SIMATS

School of Engineering

Basic Electrical and Electronics Engineering

Electrical and Electronics Engineering

Saveetha Institute of Medical And Technical Sciences,Chennai.

SAVEETHA SCHOOL OF ENGINEERING
DEPARTMENT OF EEE
CONCEPT MAP TOPICS

Engineer to Excel

EEA01 Basic Electrical and Electronics Engineering

EEA01 – ELECTRICAL CIRCUIT – INTRODUCTION

Basic Terminologies:

* **Charge (Q):** Basic Quantity of Electric circuit
  → +ve or −ve charge
  → unit columns

* **Current (I):** flow of Electrons
  → unit : Amperes

$$\boxed{I = \frac{dq}{dt} = \frac{Q}{t}}$$

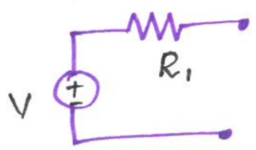
* **Voltage (V)** = Potential difference between 2 points
  → unit : volts

$$\boxed{V = \frac{\text{Workdone}}{\text{charge}} = \frac{W}{Q}}$$

* **Power (P):** V × I

or $P = \frac{\text{Energy}}{\text{Time}} = \frac{W}{t}$

* **Network** : Interconnection of 2 or more Elements



* **Circuit** : Contains atleast one closed path

* **Node** : Meeting point of 2 or more branches.
* **Loop | Mesh** : Any closed path of branches

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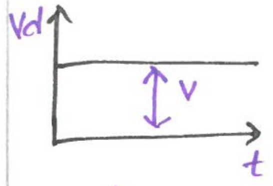
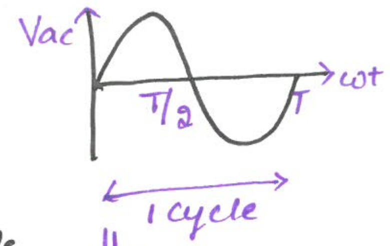
* **DC current**



⇓
Has only magnitude

AC current



⇓
Has magnitude and frequency.

Types of Electric Circuits:

→ closed circuit
→ open circuit → $I = 0$
→ Short circuit → $V = 0$
→ Earth circuit

Classification of Electrical Network

(i) Active elements : Sources of Energy
&
Passive Elements : R, L, C

(ii) Unilateral Elements : V, I relation is, 'I' not same for both direction of
&
Bilateral Elements : V, I relation is same.

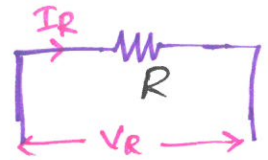
(iii) Linear Elements : obeys superposition Principle & Homogenity.
&
Non-linear Elements : Doesn't obey

(iv) Lumped elements : physically Seperable . Ex: R, L, C.
&
Distributed Elements : Not, physically Seperable elements .

Ex: Tr. line has distributed R, L, C.

Element	V & I Equation	Phasor Relation

① Resistance : opposes the 'I' flow



Unit = ohms (Ω)
Symbol = R

$V_R = I_R\, R$ (ohm's law)

$I_R = \frac{V_R}{R}$

$V_R = V \angle 0°$

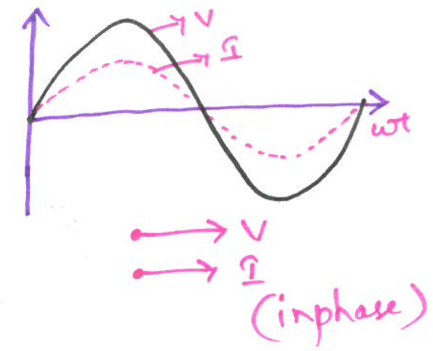
$I_R = I \angle 0°$

$\phi = 0°$

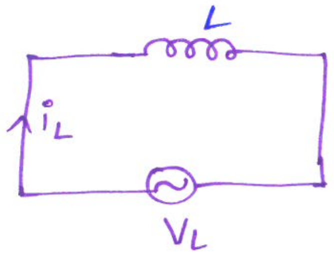
$$\boxed{Z = R + j0}$$

⇐

* Will not introduce any phase shift.



② Inductance : Stores the Energy in Electromagnetic field.



Unit : Henry (H)
Symbol : L

$V = L\frac{di}{dt}$

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

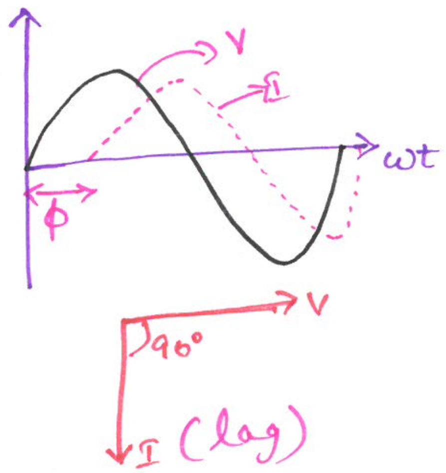
$V_L = V \angle 0°$

$I_L = I \angle -90°$

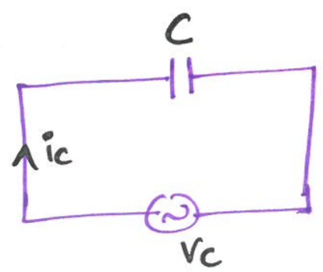
$Z = R + j\omega L$
$= R + jX_L$

$$\boxed{Z = 0 + jX_L}$$

* Introduce 90° phase Shift b/w V & I
* 'I' lags 'V' by 90°



③ Capacitance : stores the energy in Electro-Static field.



Unit : Farad (F)
Symbol : C

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

$i = C\frac{dv}{dt}$

$V_C = V \angle 0°$

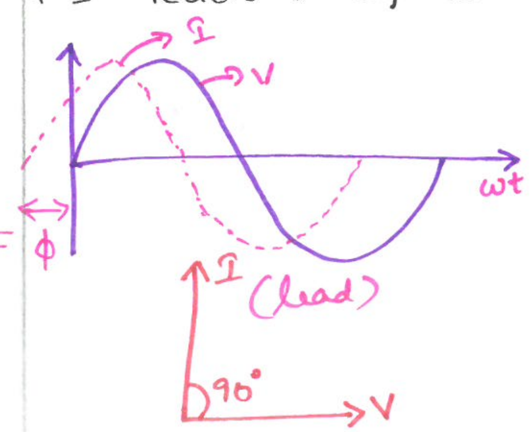
$I_C = I \angle 90°$

$Z = R - jX_C$

$$\boxed{Z = 0 - j\omega L}$$

⇐

* Introduce 90° phase Shift b/w V & I.
* 'I' leads 'V' by 90°.



I OHM'S law:

→ States relation b/w V, I & R

$V \propto I \Rightarrow \boxed{V = IR}$

Where,

$R = \frac{\rho l}{A} \Omega$

ρ = Resistivity

l = length

A = Area of x-section

Power Dissipation in Resistor:

$P = VI = I^2R = \frac{V^2}{R}$

and $R = \frac{V}{I} = \frac{V^2}{P} = \frac{P}{I^2}$

$I = \frac{V}{R} = \frac{P}{IR} = \sqrt{\frac{P}{R}}$

$V = IR = P/I = \sqrt{PR}$

Limitations:

* Can't be applied to non-linear devices
* Non- metallic conductors etc.

II KIRCHOFF'S LAWS:

→ Solving circuits which cannot be solved by ohm's law.

→ Kirchoff's current law

→ Kirchoff's voltage law

(a) Kirchoff's current law (KCL)

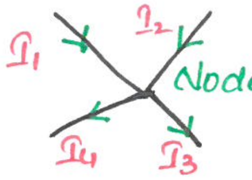
→ also called point law.

→ Algebraic sum of currents is zero.

→ Incoming current = Outgoing currents.

Illustration:

$\boxed{\Sigma I = 0}$



$I_1 + I_2 - I_3 - I_4 = 0$

(or) $I_1 + I_2 = I_3 + I_4$

(b) Kirchoff's voltage law (KVL)

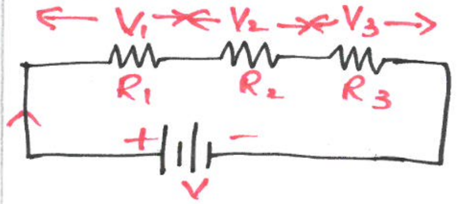
→ In any closed path/loop/mesh.

→ Algebraic sum of Voltages are Equal to zero.

→ Potential rise = Potential drop.

Illustration

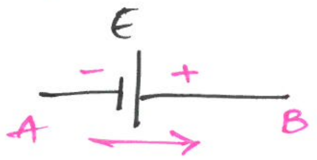
$\boxed{\Sigma V = 0}$



$V = V - V_1 - V_2 - V_3 = 0$

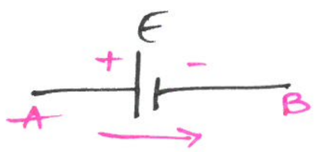
(or) $V = V_1 + V_2 + V_3$

Sign convention for Voltage:



Rise in Voltage

$(+E)$



Fall in voltage

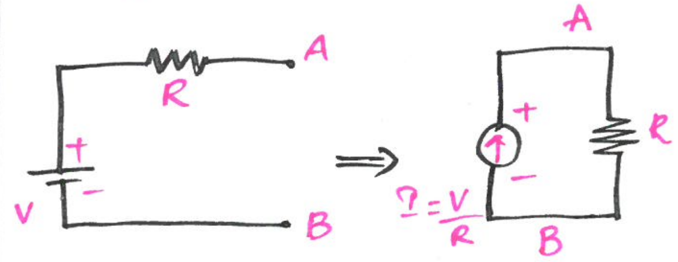
$(-E)$

III ELECTRICAL Energy Sources

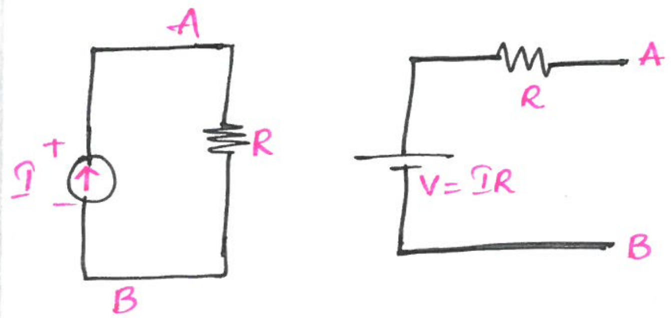
- Voltage Source
  - Independent Source
  - dependent Source
- Current Source
  - Independent Source
  - dependent Source

Source Transformation:

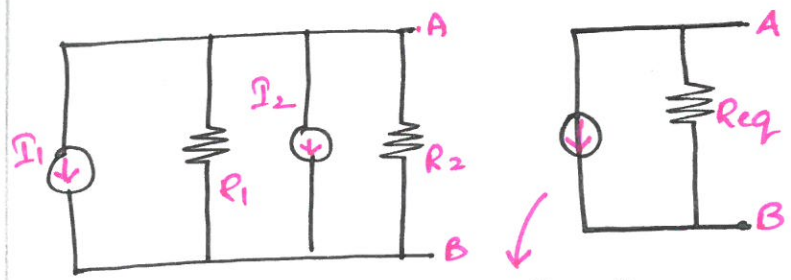
Voltage into current source



Current into voltage Source:



Current Sources in parallel:



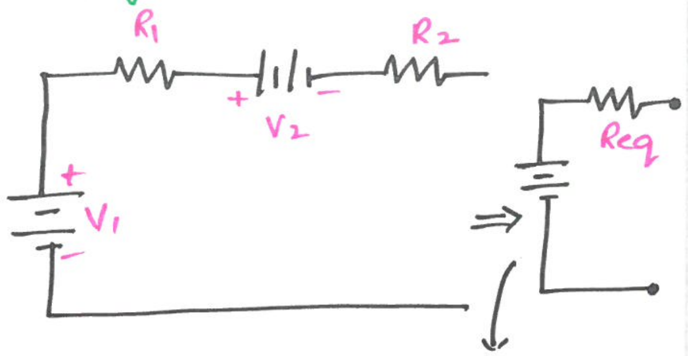
$I = I_1 + I_2$

$I = I_1 \sim I_2$

$Req = \frac{R_1 R_2}{R_1 + R_2}$

* If 'I_1' & 'I_2' are in opposite direction.

Voltage source in Series



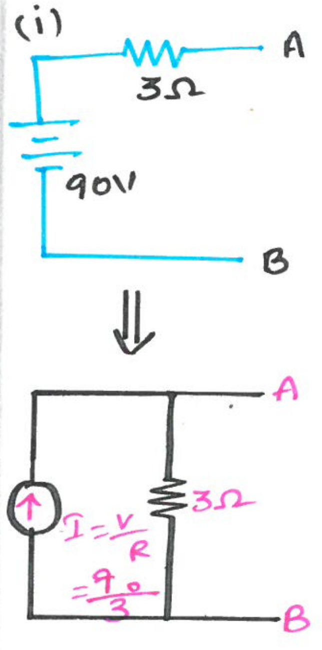
$V = V_1 - V_2$

$Req = R_1 + R_2$

Illustration:

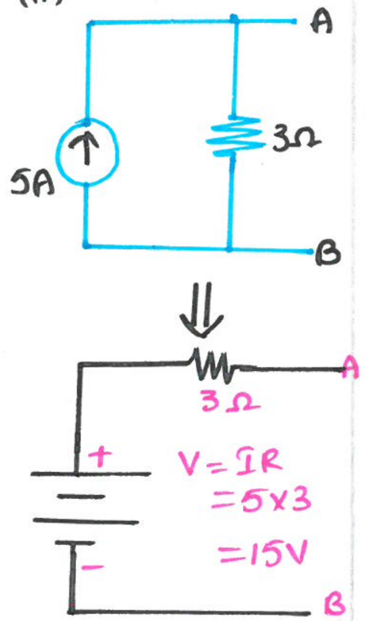
(1) Convert into equivalent Source.

(i)



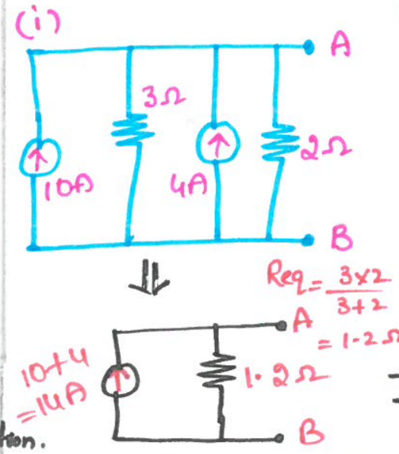
$= 30A$

(ii)

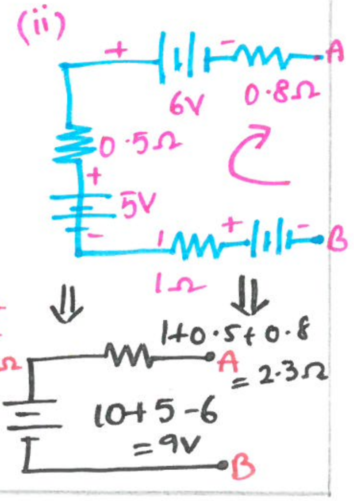


(2) Obtain single source b/w A & B.

(i)



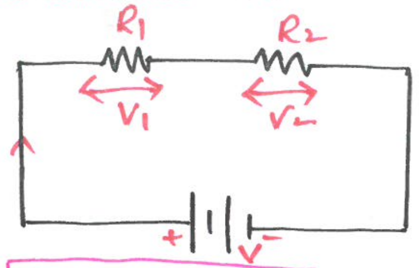
(ii)



I NETWORK REDUCTION:

→ Combination of Resistors

(i) Resistance in Series:



$\boxed{R_{eq} = R_1 + R_2}$ —— ①

Voltage Division Rule:

→ In series circuit,

I : same

V = Different.

→ acts as voltage divider.

$$I = \frac{V}{R_1+R_2} = \frac{V}{R_{eq}}.$$

$$V_1 = IR_1 = \frac{V \cdot R_1}{R_1+R_2} \rightarrow ②$$

$$V_2 = IR_2 = \frac{V \cdot R_2}{R_1+R_2} \rightarrow ③$$

In general,

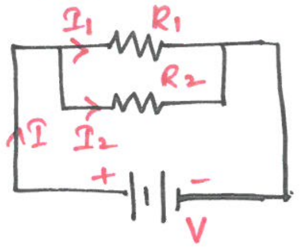
V. D across interested branch $\left\{ = \frac{\text{Branch resistance}}{\text{Total resistance}} \times \right.$ applied Voltage

* If $R_1 = R_2 = R$ (say)

$\boxed{R_{eq} = nR} \rightarrow ④$

where, n: no. of resistors in series

(ii) Resistance in parallel:



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{eq}} = \frac{R_2 + R_1}{R_1 R_2}$$

⑤ ← $\boxed{R_{eq} = \frac{R_1 R_2}{R_1+R_2}}$

Current Division Rule:

→ In parallel circuit,

V : Same

I : different

→ acts as current divider

$$I = I_1 + I_2 \longrightarrow ⑥$$

$$I_1 R_1 = I_2 R_2$$

$$I_2 = \frac{I_1 R_1}{R_2} \longrightarrow ⑦$$

Sub ⑦ in ⑥,

$$I = I_1 + I_1 \frac{R_1}{R_2}$$

$$= I_1 (1 + R_1/R_2)$$

$$\therefore \boxed{I_1 = \frac{IR_2}{R_1+R_2} \text{ and } I_2 = \frac{IR_1}{R_1+R_2}} \rightarrow ⑧$$

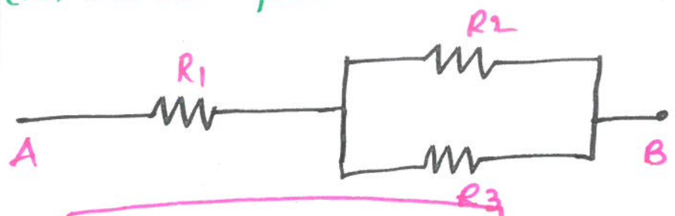
In general,

current thro' interested branch $\left\} = \frac{\text{opp. branch resistance}}{\text{Total resistance}} \times \right.$ Total current

*If $R_1 = R_2 = R$ (say)

$\boxed{R_{eq} = \frac{R}{n}} \rightarrow ⑨$

(iii) Series-parallel circuit:

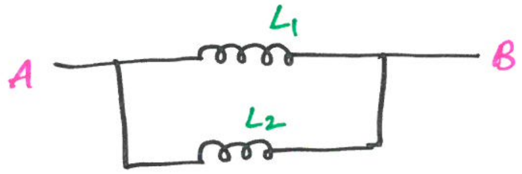


$$\boxed{R_{eq} = R_1 + \frac{R_2 R_3}{R_2+R_3}}$$

II. Inductance in Series:

$\boxed{L_{eq} = L_1 + L_2}$

Inductance in parallel

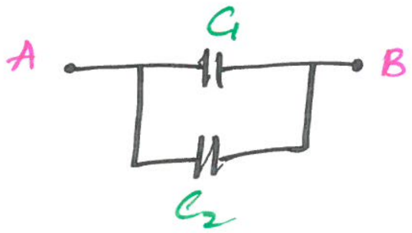


$$\boxed{L_{eq} = \frac{L_1 L_2}{L_1+L_2}}$$

III. Capacitance in Series:

$$\boxed{C_{eq} = \frac{C_1 C_2}{C_1+C_2}}$$

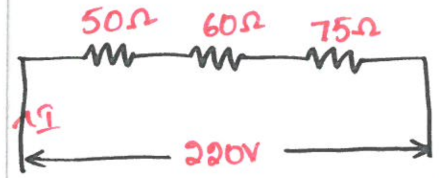
Capacitance in parallel:



$\boxed{C_{eq} = C_1 + C_2}$

Illustrations:

① 3 resistors 50Ω, 60Ω, 75Ω are connected in series across 220V mains. calculate total resistance current flowing through circuit

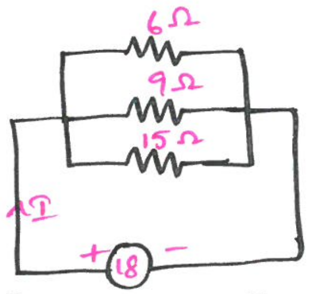


$R_T = R_1 + R_2 + R_3$

$= 185\Omega$

$I = V/R = \frac{220}{185} = 1.19A$

② 3 resistors of 6Ω, 9Ω, & 15Ω are connected in parallel to a 18V supply. calculate current in each branch, supply current, total resistance of network.



(a) $I_{6\Omega} = \frac{18}{6} = 3A$

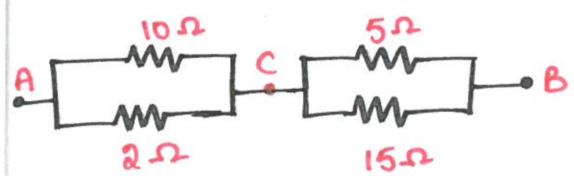
$I_{9\Omega} = \frac{18}{9} = 2A$

$I_{15\Omega} = \frac{18}{15} = 1.2A$

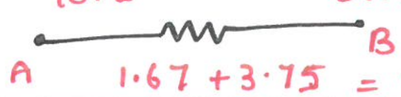
b) $I = I_{6\Omega} + I_{9\Omega} + I_{15\Omega} = 6.2A.$

c) $R = V/I = 18/6.2 = 2.9\Omega.$

③ Determine equivalent resistance between A & B



$\frac{10 \times 2}{10+2} = 1.67\Omega$ $\frac{5 \times 15}{5+15} = 3.75\Omega$



$1.67 + 3.75 = 5.42\Omega$

Problems on Kirchoff's law:

I. Mesh or Loop Analysis:

- DC circuits (only R)
- AC circuits (R, L, C)

II Nodal Analysis

- DC circuits (only R)
- AC circuits (R, L, C)

I Steps for mesh current Analysis:

⇓

o/p = I

∴ i/p = V

(i) Convert all current sources into it's Equivalent voltage source.

(ii) Identify no. of independent loop.

(iii) Assume current for each loop.

(iv) Write KVL equation in each loop.

(v) Represent in matrix form.

(vi) Solve the loop for mesh current.

II Steps for Nodal Voltage Analysis:

⇓

o/p : V

I/p : I

(i) Convert voltage source into its Equivalent current source.

(ii) Identify No. of nodes.

(iii) Assume voltage for each node

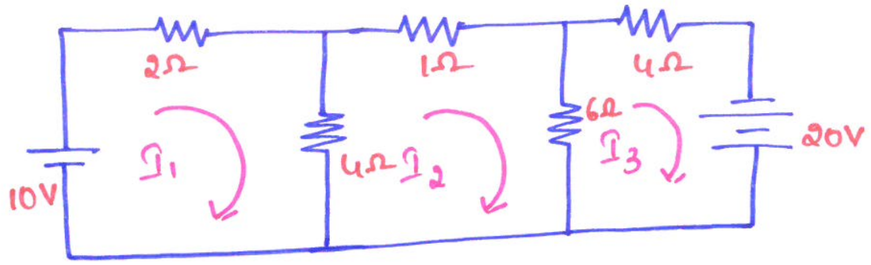
(iv) Write KCL eq. on each node.

(v) Represent matrix form.

(vi) Solve for node voltages

Illustration: (Mesh Analysis)

① Calculate current thro 6Ω resistor by KVL.



