Smart Switch Board: Solution for Reliability and Power Management

A Thesis
Submitted to the Dept. of Electrical & Electronic Engineering
Of
BRAC University
By

Mahmudul Islam (ID: 13121133)
Monoarul Alam Siddiqui (ID: 13121114)
Md. Ehtesum (ID: 13121119)

Supervised by
Dr. Md. Khalilur Rhaman

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Bachelor of Science degree in Electrical & Electronic Engineering

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DECLARATION

We, hereby declare that this thesis is based on the results established by us and it is submitted to the Department Of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. Materials of work found by other researchers are mentioned in the reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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Signature of the Advisor

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Mahmudul Islam (***ID***: **13121133**)

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Monoarul Alam Siddiqui (***ID***: **13121114**)

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Md. Ehtesum (***ID***: **13121119**)

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ABSTRACT

Current energy management system calls for reliability and reduction between power supply and demand gaps. As huge development is being made in Smart Grid & Smart Metering systems, other electric switches and components requires upgrade too. This calls for the need of introducing smart switching technology. This paper represents 'Smart Switch Board' which is the smarter version of the traditional switch boards. It is an IoT based switching device which enables it to be controlled via apps from smart devices and this feature would become very useful for the old and handicapped persons. Besides, smart switch meter can be used to control smaller areas if it is connected with the router. In that case, it will function via router's ip address which will make the system more secured. Again, physical contact is not required to operate it and due to the usage of electronics, ac/dc power conversion is required which ensure reliability and safety from fire accidents. The number of wire needed to connect the whole system can be reduced as smart switch meter is a wiring less system. This device is also capable of calculating the power consumption and cost and thus daily/weekly/monthly power consumptions and cost can be tracked which will be helpful for the consumers to create plans for reducing their electricity usage. Hardware components used in smart switch board are quite cheap and easy to replace. Altogether, we aimed for creating a slightly unconventional switch board with a few relatively modern features with a view to introducing a comparatively different lifestyle than the usual.

TABLE OF CONTENTS

TABLE OF FIGURES

CHAPTER I

MOTIVATION

Modern era can be compared to the smart era where everything is getting smart. Traditional devices are getting replaced by the smart devices. Similarly, age old switch board needs to be replaced with such a device that uses latest technology to do the same work but more efficiently, more quickly and we get motivated by this fact which has forced us to come up with smart switch board. Smart switch board is created considering the available technologies to help people. Features such as Wi-Fi control and cost calculation can provide the consumer not only the view the electricity consumption in monthly basis but to track their daily usage of electricity which will help them to create plans for power utilization or in other words power management. These two features give an edge to smart switch board over the traditional switch board. Now-a-days people look for things that are not only different but also efficient. So, considering the integration of smart grid technologies and to let people to accustom to a bit of a different lifestyle, we have been motivated to develop smart switch board.

OBJECTIVE OF THE REPORT

Broad Objective:
To utilize the experience gathered during the thesis.

Specific Objective:
To present our observation and knowledge, we attained during the thesis work.

METHODOLOGY

The data needed to prepare this report has been collected from both primary and secondary sources.

Primary Data Source:
Primary data has been collected through analysis of our project work.

Secondary Data Source:
The secondary data which are collected only for the implementation of project have been collected through various journals and research papers.

REPLACE COST

For a standard room, in average there are 2-3 switch boards consisting of 10 switches which costs worth 300-500 Taka. Additionally, internal home wiring is needed for connecting switches. On average, 800-1000 Taka will cost for a standard room to be equipped with traditional switching board. On the contrary, Smart Switch Board which costs us 2255 Taka comes with smart features, wireless connectivity, future opportunities and promises. As we made Smart Switch Board using the components from the retailer market which costs us a lot more than it would cost to manufacture and fabricate the whole thing all together industrially. Comparing with the facts, it will not cost a lot more extra to replace the traditional switch board with the Smart Switch Board.

Comparison with the similar products available in the market –

Prices from international online markets i.e. amazon, eBay.

Types and Features	Price
Home energy monitor with real time view of electricity usage and bill forecasting (Internet connectivity needed all the time)	USD 220

Single connection plug with Wi-Fi connectivity (Internet connectivity needed all the time)	USD 35
Real-time power consumption monitor with solar production monitor (Internet connectivity needed all the time)	USD 375

Table 1: Alternative Products from the Market

CURVE ANALYSIS

To test the current measuring sensor, it was connected to three different houses of different loads for 24 hours and the data were recorded hourly. Plotting the data of three houses gives the following curve which gives the idea of energy uses in different period of time.

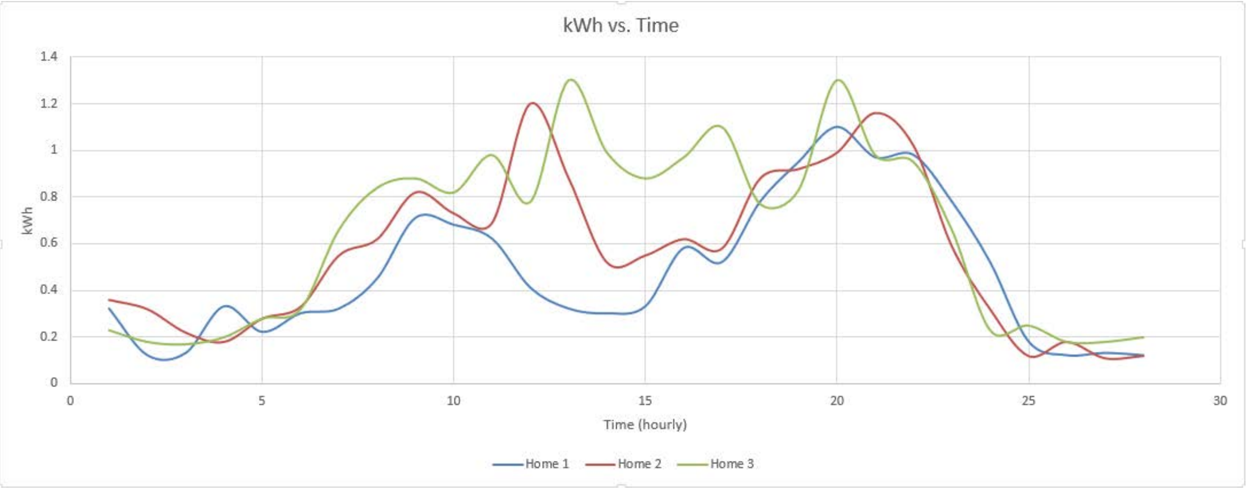


Figure 1: Hourly Curve Analysis

ANALYSIS FOR PEAK AND OFF-PEAK HOUR

For the first house, Total load of the house is approximately 1100W altogether. During the time period of 12.00 AM – 6.00 AM, total energy consumption is around 1.5 kWh which is 1.5 unit electricity. During the period of 6.00 AM – 6.00 PM, the total energy consumption is around 4.1 kWh which is 4.1 unit electricity. During the time period of 6.00 PM – 12.00 PM, the total energy consumption is around 5.38 kWh. The curve analysis for the first house is given below:

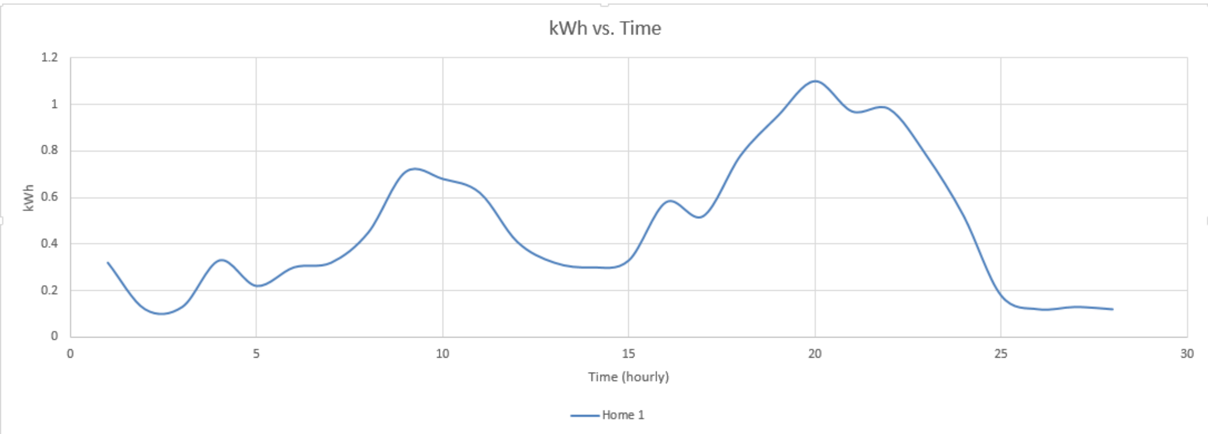


Figure 2: Curve Analysis for First House

For the second house, Total load of the house is approximately 2464W altogether. During the time period of 12.00 AM – 6.00 AM, total energy consumption is around 1.68 kWh which is 1.68 unit electricity. During the period of 6.00 AM – 6.00 PM, the total energy consumption is around 6 kWh which is 6 unit electricity. During the time period of 6.00 PM – 12.00 PM, the total energy consumption is around 5.42 kWh.

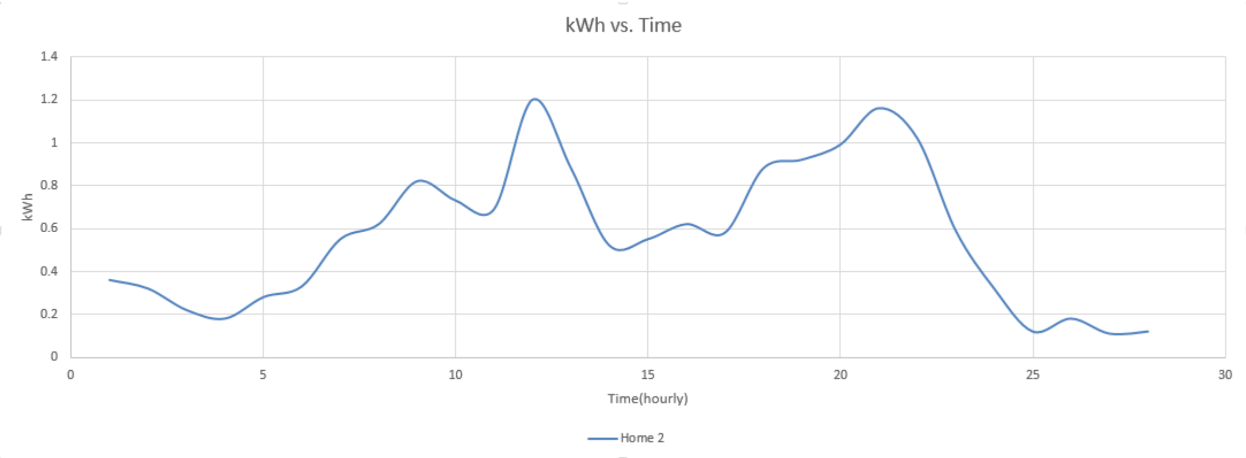


Figure 3: Curve Analysis for Second House

For the third house, Total load of the house is approximately 2810W altogether. During the time period of 12.00 AM – 6.00 AM, total energy consumption is around 1.86 kWh which is 1.86 unit electricity. During the period of 6.00 AM – 6.00 PM, the total energy consumption is around 8.23 kWh which is 8.23 unit electricity. During the time period of 6.00 PM – 12.00 PM, the total energy consumption is around 4.92 kWh.

