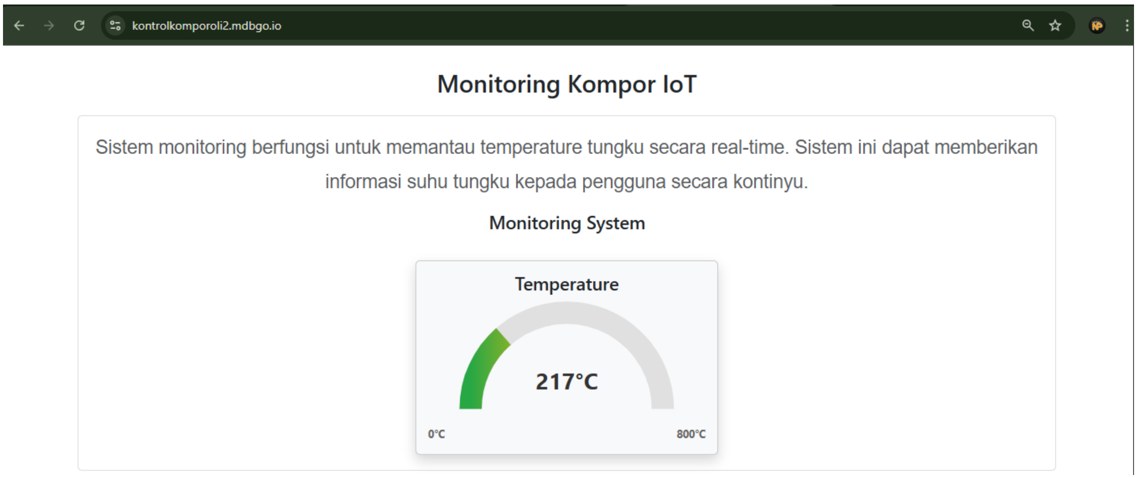

Figure 6. Real-Time Website Temperature Display

Figure 7. On-Site Temperature Measurement

Figure 6 shows the dynamic gauge display with a reading of 217°C, which corresponds to the data recorded in the database during testing. This interface provides an intuitive and easily accessible method for operators to monitor furnace conditions remotely. The reading visually matches the value behind the screen, confirming real-time data retrieval from the database. Smooth synchronization between the server and browser ensures users receive timely and accurate updates. Figure 7 presents a manual temperature measurement using a thermogun during an active furnace test, taken at the same moment as the website reading. The captured value confirms the accuracy of the displayed data on the website. To support backend data traceability, Figure 8 presents the live record entries stored in the MySQL database during system operation.

←T→				id	waktu	TEMPERATURE
☐	Edit	Copy	Delete	6	2025-07-25 17:31:24	217.0
☐	Edit	Copy	Delete	5	2025-07-25 17:31:22	214.2
☐	Edit	Copy	Delete	4	2025-07-25 17:31:20	212.1
☐	Edit	Copy	Delete	3	2025-07-25 17:31:18	210.7
☐	Edit	Copy	Delete	2	2025-07-25 17:31:15	209.5
☐	Edit	Copy	Delete	1	2025-07-25 17:31:13	207.8

Figure 8. Database Record View

Figure 8 shows The entries include temperature values ranging from 207.8°C to 217.0°C, along with precise timestamps, demonstrating that the system logs data chronologically and consistently. These entries directly correlate with the values shown in both the ESP32 output and web interface. This validates the logging function of the system and confirms the MySQL structure's effectiveness for storing and retrieving real-time data. It also allows for historical tracking, which is essential for performance analysis and fault diagnostics in industrial automation. To evaluate the latency of the system from data capture to user display, the results of the transmission delay test are presented in Table 3.

Table 3. Data Transmission Delay Test Results

Test	Data transmission time	Web latency (ms)	Data displayed	Delay (s)
1	17:31:13	210	17:31:15	2
2	17:31:15	232	17:31:18	3
3	17:31:17	219	17:31:20	3
4	07:20:19	221	17:31:22	3
5	07:20:21	227	17:31:24	3

Table 3 displays the results of the data transmission delay test, showing the time when data is sent by the ESP32. The network latency with the web server is still within acceptable limits, below 300 milliseconds. The delay remains consistent, with an average of around 3 seconds, with minor variations between 2 and 3 seconds. This low latency indicates that the ESP32 can transmit sensor data via Wi-Fi to the server and display it on the client side in near real-time. This performance falls within acceptable parameters for non-critical industrial monitoring systems, confirming the suitability of this architecture for remote temperature monitoring.

4. CONCLUSION

This research successfully demonstrates the design and implementation of a low-cost IoT-based temperature monitoring system tailored for combustion furnaces. The system integrates an ESP32 microcontroller, a Type-K thermocouple sensor. The use of a PHP-based web server and MySQL database enables real-time data logging and remote access via a web browser. System testing confirms high reliability, with sensor accuracy showing less than 5% error compared to a thermogun, and full data consistency between the ESP32, database, and website. Additionally, the measured transmission latency averaged 3 seconds, which is acceptable for real-time monitoring applications. The integration of open-source hardware and free hosting services makes this solution scalable and affordable, particularly for small and medium-sized industries. This system contributes to the advancement of digital furnace monitoring and opens possibilities for future development in remote automation and industrial IoT systems.

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