KVL at loop 1:

$$10 = 2I_1 + 4(I_1 - I_2) = 6I_1 - 4I_2 \rightarrow ①$$

KVL at loop 2

$$0 = I_2(1) + 4(I_2 - I_1) + 6(I_2 - I_3)$$

$$0 = 11I_2 - 4I_1 - 6I_3 \rightarrow ②$$

KVL at loop 3

$$20 = 6(I_3 - I_2) + 4I_3$$

$$20 = 10I_3 - 6I_2 \rightarrow ③$$

$$[R]_{3\times3}\,[I]_{3\times1} = [V]_{3\times1}$$

$$\begin{bmatrix} 6 & -4 & 0 \\ -4 & 11 & -6 \\ 0 & -6 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 20 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 6 & -4 & 0 \\ -4 & 11 & -6 \\ 0 & -6 & 10 \end{vmatrix} = 6(110-36) + 4(-40-0) = 284$$

$$\Delta_1 = \begin{vmatrix} 10 & -4 & 0 \\ 0 & 11 & -6 \\ 20 & -6 & 10 \end{vmatrix} = 10(110-36) + 4(0+120) = 1220$$

$$\Delta_2 = \begin{vmatrix} 6 & 10 & 0 \\ -4 & 0 & -6 \\ 0 & 20 & 10 \end{vmatrix} = 6(0+120) - 10(-40) = 1120$$

$$\Delta_3 = \begin{vmatrix} 6 & -4 & 10 \\ -4 & 11 & 0 \\ 0 & -6 & 20 \end{vmatrix} = 6(220-0) + 4(-80) + 10(24-0) = 1240$$

$$I_1 = \frac{\Delta_1}{\Delta} = 4.295\,A$$

$$I_2 = \frac{\Delta_2}{\Delta} = 3.94\,A$$

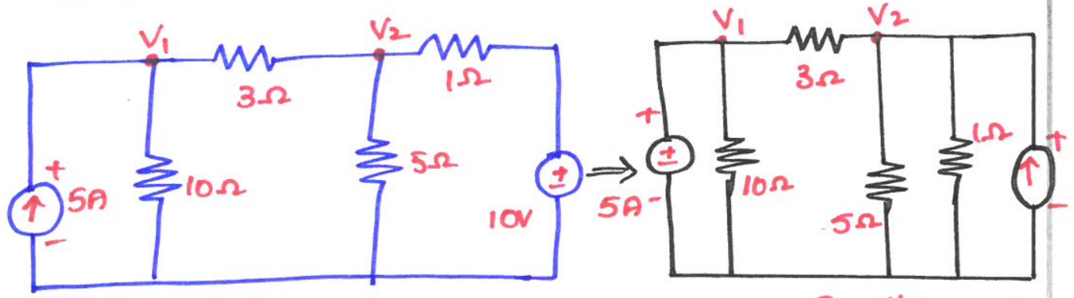
$$I_3 = \frac{\Delta_3}{\Delta} = 4.366\,A.$$

$$\therefore I_{6\Omega} = I_3 - I_2$$

$$\boxed{I_{6\Omega} = 0.42A}$$

② Nodal Analysis:

Apply KCL, find V_1 & V_2 the fig below:



$I = V/R = 10/1$

$I = 10A$

KCL at node 1:

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

$$3V_1 + 10V_1 - 10V_2 = 150 \implies 13V_1 - 10V_2 = 150 \rightarrow ①$$

KCL at node 2:

$$0 = \frac{V_2 - V_1}{3} + \frac{V_2}{5} + \frac{V_2 - 10}{1}$$

$$0 = 3V_2 + 5V_2 - 5V_1 + 15V_2 - 150 \rightarrow ②$$

$$23V_2 - 5V_1 = 150 \rightarrow$$

By solving ① & ② ⟹ $\boxed{V_1 = 19.86V,\ V_2 = 10.83V}$

(or)

$$\left[\frac{1}{R}\right][V] = [I]$$

$$\begin{bmatrix} \left(\frac{1}{10} + \frac{1}{3}\right) & \frac{1}{3} \\ \frac{1}{3} & \left(\frac{1}{1} + \frac{1}{3} + \frac{1}{5}\right) \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 10 \end{bmatrix}$$

$I_1 = \frac{\Delta_1}{\Delta}$

$I_2 = \frac{\Delta_2}{\Delta}$

find Δ, Δ_1 and Δ_2 then.

MESH & NODAL ANALYSIS FOR AC CIRCUITS:-

complex Numbers can be represented in

Polar form

* (mag $\angle$angle)
* For '×' & '÷'

Rectangular form

* (Real + j imaginary)
* For '+' & '−'

(i) Rectangular to polar form:

Rect. form : $z = (10+j15)$

$|z| = \sqrt{10^2+15^2} = 18.03$

$\angle z = \tan^{-1}\left(\frac{15}{10}\right) = 56.31^\circ$

$\Rightarrow$ polar form : $18.03 \angle 56.31^\circ$

(ii) polar to Rectangular form:

polar form : $z = 10 \angle 60^\circ$

Real part $= 10\cos 60^\circ = 5$

Imag. part $= 10 \sin 60^\circ = 8.66$

$\Rightarrow$ Rectangular form: $5+j8.66$

Illustration

(1) $z_1 = 10+j10\,\Omega$ & $z_2 = 20-j30\,\Omega$

$z_1+z_2 = (10+20)+j10-j30$

$= (30-j20)\,\Omega$

$z_1-z_2 = (-10+j40)\,\Omega$

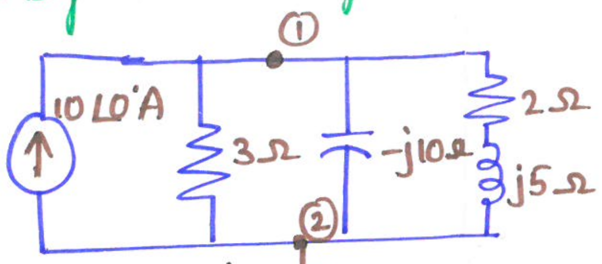
(2) $z_1 = 10\angle 60^\circ\,\Omega$, $z_2 = 20\angle 30^\circ\,\Omega$

$z_1 \times z_2 = 10\times 20 \angle 60^\circ+30^\circ = 200\angle 90^\circ$

$z_1/z_2 = \frac{10}{20}\angle 60^\circ - 30^\circ = 0.5\angle 30^\circ$

Determine the real power output of the source shown in fig. below by Nodal analysis and verify the result by using Mesh analysis.

(i) By Nodal Analysis:



* 2 nodes
* Nodes 2 taken as ref node.

KCL at node 1, $\frac{V_1}{3}+\frac{V_1}{-j10}+\frac{V_1}{2+j5} = 10\angle 0^\circ$

$\left(\frac{1}{3}+\frac{j}{10}+\frac{1}{2+j5}\right)V_1 = 10\angle 0^\circ$

$\left[\frac{1}{3}+\frac{j}{10}+\frac{2-j5}{2^2-(j5)^2}\right]V_1 = 10\angle 0^\circ$

$\left[\frac{1}{3}+\frac{j}{10}+\frac{2-j5}{29}\right]V_1 = 10\angle 0^\circ$

$(0.402-j0.072)V_1 = 10\angle 0^\circ$

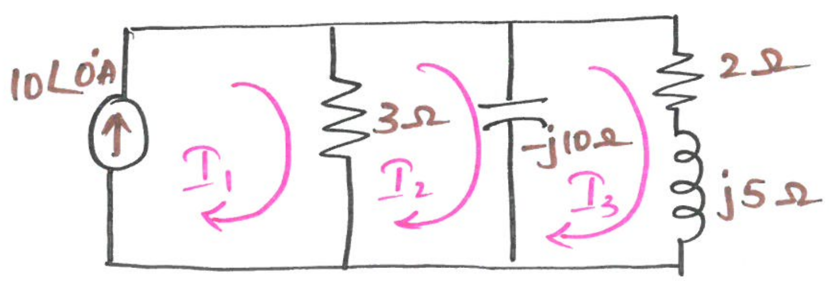
$(0.41\angle -10.2)V_1 = 10\angle 0^\circ$

$V_1 = \frac{10\angle 0^\circ}{0.41\angle -10.2^\circ} = 24.4\angle 10.2^\circ V$

$\therefore$ Real output of source $= V_1 I \cos(10.2)$

$= 24.4\times 10\times \cos 10.2 = 240\,W \rightarrow$ (A)

(ii) By Mesh current Analysis:



Here $\boxed{I_1 = 10\angle 0^\circ}$ in loop 1 — (1)

KVL at loop 2,

$+(I_2-I_3)(-j10)+(I_2-I_1)3 = 0$

$-j10 I_2 + j10 I_3 + 3I_2 - 3I_1 = 0$

$(3-j10)I_2 + j10 I_3 = 3I_1 = 3(10) = 30$ — (2)

KVL at loop 3,

$(2+j5)I_3 + (I_3-I_2)(-j10) = 0$

$2I_3 + j5I_3 - j10 I_3 + j10 I_2 = 0$

$j10 I_2 + (2-j5)I_3 = 0$

$\therefore I_3 = \frac{-j10 I_2}{(2-j5)}$ — (3)

Substitute (3) in (2)

$(3-j10)I_2 + j10\left(\frac{-j10 I_2}{(2-j5)}\right) = 30$

$\left[3-j10+\frac{100}{(2-j5)}\right]I_2 = 30$

$(3-j10+6.9+j17.24)I_2 = 30$

$12.27\angle 36^\circ I_2 = 30 \Rightarrow I_2 = \frac{30}{12.27\angle 36^\circ}$

$\Rightarrow \boxed{I_2 = 2.45\angle -36^\circ A}$

$\therefore I_{3\Omega} = I_1 - I_2 = 10 - 2.45\angle -36^\circ = 10-(1.98-j1.46)$

$= 8.02+j1.46 = 8.15\angle 10.3^\circ A$

$V_{3\Omega} = I_{3\Omega} \times R = 8.15\angle 10.3 \times 3$

$= 24.45\angle 10.3^\circ V$

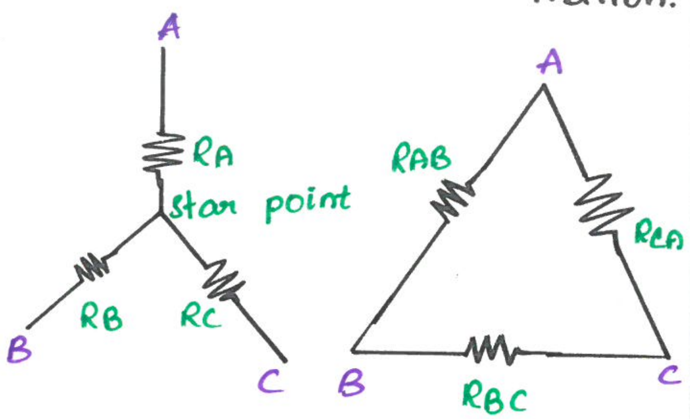
Power from the source $= 24.45\times 10 \cos 10.3^\circ$

$= 240.6$ watts — (B)

(A) = (B), Hence verified.

Star - Delta Transformation (Y) (Δ)

* Also called T and π transformation.



I Δ to Y transformation

Given : R_{AB}, R_{BC}, R_{CA}

To find : R_A, R_B, R_C

$$\Rightarrow R_A = \frac{R_{AB} R_{CA}}{\Sigma R_{AB}}$$

$$R_B = \frac{R_{AB} R_{BC}}{\Sigma R_{AB}}$$

$$R_C = \frac{R_{BC} R_{CA}}{\Sigma R_{AB}}$$

II Y to Δ transformation:

Given : R_A, R_B, R_C

To find : R_{AB}, R_{BC}, R_{CA}

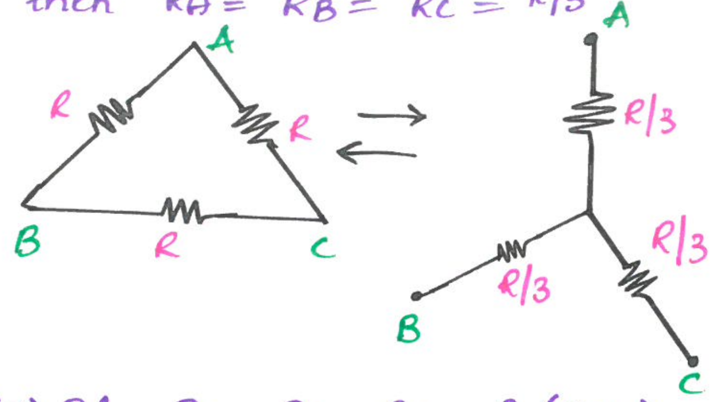
$$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$$

$$R_{BC} = R_B + R_C + \frac{R_B R_C}{R_A}$$

$$R_{CA} = R_C + R_A + \frac{R_C R_A}{R_B}$$

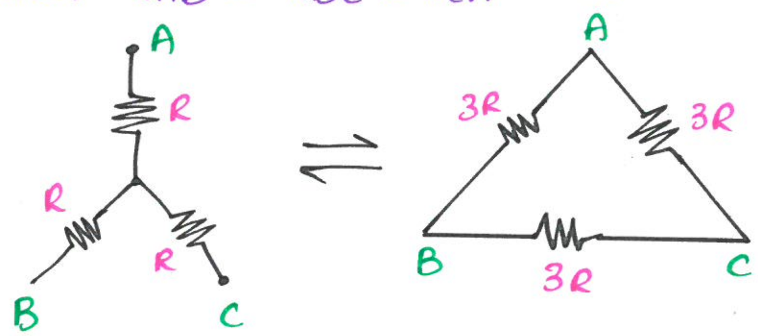
(i) If $R_{AB} = R_{BC} = R_{CA} = R$ (say)

then $R_A = R_B = R_C = R/3$



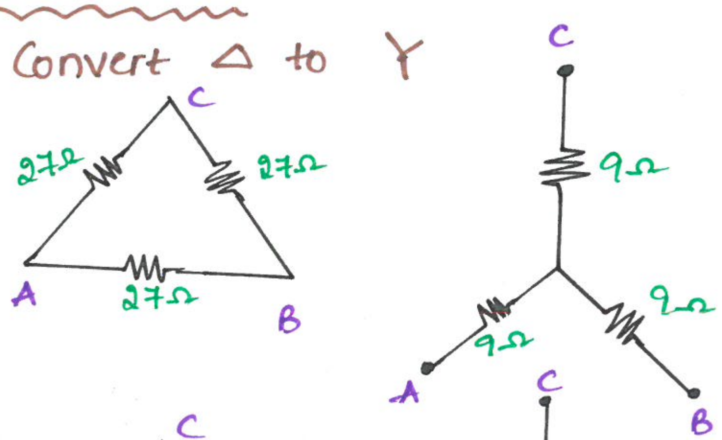
(ii) If $R_A = R_B = R_C = R$ (say)

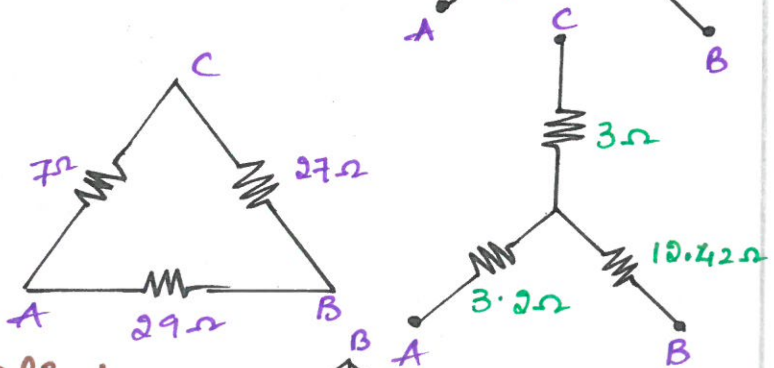
then $R_{AB} = R_{BC} = R_{CA} = 3R$



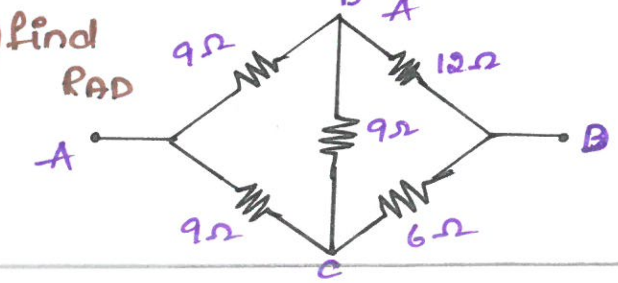
Illustrations:

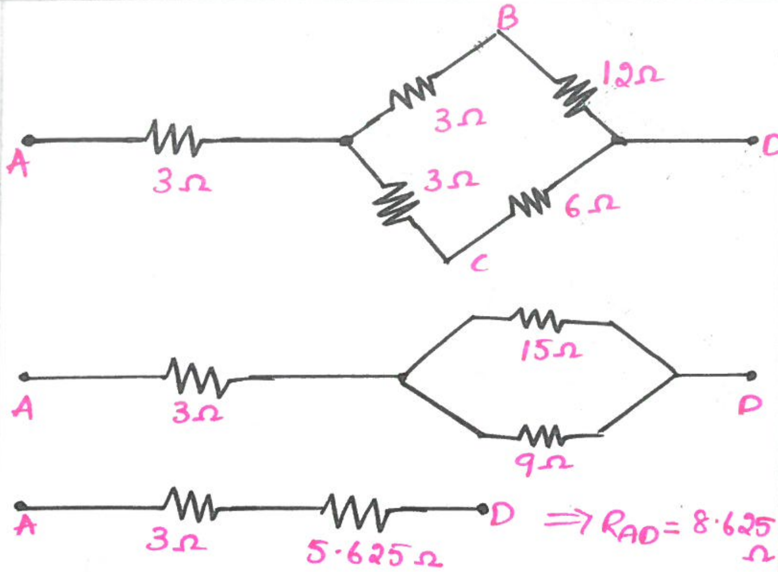
Convert Δ to Y



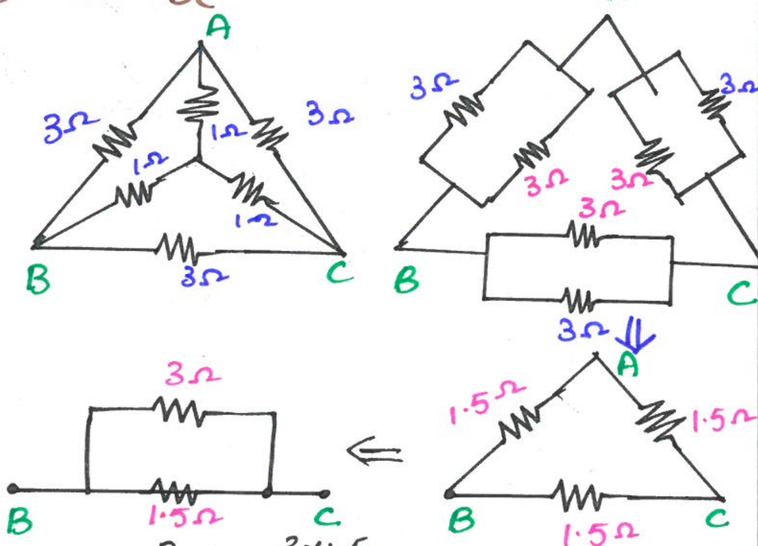


② find R_{AD}



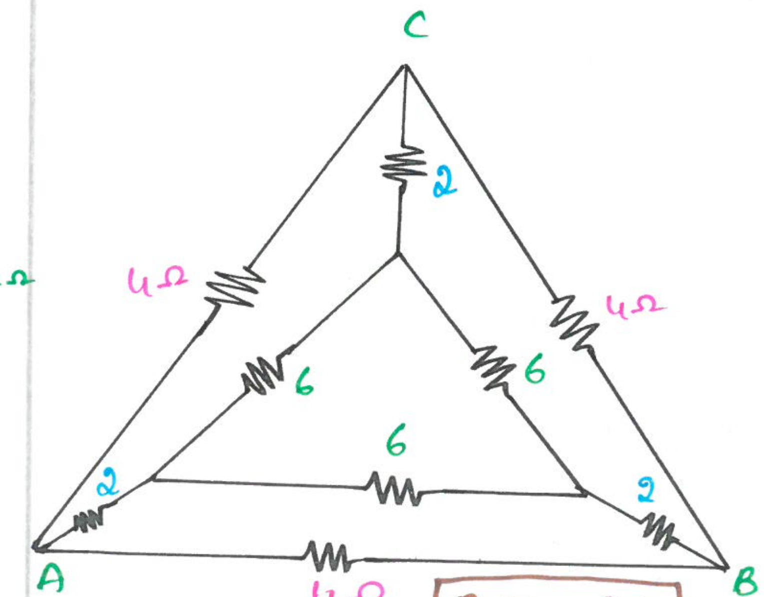


③ find R_{BC}



$$R_{BC} = \frac{3 \times 1.5}{3 + 1.5} = 1\Omega$$

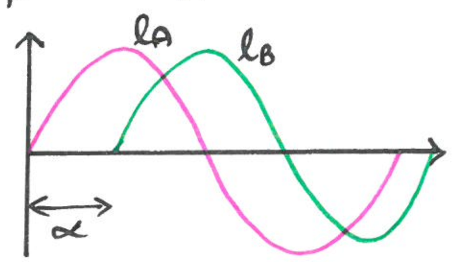
④ find R_{AB}



$\boxed{R_{AB} = 2\Omega}$

fundamentals of AC Circuits:

* AC quantity has magnitude & angle.
* Varying w.r.t to time.
* Represented in 3 ways
  - Effective value (Rms)
  - Average value.
  - Peak value.
* Amplitude : max. value of an ac quantity.
* cycle : Set of +ve and -ve halves.
* frequency : No. of cycles/sec. Hertz or c/s.
* Period : Time taken to complete one cycle $T = \frac{1}{f}$.
* Peak Value : Max. possible Value.
* phase : Time that has elasped from Zero point of reference.
* phase difference : To compare phases of 2 waveforms.

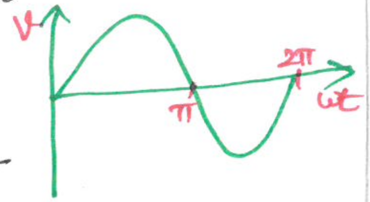


e_A : Starts & progress ahead leading

e_B : Starts & progress behind lagging.

I. RMS Value:

* Root Mean Square Value
* $V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} V^2\,dt}$



$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I^2\,dt}$

* $RMS = \sqrt{\frac{\text{Area Under Squared Wave}}{\text{Period}}}$

For Sinewave, $V_{rms} = \frac{V_m}{\sqrt{2}}$

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

II. Average Value:

* $V_{ave} = \frac{\text{Area Under One Complete cycle}}{\text{Period}}$
* $V_{ave} = \frac{1}{T}\int_0^T v\,dt$ or $\frac{1}{2\pi}\int_0^{2\pi} v\,dt$

For instantaneous values,

* $I_{ave} = \frac{i_1 + i_2 + \dots + i_n}{n}$

For Sinewave, $V_{ave} = \frac{2V_m}{\pi}$

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

III. Form Factor (K_f):

$K_f = \frac{\text{RMS Value}}{\text{Ave. Value}} = 1.11$ for Sinewave

IV. Peak Value or factor (K_p):

$K_p = \frac{\text{Peak Value}}{\text{RMS Value}} = 1.414$ for sinewave

STEADY STATE ANALYSIS OF AC CIRCUITS

* AC Quantity: Magnitude & Phase
* Complex Operator: $\boxed{j = \sqrt{-1}}$

Properties of 'j':

$j = 90°$, CCW $= \sqrt{-1}$

$j^2 = 180°$, CCW $= -1$

$j^3 = 270°$, CCW $= -j$

$j^4 = 360°$, CCW $= 1$

$\frac{1}{j} = \frac{j}{j^2} = -j$

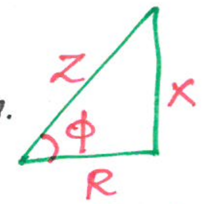
$\frac{1}{-j} = \frac{j}{-j^2} = j$.

Impedance (Z):

$Z = R + j(X_L - X_C)$ ohms.

