Lecture Notes

On

Basic Electronics

Handwritten

Prepared By

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Atom : It consists of a central nucleus of positive charge around which small negatively charged particles called electrons revolve in different orbits.

Nucleus : It is the central part of an atom & contains protons & neutrons. A proton is a positively charged particle, while the neutron has the same mass as the proton, but has no charge.

- The number of electrons in an orbit is given by $2n^2$ where n is the number of the orbit.

Electron : An electron is a negatively charge particle having negligible mass.

Charge of electron = 1.6×10^{-19} coulomb

- The energy of an electron increases as its distance from the nucleus increases. Thus an electron in the 2nd orbit possesses more energy than the electron in the first orbit.

Valence Electrons: The electrons in the outermost orbit of an atom are known as valence electrons.

Free Electrons : The valence electrons which are very loosely attached to the nucleus are known as free electrons.

Electronics

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as Electronics

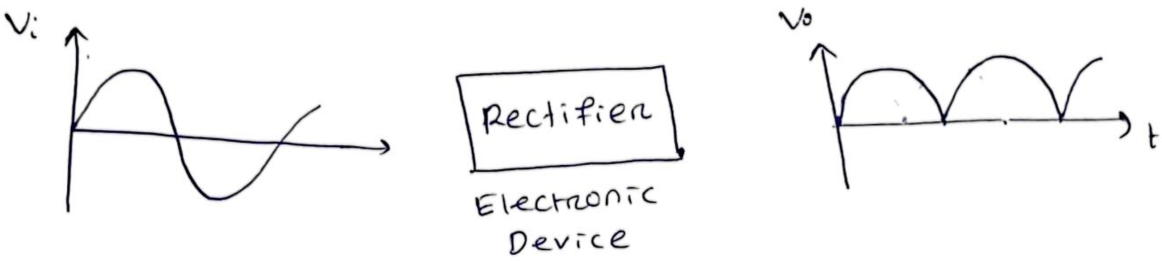
- An electronic device is that in which current flows through a vacuum or gas or semiconductor.

- The application of electronics are :-

(i) Rectification
(ii) Amplification
(iii) control
(iv) Generation (oscillator)
(v) Conversion of light into electricity
(vi) Conversion of electricity into light

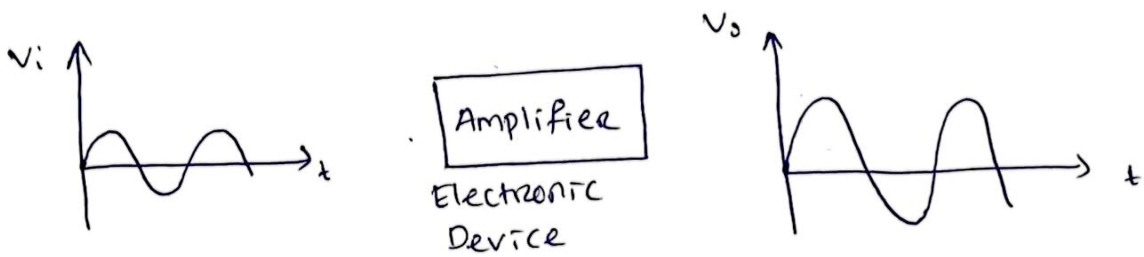
(i) Rectification

- The conversion of AC into DC is called rectification.
- This DC supply can be used for charging storage batteries, field supply of DC generators.



(ii) Amplification

- The process of raising the strength of a weak signal is known as amplification.
- Electronic devices which amplifies are called Amplifier.
- Amplifiers are used in a radio set where the weak signal is amplified, amplifiers are used in public address system, Television etc



(iii) Control

- Electronic devices have many applications in automatic control.
- ex :- Speed of a motor, voltage across a refrigerator etc. can be automatically controlled with the help of electronic device.

(iv) Generation (Oscillator)

- Electronic devices can convert DC power into AC power of any frequency. The device is called oscillator.

(v) Conversion of light into electricity

- Electronic devices can convert light into electricity.
- The conversion of light into electricity is known as photo electricity.

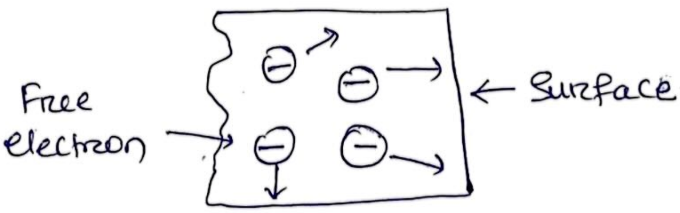
(vi) Conversion of Electricity into light

- Electronic devices can convert electricity into light.
- This property is utilised in television and radar

Electron Emission

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

- For electron emission metals are used because they have many free electrons.



- At the surface of a metal, a free electron encounters forces that prevent it to leave the metal. The metallic surface offers a barrier to free electrons & is known as surface Barrier.

Work Function: The additional energy required by an electron to overcome the surface barrier of the metal is called work function of the metal.

Types of Electron Emission

There are four principal methods of obtaining electron emission :-

(i) Thermionic Emission
(ii) Field Emission
(iii) photoelectric Emission
(iv) Secondary Emission

(i) Thermionic Emission

The process of electron emission from a metal surface by supplying thermal energy to it is known as Thermionic emission.

- At ordinary temperature the energy possessed by free electrons is insufficient to cause them to escape from the surface. When heat is applied to the metal, heat energy is converted into kinetic energy, causing accelerated motion of free electrons. If this energy is equal to the work function, the free electron overcome surface barrier.

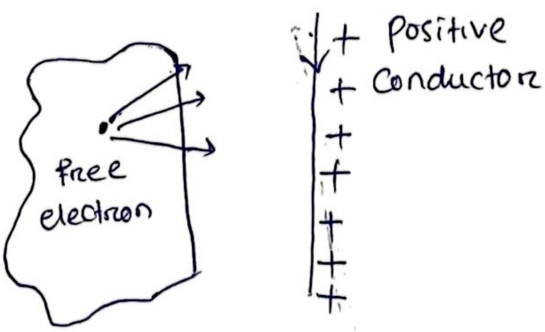
- The commonly used materials for electron emission are tungsten, thoriated tungsten & metallic oxide of barrium & strontium.

(ii) 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 with respect to the metal surface, the electric field apply attractive force on the free electrons & if the field is great enough, it will cause electron emission.

- Usually, a voltage of the order of a milli volts per centimeter distance between the emitting surface & the positive conductor is necessary to cause field emission.



Region of intense electric field

(iii) Secondary Emission

- Electron emission from a metallic surface by the bombardment of high speed electrons or other particle is known as secondary emission.
- When high speed electrons strike a metallic surface, they transfer their energy to the free electrons & it results in electron emission.
- The electron that strike the metal are called primary electrons & emitted electrons are known as secondary electron.

(iv) Photoelectric Emission

- Electron emission from a metallic surface by the application of light is known as photoelectric emission.
- When a beam of light strikes the surface of certain metals, the energy of photons of light is transfered to the electrons within metal. If the energy of the striking photons is greater than the work function of the metal the free electrons come out from the surface of metal.
- The emitted electrons are known as photo electrons & the phenomenon is known as photoelectric emission.

Energy Band Diagram

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 valence electrons is known as valence band.

Conduction band :- The range of energies possessed by conduction electrons is known as conduction band.

Forbidden energy gap: The separation between conduction band & valence band on the energy level diagram is known as forbidden band or forbidden energy gap.

Insulator

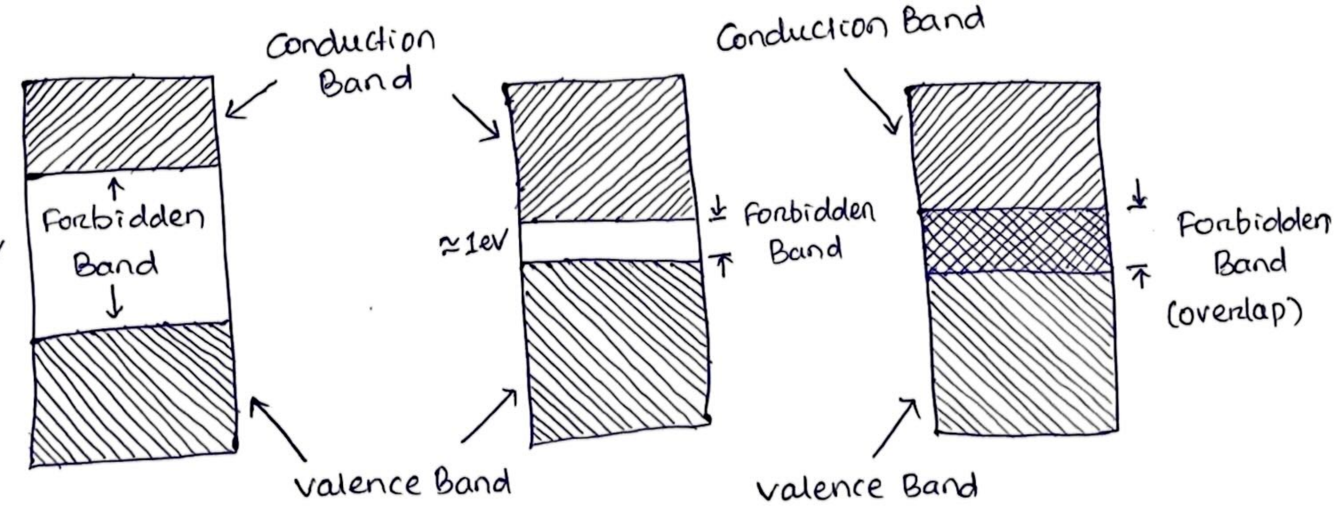
- Insulators are those substance which do not allow the passage of electric current through them. Ex - wood, glass etc.
- The energy gap between valence band & conduction band is very large.
- Therefore a very high electric field is required to push the valence electrons to conduction band. So electrical conductivity of insulator is regarded as nil.

Conductor

- Conductors are those substance which easily allow the passage of electric current through them. Ex- copper, alluminium.
- The valence band & conduction band overlap eachother. Due to this overlapping a slight potential difference across a conductor causes the free electrons to constitute electric current.

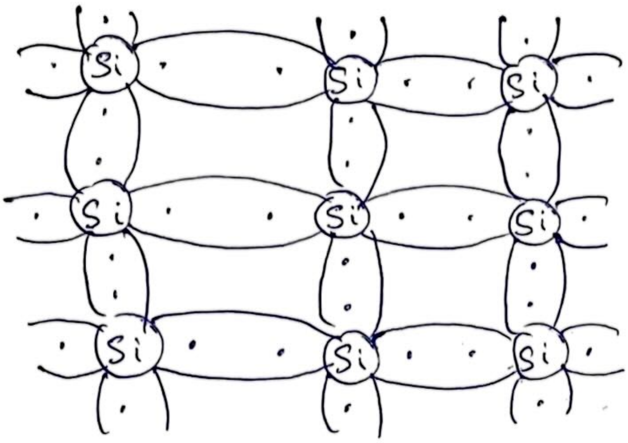
Semiconductor

- Semiconductors are those substances whose electrical conductivity lies in between conductors & insulators. Ex - Silicon, Germanium etc.
- The energy gap between valence & conduction band is very small. ($\approx 1eV$). Therefore comparatively smaller electric field is required to push the electrons from valence band to the conduction band.



Intrinsic Semiconductor

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



(Crystalline structure of Intrinsic Semiconductor)

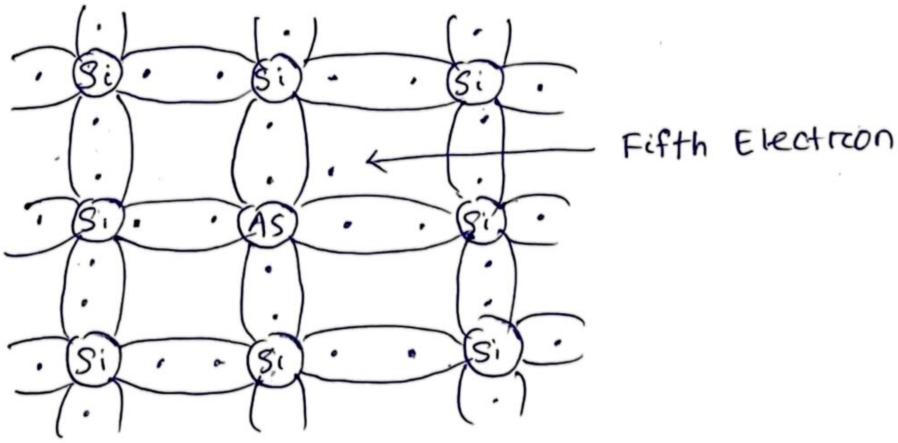
- When electric field is applied across an intrinsic semiconductor the current conduction takes place by two processes namely by electrons & holes.
- The free electrons are produced due to the breaking of covalent bonds by thermal energy. At the same time holes are created in the covalent bonds.
- Total current inside the semiconductor is the sum of currents due to free electrons & holes.
- Hole is the empty space created by the electron or hole is defined as the deficiency of an electron in the broken covalent bond.
- Intrinsic semiconductor at 0°K will be working as an insulator.

Extrinsic Semiconductor

- By adding a small amount of suitable impurity to a pure semiconductor, it becomes extrinsic semiconductor.
- The process of adding impurity is to increase either the number of free electrons or holes in the semiconductor.
- If a pentavalent impurity is added to a semiconductor, a large number of free electrons are produced.
- If a trivalent impurity is added to a semiconductor, a large number of holes are produced.

