Civinnovate

Discover, Learn, and Innovate in Civil Engineering

U:1: Electric component and circuits

Basic passive component.

(a) active components :- If power is generated. eg. battery, voltage source, current source.

(b) Passive components: if power is consumed,

Inductance and capacitor - store energy

Resistor → absorbed

(a) Resistor:

Resistance :- Resistance is defined as a property of a material to oppose the flow of electric current through it. it depends on intrensic character of material and geometry, it is denoted by R and unit is Ω and given by

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

Where,

ρ → resistivity of material

l → length of "

A → cross sectional area "

Now,

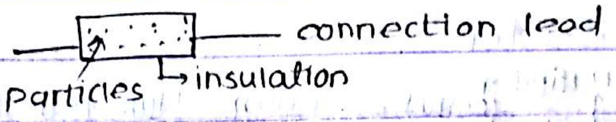
$\rho = RA/l$ if $A = 1m^2$ and $l = 1m$.

Specific resistance is defined as the resistance offered by the body to the flow of current.

Resistor = It is a electronic device built to have specific value of resistance. It is used in circuit to limit or control the flow of current and drive the voltage to produce heat.

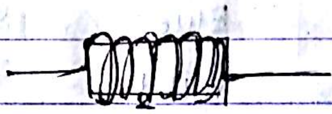
Types of resistors:- (A) ⇒ Fix value

ⓐ carbon resistor:- They are made of finely ground particles of carbon and ceramic and enclosed in a insultaion.

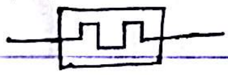


They are compact, robust and easy to manufactor, Temperature sensitive and high tolerence.

ⓑ Wirewounded :- It consists of uniform wire wounded around a insultating material. They have high accuracy so used in the circuit where the value of resistance is very critical.



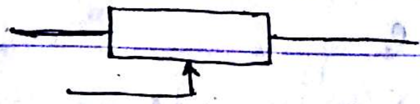
ⓒ Film resistor: Thin or thick layer of resistive material is deposited in an insulating base to make film resistor.

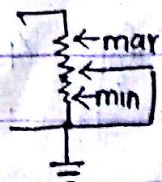


They are very compact and accurate and used in integr-ated circuits.

(B) Adjustable or variable resistor:-

→ value of resistance can be changed from min to max in given range. It is basically cylindrical wire wound resistor with a moveable arm that in contact with a resistance element.

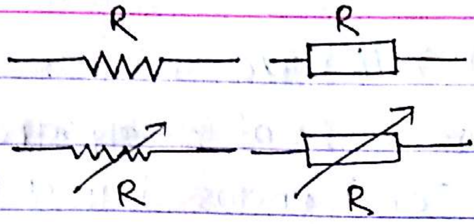
⇒  Rehostate



⇒ Potentiometer (Pot)

⇒ Trimmer if tool is needed to adjust resistance

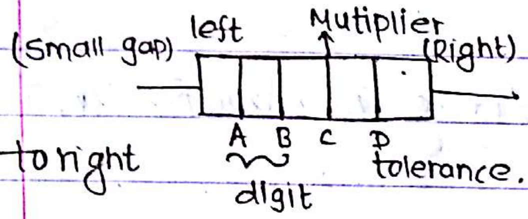
Symbol:



Fixed resistor

variable "

* Color code in Resistor



left to right

R = ABxC ± D

Color	Numerical value	Multiplying factor	tolerance
Black	0	10^0	±0%
brown	1	10^1	±1%
red	2	10^2	±2%
orange	3	10^3	
yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
voilet	7	10^7	
Grey	8	10^8	
White	9	10^9	
Gold	-	10^{-1}	±5%
Silver	-	10^{-2}	±10%
no color	-		±20%

eg: find nominial resistance and possible range of actual resistor of band having color band yellow, voilet, Orange, silver

$R = AB \times C \pm D$

$= 47 \times 10^3 \pm 10\%$ of R

$= 47\ k\Omega$

Range $42.3\ k\Omega$ to $51.7\ k\Omega$

small gap large gap.

(ii) brown, black, red, gold.

Black Boy Ride On Your Green Bike in Very Good weather.

$R = AB \times C \pm D$

$= 10 \times 10^2 \pm 5\%$

$= 1000 \pm 5\%$

$= 1\,k\Omega \pm 5\%$

$R = 1\,k\Omega$

Range $= \left(1000 - 1000 \times \frac{5}{100}\right)$ to $\left(1000 + 1000 \times 5/100\right)$

$= 950$ to 1050

(B) Capacitor

① Capacitance = capacitance is a property of element to store charge in it and oppose to any change in voltage. It is measured in Farad, most common unit µF, NF, PF(10^{-12})

A capacitor is a physical device that store energy by virtue of voltage exist in it.

When, voltage v is applied on a capacitor of capacitance C, then charge stored in it is given by,

$$Q = VC$$

current voltage relationship on capacitor,

$$I = \frac{dq}{dt}$$

$$= \frac{d(vc)}{dt}$$

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

Reactance or Impedance of capacitor :

$Z_c = \frac{1}{wC}$, where, $w \Rightarrow$ angular velocity

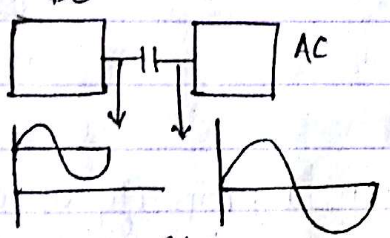
$Z_c = \frac{1}{2\pi fC}$

Application:-

ⓐ It is used to store electrical energy

ⓑ Oppose any change in voltage accross it

ⓒ To couple ac voltage between circuit and oppose DC



Types of capacitor:

ⓐ fixed value capacitor:- Based on dielectric used

- mica capacitor
- ceramic capacitor
- film capacitor.

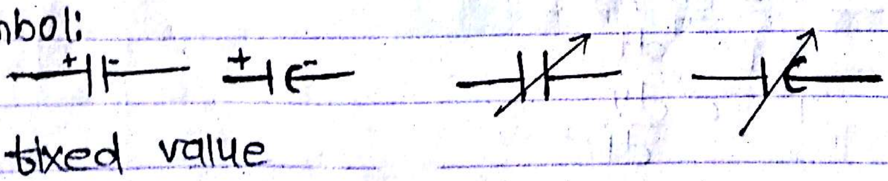
} - non polar capacitor

⊛ Electrolytic capacitor → polar capacitor

ⓑ variable capacitor : variable capacitor is usually made of air dielectric.

For parallel plate capacitor $C = \frac{\epsilon_0 A}{d}$

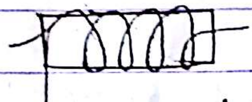
Symbol:



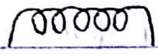
fixed value

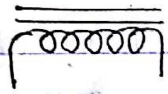
Inductor:-

It is a property of circuit to oppose the change in current through it. Its unit is Henry. Most common unit µH, mH. Inductor is a circuit elements that store energy by virtue of a current flowing through it and store energy in the form of magnetic field.



Based on core used.

air core  core is non ferros material

iron core  core is ferros

in inductor, $V \propto \frac{di}{dt}$

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

$$\therefore L = \frac{V}{\left(\frac{di}{dt}\right)}$$

impedance: $Z_L = jWL = 2\pi fL$ (complex no.)

Application of Inductor

ⓐ Store electrical energy

ⓑ To oppose any change in current through it

ⓒ To block AC signal

Types of inductor

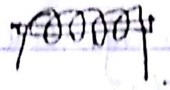
ⓐ fixed value inductor

- → filter chokes → power supply
- → Audio frequency chokes (AFC) to block audio signal

RF chokes: to block radio freq^n signals

ⓑ variables inductor:-

used in tuning circuit, phase shifting and switching of bonds in amplifiers

- movable core-type 
- Tap switching type

Ohm's law:-

Physical condition remaining constant, at constant temperature, the current flowing in any conductor is directly proportional to the potential difference between two ends, ie,

$$I \propto V$$

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

where $\frac{1}{R}$ is a proportionality constant.

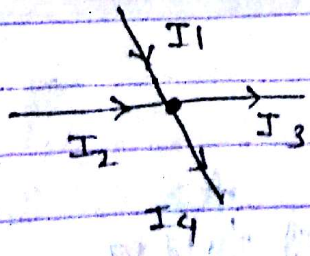
$\therefore V = IR$ → R is defined as the opposition to the flow of electric current through the conductor.

Kirchhoff's law:-

ⓐ Kirchhoff's current law: (KCL):- The algebric sum of of current at any point is zero, ie, $\Sigma I = 0$

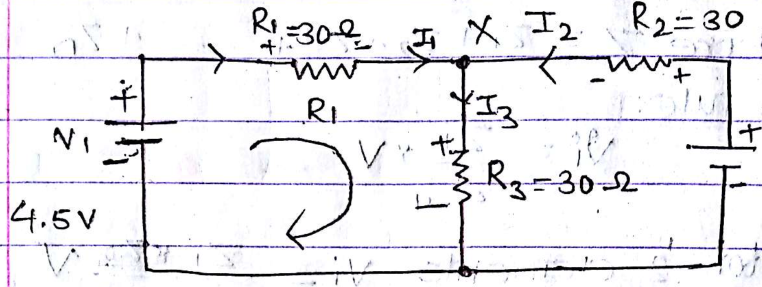
$$I_1 + I_2 = I_3 + I_4$$

$$\Sigma(I \text{ incoming}) = \Sigma(I \text{ outgoing})$$



(b) Krichhoff's voltage law (KVL): The algebric sum of voltage in any closed loop is ~~krichh~~ '0'. or The algebric sum of the product of current and resistance in a loop is zero, ie, $\Sigma V = 0$

or $\Sigma I \times R = 0$



Ans. $I_3 = 0.08\,A$

Sign convention:- voltage drop is taken as negative
voltage rise +ve

loop A ⇒ $V_1 - I_1R_1 - I_3R_3 = 0$

$\therefore V_1 = I_1R_1 + I_3R_3$ ——— (i)

loop B → $V_2 - I_2R_2 - I_3R_3 = 0$

$\therefore V_2 = I_2R_2 + I_3R_3$ ——— (ii)

at point X, KCl

$I_3 = I_1 + I_2$

using eq (i)

$V_1 = I_1R_1 + I_3R_3$

$\therefore V_1 = I_1R_1 + (I_1 + I_2)R_3$

$4.5 = 30I_1 + 30I_1 + 30I_2$

$4.5 = 60I_1 + 30I_2$

$I_1 = \left(\frac{4.5 - 30I_2}{60}\right)$

eq (ii)

$3 = I_2 30 + I_2 30 + I_1 30$

$3 = 60I_2 + 30I_1$

$3 = 60I_2 + 30 \times \frac{(4.5 - 30I_2)}{60_2}$

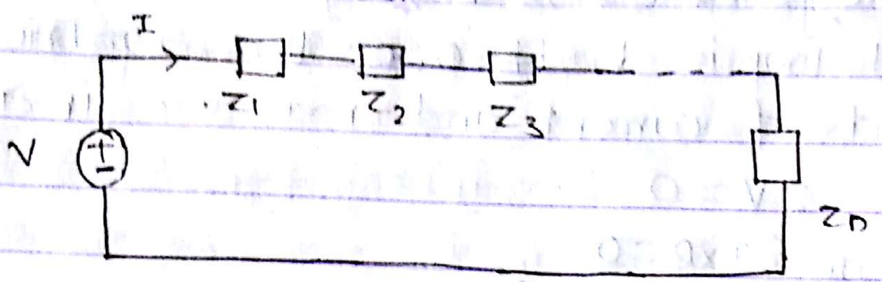
Or, $6 = 120I_2 + 4.5 - 30I_2$

Or, $1.5 = 90I_2$

$\therefore I_2 = \frac{1.5}{90} =$

Series and parallel combination of base components

ⓐ Series combination:



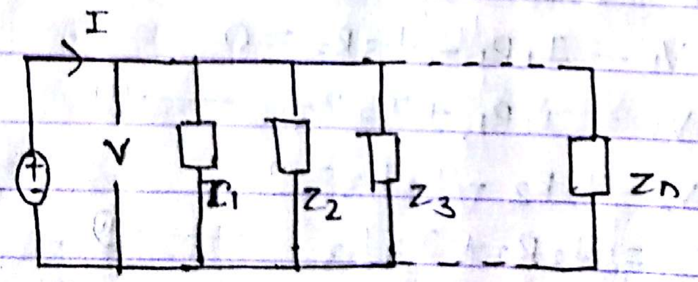
Equivalent impedence $Z = Z_1 + Z_2 + Z_3 + \cdots + Z_n$

Voltage divided rule:

$$V_i = \frac{Z_i}{Z_{eq}} \times V$$

for 2 elements $V_i = \frac{Z_1}{(Z_1+Z_2)} V$

ⓑ Parallel combination:-



$$\frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \cdots + \frac{1}{Z_n}$$

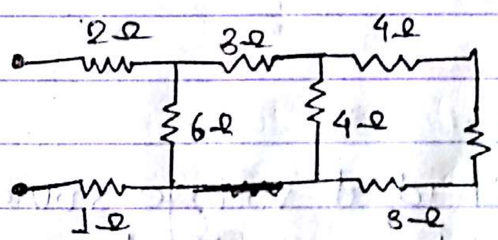
Current divide rule: $I_j = \frac{Z_{eq}}{Z_j} \times I$

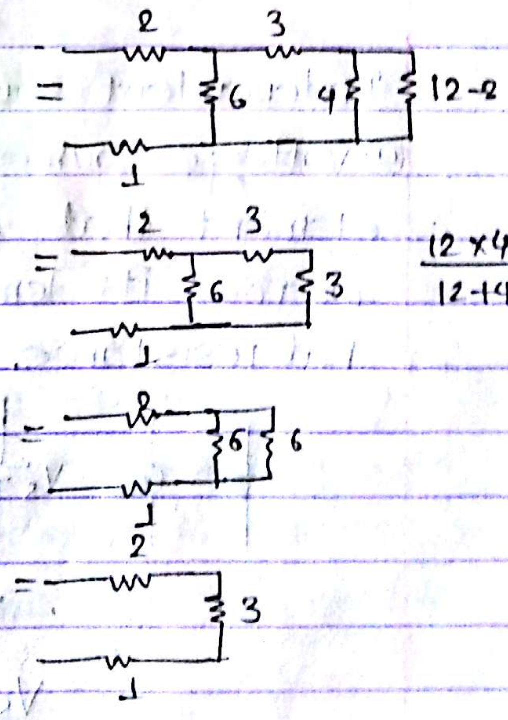
for 2 elements, $I_j = \frac{Z_2}{Z_1+Z_2} \times I$

$$I_j = \frac{Z_2}{Z_1+Z_2} \times I$$

Element	impedence	Series	Parallel.
General	Z	$Z_{eq} = \sum Z_i$	$\frac{1}{Z_{eq}} = \sum_i \frac{1}{Z_i}$
Resistor	R	$R_{eq} = \sum R_i$	$\frac{1}{R_{eq}} = \sum \frac{1}{R_i}$
Capacitor	$C = \frac{1}{JWC}$	$\frac{1}{C_{eq}} = \sum \frac{1}{C_i}$	$C_{eq} = \sum C_i$
Inductor	$L = JWL$	$L_{eq} = \sum L_i$	$\frac{1}{L_{eq}} = \sum \frac{1}{L_i}$

bind Req:



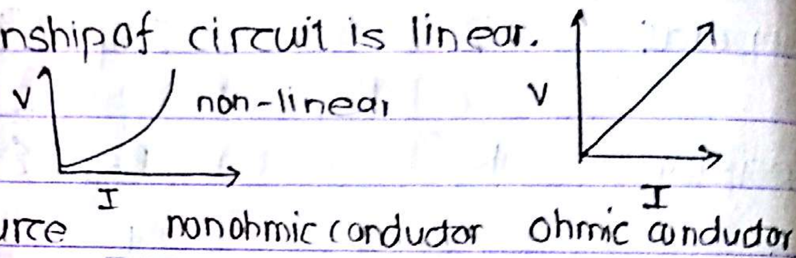


$\frac{12 \times 4}{12+4} = \frac{48}{16}$

$= 3$

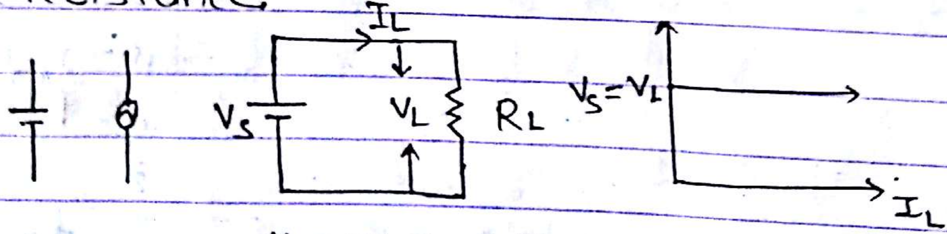
$= 6\,\Omega$

(i) Linearity :- It is a behaviour of circuit in which the input and output relationship of circuit is linear.



(ii) Signal source.
  (a) dependent signal source
  (b) independent signal
  Also it can be classified as
→ voltage source
→ current "

Independent source :-
(a) voltage source: An ideal voltage source is an active element that provide a specified amount of voltage accross its terminal regardless of load. It has no internal resistance.

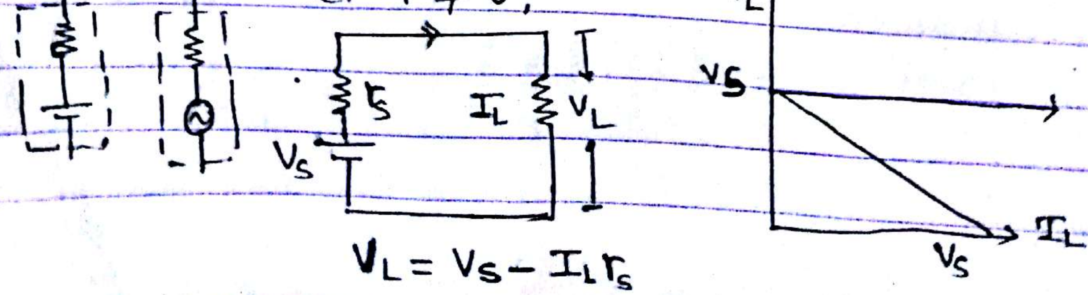


$$V_L = I_L R_L = V_s$$

$$V_s = V_L + I r_0$$

$$\boxed{V_s = V_L}$$

in practical case, internal resistance not equal to zero
ie. $r \neq 0$,

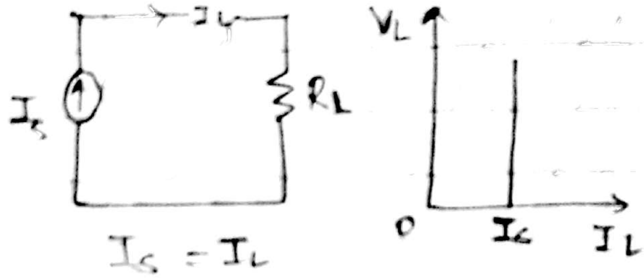


$$V_L = V_s - I_L r_s$$

Independent source

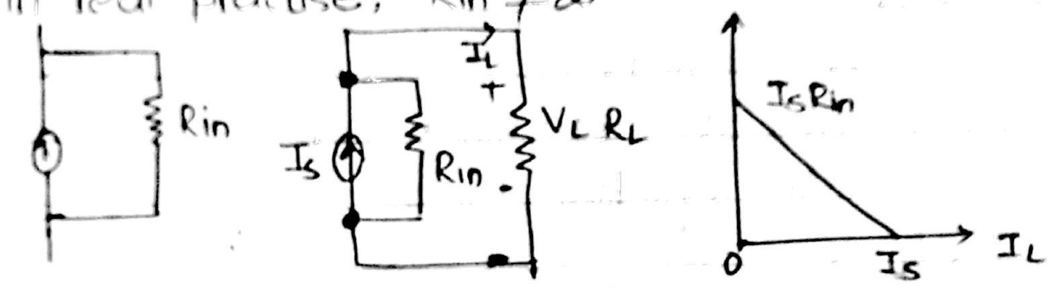
(a) current source

An ideal current source has infinite internal resistance



$I_s = I_L$

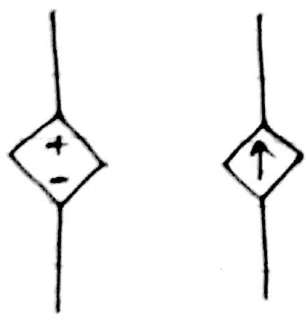
in real practise, $R_{in} \neq \infty$



$$I_L = I_s - \frac{V_L}{R_{in}}$$

1.2.2 Controlled source or dependent source.

An ideal, dependent or controlled source is ~~four~~ two terminal device which output depends on input. dependent source are usually represented by diamond shape symbol.



1. Voltage dependent voltage source : (VDVS)
2. Voltage dependent current source (VDCS)
3. Current dependent voltage source (CDVS)
4. Current dependent current source (CDCS)

① VDVS

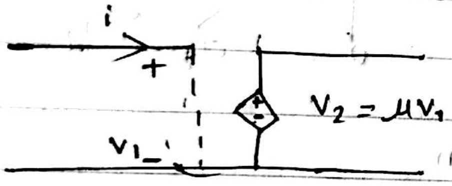
$V_2 \propto V_1$ $V_2 \rightarrow$ output, V_1 = input

or, $V_2 = \mu_1 V_1$

or, $\mu_1 = \frac{V_2}{V_1}$ (volage gain)

μ_1 is unit less and expressed in dB

$$\mu_{dB} = 20 \log (\mu)$$



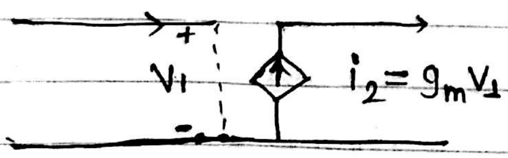
② VDCS

$i_2 \propto V_1$

$I_2 = g_m V_1$

$\therefore g_m = \frac{I_2}{V_1}$ mutual conductance / transconductance

Its unit is siemens



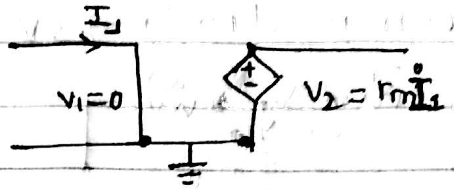
③ CDVS :

$V_2 \propto I_1$

$V_2 = r_m I_1$

$r_m \rightarrow$ mutual resistance or transresistance

unit Ω



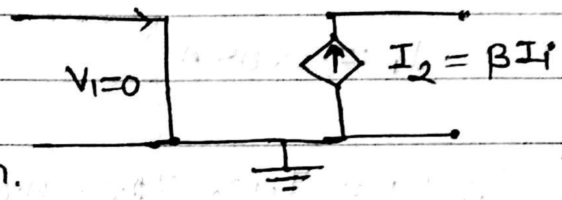
④ CDCS :-

$I_2 \propto I_1$

$\therefore \frac{I_2}{I_1} = \beta$

Where β is current gain.

$\beta_{dB} = 20\log(\beta)$

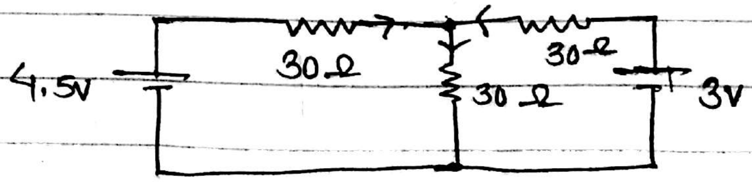


(1.3) Network Theorem:

① Superposition theorem:- 9nd linear network with multiple Source, the current in any branch is the sum of current Which would flow in that branch due to its source acting alone with all other voltage source replaced by short circuit and current source by open circuit.

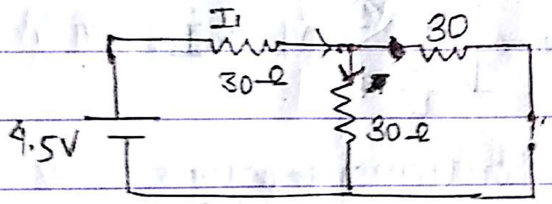
Eg:- find the current flowing through 30 Ω resistor by using superposition Theorem.

Voltage source-short Circuit -



open circuit current

① Case I: Current due to 4.5V



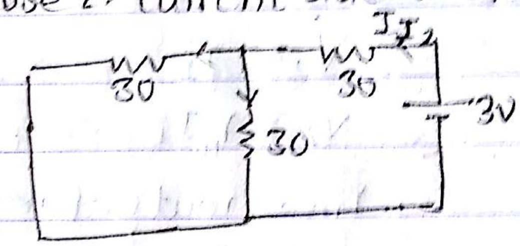
$R_{eq} = 45\ \Omega$

$I_T = \frac{V}{R_{eq}} = \frac{45}{45} = 0.1\ A$

in branch

$I_1 = 0.05\ A$

Case 2: Current due to 3V



$R_{eq} = 45\ \Omega$

$I_T = \frac{V}{R_{eq}} = \frac{3}{45} = 0.06A$

branch.

$I_2 = 0.03\ A$

$\therefore I_T = I_1 + I_2 = 0.05 + 0.03$

through $= 0.08\ A$

$30\ \Omega$

Introduction to filter:

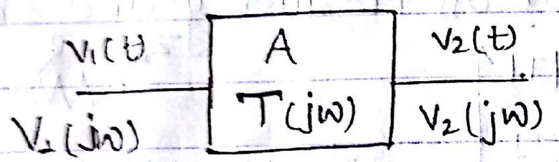
Filter is a network that transmit signal within a given frequency range, attenuates (bypass) all the remaining signal.

A filter posses one pass band (a band of frequencies in which the attenuation is theoritically zero.

* Stopband:- The band of frequency in which attenuation is theoritically infinite.
* The frequency that separate various pass band and stop band is called cut off frequency

* Transfer function and frequency response

Basically, filter circuits are analyzed in frequency domain. freq. response is a steady state response of any circu[it] while subjected to a sinusoidal input.



$v_1(t) = A\cos(\omega t)$

$= Re\left[Ae^{j\omega t}\right]$

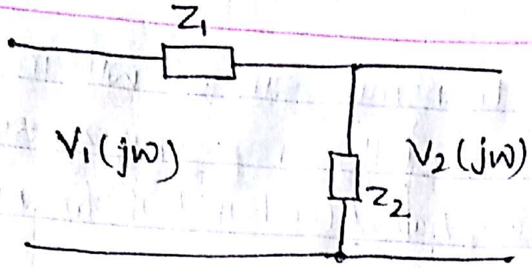
$e^{j\theta} = \cos\theta + j\sin\theta$

$$T(j\omega) = \frac{V_2(j\omega)}{V_1(j\omega)} = \frac{|V_2(j\omega)| \angle \theta_2(j\omega)}{|V_1(j\omega)| \angle \theta_1(j\omega)}$$

$$= \left|\frac{V_2(j\omega)}{V_1(j\omega)}\right| \angle \theta_2(j\omega) - \theta_1(j\omega)$$

$$= |T(j\omega)| - \theta(j\omega)$$

* Plot of Transfer function vs f ⇒ freq^n response.
* Plot of magnitude of $T(j\omega)$ vs f → magnitude respons[e]
* Plot of angle of $T(j\omega)$ vs f → phase response.