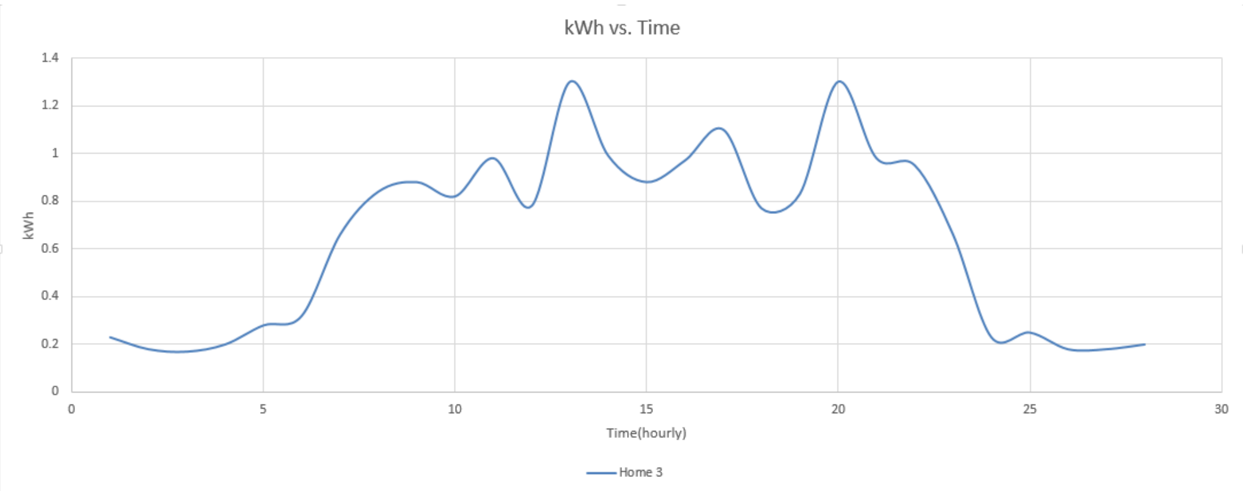
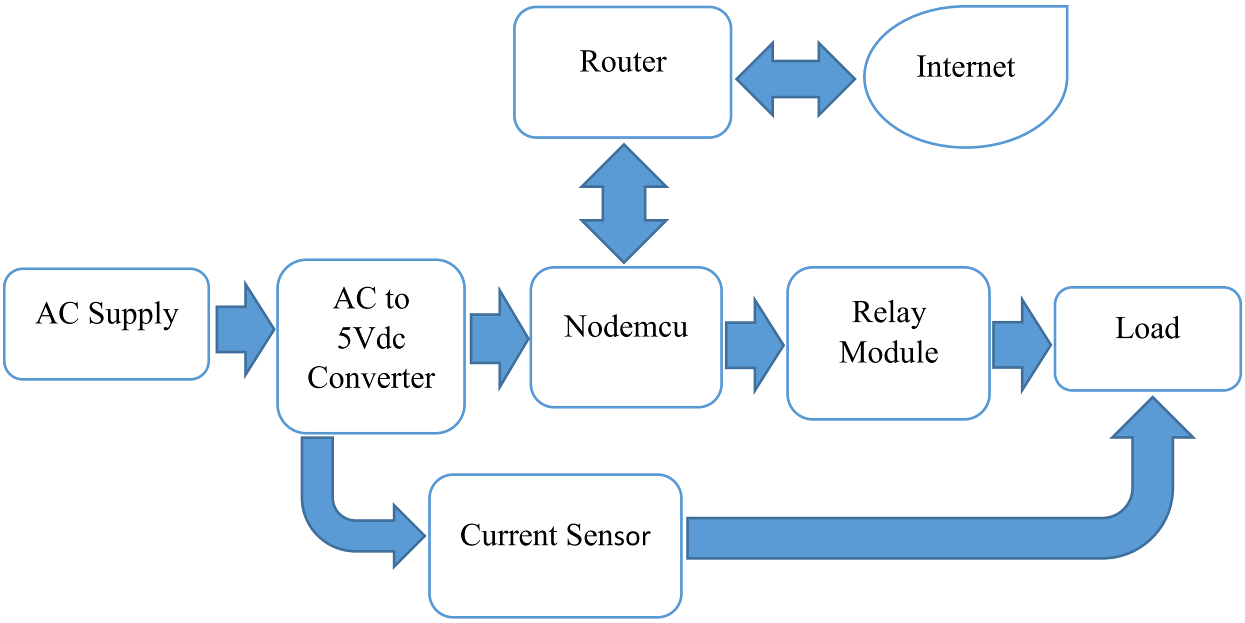


Figure 4: Curve Analysis for Third House

CHAPTER II

SYSTEM ARCHITECTURE



Above block diagram shows the system architecture of our project. Firstly, the ac supply from the outlet is converted to dc (here 5 volt dc with 1 amps dc current) through an internal circuit consisting transformer, regulator, capacitor and other components. Here, the conversion technic used is conventional and quite reliable. The converted 5 volt dc is used to give power to the nodemcu and current sensor (ACS712). The nodemcu is connected to the router and the router is connected with the internet. Hence, it can be accessed by the ip address of the router for performing switching operation with the load. One advantage of connecting with the router is that the whole system will be secured as the system cannot be accessed by outsiders. Furthermore, the nodemcu is connected with the relay module and the relay module is used for connecting the loads. When the relays are triggered, the loads connected to them gets switched off from the system. On the other hand, switching off relays connect the loads with the system. The current sensor (ACS712) is also connected with the load to measure the current, total unit of power used and the relative cost for that power consumption.

CHAPTER III

PROCESSING DEVICE

The processing device we used in this project is nodemcu. Nodemcu is an open source platform based on IoT. The firmware it includes is based on ESP-12 module and runs on ESP8266. It utilizes the Lua scripting language. Codes can be used like Arduino, but interactively in Lua script. Event-driven API for network applications, which facilitates developers writing code running on a 5mm*5mm sized MCU in node.js style and greatly speed up the IoT application developing process. There are certain specifications present in nodemcu such as USB-TTL included plug & play, 10 GPIOs (every GPIO can be PWM, I2C, 1-wire), PCB antenna etc. A handful number of processing device is present in the market such as Bluetooth device, IR device, RF transmitter and receiver device and so on but due to several key features nodemcu is used in our project which include low cost, interactivity, simplicity, smartness, Wi-Fi-enable function etc.

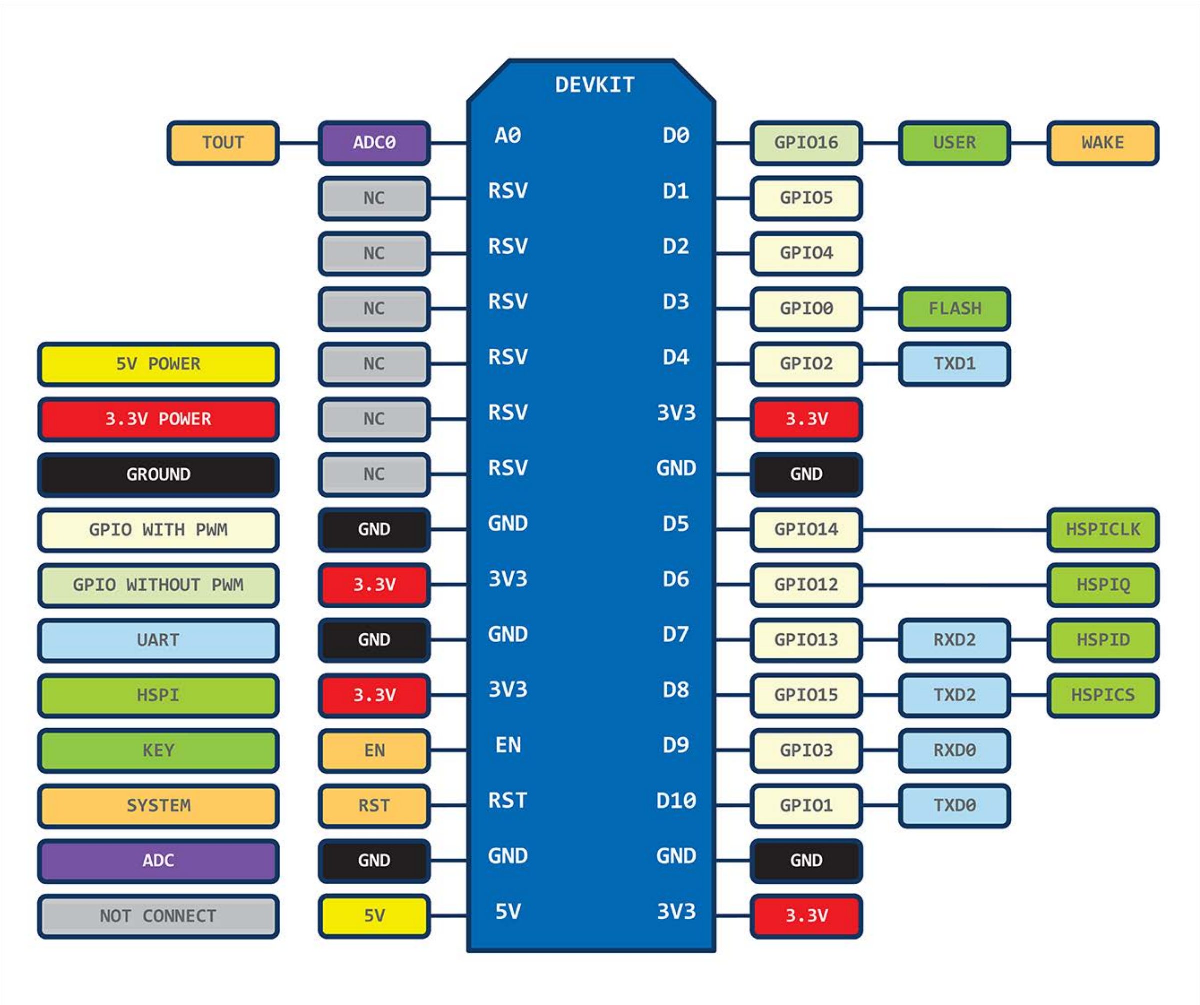


Figure 5: Internal Diagram of Nodemcu

SPACE AND COST

It is important for any project to maintain a certain cost for production and to distribute the size and space in appropriate manner. The components we found and used for the project were bought at the lowest possible price. Certain components were really hard to find which might have cost a little more. Overall, we tried our utmost to keep the price as low as possible ensuring very high efficiency. In terms of size, the metal box to cover the electronics is about 10 inch in length, 3 inch in width and has a height of 2 inch. For the purpose of easy maintenance, one side of the metal box is kept open and protected by transparent plastic which is easily replaceable. Besides, small circular holes are created to maintain the wire management. List of electrical components we used and their cost are mentioned below-