N-type Semiconductor

- When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.
- The addition of pentavalent impurity provides a large number of free electrons in the semiconductor.
- Examples are Arsenic, antimony



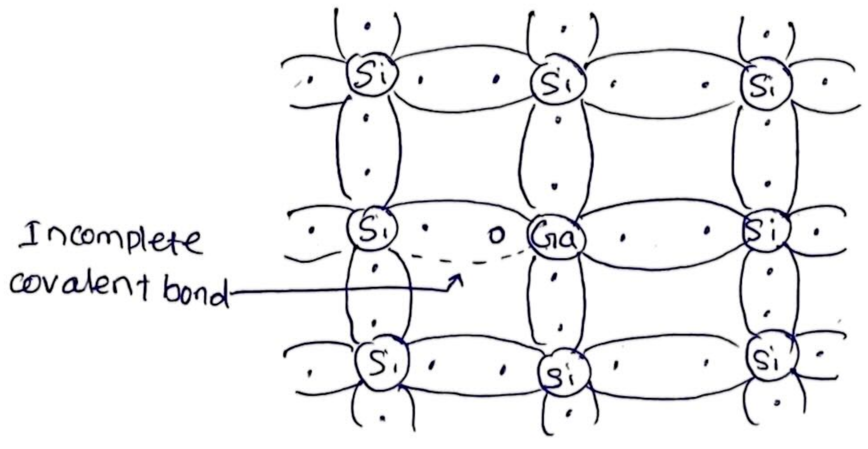
(Crystalline Structure of N-type Semiconductor)

- Impurities produce n-type semiconductor are known as donor impurity because they donate or provide electrons.
- If a pentavalent impurity is added, 4 valence electrons form covalent bonds with 4 Si atom. The fifth valence electrons is free.

- Many new free electrons are produced by the addition of pentavalent impurity.
- Thermal energy of room temperature still generates a few hole-electron pairs. However the number of free electrons provided by the pentavalent impurity far exceeds the number of holes. The number of electrons is far more than number of holes, so it is called n-type semiconductor.

P-type semiconductor

- When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type semiconductor.
- The addition of trivalent impurity provides a large number of holes in the semiconductor.
- Examples are Gallium, Indium.

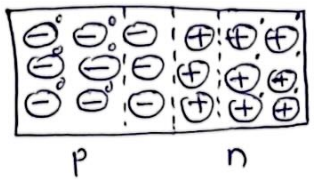


(Crystalline Structure of P-type Semiconductor)

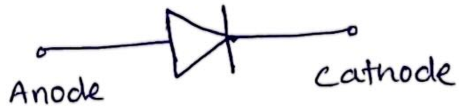
- Impurities produce P-type semiconductor are known as acceptor impurities because the hole created can accept the electrons.
- Three valence electrons of Gallium atom form three single covalent bonds with 3 Si atom. Forth bond is incomplete. This missing electron is called a hole.
- The addition of trivalent impurity has produced a large number of holes. However there are few electrons due to thermal energy. But the holes are far more than electrons. So it is called P-type semiconductor.

PN Junction

when a P-type semiconductor is suitably joined to n-type semiconductor the contact surface is called PN junction.

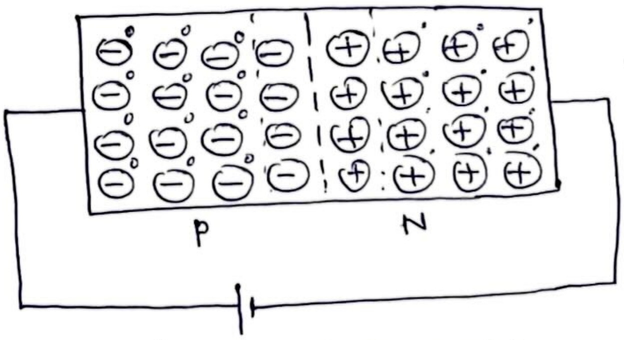


- Hole diffuse from P to N region & electron from N to P region & terminate by recombination.
- This recombination of free electrons & holes produces the narrow region at the junction called depletion region. It is so called because this region is depleted of charge carriers.
- Because of the charge separation, an electric potential V_B is established across the junction. It is known as junction or barrier potential. It stops further flow of carriers across the junction unless supplied by energy from an external source.
- At room temperature of 300°K V_B is about 0.3V for Ge & 0.7V for Si.
- Symbol :-



Forward Biasing

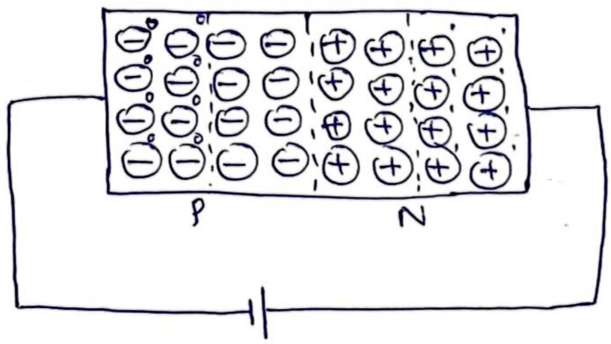
- When external DC voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting current flow, it is called forward biasing.
- In forward bias positive terminal of battery is connected to p-type & negative terminal of battery is connected to N-type.
- The potential barrier is reduced & at some forward voltage (0.1V to 0.3V), it is eliminated.
- The junction offers low resistance to current flow. Current flows in the circuit due to the low resistance path.



(Forward Biased)

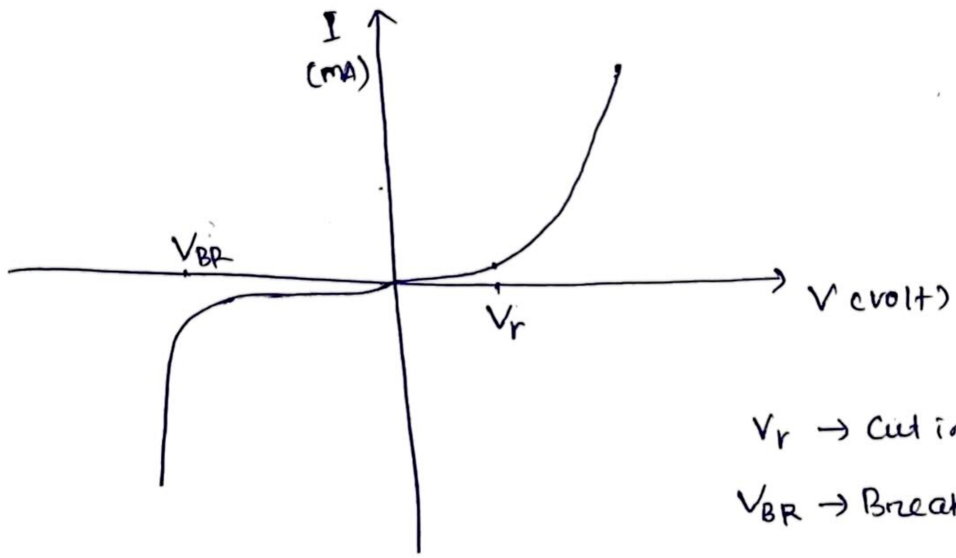
Reverse Biasing

- When the external DC voltage applied to the junction is in such a direction that potential barrier is increased, it is called reverse biasing.
- In reverse bias negative terminal of the battery is connected to p-type & positive terminal of battery is connected to n-type



- The potential barrier is increased.
- The junction offers very high resistance to current flow. No current flows in the circuit due to the high resistance path.

V-I Characteristics



V_r → Cut in voltage

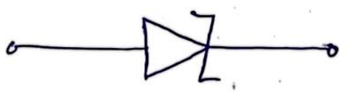
V_{BR} → Breakdown voltage

Zener Diode

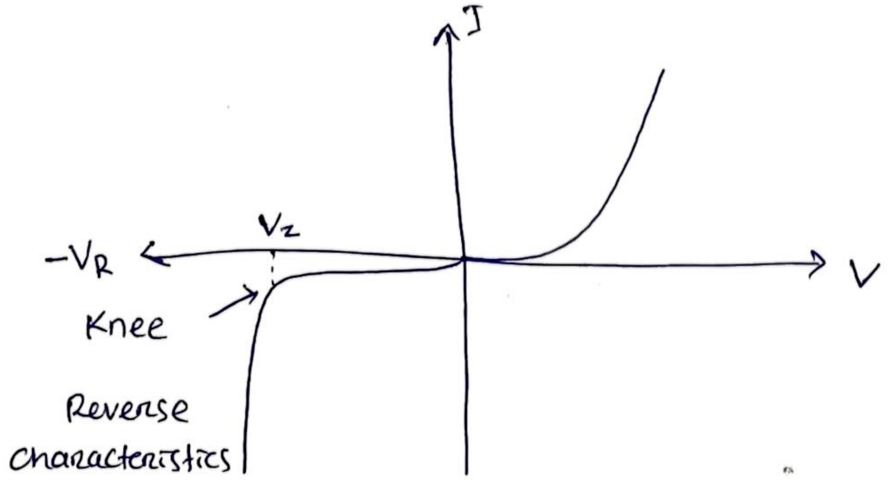
A properly doped crystal diode which has a sharp breakdown voltage is known as a zener diode

- A zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage.
- A zener diode is always reverse connected i.e it is always connected in reverse biased.
- A zener diode has sharp breakdown voltage called zener voltage V_Z.
- When forward biased, its characteristics are just those of ordinary diode.

Symbol :-



V-I characteristics



- The zener diode have a relatively constant voltage across it. This permits the zener diode to be used as a voltage regulator.

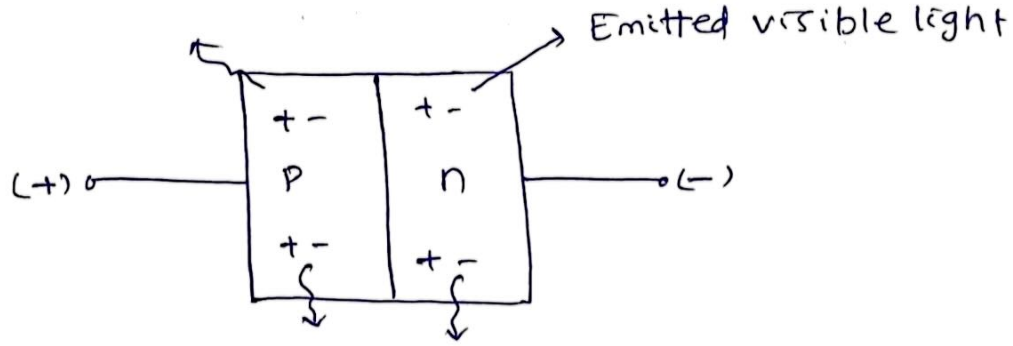
Light Emitting Diode (LED)

- A light emitting diode is a diode that gives off visible light when forward biased.

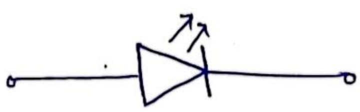
- LEDs are made using direct band gap material like Gallium, phosphorus & arsenic.

- When a LED is manufactured using gallium arsenide, it will produce a red light. If LED is made with gallium phosphide it will produce a green light.

- When recombination takes place, the recombining electrons release energy in the form of heat & light.



- Symbol :-



- The intensity of radiated light is directly proportional to the forward current of LED.

Advantages

- Low voltage
- Longer life
- Fast ON-OFF switching

Integrated Circuit

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

- An integrated circuit consists of a number of circuit components & their interconnections in a single small package to perform a complete electronic function.

- In an IC the various components are automatically part of a small semiconductor chip & the individual components can't be removed or replaced.

- The size of an IC is extremely small.

Advantages

(i) Increased reliability due to lesser number of connections.

(ii) Extremely small size due to fabrication of various circuit elements in a single chip of semiconductor material.

(iii) Lesser weight & space requirement due to miniaturized circuit.

(iv) Low power requirements.

(v) Low cost because of simultaneous production of hundreds of alike circuits on a small semiconductor wafer.

Rectifier

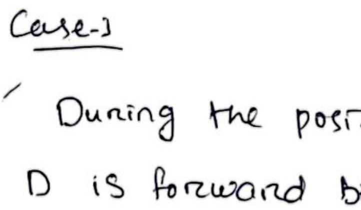
- A rectifier is an electronic device that converts an Alternating current (AC) into a direct current (DC) by usi.. one or more P-N junction diodes.

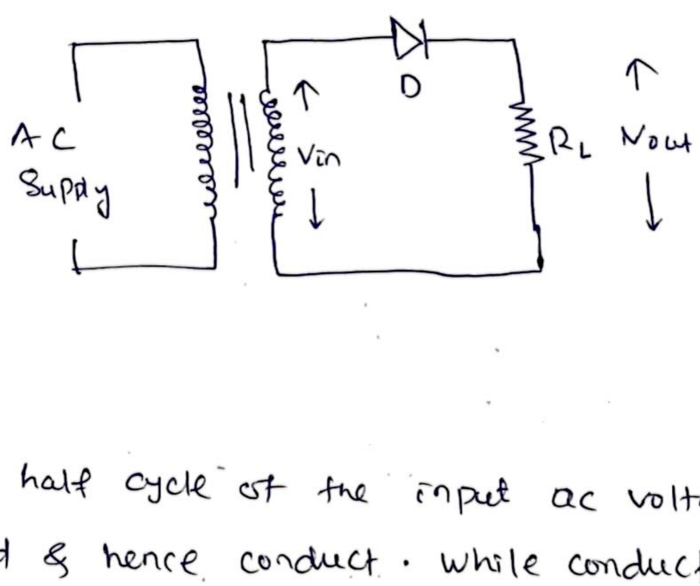
- Rectifiers are mostly used to provide continuous voltage (DC voltage) required to run almost all electronic devices & circuit.

