EXPERIMENT No. 5

1.0 Title:
To plot V-I characteristics of DIAC (Diode AC Switch).

2.0 Prior Concepts:
- Diode - It is a PN junction device having two layers, two terminals and one junction.
- Comparison between AC and DC signalling.
- Diac - The diac is a two terminal device. It is a parallel inverse combination of semiconductor layers that permits triggering in either direction.

3.0 New Concepts:

Proposition 1: VI characteristics
It is the curve drawn between voltage applied between MT₁, MT₂ and current.
Concept structure:

Proposition 2:
Regions in characteristics
The VI characteristics in forward and reverse is divided into two regions.

A. Blocking state (Off state):
For applied positive voltage less than +V₉₀ and negative voltage less than -V₉₀, a small leakage current (+I₉₀) flows through the device. Under such conditions, the diac blocks the flow of current and effectively behaves as an open circuit, +V₉₀ and -V₉₀ are breakdown voltage.
B. Conduction state (ON state):

When the positive or negative applied voltage is equal to or greater than the breakdown voltage, diac begins to conduct and the voltage drop across it becomes a few volts called as 'break back' voltage.

At this point, avalanche breakdown of the reversed biased junction occurs and the device exhibits -ve resistance i.e. current through the device increases with decreasing values of applied voltage.

Concept Structure:

- **Regions of VI characteristics**
  - **OFF state** (blocking state)
  - **ON state** (Conduction state)

**Proposition 3: DIAC characteristics**

It is the curve drawn between voltage across terminal MT₁ and MT₂ & current.

4.0 Learning objectives:

**Intellectual Skills:**
- To understand the effect of changing the polarity of I/P signal on conduction of Diac.
- To identify different regions in VI characteristics.

**Motor Skills:**
- Ability to make the connections.
- Ability to interpret different regions on graph.
- Ability to confirm that diac is a bidirectional device.
- Ability to observe and note the voltages and current and record them.

5.0 Apparatus:
- 0 - 50V DC power supply.
- 0 - 50 mA ammeter.
- 0 - 50 V voltmeter.
6.0 Circuit diagram:

7.0 Stepwise procedure:
1. Connect the milliammeter, DIAC, Voltmeter to the circuit.
2. Switch ON the power supply.
3. Increase supply voltage in steps, note the corresponding currents and voltages for each step.
4. Plot graph of VI characteristics.
5. Reverse the Terminal of Diac. Increase supply voltage in steps, note the corresponding currents and voltages for each step.
6. Plot graph of VI characteristics.

8.0 Observations:

<table>
<thead>
<tr>
<th>For DIAC 1</th>
<th>For DIAC 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading for voltage and current MT₁ is +ve and MT₂ is –ve</td>
<td>Reading for voltage and current MT₂ is +ve and MT₁ is –ve</td>
</tr>
<tr>
<td>O/P voltage (V)</td>
<td>Current (mA)</td>
</tr>
<tr>
<td>O/P voltage (V)</td>
<td>Current (mA)</td>
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<td>O/P voltage (V)</td>
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<td>O/P voltage (V)</td>
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<td>O/P voltage (V)</td>
<td>Current (mA)</td>
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<tr>
<td>O/P voltage (V)</td>
<td>Current (mA)</td>
</tr>
</tbody>
</table>
9.0 Conclusion:
- In the VI characteristics of DIAC, when voltage increases current (increases / decreases / remains) in conduction state.
- Diac is a (unidirectional / bidirectional) device.
- Student to write conclusion on the behaviour of DIAC as a switch under guidance of teacher.

10.0 Questions:
Write answers to Q..... Q..... Q..... Q..... Teacher shall allot the questions.

1. Diac resembles a Bipolar transistor with no base connection. Justify the statement.
2. Write three specifications of Diac.
3. DIAC is not a controlling device. Give reason.
4. Write two applications of Diac.
5. Name the device D in the following fig. 1

![Diagram with labels MT₁, MT₂, D, AC I/P, and a triangle symbol.]

6. Refering above fig. 1 state whether the device D is used for A.C. or D.C.
7. Write the fullform of DIAC.
8. Write two difference between DIAC and SBS.
9. Can DIAC control AC power. Justify statement by giving reason
10. Draw DIAC from SBS.
11. Write two differences between SCR and DIAC.
12. Give the names of two bidirectional triggering devices.

