BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

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Power Electronics Laboratory

Final Project Report

Section: B1 Group: 01

Phase Angle Control Method of Power Regulation Using TRIAC

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1. Abstract

AC phase angle control is a technique used to control the amount of power delivered to a load by adjusting the phase angle of the AC waveform. This technique is commonly used to control the characteristics of the load, such as speed of fans and intensity of lights by varying the amount of power delivered to the load.
In phase angle control, thyristors are used to selectively pass only a part of each AC cycle through to the load. By controlling the phase angle or trigger angle, the output RMS voltage of the load can be varied. This method is also known as AC power regulation via phase angle control. Our project proposes a method of triggering the gate of thyristor and a method of controlling it without using microcontroller. Using generic components, a method compatible to different operating frequency is simulated and verified. A 555 timer is operated by feeding the voltage output from e zero crossing detector circuit to create pulses of different duty cycle followed by fine amplification and gate driver circuit to trigger the thyristor. This method removes the use of additional control mechanism used by software and proposes a manual control over the power regulation that is used to control different aspects of loads.

2. Introduction

The main objectives of this project are:
1. To generate a gate pulse to drive a TRIAC without Arduino.
2. To control a gate pulse to cut the desired amount of phase angle of an ac wave of a load.

And we have four stages of circuit/design to achieve our goals. They are:
1. Zero crossing detector circuit by an optocoupler.
2. Pulse generating circuit by a 555 timer.
3. Inverting amplifier circuit by a BJT.
4. Phase controlling circuit with TRIAC driver (optocoupler) and TRIAC.

Among them, first three of them is for generating a gate pulse to drive the TRIAC for chopping an ac wave. This is most complicated part of our project to generate and calibrate a gate pulse with proper amplitude and frequency without the use of a microcontroller.

Alternative Solutions:

1. We can use unidirectional switching device as a bidirectional switch instead of TRIAC.
2. Arduino could be used to generate a PWM and drive the TRIAC.
   Astable/bistable configuration could also be used instead of monostable configuration keeping the frequency same.

3. Design

3.1 Problem Formulation

Design Components:

1. Breadboard
2. Jumper Wire
3. Diode D1N4007
4. Resistors: 47, 100, 470, 1k, 10k
5. Potentiometer: 20k
6. Capacitors: 0.01 μF, 0.1 μF
7. Optocoupler: PC 817, MOC 3021
8. 555 Timer NE555
9. TRIAC BTA-12 600B
10. Veroboard
11. Stapler Wire

3.1.1 Identification of Scope

Scope means goals, objectives, planning and opportunities that we will implement. So, here we write them elaborately.

Objectives:

1. To generate a gate pulse to drive a TRIAC without Arduino.
2. To control a gate pulse to cut the desired amount of phase angle of an ac wave of a load.

Planning:

1. Zero crossing detector circuit by an optocoupler.
2. Pulse generating circuit by a 555 timer.
3. Inverting amplifier circuit by a BJT.
4. Phase controlling circuit with TRIAC driver (optocoupler) and TRIAC.

Opportunities:

1. Energy efficiency can be increased by this project by a large-scale implementation.
2. Source and load can be rated with different ratings.
3. Losses can be minimized.
4. Power utilization can be maximized.

3.1.2 Literature Review

Literature review means identifying the main points/objectives of any project and provide own thinking/idea/innovation/opinion adjacent to it.

Objectives:

1. To generate a gate pulse to drive a TRIAC without Arduino.
2. To control a gate pulse to cut the desired amount of phase angle of an ac wave of a load.

Basic planning of these objectives:

1. Zero crossing detector circuit by an optocoupler.
2. Pulse generating circuit by a 555 timer.
3. Inverting amplifier circuit by a BJT.
4. Phase controlling circuit with TRIAC driver (optocoupler) and TRIAC.

Our own thoughts and opinion:

1. Applying a low pass filter at the load end could reduce the harmonics of the chopped ac wave and improve the power factor.
2. Applying the collector output of the BJT used in our project could also be used as a gate pulse directly.
3. Though our project could not use the main ac supply of 220 Volt 50 Hz, but it could be designed for this case with power diodes, BJT and resistors to supply the load to an adequate amount of energy.
4. Our project can also be designed for speed control of motor, intensity control of light, control as a regulator and other load requirements can be satisfied by adjusting the potentiometer we used here.

3.1.3 Formulation of Problem

Our problem can be divided into four major portions:

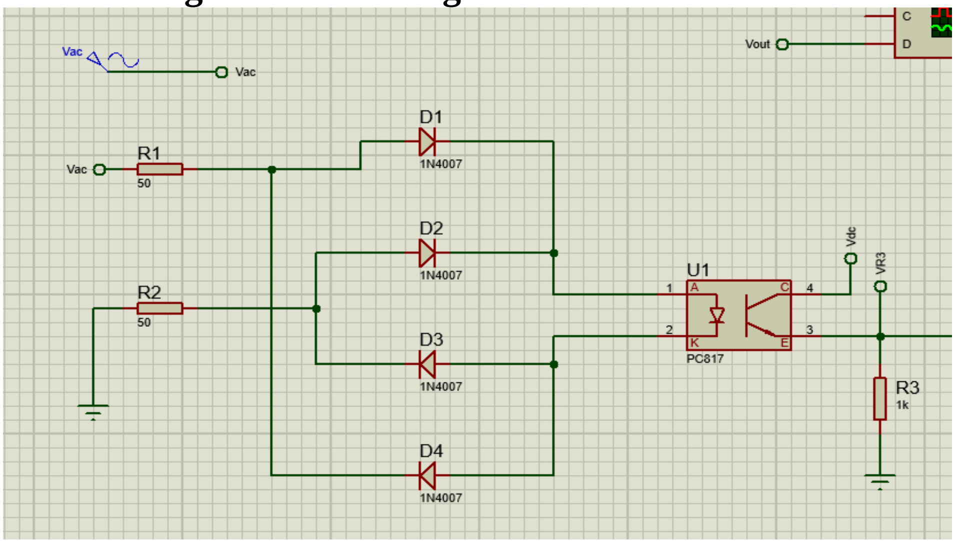
1. Producing a zero-crossing detecting pulse with FWR and optocoupler to store the information of the original ac wave frequency and to produce the gate pulse in both positive and negative cycle.
2. Generating a gate pulse from zero degree to a certain amount of angle from zero crossing pulse.
3. Amplifying and inverting the low amplitude 555 timer pulse with BJT.
4. Driving the TRIAC with this amplified pulse to generate chopped ac wave according to requirement.

3.1.4 Analysis

1. 10k resistors were used between the source and FWR at first which caused a huge voltage drop. That's why it was replaced by 50Ω resistor.
2. The amplitude of the input ac wave was adjusted in different blocks of our designed circuit and finally settled down to a value of 20V peak to peak.
3. The frequency of the input ac wave was adjusted in different blocks of our designed circuit to see the various output waveforms accurately.
4. Though the initial output across the load could be distorted after complete connection of oscilloscope, the adjustment of the potentiometer connected at pin no 6 of the 555 timer will produce the expected output gradually.

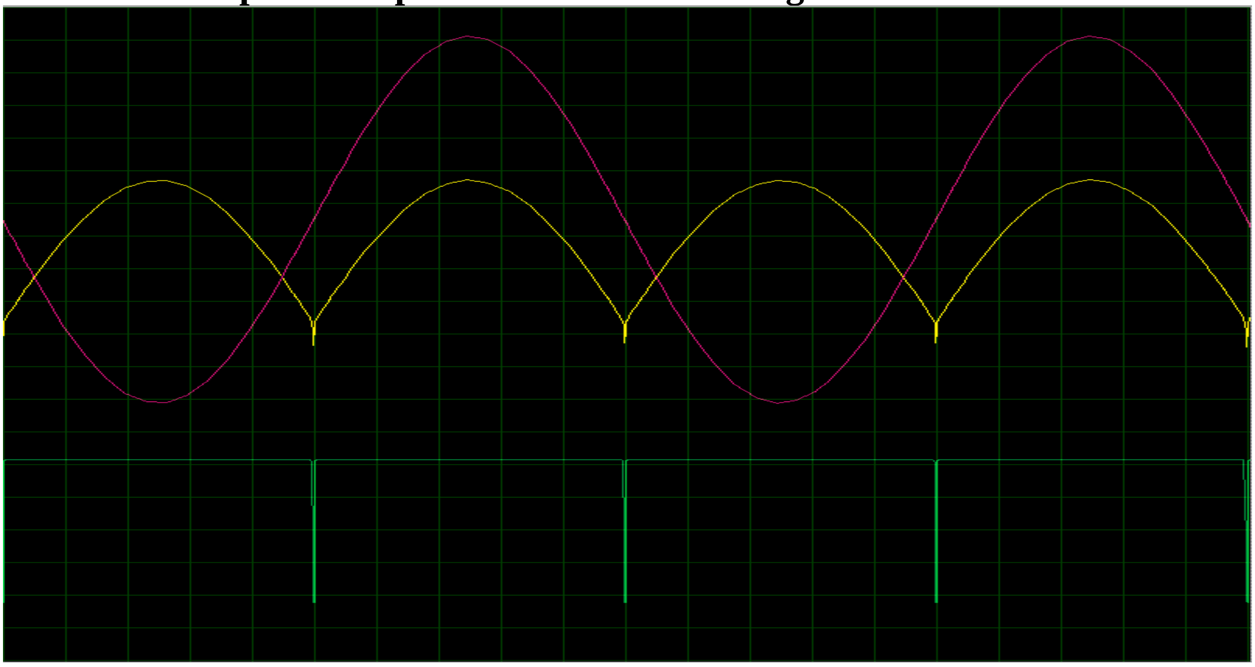
4.1 Design Method

Design and working of zero crossing detector:



