

Design and Implementation of a Smart Home Using Voice Assistant Based on Microcontroller and Internet of Things

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ABSTRACT

The rapid advancement of information and communication technology has led to the emergence of the smart home concept, which utilizes the Internet of Things (IoT) to automate and simplify the control of household devices. This study aims to design an IoT-based smart home system using the ESP32 microcontroller, integrated with Google Assistant, TTP223B touch switches, and the Google Home application to control lights and fans in three rooms. The system is also equipped with an INA219 sensor to monitor power consumption in real time through the Kodular platform. The research methodology includes hardware and software design, connectivity testing, and system performance analysis based on response time and operational stability. The test results show that the system operates effectively, with voice commands responding within 2-3 seconds and touch switches responding in less than 1 second. Overall, the system proves to be reliable, efficient, and capable of enhancing convenience, safety, and effectiveness in managing household electronic devices automatically and remotely.

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1. INTRODUCTION

The development of information and communication technology has driven various innovations in home automation (smart home) systems. The smart home concept integrates electronic devices, sensors, and control systems to help residents manage various home functions automatically or remotely. The emergence of Internet of Things (IoT) technology enhances these capabilities by connecting multiple devices to the internet, allowing real-time control and monitoring through smart devices [1]-[5]. A smart home combines technology and services to improve efficiency, comfort, and security for its occupants. Electronic devices connected within a single network enable two-way communication and remote control, providing an interactive experience that supports a modern, digital lifestyle [6]-[10].

In recent years, rapid advances in IoT technology have revolutionized how people interact with household appliances. One of the most popular implementations is the IoT-based smart home, which allows users to control and monitor electrical devices such as lights, fans, and security systems anytime and anywhere via smartphones [11]-[15]. The convenience and efficiency of daily device management are key factors driving the growth of this concept. Additionally, microcontroller-based control systems are increasingly being developed to automate household functions. Microcontrollers can be combined with sound sensors, enabling verbal commands to switch devices on or off without physical contact — a feature particularly beneficial for the elderly and physically disabled [16],[17]. Previous studies have shown that voice-based control systems using Arduino Uno and KY-038 sound sensors can effectively recognize simple

commands like “on” and “off,” although accuracy may decrease with different users due to variations in voice tone and pronunciation [18]-[20].

Based on this background, this study aims to design and implement an IoT-based smart home system integrated with Google Assistant and a NodeMCU microcontroller. The system is designed to control several household devices, such as lights and fans, through voice commands or smartphone applications. With the implementation of this system, users are expected to experience greater convenience, efficiency, and comfort in managing household equipment, while also improving energy efficiency and home security. Therefore, this study is titled “Design and Implementation of a Smart Home Using a Voice Assistant Based on Microcontroller and Internet of Things.

2. METHOD

This research was conducted by designing an Internet of Things (IoT)-based smart home system that can be controlled both manually and automatically through voice commands using Google Assistant. The system aims to simplify user control of three lamps and one fan in each of three rooms, while simultaneously monitoring electrical power consumption in real time to ensure efficient and safe household operation. An ESP32 microcontroller serves as the central controller, integrating several components such as the TTP223B touch sensor and a physical button on Google Home for remote manual control, as well as Google Assistant for voice-based operation. The system output consists of a relay module that regulates the electrical current to the lamps and fans, with each room having an independent control channel. Additionally, the system is equipped with an INA219 sensor to measure current, voltage, and power, allowing all device activities to be monitored in real time via an IoT application.

The system’s power supply is provided by a DC source that distributes energy to both the ESP32 and relay modules. It is designed to operate in three control modes—touch, button, and voice enabling flexible and user-friendly operation. With this design, the smart home system is expected to enhance comfort, energy efficiency, and electrical safety in home environments. The overall block diagram and system working principle are illustrated in Figures 1 and 2.

