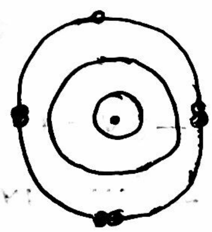
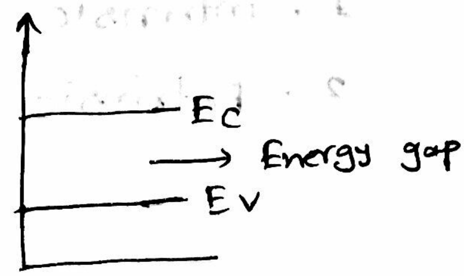
28.04.16

Atomic Structure :



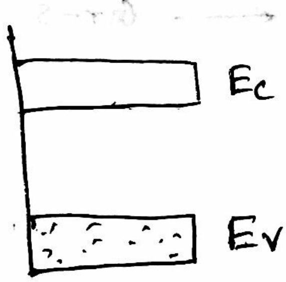


* Valence band & conduction band's defination

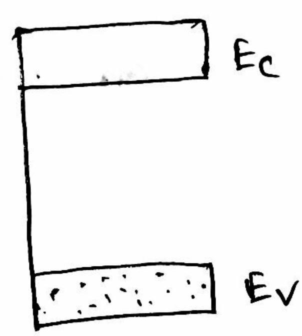
Classification ~~A~~ of solid based on Energy gap :

(Picture)

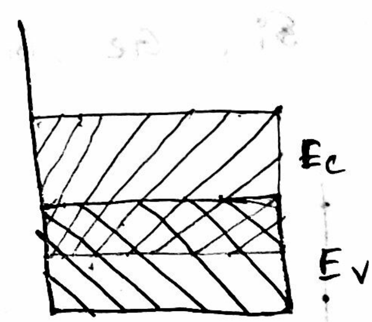
1. Insulator
2. Semi- conductor
3. Conductor



$E_g \approx 1.1 eV$
(si)



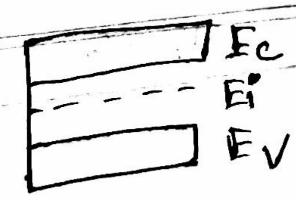
$E_g > 10 eV$
(OK)



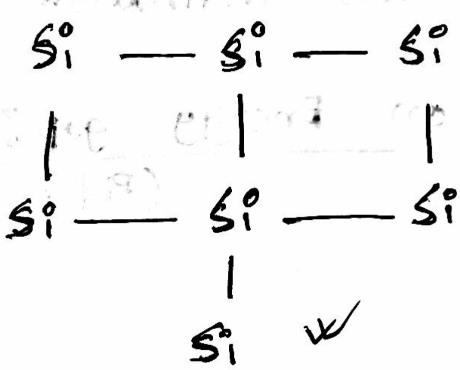
$E_g = 0$

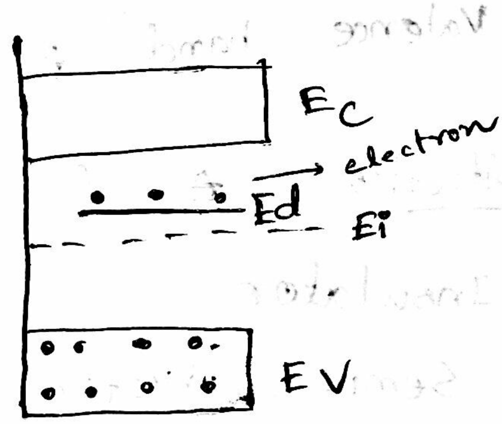
* Semi- Conductor :

1. intrinsic Material →



2. Extrinsic Material
   - → N type -(V - IV)
   - → P type - (III - IV)

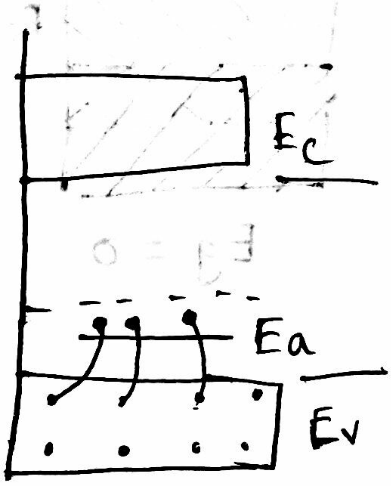




T= 0K

Si , Ge , Ga

Gr-3 → Gr-4 ← Gr-5

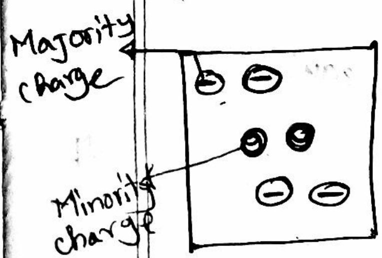


Energy Gap/
forbidden Energy
Gap

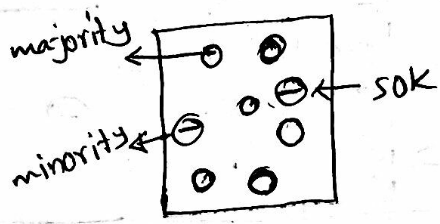
T= 0 K

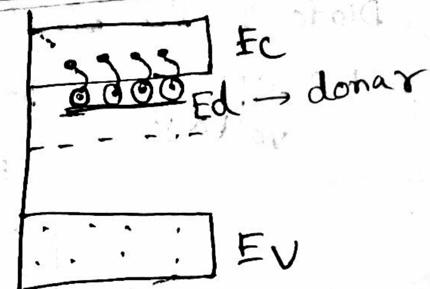
T= 50K

N – type:



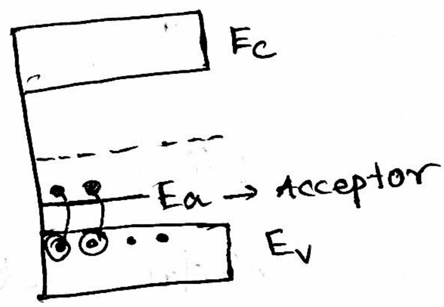
P–type:





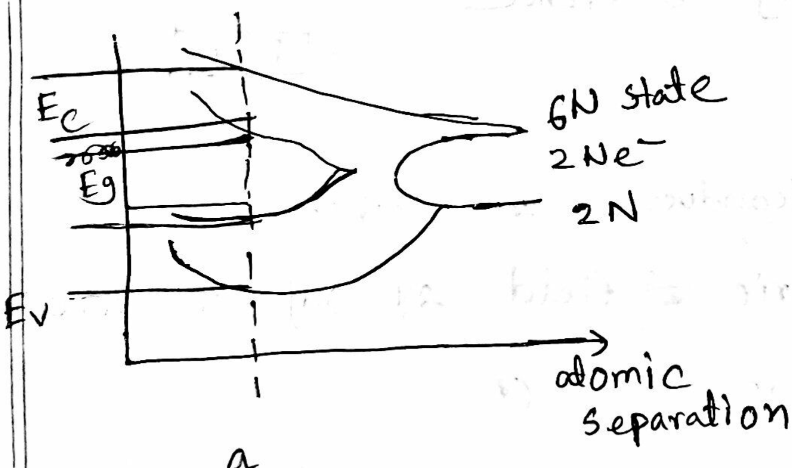
50K

* 0K এ electron ছাড়া কিছুই থাকেনা,



0K

50k

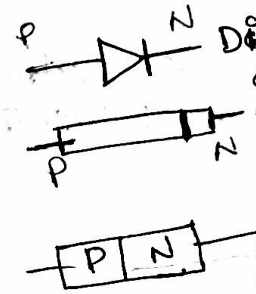


15.05.16

Diode : without bias/ No applied voltage

→ equlibrium condition

diffusion = drift



~~diffu~~

diffusion ⟷ density difference

electric field → E

1) diffusion → semiconductor : এ possible

2) drift → electric ~~ef~~ field এর জন্য যে current

* minority carrier move করে

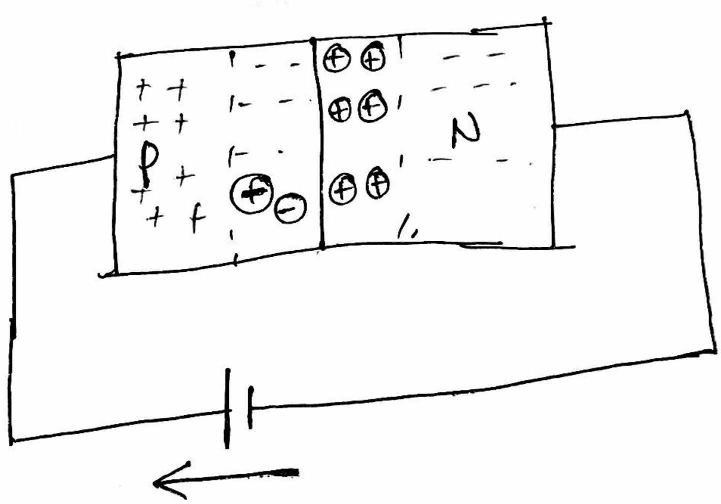
Forward Bias : [$V_d > 0$]

1) P side +ve
N side -ve

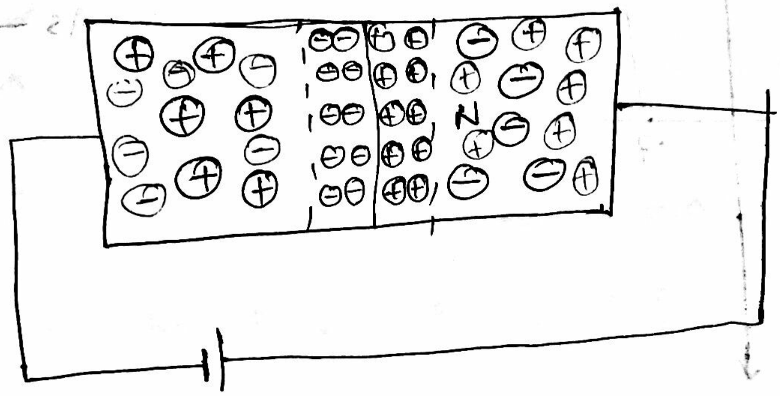
2) diffusion will increase

3) deplation area will decrease

4) current will start to flow



Reverse bias :



1] P side -ve
N side +ve

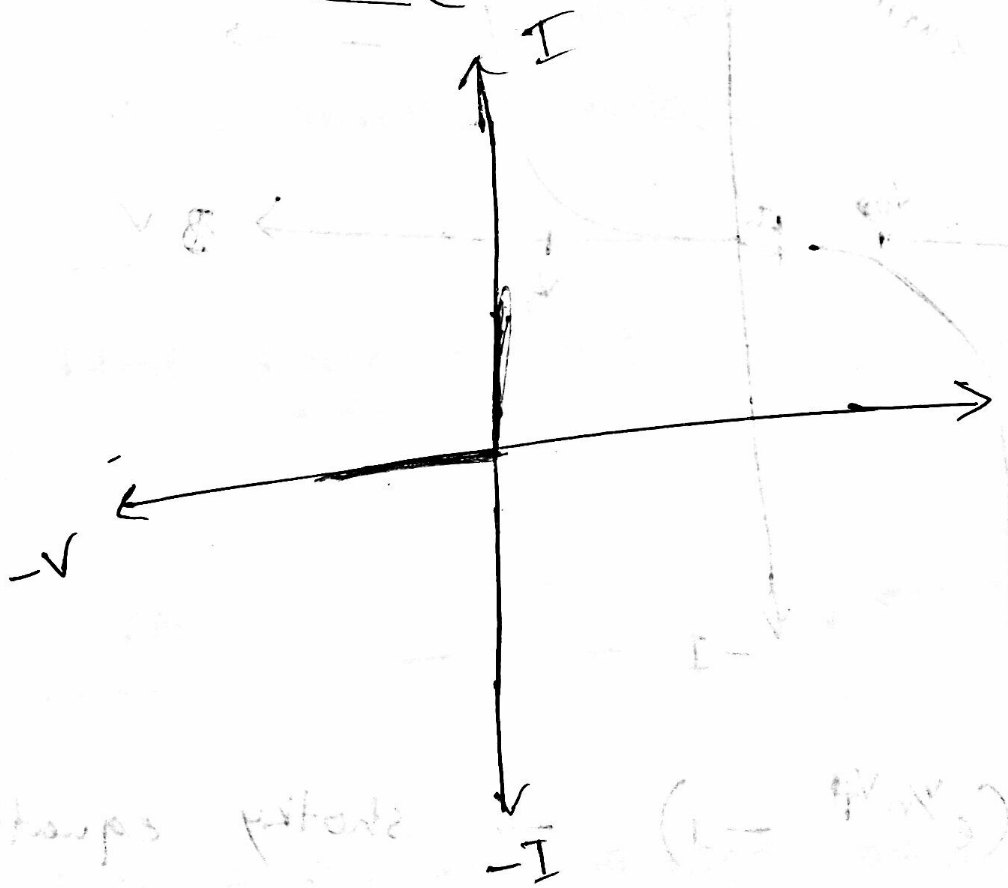
2] Deplation area will increase

3] Diffusion will decrease

4) current won't flow

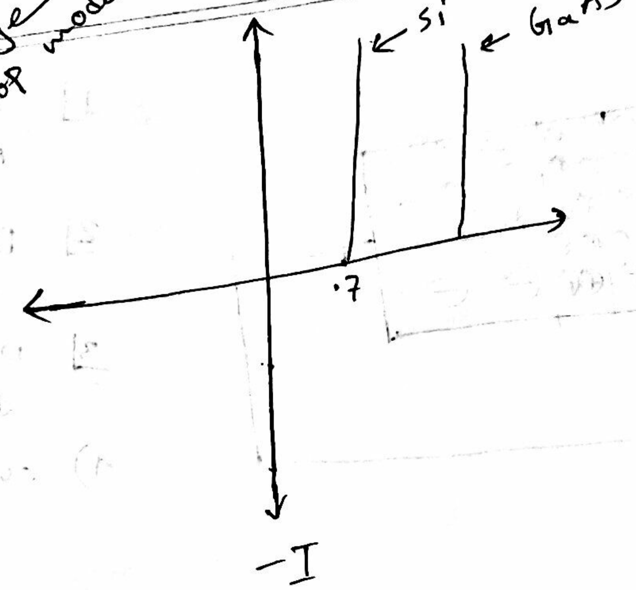
~~Diode curve~~

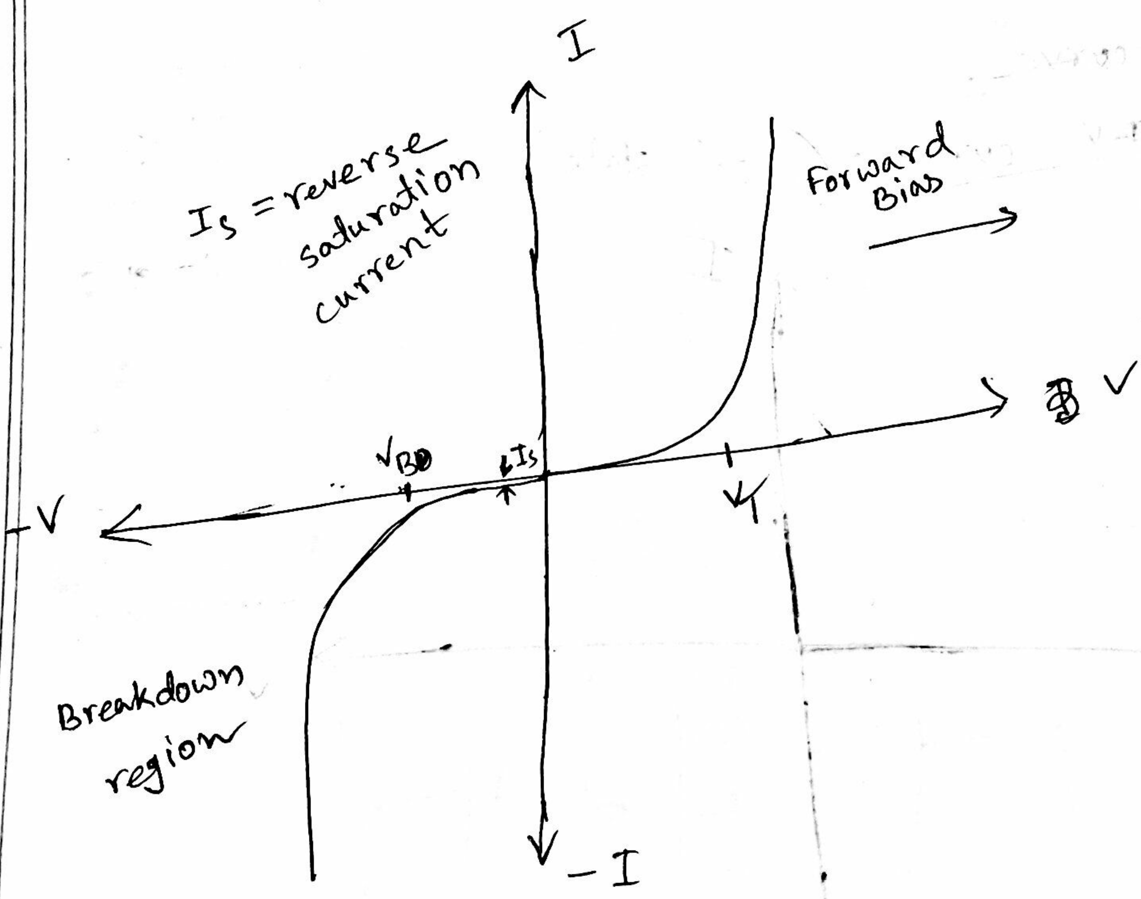
Diode I-V curve : (Ideal state)



constant voltage drop model

Si – .7 V
Ge → .3 V
GaAs → 1.2 V



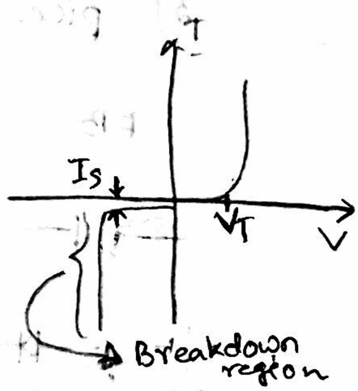


$I = I_S \left(e^{V/nV_T} - 1\right)$ → shotky equation

19.05.16

Diode models :

1) Ideal diode model
2) constant voltage drop model
3) pice-wise linear model
4) Small signal model



$n = 1, 2$

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

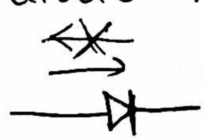
I_s = Reverse saturation current

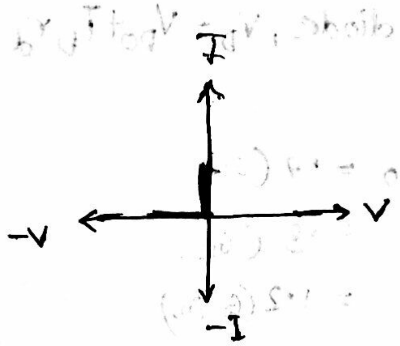
V_T = Thermal voltage

V' = Threshold voltage

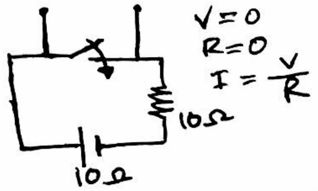
$V = -V$, $I = -I_s$

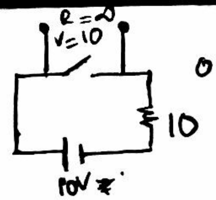
1) Ideal diode model :





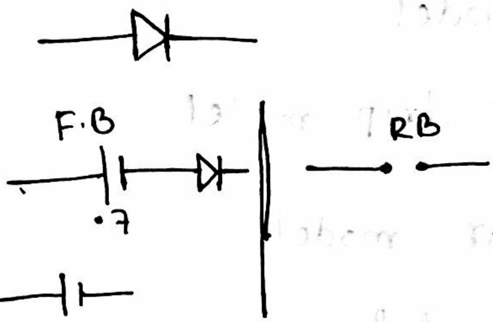
* diode এ কিছু দেওয়া না থাকে তাহলে ideal diode নিতে হবে।

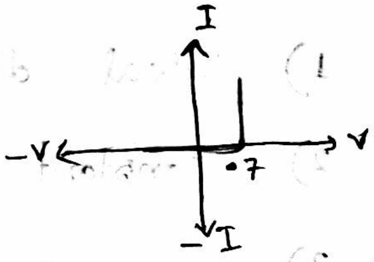




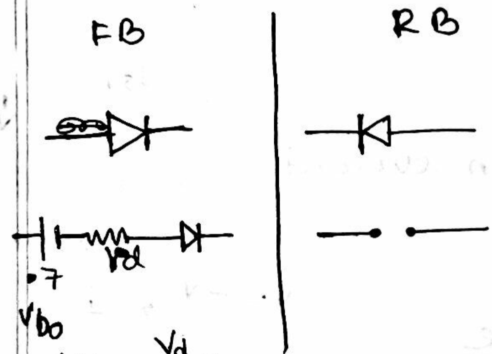
open switch

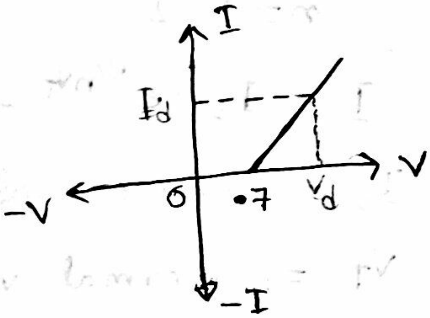
2) Constant voltage drop model :





3) pice - pise linear model :





$$r_d = \frac{V_d}{I_d}$$

Drop across

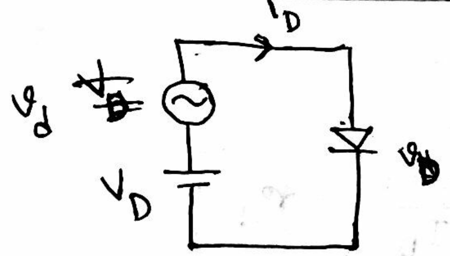
the diode, $V_D = V_{D0} + I_D r_d$

$V_{D0} = .7$ (Si)
$= .3$ (Ge)
$= 1.2$ (GaAs)

$*$ How to develop small signal model:

$*$ from photocopy

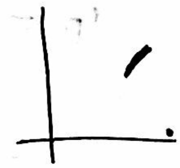
iv) Small signal model (low frequency)



