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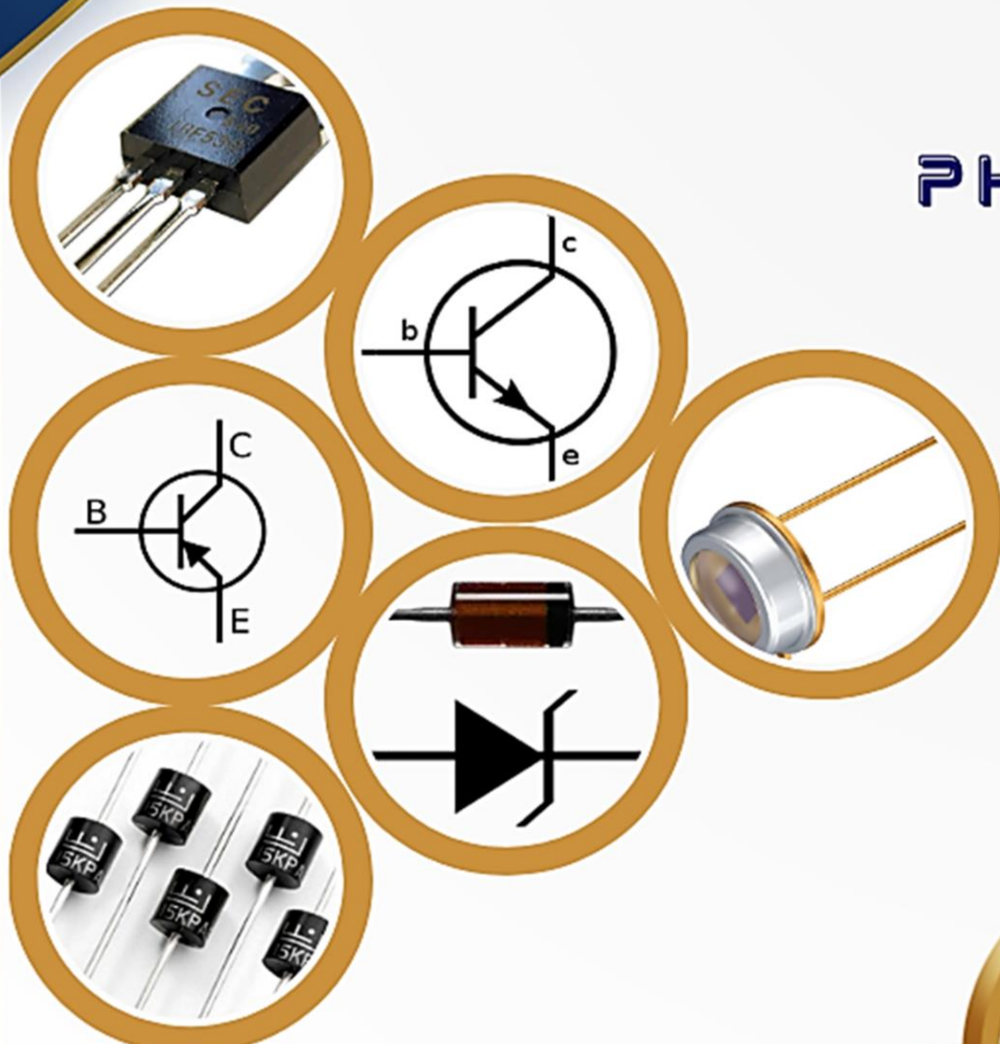

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P-N Junction

When a *p-type* semiconductor is brought into a close contact with *n-type* semiconductor crystal, the resulting arrangement is called a **p-n junction** or **junction diode**.

☞ **In the p-type semiconductor, the holes are majority carriers and electrons are minority carriers whereas in n-type semiconductor, the electrons are majority carriers and holes are minority carriers.**

➤ Formation of p-n junction:

(i) To make a p-n junction, the **n-type** and **p-type** silicon crystals are cut into thin slices called **wafers**. If on a wafer of *n* type silicon, an aluminium film is placed and heated to a high temperature, say 580° C, aluminium diffuses into silicon. In this way, a *p*-type semiconductor is formed on an *n*-type semiconductor. **Such a formation of *p*-region on *n*-region is called *p-n* junction.**

ii] Another way to make a *p-n* junction is by diffusion of phosphorous into a *p*-type semiconductor. The wafer of which a *p-n* junction is formed is cut into small pieces. Each piece is enclosed in a casing with electric connections coming out from *p* and *n* regions.

Depletion region and Barrier electric field in p-n junction:

On account of difference in concentration of charge carries in the two sections of p-n junction, the electrons from n-region diffuse through the junction into p-region and the holes from p-region diffuse into n-region.

• •Since the hole is a vacancy of an electron, when an electron from n- region diffuses into the p-region, the electron falls into the vacancy i.e. it completes the covalent bond. (This process is **called electron-hole recombination**). Due to migration of charge carriers across the junction, the n-region of the junction will have its electrons neutralised by holes from the p-region*, leaving only ionised donor atoms (positive charges) which are bound and cannot move*. Similarity, *the p-region of the junction will have ionised acceptor atoms (negative charges) which are immobile*.

The accumulation of electric charges of opposite polarities in the two regions of the junction gives rise to an electric field between these regions as if a fictitious battery is connected across the junction with its positive terminal connected to n-region and negative terminal connected to p-region.

The **strength of electric field** across the junction increases with the migration of more charge carriers across the junction. **This electric field opposes further flow of electrons from the n-region to the p-region and that of holes from the p-region to n-region.**

• • This electric field sets **a potential barrier V_B** at the junction which **opposes further diffusion of free charge carriers into opposite regions.** In the junction, a region is created, which is devoid of free charge carriers and has immobile ions. *This region in which no free charge carriers are available is called a depletion* region Fig. 1(a).

Fig. 1(b) represents the **potential distribution near the junction**. This potential acts as a barrier, hence known as **potential barrier**.

☞ A room temperature of 300 K, V_B is about 0.3 V for Ge and 0.7 V for Si. Infect, ***the value of V_B depends on doping impurity, nature of semiconductor and temperature.***

☞ The value of V_B decreases with rise in temperature of Ge and Si.

This barrier voltage stops the diffusion of majority charge carriers from p to n region and vice versa.

☞ *Due to presence of potential barrier V_B across the junction, an electron from n-region requires the energy eV_B to cross the junction. An equal amount of energy is required to move a hole, from p-region to n-region.*

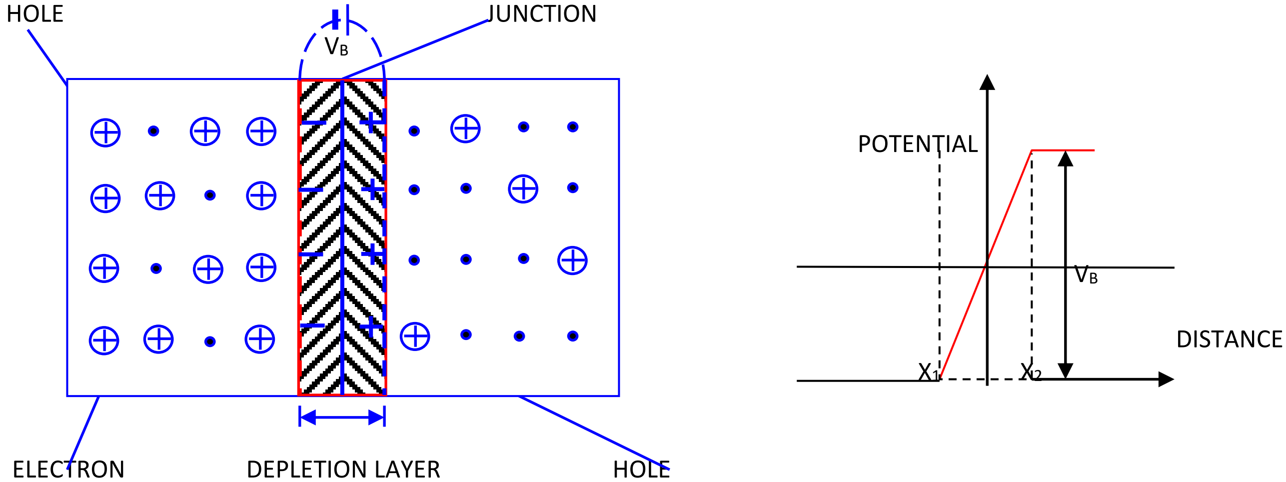


Fig 1(a) **(b)**

◈ The *width of the depletion layer* and *the magnitude of the barrier potential* depend on the nature of semiconductor and doping concentration on the two sides of *p-n* junction.

Explanation: If the doping concentration in *n*-type and *p*-type semiconductor forming *p*-*n* junction is small, the diffusing electrons and holes across the junction can move to quite large distances before suffering a collision with another hole or electron to be recombined. Due to which the width of *p*-*n* junction is large and junction field is small.

On the other hand, if the doping concentration in *n*-type and *p*-type semiconductor forming *p*-*n* junction is large, the width of *p*-*n* junction would be small and junction field would be large. It means the *p*-*n* junction will show different behaviour by changing the doping levels on both the sides.

The width of the depletion region is about 10^{-6} m. Thus, the barrier electric field E for silicon *p*-*n* junction is

$$E = \frac{V}{d} = \frac{0.7}{10^{-6}} = 7 \times 10^{5}\ \text{Vm}^{-1}$$

This is very high.

◈(1) The *p*-*n* junction can be considered to be equivalent to a capacitor with *p* and *n*-region acting as the plates of a capacitor and depletion region as the dielectric medium.

◈(2) Symbolically, a *p*-*n* junction is shown in Fig. 2. The direction of the arrow is from the p to the n-side. The *p*-side is known as anode and *n*-side is known as cathode.

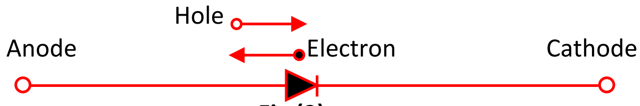


Fig (2)

◈(3) We cannot measure the potential barrier of *p*-*n* junction by putting a sensitive voltmeter across its terminals because there are no free electrons or holes in the depletion layer and in the absence of forward biasing, the depletion layer offers infinite resistance.

Biasing of the P-N Junction

There are two methods of biasing the p-n junction.

(i) Forward biasing: A *p*-*n* junction is said to be forward biased if the positive terminal of the external battery *B* is connected to *p*-side and the negative terminal to the *n*-side of *p*-n junction .Fig. 3 (a). The circuit diagram for forward biasing of *p*-*n* junction is shown if Fig. 3(b).

In forward biasing, the forward bias voltage opposes the potential barrier V_B. **Due to it, the potential barrier is considerably reduced *and the depletion region becomes thin*.** The majority carriers, electron in the n-region are **repelled** by the *negative potential due to battery B and move towards the p-n junction*. Similarly, the **majority carriers, holes** in the *p*-region are **repelled** by the *positive potential, towards the junction*.

