Chapter - 1 - Electronic Devices

1.1 Basic concept of Electronics and its applications

Electronics is the branch of science and engineering which deals with the flow of electrons through vaccum or gas or semiconductor.

Electronics is derived from the word electron, which is present inside the atom of all materials.

As such electronics is the branch of engineering which essentially deals with electronic devices and their utilization.

Applications of Electronics

Electronics plays important role in allmost all spheres of life. Some of the important applications are -

a) Communication & Entertainment :

Electronics plays a very vast role in the field of communication. Starting from telephone, telegraph to wireless, sattellite communications, world wide communi- cation in real time, in audio, video form over a short range of time.

are the contribution of Electronics.
In the field of entertainment - voice & music recording and playing visual display systems and almost all aspects of entertainment are flourished with electronics.

b) <u>Industrial Application</u>:

Industrial tasks like conveyance, transportation, extraction, lighting, process control, cutting, bending, melting, smelting, packaging etc are being performed electronically

c). <u>Defence applications</u>

RADARS, SONARS, AWACS etc are electronic systems used in military applications. Missile launching, Aeroplane war plane landing etc are controlled by electronics principles.

d) <u>Medical applications</u>

medical diagnosis and treatment processes like x-ray, endoscopy, Electrocardiography are performed by electronics systems. Oscilloscopes, various electronic measuring instruments are used in the field of medical science.

e) Automobile field:

In automobile field, ignition systems, breaking systems, control of fuel flow, speed measurement and monitoring, control of engine performance, fault tracing and automatic control systems are performed with the help of electronics.

f) Digital Electronics: measurement and recording instruments, display units are operated with digital electronics. Almost all measuring and controll instruments are now a days converting from its analog mode to digital electronics mode.

g) Instrumentation: operations like calibration, sophistication, accuracy, maintenance etc. are coming under instrumentation which is mostly electronically performed.

1.2 Basic concept of electron emission and its types

Electron emission: The liberation of electrons from the surface of a substance (usualy metals) is known as electron emission.

In some materials (usualy metals) the valence electrons in the outermost orbit are very loosely held by the nucleus.

* work function has the unit of (energy) eV (electron volt)

These electrons are called free electrons. The force by which a metal surface prevents the free electrons from escaping is called surface barrier of that metal.

If sufficient amount of external energy is applied to the metal, the kinetic energy of the free electrons will be increased over the surface barrier and they will be liberated from the surface

The amount of energy required by an electron to overcome the surface barrier of a metal to escape from its surface is called work function of that metal.

Types of electron emission:

Electrons are emitted from the surface of a metal if sufficient energy (equal to work function of the metal) is supplied externally. This external energy may come from heat, electric field, light or by bombardment of charged particles on the metal surface. Accordingly there are 4 methods of electronic emission.

a) Thermionic emission: The metallic surface is heated to very high temperature (about 2500°c) so as to enable the free electrons to leave the surface. This type of electron emission is called thermionic emission. (5)

Thus thermionic emission is the process of electron emission from a metal surface by supplying thermal energy (heat) to it. The emitter is required to have small (low) work function.

<u>Richardson - Dushman equation</u>: The amount of thermionic emission increases rapidly with rise in emitter temperature, which increases the emission current. The emission current density is given by Richardson-Dushman eqn -

$$\boxed{J_s = A T^2 e^{-b/T}} \quad \text{amp/m}^2$$

where J_s = emission current density = current per square meter of emitter surface (amp/m²)

T = absolute temp. of emitter (°K)

A = constant depending upon the type of emitter (amp/m²/K²)

b = a constant for the emitter

and $\boxed{b = \frac{\phi e}{K}}$ where ϕ = work function of emitter

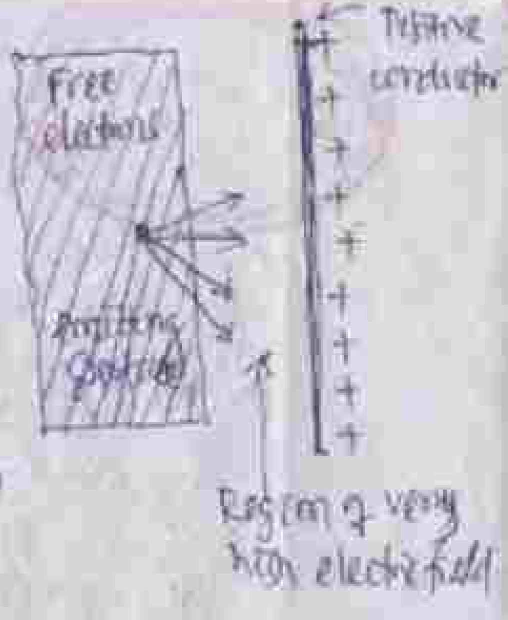
e = charge of electron (1.602×10^{-19} coul)

K = boltzmann constant = 1.38×10^{-23} J/K

$$\therefore b = \frac{\phi \times 1.602\times10^{-19}}{1.38\times10^{-23}} = 11600\phi\ K.$$

(b) <u>Field emission</u>: The process of electron emission from the surface of a material by applying very strong electric field (+ve field) at the surface is known as field emission.

A very high voltage (+vely charged) conductor is placed close to the metal surface. The very high +ve field attracts electrons from the metallic surface, because the force of attraction exceeds the ~~potent~~ surface barrier.



Electric field of the order of million volts per centimeter distance between the emitting surface and the +ve conductor is required to cause field emission. The temperature at the time of field emission may be equal to room temperature (very low as compared to thermionic emission). Hence field emission is also sometimes called as cold cathode emission or auto-electronic emission.

c) Photoelectric emission:

Electron emission from a metallic surface by the application of light is called photoelectric emission.

When rays of light of proper intensity strikes the surface of certain metals (photo emissive metals like potassium, sodium, cesium), the

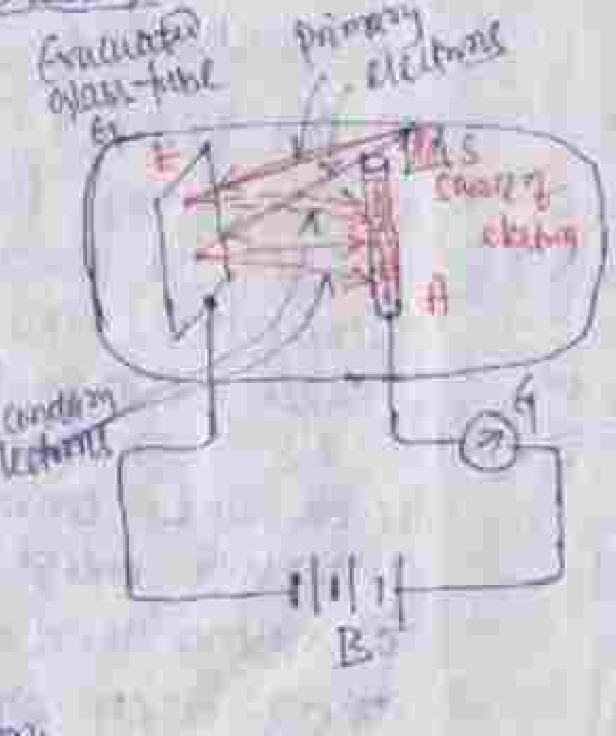
energy of photons of light is transferred to the free electrons. If the energy of the striking photons is greater than the work function of the metal (called emitter or cathode) then electrons are liberated from the metal surface.

Such electrons are called photoelectrons and are collected by a +vely charged anode. A potential difference is maintained between the anode and cathode. The whole arrangement is called a photo-tube.

The amount of photoelectric emission depends upon the intensity of light falling on the metal surface and the frequency of radiation.

(d) Secondary emission:

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



As shown in the figure, when very high velocity electrons (primary electrons) strikes a metal surface, they give part or full of their kinetic energy to the free electrons in the metal, thus enabling them to overcome the workfunction of the metal and get liberated (called secondary electrons).

These secondary electrons collected by the anode, produces emission current. Intensity of emission current depends upon the emitter material and mass and energy of the bombarding particles.

1.3 Classification of material according to electrical conductivity.

According to electrical conductivity, materials can be classified into 3 categories
a) conductor b) semiconductor c) non conductor or insulator

~~a) conductor~~ • Energy Band Structure

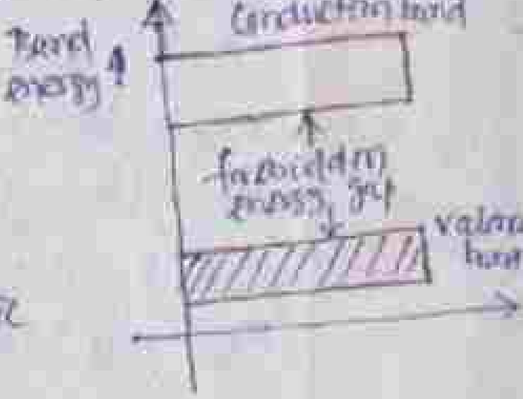
In an atom, proton and neutron are positioned inside the nucleus, where as electrons revolve around the nucleus in different orbits called energy levels.

In an isolated atom, the energy levels are converted into energy bands.
Important energy bands in an atom are
i) valence band ii) conduction band
There is an energy difference or gap between these two bands called forbidden energy gap.

valence electron: Electrons present in the outermost orbit of an atom are called valence electrons. No. of valence electrons can be maximum upto 8. If the no. of valence electrons are less than 4, then the material is a conductor, more than 4, it is non-conductor or insulator and equal to 4 is a semiconductor.

i) Valence band: The electrons in the outermost orbit of an atom are called ~~free~~ valence electrons. These electrons posses highest energy and the energy band that contains valence electrons, is called valence band. This band may be completely or partly filled.

ii) conduction band:



When the valence electrons will get some external energy they will be liberated from the surface (free from atomic bond) and will move to a next higher energy band.

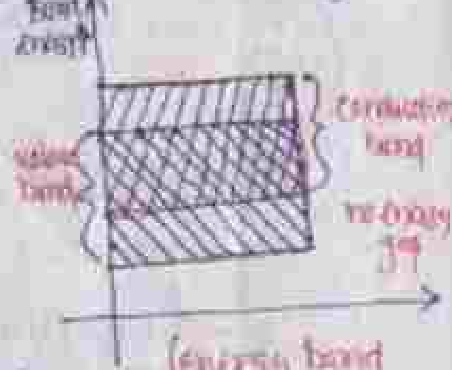
These electrons are called free electrons and are responsible for conduction of electrical current in the material. The band consisting these free (conduction) electrons is called conduction band.

iii) Forbidden energy gap:

The energy gap between valence band and conduction band is called forbidden energy gap. No electron can remain in forbidden energy gap.

a) Conductors: The materials (usually metals) which allows the passage of electric current through it without any obstruction or resistance are called ~~and~~ conductors.

Considering the energy band structure of conductors — they have filled valence bands and filled conduction bands. Actually these two bands are partly overlapping with each other and there is no forbidden energy gap. So large no. of free electrons are present in conduction band which allows large current to flow across it, with small applied potential difference.

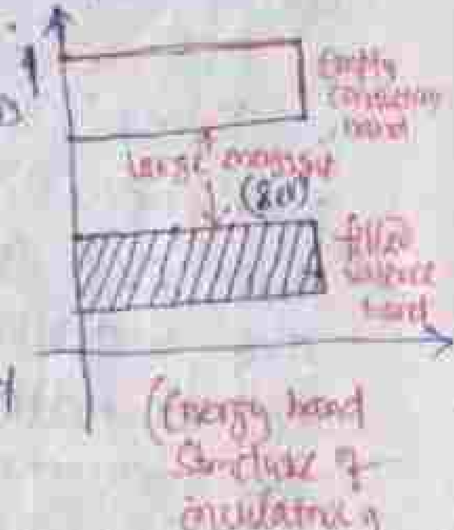


(Energy band structure of conductor)

Conductors have very high conductivity and very low (zero) resistivity. (Ex of conductors - Copper, Aluminium, Silver, etc)

b) <u>Insulators</u>:

Insulators (non conductors) are materials through which electric current cannot pass through. Insulators have very less (zero) conductivity and very high resistivity.



(Energy band structure of insulator)

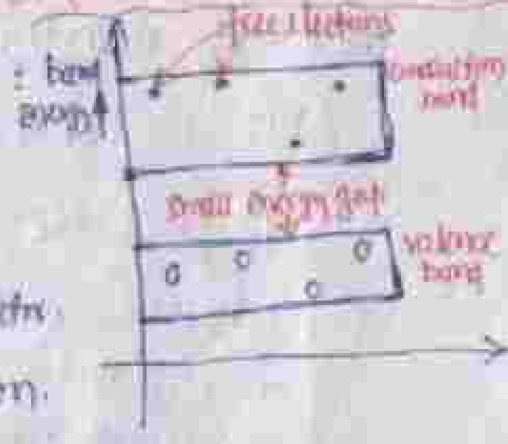
(Ex of insulators: wood, glass, mica etc)

In terms of energy band structure - insulators have completely filled valence band and completely empty conduction band with a very wide forbidden energy gap in between. As no free electrons are available in the conduction band, electric current can not flow through it.

c) <u>Semi conductors</u>. Semiconductors are materials (ex: carbon, germanium, silicon) whose electrical conductivity lies between those of conductor and insulators.

under ordinary condition, semiconductors have filled valence band and empty conduction band with a small forbidden energy gap (1eV). So applying a small electric field, valence electrons will jump to conduction band and the material will conduct electric current. Now increasing temperature, more no. of valence electrons will jump to conduction band, thus increasing the conductivity of the semiconductor.

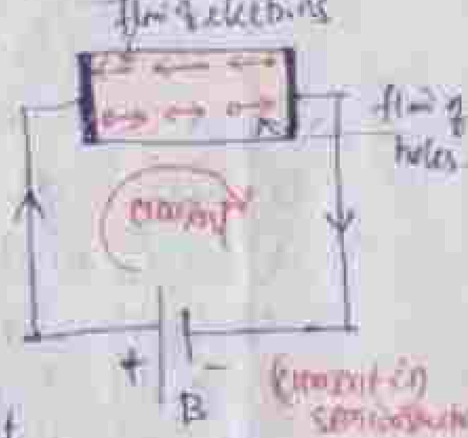
1.9: Intrinsic and extrinsic semiconductor



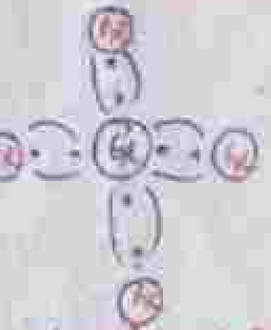
a): Intrinsic semiconductor:

A semiconductor in its extremely pure form is called intrinsic semiconductor.
Ex: pure germanium, silicon.

At absolute zero temperature, it has filled valence band and empty conduction band. But with slight increase in temperature (say upto room temperature), some valence electrons will move to conduction band and move there freely. The absence of electron (-ve charge) in valence band produces a hole (+ve charge) which also can move freely in valence band.



Now applying an external electric field, current flows through the semiconductor. This current consists of electron current (opposite in direction) and hole current (in direction).



(bond structure of pure semiconductor)

If we will consider bond structure of intrinsic semiconductor (Ge or Si) it has valency = 4, so 4 outer electrons makes covalent bond with 4 nearby germanium atoms as shown in fig.

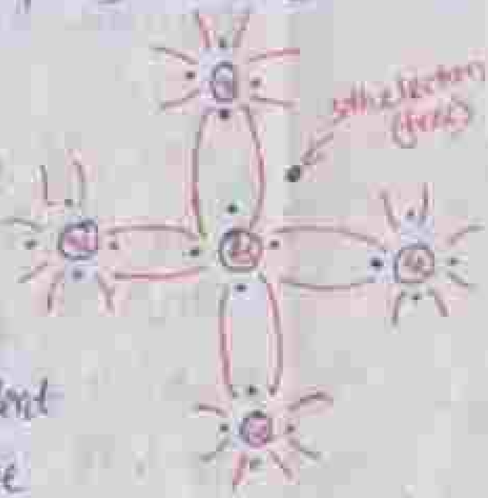
(b): Extrinsic Semiconductor

To increase the conduction ability, pure or intrinsic semiconductors are added with impurity or dopants, forming an impure or extrinsic semiconductors. The dopants are added (this process is called doping) in atomic level and the proportion is $1 : 10^8$ (impurity atom to base atoms). The dopant atom will have valency $4 \pm 1 = 5$ or 3. where 4 is the valency of Ge & Si. According there are two types of extrinsic semiconductors.

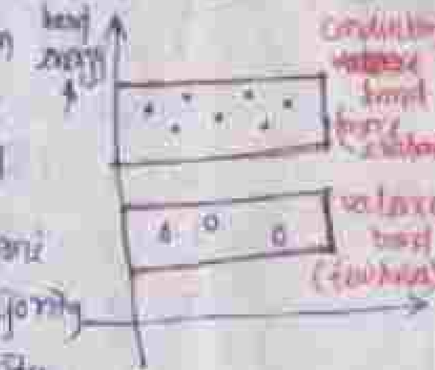
i) n-type extrinsic semiconductors: (1)

n- type (or negative type) extrinsic semiconductors are produced when pure Ge or Si is added with some pentavalent impurity atoms (ex- Arsenic, Antimony etc).

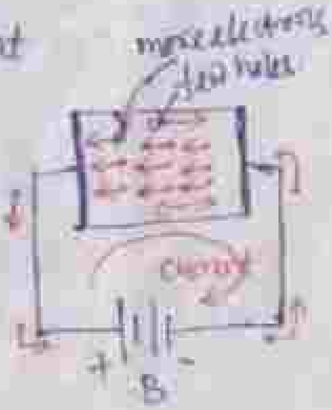
Considering the atomic structure, when pentavalent arsenic (As) is added, it has 5 valence electrons out of which 4 makes covalent bonds with 4 nearby Ge atoms and the 5th electron remains free and moves to the conduction band.



With the application of little heat or electricity no. of free electrons in conduction band becomes much more than the no. of holes in valence band.

