Acknowledgment

We would like to express our heartfelt gratitude to our project guide, Prof. D. Y. Shingare and Prof. C. S. Phutane, for constant encouragement, valuable suggestions, and continuous support throughout this mini project.

We are also thankful to the faculty and staff of the Department of Electrical Engineering, Government College of Engineering, Kolhapur, for providing me with laboratory facilities and technical assistance.

We extend our appreciation to our teammates for their cooperation, effort, and dedication. Finally,

We thank our institution for providing us with an opportunity to work on this project, which has enhanced our understanding of power electronics.

Abstract

This project focuses on the **triggering of a Silicon Controlled Rectifier (SCR) using a Uni Junction Transistor (UJT)**. SCRs require proper gate triggering for controlled rectification and power control applications. A UJT is commonly used because of its ability to produce stable and repeatable triggering pulses.

The project demonstrates the design of a **UJT relaxation oscillator** that generates a sharp pulse which is fed to the gate of the SCR. The firing angle of the SCR is controlled by varying the RC timing components of the UJT circuit.

The working of the relaxation oscillator, generation of triggering pulses, and controlled conduction of the SCR were tested and verified in the laboratory. The results show effective triggering and improved stability. The project provides a fundamental understanding of power electronics triggering circuits and their real-world applications.

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INTRODUCTION

1.1 Background

Power control is an essential requirement in modern electrical and electronic systems. Devices such as heaters, lamps, motors, and controlled rectifiers need accurate and efficient regulation of power. The Silicon Controlled Rectifier (SCR) is a widely used semiconductor device for such applications because of its high current-handling capability, fast switching speed, and robustness. However, an SCR cannot turn on by itself; it needs a properly timed gate trigger pulse. To achieve smooth and flexible control, the Unijunction Transistor (UJT) is commonly used as a triggering element. The UJT, when configured as a relaxation oscillator, can generate periodic, sharp, and reliable pulses suitable for firing an SCR at different points in an AC cycle. This combination makes phase control simple and effective.

1.2 .Relevance and Motivation

The motivation behind selecting this topic includes:

- **The need to understand practical triggering methods for SCR-based power control circuits.**
- **UJT-triggered SCR circuits are widely used in dimmer circuits, speed controllers, controlled rectifiers, and other consumer/industrial electronics.**
- **It demonstrates how analog timing circuits work in coordination with power electronics.**
- **This project helps develop understanding of oscillator design, gate triggering, and phase angle control—all fundamental concepts in power electronics.**
- **The circuit is simple, cost-effective, and ideal for laboratory design and testing.**

1.3. Objectives of the Mini-Project

The major objectives of the mini-project are:

1. **To study the working principle of the SCR and its triggering requirements.**
2. **To design and implement a UJT relaxation oscillator capable of generating sharp triggering pulses.**
3. **To interface the UJT oscillator with an SCR and achieve controlled triggering.**
4. **To demonstrate phase control of an AC load using the UJT-triggered SCR circuit.**
5. **To analyze the waveform, firing angle variation, and overall performance of the triggering method.**
6. **To understand the practical aspects such as component selection, stability, and troubleshooting.**

1.4. Scope of the Mini-Project

This mini-project covers the following:

- **Study of SCR characteristics and gate triggering methods.**
- **Design and construction of a UJT-based trigger circuit.**
- **Practical implementation of a controlled rectifier or AC lamp dimmer using the SCR.**
- **Observation of output waveforms using oscilloscope (if available).**
- **Variation of firing angle through resistance control (phase control).**
- **Basic analysis of performance and efficiency.**

The project provides a strong foundation for further work in power electronics, industrial drives, and control circuits.

1.5. Limitations

Although the project is effective for academic demonstration, it has some limitations:

- **UJT devices are becoming less common; modern circuits may use IC-based triggering (e.g., 555 timer, microcontroller PWM).**
- **Triggering accuracy may vary with temperature and supply voltage.**
- **Suitable mainly for low- to medium-power applications in a lab environment.**
- **Not intended for high-power industrial control unless additional protection and isolation are used.**
- **The firing angle range is limited by the UJT characteristics and component tolerances.**

Problem Definition

2.1. Clear Statement of the Central Problem

To develop a reliable and adjustable triggering method for an SCR by designing a UJT-based relaxation oscillator that can generate consistent, sharp gate pulses required for accurate phase control of AC power.

