IOT BASED SMART SINGLE WALL OUTLET

SAW JIAN JING

A project report submitted in partial fulfilment of the
requirements for the award of Bachelor of Engineering
(Honours) Electrical and Electronic Engineering

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature :

Name : SAW JIAN JING

ID No. : 15UEB01389

Date : 23/4/2020

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"IOT BASED SMART SINGLE WALL OUTLET"** was prepared by **SAW JIAN JING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Honours) Electrical and Electronics Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature :

Supervisor : DR. SEE YUEN CHARK

Date : 23/4/2020

Signature :

Co-Supervisor :

Date :

ABSTRACT

Wall outlets are standard household devices in our homes to power up electrical appliances. Occasionally, energy is wasted if the outlets are left switched on unintentionally. It is difficult to be detected without the aid of a measuring or monitoring device. These issues arise due to the absence of convenient wall outlets controlling and monitoring. Although there were smart wall outlets available in the market, most of them are an external plug and play device that can be controlled and monitored remotely within the same connection only. On top of that, inappropriate usage of these outlets could also lead to major catastrophic events such as electrocution or fire, particularly among toddlers and children. This project presents an Internet of Things (IoT) based smart wall outlet system with a locking mechanism that remotely monitors the usage of electrical appliances that plug into the socket. The socket uses the Radio Frequency Identification (RFID) reader as the input signal to gain access. The proposed system allows users to control and monitor energy consumption in real-time through a custom mobile application. The electricity tariff will be calculated and shown to the user. The system consists of a home control unit and two smart wall outlets. The home control unit will be set up using a Raspberry Pi loaded with Hass OS that integrates with Home Assistant. On the other hand, the smart wall outlets will be controlled by the MHET ESP32 Mini Kit with custom firmware loaded from ESPHome. The physical structure of the conventional wall outlet is redesigned by including the locking cover with a solenoid magnet. A few experiments were conducted on the proposed wall outlet system, and encouraging results were achieved.

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LIST OF SYMBOLS / ABBREVIATIONS

w	power, watt

AC	Alternating Current
BLE	Bluetooth Low Energy
GCP	Google Cloud Platform
GUI	Graphic User Interface
IDE	Integrated Development Environment
IoT	Internet of Things
IP	Internet Protocol
IR	Infrared Radiation
MQTT	Message Queuing Telemetry Transport
NB	Narrowband
NoSQL	Not Only Structured Query Language
OS	Operating System
PCB	Printed Circuit Board
PF	Power Factor
RFID	Radio Frequency Identification
RPi	Raspberry Pi
SDK	Software Development Kit
UV	Ultraviolet
VLAN	Virtual Local Area Network

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

In this day and age, electrical appliances operate by obtaining power in the form of alternating current (AC) from the wall outlet to bring comfort and convenience to human’s life. The structure of a typical standardised wall outlet, especially for commercial usage is single-phase which consists of two current-carrying connections connected from the electrical distribution board with an additional third pin for safety connection to earth ground. In the bygone era, wall outlets have been developed deliberately to dwindle the possibility of numerous hazards, for instance, electrocution or fire. However, they have not evolved substantially comparing to the pace of advancement in technology such as smart homes which are becoming increasingly prominent.

There are diverse “smart” wall outlets that have been developed and available in the market that derived from the concept of the Internet of things, bringing convenience to human’s life. However, most of the available smart wall outlets in the market are either an external plug and play smart device or have limited features and functionalities. There are a handful of wall outlet protectors that were designed to cover the wall outlet developed to prevent unintended electrocutions. Despite using these protectors, the incidents of electrocution, notably among the children, have been rising in recent years. Hence, there is a need to develop the development of a protected smart wall outlet to replace conventional wall outlets.

1.2 Problem Statement

The conventional wall outlet does not have the capability of being controlled or monitored remotely, thus, reduces user accessibility. This is particularly the case for people who are physically challenged. The situation is worsened when the wall outlet was located at hard to reach position. For example, behind the cabinet or cupboard. Although there were smart wall outlets that are equipped with such features, most of the devices can only be controlled and monitored remotely when the user is connected to the same connection as the wall outlets.

Apart from that, most of the wall outlets were positioned at the eye level of a child or toddler which may easily attract them to play with the outlets as the children may imitate their parent’s action or the little square holes that are perfectly sized for an object to be inserted. These wall outlets are extremely dangerous when the children insert their wet finger into an outlet or even more catastrophic when a piece of a conductor is inserted into the outlet. This will cause electrocution, which may result in injury or fatality.

In one of the recent cases that occur in Liaoning, China, a two-year-old toddler had lost her right palm and suffered severe burns on the face after being electrocuted at home. Based on the doctor’s report, the toddler may also have permanent damage to her heart and brain from the electrical shock. The mother claimed that she had put away the long nail that was seen holding by her daughter but still being plugged into an electrical socket by her daughter (C. Aruno, S. Hemanathani, 2020).

Another recent case occurred in Jahangirabad, India; a child was electrocuted to death after the child placed the tip of a phone charger that is switched on into the mouth. Based on the report, it was found that the mother of the child forgotten to switch off the wall outlet after removed her phone from the charger. The child was left nearby to the charger unsupervised, which consequently causes the electrocution to the child (Adu, 2019).

Based on the analysis of US Consumer Product Safety Commission (CPSC) data over ten years, it was found that more than 24,000 children of which under ten years old were sent to emergency rooms for cases that involve wall outlet electrocution. Based on the findings, the typical location of outlet electrocution accident happens at home with a percentage of 71%, 4% in school and public areas while 25% were unidentified as shown in Figure 1.1. For the home incidents, children inserting objects into the wall outlet are the majority causes, particularly hairpin and keys which have the characteristic of electrical conductivity (ESFi, 2011).

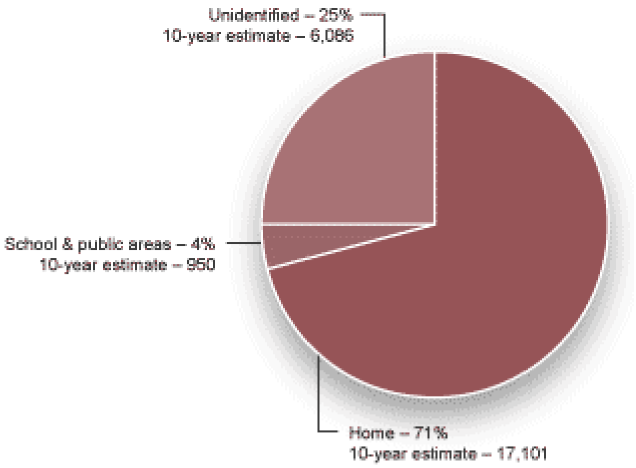


Figure 1.1: Analysis of US CPSC (ESFi, 2011)

On another 8-year study of 14 hospitals from Canadian Hospital Injury Reporting and Prevention Program (CHIRPP), it was found that approximately 465 children under nine years old were sent to emergency rooms for cases that involve wall outlet whereby 79% happened at home in which 69% were caused by insertion of object into the wall outlet (ESFi, 2011). The development of child safety mechanisms for wall outlet has to be enhanced further to not only hinder the accessibility by children but also avoid the electrical breakdown of the material inserted into the wall outlet holes which could cause a fire.

1.3 Aims and Objectives

In order to revamp the standard wall outlet into an IoT based smart wall outlet, multitudinous improvements are requisite. One of the main goals and objectives of this project is to develop a smart wall outlet with remote controlling and monitoring away from home function along with its mobile application. Apart from that, an external solenoid locking cover will be designed to prevent electrocutions from the wall outlet. Besides that, the total power consumption and its usage will be calculated in accordance with Malaysia's electricity tariff.

1.4 Scope and Limitation of the Study

In this project, there are three primary focuses which are to develop the functions of a smart wall outlet, design the physical structure of the wall outlet and develop an Android mobile application.

Every wall outlet will be connected to the home control unit. The system information of each wall outlet will be sent to the home control unit every interval while all the data collected will be sent to the Cloud by it. The system information will consist of connection status and power consumption. The wireless communication protocols used in this project will be Wi-Fi since it is readily available in both the controller and the server controller. ZigBee, however, has a lower power consumption compared to Wi-Fi, but it is less cost-effective for this small-scale project. An Android mobile application will be developed for the convenience of switching and monitoring of the wall outlets away from home.

For the physical structure of the wall outlet, it will be redesigned with a protective cover that is locked via holding electromagnet. The protective cover can be unlocked by either remote controlled via mobile app or RFID. The system of the wall outlet will be designed and produced in a printed circuit board (PCB) form to fit into the outlet box.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter gives a review of the different types of smart wall outlet development with various kinds of smart functionalities being added to the prototype. The information was taken from the articles and journals in which the review was taken based on the comparability of projects.

2.2 Smart Wall Outlet System and Management System

Smart wall outlets were commonly designed and developed for remote controlling and monitoring of power consumption. Thongkhao and Pora (2016) presented a Wi-Fi based smart plug with energy metering functions. The smart plugs were connected to a home server for unity management through a web server. The authors have conducted a few experiments on their proposed smart wall outlets system; relay driving, web application, and accuracy of measurements test. The overall measurement results from the smart plug were compared with PRS 1.3 Electronic Portable Reference Standard and CAL-Source 200 and the system yields an error of less than 0.5%.

On another approach, Han, Lee and Park (2009) presented a ZigBee based smart power outlet system as shown in Figure 2.1. The system consists of an automatic vampire power cut-off function. The power will cut-off if it falls below a threshold. A home appliance infrared remote control can be used to control the wall sockets via the infrared system. However, system implementation and the working principle are not well explained. The power outlets are not linked to a home server. Therefore, it is not possible to perform remote controlling and monitoring when the users are not in the house.

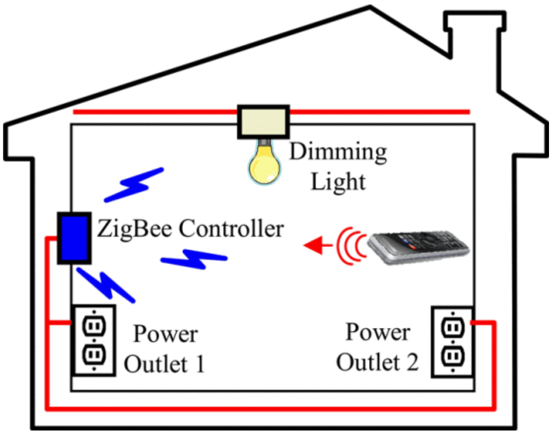


Figure 2.1: Proposed Room Architecture **(**Han, Lee and Park, 2009)

Hence, Lin *et al.* (2018) have proposed an expandable IoT-based smart socket system (MorSocket) in which multiple sockets can be controlled through webpage using MQTT protocol as shown in Figure 2.2. The proposed system allows the user to control environmental sensors such as temperature, humidity, UV and carbon dioxide remotely. The analytic and simulation models of user tolerance delay in controlling the sockets were implemented.

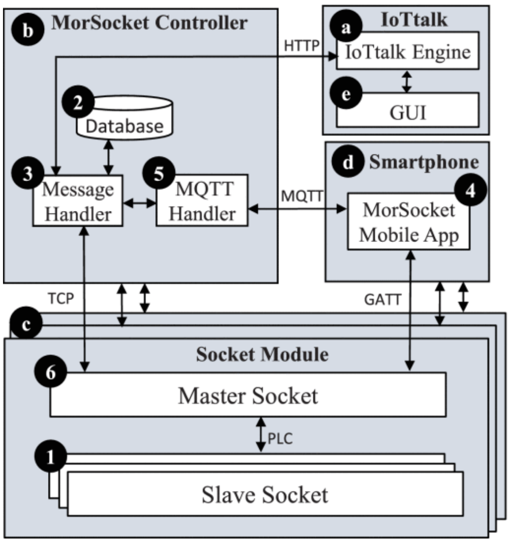


Figure 2.2: MorSocket network architecture (Lin *et al.* 2018)

A similar approach was presented by Du and Liu (2019), where Narrowband-IoT (NB-IoT) communication was used in the smart socket design. Figure 2.3 shows the overall design of NB-IoT based smart socket. The OceanConnect cloud platform was used to store the collected data and control devices. Various performance tests of smart sockets were conducted to verify the feasibility of the design scheme.

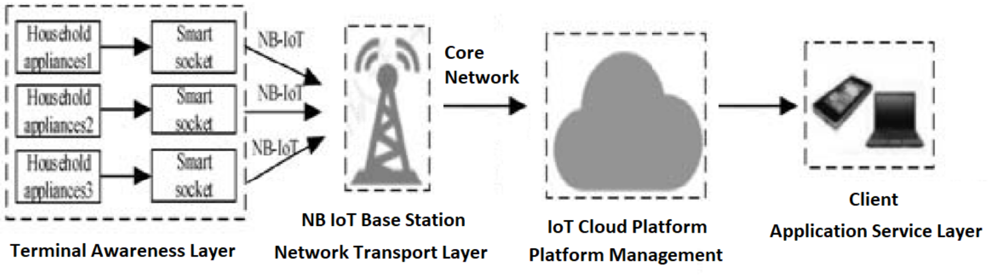


Figure 2.3: Overall design of NB-IoT based smart socket (Du and Liu, 2019)

2.3 Safety Functionality on Smart Wall Outlet

Apart from the common features of controlling and monitoring, there were still diverse smart wall outlets that were designed with extra safety and functionalities. For instance, Bai and Hung (2008) presented a ZigBee based smart socket with an overload detection function, as shown in Figure 2.4. The overload detection system will cut-off the supply to prevent further damage to the appliances. The flowchart of current measurement and overload detection is shown in Figure 2.5. A graphic user interface was designed as shown in Figure 2.6.

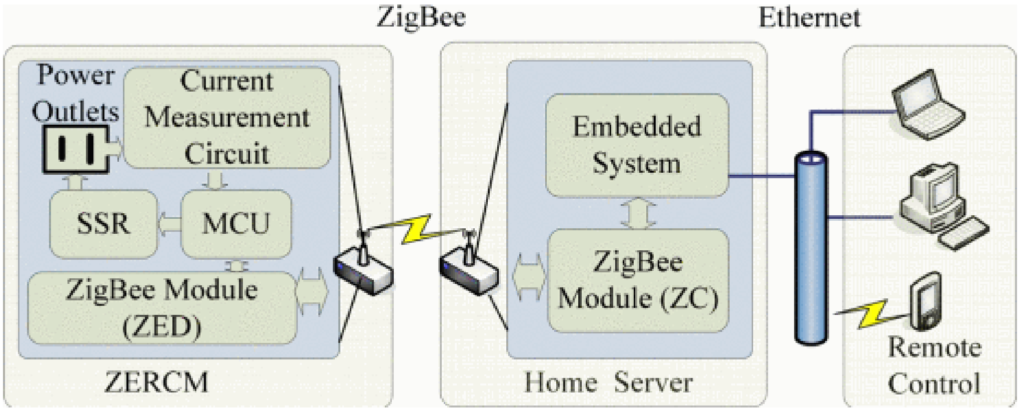


Figure 2.4: Block diagrams of the power management system (Bai and Hung, 2008)

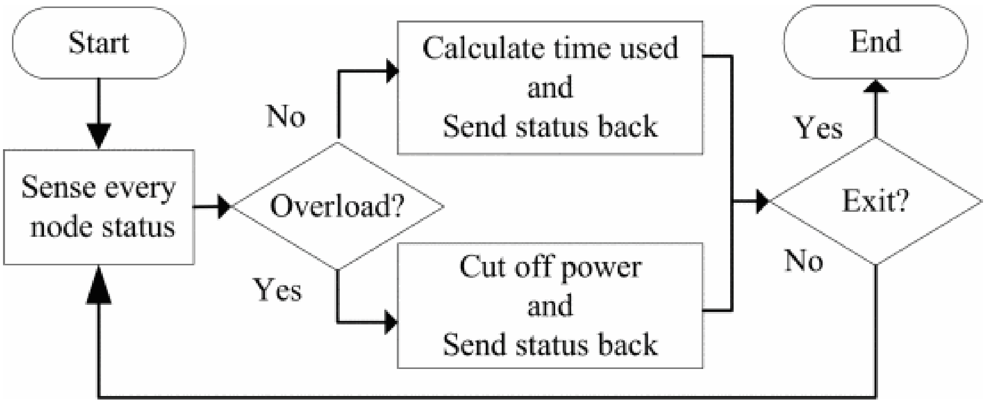
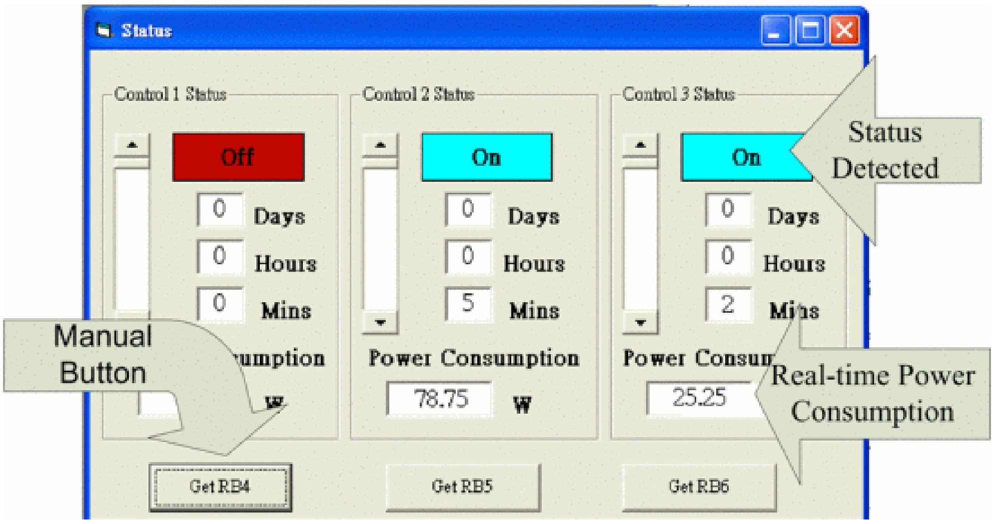


Figure 2.5: Flowchart of current measurement and overload detection (Bai and Hung, 2008)



Control 1 Status
Off
0 Days
0 Hours
0 Mins
umption
W

Control 2 Status
On
0 Days
0 Hours
5 Mins
Power Consumption
78.75 W

Control 3 Status
On
0 Days
0 Hours
2 Mins
Power Consum
25.25

Figure 2.6: GUI of Smart Socket (Bai and Hung, 2008)

Zarza Sanchez *et al.* (2014) proposed another similar system, which uses Wi-Fi VLAN protocol and a RPi as a centralized application server, as shown in Figure 2.7. The system is able to notify the user through email when there is an overload and leakage happened.

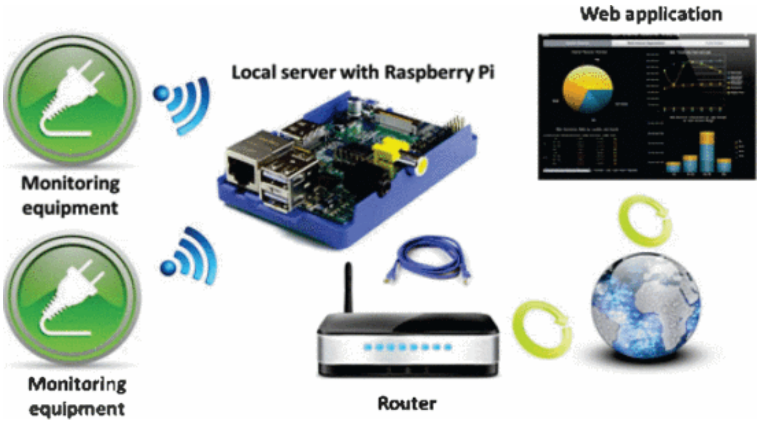


Figure 2.7: Monitoring and Control System (Zarza Sanchez et al., 2014)

Although both of the system presented by Bai and Hung (2008) and Zarza Sanchez *et al.* (2014) has a safety feature, the performance of power measurement was not recorded in the respective papers.

