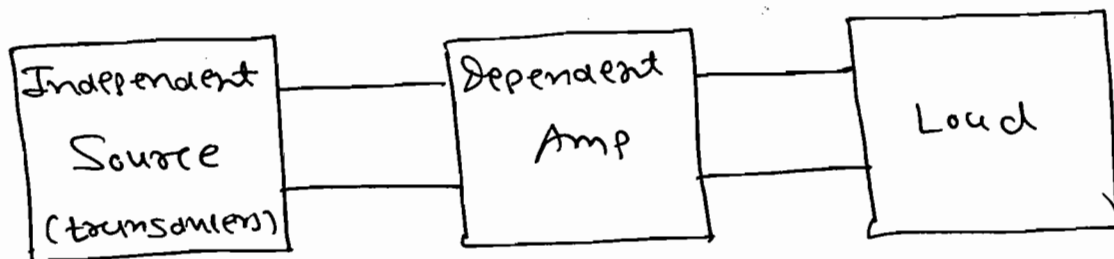
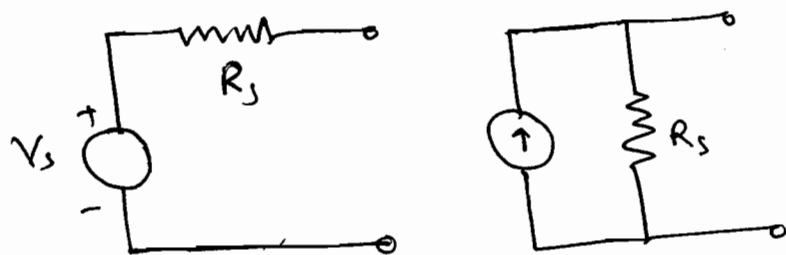


★ Amplifier Modeling:



→ microphone

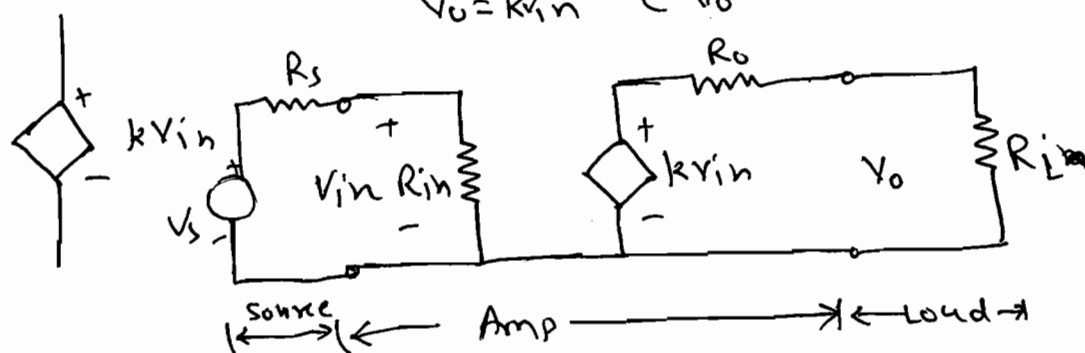


- * Voltage amp $V_o = k V_{in}$ [VCVS].
- Current amp $I_o = k I_{in}$ [CCCS].
- Transconductance amp $I_o = k V_{in}$ [VCCS].
- TransResistive amp $V_o = k I_{in}$ [CCVS].

* Four Types of Amplifier:

(1) Voltage amplifier or
Voltage control voltage source.

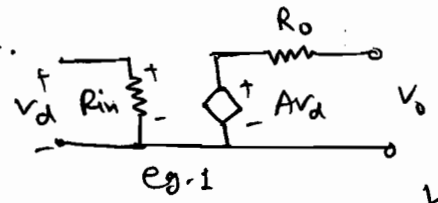
→ VCVS



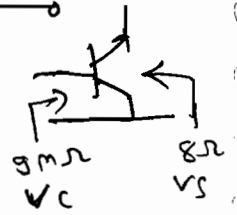
$V_o = k V_{in}$ (V_o should be inde. of R_L).

(VC) → $R_{in} = \infty$, $R_o = 0$. (Ideal),
 $V_{in} = V_s$, $V_o = k V_{in}$

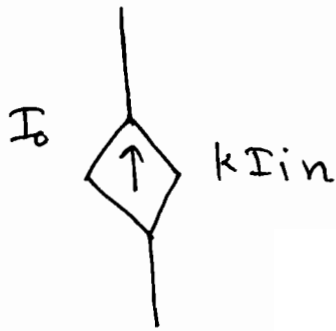
NOTE:
 → Amplifier is Unilateral amp. and doesn't violate Reciprocity theorem.
 → Eg: OPAM, CC amplifier.



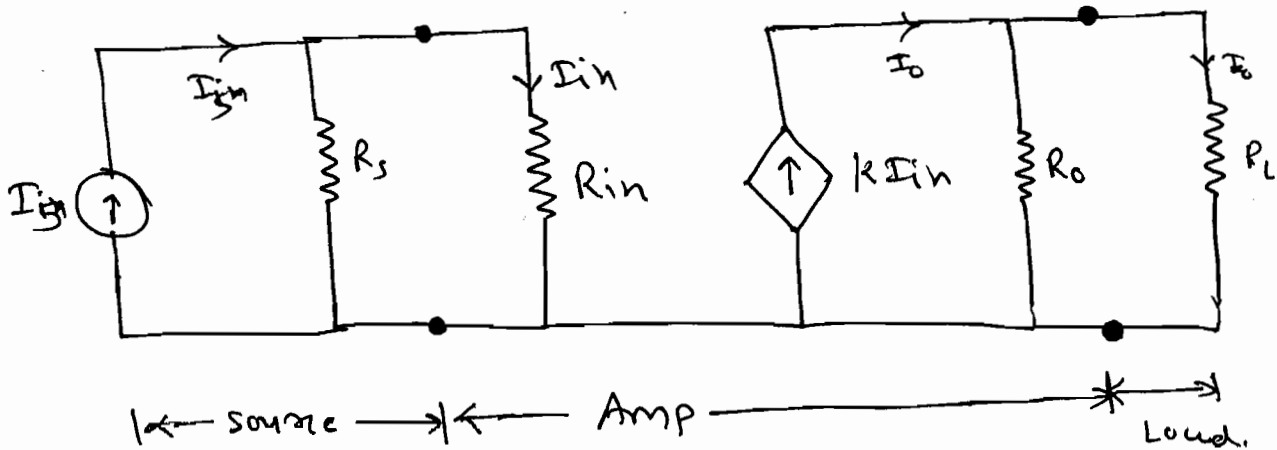
(2) Current amplifiers or current control current ^{source} amplifiers:



⇒



(I_o should be independent of Load)

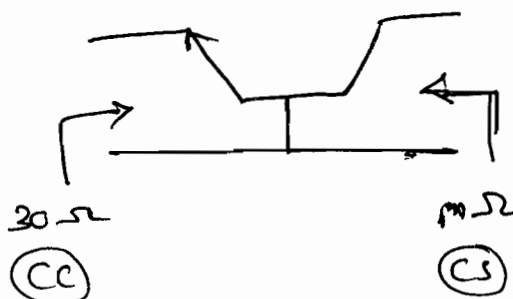


(CC) $R_{in} \approx 0$
 $\downarrow$
 $I_{in} \approx I_s$

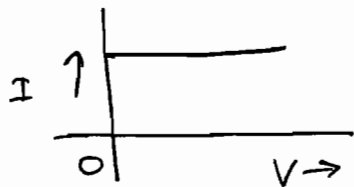
$R_o \approx \infty$
 $\downarrow$
 $I_o = k I_{in}$ (CS)

e.g.:

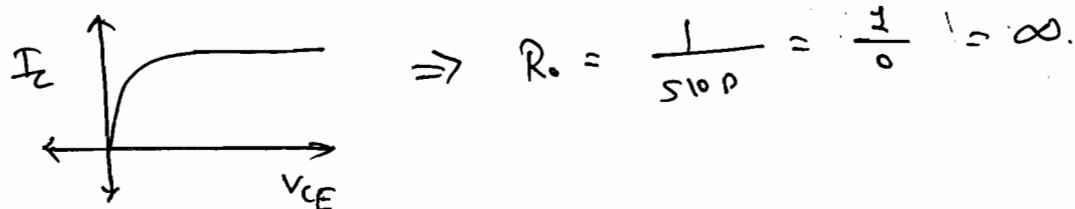
(1) CB amp



* Characteristics of current source:



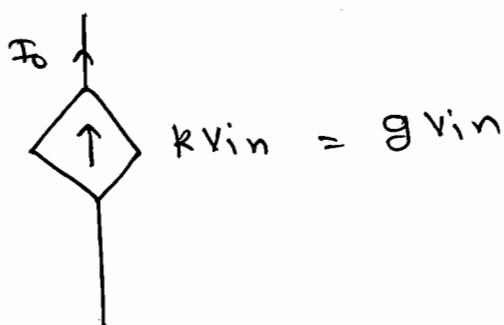
e.g. ② BJT



So, BJT is current source.

(3) Voltage Control Current Source Amp.

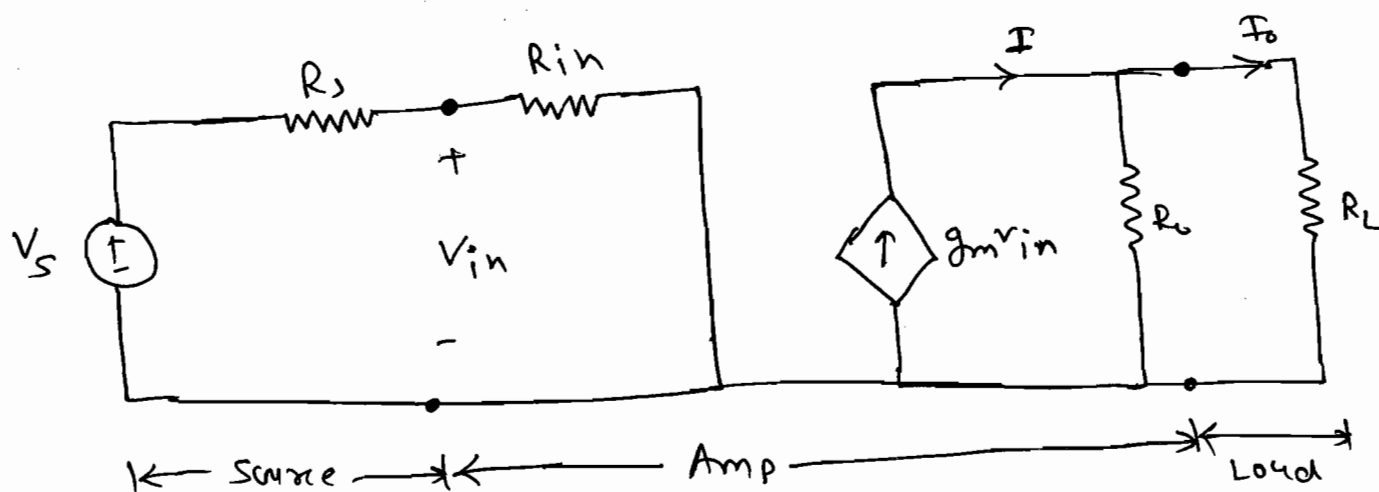
(or) Transconductance Amp.



$$g_m = \frac{I_o}{v_{in}}$$

↓
transconductance.

$$\therefore I_o = g_m v_{in}$$



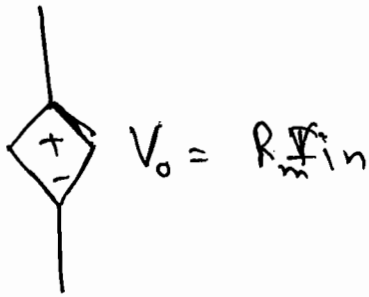
$\Rightarrow R_{in} \approx \infty$
 $\downarrow$
 $v_{in} \approx v_s$
 $\downarrow$
 voltage control

$R_o \approx \infty$
 $\downarrow$
 $I_o = g_m v_{in}$
 $\downarrow$
 current source.

e.g.: ① FET, operational transconductance amp (OTA).