2.2. Why the Problem is Important

- SCRs are widely used in **power control applications** such as light dimmers, motor controllers, and controlled rectifiers.
- The accuracy of the **triggering pulse directly affects the performance**, efficiency, and stability of these power control systems.
- Without stable and adjustable triggering pulses, the SCR may:
  - misfire,
  - produce distorted output power,
  - cause poor control over the load,
  - reduce reliability and efficiency.
- A good triggering circuit ensures:
  - **smooth phase angle control**,
  - **safe operation**,
  - **precise power regulation**,
  - and **reduced electrical noise**.

3.1. Existing Solutions / Brief Literature Review

Several triggering methods for SCRs exist in literature and industry:

a) Resistance Triggering

- Simplest method but produces **weak and inconsistent pulses**.
- Limited control and unsuitable for precise AC phase control.

b) RC (Resistance–Capacitance) Triggering

- Better than pure resistance triggering but still suffers from **poor pulse quality** and limited firing angle range.

c) Pulse Transformer Triggering

- Provides isolation and strong pulses, but the circuit becomes **more expensive and bulky**.

d) 555 Timer or IC-based Triggering

- Offers good control and adjustable pulses, but requires more components and **external synchronization** for AC control.

e) Microcontroller / PWM-based Triggering

- Highly accurate and programmable but **costlier**, more complex, and not ideal for beginner-level hardware projects.

f) UJT Relaxation Oscillator Triggering (Focus of This Project)

- Widely used in classical and educational power electronics.
- Generates **sharp, high-amplitude pulses** ideal for SCR gates.
- Simple, inexpensive, and easy to tune for different firing angles.
- Literature consistently shows its effectiveness for **AC phase control** and **controlled rectification**.

Methodology/Project stages

Stage 1:

3.1. **User Needs**

The users of this project (students, instructors, and technicians) require a system that:

- Provides a **simple and reliable method** to trigger an SCR.
- Demonstrates **phase angle control** for AC power regulation.
- Uses **low-cost and easily available components** such as a UJT and SCR.
- Produces **sharp, stable gate pulses** suitable for accurate SCR firing.
- Allows smooth and safe **adjustment of firing angle** using a variable resistor.
- Is easy to test, observe, and replicate in a laboratory environment.
- Offers **clear visibility of waveforms** for educational purposes.

3.2. **System Requirements**

The system must satisfy the following requirements to meet user expectations:

Functional Requirements

- It should generate periodic trigger pulses using a **UJT relaxation oscillator**.
- It must supply these pulses to the **SCR gate** for controlled turn-on.

- The firing angle should be adjustable over a wide range (ideally **0° to 180°**).
- The system must control the power delivered to an AC load (e.g., lamp, heater).

Performance Requirements

- Trigger pulses must be **sharp, consistent, and of sufficient amplitude** to fire the SCR.
- Oscillator frequency must remain stable under normal operating conditions.
- Component selection should ensure **proper relaxation oscillation** without misfiring.

Safety Requirements

- The circuit must maintain safe operation around AC mains.
- Proper isolation or protective components must be used (if required).
- All components must operate within their rated voltage and current limits.

Hardware Requirements

- UJT (e.g., 2N2646)
- SCR (e.g., BT169, TYN612, etc.)
- Resistors, variable resistor (for firing control)
- Capacitor (for RC timing)
- Load (lamp or small resistive load)
- Power supply (AC + auxiliary DC, if required)

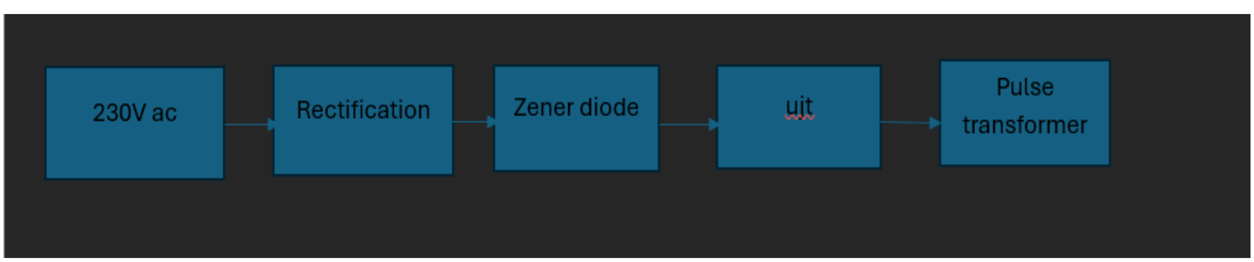
3.3. **System Specification**

The specifications define the actual characteristics of the system being designed:

- **Triggering Method:** UJT relaxation oscillator
- **Trigger Pulse Output:** Sharp, narrow pulse applied at UJT terminal B1
- **Firing Angle Control:** Adjusted by varying the charging resistor (R1)
- **Operating Voltage:**
  - AC supply for load (230 V)
  - Low-voltage DC supply for UJT if required (9–12 V)
- **Frequency of Oscillator:** Depends on RC values (generally 50–60 Hz synchronization or free-running design)
- **Load Type:** Low-to-medium power AC resistive load
- **Output Behaviour:** Variable conduction angle of SCR, enabling controlled power delivery to the load

Stage 2:

3.4. System Design / Planning



DC Bias Supply:
Provides the small DC voltage needed for the UJT to operate and charge the capacitor.

Timing Components (R1 + C1):
These determine the charging time of the capacitor, which sets the firing angle.

UJT Relaxation Oscillator:
Generates sharp trigger pulses at terminal B1 when the capacitor discharges.

SCR Triggering Circuit:
Receives trigger pulses at the gate and turns the SCR ON.

AC Supply & Load:
SCR controls the power delivered to the load by varying the firing angle.

3.5. System Architecture

The architecture describes how each subsystem interacts at a functional and electrical level.

a) Input Stage

- The system uses **AC mains supply** for powering the load.
- A **DC supply** (low voltage) is used to bias the UJT.

b) Timing and Pulse Generation Stage

- An **RC network** charges the capacitor.
- When the capacitor voltage reaches the UJT's **peak voltage (Vp)**, the UJT fires.

- This creates a **sharp pulse** at terminal B1.
- The frequency and timing depend on R1 and C1.

c) Triggering / Interface Stage

- The pulse from UJT B1 is fed to the **SCR gate** via a resistor.
- The SCR turns ON during each AC cycle at the instant the pulse is received.

d) Power Control Stage

- SCR controls the conduction angle of the AC waveform.
- The load receives **less or more power** based on firing angle.

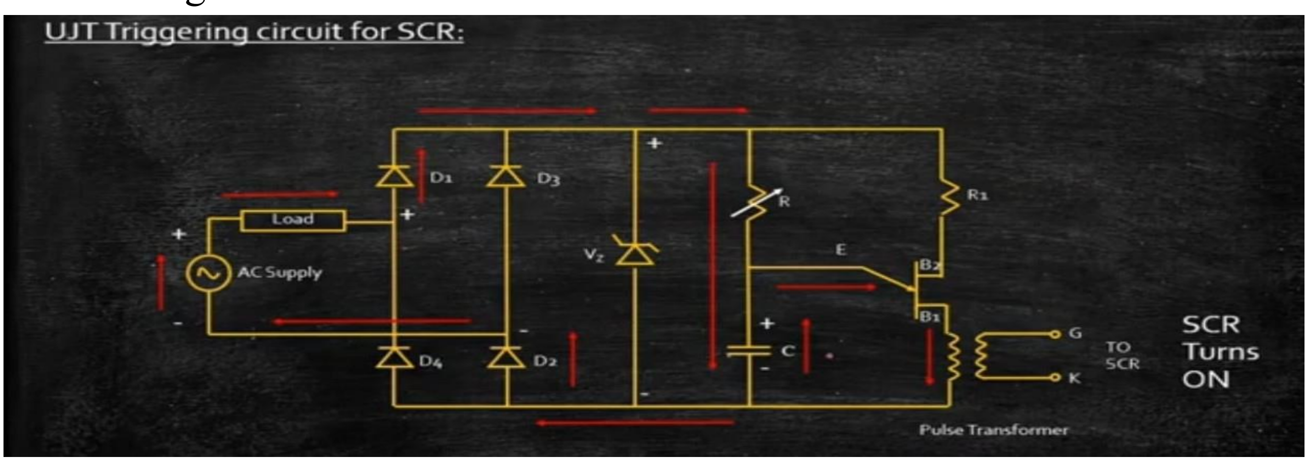
e) Output Stage

- Load power varies smoothly based on the timing of the UJT firing pulse.
- Output waveform shows clear phase control.

Stage 3:

3.6. Implementation

Circuit diagram



Step-by-Step Description of the UJT Triggering Circuit for SCR

The circuit uses:

- A **bridge rectifier** (D1–D4)
- A **Zener diode (Vz)**
- A **UJT (with E, B1, B2)**
- An RC timing network (R + C + R1)
- A **pulse transformer**
- An **SCR** controlling an AC load

Let's break down the operation step by step.