$V_D = DC$

$v_d = AC$

$v_D = AC + DC$



For DC only

$$I_D = I_s \left[e^{\frac{V_D}{nV_T}} - 1 \right]$$

$$\approx I_s \, e^{\frac{V_D}{nV_T}} \quad \text{—— (1)} \quad \text{for } e^{\frac{V_D}{nV_T}} \gg 1$$

for AC + DC

$$i_D = I_s \, e^{\frac{v_D}{nV_T}} \quad \text{—— (2)}$$

Now,

$$V_D + v_d = v_D$$

From eq-1,

$$i_D(t) = I_s \, e^{\frac{V_D + v_d}{nV_T}}$$

$$= I_s \, e^{\frac{V_D}{nV_T}} \, e^{\frac{v_d}{nV_T}}$$

$$= I_D \, e^{\frac{v_d}{nV_T}} \quad [\text{equ}^n - 1]$$

$$= I_D \left[1 + \frac{v_d}{nV_T} + \frac{(v_d/nV_T)^2}{\underline{|2}} + \cdots \right]$$

$$\cong I_D \left[1 + \frac{v_d}{nV_T} \right]$$

$$i_D = I_D + I_D \frac{v_d}{nV_T}$$

$$i_D = I_D + \frac{\frac{v_d}{nV_T}}{I_D}$$

$$= I_D + \frac{v_d}{r_d} \quad \left[\frac{nV_T}{I_D} = r_d\right]$$

$$i_D = I_D + i_d$$

<u>so</u>

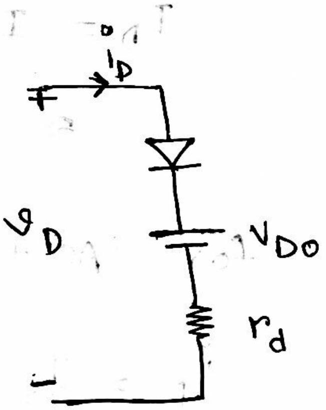
$$v_D = i_D \cdot r_d + V_{DO}$$

$$= (I_D + i_d)\, r_d + V_{DO}$$

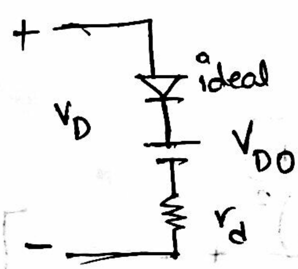
$$= I_D r_d + i_d r_d + V_{DO}$$

$$= (I_D r_d + V_{DO}) + i_d r_d$$

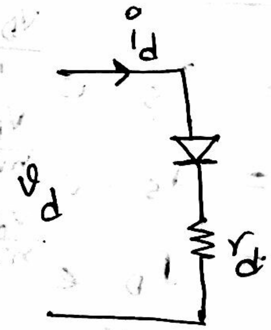
$$= V_D + i_d r_d$$

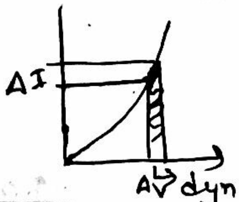


<u>DC equivalent ckt</u>



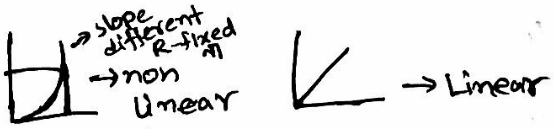
<u>AC eq ckt</u>





$\Delta r = \frac{\Delta V}{\Delta I}$

dynamic resistance



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

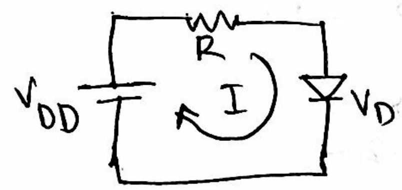
static Resistance

Load line:

→ Q (→ operating point) point is the point where characteristic curve and load line intersects

→ load line represents the linear part (resistor) of the circuit connect to the non linear device (diode)

→ load line varies with load (Resistance)



$-V_{DD} + IR + V_D = 0$

$I = 0,$

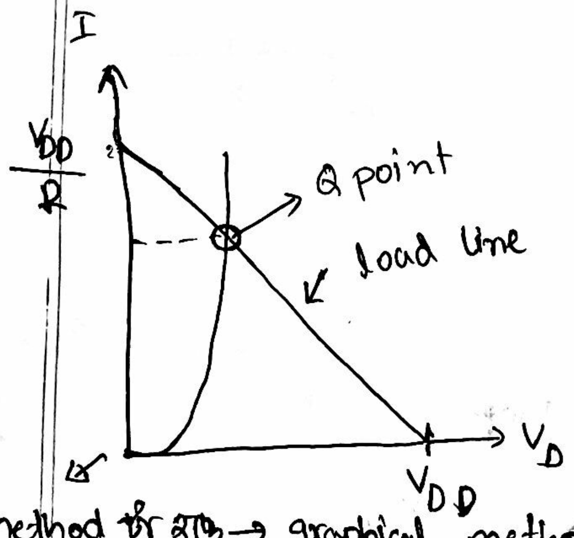
$-V_{DD} + V_D = 0$

$\Rightarrow V_D = V_{DD} \Big|_{I=0}$

$V_D = 0,$

$-V_{DD} + IR = 0$

$\Rightarrow I = \frac{V_{DD}}{R} \Big|_{V_D = 0}$



method টা হচ্ছে → graphical method of solving

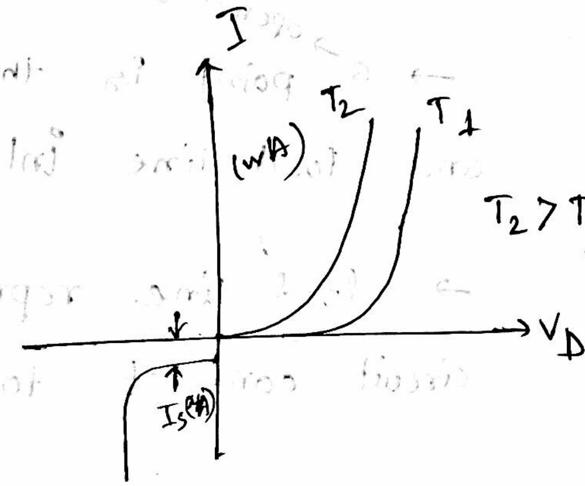
* ~~to~~ Q point ~~থেকে~~ বরাবর current হচ্ছে circuit এর current
* Q point বরাবর voltage হচ্ছে circuit এর voltage drop.

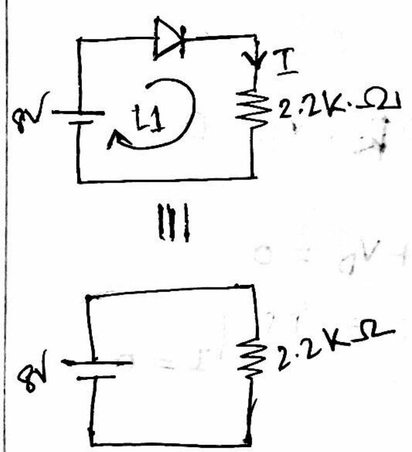
2205.2016

FB 2.5mV/°C

RB for every 10°C the

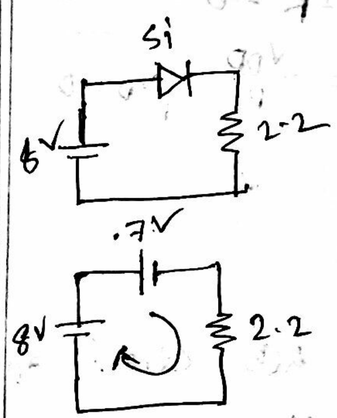
~~the~~ I_S doubles (reverse saturation current)





KVL in loop L1,

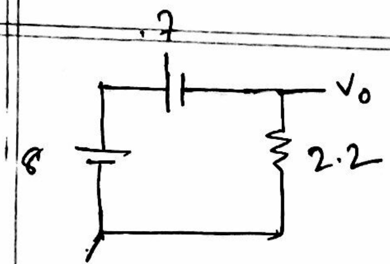
$$I = \frac{8}{2.2K}$$



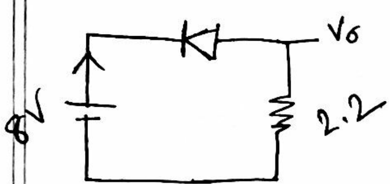
KVL in loop,

$$-8 + .7 + 2.2K\,I = 0$$

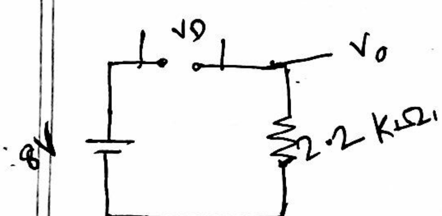
$$I = \frac{8 - .7}{2.2}$$



$V_o = 2.2 * I$ $=$



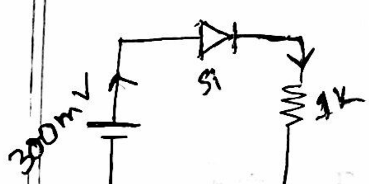
|||



$I = 0$

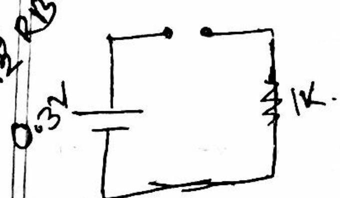
$V = 0$

$V_D = 8V$



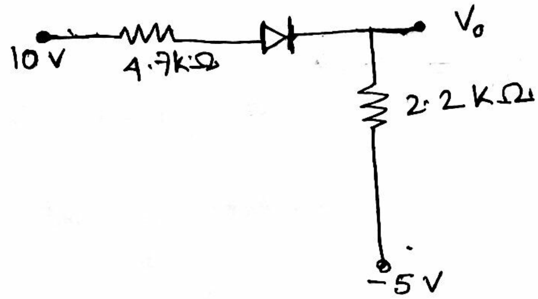
|||

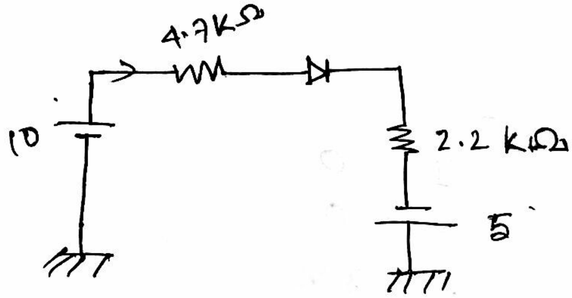
0.7 এর কম হলে off



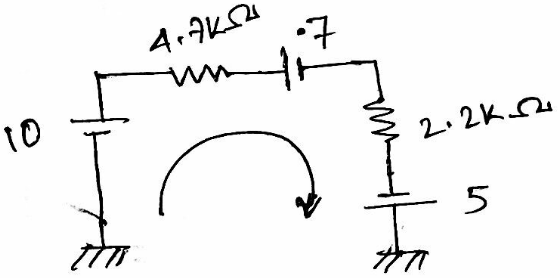
higher potential $\xrightarrow{\text{current flow}}$ lower potential

(E)





H.W

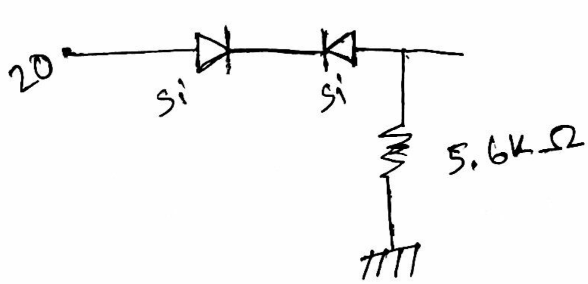


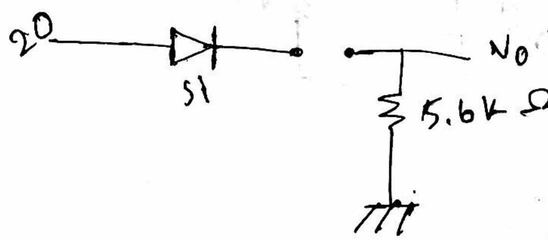
$-10 + 4.7K * I + 2.2K * I - 5 = 0$

$\Rightarrow I =$

$V_o = 2.2 * I - 5$

$=$





$V_o = 0$

Next Sunday

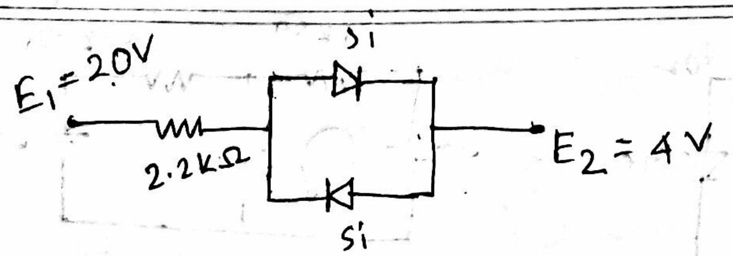
Quiz - 1 time - 20 min

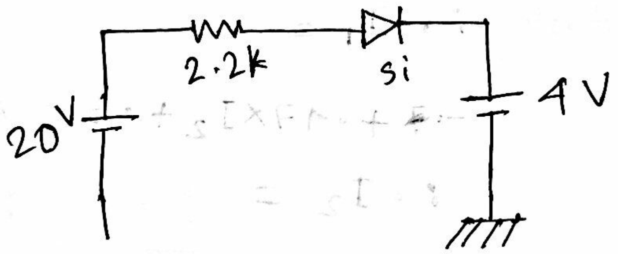
First → 25.05.16 lecture

half set Ques
- 1 set Ques

diode

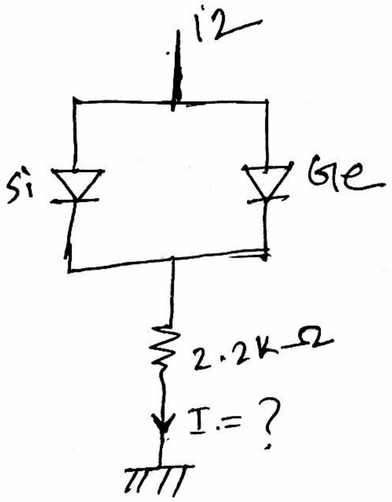
#

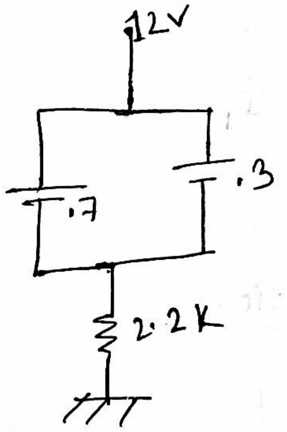


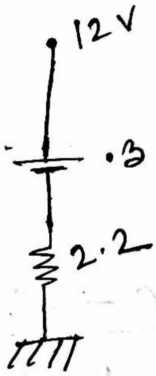


$-20 + 2.2K * I + .7 + 4 = 0$

$I =$

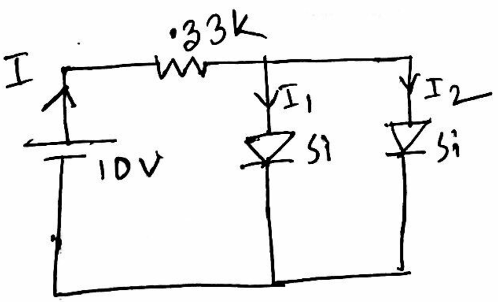






$-12 + .3 + 2.2 * I = 0$

$I =$



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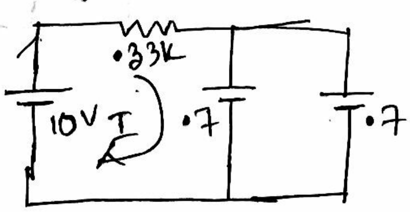


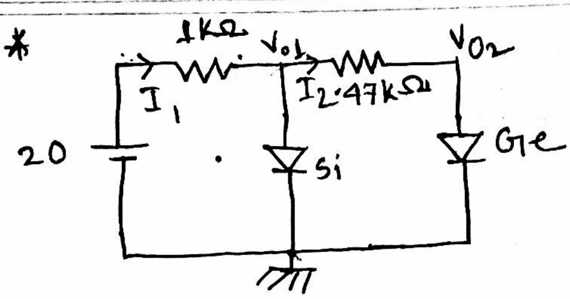
$I_1 = I_2 = \frac{I}{2}$

$-10 + .33 * I + .7 = 0$

$I = \frac{10 - .7}{.33} =$

26.05.16

*



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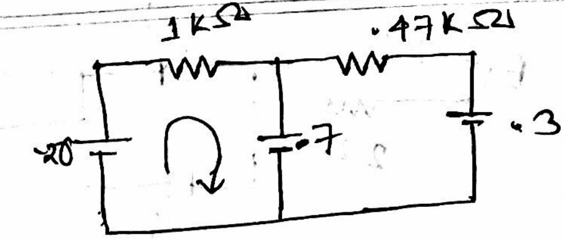


$$-20 + 1k\Omega \times I_1 + .7 = 0$$

$\therefore I_1 =$

$$-.7 + .47 \times I_2 + .3 = 0$$

$\therefore I_2 =$

$V_{o1} = 0.7V$

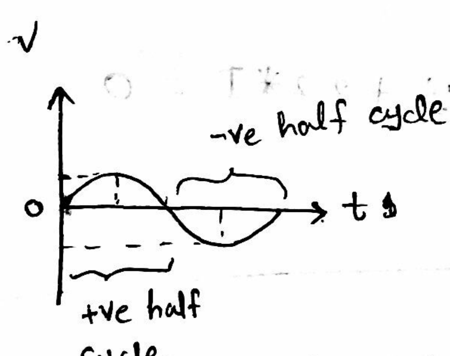
$V_{o2} = .3V$

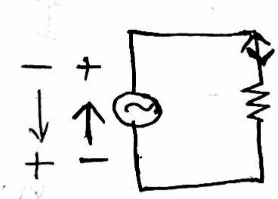
KCL at,

$$I = I_1 - I_2$$

AC → DC conversion:

Rectifier





RMS = 220V

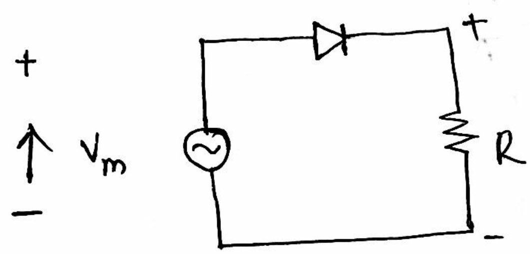
1 Time period a $V_{avg} = 0$

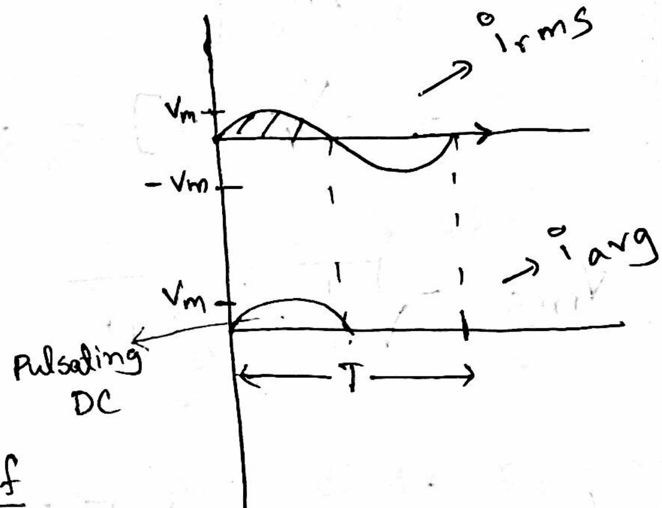
R

Rectifier (single phased uncontrolled)

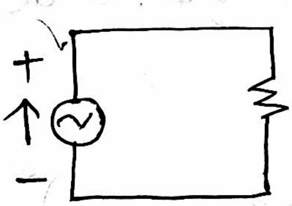
- Half wave
- Full wave
  - Center taped
  - Full Bridge

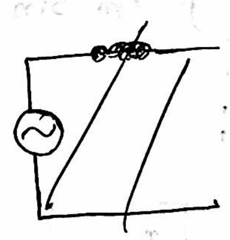
Half wave :



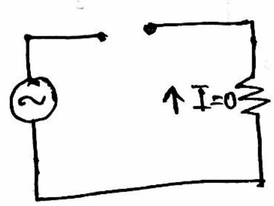


+ ve half | **−ve half**





Vavg



$V_0 = 0 * R = 0$

$$V_{avg} = \frac{1}{T}\int_0^T V_o \, d(\omega t)$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0\right]$$

$$= \frac{1}{2\pi} V_m \left[\cos\omega t\right]_0^{\pi}$$

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

$$= \frac{V_m}{2\pi}[2] = \frac{V_m}{\pi}$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_o^2 \, dt}$$

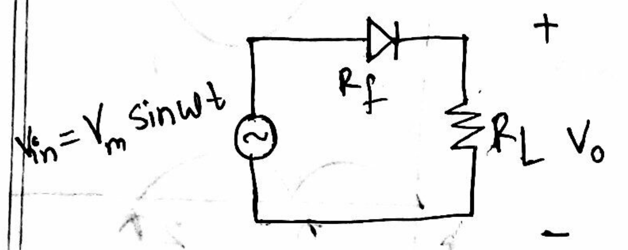
~~V_{rms}~~ $V_{rms}^2 = \frac{1}{2\pi}\left[\int_0^{\pi} V_m^2 \sin^2\omega t \, d(\omega t) + \int^{2\pi} 0 \, d(\omega t)\right]$

$$= \frac{V_m^2}{4\pi}\left[\pi - \frac{1}{2}(\sin 2\pi - \sin 0)\right]$$

$$= \frac{V_m^2}{4}$$

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

Efficiency :



R_f = diode forward resistance

R_L = load resistance

$$i = \frac{V_{in}}{R_T} = \frac{V_m \sin\omega t}{R_f + R_L}$$

$$= \left[\frac{V_m}{R_L + R_f}\right] \sin\omega t$$

$$= I_m \sin\omega t$$

Here,

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

$$i_{avg} = \frac{I_m}{\pi}$$

$$i_{rms} = \frac{I_m}{2}$$

$$\eta = \frac{P_o}{P_{in}} \times 100\%$$

$$P_o = (i_{avg})^2 R_L$$

$$= \left(\frac{I_m}{\pi}\right)^2 R_L$$

$$= \frac{I_m^2}{\pi^2} R_L$$

$$P_{in} = i_{rms}^2 (R_L + R_f)$$

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

$$\eta = \frac{4}{\pi^2} * \frac{R_L}{R_L + R_f} * 100\%$$

for ideal diode $R_f = 0$

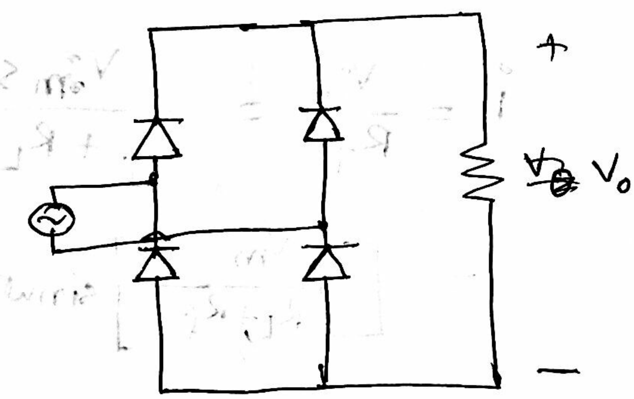
$$\eta = \frac{4}{\pi^2} \times 100\%$$

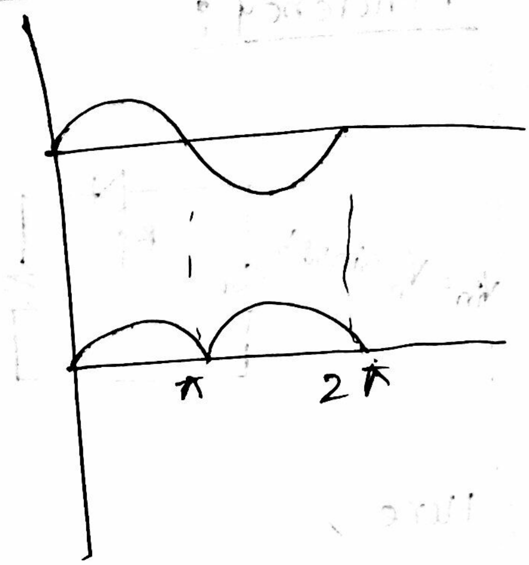
$$= 40.5\%$$

* Show that half wave rectifier's efficiency 40.5%.

