Band theory :-

→ Solid is a state of matter in which atoms are very close to each other.

→ Due to this the energy levels of various atoms intermix with each other to form energy bands.

→ Energy band is the collection of energy levels of the same kind.

→ The energy bands are further classified as lower energy bands, valance band and conduction band.

for eg :-

The sodium atom (Na) has the atomic no. 11 and its electronic configuration i.e given as: $1s^2 2s^2 2p^6 3s$

→ All '1s' energy levels of various surrounding atoms from a collection of '1s' energy band which is the lowest energy band.

→ All '2s' energy levels of various surrounding atoms intermix and form '2s' energy band lower energy

→ All '2p' energy band i.e Valence band

→ All '2p' energy levels of neighbouring atom form '2p' energy band i.e <u>Valance band</u>.

→ All '3s' energy levels of neighbouring atoms form '3s' energy band i.e; <u>Conduction band</u>.

<u>Valance band</u> :-

→ The highest occupied band is called as valence band.

→ It is <u>Completely filled</u> (or) <u>partially filled</u>.

<u>Conduction band</u> :-

→ The lowest unfilled band is called as conduction band.

→ It could be <u>empty</u> (or) <u>partially filled</u>.

<u>Forbidden Energy gap (E_g)</u> :-

It is the energy gap which is between valance band and conduction band and it is the region which is

free from charge carriers.

Note :-

When an electron jumps from valance band to Conduction band then it creates a hole in valance band and therefore Conduction takes place due to holes in valance band and due to electrons in Conduction band.

* Explanation of Insulators, Condectors and Semi-Conductors on the basis of Band-Theory :-

IMP

Insulators :-

These are the materials which do not allow the flow of current through it are called as Insulators.

→ On the basis of Band theory the forbidden energy gap between valance band and conduction band is very high (i.e); of order 10 eV. Hence the electrons cannot jump from valance band to conduction Band.

Conductors:-

In conductors the current is allowed through it.

→ On the basis of band theory the valence band and conduction band overlaps each other which results in 'negative' potential barrier and hence the electrons easily move from valance band to conduction band.

Semi-Conductors:-

The materials whose resistivity lies between the conductor and insulators are called as semi-conductors on the basis of band theory the forbidden energy gap between the valance band and conduction band is very small. Therefore the electrons by some excitation easily moves from valence band to conduction band.

The Semi Conductors are basically classified as

(1) Intrinsic Semi-Conductors.

(2) Extrinsic Semi-Conductors.

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Intrinsic Semi-Conductors :-

→ The Semi Conductor in its pure form is called as intrinsic Semi Conductor.

→ Germinium (Ge) and Silicon (Si) are the examples of intrinsic Semi conductors.

→ They both belong to group '4' of the periodic table.

→ Germenium and Silicon forms covalent bonds with its same atoms since it has four valence electrons.

→ Germanium and silicon have dimond cube crystalline structure.

→ A Intrinsic Semi conductor is a perfect insulator at 0K (-273°C)

→ The number of electrons and holes in intrinsic Semi conductors are equal.

→ The no. of electrons per unit volume in intrinsic Semi-Conductor is given as.

$$n_i^2 = N_e N_h$$

$$n_i^2 = 2\left[\frac{2\pi m_e^* k_B T}{h^2}\right]^{3/2} \exp\left[\frac{E_F - E_c}{k_B T}\right] \cdot 2\left[\frac{2\pi m_h^* k_B T}{h^2}\right]^{3/2} \exp\left(\frac{E_v - E_F}{k_B T}\right)$$

$$n_i^2 = 4\left[\left(\frac{2\pi k_B T}{h^2}\right)^{3/2}\right]^2 \left(m_e^* m_h^*\right)^{3/2} \exp\left(\frac{-[E_c - E_v]}{k_B T}\right)$$

$$n_i^2 = 4\left[\left(\frac{2\pi k_B T}{h^2}\right)^{3/2}\right]^2 \left(m_e^* m_h^*\right)^{3/2} \exp\left(\frac{-E_g}{k_B T}\right)$$

$$\because \boxed{E_c - E_v = E_g}$$

$$\Rightarrow \boxed{n_i = 2\left(\frac{2\pi k_B T}{h^2}\right)^{3/2} \left(m_e^* m_h^*\right)^{3/4} \exp\left(\frac{-E_g}{2k_B T}\right)}$$

Extrinsic Semi-conductor

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N-type Semi-Conductor :-

When a pentavalent impurity is added to a pure semi conductor then the ~~reveed~~ crystal is called as N-type semi conductor.

When the pentavalent impurity is added to the pure semi conductor then the four valence electrons forms the covalent bond with the crystal and 5th electron is a free electron and Hence in the N-type semi-conductor the majority of charge carriers are electron and minority are holes.

$$n = (2N_d)^{1/2} \left(\frac{2\pi m_c^* kT}{h^2}\right)^{3/4} \exp\left(\frac{E_n - E_c}{2}\right)$$

The donor impurity is electrons create a donor energy level E_d towards the Energy level E_c of Conduction band

$N_d \rightarrow$ Donor impurity.

Imp

P-type Semi-Conductor:-

→ In this type of Semi conductor a trivalent impurity is added (or) doped to an intrinsic Semi Conductors.

→ The example of trivalent impurties are aluminium (Al), Galium (Ga) and Indium (In)

→ The trivalent impurity makes the covalent bond with three electrons of the silicon and for the fourth covalent bond it takes one electron from the neighbouring silicon atom and thus creating a hole.

→ Since the trivalent impurity accepts one electron from silicon atom. hence it is called as Acceptor Impurity.

→ The Acceptor impurity Creats the acceptor energy level 'Ea' towards the valance band easily moves to Acceptance band energy level and Constitute current.

→ In P-type semi-conductors the majority charge carries are holes and minority charge carries are electrons.

→ The holes per unit volume (i.e); the hole density is given as

$$\boxed{P = (2N_a)^{1/2} \left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/4} \exp\left(\frac{E_v - E_a}{kT}\right)}$$

Where N_a → Acceptor impurity

M_a^* → Effeitiur mass

E_v → Valence Energy level

E_a → Acceptor Energy level

h → plank's Constant.

Fermi-level :

→ It is the characteristic energy of the material.

→ In intrinsic semi-conductors No. of electrons is equal to No. of holes.

→ In conduction band the electron concentration decreases above the conduction band and concentration of holes decreases below the top of the valence band.

$$E_f = \frac{E_c + E_v}{2}$$

→ for the N-type semi conductor the fermi-level is given by the eqn $E_f = \frac{E_c + E_d}{2}$

→ for p-type Semi Conductor the fermi-level is given as

$$\boxed{E_F = \frac{E_V + E_a}{2}}$$

Hence for n-type Semi-Conductor the fermi-level shifts towards Conduction band and for p-type it shifts towards valence band.

* <u>Electron trple pair Generation process</u> :-

→ In intrinsic Semiconductors the no. of holes in valence band is equal to no. of electrons in Conduction band at 0k.

→ Due to thermal exitation at room temperature electron from valence band jumps to Conduction band which result in the Generation of Electron pair.

<u>Recombination process</u> :-

In this process the electron which has moved from valence band in conduction band undergoes multiple

Collisions with the electrons in conduction band and therefore loses energy and comes back to valence band.

→ The electron hole pair generation and their recombination is a continuous process and the average time of generation and re-combination of electron hole pair is called as average life time of carrier.

T_p → Average life time for hole

T_n → Average life time for electrons

Drift current :-

This is the current which is due to movement of electrons under the influence of external voltage.

The drift velocity of charge carries

$V_d \propto E$

$$\boxed{V_d = \mu_p E}$$

$\mu_p \rightarrow$ mobility of hole

Therefore, the drift current of holes is given as

$$\boxed{J_p = e p v_d}$$

$$\boxed{J_p = e p \mu_p E}$$

Where $J_p \rightarrow$ current density of holes

$e \rightarrow$ charge of carrier

$p \rightarrow$ hole concentration

$E \rightarrow$ Applied voltage

Diffusion Current:

When the charge carries move from higher concentration region to the lower concentration region then it is called as diffusion current.