Note: Teacher shall add few questions.
13.
14.
15.
(Space for answers)
EXPERIMENT No. 6

1.0 Title:

To draw V-I characteristics of TRIAC for different values of gate currents

2.0 Prior Concepts:

➢ SCR
➢ PN Junction
➢ Characteristics of SCR

3.0 New Concepts:

Proposition 1: TRIAC

It is a three terminal device which can conduct in either direction when triggered either by a positive or a negative pulse irrespective of the polarity of the voltage across its main terminals. It is a bidirectional device. The three terminals are named as main terminal 1 (MT$_1$), main terminal 2 (MT$_2$) and gate. Gate is a control terminal. Since the triac conducts in both directions, the two terminals are designated by numbers instead of anode and cathode as in SCR.

Concept structure:

![Diagram of TRIAC](image1)

![Symbol of TRIAC](image2)

Proposition 2: Two SCR version of TRIAC.

Triac is equivalent to two SCRs connected in parallel but in reverse direction with common gate terminal.

Concept Structure:

![Diagram of Two SCR version of TRIAC](image3)
Proposition 3: Operation of TRIAC

There are four modes of triac operation, depending upon the polarity of voltage across its main terminals and gate terminal. These modes are described as below:

Concept Structure:

1. M.T. 2 is positive and G is positive. In this mode, the operation of the triac is identical to SCR. The current flows through the switch \( P_1N_1P_2N_2 \) from M.T.2 to M.T.1 as shown in fig. (a).

2. M.T. 2 is negative and G is positive. In this mode, the current flows through the switch \( P_2N_1P_1N_4 \) from M.T.1 to M.T.2 as shown in fig. (b). This is an inefficient mode and must be avoided.

3. M.T. 2 is positive and G is negative. In this mode, the current flows through the switch \( P_1N_1P_2N_2 \) from M.T.2 to M.T.1 as shown in fig. (c). This mode is less efficient than mode 1 but not as poor as mode 2.

4. M.T. 2 is negative and G is negative. In this mode, the current flows through the switch \( P_2N_1P_1N_4 \) from M.T.1 to M.T.2 as shown in fig. (d). This mode is slightly less efficient than mode 1.

The mode 1 and mode 4 are efficient modes in triac operation. Therefore these two modes are called normal modes of triac operation.

Proposition 4: VI Characteristics of TRIAC.

It gives the relationship between the TRIAC current and the voltage applied across its two main terminals. As discussed in proposition 3, triac is operated in two ways:

a) M.T.2 and gate both positive w.r.t. M.T.1 (Curve OABC)
b) M.T.2 and gate both negative w.r.t. M.T.1 (Curve ODEF)

In first case current flows from MT2 to MT1 and in the second case current flows from MT1 to MT2.
Concept Structure:

Note:
\( V_{MT} \) = Voltage across main terminal of TRIAC
\( I_{MT} \) = Current through TRIAC.
\( V_{BO1}, V_{BO2} \) = Break over voltage.
\( I_g \) = Gate current.

4.0: Learning Objectives.

Intellectual Skills:
- To identify the components and equipment.
- To understand the behaviour of TRIAC by observing variations in current with respect to voltage across MT₁ and MT₂.
- To predict the effect of gate current on the characteristics.
- To identify different regions on the characteristics

Motor Skills:
- Ability to make the connections as per circuit diagram.
- Ability to measure voltage and currents using meters.
- Ability to plot characteristics using observations.
5.0: Apparatus:
Experimental Kit, Multimeters (2), Milliammeters (2) Regulated Power Supply (2)

6.0: Circuit diagram:

7.0 Stepwise procedure:
1) Make connections as per the circuit diagram.
2) Rotate potentiometers $P_1$ and $P_2$ for minimum resistance.
3) Switch on the power supply.
4) Put the switch towards $+V$.
5) Vary potentiometer $P_2$ to set gate current $I_o$ to a lower value.
6) Increase voltage $V_{MT}$ gradually by varying potentiometer $P_1$.
7) Observe the current in ammeter 1. It will show zero current in initial stage.
8) Try various values of gate current. Vary voltage by $P_1$ and note down current $I_{MT}$.
9) Note down voltage $V_{MT}$ and corresponding current $I_{MT}$ after firing of TRIAC.
10) Note down readings in table 1.
11) Rotate potentiometer $P_1$ fully counterclockwise.
12) Put the switch towards $-V$ and repeat from step 3 and note down the readings in observation table 2.
13) Plot the graph of $V_{MT}$ versus $I_{MT}$ for the reading in both tables.
8.0 Observations:

Table 1

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Voltage $V_{MT}$</th>
<th>Current $I_{MT}$ at constant value of Gate current when switch is towards $+V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>$I_G = \ldots \text{mA}$ $I_O = \ldots \text{mA}$</td>
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<td>10</td>
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</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Voltage $V_{MT}$</th>
<th>Current $I_{MT}$ at constant value of Gate current when switch is towards $-V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>$I_G = \ldots \text{mA}$ $I_O = \ldots \text{mA}$</td>
</tr>
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</table>

9.0 Result:

$V_{BO} = \ldots \text{V}$ for $I_G = \ldots \text{mA}$
$V_{BO} = \ldots \text{V}$ for $I_G = \ldots \text{mA}$
$V_{BO} = \ldots \text{V}$ for $I_G = \ldots \text{mA}$
$V_{BO} = \ldots \text{V}$ for $I_G = \ldots \text{mA}$
10.0 Conclusions:
- The characteristics has .................. (same / different) shape in I and III quadrant
- As \( I_0 \) increases, \( V_{so} \) .................. (increases / decreases)
- Students to write conclusion on the basis of ON and OFF condition of TRIAC by observing characteristics.

11.0 Questions:
Write answers to questions Q. ...... Q...... Q...... Q...... (Teacher shall allot questions)

1) Why TRIAC is called bidirectional controlled device?
2) What is meant by holding current? State its significance.
3) What is meant by latching current?
4) What are the different modes of operation of TRIAC?
5) If the gate voltage is same, will the \( V_{so} \) change with MT1 positive and MT1 negative?
6) Justify the name TRIAC?
7) What is the effect of gate voltage once TRIAC comes in ON condition?
8) Is TRIAC a switch? Explain.
9) What is advantage of TRIAC over SCR?
10) What is limitation of TRIAC in comparison to SCR related to power handling capacity?
11) How will you get the function of TRIAC using SCRs?
12) How does a triac differ from DIAC?
13) Usually triac is triggered by a diac Why?
14) Why the terms anode and cathode are not applicable for terminals of TRIAC?
15) Name the device which is used to switch large power thyristor circuitry or a low power controlling device

(Space for answers)
(Space for answers)
EXPERIMENT No. 7

1.0 Title:

To understand working of pulse triggering circuit using UJT

2.0 Prior Concepts:

- SCR (Silicon Controlled Rectifier).
- Unijunction transistor as relaxation oscillator.

3.0 New Concepts:

Proposition 1: Gate triggering of SCR

The SCR can be switched into conduction either by increasing the forward voltage beyond $V_{BR}$ or by applying a positive gate signal when the device is forward biased. This second method is called the gate triggering of SCR.

It is more efficient and easy to implement for power control.

Concept structure:

- SCR Turn ON methods
  - Thermal Triggering
  - Forward voltage Triggering
  - $dv/dt$ Triggering
  - Gate Triggering
  - Radiation Triggering

Proposition 2: Methods of gate triggering

There are methods for gate triggering namely triggering by DC gate signal, AC gate signal or pulsed gate signal.

For gate triggering, signal is applied between gate and cathode.

