UEE693

CAPSTONE PROJECT

IoT enabled smart switchboard to enable remote control of existing home appliances

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THAPAR INSTITUTE
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(Deemed to be University)

Electrical and Instrumentation Engineering Department

Contents

Declaration

We hereby declare that the project entitled **"IoT enabled smart switchboard to enable remote control of existing home appliances"** is an authentic record of our own work carried out in the *Electrical & Instrumentation Engineering Department, Thapar Institute of Engineering & Technology, Patiala* under the guidance of *Dr. Mukesh Singh* during 6th and 7th semester (2018).

Date: December 18, 2018

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Acknowledgement

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Abstract

A Smart Switch Board is a compact and efficient replacement of conventional switch-board, which provides the automated control to the user. It ensures the user convenience and energy saving via modern control strategy and power electronic devices. In addition, the unnecessary wastages of electricity can be prevented by controlling the appliances even from outside the house.

The switches are made in modular fashion which provides the provision for scalability of the product as the user can increase the number of devices connected over time. So it can be put forward for the commercialization purpose.

The existing products available in the market requires replacement of the existing devices with the new smart devices which is quite costly and also the existing devices carry no use after that. The smart switch just upgrades the conventional switch boards and the existing devices then can be controlled over the internet.

In this project we provide a 5V supply to the input of the microcontroller which provides gating signals to the driver circuit. A zero cross detection circuit is formed for calculating the time at which the rectified voltage reaches zero. Feeding these values in the microcontroller, it fires interrupts to flag the initiation of counter which provides delayed pulse according to the input provided by the user. Simulation and PCB design of the Circuit were made in Orcad Cadence Software.

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List of Abbreviations

AC Alternating Current

CRO Cathode Ray Oscilloscope

DC Direct Current

DSO Digital Storage Oscilloscope

GPIO General Purpose Input Output

HAU Home Automation Unit

IEEE Institute of Electrical and Electronics Engineers

IoT Internet of Things

IP Internet Protocol

LED Light Emitting Diode

MQTT Message Queuing Telemetry Transport

PCB Printed circuit board

PLC Power Line Communication

PWM Pulse Width Modulation

RMS Root mean square

SOC System on Chip

TCP Transmission control Protocol

XML eXtensible Markup Language

Chapter 1

Introduction

1.1 Introduction

In the present day scenario, Energy efficiency is the major requirement of any power device (mechanical or electrical). By the introduction of Power Electronics systems electrical systems are aiming towards higher energy efficiency. The losses in these systems are quite low and they enable the user to control the devices to a much larger extent than was possible by using the conventional approach.

This project focuses on providing automated control of the existing home appliances by adding a control circuitry to the existing devices. The devices are controlled using wireless communication over the internet by microcontrollers. An app-driven remote control is provided for user interaction. The efficiency of usage can be improved device-by-device. This will enable the user to switch off the devices when idle even remotely and also the power consumptions of devices will be lowered when appliances are not running at their full intensities. Cumulatively, an energy efficient household can be achieved by using such smart switches for controlling appliances used in the house.

A smart switchboard is an upgrade to the conventional switches, they use novel Internet of Things (IoT) enabling them to be accessible remotely over the internet. The switches are designed in a modular fashion providing scope for scalability of the project. Based upon the monetary capability of the user and upon introduction of new devices in the household at later stages, the sockets can be easily added or removed at any time in the smart switch. This will enhance the viability and long term relevance of the project.

1.2 Literature Survey

1.2.1 National Status Review

- Archana N. Shewale, **"Renewable Energy Based Home Automation System Using ZigBee"**, International Journal of Computer Technology and Electronics Engineering (IJCTEE), 2015

  Archana N. Shewale describes the methodology of renewable energy based home automation in which two things are consider one is energy consumption and another is energy generation. In this, ZigBee is used for monitoring energy consumption of home equipment and power line communication (PLC) is used to monitoring energy generation.

- S. Anusha, **"Home Automation using ATmega328 Microcontroller and Android application"**, International Research Journal of Engineering and Technology(IRJET), 2015

  S. Anusha describes the design and development of a remote household appliance control system using ATmega328 microcontroller and android mobile through GSM technology.

- J. Chandramohan, **"Intelligent Smart Home Automation and Security System Using Arduino and Wi-Fi"**, International Journal of Engineering and Computer Science, 2017

  J. Chandramohan provides a low cost-effective and flexible home control and monitoring system with the aid of an integrated micro-web server with internet protocol (IP) connectivity for access and to control of equipment and devices remotely using Android-based smartphone application. generation.

1.2.2 International Status Review

- Debraj Basu, **"Wireless Sensor Network Based DSAda Smart Home: Sensor Selection, Deployment and Monitoring"**, IEEE, 2013

  Debraj Basu details the installation and configuration of unobtrusive sensors in an elderly person?s house - a smart home in the making - in a small city in New Zealand. The overall system is envisaged to use machine learning to analyze the data generated by the sensor nodes.

- Byeongkwan Kang, **IoT-based monitoring system using tri-level context making model for smart home services"**, IEEE International Conference, 2015

  Kang discusses about acquisition and analysis of sensor data which are going to be used across smart homes. It proposed an architecture for extracting contextual information by analysing the data acquired from various sensors and provide context aware services.

- Jeya Jeya Padmini, **"Effective Power Utilization and Conservation in Smart Home Using IoT"**, IEEE International Conference, 2015

  Jeya Jeya Padmini discusses about effective power utilization and conservation in smart homes using IoT. It uses cameras for recognizing human activities through image processing techniques.

- Pranay P. Gaikwad, **"A Survey based on Smart Home System Using Internet of Things"**, IEEE International Conference, 2015

  Pranay P.Gaikwad discusses about challenges and problems arise in smart home systems using IoT and propose possible solutions.

1.3 Need Analysis

The currently available solution and research exhibit these features

- The existing market solutions provide on/off switching of the devices. The available solutions provide comparatively lower energy efficiency and also require human intervention to achieve desired conditioning of the environment.
- Some of them also use unsuitable technologies like Bluetooth, Ethernet etc. From the present analysis of the existing solutions for automating a room environment, the technologies used suffer from a number of drawbacks. So, these protocols are limited in functionalities when used by an end user in real life.

1.4 Aim

The project aims to manage and control existing devices through a smart switchboard accessible over the internet.

1.5 Objectives

- To develop driver circuits for controlling the devices inside a room
- To develop software programs for the microcontroller to operate the driver circuits.
- To design mobile applications for users to control the devices over the internet.

1.6 Problem Formulation

In the present day scenario, user comfort and convenience is the main target for the product developers. The present conventional devices installed and their manual control does not provide benefit for monitoring and controlling them, when a person is away from home. This leads to large power losses due to unnecessary operation of the devices. This can even cause major damages to life and property if not handled properly. Also, existing commercial solutions in the market provide entire new smart devices which requires users to replace the existing devices incurring huge costs.

1.7 Deliverables

- A compact and efficient Smart Switch Board is developed.
- A user-friendly mobile application is developed for operating different appliances installed inside the room.

1.8 Novelty of work

Devices can be controlled over the internet through mobile or desktop applications. Due to the use of Power Electronics devices for the voltage control, there are negligible losses incurred. The switches are formed in a modular fashion providing user to add new devices over time. Higher levels of controllability could be achieved through individual device level control.

Chapter 2

Theory, Standards and Constraints

2.1 Theory

2.1.1 Phase Angle Control

Phase angle control is a simple AC-AC conversion technique used to convert an input AC RMS Voltage to a reduced RMS value. It uses a low frequency switch to chop the AC sine wave. The reduced output voltage is controlled using a quantity known as the Firing Angle. The firing angle controls the output of the sine wave using delayed firing of the switching elements (triac, SCR etc.) ensuring the magnitude of AC rms signal is reduced. The output voltage is calculated by the determining the area under the curve, the subsequent increase in the firing angle leads to decrease in value of rms and hence the brightness of light or speed of fan can be controlled.

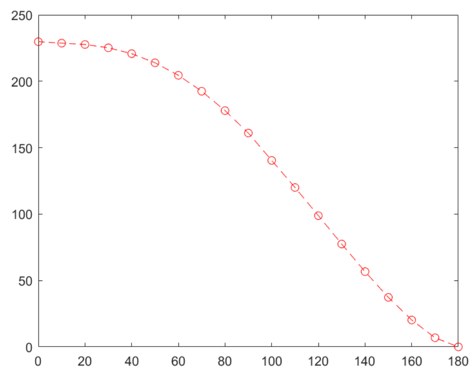


Figure 2.1: Variation in RMS Voltage Output with the Firing Angle

There are a variety of **advantages** of this approach:

- It uses simple voltage control to operate the devices at varied brightness and speeds.
- This allows the use of a low frequency switch, in our case a Triac. These low frequency switches have much higher ratings and can be applied directly to the power circuit.
- This allows for a very fine control over the voltage values and thus numerous steps for variation in device parameters can be provided.

Disadvantages of the approach can be:

- Harmonic inclusion in the AC waveform leading to shortening of life of devices.

- Reliability of the controlling switches is reduced as the switching does not occur at zero voltages and currents.

The following graphs show the variation in Output Voltage waveform with subsequent increase in firing angle. The following data is represented from the above graphs:

1. Input Voltage Waveform
2. Zero Cross Detection
3. Firing Pulse
4. Output Voltage Waveform

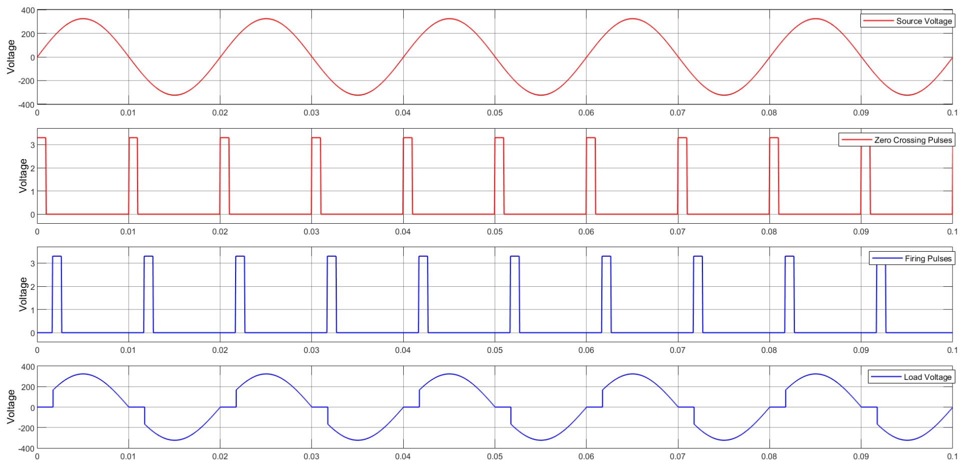


Figure 2.2: Variation in voltage waveforms for $\alpha = 30°$

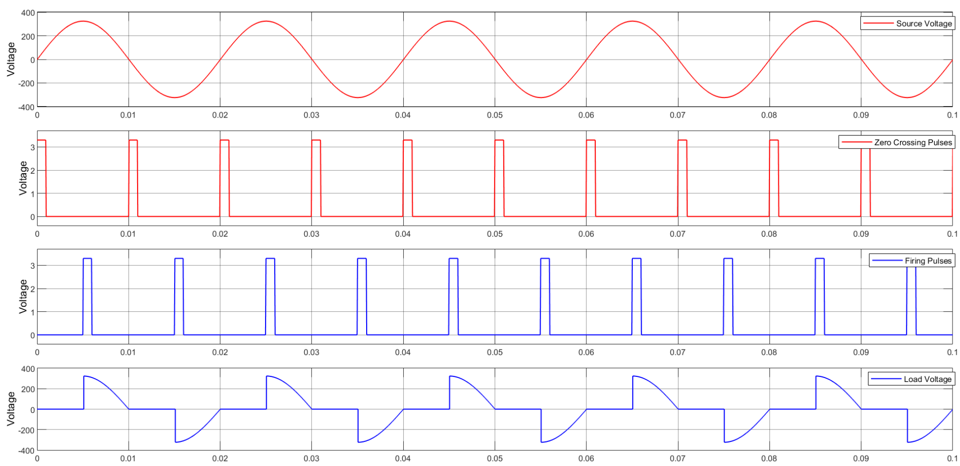


Figure 2.3: Variation in voltage waveforms for $\alpha = 90°$

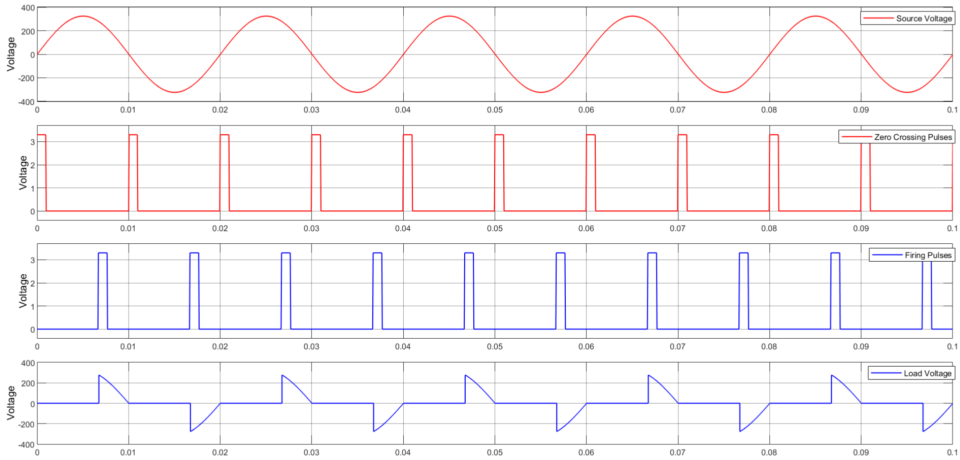


Figure 2.4: Variation in voltage waveforms for $\alpha = 120°$

2.1.2 5V Power Supply

A 5V Power supply is designed to provide uninterrupted mains supply to the microcontroller.
The 230V AC Mains is converted to a 13V AC signal using a Step Down Transformer. The transformer also provides isolation to the circuit. This stepped down voltage is passed through a bridge rectifier to convert it into a pulsating DC output. This DC supply cannot be reliably without converting removing ripples from the output and thereafter regulating the output. Hence, this output is connected to a LM7805 5V Voltage Regulator in parallel with 2200 µf and a 470 µf capacitors. This stabilises the output and reduces the input ripples to almost zero.