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

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



Imp. triangle

Admittance (Y):

$Y = \frac{1}{Z}$ ℧ (mho)

Instantaneous Power:

$p(t) = v(t) \cdot i(t)$

Average Power (P):

* Called Real or Active Power
* Unit is watts or KW

$\boxed{P = VI\cos\phi = V_{rms} I_{rms}\cos\phi}$

Reactive Power (Q):

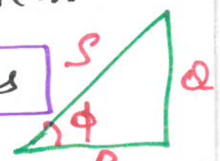
* Called Useless Power
* Unit is VAR or KVAR

$\boxed{Q = VI\sin\phi = V_{rms} I_{rms}\sin\phi}$

Apparent Power (S):

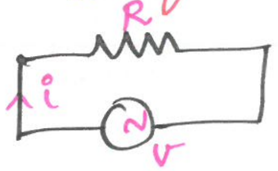
* Unit is VA or KVA

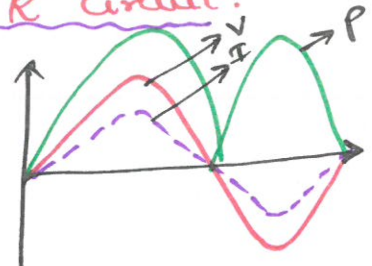
$\boxed{S = VI = V_{rms} I_{rms}}$



Power triangle

I. Analysis of 'R' circuit.

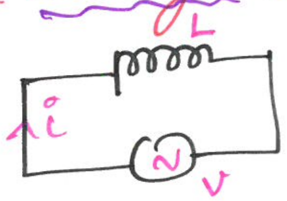


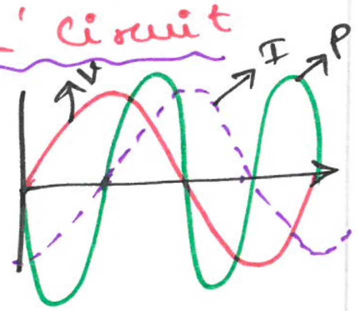


* $v = V_m \sin\omega t$
* $i = I_m \sin\omega t$; $I_m = \frac{V}{R}$
* $\phi = 0$; $\cos\phi = pf = \frac{R}{Z} = 1$.
* $Z = R$

* $P_{ave} = \frac{V_m I_m}{2}$

II. Analysis of 'L' Circuit



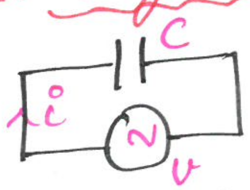


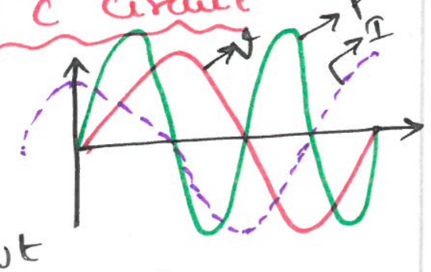
* $v = V_m \sin\omega t$
* $i = I_m \sin(\omega t - 90°)$; $I_m = \frac{V}{X_L}$
* $\phi = 90°$, 'I' lag 'v' by 90°

$\cos\phi = 0°$.

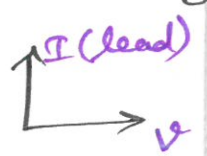
* $Z = j\omega L = jX_L$
* $P_{ave} = 0$.

III. Analysis of 'C' circuit



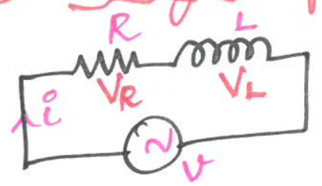


* $v = V_m \sin\omega t$
* $i = I_m \sin(\omega t + 90°)$
* 'I' leads 'v' by 90°, $\phi = 90°$, $\cos\phi = 0$
* $Z = -jX_C$



* $P_{ave} = 0$

IV. Analysis of RL Series Circuit



* $\bar{V} = \bar{V}_R + \bar{V}_L$

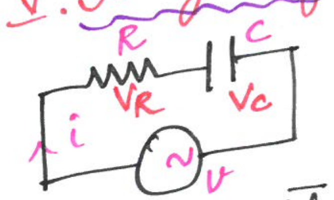
$= I(R + X_L)$

* $Z = R + jX_L = \sqrt{R^2 + X_L^2}\,.\tan^{-1}\left(\frac{\omega L}{R}\right)$

$= |Z| \angle\phi$

* $|V| = \sqrt{V_R^2 + V_L^2}$
* $I = \frac{V}{Z}$
* $\phi = \tan^{-1}\frac{\omega L}{R} \Rightarrow \cos\phi = \frac{R}{Z}$.

V. Analysis of RC Series Circuit



* $V_R = IR$

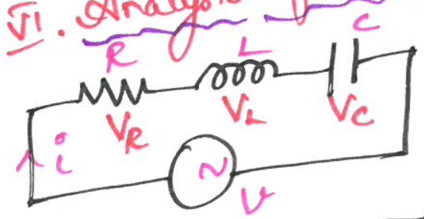
$V_C = IX_C$

* $\bar{V} = \bar{V}_R + \bar{V}_C = I(R - jX_C)$
* $Z = R - jX_C = \sqrt{R^2 + X_C^2}$

$\phi = \tan^{-1}\left(\frac{X_C}{R}\right)$

* $pf = \cos\phi = \left(\frac{R}{Z}\right)$
* $I = \frac{V}{Z}$

VI. Analysis of RLC Series Circuit



* $V_R = IR$

$V_L = IX_L$

$V_C = IX_C$

* $\bar{V} = \bar{V}_R + \bar{V}_L + \bar{V}_C$

$= I\,[R + j(X_L - X_C)]$

* $Z = R + j(X_L - X_C)$

$= \sqrt{R^2 + (X_L - X_C)^2}\,.\tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

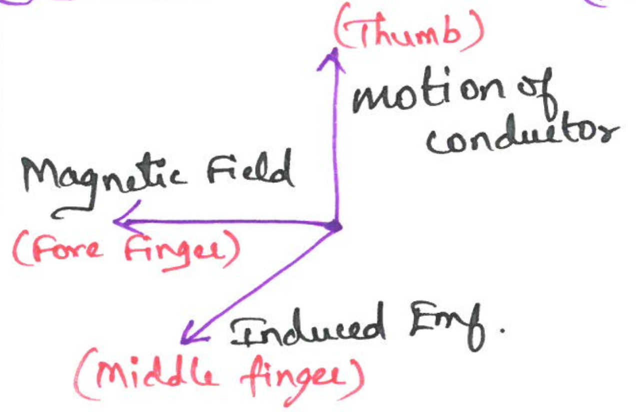
* $I = \frac{V}{Z}$; $pf = \cos\phi = \frac{R}{Z}$.
* $X_L < X_C$ Inductive ; $X_L > X_C$ Capacitive

Lenz's Law :

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

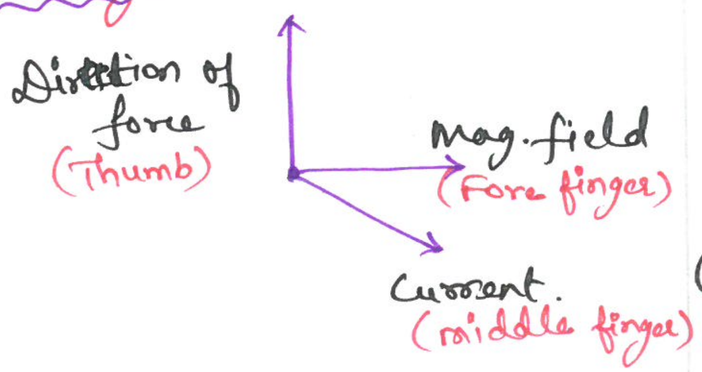
where, E : Induced emf
N : No. of turns in coil
$d\phi$: change in flux
dt : change in time

Fleming's Right Hand Rule : (FRH)



* Used to determine the direction of induced emf.
* Employed in DC Generators.

Fleming's Left Hand Rule :(RLH)



* Employed in DC motors
* To determine direction of force.

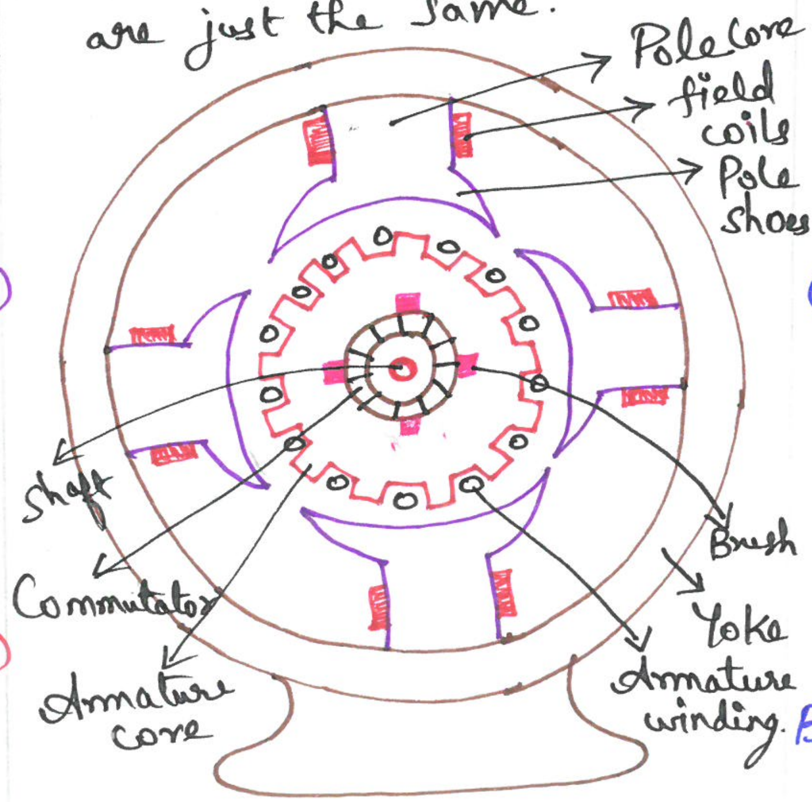
Faraday's law :

Whenever a conductor cuts the magnetic flux, dynamically induced emf is produced in the conductor.

DC Machines
- DC Generators
  * Mechanical to Electrical
  * Faraday's Law + FRH rule.
- DC Motors
  * Electrical to Mechanical
  * Faraday's law + FLH Rule

CONSTRUCTION OF DC MACHINE

* Construction of motor & Generators are just the same.



Yoke : – Provides mech. support
– Provide path for mag. flux
– Made of thin steel lamination to reduce loss

Pole Core :– Field windings are mounted on pole core.
– Made of thin steel laminations

Pole shoe – Provide Uniform distribution of mag. flux
– Made of thin steel laminations

Field Coils – Made of copper wire
– provides the mag. field

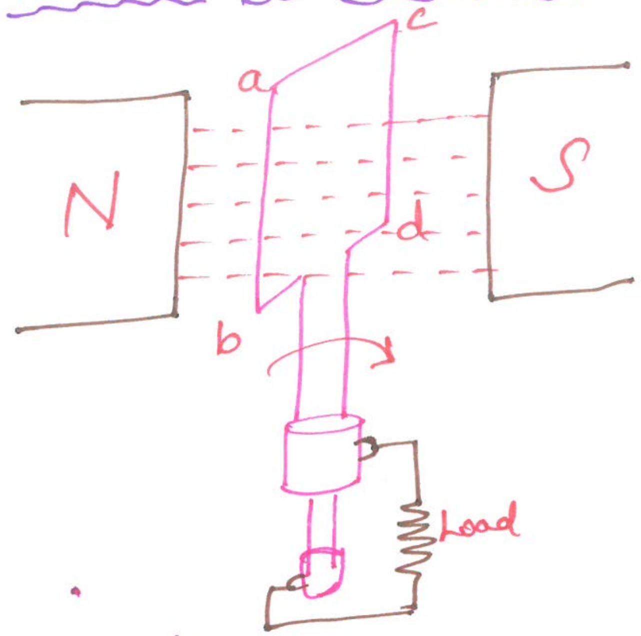
Arm. Core – Mounted on shaft
– windings are mounted in slots of arm. core
– cylindrical shape

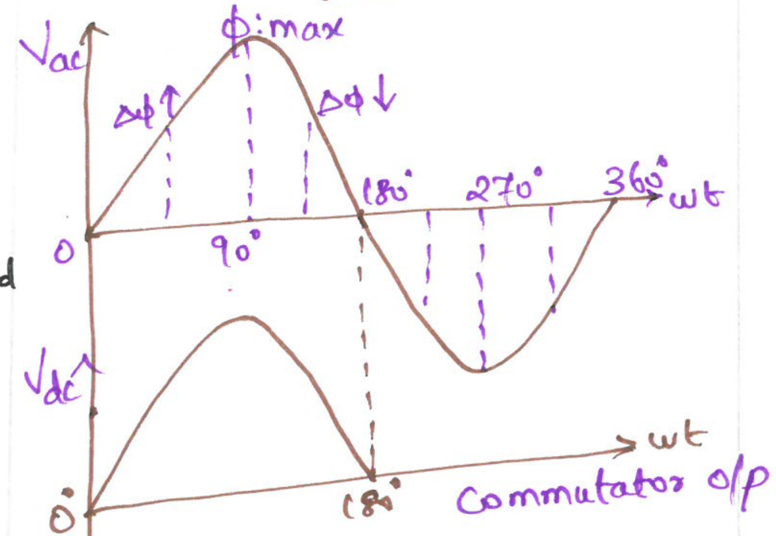
Arm. Coils – Provides emf when used as generator.
– Rotates the shaft.
– Provides torque when used as motor.
– Made of copper wire

Commutator – Mounted on shaft
– Converts AC to DC emf.
– Collects current from Arm.
– Provides unidirectional torque (For Motor)
– Provides unidirectional emf. (For Generator)

Brushes – Stationary & Press on Commutator
– Carry current towards/away from Commutator
– Made of Carbon or Copper.

PRINCIPLE OF OPERATION





* Principle : Faraday's law of Electromagnetic Induction.
* Emf. induced in arm coil is AC. Commutator Converts AC into DC.

Types of Armature winding :

(i) Lap winding : $\boxed{P = A}$
P : No. of poles
A : No. of Parallel paths

(ii) Wave winding : $\boxed{A = 2}$

EMF EQUATION OF DC GENERATOR

Let ϕ : flux/pole in wb.
P : No. of poles
A : No. of $\parallel^{el}$ paths
Z : No. of arm. conductors
N : Speed in rpm
E_g : Generated Emf in Volts

By Faraday's law,

$$\text{Ave. emf/cond.} = \frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)}$$

$$\left.\begin{array}{l}\text{Flux cut/cond. in}\\ \text{1 revolution}\end{array}\right\} = d\phi = \phi P$$

$$\text{No. of rev./sec} = N/60$$

$$\text{Time for 1 rev} = (60/N)$$

$$\therefore \text{Ave. emf generated/cond} = \frac{\phi P N}{60}$$

$$\Rightarrow \text{Total emf}, \boxed{E_g = \frac{\phi Z N}{60} \cdot \frac{P}{A}}$$

For Lap winding, P=A

$$\therefore E_g = \frac{\phi Z N}{60}$$

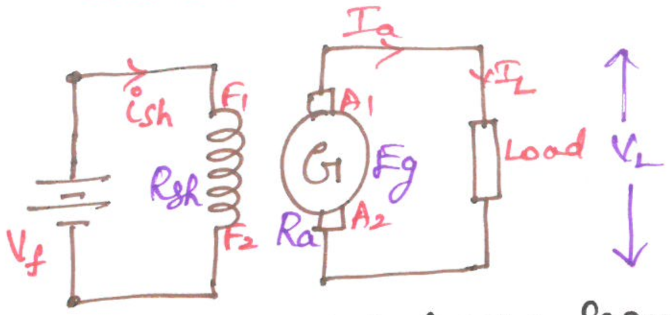
For Wave winding, A=2

$$\therefore E_g = \frac{\phi Z N P}{120}.$$

TYPES OF GENERATORS

- Separately Excited dc generator
- Self excited
  - Shunt gr
  - Series gr
  - Compound gr

① Separately Excited Dc Generator



* Field is excited from a separate DC source.

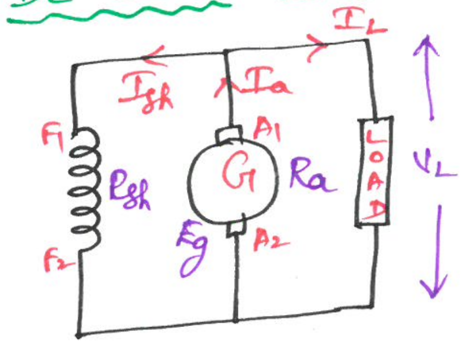
By KCL, $I_a = I_L$

By KVL, $E_g = V_L + I_aR_a + BCD$

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

② Self Excited DC Generator

DC shunt Generator



BCD : Brush Contact Drop

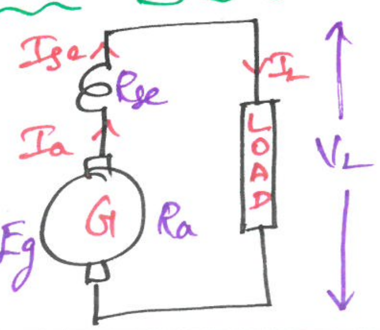
$$I_{sh} = \frac{V}{R_{sh}}$$

By KCL, $I_a = I_L + I_{sh}$

By KVL, $E_g = V_L + I_aR_a + BCD$

* R_{sh} : Has more no. of turns
  : Resistance is high

DC Series Generator



By KCL, $I_a = I_{se} = I_L$

By KVL, $E_g = V_L + I_aR_a + I_{se}R_{se} + BCD$
$= V_L + I_a(R_a + R_{se}) + BCD$

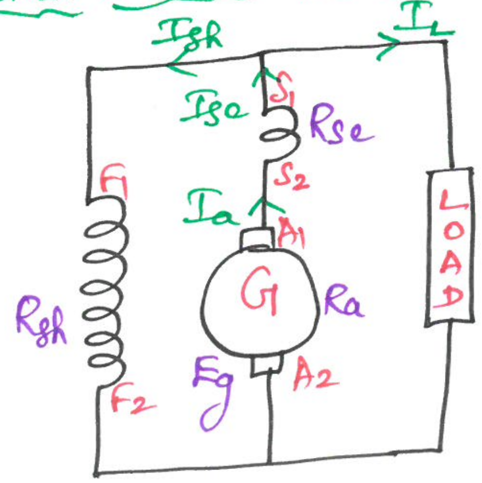
* R_{se} : Has less no. of turns
  : Resistance is less

DC Compound Generator

* Has both shunt and series field windings.

- Dc Compound gr
  - Long shunt Compound Generator
  - Short shunt compound Generator
    - Cumulative Compounded dc gr: $\phi_t = \phi_{se} + \phi_{sh}$
    - Differentially compounded DC gr: $\phi_t = \phi_{se} - \phi_{sh}$

LONG SHUNT COMPOUND GR



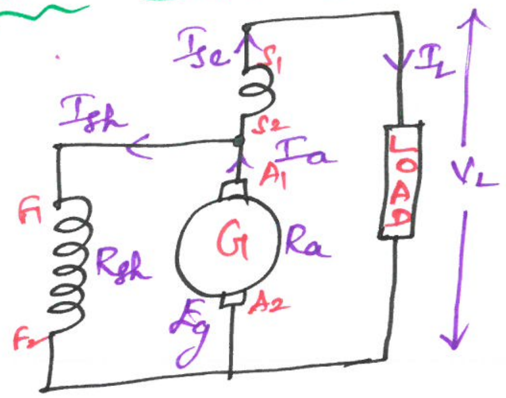
$$I_{sh} = \frac{V_L}{R_{sh}} = \frac{E_g + I_a(R_a + R_{se})}{R_{sh}}$$

By KCL, $I_a = I_{se}$
$I_a = I_{sh} + I_L$

By KVL, $E_g = V_L + I_aR_a + I_{se}R_{se} + BCD$

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

SHORT SHUNT COMP. GR



By KCL, $I_a = I_{se} + I_{sh}$
$I_{se} = I_L$

By KVL, $E_g = V_L + I_aR_a + I_{se}R_{se} + BCD$

$$I_{sh} = \frac{E_g - I_aR_a}{R_{sh}}$$

Applications of Generators:

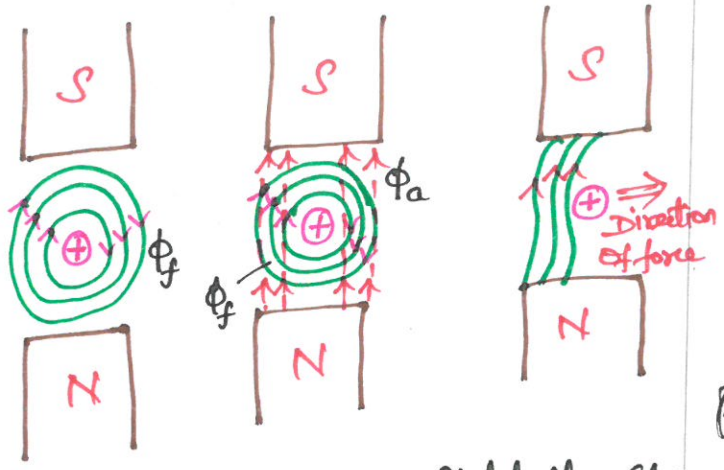
* Battery charging
* Used for electroplating & electrolysis } DC shunt gr.

* Series arc lighting
* used as Booster circuit
* Used for incandescent lighting in Series } Series gr.

* used for welding purpose
* for power supply to railways elevator etc. } Comp. gr.

PRINCIPLE OF OPERATION OF MOTOR

* Converts Elec. Energy into Mechanical Energy.
* Employs Faraday's law + FLH rule



* I_{field} produces field flux (ϕ_f)
* $I_{arm.}$ produces Armature flux (ϕ_a)
* ϕ_f and ϕ_a interacts with each other.
* LHS : Both flux aids
  RHS : Both flux opposes
* LHS flux produces twisting force called Torque.
* Motor starting Rotating.

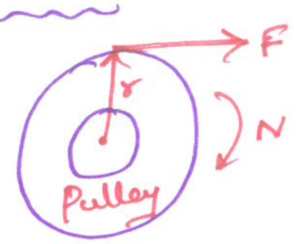
Significance of Back Emf (E_b):

* After every motoring, there is a generator action.
* Induces emf (E_b)
* E_b opposes applied voltage

$$E_b = \frac{\phi Z N}{60} \cdot \frac{P}{A}.$$

TORQUE EQUATION

Let
r : Radius
F: Circumferential force
N: speed



$\therefore$ Torque $= T = (F \times r)$ Nm.

Work done by the force/1 rev,
$= \text{Force} \times \text{distance}$
$= F \times 2\pi r$

Power developed $= F \times (2\pi r) \times N$
$= T \times 2\pi N$.

If 'N' is in rpm, $\omega = \frac{2\pi N}{60}$ rad/sec.

$$\Rightarrow P = \frac{2\pi N T}{60} \quad \text{—(1)}$$

Let Armature Torque $= T_a$

$$\therefore P = E_b \cdot I_a \quad \text{—(2)}$$

$$(1) = (2), \quad E_b I_a = \frac{2\pi N T}{60}$$

$$\boxed{T_a = \frac{1}{2\pi} \cdot \phi I_a \cdot \frac{PZ}{A}} \text{ Nm.}$$

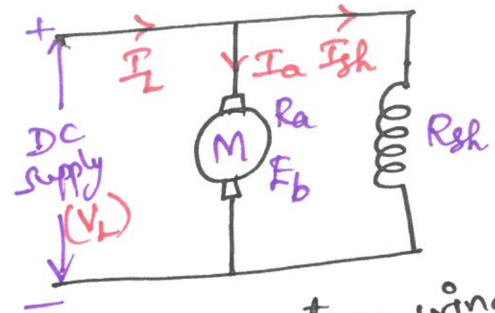
or

$$\boxed{T_a = 0.159\, \phi I_a \frac{ZP}{A}} \text{ Nm}$$

Types of DC motor:

(1) Shunt motor
(2) Series motor
(3) Compound motor → Long shunt
→ Short shunt

(1) DC Shunt motor:



* field & armature windings are in Parallel
* Called as Constant Speed motor.