Concept structure:

- Gate triggering
  - DC gate triggering
  - AC gate triggering
  - Pulse gate triggering

Proposition 3: Turn ON requirements

To turn ON SCR successfully using the pulse triggering techniques, various points must be carefully considered.
Concept structure:

- **Gate Pulse Amplitude**: Sufficiently High to FB gate cathode junction
- **Polarity of pulse**: Positive
- **Triggering pulse characteristics**
  - Rise time minimum
  - Pulse width: Greater than turn ON time of SCR
- **Gate power dissipation**: As short as possible to minimize gate power dissipation
  - Pulse Transformer
  - Isolation
    - Opto couplers
- **Shape can be other than rectangular**

**Proposition 4: Gate triggering circuits**

The triggering circuits are designed by considering the gate pulse amplitude, polarity, characteristics etc. (Refer proposition 3)

Concept structure:

- **Triggering Circuit**
  - Simple resistor
  - Resistor capacitor
  - UJT (relaxation oscillator)

**Proposition 5: Gate triggering of SCR using UJT**

The UJT relaxation oscillator produces positive pulses at point B at a rate determined by the resistor (R) and capacitor (C). These pulses are applied to the gate of SCR to turn it ON. A fixed voltage is applied between anode and cathode and a triggering pulse of sufficient amplitude triggers the SCR.
4.0 Learning objectives.

Intellectual Skills:
- To identify components on the experimental kit.
- To understand specifications of SCR related to experiment e.g. $V_{BO}$, $I_A$ etc.
- To understand values of components used in the circuit.
- To understand the concept of finding out triggering voltage of SCR.

Motor Skills:
- Ability to make the connections as per the circuit diagram.
- Ability to measure and note down the currents and voltages.

5.0 Equipments:
- Experimental kit
- Variable DC regulated power supply (0 - 30v) - 2 Nos.
- Milliammeters - 2 Nos.

6.0 Circuit diagram:

7.0 Stepwise Procedure:
1. Make connections as shown in circuit diagram
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 gate current $I_{G(mA)}$
4. Connect voltmeter between points '5' and ground to measure the anode cathode voltage $V_{AK}$.

5. Rotate the potentiometer P1 fully in clockwise direction and P2 fully in the counterclockwise direction.

6. Switch on the power supply.

7. Vary the potentiometer P2 in clockwise direction so as to increase the anode to cathode voltage. Set this voltage to 11 V.

8. Vary the potentiometer P1 in counterclockwise direction so as to increase the value of gate current in step and measure the corresponding values of anode to cathode current $I_{AK}$.

9. Initially there will not be any current flow across the SCR, while varying the gate current, the current in the ammeter connected at point '3' and '4' suddenly increases and the voltmeter connected at point '5' and ground will suddenly decrease. This shows that SCR is triggered.

10. Now vary the P1, there will not be any effect in the anode-cathode voltage and current of SCR.

11. Follow the procedure from step 6 to repeat the procedure for different $V_{AK}$.

8.0 Observations:

Reading for Anode to Cathode Current, Anode to Cathode Voltage and gate current.

Set $V_{AK} = 11$V

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Gate Current $I_g$(mA)</th>
<th>Anode to cathode current $I_{AK}$ (mA)</th>
<th>Anode to cathode Voltage $V_{AK}$(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</table>

Set $V_{AK} = 9$V

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Gate Current $I_g$(mA)</th>
<th>Anode to cathode current $I_{AK}$ (mA)</th>
<th>Anode to cathode Voltage $V_{AK}$(V)</th>
</tr>
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</table>
9.0 Conclusion:
1. Anode current suddenly ............... (increases / decreases) when SCR is triggered.
2. Once SCR is triggered, there will be .................... (increase in, decrease in, no effect on) anode to cathode voltage and anode current.
3. Students to write conclusion on the basis of effect of \( V_{ak} \) on triggering of SCR.

10.0 Questions:
Write answer to Q. ......, Q. ......, Q. ......, Q. ...... Teacher shall allot the questions.
1. What is the method of triggering used in this circuit?
2. What is the limit on forward anode to cathode voltage to trigger it by gate triggering method?
3. What type of pulses are available at the base 1 of relaxation oscillator?
4. How will you change the amplitude of the pulses at the B1 of UJT?
5. What is the need for triggering of SCR?
6. What is the advantage of using UJT as a triggering device for SCR?
7. What other devices or components can be used to trigger SCR?
8. How does the negative resistance characteristics of UJT help us to use it as a triggering device?
9. State the meaning of firing angle of SCR?
10. State the situation to change the firing angle using this experiment.
11. List any four requirements of pulse to turn ON SCR.
12. Which method is preferred to turn ON SCR?
13. What are the limitations on the triggering pulse characteristics related to its width and amplitude?
14. What is the function of UJT relaxation oscillator in this circuit?
15. What are the advantages of pulse triggering over R and RC triggering circuits?