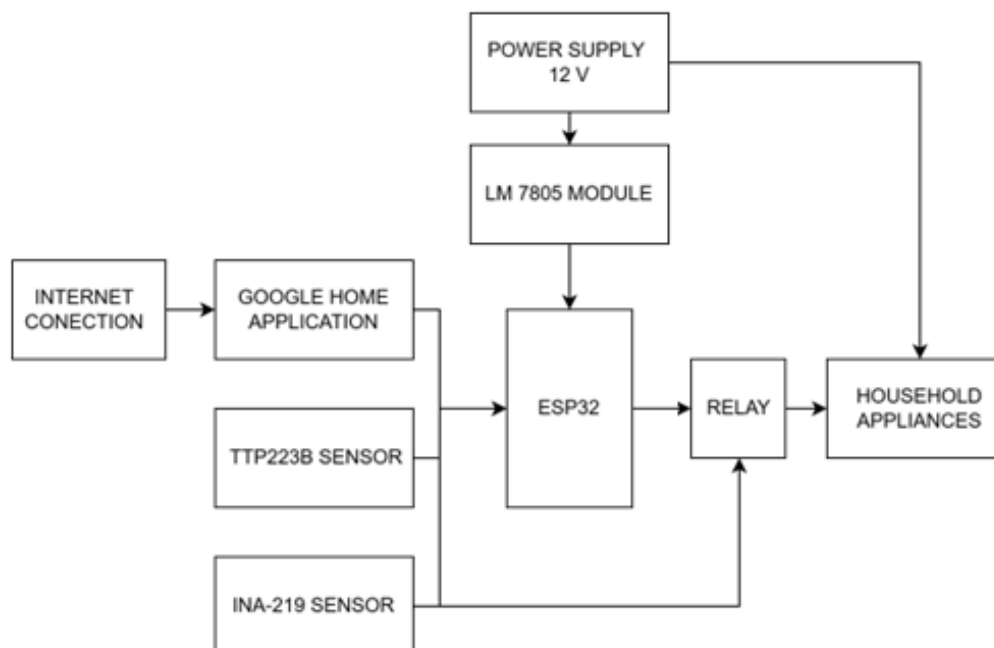


Figure 1. Block Diagram

A flowchart is a visual representation that illustrates the sequence of operations in a system using standardized symbols connected by lines or arrows to show the overall process flow and direction. In the IoT-based smart home system, the flowchart describes the working stages starting from the input of voice commands via Google Assistant, remote button control, or the TTP223B touch sensor, to the process of controlling lamps and fans through the ESP32 microcontroller. The flowchart of the smart home system is shown in Figure 3.

