

NOTES ON  
BASIC ELECTRONICS  
SEM I. - 1<sup>st</sup>/2<sup>nd</sup>

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# INTRODUCTION

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Electronics: The branch of science and engineering which deals with motion of electron in gases, vacuum and solids under different operating condition.

## Application of Electronics

Few importance application of Electronics are

1. Entertainment and Communication: TV, Radio, DVD player, video games, mobile etc.
2. Control and Instrumentation: Traffic light control, multimeter, CRO, frequency converter.
3. Application of medicine science: X-ray, ECG, EEG, EMG
4. Application in defence. Radar, missiles, Aircrafts, walky talkies.

Electron: An electron is a negatively charged particles having negligible mass.

charge of electron  $e = 1.602 \times 10^{-19}$  coulomb

mass of an electron  $m = 9.0 \times 10^{-31}$  kg

Valency: The total number of electron present at the outermost orbit is the valency of that atom.

Valence Electron: - The electron present in the outermost orbit of an atom are known as valence electron.

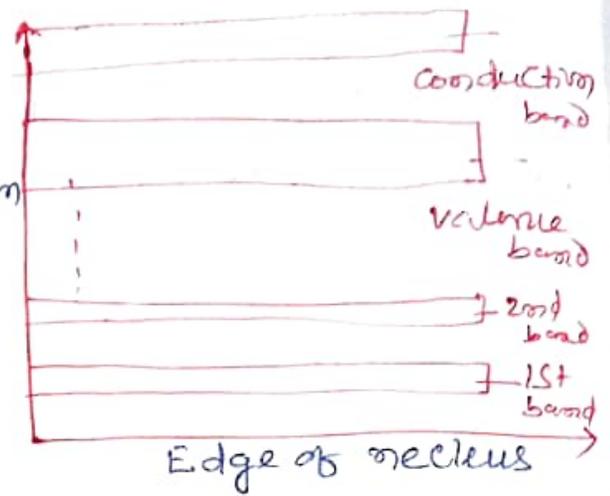
Energy level: - The graphical representation of energy of different orbits is known as energy level.

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**Energy band:** The range of energies possessed by an electron in a solid is known as energy band.

**Valence band:**

The range of energies possessed by the valence electron is known as valence band.



**Conduction band:**

The range of energies possessed by conduction electron is known as conduction band.

**Forbidden energy gap:** -

The energy gap between valence band and conduction band on energy band diagram is known as forbidden energy gap.

## Electron emission! -

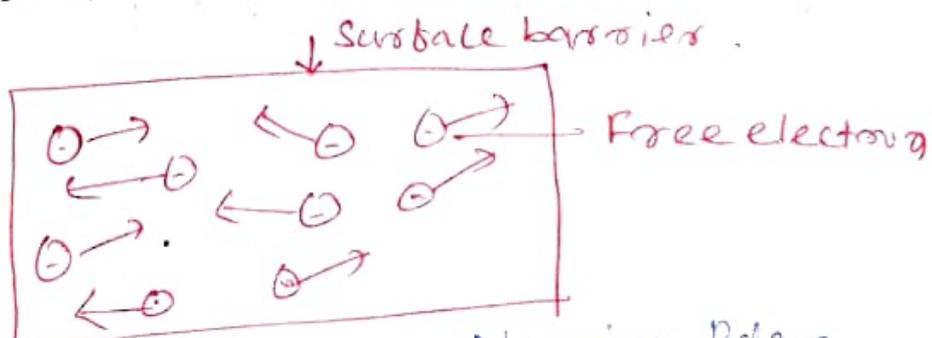
The liberation of electrons from the surface of a substance is known as electron emission.

If a piece of metal is investigated at room temperature the electrons are free only to the extent that they may transfer from one atom to another within the metal. They cannot leave the metal surface because metallic surface offers a barrier to free electrons and is known as surface barrier. If sufficient energy is given to the free electrons its kinetic energy is increased and electrons will crossover the surface barrier to leave the metal. This additional energy required by an electron to overcome the surface barrier of the metal is called workfunction of the metal.

## Surface barrier! -

The metallic surface which offers barrier to free electrons is known as surface barrier.

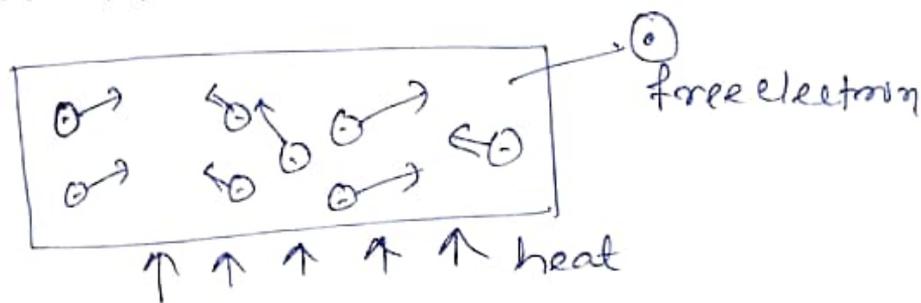
workfunction! The amount of additional energy required to emit an electron from a metallic surface is known as workfunction of that metal.



## Types of electron emission: -

1) Thermionic emission: The process of electron emission from a metal surface by supplying thermal energy to it known as thermionic emission.

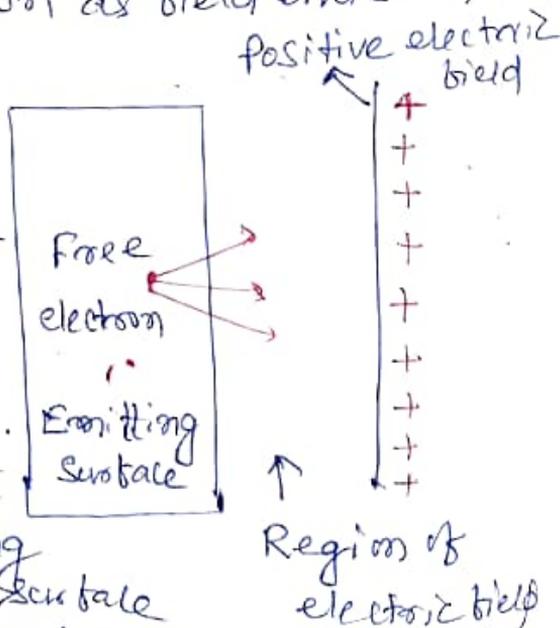
When heat is applied to the metal some of heat energy is converted into kinetic energy causing accelerated motion of free electrons. When the temperature rises sufficiently, these electrons acquire additional energy equal to the work function of the metal and leave the metal surface.



## 2) Field emission

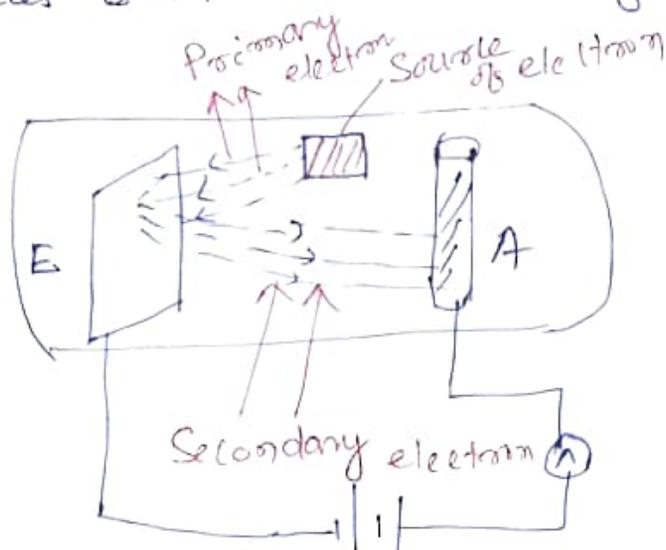
The process of electron emission by the application of strong electric field at the surface of a metal is known as field emission.

When a metal surface is placed close to a high voltage conductor which is positive w.r.t the metal surface the electric field exerts attractive force on the free electrons in the metal. If the positive potential is great enough, it succeeds in overcoming the restraining force of the metal surface and the free electron will be emitted from the metal surface.



## ⑤ Secondary emission! -

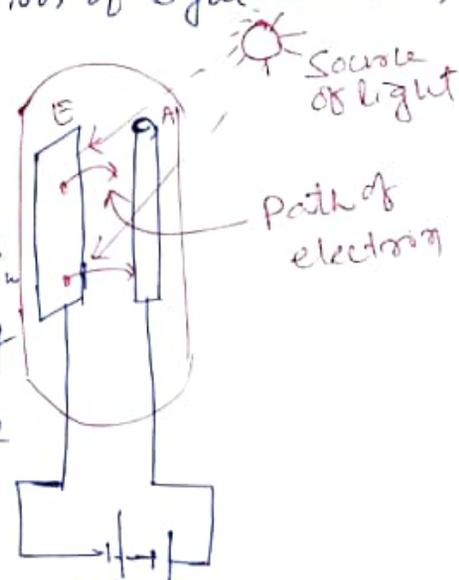
Electron emission from a metallic surface by the bombardment of high-speed electrons or other particles is known as secondary emission.



When a high speed electron suddenly strikes a metallic surface, they may give some or all of their kinetic energy to the free electrons in the metal. If the energy of the striking electron is sufficient it may cause free electrons to escape from the metal surface. This phenomenon is called electron emission. The electrons that strike the metals are called primary electron while the emitted electrons are known as secondary electrons.

## ⑥ Photo electric emission! - Electron emission from a metallic surface by the application of light is known as photo-electric emission.

When a beam of light strikes the surface of certain metal (e.g. potassium, sodium, cesium) the energy of photo light is transferred to the free electrons within the metal. If the energy of the striking photons is greater than the work function of the metal, then the free electrons will be knocked out from the surface of the metal. The emitted electrons are known as photo-electrons and the phenomenon is known as photo-electric emission.



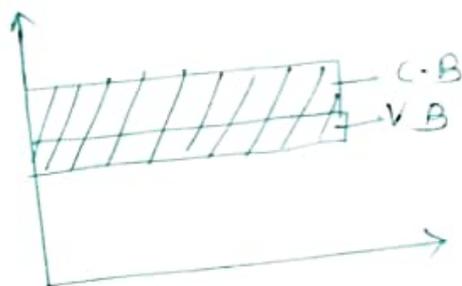
## CLASSIFICATION OF SOLIDS:

The valence band electrons determine whether the material is chemically active metal or non-metal or a gas or solid. In the basis of valence electrons the solids are classified into :-

- 1) conductor 2) Insulator 3) Semiconductor

1. conductor: conductors are those substances which easily allow the passage of electric current through them. Ex- copper, aluminium

- \* There are ~~large~~ large numbers of free electrons available in a conductor.
- \* The conduction band and valence band are overlapping in energy band diagram.
- \* The valence band is partially filled.
- \* The conduction band electrons are the valence electrons.

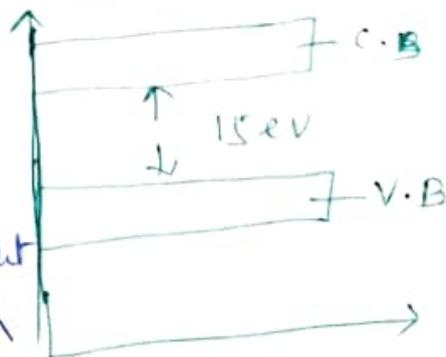


2. Insulator: Insulators are those substances which do not allow the passage of electric current through them. Ex- Glass, Paper, wood.

- \* In energy band the valence band is partially or fully filled.
- \* The conduction band is empty.

\* The forbidden energy gap is very large about 15 eV.

\* It's require a very large amount of energy to excited valence electrons to the conduction band, which is practically impossible.

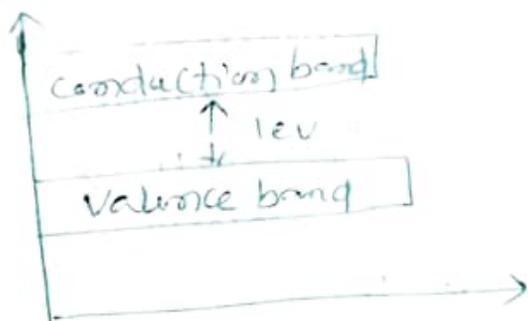


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### 3. Semiconductors : Semiconductors are those

substances whose electrical conductivity lies between conductors and insulators. Ex: Si, Ge

- \* In energy band the valence band is almost filled and conduction band is empty.
- \* The ~~band~~ forbidden energy gap between the valence band and conduction band is narrow about 1 eV.
- \* A small amount of external energy required to excited valence electron to conduction band.

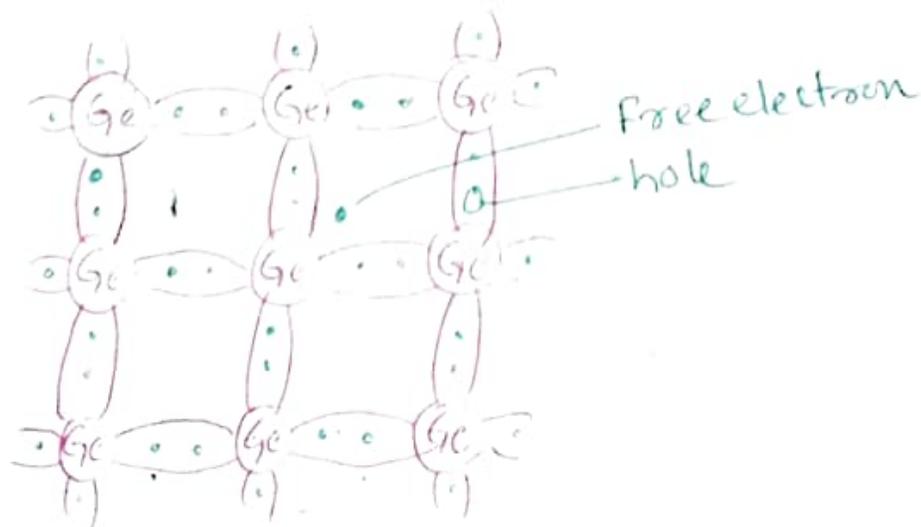


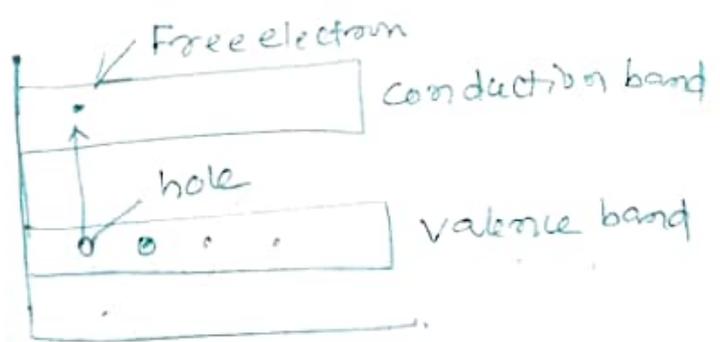
### Types of semiconductors :

1. Intrinsic Semiconductor
2. Extrinsic Semiconductor

### Intrinsic Semiconductors :

A semiconductor is in extremely pure form is known as an intrinsic semiconductor.