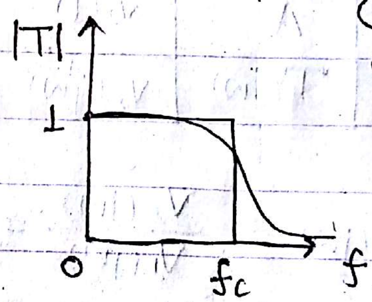
$$T(j\omega) = \frac{V_2}{V_1}$$

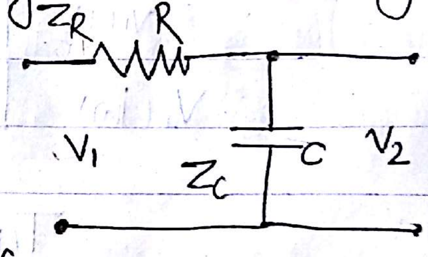
$$\because V_2 = \frac{Z_2}{Z_1+Z_2} \times V_1 \Rightarrow T(j\omega) = \frac{Z_2}{(Z_1+Z_2)}$$

* Types of Filter :- Based on the range of frequency that are allowed to pass, these are

(a) low pass filter (0 to cut off frequency)
(b) high " " (above cutof " and block low freq)
(c) band pass " pass signal betn low cutoff and high cutoff fr
(d) band stop " stop " " " " " "

(a) low pass filter:- An ideal low pass filter passes low frequency signal from 0 to cut off frequency and blocks signal above that range.





$$Z_R = R$$
$$Z_C = \frac{1}{j\omega C}$$

$$T(j\omega) = \frac{V_2}{V_1} = \frac{1/j\omega C}{R+\frac{1}{j\omega C}} = \frac{1}{1+\frac{j\omega}{\omega_0}}$$

where, $\omega_0 = \frac{1}{RC} \Rightarrow f_0 = \frac{1}{2\pi RC}$ = cutt off freqn: $= f_c$

$$|T(j\omega)| = \frac{1}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}}$$

$\omega_0 = 1 \Rightarrow |T(j\omega)| = 1$

$\omega = \omega_0 \Rightarrow |T(j\omega)| = \frac{1}{\sqrt{2}} = 0.707 \Rightarrow 3dB$

$\omega = \infty \Rightarrow |T(j\omega)| = 0$

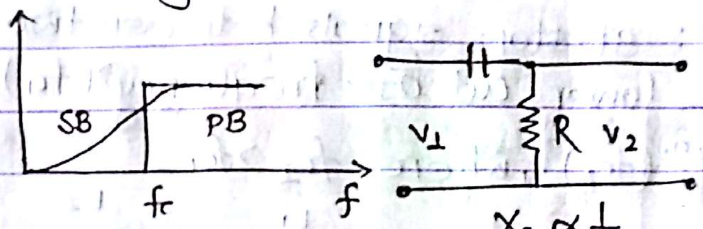
$Z_C = \frac{1}{j\omega C} \propto \frac{1}{f}$

(i) $V_2 = V_1$, $f = 0$, $X_C \to \infty \Rightarrow V_2 = V_1$

(ii) $f = f_c \Rightarrow X_C = R, \Rightarrow V_2 = 0.707 V_1$

(iii) $f = \infty \Rightarrow X_C = 0 \Rightarrow V_2 = 0$

* High Pass filter : A high pass filter passes signals above a cut off frequency and block the lower frequency.



$X_C \propto \frac{1}{f}$

$X_C = R$

$\frac{1}{2\pi f_c C} = R$

$\therefore f_c = \frac{1}{2\pi RC}$

$f = 0, X_C \to \infty, V_2 = 0$

$f = f_c, X_C = R \Rightarrow V_2 = 0.707 V_1$

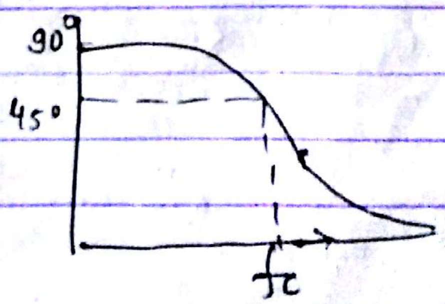
$f \Rightarrow \infty, X_C = 0, V_2 = V_1$

$$T(j\omega) = \frac{V_2}{V_1} = \frac{R}{R + \frac{1}{j\omega C}} = \frac{1}{1 - j/\omega RC} = \frac{1}{1 - j\frac{\omega_0}{\omega}}$$

Where, $\omega_0 = \frac{1}{RC} \Rightarrow f_c = \frac{1}{2\pi RC}$ = Cut off freq^n.

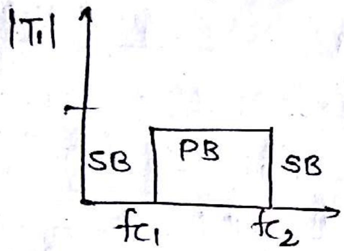
$$|T(j\omega)| = \frac{1}{\sqrt{1 + \left(\frac{\omega_0}{\omega}\right)^2}} \text{ i.e., } \angle\theta = 0 + \tan^{-1}(\omega_0/\omega)$$

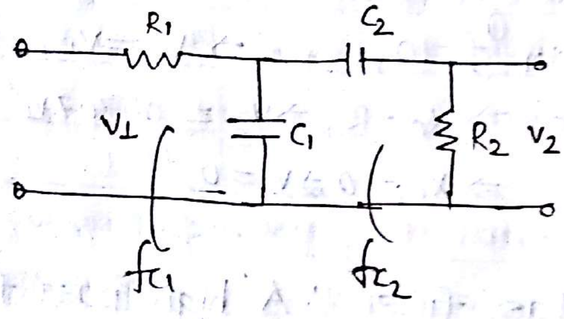
ω	$\lvert T(j\omega)\rvert$
0	0
ω_0	0.707
∞	1



* Band pass filter :

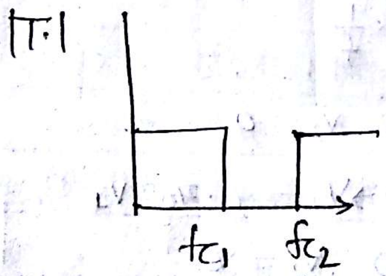
It passes signals betn two cut off frequency known as lower cut off freqn (f_{c1}) and higher cut off freq. (f_{c2}), where $f_{c2} > f_{c1}$

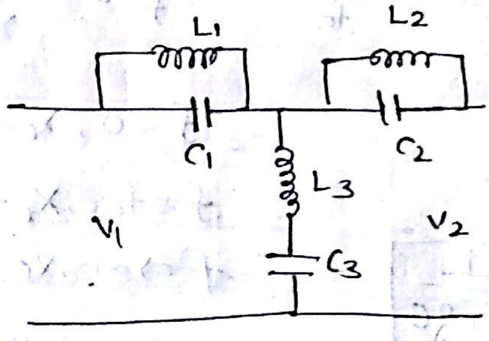


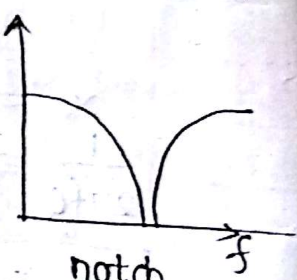


$f_{c1} = \frac{1}{2\pi R_1 C}$ $f_{c2} = \frac{1}{2\pi R_2 C}$

* Band ~~pass~~ stop filter: It stops signals between two cutoff frequency known as lower cut off frequency (f_{c1}) and higher cut off freqn. (f_{c2}), where $f_{c2} > f_{c1}$







notch filter

Remaining part:

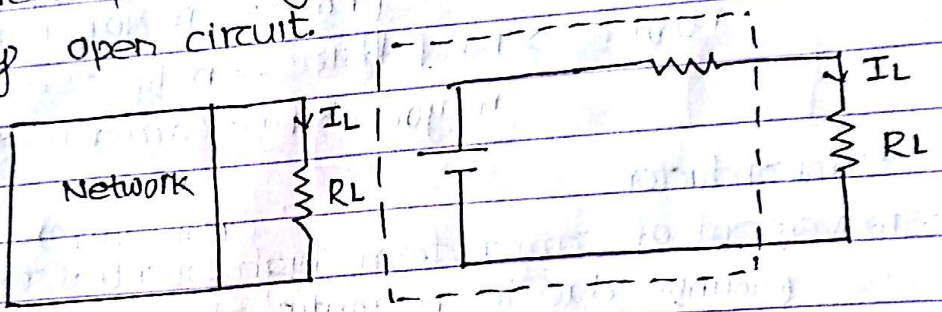
Thevenin's Theorem.

Any circuit can/be be replaced by a series combination of ideal voltage source V_{Th} and a resistance R_{Th}.

where, V_{Th} is known as Thevenin's Voltage:

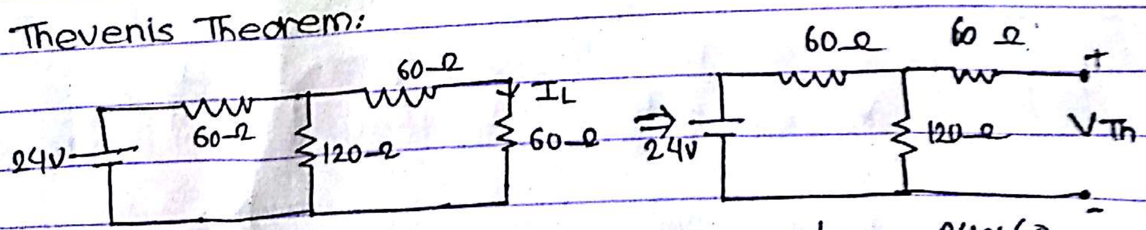
It is a open circuit voltage across load terminal equivalent.

R_{Th}: Thevenin resistance: It is the total resistance at the open circuited terminal when all voltage source are replaced by short circuit and all current source by open circuit.



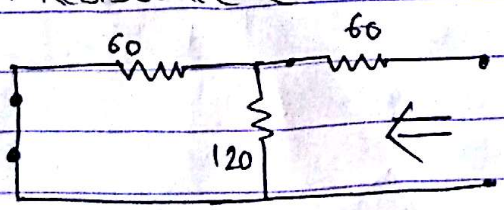
Current flowing through $R_L \Rightarrow I_L = \frac{V_{Th}}{R_L + R_{Th}}$

Eg: find current through 60Ω, by Thevenis Theorem:



$$\therefore V_{Th} = \frac{24 \times 60}{60 + 120} = 16V$$

for Resistance (R_{Th})



$$R_{Th} = 60 \| 120 + 60$$

$$= \frac{60 \times 120}{60 + 120} + 60$$

$$\therefore R_{Th} = 100\Omega$$

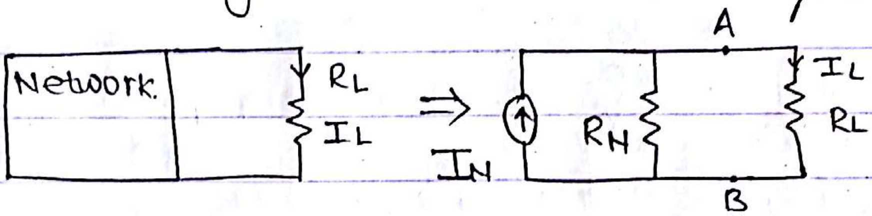
$$\therefore I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{16}{100 + 60} = 0.1\ A$$

(b) Norton's Theorem:

Any circuit can be replaced by parallel combination of current source, I_n and resistance R_n.

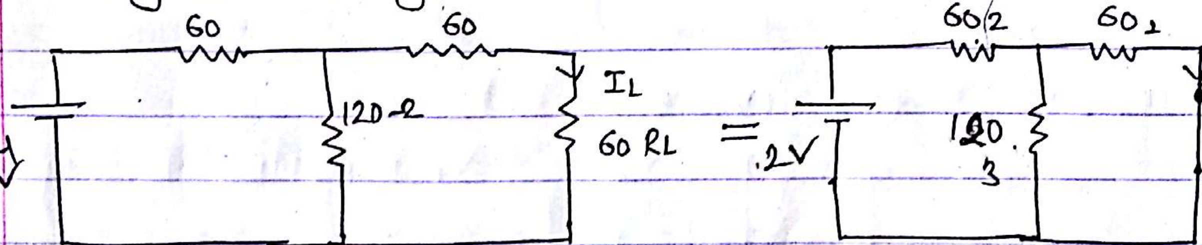
I_n → current passing through selected pair of terminal with short circuited.

R_n → It is a total resistance at the terminal AB, when all voltage source are replaced by short circuit and all current source are replaced by open circuit.



Current source is a component whose task is to provide a constant amount of current outputting as much or as little voltage necessary to maintain constant current.

eg.



① remove load Resistor from original circuit and short circuit.

I_L can be calculated as

$$I_L = \frac{I_n \cdot R_n}{(R_n+R_L)}$$

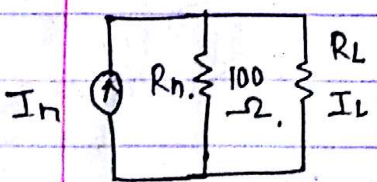
$$= \frac{R_n}{(R_n+R_L)} \times I_n$$

$$R_{eq} = (60 \parallel 120 + 60)$$

$$= \frac{60 \times 120}{60+120} + 60$$

$$\therefore R_n = 100\ \Omega$$

for I_n



$$I_n = \frac{120 \times 0.24}{120+60} = 0.16V$$

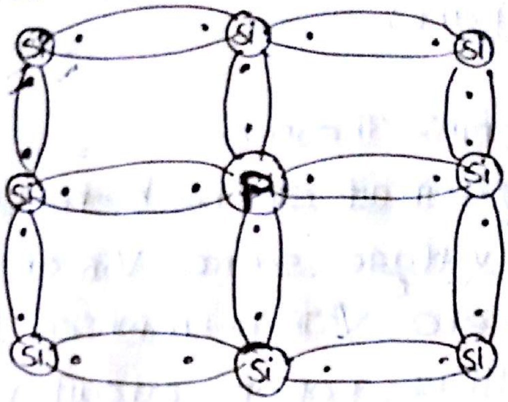
So,

$$I_L = \frac{0.16 \times 100}{100+60}$$

$$= 0.1\ A$$

$$I_t = \frac{V}{R} = \frac{24}{100} = 0.24A$$

C:2 Basic condcept of semiconductor



Si
Ge } valence electron 4

at 0 K, pure semiconductor act as insulator.

Pure semiconductor or Instrinsic — majority charge carries
impure " or Extrinsic — minority " "

adding impurities -- doping

(i) Tri-valent (B) — no of hole > no of electron. P type semiconductor (hole is major charge carrier)

(ii) Penta valent (P) — no of e^- > no of hole → n type semic conductor, major charge carrier is electron.

(1) Conduction in semiconductor

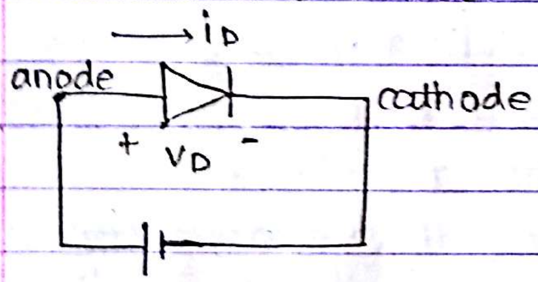
(a) Diffusion :- movement of carriers from high (concentrⁿ) potential to low potential (mainly due to majority charge carriers)

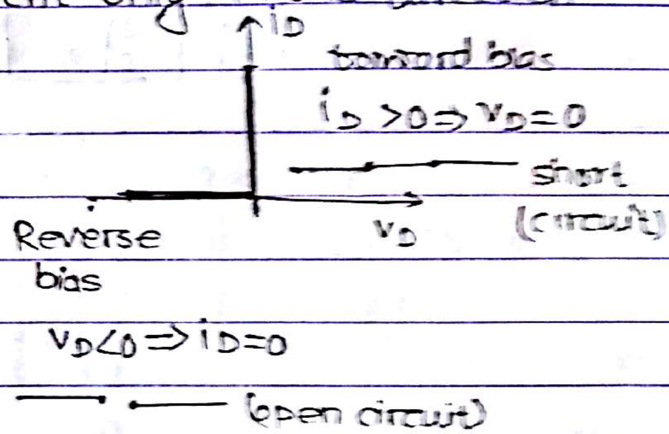
(b) Drift :- in presence of electric field:- for same material minority charge carries moves.

Semiconductor:

2.2 Diode :-

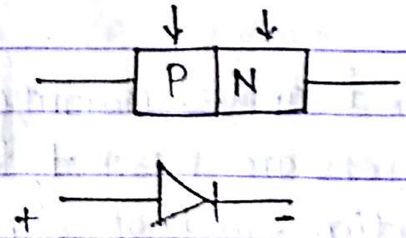
Ideal diode:- Ideal diode a fictitious two terminal element that conducts current only in one direction



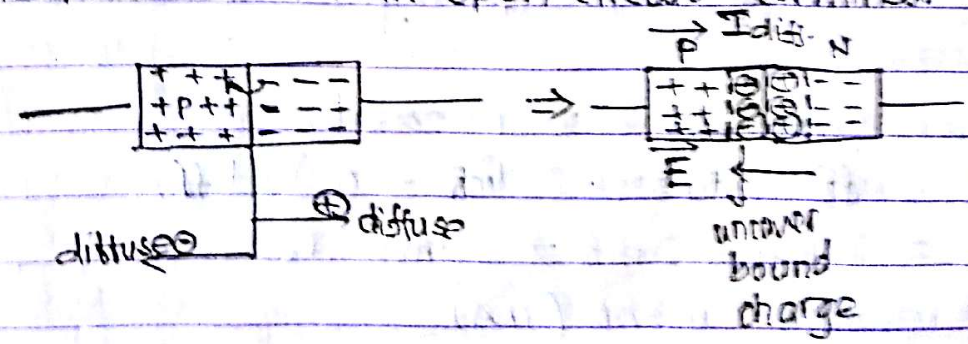


2.3: Semiconductor diode:

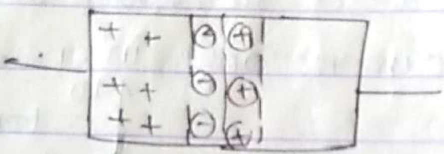
(PN) Junction diode are real diode that can be built. A PN Junction is formed by introducing donor impurities in one side and acceptor impurities into otherside of the single crystal of diode.



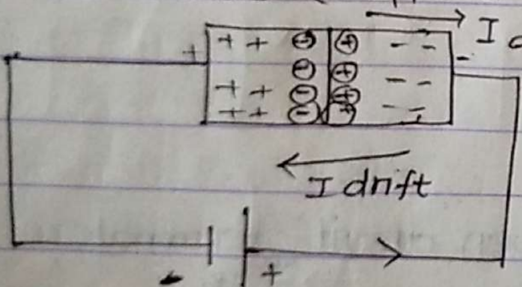
2.3.1: The PN Junction with open circuit terminal:



ⓐ Forward bias :-



Reversed bias :- (V applied < 0)



V_r is applied - Majority charge carriers are repelled from junction - width of depletion region increases and barrier potential also increased.

I diff reduces, (I diff → 0) (diff)

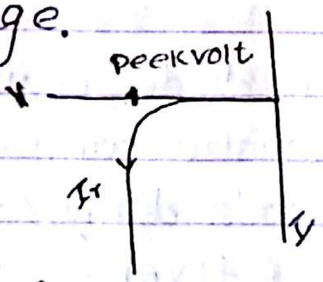
$\therefore I = I_{drift} - I_{diff} = I_{drift} = I_s$

I = reverse current (μA)

When reverse bias voltage is increased but net electric field increase, but drift current doesn't change because no of carriers drifting across the junction is small. so the current that exists under reversed biased condition is called reversed saturation current (I_s).

I_s doubled its value for every 5° centrigrade rise in temperature. The typical value range from 10^{-8} to 10^{-15} A.

When the magnitude of reverse voltage (V_r) exceed the threshold value called breakdown voltage, the reverse current increase rapidely, with small voltage increase then diode is said to be breakdown. The max. reverse bias voltage that can be applied before entering the breakdown voltage is known as peek reverse voltage or peek inverse voltage.



Break Down Method:

ⓐ Avalanche Breakdown:	Zener Breakdown
ⓐ Occurs in lightly dopped PN Junction	Occurs in heavily dopped PN-Junction.
ⓑ Breakdown voltage is greater than 5V	Zener voltage is less than 5V
ⓒ Minority carriers are generated by collision.	Minority carriers are generated by Electric field in deplition region.

Voltage current relationship of diode:

diode current:

$i_D = I_s\left(e^{V_D/nV_T} - 1\right)$

Where, I_d = current through diode

$V_D \rightarrow$ voltage across diode

$I_s \rightarrow$ saturation current

$V_T \rightarrow$ Thermal voltage $= \frac{KT}{q}$

Where, $K \rightarrow$ Boltzbann constant) $(1.38 \times 10^{-23}$

T – absolute temperature.

$q \rightarrow$ electron charge

$n \rightarrow$ Identity factor or material scale factor, it has value betn 1 and 2, asume $n=1$, unless otherwise specified.

$V_T \approx 25\,mV$ (at room temp)

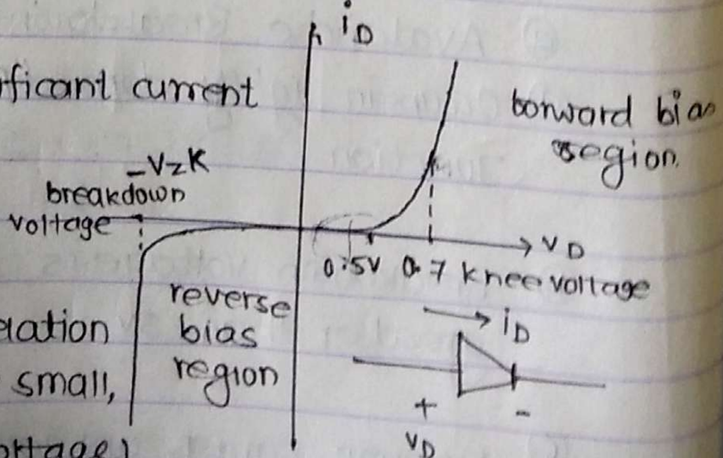
Semiconductor diode characteristic:

The characteristic curve shows the voltage ampere behaviour of diode during forward and reversed biase condition, $i_D = f(V_D)$

Ⓐ Forward Bias

In forward bias region significant current flow, ie, $(V_D > 0)$ / $(I_D >> i_s)$

So, $i_D = I_s\left[e^{V_D/nV_T}\right]$

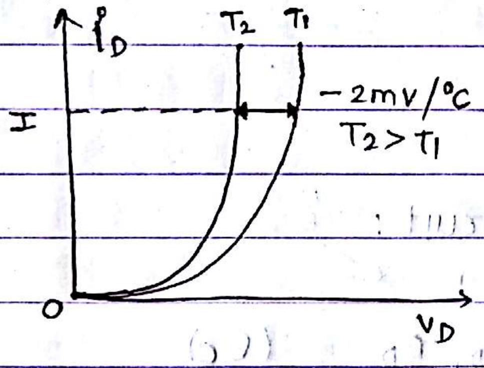


due to exponential I–V relationship current is neglisibally small, for, $V_D < 0.5V$ (cutting voltage) after the diod voltage reaches the Threshold voltage, the diode current rises sharply for small increment of diode voltage.

For fully conducting diode,

$0.6 < V_D < 0.8V$

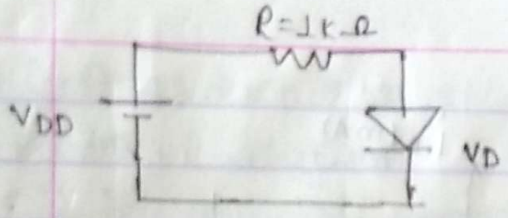
* Temperature Dependence :At given constant diode current



The diode voltage decreases approximate $-2mV/°c$, where as current approximate increase with temperature.

(B) Reverse bias Region:- ($V_D < 0$)/($i_D \approx -I_s$), Ideally, the reverse current is constant and independent of reverse bias voltage so it is called saturation current. However practically reverse current is much larger that Is, due to leakage effect and also increases some what increase in reverse bias voltage.

Temperature dependence:- Reverse current double for every 10°c rise in temperature.



decay VD = 0.1V

Now, $I_1 = 1mA$

$V_1 = 0.7V$

$V_{D2} - V_{D1} = 2.3nV_T \log\left(\frac{I_{D2}}{I_{D1}}\right)$

or, $0.1 = 2.3nV_T \log(10)$

or, $0.1 = 2.3nV_T \times 1$

$\therefore 2.3nV_T = 0.1$

for,

ite. 1: $I_1 = \frac{5-0.7}{1\times10^3} = 4.3 \text{ mA}$

$V_2 = V_1 + 0.1 \log(I_2/I_1)$

$= 0.763V$

it 2: $I_3 = \frac{5-0.763}{1\times10^3} = 4.237 \text{ mA}$

$V_3 = V_2 + 0.1 \log\left(\frac{I_{D2}}{I_{D1}}\right)$

$= 0.763 + 0.1 \times \log\left(\frac{0.4237}{4.3}\right)$

$V_3 = 0.762 \text{ V}$

$V_3 - V_2 = 0.762 - 0.763 = -0.01 \text{ V}$

$V_D = 0.762V$

$I_D = 4.237 \text{ mA}$

2.5 Modeling The diode:

Modeling is a representation of device with equivalent equipment element such as inductor, capacitor, voltage and current source. The equivalent circuit that doesn't loose functional behaviour is called modeling of diode. The model of diode for DC and AC is different.

DC Model: Large signal model:

ⓐ Ideal diode model:

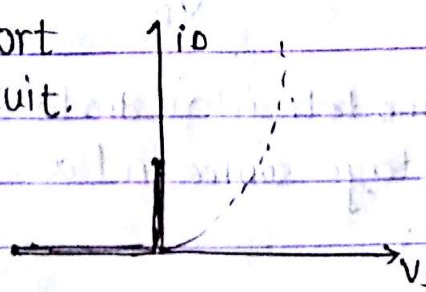
must simplified model

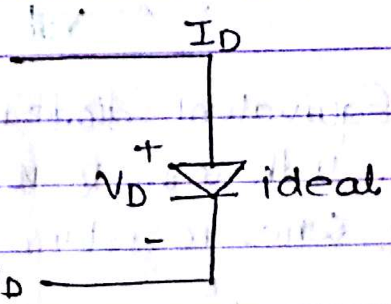
used when supply voltage is much higher than diode voltage

Mathematically. Diode on : $I_D > 0$, $V_D = 0$ [short circuit]

diode off : $V_D < 0$, $I_D = 0$. [open circuit]

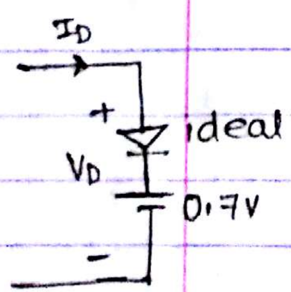
forward bias - short circuit.