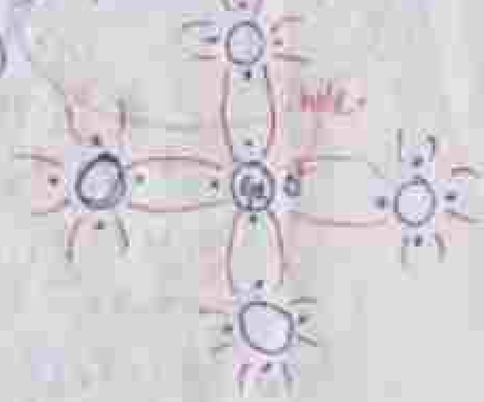


So in n-type extrinsic semiconductors, electrons are majority carriers and holes are minority carrier and total circuit current is mostly due to electrons. This can be practically verified by applying an external electric field as shown in the figure.

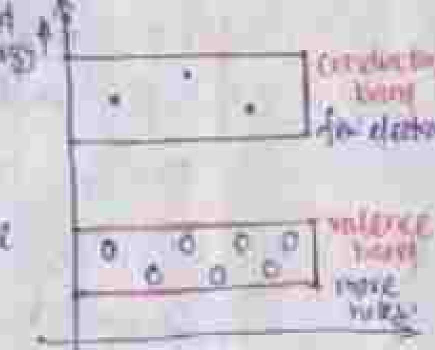


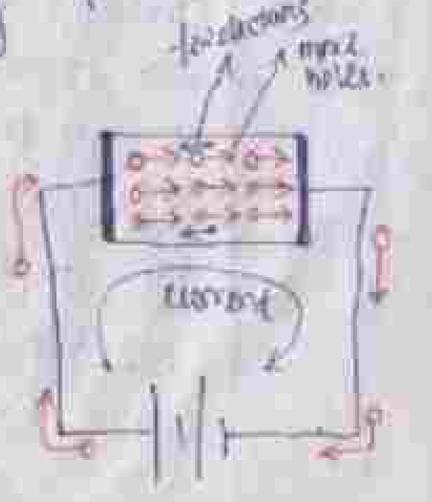
(ii) p-type extrinsic Semiconductor:

When trivalent impurities like Boron, Gallium, Indium are added to pure Ge or Si so the p-type (+ve type) extrinsic semiconductor is formed. As shown in the figure, when a Ga impurity atom is added to Ge, Ga has valency 3. So the 3 valence (outermost) electrons make covalent bonds with 3 neighbouring Ge atoms and one more electron of Ga atom is required to make bond with the 4th neighbouring Ge atom. This absence of electron is called a hole.



Considering the energy band diagram, there are a large number of holes in valence band and few electrons in conduction band. By applying an external electric field the circuit current consists of mostly holes (majority carriers) and few electrons (called minority carriers)





1.5 Difference between vaccum tube & semiconductor devices.

Both vaccum-tube devices and semiconductor (solid state) devices serves the same purpose. The initialy invented electronic devices were vaccum tubes (or gas-filled tubes) in the form of diode, triode, tetrode, pentode ... etc. Because of certain disadvantages like glass envelope structure, large volume etc, they are being replaced by solid state devices made of ~~of~~ semiconductor materials like Ge or Si.

- In solid state devices junctions formed which is not there in vaccum tubes. The solid state devices are named as P-N junction diodes. transistors, FETs, IGBTs, MOSFETs etc.

1.6 a) PN junction diode.

When a p-type semiconductor comes in close contact of an n-type semiconductor a p-n junction is formed. Actually the junction is fabricated by special techniques like growing, alloying and diffusion methods.

At the instance of junction formation, holes from p-side and electrons from n-side diffuse to the opposite side and combine with each other and depleted away (make a void) width of the junction increases till their energy is just sufficient to cross the junction, then the width of the junction remain fixed. The junction region on either side have no charge carriers and only ions (+ve ions on N side and -ve ions on P side). This region is called depletion region or space charge region.

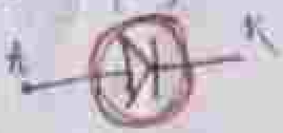
A potential difference exists between the two ends (across) the junction. This potential is called junction potential or barrier potential. Barrier potential of a junction depends upon factors like semiconductor material, amount of doping and temperature.

For Silicon, $V_0 = 0.7\,V$

for Germanium $V_0 = 0.3\,V$.

PN Junction as a diode

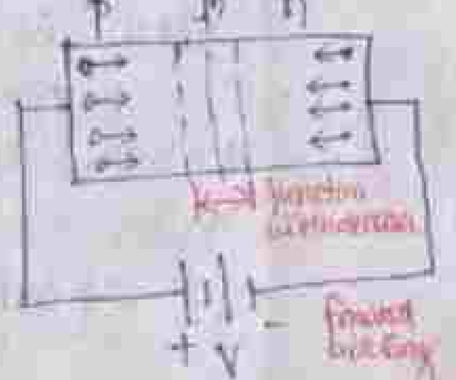
A P-N junction is also called a pn junction diode or simply diode. The terminal connected to p side is the anode(A) and terminal at n side is the cathode(K).

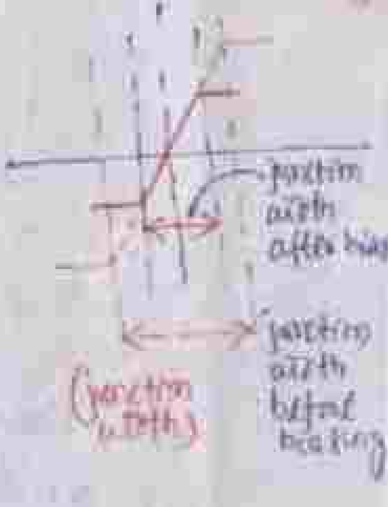


Symbol.

Working principle: A diode works only when it is properly biased. Biasing is applying an electric field (voltage) across the terminals. Biasing is of two types a) forward biasing and (b) reverse biasing.

a) Forward biasing:

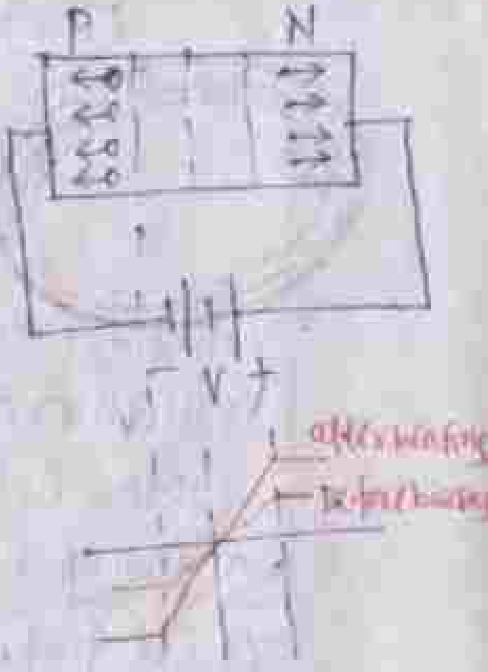




When +ve plate of the battery connected to p side and -ve plate to n side of a P-N junction, it is said to be forward biased. By forward biasing holes & electrons from p & N sides ~~[illegible]~~ moves towards the junction and so junction width decreases and in turn the barrier potential also reduces.

The junction offers very low resistance to the flow of current through it.

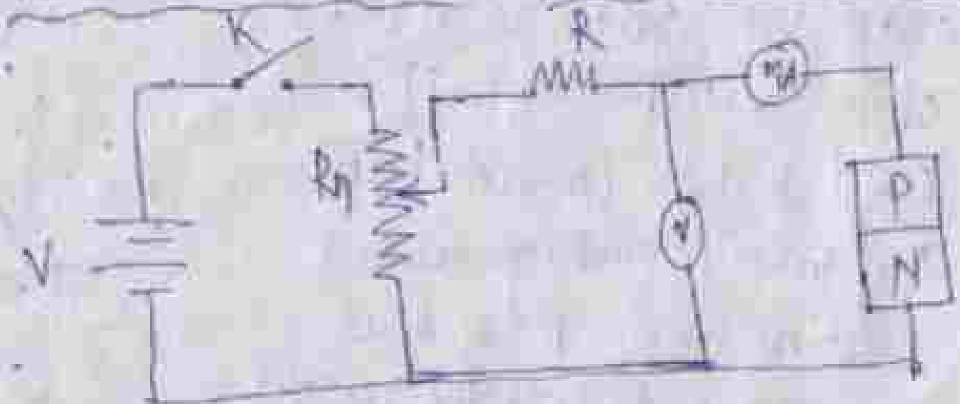
b) Reverse biasing:



When -ve plate of the battery is connected to p side and +ve plate to N side of a PN junction it is said to be reverse biased. Holes from P side and electrons from N side get attracted by the reverse bias and moves away from the junction, increasing the junction width as well as barrier potential.

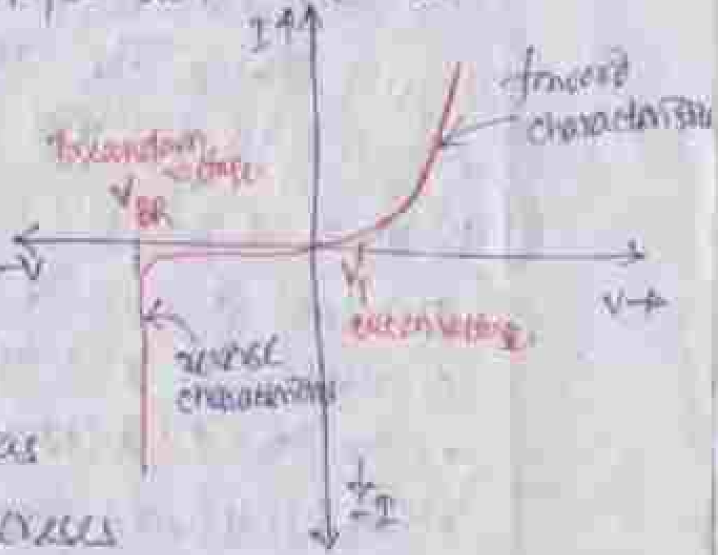
During reverse bias the junction offers a very high resistance to the current flowing through it.

VI Characteristics of PN junction diode



To draw the VI characteristic of a PN junction diode the circuit connection as shown in figure is made. The diode is biased by the external voltage V.

The voltage developed across the diode and current flowing through the diode can be changed by varying the rheostat.



a) Forward bias:

During forward bias the junction width decreases and it offers a low resistance. So forward current can flow through the diode. For '0' voltage, current is zero when forward voltage increased in small increments upto certain voltage, there will be no current this is due to the fact that the forward voltage has to overcome the junction potential barrier, then only current can flow. So, the amount of forward voltage at which forward current can flow through a PN diode is called cut in or threshold voltage (V_T). After threshold, increasing voltage, current increases.

b) Reverse bias: During reverse bias junction width increases and it offers a very high resistance to current flow. Increasing the reverse voltage, a point will be reached when the diode will breakdown (lost its property of P & N semiconductors). This voltage at which breakdown occurs is called breakdown voltage. After breakdown current flow heavily through the diode and voltage across it remains constant at (V_{BR}), breakdown voltage.

Uses of Diodes.

Diodes are used in almost all electronic circuits. Some of the applications are–

i) In power supply applications.

ii) In Rectifiers.

iii) In inverters and converters.

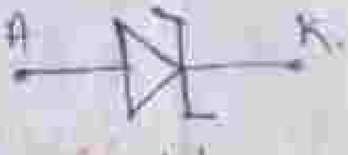
iv) For freewheeling operation.

v) For stabilization purposes.

b) Zener diode:

An ordinary diode when reverse biased and the bias voltage increases at certain value the diode will breakdown. After breakdown current increases sharply very heavily and voltage remains constant at breakdown value. The sharpness of the breakdown curve depends upon the doping concentration.

A properly doped crystal diode which has a sharp breakdown voltage is called a Zener diode



Symbol.

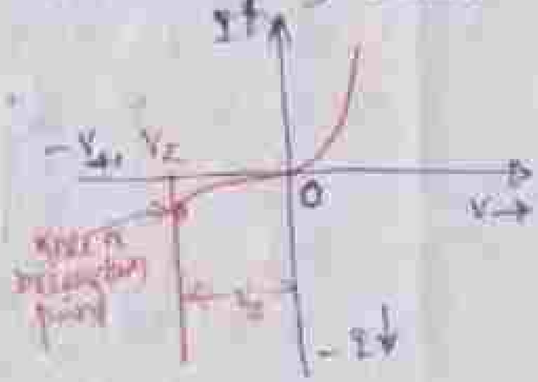
– A Zener diode is an ordinary P-N junction diode except the fact that it is properly doped to produce sharp breakdown voltage.

– It is always connected in reverse biased condition

- zener diode has a sharp breakdown voltage called zener voltage (V_z)

- If it is forward biased, it behaves like an ordinary diode.

VI characteristics:



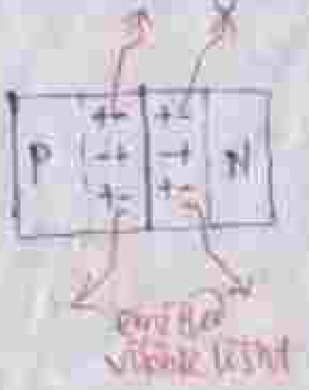
VI characteristics of a zener diode is similar to that of an ordinary PN junction diode. only fact is that the diode is operated in reverse biased condition and in break down region.

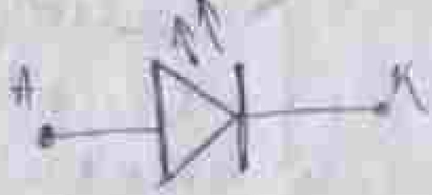
Uses of zener diode

1. on voltage stabilization circuits
2. As a voltage regulator.
3. As a -ve voltage source.

c) Light emitting diodes (LEDs)

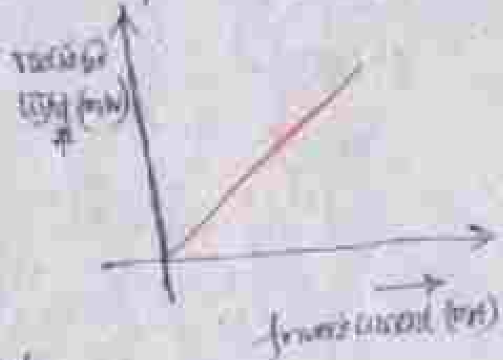
- Light emitting diodes are producing visible light of different colours (wavelength) basing upon the principle, that — when holes and electrons from p side and n side respectively recombine with each other they gives out some energy in the form of heat and light. In ordinary diodes this energy is lost in the form of heat, but in some special purpose diodes, using Gallium arsenide (GaAs) Gallium phosphide (GaP) etc as the PN type materials, during junction formation, visible intense coloured light can come out due to hole-electron recombination. These diodes are called light emitting diodes (LEDs).





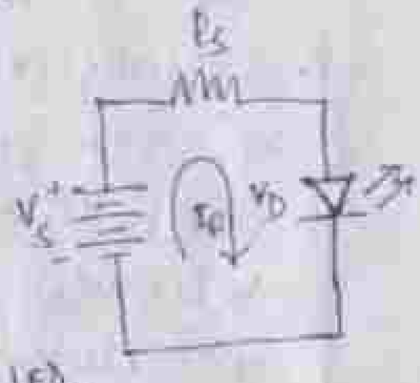
Symbol

Light is emitted from the junction, only when the diode is forward biased. When forward biased, forward current flows. Increasing forward bias, forward current increases and intensity of emitted light also increases.



LED voltage & current:

In the fig. is shown an LED connected to a voltage source V_S through a resistance R_S. If V_D is the voltage across the LED, then voltage across R_S is $V_S - V_D$. Then the forward current flowing in the circuit



$$\boxed{I_F = \frac{V_S - V_D}{R_S}}$$

1.7. Integrated Circuits

In a big electronics circuit (of computer, TV etc) thousands of discrete components like resistors, diodes, capacitors, transistors etc are used and interconnected. If all of them are to be separately placed and connected, they will require a large space. To overcome this difficulties a large no. of components (resistors, capacitors, diodes, transistors) are fabricated inside a small chip of semiconductor material. This chip is called integrated circuit (IC) or IC chip.

An integrated circuit (IC chip) is one in which circuit components like transistors, diodes, resistors etc are fabricated in such a way that they automatically become the integral part of the same chip and their interconnections also established.

- An IC is very small in size, typical size of an IC is 0.2mm x 0.2mm x 0.001mm.
- no component can be taken out separately as it is fabricated well inside the chip.
- no component or any part their of can be projected out of the chip.

Advantages of ICs

1. Increased reliability due to lesser no. of components.

2. Extremely small size as all components and interconnections are fabricated inside the chip.
3. Less weight and occupies less space.
4. Low power requirements.
5. Greater ability to operate at extreme values of temperature.
6. Low cost because of simultaneous production of hundreds of alike circuits on a small semiconductor wafer.
7. The circuit layout is greatly simplified because integrated circuits are constrained to use minimum number of external connections

Disadvantages:

1. If any one component goes out of order, the whole IC is to be replaced.
2. Capacitors of value exceeding 30 pF can not be fabricated in IC form.
3. Inductors and transformers can not be fabricated in IC form.
4. It is not possible to produce high power ICs (greater than 10W)
5. There is lack of flexibility i.e., parameters of the various components once there can not be altered

— x —

Assignment Questions

Ch-1. Electronic Devices

Q.1 Define electronics ? [2]

Q.2 Mention some important applications of electronics ? [5]

Q.3 Explain electron emission ? [2]

Q.4 What are the different types of electronic emission ? Explain each type briefly ? [5+5]

Q.5 Explain how valence electrons describe the electrical behaviour of a material ? [5]

Q.6 Explain how materials can be classified depending upon their electrical conductivity characteristics ? [5]

Q.7 What is energy band structure of an atom ? Define valence band, conduction band and forbidden energy gap ? [2+5]

Q.8 Draw energy band diagrams of conductor, semiconductor and non conductor ? [5]

Q.9 Explain how semiconductor can be classified ? What are the different types? [5]

Q.10 Differentiate between intrinsic and extrinsic semiconductor ? [5]

Q.11 Explain how p type & n type extrinsic semiconductors are produced from pure (intrinsic) semiconductor ? [5]

Q.12. Differentiate between vacuum tube and semiconductor devices? [5]

Q.13. Explain how P-N junction acts as a diode? [5]

Q.14. What is biasing of a P-N junction? How a P-N junction behaves during forward bias and reverse bias? [2+5]

Q.15. Draw the circuit diagram for obtaining the V-I characteristics of a P-N junction diode? and draw the VI characteristic? [5+5]

Q.16. Explain i) cut in voltage/knee voltage/threshold voltage and ii) Breakdown voltage of a diode from the V-I characteristics? [5]

Q.17 What are the different uses of diode? [5]

Q.18 What is a Zener diode? What are its uses? [5]

Q.19 What is an LED? [5].