Here, in this figure the four diodes constitute a full wave rectifier circuit to rectify the input ac wave. This rectified output is fed to the input terminal of an optocoupler PC 817.
Working of PC 817:
The input terminals of PC 817 are connected to a light emitting diode LED and output terminals are connected with a photo transistor with the base terminal open.
When the diode is forward biased, it emits light which triggers the base of the BJT and it conducts the collector as well as emitter current so that we get voltage across the resistor which is logic high.
When the diode is reverse biased, it does not emit any light. That's why the base terminal of the photo BJT remains open and it goes to cutoff mode. That's why voltage across the resistor becomes zero which is logic low. That's how it creates a square wave signal.

Simulation output for explanation of zero crossing detection:



The pink output is input ac, yellow output is voltage across pin 1 and 2 of the optocoupler, the green one is the output voltage across R3 resistor.

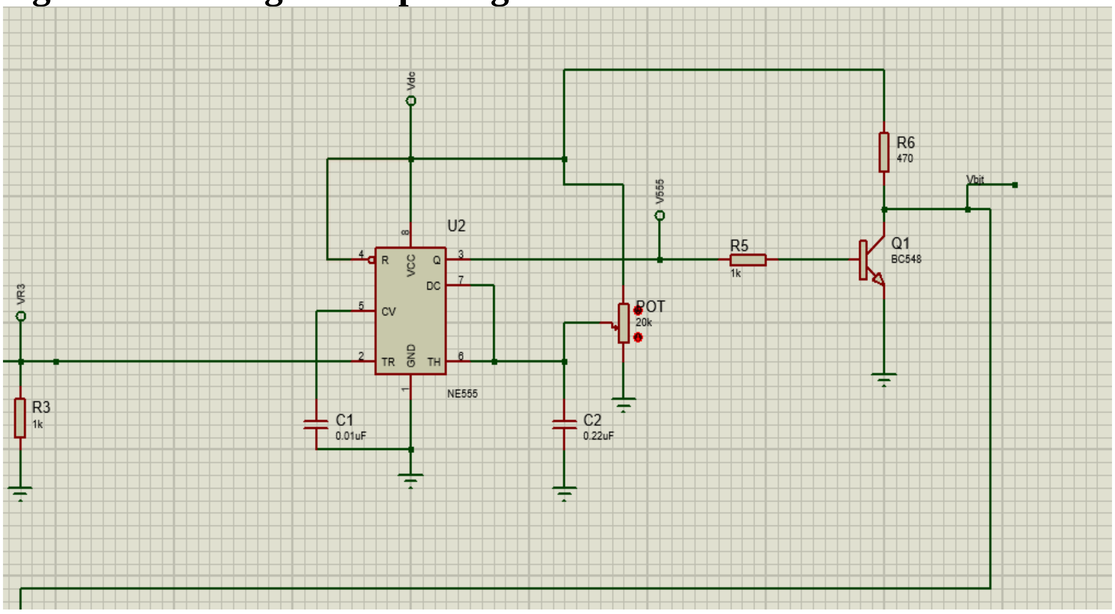
We can see that, input voltage of optocoupler is high above 0.7V and low below 0.7V. When input is high, LED is forward biased and we get high voltage across R3 resistor. When input is low, LED is reverse biased
and output is logic low.
And range of 0 to 0.7V region is the off period for the output voltage where it goes below/off/low state. As this transition period of 0 to 0.7 volt is very short with respect to total period, that's why the output voltage seems zero crossing low voltage detector. (But, actually it detects the range of 0 to 0.7V and vice versa)

Reasons for using PC 817:

1. To store the information of input frequency.
2. The optocoupler is not used here for ground isolation. If we directly connect the FWR output terminal (pin 1 or pin 2 of optocoupler) with a BJT, then it would become shorted and the photo transistor would remain in either cutoff or saturation region forever. There would no transition region.
3. That's why to have a transition period around zero (from 0 to 0.7),
   we used a LED (inside optocoupler) to utilize the bias transition of diode as the control signal of BJT on-off period to get zero crossing pulse signal.

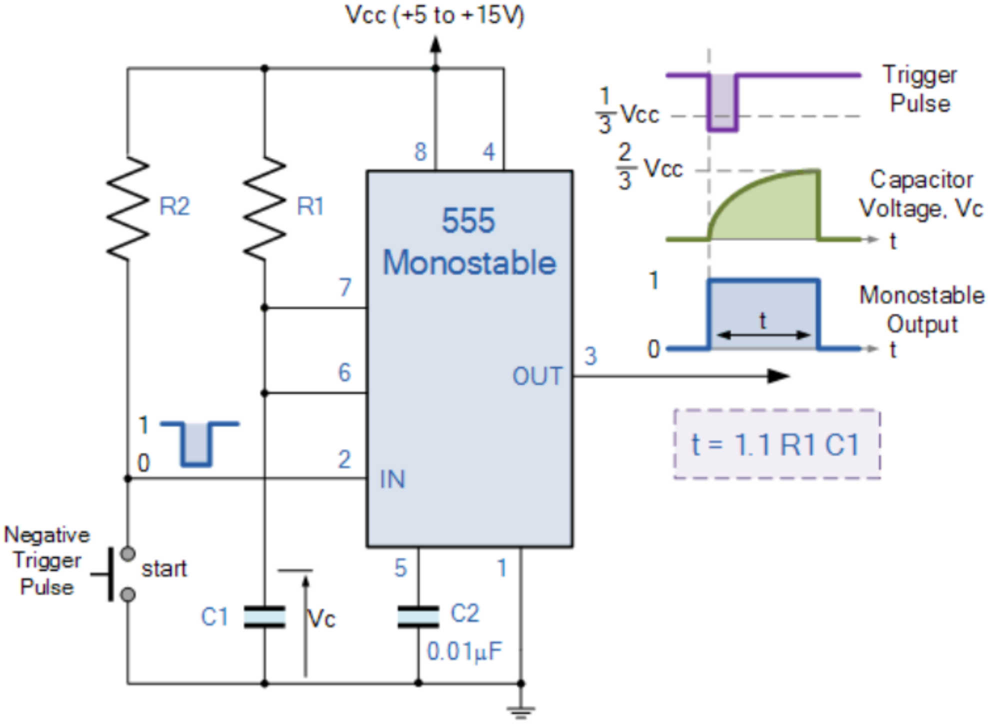
4. To provide electrical isolation and optical connection.

Design and working of 555 pulse generator:



Here, the zero crossing detector signal from R3 is fed to the trigger pin of 555 timer IC which is configured in monostable mode.

Working of 555 timer in monostable mode:



When a negative (0V) pulse is applied to the trigger input (pin 2) of the Monostable configured 555 Timer oscillator, the internal comparator, (comparator No1) detects this input and "sets" the state of the flip-flop, changing the output from a "LOW" state to a "HIGH" state. This action in turn turns "OFF" the discharge transistor connected to pin 7, thereby removing the short circuit across the external timing capacitor, C1.