ⓑ Constant voltage drop model:

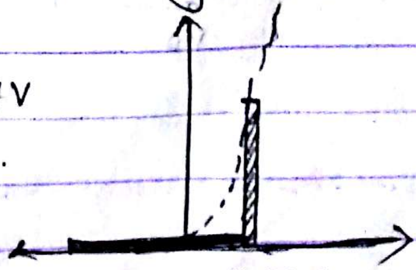
Mostly used in the initial design and analysis phase. It is assumed that the forward conducting diode exhibit a constant voltage drop V_D (usually 0.7V)



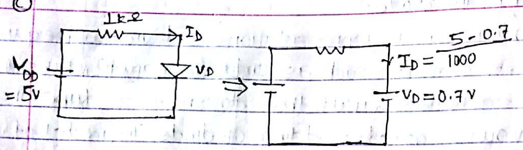
Mathematically:

Diode on $I_D > 0$, $V_D = 0.7V$

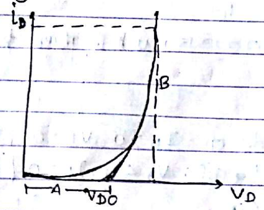
diode off $V_D < 0.7V$ $I_D = 0$.



ⓒ



* Piecewise linear model:
battery plus resistance model.



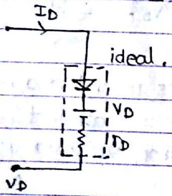
mathematically,
diode on: $I_D = \frac{V_{DD} - V_{D0}}{r_D}$

$V_D \geq V_{D0}$

diode off: $V_D \leq V_{D0}$, $I_D = 0$

where, $r_D = \frac{\Delta V_D}{\Delta I_D}\Big|_{pt\ to\ pt}$ = inverse slope of line B
= average ac resistance or toward bias resistance

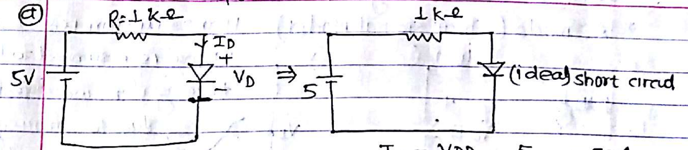
* Equivalent diode model: ideal diode with a 0.7 V voltage source and a series resistance.



Ⓐ let, $V_{DD} = 5V$, $R = 1K\Omega$, calculate I_D and V_D by
(i) ideal diode voltage model
(ii) Constant voltage "
(iii) Picewise linear model

ideal model concept

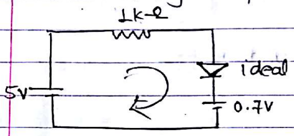
ⓐ



$I_D = \frac{V_{DD}}{R} = \frac{5}{1 \times 1000} = 5mA$

$V_D = 0$

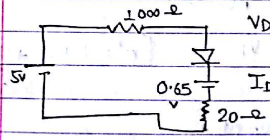
ⓑ Constant voltage drop:



$I_D = \frac{5-0.7}{1000}$
$= 4.3mA$
$V_D = 0.7V$

5.

ⓒ Picewise linear model:



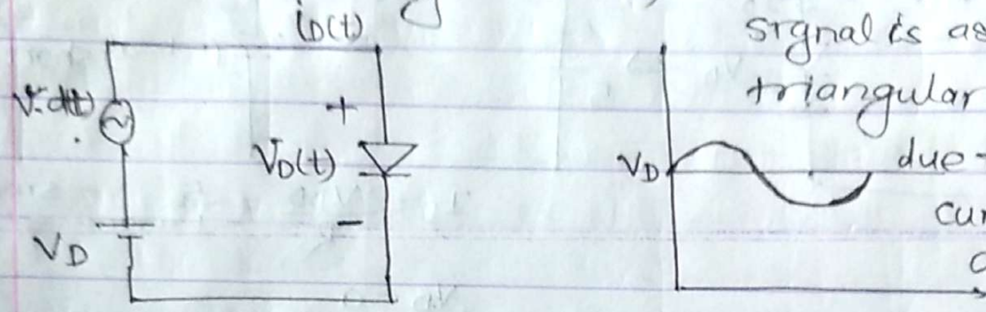
$V_{D0} = 0.65V$, $r_D = 20\Omega$

$I_D = \frac{5-0.65}{(1000+20)} = \frac{4.35}{1020} = 4.26mA$

$V_D = 0.65V + I_D \cdot r_D$
$= 0.65 + 4.26 \times 10^{-3} \times 20$
$= 0.735V$

Small signal $v_d(t)$ is superimposed on V_D due to this dc voltage the operating point of diode is $Q(V_D, I_D)$. Now, if we consists the effect of superimposed small signal $v_d(t)$ on diode voltage and current variation are shown.

* AC mode (Small signal Model)



Here superimposed small signal is assumed to be triangular waveform, due to small signal current and voltage across the diode.

Assumption : signal amplitude is subbiciently small ($v_d \leq 10mV$)

Total instantaneous diode voltage

$$v_D(t) = V_D + v_d(t)$$

instantaneous current :

$$i_D(t) = I_S e^{\frac{v_D(t)}{nV_T}}$$

$$= I_S e^{\frac{V_D + v_d(t)}{nV_T}}$$

$$= I_S e^{\frac{V_D}{nV_T}} \cdot e^{\frac{v_d(t)}{nV_T}}$$

$$i_D(t) = I_D e^{v_d(t)/nV_T}$$

$$\left[e^x = 1 + \frac{x}{1!} + \underbrace{\frac{x^2}{2!} + \frac{x^3}{3!}}_{\text{neglect}}\right]$$

under small signal assumption,

$$i_D(t) = I_D\left(1 + \frac{v_d(t)}{nV_T}\right)$$

$$= I_D + \frac{I_D v_d(t)}{nV_T}$$

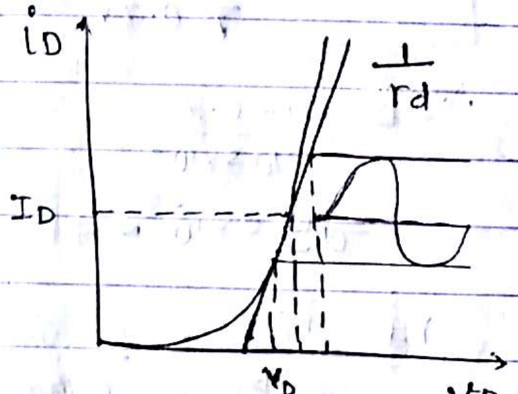
$$\therefore i_D(t) = I_D + i_d$$

$$\therefore i_d = \frac{I_D v_d(t)}{nV_T} = \frac{v_d(t)}{r_d}$$

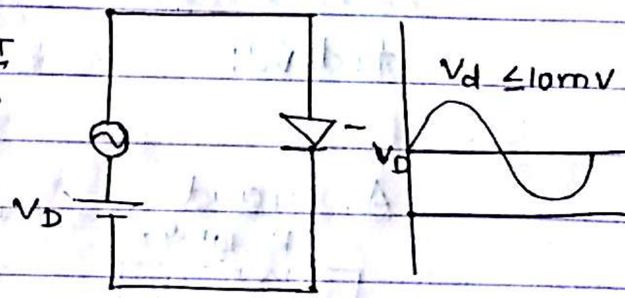
~~So, $r_d = \frac{v_d(t)}{i_d}$ is d.~~

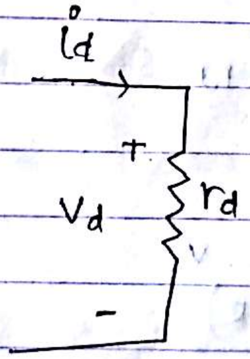
$\therefore r_d = \frac{nV_T}{I_D}$ known as diode small signal resistance or dynamic resistance.

Equivalent circuit model: dynamic resistance



$r_d = \frac{nV_T}{I_D}$

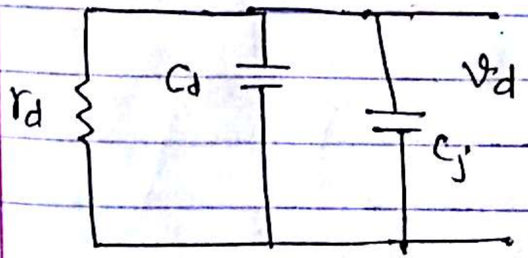




$$r_d = \frac{1}{\frac{\partial i_D}{\partial v_D}} = \frac{nV_T}{I_D}$$

$$i_D = I_S e^{\frac{v_D}{nV_T}}$$

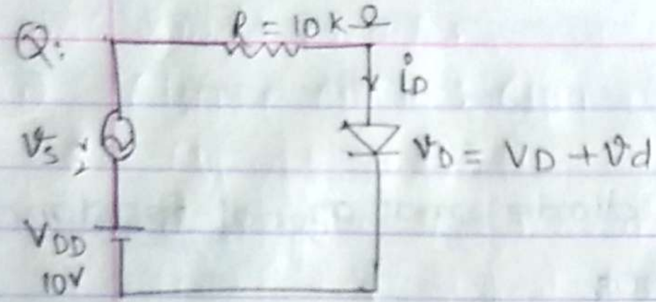
Small signal high frequency model



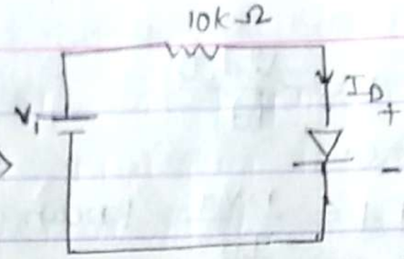
C_d → diffusion capacitance

C_j = depletion capacitance
Junction capacitance

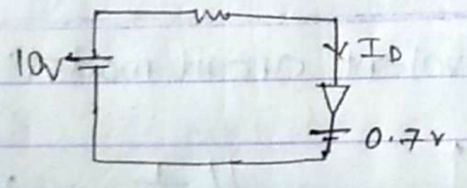
Q:



$\Rightarrow$



Equivalent DC circuit:



$V_D = 0.7V$ at 1mA

diode n = 2

$V_T = 0.025V$

find v_d;

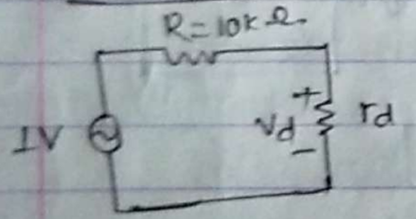
$\because I_D = \frac{10 - 0.7}{10^3 \times 10}$

$= 0.93 \times 10^{-3}$ A

$r_d = \frac{nV_T}{I_D} = \frac{2 \times 0.025}{0.93 \times 10^{-3}}$

$= 53.8\ \Omega$.

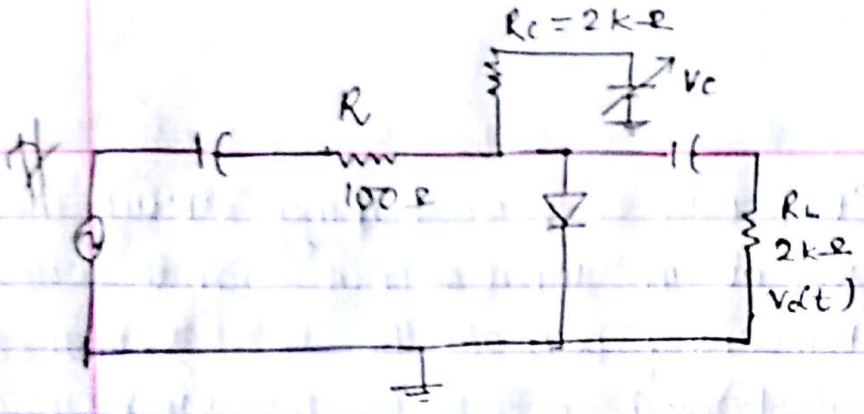
AC circuit



$\because V_d = \frac{r_d}{(r_d + R)} v_s$

$= \frac{53.8}{(53.8 + 10 \times 10^3)}$

$= 5.3$ mV



n = 1 at 300K

$V_T = 0.026V$

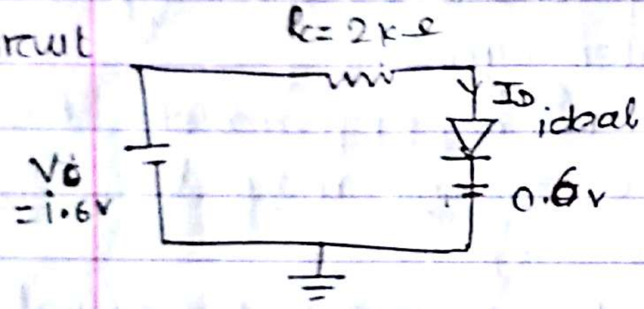
$V_D = 0.6V$

$A_V = \frac{V_o}{V_{in}}$

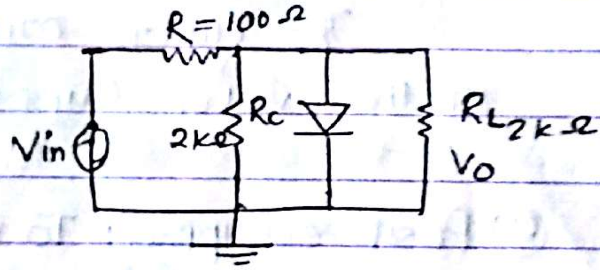
$V_c = 1.6V$

$V_c = 10.6V$

DC circuit



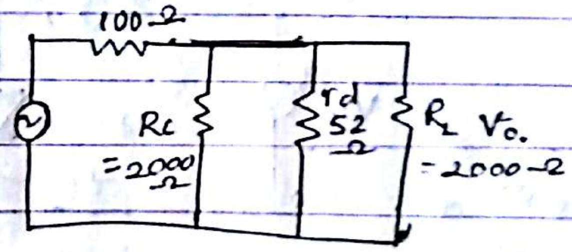
AC circuit



$I_D = \frac{1.6 - 0.6}{2 \times 1000}$

$= 0.5mA$

$r_d = \frac{nV_T}{I_D} = 52\Omega$



$R_{eq} = (2000 // 2000) // 52$

$= 1000 + 52$

$= 1052\Omega$

$R_p = 49.43\Omega$

$V_o = \frac{R_p}{R_p + R}$

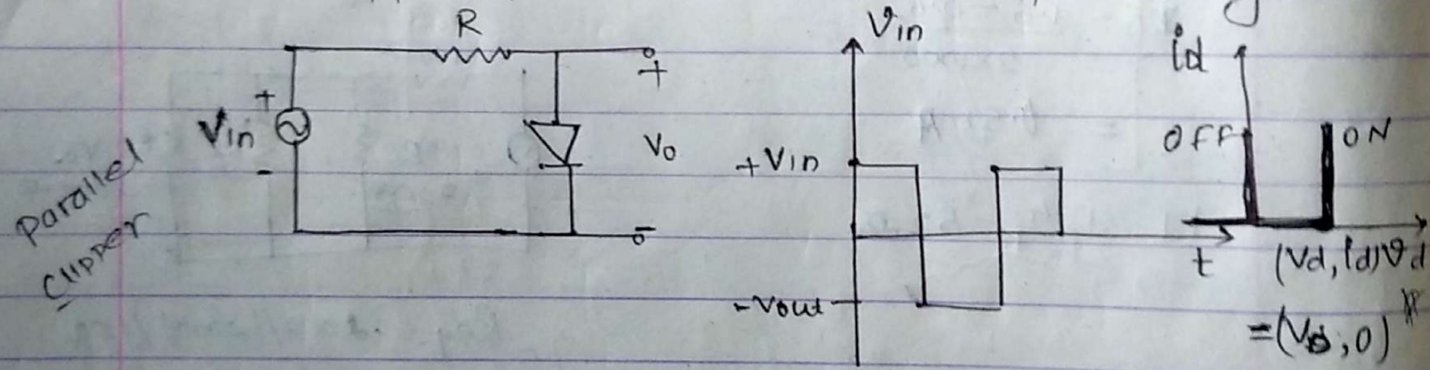
$\therefore A_V = \frac{V_o}{V_{in}}$

2.6 Diode circuit

(Imp) Clipper circuit: Clipper is a waveshaping circuit that clip off a portion of an input output signal without destroying the remaining part of the waveform. It is used for signal shaping and to the following circuit. It is also known as limiter circuit.

The cliper could be ~~reverse~~ series or parallel based on the level of clipping, the clipping may be:

(a) Positive clipper:- To remove the positive part of signal



* Input ~~output~~ voltage required to turn on diode:

apply $i_D = 0$, $V_D = V_D$

KVL

$V_{in} = V_D$

$\therefore V_{in} > V_D$ to turn on the diode.

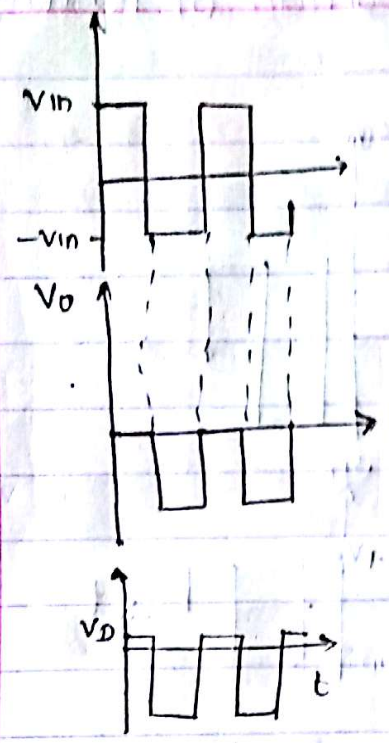
* Output in both states

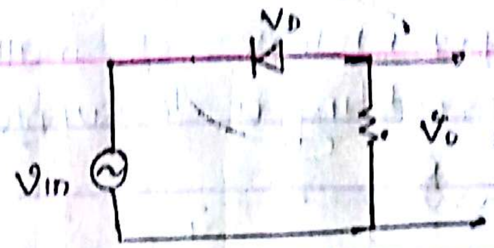
when diode is on, $V_o = V_D$

off, $V_o = V_{in}$

for ideal, $V_D = 0$, so,

~~Vin = 0~~

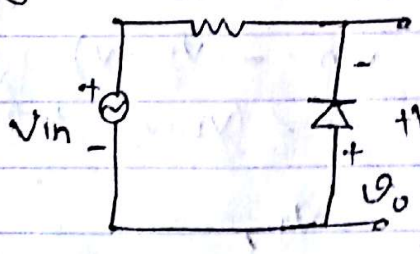


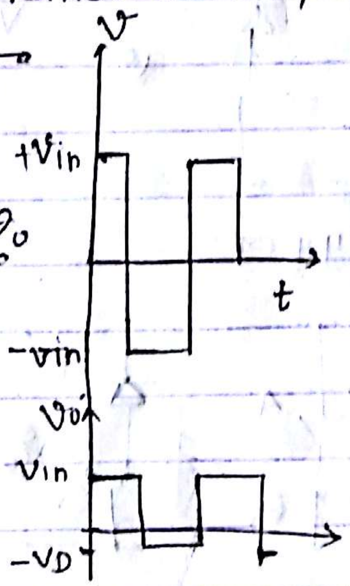


series clipper.

output is taken across resistor

Ⓑ Negative Clipper : removes -ve part of signal





applying KVL:

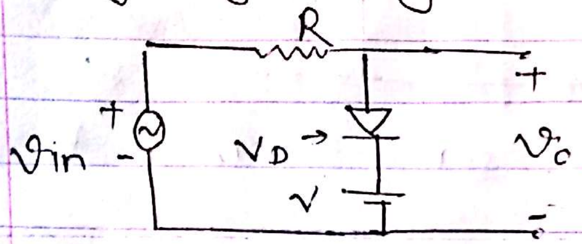
$V_{in} = -V_D$

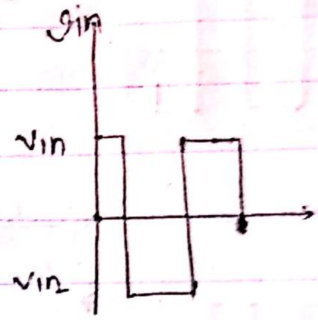
$V_{in} < -V_D$: to turn on diode

Diode is ON $\Rightarrow V_o = -V_D$

Off, $V_o = V_{in}$

(+ve) Biased clipper: removes a small portion of positive or -ve cycle by adding a dc supply:



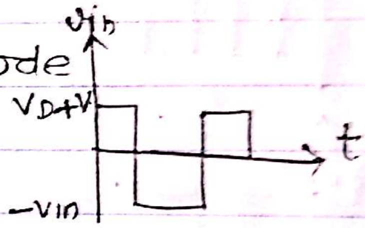


$v_{in} = V_D + V$

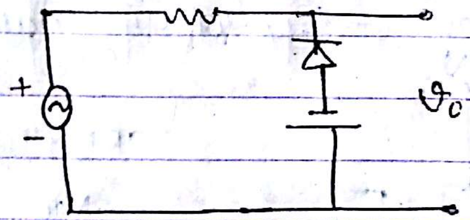
$v_{in} > (V_D + V)$ to turn on a diode

ON ⇒ $v_o = V_D + V$

OFF $v_o = v_{in}$



-ve Bias Clipper:



$v_{in} + V_D + V = 0$

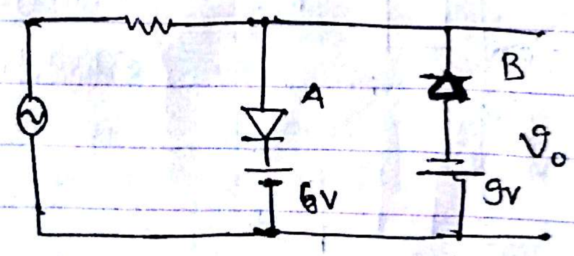
$v_{in} = -(V_D + V)$

$v_{in} < (V_D + V)$ to turn on.

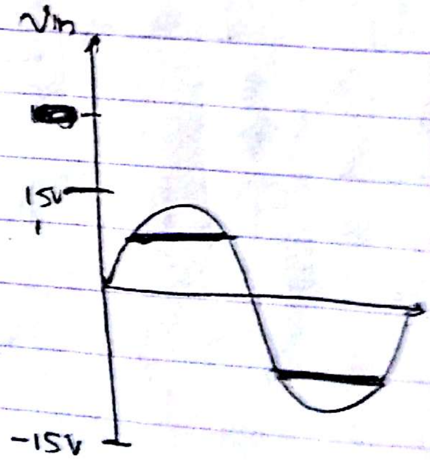
ON $v_o = -(V_D - V)$

$v_o = v_{in}$

(d) Combination Clipper:-

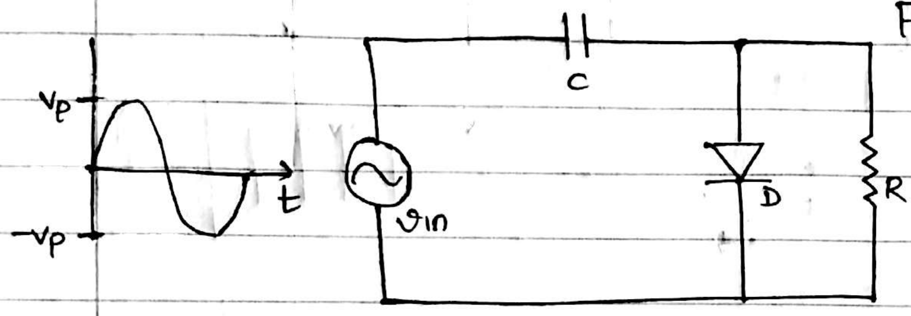


6
9



Clampar circuit:

Clampar circuit is used to add a DC voltage to AC signal so that +ve and -ve peaks are clamped to a specific dc level. It must have a capacitor, diode and resistor:



Following two assumption are used in clamper circuit

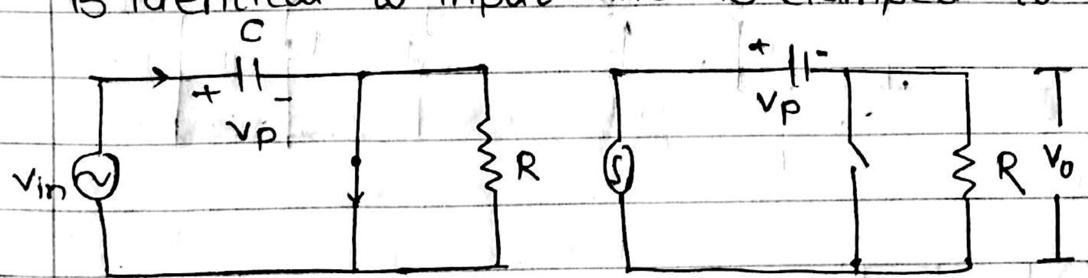
(i) capacitor charged quickly

(ii) discharge is very slow

negative clampar circuit:

On the positive half cycle, the diode turns on, shorting the resistor. The capacitor will charge upto a voltage quickly with the polarity shown. slightly beyond the +ve peak, the diode turns off. since the time constant ($t=RC$) is made very large the capacitor retains the voltage identically.