Rectifier using Diode

- Half wave rectifier
- Full wave rectifier
  - Central tapped
  - Bride rectifier

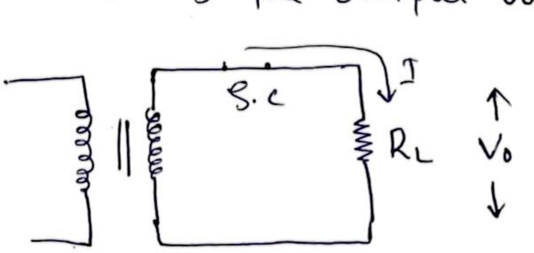
Half wave Rectifier





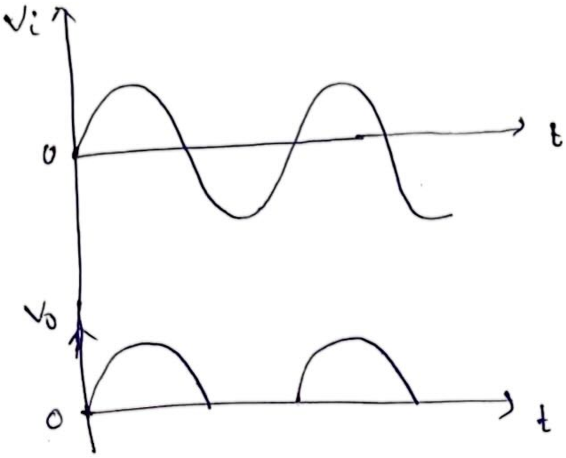
Case-1

During the positive half cycle of the input ac voltage, the diode D is forward biased & hence conduct. while conducting, the diode acts as a short circuit so that circuit current flows & hence positive half cycle of the input ac voltage is dropped across R_L. It constitutes the output voltage V_o.



Case-II

During the negative half cycle the diode is reverse-biased and hence does not conduct i.e there is no current flow. Hence there is no voltage drop across R_L. i.e $I_0 = 0$ & $V_0 = 0$.

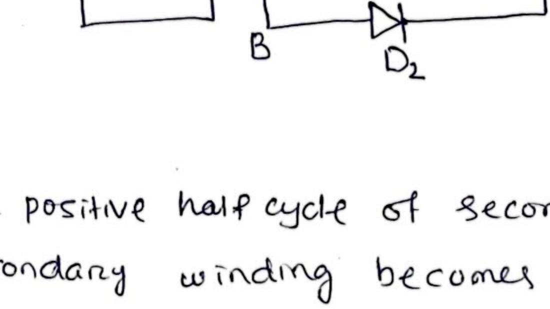


Disadvantages

(i) The pulsating current in the load contains alternating component whose basic frequency is equal to the supply frequency. Therefore more filtering is required.

(ii) The ac supply delivers power only half the time. Therefore the output is low.

Centre-tap full wave Rectifier

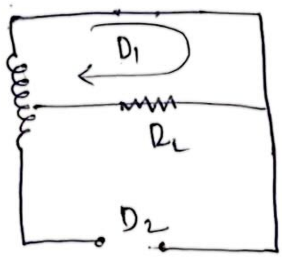


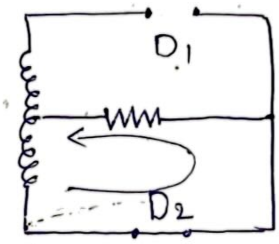
Case I

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 diode D_2 reverse biased. Therefore, diode D_1 conducts while diode D_2 does not. current flow is through diode D_1, load resistor R_L.

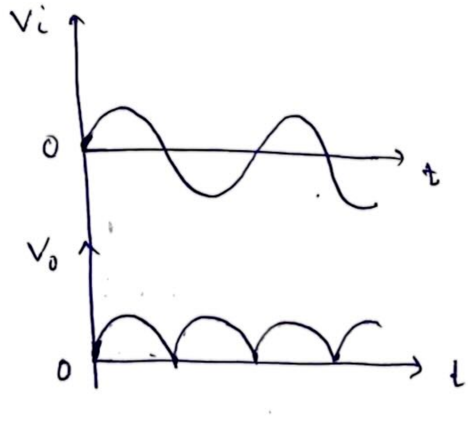
Case ii

During the negative half cycle, end A of the secondary winding becomes negative and end B positive. Therefore diode D_2 Conducts while diode D_1 does not. The current flow is through diode D_2, load R_L and lower half winding.





- Current in the load R_L is in the same direction for both half cycle of the input ac voltage. Therefore dc is obtained across the load R_L

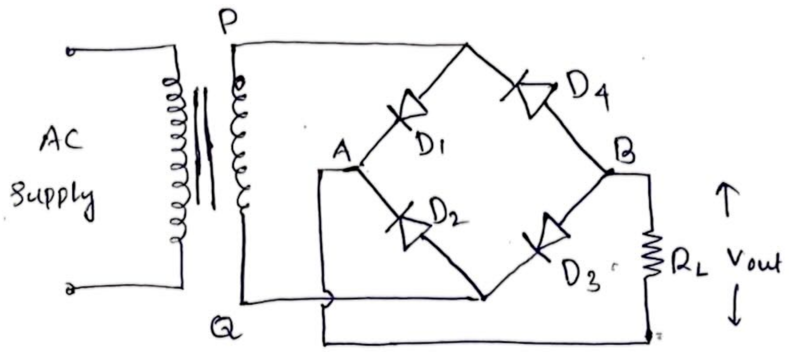


Disadvantages

(i) It is difficult to locate the centre tap on the secondary winding.
(ii) The dc output is small as each diode utilises only one half of the transformer secondary voltage.
(iii) The diodes used must have high peak inverse voltage.

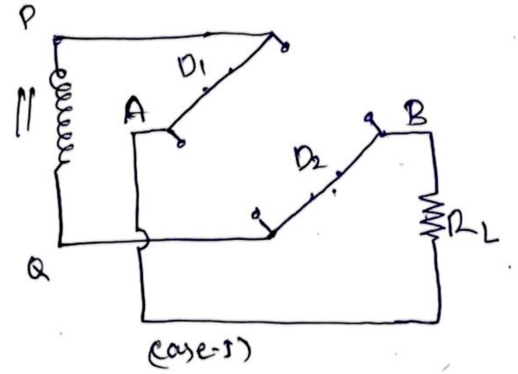
Full wave Bridge Rectifier

It consists of four diodes D_1, D_2, D_3 & D_4

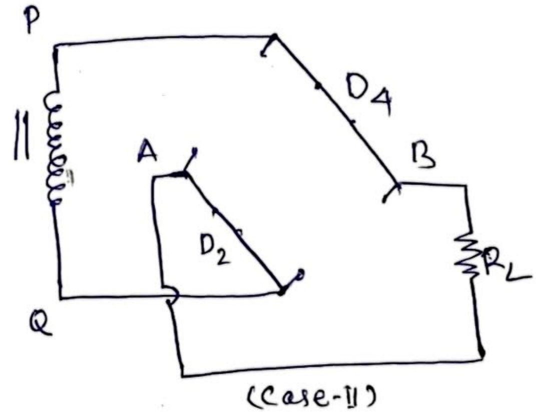


Case-I

During the positive half-cycle of secondary voltage, the end P of the secondary winding becomes positive & end Q negative. This makes diode D_1 and D_3 forward biased while diodes D_2 and D_4 are reverse biased. Therefore only diodes D_1 and D_3 conducts. It may be seen that current flows from A to B through the load R_L



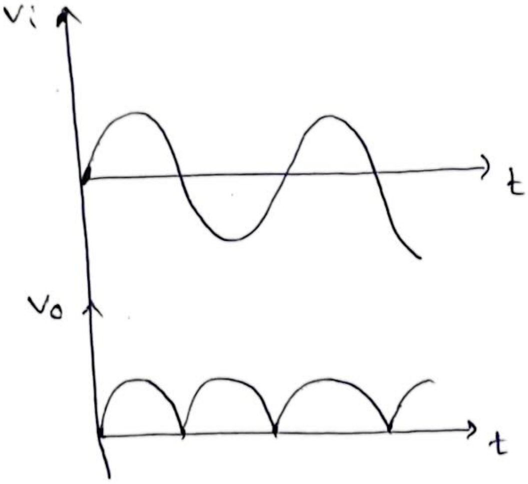
(case-I)



(case-II)

Case-II

During the negative half cycle of secondary voltage, end P becomes negative and end Q positive. This makes diodes D_2 and D_4 forward biased where as diodes D_1 & D_3 are reverse biased. Therefore only diodes D_2 and D_4 conduct. It may be seen that, as cases, here also current flows from A to B through the load i.e in the same direction as case-I or positive half cycle.



Advantages

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

Disadvantage

1. It requires 4 diodes.
2. As during each half cycle of ac input two diodes are in series, therefore voltage drop in the internal resistance also twice that of centre tap.

☆

	RMS	DC/Average	Ripple factor	Efficiency	PIV	TUF
HWR	$\frac{V_m}{2}$	$\frac{V_m}{\pi}$	1.21	40.5%	V_m	0.286
Centre tap	$\frac{V_m}{\sqrt{2}}$	$\frac{2V_m}{\pi}$	0.48	81%	$2V_m$	0.69
Bridge	$\frac{V_m}{\sqrt{2}}$	$\frac{2V_m}{\pi}$	0.48	81%	V_m	0.81

Filter

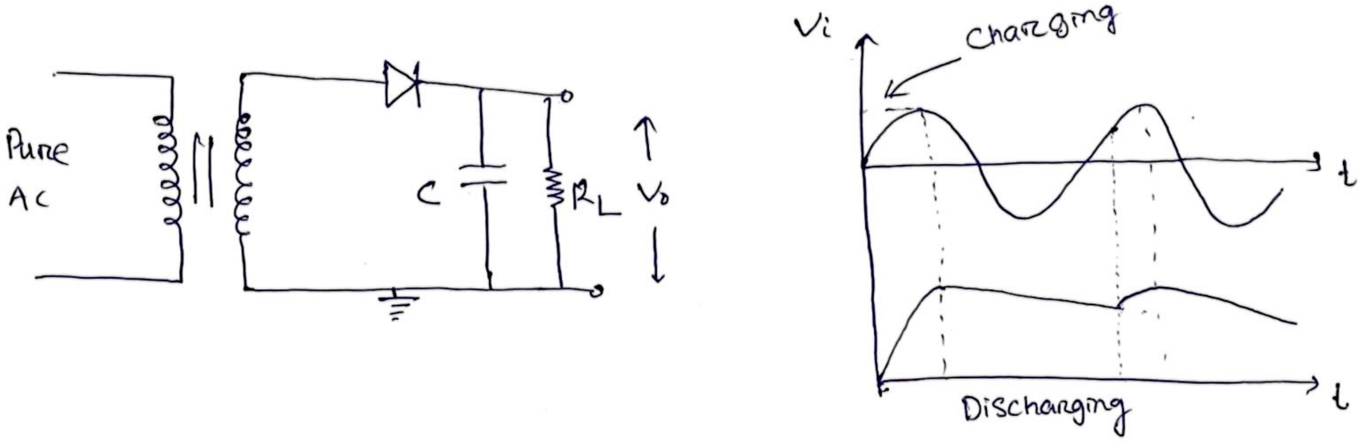
- Filter circuit is defined as a circuit which removes the unwanted ac component of the rectifier output & allows only the dc component to reach the load.

- Rectifier output, which is pulsating dc, is given as input to filter circuit to smooth out or to reduce the unwanted ac component.

Types of filter

1. Capacitor Filter
2. Choke input filter
3. π - Filter

(1) Capacitor Filter



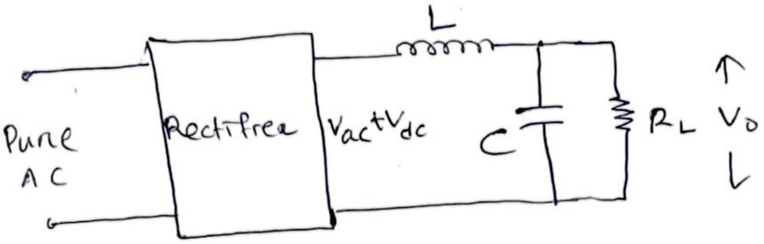
- The capacitor has a capacitive reactance $X_C = \frac{1}{2\pi f C}$

For dc signal, $f = 0$, then $X_c = \frac{1}{0} = \infty$

- It offers low reactance to ac & a very high reactance to the dc component.

- Hence a capacitor does not allow the dc to pass through it. When the pulsating output is applied the ac component experience a resistive path so bypass through the capacitor but the dc component is blocked by capacitor & appears at load. So the undesired ac component is removed / reduced.