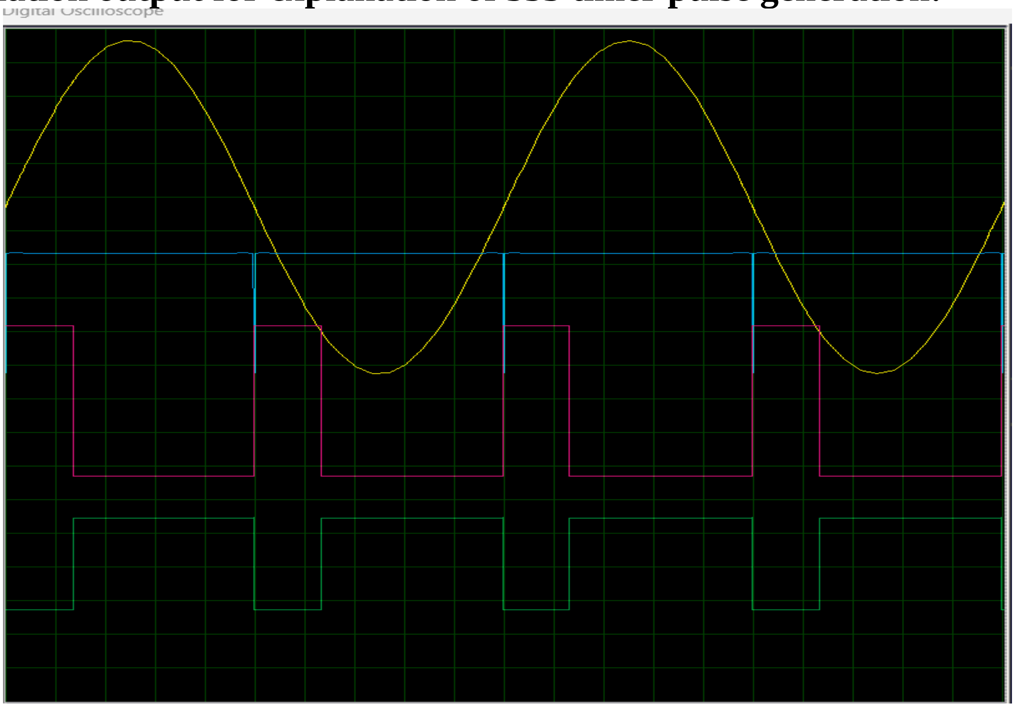
This action allows the timing capacitor to start to charge up through resistor, R1 until the voltage across the capacitor reaches the threshold (pin 6) voltage of 2/3Vcc set up by the internal voltage divider network. At this point the comparators output goes “HIGH” and “resets” the flip-flop back to its original state which in turn turns “ON” the transistor and discharges the capacitor to ground through pin 7. This causes the output to change its state back to the original stable “LOW” value awaiting another trigger pulse to start the timing process over again. Then as before, the Monostable Multivibrator has only “ONE” stable state.

The Monostable 555 Timer circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this “HIGH” unstable output state until the time period set up by the R1 x C1 network has elapsed. The amount of time that the output voltage remains “HIGH” or at a logic “1” level, is given by the following time constant equation.

$$\tau = 1.1 R_1 C_1$$

Where, t is in seconds, R is in Ω and C in Farads.

Simulation output for explanation of 555 timer pulse generation:



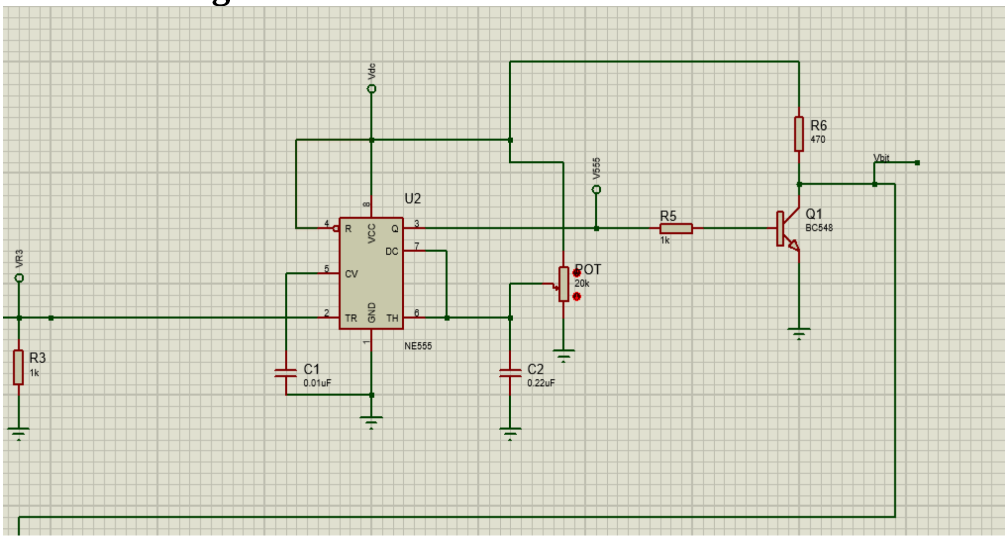
Yellow one=input ac, blue one=zero crossing signal, pink one=output of 555 timer, green one=output of BJT

As we explained before in monostable mode, when the trigger pulse get lowered, the output at pin 3 goes from high to low value and again returns to it’s initial position after a certain amount of time period set by the resistor and capacitor connected to pin 6 of the 555 timer.

Reasons for using 555:

1. To generate a pulse from zero crossing to a certain angle keeping the source frequency same.
2. To produce the gate pulse for TRIAC.

Design and working of BJT:

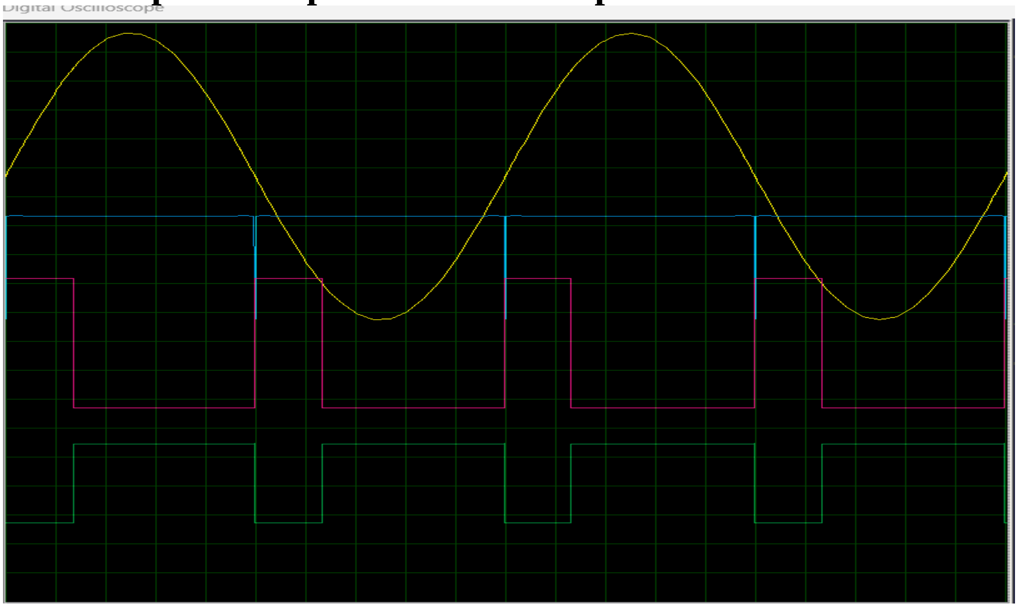


Here, output from 555 timer is fed to the base of the BJT to amplify the signal generated by 555 so that it gets strengthened.

Working of BJT

1. Amplifies the current from base.
2. Amplifies the base input ac voltage.
3. Reverses the state of the input pulse as the BJT is configured in CE configuration.