(Space for answers)
(Space for answers)
EXPERIMENT No. 8

1.0 Title:
To turn OFF SCR using Class C commutation Method and observe the waveforms at different points.

2.0 Prior Concepts:
- SCR
- Triggering of SCR

3.0 New Concepts:

**Proposition 1: Commutation of SCR**
It is the process to turn OFF conducting SCR. There are two ways of commutating an SCR.
- By reducing the forward current through the SCR below its holding current called as current commutation.
- By applying a large reverse voltage across the SCR called as voltage commutation.

**Concept structure:**

```
Commutation of Thyristor
  \( \text{(Ways)} \)

Current commutation
Voltage Commutation
```

**Proposition 2: Types of commutation:**
The two types of commutation
- **Natural Commutation:** When the thyristor is turned off due to its forward current going below holding current it is said to be naturally commutated. Natural commutation takes place in the circuits powered by an alternating supply.
- **Forced commutation:** When the thyristors operate on a pure DC input voltage, the forward current can not be reduced below holding current naturally, therefore the thyristors must be commutated 'forcibly' by using additional commutation circuit. This is called forced commutation. This external commutation circuit will turn off the SCR by either current or voltage commutation.

**Concept Structure:**

```
Types of commutation

Natural Commutation
- Used in circuits powered by AC

Forced commutation
- Used in SCR inverters and Choppers
```

**Proposition 3: Classification of forced commutation methods**
There are six different methods of forced commutation.
- **Class - A:** Self commutated by resonating load
- Class - B: Self commutated by LC circuit.
- Class - C: C or LC switched by another load carrying SCR.
- Class - D: C or LC switched by an auxiliary SCR.
- Class - E: An external pulse source for commutation.
- Class - F: AC line commutation.

Concept Structure:

Proposition 4: Class C circuit

SCR₁ and SCR₂ are capable of handling the load. C is the commutating capacitor and voltage across it is used to commutate the conducting SCR. Hence class C commutation is voltage commutation. R is load resistance.

Concept Structure:

Proposition 5: Modes of operation:

Before SCR₁ is triggered and SCR₂ is conducting

Mode I (t₀ to t₁)

At t₀, SCR₁ is triggered. Voltage across C reverse biases SCR₂ and it is turned off. Iᵣ₁ = V/R flows through SCR₁.
Mode II ($t_1$ to $t_2$)
At $t_1$, $I_C = 0$ voltage across $C = V$ with polarities as shown in Fig. (C) SCR$_1$ is continuous to conduct load current $I_{R1} = V/R$.

![Mode II Diagram](image)

Mode III ($t_2$ to $t_3$)
At $t = t_2$, SCR$_2$ is turned ON. Commutating capacitor $C$ applies reverse voltage across SCR$_1$ and turns it OFF. Current through SCR$_2$ = $I_{R2} + I_C$. At $t_3$, capacitor is fully charged.

![Mode III Diagram](image)

Mode IV ($t_3$ to $t_4$)
At $t = t_3$, SCR$_1$ capacitor is fully charged, $I_C = 0$ and $V_{SCR2} = V$. Voltage across $C$ is constant with polarities as shown in Fig (e)

![Mode IV Diagram](image)

At $t = t_4$, SCR$_1$ is triggered again to turn OFF SCR$_2$ and the cycle of operation repeats itself.
4.0 Learning objectives:

Intellectual Skills:
- To identify the components.
- To understand the ways of turning off SCR.
- To understand the concept of commutation.
- To analyse the waveforms of currents and voltages.

Motor Skills:
- Ability to make connections as per circuit diagram.
- Ability to observe waveforms of voltages and currents using CRO.
- Ability to plot the waveforms on graph paper.

5.0 Apparatus:
- Experimental Kit
- Variable DC regulated power supply (0 - 30V)
- CRO

6.0 Circuit diagram:

Note: At $G_1$ and $G_2$, the signals are to be supplied from a proper triggering circuit.
7.0 Stepwise procedure:
- Connect the circuit as shown in Figure.
- Connect G1 and G2 signals to gate of SCR.
- Switch ON the power supply.
- Connect oscilloscope across load resistance and observe waveforms.
- Draw the waveforms on graph paper.

