BE 3251 Basic Electrical & Electronics Engineering

UNIT-I Electrical Circuits

DC circuits - circuit components : conductor, Resistor, Inductor, capacitor - Ohm's Law - Kirchhoff's Laws - Independent and Dependent sources - simple Problems - Nodal Analysis, Mesh Analysis with Independent sources only (Steady state)

Introduction to AC circuits and Parameters, waveforms, Average value, RMS value, Instantaneous Power, real power, reactive power and apparent Power, Power factor - Steady state Analysis of RLC circuits (simple problems only).

DC circuits - Basic circuit components.

* Resistor
* capacitor
* Inductor

conductor

* Some materials allow electric charges to pass through them easily, these materials are called conductors.
* Materials that do not allow electric charges to pass through them easily are called Insulators.

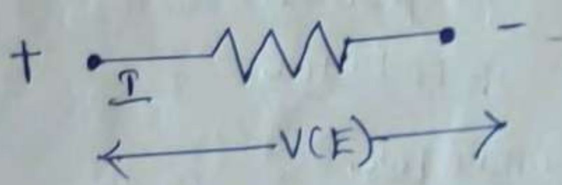
Network (Electrical circuit)

Active Elements.	Passive elements
① which supply power or energy to the network.	- Elements which either store energy or dissipate energy in the form of heat.
② Ex: Voltage source & Current source	- Ex : Resistor, capacitor Inductors.

Resistor

* Electrical component which opposes the flow of current through it. Unit of Resistance is ohm (Ω). It is denoted by R.

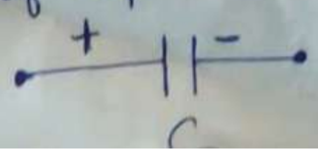
$$R = \frac{V}{I} \text{ ohm}$$



Capacitor

* Capacitor is a storage element which can store & deliver energy in a electric field.

* It is denoted by C.
* The unit of capacitence is Farad (F).



Ohm's Law

This Law gives relationship between the Voltage (V), Current (I) and resistance (R) of a d.c circuit. It states that

> At constant temperature, the current flowing through the conductor is directly proportional to the voltage across the conductor.
>
> $$V(t) \propto I(t)$$
>
> $$V(t) = R I(t)$$
>
> where R is the proportionality constant i.e, Resistance of the conductor.

The power absorbed by the resistor is,

$$P(t) = V(t) \cdot i(t)$$

$$= i^2(t) \cdot R$$

$$P(t) = \frac{V^2(t)}{R} \quad \left[\because V(t) = i(t) \cdot R\right]$$

Limitations of Ohm's Law

1. Ohm's Law cannot be applied to non-metallic conductor.
2. It cannot be applied to non-linear devices such as zener diode, Voltage Regulator, etc

3. Ohm's Law holds good only for constant temperature. If the temperature changes, the Law cannot be applied.

Electrical Energy.

Energy is the total amount of workdone and home is the product of power & time.

$$W = pt = V \cdot It$$

$$= I^2Rt \text{ Joules.}$$

$$= \frac{V^2}{R} t \text{ Joules (or) Watt sec.}$$

PROBLEMS

A resistor with a current of 3A through it converts 500J of electrical energy into heat energy in 12 sec. What is the voltage across resistor?

Solution

$$\text{Energy} = V \cdot I \cdot t$$

$$500 = V \times 3 \times 12$$

$$V = \frac{500}{3 \times 12}$$

$$\boxed{V = 13.88V}$$

A 5 Ω resistor has a voltage rating of 100 V, what is the power rating?

Solution

$$Power = \frac{V^2}{R} = \frac{100^2}{5}$$

$$\boxed{P = 2000 W}$$

An electric heater draws 8 A from 250 V. What is its power rating? Also find the resistance of the heater element.

Solution.

$I = 8A$

$V = 250 V$

$P = ?$

$R = ?$

$P = V \cdot I = 250 \times 8$

$$\boxed{P = 2000 W}$$

$$R = \frac{V}{I} = \frac{250}{8}$$

$$\boxed{R = 31.25 \Omega}$$

If 50 J of energy is available for 20 C of charge, what is the voltage?

given $W = 50 J$, $Q = 20 C$

n $$V = \frac{W}{Q} = \frac{50}{20}$$ $$\boxed{V = 2.5 V}$$

Kirchoff's Law.

In 1847, a German Physicist, Kirchoff. Formulated two fundamental laws of electricity. These laws are of tremendous importance from network simplification view point.

* Kirchoff's current Law (KCL)
* Kirchoff's voltage Law (KVL)

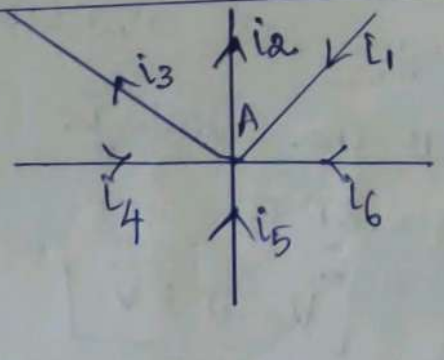
Kirchoff's Current Law (KCL)

Kirchoff's First law or current Law states that.

The sum of the currents Flowing towards a Junction is equal to the sum of the currents flowing away from it.

(or)

Algebraic sum of all currents in a node is zero.



Here, A is a Junction (or node) formed by six conductor, According to KCL,

$$i_1 + i_4 + i_5 + i_6 = i_2 + i_3$$

flowing towards A = flowing away from A

Also, $i_1 - i_2 - i_3 + i_4 + i_5 + i_6 = 0$.

By taking the currents entering the Jn. as Positive and those ~~following~~ Flowing away from the Jn as negative

<u>Note:</u>

For passive elements R, L & C the terminal where the current enters is treated as Positive with respect to the terminal where the current leaves.

<u>Steps to apply Kirchoff's Laws</u>

<u>Step 1:</u> Draw the circuit diagram and write all the values of sources and resistances.

<u>Step 2:</u> Mark all the branch currents. Keep the no. of unknown currents minimum as far as possible.

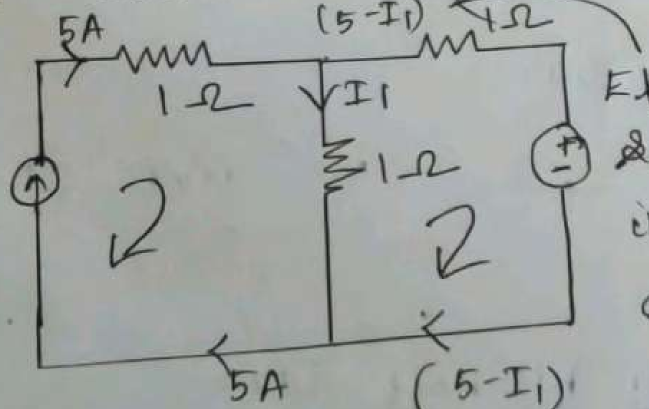
Step 3: Mark the Polarities of all the resistances as per the direction of the branch current.

Step 4: Apply KVL to different closed path in the n/w and obtain the equations

step 5: Solve the equations for the unknown currents.

Note: While applying KVL, the loops should not be considered involving current source. Because drop across current source is unknown. But current distribution from the current source can be considered.

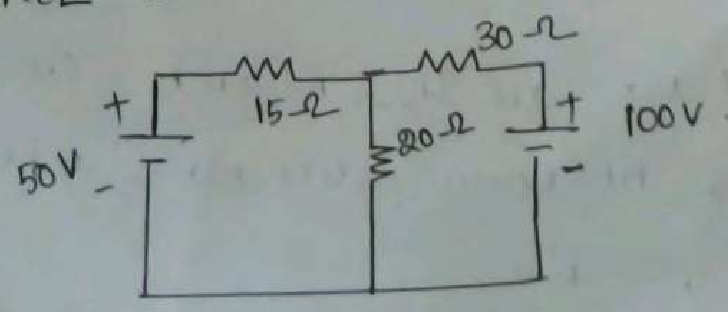
This loop cannot be considered for KVL 5A



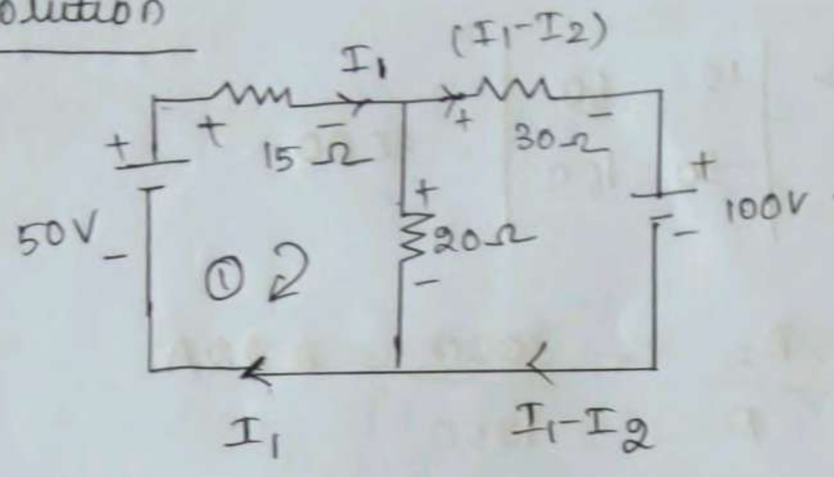
Effect of current source is considered interms of current distribution

Problem

1. Apply KCL and KVL to the circuit given below



solution



Apply KVL to loop 1,

$$-15 I_1 - 20 I_2 + 50 = 0$$

$$15 I_1 + 20 I_2 = 50 \quad \text{——— (1)}$$

Apply KVL to loop 2,

$$-30 (I_1 - I_2) - 100 + 20 I_2 = 0$$

$$-30 I_1 + 30 I_2 - 100 + 20 I_2 = 0$$

$$-30 I_1 + 50 I_2 = 100 \quad \text{——— (2)}$$

Apply Cramer's Rule.

$$D = \begin{vmatrix} 15 & 20 \\ -30 & 50 \end{vmatrix} = 1350$$

$$D_1 = \begin{vmatrix} 50 & 20 \\ 100 & 50 \end{vmatrix} = 500$$

$$I_1 = \frac{D_1}{D} = \frac{500}{1350} = 0.37\text{A}$$

$$D_2 = \begin{vmatrix} 15 & 50 \\ -30 & 100 \end{vmatrix} = 3000$$

$$I_2 = \frac{D_2}{D} = \frac{3000}{1350} = 2.22A$$

for I_1 and I_2 answer is positive and hence assume direction is correct.

$$I_1 - I_2 = 0.37 - 2.22$$

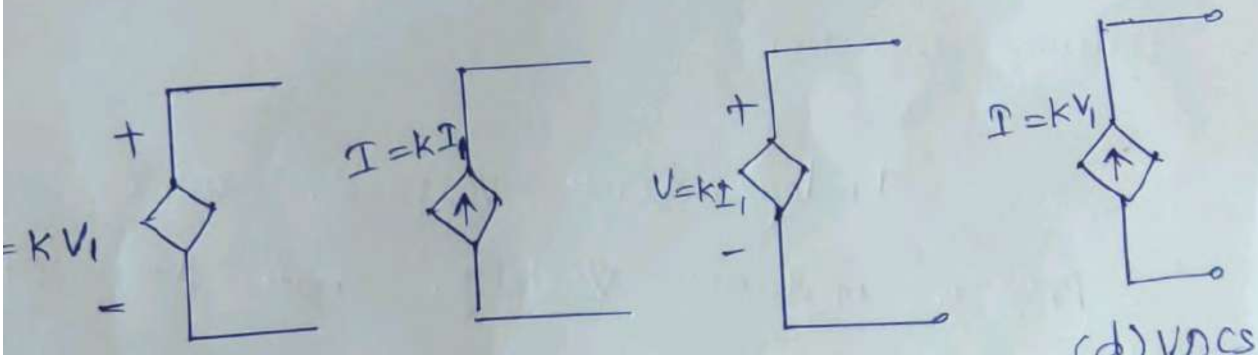
$$= -1.85A$$

Negative sign indicates assumed direction is wrong. i.e $I_1 - I_2 = 1.85A$ flows in the opposite direction to that of the assumed direction.

Dependent sources

Dependent sources are those whose value of source depends on voltage or current in the circuit. Such sources are indicated by diamond and further classified as,

(a) voltage dependent voltage source (VDVS)
(b) current dependent current source (CDCS)
(c) current dependent voltage source (CDVS)
(d) voltage dependent current source (VDVS)



(a) VDVS (b) CDCS (d) VDCS

K is constant and V_1 and I_1 are the voltage and current respectively, present elsewhere in the given circuit.

The dependent sources are also known as controlled sources.

Independent sources

Independent sources are that which does not depend on any other quantity in the circuit.

They are two-terminal devices and has a constant value.

ie, the voltage across the two terminals remains constant irrespective of all circuit conditions.

Independent voltage sources supply a constant voltage that does not depend on any other quantity within the circuit.

Ex : Batteries, DC generators or time-varying AC voltage supplies from alternators.

Branch current Method.

In branch current Method a current is assigned to each branch in an active n/w. Then KCL is applied at the principal nodes and the voltages b/w the nodes employed to relate the currents. This produces the equations which can be solved to obtain the currents.

Mesh current Method (or) Mesh Analysis (or) loop Analysis

This method of analysis is specially used for the circuits that have many nodes and loops. The difference b/w application of kirchoff's laws and loop analysis is, in loop analysis instead of branch currents, the loop currents are considered for writing the equations. Here each branch of the n/w may carry more than one current. The total current must be decided by the algebraic sum of all currents through that branch.

Mesh Equations by Inspection Method.

The procedure for writing the mesh equation in matrix form can be simplified as follows.

① convert current source into equivalent voltage source by source Transformation

② All the resistance through which I_1 flows are summed up and denoted by R_{11}. It is called self resistance of loop 1.

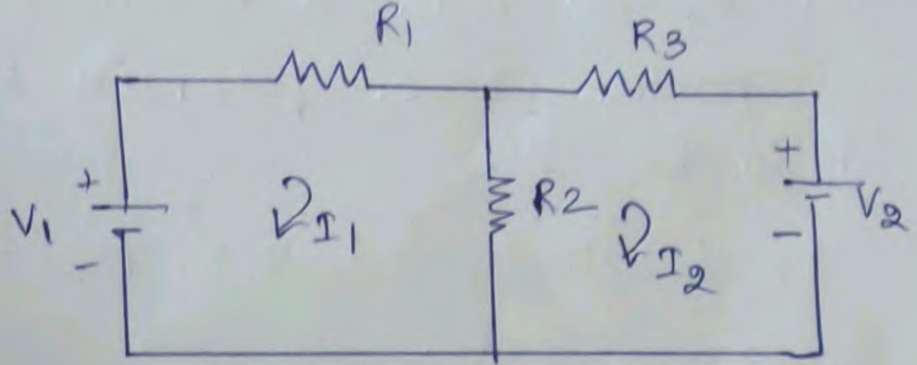
③ R_{12} is the mutual resistance through which loop currents I_1 in the first loop and I_2 in the second loop flows. The sign of R_{12} is negative if two currents I_1 and I_2 flow in opposite direction, otherwise the sign is positive.

④ Let V_1 be the effective voltage on the first loop through which the loop current I_1 flows. It is written on the right hand side of the equation. zero is written if there is no source.

The general matrix form of mesh equation is

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{12} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Example



By using inspection method the matrix form is

$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2 & R_2+R_3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ -V_2 \end{bmatrix}$$

$$\left.\begin{aligned} R_{11} &= R_1+R_2 \\ R_{22} &= R_2+R_3 \end{aligned}\right\} \text{self resistances}$$

$R_{12} = R_{21} = -R_2 \rightarrow$ mutual resistance.

Nodal Analysis or Node Voltage Method.

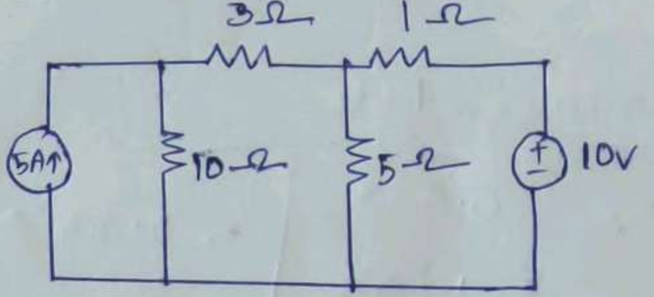
This Method is mainly based on Kirchoff's current law (KCL). This method uses the analysis of the different nodes of the n/w. Every jn. point in a n/w, where two or more branches meet is called a node. One of the node is assumed as reference node whose potential is assumed to be zero.

It is also called zero potential node or datum node. At other nodes the different voltages are to be measured with respect to this reference node.

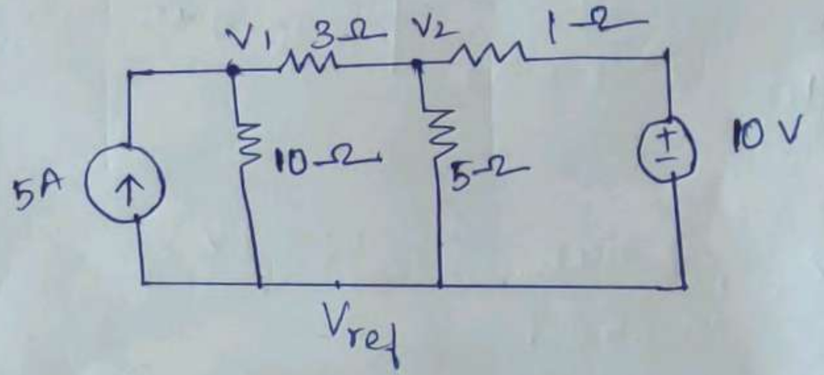
The advantage of this method lies in the fact that we get (n-1) equations to solve if there are 'n' nodes. This reduces calculation.

Problem.

Write the node voltage equation and determine the currents in each branch for the gn n/w.



Solution



(Base or reference node).

Apply KCL at node 1,

$$5 = \frac{V_1}{10} + \frac{V_1 - V_2}{3}$$

$$V_1\left(\frac{1}{10} + \frac{1}{3}\right) - V_2\left(\frac{1}{3}\right) = 5$$

Apply KCL at node 2,

$$\left(\frac{V_2 - V_1}{3}\right) + \left(\frac{V_2}{5}\right) + \frac{V_2 - 10}{1} = 0$$

$$-V_1\left(\frac{1}{3}\right) + V_2\left(\frac{1}{3}+\frac{1}{5}+1\right) = 10.$$

The matrix form is,

$$\begin{bmatrix} 0.433 & -0.333 \\ -0.333 & 1.533 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 10 \end{bmatrix}$$

By using Cramer's Rule,

$$\Delta = \begin{vmatrix} 0.433 & -0.333 \\ -0.333 & 1.533 \end{vmatrix} = 0.5529$$

$$\Delta V_1 = \begin{vmatrix} 5 & -0.333 \\ 10 & 1.533 \end{vmatrix} = 10.995$$

$$V_1 = \frac{\Delta V_1}{\Delta} = \frac{10.995}{0.5529} = 19.89\,V$$

$$\Delta V_2 = \begin{vmatrix} 0.433 & 5 \\ -0.333 & 10 \end{vmatrix} = 5.98$$

$$V_2 = \frac{\Delta V_2}{\Delta} = \frac{5.98}{0.5529} = 10.82\,V$$

current through 10Ω resistor $= \frac{V_1}{10} = 1.989\,A$

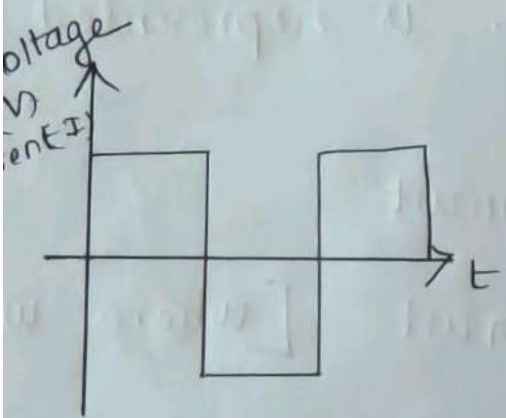
current through 3Ω resistor $= \frac{V_1 - V_2}{3} = 3.02\,A$.

current through 5Ω resistor $= \frac{V_2}{5} = 2.16\,A$

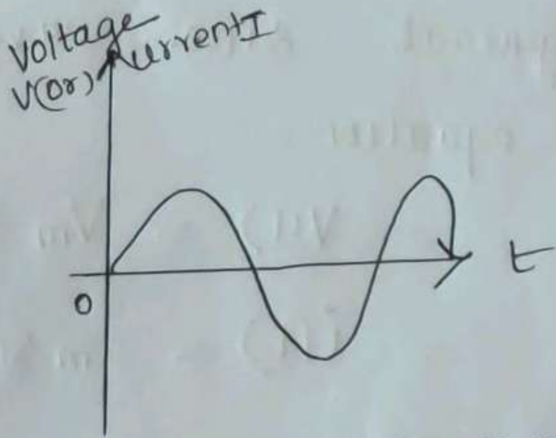
Current through 1Ω resistor $= \frac{V_2 - 10}{1} = 0.82\,A$

Introduction to AC circuit

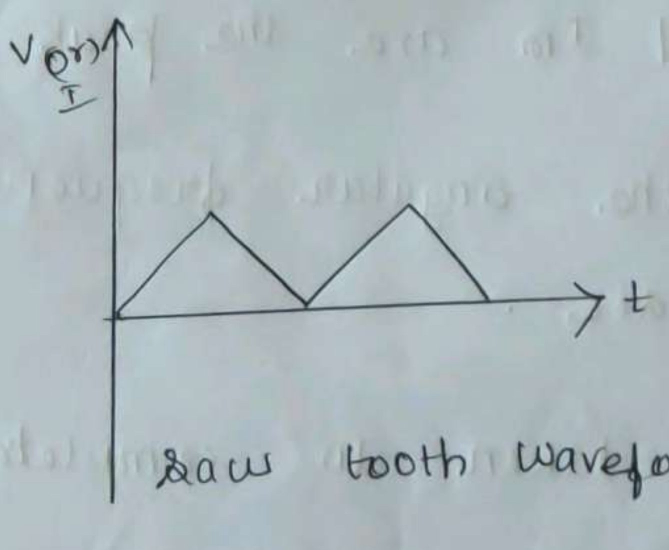
Alternating current and voltage sources are widely used in practical. The AC source gives a voltage (or current) that varies with time. The voltage changes not only in magnitude but also in direction.



square waveform



sinusoidal waveform.



saw tooth waveform.

Various shapes of alternating waveforms are shown in figure. sinusoidal waveform is more useful than other waveforms due to the reason that the response of any second order system is sinusoid in nature. The amplitude is represented by voltage or current on vertical axis and angular measurement in degrees or radians is represented on horizontal axis.

In general sine wave is represented by the equation,

$$V(t) = V_m \sin \omega t$$

$$i(t) = I_m \sin \omega t \quad [\text{where } \omega = 2\pi f)$$

where $V(t)$ and $i(t)$ are instantaneous values

V_m and I_m are the peak values

ω is the angular frequency in radians per sec.

The time taken to complete one cycle (or the time interval, T after which the waveform repeats itself) is called the time period of the quantity. The number of such cycles occuring

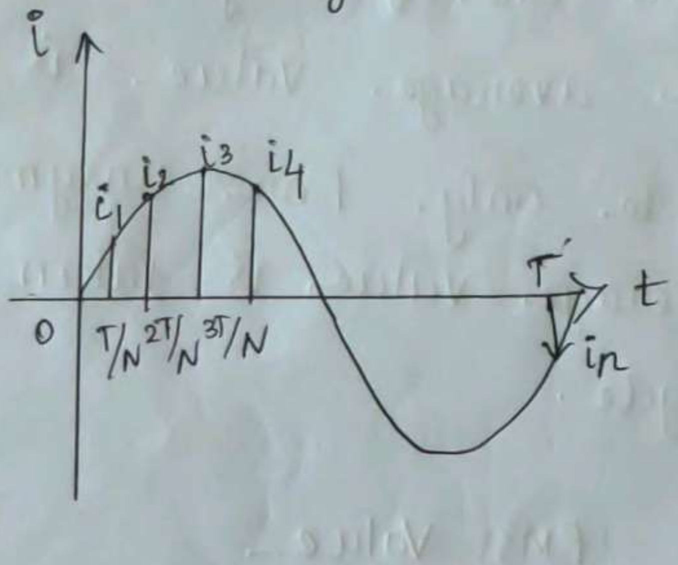
Per second is called frequency, f. Hence

$$f = \frac{1}{T} \text{ Hz} \qquad \text{Hz} \rightarrow \text{Hertz}$$

The maximum value, positive or negative of the alternating quantity is called its amplitude.

Average Value.

Since the alternating quantity is a function of time, it becomes difficult to specify the quantity. Hence one of the way of doing it is to specify an average value



The average value is

$$I_{av} = \frac{i_1 + i_2 + i_3 + i_4 + \cdots i_N}{N}$$

A better way to find the average value is integrate over a period and find the area under it and divide by T. Hence,

$$I_{av} = \frac{1}{T}\int_0^T i\,dt$$

$$\text{Average value} = \frac{\text{Area under the curve over one complete cycle}}{\text{Time Period.}}$$

For symmetrical waves the average value over one full cycle is zero and hence the average value is taken over half a cycle only. For unsymmetrical wave, average value is taken over the complete cycle.

Effective (RMS) Value

When a current passes through a resistor, he is produced irrespective of the direction of current flow. The heat produced by an alternating current of maximum value say I_m will not be equal to the heat produced by DC of I_m amperes. The effective value of an alternating current is that value of steady direct current which produce the same heat as that produced by the alternating current (AC) when passed through the same resistor for the same interval of time.

If $i(t)$ is the time varying current passed through a resistor of R ohms, then for a small interval of time, dt secs, the heat produced dH is equal to

$$dH = i^2(t)\, R\, dt$$

Over one complete cycle,

$$H = \int_0^T i^2(t)\, R\, dt$$

If this heat is equal to that produced by a steady DC of I amperes passed through R for T secs, then

$$I^2RT = \int_0^T i^2(t)R\,dt$$

$$I^2 = \frac{1}{T}\int_0^T i^2(t)\,dt$$

If $I = I_{eff}$ = RMS current

$$I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$$

RMS → Root Mean Square Value

The RMS value of a wave may also be found by finding the area under squared curve.

$$\text{RMS Value} = \sqrt{\frac{\text{Area of squared curve for one cycle}}{\text{Time period}}}$$

$$\text{RMS Value} = \sqrt{\frac{i_1^2 + i_2^2 + \ldots i_N^2}{N}}$$

Where i → instantaneous value

Form Factor and Crest Factor

Form factor is defined as the ratio between RMS Value and average Value.

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average value}}$$

Crest or peak factor is defined as the ratio between maximum value and RMS value.

$$\text{Crest (peak) factor} = \frac{\text{Maximum Value}}{\text{RMS value}}$$

Note

Sinusoidal voltage and current is

$e = E_m \sin\omega t$ (or) $V = V_m \sin\omega t$

$i = I_m \sin\omega t$

where $\omega = 2\pi f$

$$f = \frac{\omega}{2\pi} = \frac{1}{T}$$

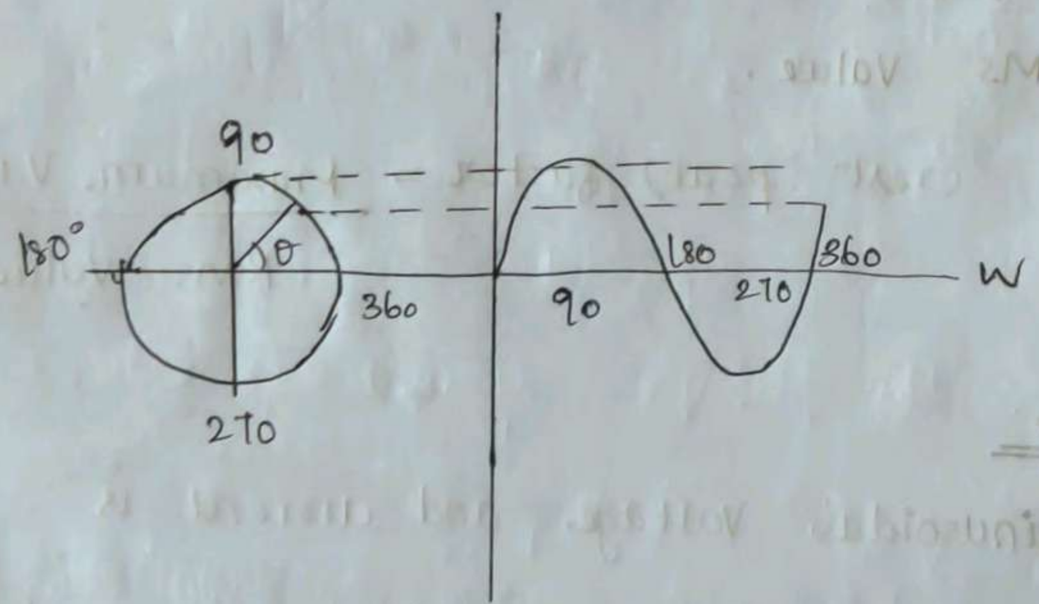
RMS Value

$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

$$V_{RMS} = \frac{V_m}{\sqrt{2}}$$

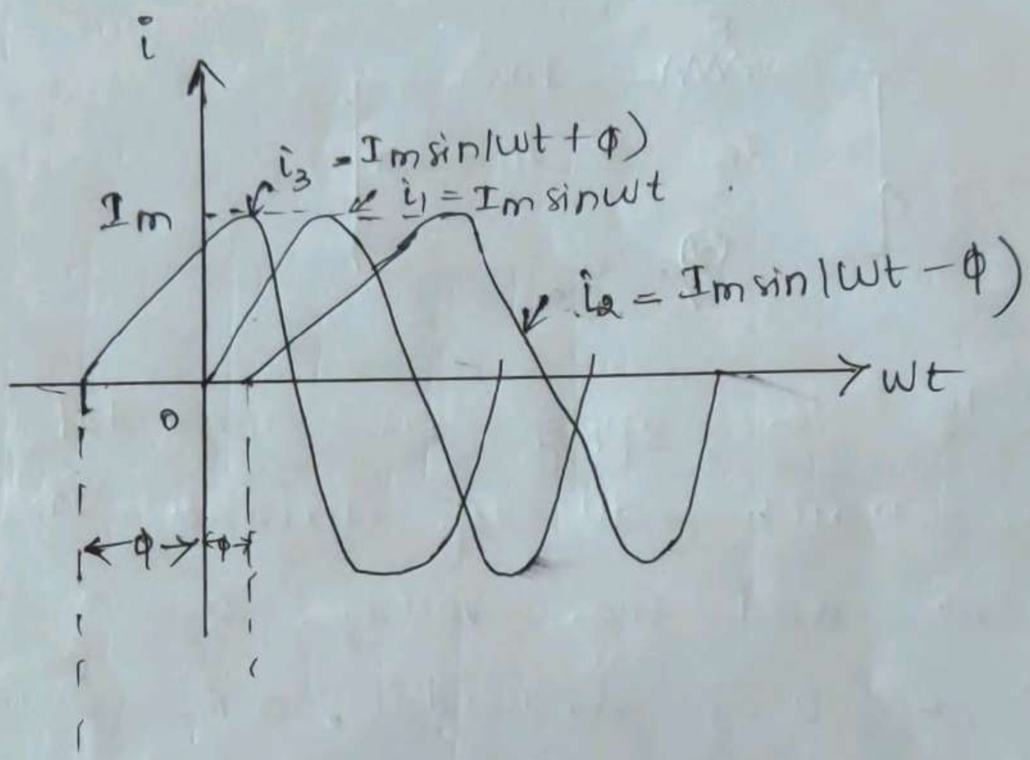
Phasor Diagram Representation

An alternating quantity (voltage or current) is a vector quantity. since the instantaneous values are continuously changing, it must be represented by a vector or phasor. A vector is a phasor that is rotating at a constant angular velocity.



The length of the arrow represents the magnitude of the sine wave and angle θ represents the angular position of the sinewave.

Phase and Phase Difference.



Here i_1, i_2 and i_3 are sinusoidally varying with same peak value and frequency. They donot reach the maximum and minimum at the sametime.

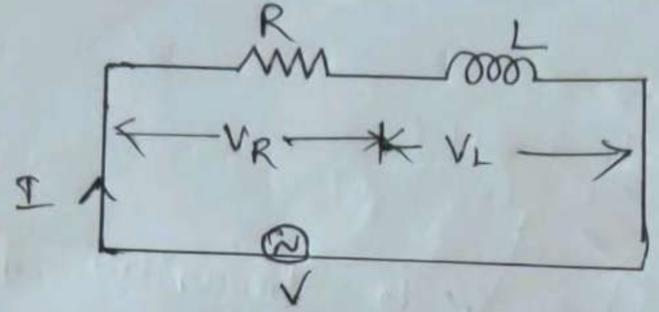
The current i_1 leads i_2 by ϕ degrees or i_2 lags behind i_1 by ϕ.
Also, i_3 leads by ϕ degrees and i_1 lags by ϕ degrees.

Sinusoidal Steady State Analysis

RL series circuit

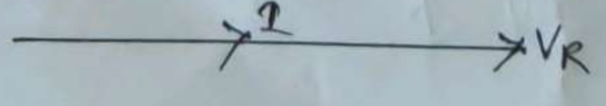
consider a circuit containing

resistance and inductance connected in series.

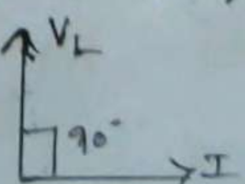


If we apply a sinusoidal input to RL circuit, all the currents in the element and the voltage across the element are sinusoidal, on Analyzing the RL series circuit, we can find the impedance, current, phase angle and voltage drop.

The voltage across resistance (V_R) and current (I) are in phase with each other

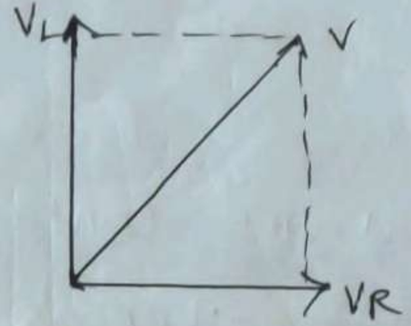


While considering inductor current I is said to be lagging with 90° with respect to V_L



combining the two figures we can get Phasor diagram for RL series circuit.

It is as follows:



$V_L \rightarrow$ Voltage drop across inductance

$V_R \rightarrow$ voltage drop across resistance

$V \rightarrow$ source voltage.

In RL circuit.

Impedance $Z = R + jX_L = \sqrt{R^2 + X_L^2}$

where X_L = inductive reactance

$X_L = 2\pi f L$

source voltage V is the phasor sum of $V_R + V_L$.

i.e., $V = \sqrt{V_R^2 + V_L^2}$

Phase angle, $\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$

$= \tan^{-1}\left(\frac{V_L}{V_R}\right)$

Power factor, $P.f = \cos\theta \text{ (lag)} = \frac{R}{Z}$

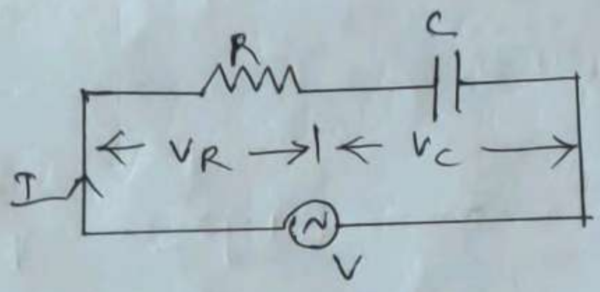
Apparent power $S = V \cdot I$

Real power $P = VI\cos\theta = S\cos\theta$

Reactive power $\theta = VI\sin\theta = S\sin\theta$

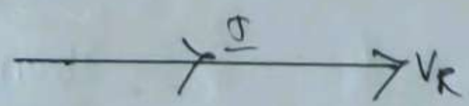
RC series circuit

Consider a circuit containing resistance and capacitence connected in series

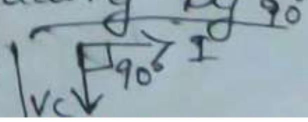


When a sinusoidal voltage is applied to RC series circuit the current in the circuit and voltage are sinusoidal.

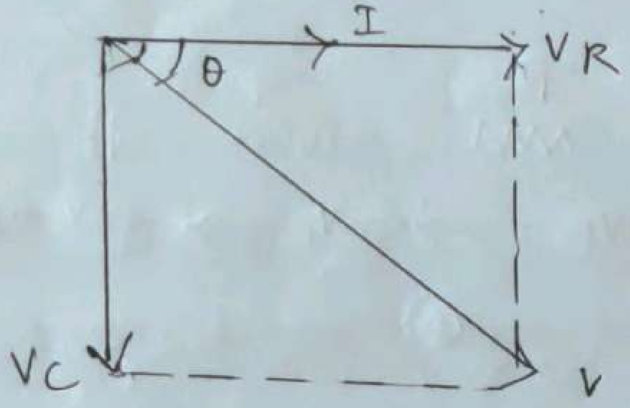
While considering resistor alone, V_R and I are in phase and is as shown



While considering capacitor alone current I is said to be leading by 90° with respect to V_C. It is as shown



combining the two figures we get the Phasor diagram for RC series circuit. It is as follows.



In RC circuit,

Impedance $Z = R + (-jX_C) = \sqrt{R^2 + X_C^2}$

Where X_C = capacitive reactance.

$$X_C = \frac{1}{2\pi f c}$$

source voltage is given by

$$V = \sqrt{V_R^2 + V_C^2}$$

Phase angle $\theta = \tan^{-1} \frac{V_C}{V_R} = \tan^{-1} \frac{X_C}{R}$ (load)

Power factor, $Pf = \cos\theta = \frac{R}{Z}$

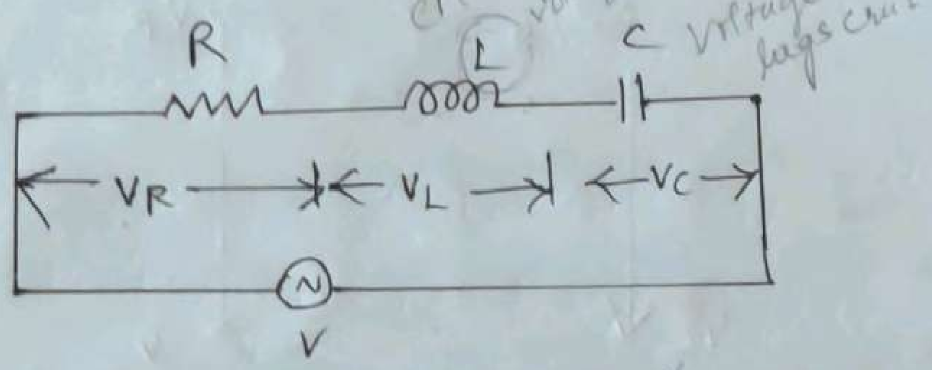
Apparent power, $S = VI$

Real power, $P = VI\cos\theta$

Reactive power, $Q = VI\sin\theta$

RLC series circuit

Consider a circuit containing resistance, inductance and capacitance connected in series.



In RLC circuit,

Impedance $Z = R + jX_L - jX_C$

$= R + j(X_L - X_C)$

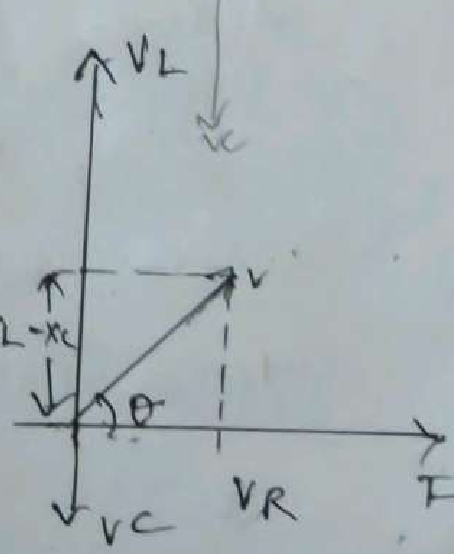
$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$

Source voltage V is given by,

$V = IR + jIX_L - jIX_C$

$= I\{R + j(X_L - X_C)\}$

$V = \sqrt{V_R^2 + (V_L - V_C)^2}$



Phase angle, $\theta = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

Power factor $P.f = \cos\theta = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

Apparent power, $S = V \cdot I$

Real power, $P = VI\cos\theta$

Reactive power, $Q = VI\sin\theta$

Apparent power, Reactive power and factor

Apparent power is the product of rms values of applied voltage and circuit current. the unit is volt-ampere (VA)

$$S = VI$$

The Power absorbed by a pure inductive reactance (X_L) in an a.c circuit is called reactive power. The unit is VAR

$$Q = I\sin\theta$$

Power factor is the cosine of the Phase angle between voltage and current.

$$P.f = \cos\theta = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{Z}$$

$$\cos\theta = \frac{\text{Real power}}{\text{Apparent Power}}$$

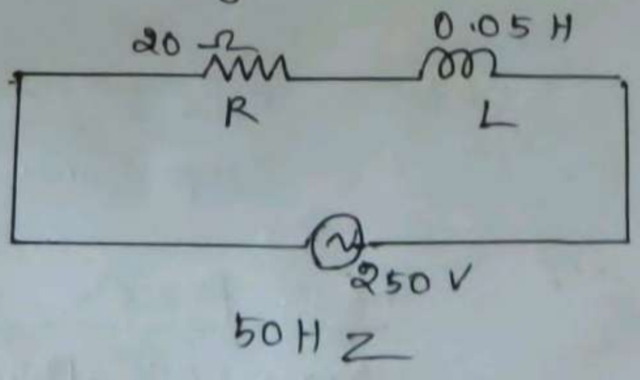
Power factor varies from 0 to 1.

For purely resistive circuits, phase angle between voltage and current is zero and P_f is unity.

In RC ckt Pf is referred as leading power factor because the current leads the voltage. In RL ckt, P.f is referred as lagging p-f. because the current lags behind the voltage.

Problem

A series R-L circuit has R = 20 Ω and L = 0.05 H and is connected to 250 V 50 cycle source. Calculate (a) the impedance (b) current (c) power factor (d) draw the phasor diagram.