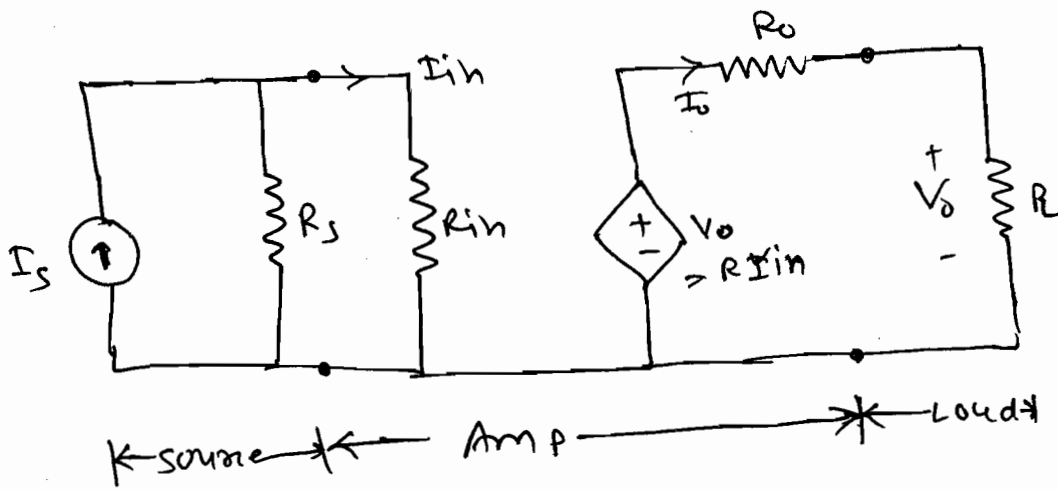
④ Current Control Voltage Source:

(or) Transresistance amp.



$$R_m = \frac{V_o}{I_{in}}$$

Transresistance



$$R_{in} \approx 0$$

$$\therefore \Downarrow$$

$$I_{in} \approx I_s$$

(CC)

$$R_o \approx 0$$

$$\Downarrow$$

$$V_o = R_m I_{in}$$

$$\Downarrow$$

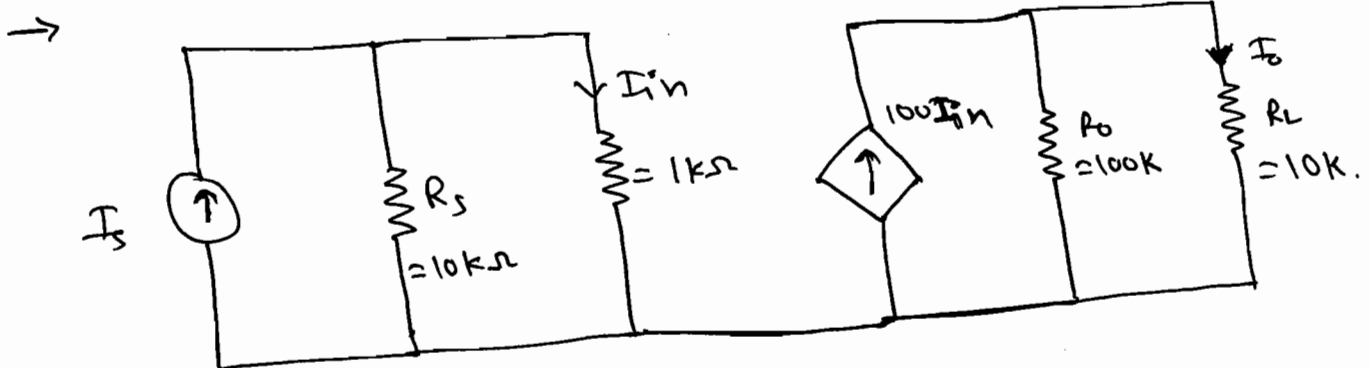
(VS)

* Summary

7

Amp	R_{in}	R_o	
1) Voltage	high	Low	$A_v = \frac{V_o}{V_{in}} \text{ (VSV)} -$
2) Current	Low	high	$A_I = \frac{I_o}{I_{in}} \text{ (CSCE)}$
3) Trans Conductance	high	High	$G_m = \frac{I_o}{V_{in}} \text{ (CSV)}$
4) Trans Resistance	Low	Low	$R_m = \frac{V_o}{I_{in}} \text{ (CVSC)}$

Ex-1 Find Voltage gain, Current gain and Power gain of the current amplifier.



$$\rightarrow I_o = \frac{100}{110} \times 100k I_{in}$$

$$\therefore \frac{I_o}{I_{in}} = A_I = \frac{100 \times 100}{110}$$

$$\therefore A_I = \frac{10^4}{110}$$

$$\therefore \text{Now, } V_o = I_o \times 10k$$

$$V_o = \frac{100}{110} \times 100 \times 10k \times I_{in}$$

$$\therefore V_o = \frac{10^8}{110} \times I_{in}$$

$$\therefore I_{in} = \frac{10k}{11k} \times I_s.$$

$$\therefore I_s = \frac{1k}{11k} \times I_{in}.$$

$$\therefore V_{in} =$$

$$\therefore I_o = \frac{100 \times 100}{110} \times \frac{100}{11} I_s.$$

$$\therefore \boxed{\frac{I_o}{I_s} = \frac{10^5}{110 \times 11}} = A_I.$$

$$\therefore \text{Current gain } A_I = \frac{10^5}{110 \times 11}.$$

$$\therefore \text{Voltage gain } (A_V) = \frac{V_o}{V_s}.$$

$$\therefore V_s =$$

$$V_s = 10k \times \frac{1k}{11k} \times I_{in}.$$

$$\therefore V_s = \frac{10 \times 10^3}{11} \times \frac{110}{10^8} \cdot V_o.$$

$$\therefore \boxed{\frac{V_o}{V_s} = A_V = \frac{10^9}{11 \times 110}}.$$

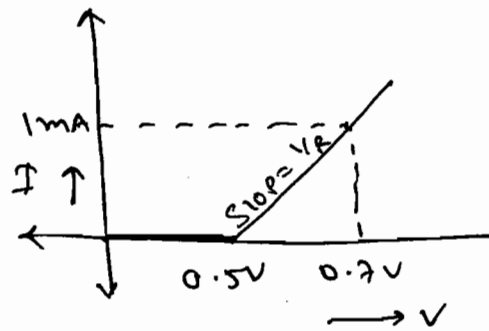
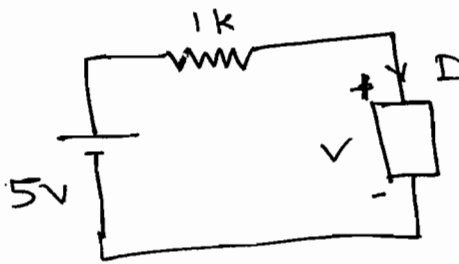
$$\text{Power gain } (A_P) = A_V \times A_I$$

$$\therefore \boxed{A_P = \frac{10^9}{(110)^2 \times (11)^2}}.$$

$\therefore$ Compounding means taking log.

$$\therefore \underline{\text{Gain db} = 10 \log A_P.}$$

Ex-1 Find I of the fig. Its characteristic is given.



$$\therefore R = \frac{0.2}{10^{-3}} = 200 \Omega.$$

$$\therefore \text{Slope} = I/V = \frac{1}{200}.$$

$$\therefore \text{Eqn. } (0.5, 0) \text{ to } (0.7, 1 \text{ m}).$$

$$\therefore \frac{y - y_1}{x_2 - x_1} = \frac{x - x_1}{x_2 - x_1}$$

$$\therefore \frac{I - 0}{1 \text{ m}} = \frac{V - 0.5}{0.2}$$

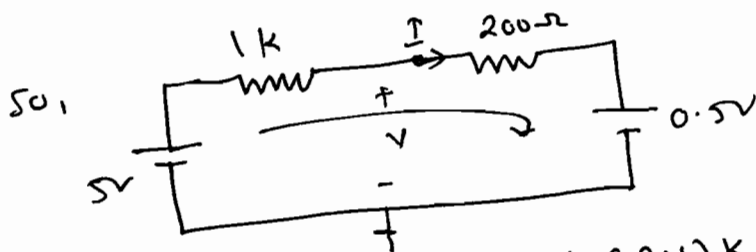
$$\therefore 200 I + 0.5 = V.$$

$$\therefore \boxed{V = 200 I + 0.5}$$

Next, $V = 8 \text{ V}$.