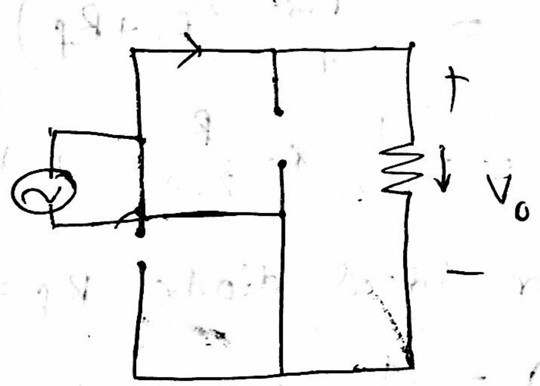
Bridge Rectifier :

~~Pos~~

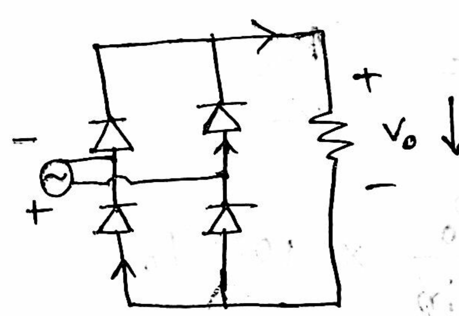




+ve half cycle :



−ve half cycle :



* half wave → avg
* half wave → efficieny

$$V_{avg} = \frac{1}{T} \int_0^T V_o \, dt$$

$$= \frac{1}{\pi} \int_0^{\pi} V_m \sin \omega t \, d(\omega t)$$

$$=$$

$$= \frac{2V_m}{\pi}$$

$$V_{rms} = \sqrt{\frac{1}{T} \int_0^T V_o \, dt}$$

$$V_{rms}^2 = \frac{1}{\pi} \int_0^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t)$$

$$= \frac{V_m^2}{2\pi} \int \left[1 - \cos 2\omega t\right] d(\omega t)$$

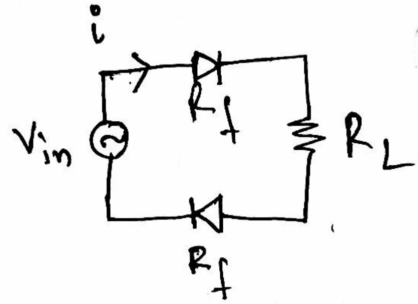
$$= \frac{V_m^2}{2\pi} \times \pi = \frac{V_m^2}{2}$$

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

*

Efficiency

$$i = \frac{V_{in}}{R_T}$$



$$= \frac{V_{in}}{2R_f + R_L}$$

$$= \left[\frac{V_m}{2R_f + R_L}\right] \sin\omega t$$

$$= \cancel{im}\ i_m \sin\omega t$$

$V_{in} = V_m \sin\omega t$

$$i_m = \frac{V_m}{2R_f + R_L}, \quad i_{avg} = \frac{2 i_m}{\pi} \quad i_{rms} = \frac{i_m}{\sqrt{2}}$$

$$\eta = \frac{P_{DC}}{P_{AC}} = \frac{P_o}{P_{in}} * 100\%$$

$$= \frac{V_{avg} I_{avg}}{V_{rms} I_{rms}} * 100\%$$

$$P_o = i_{avg}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$P_{in} = i_{rms}^2 (R_L + 2R_f) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_L + 2R_f)$$

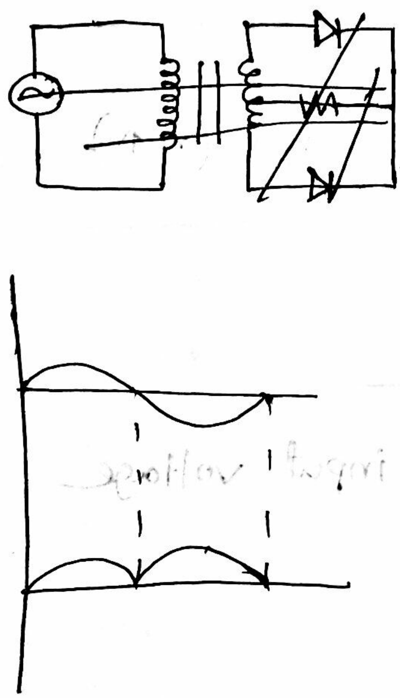
$$\eta = \frac{8}{\pi^2}\left[\frac{R_L}{R_L + 2R_f}\right] * 100\%$$

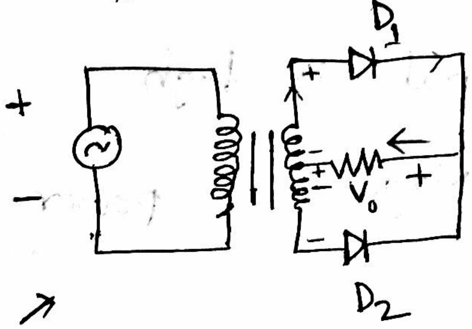
for ideal diode $R_f = 0$

$$\eta = 81\%$$

Center Tap Rectifier :

forward half cycle





full voltage পাওয়া যাবে না।

+Ve half cycle :

D1 ← current flow হচ্ছে

−Ve half cycle :

D2 ← current flow হচ্ছে

PIV :

Peak inverse voltage

"It is the voltage ratting that must not be exceeded in reverse bias region or the diode will enter jenar avalange region.

+ of full rectifier

1) output is high

2) wastage of power is less ($\eta \uparrow$)

- of half wave rectifier

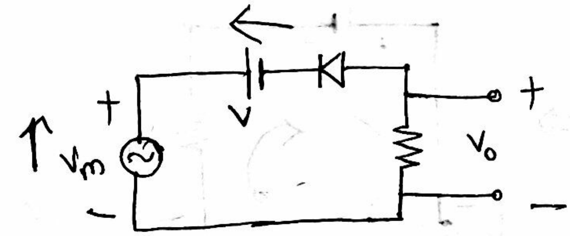
1) load receive half of input voltage

2) avg. DC is less.

3) $\eta = 41\%$

02.06.16

Clipper :



+ve (initial)

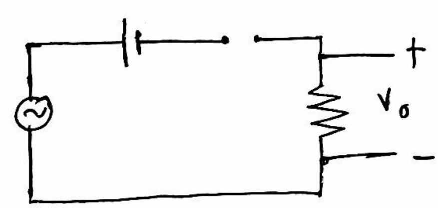
$V > V_m$

so, diode is FB

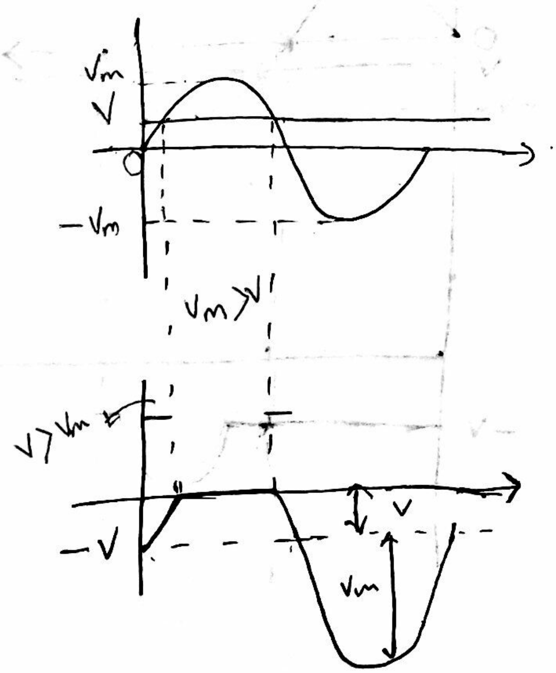
$+ V_m - V_o - V = 0$

$\Rightarrow V_o = V_m - V$ [$V_m = 0$, $V_o = -V$]

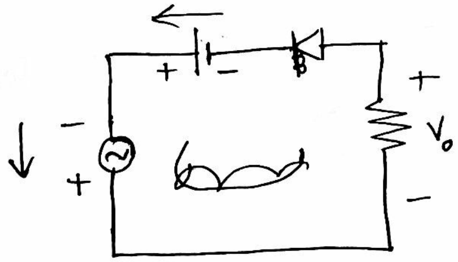
$V < V_m$ diode is RB

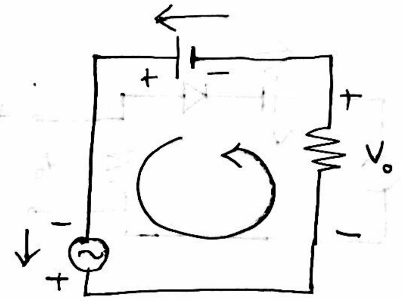


$V_o = 0$



-ve half

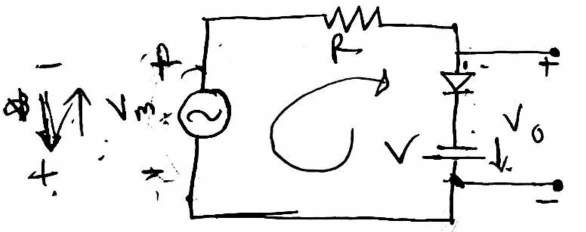




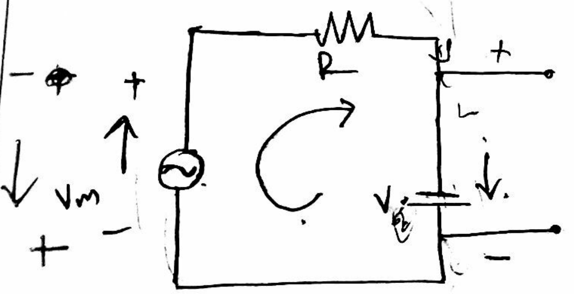
Diode is in FB

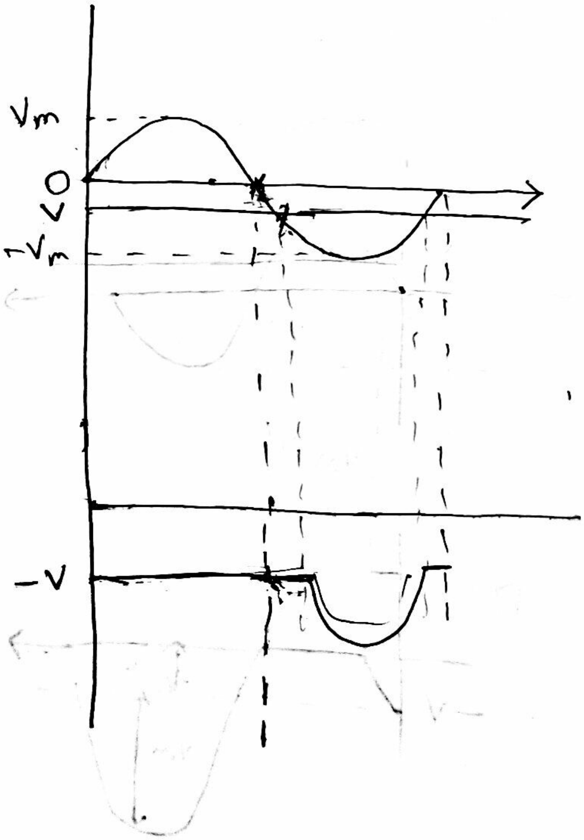
$$-V_m - V_o - V = 0$$

$$\Rightarrow V_o = -V_m - V$$
$$= -(V_m + V)$$



$\Downarrow$





+ Ve half

Diode is in FB

$V_o = -V$

- Ve half

when $V > V_m$

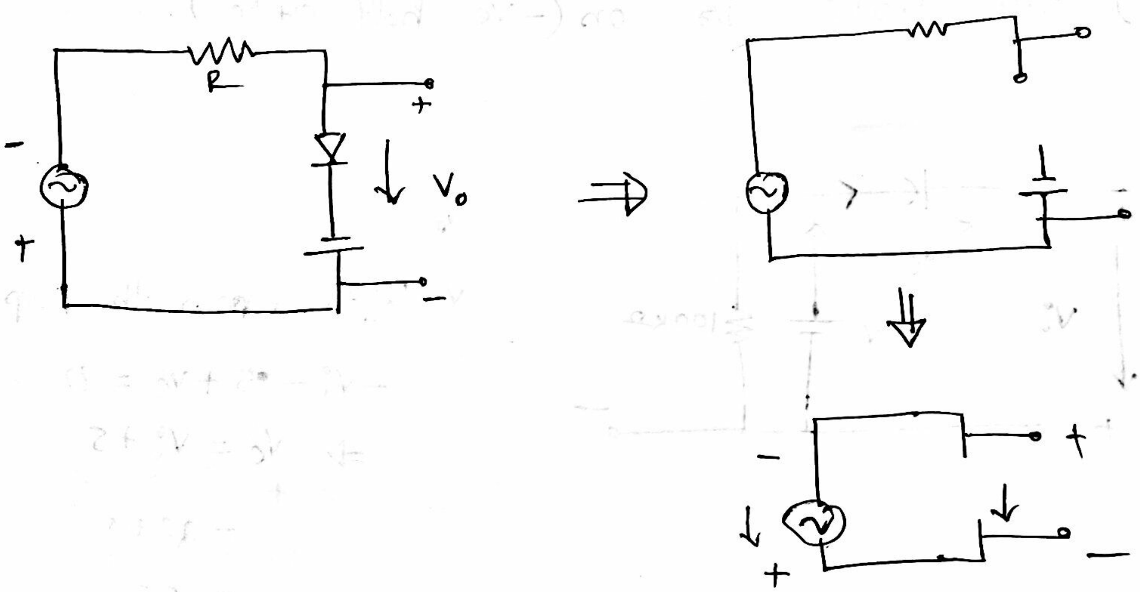
diode FB

$V_o = -V$

when $V < V_m$

Diode is in RB

$V_o = -V_m$

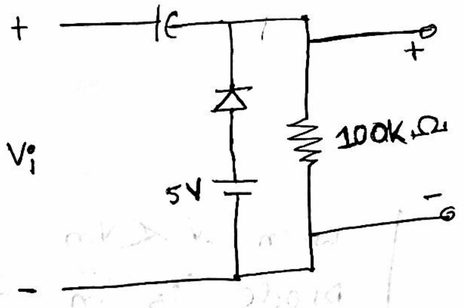


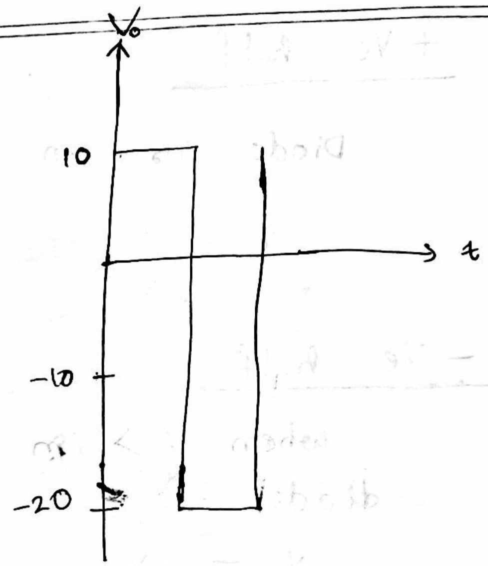
$C =$ যত জলদি / আস্তে charge হবে।

* capacitor, DC তে open থাকে।

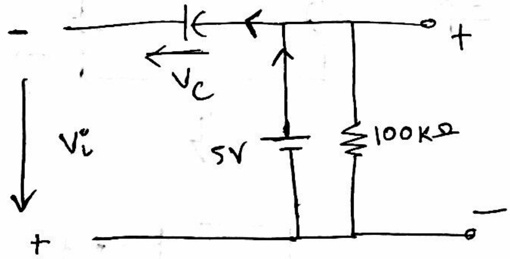
* C দিয়ে current flow হয় না।
↓
Maxwell

Clamper :





1) the diode is on (−ve half cycle)



$V_o = 5V$

voltage across the cap :

$-V_i - 5 + V_c = 0$

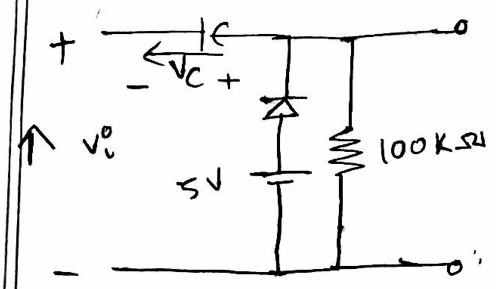
$\Rightarrow V_c = V_i + 5$

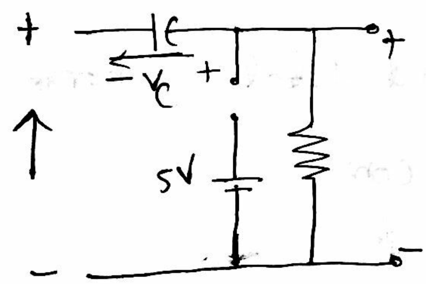
$= 20 + 5$

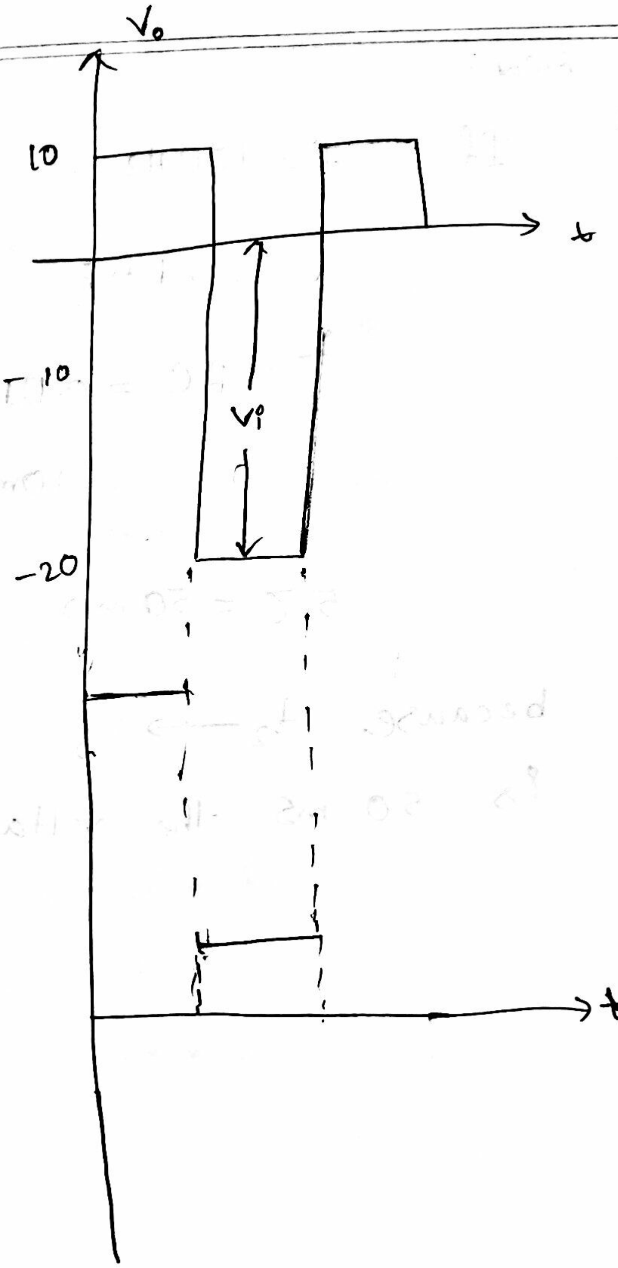
$= 25$

~~+Ve half~~

+ve half cycle







diode is in RB,

$$-V_i - V_C + V_o = 0$$

$$\Rightarrow \quad V_o = V_i + V_C$$

$$= 10 + 25$$

$$= 35$$

* Clipper, clamper math → must

Now,

If, $f = 100\,Hz$. $T = 1\,ms$

$C = .1\,\mu F$ $R = 100\,k\Omega$

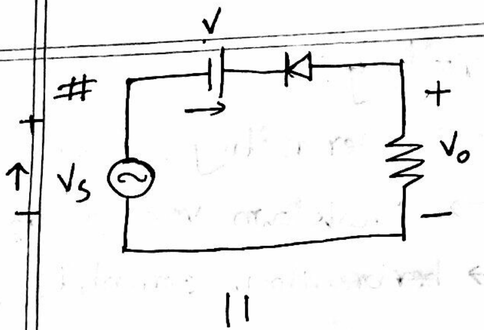
$\tau = RC = 0.01\,s$

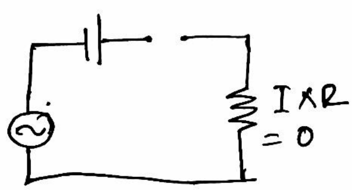
$= 10\,ms$

$5\tau = 50\,ms$

because $t_2 \longrightarrow t_3$ is $.5\,ms$ and total discharge time is $50\,ms$ the voltage we'll be const.

#

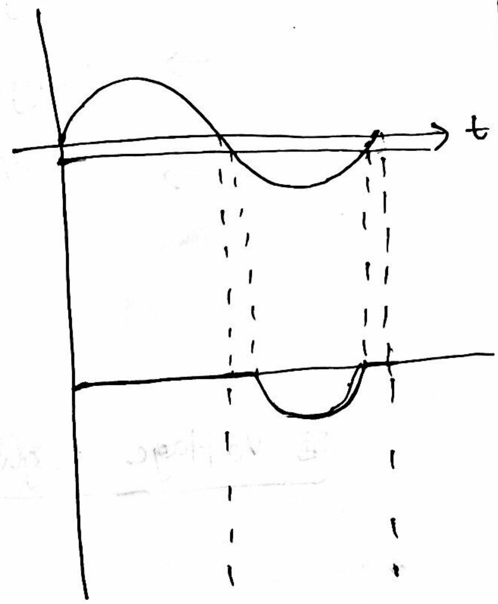




+Ve half

diode is in RB

$V_o = I \times R$
$= 0$



−ve half

$V > V_s$

diode is in RB

$V_o = 0$

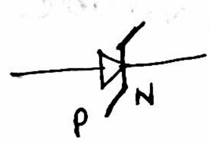
$V < V_s$

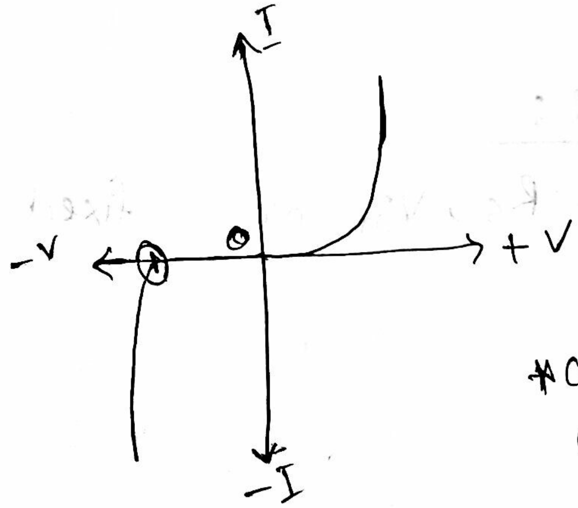
diode is in F B.

