Government Polytechnic West Champaran

Electrical Engineering

POWER ELECTRONICS LABORATORY

Subject Code 2020406	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	01
	L	T	P	ESE	:	50	
	—	—	02	Internal	:	15	
	—	—	—	External	:	35	

CONTENTS: PRACTICAL

Course objectives: The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- Maintain the proper functioning of power electronic devices.
- To understand and acquire knowledge about various power semiconductor devices.
- Maintain the proper functioning of power electronic devices
- To analyze and design different power electronics circuits

Practicals: -

1. Test the proper functioning of power transistor.
2. Test the proper functioning of IGBT.
3. Test the proper functioning of DIAC to determine the break over voltage.
4. Determine the latching current and holding current using V-I characteristics of SCR.
5. Test the variation of R, C in R and R C triggering circuits on firing angle of SCR.
6. Test the effect of variation of R, C in UJT triggering technique.
7. Perform the operation of Class–A, B, C, and turn off circuits.
8. Perform the operation of Class–D, E, F turn off circuits.
9. Use CRO to observe the output waveform of half wave-controlled rectifier with resistive load and determine the load voltage.
10. Draw the output wave form of Full wave controlled rectifier with R load, RL load, and free-wheeling diode and determine the load voltage.
11. Determine the firing angle using DIAC and TRIAC phase-controlled circuit on output power under different loads such as lamp, motor or heater
12. Simulate above firing angle control on SCIL AB software
13. Test the performance of given SMPS, UPS.
14. Troubleshoot the Burglar’s alarm, Emergency light system, Speed control system, Temperature control system.

Course outcomes: The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented Cos associated with the above mentioned competency:

a. Select power electronic devices for specific applications.
b. Maintain the performance of Thyristors.
c. Trouble shoot turn-on and turn-off circuits of Thyristors.
d. Maintain the operation of phase-controlled rectifiers.
e. Maintain the industrial control circuits.

Experiment- 01

Test the proper functioning of power transistor

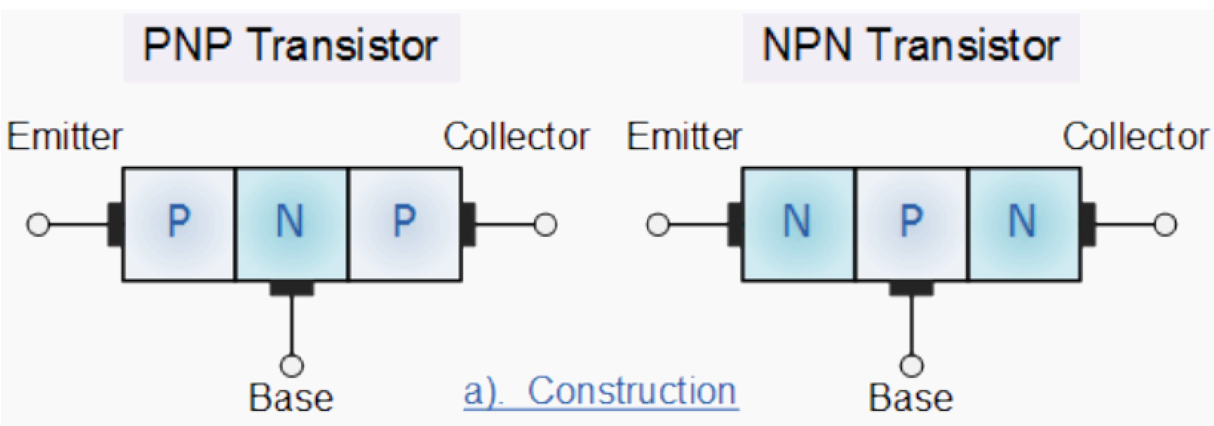
Aim- Test the proper functioning of power transistor in different Mode of configuration.

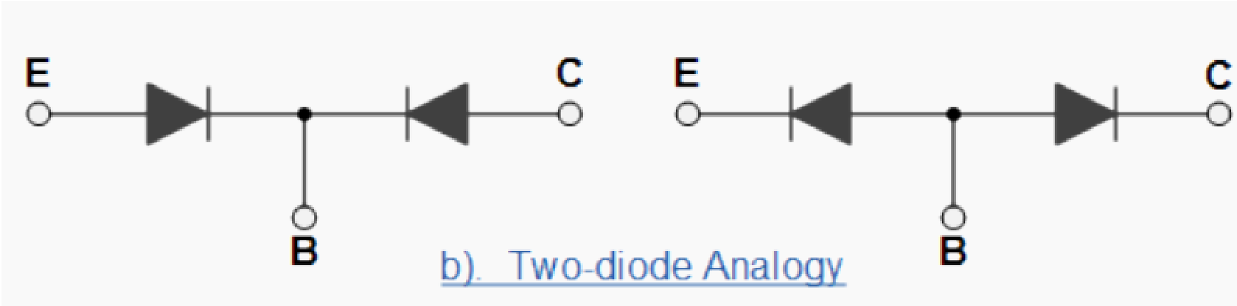
Introduction: - Power **Diodes** are made up from two pieces of semiconductor material, either silicon or germanium to form a simple PN-junction. If we now join together two individual Power diodes back-to-back, this will give us two PN-junctions connected together in series that share a common P or N terminal. The fusion of these two diodes produces a three layer, two junctions, and three terminal devices forming the basis of a **Bipolar Transistor**, or **BJT** for short. Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions

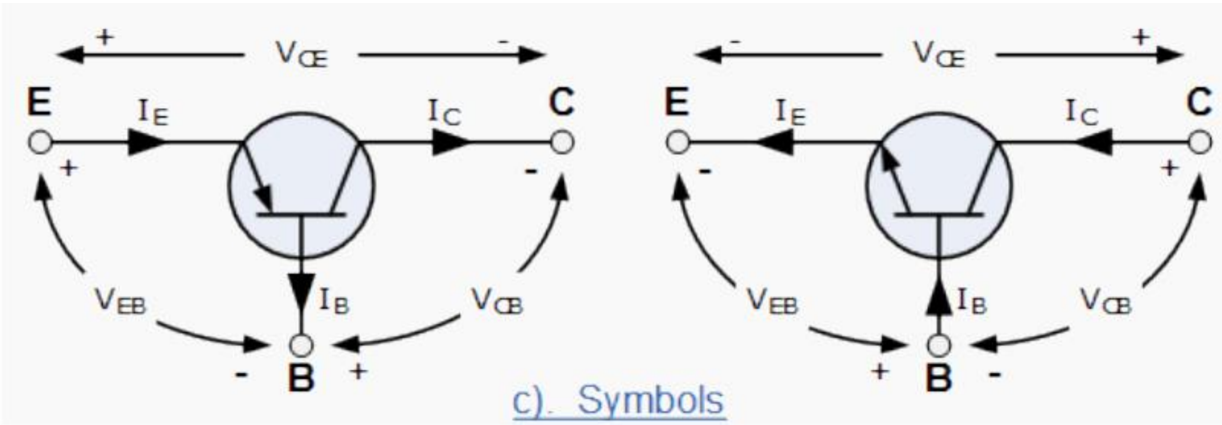
- **Active Region** - the transistor operates as an amplifier and $I_c = \beta.I_b$
- **Saturation -** the transistor is "fully-ON" operating as a switch and $I_c = I(saturation)$
- **Cut-off** - the transistor is "fully-OFF" operating as a switch and $I_c = 0$

The word **Transistor** is an acronym, and is a combination of the words Transfer Varistor used to describe their mode of operation way back in their early days of development. There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made. The **Bipolar Transistor** basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labeled as the Emitter (E), the Base (B) and the Collector (C) respectively. Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistors types NPN and PNP, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

Bipolar Transistor Construction

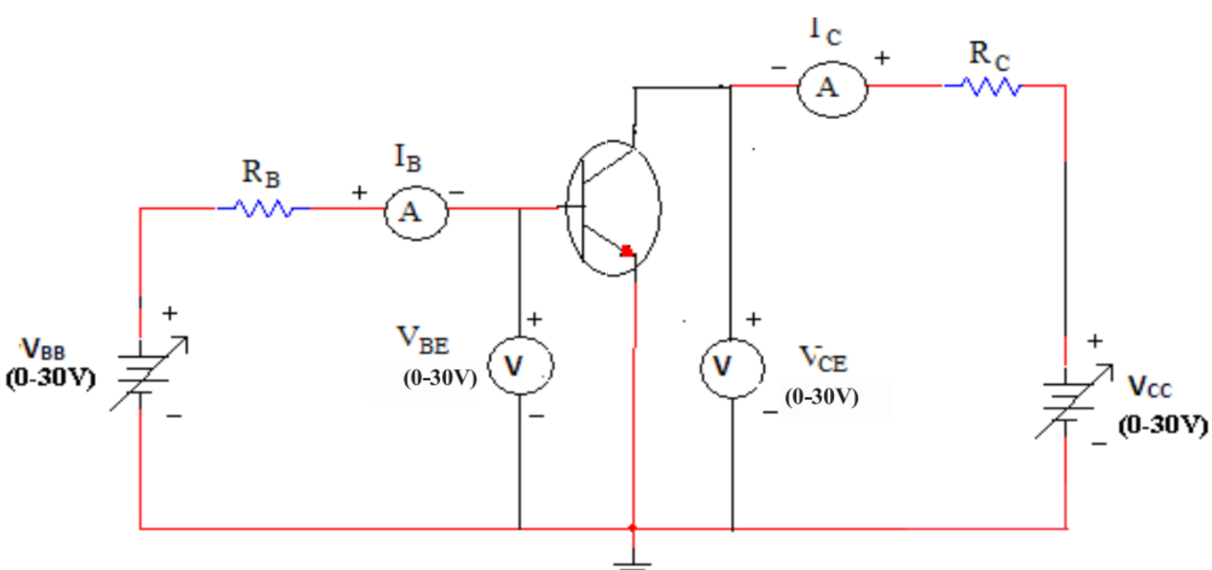






The construction and circuit symbols for both the NPN and PNP bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

Practical set-up/ Circuit diagram:-



V/I characteristics of Power transistor

Resource Required/ Apparatus Required:-

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-30/32 V_{DC}	2 No.
2	Digital Multimeter	0-200 V_{DC} , 0-1A / 10A	2 No.
3	Power Transistor	BD139 ,2N3055 or any other available	1 No.
4	Resistors	R_C = 100 Ω , 5 watt R_B = 3.3 KΩ , 1 watt	1 Each

Precautions to be Followed:-

1. Ensure that all the knobs of the power supplies are at zero value before switching them on.
2. Do not increase the base current more than its rated value.
3. The applied voltage, current should not exceed the maximum rating of the given transistor.
4. If the power transistor is getting heated, either use appropriate heat sink or limit the collector current.
5. Reading should be noted without parallax error.