Q.20 What is integrated circuit? [5]

Q.21 What are the advantages and disadvantages of an IC? [5].

Q.22 Define the terms a) surface barrier b) work function? [2]

Q.23 What general conditions must be satisfied before an electron can escape from the surface of a material? [5].

Multiple choice questions

1. The outermost orbit of an atom can have a maximum of ______ electrons.

   a) 2 b) 4 c) 8 d) 16

2. When the outermost orbit of an atom has less than 4 electrons, the material is generally a ______.

   a) conductor b) insulator
   c) semiconductor d) non of the above.

3. The valence electron have ------.

   a) very small energy b) least energy
   c) maximum energy d) non of the above

4. A large no of free electrons exist in ------

   a) semiconductors b) conductors.
   c) insulators d) none of the above.

5. When the outermost orbit of an atom have exactly 4 electrons, the material is generally ___

   a) metal b) non metal
   c) semiconductor d) ~~all the~~ none of the above

6. When the outermost orbit of an atom have more than 4 electrons, the material is generally a ______

   a) metal b) non metal
   c) semiconductor d) none of the above.

Q.7. workfunction of metals is generally measured in the unit of - - - - -

a) Joules b) erg c) watt d) electron volt

Q.8. The electrons emitted by a thermionic emitter are called - - - -

a) free electrons b) loose electrons
c) thermionic electrons d) bound electrons.

Q.9. Field emission is utilized in - - - - -

a) vaccum tubes b) TV picture tubes.
c) gas-filled tubes d) mercury pool devices

Q.10. Thermionic emitters are required to have - - - - workfunction.

a) low b) high c) medium d) very high.

Q.11 The electrons in the 3rd orbit of an atom have ——— energy than the electrons in the 2nd orbit.

a) more b) less c) same d) none of the above

Q.12 when an electron jumps from higher orbit to a lower orbit, it - - - -energy.

a) absorbs b) emits c) some time absorbs some time emits d) none of the above

Q.13 A semiconductor has ——— band.

a) almost empty valence b) almost empty conduction
c) almost full conduction d) none of the above.

Ch-2 Electronic Circuits ①

2.1 Rectifiers and its uses

Rectifier is an electronic circuit (or device) which converts ac signal into dc signal. The ac electrical signal available for our domestic use is of 220-240V peak to peak sinusoidal voltage signal of frequency 50 Hz. It runs our fans, acs, motors etc. But most of the electronic devices like phones, TVs etc needs dc voltage. So rectifiers are used to convert ac signal into dc signal.

<u>uses</u> 1) Rectifiers are used in power supplies
ii) in the dc power supply unit of almost all electronic devices.

2.2 Types of rectifiers

Rectifiers can be of two types —
a) Half wave rectifier (HWR)
b) Full wave rectifier (FWR)

Full wave rectifier can again be divided into two types —
i) centre-tap full wave rectifier
ii) Bridge full wave rectifier.

a) Half wave rectifier

In the figure(a) is shown the basic circuit of a half wave rectifier. It consists of a single diode (D) and the load resistance R_L. The ac input voltage is applied with the help of a transformer. i.e. the unit is connected to the secondary of the transformer. fig 2(a) shows the input voltage waveform. fig 2 (b) and (c) respectively shows output voltage waveform and output current waveform. output voltage is the voltage across R_L and output current is the current flowing through R_L.

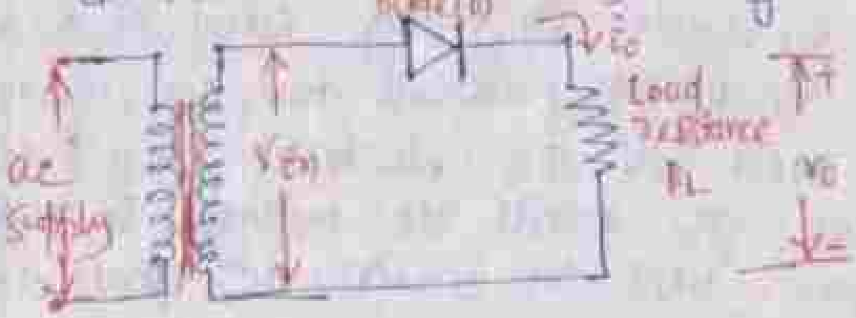


fig 2(a) Basic ckt of HWR.

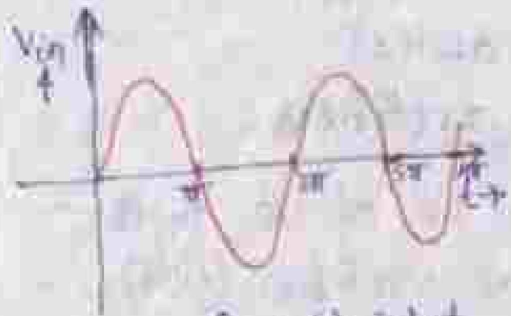


fig 2(a) input voltage

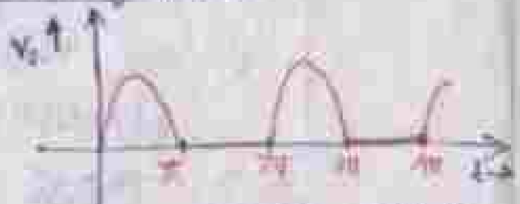


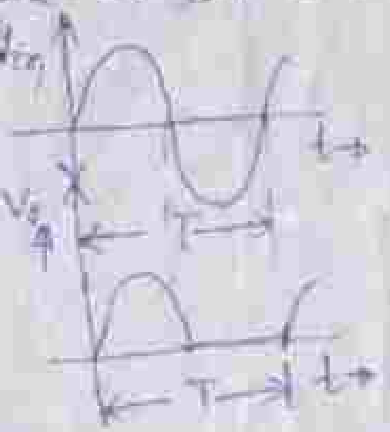
fig 2(b) output voltage.

fig 2(c) output current

Circuit operation:-

The ac input voltage is applied to the rectifier through a transformer. During +ve half cycle of the ac input, the diode is forward biased (The cutin or threshold voltage is assumed to be zero volt) and conducts during the entire +ve half cycle. Assuming forward resistance (R_f) of the diode to be negligibly small, the current in the circuit (load current) $i_0 = \frac{V_{in}}{R_L}$ and output voltage $V_0 = i_0 \cdot R_L = V_{in}$ during +ve half cycle of the input, the output equals to the input.

During -ve half cycle of the input, the diode is reverse biased. The reverse resistance of the diode (R_r) is very very large ($\simeq \infty$), so it acts as an open circuit and so load current $i_0 = 0$ and $V_0 = i_0 \cdot R_L = 0$ also. The output voltage and current waveforms are as shown in fig 2(b) & 2(c).



output frequency of HWR

output frequency of a HWR is same as input signal frequency (50 Hz) as shown in the figure. the duration of one complete cycle (time period) is same for both input as well as output signal. So their frequencies are also same.

Efficiency of HWR

Efficiency of the HWR is defined as the ratio of dc power output to ac power input.

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

dc output power (P_{dc})

dc power output $= (\text{dc output current})^2 \times R_L$

As i_0 is available between 0 to π only, the limits of integration are from 0 to π

or $P_{dc} = I_{dc}^2 \times R_L$

Now $I_{dc} = \frac{1}{2\pi} \int_0^{\pi} i_0 \cdot d\theta = \frac{1}{2\pi} \int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L} d\theta$

$\because V_0 = V_m \sin\theta$ and $i_0 = \frac{V_i}{r_f + R_L}$

where r_f = forward resistance of the diode

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

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

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

ac input power (P_{ac})

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

for a halfwave rectified wave $I_{rms} = \frac{I_m}{2}$

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

now efficiency $\eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(I_m/\pi\right)^2 \times R_L}{\left(\frac{I_m}{2}\right)^2 \times (r_f+R_L)}$

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

as $r_f <<< R_L$, $r_f/R_L <<< 1$

so $\boxed{\eta = 0.406 = 40.6\%}$

Advantages & Disadvantages of HWR

Advantages 1) The circuit is simple and contains few components.

2) The circuit is less costly.

Disadvantage 1. efficiency is less.

2. The output power is less.

3. The -ve half cycle of the input is not at all utilised.

b) Full wave Rectifier

It is the rectifier which utilises the full waveform of the ac input (both halves) to produce the dc output.

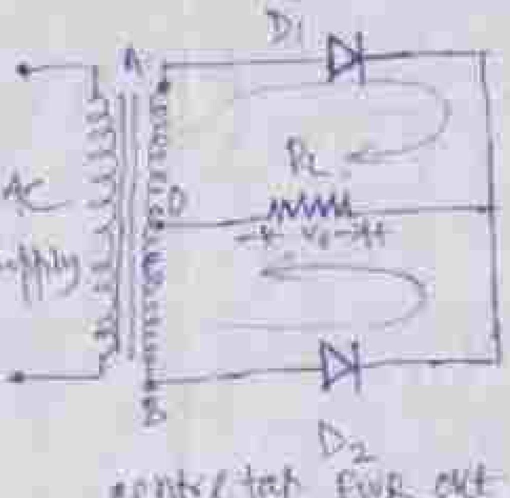
FWR can be of two types- (5)

(i) centre-tap full wave rectifier

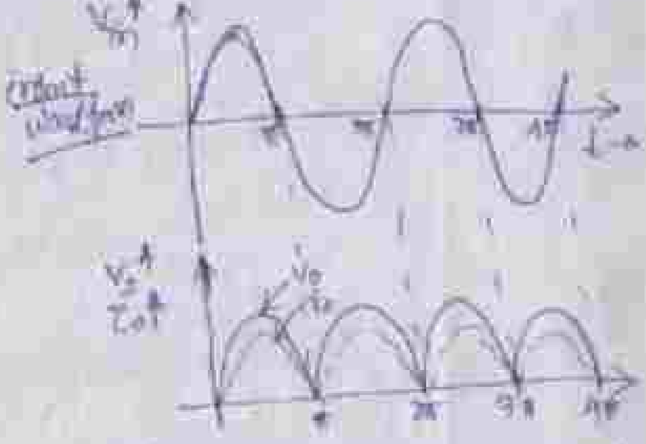
(ii) bridge full wave rectifier.

i) centre tap full wave rectifier:

Two diodes are connected to the secondary winding of a transformer and the load is connected between centre point (tap) of the transformer and junction of the two diodes cathodes. The circuit is as shown in figure.



centre tap FWR ckt



(output voltage and current waveforms)

operation: During +ve half cycle of the ac input, point A is at higher (+ve) potential and point B is at -ve potential. So current flows through diode D_1 only (as it is forward biased) and load R_L to produce V_o as shown in the figure.

During -ve half cycle point B is at +ve potential and A is -ve, so D_1 is off and D_2 conducts. current flows through D_2 and load R_L. ~~so the~~ current through R_L is in the same direction as it was before (not reversed)

So at the output we are getting dc voltage.

Peak inverse voltage: It is the maximum reverse voltage that a diode can withstand without damage.

During +ve half cycle of ac input, diode D_2 is not conducting (reverse biased) and a voltage of maximum value of $2V_m$ appears across it. Similarly in -ve half cycle, max. voltage across the reverse biased diode D_1 is also $2V_m$.

So $\boxed{PIV = 2V_m}$ in centre tap FWR.

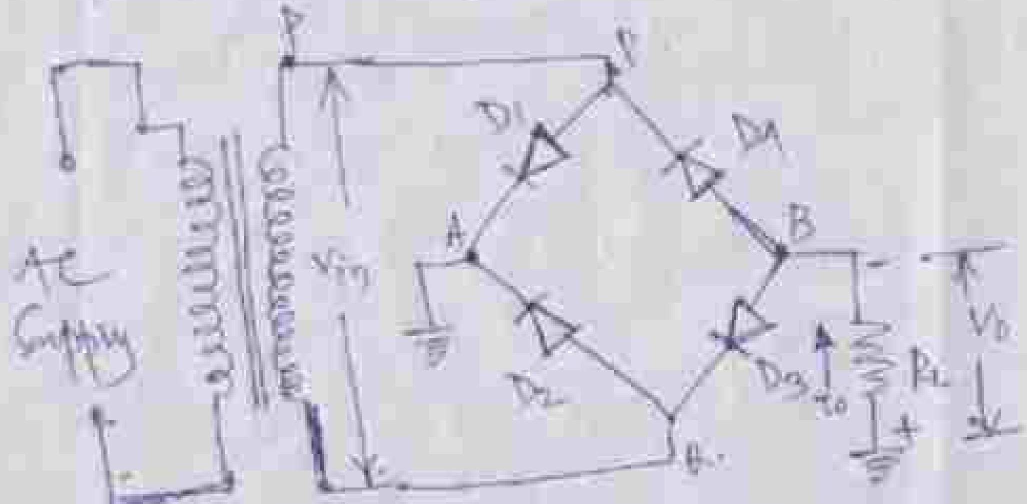
Disadvantages of FWR (centre tap)

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

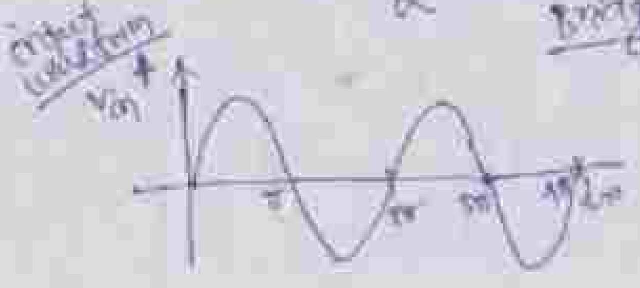
ii) The dc output is small as each diode utilizes only one half of the secondary winding voltage.

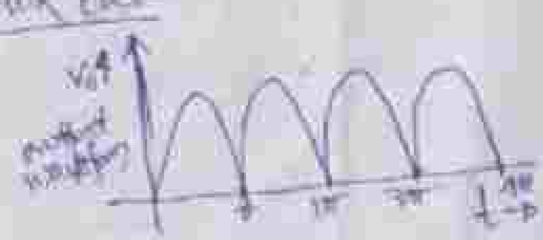
iii) The diodes used must have high PIV.

Fullwave Bridge Rectifier



Bridge FWR ckt





In the fig is shown a fullwave bridge ③
rectifier ckt. It uses 4 diodes in the 4 arms of the bridge. The load resistance is connected between two corner points A & B and ac input voltage is applied between the two other corner points P & Q.

Operation: During +ve half cycle of the ac input voltage (0 to π), point P is at higher potential (+ve) and point Q is at lower potential (−ve). So current flows through the sequence P – D_1 – A – load R_L – D_3 – Q. Diodes D_1 & D_3 are forward biased (ON) and D_2 D_4 are reverse biased (OFF). So during this period (0 to π), the output V_0 is equal to input V_i.

During −ve half cycle of the input signal (π to 2π) point Q is at higher potential and P is at lower potential. Diodes D_2 & D_4 are forward biased and D_1 & D_3 are reverse biased. So current flows from Q – D_2 – A – Load R_L – B – D_4 – P. So we get another +ve half cycle ~~in both the cas~~ at the output for the −ve half cycle of the input V_i.

In both the cases current flows in the same direction through load resistance R_L i.e. A to B. So the output current is unidirectional (dc) and output voltage V_0 (= $i_0 \times R_L$) is also dc. This is shown in the output waveform.

Peak inverse voltage: As it is the maximum reverse voltage developed across a diode when it is reverse biased –

1. During +ve half cycle of ac input (0 to π)

diodes D_2 & D_4 are reverse biased (D_1 & D_3 are ON or offers short ckt) — the maximum voltage developed across each diode is equal to V_m

ii) During -ve half cycle of a.c input (from π to 2π) D_1 & D_3 are reverse biased (D_2 & D_4 are short), the maximum reverse voltage across D_1 & D_3 is V_m

So in a FWR, PIV of the diodes, $\boxed{PIV = V_m}$

Advantages i) No need of a centre tapped transformer

2) output is twice of that of a centre tapped rectifier

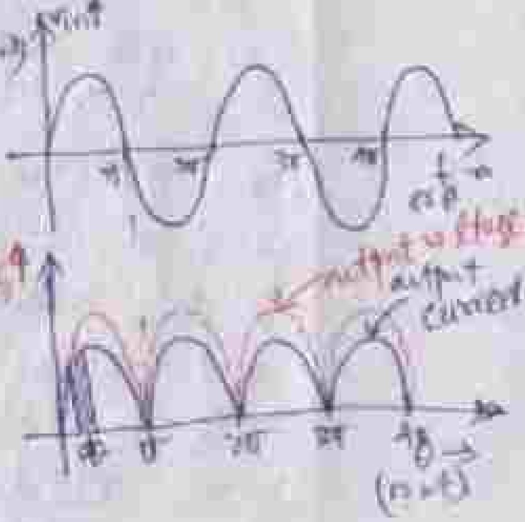
3) PIV is half of that of the centre tapped rectifier

Disadvantages i) It required four diodes.

ii) As two diodes conducts during each half cycle of the input signal, their internal resistances (though very small) comes in series which produces a measurable resistance, which is not desired, as it will affect the efficiency.

