University of Moratuwa

Department of Electronic and Telecommunication Engineering

EN2160 - Electronic Design Realization

Final Report

Index No: 200396U

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Product: Smart Plug

1. Abstraction

This report presents a concise overview of the smart plug's (also known as *'Smartie'*) development and assembly process. It includes the product description, specifications, schematics, BOM, PCB Gerber files, enclosure design, assembly instructions, and functionality testing procedures. This comprehensive guide serves as a valuable resource for understanding, replicating, and improving the smart plug's design.

Description and Specifications:

This section provides a detailed overview of the smart plug, including its functionality, target market, key features, and unique selling points. It also documents essential technical specifications, such as size, dimensions, hardware information and compatibility information.

Schematics, BOM, and PCB Gerber Files:

This section presents detailed circuit schematics for the smart plug, encompassing power supply and control circuitry. It includes a comprehensive Bill of Materials (BOM) with component names, part numbers, quantities, and sourcing information. Additionally, essential PCB Gerber files for manufacturing the printed circuit board are provided.

Enclosure Design Files:

This section provides a thorough description of the smart plug's enclosure design, featuring the 3D representations. It emphasizes user interface, material selection, and safety considerations.

Assembly and Installation Instructions:

This section offers a clear step-by-step guide for assembling the smart plug. It includes detailed instructions, accompanied by relevant images or diagrams. The assembly process covers component mounting on the PCB, enclosure assembly, and critical steps to build the final product. The installation instructions give the consumer the initial steps they need to follow to install the smart plug.

Functionality Testing:

This section outlines the testing process to ensure the smart plug's functionality. It includes procedures for verifying key features and compatibility with devices.

Contents

2. Description and Specifications

2.1 Features

The '*Smartie*' is an innovative smart plug socket that offers wireless control through a user-friendly mobile or web application. With advanced features such as temperature monitoring, automatic heating protection, and a convenient time scheduling feature, it's the perfect addition to any smart home setup.

Wireless Control:

With the '*Smartie*' smart plug socket, we can effortlessly manage our devices and appliances remotely, providing us with enhanced convenience and control. Whether we're at home or on the go, mobile or web applications allow us to easily turn devices on or off with just a tap or click.

Temperature monitoring:

One of the standout features of the '*Smartie*' is its temperature monitoring capability. We can use the mobile or web application to check the current temperature of smart plug's surroundings and keep an eye on any fluctuations.

Automatic heating protection:

The '*Smartie*' also comes equipped with automatic heating protection, providing an added layer of safety. If the plug socket detects unusually high temperatures, it will automatically cut off power to the connected device, preventing any potential hazards and ensuring peace of mind.

Time scheduling:

Additionally, the time scheduling feature allows us to set specific schedules for our devices. Whether it's turning on our coffee maker in the morning or automatically powering off our gaming console at night, we can customize the '*Smartie*' to fit our daily routine. This feature helps us save energy, reduces utility bills, and adds convenience to our everyday life.

2.2 Purposes and Intendent Usage

Remote Device Control:

The primary purpose of *Smartie* is to provide users with the ability to remotely control their devices and appliances. Whether they're at home, at work, or away on vacation, they can easily manage their devices using the mobile or web application. This allows them to turn devices on or off, and monitor their status from anywhere, providing convenience and flexibility in managing their smart home.

Energy Management:

Smartie offers energy-saving benefits by allowing users to schedule device usage. With the time scheduling feature, they can set specific times for their devices to turn on or off automatically. This helps optimize energy consumption by ensuring that devices are only active when needed, reducing unnecessary power usage, and lowering utility bills.

Safety and Protection:

Smartie includes automatic heating protection mechanisms to ensure safety when using devices that generate heat. The plug socket continuously monitors the temperature, and if it detects excessively high levels, it will automatically cut off power to the connected device. This helps prevent overheating, reduces the risk of electrical accidents, and provides peace of mind for users.

2.3 Target Users

Students:

Students living in dormitories or apartments seek efficient ways to manage their devices, control energy usage, and enhance their living environment.

Homemakers:

Homemakers who are looking to simplify their daily routines, manage household devices remotely, and promote energy-saving practices.

Travelers:

Individuals who frequently travel and who want the ability to monitor and control their home devices remotely for security, energy efficiency, and convenience purposes.

Elderly or Disabled Individuals:

Smartie can offer increased accessibility and convenience for elderly or disabled individuals, allowing them to easily control devices without physical effort or mobility challenges.

Figure 1: Smartie along with the mobile app

3. Product Specifications

3.1 Physical Specifications

- **Dimension:** 130mm x 70mm x 60mm
- **Power inlet type:** Square pin (Type G)
- **Power outlet types:** Square pin (Type G), Circular Pin (Type D)
- **Development board:** ESP 8266 NodeMCU

3.2 Development Board Specifications

The ESP8266 NodeMCU development board used in Smartie offers the following key specifications:

- **ESP8266 Chip:** Powered by the ESP8266 Wi-Fi module for wireless connectivity.
- **Microcontroller:** Includes a powerful microcontroller unit (MCU) for efficient processing.
- **Processing Power:** Operates at up to 80MHz clock speed for fast execution of tasks.
- **Memory:** Provides onboard memory (4MB to 16MB) for program code and data storage.
- **GPIO Pins**: Features GPIO pins for easy integration with external devices.
- **Programming Interface:** USB interface for programming and debugging.
- **Arduino Compatibility:** Arduino IDE compatibility for convenient development and customization.

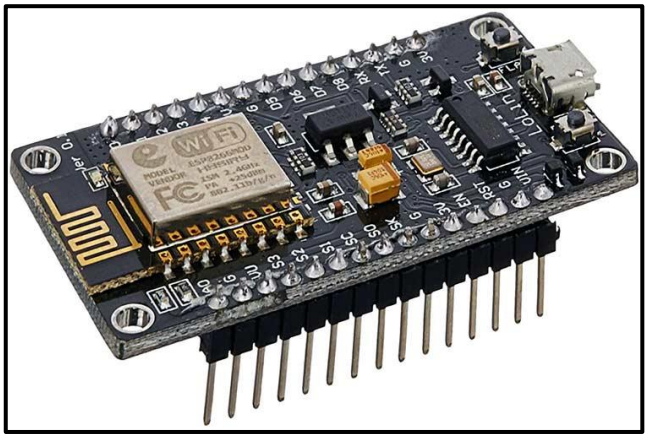


Figure 2: ESP8266 NodeMCU

3.3 Mobile Application specifications

The *Smartie* mobile application, powered by Blynk 2.0, brings seamless control and advanced features to our fingertips. Designed to work in tandem with the ESP8266 NodeMCU and *Smartie's* smart plug socket, this innovative application empowers us to effortlessly manage our devices and enhance our smart home experience.

The heart of the *Smartie* mobile application is Blynk 2.0, a powerful platform that enables intuitive and customizable control interfaces. With its user-friendly interface and extensive capabilities, Blynk 2.0 allows you to tap into the full potential of *Smartie* and its connected devices.

Through the mobile application, we gain real-time control over our devices, giving us the freedom to turn them on or off remotely with just a tap on our mobile screen. Whether we're at home or on the go, the convenience of managing our devices from the palm of our hand is now within reach.

It also integrates temperature monitoring functionality, providing us with instant access to real-time temperature readings. Stay informed about our surroundings and make informed decisions to maintain optimal comfort levels. With Blynk 2.0's seamless integration, *Smartie* can detect excessive temperatures and automatically cut off power to the connected devices, ensuring a secure environment for us and our home.

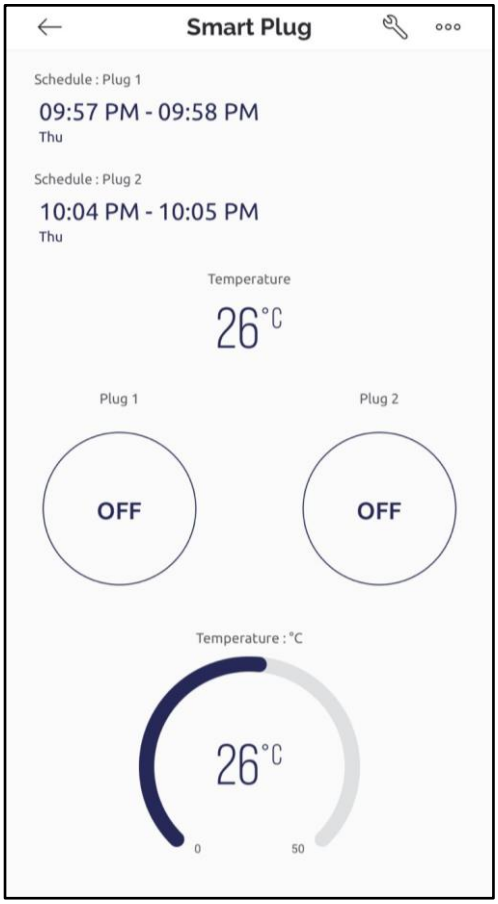


Figure 3: Blynk Mobile App Dashboard

3.4 Web Application specifications

Smartie web application, also powered by Blynk 2.0, which brings the same level of convenience and control to our desktop or laptop computer. With that we can seamlessly extend our device management capabilities beyond our mobile device and access them from the comfort of our web browser. Powered by the same robust Blynk 2.0 platform, the web application offers a familiar interface with additional functionalities and a larger screen real estate.