Procedure:-

1. Make the circuit connection on bread board as per the circuit diagram.
2. Keep knobs of DC supplies to zero.
3. Switch on power supply.
4. Increase V_{BB} power supply gradually to increase I_B to set at the given value by the teacher (say 10 V to 30 V).
5. Keep I_B constant, when increasing V_{CC} in steps of 1 volt and record I_C and V_{CE}.
6. Repeat steps 4 to 5 I increasing steps of 10 mA until I_C become constant.
7. Plot I_C versus V_{CE} curves for various values of I_B on graph paper.

Observations and calculations:-

Sr. no	I_{B1} =		I_{B2} =		I_{B3} =	
	I_c mA	V_{CE} volts	I_c mA	V_{CE} volts	I_c mA	V_{CE} volts

Experiment No.-02

Test the proper functioning of IGBT

Aim- Test the proper functioning of Insulated Gate bi-polar Transistor (IGBT).

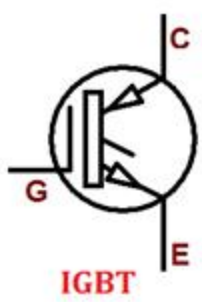
Introduction: - An insulated-gate bipolar transistor (**IGBT**) is a three-terminal power semiconductor device primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. It is a three-terminal semiconductor device, those pin are labeled **collector(C)**, **gate (G)** and **emitter (E)**.

The **Insulated Gate Bipolar Transistor** also called an **IGBT** for short, is something of a cross between a conventional Bipolar Junction Transistor*, (BJT) and a* Field Effect Transistor, *(MOSFET)* making it ideal as a semiconductor switching device.

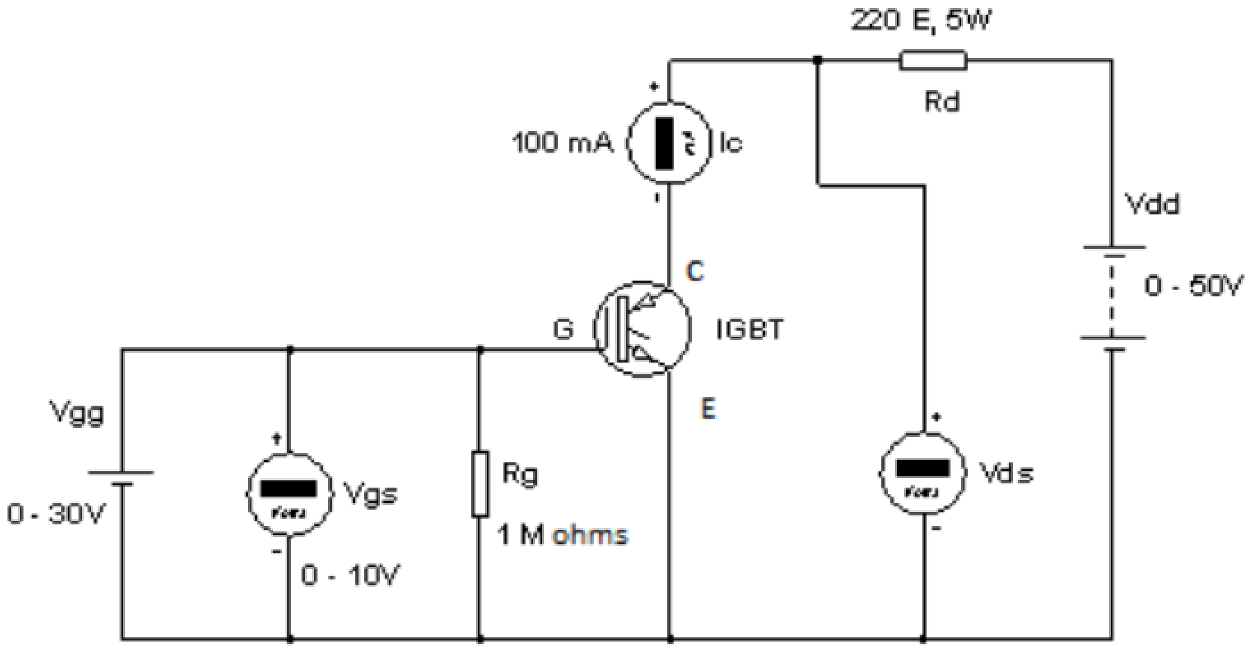
The *IGBT Transistor* takes the best parts of these two types of common transistors, the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive. The result of this hybrid combination is that the "IGBT Transistor" has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET. IGBTs are mainly used in power electronics applications, such as inverters, converters and power supplies, were the demands of the solid state switching device are not fully met by power Transistors and power MOSFETs. High-current and high-voltage Transistor are available, but their switching speeds are slow, while power MOSFETs may have higher switching speeds, but high-voltage and high-current devices are expensive and hard to achieve.

The advantage gained by the insulated gate bipolar transistor device over a BJT or MOSFET is that it offers greater power gain than the standard bipolar type transistor combined with the higher voltage operation and lower input losses of the MOSFET. In effect it is an FET integrated with a bipolar transistor in a form of Darlington type configuration as shown.

The high voltage applications like PWM, SMPS, variable speed control, AC to DC converter powered by solar and frequency converter applications which operates with a hundred's of KHz.



Practical Set-up/Circuit Diagram:-



Circuit Diagram for V/ I characteristics of IGBT

Apparatus Required:-

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-50 V DC	2 No.
2	Digital Voltmeter	0-50V DC	2 No.
3	Digital Ammeter	0-500 mA	1 No
4	IGBT	IRG4BC20U	1 No.
5	Resistors	Rg = 1 MΩ Rd = 220 Ω	2 Nos.

Precautions to be Followed:-

1. Ensure that all the knobs of the power supplies are at zero value before switching them on.
2. Identify Gate, Collector, and Emitter terminals of the given IGBT and make the connections as shown in the circuit diagram.
3. The applied voltage and current should not exceed the maximum rating of the given IGBT.
4. If IGBT is getting heated, either use appropriate heat sink or limit the collector current.
5. Reading should be noted without parallax error.

Procedure:-

a) Transfer characteristics:

1. Make the circuit connection as per the circuit diagram.
2. Keep knobs of Dc supplies to zero.
3. Switch on power supply.
4. Set V_{CE} = 10V and gradually vary power supply V_{gg} in steps of 1V and note down I_c and V_{gg}.
5. The minimum gate voltage V_{gg} required for conduction of IGBT is called the threshold voltage $V_{ge(TH)}$.
6. Plot the transfer characteristics (I_C versus V_{gg}) on graph paper.

b) Output characteristics:-

1. Switch on power supply V_{gg} and set $V_{gg} \geq V_{ge(TH)}$.
2. Now increase power supply V_{dd} gradually in steps of 2 V from zero and record V_{ce} and I_c.
3. Repeat step 2 for two more values of V_{ge}.
4. Plot the output characteristics (I_c versus V_{ce}) on graph paper.

Observations and calculations:-

a. Transfer characteristics:-

Sr. no	V_{ce} =10 V	
	V_{ge} volts	Ic mA

b. Output characteristics:-

Sr. no	V_{ge1} = V		V_{ge2} = V	
	V_{ce} volts	I_c mA	V_{ce} volts	I_c mA

Experiment No: - 03

Test the proper functioning of DIAC to determine the break over voltage

Aim: - Test the proper functioning of DIAC and determine the break over voltage of Diac.

Introduction: - A DIAC is a three-layer, two-terminal bidirectional device that is typically used as a triggering device to control the gate current of a triac. A DIAC is a special diode that can be triggered into conduction in either direction. A DIAC is a diode that conducts electrical current only after its break over voltage (V_{BO}) has been reached. DIAC stands for "Diode for Alternating Current". A DIAC is a device which has two electrodes, and it is a member of the thyristor family. DIACs are used in the triggering of thyristors. The figure below shows a symbol of a DIAC, which resembles the connection of two diodes in series. DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as a TRIAC.

The advantage of a DIAC is that it can be turned on or off simply by reducing the voltage level below its avalanche breakdown voltage. DIACs are also known as a transistor without a base. It should also be noted that a DIAC can be either turned on or off for both polarities of voltage (i.e. positive or negative voltage). They also still work when avalanche breakdown occurs.

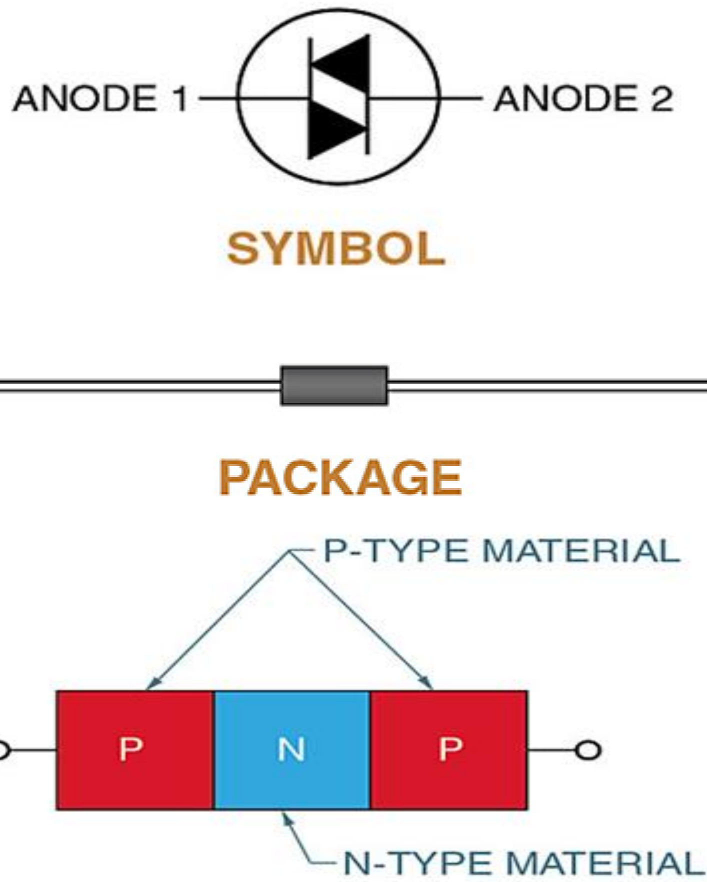


Figure 1. A diac is a three-layer, two-terminal bidirectional device.

Electrically, a diac operates in a manner similar to two zener diodes that are connected in series in opposite directions. The diac is used primarily as a triggering device. This operation is accomplished by the use of the negative resistance characteristic of the diac (current decreases with an increase of applied voltage).
A diac has **negative resistance** because it does not conduct current until the voltage across it reaches breakover voltage.
Since the diac is a bidirectional device, it is ideal for controlling a triac, which is also bidirectional. The gate-control circuits of triacs can be improved by adding a break over device in the gate lead, such as a diac.
Using a diac in the gate-triggering circuit offers an important advantage over simple gate-control circuits. The advantage is that the diac delivers a pulse of gate current rather than a sinusoidal gate current. This results in a better-controlled firing sequence. **Thus,** diacs are used almost exclusively as triggering devices.