Metal Box	75 tk
Transformer	150 tk
Nodemcu	750 tk
AC-DC Converter Circuit (PCB)	200 tk
Relay Module	450 tk
LCD Display	150 tk
Total	1775 tk

Table 2: Space and Cost

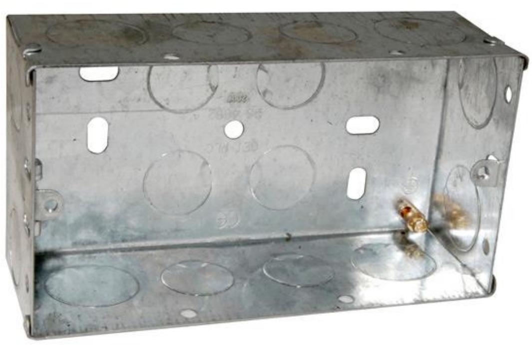


Figure 6: Metal Box

SOFTWARE

The Software for controlling the Smart Switch Board is made primarily for the Android OS which is the largest installed base of all mobile operating system. The user interface (UI) of the app is very simple and mainly based on direct manipulation using phone's touch gesture. Simply a touch on the buttons visible in the screen of the phone is enough to initiate a command. The main purpose of the app is to operate our smart switching board wirelessly using our phone by using the Wi-Fi embedded on the phones hardware.

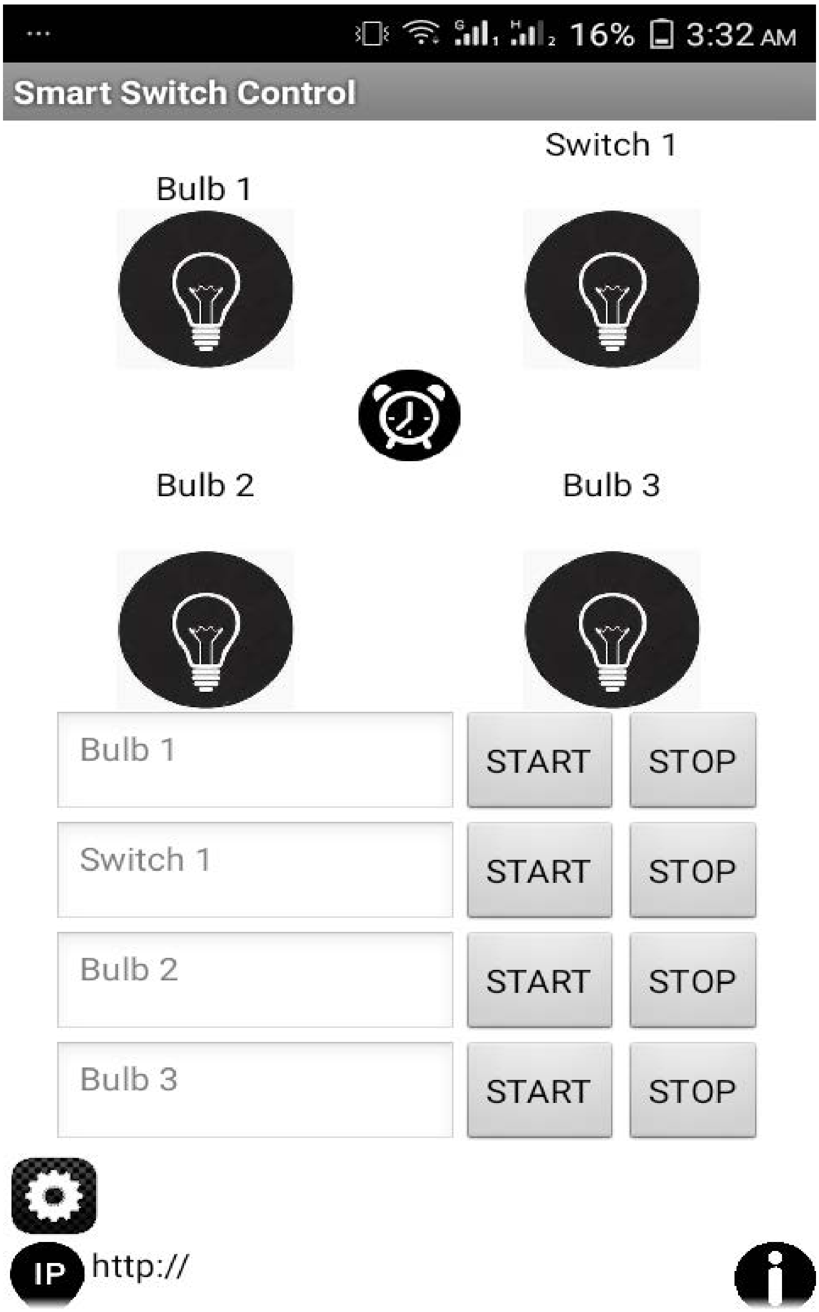
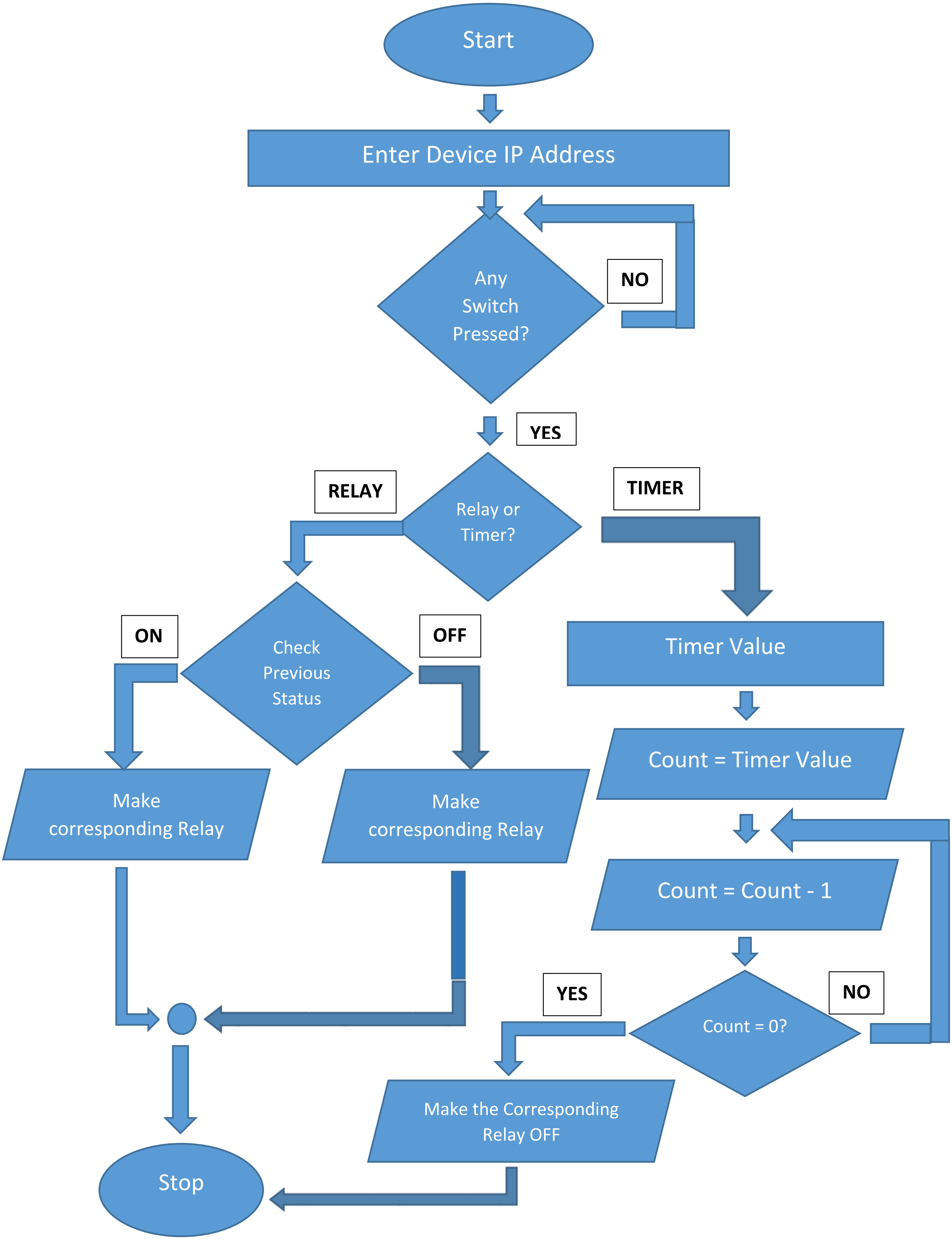
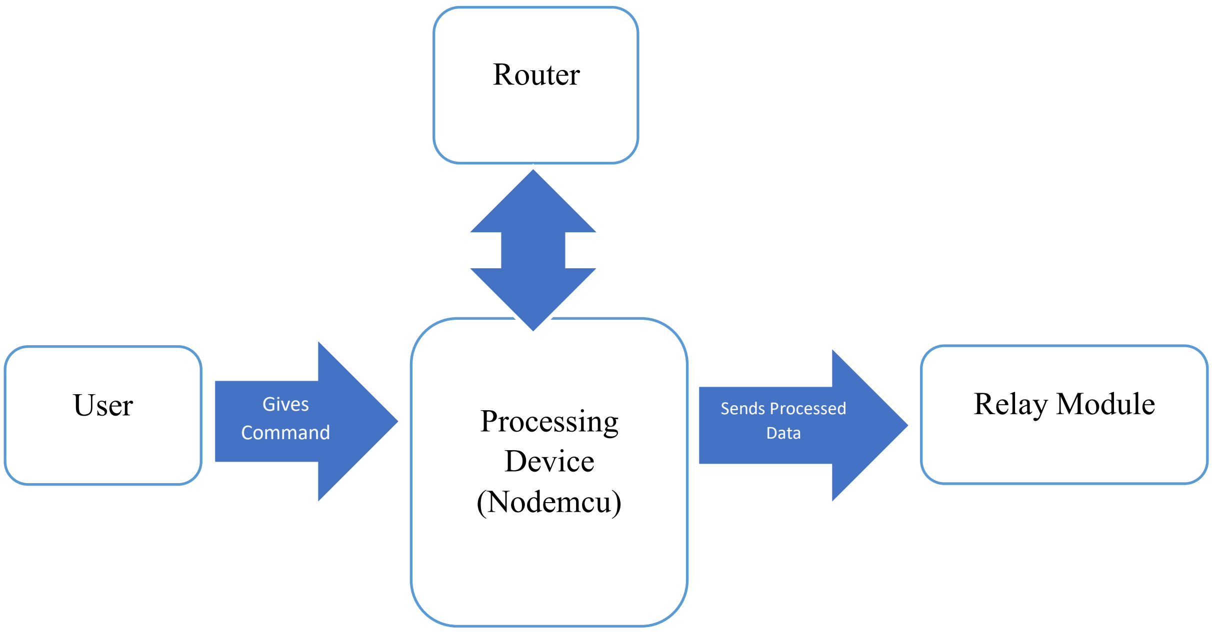


