



## Designing and Prototyping of a Smart Home System Base on IoT integration

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**Abstract.** The increasing complexity of modern home environments often leads to energy management, security, and convenience challenges. Traditional home automation systems are typically limited in functionality, requiring manual intervention and offering minimal integration with other devices. This fragmentation results in inefficiencies and a need for more user control. To address these issues, the Internet of Things (IoT) offers a comprehensive solution by enabling seamless connectivity between devices and providing real-time data management. An IoT-based home automation system integrates various household devices—lighting, security cameras, and HVAC systems—into a unified platform. This system allows users to remotely monitor and control their home environments through a centralized application, ensuring improved energy efficiency, enhanced security, and greater convenience. Implementing an IoT home automation system is intended to create a smart living space that adapts to user preferences, optimizes resource usage, and provides peace of mind through enhanced safety features. Ultimately, this solution simplifies daily tasks and contributes to a more sustainable and intelligent home ecosystem.

### 1. Introduction

New ideas and technology are desperately needed in today's modern environment to make daily tasks simpler. A special system called home automation can manage and communicate with almost every component of the house (Al-Gburi & Abdul-Rahaim, 2022). The coordination of all domestic amenities and appliances is referred to as "home automation." The majority of used microcontrollers have the ability to manage household electrical appliances, however it is crucial that the various electrical appliances are connected to one another in order to establish communication with (Abdulraheem et al., 2020).

Home automation systems are becoming increasingly necessary in daily life because to their many benefits, including comfort, convenience, centralized control of appliances, cost savings, energy efficiency, security, and safety. Users' quality of life is increased with a home automation system (Ali et al., 2020). The internet of things (IoT), a technology that allows connections between devices over the Internet, is more important in this work than the Wi-Fi-enabled gadgets that can be utilized to provide home automation. (Pujaria et al., 2020).

Wireless fidelity (Wi-Fi) is a wireless technology that transmits data across the air using radio frequency. Wi-Fi's initial speed ranges from 1 to 2 Mbps. In the 2.4 GHz frequency spectrum, Wi-Fi sends data. It uses frequency division multiplexing technology in its implementation. Wi-Fi technology has a range of 40 to 300 feet (Al-Gburi & Abdul-Rahaim, 2022).

IoT is a concept in which every device is given an IP address, and anyone may identify that device on the internet by using its IP address. The ability for different devices to connect with one another has been made possible by recent technological advancements that allow the usage of wireless controlling environments like Bluetooth and Wi-Fi (Stolojescu-Crisan et al., 2021).

The development of wireless technology has led to the emergence of a variety of connections, each with its own distinct characteristics and uses. The Wi-Fi connection is one of the most popular ones that is frequently used in Home Automation System (HASs). In this research, Wi-Fi has more than adequate capabilities. Additionally, the cost of the system will be reduced because the majority of electrical gadgets and equipment already have a built-in Wi-Fi adapter (Kadali et al., 2020).

An ESP32 DEV KIT V1 micro controller is used in this research to control the system. The research also

use of the Arduino IoT cloud infrastructure, from which a variety of linked devices may communicate real-time data with one another and be seen anywhere using a straightforward user interface (Kadali et al., 2020).

To control lights, fans, and other electrical appliances, we will connect an 8-channel relay module to an ESP32 Wi-Fi module and send ON/OFF commands from the dashboard of a computer or a mobile device using the Arduino IoT cloud platform.

## 2. Materials and Methods

Design methodology of this system has two major parts, the software and hardware design. The hardware is designed by arranging smart phone, micro-controller ESP32 DEV KIT V1, Power supply, 8- channel relays and transistors, whereas software design includes the Arduino IoT cloud software app, and the program or source code that is written and uploaded in the microcontroller. The appliances are controlled using relays via Wi-Fi. The activation of the home appliances is achieved by using the remote-control app. on the smart phone. The figure below shows the block diagram of android application using Wi-Fi and ESP32 microcontroller for home automation via the Arduino IoT cloud platform