◈ The positive potential of *p*-region attracts the electrons from the *n*-region and negative potential of *n*-region attracts the holes from the p-region. On crossing the junction, the number of the electrons and holes will combine with each other. ***For each electron hole combination, a covalent bond near the positive terminal of the battery is broken and the liberated electron enters the positive terminal of the battery B through lead wires.*** This action results in a new hole, which under the force of applied voltage moves towards the *p*-*n* junction. At the other end, the electrons from the negative terminal of the battery enters the *n*-region to replace the electrons lost due to the combination with the holes at the junction. Thus, an electric current will flow due to **migration of majority carriers across the *p*-*n* junction**; which is called forward current. Since the small increase in forward voltage shows the large increase in forward current, hence the **resistance of *p*-*n* junction is low to the flow of current when forward biased.**

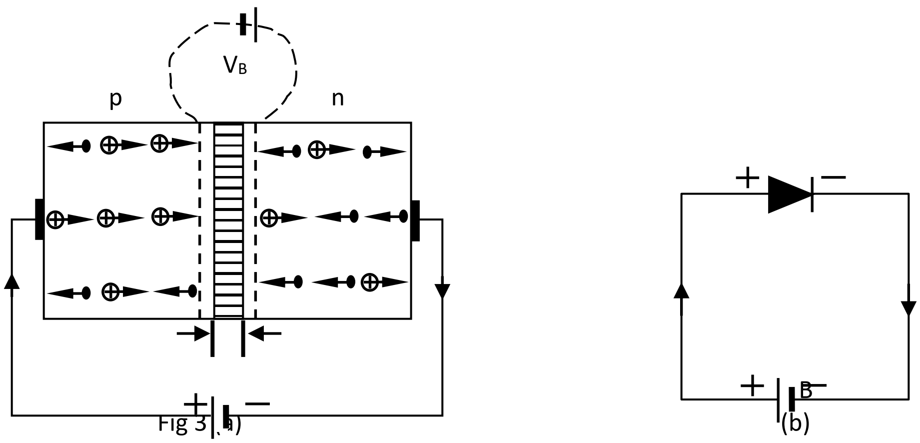


Fig 3(a) (b)

(ii) **Reverse biasing**: **A *p-n* junction is said to be reverse biased if the positive terminal of the external battery B is connected to *n*-side and the negative terminal to *p*-side of the *p-n* junction**,

☞In reverse biasing, **the reverse bias voltage supports the potential barrier V_B**. Now the majority carriers are pulled away from the junction and the **depletion region becomes thick**. There is no conduction across the junction due to majority carriers. However, a few minority carriers (holes in *n*-section and electrons in p-section) of *p-n* junction diode cross the junction after being accelerated by high reverse bias voltage. They constitute a current that flows in the opposite direction. This is called **reverse current or leakage current**.

Since the large increase in reverse voltage shows small increase in reverse current, hence the **resistance of *p-n* junction is high to the flow of current when reverse biased**.

- Potential barrier opposes the forward current and supports the reverse current.
- The voltage of external battery for forward biasing is low (about 1.5 V) and for reverse biasing is high (10 to 25 V).
- (1) In germanium diode, the ratio of reverse to forward resistance is 40000 : 1, while for silicon, this ratio is 10^6 : 1.
- (2) If *p-n* junction there is a diffusion of majority carriers across the junction in forward biasing and drifting of charge carriers in reverse biasing.

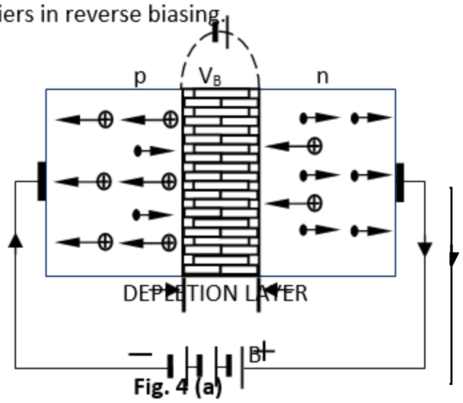
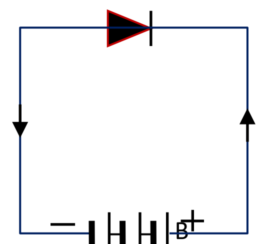


Fig. 4 (a)



(b)

Characteristics of a P-N Junction Diode

There are two types of characteristics of a *p-n* junction diode:

(i) Forward characteristics (ii) Reverse characteristics

(i) Forward characteristics: These are the graphical relations between forward bias voltage applied to *p-n* junction and the forward current through the *p-n* junction.

We connect the external battery *B* with potential dividing arrangement, to the *p-n* junction as shown in Fig. 5 (a), so that *p-n* junction is forward biased.

- For the given low forward bias voltage (noted from voltmeter *V*), note the corresponding forward current (from milliammeter *mA*), which is due to migration of majority carriers across the *p-n* junction. We Go on increasing the various values of forward bias voltage and note the corresponding forward currents. On plotting a graph between forward bias voltage and forward current, we get the **curve OAB**. This is the forward characteristics of the type shown in Fig. 5 (b). It is found that beyond forward voltage $V = Vk$, called ***KNEE VOLTAGE*** (which is 0.3 *V* for Ge and 0.7 *V* for *Si*) the conductivity is very high. It is at this [***KNEE VOLTAGE***]value of battery biasing for a *p-n* junction, that the potential barrier is overcome. Hence the current increases rapidly.
- If forward voltage is increased beyond a certain safe value, an extremely large current will be produced which may destroy the *p-n* junction diode due to overheating.
- Germanium *p-n* junction can tolerate a temperature around 100° C and silicon *p-n* junction can tolerate a temperature upto 170° C.

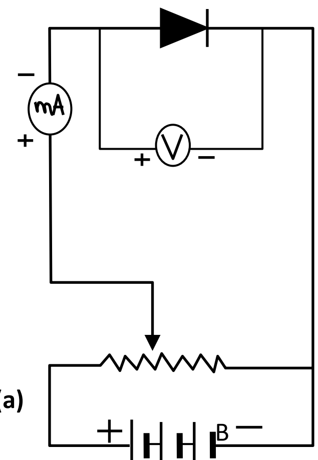
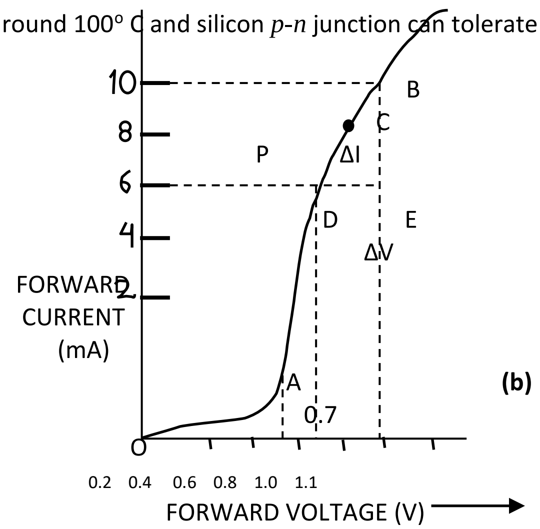


Fig 5(a)



(b)

Knee Voltage: *It is forward voltage beyond which the current through the junction starts increasing rapidly with voltage, showing the linear variation. But below the knee voltage the variation is non-linear.*

◈(ii) Reverse characteristics: These are the graphical relations between the reverse bias voltage applied to the p-n junction and the reverse current across the p-n junction.

We connect the external battery B with potential dividing arrangement to p-n junction as shown in Fig. 6 (a), so that p-n junction is reversing biased.

◈For the given small reverse bias voltage (noted from the voltmeter V) applied to the p-n junction, note the reverse current (from the micro-ammeter μA), which is due to migration to minority carriers across the p-n junction. We Go on increasing the reverse bias voltage and note the corresponding reverse current. On plotting a graph between reverse bias and reverse current, we get the reverse characteristics as shown in Fig. 6 (b). From the characteristic curve we note that in reverse biasing of p-n junction diode, the reverse current is very small (≈ μA) and almost remains constant with reverse bias voltage. It is called reverse saturation current. If the reverse bias voltage is equal to OB, the current through the p-n junction will increase abruptly. This reverse bias voltage is then known as breakdown voltage or Zener voltage.

In general purposes, the simple p-n junction diodes are never used beyond the reverse saturation current region; otherwise, they burnt out due to heavy currents.

The relation for the current I in the junction diode is given by

$$I = I_0\left(\exp\left(\frac{eV}{kT}\right) - 1\right) \qquad \text{Or,} \qquad I = I_0\,(e^{eV/kT} - 1)$$

Where k, Boltzmann constant, $k = 1.38 \times 10^{-23}\ J\ mol^{-1}\ K^{-1}$

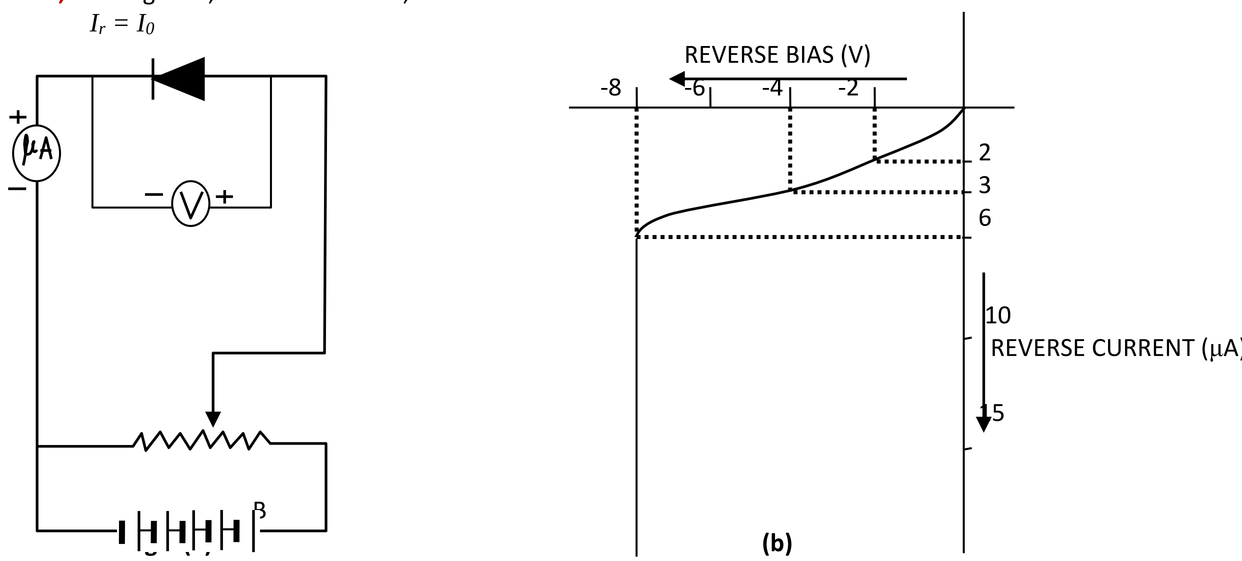
I_0 reverse saturation current.

In forward bias; V is positive and low then forward current,

$$I_f = I_0\,(e^{eV/kT} - 1)$$

In reverse bias; V is negative, so $e^{eV/kT} - 1 << 1$, then reverse current

$$I_r = I_0$$



Dynamic Resistance or A.C. Resistance of the Junction Diode

Dynamic resistance or a.c. resistance of junction diode or incremental resistance is defined as the ratio of a small change in voltage ΔV applied across the p-n junction to a small change in junction current ΔI i.e.

$$R_d = \frac{\Delta V}{\Delta I}$$

◈ In the forward characteristics of p-n junction diode, beyond the knee point, there is almost a linear region of the characteristics, showing that R_d is independent of V above the knee point. The value of R_d in forward bias beyond knee point is low (about few ohms) and is quite high (about mega ohm) in reverse bias.

◈◈ P-N Junction Diode as a Rectifier

Rectifier is a device which is used for converting alternating current/voltage into direct current/voltage. A p-n junction can be used as a rectifier in two ways: **(a) Half wave rectifier** **(b) Full wave rectifier**

◈ ◈ (a) P-N Junction diode as a half wave rectifier:

Principle: Its working is based on the fact that the ***resistance of p-n junction becomes low when forward biased and becomes high when reverse biased.***

Circuit diagram: A.C. to be rectified is connected to the primary P_1P_2 of a step-down transformer. S_1S_2 is the secondary coil of the same transformer. **S_1 is connected to the portion p of the p-n junction. S_2 is connected to the portion n through load resistance R.** Output is taken across the load resistance R. Fig. 7(a)

Working: During the positive half cycle of the input A.C., suppose P_1 is negative and P_2 is positive. On account of induction, S_1 becomes positive, S_2 becomes negative. The p-n junction is forward biased. The resistance of p-n junction becomes low. The forward current flows in the direction shown by arrow heads. Thus, we get output across-load.