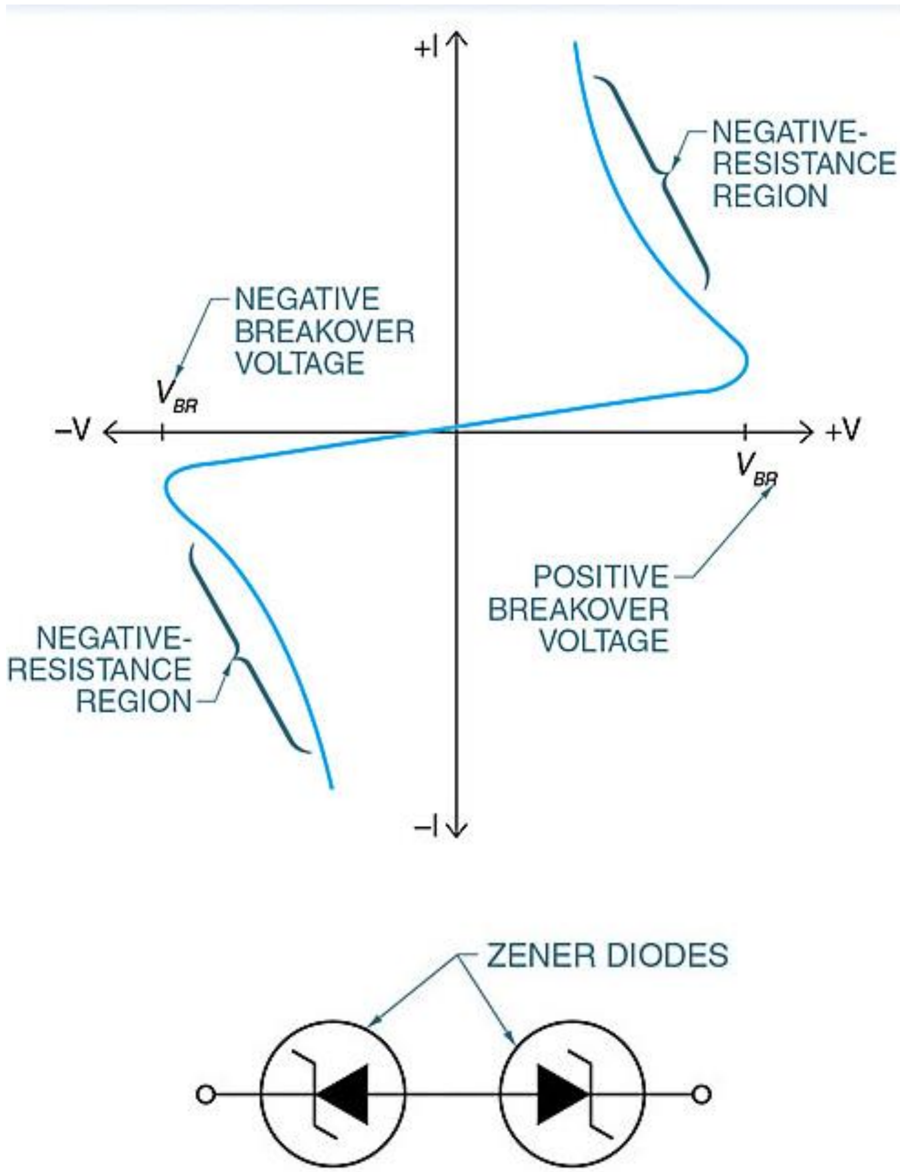
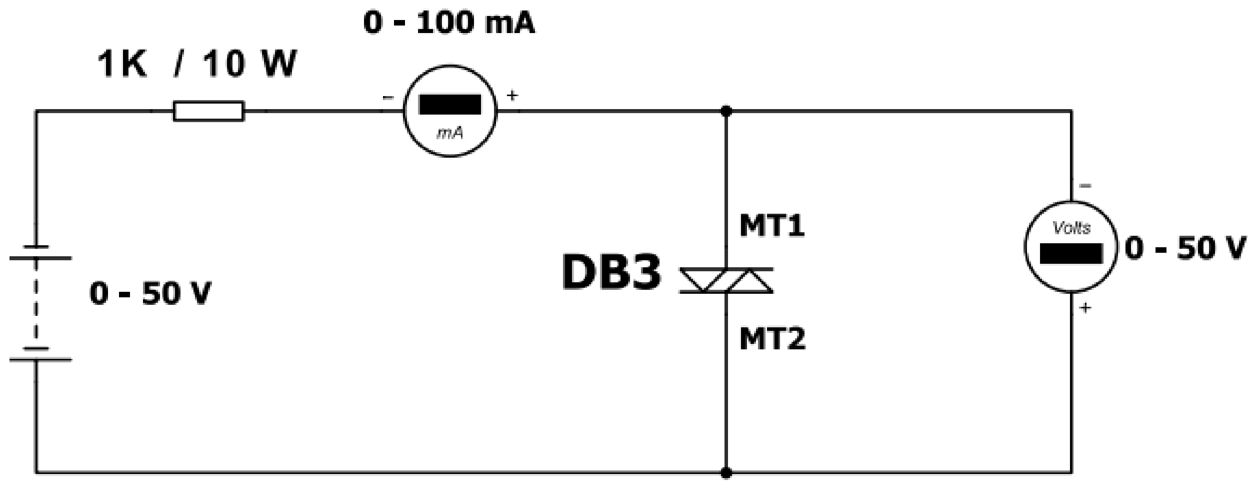
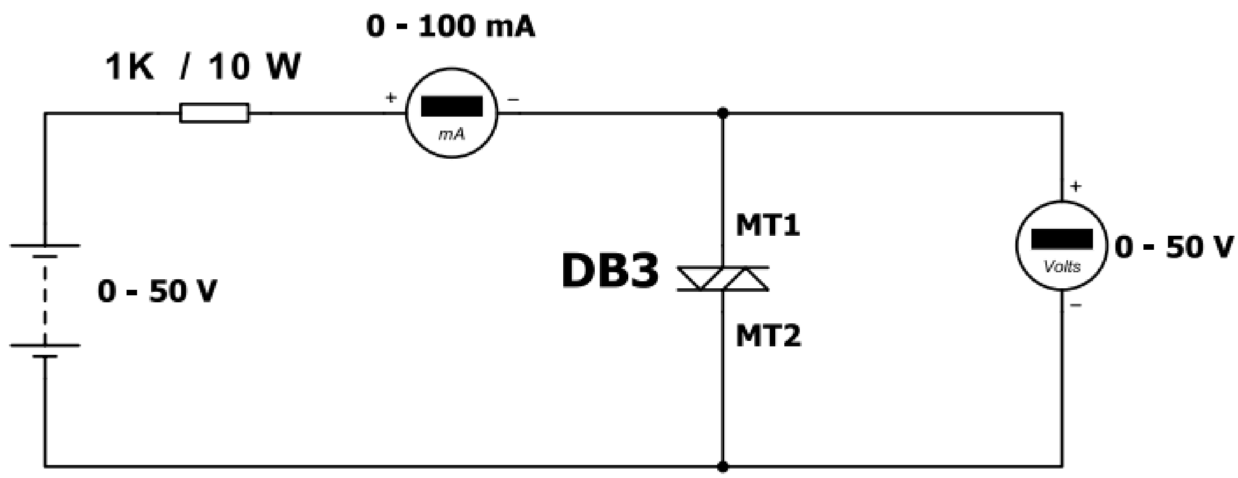


Figure 2. Diac Characteristic Curve and Equivalent Circuit



MT2 positive w.r.t MT1 (First quadrant operation)



MT1 positive w.r.t MT2 (Third quadrant operation)

Apparatus required:-

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-50 V DC	1 No.
2	Voltmeter	0-50 V	1 No.
3	Ammeter	0-100 mA	1 No.
4	DIAC	DB3/DB4 or any other available	1 No.
5	Resistor	1 KΩ , 10 watt	1 No.

Precautions to be Followed:-

1. Ensure that all the knobs of the power supplies are at zero value before switching them on.
2. The applied voltage and current should be not exceeding the maximum rating of the given DIAC.
3. Reading should be noted without parallax error.

Procedure:-

a. MT2 positive w.r.t MT1 (First quadrant operation):

1. Make the circuit connection as per the circuit diagram.
2. Keeps the knobs of DC supplies to zero.
3. Switch on the power supply.
4. Increase voltage of DC power supply in steps of 2 V and note down V and I of DIAC.
5. Increase DC supply till I increase with sudden drop in V. The maximum voltage at which DIAC turns on is called the break-over voltage V_{BO}.
6. Measure V_{BO} precisely.
7. Take at least four more reading of voltage and current after break-over voltage.

b. MT1 positive w.r.t MT2 (Third quadrant operation)

1. Reverse the polarity of power supply and meters or reverse the DIAC terminals.
2. Repeat steps 3 to 7.
3. Plot the V-I characteristics of DIAC on graph paper.

Observations and Calculations:-

Sr. no	(MT_2 is positive wrt MT_1) 1st Quadrant		(MT_1 is positive wrt MT_2) 3rd Quadrant	
	V (Volts)	I (mA)	V (Volts)	I (mA)
1				
2				
3				
4				
5				
6				

Experiment No. 04

Determine the latching current and holding current using V-I characteristics of SCR

Aim: - To obtain V-I characteristics and to find on-state forward resistance of given SCR. To determine holding, latching current and break over voltage of given SCR.

Introduction:-

Silicon controlled rectifier (SCR) is a unidirectional semiconductor device made of silicon. SCR is a three terminal, four-layers as p-n-p-n and three junctions device.