Solution

(a) Impedance, $Z = R + jX_L$

$X_L = 2\pi f L = 2\pi \times 50 \times 0.05$

$= 15.708\ \Omega$

$Z = 20 + j15.708$

$$Z = 25.43\ \angle 38.15^\circ\ \Omega$$

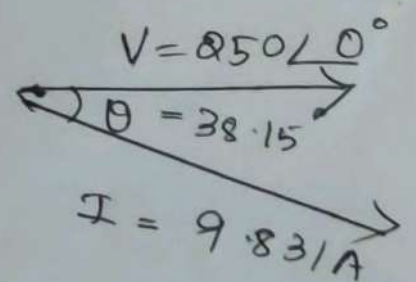
(b) current $I = \frac{V}{Z} = \frac{250}{25.43\ \angle 38.15^\circ}$

$$I = 9.831\ \angle -38.15^\circ\ A$$

(c) power factor $= \cos 38.15$

$P.f = 0.786$ (lag)

(d) phasor diagram

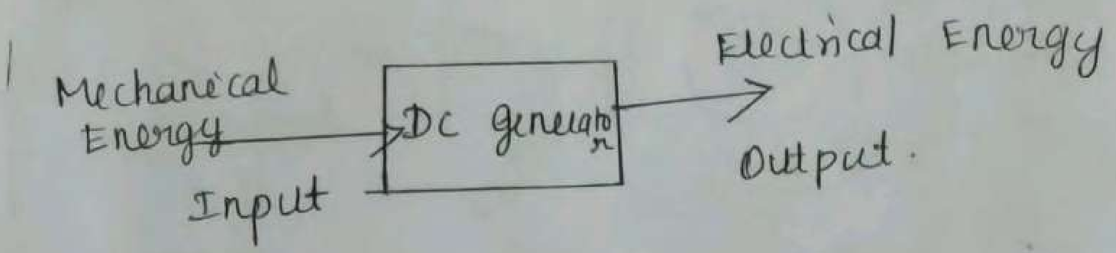


UNIT-2 Electrical Machines

construction and working Principle - DC seperately and self excited generators, EMF equation, Types and Applications, working principles of DC motors, Torque Equation, Types and Applications, construction, working principle and Applications of Transformer, Three phase Alternator, synchronous motor and Three phase induction motor.

DC Generator

"An electrical generator is a rotating machine which converts mechenanical energy into electrical energy"



The energy conversion is based on the Principle of electromagnetic induction.

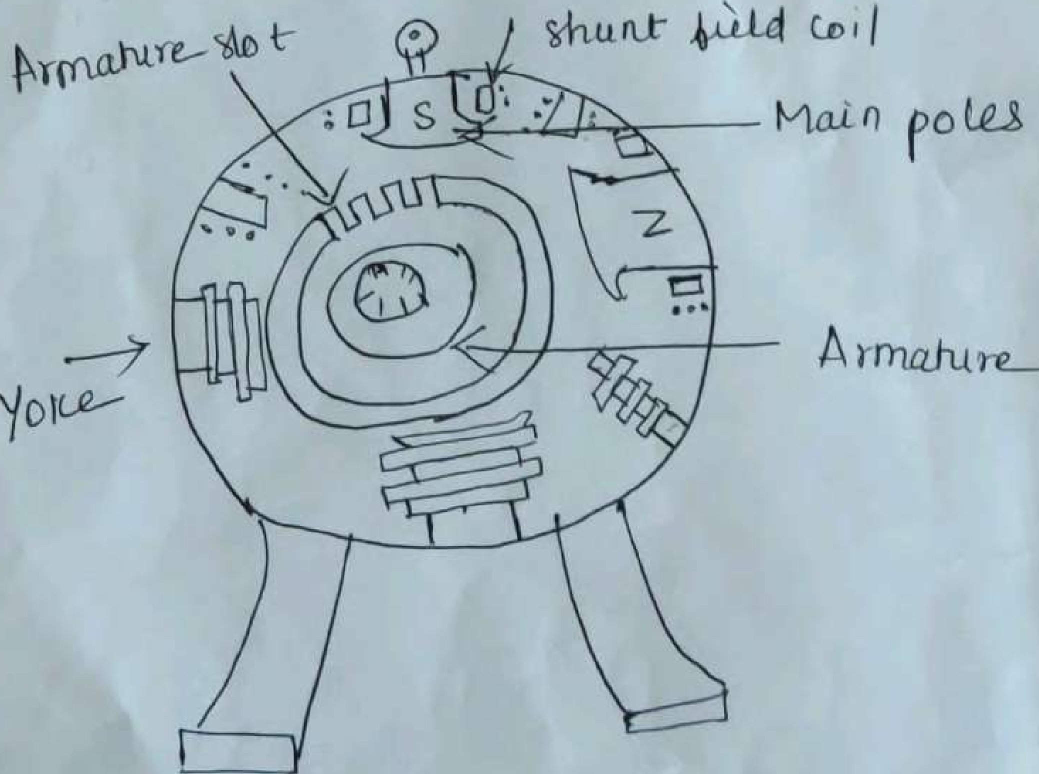
* According to Faraday's Laws of electromagnetic induction, whenever a conductor is moved in a magnetic field,

dynamically induced emf is produced in the conductor.

Parts of DC Generator

The major parts of DC generator are

1. Magnetic frame or yoke
2. Poles, interpoles, windings, pole shoes
3. Armature
4. Commutator
5. Brushes, Bearings and shaft.



Magnetic Frame.

It is used for two purpose.

* It acts as a protecting cover for the

whole machine and provides mechanical support for the poles.

* It carries the magnetic flux produced by the poles.

Poles

The pole consist of
(i) pole cores
(ii) Pole shoes.
(iii) pole coils

* It acts as a protecting cover for whole Machine. and provides mechanical support for poles.
* It carries the magnetic flux produced by the poles.

Interpoles

* commutating poles (or) interpoles are provided to improve commutation.
* The commutating poles also have exciting coils which are connected in Series with Armature
* The coils are made up of fewer turns of thicker Conductor to reduce the resistance

Armature

* The armature consists of an armature core and Armature windings.
* the armature core houses the armature conductor or coils.

Commutator

* commutator converts alternating emf into Unidirectional emf or direct emf.

* It is made up of Wedge shaped copper, insulated from each other by thin layers of built up-mica.

Brushes

* The brushes which are madeup of carbon or graphite.

* It collects the current from the commutator and to convey it to the external load resistance.

* They are rectangular in shape.

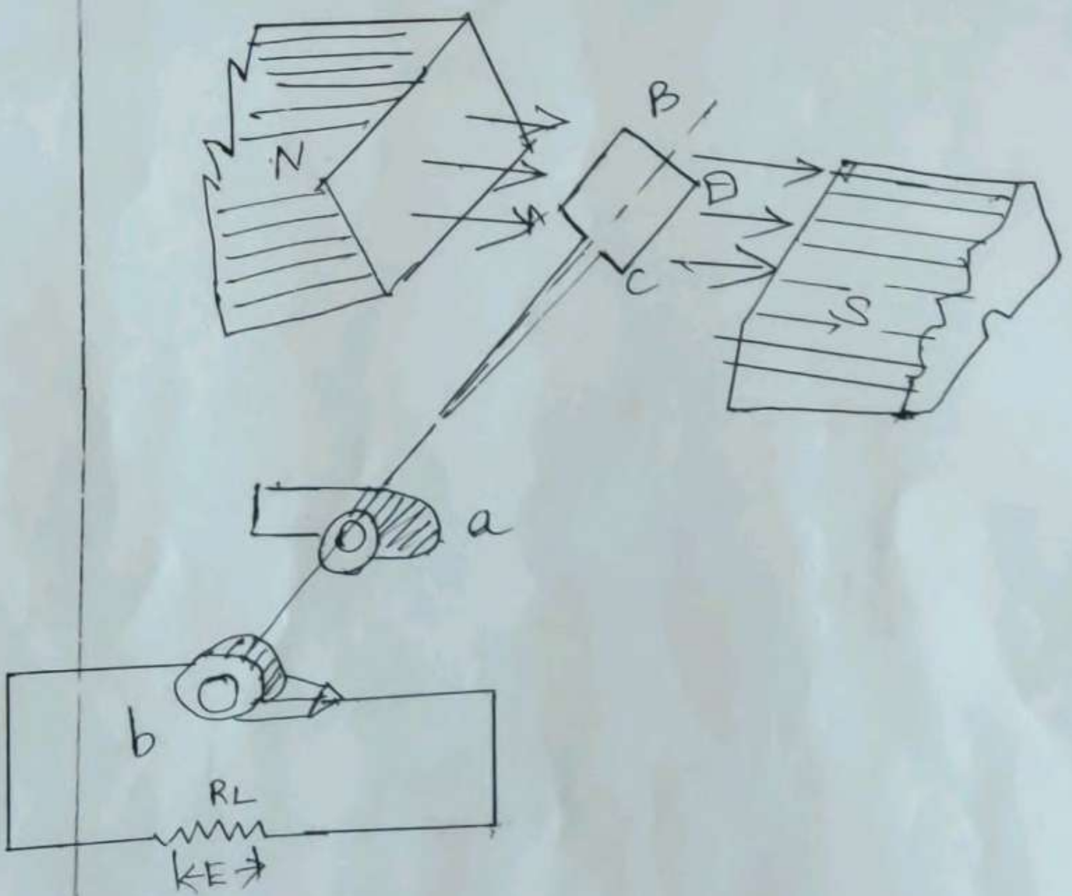
Bearings

* Ball Bearings are usually employed as they are reliable for light machines.
* For heavy duty machines roller bearings are used.

Principle of operation.

* Let us consider a single turn coil ABCD rotated on a shaft within a uniform magnetic field of flux density.
* It is rotated in an anti clockwise direction.
* Let 'L' be the length and 'b' be the breadth of coil in metres.
* When the coil sides AB and CD moving parallel to the magnetic field no flux linking the coil. hence no emf induced in it. ∴ $\boxed{\frac{d\phi}{dt} = 0}$ & $e = 0$
* When the coil sides AB and CD

be vertical to the magnetic field, flux linking the coil and an emf is induced in it. i.e $\boxed{\phi = BLb\cos\omega t}$



According to Faraday Law II, the emf induced is proportional to rate of change of flux linkages.

$$e = -N\frac{d\phi}{dt}$$

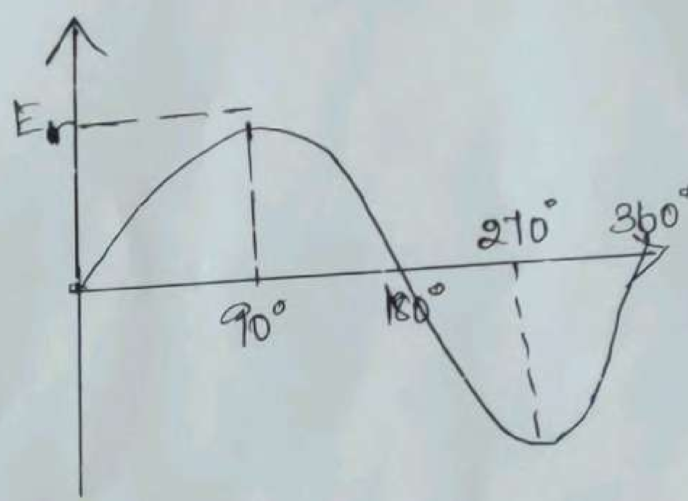
where N → No. of turns
t → time in sec
ϕ → flux in weber

$$e = -\frac{d}{dt}(BLb\cos\omega t)$$ ($\because N = 1$, $\phi = BLb\cos\omega t$)

$$\boxed{e = E_m \sin\omega t}$$

Where $E_m = BLb\omega$ (maximum induced emf)

* When $\omega t = 90°$, $e = E_m \sin 90°$ $\therefore e = E_m$ the emf induced is maximum.



* When $\theta = 180°$, $e = E_m \sin 180°$ $\therefore \boxed{e = 0}$ Now the emf induced is zero.

* When $\theta = 270°$, $e = E_m \sin 270°$ $\boxed{e = -E_m}$

The coil sides again move at right angles to flux lines but with their position reversed. Hence the induced emf is maximum in the opposite direction.

* when $\theta = 360^\circ$ $e = 0$ the coil has now back to the starting point.

* This alternating emf is made directional emf by using the commutator (split ring)

* The ring is split into two equal segments P and Q. They insulated from each other.

* The coil side AB is always attached to segment 'P' and likewise 'CD' to Q.

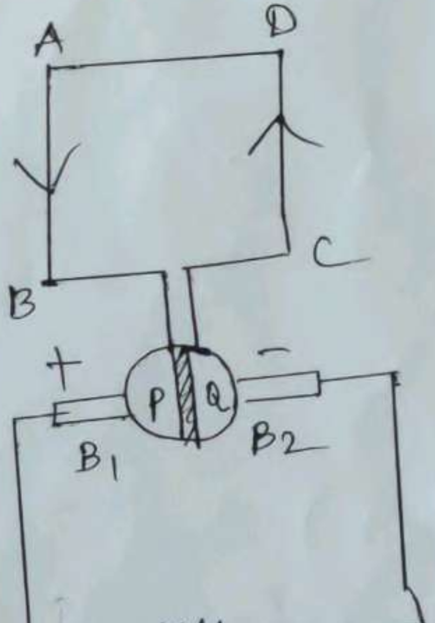


fig (a)

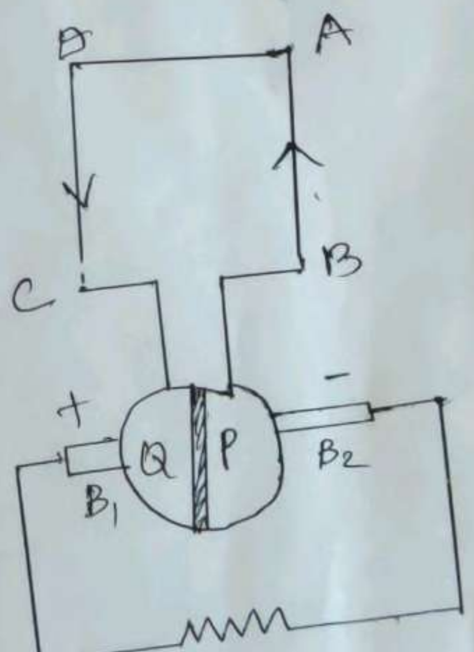


fig (b)

* During the first half revolution current flows along ABLMCD through brush B_1 (positive) and into B_2 C (Negative) (fig a)

* After a half cycle AB and CD exhausted their position along with segments P and Q and now currents flow through DCLMBA. B1 is new contact with Q and B_2 with 'P' (fig b)

* This Process repeat again and again and new unidirectional emf fed to the external load resistance "R".

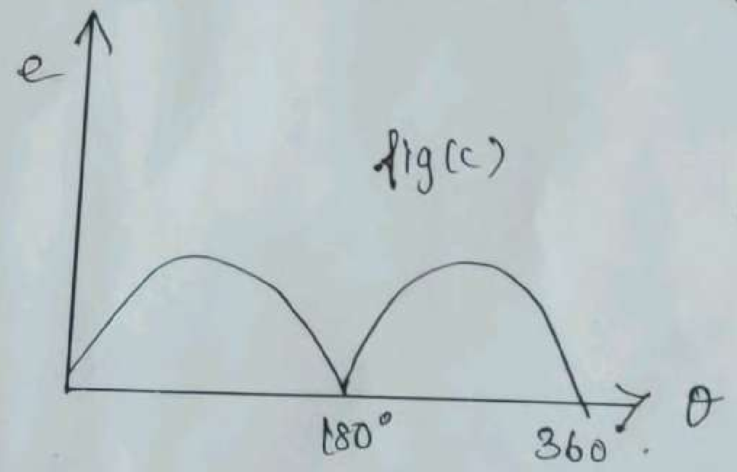


fig (c)

EMF equation of Generator & Motor

Let $\phi \rightarrow$ flux in Web

$P \rightarrow$ No. of poles

$Z \rightarrow$ Total no. of conductors.

$A \rightarrow$ No. of parallel path.

[Note $\boxed{A=2}$ for wave winding
$\boxed{A=P}$ for lap winding]

N → speed of rotation in rpm.

* consider only one conductor on the periphery of the armature.

* As this conductor makes one complete revolution it cuts $P\phi$ (wb)

* As speed is "N" rpm, the time taken for one revolution is "60/N" secs.

* We know that $e \propto \frac{d\phi}{dt}$.

$$e = \frac{P\phi}{60/N} \qquad \therefore e = \frac{\phi P N}{60} \text{ volts}$$

* since there are Z/A conductors in series in each parallel path the emf induced is

$$E_g = \frac{NP\phi}{60}\left(\frac{Z}{A}\right) \text{Volts}$$

where E_g → Generated Emf (for generator) for motor

$$E_b = \frac{\phi Z N}{60}\left(\frac{P}{A}\right) \text{ Volts}$$

Where E_b = Back emf of motor in volts

Application of DC generator

① Shunt generators are used for supplying nearly constant loads.

② It is used for battery charging, for supplying the fields of synchronous machines.

③ DC series generators are used as booster for adding a voltage to the transmission lines and to compensate for line drop.

④ compound generator as a voltage regulator in self contained generator unit.

Types of DC Generator

There are two types of DC generators.

They are,

(I) seperately excited DC generators

(II) self excited DC generators

(i) seperately excited DC generator

If the field winding is excited by a seperate DC supply, then the generator is called separately excited DC generator.

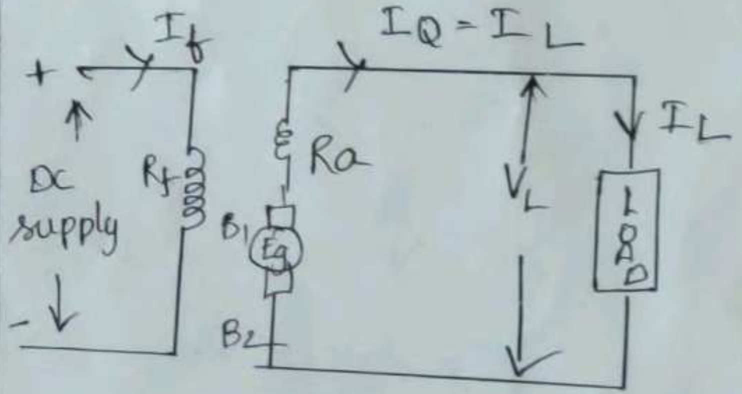


Fig: seperately exited DC generator

From this diagram,

Generated emf $\boxed{E_g = V + I_a R_a + V_{brush} \text{ (V)}}$

Where

$I_a \Rightarrow$ Armature current (A)

$R_a \Rightarrow$ Resistance of armature winding (Ω)

V_{brush} → voltage drop in brush (V)

E_g → Generated Emf.

Here $\boxed{I_a = I_L}$

I_L → Load current (A)

Electric power developed $\boxed{P_g = E_g I_a \ (W)}$

Power delivered to load $\boxed{P_L = V_L I_a \ (W)}$

where,

$\boxed{V_L = \text{Terminal voltage}}$.

(ii) **Self excited DC Generator**

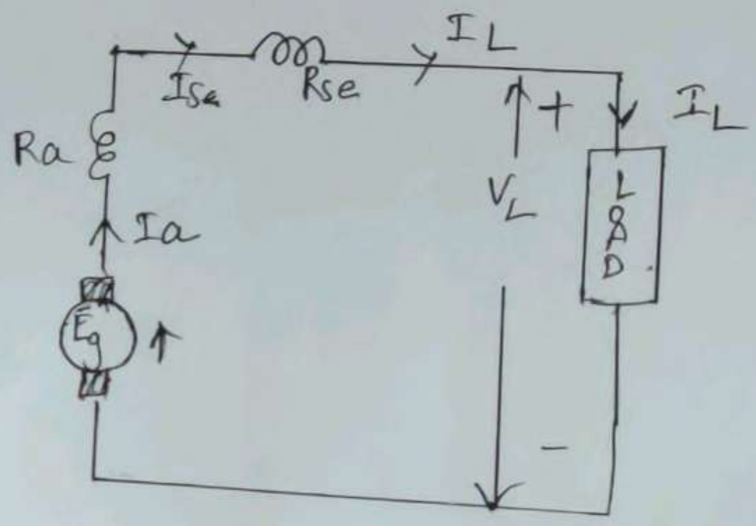
If in a DC Generator field winding is supplied from a armature of Generator itself then it is called self excited DC Generator.

The self excited DC generators can be classified depending upon how the field winding is connected to the armature. There are three types

(a) series generator (b) shunt Generator

(c) compound generator

Series Generator



* The field winding is connected in series with the armature.

* This type of DC generator is called DC Series generator.

* Here the armature current flows through the field winding as well as the load.

* The field winding has less no. of turns of thick wire.

* It has low resistance. It is denoted by Rse.

* Here armature, field and load are all in series so they carry the

same current.

$$I_a = I_{se} = I_c$$

Generated Emf $E_g = V_L + I_a R_a + I_a R_{se} + V_{brush}$ (V)

where

V_L = Terminal Voltage (V)

I_a = Armature current.

R_a = Armature Resistance

R_{se} = field winding Resistance

V_{brush} = Brush drop.

* Power developed in Armature $P_g = E_g I_a$

Power delivered to load $P_L = V_L I_a$ (or) $V_L I_C$

$$E_g = V_L + I_a (R_a + R_{se}) + V_{brush}$$

$[\because I_a = I_{se}]$

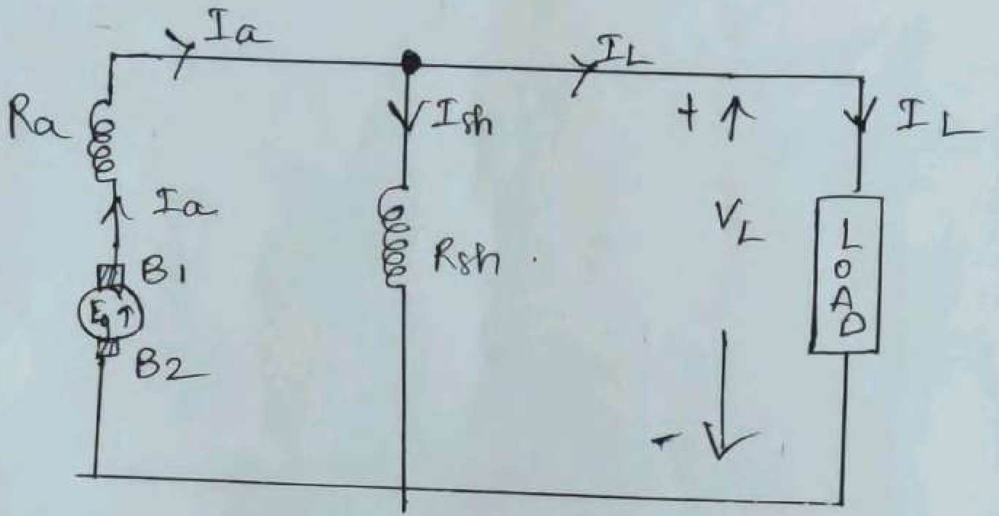
(b) Shunt Generator

* Here the field winding is connected in Parallel with Armature winding.

* The shunt field winding has more no. of

turns of thin wire. It has high resistance.

* The Load is connected across the armature..



Generated Emf $\boxed{E_g = V_L + I_a R_a + V_{brush}}$ (V)

Armature current $\boxed{I_a = I_{sh} + I_L}$ (A)

* shunt field current $\boxed{I_{sh} = \frac{V_L}{R_{sh}}}$ (A)

Power developed by Armature $\boxed{P_g = E_g I_a}$ (W)

Power delivered to load $\boxed{P_L = V_L I_L}$ (W)

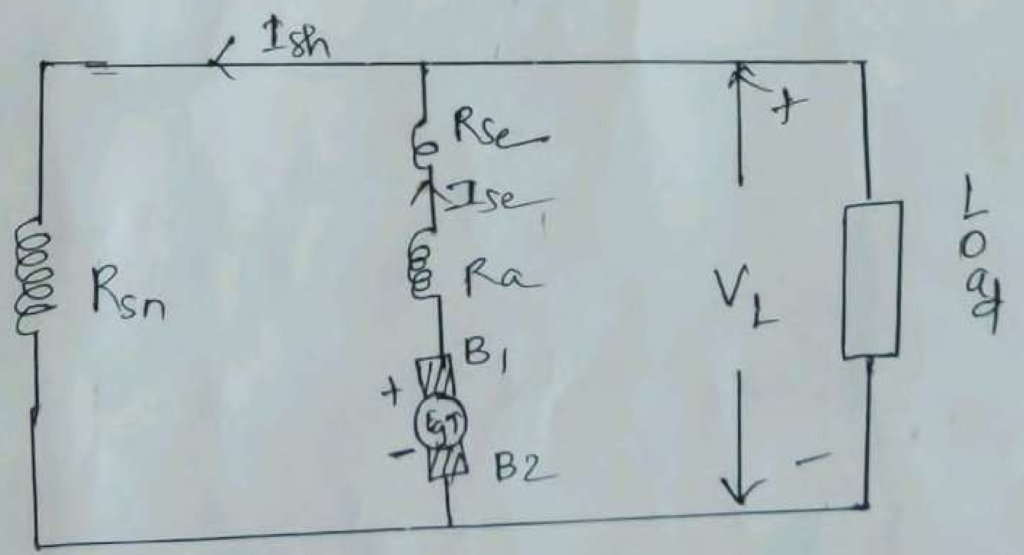
$V_L \rightarrow$ Terminal voltage.

(iii) Compound Generator

* It consists of both shunt field and series field windings
* One winding is in series and another winding is in parallel with armature
* This Generator can be classified as,
  (a) Long Shunt compound Generator
  (b) short shunt compound Generator

(a) Long Shunt compound Generator

* Here shunt field winding is connected across both series field and armature windings



From the figure

$$I_a = I_{se} = I_L + I_{sh} \ (A)$$

Shunt field current $I_{sh} = \dfrac{V_L}{R_{sh}}$

Generated Emf $E_g = V + I_a R_a + I_{se} R_{se} + V_{brush}$

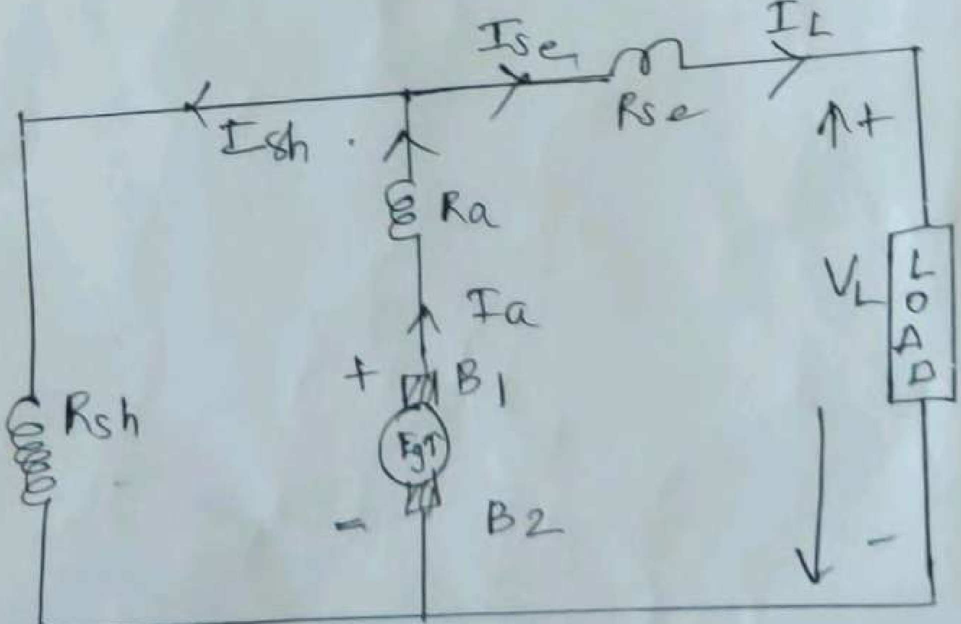
$E_g = V + I_a(R_a + R_{se}) + V_{brush}$ $[\because I_a = I_{se}]$
(V)

Power developed in armature $\boxed{P_g = E_g I_a}$ (W)

Power delivered to load $\boxed{P_L = V_L I_L}$ (W)

(b) short shunt compound Generator

* Here shunt field winding is connected in Parallel with armature and this combination is connected in series with series field winding.



Generated Emf $\boxed{E_g = V_L + I_a R_a + I_{se} R_{se} + V_{brush} \quad (V)}$

Series field current $\boxed{I_{se} = I_L}$

$I_L \rightarrow$ load current.

Armature current $I_a = I_{sh} + I_{se}$

Shunt field current

Apply KVL Across shunt field

$\therefore V_{sh} = V_L + I_{se} R_{se}$

$I_{sh} R_{sh} = V_L + I_{se} R_{se}$

$$\boxed{I_{sh} = \frac{V_L + I_{se} R_{se}}{R_{sh}} \ (A)}$$

Power developed in armature $P_g = E_g I_a (W)$

Power delivered to load $P_L = V_L I_L (W)$

Characteristics of DC Generator

There are three types of characteristics

(1) Open circuit characteristics (or) Magnetisation Characteristics (E_g Vs I_f)

(2) Internal characteristics (or) total characteristics (E_g Vs I_a)

(3) External characteristics.

Seperately excited DC Generator characteristics.

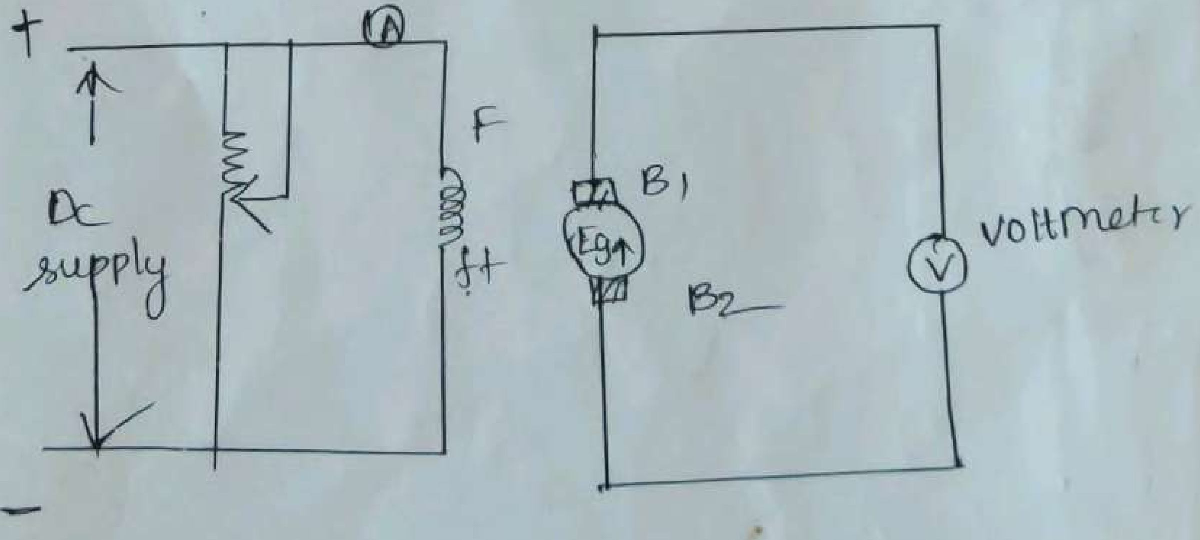
W.K.T Emf equation of Generator is

$$E_g = \frac{\phi Z P N}{60 A}$$

$E_g \propto \phi N$ If N = constant

If $\phi \uparrow$ $E_g \uparrow$ i.e, If flux increases E_g increases.

the variation of flux with the induced emf is called the open circuit characteristics (OCC) of the generator.

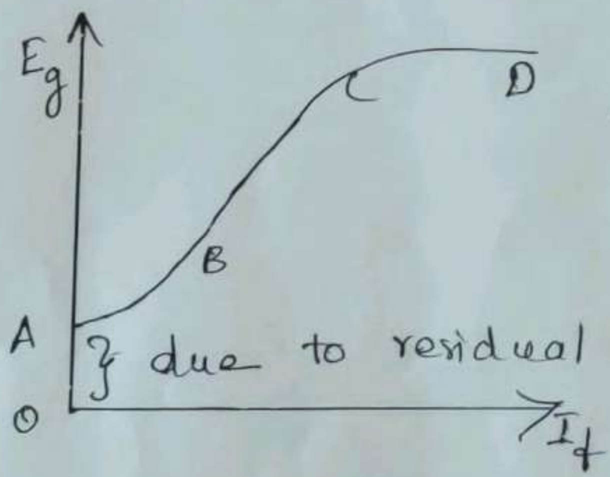


Open circuit characteristics (Eg Vs If)

As the field current is increased,

the induced emf increases, increasing linearly from A to B.

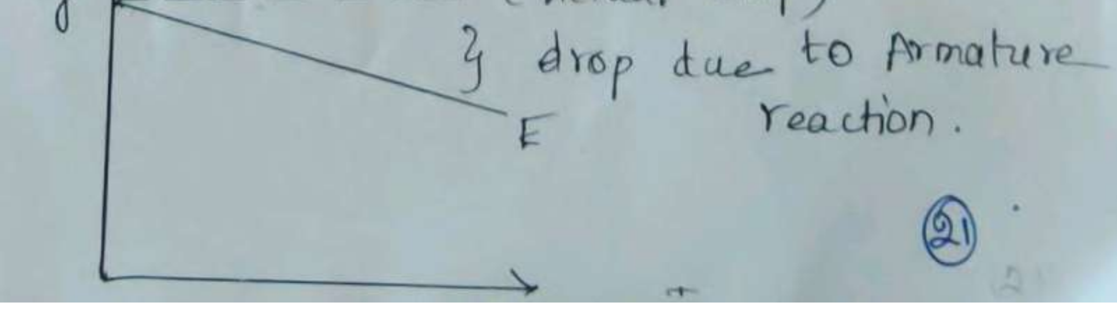
* As the field current is further increased, the increase in flux is much smaller and hence the emf also increases slowly. At point D saturation has set in.



Internal Characteristics (E_g Vs I_a)

* This curve is drawn between Emf induced and armature current (I_a)

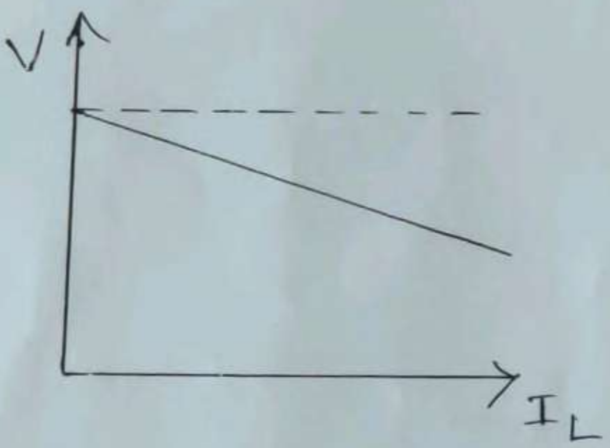
* Here by increasing the Armature current induced emf (E) will decrease due to Armature reaction.



External characteristics (V Vs IL)

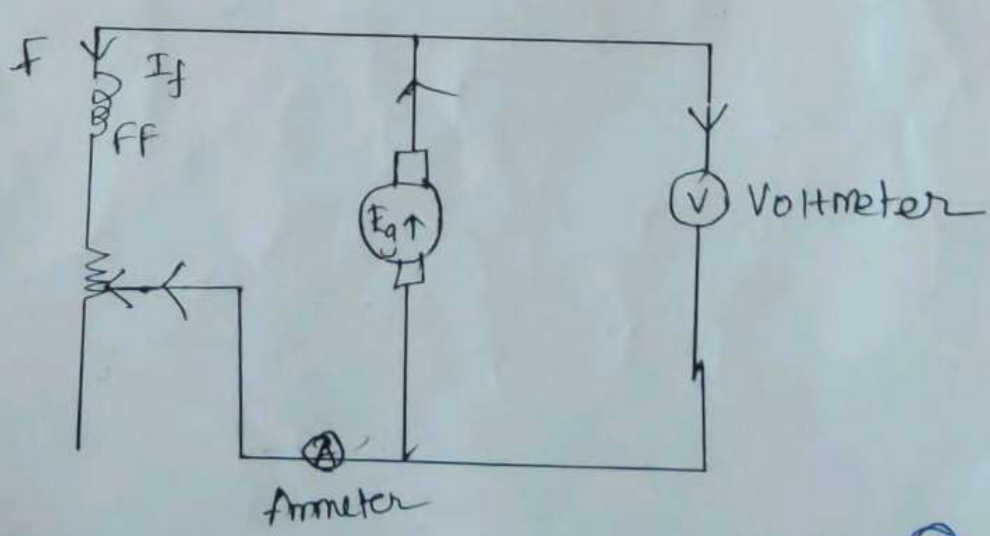
* This curve is drawn between the terminal voltage and armature current.

* Here by increasing armature current (or) load current then induced emf again decreases due to armature resistance.



DC shunt Generator characteristics.

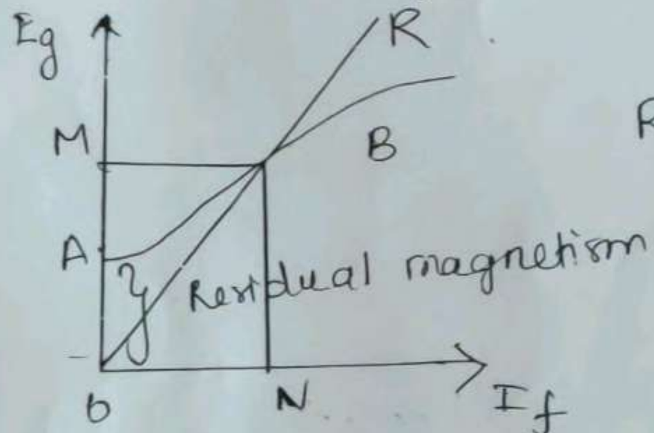
* Fig shows dc shunt generator



Open circuit characteristics

* This curve can be drawn between field Current and Induced emf.

* Initially the ~~t~~ field current is zero, but emf (OA) is induced in the generator due to residual magnetism.



$$R_C = \frac{OM}{ON} = \frac{\Delta E_g}{\Delta I_f}$$

$$\boxed{R_C = \frac{\Delta E_g}{\Delta I_f}}$$

* Due to this voltage field current increases and emf also increases and it reaches Point B.

* There is no further increase in field current (or) induced emf.

* This curve is open circuit characteristics.

Critical Resistance (R_C)

* OR is the tangent drawn to the Portion of OCC from origin

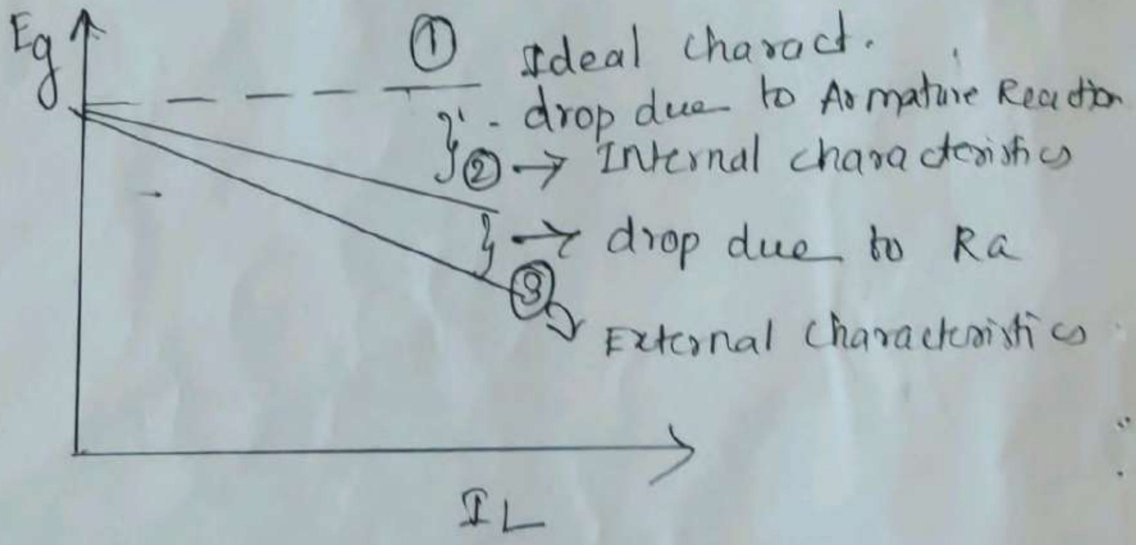
The slope of this tangent OM/ON gives the value of critical resistance, when Generator just excites.

$$R_c = \frac{\Delta E_g}{\Delta I_f}$$

ii) Internal and External characteristics.

Once the generator has built upto the specified voltage on no load it may be loaded.

If we increase the load on the generator, the voltage drop across also increases.



The curve (1) shows the Ideal dc generator. There is no drop in the armature ie $E_g = V$

* The curve (2) shows the internal Characteristics Here the drop is due to armature reaction.

* The curve can be drawn for load current Versus (E).

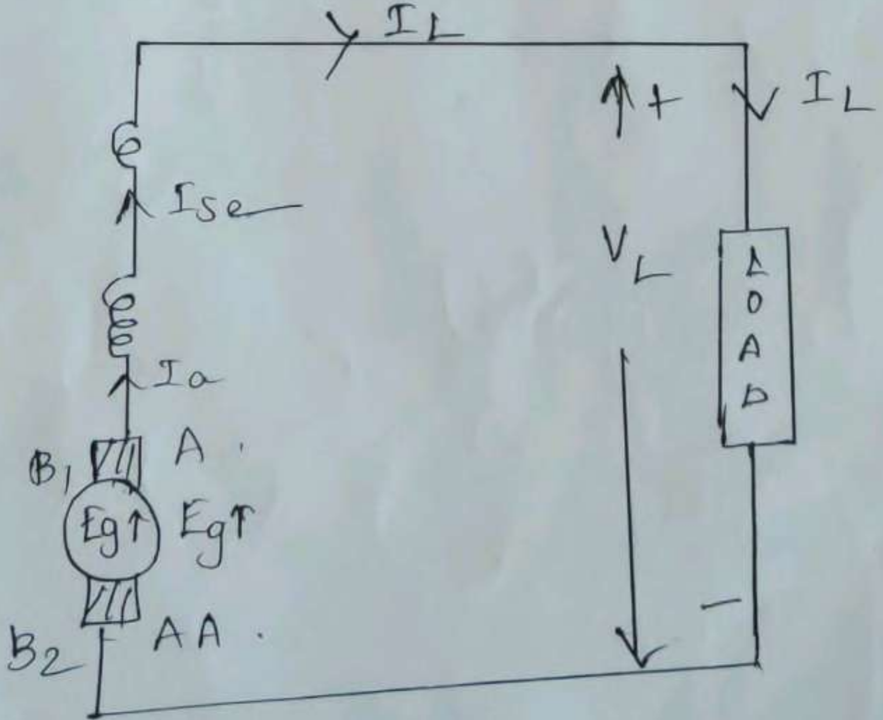
* The curve (3) shows external characteristic Here drop is due to Armature Resistance (R_a)

* By increasing the load current terminal Voltage decreases.

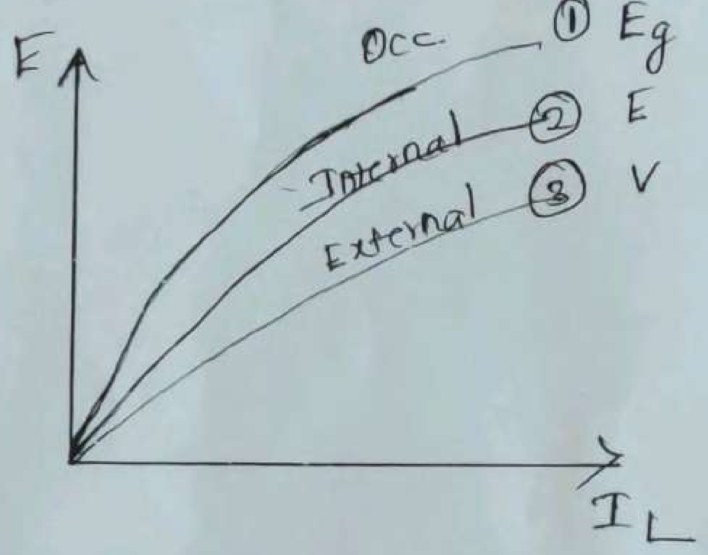
—— × —— × ——

DC Series Generator characteristics

The connection for the dc series generator is shown in fig



* The curve (1) shows open circuit characteristics. This curve can be obtained by disconnecting the field winding from the machine and excited by seperate dc source.