Just like its mobile counterpart, the web application allows us to effortlessly control and monitor our devices remotely. With a few clicks, we can turn devices on or off, adjust settings, and view real-time device status. Blynk 2.0's seamless integration ensures that the web application maintains feature parity with the mobile app. We can still benefit from temperature monitoring, automatic heating protection, time scheduling and notifications.

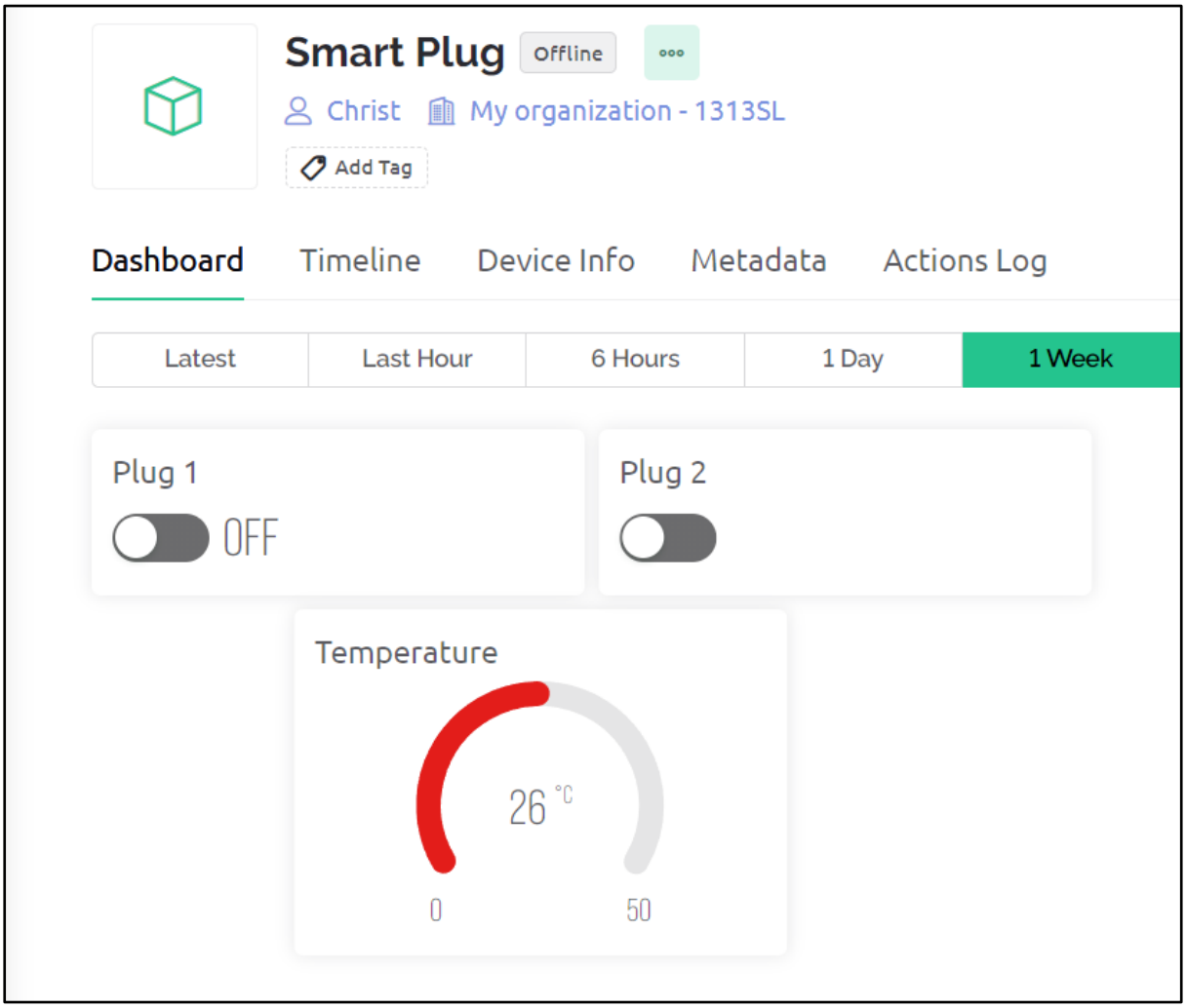


Figure 4: Blynk Web Application's Dashboard

4. Schematics, BOM, and PCB Gerber Files

4.1 Block Diagram

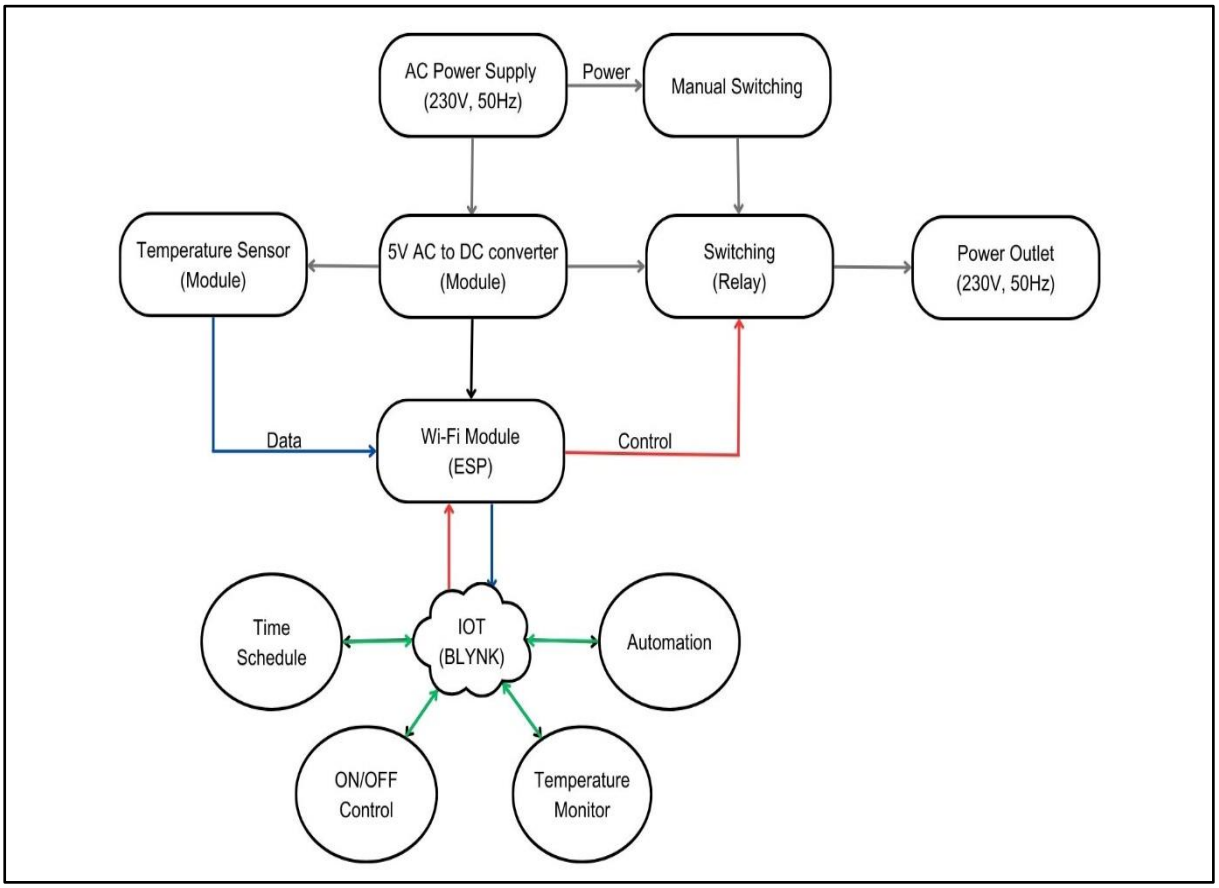


Diagram 1: Block Diagram

This is the initial block diagram that aligns with the product's specifications. To ensure efficient power supply to the Wi-Fi module (ESP8266 NodeMCU), a single module that directly converts the 230V AC input to 5V DC is used. This approach not only contributes to a compact PCB design but also facilitates the overall compactness of the product. Consequently, it becomes more convenient to power both the Wi-Fi module and the temperature sensor within the smart plug.

The BLYNK IoT platform is used because of its user-friendly nature and simplistic user interface. This choice ensures easy setup and enhances the marketability of the product. Additionally, BLYNK offers all the desired features and functionalities I had envisioned for the smart plug.

