Date:

1. Static characteristics of junction diode, point contact diode and Zener diode

**Aim:** To draw the volt-ampere characteristics of junction diode, point contact diode and zener diode and determine their knee voltage, and forward resistance.

**Apparatus:** 0-10V supply, junction diode, point contact diode, resistances, milli-ammeter, microammeter, voltmeter and connecting wires.

**Theory:**
- **PN junction diode:** A diode is a unidirectional conducting device. A PN-junction diode is a semiconductor device. PN-junction conducts current easily when forward biased and practically no current flows when it is reverse biased when the diode is forward biased, the junction offers very negligible resistance to the flow of current, but when it is reverse biased the junction offers infinite resistance to the flow of current.
- **Forward biasing:** When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting current flow, this method is called forward biasing. To apply forward bias, connect positive terminal of the battery to p-type and negative terminal to n-type of the PN diode.
- **Reverse biasing:** When the external voltage applied to the junction is in such a direction that the potential barrier is increased, it is called reverse biasing. To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type of the PN diode.
- **Break down voltage:** It is the reverse voltage at which PN-junction breaks down with sudden rise in reverse current.
- **Knee voltage:** It is the forward voltage at which the current through the junction starts to increase rapidly.

**Circuit Diagram:**

- **Forward bias**
  - Fig. 1(a)
  - Low Resistance
  - 0-10V supply
  - Forward bias

- **Reverse bias**
  - Fig. 1(b)
  - High Resistance
  - 0-10V supply

**Procedure:**

- **Forward bias:** Connect the circuit as shown in fig 1(a). By varying the external voltage from 0 to 10V in the supply, note down the corresponding forward voltage in volts and current in mA.

- **Reverse bias:** Connect the circuit in reverse bias as shown in fig 1(b). By varying the external voltage, note down the corresponding voltage and current in μA.
Now draw the graph with forward Voltage on positive x-axis and forward current on the positive Y-axis, reverse Voltage on negative x-axis and reverse current on negative Y-axis.

![Graph of Forward and Reverse Voltage and Current](image)

**Point contact diode:** The point contact diode operates on the same principle as junction diode but differs in construction.

**Procedure:** Repeat the above steps using a point contact diode in place of a junction diode with same circuit diagram, observation table and draw the following graph.

![Graph of Forward and Reverse Voltage and Current](image)

**Construction and working of a point-contact diode:**
This is a different type of diode which utilizes a point contact of a metal wire (usually tungsten) against a small rectangular slab of N-type semiconductor (Ge or Si).

In the point contact diode, N-type germanium of only a few millimeter square and a fraction of a millimeter thick with a metallic wire known as cat whisker is sealed in a capsule or cartridge. The metallic wire is of tungsten and coiled into the spring with in the enclosure so as to maintain a firm pressure at the point of contact with the crystal. The other end of cat whisker is attached to a lead wire which serves as one terminal of diode. On the back side of germanium a metal is deposited which serves as a support to germanium. A lead wire is attached at the metal base which serves as
the second terminal of diode. The important step in the fabrication (designing) of diode is to pass relatively large current from cat whisker wire to the germanium slab.

![Diagram of diode construction and symbol]

Generally this is done by the discharge of a capacitor. During the passage of the forming pulse, some cat whisker metal melts. The molten metal welds the whisker to the crystal surface which gives the contact good mechanical and electrical stability. This forms a P-germanium area around the contact shown in figure. In this way P-N semiconductor is formed.

This point contact diode operates on the same principle as junction diode. The current can easily flow from cat whisker to semiconductor when the former is positive with respect to the latter. On the other hand, negligible current flows when semiconductor side is made positive with respect to cat whisker.

The point contact diodes are suitable for operation at microwave range while the junction diodes are used for low frequency work. This is due to the fact that in case of junction diode, the barrier is very thin and represents a capacitance between two electrodes. This capacitance tends to shunt out the rectifying action at high frequencies. In point contact diode the area of contact between N and P-type germanium is relatively small i.e. the junction capacitance is very small.

**Precautions:**

1. While changing the connections from forward bias to reverse bias care should be taken to see that the voltmeter and ammeter are properly connected.
2. Current should not be sent continuously over a long period of time.

**Result:**

The forward resistance for
- Junction diode =
- Point contact diode =

Knee voltage for
- Junction diode =
- Point contact diode =

Lecturer Signature with date:
**Static characteristics of Zener diode**

**Aim:** To draw the volt-ampere characteristics of zener diode.

**Apparatus:** 0-10V supply, Zener diode, resistances, milli ammeters, voltmeter and connecting wires.

**Theory:** A PN junction normally does not conduct when reverse biased. But if the reverse bias is increased, at a particular voltage, it starts conducting heavily. This voltage is called break down voltage. High current through the diode can permanently damage it. Diodes specially fabricated to have specified breakdown voltages are called zener diodes. This is made of heavily doped semi conducting materials.

A zener diode has a very thin depletion layer, but very high potential barrier. It has a very sharp breakdown voltage. A zener diode is generally made to work in the reverse bias and is used in voltage regulators.

**Forward biasing:** When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting current flow, this method is called forward biasing. To apply forward bias, connect positive terminal of the battery to p-type and negative terminal to n-type.

**Reverse biasing:** When the external voltage applied to the junction is in such a direction that the potential barrier is increased, it is called reverse biasing. To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type.

**Zener Break down voltage:** It is the reverse voltage at which the zener diode allows a large reverse current to flow through by maintaining the voltage constant.

**Knee voltage:** It is the forward voltage at which current through the junction starts to increase rapidly.

**Procedure:**
- **Zener diode:** A Zener diode is a heavily doped junction diode, having a narrow potential barrier and sharp break down voltage. It is usually operated in the breakdown region and hence it is known as break down diode.

![Forward bias](Fig.1(a))  
**Forward bias**

0.40V supply

![Reverse bias](Fig.1(b))  
**Reverse bias**

0.40V supply

**Forward bias:** Connect the circuit as shown in fig1(a). By varying the external voltage from 0 to 10V in the supply, note down the corresponding forward voltage in volts and current in mA.

**Reverse bias:** Connect the circuit in reverse bias as shown in fig 1(b). By varying external voltage, note down the corresponding voltage and current in mA.
Now draw the graph, forward Voltage on positive x-axis and forward current on the positive Y-axis, reverse Voltage on negative x-axis and reverse current on negative Y-axis.

Precautions:

1. While changing the connections from forward bias to reverse bias care should be taken to see that the voltmeter and ammeter are properly connected. Proper range of ammeter should be chosen.
2. Current should not be sent continuously over a long period of time.
3. The resistance R should be of such a minimum value that the current through the diode will be less than the maximum allowable current through the zener diode.