Apart from implementing the safety functionalities via software, hardware type of safety mechanism was implemented to prevent electrical leakage or electrical shock. For instance, Fernández-Caramés, (2015) has presented a ZigBee based intelligent power outlet system with RFID recognition function as shown in Figure 2.8. The RFID recognition is used to recognise the connection of appliances to the socket before switching on the supply. The system was optimised such that the program response time is fast enough for automatic interruption of vampire currents.

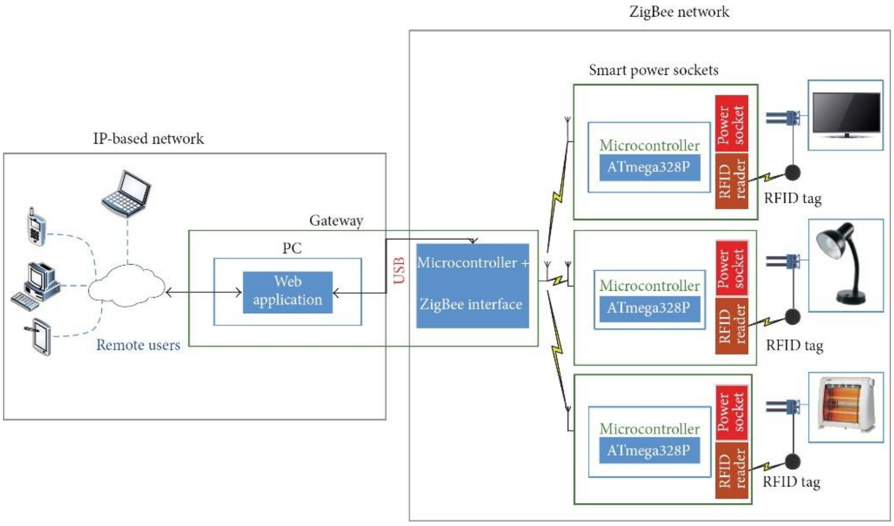
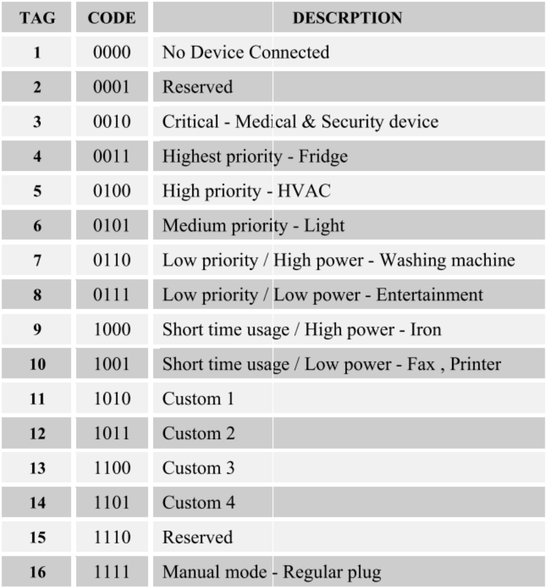


Figure 2.8: Block diagram of smart power outlet with RFID implementation (Fernández-Caramés, 2015)

Another similar RFID recognition approach was proposed by Morsali *et al.* (2012) which uses RS-485 communication. The system uses RFID recognition to identify the types of connected appliances. It identifies the magnetic tag attached to the cord of appliances. Figure 2.9 shows the 4-bit code for a magnetic tag that represents the settings of the respective appliance. The system operates according to the settings.



TAG	CODE	DESCRPTION
1	0000	No Device Connected
2	0001	Reserved
3	0010	Critical - Medical & Security device
4	0011	Highest priority - Fridge
5	0100	High priority - HVAC
6	0101	Medium priority - Light
7	0110	Low priority / High power - Washing machine
8	0111	Low priority / Low power - Entertainment
9	1000	Short time usage / High power - Iron
10	1001	Short time usage / Low power - Fax , Printer
11	1010	Custom 1
12	1011	Custom 2
13	1100	Custom 3
14	1101	Custom 4
15	1110	Reserved
16	1111	Manual mode - Regular plug

Figure 2.9: 4-bit code correspond to types of appliances (Morsali *et al.*, 2012)

2.4 Real-Time Costing Analysis on Smart Wall Outlet

In Malaysia, the electricity tariff for commercial and industrial are varied with time owing to the dynamic supply and demand conditions in the market. One of the approaches to reduce the electricity cost is by monitoring the electricity consumption patterns manually, which is not very practical. Ramavarapu, Sowers and Sreenivas (2017) presented a smart power outlet with real-time pricing monitoring. The smart outlet was controlled autonomously using the Intel Edison computer module by the switching algorithms based on the real-time pricing.

On another similar approach, Blanco-Novoa *et al.* (2018) presented a smart outlet system with appliance operation schedule based on real-time electricity price. The system determines the intervals with the lowest prices by analysing the data and pricing collected from the electrical grid. The system consists of four subsystems as shown in Figure 2.10. The sensor and actuation subsystem controls the outlet switching and collects current measurements. The communication subsystem is to exchange data between the control subsystem and the management subsystem. The management subsystem is to manage the devices and provide a web interface for remote configuration. The control subsystem is to process data through scheduling algorithm.

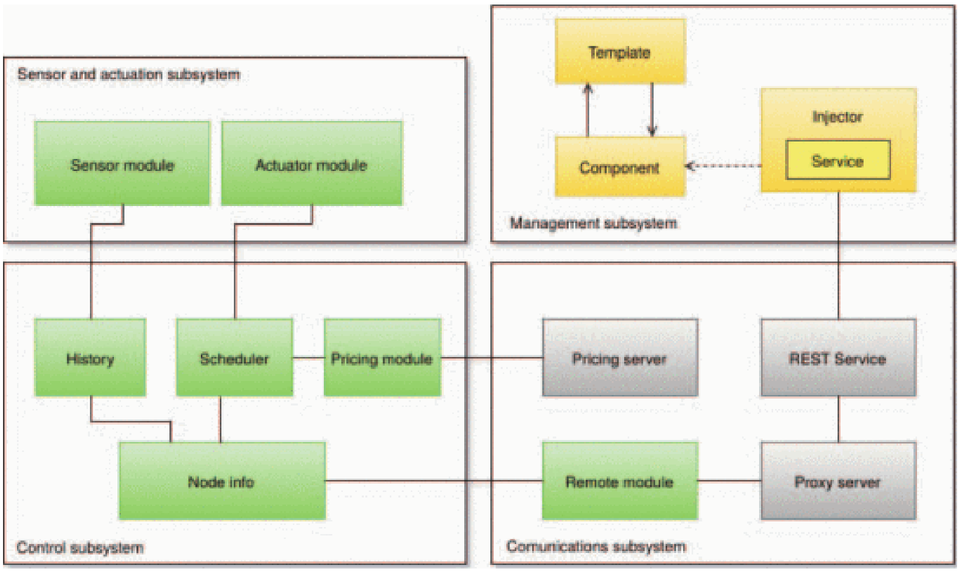


Figure 2.10: Subsystems Diagram (Blanco-Novoa *et al.*, 2018)

The system presented by Ramavarapu, Sowers and Sreenivas (2017) and Blanco-Novoa *et al.* (2018) able to shift the electricity consumption patterns and reduces the electricity bill. However, the practicalities of such implementation were not tested. It may be not suitable for certain scenarios, such as the use of surveillance camera or medical devices.

2.5 Data Analysis of Smart Wall Outlet

Besides using a real-time costing for cost reduction through the smart outlet, data analysis on the power consumption of each electronic appliances is important to determine their optimum usage. Lee and Yang (2017) presented an intelligent power monitoring system utilizing the technique of deep learning and fog computing. This is shown in Figure 2.11. This intelligent system is equipped with a power management learning system with the input of environmental parameters from sensor networks to collect the necessary data for analysis and inference decisions. Although the system was tested with only a single appliance - dehumidifier, an accuracy learning rate of 94.87% was achieved. Electricity usage was reduced by 20%.

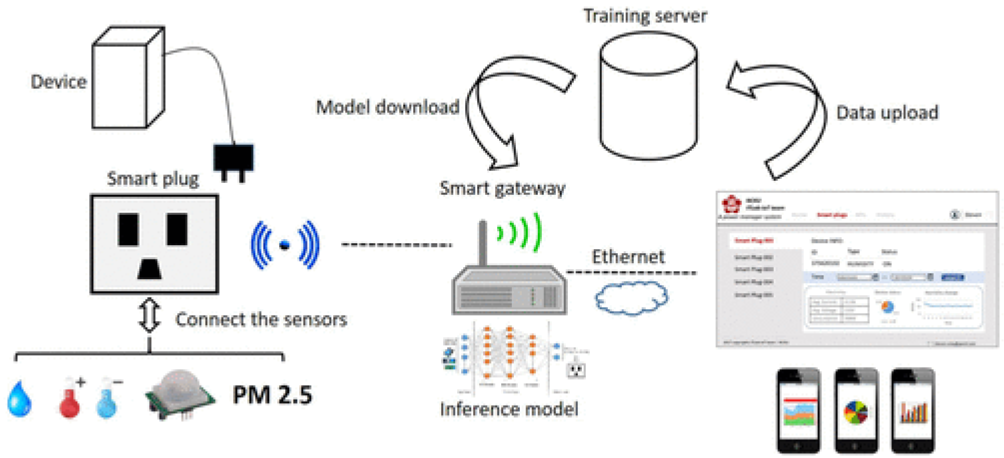


Figure 2.11: Overview of a power management framework system (Lee and Yang, 2017)

Another similar approach presented by Daly *et al.* (2018), an artificial neural network classifier is implemented in the smart home energy management system (PicoGrid) as shown in Figure 2.12. This system is to identify and reviews the energy usage of the connected electrical appliances. Although the system was able to track the appliance performance over time and compare their power consumption changes, only two devices were tested with an accuracy of 97%. While adding the third device will reduce the system accuracy to 90%.

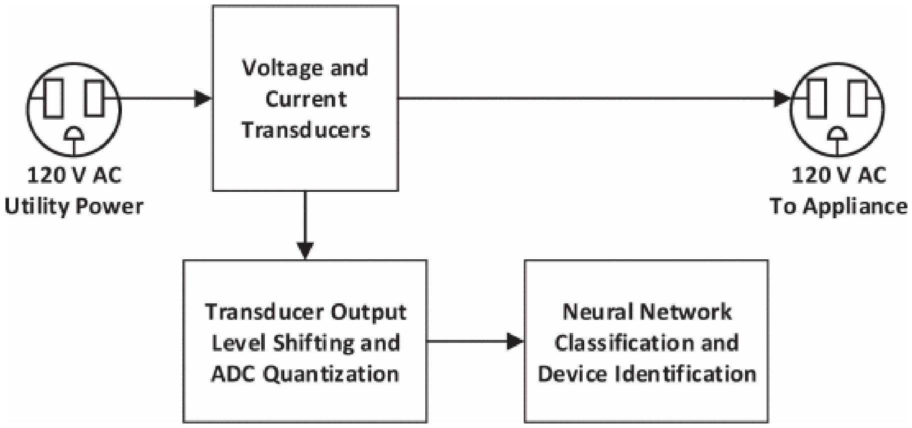


Figure 2.12: Overview of PicoGrid Measurement System (Daly *et al.*, 2018)

Al-Hassan *et al.* (2018) presented a similar development in which the ZigBee based smart power socket was implemented with an energy management algorithm.

The system analyses the data to generate control commands for proper scheduling and achieved an error of less than 6% through the management algorithm.

The use of data analysis and deep learning presented here can be useful in the long run as the high accuracy of system control able to achieve power usage reduction. However, such a system requires a robust controller for complex data analysis.

In this chapter, the progress of smart wall outlet technology is reviewed. Overall, it was shown that several features had been implemented for instance; safety features, real-time costing analysis and data analysis. These features were able to prevent electrical leakage, reduced energy consumption, and control devices autonomously based on schedule. However, if without using external data, the performance of the system is not compared and verified for feasibility. Therefore, in this project, a smart wall outlet system utilizing home server management and protective mechanism as safety features are developed.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter discusses the methods and design for the development of the smart wall outlet. The lists of hardware and software required will be explained in this chapter.

3.2 System Overview

The smart wall outlet system can be categorised into six subsystems. All six subsystems will be discussed in the respective sections. The architecture of the system is shown in Figure 3.1. The block diagram of a smart wall outlet is shown in Figure 3.2.

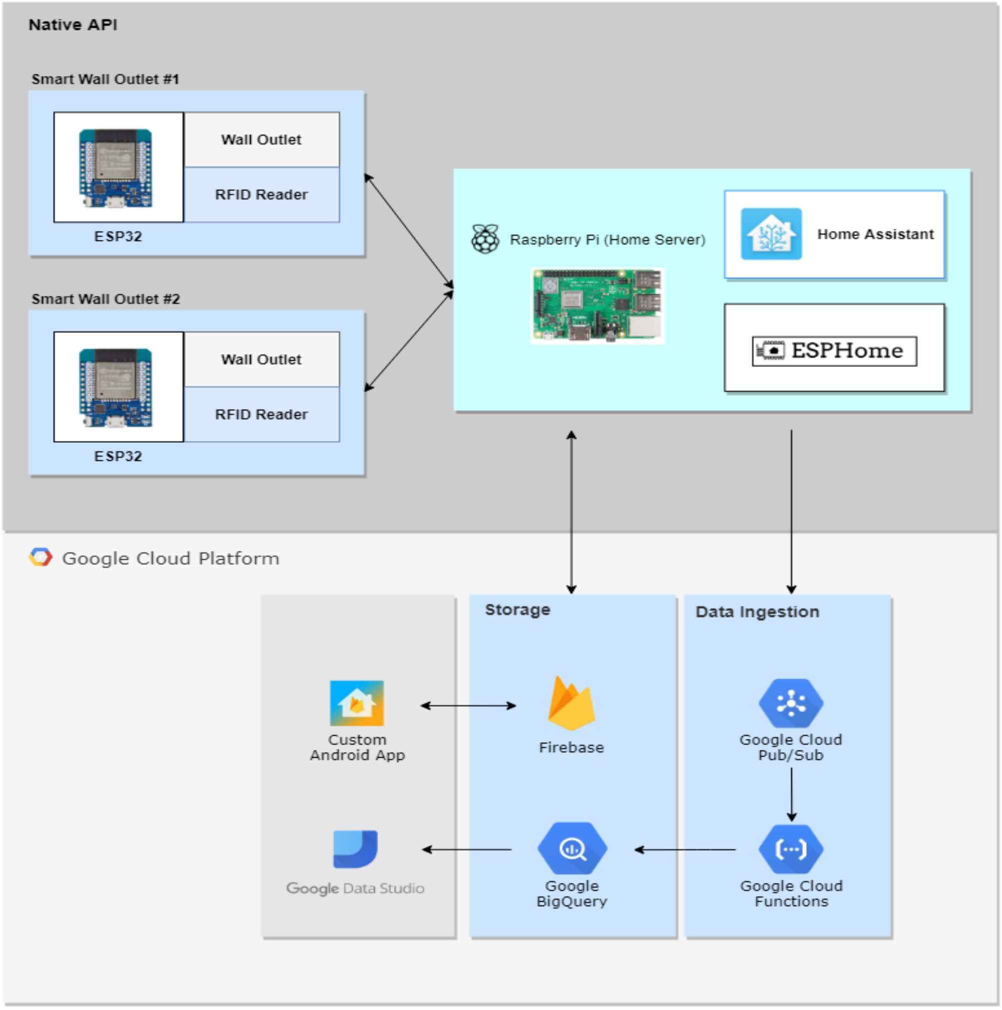


Figure 3.1: The architecture of the system

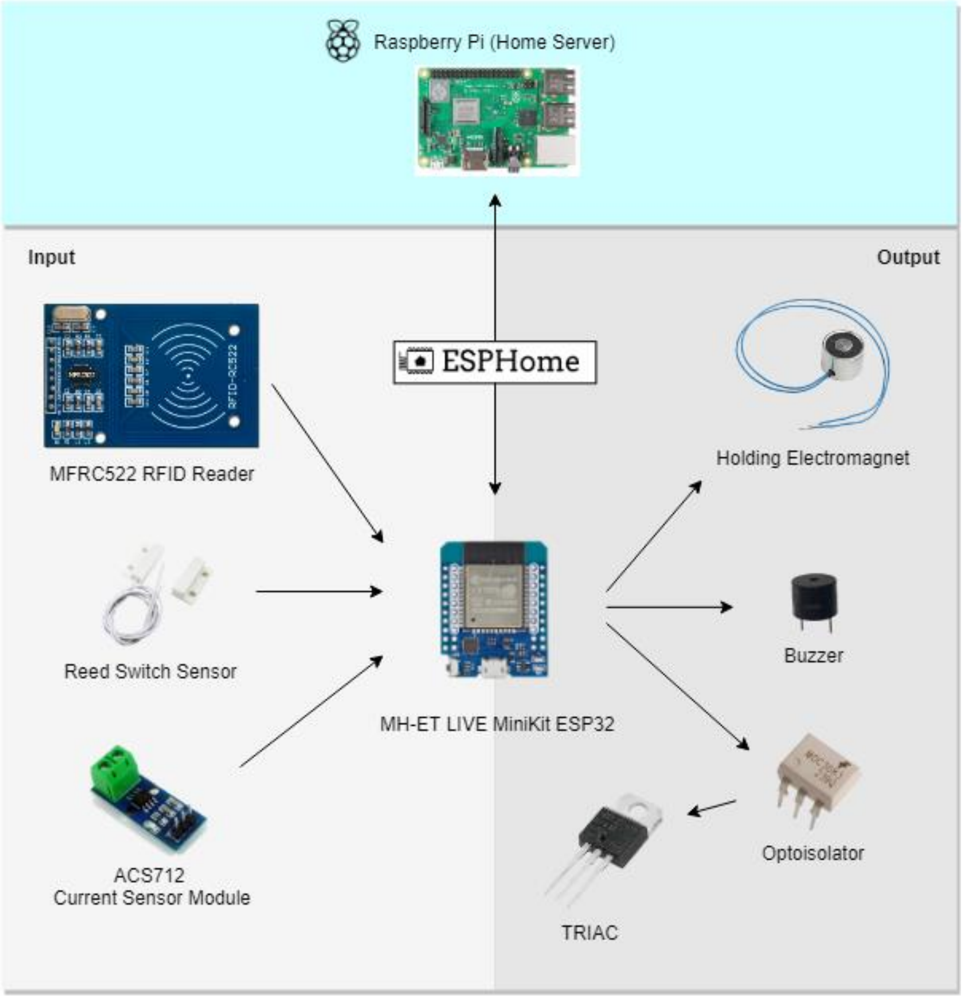


Figure 3.2: Block diagram of a smart wall outlet

3.2.1 Home Server Subsystem

A home server controller is setup using Raspberry Pi with Hass.io operating system (OS). The OS integrates a home automation hub called Home Assistant that allows easy integration and communication between different platforms with client devices, for instance; ESPHome, Google Cloud Platform, and IFTTT.

The Home Assistant provides a unified gateway to control and monitor devices across the platforms mentioned above in one hub. All the essential data collected from ESP32 will be sent to the home server controller and Google Cloud Platform for data ingestion and is stored in Firebase.

3.2.2 Control Subsystem

An ESP32 is used as the main controller in each smart wall outlet backed by Firebase Realtime Database. The ESP32 is used to collect data and control the TRIAC switching.

It sends a signal to the optoisolator to switch the TRIAC on/off. The power consumption value will be calculated and sent to Firebase when TRIAC is switched on.

3.2.3 Communication Subsystem

The ESP32 uses custom firmware which is designed accordingly by the programmer using ESPHome. ESPHome is a tool that reads in a YAML configuration file and creates custom firmware binary for a specific model of controller. The ESPHome also has a simplified flashing tool to upload the new firmware which targets to manage ESP controllers as simple as possible. All the data collected in ESP32 are transferred to the Home Assistant in Raspberry Pi via native protocol (based on TCP+ protocol buffers). The ESPHome native API is used to communicate with clients directly, with a highly-optimized protocol.