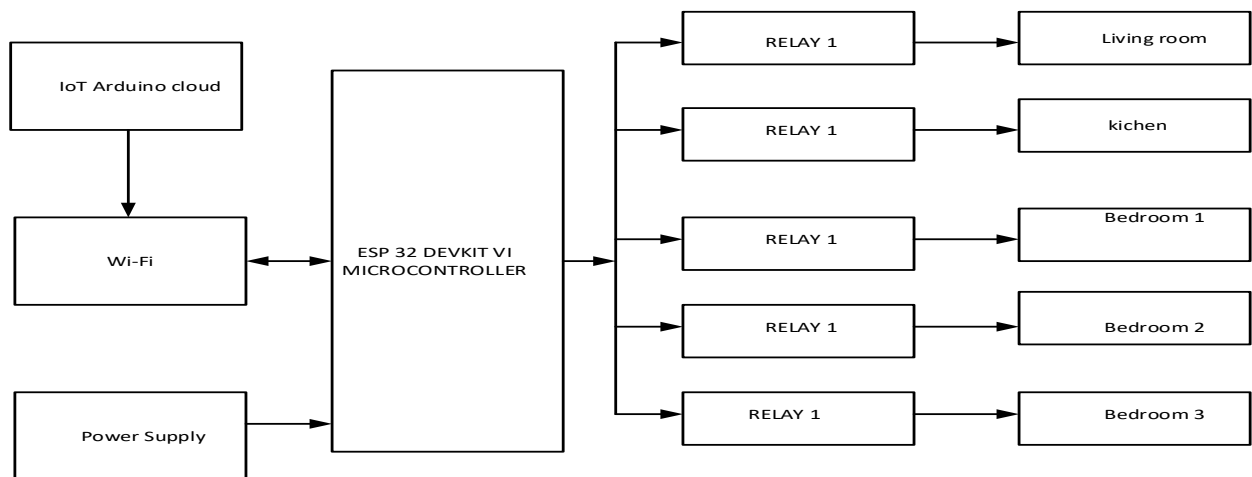


Figure 1: Block diagram of the IoT infrastructure design.

### 2.1 Power Supply Section

The input voltage ( $V_{in}$ ) range of the ESP32 DEV KIT V1 ranges between 7v-12v dc, a regulated voltage of 5v is supplied to the micro-controller, leaving the ESP32 to draw whatever current it needs. An external power supply was incorporated into the system in order to supply a regulated voltage to the micro-controller. Regulated The power supply section can also be coupled together as seen in figure 2 using components which include a transformer, bridge rectifier, a capacitor, a LED and LM7805 IC voltage regulator to give a regulated 5v dc output.

Since the input voltage range of the chosen regulator LM7805 is 7V- 35V, the minimum input voltage required to construct a 5V DC power supply circuit that can deliver a maximum load output current of 500mA is 7V. Thus, in order to scale down the main AC to at least this voltage, a transformer is required.

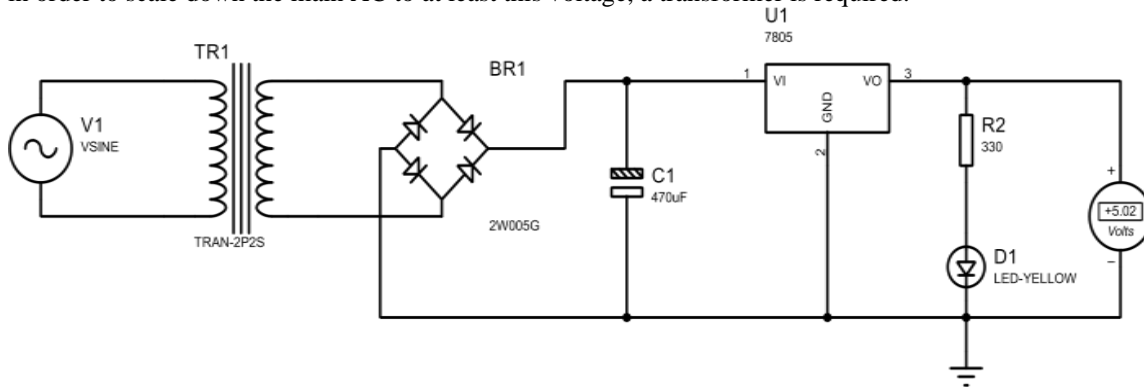


Figure 2: A 5V DC-power supply design

### 2.1.1 Esp32 Dev Kit V1

The ESP32 DEV KIT V1 is the main processing unit in the development of this project as it creates interaction between the software (written program) and the hardware components of the project. Data acquisition and Data processing are some of the stages involved during processing, in home automation system.

The research covers mainly the scope of actuation, as sensors are not used in the project development. Once the ESP32 is connected to the actuators, it can begin to control them based on the results of the data processing stage. For example, if the ESP32 has determined that the lights need to be turned on, it will send a command to the relay that controls the lights.

The operating voltage is 3.3V, but a 5V output is taken from the GPIO pins to the relays through the transistors in order to work effectively.

