

Power Electronics Course

Introduction to the
Fundamentals of Power
Electronics



PB-600
Student Lab
Manual

Power Electronics Course

PB-600

Student Lab Manual



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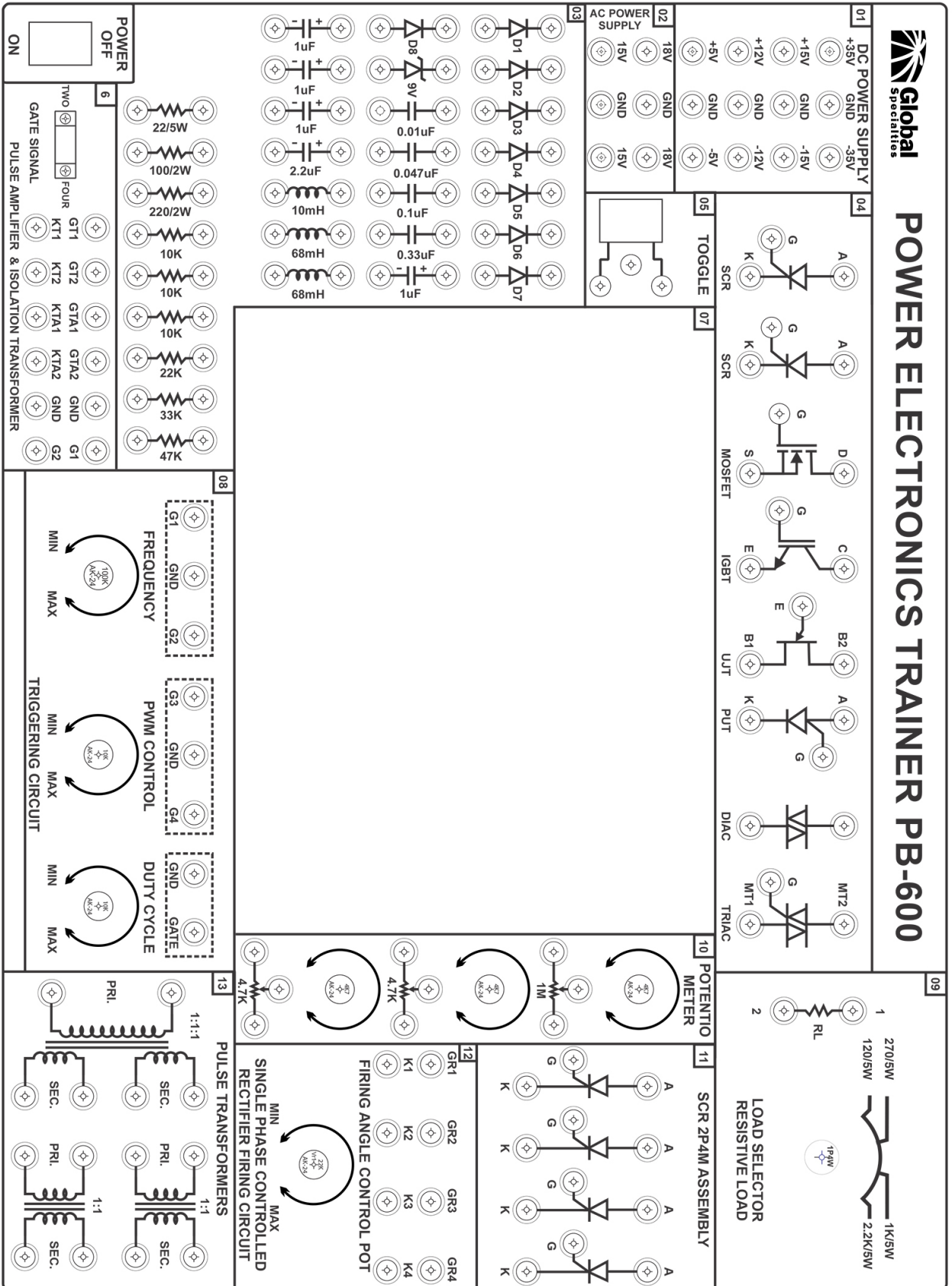
Introduction

The PB-600 provides a complete workstation for students to experiment with Power Electronics Circuits. Each exercise, presented in the lab manual, guides the students with step-by-step procedures. These experiments can be performed in the electronics laboratory of Colleges and Universities. It may also be utilized in Technical Training centers as well. The intention is to better acquaint students with the characteristics of Power Electronics devices and their applications. The Power Electronics Trainer will be beneficial to Students majoring in Engineering / Technology.

Technical Specifications

Breadboard	1280 tie points and 4 Bus Strips with 100 tie points each, totaling 1680 tie points. Size 112mm x 170mm (Approx.)
DC Power Supply	$\pm 5V$ at 100mA, $\pm 12V$ at 150mA, $\pm 15V$ at 50mA & $\pm 35V$ at 50mA
AC Power Supply	18V - 0V - 18V at 50mA, & 15V - 0V - 15V at 50mA
Triggering Circuit	5 gate signal output, Frequency range: 40Hz to 900Hz Variable, Amplitude: 12V PWM control of G1, G2, G3 and G4 Duty cycle control of "Gate" Signal is 0 to 100%
Single Phase Rectifier	Firing Angle Control 0° - 180° variables
Pulse Amplifier	Firing Circuit Four gate signal output with isolation transformer
SCR Assembly	2P4M (4 pieces) 600V, 2A
Power Devices	IGBT-G4BC20S; MOSFET-IRF540; UJT-2N2646, DIAC-DB3; TRIAC-BT136; PUT- 2N6027; SCR-TYN-612/02
Circuit Components	Capacitor: 0.01uF, 0.047uF, 0.1uF, 0.33uF, 1uF/63V (4 pieces), 2.2uF/50V
	Diode: IN4007 (8 pieces), Zener Diode 9V, Inductor: 10mH, 68mH (2 pieces)
	Resistor: 22 Ω /5W, 100 Ω /2W, 220 Ω /2W, 10K Ω (3 pieces), 22K Ω , 33K Ω , 47K Ω ,
Potentiometer	4.7K Ω (2 pieces), 1M Ω ,
Load Resistance	120 Ω , 270 Ω , 1K Ω , 2.2K Ω , (Each 5W)
Pulse Transformer	1:1 (2 pieces), 1:1:1
Toggle Switch	SPDT
Power Requirements	115V $\pm 6\%$ 60Hz or 230V $\pm 10\%$, 50Hz

Panel Layout



About the Trainer

Block 01: DC Power Supply

Fixed DC output of +5V and -5V, +12V and -12V, +15V and -15V, +35V and -35V

Block 02: AC Power Supply

Fixed AC output of 18V-0V-18V and 15V-0V-15V

Block 03: Circuit Component

Diodes: IN4007 (8 pieces), Zener Diode 9V,

Capacitors: Cap 0.01 μ F, Cap 0.047 μ F, Cap 0.33 μ F, Electrolytic Cap 1 μ F / 63V (4 pieces), 2.2 μ F / 63V

Resistors: 22 Ω /5W, 100 Ω /2W, 220 Ω /2W, 10K Ω 0.25W (3 pieces), 22K Ω 0.25W, 33K Ω 0.25W, 47K Ω 0.25W

Inductors: 68mH (2 pieces), 10mH

Block 04: Power Devices

SCR TYN-612 (2 pieces), MOSFET IRF-540, IGBT- G4BC2OS, UJT 2N2646, PUT 2N 6027, DIAC DB-3, and TRIAC BT-136

Block 5: Toggle Switch

Single Pole Double Throw (SPDT)

Block 6: Pulse Amplifier & Isolation Transformer

This block provides amplification of gate signal, and it isolates the power circuit from the triggering circuit.

Block 7: Breadboard

840 X 2 Breadboard

Block 8: Triggering Circuit

(4) Gate Pulse with PWM Control and Frequency Control.

(1) "GATE" signal with Duty Cycle Control

Block 9: Load Selector, Resistive Load

Loads: 120 Ω /5W, 270 Ω /5W, 1K Ω /5W, 2.2K Ω /5W: with Load Selector

Block 10: Potentiometer

1M Ω and 4.7K Ω (2)

Block 11: SCR Assembly

SCR 2P4M Assembly (4 pieces)

Block 12: Single Phase Controlled Rectifier Firing Circuit

(4) Gate and Cathode signal with isolation for single phase-controlled rectifiers.

Block 13: Pulse Transformers:

Pulse Transformers for circuit isolation: (2) Transformers of 1:1 and (1) Transformer of 1:1:1.

WARNING:

Because of the potential hazard of working with electrical circuits, all proper precautionary measures should be taken when operating this unit. Failure to do so could result in injury.

Operating Instructions

The trainer contains an AC and DC power supply, with various voltages. The power supply is controlled by the ON/OFF switch. When turned on, the LED on the ON/OFF switch will light up, indicating the power supply has been activated.

The 'TRIGGERING CIRCUIT' block, contains a Frequency, PWM, and Duty Cycle control. The "FREQUENCY" control will vary the frequency of pulse signals G1, G2, G3, G4 and GATE. The "PWM CONTROL" will vary the pulse width for inverter circuits. The "DUTY CYCLE" control will vary duty cycle of "GATE" only.

In the "SINGLE PHASE CONTROLLED RECTIFIER FIRING CIRCUIT" block, the gate signals for two groups of rectifier devices. The firing angle is changed by rotating "FIRING ANGLE CONTROL POT".

The "PULSE AMPLIFIER & ISOLATION TRANSFORMER" block can be used for Bedford inverter and series inverter circuits.

The experiments presented in this manual are for guidance only. The trainees are expected to apply their knowledge and skills to modify or correct any circuits wherever necessary. Pin diagrams, for the devices, are provided at the end of the manual. Use them for proper connections.

Experiment 1: Characteristics of an SCR

Introduction:

The Silicon-Controlled Rectifier (SCR) is a common and crucial component in Power Electronics circuits. Like a diode, the SCR has both an anode and cathode aspect to it. However, what distinguishes an SCR from a typical diode is that it contains a gate input. The SCR will conduct in forward conduction mode if a high enough voltage is applied across the anode and cathode. Forward conduction may also be achieved by applying a positive signal to the gate. This lab will cover the voltage characteristics of an SCR and the forward conduction mode.

Pre-Lab Questions:

1. What is the main difference between an SCR and a typical Diode?
2. What is the P-N Configuration of an SCR, and where, in this P-N structure, is the Cathode, Anode, and Gate connected?
3. A process referred to as doping is usually employed to control the number of charge carriers in a semiconductor. What is this doping process, and why is it important in a P-N junction?

<u>Apparatus Required:</u>	<u>Quantity:</u>
Resistance 510Ω , $\frac{1}{4} W$	1
Resistance $2.2K\Omega$, $5W$ (on board)	1
SCR TYN 612 (on board)	1
Potentiometer $4.7K\Omega$ (on board)	2
Multimeter	3
Patch Cord	10

Circuit Diagram:

The circuit below can be used to plot the characteristics of an SCR.

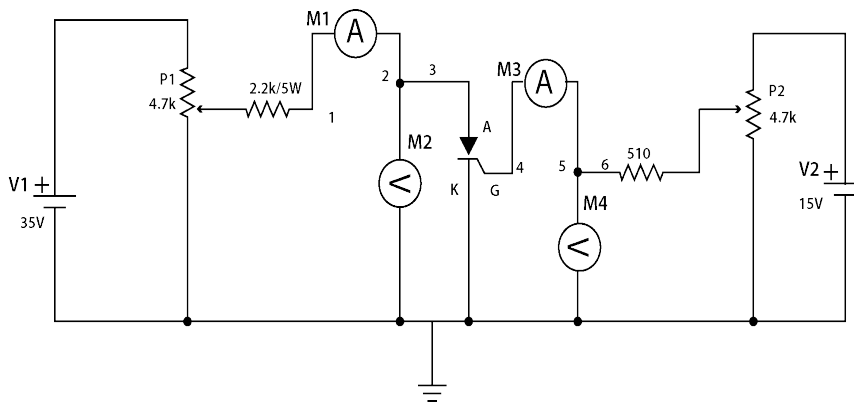


Figure 1

Procedure:

1. Connect the circuit as shown in Figure 1 using patch cords.
2. To plot the $I_A - V_A$ characteristics proceed as follows.
3. Rotate potentiometer P1 and P2 in the full counterclockwise position. Connect the voltmeter at point '6' & ground to measure V_G and at point '3' & ground to measure V_A .
4. Connect an ammeter between points '1' & '2' to measure the current I_A and between points '4' & '5' to measure the gate current I_G .
5. Switch Power ON.
6. Set the gate current I_G to a value between 3.75mA - 3.85mA, by varying potentiometer P2.
7. Gradually increase anode voltage V_A , by varying potentiometer P1.
8. Observe current I_A , it should read near zero initially.
9. At some point, the positive anode current I_A will have a sudden jump in reading. When this occurs, the voltmeter reading will drop to near zero. This will indicate the firing of the SCR.
10. If this does not occur, repeat steps 5 - 8 with a slightly higher gate current I_G value set.
11. As V_A is being increased, record the observed voltage V_A and corresponding current I_A values on the table provided.
12. After the firing of the SCR, continue to increase V_A , and record the observed V_A and corresponding I_A values.
13. Use the recorded values to plot and graph the I_A vs V_A curve.

Table 1: SCR Measured Values:

No.	Voltage V_A and Current I_A (mA)	
	Gate Current $I_G =$ _____ mA	
	V_A	I_A
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

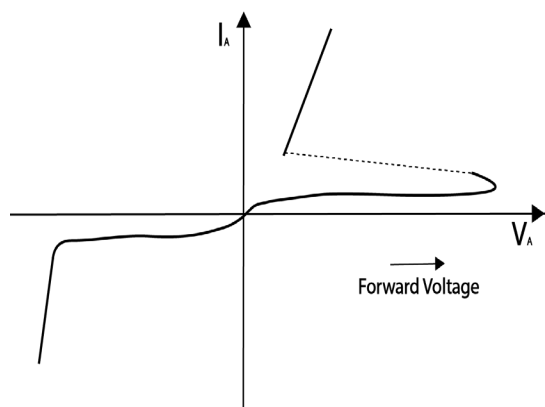


Image 1: SCR I vs V Curve

Experiment 2: Gate Control Characteristics of an SCR

Introduction:

An SCR is like a diode, but the SCR has an added gate control to it. Sending a pulse through the gate of the SCR will enable it to enter forward conduction mode. While the gate remains positive the SCR can conduct current in the forward conduction mode. This lab covers how an SCR turns on and off by controlling the gate input.

Pre-Lab Questions:

1. What are two methods that will generate forward conduction in an SCR?
2. What is Breakover Voltage in an SCR?
3. What is the holding current in an SCR?

Apparatus Required:	Quantity
Resistance 510Ω, ¼ W	1
Resistance 2.2KΩ, 5W (on board)	1
SCR TYN 612 (on board)	1
Potentiometer 4.7KΩ (on board)	2
Multimeter	4
Patch Cord	16

Circuit Diagram:

The circuit below can be used to plot the characteristics of an SCR.

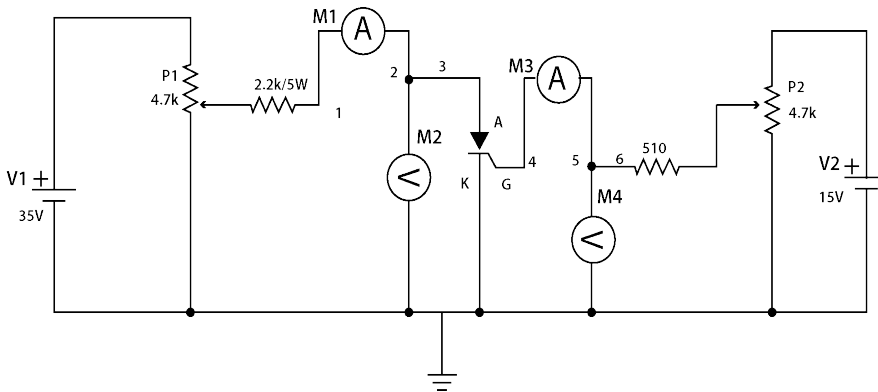


Figure 2

Procedure:

1. Connect the circuit as shown in Figure 2 using patch cords.
2. To plot the $I_G - V_A$ characteristics proceed as follows.
3. Rotate potentiometer P1 and P2 in the full counterclockwise position. Connect voltmeter at point '6' & ground to measure V_G and at point '3' & ground to measure V_A .
4. Connect ammeter between points '1' & '2' to measure the current I_A and between points '4' & '5' to measure the gate current I_G .
5. Switch Power ON.
6. Set voltage V_A to 5V by varying potentiometer P1.
7. Gradually increase the gate current I_G until the SCR is triggered. A sudden increase in the measured I_A and a drop, to a near zero reading, in the measured V_A , is an indication that the SCR has fired on.
8. On the table provided, record the measured current I_G value at which the SCR is triggered.
9. After the firing of the SCR, continue to increase the gate current I_G and observe whether it has any effect on I_A or V_A .
10. Increase V_A by increments of 5V and repeat steps 5 – 8. Continue this process until a minimum of five points, to plot, have been acquired.
11. Plot and graph the I_G vs V_A curve.