So, $200 I + 0.5 = 8$

$$\therefore I = \frac{7.5}{200}$$



$$\therefore 5 - 0.5 = I(200 \text{ k})$$

$$\therefore \boxed{I = 3.75 \text{ mA}}$$

$$\therefore V = 200 \times 3.75 \times 10^{-3} + 0.5$$

$$\therefore V = 7.5 + 0.5 = 0.8 \text{ V} \Rightarrow \boxed{V = 0.8 \text{ V}}$$

★ Operational Amplifiers: (OP-Amp)



(Voltage summing)
non-inverting

V_1

V_2

Inverting terminal
(Current summing node)

$+V_{EE} = +12V$

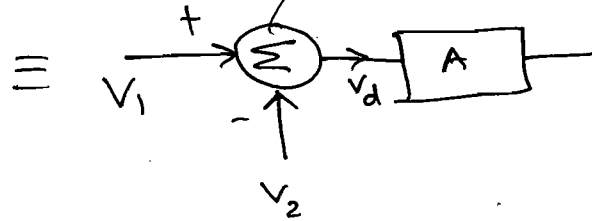
$-V_{EE} = -12V$

V_o

Differential amp

$$V_o = A V_d$$

$$V_o = A(V_1 - V_2)$$

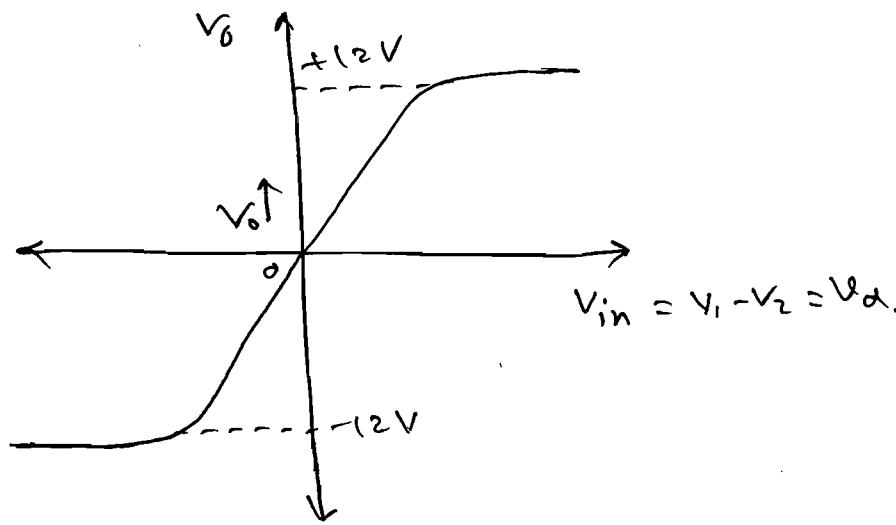


$$\therefore V_o = A_{OL} (V_1 - V_2)$$

A_{OL} = open loop gain $\rightarrow 10^6$ [MA741 Fairchild].

$\rightarrow$ OP-Amp is a high gain differential Amplifier.

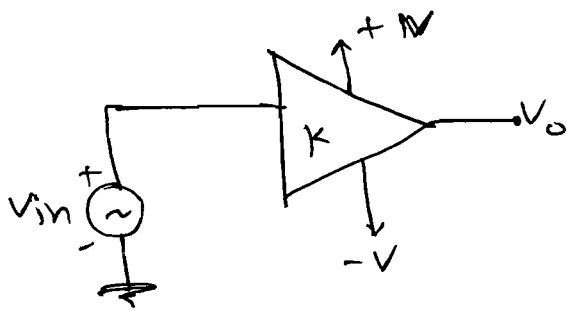
* Transfer Characteristics:



NOTE: If an amplifier works with two supplies $+V$ and $-V$ with a gain K in order to avoid clipping the input signal swing

Should $-\frac{V}{K}$ to $+\frac{V}{K}$.

11



$$-V \leq V_o \leq +V.$$

$$-\frac{V}{K} \leq V_{in} \leq +\frac{V}{K}.$$

* Three Basic Modes of Operation of an OP-Amp:

(1) Negative feedback:

*

Linear

VCVS }
CCCS } Amp
VCVS }
CCVS }

Adder

Subtractor

Instrumentation
Amp

Nonlinear

Rectifier

Peak Detector

Clipper

Clamper

Log amp

Exp amp.

*

Open loop

~~Excessed~~ Positive feedback

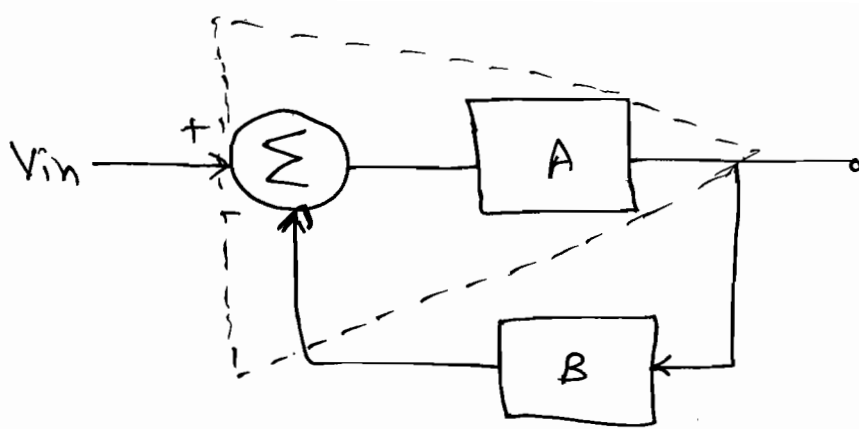
Comparator
(detector)

Schmitt trigger
→ multivibrators.

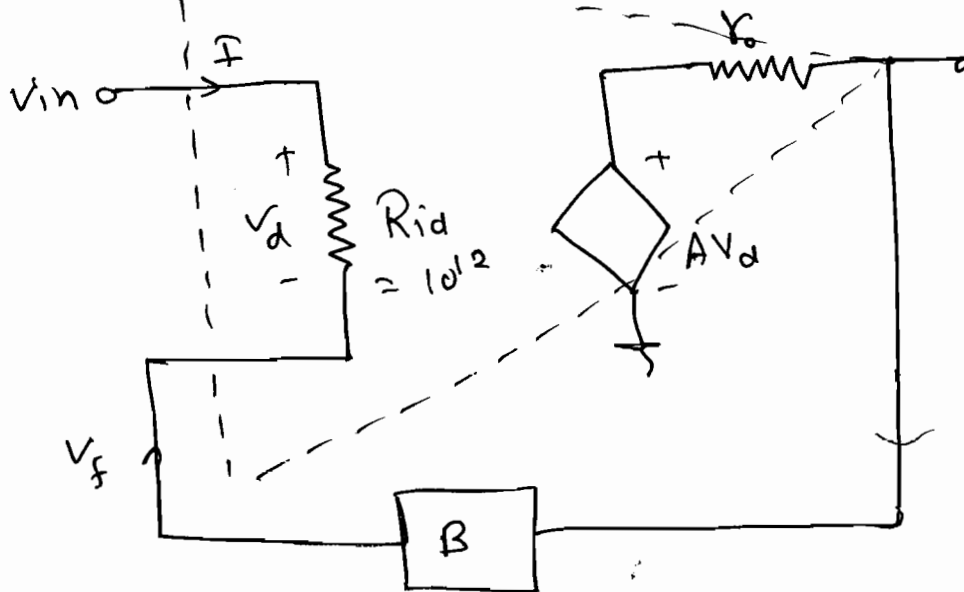
min
→

In order to solve circuits involving -ve feedback two realistic assumptions are made.

- ① $V_{noninverting} = V_{inverting}$.
- ② OP-amp draws no current.

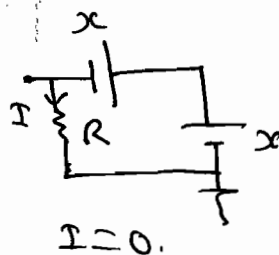
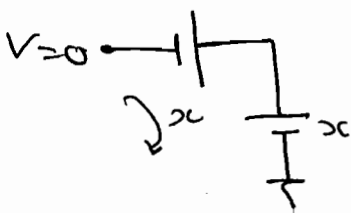


→ OP-Amp is VCVS.



$$V_d = \frac{V_o}{A} = \frac{10}{10^6} = 10^{-5}$$

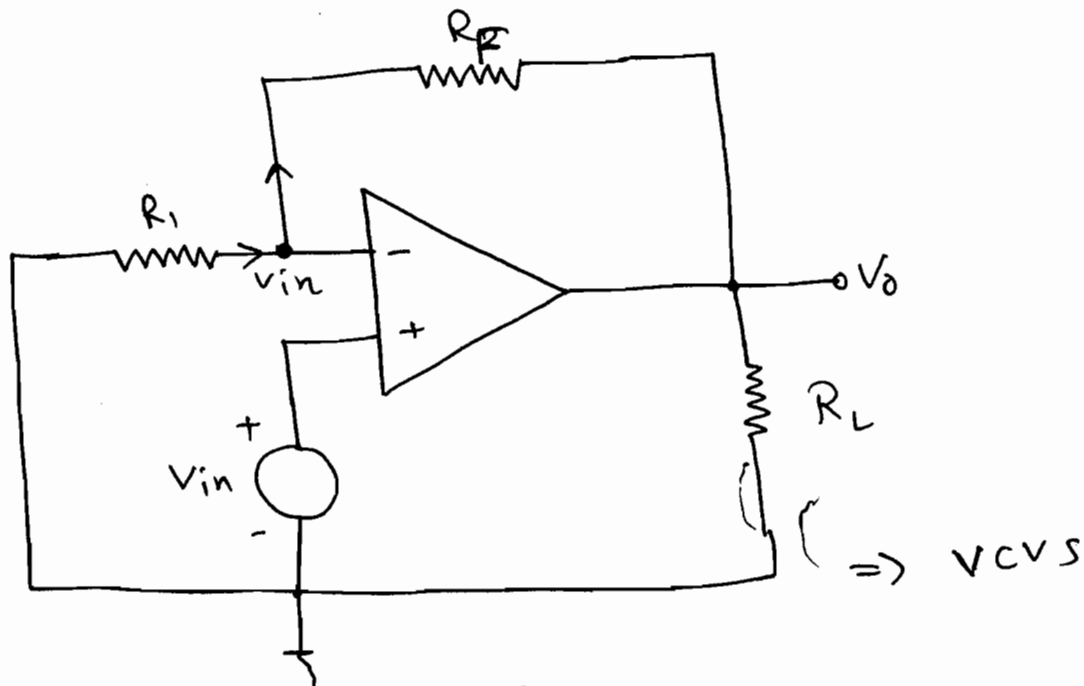
* OP-Amp is nullator.



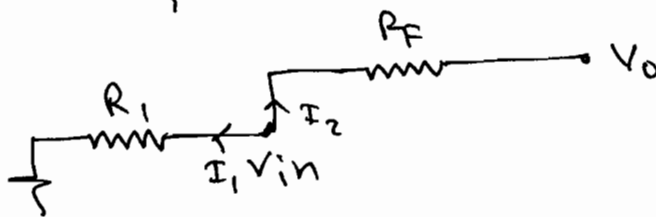
So, $V=0$ & $I=0$.

(1) Voltage Amplifier (or) Non-Inverting
Amplifier (or) Voltage Control Voltage
Source Amplifier).

