2026 Volume: 02 Issue: 05 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-06

SENSI-MUG PROMOTING SUSTAINABLE LIVING AND SMART TEMPERATURE MANAGEMENT

Dr. Sudhir P.*, Vijay K, Vinay K.M., Vinutha R.

ECE, SJCIT, Chickaballapur.

Article Received: 01 April 2026
Article Revised: 22 April 2026
Published on: 12 May 2026

***Corresponding Author: Dr. Sudhir P.**
ECE, SJCIT, Chickaballapur.

DOI: https://doi-doi.org/101555/ijrpa.4934

ABSTRACT

Maintaining the temperature of hot beverages for extended durations remains a challenge with conventional insulation-based solutions. This paper presents the design and implementation of a smart coffee mug heating system developed using the ESP32-S3 microcontroller. The proposed system continuously monitors the beverage temperature through an NTC thermistor and regulates heating using a ceramic heating element controlled by a PID- based feedback algorithm. User-defined temperature settings are provided through a rotary encoder, ensuring convenience and precision. The system activates heating only when temperature drops below the set threshold, thereby minimizing unnecessary power consumption. Wireless connectivity enables real-time monitoring and control, enhancing usability and flexibility. Experimental evaluation demonstrates stable temperature maintenance within a predefined range while ensuring safety through automatic cutoff mechanisms. The proposed solution highlights the effective integration of embedded systems and IoT technologies for energy-efficient and user-centric smart appliances.

KEYWORDS: Smart Heating System, Temperature regulation, PID control algorithm, ESP32S3 Microcontroller.

INTRODUCTION

Maintaining accurate and stable temperature control is essential in many heating and thermal regulation applications. Conventional heating systems often operate with manual control or fixed power input, which can lead to temperature fluctuations, excessive energy consumption, and safety risks due to overheating **[1]**.These limitations highlight the need for intelligent temperature control mechanisms that can adapt dynamically to changing conditions.

Advancements in embedded systems and microcontroller technology have enabled the development of smart heating solutions with real-time monitoring and automated control **[2]**.Microcontrollers integrated with temperature sensors and feedback algorithms allow precise regulation of heating elements while optimizing energy usage. The ESP32-S3 microcontroller, with its processing capability and built-in wireless communication and provides an effective platform for implementing such intelligent control systems **[5]**.

The objective of this work is to design and implement a smart temperature-controlled heating system using the ESP32-S3 microcontroller. The system continuously monitors temperature using an NTC thermistor and regulates heating through a PID control algorithm to maintain a user-defined set point. The goal is to achieve stable temperature regulation, improved energy efficiency **[3]**, and enhanced operational safety. This study demonstrates the application of embedded and IoT technologies in developing efficient and reliable temperature regulation systems

MATERIALS AND METHODS

The proposed temperature-controlled heating system is designed using the ESP32-S3 microcontroller as the main processing and control unit. The system integrates temperature sensing, control logic, power regulation, and user interaction modules to achieve stable and efficient temperature regulation **[5]**.

Materials Used:

- **Microcontroller:** ESP32-S3 development board.
- **Temperature Sensor:** NTC thermistor.
- **Heating Element:** Resistive heating element.
- **Switching Device:** Relay module.
- **Power Supply:** Regulated DC power source.
- **User Interface:** Push buttons / rotary encoder
- **Software Tools:** Arduino IDE, embedded C/C++

METHODOLOGY

The NTC thermistor is positioned in thermal contact with the heating surface to continuously measure temperature. The sensor output is connected to the analog-to-digital converter (ADC) of the ESP32-S3. The measured temperature values are processed by the microcontroller and compared with the user- defined set point.

A PID control algorithm is implemented to regulate the heating element. Based on the temperature error, the controller generates a control signal that drives the relay, enabling or disabling power to the heating element. This feedback-based control approach ensures gradual and stable temperature adjustment.

User-defined temperature settings are provided through local input controls connected to the GPIO pins of the ESP32-S3. Wireless connectivity is utilized for system monitoring and status supervision. Safety mechanisms such as temperature limit checks and automatic cut-off are incorporated in both hardware and software to prevent overheating and ensure reliable operation.

