Unit- 8
Basic Electronics

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Content

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Semiconductor

- A semiconductor is a substance which has resistivity in between conductors and insulators.
- Examples:- Germanium, Silicon, Carbon etc.

Properties of semiconductor

1. The resistivity of a semiconductor is less than an insulator but more than a conductor.
2. Semiconductors have negative temperature coefficient of resistance.
3. When a suitable metallic impurity is added to a semiconductor, its current conducting properties change appreciably.

Intrinsic Semiconductor

- A semiconductor in an extremely pure form is know as intrinsic semiconductor.

Extrinsic Semiconductor

- The intrinsic semiconductor has a little current conduction capability at room temperature.
- To be useful in electronic devices, the pure semiconductor must be altered so as to significantly increase its conducting properties.
- This is achieved by adding a small amount of suitable impurity to a semiconductor.
- It is then called extrinsic semiconductor.

PN junction diode

- A PN junction is known as a semi-conductor or crystal diode.
- The property of a crystal diode to conduct current in one direction only permits it to be used as a rectifier.

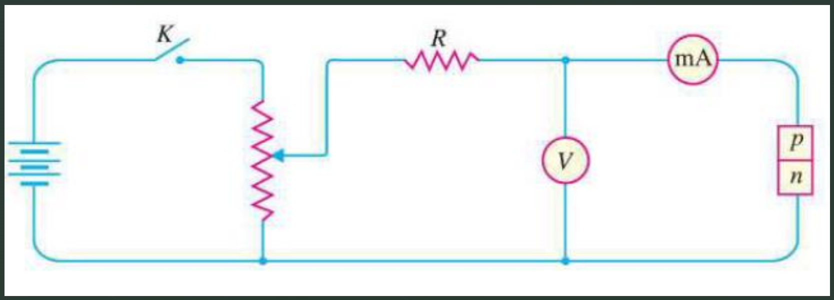
figure 1

- A crystal diode is usually represented by schematic symbol shown in figure 1.
- The arrow in the symbol indicates the direction of easier conventional current flow.

PN junction diode

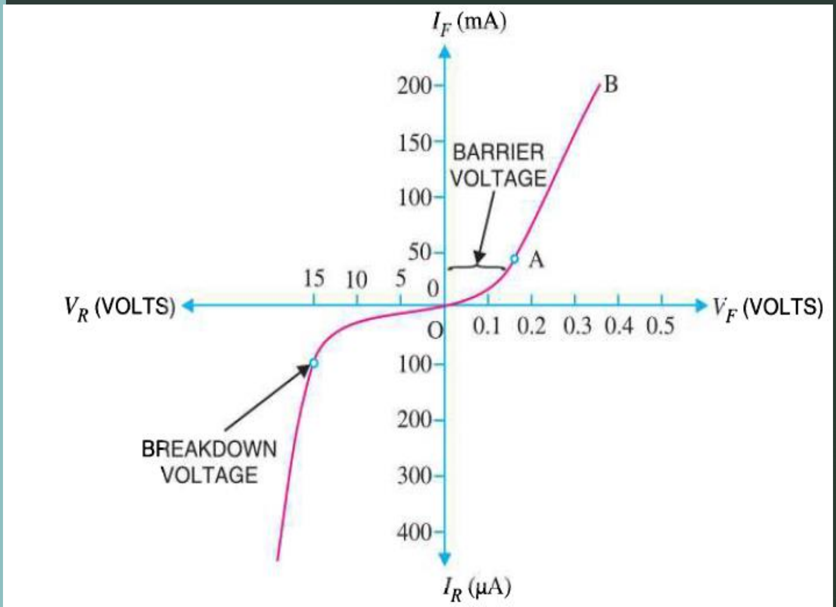
- A crystal diode has two terminals.
- When it is connected in a circuit, one thing to decide is whether the diode is forward or reverse biased.
- If the external circuit is trying to push the conventional current in the direction of arrow, the diode is forward biased.
- On the other hand, if the conventional current is trying to flow opposite to arrowhead, the diode is reverse biased.