Result:

Knee Voltage =
Forward resistance =
Break down voltage =

Lecturer Signature with date:
**OBSERVATIONS AND TABLES: JUNCTION DIODE**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Forward bias</th>
<th>Reverse bias</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage (V)</td>
<td>Voltage (V)</td>
</tr>
<tr>
<td></td>
<td>Current (mA)</td>
<td>Current (µA)</td>
</tr>
</tbody>
</table>
# POINT CONTACT DIODE:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Forward bias</th>
<th>Reverse bias</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage (V)</td>
<td>Voltage (V)</td>
</tr>
<tr>
<td></td>
<td>Current (mA)</td>
<td>Current (µA)</td>
</tr>
</tbody>
</table>
Observation table: Zener Diode

<table>
<thead>
<tr>
<th>S.No</th>
<th>Forward bias</th>
<th>Reverse bias</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage (V)</td>
<td>Voltage (V)</td>
</tr>
<tr>
<td></td>
<td>Current (mA)</td>
<td>Current (mA)</td>
</tr>
</tbody>
</table>
**Possible Viva Questions**

What are Zener breakdown and avalanche break down?
What is the difference between a Zener diode and an ordinary p-n junction diode?
Define depletion layer?
What is Forward bias, Reverse bias?
Define break down voltage, Knee Voltage, Forward resistance?
What is a Zener diode?
What is the reason for Zener break down?
What is the use of a Zener diode?
What are the Zener voltages available?
What is the main feature that distinguishes a Zener diode from an ordinary P-N junction diode?
Is there any other break down in a P-N junction diode?
How does the Zener diode behaves just as an ordinary P-N junction?
What are semiconductors?
How much will be the order of forbidden energy gap of a semiconductor?
Name some semiconductors
what type of bonding exists in silicon and germanium?
What is the valency of silicon and germanium
Is a semiconductor ohmic or non-ohmic?
What is a P-type semiconductor?
What is n-type semiconductor?
What are the charge carriers in a p-type and n-type semiconductors
what are the majority and minority charge carriers?
What happens to depletion layer in forward bias?
What happens to deplection layer in reverse bias?
In which case a p-n junction will have high resistance?
When the p-n junction is reverse biased, still there is a flow of current. How?
What are the uses of semiconductor diodes?
What happens of the reverse bias is made very high?
What is bias or biasing a diode?
Is the ordinary p-n junction an active circuit element or a passive element.
Why is silicon preferred to germanium in the manufacture of semiconductor devices?
What type of characteristics are drawn in this experiment?
Why the diode current does not start immediately when the forward bias is applied?
Is a p-n diode am ohmic device or not?
How can the conductivity of a semiconductor be increased?
What is the nature of temperature coefficient of resistance of a semiconductor?
3. Ripple factor (D.C Power Supply)

**Aim:** To construct a D.C Power Supply and measure its ripple factor for various configurations.

**Apparatus:** A.C Signal generator, Diodes, Load Resistance, Voltmeters, Multimeter, inductors, capacitors and connecting wires.

(a) Half Wave rectifier:

D.C. voltage measurement

A.C voltage measurement

Connect the circuit as shown in the fig 1(a). In the circuit 1(a), the supply voltage is alternating. A large diode current will flow only during the positive half cycles of this voltage. As a result, the load voltage \( V_L \) will practically consist of half sinusoids and will also possess a dc component. Since the negative half cycles of the input signal are almost cut off and absent from the output signal, the circuit is known as half wave rectifier. In the above circuit the diode is forward biased. The voltage measured across the load resistance is D.C voltage. To measure A.C voltage, connect the capacitor as shown in fig 1(b).

\[
\text{Ripple factor}(r) = \frac{\text{A.C Voltage}}{\text{D.C Voltage}}
\]

Full wave rectifier:

D.C voltage measurement

Fig. 2(a)
Connect the circuit as shown in fig 2(a). Here we use two diodes D1 and D2. During the positive half cycles of secondary voltage the diode D1 is forward biased and D2 is reverse biased. During the negative half cycles diode D2 becomes forward biased and D1 reverse biased. The two diodes conduct in alternate half cycles. When one diode conducts the other diode is off. The load current flows in the same direction in each half cycle of the input voltage. By varying R_L note the D.C. voltage in this circuit.

**A.C voltage measurement**

![Image of A.C voltage measurement](image1)

Fig. 2(b)

To measure A.C Voltage connect the capacitor as shown in fig 2(b).

**Bridge Rectifier:**

Four rectifier diodes arranged in the form of a bridge constitutes a bridge rectifier. Its function is similar to that of a full wave rectifier.

![Image of Bridge Rectifier](image2)

Fig. 3(a)

The circuit diagram of a bridge rectifier is shown in fig 3(a). The diodes D1, D2, D3 and D4 form the bridge. During the positive half cycle of the secondary voltage, diodes D2 and D4 are conducting and diodes D1 and D3 do not conduct. During the negative half cycle D1 and D3 conduct and the diodes D2 and D4 do not conduct. In both cases, the current passes through the load resistor in the same direction.
Single Capacitor Filter:

Connect the circuit as shown in fig 4(a). In a Single Capacitor filter, where the capacitor is placed across the load resistance, the reactance of the capacitor at the frequency of the input voltage is much smaller than the load resistance. So the capacitor will bypass the ripple components (ac components) of the load voltage. By varying $R_L$, note the D.C voltage in this circuit.

For measuring A.C voltage connect the capacitor as shown in fig 4(b).
**Inductance Filter:**

Connect the circuit as shown in figure 5(a). For the Inductor filter where the inductor is connected in series with the load resistance, the reactance of the inductor at the frequency of the input voltage is much larger than the load resistance. Thus the A.C components of the rectifier output voltage appear mainly across the inductor and the D.C component will appear across the load resistance. The inductor filter thus reduces the fluctuation of the load voltage. By varying the load resistance, note down the D.C voltage.

**L-section Filter:**

Connect the circuit as shown in fig 6(a) for the L section filter. Inductor is connected in series with the rectifier output and a capacitor across the load.
In L-Section filter, the output of the rectifier contains a.c and d.c components. The inductor which is connected in series to the rectifier output (terminals) allows only the d.c components and stops the a.c components. At terminal 3 the rectifier output contains dc component and the remaining part of a.c component which has managed to pass through the inductor (choke). Now the capacitor allows the a.c component and prevents d.c component. Therefore only D.C. component reaches the load. By varying $R_L$ note the D.C Voltage.

For measuring A.C voltage, connect the circuit as shown in figure 6(b).