$-V_s - V_o + V = 0$

$\Rightarrow V_o = -V_s + V = -(V_s - V) = -V_s$

⊞ Zener diode :





Reverse Bias এ voltage conduct করে

* Constant voltage থাকে but current বাড়তে থাকে।

যত Percentage voltage drop হবে, তত regulation

* ideal voltage source → terminal এর voltage always const থাকবে, যতই current flow হবে,

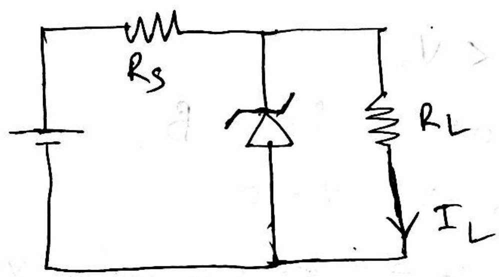
✓ $\frac{5-4.8}{4.8} \times 100\%$

- → Voltage regulation
- → Surge protection
- → waveform clipping

rattling :

- → Power rattling, P_{max}
- → breakdown voltage, V_Z
- → ~~ber~~breakdown current, $I_{Z_{max}}$

Voltage regulator circuit :



→ line regulation $= \frac{\Delta V_o}{\Delta V_s} \left(\frac{mV}{V}\right)$

ΔV_o → output এর voltage variation

ΔV_s → input এর voltage variation

→ load " $= \frac{\Delta V_o}{\Delta I_L} \left(\frac{mV}{mA}\right)$

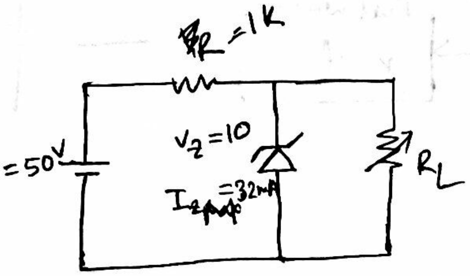
line :

R_S, R_L are fixed V_s is variable.

load :

R_S, V_{in} are fixed, R_L is variable.

Fixed V_i variable R_L:



$$V_L = V_Z = \frac{R_L}{R_L + R} V_i$$

$$\Rightarrow R_{L\,min} = \frac{V_Z}{V_i - V_Z} R$$

$$= 250\,\Omega$$

So, voltage across R is, $V_R = V_i - V_Z$

$$= 50 - 10$$

$$= 40V$$

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

$$= \frac{40}{1K\Omega}$$

$$= 40mA$$

The min I_L,

$$I_{L\,min} = I_R - I_{ZM}$$

$$= 40 - 32$$

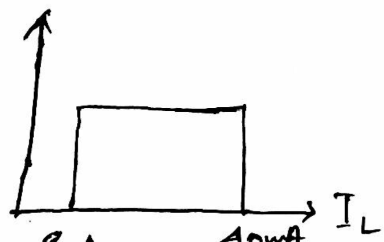
$$= 8mA$$

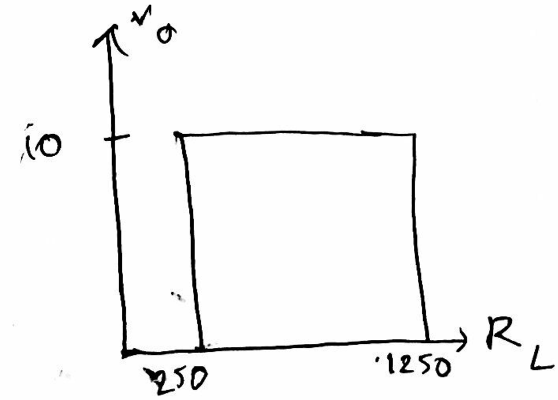
then,

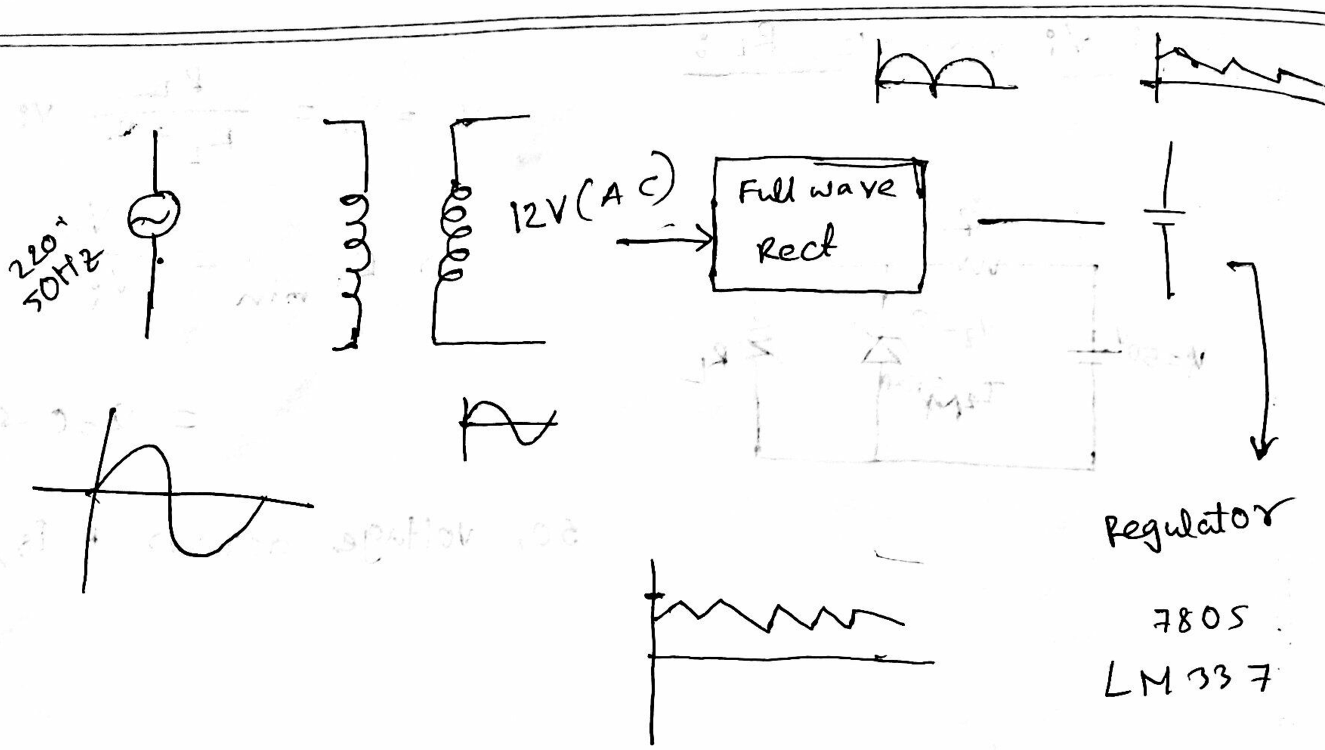
$$R_{L\,max} = \frac{V_Z}{I_{min}}$$

$$= \frac{10}{8mA}$$

$$= 1.25\,k\Omega$$







average powersupply

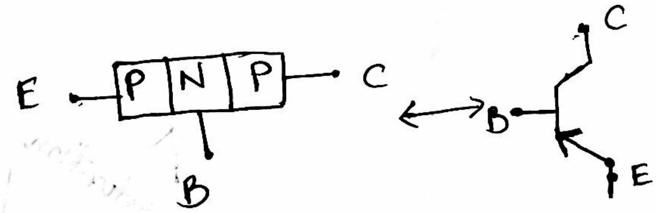
19.06.16 — Quiz 2

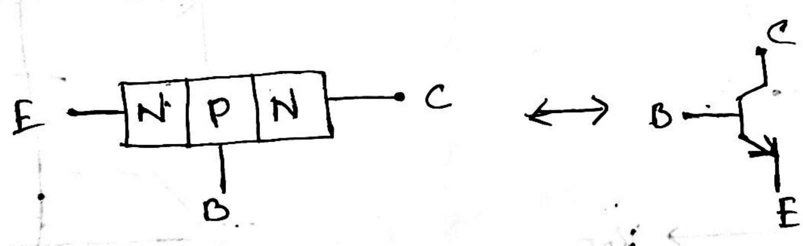
09.06.16

BJT :

Bipolar junction Transistor :

* Transitor বন্ধ হলে mosfet use করা হয়।





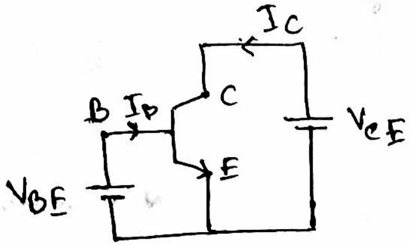
Configaration of BJT

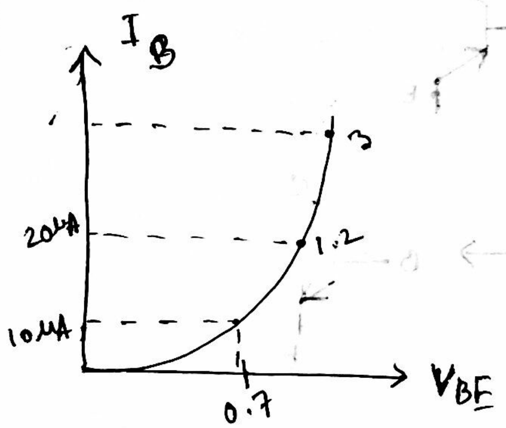
1) Common Base

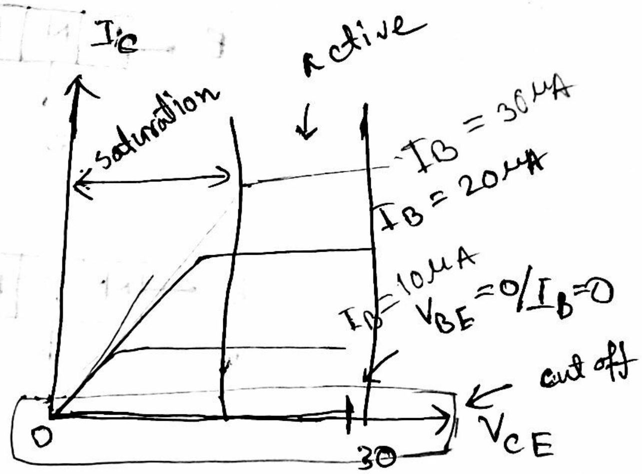
ii) " Collector

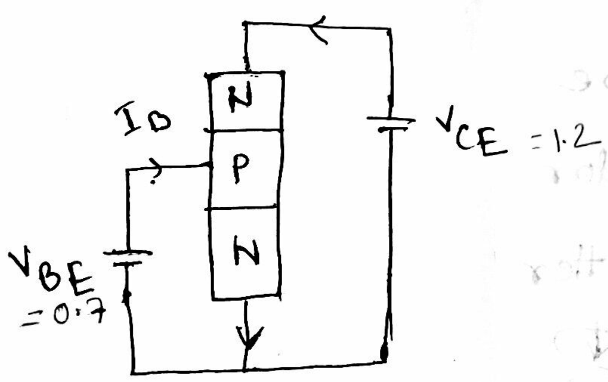
iii) " Emitter

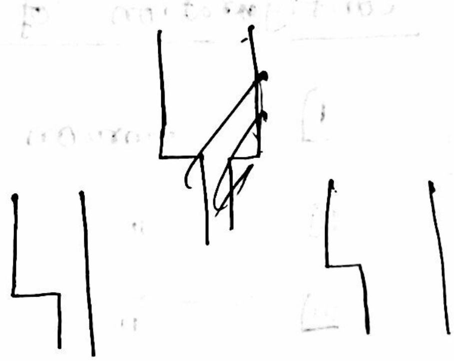
Common Emitter : (3 terminal device)



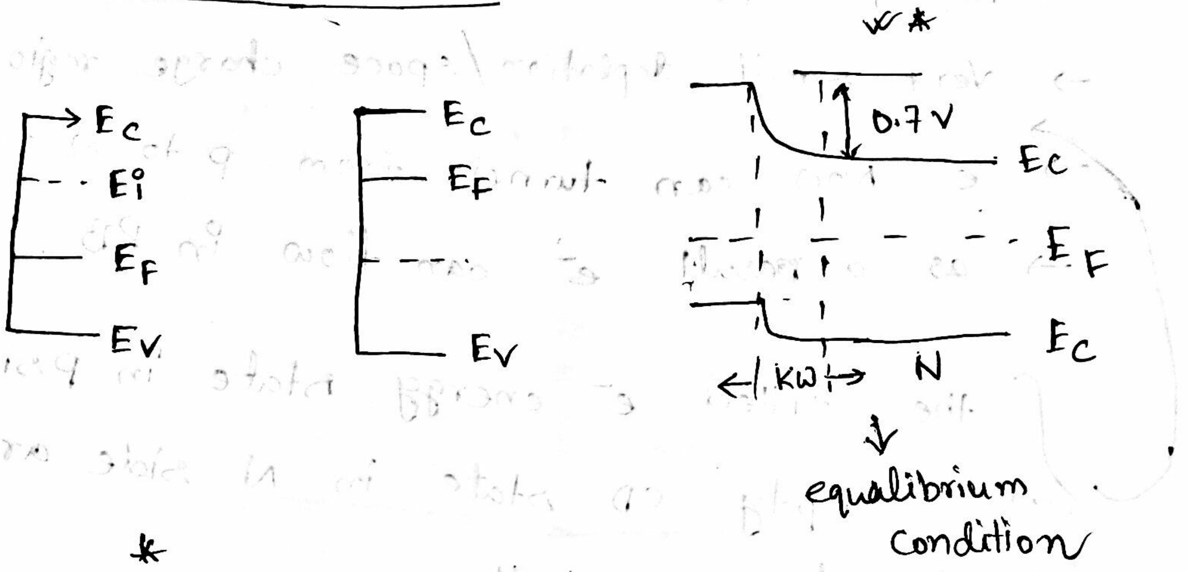


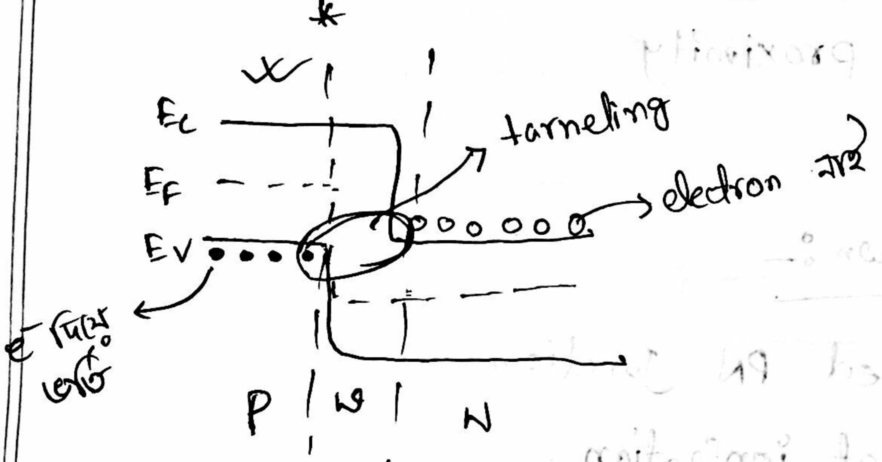




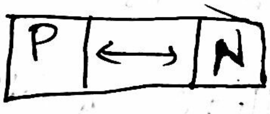


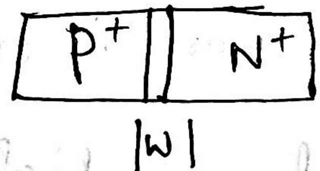
Explain : Zenar breakdown





Under Reverse Bias





→ Highly dopped

→ Very small deplation / space charge region

→ e^- Now can turnel from p to N side

→ as a result e^- can flow in RB.

the filled e^- energy state in P side (VB) and empty CD state in N side are at very close proximity

Advance breakdown :-

→ lightly dopped PN Junction

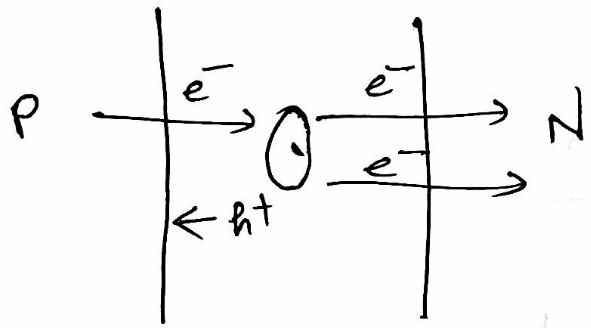
→ involve impact ionization.

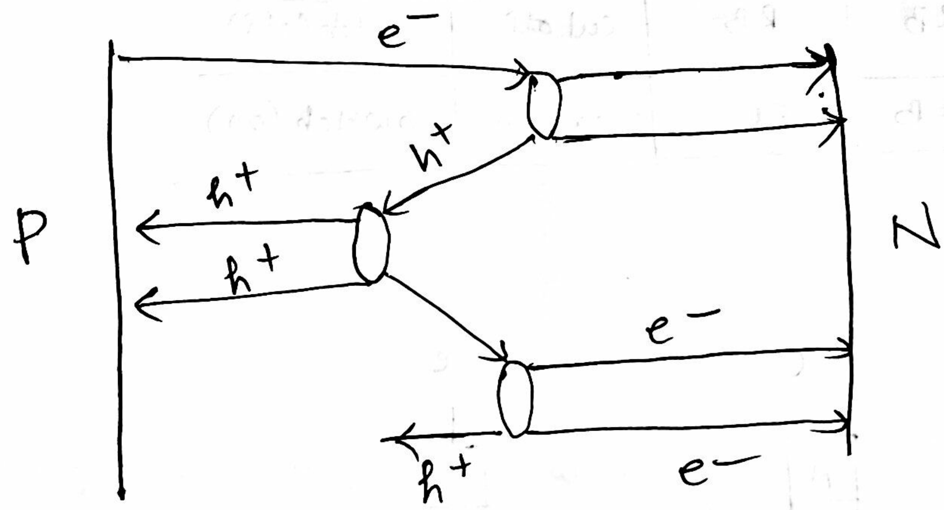
→ Electric field is very high in equilibrium region

→ e^- entering from P side is accelarated at very high speed and collide with lattice

→ as a result an $e^- - h$ pair is created.

→ this cause chain effect and high current can flow in RB.


P
e⁻
e⁻
e⁻
h+
N

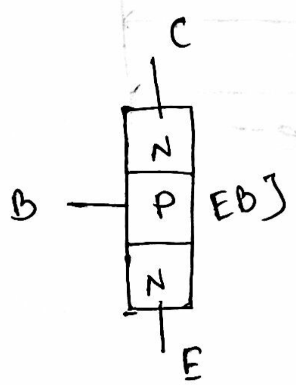

e⁻
h+
h+
h+
P
N
e⁻
h+
e⁻

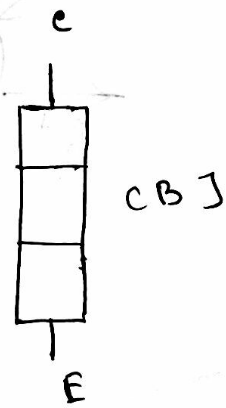
16.06.16

Transistor :

Nodes of operation :

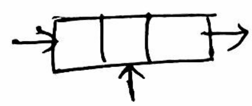
EBJ	CBJ	Mode	Use
FB	RB	Active	Amplifier
RB	RB	cut off	switch (off)
FB	FB	saturation	switch (on)

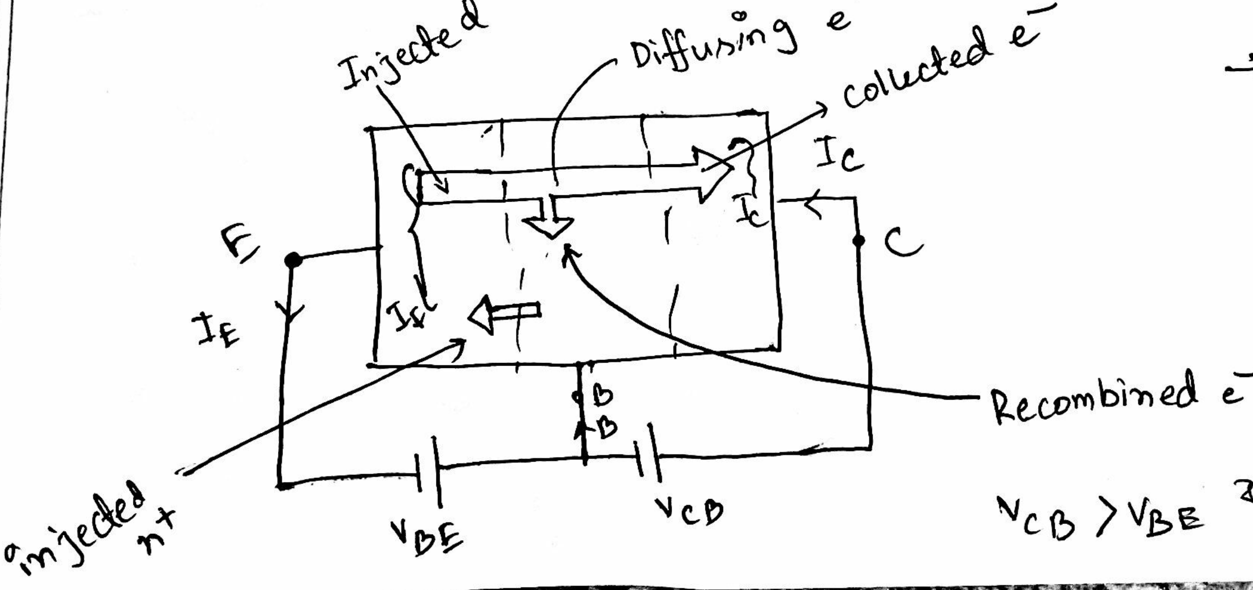




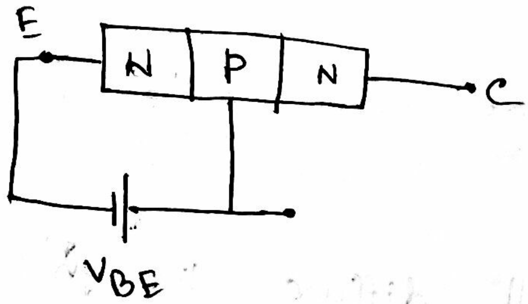
Se – 380 page

N-P-N



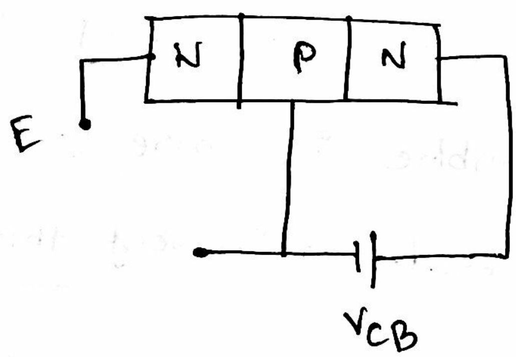


$V_{CB} > V_{BE}$ করতে হবে।



→ EBJ FB

→ majority carrier will flow across EBJ



→ CBJ is RB

→ minority carrier will flow across CBJ

→ EBJ is FB, then will be two compoment

→ e^- will be injected $E \rightarrow B$, h^+ will be injected from $B \rightarrow E$

→ e^- injection is desireable (N থেকে P তে বেশি e^- flow দরকার। আর P থেকে n এ কম hole flow দরকার)

→ so base is lightly doped and Emitter is heavely doped.