❖ Step 1: AC Supply Powers the Circuit

- The AC supply feeds the **load** and the **bridge rectifier (D1–D4)**.
- The bridge rectifier converts AC → **pulsating DC**.
- The output of the bridge serves as the DC supply for the UJT-triggering circuit.

❖ Step 2: Bridge Rectifier Provides DC Voltage

- Diodes **D1–D4** conduct in pairs depending on the AC half cycle.
- This ensures that the output polarity is always the same.
- The positive output is fed to:
    - Zener diode Vz,
    - Resistor R1,

    - Timing network,
    - And UJT circuit.

This creates a **stable DC source** for triggering.

❖ Step 3: Zener Diode Regulates the Voltage

- The Zener diode Vz ensures that the UJT receives a **constant voltage**.
- It removes any fluctuation from the rectified AC.
- This is important because the UJT needs a stable voltage to generate predictable pulses.

❖ Step 4: Capacitor C Starts Charging

- When voltage is applied, the timing capacitor **C** begins charging through
    - resistor R1
    - and variable resistor R (potentiometer)

The charging rate = firing angle control.

➤ If R increases → slower charging → late firing → low power

➤ If R decreases → faster charging → early firing → high power

❖ Step 5: Capacitor Charges Toward Peak Voltage (Vp)

- The UJT remains OFF initially.

- When the capacitor voltage (Vc) rises to the UJT's peak voltage **Vp**, the UJT becomes forward-biased.

This is the **critical moment** that triggers the oscillator.

◈ Step 6: UJT Turns ON – Sudden Discharge Occurs

Once capacitor voltage reaches Vp:

- The UJT switches ON.
- Capacitor **C rapidly discharges** through:
    - UJT emitter (E)
    - Base B1
- This discharge is very sharp → forms a **narrow pulse**.

This sharp pulse is perfect to trigger an SCR.

◈ Step 7: Sharp Pulse Appears at UJT Base B1

- At terminal **B1**, a high-amplitude, short-duration pulse is generated.
- This pulse contains enough energy to activate the gate of the SCR.

◈ Step 8: Pulse is Sent to SCR Through Pulse Transformer

- The pulse transformer:
    - Provides **electrical isolation** between low-voltage UJT circuit and high-voltage SCR circuit

    - Shapes the pulse for strong SCR triggering
- The output of the transformer connects to the **G (gate)** and **K (cathode)** of the SCR.

When the pulse reaches the gate → **SCR turns ON**.

❖ Step 9: SCR Turns ON and Conducts Load Current

Once triggered:

- SCR conducts for **the remainder of the AC half cycle**.
- Power is delivered to the **load**.

This completes one cycle of triggering.

❖ Step 10: Capacitor Begins Charging Again

At the end of each half cycle:

- Capacitor starts charging again.
- When Vc reaches Vp → next firing pulse is produced.

This repetition gives **continuous phase control** of AC power.

Stage 5: Discussion

1. Interpretation of Results

The experimental results demonstrated that the UJT relaxation oscillator successfully generated sharp and consistent triggering pulses for the SCR gate. By adjusting the variable resistor (R), the firing angle was varied, resulting in controlled conduction of the SCR and, consequently, regulated power delivery to the load.

- The **capacitor voltage waveform** showed the expected charging and sudden discharge pattern, confirming the correct operation of the timing circuit.
- The **gate pulse waveform** was a sharp, high-amplitude pulse suitable for reliably triggering the SCR.
- The **output waveform at the load** clearly showed variation in conduction angle corresponding to changes in the timing resistor, verifying effective phase control.

Overall, the system met its primary objective of controlling the SCR firing angle through UJT triggering.

2. Strengths

- **Simplicity and Cost-effectiveness:** The UJT-based triggering circuit uses minimal, inexpensive components.
- **Reliable Pulse Generation:** The relaxation oscillator provides sharp, high-quality pulses needed for consistent SCR triggering.
- **Adjustability:** The firing angle can be smoothly varied by simply changing the timing resistor.

- **Educational Value:** Demonstrates fundamental principles of analog timing, power control, and SCR operation.
- **No Complex Control Electronics:** Avoids the need for microcontrollers or digital circuits.