*



$\Rightarrow$



KCL

$$I_1 = I_2$$

$$\therefore \frac{V_{in} - 0}{R_1} = \frac{V_{in} - V_o}{R_F} = 0$$

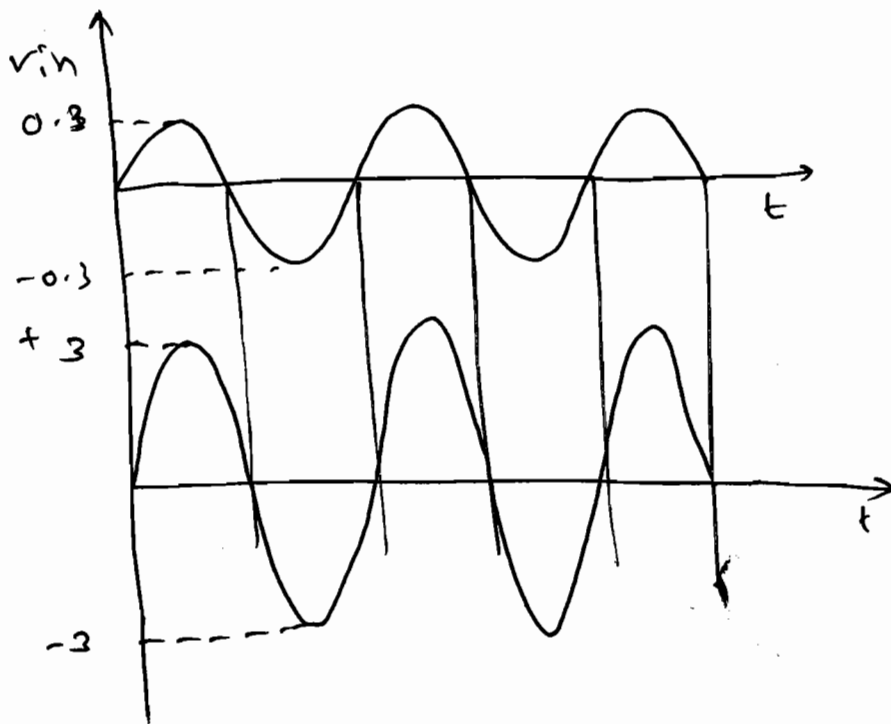
$$\therefore V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}$$

$$= \boxed{V_o = K V_{in}}$$

e.g. $V_{in} = 0.3 \sin t$, $R_F = 9k$, $R_1 = 1k$.

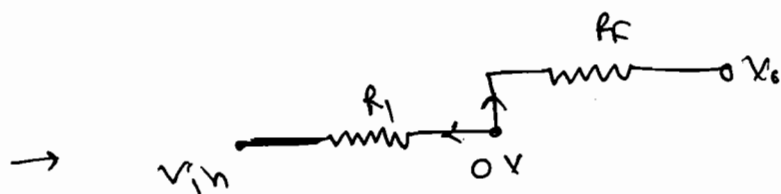
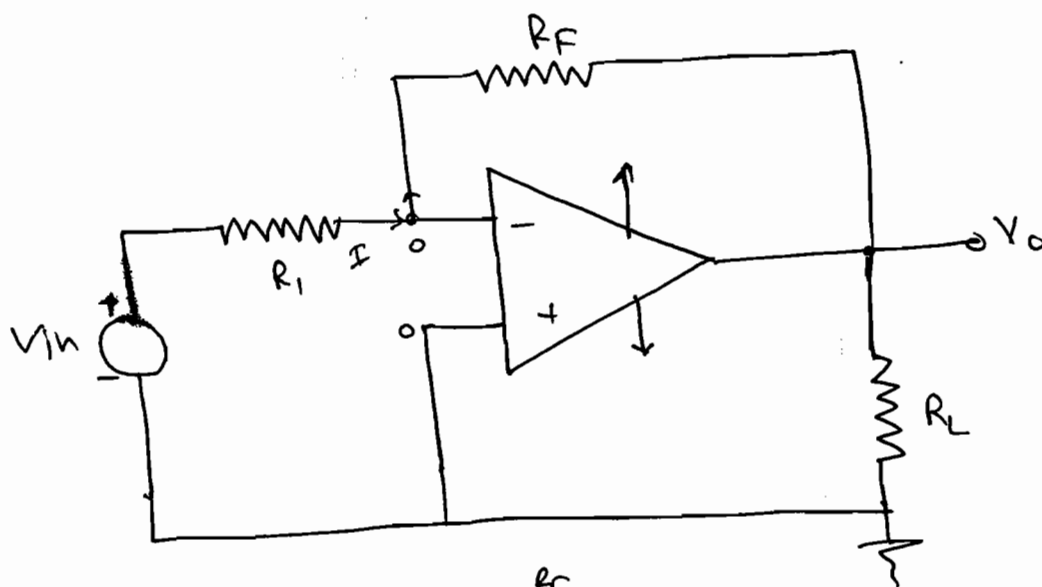
$$\therefore V_o = \left(1 + \frac{9}{1}\right) V_{in}$$

$$\therefore V_o = 10 V_{in} = 3 \sin t$$



(2) Inverting Amplifier (or) Current Control
Voltage Source (or) Trans Resistance Amplifier.

$\Rightarrow$



KCL

$$\frac{0 - v_{in}}{R_1} + \frac{0 - v_o}{R_F} = 0$$

$$\therefore v_o = \left(-\frac{R_F}{R_1} \right) v_{in}$$

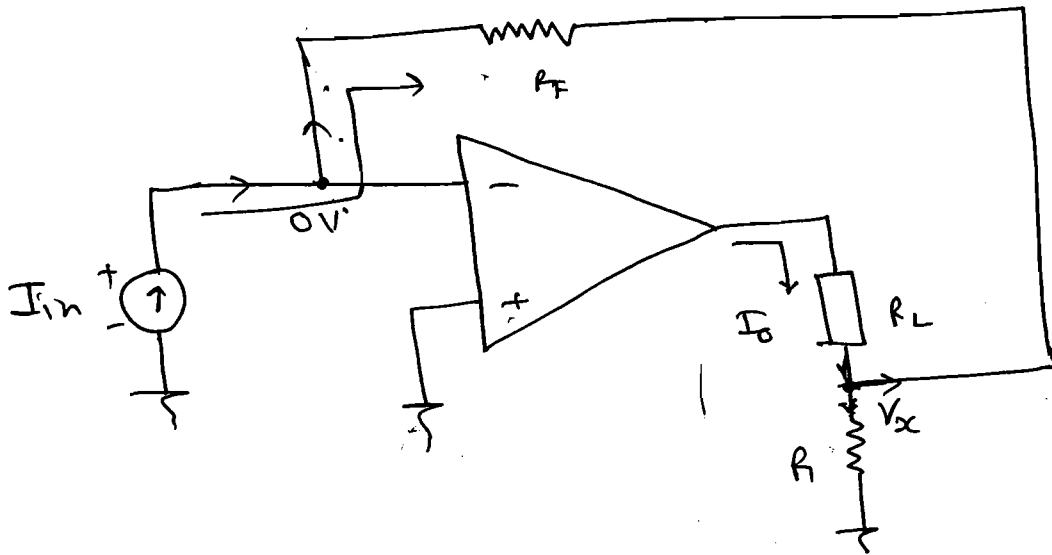
$$\rightarrow V_o = (-R_F) \left(\frac{V_{in}}{R_1} \right) \rightarrow \text{current } \cancel{\text{control.}}$$

$$\therefore V_o = -R_F I_{in}.$$

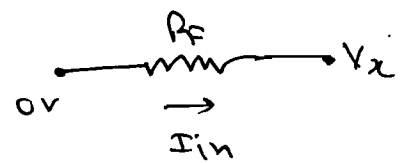
$$\therefore \text{Trans Resistance} \quad R_m \approx \frac{V_o}{V_{in}}.$$

$$\therefore \boxed{R_m = -R_F.}$$

(3) Current Amplifier (or) Current Control
Current Source:



$$\underline{\text{KCL}}: I_o = \frac{V_x}{R} + \frac{V_x - 0}{R_F}.$$



$$\therefore I_o = V_x \left[\frac{1}{R_1} + \frac{1}{R_F} \right] \quad \text{--- (1)}$$

$$\therefore I_{in} = \frac{0 - V_x}{R_F}.$$

$$\therefore V_x = (-R_F) I_{in}. \quad \text{--- (2)}$$

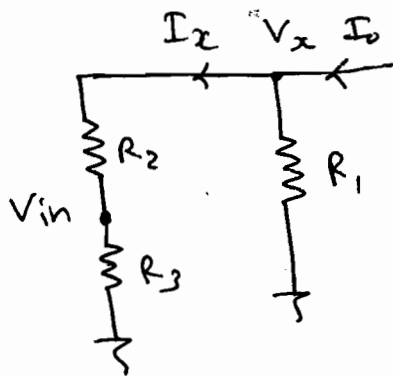
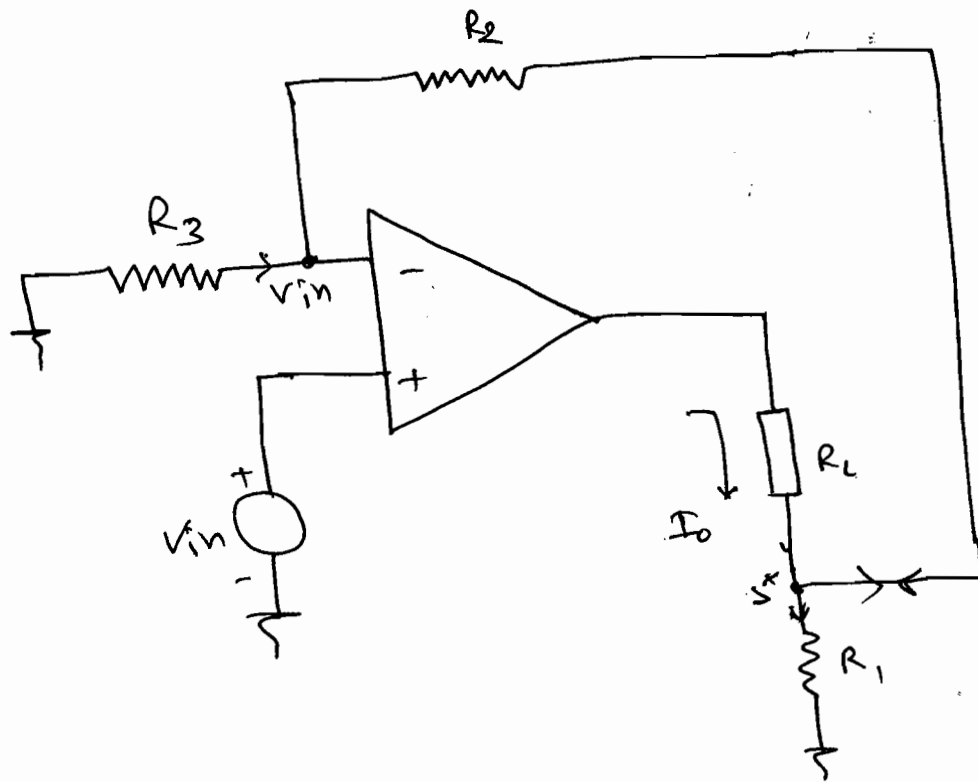
Sub (2) in (1)

$$I_o = -R_F I_{in} \left[\frac{1}{R_1} + \frac{1}{R_F} \right].$$

$$\therefore I_o = - \left[1 + \frac{R_F}{R_1} \right] I_{in} \Rightarrow$$

$$\boxed{I_o = k I_{in}.}$$

(4) Transconductance Amplifier (OR) Voltage
Control ~~Voltage~~ Current Source.