→ I_E = hole current + e^- current

→ $I_e \gg I_{nt}$

* $V_{CB} > V_{BE}$ for activation

* neutralize → recombine < ① base doping light ② base thin

in Base :

I) e^- arrived in base from Emitter is now minority.

II) the minority e^- will diffuse through base and reach EBJ.

III) e^- will be swept across the CBJ to collector

IV) some e^- will recombine in base (~5%), ~~But~~

* because the base is made ~~thin~~ very thin.

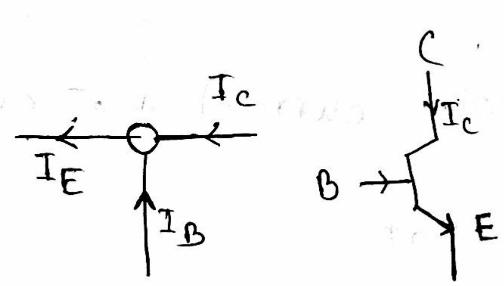
Active region :

I) $V_{CB} > V_{BE}$

II) Emitter → modarate length / highly doped.

Base → very thin / low doping

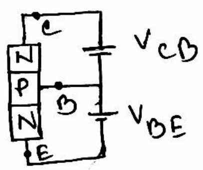
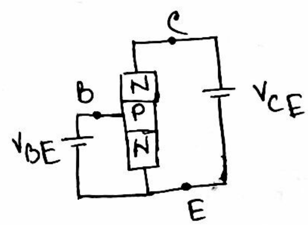
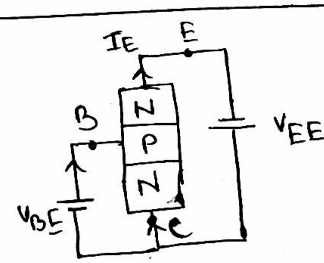
Collector → modarate length / modarate doping.



N-P-N

BJT Configuration :

1. Common Base (CB)
2. Common Emitter (CE)
3. Common Collector (CC)

<table>
<tr><th>CB</th><th>CE</th><th>CC</th></tr>
<tr><td>input → Emitter
out → collector</td><td>in → Base
out → collector</td><td>input → Base
output → Emitter</td></tr>
<tr><td>
</td><td>
</td><td>
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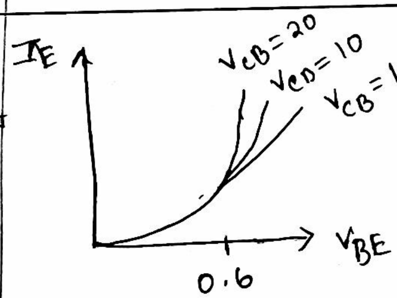
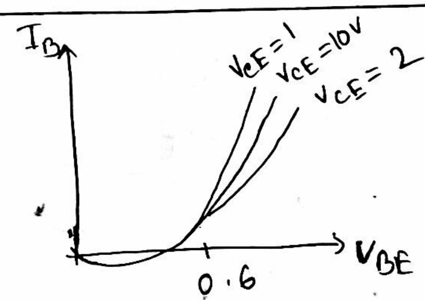
<tr><td>
</td><td>
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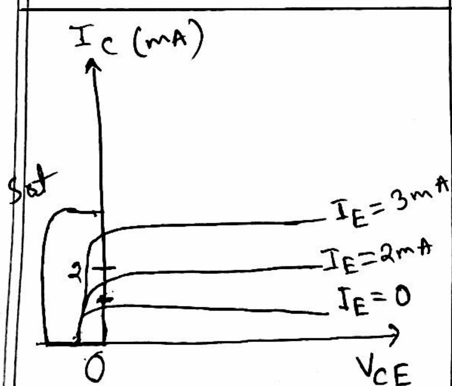
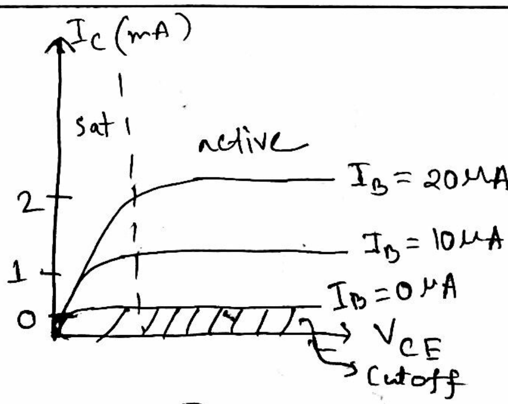
<tr><td>
</td><td>
</td><td></td></tr>
<tr><td>gain, $\alpha = \frac{I_C}{I_E}$</td><td>$\beta = \frac{I_C}{I_B}$</td><td></td></tr>
</table>

output change হলে input এ very কম না।

19.06.16

Relation between α and β :

We know,

$$\beta = \frac{I_C}{I_B} \quad \text{--- (I)} \qquad \alpha = \frac{I_C}{I_E} \quad \text{--- (II)}$$

Also,

$$I_E = I_C + I_B$$

$$\Rightarrow I_B = I_E - I_C$$

So,

$$\beta = \frac{I_C}{I_E - I_C} \quad \text{--- (III)}$$

$$= \frac{I_C/I_E}{\frac{I_E - I_C}{I_E}}$$

$$= \frac{I_C/I_E}{1 - I_C/I_E}$$

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

Similarly,

$$\alpha = \frac{I_C}{I_C + I_B}$$

$$= \frac{I_C/I_B}{\frac{I_C + I_B}{I_B}}$$

$$\boxed{\alpha = \frac{\beta}{\beta + 1}}$$

$$I_c = \alpha I_E + I_{CBO} \quad \text{—— (i)}$$

and, $I_E = I_c + I_B$ —— (ii)

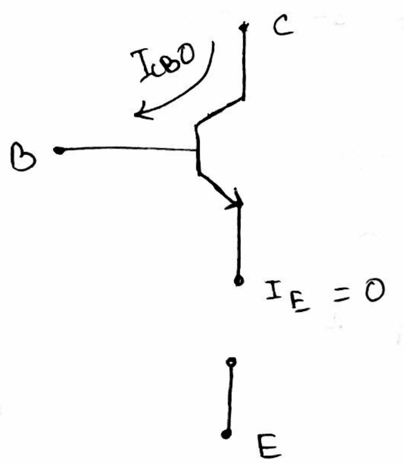
So,

$$I_c = \alpha (I_c + I_B) + I_{CBO}$$

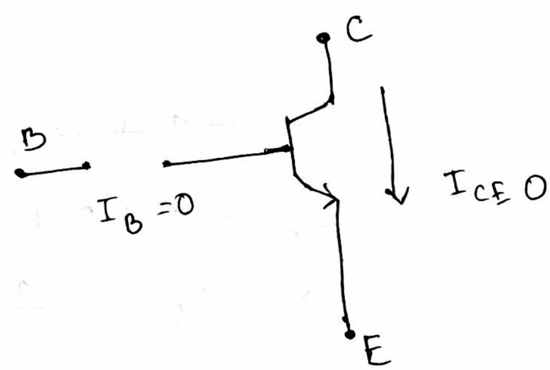
$$I_c = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$$

$$= \beta I_B + (\beta+1) I_{CBO}$$

$$= \beta I_B + I_{CEO} \qquad \left[\begin{array}{l} \because (\beta+1) I_{CBO} = I_{CEO} \\ \Rightarrow \beta I_{CBO} \cong I_{CEO} \end{array} \right]$$



CB

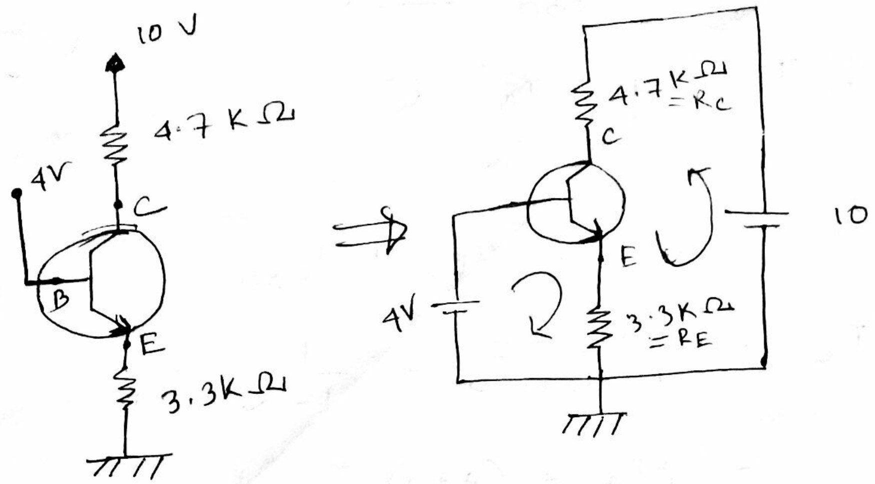


CE

I_{CBO} = collector to base current for CB configuration with CBJ RB and base to emitter junction open ckt.

I_{CEO} = collector to emitter current when base is not connected.

Sedra
5.4



→ Because $V_B = +4V$ and Emitter is connected to Ground. Lets assume V_{BE} is FB,

$$-4 + V_{BE} + I_E R_E = 0$$

$$\Rightarrow -4 + 0.7 + I_E R_E = 0$$

$$\Rightarrow I_E = \frac{4-0.7}{3.3} = 1\ mA$$

$$I_C = \alpha I_E$$

$$\Rightarrow \alpha = \frac{\beta}{\beta+1} = \frac{100}{101} = 0.99 \quad [\beta = 100 \text{ given}]$$

$$I_C = 0.99 \times 1 = 0.99\ mA$$

KVL at,

$$-V_{cc} + I_C R_C + \underbrace{V_{CE} + I_E R_E}_{V_C} = 0$$

$$\Rightarrow -V_{CC} + I_C R_C + V_{CE} = 0$$

$\Rightarrow V_C = 10 - I_C R_C$

$= 10 - 0.99 \times 4.7K$

$= 5.3$ volt

CHK

$V_{CB} = V_C - V_B$

$= 5.3 - 4$

$= +1.3$

$\longrightarrow$ active mode.

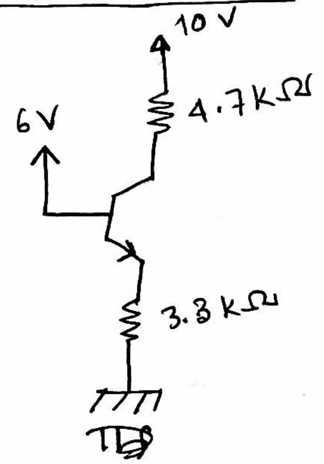
$I_B = \dfrac{I_E}{\beta + 1}$

$= \dfrac{1}{101}$

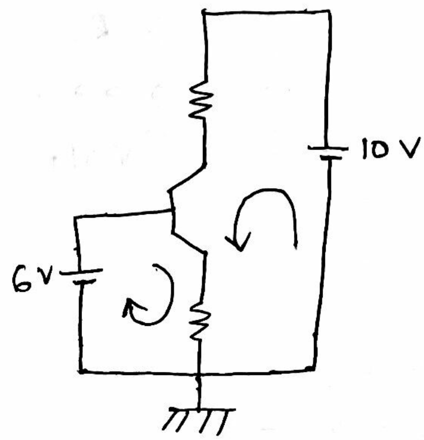
$= .01$ mA

22.06.16

Sedra Ex. 5.5



=



Assume active mode,

$$-V_B + V_{BE} + V_E = 0$$

$$\Rightarrow V_E = V_B - V_{BE}$$

$$= 6 - .7 = 5.3$$

~~Now~~ $I_E = \frac{V_E}{R_E} = 1.6\ mA$

Now, $-V_{CC} + I_C R_C + V_{CE} + V_E = 0$

$$\Rightarrow -V_{CC} + I_C R_C + V_C = 0$$

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

$$= 10 - 7.52$$

$$= 2.48$$

So, $V_{CB} = V_C - V_B$

$$= 2.48 - 6 = -3.52$$

So, BJT can't be in active state

5.5 — 5.6, 5.7, 5.8

Assume saturation mode,

$V_E = 6 - .7 = 5.3$ V

$I_E = \frac{V_E}{R_E} = \frac{5.3}{3.3} = 1.6$ mA

$V_C = V_E + V_{CE}$ sat.

$= 5.3 + .2$

$= 5.5$

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

$= 0.96$ mA

$I_C + I_B = I_E$

$\Rightarrow I_B = I_E - I_C$

$= 1.6 - .96$

$= 0.64$ mA

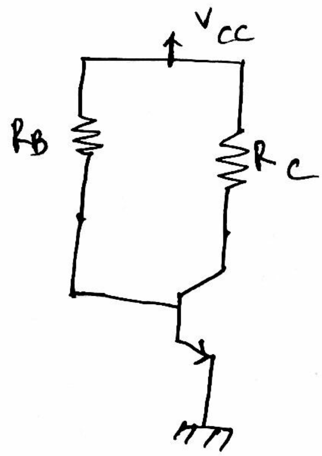
So, $\beta_{forced} = \frac{I_C}{I_B}$

$= \frac{.96}{.64}$

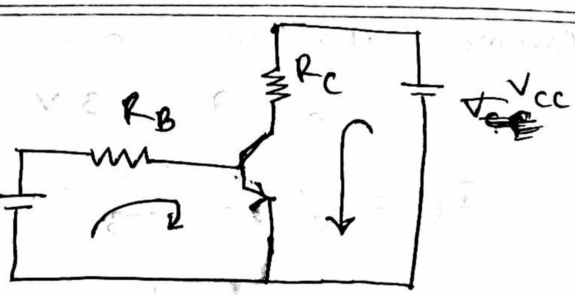
$= 1.5$

5.

fixed bias :



$\cong$



① $-V_{CC} + I_B R_B + V_{BE} = 0$

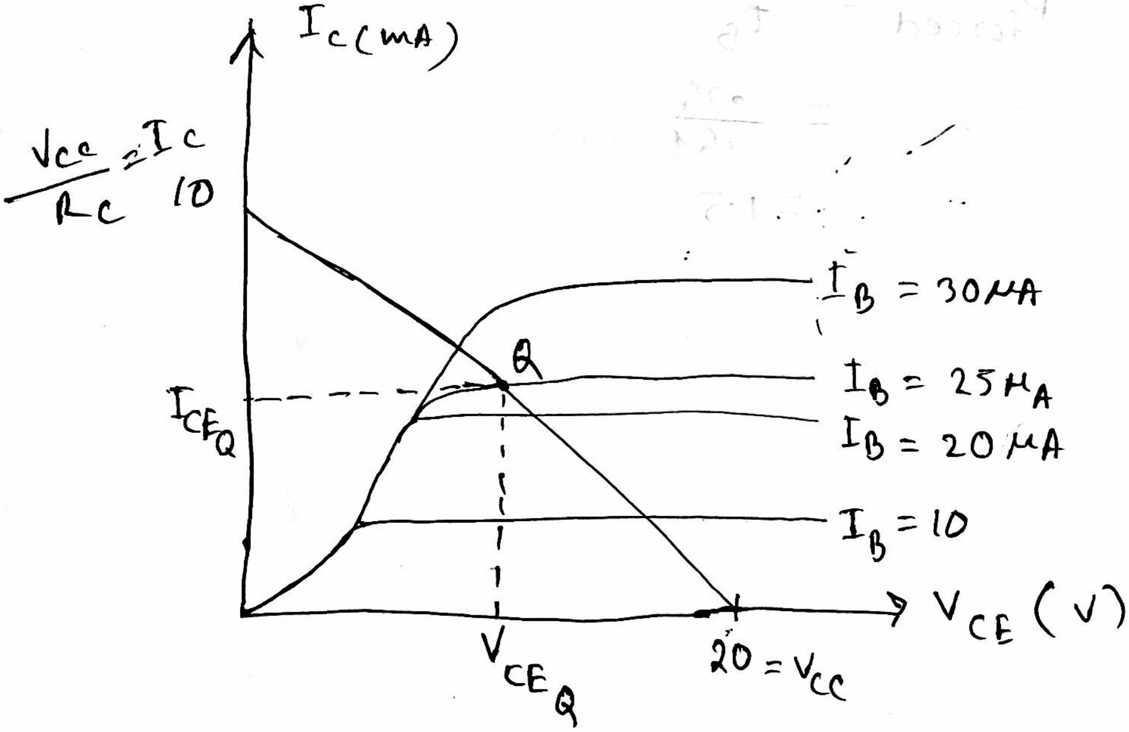
$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

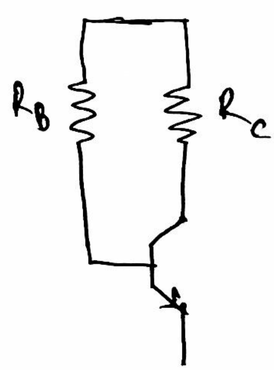
② $I_C = \beta I_B$

③ $-V_{CC} + I_C R_C + V_{CE} = 0$

$$\Rightarrow V_{CE} = V_{CC} - I_C R_C$$

Ex - 4.3





Set , $V_{CE} = 0$

$\therefore \quad -V_{CC} + I_C R_C + V_{CE} = 0$

$\Rightarrow \quad 0 = V_{CC} - I_C R_C$

$\Rightarrow \quad I_C = \frac{V_{CC}}{R_C}$

Again set $I_C = 0$

$\therefore \quad V_{CE} = V_{CC}$

$V_{CC} = 20$

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

$\Rightarrow \quad R_C = \frac{V_{CC}}{I_C} = \frac{20}{10} = 2\,k\Omega$

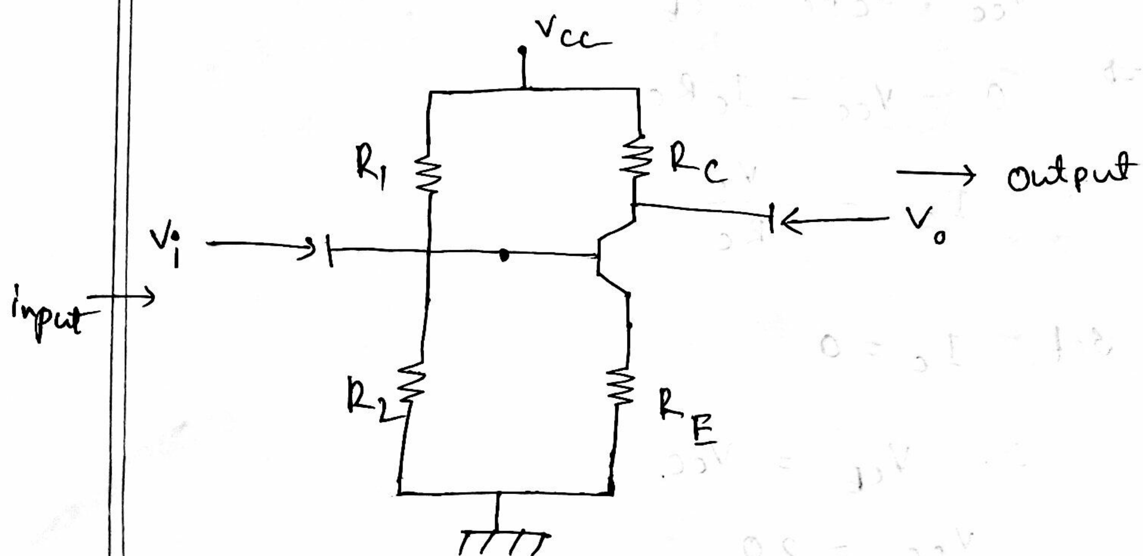
We know ,

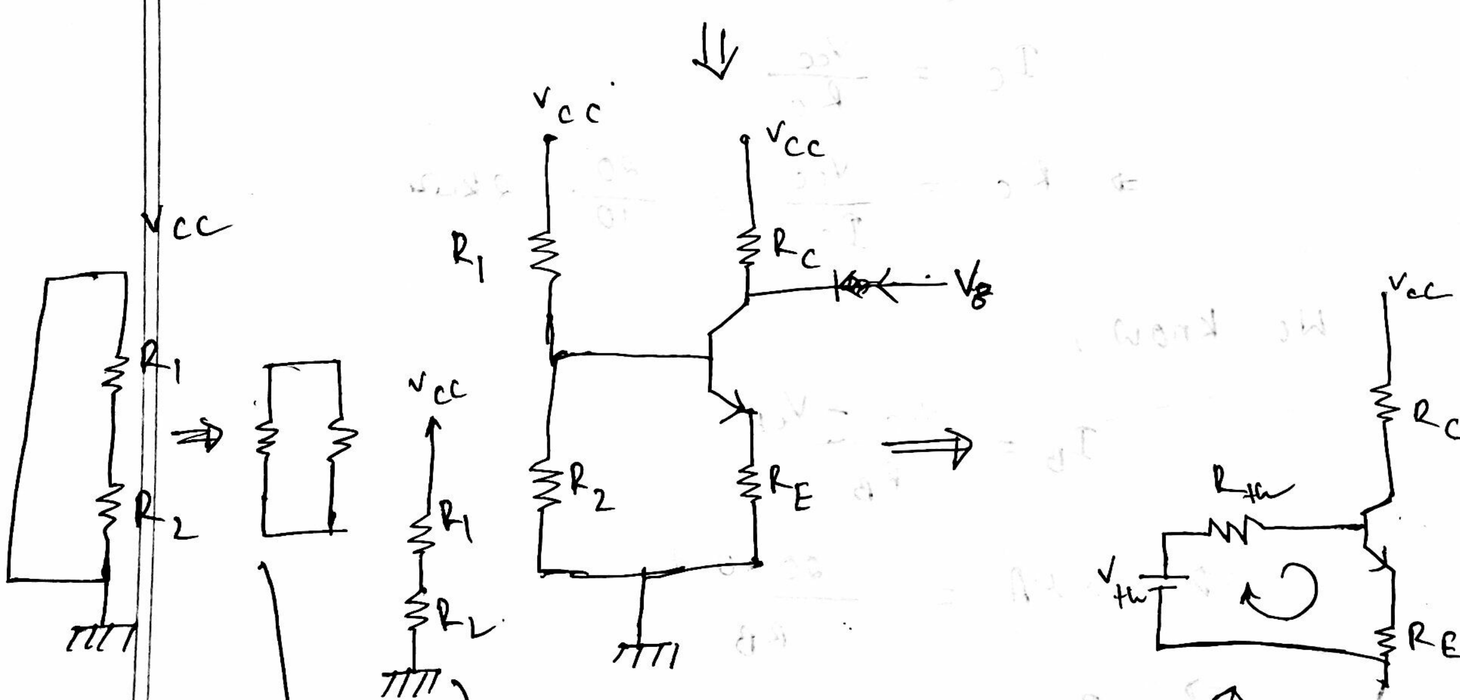
$$I_B = \frac{V_{CC} - V_{CE}}{R_B}$$

$\Rightarrow \quad 25\,\mu A = \frac{20 - 0.7}{R_B}$

$\Rightarrow \quad R_B = 772\,k\Omega$

Voltage divider bias :





