# INDEX

## Course Objectives

- To demonstrate the theoretical concepts with practical examples.
- To observe the Voltage-Current (V-I) characteristics of semiconductor devices such as diodes, transistors.
- To understand operation of electronic circuits, integrated circuits and their applications.

## Course Learning Outcomes

At the end of course, student will be able to

- Recognize and utilize the electronic components.
- Analyze, characterize and implement the electronic circuits.
- Understand the concept of logic gates and integrated circuits in electronics engineering.

## Evaluation Scheme

| | | |
|---|---|---|
| **Component 1** | Lab Performance / File work | 40 marks |
| **Component 2** | Internal Viva – Voce | 20 marks |
| **Component 3** | End Term | 40 marks |
| | **Total** | **100 marks** |

- **Details of Component 1:**
  Minimum of four lab evaluation / performance will be evaluated periodically.

| Lab Evaluation | Viva Voce (10 Marks) | Performance (5 Marks) | Practical File (5 Marks) | Total (20 Marks) |
|---|---|---|---|---|
| **L1** | | | | |
| **L2** | | | | |
| **L3** | | | | |
| **L4** | | | | |

- **Details of Component 2:**
  Internal Lab viva-voce will be held at the end of semester, with break-up of marks as given for lab evaluation.
- **Details of Component 3:**
  The End Term examination for practical courses is held at the end of the term and includes conduct of experiment and an oral examination (viva voce). The mandatory requirement of 75% attendance in all lab classes is to be met for being eligible to appear in this component.

# Laboratory Safety Precautions

## Safety Precautions

- Switch off the power supply after the completion the experiment.
- Follow the instructions sheet while making connection to avoid any mishappening.
- Don't switch on the power supply without getting it checked by the faculty.
- Use the proper range of power supply as per the given requirement.
- Don't remove the insulation of wires with mouth, use wire stripper for the same.

## General Precautions

- Don't keep your bag and books on experimental table.
- Don't leave the lab without permission during practical time.
- Connection should be neat and tight.
- Arrange the stools before leaving the lab.
- Don't use mobile phone in the lab.
- Eatables are not allowed in the lab.
- This practical manual contains 11 experiments of Basics of Electronics Engineering Lab (EC102). The numbers of experiments as conducted during the semester are required to be performed by the student and observations written by them in their practical workbook. The students are required to submit their workbook to the concerned faculty at the end of the semester.

**AIM**- Familiarization with basic electronic components. Identification of linear and non-linear elements based on VI characteristics.

**APPARATUS:** Analog/Digital Multimeter, resistors, capacitors, diodes, transistor, dc battery.

**THEORY:**

1. **Multi-meter**: It is one of the most versatile general-purpose instruments capable of measuring dc and ac voltages as well as currents and resistances. The multimeter generally consists of the following elements:

- A balanced bridge dc amplifier.
- An attenuator in input stage to select the proper voltage range.
- A rectifier for converting an ac input voltage to proportionate dc value
- An internal battery and additional circuitry for providing the capability of resistance measurement.
- A function switch for selecting various measurement functions of the meter such as voltage.
- In addition, the instrument is usually provided with a built in power supply for operation on ac mains and, in most cases, one or more batteries are provided for operation as a portable test instrument.

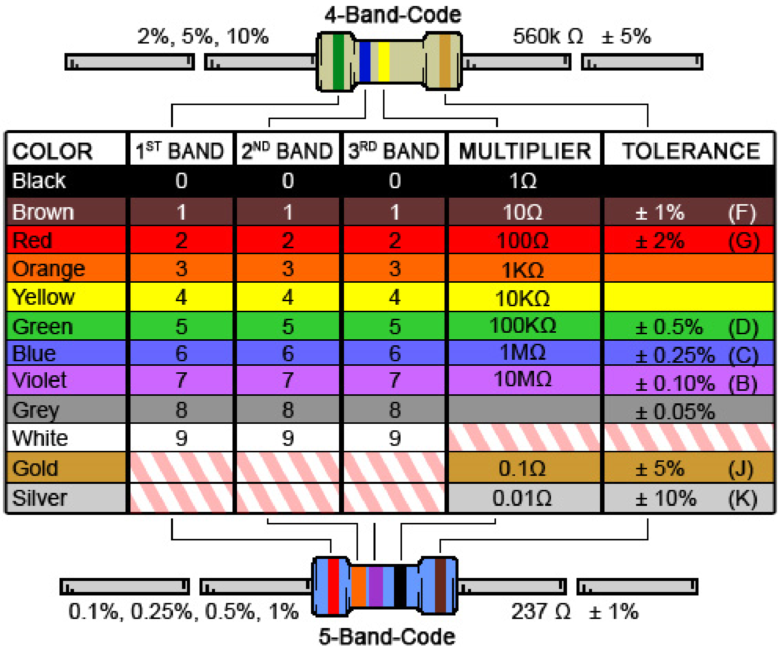
Digital Multimeter (DMM) is basically a digital voltmeter and may be used for the measurement of voltage, current (dc or ac) and resistance. All quantities other than dc voltage are first converted into an equivalent dc voltage by some device.

For measurement of resistance, a constant current, depending on the range, supplied from battery or a constant current source is passed through the resistance under measurement and voltage developed across it is measured. The resistance value is displayed in ohms.

For measurement of current, the unknown current is passed through a precision resistor in many commercial digital multimeters and the voltage developed across the precision resistor is measured. The current value is displayed in mA.

**2. Resistor:** A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits.

Figure 1.1 shows the Resistor color codes used to find out the range of values as per manufacturer's tolerance.




| COLOR | 1ST BAND | 2ND BAND | 3RD BAND | MULTIPLIER | TOLERANCE |
|---|---|---|---|---|---|
| Black | 0 | 0 | 0 | 1Ω | |
| Brown | 1 | 1 | 1 | 10Ω | ± 1% (F) |
| Red | 2 | 2 | 2 | 100Ω | ± 2% (G) |
| Orange | 3 | 3 | 3 | 1KΩ | |
| Yellow | 4 | 4 | 4 | 10KΩ | |
| Green | 5 | 5 | 5 | 100KΩ | ± 0.5% (D) |
| Blue | 6 | 6 | 6 | 1MΩ | ± 0.25% (C) |
| Violet | 7 | 7 | 7 | 10MΩ | ± 0.10% (B) |
| Grey | 8 | 8 | 8 | | ± 0.05% |
| White | 9 | 9 | 9 | | |
| Gold | | | | 0.1Ω | ± 5% (J) |
| Silver | | | | 0.01Ω | ± 10% (K) |

Figure 1.1: Resistor color codes

**3. Capacitor:** A capacitoris a passive two-terminal electrical component to store electric energy in an electric field. The most common kinds of capacitors are:

- Ceramic capacitors have a ceramic dielectric, refer figure 1.2.
- Film capacitors or plastic film capacitors are non-polarized capacitors with an insulating plastic film as the dielectric.The plastic films used as the dielectric are Polypropylene (PP), Polyester (PET), Polyphenylenesulfide (PPS), Polyethylene naphthalate (PEN), and Polytetrafluoroethylene or Teflon (PTFE), refer figure 1.3.
- Electrolytic capacitors (e-caps) are polarized capacitors whose anode electrode (+) are made of a special metal on which an insulating oxide layer originates by anodization (forming), which acts as the dielectric of the electrolytic capacitor, refer figure 1.4.

Figure 1.2: Ceramic capacitor

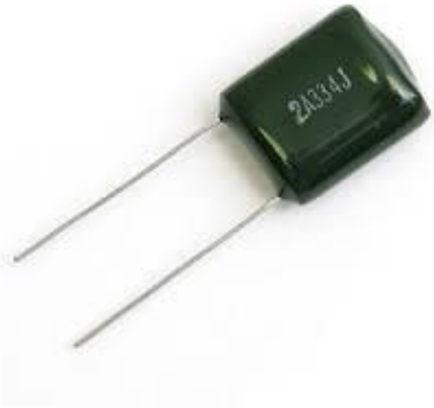



Figure 1.3: Polyester capacitor

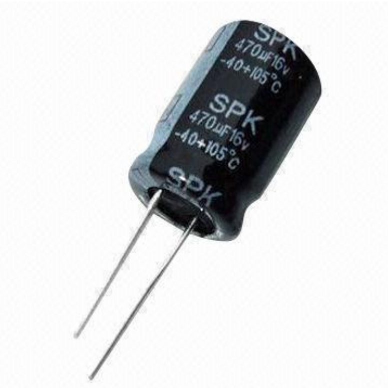



Figure 1.4: Electrolyte capacitor

**4. P-N Junction diode:** A diode is a two-terminal electronic component that conducts primarily in one direction ; it has low (ideally zero) resistance to the flow of current in one direction, and high (ideally infinite) resistance in the other.

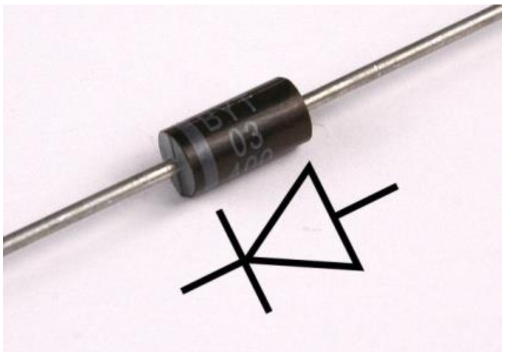


Figure 1.5: PN Junction Diode

**5. Transistor:** It is a semiconductor device used to amplify or switch electronic signals and electrical power.

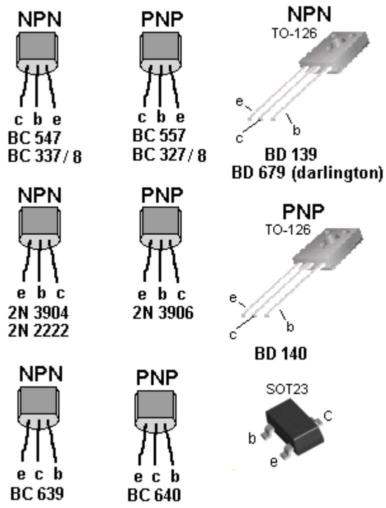



Figure 1.6: Transistor

**PROCEDURE:**

1. **Measuring AC/DC voltage:** The range selector switch should be in AC/DC voltage position. Place the leads of the multimeter across the terminal of the unknown voltage. Note down the reading.
2. **Measuring Resistance:** Select the range of resistance and after the selections place the leads of the multimeter across the terminal of the unknown resistance. Note down the values.
3. **Checking the continuity of wire:** Connect the wire across the terminals of multimeter. If resistance reading comes to zero, wire is continuous.
4. **Measuring capacitance:** Select capacitance option and place the leads of the multimeter across the terminal of the unknown capacitance. Note down the values.
5. **Checking Diode**: Turn the dial (rotary switch) to Diode Test mode ( ). It may share a space on the dial with another function. Connect the test leads to the diode. Record the measurement displayed. Reverse the test leads. Record the measurement displayed. A good forward-based diode displays a voltage drop ranging from 0.5 to 0.8 volts for the most commonly used silicon diodes. Some germanium diodes have a voltage drop ranging from 0.2 to 0.3 V.
6. **Checking transistor**: Hook the positive lead of the multimeter to the BASE (B) of the transistor. Hook the negative lead to the EMITTER (E) of the transistor. For a good NPN transistor, the meter should show a voltage drop between 0.45V and 0.9V.
7. **Typical Specifications of Digital Multimeter:**

| | |
|---|---|
| Ranges: | DC voltage upto 1,000 V in 5 ranges |
| | AC voltages upto 750 V in 5 ranges |
| | DC current upto 10 A in 5 ranges |
| | AC current upto 10 A in ranges |
| | Resistance upto 200 MΩ in seven ranges |
| Basic Accuracy: | 0.5% for dc voltages |
| | 1% for ac voltages |

1% for dc current
1.2% for ac current
0.8 % for resistance

Display: 3.5 digits, LCD

Power Source: 9 V batteries.

**OBSERVATION TABLE:**

| S.NO | ELEMENT | ACTUAL READING | MEASURED READING WITH MULTIMETER |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

**CONCLUSION:** The basic electronic components have been studied and values of resistance and capacitances have been measured.

**AIM:** Plot and analyze the forward and reverse characteristics of PN junction Si and Ge diodes and determine their knee and breakdown voltages.

**APPARATUS:** PN Junction / semiconductor diode characteristic Trainer kit, connecting leads.

**THEORY:** A P-N junction, is formed when p-type semiconductor is suitably joined to n-type semiconductor. The contact surface so formed is known as PN junction. This diode has two terminals called anode and cathode. A curve plotted between voltage across the diode (V) and the current flowing through it (I) is called V-I characteristics of a diode. This is known as response of a P-N junction.

**FORWARD BIASING:**
When positive terminal of battery is connected to p-type semiconductor & negative terminal of battery is connected to n-type semiconductor of P-N junction, the junction is said to be forward biased (figure 2.1 (A)).

**REVERSE BIASING:**
When positive terminal of battery is connected to n-type semiconductor & negative terminal of battery is connected to p-type semiconductor of P-N junction, the junction is said to be reverse biased (figure 2.1 (B)).