V-I characteristics of PN junction diode



- The characteristics can be studied under three heads, namely: zero external voltage, forward bias and reverse bias.

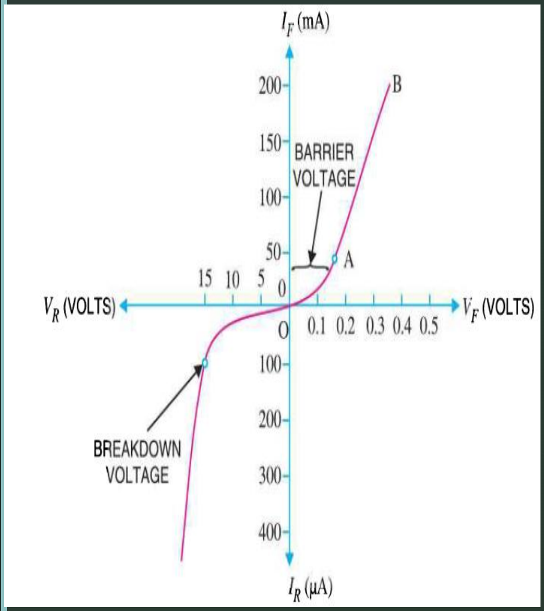
V-I characteristics of PN junction diode



1. Zero external voltage:-

- When the external voltage is zero, i.e. circuit is open at K, the potential barrier at the junction does not permit current flow.
- Therefore, the circuit is zero as indicated by point O in figure.

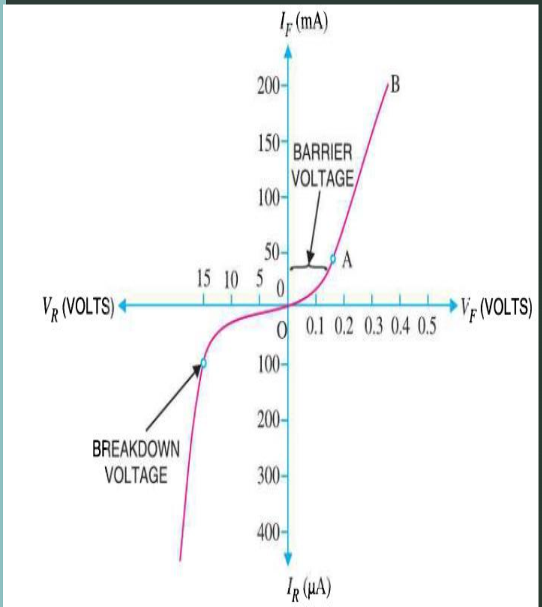
V-I characteristics of PN junction diode



2. Reverse bias:-

- With reverse bias to the pn junction, the potential barrier is increased.
- Therefore, the junction resistance becomes very high and practically no current flows through the circuit.
- However, in practice, a very small current flows in the circuit with reverse bias as shown in figure.
- This is called the reverse saturation current (Is) and is due to the minority carriers.
- If reverse voltage is increased continuously, the kinetic energy of electrons may become high enough to knock out electrons from the semiconductor atoms.
- At this stage breakdown of the junction occurs, characterised by a sudden rise of reverse current and a sudden fall of the resistance of barrier region.
- This may destroy the junction permanently.