4.2 Schematic Design

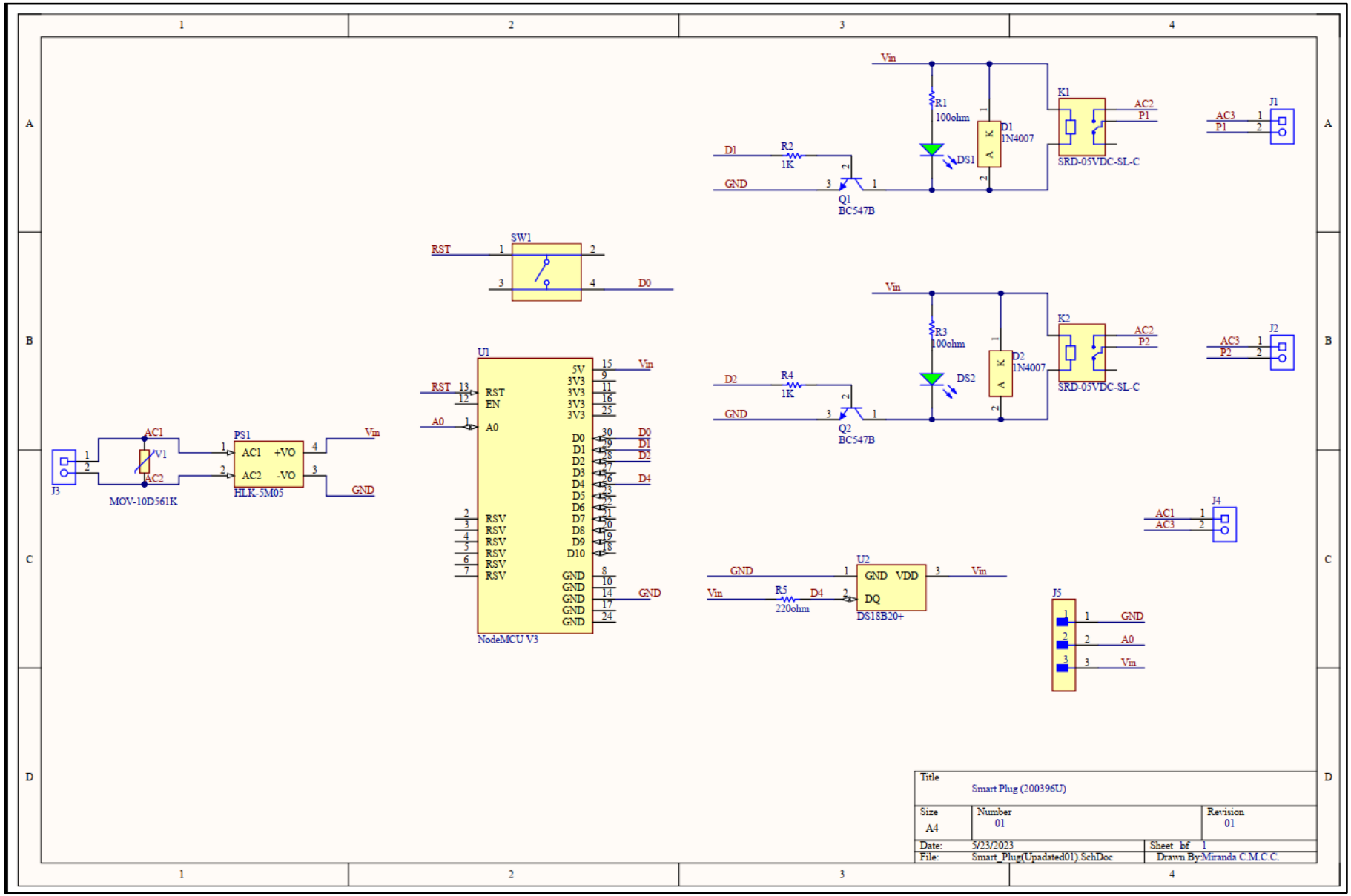


Figure 5: Schematic

4.3 Bill of Materials (BOM)

Designator	Component	Model	Unit Price	Quantity	Total Price
U1	Development Board	ESP8266 NodeMCU	1000.00	1	1000.00
PS1	230V AC to 5V DC converter	HI-LINK HLK-5M05	890.00	1	890.00
K1, K2	5V Relay	Songle SRD-5VDC	120.00	2	240.00
U2	Temperature Sensor	MSKSEMI DS18B20	170.00	1	170.00
Q1, Q2	Transistor	LGE BC547B	10.00	2	20.00
V1	Varistor	RUILON 10D561K	20.00	1	20.00
D1, D2	Diode	JUXING 1N4007	10.00	2	20.00
SW1	Button Switch	Tactile Push Button	20.00	1	20.00
R2, R4	Resistor	1KΩ	2.00	2	4.00
R5	Resistor	220 Ω	2.00	1	2.00
R1, R3	Resistor	100 Ω	2.00	2	4.00
DS1, DS2	LED	RED	10.00	2	20.00
J1, J2, J3, J4	Screw Terminal Block	2 Pin	30.00	3	90.00
Total Amount (Components only)					2500.00

Components Cost:

The components have all been imported from abroad.

Components Cost = **LKR 2500.00**

Total Cost of Shipping = **LKR 2500.00** (including VAT and other taxes)

Total Components Cost = **LKR 5000.00**

PCB Cost:

PCB was printed in JLC PCB, China.

PCB Printing Cost = LKR 1500.00

PCB Shipping Cost = LKR 2000.00 (including VAT and other taxes)

Total PCB Cost = **LKR 3500.00**

Enclosure Cost:

Enclosure was printed using 3D printing in Sri Lanka.

Printing Cost = LKR 4500.00

Shipping Cost = LKR 500.00

Total Enclosure Cost = **LKR 5000.00**

Total Cost:

Components = LKR 5000.00

PCB = LKR 3500.00

Enclosure = LKR 5000.00

Total Cost = LKR 13500.00

4.4 Supply Chain

No.	Component	Supplier
1.	Development Board	Shenzhen Jin Da Peng Technologies, China
2.	230V AC to 5V DC converter	LCSC Electronics, China
3.	5V Relay	
4.	Temperature Sensor	
5.	Transistor	
6.	Varistor	
7.	Diode	
8.	Button Switch	
9.	Resistor	
10.	LED	
11.	Screw Terminal Block	

4.5 PCB and Gerber

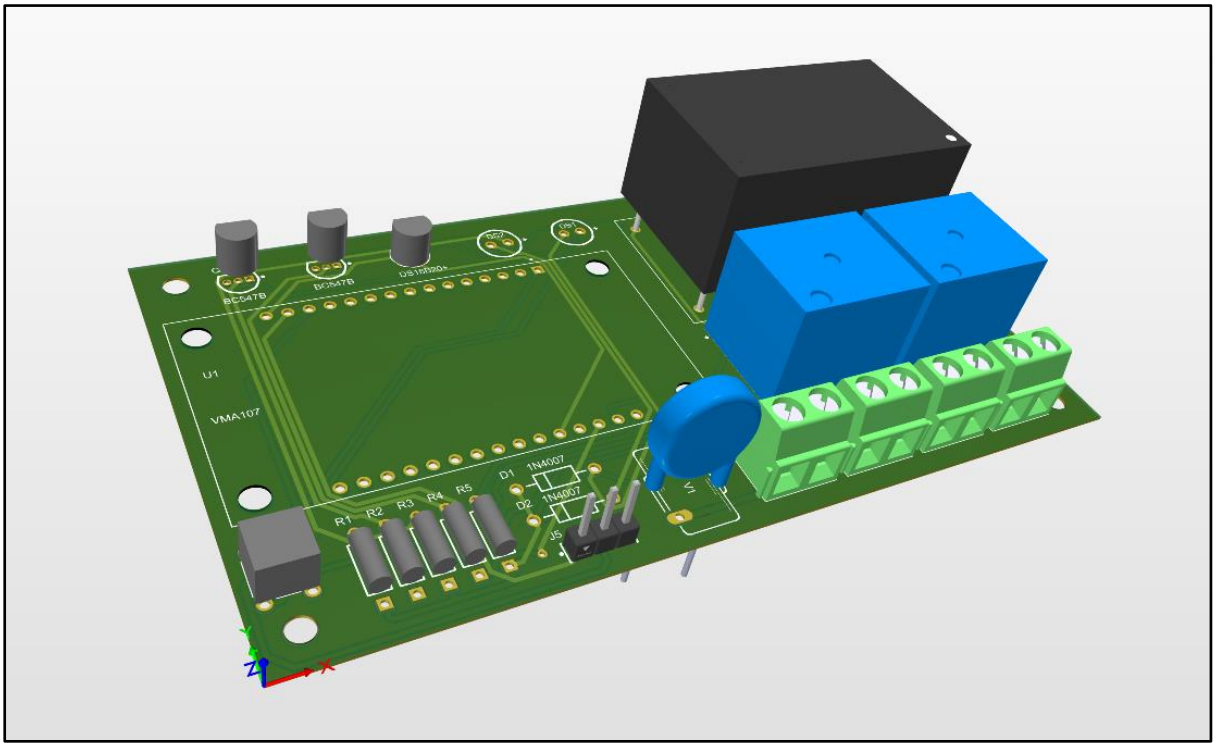


Figure 6: PCB-3D View.