$$\therefore I_x = \frac{R_1}{R_1 + R_2 + R_3} I_o.$$

$$\therefore V_{in} = I_x \cdot R_3.$$

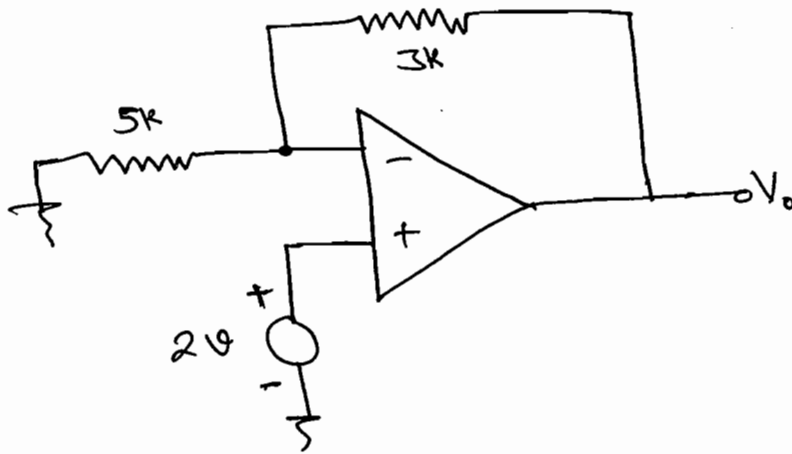
$$\therefore V_{in} = \frac{I_o R_1 R_3}{R_1 + R_2 + R_3}$$

$\therefore$ Transconductance

$$g_m = \frac{R_1 + R_2 + R_3}{R_1 R_3}$$

Ex-1 Find the op Voltage if op-Amp is 17
Consider ideal.

①

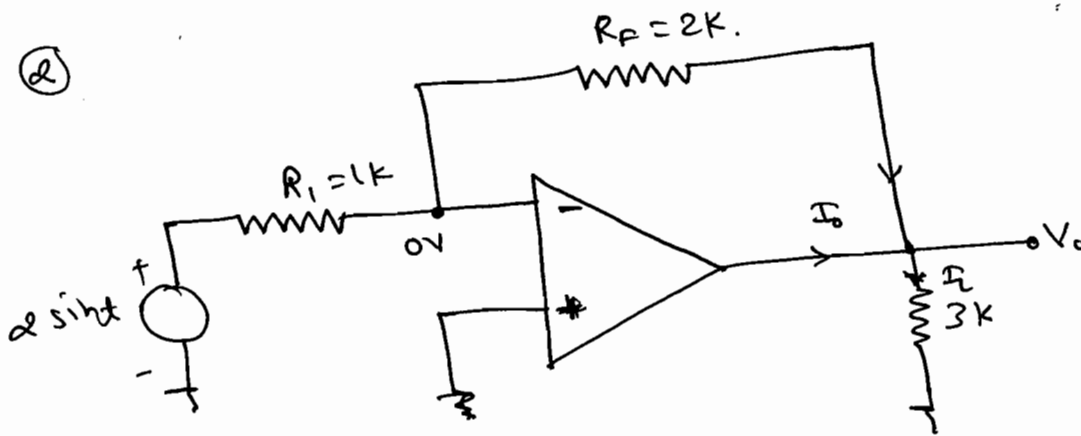


$$\therefore V_o = \left(1 + \frac{R_F}{R_i}\right) V_{in}.$$

$$\therefore V_o = \left(1 + \frac{3}{5}\right) 2V.$$

$$\therefore \boxed{V_o = \frac{16}{5} V}$$

②



$$\therefore V_o = - \frac{R_F}{R_i} \cdot V_{in}.$$

$$\therefore V_o = -4 \sin t.$$

$$\text{KCL } I_o + I_F = I_L.$$

$$\begin{aligned} \therefore I_o &= I_L - I_F \\ &= \frac{V_o}{3} - \frac{[0 \sin t - V_o]}{2k} \\ &= \cancel{\frac{4 \sin t}{3}} + \frac{4 \sin t}{3} \end{aligned}$$

$$\therefore \boxed{I_o = \frac{8 \sin t}{3} A}$$

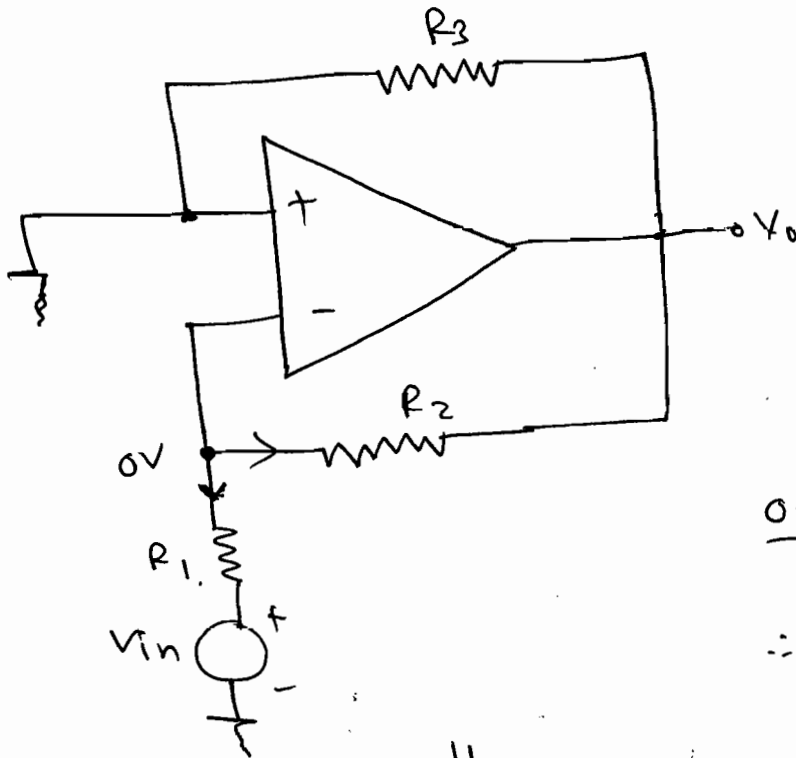
$$I_0 = \frac{V_0}{3k} + \frac{V_0}{2k}$$

$$= \frac{5V_0}{6k}$$

$$I_0 = \frac{5(-4 \sin t)}{18k}$$

$$\therefore \boxed{I_0 = -\frac{10}{3} \sin t \text{ mA}}$$

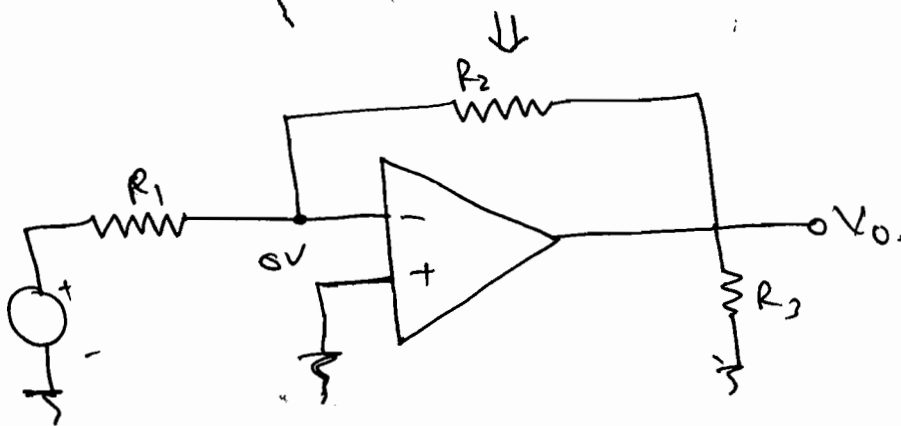
Ex-3



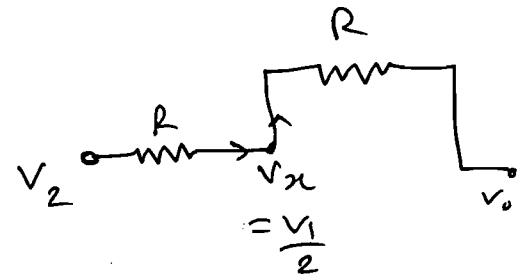
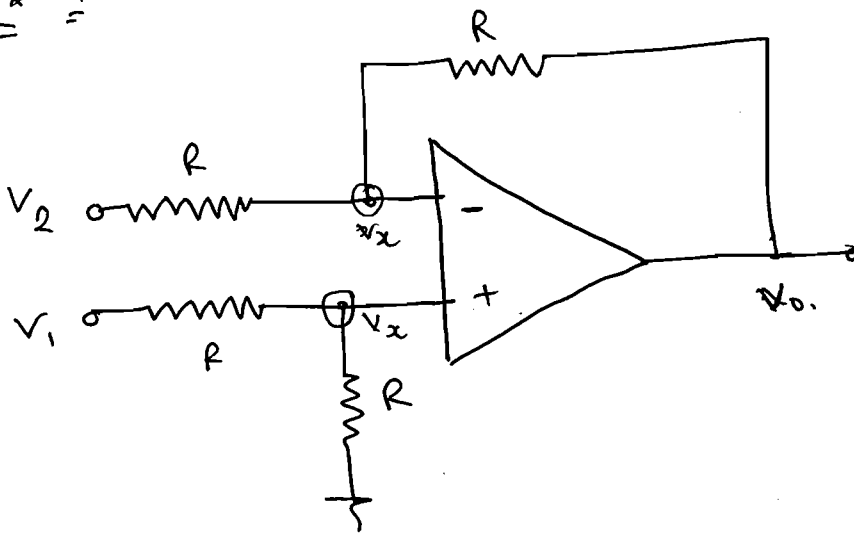
KCL

$$\frac{0 - V_{in}}{R_1} + \frac{0 - V_0}{R_2} = 0$$

$$\therefore \boxed{V_0 = -\left(\frac{R_2}{R_1}\right) V_{in}}$$



$$\therefore V_0 = -\left(\frac{R_2}{R_1}\right) V_{in}$$



→ By superposition theorem

① Let $V_2 = 0$: & V_1 is given.