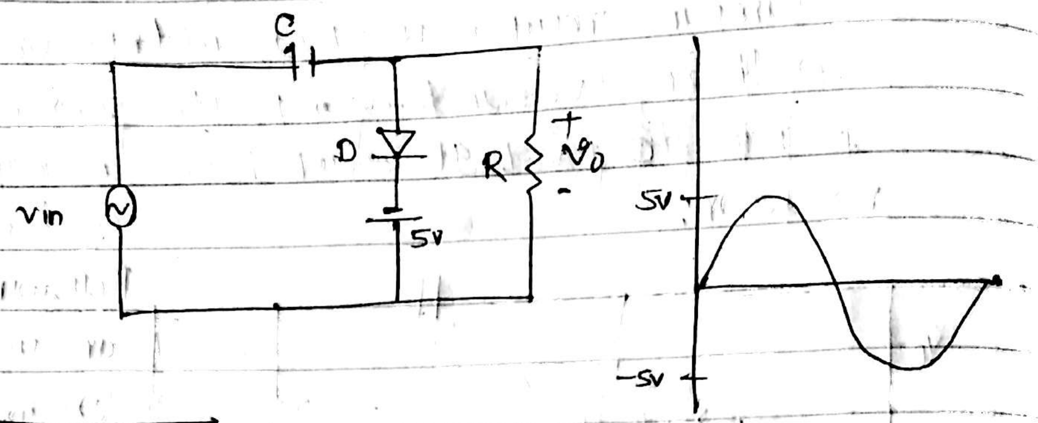
since the output as $v_o = v_{in} - V_p$, the o/p signal is identical to input and is clamped to $-V_p$ volts



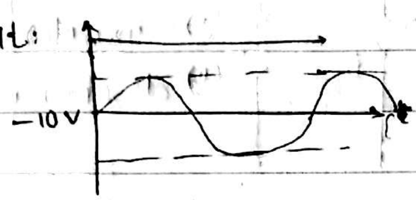
at, $t = T/4$

$V_{in} > V_p$

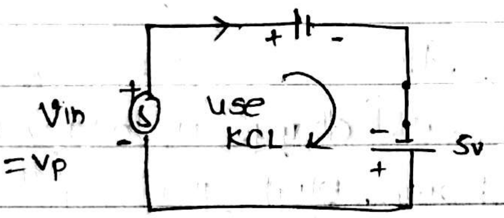
Q:



Result:



Soln:

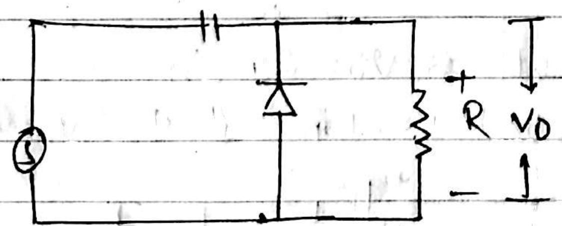


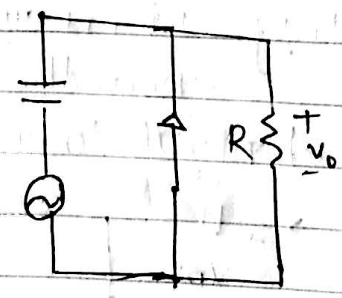
$v_c = V_{in} + 5$

$= 5 + 5$

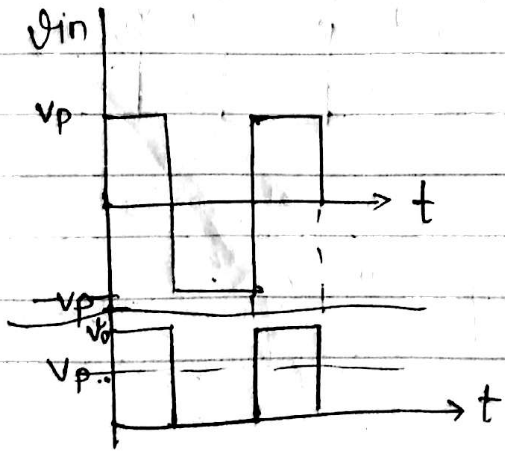
$= 10V$

Positive Clamper:





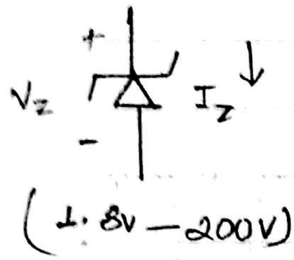
$V_0 = v_{in} + V_c$

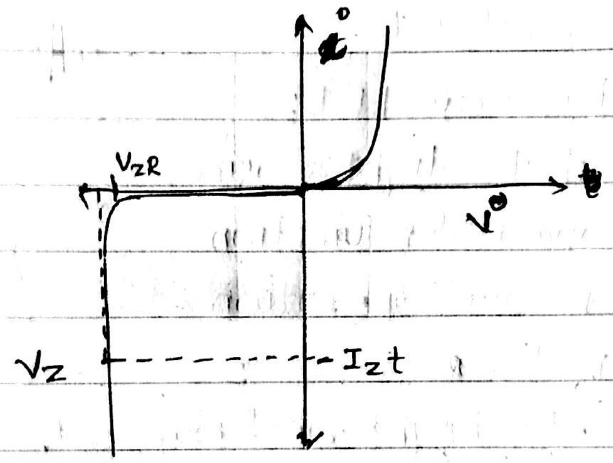


Special diode:

ⓐ Zener diode:-

Zener diode is designed to operate specially in breakdown region. It is a havily dopped semiconductor diode with smaller reverse breakdown vortage.

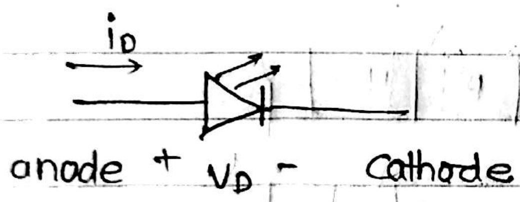


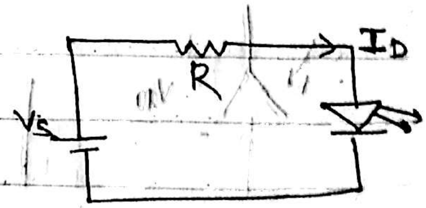


When the diode current is greater than knee current I_{zk}, the characteristic curve is almost vertical i.e voltage across diode remains constant independent of reverse current. The property is used to regulate voltage so zener diode is used as a voltage regulator.

2.7.2. LED: Light Emmiting Diode:

LED converts a forward current into light in variety of ~~cross load~~ color: red, green, yellow, orange, infra-red. LED is fabricated by using compound semi-conductor, such as gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP). LED have a typical voltage drop from 1.5 to 2.5V for currents between 10 to 50 mA.



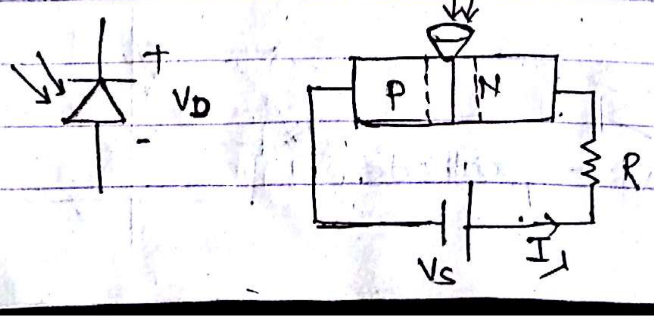


Operation of LED:
In forward bias LED, when majority carriers recombine they radiate energy in the form of light. The light emitted by LED is proportional to the forward current.

Advantage of LED:
* Solid state light source
* low power consumption
* fast on off operation
* longer life
* Extremely bright and low cost.

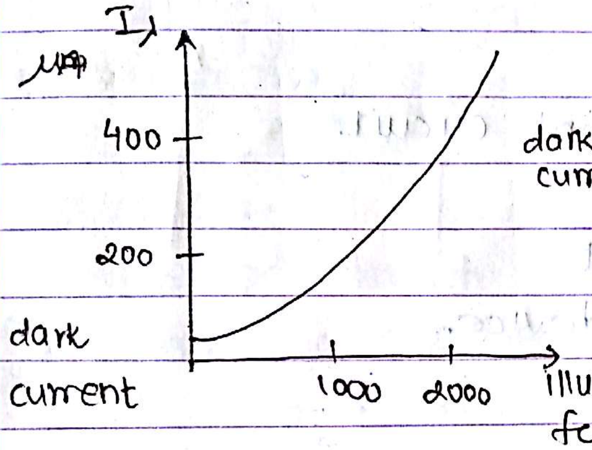
Application of LED
* Power indicator
* Displays [7 segment display]
* Engineering light
* Alarm system.

2.7.3 Photo Diode:
Photo diode is used to convert light signal into electrical signal. It is made by using compound semiconductor such as Gallium Arsenide. It is constructed such that its PN Junction can be exposed to light through the clear window or lens.



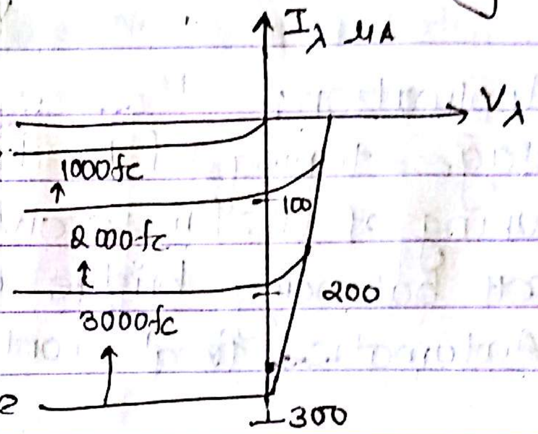
Operation:-

If a reversed biased PN Junction is exposed to incident light the photon striking the junction break the covalent bonds generating electrons holes pair. These minority carriers are swept across the junction giving rise to a reverse current that current knows as photo current, is proportional to intensity of the incident light.



fc => foot candle

Reverse current - illuminance curve



Reverse voltage-current curve.

Application:-

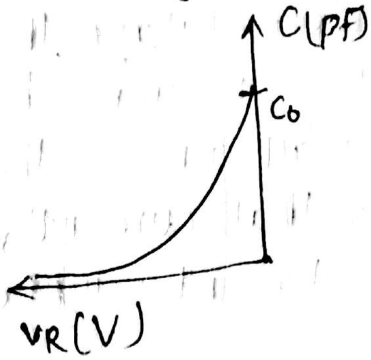
(a) Optical transmission
(b) Photo detector in alarm and counting system.
(c) Solar cell.

2.7.4: Varactor diode or varicap:

varactor diode (voltage variable capacitor, varicap or tuning diode) is a semiconductor) voltage dependent capacitor. It utlize the property of voltage dependent junction capacitance of the diode that exists in the.

reversed biased pn junction.
The capacitance can be vary from 2 to 100 pf depending on varicap.

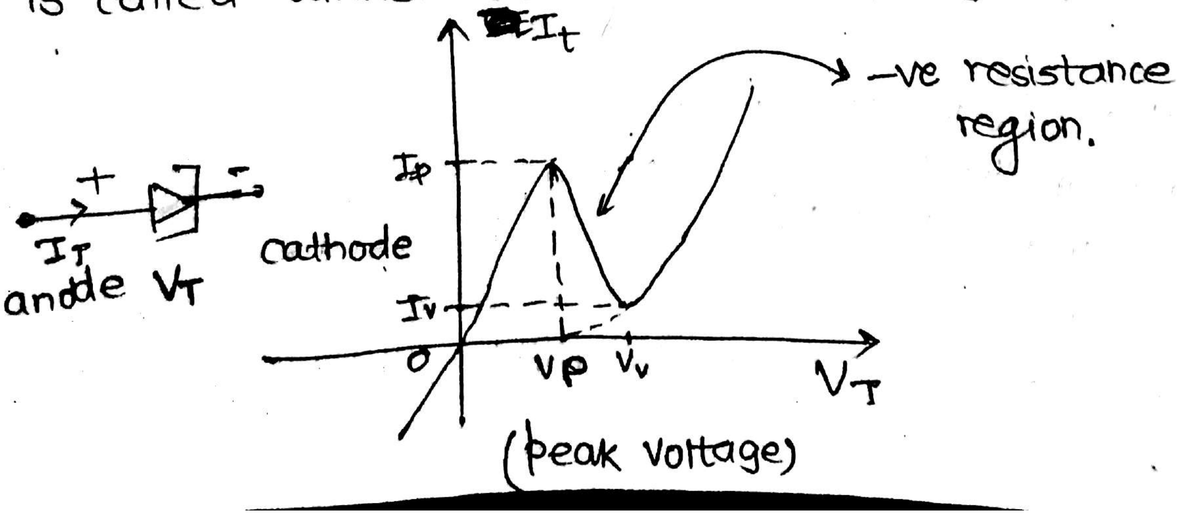
$$C_J = \frac{C_J(0)}{\left(1 + \frac{V_R}{V_0}\right)^n}$$



Application:
(a) voltage tuning of LC Resonant circuit.
(b) Tuning of TV, fm. receiver
(c) Self balancing bridge circuit
(d) Automatic freq^n control device

2.7.5 Tunnel diode

Tunnel diode is highly doped s/c diode with breakdown voltage at 0V. Due to high doping, the depletion region is too thin that many carriers can penentrate through the junction even when they do not possess enough energy This phenomenon is known as tunneling and the diode is called tunnel diode or Eraki diode



In reverse bias condition, The diode acts as an excellent conductor. Forward biased also produce immediate conduction. The current reaches a max. value (peak current) for small diode voltage Vp. if forward voltage is further increased beyond Vp, the current decreases to min. value. (Iv) (valley current) at Vv. The region betn peak and valley point is called '-ve resistance.

For voltage greater that Vv, the current start to increase exactly as a normal diode.

Application:-

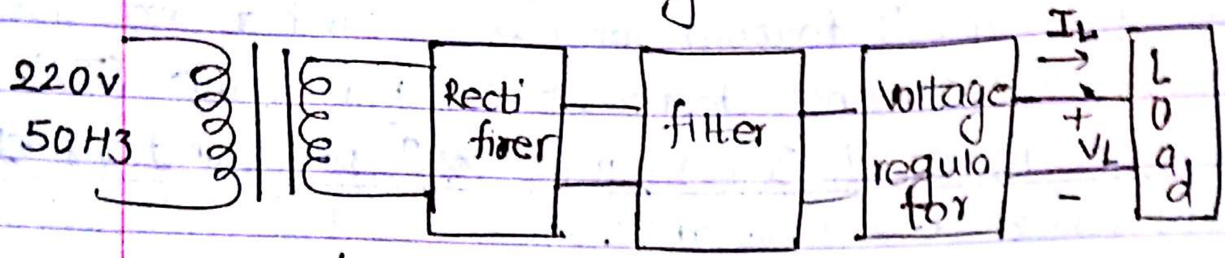
(i) High speed switch
(ii) As microwave oscillator
(iii) Relaxation oscillator circuit.

Advantages

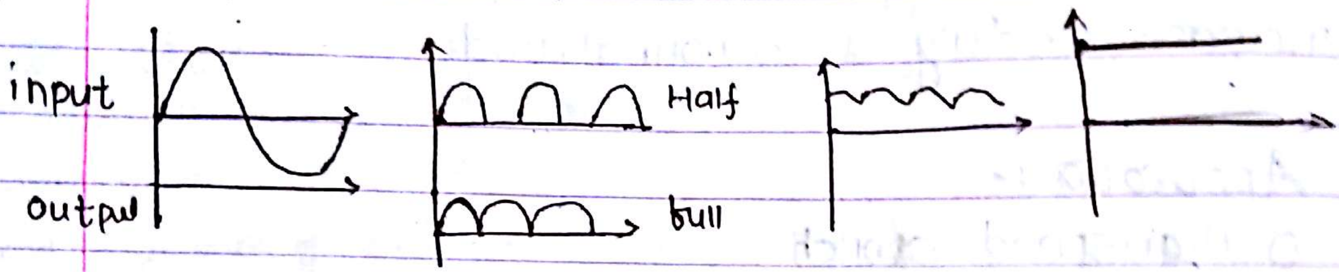
* low noise
* low power consumption
* high speed

2.8 DC Power supply:

DC power supply converts high voltage AC into one or more low DC voltage.



step down Transfer.



2.8.1 Review of AC signal:

Power AC signal:

(i) average value: $V_{DC} = \frac{1}{T}\int_0^T v_s(t)\,dt$

$= \frac{V_p}{\pi/2}$ for sine wave

$= 0.632\,V_p$

(ii) Rms value $= \sqrt{\frac{1}{T}\int_0^T v_s^2(t)\,dt}$

$= \frac{V_p}{\sqrt{2}}$

(iii) for ac+dc

$v_S(t) = V_S + v_s(t)$

DC component $V_S = \frac{1}{T}\int_0^T v_s(t)\,dt$

* ac component: $v_s(t) = V_s(t) - V_s$

rms value of (ripple) ac is,

$$V_{r\,rms} = \sqrt{\frac{1}{T}\int_0^T v_s^2(t)\,dt}$$

$$V_{r(rms)} = \sqrt{V_{rms}^2 - V_{DC}^2}$$

(ac) (ac+dc)

* ripple factor, $r = \frac{V_{r(rms)}}{V_{DC}} \times 100\%$

$$= \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} \times 100\%$$

$$= \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} \times 100\%$$

$$= \sqrt{K_f^2 - 1} \times 100\%$$

$\frac{V_{rms}}{V_{DC}} = K_f \rightarrow$ form factor

* Rectification efficiency

$$\eta = \frac{\text{DC power deliver to load}}{\text{A Cinput power}}$$

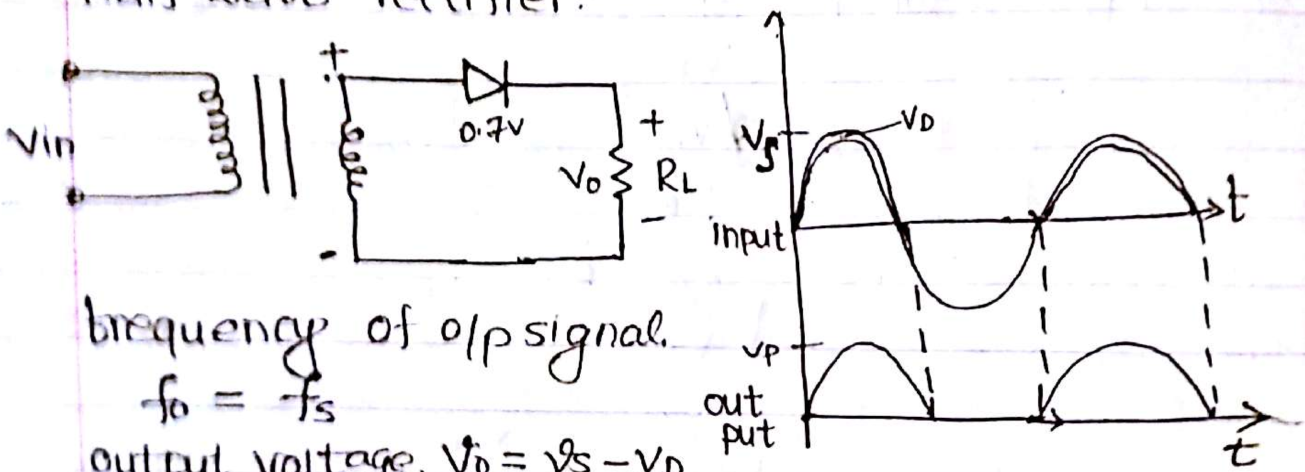
$$= \frac{P_{DC}}{P_{AC}} = \frac{I_{DC}^2 \cdot R_L}{I_{rms}^2\, R_L} = \left(\frac{I_{DC}}{I_{rms}}\right)^2$$

$$= \frac{1}{K_f^2}$$

Where, $\frac{I_{rms}}{I_{DC}} = K_f$,

* Rectifier circuit:
 converts ac signal into a signal with dc component or pulsating DC.
 Types
* Half wave rectifier
* full wave rectifier
 - → central tapped
 - → Bridge circuit

Half wave rectifier:



frequency of o/p signal.
$f_o = f_s$

output voltage, $V_o = V_s - V_D$ for, $V_s \geq V_D$
$= 0$ for $V_s < V_D$

Output peak voltage $V_P = V_S - V_D$

output rms voltage $V_{rms} = \frac{V_P}{2} = 0.5V_P$

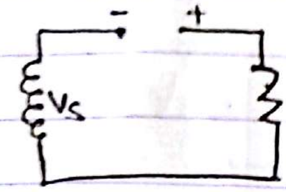
output DC " $V_{DC} = \frac{V_P}{\pi} = 0.318V_P$

form factor $K_f = \frac{V_{rms}}{V_{DC}} = 1.57$

ripple factor $r = \sqrt{K_f^2 - 1} \times 100\% = 121\%$

Efficiency $(\eta) = \frac{100\%}{K_f^2} = 40.6\%$

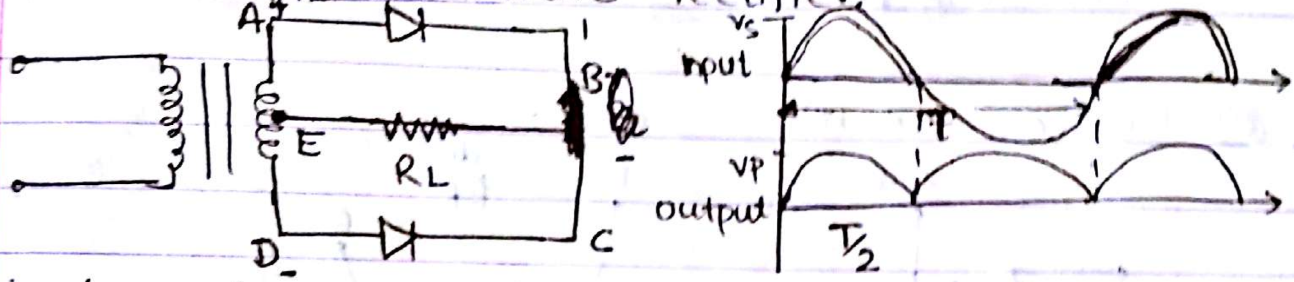
in yerers bios:



Peak inverse volt = V_s

PIV rating $\geq V_s$

ⓑ central tapped full wave rectifier



ⓐ in forward Bios, +ve half cycle. end A is +ve so current flows through ABRLEA (path).

ⓑ in -ve half cycle, end D is +ve so current flows through path DCBRLED

frequency. $f_o = 2f_s$

$v_o = v_s - V_D$ for $v_s \geq V_D$

$= 0$ for $v_s \leq -V_D$

Peak volt: $V_p = V_s - V_D$

DC volt $V_D = \frac{2V_P}{\pi} = 0.636V$

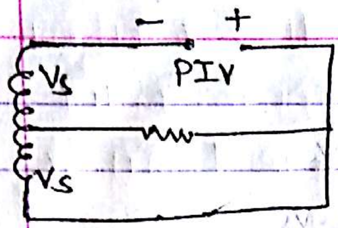
rms. volt. $V_{rms} = \frac{V_P}{\sqrt{2}} =$

$k_f = 1.11$

ripple factor: $r = \sqrt{k_f^2 - 1} \times 100\%$

$= 48.2\%$

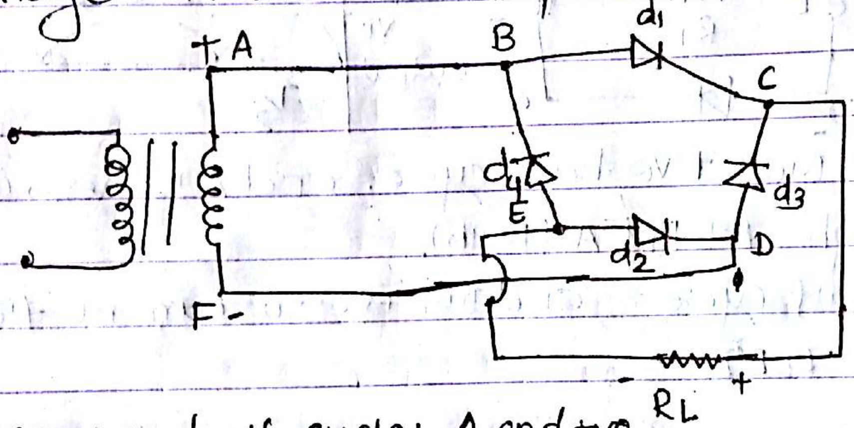
efficiency. $\eta = \frac{1}{(k_f)^2} = \frac{100\%}{(1.11)^2} = 81.2\%$



* $PIV \geq 2V_s$

PIV rating $\geq 2V_s$

(c) Bridge circuit.



* for +ve half cycle: A end +ve
  diode d_1 and d_2 are forward bias.
  so current flows through ABd_1CEd_2DF
* for -ve half cycle, F end +ve
  d_3 and d_4 are forward bias.
  So current flows along path FDd_3CEd_4BA

frequency $f_0 = 2f_s$

$v_0 = v_s - 2V_D$ for $v_s \geq V_D$

$= -v_s - 2V_D$ " $v_s < -V_D$

o/p peak volt. $V_p = V_s - 2V_D$

O/P DC " $V_{DC} = \frac{2V_p}{\pi} = 0.636\,V_p$

O/P rms " $V_{rms} = \frac{V_p}{\sqrt{2}}$

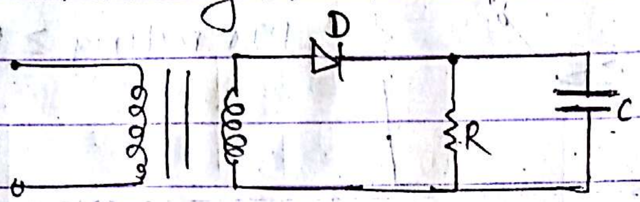
form factor $= K_f = 1.11$

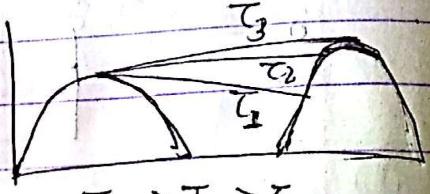
ripple factor $= 48.2\%$ efficiency $= 81.2\%$

L. RC
H C R

* Rectifier with filter capacitor:

Filter capacitor is used to minimize the ac component of rectified signal.