Table 2: SCR Measured Values

No.	Voltage V_A and Gate Current I_G (mA)	
	V_A	I_G
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Experiment 3: The UJT, Inter Base Resistance, and Intrinsic Standoff Ratio

Introduction:

A unijunction transistor (UJT) is a unique three terminal semiconductor device. When the UJT is triggered, the emitter current increases until limited by the emitter power supply. It can be used in switching pulse generators, and as a triggering device for an SCR or TRIAC. This lab will cover the characteristics of the UJT to find the inter base resistance as well as the intrinsic standoff ratio. This is done by observing the change in emitter current.

Pre-Lab Questions:

What is the UJT physical structure with respect to P-type and N-type material?

In what way will applying positive voltage to the emitter affect the total resistance between base 1 and base 2?

What is the inter-base resistance and the intrinsic stand-off ratio?

Apparatus Required:	Quantity
Resistance 510 Ω ¼ W	2
Potentiometer 4.7K (on board)	2
UJT 2N2646 (on board)	1
Multimeter	3
Patch Cord	9

Circuit Diagram:

The circuit below can be used to plot the characteristics of a Unijunction Transistor.

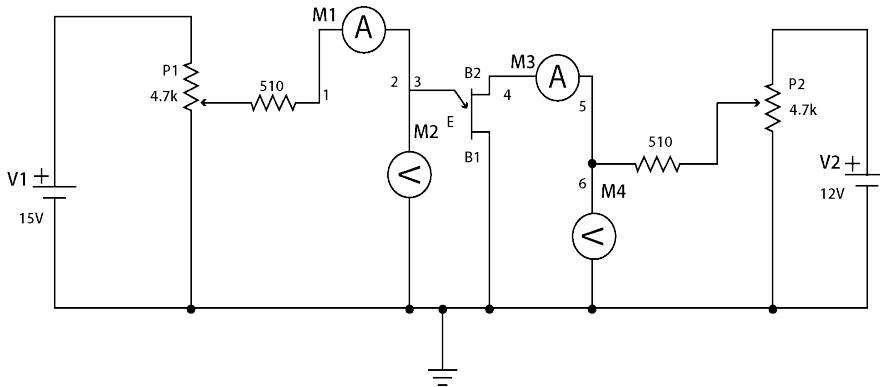


Figure 3

Procedure:

1. Connect the circuit as shown in Figure 3 using patch cords.
2. To plot the Emitter characteristics, proceed as follows:
3. Rotate potentiometer P1 and P2 in the full counterclockwise position.
4. Connect the voltmeter at point '6' and ground to read V_{BB} and at point '3' and ground to read V_E .
5. Connect ammeter between points '1' and '2' to measure the emitter current I_E , and between points '4' and '5' to measure the base current I_B .
6. Switch Power ON.
7. Vary potentiometer P2 and set a voltage value of $V_{BB} = 5V$.
8. Increase the Emitter voltage V_E in steps.
9. Continue to increase V_E until the reading on the voltmeter drops. At this point the UJT fires on and emitter

- current will flow rapidly.
10. In Table 3, record the Emitter voltage V_E and the corresponding Emitter current I_E for each observation value.
 11. Repeat steps 4 through 8 for $V_{BB} = 10V$ and $V_{BB} = 15V$.
 12. Plot the V_E vs I_E graph with the observation values recorded on table 3.

Table 3: UJT Measured Values

No.	Emitter Voltage V_E and Emitter Current I_E (mA)					
	$V_{BB} = 5V$		$V_{BB} = 10V$		$V_{BB} = 15V$	
	V_E	I_E	V_E	I_E	V_E	I_E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

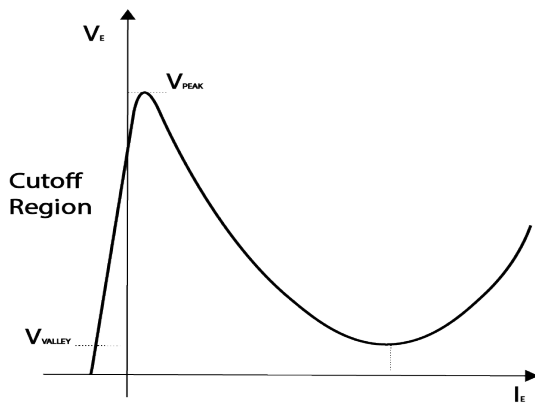


Image 3: UJT V vs I Curve

Calculations:

Inter base Resistance (R_{BB}) It is the sum of resistance between base 1 & base 2

$$R_{BB} = R_{B1} + R_{B2}$$

It ranges from 4K to 10K ohms when $I_E = 0$.

Intrinsic stand-off Ratio (η)

$$\eta = R_{B1} / (R_{B1} + R_{B2}) = R_{B1} / R_{BB}$$

It ranges from 0.51 to 0.82.

Experiment 4: Characteristics of a MOSFET

Introduction:

The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a device used in a variety of different circuits. Because of its small compact size, it is used as a switch in analog and digital circuits. It is a four terminal device consisting of a source, gate, drain and base terminal. The base and source are usually connected, so the MOSFET operates as a three-terminal transistor. This lab will cover the characteristics of a MOSFET device with a focus on the voltage and current plots.

Pre-Lab Questions:

MOSFET is an acronym for Metal Oxide Semiconductor Field Effect Transistor. Why is it considered a field effect transistor? What makes it different from an SCR or UJT?

According to the MOSFET circuit symbol printed on the face of the Trainer, Is this MOSFET an N-channel or P-channel?

What is the P-N structure of the MOSFET, used in this lab?

Apparatus Required:	Quantity
Resistance 820Ω, ¼ W	1
Resistance 1KΩ, 5W (on board)	1
Resistance 510Ω, ¼ W	1
Zener diode 9V (on board)	1
Potentiometer 4.7KΩ (on board)	2
MOSFET IRF540N (on board)	1
Multimeter	3
Patch Cord	14

Circuit Diagram:

The circuit below can be used to plot the characteristics of a MOSFET

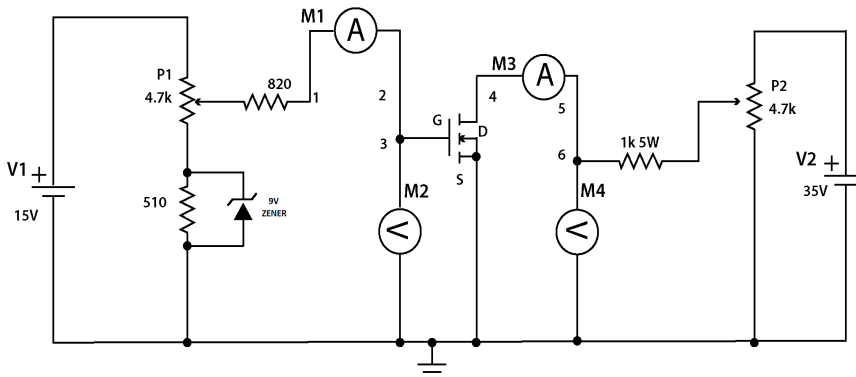


Figure 4

Procedure:

1. Connect the circuit as shown in Figure 4 using patch cords.
2. To plot the I_D vs V_{DS} characteristics, proceed as follows:
3. Connect the circuit using the breadboard
4. Rotate potentiometer P1 and P2 in the full counterclockwise position.
5. Connect an ammeter between points '1' and '2' and connect a second ammeter between points '4' and '5'.
6. Connect a voltmeter at point '6' and ground to measure drain voltage V_{DS} . Connect voltmeter at point '3' and ground to measure gate voltage V_{GS} .
7. Switch Power ON
8. Vary potentiometer P1 and set the gate voltage V_{GS} at some constant value (2.5V, 2.6V, 2.7V)
9. Increase the drain voltage V_{DS} value from 0 to 35V in steps by varying potentiometer P2. In Table 4, record the measured Drain voltage V_{DS} and corresponding Drain current I_D values, with the constant Gate voltage V_{GS} set.
10. Rotate potentiometer P2 in the full counterclockwise position.
11. Repeat steps 1 through 6 with a different gate voltage V_{GS} value set.
12. Plot and graph the I_D vs V_{DS} curve using the recorded measured values, appropriately scaled. The graph will produce the Drain characteristics curve for a MOSFET.

Table 4: Observations

No.	Voltage V_D and Current I_D (mA)					
	$V_{GS} = \underline{\hspace{2cm}}$		$V_{GS} = \underline{\hspace{2cm}}$		$V_{GS} = \underline{\hspace{2cm}}$	
	V_{DS}	I_D	V_{DS}	I_D	V_{DS}	I_D
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

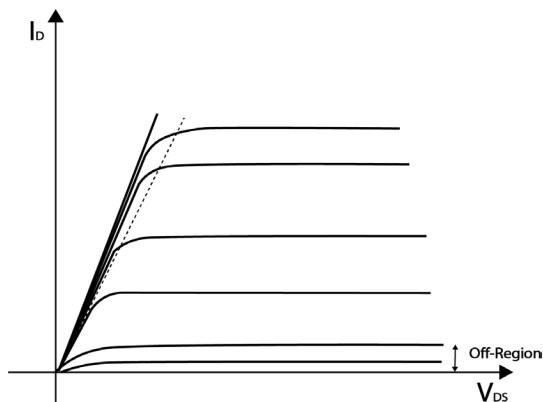


Image 4: MOSFET I vs V Curve

Experiment 5: Characteristics of an IGBT

Introduction:

The Insulated Gate Bipolar Transistor (IGBT) is a three terminal semiconductor device. Like a MOSFET, it can operate as a switch due to its high efficiency and fast switching capabilities. The IGBT is used in many high-power applications such as electric cars, variable frequency drives and refrigerator units. This lab will cover the characteristics of an IGBT device, with a focus on voltage and current plots.

Pre-Lab Questions:

How will increasing the gate current affect the current flow through the IGBT?

According to the provided Data Sheet, what is the maximum voltage V_{CES} that should be applied across the IGBT, being used in this experiment?

<u>Apparatus Required:</u>	<u>Quantity</u>
Resistance 22Ω , 5W (on board)	1
Resistance $1K\Omega$, $\frac{1}{4}$ W	1
Potentiometer $4.7K\Omega$ (on board)	2
IGBT G4BC20S (on board)	1
Multimeter	3
Patch Cord	11

Circuit Diagram:

The circuit below can be used to plot the characteristics of an IGBT.

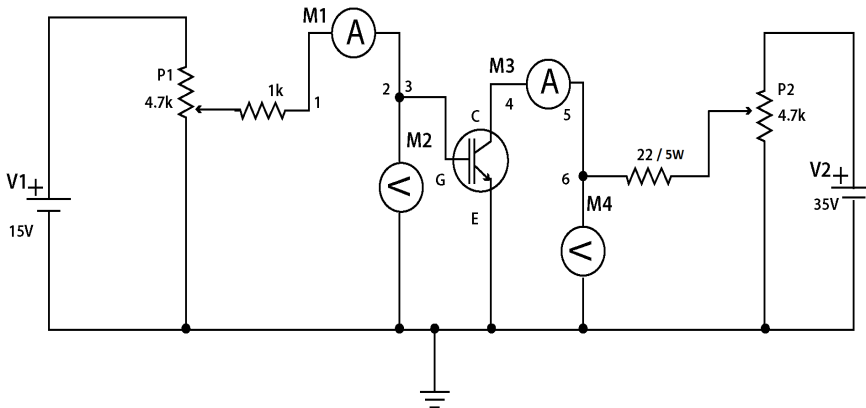


Figure 5

Procedure:

1. Connect the circuit as shown in Figure 5 using patch cords.
2. Rotate the potentiometer P1 in the full clockwise position and P2 in the full counterclockwise position.
3. Connect the first ammeter between points '4' and '5' to measure Collector current I_C (mA).
4. Connect the second ammeter between points '1' and '2'.
5. Connect voltmeter at point '3' and ground to measure the Gate voltage V_{GE} and at point '6' and ground to

- measure Collector voltage V_{CE} .
6. Switch Power ON.
7. Vary the potentiometer P1 to set the gate voltage V_{GE} between 4.8V and 5.4V.
8. Vary the potentiometer P2 to increase the value of Collector-Emitter voltage V_{CE} from 0 to 35V in steps. In Table 5, record the Collector-Emitter voltage V_{CE} and the corresponding Collector current I_C for each measured value observed.
9. Rotate the potentiometer P2 in the full counterclockwise position and potentiometer P1 in the full clockwise position.
10. Repeat steps 1 through 6 with a different gate voltage V_{GE} set.
11. Plot and graph the I_C vs V_{CE} curve using the measured values, appropriately scaled. The curve depicts the IGBT characteristics.

Table 5: IGBT Measured Values

No.	Voltage V_{CE} and Current I_C (mA)			
	$V_{GE} = \underline{\hspace{2cm}}$		$V_{GE} = \underline{\hspace{2cm}}$	
	V_{CE}	I_C	V_{CE}	I_C
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

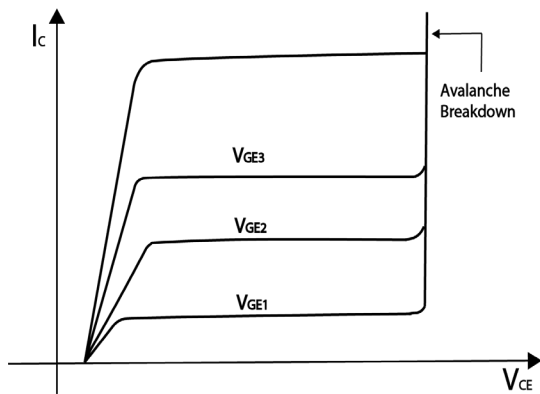


Image 5: IGBT I vs V Curve

Experiment 6: Characteristics of a DIAC

Introduction:

The Diode for Alternating Current (DIAC) is a diode that conducts after its breakover voltage has been met. After this, the DIAC experiences a drop in voltage with an increase in current. It is a bidirectional device and sometimes referred to as a symmetrical trigger diode due to its I-V characteristics. This lab will cover the characteristics of a DIAC and show the symmetrical relationship mentioned.

Pre-Lab Questions:

1. What distinguishes a DIAC from an ordinary diode?
2. What is the DIAC circuit symbol?
3. What is the typical breakover voltage for the DIAC used in this lab?

Apparatus Required:

<u>Quantity</u>	<u>Quantity</u>
Resistance 1K Ω , 5W (on board)	1
DIAC DB3 (on board)	1
Potentiometer 4.7K Ω (on board)	1
Multimeter	2
Patch Cord	6

Circuit Diagram:

The circuit below can be used to plot the characteristics of a DIAC.

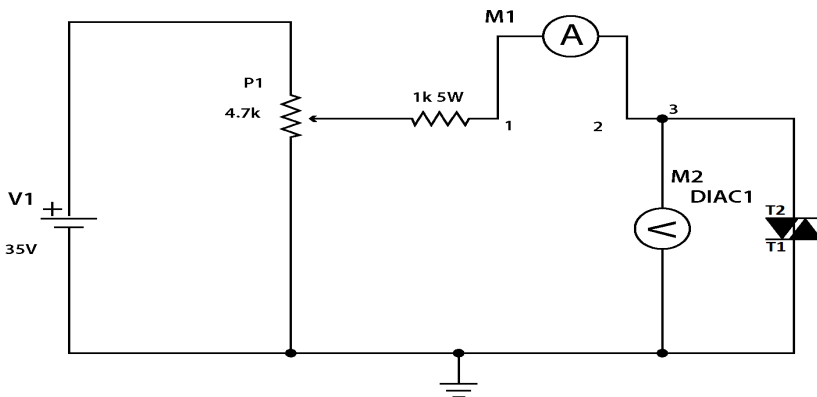


Figure 6

Procedure:

1. Connect the circuit, as shown in Figure 6, using patch cords.
2. To plot the IA-VA characteristics proceed as follows.
3. Rotate potentiometer P1 in the full counterclockwise position.
4. Connect voltmeter at point '3' & ground to read voltage VA.
5. Connect ammeter between points '1' & '2' to measure current IA.
6. Connect the circuit to +35V.
7. Switch Power ON
8. Increase DIAC voltage VA by varying the potentiometer P1. In Table 6, record the observed measured voltage values VA and the corresponding current values IA.
9. Rotate potentiometer P1 in the full counterclockwise position.
10. Switch Power OFF
11. Connect the circuit to -35V.
12. Switch Power ON.
13. Increase DIAC voltage VA by varying the potentiometer P1. In Table 6, record the observed measured voltage values VA and the corresponding current values IA.
14. Plot and graph the IA vs VA curve for both the +35V circuit and -35V circuit.

Table 6: DIAC Measured Values

No.	DIAC Voltage VA and Current IA (mA)			
	VA	IA	VA	IA
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

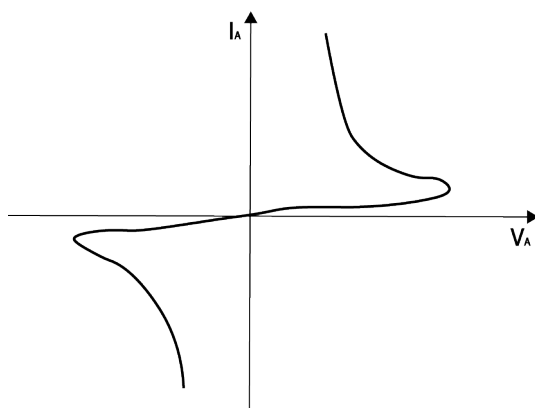


Image 6: DIAC I vs V Curve

Experiment 7: The IA - VA Characteristics of a TRIAC

Introduction:

The Triode for Alternating Current (TRIAC) is a three terminal component able to conduct current in both directions, when the gate is triggered. A TRIAC is composed of a thyristor which makes it similar to an SCR. However, an SCR can only conduct current in one direction. A TRIAC can function as a switch for alternating current. Lamp dimming, motor control, and electric heaters are just a few of its applications. This lab will cover the IA-VA characteristics of a TRIAC and show the bidirectional current control.