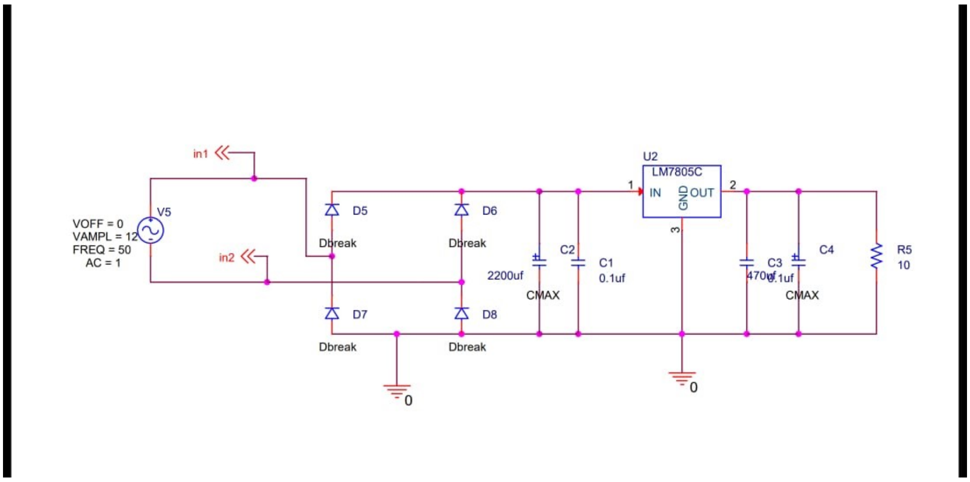


Figure 2.5: 5V DC Power Supply

2.1.3 Zero Crossing Detection Circuit

A zero cross detection circuit is a type of voltage comparator which locates point of zero voltage. In this circuit, a transistor based opto-isolator IC (4N25) is used with rectifier voltage pulse of 100 Hz provided at the input pins. The location of zero point is necessary for following the rectified voltage waveform of the circuit in order to fire the triac at required phase angles. The microcontroller (ESP8266) fires interrupts upon receiving signals from the zero crossing circuit marking the starting point of the counter timer. Now, by calculating the time corresponding to the input firing angle the pulse is fired providing gate signal to the triac, thereby turning it ON.

2.1.4 ESP8266

The ESP8266 WiFi Module has a self contained SoC with an integrated TCP/IP protocol stack which provides it access to a Wi-Fi network. The ESP8266 has the potential of either hosting an application or offloading all Wi-Fi networking functions from another application processor. The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community.
This module has a powerful on-board 32-bit processor with storage capability that allows it to be integrated in various applications. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module.

Figure 2.6: ESP8266 Wifi Microcontroller

2.1.5 Triac

The Triac is a power electronic device that is used in AC switching application. Since it consists of two thyristors connected back-to-back (in other words, anti-parallel) but on the single piece of silicon so it controls the flow of current in both half cycle of alternating current.

Similar to that of the thyristor, the TRIAC also have three terminals namely MT1, MT2 and gate terminal. For the first half cycle MT1 act as anode terminal and MT2 terminal act as cathode terminal and for the next half cycle reverse is the case. However, the gate terminal is fixed and it receives the gating pulse for the TRIAC in both half cycle thus making it capable of controlling the flow of current.
Just like thyristor, the TRIAC also needs a minimum value of gate current called as latching current. So the gating pulse must be applied till the anode current go beyond latching current after which the pulse can be removed in order to reduce losses.

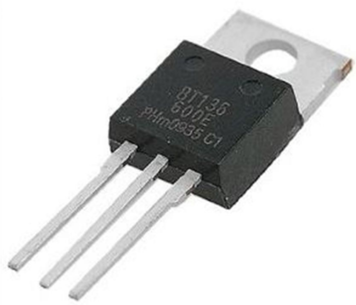


Figure 2.7: Triac BT136

The TRIAC turns off automatically when the current in the circuit goes below holding current and when the gating pulse is again given in the next half cycle, TRIAC start conducting. This process keeps on going. And thus, the RMS value of output voltage is controlled by changing the delay angle or firing angle of the TRIAC. Here in our project, the TRIAC is used in Controlling the brightness of lamp and speed of the fan.

2.1.6 Optocouplers

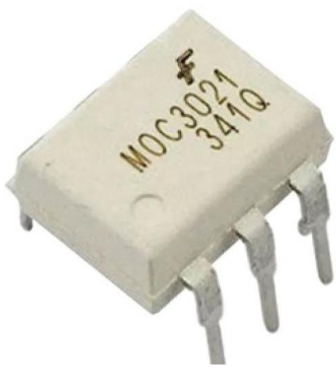


Figure 2.8: Optocoupler MOC3021

Optocoupler is an electronic component that is used to isolate circuits on PCB. It consists of two parts: an LED which receives the pulse and emits the Infrared light and the other is a photosensitive TRIAC which senses the radiation from LED and undergoes conduction. Thus, in turn, it produces a gating signal for the TRIAC of the main power circuit. As soon as the main TRIAC receives this signal it starts conducting. Now the firing pulse given to the TRIAC can be controlled by controlling the pulse firing delay given to the diode of the optocoupler.
When the pulse is removed, the currents flowing through the LED of optocoupler becomes zero and the photosensitive device i.e. TRIAC inside the optocoupler stops conducting thus making the whole circuit inoperative.
There are further other benefits of using an optocoupler which includes the removal of electrical noise. It also isolates the low-voltage side from the high-voltage side in the circuits.
Here in our project we have used two different optocoupler namely MOC3021, which is used to generate the firing pulse for TRIAC which in turn help in controlling the AC output waveform and the other one is MOC3041 which contains a Zero-Crossing Circuit inside it thus making it suitable for ON/OFF application as it generates the firing pulse at the instant when AC signal crosses the zero instant thus reducing the chances of a sudden large rise in current.
We also have to take care of the maximum amount of current that the LED inside optocoupler will withstand and hence a proper calculation is made to find out the value of limiting resistor as the peak value input pulse at the terminal of the diode is 3.3v which will be given by the microcontroller in our application.

2.1.7 L7805 Voltage Regulator

The Voltage regulator is used to regulate the input voltage to it to a fixed value. Thus it maintains fixed and hence smooth output voltage regardless of the input voltage.
The voltage equivalent to the difference of input and output is released as heat. So the greater is the difference, the more will be the heat that is released. Now in order to dissipate the heat, and to prevent the thermal breakdown of the material used inside the voltage regulator, we do use a heat sink. Thus the heat sink helps in ensuring the proper operation of the voltage regulator.

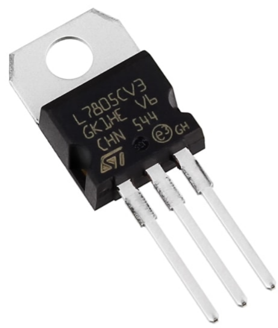


Figure 2.9: 5V Voltage Regulator LM7805

There are further other benefits of the voltage regulator as it shields and protects the electronic circuitry from any potential damage.
Here in our project, we have used voltage regulator 7805 as we need a smooth 5v dc output in order to power up the microcontroller. Also, we need to take care of the input voltage appearing at the terminal of voltage regulator so that the difference in voltage must not be very large. Also, the input voltage must be greater than 7v as according to the datasheet of 7805, the minimum voltage needed at the input terminal to regulate it to 5v is 7v.

7805 Rating

- Input voltage range 7V- 35V
- Current rating Ic = 1A
- Output voltage range Vmax=5.2V ,Vmin=4.8V

2.1.8 Snubber Circuit

Due to various conditions that generally occurs in electrical and electronics circuits like overcurrent, overvoltage, a large change in the difference of voltage etc., the components in the circuits may get fails. Now we need to protect our circuit from such anomalies. So for the protection against overcurrent, we do use fuse, heat sinks are used to dissipate the heat generated due to an excessive change in voltage.

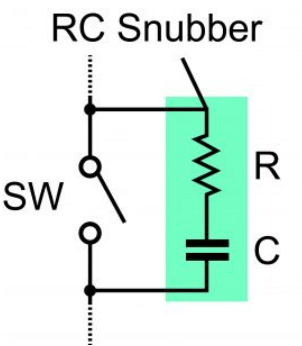


Figure 2.10: A RC Snubber Circuit

Now there appear some cases where there is a sudden rise in current(di/dt) and a sudden rise in voltage(dv/dt). These spikes are very dangerous and can burn the semiconductor devices connected in the circuit. So in order to protect the circuit against these two conditions of sudden rise we do use snubber circuit.
Snubber circuit basically has an inductor in series and capacitor in parallel along with a series resistance. The series inductor protects the circuit against the sudden rise in voltage. This is because of the property of the property of inductor which opposes the sudden rise in current. Also, the capacitor helps in protecting the circuit against the sudden rise in voltage. This is because of the property of capacitor which opposes the sudden rise in the voltage. Also, a series resistance is connected in series with the capacitor to limit the discharging current of the capacitor so that the current in the switch due to capacitor do not lead to an overcurrent condition in through the switch when it is operated.

2.2 Realistic Constraints

- Although the project will be designed with a modular approach with scope of future expansibility, it will be demonstrated on a much smaller scale, due to a lack of infrastructure and budget.
- Plug and Play modules with fine level of control will be developed only for Lights, Fans due to lack of budget and time. Rest of the devices will be controlled in only an On/Off state.
- Testing of the modules will be limited to the devices available in the institute.

2.3 Technical Standards Used

IEEE802.11 Standard for Wi-Fi

P2413 Standard for an Architectural Framework for the Internet of Things (IoT)

2755-2017 IEEE guide for terms and concepts in Intelligent Process Automation.

IEEE 61850-9-3-2016 International Standard for communication networks and systems for power utility automation

IEEE 802.15.4 Wireless sensor/control networks.

IEEE 1016 Software design description.

Chapter 3

Design Methodology

3.1 Methodology

A. Development of driver circuit

To introduce software based control, microcontroller based actuators modules are to be attached in the power supply lines of the devices (fan and lighting system control).

A.1. Study of control methodology The development of actuator modules designed for each device to be automated will be using plug and play methods so as to convert existing devices into smart ones. The actuators will operate and automate the appliances based on the commands received from the microprocessor.

A.2. Actuator circuit design

- **Incandescent Lamp** The use of pulse width modulated signals that drives a bidirectional control switch i.e., Triac which is connected to the Lamp and thereby with the AC mains. As the width of the PWM is altered the voltage across the lamp will be varied and hence the brightness of the lamp will be controlled.
- **Fans** Speed regulation of fans will be done using the Triac to reduce the energy losses that were occurring by the use of conventional voltage controller. A snubber circuit is connected in parallel with the triac in order to protect it against reverse breakdown.

Now the designed circuit of actuator modules is designed in such a way that there would be no need to interfere with the existing circuitry of the appliances. The existing switches will be simply upgraded by the smart switch boards providing automated control of each appliance over the internet.

B. Design of the software for the Smart Switch Board

The smart switch board needs a central hub for their communication and management. It will receive the inputs from the zero crossing detection circuit and give an optimized output pulse to the switch after processing it using the aforementioned algorithms.

The microcontroller ESP8266 is programmed on NodeMCU platform. The coding is done in C++ language for the microcontroller in order to generate the firing pulses accordingly to operate the driver circuits.

C. Development of a user interface to enable user interaction with the system

Applications will be developed for the most common mobile platforms, iOS and Android. A cloud-based web app will also be deployed for users to operate from laptops and desktops. The user will be able to use these apps to connect directly to the server hosted on the Home Automation Unit in their homes without any middleware services ensuring their security and privacy.

The programming of the Android Application is done in Java XML. The MQTT broker (CloudMQTT.com) is being used for machine-to-machine internet of things connectivity. It works on a publish/subscribe methodology, and is a lightweight messaging protocol developed on top of the HTTP.