* The curve (2) shows internal characteristics. Here the drop is due to armature reaction. By increasing the load current the induced emf (E) decreases.

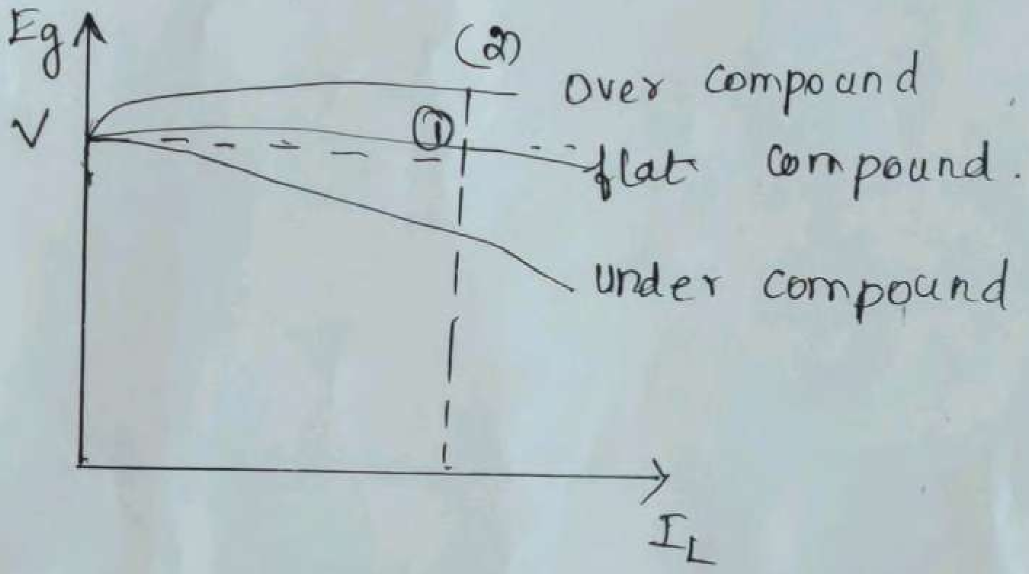
* The curve (3) shows external characteristics. Here the drop is due to the armature resistance and series field resistance.

* The curve can be drawn from load current Vs terminal voltage

——— X ———

Compound Generator characteristics.

* It consists of series field and shunt field windings. Fig shows external characteristics of compound generator.



(a) Flat compound Generator

* A compound generator has both shunt and series field and if the drop in flux in the shunt field is exactly compensated for by the rise in flux in series field then it is possible to have constant voltage characteristics

i.e. $\boxed{E_g = V}$

(b) Over compound Generator

* Curve (2) shows the characteristics of over Compound Generator.

* Here the series field excitation is more than shunt field.

i.e $V > E_g$

* (c) Under compound Generator

* curve (3) shows the characteristics of under compound Generator.

* Here the series field exitation is less than shunt field. Therefore by increasing the load current the terminal voltage decreases.

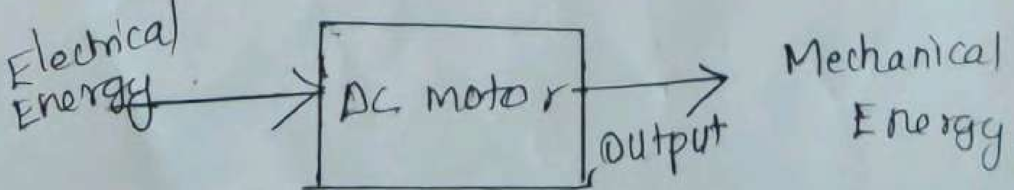
$V < E_g$

— x — x

DC Motors.

"The DC motor converts Electrical Energy into Mechanical Energy".

It is shown in fig.



Construction

The DC motor has the following part.

(i) Magnetic Frame (or) yoke
(ii) poles, Interpoles, windings, Pole shoes
(iii) Armature (iv) commutator
(v) Brushes, Bearings and shafts.

(i) Magnetic frame (or) yoke

It is used for two purpose

* It acts as a protecting cover for whole machine and provides mechanical support for poles.
* It carries the magnetic flux produced by the poles.

(ii) Poles

The pole consists of (i) pole cores
(ii) pole shoes
(iii) Pole coils

* The pole core and pole shoes form the field magnet.

* A field winding is wound over the Pole core.

* The Pole coils are madeup of copper or strip.

Interpoles

* Commutating poles (or) interpoles are Provided to improve commutation.

* the commutating poles also have exciting coils which are connected in series with Armature.

* the coils are madeup of fewer turns of thicker conductor to reduce the resistance.

Armature

* the armature consists of an armature core and Armature windings...

* the armature core houses the armature conductors or coils

Commutator

* The commutator converts the alternating emf into unidirectional (or) direct emf.

* It is made up of wedged shape copper, insulated from each other by thin layers of built-up-mica

Brushes

* the brushes which are made up of carbon or graphite

* It collects the current from the commutator and to convey it to the external load resistance.

* they are rectangular in shape.

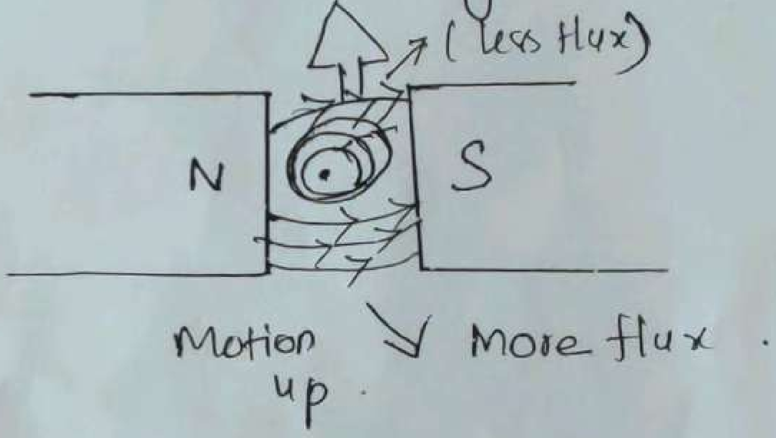
Bearings

* Ball bearings are usually employed as they are reliable for light machines.

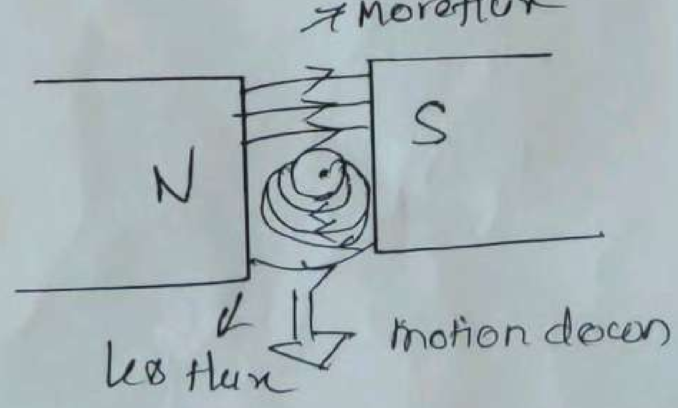
* For heavy duty machines roller bearings are used.

Principle of operation

* the basic principle of operation of DC motor is that "whenever a current carrying conductor is placed in a magnetic field, it experiences a force tending to move it".



* Above the conductor the flux is less and below the conductor, the field is more causes the motor to move upwards



* then the direction of current through the conductor is reversed as shown in fig. Here the field below the

conductor is less and field above Conductor is more.

* then the conductor tends to move downwards.

* The magnitude of force experienced by the conductor in a motor is given by

$$F = BIL \text{ newtons}$$

where B = magnetic field intensity

I = current in Amperes.

L = Length of conductors in metres.

* The direction of motion is given by Fleming's left hand rule

———— X ————

Types of DC Motors

The types of DC motors are

(i) separately excited DC motor

(ii) self excited DC motor

(a) series motor

(b) shunt motor

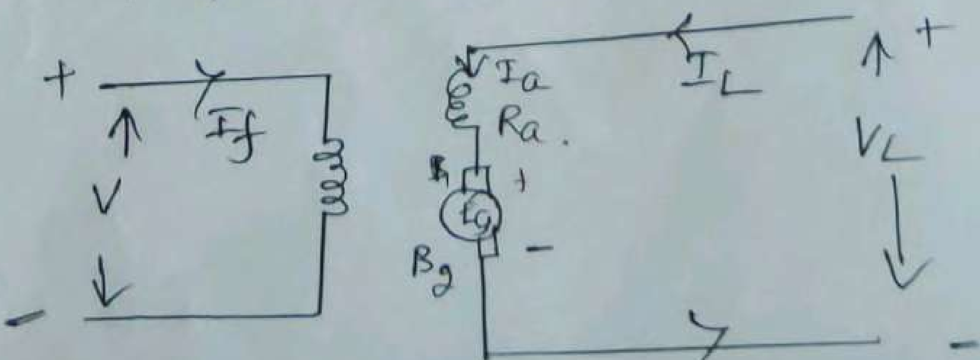
(c) compound motor.

- long shunt compound motor
- short shunt compound motor

Separately excited DC motor.

* Here the field winding and armature are seperated. The field winding is excited by seperate dc source.

* That is why it is called as separately excited DC motor.



* From the diagram

Armature current I_a = line current I_L

$$I_a = I_L \quad (A)$$

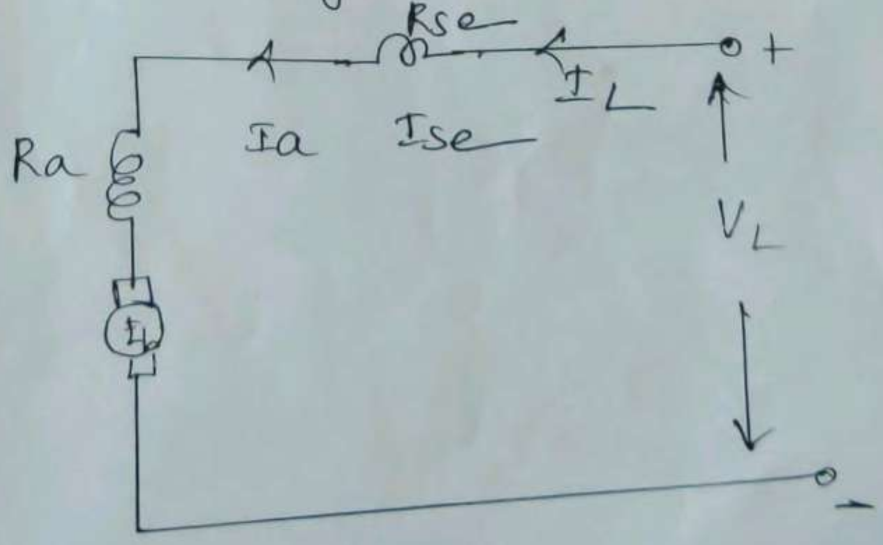
$$V_L = I_a R_a + E_b + V_{brush} \quad (V)$$

(ii) Self Excited DC motor

(a) DC series motor.

* Here the field winding is connected in series with Armature winding.

* Here the field winding has less no. of turns of thick wire "Rse" is resistance of series field winding. Its value is very small.



The voltage equation is givenby,

$$V = I_{se}R_{se} + I_aR_a + E_b + V_{brush} \quad (v)$$

In Dc series motor

$$I_a = I_{se} = I_L$$

$$\therefore V = E_b + I_a(R_a + R_{se}) + V_{brush}.$$

where

I_L → Line current

V_{brush} → Brush drop

E_b → back emf.

* In series motor flux produced is directly proportional to armature current

ie $$\phi \propto I_{se} \propto I_a$$

(ii) Dc shunt Motor.

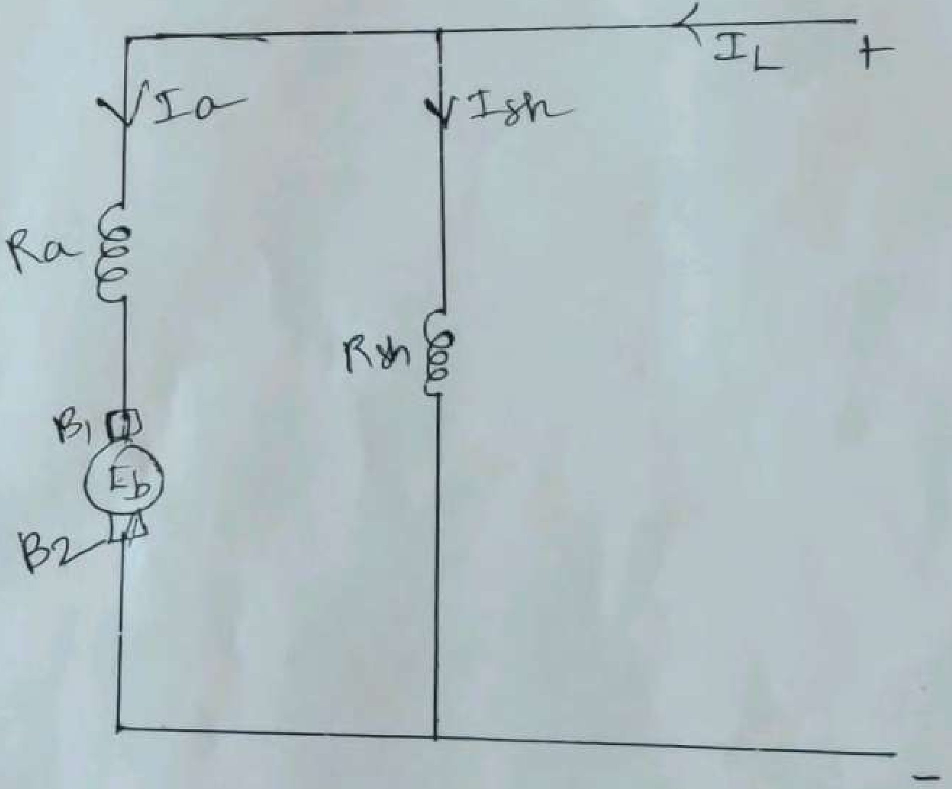
* In this motor the feild winding is connected in parallel with armature winding.

* It has more no. of turn with thin wire.

* Ra → Armature Resistance

* Rsh → shunt field winding Resistance

* I_L → Line current drawn from the supply



from the diagram $I_L = I_a + I_{sh}$ A)

$$I_{sh} = \frac{V_L}{R_{sh}} \text{ (A)}$$

voltage equation of DC Shunt motor is

$$V = E_b + I_a R_a + V_{brush} \text{ (V)}$$

* In shunt motor flux produced by field winding is proportional to field current (I_{sh})

i.e $\boxed{\phi \propto I_{sh}}$

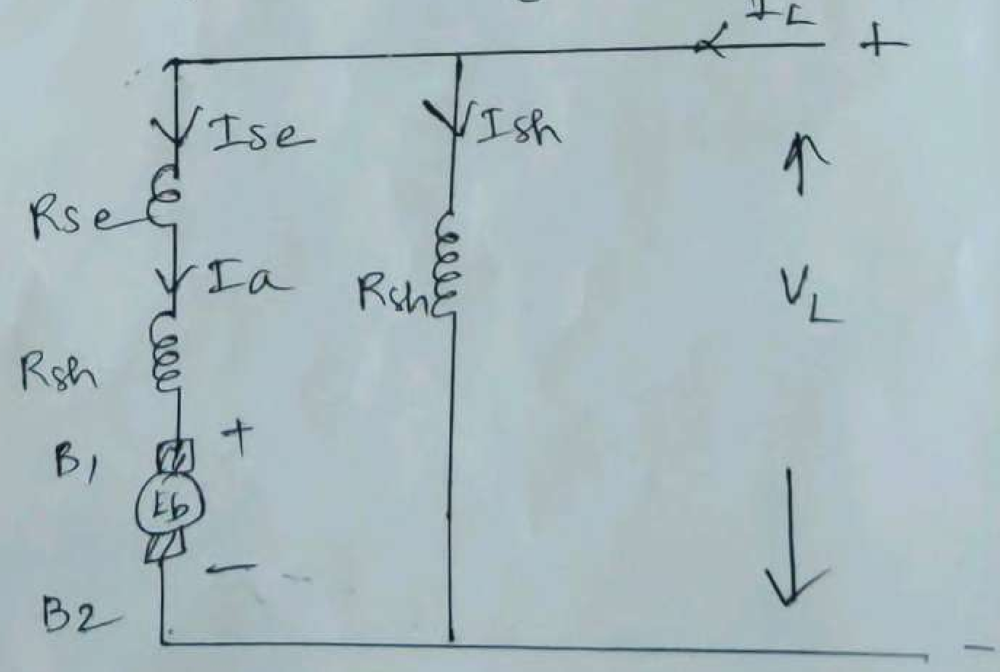
* Dc shunt motor also called a constant flux motor (or) constant speed motor.

Dc Compound Motor

A Dc compound motor consists of both series and shunt field windings.

(a) Long shunt compound motor.

In this motor shunt field winding is connected across both armature and series field winding



* From the diagram.

$$V_L = E_b + I_a R_a + I_{se} R_{se} + V_{brush} \text{ (V)}$$

$$I_a = I_{se} \text{ (A)}$$

$$I_L = I_{sh} + I_{se} \text{ (A)}$$

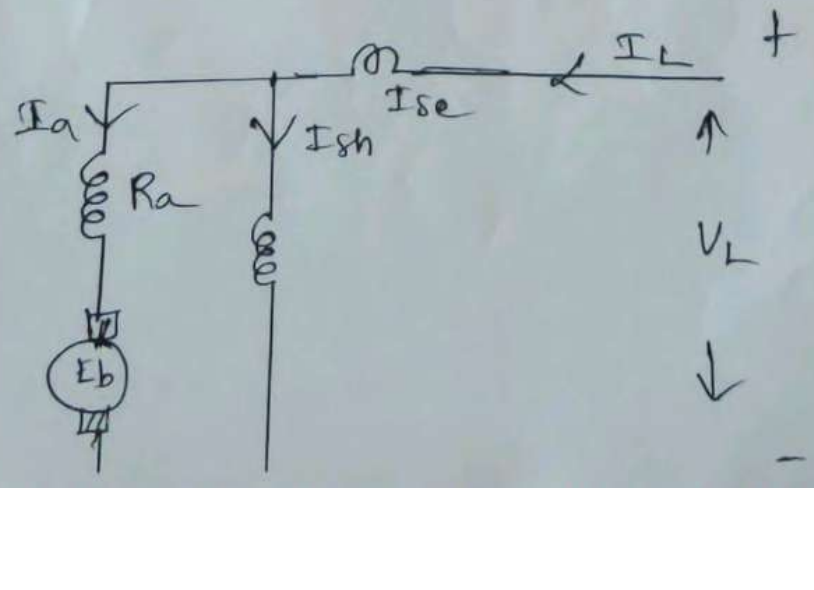
$$I_{sh} = \frac{V_L}{R_{sh}} \text{ (A)}$$

Now, $V_L = E_b + I_a(R_a + R_{se}) + V_{brush}$

$[\because I_{se} = I_a]$

(b) Short Shunt Compound Motor:

* In this type of motor, the shunt field winding is across the armature and series field winding is connected in series with this combination.



From the diagram.

$$V_L = E_b + I_a R_a + I_{se} R_{se} + V_{brush}.$$

$$I_{se} = I_L$$

$$I_L = I_a + I_{sh}$$

$$I_L = I_{se} = I_a + I_{sh}.$$

Voltage drop across shunt field winding is

$$I_{se} R_{se} + V_{sh} = V_L$$

$$\therefore V_{sh} = V_L - I_{se} R_{se}$$

$$I_{sh} R_{sh} = V_L - I_{se} R_{se}$$

$$I_{sh} = \frac{V_L - I_{se} R_{se}}{R_{sh}} \quad (A)$$

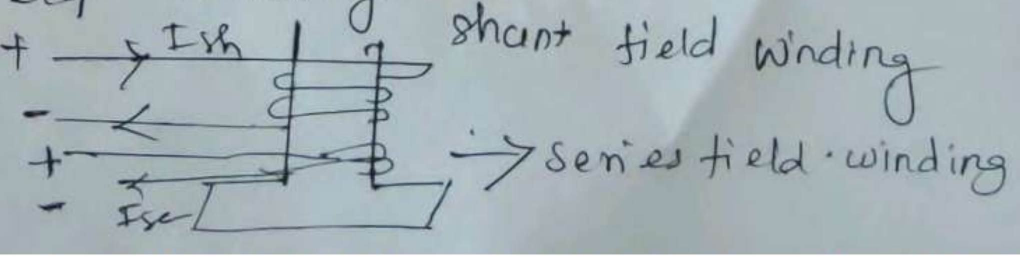
The compound motor again classified into two types

(i) cumulative compound motor

(ii) Differential compound motor.

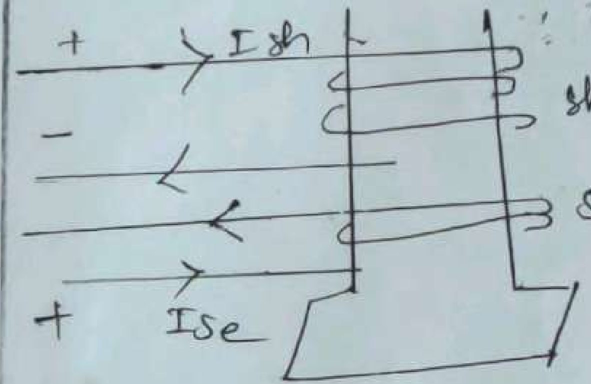
Cumulative compound motor

* In this type of motor the two field winding fluxes and each other.
* Flux due to series field winding strengthens the flux due to shunt field winding



Differential compound motor.

In this type of motor the two field winding fluxes oppose each other. i.e field due to series field winding reduces the field due to shunt field winding



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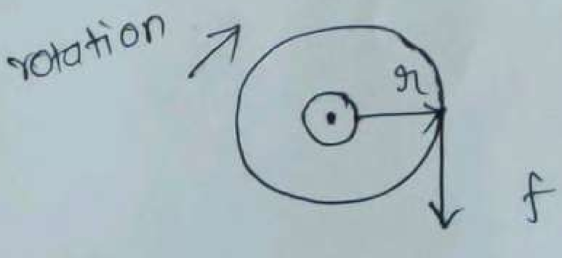
Torque Equation.

"Torque is nothing but turning (or) twisting force about an axis.

* Torque is measured by product of force and the radius at which the force acts.

* consider a wheel of radius "r" metres acted on by a circumferential force 'F' newton as shown in fig.



* Let the force 'F' cause the wheel to rotate at 'N' rpm. The angular velocity of wheel is

$$\omega = \frac{2\pi N}{60} \text{ rad/sec} \quad \left[\begin{array}{l} N \text{ rpm} = 60 \text{sec} \\ 1 \text{rpm} = \frac{60}{N} \text{sec} \end{array} \right]$$

Torque $\boxed{T = f \times r}$ N-m —— ①

work done per revolution = F × distance moved

$= F \times 2\pi r$ joules —— ②

Power developed P = workdone / time

$$= \frac{f \times 2\pi r}{\text{time for 1 rev}} = \frac{F \times 2\pi r}{60/N} \quad —— ③$$

$$P = (f \times r) \frac{2\pi N}{60}$$

$\boxed{P = T\omega \text{ (watts)}}$. —— ④

where T = Torque in N-m

ω = Angular speed in rad/sec

Power in Armature = Armature torque × ω

$$E_b I_a = T_a \times \frac{2\pi N}{60} \quad —— ⑤$$

$[\because P = E_b I_a]$

W.K.T, $E_b = \frac{\phi Z N P}{60 A}$ —— (6)

sub (6) in (5)

$$\frac{\phi Z N P}{60 A} I_a = T_a \times \frac{2\pi N}{60}$$

$$T_a = \frac{\phi Z N P}{60 A} \times I_a \times \frac{60}{2\pi N}$$

$$T_a = \frac{\phi I_a Z P}{2\pi A}$$

$$\therefore T_a = 0.159 \, \phi \, I_a \, \frac{PZ}{A} \, N\text{-}m \quad \text{—— (7)}$$

The above equation is torque equation of DC motor

$\therefore T_a = K \phi I_a$ where $K = 0.159 \phi \frac{Z}{A}$

$\therefore$ $T_a \propto \phi I_a$

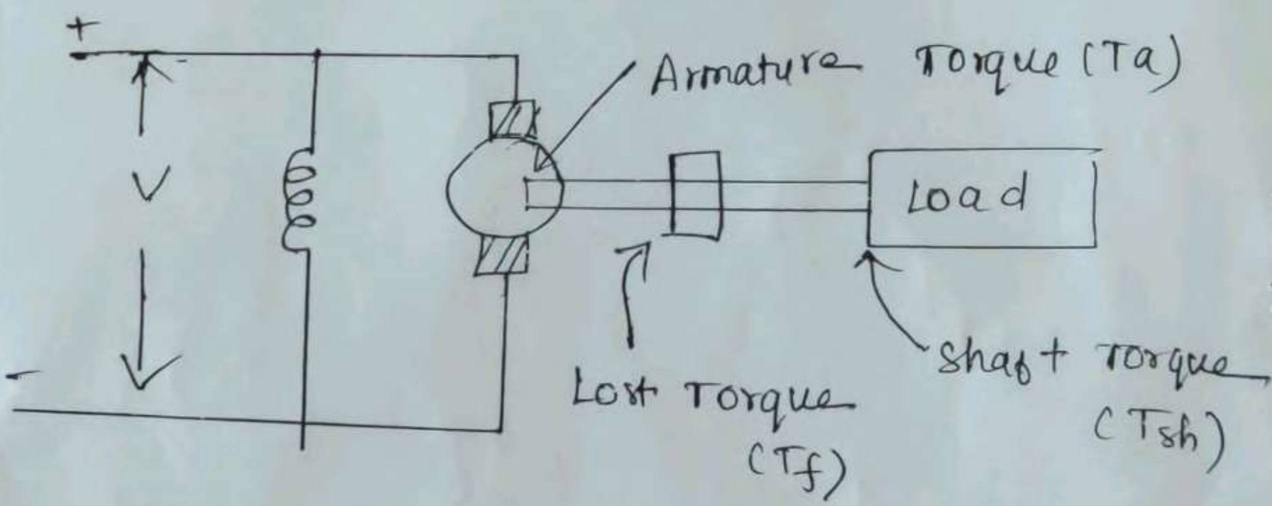
Shaft Torque

* The full armature torque is not available for doing useful work.

some amount of torque is used for supplying Iron loss and friction loss in the motor.

* This torque is called lost Torque (T_f)

* The remaining torque is available for doing useful work. This torque is known as shaft torque (or) useful Torque (T_{sh})



* The armature torque is sum of lost torque and shaft torque

$$\therefore \boxed{T_a = T_f + T_{sh}}$$

The o/p power of motor is

$$P_{out} = T_{sh} \times \frac{2\pi N}{60} \text{ watts}$$

$$T_{sh} = \frac{P_{out}}{2\pi N} \times 60$$

$$\boxed{T_{sh} = 9.55 \frac{P_{out}}{N} \text{ N-m}}$$

Speed and Torque Equation

For DC motor the speed equation is obtained as follows

W.K.T $V = E_b + I_a R_a$ — ①

$$E_b = \frac{\phi Z N P}{60 A} \quad — ②$$

Sub ② in ①

$$V = \frac{\phi Z N P}{60A} + I_a R_a$$

$$\frac{\phi Z N P}{60 A} = V - I_a R_a$$

$$N = \frac{(V - I_a R_a) \times 60 A}{\phi Z P}$$

the values A, Z and P are constant

$$N = \frac{K (V - I_a R_a)}{\phi} \quad \left[K = \frac{60A}{ZP}\right]$$

where K → constant.

Speed equation becomes $N \propto \frac{V - I_a R_a}{\phi}$

(or) $$N \propto \frac{E_b}{\phi} \quad \text{——— (3)}$$

Hence speed of the motor is directly Proportional to back emf (E_b) and inversely Proportional to flux ϕ.

Torque equation.

Torque equation of DC motor is given by

$$T \propto \phi I_a \quad \text{—— (4)}$$

Hence the flux ϕ is proportional to the current flowing through the field winding

$$\phi \propto I_f \quad \text{——— (5)}$$

DC shunt motor

* For DC shunt motor, the shunt field current (I_{sh}) is constant. Therefore flux ϕ is constant.

$T \propto \phi I_a$ becomes

$$T \propto I_a \quad \text{——— (6)}$$

DC series motor

The series field current is equal to Armature current I_a. Therefore flux $\phi \propto I_a$

Hence $T \propto \phi I_a$ becomes

$$\boxed{T \propto I_a^2}$$

* The speed and torque equations are mainly used for analyzing the characteristics of DC motors.

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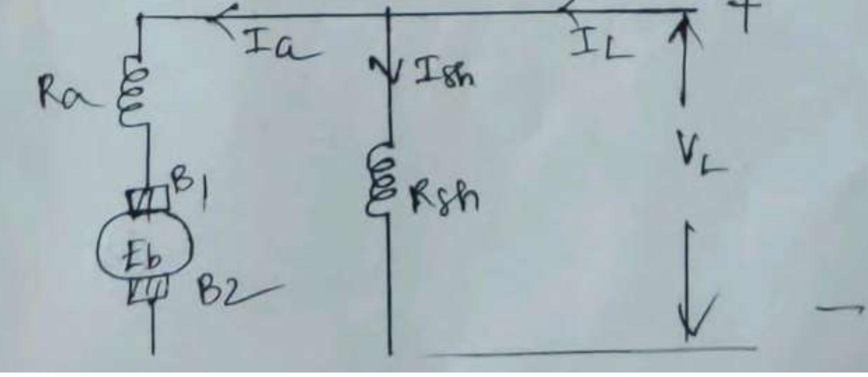
Characteristics of DC motor.

There are three types of characteristics.

1. Speed - armature current characteristics.
2. Torque - armature current characteristics.
3. Speed Torque characteristics.

DC shunt motor characteristics

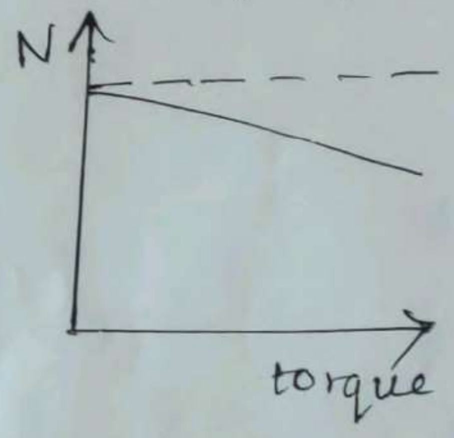


iii) Speed - Torque characteristics (N Vs T)

* It is also called mechanical characteristic.

* This characteristics can be got from the above two characteristics.

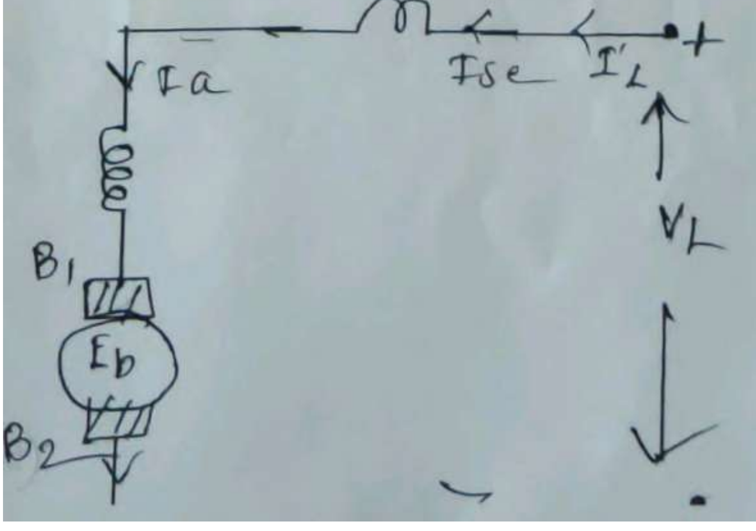
* Here when the load torque increases, the speed slightly decreases.



(b) DC series motor characteristics.

* In D.C series motor the field winding and armature winding in series.

$$I_L = I_a = I_{se}$$

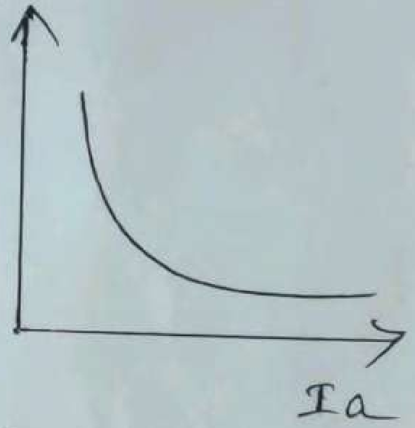


(i) **speed - Armature current Characteristics**

* In this machine field flux (ϕ) depends on field corrent through it. i.e $\phi \propto I_{se} \propto I_a$

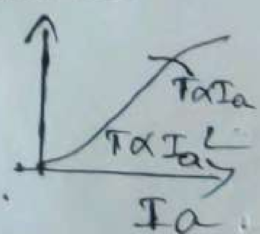
$\therefore \phi \propto I_a$

* $N \propto \frac{E_b}{I_a}$. From this equation, it is clear that by increasing the armatuere current speed will incredse.



(ii) **Torque Armature current characteristics**

* In DC series motor $\boxed{T \propto I_a^2}$. As I_a increases T_a increases as the square of the current.



* This characteristics is a parabola.
* After saturation the flux is contant.

(iii) **speed - Torque characteristics**

Here the DC series motor speed is high, the torque is low and viceversa. It is shown in fig.

Working Principle and Application of Transformer

Introduction

* A transformer is a device that changes ac electric power at one voltage level to ac electric power at another voltage level through the action of a magnetic field.

* Transformer works on the Principle of electromagnetic induction.

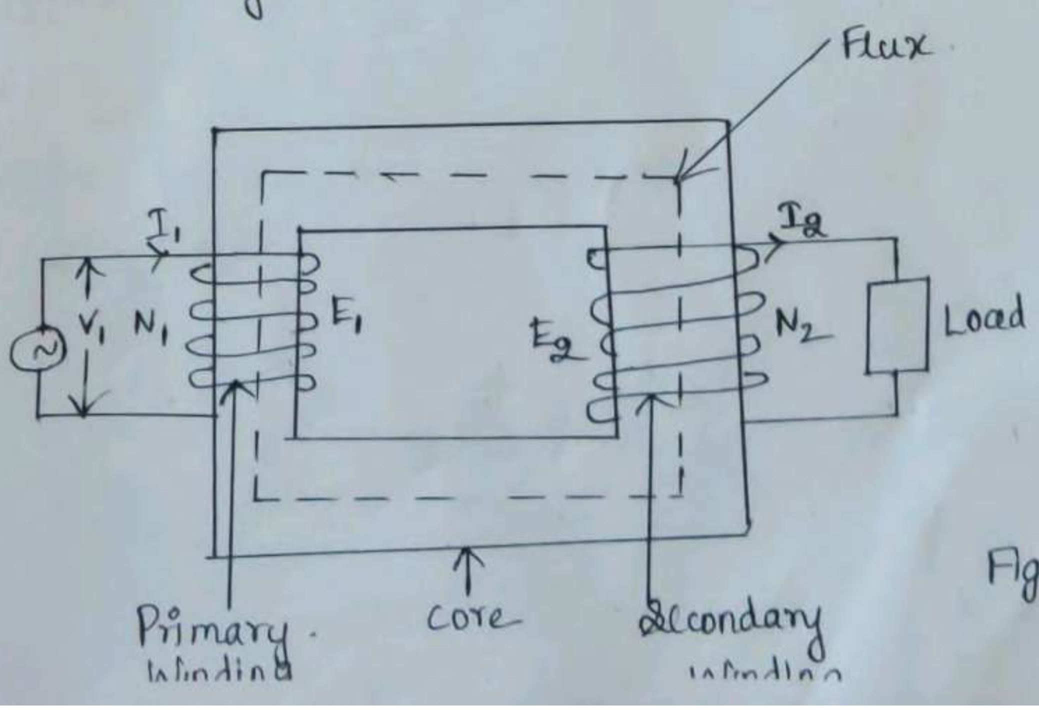


Figure 1.1

Working Principle of a Transformer.

* From the Figure 1.1, Transformer consists of two windings insulated from eachother and wound on a common core made up of magnetic material.

* Alternating voltage is connected across one of the windings called, the primary winding. In both the windings emf is induced by the electromagnetic induction. The second winding is called secondary winding.

* When the primary winding is connected to an ac source an exciting current flows through the winding. As the current is alternating, it will produce an alternating flux in the core which will be linked by both the primary and secondary windings.

* The induced emf in the primary winding (E_1) is almost equal to the applied voltage V_1 and will appose the applied voltage.

* The emf induced in the secondary winding (E_2) can be utilised to deliver

Power to any load connected across the secondary.

* Thus power is transferred from the primary to the secondary circuit by the electromagnetic Induction.

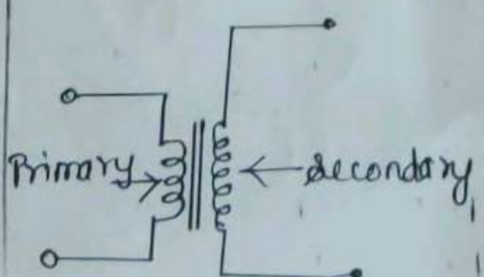
* The flux in the core will alternate at the same frequency as the frequency of the supply voltage.

* The Frequency of induced emf in the secondary is same as that of the supply voltage.

* The magnitude of the emf induced in the secondary winding will depend upon its number of turns.

* In a Transformer, if the number of turns in the secondary winding is less than that in the Primary winding, it is called a step-down Transformer fig 1.3

* When the number of turns in the secondary winding is higher than the primary winding, it is called a step-up transformer. Fig 1.2



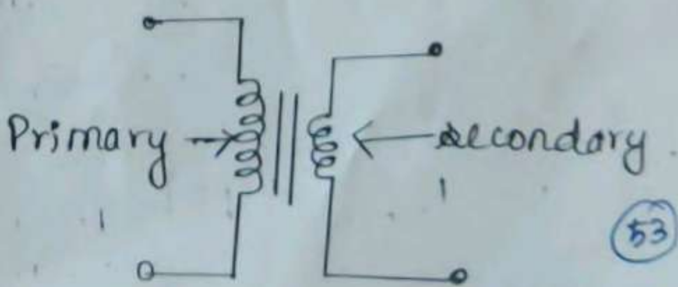


Fig 1.2 Step up Transformer

Fig 1.3 Step down Transformer

Classification of Transformers

(i) Duty they Perform.

1. Power Transformer – for transmission and distribution purposes.
2. Current Transformer – instrument transformers.
3. Potential Transformer – instrument transformers.

(ii) Construction.

1. Core Type Transformer
2. Shell Type Transformer
3. Berry Type Transformer

(iii) Voltage Output.

1. Step down Transformer (Higher to Lower)
2. Step up transformer (lower to Higher)
3. Auto Transformer (variable from '0' to rated value)

(iv) Application

1. Welding Transformer
2. Furnace Transformer.

(v) Cooling

1. Duct type Transformer (Air natural (or) Air blast)
2. Oil Immersed.
   - a. Self cooled
   - b. Forced air cooled
   - c. Water cooled
   - d. Forced oil cooled.

(vi) Input supply

1. Single Phase Transformer
2. Three phase Transformer
   - a). Star – star
   - b) Star Delta
   - c) Delta – Delta
   - [illegible]

starting by providing a special winding on the rotor poles, known as damper winding or squirrel cage winding.

* The damper winding consists of short circuited copper bars embedded in the face of the field poles.

* AC supply given to the stator produces a rotating magnetic field which causes the rotor to rotate, therefore in the begining synchronous motor provided with damper winding starts as a squirrel cage induction motor.

* The exciter moves along the rotor- when the motor attains about 95% of synchronous speed, the rotor winding is connected to exciter terminals and the rotor is magnetically locked by the rotating field of the stator and the motor runs as a synchronous motor.

(2) By Means of AC Motor

* A small direct coupled induction motor called the pony motor, may be used for starting the synchronous motor unless the motor is required to start against full load Torque.

* The induction Motor frequently has two poles less than the synchronous motor and so is capable of raising the speed of the latter to synchronous speed.

* Before switching on the AC supply to the synchronous motor, it must be synchronised with the bus bars.

* After normal operation is established, the pony motor is some times de-coupled from the synchronous motor.

(3) By means of Damper Grids in the Pole faces.

* The synchronous motor is made self

Three phase Alternator

Alternator

* The machine which produces 3 phase power from mechanical power is called an alternator or synchronous generator.

* An alternator works on the same fundamental principle of electromagnetic induction as a d.c. generator. i.e when the flux linking a conductor changes, an emf is induced in the conductor.

Working of Alternator.

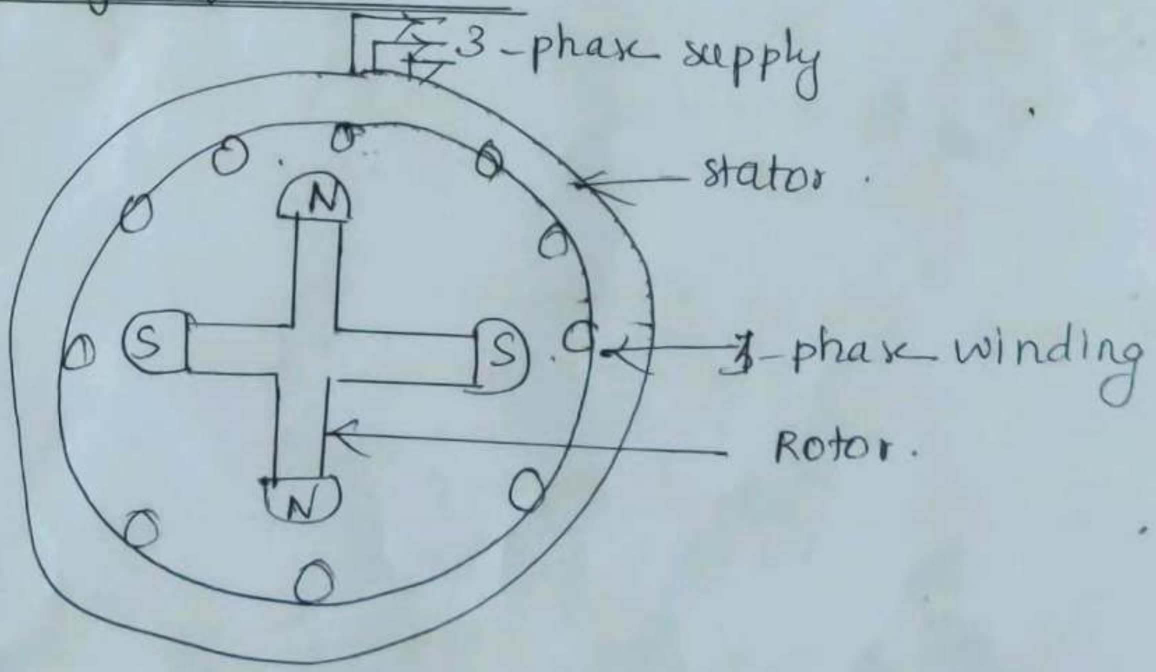


Fig: sectional view of a salient pole alternator.