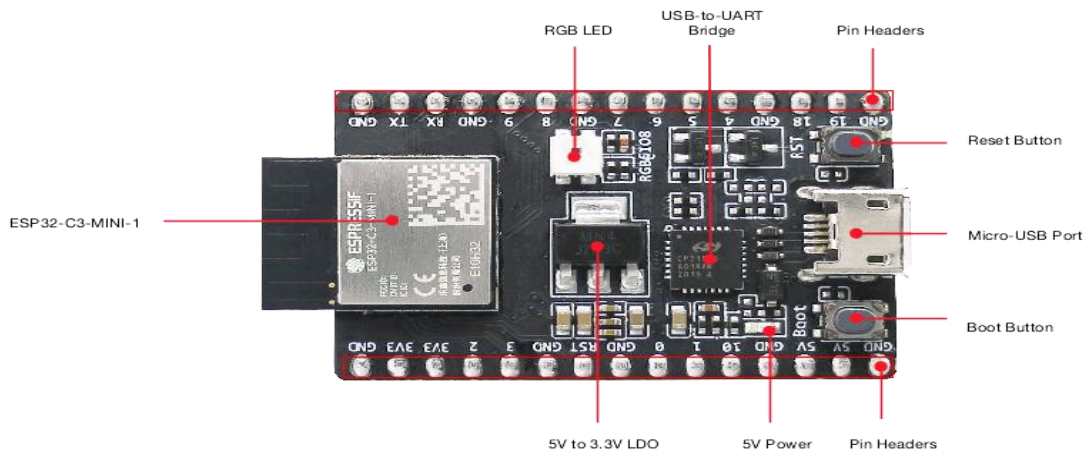


Figure 3: ESP32 micro-controller

### 2.1.2 8-Channel Relay Module

The output unit is an 8-Channel relay module that is connected and controlled by the ESP32 DEV KIT V1, and allows the load voltage to be controlled. These relays receive output signals directly from the ESP32 and energizes the coil. The load voltage connected to the relay contacts which consists of NO, NC and Common Terminal are now being controlled. The home appliances like fan, socket and bulbs can now be controlled by the relay from the ESP32 DEV KIT V1.

The ESP32 DEV KIT needs a 3.3V basically to operate, but the 8-channel relay module need a input voltage of 5V to operate. So,with the aid of the bc547 transistor the weak signals generated by the microcontroller is being amplified.

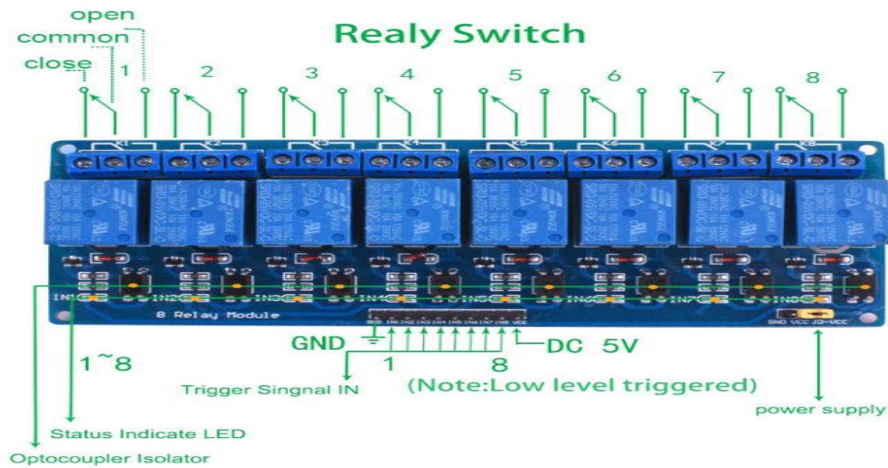


Figure 4: An 8-Channel Relay Module

### 2.1.3 Transistors (BC547 NPN)

Transistors operate as electronic switches in IoT home automation systems, making them critical components. They enable the microcontroller (ESP32) and others like Arduino, ESP8266 which are lowpower microcontroller to control and manage higher-power devices like relays, motors and lights. The microcontroller generates a low-power signal (usually 3.3V or 5V), but in this case 5V to control the transistor. Then this signal is applied to the base pin of the transistor. When a small current flow into the base pin, it allows a much larger current to flow between the collector and emitter pins. This amplification allows the lower-power signal from the micro-controller to control the power required by the connected device.