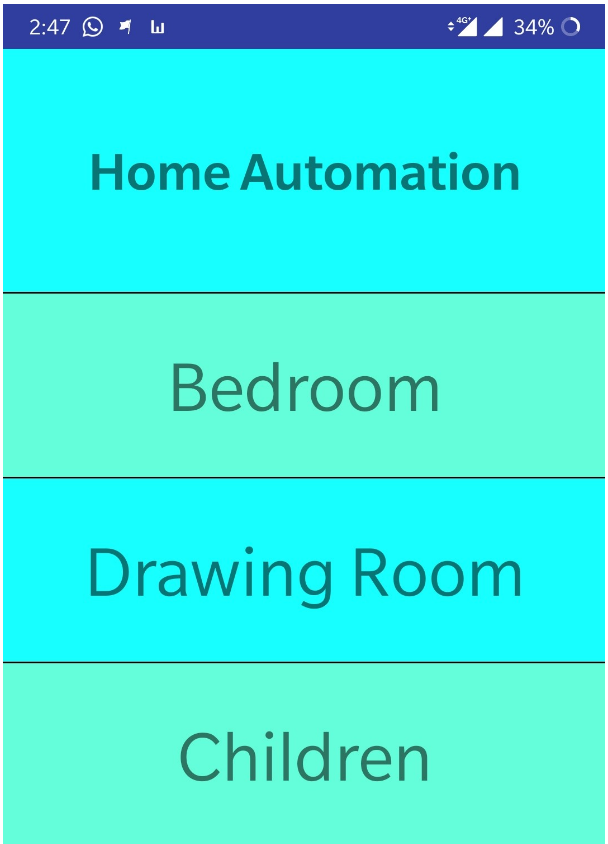


Figure 3.1: Room Selection Screen

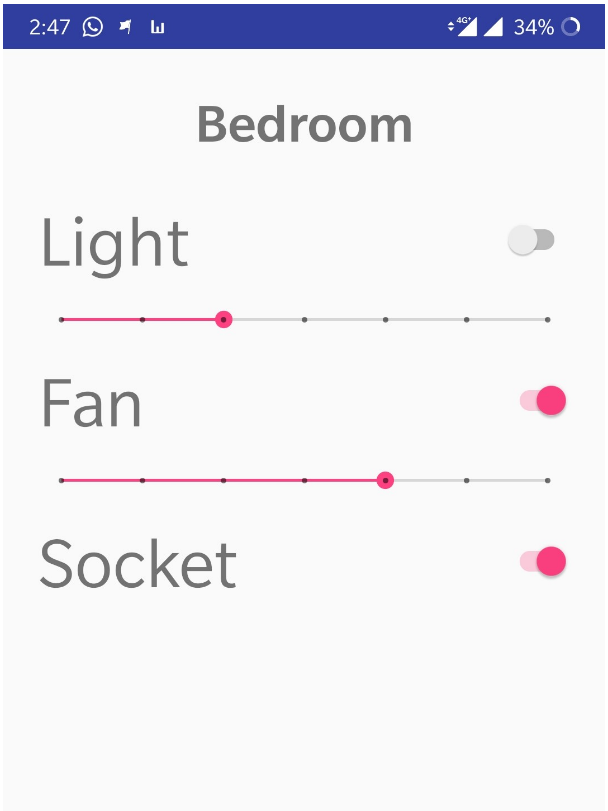


Figure 3.2: Device Control Screen

3.2 Flow Chart

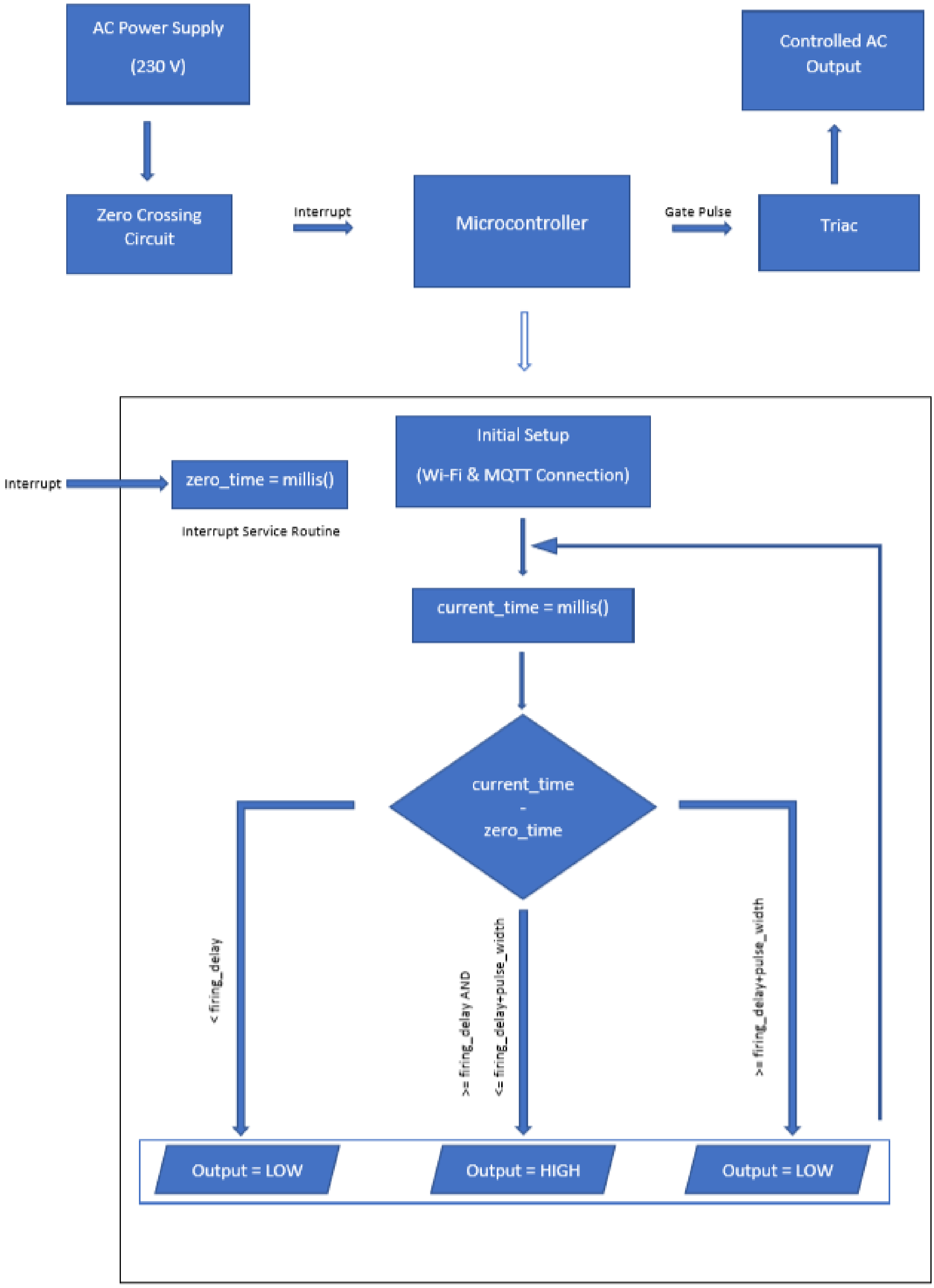


Figure 3.3: Logic flow for operation of the Smart Switchboard

3.3 Mathematical analysis and calculations

3.3.1 Power Supply

$$V_{inp} = 230V = V_{\mathrm{p}}(primary\,voltage)$$

$$V_s(secondary\,voltage) = 13.74V$$

$$V_{cp}(peak\,capacitor\,voltage) = 13.74 * \sqrt{2} - 2 * 0.7 = 18.03V \tag{3.1}$$

From the data sheet(attached) of Voltage Regulator(7805), the minimum voltage at the Input Terminal must be above 7V.
As we know the discharging equation of capacitor is :

$$V = V_{cp} * e^{\frac{-t}{T}} \tag{3.2}$$

$$7 = 18.03 * e^{\frac{-5*10^{-3}}{T}} \tag{3.3}$$

By Solving,

$$T = 5.28ms$$

$$R * C = 5.28ms$$

From Diode Bridge Rectifier,

$$V(drop) = 1.4V = I * R$$

$$I = 500mA_{(load\,current)}$$

By solving,

$$R = 2.8\Omega \tag{3.4}$$

Putting in eqn 3.7,

$$C = 1880\text{µ}F \tag{3.5}$$

So, we have used slightly larger value of capacitor i.e. 2200µF.

3.3.2 Zero Crossing Circuit

From data sheet(attached) of A4N25 Transistor based Octocoupler: For internal Diode to turn ON -

$$I(max.\,permissible\,limit) = 60mA \tag{3.6}$$

$$Rectified\,Voltage, V = 5.21V \tag{3.7}$$

$$R_{connected} = 165\Omega \tag{3.8}$$

$$I_{actual} = \frac{V}{R_{connected}} = 31.57mA \tag{3.9}$$

3.3.3 Triac Circuit

From the Triac Circuit,

$$V_{0\,rms} = \sqrt{\frac{1}{2\pi}(\int_{\alpha}^{\pi} (V_m sin\theta)^2 d\theta + \int_{\alpha+\pi}^{2\pi} (V_m sin\theta)^2 d\theta} \tag{3.10}$$

On solving, the output rms voltage of Triac is:

$$V_{0\,rms} = \frac{V_m}{\sqrt{2}}[\sqrt{\frac{1}{\pi}((\pi - \alpha) + \frac{sin2\alpha}{2})}] \tag{3.11}$$

Now, for different firing angle, the output voltage across load would be different as: for α=0°

$$V_{o\,rms} = \frac{V_m}{\sqrt{2}}$$

for α=30°

$$V_{o\,rms} = \frac{V_m}{\sqrt{2}} * 0.98$$

& so on...

3.3.4 Optocoupler

From datasheet of MOC3041 Optocoupler:

$$I(max.\,permissible\,limit) = 60mA \tag{3.12}$$

Now,

$$Voltage\,applied, V = 3.3V \tag{3.13}$$

Hence,

$$R_{reqd.} = \frac{V}{I} = \frac{3.3V}{60mA} = 55\Omega \tag{3.14}$$

3.3.5 AC Fan

From datasheet(attached) of ac axial fan:

$$L = 3H,\ R = 1.67K\Omega$$

So,

$$X_L = w * L = 3 * 2\pi * 50 = 942.477 \tag{3.15}$$

$$tan\theta = \frac{X_L}{R}$$

$$\theta = tan^{-1}(\frac{X_L}{R})$$

$$\theta = tan^{-1}(\frac{94204777}{1.67 * 1000})$$

$$\theta = 29.43^\circ \tag{3.16}$$

Now, for the circuit to start operating-

$$Firing\, angle(\alpha) >= \theta$$

Hence,

$$\alpha > 29.43^\circ \tag{3.17}$$

3.3.6 Power Rating of the Smart Switchboard

Keeping in mind the trace widths used for the high power component of our PCB, the following maximum ratings for the Smart Switchboard have been calculated.
Trace Width for High Power side,

$$t = 1.5mm$$

By referring to a professional PCB manufacturer, BITTELE (www.7pcb.com), the following maximum current limit was determined using their Trace Width Calculator.

$$I = 5.3A$$

Our circuit operates at a rated RMS voltage of 230V. Hence,

$$P_{max} = 5.3A * 230V$$

$$P_{max} = 1219W \tag{3.18}$$

3.4 Circuit Diagram

Following are the schematics prepared on the Autodesk Eagle schematic and PCB design software. The simulation for same was performed using OrCAD (PSpice).