Intrinsic semiconductor even at room temperature a hole electron pairs are created. When an electric field is applied across an intrinsic semiconductor the current conduction take place by electrons and holes. Hence semiconductor conductance consists of movement of electrons and holes in opposite directions in the conduction and valence bands respectively. In intrinsic semiconductor the number of conduction electrons is equal to the number of holes.

### Extrinsic Semiconductor

The intrinsic semiconductor has little current conduction capability at room temperature. For getting good conducting properties, some suitable impurity or doping agent is added. Such type of semiconductor are called extrinsic or impure semiconductor.

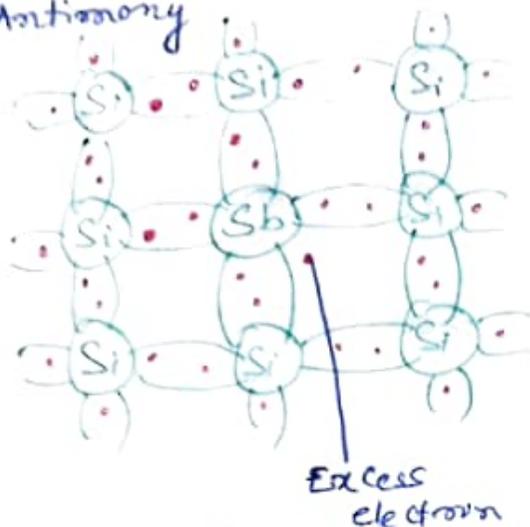
Doping: The process of adding impurity to a pure semiconductor is called doping.

The purpose of adding impurity is to increase either the number of free electrons or holes in semiconductor crystal. Depending upon the type of impurity added, extrinsic semiconductors are classified into.

- 1) n-type semiconductor
- 2) p-type semiconductor

## N-type Semiconductor :

When a small amount of a Pentavalent impurity is added to a pure Semiconductor, <sup>n-type semiconductor is formed.</sup> Example of Pentavalent impurity are Arsenic, Antimony.

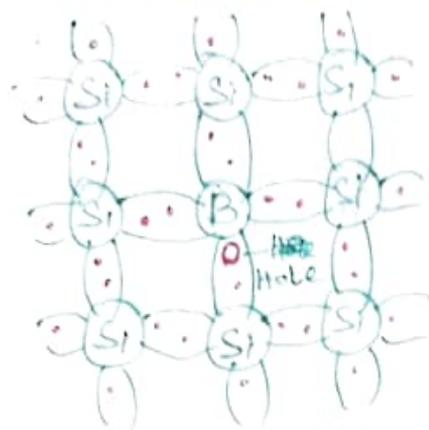


Antimony atom forms covalent bonds with the surrounding four silicon atoms with the help of its five electrons. The fifth electron is superfluous and is loosely bound to the antimony atom. Hence it is easily moved from the valence band to the conduction band by the application of electric field or increase in its thermal energy. This type of semiconductor is called n-type semiconductor and the impurity is called donor impurity because they donate free electrons to the semiconductor crystal. After donation of one electron, the pentavalent atom becomes positive donor ions (immovable).

In addition to the free electrons, some electron-hole pairs are generated with the application of electric field. In n-type semiconductor the number of electrons are more than holes. In this semiconductor the number of electrons are more than the holes. The electrons constitute majority carriers while holes constitute minority carriers.

## P type Semiconductors

When a small amount of trivalent impurity is added to a pure semiconductor, it is known as P-type semiconductor. Ex. Examples of trivalent impurities are Boron, Gallium etc.



In this case three valence electrons of boron atom form covalent bonds with four surrounding silicon atoms but one bond is left incomplete and gives rise a hole. Thus boron which is called an acceptor impurity causes as many positive holes in a silicon crystal as there are boron atoms. Boron is called acceptor impurity after acceptance of an electron it become negative fixed acceptor ions.

## Vacuum tubes and semiconductor

**Vacuum tube:** An electronic device in which the flow of electron is through a vacuum is known as vacuum tube. A vacuum tube usually contains a cathode which is the electron emitter, an anode (plate) and one or more electrodes called grids for controlling the flow of electron between cathode and plate. These electrodes are housed in a highly evacuated glass envelope.

Ex. - 1) Vacuum diode 2) Vacuum triode  
3) Vacuum tetrode 4) Vacuum pentode.

## Semiconductor device

Semiconductor is substance neither good conductor like copper nor insulator like glass.

By adding impurity to pure semiconductor one, can get two types of extrinsic semiconductor n-type and p-type semiconductors. combination of n and p-type semiconductor gives device like diode, transistor, FET etc. The conduction in semiconductor devices is due to electrons and holes.

## Integrated circuit:

An Integrated circuit is one in which circuit components such as transistors, diode, resistors, capacitors etc. are automatically part of a small semiconductor chip.

An Integrated circuit comprises of a number of circuit components such as transistor, diodes, resistors, capacitors etc. and their interconnections in a single package to perform a complete electronic function. These components are bonded and connected with in a small chip of a semiconductor material.

In an IC, the various components are automatically part of a small semiconductor chip and the individual components cannot be removed or replaced.

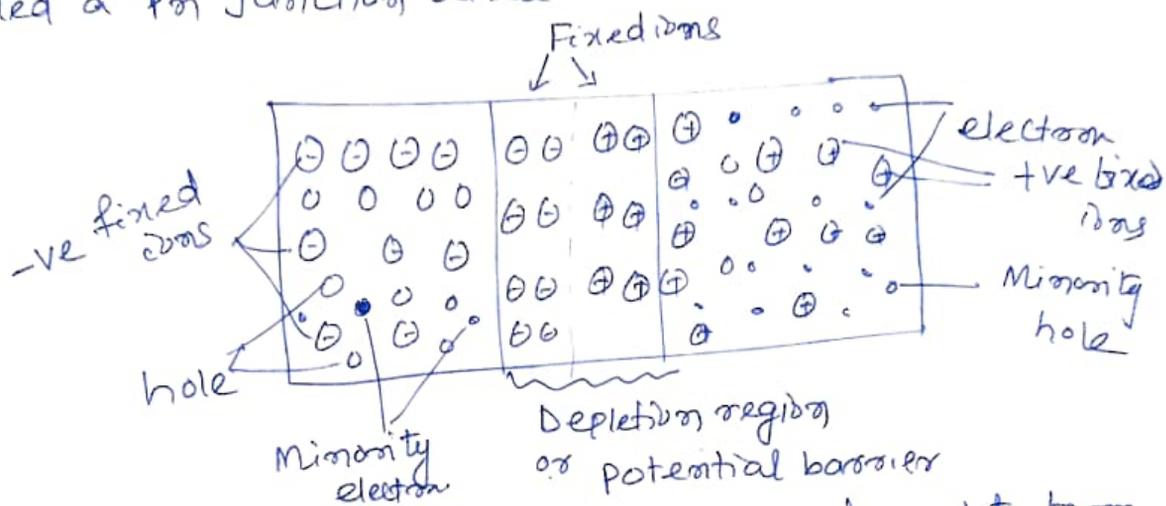
The size of an IC is extremely small. A typical semiconductor chip having dimensions  $2\text{mm} \times 2\text{mm} \times 0.1\text{mm}$ .

No component of an IC are seen to project above the surface of the chip. This is because all the components are bonded within the chip.

Application of IC: 1. Radio Receiver (2) TV receiver (3) Industrial application (4) Microwave application (5) Telephone/Teletype unit (6) Radar (7) Computers (8) calculator (9) Digital counter (10) Digital display unit and so many.

## P-n junction diode

It is possible to manufacture a single piece of semiconductor material one half of which is doped by P-type impurity and other half by n-type impurity. The plane dividing the two halves is called P-n junction. When a P-n junction is packed as a semiconductor device, it is called a P-n junction diode.



Now, suppose the two pieces are joined to form P-n junction, at the junction there is a tendency for the free electrons to diffuse over the P-side and holes the n-side. This process is called as diffusion. As the free electrons move across the junction from n-type to P-type positive donor ions are uncovered. Hence, as positive charge is built on the n-side of the junction. At the same time, the free electrons move across the junction and uncover the negative acceptor ions by filling in the holes. Therefore a negative charge is established on P-side of the junction. When a sufficient number of donor and acceptor ions is uncovered, further diffusion is prevented. Thus a barrier is set up against further movement of charge carriers i.e hole and electrons. This is called potential barrier. The potential barrier is of the order of 0.3V for germanium and 0.7V for silicon. The electric field ~~is~~ set up by a potential barrier, prevents the respective majority carrier from crossing the barrier region.

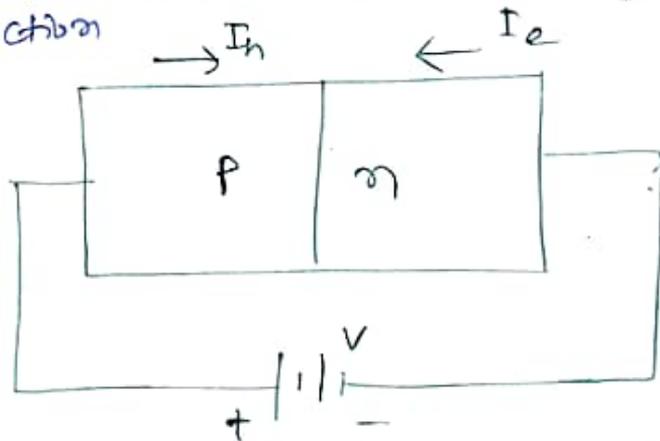
Arrow head Symbol of P-n diode



Inside the barrier, there is positive charge on n-side and negative charge on P-side. This region is called depletion region.

### Forward biased PN Junction!

When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting current flow, it is called forward biasing. Suppose positive battery terminal is connected to P-region of a semiconductor and the negative battery terminals to the n-region is called forward bias. Forward bias permits easy flow of current across the junction.

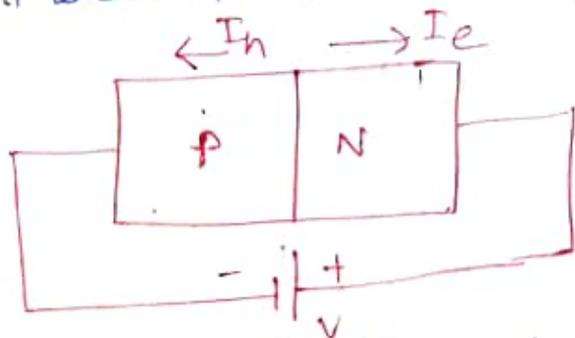


1) As soon as battery connections are made, holes are repelled by the <sup>positive</sup> negative battery terminals and electrons are repelled by the negative battery terminals with results that both the electrons and the holes are driven towards the junction. This movement of electrons and holes constitutes a large current flow through the semiconductor. The diode offers low resistance in forward direction.

2) The applied forward voltage reduce the height of potential barrier at the junction. It allows more carriers cross the junction, more current to flow across the junction. Forward bias reduce the thickness of depletion

## Reverse biased PN Junction diode!

When the external voltage applied to the junction is in such a direction that potential barrier is increased, it is called reverse biasing.



Suppose a negative terminal of the battery is connected to P-region of the diode and the positive terminal of the battery is connected to the n-region. In this case, holes are attracted by the negative battery terminal and electrons by the positive terminal, so that both holes and electrons move away from the junction. Since there is no current flow and the junction offers high resistance, the applied reverse voltage  $V$  increases the potential barrier, thereby blocking the flow of majority carriers. The reverse bias increases the thickness of the depletion layer.

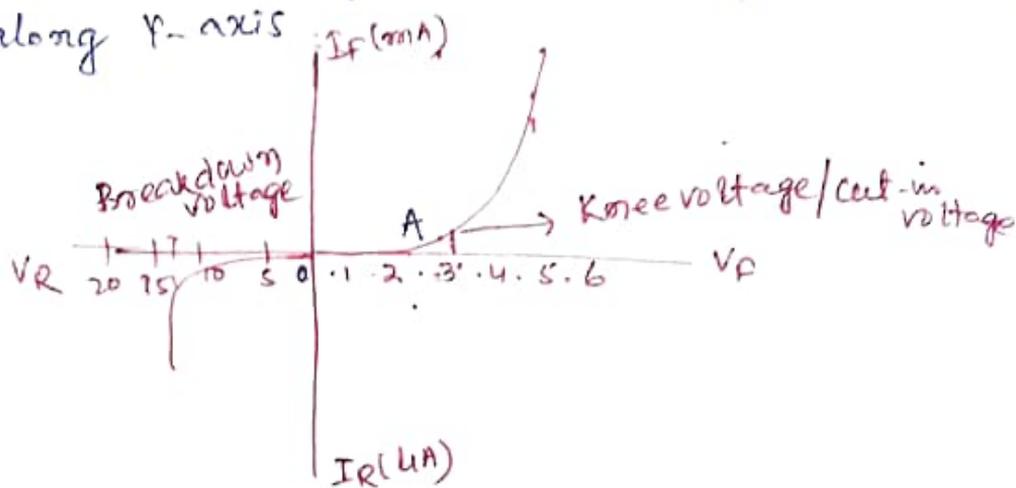
A small amount of current flow due to the flow of minority carriers. The current is called reverse saturation current.

## Junction Capacitance:

In a PN diode, the P-region and n-region act as conduction regions. The depletion region acts as a dielectric because it does not have either holes or electrons. The N-region, P-region, and depletion region are separated by insulators. The depletion region is a dielectric. From the fundamentals of components, we know that a capacitance is formed at a junction called as depletion capacitance. The depletion capacitance is inversely proportional to the width of the depletion region.

# VOLT- AMPERE CHARACTERISTICS OF PN DIODE (VI)

VI characteristics of a P-n diode is the curve between voltage across the junction and the circuit current. Voltage is taken along X-axis and current along Y-axis.



- 1. NO bias:** When the external voltage is zero i.e., circuit is open, the potential barrier at the junction does not permit current flow. Therefore the circuit current is zero and indicated by point 0.
- 2. Forward bias:** With forward bias to the P-n junction, the potential barrier is reduced. At ordinary room temp. a potential drop of about 0.3V or 0.7V is required to start conduction. This voltage is known as knee voltage or cut-in voltage. From this voltage the current starts to increase exponentially with the increase in forward voltage. From the forward characteristic, it is seen that at first region OA, the current increases slowly and the curve is non-linear. It is because the external voltage exceeds the potential barrier voltage the P-n diode behaves like an ordinary conductor. Therefore the current rises very sharply with increase in external voltage.
- 3. Reverse bias:** With reverse bias, the potential barrier is increased. Therefore the junction resistance becomes very high and practically no majority current flows through the circuit. However, in practice a very small current flows in the circuit with reverse bias. This is called reverse saturation current.

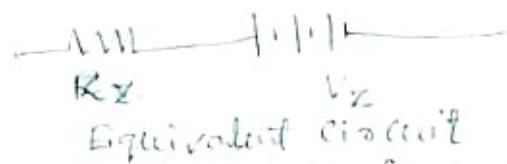
- 1) Maximum Forward current ( $I_F$ ): It is the maximum current that a diode can conduct in forward direction.
- 2) Peak inverse voltage (PIV): The maximum reverse voltage that a diode can withstand without being destroyed.
- 3) Reverse breakdown voltage: It gives the reverse voltage at which breakdown of the diode takes place.
- 4) Reverse saturation current: It gives the reverse current below the breakdown voltage.