$\rightarrow$ let 'p' is the hole concentration and it changes with the distance 'dx' then

the concentration gradient $= \frac{dp}{dx}$

Therefore the diffusion current 'J_p' is directly proportional to the concentration gradient:

$$J_p \propto \frac{dp}{dx}$$

$$\boxed{J_p = -eD_p \frac{dp}{dx}}$$

Where $D_p \rightarrow$ diffusion constant for holes.

→ Negative sign indicates as distance 'x' increases concentration of p decreases.

Imp

Equation of continuity :-

It is a differential equation which gives relationship between concentration of charge carriers with time and distance.

P → hole concentration

A → Area of cross section

dx → length of p-type semi conductor

I_p → current entering the semi-conductor

$I_p + d_p$ → current leaving the semi-conductor.

→ The concentration of charge carriers changes due to

(1) Concentration of hole decreases due to additional current 'dI_p'

Therefore the decrease of holes per second is given as $-\frac{\partial I_p}{e}$

e → magnitude of charge and negative sign indicate decrease in hole concentration.

→ Therefore decrease in hole concentration per unit volume per second is given as $= -\frac{\partial I_p}{e(A dx)}$

∴ Decrease in hole concentration $= -\frac{\partial I_p}{e dx}$

where J_p → Current density $I_p + dI_p$

$$\boxed{J_p = \frac{I_p}{A}}$$

(2) Concentration of holes increases due to temperature

→ Due to temperature their is thermal Agitation which gives rise to electron holes pair.

→ The generation rate $\boxed{g = \frac{P_o}{\tau_p}}$

Where 'P_o' is the concentration of holes at thermal equilibrium.

τ_p → Average life time for holes

(3) Due to recombination concentration of holes decreases

→ The recombination rate 'r' is given as

$$\boxed{r = -\frac{p}{\tau_p}}$$

Therefore, the increase in hole concentration is given as $\frac{\partial p}{\partial t} = -\frac{\partial J_p}{e\,dx} + \frac{p_0}{\tau_p} - \frac{p}{\tau_p}$

$$\boxed{\frac{\partial p}{\partial t} = \frac{p_0 - p}{\tau_p} - \frac{\partial J_p}{e\,dx}} \rightarrow (1)$$

Eq (1) represents equation of continuity for holes

→ for electrons (or) N-type

$$\boxed{\frac{\partial n}{\partial t} = \frac{n_0 - n}{\tau_n} + \frac{\partial J_n}{e\,dx}}$$

Imp

Diode :-

It is formed by the two terminal semi-conductor device which allows the flow of current in only one direction.

→ It is formed by joining a p-type semi-conductor with the n-type semi-conductor by diffusing p-type to one half and n-type to another half.

→ The holes from p-type and electrons from N-type which are in higher concentration, diffuse over the junction to the other. After some time the diffusion is ~~stapped~~ stoped due to the formation of potential barrier which is formed due to the depletion region which is a charge free region.

→ With the formation of Depletion region there are immobile electrons towards p-type and immobile holes towards N-type (i-e); -ve and +ve ions respectively which gives rise to junction voltage.

→ The symbol of diode is

Working of Diode:

→ Diode is operated under two condition

(i) Forward bias

(ii) Reverse bias

Forward Bias:

In the forward bias condition the +ve terminal of the external battery is connected to p-type and -ve terminal of the battery is connected to N-type.

← Unbiased

← forward bias

Ammeter

→ In the forward bias condition the majority charge carriers of p-type and N-type moves towards the junction and minority charge carriers moves away from the junction.

→ This causes the width of depletion region to decrease and more and more charge carriers cross the junction which gives huge amount of current through the diode.

→ Since width of depletion region decreases potential barrier also decreases.

Reverse Bias :-

→ In the reverse bias the -ve terminal of the external battery is connected to p-type and +ve terminal of the external battery is connected to N-type.

→ In the reverse bias condition the majority charge carriers moves away from the junction and minority charge carriers moves towards the junction.

→ Therefore the width of depletion region increases and current through the diode is due to minority charge carrier which is very small.

→ In Reverse bias the potential barrier increases

<u>Diode equation</u>:-

The diode equation is given as

$$I = I_0 \left[e^{\frac{eV}{\eta k T}} - 1 \right]$$

I_0 = Reverse saturation current at temperature TK

k = Boltzmann Constant

η = Constant,

Ge ($\eta = 1$) Si ($\eta = 2$)

V - potential difference

e - charge

V-I characteristics of Junction Diode :-

Diode characteristics is obtained by making the diode in forward and reverse bias condition

Forward bias

→ In the circuit the +ve terminal of the battery is connected to the p-type of the diode through the Resistance 'R' and N-type is connected to -ve terminal of the battery through milli Ammeter.

→ Voltmeter 'V' is connected in parallel across the P-N junction diode.

→ A graph is plotted between voltage 'V' and current 'I' and it is observed that for a particular voltage the current starts flowing through the diode which

is called as cut-in voltage (or) knee voltage.

→ In the circuit the -ve terminal, is connected to p-type of the diode through resistance 'R' and N-type is connected to the +ve terminal of the battery through the microAmmeter.

→ When the applied voltage is increased the current which is due to minority charge carriers increases from '0' to a constant value which is called as Reverse Saturation Current.

→ If the reverse voltage is further increased, then the junction breaks and maximum current flows through the diode, hence it is called as breakdown voltage.

Bridge Rectifier :-

Rectifier is a device which converts alternating current (AC) to Direct Current (DC).

→ Bridge Rectifier is advantageous over full wave Rectifier and for its efficiency and low cost.

→ The alternating input is applied to the primary coil L_1 of the transformer and due to electromagnetic induction e.m.f is produced in secondary coil 'L_2'.

→ for the +ve half signal diode 'D_1' and 'D_2' are forward bias and diode 'D_3' and 'D_4' are reverse bias. Hence the o/p is obtained due to diode 'D_1' & 'D

→ for -ve half cycle diode 'D_3' & 'D_4' they are forward bias and diode 'D_1' & 'D_2' Reverse bias. Hence the o/p is obtained across the load 'R_L' due to diode 'D_3' & 'D_4'

O/P

O/P

O/P D_1, D_2, D_3, D_4

Analysis Bridge Rectifier :-

let the applied input voltage applied is given as $V_i = V_m \sin \omega t$. For +ve half cycle the diode 'D_1' & 'D_2' are conducting i.e; they are forward bias and diode 'D_3' & 'D_4' are not conducting for this +ve half cycle

The current through diode D_1 & D_2 is

$$i_1 = I_m \sin \omega t \text{ for } 0 \le \omega t \le \pi$$

$$i_1 = 0 \text{ for } \pi \le \omega t \le 2\pi$$

for the diode 'D_3' & 'D_4' for -ve half cycle are forward bias ..

∴ Current through 'D_3' & 'D_4' is

$$i_2 = I_m \sin \omega t \text{ for } \pi \le \omega t \le 2\pi$$

$$i_2 = 0 \text{ for } 0 \le \omega t \le \pi$$

where V_m = maximum voltage

I_m = maximum current

(1) DC (or) Average current :-

The average value of o/p 'DC' current is given as

$$I_{dc} = \int_0^{\pi} (I_m \sin \omega t + 0)\, d(\omega t) + \int_{\pi}^{2\pi} (I_m \sin \omega t + 0)\, d(\omega t)$$

$$= \int_0^{\pi} (I_m \sin \omega t)\, d(\omega t) + \int_{\pi}^{2\pi} (I_m \sin \omega t \int d(\omega t)$$

$$= I_m\left[-\cos\omega t\right]_0^{\pi} + I_m\left[-\cos\omega t\right]_{\pi}$$

$$= I_m\left[-(-1)-(-(+1))\right] + I_m\left[-(+1)-(-(-1))\right]$$

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

(2) <u>RMS Current</u> :-

It is defined as root mean square value of the current or voltage and is given as

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \qquad \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

(3) <u>Rectifier efficiency (η)</u> :-

The efficiency of a rectifier is defined as the ratio of o/p 'DC' power to I/P 'AC' power i.e.

$$\boxed{\eta = \frac{P_{dc}}{P_{ac}}}$$

The efficiency of bridge rectifier is 81.2%

(4) Ripple Factor (γ) :-

It is defined as the ratio of 'RMS' value of current to 'dc' value of current

$$\boxed{\gamma = \frac{I_{rms}}{I_{dc}}}$$

→ The ripple factor of bridge rectifier is $\boxed{0.48}$.