Simulation output for explanation BJT amplification:



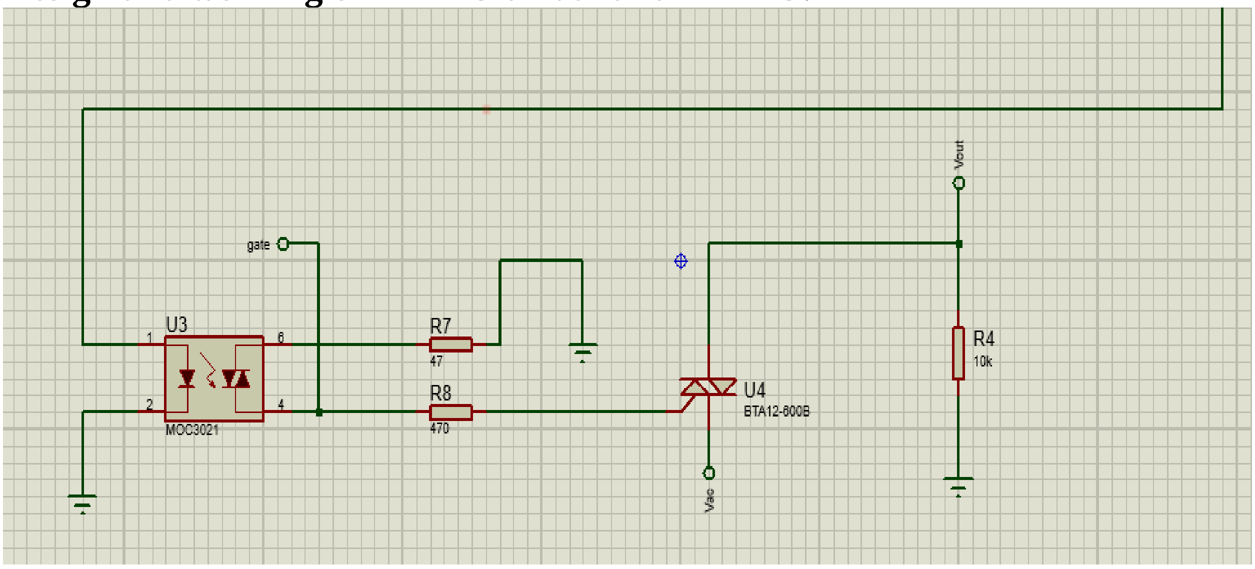
Yellow one=input ac, blue one=zero crossing signal, pink one=output of 555 timer, green one=output of BJT.

As we can see from the figure, output of BJT is flipped of that of 555 and amplified.

Reasons for using BJT:

1. Amplification.
2. Inversion. The purpose of inversion is that we want to turn off the gate pulse from zero to a certain firing angle. But if we keep logic high from zero to that angle, then the TRIAC will be turned on from the beginning. That's why we need to flip that signal so that it remains off from zero to firing angle and starts conducting after that firing angle.

Design and working of TRIAC driver and TRIAC:

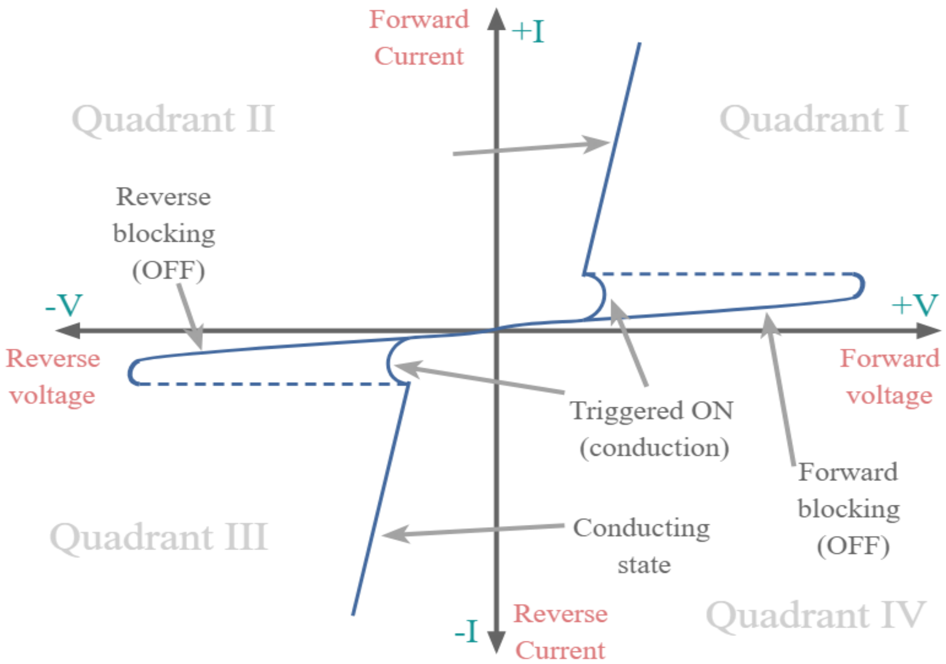


Here, the inverted amplified output of BJT is fed to the input of another optocoupler BTA12-600B and ultimate gate pulse is produced at the output of the optocoupler which is then used to chop the main ac signal.

Working of TRIAC Driver and TRIAC:

The MOC3021 comes in an internal light-emitting diode and a TRIAC based light activating based transistor. This optocoupler provides protection from HIGH resistive and inductive loads. It has the ability to flow the current up to 1A. MOC3021 Optocoupler works on the IR based and it keeps any kind of current flowing towards the circuit. The optocoupler comes only in one package but the single package could be used with any circuit. In HIGH load the operating temperature always affects the circuit performance, but MOC3021 has the ability to operate in HIGH temperature and it also increases the optocoupler life.

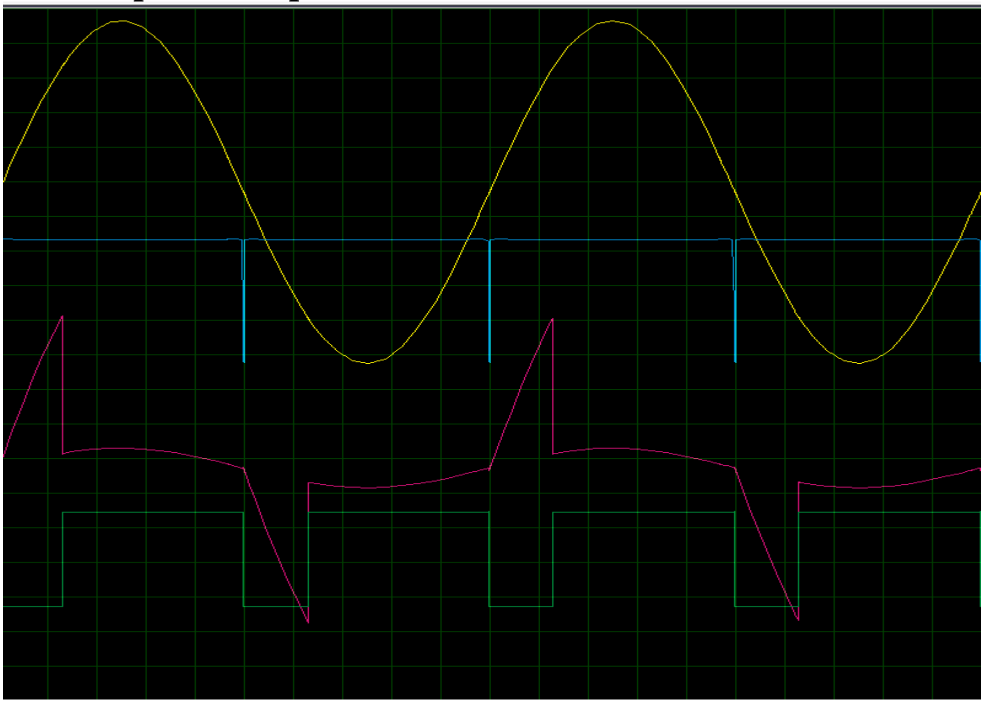
The MOC3021 is a Non-Zero Crossing optocoupler. The other optocoupler only gives the output only gives magnitude at zero but non-zero optocoupler gives the magnitude at different levels from zero to maximum. This ability of optocoupler not only allow the device to control the output as a switch, but it also allows the device to be controlled at different levels, that is the reason in IOT the optocoupler MOC3021 used in a circuit to control the Motor speed, Heater temperature, etc.



IV characteristics curve of TRIAC

TRIAC turns on when it will have both gate pulse and positive anode to cathode voltage. On it gets on, it will remain in on state until the voltage across anode to cathode becomes zero.
When the voltage from anode to cathode is negative and if another gate pulse is applied to the TRIAC, then again it will be activated to conduct until and unless the anode to cathode voltage again becomes zero.

Simulation output for explanation TRIAC driver and TRIAC:



Yellow=input ac
Blue=zero crossing signal
Pink=output of the optocoupler
Green=output of BJT/input of the optocoupler

Reasons for using TRIAC driver:

1. To provide electrical isolation.
2. To further amplify BJT output.
3. The internal TRIAC of MOC3021 can be used to drive higher rating TRIAC BTA12-600B.

Reasons for using TRIAC:

1. Provides bidirectional switching. So, the output remains ac.
2. The activating gate pulse need not to be given all the time. A small width pulse is given once for activation and don't need to be further until it becomes off again.
3. Less switching loss than other semiconductor devices in bidirectional mode.