### Applications of Pn diode:

1. Used as a rectifier in power supply
2. Used as switch
3. Used in clipper circuit
4. Used in clamper circuit
5. Used for demodulation of signal in the receiver.

### Zener diode

When an ordinary junction diodes are reverse biased, normally a small reverse saturation current  $I_0$  flows. As the reverse voltage is increased sufficiently the junction breakdown and a large reverse current flows. This large current could be enough to destroy the junction. A suitably designed diode, which have stable breakdown voltage over a wide range of reverse currents is called Zener diode. A properly doped crystal diode which has a sharp breakdown voltage is known as Zener diode.



- × It is a heavily doped diode, whose depletion layer is thin
- × When forward biased, its characteristics are just that of ordinary diode.

\* A Zener diode has sharp breakdown voltage called Zener voltage  $V_Z$ .

\* A Zener diode is not immediately burnt just because it has entered the breakdown voltage region. As long as the external circuit connected to the diode limits the diode current to less than burning current value, the diode will not burn out.

### Zener breakdown and Avalanche breakdown:

1. Zener breakdown! - It usually occurs in silicon PN junction at reverse biased of less than 5V.

Under the influence of high intensity electric field large no. of electrons with the depletion region break the covalent bonds with their atoms and thus a large reverse current flows. This is ionization by an electric field. Since a small reverse voltage can produce a very high intensity electric field within a narrow depletion region, this is known as Zener breakdown.

2. Avalanche Breakdown! It occurs because of cumulative action. The external applied voltage accelerates the minority carriers in the depletion region. They attain sufficient kinetic energy to ionize atoms by collision. This creates new electrons which are again accelerated to high enough velocities to ionize more atoms. This way an avalanche of free electrons is obtained. The reverse current sharply increases.

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# Difference between Zener breakdown and Avalanche breakdown

## Zener Breakdown

1. It occurs in heavily doped diodes i.e. in Zener diode
2. Ionization takes place by electrostatic field
3. It occurs even with less than 5V
4. The diode safely enters into Zener breakdown and comes

## Avalanche Breakdown

- It occurs in lightly doped diodes i.e. in PN diode
- Ionization takes place by collision.
- It occurs at higher voltage more than 5V
- once the diode enters into avalanche breakdown junction damage permanently.

## Application of Zener diode:

1. Used as voltage regulator
2. It is used as voltage reference standards in transmitter biasing circuit
3. It is used for clipping circuit
4. It is used for meter protection against damage from accidental application.

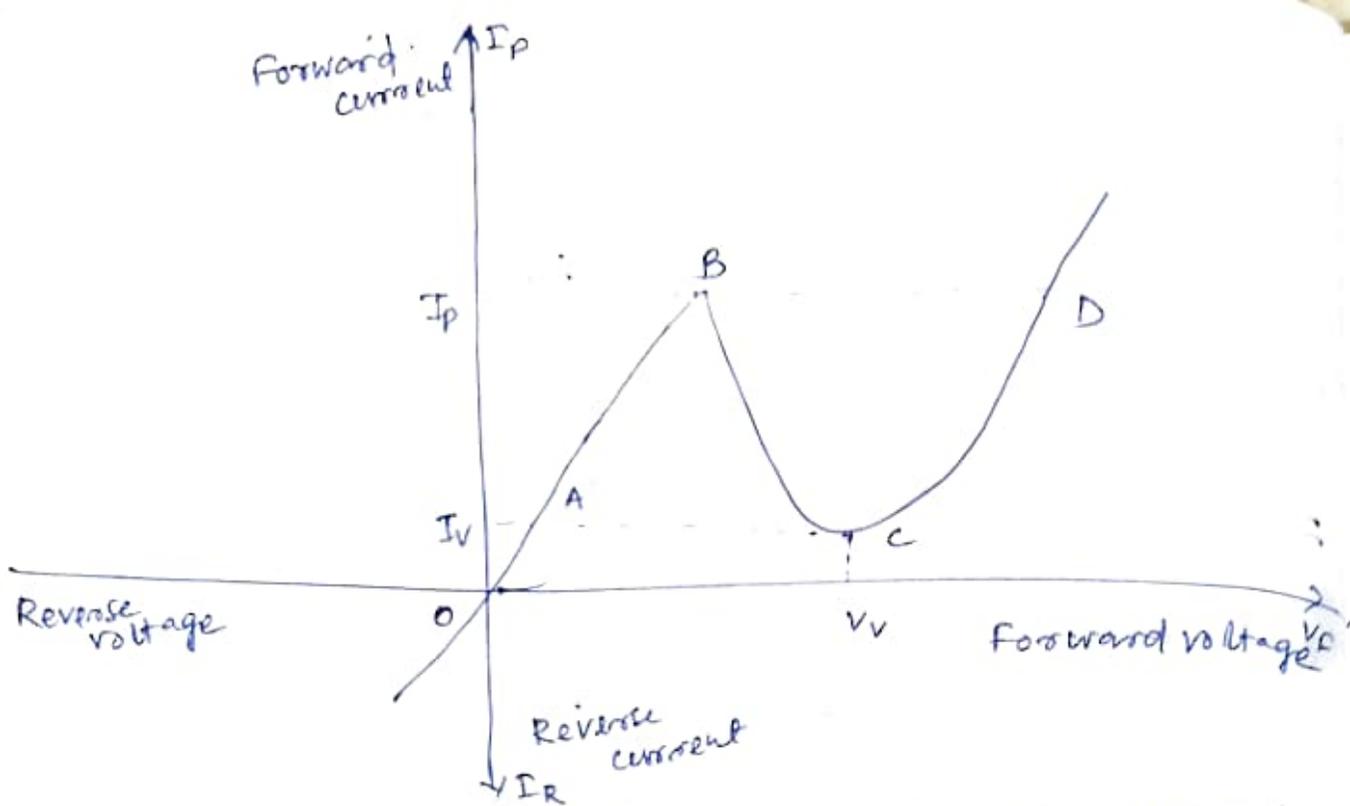
## Tunnel diode:

A tunnel diode is a P-N junction which is heavily doped. It has a negative resistance region. It works on the principle of tunneling which is obtained by creating thin depletion layer. It is also called as Esaki diode.

In tunnel diode the impurity concentration is greatly increased in the order of  $1 \text{ in } 10^3$ . The depletion layer width reduces about  $100\text{\AA}$ . because of this thin depletion layer the phenomenon of tunneling is possible.

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The tunnel diode has an excellent condition in the reverse direction. For small forward voltage the forward resistance remains small. This is because of tunneling phenomenon i.e. Penetration of electrons through the potential energy barrier. At point B the current is  $\text{max}^{\text{m}}$ .  $I_p$  corresponding forward voltage  $V_p$ . In the region BC the diode exhibits the negative resistance characteristic between the peak current  $I_p$  and valley current  $I_v$ . Beyond point C the current region reaches the value  $I_p$  at the voltage so called peak forward voltage.



### Light emitting diode: (LED)

The LED is basically a device which convert input electrical energy into output optical radiation in the visible or infrared position of spectrum ~~depend~~ depending on the semiconductor material used. LEDs have replaced incandescent lamps in many applications because of low voltage long life and fast ON-OFF switching.

The materials used in manufacturing the LEDs are: -

1. Gallium Arsenide Phosphide (GaAsP) : It provides either red light or yellow light.
2. Gallium Phosphide (GaP) : It provide red or green light
3. Gallium Arsenide (GaAs) : It provide infrared radiation



Advantage of LED : -

- ① Low working voltage and currents.
- ② Less power consumption
- ③ No warm up time
- ④ very fast action
- ⑤ small size and less in weight
- ⑥ Less fragile than glass
- ⑦ Extremely long life.

Disadvantage :

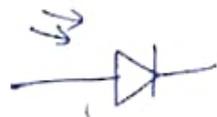
1. sensitive to damage by over voltage or over current
2. wide optical bandwidth compared to laser.

Application of LED

- ① calculator
- ② multimeter
- ③ digital meter
- ④ Microprocessors and so many.

PHOTO-DIODE

Photo diode is a opto device which is designed to respond to photo absorption. Under illumination, the carriers conduction is directly proportional to the injected carrier generation. This device when operated with reverse voltage applied, functions as a photo conductive cell and when operated without reverse voltage, functions as photo voltaic cell.



## Advantage of photo diode

- ① Low noise
- ② very good spectral response
- ③ faster photo detector

## Disadvantage : ① Light sensitive device

- ② Dark current increased with temperature
- ③ should not exceed the working temperature limit specified by the manufacturer.

## Application of photo diode

- ① Light Detector
- ② Demodulator
- ③ Encoder
- ④ Sound track films
- ⑤ Electronic control circuits
- ⑥ Optical communication spectrum
- ⑦ Light operated switches
- ⑧ computer card punching and tapes

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# Rectifier and Filter

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**Rectifier:** - A rectifier may be defined as an electronic device, such as a semiconductor diode, used for converting ac voltage or current into unidirectional voltage or current.

- ① Half-wave rectifier
- ② Full-wave rectifier

## Half-wave rectifier:

A half-wave rectifier circuit is one which conducts only during the positive half cycles of input ac supply. The negative half-cycles of ac supply are suppressed i.e. during negative half cycles, no current is conducted and no voltage appears across the load. Therefore current always flows in one direction through the load.



The ac voltage to be rectified is applied to the input of transformer and the voltage across the secondary is available for rectification. The use of transformer permits two advantages. Firstly it allows stepup or stepdown the ac input voltage. Secondly the transformer isolates the rectifier circuit from power line thus reduce the risk of electric shock.

Operation: The ac voltage across the secondary winding AB changes polarities after every half cycle. During the positive half cycle of input ac voltage, end A becomes positive with respect to end B. This makes the diode forward biased and it conducts current. During the negative half cycle end A is negative with respect to end B. Under this condition, the diode is reverse biased and it conducts no current. Thus current flows through the diode during positive half cycle of input ac voltage only. In this way current flows through load  $R_L$  always in the same direction. Hence dc output is obtained across  $R_L$ . The output is pulsating dc it means it contains both dc component and ac component.

Disadvantage:

- ① The ac supply delivers power only half the time. Therefore the output is low.
- ② The output contains more alternating components (ripples), therefore it needs heavy filter circuit to smooth out the outputs.

## Efficiency of the half wave rectifier

The ratio of dc output power to the applied ac input power is known as rectifier efficiency.

$$\eta = \frac{\text{dc output power}}{\text{ac input power}} = \frac{P_{dc}}{P_{ac}}$$

$$\text{dc output power } P_{dc} = I_{dc}^2 R_L$$

$$I_{dc} = \frac{I_m}{\pi} \quad \left( \begin{array}{l} I_{dc} = \text{average current} \\ I_m = \text{max}^m \text{ current} \\ R_L = \text{Load resistance} \end{array} \right)$$

$$\text{So } P_{dc} = \left( \frac{I_m}{\pi} \right)^2 R_L$$

$$\text{ac output power } P_{ac} = I_{ac}^2 (r_f + R_L)$$

$$I_{ac} = I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{I_m}{2}$$

( $r_f$  = diode resistance)

( $I_{rms}$  = Root mean Square current)

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

$$\therefore \eta = \frac{P_{dc}}{P_{ac}} = \frac{\left( \frac{I_m}{\pi} \right)^2 R_L}{\left( \frac{I_m}{2} \right)^2 (r_f + R_L)} = \frac{\frac{I_m^2}{\pi^2}}{\frac{I_m^2}{4}} \cdot \frac{R_L}{(r_f + R_L)}$$

$$= \frac{I_m^2}{\pi^2} \times \frac{4}{I_m^2} \times \left( \frac{R_L/R_L}{r_f/R_L + R_L/R_L} \right) = \frac{4}{\pi^2} \left( \frac{1}{1 + \frac{r_f}{R_L}} \right)$$

$$= \frac{4}{\pi^2} \left( \frac{1}{1} \right) \quad \left( \begin{array}{l} r_f \ll R_L \\ \text{So } \frac{r_f}{R_L} \text{ is negligible} \end{array} \right)$$

$$= 0.406$$

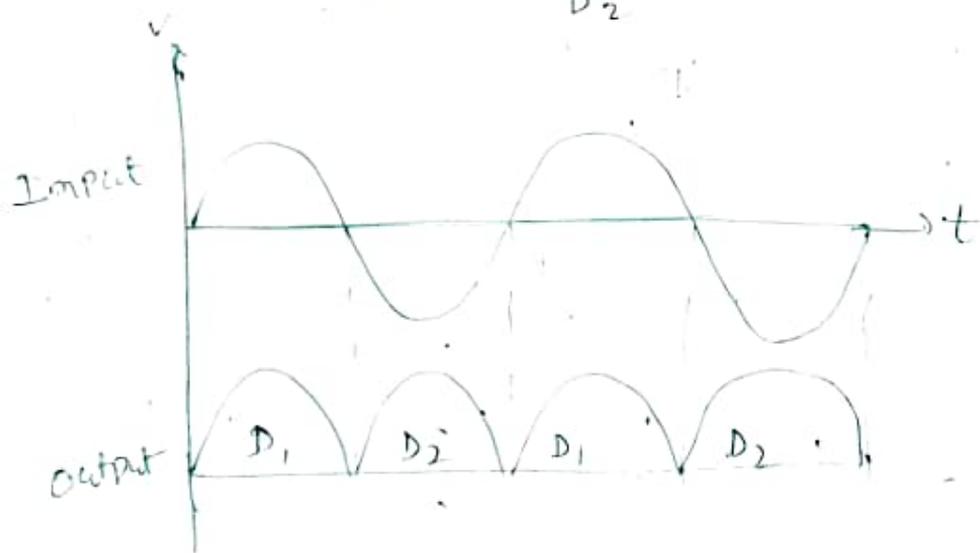
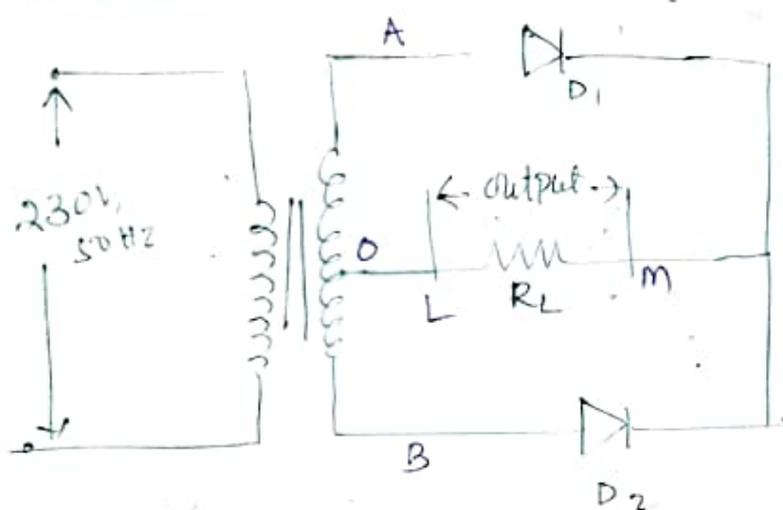
So Rectifier efficiency of half rectifier is 0.406 or 40.6%.