During the negative half cycle of the input A.C., P_1 is positive and P_2 is negative. On account of mutual induction, S_1 becomes negative and S_2 is positive. The p-n junction is reverse biased. It offers high resistance and hence there is no flow of current and thus no output across load. The process is repeated. In the output, we have current corresponding to one half of the wave, the other half is missing. The output voltage is of the type as shown in Fig. 7(b).

That is why the process is called half wave rectification. It is of no much use. The output signal is available is bursts and not continuously.

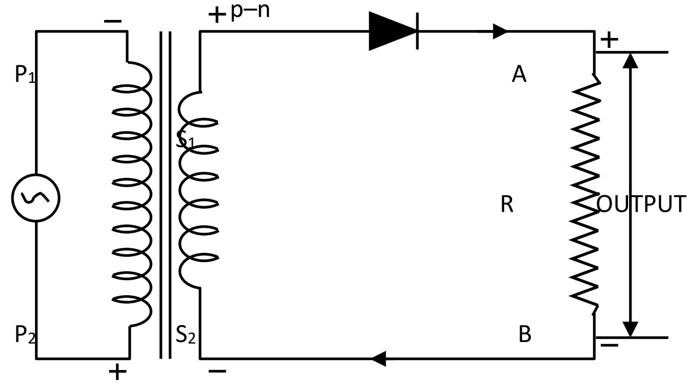
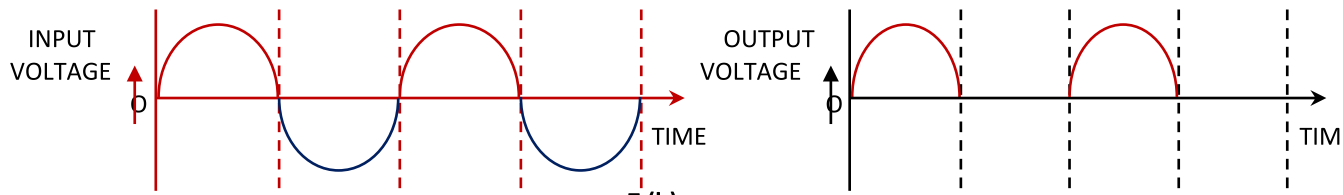


Fig. 7(a)

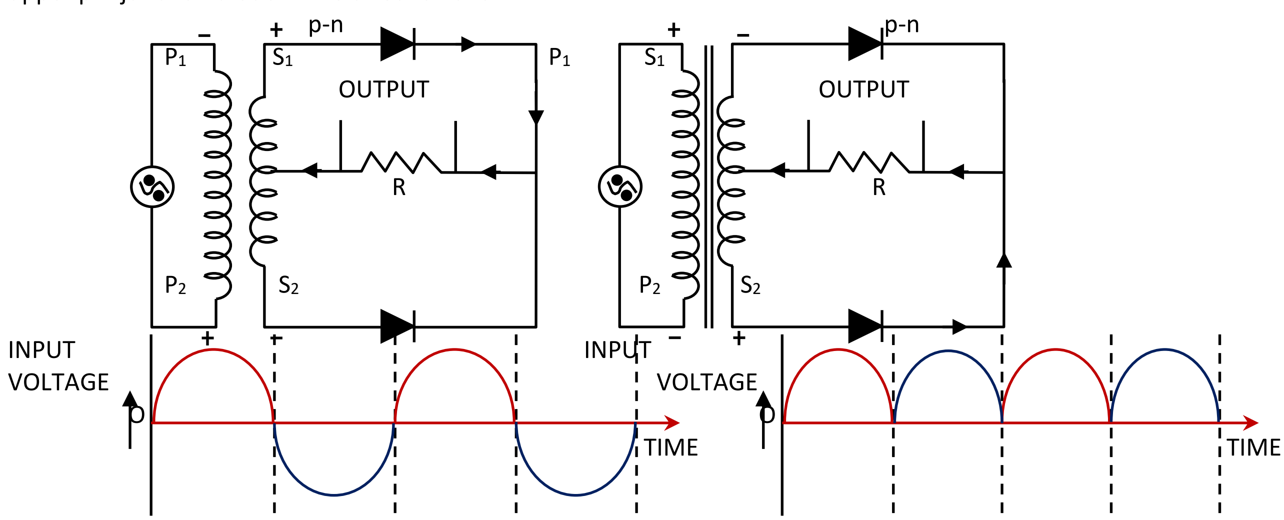


7 (b)

(b) P-N junction diode as full wave rectifier:

Circuit diagram: For full wave rectification, we have to use two p-n junctions. The arrangement is shown in Fig. 8.

Working: During the positi9ve half of the input A.C., the upper p-n junction diode is forward biased as shown in Fig. (8)(a) and the lower p-n junction diode is reverse biased. The forward current flows on account of majority carriers of upper p-n junction diode in the direction shown.



During the negative half cycle of input A.C., the upper p-n junction diode is reverse biased, and the lower p-n junction diode is forward biased, Fig. 8 (b). The forward current flows on account of majority carriers of lower p-n junction diode. We observe that during both the halves, current through R flows in the same direction. The input and output waveforms are shown in Fig. 8 (c). The output signal voltage is unidirectional having ripple contents i.e. d.c. components and a.c. components of voltage. It can be made d.c. voltage by filtering through a filter circuit, before it can be put to any use.

A single capacitor C of high value of capacitance connected across the output of rectifier, can serve the purpose of a filter circuit. Fig. 9

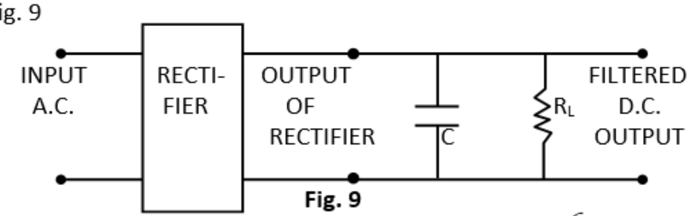


Fig. 9

The capacitor offers low impedance to a.c. component $\because X_C = \left(\frac{1}{\omega C} = \frac{1}{2\pi \nu C}\right)$ and offers infinite impedance to d.c. component is obstructed by C. It produces a voltage drop across load resistance R_L as a **filtered d.c. output** which is almost output d.c. voltage.

Ripple factor of a rectifier

$$= \frac{\text{Value of a.c. component}}{\text{Value of d.c. component}}$$

$$= \frac{I_{a.c.}}{I_{d.c.}} = \frac{E_{a.c.}}{E_{d.c.}} = \sqrt{\left(\frac{I_{r.m.s.}}{I_{d.c.}}\right)^2 - 1}$$

It can be shown **that ripple factor for half wave rectifier is 1.21 and for full wave rectifier is 0.48**.

Efficiency of rectifier,

$$\eta = \frac{\text{Output d.c. power}}{\text{Input a.c. power}} \times 100\ \%$$

◈◈: In half wave rectifier

If V_{rms} is r.m.s. primary voltage, then

Maximum primary voltage,

$$V_{pm} = \sqrt{2}\, V_{rms}$$

Maximum secondary voltage,

$$V_0 = V_{sm} = V_{pm} \times \frac{n_s}{n_p}$$

Maximum secondary current,

$$I_0 = V_0 / (R_i + R_L)$$

Half wave rectified current i.e. mean load current $I_{d.c.} = \frac{I_0}{\pi}$; $I_{rms} = \frac{I_0}{2}$

Output d.c. voltage $= I_{d.c.} \times R_L = \frac{I_0}{\pi} \times R_L$

Output r.m.s. voltage = $V_0/2$

◈◈. In full wave rectifier $V_{sm} = V_{pm} \times \frac{n_s}{n_p} = \sqrt{2}\, V_{rms} \times \frac{n_s}{n_p}$

Full wave rectified current i.e. mean load current,

$$I_{d.c.} = \frac{2 I_0}{\pi}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Output d.c. voltage $= I_{d.c.} \times R_L = \frac{2 I_0}{\pi} \times R_L$

◈◈◈◈Types of Junction Diodes ◈◈◈◈◈◈

Junction diodes are of many types. Important among them are

(a) Zener diode (b) Photo diode (c) Light Emitting Diode (LED) and (d) Solar cell

(a) Zener diode: It is a specially designed, heavily doped silicon or germanium p-n junction diode with high power rating, which can operate continuously, without being damaged in the region of reverse break down voltage. Symbolically, a zener diode is represented as shown in fig. 10 (a).

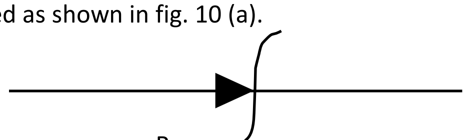


Fig 10 (a)

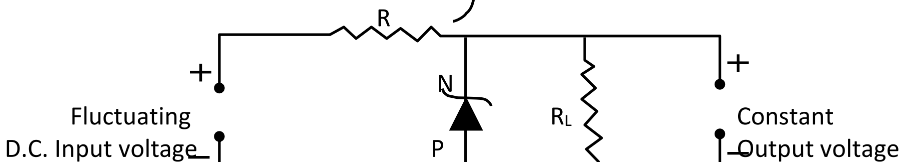


Fig 10 (b)

☞In the reverse break down region, the voltage across the Zener diode remains constant, even if the current through Zener diode increases considerably.

☞Zener diode is available having Zener voltages of 2.4 V to 200 V. Their power rating (i.e., maximum power dissipation = Zener break down voltage (V_Z) × maximum Zener current (I_Z) vary from 150 mW to 50 W.

◈ For proper working of a Zener diode in any circuit, it is essential that

(a) The Zener diode must be reverse-biased.

(b) The Zener diode must have voltage greater that Zener break down voltage (V_Z).

(c) The Zener diode is to be used in a circuit where the current is less than the maximum power current (I_Z) limited by power rating of the given zener diode.

One of the most important uses of zener diode is in making the constant voltage power supply.

Explanation: **The Zener diode is joined in reverse bias to the fluctuating d.c. input voltage through a resistance R of suitable value**, depending upon the Zener voltage and power rating of Zener diode used. The constant output voltage is taken across a load resistance R_L connected in parallel with Zener diode.

When the input d.c. voltage increases beyond a certain limit, the voltage across Zener diode becomes constant equal to Zener break down voltage, but the current through the Zener diode circuit rises sharply as the incremental resistance of Zener diode becomes almost zero, after Zener break down voltage. Due to which there is an increase in voltage drop across R. Since R_L is connected in parallel so the voltage across R_L remains the same as that of Zener break down voltage. Hence the output voltage remains constant.

(b) Photo diode: It working is based on photo conduction from light. A photo diode is a semiconductor made of **photosensitive semiconductor material.** In such a diode a provision is made to allow the light of suitable frequency to fall on it. The conductivity of p-n junction photodiode increases with the increase in intensity of light falling in it. Symbolically, a photodiode is shown in Fig. 11 (a).

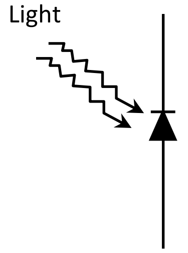
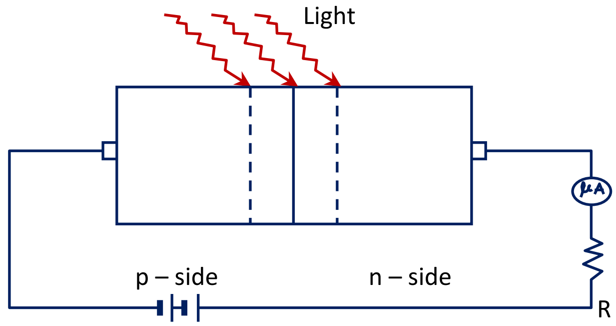


Fig 11 (a)



(b)

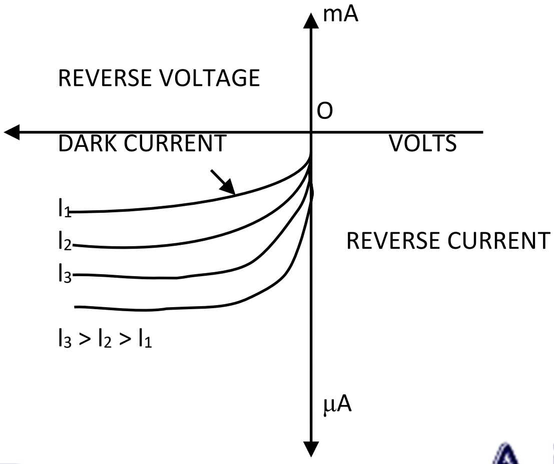
Fig. 11 (b) shows an experimental arrangement in which the photodiode is **reverse biased** but the **voltage applied is less than the break down voltage.**

When visible light of energy greater than forbidden energy gap (i.e. $h\nu > E_g$) is incident on a reverse biased p-n junction photodiode, additional electron-hole pairs are created in the depletion layer (or near the junction). These charge carriers will be separated by the junction field and made to flow across the junction, creating a reverse current across the junction. The value of reverse saturation current increases with the increases in the intensity of incident light as shown in Fig. 11 (c).