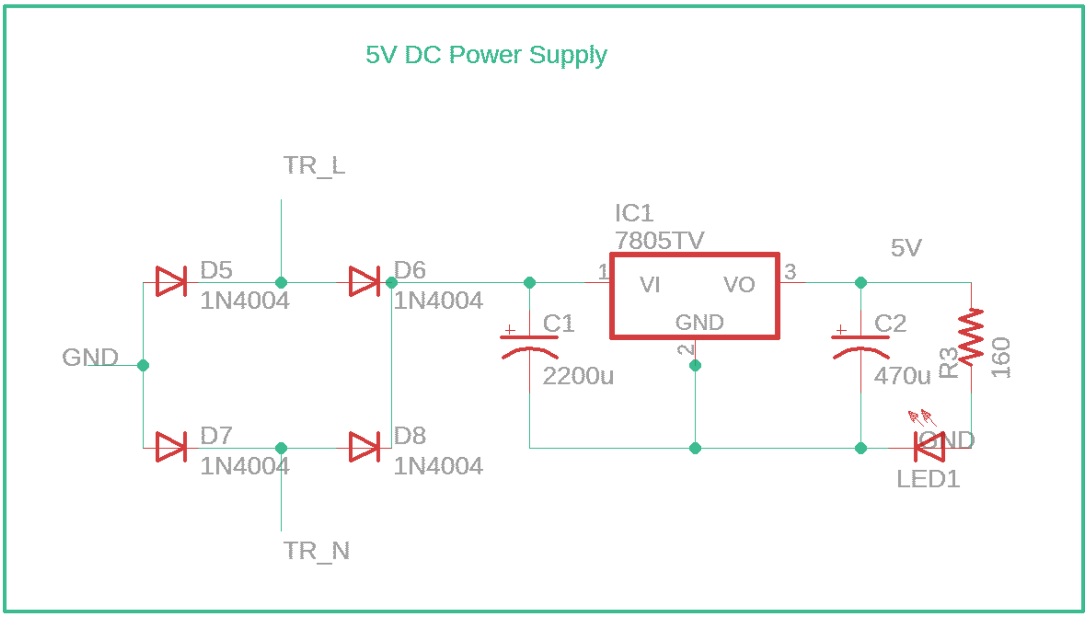


Figure 3.4: 5V DC Power Supply

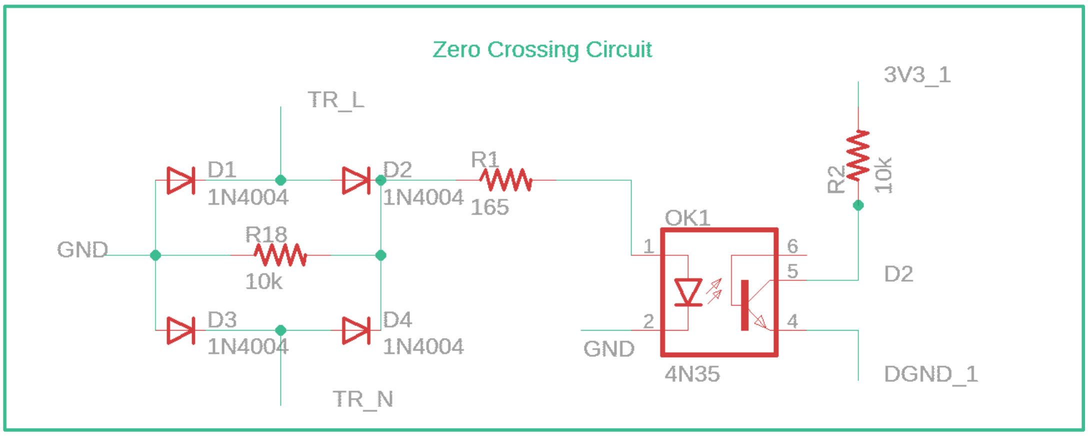


Figure 3.5: Zero Crossing Detection Circuit

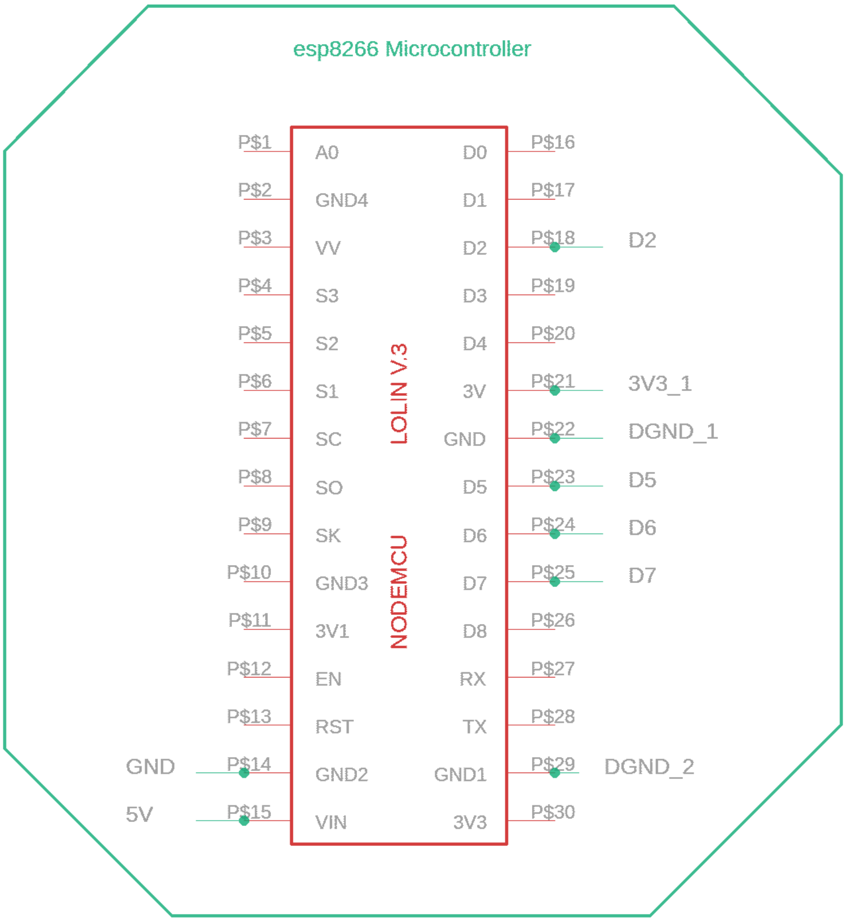


Figure 3.6: The esp8266 Microcontroller

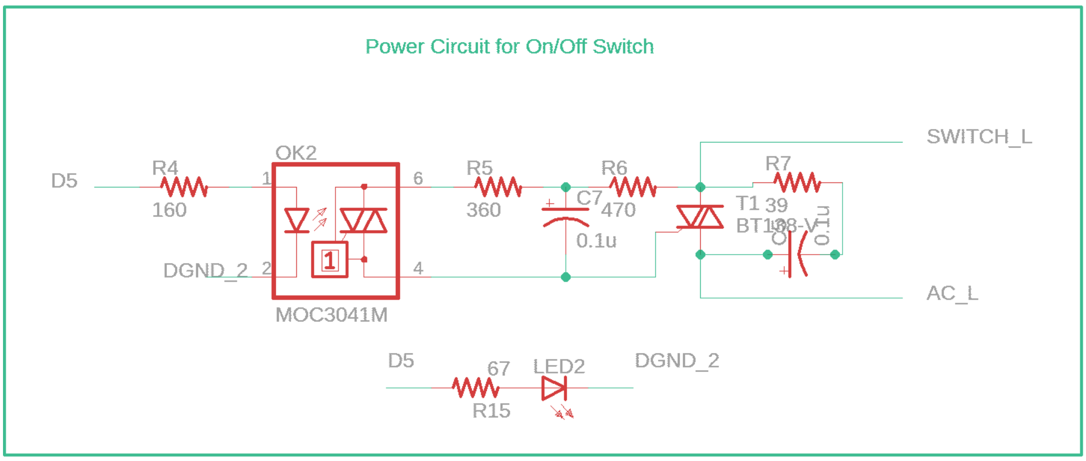


Figure 3.7: Power Circuit for On/Off Switch

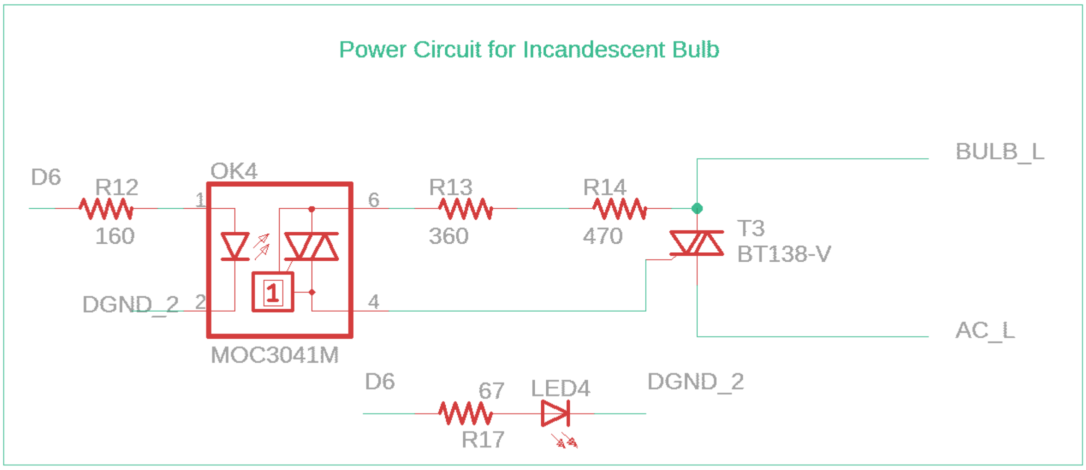


Figure 3.8: Power Circuit for Incadescent Bulb

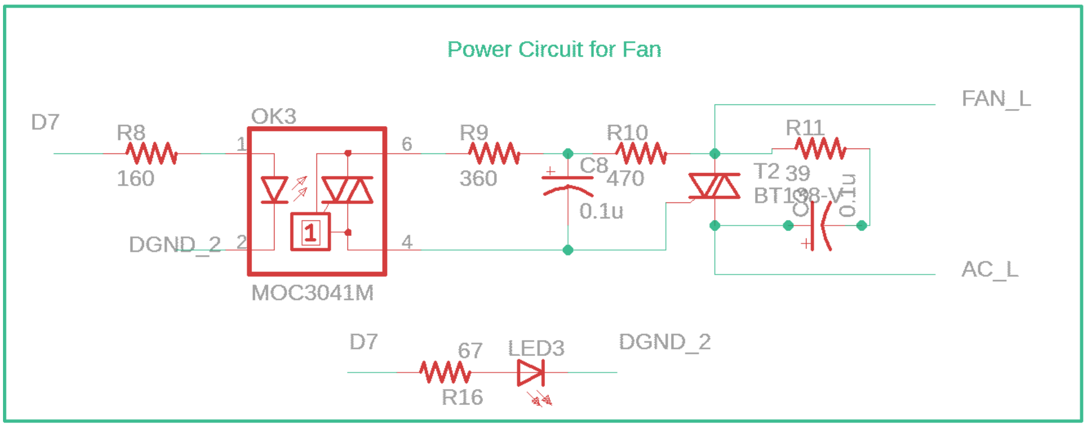


Figure 3.9: Power Circuit for Fan

3.5 Hardware Design

The prepared schematics after verification of results in the sofftware simulations were laid out on a PCB using Eagle CAD. This enabled us to minimise an otherwise complex and cumbersome circuit into a simplified design which could be installed inside a small enclosure resembling a switchboard in everyday homes.

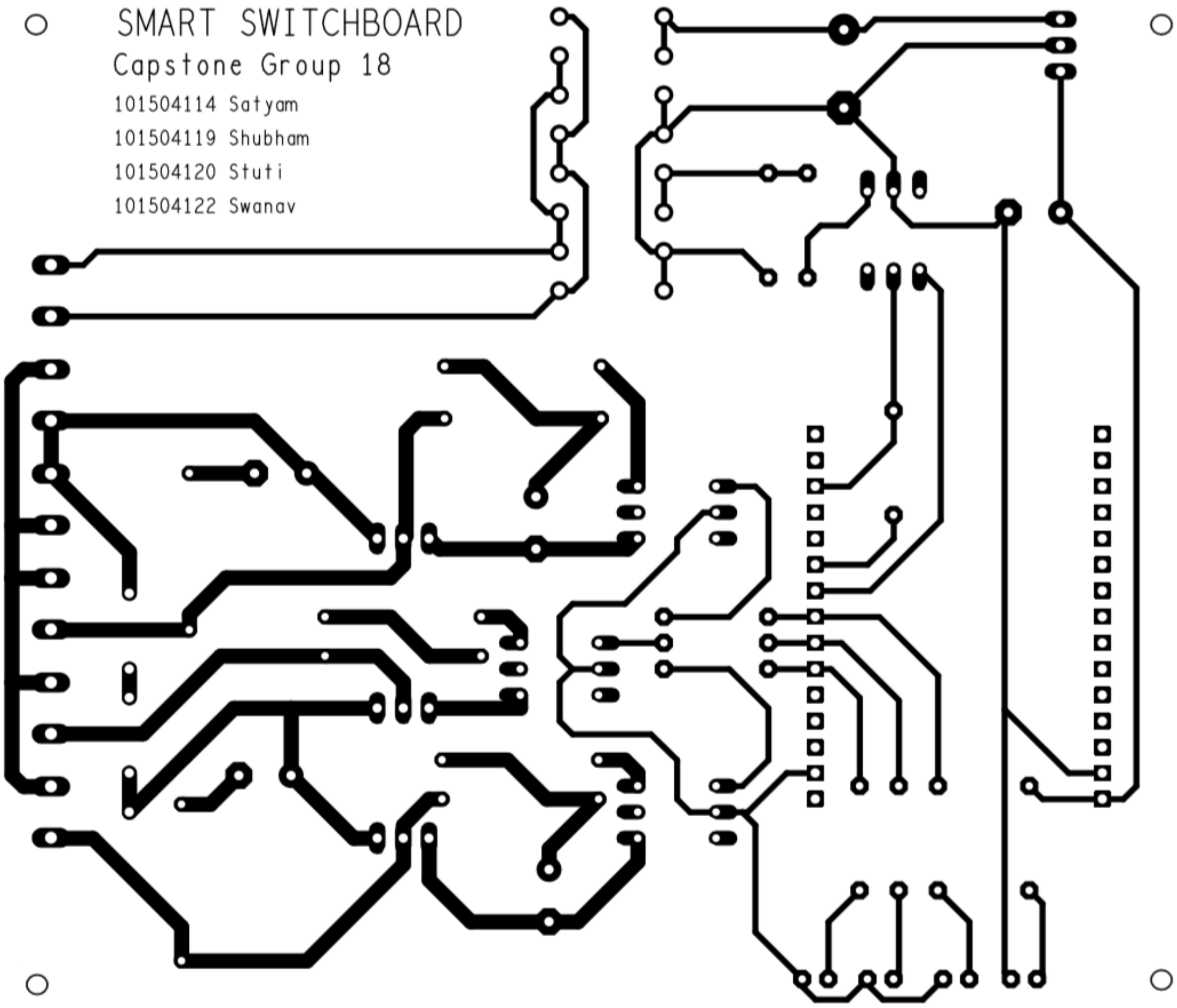


Figure 3.10: PCB Layout for the design

3.6 Hardware System

The prepared PCB was designed and ordered using a PCB prototyping facility. The components were acquired from a local retailer and soldered to create a working prototype of our concept.

The prototype went through repeated tests, and after numerous occasions of failure and fine-tuning, a working prototype was prepared for demonstration.