## Full wave rectifiers :-

In full wave rectifier current flows through the load in the same direction for both half cycle of input ac voltage. The full wave rectifiers are two types

- ① Center-tapped full wave rectifier
- ② Full wave bridge rectifier

### Center-tapped full wave rectifier



The circuit employs two diodes  $D_1$  and  $D_2$ . A center-tapped secondary winding AB is used with two diodes connected so that each uses one half cycle of input AC voltage. The diode  $D_1$  utilizes the AC

voltage appearing across the upper half (OA) of the secondary winding for rectifier while diode  $D_2$  uses the lower half winding OB.

operation! → During the positive half-cycle of secondary voltage, the end A of the secondary winding becomes positive and end B negative. This makes the diode  $D_1$  forward biased and  $D_2$  reverse biased.

→ Therefore the diode  $D_1$  conducts while diode  $D_2$  does not. The conventional current flow is through  $D_1$ , the load resistor  $R_L$  and the upper half of the secondary winding.

→ During the negative half-cycle end A of the secondary winding becomes negative and end B positive.

→ Therefore, the diode  $D_2$  conducts while diode  $D_1$  does not. The conventional current flow is through diode  $D_2$ , load  $R_L$  & lower half of the secondary winding.

→ It may be seen that current in the  $R_L$  is in the same direction for both half-cycles of input AC voltage.

Therefore DC is obtained across the load  $R_L$ .

Advantage: i) The DC output voltage and load current values are twice than that of half wave rectifier  
ii) The ripple factor is much less (0.482) than that of half wave rectifier (1.21)  
iii) The efficiency is twice (81.2%) than that of half-wave rectifier is (40.6%)

Disadvantage of center-tapped full wave rectifier

i) It is difficult to locate the center tap on the secondary winding.

ii) The DC output is small as each diode utilizes only one-half of the transformer secondary voltage.

iii) The diodes used must have high peak inverse voltage  $PIV = 2V_m$ .

### Full-wave bridge rectifier:-

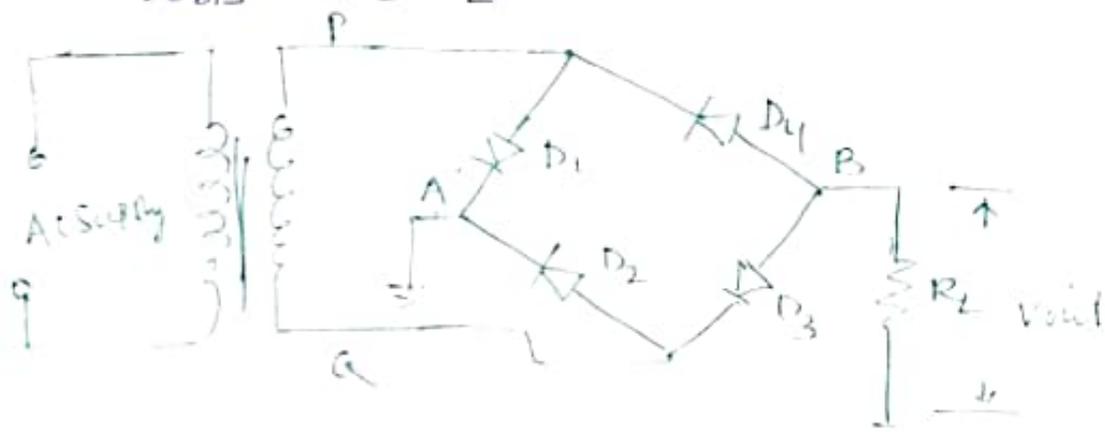
Full wave operation can be obtained even without the center tapped transformer in bridge rectifier.

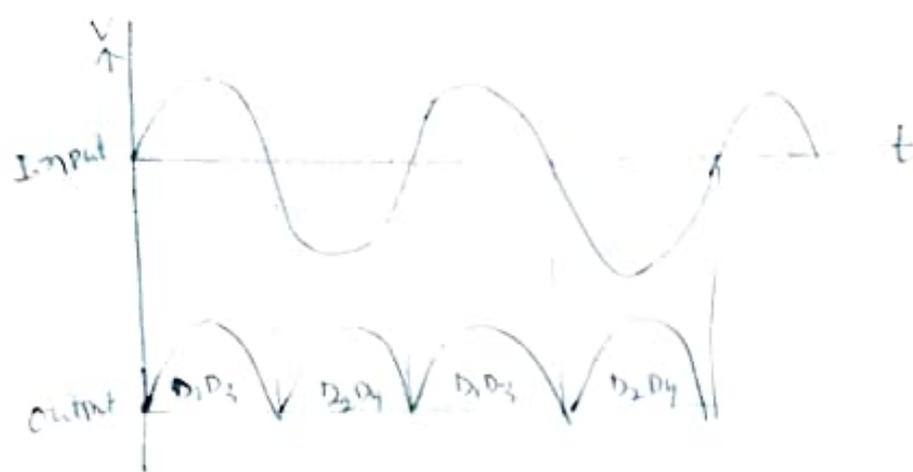
→ The need for a center tapped transformer is eliminated in the bridge rectifier.

→ It contains four diodes  $D_1, D_2, D_3$  and  $D_4$  connected to form bridge.

→ The AC supply to be rectified is applied to the diagonally opposite ends of the bridge through the transformer.

→ Between other two ends of the bridge the load resistance  $R_L$  is connected.





### Working

→ During the positive half-cycle of secondary voltage the end P of the secondary winding becomes positive and end Q negative.

→ This makes diodes  $D_1$  and  $D_3$  forward biased while  $D_2$  and  $D_4$  are reverse biased.

→ Therefore, only diodes  $D_1$  and  $D_3$  conduct current. This two diodes will be in series through the load  $R_L$  as in big. The conventional current flow is shown by dotted arrows. It may be seen that current flows from A to B through the load  $R_L$ .



(Full wave bridge rectifier in the half cycle)

→ During the negative half-cycle of secondary voltage, end P negative and Q positive. This makes diode  $D_2$  and  $D_4$  forward biased. Whereas diode  $D_1$  and  $D_3$  reverse biased.

→ Therefore only diode  $D_2$  and  $D_4$  conduct. These two diode will be series through load  $R_L$  as in figure. The current flow is shown in dotted arrow.

→ It may be seen that again, current flows through the load in the same direction as for the positive half cycle. Hence DC output is obtained across load  $R_L$ .



(Full wave bridge Rectifier - no half cycle)

### Advantage:

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

### Disadvantage:

- 1) It requires four diodes.
- 2) Internal resistance is high.

### Efficiency of Full wave rectifier

$$\text{Efficiency} = \eta = \frac{P_{dc}}{P_{ac}} = \frac{\text{DC output power}}{\text{ac input power}}$$

$$P_{dc} = I_{dc}^2 R_L = I_{av}^2 R_L$$

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

$$P_{dc} = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

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

$$I_{ac} = I_{rms} = \frac{I_m}{\sqrt{2}}$$

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

$$\text{Efficiency } \eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(\frac{2I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)}$$

$$= \frac{4I_m^2}{\pi^2} \times \frac{2}{I_m^2} \left(\frac{R_L R_L}{r_f R_L + R_L R_L}\right)$$

$$= \frac{8}{\pi^2} \left(\frac{1}{1 + \frac{r_f}{R_L}}\right)$$

$$= 0.812$$

$$r_f \ll R_L$$

So,  $\frac{r_f}{R_L}$  is negligible

Efficiency of Full wave rectifier is 0.812 or 81.2%.

Ripple factor (RF):

The ac component present in the rectifier output is called as ripple. The ratio of rms value of ac component to the DC component in the rectified output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{Rms value of ac component}}{\text{value of dc component}}$$

Ripple factor is very important in deciding the effectiveness of a rectifier.

$$\text{Ripple factor} = \frac{I_{ac}}{I_{dc}}$$

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

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

$$R.F. = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

For half wave rectifier

$$I_{rms} = \frac{I_m}{2} \quad \text{and} \quad I_{dc} = \frac{I_m}{\pi}$$

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

For full wave rectifier: -

$$I_{rms} = \frac{I_m}{\sqrt{2}} \quad \text{and} \quad I_{dc} = \frac{2I_m}{\pi}$$

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

This shows that in the output of a full wave rectifier the dc component is more than the ac component. The pulsations in the output will be less than in half-wave rectifier.

Filter: A filter circuit is a device which removes the ac component of rectifier output but allows the dc component of rectifier output to reach the load.

A filter circuit is generally a combination of inductor (L) and capacitor (C). The filter action of L and C depends upon the basic electrical properties.

Electrical properties of capacitor

$$X_c = \text{capacitive reactance} \\ = \frac{1}{2\pi fC}$$

For DC  $f = \text{frequency} = 0$

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 0 \times C} = \frac{1}{0} = \infty$$

For AC  $f = 50 \text{ Hz}$

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times C} = \frac{1}{100\pi C}$$

It shows that capacitor offers high reactance path to dc component and low reactance path to ac component.

OR  
Capacitor block the dc component and passes the ac component

Electrical Properties of inductor! -

$X_L = \text{Inductive reactance} = 2\pi fL$

For DC  $f = 0$

$X_L = 2\pi fL = 2\pi \times 0 \times L = 0$

For ac  $f = 0$

$X_L = 2\pi fL = 2 \times \pi \times 50 \times L = 100\pi L$

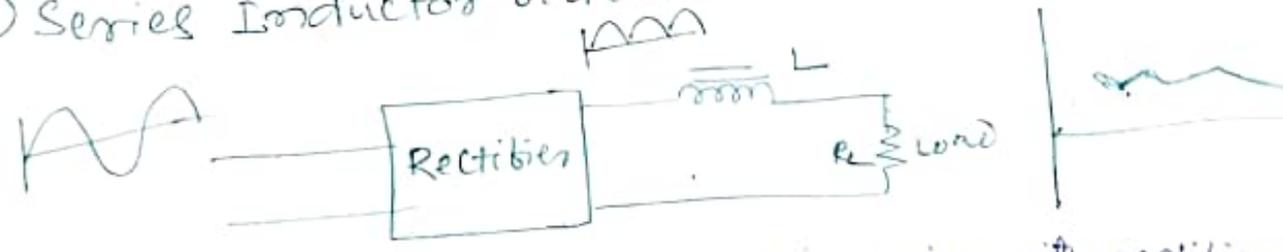
It means that inductor offers low reactance path to dc and high reactance path to ac.

OR  
Inductor block the ac component and passes the dc component.

Types of filters

- 1) Series Inductor filter
- 2) Shunt capacitor filter
- 3) Choke input LC filter
- 4) Capacitor input  $\pi$  filter

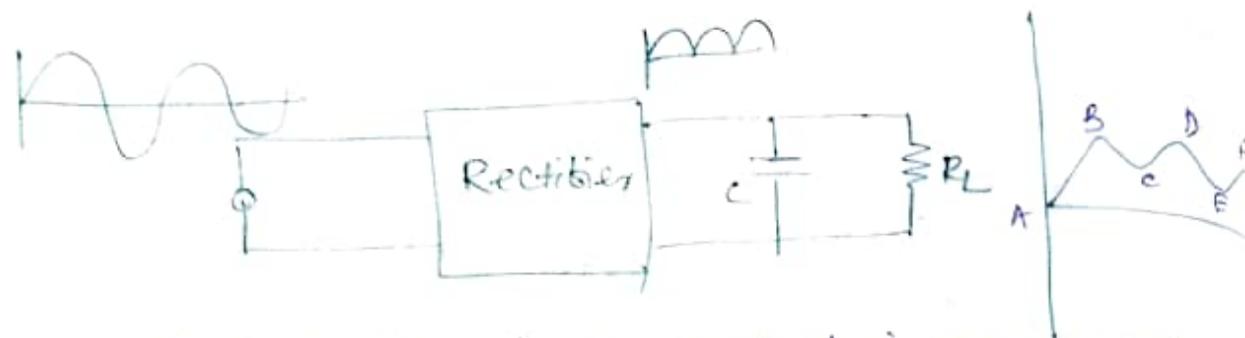
① Series Inductor filter! -



An inductor is connected in series with rectifier output and load resistance  $R_L$ . The choke offers high opposition to the passage of an ac component but no opposition to the dc component. The result is that most of the ac component appears across the choke while whole of the dc component passes

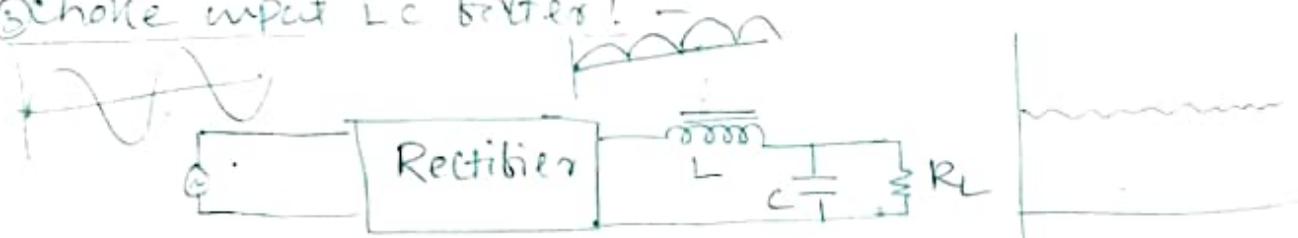
through the choke on its way to load. This results in the reduced pulsations at load resistance  $R_L$ .

## ② Shunt capacitor filter: -



A capacitor is connected in parallel to the rectifier output and load resistance  $R_L$ . The pulsating direct voltage of the rectifier is applied across the capacitor. As the rectifier voltage increases it charges the capacitor and also supplies current to the load. At the ends of quarter cycle the capacitor charges to the peak value  $V_m$  of the rectifier voltage. Now the rectifier voltage starts to decrease. The capacitor discharges through the load and recharges the capacitor. This process is repeated again and again and the output voltage becomes ABCDEFG. It may be seen that very little ripple is left in the output.

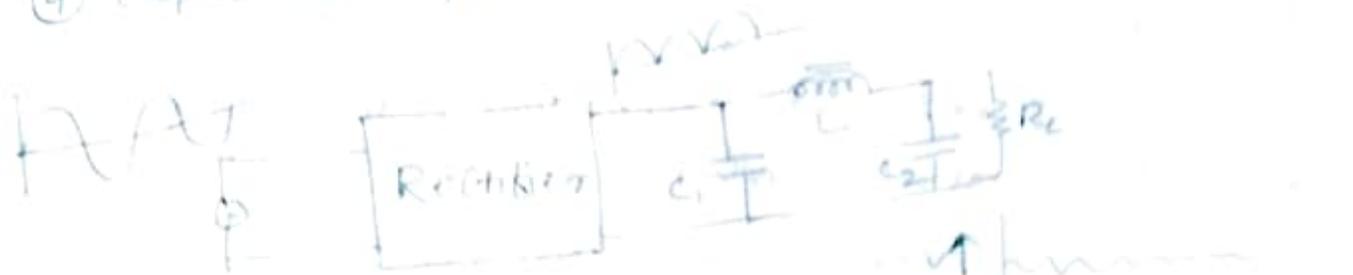
## ③ Choke input LC filter: -



It consists of a choke  $L$  connected in series with rectifier output and a filter capacitor across the load. It is two stage of filter. The inductor passes the dc component and blocks the ac component. The capacitor passes the remaining ac component and blocks the dc component which is flow through the load.

resistance  $R_L$ . This results in the reduced in pulsation as compared to the single stage filter.