→ The ripple factor is also defined as the presence of unwanted 'Ac' signals in the 'Dc' o/p. The unwanted 'Ac' signals in the o/p 'Dc' are removed by using filters. There are four types of filter.

* Series Inductor Filter
* Shunt Capacitor filter (Paraller)
* L - Section filter
* π - Section filter

Imp

Zener Diode :-

A zener diode is a reversed bias heavily doped P-N junction diode which is operated in breakdown region.

→ In the break down region the voltage accross the zener diode remains constant over a large value of current. Hence it is also used as voltage stabilizer

→ When p-type of zener diode is connected to negative terminal of the battery, and N-type is connected to the +ve terminal of battery then it is in reverse bias condition.

→ In the reverse bias condition zener diode is operated in break down region.

→ There are two mechanisms of breakdown.

(1) <u>Zener Breakdown</u> :-

In this breakdown both the sides of junctions are heavily dopped and due to this, depletion region is very small

→ When a reverse bias is applied a electric field developed accross depletion region which causes the break of covalent bond and therefore huge number of electrons and holes cross over the junction to produce reverse saturation current which is called as zener current and it is independent of applied voltage and depends on external resistance.

(2) Avlanche Breakdown:

In this breakdown both the sides of the junction are lightly doped and therefore the width of depletion region is very wide.

→ When the reverse electric field is applied. It is not sufficient to break co-valent bond.

→ In this break down the minority charge carriers collide with semi-conductor atoms in depletion region and due to this collision co-valent bonds are broke and electron-hole pairs are generated and this process continues and form a cummulative process (or) flood of charge carriers which results in a Avalanche Breakdown

Zener Breakdown

Avalanche Breakdown

Zener Diode as voltage stabilizer (or) Regulater :-

V_Z → zener break down voltage

$V_Z = 6.2V$

→ In the circuite resistance 'R' gives protection to the diode

R_L → load resistance.

→ When the voltage from the battery is increased the

current through the diode also increases. and for a particular voltage called as zener voltage. maximum current passes through the diode and the voltage accross load resistance which is in parallel with zener diode remains constant i.e; equal to zener voltage and constant output is obtained.

LAB

Analysis of Half wave Rectifier :-

A half wave rectifier is a device which converts AC voltage to DC voltage using only half cycle of the applied AC voltage

→ It consists of one diode (D) which is connected to load resistance (RL) in series.

→ The AC input is applied using the transformer which is represented by the coils L_1 & L_2. where L_1 is primary coil and L_2 is secondary coil.

Working of half wave rectifier :-

for the positive half cycle of the input AC voltage the diode (D) is forward bias and ∴ it conducts and currents flows in the circuit and there is voltage drop accross the load resistance

LAB

→ for the negative half cycle the diode (D) is reverse biase and there is no flow of current in the circuit and hence the voltage drop across load resistance is zero. The input voltage is given as $V_i = V_m \sin \omega t$ $\quad V_m \rightarrow$ maximum value of E_{ms}

AC $\quad i = I_m \sin \omega t$

$i = I_m \sin \omega t$ for $0 \leq \omega t \leq \pi$

$i = 0$ for $\pi \leq \omega t \leq 2\pi$

$$\boxed{I_m = \frac{V_m}{R_f + R_L}}$$ $I_m \rightarrow$ maximum current

* <u>DC output current</u>:

The average current I_{dc} is given as

$$I_{dc} = \frac{1}{2\pi} \int_0^{2\pi} i \, (d\omega t)$$

$$I_{dc} = \frac{1}{2\pi} \int_0^{2\pi} I_m \sin \omega t \, (d\omega t)$$

$$I_{dc} = \frac{1}{2\pi} \int_0^{\pi} I_m \sin \omega t \, (d\omega t) + \frac{1}{2\pi} \int_{\pi}^{2\pi} 0$$

$$I_{dc} = \frac{I_m}{2\pi}\left[-\cos\omega t\right]$$

$$I_{dc} = \frac{I_m}{2\pi}\left[-\cos\pi + \cos 0\right]$$

$$I_{dc} = \frac{I_m}{2\pi}\left[1 + 1\right]$$

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

* **DC output voltage :-**

The DC output voltage is given as

$$V_{dc} = I_{dc} \times R_L$$

$$V_{dc} = \frac{I_m}{\pi} \times R_L$$

$$V_{dc} = \frac{1}{\pi}\left(\frac{V_m}{R_f + R_L}\right) \times R_L$$

$R_L \rightarrow$ Load Resistance

$R_f \rightarrow$ forward bias Resistance of Diode

if $R_f << R_L$

$$V_{dc} = \frac{V_m}{\pi R_L} \times R_L$$

$$\boxed{V_{dc} = \frac{V_m}{\pi}}$$

* RMS current and voltage :-

The root mean square (RMS) current is given as

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} i^2 (d\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} I_m^2 \sin^2\omega t \, (d\omega t)\right]^{1/2}$$

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

Similarly

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

* Rectifier Efficiency (η) :-

It is defined as the ratio of dc output power to the AC input power $\boxed{\eta = \frac{P_{dc}}{P_{ac}}}$

The percentage rectifier efficiency is given as

$$\boxed{\eta = \frac{40.6}{1 + \frac{R_f}{R_L}}}$$

* Ripple factor (γ) :-

The ripple factor is the purity of rectified voltage and it is defined as the ratio of rms value of ac component to the dc value of that component

i.e; $$\boxed{\gamma = \frac{V_{rms}}{V_{dc}}}$$

→ for half wave rectifier

$$\boxed{\gamma = 1.21}$$

* form factor (F) :-

It is defined as the ratio of rms value to the average value

i.e; $$\boxed{F = \frac{V_{rms}}{V_{dc}}}$$

$$\frac{\frac{V_m}{\sqrt{2}}}{\frac{V_m}{2}}$$

$$\boxed{F = \frac{2}{\sqrt{2}}}$$

7/4/22

Full Wave Rectifier

In full wave rectifier both half cycle of the input are used with the help of two diodes alternatively.

→ for the +ve half cycle diode D_1 is forward bias and diode D_2 is reverse bias.

→ The current flows in the circuit and potential drop is obtained accross the load resistance (R_L) due to diode D_1.

→ for the -ve half cycle diode D_1 is reverse bias and diode D_2 is forward bias.

→ The current in the circuit is due to diode D_2 and pottential drop is obtained accross the load resistance (R_L)

let the input voltage is given as

$$V_i = V_m \sin \omega t$$

The current through diode D_1 is

$$i_1 = I_m \sin \omega t \quad \text{for} \quad 0 \le \omega t \le \pi$$

$$i_1 = 0 \quad \text{for} \quad \pi \le \omega t \le 2\pi$$

$$\boxed{I_m = \frac{V_m}{R_f + R_L}}$$

Similarly the current through diode

$i_2 = 0$ for $0 \le \omega t \le \pi$

$i_2 = I_m \sin\omega t$ for $\pi \le \omega t \le 2\pi$

Total current flows through R_L is :

$$\boxed{i = i_1 + i_2}$$

* <u>Dc (or) Average current</u> :

The Average value of Dc output current is given as

$$I_{dc} = \int_0^{2\pi} i_1 (d\omega t) + \int_0^{2\pi} i_2 (d\omega t)$$

$$I_{dc} = \int_0^{\pi} i_1 \, d(\omega t) + \int_{\pi}^{2\pi} 0 \, d(\omega t) + \int_0^{\pi} 0 \cdot d(\omega t) + \int_{\pi}^{2\pi} I_m \sin\omega t \, d(\omega t)$$

$$I_{dc} = \int_0^{\pi} I_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} I_m \sin\omega t \, d(\omega t)$$

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

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

* **Dc output voltage :-**

$$V_{dc} = I_{dc} \times R_L$$

$$\boxed{V_{dc} = \frac{2I_m}{\pi} R_L}$$

* **RMS current :-**

$$I_{rms} = \left[\frac{1}{\pi}\int_0^{\pi} i^2 \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{\pi}\int_0^{\pi} \sin^2 \omega t \, d(\omega t)\right]^{1/2}$$

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

* **Rectifier efficiency :-**

$$\eta = \frac{P_{dc}}{P_{ac}}$$

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

$$\boxed{P_{dc} = \frac{4I_m^2}{\pi^2} R_L}$$

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

$$\boxed{P_{ac} = \frac{I_m^2}{2}(R_f + R_L)}$$

$$\eta = \frac{\frac{4I_m^2}{\pi^2} \cdot R_L}{\frac{I_m^2}{2}(R_f + R_L)}$$

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

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

$$\eta = \frac{0.812}{1 + \frac{R_f}{R_L}}$$

if $R_L >> R_f$

$$\eta = 0.812$$

$$\boxed{\eta\% = 81.2}$$

* <u>Ripple factor</u> :-

The ripple factor is given as $\gamma = \frac{I_{rms}}{I_{dc}}$

$$\gamma = \frac{\frac{I_m}{\sqrt{2}}}{\frac{2I_m}{\pi}}$$

as $\gamma = \frac{I_{rms}}{I_{dc}}$

$\boxed{\gamma = 0.48}$

Unit 2 :- Bipolar Junction Transistor (BJT)

→ BJT stands for Bi-polar junction transistor

→ A transistor is a device which transfers the signal from low impedance region to high impedance region.