$\tau_3 > \tau_2 > \tau_1$

$T = RC$

discharge (Time constant)

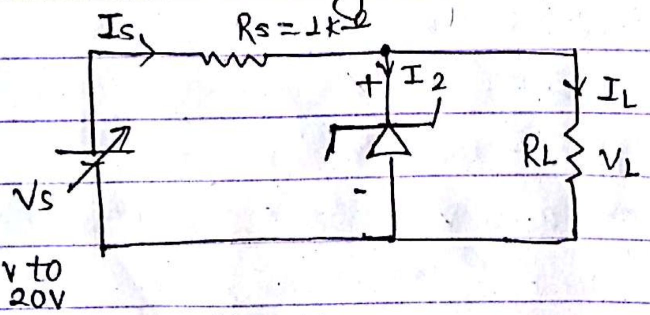
Time constant high
discharge capacity low

for Triangular wave approximation.

$$V_{r\,rms} = \frac{V_r\,(P-P)}{2\sqrt{3}}$$

* Zener diode voltage regulator circuit:

Zener diode regulator provides a regulated DC across the load regardless of the voltage fluctuation and current drawn by the load.



$$I_z = \frac{V_s - V_z}{R_s}$$

for $V_s = 15V$

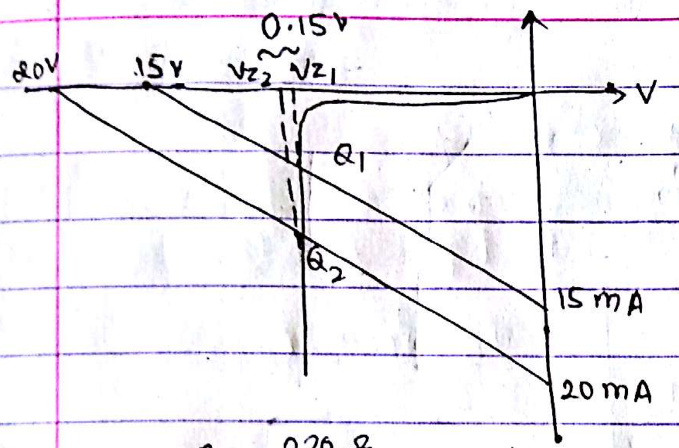
$I_z = 0 \Rightarrow V_z = 15V$

$V_z = 0 \Rightarrow I_z = \frac{V_s}{R_s} = 15mA$

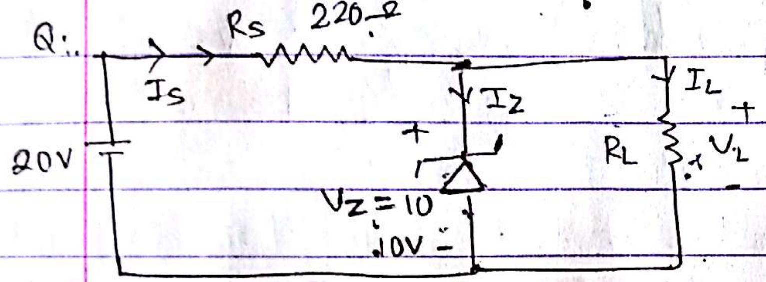
for $V_s = 20V$

$V_z = 0$, $I_z = \frac{V_s}{R_s} = 20\,mA$

$I_z = 0 \Rightarrow V_z = 20\,V$



Q:

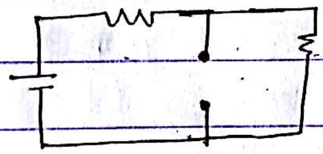


remove zener diode (open circuit voltage.) calculate V across zener.

$P_{z\,max} = 400\,mW$

find. V_L, I_L, I_S, I_L

for ⇒ $R_L = 180\,\Omega$



$$V_Z = \frac{20 \times 180}{180 + 220}$$

$$= \frac{20 \times 180}{400}$$

$V_Z = 9V < V_Z = 10V$

so it is acting as reverse biase, in reverse biase / Open circuit

$I_Z = 0$, $I_S = I_L = \frac{20}{400} = 0.05\,A$

$V_L = 9\,V$

if $R_L = 470\,\Omega$

$$V_Z = \frac{20 \times 470}{470 + 220} = 13.66 > \text{diode voltage.}$$

zener diode is in breakdown voltage

$\therefore V_L = V_Z = 10V$, $I_L = \frac{V_L}{R_L} = \frac{10}{470} = 0.021\,A$, $I_S = \frac{V_S - V_L}{R_S} = \frac{20 - 10}{220} = 0.045\,A$

$$I_{z\,max} = \frac{P}{V}$$

$$= \frac{400mW}{10}$$

$$= 40mW$$

Chapter: 3

* Transistor

The device which is able to produce gain in a circuit.

(a) Bipolar Junction Transistor

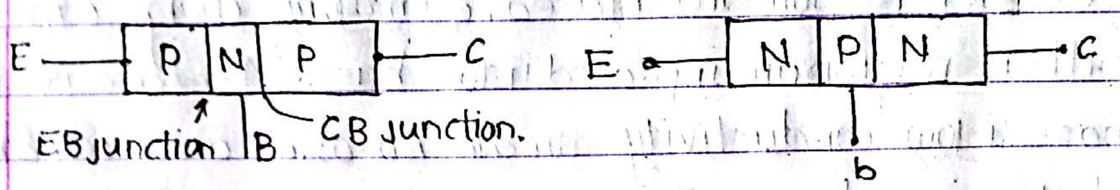
(b) Field effect Transistor.

(a) MOSFET (Metal oxide semiconductor)

(b) JFET (Junction)

3.1 Bipolar Junction Transistor:

Physical structure of BJT:



Region	doping level	Thickness	function
(a) E	high	moderate	supply charge
(b) C	moderate	Thick	collect "
(c) B	low	Thin.	control the flow of charge.

Mode of Operation

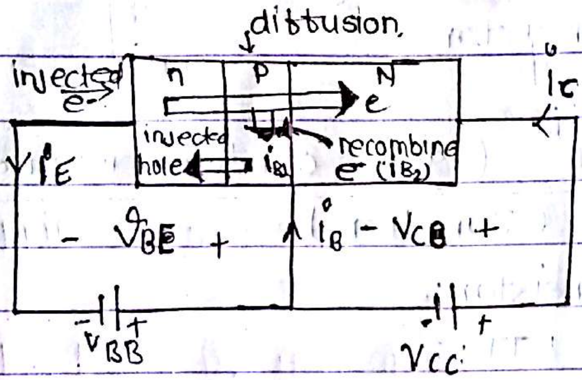
Mode	EBJ	CBJ	Remarks
Cutoff	RB	RB	switching
Saturation	FB	FB	switching
Active	FB	FB	amplifier

RB reverse bias

FB forward bias

3.1.3: Operation of npn transistors in different mode.

(a) Active mode :- (EBJ – FB, CBJ – RB)



$i_E = i_C + i_B$

$i_B < i_C < i_E$

Operation of NPN Transistor:

Since EBJ is forward biased, $\bar{e}$ (majority charge carriers) in emitter region are injected into base. As base is thin and has a low conductivity, small no. of $\bar{e}$ are recombined with hole in p base. The rest of the injected $\bar{e}$ (>95% diffuse through base region towards the edge of CBJ and sweep into collector (CBJ is reversed biased)

Terminal current of BJT.

(i) Emitter current

$i_E = i_{En}$ ($\bar{e}$ injection from E to B) + i_{EP} (hole injection from B to E)

$\approx i_{EN}$.

(ii) Collector current: $i_C = i_{Cn}$ ($\bar{e}$ drift) + i_{CBO} (CBJ reversed saturation current with emitter open)

$\approx I_{Cn} = I_S e^{V_{BE}/V_T}$

(iii) Base current: $i_B = i_{B1}$ (hole injection from B to E) + i_{B2} (recombined in base)

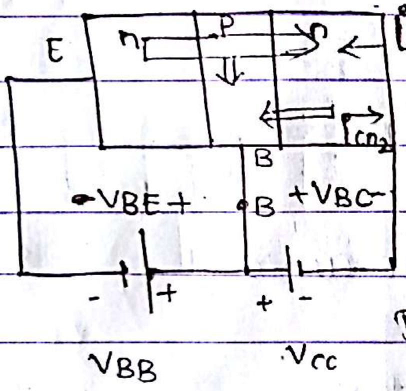
(b) Cut-off mode: (EBJ - RB , CBJ - RB)

$i_E = i_C = i_B = 0$

⇒ Transistor act as open switch

* In active mode, transistor acts as a controlled current source

* Saturation mode (EBJ - FB, CBJ - FB



Collector current (i_C) = $i_{Cn_1} - i_{Cn_2}$

if forward bias of CBJ is increased, the collector current reduces:

Barrier voltage of EBJ ⇒ $V_{BE} \approx 0.7V$ (0.6-0.8)

" " " CBJ ⇒ $V_{BC} \approx 0.5V$ (0.4-0.6)

$V_{CE} = V_{CB} + V_{BE}$

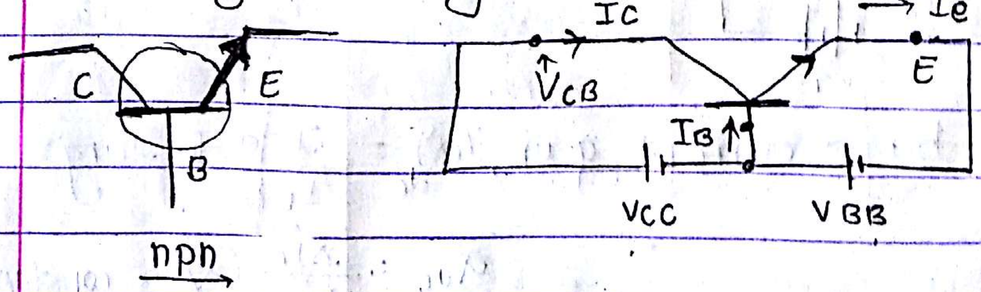
$= V_{BE} - V_{BC}$

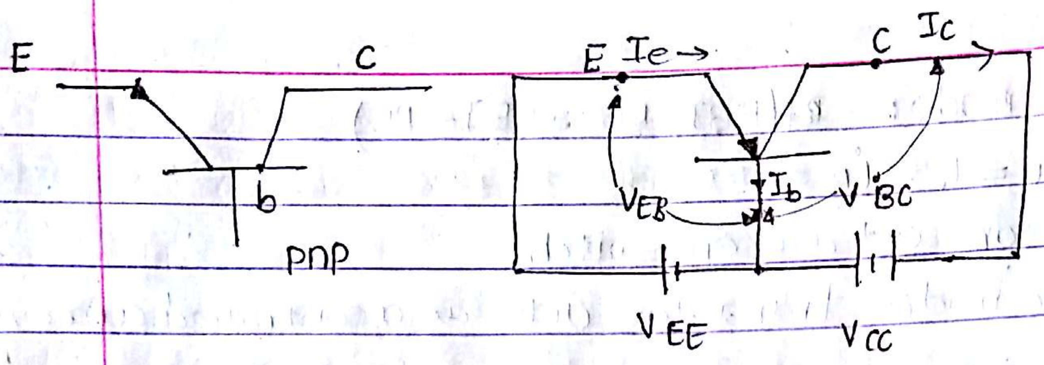
$= 0.2V$ (0.3 - 0.1)V

In saturation mode, transistor behaves as a closed switch.

* ~~Closed~~

* Circuit symbol voltage polarities and current flow.





PNP – Transistor.

* BJT configuration
  - common base configuration
  - common emitter configuration
  - common collecter ,,

Two set of DC characterstic curve

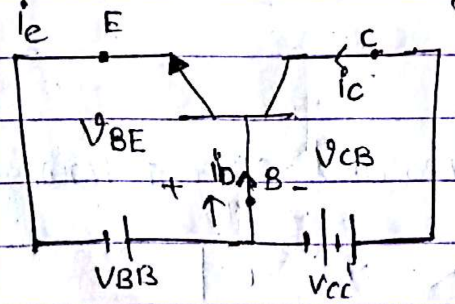
(a) Input Characteristic curve.

$i_{in} = f(V_{in})$ for V_{out} = constant

(*) output characteristic cure

$i_{out} = f(V_{out})$ for i_{in} = constant

* common base Configuration.



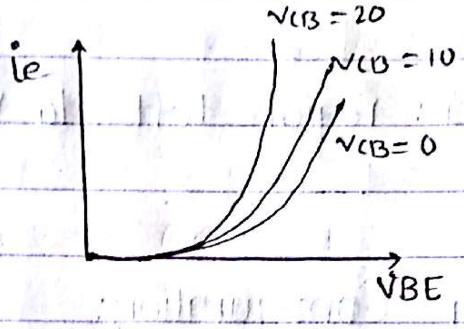
common base current gain, $(\alpha)_{dc} = \frac{I_{CQ}}{I_{EQ}}$ for large signal

$\alpha_{ac} = \frac{\Delta i_c}{\Delta i_e}$ (V_{CB} constant)

α ranges (0.95 to 0.99) ≈ 1

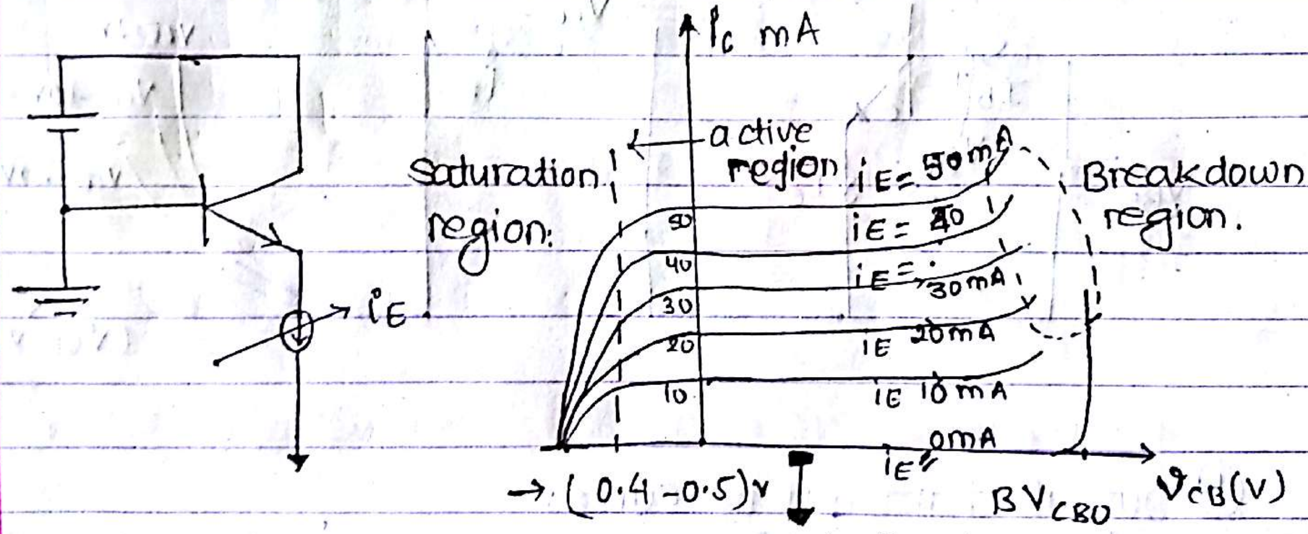
(a) Input characteristic curve:

$i_e = f(V_{BE})$ for V_{CB} = constant



(b) Output characteristic curve:

$i_C = f(V_{CB})$ for i_E = constant.



EBJ ⇒ 0.7 V

CBJ ⇒ $V_{BC} = (0.4 - 0.6)$ V

$\therefore V_{CB} < -0.4$

(a) Cut off region ⇒ region below $i_E = 0$ line. $i_C = I_{CBO} \approx 0$

I_{CBO} → Collecter to base current with emitter open (μA)

(b) Active region: Region between $i_E > 0$ and $V_{CB} > -0.4$V

$i_C \approx i_E$

The curves are approximately horizontal, small slope is due to early effect.

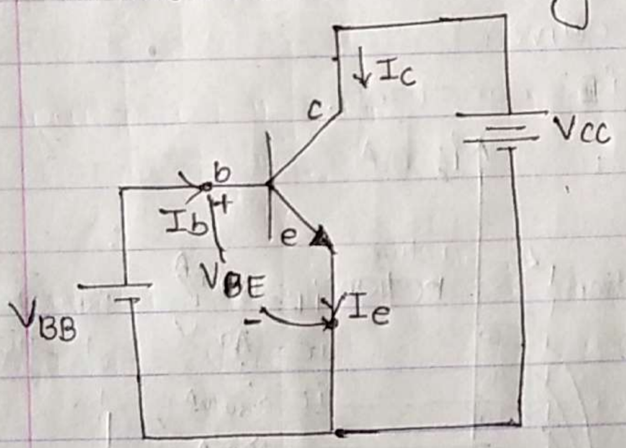
Dependence of current with V_{CB} is early effect.

(c) Breakdown region: at high v_{CB}, i_c rises rapidely, and

* CBJ breakdown at voltage BV_{CBO} for $i_E = 0$
* $BV_{CBO} \geq 50V$

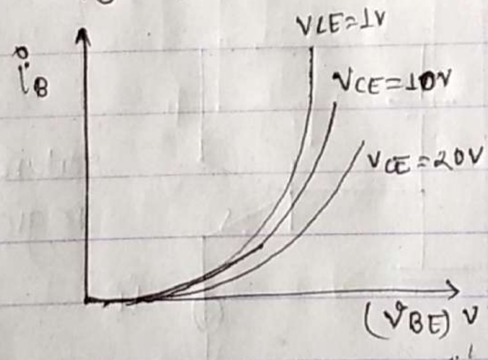
(d) Saturation Region: region left to $v_{CB} < -0.4V$

3.2.2 Common Emitter Configuration:



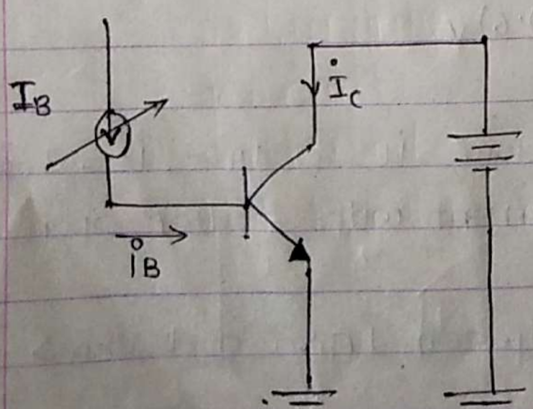
(a) Input characteristics curve

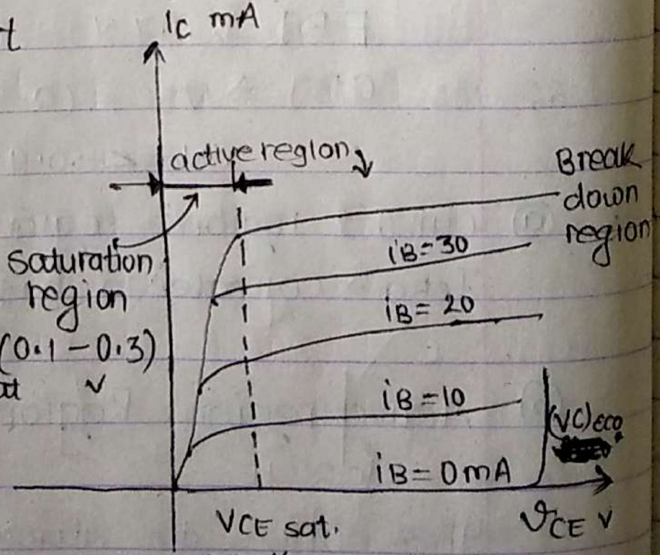
$i_B = f(V_{BE})$ at V_{CE} constant



(b) output characteristic curve:

$i_c = f(v_{CE})$ as i_B = constant





I_{CEO} = collecter to emitter with open base [leakage current]
$= (\beta+1) I_{CBO} \approx \beta I_{CBO}$

$BV_{CEO} = \frac{BV_{CBO}}{2}$

* common emitter current gain. (β)
large signal $\beta_{dc} = \frac{I_C}{I_B}$ (>50)

$\beta_{ac} = \frac{\Delta i_C}{\Delta i_B}$, v_{CE} = constant

3.2.3 common collecter configuration.

3.2.4 Properties of Transistor configuration:

Properties	CB	CE	CC
voltage gain, $A_v = \frac{V_{out}}{V_{in}}$	highest	high	less than 1 ~~highest~~
current gain, $A_I = \frac{I_{out}}{I_{in}}$	less than 1	high	highest
power gain = $A_v \cdot A_I$	not high	highest	not high
input resistance, $R_{in} = \frac{V_{in}}{I_{in}}$	small	high	highest
output resistance, $R_{out} = \frac{V_{out}}{I_{out}}$	highest	high	low.
Polarity of o/p signal	no change	180° out of phase	no change

Application	CB	CE	CC
	used for unity gain current amplifier and high freq^n amplifier	used for current, voltage and power amplification and used for audio frequency amplifier	used for impedence matching purpose voltage buffer amplifier. It is also known as emitter follower, because unity voltage gain and no inversion phase property.

3.2.5 Relation between α and β.

We have,

$$i_E = i_B + i_C \qquad \text{Where, } \alpha = \frac{I_c}{I_e}$$

$$\text{or, } \frac{i_E}{i_C} = \frac{i_B}{i_C} + \frac{i_C}{i_C} \qquad \beta = \frac{I_c}{I_B}$$

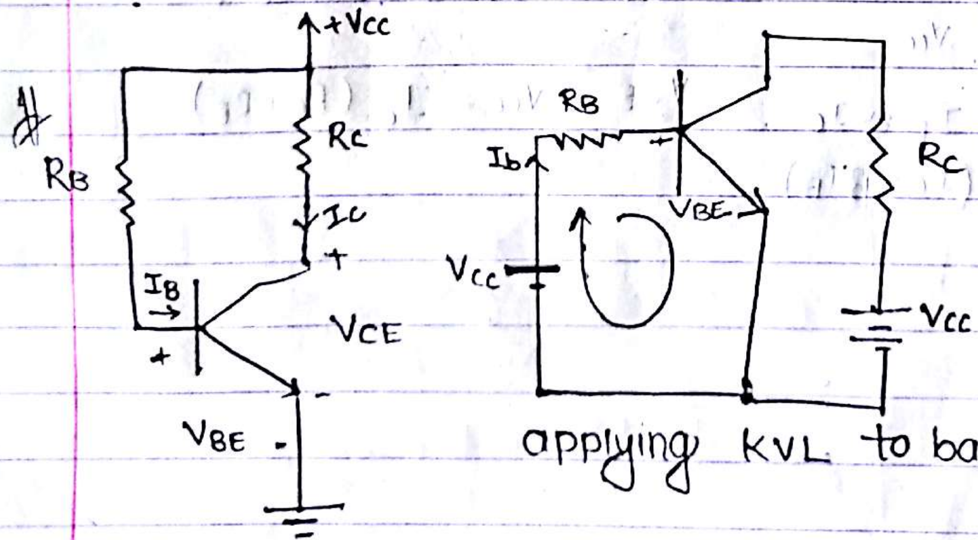
$$\text{or, } \frac{1}{\alpha} = \frac{1}{\beta} + 1$$

$$\therefore \alpha = \frac{\beta}{\beta+1}, \quad \beta = \frac{\alpha}{1-\alpha}$$

3.3 DC - Biasing:

The purpose of biasing is to set the operating point that is independent of β. change and temperature variation.

Fixed bias (base bias.)



applying KVL to base emitter loop.

$$V_{CC} = I_B R_B + V_{BE}$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

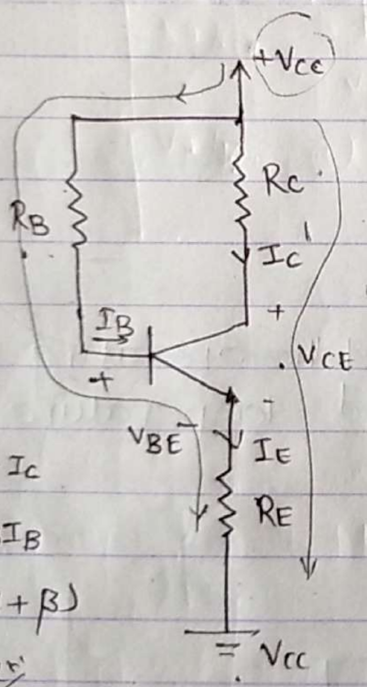
applying KVL at collector ~~too~~ emitter loop

$$V_{CC} = I_C R_C + V_{CE}$$

$$\therefore V_{CE} = V_{CC} - I_C R_C \quad , I_C = \beta I_B$$

Terminal voltage: $V_E = 0$, $V_B = V_{BE}$, $V_C = V_{CE}$

(b) Emitter feedback bias (current feedback)



applying KVL to base emitter loop.

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

$$= I_B R_B + V_{BE} + (\beta+1) I_B R_E$$

$$=$$

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

$$I_E = I_B + I_C$$

$$= I_B + \beta I_B$$

$$= I_B (1+\beta)$$

Applying KVL to collector emitter loop

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$I_E \approx I_C$$

$$(I_C = \beta I_B)$$

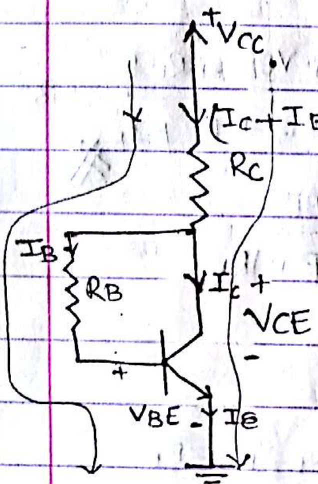
$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

not written

$$V_C = V_{CC} - I_C R_C$$

or, $= V_{CE} + V_E$

(c) Collector Feedback bias (Voltage feedback)



at input loop

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

$= (\beta I_B + I_B) R_C + I_B R_B + V_{BE}$

$= (\beta + 1) R_C I_B + I_B R_B + V_{BE}$

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

collecter emitter loop:

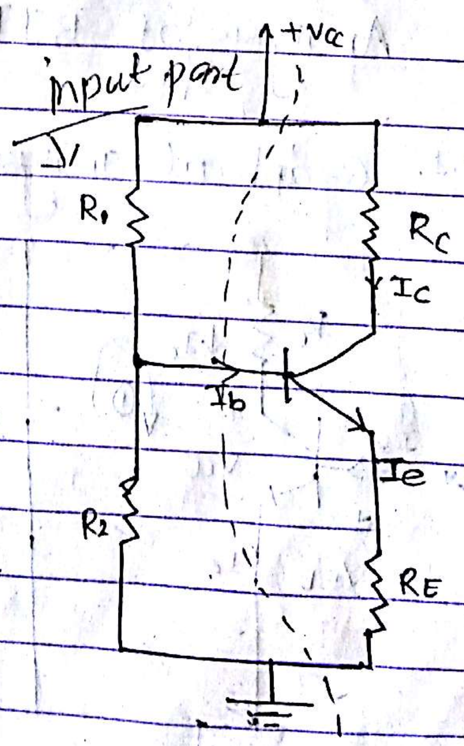
$V_{CC} = R_C I_C + I_B R_C + V_{CE}$

$V_{CC} = \beta I_B R_C + I_B R_C + V_{CE}$

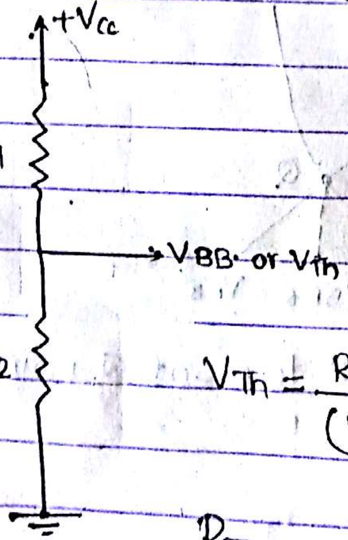
$V_{CE} = V_{CC} - (\beta + 1) I_B R_C$

(d) Voltage divider bias:

– universal biasing method.