3.2.4 Sensing Subsystem

The load current is measured using the ACS712 current sensor module. The measured value is then calculated to power consumption value.

3.2.5 Cover Locking Subsystem

A protective cover is installed on the wall outlet. The protective cover is locked by a holding electromagnet to prevent electrical leakage or electrocution. This is vital in the situation when the wall outlet is switched on accidentally. It can be unlocked by two methods, access card and software control. MFRC522 is used to identify the correct access card. A correct access card can then be used to unlock the protective cover on the wall outlet. The protective cover can be unlocked via software control such as mobile application and web application. The protective cover is unlocked by demagnetizing the holding electromagnet.

3.2.6 Alarm Subsystem

A reed switch is installed to detect the presence of cover when it is in the locked state. This is to prevent the unauthorized opening of the cover by force. If the cover was not detected, the alarm will go off through the buzzer. A notification will be sent to the user through the mobile application.

3.3 Hardware Implementation

This section discussed the descriptions of the system hardware used to develop the smart wall outlet system.

3.3.1 Raspberry Pi 3 Model B+

Raspberry Pi (RPi) is a small form factor but a powerful single-board computer. The RPi 3 Model B+ is used as a home server controller for the smart wall outlet system. It is used to store data and control the wall outlets wirelessly. The RPi runs on an unofficial operating system, Hass.io. The structure of the RPi 3 Model B+ is shown in Figure 3.3.

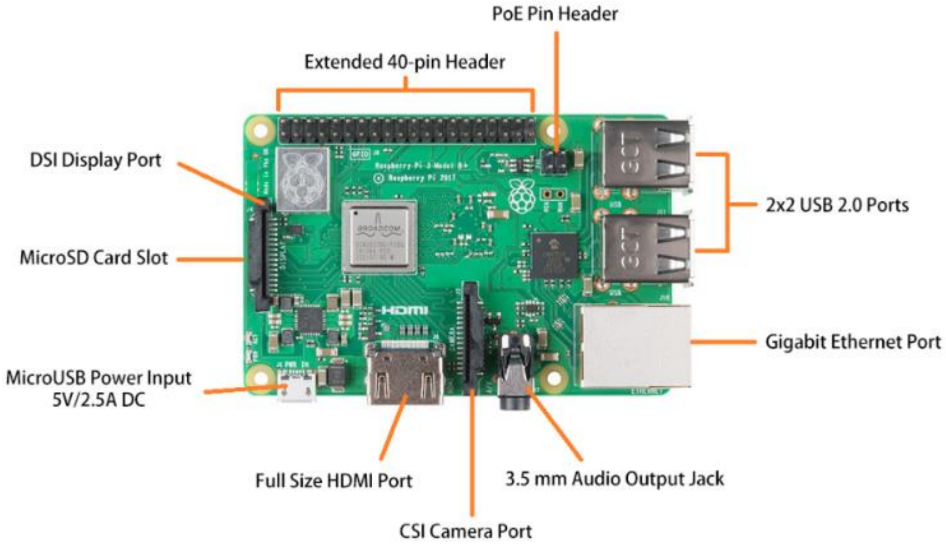


Figure 3.3: RPi 3 Model B+

3.3.2 MH-ET LIVE MiniKit ESP32

The MH-ET LIVE MiniKit ESP32 is designed based on ESP-WROOM-32. It is widely used in the Internet of Things (IoT) as it is small and supports Wi-Fi and Bluetooth. Apart from that, it is integrated with peripherals such as hall sensors and capacitive touch sensors. It is used to control the outlet switching, calculate the power consumption, and send the results wirelessly to the RPi. The pinout diagram of the ESP32 is shown in Figure 3.4.

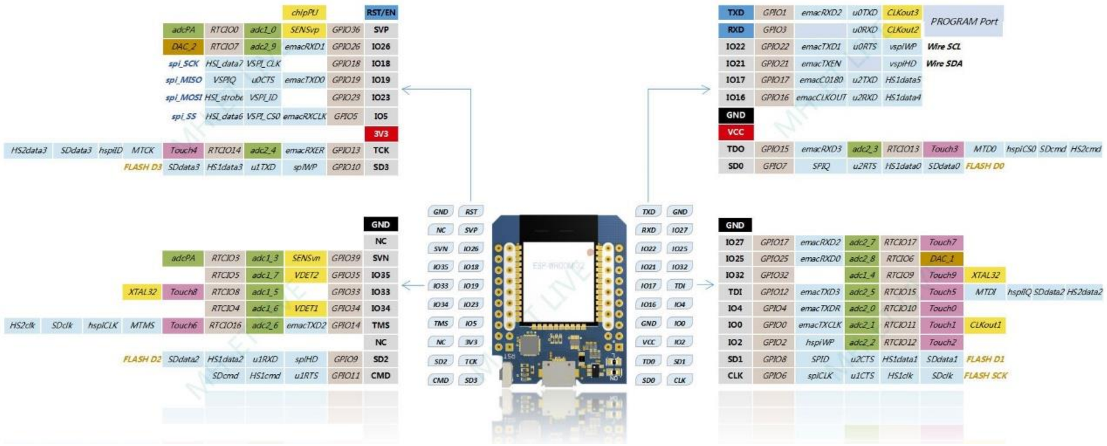


Figure 3.4: Pinout diagram of MH-ET LIVE MiniKit ESP32

3.3.3 TRIACS

TRIACS are commonly used for AC switching or can be used as an ON/OFF function in high power applications, for instance; heating regulation, phase control or motor speed control. TRIACS model BTA16-600b is used in this project for switching the AC on/off. It has an RMS on-state current of 16.0 A and can withstand a repetitive peak off-state voltage of 600 V. The structure and symbol of the BTA16-600b are shown in Figure 3.5.

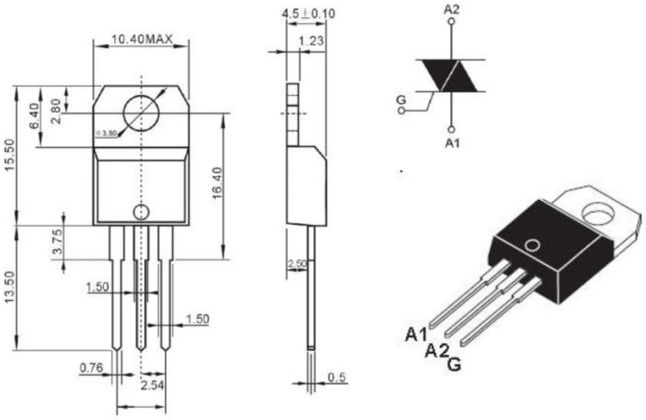


Figure 3.5: Structure and Symbol of TRIAC BTA16-600b

3.3.4 Optoisolator TRIAC Driver

Opto-isolator is an IC chip that uses light to transfer electrical signals between two isolated terminals. It is commonly used to control the switching of TRIAC via low current electrical signals from the microcontroller. The optoisolator isolates the high power at the TRIAC side from the microcontroller to prevent the flowing of high power into the microcontroller. An optoisolator model MOC3083 is used in this project. It has a typical forward voltage of 1.3 V with an off-state output terminal voltage up to 800 V AC. The schematic diagram of the optoisolator is shown in Figure 3.6.

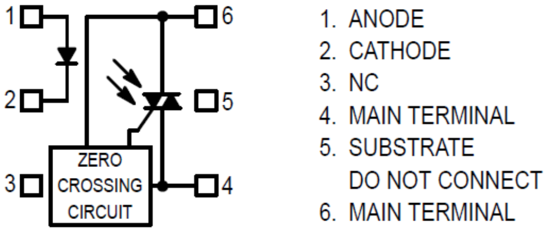


Figure 3.6: Schematic diagram of Optoisolator MOC3083

3.3.5 MFRC522 RFID Reader

Radio Frequency Identification (RFID) is a wireless application with the purpose of identifying and tracking tags. RFID access card usually contains an 8-hex value as a key for identification purposes. To identify an RFID card, an RFID reader is needed. MFRC522 is used in this project to identify an RFID card via contactless communication at 13.56 MHz. It is not only low-cost and small in size, but it also operates with only a minimum voltage of 3.3 V. It is used in the smart wall outlet to read the correct card. When a correct card is detected, the system will unlock the protective cover. The schematic of the MFRC522 is as shown in Figure 3.7.

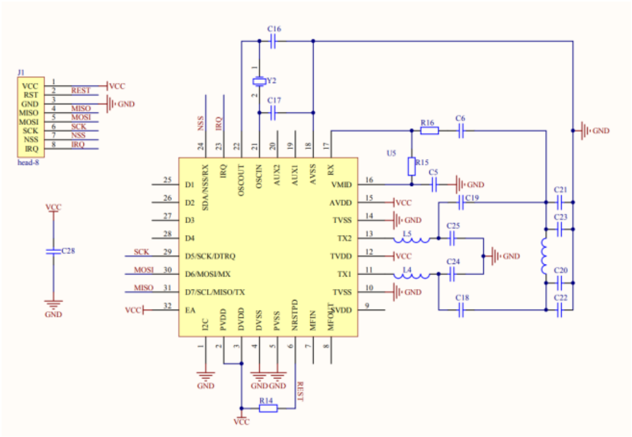


Figure 3.7: Schematic of MFRC522 RFID Reader

3.3.6 Holding Electromagnet

The holding electromagnet is used to hold the protective cover of the wall outlet. It operates at a voltage level of 12 V. It can be magnetized and demagnetized through a signal from ESP32. The holding electromagnet is shown in Figure 3.8.

Figure 3.8: Holding Electromagnet

3.3.7 ACS712 Current Sensor Module

The ACS758 current sensor IC is capable of performing AC current sensing. Typical applications of ACS758 include load detection and management and overcurrent fault detection. Its monolithic hall-effect based IC able to provide high reliability and low power loss. Besides that, it has nearly zero magnetic hysteresis with sensing sensitivity up to 10 mV/A. The current sensor IC requires a minimum operating voltage of 3V while giving an analogue output voltage ranging from 0 to 5 V. It is used in this project to measure the current consumption of load appliances. The typical connection of ACS758 is shown in Figure 3.9 where pin 4 and 5 are the input terminal for the AC line.

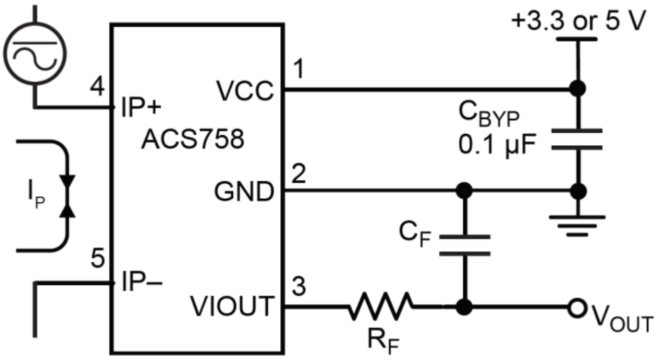


Figure 3.9: Typical connection of the ACS712 Current Sensor IC

3.4 Software Implementation

This section discussed the types of software used to develop the smart wall outlet system.

3.4.1 Home Assistant

Home Assistant is an open-source platform designed specifically as a home automation hub. Home Assistant can be integrated with different applications, for instance; Arduino, Google Assistant, Amazon Alexa, etc. It is installed in Raspberry Pi as an operating system (Hass.io) and turns the Raspberry Pi into a home server controller. The architecture of Hass.io is shown in Figure 3.10.

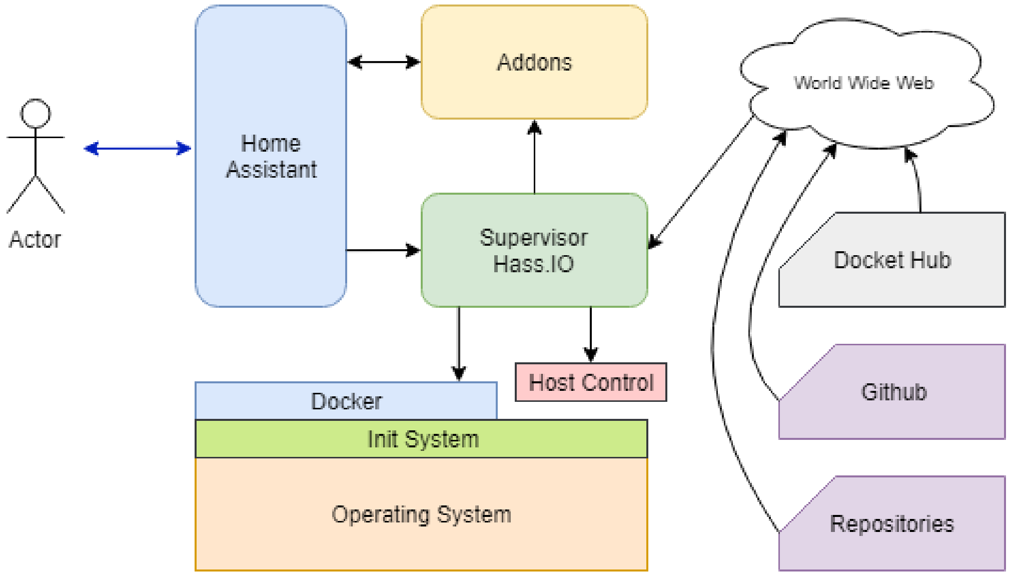
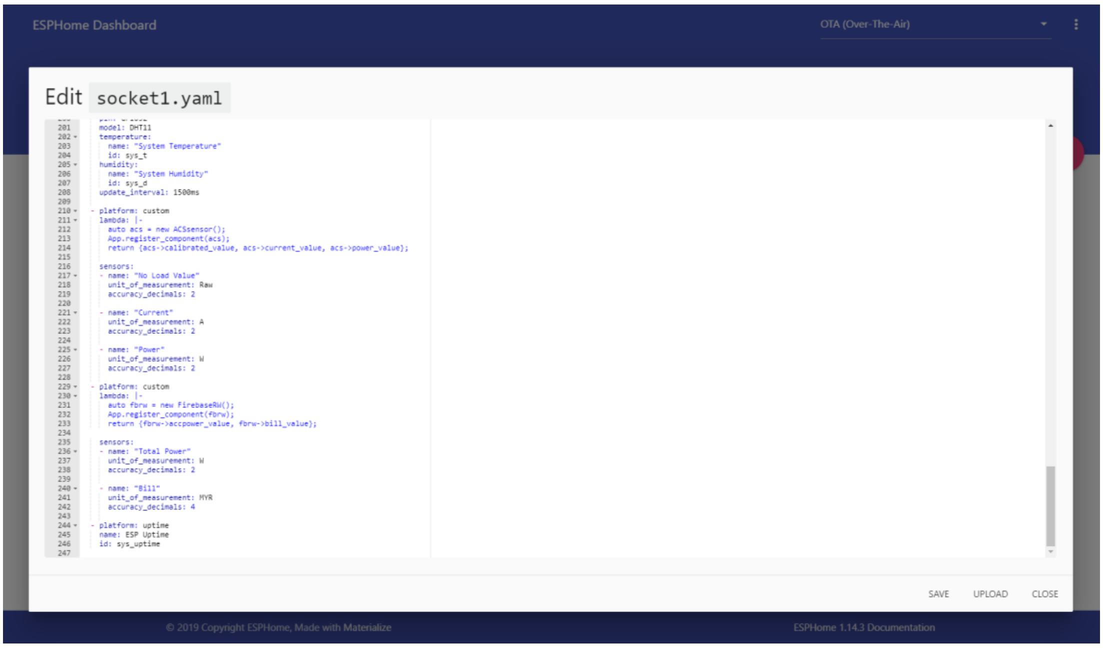


Figure 3.10: Architecture of Hass.io

3.4.2 ESPHome

ESPHome is one of the IoT solutions in creating custom firmware for Sonoff devices, Arduino and ESP boards for home automation control. By flashing its custom firmware into the devices, every each of the devices can be added as a separate node into the Home Assistant even if it contains the same program. Through the Home Assistant interface, over-the-air programming can be done to update the programs that have been flashed into the boards. The ESPHome has a built-in library that supports an abundance of sensors, switches, display and misc components for simple and easy configuration. On top of that, it also provides the ability for the user to create custom components using Arduino C++ programming. The programming interface of ESPHome is shown in Figure 3.11.



```
    model: DHT11
    temperature:
      name: "System Temperature"
      id: sys_t
    humidity:
      name: "System Humidity"
      id: sys_d
    update_interval: 1500ms

  - platform: custom
    lambda: |-
      auto acs = new ACSsensor();
      App.register_component(acs);
      return {acs->calibrated_value, acs->current_value, acs->power_value};

    sensors:
    - name: "No Load Value"
      unit_of_measurement: Raw
      accuracy_decimals: 2

    - name: "Current"
      unit_of_measurement: A
      accuracy_decimals: 2

    - name: "Power"
      unit_of_measurement: W
      accuracy_decimals: 2

  - platform: custom
    lambda: |-
      auto fbrw = new FirebaseRW();
      App.register_component(fbrw);
      return {fbrw->accpower_value, fbrw->bill_value};

    sensors:
    - name: "Total Power"
      unit_of_measurement: W
      accuracy_decimals: 2

    - name: "Bill"
      unit_of_measurement: MYR
      accuracy_decimals: 4

  - platform: uptime
    name: ESP Uptime
    id: sys_uptime
```

Figure 3.11: Programming Interface of ESPHome

3.4.3 Google Cloud Platform

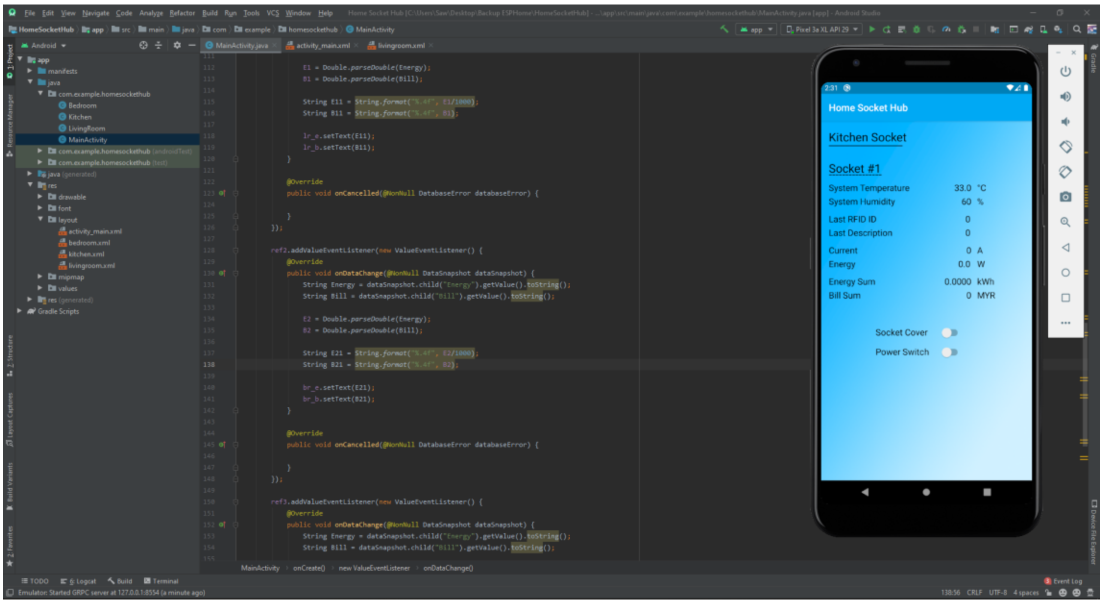
Google Cloud Platform (GCP) is a cloud computing service by Google. It has a globally and reliable infrastructure to provide a robust set of solutions to enterprise and industrial. It provides data and storage management, smart analytics, artificial intelligence and compute engine, big data and networking. Big data and compute engine are used in this project to process the incoming data from Home Assistant. Google Pub/Sub is used to receive the data via MQTT. Cloud Function is subscribed to the respective topic in Google Pub/Sub to filter and process the data into the respective BigQuery table. The BigQuery table is then export to Google Data Studio for data analysis.