By KCL, $I_L = I_a + I_{sh}$

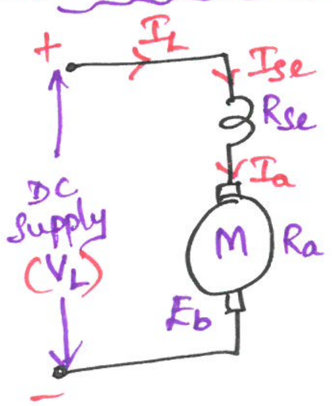
By KVL, $V_L = E_b + I_a R_a + BCD$

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

and $I_{sh} = \frac{V_L}{R_{sh}}$.

Applications:
Lathes, Centrifugal pumps, fans, Blowers, Reciprocating pumps etc.

(2) DC Series Motor:



V_L : Line voltage
I_L : Line Current

* field & armature are in Series
* Variable Speed motor.

By KCL, $I_L = I_{se} = I_a$

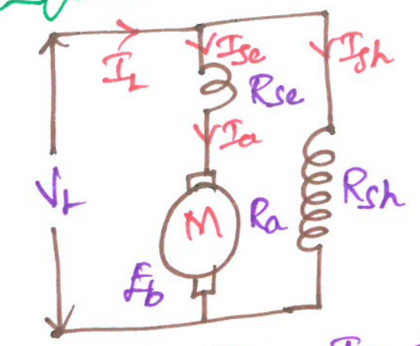
By KVL, $V_L = E_b + I_a(R_a + R_{se})$

Applications:
Trolley, Cranes, hoists, lifts, Conveyors, Electrical Locomotives etc.

(3) DC Compound motor:

* Part of field winding is in Series
* Remaining part is in parallel with armature.

Long shunt Comp. motor:



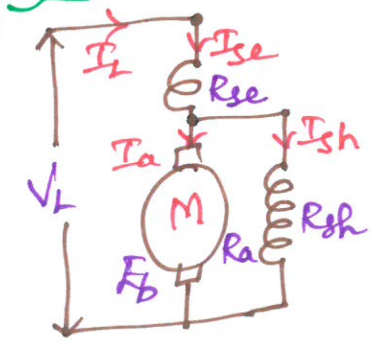
By KCL, $I_L = I_{se} + I_{sh}$
$I_a = I_{se}$

By KVL, $V_L = E_b + I_a(R_a + R_{se}) + BCD$

and $I_{sh} = \frac{V}{R_{sh}}$.

Applications:
Elevators, Conveyors, Rolling mills etc

Short shunt Comp. motor:



By KCL,
$I_L = I_{se}$
$I_L = I_a + I_{sh}$

By KVL,
$V_L = E_b + I_a R_a + I_{se} R_{se} + BCD$

and $I_{sh} = \frac{E_b - I_a R_a}{R_{sh}}$.

Applications:
R & D and Defence application.

STARTERS :

* Start and stop the motor
* Limit inrush current when necessary
* Permit automatic control when required
* Protect motor and other equipments from over voltage, no voltage, under voltage etc.

Need of starters :

W.K.T, In motors, $\boxed{V = E_b + I_a R_a}$

* At the time of start, $E_b = 0$, $\because N = 0$

V : Applied Voltage
E_b : Back Emf
I_a : Arm. Current
R_a : Arm. Resistance
$R_a \leq 3\,\Omega$

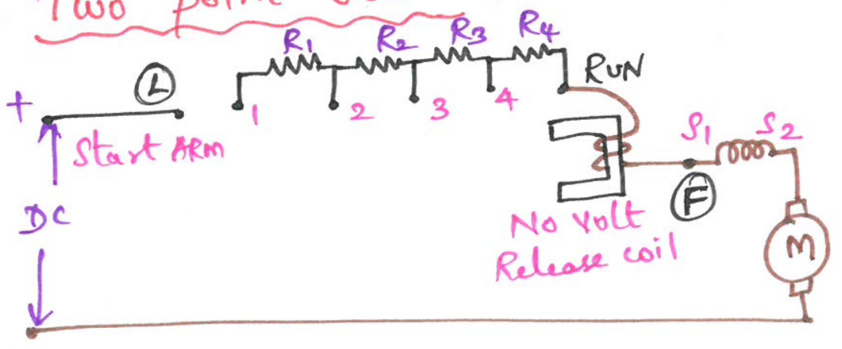
$\Rightarrow V = 0 + I_a R_a$

$\therefore \boxed{I_a = \frac{V}{R_a}}$

* Since 'R_a' is very low, 'I_a' becomes large.
* Huge 'I_a' may damage the machine.
* Starters are nothing but series connected Resistors.
* To avoid the damage, a suitable DC motor starter must be used.

Types of DC motor starters :

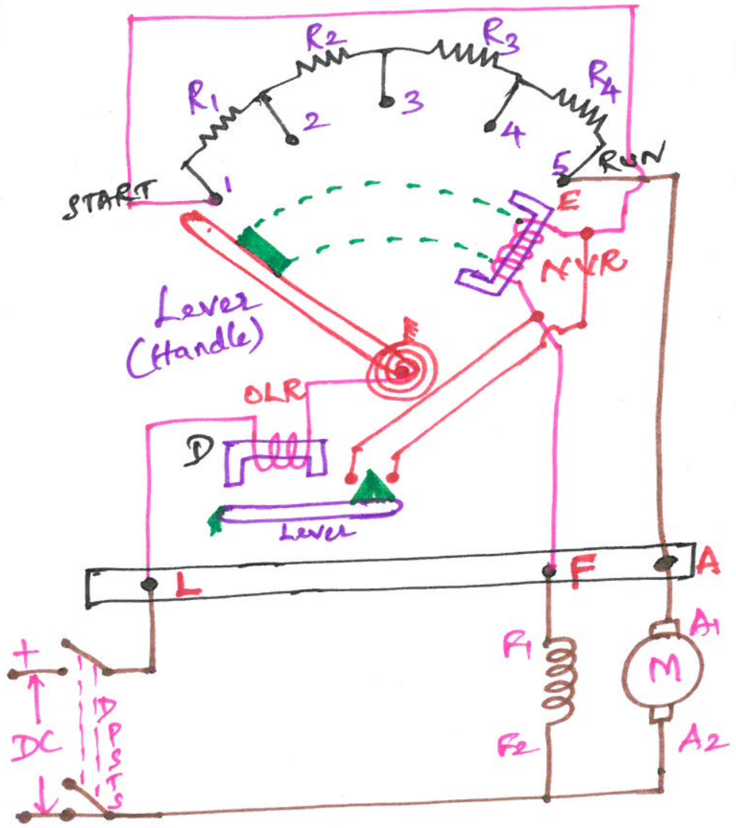
I. Two point starter :



* Used in DC series motor
* 2 points are : Line (L) and field (F)

* Start arm is moved from Left to right.
(start) (run)
* R_{max} connected at starting, then reduced gradually.
* No Volt Release (NVR) coil, hold the start arm to run position, and leaves it when voltage is lost.

II. Three Point starter :

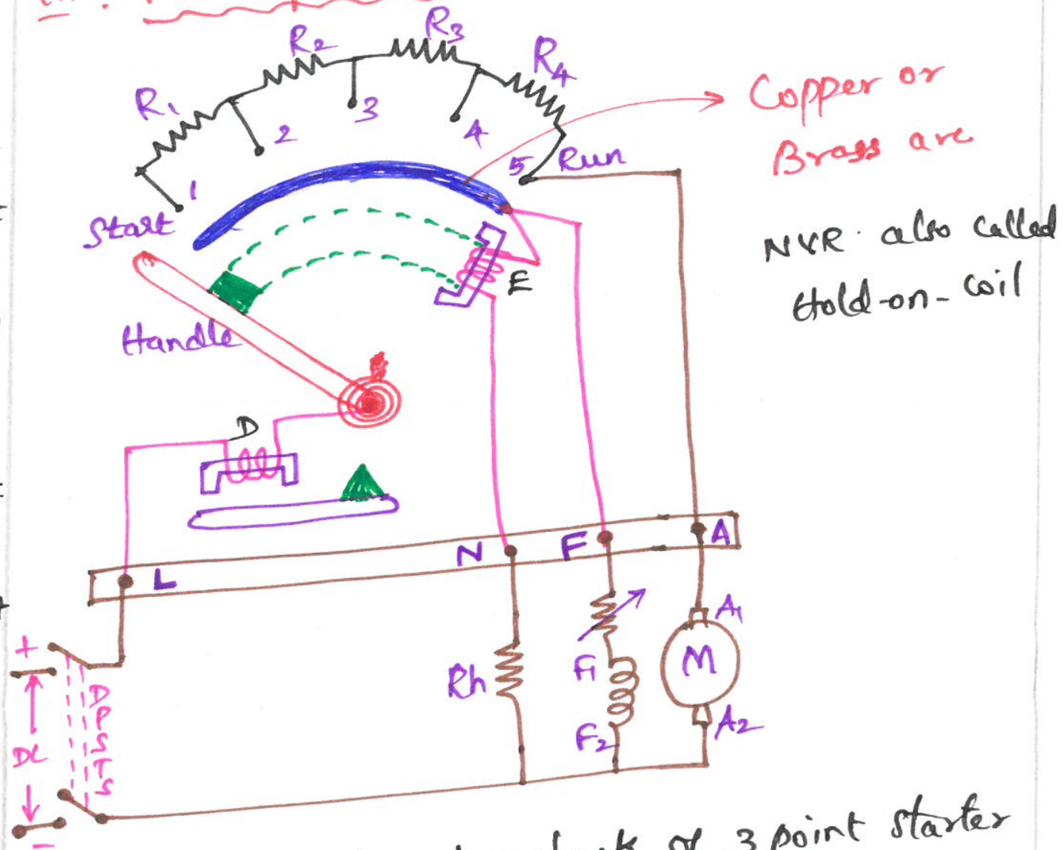


NVR : No Volt Release
OLR : Overload Release
E : No Volt Electromagnet
D : overload Electromagnet

(start)
* DC supply is connected – lever at position (1)
* Field directly connected to supply
* Armature winding connected via R_1, R_2, R_3, R_4.
* During starting : full 'R' connected
* Lever moved from pos.(1) to (5) (Run)
* At pos.(5), all starting 'R' are removed
* Now, Arm. connected across supply.
* NVR : Holds handle or lever at run position
  : Releases when there is no power.

* Moving from start to run, I_{sh} decreases hence, NVR releases handle unexpectedly.
* OLR : 'D' gets activated, when overcurrent flows, which short circuits 'E', releases the handle to start.

(ii). Four point starter :



NVR also called Hold-on-coil

* Eliminates the drawback of 3 point starter
* field flux can be varied conveniently to increase the speed. $\boxed{\phi_f \propto \frac{1}{N}}$

Diff
* Field coil is not connected in series with NVR.
* Field gets direct supply, as lever touches brass arc.
* NVR connected with current limiting resistor.

PROTECTION CIRCUITS OF STARTERS !

NVR and OLR.

Faraday's law:

$$E = N_s \cdot \frac{d\phi}{dt}$$

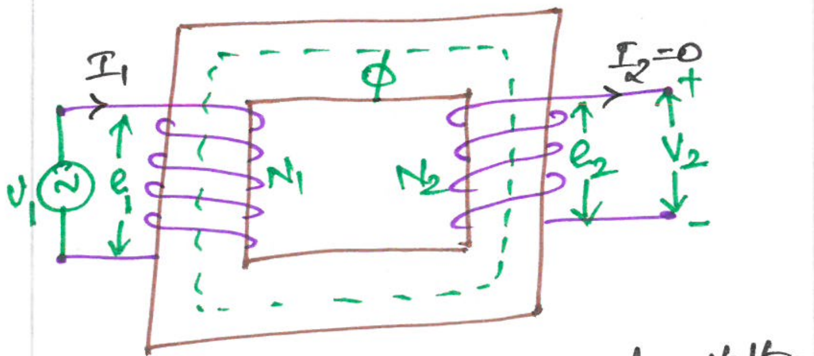
where, N_s : No. of turns.

TRANSFORMER:

* Static Electrical Machines – No Rotating parts
* Transfers Electrical Energy from one Circuit to another.
* With Constant frequency.
* Works on Mutual Induction principle.

CONSTRUCTION:

* Consists of 2 windings
* Insulated from each other
* Both are wound on a common core, made of mag. material



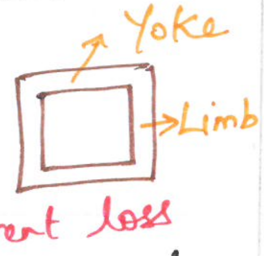
* V_1, V_2 : Primary & Secondary Voltage
* I_1, I_2 : Primary & Secondary Current
* N_1, N_2 : Primary & Secondary no. of turns
* e_1, e_2 : Primary & Secondary induced emf
* ϕ : magnetic flux

Major Parts:

(i) Magnetic Core
(ii) Windings or Coils

Magnetic Core:

* Core is either square or rectangular type.
* Further divided into 2 parts
  - Yoke : Horizontal portion
  - Limb : Vertical portion.
* Made of Laminated sheets of silicon steel



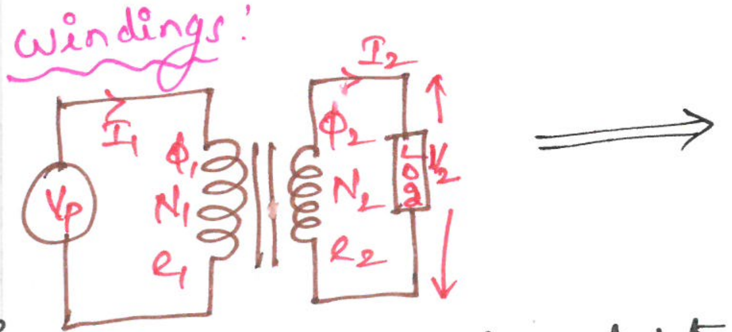
⇓
Reduces Eddy current loss

* Generally uses high grade silicon steel (0.3 to 0.5 mm thick)

⇓
To reduce hysteresis loss

* Laminations are being insulated from each other by a varnish or an oxide layer.

Windings:



* Primary : winding Connected to AC Supply
* Secondary : winding Connected to Load
* Made of Cu or Al.
* Coils are wound on Limps.
* To avoid magnetic leakage, Part of each winding wound on both limbs.

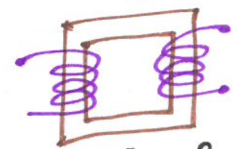
Other parts:

- Insulation of coils
- Conservator tank & Explosion Vent
- Bushings
- Buchholz Relay
- Breather
- Cooling arrangement

Types of Transformers

- Stepup: $V_2 > V_1$
- Stepdown: $V_2 < V_1$

Core Type



* Core is Surrounded by windings

Shell type

* Windings are Surrounded by

PRINCIPLE OF OPERATION:

* Principle of mutual inductance
* When 'V_1' is Connected

⇓

Forces 'I_1' to flow thro' Primary

⇓

Induces $\phi_1 \propto I_1$ according to N_1

$\therefore e_1 \neq N_1 \frac{d\phi_1}{dt}$.

⇓

ϕ_1 links Secondary coil via magnetic core.

⇓

Induces ϕ_2 according to N_2

$\therefore e_2 = N_2 \frac{d\phi_2}{dt}$.

$\phi_2 < \phi_1$ due to leakage flux.

⇓

If Secondary is closed, 'e_2' forces 'I_2' to flow.

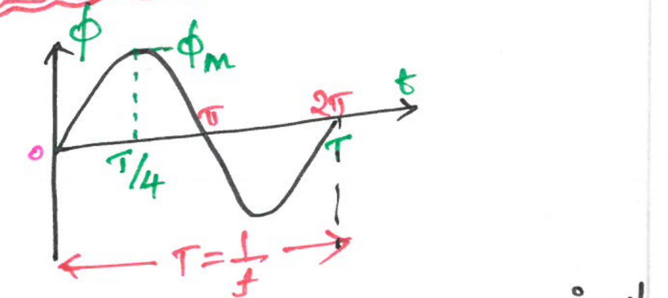
⇓

'V_2' can be controlled by ratio of N_1 & N_2.

Transformation Ratio (K)

$$K = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{I_1}{I_2}.$$

EMF EQUATION OF TRANSFORMER



* ϕ_m is max. flux in core in wb.

$\phi_m = B_m \times A$

* Consider 1 quarter of cycle,

$d\phi = \phi_m - 0 = \phi_m$

$dt = \frac{T}{4} = \frac{1}{4f}$.

* Average emf/turn $= \frac{d\phi}{dt} = \frac{\phi_m}{\left(\frac{1}{4f}\right)}$

$= 4f\phi_m$.

* ϕ Varies Sinusoidally,

$\therefore$ Form factor $= \frac{\text{rms Value}}{\text{Ave. Value}} = 1.11$

$\Rightarrow$ $\frac{\text{Rms Value of emf}}{\text{turn}} = 1.11 \times 4f\phi_m = 4.44 f\phi_m$

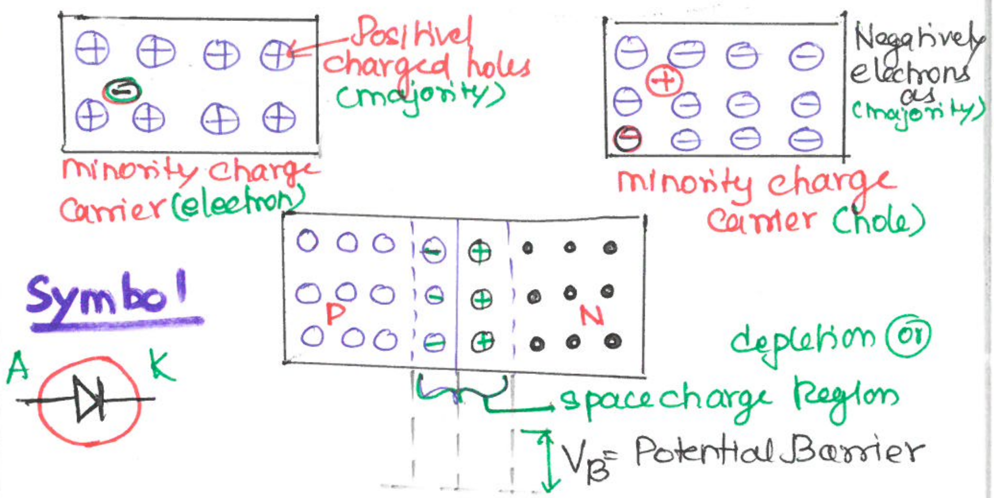
* $E_1 = 4.44 f \phi_m N_1$ Volts

$E_2 = 4.44 f \phi_m N_2$ Volts

Semiconductor devices.

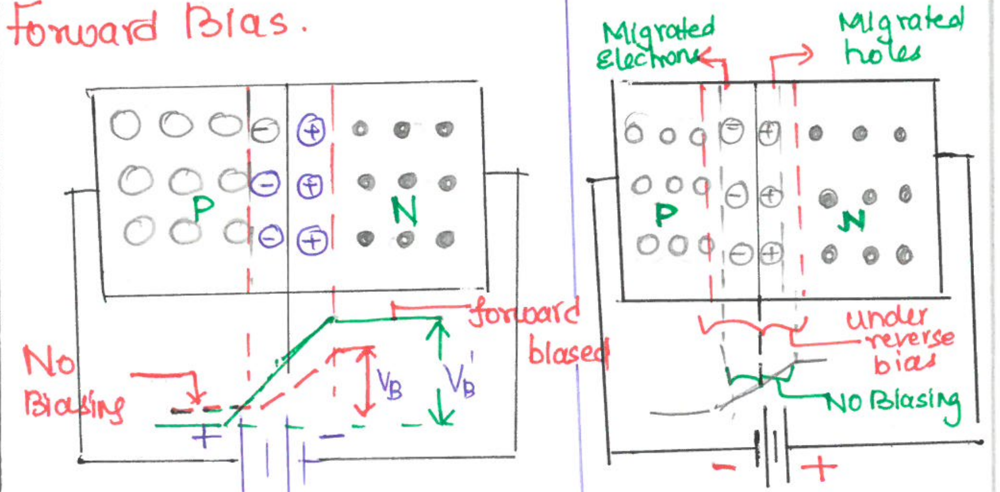
- PN Diode
- ZENER DIODE
- Bipolar Junction Transistors

① Theory of PN Junction

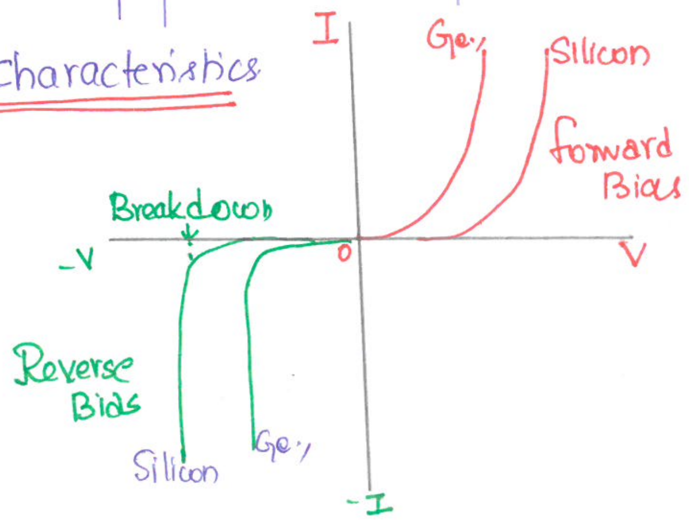


operation of PN Junction.

Forward Bias.



VI characteristics



3. SEMICONDUCTOR DEVICES.

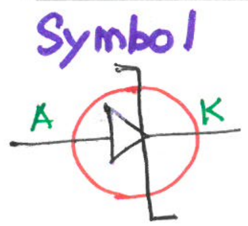
⊙ Zener diode

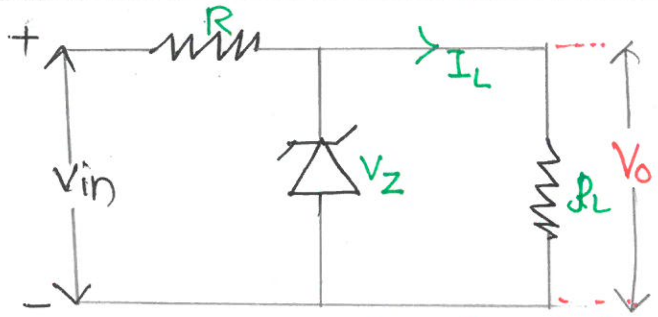
- A Diode is Reverse biased, depletion layer widens..
- Setup a Large potential barrier prevents majority carriers from one side to other.

Junction breakdown is of

(i) Zener breakdown	(ii) Avalanche breakdown.
→ occurs in heavily doped	⊙ Lightly doped junction
→ occurs with Reverse bias voltage less than 6 V	⊙ in PN junction diode with Reverse voltage greater than 6 V
→ Temp Coefficient is Negative	⊙ Temp. Coefficient is +ve

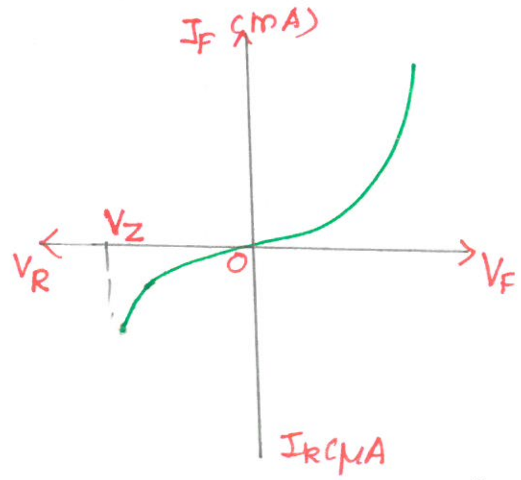
Symbol





Circuit diagram as a Voltage Regulator

VI characteristics.



(i) Zener diode is Same as of PN diode under forward bias condition

(i) Breakdown occurs under reverse bias.