Figure 7: Software


Start
Enter Device IP Address
Any Switch Pressed?
NO
YES
RELAY
Relay or Timer?
TIMER
ON
Check Previous Status
OFF
Timer Value
Make corresponding Relay
Make corresponding Relay
Count = Timer Value
Count = Count - 1
YES
NO
Count = 0?
Make the Corresponding Relay OFF
Stop

COMMUNICATION

The main communication occurs between the processing device and the relay module that is connection with it. There are 10 gpios (General-purpose input/output) which are controllable by the user at run time. As the processing device is connected with the router, it uses the router to communicate with the user which indicates that the ip address of the router is used in the apps. In the app when the user presses the bulb off button, the processing device nodemcu processes it and generate the corresponding signal through gpio to the relay module. As the relay gets the signal it trips after certain amount of time (here 1000ms) and the bulb or load which is connected with the relay is turned off. Similarly, when the bulb on button is pressed in the app, nodemcu or the processing device processes it and generate and send the corresponding signal through the gpio to the relay module. By receiving the signal, the relay gets closed and electricity passes through the load or bulb making it turned on. When the timer is set to a certain value, the app automatically sends signal to the processing device to turn the bulb off through tripping off the relay. When the communication is made through the internet, the router collects the command signal and then sends it to the whole system to complete the action.



INPUT POWER FOR THE INTERNAL COMPONENTS

In order to give power to the internal components of the system, we used ac to dc conversion via transformer which is a conventional process. Though the transformer is bulky and heavy but it is more efficient than the other type of conversion method which is the primary reason for choosing transformer. Besides, transformer is very easy to implement, relatively inexpensive, fully isolated and designed for all kind of loads. The schematic diagram of the conversion circuit is given below:

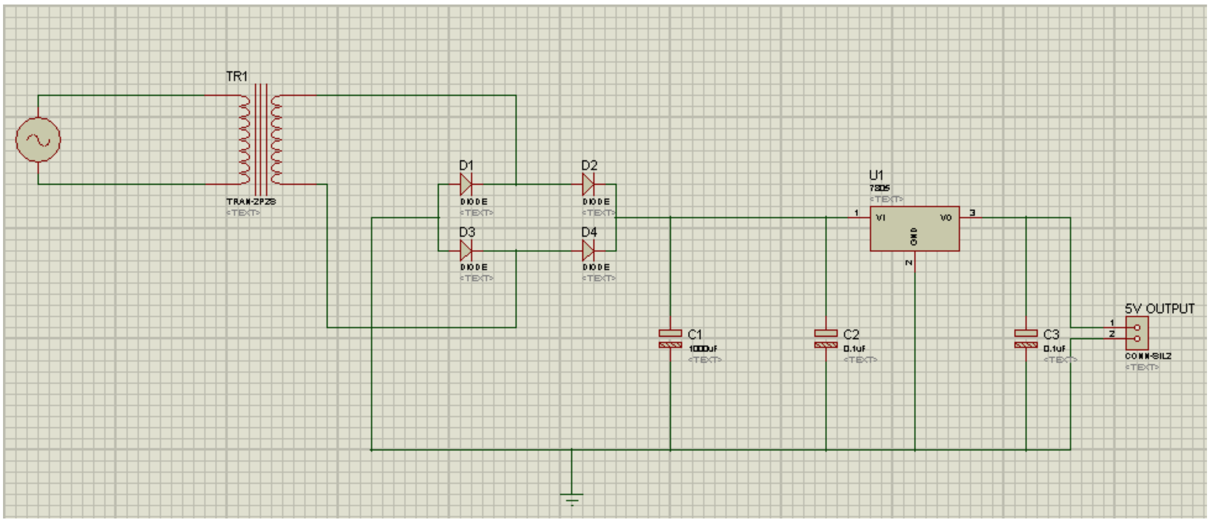


Figure 8: 220 Vac- 5Vdc Converter Circuit (Transformer)

We also implemented relatively cheap ac to dc conversion without transformer with involves X rated capacitor. It is also small in size and easy to implement which makes it excellent for light loads. Due to unavailability of proper valued X rated capacitor, load current inflexibility and lack of isolation we have not included it in our project. If accurate valued capacitor is implemented then this conversion technic will become a very good alternative for ac to dc conversion. For the purpose of future analysis on this kind of conversion technic, our analysis on it is described in the next section.

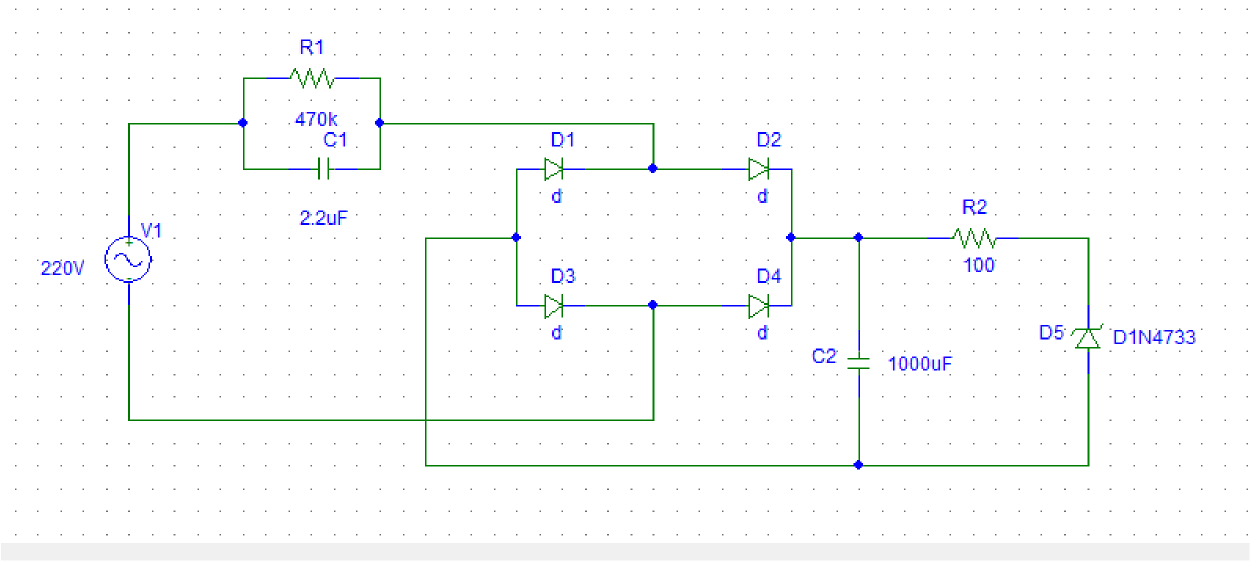


Figure 9: 220 Vac- 5Vdc Converter Circuit (Capacitor)

X Rated capacitor 400 Volt:

The X rated capacitor is designed for 250, 400, 600 VAC. Higher voltage versions are also available. The Effective Impedance (Z), Reactance (X) and the mains frequency (50 – 60 Hz) are the important parameters to be considered while selecting the capacitor. The reactance (X) of the capacitor (C) in the mains frequency (f) can be calculated using the formula:

X = 1/ (2*Pi*f*C)

Reactance of the capacitor 2.2 uF is calculated as **X = 1/2Pi*f*C**, Where **f** is the 50 Hz frequency of mains and **C** is the value of capacitor in Farads. That is 1 microfarad is 1/1,000,000 farads. Hence 2.2 microfarad is 2.2 x 1/1,000,000 farads. Therefore the reactance of the capacitor appears as 1446.86 Ohms or 14.5 K Ohms. To get current, voltage is divided by the reactance in kilo-ohm which is 220 / 14.4 = 15.2 mA.

Effective impedance (Z) of the capacitor is determined by taking the load resistance (R) as an important parameter. Impedance can be calculated using the formula:

$$\mathbf{Z} = \sqrt{(R^2 + X^2)}$$

X Rated AC capacitors – 250V, 400V, 680V AC:

No	uF	No	uF	No	uF
103K	0.01	153K	0.015	223K	0.022
333K	0.033	473K	0.047	683K	0.068
104K	0.1	154K	0.15	224K	0.22
334K	0.33	474K	0.47	684K	0.68
105K	1	155K	1.5	225K	2.2
335K	3.3	475K	4.7	685K	6.8
106K	10				

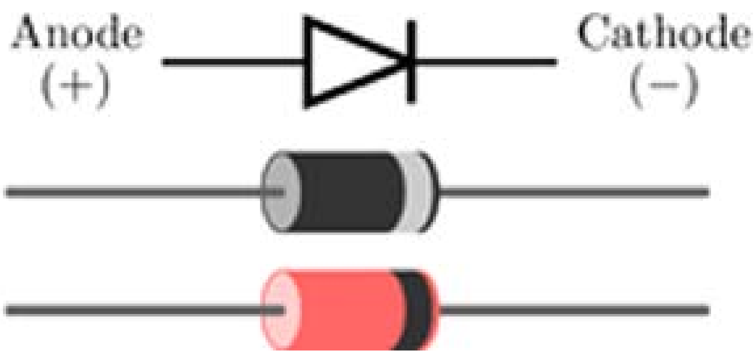
Figure 10: X-Rated AC Capacitors

Rectification:

Diodes used for rectification have sufficient Peak inverse voltage (PIV). The peak inverse voltage is the maximum voltage a diode can withstand when it is reverse biased. 1N4001 diode can withstand up to 50 Volts and 1N4007 has a toleration of 1000 Volts. The important characteristics of general purpose rectifier diodes are given in the table.