It is found that the **reverse saturation current through the photodiode varies almost linearly with the light flux**.

When the photodiode is reverse biased, then a certain current exists in the circuit even when no light is incident on the p-n junction of photodiode. ***This current is called dark current***.

☝A photodiode can turn its current **ON** and **OFF** in nanoseconds. Hence photodiode is one of the fastest photo detectors.



☞**Photodiodes are used for:**
1. **In photo detection for optical signals.**
2. **In demodulation for optical signals.**
3. **In switching the light on and off.**
4. **In optical communication equipment's.**
5. **In logic circuits that require stability and high speed.**
6. **In reading of computers, punched cards and tapes etc.**

(c) Light Emitting Diode (LED): **It is a forward biased *p-n* junction diode which emits light when recombination of electrons and holes takes place at the junction.** When the *p-n* junction is forward biased, the diffusion of majority charge carriers move from *n*-side to *p*-side through the junction and holes move from *p*-side to *n*-side through the junction.

☞In p-n junction, the majority carrier electrons are in the higher conduction band on the n-side whereas holes are in the lower valence band on the p-side. When p-n junction is forward biased, the electrons from n-side cross the junction and combine with the holes on the p-side. During recombination of electrons and holes, some of this energy difference is given out in the form of heat and light (i.e. photons).

☞ For a p-n junction of Ge and Si, the larger percentage of this energy is given out in the form of heat. Due to which the emitted light is insignificant. But in other p-n junction semiconductor diode made of materials like ***gallium arsenide (GaAs)***, ***Gallium phosphide (GaP)*** and **gallium-arsenide-phosphide (GaAsP)**, a greater percentage of energy released during recombination is in the form of visible light. If the semiconducting material of p-n junction is transparent to the light, the light is emitted and the junction becomes a light source i.e. it becomes a Light Emitted Diode (LED). The colour of the light emitted depends upon the type of material used in making the semiconductor diode :

◈1. Gallium-arsenic (GaAs) – infrared radiation.
◈2. Gallium-phosphide (GaP) – red or green light.
◈3. Gallium-arsenide-phosphide (GaAsP) – red or yellow light.

☝LEDs emit no light when reverse-biased. Rather the LEDs will be destroyed when reverse biased.

Symbolically LED is shown in Fig. 12 (a) and its construction and circuit used is shown in Fig. 12(b).

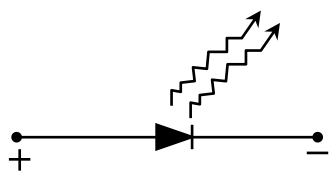
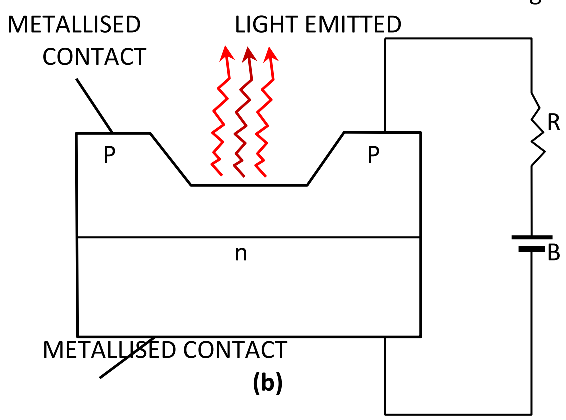


Fig. 12 (a)



(b)

☞In an LED, the upper layer of p-type semiconductor is deposited by diffusion on n-type layer of semiconductor. The metallised contacts are provided for applying the forward bias voltage to the p-n junction diode from battery B through a resistance R which controls the brightness of light emitted.

USES:
1. **In Burglar-alarm systems**, infrared LEDs are used.
2. **In calculators and digital watches**, LEDs are used for numeric displays.
3. **In the field of optical communication**, where high radiance GaAs diode are matched into the optical fibre cable.
4. For **displaying letters and numbers or for entering information into optical computer memories**.
5. In image sensing circuits for **picture phone**.

d) Solar cell: Solar cell is basically a solar energy converter. ***It is a p-n junction device which converts solar energy into electric energy***.

☞ A solar cell consists of silicon or gallium-arsenide p-n junction diode packed in a can with glass window on top. The upper layer is of p-type semiconductor. ***It is very thin*** so that the incident light photons may easily reach the p-n junction. On the top face of p-layer, the metal finger electrodes are prepared in order to have enough spacing between the fingers for the light to reach the p-n junction through p-layer.

☞ When photons of light (of energy hν > E_g) falls at the junction, electron-hole pairs are generated in the depletion layer (or near the junction) which move in opposite directions due to junction field. The photo generated electrons move towards n-side of p-n junction. The photo generated holes move towards p-side of p-n junction. They will be collected at the two sides of the junction, giving rise to a photo voltage between the top and bottom metal electrodes. The top metal contact acts as positive electrodes and bottom metal contact acts as negative electrode. When an external load is connected across metal electrodes a photo current flow.

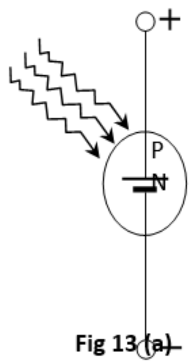
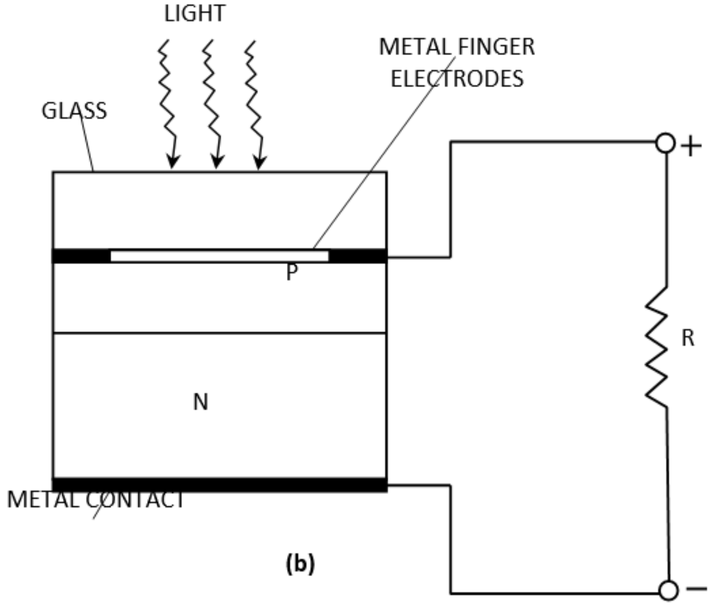


Fig 13 (a)



(b)

USES:

1. **Solar cells are used for charging storage batteries in day time, which can supply the power during night times.**
2. **The solar cells are also used in artificial satellite to operate the various electrical instruments kept inside the satellite.**
3. **They are used for generating electrical energy in cooking food.**
4. **Solar cells are used in calculators, wrist watches and light meters (in photography).**

ΔΔ Junction Transistor

A junction transistor is obtained by growing a thin layer of one type semiconductor in between two thick layers of other similar type semiconductor. Thus, a junction transistor is a semiconductor device having two junctions and three terminals.

☞The two types of junction transistor are p-n-p transistor and n-p-n junction transistor.

A p-n-p junction transistor **is obtained by growing a thin layer of n-type semiconductor in between two relatively thick layers of p type semiconductor.**

A n-p-n junction transistor is obtained by growing a thin layer of p-type semiconductor in between two relatively thick layers of n type semiconductor.

➤**The thin layer of junction transistor is said to form the base (B).**

◈ **Base provides the proper interaction between the emitter and the collector.**

➤**One of the thick layers serves as the emitter (E).**

◈**The function of emitter is to emit the majority carriers.**

➤**the other thick layer serves as the collector (C).**

◈ **Function of collector is to collect the majority carriers.**

Symbolically, the two types of transistors are represented in Fig. 14.

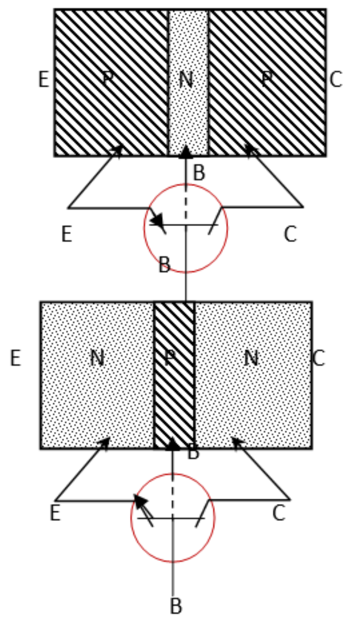
◈The direction of ***arrowhead indicates*** the ***direction of flow of positive charge***.

☞***In case of p-n-p transistor***, Fig. 14 (a), the arrowhead is inwards, because majority carriers are holes.

☞ ***In case of n-p-n transistor***, Fig 14 (b), the arrowhead is outwards, because majority carriers are electrons.

A junction transistor is a transformer of resistance, which can be achieved by interchanging the biasing across the junction triode; hence its name is junction transistor. The **transistor is a current driven device**, in which the emitter current controls the collector current.

Fig 14 (a)



(b)

ΔΔ Transistor Action or Working of Junction Transistor

Δ (a) p-n-p Transistor: ***The emitter base junction is forward biased***.

It means the positive pole of emitter base battery V_{BB} is connected to emitter, and its negative pole to the base. Collector base junction is reverse biased i.e. the negative pole of the collector base battery V_{CC} is connected to collector and its positive pole to the base.

- ***The resistance of emitter base junction is very low***. So, the voltage of V_{BB} (*i.e.* V_{EB}) is quite small (≈ 1.5 volt).
- ***The resistance of collector base junction is very high***. So, the voltage of V_{CC} (*i.e.* V_{CB}) is quite large (≈ 45 volt).

Holes which are majority carriers in emitter (p-type semiconductor) are repelled towards base by positive potential on emitter due to battery V_{BB}, resulting emitter current I_e. The base being thin and lightly doped (n-type semiconductor) has low number density of electrons.

When holes enter the base region, then only a few holes (says 5%) get neutralised by the electron – hole combination, resulting base current I_b (=5 % I_e = 0.05 I_e). The remaining 95% holes pass over to the collector on account of high negative potential of collector due to battery V_{CC}, resulting collector current I_e (= 95 % I_e = 0.95 I_e).

As one hole reaches the collector, it is neutralised by the flow of one electron from the negative terminal of the battery V_{CC} to collector through connecting wire. At the same time a covalent bond is broken in the emitter, the electron goes to the positive terminal of the battery V_{BB} through connecting wire and hole produced begins to move towards base. Then one electron flows from negative terminal of battery V_{BB} to positive terminal of battery V_{CC}. When the hole coming from emitter combines with the electron in base, the deficiency of electron in base is compensated by the flow of electron from negative terminal of battery V_{BB} to the base through connecting wire. Thus, the current in p-n-p transistor is carrier by holes and at the same time their concentration is maintained. But in the external circuit the current is due to flow of electrons. The direction of conventional current (of holes currents) in the various arms of the circuit has been shown by arrow heads in the Fig. 15. Thus, in this case, $\boldsymbol{I_e = I_b + I_c}$. In the base I_e and I_c flow in opposite directions.