→ The transistor is a combination of two words i.e; transfer, resistor

→ Transistor is of two types, and it is a three terminal device.

Types of transistor :-

Transistor are of two types.

(i) NPN Transistor :-

→ In the NPN transistor a p-type semi-conductor is sandwitched between two layers of N-type semi-conductor

Symbol

E → Emitter

B → Base

C → Collector

(2) PNP Transistor :-

→ In the PNP transistor a n-type semiconductor is sandwitched between two layer's of p-type semiconductor

E - emitter
B - Base
C - collector

→ The terminals of a transistor are :-

* Emitter :- The function of emitter is to supply majority charge carriers i.e; electrons for n-type and holes for p-type and therefore this region is very heavily doped as compared to other regions.

* Base :- The middle section of the transistor is called as Base which is very lightly doped and is very thin.

* Collector :- The function of the collector is to collect majority charge carriers and it is moderately doped

and its size is also big as compared to emitter and base.

Note :- Transistor is a voltage controller device.

* Transistor - Biasing :-

The emitter - base junction of the transistor is always forward bias and the collector - base junction is always reversed bias.

$$I_E = I_B + I_C$$

$I_E \rightarrow$ Emitter current

$I_B \rightarrow$ Base current

$I_C \rightarrow$ collector current.

Note :-

Sign Convention :- A current entering into transistor is taken as positive and current flowing out of transistor is taken as Negative.

→ Therefore, for NPN; $I_E = -ve$, $I_B = +ve$, $I_C = +ve$

for PNP $I_E = +ve$, $I_B = -ve$, $I_C = -ve$

* Transistor Configuration:-

There are three types of transistor configuration.

Common Base: In this configuration the base terminal is common to both I/P and O/P

In the common base configuration the input is applied between emitter and base and the output is taken between collector and base.

→ In this configuration the current amplification factor 'α' is defined as the ratio of collector current to emitter current i.e;

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

Common Emitter:- In this configuration, the emitter is common to both Input and output.

→ In the common-emitter configuration the input is applied between base and the output is taken between collector and emitter.

→ In this configuration the current amplification factor 'β' is defined as collector current and base current ratio i.e;

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

Common Collector:- In this configuration the collector is common between input and output.

→ In this configuration the input is applied between base and collector and the output is taken between emitter and collector.

→ The current amplification factor 'γ' is defined as Base current and emitter current.

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

* Transistor as a Amplifier:

A amplifier is a device which is used to strengthen the weak signal.

→ The weak signal is applied between emitter base and output is taken accross load resistance 'R_L' connected accross collector and base.

→ In the circuit V_{EE} is used to make emitter-base always in forward bias condition.

→ A small change in signal voltage produces a big change in emitter current since input circuit is forward bias and therefore has low resistance.

→ Due to transistor the change in emitter current causes almost similar change in collector current flowing in the load resistance 'R_L' and a large voltage is developed across load resistance and therefore a small weak signal at input is amplified at the output.

→ If 'ΔV_i' is the small change in voltage between emitter and base which causes change in emitter current 'ΔI_E'.

Therefore current amplified on factor $\boxed{\alpha = \frac{\Delta I_C}{\Delta I_E}}$

$$\Rightarrow \Delta I_C = \alpha \Delta I_E \rightarrow (1)$$

let 'ΔV_o' is the change in output voltage due to change in collector current 'ΔI_C'.

$$\therefore \Delta V_o = \Delta I_C \times R_L \rightarrow (2)$$

Sub (1) in (2)

$$\boxed{\Delta V_o = \alpha \Delta I_E \times R_L} \rightarrow (3)$$

→ The voltage gain 'A'

$$\boxed{A = \frac{\Delta V_o}{\Delta V_i}}$$

$$\Delta V_o = A \cdot \Delta V_i$$

$$\boxed{A = \frac{\Delta I_c \times R_L}{\Delta V_i}} \rightarrow (4)$$

$$\Delta V_i = r_e \Delta I_E \rightarrow (5)$$

r_e → resistance of emitter junction

Sub (5) in (4)

$$A = \frac{\Delta I_c \times R_L}{r_e \Delta I_E}$$

$$\boxed{A = \frac{\alpha R_L}{r_e}} \quad \text{Where } \boxed{\alpha = \frac{\Delta I_c}{\Delta I_E}}$$

* <u>RC Coupled Transistor Amplifier</u>:-

An amplifier is a device which strength weak input signal.

→ Power supply $+V_{cc}$ is applied to NPN transistor.

→ The resistance R_1, R_2 & R_E from the biasing and stabilization network.

→ Emitter capacitor C_E is the Bypass capacitor, which allow high frequency signals.

→ Resistor 'R_c' → load resistance.

→ The input capacitor 'C_{in}' couples AC signal voltage to the base of transistor.

→ In absence of C_{in} the signal will be parallel with 'R_2' and therefore 'C_{in}' is used for the proper functioning.

→ The output of first stage is coupled to the second stage by the coupling capacitor 'C_c'.

→ When 'A_c' signal is applied to the base of first transistor it appears at load 'R_c' in amplified form. and the phase of output of first stage is opposite to input stage.

→ The gain of amplifier is defined as the ratio of output voltage to the input voltage i.e; $\boxed{A = \frac{V_o}{V_i}}$

→ If a graph is plotted between the frequency of input signal and again 'A' then for lower frequencies gain increases, for mid frequencies the gain remains constant and for the high frequencies the gain decreases.

* Feed-Back in Amplifiers :-

When a part (or) portion of output is given back to input then it is called as feed back.

→ It is of two types.

- **+ve feed back** :- If the net effect increases the magnitude of input signal then it is called as +ve feedback

- **-ve feed back** :- If the net effect decreases the magnitude of input signal then it is called as -ve feedback

$V_s \rightarrow$ Source Voltage

$V_i \rightarrow$ input voltage

$V_o \rightarrow$ output voltage

$V_f \rightarrow$ feed back voltage

$A \rightarrow$ gain of amplifier without feedback.

$$\boxed{A = \frac{V_o}{V_i}}$$

$\beta \rightarrow$ feedback factor

$$\boxed{\beta = \frac{V_o}{V_f}}$$

$\rightarrow$ for +ve feedback

$$V_i = V_s + \beta V_o \rightarrow (1)$$

$\rightarrow$ for -ve feedback

$$V_i = V_s - \beta V_o \rightarrow (2)$$

but $V_o = AV_i \rightarrow (3)$

Sub (3) in (1)

$$V_i = V_s + \beta A V_i \rightarrow (4)$$

Sub (4) in (3)

$$V_o = A[V_s + \beta A V_i]$$

$$V_o = A[V_s + \beta V_o]$$

$$V_o = V_s A + \beta V_o A$$

$$V_s A = V_o - \beta V_o A$$

$$V_s A = V_o(1-\beta A)$$

$$\boxed{\frac{V_o}{V_s} = \frac{A}{1-\beta A}} \rightarrow (5)$$

The gain of amplifier with feedback is given as

$$\boxed{A_f = \frac{V_o}{V_s}} \rightarrow (6)$$

Comparing Eq (5) & (6)

$$\boxed{A_f = \frac{A}{1-\beta A}}$$ for +ve feedback

$$\boxed{A_f = \frac{A}{1+\beta A}}$$ for -ve feedback

* <u>Backhousen Criteria</u> :-

For the amplifier with +ve feedback the gain is given as $A_f = \frac{A}{1-\beta A}$

If $\beta A = 1$ $A_f = \infty$; then this condition is called as Backhousen Criteria and in this condition the amplifier works as an oscillator

Phase shift oscillator:-

An oscillator is a device which generates Ac output signal without any applied Ac input used. it is a circuit which converts Dc to Ac.