The amplified current flowing through the collector and emitter pins can then activate the relay and the other devices connected to it and this allows the microcontroller to turn the devices ON/OFF remotely based on the user input. They amplify current from base to the emitter. Ultimately, DC bias is essential for making sure the transistor works smoothly and amplifies signals correctly. The fixed bias approach was used, as a resistor was used to get a fixed current at the base and emitter terminal.

value of resistor used for biasing =  $1k\Omega$  ;

To find the Base current of the transistor:

$$\text{Base Current}(i_b) = \frac{V_{cc} - V_{be}}{R_b} \quad (1)$$

Parameters given:

$$V_{cc} = 5v ; V_{be} = 0.6v ; R_b = 1k\Omega$$

$$\text{Base Current}(i_b) = \frac{5 - 0.6}{1000} = 4.4mA$$

Collector current;

$$i_c = \beta \times i_b \quad (2)$$

$\beta$  for npn BC547 = 310 as depicted in the figure below using a multimeter.

$$i_c = 310 \times 4.4mA = 1.364 A$$

Once the relay is active then the current is  $\sim 70mA$  which is still less than the collector current. Quiescent current (the amount of current it uses when not actively working) is 2mA. The maximum current is 10A.

Now to calculate the current, power and voltage gain of the transistor;

$$\text{Voltage Gain}(A_v) = \frac{\Delta V_c}{\Delta V_b} = \frac{4.56v}{0.6} = 7.6$$

$$\text{Current gain}(A_i) = \frac{\Delta i_c}{\Delta i_b} = \frac{1.364}{4.4 \times 10^{-3}} = 310$$

$$\text{Power Gain}(A_p) = A_v \times A_i = 310 \times 7.6 = 2,356 = 2.36 kw$$



Figure 5: transistor measurement (a) the  $h_{fe}$  measurement and the (b) collector current measurement

### 2.1.4 Arduino Web Editor

The software part of this system consists the written C++ programming language that actually defines the operations of each button on the Smartphone “Arduino Remote Control” application. This program is written using the Arduino Web Editor. The Arduino Web Based Editor is a cloud-based application that is supported by any operating system with a web browser.

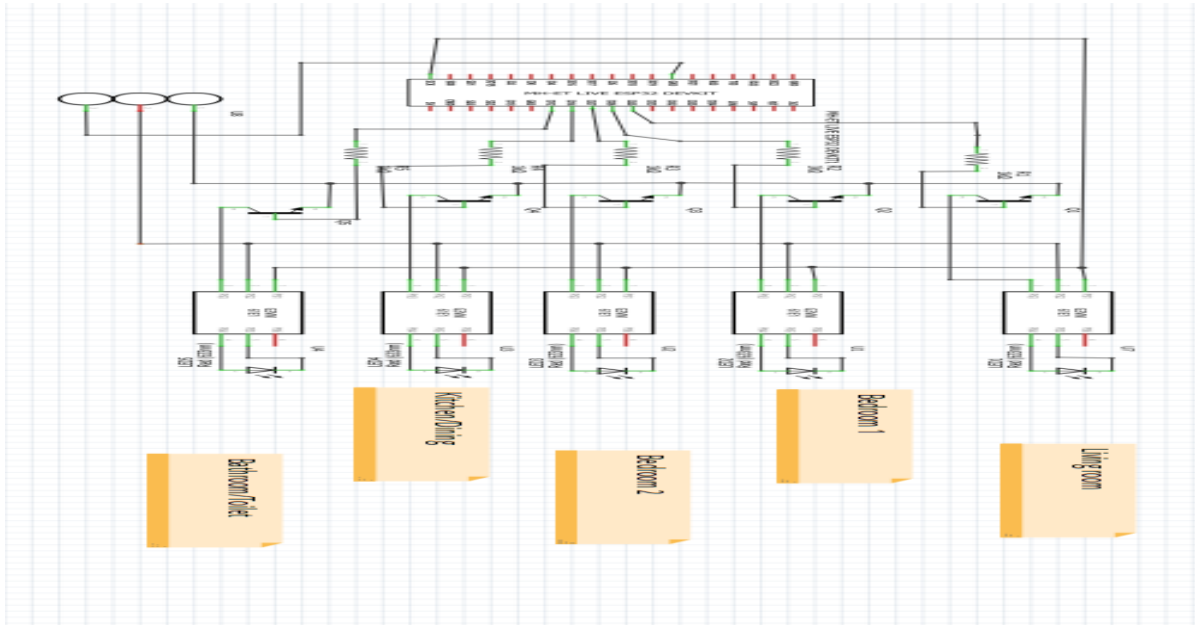
Writing and uploading programs to Arduino-compatible boards, like the microcontroller ESP32 DEV KIT V1, is done with this tool. The Arduino Web Based Editor is a cloud-based application that is supported by any operating system with a web browser. Writing and uploading programs to Arduino-compatible boards, like the microcontroller ESP32 DEV KIT V1, is done with this tool. The microcontroller receives data from the Smartphone using the *IoT Remote control* application available on goggle play store, and processes the data sent with already written and uploaded program. Although using the main Arduino IDE provides a more powerful and feature-rich platform than the Arduino web editor, the Arduino web editor is a good option for beginners and users who needs a simple and easy-to-use platform.