3. Weaknesses

- **Limited Precision:** The firing angle control depends on RC components and UJT characteristics, which may vary with temperature and aging, causing slight instability.
- **Obsolete Component:** UJTs are less commonly available compared to modern ICs and microcontrollers.
- **Limited to Low/Medium Power:** Without additional protective components, this circuit suits mainly low-power applications.
- **Lack of Isolation:** The basic design might lack sufficient isolation from high-voltage AC mains, requiring careful handling or additional components (e.g., pulse transformer).
- **Frequency Synchronization:** The UJT oscillator runs free and may not synchronize perfectly with the AC waveform, limiting firing angle accuracy.
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How to Approach Improvements

- **Use a Pulse Transformer:** To enhance isolation and pulse integrity, improving safety and triggering reliability.
- **Temperature Compensation:** Use temperature-stable components or feedback mechanisms to stabilize firing angle.

- **Synchronization with AC Supply:** Add zero-cross detection circuitry to synchronize pulses with AC mains for precise phase control.
- **Modern Alternatives:** Consider using 555 timer ICs or microcontrollers with PWM for better accuracy and flexibility, especially in commercial or high-power applications.
- **Add Snubber Circuits:** Protect the SCR and improve transient response.

Comparison with Alternative Triggering Methods

Method	**Advantages**	
UJT Relaxation Oscillator	Simple, low cost, good pulse quality	Component variability, less precise, obsolete
555 Timer IC	Adjustable, stable timing, widely available	More components, needs synchronization circuit
Microcontroller PWM	Highly precise, programmable, flexible	Complex, expensive, requires programming
Pulse Transformer Triggering	Good isolation and pulse strength	Bulkier, costlier, more complex
Resistance or RC Triggering	Very simple, minimal parts	Weak pulses, poor control, unreliable firing

Conclusion

The project successfully demonstrated the design and implementation of a UJT-based triggering circuit for an SCR. The UJT relaxation oscillator generated sharp and reliable gate pulses, allowing precise control over the SCR’s firing angle and, consequently, the power delivered to the AC load.

The system proved to be simple, cost-effective, and suitable for educational purposes, illustrating fundamental concepts of phase control and power electronics. While there are limitations in terms of precision and component sensitivity to environmental changes, the project effectively met its objectives within the scope of a basic triggering circuit.

This project provides a solid foundation for further exploration into more advanced and precise triggering methods, such as microcontroller-based control or synchronized pulse generation for industrial applications.

Future Scope and Possible Improvements

The current UJT-based SCR triggering system demonstrates the fundamental principles of phase control and pulse generation. However, there are several opportunities for improvement, feature enhancement, and research extensions:

1. Possible Improvements

- **Improved Accuracy:**
  Incorporate zero-cross detection circuits to synchronize the triggering pulse precisely with the AC waveform for accurate phase control.
- **Temperature Compensation:**
  Use temperature-stable components or feedback mechanisms to maintain consistent triggering under varying environmental conditions.
- **Enhanced Safety:**
  Implement opto-isolators or pulse transformers to provide better electrical isolation between the low-voltage control circuit and high-voltage load, reducing risk of shock.
- **Component Optimization:**
  Replace aging or less commonly available UJTs with modern equivalents or IC-based relaxation oscillators to improve reliability and reproducibility.
- **Snubber Circuit Addition:**
  Add RC snubber circuits across the SCR to protect against voltage spikes and improve transient response.

2. Additional Features

- **Adjustable Pulse Width:**
  Design the circuit to allow control over the gate pulse width, enabling finer SCR triggering control for sensitive loads.
- **Digital Interface:**
  Integrate a microcontroller to allow programmable firing angles, automated adjustments, and remote control of the load.
- **Multi-SCR Control:**
  Extend the design to trigger multiple SCRs simultaneously for three-phase loads or more complex power control applications.
- **Real-Time Monitoring:**
  Include current and voltage sensing with display or logging features to monitor performance and visualize firing angles in real-time.

3. Research Extensions

- **Integration with Smart Systems:**
  Explore combining SCR control with IoT platforms for remote monitoring, load optimization, and smart home/industrial applications.
- **Hybrid Triggering Techniques:**
  Research combining UJT, 555 timers, and microcontrollers for hybrid triggering circuits that balance simplicity with accuracy.
- **High-Power Industrial Applications:**
  Investigate scaling the circuit for industrial loads such as induction motors, heaters, and renewable energy systems.

Reference

Prof. D. Y. Shingare

Prof. C. S. Phutane

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Datasheet: ujt 2n2646