* The field magnets are magnetised by applying 125 volts or 250 volts through slip rings.
* The field windings are connected such that, alternate N and S poles are produced.
* The rotor and hence the field magnets are driven by the prime mover.
* As, the rotor rotates, the armature conductors are cut by the magnetic flux.
* Hence an emf is induced in the armature conductors.
* As the magnetic poles are alternately N and S pole, this emf acts in one direction and then in the other direction.
* Hence an alternating emf is induced in the stator conductors.
* The frequency of induced emf depends on the Number of N and S poles moving past an armature conductor in one second.
* The direction of induced emf can be found by fleming's right hand rule and

frequency is given by

$$f = \frac{PN}{120}$$

where N → speed of the rotor in r.p.m

P → Number of rotor poles.

Equation of Induced EMf

Let Z = number of conductors or coil sides in series/phase

Z = 2T where T is the number of coils or turns per phase

P = number of poles

f = frequency of induced emf in Hz

ϕ = flux/pole in webers

$$k_d = \text{distribution factor} = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}}$$

K_c or K_p = pitch factor (or) coil span factor

$= \cos \alpha/2$

k_f = form factor = 1.11 - if emf is assumed sinusoidal

N = rotor speed in r.p.m.

* For one revolution of the rotor each stator conductor is cut by a flux of ϕP webers.

$$d\phi = \phi P \quad \text{and} \quad dt = \frac{60}{N} \text{ second.}$$

Average emf induced per conductor

$$= \frac{d\phi}{dt} = \frac{\phi P}{60/N} = \frac{\phi P N}{60}$$

W.K.T, $f = \frac{PN}{120}$ (or) $N = \frac{120f}{P}$

sub value of N, we get average emf per conductor

$$= \frac{\phi P}{60} \times \frac{120 f}{P} = 2f\phi \text{ volt}$$

If there are Z conductors in series/phase, then, Average e.m.f / phase = $2f\phi Z$ volts = $4f\phi T$ Volts.

RMS value of e.m.f / phase = $1.11 \times 4f\phi T$

$= 4.44 f\phi T$ volts

The above equation is true only, If the winding is concentrated in one slot.

* But practically it is not true, as the winding for each phase under each pole is distributed and for such cases k_p and k_d must be considered.

∴ Actually available voltage / phase

$= 4.44\, k_p k_d f\phi T$ volts.

If the alternator is star connected, then the line voltage is $\sqrt{3}$ times the phase voltage.

Voltage Regulation.

Voltage Regulation of an alternator is defined as the increase in terminal voltage when full Load is thrown off, assuming field current and speed remaining the same. The percentage regulation is defined as the ratio of change in terminal voltage from full load to no Load to rated terminal voltage.

$$\text{Percentage regulation} = \frac{E_0 - V}{V} \times 100$$

where

E_0 = No load terminal voltage

V = Full Load terminal voltage.

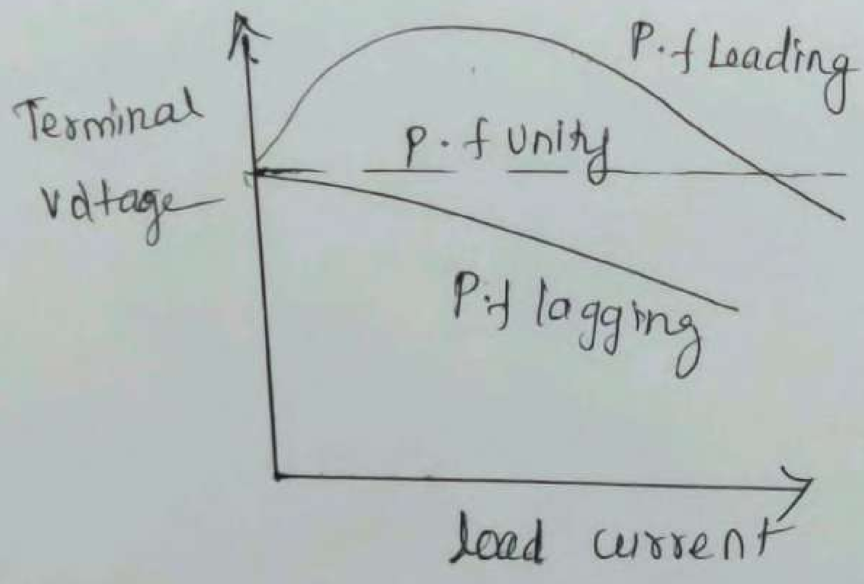


fig: voltage characteristics of an alternator.

Synchronous Motor

* The synchronous motor is one type of 3 phase A.C motors which operate at a constant speed from no load to full load.

* It is similar in construction to 3 phase A.C generator in that it has a revolving field which must be separately excited from a D.C source.

* By changing the D.C field excitation, the power factor of this type of motor can be varied over a wide range of lagging and leading values.

* This motor is used in many applications because of its fixed speed from no load to full load, its high efficiency and low initial cost.
* It is also used to improve the power factor of 3-phase AC industrial circuits.

Working Principle

* When a sinusoidal (single phase) voltage is applied to a winding, the magnetic

field produced by the resultant current flow will also be sinusoidally varying with respect to time.

* This means that the field is pulsating.

* Now when a three-phase voltage is applied to a three phase winding, the flux produced will be the resultant of all the three pulsating fields.

* It can be shown that the resultant field has a magnitude of $1.5 \phi_m$ where ϕ_m is the maximum value of the flux due to a single phase current.

* Further, it can also be shown that the direction of the field changes continuously, i.e., the field is rotating in space at a speed given by

$$N_s = \frac{120 \times f}{P}$$

where f is the frequency of supply

P is the Number of poles.

$N_s \Rightarrow$ synchronous speed.

* When a three-phase supply is given to a three-phase winding a magnetic field of constant magnitude but rotating

* N_S and S_R and similarly S_S and N_R get attracted and the rotor tries to rotate in the clockwise direction.

* This implies that the rotor experiences torque in different direction every half a cycle.

* As a result, the rotor is at standstill due to its large inertia.

* This explains why a synchronous motor has no starting torque and cannot start by itself.

* If the rotor is now rotated seperately by a prime mover in the same direction as the synchronously rotating stator field and at a speed near N_S, then it is possible that at some instant N_S and S_R and similarly S_S and N_R get attracted and locked to one another.

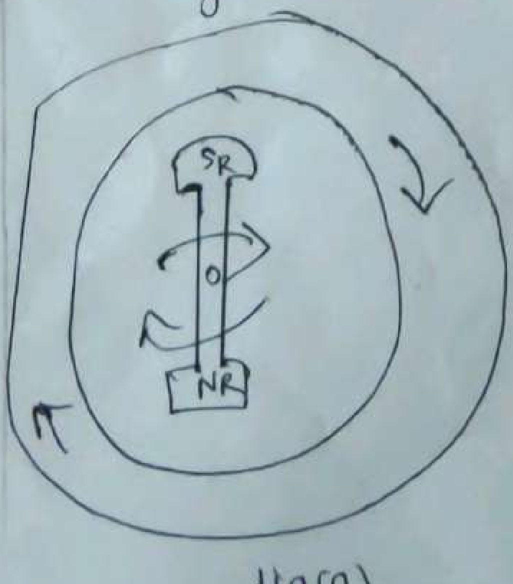


fig (a)

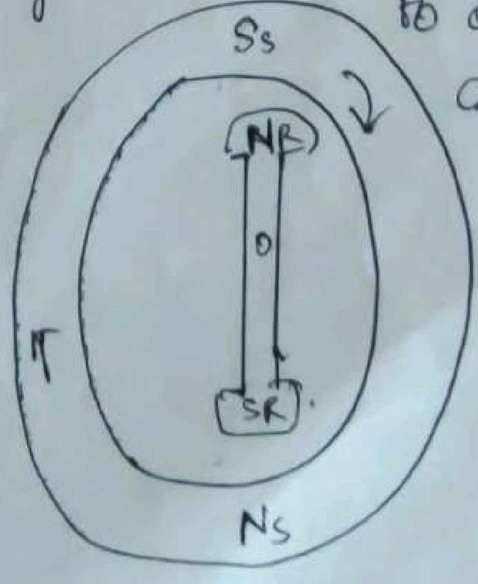
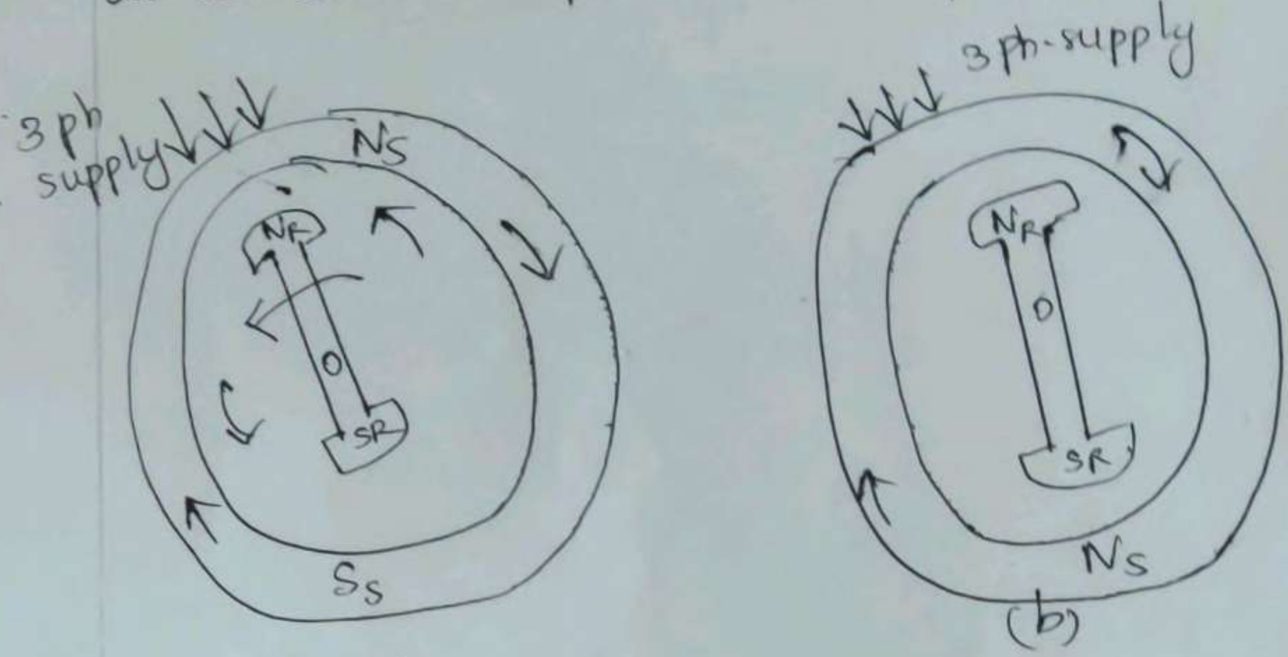


fig (b).

at a constant speed, Ns is produced.



(a) (b)

* Diagram above shows the two fictitious assumed stator poles marked N_s and S_s to rotate clockwise at a synchronous speed N_s.

* The rotor poles N_R and S_R are formed by the dc excitation.

* When N_s and N_R are together likes poles repel each other, since N_s and S_s are moving in the clockwise direction, N_R and S_R tend to figure (a).

* Half a cycle later, the stator poles have moved, whereas the rotor poles have moved significantly is shown fig (b).

starting by providing a special winding on the rotor poles, known as damper winding or squirrel cage winding.

* The damper winding consists of short circuited copper bars embedded in the face of the field poles.

* AC supply given to the stator produces a rotating magnetic field which causes the rotor to rotate, therefore in the begining synchronous motor provided with damper winding starts as a squirrel cage induction motor.

* The exciter moves along the rotor - when the motor attains about 95% of synchronous speed, the rotor winding is connected to exciter terminals and the rotor is magnetically locked by the rotating field of the stator and the motor runs as a synchronous motor.

② By Means of AC Motor

* A small direct coupled induction motor called the pony motor, may be used for starting the synchronous motor unless the motor is required to start against full load Torque.

* The induction Motor frequently has two poles less than the synchronous motor and so is capable of raising the speed of the latter to synchronous speed.

* Before switching on the AC supply to the synchronous motor, it must be synchronised with the bus bars.

* After normal operation is established, the pony motor is some times de-coupled from the synchronous motor.

③ By means of Damper Grids in the Pole faces.

* The synchronous motor is made self

* Hence a synchronous motor, though not self starting, starts working as a motor if it is started up by some means.

* It needs two seperate supplies — one a d.c source for excitation of the rotor and other, a three phase supply for the stator.

* Because of the Interlocking between the stator and rotor poles, the motor runs only at one speed, the synchronous speed.

Starting Methods of Synchronous Motor.

① From DC source

* when Dc supply and dc compound motor are available, the synchronous motor is coupled and started by means of a dc compound motor.

* The speed of dc motor is adjusted by the speed regulator

* The synchronous motor is then excited and synchronised with AC supply mains.

* At the moment of synchronising, the synchronous motor is switched on with the AC mains and either the dc motor is disconnected from the dc supply. mains.

* Now the synchronous machine is operating as a motor, from ac supply mains and dc machine acts as load on it.

* The synchronous motor can also be started by the exciter mounted on an overhung synchronous motor bracket and shaft extension.

* An available dc source operates the exciter as a motor during the starting period then after the synchronous machine is brought up to speed and synchronised, the exciter assumes its normal function.

Torque of a synchronous Motor.

① Starting Torque

* It indicates the ability of the motor to accelerate the load. It is also sometimes called "break away Torque"

* It may be as low as 10% in case of centrifugal pumps and as high as '200 or 250% of full load Torque". as in case of loaded reciprocating two-cyclinder compressor.

* The synchronous motor posseses no self starting torque, in modern synchronous motors, by making changes in the design of damper windings, torque canbe developed.

② Running Torque.

* Running Torque is the torque developed by the motor under running condition.

* It is determined by the o/p power and speed of the driven machine.

* Peak output power determines the maximum torque that would be required

by the driven machine.

* The breakdown or maximum running Torque of a motor must be greater than this value in order to avoid stalling of the machine.

* ~~Push~~ ③ Pull in Torque

* It pertains to the ability of the machine to pull in to synchronism when changing from induction to synchronous motor operation.

④ Pullout Torque.

* It is the maximum Torque that the synchronous motor will develop without pulling out of synchronism.

* Its value ranges from 1.25 to 3.5 times the full load torque.

Three phase Induction Motor.

* Three phase Induction Motors are extensively used for electric drives

Advantages

* It is simple and extremely rugged construction
* High reliability.
* Low cost
* High efficiency.
* It requires little maintenance.
* Its ability to start off from rest unlike synchronous motors which have to be started and run up by seperate prime movers.

Disadvantages

(i) The speed is not constant, when load is varied.

(ii) Low starting torque compared to DC shunt motor.

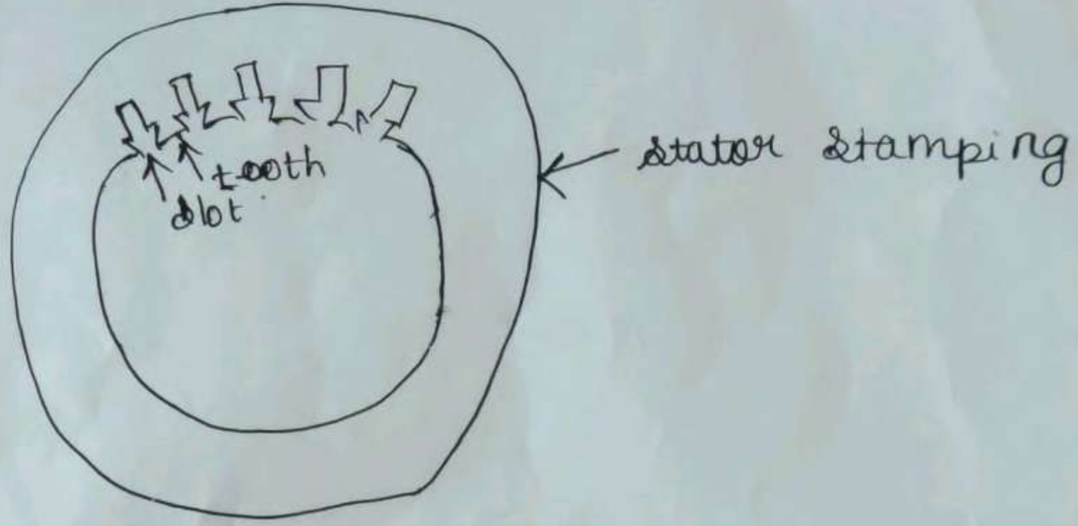
(iii) Reduction in efficiency when speed is varied.

construction

The induction motor consists of two main Parts. Viz (a) Stator
(b) rotor.

Stator

* The stator is made up of a number of stampings with alternate slot and tooth.
* stampings are insulated from each other
* Each stamping is 0.4 and 0.5 mm thick.
* Number of stampings are stamped together to build the stator core.
* The stator core is then fitted in a casted or fabricated steel frame.
* Three-phase winding is called stator winding
* It may be connected either in star or delta.



Rotor

There are two types of rotors used in induction motors.

They are 1. squirrel cage rotor
2. slip ring or wound rotor.

(1) Squirrel cage rotor

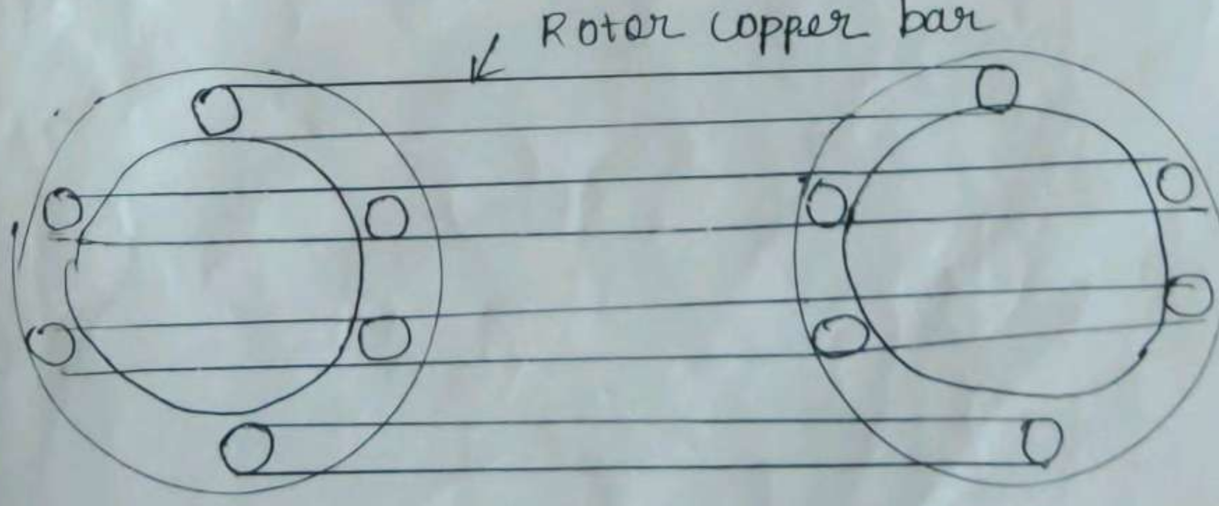


Fig : Squirrel cage rotor.

* This is made up of a cylindrical laminated core with slots to carry the rotor conductors.
* The rotor conductors are heavy bars of copper or aluminium short circuited at both ends by end rings.
* Hence this rotor is also called a short circuited rotor.
* The entire rotor resistance is very small.
* External resistance cannot be connected in the rotor circuit.
* Such motors are extremely rugged in construction.
* Motors using such rotors are called squirrel cage induction motors.
* The majority of induction motors are cage rotors.

② Slip ring or wound rotor

* In this type of rotor, rotor windings are similar to the stator winding.
* The rotor winding may be star or delta connected, distributed winding.

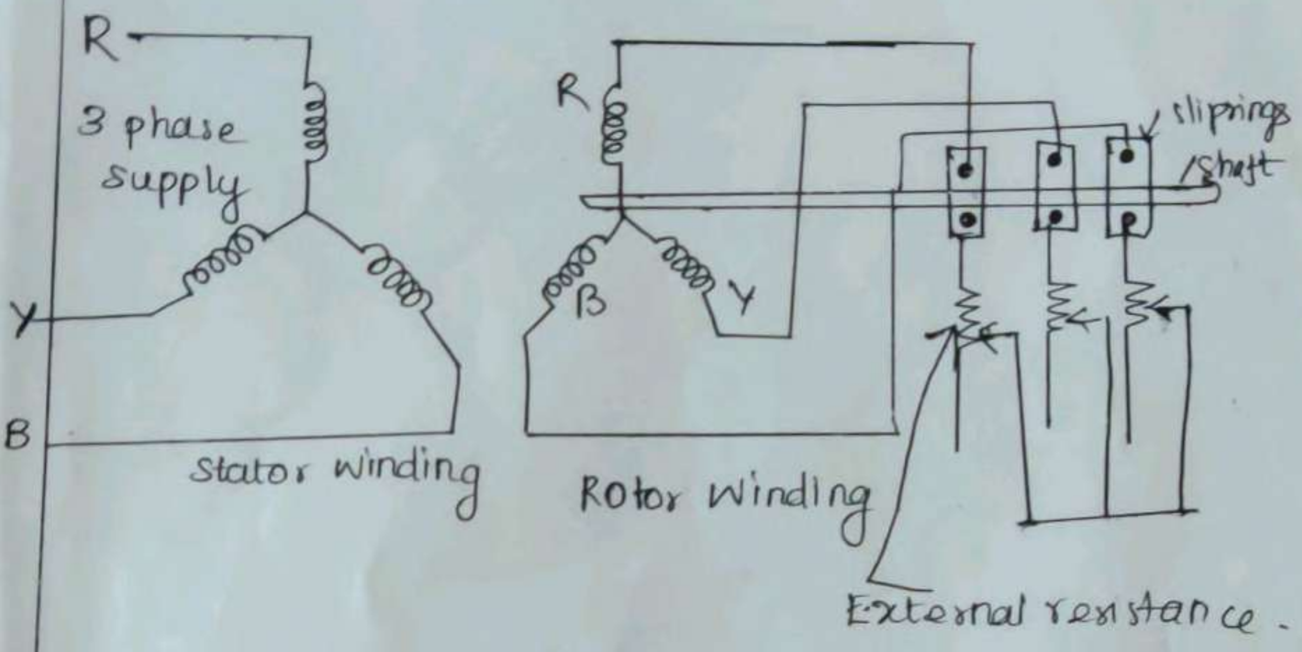


Fig: slipRing (or) wound Rotor

* The three phases are connected to slip rings mounted on the rotor shaft.

* Variable External resistance can be connected in the rotor circuit, with the help of brushes and slip ring arrangements.

* By varying the external resistance in the rotor circuit, the motor speed and torque can be controlled.

* This motor is called slipring induction motor or wound rotor induction motor.

Types of 3 phase induction motors

There are two types of 3-phase induction motors.

1. Squirrel cage induction motor
2. Wound rotor or slip ring Induction motor.

Principle of operation of three phase Induction motor

* Three-phase supply is given to the stator winding.
* Due to this, current flows through the stator winding.
* This current is called stator current.
* It produces a rotating magnetic field in the space between stator and rotor.
* This magnetic field rotates at synchronous speed given by

$$N_s = \frac{120f}{P}$$

N_s = synchronous speed

f = supply frequency

P = number of poles for which the stator is wound.

* As a result of the rotating magnetic field cutting the rotor conductors, an emf is induced in the rotor.

* If the rotor winding is shorted, then the induced emf produces current.

* This current produces a rotor field.

* The interaction of stator and rotor fields develops torque.

* then the rotor rotates in the same direction as the rotating magnetic field.

* when the rotor is at standstill, the frequency of rotor emf is equal to the supply frequency.

* As the rotor speed picks up, the frequency of rotor emf and the magnitude of rotor emf decrease.

* The rotor tries to catch up with the rotating magnetic field.
* However, the rotor cannot really catch up and rotate at the synchronous speed, because if it does so, the relative speed would become zero.
* And then there is no rotor induced emf, no current and hence no torque.
* Therefore, the rotor runs at a speed slightly less than the synchronous speed.
* In an induction motor, the rotor speed is always less than the synchronous speed.
* Therefore this machine is called an asynchronous machine.
* The difference between synchronous speed and rotor speed is called the slip speed.

$$\text{Slipspeed} = N_s - N$$

$$\text{Slip, } s = \frac{N_s - N}{N_s}$$

$$N = N_s(1-s)$$

$$\% \text{ slip} = \frac{N_s - N}{N_s} \times 100$$

* At <u>no load</u>, the difference between synchronous speed and rotor speed is only about 1%.
* At <u>loaded condition</u>, the rotor slows down.
* The emf induced in the rotor and hence the rotor current increase.
* Due to this, torque also increases
* Under steady state conditions, the electromagnetic torque is equal to the load torque.
* The variation of speed from no load to full load is very small.
* Thus a three phase induction motor is also called a constant speed motor.

Advantages of squirrel cage induction motor

1. cheaper
2. Light weight.
3. Rugged construction.
4. More efficient.
5. Requires less maintenance.
6. It can be operated in dirty & explosive environmen

Disadvantages of squirrel cage induction Motor

1. Moderate starting torque.
2. External resistance cannot be connected to rotor circuit. So starting torque cannot be controlled.

Applications of squirrel cage induction Motor

Lathes, drillilling machines, fans, blowers, water pumps, grinders, printing machines.

Advantages of slip ring induction motor.

1. the starting torque can be controlled by varying the rotor circuit resistance.
2. the speed of the motor can be controlled.

Disadvantages of slip ring induction motor

1. High cost
2. High rotor inertia.
3. High speed limitation.

Application

Lifts, hoists, cranes, elevators,

UNIT - III

ANALOG ELECTRONICS

Resistor, Inductor and capacitor in Electronic circuits - Semiconductor materials: Silicon & Germanium - PN Junction Diode, Zener Diode - Characteristics Applications - Bipolar Junction Transistor - Biasing - JFET, SCR, MOSFET, IGBT - Types I-V characteristics and Applications, Rectifier and Inverters.

Resitor, Inductor and capacitor in Electronic circuits.

DC circuits - Basic circuit components.

* Resistor
* capacitor
* Inductor

Conductor

* Some materials allow electric charges to pass through them easily, these materials are called conductors.

* Materials that do not allow electric charges to pass through them easily are called Insulators.

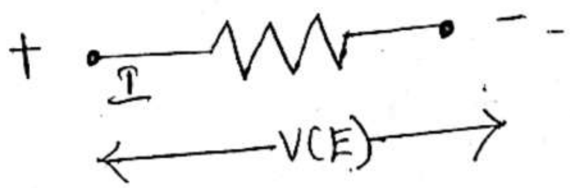
Network (Electrical circuit)

Active Elements	Passive elements
① which supply power or energy to the network.	- Elements which either store energy or dissipate energy in the form of heat.
② Ex: Voltage source & Current source	- Ex: Resistor, capacitor Inductors.

Resistor

* Electrical component which opposes the flow of current through it. Unit of Resistance is ohm (Ω). It is denoted by R.

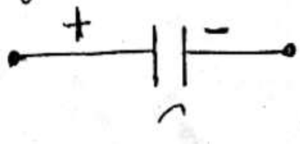
$$R = \frac{V}{I} \text{ ohm}$$



Capacitor

* Capacitor is a storage element which can store & deliver energy in a electric field.

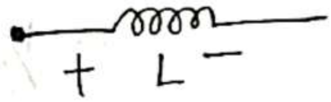
* It is denoted by C.
* The unit of capacitence is Farad (F).



Inductor

Inductor is the element in which energy is stored in the form of electromagnetic field. It is a device that resists change in current.

The inductance is denoted by 'L' and its unit is Henry (H).



V-I Relation:

For inductance the voltage is proportional to rate of change of current.

$$V \propto \frac{di}{dt}$$

$$V = L\frac{di(t)}{dt}$$

$$\Rightarrow i = \frac{1}{L}\int V\,dt$$

Assuming that initially zero current flows through the inductance, if a current i is made to follow flow through a coil, the energy stored in time t is

$$W = \int_0^t V.i\,dt$$

$$= \int_0^t \left(L\frac{di}{dt}\right) i\,dt$$

$$= L\int_0^t i.di$$

$$W = \frac{1}{2} i^2 L \text{ Joules.}$$

⇓

Energy stored in inductor.

Henry is the unit of inductance in which an induced electromotive force of one volt is produced when current is varried at the rate of one ampere per second.

SEMICONDUCTOR MATERIALS : Silicon & Germanium

Basics of Semiconductor

Materials are classified according to the Resistivity/conductivity:
- Insulator (Resistance ↑, conductance ↓)
- conductor (Resistance ↓, conductance ↑)
- semiconductor. (Conductance ↓, Resistance moderate)

Semiconductor.

* The small electric field is required to push the electrons from the Valence Bond to Conduction Band. At low temperature, valence band is completely filled and conduction band is empty. It acts like insulator at low temperature.

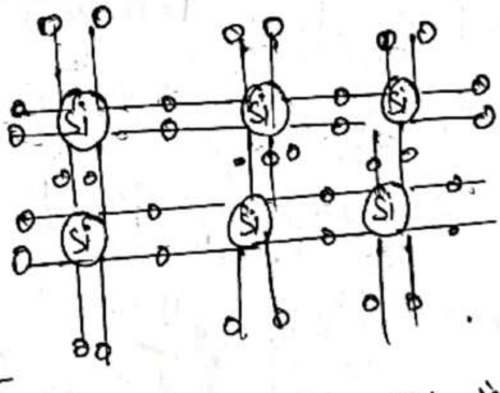
* As the temperature increases, number of electrons crossing over to the conduction band from valence Band increases and electrical conductivity Increases. Thus semiconductor has negative temperature Coefficient of Resistance.

Types of semiconductor.

1) Intrinsic semiconductor	2) Extrinsic semiconductor
* Pure form of Semiconductor or (No doping)	* Due to the poor Conduction of current at Room temperature,

	the Intrinsic semiconductor is not useful.
* Electron hole pairs are created by applying electric field at room temperature. Thus Produces current in lower manner Eg: Silicon, Germanium.	* Extrinsic semiconductor is adding impurities to the intrinsic semiconductor [Doping]

<u>Silicon</u> A silicon crystal lattice has a diamond cubic crystal structure in a repeating pattern of eight atoms. Each silicon atom is combined with four neighbouring silicon atoms by four bonds. silicon, a very common element, is used as the raw material of semiconductors because of its stable structure

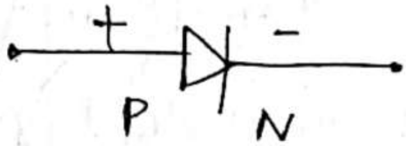


<u>Germanium.</u>

Germanium is a chemical element with the symbol Ge and atomic number 32. It is a lustrous, hard brittle, grayish - white metalloid in the carbon group, chemically similar to its group neighbours silicon and tin. Pure Germanium is a semiconductor with an appearance similar to elemental silicon. Like silicon, Germanium naturally reacts and forms complexes with oxygen in nature.

P-N Junction Diode.

* The PN Junction diode is formed by simply bringing P-type and n-type materials together.



Depletion Region.

* At the instant, two materials are "joined", the electrons and holes in the region of the Junction will combine, results in lack of carriers in the carrier near the Junction.

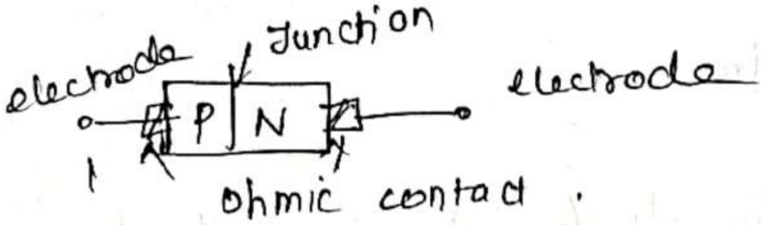
* This region of uncovered positive and negative ions is called the depletion region, due to the depletion of carriers in this region.

* Diode will operate in three Biases.

(i) No Bias/ Zero Bias ($V_D = 0V$)

(ii) Forward Bias ($V_D > 0V$)

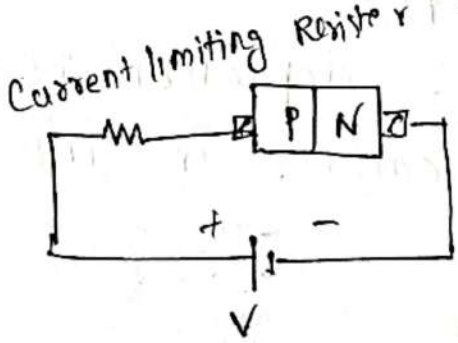
(iii) Reverse Bias ($V_D < 0V$)

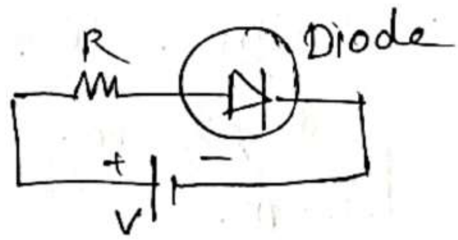


Forward Biased PN junction.

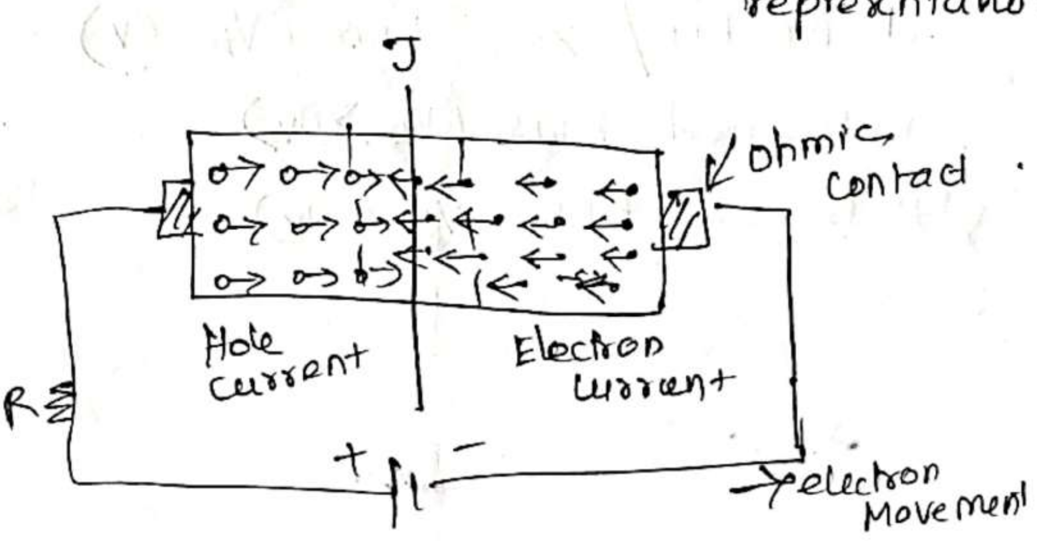
If an external DC - Voltage is connected in such a way that the p-region terminal is connected to the positive of the DC - Voltage and n region is connected to the negative of the DC - voltage, this biasing condition is called "forward biasing".

Operation of forward biased diode.

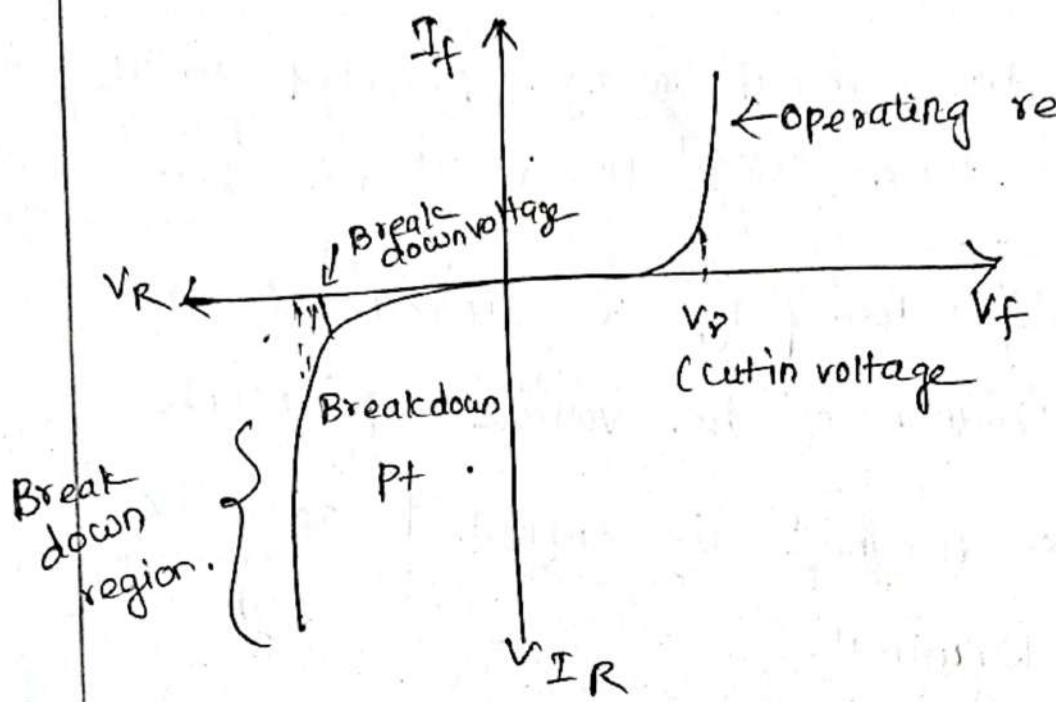




(a) forward biasing. (b) symbolic representation.



VI Characteracteristics of PN Diode



The response of a diode when connected in an electrical circuit can be judged from its characteristics known as volt-ampere commonly called VI-characteristics.

Biasing conditions for the p-n Junction Diode.

In a p-n junction diode, there are two operational regions.

1. p-type
2. n-type.

The voltage applied determines one of three biasing conditions for p-n junction diode.

* There is no external voltage provided to the p-n junction diode while it is at Zero bias.
* Forward bias: The p-type is linked to the positive terminal of the voltage potential, while the n-type is connected to the negative terminal.
* Reverse bias: This p type is linked to the negative terminal of the voltage potential, while the n-type is connected to the positive terminal.

Applications

* Diode may be utilised as a photodiode.
* It has the potential to be utilised as a solar cell.
* The diode can be utilised in LED lighting applications when it is forward-biased.
* Many electric circuits utilise it as a rectifier, while varactors employ it as a voltage-controlled oscillator

Zener Diode

* In a general purpose PN diode, the doping is light. As a result of this, the breakdown voltage is high. If P and N region are heavily doped, then the breakdown voltage can be reduced.

* When the doping is heavy, even if the reverse voltage is low, the electric field at barrier will be so strong and thus the electrons in the covalent bonds can break away from the bonds. This effect is known as zener effect.

* A diode which exhibits the zener effect is called as zener diode.

* Hence, It is defined as a reverse biased heavily doped PN Junction diode which Operates in breakdown region.

* Zener breakdown occurs in Junction which is heavily doped and have narrow depletion layers.

* The breakdown voltages sets up a very strong electric field.

* This field is strong enough to break or

rupture the covalent bonds thereby generating electron hole pairs

* Even a small reverse voltage is capable of Producing large number of current carrier.

* when a zener diode is operated in the breakdown region, care must be taken to notice that the Power dissipation across the Junction is within the power rating of the diode.

* otherwise heavy current will flow through the diode and may destroy it.

Equivalent circuit of zenerdiode

The schematic symbol of zener diode and its equivalent circuit is shown in figure. It is similar to that of normal diode except the line representing cathode is bent at both end.

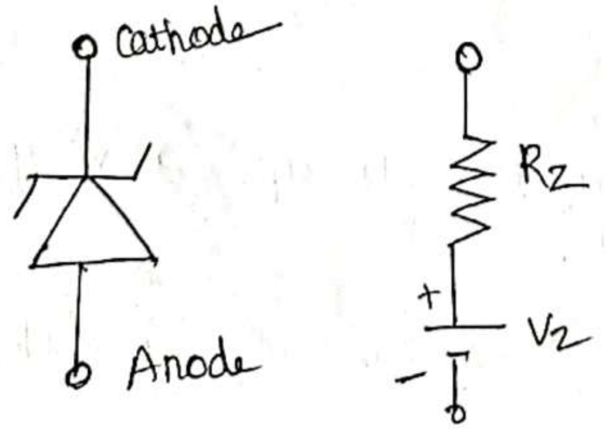


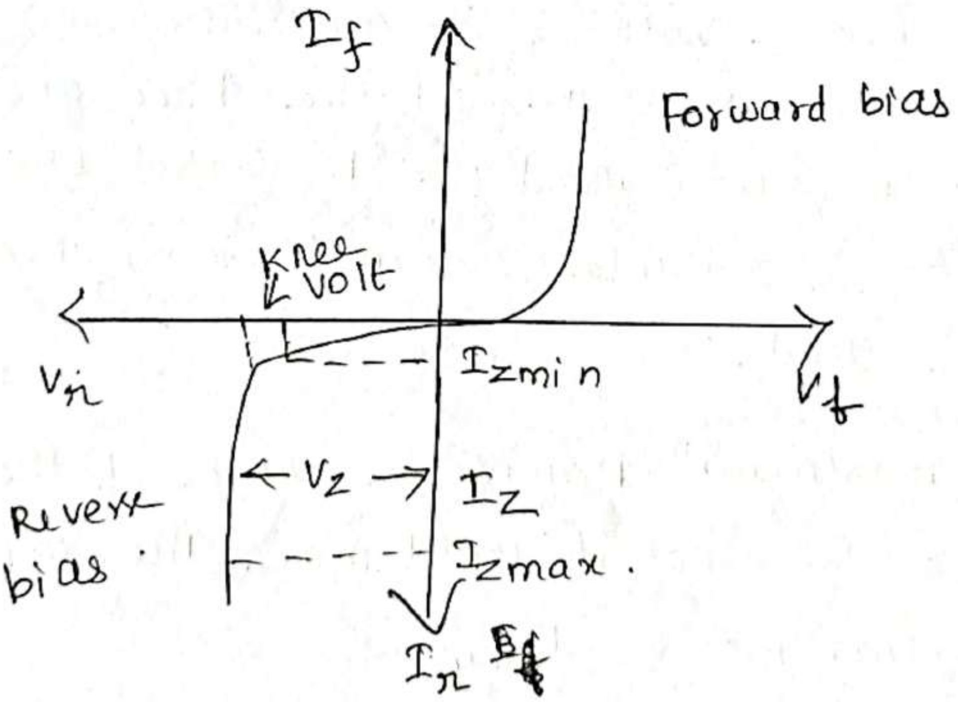
fig: symbolic representation of zener diode and its equivalent circuit.