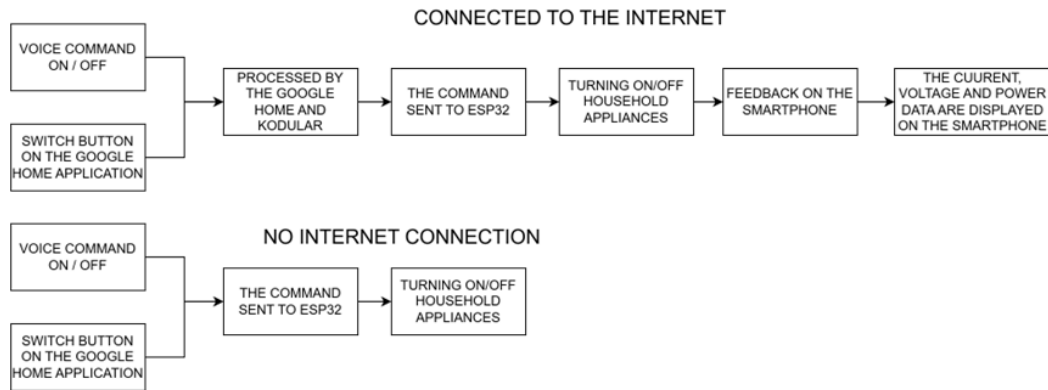


Figure 2. Working Principle of the Device

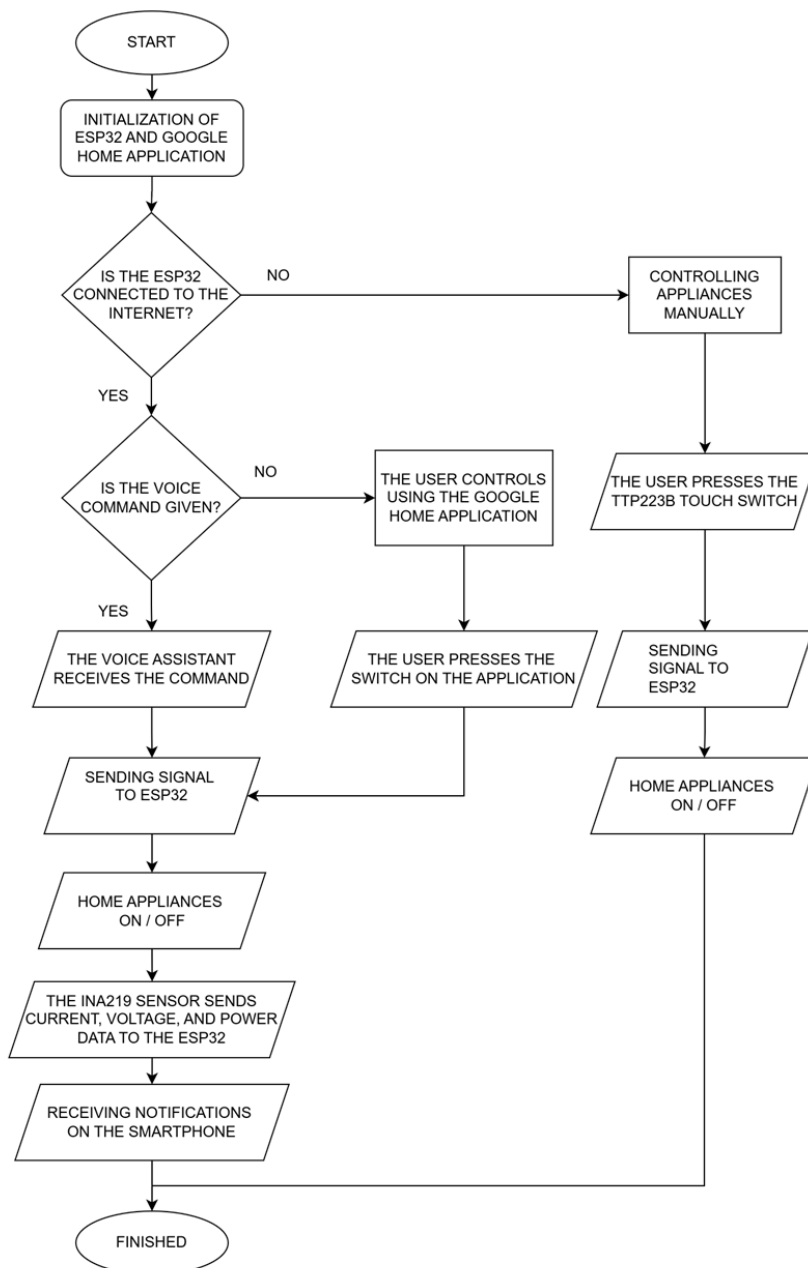


Figure 3. Flowchart System

The mechanical design aims to illustrate the physical structure and layout of components to ensure that each part functions properly when the system operates. The design is created in a 3D model using SolidEdge software to simplify the assembly process and component placement. The appearance of the control box design and the overall device, along with its dimensions, is shown in Figure 4.

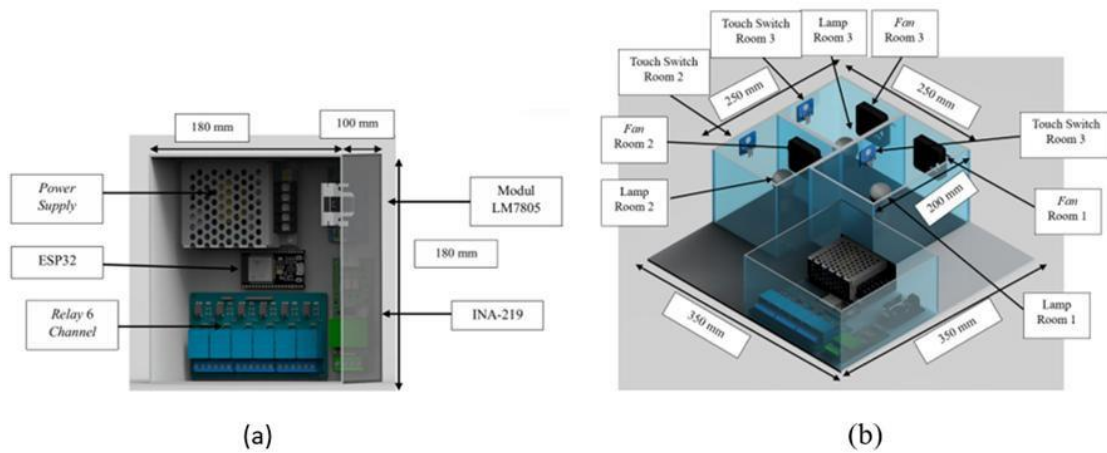


Figure 4. (a) Box Control Panel Design, (b) Overall Tools Design

The electrical design is the process of arranging and configuring electrical circuits to ensure all system components operate safely and efficiently according to their intended function. In this study, the main power source of 220 VAC is converted to 12 VDC through a power supply to operate DC lamps and fans, and then stepped down to 5 VDC using the LM7805 module to supply the ESP32, INA219 sensor, and relay module. The relays are connected to the ESP32's I/O pins to control the lamps and fans in each room, while the TTP223B touch switch serves as a manual control when the device is not connected to the internet. The electrical design illustrating the wiring diagram of the IoT-based smart home system with voice assistant control is shown in Figure 5.