$$\therefore V_x = \frac{R}{R+R} \cdot V_1$$

$$\therefore V_x = V_1/2$$

$$\therefore V_{o1} = \left(1 + \frac{R}{R}\right) \frac{V_1}{2}$$

$$V_{o1} = V_1$$

② Let $V_2 = V$ and $V_1 = 0$.

$$\therefore V_{o2} = \left(-\frac{R}{R}\right) V_2$$

$$\therefore V_{o2} = -V_2$$

$$\therefore V_o = V_{o1} + V_{o2}$$

$$\therefore \boxed{V_o = V_1 - V_2}$$

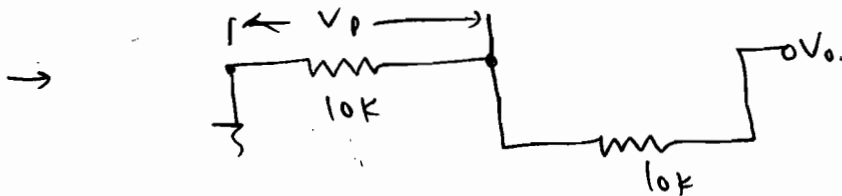
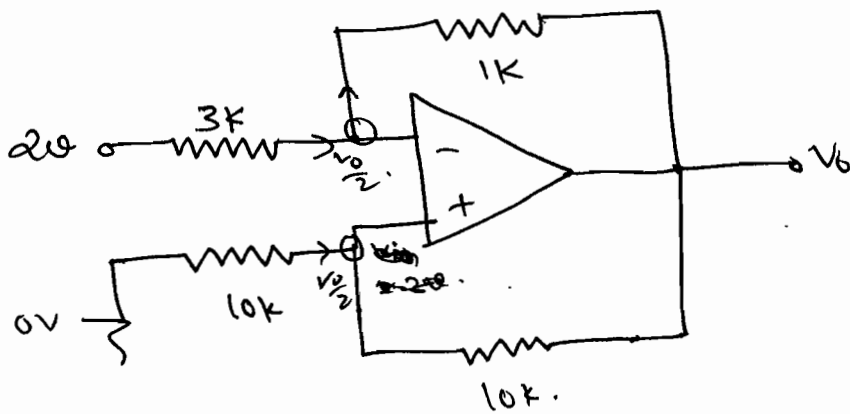
$$\therefore \frac{V_2 - \frac{V_1}{2}}{R} = \frac{\frac{V_1}{2} - V_o}{R}$$

$$\therefore V_2 - V_1 = -V_o$$

$$\therefore \boxed{V_o = V_1 - V_2}$$

Subtractor.

Ex-5



$$\therefore V_p = \frac{V_o}{2}$$

$$\therefore \frac{2 - \frac{V_o}{2}}{3} = \frac{\frac{V_o}{2} - V_o}{1}$$

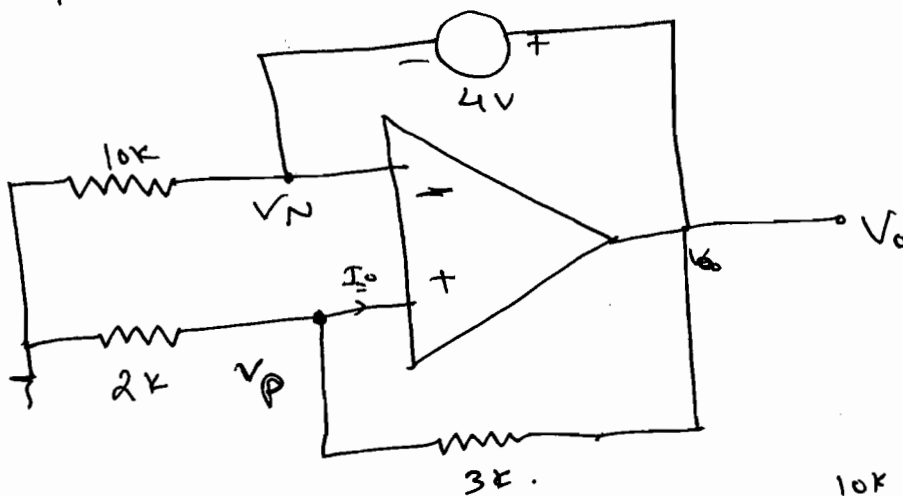
$$\therefore \frac{4 - V_o}{3} = -\frac{V_o}{2}$$

$$\therefore 4 - V_o = -3V_o$$

$$2V_o = -4$$

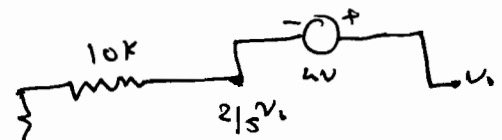
$$\boxed{V_o = -2V}$$

Ex-6 Find V_p , V_n & V_o .



$$\therefore V_p = \frac{2}{5} \times V_o$$

$$\therefore \boxed{V_N = V_p = \frac{2}{5} \times V_o}$$



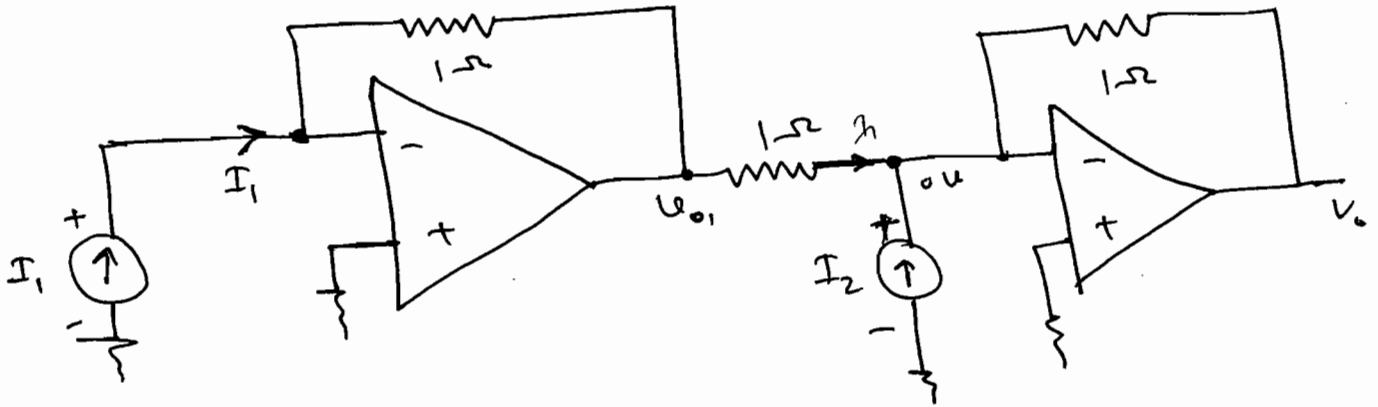
$$\therefore V_o - \frac{2}{5} V_o = 4V$$

$$\therefore \frac{3}{5} V_o = 4$$

$$\boxed{V_o = \frac{20}{3} V}$$

Ex-6 Find V_o in terms I_1 & I_2 .