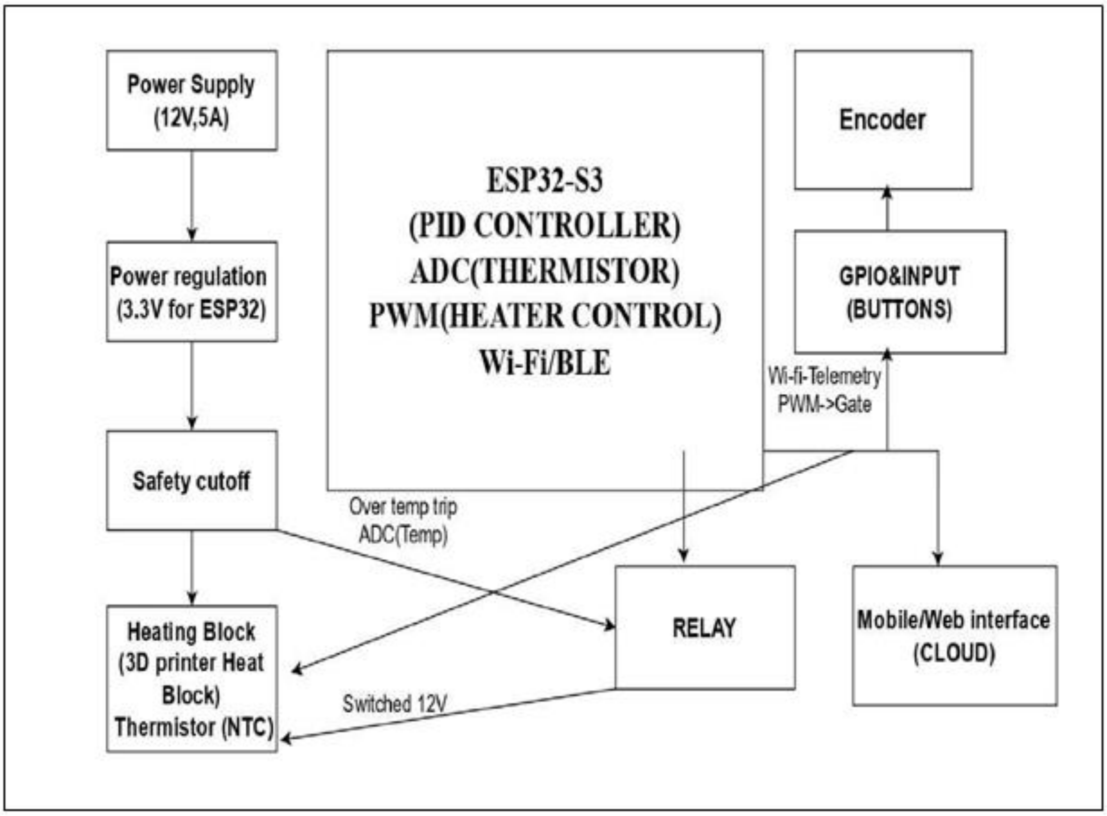

Figure 1.Block Diagram of proposed methodology.

Table 1. Hardware Requirements

Sr. No.	Component	Specification
1	Microcontroller	ESP32-S3
2	Temperature Sensor	NTC Thermistor
3	Heating Element	Resistive Type
4	Switching Device	Relay Module
5	Power Supply	Regulated DC Source

RESULT AND DISCUSSION

The performance of the proposed temperature-controlled heating system was evaluated to verify its accuracy, stability, and safety. The system was tested by setting different temperature values and observing the response of the heating element under controlled conditions. The measured temperature was continuously monitored through the NTC thermistor, and the control action was executed by the ESP32-S3 microcontroller **[4]**.

The PID control algorithm effectively regulated the heating process by adjusting the power supplied to the heating element based on real-time temperature feedback. Smooth temperature transitions were observed without sudden overshoot or oscillations. The system maintained the temperature within the desired range, demonstrating stable control performance.

Safety mechanisms were also validated during operation. When the temperature exceeded the predefined threshold, the automatic cut-off function disabled the heating element, preventing overheating. The relay- based switching ensured proper electrical isolation between high-power and low-power components. Wireless monitoring allowed real-time supervision of system status, improving usability and operational awareness.

The results confirm that the proposed system provides reliable temperature regulation with improved energy efficiency. The integration of sensor feedback, embedded control, and safety features demonstrates the effectiveness of the system for smart heating applications. Figures and tables, if included, further support the observed system performance and operational behavior.