Δ (b) **n-p-n Transistor**: In this case also, the emitter base junction is forward biased i.e. **The positive pole of emitter base battery V_{BB} is connected to base and its negative pole to emitter**.

- The ***resistance of emitter base junction is very low***. So, the voltage of V_{BB} (*i.e.* V_{EB}) is quite small (≈ 1.5 V).
- **The collector base junction is reverse biased** i.e. **the positive pole of the collector base battery V_{CC} is connected to collector and negative pole to base.** ***The resistance of this junction is very high***. So, the voltage of V_{CC} (*i.e.* V_{CB}) is quite large (≈ 45 V).
- Electrons which are majority carriers in emitter (n-type semiconductor) are repelled towards base by negative potential of V_{BB} on emitter resulting emitter current I_e. The base being thin and lightly doped (p-type semiconductor) has low number density of holes.

When electrons enter the base region, then only a few holes (say 5%) get neutralised by the electron – hole combination, resulting base current I_b (= 5% I_e = 0.05 I_e). The remaining 95% electrons pass over to the collector, on account of high positive potential of collector due to battery V_{CC}, resulting collector current I_c (= 95 % I_e = 0.95 I_e).

As one electron reaches the collector, it flows to the positive terminal of battery V_{CC} through connecting wire. At the same time one electron flows from negative terminal of V_{CC} to positive terminal of V_{BB} and one electron flows from negative terminal of V_{BB} and one electron flows from negative terminal of V_{BB} to emitter. When the electron coming from emitter combines with the hole on base, the deficiency of hole in base is compensated by the breakage of covalent bond there. The electron so released flows to the positive terminal of battery V_{BB}, through connecting wire. Thus, in n-p-n transistor, the current is carried inside the transistor as well as in external circuit by the electrons. The direction of conventional current in the various arms of the circuit has been shown by arrow heads in Fig. 16. Thus, in this case,

$$I_e = I_b + I_c$$

In this base I_e and I_c flow in opposite directions.

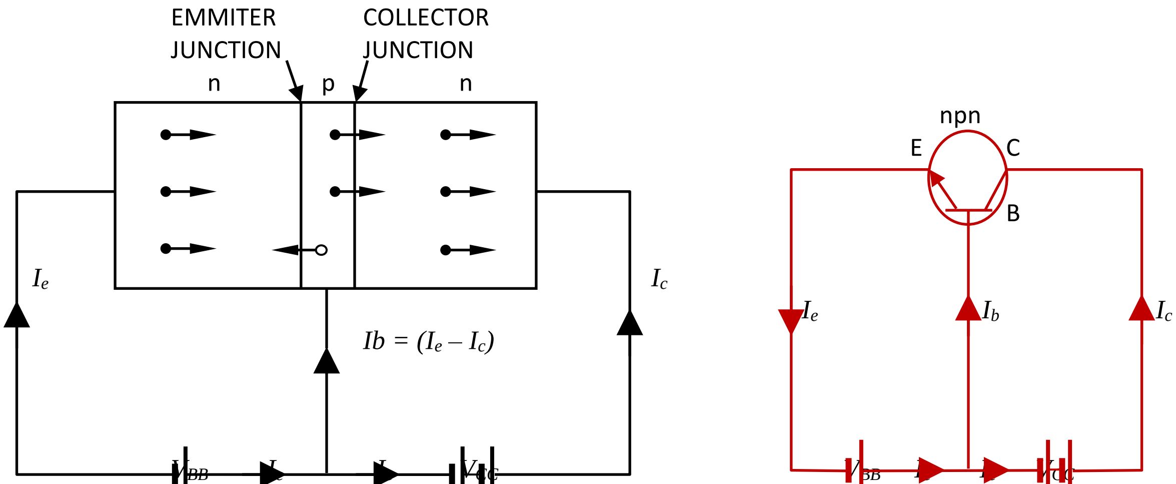


Fig 16

ΔΔModes of Study of Junction Transistors

A transistor can be studied with any one of its three terminals grounded which would serve as a link for both, the input and output voltages. Thus, there are three external circuit connections for transistors as shown in Fig. 17. Fig 17 (a) represents the **common base configuration** (CB). Fig 17 (b) represents **common emitter** (CE) and Fig. 17 (c) represents **common collector** (CC) configuration of n-p-n transistor.

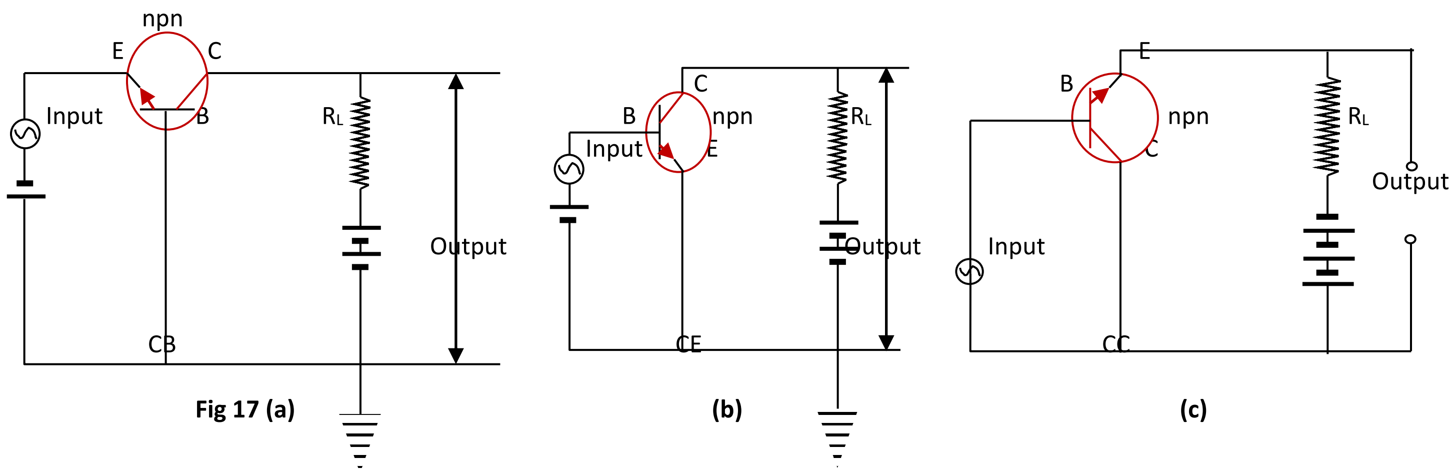


Fig 17 (a) **(b)** **(c)**

ΔΔ Common Base Transistor Characteristics

The graphical representation of the variations among the various current and voltage variables of a transistor are called the transistor characteristics. The common base transistor characteristics are of two types:

(i) (ii) **Emitter or Input characteristics**: *A graphical relation between the emitter voltage and the emitter current when collector voltage is kept constant is called the emitter or input characteristics of the transistor.*

(iii) **Collector or Output characteristics**: *A graphical relation which shows the variation of collector voltage and collector current when emitter current is kept constant is called collector or output characteristics of the transistor.*

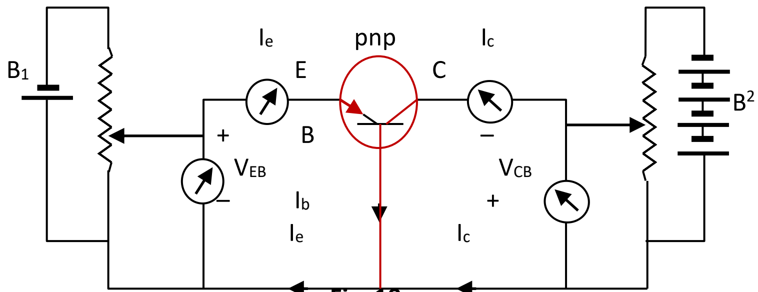


Fig. 18

To study the characteristics of common base transistor using pnp transistor: Here emitter base circuit is biased in forward direction with battery B_1 and collector base circuit is biased in the reverse direction with battery B_2. The emitter voltage and emitter current can be studied by voltmeter V_{EB} and ammeter I_e respectively, whereas the collector voltage and collector current by voltmeter V_{CB} and ammeter I_c respectively. The various currents obey the condition $I_e = I_b + I_c$.

∆ I. Input or Emitter Characteristics:

To get characteristics, apply a suitable constant voltage on collector and by applying the various values of emitter voltage, note the corresponding values of emitter current. Repeat the experiment for the various constant collector voltages. Plot a graph between emitter voltage and emitter current, we get the curves of the type shown in Fig. 19, *called input characteristics of common base transistor*.

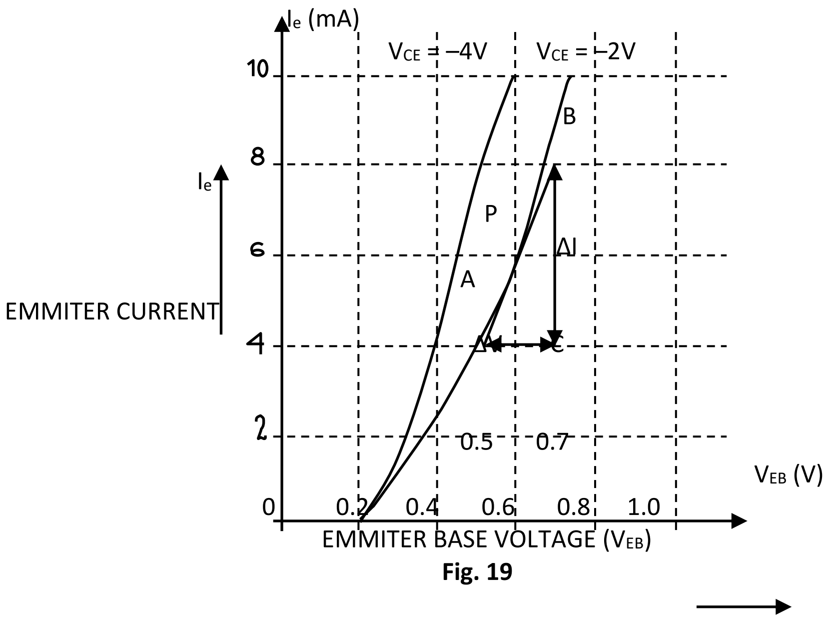


Fig. 19

From the graphs, it can be concluded that:

(i) For a given collector voltage, the emitter current increases rapidly with increasing values of emitter base voltage. It means that input resistance is very small.

(ii) For a higher negative collector voltage, the emitter current rises more rapidly with the collector voltage.

In order to find input resistance of transistor corresponding to emitter voltage 0.6 V, mark the point P on the input characteristics. Draw a tangent to the curve at P. The reciprocal of the slope of the line AB will give us input resistance R_i of transistor.

Here, $R_i = \frac{\Delta V}{\Delta I} = \frac{AC}{BC} = \frac{0.7 - 0.5}{8 - 4} = \frac{0.2\ V}{4mA} = \mathbf{50\ \Omega}$

∆ II. Output or Collector Characteristics:

To get the output or collector characteristics, adjust a suitable constant value of collector voltage, note the corresponding values of collector currents. Repeat the experiment for the various constant emitter currents. Plot a graph between collector voltage (V_{CB}) and collector current (I_c). We get the curves of the type shown in Fig. 20 called output characteristics of *common base transistor*.