3.4.4 Firebase

The Firebase is a cloud-hosted NoSQL database built on Google infrastructure. It allows real-time data storing and synchronizing across all clients. It also provides functionality like analytics, messaging and crash reporting. The Firebase SDKs use local cache on the client for data storing when the device goes offline. The local data is then synchronized automatically to the cloud when the client is back online. Firebase is used to store the wall outlet status and power consumption readings obtained from the sensor.

3.4.5 Android Studio

Android Studio is an official Integrated Development Environment (IDE) for Android application development. Android Studio not only supports Kotlin and Java but also C++ language for development. Android Studio is used to develop a custom android application for the home outlet hub controlling and monitoring which will be backed by Firebase Realtime Database. The IDE is as shown in Figure 3.12.



```
                E1 = Double.parseDouble(Energy);
                B1 = Double.parseDouble(Bill);

                String E11 = String.format("%.4f", E1/1000);
                String B11 = String.format("%.4f", B1);

                lr_e.setText(E11);
                lr_b.setText(B11);
            }

            @Override
            public void onCancelled(@NonNull DatabaseError databaseError) {

            }
        });

        ref2.addValueEventListener(new ValueEventListener() {
            @Override
            public void onDataChange(@NonNull DataSnapshot dataSnapshot) {
                String Energy = dataSnapshot.child("Energy").getValue().toString();
                String Bill = dataSnapshot.child("Bill").getValue().toString();

                E2 = Double.parseDouble(Energy);
                B2 = Double.parseDouble(Bill);

                String E21 = String.format("%.4f", E2/1000);
                String B21 = String.format("%.4f", B2);

                br_e.setText(E21);
                br_b.setText(B21);
            }

            @Override
            public void onCancelled(@NonNull DatabaseError databaseError) {

            }
        });

        ref3.addValueEventListener(new ValueEventListener() {
            @Override
            public void onDataChange(@NonNull DataSnapshot dataSnapshot) {
                String Energy = dataSnapshot.child("Energy").getValue().toString();
                String Bill = dataSnapshot.child("Bill").getValue().toString();
```

Home Socket Hub

Kitchen Socket

Socket #1

System Temperature 33.0 °C
System Humidity 60 %
Last RFID ID 0
Last Description 0
Current 0 A
Energy 0.0 W
Energy Sum 0.0000 kWh
Bill Sum 0 MYR

Socket Cover
Power Switch

Figure 3.12: IDE of Android Studio

3.4.6 Solidworks

Solidworks is a 3D solid modelling design software tool with integrated analytical tools. Solidworks supports exporting files for 3D printing in *.STL* file format. This software is used to redesign the outlet with safety cover features as shown in Figure 3.13 and Figure 3.14.

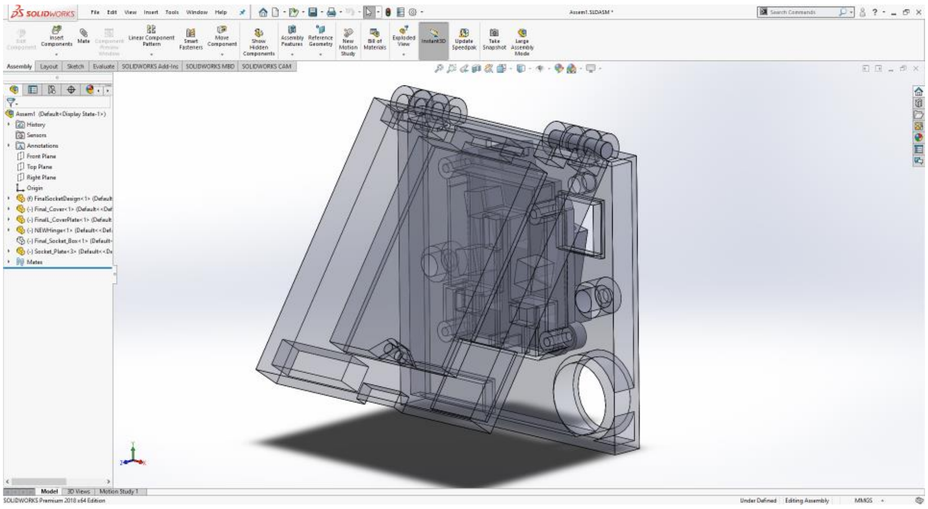


Figure 3.13 Development of Outlet with Safety Cover using Solidworks

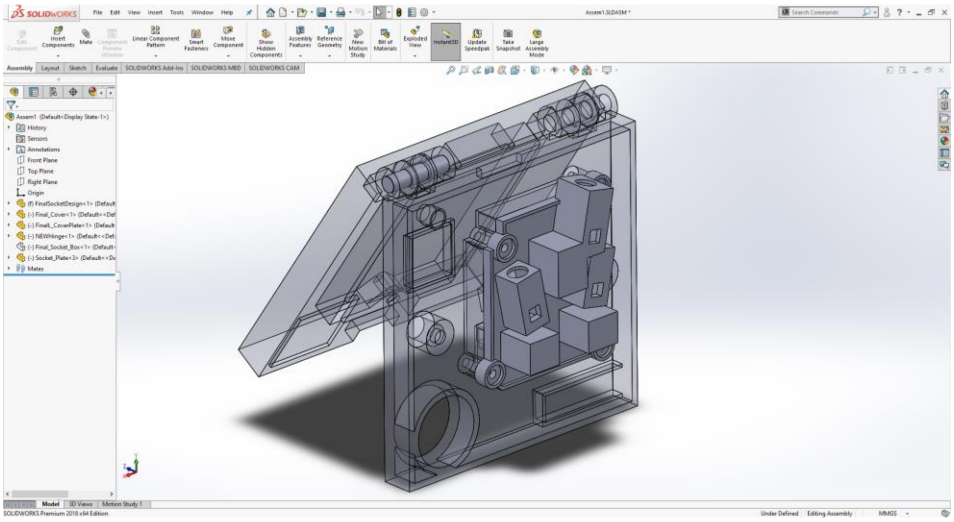


Figure 3.14 Development of Outlet with Safety Cover using Solidworks

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter discusses the final development of the smart wall outlet system. The final prototype and results will be discussed in this chapter.

4.2 Hardware Prototype

There are three hardware prototypes in this project which are the home control unit and two smart wall outlets. The home control unit is shown in Figure 4.1 while the smart wall outlet is shown in Figure 4.2. The home control unit only consists of a RPi powered by a 5V 2.5A power adapter.

Figure 4.1 Home Control Unit (RPi)

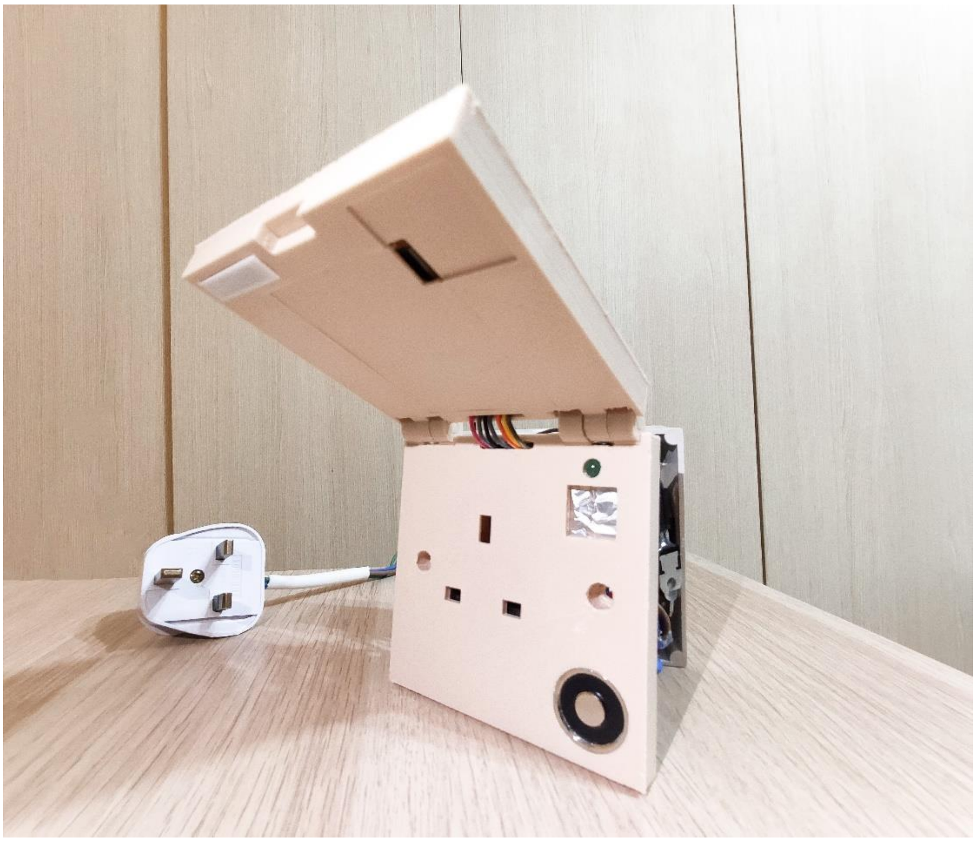


Figure 4.2 Prototype of The Smart Wall Outlet

4.2.1 Smart Wall Outlet Prototype

The smart wall outlet prototype consists of two phases which are the redesign of the physical structure phase and producing the system in PCB form phase. The physical structure of the wall outlet was designed and printed via a 3D printer. On the other hand, the circuit board is designed using EasyEDA software and printed by JLCPCB.

4.2.1.1 Physical Structure of Smart Wall Outlet

The physical structure of the smart wall outlet was redesigned to support a locking cover and to fit the following hardware; LED, MFRC522 reader, reed switch and solenoid magnet. The locking cover is attached to the outlet by two hinges and works as a protection to the outlet holes as shown in Figure 4.3. On the outlet itself, the conventional protection through locking the live and neutral pin remains in the design as shown in Figure 4.4. Figure 4.5 shows the rear view of a complete wall outlet structure.

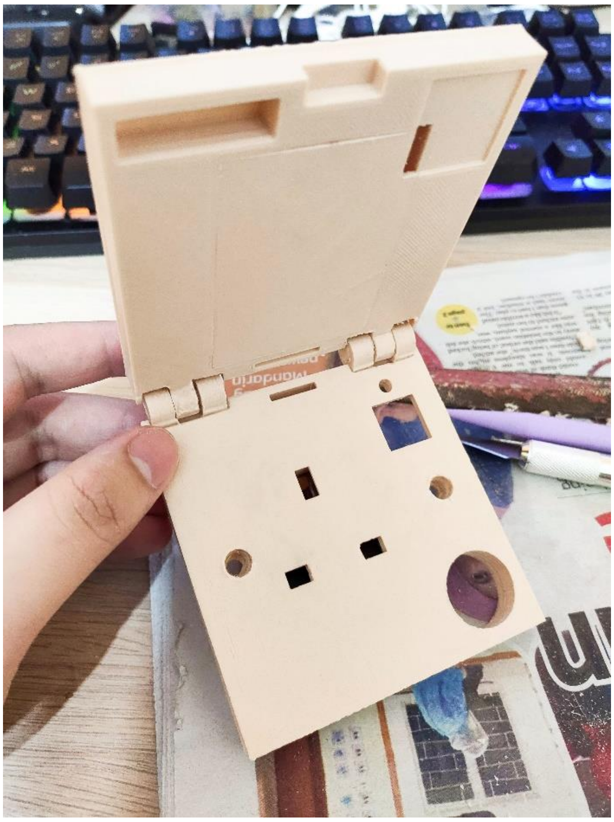


Figure 4.3 Front View of The Smart Wall Outlet Structure

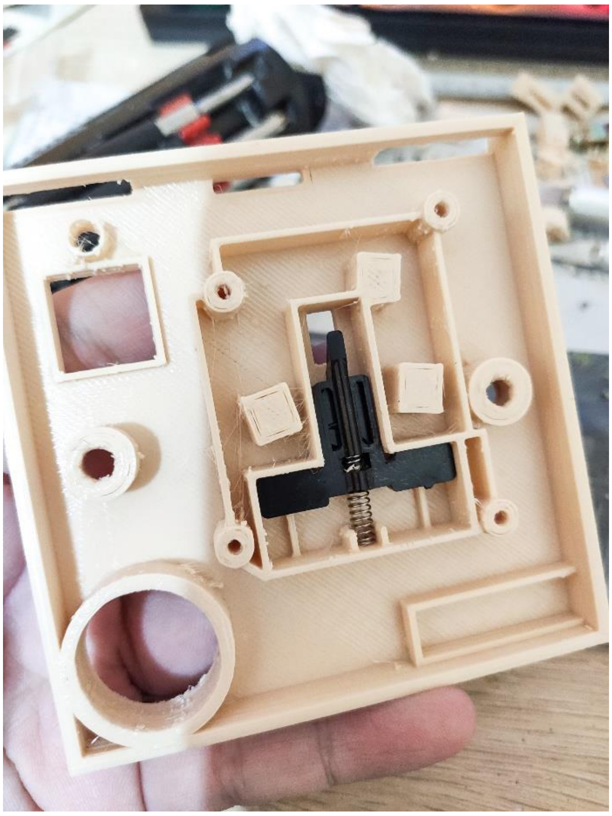


Figure 4.4 Conventional Protection of The Smart Wall Outlet Structure

Figure 4.5 Rear View of The Smart Wall Outlet Structure

4.2.1.2 The Smart Wall Outlet System

The schematic diagram of the smart wall outlet is shown in Figure 4.6. The schematic is then converted into a PCB layout. The circuit board utilizes two layers of sealed routing and has a dimension of 75 mm x 50 mm that can be fitted into the standard outlet box as shown in Figure 4.7. The actual front and rear view of the PCB board are shown in Figure 4.8.

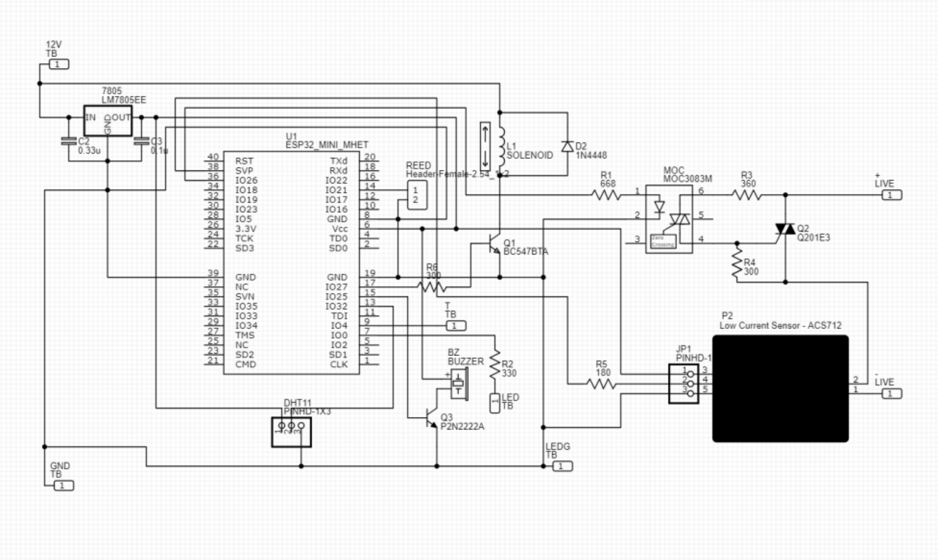


Figure 4.6 Final Circuit of The Smart Wall Outlet

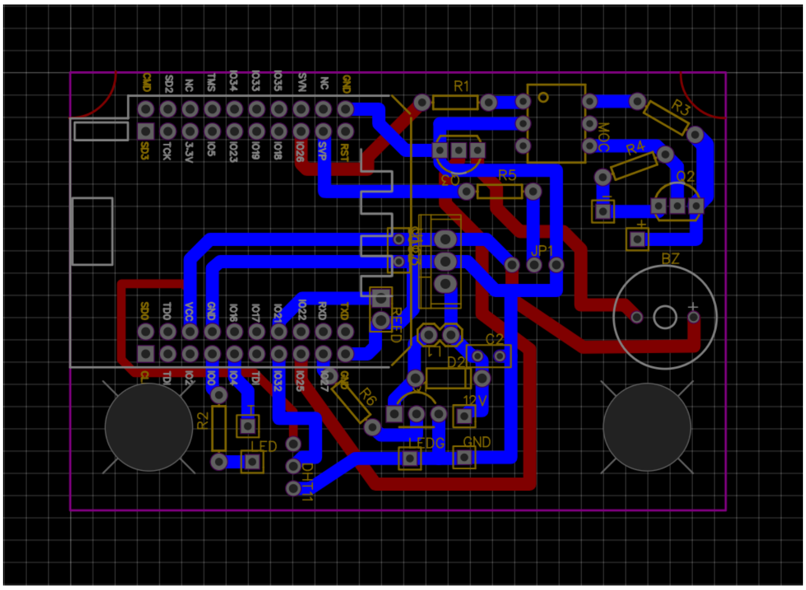


Figure 4.7 PCB Layout of The Smart Wall Outlet System

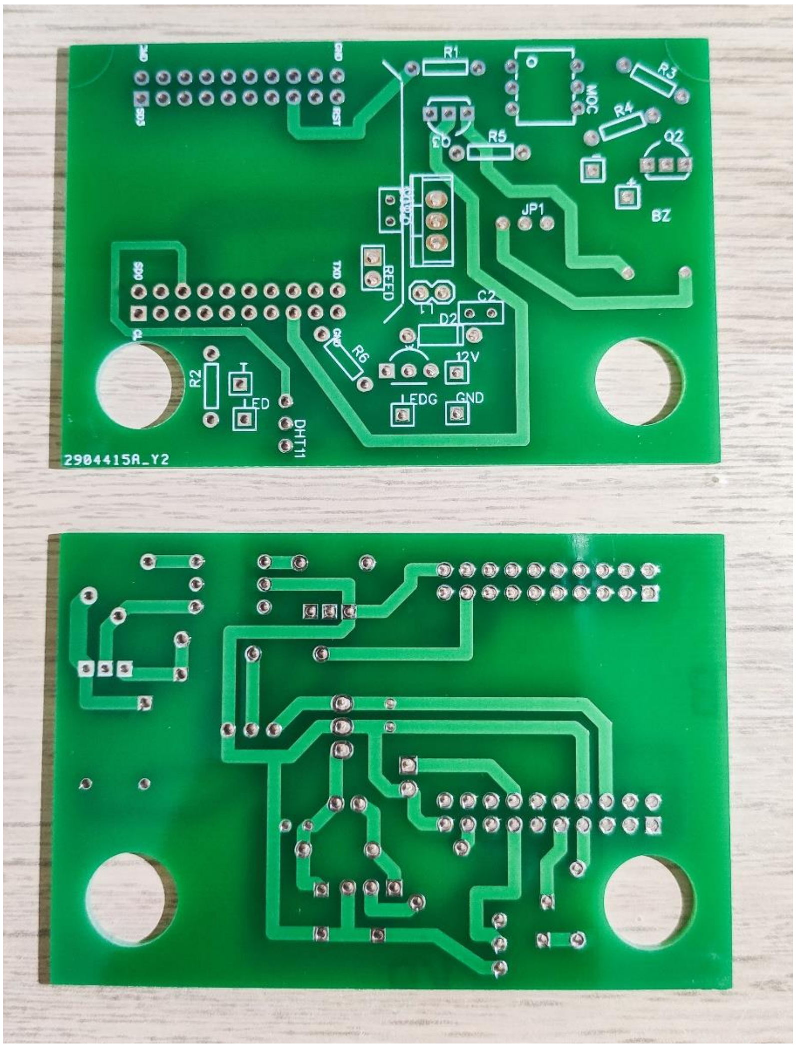


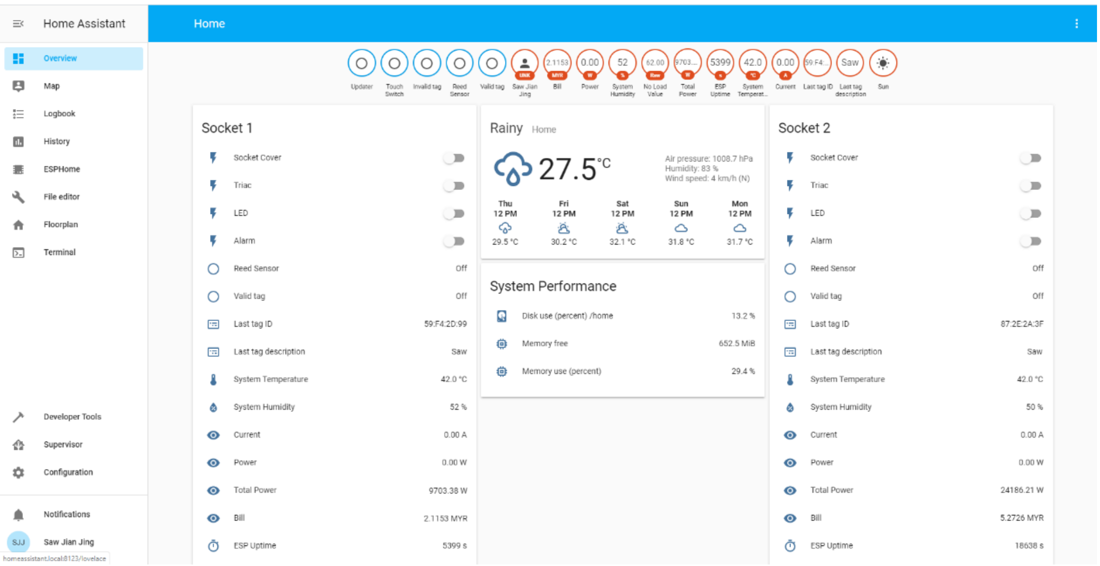
Figure 4.8 Front and Rear View of The PCB Board

4.3 Software and Interface of The Smart Wall Outlet System

The smart wall outlet system consists of two platforms for remote controlling and monitoring which are the home control unit's interface and custom mobile application.