**CIRCUIT DIAGRAM:**

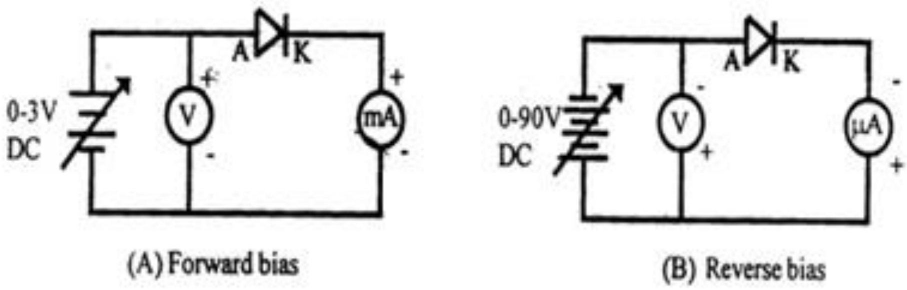



Figure 2.1: Biasing of PN junction diode

**PROCEDURE:**

**(A) FORWARD BIASING**
1. On the trainer board, the solid lines signify the connections already made as shown in figure 2.2; whereas dotted lines are used to indicate the connections which can be made using connecting leads. There is a provision to select Silicon diode and Germanium diode.
2. Make the connections as shown in Figure 2.1(A) by selecting Silicon diode.
3. Keep the DPDT (Double-Pole-Double-Throw) switches towards 3 V and 10 mA position.
4. Keep the variable control of the power supply towards minimum position i.e. anticlockwise.
5. Connect positive terminal of supply voltage (variable DC, 0-3V) to Anode (A) terminal of the selected semiconductor diode.

6. Now connect negative terminal of supply voltage to Cathode (K) terminal of the selected semiconductor diode.
7. Connect the voltmeter in parallel with the supply voltage source by connecting positive terminal of supply voltage source with positive terminal of the voltmeter and negative terminal of supply voltage source with negative terminal of the voltmeter.
8. Connect the ammeter in series with the diode by connecting Cathode (K) terminal of the diode with positive terminal of the ammeter and negative terminal of the ammeter with the negative terminal of the voltage source.
9. Put the power ON/OFF switch to 'ON' position. Jewel light will indicate the power supply is ON.

10. Now with the help of the coarse variable control of the power supply, increase the DC power supply voltage from 0V to higher values in small steps and observe the voltage across the diode ($V_F$) on voltmeter and current ($I_F$) on ammeter.
11. Plot V – I characteristics taking $V_F$ on x-axis and $I_F$ on y-axis.
12. Repeat steps 2 to 11 for Germanium diode.

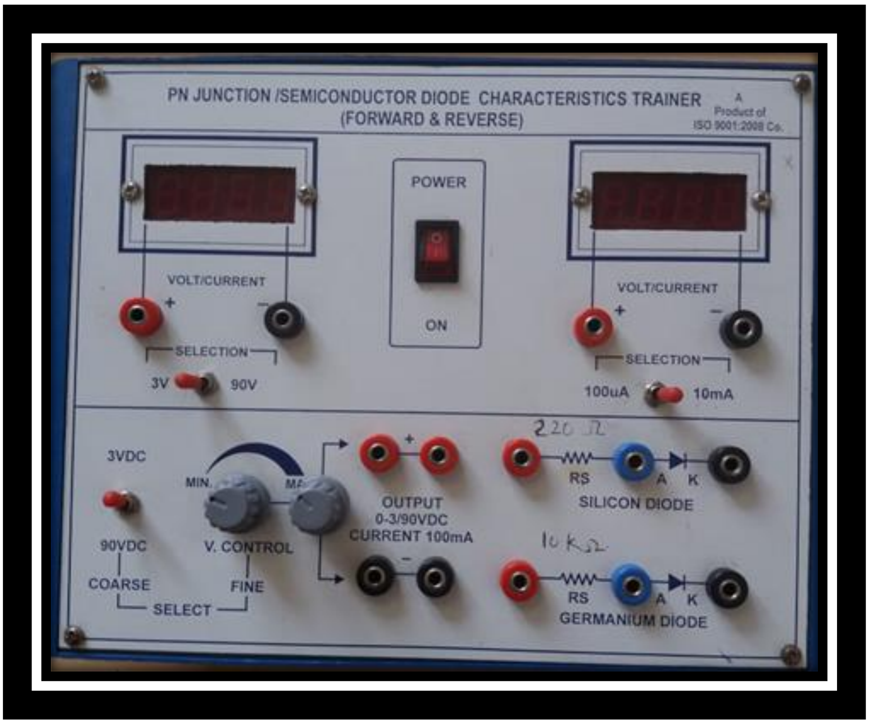



Figure 2.2: Trainer Board for studying the V-I Characteristics of PN junction diode

**(B) REVERSE BIASING:**

1. Make the connections as shown in Figure 2.1(B) by selecting either Silicon diode or Germanium diode.
2. Keep the DPDT switches towards 90 V and 100 μA position.
3. Keep the variable control of the power supply towards minimum position i.e. anticlockwise.
4. Connect positive terminal of supply voltage (variable DC, 0-90V) to Cathode (K) terminal

of the selected semiconductor diode.
5. Now connect negative terminal of supply voltage to Anode (A) terminal of the selected semiconductor diode.
6. Connect the voltmeter in parallel with the supply voltage source by connecting positive terminal of supply voltage source with positive terminal of the voltmeter and negative terminal of supply voltage source with negative terminal of the voltmeter.
7. Connect the ammeter in series with the diode by connecting Cathode (K) terminal of the diode with positive terminal of the ammeter and negative terminal of the ammeter with the negative terminal of the voltage source.
8. Put the power ON/OFF switch to 'ON' position. Jewel light will indicate the power supply is ON.
9. Now with the help of the coarse variable control of the power supply, increase the DC power supply voltage from 0V to higher values in steps and observe the voltage across the diode ($V_R$) on voltmeter and current ($I_R$) on ammeter.
10. Plot V – I characteristics taking $V_R$ on negative x-axis and $I_R$ on negative y-axis.
11. Repeat steps 2 to 10 for Germanium diode.

**OBSERVATION TABLE:**

| | **For Silicon diode** | | | | **For Germanium diode** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Forward Biasing** | | **Reverse Biasing** | | **Forward Biasing** | | **Reverse Biasing** | |
| | **Forward voltage ($V_F$) (Volts)** | **Forward current ($I_F$)(mA)** | **Reverse Voltage ($V_R$)(Volts)** | **Reverse Current ($I_R$)(μA)** | **Forward voltage ($V_F$) (Volts)** | **Forward current ($I_F$) (mA)** | **Reverse Voltage ($V_R$)(Volts)** | **Reverse Current ($I_R$) (μA)** |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

**PRECAUTIONS:**

1. To avoid over heating of diode, current should not be passed for long durations.
2. Voltage applied should be well below the safety limit of the diode.
3. Connection should be made carefully and must be tight.

**GRAPH:**

Plot a graph between voltage and current applied across the PN – Junction diode, taking values of voltage along x-axis & the corresponding value of current along y-axis. Take the forward voltage $V_F$ and forward current $I_F$ along positive x-axis and y-axis respectively. Similarly plot the reverse voltage $V_R$ and reverse current $I_R$ along negative x-axis and y-axis respectively.

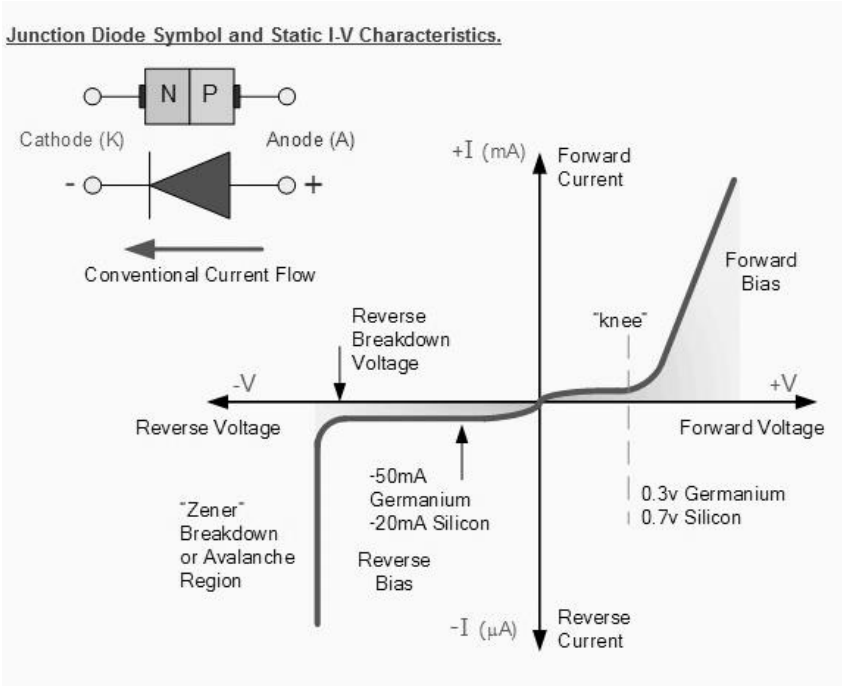



Figure 2.3: Characteristics of PN junction diode

**RESULT**:

1. The Curve shows that only a very small current flow through the diode during the initial stage until the potential barrier is wiped-off in forward bias. Once the potential barrier wiped-off, current rises quickly.
2. The knee voltage of germanium diode is quite lower than the silicon diode. This is the major difference between the two types of diodes.
3. Knee Voltage of a diode is……….
4. Breakdown voltage of a diode is………

**AIM:** Analyze Zener diode as voltage regulator and observe the output voltage with variable input voltage and fixed load resistance for zener diodes with breakdown voltages of 6 V,8V and 12 V.

**APPARATUS:**

Zener diode Trainer Board (With zener diode of different breakdown voltages such as 2V, 6V, 8V, 9V or 12V, eg. IN4735A, IN4738A, IN4742A etc), Power supply (0 – 20V), Multi meter, Connecting leads

**THEORY:**

A Zener Diode is a special kind of diode which permits current to flow in the forward direction as normal diode, but will also allow it to flow in the reverse direction when the voltage is above a certain value - the breakdown voltage known as the Zener voltage.A zener diode exhibits almost the same properties, except the device is specially designed so as to have a greatly reduced breakdown voltage, the so-called zener voltage. By contrast with the conventional device, a reverse-biased zener diode will exhibit a controlled breakdown and allow the current to keep the voltage across the zener diode close to the zener breakdown voltage. For example, a diode with a zener breakdown voltage of 3.2 V will exhibit a voltage drop of very nearly 3.2 V across a wide range of reverse currents. The zener diode is therefore ideal for applications such as the generation of a reference voltage (e.g. for an amplifier stage), or as a voltage regulator for low-current applications.

**CIRCUIT DIAGRAM:-**

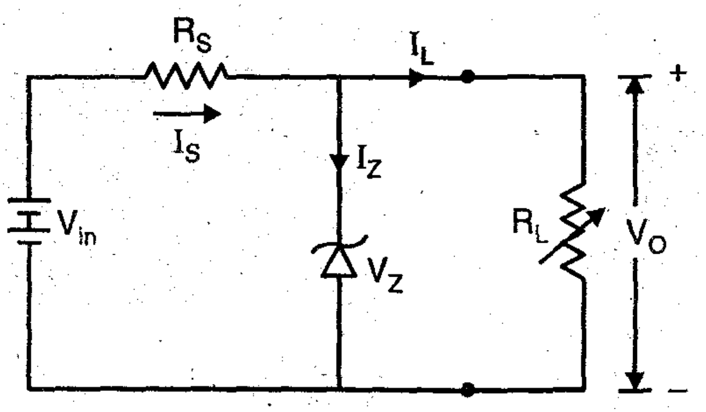



**Figure 3.1: Zener Diode as a Voltage Regulator**

**PROCEDURE:-**

1. On the trainer board, as shown in Figure 3.2, the solid lines signify the connections already made; whereas dotted lines are used to indicate the connections which can be made using connecting leads. There is a provision to select one zener diode from three options with different breakdown voltages ($V_z$).
2. Make the connection as shown in diagram 3.1 by selecting one of the diodes for the circuit, for a particular breakdown voltage (say $V_{z1}$), by connecting leads.
3. Connect positive terminal of supply voltage (variable DC, 0-20 V) to negative terminal of the selected zener diode through series current limiting resistor Rs.

4. Now connect positive terminal of the selected zener diode to negative terminal of supply voltage.
5. Connect the voltmeter in parallel with the supply voltage source by connecting positive terminal of supply voltage source with positive terminal of the voltmeter and negative terminal of supply voltage source with negative terminal of the voltmeter.
6. Keep variable control of power supply on minimum position.
7. Put power switch on ON position, glowing LED indicates that power supply is ON.
8. Slowly and steadily, increase the regulated power supply voltage($V_{in}$)from 0V to higher values in steps and check the value of output voltage across the selected zener diode ($V_{out}$) using a multimeter (where setting on the multimeter is done to measure the dc voltage).
9. The input voltage($V_{in}$) and output voltage($V_{out}$) are observed and then noted in tabular form as given in the observation table.
10. When applied voltage, $V_{in}$becomes equal to the breakdown voltage of the diode, $V_z$; then output voltage $V_{out}$ will saturate.
11. A graph is plotted between input voltage($V_{in}$) and output voltage($V_{out}$) to verify the voltage regulation done by the selected zener diode.
12. Repeat the steps 2-5 for zener diodes with breakdown voltages $V_{z2}$ and $V_{z3}$ by selecting the appropriate diode from the trainer board.