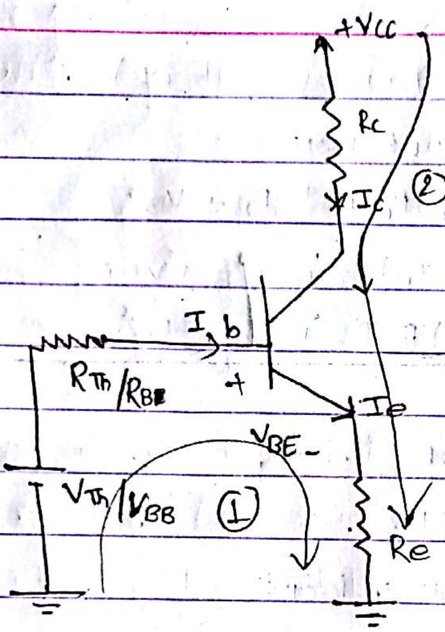
input part. (Thevenize circuit)



$$V_{Th} = \frac{R_2 \times V_{CC}}{(R_1 + R_2)}$$

$$R_{Th} = \frac{R_1 \times R_2}{(R_1 + R_2)}$$

V_{BB} → Base & ground.



$\alpha = \frac{I_c}{I_e}$

in input loop ①

$V_{BB} = R_B I_B + V_{BE} + R_e I_e$

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

$V_{BB} - V_{BE} = I_B R_B + R_E \beta I_B$

$I_B = \dfrac{V_{BB} - V_{BE}}{R_B + (\beta+1) R_E}$

$V_{CC} = R_C I_C + V_{BE} + I_e R_E$

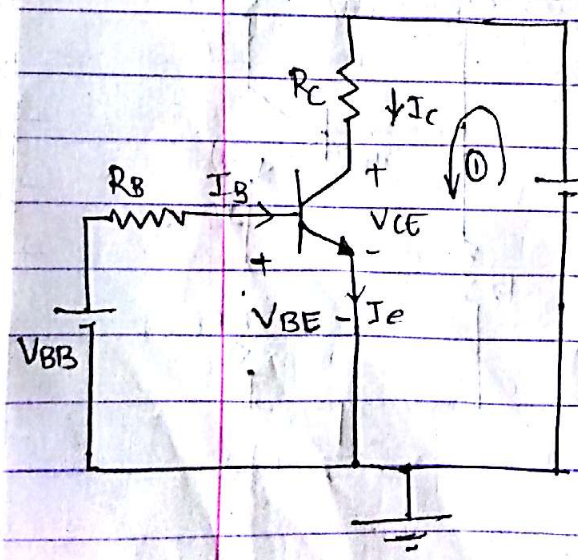
$V_{BE} = V_{CC} - (R_C I_C + I_e R_e)$

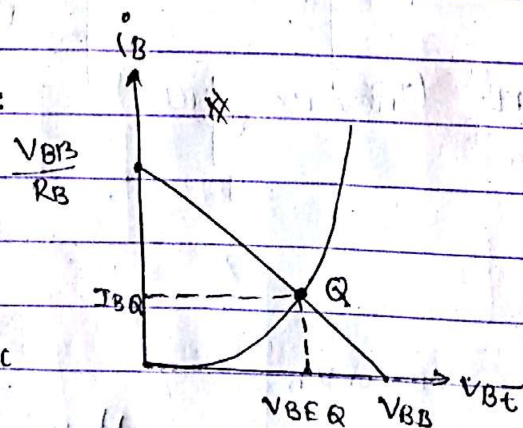
$V_{BE} = V_{CC} - (\alpha R_C I_e + I_e R_e)$

$I_c \approx I_e \quad V_{BE} = V_{CC} - (R_c + R_e) I_C$

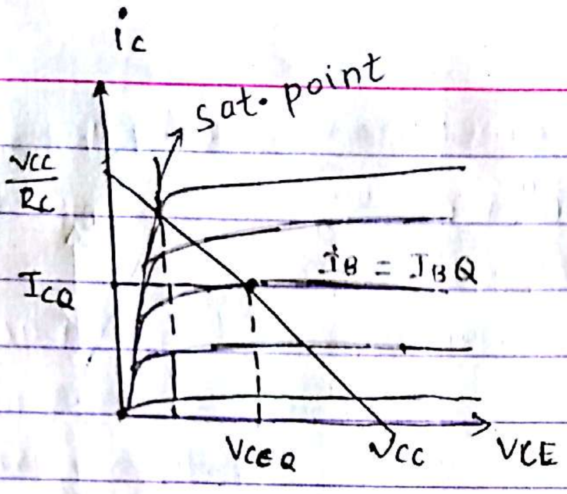
Analysis of BJT circuit

3.4.1. Graphical analysis:





load line: locus of Q point.



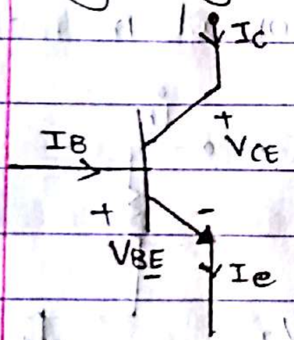
$V_{CC} = I_C R_C + V_{CE}$ from loop ①

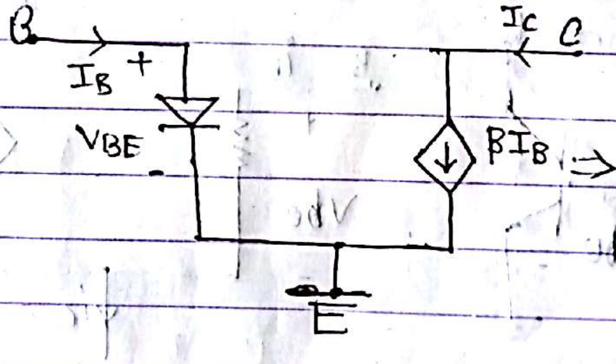
transistor
active mode — controlled current source
saturation: closed s/w
cut off - open s/w
EB-R.B

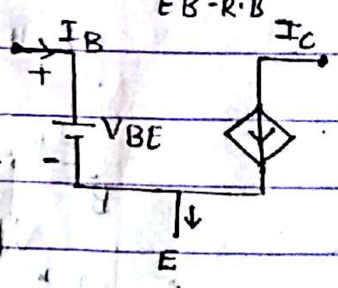
3.4.2 Modeling the BJT:

ⓐ large signal model:-

ⓘ active model:

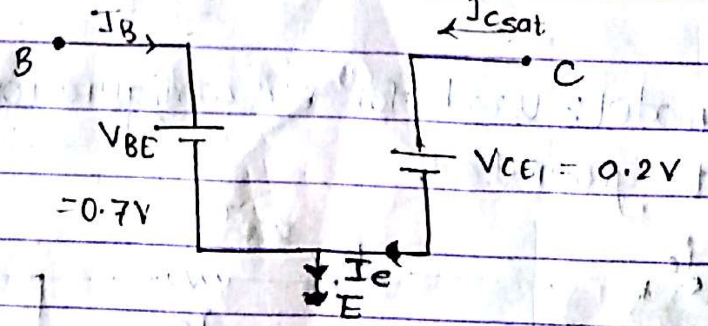




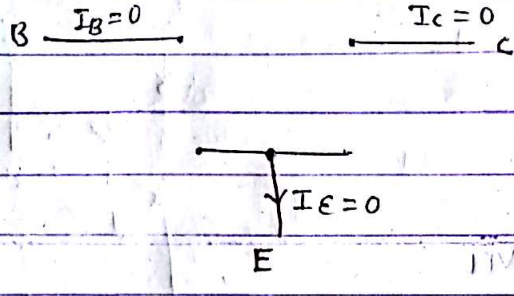


ⓑ

Saturation mode

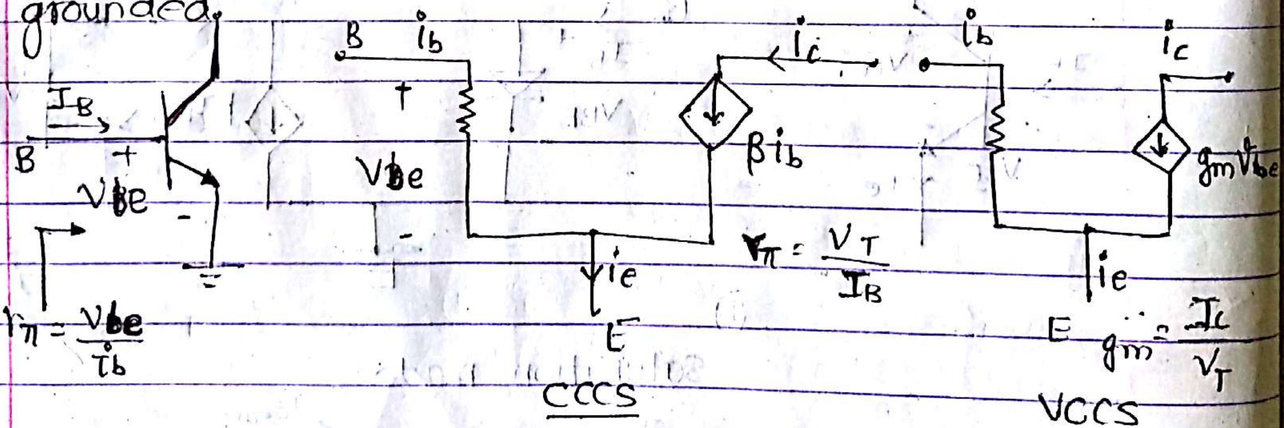


* Cut off :



(B) Small signal Model (ac model)
re model: (resistance at emitter model)
* small signal model of diode: is $r_d = \frac{V_T}{I_D}$

(a) π model: used for CE configuration or when emitter is grounded.

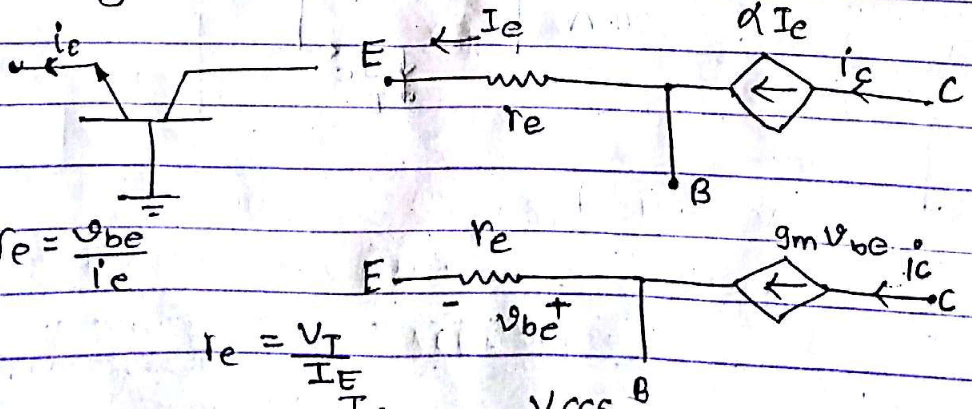


$r_\pi = \frac{V_{be}}{i_b}$

$r_\pi = \frac{V_T}{I_B}$

$g_m = \frac{I_c}{V_T}$

(b) T model:- used for CB configuration or when emitter is not grounded.



$r_e = \frac{v_{be}}{i_e}$

$r_e = \frac{V_T}{I_E}$

$g_m = \frac{I_c}{V_T}$

Relationship between r_e and r_π

$$r_\pi = \frac{v_{be}}{i_b} = \frac{(\beta+1)\, v_{be}}{i_e} = (1+\beta)\, r_e$$

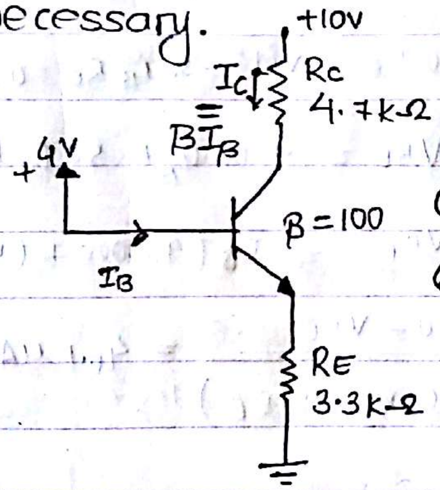
$$\therefore r_\pi = (\beta+1)\, r_e$$

3.4.3 DC analysis of BJT circuits:

~~Produ~~ Procedure:

* always assume the model as active.
* use corresponding mode and analysis.
* verify the soln if $V_{CE} > 0.3$ V or $V_{CB} > -0.4$ V (assumption correct)
* Repeat the above steps with another assumption if necessary.

Q: Find all terminal currents.



(c) $I_C \approx I_E = 1\,mA$

(1) $V_E = 4 - 0.7 = 3.3$ V

(2) $I_E = \frac{3.3\,V}{3.3 \times 1000} = 1\,mA$

$I_C = \beta I_B$, $I_B = 10\,\mu A$

$V_C = 10 - I_C \times 4.7 = 5.3$ V

$V_{CE} = V_C - V_E = 2V > 0.3$ V (assumption correct)

(b) if $V_{BB} = 6V$

$V_E = 6 - 0.7 = 5.3V$

$I_E = \frac{5.3V}{3.3 \times 1000} = 1.6\,mA$

$I_C \neq \beta I_B =$ ~~1~~. I_C.

$V_C = 10 - I_C \cdot 4.7$ ~~1000~~

$= 10 - 2.0 \times 10^{-3} \times 4.7 \times 1000$

$= 0.6$ V

Given $V_{CE} = 0.2$ V, $V_C = 2.48$

$V_{CC} = 10$ V

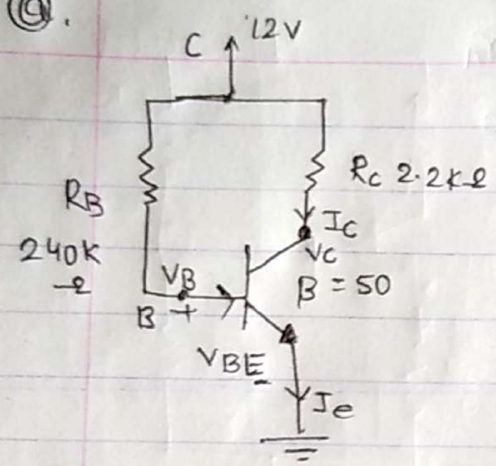
$I_C = \frac{V_{CC} - V_C}{R_C} = \frac{10 - 2.48}{4.7 \times 1000}$

$= 2\,mA$

$I_B = 0.64\,mA$

$I_C = 0.96\,mA$

(a).



$12 - 240 \times 1000 I_B - V_{BE} = 0$

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

$I_C = 50 I_B$

$\frac{12 - V_{BE}}{240 \times 1000} = I_B$

$12 - 2.2 \times 1000 \, I_C$

$I_B = 47 \mu A$

$I_C = 2.35 \, mA$

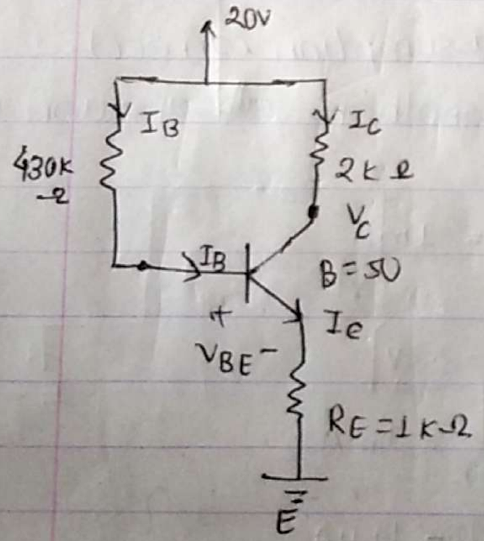
$I_E \approx 2.35 \, mA$

$V_B = 0.7V$

$V_C = 6.83 = V_{CE} \, V$

$I_C = I_e + I_B$

$V_{BC} =$



$20 - 430 \times 1000 I_B - V_{BE} - I_e R_e = 0$

$20 - 430000 I_B - V_{BE} - 50 I_B R_e = 0$

or $20 - V_{BE} = 430000 I_B + 50 I_B R_e$

or $\frac{20 - V_{BE}}{} = I_B (430000 + (50+1) R_E)$

(i) $I_B = \frac{20 - V_{BE}}{(430000 + 51 R_E)} = 40.1 \mu A$

(ii) $I_C = \beta I_B = 50 \times 40.1 \mu A$
$= 2.01 mA$

$\frac{V_{CC} - V_C}{R_C} = I_C$

$\therefore V_{CC} - I_C R_C = V_C$

(iii) $\therefore V_C = 15.98 \, V$

(iv) $I_E \approx I_C = 2.01 \, mA$

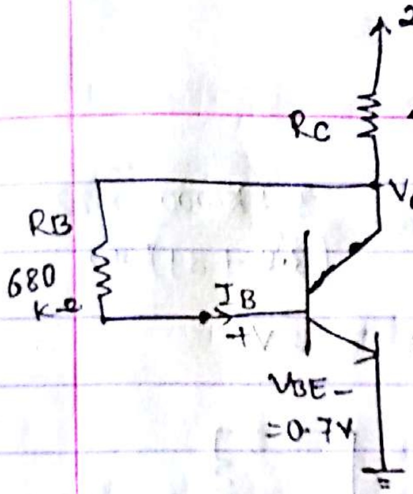
$V_{CE} =$

(v) $V_E = 2.01 \, V$

$V_{CE} = V_C - V_E$
$= 15.98 - 2.01$
$= 13.97V > 0.3V$

$V_B = 2.71V$

$V_{BC} =$



$$I_B = \frac{V_{cc} - V_{BE}}{R_c(\beta+1) + R_B} = \frac{20 - 0.7}{4.7\times1000(120+1) + 680\times1000}$$

$$= \frac{19.3}{1248700}$$

$$= 1.54 \times 10^{-5} A$$

$$I_C = \beta I_B$$

$$= 120 \times 1.54 \times 10^{-5} A$$

$$= 1.85 mA$$

$$I_E = I_C + I_B$$

$$= (1.85\times10^{-3} + 1.54\times10^{-5})$$

$$= 1.87 \times 10^{-3} A$$

$$V_C = V_{CE} = +V_{CC} - I_C R_C$$

$$= 20 - 1.85\times10^{-3}\times4.7\times10^{3}$$

$$= 20 - 8.695$$

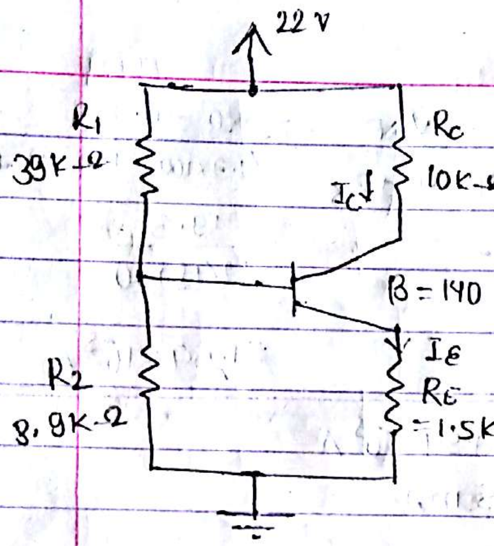
$$= 11.305 V$$

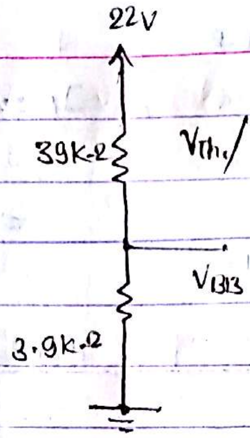
VCC –

ie,

$$\frac{V_{CC} - V_C}{R_C} = I_C$$

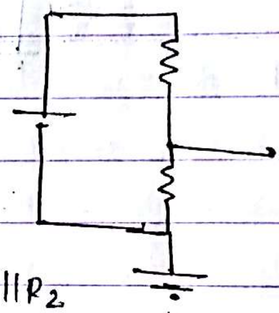
$$V_{BE} = V_B = 0.7 V$$

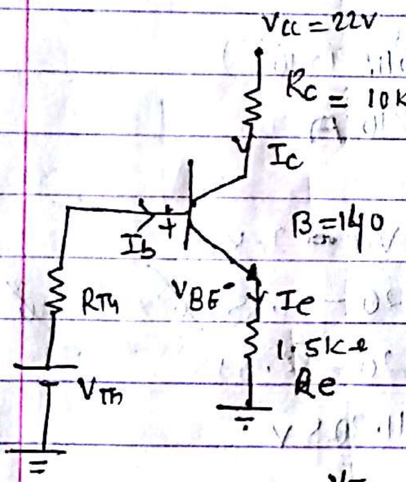




$V_{Th}/V_{BB} = \frac{3.9 \times 1000}{(3.9+39)1000} \times 22$

$= 2V$





$R_{Th}/R_B = R_1 \| R_2$

$= \frac{(39 \times 3.9)10^3 \times 10^3}{(39+3.9)10^3}$

$= 3.5\ K\Omega$

$V_{Th} - I_b R_{Th} - V_{BE} - I_e R_e = 0$

$I_B = \frac{V_{Th} - V_{BE}}{R_B + (\beta+1)R_E} = \frac{2-0.7}{10 \times 1000 + 141 \times 1.5 \times 1000}$

$= \frac{1.3}{221500}$

$= 5.8\ \mu A$

$I_C = \beta I_B$

$= 140 \times 5.8\ \mu A$

$= 8.21 \times 10^{-4} A$

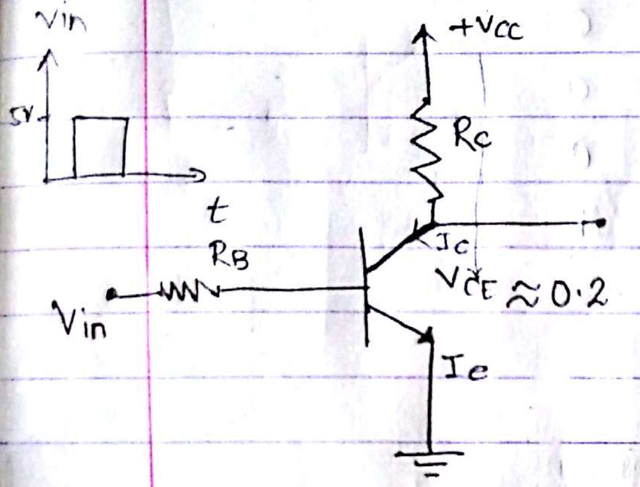
$V_E = I_C R_E$

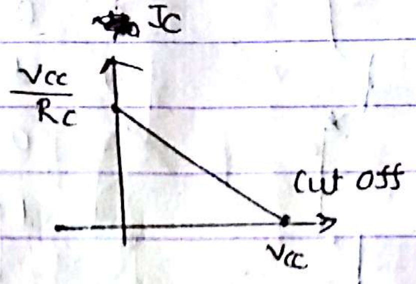
$V_C = 22 - I_C R_C = 22 - 0.85 \times 10^{-3} \times 10 \times 10^3$

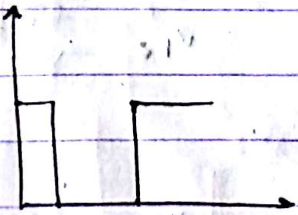
$= 13.5\ V$

3.5 BJT switch and logic circuit:

Cut off and sotuation mode:



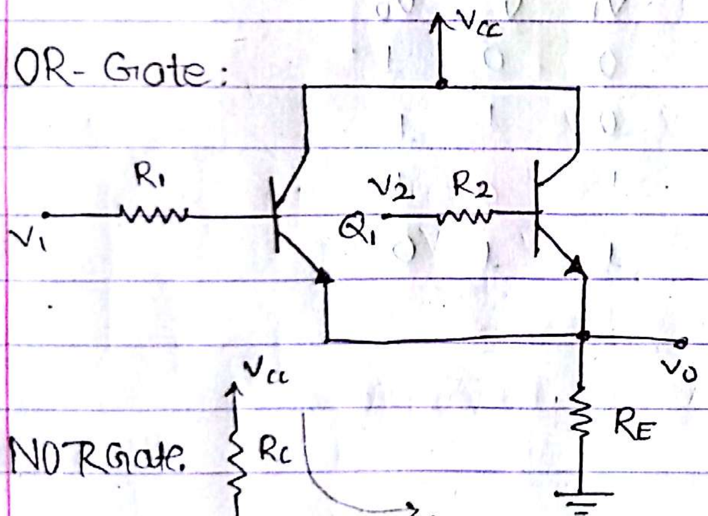




Vin	Vout
1	0
0	1

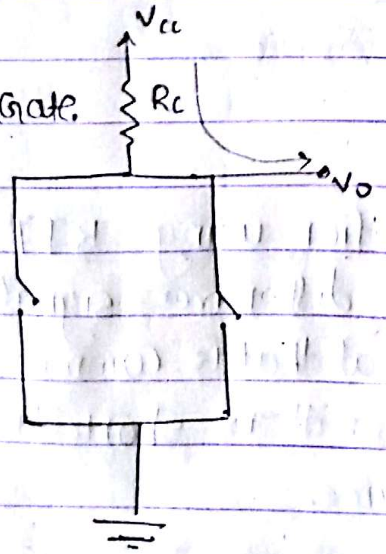
@ inverter.

OR- Gate:



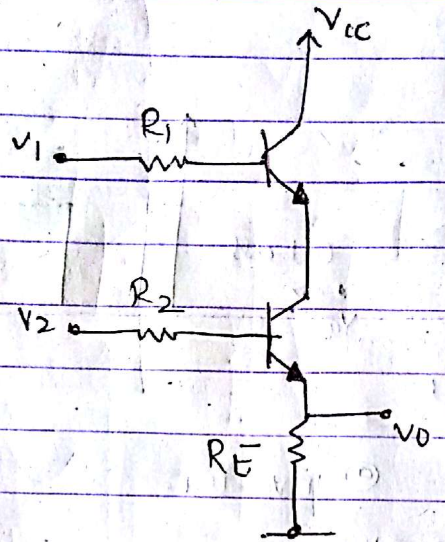
V1	V2	Vo
0	0	0
0	1	1
1	0	1
1	1	1

NOR Gate.