4.3.1 Home Assistant

The home control unit integrates an automation hub interface called Home Assistant as shown in Figure 4.9. The Home Assistant can be accessed via default IP addresses in computers, mobiles and tablets. It has a flexible and customisable user interface. The status and power usage of both sockets were shown in the interface along with the home control unit's performance and weather. However, this interface is only available when users were connected to the same network as the home control unit.



Socket 1

Socket Cover	
Triac	
LED	
Alarm	
Reed Sensor	Off
Valid tag	Off
Last tag ID	59:F4:2D:99
Last tag description	Saw
System Temperature	42.0 °C
System Humidity	52 %
Current	0.00 A
Power	0.00 W
Total Power	9703.38 W
Bill	2.1153 MYR
ESP Uptime	5399 s

Rainy Home

27.5 °C

Air pressure: 1008.7 hPa
Humidity: 83 %
Wind speed: 4 km/h (N)

Thu 12 PM	Fri 12 PM	Sat 12 PM	Sun 12 PM	Mon 12 PM
29.5 °C	30.2 °C	32.1 °C	31.8 °C	31.7 °C

System Performance

Disk use (percent) /home	13.2 %
Memory free	652.5 MiB
Memory use (percent)	29.4 %

Socket 2

Socket Cover	
Triac	
LED	
Alarm	
Reed Sensor	Off
Valid tag	Off
Last tag ID	87:2E:2A:3F
Last tag description	Saw
System Temperature	42.0 °C
System Humidity	50 %
Current	0.00 A
Power	0.00 W
Total Power	24186.21 W
Bill	5.2726 MYR
ESP Uptime	18638 s

Figure 4.9 Home Assistant Interface

The floorplan of a home was added into the Home Assistant for an easy glance at all the status of each smart wall outlet in the home as shown in Figure 4.10. There are three indicators on each wall outlet that represents cover status, alarm and switch. Red color indicates “off” state while green color indicates “on” state. Black color indicates the smart wall outlet is not operating or not connected to the WiFi.

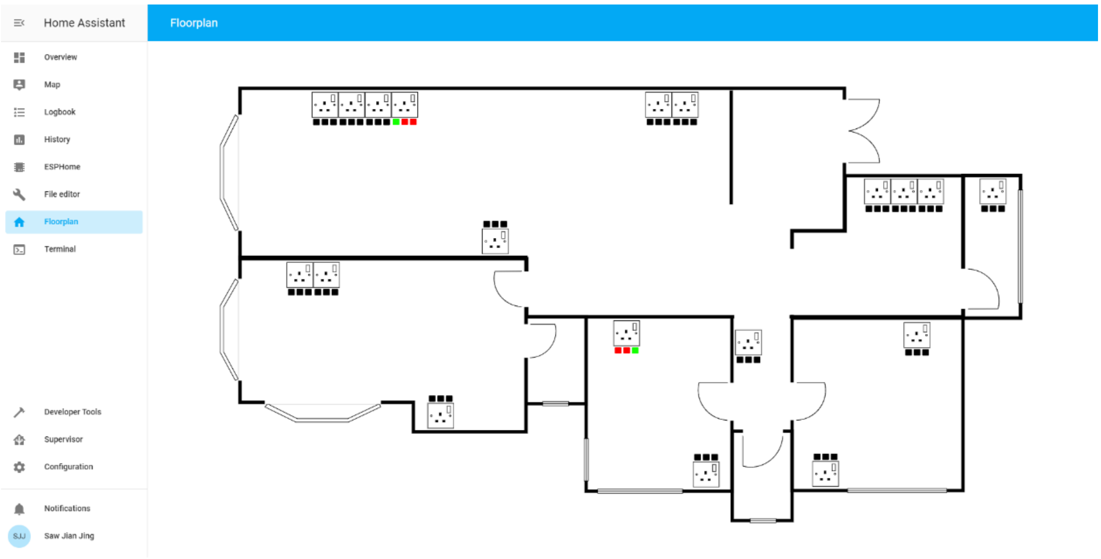
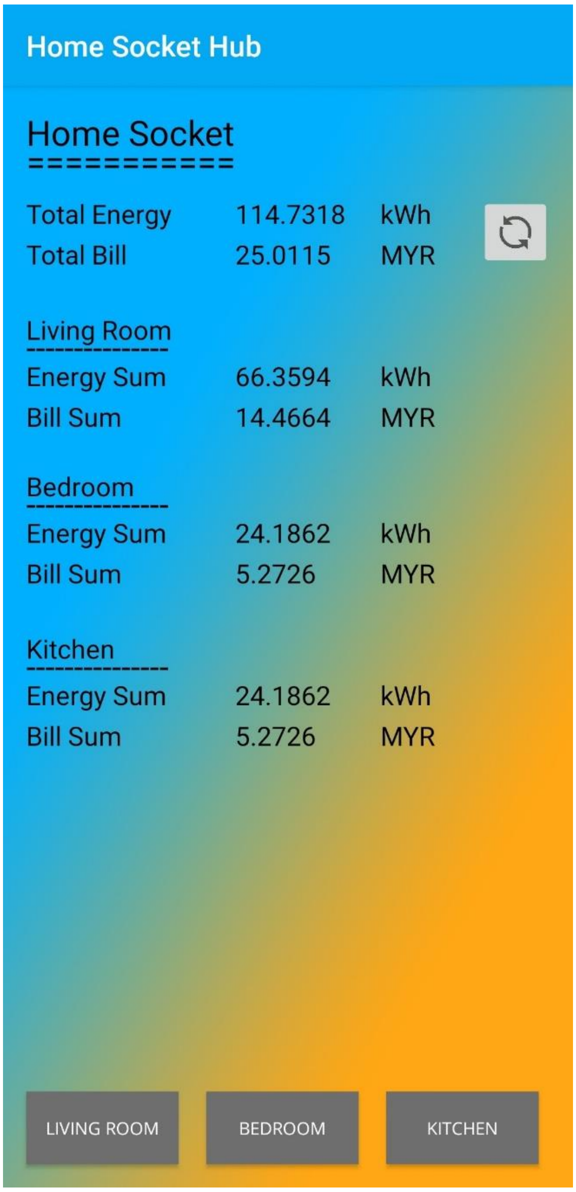


Figure 4.10 Floorplan Interface in Home Assistant

4.3.2 Home Socket Hub

An Android mobile application named Home Socket Hub was developed for remote monitoring and controlling away from home. The mobile application is backed by the Firebase Realtime Database and connects to each of the wall outlets, which made the control and monitor away from home possible. The logo of the mobile application is shown in Figure 4.11. The main interface of the mobile application is shown in Figure 4.12. An overview of the overall power usage and each wall outlet is shown in the main interface. Details status and usage of each wall outlet can be shown by selecting the button “Living Room”, “Bedroom” and “Kitchen”. Figure 4.13 and Figure 4.14 shows the interface of each wall outlets respectively. Figure 4.15 shows the Firebase Realtime Database used in the mobile application.

Figure 4.11 Home Socket Hub Application Logo



Home Socket
===========

Total Energy	114.7318	kWh
Total Bill	25.0115	MYR

Living Room

Energy Sum	66.3594	kWh
Bill Sum	14.4664	MYR

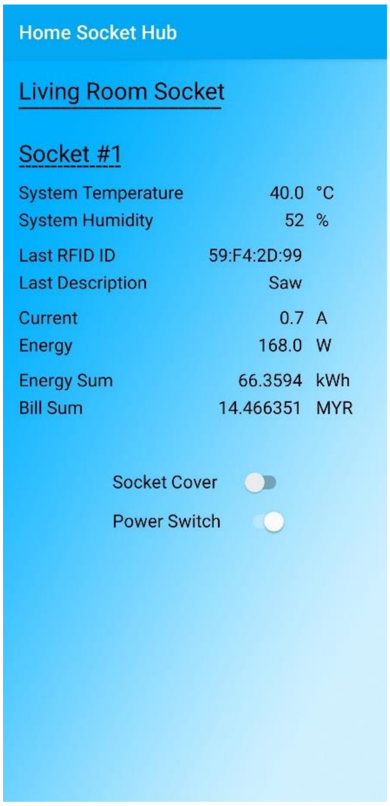
Bedroom

Energy Sum	24.1862	kWh
Bill Sum	5.2726	MYR

Kitchen

Energy Sum	24.1862	kWh
Bill Sum	5.2726	MYR

Figure 4.12 Main Interface of Home Socket Hub Application



Home Socket Hub

Living Room Socket

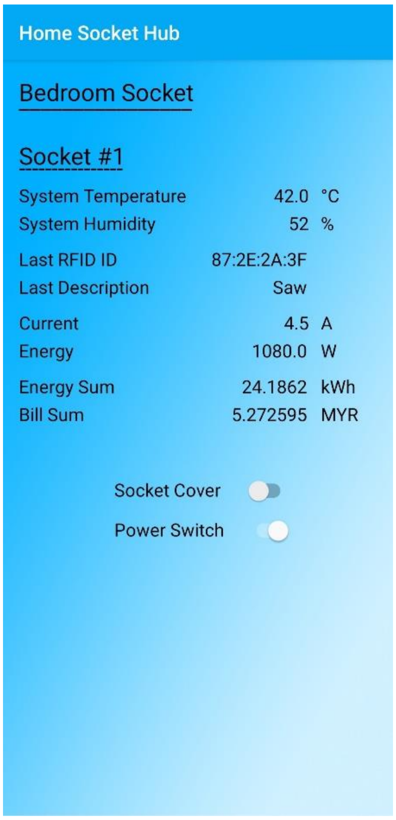
Socket #1

System Temperature	40.0	°C
System Humidity	52	%
Last RFID ID	59:F4:2D:99	
Last Description	Saw	
Current	0.7	A
Energy	168.0	W
Energy Sum	66.3594	kWh
Bill Sum	14.466351	MYR

Socket Cover

Power Switch

Figure 4.13 Overview of Wall Outlet in Living Room



Home Socket Hub

Bedroom Socket

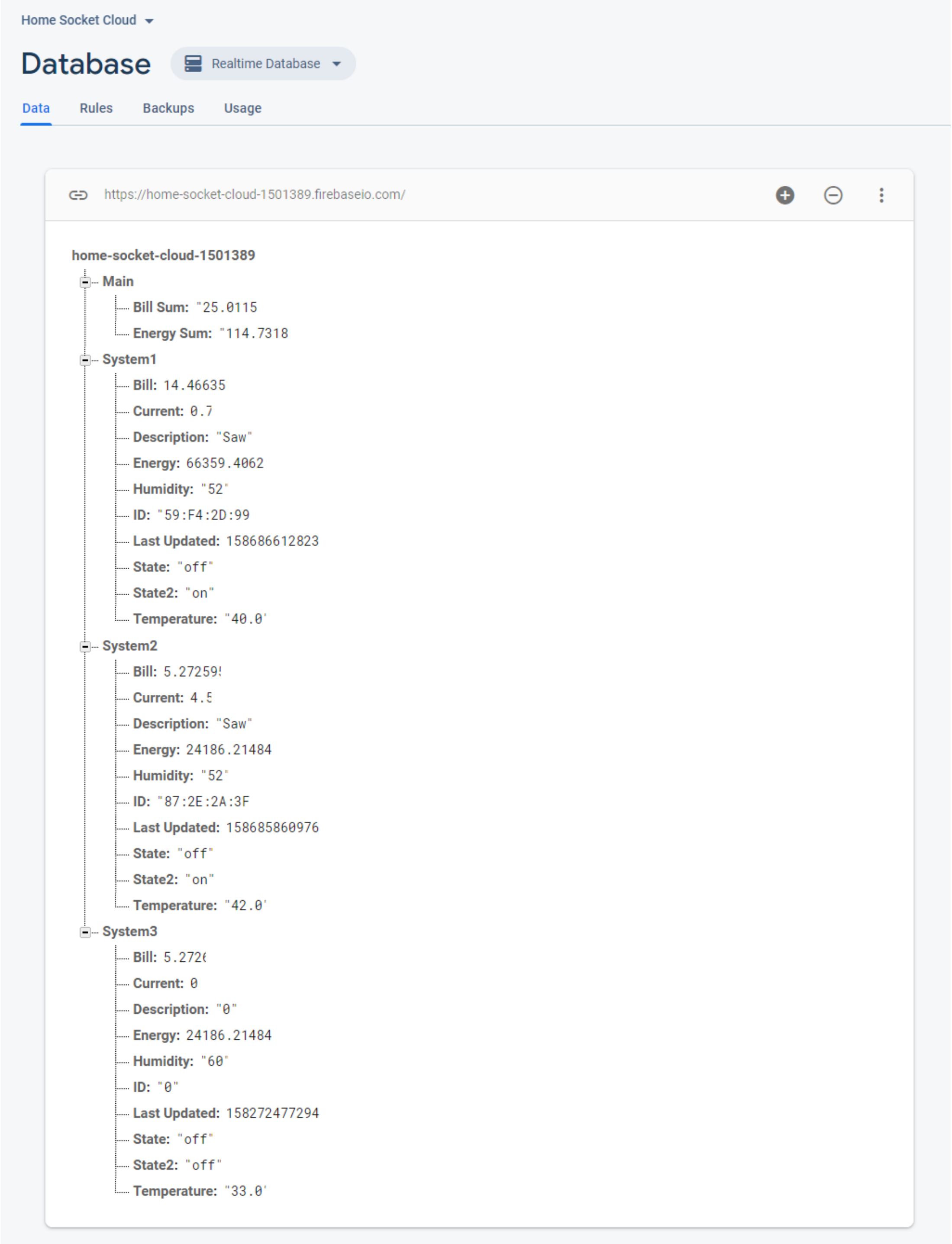
Socket #1

System Temperature	42.0	°C
System Humidity	52	%
Last RFID ID	87:2E:2A:3F	
Last Description	Saw	
Current	4.5	A
Energy	1080.0	W
Energy Sum	24.1862	kWh
Bill Sum	5.272595	MYR

Socket Cover

Power Switch

Figure 4.14 Overview of Wall Outlet in Bedroom



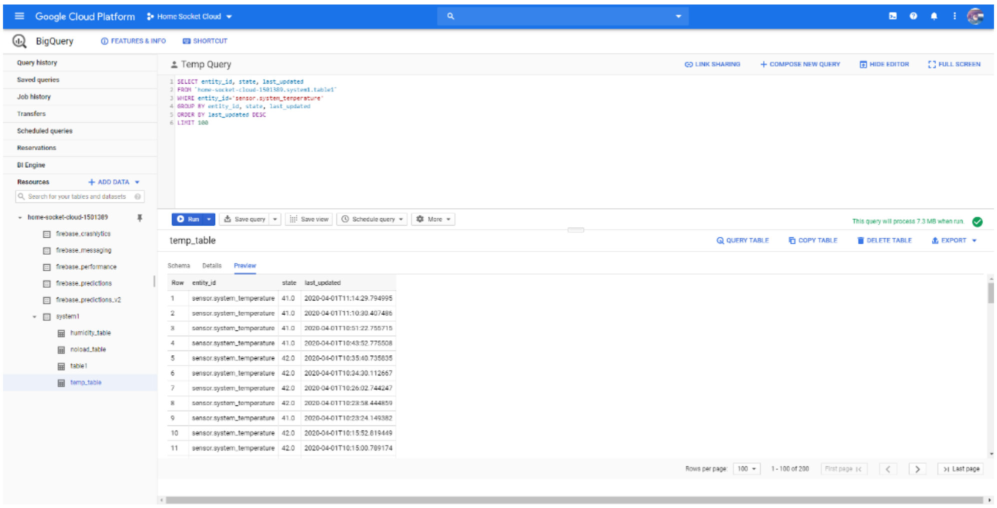
```
https://home-socket-cloud-1501389.firebaseio.com/

home-socket-cloud-1501389
  Main
    Bill Sum: "25.0115
    Energy Sum: "114.7318
  System1
    Bill: 14.46635
    Current: 0.7
    Description: "Saw"
    Energy: 66359.4062
    Humidity: "52"
    ID: "59:F4:2D:99
    Last Updated: 158686612823
    State: "off"
    State2: "on"
    Temperature: "40.0'
  System2
    Bill: 5.27259
    Current: 4.5
    Description: "Saw"
    Energy: 24186.21484
    Humidity: "52"
    ID: "87:2E:2A:3F
    Last Updated: 158685860976
    State: "off"
    State2: "on"
    Temperature: "42.0'
  System3
    Bill: 5.272
    Current: 0
    Description: "0"
    Energy: 24186.21484
    Humidity: "60"
    ID: "0"
    Last Updated: 158272477294
    State: "off"
    State2: "off"
    Temperature: "33.0'
```

Figure 4.15 Firebase Realtime Database

4.3.3 Google Cloud Platform

Google Cloud Platform is integrated with Home Assistant to collect the data from the smart wall outlets for data analysis. The data was sent to the Google Pub/Sub via MQTT for data ingestion by GCP. The data is then processed by Cloud Functions to store into a BigQuery table as shown in Figure 4.16. The processed data can be sent to Google Data Studio or exported into an Excel file to perform the data analysis as shown in Figure 4.17.



```
SELECT entity_id, state, last_updated
FROM `home-socket-cloud-1501389.system1.table1`
WHERE entity_id='sensor.system_temperature'
GROUP BY entity_id, state, last_updated
ORDER BY last_updated DESC
LIMIT 100
```

temp_table

Row	entity_id	state	last_updated
1	sensor.system_temperature	41.0	2020-04-01T11:14:29.794995
2	sensor.system_temperature	41.0	2020-04-01T11:10:30.407486
3	sensor.system_temperature	41.0	2020-04-01T10:51:22.755715
4	sensor.system_temperature	41.0	2020-04-01T10:43:52.775508
5	sensor.system_temperature	42.0	2020-04-01T10:35:40.735635
6	sensor.system_temperature	42.0	2020-04-01T10:34:30.112667
7	sensor.system_temperature	42.0	2020-04-01T10:26:02.744247
8	sensor.system_temperature	42.0	2020-04-01T10:23:58.444859
9	sensor.system_temperature	41.0	2020-04-01T10:23:24.149382
10	sensor.system_temperature	42.0	2020-04-01T10:15:52.819449
11	sensor.system_temperature	42.0	2020-04-01T10:15:00.789174

Figure 4.16 BigQuery – Google Cloud Platform

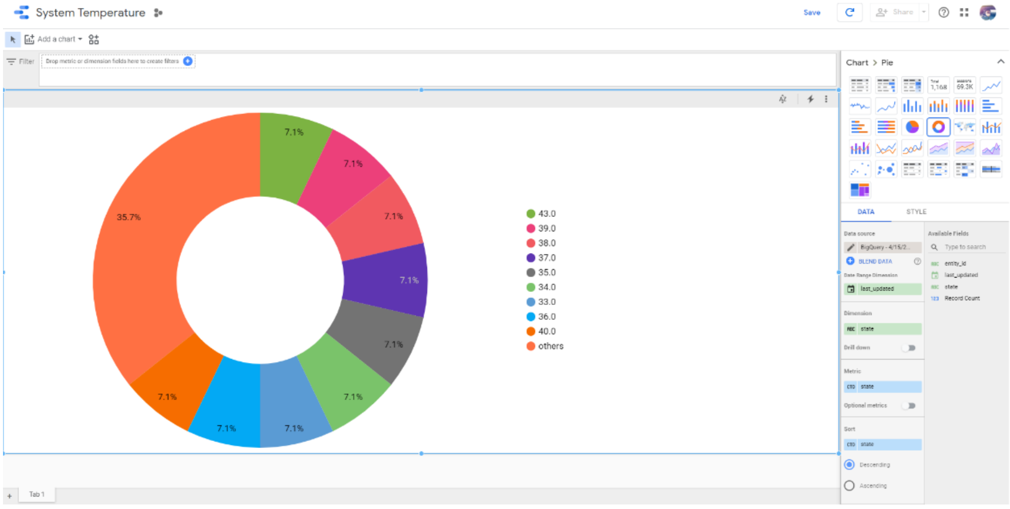


Figure 4.17 Google Data Studio

4.4 Program Operation

The working principle of the smart wall outlet system is shown in a flow chart format. Figure 4.18 shows the connectivity flow of the overall system. Figure 4.19 shows the main program flow of the smart wall outlet.