1. $$V_{th} = \frac{R_2}{R_1 + R_2} \times V_{CC}$$

2. $$R_{th} = R_1 \parallel R_2$$

③ $-V_{th} + I_B R_{th} + V_{BE} + I_E R_E = 0$

$\Rightarrow -V_{th} + I_B R_{th} + V_{BE} + (1+\beta) I_B R_E = 0$

$$\Rightarrow I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}$$

④ $I_C = I_B \times \beta$

⑤ $-V_{CC} + I_C R_C + V_{CE} + I_E R_E = 0$

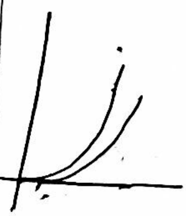
$\Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E) \quad [\because I_E \cong I_C]$

* $I_C \xrightarrow{I_C = \beta I_B}$ বের করতে হবে [এটার জন্য I_B বের করতে হয়]

* V_{CE} বের হয়।

* β temperature sensitive

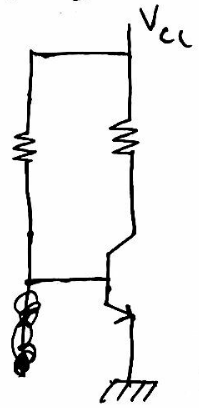
14.07.16



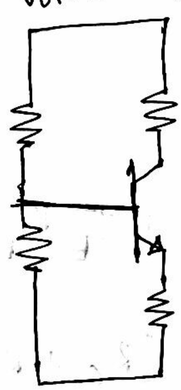
$$I_B = \frac{E_{th} - V_{BE}}{R_{th} + (1+\beta)R_E}$$

$$I_C = \beta I_B \qquad \boxed{\beta = \frac{I_C}{I_B} = f(t)}$$

fixed



voltage divider bias



stable

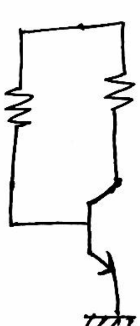
$$V_{CE} = V_c - I_c(R_c + R_E) \quad [I_c \approx I_E]$$

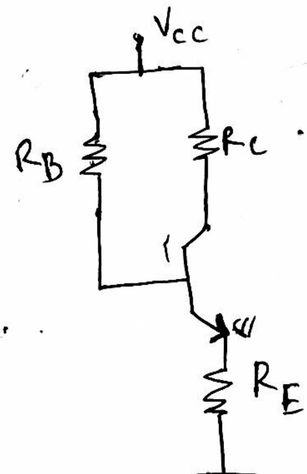
β	I_c	V_{CE}
100	0.84	12.34
50	0.81	12.64

Voltage change = 3%

* Emitter stabilized bias ckt:

* Capacitor বাদ দিতে হবে





BE Loop

$$-V_{cc} + I_B R_B + V_{BE} + I_E R_E = 0$$

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

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

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

$$\boxed{\Rightarrow I_B = \frac{V_{ce} - V_{BE}}{R_B + R_E(\beta+1)}} \quad \text{— (1)}$$

Ex- 4.4

CE loop

$$-V_{ce} + I_C R_C + V_{CE} + I_E R_E = 0$$

$$\Rightarrow V_{CE} \cong V_{cc} - I_C (R_C + R_E) \quad [I_E \approx I_C]$$

Here,

$\Rightarrow$ Temp $\uparrow\uparrow$

$\Rightarrow$ β $\Uparrow$

$I_B \downarrow$ to balance $I_C \downarrow$

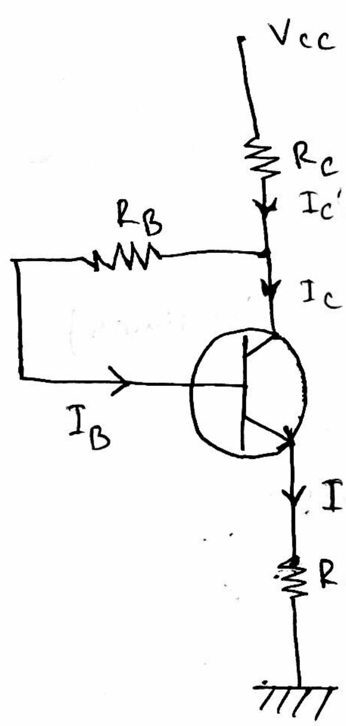
fixed bias

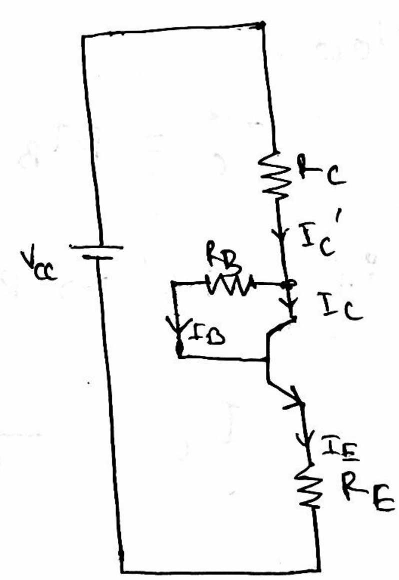
temp $\uparrow\uparrow$

$\beta \uparrow\uparrow$

I_B = const $I_C \uparrow\uparrow$

Collector Feedback : (best ckt)





imp * Collector feedback is β independent proved

$$-V_{cc} + I_c' R_c + I_B R_B + V_{BE} + I_E R_E = 0$$

$\because$ I_B is μA
I_c is mA
so $I_c' \approx I_c$

$$\approx -V_{cc} + I_c R_c + I_B R_B + V_{BE} + I_E R_E = 0$$

$$\Rightarrow -V_{cc} + \beta I_B R_c + I_B R_B + V_{BE} + \beta I_B R_E = 0$$

$I_E \approx I_C$,
and $I_C = \beta I_B$
so $I_E \cong \beta I_B$

$$\Rightarrow -V_{cc} + V_{BE} + I_B (\beta R_c + R_B + \beta R_E) = 0$$

$$\Rightarrow \boxed{I_B = \frac{V_{cc} - V_{BE}}{R_B + \beta(R_c + R_E)}} \quad \text{--- } (1)$$

$$I_c = \beta I_B \quad \text{--- } (2)$$

* β independent:

So,

$$I_B = \frac{V'}{R_B + \beta R'}$$

$R' = R_c + R_E$
$V' = V_{cc} - V_{BE}$

Now,

$$I_c = \beta I_B = \frac{V'\beta}{R_B + \beta R'}$$

if $\beta R' >> R_B$ then, [10 times]

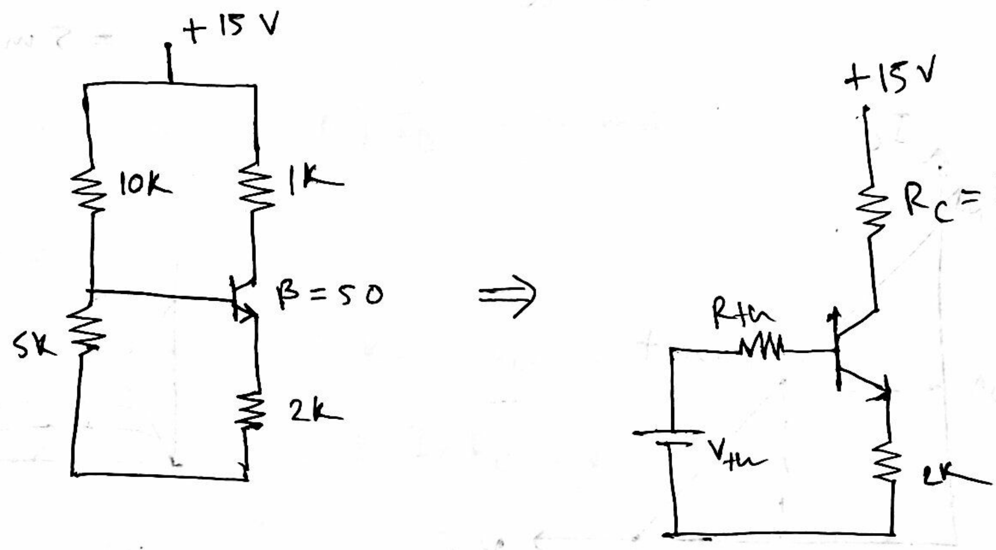
$$I_c = \frac{V'\beta}{\beta R'} = \frac{V'}{R'}$$

$-V_{CC} + R_C I_C' + V_{CE} + I_E R_E = 0$

$\Rightarrow -V_{CC} + R_C I_C + V_{CE} + I_C R_E = 0$ $\quad [\because I_C' \cong I_C,\ I_C \approx I_E$

$\Rightarrow \boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)}$ —— ③

* Find out Load line & Q point.



$V_{th} = \frac{5k}{10+5k} * 15V = 5V$

$R_{th} = 5k \parallel 10K = 3.33\ k\Omega$

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

$= \frac{5 - 0.7}{3.33 + (1+50)2K}$

$= 40.84\ \mu A$

$I_C = \beta I_B$

$= (50 \times 40.84)\ \mu A$

$= 2.04\ mA$

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

$= 15 - 2.04(1+2)$

$= 8.87$ Volt

Load Line

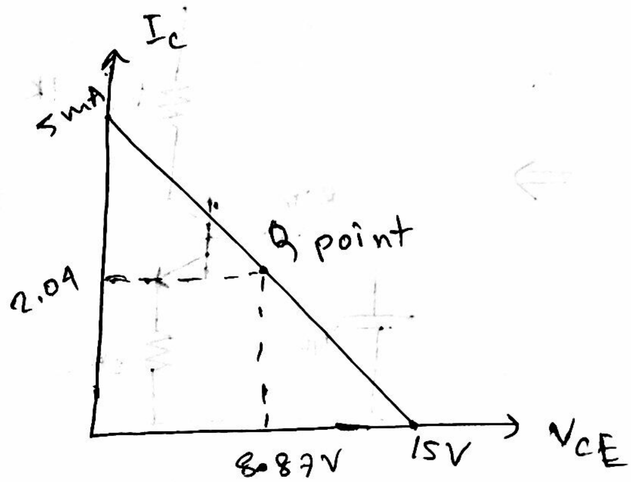
$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

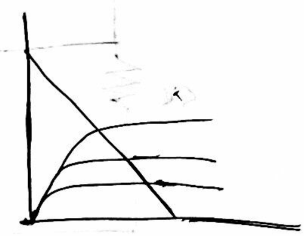
Now, $I_C = 0$

$$V_{CE} = V_{CC} = 15V$$

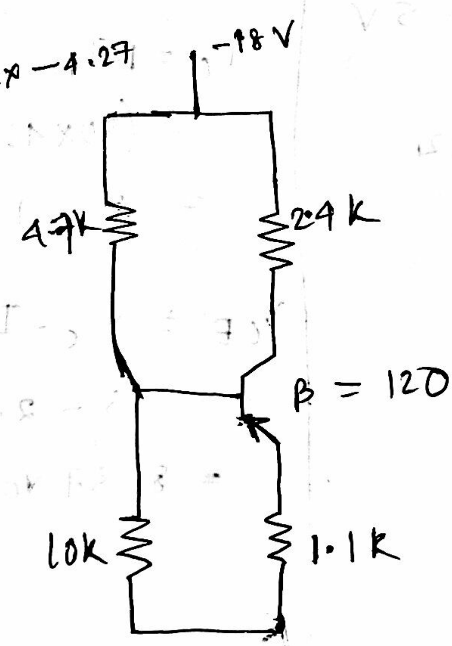
$V_{CE} = 0$

$$I_C = \frac{V_{CC}}{3k} = 5mA$$

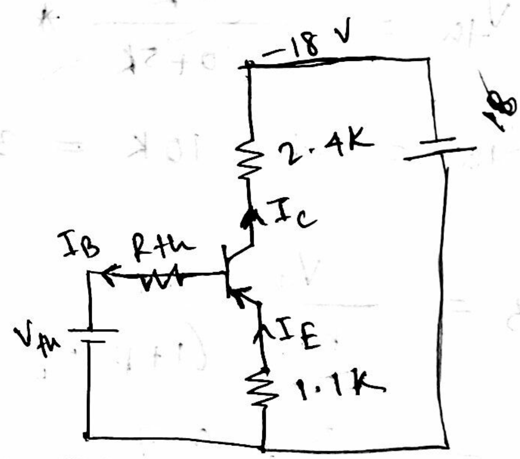




* Ex - 4.27



$\equiv$



$$R_{th} = 47K \parallel 10K = 8.25K$$

$$V_{th} = \frac{10k}{10k + 47k} * -18 = -3.16V$$

* clipper, clamper - quiz

BE loop.

$$I_E R_E - V_{BE} + I_B R_{th} - 3.16 = 0$$

$$\Rightarrow I_B = \frac{3.16 + V_{BE}}{R_{th} + R_E(1+\beta)} = 17.40\,\mu A$$

Now.

$$I_E = (1+\beta) I_B = 2.1\,mA$$

CE loop

$$I_E R_E - V_{CE} + I_C R_C - V_{CC} = 0$$

$$\Rightarrow I_C R_E - V_{CE} + I_C R_C - V_{CC} = 0$$

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

$$= 7.35 - 18$$

$$=$$

21·07·16

Field Effect Transistor : (FET)

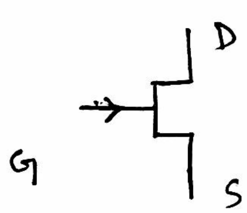
FET
- → JFET
- → MOSFET
  - E-MOS
  - D-MOS
- → MODFET
- → HEMT
- ⋮
- etc

⊞ JFET :

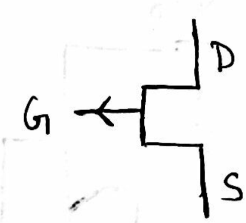
→ Junction Field Effect Transistor

→ N ch and P channel.

→



n – CH



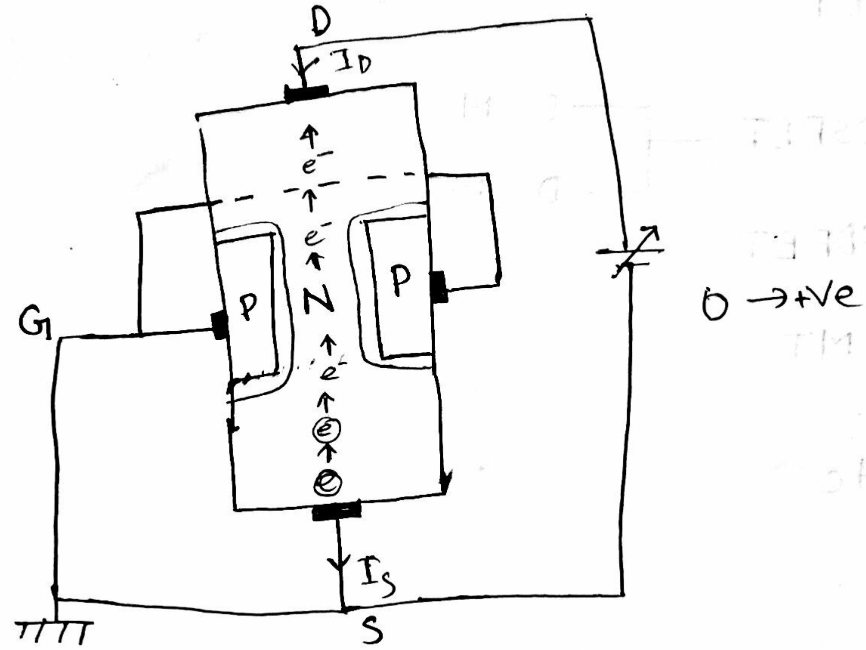
P CH

G – Gate

D – Drain

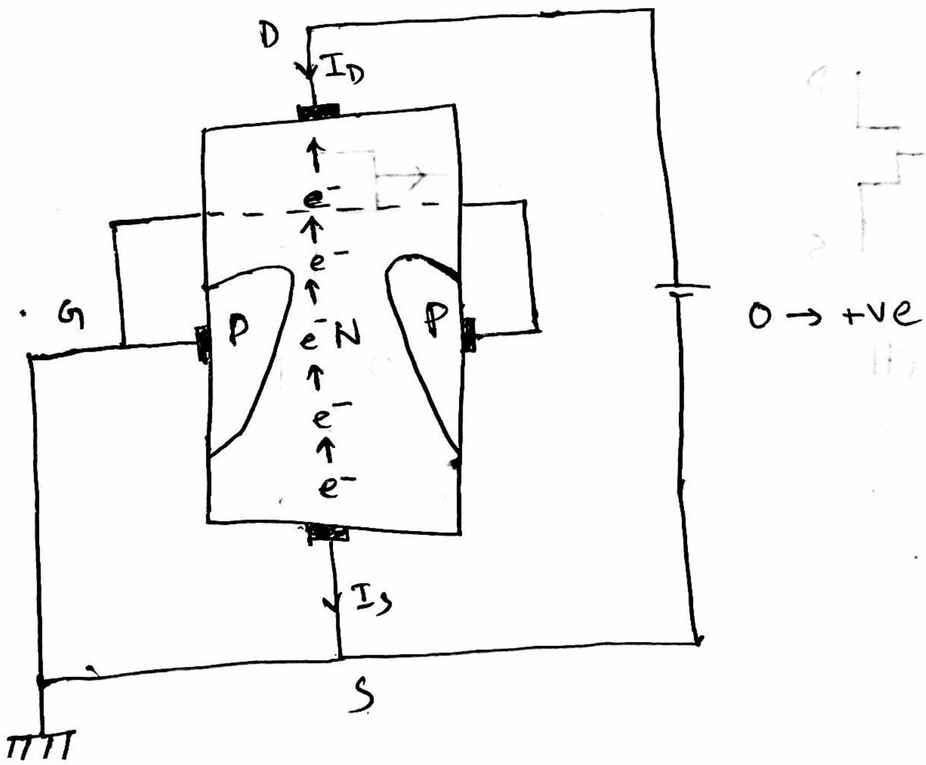
S – Source

Construction n-CH JFET :



Operation :

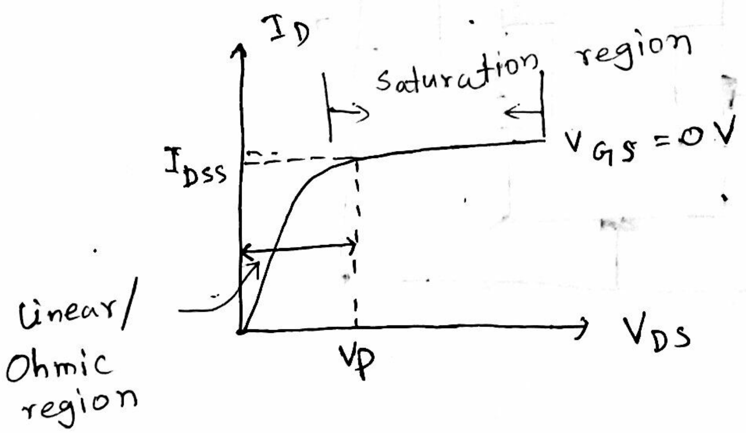
□ $V_{GS} = 0V$ and $V_{DS} \rightarrow$ Some positive value



→ When V_{DS} is applied there will be a current I_D and the Deplation layer will be wide in the top of both p type material.

→ When V_{DS} ↑↑ the deplation layer will increase and the resistance will increase due to narrowing of channel.

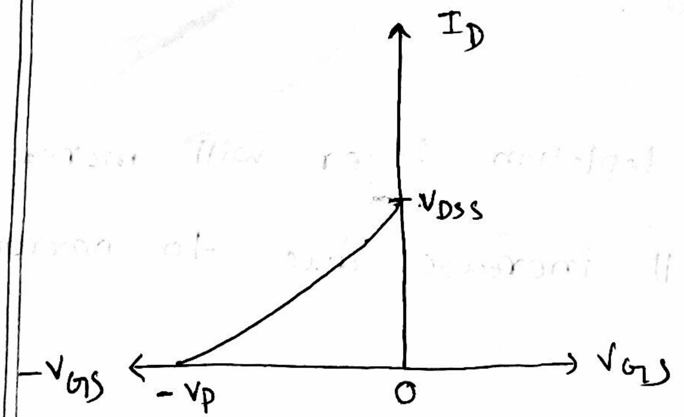
→ At V_{DS} = some positive value the deplation region of both p-type region will touch. This is called pinch-off and voltage called pinch off voltage (V_P).

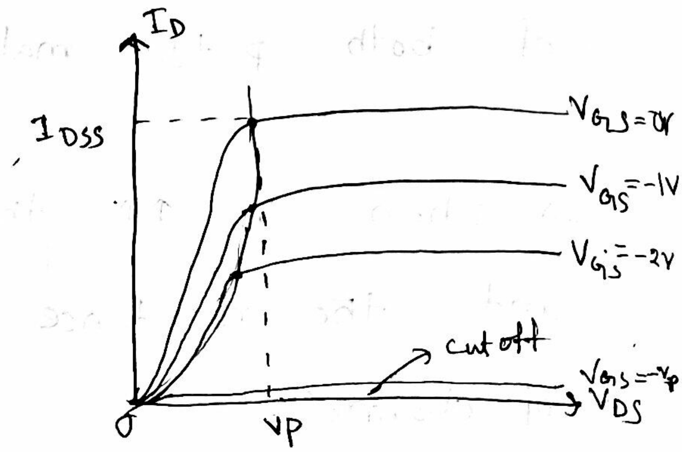


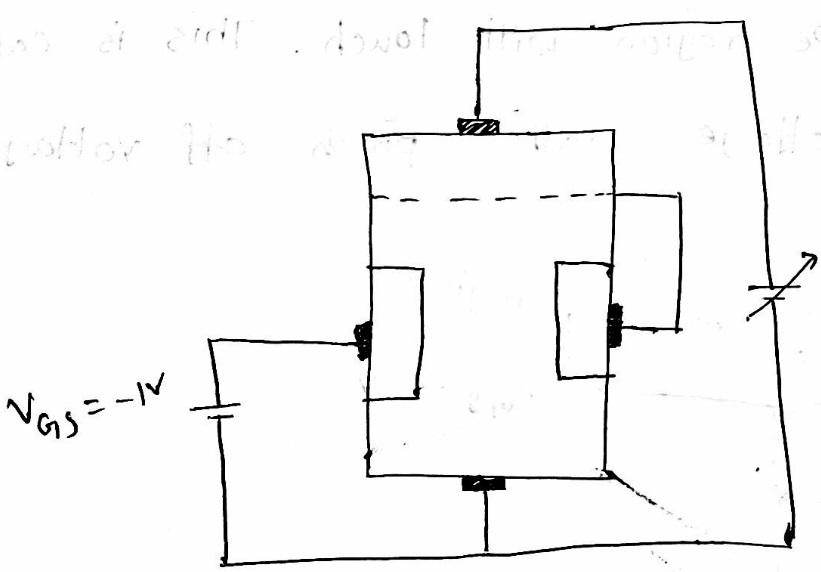
→ At $V_{DS} > V_P$, the current will be fixed at $I_D = I_{DSS}$

(JFET act like constant current source, Operation:

- $V_{GS} < 0\,V$ and $V_{DS} \rightarrow$ some positive value.







* MOSFET ~~consruto~~ construction.