8.0 Conclusion:
- When SCR1 is triggered, the voltage across commutating capacitor ........................................ (reverse biases / Forward Biases) the conducting SCR2.
- The SCR turns off in this method due to ........................................ (voltage / current) commutation.
- Students to write conclusion on the basis of variation of voltage by observing voltage waveform across SCR.

9.0 Questions:
Write answer to Q. Q Q Q Q. Teacher shall allot the questions.
1. What are the different ways of turning Off an SCR?
2. What is meant by natural commutation?
3. Define forced commutation.
4. What should be the value of thyristor forward current to turn it off?
5. In which method of commutation, LC circuit is used in series of SCR?
6. What are the six basic methods of forced commutation?
7. In DC application, which commutation method is preferred?
8. What is the limitation of circuit recovery time in class C commutation?
9. State advantages of class C commutation.
10. What are the devices used for commutation of thyristor?
11. What is another name for class C commutation?
12. Compare Class B and Class C commutation in context to their circuit.
13. State two applications of class C commutation.
Note: Teacher shall add few questions as numbered below.
(Space for Answers)
EXPERIMENT No. 9

1.0 Title:
To understand operation and draw waveforms of single phase half wave controlled rectifier with R load.

2.0 Prior Concepts:
- Rectifier (uncontrolled): A circuit which converts AC to DC.
- Types: Two types of rectifier
  - Controlled rectifier
  - Uncontrolled rectifier

- Phase controlled rectifier: A circuit which converts AC input voltage to a controllable DC output voltage.
- SCR: A silicon controlled rectifier is a three terminal, four layer, three junction device.

3.0 New Concepts:
Proposition 1: Types of single phase controlled rectifiers
Different types of single phase controlled rectifiers are
- Half wave controlled rectifier
- Full wave controlled rectifier
- Half controlled bridge rectifier
- Full controlled bridge rectifier

Proposition 2: Basic principle of single phase controlled rectifier
The basic principle of phase-controlled rectifier is to control the point in time at which the SCRs are allowed to conduct during each AC cycle.
Thus it is possible to select the time segments of the AC voltage waves which appear at the DC terminals and the mean output voltage is controlled continuously.
When the voltage across SCR is negative, they are turned off.

**Concept Structure:**

![Concept Structure Diagram]

**Proposition 3:** Single phase half wave controlled rectifier with load classification

In a single phase half wave controlled rectifier circuit, there is only one SCR used.

**Classification of Single Phase half wave controlled rectifier.**

- R load
- RL load
- RL load and flywheel diode
- RL load & battery
- R load and battery

**Proposition 4:** Working principle of single phase half wave controlled rectifier

The working principle of a single phase half wave controlled rectifier is as follows:

- During positive half cycle of supply voltage, i.e., when the anode of SCR is positive with respect to cathode and the SCR is fired, power is delivered to the load.
- During negative half cycle, the SCR is reverse biased and blocks the line voltage and no current can flow through the load.

**Proposition 5:** O/P waveforms of single phase half wave controlled rectifier.

![Waveform Diagram]
4.0 Learning objectives.

Intellectual Skills:
- To understand SCR as a controlled rectifier.
- To discriminate between half wave controlled rectifier and half wave uncontrolled rectifier.
- To interpret different waveforms.

Motor Skills:
- Ability to observe waveforms and interpret.
- Ability to change firing angle and observe waveforms.

5.0 Apparatus:
- Trainer kit
- Power Supply
- Connecting wires
- CRO (Cathode Ray Oscilloscope)

6.0 Circuit diagram: (Student shall draw)

7.0 Stepwise procedure:
1. Make the connections as per circuit diagram.
2. Switch ON power supply.
3. Apply gate triggering voltage at firing angle $\alpha_1$ and observe the waveform at load $R$.
4. Repeat step 3 by changing firing angle as $\alpha_2$ and $\alpha_3$.
5. Draw graph for different firing angles.