Pre-Lab Questions:

1. How are a TRIAC and a DIAC alike?
2. How are they different?

Apparatus Required:	Quantity
Resistance 510Ω, ¼ W	1
Resistance 2.2KΩ, 5W (on board)	1
TRIAC BT136 (on board)	1
Potentiometer 4.7KΩ (on board)	2
Multimeter	4
Patch Cord	10

Circuit Diagram:

The circuit below can be used to plot the characteristics of a TRIAC.

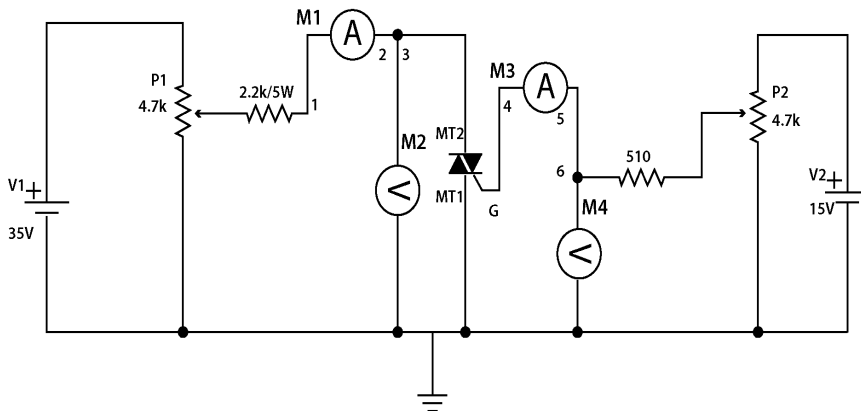


Figure 7

Procedure:

1. Connect the circuit, as shown in Figure 7, using patch cords.
2. To plot the IA-VA characteristics proceed as follows:
3. Rotate potentiometer P1 in the full counterclockwise position and P2 in the full clockwise position.
4. Connect voltmeter at point '6' and ground to measure VG and at point '3' and ground to measure VA.
5. Connect one ammeter between points '1' & '2' to measure current IA. Connect a second ammeter between points '4' & '5' to measure gate current IG.
6. Connect circuit to +35V.
7. Switch Power ON
8. Vary potentiometer P2 to set the gate current IG to a value between 0 - .5mA.
9. Increase anode voltage VA gradually by varying potentiometer P1.
10. Observe the current IA in the anode circuit. In the initial stage the measured value is nearly zero.
11. If this does not happen, repeat the steps 8 through 10 with a slightly higher gate current IG set.
12. Experiment with different Gate current values to fire up the TRIAC.
13. When the TRIAC fires on, record the measured VA voltage value and the corresponding measured IA current value in Table 7.
14. Rotate potentiometer P1 in the full counterclockwise position.
15. Connect the circuit to -35V and repeat from steps 7 through 13 and record the measured values on Table 7A.
16. Plot and graph the IA vs VA curve for both +35V circuit and -35V circuit.

Table 7A: TRIAC Measured Values (+35V)

No.	Voltage VA and Current IA (mA)					
	IG = _____		IG = _____		IG = _____	
	VA	IA	VA	IA	VA	IA
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Table 7B: TRIAC Measured Values (-35V)

No.	Voltage V_A and Current I_A (mA)					
	$I_G = \underline{\hspace{2cm}}$		$I_G = \underline{\hspace{2cm}}$		$I_G = \underline{\hspace{2cm}}$	
	V_A	I_A	V_A	I_A	V_A	I_A
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

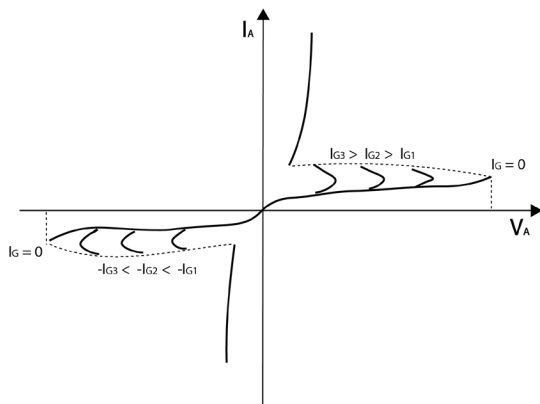


Image 7: TRIAC I vs V Curve

Experiment 8: Characteristics of a PUT

Introduction:

The Programmable Unijunction Transistor (PUT) is a three-terminal component, like a UJT. However, in a PUT the peak voltage and intrinsic standoff ratio can be controlled using external resistors. A PUT is used for relaxation oscillators, thyristor firing, and timing circuits. This lab will cover the characteristics of a PUT, and it will go over how the voltage peak and intrinsic standoff ratio can be programmed.

Pre-Lab Questions:

1. What is the mathematical formula to determine the peak voltage of a PUT?
2. Given the predetermined gate voltage, for this lab, what should be the peak voltages for each run?
3. Looking at the circuit for this lab experiment, explain how the resistors control the peak voltage?

Apparatus Required: Quantity

Resistance 2.7K Ω , ¼ W	1
Resistance 10K Ω , ¼ W (on board)	1
Resistance 2.2K Ω , 5W (on board)	1
PUT 2N 6027 (on board)	1
Potentiometer 4.7K Ω (on board)	2
Multimeter	3
Patch Cord	14

Circuit Diagram:

The circuit below can be used to plot the characteristics of a PUT.

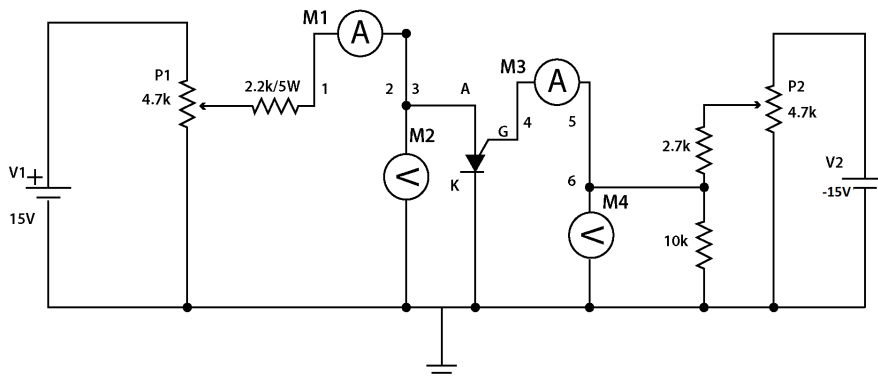


Figure 8

Procedure:

1. Connect the circuit, as shown in Figure 8, using patch cords.
2. To plot the PUT characteristics proceed as follows:
3. Rotate potentiometers P1 and P2 in the full clockwise position.
4. Connect the first ammeter between points '1' and '2' to measure Anode current I_A (mA). Connect the second ammeter between points '4' and '5' to measure Gate current I_g (mA).
5. Connect voltmeter at point '3' and ground to measure the Anode voltage V_A .
6. Connect voltmeter at point '6' and ground to measure the Gate voltage V_G .
7. Switch Power ON.
8. Vary potentiometer P2 to set Gate voltage V_G to a constant value (2.0V, 5.0V, 10V).
9. Vary potentiometer P1 to increase the anode voltage V_A from 0 to 15V in steps. In Table 8, record the measured Anode voltage V_A value and corresponding Anode current I_A value at each step.
10. Rotate potentiometer P2 in the full counterclockwise position.
11. Set the Gate voltage V_G to a different value and repeat steps 6 through 7.
12. Plot and graph the V_A vs I_A curve.

Table 8: PUT Measured Values

No.	Voltage V_A and Current I_A (mA)					
	$V_G = \underline{\hspace{2cm}}$		$V_G = \underline{\hspace{2cm}}$		$V_G = \underline{\hspace{2cm}}$	
	V_A	I_A	V_A	I_A	V_A	I_A
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

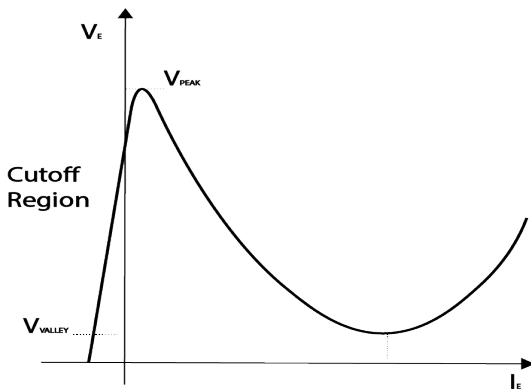


Image 8: PUT V vs I Curve

Experiment 9: Class B Commutation Circuit

Introduction:

Commutation is the process of shutting off an SCR. This process is done by reducing the forward current to zero. There are three different types of commutation methods natural, forced, and dynamic. Class B commutation is considered forced commutation. It is commonly used in chopper and inverter circuits. The inductor and capacitor, connected in parallel with the SCR, create a resonant pulse commutation. This lab will cover shutting off an SCR by means of a Class B commutation circuit setup.

Pre-Lab Questions:

As mentioned, commutation is the process of turning off an SCR. Explain how this process is achieved in this circuit, after the SCR is triggered?

Apparatus Required: Quantity

Resistance 1K, ¼ W	1
Electrolytic capacitor 2.2uF/63V (on board)	1
Inductor 10mH (on board)	1
SCR 2P4M (on board)	1
Patch cord	6

Circuit Diagram:

The class B commutation circuit diagram is shown below:

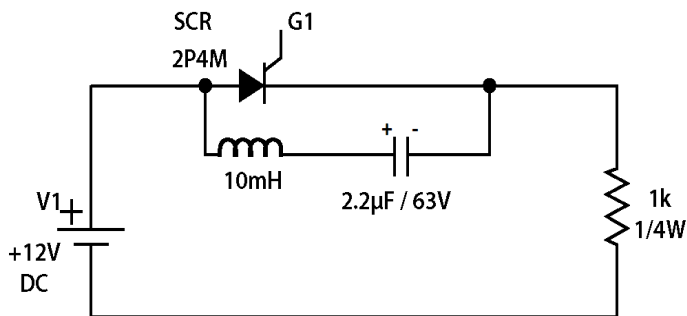


Figure 9

Procedure:

1. Connect circuit as shown in Figure 9.
2. Connect Gate of SCR to G1 signal, in the "TRIGGERING CIRCUIT" block.
3. Switch on the LAB.
4. Adjust "PWM CONTROL" to pulse the gate.
5. Connect oscilloscope across SCR and observe the waveform.
6. Connect oscilloscope across load resistance and observe waveform.

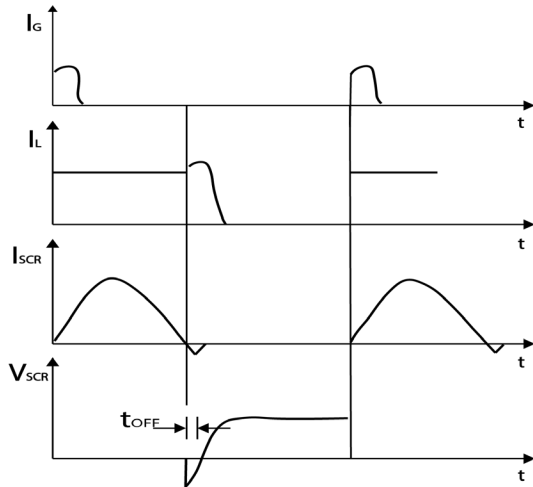


Image 9: Class B Commutation Waveform

Experiment 10: Class C Commutation Circuit

Introduction:

The class C commutation circuit is considered forced commutation. It differs from class B in that it utilizes two SCRs connected in parallel. The class C circuit is referred to as complementary commutation. The circuit consists of a main SCR and an auxiliary SCR. When the main SCR is turned on the capacitor connecting them charges to peak value. When this occurs, the auxiliary SCR will turn on, shutting off the first SCR. This process will continue to repeat while the circuit is powered. This lab will cover the mentioned effect by using an oscilloscope to view the output at both SCRs.

Pre-Lab Questions:

Both Class B and Class C are considered forced commutation. However, Class C utilizes two SCRs. Explain how, in the circuit for this lab, resonant current will shut off both SCR, once they are triggered?

Apparatus Required: Quantity

Resistance 2.7K Ω , 1/4 W	2
CAP. 0.1 MFD (on board)	1
SCR TYN 612 (on board)	2
Patch cord	10

Circuit Diagram:

The class C commutation circuit diagram is shown below:

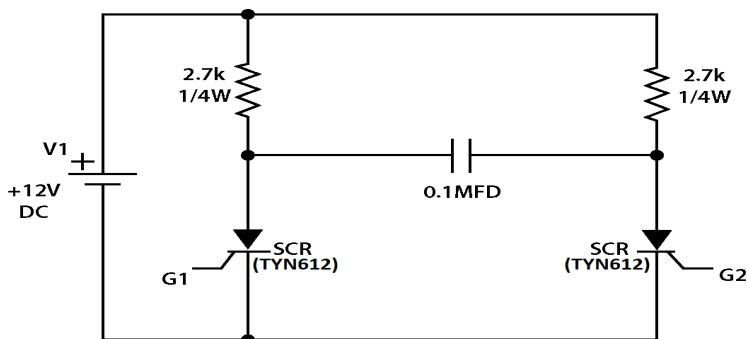


Figure 10

Procedure:

1. Connect the circuit as shown in Fig. 10.
2. Connect G1 & G2 signal to gate of SCR.
3. Switch Power ON.
4. Connect Oscilloscope across SCR and observe waveform.
5. Connect oscilloscope across load resistance and observe waveform.

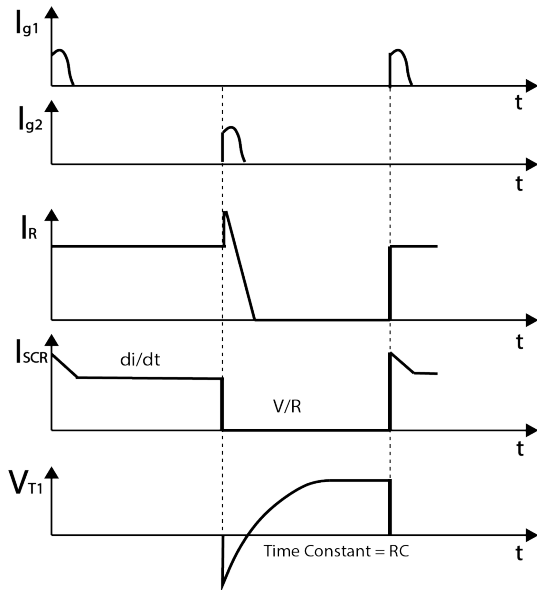


Image 10: Class C Commutation Waveform

Experiment 11: Class D Commutation Circuit

Introduction:

The class D commutation circuit is also considered forced commutation. Like class C, the class D circuit consists of a main SCR and an auxiliary SCR. Class D, however, has an added diode and inductor connected in parallel with the main SCR. It is commonly referred to as impulse commutation or voltage commutation due to the waveforms of the SCRs. This lab will cover the characteristics of a class D commutation circuit by using an oscilloscope to view the output at both SCRs.

Pre-Lab Questions:

In Class C commutation, SCR1 shuts off whenever SCR2 is triggered and vice versa. Does the same process apply in Class D commutation? Why?

Apparatus Required: Quantity

Resistance 510 Ω , 1/4 W	1
Met. Cap 0.33 MFD (on board)	1
SCR 2P4M (on board)	2
Inductor 68mH (on board)	1
Diode 1N4007 (on board)	1
Patch cord	10

Circuit Diagram:

The class D commutation circuit diagram is shown below:

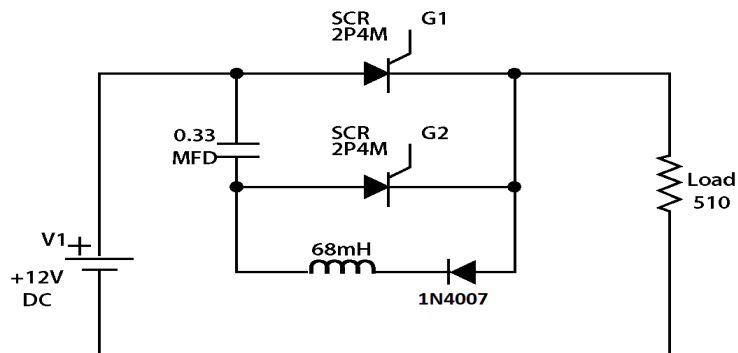


Figure 11

Procedure:

1. Connect the circuit as shown in Fig. 11.
2. Connect G1 & G2 signal to gate of SCR1 & SCR2.
3. Switch Power ON.
4. Connect oscilloscope across SCR1 & SCR2 and observe waveforms.
5. Connect oscilloscope across Load and observe waveforms.