V-I characteristics of PN junction diode

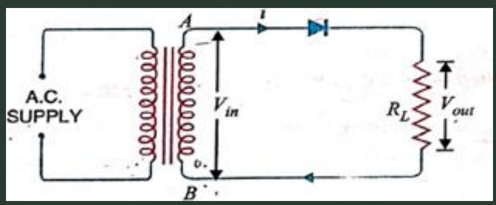


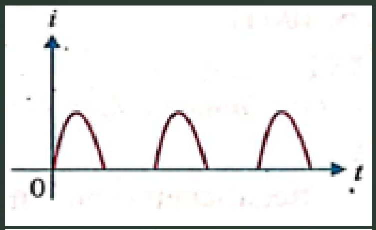
3. Forward bias:-

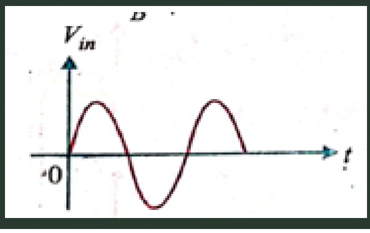
- With forward bias to the pn junction, the potential barrier is reduced.
- At some forward voltage, the potential barrier is altogether eliminated and current starts flowing in the circuit.
- From that, the current increases with the increase in forward voltage.
- Thus, a rising curve OB is obtained with forward bias as shown in figure.
- Form the forward characteristics, it is seen that at first (region OA), the current increases very slowly and the curve is non-linear.
- It is because the external applied voltage is used up in overcoming the potential barrier.

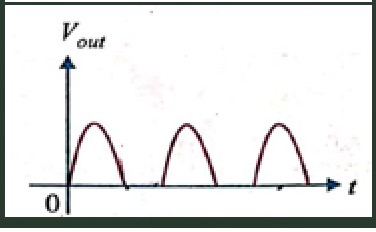
Half-wave rectifier

- In half-wave rectification, the rectifier conducts current only during the positive half-cycles of input a.c. supply.
- During negative half-cycles, no current is conducted and hence no voltage appears across the load.
- Therefore, current always flows in one direction through the load though after every half-cycle.







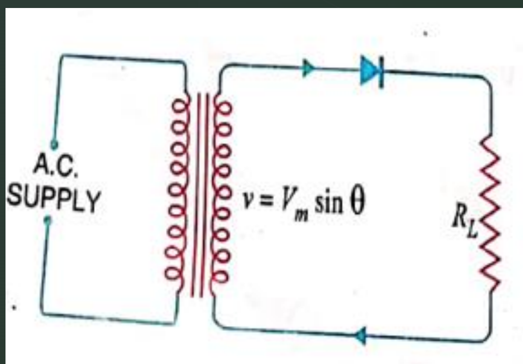


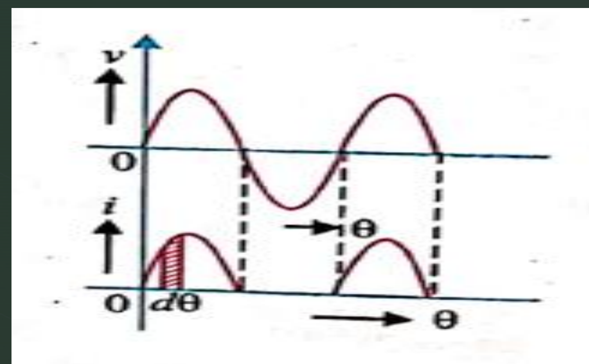
Disadvantages of Half- Wave Rectifier

1. The pulsating current in the load contains alternating component whose basic frequency is equal to the supply frequency. Therefore, an elaborate filtering is required to produce steady direct current.
2. The a.c. supply delivers power only half the time. Therefore, the output is low.

Efficiency of Half- Wave Rectifier

$$\text{Rectifier efficiency, } \eta = \frac{\text{d.c. power output}}{\text{Input a.c. power}}$$





D.C. Power:-

- The output current is pulsating direct current.

$$*I_{av} = I_{dc} = \frac{1}{2\pi}\int_0^{\pi} i\, d\theta = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L} d\theta$$

$$= \frac{V_m}{2\pi(r_f + R_L)}\int_0^{\pi} \sin\theta\, d\theta = \frac{V_m}{2\pi(r_f + R_L)}[-\cos\theta]_0^{\pi}$$

$$= \frac{V_m}{2\pi(r_f + R_L)} \times 2 = \frac{V_m}{(r_f + R_L)} \times \frac{1}{\pi}$$

$$= \frac{**I_m}{\pi} \qquad \left[\because I_m = \frac{V_m}{(r_f + R_L)}\right]$$

$$\text{d.c. power, } P_{dc} = I_{dc}^2 \times R_L = \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