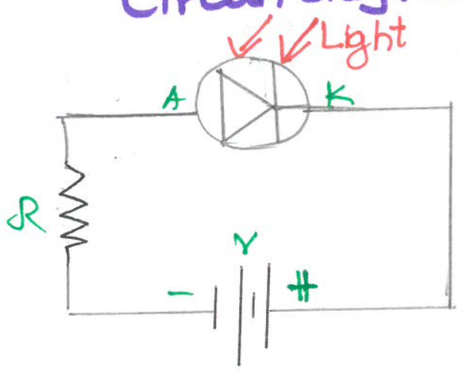
(i) It depends on amount of Doping

⊙ PHOTO DIODE

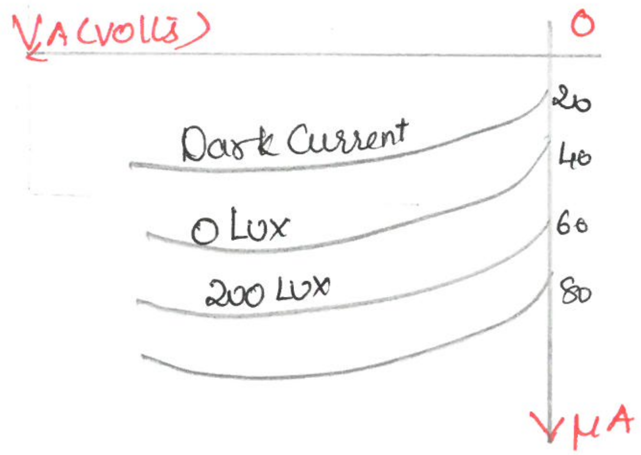
⊙ Silicon photo Diode - light Sensitive called photo detector - converts Light Signals into Electrical Signals.

Symbol

Circuit diagram



characteristics of Photo diode



⊙ The Reverse Current increases in direct proportion to the Level of illumination.

⊙ when No Current - minimum Reverse Leakage Current - Called dark Current flowing through device

⊙ Applications:-

→ PN Diode :- As Switches, Rectifiers, clippers, clampers.

→ Zener diode :- as voltage Regulators, peak clippers,

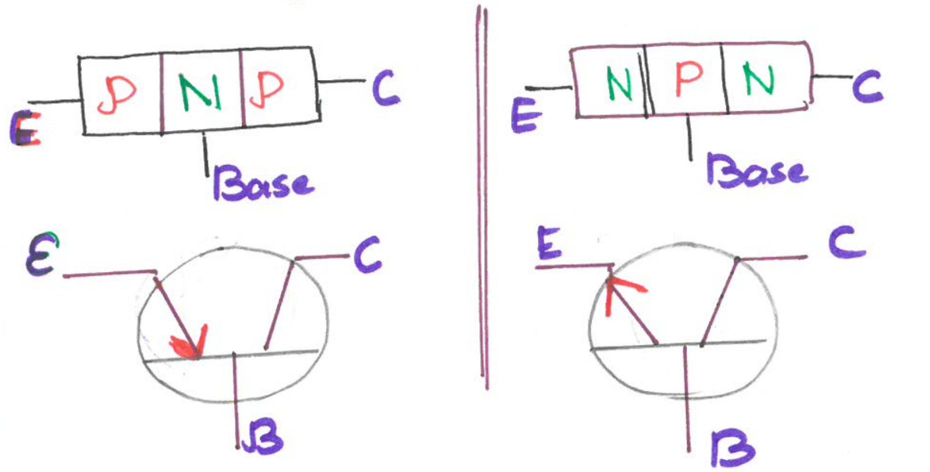
→ Photo diode as Light detectors, Encoders and demodulators

Bipolar Junction Transistor

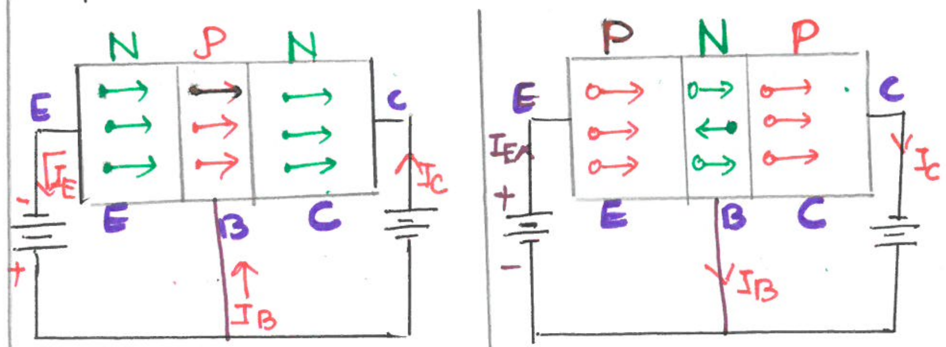
- A BJT is a Three Layer – Emitter, Base, Collector
- Two junction and three terminal device

NPN Transistor   PNP transistor

Circuit Representantion and Symbol



Operation in NPN and PNP Transistor



I_C = Collector Current

I_B = Base Current

I_E = Emitter Current

$I_B + I_C = I_E$

$I_C \approx I_E$

Current Amplification factor

In CE Configuration $\beta = \frac{\Delta I_C}{\Delta I_B}$

In CC Configuration $\gamma = \frac{\Delta I_E}{\Delta I_B}$

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

BJT – Types of Configuration

- Common Emitter Configuration (CE)
- Common Base Configuration (CB)
- Common Collector Configuration (CC)

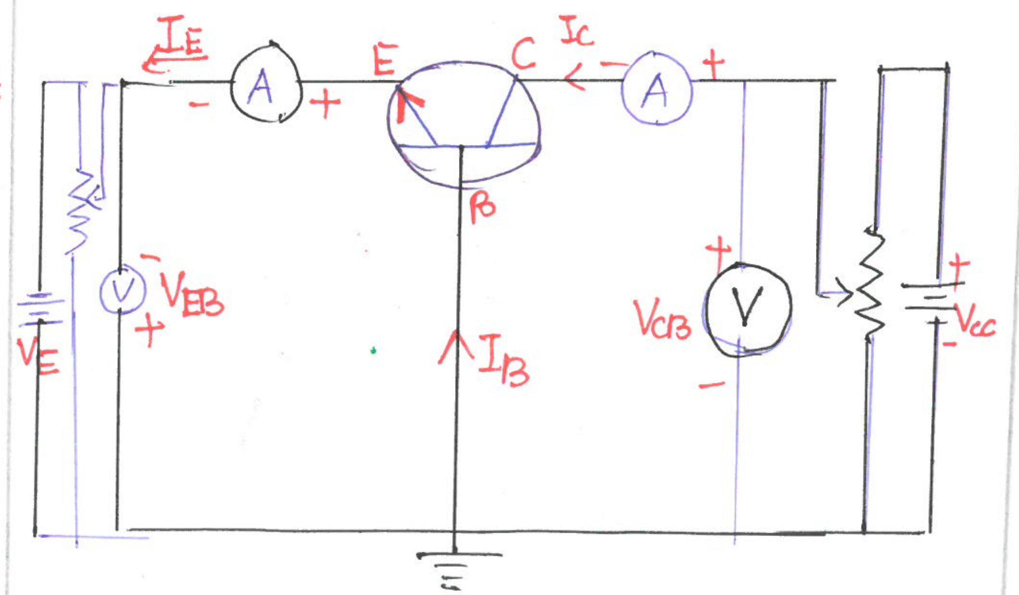
Common Base :– Also Called Grounded Base Configuration

Common Emitter :– Grounded Emitter – Input is Base and Collector is Output

Common Collector :– Grounded Collector. Base is Input and Emitter is Output

Common Base Configuration –

Circuit Diagram & Operation

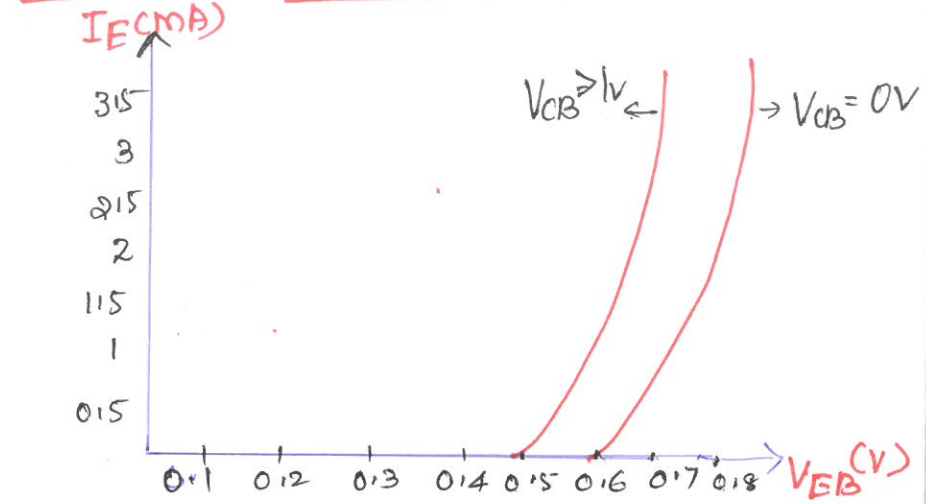


V_E Emitter Voltage

V_{CC} = Collector-Collector Voltage

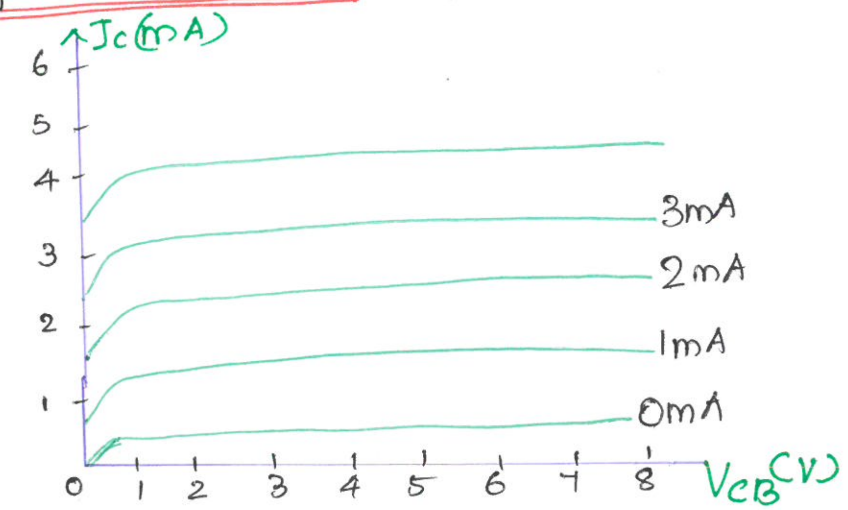
V_{CB} = Collector – Base Voltage

CB Input Characteristics



- when $V_{CB} = 0$, emitter base jn is forward biased, So I_E increases.
- when V_{CB} is increased, V_{EB} as Constant, width of base decrease, thus increases I_E.

Output characteristics.



- To determine output characteristics Emitter Current I_E is Constant,
- Adjusting Emitter-base voltage V_{EB}, V_{CB} is increased
- for a constant value of I_E, I_C is independent of V_{CB}.

Applications :–

→ To Amplify weak Signals

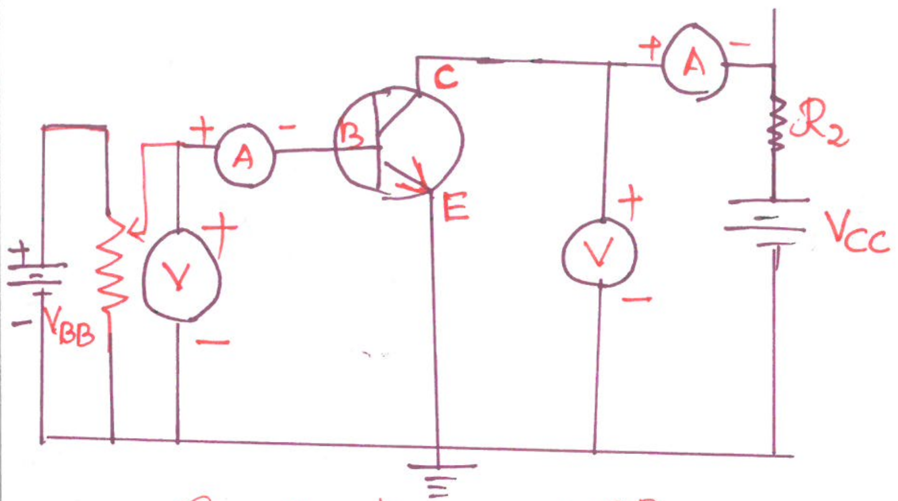
→ used as a Switch in Digital Circuits

→ used in Oscillator Circuits

Common Emitter Configuration.

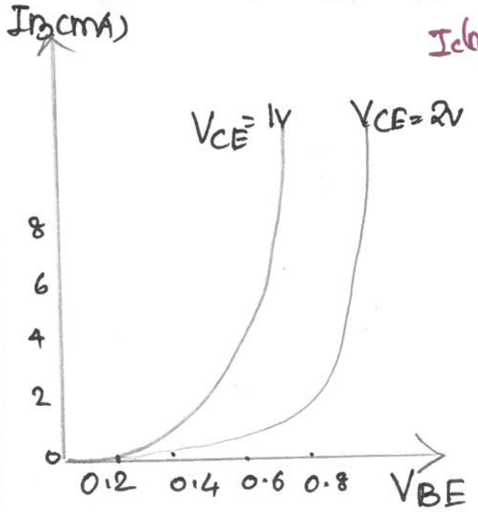
① Input applied between Base & Emitter and output taken from Collector and Emitter.

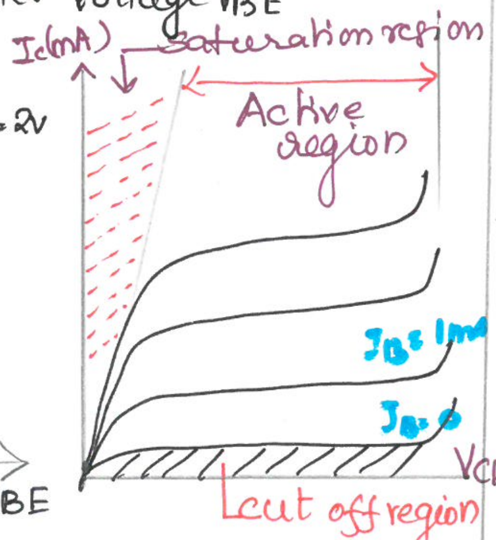
Input Characteristics:



Circuit diagram of CE.

① Input characteristics between base current I_B & Base Emitter Voltage V_{BE}





Output characteristics

① Output characteristics is between Collector Current I_C and Collector Emitter Voltage V_{CE}

Input Resistance $R_{in} = \frac{\Delta V_{BE}}{\Delta I_B}\Big|$ constant V_{CE}

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

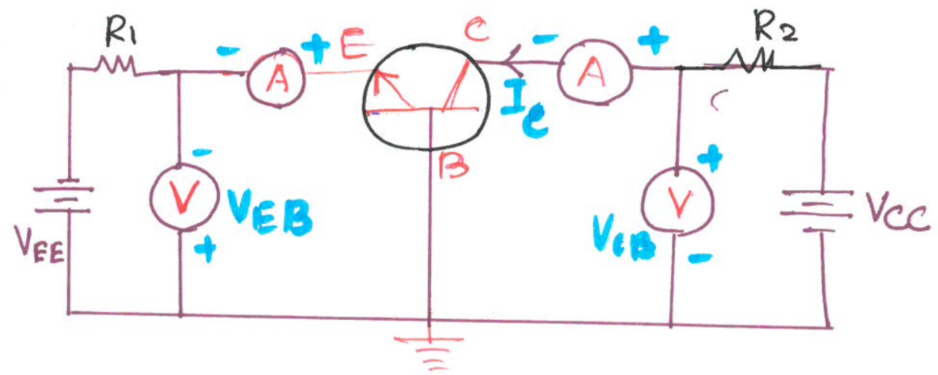
characteristics:-

◎ Input Impedance is low (750Ω)
◎ Output resistance is high (45kΩ)
◎ Voltage Gain is high (about 500)
◎ Current Gain is high

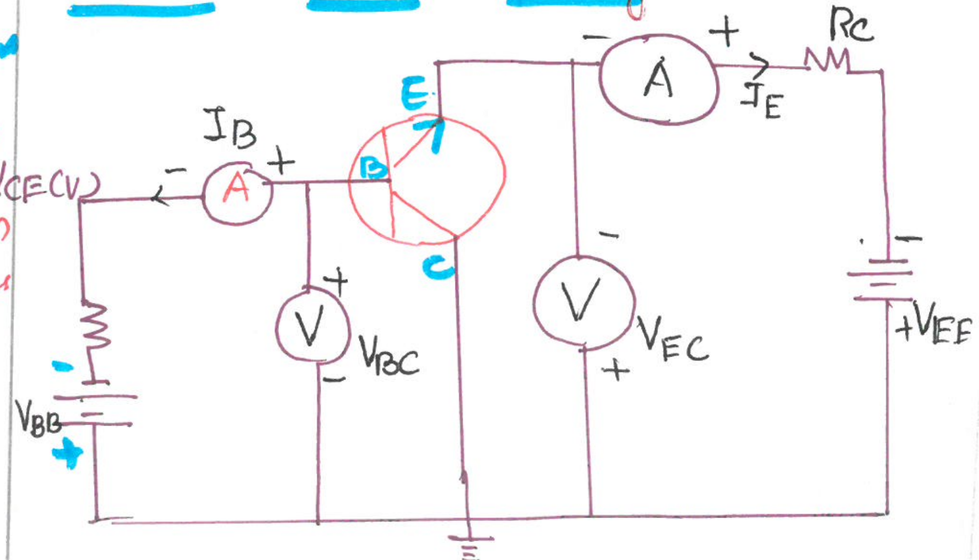
Application:- used for Audio frequency application

Common ~~Collector~~ Base Configuration.

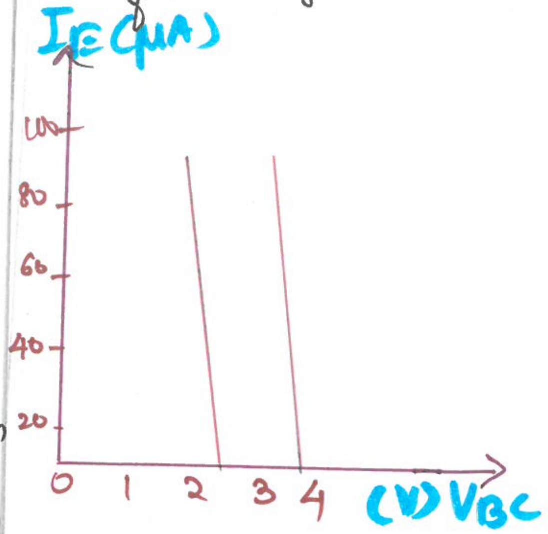
To determine the static characteristics of NPN transistor is shown.



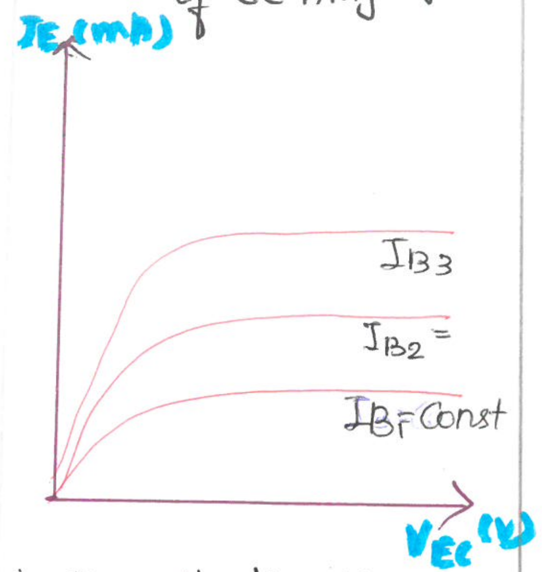
Common Collector Configuration



Input characteristics of CC Amplifier



Output characteristics of CC Amplifier



① Base current kept Constant, adjusting V_{BC} & Output Current I_E is measured.

$$R_{out} = \frac{\Delta V_{BC}}{\Delta I_E}\Big| \text{constant } I_B$$

$$\text{Current Amplification factor } (\gamma) = \frac{\Delta I_E}{\Delta I_B}\Big|_{V_{CE}=\text{const.}}$$

Characteristics

◎ Input Impedance is high (about 750kΩ)
◎ Output Impedance is Low (about 50Ω)
◎ Voltage Gain is Less than 1
◎ Current Gain is high.

application:- used for Impedance Matching.

Problem:- Calculate I_E in a Transistor for which $\beta = 50$ and $I_B = 20\mu A$

$$I_C = \beta I_B = 50 \times 20 \times 10^{-6} = 1 \times 10^{-3} A$$

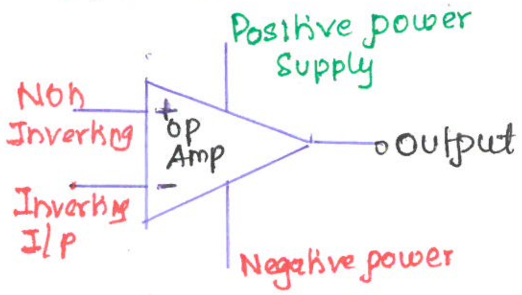
$$I_E = I_B + I_C = 1\times10^{-3} + 20\times10^{-6} = 1.02\times10^{-3} A$$

$\alpha = \frac{\Delta I_C}{\Delta I_E}$ at Const V_{CB} $\beta = \frac{\Delta I_C}{\Delta I_B}$ $\gamma = \frac{\Delta I_E}{\Delta I_B}\Big|_{V_{CE}=\text{const}}$

Operational Amplifier

Operational Amplifier is a Three Terminal device - consists of Two high Impedance inputs

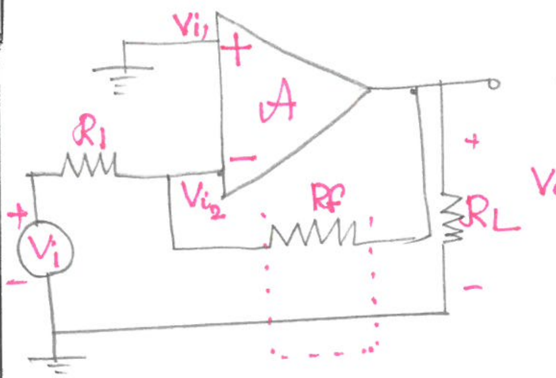
Symbol



- Is use to amplify and output the Voltage difference between Two input pins.

Key characteristics and Parameters

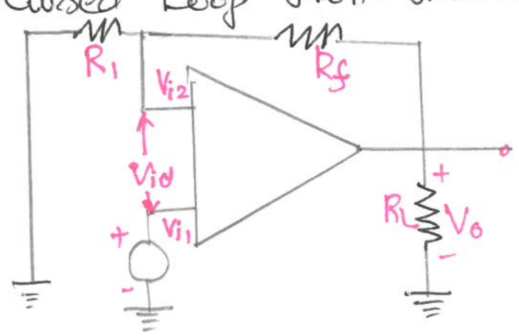
Closed Loop Inverting Amplifier.



Closed Loop Voltage Gain

$$A_0 = \frac{V_0}{V_i} = \frac{-R_f}{R_1}$$

Closed Loop Non-Inverting Amplifier.