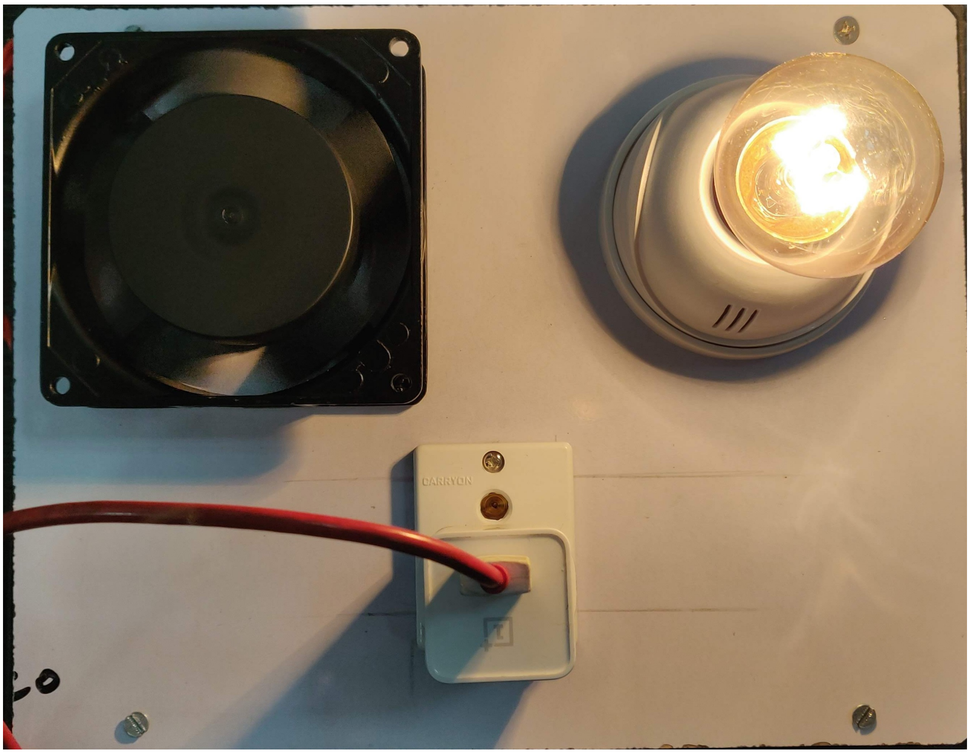


Figure 3.11: Demonstration of the complete project

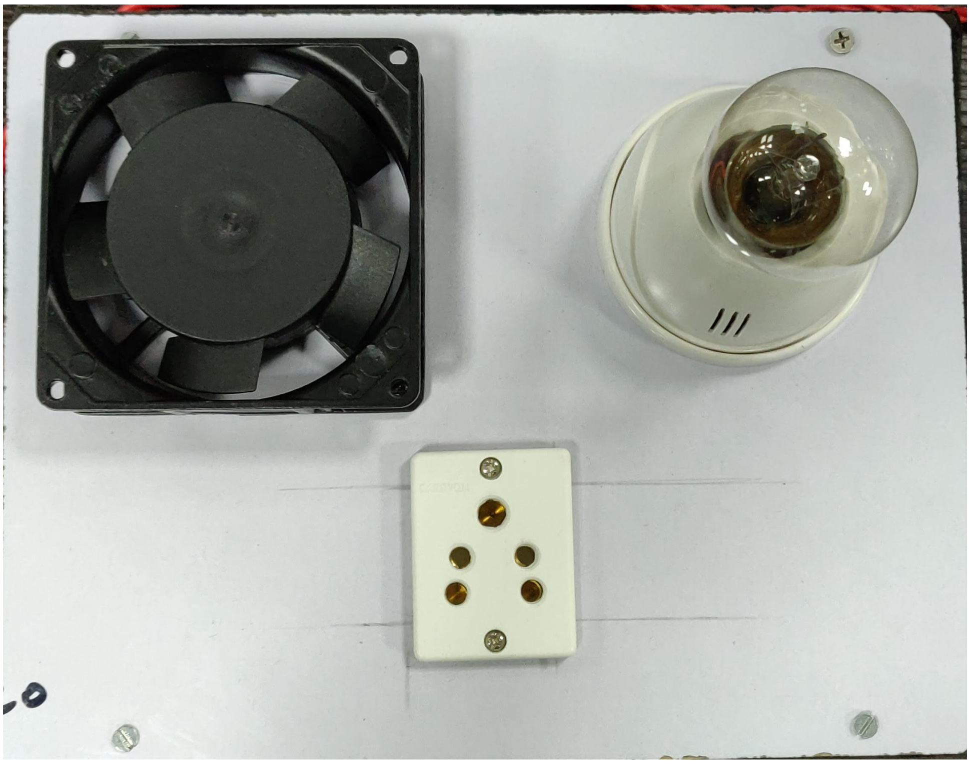


Figure 3.12: Demonstration of the complete project

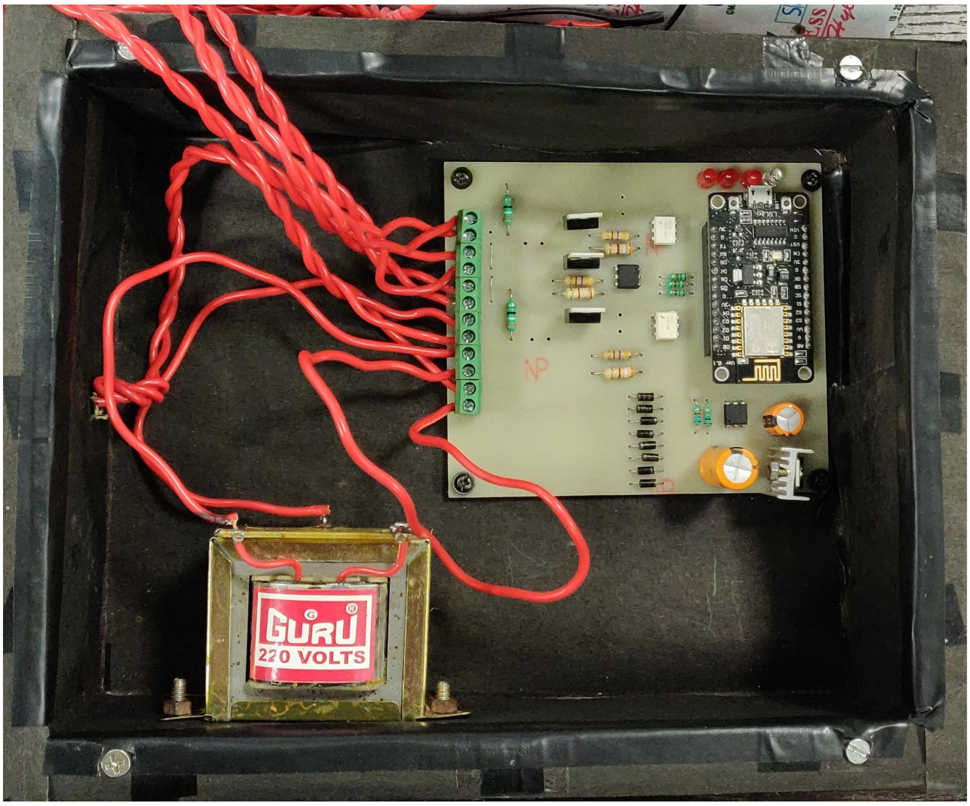


Figure 3.13: Demonstration of the complete project

Chapter 4

Results and Discussion

4.1 Results and Discussion

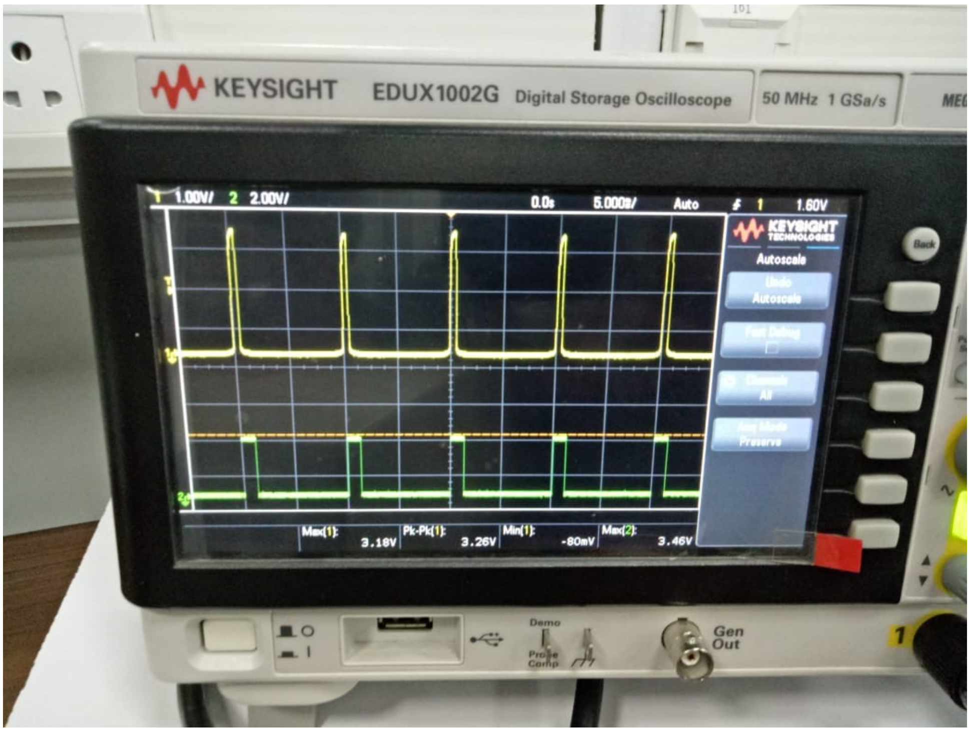


Figure 4.1: Gate signal for the driver circuit

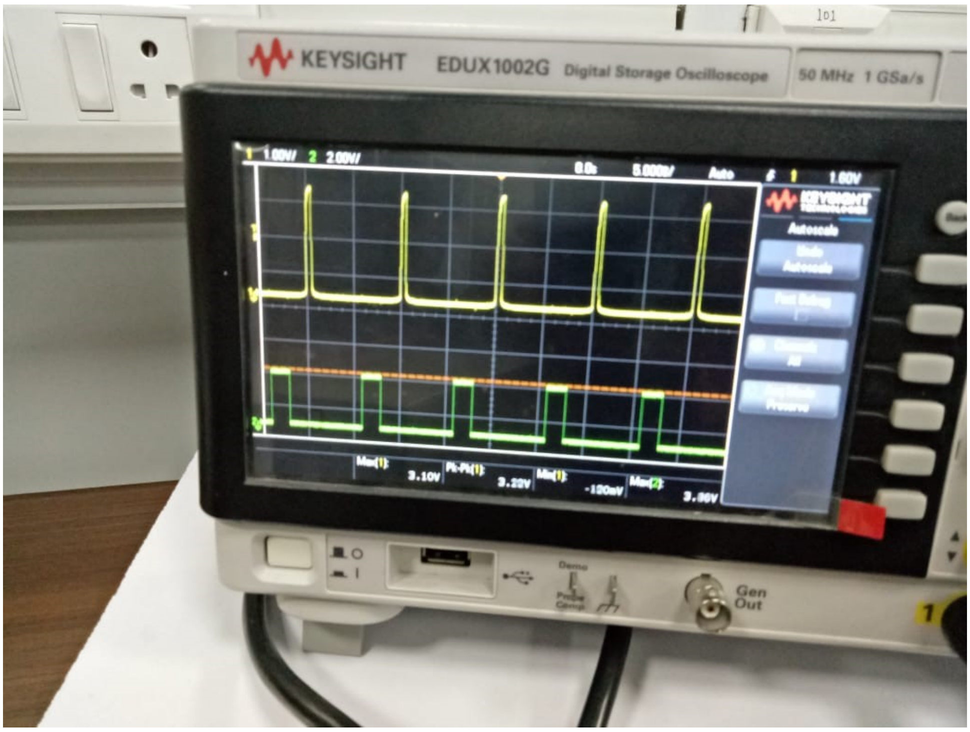


Figure 4.2: Shifted Firing pulses lead to reduced apparent voltage

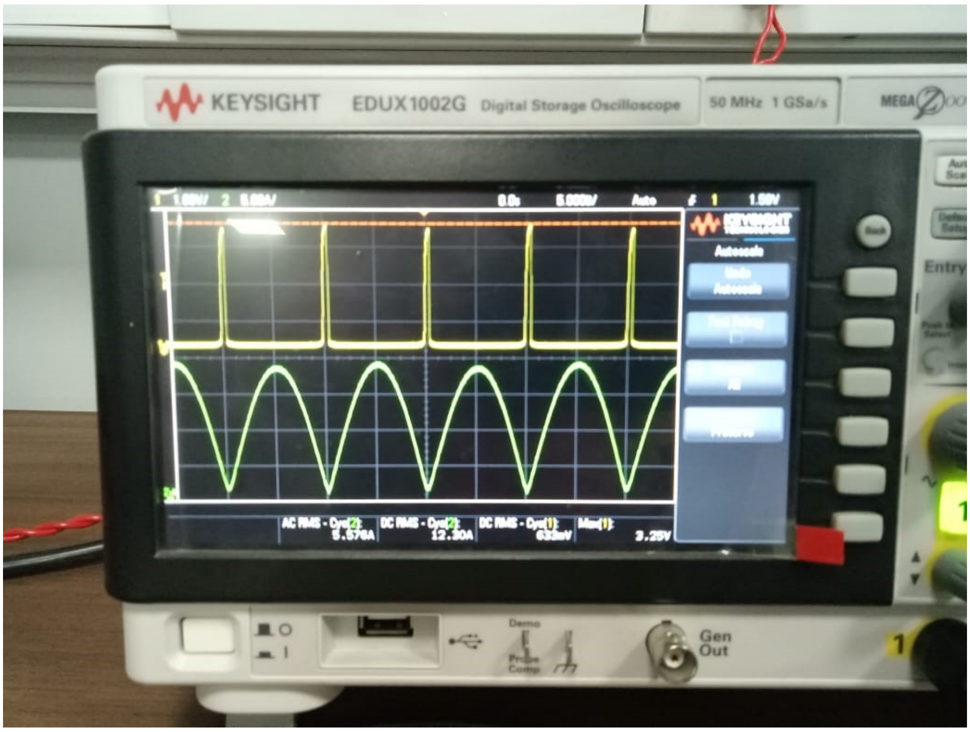


Figure 4.3: Rectified Output for Zero Detection

4.2 Justification of objectives achieved

1. With the help of power electronics devices such as triac, optocoupler etc., we designed the control circuitry for controlling the speed of fan, brightness of lights etc. We have also provided socket (Switch On/Off) for external device connection. A ripple free constant power supply of 5V for power supply of the microcontroller is designed using full bridge rectifier and smoothing capacitors. A zero cross detection circuit is also designed for detection of zero instant of the AC mains so that a reliable firing pulse can be generated from microcontroller in order to control the appliances.