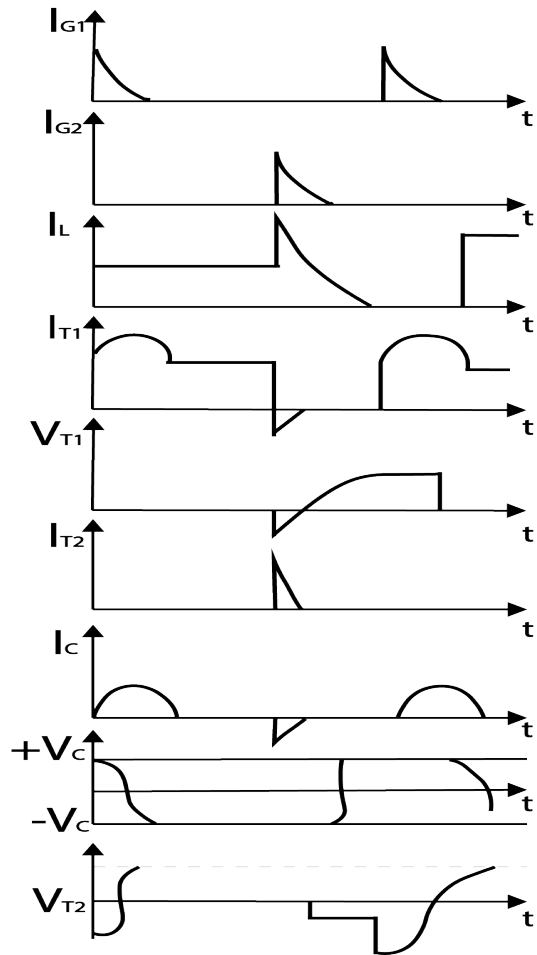


Image 11: Class D Commutation Waveform

Experiment 12: Class F Commutation Circuit

Introduction:

The class F commutation circuit is considered natural commutation, also known as source or line commutation. In class F commutation, the SCR is switched on and off by the voltage source and not the circuit components. An AC supply source is used to turn off the SCR at the end of every positive cycle. The class F circuit is used in commutated inverters, controlled rectifiers and cycloconverters. This lab will cover the characteristics of the class F commutation circuit by using an oscilloscope to view the output of the SCR.

Pre-Lab Questions:

The Class F commutation circuit is much simpler than the previous ones that have been presented. It consists of a power source, SCR, and load. How is the SCR shut off in this circuit, after it has been triggered on?

Apparatus Required: Quantity

Resistance 1K Ω , 5W (on board)	1
SCR 2P4M (on board)	1
Patch cord	5

Circuit Diagram:

The class F commutation circuit diagram is shown below:

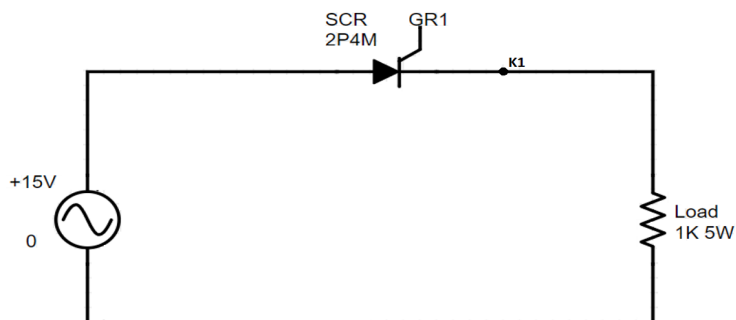


Figure 12

Procedure:

1. Connect the circuit, as shown in Figure 12, using patch cords.
2. Connect GR1 signal to Gate of SCR.
3. Switch Power ON
4. Vary the Firing Control Pot and observe waveform across Load.
5. Vary the Firing Control Pot and observe waveform across the SCR

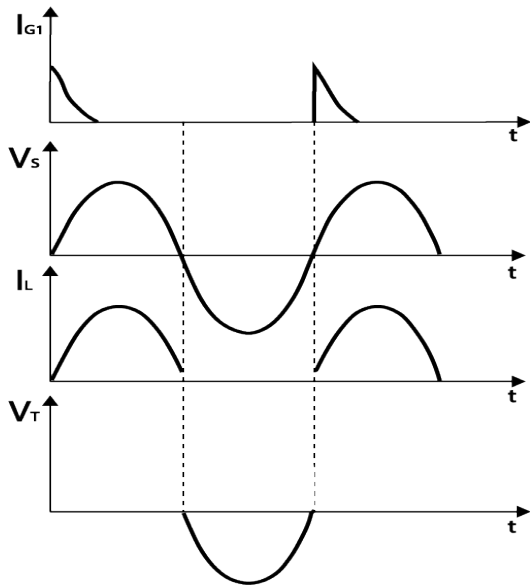


Image 12: Class F Commutation Waveform

Experiment 13: Resistor Triggering Circuit

Introduction:

The resistor triggering circuit is used to control the SCR over a 90° range. The resistors and diodes connected in this circuit act as a gate control to trigger the SCR. It is the simplest resistor triggering circuit, but it has many disadvantages. The circuit is very inefficient and leads to huge power losses. Resistors are very bulky in size and take up a lot of room on circuit boards. This circuit is useful to understand simple triggering of an SCR before moving on to a more complex circuit. This lab will cover the characteristics of a resistor triggering circuit by using an oscilloscope to view the output of the SCR.

Pre-Lab Questions:

1. How does the Potentiometer control the triggering of the SCR?
2. Why is the firing angle control limited to 90° ?

Apparatus Required: Quantity

Resistance $1K\Omega$, $\frac{1}{4} W$	1
Resistance 510Ω , $\frac{1}{4} W$	2
Potentiometer $1M\Omega$ (on board)	1
SCR 2P4M (on board)	1
Diode 1N4007 (on board)	1
Patch cord	10

Circuit Diagram:

The SCR Resistor Triggering Circuit diagram is shown below:

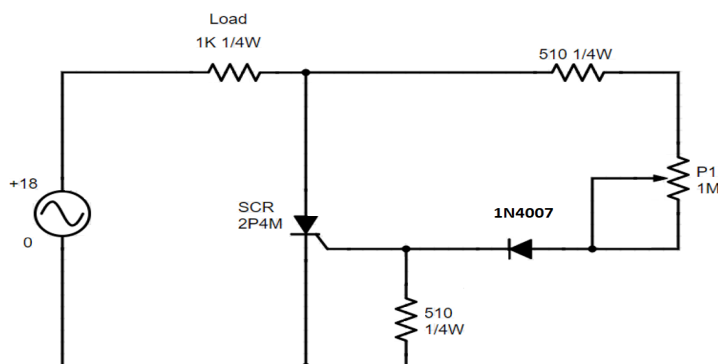


Figure 13

Procedure:

1. Connect the circuit, as shown in Figure 13, using patch cords.
2. Rotate potentiometer P1 in the full clockwise position.
3. Switch Power ON.
4. Connect the oscilloscope CH1 across the load and observe the phase angle and voltage.
5. Now, connect the oscilloscope across the thyristor and observe the waveform.
6. To see the phase angle variation, slowly vary the potentiometer.
7. Repeat the experiment from step 5 for various angles and plot the graphs by $T = (\alpha \times 10\text{ms})/180$.

Table 13: Observed Values

No.	Load Voltage (V)	Phase Angle (α)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

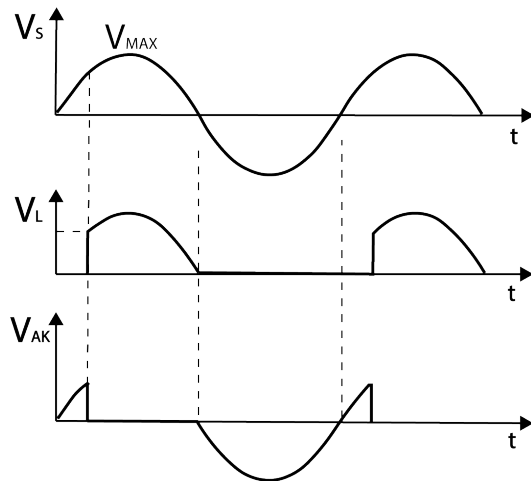


Image 13: Waveforms of R firing circuit

Experiment 14: Resistor Capacitor Triggering Circuit (Half Wave)

Introduction:

The resistor capacitor triggering circuit, half wave, is used to control the SCR over the entire 180° range. This circuit differs from the previous one in that it has an additional diode and capacitor in the circuit. This circuit produces a half wave, on the positive side of the waveform. This is due to the additional diode blocking the negative direction of current flow resulting in a half wave circuit.

Pre-Lab Questions:

Both Resistor triggering and resistor capacitor triggering circuits have a similar wave form for voltage across the SCR. What is the major difference between these two circuits?

Apparatus Required: Quantity

Resistance 1K Ω , ¼ W	1
Potentiometer 1M Ω (on board)	1
SCR 2P4M (on board)	1
Diode 1N4007 (on board)	2
Met. Cap. 0.1 MFD (on board)	1
Patch cord	11

Circuit Diagram:

The Resistor Capacitor Triggering Circuit (Half Wave) diagram is shown below:

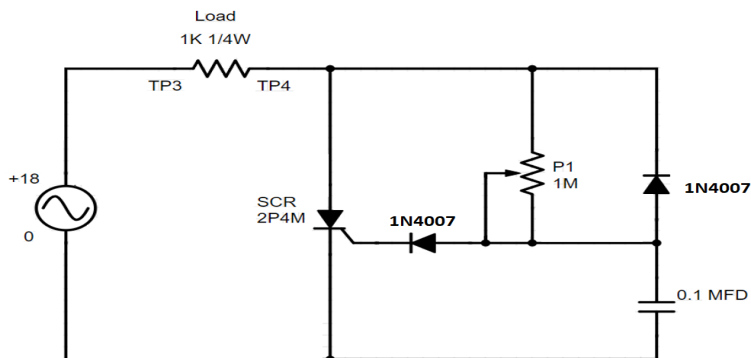


Figure 14

Procedure:

1. Connect the circuit, as shown in Figure 14, using patch cords.
2. Rotate potentiometers P1 in the full counterclockwise position.
3. Switch Power ON.
4. Connect the Oscilloscope probe across the Load and observe the phase angle and voltage.
5. Now, connect the oscilloscope probe across the thyristor and observe the waveform.
6. Vary the potentiometer slowly to see the phase angle variation.
7. Repeat the experiment from step 5 for various angles and plot the graphs. $T = (\alpha \times 10\text{ms})/180$

Table 14: Observed Values

No.	Load Voltage (V)	Phase Angle (α)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

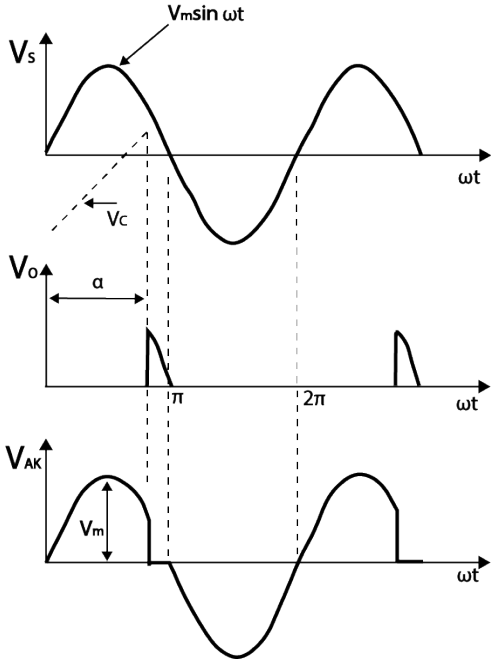


Image 14: RC Half Wave Firing Circuit Waveform

Experiment 15: Resistor Capacitor Triggering Circuit (Full Wave)

Introduction:

The resistor capacitor triggering circuit, full wave, is used to control an SCR over the entire 180° range while triggering negative side voltage waveforms. This circuit is very similar to the halfwave with the main difference being the additional diodes at the source voltage which allow the circuit to conduct over the entire cycle. This lab will cover the characteristics of the full wave circuit by using an oscilloscope to look at the waveform obtained at the output of the SCR.

Pre-Lab Questions:

How will varying potentiometer P1 affect the triggering phase angle?

Apparatus Required: Quantity

Resistance 510Ω , $\frac{1}{4}$ W	1
Resistance $1K\Omega$, 5W (on board)	1
SCR 2P4M (on board)	1
Potentiometer $1M\Omega$ (on board)	1
Ele. Cap 1MFD (on board)	1
Diode IN4007 (on board)	4
Patch cord	15

Circuit Diagram:

The Resistor Capacitor Triggering Circuit (Full Wave) diagram is shown below:

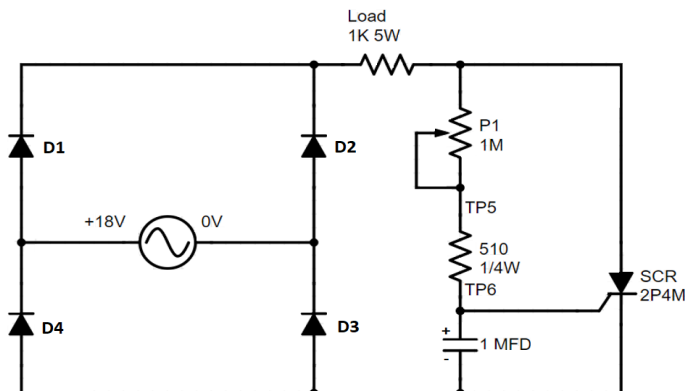


Figure 15

Procedure:

1. Connect the circuit, as shown in Figure 15, using patch cords.
2. Rotate potentiometer P1 in the full clockwise position.
3. Switch Power ON.
4. Connect the oscilloscope probe across the 510Ω resistor, observe the phase angle and voltage.
5. Now, connect the oscilloscope probe across the thyristor, observe the waveform.
6. Vary the potentiometer slowly to see the phase angle variation.
7. Repeat the experiment from step 5 for various angles and plot the graphs. $T = (\alpha \times 10\text{ms}) / 180$

Table 15: Observed Values

No.	Load Voltage (V)	Phase Angle (α)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

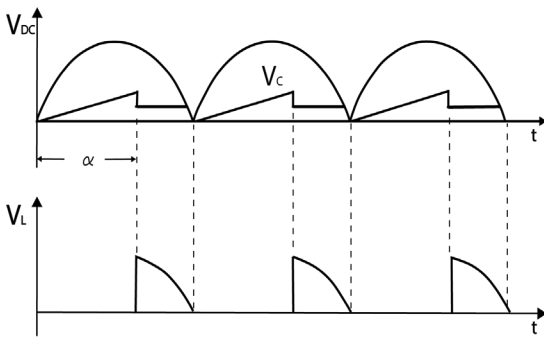


Image 15: RC Full Wave Firing Circuit Waveform

Procedure:

1. Connect the circuit, as shown in Figure 16, using patch cords.
2. Connect Ammeter between points '3' and '4' to measure Anode-cathode current I_{AK} (mA).
3. Connect Ammeter between points '1' and '2' to measure the gate current I_g (mA).
4. Connect voltmeter at point '5' and ground to measure the anode-cathode voltage V_{AK} .
5. Rotate potentiometer P1 in the full clockwise position and P2 in the full counterclockwise position.
6. Switch Power ON.
7. Vary potentiometer P2 to increase the anode to cathode voltage. Set this voltage above 11V.
8. Vary potentiometer P1 to increase the value of gate current in steps. Record the measured current I_{AK} values on the table provided.
9. Initially there will be no current flow across the SCR. While increasing the gate current, the measured I_{AK} value will have a sudden jump and the measured V_{AK} will have a sudden drop. This is an indication that the SCR has been triggered.
10. After the firing on of the SCR, vary P1. There will be no effect on I_{AK} or V_{AK} .
11. To repeat this experiment, switch power OFF then follow the above Procedure from step 7.

Table 16: Measured Values

No.	Gate Current	Anode to Cathode Current	Anode to Cathode Voltage
	I_g (mA)	I_{AK} (mA)	V_{AK} (V)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Experiment 17: Triggering an SCR with a IC-555

Introduction:

The 555 timer is an integrated circuit that can be used for such things as pulse generation and oscillator applications. In this circuit, the 555 timer will act as an oscillator. The frequency of the 555 timer can be controlled by adjusting the values of the two resistors and capacitor depicted on the left side of the circuit.

Pre-Lab Questions:

The 555 pinout diagram contains 8 pins. What is the function of each pin?