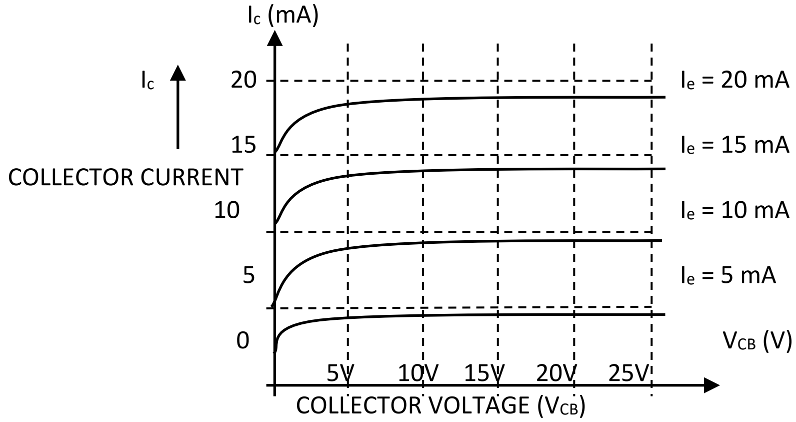


Fig. 20

From the graphs, it can be concluded that:

(i) *For a given value of emitter current,* the **collector current is not zero when collector voltage is zero.**

(ii***) For a given emitter current,*** *there is a rapid increase in the collector current for an increase in low negative* collector resistance. The transistor is never operated in this region.

(ii) For a given emitter current, the collector current becomes saturated for a certain collector voltage shown by horizontal line. Beyond this there is no change in collector current for a further increase in negative collector voltage. This indicates a *region of high* collector resistance. This means that output resistance is very high.

ΔΔ Common Emitter Transistor Characteristics

Fig. 21 shows the experimental set up for the study of characteristics of a transistor when grounded emitter is kept as a common terminal. Base is the input terminal and collector is the output terminal as shown. The various currents are marked keeping in view the condition $I_e = I_b + I_c$.

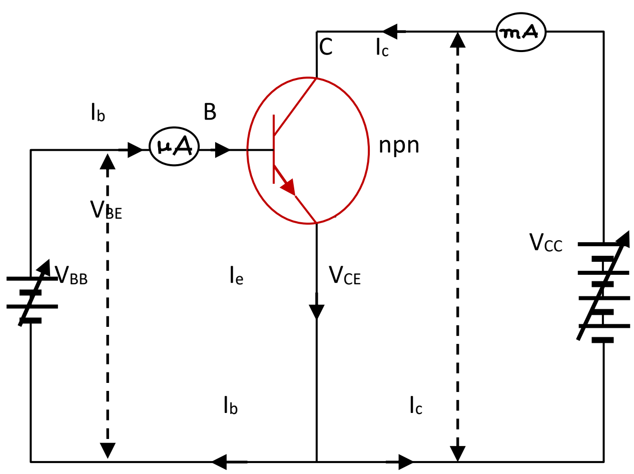


Fig. 21

- The **input characteristics** of the transistor represent the variation of the base current I_b with base emitter voltage V_{BE}, keeping V_{CE} fixed. Their shape is shown in Fig. 22 (a). ***The current is small as long as V_{BE} is less than the barrier voltage.***

- **When V_{BE} is greater than the barrier voltage**, the curves look similar to that of the forward biased diode. More than 95% of emitter electrons (in npn transistor) and emitter holes (in pnp transistor) go to the collector to form the collector currents. That is why I_b is much smaller (in microscope).
- As long as the collector emitter junction is reverse biased, the input characteristics are not affected much by small changes in V_{CE}. At a fixed point on the characteristics, we define

  Input Resistance (R_i) = reciprocal of slope of the curve at that pt. $\Delta V_{BE}/\Delta I_b$
- To find the input resistance corresponding to base emitter voltage V_{BE} = 0.8 V, mark the point P on the proper input characteristic. Draw a tangent AB at P. The reciprocal of slope of AB will give us the input resistance of transistor (R_i).

$$\text{Here } R_i = \frac{\Delta V_{BE}}{\Delta I_b} = \frac{BC}{AC}$$

$$= \frac{(0.9 - 0.7)\ V}{(600 - 200)\ \mu A} = \mathbf{500\ \Omega}$$

The output characteristics of the transistor represent the variation of collector current I_c with collector emitter voltage V_{CE}, keeping I_b fixed. The shape of output characteristic curves of npn transistor is shown in Fig. 22 (b). From the curves, we find that for a given value of V_{CE}, I_c is large for larger value of I_b. Further, as long as collector emitter junction is reverse biased ($V_{CE} > V_{BE}$), we get I_c which is almost independent of V_{CE}. The value of I_c is however controlled by I_b, as a clear from Fig. 21.

The output resistance, $R_O = \dfrac{\Delta V_{CE}}{\Delta I_C}$

➤To find the output resistance for a given base current at a given collector voltage, mark a point on the proper output characteristic. Draw a tangent on this proper output characteristic. Draw a tangent on this characteristic at point P. The reciprocal of slope of this tangent will give us output resistance. The output resistance of a transistor of a transistor is very high (of the order of 50 to 100 k Ω).

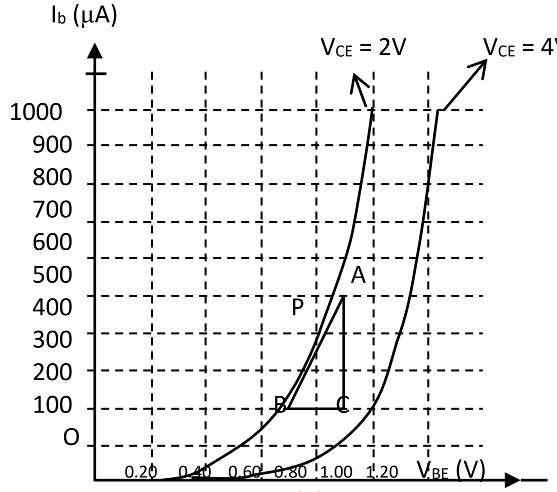
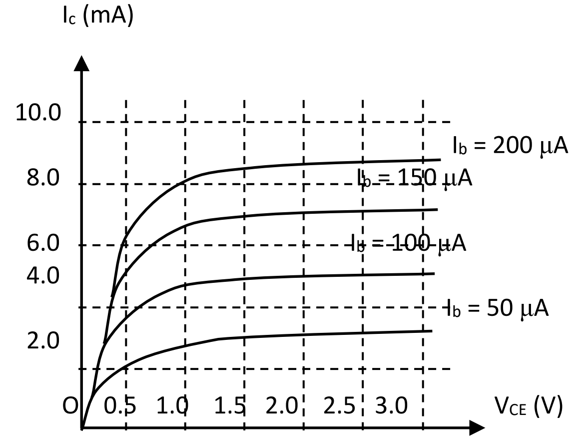


Fig 22 (a)



(b)

ΔΔ Concept of an Amplifier

An amplifier is a device which is used for increasing the amplitude of variation of alternating voltage or current or power.

➤The amplifier thus produces an enlarged version of the input signal.

The general concept of amplification is represented in Fig. 23. There are two input terminals for the signal to be amplified and two output terminals for connecting the load; and a means of supplying power to the amplifier.

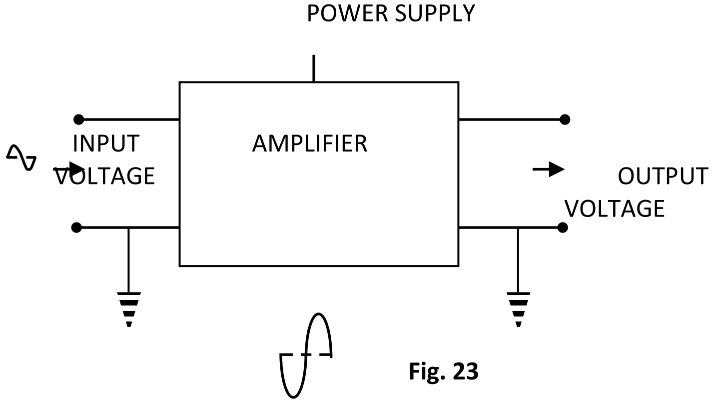


Fig. 23

ΔΔ Transistor as Common Base Amplifier

(a) Amplifier circuit using an n – p – n transistor: Here base is common to both the input and the output circuits.

➤The input (emitter base) circuit is forward biased by using a low voltage battery V_{BB} of voltage V_{EB}. ***As a result, the resistance of input circuit is small***.

➤The output (collector base) circuit is reverse biased by using a high voltage battery V_{CC} of battery voltage V_{CB}. ***Due to which, the resistance of output circuit is large***.

➤R_L is a load resistance **connected in collector circuit**. The low input a.c. voltage signal is applied across emitter base circuit and the amplifier a.c. voltage signal (i.e. output) is obtained as the change in collector voltage.

- In circuit diagram, arrows represent the direction of conventional current or hole current which is opposite to the direction of electronic current. When no a.c. signal voltage is applied to the input circuit by emitter base circuit is closed then let us consider that I_e, I_b and I_c be the emitter current, base current and collector current respectively. Then, according to Kirchhoff's first law

$$I_e = I_b + I_c. \quad \text{... }(i)$$

Let us consider 5 % of the emitter current appears as base current due to electron hole combination in base current due to electron hole combination in base and 95% of the emitter current flows as a collector current. i.e., I_b = 5% of I_e = 0.05 I_e and I_c = 95 % of I_e = 0.95 I_e. Due to collector voltage (i.e., potential difference between collector and base) then

$$V_{CB} = V_c + I_c R_L$$

Or $$V_c = V_{CB} - I_c R_L \quad \text{... }(ii)$$

When the input signal voltage is fed to the emitter base circuit, it will change the emitter voltage and hence to the emitter current; which the collector current. Due to which the collector voltage V_c will vary in accordance with relation (*ii*). This variation in collector voltage appears as an amplified output. **Phase relationship between input and output voltages**.

When the positive half cycle of input a.c. signal voltage comes, it opposes the forward biasing of the emitter base circuit. Due to which the emitter current decreases and consequently the collector current decreases. As a result of which, the collector voltage V_c increases [from relation (*ii*)].

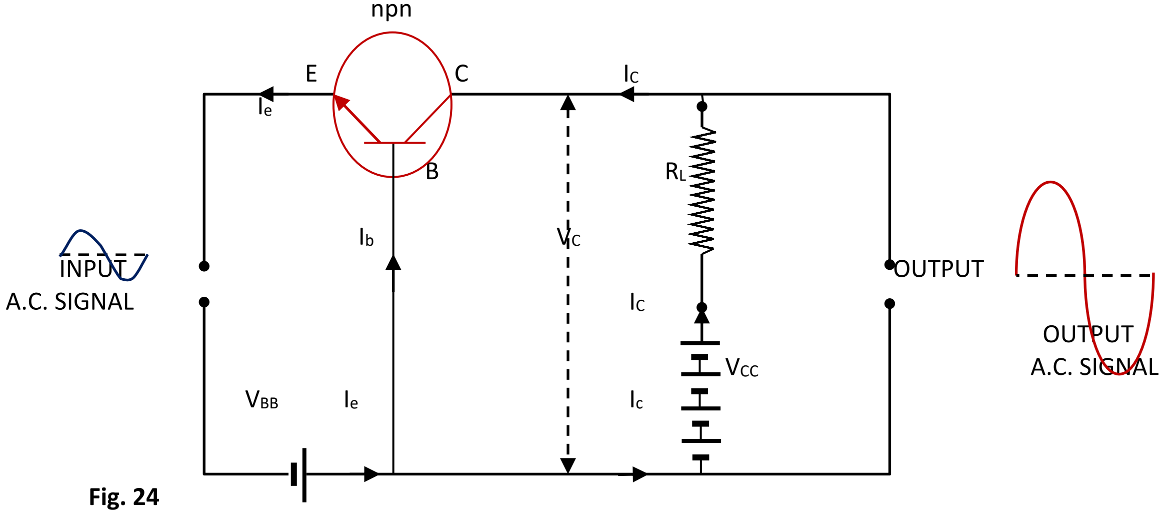


Fig. 24

- Since the collector is connected to the positive terminal of V_{CC} battery, therefore the increase in collector voltage means the collector will become more positive. This indicates that *during positive half cycle of input a.c signal voltage, the output signal voltage at the collector also varies through a positive half cycle*.