21



$$\therefore V_{01} = -1(I_1)$$

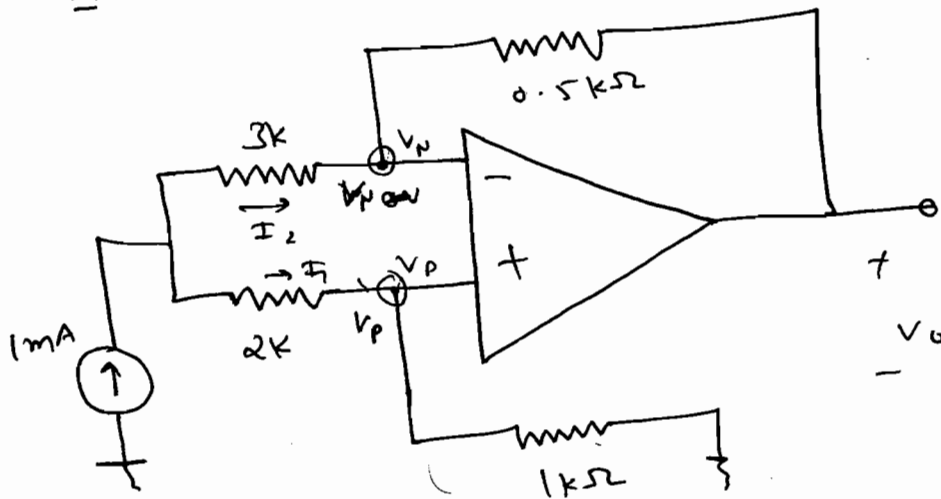
$$\boxed{V_{01} = -I_1}$$

$$\therefore \frac{V_{01} - 0}{1} + I_2 = \frac{0 - V_o}{1}$$

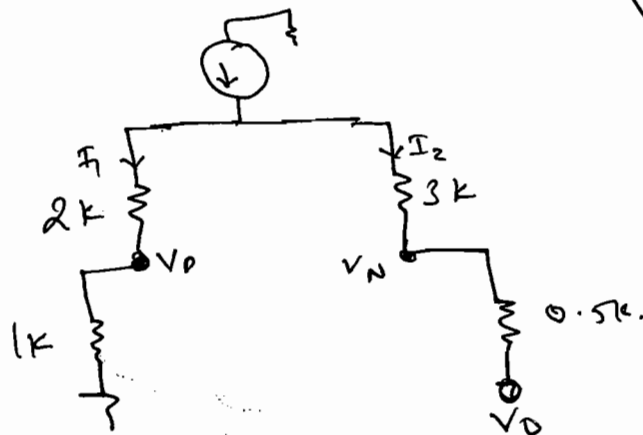
$$\therefore -I_1 + I_2 = -V_o$$

$$\therefore \boxed{V_o = I_2 - I_1}$$

Ex-8



$$V_p = V_n$$



$$I_1 = \frac{1\text{m}(3\text{k})}{2\text{k} + 3\text{k}} = 0.6\text{mA}$$

$$\therefore I_2 = I - I_1$$

$$I_2 = 0.4\text{mA}$$

$$\therefore V_o = I_1 \times 1\text{k}$$

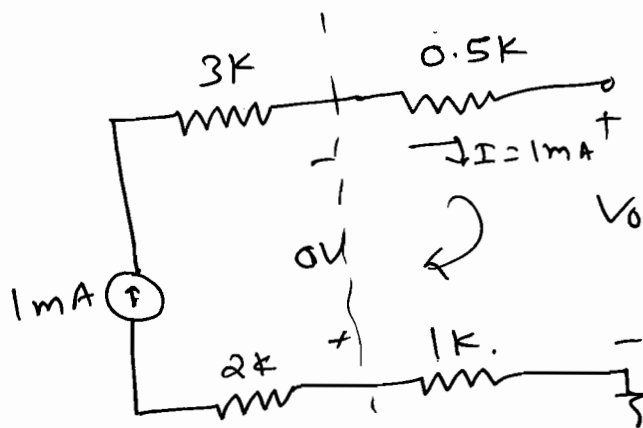
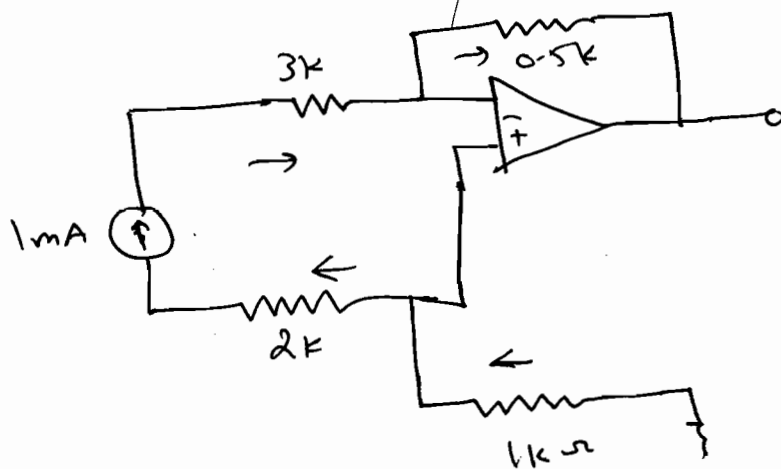
$$V_o = 0.6\text{V}$$

$$\therefore I_2 = \frac{V_i - V_o}{0.5\text{k}}$$

$$\therefore 0.4\text{mA} = \frac{0.6 - V_o}{0.5\text{k}}$$

$$V_o = -0.2 + 0.6$$

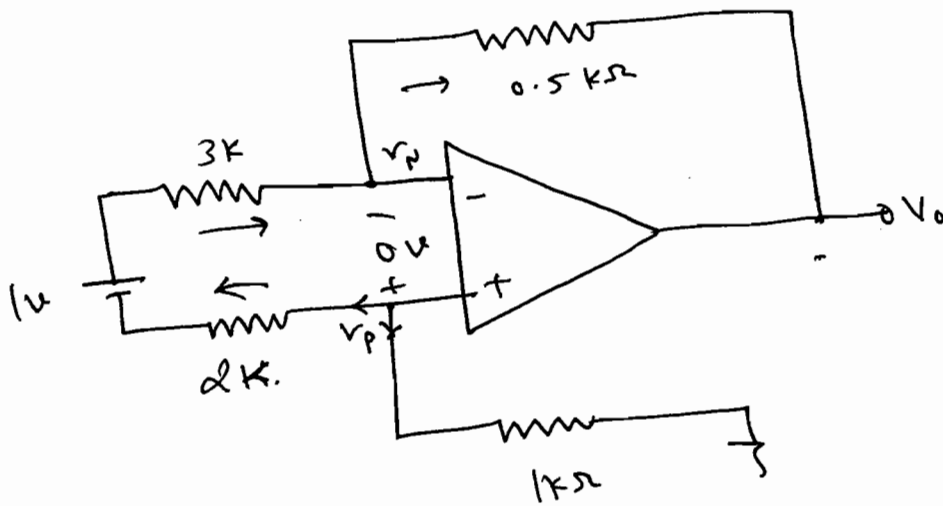
$$V_o = +0.4\text{V}$$



$$0 + I(0.5\text{k}) + V_o + I(1\text{k}) = 0$$

$$\therefore V_o = -I(1.5\text{k})$$

$$V_o = -1.5\text{V}$$



$$V = (3I) - 0.5 \times 1 \times 2I$$

$$-1 + I(3k) = 0 + I(2k) \Rightarrow$$

$$\therefore \boxed{I = 0.2 \text{ mA}}$$

$$\therefore V_p = (-1k)(0.2),$$

$$\therefore \boxed{V_p = -0.2 \text{ V}}$$

$$\therefore \boxed{V_N = -0.2 \text{ V}}$$

$$\therefore I = \frac{V_N - V_o}{0.5k}$$

$$\therefore 0.2 \text{ m} = \frac{-0.2 - V_o}{0.5}$$

$$-0.1 - 0.2 = V_o$$

$$\therefore \boxed{V_o = -0.3 \text{ V}}$$

$$\therefore \boxed{V_o = -0.3 \text{ V}}$$

$$V_p =$$

$$I \oplus V_p \quad I + \frac{V_p}{1k} = 0$$

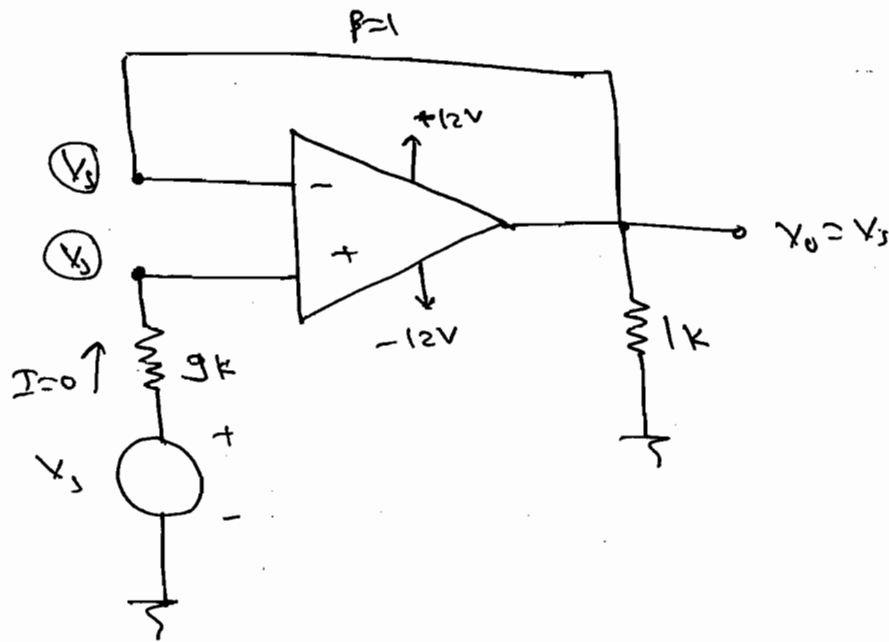
$$V_p = (-I)(1k)$$

$$V_p = (0.2 \text{ m})(-1k)$$

$$\boxed{V_p = -0.2 \text{ V}}$$

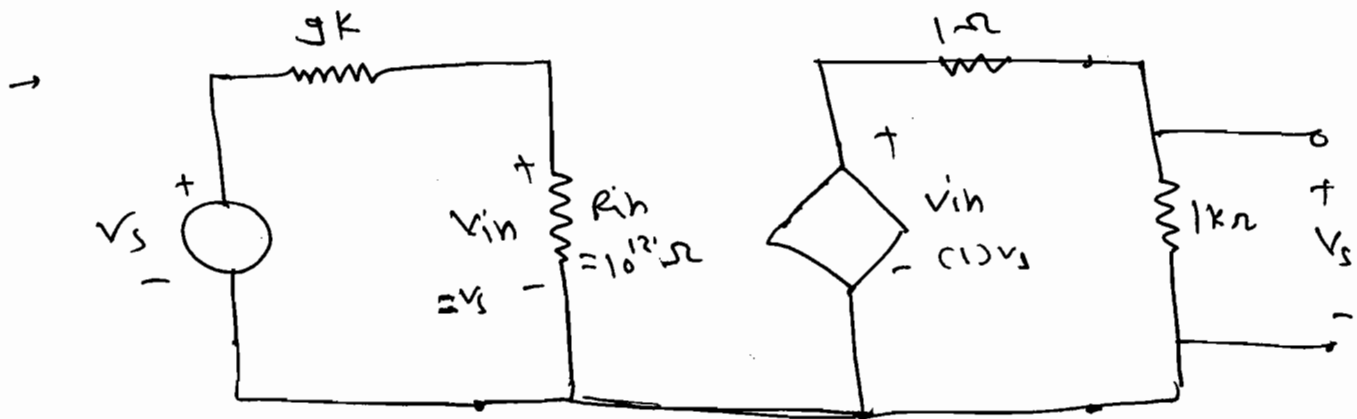
* Buffer (or) Voltage follower (or) Unity gain Amplifier.

→ Impedence matching device is device which connect high impedence source to low impedence Load.



$$\rightarrow A_f = \frac{A}{1+AB} = \frac{10^6}{1+10^6(1)} \approx 1$$

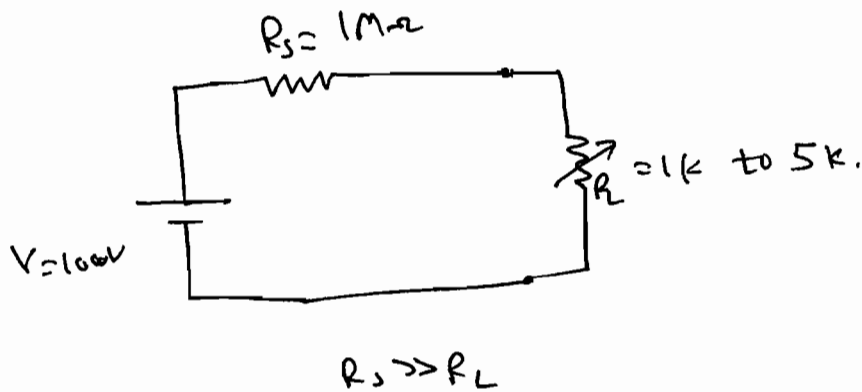
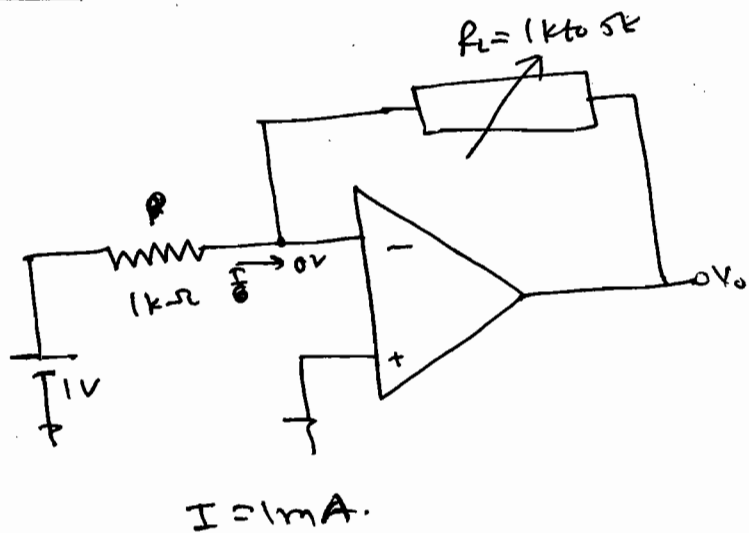
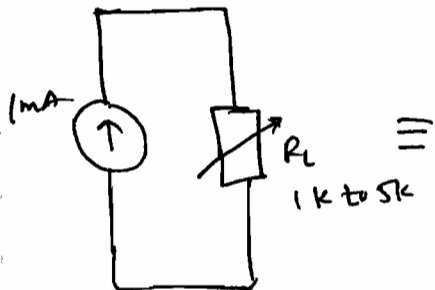
$$\therefore \boxed{A_f = 1}$$