* When the reverse bias voltage across zener diode exceeds the breakdown voltage V_Z, the current increases very sharply.

* It means that voltage across zener diode is constant at V_Z even though the current through it changes.

* Therefore in breakdown region, a zenerdiode may be represented by a battery of voltage V_Z in series with the zener resistance as shown in diagram.

V-I characteristics of Zener Diode



* Figure shows the V-I characteristics of zener diode.

* The forward characteristics of a zener diode is similar to that of a P-N junction diode.

* The reverse characteristics of zener diode is obtained as follows.

* the reverse current that is present at the Origin and the knee of the curve is due to the reverse leakage current due to the minority carriers. this current is specified by stating its value at 80% of the zener voltage V_Z.

* As the reverse voltage is gradually increased, the breakdown occurs at the knee and the current increases rapidly. To control this current, a suitable external resistance has to be used.

* The maximum permissible value of the current is denoted by I_{zmax}. The minimum usable current is I_{zmin}.

* The voltage across the terminals of the diode for a current I_Z. which is the approximate midpoint of the linear

Linear range of the reverse characteristics is called a zener voltage V_Z. At the knee point, the breakdown voltage remains constant between I_{Zmax} and I_{Zmin}. This ability of a diode is called the regulating ability and is an important feature of a zener diode.

Application of zener Diode.

It can be used as

a) as voltage regulators.

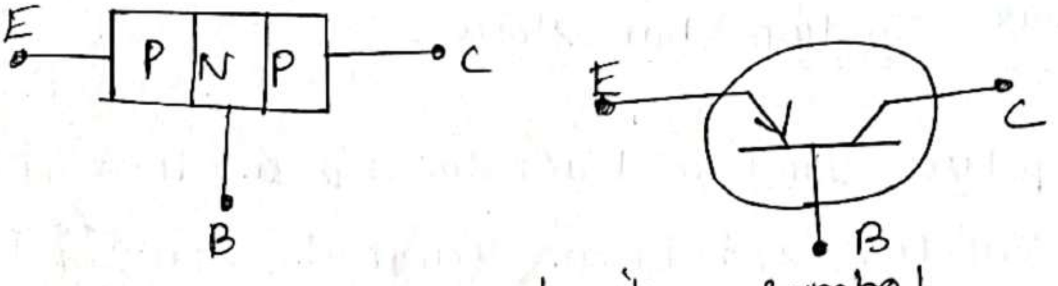
b) as peak clippers

c) for reshaping waveforms

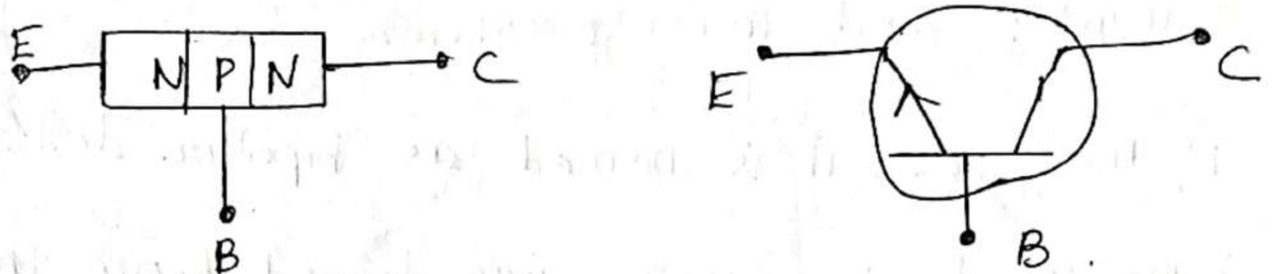
d) Protection of meter against damage from accidental application of excessive voltage.

Bipolar Junction Transistors

* A Bipolar Junction transistor is a three layer, two Junction and three terminal semiconductor device.
* Its operation depends on the interaction of majority and minority carriers.
* Therefore, it is named as bipolar device.
* The word transistor was derived from the two word combination, (TRANsfer + reSISTOR =TRANSISTOR)
* Transistor means, signals are transferred from low resistance circuit (input) into high resistance (output) circuit.
* Transistor consists of two back to back PN junction joined together to form single piece of semiconductor device.
* The two Junctions gives three region named as emitter, base and collector.
* There are two types of transistors such as NPN Type or PNP type.



(a) PNP Transistor and its symbol.



(b) NPN transistor and its symbol.

* The arrow on the emitter specifies whether the transistor is NPN Type or PNP Type.

* This arrow also indicates the direction of current flow, when the emitter base Junction is forward biased.

* The diagram above shows the circuit representation and symbols of NPN and PNP Transistor.

Emitter

* It is more heavily doped than any of other regions because, its main function is to supply majority charge carriers (either electrons or holes) to the base.

* The current through the emitter is emitter current. It is noted as I_E.

Base

* Base is the middle section of the transistor. It seperates the emitter and collector.

* It is very lightly doped.

* It is very thin as compared to either emitter or collector.

* the current flows through the base section is base current. It is denoted as I_B.

Collector

* It forms the right hand side section of the transistor.

* It is shown in diagram.

* The main function of the collector is to collect the majority charge carriers coming from the emitter and passing through the base.

* Generally, collector region is made physically larger than the emitter region, because it has to dissipate much greater power.

* Collector is moderately doped. The current flows through the collector section is collector current.

* It is denoted as I_C.

PNP and NPN Transistors.

To understand the basic operation of transistor, the followings points are need to be kept in mind.

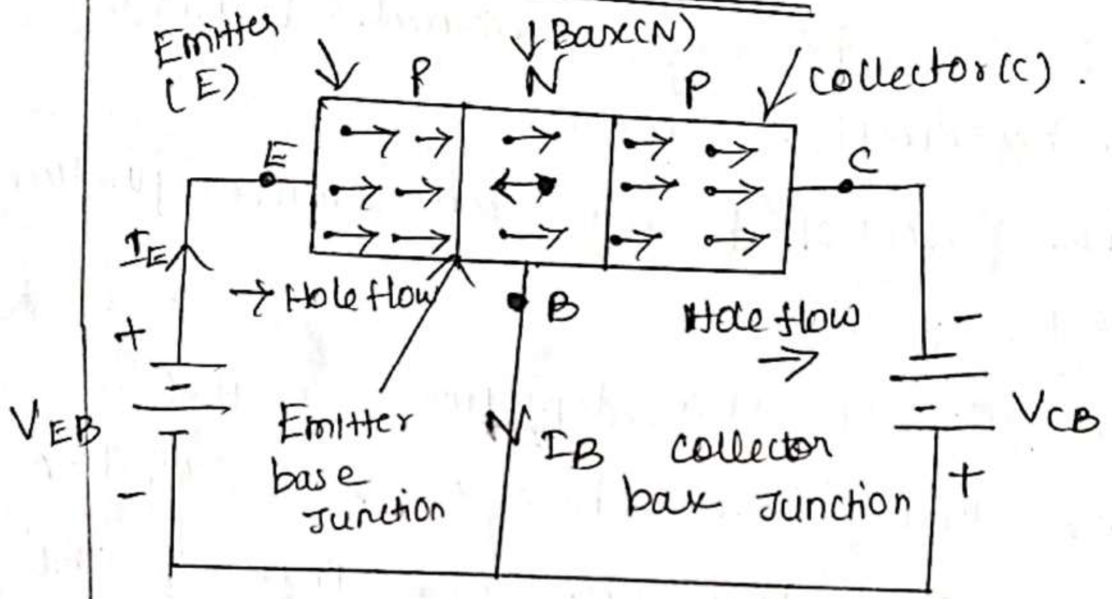
① Emitter section is meant to provide charge carriers, therefore, It is always forward biased.

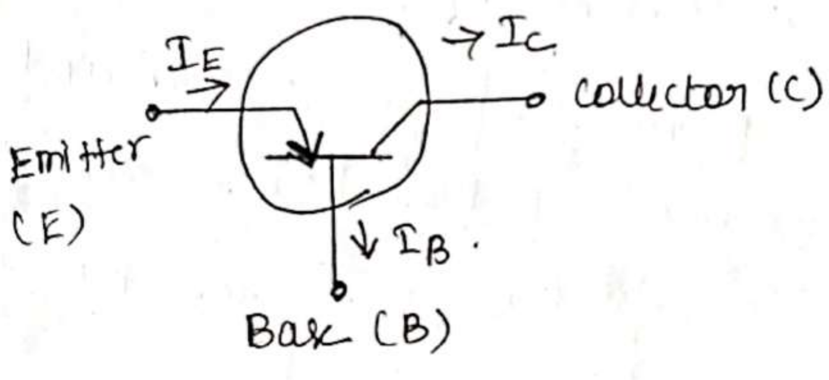
② First letter of transistor type Indicates the Polarity of the emitter Voltage with respect to base.

③ the main function of collector is to collect or attract those carriers through

4) Second letter of transistor type indicates the polarity of collector voltage with respect to the base.

Working of PNP Transistor





* Figure shows the connection diagram of PNP Transistor.

* In this circuit diagram, the emitter base junction is forward ~~diagra~~ biased (i.e, positive polarity of the battery is connected with 'p' type semiconductor and negative polarity

of the battery is connected with 'p' type semiconductor and negative polarity of the battery is connected with 'N' type semiconductor and collector base Junction is reverse biased.

* The holes in the emitter are repelled by the positive battery terminal towards the PN or emitter Junction.

* Then the potential barrier at emitter junction is reduced.

* As a result of this, depletion region disappears and hence holes cross the Junction and enter in to N-region (base). This constitutes the emitter current I_E.

* Because of base region is thin and lightly doped, majority of the holes (about 97.5%) are able to drift across the base without meeting electrons.

* Only 2.5% of the holes recombine with the free electrons or N-region.

* This constitutes the base current I_B which is very small.

The following points about transistor circuits are,

① In a PNP transistor, majority charge carriers are holes.

② Emitter arrow shows the direction of flow of conventional current. But electrons flows will be in the opposite direction.

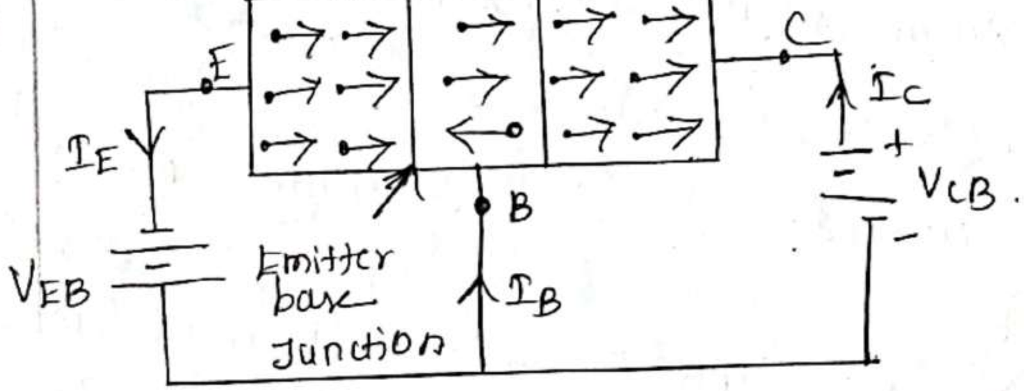
③ Emitter base Junction is always forward biased and collector base Junction is always reverse biased.

④ The collector current is always less than the emitter current because same recombination of holes and electrons takes place.

$$I_C = I_E - I_B.$$

$$\boxed{I_E = I_B + I_C}$$

Working of NPN Transistor



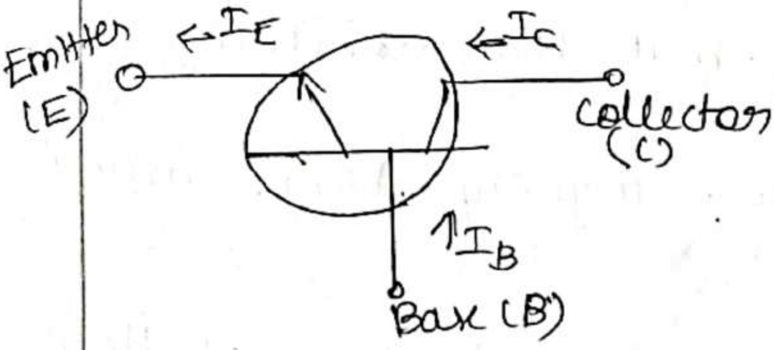


Figure shows the connection diagram of NPN Transistor. In this circuit diagram, the emitter base Junction is forward biased. (ie, Negative polarity of the battery is connected with 'N' type semiconductor and positive polarity of the battery is connected to with P type semiconductor) and collector base Junction is reverse biased.

⇒ The following points about transistor circuits are.

① In a NPN Transistor, majority charge carriers are electrons

② Emitter arrow shows the direction of flow of conventional current.

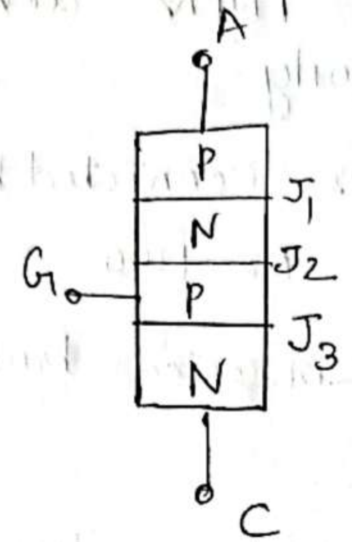
③ collector current I_C is less than emitter current I_E

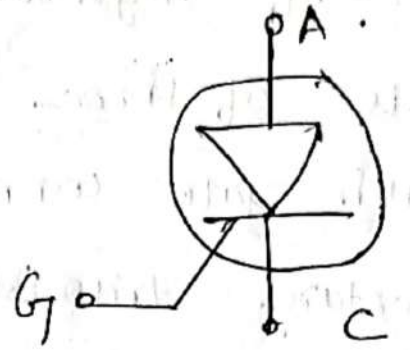
The choice of NPN Transistor is made more often because majority charge carriers are electrons whose mobility is much more than that of holes

SCR - Silicon controlled Rectifier

* SCR is a four layered PNPN device and a member of thyristor family
* It consists of three diodes connected back to back with gate connection or two complementary transistors connected back to back.
* It is widely used as switching device in power control applications.
* It can switch ON for variable length of time and delivers selected amount of power to load.
* It can control loads, by switching the current OFF and ON up to many thousand times a second.
* Hence it posses advantage of RHEOSTAT and a switch with none of their disadvantages.

Symbol of SCR.





Construction

→ It is a four layered three terminal device layers being alternately p-type and n-type silicon.

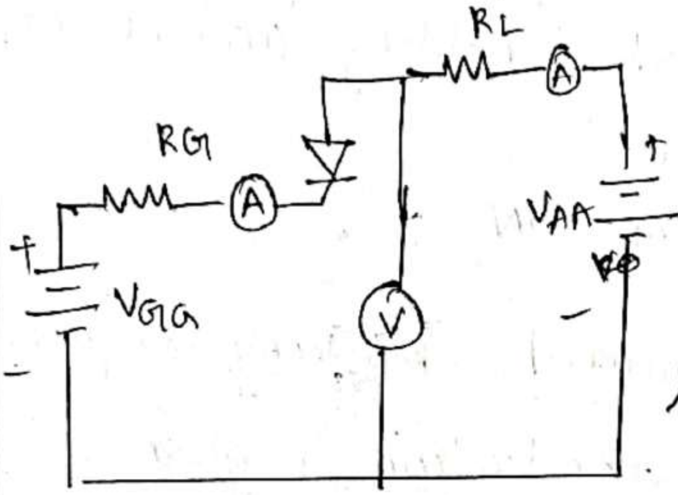
→ Junctions are marked J_1, J_2, J_3.

→ where as terminals are anode (A), Cathode (C) and Gate (G)!

→ The gate terminal is Connected to inner p-type layer and it controls the firing or switching of SCR

VI characteristics of SCR

* The forward characteristics of SCR may be obtained using the fig (a).
* The volt ampere characteristics of a SCR for $I_G = 0$ is shown in fig (b)



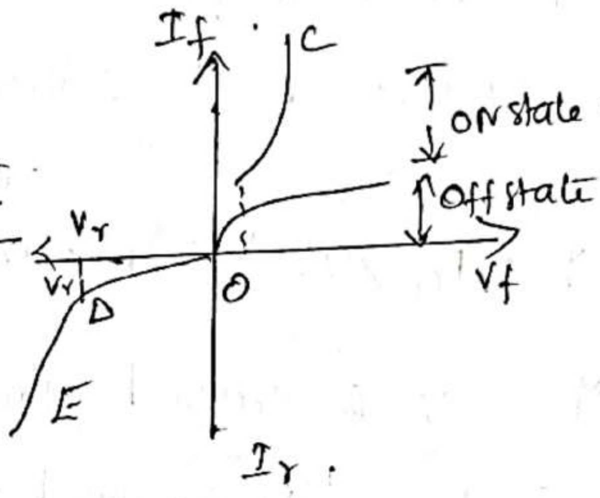


fig (b)
VI characteristics of SCR.

* As the applied anode to cathode voltage is increased above zero, a very small current flows through the device, under this condition the SCR is off. It will be continued until, the applied voltage reaches the forward breakover voltage (point A).

* If the anode-cathode voltage exceeds the breakover voltage it conducts heavily the SCR turns ON and anode to Cathode voltage decreases quickly to a point B.

* The current corresponding to the point 'B' is called "holding current (I_H)".

* $I_G > 0 \Rightarrow$ SCR turn ON.

* OA is called forward blocking region.
  BC ⇒ forward conduction region.

Application

relay controls
phase controls
static switches.
regulated power supplies.
heater controls.
inverters
motor controls.

JFET

FET - Field Effect Transistor

* FET is a three terminal unipolar semiconductor device.

* In FET, current is controlled by an electric field and so called field effect Transistor.

* There are two types of FET,

① Junction field effect Transistor (JFET)

② Metal oxide semiconductor FET (MOSFET) or Insulated Gate FET (IGFET).

JFET

* Junction - gate field Effect Transistor (JFET) is one of the simplest types of FET.

* JFETs are three-terminal semiconductor devices that can be used as electronically controlled switches or resistors or to build amplifiers.

Types of JFET

1. N-channel JFET
2. P-channel JFET.

JFET has the following Notation,

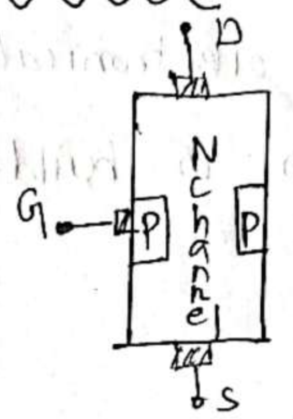
Source : the source S is a terminal through which the majority carriers enters the bar.

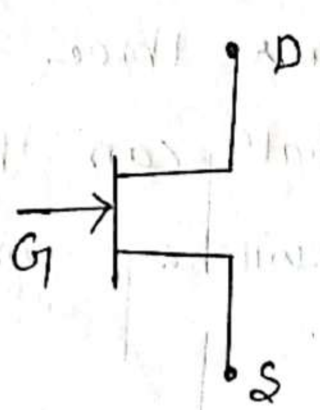
Drain : The drain D is a terminal through which the majority carriers leave the bar.

Gate : These are two internally connected heavily doped impurity regions which form two P-N Junctions.

Channel : the space b/w gate through which majority carriers pass.

N-channel JFET :





Construction of N-channel JFET

* N-channel JFET consists of an N-Type semiconductor bar.

* On both the ends of the bar metal contacts are made, they are called source and drain.

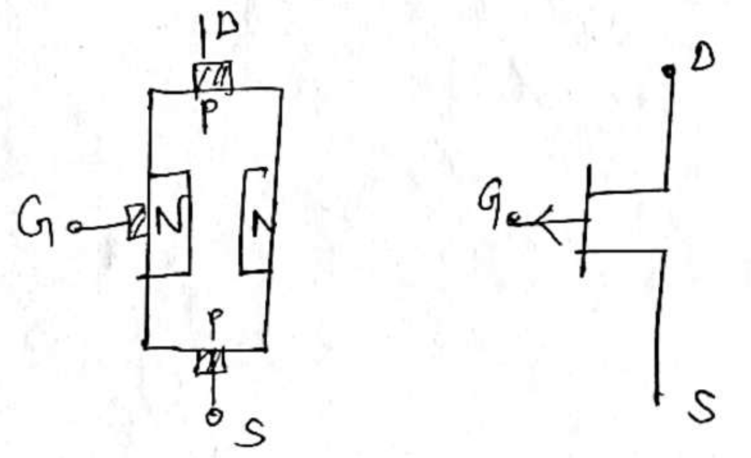
* Electrons are the majority carriers in N-channel JFET.

P-channel JFET.

* P channel JFET consists of a P-type semiconconductor bar.

* on both the ends of the bar metals contacts are made they are called source and drain.

* Holes are the majority carriers.



IGBT

IGBT - Insulated Gate Bipolar Transistor.

* IGBT is a minority - carrier device with high input impedance and Large bipolar Current - carrying capability.
* Combination of BJT & MOSFET.
* High i/p impedance like a PMOSFET
* Low on State power loss like a BJT
* In IGBT second breakdown problem is not present.
* Voltage controlled device.
* Three terminal device.

Symbol of IGBT.

* The IGT device has undergone many improvement cycles to result in the modern insulated gate bipolar transistor (IGBT)

* These devices have near ideal characteristics for high voltage (> 100 V) medium frequency (< 20kHz) applications.

* This device along with the MOSFET have the potential to replace the BJT completely.

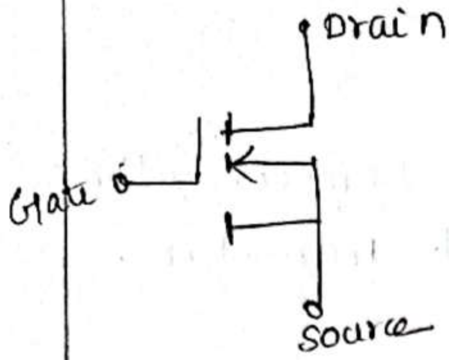


fig: Nchannel MOSFET.

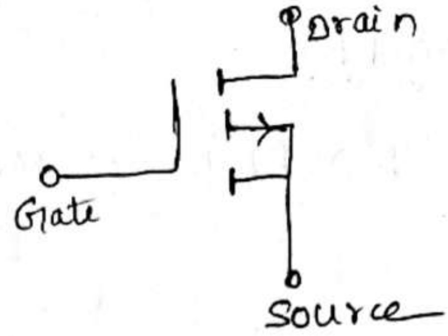
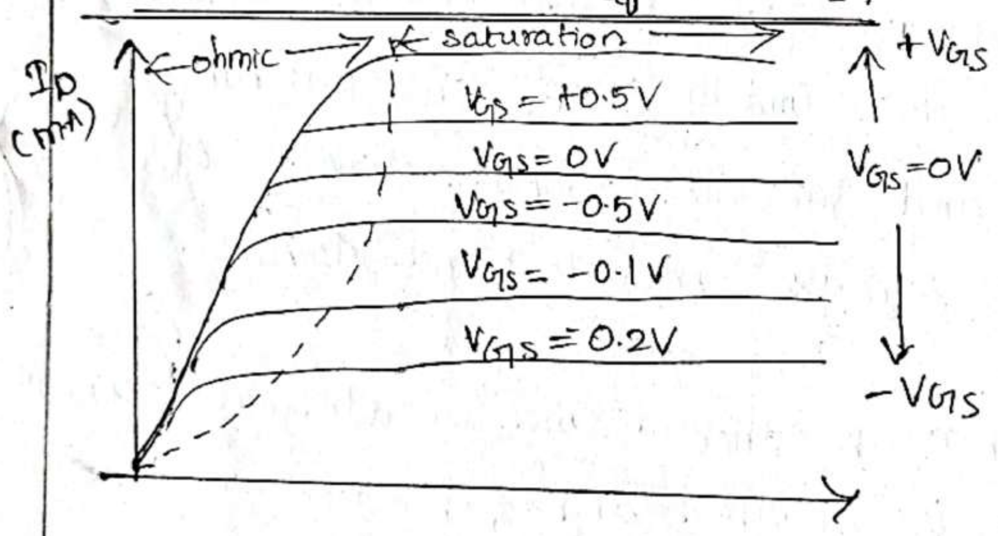


fig: P channel MOSFET.

and a Body (B) / substrate terminals. The body terminal will always be connected to the source terminal hence the MOSFET will operate as a three-terminal device.

VI characteristics of MOSFET.



Applications of MOSFET.

* MOSFET amplifiers are extensively used in radio frequency applications.
* It acts as a passive element like resistor, capacitor and inductor.
* DC motors can be regulated by POWER MOSFETs.
* High switching speed of MOSFETS make it an ideal choice in designing chopper circuits.

MOSFET

MOSFET – Metal oxide semiconductor field Effect Transistor.

* MOSFET is the common term for Insulated Gate field Effect Transistor (IGFET).

* There are two basic forms of MOSFET,
  - (i) enhancement MOSFET
  - (ii) Depletion MOSFET.

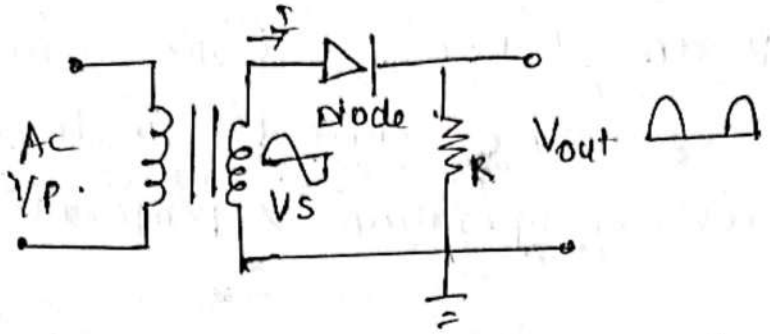
* The MOSFET transistor is a semiconductor device that is widely used for switching purposes and for the amplification of electronic signals in electronic devices.

* A MOSFET is either a core or integrated circuit where it is designed and fabricated in a single chip because the device is available in very small sizes.

Symbol of MOSFET

In general, the MOSFET is a four terminal device with a Drain (D), Source (S), Gate (G)

* For small power levels this type of Rectifier circuits is commonly used.

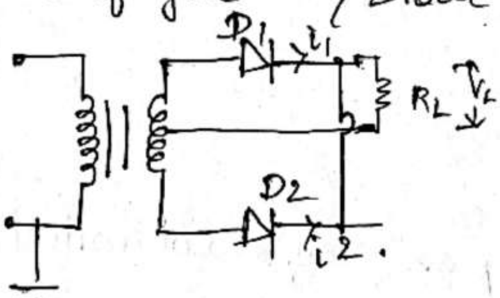


+ive half cycle ⇒ diode ⇒ becomes ⇒ Forward Biased.
-ive half cycle ⇒ diode ⇒ becomes ⇒ Reverse Biased.

Full Wave Rectifier

* This type of rectifier uses two diodes and a transformer with centre tapped secondary winding.

+ive half cycle ⇒ Diode D_1 ⇒ forward Biased.
-ive half cycle ⇒ Diode D2 ⇒ Reverse Biased.



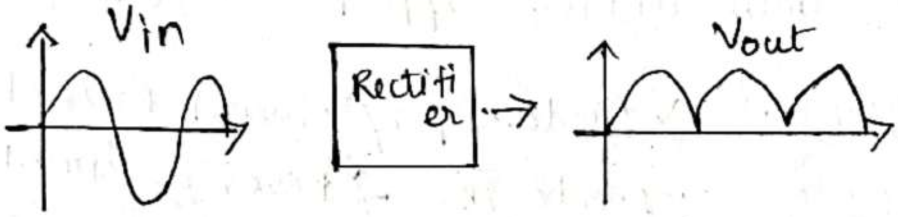
Applications of Rectifiers

* Rectifiers are used in electric Welding to Provide Polarized Voltage.
* Half wave rectifiers are used as a mosquito repellent.
* Half-Wave rectifiers are used as a signal Peak detector in AM radio.
* Rectifiers are used in modulation, demodulation and voltage Multipliers.

Rectifiers

Rectifier is an electronic device or circuit that converts alternating current to direct current. The reverse operation is performed by the inverter.

* These bridge rectifiers are available in different packages as modules ranging from few amperes to several hundred amperes.



Types of Rectifiers

There are two types of controlled Rectifiers

* Half wave Rectifier
* Full wave Rectifier

Half wave Rectifier

* It is a simple type of rectifier made with single diode which is connected in series with load.

Inverters

* Inverters are also called AC Drives (or) VFD (Variable Frequency Drive).
* They are electronic devices that can turn DC (Direct current) to AC (Alternating current)
* It is also responsible for controlling speed and torque for electric motors.
* Basically, Inverter is a kind of oscillator.
* Transistors are the key components of inverter, which convert DC power into AC power.
* In otherwords, the inverter is a static device.
* It can convert one form of electrical energy into other forms of electrical energy. But it cannot generate electrical power.

Applications of Inverter.

* When the AC main power supply is not available, an uninterruptible power supply (UPS) uses battery and inverter.
* Power inverters are basically used in the HVDC transmission line. It is also used to connect two Asynchronous AC systems.

* The output of the solar panel is DC power. The solar inverter used to convert DC Power into AC power.

UNIT-IV Digital Electronics

Review of Number system, binary codes, error detection and correction codes, combinational Logic - Representation of Logic functions - SOP and POS forms, K-map representations - Minimization using K maps (simple Problems only)

1. Review of Number systems.

* A Number system is developed by the base or radix.

* There are four Types of Number system, They are.

		Numbers	Example
Base ⇒ 2 ⇐	① Binary Number system	0, 1	⇒ $(1010)_2$
Base ⇒ 10 ⇒	②. Decimal Number system	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	⇒ $(7103)_{10}$
Base ⇒ 8 ⇒	③ Octal Number system	0, 1, 2, 3, 4, 5, 6 & 7	⇒ $(743)_8$
Base ⇒ 16 ⇒	④. Hexa-Decimal Number system	⇒ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F	Eg: $(1CF37)_{16}$

A, B, C, D, E, F.
⇓ ⇓ ⇓ ⇓ ⇓ ⇓
11 12 13 14 15 16

2. Binary codes

A code that represents each digit of a decimal number represented by a binary value.

* Binary coded Decimal (BCD) is a way to express each of the decimal digits with binary code.

Classification of binary codes

⇒ Weighted code.

⇒ Non-Weighted code.

⇒ Binary coded Decimal code.

⇒ Alphanumeric code.

3. Error Correcting code & Error detection.

Error detection codes => are used to detect the error present in the received data bitstream. These codes contain some bits which are included appended to the original bit stream. These codes detect the error, if it is occurred during transmission of the original data.

Example parity code, Hamming code.

Error correction codes => are used to correct the errors present in the received data bitstream so that, we will get the original data.

* Error correction codes also use the similar strategy of error detection codes.

Example Hamming code.

4. Combinational Logic.

* A combinational circuit consists of logic gates whose outputs at any time are determined from only the Present combination of inputs.

* A combinational circuit performs an operation that can be specified logically by a set of boolean functions

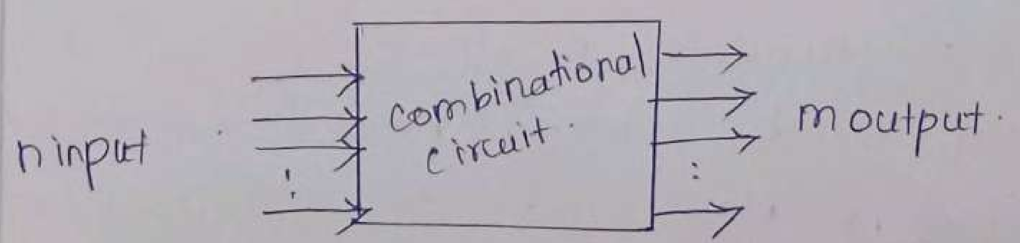
* It consists of an interconnection of logic gates.

* Combinational Logic gates react to the values of the signals at their inputs and produce the value of the output signal, transforming binary information from the given input data to a required output data.

* A block diagram of a combinational circuit as shown in the below figure.

* The n input binary variables come from an external source. the m output variables are produced by the internal combinational logic circuit and go to an external destination.

* Each input and output variable exists physically as an analog signal whose values are interpreted to be a binary signal that represents logic 1 & logic 0



5. Representation of Logic functions

* The boolean expressions are expressed in terms of logical variables
* the binary variable may appear in its normal form (A) or in its complement form $\bar{A}$

* Now consider two binary variables A and B combined with an AND operation. since each variable may appear in either form, there are four possible combinations $\bar{A}\bar{B}$, $\bar{A}B$, $A\bar{B}$ & AB.

* Each of these four AND Terms is a distinct combination & is called a min-term or a standard product.

* In a similar manner, n Variable can be combined to form 2^n minterms.
* The 2^n different min-terms may be determined by a method similar to one shown in table for three variables.

* In similar fashion, n variable foring OR Terms, with each variable being primed or unprimed, provide 2^n possible combinations called max-terms or standard sums.

Variables			Minterm		Maxterm	
A	B	C	Term	Designation	Term	Designation
0	0	0	$\bar{A}\bar{B}\bar{C}$	m_0	$A+B+C$	M_0
0	0	1	$\bar{A}\bar{B}C$	m_1	$A+B+\bar{C}$	M_1
0	1	0	$\bar{A}B\bar{C}$	m_2	$A+\bar{B}+C$	M_2
0	1	1	$\bar{A}BC$	m_3	$A+\bar{B}+\bar{C}$	M_3
1	0	0	$AB\bar{C}$	m_4	$\bar{A}+B+C$	M_4
1	1	0	$A\bar{B}C$	m_5	$A+B+\bar{C}$	M_5
1	1	1	ABC	m_6	$\bar{A}+\bar{B}+C$	M_6

6. Sop 4 pos terms

SOP (sum of products) -

A type of boolean expression where several product terms are summed (ORed) together.

The logical sum of the two or more logical product terms is called a Product terms are summed.

$$Z = AB + BC + ACD$$

POS Product of sums

* A type of boolean expressions where several sum terms are multiplied (ANDed) together.

* A product of sums expression is a logical Product of two or more logical sum terms.

It is basically an AND operation of OR operated Variables such as.

1. $Z = (A+B)(B+C)(A+C)$.
2. $Z = (A+B+C)(A+C+D)$

Minterm: products of Boolean expression where all Possible variables appear once in complement or uncomplement Variables.

Maxterm: A sum term in a boolean expression where all possible Variables appear once, in uncomplement or complement form.

1 => Complement Variable
Represents

0 => Uncomplement variable
Represents

7. K-map Representation

K-map (or) Karnaugh map:

A graphical tool for finding the SOP or POS simplification of a boolean function. A Karnaugh Map works by arranging the terms of expressions in such a way that variables can be cancelled by grouping minterms or maxterms.

Cell:

The smallest unit of a Karnaugh Map, corresponds to one row of a truth table. The input variables are the cell coordinates and the output variable is the cells content.

Pair: A group of two adjacent cells in a Karnaugh map. A pair cancels one variable in a K-map simplification.

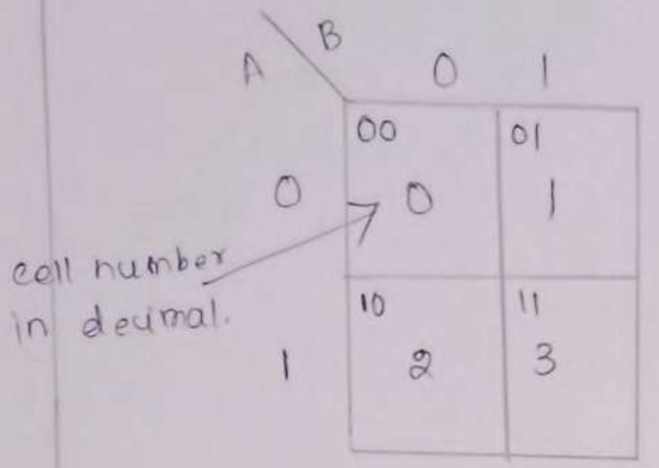
Quad: A group of four adjacent cells in a Karnaugh map. A quad cancels two variable in a K-map simplification.

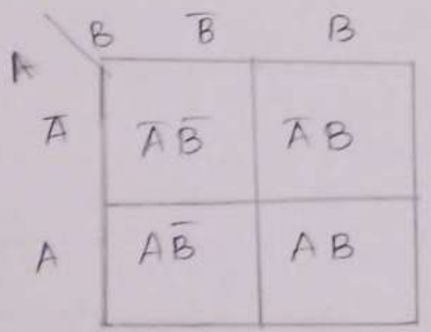
Octet: A group of eight adjacent cells in a Karnaugh map. A octet cancels three variable in a K-map simplification.

* For three variables, number of cells is $2^3 = 8$

For four variables, number of cells is $2^4 = 16$.

Two Variables K-map





* The number of variables n is 2 and hence ($2^2 = 4$) four cells are needed to form two variable k-map.

* The coordinate of each cell correspond to a unique combination of input variables (A, B)

④ Ⓑ

Boolean Algebra

→ In 1854, George Boole introduced a systematic treatment of logic and developed for this purpose an algebraic system now called Boolean algebra.

→ Boolean algebra is a system of mathematical logic.

Boolean algebra Terminology

Variable : The symbol which represents an arbitrary elements of an boolean algebra is known as variable.

Ex: In expression $y = A + BC$, Variables A, B, and C can have either a '1' or '0'.

Complement : A complement of a variable is represented by a "bar" over the letter.

Ex: The complement of a variable A will be denoted by $\overline{A}$.

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Boolean Addition :

Basic rules of Boolean addition

$$0+0 = 0$$
$$0+1 = 1$$
$$1+0 = 1$$
$$1+1 = 1$$

Boolean addition is same as the logical OR operation.

Boolean Multiplication:

Basic rules of Boolean multiplication.

$$0 \cdot 0 = 0$$
$$0 \cdot 1 = 0$$
$$1 \cdot 0 = 0$$
$$1 \cdot 1 = 1$$

Boolean multiplication is same as the logical AND operation.

COMMUTATIVE LAW 1:

$$(A+B) = (B+A)$$

The order in which the variables are ORed makes no difference in the output.

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$(A \cdot B) = (B \cdot A)$

The order inwhich the variables are ANDed makes no difference in the output.

(2) DISTRIBUTED LAW

$A \cdot (B+C) = (A \cdot B) + (A \cdot C)$

It states that ORing several variables and ANDing the result with a single variable is equivalent to ANDing the result with a single variable with each of the several variables and then ORing the products.

$A + (B \cdot C) = (A+B) \cdot (A+C)$

It states that ANDing several variables and ORing the result with a single variable is equivalent to ORing the result with a single variable with each of the several variables and then ANDing the sums.

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Associative law:

$$A+(B+C) = (A+B)+C$$

It states that in the ORing of several variables, the result is the same regardless of the grouping of the variables.

$$(A \cdot B) \cdot C = A \cdot (B \cdot C)$$

It states that it makes no difference in what order the variables are grouped when ANDing several variables.

BASIC THEOREMS

$$A+\overline{A} = 1$$

$$A \cdot \overline{A} = 0$$

$$A+0 = A$$

$$A \cdot 1 = A$$

$$A+A = A$$

$$A \cdot A = A$$

$$A+1 = A$$

$$A \cdot 0 = 0$$

$$\overline{\overline{A}} = A$$

$$A+AB = A$$

$$A(A+B) = A$$

$$A+\overline{A}B = A+B$$

$$A \cdot (\overline{A}+B) = AB$$

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DeMorgan's Theorems:

1. $\overline{AB} = \overline{A} + \overline{B}$

   * The complement of a product is equal to the sum of the complements.

2. $\overline{A+B} = \overline{A} \cdot \overline{B}$

   * The complement of a sum is equal to the product of the complements

EXAMPLES:

1) Simplify $x + \overline{x}y$

Soln: $z = x + \overline{x}y$

$= x + xy + \overline{x}y \quad \because A + AB = A$

$= x + y(x + \overline{x}) \quad \because x + \overline{x} = 1$

$= x + y \cdot 1$

$$\boxed{z = x + y}$$

2) $\overline{A}BC\overline{D} + BC\overline{D} + B\overline{C}\overline{D} + B\overline{C}D$

Soln:- $= BC\overline{D}(\overline{A} + 1) + B\overline{C}\overline{D} + B\overline{C}D$

$= BC\overline{D} + B\overline{C}\overline{D} + B\overline{C}D \quad [\because A + 1 = 1]$

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$= B\bar{D}(C+\bar{C}) + B\bar{C}D$ $\quad [\because A+\bar{A}=1]$

$= B\bar{D} + B\bar{C}D$

$= B(\bar{D} + \bar{C}D)$ $\quad [\because A+\bar{A}B = A+B]$

$= B(\bar{D}+\bar{C})$ //.