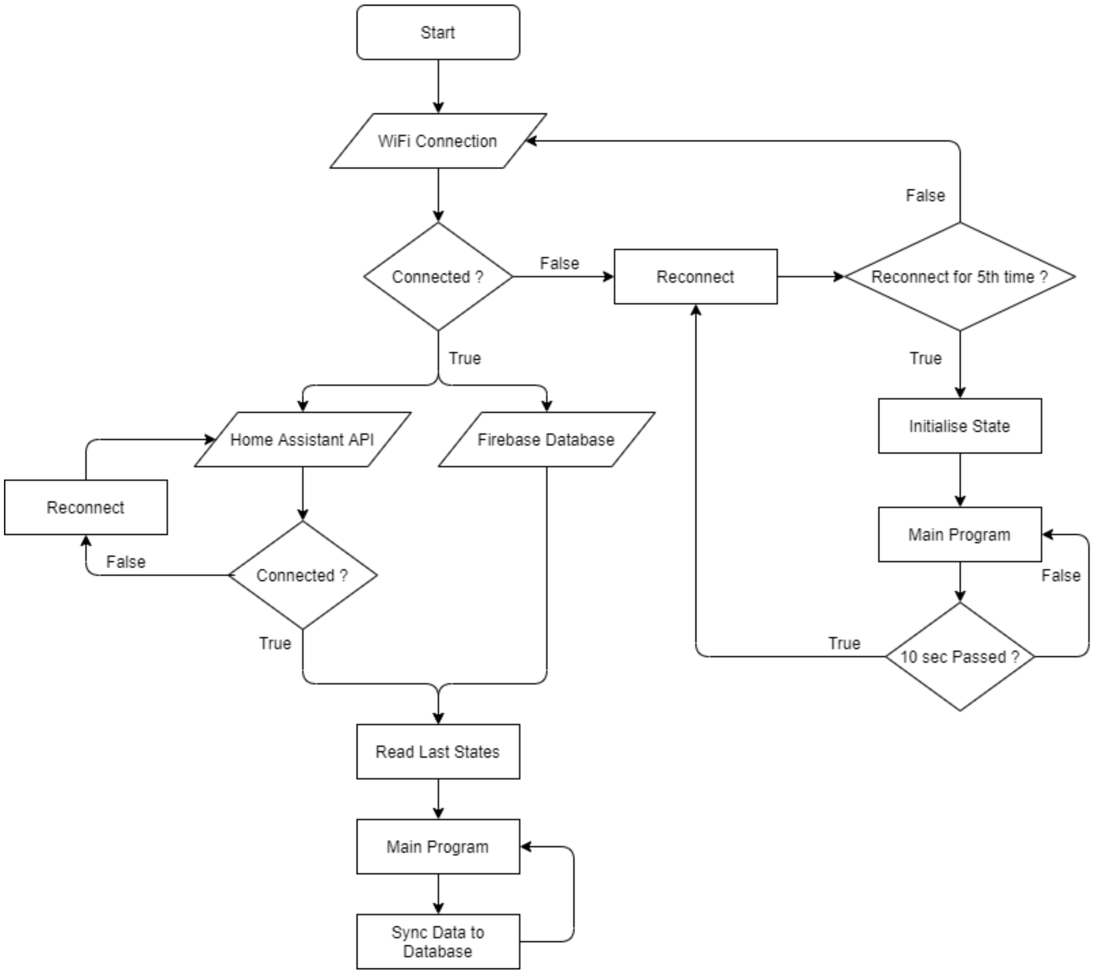


Figure 4.18 Connectivity Flow of The Smart Wall Outlet System

The home control unit is to be connected to the WiFi preceeding the smart wall outlets. The smart wall outlets are then connected to the WiFi. If the connection lost or failed, it will attempt to reconnect for five times. After five times of fail connection, the main program will start to operate as a conventional wall outlet. Once the WiFi is connected, the smart wall outlets will connect to the Firebase Database and Home Assistant to read the last status of respective outlets. The smart wall outlet is then operated with smart features.

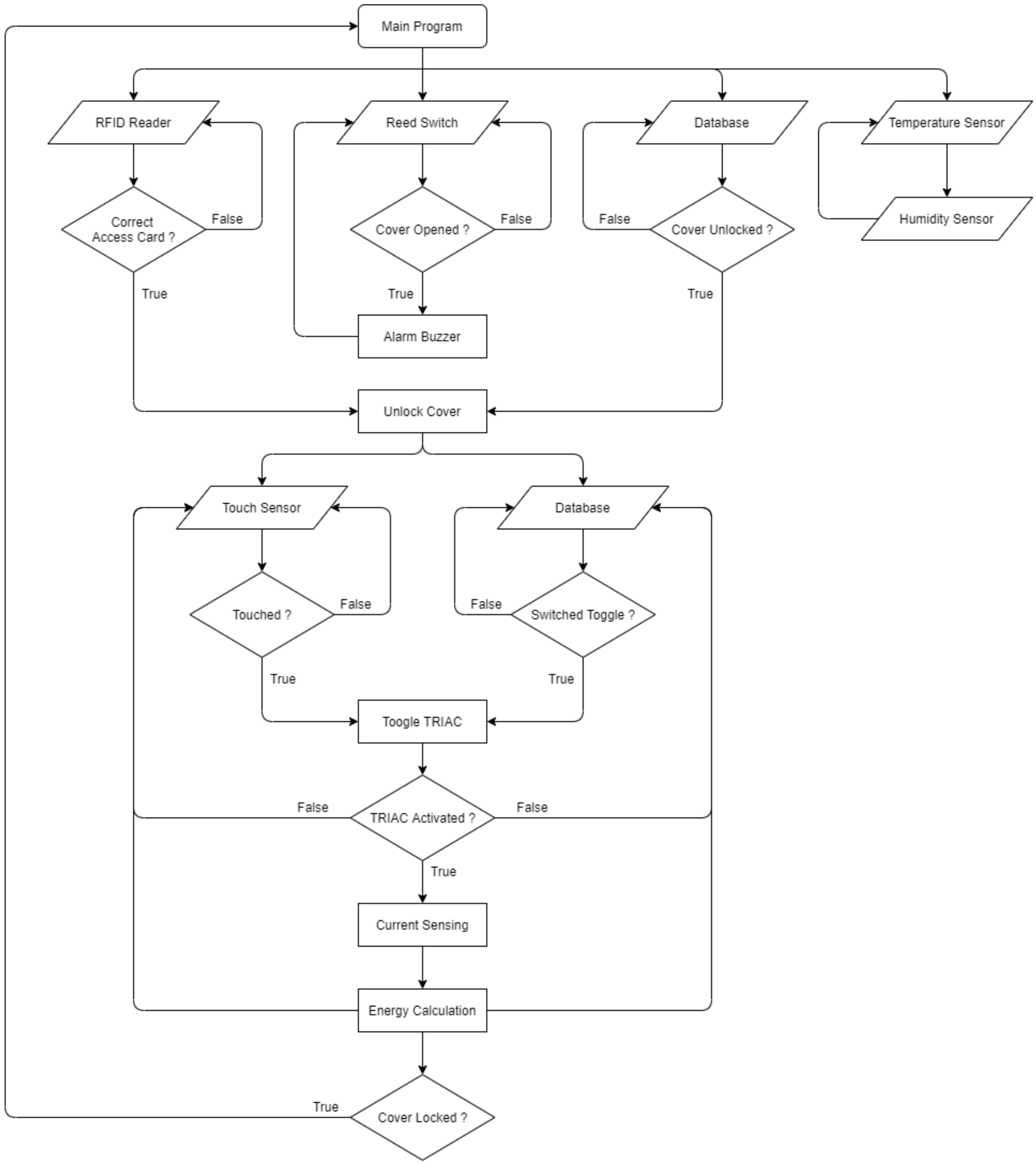


Figure 4.19 Program Flow of The Smart Wall Outlet

The smart wall outlets can be operated in online mode and offline mode. The program flow as shown in Figure 4.19 is for the online mode. The working principle of the offline mode is identical except for the flow of the database. Data will be sync with the database every 1.5 seconds. Current sensing is performed every 20 milliseconds. The temperature and humidity of the system will be measured every 30 seconds.

4.5 Smart Wall Outlet System Performance

The performance and power consumption of the smart wall outlet system were tested in respective experiments. These experiments will be discussed in the following sections.

4.5.1 Power Consumption of the Home Control Unit

The power consumption of the home control unit is measured using a power meter for an 8 hours period daily for 5 consecutive days and the daily average was recorded in Table 4.1. The experiment is carried out in three phases;

i. Only Raspberry Pi in operation.
ii. Raspberry Pi and 1 smart wall outlet is activated.
iii. Raspberry Pi and 2 smart wall outlets are activated.

A laptop charger was plugged into the smart wall outlets to simulate the actual power usage of the system.

Table 4.1 Power Consumption of Home Control Unit - RPi (Watts)

Operations Scenario	**Average Power Measurement of Each Day (W)**					**Average Power (W)**
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	
i	3.0	2.8	3.1	3.0	2.9	2.96
ii	3.2	3.3	3.2	3.0	3.3	3.17
iii	3.3	3.2	3.3	3.1	3.2	3.22

Based on Table 4.1, when none of the smart wall outlets are operating, the results show that the home control unit consumes an average of 2.96 W. As more smart wall outlets are operating, the home control unit consumes slightly more power. The heavier load can explain the increase in power consumption in processing the data with more wall outlets. However, such results can only be justified when there are higher numbers of wall outlets running at the same time.

4.5.2 Power Consumption of the Smart Wall Outlet

The power consumption of both smart wall outlets is measured using a power meter in different operating mode. Both measurement of power consumption was taken for an 8 hours period daily for 5 consecutive days and the daily average of both wall outlets were recorded in Table 4.2. The experiment is carried out in two phases;

i. Smart wall outlet is connected to the WiFi
ii. Smart wall outlet is not connected to the WiFi

In each of the phases, the experiment is further divided into three phases;

i. Solenoid is activated but alarm is off
ii. Solenoid is activated and the alarm is on
iii. Both solenoid and alarm are deactivated

No electrical appliances were connected during the measurement of the smart wall outlets at all phases.

Table 4.2 Power Consumption of The Smart Wall Outlets (Watts)

Operations Scenario			**Average Power Measurement of Each Day (W)**					**Average Power (W)**
			Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	
WiFi Disconnected	Solenoid On	Alarm Off	4.0	3.9	4.0	4.0	3.9	3.96
		Alarm On	4.1	4.1	4.2	4.2	4.1	4.14
	Solenoid Off Alarm Off		3.4	3.5	3.4	3.3	3.5	3.42
WiFi Connected	Solenoid On	Alarm Off	6.1	6.0	6.0	6.1	6.0	6.04
		Alarm On	6.3	6.2	6.3	6.4	6.3	6.30
	Solenoid Off Alarm Off		5.3	5.3	5.4	5.3	5.5	5.36

Based on Table 4.2, the results show that the smart wall outlet consumes an average of 3.42 W when WiFi is not connected and an average of 5.36 W when WiFi is connected. By comparing these results, it can be shown that the connection of WiFi consumes approximately 2 W for the wall outlets. The increase in power consumption can be seen when the solenoid magnet is activated. However, the alarm consumes 4.54% of power when the alarm goes on.

4.5.3 Electricity Tariff of The System

The electricity cost of the proposed system at different operation phases were calculated based on Table 4.1 and Table 4.2 using Malaysia's TNB domestic electricity tariff system and is recorded in Table 4.3. The power consumption of the home control unit is taken respective to the operation phases as explained in Section 4.5.1. The power consumption of each wall outlet is taken as 5.36 W.

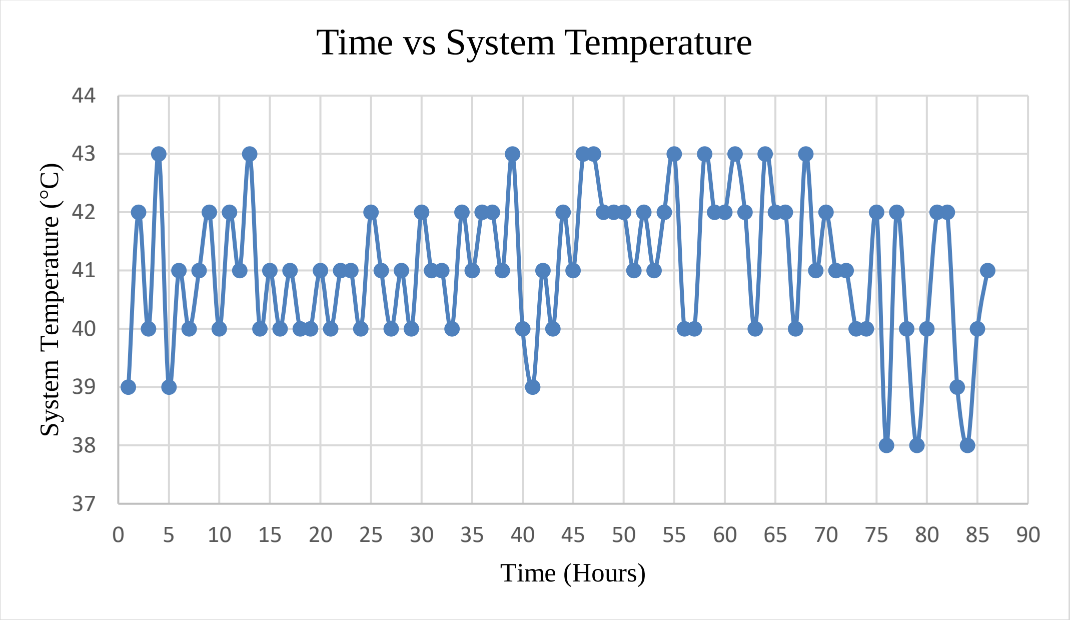
Table 4.3 Electricity Tariff of The Smart Wall Outlet System (RM)

Operations Scenario	**Average Power per Day (W)**	**Electricity Tariff (RM)**			
		1 Day	**1 Week**	**1 Month**	**1 Year**
i	71.04	0.02	0.11	0.43	5.20
ii	204.72	0.04	0.31	1.25	15.00
iii	334.56	0.07	0.51	2.04	24.51

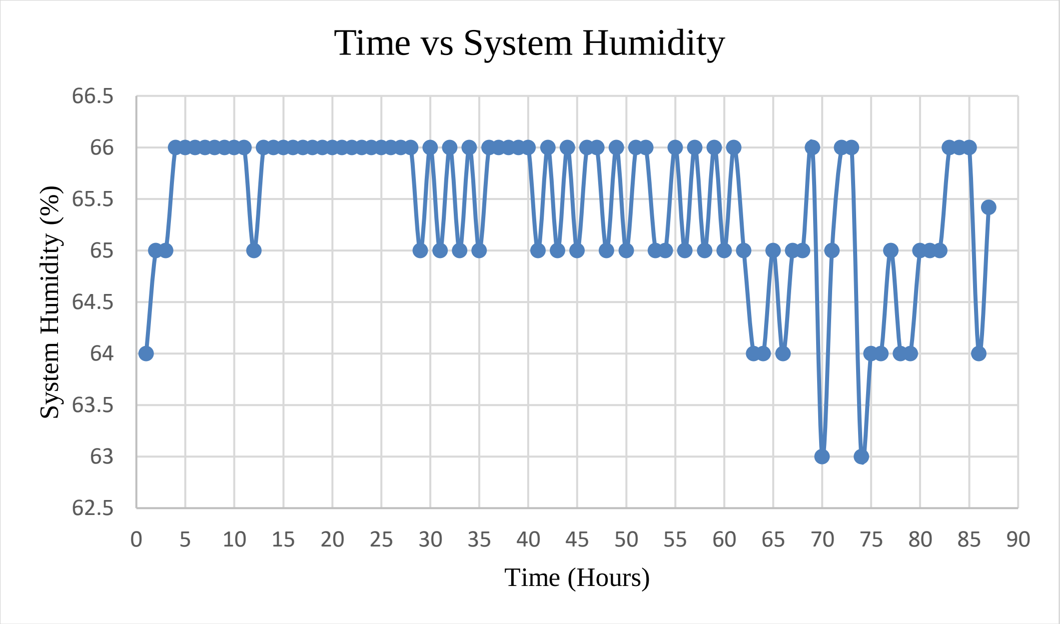
Based on Table 4.3, the results show that the smart wall outlet system requires an average of RM 24.51 when the home control unit and two wall outlets are running 24 hours consecutively for a year. However, the tariff calculated as shown in Table 4.3 are not accurate as the calculation does not take into account actual electricity usage in a home. The increasing number of wall outlets consumes more power hence higher the electricity tariff.

4.5.4 System Temperature and Humidity

The system temperature and system humidity of the smart wall outlets were measured every 30 seconds using the DHT11 sensor for 90 consecutive hours as shown in Graph 4.1 and Graph 4.2. The sensor is installed onto the circuit board while the system is enclosed in a standard outlet box. The current sensor is sensitive to ambient temperature which may affect its sensitivity when measuring the current.