Efficiency of FWR

Consider the FWR circuit, its input voltage and output voltage and current waveforms are as shown



Let r_f and R_L be the forward resistance of diode and load resistance respectively instantaneous current in the ckt, $i = \frac{v}{r_f + R_L} = \frac{V_m \sin\theta}{r_f + R_L}$

$= I_m \sin\theta$, where $I_m = \frac{V_m}{r_f + R_L}$

dc output power

we know for a fullwave rectified wave $I_{dc} = \frac{2I_m}{\pi}$

$\therefore$ dc output power $= P_{dc} = I_{dc}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 \cdot R_L$

ac input power

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

for a fullwave rectified wave $I_{rms} = \frac{I_m}{\sqrt{2}}$

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

$\therefore$ fullwave rectification efficiency -

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(2I_m/\pi)^2 \cdot R_L}{(I_m/\sqrt{2})^2 (r_f + R_L)}$$

$$= \frac{8}{\pi^2} \cdot \frac{R_L}{r_f + R_L} = 0.812 \frac{R_L}{r_f + R_L} = \frac{0.812}{1 + \frac{r_f}{R_L}}$$

The efficiency will be maximum, if $r_f << R_L$ then r_f/R_L is very very less incomparison to 1 and $\boxed{\eta = 0.812 = 81.2\%}$

nature of rectifier output & ripple factor

The output of a rectifier is not pure dc but actually pulsating dc in nature so it contains dc component along with ac component. This ac component is also called as ripple.

The ratio of rms value of ac component to the dc component in the rectifier output is known as ripple factor

$$\text{ripple factor} = \frac{\text{rms value of ac component}}{\text{value of dc component}} = \frac{I_{ac}}{I_{dc}}$$

Mathematical analysis

As the output current of a rectifier contains ac component as well as dc component, its rms value is $I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$

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

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

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

dividing both sides by I_{dc} —

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

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

i) for half wave rectifier:-

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

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

ii) for fullwave rectifier:-

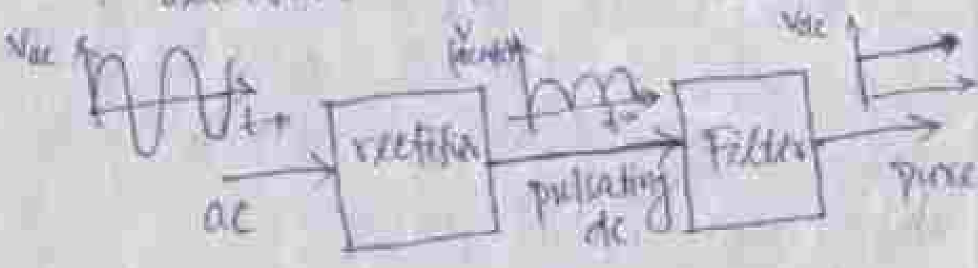
$$I_{rms} = I_m/\sqrt{2}, \quad I_{dc} = \frac{2I_m}{\pi}$$

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

It is seen that pulsating component is very less in FWR output than that in HWR output.

2.3 Filters : classification and function ①

Filter is an electronic circuit which filters out the pulsating ac components present in the rectifier output and produces pure dc output.



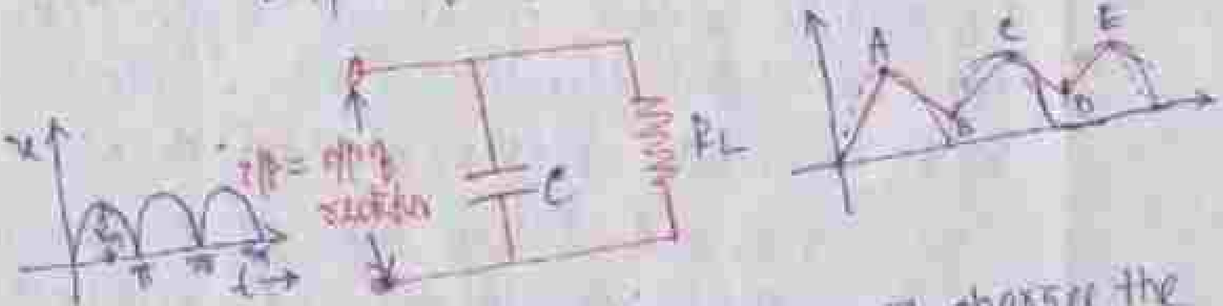
Basically there are 3 types of filters-

a) capacitor filter b) choke input filter

c) capacitor input or π (pie) filter

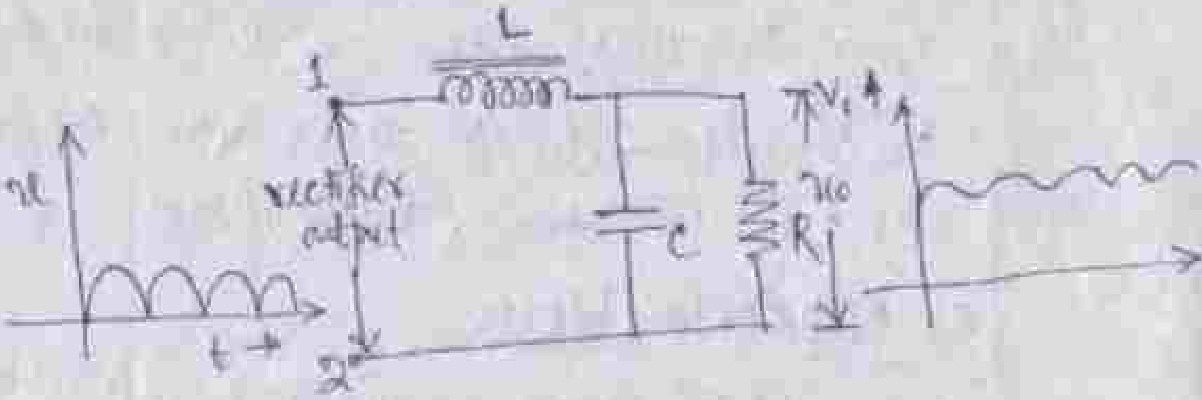
a) Capacitor filter

In the below figure is shown a capacitor filter which contains a single capacitor filter to which the load resistance R_L is connected in parallel and input is the pulsating dc output of a rectifier.



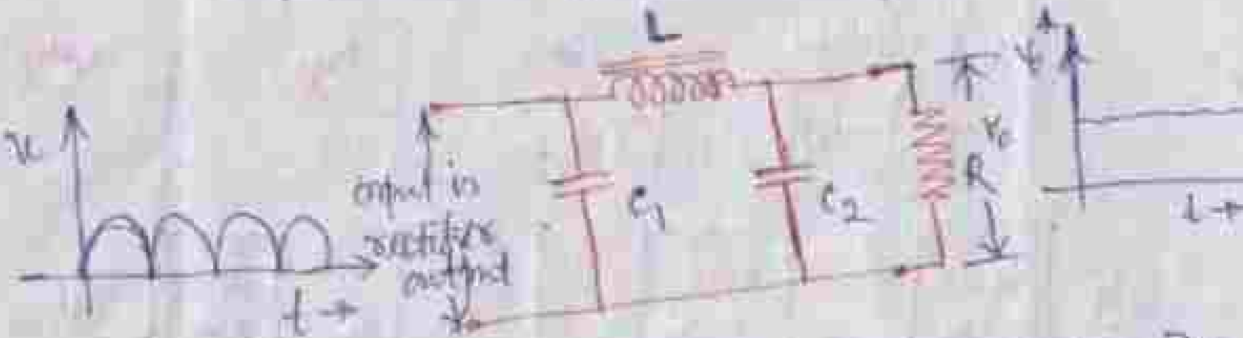
when rectifier output increases it charges the capacitor and at peak value of input the capacitor is fully charged to V_m (point A in the output). Then when input decreases from V_m to 0, the capacitor discharges through R to a value as represented by point B. Again in the next input cycle charging (B to C) and discharging (C to D) of capacitor takes place. This process continues and the output is ABCDEF, which is a waveform containing less ripples.

b) Choke input filter



In the fig. as shown a choke (inductor) input filter which contains an inductor in series with a capacitor filter C and a resistance R. The pulsating output of the rectifier output is applied to the filter end at input terminals 1 & 2. A choke offers very high resistance (opposes) to ac components and passes only dc components to further pass through R & C combination. So the final output is a dc contains very less pulsating components.

c) capacitor input (or Π) filter :



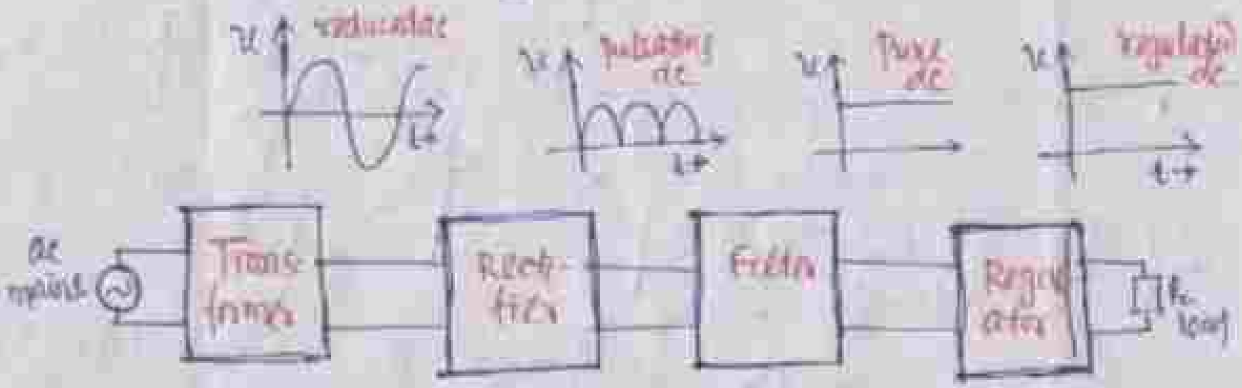
In the fig. is shown a π or capacitor input filter which contains two capacitors in parallel path and an inductor (choke) in series path. The operation can be explained as -

a) capacitor C1 : It offers low reactance to ac and high reactance to dc; as it in the parallel path, dc component goes forward to the next component that is inductor and by passes the ac component.

b) inductor L : It is in series path and offers high reactance to ac component and so opposes it and passes the dc component unopposed through it. So ~~ac~~ ac components are further filtered out.

c) capacitor C2 : It is in parallel path and offers high reactance to dc components (passes it) and low reactance to ac component (opposes). So the remaining amount of ac component is filtered out and almost pure dc goes to the load to produce output.

2.4 Working of DC power supply (Block diagram)



In the figure is shown the basic block diagram of a regulated dc power supply. If the regulator is there then it is called unregulated power supply.

The regulated dc power supply consists of following blocks —

a) Transformer: Usually a stepdown transformer is used which reduces the amplitude of the ac mains supply and provides it to the rectifier.

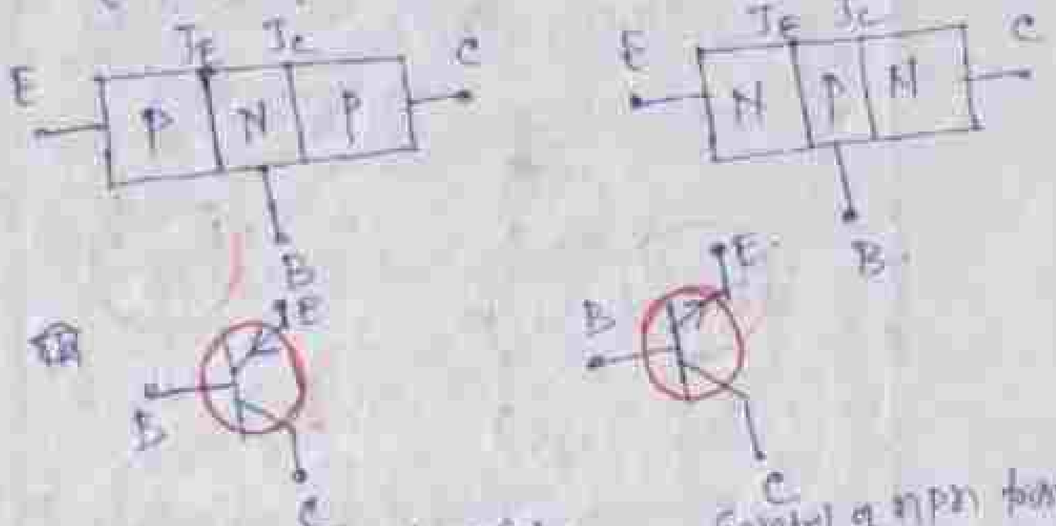
b) Rectifier: The rectifier converts ac input to pulsating dc at its output.

c) Filter: Filter ckt, filters out the pulsating (ac) components and provides pure dc at its output.

d) Regulator: Regulator is used in only regulated power supply, to regulate the output (load) voltage and current.

2.5 (a) Transistor and its types

Transistor is a 3 terminal 2-junction, alternate p-n semiconductor device. A p or n type semiconductor is sandwitched between a pair of opposite type. Accordingly there are two types of transistor PNP and NPN as shown below.



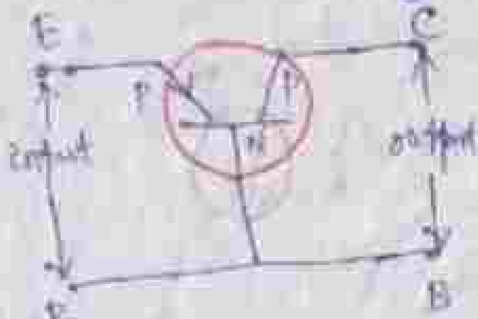
Symbol of PNP transistor Symbol of npn transistor

- The terminals connected to the extreme ends are one is emitter (E) & other is collector (C).
- The middle one is base (B).
- The emitter is wider than base and heavily doped, the base is the thinest piece and lightly doped and collector is moderately doped and the thickest (most wide).
- The junction between emitter & base is called emitter base junction or emitter junction or emitter diode.
- The junction between collector & base is called collector base junction, or collector junction or collector diode.

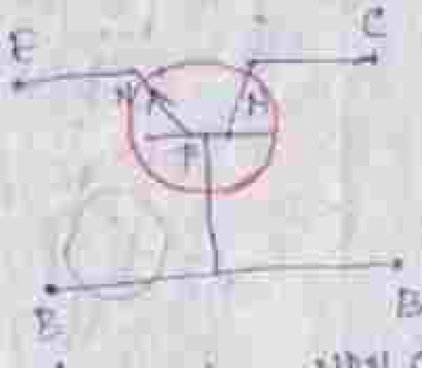
(b) Transistor configurations.

Transistor is a 3-terminal device but in its operation it is connected as a two port or four terminal device, by converting any one terminal into two, or in other words it can be said as one terminal (B, E or C) is made common to both input and output. Accordingly there are 3 configurations—

i) Common base configuration:

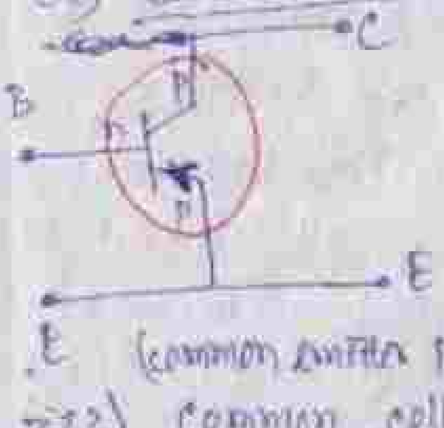


(common base PNP config)

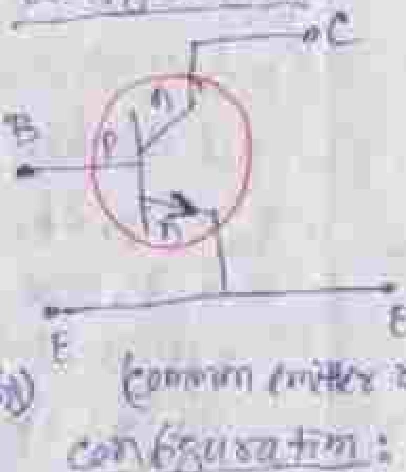


(common base NPN config)

ii) Common emitter configuration:

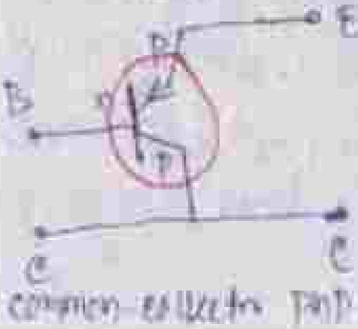


(common emitter PNP config)

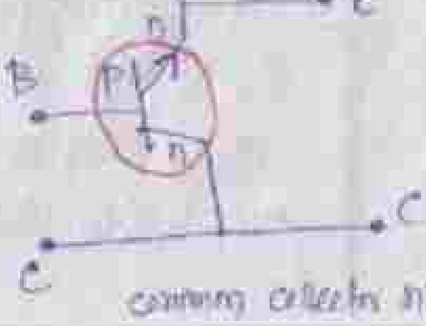


(common emitter npn config)

iii) Common collector configuration:



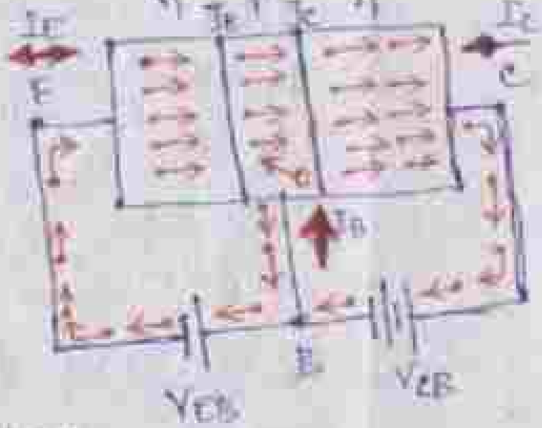
common collector PNP config.



common collector npn config

(c) Operation of a transistor (npn type)

In npn transistor, the current is mainly due to electrons

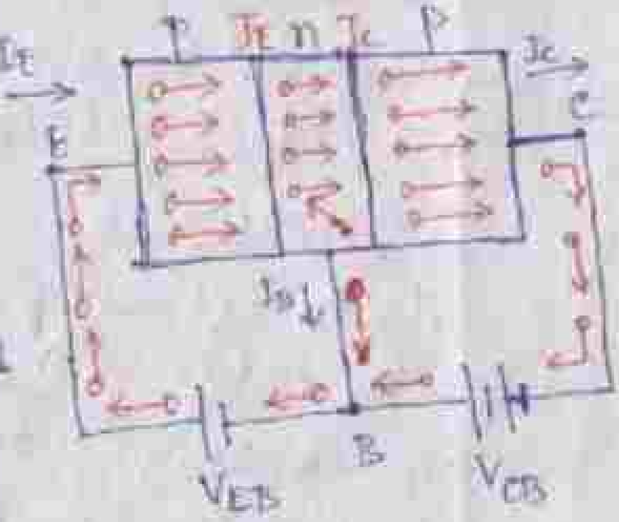


In the fig. is shown an npn transistor in common base configuration. Emitter junction is forward biased by V_{EB} and collector junction is reverse biased by V_{CB}.