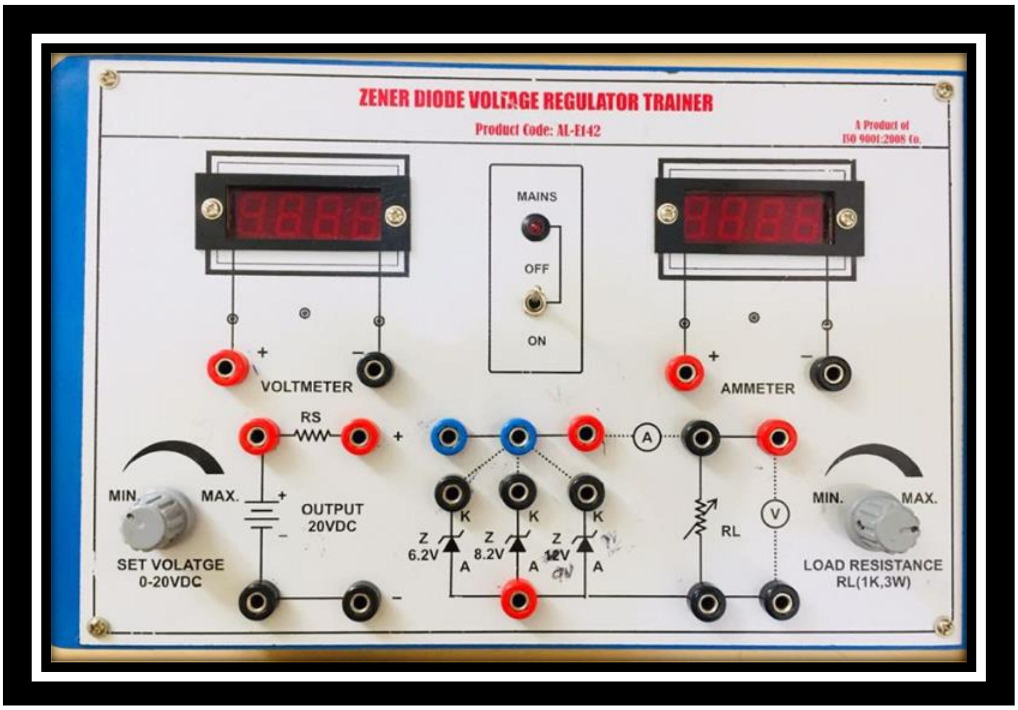



**Figure 3.2: Trainer Board for Zener Diode as a Voltage Regulator**

**OBSERVATION TABLE:-**

| | Zener Diode with $V_{z1}$ = | | Zener Diode with $V_{z2}$ = | | Zener Diode with $V_{z3}$ = | |
|---|---|---|---|---|---|---|
| | **Vin** | **Vout** | **Vin** | **Vout** | **Vin** | **Vout** |

| S No. | (V) | (V) | (V) | (V) | (V) | (V) |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |

**GRAPH:**

Plot a graph between input voltage ($V_{in}$) and output voltage ($V_{out}$) to verify the voltage regulation done by the selected zener diode, taking values of input voltage along x-axis & the corresponding value of output voltage along y-axis.

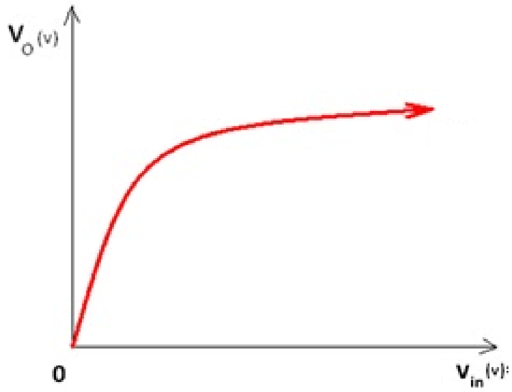



**Figure 3.3: Zener Diode Voltage Regulation**

**PRECAUTION:-**

1. The connections should be neat and tight.
2. Do not switch ON the trained board without checking and verifying the connections.
3. The terminal of the zener diode should be properly identified; as the diode should be reverse biased for working as a voltage regulator.
4. It should be ensured that the applied voltage does not exceed the rating of the diode (maximum by 2V).
5. Inclusion of $R_L$ (load resistance) in the circuit causes a voltage drop of around 2V across the zener diode. Therefore, to study the operation of zener diode as a voltage regulator, it can be excluded from the circuit.

**CONCLUSION:-**

Hence the zener diode is used as a voltage regulator.When applied voltage, $V_{in}$is more than the breakdown voltage of the diode, $V_z$; then output voltage $V_{out}$ will be nearly equal to the breakdown voltage of the diode, $V_z$. This is the voltage regulation done by zener diode.

**AIM:** Study and observe the output waveform of half-wave and full wave rectifiers on CRO and calculate the average and rms values of output voltage and current.

**APPARATUS:**

a) Half wave and full wave rectifier kit (using IN4007 Diodes)
b) Digital Multimeter
c) Connecting wires
d) CRO
e) CRO probes.

**THEORY:**

**Half Wave Rectifier**

In Half Wave Rectification, When AC supply is applied at the input, only Positive Half Cycle appears across the load whereas, the negative Half Cycle is suppressed. This can be explained as follows:

As shown in Figure 4.1, during positive half-cycle of the input voltage, the diode D1 is in forward bias and conducts through the load resistor $R_L$. Hence the current produces an output voltage across the load resistor $R_L$, which has the same shape as the +ve half cycle of the input voltage. During the negative half-cycle of the input voltage, the diode is reverse biased and there is no current through the circuit. i.e., the voltage across RL is zero. The net result is that only the +ve half cycle of the input voltage appears across the load. The average value of the half wave rectified o/p voltage is the value measured on dc voltmeter.For practical circuits, transformer coupling is usually provided for two reasons.

1. The voltage can be stepped-up or stepped-down, as needed.
2. The ac source is electrically isolated from the rectifier. Thus preventing shock hazards in the secondary circuit.

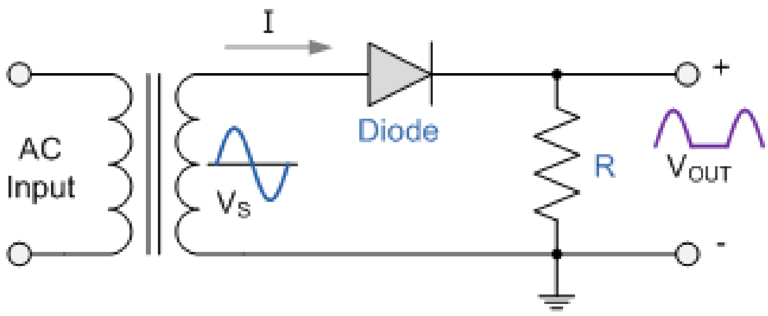
The efficiency of the Half Wave Rectifier is 40.6%

**Full Wave Rectifier**

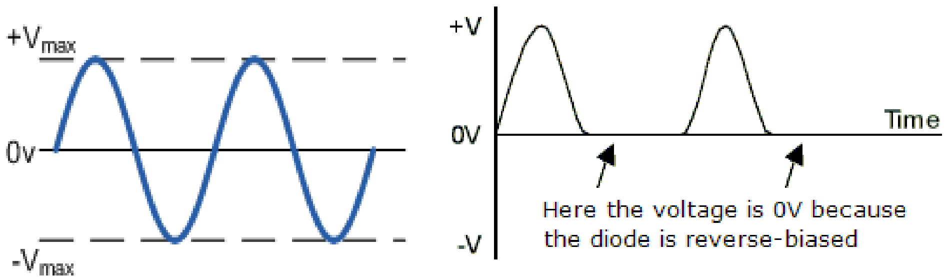
The circuit of a center-tapped full wave rectifier uses two diodes D1&D2 as shown in Figure 4.2. During positive half cycle of secondary voltage (input voltage), the diode D1 is forward biased and D2is reverse biased. So the diode D1 conducts and current flows through load resistor $R_L$. During negative half cycle, diode D2 becomes forward biased and D1 reverse biased. Now, D2 conducts and current flows through the load resistor $R_L$ in the same direction. There is a continuous current flow through the load resistor $R_L$, during both the half cycles and will get unidirectional current as show in the model graph. The difference between full wave and half wave rectification is that a full wave rectifier allows unidirectional (one way) current to the load during the entire 360 degrees of the input signal and half-wave rectifier allows this only during one half cycle (180 degree).

**CIRCUIT DIAGRAM:**

**A) Half Wave Rectifier:**



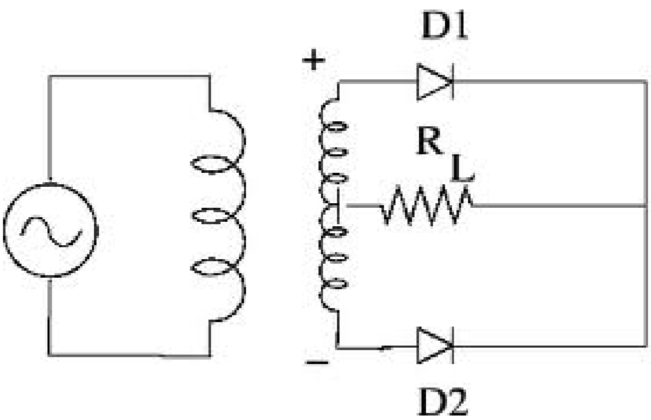

**Waveforms:**




AC Input Waveform    **Rectifier Output Waveform**

**Fig 4.1: Circuit Diagram of Half Wave Rectifier with input and output Waveforms**

**B) Full Wave Rectifier**




**Waveforms:**

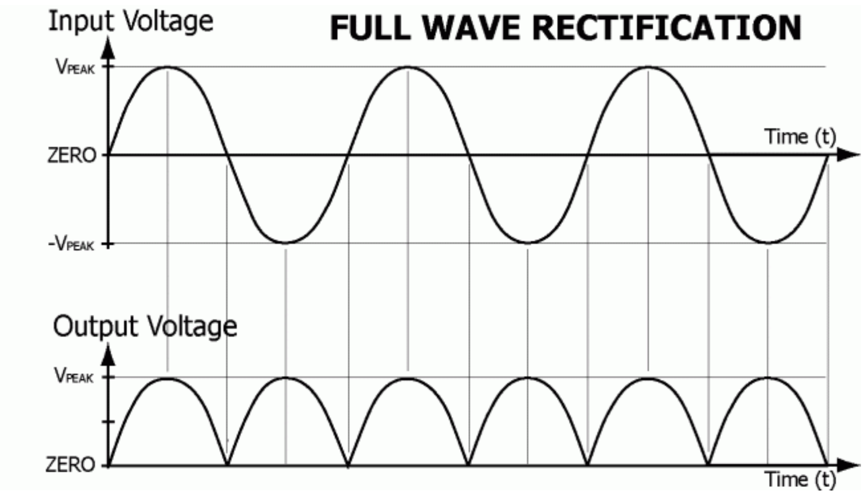



**Fig 4.2:Circuit Diagram of Centre-Tap Full Wave Rectifier with input and output waveforms**

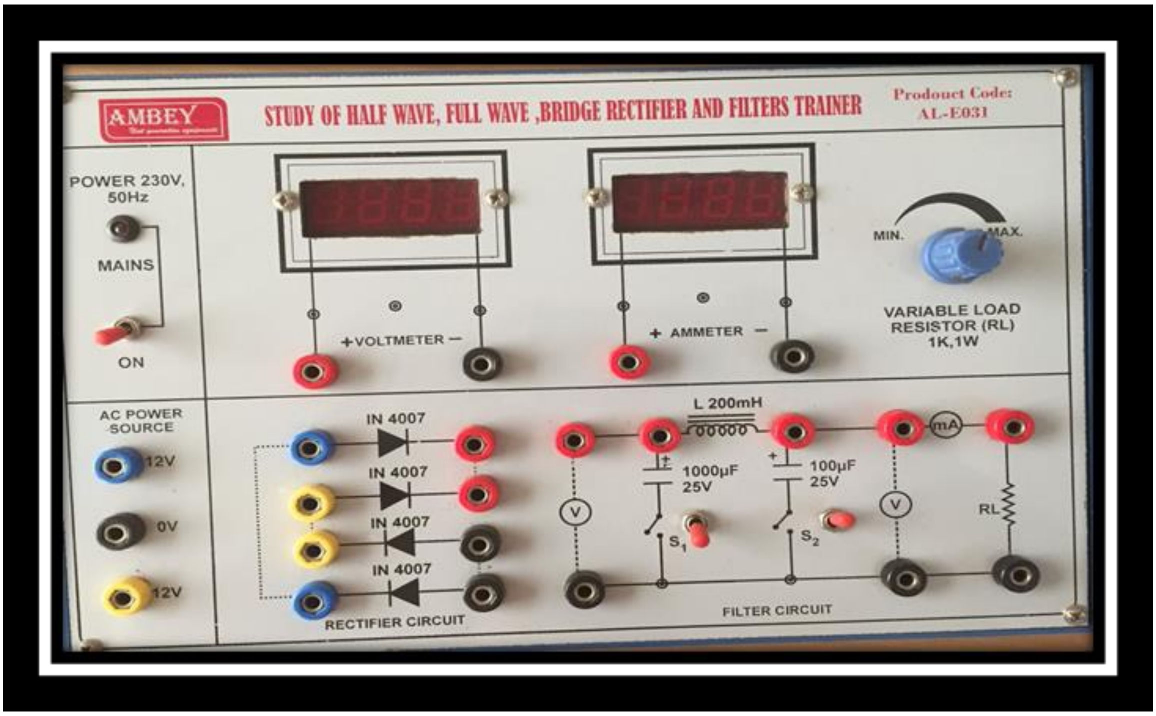



**Fig. 4.3: Trainer Board for Rectifier**

**PROCEDURE:**

**(For Half Wave Rectifier)**

1. On the trainer board, as shown in Figure 4.3, the solid lines signify the connections already made; whereas dotted lines are used to indicate the connections which can be made using connecting leads.