(2) Choke input Filter

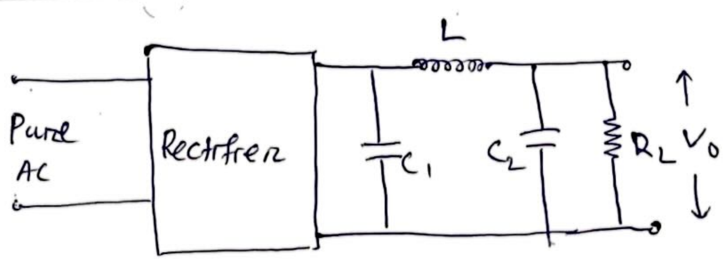


- It consists of a choke L connected in series with the rectifier output and a filter capacitor C across the load.
- The pulsating output of rectifier is applied across inductor. pulsating output of rectifier contains ac & dc components. The choke offers high opposition to the passage of ac component but negligible opposition to the dc component.
- Before capacitor, the rectifier output contains dc component & the remaining part of ac component which has managed to pass through the choke. Now the capacitor bypasses the ac component but prevents the dc component to flow through it. Therefore only dc component reaches the load.

Inductive reactance $X_L = \omega L = 2\pi f L$

For dc $f = 0$, $X_L = 0$

(3) π-Filter



- It consists of two capacitors C_1 & C_2 and an inductor L connected in the form of a π.
- The pulsating o/p from the rectifier is applied at the input terminals of the π-filter.

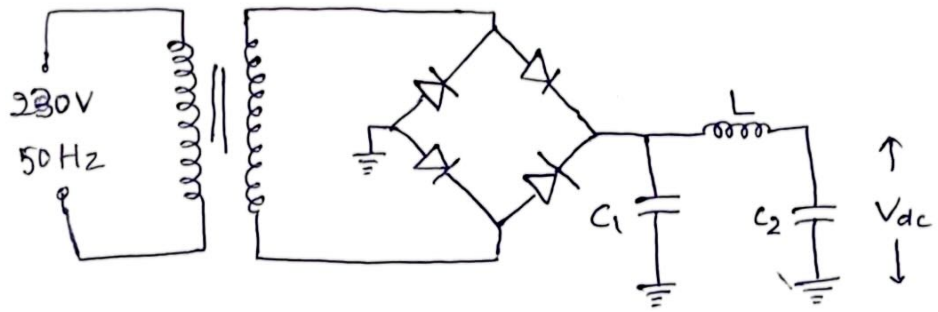
(i) Capacitor C_1 :- It offers a low reactance to ac component of rectifier output. But it offers infinite resistance to the dc component. Therefore, the capacitor C_1 bypasses an appreciable amount of ac component to the ground, while dc component moves towards inductor L.

(ii) Inductor L :- It offers a high resistance to the ac component of rectifier output but zero resistance to the dc component. Therefore it allows the dc component to pass through it and blocks the ac component, which can't pass by the capacitor C_1

(iii) Capacitor C_2 :- Its behaviour is similar to the capacitor C_1. It bypasses the ac component of rectifier output, which can not block by inductor L. As a result, only the dc component is available at the output.

Unregulated DC Power Supply

- An unregulated DC power supply contains a rectifier and a filter circuit.



- The output from the rectifier is pulsating DC. These pulsations are due to the presence of AC component in the rectifier output
- The filter circuit removes the AC component so that steady DC voltage is obtained across the load.

Disadvantages

(i) The DC output voltage changes directly with input AC voltage.

(ii) The DC output voltage decreases as the load current increases.

Conclusion

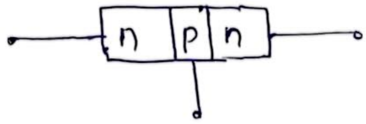
The variation in dc output voltage may cause inaccurate operation of many electronic circuits. Therefore unregulated power supply is unsuited for many electronic applications and is being replaced by regulated power supply

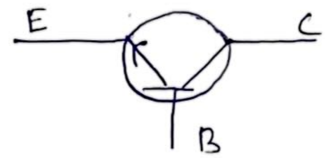
Transistor (BJT)

A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.

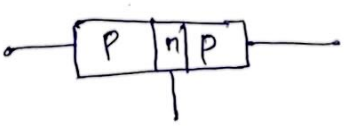
There are two types of transistors :-

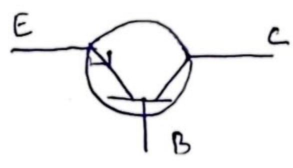
(i) <u>n-p-n transistor</u> :- An n-p-n transistor is composed of two n-type semiconductors separated by a thin section of p-type.





(ii) <u>p-n-p transistor</u> :- A p-n-p transistor is formed by two p-type semiconductor separated by a thin section of n-type.





Transistor Terminals

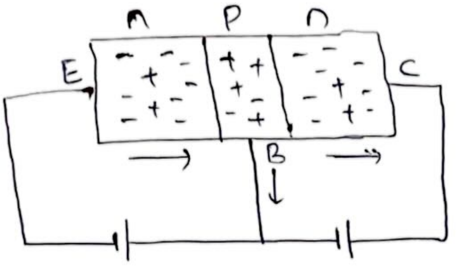
A transistor has three sections. The section on one side is the emitter and the section on the opposite side is the collector. The middle section is called the base and forms two junctions between the emitter & collector.

(i) <u>Emitter</u> :- The section on one side that supplies charge carriers is called the emitter. It is heavily doped material.

(ii) <u>Collector</u> : The section on the other side that collects the charges is called the collector. It is moderately doped material.

(iii) <u>Base</u> :- The middle section which forms two p-n junctions between the emitter and collector is called the base. It is lightly doped material.

working



- Consider a npn transistor with emitter-base junction and forward biased & collector base junction as reverse bias.
- The forward bias causes the electrons in the n-type emitter to flow towards the base. This results in 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 combine with the holes to constitute base current I_B.
- The remaining electrons cross over into the collector region to constitute collector current I_C
-) So emitter current is the sum of collector & base current i.e

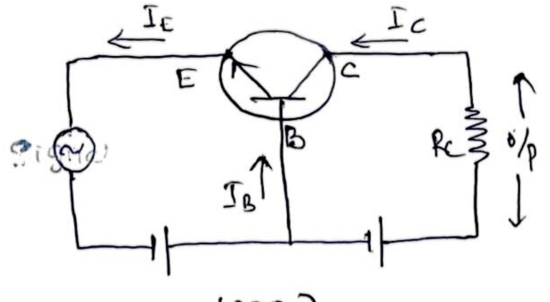
$$I_E = I_B + I_C$$

Transistor Configuration

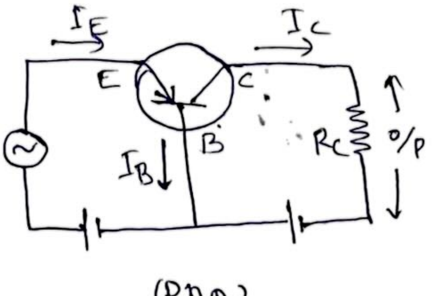
There are 3 transistor configuration.

① common base configuration (CB)

- In CB configuration, input is applied between emitter & base and output is taken from collector & base. Here base of the transistor is common to both input & output circuits.



(npn)



(pnp)

Current Amplification factor (α)

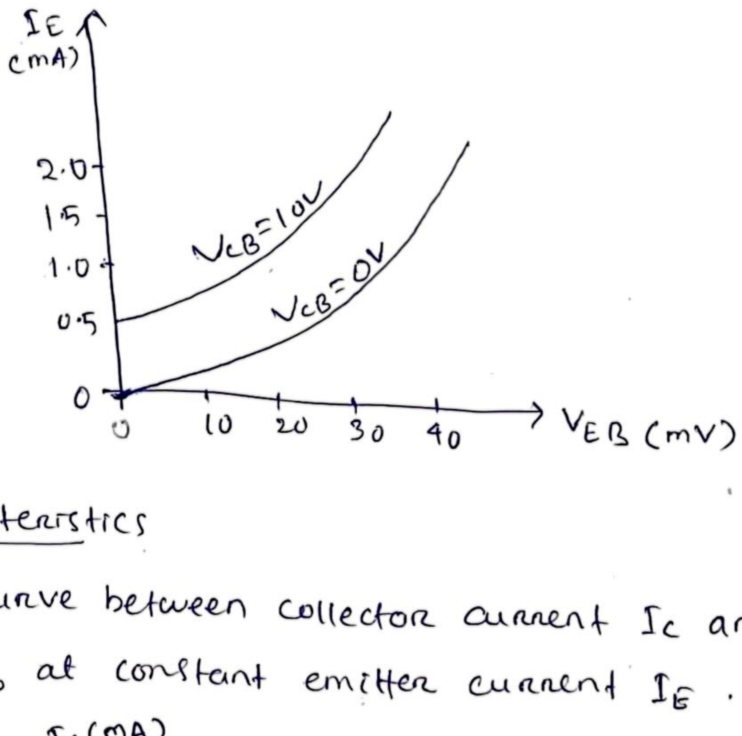
It is the ratio of output current to input current. In a common base configuration, the input current is the emitter current I_E & output current is the collector current I_C

$$\alpha = \frac{I_C}{I_E}$$

- Practical values of α is ranging from 0.9 to 0.99.

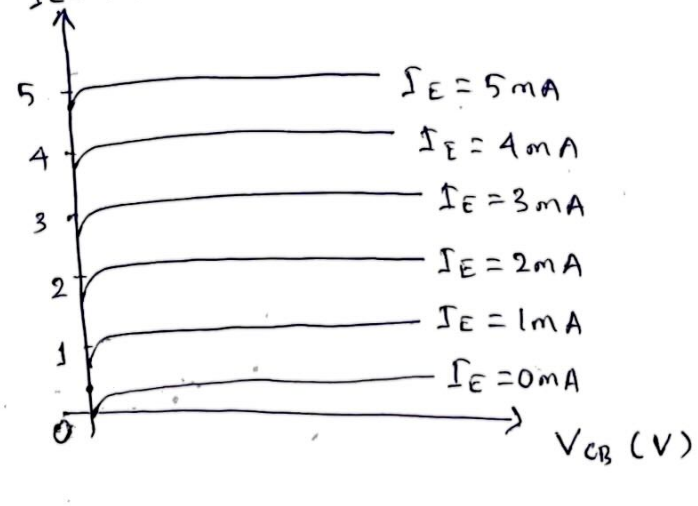
Input characteristics

It is the curve between emitter current I_E and emitter-base voltage V_{EB} at constant collector-base voltage V_{CB}.



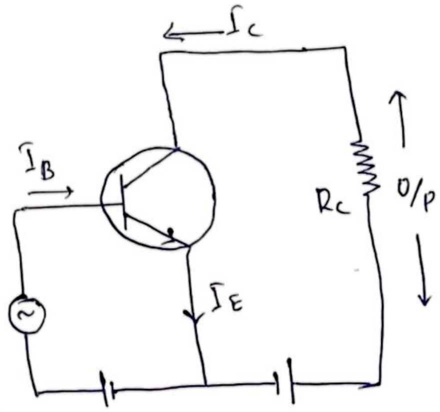
Output characteristics

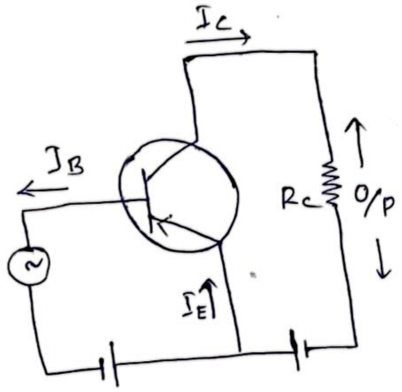
It is the curve between collector current I_C and collector-base voltage V_{CB} at constant emitter current I_E.



② Common Emitter Configuration

In CE configuration input is applied between base & emitter and output is taken from the collector and emitter. Here emitter of the transistor is common to both input and output circuit.





Current amplification factor (β)

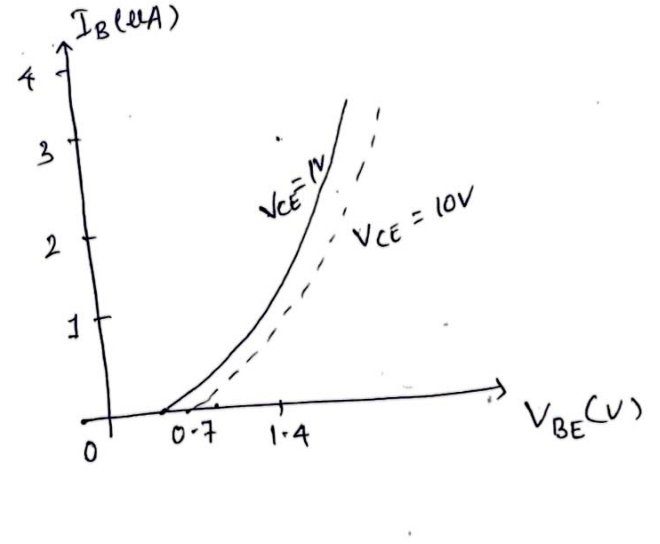
It is the ratio of output current I_C to the input current I_B

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

- β value ranges from 20 to 500.