Forward bias pushes electrons towards the junction, this constitute the emitter current I_E. As the base region (p-type) is thin and lightly doped, only few electrons (about 5%) coming from emitter side combines with the holes in base region and constitute the base current I_B. The remaining electrons passes to collector region (n-type) and produces collector current (I_C).

So the total emitter current $\boxed{I_E = I_B + I_C}$

Operation of pnp transistor



Emitter junction is forward biased and collector junction is reverse biased.

The forward bias pushes the holes in emitter region (p type) towards base which produces emitter current I_E. Few holes (about 5%)

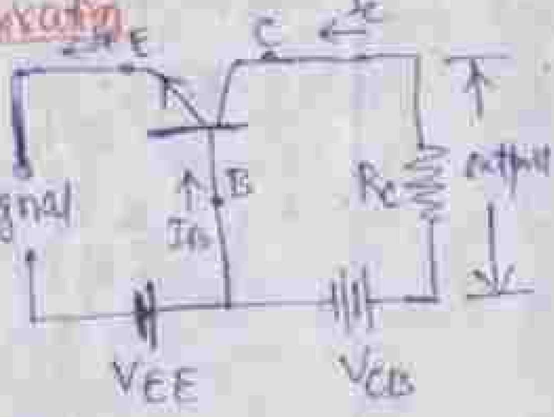
combine with the few electrons present in lightly doped and thin (n type) base region and produces base current (I_B). Remaining holes passes to collector region and constitute collector current (I_C). Here also the same equation holds good $\boxed{I_E = I_B + I_C}$

In a pnp transistor, the current is mostly due to flow of holes.

Expression of current gain

i) common base configuration

In the fig is shown an npn transistor in CB configuration. The signal to be amplified is applied between emitter and base terminals (input port) and output is taken across collector and base terminals (output port) through the resistance R_C.



current gain or current amplification factor is always the ratio of output current to input current (in case of dc operation). In CB config., input current is I_E and output current is I_C. The signal to be amplified is an ac signal. In this case the current gain or current amplification factor

(α) is defined as the ~~the~~ ratio of change in collector current to change in ~~bas~~ emitter current at constant collector to base voltage (V_{CB}). (6)

$$\boxed{\alpha = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{\text{at const } V_{CB}}}$$

It can be assumed that total collector current I_C consists of two parts — i) amplified emitter current ($= \alpha I_E$) and leakage current which can be represented as I_{CBO} (that is the collector to base current when emitter is open.

$$\therefore \ I_C = \alpha I_E + I_{CBO} \quad \text{— (1)}$$

we know $I_E = I_C + I_B$

putting in (1) $I_C = \alpha(I_C + I_B) + I_{CBO}$ — (2)

$$\text{or, } I_C - \alpha I_C = \alpha I_B + I_{CBO}$$

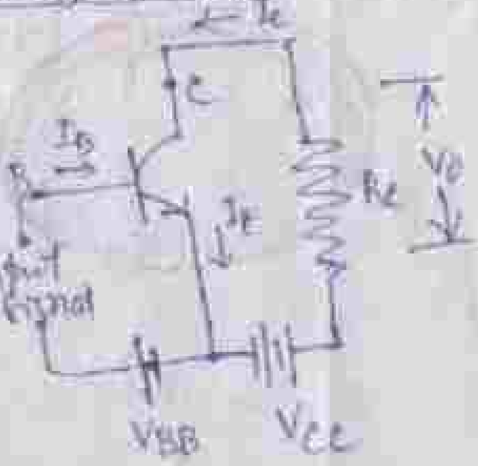
$$\text{or, } I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$\text{or, } \boxed{I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}}$$

from eqn (2), $I_C - I_{CBO} = \alpha(I_C + I_B)$

$$\text{or } \boxed{\alpha = \frac{I_C - I_{CBO}}{I_C + I_B}}$$

ii) common emitter configuration :



current amplification factor or current gain of CE configuration (β) is defined as the ratio of change in collector current to change in base current at constant V_{CE}.

$$\boxed{\beta = \frac{\Delta I_C}{\Delta I_B}\Big|_{\text{at constant } V_{CE}}}$$

relation ship between α & β:

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

for a transistor $I_E = I_B + I_C$

or, $\Delta I_E = \Delta I_B + \Delta I_C$

or, $\Delta I_B = \Delta I_E - \Delta I_C$

putting in the eqn for β, $\beta = \dfrac{\Delta I_C}{\Delta I_E - \Delta I_C}$

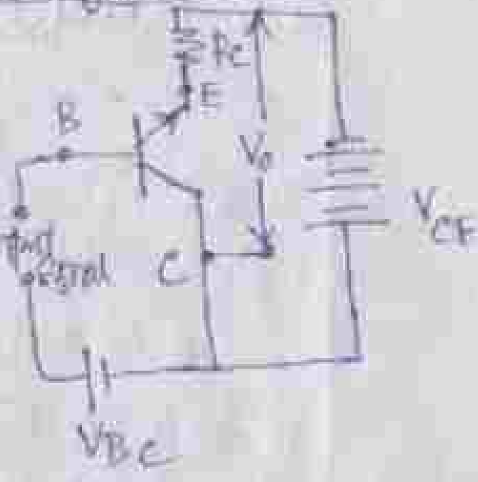
dividing N^r & D^r by ΔI_E, $\beta = \dfrac{\Delta I_C / \Delta I_E}{1 - \frac{\Delta I_C}{\Delta I_E}} = \dfrac{\alpha}{1-\alpha}$

$$\therefore \boxed{\beta = \frac{\alpha}{1-\alpha}}$$

Similarly $\beta(1-\alpha) = \alpha$ or, $\beta = \alpha + \alpha\beta = \alpha(1+\beta)$

$$\text{or} \quad \boxed{\alpha = \frac{\beta}{1+\beta}}$$

iii) Common collector configuration



current amplification factor or current gain of a transistor in common collector configuration (γ) is given as the ratio of change in emitter current to that in base current.

$$\boxed{\gamma = \frac{\Delta I_E}{\Delta I_B}\bigg|_{\text{const } V_{CE}}}$$

relationship with α

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

we know, $I_E = I_B + I_C$ or, $\Delta I_E = \Delta I_B + \Delta I_C$

or, $\Delta I_B = \Delta I_E - \Delta I_C$

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

dividing N^r & D^r by ΔI_C —

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

$\boxed{\gamma = \frac{[illegible]}{\alpha [illegible]}}$

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

now $\gamma(1-\alpha) = 1$

or, [illegible] α

or, [illegible] γ

or, $\alpha(\gamma - 1) = \gamma$ [illegible]

or, $\boxed{\alpha = \frac{[illegible]}{\gamma [illegible]}}$

So we have $\boxed{\alpha = \frac{\beta}{\beta+1} = \frac{\gamma - 1}{\gamma [illegible]}}$

2.6 Need of Biasing and different types of biasing

Transistors are used for two purposes –

1. for switching (as an ON-OFF switch)
2. for amplification (enhancing strength of a weak signal)

Faithful amplification is the process of raising the strength of a weak signal without any change in its general shape.

For faithful amplification, the transistor must fulfill the 3 basic conditions —

1. Flow of proper zero signal collector current
2. maintaining minimum proper base emitter voltage (V_{BE}) at any instant [V_{BE} = 0.3V Ge / 0.7V Si]
3. maintaining minimum proper collector-emitter voltage (V_{CE}) at any instant [V_{CE} = 0.5V (Ge) / 1V (Si)]

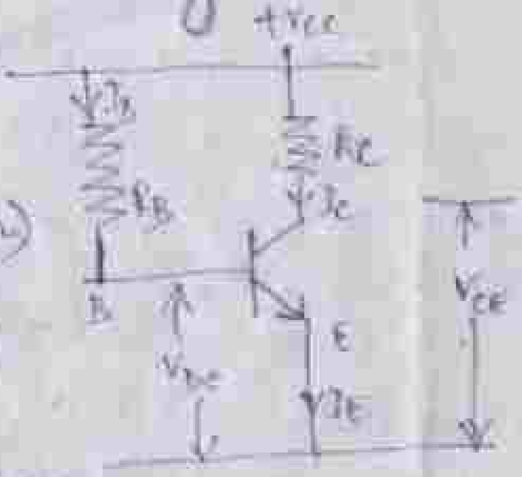
Above 3 conditions are fulfilled when the transistor is operated in the active region of operation (of its output characteristics) i.e., base-emitter junction is forward biased and base collector junction is reverse biased.

Transistor biasing: Transistor biasing is the method by which we can ensure flow of proper zero signal collector current and maintain proper base-emitter voltage and collector-emitter voltage at any instant.

Types of Biasing 1) Base resistor method 2) Emitter bias method 3) Biasing with collector feedback resistor 4) voltage divider bias

i) Base resistor method of biasing

In this method of biasing a very high resistance (several hundred kΩ) is connected between the base and +ve terminal of supply for npn transistor (base & -ve terminal of supply for pnp transistor).

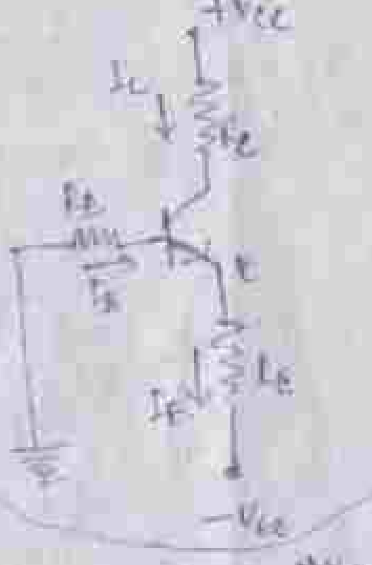


The required zero signal base current I_B flows through R_B by the supply V_{CC}. The value of I_B (and hence $I_C = \beta I_B$) can be varied by varying the values of R_B.

ii) Emitter bias method

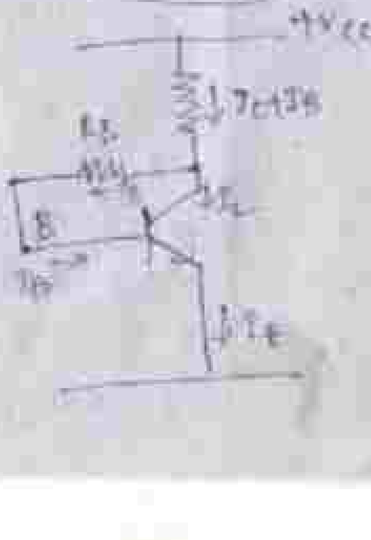
In emitter bias method two voltage supplies are used (usually both are equal & opposite) along with an emitter resistance R_E.

This bias provides better performance of amplification.



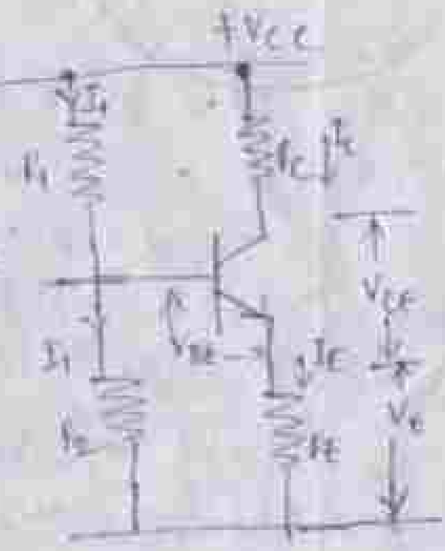
iii) Collector feedback bias

In this method the base resistor R_B is connected to collector to provide a feedback circuit that the zero signal base current I_B (and hence $I_C = \beta \cdot I_B$) is not



controlled by V_{CC} and controlled by V_{CE}.

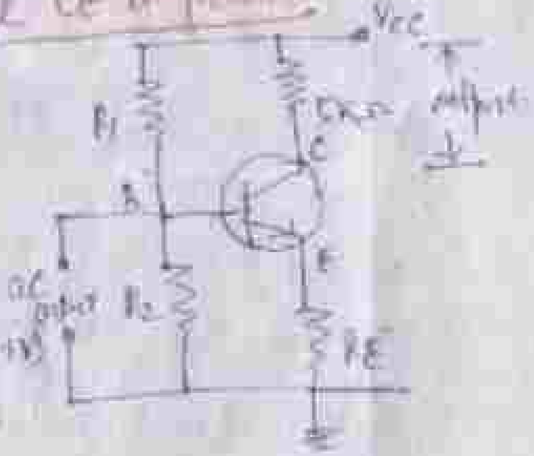
iv) Voltage divider bias:



This is the most widely used method of biasing which provides proper stabilization.

Two resistors R_1 & R_2 provides the potential (voltage) divider network. The voltage drop across R_2 $\left(= V_{CC}\cdot\frac{R_2}{R_1+R_2}\right)$ forward biases the base emitter junction and zero signal base current ($\because I_C = \beta \cdot I_B$) flows in the transistor.

2.7. Amplifiers (concept), working principle of single stage CE amplifier:



Basic concept:

To analyze the basic concept of amplification by a transistor, let consider the CE, npn transistor with potential divider bias as shown in fig.

The signal to be amplified is applied at the base terminal, and the output is taken from the collector (output) terminal.

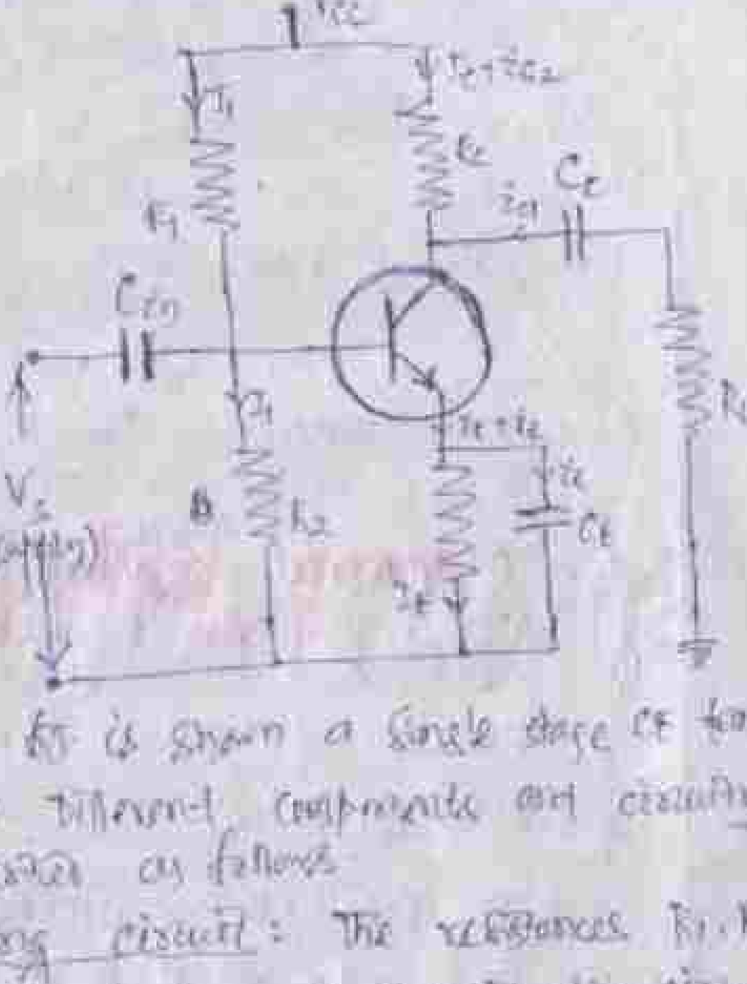
Let the input signal is given and can produce only a voltage change of about 0.1V. Let this small voltage change produces a small base current which is then amplified by the transistor (β times) and produces a larger collector current ($I_C = \beta I_B$). This current passing through the high collector resistance (usually 1 to 10 kΩ) produces a large output voltage.

For ex: let the 0.1 V change in base ckt, produces a current change of 2mA in collector ckt (I_C) and let $R_C = 5k\Omega$. Then output voltage V_o = 2mA × 5 kΩ
= 10 V.

input voltage was = 0.1 V.

∴ voltage amplification factor or voltage gain = $\frac{10}{0.1}$ = 100

Single stage Common Emitter Amplifier



In the fig is shown a single stage CE transistor amplifier. Different components and circuitry can be discussed as follows

i) Biasing circuit: The resistances R_1, R_2 & R_E from the biasing and stabilization circuit. By proper biasing the operating point is made proper and stable.

ii) Input capacitor C_{in}: Input capacitor C_{in}

couples the input ac signal to the base of transistor. It only allows ac signal to flow into the transistor & blocks any dc signal.

(iii) Emitter bypass capacitor C_E: Emitter bypass capacitor C_E allows the amplified ac signal to bypass the emitter resistance R_E.