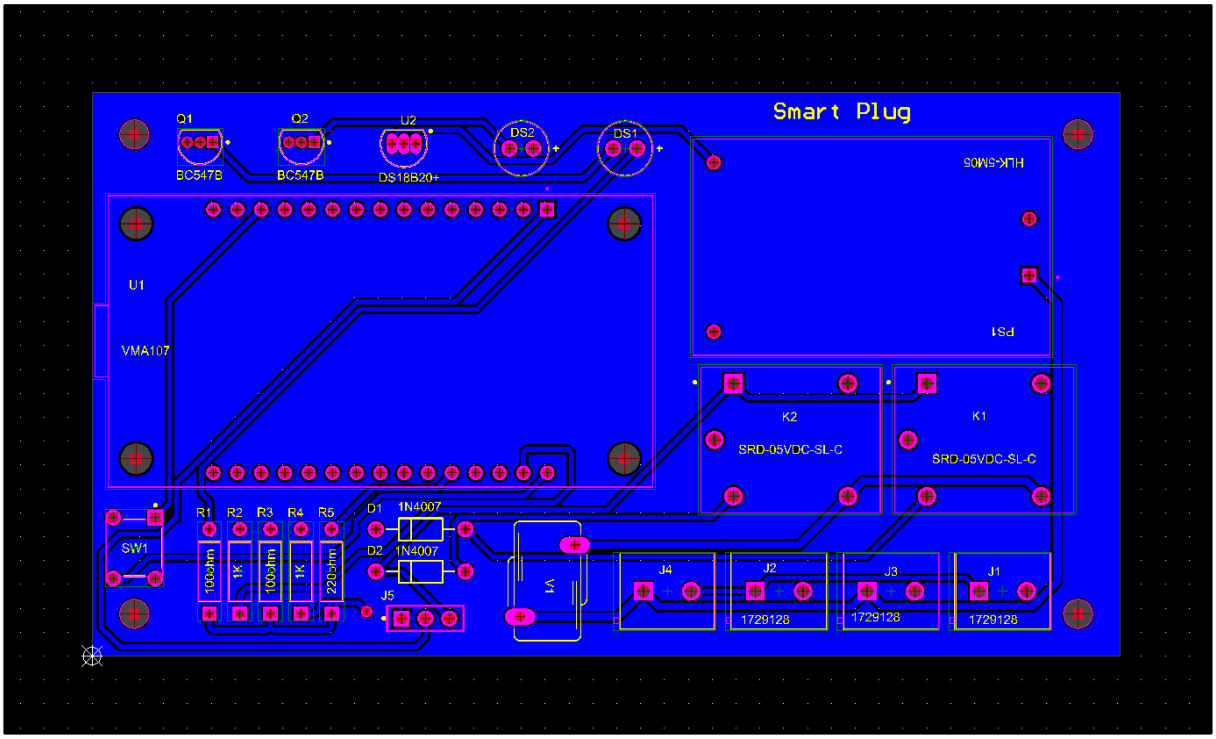


Figure 7: .CAM file

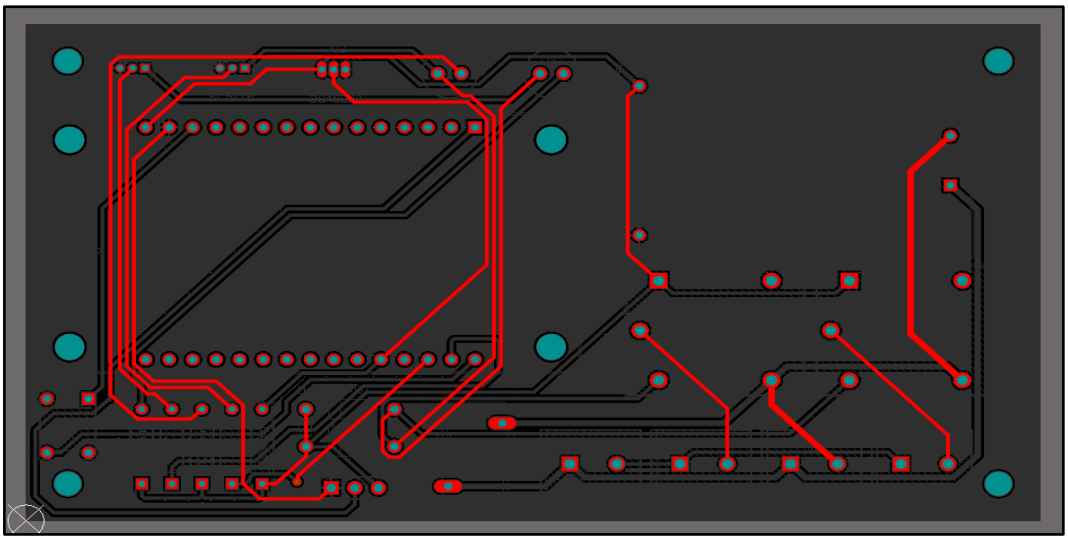


Figure 8: Top Layer

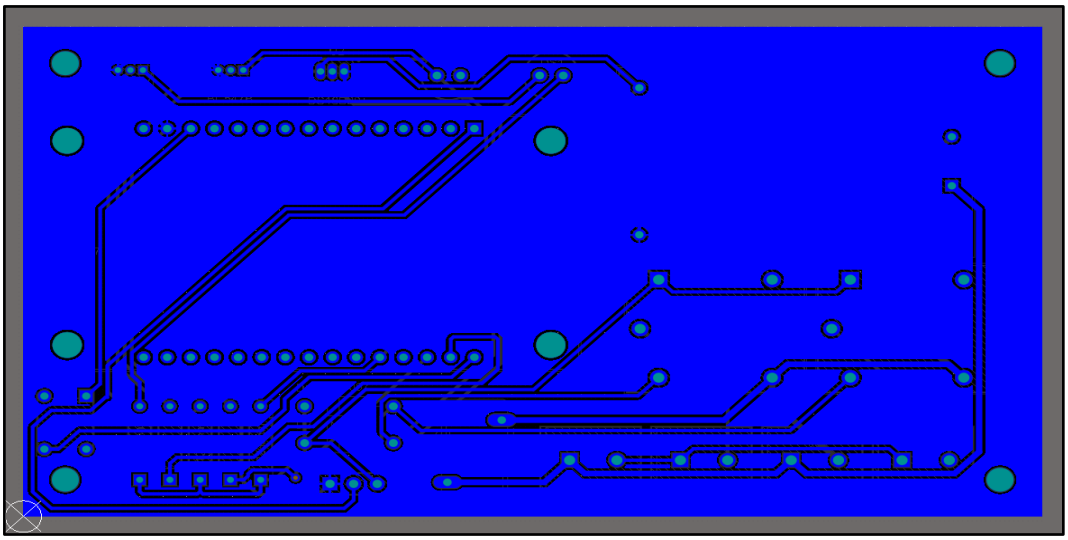


Figure 9: Bottom Layer

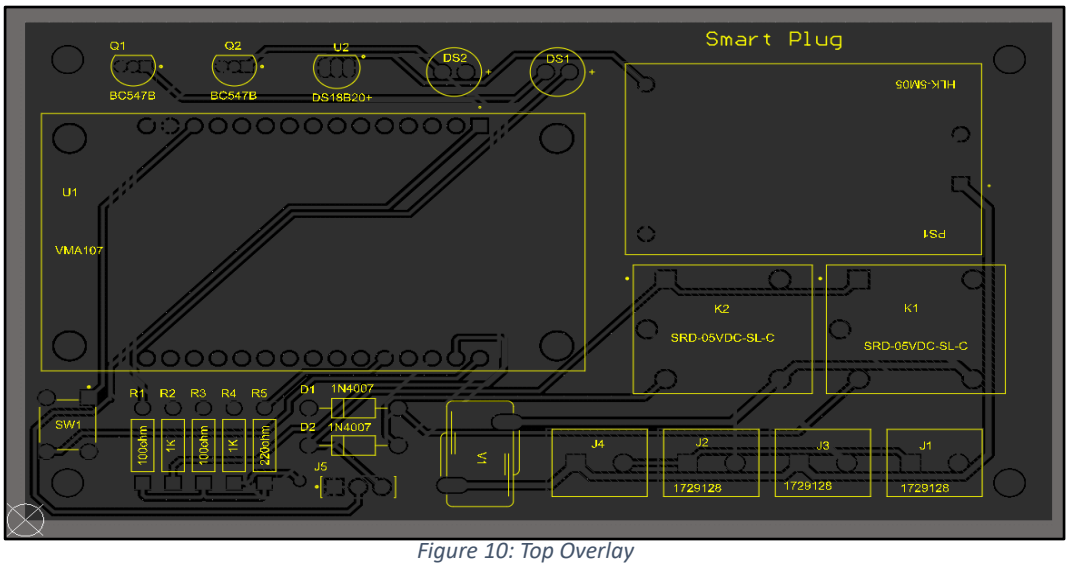


Figure 10: Top Overlay

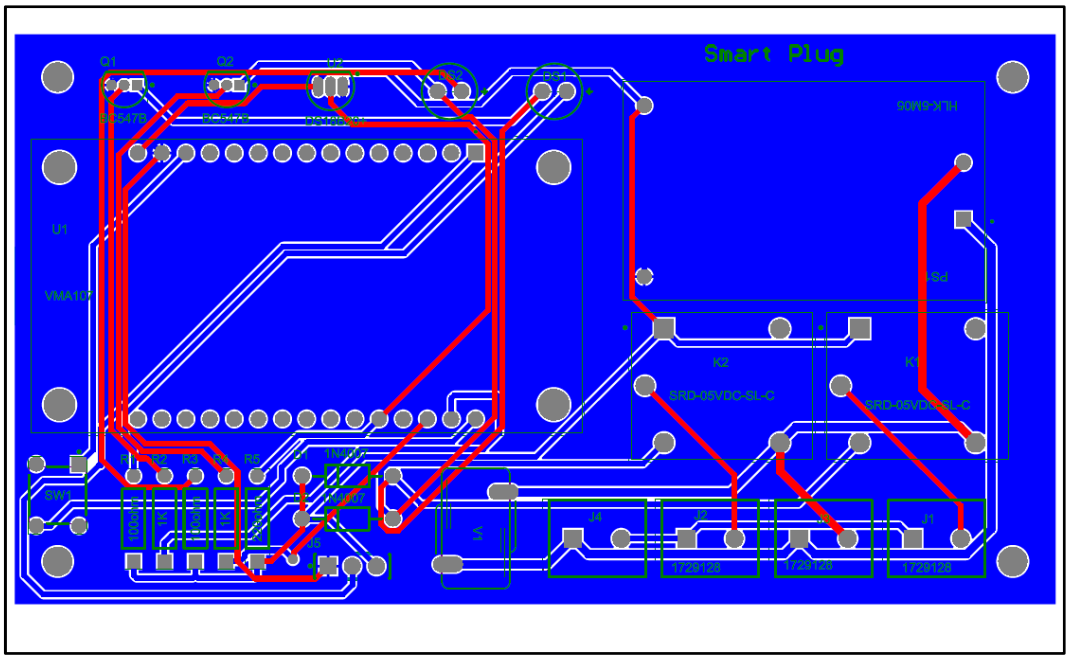


Figure 11: PCB

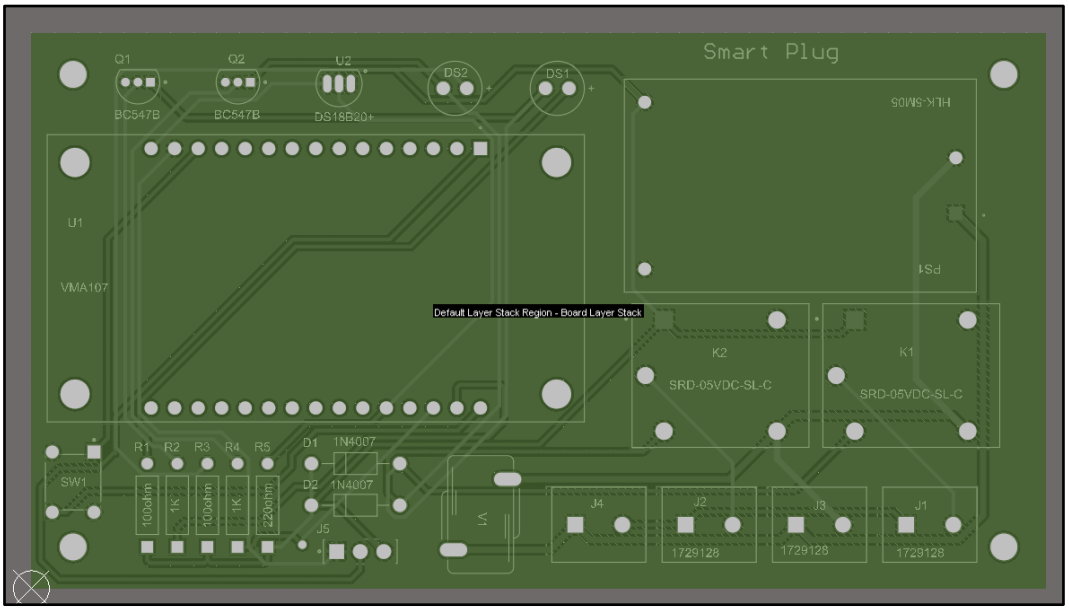


Figure 12: PCB-2D View.

Board Specification

- Board Size = 109.5000mm x 60.0000mm
- Components on board = 23

4.6 Arduino Code for ESP8266

[Arduino Code: GitHub Link]

5. Enclosure Design Files

5.1 Hand-drawn Sketches