**II – Section filter:**

Connect the circuit as shown in fig 7(a). $\pi$ – filter consists of a filter capacitor $C_1$ connected across rectifier output, a choke $L$ in series and another filter capacitor $C_2$ across the load. The filter capacitor $C_1$ by passes a.c component while the d.c component reaches the inductor. Now the inductor allows the D.C. component and stops the a.c component. The capacitor $C_2$ by passess the a.c component which the inductor has failed to stop. Therefore only D.C component across the load appears. By varying $R_L$ note down the D.C voltage. For measuring A.C voltage, connect the capacitor as shown in fig 7(b).
Precautions:

1. Switch on the board only after making proper connections.
2. Multimeter should be in D.C made for measuring D.C voltage and should be in A.C made for measuring A.C voltage.
3. In a half wave rectifier and a bridge rectifier, the input voltage ‘V’ given should be only taken between the centre of the transformer and one end of the transformer.

Result:

Lecturer Signature with date:
**Observations:**

**Half Wave Rectifier:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Load Resistance Ohms</th>
<th>D.C Voltage</th>
<th>A.C Voltage</th>
<th>Ripple factor $\gamma = \text{A.C}/\text{D.C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Full Wave Rectifier:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>$R_L$ Ohms</th>
<th>D.C Voltage</th>
<th>A.C Voltage</th>
<th>Ripple factor $\gamma = \text{A.C}/\text{D.C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Bridge Rectifier:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>$R_L$ Ohms</th>
<th>D.C Voltage</th>
<th>A.C Voltage</th>
<th>Ripple factor $\gamma = \frac{A.C}{D.C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ripple Factor(\(\gamma\)):

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Load</th>
<th>A.C Voltage</th>
<th>D.C Voltage</th>
<th>(\gamma = \text{A.C/D.C})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single capacitor filter</td>
<td>(R_1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductor filter</td>
<td>(R_1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L- section filter</td>
<td>(R_1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II – section filter</td>
<td>(R_1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Possible Viva questions

1. What is a rectifier?
2. What is the function of capacitor?
3. What is the function of Inductor?
4. What are the advantages of bridge rectifier over full wave rectifier?
5. What is a transformer?
6. What is a diode?
7. What is a ripple factor?
8. Why two diodes are used in full wave rectifier?
9. What is ripple?
10. How is ripple factor related to ripple?
11. How do you construct a filter circuit?
12. Why the inductor prevent passage of ripple current?
13. How does the capacitor act?
14. What is the purpose of having the filter?
15. What is the advantage of an electrolyte capacitor?
4. Percentage Regulation And Zener Regulated Power Supply

**Aim:** (a) To determine the percentage regulation of a π-section filter and L-section Filter.
(b) To construct a zener – regulated power supply.

**Apparatus:** A.C Signal generator, diodes, inductors, capacitors, load resistance, voltmeters and multimeter and connecting wires.

**Theory:** Same as in D.C. power supply for working of filters.

**Zener diode as voltage regulator:** A zener diode can be used as a voltage regulator to provide a constant voltage from a source whose voltage may vary over sufficient range. The circuit arrangement is shown in fig(A). The zener diode of zener voltage $V_Z$ is reverse connected across the load $R_L$ across which constant output is desired. The series resistance $R$ absorbs the output voltage fluctuations so as to maintain constant voltage across the load. It may be noted that the zener will maintain a constant voltage $V_Z (= E_0)$ across the load so long as the input voltage does not fall below $V_Z$.

When the circuit is properly designed, the load voltage $E_O$ remains essentially constant (equal to $V_Z$) even though the input voltage $E_i$ and load resistance $R_L$ may vary over a wide range.

(1) Suppose the input voltage increases. Since the zener is in the breakdown region, the zener diode is equivalent to a battery $V_Z$ as shown in Fig(B). It is clear that voltage remains constant at $V_Z(= E_0)$. The excess voltage is dropped across the series resistance $R$. Thus will cause an increase in the value of total current $I$. The zener will conduct the increase of current in $I$ while the load current remains constant. Hence, output voltage $E_O$ remains constant irrespective of the changes in the input voltage $E_i$.

(2) Now suppose that input is constant but the load resistance $R_L$ decreases. This will cause an increase in load current. The extra current can not come from the source because drop in $R$ (and hence source current $I$) will not change as the zener is within its regulating range. The additional load current will come from a decrease in zener current $I_Z$. Consequently, the output voltage stays at constant value.

\[
\begin{align*}
\text{Voltage drop across } R &= E_i - E_O \\
\text{Current through } R, I &= I_Z + I_L \\
\text{E}_i - E_O \\
\text{Applying ohm’s law, we have, } R &= \frac{E_i - E_O}{I_Z + I_L}
\end{align*}
\]
**Procedure**: **Part (a)**: Construction of regulated power supply with out zener

**L-section filter:**

![Diagram](image1)

Fig. (1)

Note: $V = V_0 \sin \omega t$ is the actual voltage given to the circuit.

**π-section filter:**

![Diagram](image2)

Fig. (2)

Connect the L-section filter with the ammeter and the voltmeter connected, as shown in the fig.(1). Now for different values of the load resistance $R_L$, starting from some minimum value, note the load current in the ammeter, and voltage across the load resistance in the volt meter, till $R_L$ reaches maximum value.

Connect the π-section filter with the ammeter and the voltmeter connected, as shown in the fig.(2). Now for different values of the load resistance $R_L$, starting from some minimum value, note the load current in the ammeter, and voltage across the load resistance in the voltmeter, till $R_L$ reaches maximum value.
Draw a graph with voltage along the Y-axis and load current along the X-axis using the given expression calculate the value of percentage regulation.

\[
\% \text{ regulation} = \frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{full load}}} \times 100
\]

**Part (b):** Construction of a regulated power supply using zener

**L-section filter with zener:**

![L-section filter with zener](image)

**π-section filter with zener:**

![π-section filter with zener](image)

Connect the zener diode to the L-section and π-section filters as shown in the above figures. Now for different values of the load resistance \(R_L\), starting from some minimum value, note the load current in the ammeter, and voltage across the load resistance in the volt meter, till \(R_L\) reaches maximum value.
Draw the graph by taking voltage (V) along the Y-axis and current (mA) on X-axis. Using the given expression calculate the value of percentage regulation.

\[
\text{% regulation} = \frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{full load}}} \times 100
\]

**Precautions:**

1. Switch on the board only after making proper connections.
2. Multimeter should be in D.C for measuring D.C voltage and should be in A.C for measuring A.C voltage.
3. In a half wave rectifier and a bridge rectifier, the input voltage ‘V’ given should be only taken from the centre of the transformer and one end of the transformer.
4. Use a zener diode which has a suitable break down voltage.
5. Adjust the value of \( R_L \) such that there is a variation in current / voltage.

