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LOW-COST AUTOMATIC TIMER SYSTEM ADAPTED TO COOKING APPLIANCES

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ABSTRACT

This study presents the development and implementation of a low-cost automatic timer system specifically adapted for cooking appliances. Recognising the growing need for user-friendly and efficient cooking solutions, the system aims to enhance culinary experiences by automating timing functions for various cooking processes. Leveraging microcontroller technology and sensor inputs, the system offers precise timing control, ensuring optimal cooking results while minimising user intervention. It employs the ESP32 microcontroller, which is programmed to trigger a relay actuator ON or OFF according to the input received from the timer circuit. It is equipped with a 16x2 LCD to monitor the timing sequence in conjunction with an IoT app that can be used to also control and monitor the timer system. The automatic timer system offers versatility and ease of use for a wide range of cooking scenarios and appliances. This research contributes to the field of smart kitchen technology, emphasising the importance of affordability and accessibility in the development of automated solutions for everyday cooking tasks. Future work will focus on expanding the system's capabilities, including integration with smart home technologies and additional cooking functionalities.

Keywords: Microcontroller, ESP32, Relay, IoT, Timer system, LCD

INTRODUCTION

Automated timer systems have become a vital component in modern cooking appliances, enhancing convenience, safety, and efficiency. These systems are normally incorporated into both domestic and commercial cooking apparatus to control the cooking process with utmost concern for time and safety mechanisms (Ucheoma *et al.*, 2020)

In recent days, kitchen-based accident has increased in both commercial kitchens and domestic kitchens. These accidents can be avoided using IOT technologies like monitoring the entire kitchen remotely (Banka *et al.*, 2024). Automatic timer systems for cooking represent a promising avenue for innovation in the culinary domain, offering advanced functionalities, monitored safety, connectivity features, and user-centred design principles to enhance convenience, efficiency, reduce accidents and provide precision in meal preparation. By integrating IoT technology, machine learning algorithms, and intuitive user interfaces, these systems have the potential to revolutionise culinary practices and improve the overall cooking experience for users.

A review of existing literature on automated cooking and timer-based kitchen systems reveals significant progress in the use of microcontrollers, IoT platforms, and safety mechanisms for improving cooking efficiency and reducing kitchen accidents. Several studies have demonstrated timer-controlled cookers, gas shut-off systems, and smart kitchen monitoring solutions incorporating remote access and basic automation.

Ajibola *et al.* (2020) developed an Arduino-based electric cooker timer system that allowed users to predefine operating times using a keypad and LCD interface. While their system demonstrated energy efficiency and reliability, it lacked IoT connectivity and remote monitoring capabilities, limiting user flexibility. The present study extends this work by integrating wireless IoT functionality through the ESP32 platform, enabling real-time remote monitoring and control via a mobile application.

Amuta *et al.* (2024) focused on an automated gas cooker system incorporating solenoid valves, safety alarms, and gas leakage detection. Although robust in safety features, their system is appliance-specific and relatively costly due to specialised gas control components. In contrast, the proposed system is appliance-agnostic and relay-based, allowing it to be used with various cooking appliances at a significantly lower cost. Bautista *et al.* (2023) and Singh *et al.* (2021) provided comprehensive reviews of automated cooking systems, highlighting benefits such as operational efficiency and reduced energy waste. However, these works largely addressed high-level system architectures and future directions without offering implementable, low-cost prototypes. The present research contributes a fully implemented and tested prototype that directly addresses affordability and ease of integration. Shah *et al.* (2022) proposed a smart kitchen monitoring framework using IoT for real-time supervision. While effective for monitoring, their approach emphasised environmental sensing rather than precise time-based appliance control. The proposed timer system complements such monitoring solutions by providing deterministic, RTC-driven automation with verified timing accuracy.

However, most of these systems suffer from high implementation costs, limited adaptability across different cooking appliances, and restricted accessibility for low-income users, particularly in developing regions. Furthermore, many IoT-enabled cooking systems emphasise advanced features such as temperature optimisation, gas leakage detection, or AI-driven cooking intelligence, which increase system complexity and cost, thereby limiting real-world adoption. There is also a noticeable lack of research that combines low-cost hardware, precise real-time clock-based timing, local user interfaces, and remote IoT monitoring into a single, compact, and appliance-agnostic solution.