A.C. Power:-

- The a.c. power input is given by:

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

For a half-wave rectified wave, $I_{rms} = I_m/2$

$$P_{ac} = \left(\frac{I_m}{2}\right)^2 \times (r_f + R_L)$$

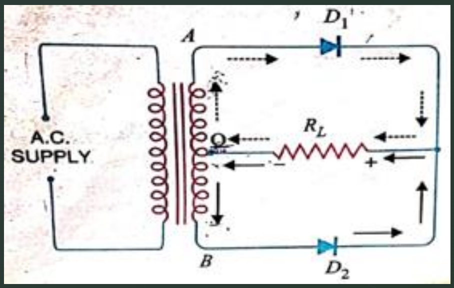
$$\text{Rectifier efficiency} = \frac{\text{d.c. output power}}{\text{a.c. input power}} = \frac{(I_m/\pi)^2 \times R_L}{(I_m/2)^2 (r_f + R_L)}$$

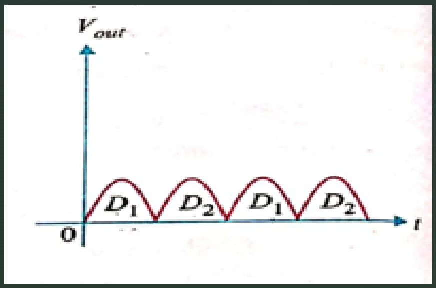
$$= \frac{0.406\, R_L}{r_f + R_L} = \frac{0.406}{1 + \frac{r_f}{R_L}}$$

The efficiency will be maximum if r_f is negligible as compared to R_L.

$\therefore$ Max. rectifier efficiency = 40.6%

Center-tap Full-wave rectifier

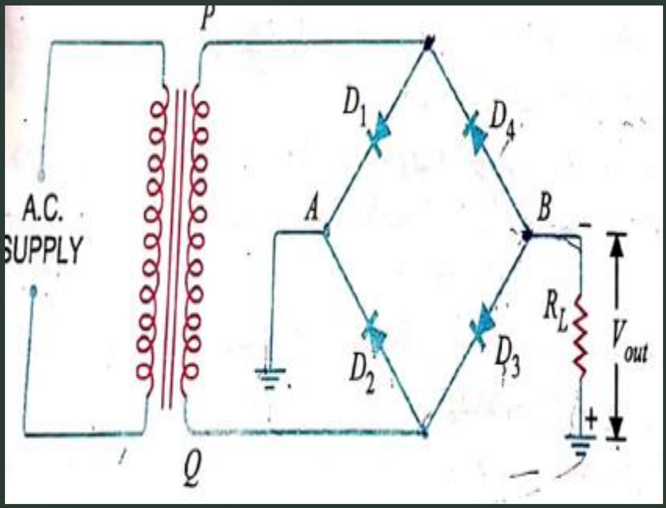


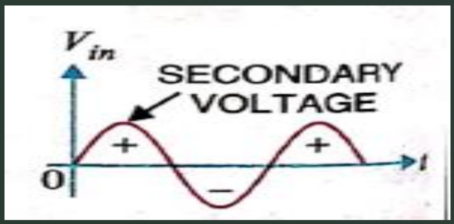


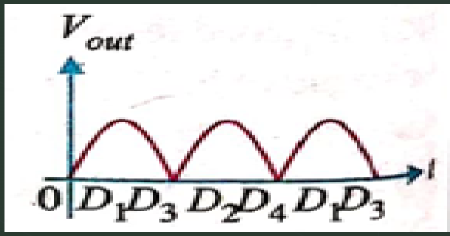
Disadvantages of Center-tap Full-wave Rectifier

1. It is difficult to locate center-tap o n the secondary winding.
2. The d.c. output is small as each diode utilise only one-half of the transformer secondary voltage.
3. The diode used must have high peak inverse voltage.