(iv) Output coupling capacitor C_C: It couples the amplified output to next stage or to the load. Various current components in the circuit can be designated as follows —

a) Base current: Without applying ac signal, the base current (dc) due to biasing is I_B and after due to ac signal it is i_b. Therefore total base current $\boxed{i_B = I_B + i_b}$.

b) Collector current: dc part is I_C and ac part (applying signal) is i_c. So total collector current $\boxed{i_C = I_C + i_c}$

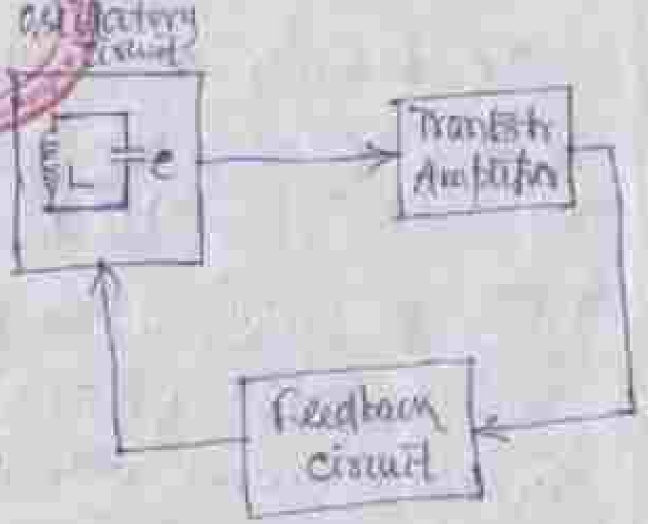
c) Emitter current: I_E is dc current and i_e is ac current and total current $\boxed{i_E = I_E + i_e}$

~~2.8. Electronic oscillators & its classification~~ through simple block diagram

2.9 Working of basic oscillator with any elements

An electronic device that generates sinusoidal oscillations of desired frequency is called sinusoidal oscillator.

An oscillator contains 3 basic components, one is the oscillatory circuit or tank circuit, 2nd unit is a transistor amplifier and 3rd unit is a feed back circuit. The interconnection as shown in the figure can produce sinusoidal oscillations



working principle of the oscillator

The tank circuit consists of a capacitor and an inductor in parallel with each other. The capacitor is initially charged. When the connection is made it starts discharging, so the inductor starts charging. The electrical energy stored in the capacitor converts to magnetic energy in the inductor. When the capacitor is fully discharged, the inductor becomes fully charged. Now inductor discharges and capacitor starts charging but this time in opposite direction.

This process of charging and discharging between L & C (conversion of energy from electrical to magnetic and vice-versa) continues. If there will be no losses in L or C, then this oscillation will continue indefinitely. ~~This~~ This oscillation signal is amplified by the transistor amplifier. To compensate any loss in L or C or in the process of energy conversion, a part of the output is truly feedback to the input (tank circuit) by the feedback circuit.

The frequency of oscillation is given as:-

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

Types of electronic (transistor) oscillators—

The transistor amplifier along with the oscillatory circuit and feedback network can produce continuous undamped oscillations of any desired frequency.

Different types of oscillators differs from each other in the way of feedback employed to compensate the losses in the oscillatory circuit. Different oscillators are-

1. Tuned collector oscillator 2. Hartley oscillator 3. Wien bridge oscillator 4. Phase shift oscillator. 5. Colpitt's oscillator 6. Crystal oscillator.

2.8 Electronic oscillation and its classification

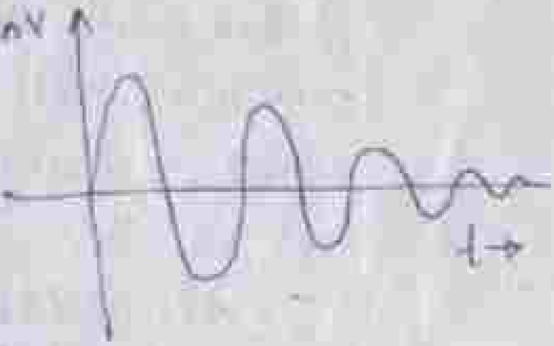
- An electronic device that generates sinusoidal oscillations of desired frequency is known as sinusoidal oscillator.

An oscillator actually does not generate frequency or energy, it on ly acts as an energy converter. It takes dc energy in and converts it into ac energy (signals) of desired frequency.

Types of sinusoidal oscillations

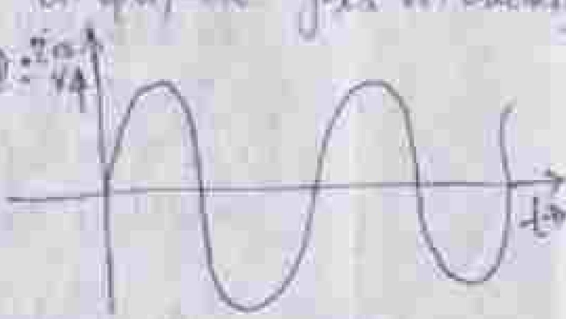
Sinusoidal oscillations are of two types—
a) Damped oscillation b) Undamped oscillations

Damped oscillation:



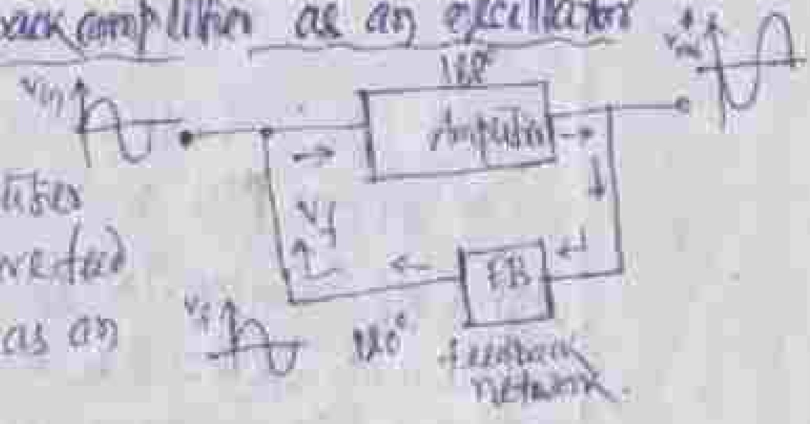
The oscillation in which the amplitude of the signal decreases from cycle to cycle, is called damped oscillation. It is due to the fact that in every cycle of operation, some amount of energy is lost. This loss goes on increasing cumulatively from cycle to cycle, so the amplitude goes on decreasing.

Undamped oscillation:



If the amount of energy lost during the cycle can be compensated by supplying it externally, then the amplitude of signal will remain constant in every cycle, this type of oscillation is called undamped oscillation.

A +ve feedback amplifier as an oscillator



A transistor amplifier with proper positive feedback can act as an oscillator.

A sinusoidal input signal is amplified by the amplifier which produces 180° phase shift. This signal is again passed through a feedback network that produces another 180° phase shift so the feedback signal is in phase with the input signal. Now the input signal is removed and the feedback signal is amplified. The above facts can be summerised as —

1. A transistor amplifier with proper positive feedback will work as an oscillator.
2. The circuit needs only a quick trigger to start the oscillation. Once oscillation started, no external signal source is needed.
3. In order to get continuous undamped output from the circuit, the following condition must be met — $\boxed{m_v \cdot A_v = 1}$

where A_v = voltage gain of amplifier without feedback
m_v = feedback fraction.

This relation is called Barkhausen criterion.

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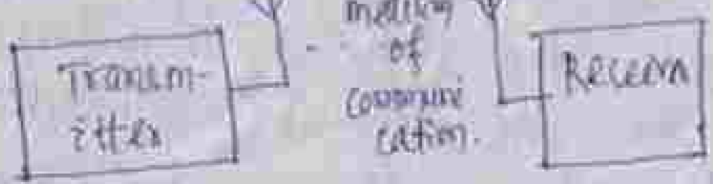
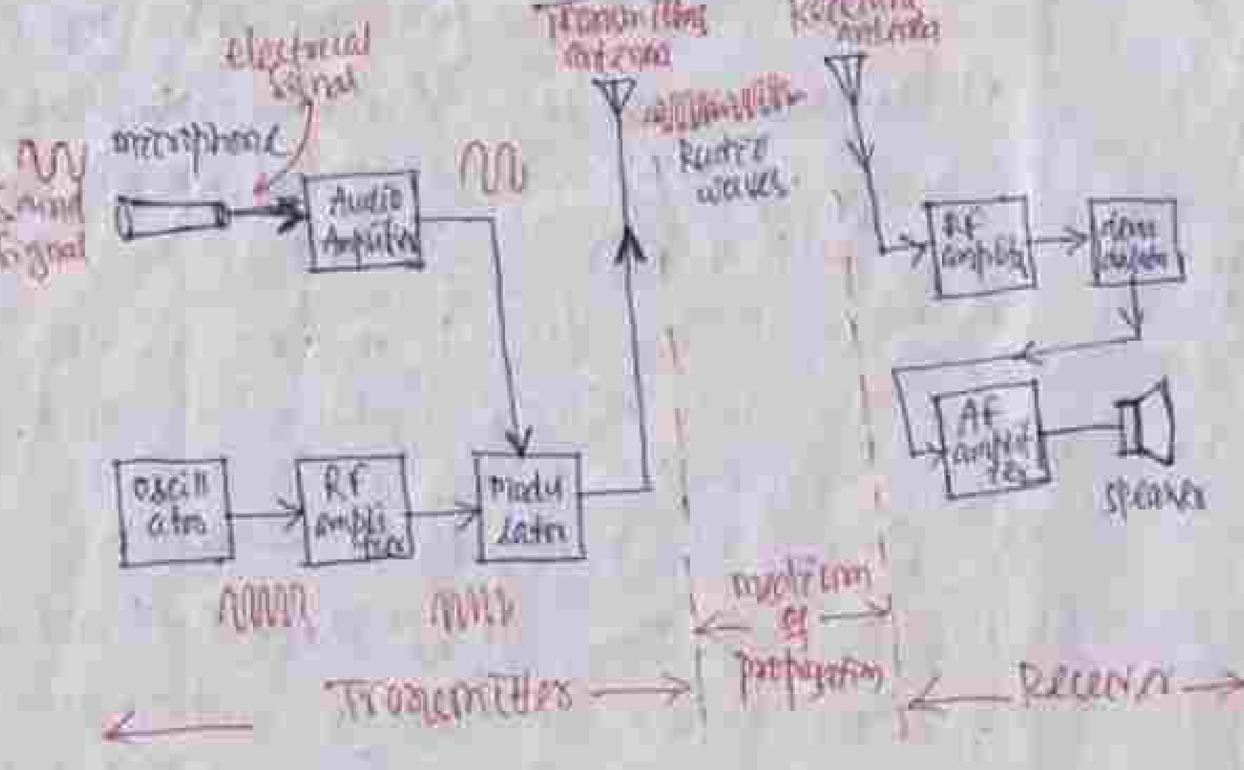
Ch: 3 Communication System

3.1 Basic communication System:

Communication is the process of connecting or transporting information from the transmitter (sender) to the receiver (may be at a distant place), through a medium. The entire system consists of 3 parts.



The above block diagram can be extended as-



1. Transmitter converts the audio signal into electrical signal, modulates it with high frequency RF carrier and transmits to air (space) which is the medium. Different components in transmitter are-

a) microphone: microphone converts sound signal to electrical signal. There is a very thin film called diaphragm which vibrates with the air pressure created on it and produces electrical signal in audio range (20 Hz to 20 KHz)

b) Audio amplifier: output of the microphone is fed to the audio amplifier which improves the strength (amplitude) of the audio signal

c) oscillator: It is a circuit which produces high frequency signal called carrier signal having frequency in radio frequency (RF) range.

d) Modulator: It is the circuit in which the audio signal is modulated (superimposed) with the help of RF carrier signal.

e) Transmitting antenna: Antenna radiates out the high frequency modulated waveform into space

2. Medium of propagation: The very high frequency radio signals (electromagnetic waves) radiated by the transmitter propagates (move) in all directions in space (air medium) with the velocity of light (3×10^8 m/

3. Receiver: It is the part of communication system in which the received RF signal is again converted to low frequency audio signal and converted to sound signal by a loudspeaker.

a) Receiving antenna: It is an antenna (called ariel) which receives the high frequency (RF) electromagnetic waves from space and provides it to RF amplifier.

b) RF amplifier: The received EM signals are amplified by RF amplifier, to increase its strength (amplitude)

c) Demodulator or detector: Demodulator does the reverse operation of a modulator i.e., the audio signal is separated from the RF signal.

d) Audio amplifier: Audio amplifier (sometimes multistages) amplifies the weak audio signal to increase its strength.

e) Loud speaker: It does the reverse operation of a microphone, i.e, converts the electrical signals into sound signals.

3.2: Concept of modulation & Demodulation

Modulation is the process of varying some characteristics (i.e, amplitude, frequency or phase) of a carrier wave with the help of modulating signal (information signal) modulation is done by a modulator at the transmitter end of the communication system.

If we want to transmit a sound (audio) signal or picture (video) signal, then it is the modulating signal. It will modulate the amplitude, frequency or phase of a carrier signal.

Demodulation is a process in which the modulating signal is recovered from the modulated signal (transmitted through the transmitting antenna) with the help of the same carrier signal. (used during modulation)

Demodulation is done by a demodulator or detector in the receiver end of a communication system.

<u>difference between modulation and demodulation</u>

Modulation	Demodulation
① It is the process of changing some characteristics like amplitude, phase or frequency of a carrier signal by the modulating signal	① It is the process of recovering the modulating signal from the modulated signal, with the help of the carrier signal.
② Depending upon the characteristic, which is modulated, the name of the modulation process is given like amplitude modulation, phase or frequency modulated.	② The modulating signal is recovered from the amplitude, frequency or phase modulated signal.
③ Modulation is superimposing (mixing) of modulating	③ Demodulation is decomposing the modulated signal into modulating and carrier signals.

signal and carrier signal to produce modulated signal. (2)

(4) Modulation is done in the transmitter part of the communication system.	(4) Demodulation is done in the receiver part of the communication system.
(5) modulating signal + carrier signal $\Rightarrow$ modulated signal.	(5) modulated signal $\Rightarrow$ modulating signal + carrier signal.

3.3 Different types of modulation

A carrier signal can be represented as -

$$x_c(t) = V_c \sin(\omega_c t + \phi_c)$$

where $x_c(t)$ is $\Rightarrow$ instantaneous value of the carrier signal at any time instant t

$V_c \Rightarrow$ peak or amplitude of the signal

$\omega_c \Rightarrow$ angular frequency of the signal

$\omega_c = 2\pi f_c$, where f_c is the linear frequency.

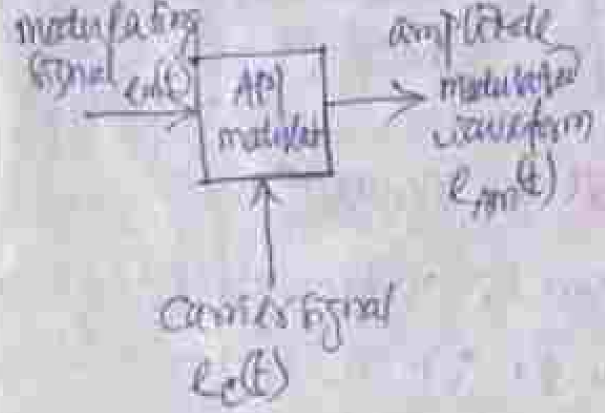
$\phi_c \Rightarrow$ phase of carrier signal.

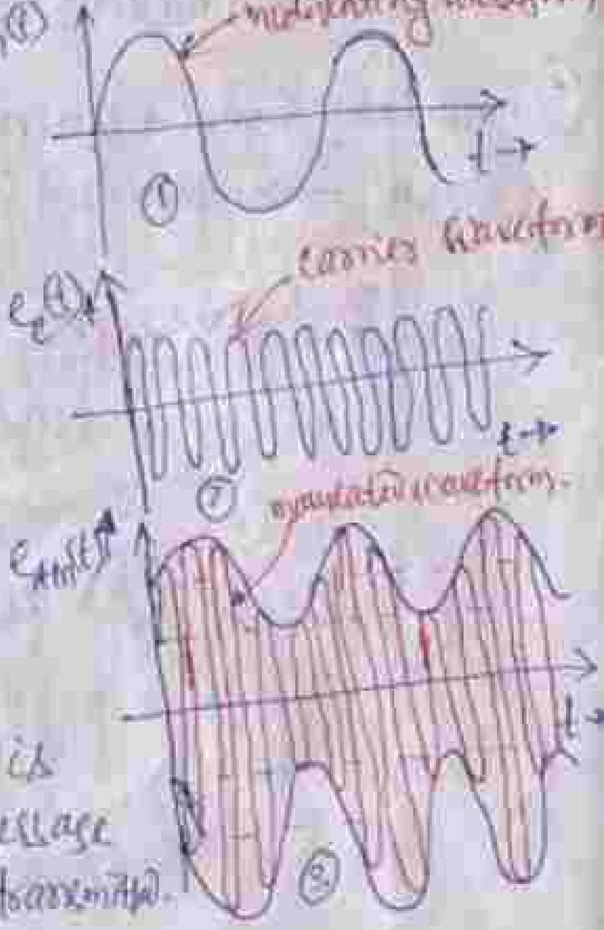
$$\omega_c = \frac{d}{dt}(\phi_c)$$

we can change (modulate) the amplitude or frequency or phase of the carrier signal and accordingly the modulation will be amplitude, frequency or phase modulation respectively.

3.3(a) amplitude modulation

The process by which amplitude of a carrier signal is varied in accordance with the modulating signal is called amplitude modulation.





- In the figs are shown 3-waveforms.
- The modulating signal is $e_m(t)$ which is the message signal required to be transmitted.
- A high frequency carrier $e_c(t)$ is utilized for such modulation i.e, amplitude of the carrier signal is varied according to the modulating signal, resulting the amplitude modulated waveform $e_{am}(t)$.
- Only amplitude of the carrier signal varies keeping frequency and phase constant (unchanged).
- In amplitude modulation, amplitude of the

and $e_{am}(t) = E_c \sin\omega_c t + \frac{m E_c}{2}\cos(\omega_c - \omega_m)t + \frac{m E_c}{2}\cos(\omega_c + \omega_m)t$ is the amplitude modulated waveform.

carrier signal varies according to the modulating signal in both halfes (+ve & -ve) so that the amplitude modulated waveform is an envelope (as shown in fig ③)

modulating index or modulating factor

Modulating index or modulating factor is defined as the ratio of change in amplitude of the carrier to the amplitude of the carrier

$$m = \frac{\text{change in amplitude of carrier signal}}{\text{amplitude of carrier signal.}}$$

or $\boxed{m = \frac{E_m}{E_c}}$ where $e_m(t) = E_m \sin\omega_m t$ is the modulating signal and $e_c(t) = E_c \sin\omega_c t$ is the carrier signal.