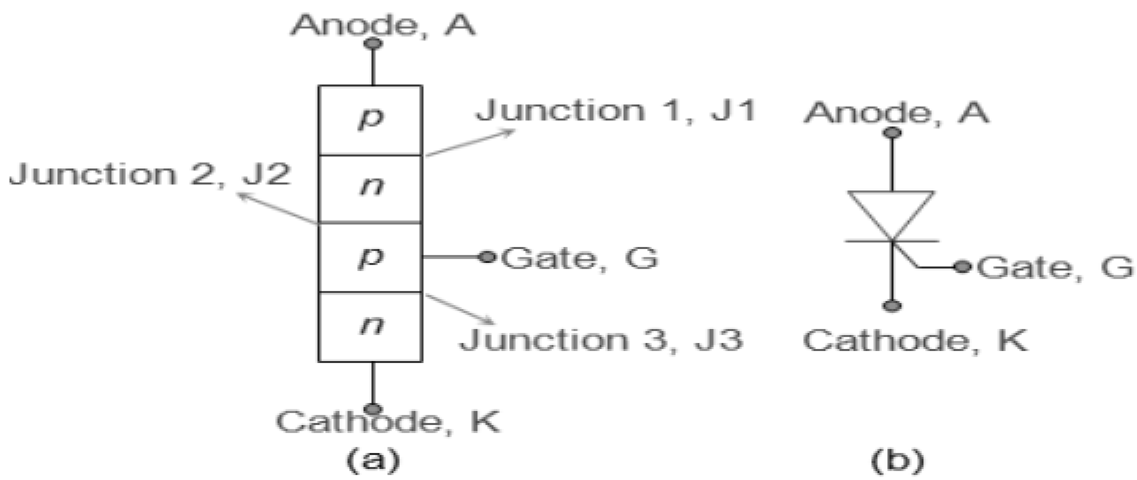


Fig. 1 silicon controlled rectifier (a) layered structure (b) symbol

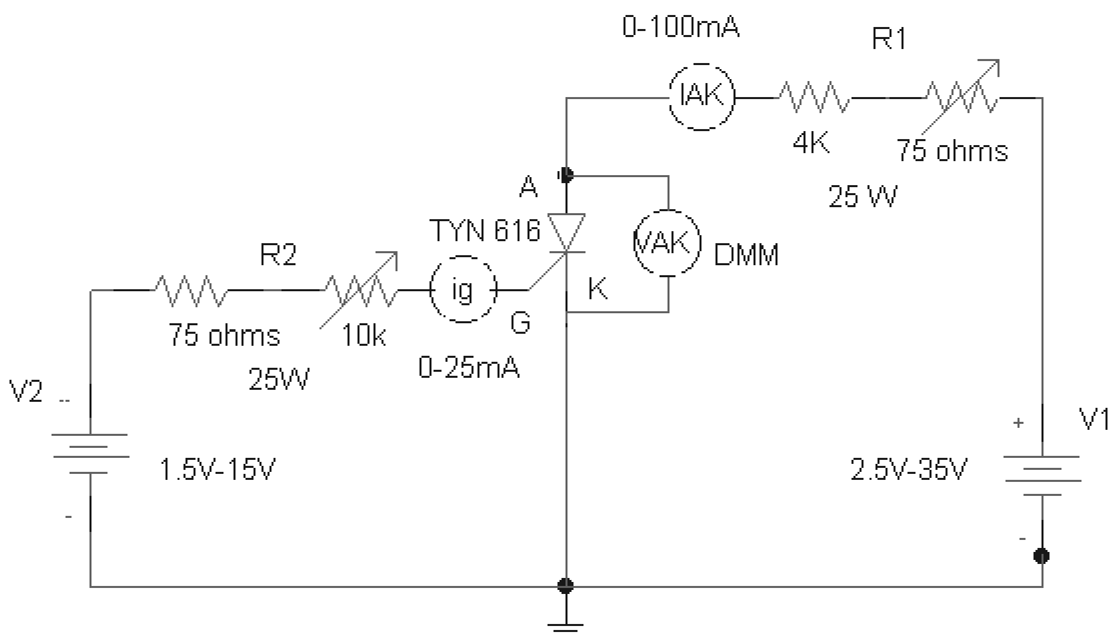


Fig1.1 (a). Circuit diagram for VI characteristics of SCR.

VBO = Forward break over voltage, VBR = Reverse break over voltage, I_g = Gate current

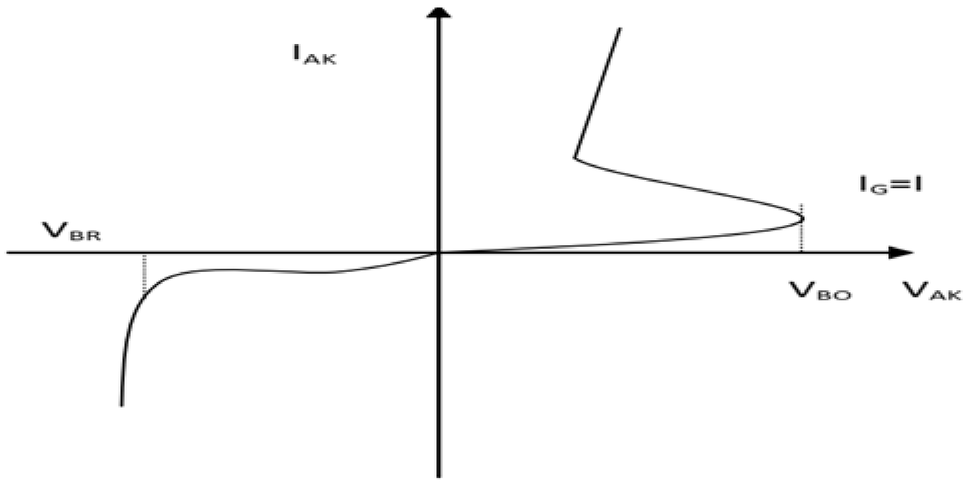


Fig. 1.2 (a) static characteristics of SCR

TABULAR COLUMN:

Gate current $I_G = I_{G1}$ =…..mA

I_g (mA)							
V_{AK}(Volt)							
I_A(Amp)							

APPARATUS REQUIRED:

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-150 V_{DC} , 0-30 V_{DC}	2 No.
2	Ammeters	0-30 mA , 0-150 mA	2 No.
3	Voltmeter	0-100 V	1 No.
4	SCR	TYN604 / TYN612 or any other available	1 No.
5	Resistors	R_L = 10 KΩ , 10 watt R_G = 3.3 KΩ , 0.25 watt	1 Each

PROCEDURE:

- Connection is made as shown in the circuit Diagram. Set R_1 and R_2 to mid position and V_1 and V_2 to minimum.

- Set the gate current $I_G = I_{G1}$ (such that forward break over voltage is between 15 to 20 V), by varying R_2 and V_2.
- Slowly vary V_1 in steps of 2V and note down V_{AK} and I_{Ak} at each step till SCR conducts. (Note down maximum V_{AK}, which is forward break over voltage just before SCR conducts).

FINDING LATCHING CURRENT:

- Ensure that the SCR is in the state of conduction.
- Start reducing (V_{AK}) anode voltage in steps of 2V; simultaneously check the state of SCR by switching off gate supply V_2. If SCR switches off just by removing gate terminal, and switches on by connecting gate supply, then the corresponding anode current I_A is the latching current (I_L) for the SCR.

FINDING HOLDING CURRENT*:*

- Ensure that the SCR is in the state of conduction.
- Switch off the gate supply permanently.
- Start reducing (V_{AK}) anode voltage in steps of 2V; simultaneously check the state of SCR. If SCR switches off. Note down the anode current (I_A) just before it drops to zero, which will be I_H.
- Reverse the anode voltage polarity.
- Vary V_{AK} in steps of 5V till 25V and note down V_{AK} and I_A values at each step.
- Plot forward and reverse characteristics using the above-tabulated values. Find the SCR forward resistance using the graph.
- Repeat the above procedure for the forward and reverse characteristics of SCR for a gate current $I_g = I_{g2}$.

Observation and Calculation:-

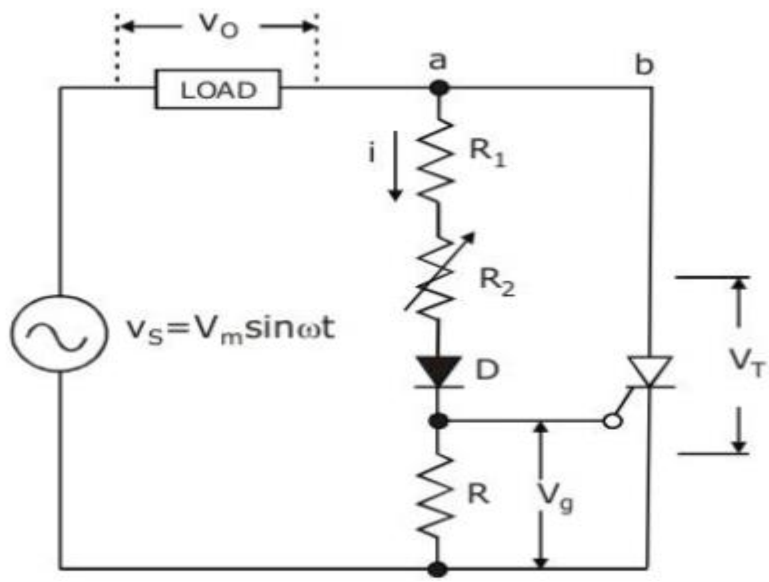
Sr. no	**I_{G1} = mA**		**I_{G2} = mA**		**I_{G3} = mA**	
	V_{AK}	**I_A mA**	**V_{AK}**	**I_A mA**	**V_{AK}**	**I_A mA**
1						
2						
3						
4						
5						
6						

Experiment No. – 05 (A)

Test the variation of Resistance in Resistance triggering circuits on firing angle of SCR.

Aim: - To study the variation of resistance in resistance triggering circuits on firing angle of SCR.

Introduction: - This firing circuit is the simplest method of controlling the firing angle of SCR. In this firing circuit, the firing angle can vary over a limited range of 0° to 90°. Instead of giving gate pulses to the thyristor, an ac supply is given to the gate terminal for firing.

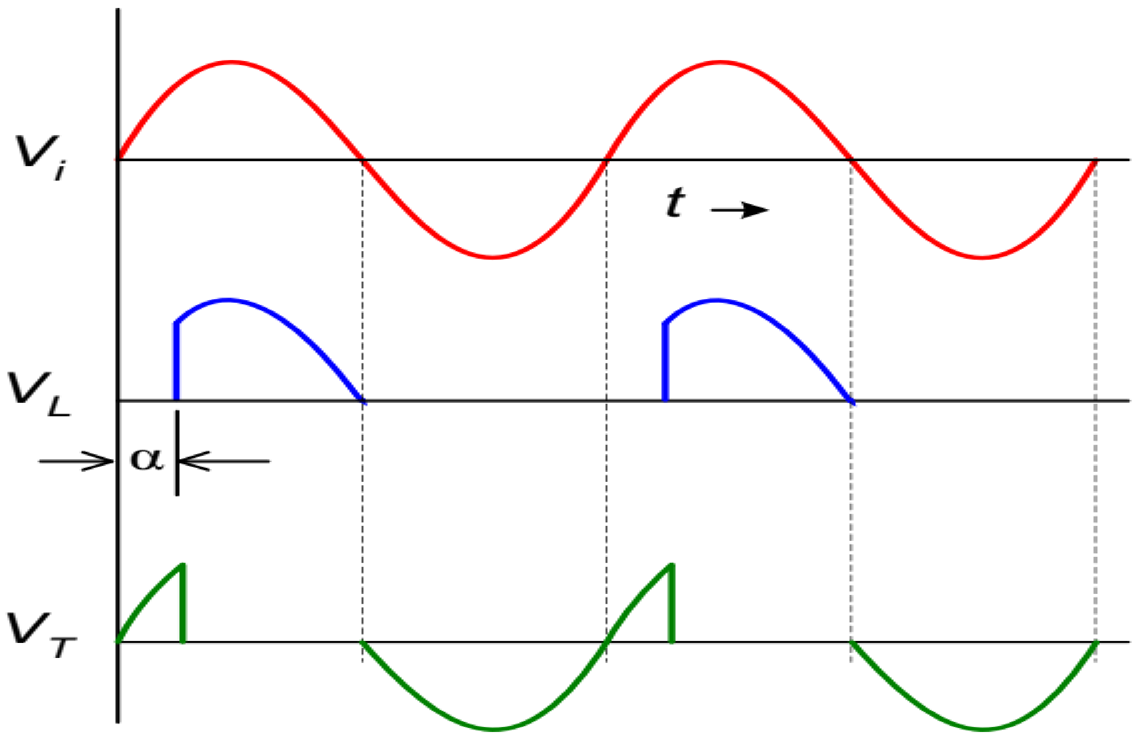


The working of the resistance firing circuit is as follows,

- During the positive half-cycle of the voltage source V_S, thyristor, T is forward-biased, but it doesn't conduct because of insufficient gate current. Hence, load voltage V_0 is zero.