(4) Capacitor Impact filter or  $\pi$  filter -



It consists of a filter capacitor  $C_1$  connected across the rectifier output, a choke  $L$  in series and another filter capacitor  $C_2$  connected across the load.

Several ~~unit~~ identical sections are often used to improve the smoothing action.

(a) The filter capacitor  $C_1$  offers low resistance to AC component of rectifier output while it offers infinite reactance to the DC component while DC component block and passes to the choke  $L$ .

(b) The choke  $L$  offers high reactance to the AC component but it offers almost zero reactance to the DC component. Therefore it allows the DC component flow through it while the AC component is blocked.

(c) The filter capacitor  $C_2$  by passes the AC component which the choke has failed to block. Therefore only DC component appears across the load and that is what we desire.

## Ripple factor (RF)

The ac component present in the rectified output is called as ripple. The ratio of rms value of ac component to the dc component in the rectified output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{RMS value of ac component}}{\text{value of dc component}}$$

Ripple factor is very important in deciding the effectiveness of a rectifier.

$$\text{Ripple factor} = \frac{I_{ac}}{I_{dc}}$$

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

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

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

For half wave rectifier -

$$I_{rms} = \frac{I_{m}}{2} \quad \text{and} \quad I_{dc} = \frac{I_{m}}{\pi}$$

$$\text{Ripple factor of H.W.R} = \sqrt{\left(\frac{I_{m}/2}{I_{m}/\pi}\right)^2 - 1} = 1.21$$

For full wave rectifier:  $I_{rms} = \frac{I_{m}}{\sqrt{2}}$  and  $I_{dc} = \frac{2I_{m}}{\pi}$

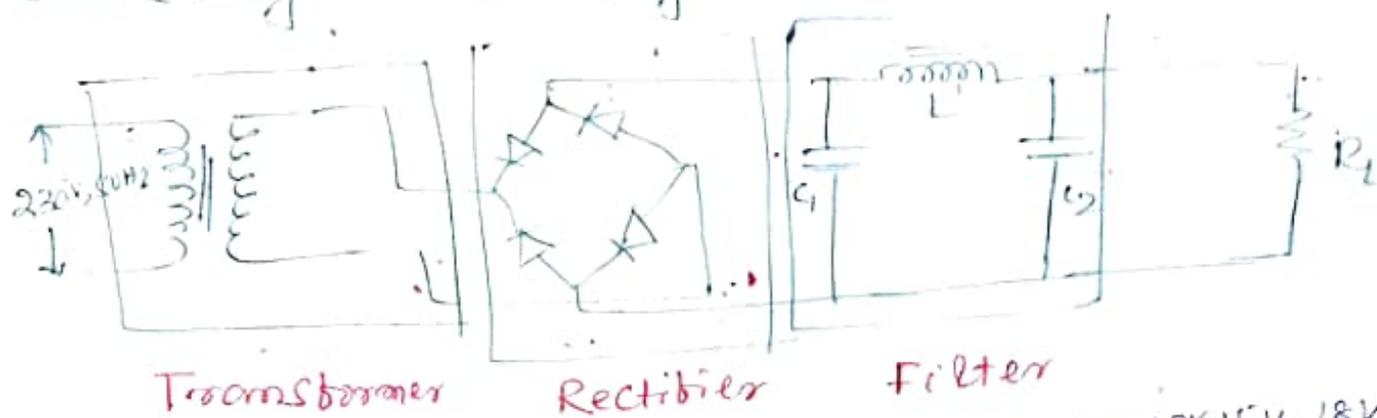
$$\text{Ripple factor} = \sqrt{\left(\frac{I_{m}/\sqrt{2}}{2I_{m}/\pi}\right)^2 - 1} = 0.48$$

This shows that in the output of a full wave rectifier the dc component is more than the ac component. The pulsations in the output will be less than in half-wave rectifier.

## Unregulated power supply :-

A combination of a rectifier and a smoothing (filter) circuit is the unregulated power supply.

Block diagram of unregulated power supply:



A small dc voltage (3V, 4.5V, 6V, 9V, 12V, 15V, 18V or 24V) is required for the operation of various electronics circuits. Therefore a small step-down transformer is employed at the beginning which decreases the voltage level. The output of the transformer is connected to the rectifier which convert ac to dc. The dc available at the output of a rectifier is pulsating in nature. The output of the rectifier is connected to the filter circuit which suppresses the ripples and supplies the dc voltage at the output.

Drawback (i) The output voltage changes with the change in ac supply.

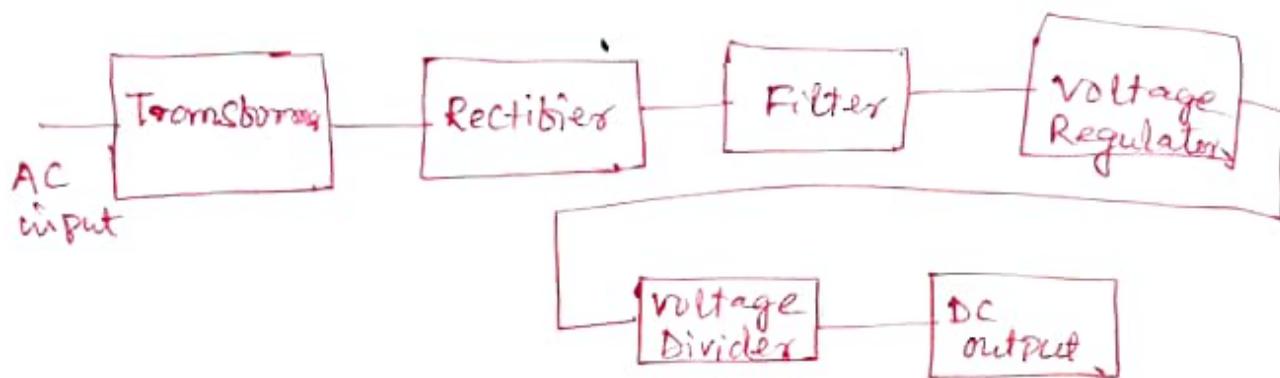
(ii) The dc output voltage decreases considerably with the increase in load due to voltage drop in 1) transformer winding 2) rectifier and (iii) Filter circuit.

Niranjana Behera

Sr. Lect. PKAIG, BARGACHA

## Regulated Power Supply :-

A power supply that maintains the output voltage constant irrespective of AC mains fluctuation, load variations is known as a regulated power supply.



### BLOCK DIAGRAM OF REGULATED POWER SUPPLY

1. Transformer: The transformer is used to step down voltage to suit the requirement of the solid state electronic device and circuit.
2. Rectifier: - The rectifier is used to convert AC voltage to DC voltage.
3. Filter: - The function of the filter is to remove the fluctuation or pulsations present in the output voltage supplied by the rectifier.
4. Voltage Regulator: - Its main function is to keep the terminal voltage of the DC supply constant even when:
  - a) AC input voltage to the transformer varies
  - b) The load variesUsually Zener diode and transistor are used for voltage regulation.
5. Voltage divider: - Its function is to provide different DC voltage needed by different electronic circuit. It consists of a number of resistors connected in series across the output terminals of the voltage regulator.

# Transistor

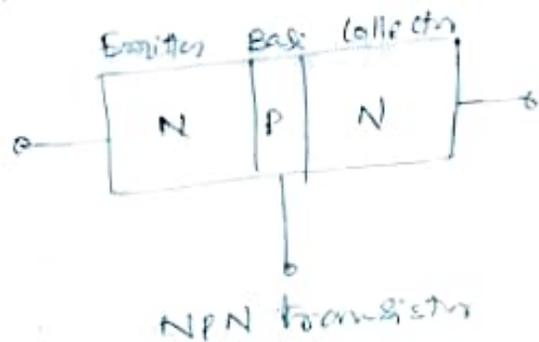
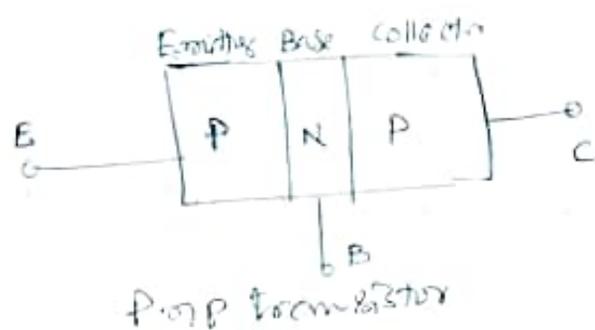
Niranjan Behera  
Sr. Lect PKAIEJ, BARGAR

1948 J. Bardeen and W.H. Brattain of Bell Telephone Laboratories USA developed the transistor.

A transistor has two junctions formed by sandwiching either P-type or n-type semiconductor between a pair of opposite types. It is also called as bipolar junction transistor.

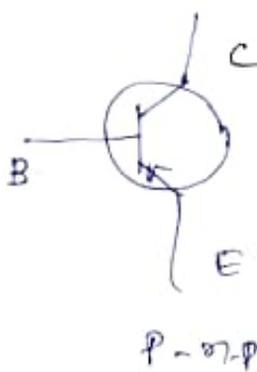
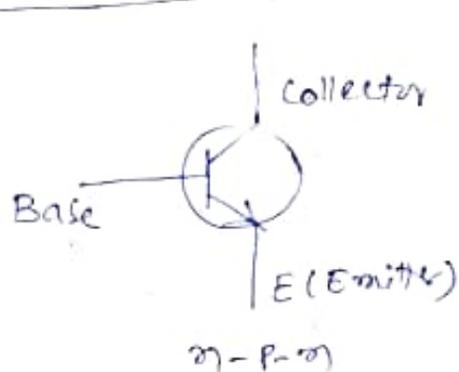
There are two types of transistor:

1. PNP Transistor
2. NPN Transistor



- It has three terminals ① Emitter ② Base and ③ Collector
- It is named as Bipolar Junction Transistor as both majority carrier and minority carrier take part in current flow
- It has two P-n junctions
- Emitter base junction is I/p junction and collector-emitter junction is o/p junction
- I/p junction is always forward biased and o/p junction is reverse biased.

Symbol of transistor:-



1. **Emitter!** The section on one side supplies charge carriers is called the emitter. The emitter is heavily doped than of the other two regions because its main function is to supply major charge carrier to the base. The emitter may be distinguished from the collector by a arrow head represents the direction of the emitted current with the forward bias on the emitter.
2. **Base!** - The middle section which forms two PN junctions between the emitter and collector is called the base. It is very thin as compared to other two region and lightly doped.
3. **Collector!** - The section on the other side collects the charge carriers is called collector. The collector region is physically larger than the emitter region because it has to dissipate much power.

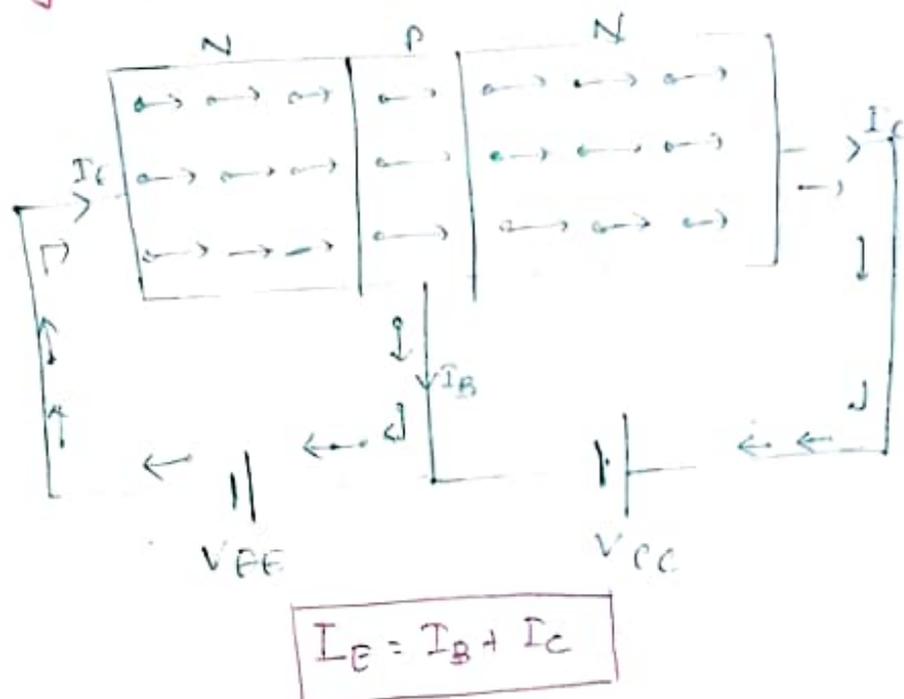
### Biasing of Transistor! -

A transistor has two junctions. Each junction can be connected in forward or reverse bias. Therefore there are four ways of biasing these two junctions of transistor

Emitter junction	Collector junction	Region of operation
Forward bias	Reverse bias	Active
Forward bias	Forward bias	Saturation
Reverse bias	Forward bias	Inverted
Reverse bias	Reverse bias	Cut-off

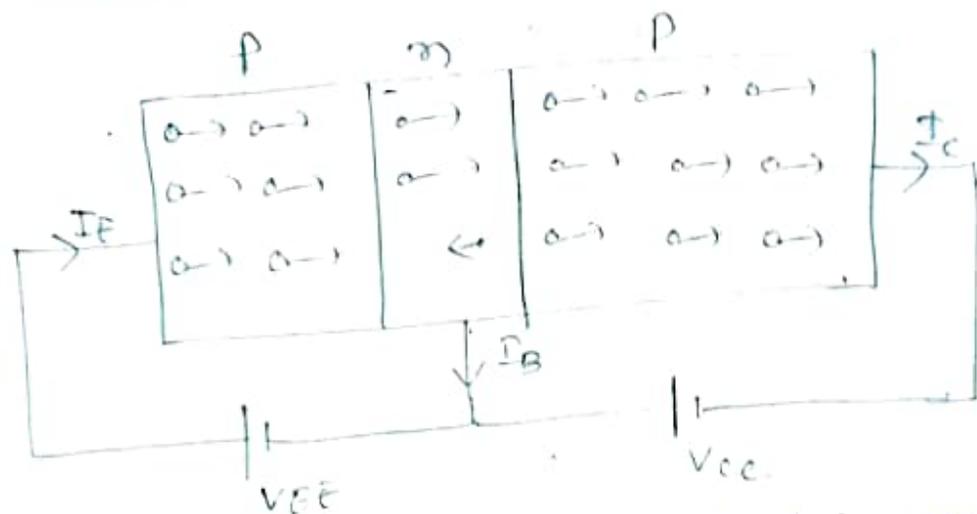
Transistor is operated in the active region for the most of time. It works as an amplifier in this region. Transistor can also be used as switch. In saturation region it acts as ON switch in cut-off region it acts as OFF switch.

## Working of NPN Transistor :-



The NPN transistor in active region emitter junction is forward biased by  $V_{EE}$  and collector junction is reverse biased by  $V_{CC}$ . The forward bias in the emitter junction causes the electron flow from N-type emitter to P-type base. This constitutes the emitter current  $I_E$ . As these electrons flow through the P-type base, they tend to combine with holes. As the base is lightly doped and very thin, therefore only a few electrons (less than 5%) combine with holes to constitute base current  $I_B$ . The base current is very less. The remaining electron (more than 95%) cross over into the collector region because collector base junction reverse bias. This constitutes collector current  $I_C$ . It is clear that emitter current is the sum of collector and base current.