2. Programming of the microcontroller is done on NodeMCU platform. The coding of the microcontroller is done in C++ language. The program formed allows the microcontroller to generate PWM gating pulses based on the user input to achieve the desired output by the user.

3. For the user interaction mobile applications enlisting rooms of each household. The rooms are further divided into lists of appliances which provides control over the devices to the user over the internet. The application is made simple and handy for the user to access easily.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

We successfully completed the following work areas, including their simulations and hardware representation:

1. 5V Supply for Microcontroller Power Supply.
2. Zero Crossing Circuit for detection of Zero Voltage instant of AC supply.
3. Firing pulse generation based on Zero Crossing Circuit fed as input to microcontroller.
4. On/Off and dimming control of lamp and fan using Optoisolators and Triac.
5. Android application for managing and control of lamp.

5.2 Future Work

The project can involve further development of-

- Plug and Play modules for AC and other household appliances.
- Machine Learning based autonomy algorithms.
- A centralised Home Automation Software to coordinate between various switchboard modules and house the machine learning algorithms.
- Sensor Aggregator Modules to provide environmental parameters to the device

Chapter 6

Project Metrics

6.1 Challenges faced and Troubleshooting

Various challenges were faced during the simulations and hardware design of the Smart Switch Board-

1. **Working with 230V power supply**

   One of our major challenges was to tackle the 230V supply as majority of the components got damaged due to excess currents in the lines, inadequate ratings of the devices used in the power circuit, shorting of lines during measurements of voltages and currents or improper soldering.

2. **Familiarization with various circuit simulation platforms**

   For the simulation of control circuits, we were required to have a good command over various simulation platforms. The circuit simulation softwares used were Orcad Cadence, Matlab R2015a and EasyEda.

3. **Grasp over programming tools and android applications**

   For software programming of the controllers, single board computers and android application development Java, Android Studio and C++ platforms were learned.

4. **Proper grounding**

   We damaged many circuits in the process due to earthing problems. In one case, the analog ground of the circuit was shorted with the digital ground of the DSO. As both of them were at different potentials an overflow of current was observed which lead to damaging of the analog circuit.

   Solution: Proper grounding of the circuits is required ensuring the excess charges in the circuit during faults flow through ground to prevent damage.

5. **Problems of Voltage Fluctuations**

   The voltage fluctuations in the transformer were observed upon applying load to the circuit.

   This lead to very low values of currents at the load ends and the devices could not be operated.

These fluctuations occur upon exceeding a permitted range of per unit impedance (upto 5

Solution: Higher current ratings of transformers were taken(230V, 1A) in order to obtain steady output at the load end.

6. **Ratings of the components used**

   The calculations were done before hand of the circuit parameters for analysing the circuit. The component ratings of some devices that came out from the calculations were not available in the market.

   Solution: Either using series/parallel combination of devices or recalculation of the values of component ratings were done to achieve the desired results.

7. **Difficulty in analysis:**

   The Power Electronics circuit was difficult to analyse. The values of filter circuits, current limiting resistors and waveform analysis were quite cumbersome. Snubber circuit designed for inductive loads was difficult to analyse as it involved second order differential equations.

8. **Fine Soldering Requirements:**

   The circuit consisted of too many connections and also in order to make it appear as a single switch board, the connections were done very close to one another.

   Solution: This required very fine soldering of the circuit and also it took long hours to plan the placement and solder the circuit elements to minimize number of connections and obtain a neat and presentable circuit.

9. **Smoothing Capacitor values:**

   Maximum permissible values of Smoothing capacitors required to provide ripple free supply had to be calculated, exceeding which the capacitors would generate sparks in the circuit and also provide excessive boost to the circuit voltage.

10. **Operation of full wave rectifier under no load:**

    The full wave rectifier shows a distorted output when connected without load. This happens because on no load condition the current drawn by the circuit is zero and hence the other pair of diodes do not actually go into conduction mode thus generating either a half wave rectified output or the CRO was showing abnormal waveform at the output.

    Solution: A resistive load of 33k was applied to the output terminals of the full wave rectifier circuit for measurement of the voltage waveform across it.

11. **Matching of auto-reload of microcontroller with zero crossing signals:**

    The zero crossing signals to the microcontroller were provided at a time interval of 10ms which could not be sometimes not interpreted by the microcontroller. This was due to defective microcontroller used in the testing phase.

    Solution: It was replaced by a new controller and the problem was rectified.

6.2 Relevant Subjects

Subject Code	Subject Code	How was the subject used?
UTA007	Computer Programming-I	Used in Microcontroller Programming for operating the driver circuits.
UTA009	Computer Programming-II	Used in Programming of Single Board Computer.
UTA011	Engineering Design-III	Operation of Fan circuitry.
UEE301	Direct Current Machines and Transformers	Transformer used for stepping down the supply for input to the controller.
UEE505	Analog and Digital Systems	Analysis & calculations of formed circuit for device control.
UEE401	Alternating Current Machines	Voltage control of single phase capacitor run induction motor for fan circuit.
UEE504	Power Electronics	For understanding the power electronic (Triac, Optoisolators, etc.) device characteristics and operation used in control circuitry.
UEI609	Fundamentals of Microprocessors and Microcontrollers	For understanding basics of microcontrollers.
UEE603	Switch Gera & Protection	Use of fuses for overcurrent protection of devices & optocouplers for Isolation of circuit.
UEE801	Electric Drives	Input voltage control of Ac motors for speed control of fan.

6.3 Interdisciplinary Aspect

This project consists of extensive multidisciplinary efforts.
The user application developed for providing a user interface is a component of Software Engineering.
The enclosure for the smart switchboard was designed with inputs from our friends in Mechanical Engineering.

6.4 Components Used

6.4.1 Software Used

- MATLAB
- OrCad (PCB Design software)

- Autodesk Eagle (PCB Design software)
- Pspice (Electrical simulation software)
- MQTT Dashboard (Android Application)
- CloudMQTT.com (A cloud based secure MQTT Broker)

6.4.2 Hardware Used

Sr. No.	**Component Used**	**Quantity**
1	OptoCoupler(MOC 3021)	2
2	OptoCoupler(MOC3041)	1
3	Triac(BT136)	3
4	Volatage Regulator(LM 7805)	1
5	Diode(1N 4007A)	8
6	OptoCoupler(A4N25)	1
7	Capacitor(2200µFF)	1
8	Capacitor(470µFF)	1
9	Resistor(0.54w,54Ω)	3
10	Resistor(0.5w,165Ω)	1
11	Resistor(1w,390Ω)	3
12	Resistor(1w,470Ω)	3
13	Resistor(39Ω)	3
14	Capacitor(0.01µFF)	2
15	2 Pin PCB Mount Connector	5
16	PCB	1
17	Micro Controller(ESP8266)	1

Table 6.1: List of coomponents used in the finished product

6.5 Team Assessment Matrix

	Evaluation of			
Evaluation by	Satyam Kumar	Shubham Gupta	Stuti Sidhu	Swanav Swaroop
Satyam Kumar	5.0	4.5	4.5	4.5
Shubham Gupta	4.5	5.0	4.5	4.5
Stuti Sidhu	4.5	4.5	5.0	4.5
Swanav Swaroop	4.5	4.5	4.5	5.0

Table 6.2: Team Assessment Matrix

6.6 Work Schedule

	2018 Work Schedule (Satyam)											
	01	02	03	04	05	06	07	08	09	10	11	12
Literature Survey												
A. Development of Driver Circuit												
A1. Study of Control Methodology												
A2. Actuator Circuit Design												
B. Software Design												
C. User Interface Development												
Documentation												
Hardware Implementation and Testing												
Project Demonstration												

Table 6.3: Work Schedule for Satyam

	2018 Work Schedule (Shubham)											
	01	02	03	04	05	06	07	08	09	10	11	12
Literature Survey												
A. Development of Driver Circuit												
A1. Study of Control Methodology												
A2. Actuator Circuit Design												
B. Software Design												
C. User Interface Development												
Documentation												
Hardware Implementation and Testing												
Project Demonstration												

Table 6.4: Work Schedule for Shubham

	2018 Work Schedule (Stuti)											
	01	02	03	04	05	06	07	08	09	10	11	12
Literature Survey												
A. Development of Driver Circuit												
A1. Study of Control Methodology												
A2. Actuator Circuit Design												
B. Software Design												
C. User Interface Development												
Documentation												
Hardware Implementation and Testing												
Project Demonstration												

Table 6.5: Work Schedule for Stuti

	2018 Work Schedule (Swanav)											
	01	02	03	04	05	06	07	08	09	10	11	12
Literature Survey												
A. Development of Driver Circuit												
A1. Study of Control Methodology												
A2. Actuator Circuit Design												
B. Software Design												
C. User Interface Development												
Documentation												
Hardware Implementation and Testing												
Project Demonstration												

Table 6.6: Work Schedule for Swanav

6.7 Student Outcome Mapping

A1.	Applied mathematics (partial differentiation, vector calculus, linear algebra, complex variables, Laplace transform, probability, statistics, discrete mathematics etc.) to obtain analytical, numerical and statistical solutions.	Used in calculating the values of various devices used in the circuit w.r.t circuit ratings.
A2	Demonstrate and apply knowledge of fundamentals, scientific and engineering principles towards solving engineering problems.	The project requires analysis of the wave form across the output & their variation upon changing the firing angle.The project demonstrates the use of microcontrollers, Ac motors, triacs.
B2	Utilize suitable hardware equipment for data collection.	The project used digital signal oscilloscope for data acquisation.
D1	Share responsibility and information schedule with others in team.	Each & every member in the team was assigned a particular section of the project & they discussed the project status with every member.
E1	Classify information to identify engineering problems.	Various practical problems were encountered during the hardware assembly.
G1	Prepare and present variety of documents such as project or laboratory reports and inspection reports with discipline specific standards.	The team members presented their idea to the mentor & the report has been prepared following proper IEEE standards used in the design.
I1	Able to use resources to adopt new technologies not included in curriculum.	We have used OrCAD Cadence for design & simulation of circuits. Eagle CAD was used for design of the PCB.
J2	Recognize the impact of engineering decisions reduces on energy resources and environment.	The devices used consume negligible power & the control strategy is efficient in reducing power consumption.
K3	Able to analyze engineering problems using software tools.	The results & calculations have been compared with the software used.

References

1. Archana N. Shewale, **"Renewable Energy Based Home Automation System Using ZigBee"**, International Journal of Computer Technology and Electronics Engineering (IJCTEE), 2015

2. S. Anusha, **"Home Automation using ATmega328 Microcontroller and Android application"**, International Research Journal of Engineering and Technology(IRJET), 2015

3. J. Chandramohan, **"Intelligent Smart Home Automation and Security System Using Arduino and Wi-Fi"**, International Journal of Engineering and Computer Science, 2017

4. Kumar Mandula, **"Mobile based home automation using Internet of Things(IoT)"**, IEEE International Conference, 2015

5. Debraj Basu, **"Wireless Sensor Network Based Smart Home: Sensor Selection, Deployment and Monitoring"**, IEEE, 2013

6. Byeongkwan Kang, **"IoT-based monitoring system using tri-level context making model for smart home services"**, IEEE International Conference, 2015

7. Jeya Jeya Padmini, **"Effective Power Utilization and Conservation in Smart Home Using IoT"**, IEEE International Conference, 2015

8. Pranay P. Gaikwad, **"A Survey based on Smart Home System Using Internet of Things"**, IEEE International Conference, 2015