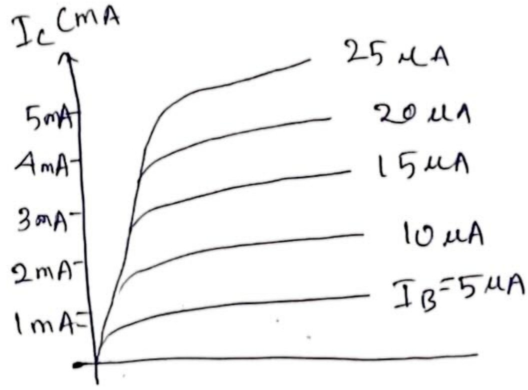
Input characteristics

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



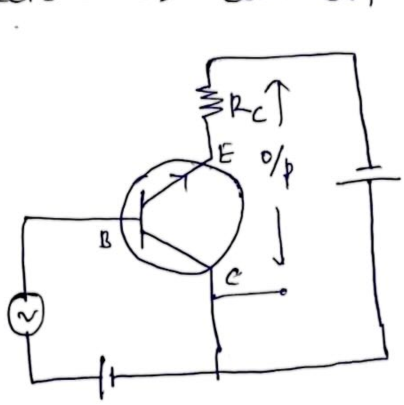
Output characteristics

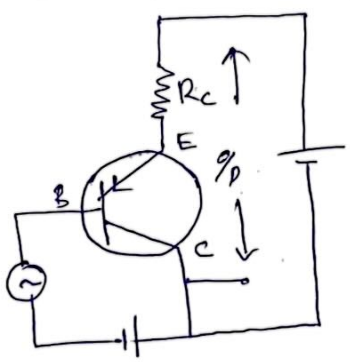
It is the curve between collector current I_C and collector-emitter voltage V_{CE} at constant base current I_B.



(3) Common collector Configuration (CC)

In CC configuration input is applied between base and collector while output is taken between the emitter and collector. Here collector is common to both input and output circuit.





Current Amplification factor

Here input current is base current & output current is emitter current. There-fore current amplification factor is the ratio of emitter current to the base current.

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

Relation between current gain α & β

we have, $\beta = \frac{I_C}{I_B} \Rightarrow I_B = \frac{I_C}{\beta}$

$\alpha = \frac{I_C}{I_E} \Rightarrow I_E = \frac{I_C}{\alpha}$

we know, $I_E = I_C + I_B$

$$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

dividing both side by I_C

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\Rightarrow \frac{1}{\alpha} = \frac{\beta + 1}{\beta}$$

$$\Rightarrow \beta = \alpha\beta + \alpha$$

$$\Rightarrow \beta - \alpha\beta = \alpha = \beta(1-\alpha) = \alpha$$

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} \quad \text{---- (1)}$$

from eq (1) $\beta(1-\alpha) = \alpha$

$$\Rightarrow \beta - \alpha\beta = \alpha$$

$$\Rightarrow \beta = \alpha + \alpha\beta = \alpha(1+\beta)$$

$$\Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}}$$

Relation Between α, β & γ

$$\gamma = \frac{I_E}{I_B} = \frac{I_E}{I_B} \cdot \frac{I_C}{I_C}$$

$$\gamma = \frac{I_E}{I_C} \cdot \frac{I_C}{I_B}$$

$$\gamma = \frac{1}{\alpha} \cdot \beta$$

$$\boxed{\beta = \alpha\gamma}$$

Transistor Biasing

Biasing refers to providing DC current and DC voltage to an electronic device to obtain desired functionality from the device.

Need for BJT Biasing :-

1. To operate BJT in active region so that BJT can be used as amplifier.
2. To maintain collector current stable & thereby operating point becomes stable & Thermal runaway can be prevented.

Thermal Runaway

The self destruction of a transistor due to the cummulative rise in the collector junction temperature during reverse bias operation is called thermal runaway.

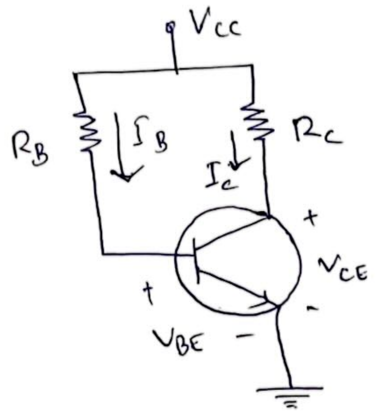
Stabilization

The process of making operating point independent of temperature changes or variations in transistor parameters is known as stabilization.

Biasing circuits

1. Fixed Bias / Base resistor method
2. Collector to Base Bias
3. Self Bias or voltage divider Bias

① Base resistor / Fixed bias method



- V_{cc} provides the necessary currents & voltages to BJT.

Applying KVL to input :-

$$V_{cc} - I_B R_B - V_{BE} = 0$$

$$\Rightarrow I_B R_B = V_{cc} - V_{BE}$$

$$\Rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B}$$

$$\boxed{I_{CQ} = \beta I_B}$$

Applying KVL to output :-

$$V_{cc} - I_C R_C - V_{CE} = 0$$

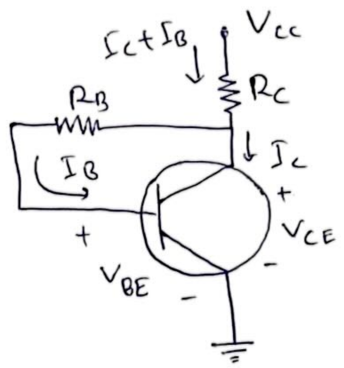
$$\Rightarrow \boxed{V_{CEQ} = V_{cc} - I_{CQ} R_C}$$

Drawbacks

① Highly unstable operating point.

② Possibility of thermal Runaway.

(2) Collector to Base Bias



Applying KVL to input :-

$$V_{CC} - (I_C + I_B) R_C - I_B R_B - V_{BE} = 0$$

$$\Rightarrow V_{CC} - (\beta I_B + I_B) R_C - I_B R_B - V_{BE} = 0$$

$$\Rightarrow \beta I_B R_C + I_B R_C + I_B R_B = V_{CC} - V_{BE}$$

$$\Rightarrow I_B [(1+\beta) R_C + R_B] = V_{CC} - V_{BE}$$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{(1+\beta) R_C + R_B}$$

$$\boxed{I_{CQ} = \beta I_B}$$

Applying KVL to output :-

$$V_{CC} - (I_C + I_B) R_C - V_{CE} = 0$$

$$\Rightarrow V_{CE} = V_{CC} - (I_C + I_B) R_C$$

$$\Rightarrow V_{CE} = V_{CC} - \left(I_C + \frac{I_C}{\beta}\right) R_C$$

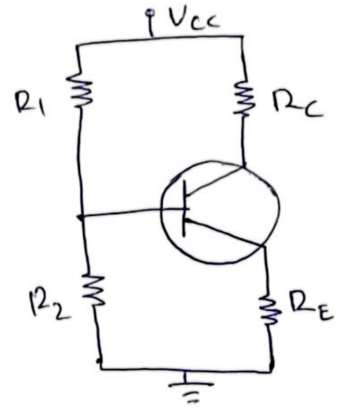
$$\Rightarrow V_{CE} = V_{CC} - I_C R_C \left(1 + \frac{1}{\beta}\right)$$

$$\boxed{V_{CEQ} \approx V_{CC} - I_C R_C}$$

Drawback

- The resistance R_B connected between collector & base provides negative feedback which reduce the overall AC gain of Amplifier.

③ Self Bias / Voltage divider Bias



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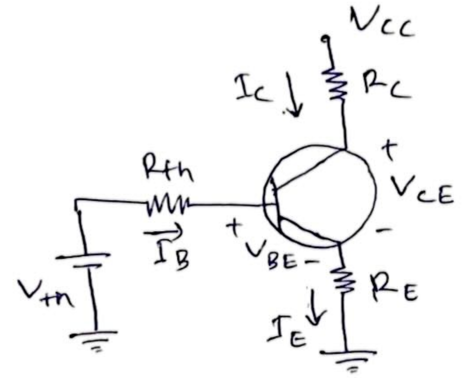
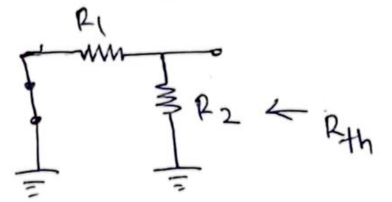
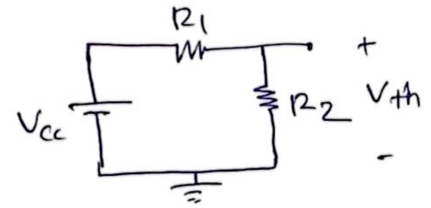






$$R_{th} = R_1 \parallel R_2$$

$$V_{th} = \frac{V_{cc} R_2}{R_1 + R_2}$$

Applying KVL to input :-

$$V_{th} - I_B R_{th} - V_{BE} - I_E R_E = 0$$

$$\Rightarrow V_{th} - I_B R_{th} - V_{BE} - (I_C + I_B) R_E = 0$$

$$\Rightarrow V_{th} - I_B R_{th} - V_{BE} - \beta I_B R_E - I_B R_E = 0$$

$$\Rightarrow I_B (R_{th} + \beta R_E + R_E) = V_{th} - V_{BE}$$

$$\Rightarrow I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}$$

$$\boxed{I_{CQ} = \beta I_B}$$

Applying KVL to output :-

$$V_{cc} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$\Rightarrow V_{CE} = V_{cc} - I_C R_C - (I_C + I_B) R_E$$

$$\Rightarrow V_{CE} = V_{cc} - I_C R_C - I_C R_E - \frac{I_C}{\beta} R_E$$

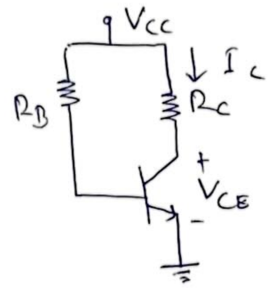
$$\Rightarrow V_{CE} = V_{cc} - I_C \left[R_C + \left(1 + \frac{1}{\beta}\right) R_E \right]$$

$$\Rightarrow \boxed{V_{CEQ} = V_{cc} - I_C (R_C + R_E)}$$ (β is large)

- with proper selection of R_1, R_2 & R_E, the stability factor of self bias may be obtained below 10.

DC load line & Operating point

- It is a straight line plotted on I_c versus V_{CE} graph.
- DC load line is useful in graphical analysis of BJT circuit.
- It can be used to calculate V_{CE} & I_c graphically for a given BJT circuit.
- Equation of DC load line is obtained by applying KVL in collector loop.



KVL at output :-

$$V_{CC} - I_C R_C - V_{CE} = 0$$

$$\Rightarrow I_C R_C = V_{CC} - V_{CE}$$

$$\Rightarrow I_c = \left(-\frac{1}{R_c}\right) V_{CE} + \frac{V_{CC}}{R_C} \quad \text{——— (1)}$$

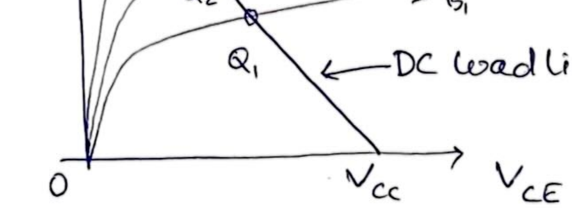
slope

Equation (1) represents straight line having slope $\left(-\frac{1}{R_c}\right)$ & y-intercept $\left(\frac{V_{CC}}{R_C}\right)$. It is called DC load line.

From eqn (1) :-

For $I_C = 0$; $0 = -\frac{1}{R_C} V_{CE} + \frac{V_{CC}}{R_C}$

$\Rightarrow$ $\boxed{V_{CE} = V_{CC}}$

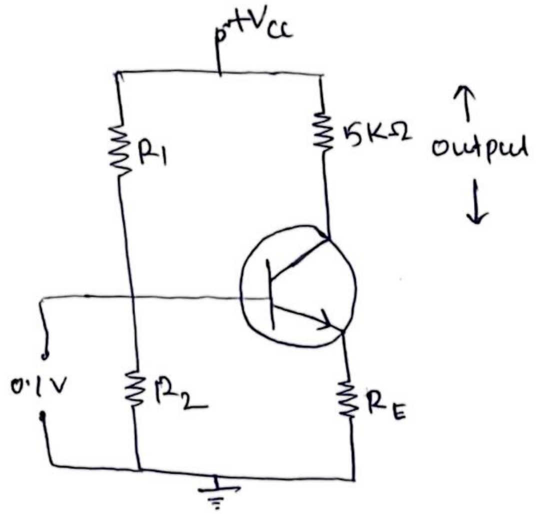


Operating point/Q-point

For a given value of I_B, the point of intersection of characteristics curve & DC load line is known as operating point or Q-point or Quiescent point.

- Operating point is kept at centre of load line for distortionless output from Amplifier.

Amplifier



- It is a single stage CE Amplifier.
- When a weak signal is given to the base of transistor, a small base current start flowing.
- Due to large β, a large a.c current flows through the collector Load R_C. As R_C is quite high, Therefore a large voltage appears across R_C.
- Thus a weak signal applied in the base circuit appears in amplified form in the collector circuit.