Apparatus Required: Quantity

Resistance 1K Ω , 1/4 W	1
Resistance 100 Ω , 2W (on board)	1
Resistance 5.1K Ω , 1/4 W	1
IC 555 timer	1
Capacitor 0.01 MFD (on board)	1
Ele. Cap 1MFD (on board)	1
Diode 1N4007 (on board)	1
SCR TYN 612 (on board)	1
Potentiometer 4.7K Ω (on board)	2
Multimeter	3
Patch Cord	17

Circuit Diagram:

The circuit diagram for Triggering of SCR using 555 IC is shown below:

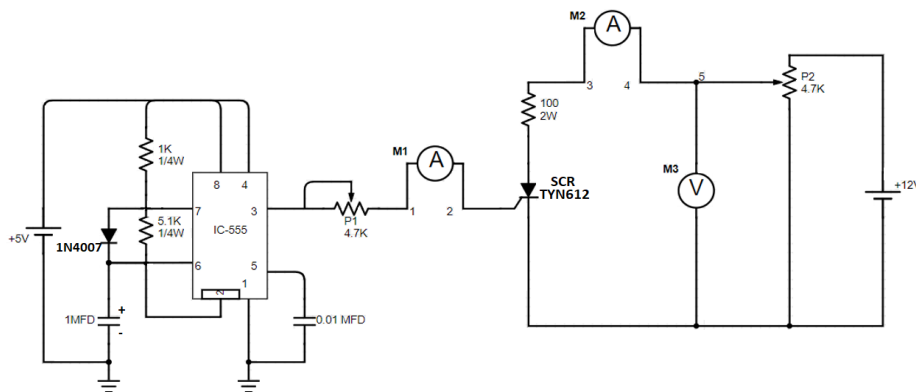


Figure 17

Procedure:

1. Connect the circuit, as shown in Figure 17, using patch cords.
2. Connect ammeter between points '3' and '4' to measure Anode-cathode current I_{AK} (mA).
3. Connect a second ammeter between points '1' and '2' to measure the gate Current I_G (mA).
4. Connect voltmeter at point '5' and ground to measure the anode-cathode voltage V_{AK} .
5. Rotate potentiometer P1 in the full clockwise position and P2 in the full counterclockwise position.
6. Switch Power ON.
7. Vary potentiometer P2 to increase V_{AK} . Set this voltage above 11V.
8. Vary potentiometer P1 to increase the value of gate current in steps. Record the measured I_G values and corresponding I_{AK} measured values on the table provided.
9. Initially, there will be no current flow across the SCR. While increasing the gate current I_G , there will be a sudden increase in the measured I_{AK} value and a sudden drop in the measured V_{AK} value. This is an indication that the SCR has been triggered.
10. Now vary the P1, there will be no effect on V_{AK} or I_{AK} .
11. To repeat this experiment switch power OFF and follow the Procedures starting from step 7.

Table 17: Measured Values

No.	Gate Current	Anode to Cathode Current	Anode to Cathode Voltage
	I_G (mA)	I_{AK} (mA)	V_{AK} (V)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Experiment 18: Triggering an SCR with a IC-741

Introduction:

An op amp is a device that converts a small signal input into a higher output. In this circuit the op amp is configured as a multivibrator circuit. The op amp will create a PWM signal to go through the Zener diode and become the input of the SCR gate. This is an advanced circuit design that demonstrates one of the many ways to trigger an SCR. Because it is advanced and impractical, this circuit is not used in typical electronic applications. In this lab, the focus will be on the voltage across the SCR, to see when the op amp turns it off and on.

Pre-Lab Questions:

An Op Amp contains an inverting and noninverting terminal. Which pin, on the IC 741, is the inverting input and which is the noninverting input?

Apparatus Required: Quantity

Resistance 10K Ω , 1/4 W (on board)	3
Resistance 120 Ω , 5W (on board)	1
Zener 9V (on board)	1
SCR TYN 612 (on board)	1
Potentiometer 4.7K Ω (on board)	2
IC 1M 741	1
Cap 0.047 MFD (on board)	1
Multimeter	3
Patch Cord	16

Circuit Diagram:

The circuit diagram for Triggering an SCR using IC -741 is shown below.

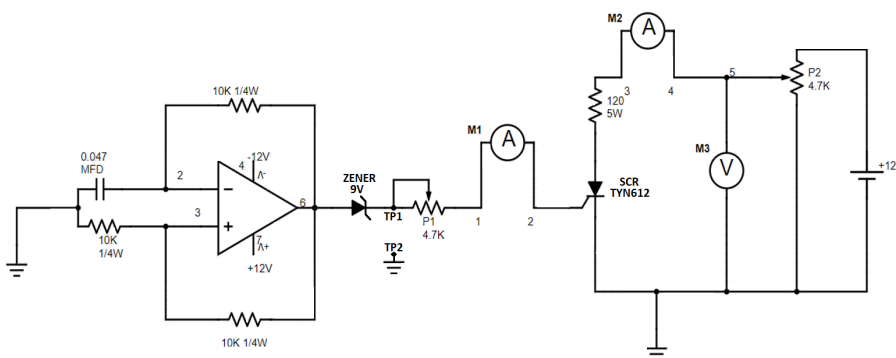


Figure 18

Procedure:

1. Connect the circuit, as shown in Figure 18, using patch cords.
2. Connect ammeter between points '3' and '4' to measure anode-cathode current I_{AK} (mA).
3. Connect ammeter between points '1' and '2' to measure the gate Current I_G (mA).
4. Connect voltmeter at point '5' and ground to measure the anode-cathode voltage V_{AK} .
5. Rotate the potentiometer P1 in the full clockwise position and P2 in the full counterclockwise position.
6. Switch Power ON.
7. Vary potentiometer P2 to increase V_{AK} . Set this voltage above 11V.
8. Vary potentiometer P1 to increase the gate current I_G value in steps. Record the measured V_{AK} and corresponding I_{AK} values on the table provided.
9. Initially there will be no current flow across the SCR. While increasing the gate current I_G , there will be a sudden increase in the I_{AK} measured value and a sudden drop in the V_{AK} measured value. This is an indication that the SCR has been triggered.
10. After the firing on of the SCR, vary the P1. There will be no effect on I_{AK} or V_{AK} .
11. To repeat this experiment switch power OFF and follow the Procedures starting from step 5.

Table 18: Measured Values

No.	Gate Current	Anode to Cathode Current	Anode to Cathode Voltage
	I_G (mA)	I_{AK} (mA)	V_{AK} (V)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Experiment 19: RAMP and Pedestal Triggering Using Anti parallel SCR

Introduction:

The ramp and pedestal triggering circuit is used to turn on and off two SCRs, connected in antiparallel, to power an AC load. The potentiometer controls the pedestal voltage value and acts as the input voltage of the UJT. When the UJT starts to conduct, a pulse is produced at the primary and secondaries of the transformer supplying a pulse to the gate of the SCRs. In this lab the output across the load will be measured with an oscilloscope at different firing angles of the two SCRs. The output should look like a sawtooth wave or a ramp as the title of the circuit implies.

Pre-Lab Questions:

Through analysis of the circuit schematic for this lab, explain how potentiometer P1 controls the firing angle?

Apparatus Required: Quantity

Resistance 220 Ω , 2W (on board)	1
Resistance 22K Ω , ¼ W (on board)	1
Resistance 220 Ω , ¼ W	1
Resistance 1K Ω , 5W (on board)	1
Ele. Cap 1MFD (on board)	1
Diode IN4007 (on board)	8
Zener 9V (on board)	1
Potentiometer 4.7K Ω (on board)	1
UJT 2N2646 (on board)	1
SCR 2P4M (on board)	2
Pulse transformer 1:1:1 (on board)	1
Inductance 68mH (on board)	1
Patch cord	16

Circuit Diagram:

The circuit diagram of basic anti-parallel SCR in AC load is shown in the below Fig.19

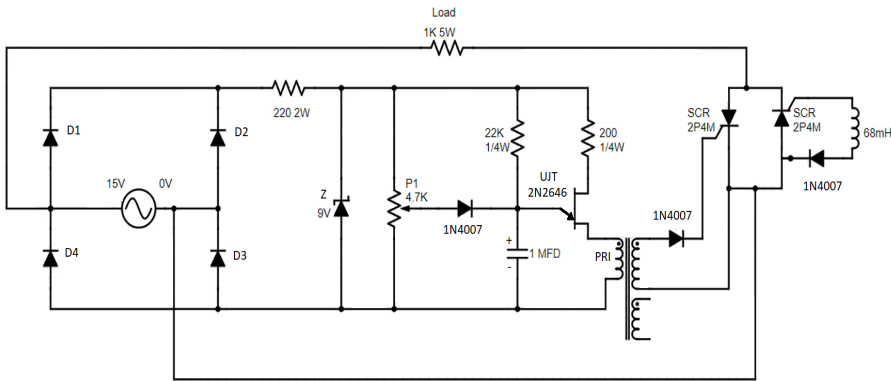


Figure 19

Procedure:

1. Connect the circuit, as shown in Figure 19, using patch cords.
2. Rotate potentiometer P1 in the full clockwise position.
3. Switch Power ON.
4. Connect the oscilloscope and observe the output waveform across the load resistor and connect the voltmeter across the load resistor.
5. Set the firing angle at 30°, 60°, 90°, 120°, and 150° by varying P1 and note the reading of output voltage. Angle in time convert using $T = (\alpha \times 10\text{ms}) / 180$.
6. Observe the output waveform across load and across SCRs when firing angle is set to 90°.

Table 19: Observed Values

No.	Input AC Voltage (V _{rms})	Output Across AC Load Circuit	
		Firing Angle (Degrees)	Output Voltage (V _{rms})
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

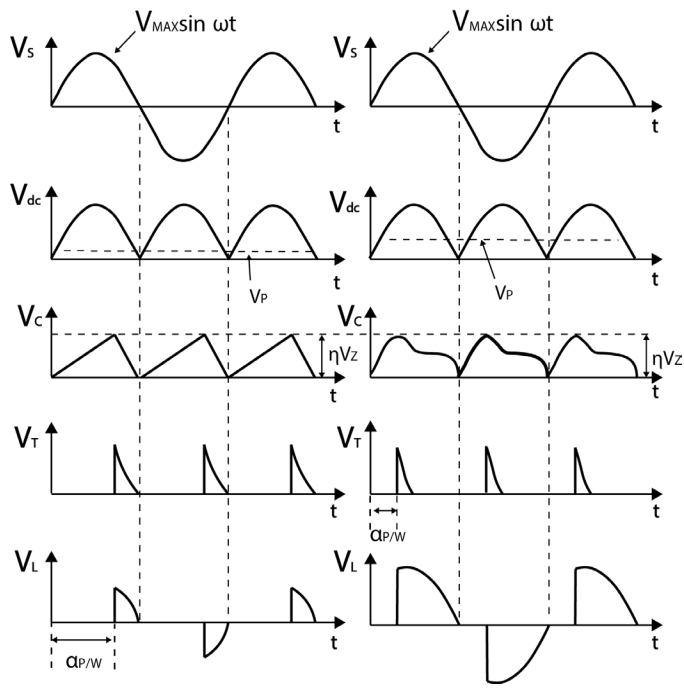


Image 19: Ramp and Pedestal Circuit Waveform

Experiment 20: UJT Relaxation Oscillator

Introduction:

The UJT component is commonly used in the UJT Relaxation Oscillator circuit. The relaxation oscillator is controlled by the charging and discharging of a capacitor. This causes the oscillation of the circuit and allows the UJT to be used in many different applications. Paired with an SCR, the UJT can be used to apply a pulse to the gate of an SCR making a triggering circuit with the two power components. The oscillation time is in the range of nanoseconds making it a fast and efficient switching device.

Pre-Lab Questions:

For the circuit in this lab, will the capacitor charge and discharge at the same rate? Why?
When will the capacitor trigger the UJT?

Apparatus Required: Quantity

Resistance 10K Ω , 1/4 W (on board)	1
Resistance 220 Ω , 1/4 W	1
Resistance 100 Ω , 1/4 W (on board)	1
Diode 1N4007 (on board)	1
Cap. 0.1MFD (on board)	1
UJT 2N2646 (on board)	1
Potentiometer 4.7K Ω (on board)	1
Patch cord	10

Circuit Diagram:

The UJT Relaxation Oscillator circuit diagram is shown below:

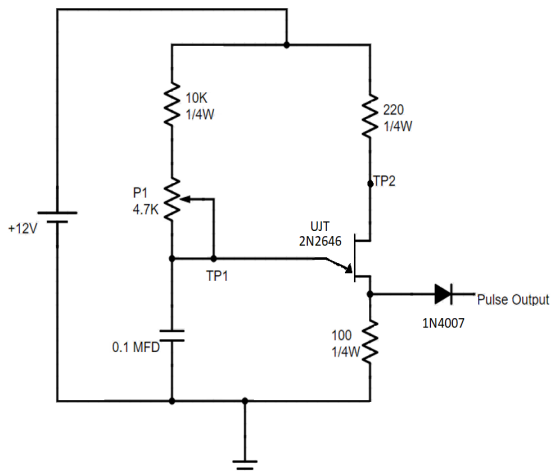


Figure 20

Procedure:

1. Connect the circuit, as shown in Figure 20, using patch cords.
2. Rotate potentiometer P1 in the full clockwise position.
3. Switch Power ON.
4. Connect the oscilloscope CH1 between output and ground and CHII between TP1 and ground, observe the waveform of pulse output and RC time constant.
5. Vary potentiometer P1 to increase the frequency of the output.
6. Connect the oscilloscope CH1 between output and ground and CHII between TP1 and ground, observe the waveform of pulse output and RC time constant.
7. Vary potentiometer P1 to increase the frequency of the output.

Table 20: Observed Values

No.	Minimum Frequency	Maximum Frequency

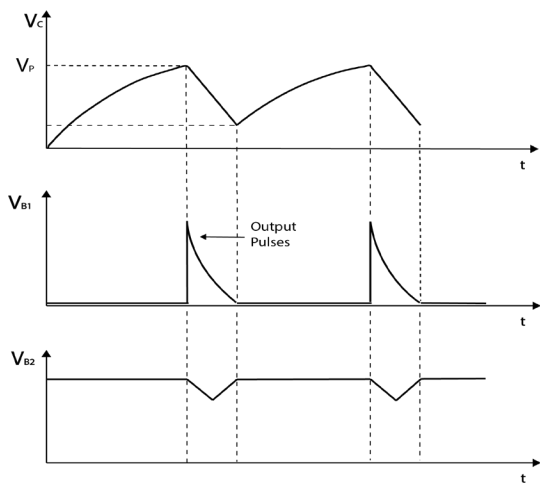


Image 20: UJT Relaxation Oscillator Waveform

Experiment 21: Voltage Commutated Chopper

Introduction:

The Voltage Commutated Chopper circuit is used to control the power consumed at the load. The circuit does this by chopping the source voltage waveform to a lower value. It was commonly used in dimmer switches and incandescent lamps to control power output. The advantage of this circuit is the components, used in it, are inexpensive. The disadvantage of this circuit is the harmonics created inside the circuit as well as its limitations when working with inductive loads.

Pre-Lab Questions:

The Voltage Commutated Chopper can be broken up into 4 modes. What occurs at each of these modes when the circuit is on?

Apparatus Required: Quantity

Resistance 510Ω, ¼ W	1
Met. Cap. 0.33MFD (on board)	1
Inductor 68mH (on board)	1
Inductor 10mH (on board)	1
SCR 2P4M (on board)	2
Diode 1N4007 (on board)	2
Patch cord	10

Circuit Diagram:

Circuit diagram of voltage commutated chopper is shown below:

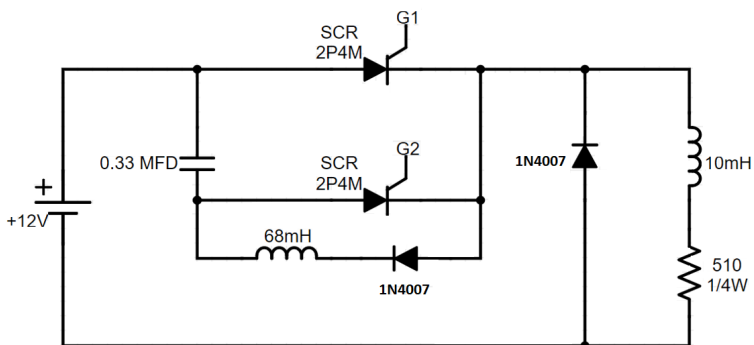


Figure 21

Procedure:

1. Connect the circuit as shown in Figure 21
2. Connect G1 & G2 to the gate of SCR1 and SCR2.
3. Switch ON the LAB.
4. Vary the PWM Pot in fully clockwise direction.
5. Connect the oscilloscope across the load.
6. Vary the frequency potentiometer and observe the output across load, SCR1, and SCR2.

Table 21: Observed Values

No.	Frequency	Output Voltage
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

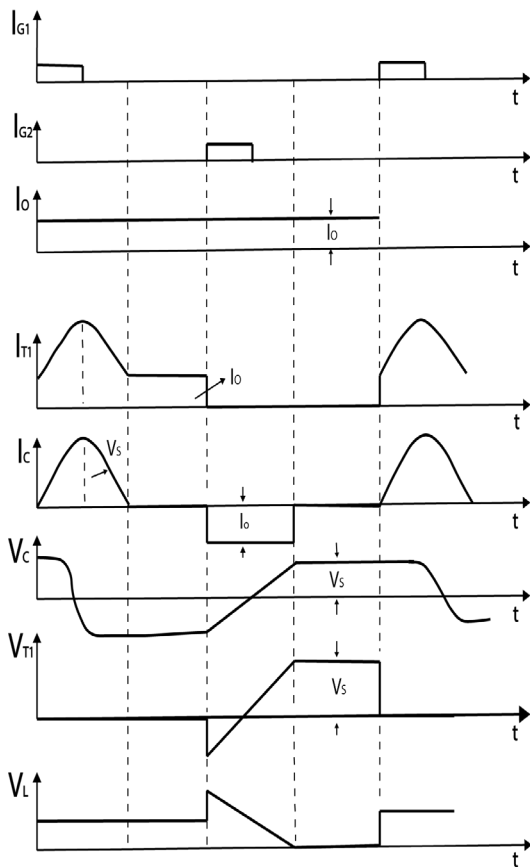


Image 21: Voltage Commutated Chopper Waveform

Experiment 22: Bedford Inverter

Introduction:

Inverters are typical Power Electronics circuits that take in a DC voltage and convert it to an AC voltage. This is helpful when transmitting voltages across components that are DC sensitive. The Bedford inverter is a full bridge converter that converts DC voltage into AC voltage. It uses SCRs to form two separate half bridge circuits when connected from a full AC voltage wave. This is a very powerful converter, and many variations of this circuit are used in common electronic appliances.