Full-wave bridge rectifier







Advantages of Full- Wave Bridge Rectifier

1. The need for center tap is eliminated.
2. The output is twice that of the center-tap circuit for the same secondary voltage.
3. The PIV is one-half that of the center-tap circuit.

Disadvantage of Full- Wave Bridge Rectifier

1. It requires four diodes.
2. As during each half-cycle of a.c. input two diodes that conduct are in series , therefore voltage drop in the internal resistance of the rectifying unit will be twice as great as in the center-tap circuit.

D.C. Power:-

- The output current is pulsating direct current.
- Therefore, in order to find d.c. power, average current has to be find out.

$$I_{dc} = \frac{2I_m}{\pi}$$

$$\therefore \quad \text{d.c. power output, } P_{dc} = I_{dc}^2 \times R_L = \left(\frac{2I_m}{\pi}\right)^2 \times R_L$$

A.C. Power:-

- The a.c. power input is given by:

$$P_{ac} = I_{rms}^2 (r_f + R_L)$$

For a full-wave rectified wave, we have,

$$I_{rms} = I_m / \sqrt{2}$$

$$\therefore \quad P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)$$

$\therefore$ Full-wave rectification efficiency is

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(2 I_m / \pi)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)} = \frac{8}{\pi^2} \times \frac{R_L}{(r_f + R_L)} = \frac{0.812 R_L}{r_f + R_L} = \frac{0.812}{1 + \frac{r_f}{R_L}}$$

The efficiency will be maximum if r_f is negligible as compared to R_L.

$\therefore$ Maximum efficiency $= 81.2\%$

This is double the efficiency due to half-wave rectifier. Therefore, a full-wave rectifier is twice as effective as a half-wave rectifier.

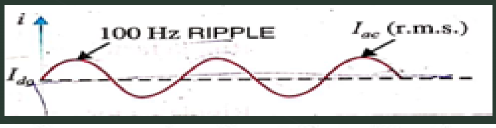
Ripple Factor

- The output of a rectifier consists of a d.c. component and an a.c. component known as ripple factor.
- The a.c. component is undesirable and accounts for the pulsations in the rectifier output.
- The effectiveness of a rectifier depends upon the magnitude of a a.c. component in the output: the smaller this component, the more effective is the rectifier.
- The ratio of r.m.s value of a.c. component to the d.c. component in the rectifier output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{r.m.s. value of a.c component}}{\text{value of d.c. component}} = \frac{I_{ac}}{I_{dc}}$$

Mathematical Analysis

- The output of a rectifier contains d.c. as well as a.c. components.
- The undesired a.c. component has a frequency of 100 Hz and is called the ripple.
- It is fluctuation superimposed on the d.c. component.



By definition, the effective (*i.e.* r.m.s.) value of total load current is given

$$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

or

$$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

Dividing throughout by I_{dc}, we get,

$$\frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2}$$

But I_{ac}/I_{dc} is the ripple factor.

$$\therefore \quad \text{Ripple factor} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

(*i*) **For half-wave rectification.** In half-wave rectification,

$$I_{rms} = I_m/2 \quad ; \quad I_{dc} = I_m/\pi$$

$$\text{Ripple factor} = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} = 1.21$$

(*ii*) **For full-wave rectification.** In full-wave rectification,

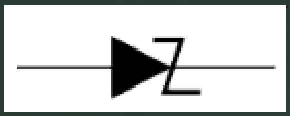
$$I_{rms} = \frac{I_m}{\sqrt{2}} \quad ; \quad I_{dc} = \frac{2\,I_m}{\pi}$$

$$\therefore \quad \text{Ripple factor} = \sqrt{\left(\frac{I_m/\sqrt{2}}{2\,I_m/\pi}\right)^2 - 1} = 0.48$$