Voltage Gain:-

Voltage Gain

$$A_v = \frac{1}{\beta} = \frac{R_1 + R_f}{R_1}$$

$$A_v = 1 + \frac{R_f}{R_1}$$

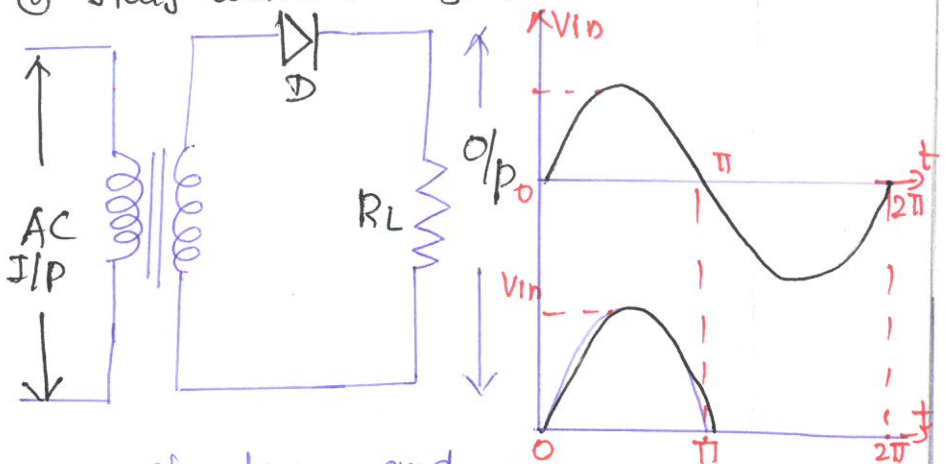
Applications:

- performs Summation, Scaling, differentiation, Integration in Analog Computers

Application of Semiconductor devices

Diode as a Rectifier

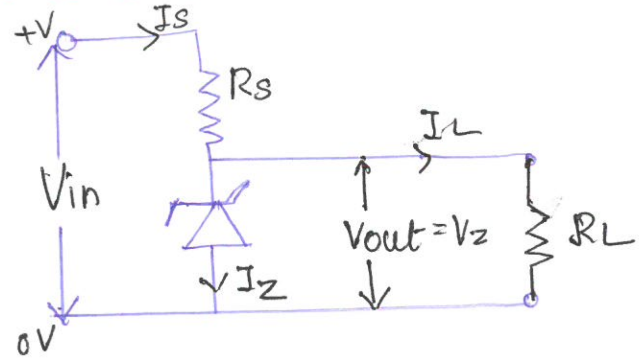
- Rectifier used for Converting AC Voltage into unidirectional Voltage
- Half-wave Rectifier



Basic structure and Input/output charac,

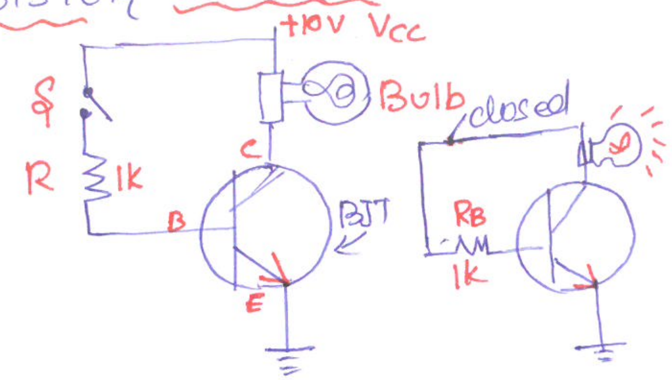
$$\text{Efficiency } \eta = \frac{\text{dc output power}}{\text{ac input power}}$$

Zener Diode As a Regulator



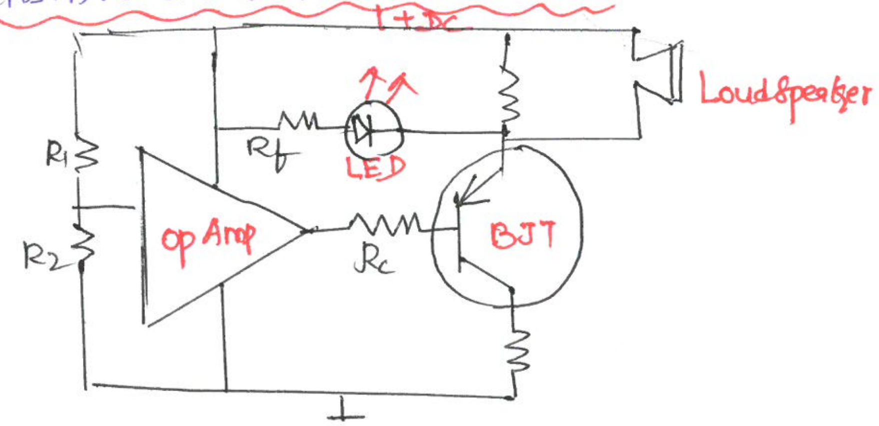
- Designed using a Zener diode to maintain a constant DC output Voltage across the Load.

Transistor as a Switch



For Switching - BJT is biased to operate in the Saturation or Cut-off Region

Sensitive Intruder Alarm Circuit



Some other Applications are

- Sound operated flipflop
- Sound Pressure meter
- Infrared Motion Detector Circuit
- Car Subwoofer filter
- DIY Headphone Amplifier
- Tone Control for Guitar Amplifier
- Temperature Deviation Indicator using OpAmp
- Operation Amplifier Tester.

Number systems:

- Binary [base 2 (0, 1)]
- Octal [base 8 (0 - 7)]
- Hexa decimal [base 16, (0-9, A - F)]
- decimal [base 10, (0-9)]

Conversions:

Binary to decimal

Eg 1 0 0 1

$1 \times 2^0 = 1 \times 1 = 1$

$0 \times 2^1 = 0 \times 2 = 0$

$0 \times 2^2 = 0 \times 4 = 0$

$1 \times 2^3 = 1 \times 8 = 8$

$= 9$

$1001_2 = 9$

Binary to Octal

Eg: 011100101_2

011 100 101

3 4 5

$111001 01_2 = 345_8$

* group three bits from LSB

* Convert to decimal

Binary to Hexadecimal

1110 0101 0111 1111

group four bits from LSB

1110 0101 0111 1111

E 5 7 F

Octal to binary

Eg: 345_8

3 4 5

011 100 101

$345_8 = 011100101_2$

Three bit representation of decimal number

Octal to Hexadecimal

Eg: 615.25_8

Steps

Octal → three bit representation of each octal digit → group 4 bit start from LSB → Equivalent Hexadecimal Number

615 . 25

000 110 001 101 . 010 101 00

1 8 D . 5 4

$615.25_8 \rightarrow 18D.54_{16}$

Octal to decimal

Eg 3 4 5

$5 \times 8^0 = 40$

$4 \times 8^1 = 32$

$3 \times 8^2 = 192$

$= 264$

Decimal to Binary

Eg: 24_{10}

2 | 24

2 | 12 - 0 (LSB)

2 | 6 - 0

2 | 3 - 0

1 - 1 (MSB)

$24_{10} = 11000_2$

Decimal to Octal

Eg 12345_{10}

8 | 12345

8 | 1543 - 1 (LSB)

8 | 192 - 7

8 | 24 - 0

3 - 0 (MSB)

$12345_{10} = 30071_8$

Decimal to Hexa decimal

eg: 725_{10}

16 | 725

16 | 45 - 5

2 - 13 - D

$725_{10} = 2D5_{16}$

Hexadecimal to Binary

Eg A 2 D E_{16}

Four bit representation

A 2 D E

1010 0010 1101 1110

$A2DE_{16} = 1010001011011110_2$

Hexadecimal to Octal

Eg BC66 . AF

B C 6 6 . A F

00 1011 1100 0110 0110 . 1010 1111 0

1 3 6 1 4 6 . 5 3 6

$BC66.AF_{16} = 136146.536_8$

Hexa decimal to decimal

$F0_{16}$

$0 \times 16^0 = 0$

$15 \times 16^1 = 240$

$(240)_{10}$

Problems

1) Find decimal equivalent of $(231.23)_4$

$N = 2 \times 4^2 + 3 \times 4^1 + 1 \times 4^0 + 2 \times 4^{-1} + 3 \times 4^{-2} = 45.6875_{10}$

2) Convert $(12.125)_{10}$ to binary

Integer part

2 | 12

2 | 6 - 0

2 | 3 - 0

1 - 1

Fractional part

$0.125 \times 2 = 0.25 \rightarrow 0$

$0.25 \times 2 = 0.50 \rightarrow 0$

$0.50 \times 2 = 1.00 \rightarrow 1$

Ans. 1100.001_2

3) Convert 658.825 to octal.

8 | 658

8 | 82 - 2

8 | 10 - 2

1 - 2

$0.825 \times 8 = 6.6 \rightarrow 6$

$0.6 \times 8 = 4.8 \rightarrow 4$

$0.8 \times 8 = 6.4 \rightarrow 6$

$658.825_{10} = 1222.646_8$

4) Convert $(101101.1101)_2$ to decimal and Hexa decimal.

$101101.1101_2 = 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2} + 0 \times 2^{-3} + 1 \times 2^{-4} = 32 + 8 + 4 + 1 + 0.5 + 0.25 + 0.0625$

$= 45.8125$

0 0 1 0 1 1 0 1 . 1 1 0 1

2 D . D

$0101101.1101_2 = 2D.D_{16}$

LOGIC GATES

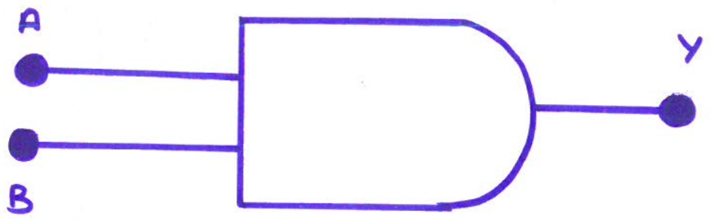
GATES

AND GATE

$Y = A$ AND B AND $C \ldots N$

$Y = A \cdot B \cdot C \cdots N$

LOGIC DESIGN

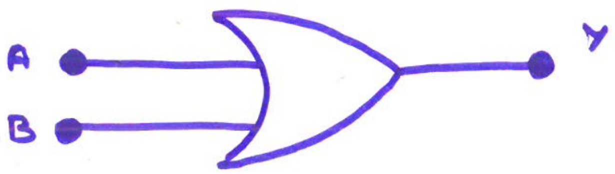


TRUTH TABLE :-

INPUTS		OUTPUTS
A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

OR GATE

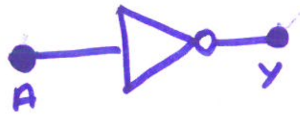
$Y = A+B+C \ldots N$



Truth Table :-

INPUT		OUTPUT
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

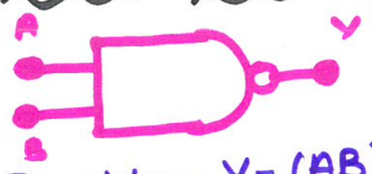
NOT GATE



TRUTH TABLE

Input	Output
A	B
0	1
1	0

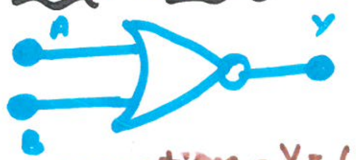
NAND GATE



Equation = $Y = (AB)'$

A	B	O/P
0	0	1
0	1	1
1	0	1
1	1	0

NOR GATE



Equation = $Y = (A+B)'$

A	B	O/P
0	0	1
0	1	0
1	0	0
1	1	0

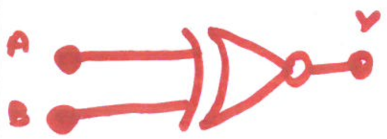
XOR GATE

Equation =

$Y = A \oplus B$

A	B	O/P
0	0	0
0	1	1
1	0	1
1	1	0

XNOR GATE



Equation =

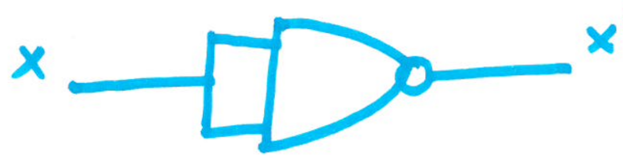
$Y = A \odot B$

A	B	O/P
0	0	1
0	1	0
1	0	0
1	1	1

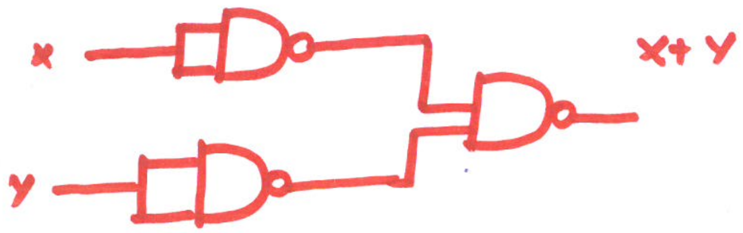
IMPLEMENTATION

NAND Implementation

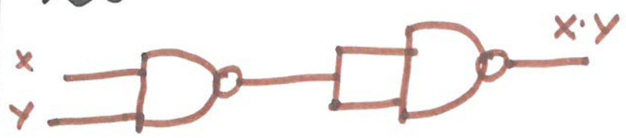
NOT GATE USING NAND GATE



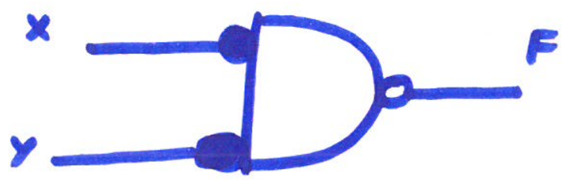
OR USING NAND



AND USING NAND

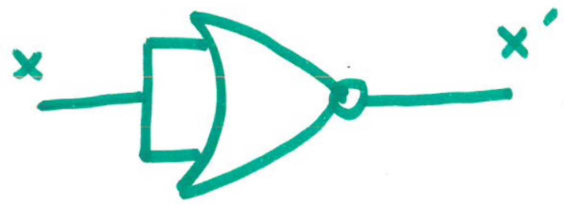


NOR USING NAND

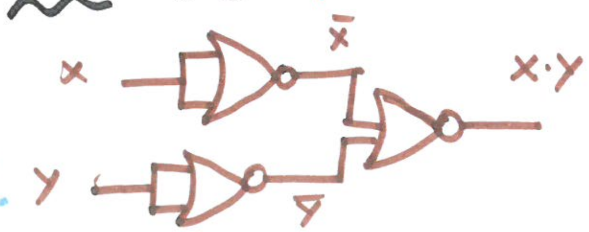


NOR Implementation

Inverter using NOR



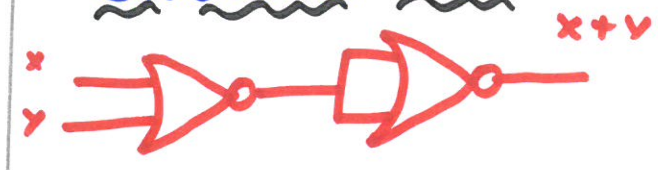
AND using NOR



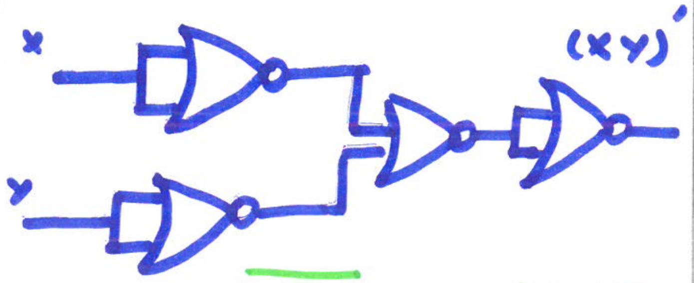
$Y = \bar{X} + \bar{Y}$

$= \bar{\bar{X}} \cdot \bar{\bar{Y}} = XY$

OR USING NOR



NAND using NOR.



$Y = \overline{\overline{\bar{X}+\bar{Y}}}$ $= \bar{X}+\bar{Y}$

$= \overline{X \cdot Y}$

Boolean Algebra:

- Simplify the design of logic circuit
- binary variable and logic operations.

Boolean function:

- algebraic expression consist of binary variable, constants 0 & 1, logic operation symbols.

Simplification of Boolean function

* Using Boolean axioms & laws
* K-Map
* Tabulation Method

The literals, Product terms or Sum terms are arranged in two form

Individual term does not involve all literal

SOP → POS

Sum of product — Product of sum

Eg. $Y = AB + AC$ — $Y = (A+B)(A+C)$

Canonical or standard form:

- Individual term has all literals

Eg: Standard SOP $Y(A,B,C) = ABC + ABC'$

Standard POS $Y(A,B,C) = (A+B+C)(A+B+C')$

Postulates and theorems of B A.

1. $x+0 = x$ — $x \cdot 1 = x$
2. $x+x' = 1$ — $x \cdot x' = 0$
3. $x+x = x$ — $x \cdot x = x$
4. $x+1 = 1$ — $x \cdot 0 = 0$
5. Involution $(x')' = x$
6. Commutative $x+y = y+x$
7. Associative $x+(y+z) = (x+y)+z$
8. Distributive $x(y+z) = xy + xz$; $x+(yz) = (x+y)(x+z)$
9. Demorgan's law $(x+y)' = x' \cdot y'$; $(x \cdot y)' = x'+y'$
10. absorption $x + xy = x$; $x \cdot (x+y) = x$

Convert given Expression in to Standard form (SOP).

Eg:1 $F(A,B,C) = AC + AB + BC.$

C Missing — B Missing — A Missing

$F = AC(B+B') + AB(C+C') + BC(A+A')$

$= ABC + AB'C + ABC' + A'BC.$

Eg:2: Draw the truth table for. $Y = a'b + bc$.

* Convert to canonical form
* Draw truth table by placing 1 against the minterm.

SOP

$Y = a'bc' + a'bc + abc$

$Y = \Sigma_m(2,3,7).$

a	b	c	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

POS

$Y = \Sigma_m(2,3,7)$ SOP

Missing variables

$Y = \Pi_M(0,1,4,5,6)$ (POS)

Eg3: Obtain the Sop and Pos form

$F = \Sigma m(1,3)$

$= a'b + ab$ (SOP) $= b(a+a') = b$

$F = \Pi_M(0,2)$

$= (a+b)(a'+b)$ – POS

$= a'b + ab + b = b$

Boolean function Simplification

Eg 4: Given in SOP form as

$F = A'BC + A'B'C + C'$

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

$= A'C + C' = C' + CA'$

$\boxed{F = C' + A'}$

Eg:5 Given in POS form

$F_2 = (A'+B+C')(A'+B')(C+A)$

$F_2 = (A'A' + A'B' + BA' + BB' + C'A' + C'B')(C+A)$

$= A'A'C + A'B'C + BA'C + BB'C + C'A'C + C'B'C + A'A'A + A'B'A + B'A'A + BB'A + C'A'A + C'B'A$

$F_2 = A'C + AB'C'$

Simplification Using K-Map

Karnaugh Map (K Map)

* graphical Representation of logic
* Reduce logic function quickly & easily.
* Reduces No of gates.

Steps Involved

Step:1 Identify no of input variable

Step:2 Bring given function in Canonical form

Step 3 Draw suitable 'n' variable K-Map.

One variable K-Map

	0	1
0	m_0	m_1

gray mapping

Two variable

A \ B	$\bar{B}$ 0	B 1
0 $\bar{A}$	m_0 $\bar{A}\bar{B}$	m_1 $\bar{A}B$
1 A	m_2 $A\bar{B}$	m_3 AB

A \ BC	$\bar{B}\bar{C}$ 00	$\bar{B}C$ 01	BC 11	$B\bar{C}$ 10
0 $\bar{A}$	m_0 $\bar{A}\bar{B}\bar{C}$	m_1 $\bar{A}\bar{B}C$	m_3 $\bar{A}BC$	m_2 $\bar{A}B\bar{C}$
1 A	m_4 $A\bar{B}\bar{C}$	m_5 $A\bar{B}C$	m_7 ABC	m_6 $AB\bar{C}$

Three Variable

Four variable K-Map

AB \ CD	$\bar{C}\bar{D}$ 00	$\bar{C}D$ 01	CD 11	$C\bar{D}$ 10
$\bar{A}\bar{B}$ 00	m_0 $\bar{A}\bar{B}\bar{C}\bar{D}$	m_1 $\bar{A}\bar{B}\bar{C}D$	m_3 $\bar{A}\bar{B}CD$	m_2 $\bar{A}\bar{B}C\bar{D}$
01 $\bar{A}B$	m_4 $\bar{A}B\bar{C}\bar{D}$	m_5 $\bar{A}B\bar{C}D$	m_7 $\bar{A}BCD$	m_6 $\bar{A}BC\bar{D}$
11 AB	m_{12} $AB\bar{C}\bar{D}$	m_{13} $AB\bar{C}D$	m_{15} $ABCD$	m_{14} $ABC\bar{D}$
10 $A\bar{B}$	m_8 $A\bar{B}\bar{C}\bar{D}$	m_9 $A\bar{B}\bar{C}D$	m_{11} $A\bar{B}CD$	m_{10} $A\bar{B}C\bar{D}$

Example 6:

$Y = A\bar{B}C + \bar{A}\bar{B}C + \bar{A}BC + A\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C}$

A \ BC	$\bar{B}\bar{C}$ 00	$\bar{B}C$ 01	BC 11	$B\bar{C}$ 10
$\bar{A}$ 0	1	1	1	0
A 1	1	1	0	0

$Y = \bar{B} + \bar{A}C$

Example 7: $Y = a'bc + bc' + ac$.

Convert to canonical form

$Y = a'bc + (a+a')bc' + a(b+b')c$

$= a'bc + abc' + a'bc' + ab'c + abc'$

011 — 110 — 010 — 001 — 101

$Y = \Sigma m(2,3,5,6,7)$

a \ bc	00	01	11	10
0	m_0	m_1	1 m_3	1 m_2
1	m_4	1 m_5	1 m_7	1 m_6

Sop form.

$Y = b + ac$

$Y = \Pi_M(0,1,4)$

a \ bc	$b+c$	$b+\bar{c}$	$\bar{b}+\bar{c}$	$\bar{b}+c$
a 0	0	0		
$\bar{a}$ 1	0	0		

Pos form.

$b+c$ — $a+b$

$Y = (a+b) \cdot (b+c)$

grouping can be done as pair, quad, octet.

Adders:

- Half adder (add 2 bit)
- Full adder (add three bit).

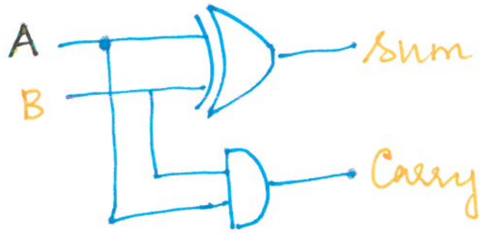
Half adder:

Truth table.

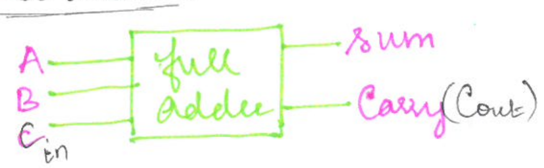
Inputs		Outputs	
A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Carry = AB

Sum = $A \oplus B$ $[A\bar{B} + \bar{A}B]$



Full adder



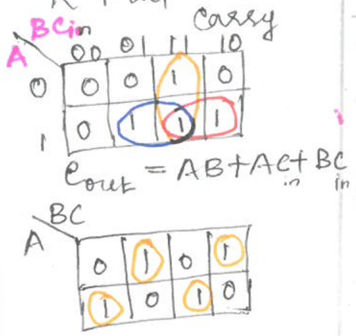
$C_{out} = AB + AC_{in} + BC_{in}$

$Sum = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in}$

Truth table

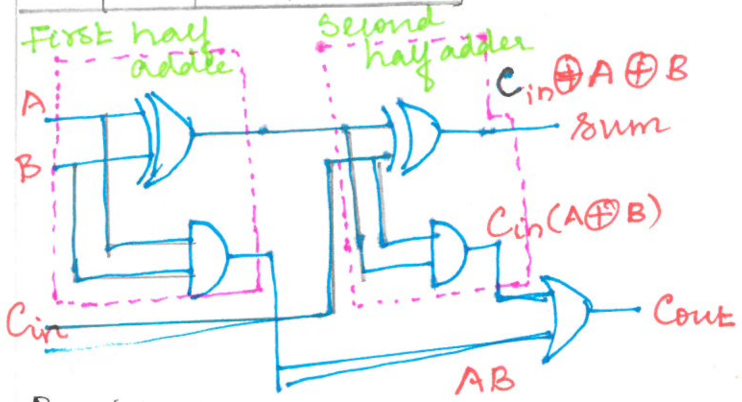
A	B	C	Carry	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

K Map



$C_{out} = AB + AC_{in} + BC_{in}$

$Sum = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in}$



Registers.