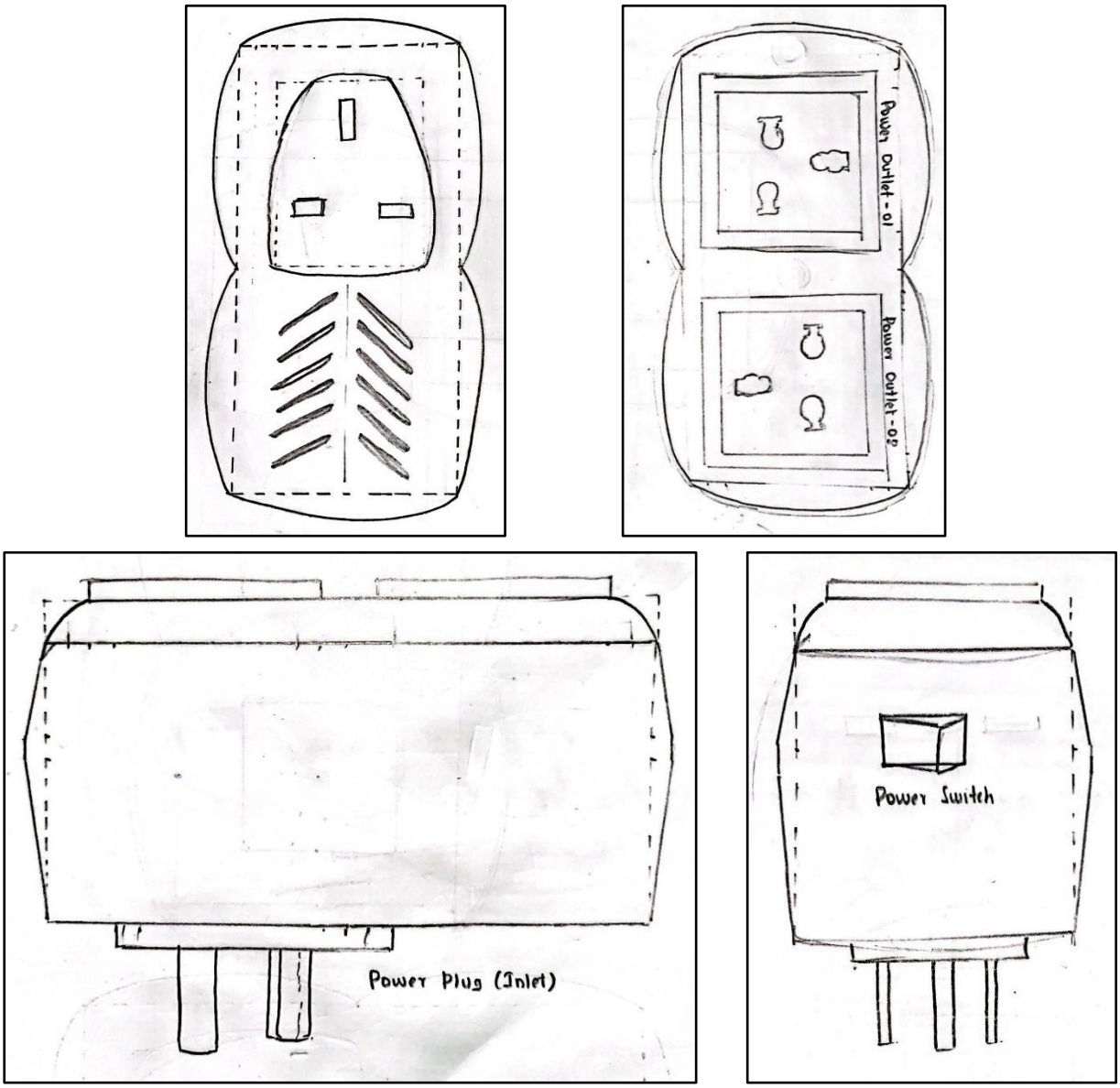


Figure 6: Hand-drawn sketches

This design aimed to address the limitations of traditional multiplugs commonly used in our daily lives. Many of those multiplugs lack multiple outlets and a convenient power switch. So that I chose this design featuring two power outlets, along with a shared power switch for simultaneous control.

Furthermore, as the outlets were placed vertically, they are positioned in opposite directions to prevent any potential collision between connected plugs. To ensure proper airflow and prevent overheating, air vents have been incorporated into the design.