3.3 (b) Frequency modulation

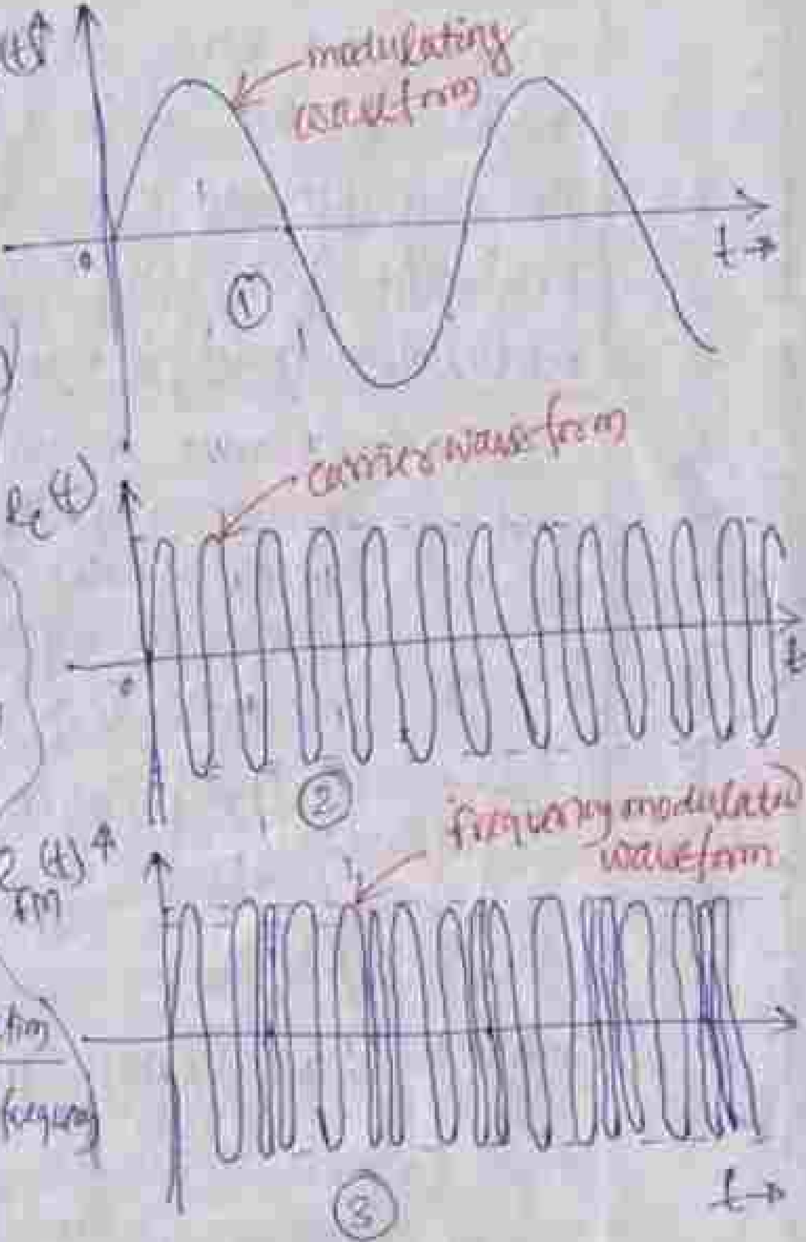
The process by which frequency of the carrier signal changes in accordance with the modulating signal (keeping its amplitude & phase unchanged) is called frequency modulation.

In frequency modulation, the frequency (f_c) of the carrier signal $e_c(t) = E_c \sin\omega_c t$ changes according to the modulating signal $e_m(t) = E_m \sin\omega_m t$ producing the frequency modulated waveform $e_{fm}(t)$ given by $e_{fm}(t) = E_c \sin\left(\omega_c t + \frac{\delta}{f_m}\sin\omega_m t\right)$

where δ = maximum frequency deviation and $\delta = K E_m f_c$

where $K \Rightarrow$ proportionality constant

frequency modulation index (m_f)



frequency modulation index is defined as the ratio of maximum frequency deviation to the frequency of the modulating signal.

$$m_f = \frac{\text{max. freq. deviation}}{\text{modulating signal frequency}}$$

or $\boxed{m_f = \frac{\delta}{f_m}}$

As seen from fig ③, the frequency of the frequency modulated waveform varies according to the modulating signal (i.e, where the amplitude of the modulating signal is more, frequency at that point is more in the modulated signal).

Advantages and Disadvantages of Frequency modulation

Advantages:

i) High transmission efficiency

ii) Noiseless reception.

iii) Better audio quality.

Disadvantages:

i) wider channel is required.

ii) Equipements used are complex and costly.

iii) smaller area of reception (only upto line of sight)

3.3(c) Phase Modulation

The process by which phase of the carrier signal is varied in accordance with the modulating signal (keeping its amplitude and frequency unchanged) is called phase modulation.

In phase modulation, the phase deviation is proportional to the amplitude of the modulating signal (Em) but is independent of its frequency (fm). In this case the phase of the modulated wave leads the reference position during +ve half cycle of the modulating signal and lags the reference position during the -ve half cycle of the modulating signal.

PM can be obtained from FM and vice-versa.

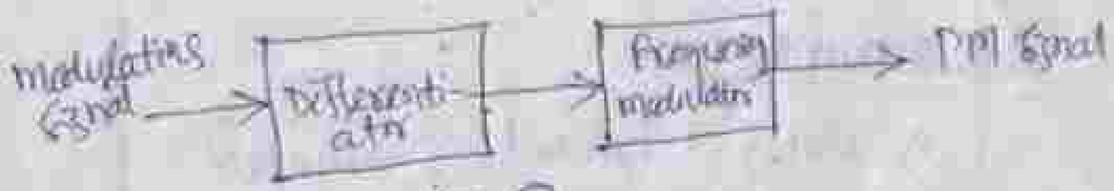


fig ⓐ

fig ⓑ

we know, $\omega = \frac{d\theta}{dt}$ where $\omega \rightarrow$ ang. freq.
$\theta \rightarrow$ phase.

- derivative of phase is frequency and integration of frequency is phase.
- therefore if a modulating signal is first differentiated and then applied to a frequency modulator, then phase modulated signal (PM) will be obtained [fig ⓐ].
- Similarly, if the modulating signal is first integrated and then applied to a phase modulator, then frequency modulated (FM) signal will be obtained [fig ⓑ]

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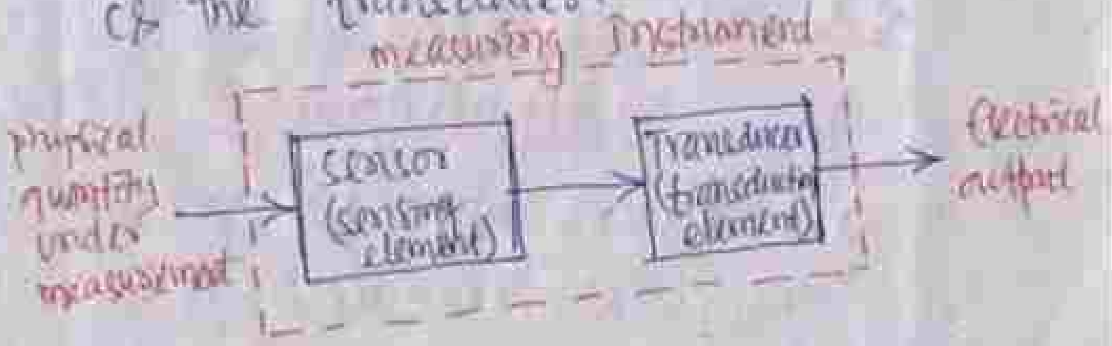
Ch-4 : Transducers and measuring instruments

4.1 Concept of transducer and sensor with their differences.

Transducer is a device which converts energy from one form to other. The energy may be of any from like electrical, mechanical, chemical, thermal, solar, tidal, muscular etc..

Sensor is a device, which can sense the presence of any form of energy or its effect which is in a sensible (measurable) form. sensors are also called detectors.

All measuring instrument (device) consists of two basic elements, the first one is the sensor or detector and second is the transducer.



Difference between sensor and transducer

Sensor	Transducer
1. Sensor is a device which detects the presence of the measurable quantity.	1. Transducer is a device which converts energy from one form to another
2. It is the primary or first element of a measuring instrument	2. It takes the output of the sensor and converts to suitable form for measurement
3. Sensor, for its performance may not depend upon a transducer.	3. A transducer always depends upon a sensor before measuring the quantity.
4.	4.

4.2 Different types of transducers and concept of active and passive transducer

Transducers may be classified as —

1. Electrical transducers: The transducer which produces electrical energy at its output is an electrical transducer. The output may be in the form of voltage, curr

or frequency etc.

2. <u>Displacement transducers</u>: These transducers convert mechanical displacement into electrical energy.

3. <u>opto electronic transducers</u>: These transducers converts optical (light) energy into electrical energy.

<u>concept of active & passive transducers.</u>

Electrical transducers are the important and most popular transducers which converts non electrical quantities like force, pressure, ~~etc~~ etc into electrical energy form. ~~and~~

<u>various classifications of electrical transducers</u>

(1) <u>Active and passive transducers</u>

<u>Active</u> transducers develops their own voltage or current as the output. for this they obtain energy from the physical quantity to be measured.

Ex: thermocouples, piezoelectric transducers, photovoltaic cell etc.

passive transducers don't develope output of their own and need an external power source for the purpose.

Ex: strain gauges, thermistors, LVDT etc.

ii) primary and secondary transducers.

primary transducers converts physical quantity under measurement directly into electrical output after sensing the quantity.

Ex: thermocouple.

secondary transducers, in which physical quantity is sensed and is converted first into an analogous output, which is further converted into an electrical quantity.

Ex: LVDT used with Bourdon tube to measure pressure.

(iii) Analog and Digital transducer

In Analog transducer the output is displayed in analog form.

Ex: strain gauge & LVDT.

In digital transducer the output is displayed in digital form.

Ex: digital multimeter, digital CRO

4.3 working principle of photoemissive photo conductive & photo voltaic transducers.

The photoelectric transducer absorbs the radiation of light which falls on their semiconductor material. The absorption of light energizes the electrons of the material and hence the electrons start

moving. The mobility of the electrons produ- (2)
ces one of the 3 effects -
1. The resistance of the material changes.
2. The output current of the semiconductor changes.
3. The output voltage of the semiconductor changes.

photoelectric transducers are of 3 types -

1. photoemissive transducer.

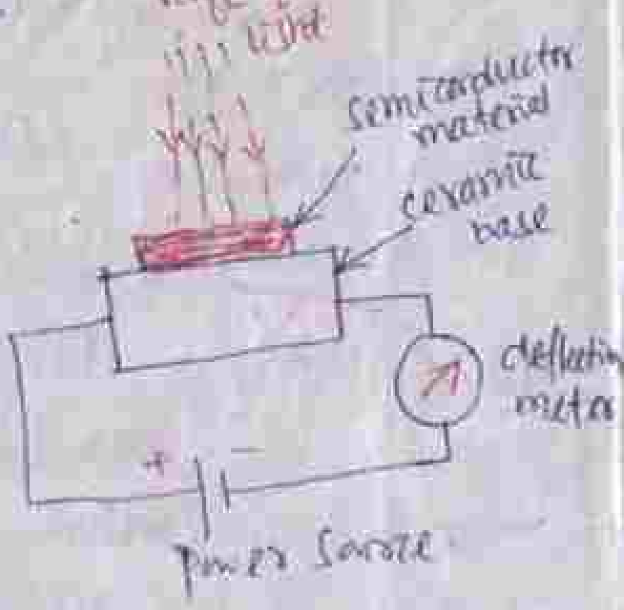
when light of appropriate intensity falls on the photo cathode (emitter) electrons are emitted. These electrons are collected by a highly +ve anode. cathode is made -ve.

no. of electrons liberated is proportional to the intensity of light and produces current in the external circuit which can be measured by a meter.

Thus the measured current is a direct measure of the intensity of light.

photo conductive (cell) transducers

In a photo conductive cell, the conductivity (or resistivity) property of the semiconductor material is utilised. The semiconductor material like cadmium selenide, Ge, Se are used as photo sensing element.

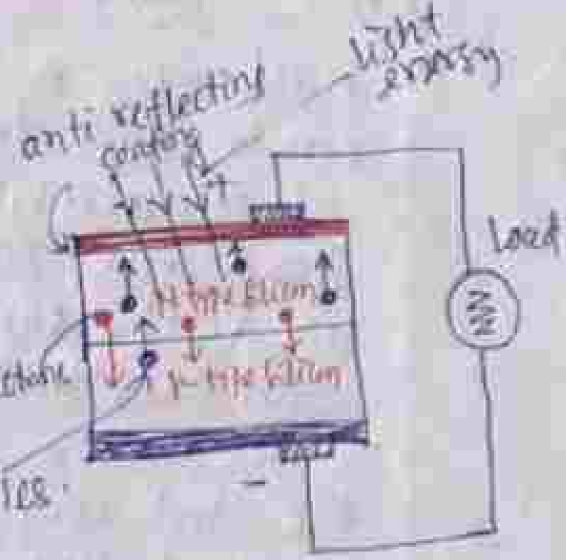


when light of appropriate intensity falls on the semiconductor material, their conductivity increases and the material works like a closed switch. current starts flowing through the material which turns to be a conductor (from insulator) and the deflection meter measures the current.

The current is directly proportional to the increase in (change) conductivity or decrease in resistivity which is directly proportional to the intensity of light

photovoltaic transducers

It is a type of active transducer in which a junction is made between a p-type and an n-type silicon material. Anti reflecting coatings are made over them and terminals are taken out. A suitable load is connected.



When light of appropriate wavelength (intensity) falls on the semiconductor material (both P & N types), they absorb light energy and converts it into heat energy. So holes from p-type & electrons from N-type cross over the junction and conductivity increases in the form of current in the external circuit with an appropriate load connected across the terminals. The entire arrangement can be utilized as a voltage source and so called a photovoltaic cell.

4.1. Multimeter and its application.

Multimeter is a measuring instrument which can be used for multipurpose measurements i.e., measurement of a number of electrical parameters like voltage, both ac & dc (in volt), current ac & dc (in ampere) and resistance (in ohm).

It is a small, handy and very versatile tool very of much use to all maintenance personnel.

It can measure in units like Ampere (current), Volt (voltage) and Ohm (resistance) therefore it is also called AVO meter.

It is available in analog or digital form. due to better accuracy and less error in reading and measurement now adays digital multimeters are frequently used.

A multimeter (both analog and digital) has two selector switches on its front (face) panel.

1. Function selector ~~switch~~ : This switch selects the function to be measured (like ac or dc voltage, ac or dc current and resistance).

2. Range selector : After a function is being selected by ~~a~~ the function selector, the maximum range is selected (by guess) by the range selector. If the measuring quantity is above the range, then it will show overload, so that next higher range is to be selected

Applications of multimeter

1. As it can measure a number of electrical parameters (both in ac & dc circuits), it is used in almost all measuring purposes.
2. In trouble shooting of electronic appliances it plays a vital role.
3. In calibrating units, multimeters are used for calibration.
4. In electrical network analyzers or in electronic circuit analyzers, multimeters are used.
5. In maintenance and repair workshops / workfloors multimeters are used.

4.5 Analog & Digital Multimeters

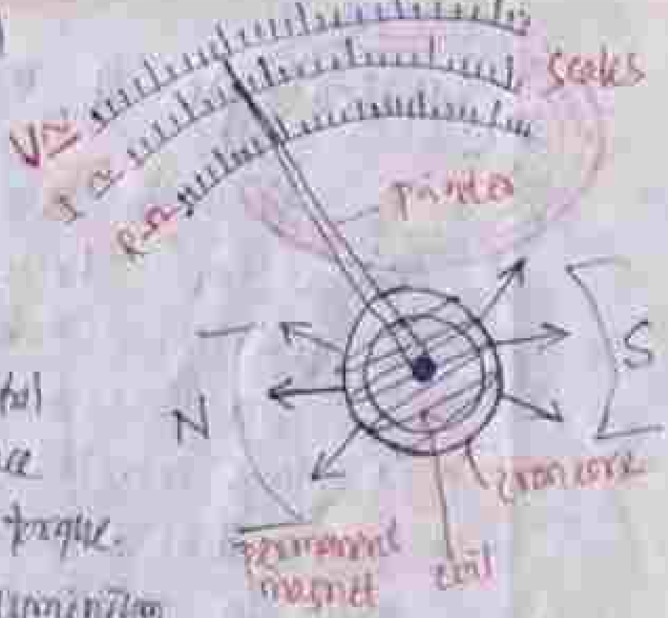
Multimeters are available in two forms
1. Analog multimeter 2. Digital multimeter.

The 3 basic parameters like current, voltage and resistance, which are measured by the multimeter, are actually measured by measuring the voltage only, which is then converted to current or resistance as the relationship in ohm's law $\boxed{V = I \cdot R}$.