* group of flipflop - store a word - Registers
* 1 flipflop store 1 bit, n bit register - n flip flop - store n bits

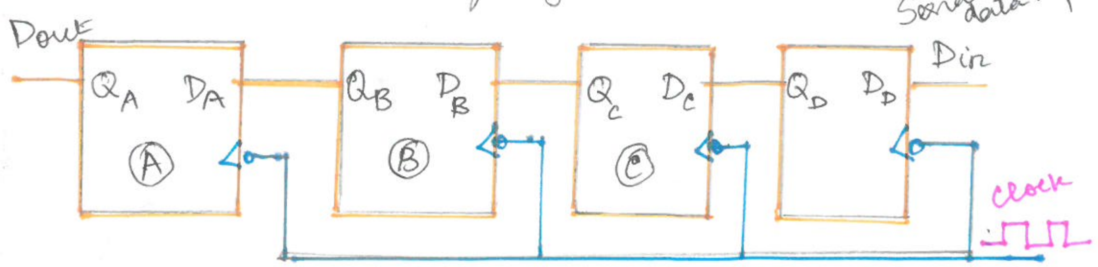
Shift Registers:

* data moved within register - Clock pulses
* shifting - arithmetic and logic operation - Microprocessors - shift registers.

Types of shift register.

1. Serial in serial out Register
2. Serial in Parallel out
3. Parallel in Serial out
4. Parallel in Parallel out

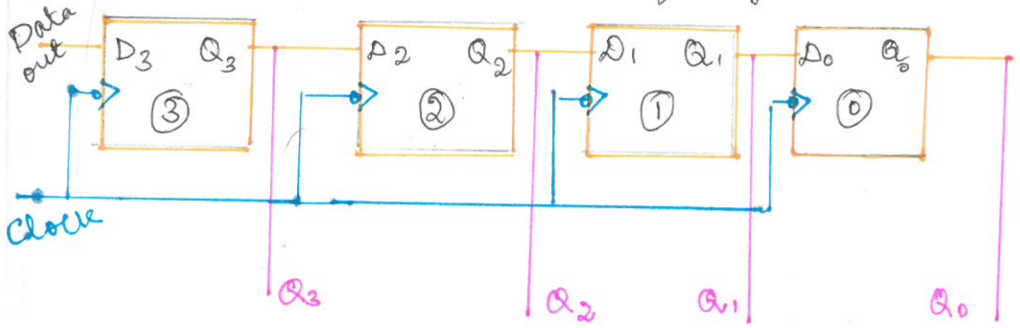
Serial in Serial out Shift Register



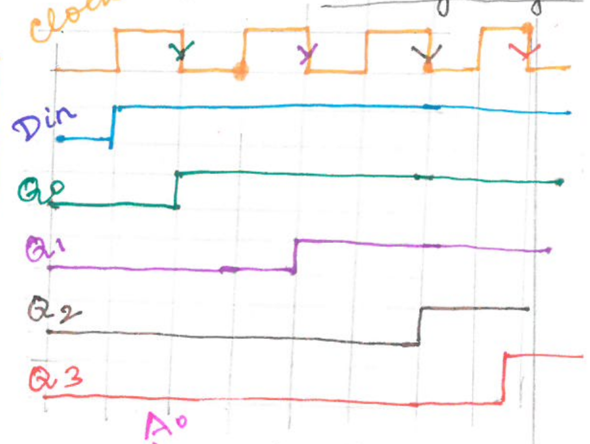
Shift register operation

CP	Q_3	Q_2	Q_1	Q_0	D_{in}
0	0	0	0	0	1
1	0	0	0	1	1
2	0	0	1	1	1
3	0	1	1	1	1
4	1	1	1	1	1

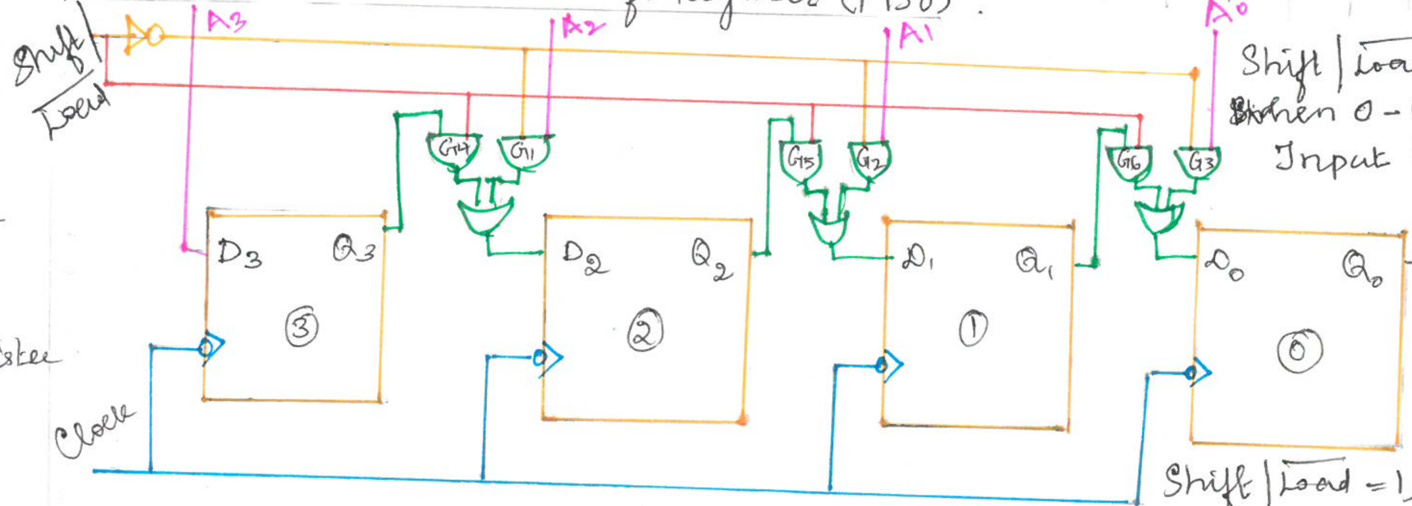
Serial in Parallel out (SIPO) shift Register.



Timing Diagram



Parallel in Serial out Shift Register (PISO).



Shift / Load - Control input

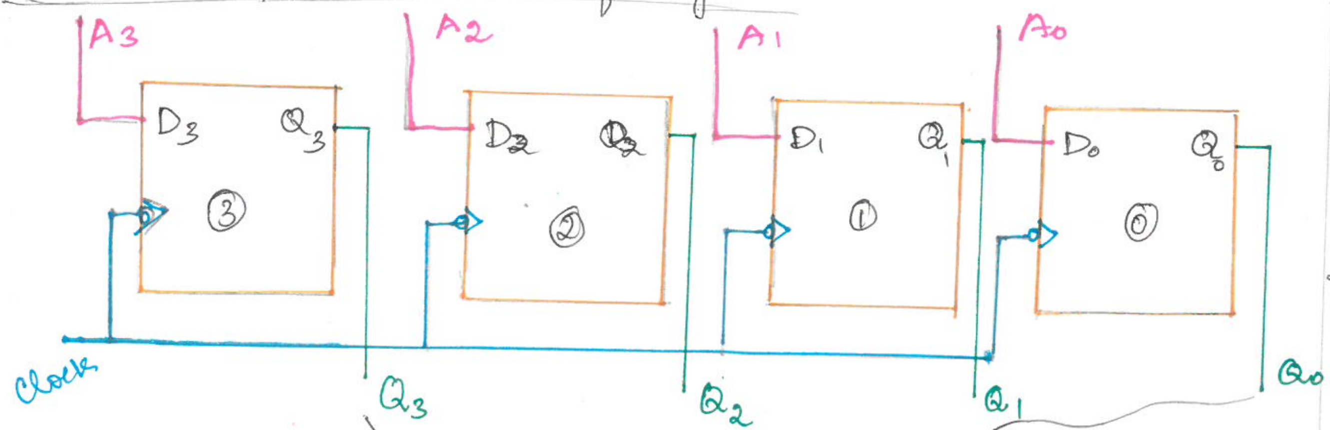
When 0 - G_1, G_2, G_3 - enable

Input to flip flop

Shift / Load = 1, G_1, G_2, G_3 disable

G_4, G_5, G_6 - enable, data shift

Parallel in parallel out shift register



Parallel data output

- Simultaneous entry of all data bit

bit appears on parallel outputs simultaneously

Application: Delay line, Pseudo random Binary sequence generator, Sequence generator, sequence detector, Serial in parallel Convertor etc

Register Shift in one direction - Unidirectional shift register

Shift both direction - Bidirectional Shift Register

both shift & Parallel load - Universal Register

Digital Circuits

→ Combinational ckt

→ Sequential ckt.

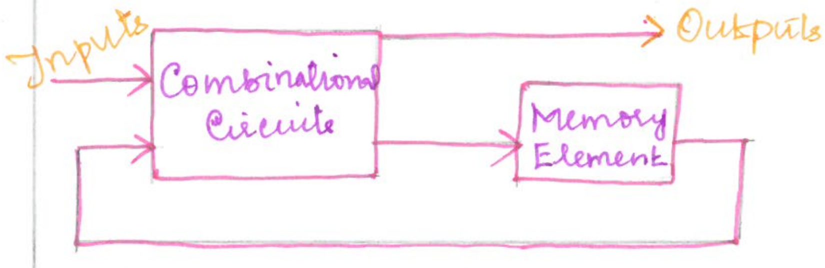
Combinational Circuit:

* consist logic gates – output depends on present combination of input
* Operation specified by Boolean function.

Eg, Adder, Subtractor, encoder, mux etc

Sequential Circuit:

* employ storage elements & logic gates
* output depend on present and past value of inputs.



– Storage elements ~~are~~ store binary info – Flip flops.

Flipflops

* Storage element – Clocked Seq. ckt.
* store one bit of information.

Types of flip flop

1. D flip flop
2. SR flipflop
3. JK flipflop
4. T flip flop

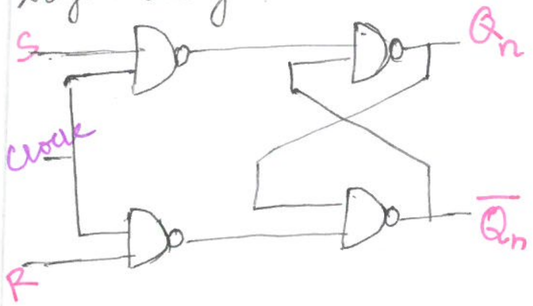
Triggering – level / edge.

Triggering

* Proper operation – trigger it only during signal transition
* 1 to 0, 0 to 1
* Positive transition – Positive edge
* Negative transition – Negative edge

SR flip flop

logic diagram



Truth table

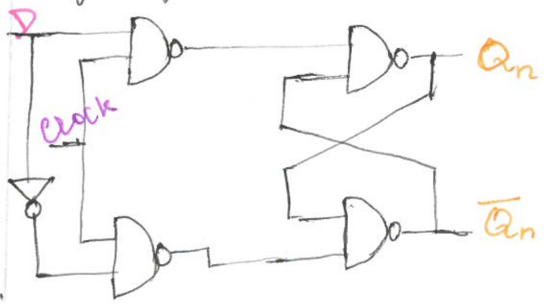
S	R	Q_{n+1}	State
0	0	Q_n	No change
0	1	0	Reset
1	0	1	Set
1	1	X	Undefined

$Q_{n+1} = S + \overline{R} Q_n$.

Excitation table

Q_n	Q_{n+1}	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

D flip flop



Truth table

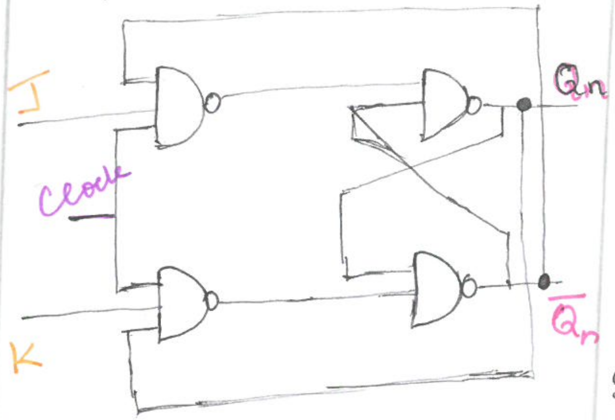
D	Q_{n+1}	State
0	0	reset
1	1	set

Excitation table

Q_n	Q_{n+1}	D
0	0	0
0	1	1
1	0	0
1	1	1

$Q_{n+1} = D$

JK flip flop



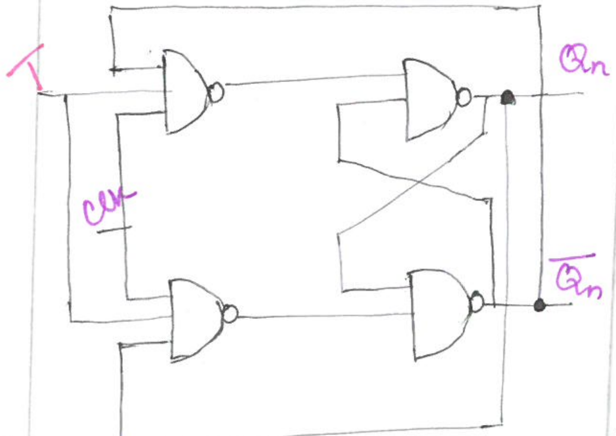
Truth table

J	K	Q_{n+1}	State
0	0	Q_n	No change
0	1	0	Reset
1	0	1	set
1	1	$\overline{Q}_n$	Toggle

Q_n	Q_n	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

$Q_{n+1} = J\overline{Q}_n + \overline{K} Q_n$

T flip flop



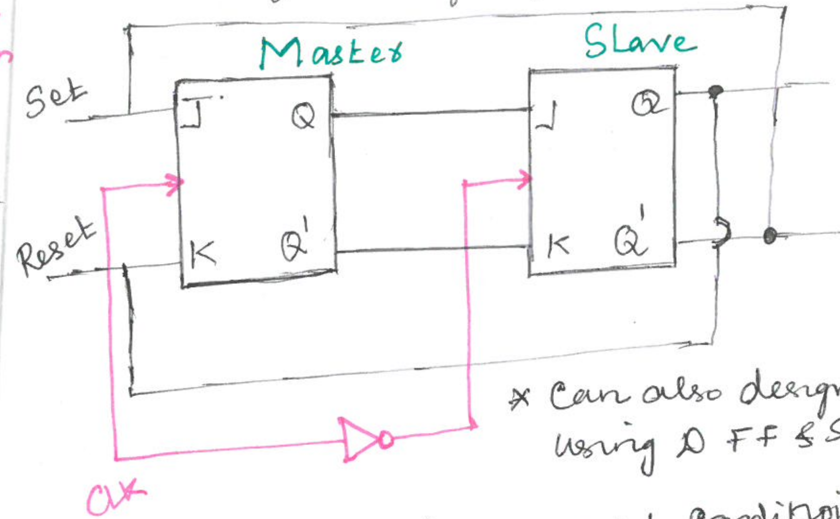
T	Q_{n+1}	State
0	Q_n	No Change
1	$\overline{Q}_n$	Toggle

$Q_{n+1} = T\overline{Q}_n + \overline{T} Q_n$

T → Toggle

Master slave flip flop

* Pulse triggered flip flop
* Master triggered by external clock pulse train
* output from master connected to input of slave flip flop.



* Can also designed using D FF & SR FF also

Why Master Slave – Race around condition.

* In JK FF, when J = K = 1, output toggles.
* Initially Q = 0, J = K = 1, after Δt, [propogation delay through two NAND in series] output change to Q = 1 after time Δt, the output change to Q = 0.
* toggling continue until flip flop is enabled and J = K = 1.
* At the end of clock pulse, the flip flop is disable value of Q is uncertain – race around condition.

Clock pulse width

* This exist where $t_p \geq \Delta t$.
* $t_p < \Delta t$, avoid race around condition.
* Most practical Method – Master slave Configuration

Operation: J = 1; K = 0 Master sets on positive clock.

Output – high → J input to slave,

Negative clock – slave sets.

* J = 0, K = 1, Master resets on positive clock, output - high → K input of slave, Negative clock - slave resets.
* J = K = 1, Master toggle on positive clock, slave copies the o/p of master on negative clock
* J = K = 0, o/p of master remain same in + & – clock.

Counter:

- Register capable of counting the number of clock pulse.
- n-bit counter – n flip flop – 2^n distinct state of outputs.
- reaching maximum count – reset to zero on next clock pulse

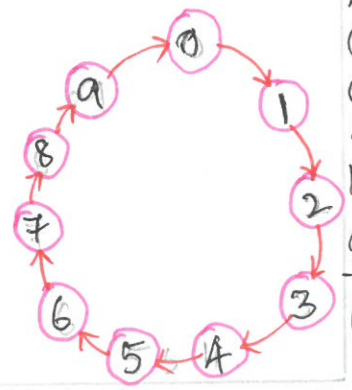
Types
- → Synchronous Counter [flipflop in counter triggered at same time]
- → Asynchronous Counter [Output of each flipflop → Clock input of next flipflop]

Modulus of Counter.

- total Number of Counts or stable states
- 4 stage Counter → Mod 16 → 0000_2 to 1111_2
- Modulo — Count capability.

Mod 10 Counter State diagram.

Ex:1



Ex:2: Let 5 bit Counter starts in 00000. What will be count after 144 i/p pulses.

Solution:

$(144)_{10} = 10010000_2$

Since 5 bit it resets after $2^5 = 32$ clock pulse

$32 \overline{)144}$ 4, 128, 16

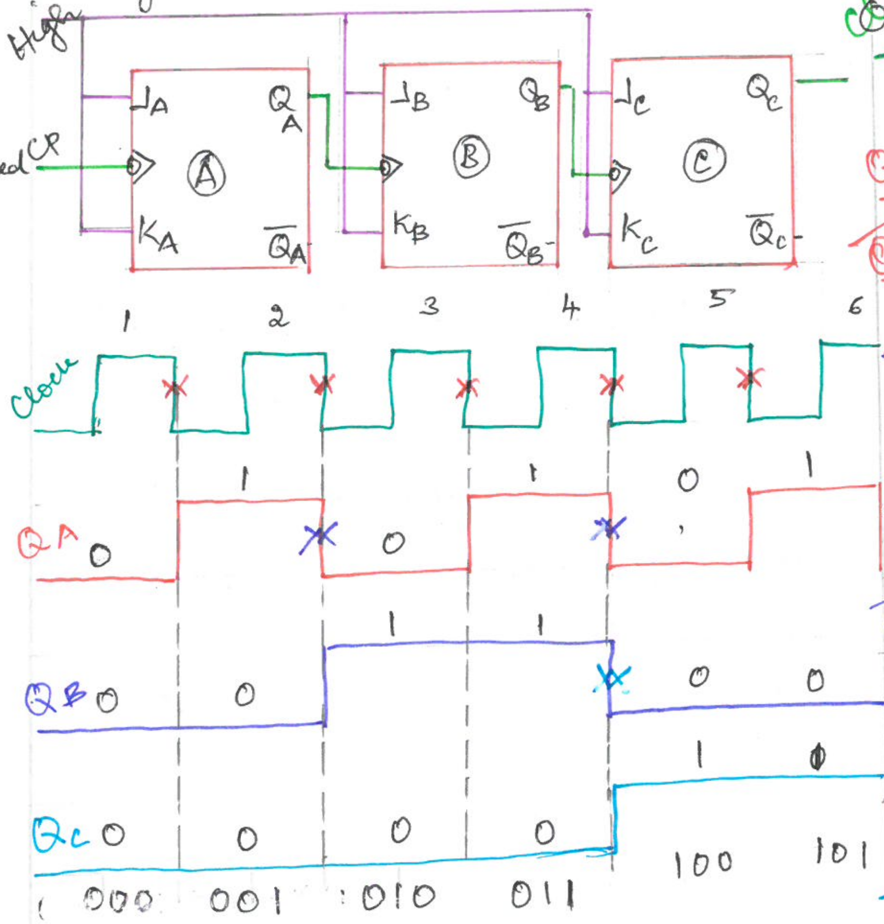
Counter resets four times and then it counts remaining 16 clock pulse. Count will be $(1000)_2$ 16 in decimal.

Design of Counter

Steps
1. Identify the No of variables
2. Construct state table
3. Get the state equation
4. Construct ckt using flipflop.

Asynchronous up counter (Ripple).

3 stage Counter — 3 flipflops, JK flipflop



Clock	Q_C	Q_B	Q_A
1	0	0	0
2	0	0	1
3	0	1	0
4	0	1	1
5	1	0	0
6	1	0	1
7	1	1	0
8	1	1	1

Ex:1 A Counter has 14 stable states 0000 to 1111. if the input frequency is 50KHz. what is o/p frequency

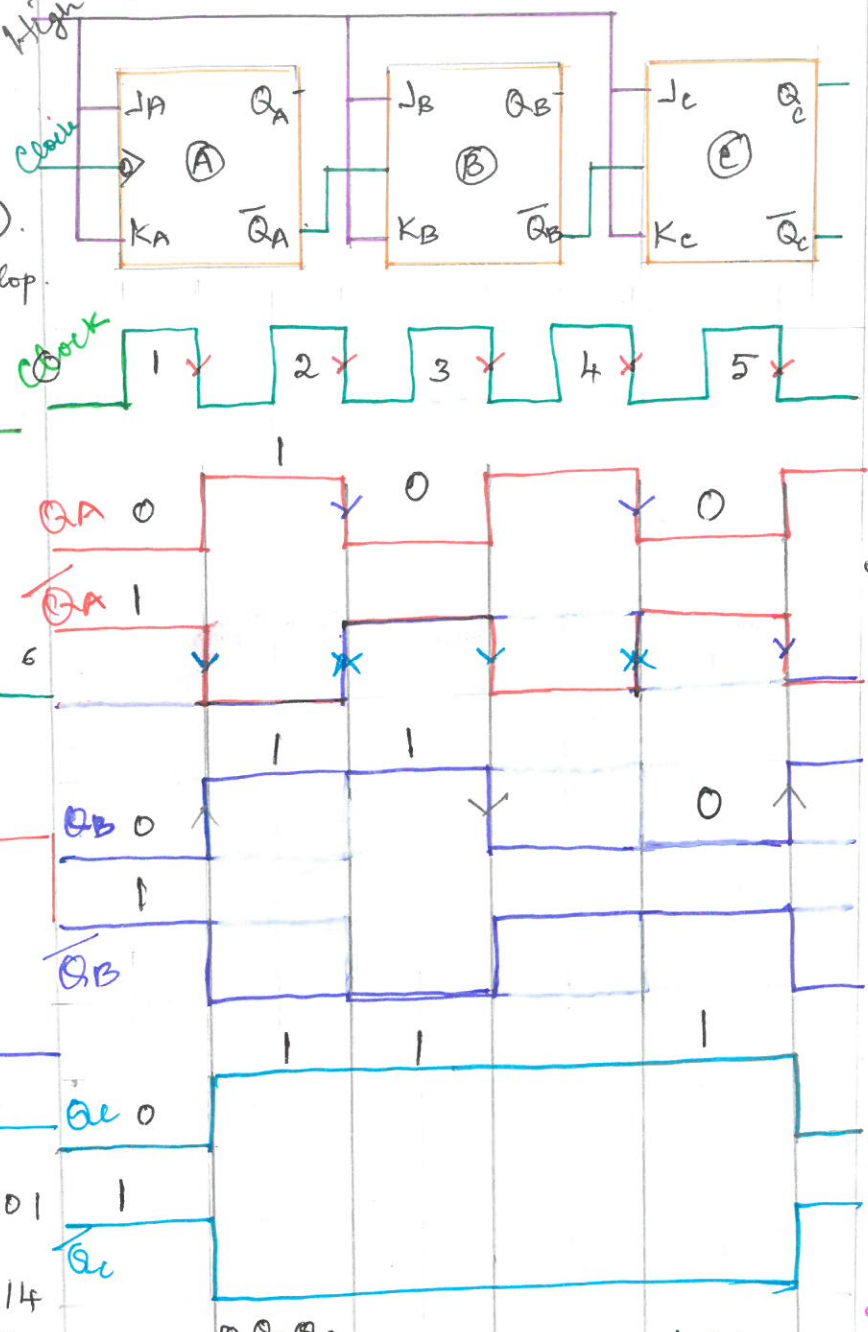
Solution: $\frac{50KHz}{14} = 3.57KHz$

Ex:2 The tpd of each flipflop is 50ns, determine the maximum operating frequency for Mod 32 ripple Counter.