Annexures

6.8 Code

On Board Controller (esp8266)

```
#include <Arduino.h>
#include <ESP8266WiFi.h>
#include <PubSubClient.h>

unsigned long zeroTime = 0;
int pulseWidth = 2;
int light_state = 0;
int fan_state = 0;

// Enter credentials generated by yourself

// WIFI SETTINGS
#define WIFI_SSID "***********"
#define WIFI_PSK  "***********"

// MQTT SETTINGS
#define MQTT_SERVER "*************"
#define MQTT_PORT ****
#define MQTT_USER "*******"
#define MQTT_PASS "*************"

#define TOPIC_LIGHT "hercules/sub/ESP_52F5B5/light"
#define TOPIC_FAN "hercules/sub/ESP_52F5B5/fan"
#define TOPIC_SWITCH "hercules/sub/ESP_52F5B5/switch"
#define TOPIC_PUB "message"

WiFiClient espClient;
PubSubClient client(espClient);

const int LED = D4;
const int Switch = D5;
const int Fan = D6;
```

```
const int Light = D7;


int fireDelay(int firingAngle) {
        return (20*firingAngle)/360;
}

void toggle();
void onMessage(char* topic, byte* payload, unsigned int length);

void setup() {
        Serial.begin(9600);

        pinMode(LED, OUTPUT);
        pinMode(Light, OUTPUT);
        pinMode(Fan, OUTPUT);
        pinMode(Switch, OUTPUT);
        attachInterrupt(digitalPinToInterrupt(D2),toggle,RISING);

        WiFi.mode(WIFI_STA);
        WiFi.begin(WIFI_SSID, WIFI_PSK);
        Serial.println("Connecting");
        while(!WiFi.isConnected()) {
                Serial.print(".");
                delay(100);
        }
        Serial.println("\nConnected to WiFi Network");

        client.setServer(MQTT_SERVER, MQTT_PORT);
        client.setCallback(onMessage);

        Serial.println("Attempting connection to Tesseract...");
        while(!client.connected()) {
               if(client.connect("ESP_52F5B5", MQTT_USER,
               MQTT_PASS)) {
                        Serial.println("\nConnected!");
                        client.subscribe(TOPIC_LIGHT);
                        client.subscribe(TOPIC_FAN);
                        client.subscribe(TOPIC_SWITCH);
                        client.publish(TOPIC_PUB,
                        "Connection established");
                } else {
                         Serial.print(".");
                         delay(1000);
                }
        }
        digitalWrite(LED, LOW);
```

```
        Serial.println("Connected");
}


int firingAngle_light = 0;
int firingAngle_fan = 0;
unsigned long currentTime;

void loop() {
        currentTime = millis();
        int firingDelay_light = fireDelay(firingAngle_light);
        if(currentTime - zeroTime < firingDelay_light) {
                light_state = LOW;
        } else if(currentTime - zeroTime >= firingDelay_light
         && currentTime - zeroTime < firingDelay_light
          + pulseWidth) {
                light_state = HIGH;
        } else if(currentTime - zeroTime >= firingDelay_light
         + pulseWidth) {
                light_state = LOW;
        }
        currentTime = millis();
        int firingDelay_fan = fireDelay(firingAngle_fan);
        if(currentTime - zeroTime < firingDelay_fan) {
                fan_state = LOW;
        } else if(currentTime - zeroTime >= firingDelay_fan
         && currentTime - zeroTime < firingDelay_fan + pulseWidth)
                fan_state = HIGH;
        } else if(currentTime - zeroTime >= firingDelay_fan
         + pulseWidth) {
                fan_state = LOW;
        }

        digitalWrite(Light, light_state);
        digitalWrite(Fan, fan_state);

        client.loop();
}

void toggle() {
        zeroTime = millis();
}

void onMessage(char* topic, byte* payload, unsigned int length) {

if(strcmp(topic,TOPIC_LIGHT)==0) {
        if(payload[0] == 'o') {
```

```
                if(payload[1] == 'f') {
                        digitalWrite(Light, 0x00);
                }
            } else {
                    int val = (int) payload[0] - 48;
                    firingAngle_light = val*30;
        }
        Serial.print("Firing light: ");
        Serial.println(firingAngle_light);
}

if(strcmp(topic,TOPIC_FAN)==0) {
        if(payload[0] == 'o') {
                if(payload[1] == 'f') {
                        digitalWrite(Fan, 0x00);
                }
        } else {
                int val = (int) payload[0] - 48;
                firingAngle_fan = val*30;
        }
        Serial.print("Firing fan: ");
        Serial.println(firingAngle_fan);
}

if(strcmp(topic,TOPIC_SWITCH)==0) {
        if(payload[0] == 'o') {
                if(payload[1] == 'f') {
                        digitalWrite(Switch, 0x00);
                } else {
                        digitalWrite(Switch, 0x01);
                }
        }
}
```

6.9 Datasheet of Components

recommended operating conditions

			MIN	MAX	UNIT
V_I	Input voltage	μA7805C	7	25	V
		μA7808C	10.5	25	
		μA7810C	12.5	28	
		μA7812C	14.5	30	
		μA7815C	17.5	30	
		μA7824C	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature	μA7800C series	0	125	°C

electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	μA7805C			UNIT
			MIN	TYP	MAX	
Output voltage	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, $P_D \leq$ 15 W	25°C	4.8	5	5.2	V
		0°C to 125°C	4.75		5.25	
Input voltage regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to 125°C	62	78		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		μV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

APPLICATION INFORMATION

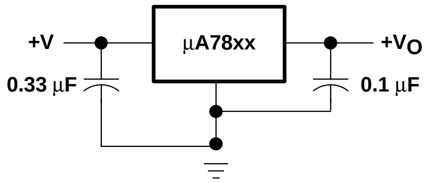


Figure 1. Fixed-Output Regulator

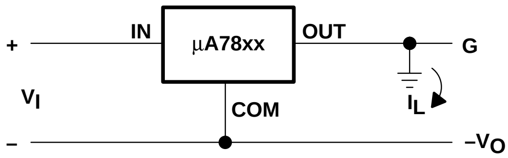
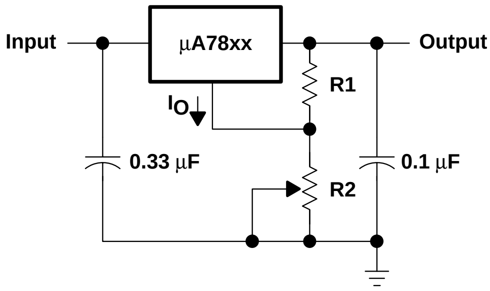


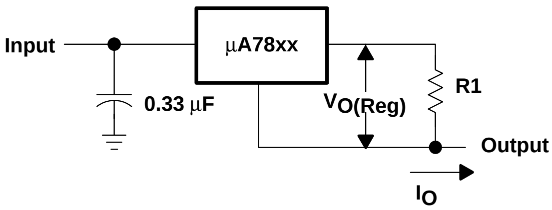
Figure 2. Positive Regulator in Negative Configuration (V_I Must Float)



NOTE A: The following formula is used when V_{XX} is the nominal output voltage (output to common) of the fixed regulator:

$$V_O = V_{xx} + \left(\frac{V_{xx}}{R1} + I_Q\right)R2$$

Figure 3. Adjustable-Output Regulator



$I_O = (V_O/R1) + I_O$ Bias Current

Figure 4. Current Regulator

Triacs sensitive gate

BT136 series E

GENERAL DESCRIPTION

Passivated, sensitive gate triacs in a plastic envelope, intended for use in general purpose bidirectional switching and phase control applications, where high sensitivity is required in all four quadrants.

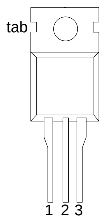
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	MAX.	UNIT
	BT136-	**600E**	**800E**	
V_{DRM}	Repetitive peak off-state voltages	600	800	V
$I_{T(RMS)}$	RMS on-state current	4	4	A
I_{TSM}	Non-repetitive peak on-state current	25	25	A

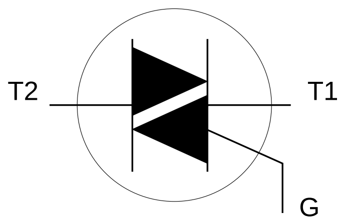
PINNING - TO220AB

PIN	DESCRIPTION
1	main terminal 1
2	main terminal 2
3	gate
tab	main terminal 2

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.		UNIT
				-600	**-800**	
V_{DRM}	Repetitive peak off-state voltages		-	600[1]	800	V
$I_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq 107$ ˚C	-	4		A
I_{TSM}	Non-repetitive peak on-state current	full sine wave; $T_j = 25$ ˚C prior to surge				
		t = 20 ms	-	25		A
		t = 16.7 ms	-	27		A
I^2t	I^2t for fusing	t = 10 ms	-	3.1		A^2s
dI_T/dt	Repetitive rate of rise of on-state current after triggering	$I_{TM} = 6$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/µs				
		T2+ G+	-	50		A/µs
		T2+ G-	-	50		A/µs
		T2- G-	-	50		A/µs
		T2- G+	-	10		A/µs
I_{GM}	Peak gate current		-	2		A
V_{GM}	Peak gate voltage		-	5		V
P_{GM}	Peak gate power		-	5		W
$P_{G(AV)}$	Average gate power	over any 20 ms period	-	0.5		W
T_{stg}	Storage temperature		-40	150		˚C
T_j	Operating junction temperature		-	125		˚C

1 Although not recommended, off-state voltages up to 800V may be applied without damage, but the triac may switch to the on-state. The rate of rise of current should not exceed 3 A/µs.

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$R_{th\ j\text{-}mb}$	Thermal resistance junction to mounting base	full cycle	-	-	3.0	K/W
		half cycle	-	-	3.7	K/W
$R_{th\ j\text{-}a}$	Thermal resistance junction to ambient	in free air	-	60	-	K/W

STATIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

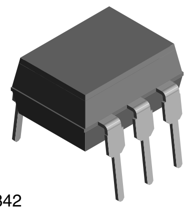
SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{GT}	Gate trigger current	V_D = 12 V; I_T = 0.1 A				
		T2+ G+	-	2.5	10	mA
		T2+ G-	-	4.0	10	mA
		T2- G-	-	5.0	10	mA
		T2- G+	-	11	25	mA
I_L	Latching current	V_D = 12 V; I_{GT} = 0.1 A				
		T2+ G+	-	3.0	15	mA
		T2+ G-	-	10	20	mA
		T2- G-	-	2.5	15	mA
		T2- G+	-	4.0	20	mA
I_H	Holding current	V_D = 12 V; I_{GT} = 0.1 A	-	2.2	15	mA
V_T	On-state voltage	I_T = 5 A	-	1.4	1.70	V
V_{GT}	Gate trigger voltage	V_D = 12 V; I_T = 0.1 A	-	0.7	1.5	V
		V_D = 400 V; I_T = 0.1 A; T_j = 125 ˚C	0.25	0.4	-	V
I_D	Off-state leakage current	$V_D = V_{DRM(max)}$; T_j = 125 ˚C	-	0.1	0.5	mA

DYNAMIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
dV_D/dt	Critical rate of rise of off-state voltage	V_{DM} = 67% $V_{DRM(max)}$; T_j = 125 ˚C; exponential waveform; gate open circuit	-	50	-	V/µs
t_{gt}	Gate controlled turn-on time	I_{TM} = 6 A; $V_D = V_{DRM(max)}$; I_G = 0.1 A; dI_G/dt = 5 A/µs	-	2	-	µs

Optocoupler, Phototransistor Output, with Base Connection



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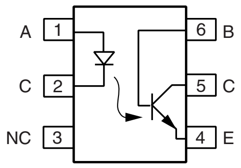

i179004-5

DESCRIPTION

The 4N25 family is an industry standard single channel phototransistor coupler. This family includes the 4N25, 4N26, 4N27, 4N28. Each optocoupler consists of gallium arsenide infrared LED and a silicon NPN phototransistor.

FEATURES

- Isolation test voltage 5000 V_{RMS}
- Interfaces with common logic families
- Input-output coupling capacitance < 0.5 pF
- Industry standard dual-in-line 6 pin package
- Compliant to RoHS directive 2002/95/EC and in accordance to WEEE 2002/96/EC

Pb-free
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RoHS
COMPLIANT

APPLICATIONS

- AC mains detection
- Reed relay driving
- Switch mode power supply feedback
- Telephone ring detection
- Logic ground isolation
- Logic coupling with high frequency noise rejection

AGENCY APPROVALS

- UL1577, file no. E52744
- BSI: EN 60065:2002, EN 60950:2000
- FIMKO: EN 60950, EN 60065, EN 60335

ORDER INFORMATION

PART	REMARKS
4N25	CTR > 20 %, DIP-6
4N26	CTR > 20 %, DIP-6
4N27	CTR > 10 %, DIP-6
4N28	CTR > 10 %, DIP-6

ABSOLUTE MAXIMUM RATINGS (1)

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
INPUT				
Reverse voltage		V_R	5	V
Forward current		I_F	60	mA
Surge current	t ≤ 10 μs	I_{FSM}	3	A
Power dissipation		P_{diss}	100	mW
OUTPUT				
Collector emitter breakdown voltage		V_{CEO}	70	V
Emitter base breakdown voltage		V_{EBO}	7	V
Collector current		I_C	50	mA
	t ≤ 1 ms	I_C	100	mA
Power dissipation		P_{diss}	150	mW

For technical questions, contact: optocoupleranswers@vishay.com
Document Number: 83725
Rev. 1.8, 07-Jan-10

ABSOLUTE MAXIMUM RATINGS (1)				
PARAMETER	**TEST CONDITION**	**SYMBOL**	**VALUE**	**UNIT**
COUPLER				
Isolation test voltage		V_{ISO}	5000	V_{RMS}
Creepage distance			≥ 7	mm
Clearance distance			≥ 7	mm
Isolation thickness between emitter and detector			≥ 0.4	mm
Comparative tracking index	DIN IEC 112/VDE 0303, part 1		175	
Isolation resistance	V_{IO} = 500 V, T_{amb} = 25 °C	R_{IO}	10^{12}	Ω
	V_{IO} = 500 V, T_{amb} = 100 °C	R_{IO}	10^{11}	Ω
Storage temperature		T_{stg}	- 55 to + 125	°C
Operating temperature		T_{amb}	- 55 to + 100	°C
Junction temperature		T_j	125	°C
Soldering temperature (2)	max.10 s dip soldering: distance to seating plane ≥ 1.5 mm	T_{sld}	260	°C

Notes

(1) T_{amb} = 25 °C, unless otherwise specified.
Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operational sections of this document. Exposure to absolute maximum ratings for extended periods of the time can adversely affect reliability.

(2) Refer to reflow profile for soldering conditions for surface mounted devices (SMD). Refer to wave profile for soldering condditions for through hole devices (DIP).