Apparatus Required: Quantity

Resistance 33K Ω , 1/4 W (on board)	1
Met. Cap 1MFD 63V (on board)	4
SCR 2P4M (on board)	4
Diode IN4007 (on board)	4
Patch cord	10

Circuit diagram:

Circuit diagram of Bedford inverter is shown below:

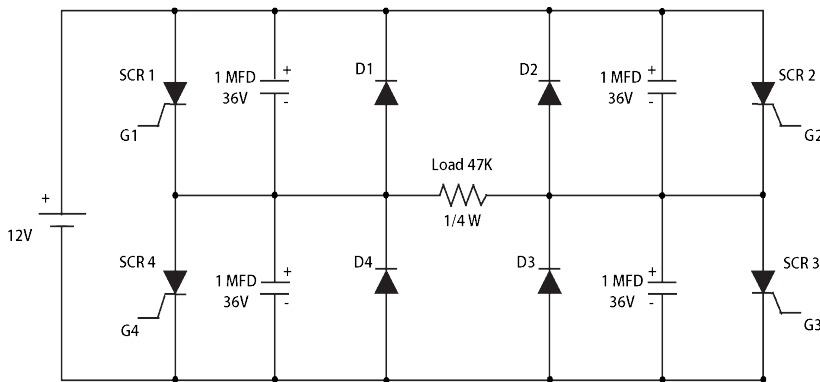


Figure 22

Procedure:

1. Connect the circuit as shown in Figure 22
2. Connect G1, G2, G3, and G4 to the gate of SCR1, SCR2, SCR3, and SCR4 respectively.
3. Switch Power ON.
4. Rotate the PWM and Frequency CONTROL to set between the full counterclockwise and midpoint position.
5. Connect oscilloscope across the load and SCR'S.
6. Vary FREQUENCY pot and observe the output across load and across SCR1 & SCR2

Table 22: Observed Values

No.	Frequency	Output Voltage
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Experiment 23: Single Phase PWM Inverter with MOSFET

Introduction:

While utilizing an SCR is a common way to create an inverter, the same can be achieved with MOSFETS. The single phase PWM inverter uses MOSFETS to control the fast switching of the voltage across the load. Connecting a DC input and switch to this MOSFET circuit formation inverts the signal into an AC output. When G1 and G3 are conducting there is a positive voltage drop across the resistor. When G2 and G4 are conducting there is negative voltage across the resistor. This along with the current direction change results in a DC to AC conversion.

Pre-Lab Questions:

In this circuit, how is DC converted to AC?

Why is the firing sequence of G1, G2, G3, and G4 important for the circuit to operate effectively?

Apparatus Required: Quantity

MOSFET IRF540 (on board)	1
MOSFET IRF 540	3
Resistance 1K Ω , 1/5 W (on board)	1
Switch 1P-2W (SPOT) on board	1
Patch cord	10

Circuit Diagram:

Circuit diagram of a Single Phase PWM Inverter is shown below:

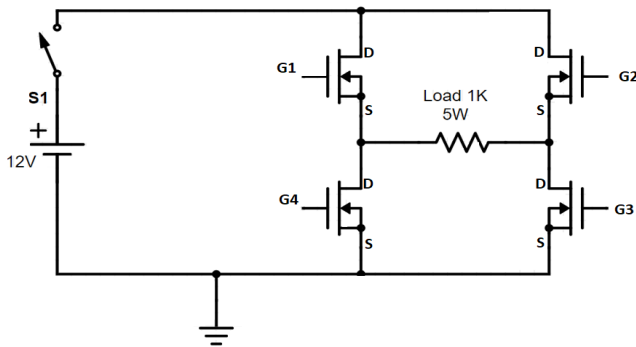


Figure 23

Procedure:

1. Connect the circuit as shown in Figure 23
2. Rotate the FREQUENCY pot. in the full counterclockwise position and the PWM CONTROL in the full clockwise position.
3. Switch Power ON.
4. Vary FREQUENCY pot. and observe waveform across load on oscilloscope.
5. Set the maximum frequency.
6. Connect the voltmeter across the load and measure the AC voltage.
7. Vary PWM CONTROL and observe output waveform across load and note the readings of pulse width and corresponding output AC (rms) voltage across load.

Table 23: Observed Values

No.	Pulse Width (ms)	AC Voltage Across Load

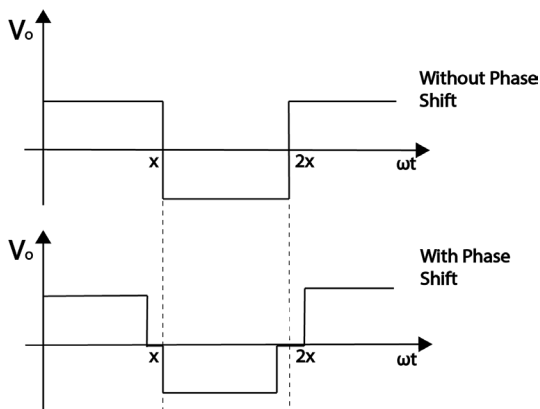


Image 23: PWM Inverter Waveform

Experiment 24: Single Phase PWM Inverter with IGBT

Introduction:

The single phase PWM inverter using IGBTs is very similar to the MOSFET equivalent in experiment 23. The IGBTs are triggered in the same fashion as the MOSFETs, with a signal applied to the gate. The DC input voltage is regulated using a control switch. The two circuits produce the same result and mirror each other in circuit design and complexity. This lab will demonstrate how the PWM Inverter circuit produces the same results when using either IGBTs or MOSFETs

Pre-Lab Questions:

In this circuit, how is DC converted to AC?

Why is the firing sequence of G1, G2, G3, and G4 important for the circuit to operate effectively?

Apparatus Required: Quantity

IGBT G4BC20S (on board)	1
IGBT G4BC20S	3
Resistance 1K Ω 5W (on board)	1
Tiny Toggle switch SPDT (on board)	1
Patch cord	10

Circuit Diagram:

Circuit diagram of a Single Phase PWM Inverter is shown below:

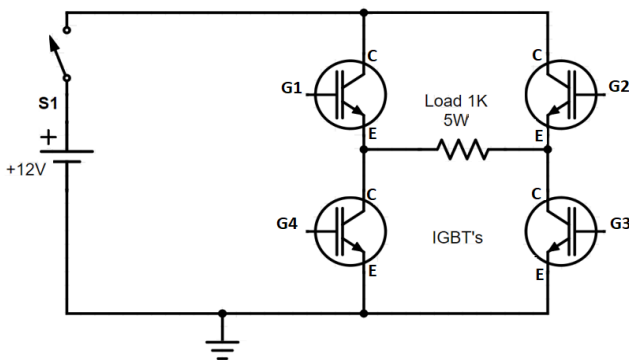


Figure 24

Procedure:

1. Connect the circuit as shown in Figure 24.
2. Rotate the FREQUENCY pot. in the full counterclockwise position and PWM CONTROL in the full clockwise position.
3. Switch Power ON.
4. Vary the FREQUENCY pot. and observe waveform across load on oscilloscope.
5. Set the maximum frequency.
6. Connect the voltmeter across the load and measure the AC voltage.
7. Vary PWM CONTROL and observe output waveform across load and note the readings of pulse width and corresponding output AC (rms) voltage across load.

Table 24: Observed Values

No.	Pulse Width (ms)	AC Voltage Across Load

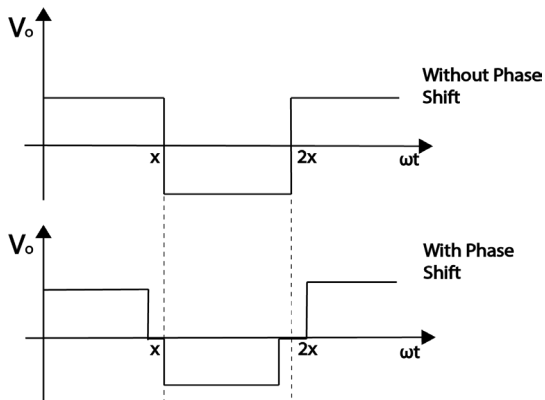


Image 24: PWM Inverter Waveform

Experiment 25: Half Wave Controlled Rectifier with Resistive Load

Introduction:

The half wave rectifier circuit converts an AC source into DC voltage for a load. The SCR can be triggered at different firing angles. This can only be done during the positive cycle of the AC voltage, making it a half wave circuit. This circuit is used in many basic dimmer switch applications but is usually replaced by the full wave version of it. In this lab the firing angle will be varied to see the change in output voltage, using an oscilloscope. The oscilloscope will show how output voltage is only present during the positive AC source voltage cycle.

Pre-Lab Questions:

Why does the V vs ωt graph, for this circuit, equal 0 between π and 2π ?
How is the firing angle α being controlled in this circuit?

Apparatus Required: Quantity

SCR 2P4M (on board)	1
Resistance 1K Ω , 5W (on board)	1
Multimeter	2
Patch cord	5

Circuit Diagram:

The circuit diagram of a basic Half-wave Controlled Rectifier is shown below.

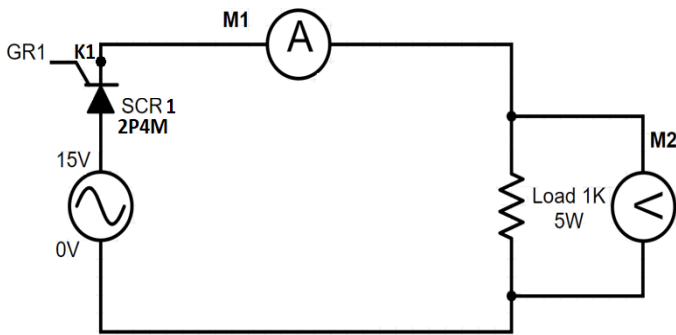


Figure 25

Procedure:

1. Connect the circuit as shown in Figure 25.
2. Rotate "FIRING ANGLE CONTROL POT" in the full clockwise position.
3. Switch Power ON.
4. Measure the AC voltage (V_{rms}) by voltmeter between point 0V-15V and calculate E_m by $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect circuit as shown in Figure 25.
7. Switch Power ON.
8. Connect the oscilloscope across the Load.
9. Connect the ammeter between Load and SCR.
10. Vary the firing control pot and set on 30° , 60° , 90° , 120° and 150° firing angles using $T = (a \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across Load at different firing angles.
12. Observe the waveform across the SCR1 when firing angle is 90° .
13. Calculate the average load I_{dc} current and power P_{dc} from measured load voltage V_o .

Table 25: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
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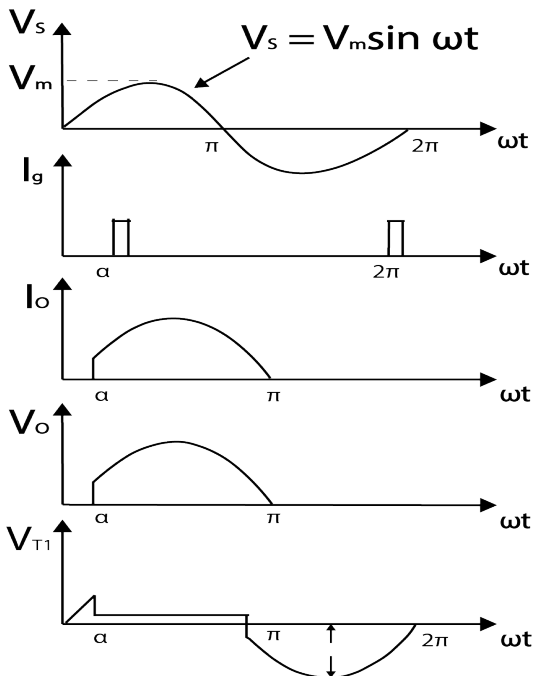


Image 25: Half Wave Rectifier with Resistive Load Circuit Waveform

Experiment 26: Half Wave Controlled Rectifier with RL Load

Introduction:

The half wave rectifier circuit with an RL load is similar to the purely resistive load circuit. The added inductor makes it a more realistic circuit, as loads usually have both resistance and inductance. The circuit is still a half wave rectifier, so it only conducts during the positive cycle of the AC source. The output will continue to conduct after the SCR has been turned off due to the inductor at the load resulting in a different output voltage. This lab will focus on the output voltage waveform to see how it differs from the previous lab.

Pre-Lab Questions:

- 1) Why does the V vs ωt graph, for this circuit, equal 0 between π and 2π ?
- 2) How is the firing angle α being controlled in this circuit?
- 3) How will adding an inductor to the resistive load affect the V vs ωt graph?

Apparatus Required: Quantity

SCR 2P4M (on board)	1
Resistance 270 Ω / 5W (on board)	1
Inductor 68mH (on board)	2
Multimeter	2
Patch cord	7

Circuit Diagram:

The circuit diagram for a basic Half-Wave Controlled Rectifier is shown below.

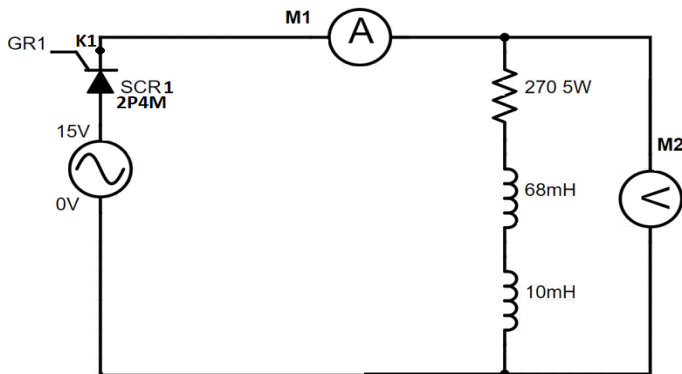


Figure 26

Procedure:

1. Connect the circuit as shown in Figure 26.
2. Rotate "FIRING ANGLE CONTROL POT" in the full clockwise position.
3. Switch Power ON.
4. Measure the AC voltage (V_{rms}) by voltmeter between points 0V-15V. Calculate $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect the circuit as shown in Figure 26.
7. Switch Power ON.
8. Connect the oscilloscope across load.
9. Connect the ammeter between Load and SCR.
10. Vary the "FIRING ANGLE CONTROL POT" and set to 30° , 60° , 90° , 120° and 150° firing angles using $T = (\alpha \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across load at different firing angles.
12. Observe the waveform across the SCR1 when firing angle is 90° .
13. Calculate the average load I_{dc} current and power P_{dc} from measured load voltage V_o .

Table 26: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
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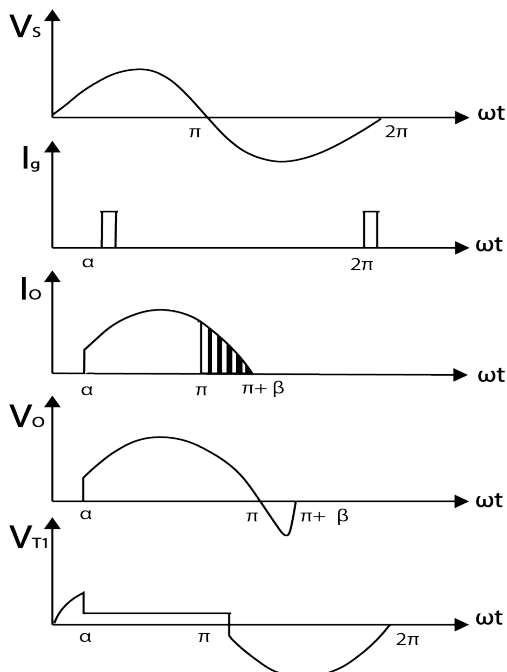


Image 26: Half Wave Rectifier with Resistive- Inductive Load Circuit Waveform

Experiment 27: Full-Wave Controlled Rectifier (Mid Point Configuration) with Resistive Load

Introduction:

The full bridge rectifier, midpoint configuration, is a continuation of the half wave rectifier. This circuit contains an additional SCR. Both SCRs are connected to an AC source. During the positive cycle of the source voltage, the first SCR is triggered based on the firing angle while the second SCR is triggered during the negative cycle. This circuit utilizes the entire AC voltage source wave, making it more efficient. In this lab the firing angle will be varied to view, on an oscilloscope, the change in the output voltage.

Pre-Lab Questions:

If the power source for this lab is AC, why isn't the voltage across the load ever negative?

Apparatus Required: Quantity

SCR 2P4M (on board)	2
Resistance 1K Ω , 5W (on board)	1
Multimeter	2
Patch cord	9

Circuit Diagram:

The circuit diagram for a basic Full-Wave Controlled Rectifier (Mid-Point configuration) is shown below.