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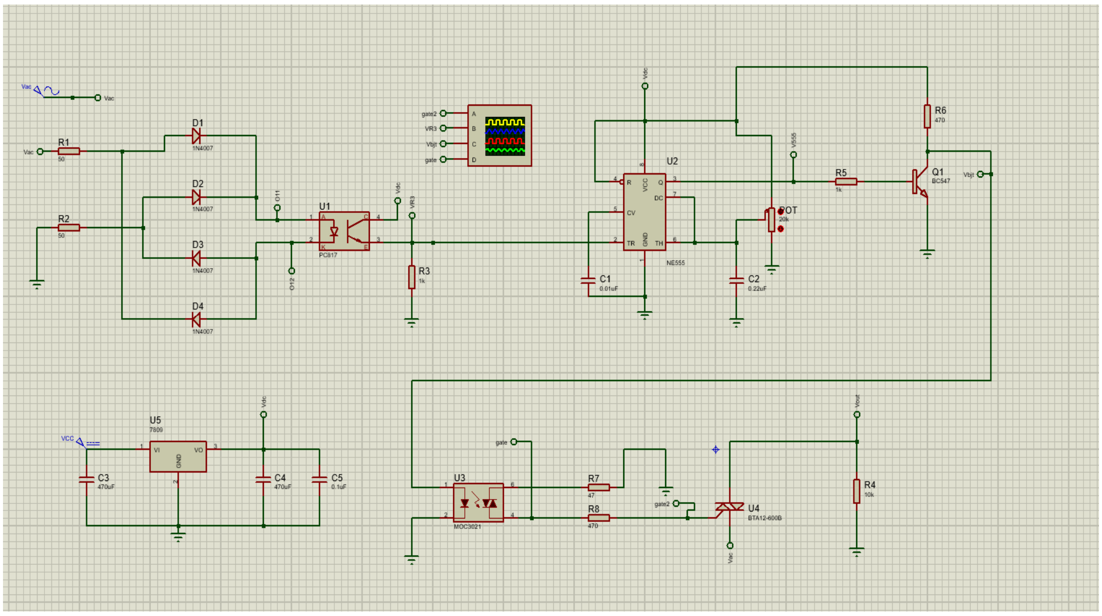
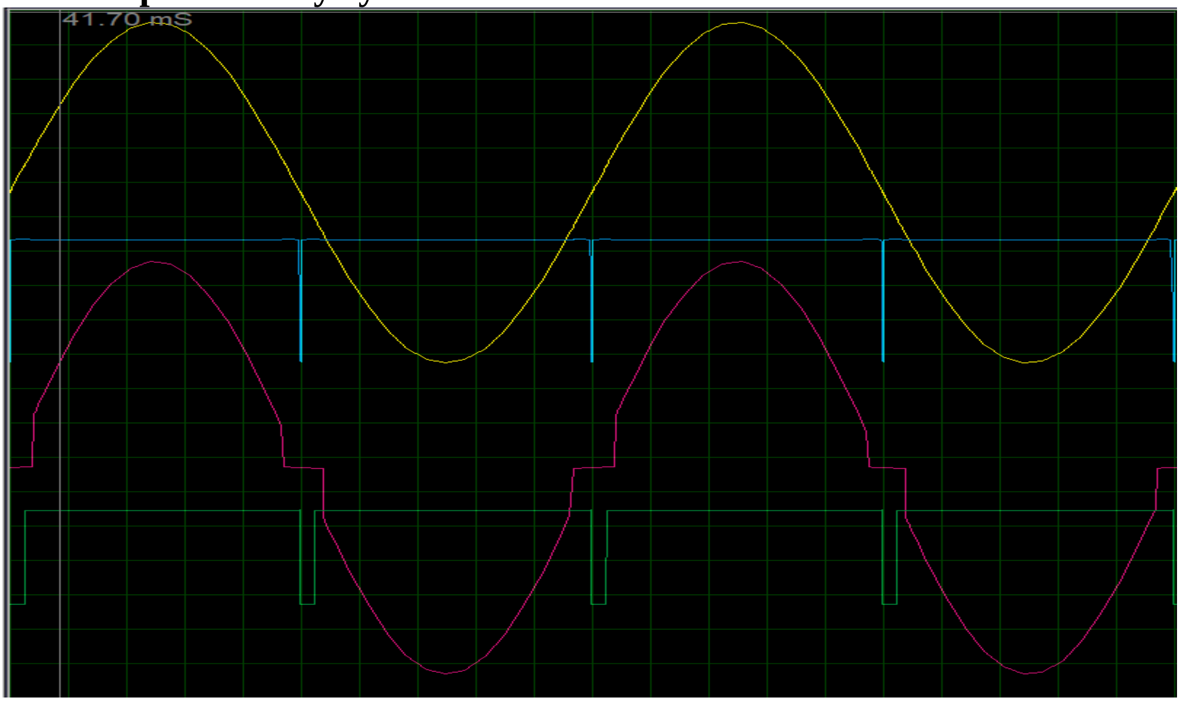
4.2 Circuit Diagram



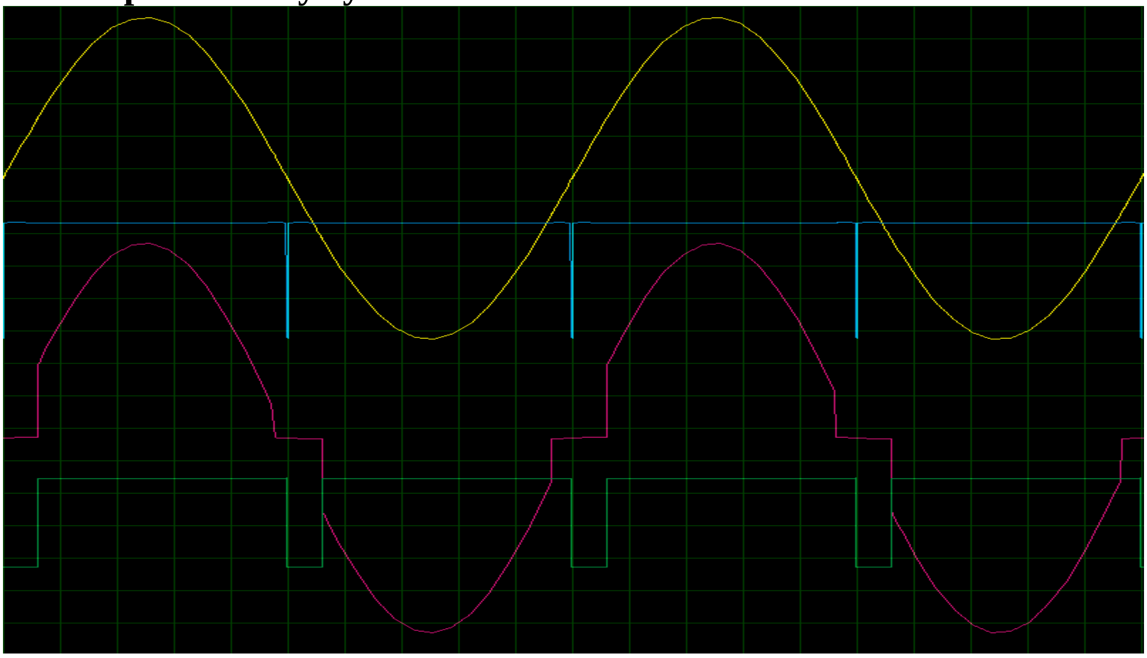
4.3 Simulation Model

Though the simulation of different blocks are already explained before, now we'll see the control mechanism of firing angle by changing the duty cycle via potentiometer.