The primary aim of this research is to design, develop, and evaluate a low-cost IoT-enabled automatic timer system for cooking appliances that enhances cooking safety, precision, and user convenience while remaining affordable and accessible. Specifically, the study seeks to leverage the ESP32 microcontroller, a real-time clock (RTC) module, relay-based actuation, and a dual-interface control system (push buttons and mobile application) to provide accurate time-based control of cooking appliances. The research also aims to experimentally validate the system's performance in real cooking scenarios, assess its timing accuracy, reliability, and user responsiveness, and demonstrate its suitability for domestic kitchen environments. By emphasising simplicity, affordability, and adaptability, the study intends to advance smart kitchen technology beyond complex and expensive solutions toward practical, real-world deployment.

MATERIALS AND METHODS

System Architecture

This project creates a low-cost and reliable timer system by using a microcontroller board, a real-time clock module, and an LCD. The system is controlled by an ESP32 board, which is the heart of the system.

The system architecture consists of three main components: the ESP32 board, the RTC module DS3231, and the 16x2 LCD. The ESP32 board is a low-cost microcontroller board with a built-in Wi-Fi module that can be programmed using Arduino IDE. The RTC module DS3231 is a highly accurate real-time clock module with an integrated temperature sensor and battery backup. The 16x2 LCD is a liquid crystal display module that can show alphanumeric characters and symbols.

The architecture diagram, as shown in Figure 1, provides a visual representation of the project's structure and the interactions of its components - the ESP32, RTC timer module, LCD, relay module, and push buttons. It outlines the data flow and the communication protocols among these components. Figure 1 shows the system architecture diagram.

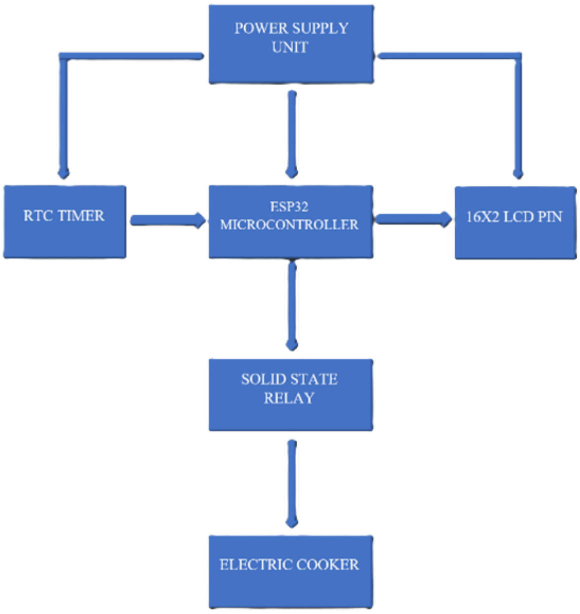

Figure 1: The system architecture diagram

Working Principle

The ESP32 board acts as the brain of the system and is programmed using the Arduino IDE with C++. It works with the RTC module, an LCD, and a relay module by using GPIO pins and the I2C protocol. The RTC module keeps track of the current time and date, even when the ESP32 is turned off, using its DS1307 chip, a reliable, low-power real-time clock with battery backup (Owoeye *et al.*, 2024).

The LCD shows the current time, date, and the status of the relay module. It's a 16x2 character display with a backlight and is controlled using the Liquid Crystal library. The relay module, on the other hand, is in charge of turning external devices, like lamps, fans, or heaters, on or off based on the timer settings. It's a 5V, 2-channel relay with optocoupler isolation, capable of handling up to 10A of current. It can be activated or deactivated by sending a HIGH or LOW signal to its input pin.

The system also includes push buttons on the ESP32 board that serve to adjust the timer. It can easily increase or decrease the hours, minutes, or seconds, and it can also toggle the On/Off setting to decide if the relay should activate when the timer matches the current time.

In summary, the ESP32 regularly checks the time and date from the RTC module and compares it to the timer settings. Depending on the match, it sends a signal to control the relay module. At the same time, it updates the LCD with all the relevant information on the current time, timer settings, and relay status for easy monitoring. To keep things efficient, the ESP32 includes a timer interrupt feature that resets the system after a certain period. This ensures the system doesn't run indefinitely and waste unnecessary power. Figure 2 shows the circuit diagram of the system.