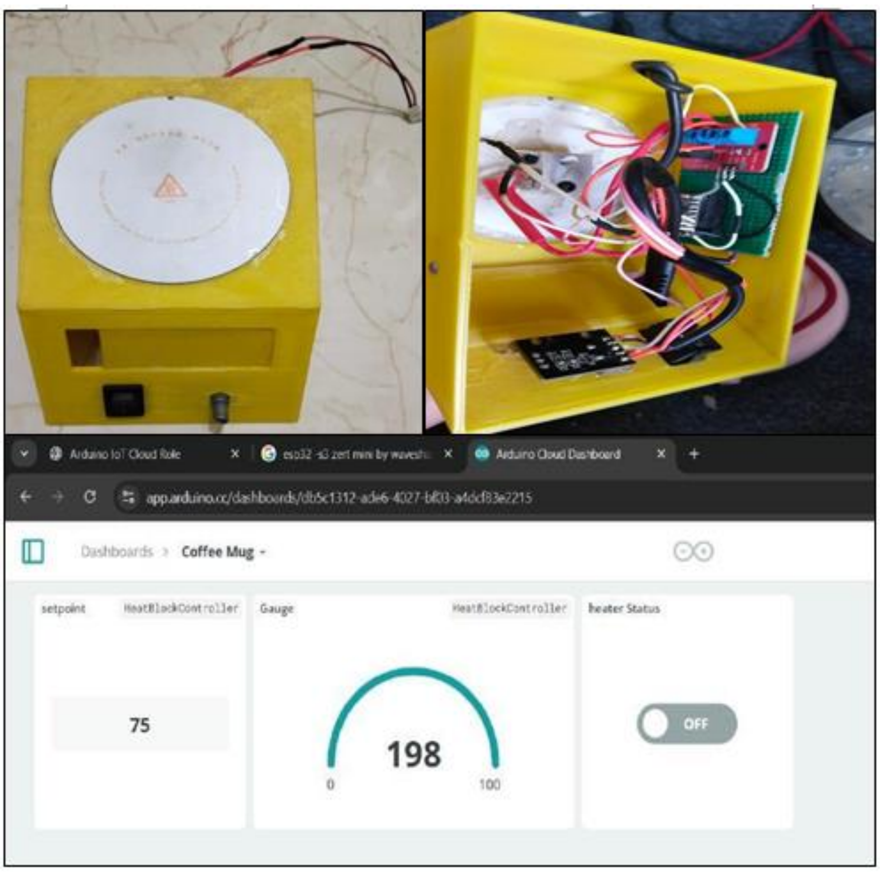

Figure 2 Prototype of the proposed methodology.

CONCLUSION

The proposed temperature-controlled heating system based on the ESP32-S3 microcontroller was successfully designed and implemented. The system demonstrated effective temperature regulation through continuous sensing and PID-based control, ensuring stable operation and improved energy efficiency. Automated control reduced unnecessary power consumption by activating the heating element only when required.

The integration of safety mechanisms such as temperature limit monitoring and automatic cut-off enhanced system reliability and operational safety. Wireless monitoring further improved usability by enabling real-time supervision of system status. The results confirm that embedded and IoT-based control techniques provide a reliable and efficient solution for smart heating applications. The developed system serves as a scalable and adaptable platform for future enhancements in intelligent temperature regulation and energy-efficient heating systems.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENT

The authors respectfully offer their pranams at the lotus feet of Paramapoojya Jagadguru Padmabhushana Sri Sri Sri Dr. Balagangadharanatha Mahaswamiji and seek the blessings of His Holiness Paramapoojya Jagadguru Padmabhushana Sri Sri Sri Dr. Nirmalanandanatha Mahaswamiji and Poojya Sri Sri Mangalanath Swamiji for their divine guidance and inspiration.

The authors express their sincere gratitude to **Dr. G. T. Raju**, Principal, SJC Institute of Technology, Chikkaballapur, for his continuous support, encouragement, and for providing the opportunity to carry out this project work. The authors would like to thank **Dr. C. Rangaswamy**, Head of the Department, Electronics and Communication Engineering, SJC Institute of Technology, Chikkaballapur, for his valuable guidance and support throughout the project.

Special thanks are extended to **Dr. Sudhir P**, Associate Professor and Project Coordinator, Department of Electronics and Communication Engineering, SJC Institute of Technology, Chikkaballapur, for his constant guidance, motivation, and constructive suggestions, without which this work would not have been possible. The authors also acknowledge the support and cooperation of all the faculty members and staff of the Department of Electronics and Communication Engineering.

Finally, the authors express heartfelt gratitude to their parents and friends for their continuous encouragement and support during the successful completion of this project work.

REFERENCES

1. Sharma A, Singh P. Design of an embedded temperature control system using feedback regulation. Int J Embedded Syst Appl. 2021;9(2):45–51.
2. Kazim K, Verma R. IoT-based temperature monitoring and control using ESP32 microcontroller. Int J Smart Technol. 2022;6(3):112–118.
3. Perumal S, Vadivel R. Implementation of sensor-based heating control systems for energy efficiency. J IoT Appl. 2023;5(1):28–34.
4. Hercog M, Novak T. Embedded system architectures for real-time temperature regulation. IEEE Internet Things J. 2022;9(14):11890–11897.
5. Espressif Systems. ESP32-S3 technical reference manual [Internet]. 2023 [cited 2024 Jan 10]. Available from: https://www.espressif.com