Equation :

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$V_{GS} \rightarrow$ control voltage

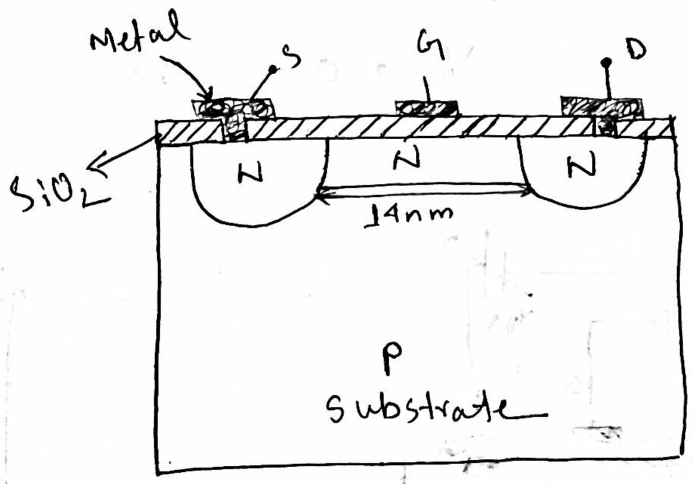
for $V_{GS} = 0V$, $I_D = I_{DSS}$ (max)

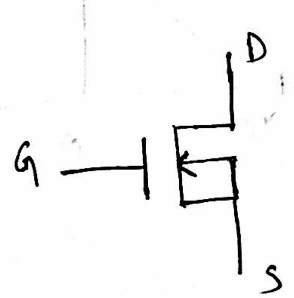
for $V_{GS} = -V_P$, $I_D = 0$

$\Rightarrow I_D \approx I_S$

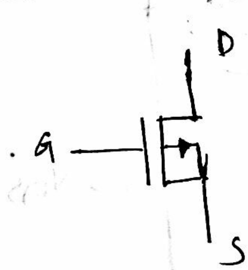
$\Rightarrow I_G \approx 0A$

Deplation type MOSFET : (Metal oxide semiconducton Field Effect Transistor)





N-CH



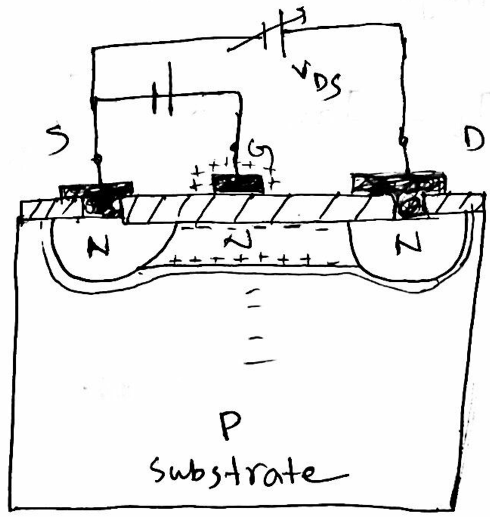
P-CH

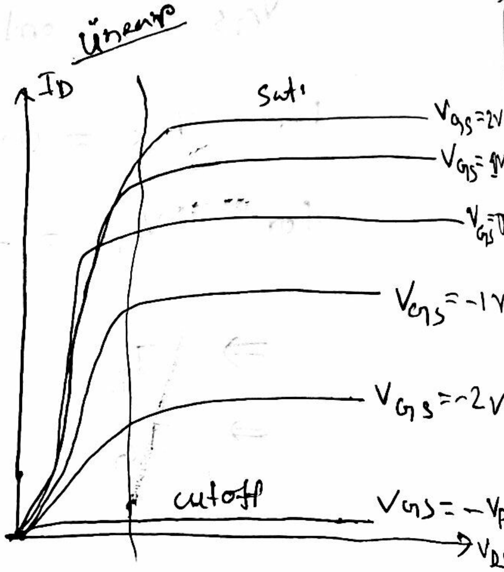
* MOSFET → G দিয়ে current যেতে পারে না

Next Quiz
31/07/16

Operation

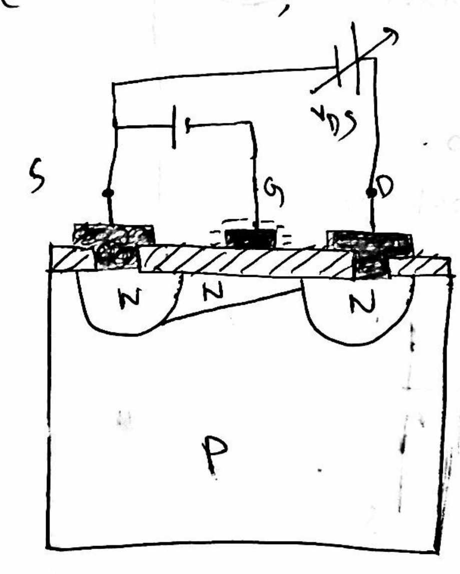
$V_{GS} = 0\,V$ and $V_{DS} \rightarrow +ve$

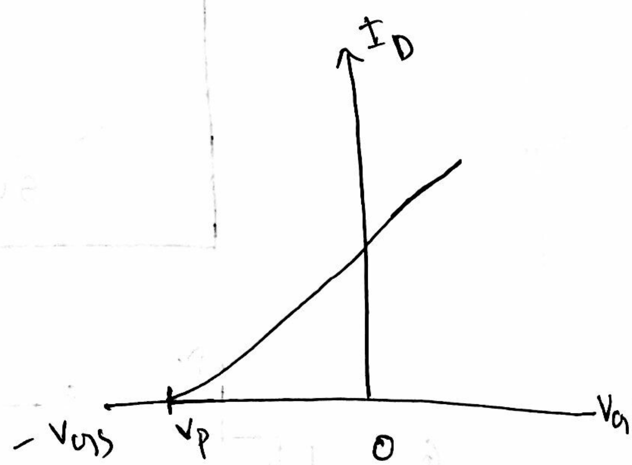




$V_{GS} = +ve$, $V_{DS} : 0 \rightarrow +ve$

$V_G = -ve$

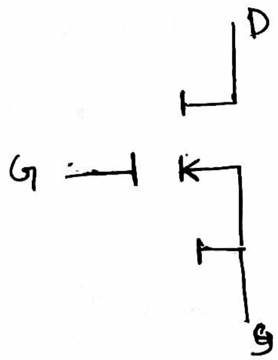




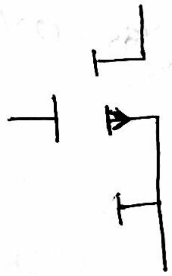
24.07.16

Enhancement type MOSFET :-

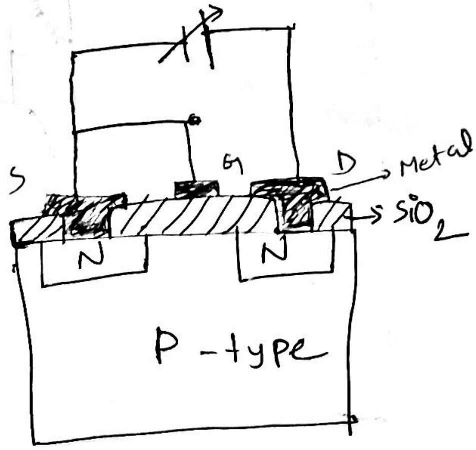
Symbol



N channel

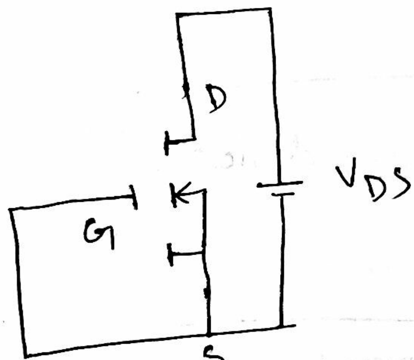


P channel

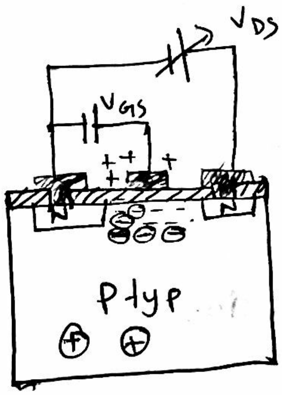


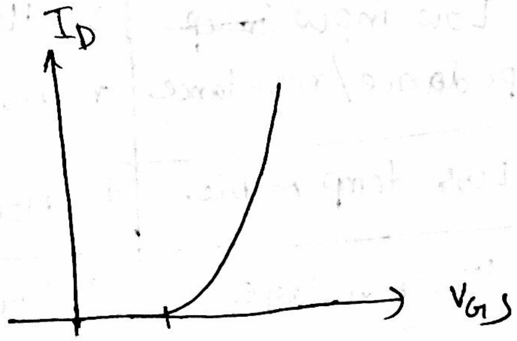
i) $V_{GS} = 0$, V_{DS} , $0 \rightarrow +ve$

ii) $V_{GS} = +3$, V_{DS} , $0 \rightarrow +ve$



n channel

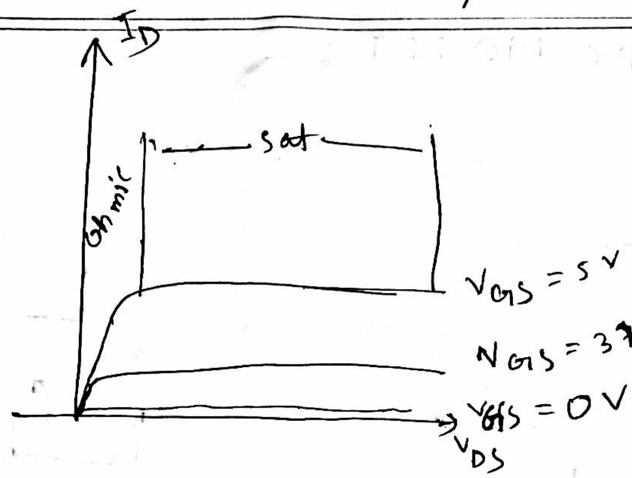




$V_T \rightarrow$ threshold voltage.

* Transistor → current control device (I_B)
* FET → Voltage control device (V_{GS})

* Draw JFET, I
* operation
* difference → BJT/FET



BJT	FET
1) Bipolar device, depends on both e^- and hole for conduction	1) unipolar device, depends on e^- or h^+ for conduction
2) Current controlled device, $I_c = f(I_B)$	2) Voltage controlled device $I_D = f(V_{GS})$
3) Low input ~~indep~~ Impedance/resistance	3) High input impedance/resistance
4) Less temp stable	4) More temp stable
5) Higher voltage gain	5) Lower voltage gain
6) larger in size	6) smaller in construction then BJT

28.07.16

Op amp :

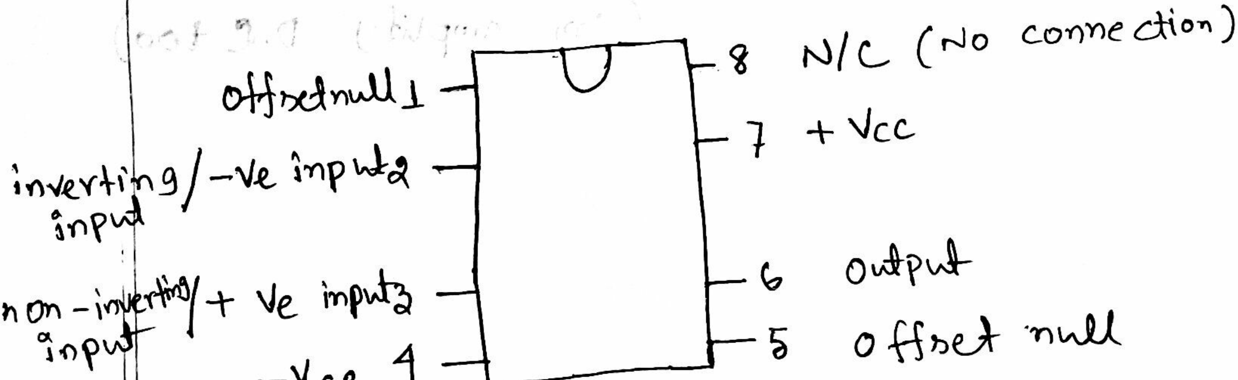
Operational amplifier :

A high gain amplifier which can do many mathematical operation and to which a feedback can be used to control its gain and output characteristics.

Operation (addition, subtraction, multiplication, differentiation, integration etc)

Amplification amplify input signal

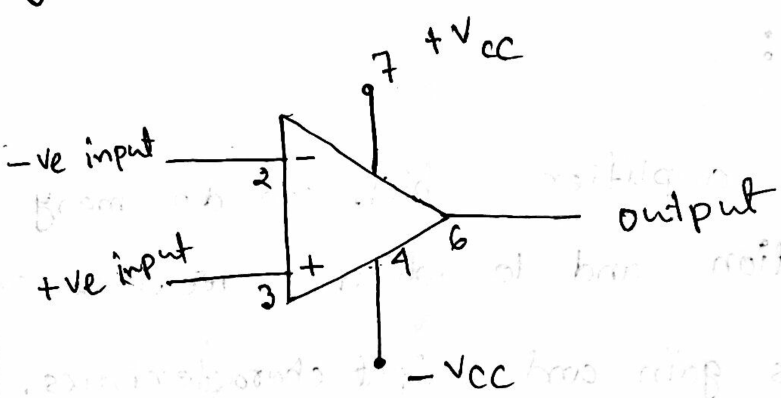
Pin configuration:



offset null − is used to ~~prod~~ provide a way to balance out the internal voltage.

* 14 টা BJT + MOSFET এর combination

Symbol of opamp :

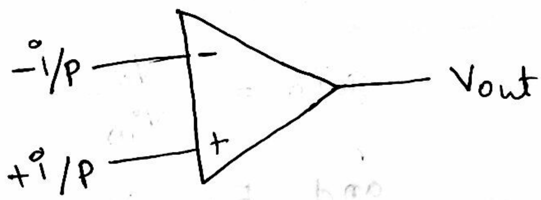


Characteristics of Ideal opamp :

1) I/P impedance — ∞
2) O/P impedance — 0
3) gain (open loop) — ∞
4) BW (bandwidth) — ∞
5) Direct coupling — no capacitor, so ~~cot~~ direct coupling (can amplify D.C too)

741

Open loop voltage gain :



$V_o = E_d \times A_{OL}$

V_o = output voltage

E_d = difference between input voltages

A_{OL} = open loop gain

ex – $+ I/P \rightarrow 2V$

$- I/P \rightarrow 1V$

$V_{out} = (2-1) \times 10$

$= 10V$

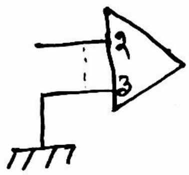
$\boxed{}$ if gain ($A_{OL} = \infty$) then $V_{out} = \infty$ but V_{out} should be limited within $+V_{ce}$ and $-V_{cc}$

so max $V_{out} = +V_{cc}$

min $V_{out} = -V_{ce}$

Virtual short, virtual ground :

pin 2 and 3 are said to be virtually short.



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

and $E_d = V_3 - V_2$

$$V_o = E_d * gain$$

$$\Rightarrow E_d = \frac{V_o}{gain}$$

$$\Rightarrow V_3 - V_2 = \frac{V_o}{\infty}$$

$$\Rightarrow V_3 - V_2 = 0$$

$$\Rightarrow V_3 = V_2$$

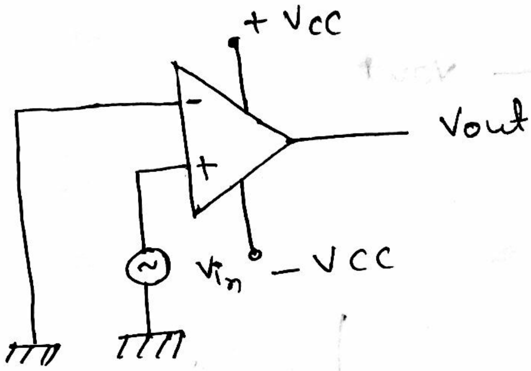
$\therefore$ open loop gain $= \infty$

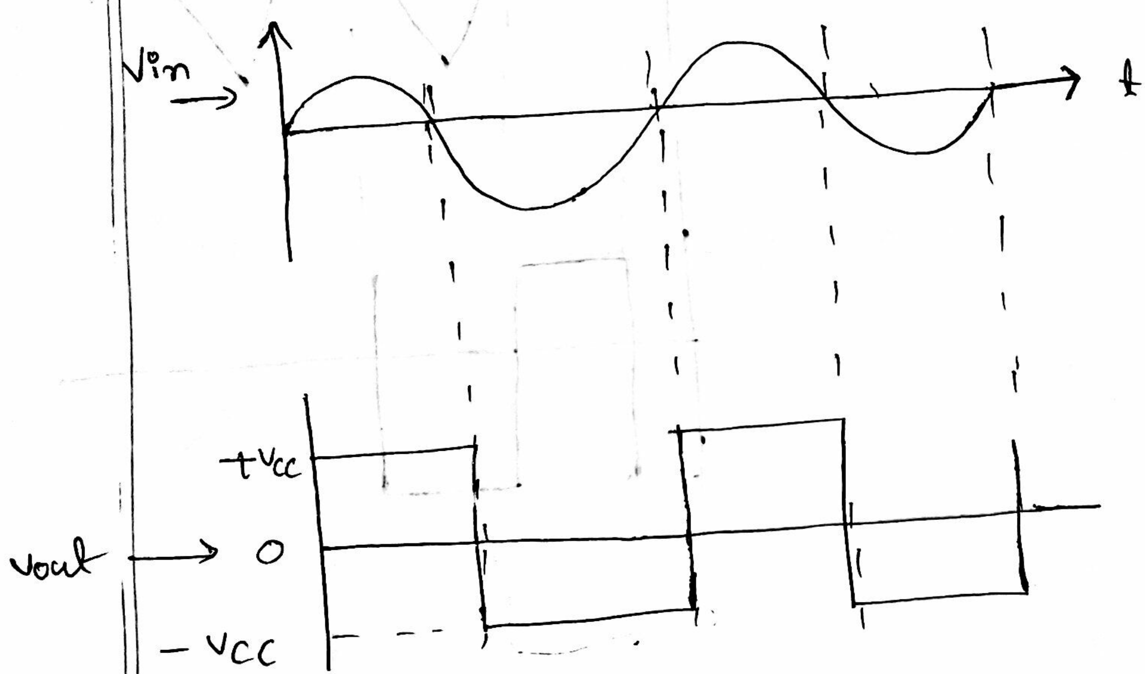
Operational mode :

1) comparator : without feedback
2) Amplifier : with feedback

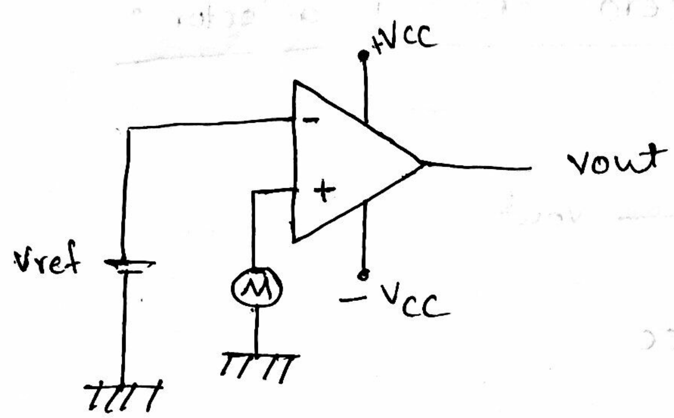
Comparator :

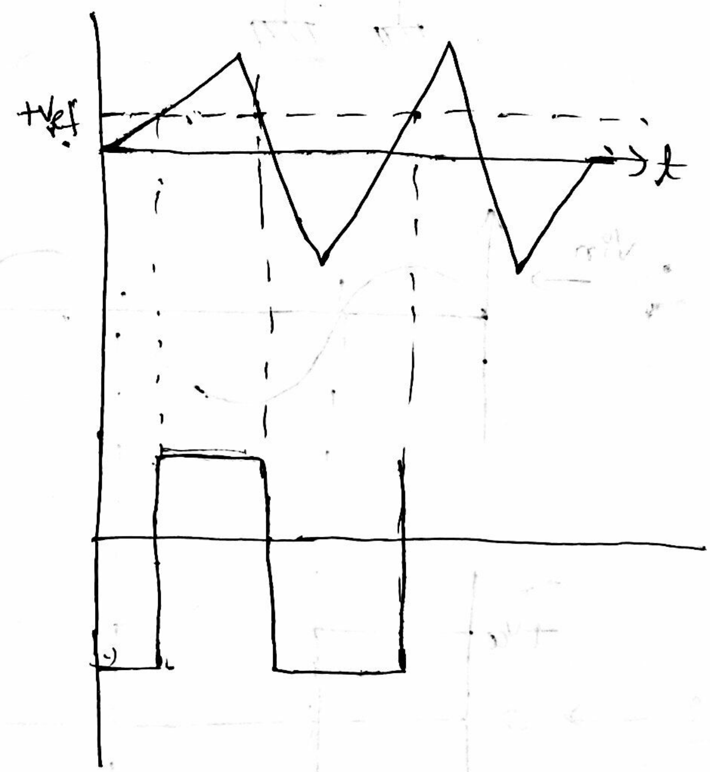
NON inverting zero crossing detector :



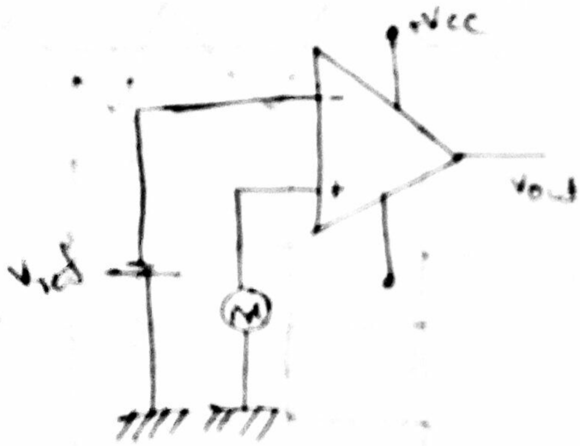


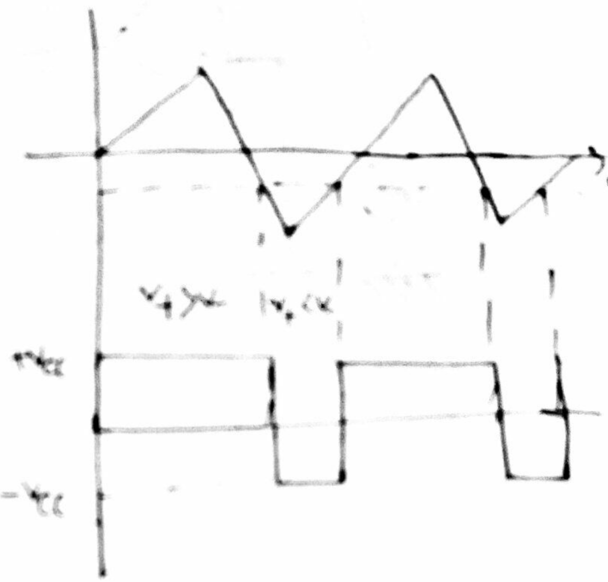
Positive level detector :





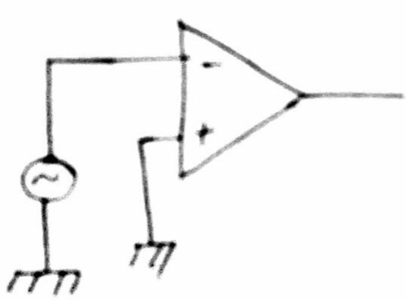
Negative level detector :