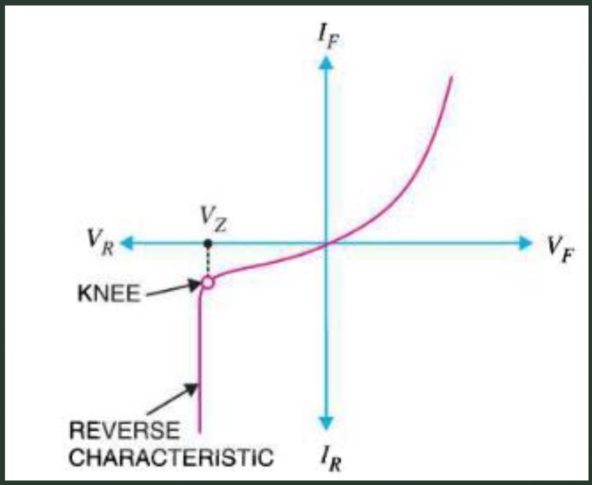
- This shows that in the output of a full-wave rectifier, the d.c. component more than the a.c. component.

Zener Diode

- A properly doped crystal diode which has a sharp breakdown voltage is know as a Zener diode.
- Figure shows the symbol of a Zener diode.



- It may be seen that the bar is turned into z-shape.



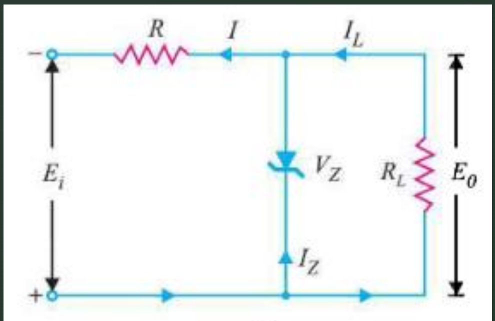
Zener Diode

- The following points may be noted about the Zener diode.

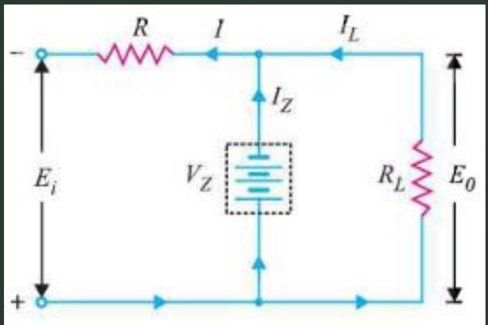
1. A Zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage.
2. A Zener diode is always reverse connected i.e. it is always reverse biased.
3. A Zener diode has sharp breakdown voltage, called Zener voltage Vz.
4. The Zener diode is not immediately burnt just because it has entered the breakdown region.

Zener Diode as Voltage Stabiliser

- 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 figure (i).
- The Zener diode of Zener voltage Vz is reverse connected across the load RL across which constant output is desired.



(i)



(ii)

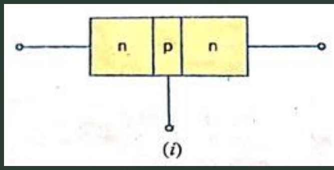
- The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across load.
- It may be noted that the Zener will maintain a constant voltage Vz across the load so long as the input voltage does not fall below Vz.
- When the circuit is properly designed, the load voltage Eo remains essentially constant even though the input voltage Ei and load resistance RL may vary over a wide range.
- Suppose the input voltage increases. Since the Zener is in the breakdown region, the Zener diode is equivalent to a battery Vz as shown in figure.
- The excess voltage is dropped across the series resistance R.
- This 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.

Transistor

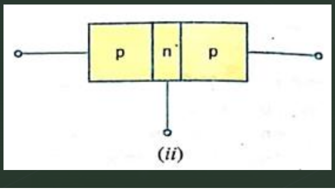
- A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.
- Accordingly, there are two types of transistors, namely:

1. n-p-n transistor
2. p-n-p transistor

- An n-p-n transistor is composed of two n-type semiconductors separated by a thin section of p- type as shown in Fig (i).



- However, a p-n-p transistor is formed by two p-sections separated by a thin section of n-type as shown in Fig (ii).