5.2 Bottom Case – SolidWorks

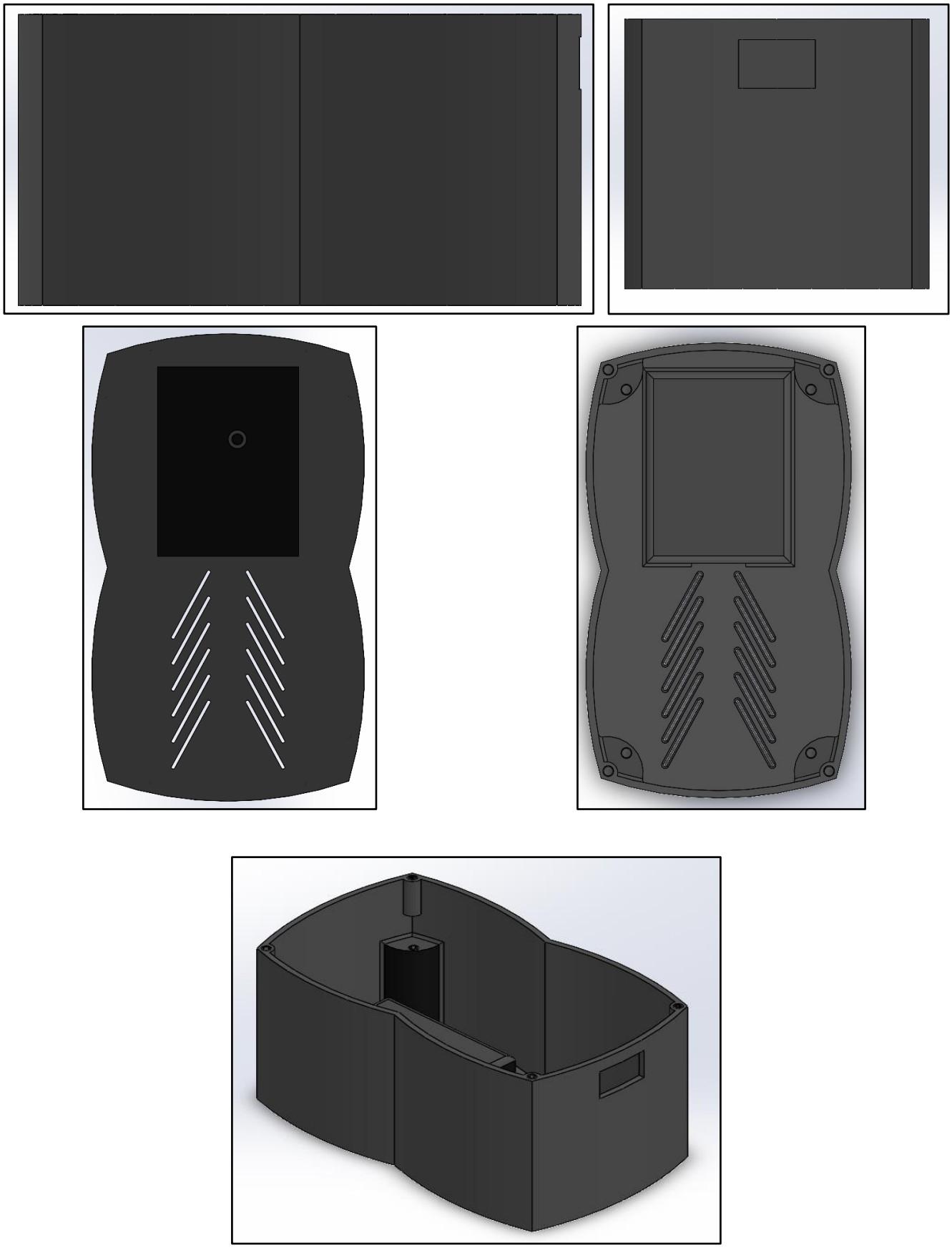
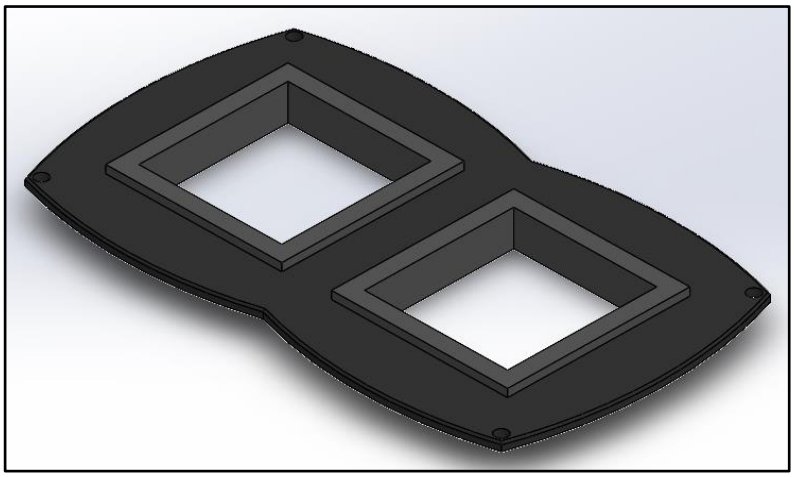


Figure 7: Bottom Case - SolidWorks

5.3 Top Lid – SolidWorks



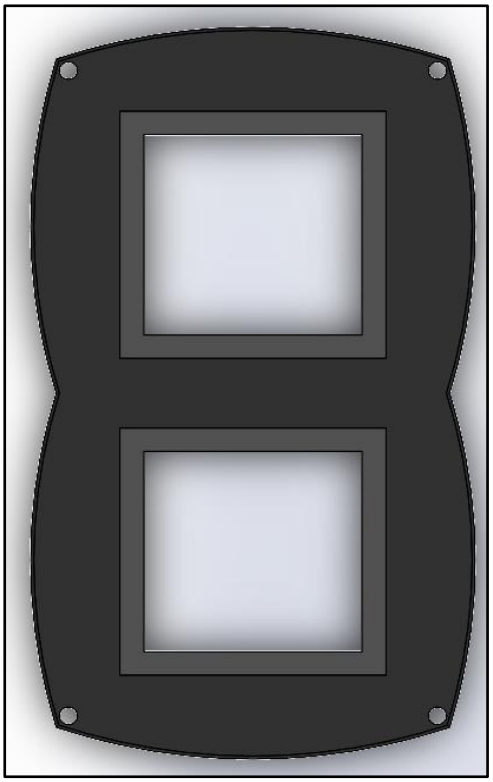


Figure 15: Top Lid - SolidWorks

5.4 Assmble Enclsoure with PCB- SolidWorks

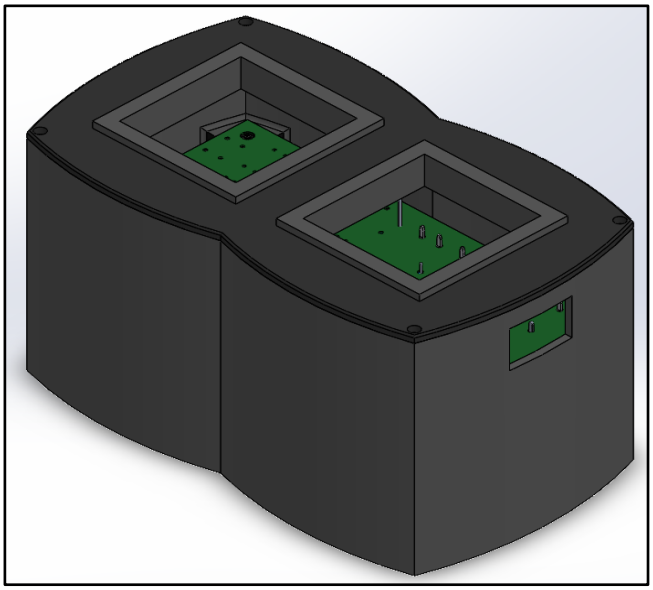


Figure 16: Assembled Enclosure with PCB mounted.