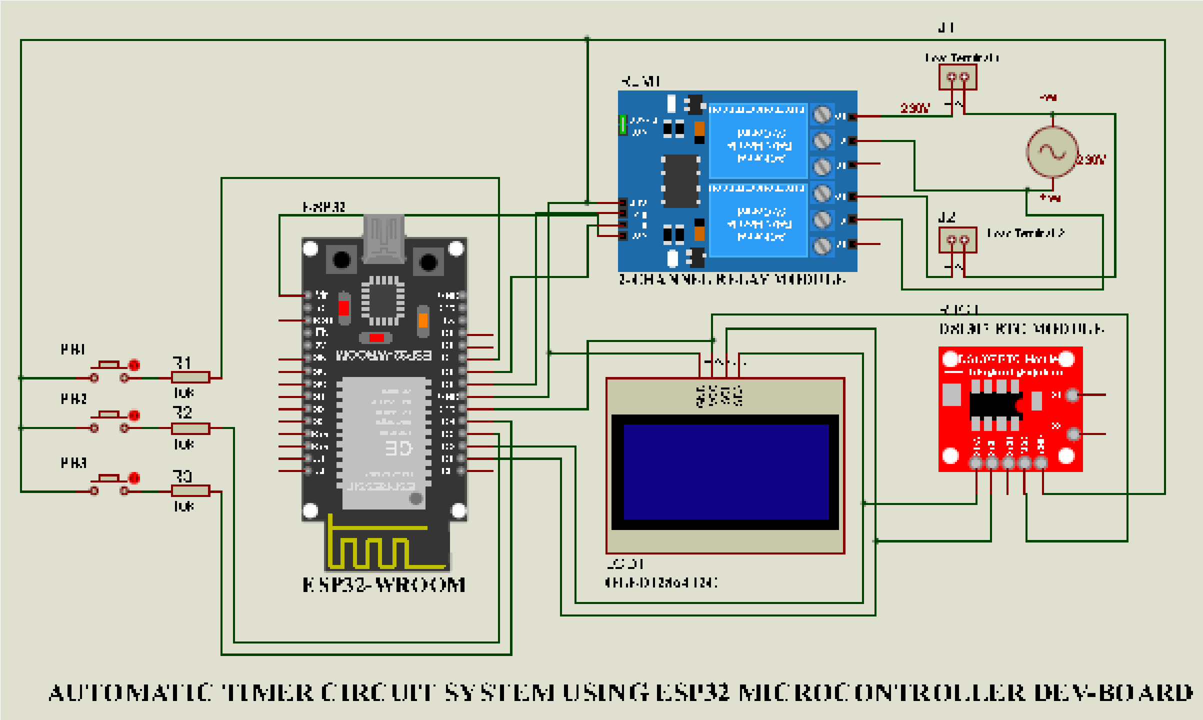

Figure 2: The circuit diagram of the designed system

Hardware Design

The hardware configuration involves using all the hardware accessories, which comprise a computer system, a programming kit, the electronic modules such as the DS1307 RTC module and relay module, an electrical component integrated development environment, and all other peripheral devices, as well as the circuit board, where we have the power supply unit.

The hardware unit is also connected with the real-time clock device, which sets the time using a real-time update. The microcontroller will process all data received from the RTC and transmit it to the 16x2 LCD, which displays the current time. Then the microcontroller will send input to the relay module to power on the electrical appliance.

The hardware design of the automatic timer system using ESP32 is as follows:

- The ESP32 board is the main controller of the system. It is a low-power, dual-core microcontroller with built-in Wi-Fi and Bluetooth. It can be programmed using Arduino IDE or other compatible platforms.
- The RTC module is used to keep track of the current time and date, even when the ESP32 board is not powered. It uses a DS1307 chip, which is a low-power, serial real-time clock with battery backup. It communicates with the ESP32 board using the I2C protocol, which requires two wires: SDA (data) and SCL (clock).
- The LCD is used to show the time and date, as well as the status of the relay module. It is a 16x2 character LCD with a backlight, which can be controlled using the Liquid Crystal library. It connects to the ESP32 board using six wires: RS (register select), EN (enable), D4-D7 (data), and V0 (contrast).
- The relay module is used to switch on or off an external device, such as a lamp, fan, or heater, according to the timer settings. It is a 5V, single-channel relay module with optocoupler isolation, which can handle up to 10A of current. It connects to the ESP32 board using three wires: VCC (power), GND (ground), and IN (signal).