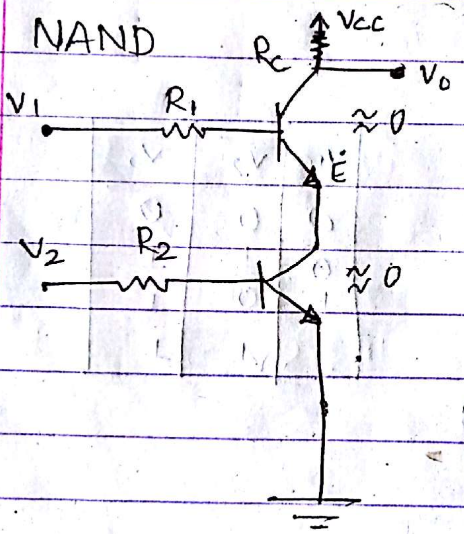
V1	V2	~~Y~~	Vo
0	0	~~0~~	1
0	1	~~1~~	0
1	0	~~1~~	0
1	1	~~1~~	0

AND Gate :



V_1	V_2	V_0
0	0	0
0	1	0
1	0	0
1	1	1

NAND

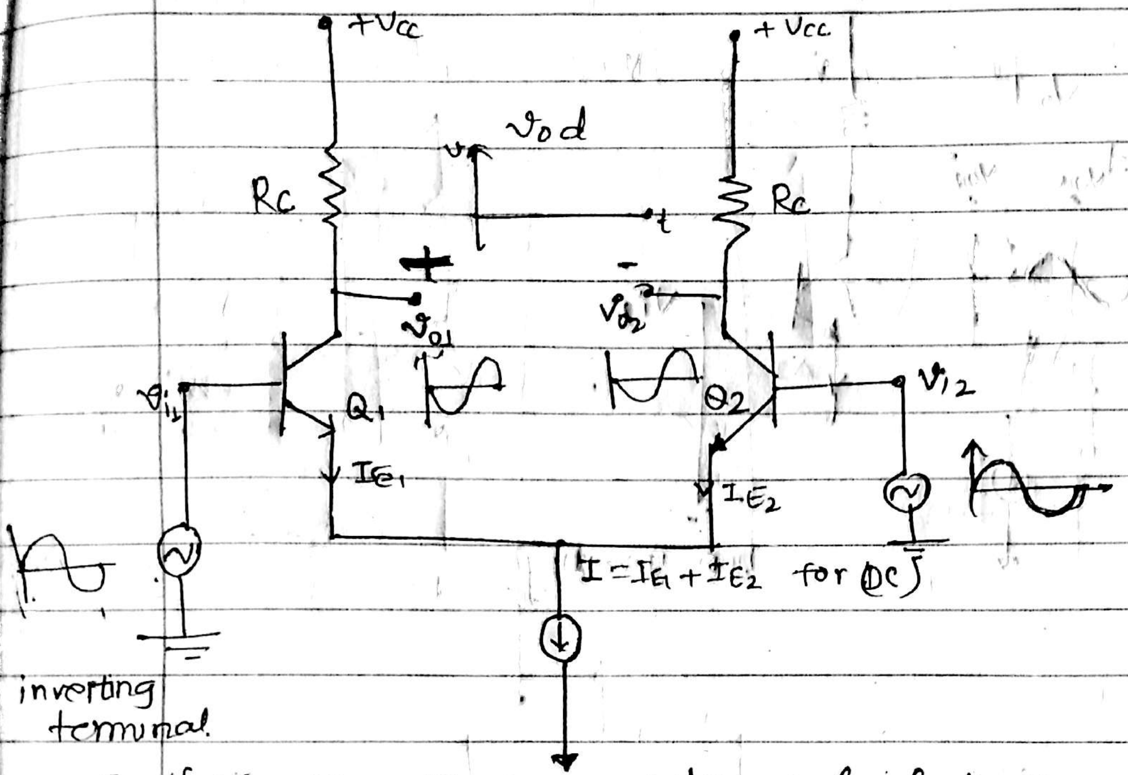


V_1	V_2	V_0
0	0	1
0	1	1
1	0	1
1	1	0

Concept of differential amplifier using BJT

→ Differential amp. amplifier the difference signal betn two inputs and ideally rejects signal that is common on both.

→ two matched transistors with emitters shorted together and connected to current source.

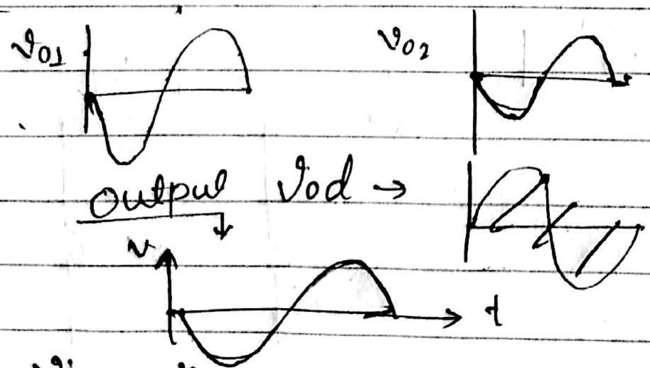


(a) if $V_{i1} = V_{i2}$ common mode. output is zero.

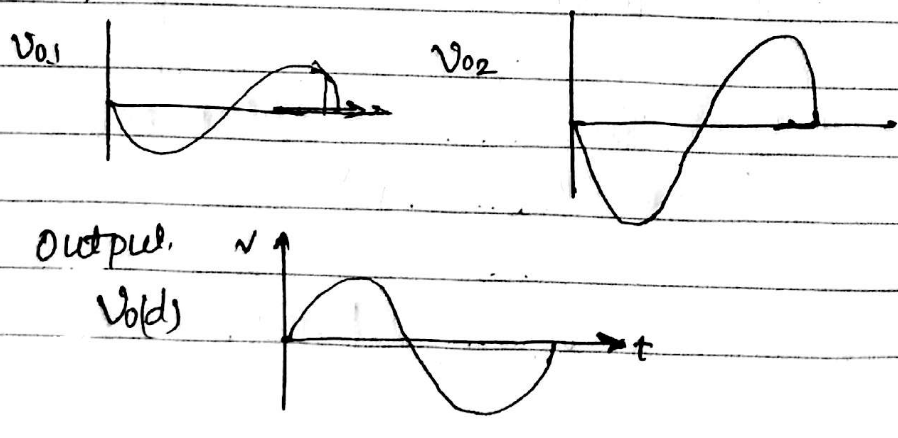
$V_{od} = A(v_{i2} - v_{i1})$

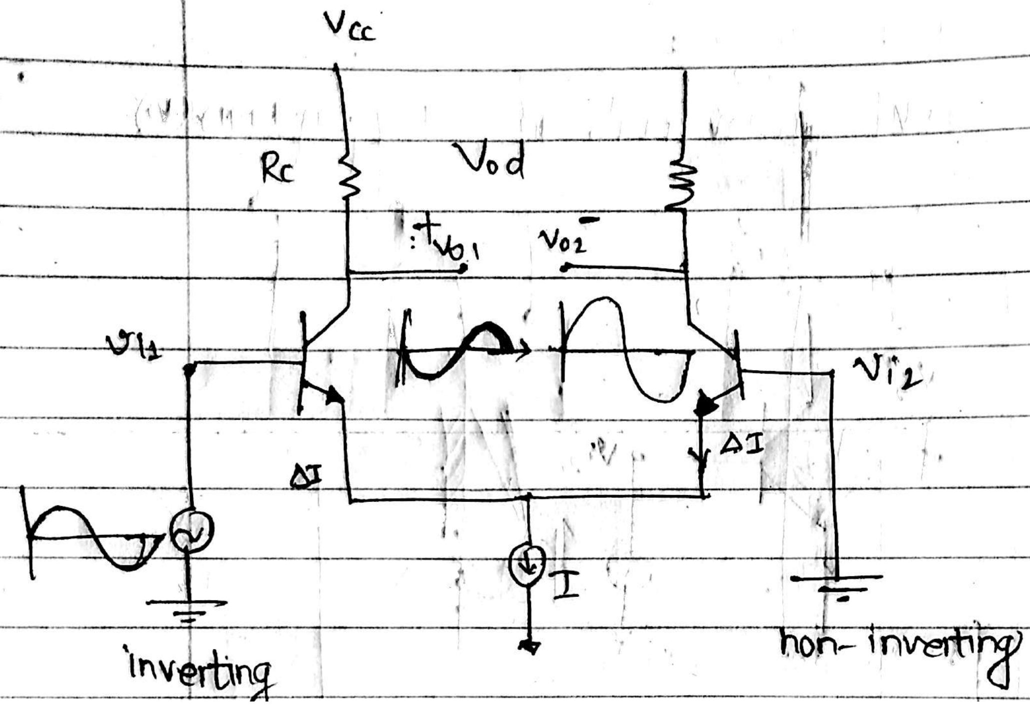
$\therefore V_{od} = V_{o1} - V_{o2}$

(b) if $V_{i1} > V_{i2}$



(c) if $v_{i2} > v_{i1}$



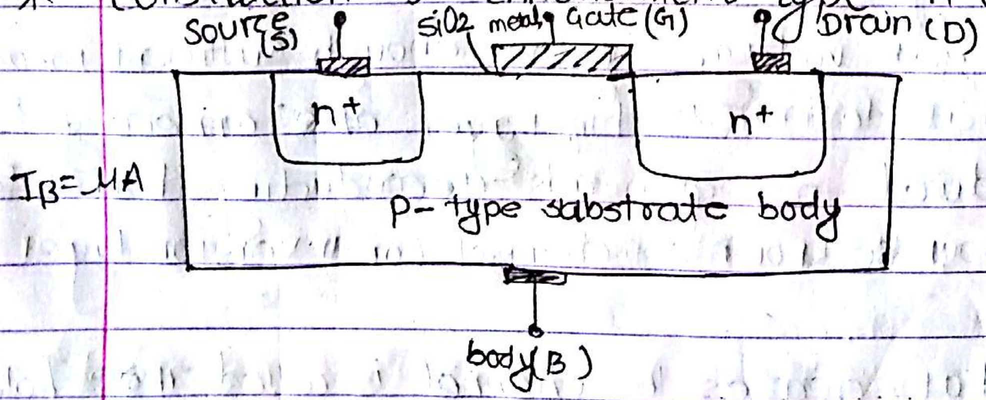

Vcc
Rc
Vod
+ Vo1
Vo2 −
vi1
Vi2
ΔI
ΔI
I
inverting
non-inverting

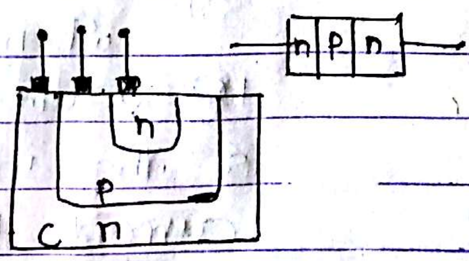
Metal oxide semiconductor
Field ebbect transistor
MOSFET

FET is
voltage controlled device
Unpolor device
high i/p impedance and low.

FET
- JFET
  - Junction FET
- MOSFET
  - Depletion type
    - p-channal
    - n-channel
  - Enhancement type
    - p-channel
    - n-channel.

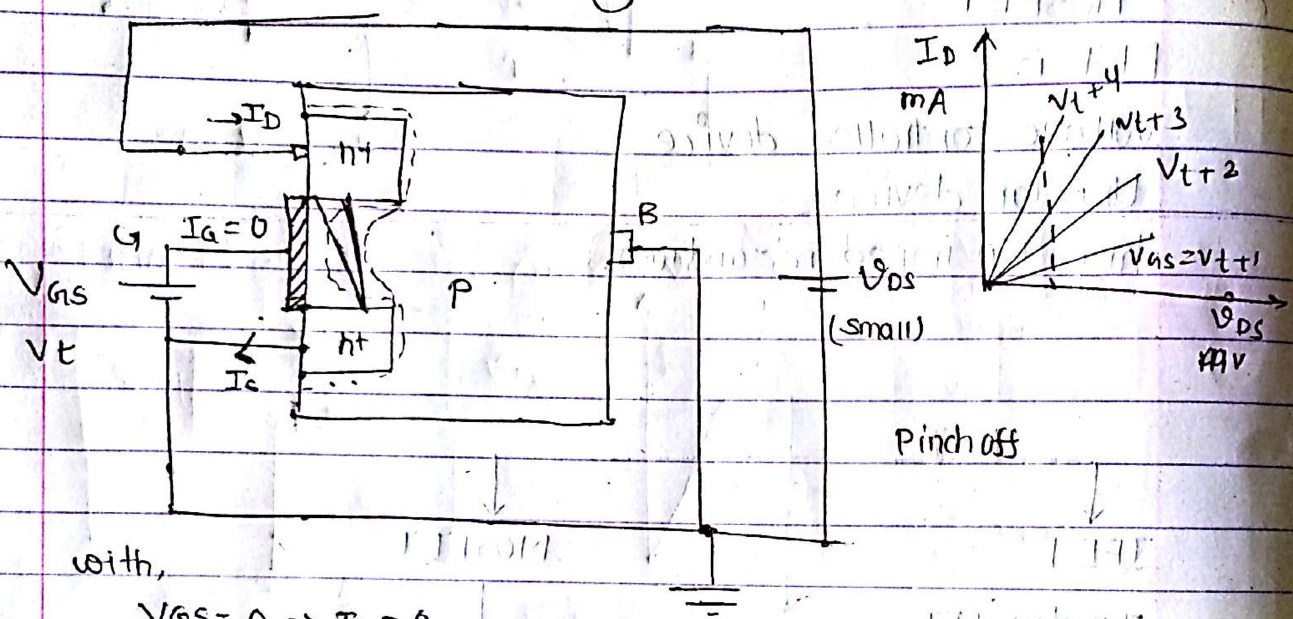
* construction of enhancement type n-channel MOSFET





Insulated gate. FET
$I_G = 0$

ⓐ applying a small drain voltage v_{DS}



with,

$V_{GS} = 0 \Rightarrow I_D = 0$

$V_{GD} = V_{GS} + V_D$

with positive gate voltage $V_{GS} > 0$

+ve voltage on gate repel hole in p substrate creating carrier deplition region e^- from D and S and accumulate into region under gate.

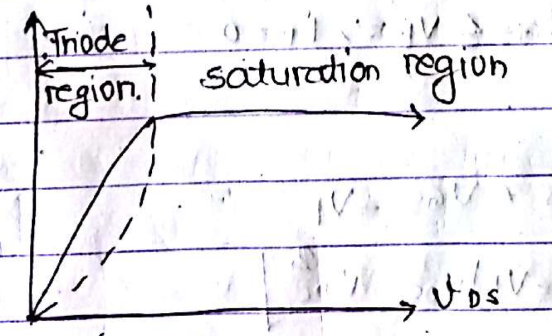
When gate voltage is +ve enough sufficient no. of e^- lag accumulate to form a thin layer of e^- connecting D and S. The induced n region acts a conducting channel for current flow so known as channel (or inversion layer)

Min. VGs that creates the channel is called threshold voltage Vt (typically 1 to 3v)

When small v_{DS} is applied the channel is uniform

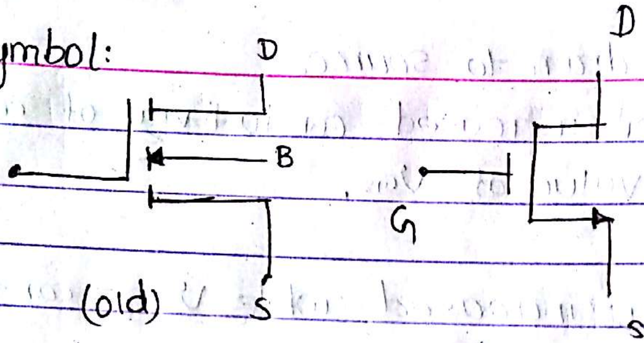
and current flows drain to source.
if V_{GS} is further increased conductivity of ch ↑ – i_D ↑ for higher value of V_{GS}.

ⓑ Operation as V_{DS} is increased while V_{GS} = constant.
if V_{GS} = constant, V_{DS} ↑
$V_{GD} = (V_{GS} - V_{DS})$ ↓ so less e^- are attracted at drain and channel is no longer uniform but is tapered. The i_D doesn't rise linearly.
at certain value of V_{DS}, at which $V_{GD} = V_{GS} - V_{DS} = V_t$,
The depth at drain decreases to zero and ch is said to be pinched off.
Increasing V_{DS} beyond this value has no effect on channel shape and i_D saturates
voltage at which saturation occurs is $V_{DS\,sat} = V_{GS} - V_t$

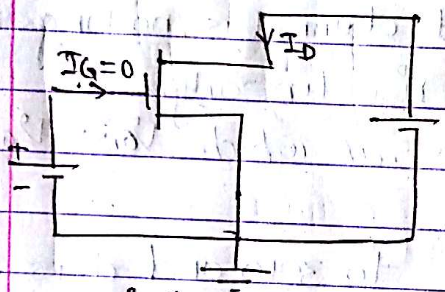


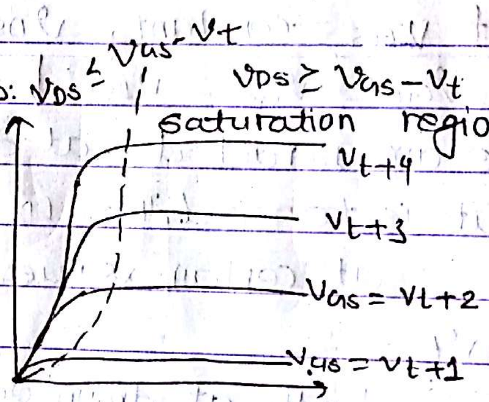
Expression for I_D
$$i_D = K\left[2(V_{GS} - V_t)V_{DS} - V_{DS}^2\right]$$
where, K = constant depends on construction of device

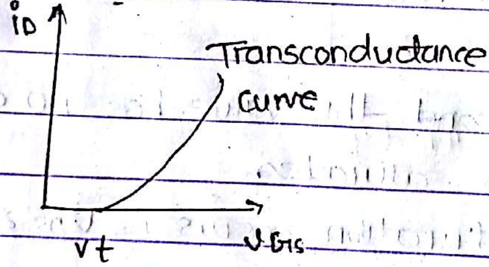
Symbol:



Static characteristic curves:







Cut off region. $v_{GS} \le v_t \Rightarrow i_D = 0$

Triode region:

$v_{GS} > v_t$ and $v_{DS} \le v_{GS} - v_t$

$\Rightarrow i_D = k\left[2(v_{GS} - v_t)v_{DS} - v_{DS}^2\right]$

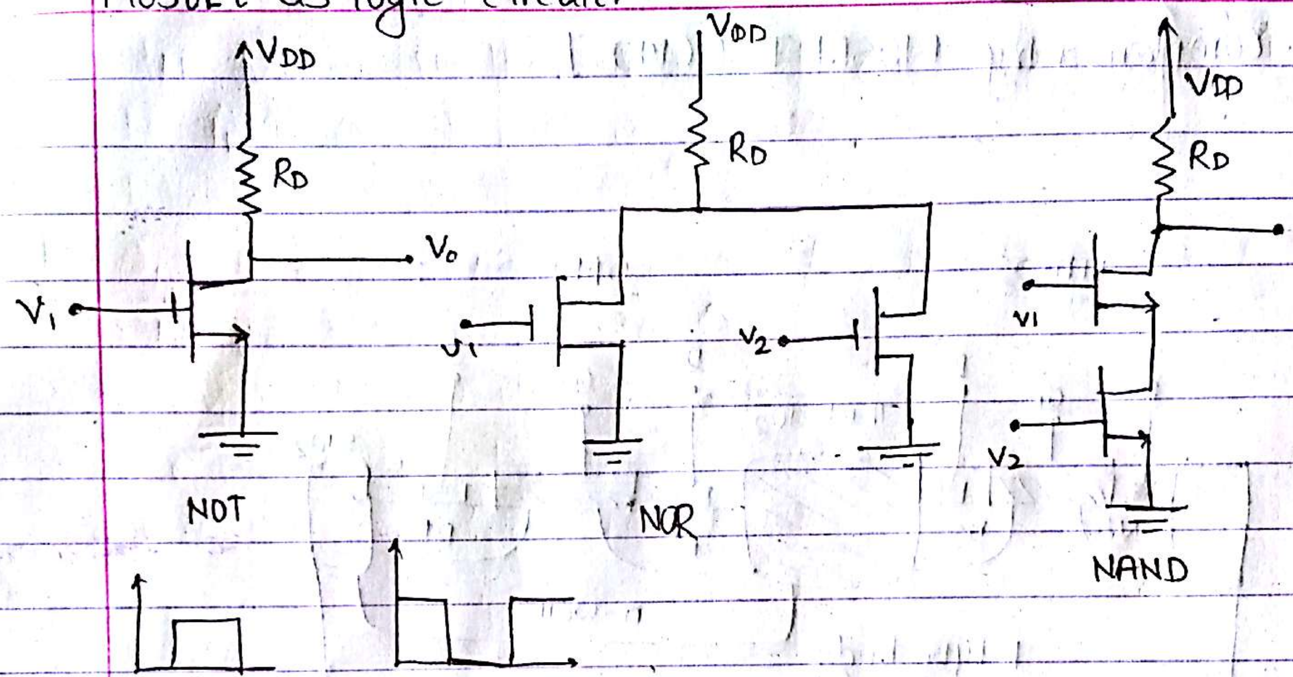
if v_{DS} is sufficiently small

$i_D \approx 2k(v_{GS} - v_t)v_{DS}$

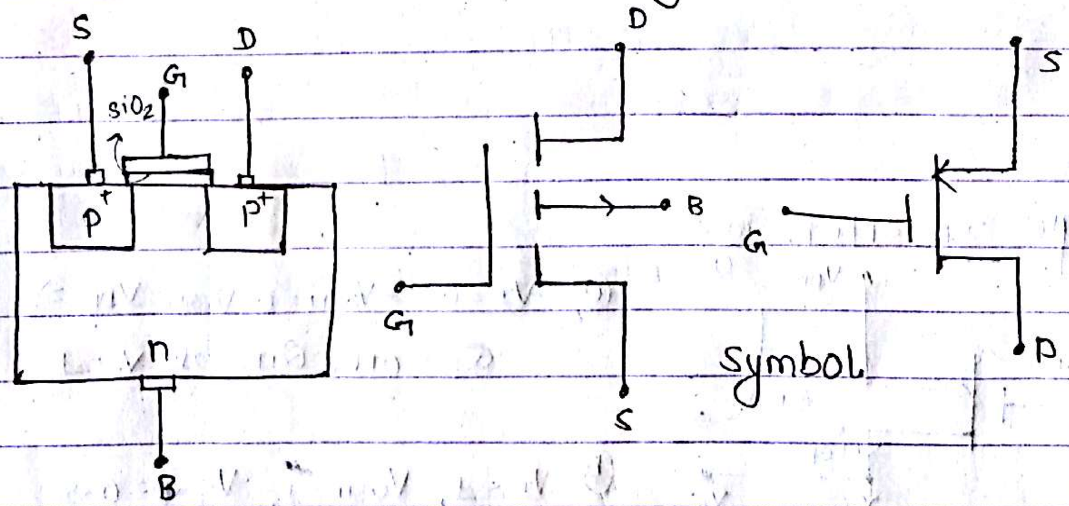
Saturation region.

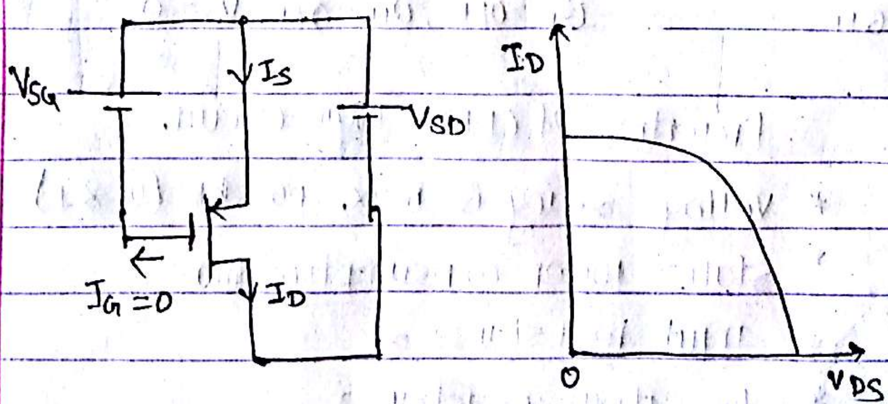
$v_{DS} > v_t$ and $v_{DS} \ge v_{DS} - v_t \Rightarrow i_D = k(v_{GS} - v_t)^2$

MOSFET as logic circuit:

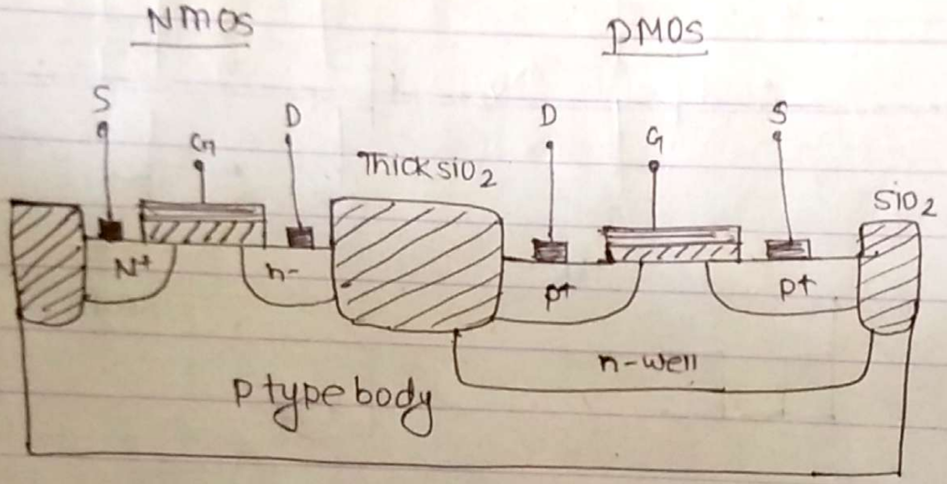


(3.8) The P-channel enhancement type MOSFET

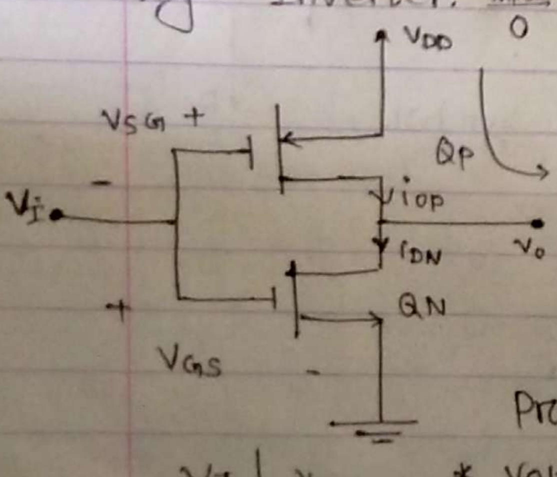




3.9. Complementary MOSFET [CMOS]



Logic Inverter.



(a). $V_I = 0, \Rightarrow V_{GSN} = 0, V_{SGP} = V_{DD} \Rightarrow$
$Q_P = ON, Q_N = off, V_o = 1$

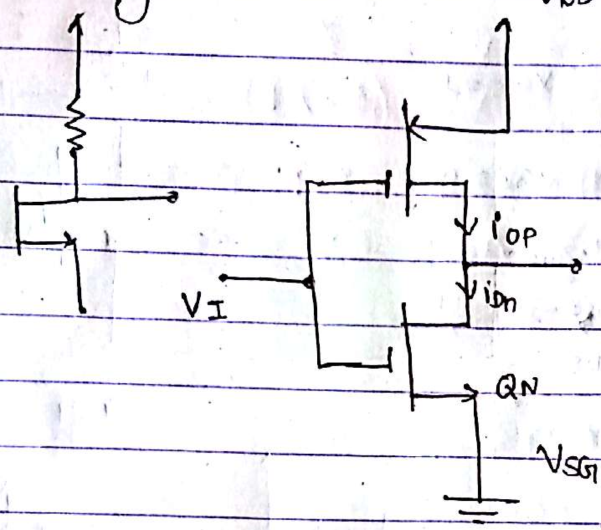
(b). $V_I = 1, V_{GSN} = 1, V_{SGP} = 0 \Rightarrow$
$Q_P = OFF, Q_N = ON, V_o = 0.$

V_I	V_o
0	1
1	0

Properties of CMOS logic circuit.