- As voltage source V_S increases, thyristor and diode both are forward-biased, and gate current I_G flows in the circuit. When gate current I_G reaches to value equal to $I_{G(min)}$, the thyristor is turned-ON and load voltage follows source voltage, and the voltage drop across the thyristor is equal to the on-state drop.

- During the negative half cycle of the supply voltage, the thyristor is reverse-biased, and hence it is turned OFF. Thus load voltage V_L becomes zero and voltage across the thyristor V_T will be equal to source voltage V_S.



- The diode in the gate circuit prevents the reverse voltage of the thyristor during the negative half-cycle from exceeding peak reverse voltage. The limiting resistance R_1 placed between anode and gate of thyristor limits the gate current not to exceed peak gate current $I_{G(max)}$.

- From the waveforms above, the firing angle and the output voltage can be controlled by varying the variable resistance R_2. If R_2 is large, then the current will be small and hence firing angle (α) increases and vice versa.

Advantages of Resistance Firing Circuit:

- The firing circuit is very easy and simple to operate.
- The firing angle can be varied from 0° to 90°.
- By using a capacitor and a diode, the limited firing angle issue is resolved.

Disadvantages of Resistance Firing Circuit:

- Limited firing angle i.e., up to 90° only.
- The firing angle is totally dependent on the minimum gate current of thyristors.
- The value of minimum gate current changes between the thyristors.
- It is a temperature-dependent circuit.

Observation table:-

S.No.	Load Voltage (V_0) (Volt)	Phase angle (α)
1.		
2.		
3.		
4.		
5.		

Experiment No. - 5 (B)

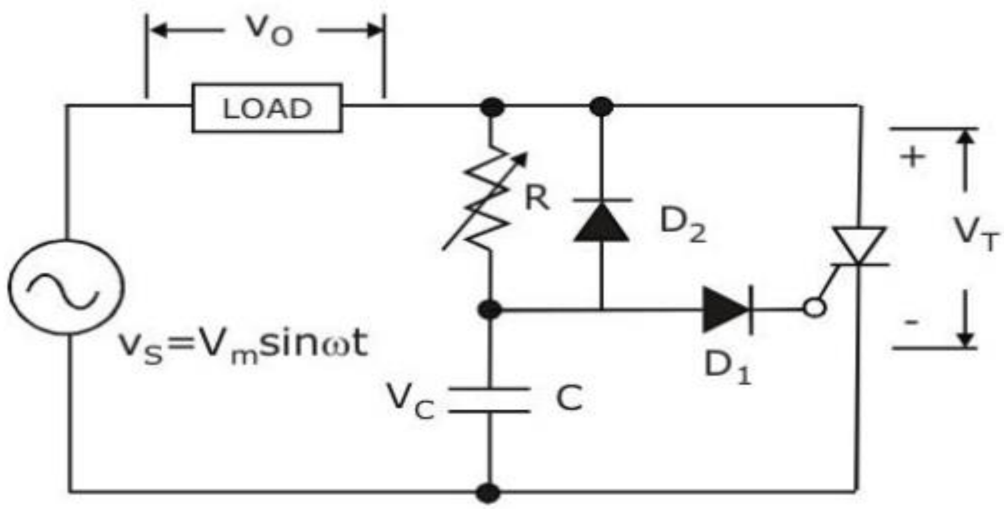
Test the variation of capacitance in RC triggering circuits on firing angle of SCR.

Aim: - To study the variation of capacitance in RC triggering circuits on firing angle of SCR.

Introduction: - The limitations of the resistance firing circuit can be overcome by using a resistance-capacitance firing circuit. Using an RC-firing circuit the firing angle can be controlled from 0 to 180 electrical degrees. There are two types of RC-firing circuits,

- RC half-wave firing circuit, and
- RC full-wave firing circuit.

RC half-wave firing circuit



- Capacitor charges during the negative half cycle through D2.
- When SCR is turned on, capacitor C is suddenly discharged through D2.
- D1 protects the SCR during negative half cycle.

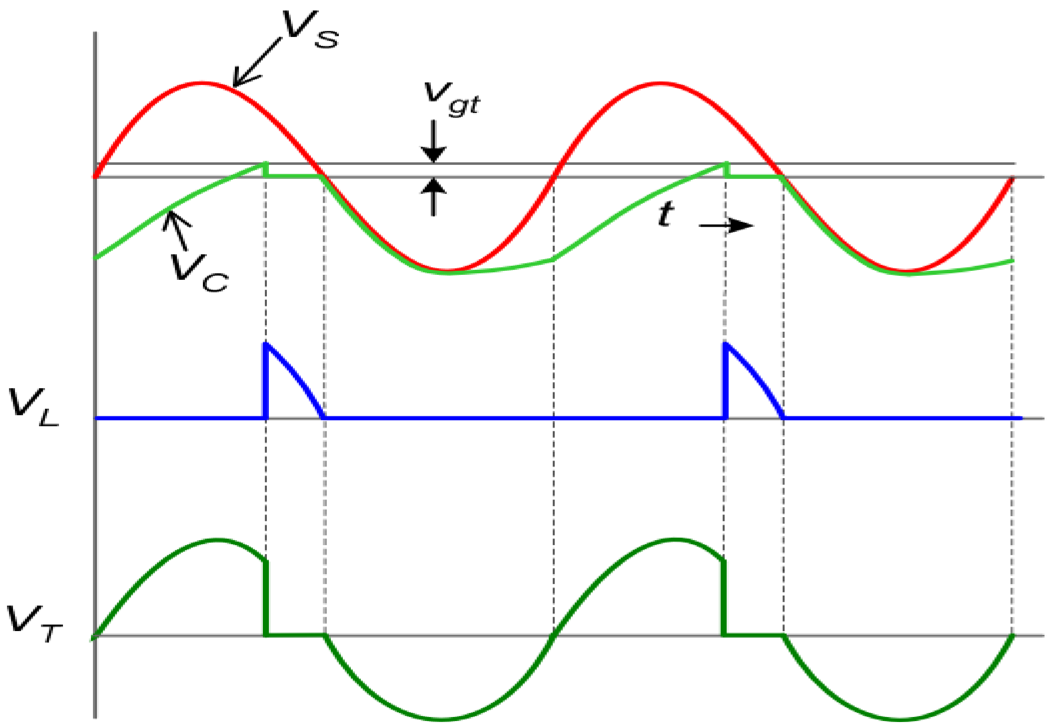
Advantage over R-triggering Circuit: it Controls up-to 180 degrees