### 2.1.5 Arduino IoT Cloud Remote Application

The Arduino IoT remote application is the mobile software that is used to control and also monitor all of our connected appliances. This IoT remote app by Arduino Cloud allows for monitoring in real-time the IoT devices from anywhere at any time. The IoT remote application (App) receives the compiled code from the Arduino web editor and in turn is able to trigger the relay that controls a specific home appliance via the microcontroller.

## 3. Results and Discussions

This study investigated the performance of an IoT home automation system in residential settings and at various locations. The results showed that the system was able to achieve significant energy savings and improve user comfort.

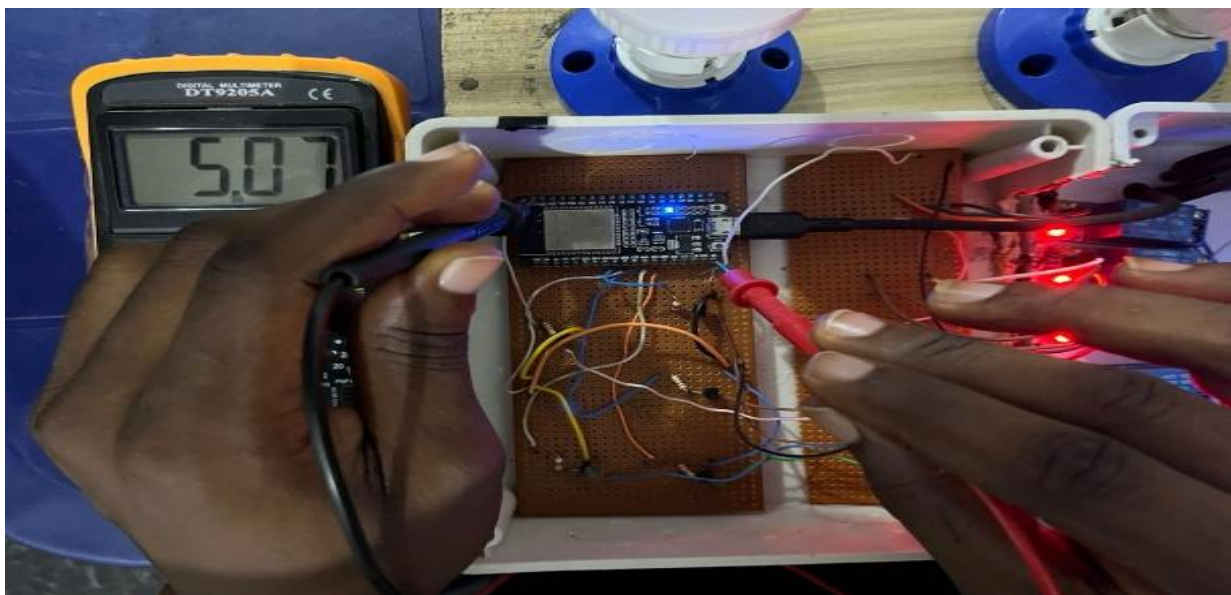


**Figure 6:** Circuit diagram of the system

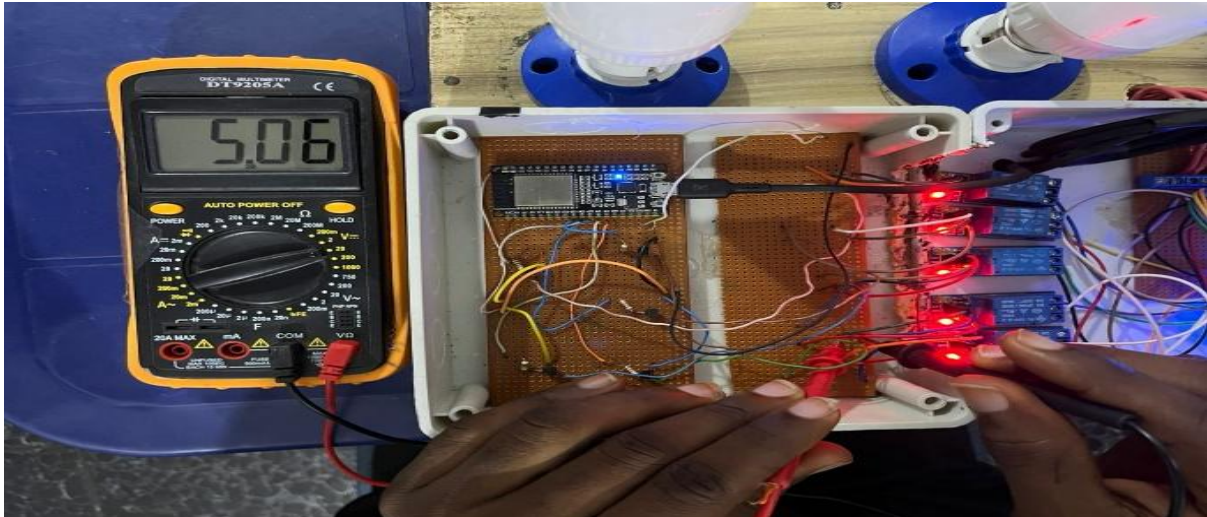
### 3.1 Component Testing-Hardware

The hardware testing is presented in Figures 7 and 8 below. Once all of the schematic design and analysis is completed, the system is realized physically. The designed system was eventually built after being put into use and tested to make sure it functioned as intended to meet desired specifications. The process of testing and implementation involved the use of basically a digital multimeter.

Continuity testing was carried out between the various components of the system and at various points, such as between the relays, ESP32 DEV kit V1, the N-P-N transistors (BC-547) and the 5V dc supply, using a digital multimeter to ensure proper connections exist between them. A test was also carried out on the ESP32 DEV KIT V1 microcontroller, which enables one to clarify the signal output voltage whenever an input signal is sent from the smartphone application, which is already connected to the ESP32 via Hot-Spot.