* $A+AB = A$

soln: $A+AB$

$= A(1+B)$

$= A \cdot 1 = A$

* $A\cdot(A+B) = A$

soln: $A(A+B) = A\cdot A + A\cdot B$

$= A + AB$

$= A(1+B)$

$= A\cdot 1$

$\boxed{A(A+B) = A}$

* $A+\bar{A}B = A+B$

soln: $A+\bar{A}B = (A+\bar{A})(A+B)$

$= 1\cdot(A+B)$

$\boxed{A+\bar{A}B = A+B}$

* $A\cdot(\bar{A}+B) = AB$

$A\cdot(\bar{A}+B) = A\cdot\bar{A} + A\cdot B$ $\quad [\because A\cdot\bar{A} = 0]$

$= 0 + AB$

$\boxed{A\cdot(\bar{A}+B) = AB}$

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* $AB + \bar{A}C + BC = AB + \bar{A}C$

soln: $AB + \bar{A}C + BC = AB + \bar{A}C + BC \cdot 1$

$= AB + \bar{A}C + BC(A + \bar{A})$

$= AB + \bar{A}C + ABC + \bar{A}BC$

$= AB(1 + C) + \bar{A}C(1 + B)$

$$\boxed{AB + \bar{A}C + BC = AB + \bar{A}C}$$

* $(A + B)(\bar{A} + C)(B + C) = (A + B)(\bar{A} + C)$

soln: $(A + B)(\bar{A} + C)(B + C) = (A + B)(\bar{A} + C)(B + C + 0)$

$= (A + B)(\bar{A} + C)(B + C + A\bar{A})$

$= (A + B)(\bar{A} + C)(B + C + A)(B + C + \bar{A})$

[∵ $A + BC = (A + B)(A + C)$]

$= (A + B)(A + B + C)(\bar{A} + C)(B + C + \bar{A})$

$$\boxed{(A + B)(\bar{A} + C)(B + C) = (A + B)(\bar{A} + C)}$$

[∵ $A(A + B) = A$]

EXAMPLE Prove that $AB + BC + \bar{B}C = AB + C$

Soln: $AB + BC + \bar{B}C = AB + C(B + \bar{B})$

$= AB + C \cdot 1$

$= AB + C$ //

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EXAMPLE 2: Simplify the expression $\overline{A}.B + A.B + \overline{A}.\overline{B}$

Soln: $\overline{A}.B + A.B + \overline{A}.\overline{B} = (\overline{A} + A)B + \overline{A}.\overline{B}$

$= 1.B + \overline{A}.\overline{B}$

$= B + \overline{A}.\overline{B}$ $[\because A + \overline{A}.B = A + B]$

$= B + \overline{A}$

EXAMPLE 3: Simplify the given expression $A + A.\overline{B} + \overline{A}.B$

Soln:

$A + A.\overline{B} + \overline{A}.B = A(1 + \overline{B}) + \overline{A}.B$

$= A.1 + \overline{A}B$

$= A + \overline{A}B$

$= A + B$

EXAMPLE 4: Complement the expression $\overline{A}B + C\overline{D}$

Soln: $= \overline{A}B + C\overline{D}$

$= \overline{\overline{A}B + C\overline{D}}$

$= (\overline{\overline{A}B}).(\overline{C\overline{D}})$

$= (\overline{\overline{A}} + \overline{B}).(\overline{C} + \overline{\overline{D}})$

$= (A + \overline{B}).(\overline{C} + D)$

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EXAMPLE 5: Simplify the expression $AB+\overline{AC}+A\overline{B}C\,(AB+C)$

Soln:

$$= AB+\overline{AC}+A\overline{B}C\,(AB+C)$$

$$= AB+\overline{AC}+A\overline{B}C\cdot AB+A\overline{B}C\cdot C$$

$$[\because B\cdot\overline{B}=0,\ C\cdot C=C]$$

$$= AB+\overline{AC}+0+A\overline{B}C$$

$$= \underbrace{AB+\overline{A}}+\overline{C}+A\overline{B}C \qquad [\because A+\overline{A}B = A+B]$$

$$= \overline{A}+B+\overline{C}+A\overline{B}C$$

$$= \overline{A}+A\overline{B}C+B+\overline{C}$$

$$= \overline{A}+\overline{B}C+B+\overline{C}$$

$$= \overline{A}+B+\underbrace{\overline{C}+\overline{B}C}$$

$$= \overline{A}+B+\overline{C}+\overline{B}$$

$$= \overline{A}+\overline{C}+B+\overline{B}$$

$$= (\overline{A}+\overline{C})+1$$

$$= 1 \qquad [\because (A+1)=1.]$$

EXAMPLE 6: Simplify the expression $\overline{\overline{A\overline{B}+ABC}+A\,(B+A\overline{B})}$

Soln:

$$= \overline{\overline{A\overline{B}+ABC}+A\,(B+A\overline{B})}$$

$$= \overline{\overline{A\,(\overline{B}+BC)}+A\,(B+A\overline{B})}$$

$$= \overline{\overline{A\,(\overline{B}+C)}+A(B+A)}$$

$= \overline{\overline{A(\overline{B}+C)} + AB + A\cdot A}$

$= \overline{\overline{A\overline{B} + AC} + AB + A}$

$= \overline{\overline{A\overline{B} + AC} + A(B+1)}$

$= \overline{\overline{A\overline{B} + AC} + A\cdot 1}$

$= \overline{(\overline{A\overline{B}}).(\overline{AC}) + A}$

$= \overline{(\overline{A}B).\overline{AC} + A}$

$= \overline{(\overline{A}+B).(\overline{A}+\overline{C}) + A}$ $[\because (A+B)(A+C) = A+BC]$

$= \overline{(\overline{A}+B\overline{C}) + A}$

$= \overline{\overline{A}+B\overline{C}+A}$

$= \overline{1+B\overline{C}}$

$= \overline{1}$ $[\because 1+A=1]$

$= 0$ //

SWITCHING FUNCTIONS

→ Boolean expressions are constructed by connecting the boolean constants and variables with the boolean operations

→ we use boolean expressions to describe switching function or boolean functions.

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→ In this boolean function the variables are appeared in either a complemented or an uncomplemented form is called a literal.

An arbitrary logic function can be expressed in the following forms:

1. Sum of Products (SOP)
2. Product of Sums (POS)

Product Term :- The AND function is referred to as a product.

Sum Term :- An OR function is generally used to refer a sum.

Sum of Products (SOP) :

The logical sum of two or more logical product terms, is called a sum of products expression.

ex: $Y = AB + BC + AC$

Product of sums (POS) :

The logical product of two or more logical sum terms.

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ex: $Y = AB + BC + AC$

Product of sums (POS) :

The logical product of two or more logical sum terms.

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Eg: $Y = (A+B)(B+C)(C+\bar{A})$

MINTERM:

A product term containing all the K variables of the function in either complemented or uncomplemented form is called a Minterm.

Eg: A 2 variable function has four possible combinations,

0 0	$\bar{A}\bar{B}$
0 1	$\bar{A}B$
1 0	$A\bar{B}$
1 1	AB

These product terms are called minterms or standard products or fundamental products.

CANONICAL SUM OF PRODUCT EXPRESSION:

It is defined as the logical sum of all the minterms derived from the rows of a truth table, for which the value of the function is 1. It is also called a minterm canonical form.

Eg $Y = \sum_m (0, 5, 6)$

$= m_0 + m_5 + m_6$

$= \bar{A}\bar{B}\bar{C} + A\bar{B}C + AB\bar{C}$

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PROCEDURE FOR OBTAINED 'SOP':

1. Examine each term in the given logic function. Retain it if it is a minterm, continue to examine the next term in the same manner.

2. check for variables that are missing in each product which is not a minterm. Multiply the product by $(x+\overline{x})$, for each variable x that is missing.

3. Multiply all the products and omit the redundant terms.

Example:1) obtain the canonical sum of product form of the function.

$$Y(A,B,C) = A+BC$$

$$A+BC = A(B+\overline{B})(C+\overline{C}) + BC(A+\overline{A})$$

$$= (AB + A\overline{B})(C+\overline{C}) + BCA + BC\overline{A}$$

$$= ABC + AB\overline{C} + A\overline{B}C + A\overline{B}\overline{C} + BCA + BC\overline{A}$$

$$= ABC + AB\overline{C} + A\overline{B}C + A\overline{B}\overline{C} + BC\overline{A}$$

$$\therefore \boxed{A+BC = ABC + AB\overline{C} + A\overline{B}C + A\overline{B}\overline{C} + \overline{A}BC}$$

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Example 2: Convert the given expression in standard SOP form.

$$f(A,B,C) = AC + AB + BC$$

$$= AC(B+\bar{B}) + AB(C+\bar{C}) + BC(A+\bar{A})$$

$$= ACB + AC\bar{B} + ABC + AB\bar{C} + ABC + \bar{A}BC$$

$$\boxed{f(A,B,C) = ABC + A\bar{B}C + AB\bar{C} + \bar{A}BC}$$

(omit repeated product terms)

MAXTERM:

A sum term containing all the K variables of the function in either complemented or uncomplemented form is called a Max term.

Eg: A 2 variable function has four possible combinations

1+1	$A+B$
1+0	$A+\bar{B}$
0+1	$\bar{A}+B$
0+0	$\bar{A}+\bar{B}$

These sum terms are called Maxterms.

CANONICAL PRODUCT OF SUM EXPRESSION:

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The canonical product of sum expression can be given in a compact form by listing the decimal codes corresponding to the maxterms containing a function value of '0'.

$$Ex: Y = \Pi(0, 2, 4, 7)$$

$$= M_0 \cdot M_2 \cdot M_4 \cdot M_7$$

$$= (A+B+C)(A+\overline{B}+C)(\overline{A}+B+C)(\overline{A}+\overline{B}+\overline{C})$$

STEPS TO CONVERT POS to standard POS FORM:

step 1: Find missing literals

step 2: OR each sum term having missing literal with term form by ANDing the literal and its complement.

step 3: Expand the terms by applying distributive law and reorder the literals in the sum terms.

step 4: Omitting repeated sum terms.

Example: Express the canonical product of the sum of $Y(ABC) = (A+\overline{B})(B+C)(A+\overline{C})$

$$= (A+\overline{B}+0)(B+C+0)(A+\overline{C}+0)$$

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$= (A+\overline{B}+C\overline{C})(B+C+A\overline{A})(A+\overline{C}+B\overline{B})$

using distributive property

$= (A+\overline{B}+C)(A+\overline{B}+\overline{C})(A+B+C)(\overline{A}+B+C)(A+B+\overline{C})(A+\overline{B}+\overline{C})$

$$\boxed{Y(ABC) = (A+\overline{B}+C)(A+\overline{B}+\overline{C})(A+B+C)(\overline{A}+B+C)(A+B+\overline{C})}$$

EXAMPLE: Express the function $Y = A + \overline{B}C$ in canonical POS form.

$Y = A + \overline{B}C$

$= (A+\overline{B})(A+C)$

$= (A+\overline{B}+0)(A+C+0)$

$= (A+\overline{B}+C\overline{C})(A+C+B\overline{B})$

$= (A+\overline{B}+C)(A+\overline{B}+\overline{C})(A+C+B)(A+C+\overline{B})$

$= (A+\overline{B}+C)(A+\overline{B}+\overline{C})(A+B+C)(A+\overline{B}+C)$

$= (A+\overline{B}+C)(A+\overline{B}+\overline{C})(A+B+C)$

$= (A+B+C)(A+\overline{B}+C)(A+\overline{B}+\overline{C})$

$Y = \Pi(0, 2, 3)$

Example: Convert the given expression in standard POS form

$Y = A.(A+B+C)$

$f(A, B, C) = A.(A+B+C)$

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$$f(A,B,C) = (A + B\cdot\overline{B} + C\cdot\overline{C})(A+B+C)$$

$$= (A + B\cdot\overline{B} + C)(A + B\cdot\overline{B} + \overline{C})(A+B+C)$$

$$= (A+B+C)(A+\overline{B}+C)(A+B+\overline{C})(A+\overline{B}+\overline{C})(A+B+C)$$

$$= (A+B+C)(A+\overline{B}+C)(A+B+\overline{C})(A+\overline{B}+\overline{C})$$

$$= (A+B+C)(A+B+\overline{C})(A+\overline{B}+C)(A+\overline{B}+\overline{C})$$

$y = \Pi(0, 1, 2, 3)$

KARNAUGH MAPS (K-MAPS)

- A Graphical chart is known as karnaugh Map.
- The map method gives us a systematic approach for simplifying a boolean expression.

Representing standard SOP on K-Map.

- The sum of products form can be plotted on the K-map by placing a 1 in each cell corresponding to a minterm.
- Remaining cells are filled with zeros.

Example: Plot boolean expression $y = AB\bar{C} + ABC + \bar{A}\bar{B}C$ on the karnaugh map.

A \ BC	00	01	11	10
0	0 (0)	[1] (1)	0 (3)	0 (2)
1	0 (4)	0 (5)	[1] (7)	[1] (6)

EXAMPLE: Plot boolean expression.

$y = \bar{A}B\bar{C}\bar{D} + A\bar{B}C\bar{D} + \bar{A}BC\bar{D} + AB\bar{C}D$ on the karnaugh map.

AB \ CD	00	01	11	10
00	0 (0)	0 (1)	0 (3)	0 (2)
01	[1] (4)	0 (5)	0 (7)	[1] (6)
11	0 (12)	[1] (13)	0 (15)	0 (14)
10	0 (8)	0 (9)	[1] (11)	[1] (10)

EXAMPLE: Plot Boolean expression $Y = (A+\overline{B}+C)(A+\overline{B}+\overline{C})(\overline{A}+\overline{B}+C)(A+B+\overline{C})$ on the karnaugh map.

A \ BC	00	01	11	10
0	1 (0)	0 (1)	0 (3)	0 (2)
1	1 (4)	1 (5)	1 (7)	0 (6)

EXAMPLE: Plot Boolean expression

$$Y = (A+B+C+\overline{D})(A+\overline{B}+\overline{C}+D)(A+B+\overline{C}+\overline{D})(\overline{A}+\overline{B}+C+\overline{D})(\overline{A}+\overline{B}+\overline{C}+D)$$

AB \ CD	00	01	11	10
00	(0)	0 (1)	0 (3)	(2)
01	(4)	(5)	(7)	0 (6)
11	(12)	0 (13)	(15)	0 (14)
10	(8)	(9)	(11)	(10)

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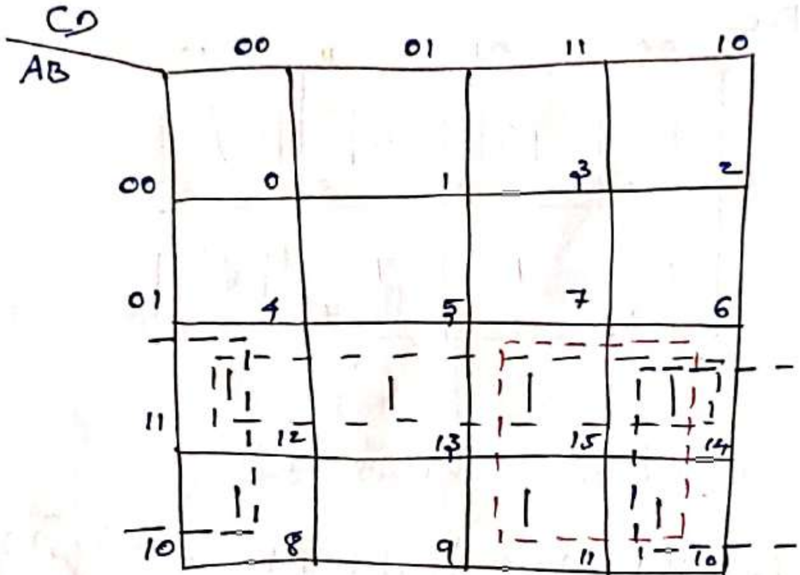
EXAMPLE: Plot the logical expression $ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}C + AB$ on a 4 variable K-map; obtain the simplified expression from the map.



$Y = AB + AC + A\bar{D}$

$$Y = ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}C + AB$$

$$= ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}C(D+\bar{D}) + AB(C+\bar{C})(D+\bar{D})$$

$$= ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + A\bar{B}C\bar{D} + (ABC + AB\bar{C})(D+\bar{D})$$

$$= ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + A\bar{B}C\bar{D} + ABCD + AB\bar{C}\bar{D}$$

$$= ABCD + A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + A\bar{B}C\bar{D} + AB\bar{C}\bar{D}$$

$$= m_{15} + m_8 + m_{11} + m_{10} + m_{14} + m_{13} + m_{12}$$

$$= \Sigma m\,(8, 10, 11, 12, 13, 14, 15)$$

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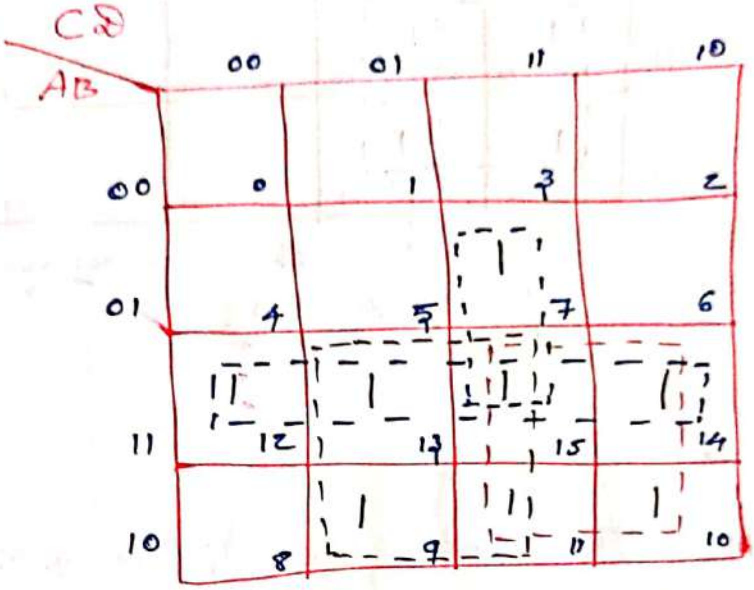
EXAMPLE: Simplify the expression $y = \Sigma m(7, 9, 10, 11, 12, 13, 14, 15)$ Using the K_map method.



$y = AB + AD + AC + BCD$

$y = A(B + D + C) + BCD$

EXAMPLE: Simplify the following expression using the Karnaugh map for the 4-variables A, B, C and D.

$y = m_1 + m_3 + m_5 + m_7 + m_8 + m_9 + m_{12} + m_{13}$

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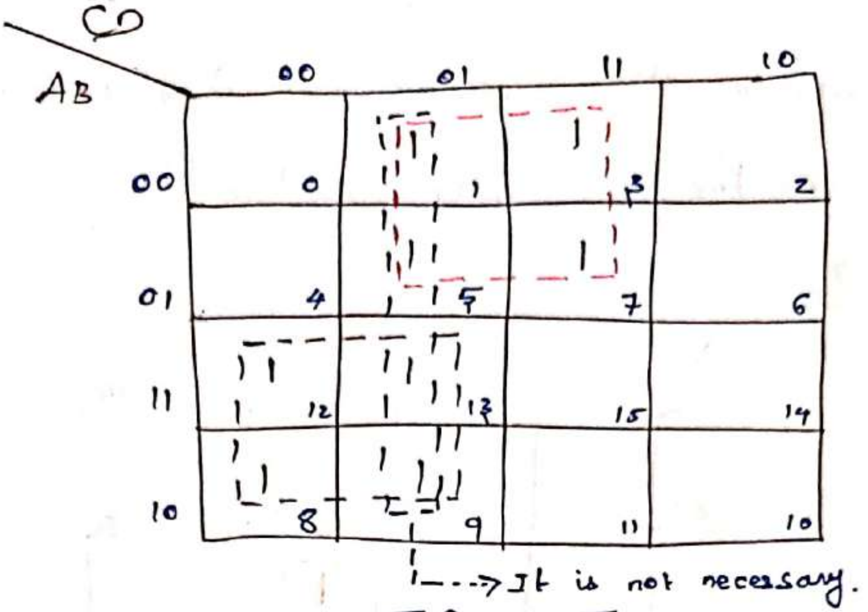


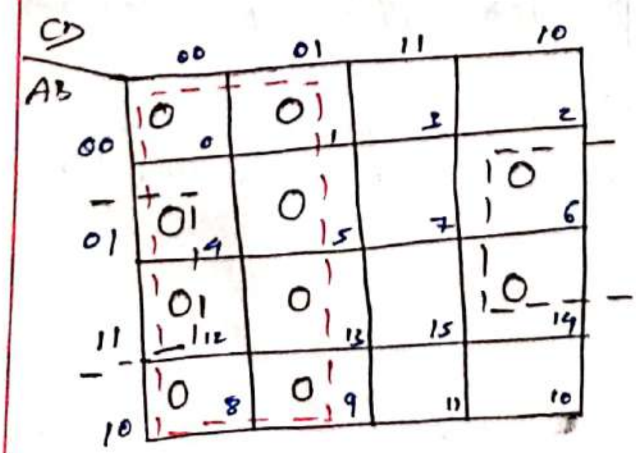
$Y = \overline{A}D + A\overline{C}$

ASSIGNMENT

1. simplify the expression $Y = m_1 + m_5 + m_{10} + m_{11} + m_{12} + m_{13} + m_{15}$, using the K-map method.

2. simplify the expression $Y = \sum_m (3, 4, 5, 7, 9, 13, 14, 15)$ using the K-map method.

EXAMPLE: 1: Simplify the expression $Y = \pi(0, 1, 4, 5, 6, 8, 9, 12, 13, 14)$ using the K-map method.



$Y = C(\overline{D} + \overline{B})$

$Y = C(\overline{B} + \overline{D})$

FIVE VARIABLE K- MAP :

EXAMPLE 1: Simplify $y = \Sigma_m (3, 6, 7, 8, 10, 12, 14, 17, 19, 20, 21, 24, 25, 27, 28)$ using the K-map method.

A = 0

BC \ DE	00	01	11	10
00	0	1	1 (3)	2
01	4	5	1 (7)	1 (6)
11	1 (12)	13	15	1 (14)
10	1 (8)	9	11	1 (10)

A = 1

BC \ DE	00	01	11	10
00	16	1 (17)	1 (19)	18
01	1 (20)	1 (21)	23	22
11	1 (28)	29	31	30
10	1 (24)	1 (25)	1 (27)	26

$= B\bar{D}\bar{E} + \bar{A}\bar{B}DE + \bar{A}B\bar{E} + A\bar{C}E + \bar{A}\bar{B}CD + A\bar{B}C\bar{D}$

EXAMPLE:2: Reduce the function using K-map technique

$F(A, B, C, D, E) = \Sigma m (1, 4, 8, 10, 11, 20, 22, 24, 25, 26) + d(0, 12, 16, 17)$

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EXAMPLE 2: Obtain (i) minimal sum of product and (ii) minimal product of sum expressions for the function given below.

$$F(A, B, C, D) = \Sigma_m (0, 1, 2, 5, 8, 9, 10)$$

Soln:-

AB \ CD	00	01	11	10
00	1 (0)	1 (1)	0 (3)	1 (2)
01	0 (4)	1 (5)	0 (7)	0 (6)
11	0 (12)	0 (13)	0 (15)	0 (14)
10	1 (8)	1 (9)	0 (11)	1 (10)

minimal sum of product

$$Y = \overline{B}\,\overline{D} + \overline{A}\,\overline{C}D + A\overline{B}\,\overline{C}$$

minimal product of sum

$$Y = (\overline{B} + D)(\overline{C} + \overline{D})(\overline{A} + \overline{B})$$

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EXAMPLE: 2 Simplify the five variable switching function.

$$F(EDCBA) = \Sigma_m(3, 5, 6, 8, 9, 12, 13, 14, 19, 22, 24, 25, 30).$$

E = 0

DC \ BA	00	01	11	10
00	0	1	1 (3)	2
01	4	1 (5)	7	1 (6)
11	1 (12)	1 (13)	15	1 (14)
10	1 (8)	1 (9)	11	10

E = 1

BC \ DE	00	01	11	10
00	16	17	1 (19)	18
01	20	21	23	1 (22)
11	28	29	31	1 (30)
10	1 (24)	1 (25)	27	26

$$f(E, D, C, B, A) = \bar{D}\bar{C}BA + \bar{E}C\bar{B}A + CB\bar{A} + \bar{E}D\bar{B} + D\bar{C}\bar{B}.$$

EXAMPLE: 1 Using the K-map method, simplify the following Boolean function and obtain (i) minimal SOP and (ii) minimal POS expressions:

$$Y = \Sigma_m(0, 2, 3, 6, 7) + \Sigma_d(8, 10, 11, 15)$$

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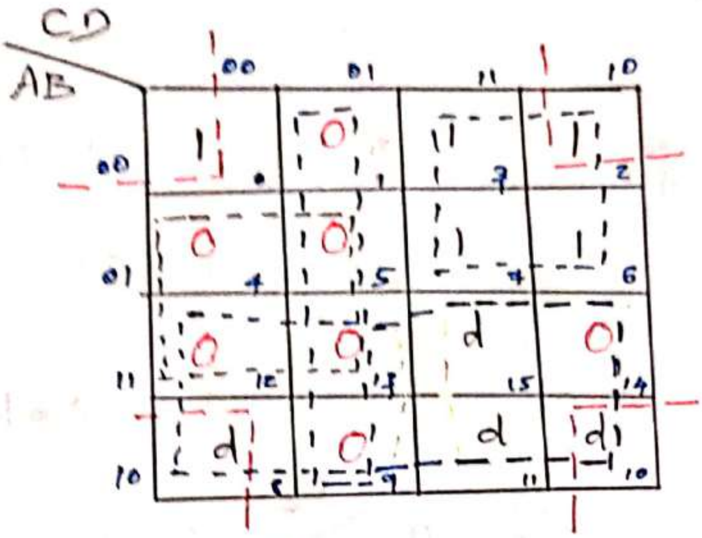


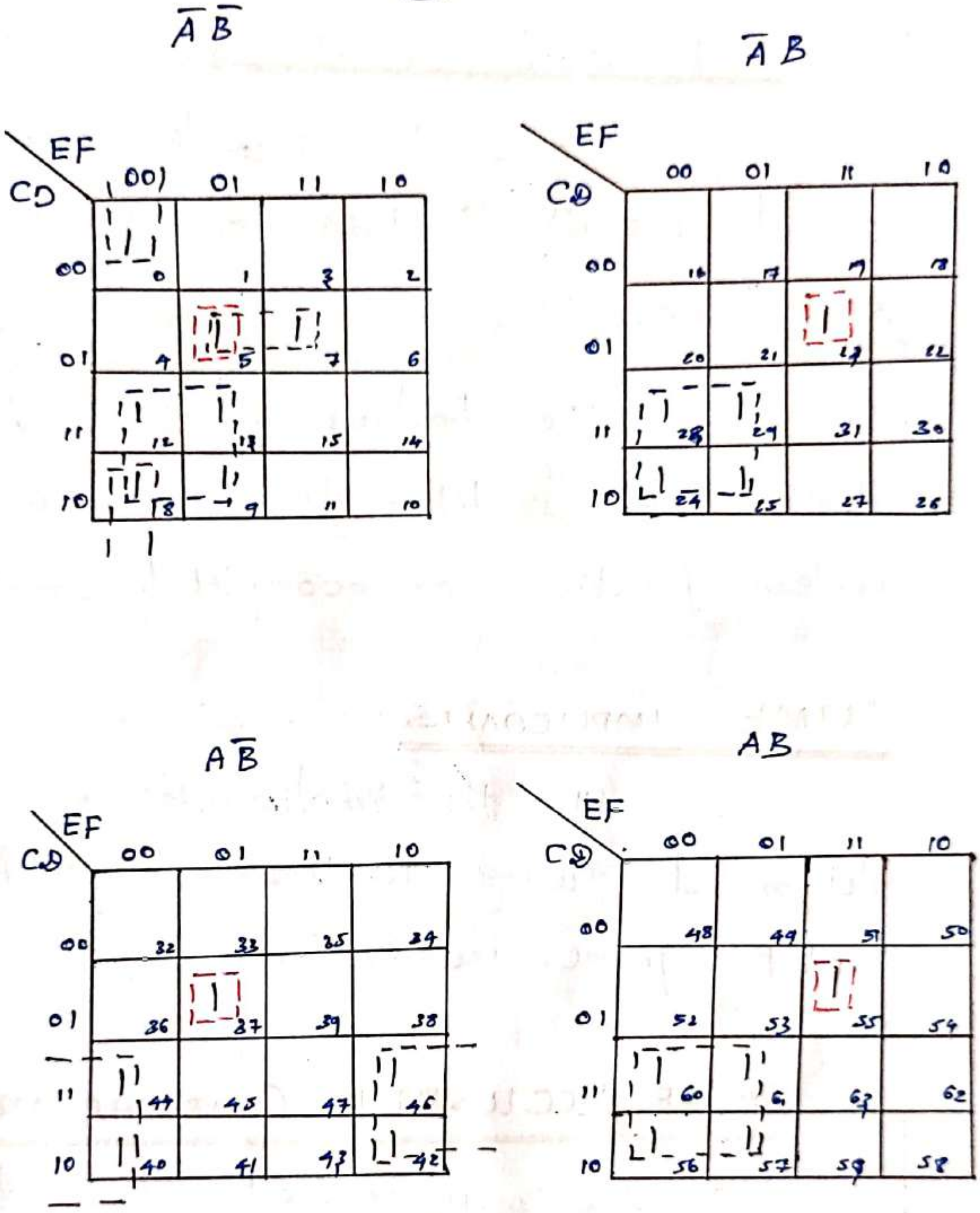
Minimal SOP form $Y = \bar{A}C + \bar{B}\bar{D}$

Minimal POS form $Y = (\bar{B}+C)\,\bar{A}\,(C+\bar{D})$

SIX VARIABLE K-MAP:

EXAMPLE: Simplify the Boolean function

$F(A, B, C, D, E, F) = \sum m\,(0, 5, 7, 8, 9, 12, 13, 23, 24, 25, 28, 29, 37, 40, 42, 44, 46, 55, 56, 57, 60, 61)$



$$F = \bar{A}\bar{B}\bar{D}\bar{E}\bar{F} + \bar{A}\bar{B}\bar{C}DF + \bar{B}\bar{C}\bar{D}\bar{E}F +$$

$$\bar{A}C\bar{E} + BC\bar{E} + B\bar{C}DEF + A\bar{B}C\bar{F}$$

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IMPLEMENTATION OF SWITCHING FUNCTION USING LOGIC GATES.

* Logic gates are the basic elements that make up a digital system.

* The electronic gate is a circuit that is able to operate on a number of binary inputs inorder to perform a particular logical function.

TYPES OF LOGIC GATES:

NOT GATE: The o/p is a complement of i/p.

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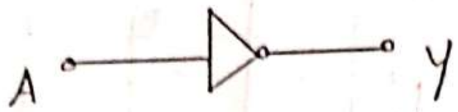
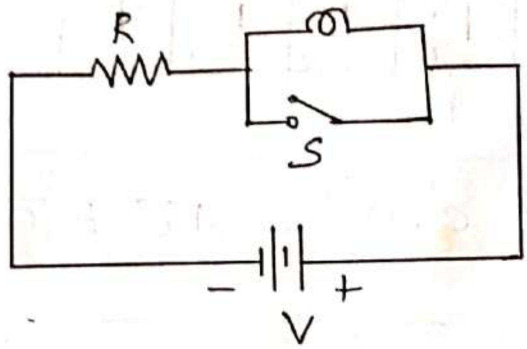
LOGIC DIAGRAM:



SWITCH EQUIVALENT:



TRUTH TABLE:

I/P	O/P
A	Y
0	1
1	0

BOOLEAN EXPRESSION:

$$Y = \overline{A}$$

APPLICATION:

Used to complement (invert) digital signal.

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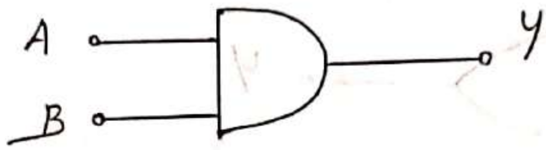
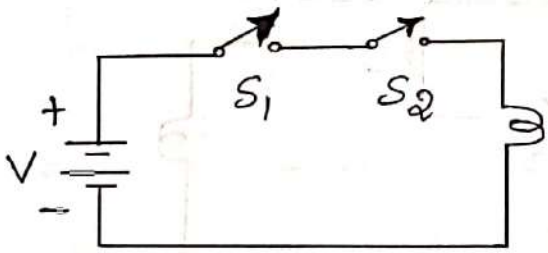
AND GATE : The o/p is high only when all inputs are high.

LOGIC DIAGRAM (SYMBOL) :



SWITCH EQUIVALENT :



TRUTH TABLE :

I/p		o/p
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

BOOLEAN EXPRESSION : $Y = A \cdot B$

APPLICATION : Used to implement logical 'AND' operation.

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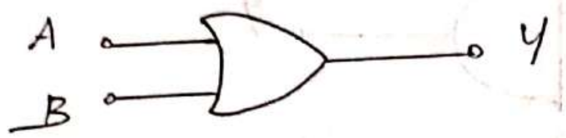
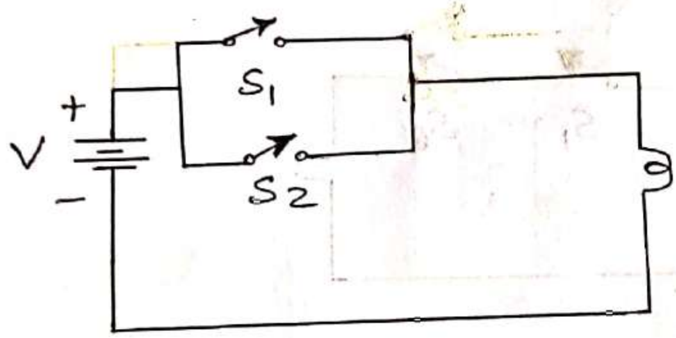
OR GATE:

The o/p is high when any of the i/p is high.

LOGIC DIAGRAM:



SWITCH EQUIVALENT:



TRUTH TABLE:

I/P		O/P
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

BOOLEAN EXPRESSION: $Y = A + B$

APPLICATION: Used to implement logical OR operation.

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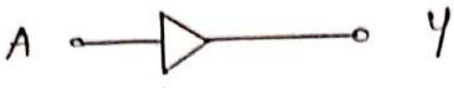
BUFFER:

The o/p is same as i/p.

SYMBOL:



BOOLEAN EXPRESSION:

$$Y = A$$

TRUTH TABLE:

I/P	O/P
A	Y
0	0
1	1

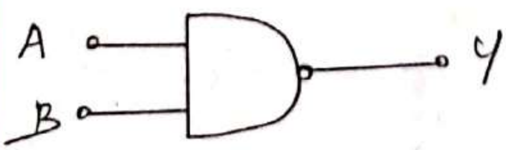
APPLICATION:

It is used to increase output driving capacity.

NAND GATE:

The o/p is high only when one of the i/p is low.

SYMBOL:



TRUTH TABLE:

I/P		O/P
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

BOOLEAN EXPRESSION:

$$Y = \overline{A \cdot B}$$

APPLICATION: It can be used to impliment any digital circuit.

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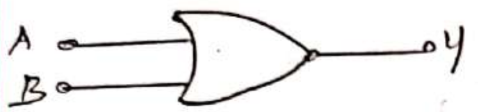
NOR GATE:

The o/p is high when all the inputs are low.

SYMBOL:



BOOLEAN EXPRESSION:

$$Y = \overline{A+B}$$

TRUTH TABLE:

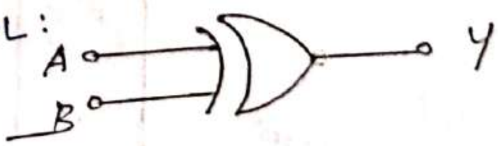
i/p		o/p
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

APPLICATION: It can be used to implement any digital circuit.

EXCLUSIVE OR (EX-OR) GATE:

The o/p is high only when odd number of inputs are high.

SYMBOL:



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BOOLEAN EXPRESSION:

$$Y = A \oplus B$$

TRUTH TABLE:

i/p		o/p
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

APPLICATION:

It is used to implement magnitude comparator, gray code converter, adder/subtractor circuits, parity generator, modulo-2 adder, etc.

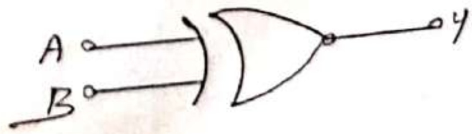
EXCLUSIVE NOR (EX-NOR) GATE:

The o/p is high only when even number of ones at the i/p or all inputs are high.

BOOLEAN EXPRESSION:

$$Y = \overline{A \oplus B}$$

SYMBOL:



TRUTH TABLE:

I/P		O/P
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

APPLICATIONS:

It is used to implement even parity generator, comparator, even parity checker etc.

UNIVERSAL GATES:

The NAND and NOR gates are known as universal gates, since any logic function can be implemented using NAND or NOR gates.

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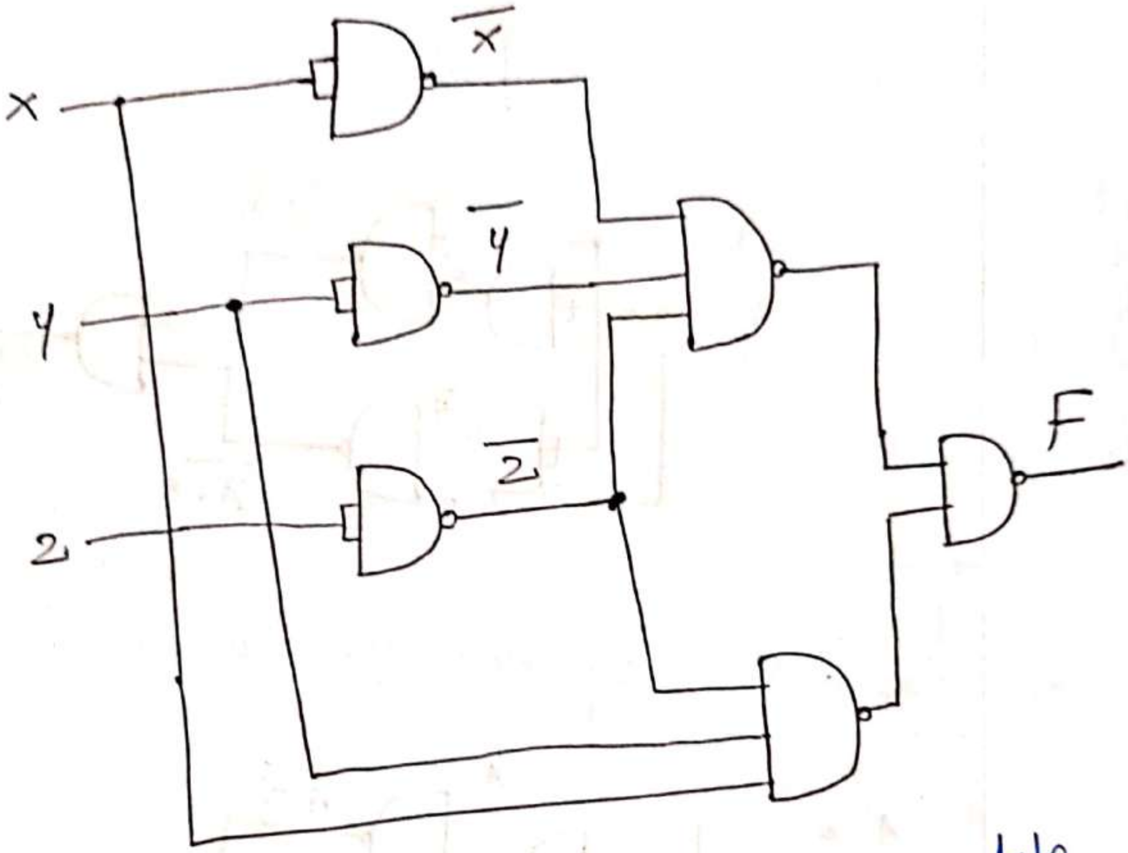
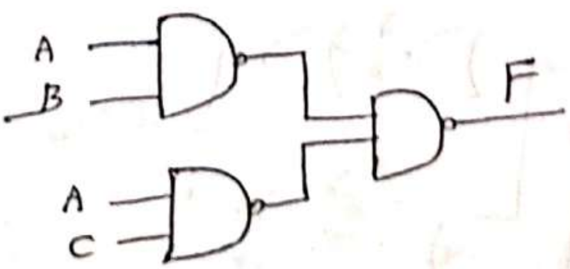
(22)

Example: Implement the following function with NAND gates. $F(x, y, z) = \sum(0, 6)$



Example: Design a logic circuit to simulate the function $f(A, B, C) = A(B+C)$ by using only NAND gates.



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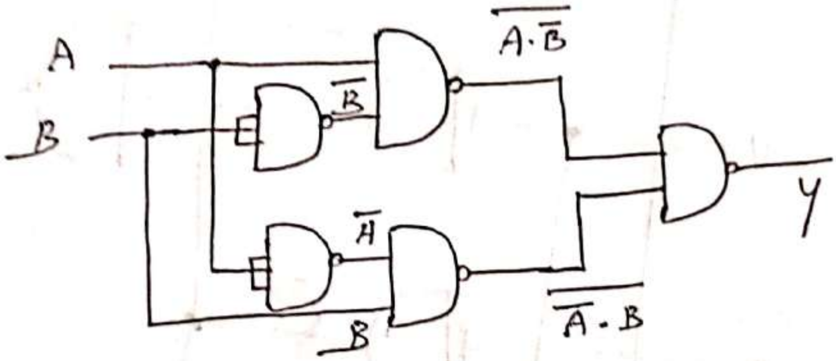
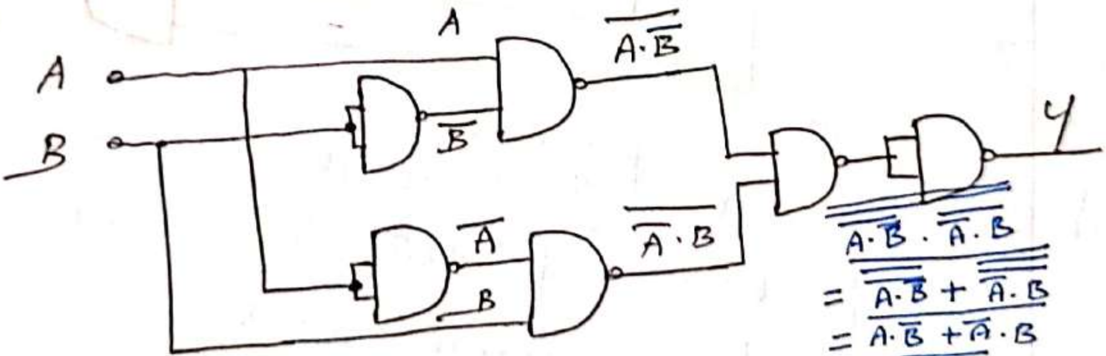
Example: Implement EX-OR gate using only NAND gates

Boolean expression for Ex-OR gate is

$$y = A\overline{B} + \overline{A}B$$

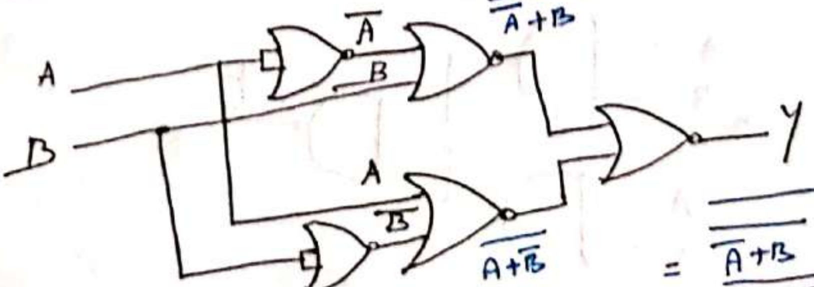


Example: Implement EX-NOR gate using only NAND gates



$$\overline{\overline{A\cdot\overline{B}}\cdot\overline{\overline{A}\cdot B}}$$
$$= \overline{\overline{\overline{A\cdot\overline{B}}} + \overline{\overline{\overline{A}\cdot B}}}$$
$$= \overline{A\cdot\overline{B} + \overline{A}\cdot B}$$
$$= \overline{A\oplus B}$$

Example Implement EX-NOR gate using only NOR gate.



$$y = AB + \overline{A}\overline{B}$$
$$y = \overline{A\oplus B}$$

$$= \overline{\overline{\overline{A}+B} + \overline{A+\overline{B}}}$$
$$= \overline{\overline{\overline{A}}\cdot\overline{B} + \overline{A}\cdot\overline{\overline{B}}}$$
$$= \overline{A\cdot\overline{B} + \overline{A}\cdot B} = \overline{A\oplus B}$$

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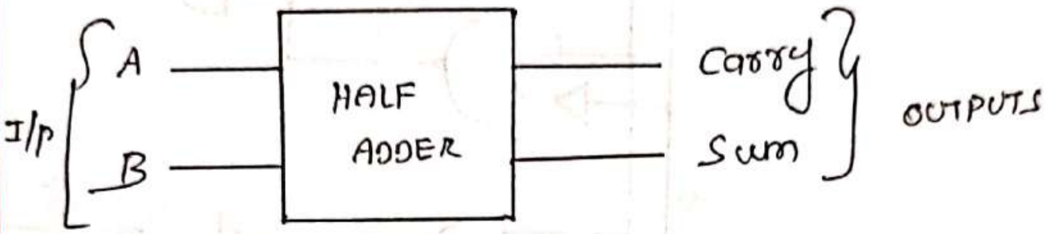
DESIGN OF ADDERS

HALF ADDER

Binary input → Augend and addend bits.
Binary output → sum and carry



Truth table

I/P		O/P	
A	B	CARRY	SUM
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

K map simplification.