→ A RC phase shift oscillator provides a current which leads by the applied voltage one RC combination gives 60° of phase shift and by using three RC combinations the total phase shift is 180°.

→ The Resistor 'R1' are the resistance 'R' which is near to transistor gives voltage Divider bias to transistor.

→ Resistor 'R_L' limits the collector current.

→ Emitter Resistance 'R_E' provides the thermal stability

→ The Emitter capacitor 'C_E' is the by-pass capacitor which allows high frequency signals.

→ The capacitor C_{output} is the coupling capacitor.

→ Each 'RC' combination provides 60° of phase shift for a choosen value of 'R' & 'C' and therefore, three RC combinations provides a phase shift of 180°.

→ The rest of 180° is provided by the transistor and therefore a phase shift oscillator provides total phase shift of 360°.

→ The frequency of oscillations produced is given by the formula

$$f = \frac{1}{2\pi\sqrt{2N}\,RC}$$

R → Resistance

C → capacitor

N → no. of RC combination

if N = 3

$$\boxed{f = \frac{1}{2\pi\sqrt{6}\,RC}}$$

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Mathametical Analysis of phase shift oscillator:

A hybrid equilate circuit of phase shift oscillator is used to derive the frequency of oscillations produce

$h_{fe} I_3 R_L$ → represents thevinins voltage generated from the source

V_i = input voltage

R = Resistance

C = Capacitor

V_o = output voltage

V_f = feedback voltage

Applying KVL to the three loops

X_c → Capacitence reactence

$$X_c = \frac{1}{j\omega c}$$

$$\frac{I_1}{j\omega c} + I_1 R - I_2 R = V_i$$

$$\boxed{0 I_3 + \left\{ I_1 \left(R + \frac{1}{j\omega c} \right) - I_2 R = V_i \right\}} \rightarrow (1)$$

for the second loop

$$\frac{I_2}{j\omega C} + I_2 R + I_2 R - I_3 R - I_1 R = 0$$

$$-I_1 R + 2I_2 R + \frac{I_2}{j\omega C} - I_3 R = 0$$

$$\boxed{-I_1 R + \left(2R + \frac{1}{j\omega C}\right) I_2 - I_3 R = 0} \rightarrow (2)$$

for the third loop

$$\frac{I_3}{j\omega C} + I_3 R + I_3 R - I_2 R = 0$$

$$0 I_1 - I_2 R + 2 I_3 R + \frac{I_3}{j\omega C}$$

$$\boxed{0 I_1 - I_2 R + 2R + \frac{1}{j\omega C} I_3 = 0} \rightarrow (3)$$

writing eq (1) (2) & (3) in matrix form

$$\begin{pmatrix} R + \frac{1}{j\omega C} & -R & 0 \\ -R & 2R + \frac{1}{j\omega C} & -R \\ 0 & -R & 2R + \frac{1}{j\omega C} \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ I_3 \end{pmatrix} = \begin{pmatrix} V_i \\ 0 \\ 0 \end{pmatrix}$$

using Cramers rule. the determinent is

found and $D = \begin{vmatrix} R+\frac{1}{j\omega C} & -R & 0 \\ -R & 2R+\frac{1}{j\omega C} & -R \\ 0 & -R & 2R+\frac{1}{j\omega C} \end{vmatrix}$

solving the other determinent the result obtained

$$\frac{1}{\omega RC} = \sqrt{6}$$

$$\omega = \frac{1}{\sqrt{6}\,RC}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{6}\,RC}}$$

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Unit :- III

Special Devices

photo diode :-

It is a oppto electronic divice in which light signals are converted into electrical signals by using photo emissive effect.

Symbol of photo diode

A → Anode

C → cathode

→ The incident light produces electron - hole pairs in the diplition region

→ Then these electrons and hole pairs separation takes place and photo current is produced.

→ A photo diode is constructed by using thin heavily doped p-type layer which is placed on the top of lightly doped n-type layer.

→ The diplition region is formed between the p-type and n-type layer and it deply penitrates into n-type layer.

→ The p-type is exposed to the light.

→ A photo diode is operated in the reverse bias ~~direction~~ condition.

When the light falls on the depletion region the photons from light energy will collide with valence electrons from p-type layer

→ The valence electrons due to this collision get sufficient energy and are seperated from their parent atom and hence electron hole pairs are generated and minority charge carriers results in the reverse current flow.

→ With the increase of intensity of light a photo current also increases

→ The charecteristic of a photo diode is drawn in the reverse bias condition.

→ When there is no light the current to the photo diode is zero and this is called as Dark current.

Uses (or) Application of photo diode:

1) lie detector:
2) Optical detectors
3) Sound track
4) Electronic Control circuit

5) light operated switches

6) Computer punching cards

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Shockley Diode :-

It is a four layer PNPN Silicon dio. device with two terminals.

→ When an external voltage is applied to the device such that Anode is positive with respect to Cathode.

Symbol of shockley diode

The junctions J_1 & J_3 are forward bias and junction J_2 is reverse bias.

→ Therefore the applied voltage appears across the reverse bias junction J_2 and the current flowing through the device is only the reverse saturation current.

→ Once the device is fired into conduction a minimum amount of current called as "holding current" (I_H) is required to keep the device in on state.

→ To turn the device from OFF state to ON state the current has to be reduced below I_H by reducing the applied voltage close to zero i.e, to the holding voltage V_H and therefore the diode acts as switch in forward bias condition.

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Opto - Coupler's :- It is a device which is form by Combining a LED and photo transistor in one Package Called as dual - In - Package (DIP)

→ When the LED is forward bias the charge recombination process takes place at PN junction of LED.

→ during the charge recombination the electrons recombine with the holes and the energy is released in the form of light.

→ This light falls on base of photo-transistor and causes the flow of current into it.

Hence current in LED causes current in photo-~~transi~~ transistor

Applications of opto - Coupler :-

1) It is used in DC coupling circuits.

2) It is used in fibre optical communication.

3) It is used in switching applications.

Solar cell (or) Protovoltaic cell :-

A device in which solar energy is converted into electrical energy is called as solar cell (or) protovoltaic cell.

A solar cell consist of PN junction diode which is surrounded by a glass window on top of P Type material

A glass layer is very thin so that the light energy directly reach PN junction diode.

When the light is incident on the PN junction the photons of light energy collids with valence electrons from this the valence electrons gains sufficient energy and seperate from parent atom.

→ The free electrons causes the electron the current flow at the junction and it is called as minority current is directly proportional to intensity of light and surface area on which it is falling.

→ When the diode is forward bias the electric field at the junction dicreases but the direction of current flow doesnot change and hence the net current in reverse direction is given as $\boxed{I = I_L - I_f}$ → (1)

where I_L → Photocurrent

I_f → forward current

from the diode equation the forward current

$$I_f = I_s\left(\frac{qV}{e^{kT}-1}\right) \rightarrow (2)$$

Where I_s → Saturation current.

q is the charge V is the voltage k → boltzmen constant

T → temperature

sub eq (2) in eq (1)

$$I = I_L - I_s\left[e^{\frac{qV}{kT}} - 1\right] \rightarrow (3)$$

if the resistance R of the device becomes infinite then the net current I becomes zero and the voltage becomes V_{oc} i.e; open circuite voltage.

$$I = 0$$

$$0 = I_L - I_s\left[\frac{qV_{oc}}{e^{kT}-1}\right]$$

$$I_L = I_s\left[\frac{qV_{oc}}{e^{kT}-1}\right]$$

$$\frac{I_L}{I_s} = e^{\frac{qV_{oc}}{kT}} - 1$$

$$1 + \frac{I_L}{I_s} = e^{\frac{qV_{oc}}{kT}} \rightarrow (4)$$

Taking log on b.s of eq^n (4)

$$\log_e\left(1 + \frac{I_L}{I_s}\right) = \frac{qV_{oc}}{kT}$$

$$\boxed{V_{oc} = \frac{kT}{q}\log_e\left(1 + \frac{I_L}{I_s}\right)}$$

If the device resistance is very small

$$V = 0$$

$$I = I_L - I_s\left[e^{\frac{qV}{kT}} - 1\right]$$

$0 = I_L - I_{sc}$

$$\boxed{I_L = I_{sc}}$$

Where I_{sc} → short circuit current

Application of solar cell:-

1) used as board satilites to recharge their batteries.