**Figure 7:** ESP32 voltage test



**Figure 8:** Relay voltage test

### 3.2 Component Testing-Software Testing

The software components of the produced system were tested to guarantee an effective integration after the hardware components had been successfully tested to determine correctness and system workability. In order to send commands to the web for desirable actions, the commands can be entered from the IoT remote app on any mobile device, provided that the hotspot connectivity is secured with the ESP32 kit and the corresponding results are achieved at any location.

The system's workability and its integration with the software were also tested at different landmarks and reference points. The Google map was employed to get the landmark points (longitudes and latitudes) at different locations. The system is placed at a given (fixed) landmark position. The user then controls the home appliances by switching ON the buttons correlating to each home appliance at different landmark positions far away from the system at a given time using the IoT remote app. The required activation is then achieved. Observing at the control of one of the appliances located in bedroom two;

**(BEDROOM 2):** when it is pressed, it sends commands to the ESP32 via the cloud. The ESP32 will then give out +5V output for ON, the corresponding relay controlling bedroom 2 will be energized, and the bulb will be powered.

The user landmark position and the time at which the control was initiated via the IoT control app are displayed below. Also, the landmark position of the system and the bedroom 2 bulb coming up is shown below, which correlates to the time the control was initiated.

At user's end:

The user landmark position: **6°50'03.2"N 3°06'29.0"E**

Time of Control of bedroom 2 via app: 1:48pm

At system end:

System landmark position: **6°49'07.7"N 3°06'23.2"E**

Time the Bulb came UP: 1:48pm

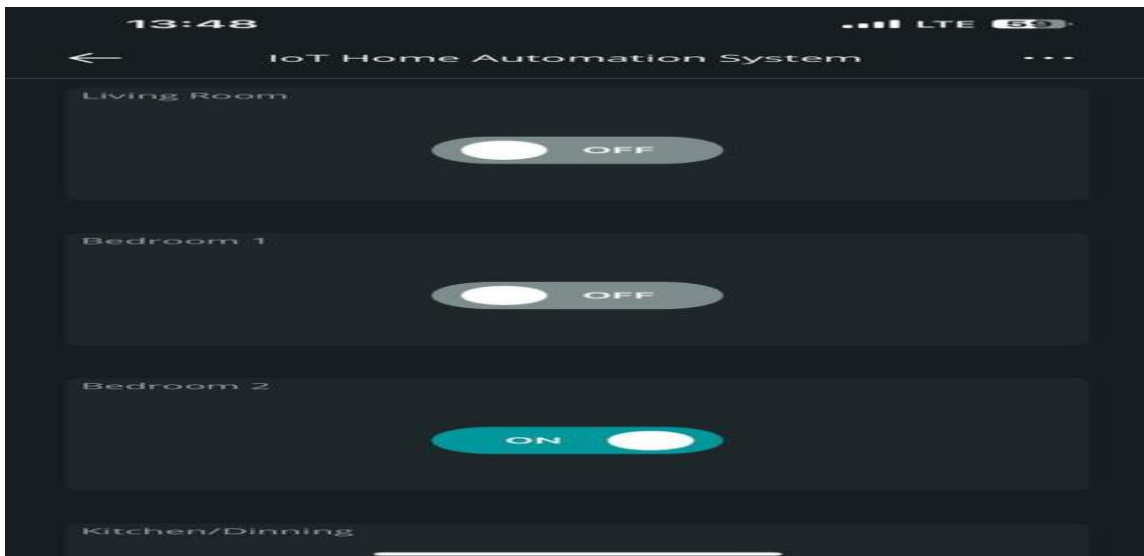


Figure 9: Interface of IoT app controlling B/R 2 appliance

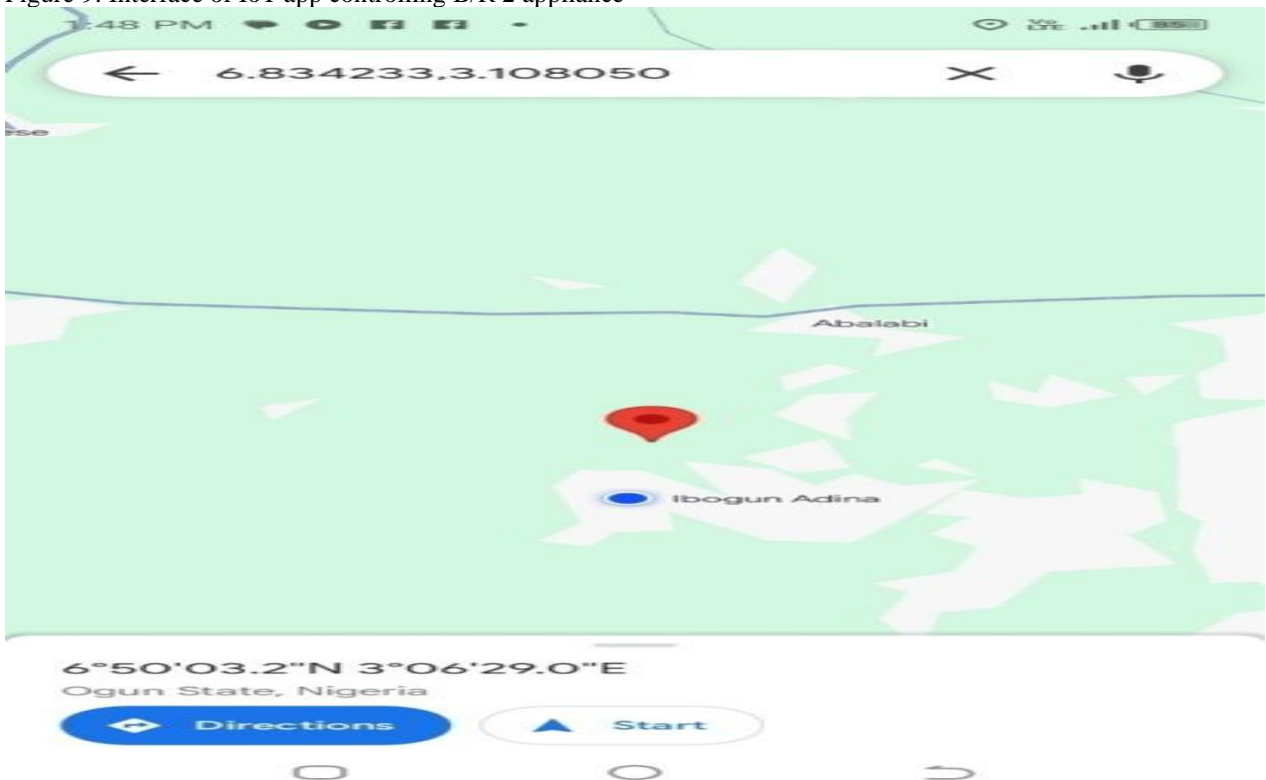


Figure 10: Landmark position of the user at time of control

### 3.3 The System Casing

In order to ensure that the circuits are compatible before soldering, this task has been implemented using a breadboard. Prior to beginning the process of soldering the circuit on the Vero board, a series of tests were conducted on the breadboard in accordance with the schematic specification found in figure 6 above. As seen in figures 11 and 12, the system was connected to a plastic enclosure. Because the casing is made of plastic, it was specially perforated and has vents to add a calming effect.