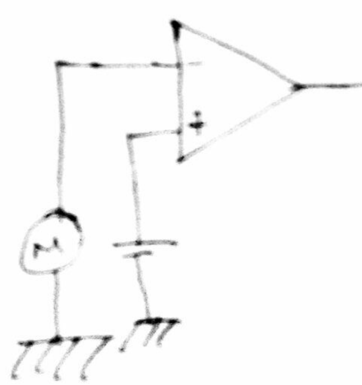




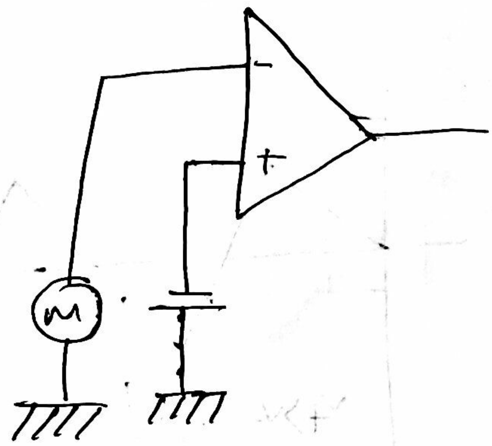
Inverting zero crossing detector :

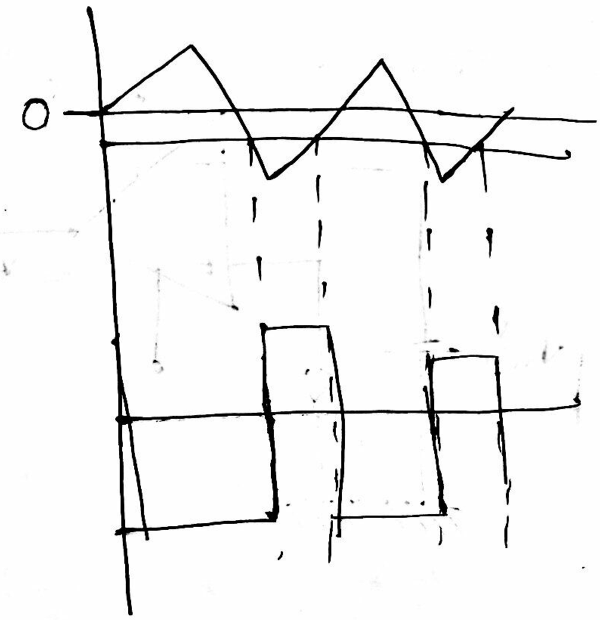
H.W





Negative level detector:



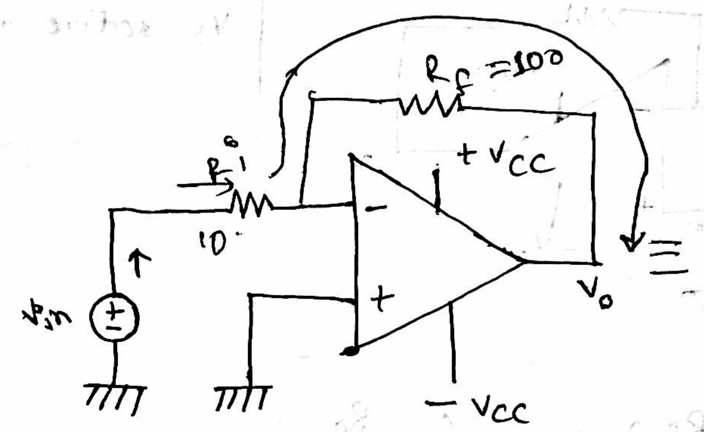


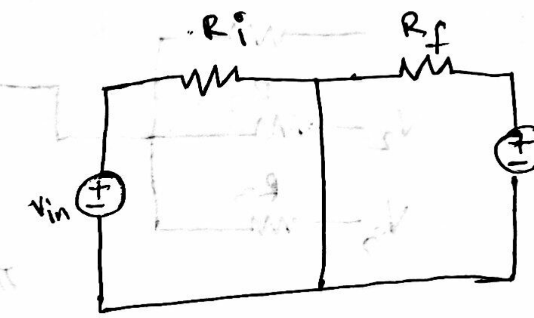
*+/− terminal দিয়ে current যাবে না, তাই input impedence = ∞

04.08.16

Close loop:

⊞ inverting amplifier:





$V_{in} = iR_i$

$\Rightarrow i = \frac{V_{in}}{R_i}$

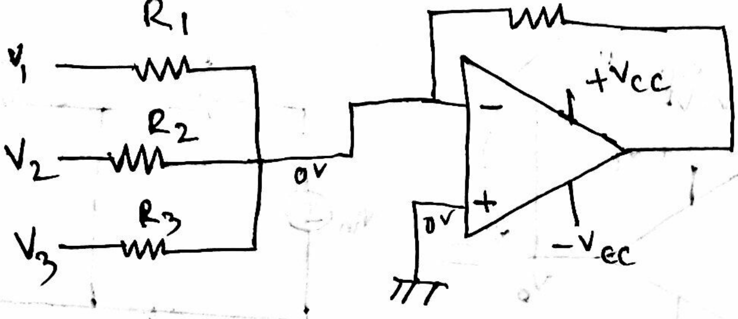
Also, $iR_f + V_{out} = 0$

$\Rightarrow \frac{V_{in}}{R_i} R_f + V_{out} = 0$

$\Rightarrow V_{out} = -\frac{R_f}{R_i} V_{in}$

gain, $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i} V_{in}$

Inverting Adder:



V_1 active $V_{o1} = -\frac{R_f}{R_1} V_1$

V_2 active $V_{o2} = -\frac{R_f}{R_2} V_2$

V_3 active $V_{o3} = -\frac{R_f}{R_3} V_3$

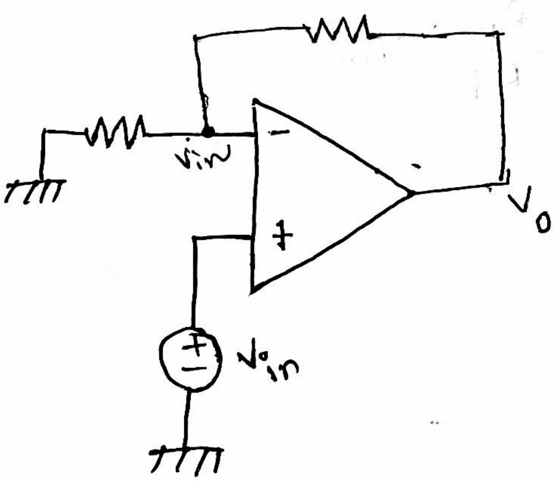
$$V_o = -\frac{R_f}{R_1} V_1 + \left(-\frac{R_f}{R_2}\right) V_2 + \left(-\frac{R_f}{R_3}\right) V_3$$

$$= -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right)$$

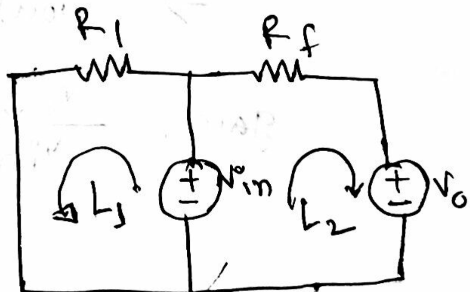
if, $R_1 = R_2 = R_3 = R_f$

$$V_o = -(V_1 + V_2 + V_3)$$

Non-Inverting amplifier:



$\equiv$



loop 1

$$-V_{in} + R_1 I = 0$$

$$\Rightarrow I = \frac{V_{in}}{R_1}$$

loop 2

$$-V_{out} + I R_f + V_{in} = 0$$

$$\Rightarrow V_{out} = I R_f + V_{in}$$

$$\Rightarrow V_{out} = V_{in} + \frac{V_{in}}{R_1} R_f$$

$$\boxed{V_{out} = V_{in}\left(1 + \frac{R_f}{R_1}\right)}$$

$$\text{gain } \frac{V_o}{V_i} = 1 + \frac{R_f}{R_1} = 2$$

$$\Rightarrow \frac{R_f}{R_1} = 1$$

$$\Rightarrow R_f = R_1$$

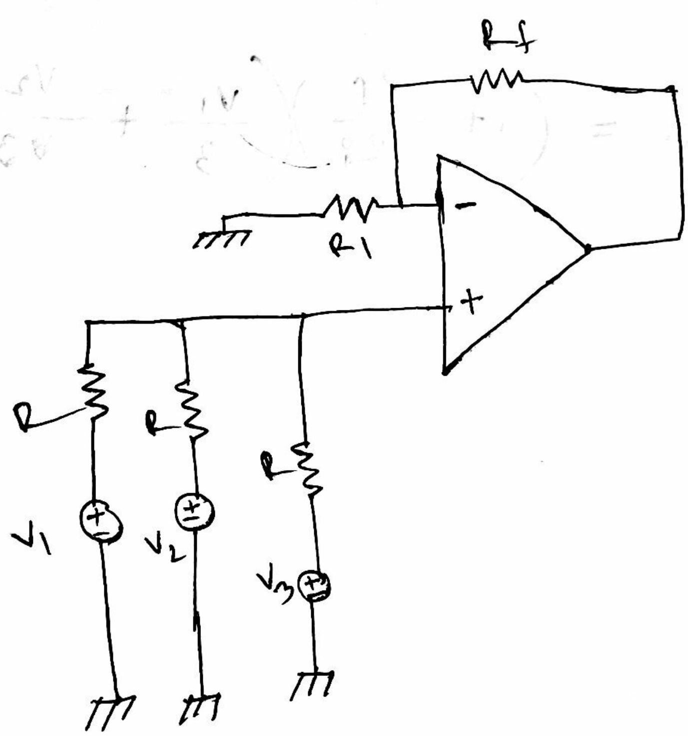
gain 3 time,

$$1 + \frac{R_f}{R_1} = 3$$

$$\frac{R_f}{R_1} = 2$$

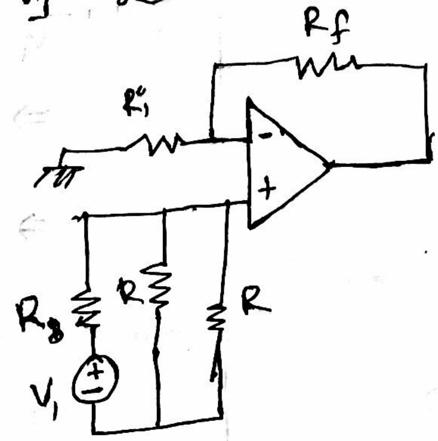
$$\therefore R_f = 2R_1$$

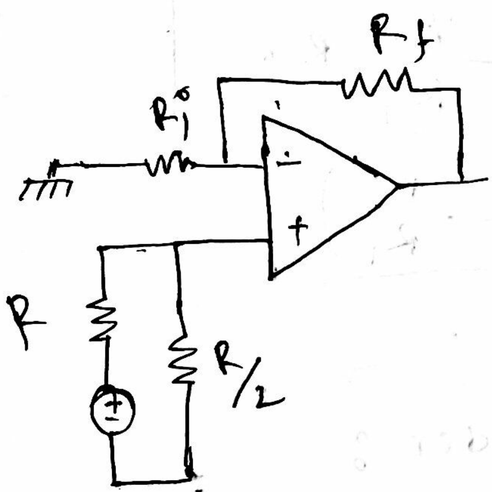
Non inverting Adder :



$$R \parallel R = \frac{R \times R}{R+R} = \frac{R}{2}$$

when V_1 active,





$$V_{i1} = \frac{R/2}{R + R/2} V_1$$

$$= \frac{R/2}{3R/2} V_1$$

$$= \frac{R}{2} \times \frac{2}{3R} V_1$$

$$= \frac{V_1}{3}$$

Simillarly,

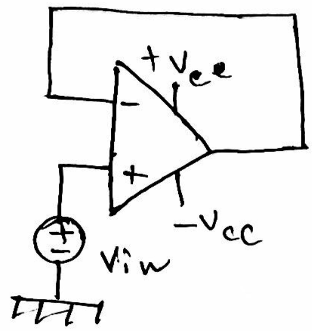
$$V_{i2} = \frac{V_2}{3}$$

$$V_{i3} = \frac{V_3}{3}$$

$$\therefore V_{out} = \left(1 + \frac{R_f}{R_i}\right)\left(\frac{V_1}{3} + \frac{V_2}{3} + \frac{V_3}{3}\right)$$

Voltage follower / Buffer :

→ unity gain amplifier / Source follower / isolation amplifier Buffer



$$V_o = \left(1 + \frac{R_f}{R_i}\right) V_{in}$$

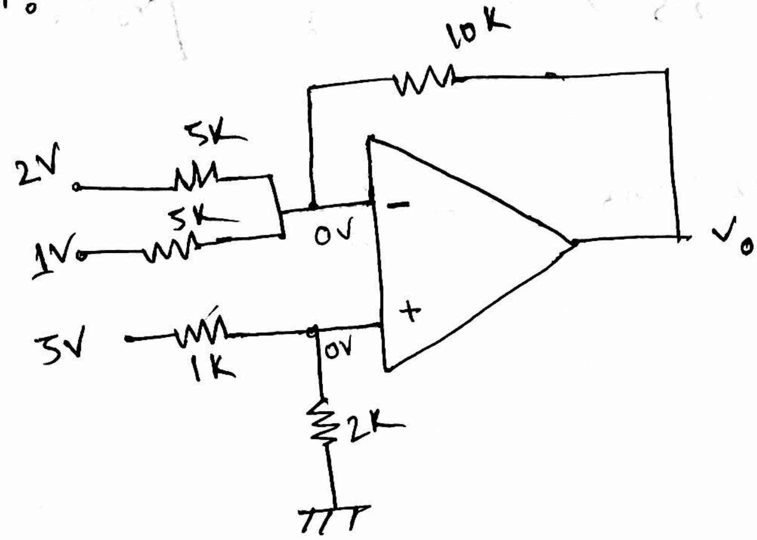
$$R_f = 0\,\Omega$$

$$R_i = \infty$$

$$V_o = (1+0)\,V_{in}$$

$$V_o = V_{in}$$

Problem :



Soln :

When 2 V active,

$$V_{o1} = \frac{10}{5}(-2) = -4 \text{ Volt} \quad \left[V_o = -\frac{R_f}{R_i} V_{in}\right.$$

When 1 V active,

$$V_{o2} = \frac{10}{5}(-1) = -2 \text{ Volt}$$

When 5V active,

$$V_x = \frac{2K}{2K+1K} \times 5$$

$$= \frac{2K}{3K} \times 5$$

$$= \frac{10}{3}$$

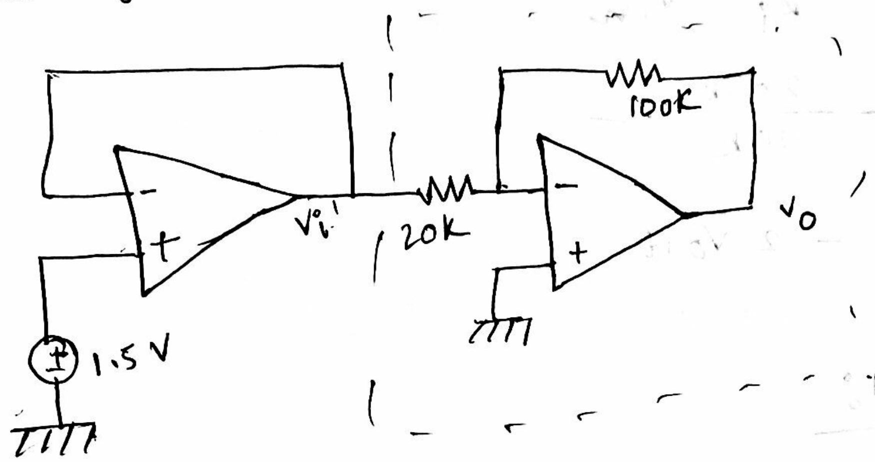
$$R_{in} = 5 \parallel = \frac{5 \times 5}{5+5} = 2.5$$

So, $V_{03} = \left(1 + \frac{10}{2.5}\right) \frac{10}{3} = \frac{50}{3}$ $\left[V_o = \left(1 + \frac{R_f}{R_i}\right) V_{in}\right]$

So, $V_o = V_{01} + V_{02} + V_{03} = -\frac{32}{3}$

7/08/16

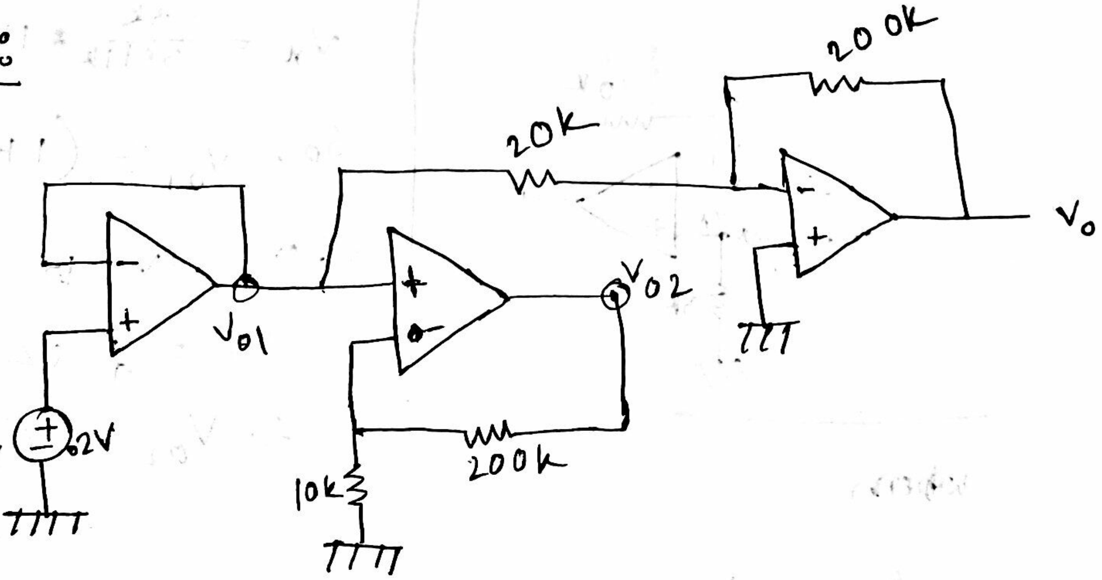
Problem 2:



$V_i' = 1.5\ V$

$V_o = -\frac{R_f}{R_i} V_{in} = \frac{-100k}{20k} * 1.5 = -7.5$ Volt (Ans)

Problem 3:



$V_{01} = \cancel{0.02\ V}\ 0.2\ V$

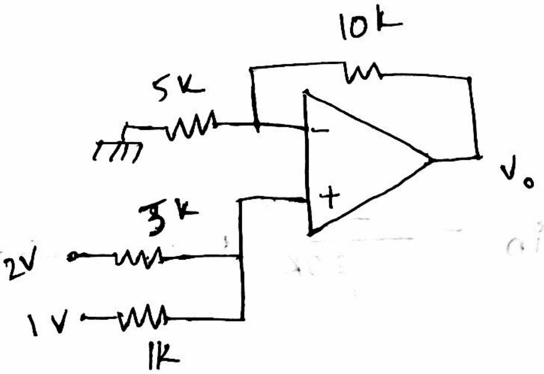
$V_{02} = \left(1 + \frac{R_f}{R_i}\right) V_{in} = \left(1 + \frac{200k}{10k}\right) .2 =$

$$V_o = -\frac{R_f}{R_i} V_{in}$$

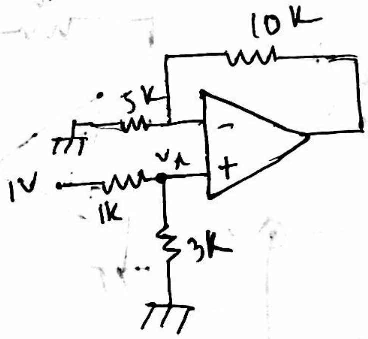
$$= -\frac{200k}{20k} \cdot 2$$

$$= -2 \text{ Volt}$$

☐ Problem 4:



When 1V is active



Here,

$$V_x = \frac{3k}{3k+1k} \times 1V = \frac{3}{4} \text{ Volt}$$

So, $V_{o1} = \left(1+\frac{10}{5}\right)\frac{3}{4} = \frac{9}{4}$ Volt

When 2V is active

$$V_x = \frac{1}{4} \times 2 = \frac{1}{2} V$$

$$\therefore V_{o2} = \left(1+\frac{10}{5}\right)V_x$$

$$= \frac{3}{2} \text{ Volt}$$

~~when~~

So, when 1V and 2V source are active

$$V_o = V_{o1} + V_{o2} = \frac{9}{4} + \frac{3}{2} = \frac{15}{4} \text{ (Ans)}$$

when, V_1 is active

$V_{o1} = -\frac{R_f}{R_1} V_1$

$\Rightarrow -3V_1 = -\frac{R_f}{R_1} V_1$

$\Rightarrow 3 = \frac{R_f}{R_1}$

$\Rightarrow R_1 = \frac{R_f}{3}$

V_2 is active

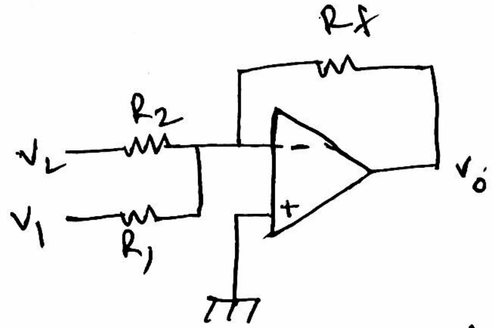
$V_{o2} = -\frac{R_f}{R_2} V_2$

$\vdots$

$\Rightarrow R_2 = \frac{R_f}{4}$

Design

$V_o = -3V_1 - 4V_2$

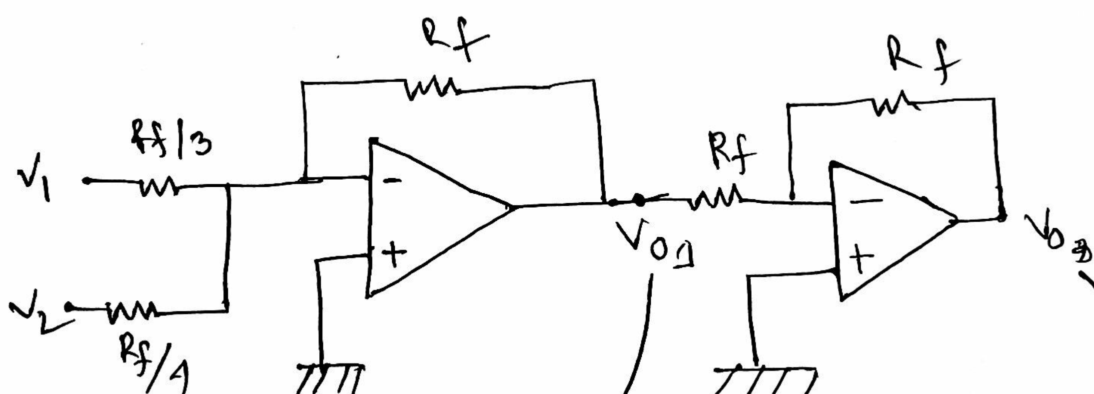


Let, $R_f = 100k$

$R_1 = \boxed{}$

$R_2 = \boxed{}$

Q2: $V_o = -3V_1 + 4_2$



$-3V_1 - 4V_2$

$V_o = -V_{o1}$
$= 3V_1 + 4V_2$