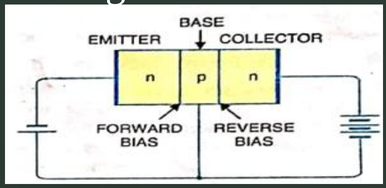


Transistor Terminology

1. Emitter:- The section on one side that supplies charge carriers (electrons or hole) is called the emitter.

- The emitter is always forward biased w.r.t base so that it can supply a large number of majority carriers.

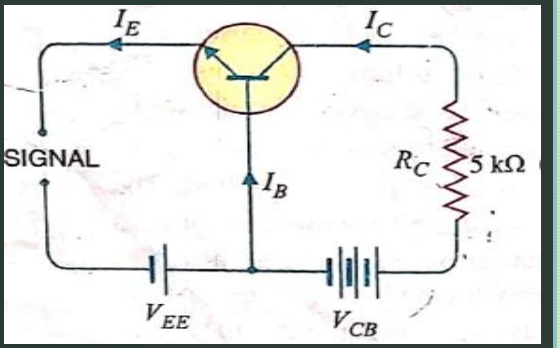
2. Collector:- The section on the other side that collects the charges is called the collector.



- The collector is always reverse biased.
- Its function is to remove charges from its junction with the base.

3. Base:- The middle section which forms two pn-junctions between the emitter and collector is called the base.

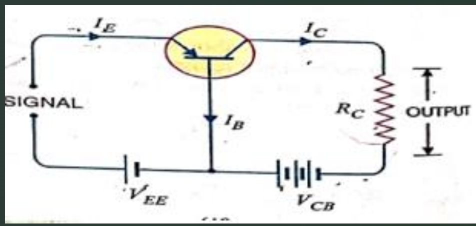
Transistor circuit as an Amplifier

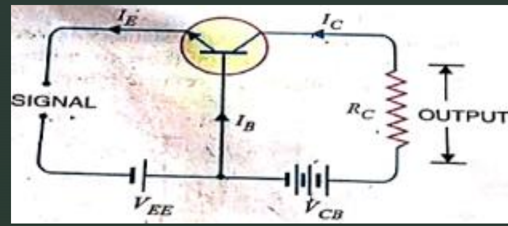


- A transistor raises the strength of a weak signal and thus acts as an amplifier.
- Figure shows the basic circuit of a transistor amplifier.
- The weak signal is applied between emitter-base junction and output is taken across the load Rc.
- In order to achieve faithful amplification, the input circuit should always remain forward biased.
- To do so, a d.c. voltage V_{EE} is applied in the input circuit in addition to the signal as shown.

- This d.c. voltage is know as bias voltage and its magnitude is such that it always keeps the input circuit forward biased regardless of the polarity of the signal.
- As the input circuit has low resistance, therefore, a small change in signal voltage causes an appreciable change in emitter current.
- This causes almost the same change in collector current due to transistor action.
- The collector current flowing through a high load resistance Rc produces a large voltage across it.
- Thus, a week signal applied in the input circuit appears in the amplified from in the collector circuit.
- It is in this way that a transistor acts as a amplifier.

Common Base Connection





1. Current amplification factor (α):- It is the ratio of output current to input current.

- In a common base connection, the input current is the emitter current I_E and output current is the collector current I_C.
- The ratio of change in collector current to the change in emitter current at constant collector base voltage V_{CB} is know as current amplification factor

$$^*\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

2. Expression for collector current:- The whole of emitter current does not reach the collector.

- It is because a small percentage of it, as a result of electron- hole combinations occurring in base area, gives rise to base current.
- Moreover, as the collector-base junction is reverse biased, therefore, some leakage current flows due to minority carriers.
- Therefore, total collector current consists of

i. That part of emitter current which reaches the collector terminal αI_E.

ii. The leakage current $I_{leakage}$. This current is due to the movement of minority carriers across base-collector junction on account of it being reverse biased.

$$\text{Total collector current, } I_C = \alpha I_E + I_{leakage}$$

- It is clear that if $I_E=0$, a small leakage current still flows in the collector circuit.
- This $I_{leakage}$ is abbreviated as I_{CBO}, meaning collector-base current with emitter open.