When negative half cycle of input a.c. signal voltage comes, it supports the forwards biasing of emitter base circuit. Due to which the emitter current increases and consequently the collector current increases. As a result of which, the collector voltage V_c decreases [from relation (ii)] i.e., the collector becomes less positive. This indicates that *during negative half cycle of input a.c. signal voltage, the output signal voltage at the collector also varies through the negative half cycle*. Thus, *in common base amplifier circuit, the input signal voltage and the output collector voltage are in the same phase*.

(b) **Amplifier circuit using p-n-p transistor**:. The basic theory of this circuit is the same as in case of n-p-n transistor or circuit. In this case also, output voltage signal obtained across collector is in phase with the input voltage signal as explained below:

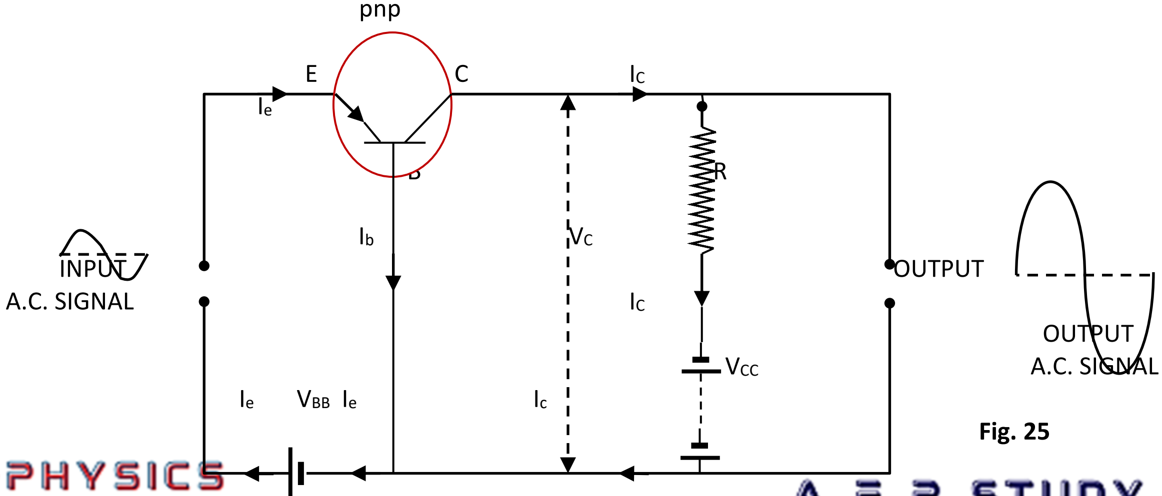


Fig. 25

- When the positive half cycle of input a.c. signal voltage comes, it supports the forward biasing of the emitter – base circuit. Due to which the emitter current increases and consequently the collector current increases. As a result of which, the collector voltage V_c decreases, according to relation (2). Since the collector is connected to the negative terminal of V_{CC} battery of voltage V_{CB}, therefore, the decreases in collector voltage means the collector will become less negative. This indicates that during positive half cycle of input a.c. signal voltage, the output signal voltage at the collector also varies through the positive half cycle.

Similarly, it can be shown that during negative half cycle of input a.c. signal voltage, the output signal voltage at the collector also varies through the negative half cycle. Thus, **in common base transistor amplifier circuit the input signal voltage and the output collector voltage are in the same phase**.

VARIOUS GAINS IN COMMON BASE AMPLIFIER:

- (1) **Current gain or current transfer ratio**: Its value depends on whether the current flowing is d.c. or a.c. in nature.

(a) d.c. Current gain: It is defined as the ratio of collector current (I_e) to the emitter current (I_e). It is denoted by α. Thus

$$\alpha = I_c/I_e \qquad \text{... } (i)$$

The value of d.c. current gain is always less than 1. Its maximum value is 0.98.

(b) **a.c. Current gain**: It is defined as the ratio of change in collector current (ΔI_c) to the change in emitter current (ΔI_e) at constant collector voltage. It is denoted by $\alpha_{a.c.}$.

$$\therefore \quad \alpha_{a.c.} = \left(\frac{\Delta I_c}{\Delta I_e}\right), \text{ when } V_c \text{ is constant} \qquad \text{... } (ii)$$

- (2) **a.c. Voltage gain**: It is defined as the ratio of change in output voltage ΔV_c to the change in input voltage i.e. emitter-base voltage (ΔV_i). It is denoted by A_V.

$$\therefore \quad A_V = \frac{\Delta V_c}{\Delta V_i} \qquad \text{... } (iii)$$

Let R_o = the output resistance of the circuit

R_i = the input resistance of the circuit of a transistor,

Then, $$A_V = \frac{\Delta V_c}{\Delta V} = \frac{\Delta I_c}{\Delta I_e} \times \frac{R_o}{R_i}$$

$$= \alpha_{a.c.} \times \text{Resistance gain} \qquad \text{... } (iv)$$

Where R_o/R_i is called *resistance gain*.

For example, if $R_o = 1000\ R_i$ and $\alpha_{a.c.} = 0.95$, then

$A_V = 0.95 \times 1000 = 950$ This is the order of voltage gain.

- (3) **a.c. Power gain**: It is defined as the ratio of change in output power to the change in input power i.e.

$$\text{a.c. power gain} = \frac{\text{change in output power}}{\text{change in input power}} = \frac{\Delta V_c \times \Delta I_c}{\Delta V_i \times \Delta I_e} \qquad \text{... } (v)$$

$$= \frac{\Delta V_c}{\Delta V_i} \times \left(\frac{\Delta I_c}{\Delta I_e}\right) = A_V \times \alpha_{a.c.} \qquad \text{... } (vi)$$

From (*v*),

$$\text{a.c. power gain} = \left(\frac{\Delta I_c}{\Delta I_e}\right)^2 \times \frac{R_o}{R_i} = \alpha^2_{a.c.} \times \text{Resistance gain} \qquad \text{... } (vii)$$

As current gain < 1, power gain is slightly less than the voltage gain.

- The whole working and gains of p-n-p common base transistor amplifier are exactly the same as explained in the n-p-n transistor amplifier.

ΔΔ Transistor as Common Emitter Amplifier

(a) Amplifier circuit using n-p-n transistor: Here emitter is common to both the input and the output circuit. The input (Emitter base) circuit is **forward biased** with battery V_{BB} of voltage V_{EB}, and the output (collector-emitter) circuit is reversed biased with battery V_{CC} of voltage V_{CE}. Due to which the resistance of input circuit is low and that of output circuit is high, R_L is a load resistance connected in collector circuit. The low input a.c. voltage signal is applied across base - emitter circuit and the amplified a.c. voltage signal (i.e. output) is obtained as the change in collector voltage. In circuit diagram arrows represent the direction of conventional current or hole current, which is opposite to the direction of electronic current.

When no a.c. signal voltage is applied to the input circuit but emitter base circuit is closed let us consider, that I_e, I_b and I_c be the emitter current, base current and collector current respectively. Then according to Kirchhoff's first law $$I_e = I_b + I_c. \qquad \text{... } (i).$$

Let us consider 5% of the emitter current appears as base current due to electron hole combination in base and 95% of emitter current flows as a collector current i.e., I_b = 5% of $I_e = 0.05\ I_e$ and I_c = 95% of $I_c = 0.95\ I_e$.

➤ Due to collector current I_c, voltage drop across $R_L = I_cR_L$. If V_c is collector voltage (i.e., potential difference between collector and emitter) then

$$V_{CE} = V_c + I_cR_L$$

Or $$V_c = V_{CE} - I_cR_L \quad \text{... } (ii)$$

When the input signal voltage is fed to the emitter base circuit, it will change the emitter voltage and hence to the emitter current, which in turn will change the collector current. Due to which the collector voltage V_c will vary in accordance with relation (***ii***). These variations in collector voltage appear as amplified output.

☑ Phase relationship between input and output voltages

When the positive half cycle of input a.c. signal voltage comes, it supports the forward biasing of the emitter-base circuit. Due to which, the emitter current increases and consequently the collector current increases. As a result of which, the collector voltage V_c decreases [from relation (***ii***)]. Since the collector is connected to the positive terminal of V_{CE} battery, therefore decrease in collector voltage means the collector will become less positive, which means the collector will become less positive, which means negative w.r. to initial value. This indicates that *during positive half cycle of input a.c. signal voltage, the output signal voltage at the collector varies through a negative half cycle*.

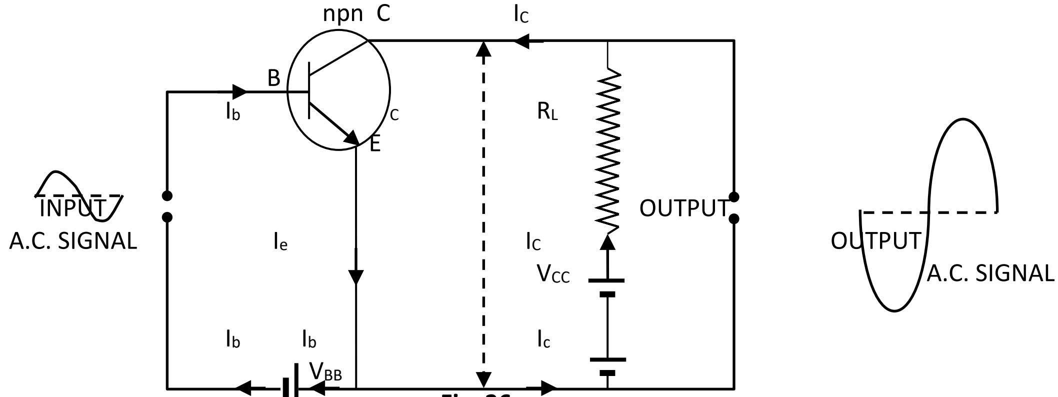


Fig. 26

When negative half cycle of input a.c. signal voltage comes, it opposes the forward biasing of emitter-base circuit, due to which the emitter current decreases and hence collector current decreases; consequently, the collector voltage V_c increases [from relation (***ii***)]. i.e., the collector becomes more positive.

This indicates that during the negative half cycle of input a.c. signal voltage, the output signal voltage varies through positive half cycle.

Thus, in a common emitter amplifier circuit, the input signal voltage and the output collector voltage are in opposite phase i.e., 180° out of phase, as shown in Fig. 26.

(b) Amplifier circuit showing p-n-p transistor: The basic theory of this circuit is the same as in case of n-p-n transistor circuit. In this case also the output signal voltage obtained across collector is 180° out of phase with the input voltage signal as :

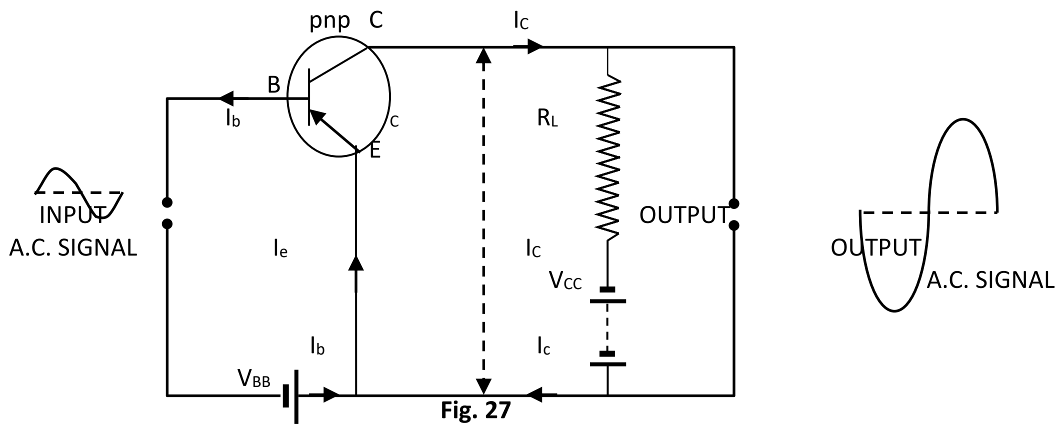


Fig. 27

When the positive half cycle of input a.c. signal voltage comes, it opposes the forward biasing of emitter base circuit. Due to which, the emitter current decreases and hence collector current decreases; consequently, the collector voltage V_c increases according to relation (***ii***). Since the collector is connected to the negative terminal of V_{CC} battery of voltage V_{CE}, therefore, the increase in collector voltage means, the collector will become more negative. This indicates that *during positive half cycle of input a.c. signal voltage, the output signal voltage at the collector varies through negative half cycle i.e., 180° out of phase*.