Figure 11: Coupled system with lights OFF, Figure 12: Coupled system with lights ON

### 3.4: Flow Chart of the System

The flow chart in figure 13 shows a visual representation of the process. This flowchart shows the basic steps involved in operating the IoT home automation system. After the system is turned on and connection is established between the device and the system via hotspot, the user launches the IoT remote control app. It then checks for user input, after which the input is then sent over the cloud for processing, and the appliances is in turn activated in response to the user input.

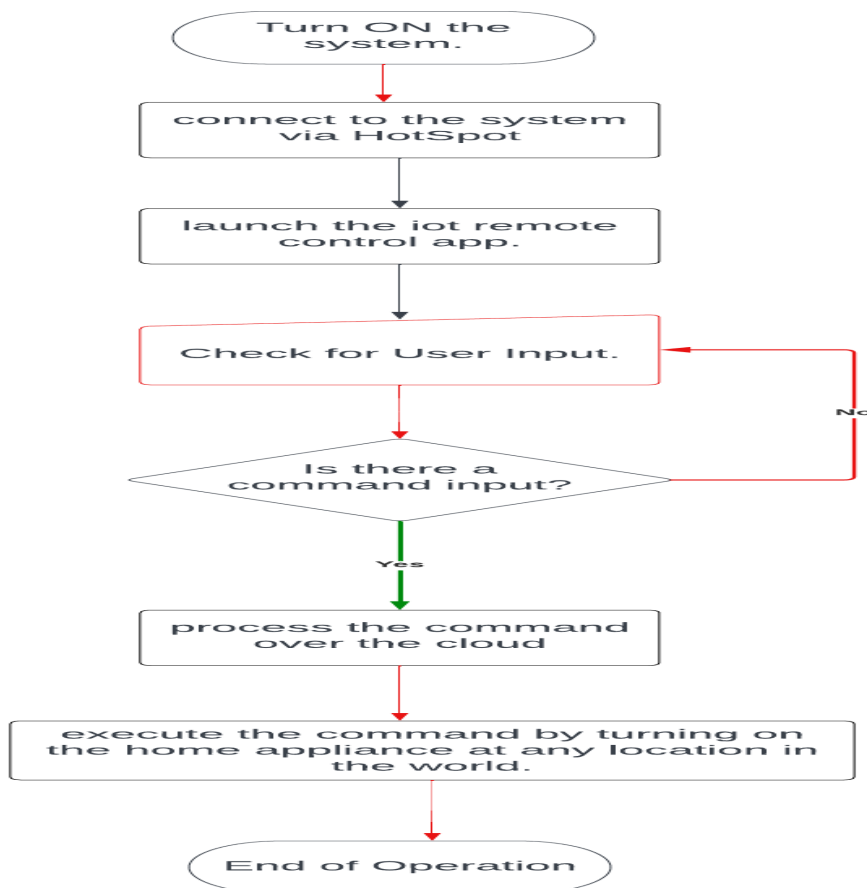


Figure 13: Flow chart showing sequence of operation

#### 4. Conclusion

IoT-based smart home automation systems provide a wealth of advantages and opportunities. These systems allow for the intelligent control, monitoring, and automation of many aspects of a home environment, including security, energy management, and convenience, by linking devices, sensors, and actuators.

The step-by-step instructions for the smart home automation unit have been included in this work. Home appliances can be transformed into smart and intelligent IoT devices with the aid of the specified system. Real-time monitoring of home appliances and their conditions is made possible by the developed Smart Home Automation system, which is simple to install in a home. Using the IoT remote application, controlling household appliances is simple and effective. The user interface functions well and is simple to use on all Android mobile phones. It does not require an internet connection, except the login details, which are required for the first users.

The system has two advantages. First, using the cloud connectivity, we can monitor and access our smart home easily from anywhere, which facilitates energy efficiency.

Second, it aids the elderly and people with disabilities. Other actuators and sensors can be added to the system. It is also possible to enhance the developed system to make it ready for eventual commercialization. All things considered, IoT-based smart home automation systems have the power to make our homes more intelligent, comfortable, and efficient.

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