**Result:**

Lecturer Signature with date:
**Observations:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Load Resistance $R_L$</th>
<th>$L$ – section</th>
<th>$\pi$ – section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Voltage(V)</td>
<td>Current(mA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Voltage(V)</td>
<td>Current(mA)</td>
</tr>
</tbody>
</table>
**Observations:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Load Resistance $R_L$</th>
<th>L – section</th>
<th>$\pi$ – section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Voltage(V)</td>
<td>Voltage(V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current(mA)</td>
<td>Current(mA)</td>
</tr>
</tbody>
</table>
**Date:**

**5. TRANSISTOR PNP**

**Aim:** To draw the static characteristic curves of a PNP transistor with common emitter configuration.

**Apparatus:** PNP-transistor, resistors, variable power supplies, voltmeters, micro ammeter, milli ammeter and connecting wires.

**Transistor:**

A transistor consists of two PN junctions formed by sandwiching either P-type or n-type semiconductor between a pair of opposite types. The emitter-base junction is forward biased whereas the collector base junction is reverse biased.

**Theory:**

The different parts of a transistor are (1) Emitter (2) Base (3) Collector

(1) **Emitter:** The left hand side part of the transistor is called an emitter. The emitter supplies majority charge carriers to the base and hence it is heavily doped compared to the other parts.

(2) **Base:** The middle part of the transistor is called the base. This is very lightly doped and is very thin. It has a thickness of the order of $10^{-6}$ m. It transmits the charge carriers received from emitter to the collector.

(3) **Collector:** The right hand side part of the transistor is called a collector. This is moderately doped and it collects majority charge carriers through the base.

**Transistor Biasing:** The transistor biasing is as shown in figure

In transistors, the emitter base junction should always be forward biased and the collector base junction should always be reverse biased. For this a battery $V_{BE}$ is connected between emitter and base and a battery $V_{BC}$ is connected between collector and base. The emitter base junction of PNP transistor is forward biased by connecting the positive terminal of a battery (Voltage $V_{BE}$) to the emitter and the negative terminal to the base as shown in the figure.
Transistor biasing p-n-p transistor

The collector base junction of a PNP transistor is reverse biased by connecting the negative terminal of the battery (voltage $V_{BC}$) to collector and the positive terminal to the base as shown in figure. In emitter circuit, low resistance is offered in forward biasing whereas in collector circuit, high resistance is offered in reverse biasing.

Thus in a transistor, a weak signal is passed into low resistance circuit and the output is taken out from the high resistance circuit. So a transistor transfers a signal from low resistance circuit to high resistance circuit.

**Configurations of a transistor:**

There are three types of configurations to a transistor.

1. common-base(CB)
2. Common-emitter(CE)
3. Common-collector(CC)

The common emitter(CE) configuration of p-n-p transistor is used here to draw the input and output characteristics.

When a transistor is operated in such a way that the emitter terminal is common to both the input and the output circuits the mode of operation is called the common emitter (CE) mode. In this mode emitter is grounded.

**Circuit Diagram:**

**Input characteristics:**

It is the curve between base current $I_B$ and base-emitter voltage $V_{BE}$ at constant collector emitter voltage $V_{CE}$. 
Output characteristics:

It is the curve between collector current $I_c$ and collector emitter voltage $V_{CE}$ at constant base current $I_B$.

Procedure:

**Input characteristics:** The input characteristic of a CE connection can be determined by the circuit shown in fig. Keeping $V_{CE}$ (say 0V) constant, note $V_{BE}$ for various values of $I_B$. Then plot the readings obtained on the graph, taking $I_B$ along y-axis and $V_{BE}$ along x-axis. This gives the input characteristics at $V_{CE}=0V$ as shown in the graph. Following a similar procedure, a family of input characteristics can be drawn.

The following points may be noted from the characteristics

(i) The characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.

**Output characteristics:** The output characteristics of a CE circuit can be drawn with the help of circuit shown in fig.

Keeping the base current $I_B$ constant (say 10 μA), note the collector $I_C$ for various values of $V_{CE}$. Then plot the readings on a graph $I_C$ along Y-axis and $V_{CE}$ along X-axis. This gives the output
characteristic at $I_B=10\mu A$. Following similar procedure a family of output characteristics can be drawn as shown in graph.

The following points may be noted from the characteristics:

The collector current $I_C$ varies with $V_{CE}$ for $V_{CE}$ between 0 and 1v. After this the collector current becomes almost constant and independent of $V_{CE}$. This value of $V_{CE}$ up to which the collector current $I_C$ changes is called the knee voltage.

Note:

The values of $V_{CE}$ in input characteristics and $I_B$ in output characteristics may be selected as per the conditions of the board and the transistor used.

Precautions:

1. Check the circuit connections properly before switching on the board.
2. Before connecting the circuit identify the three elements of the transistor properly.
3. While taking the input characteristics $V_{CE}$ should be maintained constant at every step while noting $I_B$ and $V_{BE}$.
4. While taking the output characteristics $I_B$ should be maintained constant at every step while noting $I_C$ and $V_{CE}$.

Result:

Lecturer Signature with date:
### Input characteristics:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Base current $I_B$ μA</th>
<th>$V_{CE} = 0$ V (Kept constant) $V_{BE}$ V</th>
<th>$V_{CE} = 0.2$ V $V_{BE}$ V</th>
<th>$V_{CE} = 0.4$ V $V_{BE}$ V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Output Characteristics:**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Collector current Ic mA</th>
<th>$I_B = 30 \mu A$ (Kept Constant) $V_{CE}$ Volts</th>
<th>$I_B = 50\mu A$ (Kept Constant) $V_{CE}$ Volts</th>
<th>$I_B = 70\mu A$ (kept Constant) $V_{CE}$ Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Possible Viva questions

1. What is the difference between PNP and NPN transistor.
2. Define $\alpha$ and $\beta$ of a transistor. What is the relation between them?
3. What are the different modes of operation of a transistor?
4. What are the junctions in a transistor? How are they biased for normal transistor amplifier operation?
5. Why the junction transistors are called bipolar devices?
6. What is reverse saturation current in a transistor?
7. What do you mean by the input characteristics of a transistor?
8. How does a transistor act as a switch?
9. Why is the base of transistor made very thin?
6. RC COUPLED AMPLIFIER

**Aim**: To study the frequency response of a RC Coupled amplifier and determine its band width.

**Apparatus**: NPN Transistor, a battery, signal generator, resistors, capacitors and oscilloscope.

**Theory**: An amplifier is a device which amplifies a small signal voltage without any change in the waveform. The amplifier circuit consists of a network of resistors and capacitors with a transistor in the common emitter mode. Most amplifiers contain many stages of a basic unit – amplifier which are coupled together. An amplifier which uses a resistance and capacitance for coupling the different stages is called a “RC Coupled amplifier”. A voltage divider bias with emitter follower is used to bias the transistor.

The amplification produced by the amplifier varies with the frequency of the input signal voltage. Hence it is necessary to study the frequency response of the amplifier.