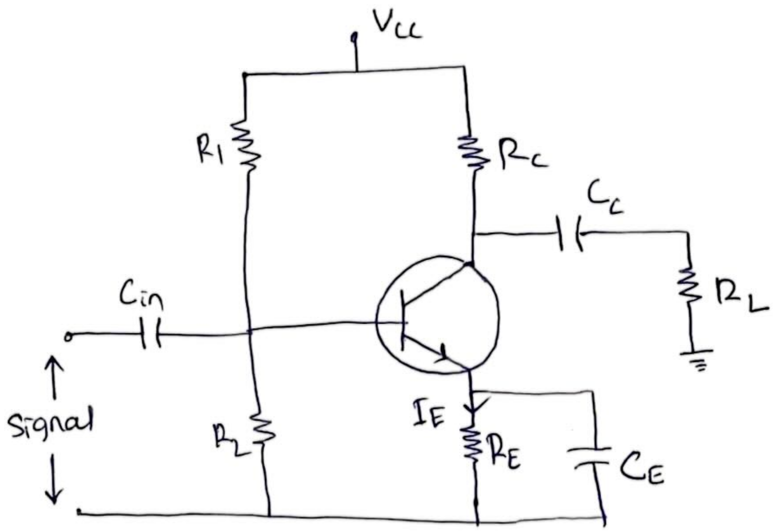
Ex Suppose a change of 0.1 V in signal voltage produces a change of 2mA in the collector current.

Then output voltage $= 2mA \times 5K\Omega = 10V$.

Thus a voltage amplification of $\frac{10}{0.1} = 100$ is obtained.

- This is how a transistor Amplify weak signal.

Single Stage CE Amplifier



- The resistances R_1, R_2 & R_E form the biasing & stabilization circuit. The biasing circuit must establish a proper operating point.

- Capacitor Cin is used to couple the signal to the base of the transistor. If it is not used, the signal source resistance will come across R_2 & thus change the bias.

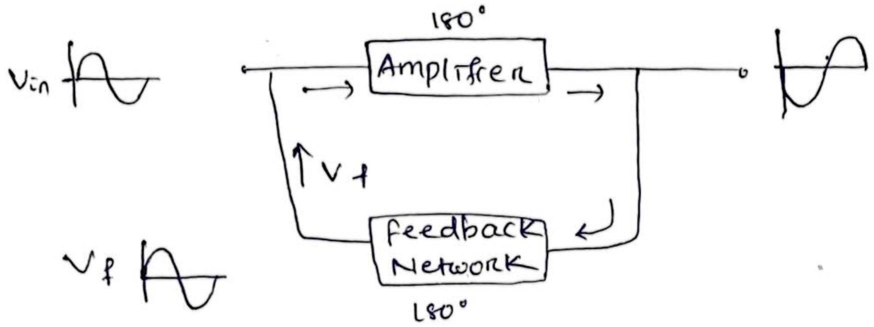
- An Emitter bypass capacitor C_E is used in parallel with R_E to provide a low reactance path to the amplified ac signal. It is used to avoid voltage drop across it.

- The coupling capacitor couples one stage of amplification to the next stage. The coupling capacitor C_c isolates the dc of one stage from the next stage but allows the passage of ac signal.

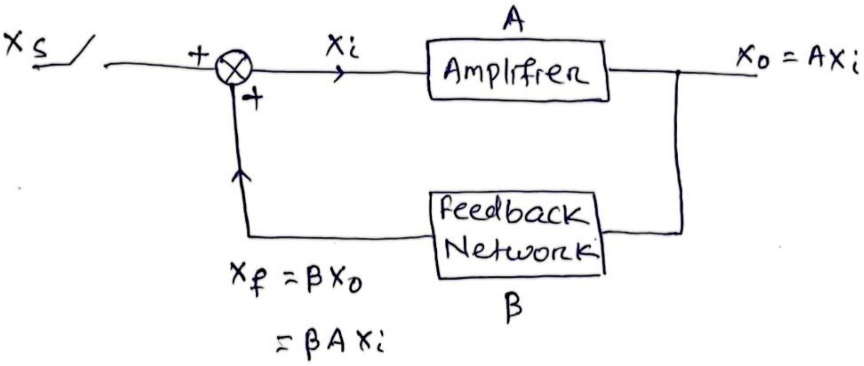
- The output of common Emitter amplifier is 180° phase shift or out of phase with the input.

Oscillator

A transistor amplifier with proper positive feedback can act as an oscillator. i.e it can generate oscillations without any external signal source.



- A positive feedback amplifier is one that produces a feedback voltage V_f that is in phase with the original input signal.
- A phase shift of 180° is produced by the amplifier and a further phase shift of 180° is introduced by feedback network. So the signal is shifted by 360° & fed to the input i.e feedback voltage is in phase with the input signal.



$X_s \to$ Initial Input

$\beta \to$ Feedback fraction

$A \to$ Gain of Amplifier

- Initial input to oscillator is noise or a DC transient. This input gets amplified & output X_o is generated. X_o gets multiplied by factor β inside feedback network & signal X_f is obtained.

$$X_f = \beta X_o$$

$$X_f = A\beta X_i$$

If $A\beta = 1$, then $X_f = X_i$

- Therefore feedback network can reproduce input x_i. Hence oscillator doesn't require external input.

- As β is frequency dependent, the condition "$A\beta = 1$" can be satisfied only for a single frequency f_0 known as frequency of oscillations.

Barkhausen Criterion

Barkhausen criterion is that in order to produce continuous undamped oscillations at the output of an amplifier, the positive feedback should be such that :-

$$\boxed{A\beta = 1}$$

Different types of transistor oscillators

(i) Tuned collector oscillator
(ii) Colpitt's oscillator
(iii) Hartley oscillator
(iv) phase shift oscillator
(v) wien Bridge oscillator
(vi) Crystal oscillator

Classification of oscillators

1. Audio frequency oscillators (AF) :- RC oscillators
   - RC phaseshift
   - wein-Bridge

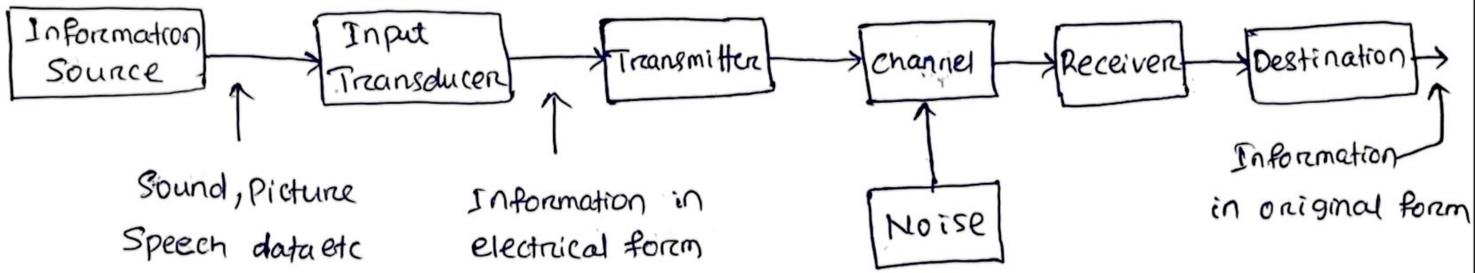
2. Radio frequency oscillators (RF) :- LC oscillators (High frequency)
   - Hartley
   - Colpitts
   - Clapp
   - Crystal

Communication System

communication is the process of establishing connection or link between two points for information exchange.

- The electronic equipments which are used for communication purpose are called communication equipments. Different communication equipments when assembled together form a communication system.

Block diagram of a communication system



- The essential components of a communication system are information source, input transducer, transmitter, communication channel, receiver & destination.

Information Source

Function of information source is to produce required message which has to be transmitted.

Input Transducer

A transducer is a device which converts one form of energy into another form. when the message signal produced by the information source is not electrical in nature, an input transducer is used to convert it into a time varying electrical signal

Transmitter

Inside the transmitter the signal processings such as restriction of range of audio frequencies, amplification and modulation are achieved.

The channel & The Noise

- Channel is the medium through which the message travels from the transmitter to receiver. The function of the channel is to provide a physical connection between the transmitter & receiver.

- Noise is an unwanted signal which tend to interfere with the required signal.

Receiver

The function of the receiver is to reproduce the message signal in electrical form from the distorted receive signal. This reproduction of the original signal is accomplished by a process known as the demodulation or detection.

Destination

Destination is the final stage which is used to convert an electrical message signal into its original form.

Modulation

The process of changing some characteristics (i.e amplitude, frequency or phase) of a carrier wave in accordance with the intensity of the signal is known as modulation.

- The resultant wave is called modulated wave.

Need for Modulation

(i) practical antenna length :- To transmit a wave effectively, the length of the transmitting antenna should be approximately equal to the wavelength of the wave.

$$\text{wave length} = \frac{\text{velocity}}{\text{frequency}} = \frac{3\times10^8}{f\,(Hz)} \text{ meters}$$

- To radiate a frequency of 20KHz directly into space, we need an antenna length of $\frac{3\times10^8}{20\times10^3} = 15000$ meter or 15 km.
- It is practically not possible to construct an antenna of 15 km.
- If a carrier wave of 1 MHz is used, we need antenna length of $\frac{3\times10^8}{1\times10^6} = 300$ meter. which is practically possible to construct.

(ii) operating range : The energy of a wave depends upon its 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 distances if radiated directly into space. To transmit over large distance in space the signal need more energy. Hence a high frequency carrier wave is used to modulate.

(iii) Wireless communication: At audio frequencies, radiation is not practicable because the efficiency of radiation is poor. Efficiency of high frequency carrier wave is high, so efficient radiation is possible if modulation is done.

Demodulation

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

- At the broadcasting station, modulation is done to transmit the audio signal over a larger distances to a receiver. When the modulated wave is received by the radio receiver, it is necessary to recover the audio signal from it. This process of recovering is called demodulation.

Modulation	Demodulation
- Data is collected and modified into the carrier.	- Data is recovered.
- Modulation is carried out on the sender's side.	- Demodulation takes place on the receiver's side.
- Modulation is a process in which the original message signal is mixed with a carrier wave whose parameters need to be altered.	- Demodulation takes place in order to create an original information signal by separating the carrier signal from the message signal.
- Modulation is done to transmit data over longer distances.	- Demodulation is the process that prevents the signal from being modified.

Types of modulation

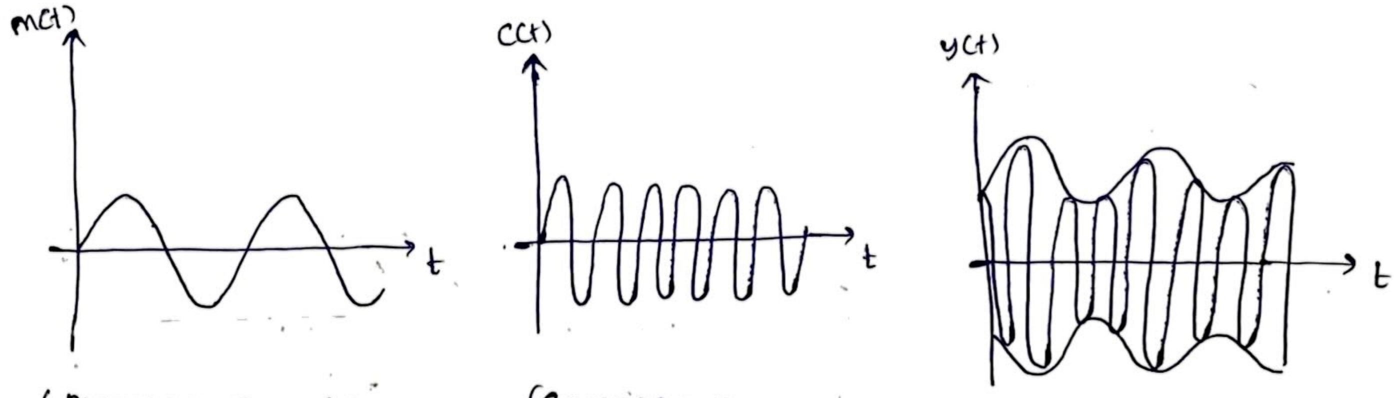
modulation is the process of changing amplitude or frequency or phase of a carrier wave in accordance with the intensity of the signal. Accordingly, there are 3 basic types of modulation,

(i) Amplitude modulation
(ii) Frequency modulation
(iii) Phase Modulation

(i) Amplitude modulation (AM)

when the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal, it 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 carrier frequency.



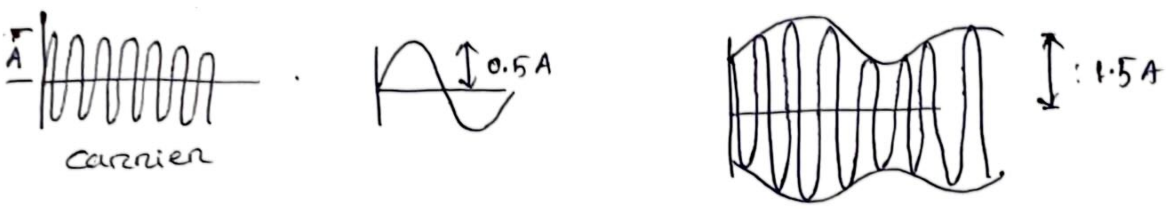
(message signal) (carrier) (AM wave)

modulation Factor

The ratio of change of amplitude of carrier wave to the amplitude of normal carrier wave is called the modulation factor m (or) modulation index.

$$m = \frac{\text{Amplitude change of carrier wave}}{\text{Normal carrier amplitude (unmodulated)}}$$

ex



Amplitude Change of carrier = 1.5A − A = 0.5A

Normal carrier amplitude = A

$$m = \frac{0.5A}{A} = 0.5 \text{ (OR) } 50\%$$

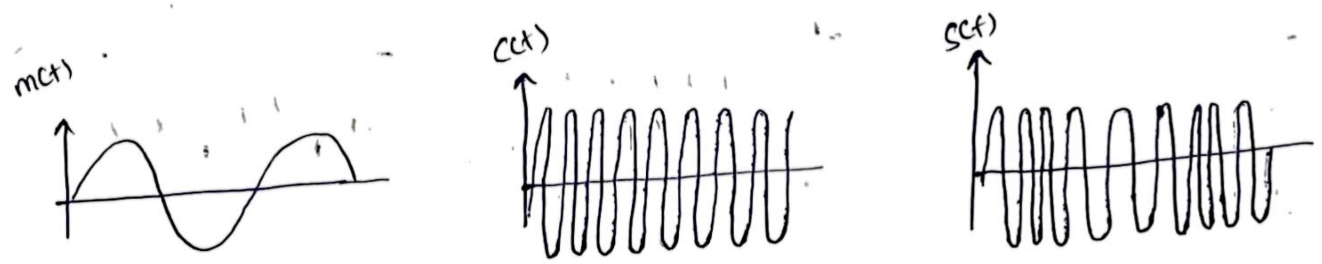
Note

- If the carrier is overmodulated (i.e $m>1$), distortion will occure during reception. Therefore degree of modulation should never exceed 100%

(ii) Frequency modulation (FM)

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

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



(message signal) (Carrier signal) (FM wave)

- The frequency deviation of FM signal depends on the amplitude of the modulating signal.
- The centre frequency is the frequency without modulation or when the modulating voltage is zero.