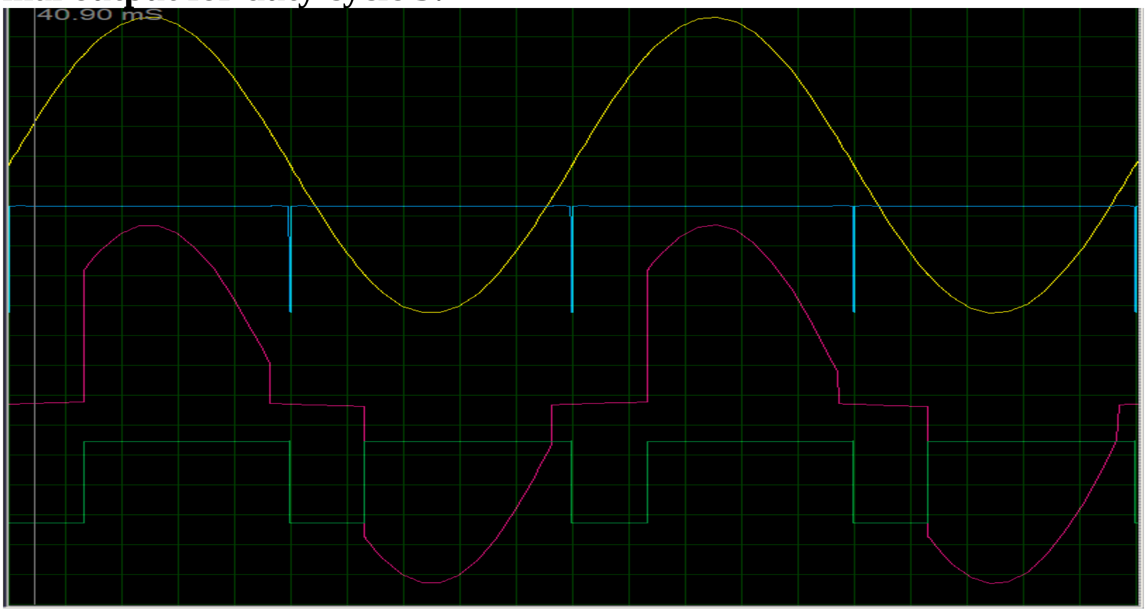
Final output for duty cycle 1:



Final output for duty cycle 2:



Final output for duty cycle 3:



Now, we'll see how to make a certain firing angel:

Let us say, we want $\alpha=30^o$,
As the 555 timer pulse is flipped by the BJT, that's why we'll consider the on time of the output of 555 as the firing angle starting period.
Again, we let $V_{in}=V_m\sin(\omega t)$,
So, we have $\omega t=30^o$, where $\omega=2\pi f=2*\pi*50$

$=>100\pi t=30*(\pi/180)$

$=>t=(1/600)s$

$=>1.1RC=(1/600)$ and here $C=0.22u$

$=> 1.1*R*0.22u=(1/600)$

$=> R=6.8k$

That's how by putting 6.8k fixed resistor in place of potentiometer, we can create a firing angle of 30^o
Similarly, we can create any firing angle upto 180^o. Firing angle cannot be more than 180 degree because the frequency of the zero-crossing signal is twice the input frequency which means 180 degree angle is the 100% duty cycle here.

5. Implementation

5.1 Description

The hardware implementation of the project was done according to our simulation schematic file.

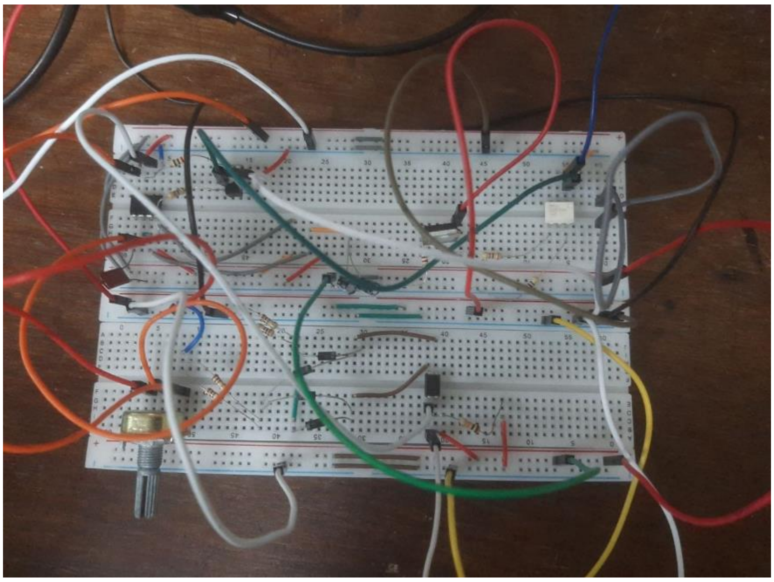


Fig. Hardware implementation

Also, a Veroboard implementation was also done for better portability and compactness of the system.