2. In order to make circuit diagram for half wave rectifier follow the circuit shown in fig. 4.1.
3. Connect the P terminal of IN4007 diode with the secondary winding of transformer producing 12 V AC.
4. Connect the N terminal of diode with one end of load resistance R.
5. Complete the circuit by connecting the other end of resistor with ground terminal of transformer.
6. Now connect the CRO before diode to see the input waveform.
7. Now connect the CRO after diode to see the output waveform (output of the rectifier).
8. Measure the peak voltages across the input terminal $V_m$(in) and across the load $V_m$(out) using CRO.
9. Use Equation 4.1 and 4.2 to calculate $V_{rms}$(out), $V_{av}$(out) at the output. Use equation 4.3 to calculate $V_{rms}$(in) at the input terminal.
10. Measure the $V_{rms}$(in) at the input and $V_{rms}$(out) at the output by connecting voltmeter across input and output terminals.
11. Now connect the filter circuit with rectifier and connect CRO after it to get output waveform

For Half Wave Rectifier (equation 4.1 and 4.2):

$$V_{rms} = \frac{V_m}{2}$$

$$V_{av} = \frac{V_m}{\pi}$$

For Full Wave Rectifier (equation 4.1 and 4.2):

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$V_{av} = \frac{2V_m}{\pi}$$

**(For Full Wave Rectifier)**

1. In order to make circuit diagram for full wave rectifier follow the circuit shown in fig. 4.2.
2. Connect the P terminal of IN4007 diode $D_1$ with the secondary winding of transformer marked as 12 V AC.
3. Connect the N terminal of diode $D_1$ with one end of variable load resistance R.
4. Similarly Connect the P terminal of IN4007 diode $D_2$ with the secondary winding of transformer marked as 12 V AC.
5. Connect the N terminal of diode $D_1$ with one end of variable load resistance R.

6. Complete the circuit by connecting the other end of resistor with center terminal of transformer marked as 0V.
7. Using a CRO, measure the maximum voltage $V_m$ of the AC input voltage (at the anode) of the rectifier and AC voltage (at the cathode) at the output of the rectifier.
8. Use Equation 4.3 and 4.4 to calculate $V_{rms}$(out), $V_{av}$(out) at the output. Use equation 4.3 to calculate $V_{rms}$(in) at the input terminal.
9. Measure the $V_{rms}$(in) at the input and $V_{rms}$(out) at the output by connecting voltmeter across input and output terminals.
10. Now connect the filter circuit with rectifier and trace the input and output waveforms in oscilloscope and notice the change.

**OBSERVATION TABLE:**

| | **Half Wave** | | **Full Wave** | |
|---|---|---|---|---|
| **Waveshape:**<br><br>**Before Filtration**<br><br>**After Filtration** | | | | |
| | **Theoretical Value** | **Practical Value** | **Theoretical Value** | **Practical Value** |
| **Vin(rms)** | | | | |

| | | | | |
|---|---|---|---|---|
| **Vout(rms)** | | | | |
| **Vout(av)** | | | | |

**WAVEFORMS:**

| | |
|---|---|
| Half Wave Rectifier Input Waveforms | Half Wave Rectifier Output Waveforms |
| Full Wave Rectifier Input Waveforms | Full Wave Rectifier Output Waveforms |

**PRECAUTIONS:**

1. The connections should be neat and tight.
2. Do not switch ON the trainer board without checking and verifying the connections.
3. It should be ensured that the applied voltage do not exceed the ratings of the diode (maximum by 2V).
4. The polarities of all the diodes should be carefully identified.
5. The primary and secondary side of the transformer should be carefully identified.

**CONCLUSION:-**

Hence the wave shapes have been verified along with Vrms.

**AIM:** Analyze the npn and pnp transistors in common emitter configuration and plot their input and output characteristics.

**APPARATUS:**

1. Digital Transistor (NPN/PNP) characteristics trainer kit with the following in-built electronic components and devices:
   a) Regulated DC power supplies
   b) Voltmeter (0 – 10 V)
   c) Ammeter (0 – 200 mA)
   d) Ammeter (0-200µA)
   e) Transistor (NPN and PNP type)
2. Connecting leads

**THEORY:**

A junction transistor is simply a sandwich of one type of semiconductor material between two layers of the other type. Accordingly, there are two types of transistors (1) N-P-N transistor and (2) P-N-P transistor. When a layer of P type material is sandwich between two layers of N type material, the transistor is known as N-P-N transistor. Similarly, when a layer of N type material is sandwich between two P type materials, the transistor is known as P-N-P transistor. This is shown in figure 5 as given below.

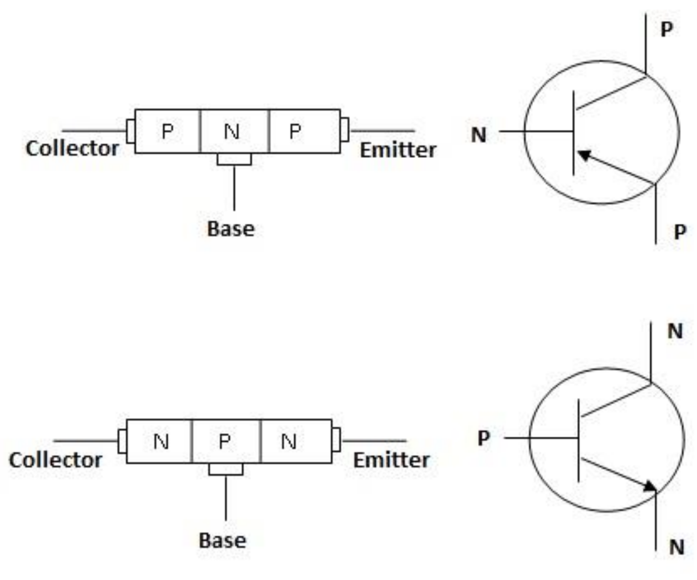



**Figure 5: Transistor symbols**

A transistor (N-P-N or P-N-P) has the following sections:

(I) **Emitter:** the main function of this region is to supply majority charge carriers to the base and it is more heavily doped in comparison to other two regions.

(II) **Base**: this region is very lightly doped so that it may pass most of the injected charge carriers to collector.

(III) **Collector:** the main function of the collector is to collect majority charge carriers through the base thus moderately doped it is.

**CIRCUIT DIAGRAM:**

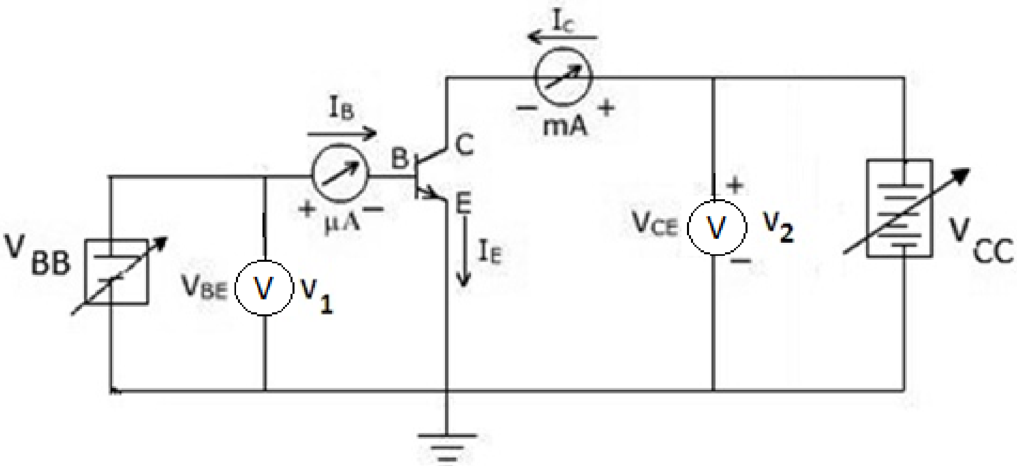



**Figure 5.1: Circuit showing n-p-n transistor CE configuration**

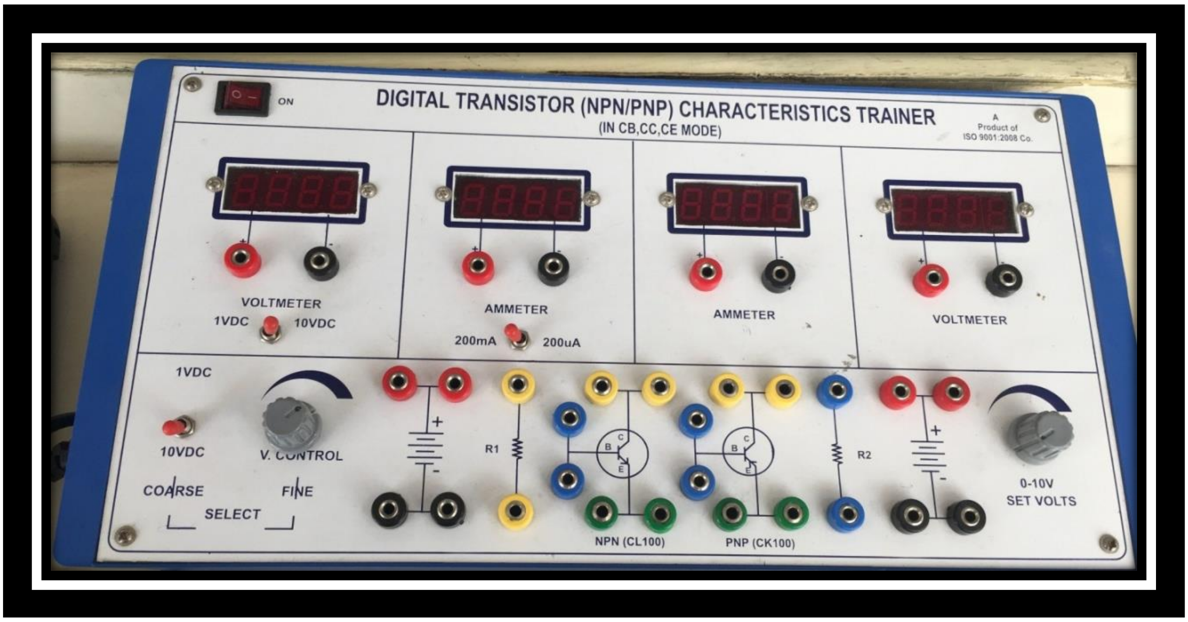



**Figure 5.2: Trainer Board for NPN/PNP in CE, CC and CB mode**

**PROCEDURE:**

1. Start making the connections for NPN transistor in CE configuration as given in figure 5.1.

2. Apply forward bias to the base-emitter junction by connecting base terminal (p-type) to the positive terminal of the dc battery and emitter terminal (n-type) to its negative terminal.
3. Connect a voltmeter in parallel to the dc voltage source in order to measure the bias voltage between base and emitter ($V_{BE}$).
4. Also connect an ammeter in series to the base terminal of the transistor and the dc voltage source to measure the base current ($I_B$).
5. Similarly, apply the reverse biasing across collector-emitter junction by connecting the collector terminal (n-type) with positive of the dc battery and emitter (n-type) to its negative terminal.
6. Also, connect the voltmeter in parallel to dc voltage source and ammeter in series with collector and voltage source, to measure bias voltage ($V_{CE}$) and collector current($I_C$) respectively.
7. Get the connections checked from the teacher in charge.
8. Set both the power supplies at zero. Switch on the a.c. input of the power supplies.
9. For the input characteristics, fix the voltage $V_{CE}$=1V. Now increase the voltage $V_{BE}$ in steps of 0.05 V and note down the corresponding value of base current, $I_B$(µA) and record them in observation table.
10. Draw the input characteristics taking $V_{BE}$ on x-axis and $I_B$ on y-axis.
11. Repeat steps 9 and 10 for $V_{CE}$ =5 V and the $V_{CE}$ =10 V.
12. For output characteristics, fix $I_B$=0 i.e. keep the input circuit open. Change the collector-emitter voltage in steps of 0.05 V and note down the corresponding values of $I_C$. Record these readings in observation table.
13. Repeat step 12 for $I_B$ = 50 µA and 100µA.
14. Draw the output characteristics taking $V_{CE}$ on x-axis and $I_C$ on y-axis.

**CHARACTERSTICS OF CE CIRCUIT:**

Figure 5.1 shows the circuit arrangement for plotting the static characteristics of N-P-N transistor in common emitter configuration. In this circuit battery $V_{BB}$ provides the forward bias to emitter-base junction and the voltmeter $V_1$ is used to measure voltage $V_{BE}$. The micro-ammeter measure the base current $I_B$. a battery $V_{CC}$ is connected between collector and emitter. The collector emitter junction is reversed biased and voltmeter $V_2$ measures the voltage $V_{CE}$ and the milli-ammeter measures the collector current.

**Input Characteristics:** In CE configuration the curve plotted between base current $I_B$ and base emitter voltage $V_{BE}$ at constant collector emitter voltage is called input characteristics. Input characteristics are shown in figure 5.3. The following points are noted from the characteristics:

1. The characteristic resembles that of forward biased diode curve. This is expected because the emitter base section of transistor is a diode and it is forward biased.
2. The curve shows that input resistance of the common emitter circuit is higher than that of common base circuit.