$$RC \geq \frac{1.3\,T}{2}$$

To ensure minimum gate current

$$v_s \geq R\, I_{g\min} + V_{g\min} + V_{D_1}$$

$$R \leq \frac{v_s - V_{g\min} - V_{D_1}}{I_{g\min}}$$

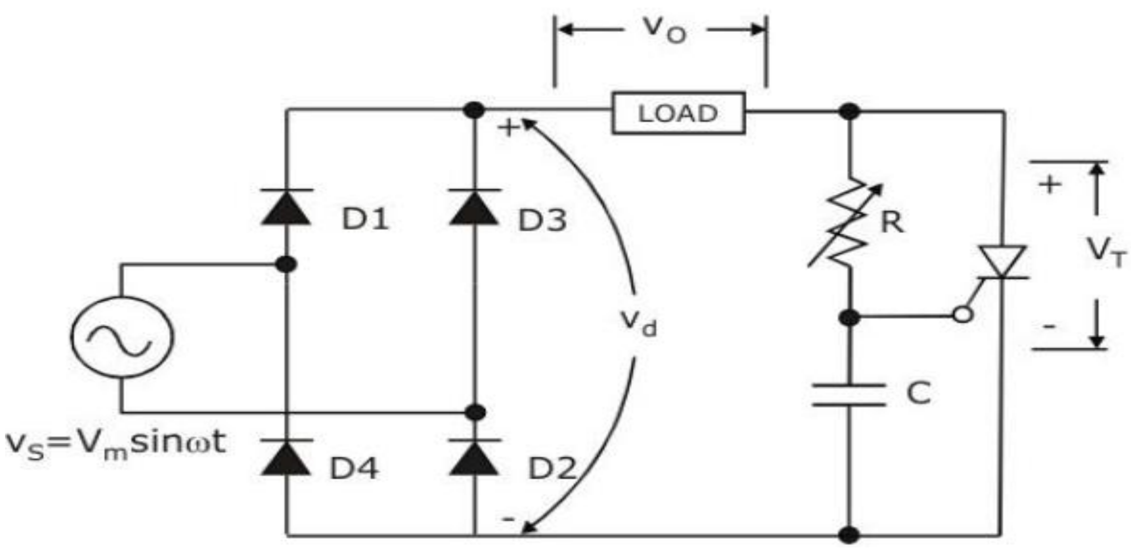


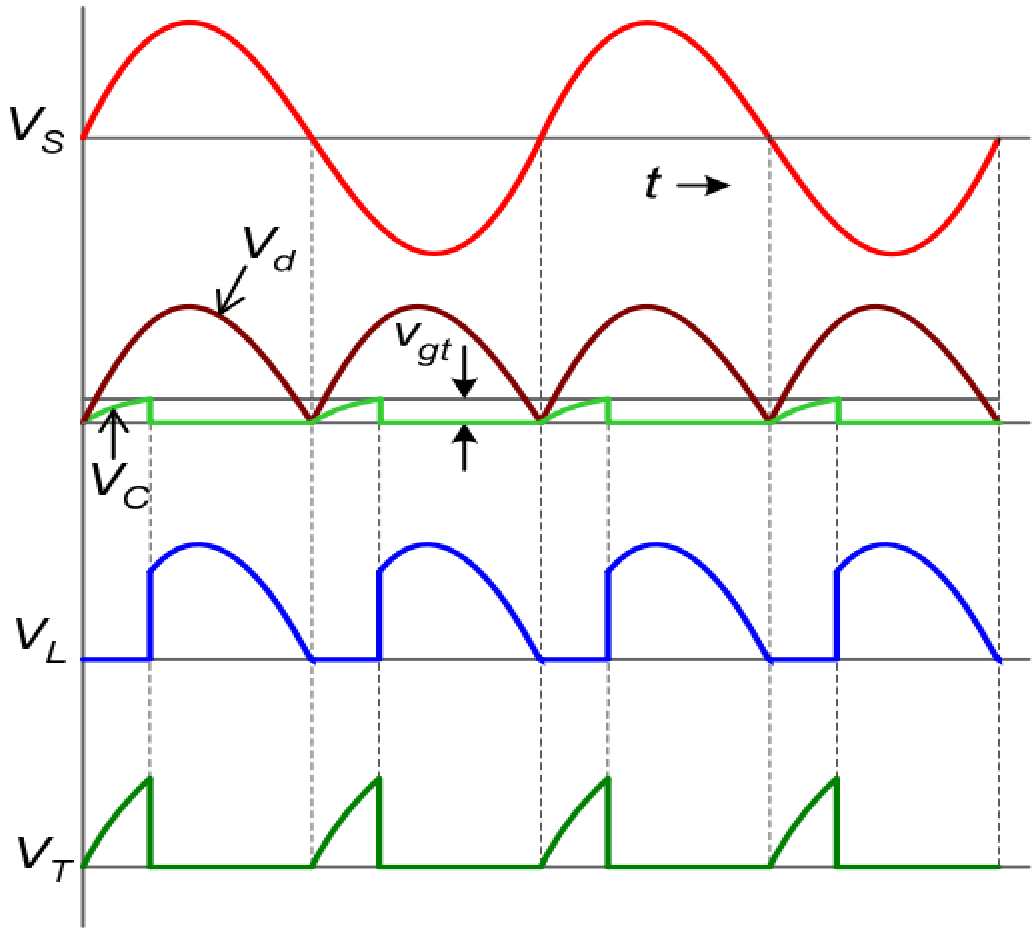
RC full wave firing circuit

The advantages of a full-wave firing circuit over a half-wave firing circuit are,

- Power can be delivered to load both during positive and negative half-cycles because of the full-wave bridge diode.
- The firing angle can be controlled from 0° to 180°.
- The power delivered to the load is doubled.
- The output voltage is present even in the negative half cycle.

The below figures illustrates the RC full-wave firing circuit.





Initially, the capacitor starts charging from zero voltage, and this low voltage is achieved by the clamping action of the SCR gate. When V_C reaches V_{gt}, SCR is turned-ON and ac line voltage which is rectified into dc by a full-wave diode bridge appears across the load. In this circuit, RC and R are given by,

$$RC \geq \frac{50\,T}{2} \qquad\qquad R \leq \frac{v_s - V_{g\min}}{I_{g\min}}$$

Advantages of RC Firing Circuit:

- The firing angle limitation in the R-firing circuit is overcome by the RC-firing circuit.
- The firing angle range is between 0 and 180°.
- The circuit is cheap, simple, and also acts as a snubber circuit.

Disadvantages of RC Firing Circuit:

- The values of R and C changes with respect to temperature
- The firing angle depends upon the RC time constant.
- Supply fluctuations have effects on firing angle.
- It is only applicable in power circuits where only one thyristor is used.
- It can be used only in open-loop control systems.

Observation table

RC half wave firing circuit			RC full wave firing circuit	
S.No.	Load Voltage (V_0)	Phase angle (**α**)	Load Voltage (V_0)	Phase angle (**α**)
1.				
2.				
3.				
4.				
5.				

Experiment No. - 06

Test the effect of variation of R, C in UJT triggering technique

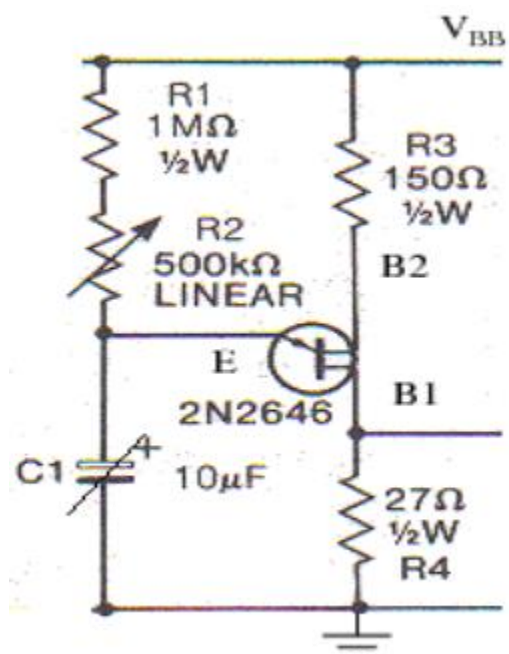
Aim: - Test the effect of variation of R, C in UJT technique.

Introduction:-

A unijuction transistor (UJT) is an electronic semiconductor device that has only one junction. The UJT has three terminals- emitter (E) and two bases (B_1 and B_2). The base is formed by lightly doped n-type bar of silicon. Two ohmic contacts B_1 and B_2 are attached at its ends. The emitter is of p-type and it is heavily doped. The resistance between B_1 and B_2, when the emitter is open-circuit is called inter base resistance.

Now the capacitor discharge through minimum emitter base resistance of the device and o/p resistance RB_1.

Circuit Diagram:



Apparatus requirement:-

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-30 V DC	1 No.
2	UJT	2N2646 or any other	1 No.
3	Capacitor (variable)	C1 = 100 µF or any other available	1 No.
4	Resistors	R1 = 10K, 1/4 watt R2 (pot) = 500 KΩ R3 = 150 Ω , 0.25 watt R4 = 27 Ω , 0.25 watt	1 Each

Precaution to be Followed:-

- Ensure that all the knobs of the power supplies are at zero value before switching them on.
- The applied voltage and current should not exceed the maximum rating of the given UJT.
- Reading should not be noted without parallax error.

Procedure:-

1. Make the circuit connection as per the circuit diagram.
2. Keep knobs of DC supplies to zero.
3. Switch on power supply.
4. Increase V_{BB} power supply gradually to increase I_B to set at the given value by the teacher (say 10 V to 15 V).
5. Keep R_2 at maximum value.
6. Keep C_1 constant, while decrease R_2 in steps till waveform observed on CRO at B_1 and across C_1.
7. Measure the value of R_2.
8. Measure the time period of charging and discharging of capacitor (a saw tooth waveform).
9. Repeat steps 6 for 2/3 values of R_2.
10. Now, keep R_2 constant and vary C_1 till waveform observed on CRO at B_1.
11. Measure the time period of charging and discharging of capacitor (a saw tooth waveform).
12. Repeat steps 10 and 11 for 2/3 values of C_1.
13. Draw the waveform for different values of R_2 and C_1.

Observation and calculation:-

Sr. No	R2	C1	T measured	T calculated
1				
2				
3				
4				
5				

$f = \frac{1}{RC\ln(1/(1-\eta))}$ ....$\eta = 0.65$ to 0.8 ..... formula

Experiment No. - 7

Perform the operation of class- A, B, C turn off circuits or commutation circuit.

Aim: - Perform the operation of class- A, B, C commutation circuit.

Introduction: - Continuous conduction causes problems in choppers, inverters and cyclo-converters. By the commutation process, the thyristor operating mode is changed from forward conducting to forward blocking mode. In class A,B and C commutation, thyristor can be turned off by reducing the anode current below the holding current with the help of active and passive components. Thyristor current can be reduced to a value below the value of holding current. Since, the thyristor is turned off forcibly it is termed as a forced commutation process.

Class A commutation: - This is also known as commutation, or load commutation. In this commutation, the source of commutation voltage is in series with SCR. The load must be an under damped RLC supplied with a DC supply so that natural zero current is obtained at the ringing frequency.

Class B commutation:- This is also called as a self commutation circuit in which commutation of SCR is achieved automatically by L and C components. Once the SCR is turned ON. In this, the LC resonant circuit is connected across the SCR but not in series with load as in case of class A commutation and hence the L and C components do not carry the load current.

Class C commutation:- In this commutation method, main SCR that is to be commutated gets connected in series with the load and in additional or complementary SCR is connected in parallel with main SCR. This method is also called as complementary commutation.