2) Is used in calculators

3) watchs and toys

4). Agriculture pumps

5) street lights

Advantages

1) Operating cost is less

2) More ~~reliable~~ reliable

3) Easy to install

4) It can be operated for various temperature ranges

5) fual source is vast

Disadvantages:-

1) Installation cost is very high

2) Energy can be generated only during daytime

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Field Effect Transistor (FET):-

difference between BJT & FET

BJT

* Three terminal semiconductor device.
* Emitter, base, collector
* current controlled device
* Bipolar device
* Two types - npn & pnp

FET

* Three terminal semiconductor device
* source, gate, drain
* voltage controlled device
* unipolar device
* two types - JFET & MOSFET

classification of FET

Symbols of JFET (N-type)

P-type (channel)

P-channel JFET

Construction of N-channel JFET

* It consists of N-type semiconductor bar.
* One end is connected to ohmic contact and is called drain.
* The other end connected through an ohmic contact and is referred as source (S).

* The N-type bar is heavily doped on two sides by P-type Material.

* Both P-type are internally conducted and is taken as Gate.

* JFET has two pn junctions under no bias condition.

JFET operating characteristics $V_{GS} = 0V$

* When $V_{GS} = 0V$ and V_{DS} is connected between drain and source, then a current called drain current I_D flows from drain to source.

* The I_D current can be now controlled by the application of negative gate voltage (V_{GS}).

* As the gate voltage is made more negative, the depletion region starts increasing.

* This increase in the depletion region starts to restrict the drain current.

* Source is forward bias, Drain is reversed bias

JFET drain characteristics

* Plot between V_{ds} vs I_d for different values of V_{gs}.

* When $V_{gs} = 0V$ & V_{ds} is positive, I_d increases linearly.

* When V_{ds} is more positive voltage I_d gets saturated as I_{dss}.

& When V_{gs} = -ve & V_{ds} positive voltage I_d current reduces from the previous value of I_d.

JFET as Amplifier:-

An amplifier is a device which transforms the signals from low resistance to high resistance region.

→ The resistors R_1 & R_2 behaves like potential divider

→ Resistance R_2 is the load resister coupled to source terminal through the capacitor C_2 and the input is applied at the gate terminal through capacitor C_1.

→ For the JFET (Junction field effect transistor) amplifier circuit output voltage is developed accross source resistance (R_s)

→ The source voltage (V_s) is given as

$$\boxed{V_s = V_G - V_{GS}}$$

where V_G → Gate voltage

V_{GS} → Gate Source voltage.

→ The Gate voltage (V_G) is derived from V_{DD} through potential divider R_1 & R_2.

→ The V_{GS} is assume to be constant.

→ When input signal is applied to the gate terminal through capacitor C_1 the gate voltage V_G increases or decreases in accordance with increase or decreases with input signal.

→ Hence the increases (or) decreases of output voltage V_s with changing V_i proves that JFET is an amplifier.

MOSFET :- (metal oxide Semiconductor field effect transistor)

→ A MOSFET is metal oxide Semiconductor field effect transistor

→ A p channel MOSFET consists of the two highly dopped P- regions as Source & drain.

→ Between these two a thin layer of SiO_2 is deposited on the Surface

→ If the gate voltage is made negative and n-type is grounded then due to capacitor action the Positive charges are induced near the Semi-conductor layer which generates an inversion layer.

→ As the negative gate voltage is increased the induced positive charges i.e; p-type carriers are restricted to enter into the channel diffused into the semi-conductor.

→ for an applied positive voltage between Source and drain the induced p-type carriers transmit current from source to drain.

→ Hence it is observed that for negative gate voltage the conductivity of induced channel increases which increases drain current

→ A graph is plotted between drain current (I_D) along y-axis and V_{DS} along x-axis keeping V_{GS} fixed

The above characteristic is called as drain charactristic

→ for the transfer characteristic a graph is plotted between I_D along Y-axis and V_{GS} along x-axis

Uni-Junction transistor (UJT):-

It is a three-terminal silicon diode.
As its name indicates, it has only one P-N junction.
It differs from an ordinary diode by having three terminals
like BJT it has 3 terminals but only one junction

The P-type is very close to the base 2

→ A bar of lightly doped n-type silicon material is taken. Two metal contacts attached to both ends acts as Base (B1) and Base (B2).

→ A P-type semiconductor is heavily doped on one side of the bar. A metal contact is made and it acts as emitter (E).

→ The emitter junction is placed such that it is more close to terminal Base 2 than Base 1.

→ The symbol of both UJT is shown where the arrow marks represent the direction in which current flow

UJT Equivalent circuit:-

* The equivalent circuit shows that the N-type channel consists of two resistors RB_2 and RB_1.
* A diode is connected between the resistors.
* Since junction is more close to B_2, $RB_2 < RB_1$
* $R_{BB} = RB_1 + RB_2$ is called Interbase Resistance.

Intrinsic standoff Ratio 'η'.

* The intrinsic standoff ratio is given by

$$\boxed{V_{RB_1} = \frac{R_{B1}}{R_{B1} + R_{B2}} \cdot V_{BB}}$$

Working of UJT

* When V_{BB} is applied with emitter open. A potential is established along the n-type silicon bar

→ As the emitter is located close to the base B_2, thus a major part of V_{BB} appears between the emitter and base B_1.

→ This voltage establishes a reverse bias condition and thus no emitter current is present and the device is in off state.

* When emitter is positive, the junction is reverse biased until $V_E < V_1$.

* When $V_E > V_1$, the junction becomes forward biased

* holes are released from p-region to n-type bar

* These holes are repelled by '+ve' terminal charge at B_2 and attracted towards B_1

* This results in decrease of resistance as well voltage drop.

* Thus emitter current increases.

* As more holes are released, a condition of saturation is reached.

Hence the device is in ON state.

Characteristic of UJT :

* A leatage currents exists during lower values of emitter voltage.
* Above certain value of V_E, the emitter current increases until the peak point 'P' is reached.
* After the point 'P', the current increases forcing the V_E to decrease.
* The negative resistance region ends at a point 'V'.
* After the valley the UJT enters into saturation region.

UJT - Application

UJT as Relaxation Oscillator

* Initially the charge across the capacitor is '0'.
* When the voltage V_s is applied, the capacitor begins to charge.
* As long as capacitor voltage is greater than the diode drop voltage, the device is 'ON'.
* Now the capacitor discharges due to low value of R_1 and thus enters into OFF state.

Silicon Controlled Rectifier (SCR)

* It is one of the prominent member of the thyristors family. It was introduced in 1956 by Bell Telephone laboratories

* It is a three terminal four layer or PNPN device. Basically, it is a rectifier with a control element

* It consists of three diodes connected back-to-back with a gate connection.

* It is widely used as a switching device in power control applications. It can control loads by switching current off and on up to many thousand times a second.

Basic symbol and construction of SCR

SCR as a switch

* The switching operation is one of the most important application of SCR. The SCR is often used as solid state relay and has more advantages than electromagnetic relays or switches as there are no moving parts in SCR.

* The above figure shows the application of SCR as a switch to ON and OFF the power supplied to the load. The AC power supplied to the load is controlled by applying alternate triggering pulses to the SCR. The resistors R_1 and R_2 protect the diodes D_1 and D_2 respectively. The resistor R limits the gate current flow.

* During the positive half cycle of the input, SCR_1 is forward biased and SCR_2 is reverse biased. If the switch S is closed, gate current is applied to the SCR_1 through diode D_1 and hence SCR_1 is turned on. Therefore, the current flows to the load through

SCR_1.