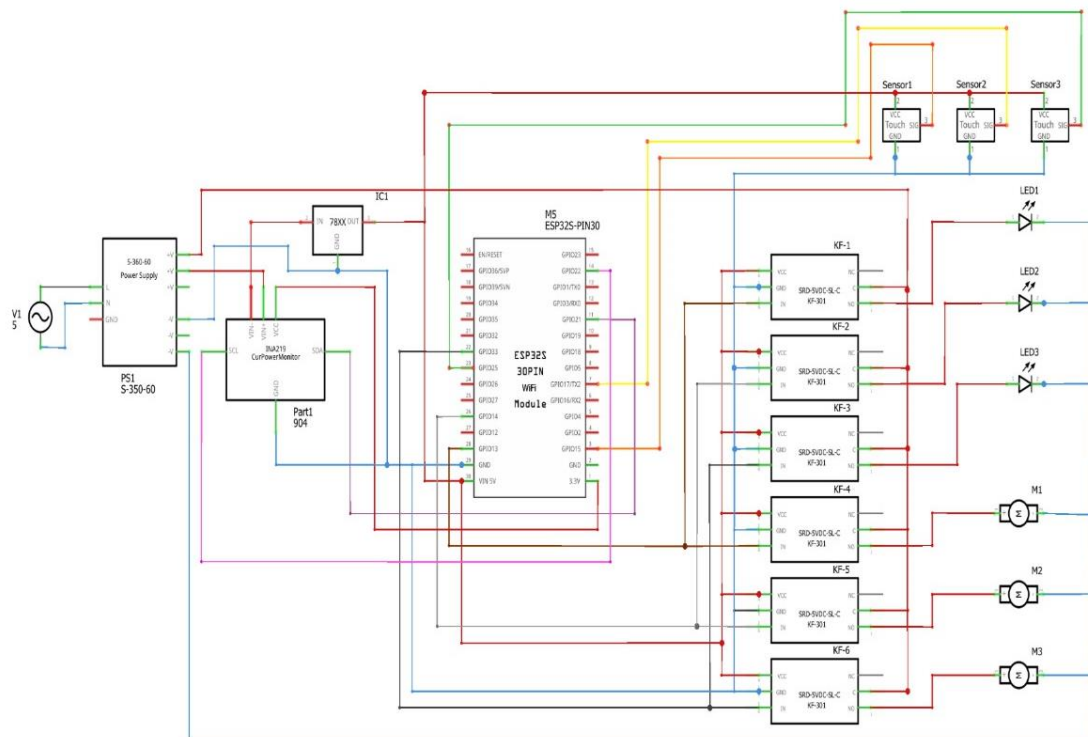


Figure 5. Circuit scheme

3. RESULTS AND DISCUSSION

This section discusses the overall testing results of the IoT-based smart home system, which was designed to control lamps and fans in three rooms using three main methods: voice commands via Google Assistant, touch switches (TTP223B), and manual control through the Google Home application. The system is also equipped with a real-time power consumption monitoring feature using the Kodular platform. Table 1 shows the TTP223B Touch Switch Testing, Table 2 illustrate the Voice Assistant Testing System and Table 3 show the results of Manual Control Testing Via Google Home

Table 1. TTP223B Touch Switch Testing

No	Switch	Input/ touching	Lamp and Fan Condition		
			Room 1	Room 2	Room 3
1	A	Touch 1	ON	OFF	OFF
2	A	Touch 2	OFF	OFF	OFF
3	B	Touch 1	OFF	ON	OFF
4	B	Touch 2	OFF	OFF	OFF
5	C	Touch 1	OFF	OFF	ON
6	C	Touch 2	OFF	OFF	ON
7	A-B	Touch 1	ON	ON	OFF
8	A-B	Touch 2	OFF	OFF	ON
9	A-C	Touch 1	ON	OFF	ON
10	A-C	Touch 2	OFF	OFF	OFF