Soln. MOD 32 – 5 flip flop ; $t_{pd} = 50ns$

$f_{max}(\text{ripple}) = \frac{1}{5 \times 50ns} = 4MHz$

Asynchronous down Counter



Frequency at the MSB output of Counter is $\frac{F_{CLK}}{2^N}$, N → No of stages/bits of the counter.

F_{CLK} → frequency of the clock.

Up Counter – Q_A is clock input to next stage.

Down Counter – $\bar{Q}_A$ is clock to next stage

Asynchronous Up / Down Counter

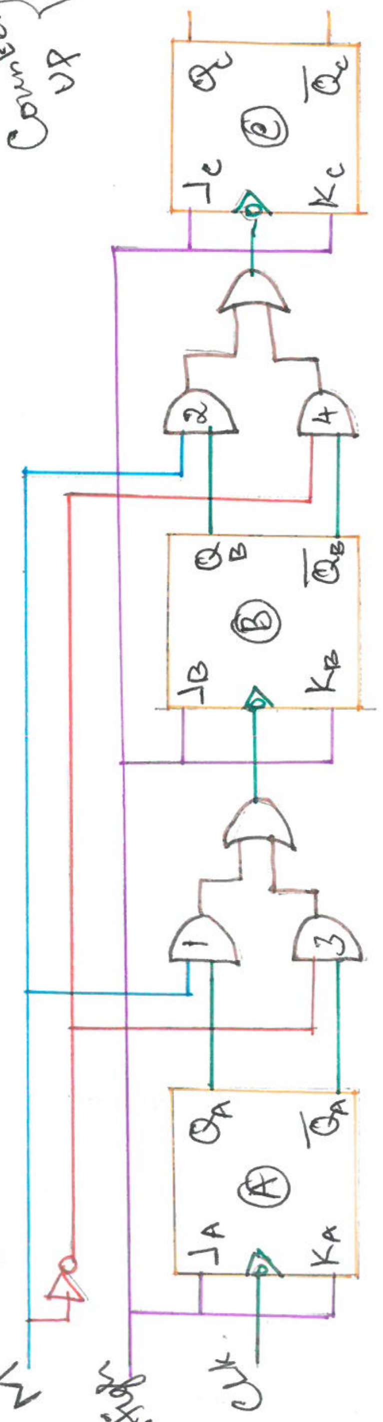
Counter UP { logic 1 → M – enable AND 1, 2; disable AND 3, 4

Q_A & Q_B - clock i/p to next stage.

Counter Down

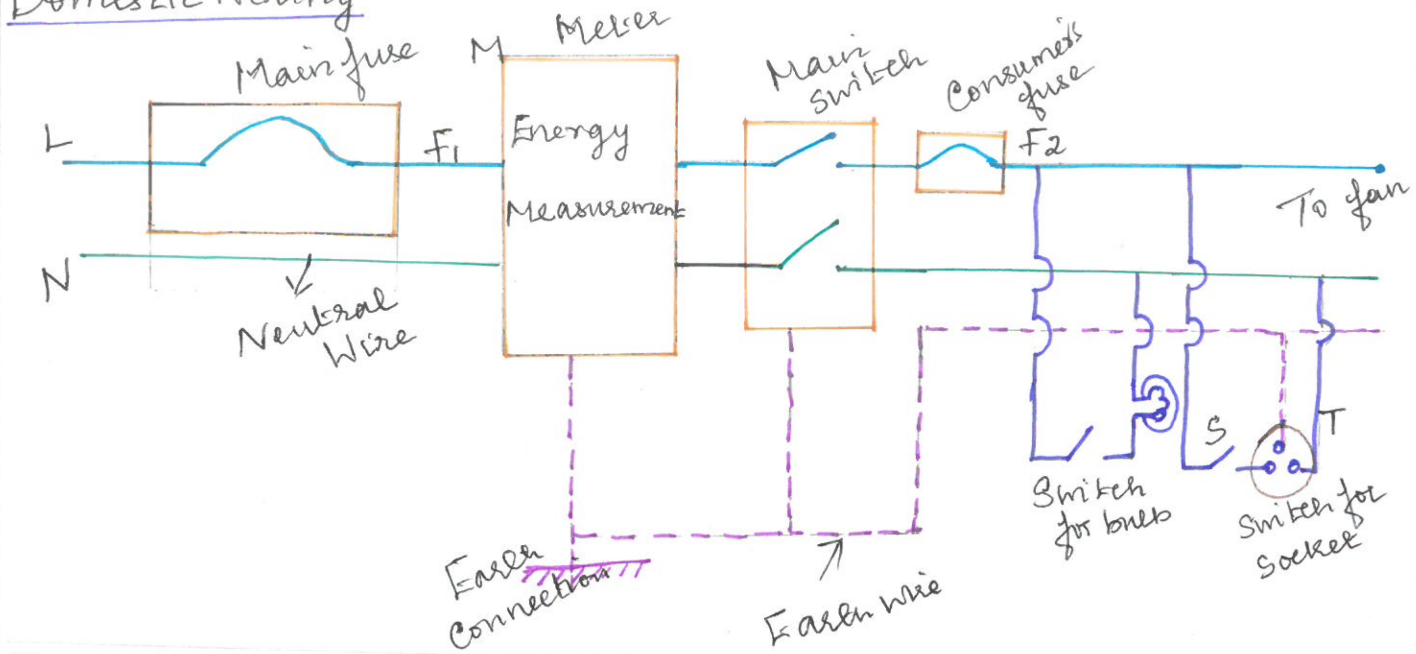
logic 0 – M – Enable AND 3, 4; disable AND 1, 2.

$\bar{Q}_A$ & $\bar{Q}_B$ - clock i/p to next stage



M – Control input – Control the operation.

Domestic Wiring.

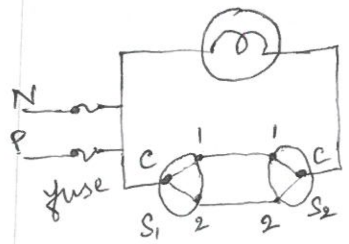


Domestic wiring:
- deals with power distribution inside house, 230V, 1 phase or 400V, 3 phase
- Electricity generated at power station → home – transmitted by parallel wires [live (L), Neutral, Earth]
- Residential loads – connected in ||el voltage remains same through loads, if a circuit fails, it does not affect other.
- House – two seperate circuit
  1. Lighting ckt with 5A fuse
  2. Power circuit with 15A fuse

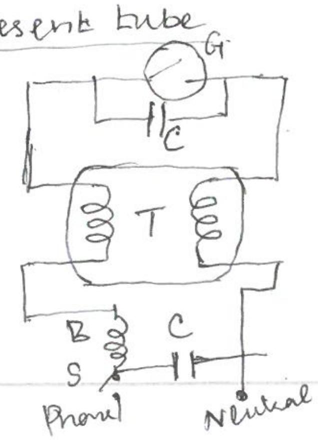
Components of wiring:
1. Switches
2. Lamp holders
3. Ceiling Roses
4. Mounting Blocks
5. Socket outlets
6. Plug
7. Main Switch
8. Distribution fuse boards
9. Accessories used.
10. Two way switch

Types of Wiring
1. Cleat wiring
2. Wooden Casing Capping
3. TRS Wiring
4. Conduit wiring
5. Wiring Circuits
   a) stair case wiring
   b) flouresent wiring

Staircase Wiring
- single Lamp Controlled from two places
- 2, two way switches used.



Flouresent tube

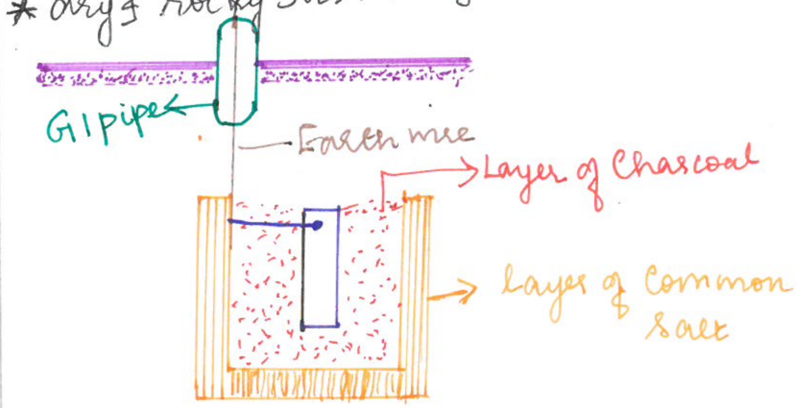


Earthing
- Connected to the Mass of the earth
- Safe discharge of electric Current due to leakage, faults etc.
- Use low resistance wires.
- Before electric Supply lines or apparatus are energized, all earth system – tested for electrical resistance – efficient earthing

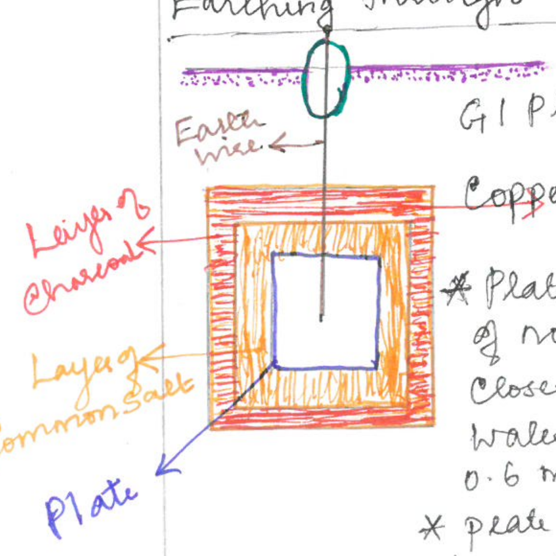
Earthing through a GI pipe

* GI pipe is used as earth electrode
* Size of pipe – Current Carried, type of Soil electrode buried.
* Orginary Soil – Earth electrode
   2m long, 38mm diameter
   1.37m long, 51 mm dia.

* dry & rocky soil, length – 2.75mm



Earthing through a plate



GI Plate – 0.3×0.3m dimen, 6.35mm thick

Copper plate – 0.3×0.3m dimen, 3.2mm thick

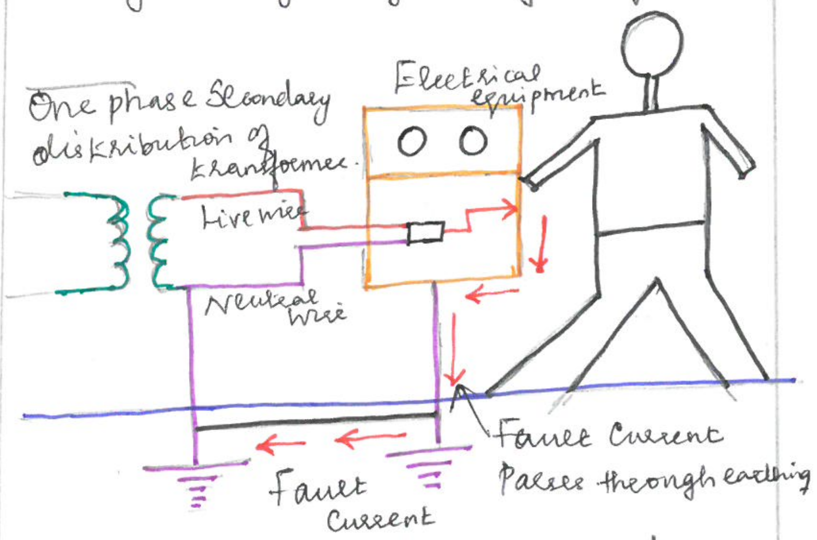
* Plates buried to a depth of not less than 2m in moist, close proximity to water tap, water pipe or water drain. 0.6 m away from Construction

* plate Covered by 80mm charcoal layer of common salt 30mm.

Types of Earthing
a) Neutral Earthing – Neutral – earth, System earthing, System with star winding generator, transformer, motor etc.

b) Equipment Earthing:
- * Electrical Equipment.
- * Non Current Carrying part of equipment – connected to earth

Importance of Earthing:
- Protects from short circuit current
- Provide easiest path to flow short circuit current after failure of insulation
- Protect apparatus and personal from High voltage surge & lightning discharge.



* Fault occurs – Fault current from equipment flows through earthing system to earth.

* Earth mat Conductor rise to the Voltage = resistance of earth mat × ground fault

* Contacting assembly – earthing

* Metallic conductor connect part of installation with earthing – Electrical Connection

* Earthing and Earthing Connection – Earthing system.

Types of Batteries and Characteristics of Batteries

Types of Batteries:

Def:

* Collection of one or more cells.
* Undergo chemical reaction
* Create flow of electrons.

Components:

1) Cathode (Negative Electrode)
2) Anode (Positive Electrode)
3) Electrolytes

Types of Batteries:

1) Primary Batteries
2) Secondary Batteries

Primary Batteries:

* Cannot be recharged.
* Made of electrochemical cells.
* Electrochemical reaction cannot be reversed.
* Ranges: coin cells to AA Batteries
* These batteries always have high specific energy.

Applications:

* Used in standalone applns, where charging is impractical and impossible.
* Pace makers, Animal trackers, Wrist watches, Children toys.

Secondary Batteries:

* Chemical reaction can be reversed
* Can be recharged.
* Used in high drain applications.
  (eg) Mobile phones
  Electric Vehicles

Types of Secondary Batteries:

1.) Lithium-ion (Li-ion)
2.) Nickel Cadmium (Ni-Cd)
3) Nickel-Metal hydride (Ni-MH)
4) Lead-Acid.

1) Lithium ion (Li-ion)

* Lightweight in nature.
* Used in mobile phones

2) Nickel Cadmium (Ni-Cd)

* Hold the charge when not in use.
* Have good life cycle
* Used in electric vehicles, air craft starting batteries.

3) Nickel-Metal hydride (Ni-MH)

* Chemical reaction at the positive electrode is same as (Ni-Cd)
* In negative electrode Hydrogen absorbing alloy is used instead Cd.

4) Lead Acid:

* Used in heavy duty applications
* Low cost.
* Used in non portable applications.

(eg) Solar Panel Energy Storage.

Characteristics of Battery:

1. Types:

* classified based on chemical composition, size, form factor and uses.

2. Voltage:

* Actual voltage is lower than theoretical voltage (IR drop, and polarization - reason)
* Depend on load current, internal impedance

3) Discharge Curve:

* It is plot
* Voltage Vs Percentage of Capacity discharged.

4) Capacity:

$Q = xnF$

$x \rightarrow$ no. of moles of reaction

$n \rightarrow$ no. of electrons transfer per mole of reaction.

$F \rightarrow$ Faraday's Constant.

$Q \rightarrow$ Quantity of electricity.

5) Energy Density:

Energy derived per unit volume of the weight of the cell.

6) Specific Energy Density:

* Energy derived from unit weight of the cell.

7) Power Density:

* Power derived from unit weight of the cell (W/kg)

8) Temperature dependance:

* Rate of reaction will be temperature dependent.
* Low temperatures, higher internal resistance.

9) Service life:

* No. of charge/recharge cycles before its capacity falls to 80%
* 500 to 1200 cycles.

10) Physical Requirements:

* Includes geometry
* Size, weight, shape and location of the terminals.

11) Cycle life:

* No. of discharge/charge cycles before its capacity falls to 80%

12) Cost:

* Cost of battery, Cost of charge, Cost of maintenance.

Elementary calculations for Energy consumption:

Energy consumption – use of Power or energy of a system

Giga joule / year, watts.

Energy consumption formula

$$E = \frac{P \times t}{1000}$$

E → Energy in Kilowatt hours

P → Power in Watts

t → hours.

Power factor

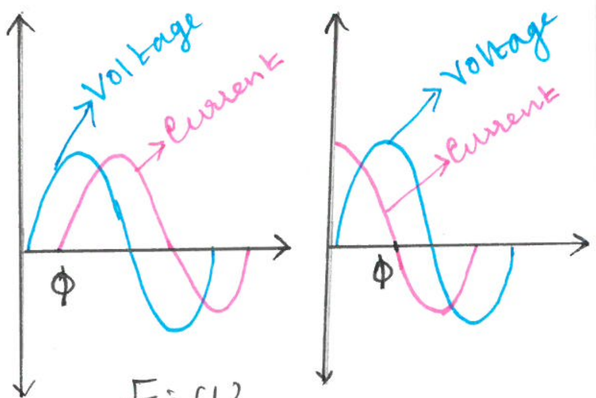
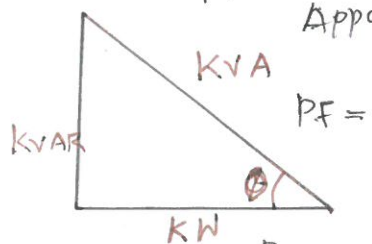


Fig (1)

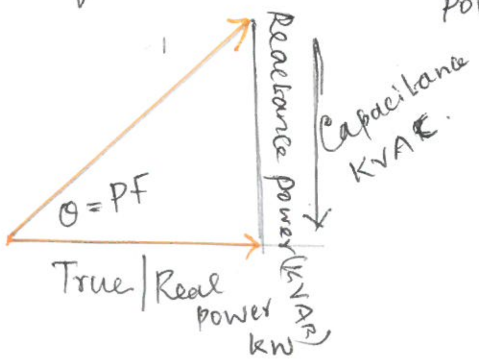
$$PF = \frac{\text{Actual power}}{\text{Apparent power}}$$



PF = Cos θ

Fig (2)

Power factor = Real power / Apparent power



(Fig (3))

Power – Capacity to do work

Electrical power = Electrical energy transferred from one form to other / unit time

Power = Voltage drop across the element × Current flowing through it.

DC circuit with DC voltage source – Inductor & Capacitor – Short ckt & open ckt – Steady state.

AC circuit – Inductor and capacitor – impedence $\boxed{X_L = 2\pi f L, X_C = \frac{1}{2\pi f C}}$

Inductor – Store electrical energy – Magnetic energy; capacitor – electrostatic energy.

Neither dissipiate – Phase shift V & I.

Ckt with resistor, inductor and capacitor – Phase difference b/w source voltage & I – Cosine of phase difference – Power factor $\boxed{-1 < \cos\phi < 1}$

Total power = Voltage across element × Current through the element

apparent power unit VA – S

* Active power – fraction of electric power does our useful work (P) watts

* Reactive power – does no useful work – require for active work to be done. Q

Total electrical power unit = VAR

* reactive power oscillates between source and load.

Ref fig (3) $\boxed{S^2 = P^2 + Q^2}$

Power factor improvement:

$$\cos\phi = \frac{\text{Active power}}{\text{Apparent power}}$$

Need for power factor improvement:

* Electrical current $\propto \frac{1}{\cos\phi}$

* higher the power factor, lower the current flow.

* Small current requires less cross section area of conductor – Save conductor & money

* Poor power factor increase, current flow – Copper loss increases – Poor Voltage regulation.

* KVA rating reduced

$$KVA = \frac{KW}{\cos\phi}.$$

Methods to improve PF.

* Capacitor bank
  - Most loads are inductive
  - Capacitor connected in ||el reduce phase difference.

* Synchronous Condensor:
  - Compensate leading or lagging power factor
  - absorbs or supply reactive power to the line.

* Phase Advancer
  - provides Exciting Ampere turn to produce required flux.

Power factor Calculation.

$$\cos\phi = \frac{P}{VI} = \frac{\text{Wattmeter reading}}{\text{Voltmeter reading} \times \text{Ammeter reading}}$$

General saftey requirements as per IE rules

- All power supply lines & apparatus with
  * proper power rating
  * proper insulation
- Supplier to ensure – Saftey of Apparatus & wires
- Switches on live conductors
- No cut out on Neutral wire
- Code of practice for wiring.
- Energy not to be supplied.

Problem: 1

Compute the energy consumption in a system that consumes 190 W of power and works for 3 hrs / day.

Soln P = 190 W. total hours = 3.

Energy consumption $E = \frac{Pt}{1000}$

$$E = \frac{190 \times 3 \times 60 \times 60}{1000}$$

$$E = 2052 \text{ kWh}.$$

Problem 2: A toy car consume 500 watts of power if it works for 2 hr / day. Calculate energy consumption.

P = 500 W, total hours = 2 hrs

$$E = \frac{Pt}{1000} = \frac{500 \times 2 \times 60 \times 60}{1000}$$

$$= 3600 \text{ k Wh}$$

APPLICATIONS & FUTURE SCOPE OF ELECTRICAL and ELECTRONICS.

Electronics
builds on base of Electric Circuits
Along with concepts of Semiconductor Physics
to create Diodes, Transistors and Integrated Circuits
and basic Circuit Components
Junctional Circuits
Includes Audio Electronics
Includes Digital Electronics
Microprocessors
Makes use of Test Equipment
Transducer
Waveform Generators
Power Supplies.
Find application in Operational amplifiers
Opto Electronic Devices

Digital Circuits
types Combinational Circuits
[eg] encoder, adder, subtractor, code converter etc - [basic gates]
Sequential Circuits
Combinational ckt + flip flops [memory]
Store 1 bit
(eg) counter
Involve Digital logic
Theorems of Boolean algebra
Codified in the logic families
with hardware
Implemented as Integrated Circuits
for Data Collection & control
involve Analog to Digital
and Digital to Analog
have characteristic Basic Vocabulary
and Number System
and standard data Protocol
Alphanumeric Coding
for Communication

Semiconductor Physics
has application of Zener effect
LED
Tunnel diode
Concerns Properties of Si & Ge
Production of P & N type Material
Conduct by Electrons and holes
Can form PN junction
Diodes
and Transistors
operating in Forward bias
or Reverse bias
which form of regular Crystal Lattice
analysed by Band theory of solids

Diode Application
→ Rectification
→ AM detector
→ FM detector
→ Voltage doubler
Varieties
Photodiode
SCR
Triac
Diac
LED
Tunnel diode
Varactor diode
Zener diode
Schottky diode
junction diode

~~Junction transistor~~
JFET
P channel
N channel
MOSFET
depletion mode
Enhancement Mode
Bijunction transistor
Unijunction transistor
Photo transistor

Operational Amplifiers
high gain amplifier
General description
The 741
used for Amplifier Varieties
as well as Switches
and Digital Application
take advantage of large Open loop gain
to make use of Negative feedback
Can be used with Positive feedback
Produce Oscillators
In many cases approach the Ideal OP AMP
which can be analysed by OPAMP rules
→ o/p attempts to do voltage diff b/w i/p zero
→ Input draws no current
but there are Practical limitation

Application of flip flops
1. Shift Registers
2. Counters

Optoelectronics
Involves Light sources
such as LEDs
LCDs
Laser diode
employs light detectors
such as Photoresistors
Solar Cells
Photo transistors
Photodiodes

Core areas of Industrial Electronics
1. Power electronics
2. Factory automation
3. Mechatronics
4. Intelligent systems
5. Internet based applications.

Application of Electronics
1. Calculators
2. digital watches
3. Mobile Phones
4. Laptops
5. Computers.
6. Television
7. Refrigerators etc.

Digital devices
1. LED TV
2. Computer keyboard
3. Digital Clock
4. Proximity Switch
5. Limit Switch
6. Solenoid
7. logic gates
8. Microprocessor
9. Random Access memory
10. Solid state drive
11. Micro Controller
12. Photo diode
13. Relay Contact
14. TV remote
15. Digital Camera
16. Stop watch

Electric Machines
Recent trends → AI
Expert system
Fiber com
Integrated electronics
magnetic levita

* All these New Ideas helps young Engineer to develop newer, cheaper, effective electrical converters and Controllers.
* Area – electrical machines.
→ Availability of Solid state devices of large Current/voltage handling
→ Cheap microprocessors based system for operation and Control
→ development of AI tools, expert system for machine design, operation & control, CAD/CAM techniques.

SIMATS

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