* Similarly, during the negative half cycle of the supply SCR_2 is forward biased and SCR_1 is reverse biased. If the switch s is closed, gate current flows to SCR_2 through diode D_2. Hence the SCR_2 is turned on and the load current flows through it.

* Therefore, by controlling the switch s the load current can be controlled at any desired position. It is observed that, this switch handles a few mill amp current to control the serveral hundred ampere current in the load. So, this method of switching is more advantageous than mechanical or electromechanical switching.

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Unit :- IV

Digital Electronics

* Number System :-

There are basically four types of number systems.

(i) Decimal System (0 to 9)

(ii) Binary System (0 or 1)

(iii) octal System (0 to 7)

(iv) Hexa decimal System (0 to 9, A, B, C, D, E, F)

Decimal Number System :-

The Decimal Number System contains ten digits i.e; (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) i.e; it has a base or redix of '10'

→ The charectaristic of any number system is

(i) Base or redix is equal to no. of digits in the system.

(ii) The largest value of digit is one less than the radix or base.

(iii) Each digit is multiplied by the base raised to appropriate power depending on digit position.

for eg:- $(8765)_{10} = 8\times10^3 + 7\times10^2 + 6\times10^1 + 5\times10^0$

in this example 5 → LSD → least Significant Digit

8 → MSD → Most Significant Digit

eg:- $(438.528)_{10} = 4\times10^2 + 3\times10^1 + 8\times10^0 + 5\times10^{-1} + 2\times10^{-2} + 8\times10^{-3}$

Binary Number System:-

In Binary Number System there are 2 digits 0 & 1 and has a base or radix 2.

The decimal number is converted to its binary equivalent by double-dabble method

→ In this method the decimal number is progressively divided by 2 writting down remender after each division.

→ The remenders are taken in reverse order from the binary number

for eg:- $(11)_{10} = (1011)_2$

2 | 11

2 | 5 → 1

2 | 2 → 1

1 → 0

$(9)_{10} = (1001)_2$

$$\begin{array}{r|l} 2 & 9 \\ \hline 2 & 4 \rightarrow 1 \\ \hline 2 & 2 \rightarrow 0 \\ \hline & 1 \rightarrow 0 \end{array}$$

$(6)_{10} = (110)_2$

$$\begin{array}{r|l} 2 & 6 \\ \hline 2 & 3 - 0 \\ \hline & 1 - 1 \end{array}$$

→ The decimal fraction numbers are converted to binary equivalent by multiplying the number continously by 2.

→ We have to record each time a carry in the integer position and it is recorded downwards

<u>for eg</u>:- $(0.435)_{10} = (0.11)_2$

$= 0.435 \times 2 = 0.870$ with a carry of 0

$0.870 \times 2 = 1.74$ with a carry of 1

$0.74 \times 2 = 1.48$ with a carry of 1

$0.48 \times 2 = 0.98$ with a carry of 0.

Convert $(100)_{10}$ to binary

$$
\begin{array}{r|l}
2 & 100 \\
2 & 50 - 0 \\
2 & 25 - 0 \\
2 & 12 - 1 \\
2 & 6 - 0 \\
2 & 3 - 0 \\
 & 1 - 1
\end{array}
$$

$(100)_{10} = (1100100)_2$

Convert $(100.4375)_{10}$ to binary

$0.4375 \times 2 = 0.875$ with a carry 0

$0.875 \times 2 = 1.75$ with a carry 1

$0.75 \times 2 = 1.5$ with a carry 1

$0.5 \times 2 = 1.0$ with a carry 1

$(0.4375)_{10} = (.0111)_2$

$(100.4375)_{10} = (1100100.0111)_2$

Binary to Decimal Conversion:-

The decimal equivalent of a binary number is obtained by multiplying the individual digits by the asciending power of 2 from right to left and adding them.

for eg:- $(1101)_2$

$$(1101)_2 = (1\times 2^3) + (1\times 2^2) + (0\times 2^1) + (1\times 2^0)$$

$$= 8 + 4 + 0 + 1$$

$$= (13)_{10}$$

→ To convert a binary fraction into decimal number system each digit in the fraction is succesively multiplied as $2^{-1}, 2^{-2}, 2^{-3} \ldots$ and then they are added.

for eg:- $(0.1011)_2$

$$= (1\times 2^{-1}) + (0\times 2^{-2}) + (1\times 2^{-3}) + (1\times 2^{-4})$$

$$= \frac{1}{2} + 0 + \frac{1}{8} + \frac{1}{16}$$

$$= \frac{8+2+1}{16}$$

$$= \frac{11}{16}$$

$$= (0.687)_{10}$$

Q) $(110111)_2$ to decimal

$$= (1\times2^{-1}) + (1\times2^{-2}) + (0\times2^{-3}) + (1\times2^{-4}) + (1\times2^{-5})$$

$$= \frac{1}{2} + \frac{1}{4} + 0 + \frac{1}{16} + \frac{1}{32} + \frac{1}{64}$$

$$= (1\times2^{5}) + (1\times2^{4}) + (0\times2^{3}) + (1\times2^{2}) + (1\times2^{1}) + (1\times2^{0})$$

$$= (55)_{10}$$

Q) $(0.101)_2$ to decimal

$$= (1\times2^{-1}) + (0\times2^{-2}) + (1\times2^{-3})$$

$$= \frac{1}{2} + 0 + \frac{1}{8}$$

$$= \frac{1+4}{8} = \frac{5}{8}$$

$$= (0.625)_{10}$$

Q) $(0.1100101)_2$ to decimal

$$= (1\times2^{-1}) + (1\times2^{-2}) + (0\times2^{-3}) + (0\times2^{-4}) + (1\times2^{-5}) + (0\times2^{-6}) + (1\times2^{-7})$$

$$= \frac{1}{2} + \frac{1}{4} + 0 + 0 + \frac{1}{32} + 0 + \frac{1}{128}$$

$$= \frac{64+32+4+0+1}{128}$$

$$= \frac{101}{128}$$

$$= (0.789)_{10}$$

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Binary Addition :-

The rules for binary additions are

(i) $0+0 = 0$

(ii) $0+1 = 1$

(iii) $1+0 = 1$

(iv) $1+1 = 0$ with carry of 1

Q1) Add $(110)_2$ and $(1011)_2$

$$\begin{array}{r} 110 \\ +\ 1011 \\ \hline 10001 \end{array}$$

Q2) Add $(11)_2$ and $(101)_2$

$$\begin{array}{r} 11 \\ 101 \\ \hline 1000 \end{array}$$

$(11)_2 \rightarrow$ Decimal

$(11)_2 = (1 \times 2^1) + (1 \times 2^0)$

$= 2 + 1$

$= 3$

$(101)_2 \rightarrow$ Decimal

$(101)_2 = (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$

$= 4 + 0 + 1$

$= 5$

$(1000)_2 \rightarrow$ Decimal

$(1000)_2 = (1 \times 2^3) + (0 \times 2^2) + (0 \times 2^1) + (0 \times 2^0)$

$= (8)_{10}$

③ Add $(110011)_2$ to $(101101)_2$

$$\begin{array}{r} 110011 \\ 101101 \\ \hline 1000000 \end{array}$$

$(110011)_2 \rightarrow$ Decimal

$$(110011)_2 = (1\times2^5) + (1\times2^4) + (0\times2^3) + (0\times2^2) + (1\times2^1) + (1\times2^0)$$

$$= 32 + 16 + 0 + 0 + 2 + 1$$

$$= (51)_{10}$$

$(101101)_2 \rightarrow$ Decimal

$$(101101)_2 = (1\times2^5) + (0\times2^4) + (1\times2^3) + (1\times2^2) + (0\times2^1) + (1\times2^0)$$

$$= 32 + 0 + 8 + 4 + 0 + 1$$

$$= (45)_{10}$$

$$(1100000)_2 = (1\times2^6) + (1\times2^5)$$

$$= 64 + 32$$

$$= (96)_{10}$$

(4) At binary numbers $(110)_2$ $(111)_2$ and $(101)_2$

$$\begin{array}{r} 110 \\ 111 \\ \hline 1101 \end{array} \qquad \begin{array}{r} 110 \\ 101 \\ \hline \end{array} \qquad \begin{array}{r} 101 \\ 101 \\ \hline 10010 \end{array}$$