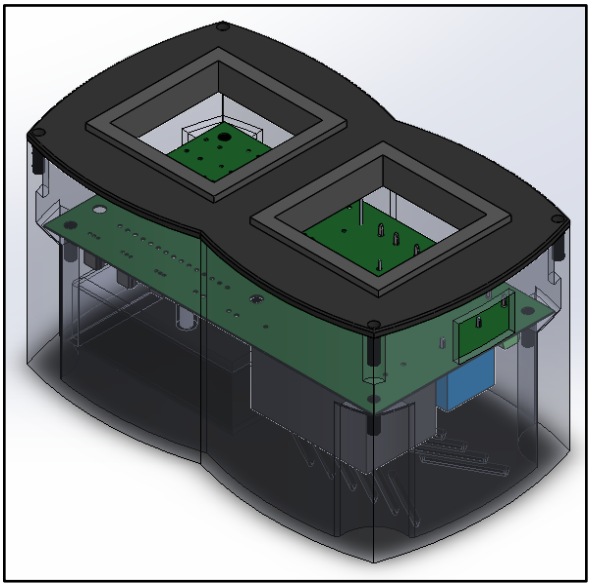


Figure 17: Assembled enclosure with screw holes

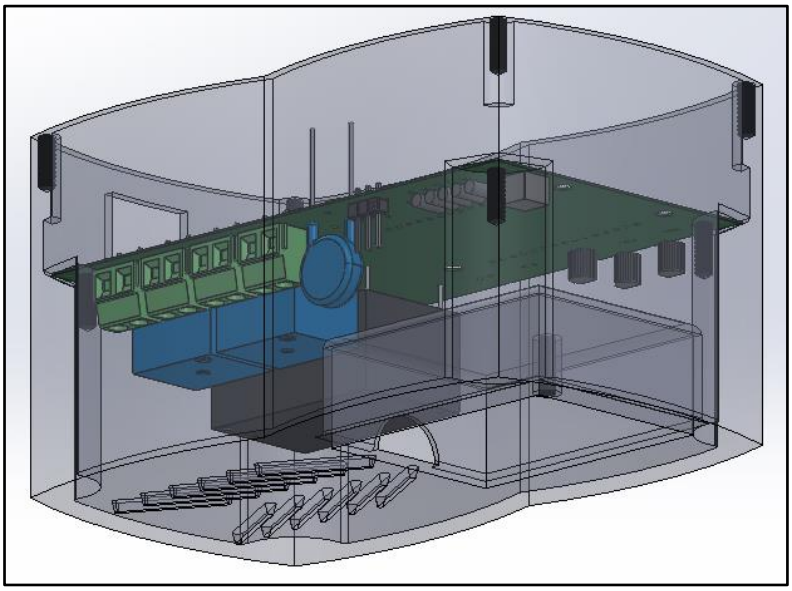


Figure 18: Bottom case with screw holes for PCB and PCB mounted.

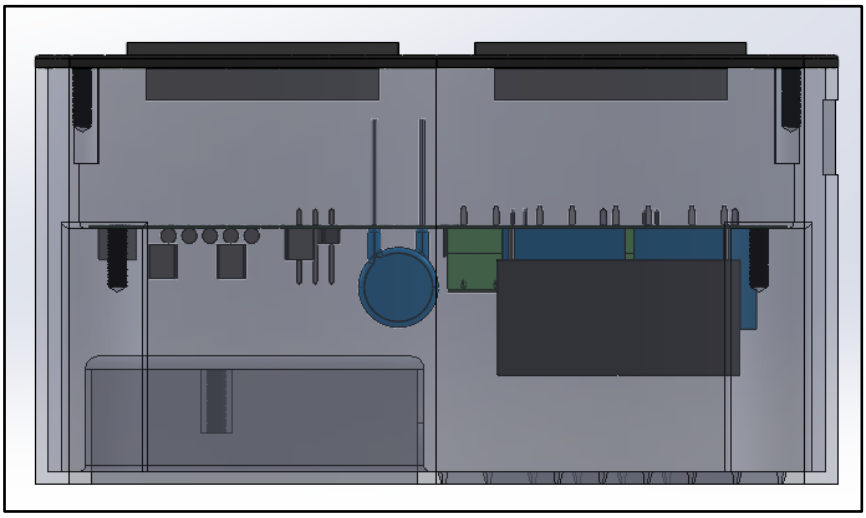


Figure 19: Screw holes for mounting PCB and top Lid with bottom case

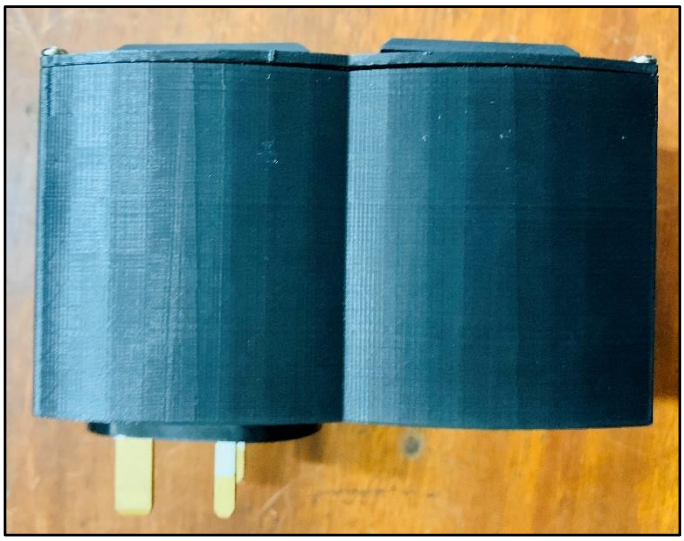


Figure 20: Enclosure

5.5 User Interface

The *'Smartie'* is designed with a minimalist enclosure, focusing on convenience and seamless integration into a smart home ecosystem. While the primary user interface lies in the mobile and web applications, I've paid attention to the enclosure's subtle details to enhance the overall experience.

Sleek Power Switch:

On the front of the *'Smartie'*, there's a smooth, easy-to-use power switch. With just a gentle flick, we can conveniently disconnect power to both power outlets, ensuring maximum safety and energy efficiency.

Dual Power Outlets:

The *'Smartie'* features not just one but two power outlets. Designed to make the most out of its vertical form, the outlets are thoughtfully positioned in opposite directions, one facing left and the other right. This unique layout allows for efficient usage of space and ensures that you can plug in two devices without any hassle. Whether it's a Type G (Square Pin) or Type D (Circular Pin) plug, both fit seamlessly into the outlets, accommodating various input devices.

Universal Power Inlet:

Located at the back of the *'Smartie'*, you'll discover a square pin power inlet. Universally compatible with the standard wall sockets prevalent in most homes in Sri Lanka, this feature makes the Smart Plug the perfect companion for local distribution.

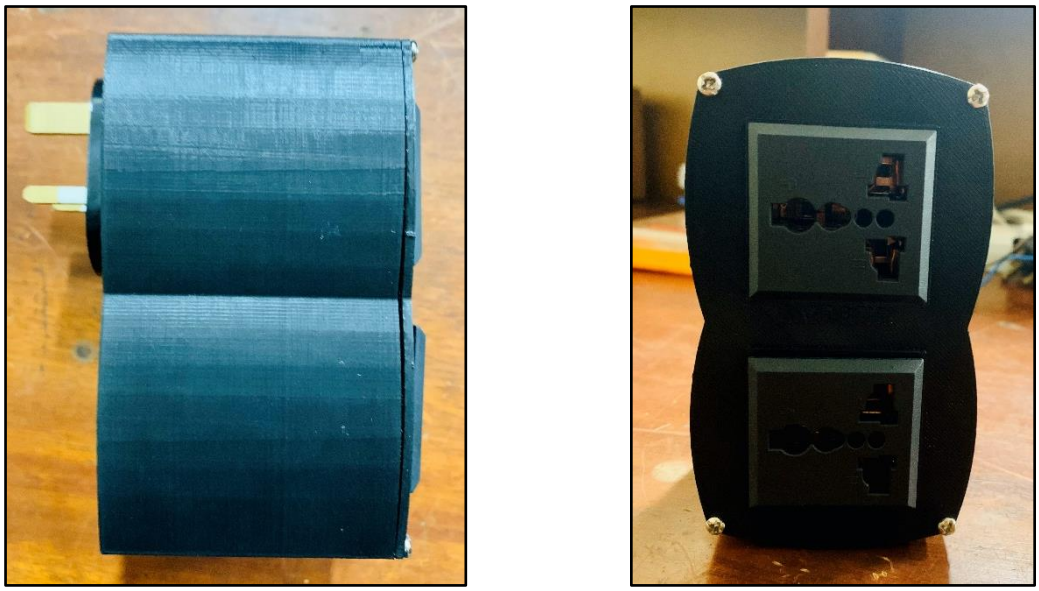


Figure 21: User Interface (Power Inlet and Power Outlets)

5.6 Material Selection for Enclosure

When creating the enclosure for a smart plug, choosing the right materials is crucial to guarantee its strength, safety, and overall effectiveness. Initially, for the prototype, I used 3D printing to manufacture the enclosure. However, for mass production, we need to explore more professional manufacturing methods such as injection molding. In this process, the following factors must be taken into consideration:

Heat Resistance:

The material should have good heat resistance to withstand the heat generated by the electrical components within the enclosure. This is crucial to prevent warping or deformation and maintain the structural integrity of the smart plug.

Impact Resistance:

The enclosure should be able to withstand accidental impacts or drops without cracking or breaking. This ensures the safety of both the user and the internal electronics.

Electrical Insulation:

The chosen material must provide proper electrical insulation to prevent any electrical leakage or short-circuits that could be hazardous to users or connected devices.

Environmental Considerations:

The material should be environmentally friendly and, if possible, recyclable to minimize its impact on the environment.

5.7 Safety Considerations for Enclosure

Proper Insulation:

To ensure safety and minimize the risk of electric shocks, the enclosure must offer sufficient insulation to prevent direct contact with live electrical components. To achieve this, heat sleeves have been incorporated into all connections within the enclosure. These heat sleeves act as protective barriers, safeguarding users from any potential electrical hazards.