Type of Diode	Repetitive Peak Reverse Vrrm	Average Forward Current Vr	Forward Voltage Vf	Reverse Current Ir
IN 4001	50V	1A	1.1V	10uA
IN 4002	100V	1A	1.1V	10uA
IN4003	200V	1A	1.1V	10uA
IN 4004	400V	1A	1.1V	10uA
IN 4005	600V	1A	1.1V	10uA
IN4007	1000V	1A	1.1V	10uA

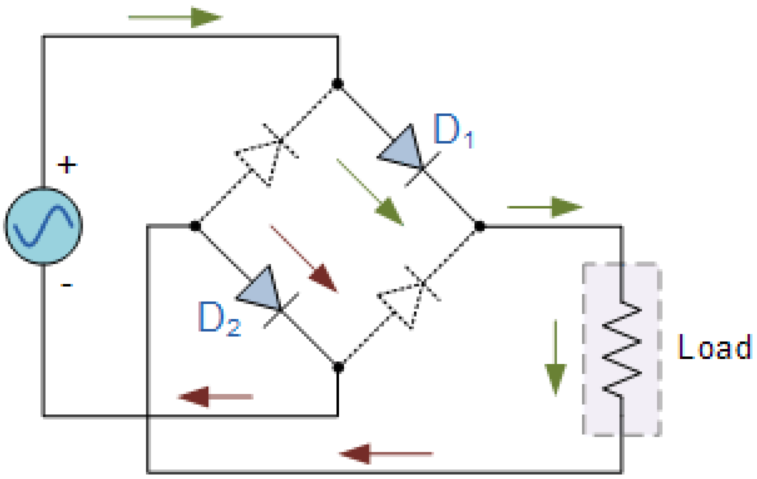
Figure 11: Different Type of Diodes



So a suitable option is a rectifier diode 1N4007. Usually a silicon diode has a Forward voltage drop of 0.7 V. The current rating (Forward current) of rectifier diodes also vary. Most of the general purpose rectifier diodes in the 1N series have 1 ampere current rating.

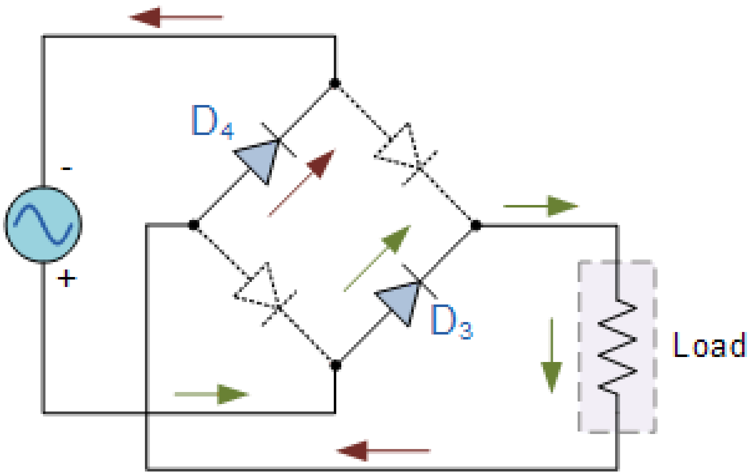
During the Positive half cycle of the supply, diodes D1 and D2 conduct in series, but diodes D3 and D4 is switched "OFF" as they are now reverse-biased. The current flowing through the load is in a certain direction.

The Positive Half-cycle

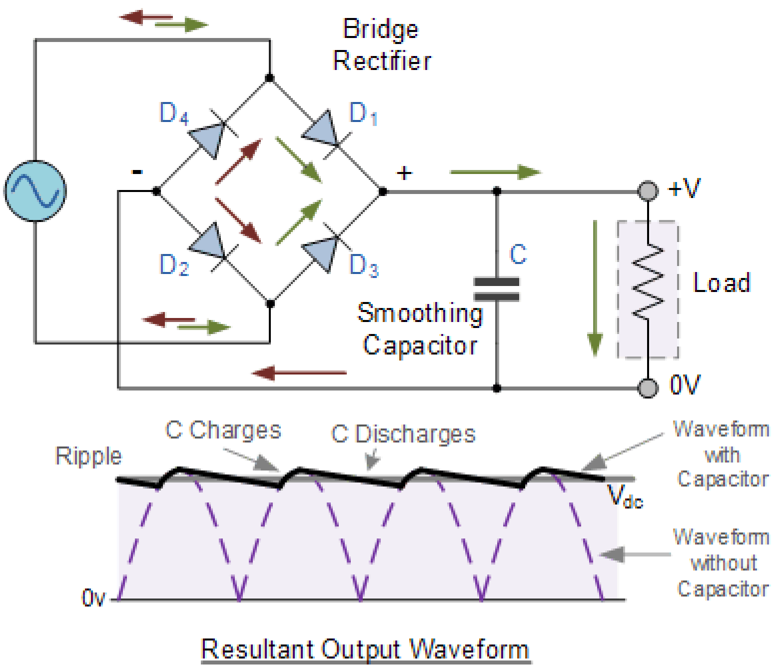


During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch "OFF" as they are now reverse-biased. The current flowing through the load is the same direction as before.

The Negative Half-cycle



Full-wave Rectifier with Smoothing Capacitor



DC Smoothing:

A Smoothing Capacitor is used to generate ripple free DC. Smoothing capacitor is also called Filter capacitor and its function is to convert half wave / full wave output of the rectifier into smooth DC. The power rating and the capacitance are two important aspects to be considered while selecting the smoothing capacitor. The power rating must be greater than the off load output voltage of the power supply.

The capacitance value determines the amount of ripples that appear in the DC output when the load takes current. For example, a full wave rectified DC output obtained from 50Hz AC mains operating a circuit that is drawing 100 mA current will have a ripple of 700 mV peak-to-peak in the filter capacitor rated 1000 uF.

The ripple that appears in the capacitor is directly proportional to the load current and is inversely proportional to the capacitance value. It is better to keep the ripple below 1.5 V peak-to-peaks under full load condition. So a high value capacitor (1000 uF or 2200 uF) rated 25 volts or more must be used to get a ripple free DC output. If ripple is excess it will affect the functioning of the circuit especially RF and IR circuits.

Voltage Regulation:

Zener diode is used to generate a regulated DC output. A Zener diode is designed to operate in the reverse breakdown region. If a silicon diode is reverse biased, a point reached where its reverse current suddenly increases. The voltage at which this occurs is known as 'Avalanche or Zener value' of the diode. Zener diodes are specially made to exploit the avalanche effect for use in 'Reference voltage' regulators.

A Zener diode can be used to generate a fixed voltage by passing a limited current through it using the series resistor (R). The Zener output voltage is not seriously affected by R and the output remains as a stable reference voltage. But the limiting resistor R is important, without which the Zener diode will be destroyed. Even if the supply voltage varies, R will take up any excess voltage. The value of R can be calculated using the formula:

$R = (V_{in} – Vz) / Iz$

Where **V_{in}** is the input voltage, **Vz** output voltage and **Iz** current through the Zener In most circuits, Iz is kept as low as 5mA. If the supply voltage is 18V, the voltage that is to be dropped across R to get 12V output is 6volts. If the maximum Zener current allowed is 100 mA, then R will pass the maximum desired output current plus 5 mA. So the value of R appears as-

R = 18 – 12 / 105 mA = 6 / 105 x 1000 = 57 ohms

Power rating of the Zener is also an important factor to be considered while selecting the Zener diode. According to the formula **P = IV**. P is the power in watts, I current in Amps and V, the voltage. So the maximum power dissipation that can be allowed in a Zener is the Zener voltage multiplied by the current flowing through it. For example, if a 12V Zener passes 12 V DC and 100 mA current, its power dissipation will be 1.2 Watts. So a Zener diode rated 1.3W should be used.

CHAPTER IV

CURRENT MEASUREMENT

Root conception of basic current measuring comes from a man named Michael Faraday. He gave one of the most basic laws of electromagnetism called **Faraday's law of electromagnetic induction**. It shows the relationship between electric-circuit and magnetic field.

Faraday's First Law says that for a certain current flow, a proportional magnetic field is produced around the current carrying conductor and change in the magnetic-field of a coil of wire will cause an emf to be induced, which is called induced emf and when the conductor circuit is closed, the current will also circulate through the circuit which is called induced current.

Applications of Faraday Law includes in the method of measuring current, which is the desirable application for our purpose.

TYPES OF CURRENT SENSING

There are two types of current sensing which are direct and indirect.

Indirect current sensing-

Indirect current sensing is based on Ampere's and Faraday's laws, by placing a coil around a current-carrying conductor, a voltage is induced across the coil which is proportional to the current. This allows for a non-invasive measurement where the circuitry is not electrically connected to the system. As there is no direct connection between the sensing circuit and the system, the system is inherently isolated from each other. Indirect current sensing typically is used for load currents in between 100A-1000A range.

Direct current sensing-

Direct current sensing is based on Ohm's law. By placing a shunt resistor in series with the system load, a voltage is generated across the shunt resistor which is proportional to the system load current. The voltage across the shunt can be measured by many voltage measuring way like operational amplifiers or instrumentation amplifiers etc. This method is an invasive measurement of the current because the shunt resistor and sensing circuitry are electrically connected to the system. The shunt resistor also dissipates power, which may not be desirable. Direct current sensing typically is implemented for load currents which is less than 100A.

HALL EFFECT SENSOR

Hall Effect is the incident, helps us to measure the current. Hall Effect was discovered in 1879 by Edwin Hall.

The Hall Effect occurs due to the nature of the electricity in a conductor. Current consists of many small charge carriers, typically electrons, holes, ions. When a magnetic field is present, these charges experience a force, which is called the Lorentz force. When such force is absent, the charges follow almost straight. When a magnetic field with a perpendicular component is applied, paths between collisions are curved so that moving charges accumulate on one direction. This results equal and opposite charges exposed on the other face. The result is an asymmetric distribution of charge density across the Hall element, arising from a force that is perpendicular to both the line of sight path and the applied magnetic field. The separation of charge establishes an electric field that opposes the migration of further charge, so a steady electrical potential is established for as long as the charge is flowing. Magnetic sensors have a wide range of positive and negative magnetic fields in a variety of different applications and one type of magnetic sensor whose output signal is a function of magnetic field density, it is called the Hall Effect Sensor.

Hall Effect Sensors are devices which are driven by an external magnetic field. A magnetic field has two prime characteristics, which are flux density and polarity. The output signal from a Hall Effect sensor is the function of magnetic field density around the device. When the magnetic flux density around the sensor exceeds a certain pre-set threshold, the sensor detects it and generates an output voltage called the Hall Voltage, which is denoted by V_H. Concept of the theory is reflecting in the diagram below.