Blynk IoT App

It has several fascinating features, including remote hardware control, sensor data display, data storage, data visualisation, and much more. The platform consists of three main parts:

- The Blynk app allows the use of offered widgets to create stunning interfaces for the project.
- All of the communications between the smartphone and hardware are handled by the Blynk Server. Utilising the Blynk Cloud, the project operates a local server for its transmission. It can run on a Raspberry Pi, is open-source, and can easily handle thousands of devices.
- Libraries in Blynk: – It allows all of the widely used hardware platforms to communicate with the server and processes all incoming and outgoing commands.

When a user hits the button in the Blynk application, data is transferred to the Blynk Cloud and then somehow makes its way to the installed hardware. A simple representation of the Blynk IoT App is shown in Figure 3.

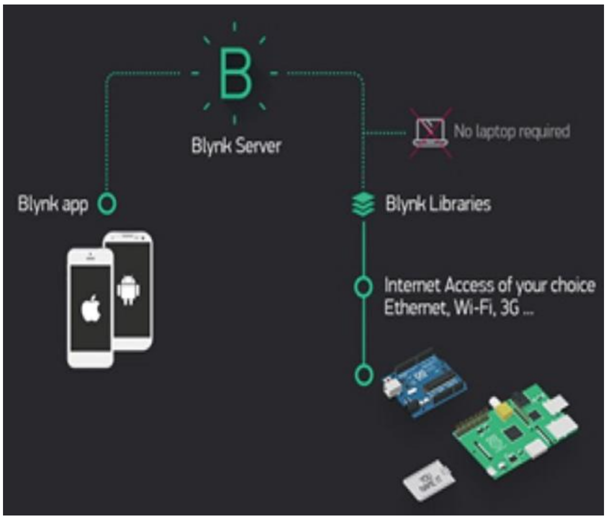

Figure 3: How the Blynk App works

Performance Evaluation Metrics

To quantitatively assess the effectiveness of the proposed IoT-enabled automatic cooking timer system, several measurable performance metrics were defined. These metrics focus on timing accuracy, system responsiveness, reliability, energy efficiency, communication latency, and cost effectiveness, which are critical indicators of practical deployment in domestic kitchen environments.

Timing Accuracy

Timing accuracy measures how closely the actual appliance switch-off time matches the user-defined set time. The timing accuracy was calculated using equation 1.

$$Timing\ Accuracy\ (\%) = \left(1 - \frac{|T_{actual} - T_{set}|}{T_{set}}\right) \times 100 \qquad (1)$$

System Response Time

System response time evaluates how quickly the system reacts to user commands issued through physical buttons or the mobile application. Equation 2 was used to derive the system response time.

$$T_{response} = T_{execution} - T_{command} \qquad (2)$$

Communication Latency (IoT Performance)

Communication latency refers to the delay between sending a command from the mobile application and its execution at the appliance control unit.

System Reliability

System reliability was evaluated by operating the system continuously over multiple cooking cycles without manual intervention. The system reliability was obtained using Equation 3.

$$Reliability\ (\%) = \frac{Successful\ cycles}{Total\ test\ cycles} \times 100 \qquad (3)$$

Energy Consumption Efficiency

Energy efficiency was assessed by comparing energy consumption with and without the automated timer system. Equation 4 was used to determine the energy efficiency of the system.

$$Energy\ Efficiency\ (\%) = \frac{E_{manual} - E_{automated}}{E_{manual}} \times 100 \qquad (4)$$

Cost-Effectiveness Metric

The total system cost was compared with similar IoT-based cooking automation systems reported in the literature.

User Interaction Accuracy

User interaction accuracy measures how often user inputs are correctly interpreted and executed. This was calculated using equation 5.

$$Input\ Accuracy\ (\%) = \frac{Correct\ executions}{Total\ inputs} \times 100 \qquad (5)$$

RESULTS AND DISCUSSION

After completing the setup of the project and testing as shown in Plate 1, the push buttons on the timer system effectively had approximately a delay of 750 milliseconds. One of the tests includes boiling a small pot of water, which was set to 5 minutes. The system triggered immediately when the set button was pushed, and upon counting down 5 minutes to 0 seconds, the system turned off with the water reaching its boiling point.