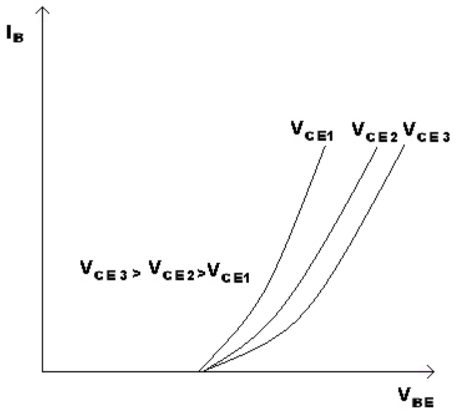



**Figure 5.3: Input characteristics**

**Output Characteristics:** In CE configuration, curve plotted between collector current, $I_C$ and collector emitter voltage, $V_{CE}$ at constant base current $I_B$ is called Output Characteristics.Output characteristics are shown in figure 5.4.

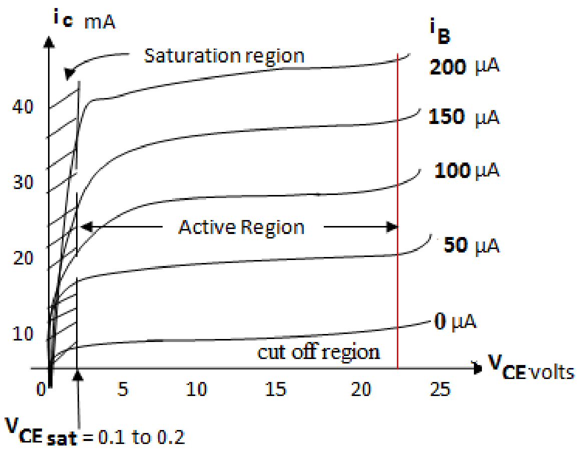



**Figure 5.4: Output characteristics**

The following conclusions are drawn:

1. In the active region for small values of base current, the effect of collector voltage over collector current is small while for large base current values this effect increases. Thus the current gain of this configuration is greater than unity. The operation of the transistor, when used as an amplifying device, must be restricted in the active region only, if much distortion is to be avoided.
2. When $V_{CE}$ has very low value, the transistor is said to be saturated and it operates in the saturation region. In this region change in base current does not produce a corresponding change in collector current.
3. When $V_{CE}$ is allowed to increase too far, collector base junction completely break down and due to this avalanche breakdown, collector current increase rapidly. In this case transistor is damaged.

4. In the cut off region a small amount of collector current flows even the base current is zero. This is called $I_{CEO}$. Since main collector current is zero the transistor is said to be cut off.

**OBSERVATION TABLE:**

**Input Characteristics:**

| S. No | $V_{CE1}$ = __V | | $V_{CE2}$ = __V | | $V_{CE3}$ = __V | |
|---|---|---|---|---|---|---|
| | $I_B$(μA) | $V_{BE}$ (V) | $I_B$(μA) | $V_{BE}$(V) | $I_B$(μA) | $V_{BE}$(V) |
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |
| 7. | | | | | | |
| 8. | | | | | | |
| 9. | | | | | | |
| 10. | | | | | | |

**Output characteristics:**

| S. No | $I_{B1}$ =__ μA | | $I_{B2}$ = __ μA | | $I_{B3}$ = __μA | |
|---|---|---|---|---|---|---|
| | $I_C$(mA) | $V_{CE}$(V) | $I_C$(mA) | $V_{CE}$(V) | $I_C$(mA) | $V_{CE}$(V) |
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |
| 7. | | | | | | |
| 8. | | | | | | |
| 9. | | | | | | |
| 10. | | | | | | |

**PRECAUTIONS:**

1. The input supply to the training board should be of the correct polarity and voltage level.
2. Ensure the connections are right and tight.
3. Note down the zero error of the instruments.

**CONCLUSION:**

Input and output characteristics of CE configuration plotted.

**AIM:** Analyze the truth tables of various basic digital gates. Implement 2-input XOR and 2-input XNOR gate using basic gates.

**APPARATUS**:

a) Logic Gates Trainer board having IC's 7400, 7402, 7404, 7408, 7432, 7486
b) Connecting wires.

**Features of trainer Kit:**

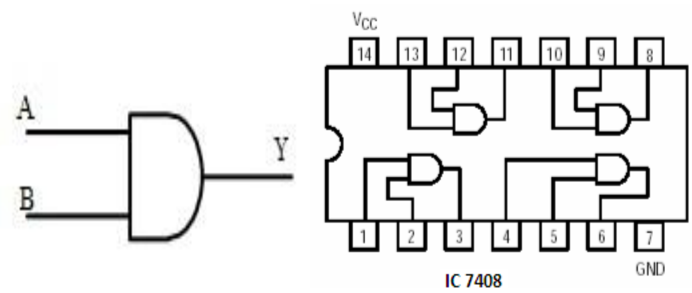
c) Built in regulated DC power supply
d) Power supply: voltage range AC 100V – 230V, Frequency 50Hz.

**THEORY:**

Circuits which are used to process digital signals are called logic gates. Gate is a digital circuit with one or more input voltages but only one output voltage. The most basic gates are called the AND gate, OR gate and NOT gate. Universal gates are NAND gate and NOR gate.

**AND gate:** The AND gate is a circuit which provides an output high when all the inputs are simultaneously high. The symbolic representation of a two input AND gate is shown in Fig 6.1. Mathematically, we can write

$$Y = A * B$$

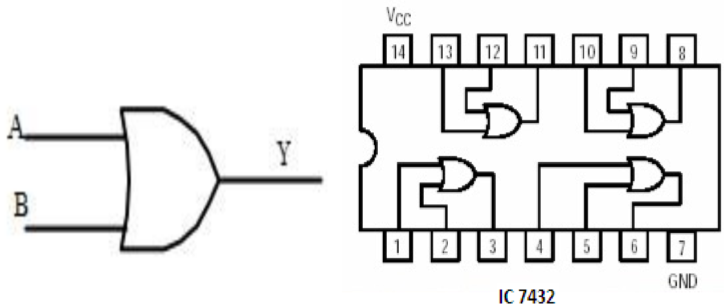



| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 1 | 1 |

**Figure 6.1: AND Gate**

**OR gate:** An OR gate has two or more input signals but only one output signal. It is called an OR gate because the output is high if any or all of the inputs are high. The symbolic representation of a two input OR gate is shown in Fig 6.2. Mathematically, we can write

$$Y = A + B$$

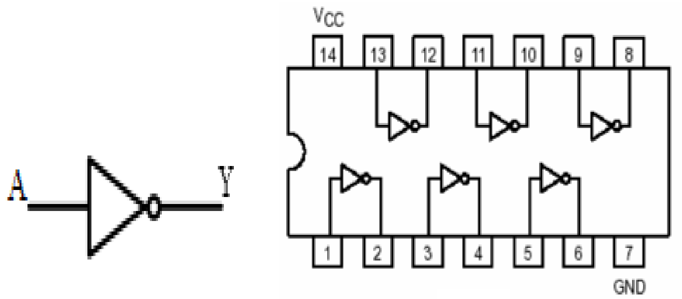



| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 1 |

**Figure 6.2: OR Gate**

**NOT gate:** The NOT gate is a gate which has only one input and one output. It is called so because the output state is always opposite to that of input state i.e. if input is 0, then output is 1 and vice versa. The NOT gate is called an inverter. The symbolic representation of NOT gate is shown in figure 6.3. Boolean equation is:

$$Y = \overline{A}$$



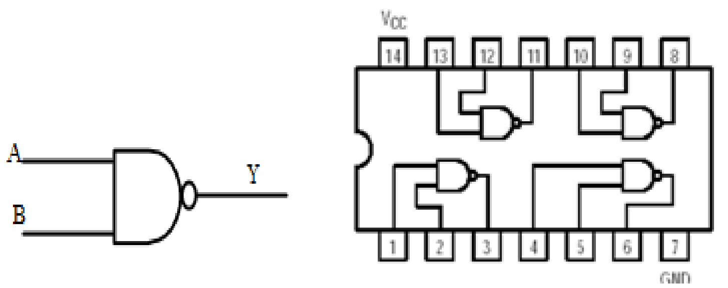

IC 7404

| Input A | Output |
|---|---|
| 0 | 1 |
| 1 | 0 |

**Figure 6.3: NOT Gate**

**NAND gate:** It is combination of NOT gate followed by an AND gate. The output is low when both of the inputs are high else it will give high output. The symbol for NAND gate is shown in figure 6.4. Mathematically, we can write:

$$Y = \overline{AB}$$



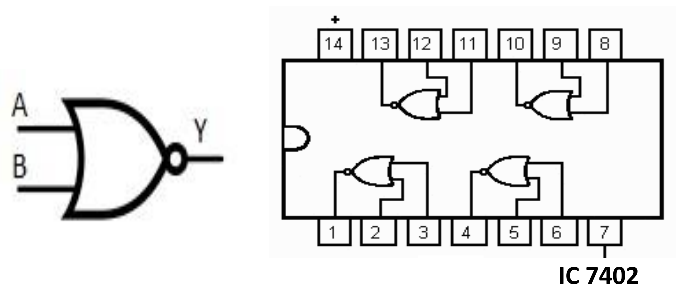

IC 7400

| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 0 |

**Figure 6.4: NAND Gate**

**NOR gate:** It is combination of NOT gate followed by an OR gate. The output is high when both of the inputs are low else it will give low output. The symbol for NOR gate is shown in figure 6.5. Mathematically, we can write

$$Y = \overline{A + B}$$

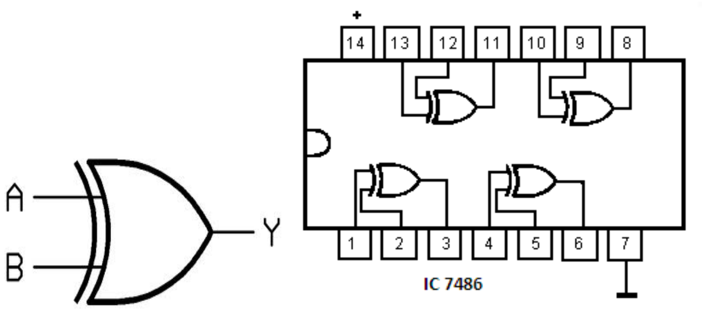



| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 1 | 0 |

**Figure 6.5: NOR Gate**

**EX-OR gate:** The symbol for XOR gate is shown in figure 6.6. There are two or more inputs and one output. The exclusive –OR operation is denoted by $\oplus$. The output is 1 only when the inputs are different. XOR operation is also called *mod-2 addition.* Boolean equation is given as

$$Y = \bar{A}\,B + A\,\bar{B}$$

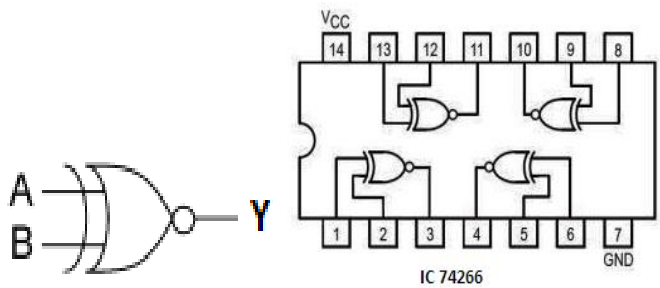



| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 0 |

**Figure 6.6: EX-OR Gate**

**EX-NOR gate:** The symbol for XNOR gate is shown in figure 6.7. There are two or more inputs and one output. The output is high if and only if it's both inputs are same. On the other hand, the output is low if both inputs are different. Boolean expression is given as:

$$Y = A\,B + \bar{A}\,\bar{B}$$




| Input A | Input B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 1 | 1 |

**Figure 6.7: EX-NOR Gate**

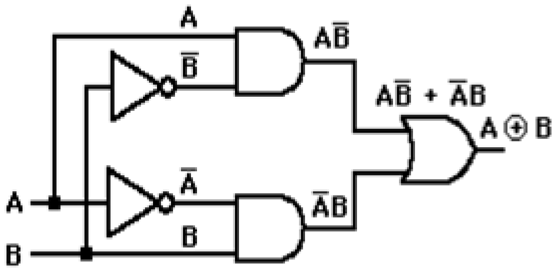



**Figure 6.8: X-OR Gate using Basic Gates**

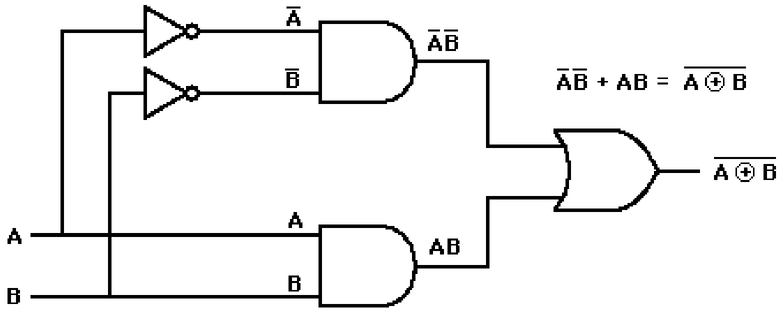



**Figure 6.9: X-NOR Gate using Basic Gates**

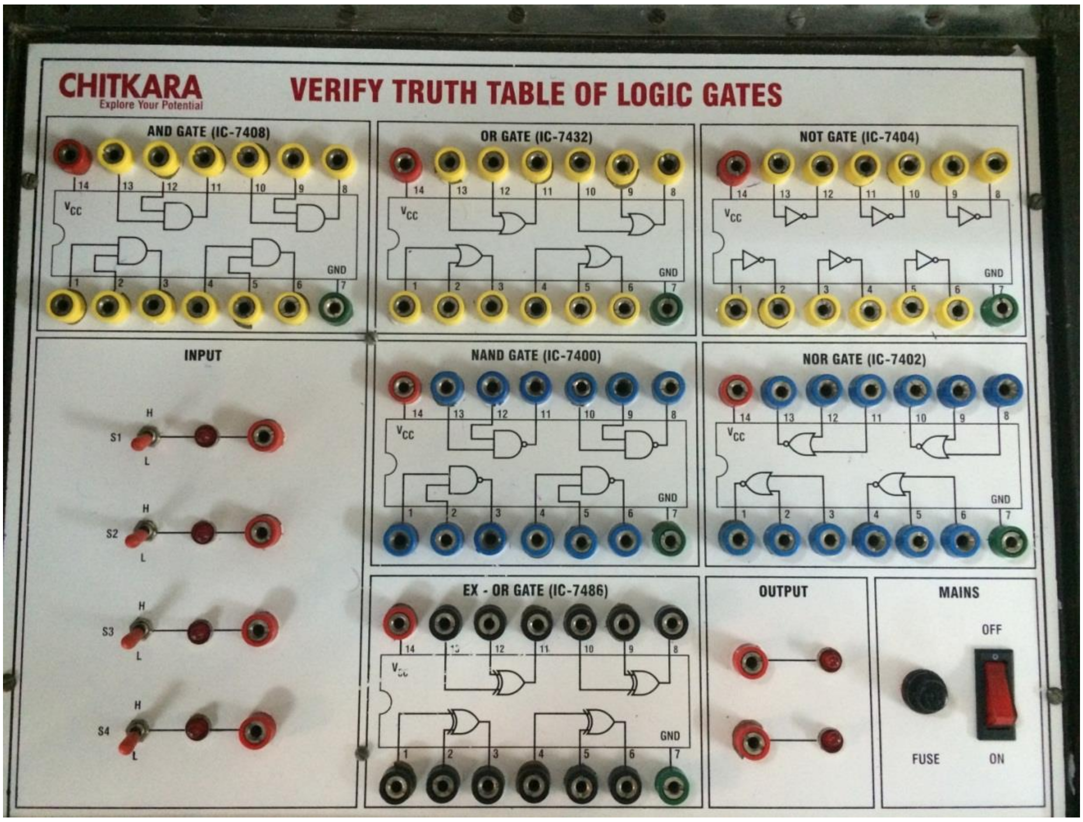



**Figure 6.10: Logic Trainer Board**

**PROCEDURE:**

1. Select any gate on the trainer board (as shown in Fig. 6.10) for truth-table analysis.
2. Connect the input terminals of the gate from trainer board input section.
3. Connect the output terminal of gate to output section of trainer board.
4. Switch on the power supply.
5. Vary the inputs of gate i.e. high or low and note down the output.
6. Draw the table and verify it from truth table of the gate.

**CONCLUSION:**

Truth tables of various logic gates are verified. Also, the 2-input XOR and 2-input XNOR gates have been implemented using basic logic gates.

**AIM:** Study the operation of astable, monostable and bistable multivibrators using 555 timer.

**APPARATUS:** 555 timer trainer kit with built-in regulated power supply, Connecting Wires.

**THEORY:** The 555 IC is a popular chip for acting as multivibrators. It consists of following circuits integrated in the IC:

1. The Comparators: A comparator circuit is an op-amp circuit that is designed to compare an input with a fixed threshold voltage. The output will be high if the input voltage is higher, or lower depending on the comparator's design, than the threshold voltage. In the 555 IC, if the threshold pin input (pin 6) is higher than 2/3Vcc, the output of CP1 (upper comparator) goes high. When the trigger pin in put is lower than 1/3Vcc, then the output of CP2 (lower comparator) is high.

2. The RS Flip-Flop (Control F/F): The second segment of the 555 IC to analyze is the RS flip-flop. When the output of CP2 is high, and thus the output of CP1 is low, then the flip-flop has inputs, R=0 and S=1. This causes the output of the RS flip-flop to be high, or logic 1. Thus, the inverted output of the flip-flop will be logic 0, or low. When the output of CP1 is high, and thus the output of CP2 is low, then the flip- flop has the inputs, R=1 and S=0. This causes the output of the RS flip-flop to be logic 0 and the inverted output of the flip-flop to be logic 1.

3. The last input pin is pin 4, reset. The reset feature of the RS flip-flop is active low. Thus, when the input to the reset pin is low, the flipflop's output will be logic 0 and the inverted output will be logic 1. To disable the reset feature, the reset input of the flip-flop, and thus the reset pin of the 555 IC, should be tied high.

4. The Discharge Transistor (T1): The last aspect of the 555 IC to be analyzed is the discharge transistor. When the output of the flip-flop is high, and thus the inverted output is low, the transistor is off. Since, the transistor is connected to the inverted output of the flip-flop, when the inverted output is low the transistor is off because there is no current flowing in to the base of the transistor. When the output of the flip flop is low, and thus the inverted output of the flip-flop is high, the discharge transistor turns on and thus current flows in through the discharge pin (pin 7) and to ground through the discharge transistor.

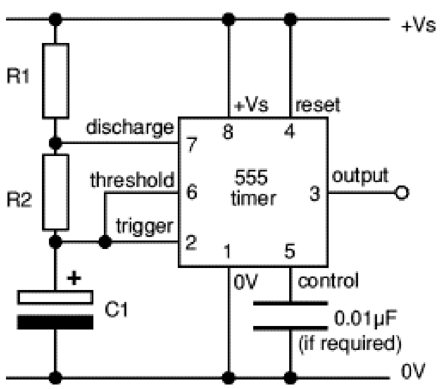
**MODES OF OPERATION:**

1. 555 Timer as astable multivibrator (Figure 7.1a): By adding two timing resistors $R_1$, $R_2$ and a capacitor $C_1$ to the 555 IC forms an astable multivibrator. An astable

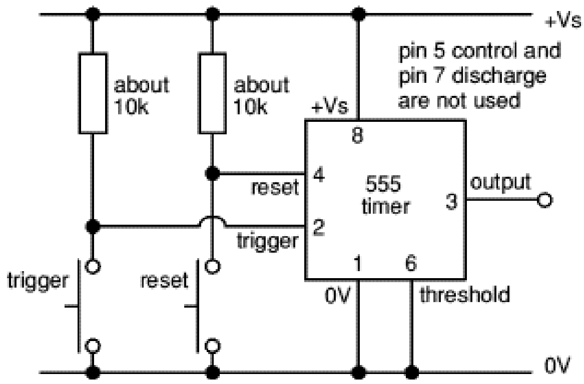
multivibrator is an oscillator that generates a square wave output. It is also called Free Running Mode of IC-555 Timer.

2. 555 timer as monostable multivibrator (Figure 7.1b): Monostable 555 timer multivibrator circuit (one shot monostable multivibrator) is a re-triggerable mono shot pulse generator. The name 'Mono stable' indicates that it has only one stable state. The unstable state is called 'Quasi stable state'.
3. 555 timer as bistable multivibrator (Figure 7.1c): A Bistable multivibrator is a type of circuit which has two stable states (high and low). It stays in the same state until and unless an external trigger input is applied.

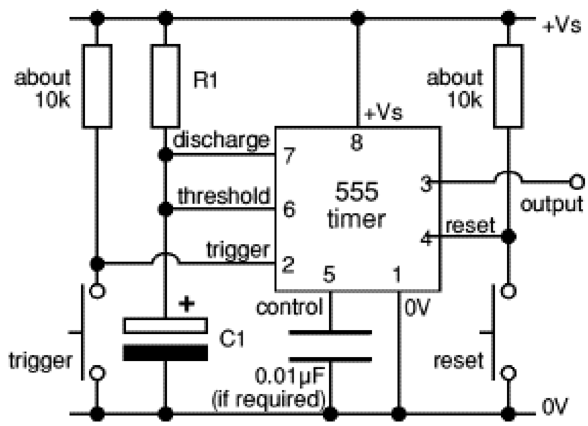
**CIRCUIT DIAGRAMS:**




**(a)**




(b)




**(c)**

**Figure 7.1: Pin Connections of 555 Timer (a) Astable mode (b) Bistable mode (c) Monostable mode**

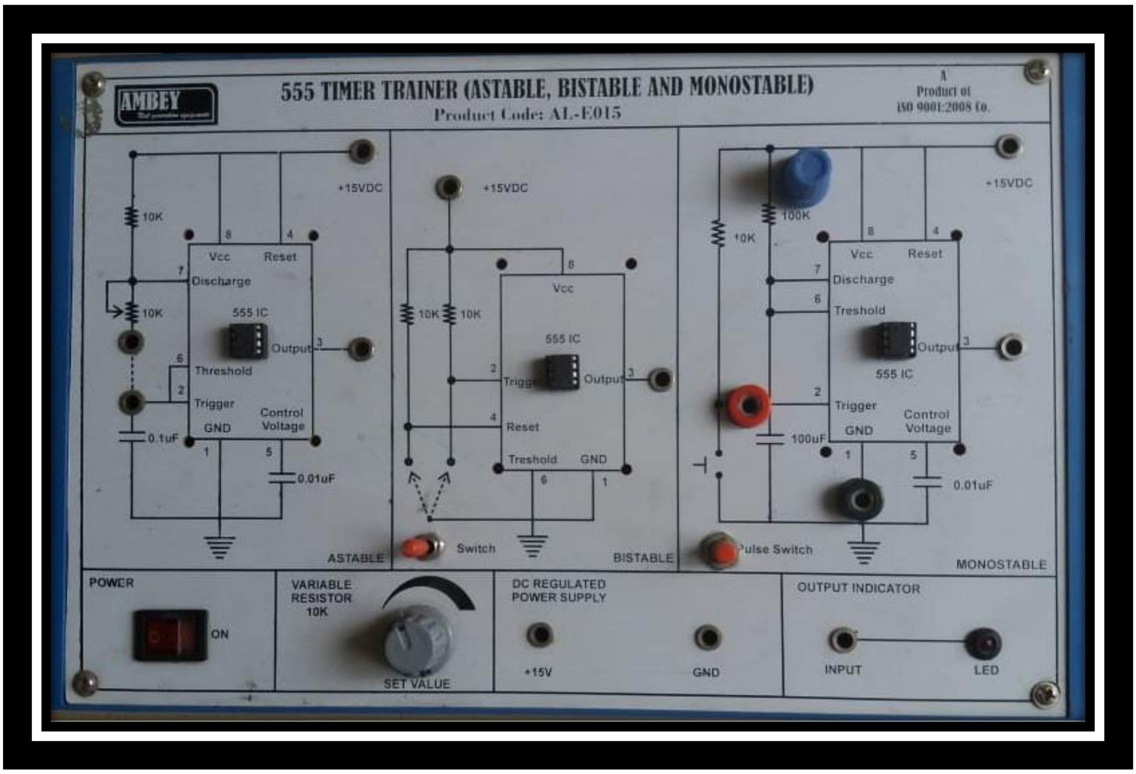



**Figure 7.2: Trainer Board for 555 Timer in Astable, Bistable and Monostable mode.**

**PROCEDURE:**

<u>For Astable mode of Operation:</u>

1. On the trainer board, as shown in Figure 7.2, the solid lines signify the connections already made; whereas dotted lines are used to indicate the connections which can be made using connecting wires.
2. Make the connection as shown in Figure 7.2 by connecting +15V DC supply with the regulated power supply and output Pin 3 with an LED input.
3. Now connect the discharge pin 7 with the trigger pin 2 by using connecting wire.
4. As soon as the connection is made, the output Pin 3 switches between logic 1 and logic 0. The LED connected to Pin 3 flashes “ON” and “OFF”.
5. Now adjust the variable resistor knob of 10K to change the blinking time of an LED.

<u>For Bistable mode of Operation:</u>

1. On the trainer board, as shown in Figure 7.2, the solid lines signify the connections already made; whereas dotted lines are used to indicate the connections which can be made using connecting wires.
2. Make the connection as shown in Figure 7.2 by connecting +15V DC supply with the regulated power supply and output Pin 3 with an LED input.

3. For bistable mode of operation, firstly slide the Toggle switch towards right (Trigger Pin 2) direction.
4. The Trigger (pin 2) gets connected and switches the output at logic “HIGH”. The LED connected at the output Pin 3 flashes to “ON” state.
5. Now, slide the Toggle switch towards left (RESET Pin 4) direction.
6. The RESET (Pin 4) gets connected and switches the output at logic “LOW”. The LED connected at the output Pin 3 goes to “OFF” state.

For Monostable mode of Operation:

1. Make the connection as shown in Figure 7.2 by connecting +15V DC supply with the regulated power supply and output Pin 3 with an LED input.
2. Press the “Pulse Switch”, it will trigger the Pin 2 which switches the output Pin 3 to logic “HIGH”, the LED connected at the output Pin 3 flashes to “ON” state.
3. Now, release the “Pulse Switch”, it will disconnect the Trigger Pin 2 and output switches to logic “LOW”, the LED connected at the output Pin 3 switches to “OFF” state.

**PRECAUTIONS:**

1. The connections should be neat and tight.
2. Do not switch ON the trained board without checking and verifying the connections.

**CONCLUSION:**

IC 555 timer has been studied as astable, monostable and bistable multivibrator.

1. In Astable mode, the LED was blinking continuously.
2. In bistable mode, it was manually made ON-OFF.
3. Whereas, in monostable mode, LED was made to glow infinite times (the glowing time depends upon the capacity of electrolytic capacitor)

**AIM:** Plot and analyze the V-I characteristics of Light Emitting Diode in forward biasing.

**APPARATUS:** LED characteristics Trainer kit with in-built Power supply (0 – 90V), Voltmeters (0 – 5V at 150mA), Ammeter (0 -150mA), Connecting Wires.