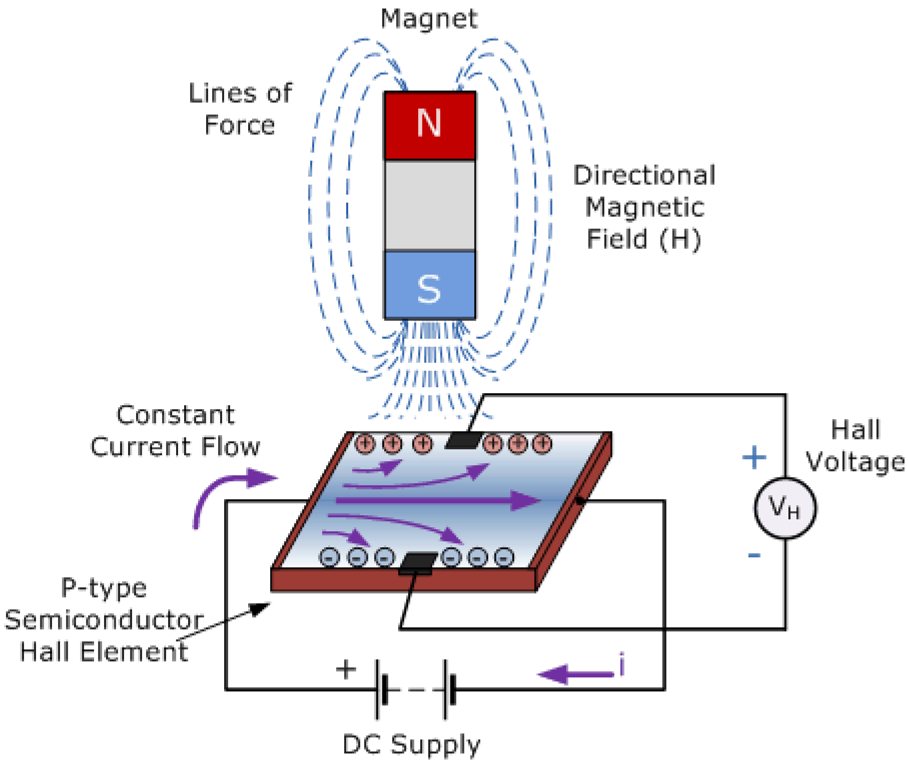


Figure 12: Hall Effect in the Semiconductor

Hall Effect Sensors consist of a thin sheet of rectangular p-type semiconductor material such as gallium arsenide (GaAs) or indium arsenide (InAs) passing a continuous charge through itself. When the device is placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes. This movement of charge carriers is a result of the magnetic force which experience passing through the semiconductor material. As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material. The effect of generating a measurable voltage by using a magnetic field is called the Hall Effect.

Hall Effect Sensors are available with either linear or digital outputs. The output signal for linear (analogue) sensors is taken from the output of the operational amplifier with the output voltage being directly proportional to the magnetic field passing through the Hall sensor. This output Hall voltage is given as:

$$V_H = R_H \left(\frac{I}{t} \times B \right)$$

Where:

- V_H is the Hall Voltage in volts
- R_H is the Hall Effect co-efficient
- I is the current flow through the sensor in amps
- t is the thickness of the sensor in mm

B is the Magnetic Flux density in Tesla

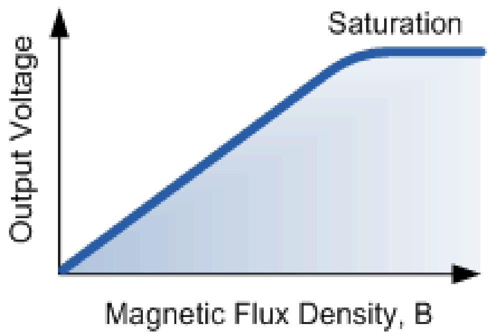


Figure 13: Magnetic Flux Density vs Saturation

This graph shows the relation status between output voltage or Hal Voltage and magnetic flux density.

METHODS OF CURRENT SENSING

The most common ways to sense current are resistive shunt, Hall Effect, and induction.

In our system we have used the Hall Effect Sensor.

The Basics of Current Sensors

Current sensors have two types, they are either

1. Open-loop
2. Closed-loop

Open-loop current sensors-

Open-loop current sensors measure both AC and DC currents and provide excellent electrical isolation between the output of the sensor and the circuit being measured. Less expensive than closed-loop. Open-loop current sensors are generally preferred in battery-powered circuits.

Closed-loop current sensors-

Closed-loop sensors measure AC and DC currents and also provide electrical isolation. They offer fast response, high linearity with low temperature drift, which is efficient. The current output of the sensor is relatively immune to electrical noise. The Closed- Loop sensor is called 'Zero-Flux' sensor because its Hall-Effect sensor feeds back an opposing current into a secondary coil, which wound on the magnetic core to zero the flux produced in the magnetic core by the primary current. Closed-loop sensors are the sensor of choice for high accuracy.

Open loop current sensors consist of a Hall sensor mounted in the air gap of a magnetic core (Fig. 14). A conductor produces a magnetic field comparable to the current. The magnetic field is concentrated by the core and measured by the Hall sensor. The signal from the Hall generator is quite low, so it is amplified, and it is this amplified signal that becomes the sensor's output. Open-loop sensors normally have circuitry that provides temperature compensation and calibrated high-level voltage output. While they have a definite price advantage over closed-loop counterparts, their downside is that they can be prone to saturation and temperature drift.

The drift can be minimized to some extent, however, by injecting a positive coefficient in the control current to reduce the drift in sensitivity over temperature.

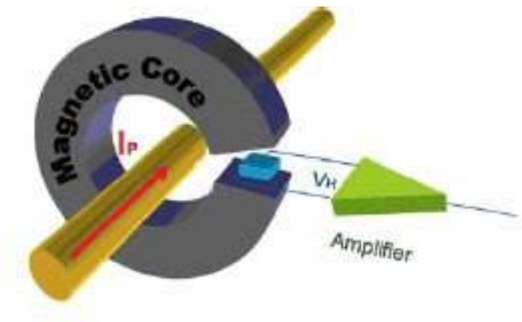


Figure 14: Illustration of the Basic Principle and Structure of the Hall-Effect Open Loop Current Sensor

Both types of sensors can be economical depending on the application requirements, open-loop sensors provide the best cost advantage in the high current ranges (over 100 A). They are also the small in size and weight. They maintain constant power consumption, no matter the sensed current, which is very helpful for any calculation. The price advantage of open sensors is visible where temperature variation can be restricted and appropriate system is present.

Closed-loop current sensors, on the other hand, are more suitable for commercial and industrial applications. These sensors have the highest accuracy at ambient and high temperature. They are ideal for noisy environments and their output is easily converted to voltage.

COMPONENT DESCRIPTION

The core component that measures the current is ACS 712 current sensor which is basically Hall Effect based. It has various current measuring limits. For example up to 10A/20A or 30A current measuring limit. For this project 30A (ACS712T ELC-30A) has served our purpose.

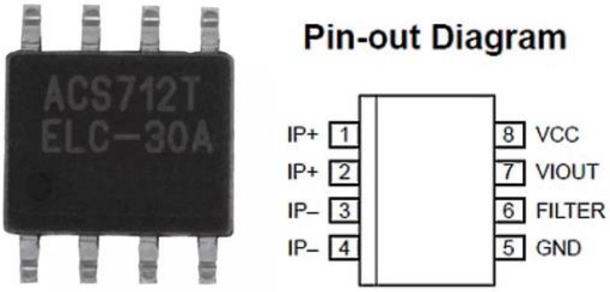


Figure 15: Pinout Diagram of Current Sensor

Here for simplification a module has been used, which has integrated circuitry to provide the expected output we need. In the module there is a 5V power pin, a ground pin and an output pin.

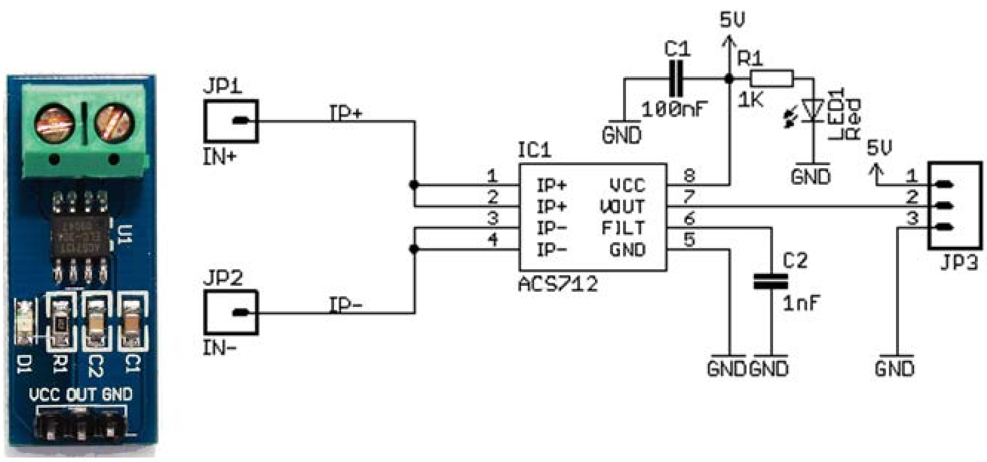
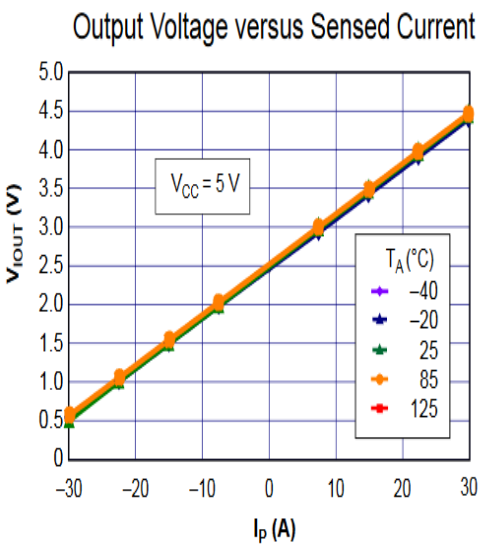
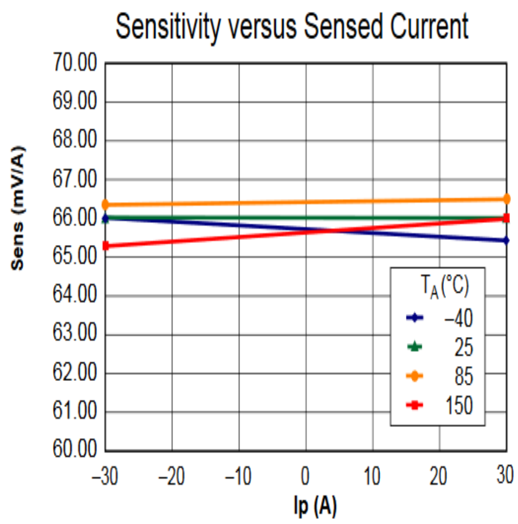


Figure 16: Internal Circuit Diagram of Current Sensor

Except the module, an output device is needed to show the current and related items. This data can be analysed by a microcontroller for further calculation for example from this data power, voltage, unit, cost etc. can be measured. The processed data can be stored in a database from where other device can access the information for further calculation and it can be also showed on a display.