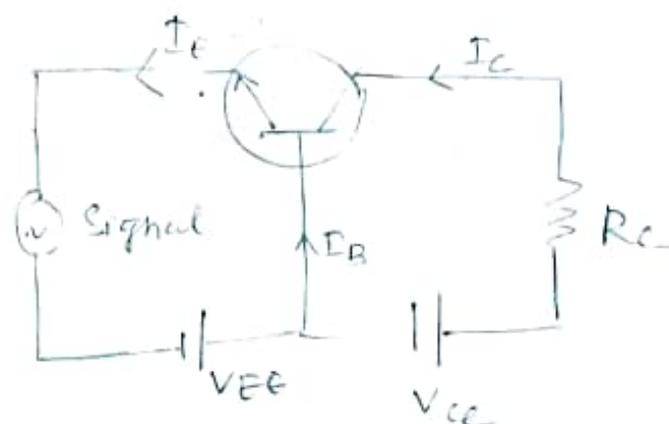
## Working of PNP Transistor



The PNP transistor connected in active region as in fig. emitter junction is forward biased by  $V_{EE}$  and collector junction is reverse biased by  $V_{CC}$ . The forward biased in emitter junction causes the flow of holes from P-type emitter to N-type base. This constitutes the emitter current  $I_E$ . In this holes flow through the N-type base they tend to combine with electrons. As the base is lightly doped and very thin, therefore a few (less than 5%) combine with electrons to constitute the base current  $I_B$ . The base current is very less. The remaining holes (more than 95%) cross over into the collector region because collector base junction is reverse biased. This constitutes collector current  $I_C$ . So the emitter current is the sum of collector and base current i.e.

$$I_E = I_B + I_C$$

## Transistor as An amplifier:



The signal is applied between emitter and base junction and output is taken across the load  $R_C$  connected in the collector circuit. To achieve amplification, the input circuit should always remain forward biased for this a dc voltage  $V_{EE}$  is applied in the series with the signal. The dc voltage is known as bias voltage and its magnitude should always be such that it keeps the input circuit forward biased.

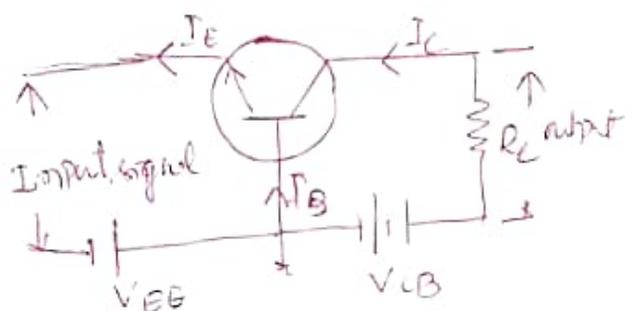
A small change in the input voltage causes a large change in emitter current. The change in emitter current is transferred to collector due to transistor action. This causes large change in collector circuit current. The collector current flowing through load resistance  $R_C$  produced a large change in voltage across it because the load resistance is of the order of  $k\Omega$ . The transistor is increasing the small input to a large output. Hence transistor acts as amplifier, which raises the signal strength.

For example Load resistance  $R_C = 5k\Omega$ . Assume that a change of  $0.2V$  in signal voltage produce a change of  $1mA$  in emitter current. The change in collector current would also be approximately  $1mA$ . This collector current through  $R_C$  would produce a voltage  $5k\Omega \times 1mA = 5V$ . Thus a change of  $0.2V$  in the signal produce a change of  $5V$  in the output circuit. It means the voltage amplification is  $25\times$ .

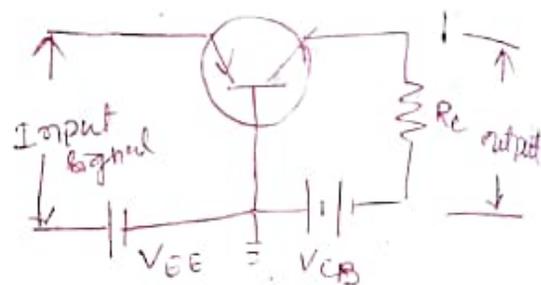
# TRANSISTOR CONFIGURATION

- ① Common base configuration
- ② Common emitter configuration
- ③ Common collector configuration

## ① Common base configuration (CB)



CB in NPN transistor



CB in PNP transistor

The input is connected between emitter and base while output is taken across collector and base. Thus the base of transistor is common to both input and output circuits and hence the name common base configuration.

### Current amplification factor ( $\alpha$ )

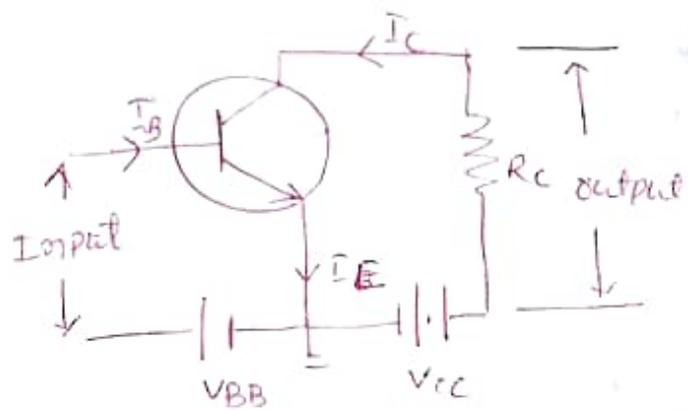
The ratio of output current to input current is known as current amplification factor. In CB connection, the output current is collector current  $I_C$  whereas the input current emitter current  $I_E$ .

The ratio of change in collector current ( $\Delta I_C$ ) to change in emitter current ( $\Delta I_E$ ) at constant collector base voltage  $V_{CB}$  is known as current amplification factor of CB transistor. It is generally represented by Greek letter  $\alpha$  (alpha)

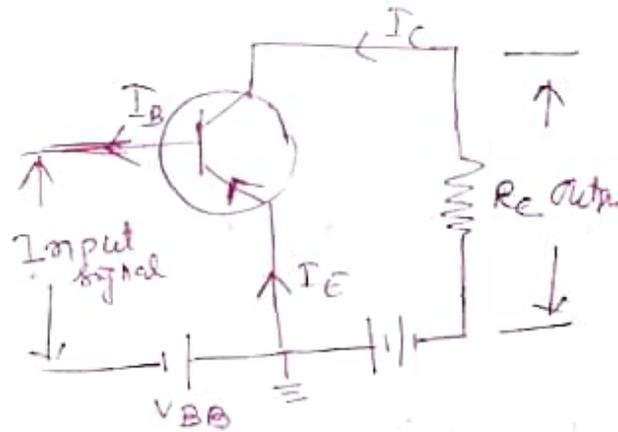
$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

The value of  $\alpha$  is less than 1

## ② Common emitter configuration (CE)



CE in NPN transistor



CE in PNP transistor

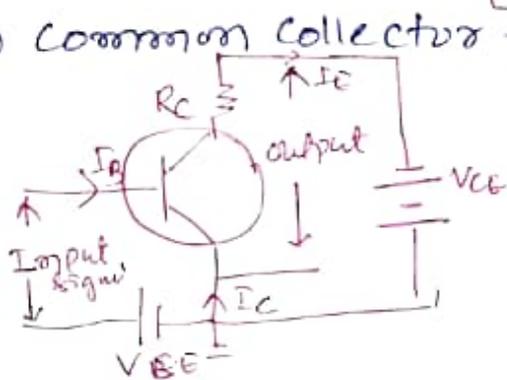
In this arrangement, the input is connected between base and emitter while output is taken from the collector and emitter. Thus the emitter of the transistor is common to both input and output circuits and hence the name common emitter configuration.

### Base current amplification factor: -

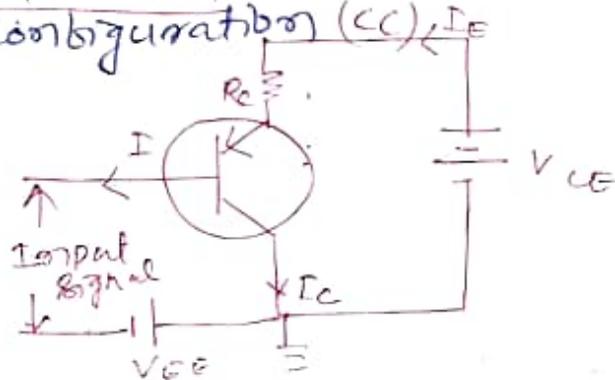
The ratio of change in collector current to the change in base current is known as base current amplification factor. It is generally represented by Greek letter  $\beta$  (beta)

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

## ③ Common collector configuration (CC)



CC in NPN transistor



CC in PNP transistor

The input is connected between base and collector while output is taken across the emitter and collector. Thus the collector of the transistor is common to both input and output circuits. Hence the name is common collector configuration.

## Current amplification factor ( $\gamma$ )

The ratio of change in emitter current to the change in base current  $I_B$  is known as current amplification factor. It is generally represented by Greek letter  $\gamma$  (Gamma)

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

## Relation between $\alpha$ and $\beta$ .

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad \text{and} \quad \alpha = \frac{\Delta I_C}{\Delta I_E}$$

$$I_E = I_B + I_C$$

$$\text{or, } \Delta I_E = \Delta I_B + \Delta I_C$$

$$\text{or, } \Delta I_B = \Delta I_E - \Delta I_C$$

Substituting the value of  $\Delta I_B$  in  $\beta$

$$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

Dividing both side by  $\Delta I_E$

$$= \frac{\Delta I_C / \Delta I_E}{(\Delta I_E - \Delta I_C) / \Delta I_E} = \frac{\Delta I_C / \Delta I_E}{\left(1 - \frac{\Delta I_C}{\Delta I_E}\right)}$$
$$= \frac{\alpha}{1 - \alpha}$$

$$\text{or, } \beta = \frac{\alpha}{1 - \alpha}$$

## Relation between $\alpha$ and $\gamma$

$$\gamma = \frac{\Delta I_E}{\Delta I_B} \quad \alpha = \frac{\Delta I_C}{\Delta I_E}$$

$$I_E = I_B + I_C$$

$$\text{or, } \Delta I_E = \Delta I_B + \Delta I_C$$

$$\text{or, } \Delta I_B = \Delta I_E - \Delta I_C$$

Substituting the value of  $\Delta I_B$  in  $\gamma$

$$\gamma = \frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

Dividing both side by  $\Delta I_E$

$$= \frac{\Delta I_C / \Delta I_E}{(\Delta I_C - \Delta I_C) / \Delta I_E} = \frac{1}{1 - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1 - \alpha}$$

$$\boxed{\gamma = \frac{1}{1 - \alpha}}$$

### Faithful amplification:

The process of raising the strength of a weak signal without any change in its general shape is known as faithful amplification. For faithful amplification the base-emitter junction of transistor remain forward biased and collector junction is reverse biased.

1. Proper zero signal collector current! - The value of zero signal collector current should be at least equal to the maximum collector current due to signal alone.
2. Proper minimum base-emitter voltage! - The base emitter voltage  $V_{BE}$  should be not be fall below 0.3V for germanium and 0.7V for silicon transistor.
3. Proper minimum collector-emitter voltage! - The collector emitter voltage should not be fall below 1.0V for Si and 0.5V for Ge transistor.

### Transistor biasing

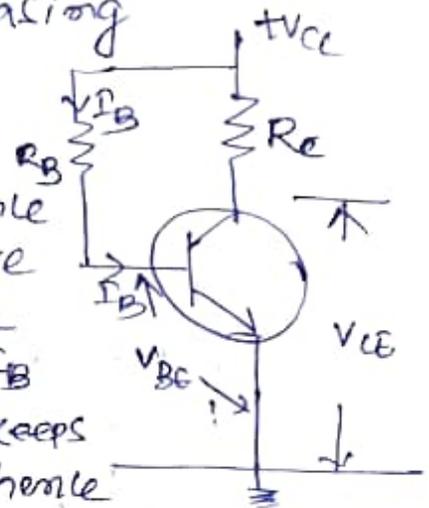
The process by which the required conditions such as proper flow of zero signal collector current and the maintenance of proper collector-emitter voltage during the passage of signal are obtained is known as transistor biasing.

# Types of transistor biasing:

- ① Base resistor biasing
- ② Feedback resistor biasing
- ③ Emitter resistor biasing
- ④ voltage divider biasing

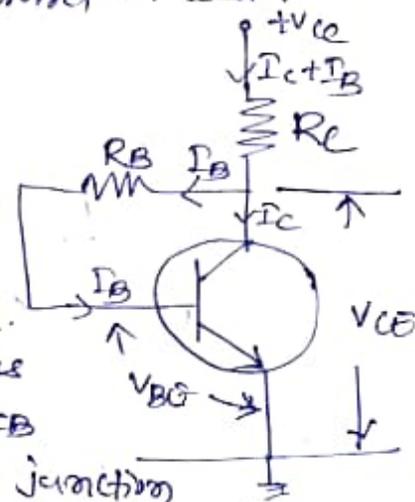
## ① Base resistor biasing

In this method a high resistance  $R_B$  is connected between the positive end of the supply and the base. The required zero signal base current  $I_B$  is provided by  $V_{CC}$ . The supply also keeps the base positive w.r.t emitter and hence makes the base-emitter junction forward biased.



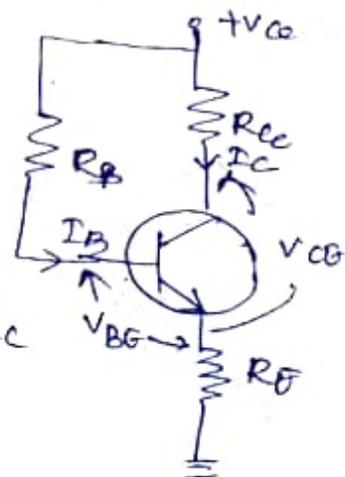
## ② Feedback resistor biasing

The feedback resistor biasing is also known as collector to base resistor biasing. Here a high resistance  $R_B$  is connected between collector and base. The required zero signal base current is determined by collector-base voltage  $V_{CB}$  and by  $V_{CC}$ . Hence the base-emitter junction is forward biased and base current  $I_B$  flows through  $R_B$ . This causes the zero signal collector current  $I_C$  to flow in the circuit.



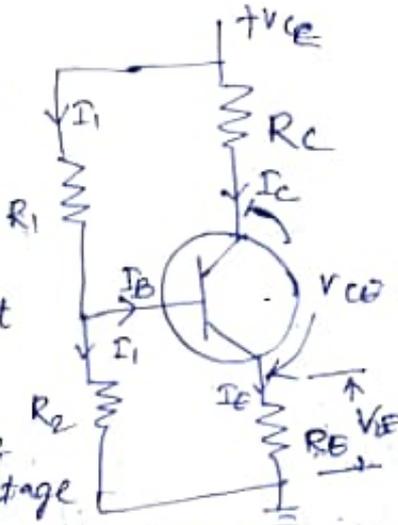
## ③ Emitter resistor biasing:

In this biasing circuit an additional resistor  $R_E$  is connected in emitter. Hence the circuit contains three resistors  $R_B$ ,  $R_E$  and  $R_C$ .