ELECTRICAL CHARACTERISTICS (1)							
PARAMETER	**TEST CONDITION**	**PART**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
INPUT							
Forward voltage (2)	I_F = 50 mA		V_F		1.3	1.5	V
Reverse current (2)	V_R = 3 V		I_R		0.1	100	µA
Capacitance	V_R = 0 V		C_O		25		pF
OUTPUT							
Collector base breakdown voltage (2)	I_C = 100 µA		BV_{CBO}	70			V
Collector emitter breakdown voltage (2)	I_C = 1 mA		BV_{CEO}	30			V
Emitter collector breakdown voltage (2)	I_E = 100 µA		BV_{ECO}	7			V
I_{CEO}(dark) (2)	V_{CE} = 10 V, (base open)	4N25			5	50	nA
		4N26			5	50	nA
		4N27			5	50	nA
		4N28			10	100	nA
I_{CBO}(dark) (2)	V_{CB} = 10 V, (emitter open)				2	20	nA
Collector emitter capacitance	V_{CE} = 0		C_{CE}		6		pF
COUPLER							
Isolation test voltage (2)	Peak, 60 Hz		V_{IO}	5000			V
Saturation voltage, collector emitter	I_{CE} = 2 mA, I_F = 50 mA		$V_{CE(sat)}$			0.5	V
Resistance, input output (2)	V_{IO} = 500 V		R_{IO}	100			GΩ
Capacitance, input output	f = 1 MHz		C_{IO}		0.6		pF

Notes

(1) T_{amb} = 25 °C, unless otherwise specified.
Minimum and maximum values are testing requirements. Typical values are characteristics of the device and are the result of engineering evaluation. Typical values are for information only and are not part of the testing requirements.

(2) JEDEC registered values are 2500 V, 1500 V, 1500 V, and 500 V for the 4N25, 4N26, 4N27, and 4N28 respectively.

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MOC3021
MOC3022
MOC3023

6-Pin DIP Random-Phase Optoisolators Triac Driver Output
(400 Volts Peak)

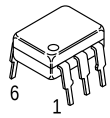
The MOC3020 Series consists of gallium arsenide infrared emitting diodes, optically coupled to a silicon bilateral switch.

- ***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.***

They are designed for applications requiring isolated triac triggering.

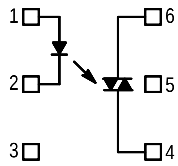
Recommended for 115/240 Vac(rms) Applications:

- Solenoid/Valve Controls
- Lamp Ballasts
- Interfacing Microprocessors to 115 Vac Peripherals
- Motor Controls
- Static ac Power Switch
- Solid State Relays
- Incandescent Lamp Dimmers



STANDARD THRU HOLE

SCHEMATIC



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

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
INFRARED EMITTING DIODE			
Reverse Voltage	V_R	3	Volts
Forward Current — Continuous	I_F	60	mA
Total Power Dissipation @ T_A = 25°C Negligible Power in Triac Driver Derate above 25°C	P_D	100 1.33	mW mW/°C
OUTPUT DRIVER			
Off–State Output Terminal Voltage	V_{DRM}	400	Volts
Peak Repetitive Surge Current (PW = 1 ms, 120 pps)	I_{TSM}	1	A
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 4	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	330 4.4	mW mW/°C
Junction Temperature Range	T_J	–40 to +100	°C
Ambient Operating Temperature Range	T_A	–40 to +85	°C
Storage Temperature Range	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.

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

Characteristic	Symbol	Min	Typ	Max	Unit
INPUT LED					
Reverse Leakage Current (V_R = 3 V)	I_R	—	0.05	100	μA
Forward Voltage (I_F = 10 mA)	V_F	—	1.15	1.5	Volts
OUTPUT DETECTOR (I_F = 0 unless otherwise noted)					
Peak Blocking Current, Either Direction (Rated V_{DRM}(1))	I_{DRM}	—	10	100	nA
Peak On–State Voltage, Either Direction (I_{TM} = 100 mA Peak)	V_{TM}	—	1.8	3	Volts
Critical Rate of Rise of Off–State Voltage (Figure 7, Note 2)	dv/dt	—	10	—	V/μs
COUPLED					
LED Trigger Current, Current Required to Latch Output (Main Terminal Voltage = 3 V(3))	I_{FT}				mA
MOC3021		—	8	15	
MOC3022		—	—	10	
MOC3023		—	—	5	
Holding Current, Either Direction	I_H	—	100	—	μA

1. Test voltage must be applied within dv/dt rating.
2. This is static dv/dt. See Figure 7 for test circuit. Commutating dv/dt is a function of the load–driving thyristor(s) only.
3. 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 MOC3021, 10 mA for MOC3022, 5 mA for MOC3023) and absolute max I_F (60 mA).

TYPICAL ELECTRICAL CHARACTERISTICS

T_A = 25°C

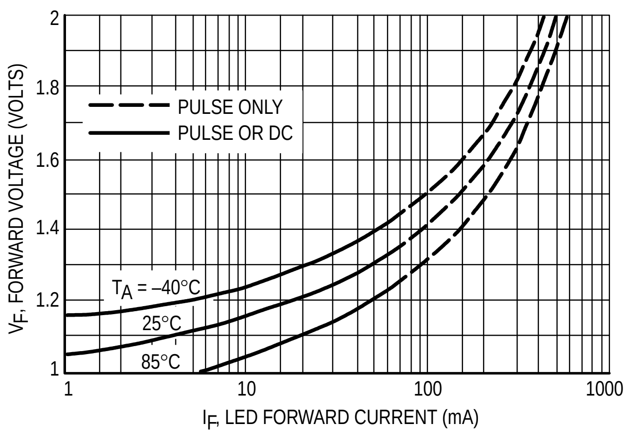


Figure 1. LED Forward Voltage versus Forward Current

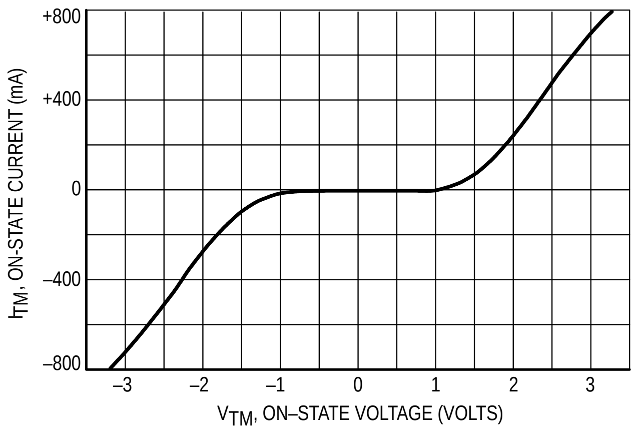


Figure 2. On–State Characteristics

FAIRCHILD

August 2015

MOC3031M, MOC3032M, MOC3033M, MOC3041M, MOC3042M, MOC3043M 6-Pin DIP Zero-Cross Triac Driver Output Optocoupler (250/400 Volt Peak)

Features

- Simplifies Logic Control of 115 VAC Power
- Zero Voltage Crossing
- dv/dt of 2000 V/µs Typical, 1000 V/µs Guaranteed
- Peak Blocking Voltage
  - 250 V, MOC303XM
  - 400 V, MOC304XM
- Safety and Regulatory Approvals
  - UL1577, 4,170 VAC_{RMS} for 1 Minute
  - DIN EN/IEC60747-5-5

Applications

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

Description

The MOC303XM and MOC304XM devices consist of a GaAs infrared emitting diode optically coupled to a monolithic silicon detector performing the function of a zero voltage crossing bilateral triac driver.

They are designed for use with a triac in the interface of logic systems to equipment powered from 115 VAC lines, such as teletypewriters, CRTs, solid-state relays, industrial controls, printers, motors, solenoids and consumer appliances, etc.

Schematic

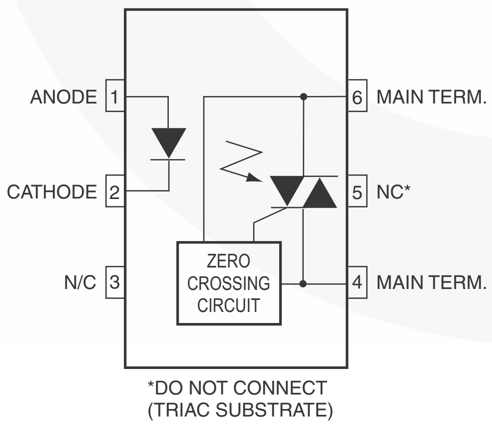


Figure 1. Schematic

Package Outlines

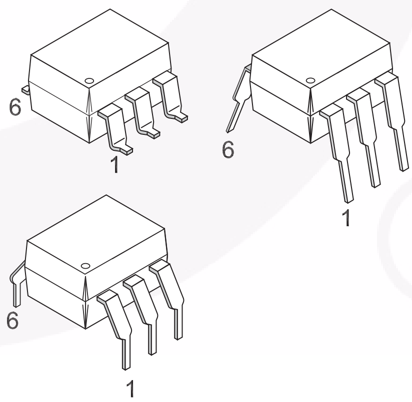


Figure 2. Package Outlines

Safety and Insulation Ratings

As per DIN EN/IEC 60747-5-5, this optocoupler is suitable for "safe electrical insulation" only within the safety limit data. Compliance with the safety ratings shall be ensured by means of protective circuits.

Parameter		Characteristics
Installation Classifications per DIN VDE 0110/1.89 Table 1, For Rated Mains Voltage	< 150 V_{RMS}	I–IV
	< 300 V_{RMS}	I–IV
Climatic Classification		40/85/21
Pollution Degree (DIN VDE 0110/1.89)		2
Comparative Tracking Index		175

Symbol	Parameter	Value	Unit
V_{PR}	Input-to-Output Test Voltage, Method A, V_{IORM} x 1.6 = V_{PR}, Type and Sample Test with t_m = 10 s, Partial Discharge < 5 pC	1275	V_{peak}
	Input-to-Output Test Voltage, Method B, V_{IORM} x 1.875 = V_{PR}, 100% Production Test with t_m = 1 s, Partial Discharge < 5 pC	1594	V_{peak}
V_{IORM}	Maximum Working Insulation Voltage	850	V_{peak}
V_{IOTM}	Highest Allowable Over-Voltage	6000	V_{peak}
	External Creepage	≥ 7	mm
	External Clearance	≥ 7	mm
	External Clearance (for Option TV, 0.4" Lead Spacing)	≥ 10	mm
DTI	Distance Through Insulation (Insulation Thickness)	≥ 0.5	mm
R_{IO}	Insulation Resistance at T_S, V_{IO} = 500 V	> 10^9	Ω

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. T_A = 25°C unless otherwise specified.

Symbol	Parameters	Device	Value	Unit
TOTAL DEVICE				
T_{STG}	Storage Temperature	All	-40 to +150	°C
T_{OPR}	Operating Temperature	All	-40 to +85	°C
T_J	Junction Temperature Range	All	-40 to +100	°C
T_{SOL}	Lead Solder Temperature	All	260 for 10 seconds	°C
P_D	Total Device Power Dissipation at 25°C Ambient	All	250	mW
	Derate Above 25°C		2.94	mW/°C
EMITTER				
I_F	Continuous Forward Current	All	60	mA
V_R	Reverse Voltage	All	6	V
P_D	Total Power Dissipation at 25°C Ambient	All	120	mW
	Derate Above 25°C		1.41	mW/°C
DETECTOR				
V_{DRM}	Off-State Output Terminal Voltage	MOC3031M MOC3032M MOC3033M	250	V
		MOC3041M MOC3042M MOC3043M	400	
I_{TSM}	Peak Repetitive Surge Current (PW = 100 µs, 120 pps)	All	1	A
P_D	Total Power Dissipation at 25°C Ambient	All	150	mW
	Derate Above 25°C		1.76	mW/°C

Electrical Characteristics

T_A = 25°C unless otherwise specified.

Individual Component Characteristics

Symbol	Parameters	Test Conditions	Device	Min.	Typ.	Max.	Unit
EMITTER							
V_F	Input Forward Voltage	I_F = 30 mA	All		1.25	1.50	V
I_R	Reverse Leakage Current	V_R = 6 V	All		0.01	100	µA
DETECTOR							
I_{DRM1}	Peak Blocking Current, Either Direction	Rated V_{DRM}, $I_F = 0^{(1)}$	All			100	nA
V_{TM}	Peak On-State Voltage, Either Direction	I_{TM} = 100 mA peak, I_F = 0	All		1.8	3.0	V
dv/dt	Critical Rate of Rise of Off-State Voltage	I_F = 0 (Figure 11)$^{(2)}$	All	1000	2000		V/µs

Transfer Characteristics

Symbol	DC Characteristics	Test Conditions	Device	Min.	Typ.	Max.	Unit
I_{FT}	LED Trigger Current	Main Terminal Voltage = 3 V$^{(3)}$	MOC3031M MOC3041M			15	mA
			MOC3032M MOC3042M			10	
			MOC3033M MOC3043M			5	
I_H	Holding Current, Either Direction		All		400		µA

Zero Crossing Characteristics

Symbol	Characteristics	Test Conditions	Device	Min.	Typ.	Max.	Unit
V_{IH}	Inhibit Voltage	I_F = rated I_{FT}, MT1-MT2 voltage above which device will not trigger off-state	All			20	V
I_{DRM2}	Leakage in Inhibited State	I_F = rated I_{FT}, rated V_{DRM} off-state	All			2	mA

Isolation Characteristics

Symbol	Parameter	Test Conditions	Device	Min.	Typ.	Max.	Unit
V_{ISO}	Isolation Voltage$^{(4)}$	t = 1 Minute	All	4170			VAC_{RMS}

Notes:

1. Test voltage must be applied within dv/dt rating.
2. This is static dv/dt. See Figure 11 for test circuit. Commutating dv/dt is a function of the load-driving thyristor(s) only.
3. 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 MOC3031M and MOC3041M, 10 mA for MOC3032M and MOC3042M, 5 mA for MOC3033M and MOC3043M) and absolute maximum I_F (60 mA).
4. Isolation 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.

Swanav_cap_v2

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