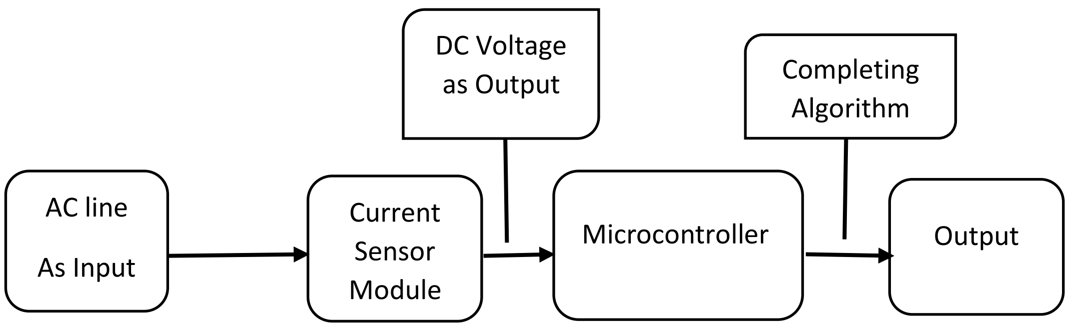




These graphs show the characteristics of ACS 712 sensor.

CIRCUIT ANALYSIS

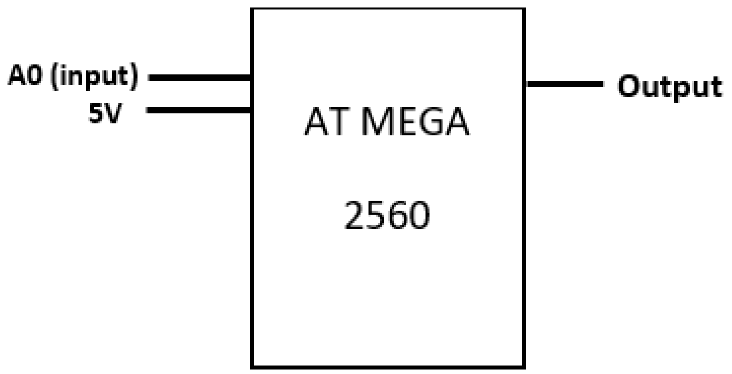
The basic circuit's block diagram as follows

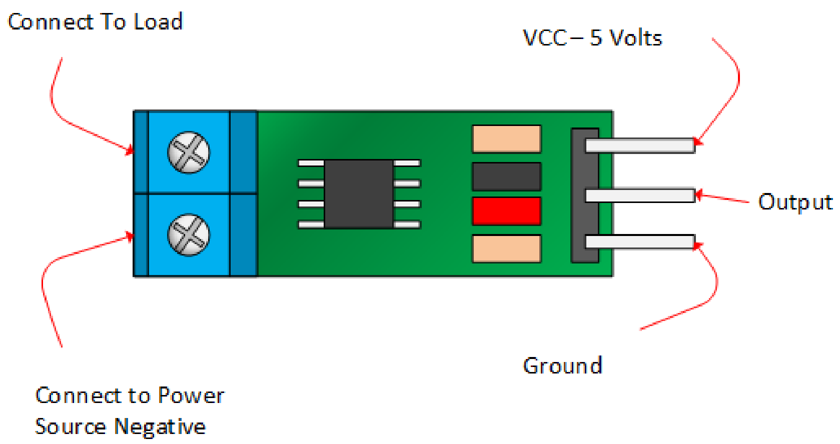


The complete circuit includes a current sensor, micro controller and an output device. AC line passes through the sensor. The sensor gives an output to the microcontroller. The microcontroller follow the algorithm and gives the output. Output can be shown in a display and stores in database for further analysis.

INPUT/OUTPUT

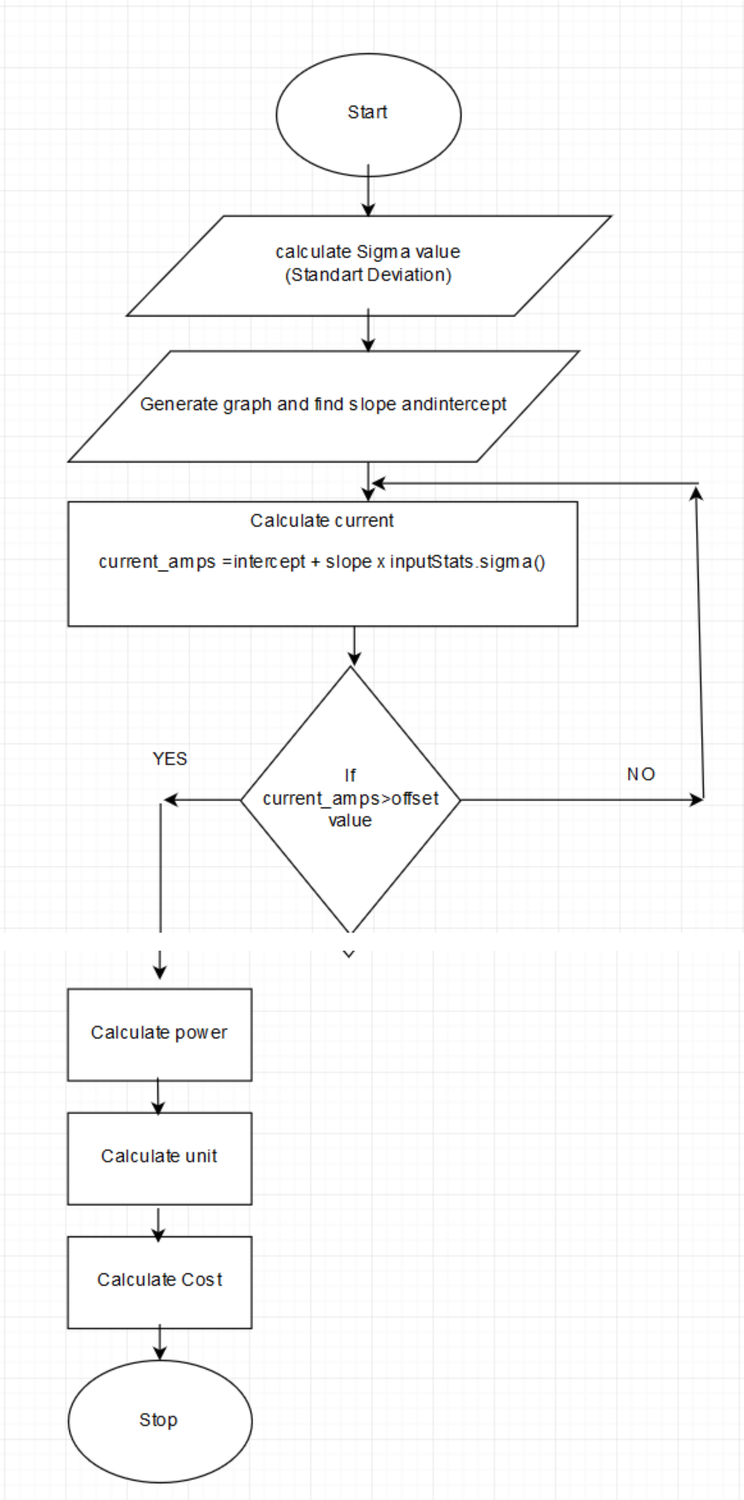
Current sensor ACS712 needs a 5V power supply, another pin goes for the ground and third no pin is for the output. Output goes to microcontroller AT MEGA 2560 pin (A0), which is the input pin for the microcontroller. The AC live line is the input for the current sensor. The microcontroller also needs a 5V power supply to operate.





OPERATING ALGORITHM

This algorithm shows how the microprocessor analysis the data output of the current sensor



DATA ANALYSIS

Data analysis part has two steps to follow. As it is needed to be calibrated, first time intercept and slope value are set on assumption.

float intercept = -0.1310; // to be adjusted based on calibration testing

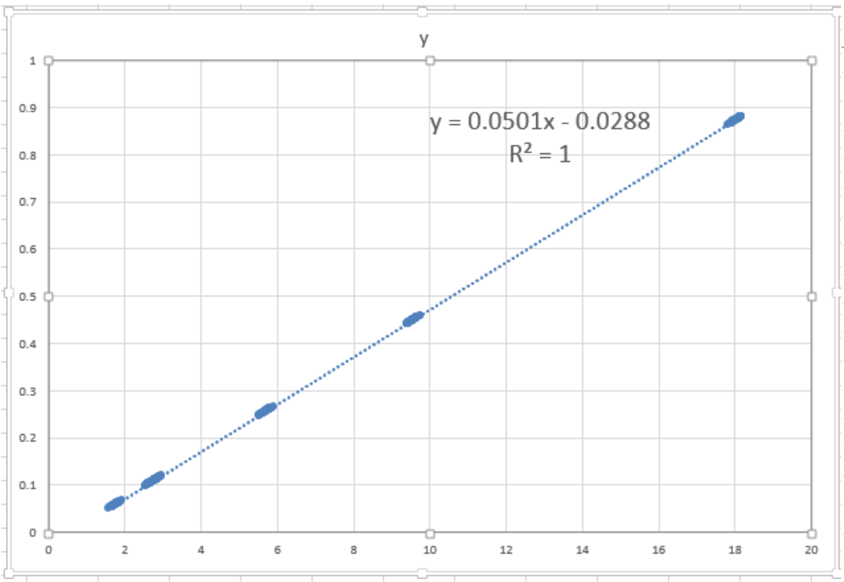
float slope = 0.04099; // to be adjusted based on calibration testing

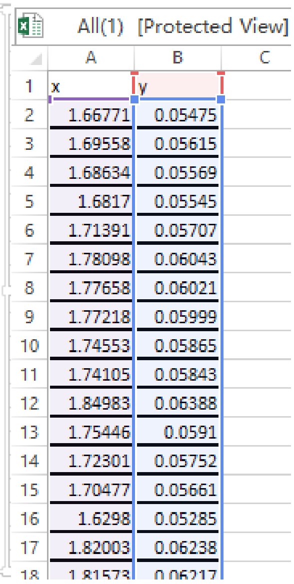
Then after taking all values for multiple loads a graph has been generated, which gives the slope and intercept values. The equation is

$$y = 0.0501x - 0.0288$$

Slope =0.0501

Intercept =-0.0288




All(1) [Protected View]

	A	B	C
1	x	y	
2	1.66771	0.05475	
3	1.69558	0.05615	
4	1.68634	0.05569	
5	1.6817	0.05545	
6	1.71391	0.05707	
7	1.78098	0.06043	
8	1.77658	0.06021	
9	1.77218	0.05999	
10	1.74553	0.05865	
11	1.74105	0.05843	
12	1.84983	0.06388	
13	1.75446	0.0591	
14	1.72301	0.05752	
15	1.70477	0.05661	
16	1.6298	0.05285	
17	1.82003	0.06238	
18	1.81573	0.06217	

Figure 17: Data Analysis for Current Sensor

So using the new value the programme code need to be adjusted.

float intercept = -0.0288;   float slope = 0.0501;

TEST AND RESULT

After setting the slope and intercept values, current can be calculated easily by following equation.

current_amps = intercept + slope x inputStats.sigma();

A kill A Watt has been used to compare the sensor values with the real current values. Kill A Watt meter is a power meter that able to provide power, voltage, current, unit and cost information.