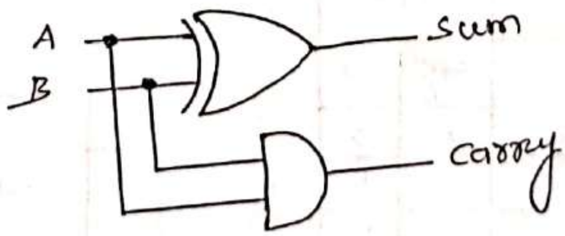
A \ B	0	1
0	0	0
1	0	1

Carry = AB
For carry

A \ B	0	1
0	0	1
1	1	0

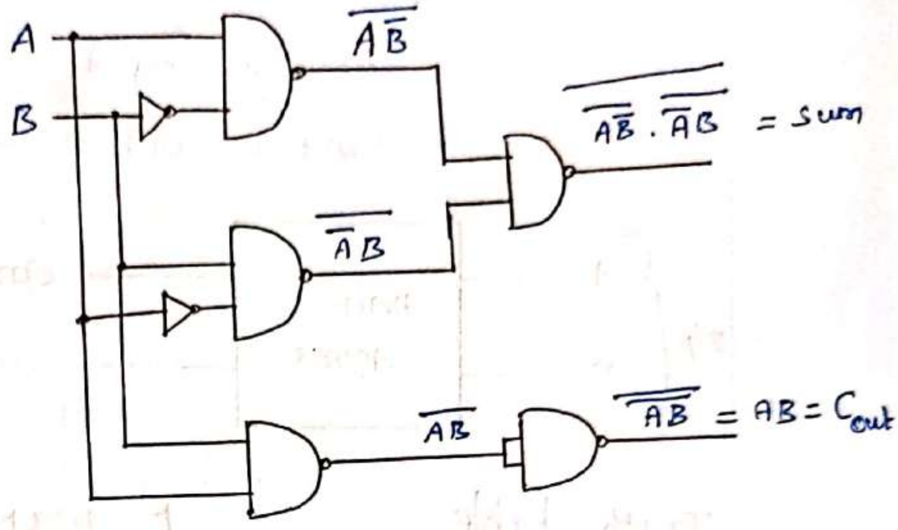
Sum = $A\bar{B} + \bar{A}B$
= $A \oplus B$
For Sum

LOGIC DIAGRAM:



Limitations: In multi addition we have to add two bits along with the carry of previous digit addition. Effectively such addition requires addition of three bits. This is not possible with half adder. Hence half adders are not used in practice.

Example: Draw half adder using NAND Gates.



FULL ADDER:

A full adder is combinational circuit that forms the arithmatic sum of 3 input bits.

three inputs → A, B, Cin

Two output → carry, sum

Truth Table:

Inputs			outputs	
A	B	Cin	carry	sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

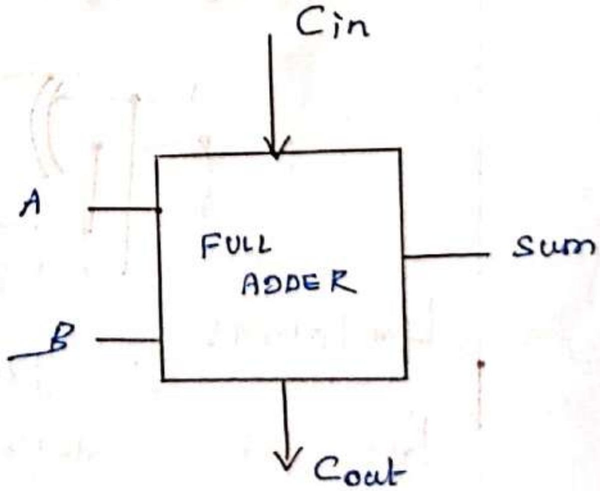


Fig. Block schematic of Full-adder.

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K map simplification:

FOR CARRY (C_{out})

A \ BC_{in}	00	01	11	10
0	0 (0)	0 (1)	1 (3)	0 (2)
1	0 (4)	1 (5)	1 (7)	1 (6)

$C_{out} = AB + AC_{in} + BC_{in}$

FOR SUM

A \ BC_{in}	00	01	11	10
0	0	1	0	1
1	1	0	1	0

$Sum = \overline{A}\,\overline{B}C_{in} + \overline{A}B\overline{C_{in}} + A\overline{B}\,\overline{C_{in}} + ABC_{in}.$

The boolean function for sum can be further simplified as follows.

$$Sum = \overline{A}\,\overline{B}C_{in} + \overline{A}B\overline{C_{in}} + A\overline{B}\,\overline{C_{in}} + ABC_{in}$$

$$= C_{in}(\overline{A}\,\overline{B} + AB) + \overline{C_{in}}(\overline{A}B + A\overline{B})$$

$$= C_{in}(\overline{A \oplus B}) + \overline{C_{in}}(A \oplus B)$$

$$= C_{in} \oplus A \oplus B$$

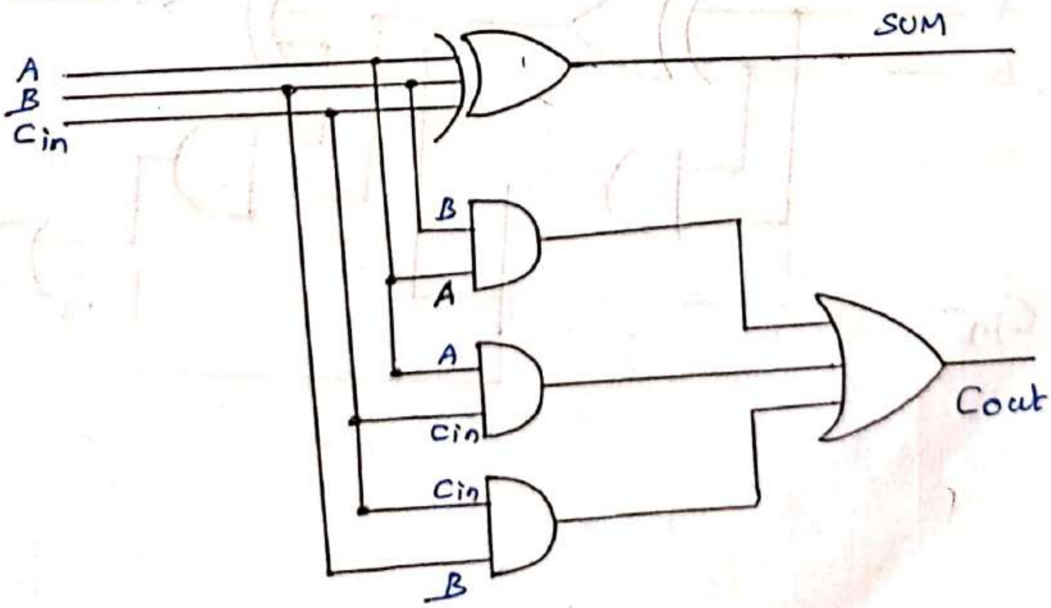

Fig. IMPLEMENTATION OF FULL ADDER

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Draw and Explain full adder using two half adders.

A Full adder can also be implemented with two half-adders and one OR gate.

$$C_{out} = AB + A\,C_{in} + B\,C_{in}$$

$$= AB + A\,C_{in}(B+\bar{B}) + B\,C_{in}(A+\bar{A})$$

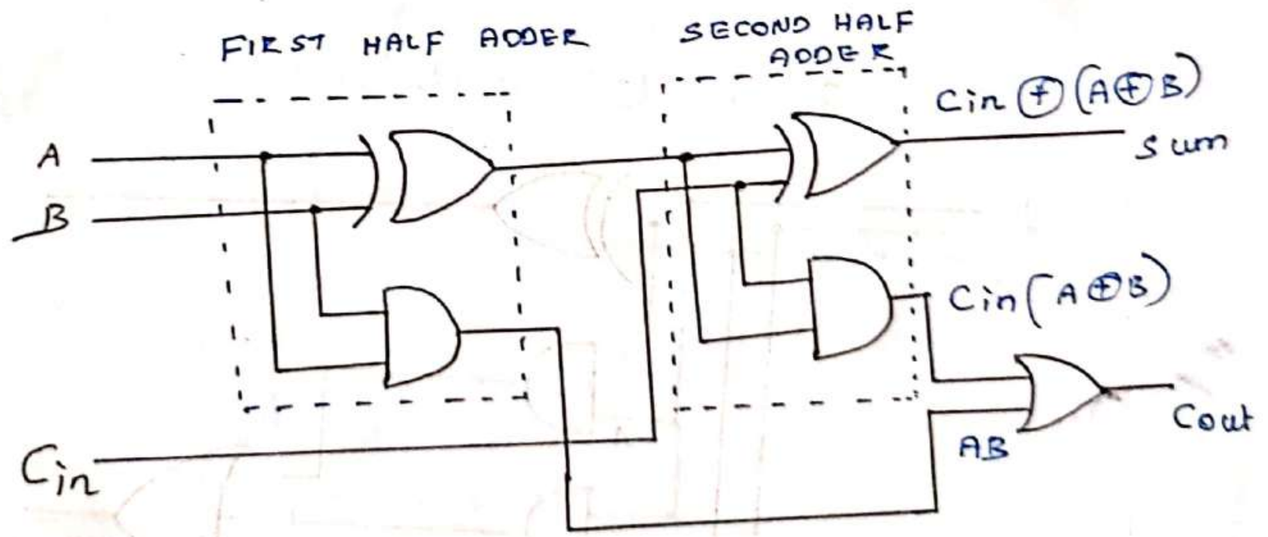
$$= AB + ABC_{in} + A\bar{B}C_{in} + ABC_{in} + \bar{A}BC_{in}$$

$$= AB(1 + C_{in} + C_{in}) + A\bar{B}C_{in} + \bar{A}BC_{in}$$

$$= AB + A\bar{B}C_{in} + \bar{A}BC_{in}$$

$$= AB + C_{in}(A\bar{B} + \bar{A}B)$$

$$= AB + C_{in}(A \oplus B)$$



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HALF SUBTRACTOR :

A half-subtractor is a combinational circuit that subtract two bits and produces their difference.

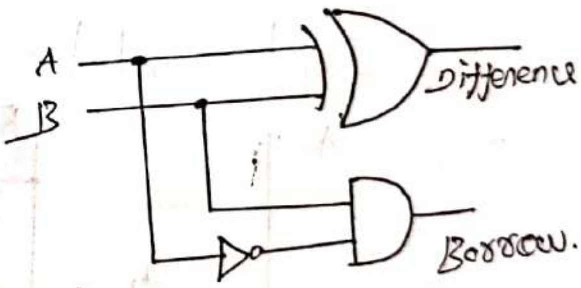
Two i/p ⇒ minuend(A), subtrahend(B).

Two o/p ⇒ Difference and borrow.

Boolean expression as

I/P		O/P	
A	B	Difference	borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Logic Diagram



K-MAP

For difference

A \ B	0	1
0	0	1
1	1	0

A \ B	0	1
0	0	1
1	0	0

Difference $= A\bar{B} + \bar{A}B$

$= A \oplus B$

Borrow $= \bar{A}B$

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Limitations:

Three bit subtraction is not possible with half subtractor.

Example. Draw half subtractor using NAND gates.

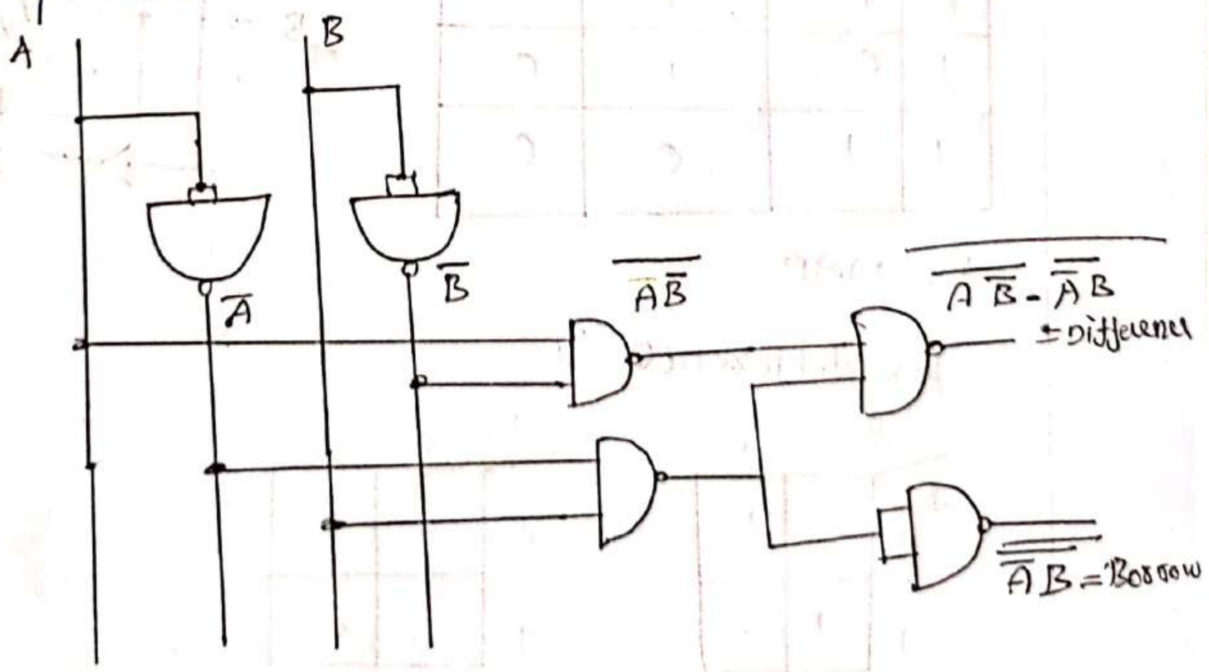
$$\text{Difference} = A\overline{B} + \overline{A}B$$

$$= \overline{\overline{A\overline{B} + \overline{A}B}}$$

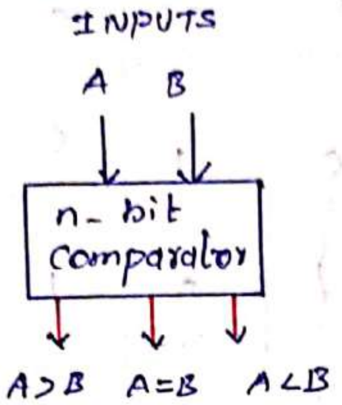
$$= \overline{\overline{A\overline{B}} \cdot \overline{\overline{A}B}}$$

$$\text{Borrow} = \overline{A}B = \overline{\overline{\overline{A}B}}.$$

Implementation:



Magnitude Comparator.



A comparator is a special combinational circuit designed primarily to compare the relative magnitude of two binary numbers.

Inputs : A and B

Outputs : A>B, A=B, A<B.

Example: Design 2-bit comparator using gates.

soln: Truth Table.

Inputs				Outputs.		
A_1	A_0	B_1	B_0	A>B	A=B	A<B
0	0	0	0	0	1	0
0	0	0	1	0	0	1
0	0	1	0	0	0	1
0	0	1	1	0	0	1
0	1	0	0	1	0	0
0	1	0	1	0	1	0
0	1	1	0	0	0	1
0	1	1	1	0	0	1
1	0	0	0	1	0	0
1	0	0	1	1	0	0
1	0	1	0	0	1	0
1	0	1	1	0	0	1
1	1	0	0	1	0	0

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1	1	0	1	1	0	0
1	1	1	0	1	0	0
1	1	1	1	0	1	0

K_map simplification.

A > B

A_1A_0 \ B_1B_0	00	01	11	10
00	0	0	0	0
01	1	0	0	0
11	1	1	0	1
10	1	1	0	0

$A > B = A_0\overline{B_1}\,\overline{B_0} + A_1\overline{B_1} + A_1 A_0 \overline{B_0}$

A = B

A_1A_0 \ B_1B_0	00	01	11	10
00	1	0	0	0
01	0	1	0	0
11	0	0	1	0
10	0	0	0	1

A < B

A_1A_0 \ B_1B_0	00	01	11	10
00	0	1	1	1
01	0	0	1	1
11	0	0	0	0
10	0	0	1	0

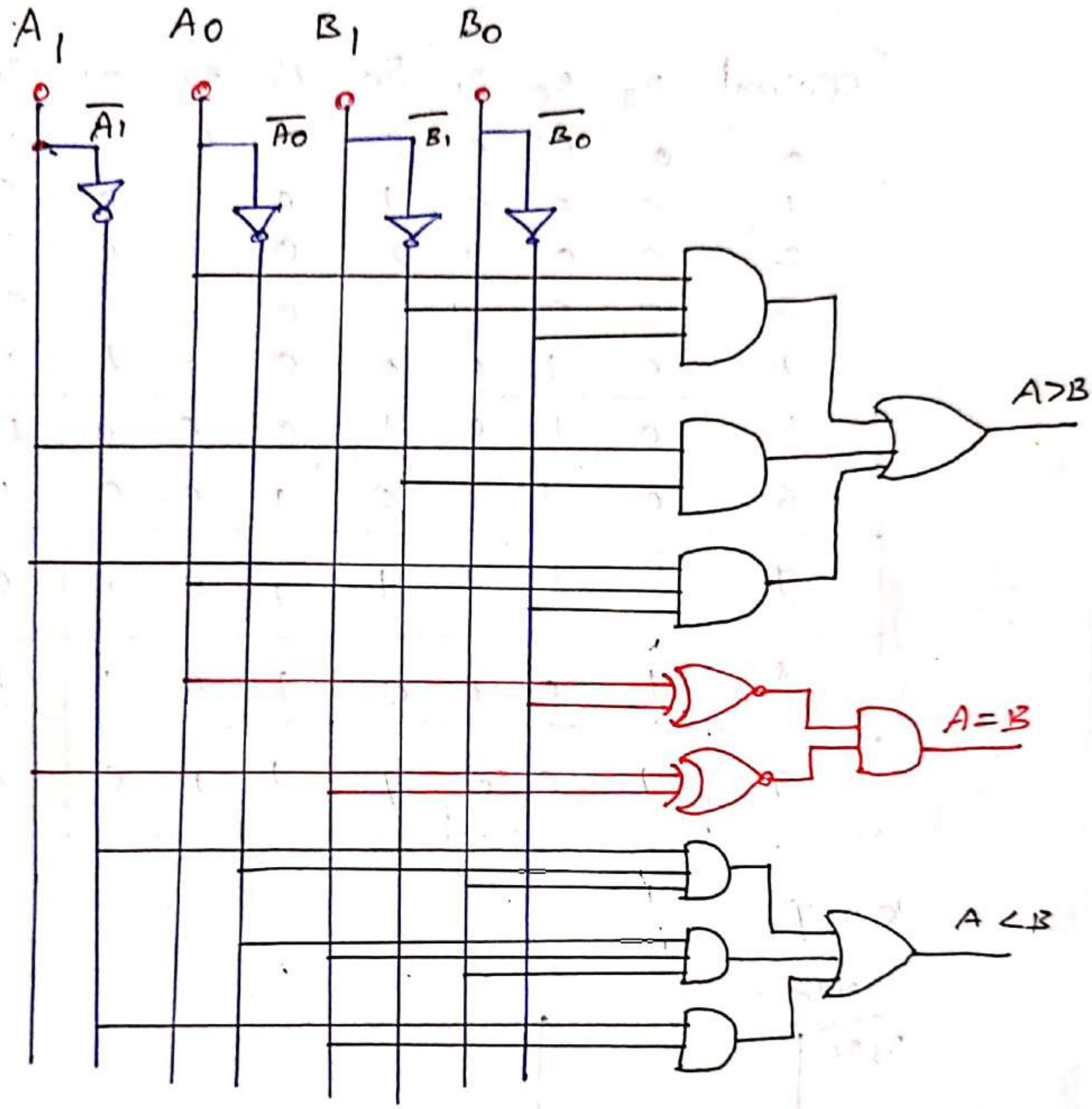
$(A<B) = \overline{A_1}\,\overline{A_0}B_0 + \overline{A_0}B_1B_0 + \overline{A_1}B_1$

$(A=B) = \overline{A_1}\,\overline{A_0}\,\overline{B_1}\,\overline{B_0} + \overline{A_1}A_0\overline{B_1}B_0 + A_1A_0B_1B_0 + A_1\overline{A_0}B_1\overline{B_0}$

$= \overline{A_1}\,\overline{B_1}(\overline{A_0}\,\overline{B_0} + A_0B_0) + A_1B_1(A_0B_0 + \overline{A_0}\,\overline{B_0})$

$= (A_0 \odot B_0)(A_1 \odot B_1)$

Logic diagram.



BCD to Excess 3

The Excess 3 code can be derived from the natural BCD code by adding 3 to each coded number.

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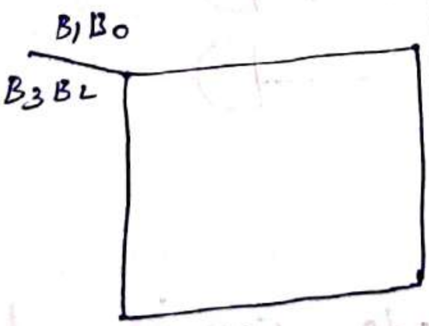
Truth table :

Decimal	B_3	B_2	B_1	B_0	E_3	E_2	E_1	E_0
0	0	0	0	0	0	0	1	1
1	0	0	0	1	0	1	0	0
2	0	0	1	0	0	1	0	1
3	0	0	1	1	0	1	1	0
4	0	1	0	0	0	1	1	1
5	0	1	0	1	0	0	0	0
6	0	1	1	0	1	0	0	1
7	0	1	1	1	1	0	1	0
8	1	0	0	0	1	0	1	1
9	1	0	0	1	1	1	0	0

Kmap.



$\therefore E_3 = B_3 + B_2(B_0 + B_1)$

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Hamming code.

The hamming code can be used for data words of any length. In general, the hamming code consists of k check bits and n data bits, for a total of n+k bits. The syndrome value C consists of k bits and has a range of 2^k values between 0 and $2^k - 1$. One of these values, usually zero is used to indicate that no error was detected, leaving $2^k - 1$ values to indicate which of the n+k bits was in error. Each of these $2^k - 1$ values can be used to uniquely describe a bit in error. Therefore, the range of k must be equal to or greater than n+k, giving the relationship

$$2^k - 1 \geq n+k$$

Solving for n in terms of k, we obtain $2^k - 1 - k \geq n$.

For Ex $k=4$, we have $2^4 - 1 - 4 = 11$

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The data word may be less than 11 bits, but must have atleast 5 bits.

Single Error correction, Double Error detection.

The hamming code can detect and correct only a single error. By adding another parity bit to the coded word, the hamming code can be used to correct a single error and detect double errors.

If we include this additional parity bit then the previous 12 bit coded word becomes 001110010100P_{13} where P_{13} is evaluated from the exclusive OR of the other 12 bits. This produces the 13 bit word 0011100101001 (even parity)

If C = 0 and P = 0 no error occurred.

If C ≠ 0 and P = 1 a single error occurred that can be corrected.

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If $C \neq 0$ and $P = 0$, a double error occurred that can be corrected.

If ~~C ≠ 0~~ $C = 0$ and $P = 1$ an error occurred in the P_{13} bit.

This scheme may detect more than two errors, but is not guaranteed to detect all such errors.

Ex: On the 8 bit data word 01011011, generate the 13 bit composite word for the hamming code that corrects single errors and detects double errors.

1	2	3	4	5	6	7	8	9	10	11	12	13
P_1	P_2	0	P_4	1	0	1	P_8	1	0	1	1	1

P_1 = XOR of bits (3, 5, 7, 9, 11, 13) = 1

P_2 = XOR of bits (3, 6, 7, 10, 11) = 1

P_4 = XOR of bits (5, 6, 7, 12, 13) = 0

P_8 = XOR of bits (9, 10, 11, 12, 13) = 0

1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	0	0	1	0	1	0	1	0	1	1	1

C_1 = XOR of bits (1, 3, 5, 7, 9, 11, 13) = 0

C_2 = XOR of bits (2, 3, 6, 7, 10, 11) = 1

C_3 = XOR of bits (4, 5, 6, 7, 12, 13) = 0

C_8 = XOR of bits (8, 9, 10, 11, 12) = 1

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24/7/19 Multiplexer

Multiplexer is a digital switch, it allows digital information from several sources to be routed on to a single output line.

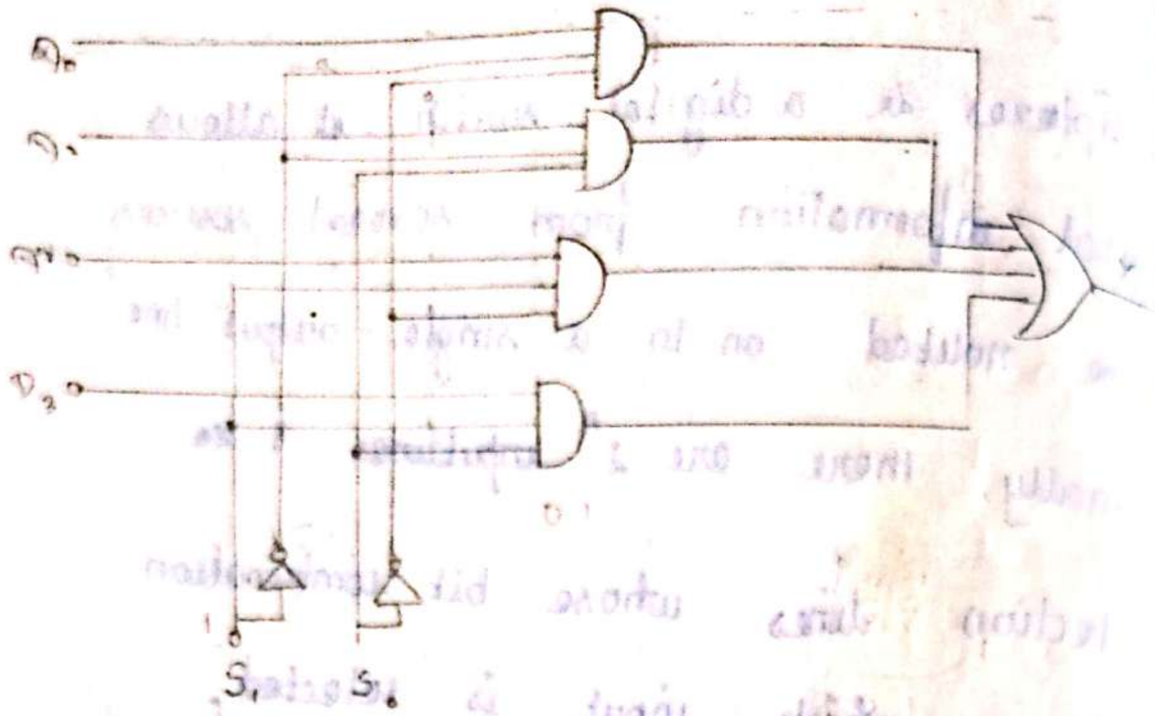
Normally, there are 2^n inputlines & an n-selection lines whose bit combination determine which input is selected.

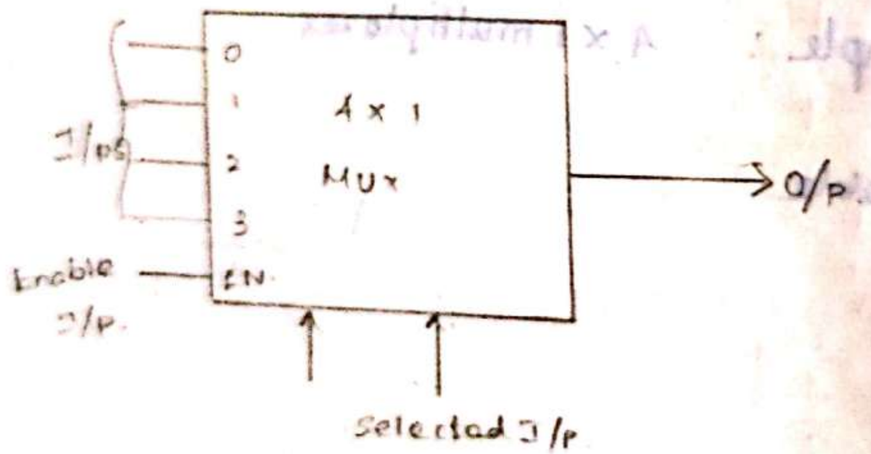
For example: 4×1 multiplexer.

Truth Table:

S_1	S_0	Y
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

$D_0 \Rightarrow D_0 S_1' S_0'$





1) Implement the following Boolean function using 8 : 1 Multiplexer

$$F(A,B,C,D) = \bar{A} B \bar{D} + A C D + \bar{B} C D + \bar{A} \bar{C} D$$

$$= \bar{A} B \bar{D}(C+\bar{C}) + ACD(B+\bar{B}) + \bar{B} CD(A+\bar{A}) + \bar{A}\bar{C}D(B+\bar{B})$$

$$= \bar{A}BC\bar{D} + \bar{A}B\bar{C}\bar{D} + ABCD + A\bar{B}CD + A\bar{B}CD + \bar{A}\bar{B}CD + \bar{A}B\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}$$

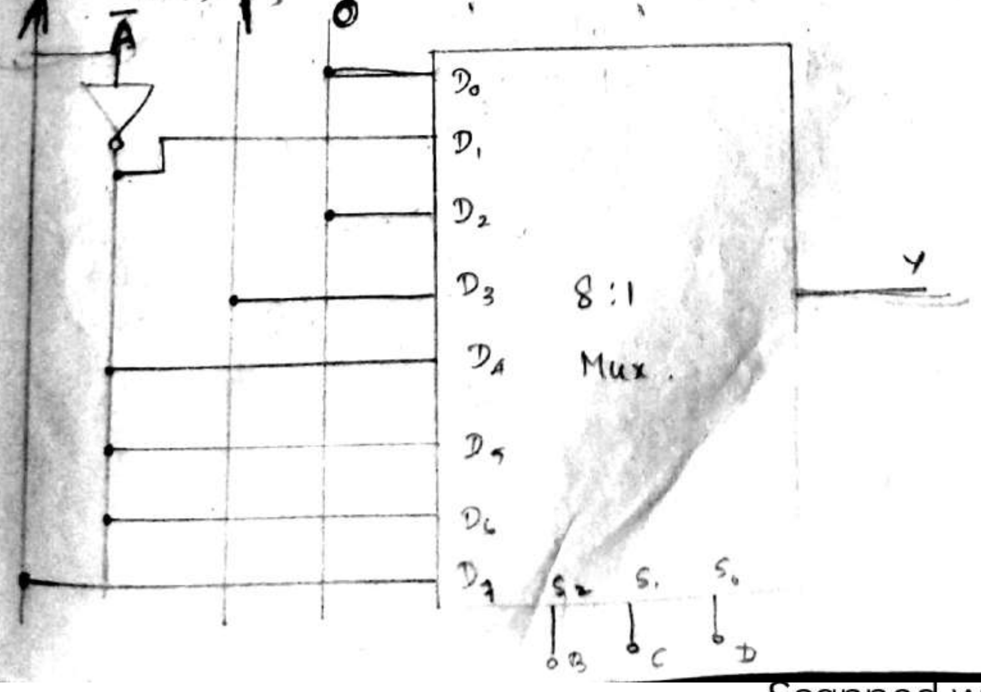
$$= \sum m(6, 4, 15, 11, 3, 5, 1)$$

Truth table . (optional)

NO	mintorms	A	B	C	D	Y
1	$\bar{A}\bar{B}\bar{C}D$	0	0	0	1	1
3	$\bar{A}\bar{B}CD$	0	0	1	1	1
4	$\bar{A}B\bar{C}\bar{D}$	0	1	0	0	1
5	$\bar{A}B\bar{C}D$	0	1	0	1	1
6	$\bar{A}BC\bar{D}$	0	1	1	0	1
11	$A\bar{B}CD$	1	0	1	1	1
15	$ABCD$	1	1	1	1	1

Implementation Table.

	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
$\bar{A}$	0	(1)	2	(3)	(4)	(5)	(6)	7
A	8	9	10	(11)	12	13	14	(15)
	0	$\bar{A}$	0	1	$\bar{A}$	$\bar{A}$	$\bar{A}$	A



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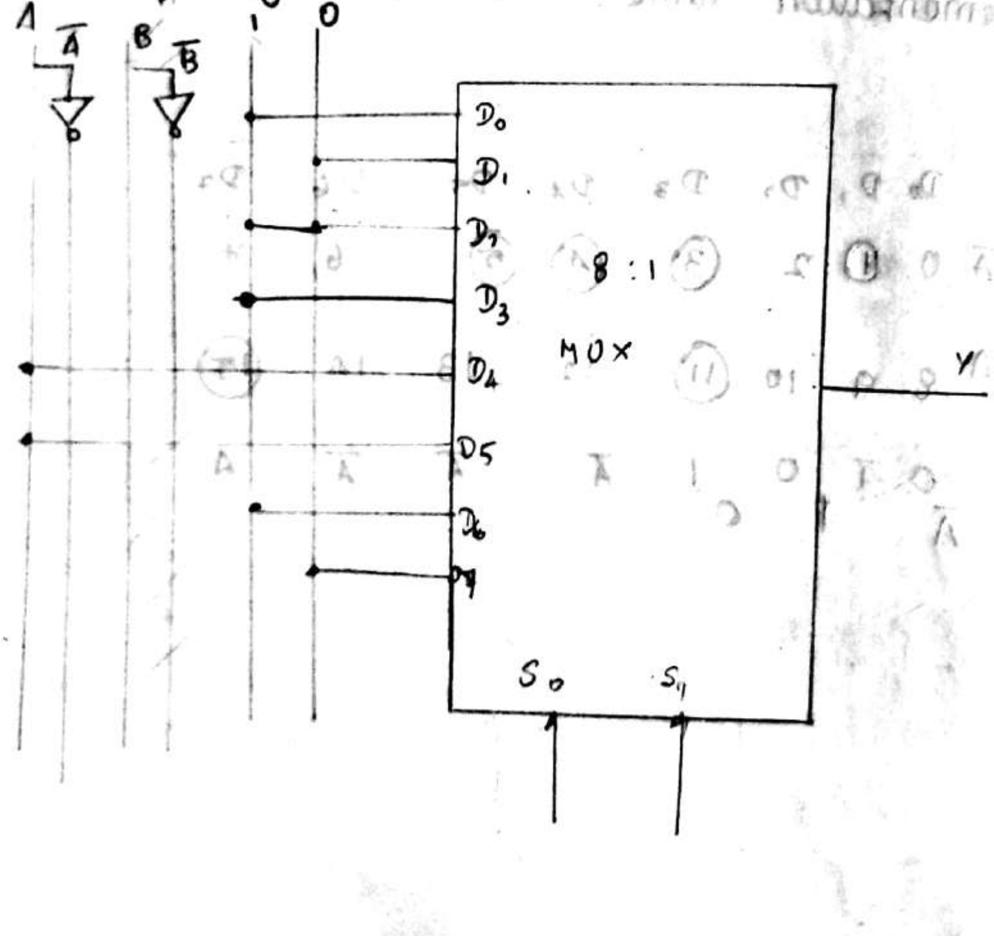
3) Implement the following Boolean function with 8 : 1 multiplexer

$$F(A,B,C,D) = \Sigma m(0,2,6,10,11,12,13) + d(3,8,14)$$

	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
$\bar{A}$	(0)	1	(2)	(3)	4	5	(6)	7
A	(8)	9	(10)	(11)	(12)	(13)	(14)	15
	1	0	1	1	A	A	1	0



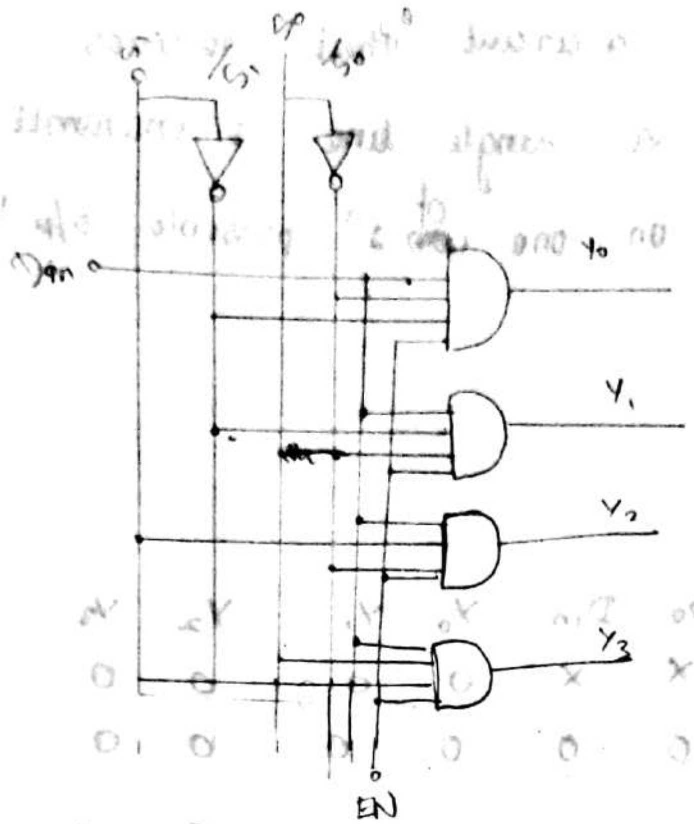
Demultiplexer.

23/9/14

A demultiplexer is a circuit that receives information on a single line & transmit this information on one of 2^n possible o/p lines

Draw 1×·
Truth table

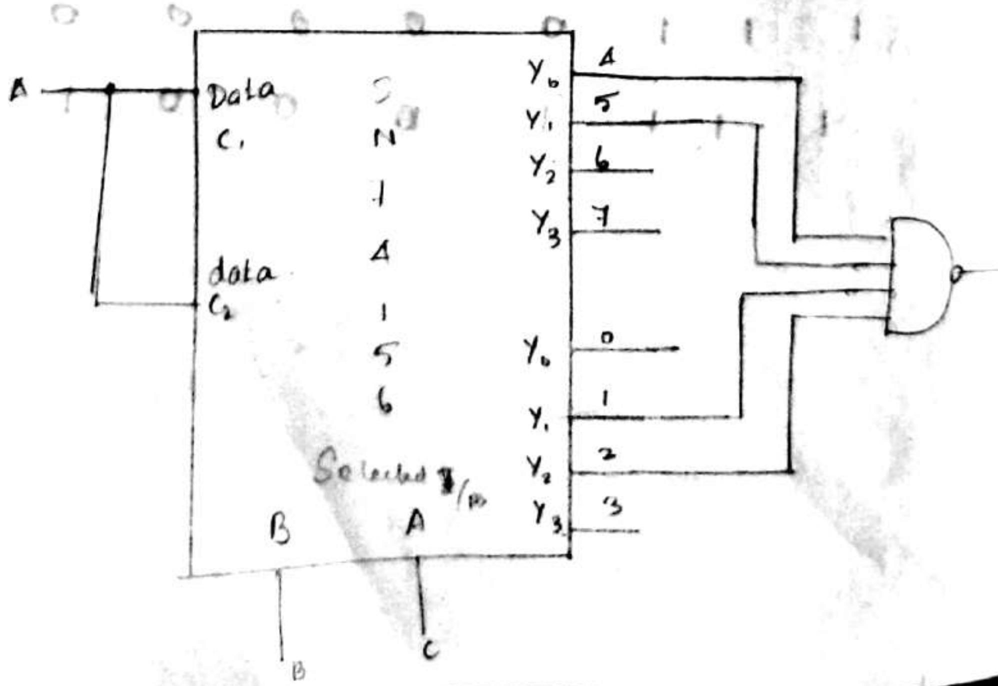
EN	S_1	S_0	D_{in}	Y_0	Y_1	Y_2	Y_3
0	×	×	×	0	0	0	0
1	0	0	0	0	0	0	0
1	0	0	1	1	0	0	0
1	0	1	0	0	0	0	0
1	0	1	1	0	1	0	0
1	1	0	0	0	0	0	0
1	1	0	1	0	0	1	0
1	1	1	0	0	0	0	0
1	1	1	1	0	0	0	1



1) Implement the switching function

F = $\sum(1, 2, 4, 5)$ using the dual 2 line to 4 line decoder demultiplexer SN 74156

F = $\sum(1, 2, 4, 5)$, SN 74156



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3

C_1 should be high and C_2 should be low.

to operate as decoder

Distinguies b/w a decoder & a demultiplexer.

A decoder is a multiple input, multiple o/p logic circuit which converts coded inputs into coded output.

A demultiplexer is a circuit that receives information on a single line and transmits this information on one of 2^n possible o/p lines.

30/7/14

parity Generator / (or) checker.

A parity bit used for the purpose of detecting errors during transmission binary information. A parity bit is an extra bit included with a binary message to make the number of ones (1's) either odd (or) even.

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* 2mk

The circuit that generates the parity bits in the transmitter is called a parity generator and the circuit that checks the parity in the receiver is called a parity checker.

Truth table:

3 bit message			Odd	Even
A	B	C	parity	parity
0	0	0	1	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	0	1

1 → wrong
0 → right

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For odd parity

A \ BC	00	01	11	10
0	(1)	0	(1)	0
1	0	(1)	0	(1)

$$= \overline{A}\,\overline{B}\,\overline{C} + \overline{A}BC + A\overline{B}C + AB\overline{C}$$

$$= \overline{A}\,\overline{B}\,\overline{C} + \overline{A}BC + A(\overline{B}C + B\overline{C})$$

$$= \overline{A}(\overline{B}\,\overline{C} + BC) + A(\overline{B}C + B\overline{C})$$

$$= \overline{A}(\overline{B \oplus C}) + A(B \oplus C).$$

$$= \overline{A \oplus B \oplus C}$$

For Even parity.

A \ BC	00	01	11	10
0	0	[1]	0	[1]
1	[1]	0	[1]	0

$$= \overline{A}\,\overline{B}C + \overline{A}B\overline{C} + A\overline{B}\,\overline{C} + AB\overline{C}$$

$$= \overline{A}(\overline{B}C + B\overline{C}) + A(\overline{B}\,\overline{C} + BC)$$

$$= \overline{A}(B \oplus C) + A(\overline{B \oplus C})$$

$$= A \oplus (B \oplus C)$$

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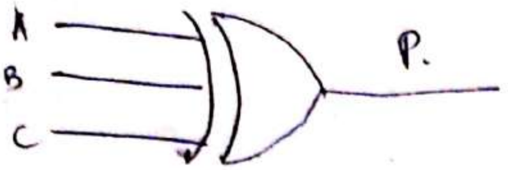
even



odd

Pbm

1) Determine which bit, if any error in the even parity haming coded character 1100111 decode the message.

Bit designation	D_7	D_6	D_5	P_4	D_3	P_2	P_1
Bit Location	7	6	5	4	3	2	1
Bit location ~~number~~ code.	1	1.	0	0	1	1	1
Bit location number	111	110	101	100	011	010	001

~~Step 2~~.