8.0 Observations:
Readings for variation of load voltage with supply voltage at different values of $\alpha$.

<table>
<thead>
<tr>
<th>For $\alpha = 30$</th>
<th>For $\alpha = 45$</th>
<th>For $\alpha = 60$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s$ (V)</td>
<td>$V_s$ (V)</td>
<td>$V_s$ (V)</td>
</tr>
<tr>
<td>$V_L$ (V)</td>
<td>$V_L$ (V)</td>
<td>$V_L$ (V)</td>
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</table>
9.0 Conclusion:
- As firing angle is increased, the voltage across load ............. (increases/decreases/remains constant)
- Phase controlled rectifier circuits convert AC input voltage to a ............... (controllable / uncontrollable) DC voltage.
- Student to write conclusion on the basis of output waveform at R load under guidance of teacher.

9.0 Questions:
Write answer to Q. ........, Q....... Q....... Q........ Teacher shall allot the questions.
1. Write two differences between SCR and diode.
2. Write two differences between controlled rectifier and uncontrolled rectifier.
3. State two applications of controlled rectifiers.
4. Define the following terms
   1. Form factor
   2. Ripple factor
   3. Utility factor
5. Half wave controlled rectifier have high percentage of ripple (say true or false). What is the remedy?
6. Define:
   1. Direct current
   2. Alternating current.
7. Silicon diodes are preferred over germanium diode in rectifiers. State reasons.
8. Define an ideal rectifying element.
9. Why semiconductor diodes are preferred over gas tubes? Give reason.
10. Does type of load affect the behaviour of rectifier?
11. Write differences between half wave controlled rectifier with R load and RL load.
Note: Teacher shall add few questions.
12. ...................................................................................................................
13. ...................................................................................................................
14. ...................................................................................................................
15. ...................................................................................................................
EXPERIMENT No. 10

1.0 Title:
To draw waveforms of single phase fully controlled bridge rectifier with RL load

2.0 Prior Concepts:
- Controlled rectifiers: Rectifier circuit using SCR is a controlled rectifier.
- Single phase half wave controlled rectifier.
- Different types of load: R load, RL load.

3.0 New Concepts:

Proposition 1: Types of single phase fully controlled rectifier
The circuit having four SCRs connected in bridge configuration with transformer primary as input is a single phase fully controlled rectifier.
- Single phase fully controlled bridge with RL load.
- Single phase fully controlled bridge with R load.

Concept Structure:

- Types of 1φ fully controlled rectifier
- With R load
- With RL load

Proposition 2: Working principle of single phase fully controlled rectifier.
The working principle is explained by considering different time intervals as follows.

MODE - I (α ≤ ωt ≤ π)

- In positive half cycle of input ac supply, L is positive with respect to neutral N, therefore SCRs 1 and 2 are forward biased and can be turned on at the desired value of α.
- At instant α, SCRs 1 and 2 are triggered and load voltage is equal to instantaneous supply voltage.
- SCRs 3 and 4 are commutated that are already conducting as they are reversed biased.
- As polarity of load voltage and load current both is positive, the load inductance will store the energy.

MODE - II (π ≤ ωt ≤ π + α)
• At instant \( \pi \) the input AC supply voltage passes through zero, and after \( \pi \) radians it becomes negative. The inductive load will try to oppose any change in current through it and a self induced voltage appears across the load.
• This self induced voltage maintains SCRs 1 and 2 forward biased even if supply voltage is negative.
• The load voltage is negative and equal to instantaneous AC supply voltage whereas load current continues to be positive.

\[
\text{MODE - III } \quad \left[ (\pi + \alpha) \leq \omega t \leq 2\pi \right]
\]

• At instant \( \pi + \alpha \), SCRs 3 & 4 are turned on and negative input voltage appears across SCRs 1 and 2 and they are commutated.
• The load voltage becomes positive and load current also positive. So load will store energy in this mode.

**Proposition 3 : Waveforms**

Waveforms of voltages and currents.

**Proposition 4 : Different configurations of single phase fully controlled rectifier.**
The following are the configurations of 1\( \phi \) fully controlled rectifier
• Midpoint configuration (\( M_s \))
• Bridge configuration (\( P_s \))
4.0 Learning objectives:

Intellectual Skills:
- To identify components and equipments required for the experiment.
- To discriminate the functioning of single phase halfwave controlled rectifier and single phase fully controlled bridge rectifier.
- To interpret different waveforms.