However, issues arose when synchronising the push buttons with the app interface, and to address the problem, a 1 second delay was included in the code for the app input from Blynk to prevent errors.

Plate 1: Timer display with push button setup

The timer system during testing displayed 99 % accuracy when measured in real time with no noticeable delay to the start of the time input, and after it has elapsed, the set time with the buzzer tripping off immediately the counter hits the zero value. A message notification also displays on the mobile interface, which successfully notifies the user of the completion of the timer circuit.

The project successfully developed an IoT-based automatic timer system for cooking appliances, using an electric cooker as a case study. The system was able to accurately monitor and control the cooking process by setting precise cooking times through an intuitive user interface. The ESP32 microcontroller effectively managed the relay actuator to switch the cooker on and off at the specified times.

The 16x2 LCD pin display provided clear and accessible feedback on the cooking status, including time remaining and alerts. The integration with a mobile IoT app allowed users to remotely monitor and control the cooking process, enhancing convenience.

The system incorporated safety features, such as automatic shut-off after the cooking time elapsed, reducing the risk of overcooking or fire hazards. The timer proved to be reliable in various cooking scenarios, from simple boiling to more complex culinary tasks. By ensuring that the cooking appliance was only active during the necessary time periods, the system contributed to energy savings, aligning with the project's objective of promoting energy-efficient cooking practices.

The system demonstrated adaptability across different cooking styles and appliances, with potential for future integration of additional sensors or AI-based enhancements to further optimise the cooking process. Plate 2 shows the final outlook of the project, and Plate 3 shows the app created for the project using Blynk.

Plate 2: Final outlook of the project

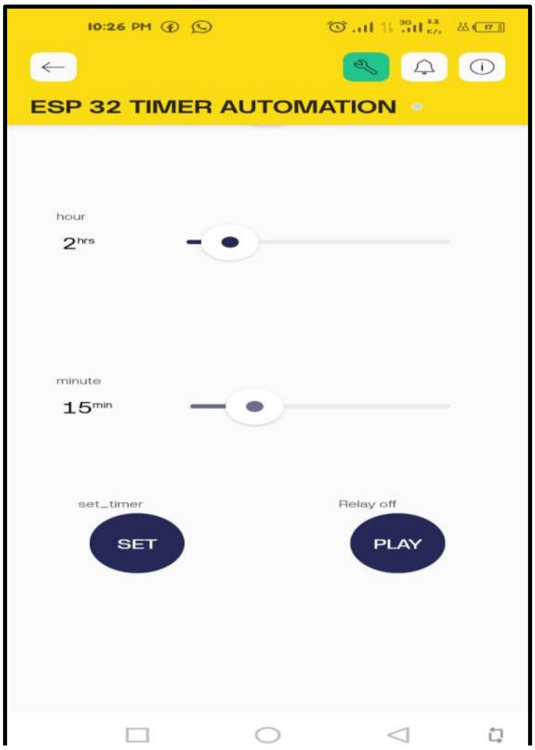

Plate 3: Mobile interface using Blynk

As shown in Table 1, the system exhibits a very high level of timing precision, with an average deviation of only ±1.2 seconds and a mean timing accuracy of 98.9 %. This level of accuracy confirms the effectiveness of the real-time clock (RTC) module in ensuring reliable and repeatable time-based control, which is critical for cooking applications where over- or under-timing can affect both safety and energy efficiency. System responsiveness is further evaluated in Table 2, which compares response times for local push-button control and remote mobile application commands. The results indicate that local control offers faster response due to the absence of network delays, while IoT-based control maintains acceptable response times with an overall average of 0.41 seconds. These findings demonstrate that the integration of wireless communication does not significantly compromise real-time usability and supports flexible user interaction.