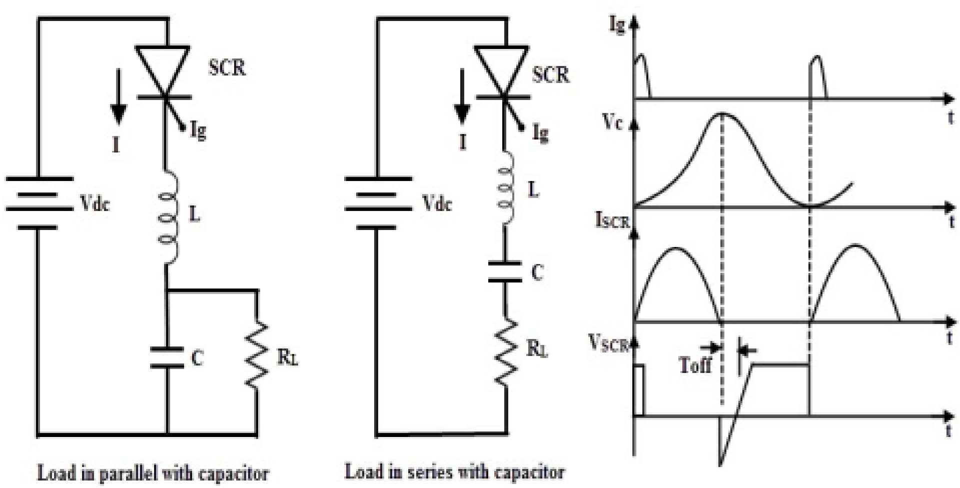


Figure 1 Class A Commutation

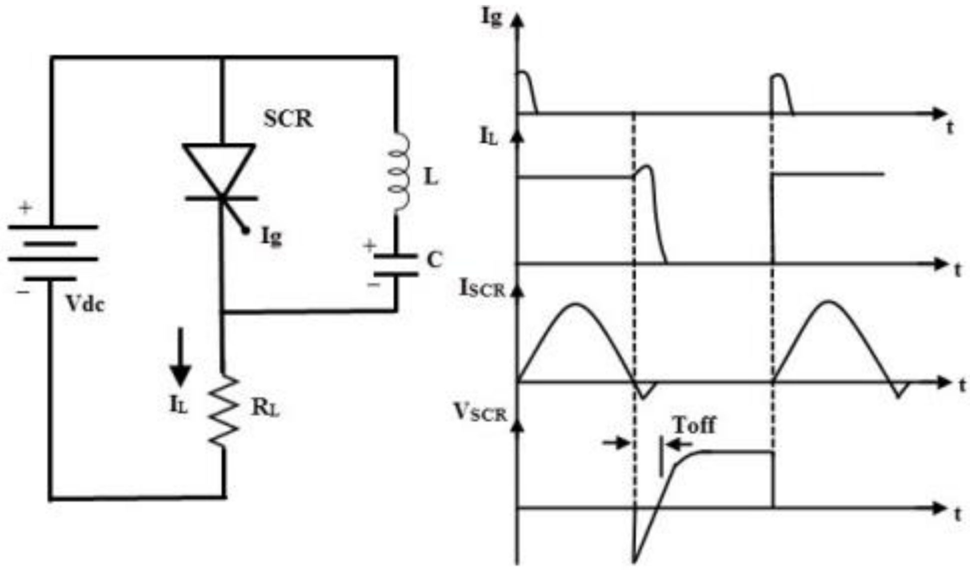


Figure 2 Class B Commutation

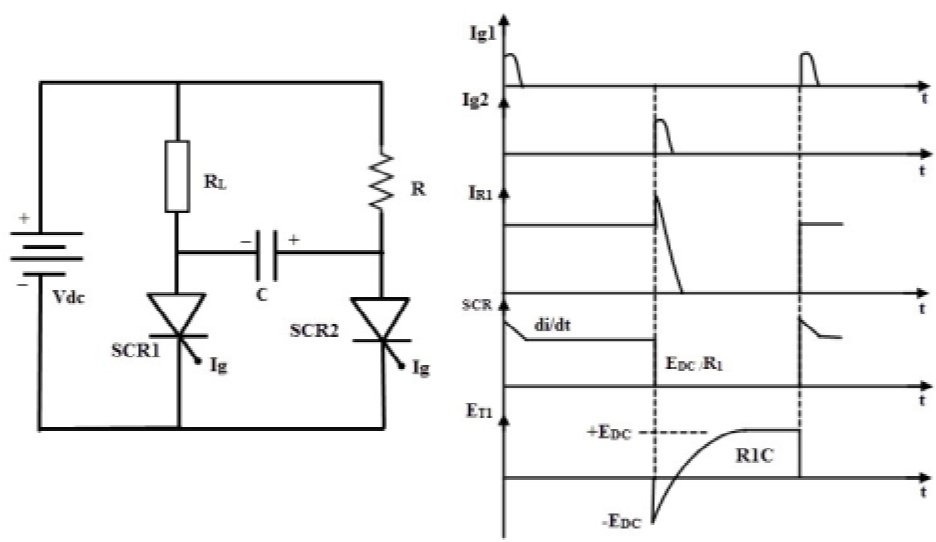


Figure 3 Class C Commutation

Apparatus Required:-

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-300/32 V DC	1 No.
2	Dual Trace CRO	20 MHz	2 No.
3	SCR	2N6394 / TYN612 or any other available	2 No.
4	Resistors	1 KΩ or any other available	1 No.
5	Inductor	5 mH or any other available	1 No.
6	Capacitor	1 μF or any other available	1 No.
7	UJT triggering circuit		1 No.

Precaution to be followed:

- Ensure that all the knobs of the power supplies are at zero value before switching them on.
- The applied voltage and current should not exceed the maximum rating of the given SCR.
- Reading should not be noted without parallax error.

Procedure:

1. Make the circuit connection as per the circuit diagram.
2. Switch on the power supply.
3. Observe and note output V_{AK} if gate voltage is not applied.
4. Now apply gate signal to the SCR.
5. Observe the change in output with respect to gate pulse.
6. Observe and record the load voltage and V_{AK}.
7. Draw the waveforms on graph paper.

Observation and calculation:-

1. Time period of gate signal = …………….
2. Amplitude of gate signal = ………………
3. V_{AK} when gate is not applied = ………….
4. V_{Ak} when gate is applied = ………………

Experiment No. - 08

Perform the operation of Class–D, E, F turn off circuits.

Aim: - Perform the operation of class- D, E, F commutation circuit

Introduction:- Continuous conduction causes problems in choppers, inverters, and cyclo-converters. By the commutation process the thyristor operating mode is changed from forward conducting to forward blocking mode. In class D and E, thyristor can be turn off by applying reverse voltage across SCR and external pulse respectively. In case F commutation, thyristor is turned off due to negative half cycle of applied ac voltage. Thyristor current can be reduced to a value below the value of holding current. Since, the thyristor is turned off forcibly it is termed as a forced commutation process. No separate commutation components are required in class F commutation. Due to negative half cycle of ac input, thyristor are turned off. Hence controlled rectifiers are also called as line commutated converters.

Class D commutation: - This is also known as auxiliary commutation. The source of commutation voltage is in the commutating capacitor. The load current flows through main SCR. Auxiliary SCR is used for initial charging of commutating capacitor and to turn of the main SCR. Reverse voltage across this capacitor is used to turn off the main SCR.

Class E commutation:- This is also known as external pulse commutation circuit in which a reverse voltage is applied across the SCR. Load current flows through the SCR becomes zero when reverse voltage of equal magnitude to that of supply voltage is applied across the SCR.

Class F commutation:- AC input is given to the controlled rectifier circuits. In single phase half wave controlled rectifier SCR conducts in positive half cycle and turned off naturally due to reverse voltage in negative half cycle. Turn of time of converter grade SCR is in the range of 200 to 300 µsec and duration of negative half cycle for 50Hz frequency is 10msec. As turn off time of SCR is very less and duration of negative half cycle is too large with compared to turn off time. SCR is turned off during each negative half cycle. Hence controlled rectifiers are also called as line commutated converters. This type of commutation is called as class F or natural commutation.

Circuit diagram/ practical set up:-

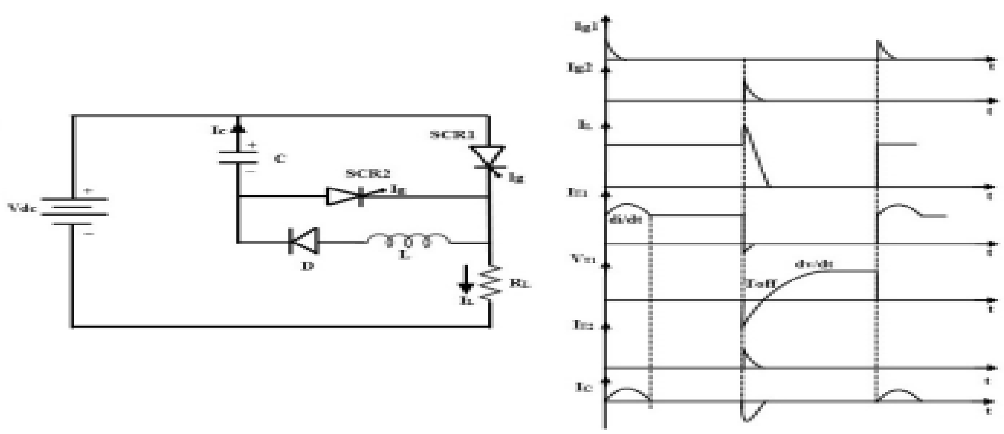


Figure 1 ..Class D Commutation..

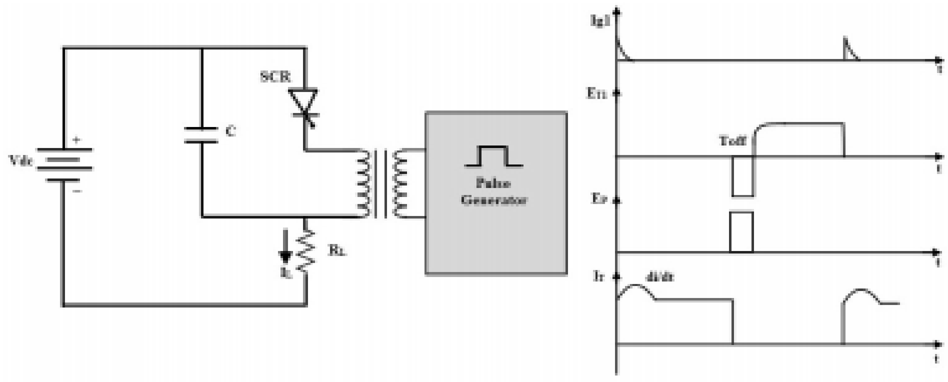


Figure 2 Class E Commutation

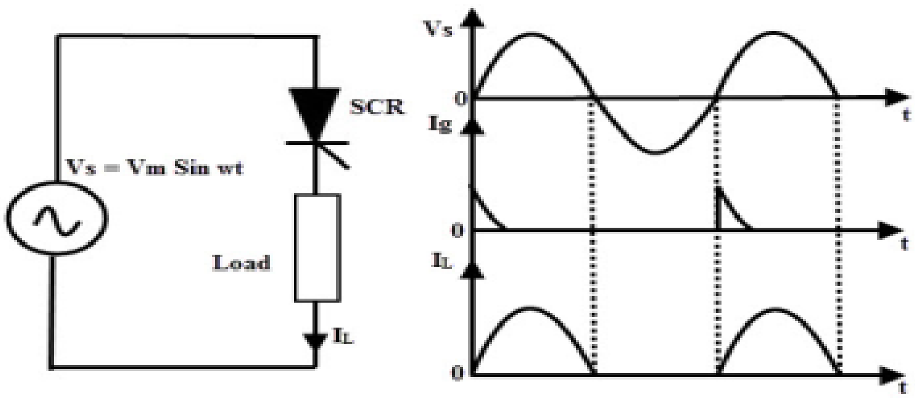


Figure 3 Class F Commutation

Apparatus requirement:

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Power supply	0-50 V_{DC} , AC power supply	1 No.
2	Dual Trace CRO	20 MHz	2 No.
3	SCR	2N6394 / TYN612 or any other available	2 No.
4	Resistors		1 No.
5	Inductor		1 No.
6	Capacitor		1 No.
7	UJT triggering circuit		1 No.

Precaution to be followed:

- Ensure that all the knobs of the power supplies are at zero value before switching them on.
- The applied voltage and current should not exceed the maximum rating of the given SCR.
- Reading should not be noted without parallax error.

Procedure:

1. Make the circuit connection as per the circuit diagram.
2. Switch on the power supply.
3. Observe and note output V_{AK} if gate voltage is not applied.
4. Now apply gate signal to the SCR.
5. Observe the change in output with respect to gate pulse.
6. Observe and record the load voltage and V_{AK}.
7. Draw the waveforms on graph paper.

Observation and calculation:-

1. V_{AK} when gate is not applied = ………….
2. V_{Ak} when gate is applied = ………………
3. Time period of gate signal (class E) = …………….
4. Amplitude of gate signal (class E)= ………………
5. AC input voltage (class F) = ……………………
6. Average load voltage (class F) = ………………..