④ Voltage-divider biasing!

In this biasing circuit, two resistors  $R_1$  and  $R_2$  are connected across the supply voltage  $V_{CC}$  and provide the necessary biasing. Whereas a resistor connected in the emitter circuit  $R_E$  provide stability. Since the resistors  $R_1$  and  $R_2$  form the voltage divider hence the name voltage divider biasing. The voltage drop across  $R_2$  forward bias the base-emitter junction. Hence collector current flows which sets up the zero signal conditions. This is the most widely used method of providing biasing and stabilisation to transistors since the operating point in this case can be made almost independent of  $\beta$  (beta)



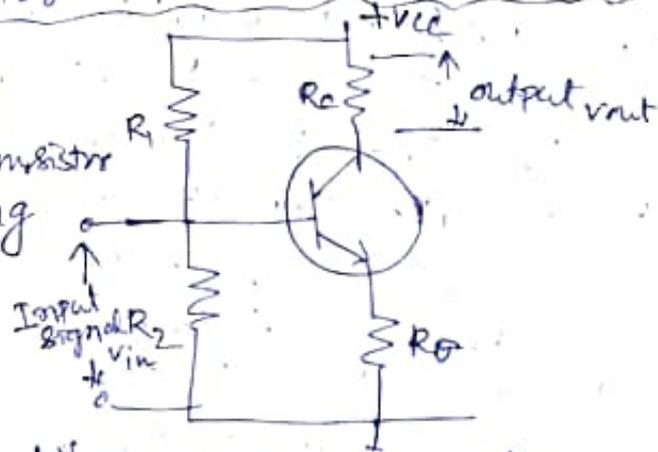
AMPLIFIER:

The basic function of transistor is to do amplification. The process of raising the amplitude of a weak signal without change in its frequency and shape is known as amplification.

When only one transistor with its associated circuit is used to increase the strength of a weak signal, the complete circuit is known as a single stage transistor amplifier.

Single stage transistor amplifiers in CE mode:

Single stage transistor amplifier contains one transistor and its associated biasing circuit. The resistors  $R_1$  and  $R_2$  provide biasing and  $R_E$  provide stabilisation.

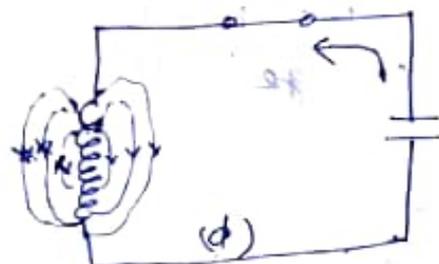
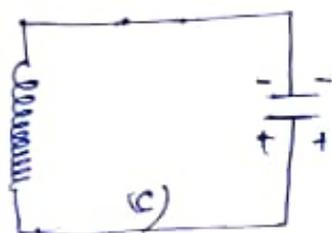
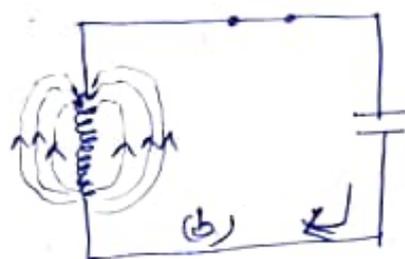
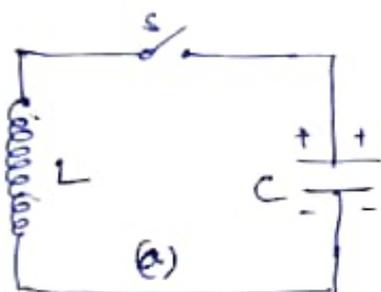


When a weak signal ( $V_{in}$ ) is applied to the base of transistor a small current  $I_B$  flows through it. This causes a much larger ac current through the collector

As the value of  $R_c$  is quite high (5 to 10k $\Omega$ ) a large voltage ( $V_{out} = i_c R_c$ ) appears across it. Thus a large output ( $V_{out}$ ) is obtained across  $R_c$ . This is how a transistor amplifier a weak signal.

### OSCILLATOR CIRCUIT:-

A circuit which produce electrical oscillation of any desired frequency is known as an oscillatory circuit or tank circuit. A simple oscillatory circuit consists of a capacitor (C) and inductance (L) in parallel.



Initially the capacitor (c) is charged from dc source with a polarity. In this position, the upper plate of capacitor charge with positive and lower plate with negative. Therefore there is a voltage across capacitor and the capacitor has electrostatic energy.

When switch is closed the capacitor will discharge through inductance and the electrons will be in direction indicated by arrow. This current will setup magnetic field around the coil. Due to the inductive effect, the current builds up slowly towards a maximum value. The circuit current will

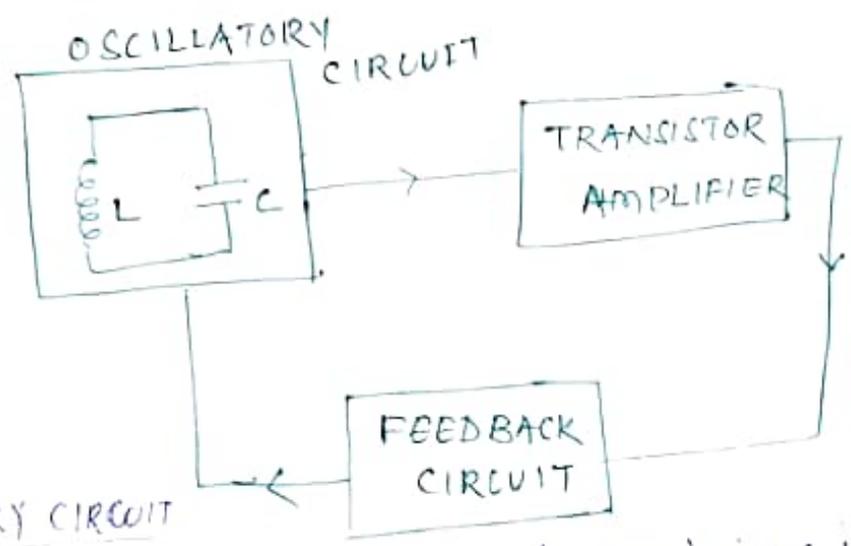
be maximum when the capacitor is fully discharged

At this instant electrostatic energy across the capacitor is zero but the magnetic field around the coil is maximum. obviously the electrostatic energy across the capacitor is completely converted into magnetic field. This will begin to collapse and produce a counter emf. This counter emf will keep the current flowing in the same direction. The result is the capacitor is now charged with opposite polarity as before

After the collapsing field has recharged the capacitor now begins to discharge, current flowing in the opposite direction. Fig (d) shows capacitor fully charged and maximum current flowing. The sequence of charge and discharge results in alternating motion of electrons or an oscillating current. This produces an oscillation.

The frequency of oscillation  $f = \frac{1}{2\pi\sqrt{LC}}$

### Essentials of a transistor oscillator.



An oscillatory circuit contains inductive coil L and capacitor C connected in parallel with each other. The frequency of oscillations depends upon the value of inductance of the coil and capacitance of the capacitor

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Transistor amplifiers: To compensate losses that occur in the oscillatory circuit, a source of energy is required. That source of energy is combination of battery and transistor working as an amplifier. The oscillations produced by the oscillatory circuit are fed at the input of a transistor amplifier. The transistor amplifier amplifies these oscillations. The output of the transistor is supplied back to the oscillatory circuit to compensate the losses.

### Feedback circuit

The circuit is used to feed back a fraction of amplifier output to the oscillatory circuit in correct phase so that it adds the oscillations and compensates the losses. It is positive feedback.

### CLASSIFICATION OF OSCILLATORS

i) sinusoidal oscillators: sinusoidal oscillators produce an output having sine wave.

② Non-sinusoidal oscillators -

They produce an output which is square, rectangular or sawtooth waveform or is of pulse shape.

a) LC oscillator

i) Hartley oscillator

ii) Colpitt oscillator

iii) Tuned collector oscillator

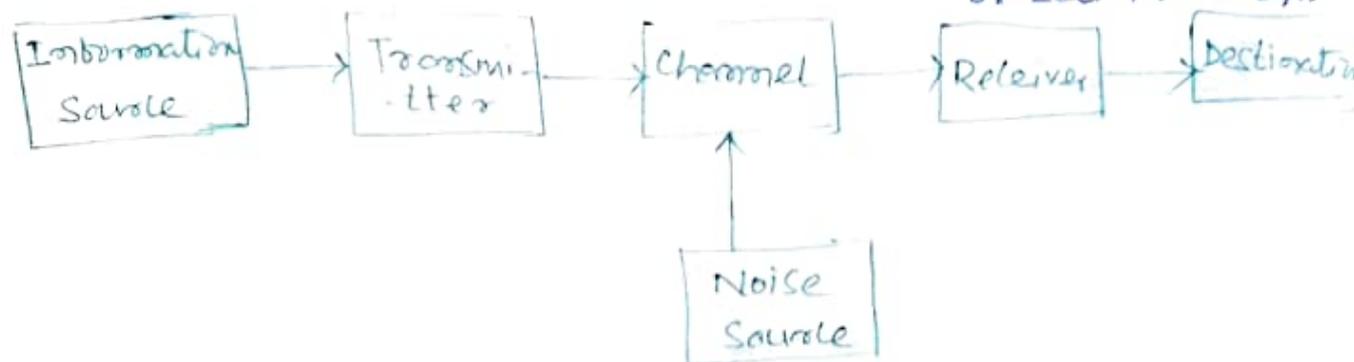
b) RC oscillator

i) RC phase shift oscillator

ii) Wien-bridge oscillator

# COMMUNICATION SYSTEM

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## BLOCK DIAGRAM OF COMMUNICATION SYSTEM

The communication system is defined as the process of sending, processing and receiving information by electrical means. The information may be text message or speech or still picture. Depending upon the type of information to be sent and received different communication systems :- radio telephony, ~~inter~~ telegraphy, broadcasting, radar and radio aids to navigation.

The information to be transmitted comes from the information source. The message which comes from information sources should be electrical in nature. The transmitter processes the information and makes it fit for transmission.

The channel may be a pair of wires or may be an open space as the channel is vital link connecting the transmitter and receiver. The receiver receives the information and converts it to a suitable form. The output of a receiver may be fed to a loud speaker, audio display, television picture tube or computer.

Modulation: The process of changing any of three parameters i.e. amplitude, frequency or phase of a carrier wave in accordance with the amplitude of signal is known as modulation. The resultant wave is called modulated wave.

Need of modulation: -

1. Practical Antenna length: In order to transmit a wave the length of the transmitting antenna should be at least half of the wavelength. Let us assume that we have supplied an antenna with the audio frequency signal of 1 kHz frequency. The antenna must be of 150 km from the following relation.

$$\text{wavelength } \lambda = \frac{\text{velocity}}{\text{frequency}} = \frac{3 \times 10^8}{1000} = 300 \text{ km}$$

$$\therefore \text{half wave length } \lambda/2 = \frac{300}{2} = 150 \text{ km}$$

This is too long for fabrication and impractical.

Suppose we have to transmit 2 MHz modulated signal.

$$\lambda = \frac{3 \times 10^8}{2 \times 10^6} = \frac{3 \times 10^2}{2} = 1.5 \times 10^2 = 150 \text{ meter}$$

$$\text{or } \lambda/2 = \frac{150}{2} = 75 \text{ meter.}$$

2. Operating range: - The energy of a wave depends upon the frequency, the greater the frequency of the wave, the greater the energy possessed by it. As the audio signal frequencies are small, therefore these cannot be transmitted over large distance if radiated directly into space.

3. Wireless Communication: - One desirable feature of radio communication transmission is that it should be carried out without wires i.e. radiated into space. At audio frequencies, radiation is not practicable because the efficiency of radiation is poor.

## Types of Modulation

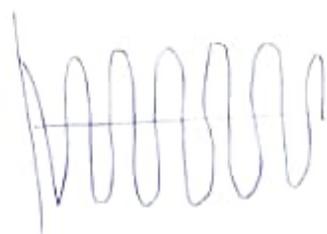
### ① Amplitude Modulation: -

When the amplitude of high frequency carrier wave is changed in accordance with the intensity of the audio signal is called amplitude modulation.

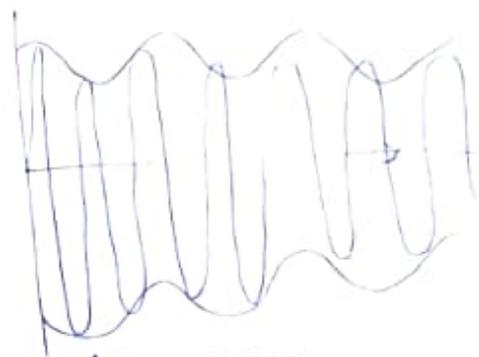
In amplitude modulation only the amplitude of the carrier wave is changed in accordance with the intensity of the signal. The frequency of the modulated wave remains the same i.e. frequency of the carrier.



Signal



Carrier

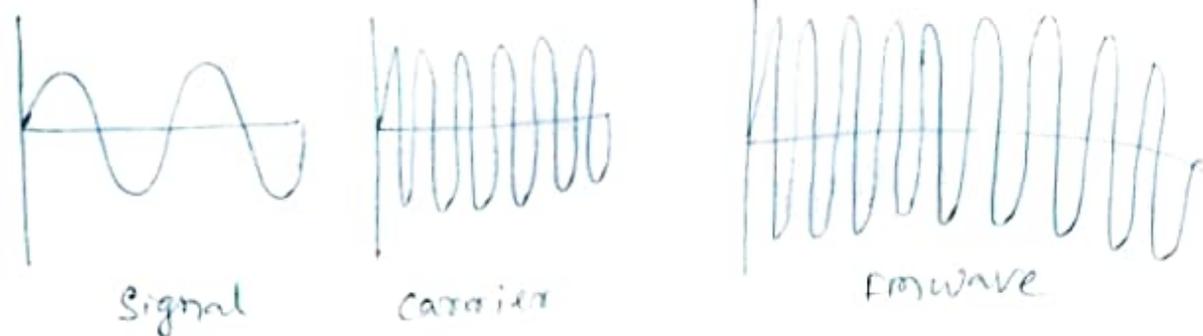


Am wave

### ② Frequency Modulation: -

When the frequency of carrier wave is changed in accordance with the intensity of the audio signal it is called frequency modulation.

In frequency modulation, only the frequency of the carrier wave is changed in accordance with the signal. However, the amplitude of the modulated wave remains the same i.e. amplitude of the carrier wave. The frequency variations of carrier wave depends upon the instantaneous amplitude of the signal.