Similarly, it can be shown that during negative half cycle of input a.c. signal voltage, the output signal voltage at the collector varies through the positive half cycle i.e., 180° out of phase. **Thus, in common emitter transistor amplifier circuit, the input signal voltage and the output collector voltage are 180° out of phase**.

➢ **VARIOUS GAINS IN COMMON EMITTER AMPLIFIER**:

❖ **(1) Current gain or Common emitter current Amplification factor**. It is two types:

(i) **d.c. Current gain**: It is defined as the ratio of the collector current (I_c) to the base current (I_b). It is denoted by β.

$$\therefore \quad \beta = \frac{I_c}{I_b} = \frac{I_c}{I_e - I_c} = \frac{I_c/I_e}{1 - I_c/I_e} \qquad (\because I_e = I_b + I_c)$$

$$= \frac{\alpha}{1-\alpha} \qquad (\because \alpha = I_c/I_e)$$

If α = 0.95, $\beta = \frac{0.95}{1 - 0.95} = 19$

(ii) **a.c. current gain**: It is defined as ratio of change in collector current (ΔI_c) to the change in base current (ΔI_b) at constant collector voltage. It is denoted by $\beta_{a.c.}$

$$\therefore \quad \beta_{a.c.} = \frac{\Delta I_c}{\Delta I_b}$$

Its value lies between 15 to 50, for a transistor.

❖ **(2) Trans-conductance (g_m)**: It is defined as the ratio of change in collector current (ΔI_c) to the change in base emitter voltage (ΔV_i). Therefore

$$gm = \frac{\Delta I_c}{\Delta V_i} = \frac{\Delta I_c}{\Delta I_b} \times \frac{\Delta I_b}{\Delta V_i}$$

Or $$gm = \frac{\beta_{a.c.}}{R_i} \qquad [\because R_i = \Delta V_i/\Delta I_b]$$

Its unit is Ω^{-1} or Siemens (denoted by S)

(3) a.c. voltage gain (A_v): It is defined as the ratio of the change in output voltage (ΔV_c) to the change in input voltage (ΔV_i) to the change in input voltage (ΔV_i) i.e.

$$A_v = \frac{\Delta V_c}{\Delta V_i} = \frac{\Delta I_c \times R_o}{\Delta I_b \times R_i}$$

$$= \beta_{a.c.} \times \frac{R_o}{R_i} \qquad \dots (i)$$

$$= \beta_{a.c.} \times \textit{Resistance gain}$$

Here $\beta_{a.c.} >> \alpha_{a.c.}$, but resistance gain ($R_o/R_i$) is less than that in case of common base transistor amplifier, hence the a.c. voltage gain in common emitter amplifier is greater as compared to that of common base transistor amplifier.

From (i), $A_v = \beta_{a.c.} \times R_o = g_m \times R_o$.

Actually, $A_v = -g_m \times R_0$, here negative sign indicates phase reversal of output.

(4) a.c. power gain: It is defined as the ratio of the change in output power to the change in input power i.e.

$$\text{a.c. power gain} = \frac{\text{Change in output power } (P_0)}{\text{Change in input power } (P_i)}$$

$$= \frac{\Delta I_c^2}{\Delta I_b^2} \times \frac{R_o}{R_i} = \beta^2_{a.c.} \times \text{resistance gain}$$

$$= \beta_{a.c.} \times (\beta_{a.c.} \times \text{Resistance gain}) = \beta_{a.c.} \times A_v$$

Since $\beta_{a.c.} > \alpha_{a.c.}$, therefore, extremely high power gain is possible in common emitter amplifier as compared to that in common base amplifier.

☑: Voltage gain (in dB) = $20 \log_{10} \frac{V_0}{V_i}$

Current gain (in dB) = $20 \log_{10} \frac{I_c}{I_e}$

Power gain (in dB) = $10 \log \frac{P_o}{P_i}$

Transistor as an Oscillator

A simple L-C circuit can be used to produce electrical oscillation of desired frequency.

The ratio waves which are used as carrier waves in radio communication are produced by these circuits called oscillators.

Tank circuit consisting of an inductance L and a capacitor C, connected in parallel is the simplest type of electrical oscillating system. In this circuit, electrical energy once given to the circuit oscillates as magnetic energy in the inductance and electrostatic energy in the capacitance.

◈The frequency of oscillations of the tank circuit is given by

$$v = \frac{1}{2\pi\sqrt{LC}}$$

◈However due to the **internal resistance of the inductance coil**, there occurs a small but constant energy loss and hence the oscillations produced are **damped**.

The damped waves are suitable for the transmission of code message or telegraphic messages but to transmit speech or music, we require undamped electromagnetic waves or carrier waves. The same can be produced by using transistor as an oscillator. The **block diagram of oscillator** is shown in Fig. 28.

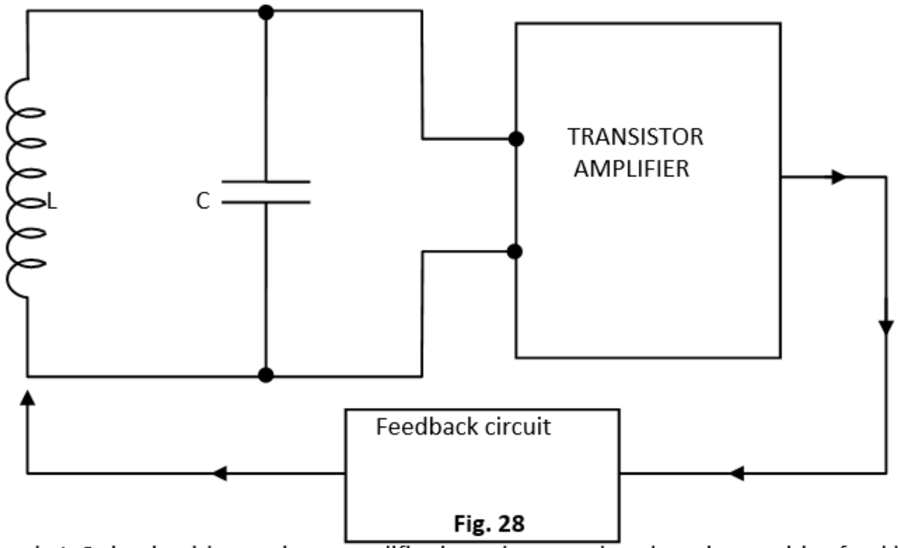


Fig. 28

Here, we couple L-C circuit with transistor amplifier in such a way that there is a positive feed back to the L-C circuit i.e. there is a proper supply of energy to the L-C circuit at the proper supply of energy to the L-C circuit remains the same throughout oscillations.

Circuit diagram of transistor as an oscillator: It is shown in Fig 29. Here L-C circuit is inserted in emitter base circuit of transistor which is forward biased with battery B_1. The collector emitter circuit is reversed biased with battery B_2. A coil L_1, is inserted in collector emitter circuit. It is coupled with L in such a way that if increasing magnetic flux is linked with L, it will support the forward bias of emitter base circuit and if decreasing magnetic flux is linked with L, it will oppose the forward bias of emitter base circuit.

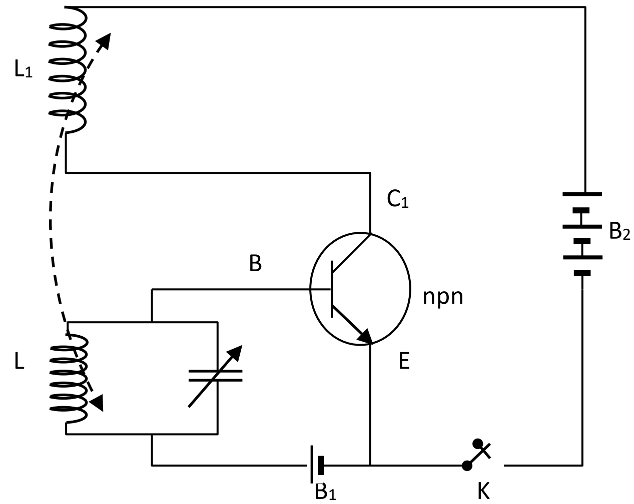


Fig. 29

Working: If we close the key K, the collector attains positive potential, due to which there will be a weak collector current which will start rising with time due to the inductance L_1. As a result of it, an increasing magnetic flux is linked with L_1 and hence with L. Due to mutual induction, an e.m.f. is induced in L which will charge the upper plate of capacitor with positive charge, consequently there will be support to the forward biasing of emitter base circuit. This results in an increase in the emitter current and hence an increase in the emitter current and hence an increase in the emitter current and hence an increase in the collector current. Due to it, more increasing magnetic flux is linked with L_1 and hence with L. As a result of which more e.m.f. is induced in L, charging the upper plate of capacitor with more positive charge and hence providing more support to the forward biasing of emitter-base circuit, which results further increase in the emitter current and hence in the collector current. The process continues till the collector current becomes maximum or saturated.

Now the mutual induction stops playing its part. The capacitor C gets discharged through inductance L. As a result of it, the support to the forward biasing of emitter-base circuit is withdrawn, thereby the emitter current decreases and hence collector current also decreases. Due to which, a decreasing magnetic flux is linked with L_1 and hence with L. Due to mutual induction, an e.m.f. is induced in L which will charge the lower plate of capacitor C with positive charge, consequently there will be opposition to the forward biasing of emitter base circuit. This results in further decreases in emitter current and hence in collector current. This process continues till the collector current becomes zero. Now again mutual induction stops playing its part. The condenser gets discharged through inductance L. As a result of it, the opposition to the forward biasing of emitter-base circuit is withdrawn, thereby the emitter current increases and hence collector current also increasing and the process repeats. Thus, the collector current oscillates between a maximum and zero value.

We know that in common emitter circuit, a signal voltage applied to the emitter base circuit suffers a phase change of 180^o in the collector emitter circuit. By coupling L_1, with L, we bring about a further phase change of 180^o. Thus, the energy which is fed to the L-C circuit is in proper phase at proper timing and hence we get undamped oscillations in L-C circuit of frequency.

$$v = ½ \pi \sqrt{LC}$$

Therefore we get the carrier waves from the oscillator.

In this oscillator, the energy is being supplied by the battery B_2 to the L-C circuit at proper time and in proper phase, therefore the battery gets consumed in oscillator. It means in oscillator D.C., is converted into A.C.

Advantages of Semiconductor Devices

1. Semiconductor devices are much smaller in size and weight as compared to vacuum tubes.
2. Semiconductor devices are not to be heated for emission of electrons. They start operating instantly. This saves a lot of electric power.
3. A transistorised equipment does not get heated, while operating. Therefore, no cooling arrangement is required.
4. The semiconductor devices are more rugged than the vacuum tubes. They can withstand rough handling.
5. Semiconductor devices have much longer life as compared to the life of vacuum tubes.
6. Semiconductor devices are cheaper than vacuum tube devices.
7. Semiconductor devices are low power devices.

Disadvantages of Semiconductor Devices

1. Semiconductor devices are very sensitive to changes of temperature whereas the vacuum tubes are less sensitive.
2. It is difficult to produce semiconductor devices with exactly identical characteristics.
3. The noise level in semiconductor devices is higher than that of vacuum tubes.
4. Semiconductor devices cannot handle as much power as vacuum tubes.

In modern times, semiconductor devices are almost replacing vacuum tubes on account of their merits.

..... End.