Motor Skills:
- Ability to observe and draw the waveforms.
- Ability to compare the output of single phase fully controlled bridge circuit with that of single phase halfwave controlled bridge.

5.0 Apparatus:
- Experimental Kit.
- Power Supply (AC).
- Connecting wires.
- CRO

6.0 Circuit diagram:(Student to draw)

7.0 Stepwise procedure:
1. Rotate the firing control Potentiometer in full clockwise direction.
2. Switch ON the power.
3. Measure the ac voltage (Vrms) by voltmeter and calculate Em by \( Em = 1.414 \times Vrms \).
4. Switch OFF the power.
5. Connect the circuit of fully-controlled bridge rectifier.
6. Switch ON the power.
7. Connect the oscilloscope and voltmeter across the load.
8. Vary the firing control pot and set on 30°, 60°, 90°, 120° and 150° firing angles using \( T = (\alpha \times 10 \text{ ms})/180 \).
9. Observe the output waveforms and note the readings of voltage across load on different firing angle.
10. Connect the oscilloscope one by one across SCR1, SCR2 and SCR3 and SCR4 and observe the waveforms.
8.0 Observations:

Readings for Input and Load Voltage

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Input AC Voltage</th>
<th>Firing Angle</th>
<th>Average Output Voltage Across Load</th>
<th>Average Load current (Idc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (V_RMS)</td>
<td>In (Deg.)</td>
<td>In Time (ms)</td>
<td>Measured Voltage (Vo)</td>
</tr>
<tr>
<td></td>
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</table>

9.0 Conclusion:

- In single phase fully controlled bridge the average output voltage becomes ..................

  (Zero / Positive Maximum / Negative Maximum) at \( \alpha = \frac{\pi}{2} \)

- The load voltage has a ......................... (negative value / positive value) from \( \pi \) to \( \alpha + \pi \) in single phase fully controlled bridge rectifier.

- Student to write conclusion on the basis of load current in the waveform under the guidance of teacher.

10.0 Questions:

Write answer to Q. ........ Q........ Q........ Q........ Teacher shall allot the questions.

1. Compare half and full controlled bridge on the basis of following points.
   - Average load voltage (RL load)
   - Quadrant of operation.

2. Define the following
   - Regeneration
   - Free wheeling.

3. Why semiconductor is preferred over full converter where regenerative braking is not required.

4. State the principle of phase control.

5. Compare phase control using SCR and phase control using UJT.

6. Sketch the output load voltage and load current waveforms for resistive load of single phase fully controlled bridge rectifier.
7. For 1\phi full controlled bridge with resistive load, the table shows average load voltage for different values of $\alpha$.

<table>
<thead>
<tr>
<th>$\alpha$ Degrees</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>150</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average load</td>
<td>0.63Vm</td>
<td>0.59Vm</td>
<td>0.47Vm</td>
<td>0.31Vm</td>
<td>0.16Vm</td>
<td>0.04Vm</td>
<td>0</td>
</tr>
<tr>
<td>voltage R Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Show graphically the variation of average load voltage with $\alpha$. From this graph state whether resistive load increases or decreases.

8. Observe the waveforms of single phase full controlled bridge rectifier and state whether the power flow is bidirectional or unidirectional.

9. Which converter is used in Unidirectional DC motor? (Semiconverter / Full converter / Half wave converter)

10. Name the converter used in reversible regenerative DC motor controllers.

11. Name the operating mode for $\alpha \leq 90^\circ$.

12. Which of the following two operating mode is for $\alpha > 90^\circ$.
   - Rectification
   - Inversion.

13. Draw the circuit diagram of single phase fully controlled rectifier in mode (IV) ($\alpha t = 0$ to $\alpha$ or $2\pi$ to $2\pi + \alpha$)

   Showing the situation of SCRs 1, 2, 3, 4 as on/off (close / open)

14. In half controlled bridge the average output voltage is zero only at $\alpha = \pi$. State when average output voltage is zero in case of full controlled bridge.

15. The figure below shows load voltage waveform.

   ![Load Voltage Waveform](image)

   - Energy stored by load
   - Energy returned back

   Observe the above waveform and state the value of $\alpha$ for which the above load voltage waveform is drawn.
(Space for answers)
(Space for answers)

Signature of Teacher