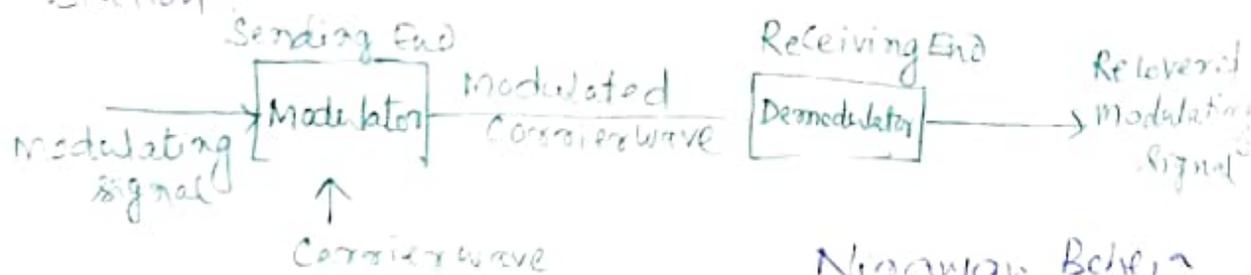
③ Phase modulation: The process by which the phase angle of a carrier wave is varied in accordance with the modulating signal is called phase modulation.

### DEMODULATION OR DETECTION

The process of recovering AF signal from the modulated carrier wave is known as demodulation or detection.

Need of demodulation: — When the RF modulated wave is radiated out from the transmitter antenna, after travelling through space, strike the receiving aerials, they induce very weak RF currents and voltage in them. If these high-frequency currents are passed through headphones or loudspeakers, they produce no effect on them because all such sound-producing devices are unable to respond to such high frequencies due to large inertia of their vibrating discs etc. Such RF currents will produce no effect on human ear because their frequencies are much beyond the audible frequencies.

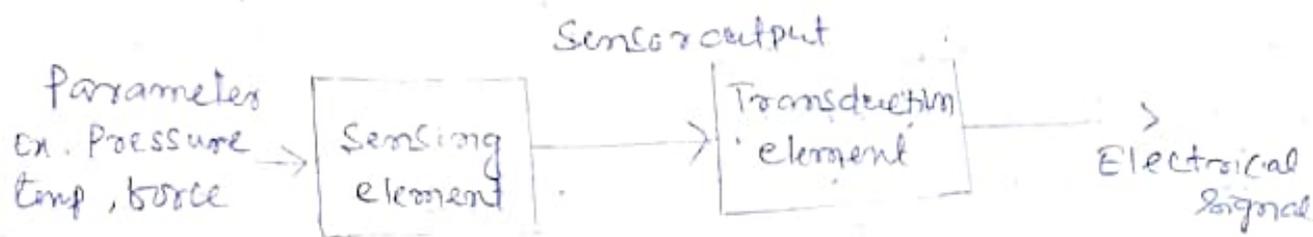
Hence, it is necessary to demodulate them first in order that the sound-producing devices may be actuated by audio-frequency current similar to that used for modulating the carrier wave at the broadcasting station.



# TRANSDUCERS AND MEASURING INSTRUMENTS

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Transducers: A transducer is a sensing device by which the physical, mechanical, optical, thermal etc. to be measured is transformed directly by the suitable mechanisms into an electrical voltage or current proportional to the input measured.



Transducer contains two parts that are closely related to each other i.e. the sensing element and transduction element.

The sensing element is called as the sensor. It is a device producing measurable response to change in physical conditions.

The transduction element converts the sensor output to suitable electrical form.

## Characteristics of Transducer:

1. Ruggedness
2. Linearity
3. Repeatability
4. Accuracy
5. High stability and reliability
6. Speed of response
7. Sensitivity
8. Small size

## Classification of Transducers:

(I) on the basis of transduction principle

- a) capacitive transducer
- b) Electromagnetic
- c) Inductive transducer
- d) Piezoelectric transducer
- e) Photo voltaic transducer
- f) photo conductive

(II) Active transducers are classified as

- a) Photo voltaic cells
- b) Thermocouple
- c) Piezoelectric Pickup
- d) Moving coil

III) Passive transducers are classified as

- Resistance transducers
- capacitance transducers
- Inductance transducers
- Analog and digital transducers
- Primary and secondary transducers

Difference between sensor and transducer

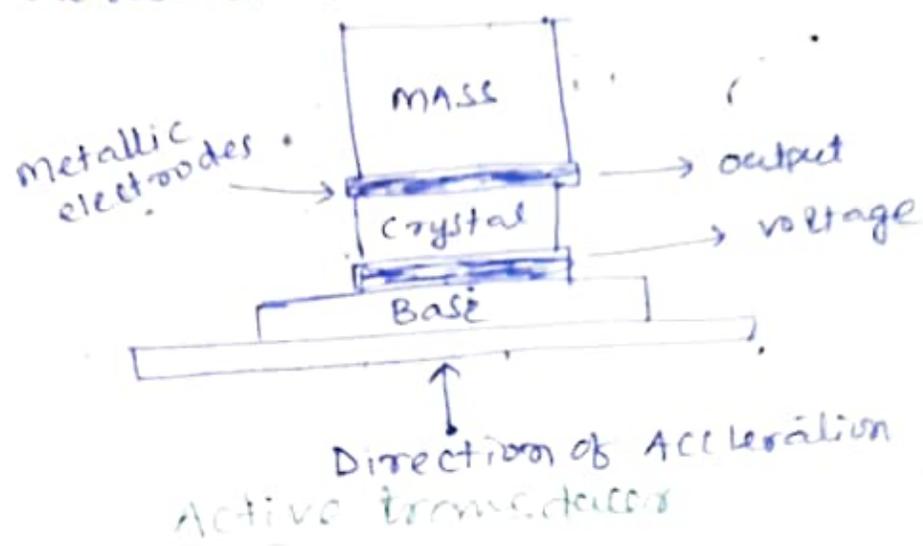
- The sensor senses the physical change about the surrounding whereas the transducer transmits the one form of energy into another.
- The sensor itself is the major component of the sensor, whereas the sensor and the signal condition are the major elements of the transducer.
- The primary function of the sensor is to sense physical changes, whereas the transducer converts the physical quantities into an electrical signal.
- The accelerometer, barometer, gyroscope are the examples of the sensor whereas the thermistor and thermocouples are the examples of the transducer.

Active transducers:

- The transducer which does not require the external power source is known as active transducer.
- Such type of transducer develops their own voltage or current, hence known as self-generating transducers.
- The energy required for generating the output signals are obtained from the physical quantity which is to be measured.

## Examples

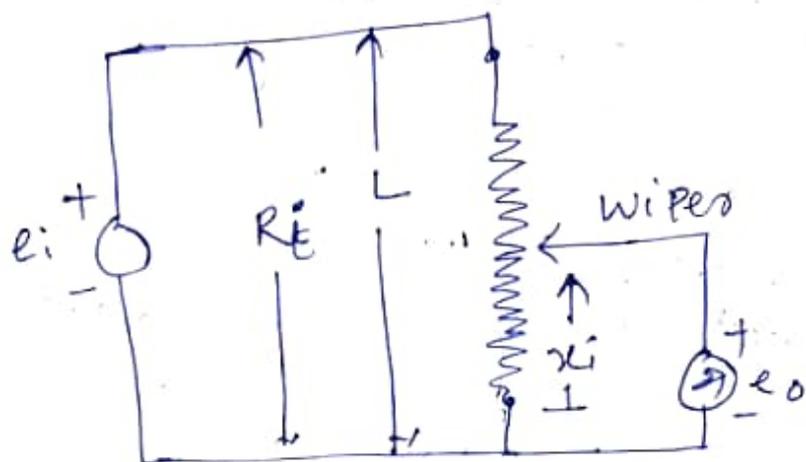
The Piezo electric crystal is the examples of the natural active transducers. The crystal has the property of producing the output voltage when the external force applied to them. The Piezo-electric crystal is placed between the two metallic electrodes when the force applied to the crystal; the voltage induces across it.



## Passive-transducers

- The transducer which requires the power from an external supply source is known as the passive transducer.
- They are also known as the external power transducer. The capacitive, resistive and inductive transducers are the examples of the passive transducers.
- The passive transducer takes power from the external energy source for transduction. The transduction means conversion of energy from one form to another.

Example! The linear potentiometer is the example of the passive transducer. It is used for measuring the displacement. The POT requires the external power source for work. It measures the linear displacement  $x_i$ .



Linear Potentiometer (POT), a passive transducer.

$L$  is the length of the potentiometer,  $R_i$  is the total internal resistance and  $x_i$  is the input displacement. The output voltage is calculated

$$e_o = \frac{x_i}{L} e_i$$

$$\text{Or, } x_i = \left( \frac{e_o}{e_i} \right) L$$

### Photoelectric transducer

The photoelectric transducer converts the light energy into electric energy. It is made of semiconductor material. The photoelectric transducer uses a photosensitive element which ejects the electrons when the beam of light absorbs through it.

There are five type photoelectric transducers.

- Photo-emissive cell
- Photo diode
- Photo transistor
- Photo-voltaic cell
- Photo-conductive cell

### Photo emissive cell :

The photo-emissive cell converts the photons into electric energy. It consists the anode rods and the cathode plate. The anode and cathode are coated with photo-emissive material called caesium antimony.

### Photo - conductive cell :

The photo-conductive cell converts the light energy into an electric current. It uses the semiconductor material like cadmium selenide, Ge, Se as a photosensing elements.

### Photo - voltaic cell

The photo-voltaic cell is the type of active transducer. The current starts flowing into the photovoltaic cell when the load is connected to it. The silicon and selenium are used as a semiconductor material. When the semiconductor material absorb heat, the free electrons of the material starts moving. This phenomenon is known as the photovoltaic effects.

# Multimeters !

A multimeter is an electronic measuring instrument that combines several measurement functions in one unit.

A typical multimeter can measure voltage, current and resistance. It can be used for measuring dc as well as ac voltage and currents.

Two types of multimeters:

- ① Analog multimeter
- ② Digital multimeter

## Analog Multimeter ! -

Analog multimeter is basically a moving coil instrument. A ~~rectifier~~ rectifier unit is also provided with the instrument. It is a multi-range instrument and various ranges are obtained by different resistance elements in series or in parallel with the movement of the instrument. With the help of a rotary selector switch the various ranges are used.

## Digital multimeter ! -

The digital multimeter is an instrument capable of measuring dc voltage, ac voltage, dc current, ac current, resistance, conductance and decibels. Thus DMM offers increased versatility. Some DMMs can measure the temp. frequency etc.

A DMM has a digital display and a function selector switch. The range selection takes place automatically. There are four input terminals out of which two terminals are used for measurement of all general purpose quantities such as AC/DC voltage, resistance, capacitance and diode, transistor testing.

### Comparison between Analog and Digital multimeters

#### Analog multimeter

1. d'Arsional movement is used for measurement
2. Parallax error present
3. Recording of data is not possible
4. Observational errors may present
5. Speed reading is less
6. Circuit loading present on voltage measurement

#### Digital multimeter

1. Digital display is used by measurement
2. No Parallax error present
3. Automatic recording of data is possible
4. Observational errors completely eliminate
5. Speed reading is more
6. No circuit loading on voltage measurement.

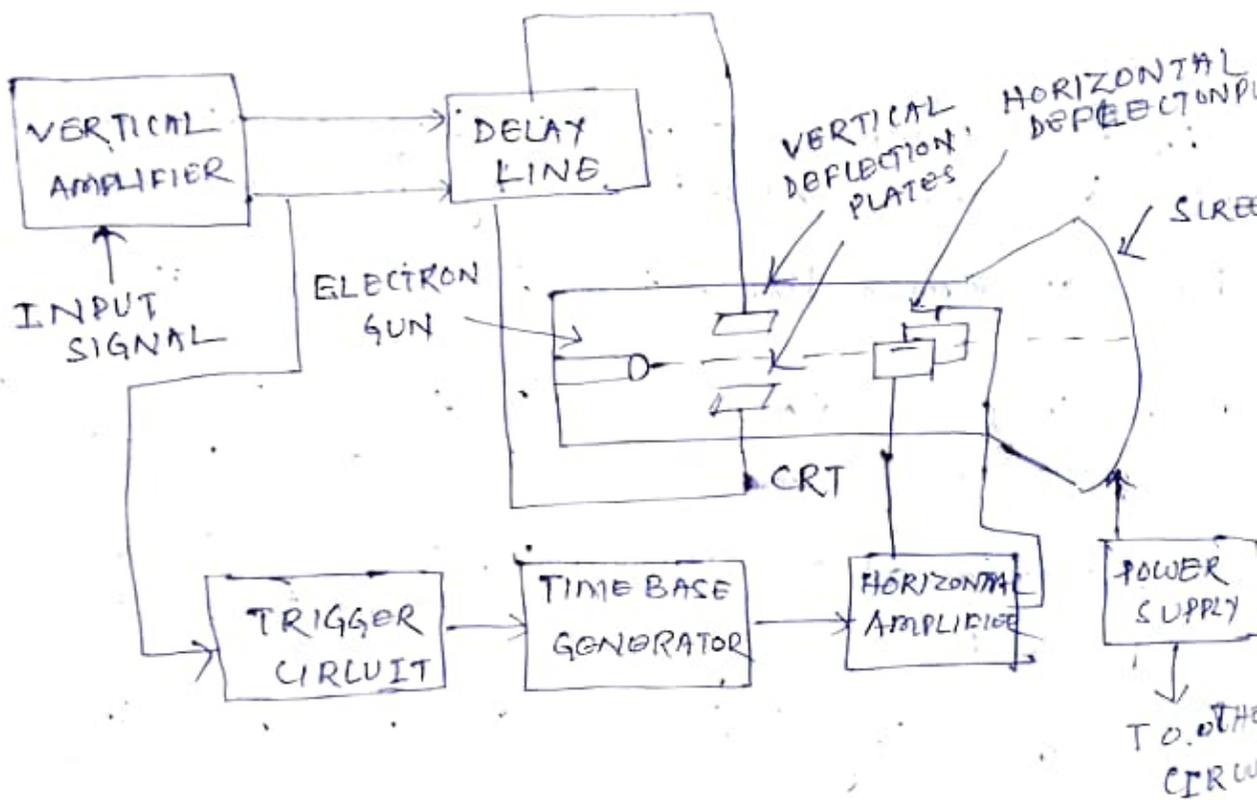
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# Cathode Ray Oscilloscope - (CRO)

Cathode ray oscilloscope is a most important and versatile measuring instrument used in laboratories. It gives a visual indication of a signal waveform. It is used for trouble shooting in radio and television receivers and for laboratory measurement. The CRO can measure voltage amplitude, frequency and phase shift.

## Block diagram of CRO



Vertical amplifier: It amplifies the input signal which is to be displayed on the screen of CRT.

Delay line: It provides some amount of delay to the signal, which is obtained at the output of vertical amplifier. This delayed signal is then applied to vertical deflection plates of CRT.

Trigger circuit: It produces a triggering signal in order to synchronize both horizontal and vertical deflection of electron beam.

Time base generator: - It produces a sawtooth signal which is useful for horizontal deflection of electron beam.

Horizontal amplifier: - It amplifies the sawtooth signal and then connects it to the horizontal deflection plates of CRT.

Power supply: It produce both high and low voltages. The negative high voltage and positive low voltage are applied to CRT and other circuit respectively.

Cathode ray tube (CRT): - It is the major important block of CRO and mainly consist of four parts.

Those are electron gun, vertical deflection plates, horizontal deflection plates and the fluorescent screen. The electron beam, which is produced by an electron gun gets deflected in both vertical and horizontal directions by a pair of vertical deflection plates and a pair of horizontal deflection plates respectively. Finally the deflection beam will appear as a spot on the fluorescent screen.

In this way CRO will display the applied input signal on the screen of CRT. So we can analyse the signals in time domain by using CRO.