Gain of the amplifier  \[ A = \frac{V_{\text{output}}}{V_{\text{input}}} \].

When the gain of the amplifier falls to 0.707 (or \(1/\sqrt{2}\)) times its maximum gain, the power is halved. The frequencies corresponding to the half power points are called lower and higher cut-off frequencies \(f_1\) and \(f_2\).

\[
\text{Band width} = f_2 - f_1
\]

**Voltage divider bias method**:

This is the most widely used method of providing biasing and stabilization to a transistor. In this method, two resistances \(R_1\) and \(R_2\) are connected across the supply voltage \(V_{CC}\), and provide biasing.

The emitter resistance \(R_E\) provides stabilization. The name “voltage divider” comes from the voltage divider formed by \(R_1\) and \(R_2\). The voltage across \(R_2\) forward biases the base-emitter junction. This causes the base current and hence collector current flow in the zero-signal condition. In this circuit excellent stabilization is provided by \(R_E\)

1. Transistor biasing is ensuring proper flow of zero signal collector and maintenance of proper collector-emitter voltage during the passage of signal.
2. Transistor biasing is required for faithful amplification.
The biasing network associated with the transistor should meet the following requirements.

i) It should ensure proper zero-signal collector current.

ii) It should ensure that $V_{CE}$ does not fall below 0.5 V for Ge transistor and 1 V for silicon transistor at any instant.

iii) It should ensure the stabilization of operating point.

Operating point defines the collector current $I_C$, base current $I_B$ and the collector emitter voltage $V_{CE}$ under no signal condition.

**Circuit Diagram:**

```
+Vcc for biasing the transistor

Input voltage

Vi

RB1 27K
CB

RB2 11k
RE

15k
Cc

Vc Output voltage
connect to Oscilloscope

RL

6.8k
CE
```

**Working of RC coupled amplifier:**

**Frequency response:** Graph shows the frequency response of a typical RC coupled amplifier. The voltage gain drops off at low (<50 Hz) and high (>20 KHz) frequencies. Whereas it is uniform over mid frequency range (50Hz to 20KHz).

i) At low frequencies (<50 Hz), the reactance of coupling capacitor $C_B$ is quite high and very small part of signal will pass from one stage to the next stage. $C_E$ cannot shunt the emitter resistance $R_E$ effectively because of its large reactance at low frequencies. These two factors cause a falling off voltage gain at low frequencies.

ii) At high frequencies (>20 KHz) the reactance $C_C$ is very small and it behaves as a short circuit. This increases the loading effect of next stage and serves to reduce the voltage gain. At high frequency, capacitive reactance of base emitter junction is low which increases the base current. This reduces the current amplification factor $\beta$. Due to these two reasons, the voltage gain drops off at high frequency.

iii) At mid frequencies (50Hz to 20KHz) the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is to maintain a uniform voltage gain. As the frequency increases in this range, reactance of $C_C$ decreases which tends to increase the gain. At the same time, lower reactance means higher loading of first stage and lower gain. These two factors almost cancel each other resulting in a uniform gain at mid frequency.
Procedure:

Connections are made as shown in Fig. (1). The unit and the signal generator are switched on. The frequency of the oscillator is first kept at 100 Hz and the amplitude of the input signal is adjusted to be \( V_i \). This should be kept constant throughout the experiment. While changing the frequency, \( V_i \) and \( V_o \) are measured by using an oscilloscope. \( V_i \) should be as small as possible. So that distortions do not arise in the output.

Next the frequency is gradually changed in convenient steps. At each frequency \( V_i \) (should be constant) and \( V_o \) are measured with an oscilloscope. Note down the readings in the following table.

Graph: Graph is drawn by taking \( \log f \) on X- axis and gain A on Y-axis.

Precautions:
1. Switch of the oscilloscope when you are not using.
2. Measure the input \( V_i \) for every range of frequencies and check if it is constant or not.
3. The input and output signals should have a perfect sine wave form
4. Try to give a very small input voltage.

Result:

Lecturer Signature with date:
Possible viva questions

1. What do you mean by amplification?
2. Why the CE mode configuration of a transistor is preferred in amplification?
3. What is distortion?
4. What purpose does the coupling capacitor $C_C$ serve?
5. What is the use of $R_E - C_E$ combination?
6. What is the use of $R_{B_1}$ and $R_{B_2}$ resistors?
7. Why is the arrow pointing towards E from B in the transistor?
8. What are the other kinds of coupled amplifiers available?
9. What are the advantages of RC coupled amplifier?
10. What are the disadvantages of RC coupled amplifier?
Observations:

Table:

<table>
<thead>
<tr>
<th>Frequency f Hz</th>
<th>$\log_{10} f$</th>
<th>$V_i$</th>
<th>$V_o$</th>
<th>Gain $A = \frac{V_o}{V_i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Aim:

(a) To construct a phase-shift oscillator and measure its frequency.
(b) To measure the phase shift produced by the different RC stages.

OR

To study the output and input wave forms of the oscillator and measure the phase-shift between them.

Apparatus:

A PNP transistor, power supply, (CRO) Cathode ray oscilloscope, suitable resistors and capacitors and connecting wires.

Theory:

An oscillator is an electronic device which provides an alternating output from a direct current source. A transistor oscillator circuit is similar in many respects to a positive feedback amplifier circuit.

Feedback: The process of injecting a fraction of output energy of some device back to the input is known as feedback. Depending upon whether the feedback energy aids or opposes the input signal, there are two basic types of feedbacks in amplifiers i.e. positive feedback and negative feedback.

Positive Feedback: When the feedback energy (voltage or current) is in phase with the input signal and aids it, it is called positive feedback. Positive feedback increases gain of the amplifier, however it has the disadvantage of increased distortion and instability.

Negative Feedback: When the feedback energy (voltage or current) is out of phase with the input signal and opposes it, it is called negative feedback. Negative feedback reduces gain of the amplifier. The advantages are reduction in distortion, stability in gain, increased bandwidth and improved input and output impedance. Due to these advantages, the negative feedback is frequently employed in amplifiers.

The two basic conditions for oscillations to occur, known as Barkhausen Criterion are:

1) The loop gain must be equal to one.
2) The feedback should be positive.

An oscillator which uses a RC feedback network is called a phase-shift oscillator.

The frequency of oscillations is given by \[ f = \frac{1}{2\sqrt{6\pi RC}} \]

Principle of phase shift oscillator:

An amplifier employing resistive and capacitive elements is called a phase shift oscillator. In a phase shift oscillator, a phase shift of 180° is obtained with a phase shift circuit using resistor and capacitors. A further phase shift of 180° is introduced due to the transistor properties. Thus energy supplied back to the tank circuit is assured of correct phase.