Table 2. Voice Assistant Testing

No	Voice Command	Lamp and Fan Condition		
		Room 1	Room 2	Room 3
1	Oke google nyalakan ruangan satu	ON	OFF	OFF
2	Oke google matikan ruangan satu	OFF	OFF	OFF
3	Oke google nyalakan ruangan dua	OFF	ON	OFF
4	Oke google nyalakan ruangan tiga	OFF	ON	ON
5	Oke google matikan ruangan dua dan tiga	OFF	OFF	OFF
6	Oke google nyalakan ruangan satu dan dua	OFF	OFF	OFF
7	Oke google matikan ruangan satu dan dua	OFF	OFF	OFF
8	Oke google nyalakan ruangan satu dan tiga	ON	OFF	ON
9	Oke google nyalakan semua ruangan	ON	ON	ON
10	Oke google matikan semua ruangan	OFF	OFF	OFF

Table 3. Manual Control Testing Via Google Home

No	Control Button Status			Lamp and Fan Condition		
	Room 1	Room 2	Room 3	Room 1	Room 2	Room 3
1	Active	Inactive	Inactive	ON	OFF	OFF
2	Inactive	Inactive	Inactive	OFF	OFF	OFF
3	Inactive	Active	Inactive	OFF	ON	OFF
4	Inactive	Active	Active	OFF	ON	ON
5	Inactive	Inactive	Inactive	OFF	OFF	OFF
6	Active	Active	Inactive	ON	ON	OFF
7	Inactive	Inactive	Inactive	OFF	OFF	OFF
8	Active	Inactive	Active	ON	OFF	ON
9	Active	Active	Active	ON	ON	ON
10	Inactive	Inactive	Inactive	OFF	OFF	OFF

The monitoring system testing on the Kodular platform aims to ensure that the power consumption data transmitted from the microcontroller can be received and displayed accurately and in real time. The testing was carried out by monitoring the power consumption of lamps and fans in three rooms. Figure 6 shows the data recording display of the system's power consumption usage. Based on the testing results of the TTP223B touch switch, voice assistant, manual control via Google Home, and power monitoring on the Kodular platform, it can be concluded that all system components functioned properly and as intended. The touch switch responded quickly and stably to user input in controlling the devices. The Google Home-based voice assistant successfully recognized and executed voice commands with high accuracy, providing convenience for users to control devices without direct interaction. In addition, manual control via Google Home operated smoothly, offering an alternative method of control. The power monitoring system on the Kodular platform effectively displayed real-time and accurate power consumption data, allowing users to monitor the energy usage of each device. Overall, the designed smart home system performed optimally and met its objectives by providing efficient and integrated control and monitoring of electronic devices.

101	20/09/2025 19:14:29	11,7	1,2	13,9
102	20/09/2025 19:15:29	11,8	1,2	13,9
103	20/09/2025 19:16:29	11,8	1,2	14,2
104	20/09/2025 19:17:29	11,8	1,2	14,3
105	20/09/2025 19:18:30	11,8	1,2	14,5
106	20/09/2025 19:19:31	11,8	1,2	14,3
107	20/09/2025 19:20:31	11,8	0,8	9,4
108	20/09/2025 19:21:31	11,8	1,2	14,5
109	20/09/2025 19:22:31	11,8	1,2	14,5
110	20/09/2025 19:23:32	11,8	1,2	14,6
111	20/09/2025 19:24:32	11,8	1,2	14,3
112	20/09/2025 19:25:33	11,8	1,3	14,7
113	20/09/2025 19:26:33	11,8	1,2	14,5
114	20/09/2025 19:27:34	11,8	1,2	14,7
115				

Figure 6. Data Logger Display on the Kodular Platform

4. CONCLUSION

Based on the results of the design and testing, it can be concluded that the voice assistant system based on Google Home and Kodular was successfully implemented to control lamps and fans in three rooms with a high level of reliability. The system responded to voice commands within an average of 2–3 seconds, while manual control via the TTP223B touch switch showed a faster response of less than 1 second. Integration with the Kodular application also enabled real-time device monitoring, allowing users to control the system flexibly through voice commands, the application, or manual operation. Thus, the designed system proved to be reliable, efficient, and aligned with the goal of enhancing comfort and effectiveness in managing household electronic devices.

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