Step 2 => check for parity bits

for P_1 => P_1 checks location 1, 3, 5, 7

~~for P_2 => P_2 c~~

There are three 1's in the group

∴ parity check for even parity is wrong

Even parity wrong → 1(LSB)

for P_2 ⇒ checks location ⇒ 2, 3, 6, 7,

There are 4 1's in the group ∴ parity check for even parity is correct.

even parity = 0

for P_4 ⇒ checks location ⇒ 4, 5, 6, 7

There are 2 1's in the group

∴ parity check for even parity is correct

even parity = 0 (MSB)

The resultant word is 001

This says that the number 1 location is in error.

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Measurements and Instrumentation

Functional elements of an instrument, Standards and calibration, Operating Principle, Types - Moving coil and Moving iron meters, Measurement of three phase power, Energy Meter, Instrument Transformers - CT and PT, DSO - Block diagram - Data acquisition.

① Functional Elements of an instrument

* The measurement of a given parameter or quantity is the act or result of a quantitative comparision between a predefined standard and an unknown quantity to be measured.

* Instruments -> An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc.

* Measurand -> The physical, chemical, electrical quantity, property, process, variable or a condition to be measured is referred as Measurand.

* Most of the Measurement systems contain three main functional elements. They are.

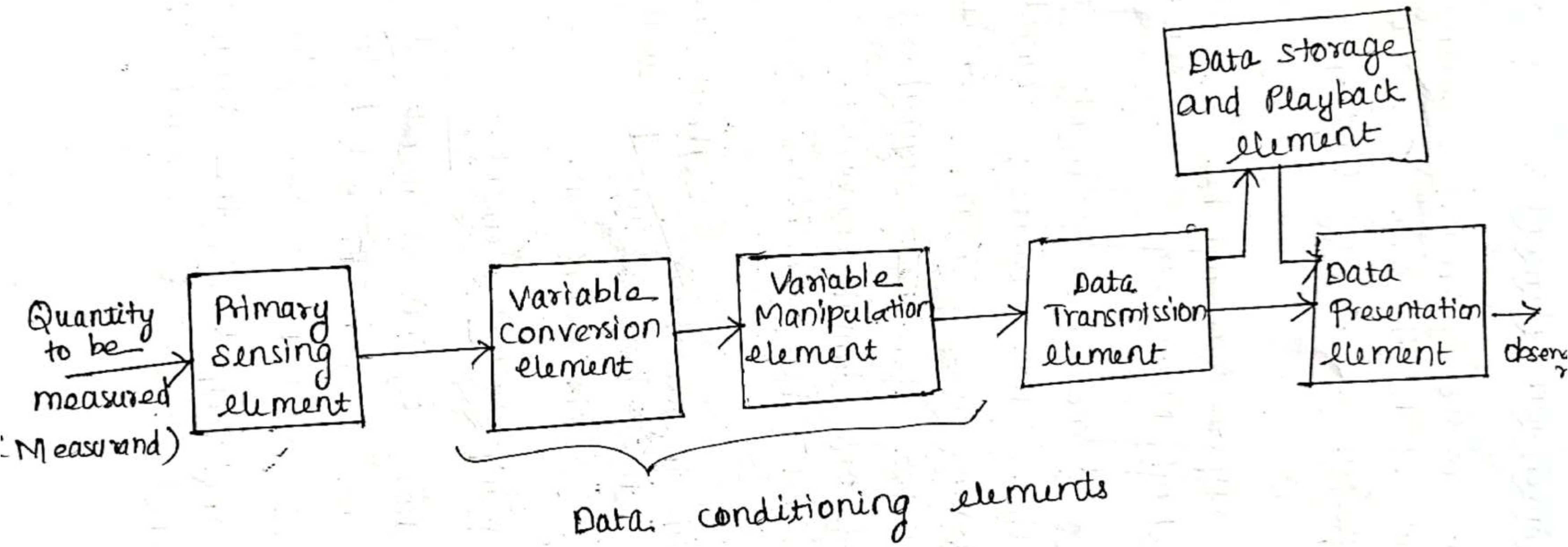
1. Primary sensing element
2. Data conditioning elements
3. Data presentation element.

* Any instrument or a measuring system can be described in general with the help of a block diagram.

① Primary sensing element

* An element of an instrument which makes first, contact with the quantity to be measured is called primary sensing element.
* Thus first detection of the measurand is done by the primary sensing element.
* In ammeter, coil carrying current to be measured is a primary sensing element.
* In most of the cases, a transducer follows Primary sensing element which converts the measurand into a corresponding electrical signal.

FUNCTIONAL ELEMENTS OF AN INSTRUMENT



② Variable Conversion Element.

* The output of the primary sensing element is in electrical form such as voltage, frequency or any other electrical parameter.

* such an output may not be suitable for the actual Measurement System.

* For Example if the measurement system is digital then the analog signal obtained from the primary sensing element is not suitable for the digital system. Thus analog to digital converter is required which is nothing but Variable Conversion element.

* The original Information about the measurand must be retained as it is while doing such conversion.

③ Variable Manipulation element:

* The function of this element is to manipulate the signal presented to it preserving the original nature of the signal.

* Sometimes, the output of the transducer may get affected due to unwanted signals like noise.

* Thus, such signals are required to be Processed with some processes like modulation, clipping, clamping etc.
* This process of conversion is called <u>signal Conditioning</u>.

④ Data Transmission Element.

* When the elements of the system are Physically seperated, it is necessary to transmit the data from one stage to other
* This is achieved by the data transmission element.
* The signal conditioning and data transmission together is called <u>intermediate stage</u> of an instrument

⑤ Data Presentation Element

* The information about the quantity under measurement has to be conveyed to the Personnel handling the instrument or the system for monitoring control, or analysis purposes. This function is done by data presentation element.

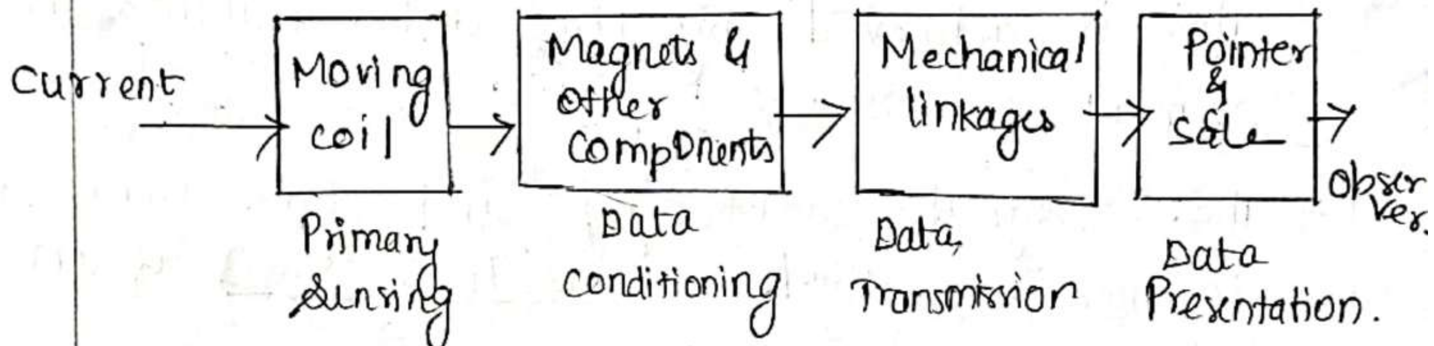
Ex! Ammeters, Voltmeters, magnetic tapes, high speed cameras & TV equipment, printers etc.

* For control & Analysis purpose microprocessor or computers are used.

* The final stage in a measurement system is known as terminating Stage.

Example

For Example, consider a simple analog meter used to measure current or voltage as shown in figure.



* The moving coil is primary sensing element.
* The magnets and coil together act as data conditioning stage to convert current in a coil to a force.

* This force is transmitted to the pointer through mechanical linkages which act as data transmission element.

* The pointer and scale act as data Presentation element.

(2) Standards in Measurement

* All the instruments are calibrated at the time of manufacture against a measurement standards.

* A standard of measurement is a physical representation of a unit of measurement.

* A standard means known accurate measure of physical quantity.

* The different types of standards of measurement are classified as,

1. International standards
2. Primary standards
3. Secondary standards
4. Working standards.

International standards

* International standards are defined as the international agreement.
* These standards as mentioned above are maintained at the international bureau of weights and measures and are periodically evaluated and checked by absolute measurements in terms of fundamental units of physics.

Standard Chart.

International Standards

↓

National standard Laboratories

↓

Industries & secondary laboratories.

↓

Measurement Laboratory

↓

Process Instrument.

* these international standards are not available to the ordinary users for the calibration purpose.

Primary Standards.

* These are highly accurate absolute standards, which can be used as ultimate reference standards.

* These primary standards are maintained at National standard laboratories in different countries.

* These standards representing fundamental units as well as some electrical and

③ Calibration

* The calibration is the procedure for determining the correct values of measurand by comparison with the standard ones.

* The standard of device with which comparison is made is called a standard instrument.

* The instrument which is unknown and is to be calibrated is called test instrument.

* Thus in calibration, test instrument is compared with the standard instrument.

* The calibration procedure involves the steps like visual inspection for various defects, installation according to the specifications, zero adjustment etc.

* The calibration characteristics can be determined by applying known values of quantities to be measured and recording the corresponding output of the instrument. Such output values are then compared with the input, to determine the error.

* Such a record obtained from calibration is called calibration record.

* ~~If~~ It is generally recorded in the tabular form. If it is represented in the graphical form, it is called <u>calibration curve</u>.

* If the device has been repaired, aged, adjusted or modified, then <u>recalibration</u> is carried out.

④ Operating principle, Types, Moving coil and Moving Iron Meters

Moving coil Instruments

* There are two types of Moving coil instruments namely
  ⇒ Permanent Magnet moving coil Type (PMMC)
  ⇒ Dynamometer Type

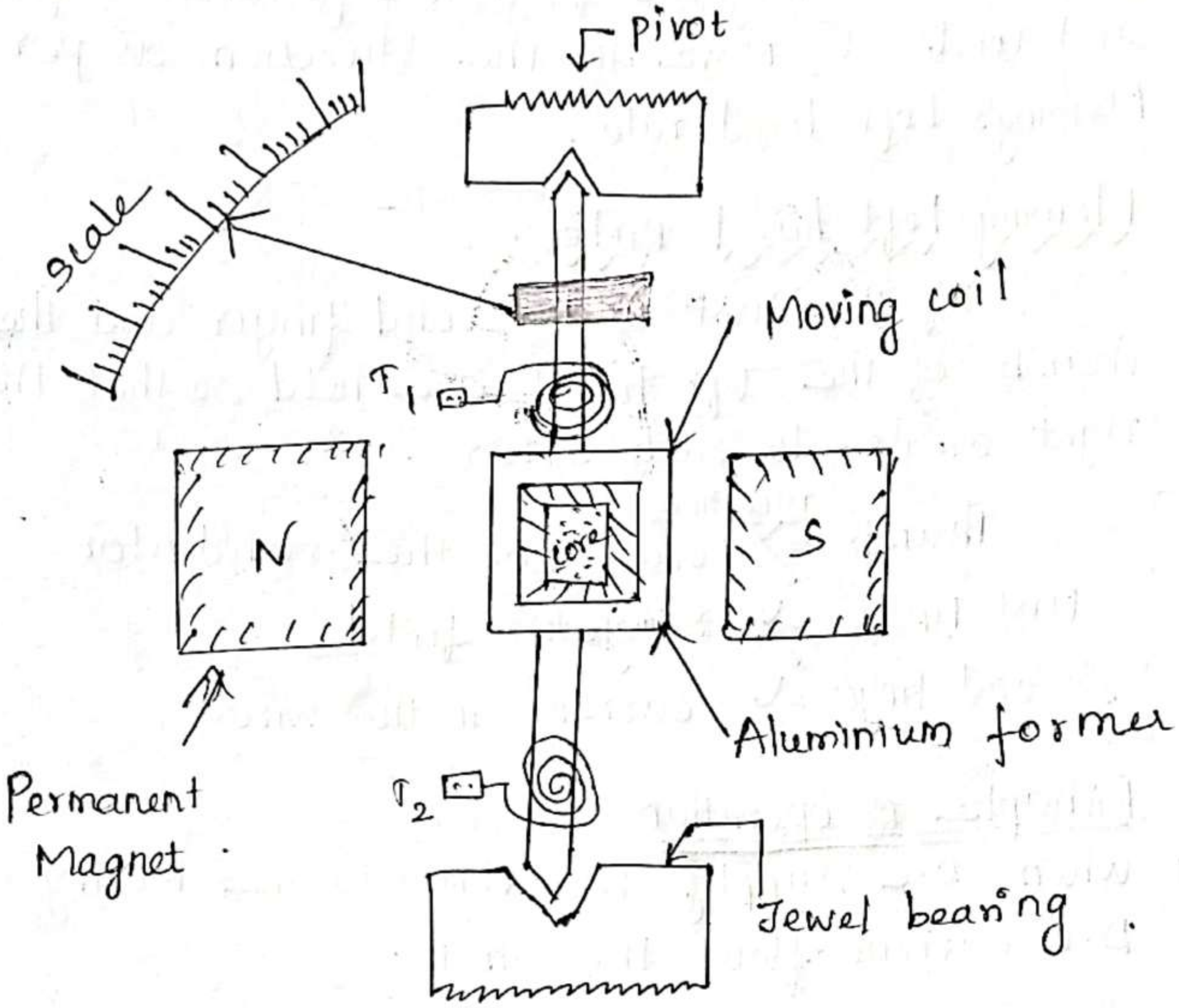
Permanent Magnet Moving coil Instrument (PMMC)

* This type can be only used for <u>direct</u> current, Voltage Measurements.

Construction

* A Permanent Magnet is used in this type Instrument.
* Aluminium former is provided in the cylindrical in between two Poles of the Permanent magnet.
* Coils are wound on the aluminium former which is connected with the spindle.
* This spindle is supported with Jeweled bearing.

PMMC



* Two springs are attached on either end of the spindle.
* The terminals of the moving coils are connected to the spring.
* The current flows through spring 1, moving coil & spring 2.

Damping : Eddy current damping is used. This is produced by aluminium former.

Control : Spring control is used.

Principle. When the current carrying conductor is placed in a magnetic field, it experiences a force and tends to move in the direction as per Fleming's left hand rule.

Fleming Left hand Rule.

If the first and second finger and the thumb of the left hand are held, so that they are right angle to each other.

	Direction
Thumb ⇒	Force on the conductor
First Finger ⇒	Magnetic field
Second finger ⇒	current in the wire.

Principle of operation.

* When D.C supply is given to the moving coil, D.C current flows through it.
* When the current carrying coil is kept in the magnetic field, it experiences a force.
* This force produces a torque and the former rotates.
* The pointer is attached with the spindle.
* When the former rotates, the pointer moves over the calibrated scale.
* When the polarity is reversed a torque is produced in the opposite direction.

Deflecting Torque The force F will be perpendicular to both the direction of current flow & magnetic field.

⇒ By Fleming Left hand Rule, $F = NBIL$ N → Number of turns of wire

B → flux density I ⇒ current in the coil

L → vertical length of coil

Energy Meter.

* Energy meters are the basic part to measure the Power consumption.
* It is also known as Watt-hour meter.
* The essential components of Energy meter are.

1. Driving system.
2. Moving system.
3. Braking system.
4. Registering system.

1. Driving system.

* The components of this system are two silicon steel laminated electromagnets.
* The upper electromagnet is called shunt Magnet.
* It carries a voltage coil consisting of many turns of thin wire.
* The lower electromagnet is called series magnet.
* It carries the two current coils consisting of a few turns of thick wire.

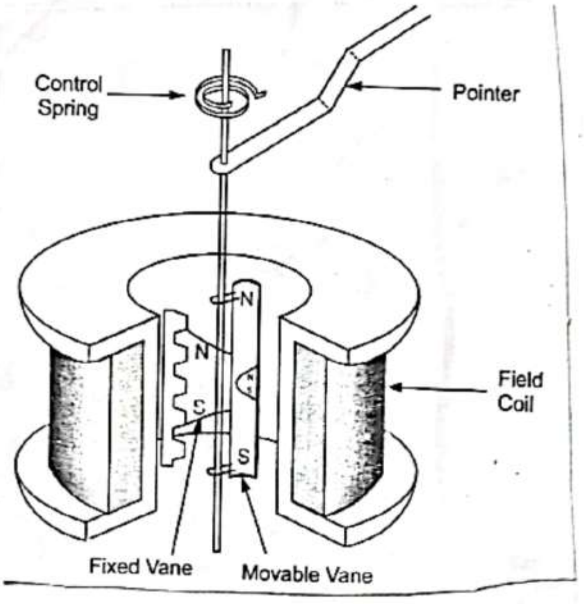
2. Moving system.

* There is a thin aluminium disk placed in the gap between the two electromagnets.
* It is mounted on a vertical shaft.
* The eddy currents are induced in the aluminium disk when it cuts the flux produced by both the magnets
* As a result, two magnetic fields constitute a deflecting torque in the disk.
* The disk slowly starts rotating & the several rotation of the disk displays the power consumption.

* The current through the coil is alternating.
* There is always repulsion between the like poles of the fixed and the movable vane.
* The deflection of the pointer is always in the same direction.
* The deflection is proportional to the current.
* The scale is calibrated directly to read amperes or volts.

Co-axial vane Type.

* In this type, the fixed and moving vanes are sections of co axial cylinders.
* The controlling torque is provided by springs.
* The instrument has two concentric vanes.
* One is attached to the coil frame.
* Other can rotate coaxially inside the stationary vane.
* Both the vanes are magnetised to the same polarity.
* movable vane rotates under the repulsive force.
* The pointer deflection is proportional to the current in the coil.



(ii) Repulsion Type

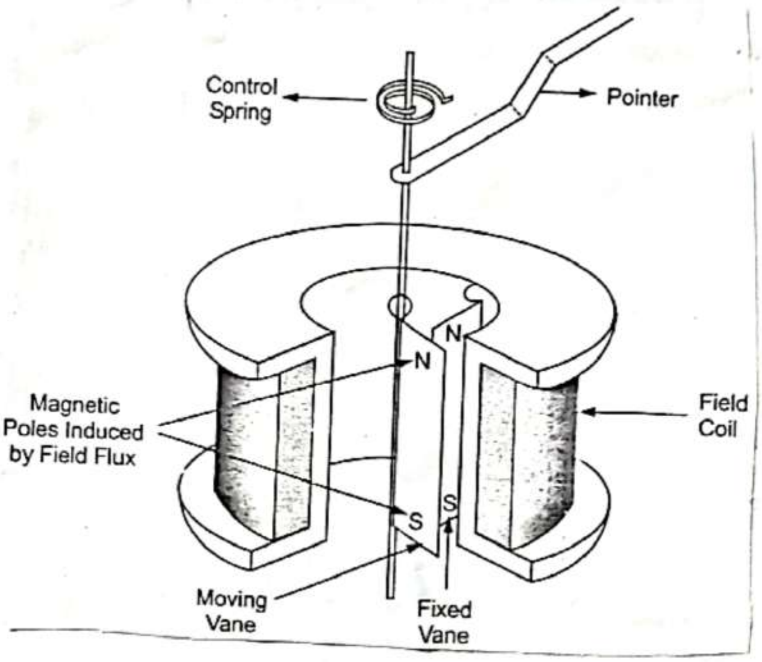
* These instruments have two vanes inside the coil,
* One is fixed & other is movable.
* When the current flows in the coil, both the Vanes are magnetised with like polarities induced on the same side.
* There is a force of repulsion between the two vanes resulting in the movement of the moving vane.
* The repulsion type instruments are the most commonly used instruments.
* The two different designs of repulsion type instruments are:

(i) Radial vane Type.

(ii) Co-axial vane Type.

Radial vane Type.

* In this type, the vanes are radial strips of iron.
* The fixed vane is attached to the coil & the movable one to the spindle of the instrument.



Moving Iron Meter

Classification of Moving Iron Meters

* Moving Iron Meters are of two Types.
  (i) Attraction Type
  (ii) Repulsion Type

(I) Attraction Type

* The working Principle of these instruments is very simple, that a soft iron piece if brought near the magnet gets attracted by the magnet

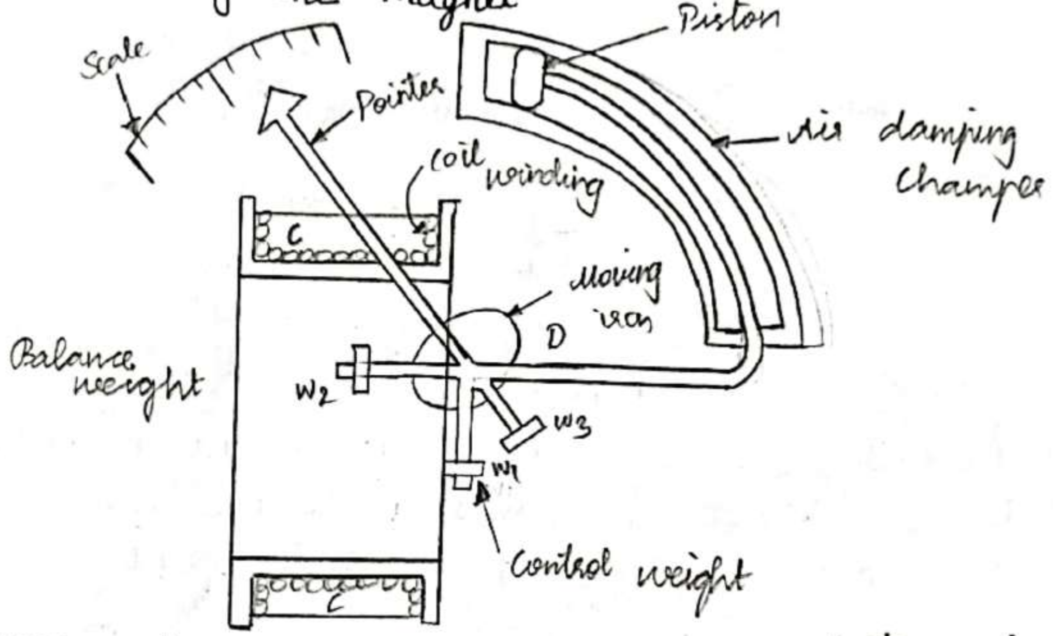


fig. Moving iron attraction type instrument

Construction

* It consists of a fixed coil C and Moving iron piece D.
* The coil is flat and has a narrow slot like opening.
* The Moving Iron is a flat disc or a sector eccentrically mounted on the spindle
* The spindle carries a pointer which moves over a graduated scale.
* The controlling Torque is provide by springs but gravity control can be used.
* Damping is provided by air friction with the help of a light aluminium piston.

Measurement of three phase power

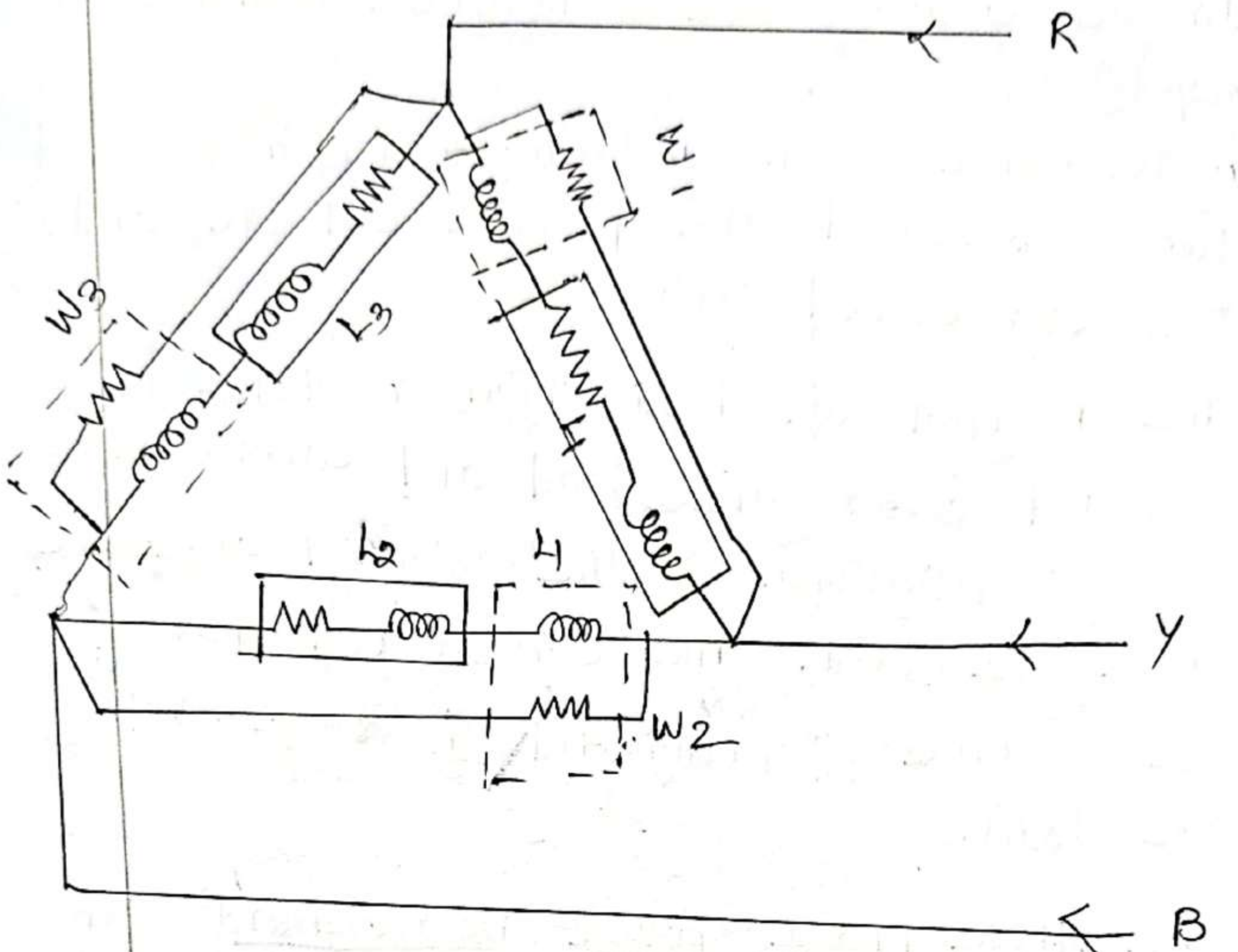
* In ac circuits, Power is measured with the help of wattmeter.
* A wattmeter is an instrument, which consists of two coils called the potential coil (PC) and the current coil (CC)
* The Potential coil having high resistance is connected across the load and carries the current proportional to the potential difference across the load. The current coil having low resistance is connected in series with the load.
* The three phase power measurement can be carried out using the following methods.

  => One wattmeter Method.
  => Two Wattmeter Method.
  => Three wattmeter Method.

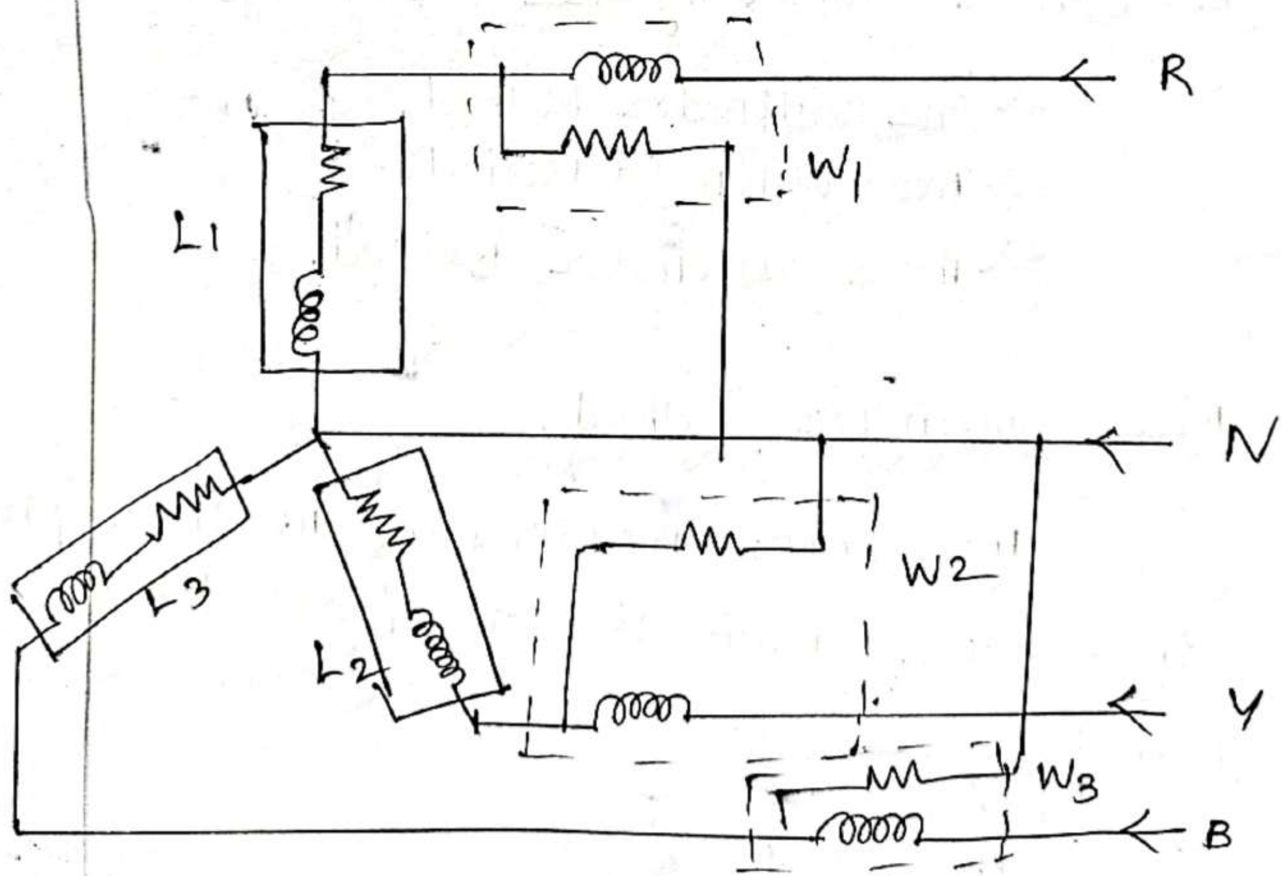
Three Wattmeter Method.

The power measurement in three-phase, three-wire circuit is carried out by this Method.

Delta connection load.



Star connection Load.



* As the neutral wire is common to the three phases, each wattmeter reads power in its own phase, and the total power is given by the sum of the readings of three wattmeters.

Total power of load circuit, $P_{3-\phi} = W_1 + W_2 + W_3$

* In the case of delta connected circuits, Power measurement by three wattmeter method is very difficult because phase coils of load are required to be broken for inserting the current coils of wattmeters.

Instrument Transformers.

* In power system, the currents and voltages are very large, Therefore, their direct Measurements are not possible.

* For such cases, specially constructed ratio transformers are used in conjunction with measuring instruments called Instrument transformers.

* Instrument Transformer generally classified as.

  (i) current Transformer (C.T) → used for current Measurement

  (ii) Potential transformer (P.T) → used for voltage Measurement.

Current Transformer (CT)

* CT consists of two windings called primary and secondary.

* Primary winding is connected in series with the line carrying current which is to be measured.

* The primary winding consists of very few turns and the secondary winding has large number of turns (step up).

* The secondary winding is connected to the ammeter.

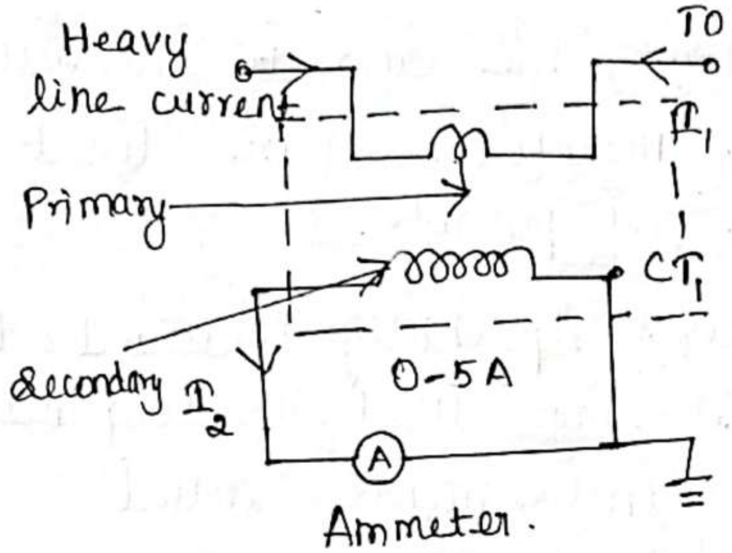


fig: current Transformer

Working Principle of CT

* These transformers are basically step up transformers
* Thus the current reduces from primary to secondary
* so from current point of view, these are step down transformers, stepping down the current value considerably from primary to secondary.

Let N_1 = Number of turns of primary

N_2 = Number of turns of secondary

I_1 = Primary current

I_2 = secondary current.

For a Transformer

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

* As N_2 is very high compared to N_1, the ratio I_1 to I_2 is also very high for current transformers.

* Such a current ratio is indicated for representing the range of current transformer.

* Example : consider a 500 : 5 range. then it indicates that C.T steps down the current from Primary to secondary by a ratio 500 to 5.

$$\frac{I_1}{I_2} = \frac{500}{5}$$

Knowing this current ratio and the meter reading on the secondary, the actual high primary line current flowing through the primary can be obtained.

Example Problem

A 250 : 5 CT is used along with an ammeter. If ammeter reading is 2.7 A, estimate the line current.

Soln $\frac{I_1}{I_2} = \frac{250}{5}$

But, as ammeter is in secondary $I_2 = 2.7\,A$

$$\frac{I_1}{2.7} = \frac{250}{5} \qquad I_1 = 135A.$$

So line current is 135 A.

Why secondary of C.T should not be open?

* It is very important that the secondary of C.T should not be kept open.
* Either it should be shorted or must be connected in series with a low resistance coil such as current coils of wattmeter, coil of ammeter etc.
* If it is left open, then current through secondary becomes zero hence the ampere turns produced by secondary which generally oppose primary ampere turns becomes zero.
* This produce excessive core losses, heating the core beyond limits.
* Similarly heavy emfs will be induced on the primary and secondary side.
* This may damage the insulation of the winding.
* This is danger from the operator point of view as well.
* It is usual to ground the C.T on the secondary side to avoid a danger of shock to the operator.

Potential Transformers (P.T)

* The basic principle of these transformers is same as current Transformers.

* Primary winding consists of large number of turns while secondary has less number of turns.

* The Primary is connected across the high voltage line while Secondary is connected to the low range voltmeter coil.

* One end of the secondary is always grounded for safety purpose.

* The connections are shown in the figure.

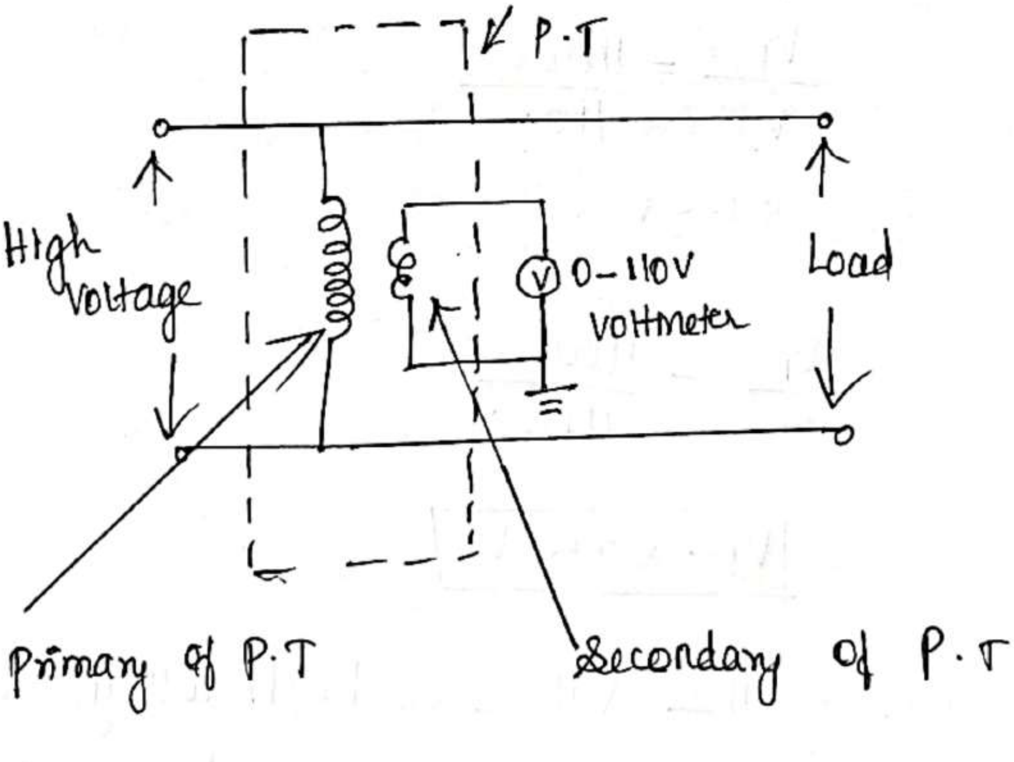


fig: Potential Transformer.

* As a normal Transformer, its ratio can be specified as,

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}.$$

* So if the voltage ratio of P.T is known and the Voltmeter reading is known then the high voltage to be measured, can be determined.

Example

A 1100 : 110 potential transformer is used along with a voltmeter reading 87.5V. Estimate the value of Line voltage.

Soln for a P.T

$$\frac{V_1}{V_2} = \frac{11000}{110}.$$

& $V_2 = 87.5\,V$

$$\frac{V_1}{87.5} = \frac{11000}{110}.$$

$$\boxed{V_1 = 8750V}$$

This is the value of high voltage to be measured.

DSO

DSO - Digital Storage Oscilloscope

* Digital storage oscilloscope is an instrument which gives the storage of a digital waveform or the digital copy of the waveform. or the

* It allows us to do the digital signal processing techniques over that signal.

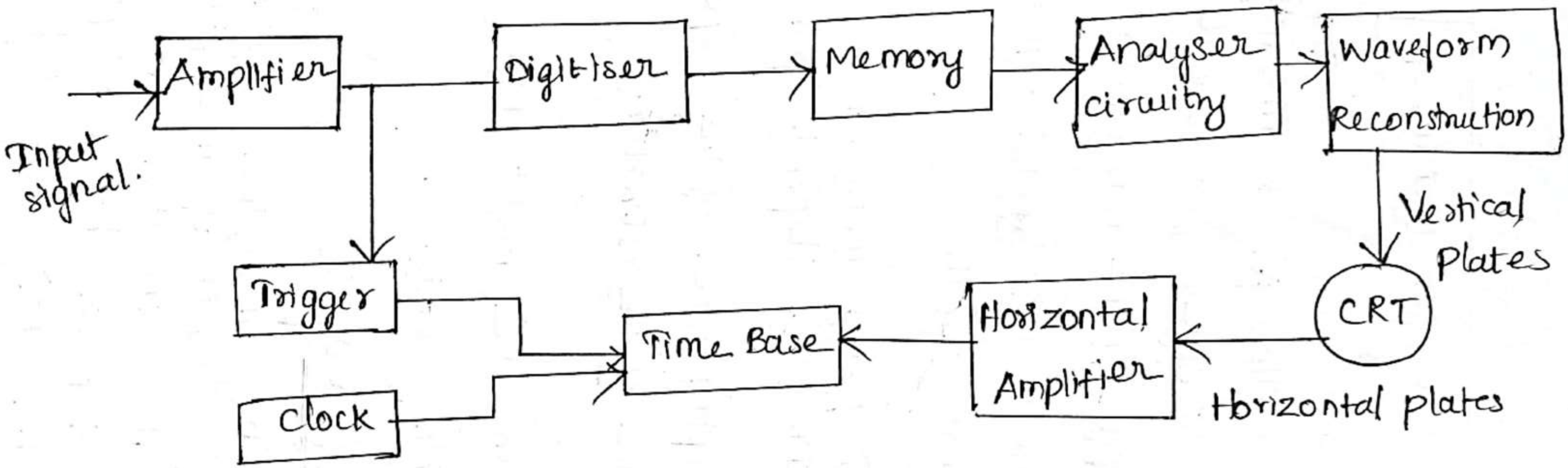
* The maximum frequency measured on the digital signal oscilloscope depends upon two things. They are: => sampling rate of the scope.
  => Nature of the converter.

* The traces in DSO are bright, highly defined and displayed within seconds.

Block diagram of DSO

The block diagram of the digital storage oscilloscope consists of an amplifier, digitizer, memory, analyzer circuitry, Waveform reconstruction, Vertical plates, horizontal plates, cathode Ray tube (CRT), horizontal amplifier, time base circuity, trigger and clock.

Block diagram of Digital storage Oscilloscope.



* Then the ramp signal is amplified by the horizontal amplifier, and this horizontal amplifier will provide input to the horizontal plate.

* On the CRT screen, we will get the waveform of the input signal versus time.

* The digitizing occurs by taking a sample of the input waveform at periodic intervals.

* At the periodic time interval means, when half of the time cycle is completed then we are taking the samples of the signal.

* The process of digitizing or sampling should follow the sampling theorem.

* The sampling theorem, says that the rate at which the samples are taken should be greater than twice the highest frequency present in the input signal.

* When the analog signal is properly converted into digital then the resolution of the A/D converter will be decreased.

* As seen in the diagram, at first digital storage oscilloscope digitizes the analog input signal, then the analog input signal is amplified by amplifier if it has any weak signal.

* After amplification, the signal is digitized by the digitizer and that digitized signal stores in memory.

* The analyzer circuit process the digital signal after that the waveform is reconstructed & then that signal is applied to vertical plates of cathode Ray tube (CRT)

* The cathode Ray tube has two inputs they are vertical input and horizontal input.

* The vertical input signal is the 'y' axis and the horizontal input signal is the 'x' axis.

* The time base circuit is triggered by the trigger and clock input signal, so it is going to generate the time base signal which is a ramp signal.

* when the input signals stored in analog store registers can be read out at a much slower rate by the A/D converter, then the digital output of the A/D converter stored in the digital store and it allows operation up to 100 Mega samples per second.

* This is the working principle of digital storage Oscilloscope.

Data Acquisition

* The system used for data processing, data conversion, data transmission, data storage is called Data acquisition system.
* The typical data acquisition system consists of sensors with necessary signal conditioning, data conversion, data Processing, data handing & transmission, storage and display systems.

Objectives of Data Acquisition

* Must acquire the necessary data at correct speed and at the correct time.
* It must monitor the operation of complete Plant so that Optimum online safe operations are maintained.
* It must be able to collect, summarise and store data Properly for diagnosis and record purpose of any operation.
* It must be flexible. Also the expansion facility for the future requirement must be Provided by its.
* It must provide effective human communication system which helps in Identifying the Problem areas.

* The data acquisition systems are basically used to measure.