Smart Electric Stove

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***Abstract*—In recent years, the demand for automation in kitchen appliances has significantly increased due to the growing interest in smart home technologies. This project presents the design and implementation of a Smart Electric Stove based on the ESP32 microcontroller, aimed at improving the efficiency, safety, and convenience of cooking processes. The system is designed to automatically turn off the heater once the cooking process is complete, thereby preventing food overcooking and saving energy. Key features include dual-mode operation (manual and automatic), pulse-based whistle detection using an IR proximity sensor, and real-time IoT monitoring via the Thing Speak platform**

***Index Terms*—Smart Electric Stove, ESP32, IoT, Cooking, Thing Speak**

I. INTRODUCTION

Smart home technologies have driven a significant surge in demand for kitchen appliance automation to enhance daily efficiency and safety. In modern households, the kitchen serves as a primary area where embedded systems can reduce human error and improve energy management. A critical component of many traditional diets involves the use of pressure cookers, which require precise monitoring of temperature, time, and whistle counts to achieve consistent results.

The conventional approach to this process is entirely manual. Users must physically supervise the stove to prevent food overcooking or spoilage a practice that is time-consuming and prone to inconsistency. This reliance on manual intervention presents three principal challenges. First, it is human-dependent, requiring constant attention that is often difficult to maintain in busy lifestyles. Second, it is inefficient, as basic electric or gas heaters lack the precision to regulate temperature accurately, leading to energy wastage. Third, safety risks are heightened when users forget to manually switch off the device, potentially leading to accidents.

This paper addresses these challenges through an integrated smart system designed around the ESP32 microcontroller. The proposed Smart Electric Stove automates the cooking cycle by combining real-time sensor feedback with intelligent control logic.

The contributions of this work are as follows:

- A multi-mode intelligent cooking platform that supports both manual temperature/time settings and an automatic mode based on pressure cooker whistle detection.
- A precision power-regulation system utilizing a Solid-State Relay (SSR) for Pulse Width Modulation (PWM)-based dimming of the heating coil.
- An automated sensing framework incorporating an IR proximity sensor to count whistles and a real-time 20x4 I2C LCD for user feedback.
- IoT-enabled remote monitoring via the ThingSpeak cloud platform, allowing users to track temperature, duty cycle, and cooking status from any internet-connected device

II. LITERATURE SURVEY

Recent research relevant to this project spans three primary domains: intelligent kitchen automation, renewable energy integration, and IoT-based monitoring systems.

Saleem [1] established that a fuzzy logic-based retrofit system can significantly enhance the energy efficiency of conventional electric stoves by dynamically optimizing heating behavior based on cooking parameters. While effective for minimizing wastage, such systems often lack the remote accessibility required for modern smart homes. Hossain et al. [2] introduced a solar-powered double-coil electric stove utilizing an MPPT (Maximum Power Point Tracking) controller to integrate renewable energy with smart temperature control. This approach demonstrates the technical feasibility of environment-friendly cooking solutions but requires specific hardware for solar-to-DC conversion The integration of low-cost microcontrollers has been a significant trend in the literature. Yulianto et al. [3] further expanded on infrastructure by implementing Advanced Metering Infrastructure (AMI) for induction stoves, enabling real-time power consumption tracking and utility transparency a concept that informs the data logging requirements for connected appliances LPG. Yulianto et al. [4] further expanded on infrastructure by implementing Advanced Metering Infrastructure (AMI) for induction stoves, enabling real-time power consumption tracking and utility transparency a concept that informs the data logging requirements for connected appliances

In [5], presented the integration of low-cost microcontrollers has been a significant trend in the literature. Mohan and Ganesan presented an IoT-enabled smart cooking system using the ESP8266, highlighting how real-time sensor data can be transmitted to cloud platforms. Similarly, Kumar and Singh [6] discussed the post-harvest spreading and turning of sun-drying crops Furthermore, quality grading during drying remains sub-jective. This project addresses both gaps by combining a specialised stirring robot with an objective DL-based grading pipeline.

A. Gap Analysis

The literature reveals a significant gap: while general kitchen automation and energy monitoring have been explored, there is a distinct absence of affordable, integrated systems specifically designed to automate pressure-based cooking by detecting mechanical cooker whistles. This project addresses this gap by combining automated temperature control with a proximity-based pulse counting mechanism and real-time ThingSpeak IoT monitoring presented an IoT-enabled smart cooking system using the ESP8266, highlighting how real-time sensor data can be transmitted to cloud platforms to reduce manual supervision. Similarly, Kumar and Singh discussed an embedded-system-based approach to kitchen automation, emphasizing how sensors and relays can simplify routine tasks while improving safety.