Phase shift circuit: A phase shift circuit essentially consists of a R-C network.
According to the alternating current theory the voltage across ‘R’ in a AC circuit consisting of R and C, leads the applied voltage by a phase angle $\Phi$. The value of $\Phi$ depends upon the value of R and C. The value of ‘R’ may be varied to change the value of $\Phi$. In this circuit the value of R and C are so chosen that the voltage across R ($V_R$) leads the input voltage $V_O$ by 60°.

There are three sections of RC networks each giving a phase-shift of 60°, consequently a total phase shift of 180° is produced. i.e. $V_i$ leads $V_O$ by 180°.

**Circuit operation:**

When the circuit is switched on, it produces oscillation of frequency given by $f = 1/2\sqrt{6} \pi RC$. The output $V_O$ of the amplifier is feedback to RC feedback network. Thus network produces a phase shift of 180° and voltage $V_i$ appears at its output which is applied to the transistor amplifier. The feedback fraction is $V_i/V_O$. The feedback phase is correct (i.e. positive feedback). A phase shift of 180° is produced by the transistor amplifier. A further phase shift of 180° is produced by the RC network, as a result the phase shift around the entire loop is 360°. A voltage divider biasing is used to bias the transistor, by applying $+V_{CC}$ through $R_{B1}$ and $R_3$ (read the theory for this in RC coupled amplifier experiment).

**Circuit Diagram:**

\[ f = 1/2\pi RC\sqrt{6} \]
\[ C_1 = C_2 = C_3 = C \]
\[ R_1 = R_2 = R_3 = R \]
**Procedure:** Connect the circuit as shown in the figure choosing one combination of R and C. Display the output waveform on the CRO. Adjust the collector resistance $R_c$ so as to obtain oscillations of constant amplitude.

(a) **To measure the frequency:**
1. Form a single loop Lissajous figure on the screen of the CRO by using a standard signal generator and the output of the oscillator. Note the frequency of the signal generator $f_s$ which gives the frequency of the oscillator.
2. Repeat the experiment for different sets of capacitors.

(b) **To measure the phase shift:**
1. Use a dual channel (or trace) oscilloscope.
2. Connect the final output of the oscillator to the first channel of the oscilloscope and measure the distance between any two crests (AB) of the waveform. This distance corresponds to a phase difference of $2\pi$ or $360^\circ$.
3. Connect the output of the first stage of the RC network to the second channel of the CRO and adjust the position of the waveform such that crests of the two waveforms are in one line. Measure the distance $(AA)$ or $(BB)$

$$\text{Phase – shift} = \frac{360^\circ \times AA}{AB}$$

4. Repeat the experiment for the second and third stages of RC network.

**Precautions:**

1. The polarity of the power supply and the emitter bypass capacitor should be as indicated in the figure.
2. The CRO should be handled with care.

**Result:**

Lecturer signature with date:
Possible viva questions:

1) How does the phase shift oscillator get its name?
2) Discuss the conditions under which an amplifier behaves as an oscillator?
3) What is the phase shift introduced by a single RC section?
4) Why is it that an oscillator can be considered as a dc to ac convertor?
5) What are the uses of an oscillator?
6) What is the main purpose of feedback?
7) What kind of biasing are you providing in the circuit?
8) How do the oscillators start initially?
9) What kind of transistor are you using in your circuit?
10) If you use the other kind of transistor what changes should you bring about in the circuit?
11) How do you stabilize the oscillations?
12) Locate the feedback circuit on your board?
**Observations**: 

Resistance $R =$ Ohms.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Capacitance $C$ ($\mu$F)</th>
<th>Frequency of the signal generator when the single loop is formed on the oscilloscope $f_s$ Hz</th>
<th>Calculated frequency $f_c = \frac{1}{2\sqrt{6}} \pi RC$ Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Aim**: To design, assemble and test the functioning of logic gates OR, AND, NOT, NAND, NOR and XOR.

**Apparatus**: Diodes, Resistances, Transistor and LED indicators.

**Description**: Logic gates are basic building blocks for all types of digital circuits, which are employed in construction of computers, communication systems, digital test & measurement instruments etc. In the construction of logic gates mainly we will be using ICs which are integrated circuits. ICs consists of monolithic semiconductor devices on which components such as resistors, diodes, transistors etc., are directly fabricated by special etching & deposition processes. An example of IC in this experiment is the exclusive OR based on CMOS technology.

There are two aspects to logic gates design.
(1) Functions of logic gates
(2) Realization of logic gates

**OR GATE**:
**Theory**: It has two or more inputs and only one output. It follows the rule that “The output of an ‘OR gate’ assumes 1 state if any one or more inputs assume 1 state”. This is called an OR gate because the output will be true if any one OR all of the inputs are true. The equivalent voltage mode circuit and the symbolic representation of a two input OR gate is shown in the fig (1). The functional symbol of OR gate is (+) plus sign placed between the input signals.

![Circuit](image)

**Procedure**: Connect the circuit as given

1. Apply level O (O voltage) to both the inputs A & B. As both the diodes are in the forward bias mode, the output thus is at level O. Satisfying the requirement of an OR Gate.
2. Apply level 1 (Vcc = 5V) to input A, retaining level O on the input B. In this case the first diode conducts due to application of +5V on its anode. Cout rises to approx. 4.4Volts (i.e., Vcc – Vd) where Vd is the voltage drop across diode. The second diode is reverse biased, due to this positive voltage on its cathode w.r.t its anode potential of O volts. This condition of 4.4 Volts appearing at Cout fulfills the OR function.
3. Now apply level O to input A & level 1 to input to B. The results are similar to the previous case except that the second diode conducts now & first diode is reverse biased.
4. Lastly apply level 1 to both the inputs A & B. Both the diodes are forward biased as a result of the positive voltage (+5 volts) applied on their anodes. Cout is now pulled up to 4.4volts or state 1, thus satisfying the OR function.

**AND GATE:**

**Theory:** It has two or more inputs and only one output. It follows the rule “The output of an AND gate assumes 1 state if and only if all its inputs assume 1 state”. The AND gate is a circuit which provides an output only when all the inputs are simultaneously present. The equivalent voltage mode circuit and the symbolic representation of a two input AND gate is shown in the fig (2). The function symbol for AND operation is (.) dot sign placed between the input signals.

<table>
<thead>
<tr>
<th>CIRCUIT</th>
<th>SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Circuit Diagram" /></td>
<td><img src="image" alt="Symbol Diagram" /></td>
</tr>
</tbody>
</table>

**Procedure:** Connect the circuit as given

1. Apply level 0 (0 voltage) to both the inputs A & B. As both the diodes are in the forward bias mode due to application of positive voltage on the anodes. The resulting voltage at $C_{out}$ is +0.6V. The output thus is at level 0. Satisfying the requirement of an AND Gate.