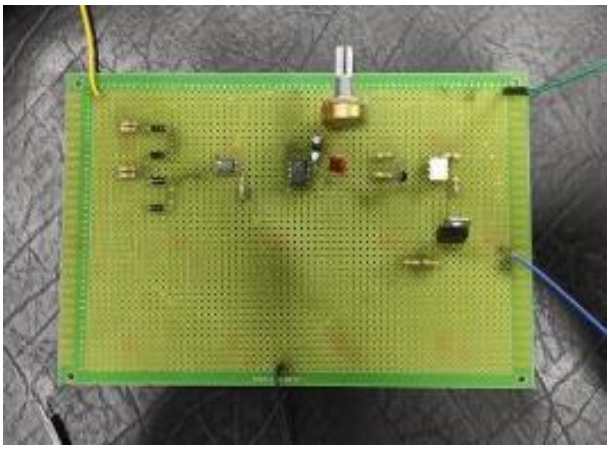


Fig. Veroboard implementation

5.2 Experiment and Data Collection

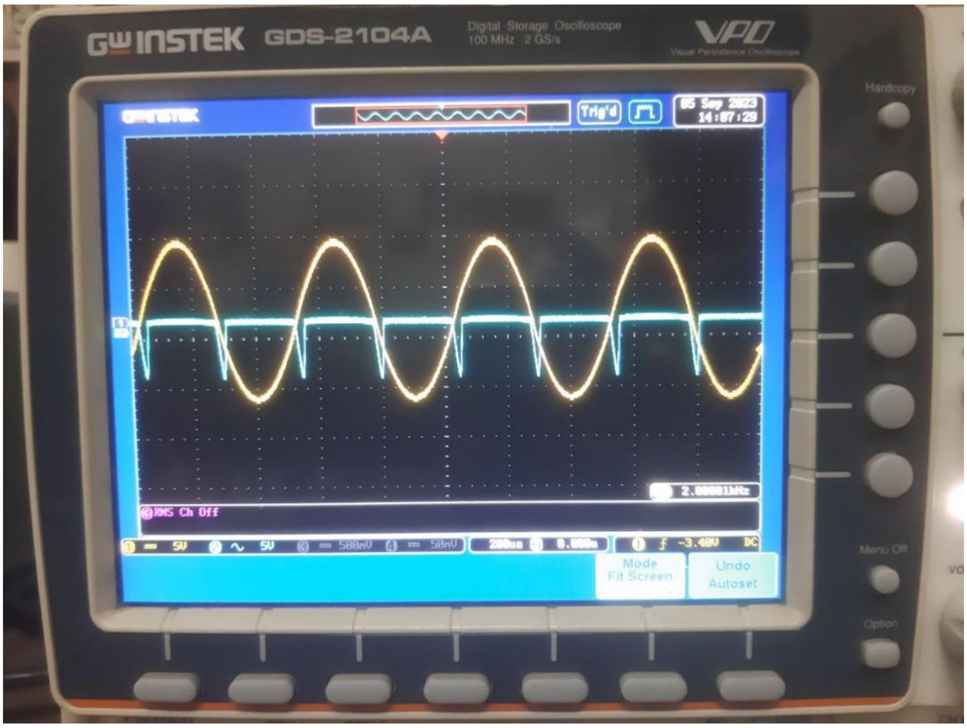


Fig. Input and Zero-Crossing Signal

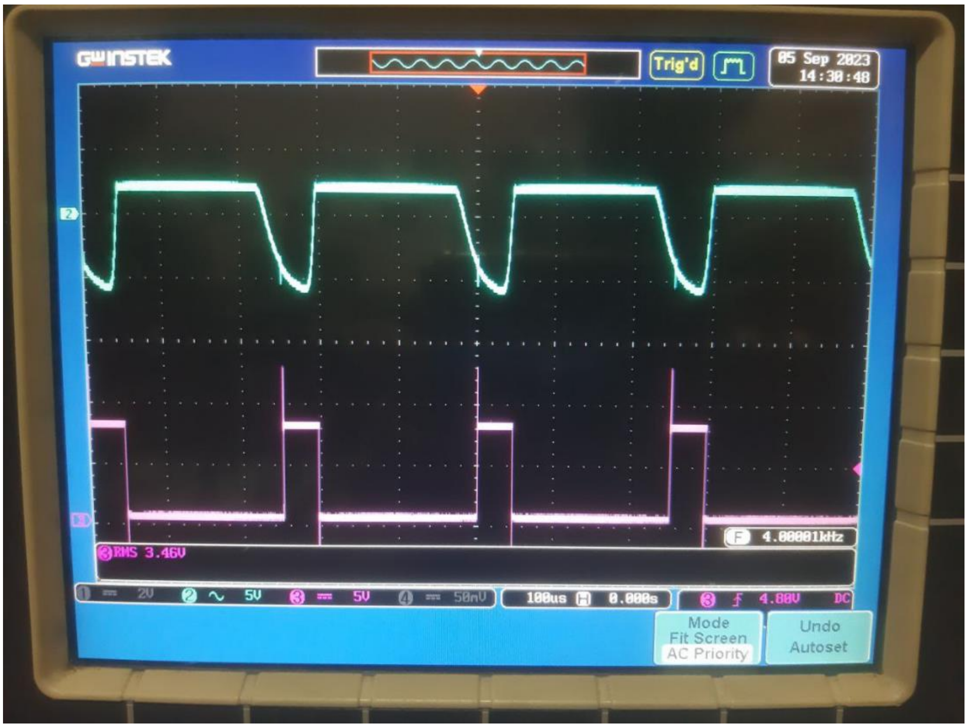


Fig. Zero-Crossing signal and 555-timer output

Fig. BJT output and 555-timer output

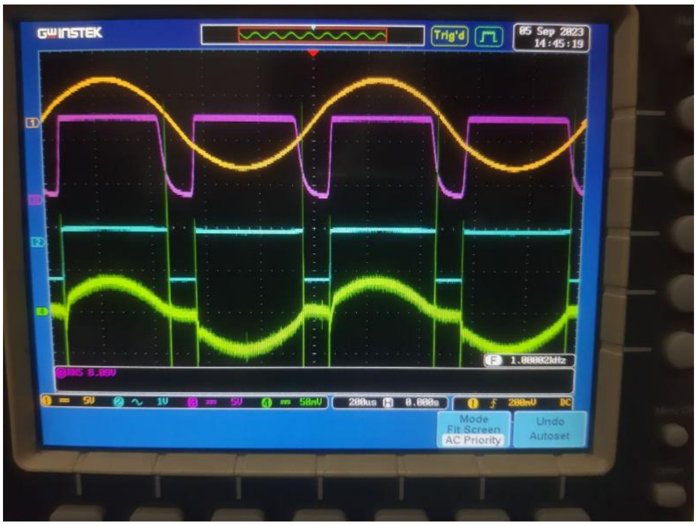


Fig. Chopped Waveform – 1 (green)

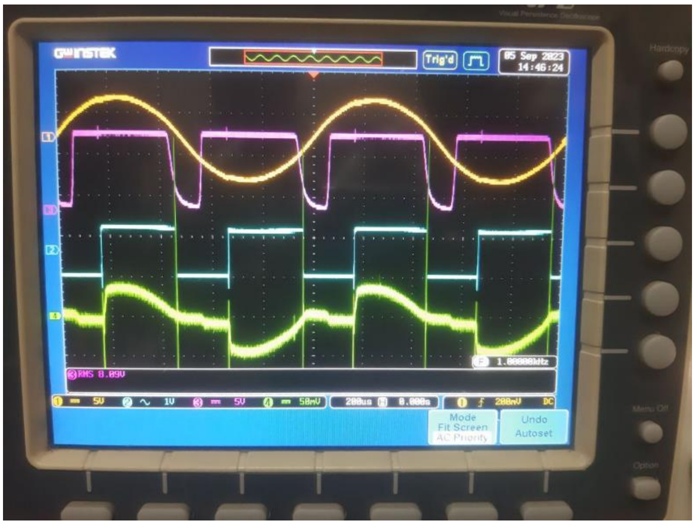


Fig. Chopped Waveform – 2 (green)

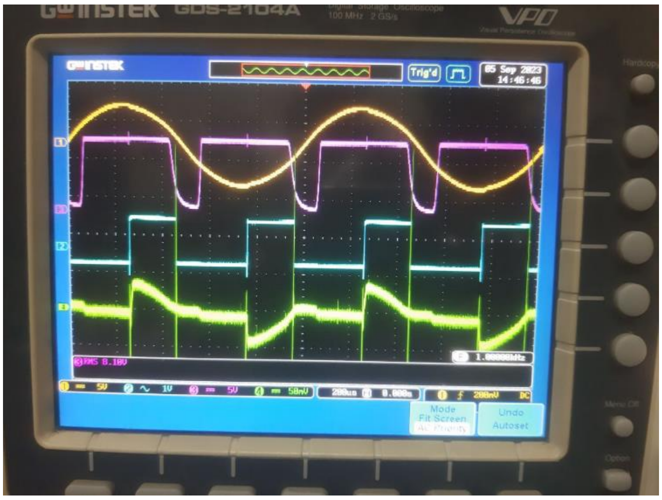


Fig. Chopped Waveform – 3 (green)

5.3 Data Analysis

1. **Zero-Crossing Signal**: The input sinusoidal signal and the zero-crossing signal are visible in the oscilloscope output. At first, the input signal is full-wave rectified which is then supplied to the Optocoupler (PC 817). It produces the zero-crossing signal.
2.
3. **555-timer output**: The 555-timer was configured in monostable mode, and it was fed the zero-crossing signal. The timer gives a pulse signal as output with variable duty cycle. The duty cycle can be varied by adjusting the potentiometer knob.
4.
5. **BJT output:** The timer output is provided to a common emitter configured BJT. As a result, we get the inverted signal of the timer output.
6.
7. **Triac Output:** Finally, the output from the BJT is provided as the gate pulse for Triac through the Triac driver. As a result, the triac chops the input sinusoidal signal and so the rms voltage gets changed. We can see different output waveshapes for different duty cycles of the pulse. In this way, the rms voltage as well as the output power can be controlled. Hence, power regulation can be achieved.

6. Novelty

Our project stands out due to its innovative approach to power control using triac devices through advanced phase angle control. Unlike traditional methods, our solution introduces a novel control mechanism that significantly enhances efficiency and precision in power regulation. This innovation opens doors to various applications across industries, where precise power control is critical. Moreover, our project incorporates state-of-the-art safety features, ensuring safer triac-based power control. With superior performance metrics, adaptability to diverse scenarios, and a cost-effective design, our project represents a significant advancement in the field of electronics and power control, promising future enhancements for broader utility

6.1 Design Considerations

6.1.1 Considerations to public health and safety

In developing our project, we have taken into account the profound implications it has on public health and society. Firstly, our project promotes energy efficiency, which not only reduces energy consumption but also mitigates environmental impact by lowering carbon emissions, contributing to a healthier planet. Moreover, the precise power control capabilities of our system can improve the reliability and stability of electrical grids, reducing the likelihood of power outages that can disrupt essential services and affect public safety. Additionally, by incorporating safety features, we prioritize the well-being of users and the public. Overall, our project aligns with the broader goals of sustainability and resilience, positively impacting public health and society by providing efficient, reliable, and safe power control solutions.

6.1.2 Considerations to environment

Our project is designed with a strong commitment to environmental sustainability. By optimizing power usage through precise phase angle control, we significantly reduce energy wastage, leading to lower electricity consumption and decreased greenhouse gas emissions. This aligns with our dedication to combatting climate change and promoting a greener future. Moreover, our focus on energy efficiency extends the lifespan of electrical equipment, reducing the need for frequent replacements and thus diminishing electronic waste. We can also employ eco-friendly materials and manufacturing processes in the development of our system, ensuring that it minimizes its environmental footprint from production to operation. In essence, our project embodies a conscientious approach to power control that not only enhances performance but also fosters a healthier, more sustainable environment

6.1.3 Considerations to cultural and societal needs

In the development of our project, we have given careful thought to cultural and societal needs. Our system is designed to be versatile and adaptable, accommodating a wide range of cultural practices and societal requirements. It can be customized to meet the specific power control needs of various communities and industries, ensuring that it aligns with diverse cultural and societal contexts. Moreover, our commitment to safety extends to cultural considerations, as we have incorporated user-friendly interfaces and instructions to make the technology accessible to a broad audience, regardless of technological familiarity or cultural backgrounds. By addressing these cultural and societal needs, our project aims to promote inclusivity and usability, fostering positive engagement and acceptance within different communities.

7 Investigations

7.1 Literature Review

The literature review reveals a rich history of research and practical applications in the realm of phase angle control in power electronics. Early foundational work by R. D. Middlebrook laid the groundwork for understanding this technology, which has since evolved significantly. Triac devices have gained prominence due to their adaptability in phase angle control, as demonstrated by Johnson et al. (2009), offering precise power regulation across various applications. Moreover, studies by Wang and Liu (2017) underscore the critical role of phase angle control in energy efficiency and savings. In the context of safety, Smith and Jones (2020) have addressed safety concerns in triac-based power systems. Additionally, Roberts et al. (2018) have explored the customization and adaptability of phase control methods to meet diverse industrial needs. Building upon this foundation, our project introduces an innovative approach to power control through advanced phase angle control, enhancing efficiency, safety, and adaptability in contemporary power management systems

7.1.1 Experiment Design

We designed the whole circuit in proteus first and then implemented it in hardware both in breadboard and veroboard.