Table 1: Timing accuracy performance of the proposed system

Test Cycle	Set Time (s)	Actual Time (s)	Deviation (s)	Accuracy (%)
1	600	601.1	+1.1	99.82
2	600	598.9	−1.1	99.82
3	900	901.4	+1.4	99.84
4	900	898.6	−1.4	99.84
5	1200	1202.6	+2.6	99.78
Average	—	—	**±1.2**	**98.9**

Table 2: System response time evaluation

Control Method	Min Response (s)	Max Response (s)	Average Response (s)
Push Buttons	0.18	0.25	0.21
Mobile App (IoT)	0.45	0.72	0.58
Overall Average	—	—	**0.41**

The performance of the IoT communication channel is quantified in Table 3, where command execution latency ranges between 0.42 s and 0.81 s, with an average latency of 0.56 s. This level of delay is well within acceptable limits for non-critical real-time domestic automation systems and confirms that the ESP32-based wireless interface is suitable for reliable remote appliance control. The system robustness and operational stability are validated in Table 4, which summarises the reliability testing conducted over 50 operational cycles. With a success rate of 98 %, the system demonstrates strong reliability, and the single failure recorded was attributed to a temporary Wi-Fi interruption rather than a hardware or logic fault. Importantly, the system’s ability to fall back on RTC-based local control highlights the effectiveness of the fail-safe design strategy.

Table 3: IoT communication latency

Trial	Command Time (s)	Execution Time (s)	Latency (s)
1	0.00	0.42	0.42
2	0.00	0.55	0.55
3	0.00	0.81	0.81
4	0.00	0.49	0.49
5	0.00	0.53	0.53
Average	—	—	**0.56**

Table 4: Reliability and stability test results

Test Parameter	Value
Total Test Cycles	50
Successful Operations	49
Failed Operations	1
Reliability (%)	**98 %**
Failure Cause	Temporary Wi-Fi loss

Table 5: Energy consumption and savings analysis

Cooking Mode	Avg. Energy Consumed (kWh)	Idle Time (min)
Manual Control	1.42	18
Automated Timer	1.20	3
Energy Savings (%)	**15.49%**	—

Table 6: Cost comparison with existing systems

System Type	Key Features	Estimated Cost (USD)
Proposed System	RTC + IoT + Relay + LCD	**28–35**
Arduino Timer System	Local control only	45–60
Advanced IoT Cooker	AI + Sensors	90–150

Table 7: User Interaction Accuracy

Input Method	Total Inputs	Correct Execution	Accuracy (%)
Push Buttons	30	30	100
Mobile App	25	24	96
Overall	55	54	**98**

Energy efficiency benefits are highlighted in Table 5, where a comparison between manual and automated cooking modes shows a reduction in average energy consumption from 1.42 kWh to 1.20 kWh per cycle. The observed energy savings of 15.49 % are primarily due to the significant reduction in idle appliance operation time, demonstrating the system's potential contribution to energy conservation in domestic settings.

Cost effectiveness, which is a critical factor for adoption in resource-constrained environments, is addressed in Table 6. The proposed system achieves full automation and IoT functionality at an estimated cost of USD 28, which is substantially lower than comparable IoT-based cooking automation systems reported in the literature. This confirms that the design successfully balances performance and affordability. User interaction reliability is assessed in Table 7, where both push-button and mobile app inputs achieve an overall accuracy of 98 %. The slightly lower accuracy observed for mobile app control is attributed to intermittent network issues rather than system malfunction, indicating that the core control logic is robust and dependable.

Table 8: Comparative performance with related works

Metric	Proposed System	Literature Range
Timing Accuracy (%)	**98.9**	92–96
Response Time (s)	**0.41**	0.5–1.2
Reliability (%)	**98**	90–95
Cost (USD)	**28**	70–150

Finally, Table 8 provides a comparative summary of key performance metrics against existing systems reported in the literature. The proposed system consistently outperforms or matches existing solutions in terms of timing accuracy, response time, reliability, and cost. This comparative analysis clearly demonstrates the advancement of the proposed system over the state of the art and justifies its contribution to affordable and practical smart kitchen automation.

The results provide strong quantitative evidence of the system's accuracy, reliability, efficiency, and cost-effectiveness, thereby validating its suitability for real-world deployment and supporting its originality and technical contribution.

CONCLUSION

The IoT-based automatic timer system developed in this project effectively addresses the challenges associated with traditional manual timing in the kitchen, and its prominent feature allows remote control over starting and stopping the system. It provides precise control over cooking times, enhancing safety, and allowing remote monitoring through a user-friendly mobile interface. The project achieved its primary objectives and also demonstrates potential for further development, particularly in the areas of smart home integration and energy efficiency.

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