Experiment No.: - 10

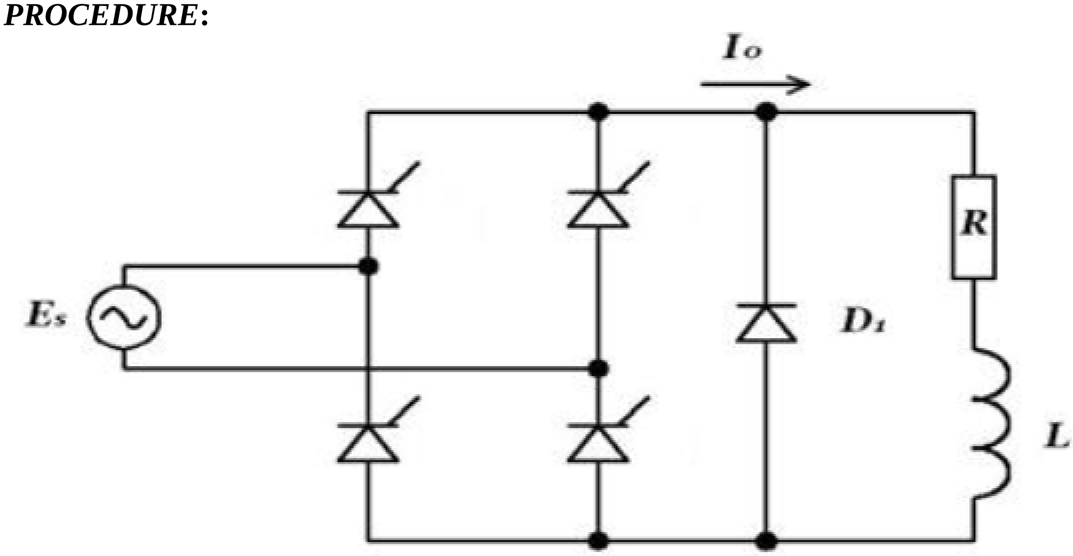
Draw the output wave form of Full wave controlled rectifier with R load, RL load, free- wheeling diode and determine the load voltage.

Aim:-

- To study the performance and waveforms of full wave controlled rectifier with Resistance load, Inductive load and free-wheeling diode.
- Plot the output wave form for R-load, RL-load and free-wheeling diode.

Apparatus Required: Trainer module, Multi-meters, CRO, Patch cords Rheostat and inductor.

***PROCEDURE*:**



1. Connections are made as shown in the circuit diagram.
2. By varying a resistance R gradually in step by step, note down the corresponding values of Vn & Vm from CRO and VOdc (Vo Practical) from D.C voltmeter. The readings are tabulated in the tabular column.
3. If firing angle ranges from 0 to 900, then firing angle can be calculated

   From

   $$\alpha = \sin^{-1}(Vn/Vm) \quad \text{in degrees}$$

   If firing angle ranges from 900 to 1800, then firing angle can be calculated by using a formula,

   $$\beta = 180 - \sin^{-1}(Vn/Vm) \quad \text{in degrees}$$

4. The conduction angle β can be calculated by using a formula,

$\beta = 180 - \alpha$ in degrees

5. The current & power is calculated by

$$Idc = Vdc / R \text{ Amps}$$

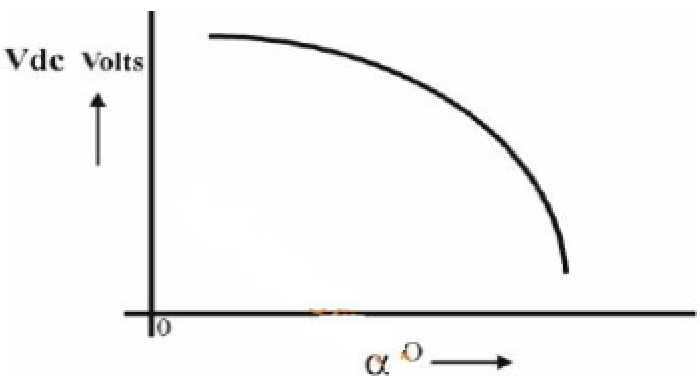
$$Pdc = V2dc / R \text{ Watts}$$

Compare Voth with VoPractical, Where

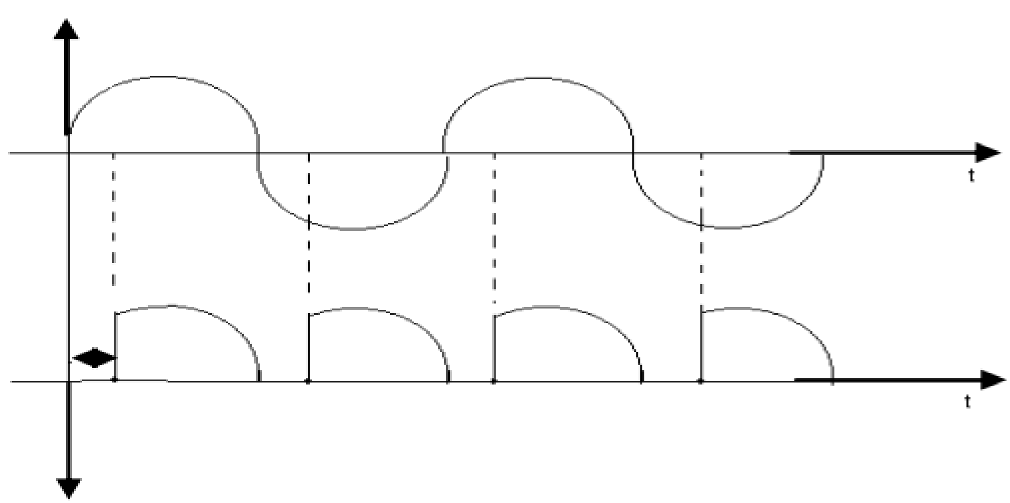
$$V_{oth} = (V_m / \pi)(1 + \cos \alpha)$$

6. A graph of Vdc v/s α, Vdc v/s β, Idc v/s α, Idc v/s β, Pdc v/s α, and Pdc v/s β are to be plotted on a graph sheet.
7. Plot a graph of VDC or Vload or VO v/s firing angle α, with R load, R-L load without freewheeling diode, RL with Free- wheeling diode.

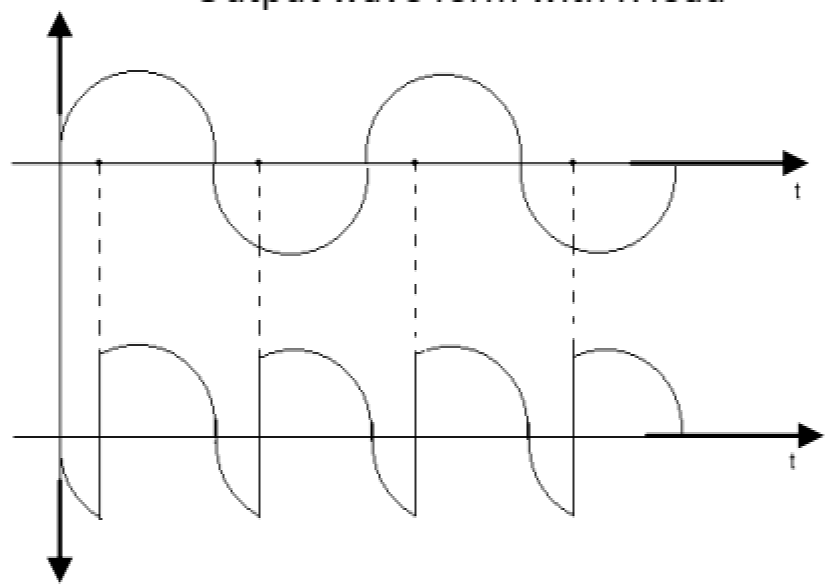
Graph



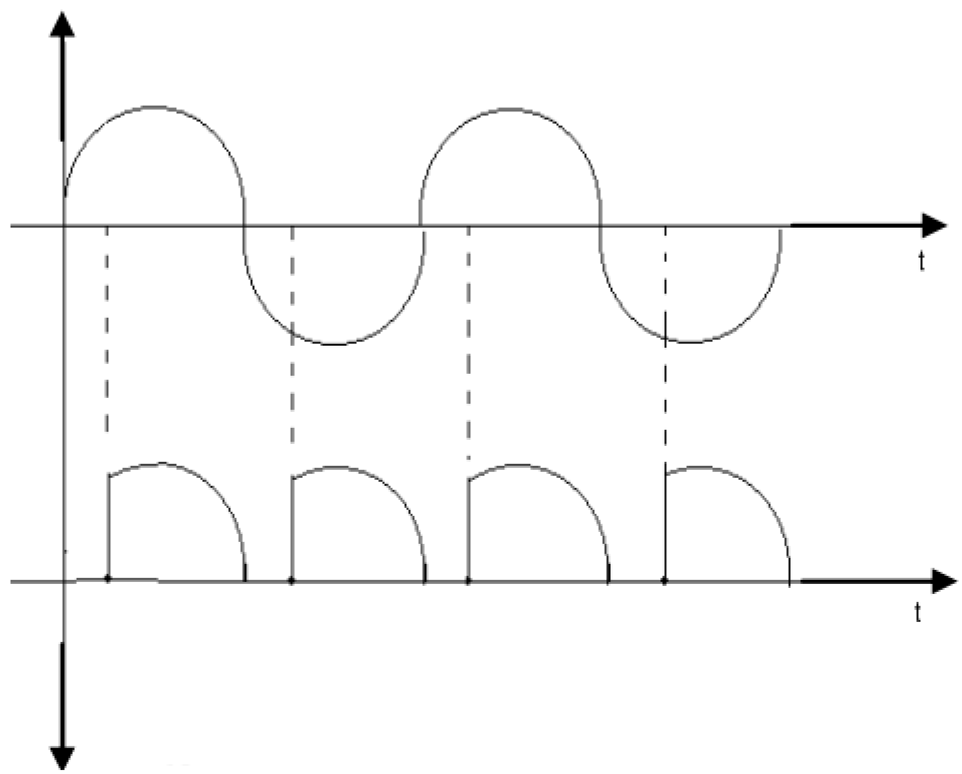
Expected Wave forms:



Output wave form with R load



Output waveforms across R-L load without freewheeling diode



Output waveforms across R-L load with freewheeling diode.

Tabular Column: - Draw the table for Output wave form with R load**,** Output waveforms across R-L load without freewheeling diode, R L with Free-wheeling diode.

Sl. No	FROM C.R.O								V_{DC} (V_{load}) volts	I_{dc} = V_{dc}/R A	P_{dc} = V_{dc}^2/R Watts	V_{oth}
	0 TO 90^0				90^0 TO 180^0							
	V_n volts	V_m volts	$\alpha = \sin^{-1}\left(\frac{V_n}{V_m}\right)^0$	$\beta=180-\alpha$	V^n volts	V^m volts	$\alpha = 180 - \sin^{-1}\left(\frac{V_n}{V_m}\right)^0$	$\beta=180-\alpha$				