Construction of AMM

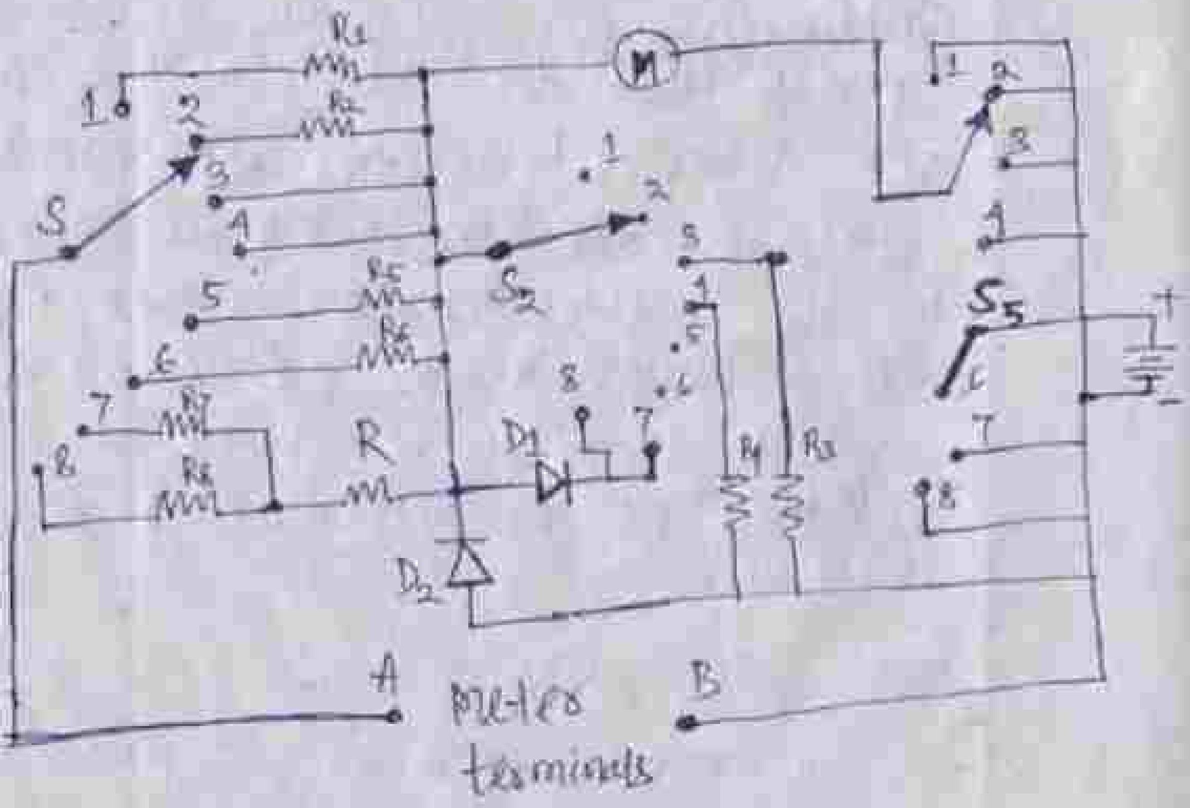
- A multimeter is basically a permanent magnet moving coil D'Arsonval meter.

— It has a coil wound on an aluminium frame which can freely move in the field of a magnet.



- There are two control springs which produce controlling/restoring torque.
- With the coil an aluminium pointer is attached which moves on calibrated scale.
- The coil is mounted on a fixed iron core, which makes the magnetic field of the permanent magnet as radial within the air gap, in which the coil is to move.

<u>Schematic diagram of AMM</u>



Measurement of dc current & dc voltage

- In the fig (a) is shown the arrangement for dc current measurement when the function selector is on current (DC)

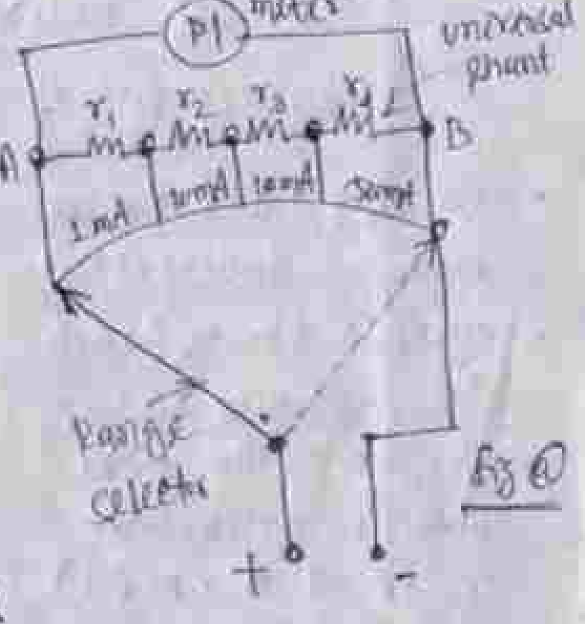


fig (a)

- Any range of dc current can be measured by the universal ~~ohms~~ shunt AB
- A no of low resistances are connected in parallel with the meter, through the selector switch.

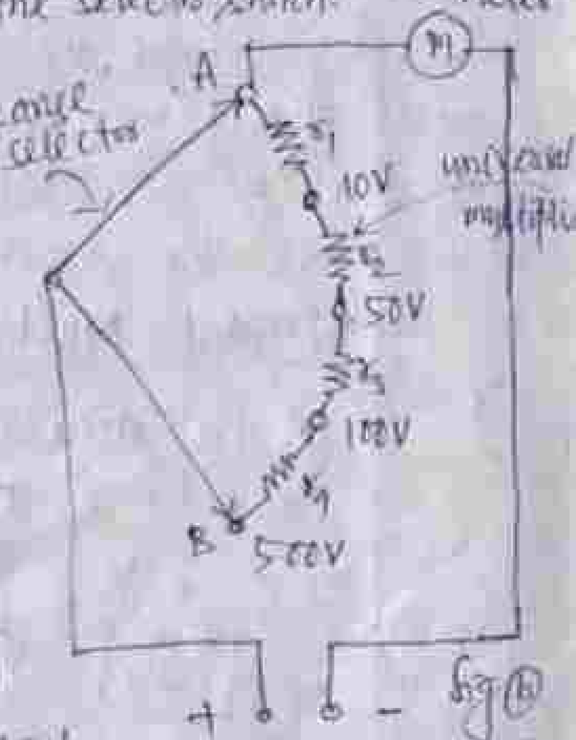
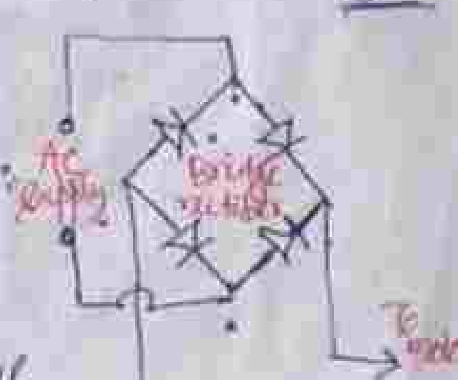


fig (b)

- In the fig (b) is shown the arrangement for dc voltage measurement when the function selector is on voltage (DC) and the range selector is set to a particular range
- A number of high resistance values are connected in series called the universal multiplier AB.

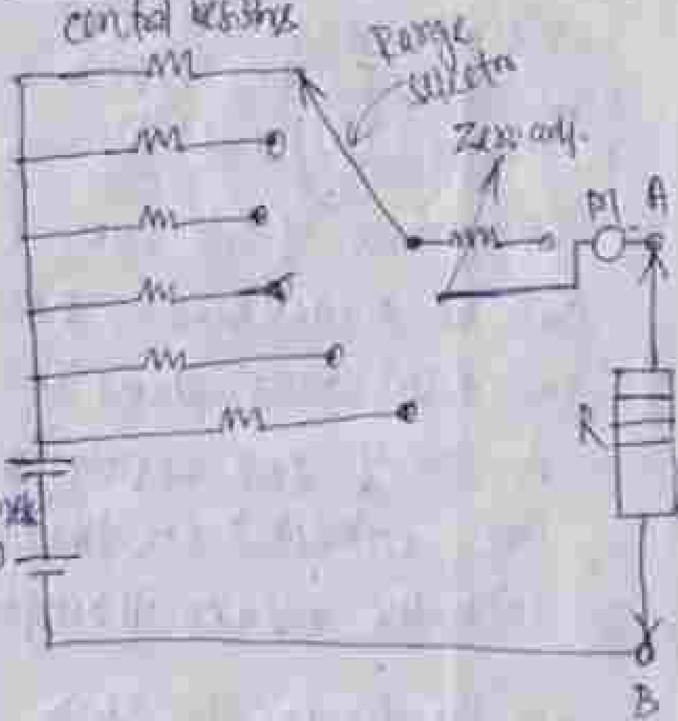
Measurement of ac current & voltage:

For measurement of ac current and voltage, a bridge rectifier is used to convert the ac value



into dc form and then it is measured by the dc meters

Measurement of resistance



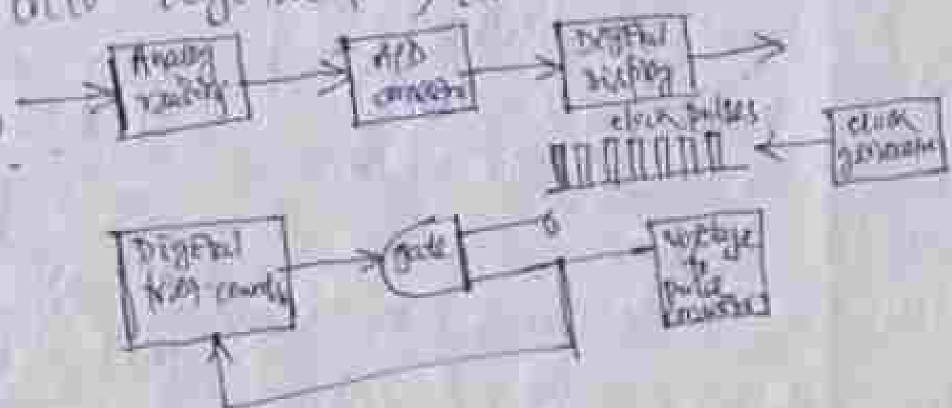
- For resistance measurement a battery is used.
- Current flowing through the resistance is measured by the meter which is calibrated in terms of ohm(Ω)
- When the resistor under measurement is out of circuit, the meter should read zero.

If it is not so, a zero adjustment resistor is used to make the meter zero, before measurement.

Digital Multimeter (DMM)

In a ~~digital~~ multi meter, the analog quantity is measured and then converted into digital form with the help of an ADC.

(ADC — Analog to digital converter)



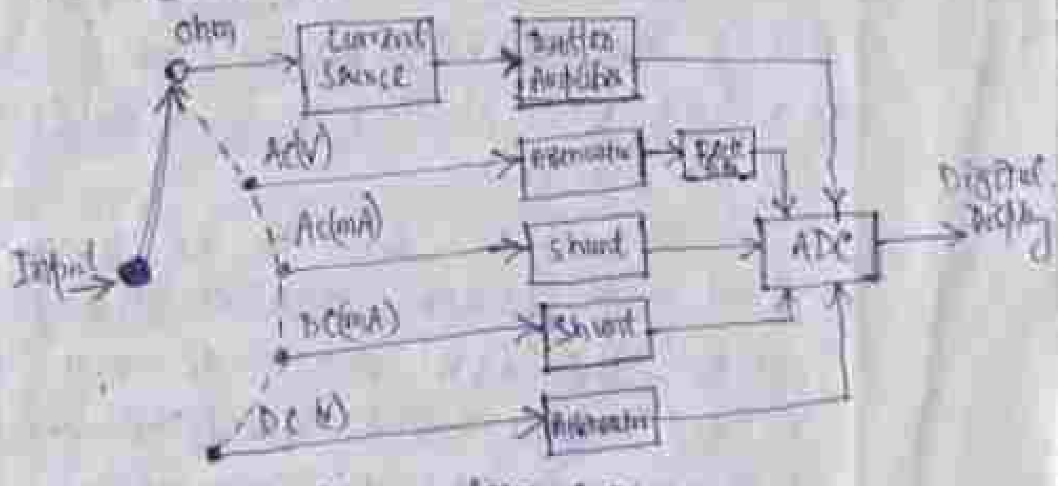
The digital multimeter contains three elements-

A digital meter contains 3 elements (4)

1. clock generator which produces fixed freq. clock pulses.
2. A circuit which converts the quantity to be measured into pulses (whose width is linearly proportional to the amplitude of the quantity).
3. A digital frequency counter.

Block diagram of Digital multimeter.

A digital multimeter is basically a digital voltmeter and may be used for measurement of dc/ac voltages, dc/ac currents & resistance. All quantities other than voltage is first converted into equivalent dc voltage. In the fig. is shown the blockdiagram.



Differences between APM & DPM.

A Meter	D. Meter
① These display quantity in terms of deflection of a pointer on a calibrated scale.	① These instruments display a quantity in decimal numbers format.
② It has comparatively poor accuracy.	② It has much better accuracy.

③ Resolution is comparatively poor.	③ Resolution is very high.
④ Analog instruments consume large power.	④ They consume negligible power.
⑤ They load the circuit while measurement is made.	⑤ They dont load the circuit.
⑥ Simple in construction.	⑥ Complex in construction.
⑦ Less affected by environment.	⑦ Greatly affected by environment.
⑧ Suffer from parallax and other human errors.	⑧ Free from human errors.

4.7 Cathode Ray Oscilloscope (CRO)

CRO is the most versatile electronic equipment used for measurement and many other functions like display of a signal (its waveshape) on its screen.

It can be said to be a very high speed X-Y plotter, in which the Y axis represents the signal amplitude and X-axis is the time. The pen (stylus or needle) of this plot is the luminous spot which moves on the screen and draws the waveshape of the signal.

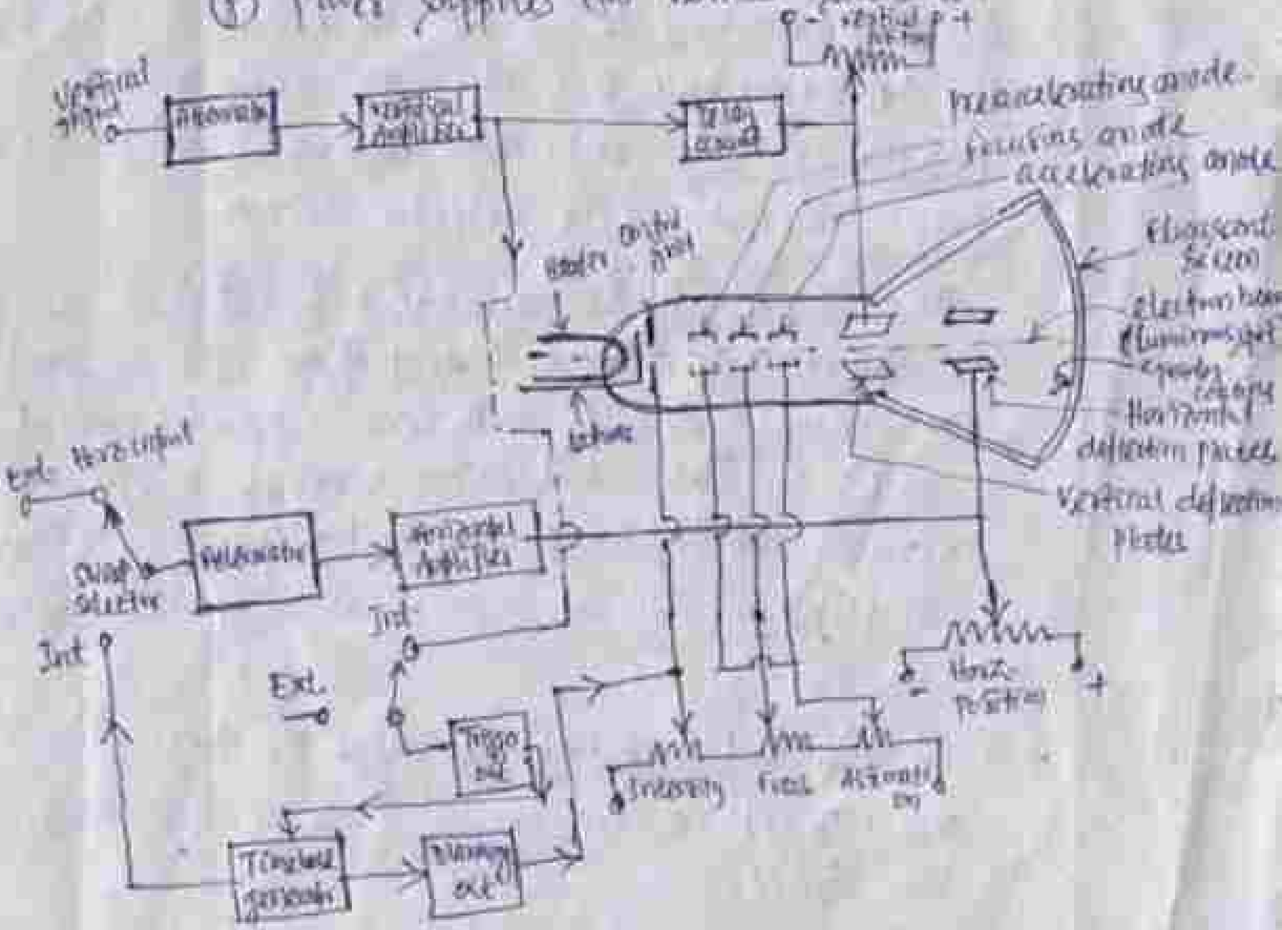
Block diagram of the CRO

Important components of a CRO are -

a) Electron gun assembly — consisting heater, cathode and control grid, accelerating and focusing anodes.

b) Horizontal & vertical amplifiers and H/V deflection systems.

(c) Time base circuits, synchronizing circuits and blanking circuits.
(d) Astigmatism (e) Attenuators (f) CRO probes
(g) Power supplies for various sections.



Block diagram of CRO

Working of CRO

- An electron beam is generated from a cathode, heated by a heater. The surface of the cathode is coated with a material of low work function.
- control grid controls the flow of electrons in the beam
- The electron beam is accelerated by the pre accelerating and accelerating anodes and get focused on the centre of the screen by focusing anodes which are supplied with +ve voltages

- The signal to be displayed (or analyzed) is called Y-input (or vertical input) & provided to the vertical amplifier and then to the vertical deflection plates.
- The X (horizontal input) is a sawtooth (time base) signal which may be given externally or internally by the time base generator triggered by the trigger circuit ~~sequence~~ activated by triggering signal through time selector switch.
- The signal to be analyzed (displayed) is a function of time (amplitude vs time) and its amplitude at different times (horizontal axis) provides deflection voltages through the vertical deflection plates amplified by vertical amplifiers so we can visualise the waveform on the screen.
- If Y input (signal) is absent, then only we will get a horizontal line, called horizontal trace.
- The electron gun assembly, deflection plate assembly are mounted inside a thick walled cylindrical evacuated glass envelope (tube) called cathode ray tube CRT, terminated with glass cover called screen at one end and at the other end with pins for external power/signal connection.