2. Apply level 1 ($V_{cc} = 5V$) to input A, retaining level 0 on the input B. In this case the second diode conducts as in the previous case. $C_{out}$ is again clamped to 0.6 volts. The first diode is reverse biased due to the positive voltage on its Cathode with respect to its anode potential of 0.6 volt. This condition of 0.6 volts appearing at $C_{out}$ fulfills the AND function.

3. Now apply level 0 to input A & level 1 to input to B. The results are similar to the previous case except that the first diode conducts now & second diode is reverse biased.

4. Lastly apply level 1 to both the inputs A & B. Both the diodes are reverse biased as a result of the positive voltage (+5 volts) applied on their cathodes. $C_{out}$ is now pulled up to 2.5 volts or state 1, thus satisfying the AND function.

**NOT GATE:**

**Theory:** This gate has got only one input and one output. It follows the rule “The output of a NOT gate is 1 if input is 0 and the output is 0 if input is 1. Thus a NOT gate produces as its output exactly opposite to the input. An inversion takes place as the input passes through the NOT gate. The main purpose of NOT gate is to complement its input value. The equivalent voltage mode circuit and symbolic representation of a NOT gate is shown in fig (3). A circle o separating a logic gate from an input or output lead indicates that inversion takes place as a signal is transmitted through that circle. The function symbol for NOT (Invert) operation is a bar on the input.
Transistor states in a NOT gate:
The output characteristics of a transistor with the d.c load line is shown below:

A transistor in a digital circuit always works either in the cutoff region or in the saturation region. In the saturation region, the emitter-base junction and the base-collector junction are in the forward bias and the output current $I_C$ does not depend on the input current $I_B$. In the cutoff region both the junctions become reverse biased.

Circuit Operation:
Apply level 0 (0 voltage) to input A. In this condition the base drive (base current) is zero. As a result of this the collector current and the emitter current are also 0 for all practical purposes. The transistor is now in the cutoff condition. The $V_{out}$, which is also the collector terminal is pulled up to $V_{cc}$ (level 1) through the resistor $R_1$, satisfying the requirement of a NOT gate.

Next let us apply level 1 ($V_{cc}$) to the input A. In this case the transistor is driven to conduction. If the base current $I_B$ is greater than $Ic/hfe$ then the transistor shall be in the saturation region. $I_b$ in this case is $(V_{cc}-V_{be})/R_b = 1$ milliamp. Assuming a $hfe$ of approximately 50, the collector current should be $I_b * hfe = 50$ milliamp. However, thus ensuring that the transistor is in saturation. In the saturation mode $V_{out}$ is equal to $V_{ce}$ sat which is +0.2 volts (approx). This also fulfills the function of the NOT gate.
**Procedure:**

Connect the circuit as shown in the figure 3. Test the circuit as described above and tabulate the results as in table 3. Verify whether the functions of the simple NOT gate has been satisfied.

**NOR GATE:**

**Theory:**

The NOR gate follows the rule “The output of a NOR gate is 1 if and only if both the inputs are each 0”. As such, a NOR gate produces the complement of an OR gate output. The equivalent voltage mode circuit and symbolic representation are shown in the fig (4).

**Circuit Operation:**

The NOR gate is a combination of the OR gate followed by a NOT gate. Hence the description given for these gates are applicable here. The output of the OR gate is given to the input of the NOT gate to realise the NOR functions.

**Procedure:**

Connect the circuit as shown in the figure 4. Test the circuit as described above and tabulate the results as in the table 4. Verify whether the functions of the simple OR gate has been fully satisfied.

**NAND GATE:**

**Theory:**

The NAND gate follows the rule “ the output of a NAND gate is ‘1’ only if at least one of its input is ‘0’”. As such, a NAND gate produces the complement of a AND gate output. The equivalent voltage mode circuit and symbolic representation are shown in the fig (5).
**Circuit Operation:**
The operation of the NAND gate is a combination of the AND gate followed by a NOT gate. Hence the description given for these gates are applicable here. The output of the AND gate is given to the input of the NOT gate to realise the NAND functions.

**Procedure:**
Connect the circuit as shown in the figure 5. Test the circuit as described above and tabulate the results as in the table 5. Verify whether the functions of the simple NAND gate has been fully satisfied.

**EXCLUSIVE OR GATE:**

**Theory:** An Exclusive OR gate obeys the definition. “The output of a two input Exclusive OR assumes the 1 state if one and only one input assumes the 1 state. A special symbol $\oplus$ is used to denote the Exclusive OR operation.

![EXCLUSIVE OR GATE Diagram](image)

**Circuit Description:**
The XOR gate is based on an integrated circuit belonging to the CMOS family of devices. The schematic diagram of the CMOS IC MC 4030 is given below. The IC consists of 4 XOR gates. Only one of these gates is being tested in this experiment.

**Procedure:**
Connect the circuit as shown in the figure 6. Test the circuit and tabulate the results as in table 6. Verify whether the functions of the CMOS XOR gate has been fully satisfied.

**Precautions:**
1. Switch off the board when it is not operated.
2. Connecting wires should be short and straight.

**Result:**

Lecturer signature with date:
**Observation**: The truth table of the OR Gate which describes the functional aspects of the gate is given in Table 1. A and B are two inputs of the gate, whereas C is the output.

### Table 1:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>B (INPUT)</th>
<th>C = A + B (OUTPUT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level 0 corresponds to < 0.6 Volts
Level 1 corresponds to > 2.5 Volts

**Observation**: The truth table of the AND Gate which describes the functional aspects of the gate is given in Table 2. A and B are two inputs of the gate, whereas C is the output.

### Table 2:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>B (INPUT)</th>
<th>C (OUTPUT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level 0 corresponds to < 0.6 Volts
Level 1 corresponds to > 2.5 Volts
Observation: The truth table of the NOT Gate which describes the functional aspects of the gate is given in Table 3. A is the input of the gate, whereas C is the output.

Table 3:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>C (OUTPUT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level 0 corresponds to \(< 0.6\) Volts
Level 1 corresponds to \(> 2.5\) Volts

Observation: The truth table of the NOR gate, which describes the functional aspects of the gate is given in the table 4. A and B are the two inputs of the gate, whereas C is the output.

Table 4:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>B (INPUT)</th>
<th>C (OUTPUT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(= \overline{A + B})</td>
</tr>
</tbody>
</table>

Level 0 corresponds to \(< 0.6\) Volts
Level 1 corresponds to \(> 2.5\) Volts
**Observation**: The truth table of the NAND gate, which describes the functional aspects of the gate is given in the table 5. A and B are the two inputs of the gate, whereas C is the output.

Table 5:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>B (INPUT)</th>
<th>C (OUTPUT) = \overline{A B}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level 0 corresponds to < 0.6 Volts
Level 1 corresponds to > 2.5 Volts

**Observation**: The truth table of the XOR gate, which describes the functional aspects of the gate is given in table 6. A and B are the two inputs of the gate, whereas C is the output.