Graph 4.1 Time vs System Temperature



Graph 4.2 Time vs System Humidity

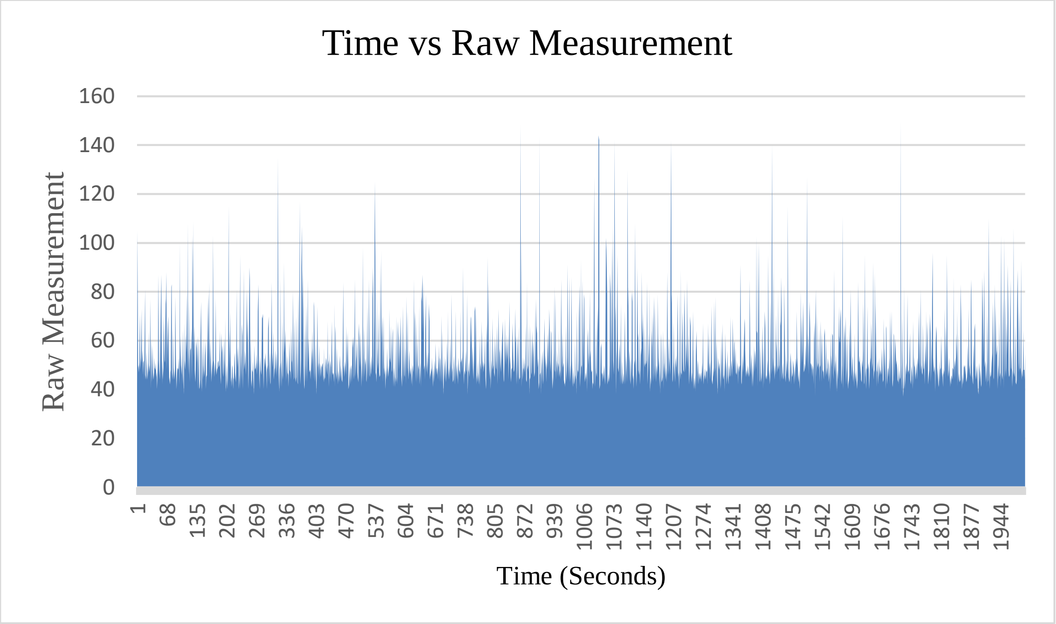
Based on the results, the average system temperature is 41.04 °C and the average system humidity is 65.42 %. The measurements are vital as higher temperatures represent more heat and more power drawn by the system. The rise in temperature of the system can be explained by the heat produced by LM7805 and the solenoid magnet. The heat loss in LM7805 is produced when 12 V DC is step down to 5 V DC. When the system draws more current, the heat loss in LM7805 will increase. However, the effect of ambient temperature and humidity on the changes of system temperature and humidity could not be justified as the ambient temperature and humidity were stable.

Based on the datasheet of the ACS712 current sensor, the sensitivity of the sensor ranges from 66.2 to 66.3 mv/A over a range of temperatures from 25 °C to 50 °C. In this project, 66.3 mV/A is used as the sensitivity in the computation of current measurement for higher accuracy. However, humidity does not affect the sensitivity of the ACS712 current sensor. Such changes on temperature and humidity does not affect the other components in the system.

4.5.5 Accuracy and Sensitivity of Current Sensor

The ACS712 current sensor module is capable to measure up to 30 A but its capability couldn’t be verified without high power applications. Thus, its capability is limited to household common electrical appliances. The sensor is unstable and very susceptible to noise particularly due to the magnetic field produced by the live wire. An appropriate capacitor value of 100 nF was also added to the filter pin of the IC chip to further suppress the noises. Programming techniques such as moving average filter and non-linear equations were also implemented to increases the accuracy and repeatability of the current sensing. Graph 4.3 shows the raw value measured by the current sensor during no load.

Based on the graph, it could be shown that the sensor remains unstable despite applying filters on both hardware and software. The results show low repeatability with some spikes during no load. The results of its accuracy were measured on common household electrical appliances over 10 times and the average was recorded and compared with a power meter measurement as shown in Table 4.4.



Graph 4.3 Time vs Raw Measurement

Table 4.4 Current Measurement of Different Electrical Appliances (Amperes)

Appliances		**Average Current Measurement (A)**		**Percentage of Error (%)**
		Power Meter	**Smart Wall Outlet***	
6W AA Battery Charger		0.023	0.050	117.39
25W Monitor Adapter		0.086	0.150	74.42
39W Table Fan		0.160	0.222	38.75
20W Phone Charger		0.130	0.180	38.46
130W Laptop Charger		0.300	0.36	20.00
1000W Hair Dryer	Cool Mode	1.364	1.390	1.87
	Heat Mode	4.551	4.490	1.34
2800W Electrical Hob		4.780	4.910	2.72

*Average value from 10 readings

Based on Table 4.4, the results show that the overall percentage of error of current measurement is decreasing proportionally with the magnitude of the current. At the current magnitude lower than 1A, it has a high margin of error. In contrast, the margin of error is less than 3 % when the current is above 1 A. This shows that the ACS712 current sensor is not performing well in measuring AC current that is lower than 1A especially when the device was exposed to magnetic field and noises.

However, the power wattage is not calculated and shown in the table as the power could not be calculated due to the smart wall outlet unable to measure the voltage and power factor. Since the voltage of the outlet is not maintaining a constant 240 V and not all electrical appliances have an ideal power factor of 1, the voltage, power factor and power consumption of the electrical appliances were measured using the power meter and the comparison results are shown in Table 4.5.

Table 4.5 Power Factor and Power Consumption of The Electrical Appliances

Appliances		**Measured Voltage (V)**	**Measured Power Factor* (PF)**	**Measured Power Consumption (W)**	**Calculated Power Consumption (W)**
6W AA Battery Charger		255.0	0.87	5.1	12.0
25W Monitor Adapter		250.0	0.46	9.9	36.0
39W Table Fan		237.5	1.00	38.0	53.3
20W Phone Charger		256.4	0.57	19.0	43.2
130W Laptop Charger		238.0	0.88	62.8	86.4
1000W Hair Dryer	Cool Mode	249.3	1.00	340.0	333.6
	Heat Mode	237.3	1.00	1080.0	1077.6
2800W Electrical Hob		245.3	1.00	1172.5	1178.4

*Power factor is the ratio of working power to apparent power. It is also the efficiency of an electrical appliances.

The measured power consumption can be hand calculated using Equation 4.1.

$$P = V * I * PF \qquad (4.1)$$

where

P = power consumption, W

V = voltage, V

I = current, A

PF = power factor

The calculated power consumption by the smart wall outlet is calculated using Equation 4.2.

$$P = 240 * I_m \quad (4.2)$$

where

P = power consumption, W

I_m = measured current, A

The measured power consumption and calculated power consumption of the 25W monitor adapter is shown in Equation 4.3 and Equation 4.4 respectively.

$$P = 250.0 * 0.086 * 0.46 = 9.89\ W \qquad (4.3)$$

$$P = 240.0 * 0.15 = 36\ W \qquad (4.4)$$

The measured power consumption and calculated power consumption of the 2800 W electrical hob is shown in Equation 4.5 and Equation 4.6 respectively.

$$P = 245.3 * 4.78 * 1 = 1172.5\, W \qquad (4.5)$$

$$P = 240.0 * 4.91 = 1178.4\, W \qquad (4.6)$$

Based on Table 4.5, the results show that the measured power consumption is differed from the calculated power consumption with a high margin of error for electrical appliances with low current drawn and power factor of lesser than 1. Comparing the 25W monitor adapter as shown in Equation 4.3 and Equation 4.4, the margin of error is 264 %. When the power factor of the electrical appliance is 1, such as an electrical hob, the margin of error is 0.5 % comparing Equation 4.5 and Equation 4.6.

Hence, the power usage calculated by the smart wall outlet will be incorrect for some appliances since the voltage measured through power meter fluctuates between 235 V to 250 V. The calculation also does not take into account of power factor as well since the smart wall outlet is not capable to measure power factor. Thus, the power calculated can only be used as a reference.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This project presents an IoT based smart single wall outlet system with a locking cover. The proposed system was able to provide the features of remote controlling and monitoring of outlets through a web interface via local connection. The system also allows remote controlling and monitoring of outlets away from home through the mobile application. Besides that, real-time power usage and electricity tariffs can be calculated, stored and shown to the user. On top of that, an external locking cover with RFID access was designed to prevent electrocutions from the wall outlet by hindering the conductive holes of the outlets. The power consumption of the designed system is 334.56 W with a home control unit and both smart wall outlets running.

5.2 Recommendations for Future Work

The smart wall outlet system should be designed with circuit protection features such as short circuit protection and power supply protection. This can avoid the spike current or short circuit from damaging the system. Besides that, the hardware components used in the system should also be optimized such that it provides the best performance while keeping the heat loss and power consumption to a minimum. Additional functions can be added such as voltage and power factor measurement to increase the accuracy of power measurement. The platform and backend services used by the system should also be kept to a minimum to reduce the load and latency of data exchange.

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APPENDICES

APPENDIX A: Specification of Raspberry Pi 3 Model B+

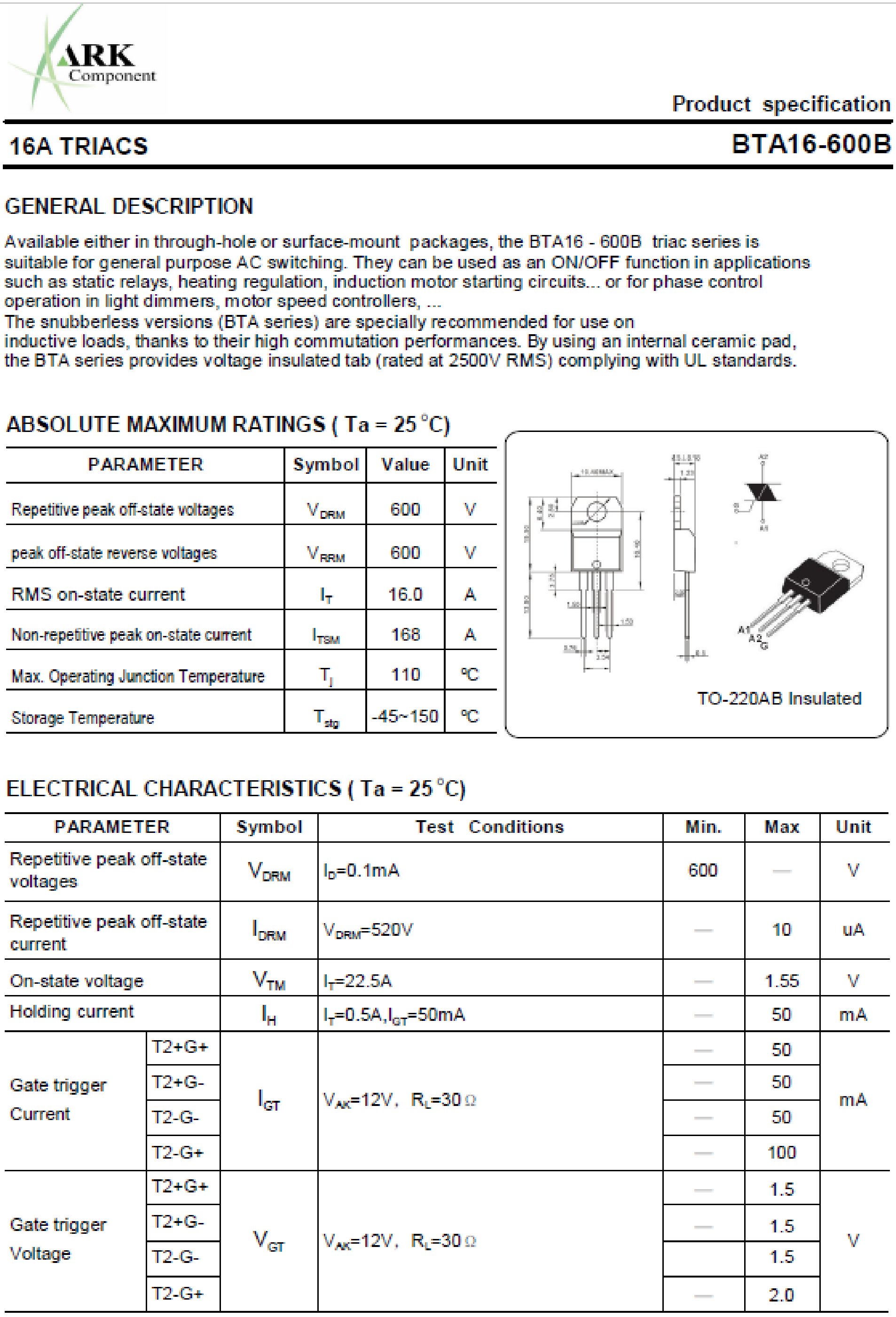
Raspberry Pi 3 Model B+ 2

Specifications

Processor:	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz
Memory:	1GB LPDDR2 SDRAM
Connectivity:	■ 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE ■ Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps) ■ 4 × USB 2.0 ports
Access:	Extended 40-pin GPIO header
Video & sound:	■ 1 × full size HDMI ■ MIPI DSI display port ■ MIPI CSI camera port ■ 4 pole stereo output and composite video port
Multimedia:	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics
SD card support:	Micro SD format for loading operating system and data storage
Input power:	■ 5 V/2.5 A DC via micro USB connector ■ 5 V DC via GPIO header ■ Power over Ethernet (PoE)–enabled (requires separate PoE HAT)
Environment:	Operating temperature, 0–50 °C
Compliance:	For a full list of local and regional product approvals, please visit www.raspberrypi.org/products/raspberry-pi-3-model-b+
Production lifetime:	The Raspberry Pi 3 Model B+ will remain in production until at least January 2023.

raspberrypi.org

APPENDIX B: BTA16-600b Datasheet



ARK Component

Product specification

16A TRIACS **BTA16-600B**

GENERAL DESCRIPTION

Available either in through-hole or surface-mount packages, the BTA16 - 600B triac series is suitable for general purpose AC switching. They can be used as an ON/OFF function in applications such as static relays, heating regulation, induction motor starting circuits... or for phase control operation in light dimmers, motor speed controllers, ...
The snubberless versions (BTA series) are specially recommended for use on inductive loads, thanks to their high commutation performances. By using an internal ceramic pad, the BTA series provides voltage insulated tab (rated at 2500V RMS) complying with UL standards.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

PARAMETER	Symbol	Value	Unit
Repetitive peak off-state voltages	V_{DRM}	600	V
peak off-state reverse voltages	V_{RRM}	600	V
RMS on-state current	I_T	16.0	A
Non-repetitive peak on-state current	I_{TSM}	168	A
Max. Operating Junction Temperature	T_j	110	℃
Storage Temperature	T_{stg}	-45~150	℃

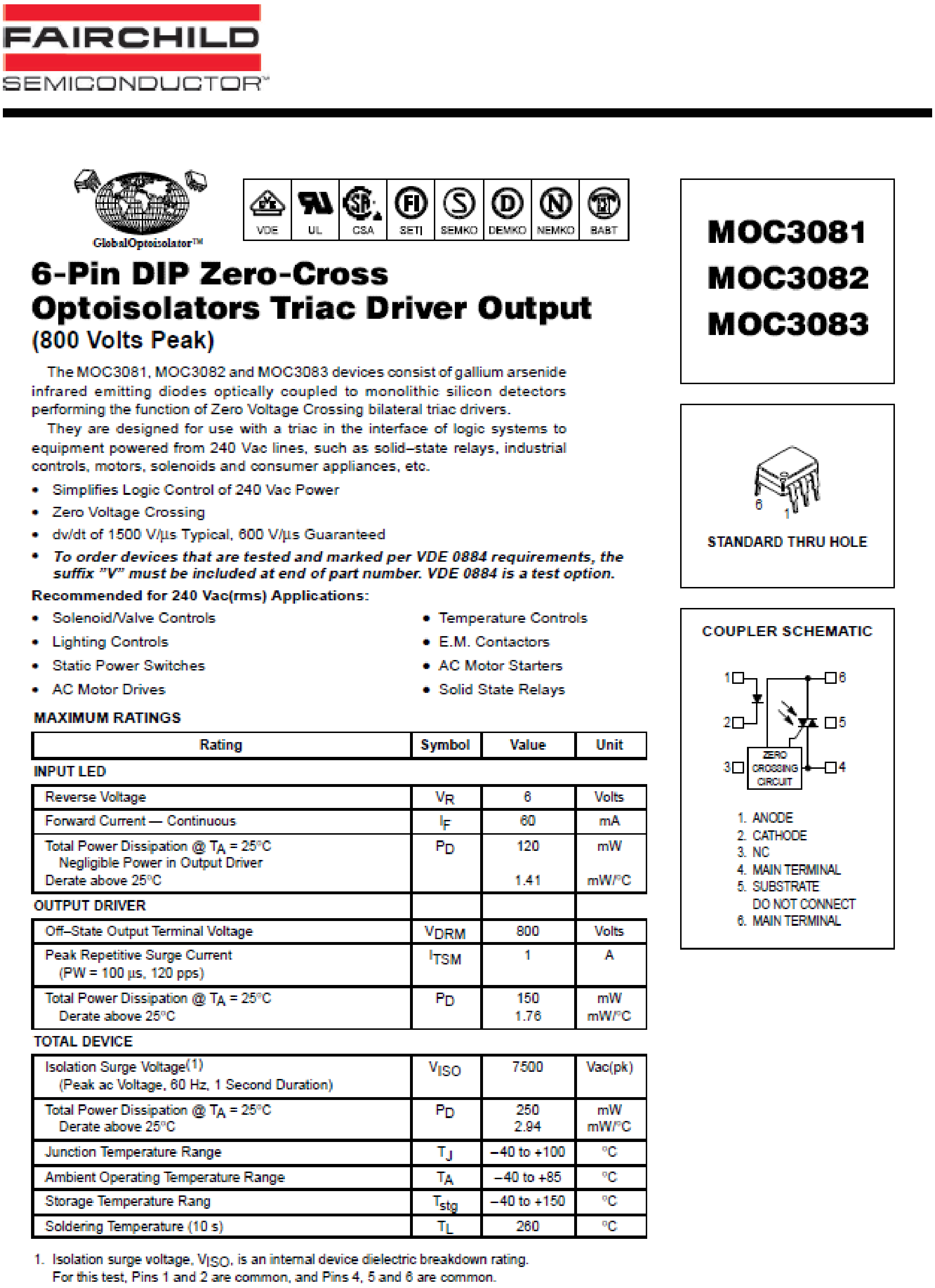
A1 A2 G

TO-220AB Insulated

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

PARAMETER		Symbol	Test Conditions	Min.	Max	Unit
Repetitive peak off-state voltages		V_{DRM}	I_D=0.1mA	600	—	V
Repetitive peak off-state current		I_{DRM}	V_{DRM}=520V	—	10	uA
On-state voltage		V_{TM}	I_T=22.5A	—	1.55	V
Holding current		I_H	I_T=0.5A,I_{GT}=50mA	—	50	mA
Gate trigger Current	T2+G+	I_{GT}	V_{AK}=12V, R_L=30Ω	—	50	mA
	T2+G-			—	50	
	T2-G-			—	50	
	T2-G+			—	100	
Gate trigger Voltage	T2+G+	V_{GT}	V_{AK}=12V, R_L=30Ω	—	1.5	V
	T2+G-			—	1.5	
	T2-G-				1.5	
	T2-G+			—	2.0	

APPENDIX C: MOC3083 Datasheet



FAIRCHILD
SEMICONDUCTOR™

MOC3081
MOC3082
MOC3083

6-Pin DIP Zero-Cross Optoisolators Triac Driver Output

(800 Volts Peak)

The MOC3081, MOC3082 and MOC3083 devices consist of gallium arsenide infrared emitting diodes optically coupled to monolithic silicon detectors performing the function of Zero Voltage Crossing bilateral triac drivers.

They are designed for use with a triac in the interface of logic systems to equipment powered from 240 Vac lines, such as solid–state relays, industrial controls, motors, solenoids and consumer appliances, etc.