* Voltage swing is max possible (0, & 1)
* static power consumption low
* input resistance ∞
* low output resistance

3.9.1 CMOS logic inverter:

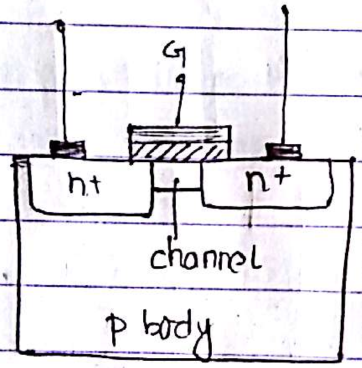


$V_{SG} = V_S - V_G$

$= V_{DD} - V_{DD}$

$= 0$

3.10 Depletion type n channel MOSFET.



it has physically implanted channel beth source and drain.

Working Principle:

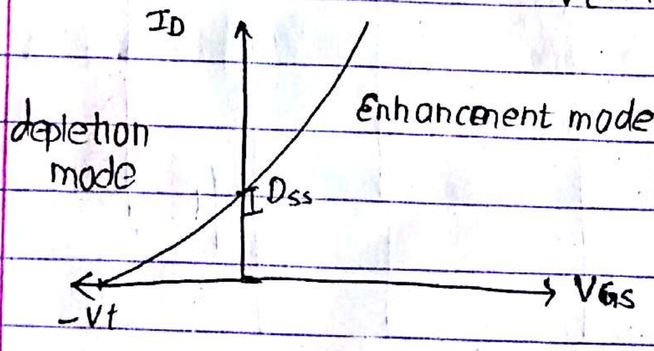
(a) $V_{GS} = 0 \Rightarrow I_D$: finite

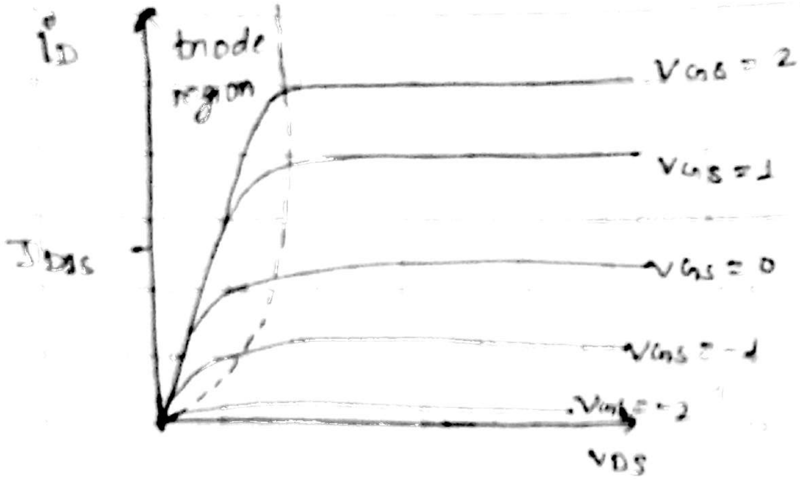
(b) $V_{GS} > 0 \Rightarrow I_D \uparrow$

(c) $V_{GS} < 0 \Rightarrow I_D \downarrow$

at, $V_{GS} = V_t \Rightarrow$ channel is depleted of charge carriers $I_D = 0$

$V_t \rightarrow$ threshold voltage (negative)

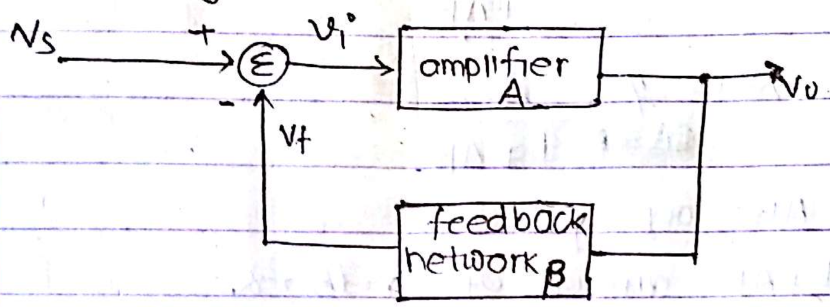



i_D
triode region
$V_{GS} = 2$
$V_{GS} = 1$
I_{DSS}
$V_{GS} = 0$
$V_{GS} = -1$
$V_{GS} = -2$
V_{DS}

Chapter 4:
The operational amplifier and Oscillator.

4.1: Basic feedback theory

The process of applying a fraction of output signal back to the input signal is known as feedback.



$A = \frac{v_o}{v_i}$ open loop gain,

$\beta = \frac{V_f}{V_o}$ ⇒ feedback factor

total input, $v_i = V_s + V_f$

closed loop gain, $= \frac{v_o}{V_s}$

* Negative (degenerative) feedback ⇒ feedback signal is out of phase with input signal. ie, $V_f = -\beta V_o$ input to amplifier is reduced,

$$v_i = v_s - \beta V_o$$

* Positive (regenerative) feedback: feedback signal is in phase with input signal. ie, $V_f = \beta V_o$, input to amplifier is increased,

$$v_i = V_s + \beta V_o$$

Consider a positive feedback system: $V_f = \beta V_o$

$$\therefore v_o = A v_i$$

$$= A(V_s + V_f)$$

$$v_o = AV_s + A\beta V_o$$

$V_0(1 - A\beta) = V_s A$

Gain of feedback amp. $A_{\text{closed loop}} = \frac{V_0}{V_s} = \frac{A}{(1 - A\beta)}$

Similarly, for -ve feedback amplifier:

$$A_{closed} = \frac{A}{1 + A\beta}$$

In General, $A_{cl} = \frac{A}{1 \mp A\beta}$

where, $A\beta$ = loop gain and

$1 \mp A\beta$ = amount of feedback.

Generally $A \to \infty$

$$A_{cl} = \frac{1}{\frac{1}{A} \mp \beta} \approx \frac{1}{\mp \beta}$$

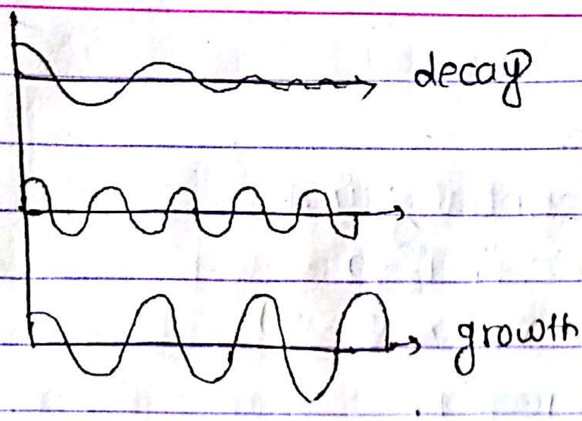
* Negative feedback results in
* decreased voltage gain.
* improved freq^n respone
* reduced noise
* more linear operation.

Positive feedback : increases the gain and stability of amplifier is determined by magnitude of loop gain

if, $A\beta < 1$, oscillation decays

if, $A\beta = 1$, oscillation

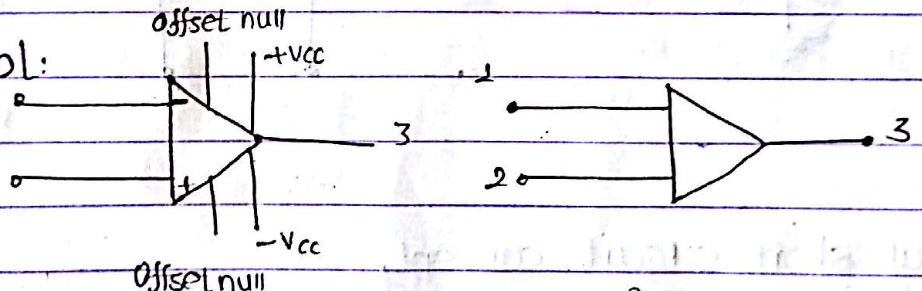
if, $A\beta > 1$ oscillation growth } unstable



4.2: Operation amp: (Op amp)

* a very high gain differential amp with high I/P impedance and low O/P impedance
* performs addition, subtraction, integration, differentiation etc so named op-amp.
* available in : Ic (IC 741)
* It has two i/p and one output.

Symbol:



+ ve, non inverting terminal
-ve, Inverting "
3 - output
1, 2, input

Application

(a) analog computation (add, sub, etc) and instrumentation
(b) voltage buffer
(c) Oscillator circuits and active filter circuits.

4.2.1: Ideal Op-amp

Characteristic of Op-amp.

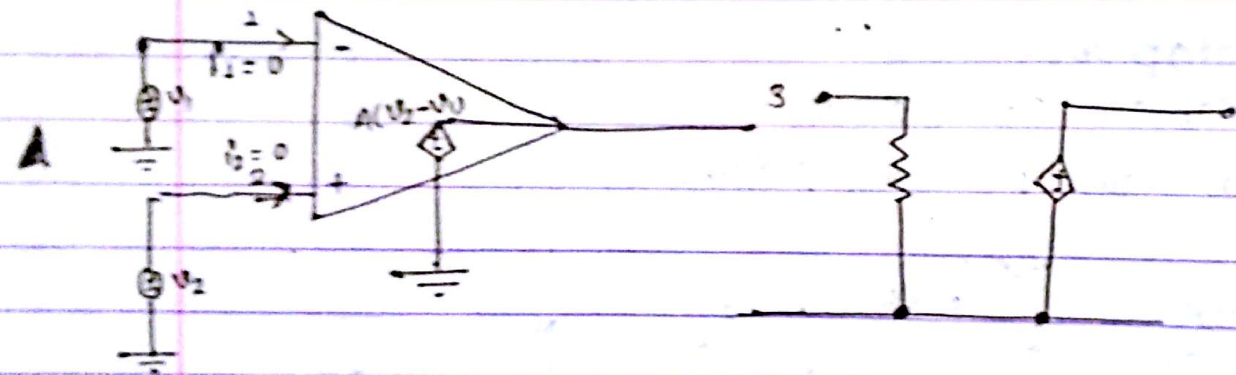
1. Infinite open loop differential gain A
2. infinite input impedance. $i_1 = i_2 = 0$
3. Zero output impedance, $v_0 = A(v_2 - v_1)$
4. Infinite common mode rejection.

$$CMRR = \frac{A_d}{A_{cm}} = \infty$$

↳ common mode gain

5. Infinite bandwith.

Ad - diff gain.



* Virtual short circuit concept.

$$v_0 = A(v_2 - v_1)$$

$$\therefore v_2 - v_1 = v_0/A$$

$$A \longrightarrow \infty$$

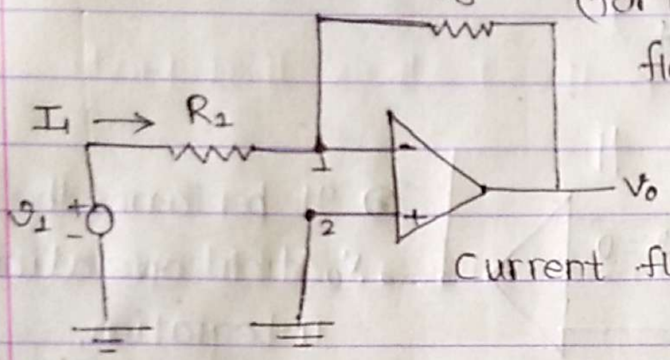
$$v_2 - v_1 = \frac{v_0}{\infty} \approx 0$$

$\Rightarrow v_2 = v_1$ Virtual short circuit

It means whatever voltage is at 2 will automatically appears at 1.

731 / 26

(a) Inverting amplifier



(for ideal op-amp) – Resistance ∞ so total current flows through Rf

from virtual ground concept

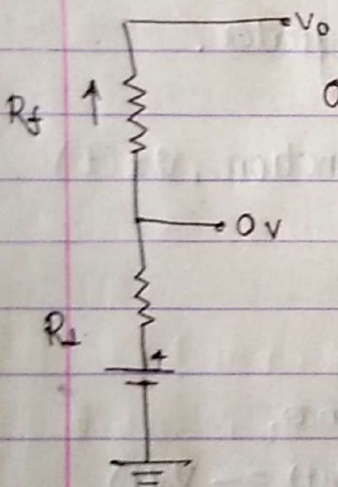
$v_1 = v_2 = 0$

Current flowing through R1 ⇒ $I_1 = \frac{V_I - V_o}{R_1}$

$= \frac{V_I}{R_1}$

So, $I_f = I_1$ (ideal op-amp) $R \to \infty$

$= \frac{V_I}{R_1}$



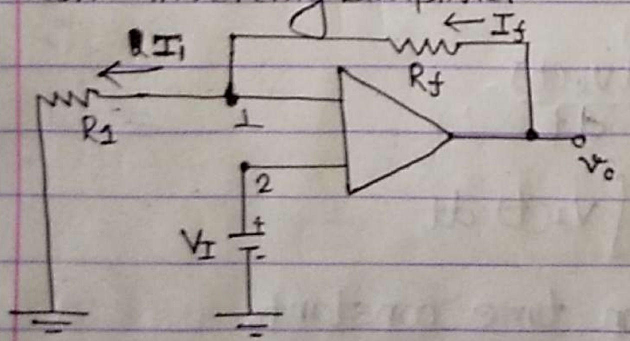
Output voltage, $V_o = V_1 - I_f R_f$

$= 0 - \frac{V_I}{R_1} \cdot R_f$

$= -\frac{R_f}{R_1} \cdot V_I$

$\therefore A_{closed} = \frac{V_o}{V_I} = -\frac{R_f}{R_1}$

(b) Non-inverting amplifier:



from virtual short circuit concept

$v_1 = v_2 = v_I$

Current flowing through R1

$I_1 = \frac{V_I}{R_1}$

for ideal op amp → $R_{in} = \infty$

$I_1 = I_f$

Output voltage, $V_o = V_1 + I_f R_f$

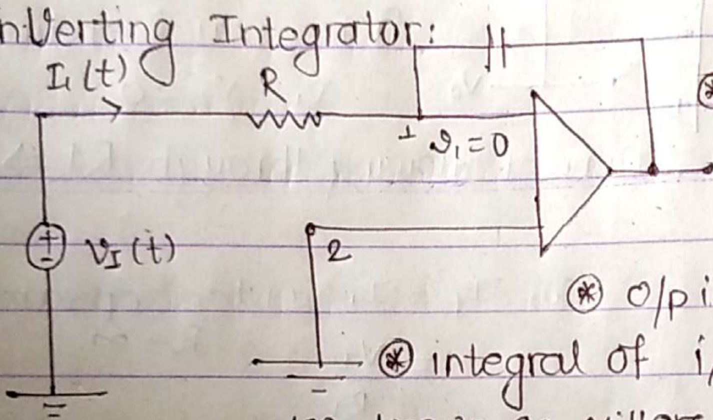
$= V_I + \frac{V_I}{R_1} \cdot R_f$

$= \left(1 + \frac{R_f}{R_1}\right) V_I$

$\therefore \frac{V_o}{V_I} = \left(1 + \frac{R_f}{R_1}\right)$

$$\therefore A_{open} = \frac{v_o}{v_I} = \left(1 + \frac{R_f}{R_1}\right)$$

4.2.4. Inverting Integrator:



* It performs the mathematical operation of integration.
* o/p is proportional to time integral of i/p.

also known as Millers integrator.

Let the input be the time varying function, $v_I(t)$

$$I_1(t) = \frac{v_I(t)}{R}$$

current flowing through C,

$$I_f(t) = C\frac{d(V_c)(t)}{dt} = -C\frac{dV_o(t)}{dt}$$ since, $V_c(t) = -V_o(t)$

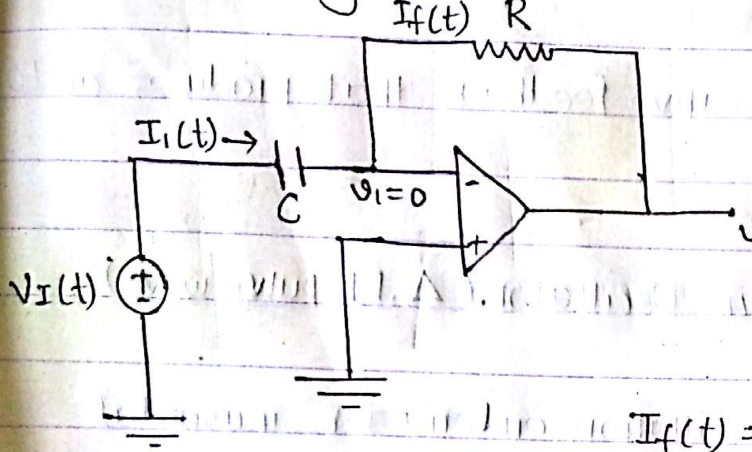
But,

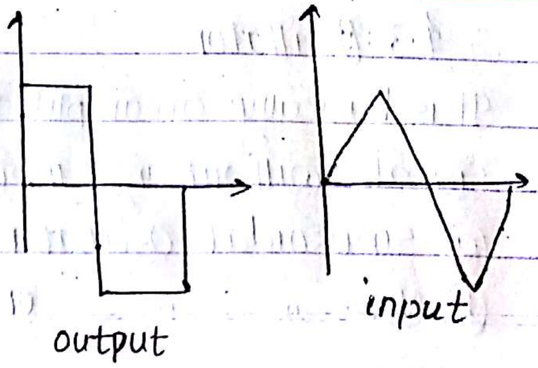
$$\frac{v_I(t)}{R} = -C\frac{dv_o(t)}{dt}$$

$$\therefore V_o(t) = -\frac{1}{RC}\int V_I(t)\,dt$$

RC → integration time constant.

4.2.5: Inverting differentiator:





$$I_f(t) = I_1(t)$$

let, the input be the time varying function, $v_I(t)$,

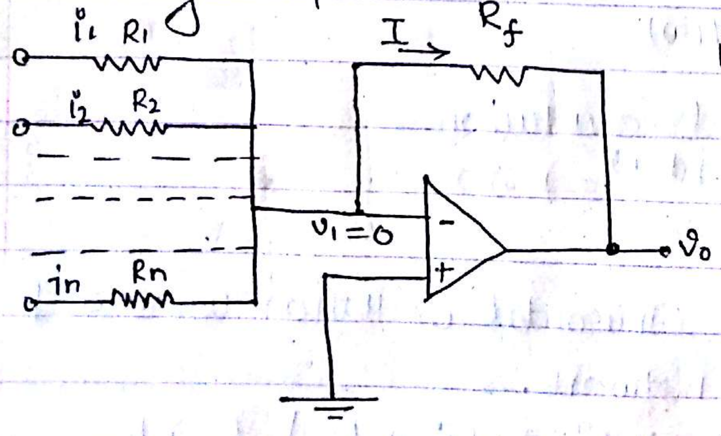
$$I_1(t) = \frac{c\,d(v_I(t) - v_1)}{dt} = \frac{c\,d\,v_I(t)}{dt} \quad \because (v_1 = 0)$$

$$\therefore v_0 = -I_f(t)R \quad \text{(for inverting configuration)}$$

$$= -c\frac{d\,v_I(t)}{dt} \cdot R$$

$$= -RC\frac{d\,v_I(t)}{dt}$$

4.2.6 Summing amplifier:



$$i_1 = \frac{v_1}{R_1},\ i_2 = \frac{v_2}{R_2} \ldots i_n = \frac{v_n}{R_n}$$

$$\therefore I = i_1 + i_2 + i_3 + \ldots + i_n$$

$$V_0 = -I R_f$$

$$= -\left(\frac{v_1}{R_1}R_f + \frac{v_2}{R_2}R_f + \frac{v_3}{R_3}R_f + \ldots + \frac{v_n}{R_n}R_f\right)$$

If $R_1 = R_2 = \ldots = R_n = R$

$$v_0 = -\left(\frac{v_1 R_f}{R} + \frac{v_2 R_f}{R} + \frac{v_3}{R}R_f + \ldots + \frac{v_n}{R_n}R_f\right)$$

$$v_0 = -\frac{R_f}{R}\left[v_1 + v_2 + \ldots + v_n\right]$$

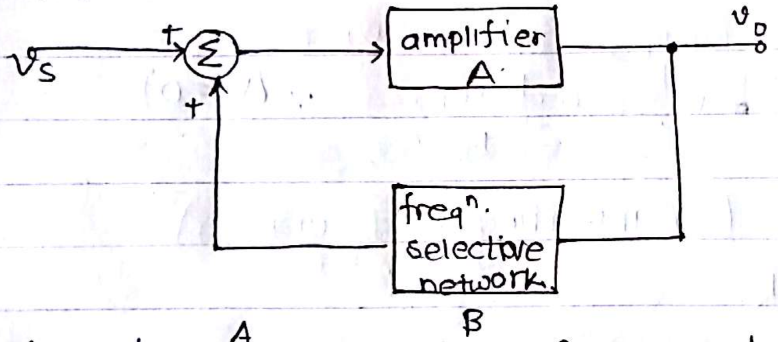
4.3 : Oscillator

It is basically an amplifier with positive feedback that produces and o/p Signal without any input to it.

ⓐ Sinusoidal Oscillator

ⓑ Non- " " or relaxation Oscillator. (△, □ pulse wave)

4.3.1: Positive feedback loop and oscillation criteria for sinusoidal Oscillation.



$$A_{closed} = \frac{A}{1 - A\beta}$$

if $v_o \Rightarrow A\beta = 1, A_{cl} = \infty$

Generally both amplifier and feedback factor is function of freq^n so loop gain is complex.

$$L(j\omega) = A(j\omega)\,\beta(j\omega)$$
$$= |A(j\omega)\,\beta(j\omega)|\, e^{i\phi(\omega)}$$

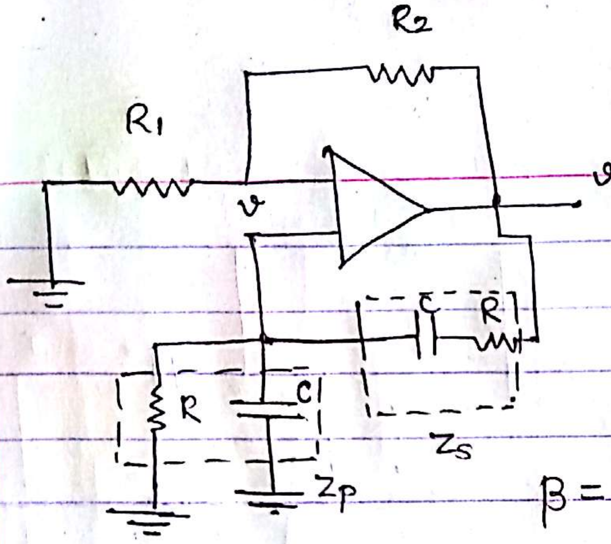
condition for sinusoidal oscillation.

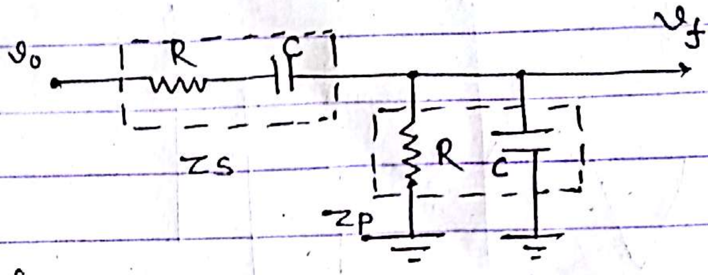
$$L(j\omega) = |A(j\omega)\,B(j\omega)|\, e^{j\phi(\omega)} = 1 \angle 0^\circ$$

1.3.2. Wien bridge Oscillator for Sinusoidal oscillation uses a feedback network called lead lag network.

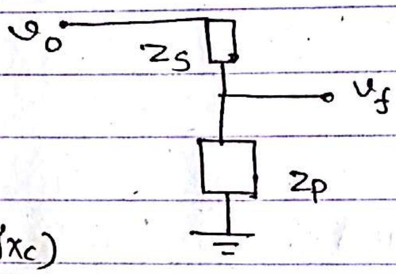
amplifier is non inverting conf^n. $A = \left(1 + \frac{R_f}{R_1}\right)$ be ph.

$\sqrt{RC}$





$$\beta = \frac{v_f}{v_0}$$



$$v_f = \frac{Z_p}{(Z_p + Z_s)} v_0$$

$$\therefore \beta = \frac{v_f}{v_0} = \frac{Z_p}{(Z_p+Z_s)} = \frac{R \parallel (-jx_c)}{[R \parallel (-jx_c)] + (R - jx_c)}$$

$$= \frac{v_f}{v_0} = \frac{1}{3 + j\left(\frac{R}{x_c} - \frac{x_c}{R}\right)}$$

$$= \frac{1}{\sqrt{9 + \left(\frac{R}{x_c} - \frac{x_c}{R}\right)^2}} \angle \tan^{-1}\left(\frac{\frac{R}{x_c} - \frac{x_c}{R}}{3}\right)$$

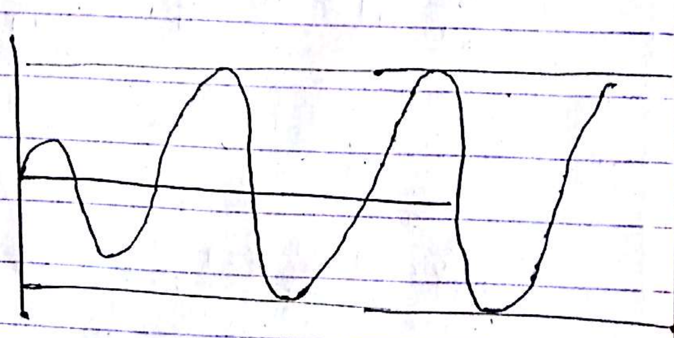
The phase of lead-lag network will be zero when imaginary term vanishes,

$$\frac{x_c}{R} - \frac{R}{x_c} = 0$$

or, $R^2 = x_c^2$

$\therefore R = x_c$

$$R = x_c = \frac{1}{\omega C} = \frac{1}{2\pi RC}$$



For oscillation, $|\beta| = 1/3$, $|A\beta| = 1$

or, $|A\beta| = 1$

$$\left(1 + \frac{R_f}{R_1}\right)\frac{1}{3} = 1 \;\rightarrow\; \boxed{\therefore \frac{R_f}{R_1} = 2}$$

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