III. SYSTEM REQUIREMENTS

Table 1 and 2 summarizes the hardware and software components selected for this system.

A. Hardware Requirements

Table 1. Hardware Requirements

Component	Role and Rationale
ESP32 Microcontroller	Main controller that processes all peripheral inputs (potentiometers, sensors, buttons) and executes the display and heating logic.
Solid State Relay (SSR)	Provides smooth, silent AC heating control via PWM signals from the ESP32, handling up to 240V AC.
Potentiometers (2 units)	Used as an intuitive control interface to set manual mode temperature (1–100%) and cooking duration (1–30 s).
IR Proximity Sensor	Detects pressure cooker whistles by sensing lid movement, enabling automated pulse-based cooking.
20×4 I2C LCD	Displays real-time parameters including system mode, current temperature, remaining time, and whistle progress.
Heating Coil	The primary heating element (1000–1500W) controlled by the SSR and ESP32 system.

B. Software Requirements

Table 2. Software Requirements

Software/Platform	Purpose / Usage
Arduino IDE	Primary environment for writing, compiling, and uploading C++ firmware to the ESP32 microcontroller.
ThingSpeak IoT Platform	Cloud-based service used to visualize real-time sensor data (temperature, mode, duty cycle) through live charts.
KiCAD	Open-source EDA suite used for designing the circuit schematics and PCB layout for the stove system.
ESP32 Board Manager	Required to add ESP32 libraries, Wi-Fi functions, PWM, and GPIO handling support.

IV. METHODOLOGY AND DESIGN

A. System Architecture

The system follows a three-layer hierarchical architec-true:

I. Input Layer: Users provide three critical parameters: temperature settings, cooking time, and whistle counts. These are input via potentiometers or digital buttons and sent to the central controller.
II. Processing Layer: The ESP32 microcontroller serves as the brain of the system, receiving inputs and managing data flow. It calculates mapped conversion formulas for temperature and time and manages the logical switching points for the heater.
III. Output Layer: This layer includes a 20x4 I2C LCD for real-time status display and a Solid-State Relay (SSR) module that activates the heating coil based on microcontroller signals.

B. Control Logic and Communication Protocol:
The Smart Electric Stove operates through a sequential control algorithm to ensure automated precision:
Cooking Logic: A countdown timer or a proximity sensor monitors the progress. The proximity sensor detects lid vibrations or sound pulses to increment the whistle count.
IoT Integration: The ESP32 uses built-in Wi-Fi to transmit real-time data including operating mode, temperature, duty cycle, and whistle count to the Thing Speak cloud platform. This allows for remote supervision and live chart visualization of cooking behavior.

C. Electronic Circuit Design
The circuit integrates high-voltage AC control with low-voltage DC logic. The ESP32 triggers a specific channel in the relay module, which connects to a TRIAC-DIAC circuit for smooth zero-cross switching of the 1000–1500W heating coil. A power supply module regulates 230V AC down to 5V and 3.3V rails for the sensors and microcontroller.

Table 3. Key Arduino Mega Pin Assignments.

Function	Driver/Component	Pin
I2C Data Line (SDA)	20x4 LCD	GPIO 21
I2C Clock Line (SCL)	20x4 LCD	GPIO 22
PWM Heater Control	Solid State Relay	GPIO 18
Whistle Detection	IR Proximity Sensor	GPIO 27
Temperature Input	Potentiometer 1	GPIO 32 (ADC)
Time/Pulse Input	Potentiometer 2	GPIO 34 (ADC)
Preset Dish Selection	Push Buttons (4)	Various GPIO

V. IMPLEMENTATION, TESTING, AND RESULTS

A. Firmware Implementation
The firmware is written in C++ using the Arduino IDE. It features a non-blocking logic that allows simultaneous sensor reading, LCD updates, and IoT data transmission. Manual mode utilizes potentiometer mapping to set parameters, while automatic mode relies on debounced signal detection from the proximity sensor for whistle counting.

B. System Testing
- Hardware Stability: Voltage measurements at the ESP32 VCC pin remained stable at approximately 4.7V, ensuring reliable peripheral power.
- Response Accuracy: Potentiometer inputs were successfully mapped to 12-bit ADC values (0–4095), providing smooth temperature and time selection.
- Operational Validation: Testing confirmed that once the cooking condition is met, the relay cuts off power to the coil immediately, displaying a "Cooking Done" message.