- Simplifies Logic Control of 240 Vac Power
- Zero Voltage Crossing
- dv/dt of 1500 V/µs Typical, 600 V/µs Guaranteed
- ***To order devices that are tested and marked per VDE 0884 requirements, the suffix "V" must be included at end of part number. VDE 0884 is a test option.***

Recommended for 240 Vac(rms) Applications:

- Solenoid/Valve Controls
- Lighting Controls
- Static Power Switches
- AC Motor Drives
- Temperature Controls
- E.M. Contactors
- AC Motor Starters
- Solid State Relays

STANDARD THRU HOLE

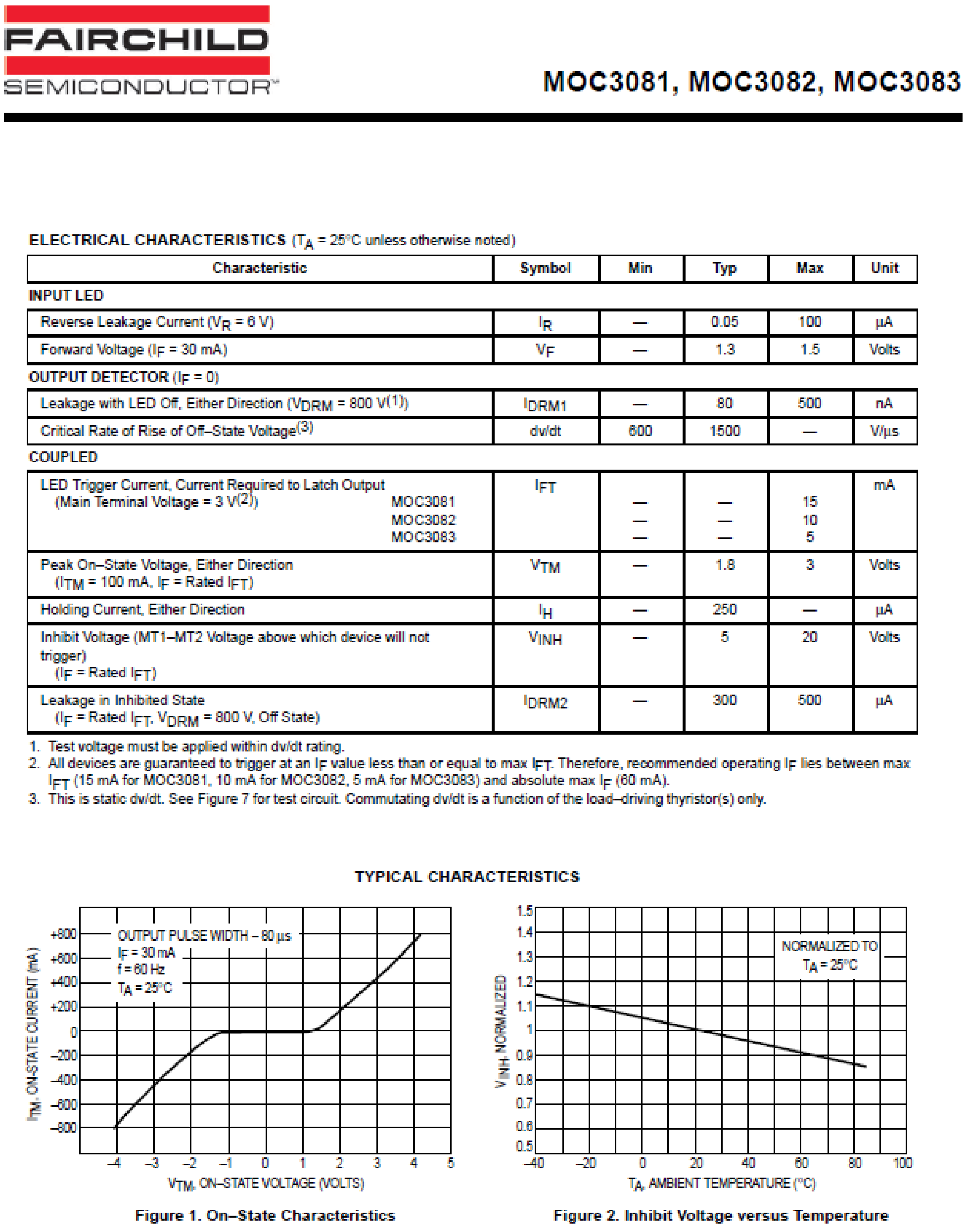
COUPLER SCHEMATIC

1. ANODE
2. CATHODE
3. NC
4. MAIN TERMINAL
5. SUBSTRATE
   DO NOT CONNECT
6. MAIN TERMINAL

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
INPUT LED			
Reverse Voltage	V_R	6	Volts
Forward Current — Continuous	I_F	60	mA
Total Power Dissipation @ T_A = 25°C Negligible Power in Output Driver Derate above 25°C	P_D	120 1.41	mW mW/°C
OUTPUT DRIVER			
Off–State Output Terminal Voltage	V_{DRM}	800	Volts
Peak Repetitive Surge Current (PW = 100 µs, 120 pps)	I_{TSM}	1	A
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 1.76	mW mW/°C
TOTAL DEVICE			
Isolation Surge Voltage[1] (Peak ac Voltage, 60 Hz, 1 Second Duration)	V_{ISO}	7500	Vac(pk)
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	250 2.94	mW mW/°C
Junction Temperature Range	T_J	–40 to +100	°C
Ambient Operating Temperature Range	T_A	–40 to +85	°C
Storage Temperature Rang	T_{stg}	–40 to +150	°C
Soldering Temperature (10 s)	T_L	260	°C

1. Isolation surge voltage, V_{ISO}, is an internal device dielectric breakdown rating. For this test, Pins 1 and 2 are common, and Pins 4, 5 and 6 are common.



FAIRCHILD
SEMICONDUCTOR™

MOC3081, MOC3082, MOC3083

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
INPUT LED					
Reverse Leakage Current (V_R = 6 V)	I_R	—	0.05	100	µA
Forward Voltage (I_F = 30 mA)	V_F	—	1.3	1.5	Volts
OUTPUT DETECTOR (I_F = 0)					
Leakage with LED Off, Either Direction (V_{DRM} = 800 V[1])	I_{DRM1}	—	80	500	nA
Critical Rate of Rise of Off–State Voltage[3]	dv/dt	600	1500	—	V/µs
COUPLED					
LED Trigger Current, Current Required to Latch Output (Main Terminal Voltage = 3 V[2]) MOC3081 MOC3082 MOC3083	I_{FT}	— — —	— — —	15 10 5	mA
Peak On–State Voltage, Either Direction (I_{TM} = 100 mA, I_F = Rated I_{FT})	V_{TM}	—	1.8	3	Volts
Holding Current, Either Direction	I_H	—	250	—	µA
Inhibit Voltage (MT1–MT2 Voltage above which device will not trigger) (I_F = Rated I_{FT})	V_{INH}	—	5	20	Volts
Leakage in Inhibited State (I_F = Rated I_{FT}, V_{DRM} = 800 V, Off State)	I_{DRM2}	—	300	500	µA

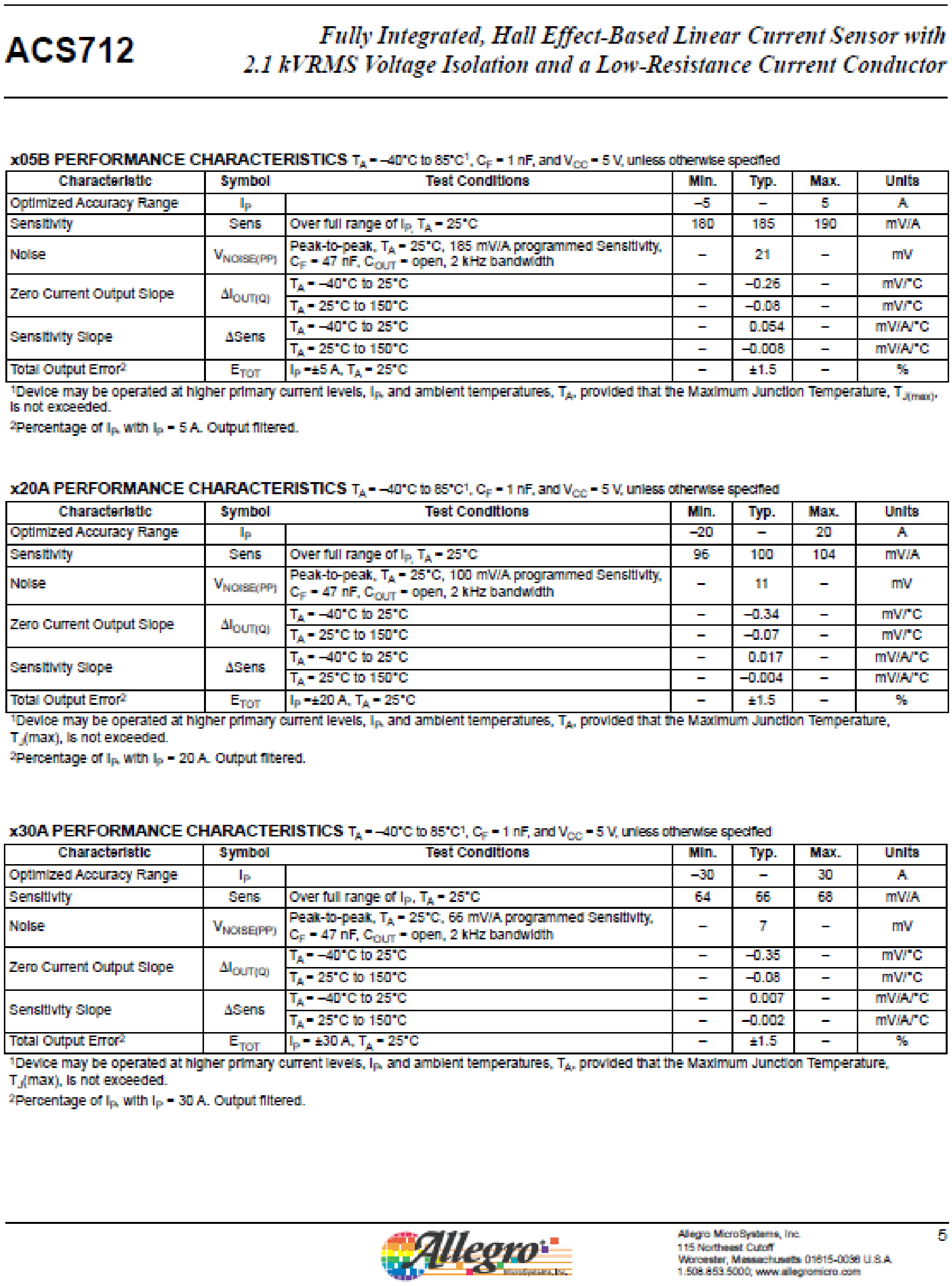
1. Test voltage must be applied within dv/dt rating.
2. All devices are guaranteed to trigger at an I_F value less than or equal to max I_{FT}. Therefore, recommended operating I_F lies between max I_{FT} (15 mA for MOC3081, 10 mA for MOC3082, 5 mA for MOC3083) and absolute max I_F (60 mA).
3. This is static dv/dt. See Figure 7 for test circuit. Commutating dv/dt is a function of the load–driving thyristor(s) only.

TYPICAL CHARACTERISTICS

Figure 1. On–State Characteristics

Figure 2. Inhibit Voltage versus Temperature

APPENDIX D: ACS712 Datasheet



ACS712

Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

x05B PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	180	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.26	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.054	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.008	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±5 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.

[2] Percentage of I_P, with I_P = 5 A. Output filtered.

x20A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	96	100	104	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	11	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.34	–	mV/°C
		T_A = 25°C to 150°C	–	–0.07	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.017	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.004	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±20 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] Percentage of I_P, with I_P = 20 A. Output filtered.

x30A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	64	66	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.35	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.007	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.002	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] Percentage of I_P, with I_P = 30 A. Output filtered.

Allegro MicroSystems, Inc.
115 Northeast Cutoff
Worcester, Massachusetts 01615-0036 U.S.A.
1.508.853.5000; www.allegromicro.com

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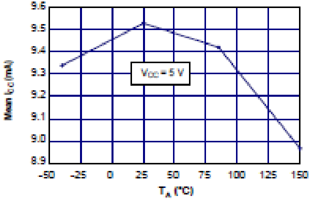
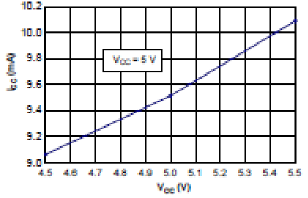
Characteristic Performance

I_P = 30 A, unless otherwise specified

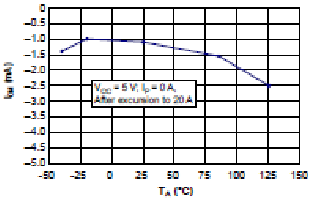
Mean Supply Current versus Ambient Temperature



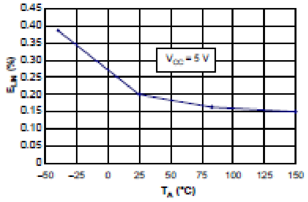
Supply Current versus Supply Voltage



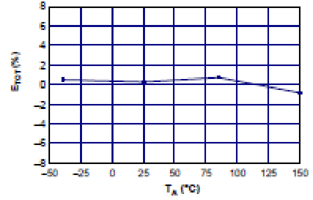
Magnetic Offset versus Ambient Temperature



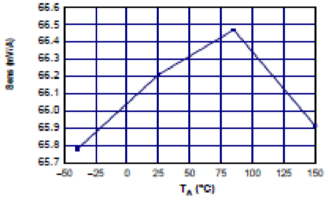
Nonlinearity versus Ambient Temperature



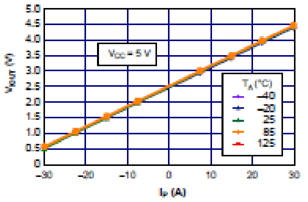
Mean Total Output Error versus Ambient Temperature



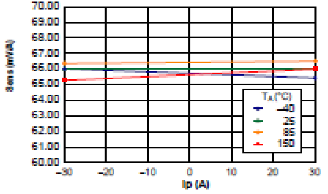
Sensitivity versus Ambient Temperature



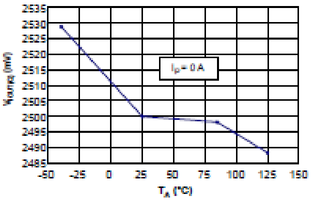
Output Voltage versus Sensed Current



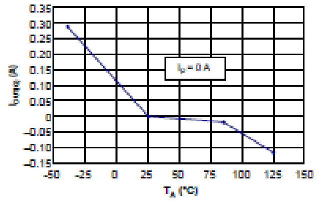
Sensitivity versus Sensed Current



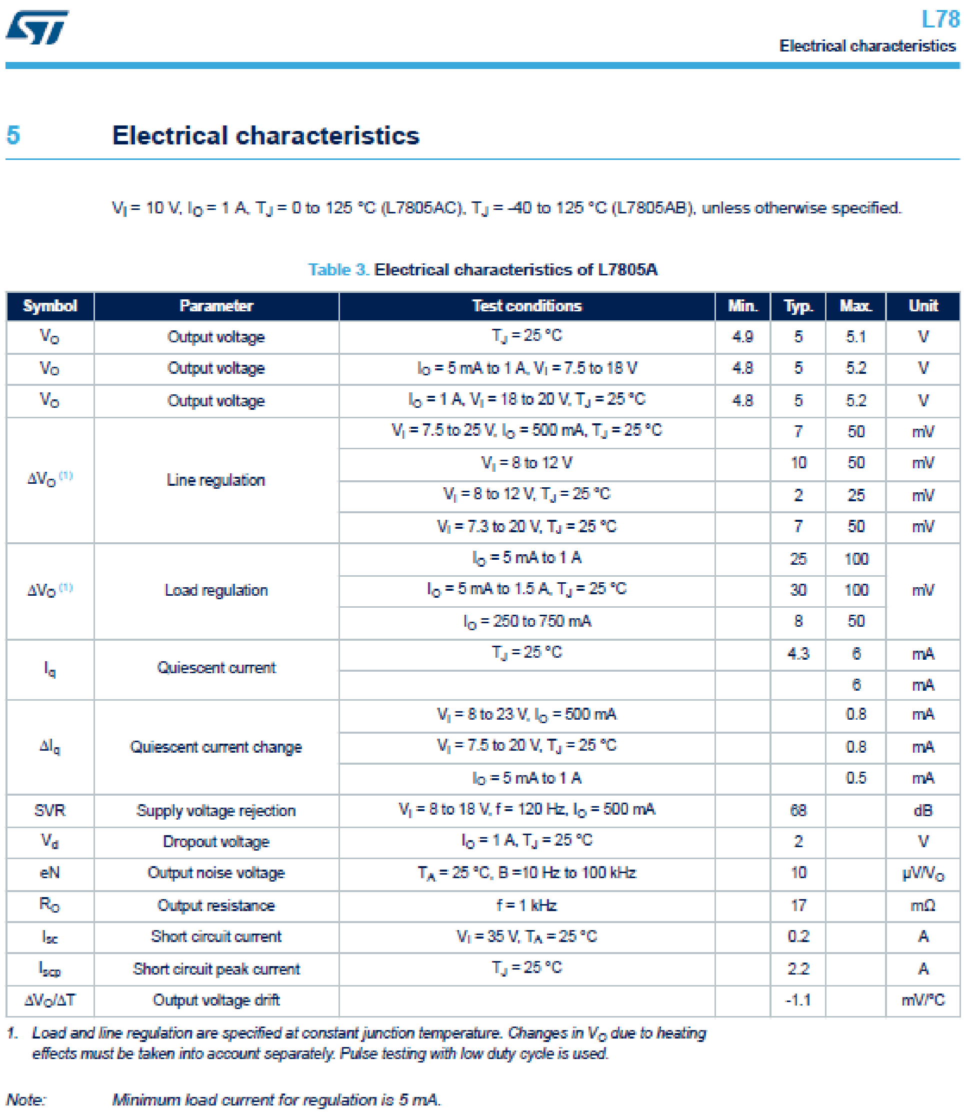
0 A Output Voltage versus Ambient Temperature



0 A Output Voltage Current versus Ambient Temperature



APPENDIX E: L78 Datasheet



5 Electrical characteristics

V_I = 10 V, I_O = 1 A, T_J = 0 to 125 °C (L7805AC), T_J = -40 to 125 °C (L7805AB), unless otherwise specified.

Table 3. Electrical characteristics of L7805A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25 °C	4.9	5	5.1	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 7.5 to 18 V	4.8	5	5.2	V
V_O	Output voltage	I_O = 1 A, V_I = 18 to 20 V, T_J = 25 °C	4.8	5	5.2	V
ΔV_O (1)	Line regulation	V_I = 7.5 to 25 V, I_O = 500 mA, T_J = 25 °C		7	50	mV
		V_I = 8 to 12 V		10	50	mV
		V_I = 8 to 12 V, T_J = 25 °C		2	25	mV
		V_I = 7.3 to 20 V, T_J = 25 °C		7	50	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25 °C		30	100	
		I_O = 250 to 750 mA		8	50	
I_q	Quiescent current	T_J = 25 °C		4.3	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 8 to 23 V, I_O = 500 mA			0.8	mA
		V_I = 7.5 to 20 V, T_J = 25 °C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 8 to 18 V, f = 120 Hz, I_O = 500 mA		68		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25 °C		2		V
eN	Output noise voltage	T_A = 25 °C, B =10 Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25 °C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25 °C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-1.1		mV/°C

1. *Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.*

Note: *Minimum load current for regulation is 5 mA.*

3 Maximum ratings

Table 1. Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_I	DC input voltage	for V_O= 5 to 18 V	35	V
		for V_O= 20, 24 V	40	
I_O	Output current		Internally limited	
P_D	Power dissipation		Internally limited	
T_{STG}	Storage temperature range		-65 to 150	°C
T_{OP}	Operating junction temperature range	for L78xxC, L78xxAC	0 to 125	°C
		for L78xxAB	-40 to 125	

Note: *Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these condition is not implied.*

Table 2. Thermal data

Symbol	Parameter	D²PAK	DPAK	TO-220	TO-220FP	Unit
R_{thJC}	Thermal resistance junction-case	3	8	5	5	°C/W
R_{thJA}	Thermal resistance junction-ambient	62.5	100	50	60	°C/W

Figure 5. Application circuits