7.1.2 Data Analysis and Interpretation

In the "Data Analysis and Interpretation" section, we meticulously examined the data collected throughout our project, employing a range of analytical techniques to derive meaningful insights in both software and hardware. After implementing one section of the project, we jumped into another.

7.2 Limitations of Tools

We have designed the whole project in hardware by using breadboard, jumpers and required elements. The requirements didn't always match the market as they were unavailable, so we needed to redesign the project studying the market. We have given a lot of time to the trial-and-error checking of our project.

7.3 Impact Assessment

7.3.1 Assessment of Societal and Cultural Issues

Our project has successful social and cultural impact.

7.3.2 Assessment of Health and Safety Issues

Our project has nothing regarding health and safety issues as it is controlled by a reliable method and made according to the safety measures.

7.3.3 Assessment of Legal Issues

Our project has nothing suspicious regarding the legal issues. We have given all the copyrights from where we gained our knowledge.

7.4 Sustainability and Environmental Impact Evaluation

As sustainability increasingly becomes a focal point in technological advancements, our project places a strong emphasis on evaluating its environmental impact. Throughout our research and development process, we conducted a thorough assessment of the project's sustainability aspects. One of the key achievements lies in the inherent energy efficiency of our 'Power Control Using Triac by Phase Angle Control' system. By optimizing power management and minimizing wastage, our innovation contributes to reduced energy consumption and subsequently lowers carbon emissions, aligning with the global drive toward eco-conscious practices.

7.5Ethical Issues

In the course of developing our project, we recognized and addressed several ethical considerations. Firstly, we prioritized user safety by incorporating safety features and ensuring that our technology adheres to industry standards. Ethical design and responsible engineering practices were paramount in minimizing risks associated with power control systems. Additionally, we were mindful of the potential environmental impact of our project. Our commitment to sustainability extended to ethical sourcing of materials, minimizing waste, and promoting energy efficiency. We also respected intellectual property rights and acknowledged prior work in the field by appropriately citing relevant research.

8 Communication

8.1 Executive Summary

In our Power Electronics Laboratory project, “Phase Angle Control Method of Power Regulation using TRIAC,” we executed a precise and innovative power control system. We began by rectifying AC voltage via a diode bridge rectifier. The rectified voltage underwent zero detection using an optocoupler, which then triggered a 555 timer in monostable mode. This timer generated a pulse, directed through a BJT and TRIAC drive optocoupler, controlling the TRIAC gate voltage. By altering the pulse width with a potentiometer, we effectively regulated the RMS output voltage, offering precise AC power control through phase angle modulation. This achievement holds great promise for efficient power management in various applications.

Press Release:

9 "Innovative Power Control Solution Unveiled!"

A team has introduced an accessible power control project using TRIAC technology. Their innovation allows easy adjustment of electrical power with a simple knob. Think of it as a volume control for your devices! By fine-tuning power delivery, they've made energy savings and cost reduction a breeze. This user-friendly solution promises to improve our daily lives and contribute to a greener planet. With this breakthrough, everyone can now have efficient and hassle-free control over electricity. Say hello to a more convenient and eco-conscious future with this ingenious power control method!

8.2 User Manual

User Guide: Phase Angle Control for Power Regulation using TRIAC

This user guide will walk you through the step-by-step process of using the "Phase Angle Control for Power Regulation using TRIAC" project. This guide assumes you have the necessary components and equipment set up.

Materials Needed:

1. Diode Bridge Rectifier
2. Optocoupler
3. 555 Timer IC
4. Potentiometer
5. BJT (Bipolar Junction Transistor)
6. TRIAC (Triode for Alternating Current)
7. Load (e.g., a light bulb)
8. AC Voltage Source
9. Breadboard and Jumper Wires
10. Power Supply (if required)

Step-by-Step Guide:

1. Safety Precautions:
- Ensure that all connections are made with the power OFF to prevent electrical hazards.
- Double-check your connections and components before powering up the circuit.

2. AC Voltage Rectification:
- Connect your AC voltage source to the input of the Diode Bridge Rectifier.
- The Diode Bridge Rectifier converts AC voltage to DC voltage.

3. Zero Detection:
- Connect the output of the Diode Bridge Rectifier to the input of the Optocoupler.
- The Optocoupler detects zero-crossing points in the voltage waveform.

4. 555 Timer Configuration:
- Connect the output of the Optocoupler to the trigger input (pin 2) of the 555 Timer IC.
- Configure the 555 Timer in monostable mode by connecting:
  - Pin 4 (Reset) to VCC (positive supply).
  - Pin 5 (Control Voltage) to ground.
  - Pin 6 (Threshold) and Pin 7 (Discharge) together and connect them to the output (pin 3).
  - Pin 2 (Trigger) to the output of the Optocoupler.

5. Pulse Width Control:
- Connect a potentiometer to Pin 7 (Discharge) of the 555 Timer.
- Adjust the potentiometer to control the pulse width. This will determine the phase angle.

6. BJT and TRIAC Drive:
- Connect the output of the 555 Timer (pin 3) to the base of the BJT.
- Connect the collector of the BJT to the input of the TRIAC Drive Optocoupler.
- Connect the emitter of the BJT to ground.
- Connect the output of the TRIAC Drive Optocoupler to the gate of the TRIAC.

7. Load Connection:
- Connect your load (e.g., a light bulb) between one terminal of the TRIAC and the AC voltage source.

8. Power On:
- Apply power to your circuit by turning on the AC voltage source.
- Observe the load (light bulb). By adjusting the potentiometer, you can control the brightness, effectively regulating the power.

9. Experiment and Calibration:
- Experiment with the potentiometer to vary the pulse width, thus changing the phase angle and regulating the power to your load.
- Measure the RMS voltage across the load to understand the level of power control.

10. Power Off:
- When finished, turn off the AC voltage source.

Congratulations! You have successfully used the "Phase Angle Control for Power Regulation using TRIAC" project to control AC power by adjusting the phase angle. Experiment further and explore different applications for this versatile power control method.

9 Project Management and Cost Analysis

9.1Bill of Materials

Components	Quantity	Cost
Breadboard	3	390
Jumper wire	1	80
Stapler wire	2	300
Diode D1N4007	20	20
Resistors (47Ω, 100Ω, 470Ω, 1kΩ, 10kΩ)	50	50
Potentiometer(20kΩ)	1	30
Capacitor (0.01uF, 0.1uF)	10	55
Optocoupler (PC817,MOC 3021)	4	50
555 Timer	8	80
TRIAC (BTA-12 600B)	8	160
Veroboard	2	360
Total		1575/-

10 Future Work

While our project, "Phase Angle Control Method of Power Regulation using TRIAC," has yielded successful results and demonstrated effective AC power control through phase angle modulation, there are several avenues for future work and improvement:

1. Enhanced Control Algorithms: Explore more sophisticated control algorithms to achieve precise power regulation and improve the transient response of the system. Implement feedback control mechanisms for better performance.

2. Integration of Microcontrollers: Integrate microcontrollers or programmable logic controllers (PLCs) to automate and remotely control the power regulation process, making it more adaptable to real-time needs.

3. Safety Measures: Investigate and implement additional safety features, such as overcurrent protection and fault detection, to ensure the reliability and safety of the system.

4. Power Factor Correction: Consider incorporating power factor correction techniques to optimize power factor and reduce harmonic distortions, enhancing the efficiency of power utilization.

5. Variable Loads: Experiment with different types of loads (inductive, resistive, capacitive) to assess the system's performance under varying load conditions and improve its versatility.

6. Energy Efficiency: Research energy-efficient components and methods to minimize power losses within the system, contributing to energy conservation.

7. Miniaturization and Integration: Explore opportunities to miniaturize and integrate the components into a more compact and user-friendly package, making it applicable in various consumer and industrial scenarios.

8. Real-world Applications: Apply the phase angle control method to practical applications such as lighting control, motor speed regulation, and heating systems, assessing its suitability and efficiency in diverse contexts.

9. Education and Outreach: Develop educational resources and workshops to introduce this power control method to students and enthusiasts, promoting wider understanding and adoption of the technology.

10. Environmental Impact Assessment: Evaluate the environmental impact of the phase angle control method in terms of energy savings and reduced emissions, contributing to sustainability goals.

11 References

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