C. Results and Discussion
The system demonstrated precise power regulation through SSR-based PWM control. The IoT dashboard on Thing Speak successfully mirrored real-time hardware values, validating the synchronization between the stove and the cloud

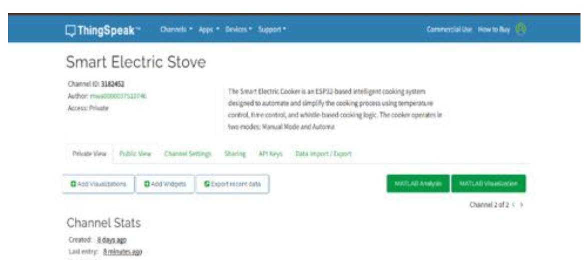

Figure 1. Smart Electric Stove Control Interface


Figure 2. Front view of the final assembled Smart Electric Stove

Figure 3. Temperature Monitoring in Thing Speak

In this Fig 3 represents the temperature set by the user or the preset temperature in automatic mode. It shows how temperature values change during different cooking cycles. By monitoring this graph, you can confirm whether the Stove is receiving correct temperature inputs and maintaining stable temperature control during operation

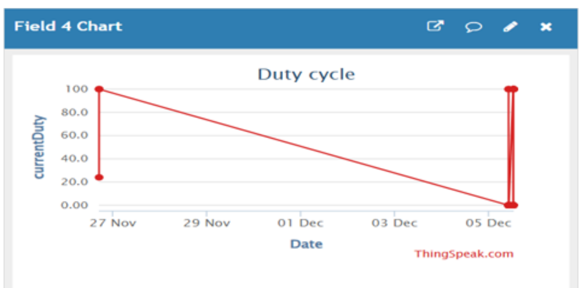

Figure 4. Duty Cycle Monitoring in ThingSpeak

In this Fig 4 chart displays the duty cycle of the heating element controlled by PWM or relay switching logic. It indicates how much power is being delivered to the heating coil at any moment. A higher duty cycle means the Stove is heating more aggressively, while a lower value means reduced heating. This helps analyze whether the Stove is regulating heat properly according to temperature settings.

Figure 5. Whistle Count Monitoring in ThingSpeak

In this Fig 5 shows the number of whistles detected over time by the proximity sensor. It helps you verify if the whistle detection mechanism is functioning accurately and if the Stove is updating the count correctly. This is crucial for automatic mode, where the cooking process ends after the target number of whistles.

Figure 6. 29% Duty Cycle

In Fig 6 When the temperature reaches 317°C, the duty cycle is increased to 29%. The oscilloscope reflects this change by displaying a square wave with a short "on" period (pulse). This confirms that the system is actively supplying controlled power to the heating element.

Figure 7. 45% Duty Cycle

In Fig 7 As the temperature climbs to 349°C, the system further increases the power output, resulting in a duty cycle of 45%. The waveform on the oscilloscope shows a visibly wider pulse compared to the previous case, indicating a longer "on" time and more power being delivered.

Figure 8. 54% Duty Cycle

In Fig 8 At the highest recorded temperature of 417°C, the duty cycle is at 54%. The oscilloscope waveform shows a correspondingly wide pulse, occupying more than half of the cycle period.

VI. CONCLUSION

This paper presented a Smart Electric Stove project that successfully demonstrates the seamless integration of hardware and software to automate cooking operations based on user-defined parameters. By enabling users to set temperature, time, and whistle counts, the system offers an intelligent solution for preparing pressure-based recipes like rice and dal. The project successfully bridges the gap between traditional cooking requirements and modern embedded system technologies, ensuring accuracy, safety, and efficiency. The system's reliable performance and the successful synchronization of real-time data with the Thing Speak IoT platform confirm the viability of its components for practical smart kitchen deployment.

VII. FUTURE WORK

- Mobile App Control: Development of a dedicated mobile application to provide a more user-friendly interface for remote control and monitoring.
- AI-Based Recipe Suggestions: Integration of artificial intelligence to suggest cooking parameters based on specific dish selections and user preferences.
- Wireless Control Enhancements: Expanding the use of ESP32's built-in Bluetooth and Wi-Fi for complete wireless integration within smart home ecosystems.
- Scalability for Industrial Use: Adapting the automated heating and monitoring logic for large-scale commercial kitchens and laboratories.
- Advanced Power Management: Further optimizing PWM-based dimming and SSR switching to maximize energy savings during long cooking cycles.

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