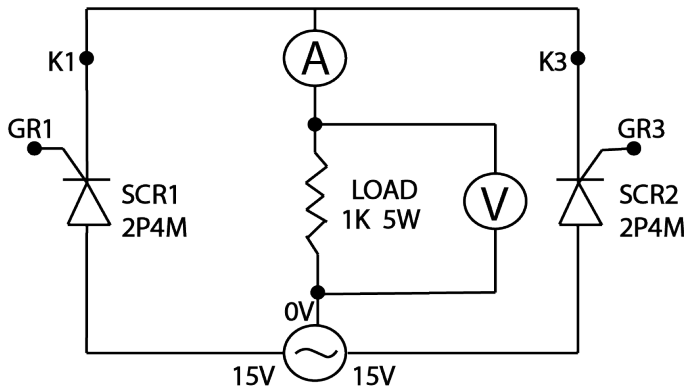


Figure 27

Procedure:

1. Connect the circuit as shown in Figure 27.
2. Rotate "FIRING ANGLE CONTROL POT" in the clockwise position.
3. Switch Power ON.
4. Measure the ac voltage (V_{rms}) by voltmeter between points 0V-15V. Calculate E_m . $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect circuit, as shown in Figure 27, using patch cords.
7. Switch Power ON.
8. Connect the oscilloscope across the Load.
9. Connect the ammeter between Load and SCR, as shown in circuit diagram.
10. Vary "FIRING ANGLE CONTROL POT" and set to 30° , 60° , 90° , 120° and 150° firing angles using $T = (\alpha \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across Load at different firing angle.
12. Connect oscilloscope across SCR1 only and observe the waveform when firing angle is 90° .
13. Connect oscilloscope across SCR2 only and observe the waveform when firing angle is 90° .
14. Calculate the average Load I_{dc} current and power P_{dc} from measured load voltage V_o .

Table 27: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
1										
2										
3										
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8										
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10										

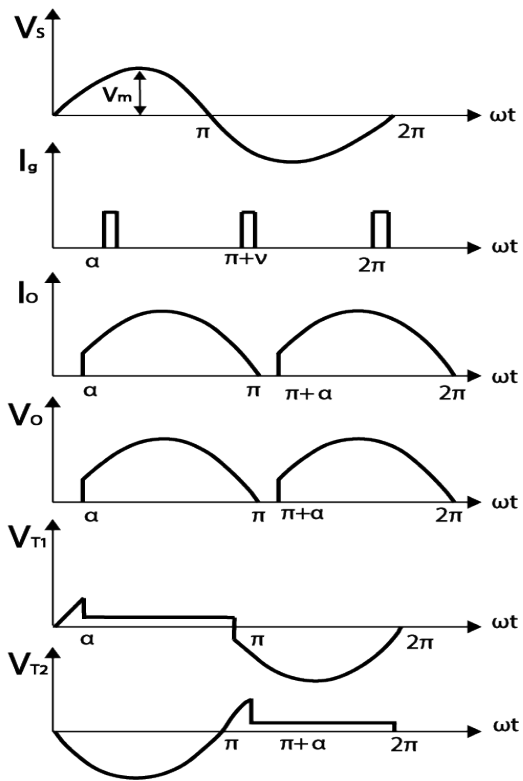


Image 27: Full Wave Rectifier (Mid-Point) with Resistive Load Circuit Waveform

Experiment 28: Full-Wave Controlled Rectifier (Mid Point Configuration) with RL Load

Introduction:

The full bridge rectifier, midpoint configuration, with an RL load is similar to the circuit with only a resistive load. The inductor continues to store charge after the SCR has been turned off causing the output waveform to produce a negative voltage. This is common in many electronic load circuits. In this lab the firing angle will be varied to view, on an oscilloscope, the change in the output voltage.

Pre-Lab Questions:

How will the inductor, added to this circuit, affect the voltage across the load?

Apparatus Required: Quantity

SCR 2P4M (on board)	2
Resistance 270Ω/5W (on board)	1
Inductors 68mH (on board)	2
Multimeter	2
Patch Cord	11

Circuit Diagram:

The circuit diagram for a basic Full-Wave Controlled Rectifier (Mid-Point configuration) is shown below.

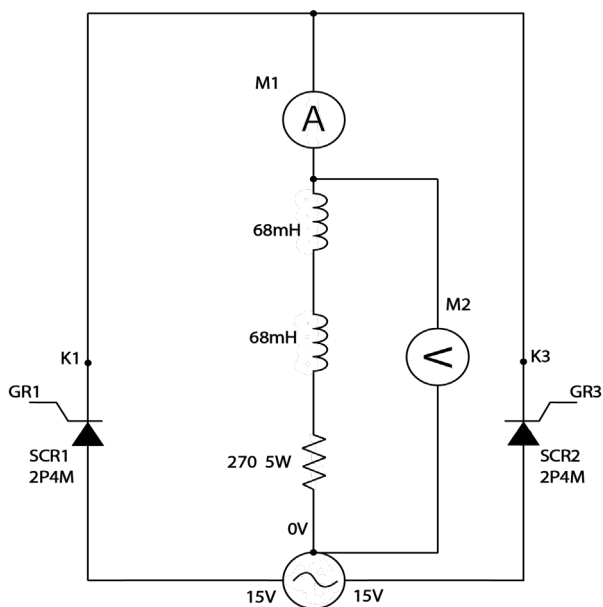


Figure 28

Procedure:

1. Connect the circuit as shown in Figure 28.
2. Rotate "FIRING ANGLE CONTROL POT" in the full clockwise position.
3. Switch Power ON.
4. Measure the AC voltage (V_{rms}) by connecting the voltmeter between points 0V-15V and calculate E_m by $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect circuit as shown in Figure 28.
7. Switch Power ON.
8. Connect the oscilloscope across the Load.
9. Connect the ammeter between Load and SCR, as shown in circuit diagram.
10. Vary "FIRING ANGLE CONTROL POT" and set to 30° , 60° , 90° , 120° and 150° firing angles using $T = (\alpha \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across Load at different firing angle.
12. Connect oscilloscope across SCR1 only and observe the waveform when firing angle is 90° .
13. Connect oscilloscope across SCR2 only and observe the waveform when firing angle is 90° .
14. Calculate the average Load I_{dc} current and power P_{dc} from measured Load voltage V_o .

Table 28: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
1										
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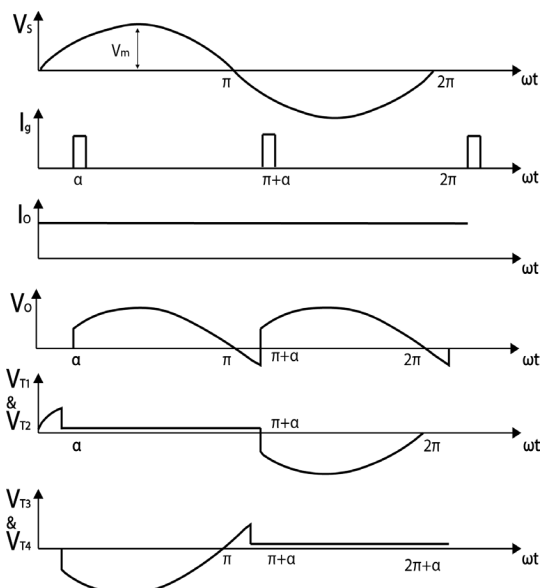


Image 28: Full Wave Rectifier (Mid-Point) with Resistive-Inductive Load Circuit Waveform

Experiment 29: Fully Controlled Bridge Rectifier with Resistive Load

Introduction:

The fully controlled bridge rectifier circuit takes an AC source and converts it into a DC voltage output load. It is a full bridge rectifier because it supplies power across the entire AC wave. A normal full bridge rectifier, using diodes, supplies the signal after the diode voltage is met. Using SCRs, the firing angle can be adjusted to trigger the output supply to the load voltage at a specific point on the AC wave. In this lab the firing angle will be varied to view, on an oscilloscope, the change in the output voltage.

Pre-Lab Questions:

In this lab AC will be converted to DC, using four thyristors as labeled on the circuit diagram provided. To achieve this, two thyristors must be fired on simultaneously as pairs. What should be the thyristor firing sequence for the circuit to operate correctly?

Apparatus Required: Quantity

SCR 2P4M (on board)	4
Resistance 1K Ω , 5W (on board)	1
Multimeter	2
Patch Cord	16

Circuit Diagram:

The circuit diagram for a basic Fully Controlled Bridge Rectifier is shown below.

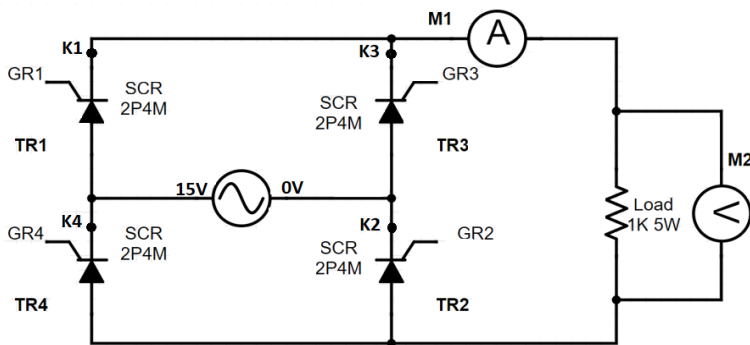


Figure 29

Procedure:

1. Connect the circuit as shown in Figure 29.
2. Rotate "FIRING ANGLE CONTROL POT" in the full clockwise position.
3. Switch Power ON.
4. Measure the AC voltage (V_{rms}) by connecting voltmeter between points 0V-15V and calculate E_m by $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect circuit as shown in Figure 29.
7. Switch Power ON.
8. Connect the oscilloscope across the Load.
9. Connect the ammeter between SCR and Load, as shown in Figure 29.
10. Vary "FIRING ANGLE CONTROL POT" and set to 30° , 60° , 90° , 120° and 150° firing angles using $T = (\alpha \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across Load at different firing angle.
12. Connect the oscilloscope one by one across SCR1, SCR2, SCR3, and SCR4, observe the waveforms for each when firing angle is 90° .
13. Calculate the average Load I_{dc} current and power P_{dc} from measured load voltage V_o .

Table 29: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

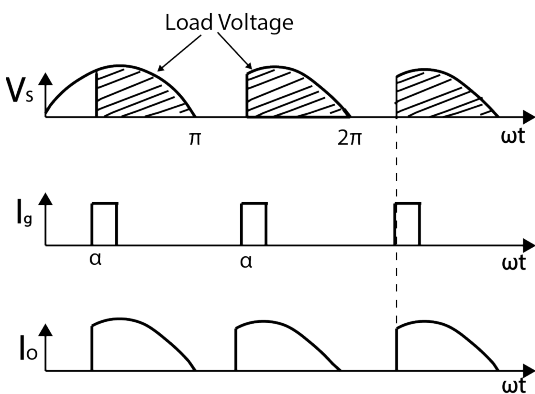


Image 29: Full Wave Bridge Rectifier with Resistive Load Circuit Waveform

Experiment 30: Fully Controlled Bridge Rectifier with RL Load

Introduction:

The fully controlled bridge rectifier circuit with an RL load is like the previous circuit with a varying output. The full bridge circuit with only a resistor at the load will have time periods where the voltage output is zero. With the addition of an inductor, to the load, the output voltage becomes continuous as the inductor supplies additional power during the time period where the SCR has not been triggered. This helps create a more realistic output curve as many common loads have both a resistive and inductive portion. In this lab the firing angle will be varied to see the change in the output voltage on an oscilloscope.

Pre-Lab Questions:

1. In this lab AC will be converted to DC, using four thyristors as labeled on the circuit diagram provided. To achieve this, two thyristors must be fired on simultaneously as pairs. What should be the thyristor firing sequence for the circuit to operate correctly?
2. How will the inductor, added in this circuit, affect the voltage across the load?

<u>Apparatus Required:</u>	<u>Quantity</u>
SCR 2P4M (on board)	4
Resistance 270 Ω , 5W (on board)	1
Inductor 68mH (on board)	2
Multimeter	2
Patch Cord	10

Circuit Diagram:

The circuit diagram for a basic Fully Controlled Bridge Rectifier is shown below.

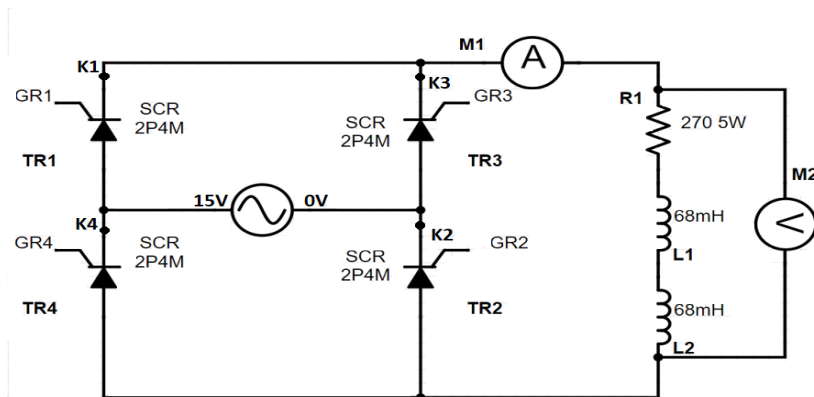


Figure 30

Procedure:

1. Connect the circuit as shown in Figure 30.
2. Rotate "FIRING ANGLE CONTROL POT" in the full clockwise position.
3. Switch Power ON.
4. Measure the AC voltage (V_{rms}) by connecting voltmeter between points 0V-15V and calculate E_m by $E_m = 1.414 \times V_{rms}$.
5. Switch Power OFF.
6. Connect circuit, as shown in Figure 30, using patch cords.
7. Switch Power ON.
8. Connect the oscilloscope across the Load.
9. Connect the ammeter between SCR and Load, as shown in Figure 30.
10. Vary "FIRING ANGLE CONTROL POT" and set to 30° , 60° , 90° , 120° and 150° firing angles using $T = (\alpha \times 10ms) / 180$.
11. Observe the output waveforms and note the readings of voltage across Load at different firing angles.
12. Connect the oscilloscope one by one across SCR1, SCR2, SCR3, and SCR4, observe the waveforms for each when firing angle is 90° .
13. Calculate the average Load I_{dc} current and power P_{dc} from measured load voltage V_o .

Table 30: Observed Values

No.	Input AC Voltage		Firing Angle		Average Output Voltage Across Load		Average Load Current		Average Output Power	
	V_{rms}	V_M	Degrees	Time (ms)	Measured (V_o)	Calculated (V_{dc})	Measured (I_o) V_o/R_L	Calculated (I_{dc}) V_{dc}/R_L	Measured (P_o) $I_o \times V_o$	Calculated (P_{dc}) $I_{dc} \times V_{dc}$
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

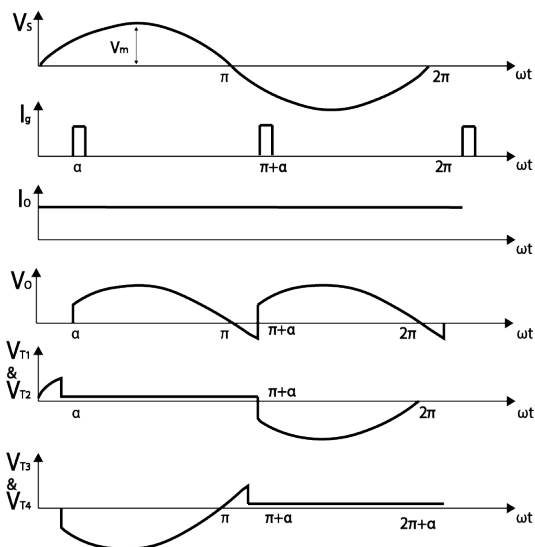


Image 30: Full Wave Bridge Rectifier with Resistive- Inductive Load Circuit Waveform

Experiment 31: Low Side Buck Converter with Resistive Load

Introduction:

The buck converter with a resistive load is a very common and critically important circuit in many electrical circuit designs. The purpose of the buck converter is to take a DC input supplied at a certain voltage and “buck” it down to a different voltage level. The reason a buck converter is used over a simple voltage divider is due to the efficiency. Buck converters maintain an overall efficiency of 90% or higher while voltage dividers can lose up to half the energy to the resistor in the divider circuit. The buck converter is used in cell phones, LED applications, almost anywhere where multiple circuit components are being powered but at different voltage levels. In this lab the duty cycle will be changed to show how the output voltage is affected by this.

Pre-Lab Questions:

What feature of this circuit enables it to step down the voltage?

<u>Apparatus Required:</u>	<u>Quantity</u>
Patch Cords	9
MOSFET Switch (on board)	1
Resistance 120, 5W (on board)	1
Inductance $250\mu\text{H}$	1
Capacitance $100\mu\text{F}$	1
Diode IN4007 (on board)	1
Function Generator	1

Circuit Diagram:

The circuit diagram of the low side buck converter is shown in the below.

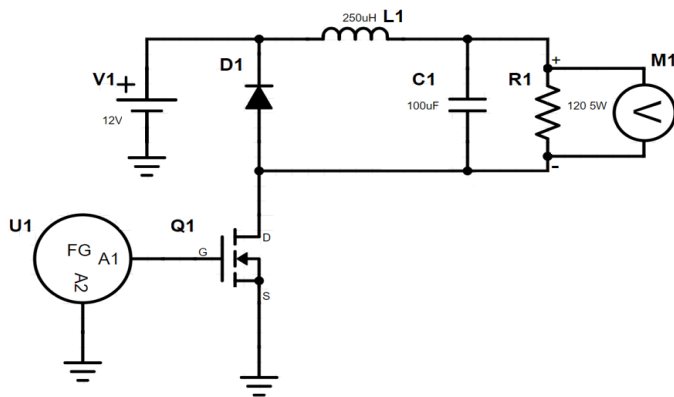


Figure 31

Procedure:

1. Make connections according to Fig.31
2. The function generator (FG) has the positive lead (A1) connected to the MOSFET gate G
3. The negative lead (A2) of the function generator is connected to ground
4. The inductor (L1) and capacitor (C1) components are found in the kit and should be placed onto the bread board for this lab section.
5. Set the function generator to a 5V, 100 kHz square wave with a 2.5V offset
6. Set the duty cycle to an initial value of 50%
7. Switch ON the power
8. Connect the voltmeter across the load
9. Vary the duty cycle from 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75% on the function generator
10. Observe the readings of the voltage across the load at different duty cycles
11. Create a graph of V_o/V_{in} vs Duty Cycle. Is there a trend?