Table 6:

<table>
<thead>
<tr>
<th>A (INPUT)</th>
<th>B (INPUT)</th>
<th>C (OUTPUT) A\oplus B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level 0 corresponds to < 0.6 Volts
Level 1 corresponds to > 2.5 Volts
**Date:**

1. OBSERVATION OF LISSAJOUS FIGURES FROM – CRO

**Aim:** To observe Lissajous figures on CRO and calculate the ratio of component frequencies.

**Apparatus:** A Cathode Ray Oscilloscope, two signal generators.

**Theory:** When two simple harmonic motions having their frequencies $n_1$ and $n_2$ in a simple ratio act in mutually perpendicular directions superimpose the resulting patterns are called Lissajous figures. These patterns were first studied by Lissajous and hence the name Lissajous figure. When these Lissajous figures are formed on a CRO, they will appear as in figure-1. Now, let the frequency of the wave applied to $x$ plates of CRO be $n_X$, and the frequency of the wave applied to $Y$ plates of CRO be $n_Y$. Then

![Figure 1](image)

No. of loops formed along $x$– axis is $L_X = 3$
No. of loops formed along $y$– axis is $L_Y = 2$

\[
\frac{n_X}{n_Y} = \frac{2}{3} \quad \text{and} \quad \frac{L_X}{L_Y} = \frac{3}{2}
\]

Here, the frequency of wave applied to $X$ plates is $n_X$ and the frequency of wave applied to $Y$ plates is $n_Y$.

\[
\frac{n_X}{n_Y} = \frac{2}{3} \quad \text{and} \quad \frac{L_X}{L_Y} = \frac{3}{2}
\]

**Description:** An ordinary common CRO will be as shown in figure.2. In this CRO, cathode $C$ emits electrons. The cathode ray beam passes through the circular central hole of the hollow metal cylinder $G$. Afterwards the cathode ray beam passes through a metal tube $A$ and falls on the screen $S$ that is coated with a fluorescent material. The metal cylinder $G$ will be at a negative voltage relative to the cathode $C$ and controls the number of electrons reaching the fluorescent screen. Thus the control grid $G$ controls the intensity of light on the screen. The anode tube will be at a higher positive voltage relative to the cathode and $G$ and hence the electrons coming out of $G$ will be accelerated as they move from $G$ to $A$. The fluorescent screen is connected to $A$. This ensures that electrons will not loose energy and velocity as they reach the screen $S$. In this way, a bright light spot will be obtained on the screen due to the electron beam.

The $XX$ plates deflect the cathode ray beam in the horizontal plane where as the $YY$ plates deflect the beam in the vertical plane.
As we look towards the screen S, through the cathode C the XX and YY plates appear as shown in figure 3. Usually we apply the (wave) voltage V to be studied to the YY plates. Now, in order that the voltage form of V appears on the screen, the way in which the voltage changes between the XX plates with time should be exactly the same as that of V. The time base helps us in this process. The circuit concerned is called ‘time base circuit’. The X plates and Y plates will be connected to as shown such that the potential differences across them will be the same.

However, in the present experiment of observing Lissajous figures, we do not make use of the time base. We directly connect the two waves (voltage) to the X and Y plates respectively. A CRO will have usually the following control knobs and terminals.

**Theory of Experiment**:

The block diagram of a CRO is as shown in figure

In our present experiment of forming Lissajous figures or comparing frequencies of component waves, we do not make use of either time base or saw tooth sweep generator. The two voltages (waves) are directly applied to the XX and YY plates respectively. Suppose we have two voltages (waves) having frequencies $n_X$ and $n_Y$ in the ratio $2:3$. That is $n_X : n_Y = 2 : 3$ we apply the wave ($n_X$) to X plates and the wave ($n_Y$) to Y plates. Evidently these two waves are in mutually perpendicular directions. Now, on the fluorescent screen S of the CRO we obtain Lissajous figures as in figure-5. Here the number of loops touching the X – axis is $L_X = 3$ and the number of loops touching the y axis $L_Y = 2$. And hence

$$\frac{n_X}{n_Y} = \frac{L_Y}{L_X} = \frac{2}{3}$$
In a similar manner, the voltages (waves) having frequencies in the ratio \( n_X : n_Y = 1 : 2 \)
When applied to X and Y plates result in Lissajous figures of pattern in figure-6 as can be seen on
the CRO screen. In all these figures \( L_X = 2 \) and \( L_Y = 1 \) and hence
\[
\frac{L_X}{n_X} = \frac{1}{2} \quad \text{and} \quad \frac{L_Y}{n_Y} = \frac{1}{2}.
\]

**Experimental Procedure:**

In this experiment we do not make use of the time base. First of all we select a frequency of
100 Hz form the first signal generator and the output is applied to the X plates of CRO as an input.

Then we select a frequency of 200 Hz from the second signal generator and apply its output
input into the y plates of the CRO. The resultant Lissajous figure will appear on the CRO. If
necessary, we adjust the amplitudes of the waves (in signal generator) and the figures are made to be
stable and well defined. Each time the number of loops \( L_X \) touching the x axis, and the number of
loops \( L_Y \) touching the y axis are counted down
\[
\frac{L_Y}{n_X} = \frac{n_Y}{n_X}
\]
and \( \frac{L_X}{n_Y} = \frac{n_X}{n_Y} \) is calculated and verified.

Next, keeping \( n_X = 100 \) Hz constant and changing \( n_Y \) to 150 Hz, 200 Hz, 250 Hz, 300 Hz and
again to 100 Hz, 80 Hz, 60 Hz and 50 Hz each time the Lissajous figures are
formed and the relation \[
\frac{n_X}{n_Y} = \frac{L_Y}{L_X}
\] is verified.

**Precautions:**

The following precautions are to be carefully observed during this experiment.

1. If the ratio \( n_X : n_Y \) is not a simple ratio (a simple ratio is of the form 1:2, 2:3, 2:5, 6:7,5:6 …etc) then the Lissajous figures will not be stable. The figure will be rotating either about x axis or about y axis in an unsteady manner. We have to adjust the frequency knob of one or two signal generators so as to get a steady picture.

2. We have to adjust the amplitudes also to get a steady and well defined Lissajous figure.

**Result:**

Lecturer Signature with Date
**Observations:**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Frequency from signal generator $n_x$ (Hz)</th>
<th>Frequency from signal generator $n_y$ (Hz)</th>
<th>No. of loops touching X axis $L_X$</th>
<th>No. of loops touching Y axis $L_Y$</th>
<th>$n_x$ --- = $n_y$</th>
<th>$L_Y$ --- = $L_X$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>