**THEORY:** A Light Emitting Diode (LED) is a semiconductor diode that emits light when an electric current is applied in forward direction of the device. LED lighting can be more versatile, efficient and long lasting as compare to compact fluorescent lightning.

**CIRCUIT DIAGRAM:**

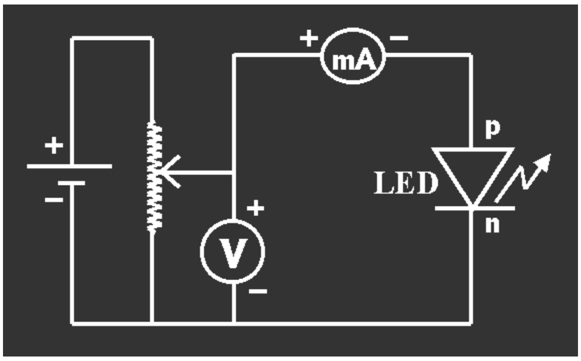



**Figure 8.1: Biasing of Light emitting diode**

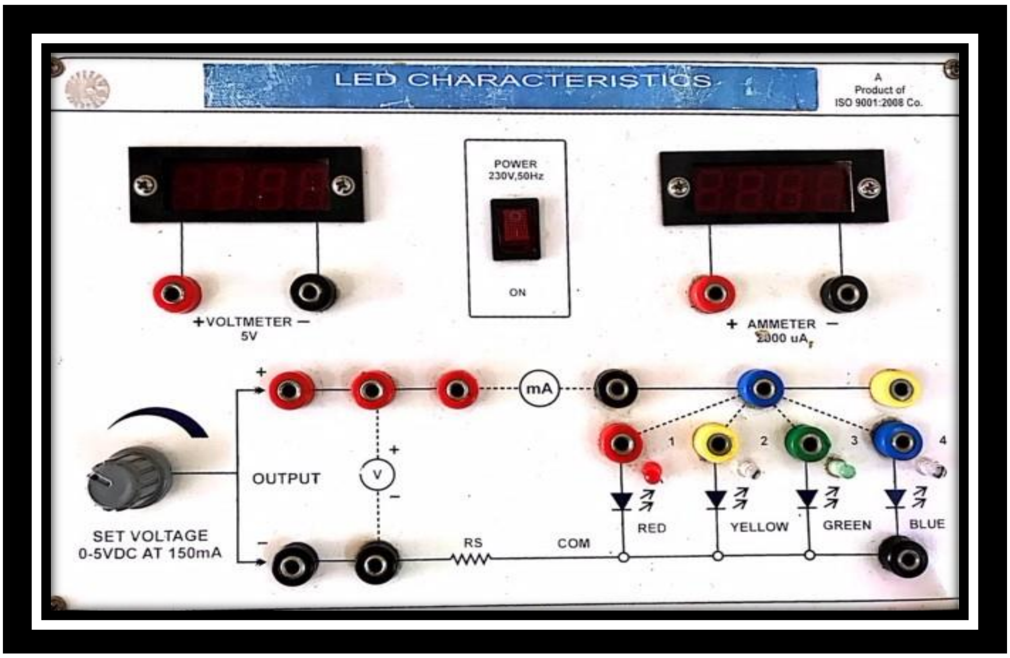



**Figure 8.2: Trainer kit of Light emitting diode**

**PROCEDURE:**

1. Make the connections as shown in the figure 8.1 on the trainer kit figure 8.2
2. Connect positive terminal of battery to p-type semiconductor & negative terminal to n-type semiconductor of a light emitting diode.
3. Keep the variable contact of the power supply towards minimum position i.e. anticlockwise.

4. Put the ON/OFF switch to 'ON' position. Jewel light will indicate the power supply is ON.
5. Now with the help of the variable contact of the power supply, starting from zero, increase DC voltage applied across the light emitted diode in small steps of about 0.1V. Note the voltmeter reading and corresponding reading of current.

**OBSERVATION TABLE:**

| Sr. No. | Forward voltage ($V_F$) (V) | Forward current ($I_F$) (mA) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

**OUTPUT CHARACTERISTICS:**

A curve plotted between voltage across the diode (V) and the current flowing through it (I) is called VI characteristics of a diode. This is known as response of a light emitting diode taking values of voltage along x-axis & the corresponding value of current along y-axis.

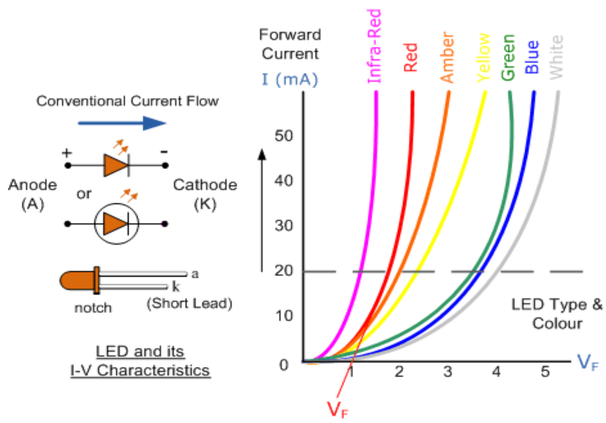



**Figure 8.3: Characteristics of LED**

**PRECAUTIONS:**

1. To avoid over heating of diode, current should not be passed for long durations.
2. Voltage applied should be well below the safety limit.
3. Connection should be made carefully and must be tight.

**CONCLUSION**:

1. The Curve shows that only a very small current flow through the diode during the initial stage till the potential barrier is wiped-off. Once the potential barrier is wiped-off, current rises quickly.
2. Knee Voltage of …….. colored LED is………

**AIM**: Plot and analyze V-I characteristics of Avalanche photo diode.

**APPARATUS:** Avalanche Photodiode Trainer kit, Light Source, Avalanche photo diode, connecting leads

**THEORY:**

Avalanche photodiode is a semiconductor device that converts light into current. The current is generated when photons are absorbed in the photodiode. A small amount of current is also produced when no light is present. This current is termed as the dark current of the photo diode. Photodiodes may contain optical filters, built-in lenses, and may have larger or small surface areas. These Photodiodes usually have a slower response time as their surface area increases. The common, traditional solar cell used to generate electric solar power is a large area photodiode. Photodiodes are similar to regular semiconductor diodes except that they may be either exposed (to detect vacuum UV or X-rays) or packaged with a window or optical fiber connection to allow light to reach the sensitive part of the device. A photodiode is designed to operate in reverse bias.

**PRINCIPLE OF OPERATION:** A photodiode is a p-n junction. When a photon of sufficient energy strikes the diode, it creates an electron-hole pair. This mechanism is also known as the inner photoelectric effect. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in electric field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photo current is produced. The total current through the photodiode is the sum of the dark current (current that is generated in the absence of light) and the photocurrent, so the dark current must be minimized to maximize the sensitivity of the device. A photo diode can turn on and off at a faster rate and so it is used as a fast acting switch. It can work in following modes:

- Photovoltaic mode: When used in zero bias or photovoltaic mode, the flow of photocurrent out of the device is restricted and a voltage builds up. This mode exploits the photovoltaic effect, which is the basis for solar cells – a traditional solar cell is just a large area photodiode.
- Photoconductive mode: In this mode the diode is often reverse biased (with the cathode driven positive with respect to the anode). This reduces the response time because the additional reverse bias increases the width of the depletion layer, which decreases the junction's capacitance. The reverse bias also increases the dark current without much change in the photocurrent. For a given spectral distribution, the photocurrent is linearly proportional to the luminance (and to the irradiance). Although this mode is faster, the photoconductive mode tends to exhibit more electronic noise.
- Other modes of operation: Avalanche photodiodes have a similar structure to regular photodiodes, but they are operated with much higher reverse bias. This allows each photo-generated carrier to be multiplied by avalanche breakdown, resulting in internal gain within the photodiode, which increases the effective response of the device.

**CIRCUIT DIAGRAM:**

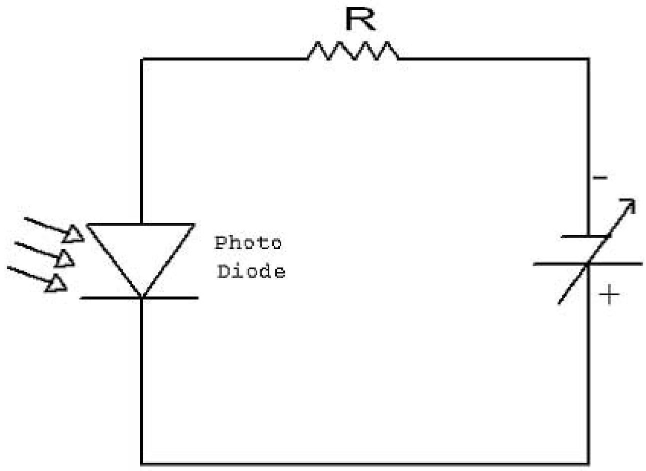



**Figure 9.1: Circuit of Photodiode**

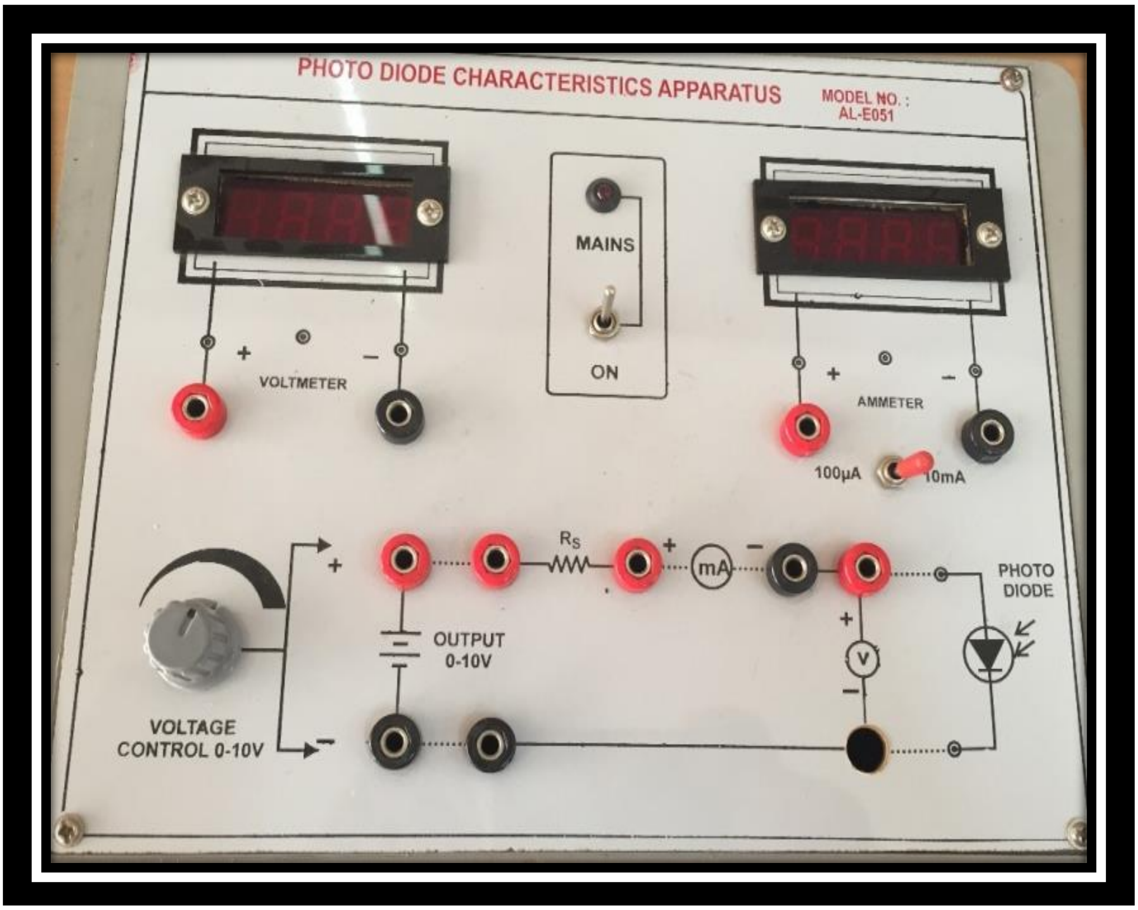



**Figure 9.2: Trainer Board for Photodiode characteristics**

**PROCEDURE:**

1. Rig up the circuit as per the connections in diagram as shown in figure 9.1.
2. Maintain a known distance (say 5 cm) between the DC bulb and the photo diode. Light intensity can be measured with the help of lux meter.
3. Set the voltage of the bulb with different lumens. Vary the voltage of the diode in steps of 1V and note down the corresponding diode current, $I_d$.
4. Note the photo diode always works in reverse bias condition.
5. Repeat the above procedure for the various lumen of DC bulb by varying the distance between photodiode and light source.
6. Plot the graph: $V_D$ vs $I_d$ for a constant intensity of the bulb.

**OBSERVATION TABLE:**

| S.No. | Voltage, $V_D$ (in V) | Current, $I_d$ (in mA) | Distance between light source and photodiode (in cm) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

**OUTPUT CHARECTERISTICS:**

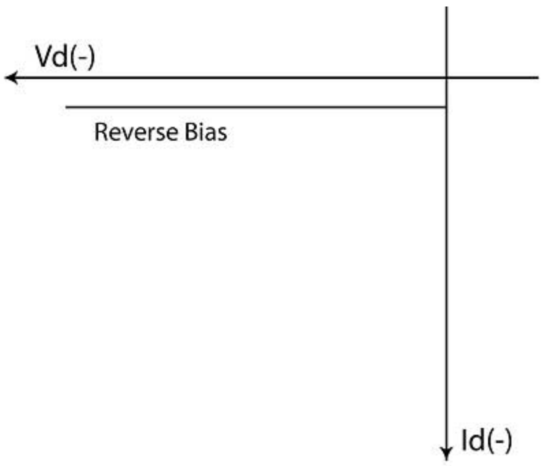



**Figure 9.3: Reverse biasing characteristics of Avalanche photodiode**

**PRECAUTIONS:**

1. The connections should be neat and tight.
2. Do not switch ON the trained board without checking and verifying the connections.