Table 31: Observed Values:

Duty Cycle	V_o	V_o / V_{in}
20%		
25%		
30%		
35%		
40%		
45%		
50%		
55%		
60%		
70%		
75%		

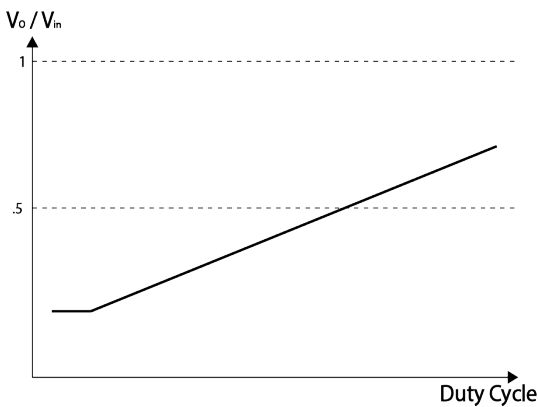


Image 31: Low Side Buck Converter with Resistive Load

Experiment 32: Boost Converter with Resistive Load

Introduction:

The Boost Converter circuit can be referred to as a power converter. It will step up voltage, resulting in an output voltage greater than the input. Because power is directly proportional to voltage, this circuit is sometimes referred to as a power converter. It operates with a suitable DC power source, such as a battery. This makes it ideal for battery power systems where space is limited. Hybrid Vehicles utilize this type of system. Rather than stacking battery cells to increase power, a boost converter may be employed to increase power. The benefits of a boost converter circuit are easily recognizable in these type of circuits.

Pre-Lab Questions:

1) What feature of this circuit enables it to produce a higher output than input voltage?

Apparatus Required: Quantity

Patch Cords	9
MOSFET Switch (on board)	1
Resistance 120/5W (on board)	1
Inductance 250 μ H	1
Capacitance 100 μ F	1
Diode (on board)	1
Function Generator	1

Circuit Diagram:

The circuit diagram of the boost converter is shown in the below.

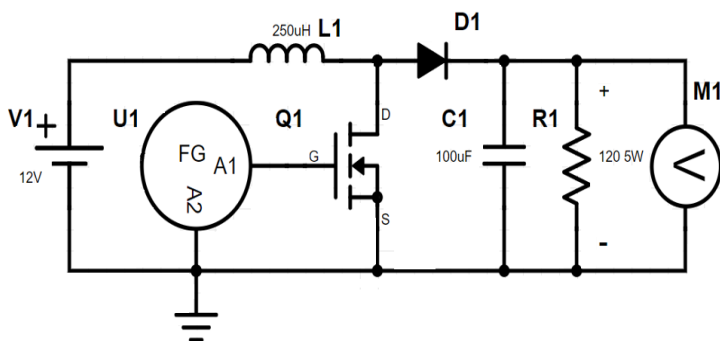


Figure 32

Procedure:

1. Make connections according to Fig.32
2. The function generator (FG) has the positive lead (A1) connected to the MOSFET gate G
3. The negative lead (A2) of the function generator is connected to ground.
4. The inductor (L1) and capacitor (C1) components are found in the kit and should be placed onto the bread board for this lab section.
5. Set the function generator to a 5V, 50 KHz square wave with a 2.5V offset
6. Set the duty cycle to an initial value of 50%
7. Switch ON the power
8. Connect the voltmeter across the load
9. Vary the duty cycle from 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75% on the function generator
10. Observe the readings of the voltage across the load at different duty cycles
11. Create a graph of V_o/V_{in} vs Duty Cycle. Is there a trend?

Table 32: Observed Values:

Duty Cycle	V_o	V_o / V_{in}
20%		
25%		
30%		
35%		
40%		
45%		
50%		
55%		
60%		
70%		
75%		

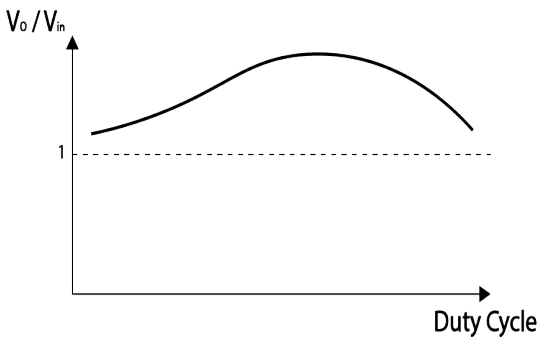


Image 32: Boost Converter with Resistive Load

Experiment 33: Buck-Boost Converter with Resistive Load

Introduction:

The Buck-Boost Converter can perform the functions of both a Buck Converter and Boost Converter. Because both circuits use similar components, the Buck-Boost Converter can be constructed by rearranging and connecting these components accordingly. It can step down or step up the voltage of any compatible DC power source connected to it.

<u>Apparatus Required:</u>	<u>Quantity</u>
Patch Cords	9
MOSFET Switch (on board)	1
Resistance 120/5W (on board)	1
Inductance $250\mu\text{H}$	1
Capacitance $100\mu\text{F}$	1
Diode (on board)	1
Function Generator	1

Circuit diagram:

The circuit diagram of the buck-boost converter is shown in the below.

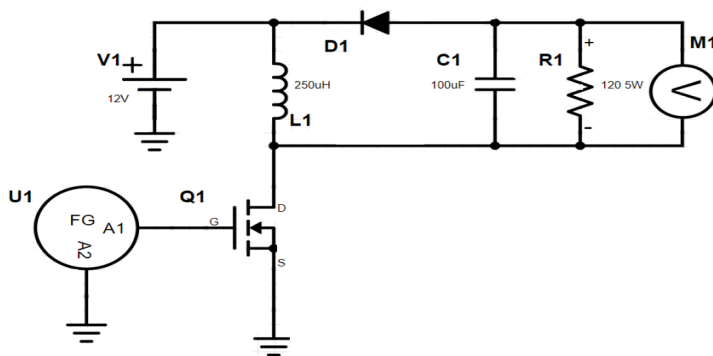


Figure 33

Procedure

1. Make connections according to Fig.33
2. The function generator (FG) has the positive lead (A1) connected to the MOSFET gate G.
3. The negative lead (A2) of the function generator is connected to ground
4. The inductor (L1) and capacitor (C1) components are found in the kit and should be placed onto the bread board for this lab section.
5. Set the function generator to a 5V, 50 KHz square wave with a 2.5V offset
6. Set the duty cycle to an initial value of 50%
7. Switch ON the power
8. Connect the voltmeter across the load
9. Vary the duty cycle from 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75% on the function generator
10. Observe the readings of the voltage across the load at different duty cycles
11. Create a graph of V_o/V_{in} vs Duty Cycle. Is there a trend?

Table 33: Observed Values:

Duty Cycle	V_o	V_o / V_{in}
20%		
25%		
30%		
35%		
40%		
45%		
50%		
55%		
60%		
70%		
75%		

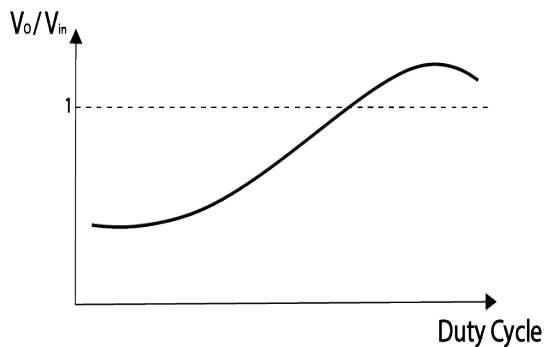


Image 33: Buck-Boost Converter with Resistive Load

Answers (Pre-Lab)

Lab 1

1. An SCR has three leads whereas a diode is a two lead component. In addition, the P-N structure of an SCR contains three junctions, a diode only has one.
(ANODE) → P - N - P - N ← (CATHODE)

|
 GATE
- 2.
3. Doping Is the process where impurities are added to the crystalline structure of the semiconductor material. The impurities will either provide free electrons (donor) or holes (acceptor) to the material. N-type semiconductors are doped with donor elements, and P-type semiconductors are doped with acceptor elements.

Lab 2

1. With forward biased at the anode and cathode, the SCR can produce current with the gate open or with a positive voltage applied to the gate.
2. Breakover voltage is the voltage at which the SCR begins producing forward current. With no gate current, the breakover voltage is much higher.
3. The holding current is the minimum anode current required to keep the SCR operating. If the anode current is less than the holding current, the SCR will shut off.

Lab 3

The UJT is made up of lightly doped N-Type material bar with a heavily doped P-typed strip of material attached to the end, creating a P-N junction. Base 1 and Base 2 leads are in ohmic contact at the ends of the N-type material, and the gate is connected to the P-type material.

Because the emitter is connected to the P-type material, P-N junction acts as a diode allowing the emitter current to flow in only one direction. The emitter current induces in to the base region, and the resistance between emitter junction and base 1 lowers.

The inter-base resistance is the resistance between base 1 and base 2, when the emitter acts as an open circuit.

The intrinsic stand-off ratio is the resistance between the emitter junction and base 1 as a ratio to the inter-base resistance.

Lab 4

As the name implies, this type of transistor uses an electric field effect to create channels. When a positive voltage is applied to the gate, the positive charge will repel the positive charge carriers away from the P-type substrate surface and form a narrow channel of negative charge carriers. The SCR and UJT do not depend on electric field effects for the makeup of their P-N junctions.

N-Channel

It consists of a P-type substrate with two sections of N-type material. The N-type sections are near the surface of the bulk and separated. In the separated space is where the channel will form.

Lab 5

A higher gate current will result in a higher current flow through the device
600V

Lab 6

A DIAC is different from an ordinary diode in that it can conduct current flow in a bi-directional manner.
Two diodes in parallel and in opposite directions
32V

Lab 7

A TRIAC and a DIAC can both conduct current in a bidirectional fashion
A TRIAC is triggered by a gate. A DIAC does not contain a gate lead.

Lab 8

The peak voltage is the sum of the gate voltage and one diode drop. $V_p = V_G + .7$
2.7V, 5.7V, 10.7V

Given the circuit connection, the resistors determine the voltage drop at V_G . This directly affects V_G which determines the value of V_P .

Lab 9

When the power is switched on, the SCR is off and the capacitor charges up with the polarity depicted on the circuit. A pulse triggers the SCR, causing it to begin conducting. The capacitor will discharge and begin to recharge with the reverse polarity. As a result, a commutating current, from the capacitor, will begin to flow in opposite direction of the load current. When the commutating current becomes greater than the load current, the SCR will shut off.

Lab 10

In this lab, if SCR1 is first triggered, by a pulse to the gate, the capacitor will charge with a positive voltage on the right and negative voltage on the left. When SCR2 is triggered, by a pulse to the gate, the negative polarity from the capacitor will be applied to the anode of SCR1, and SCR1 will also have a positive polarity at the cathode. This reverse bias, across SCR1, will effectively shut it off. SCR2 will shut off in the same manner, once SCR1 is triggered again.

Lab 11

The same does not occur in the class D commutation circuit. IF SCR2 is fired on first the capacitor will begin to charge. Once the capacitor is fully charged the negative polarity of it will be connected to the anode of SCR2. This will decrease the current flowing through SCR2 eventually shutting it off. In Class D commutation, SCR2 will shut off without ever having to fire on SCR1.

Lab 12

Once the SCR is triggered, it will remain on between 0 and π because the power source is alternating current. The SCR will shut off and remain off between π and 2π because the SCR will be in reverse biased.

Lab 13

The potentiometer affects when the SCR fires on because it can increase and decrease the gate current. Breakover voltage is contingent on gate current. Because the maximum applied voltage is at 90° , the minimum gate current, to trigger the SCR, is reached between 0 and 90° .

Lab 14

Resistor triggering circuit can only fire on the SCR between phase angle 0 to 90° . Resistor capacitor triggering circuit has a firing angle range of 0 to 180°

Lab 15

The Resistance value determines the capacitor time constant. By varying the potentiometer, the capacitor charging time increases or decreases. The faster the capacitor charges to the triggering gate voltage, the sooner it will trigger the SCR.

Lab 16

The capacitor

When the capacitor voltage reaches the peak value of the UJT, it begins to conduct. The conduction will continue until the capacitor voltage is equal to the valley voltage of the UJT. This will be a repeating process, effectively creating pulses.

Base 1 of the UJT is connected to the gate of the SCR. Because of this, the pulse output at base 1 will fire on the SCR.

Lab 17

Pin1 = Ground; Pin2 = Trigger; Pin3 = Output; Pin4 = Reset; Pin5 = Control; Pin6 = Threshold; Pin7 = Discharge; Pin8 = Supply Voltage

Lab 18

Pin2 = inverting input; Pin3 = noninverting input

Lab 19

Adjusting the potentiometer will control the pedestal voltage. The pedestal voltage directly affects the charging time of the capacitor to reach the threshold voltage of the UJT. When the capacitor charges to the threshold voltage of the UJT, it triggers it sending a pulse to the SCR. The higher the pedestal voltage the sooner the capacitor will charge to the threshold voltage, resulting in the firing angle being less. With a lower pedestal voltage value, the capacitor will take longer to charge increasing the firing angle.

Lab 20

The capacitor will discharge more rapidly than it charges. This is due to the resistor connected at base 1 having such low resistance.

Because the capacitor is connected to the emitter, the UJT is triggered when the capacitor voltage reaches the diode volt drop value.

Lab 21

Mode 1 = T1 is fired on and the capacitor begins to discharge and recharge with reverse polarity

Mode 2 = The capacitor is fully charged and T1 continues to conduct.

Mode 3 = T2 is triggered and the capacitor begins to discharge again. The voltage across T1 is negative, shutting it off.

Mode 4 = The capacitor discharges and recharges with opposite polarity. The current through T2 decays shutting it off.

Lab 23

DC is being converted into AC through the 1K Load only. This is achieved by simultaneously triggering two MOSFET at a time.

It is important G1 and G3 be triggered simultaneously while G2 and G4 remain off, and vice versa. This will strictly control the current through the load in an alternating manner.

Lab 24

DC is being converted into AC through the 1K Load only. This is achieved by simultaneously triggering two IGBT at a time.

It is important G1 and G3 be triggered simultaneously while G2 and G4 remain off, and vice versa. This will strictly control the current through the load in an alternating manner.

Lab 25

Between these two points the AC voltage is negative. The SCR shuts off because it is reversed biased.

The firing angle α is being controlled through the gate of the SCR. The pulse, which is controlled by the on board

“FIRING ANGLE CONTROL POT”, to the gate activates the SCR.

Lab 26

Between these two points the AC voltage is negative. The SCR shuts off because it is reversed biased. The firing angle α is being controlled through the gate of the SCR. The pulse, which is controlled by the on board “FIRING ANGLE CONTROL POT”, to the gate activates the SCR. The voltage across the load becomes negative between certain intervals

Lab 27

The SCR will only fire when voltage across it is forward biased. Of the two in the circuit, one is forward biased when the power source is positive voltage, and the other is in forward biased when power source is negative voltage. When either is triggered, they restrict the current flow to the load. This prevent the voltage across the load from being negative.

Lab 28

The current from the inductor will cause a negative voltage across the load.

Lab 29

SCR1 and SCR2 should be fired on simultaneously, and SCR3 and SCR4 should be paired when triggered.

Lab 30

SCR1 and SCR2 should be fired on simultaneously, and SCR3 and SCR4 should be paired when triggered. Voltage across the load is negative between π and $\pi+\alpha$

Lab 31

Because of where the inductor is situated, the voltage across it will oppose the current flow produced by the power source when the switch is closed. This lowers the voltage across the load and the voltage the capacitor charges to.

Lab 32

The Inductor is connected in series with the power source. When the switch is open, the positive voltage of the inductor is towards the diode. This results in two power sources being connected in series and the capacitor charging to a higher voltage.

List of Included Accessories

1.	Breadboard, 1680 tie-points, PB-2	x1
2.	Patch cords 2 mm to 2mm 50 cm, red	x12
3.	Patch cords 2 mm to 2mm 50 cm, black	x12
4.	Patch cords 2 mm to 1mm 50 cm, red	x6
5.	Patch cords 2 mm to 1mm 50 cm, black	x6
6.	Jumper wire kit, 70 pcs, WK-3 BULK	x1
7.	Power cord	x1
8.	Student Lab Manual (Digital Version Only)	Download
9.	Component Kit, PB-600KIT	x1
	• Resistor, 1/4W $\pm 5\%$ 47	x2
	• Resistor, 1/4W $\pm 5\%$ 100	x2
	• Resistor, 1/4W $\pm 5\%$ 220	x2
	• Resistor, 1/4W $\pm 5\%$ 510	x4
	• Resistor, 1/4W $\pm 5\%$ 820	x2
	• Resistor, 1/4W $\pm 5\%$ 1K	x2
	• Resistor, 1/4W $\pm 5\%$ 2.7K	x4
	• Resistor, 1/4W $\pm 5\%$ 5.1K	x2
	• IC NE-555	x2
	• IC LM-741	x2
	• MOSFET, IRF 540	x4
	• IGBT, G4 4B C2 05	x4
	• Capacitor, 100 μ F	x1
	• Inductor, 250 μ H	x1

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