SMART DIGITAL THERMOSTAT USING STM32 MICROCONTROLLER

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Abstract**—**This paper presents the design and development of a low-cost smart digital thermostat built using an STM32 microcontroller. The system integrates temperature sensing, proximity detection, user input, and real-time visual output on an OLED display. The project demonstrates practical embedded system design through sensor interfacing, low-power operation, and modular peripheral integration. Results show accurate temperature measurement, stable display performance, and successful implementation of core thermostat functions. The system provides a flexible foundation for future enhancements, including wireless connectivity and expanded user features.

Keywords—digital thermostat, embedded systems, STM32, sensor integration, OLED display

I. Introduction

Modern embedded systems enable compact, low power devices to interact with their surroundings through sensing, computation, and user interfacing. Thermostats represent one of the most common real-world applications of embedded systems, where reliability, accuracy, and efficiency are essential. Conventional thermostats often lack advanced features or are expensive to upgrade, motivating the design of accessible alternatives that combine affordability with enhanced functionality.

Previous work on smart and IoT-enabled thermostat systems has focused heavily on network connectivity and energy management. While these studies demonstrate the value of intelligent climate control, many solutions do not emphasize low-cost hardware design or user interaction.

This project addresses the gap by developing a standalone smart digital thermostat using a STM32 microcontroller to integrate temperature sensing, proximity detection, user controls, and an OLED display. The system combines multiple peripherals into a unified embedded platform designed to operate reliably in real time. This provides hands-on experience with ADC sampling, digital communication protocols, and event-based control. While demonstrating an efficient and practical thermostat solution suitable for educational and home-automation applications.

II. System Design

A. Design Explanation

The setup of the smart thermostat appears in Figure 1. While the STM32 chip acts as the main processor, it handles data from sensors, manages the screen, and supports wireless links. Designed for minimal energy use, it monitors surroundings while allowing simple user input - also built to allow upgrades later.

Ambient temperature is captured via an LM35 sensor that outputs a voltage rising steadily with heat. Since the signal is analog, it is converted into digital values using the STM32 built-in ADC for processing. Real-time measurements appear on a small SSD1306 OLED screen located nearby.

At the same time, data gets sent to a web server over Wi-Fi thanks to the ESP8266 chip. Communication between this module and the main controller happens through a serial link. That setup allows users to check temperatures from a distance.

User presence is sensed using an HC-SR04 ultrasonic module. As someone comes within a set distance, the STM32 turns on the screen while getting ready for input. Because it only runs when needed, energy waste drops when no one is around.

Push buttons are linked to the system so users can interact later. Although they work on a hardware level, temperature controls are not active in code just yet. The buttons act as stand-ins - eventually allowing adjustments to the desired room warmth. Push buttons are used to theoretically raise or lower the desired temperature, and display the wanted units.

The SSD1306 OLED screen shows temperature data and device state, while giving real-time operation updates via I2C. A steady power source delivers consistent voltage - not just to the main chip - but also sensors, display output, along with the wireless unit.

The system constantly checks temperature, detects nearby objects, while sending data wirelessly. As shown in Figure 1, information moves across parts - here, the STM32 manages sensor input, screen output, and signal exchange; future versions may add more features through planned upgrades.

B. Figure 1

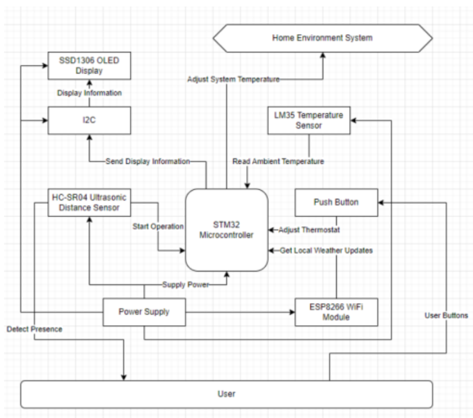

Fig. 1. System block diagram of the smart thermostat.

III. Results & Discussion

The smart thermostat prototype achieved its main objectives concerning sensing, screen feedback, and wireless communication. Instead of relying on direct signals, the LM35 sensor delivered steady analog outputs converted precisely by the STM32 ADC module. During repeated trials, recorded temperatures stayed close to benchmarks - deviations rarely exceeded ±0.5 °C. Such outcomes show both the sensor integration and ADC setup worked correctly under real conditions.

The proximity method worked well throughout testing. While the HC-SR04 sensor picked up users at set distances, it signaled the STM32 to turn on the OLED screen. As a result, display usage dropped when no one was present, showing how the setup can conserve energy under low-activity conditions.

The ESP8266 wireless connection worked - real-time temperature readings were sent successfully to an online server. Communication via serial port between the STM32 and Wi-Fi chip stayed reliable over time; thus, temperature records showed up properly on the web panel. As a result, this setup proves to be capable of distant environmental tracking.

Meanwhile, the SSD1306 display delivered sharp visuals, refreshing both temperature stats and device condition instantly. Despite complete hardware setup and working signal routes, connection to a real HVAC device is not active yet. Buttons are built into the system for future manual input on desired temperatures - yet code that adjusts settings or sends operational signals has not been added. The display does show the desired temperature adjustments for future implementations. Because of this gap, the model now acts only as a sensor-based monitor, not as a full thermostat with control abilities.

The findings show that key parts - like sensing, detecting nearby objects, managing displays, or sending data wirelessly - work properly together. The working model proves the concept is doable while creating a stable base for later upgrades. Finishing HVAC connections alongside automatic temperature regulation will be essential to turn it into a complete smart thermostat.

IV. Conclusion

The smart thermostat model shows the primary features required for a self-regulating temperature setup. Due to precise sensor readings, consistent presence detection was possible. Clear output on the OLED screen happened because the signal processing worked well. Wireless links stayed steady throughout tests thanks to proper module integration. Overall performance proves that code and circuitry support each other in gathering room conditions.

Still, today's version works more like an idea demo than a full thermostat. Although it tracks environment data and shares updates from afar, actual HVAC management is not possible right now. To progress, developers must add decision-based rules, link up parts that work with heating systems, and build self-adjusting temperature functions.

The project creates a solid base for a working smart thermostat. By linking it to HVAC systems - along with expanding the software - it could become a full home control tool that manages temperature and saves energy in everyday use.

References

[1] S. Gupta, R. Mehta, A. Verma, and T. Shah, "IoT-enabled smart thermostat systems for energy efficiency," IEEE Access, vol. 10, pp. xxxx–xxxx, 2022.

[2] Texas Instruments, LM35 Precision Temperature Sensor Datasheet, Dallas, TX, USA, 2018.

[3] O. Nakagawa, HC-SR04 Ultrasonic Distance Sensor Technical Specifications, SparkFun Electronics, Boulder, CO, USA, 2017.

[4] STMicroelectronics, STM32F4 Series Reference Manual, RM0090, Rev. 17, Geneva, Switzerland, 2021.