**CONCLUSION:**

The V-I characteristics of Avalanche photo-diode were studied under reverse bias conditions.

**AIM:** Plot and analyze V-I characteristics of PIN diode.

**APPARATUS:** PIN Photodiode Trainer kit, Connecting Wires

**THEORY:** A PIN photodiode is a semiconductor device that converts light into current. The current is generated when photons are absorbed in the photodiode. A small amount of current is also produced when no light is present, called dark current. Many diodes designed for use specifically as a photodiode use a PIN junction rather than a p-n junction, to increase the speed of response. A Pin photodiode is designed to operate in reverse bias. A PIN photodiode consists of an intrinsic layer of semiconductor in between p and n layers in its structure.

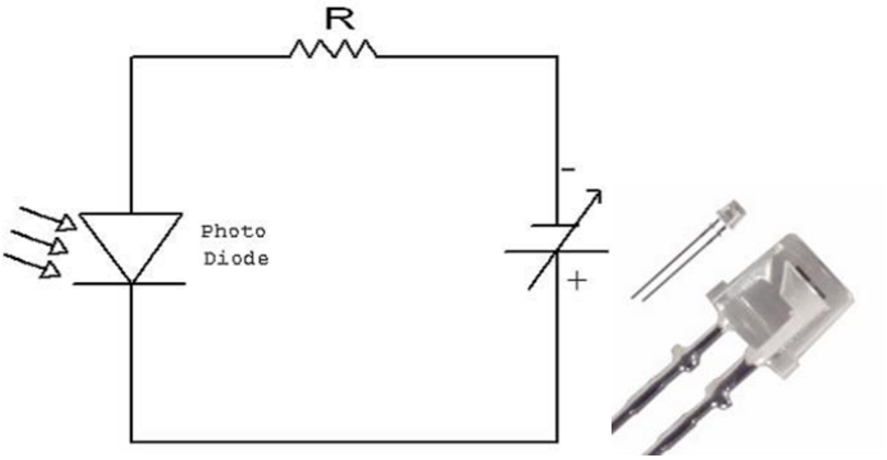



**Figure 10.1: Biasing of PIN photodiode and physical appearance**

**PRINCIPLE OF OPERATION:** When a photon of sufficient energy strikes the diode, it creates an electron-hole pair. This mechanism is also known as the inner photoelectric effect. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in electric field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photo current is produced. The total current through the photodiode is the sum of the dark current (current that is generated in the absence of light) and the photocurrent, so the dark current must be minimized to maximize the sensitivity of the device.

**PROCEDURE:**

1. Rig up the circuit as per the connections in diagram as shown in figure 10.1.
2. Maintain a known distance (say 5 cm) between the DC bulb and the photo diode. Light intensity can be measured with the help of lux meter.
3. Set the voltage of the bulb with different lumens. Vary the voltage of the diode in steps of 1V and note down the corresponding diode current, $I_d$.
4. Note the photo diode always works in reverse bias condition.
5. Repeat the above procedure for the various lumen of DC bulb by varying the distance between photodiode and light source.
6. Plot the graph: $V_D$ vs $I_d$ for a constant intensity of the bulb.

## Observation Table:

| S.No. | Voltage (in V) | Current (in mA) | Distance between light source and photodiode (in cm) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

## Output Characteristics:

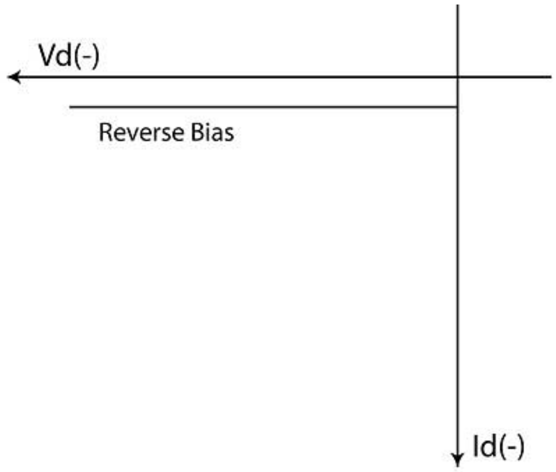



**Figure 10.2: Reverse biasing characteristics of PIN photodiode**

## CONCLUSION:

The V-I characteristics of P-I-N photo-diode were studied under reverse bias conditions.

**AIM:** Plot and analyze V-I characteristics of Varactor diode. Also plot the graph between applied reverse voltage (Vr) and capacitance (C).

**APPARATUS:** Varactor Diode Trainer Kit, Connecting wires.

**THEORY:**

Varactor Diode is a reverse biased p-n junction diode, whose capacitance can be varied electrically. As a result, these diodes are also referred to as varicaps, tuning diodes, voltage variable capacitor diodes, parametric diodes, parametric diodes and variable capacitor diodes. It is well known that the operation of the p-n junction depends on the bias applied which can be either forward or reverse in characteristic. It is also observed that the span of the depletion region in the p-n junction decreases as the voltage increases in case of forward bias.

On the other hand, the width of the depletion region is seen to increase with an increase in the applied voltage for the reverse bias scenario. Under such condition, the p-n junction can be considered to be analogous to a capacitor where the p and n layers represent the two plates of the capacitor while the depletion region acts as a dielectric separating them.

Hence, mathematical expression for the capacitance of varactor diode is given by: $C_j = \varepsilon A/d$, where $C_j$ is the total capacitance of the junction. $\varepsilon$ is the permittivity of the semiconductor material. A is the cross-sectional area of the junction. d is the width of the depletion region.

Further the relationship between the capacitance and the reverse bias voltage is given as: $C_j = CK/(V_b - V_R)m$, where: $C_j$ is the capacitance of the varactor diode. C is the capacitance of the varactor diode when unbiased. K is the constant, often considered to be 1. $V_b$ is the barrier potential. $V_R$ is the applied reverse voltage. m is the material dependent constant.

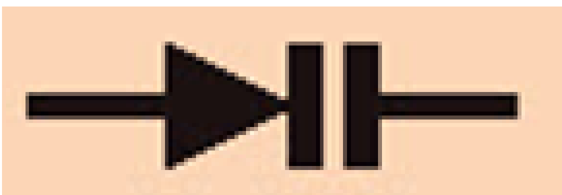


**Figure 11.1: Symbol of Varactor diode**

**CIRCUIT DIAGRAM:**

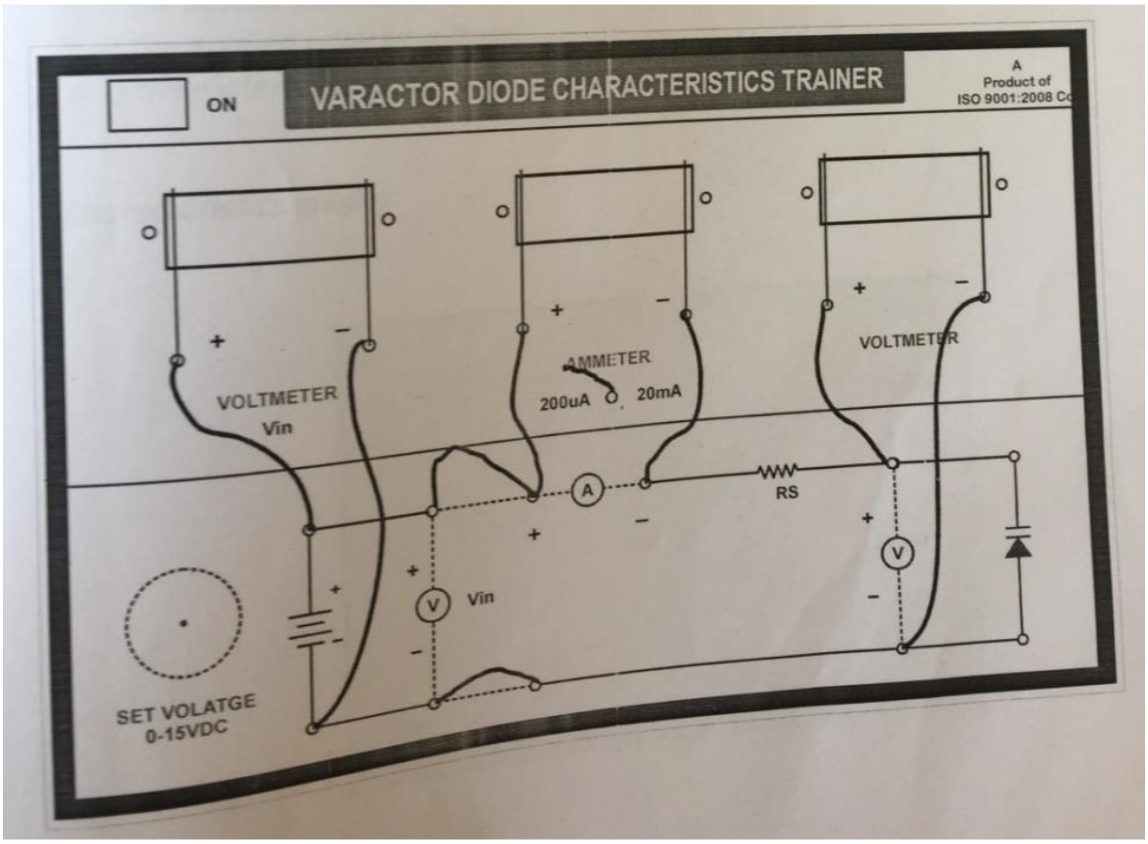



**Figure 11.2: Biasing of Varactor diode**

**PROCEDURE:**

1. On the trainer board, as shown in Figure 11.2, the solid lines signify the connections already made; whereas dotted lines are used to indicate the connections which can be made using connecting wires.
2. Make the connection as shown in figure 11.2. Connect two inbuilt voltmeters (Vin and V) and one inbuilt Ammeter (A) in the circuit with the help of connecting wire.
3. As varactor diode works in reverse biased, so slowly vary the voltage (using voltage Knob 0-15 VDC) and corresponding to this input voltage, current in ammeter also varies in µA.
4. Cj is the capacitance of the varactor diode varies with reverse biased voltage.
5. Plot graph between Cj and $V_R$ (reverse biased voltage).
6. You can also check the diode characteristics in forward bias. For this, select ammeter range 20 mA.

**OBSERVATION TABLE:**

| Sr. No. | Reverse voltage ($V_R$) (Volts) | Reverse current ($I_R$) (mA) | Bias Voltage (V) (Volts) | Capacitance (Cj) (pf) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |

**OUTPUT CHARACTERISTICS:**

Plot a graph between voltage and current applied across the varactor diode, taking values of voltage along x-axis & the corresponding value of current along y-axis. Take the reverse voltage $V_R$ and reverse current $I_R$ along positive x-axis and y-axis respectively. The graph thus obtained for capacitance with respect to applied voltage is shown in figure 11.3.

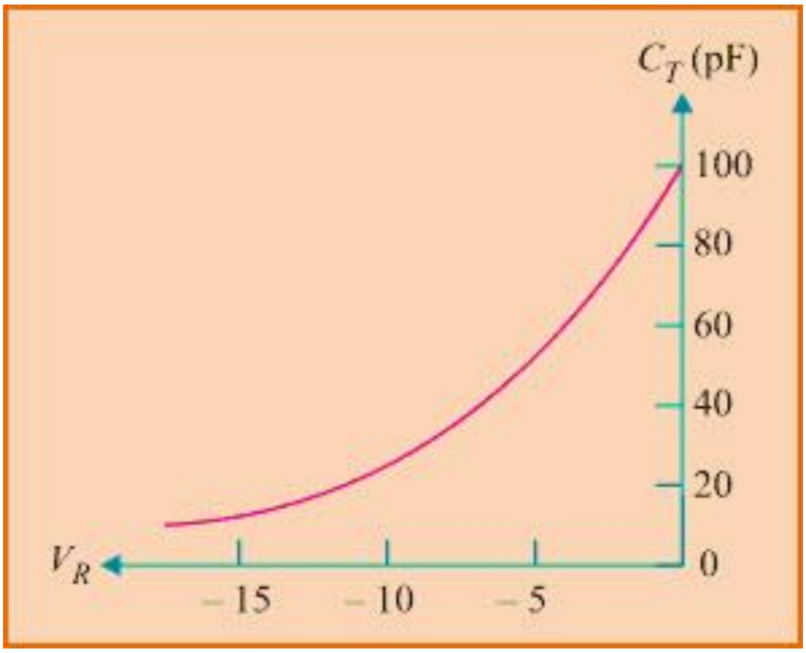



**Figure 12.3: Characteristics of Varactor Diode**

**CALCULATIONS:** Formula to be used is $\boldsymbol{Cj = \frac{Ck}{(Vr - V)^m}}$

(Consider value of k=1 and m =0.5 for given diode)

**PRECAUTIONS:**

1. To avoid over heating of diode, current should not be passed for long durations.
2. Voltage applied should be well below the safety limit.
3. Connection should be made carefully and must be tight.

**CONCLUSION**:

A graph is plotted between current, I and applied voltage, V; and V-I characteristics of Varactor diode are studied.