$$I_C = \alpha I_E + I_{CBO}$$

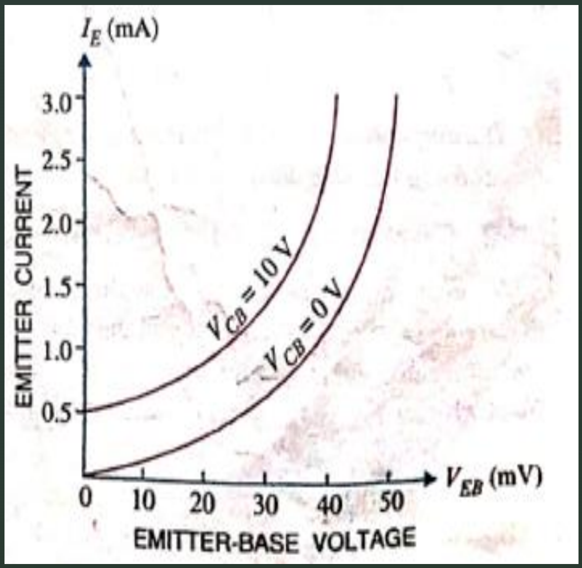
$$I_E = I_C + I_B$$

$$I_C = \alpha (I_C + I_B) + I_{CBO}$$

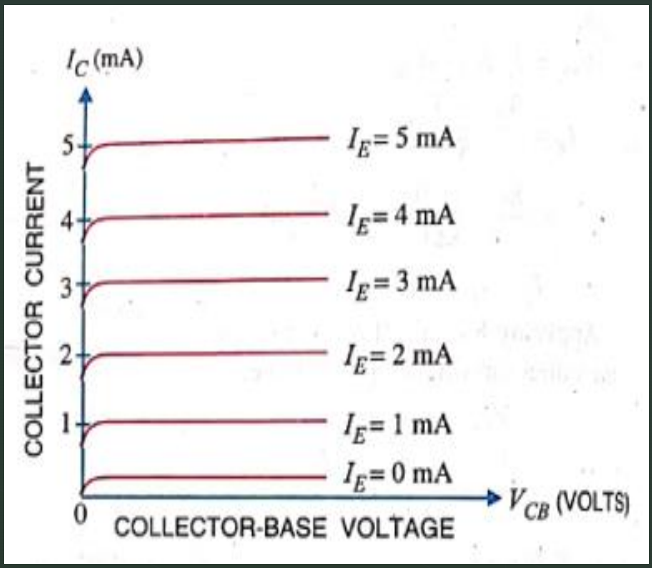
$$I_C (1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

Characteristics of Common Base Connection

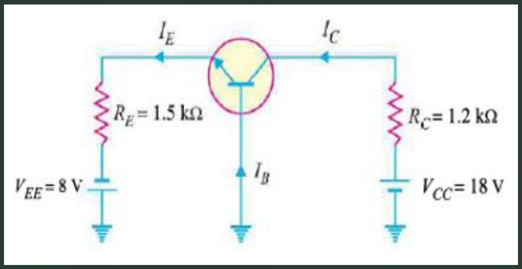


Input Characteristics



Output Characteristics

Example: For common base circuit shown in Figure. Determine IC and VCB. Assume transistor to be of silicon.



Since the transistor is of silicon, VBE= 0.7V.

Applying KVL, to the emitter side loop, $V_{EE} = I_E R_E + V_{BE}$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = \frac{8V - 0.7V}{1.5\ \text{k}\Omega} = 4.87\ \text{mA}$$

$$\therefore\quad I_C \simeq I_E = \mathbf{4.87\ mA}$$

Applying KVL, to the collector side loop,

$$\begin{aligned} V_{CC} &= I_C R_C + V_{CB} \\ \therefore\quad V_{CB} &= V_{CC} - I_C R_C \\ &= 18\ \text{V} - 4.87\ \text{mA} \times 1.2\ \text{k}\Omega = \mathbf{12.16\ V} \end{aligned}$$

Thank you