Load	Kill A Watt Meter Reading(AMPS)	Sensor Values(AMPS)
OFF	0A	0.03-0.05A
24W bulb(CFL)	0.168A	0.11-0.162A
60W bulb(Incandescent)	0.275A	0.261-0.28A
100W bulb (Incandescent)	0.465A	0.44-0.468A
200W bulb (Incandescent)	0.88A	0.82-0.89A

Table 3: Actual Current and Sensor Value Comparison

So comparison shows that it has 2% accuracy with the Kill-A-Meter. Observation says that higher the load higher the accuracy.

DIFFICULTIES

The current sensor gives a voltage value which proportional to AC current rather than the AC current is reading directly. To get the current value which requires ‘Filters’ function in the microcontroller which is too complicated.

LIMITATIONS

The challenge with using the ACS712 sensor is that there is always an offset voltage even though the load is not connected. So, the microcontroller shows a current which is 0.03-0.05A regardless of the AC current being drawn. In this situation when the load is below 12W, actual load existence can’t be specified. So there will be always a fixed cost though it’s very low.

ADVANTAGES OVER AVAILABLE OPTIONS

Non-invasive AC Current Sensor cost around 1100-2000 TK whereas ACS 712 cost only 150TK. Besides it is more available and for the non-invasive AC Current Sensor right placement is important. So misplace may change the original value.

CHAPTER V

DATABASE CONNECTION

Smart Switch Board is equipped with wireless connectivity feature which is embedded on its core processing unit which is the NODEMCU. NODEMCU is made based on the ESP8266 chip which is one of the most popular chip for Wi-Fi connectivity and IoT implementation. ESP8266 is a low cost wireless connectivity enabled chip with TCP/IP stack and Micro Controller Unit capability at very affordable price tag. The core processing unit of Smart Switch Board is capable of creating local database for temporarily storing value and data processing.

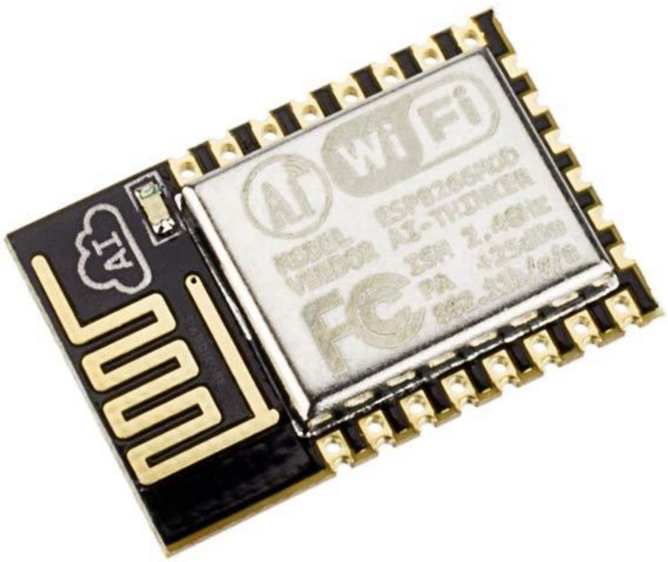


Figure 18: ESP-8266 Wi-Fi Module

Due to memory limitation, it is not wise to use its internal memory to analyse data. On the contrary, it has the capability to connect to any online database using internet with TCP/IP protocol. So, the features stated above gives an enormous possibilities to the Smart Switch Board in the field of IoT.

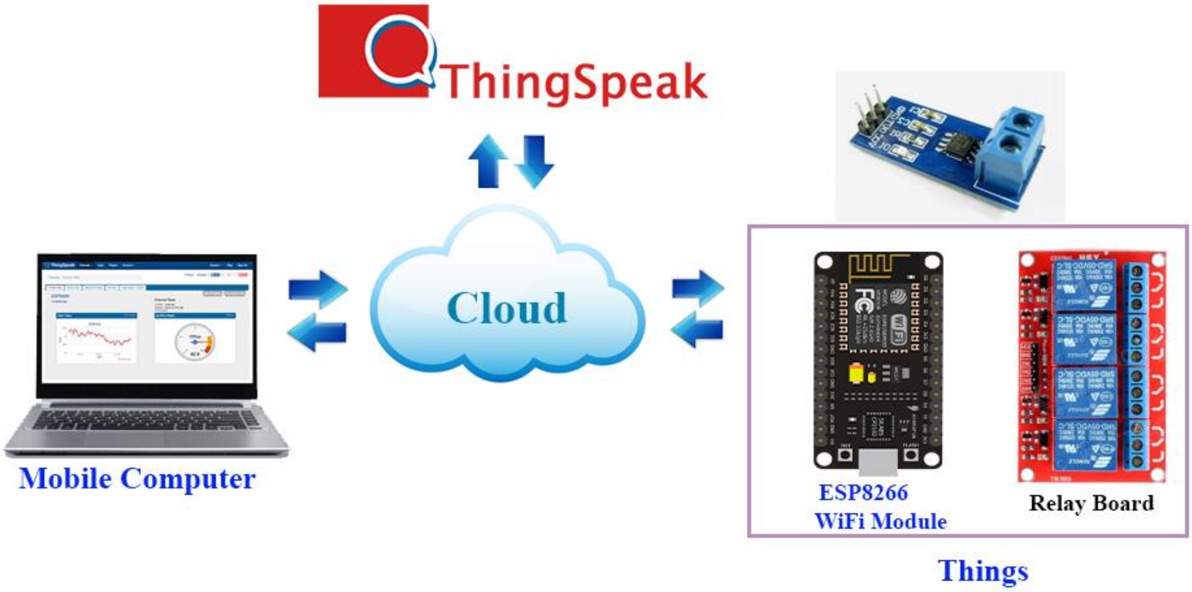


Figure 19: Database Connection

For testing purpose, ThingSpeak is an IoT platform where data can be uploaded for data analysis and IoT application. To connect the Smart Switch Board to the ThingSpeak IoT server TCP/IP protocol needed to be used to send HTTP data packet. At the beginning, Smart Switch Board needed to be connected to an access point in the home network. Then, the ESP8266 chip needed to be enabled for establishing multiple connection. To enable it, CIPMUX need to be used.

AT + CIPMUX = 1

After that, a TCP connection need to be established to the ThingSpeak server using its IP address which is 184.106.153.149, using the HTTP port number which is 80.

AT+CIPSTART=4,"TCP","184.106.153.149", 80

It will establish a connection with the server with a confirmation message. To send data to the linked server CIPSEND command need to be used.

CHAPTER VI

DISCUSSION

The whole project is aimed to introduce to a relatively new system equipped with latest technologies to overcome the limitations of traditional switch board. But in the way of coming up with this project, we faced several problems. Firstly, all the components we have used are not readily available in the local market as a result cost is increased. This cost can be reduced further if the components are manufactured and fabricated all together for industrially. Secondly, in the current sensor there is an offset voltage due to which a very small amount of current is always present even though in no load condition. Thirdly, we used test server for data storage which has limited capacity as well as limited security options. This problem can be solved by creating dedicated server and storing data in it. Initially, we have developed this board considering a single room. It can be further developed for broader areas such as a whole apartment or for several apartments. If the shortcomings are solved then smart switch board can be used industrially as well. At present, the whole device contains limited number of features but it can be further developed including features such as temperature detection, automatic light on/off using motion sensor and so on. In short, smart switch board can be elevated further to turn it to such a device that can exhibit a lot of additional functions alongside the cost calculation and Wi-Fi control interface. Apart from all the features and future scope of smart switch meter, it has great significance as well. Due to this, people will be more conscious about their usage of electricity and will be able to predict and plan their power consumption in daily/weekly and monthly basis. Also motive of the people will get changed as they will try to buy less energy consumed and eco-friendly products as home appliances. Usage of energy efficient devices will reduce the overall usage of electricity and hence power loss will be minimized. Lastly, it can be said that smart switch board is not just a device with some fancy features but also a device that can perform according to the need of its user.

REFERENCE

N. K. Walia, P. Kalra and D. Mehrotra, "An IOT by information retrieval approach: Smart lights controlled using WiFi," *2016 6th International Conference - Cloud System and Big Data Engineering (Confluence)*, Noida, 2016, pp. 708-712.
doi: 10.1109/CONFLUENCE.2016.7508211

P. Paethong, M. Sato and M. Namiki, "Low-power distributed NoSQL database for IoT middleware," *2016 Fifth ICT International Student Project Conference (ICT-ISPC)*, Nakhon Pathom, 2016, pp. 158-161.
doi: 10.1109/ICT-ISPC.2016.7519260

A. Škraba, A. Koložvari, D. Kofjač, R. Stojanović, V. Stanovov and E. Semenkin, "Streaming pulse data to the cloud with Bluetooth LE or NODEMCU ESP8266," *2016 5th Mediterranean Conference on Embedded Computing (MECO)*, Bar, 2016, pp. 428-431.
doi: 10.1109/MECO.2016.7525798

C. Liu, H. Yi, J. G. Liu and Q. Zhang, "A Novel Method for Measuring Current Derivative Signal with Closed Loop Hall-Effect Current Sensor," *Proceedings of PCIM Europe 2015; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management*, Nuremberg, Germany, 2015, pp. 1-8.

A. Kumar and V. John, "Power electronic converter for characterization of hall-effect current sensors," *2014 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)*, Mumbai, 2014, pp. 1-6.
doi: 10.1109/PEDES.2014.7042086

C. Liu and H. J. G. Liu, "Offset error reduction in Open Loop Hall Effect current sensors powered with single voltage source," *2014 IEEE International Workshop on Applied Measurements for Power Systems Proceedings (AMPS)*, Aachen, 2014, pp. 1-6.
doi: 10.1109/AMPS.2014.6947705