Modulation Index

Modulation index m_f is the ratio of maximum frequency deviation (Δf) to the frequency of the modulating signal (f_s).

$$\text{modulation index}, \; m_f = \frac{f_{c\,max} - f_c}{f_s} = \frac{\Delta f}{f_s}$$

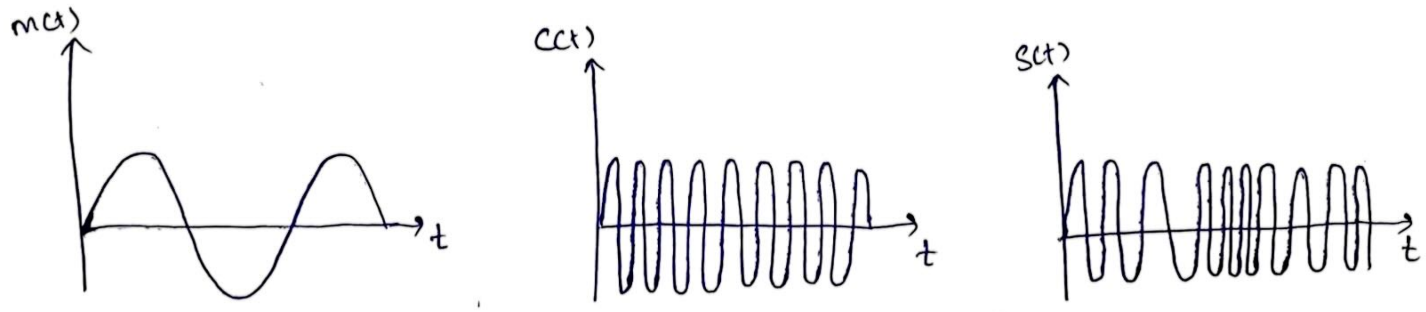
Advantage of FM over AM

- It gives noiseless reception
- The operating range is quite large
- The efficiency of transmission is very high.

(iii) Phase Modulation (PM)

In phase modulation the phase of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.

- In phase modulation the amplitude and the frequency of the carrier remains constant.



(message signal or modulating signal) (Carrier wave) (PM wave or modulated wave)

- The instantaneous amplitude of the modulating signal changes the phase of the carrier signal.

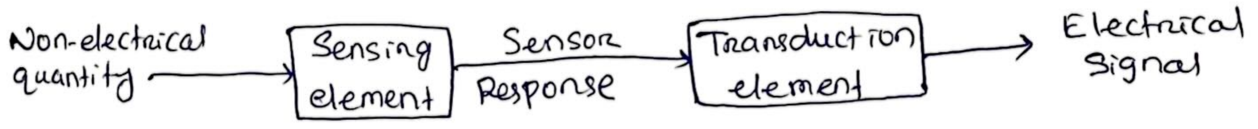
Difference between AM & FM

Frequency Modulation	Amplitude modulation
- The amplitude of carrier remains constant with modulation.	- The amplitude of carrier changes with modulation.
- The carrier frequency changes with modulation	- The carrier frequency remains constant with modulation.
- The carrier frequency changes according to the strength of the modulating signal.	- The carrier amplitude changes according to the strength of the modulating signal.
- The value of modulation index can be more than 1.	- The value of modulation factor can not be more than 1 for distortionless AM signal.

Transducer

A transducer is an electronic device that converts energy from one form to another. The process of converting energy from one form to another is known as transduction.

- The transducer which converts non-electrical form of energy into electrical form of energy is known as electrical transducer.



Sensing Element

It is the part of a transducer that responds to the physical sensation. The response of the sensing element depends on the physical phenomenon.

Transduction Element

The transduction element of the transducer converts the output of the sensing element into an electrical signal. The transduction element is also called the secondary transducer.

ex - Thermocouple, microphones

Sensor

Sensor is a device used to measure the physical changes that occur in the surroundings like temperature, light etc and convert it into a readable signal.

- A sensor is a component itself and it doesnot have signal conditioning unit.

ex - Barometer, Accelerometer

Difference Between Transducer & Sensor

Transducer	Sensor
- It helps in converting one form of energy into another form.	- It senses physical quantities and converts into signals which are read by an instrument.
- Transducer is made up of a sensor and a signal conditioning circuit.	- A sensor itself is a component.
- A transducer does not require any processing circuit. Its output is directly interfaced with a device or display.	- A sensor requires an additional circuit to process its output signal into a readable form.
- A transducer can generate analog as well as digital output	- A sensor's output is analog in nature.
- Examples of transducers are thermistor, potentiometer etc.	- Examples of sensors are thermometer, pressure sensor etc.

Classification of Transducers

- Transducer
  - Based on nature of o/p
    - Mechanical
    - Electrical
  - Based on Role
    - Input
    - Output
  - Based on operation
    - Active
    - Passive

Mechanical Transducer :- If a transducer produces mechanical nature signal as its output, then it is called mechanical transducer.
Ex. Thermocouple, capillary tube etc.

Electrical Transducer :- If a transducer produces electrical signals as output, then it is called an electrical transducer. Examples- Photovoltaic cell, Thermistor etc.

Input Transducer:- It can be used as a measurement device & is known as an instrument transducer.

Output Transducer:- It delivers output signals like force, torque, pressure or displacement when the electrical signal is applied as an input. It is known as power transducer.

Active Transducer:- It develops a voltage or current as the output signal from the physical parameter being measured. It does not require any external source of power for its operation. Examples Thermocouple, photoelectric cell, photovoltaic cell etc

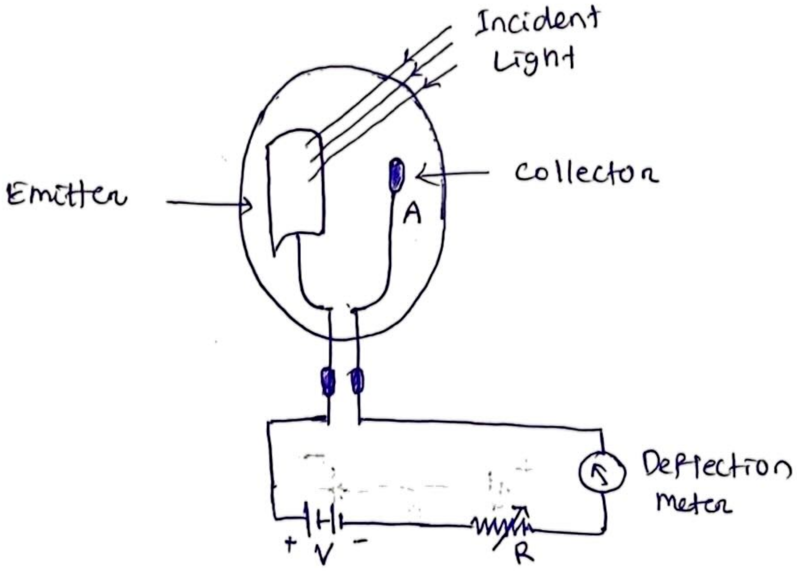
Passive Transducer:- It requires an external source of power. It produces a change in the electrical parameters such as resistance, inductance or capacitance in response to the physical parameter being measured. Examples - Thermistor, resistance thermometer etc.

Difference Between Active & Passive transducer

Active Transducer	Passive Transducer
- They donot require any external source of power for their operation.	- They require an external source of power for their operation.
- They are self generating type of transducers.	- They are not self generating type of transducers.
- They produce electrical parameter such as Voltage or current propotional to the physical parameter being measured.	- They produce a change in the electrical parameters such as resistance inductance or capacitance in response to the physical parameter being measured.
- Examples: Thermocouple, photovoltaic cell, photoelectric cell etc	- Examples: Resistance thermometer, LVDT, thermistor etc.

Photoemissive Transducer

The photoemissive transducer converts the photons into electric energy. It consists the anode rod & the cathode plate. The anode and cathode are coated with a photoemissive material called caesium antimony.



- when the radiation of light fall on cathode plates the electrons starts flowing from anode to cathode. Both the anode & the cathode are sealed in a closed, opaque evacuated tube. when the radiation of light fall on the sealed tube, the electrons starts emitting from the cathode and moves towards the anode.

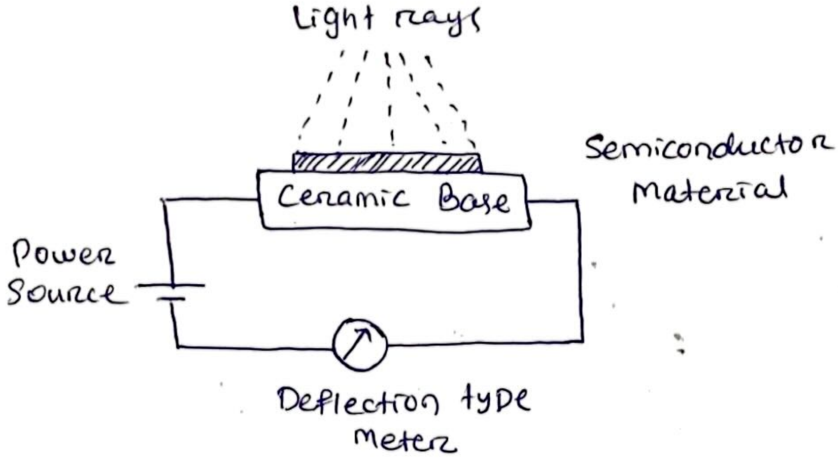
- The anode is kept to the positive potential. Thus, the photoelectric current starts flowing through the anode. The magnitude of the current is directly proportional to the intensity of light passes through it.

Application

- Field of photometry and calorimetry
- It is concerning the counting or sorting of objects on a conveyor belt.
- Automatic opening of a door.

Photoconductive Transducer

The photoconductive transducer converts the light energy into an electric current. It uses the semiconductor material like cadmium selenide, Ge, as a photo sensing element.



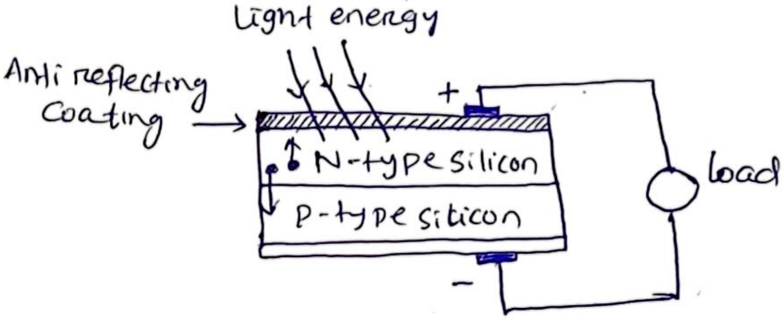
- when the beam of light falls on the semiconductor material, their conductivity increases & the material works like a closed switch. The current start flowing into the material and deflects the pointer of the meter.

Application

- They are effectively used in relay control circuits, burglar alarms & light controlled switches.
- They are used to measure the attenuation of light
- In industrial control equipment to count the number of packages moving on conveyor belts.

Photovoltaic Transducer

The photovoltaic transducer is the type of active transducer. The current starts flowing into the photovoltaic cell when the load is connected to it. The silicon & selenium are used as a semiconductor material. When the semiconductor material absorbs heat, the free electrons of the material starts moving. The phenomenon is known as the photovoltaic effect.



- The movements of electrons develop the current in the cell, and the current is known as the photoeleltric current.

Application

- They can be used as energy converters.
- Used in space crafts, data processing industries, switching and trigger circuits, earth-based applications.
- Can be used to determine the width of material processing.
- Cells with gold doped germanium material can be used as infrared detectors.

Multimeter

- A multimeter is an electronic instrument which can measure resistance current & voltage.
- It is an indispensable instrument & can be used for measuring dc as well as ac voltages & currents.
- Multimeter is the most inexpensive equipment & can make various electrical measurements with reasonable accuracy.
- A multimeter consists of an ordinary pivoted type of moving coil galvanometer. It consists of a coil pivoted on jeweled bearings between the poles of a permanent magnet.
- The indicating needle is fastend to the coil. When electric current is passed through the coil, mechanical force acts & the pointer moves over the scale.
- The Galvanometer in a multimeter is always of left zero type i.e normally its needle rests in extreme left position as compared to centre zero position of ordinary galvanometer.