Ventilation and Heat Dissipation:

Sufficient ventilation is a crucial aspect of the enclosure design to prevent internal components from overheating, especially when the smart plug supports high-power devices. To address this, air vents have been strategically incorporated at the bottom of the product, ensuring a continuous and ample airflow within the device. This effective ventilation system helps maintain optimal operating temperatures and enhances the overall performance and safety of the smart plug.

6. Assembly and Installation Instructions

6.1 Assembly Instructions

For manufacturers, the installation process involves several steps to ensure a successful assembly:

Components placing on the PCB:

Begin by placing the components on the PCB with precise orientation and appropriate values. While all components used are through-hole, consider incorporating surface mount components to enhance PCB compactness without compromising product functionality.

Mounting PCB in the enclosure:

Once the enclosure is ready, typically through 3D printing, (For bulk production they will be made via molding procedure) securely mount the PCB using screws and a beam-like structure inside the enclosure. To maintain compactness, position the PCB upside down within the enclosure.

Basic Wiring:

Proceed with the proper wiring, connecting the inlet plug to the PCB. Integrate a control switch into the circuit to enable manual control functionality. This will be done using the live wire connectivity.

Installing power outlets:

Install the power outlet on the top lid with utmost care for orientation. Connect the Neutral wire from the appropriate connector on the PCB in parallel with the outlets. Similarly, connect the Live wire. For safety, directly link the earth wire from the inlet plug to the power outlets.

Placing Inlet Plug:

Carefully place the inlet plug into its designated slot and secure it with a screw for stability.

Finishing:

Finally, close the top lid, securing it with 3mm tap-in screws for a polished finish.

By following these steps diligently, the manufacturing process will result in a high-quality product that meets both functionality and aesthetic requirements.

6.2 Installation Guide

The installation process for Smartie is straightforward and user-friendly. Upon purchasing the product, customers are required to establish a connection between Smartie and either a mobile hotspot or a Wi-Fi router. It is crucial to note that Smartie operates exclusively on a 2.4GHz network band. Consequently, users must ensure compatibility with this specific frequency range before proceeding with the setup process.

The procedure is,

1. To begin the installation process, **download the Blynk application** from either the App Store or the Play Store.
2. Proceed with **creating a Blynk account** by completing the registration process. Once successfully registered, **sign in to your Blynk account** using the provided credentials.
3. To get started, simply **plug your Smart Plug into any standard wall socket.**
4. To initiate the setup process, **navigate to the device search option**.

   (Before proceeding, ensure that the Wi-Fi network you intend to connect the smart plug to is active and operational. Additionally, it is essential that the device you are utilizing to search for the smart plug is connected to the same Wi-Fi network.)
5. Once the **smart plug device has been successfully detected during the search process, simply select, and connect to it.**

   (This will establish a secure and reliable connection between your device and the smart plug. With this connection established, you are now ready to enjoy the full functionality and convenience that the smart plug offers.)
6. Take full advantage of the customization options available to you and **personalize your dashboard according to your preferences.**
7. Enjoy the convenience of accessing and controlling your smart plug from any device or web application by simply logging in to your Blynk account.

With this seamless integration, you gain the ability to manage your smart plug effortlessly from the comfort of your preferred device or through the user-friendly web interface. Whether you're at home, at work, or on the go, the power to control and monitor your smart plug is always at your fingertips.

Reference: Blynk.Documentation

7. Functionality Testing

These are the results of the functionality testing conducted on 'Smartie'. The purpose of these tests is to ensure that the smart plug performs its intended functions accurately and reliably. The tests were conducted in a controlled environment to simulate real-world usage scenarios.

On/Off Functionality:

Test Procedure:

The smart plug was connected to various devices, including lamps, chargers, and electronic gadgets, to verify the on/off functionality.

Test Result:

The smart plug successfully turned connected devices on and off as expected, both through the mobile app and the web app.

Compatibility Testing:

Test Procedure:

The smart plug was tested with devices of different power ratings to check for compatibility.

Test Result:

All devices tested, ranging from 50W to 1500W, were compatible with the smart plug, and it handled varying loads effectively.

Communication with Mobile App:

Test Procedure:

The smart plug was paired with the Blynk app, and commands were sent to control the plugs remotely.

Test Result:

The mobile app communicated seamlessly with all five smart plugs, and commands were executed promptly without any failures.

Timer and Scheduling:

Test Procedure:

The timer and scheduling features were tested by setting the plugs to turn devices on/off at specified times.

Test Result:

All smart plugs adhered to the predefined schedules, and devices were switched on/off at the correct times consistently.

Overheating Protection:

Test Procedure:

The smart plugs were tested under continuous high-load conditions to evaluate overheating protection.

Test Result:

All smart plugs effectively detected overheating and shut down to prevent potential fire hazards.

Based on the functionality testing results, *'Smartie'* has demonstrated excellent performance and reliability. All key features, including on/off functionality, timer, scheduling, and safety mechanisms, functioned flawlessly. The smart plug exhibited compatibility with a wide range of devices and maintained stable Wi-Fi connectivity within a reasonable range. The remote-control capabilities and manual operation provided users with convenient control options. Overall, the smart plug meets the highest standards for quality, functionality, and safety.

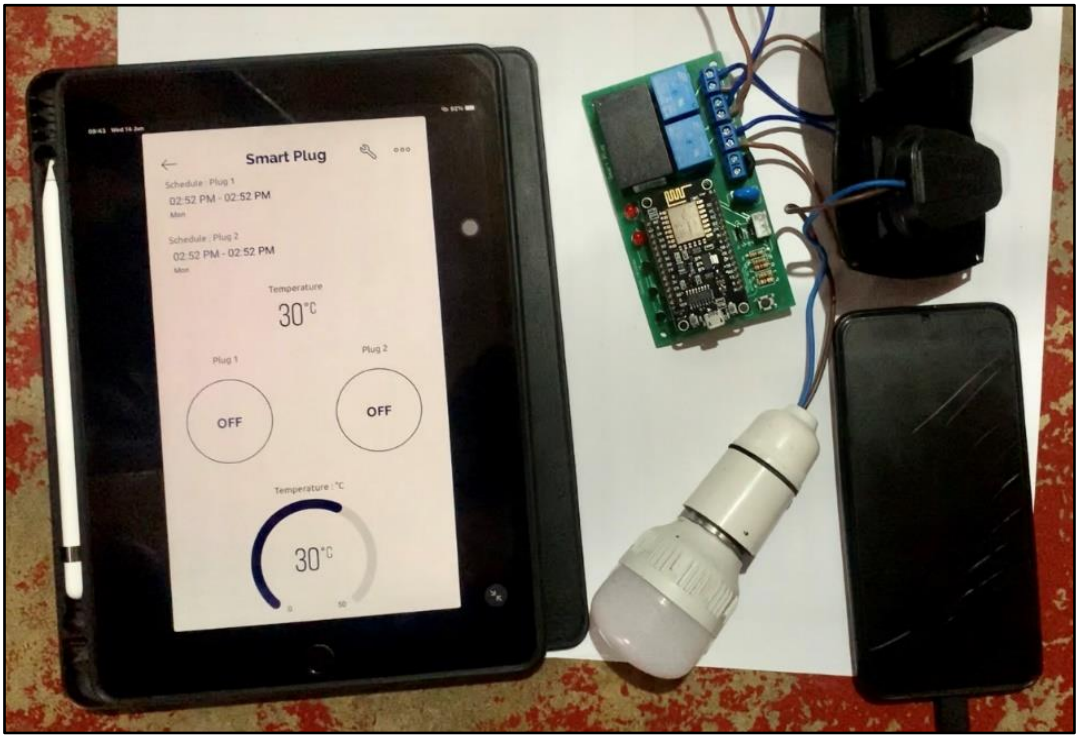


Figure 22: Testing

8. Summary and Conclusion

During the initial stages of development, I successfully implemented several exciting features for the smart plug, as mentioned in the introduction. However, due to certain technical challenges, I couldn't achieve all the planned and recommended features. Nevertheless, I am committed to continuously improving the product, and here are some future upgrades that I am considering:

Voice Control:

I understand the importance of voice control for seamless user experience. Therefore, integrating the smart plug with popular voice assistants like Alexa and Google Voice Assistant will be a much-needed upgrade. With this upgrade, users will be able to control the plug's functionalities using simple voice commands.

Enhanced Charging Options:

Incorporating both USB-C and USB-A outlets into the smart plug will be a valuable addition. This addition will enable users to charge a wider range of devices simultaneously, catering to various charging needs.

Separate Power Switches:

To offer greater manual control and convenience, it'll be more useful to add individual power switches for each outlet on the smart plug. This way, users can turn on/off specific devices connected to the plug without affecting others.

Power Monitoring Features:

Recognizing the growing demand for energy efficiency, developing power monitoring capabilities for the smart plug will be more appropriate. This feature will allow users to track energy consumption of connected devices and gain insights into their power usage, promoting responsible energy practices.

9. Bibliography

1. Inclusive Design Toolkit – Cambridge University
2. ESP8266 NodeMCU Datasheet
3. Blynk Documentation
4. 230V AC to 5V DC converter Datasheet