$(110)_2 \rightarrow$ Decimal

$$(110)_2 = (1\times 2^2) + (1\times 2^1) + (0\times 2^0)$$

$$= 4 + 2$$

$$= 6$$

$$(111)_2 = (1\times 2^2) + (1\times 2^1) + (1\times 2^0)$$

$$= 4 + 2 + 1$$

$$= 7$$

$$(101)_2 = (1\times 2^2) + (0\times 2^1) + (1\times 2^0)$$

$$= 4 + 1$$

$$= 5$$

$$(10010)_2 = (1\times 2^4) + (0\times 2^3) + (0\times 2^2) + (1\times 2^1) + (0\times 2$$

$$= 16 + 2$$

$$= (18)_{10}$$

Binary Subtraction:-

The rules for binary subtraction

(i) $0 - 0 = 0$ → No borrowing

(ii) $1 - 0 = 0$ → No borrowing

(iii) $1 - 1 = 0$ → No borrowing

(iv) $0 - 1 = 1$ → with a borrowing of 1 from next higher coloumn

(i) Subtract $(1101)_2$ and $(1010)_2$

$$\begin{array}{r} 1101 \\ 1010 \\ \hline \end{array}$$

$(1101)_2$ → Decimal

$(1101)_2 = (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$

$= 8 + 4 + 0 + 1$

$= 13$

$(1010)_2$ → Decimal

$(1010)_2 = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (0 \times 2^0)$

$= 8 + 0 + 2 + 0$

$= 10$

$$\begin{array}{r} 1101 \\ -\ 1010 \\ \hline 0011 \end{array}$$

$(0011)_2 \rightarrow$ Decimal.

$$(0011)_2 = (0 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$$

$$= 2 + 1$$

$$= 3$$

1's Complemental Subtraction:-

1's Complement:-

It is also called as radix - minus - one complement.

→ The 1's complement of a binary number is obtained by changing 0 to 1 and 1 to 0.

→ for eg:- 1's complement of $(1101)_2 = (0010)_2$

2's Complement:-

The 2's complement of a binary number is

obtained by adding 1 to its 2's complement.

for eg:

$(1101)_2 = (0010)$

$$\begin{array}{r} 0010 \\ 1 \\ \hline 0011 \end{array}$$

$(0011)_2$

hexa decimal Number System:-

The meaning of hexa decimal is 16. It has base or radix of 16.

→ The hexa decimal Number are given as

(0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

A → 10

B → 11

C → 12

D → 13

E → 14

F → 15

Convert $(3A45)_{16}$ into decimal Number.

$$(3A45)_{16} = (3\times(16)^3) + (10\times(16)^2) + (4\times(16)^1) + (5\times(16)^0)$$

$$= 12,288 + 2,560 + 64 + 5$$

$$= (14917)_{10}$$

Convert $(56BE)_{16}$

$$(56BE)_{16} = (5\times(16)^3) + (6\times(16)^2) + (11\times(16)^1) + (14\times(16)^0)$$

$$= 20,480 + 1,536 + 176 + 14$$

$$= (22206)_{10}$$

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Convertion of decimal Number into hexadecimal Number

To Convert a ~~hexa~~ decimal Number into hexa decimal Number a decimal Number is divided by 16 and the reminders are Converted to hexa decimal Notations.

for eg:- Convert $(5000)_{10}$ to hexadecimal Number

$$
\begin{array}{r|l}
16 & 5000 \\
\hline
16 & 312 - 8 \\
\hline
16 & 19 - 8 \\
\hline
 & 1 - 3
\end{array}
$$

$(5000)_{10} = (1388)_{16}$

Convert $(2047)_{10}$ to hexa decimal Number.

$$
\begin{array}{r|l}
16 & 2047 \\
\hline
16 & 127 - 15 \\
\hline
 & 7 - 15
\end{array}
$$

$(2047)_{10} = (7FF)_{16}$

Converstion of binary Number into hexadecimal Number

To Convert a binary Number into hexadecimal Number the binary Number is split into 4 bit groups. The hexadecimal values corresponding to binary Numbers are

Binary	Hexa decimal
0000	0
0001	1
0010	2

0011	3
0100	4
0101	5
0110	6
0111	7

Convert $(10\ 1101\ 0111\ 1011)_2$ into hexadecimal

$(0010)_2 \rightarrow 2 \rightarrow$ Hexadecimal

$(1101)_2$

$(1\times2^3) + (1\times2^2) + (0\times2^1) + (1\times2^0)$

$8+4+1$

$13 \rightarrow D \rightarrow$ Hexadecimal

$(0111)_2 \rightarrow 7 \rightarrow$ Hexadecimal

$(1011)_2$

$(1\times2^3) + (0\times2^2) + (1\times2^1) + (1\times2^0)$

$8+2+1$

$11 \rightarrow B \rightarrow$ Hexadecimal

$\Rightarrow (207B)_{16}$

Convert $(1110\ 1001\ 1111)_2$ into hexadecimal.

$(1110)_2$

$(1\times2^3)+(1\times2^2)+(1\times2^1)+(0\times2^0)$

$8+4+2$

$14 \rightarrow E \rightarrow$ Hexadecimal

$(1001)_2$

$(1\times2^3)+(0\times2^2)+(0\times2^1)+(1\times2^0)$

$8+1$

$9 \rightarrow$ Hexadecimal

$(1111)_2$

$(1\times2^3)+(1\times2^2)+(1\times2^1)+(1\times2^0)$

$8+4+2+1$

$15 \rightarrow f \rightarrow$ Hexadecimal

$\Rightarrow (E9F)_{16}$

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Logic Gates :-

Gate is a digital circuite with one or more input voltage but only one output voltage.

→ The basic logic gates are "AND, OR, NOT"

"OR" Gate :-

An "OR" gate has two or more input signals but only one output signal

→ In "OR" gate the output voltage is high if either or both the inputes are high

Symbol :-

for the two inputes A & B the output is given as $Y = A + B$

Truth table

A	B	Y=A+B
0	0	0
1	0	1
0	1	1
1	1	1

OR gate using discrete elements:-

→ If A = 0 and B = 0 then both the diodes D_1 & D_2 are non-conducting and hence output y = 0

→ If A = 0 and B = 1 then the diode D_2 is conducting and D_1 is non-conducting and hence output y = 1

→ If A = 1 and B = 0 then the diode D_1 is conducting and diode D_2 is non-conducting. hence output y = 1

→ If A = 1 and B = 1 then ~~the~~ both the diodes D_1 and D_2 are conducting. hence output y = 1

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AND Gate :-

The "AND" gate is a circuit which provides an output when all the inputs are simultaneously high

Symbol

Truth table

A	B	Y = AB
0	0	0
1	0	0
0	1	0
1	1	1

Electronic Diagram :-

If both the inputs A & B are on then the output is obtained and if either of the input is off then their is no current passes and the output is zero.

AND gate using discrete elements :-

→ When A & B are zero, both the diodes D_1 & D_2 are forward bias and hence the whole V_{cc} will be accross the load resistance and output is zero

Case 2 :- When A is zero and B is high then diode D_1 is grounded and diode D_2 is reverse bias and diode D_2 will not conduct. diode D_1 is forward bias and hence output is zero.

Case 3 :- When A is high and B is zero then in diode case this case the output is short circuited due to diode D_2 and hence output is zero.

Case 4 :- When A & B are high then both the diodes are in reverse bias and they do not conduct and hence the output is equal to high i.e; $\boxed{V_{cc} = +5V}$

NOT Gate :-

"NOT" gate has only one input and one output. The output of "NOT" gate is always opposite to the input state.

→ Hence the "NOT" gate is also called as inverter

Electronic Diagram

When the input A is high i.e; the switch is closed then their is no output and if the switch A is glow then the bulb will glow and then their will be output.

Truth table :-

A	$Y = \bar{A}$
0	1
1	0

NOT using Discrite elements :-

→ If V_{in} is low i.e, base voltage is not present and therefore transistor is in cutoff state and therefore V_{op} → high

→ When the V_{in} is high the transistor is in active state and the output is low.