Applications of multimeter

(i) It is used for checking the circuit continuity. When the multimeter is employed as continuity checking device, the ohmmeter scale is utilised & the equipment to be checked is disconnected from the power mains.

(ii) For measuring dc current flowing through the cathode, plate, screen & other vacuum tube circuits, multimeter is used.

(iii) For measuring dc voltages across various resistors in electronic circuits.

(iv) For measuring ac voltages across power supply transformers.

(v) ~~It~~ Is used for ascertaining whether or not open or short circuit exists in the circuit under study.

Analog Multimeter

An analog multimeter is a permanent magnet moving coil (PMMC) meter type measuring instrument. It works on the principle of d'Arsonval galvanometer.

- An analog multimeter has an analog display that uses the deflection of a pointer on the scale to indicate the level of measurement being made. The pointer deflects from its initial position increasingly as the measuring quantity increases.

Digital Multimeter

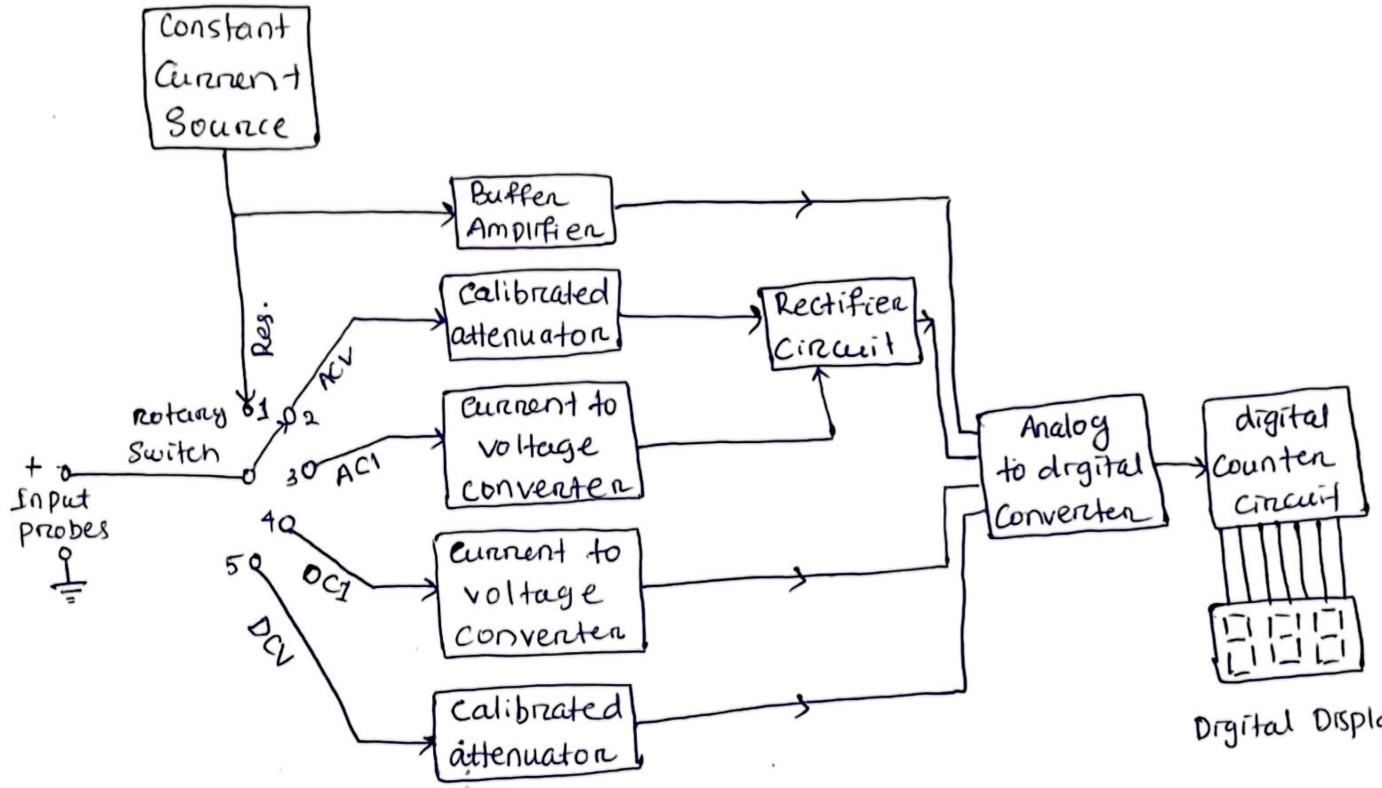
A digital multimeter is a measuring instrument used to measure various electrical quantities. The standard measurements that are performed by a digital multimeter are current, voltage & resistance. It can also measure temperature, frequency, capacitance, continuity, transistor gains etc.

- A typical digital multimeter has a rotary switch, digital display and connecting jacks for the probes.

Difference Between Analog & Digital Multimeter

Analog Multimeter	Digital multimeter
- An analog multimeter is a device used to measure limited electrical quantities such as current, voltage and resistance etc.	- Digital multimeter is a device used to measure multiple electrical quantities such as current, voltage resistance, capacitance, diode etc..
- Analog multimeter primarily measures the current using a Galvanometer.	- Digital multimeter measures voltage using Analog to digital converter.
- Anolog multimeter shows the values on a printed value scale against moving pointer.	- Digital multimeter shows reading on a digital display in the form of numeric values.
- Analog multimeters should be calibrated manually.	- Digital multimeter provide automatic calibration.

working of Multimeter



- To measure unknown resistance using digital multimeter, unknown resistor is connected across its input probes & the rotary switch is kept at position 1. The proportional current flows through the resistor, from constant current source. According to ohm's law voltage is produced across it. This voltage is directly proportional to its resistance. This voltage is buffered & fed to A to D converter, to get digital display in ohms.

- To measure an unknown AC voltage, it is kept in position-2. The voltage is attenuated, if it is above the selected range & then rectified to convert it into proportional DC voltage. It is then fed to A to D converter to get the digital display in volts.

- Current is indirectly measured by converting it into proportional voltage. For AC current the switch is kept at position 3. The current is converted into voltage proportionally with the help of I-V converter & then rectified.

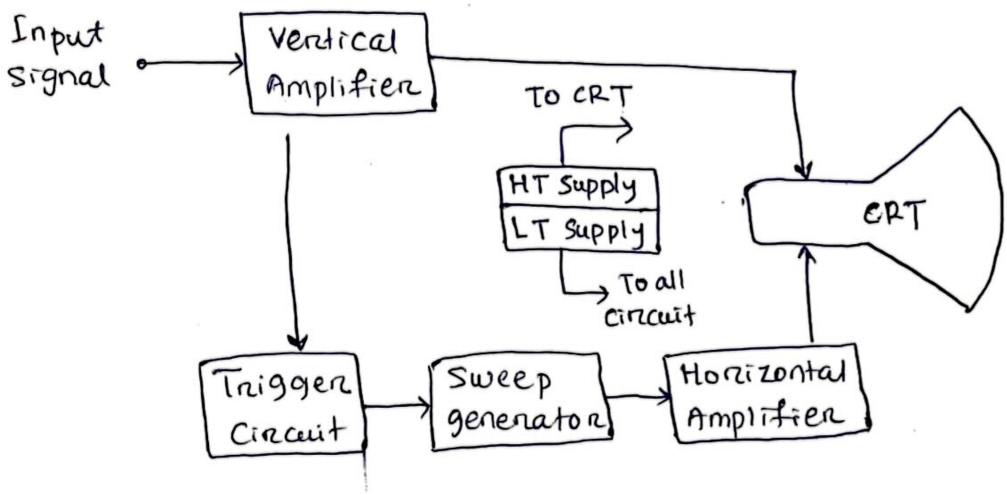
- Now the voltage interms of AC Current is fed to A to D converter to get digital display in Amperes.

- The DC Current is also measured indirectly. Switch is kept at position 4. The current is converted into voltage proportionally with the help of I-V converter. Now the voltage in terms of DC current is fed to A to D converter to get the digital display in Amperes.

- For DC voltage the switch is kept at position 5. The voltage is attenuated, if it is above the selected range, then directly fed to Analog to digital converter to get the digital display in volts.

Cathode Ray oscilloscope (CRO)

An oscilloscope can display & also measure many electrical quantities like ac/dc voltages, time, phase relationships, frequency & a wide range of waveform characteristics like rise-time, fall time & overshoot etc.



Cathode Ray Tube (CRT) :- It displays the quantity being measured.

Vertical amplifier :- It amplifies the signal waveform to be viewed.

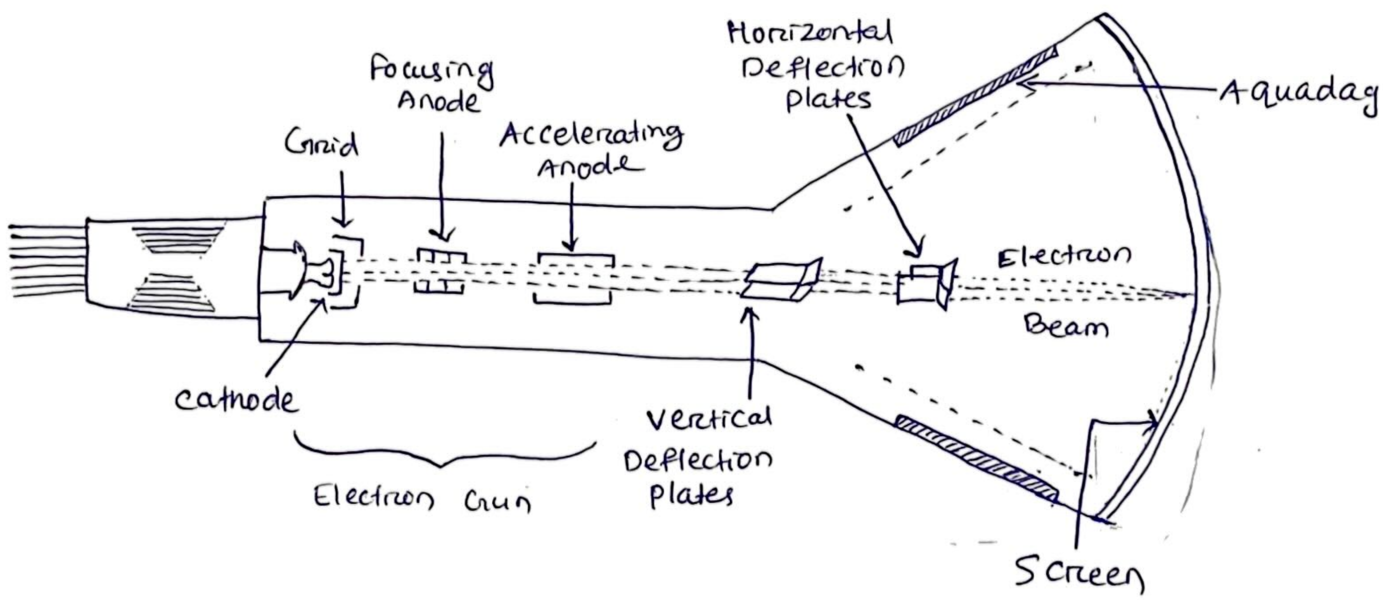
Horizontal Amplifier :- It is fed with a sawtooth voltage which is then applied to the X-plates.

Sweep generator :- Produces sawtooth voltage waveform used for horizontal deflection of the electron beam.

Trigger circuit :- produces trigger pulses to start horizontal sweep.

Cathode Ray Tube

A cathode ray tube is the heart of the oscilloscope. It is a vacuum tube of special geometrical shape and converts an electrical signal into visual one.



Glass envelop

It is conical highly evacuated glass housing & maintains vacuum inside & supports the various electrodes. The inner wall of CRT between neck & screen are usually coated with a conducting material called Aquadag. This coating is electrically connected to the accelerating anode so that electrons which accidentally strikes the wall are returned to the anode.

Electron gun assembly

The arrangement of electrodes which produce a focussed beam of electrons is called the electron gun. It consists of an indirectly heated cathode, a control grid, a focussing anode & an accelerating anode.

- The control grid encloses the cathode & consists of a metal cylinder with a tiny circular opening to keep the electron beam small in size.
- The focussing anode focuses the electron beam into a sharp pin-point by controlling the positive potential on it. The positive potential on the accelerating anode is much higher than on the focussing anode. For this reason, this anode accelerates the narrow beam to a high velocity.
- Therefore, the electron gun assembly forms a narrow, accelerated beam of electrons which produces a spot of light when it strikes the screen.

<u>Deflection plate assembly</u>

<u>Vertical deflection plates</u> :- They are mounted horizontally in the tube. By applying proper potential to these plates, the electron beam can be made to move up & down vertically on the fluorescent screen.

<u>Horizontal deflection plates</u> :- They are mounted in the vertical plane. An appropriate potential on these plates can cause the electron beam to move right & left horizontally on the screen.

<u>Screen</u>

- The screen is the inside face of the tube & is coated with some fluorescent material such as zinc orthosilicate, zinc oxide etc.
- When high velocity electron beam strikes the screen, a spot of light is produced at the point of impact.
- The colour of the spot depends upon the nature of fluorescent material. If zinc orthosilicate is used as the fluorescent material, green light spot is produced.