← Impedence matching →

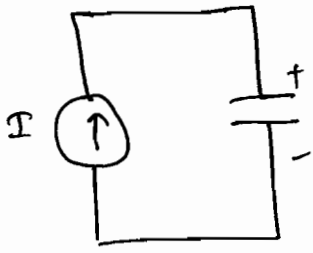
* Voltage Buffer	Current Buffer
High R_{in}	Low R_{in}
Low R_o	High R_o
$A_v \approx 1$	$A_I \approx 1$
High A_I	High A_v
$A_p = A_v A_I$	$A_p = A_v A_I$
$A_p = A_I$	$A_p = A_v$
e.g. Common Collector.	e.g. Common Base.

* Building Current Sources:



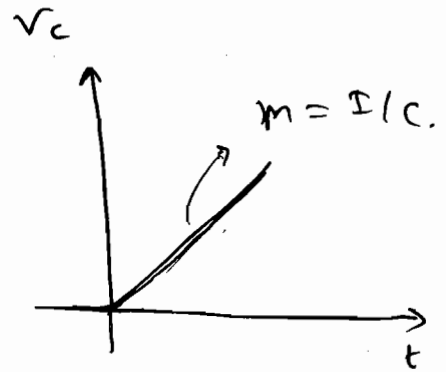
* Miller Integrator:

*



$$V_c = \frac{1}{C} \int I \, dt$$

$$V_c = \left(\frac{I}{C} \right) \int dt$$



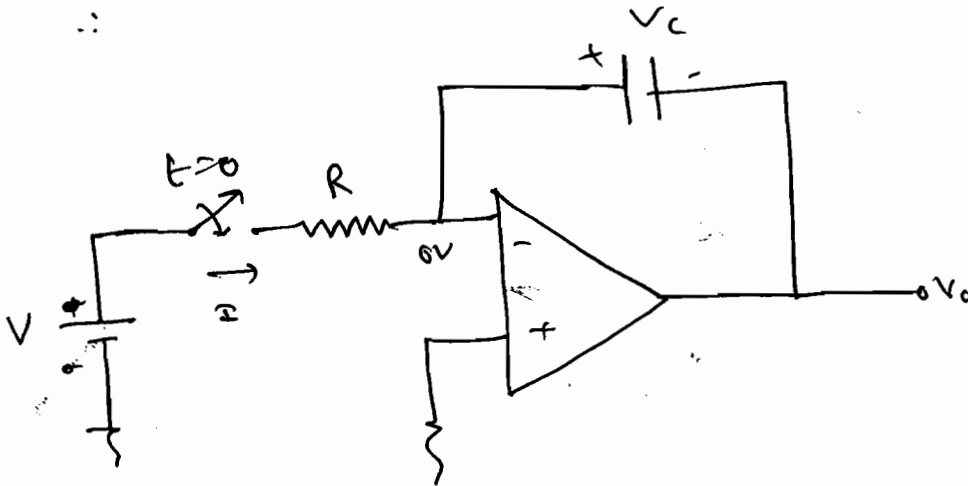
$$V_c = \left(\frac{I}{C} \right) t$$

$$\therefore y = mx + c$$

$\Rightarrow$

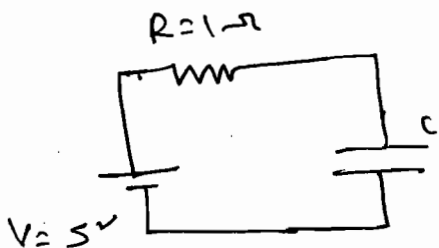
$$y = V_c$$

$$x = t$$

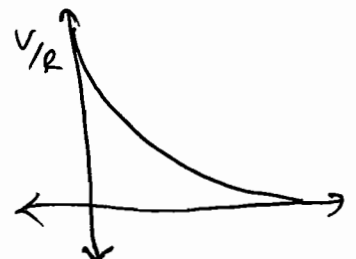


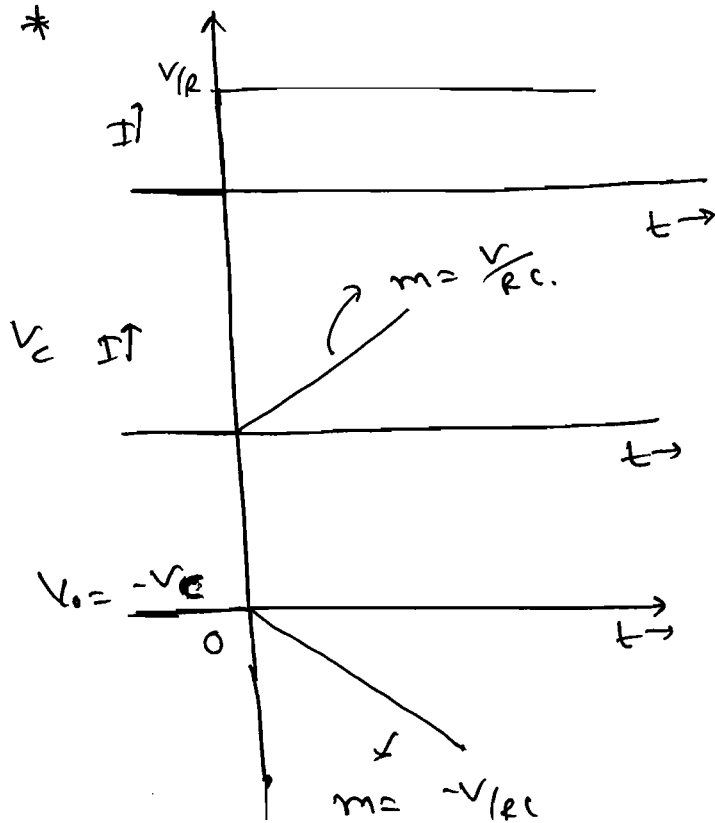
$$I = V/R = \text{const.}$$

$$\therefore V_c = \frac{1}{C} \int I \, dt = \left(\frac{I}{C} \right) t = \left(\frac{V}{RC} \right) t$$



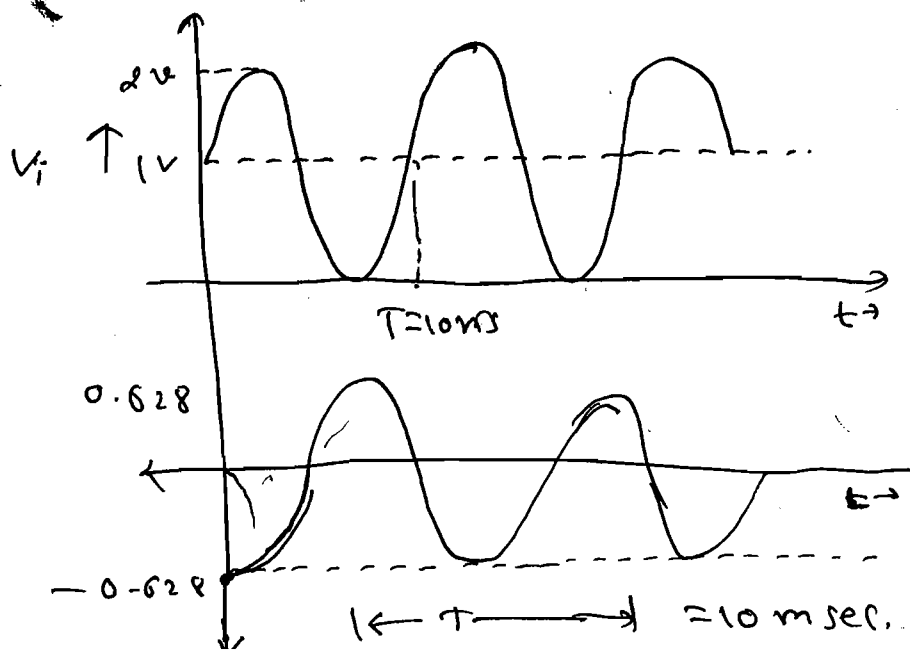
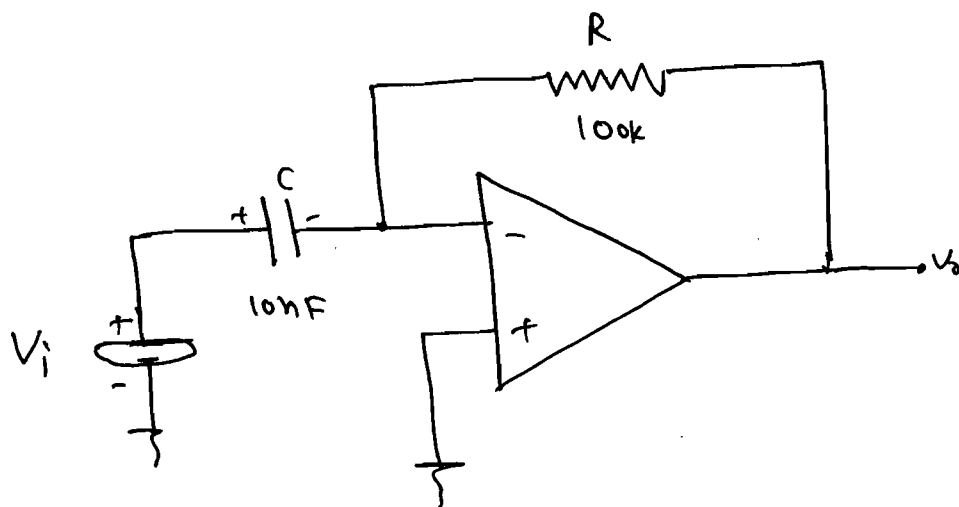
V_c	$I = \frac{5 - V_c}{1}$
0V	5A
1V	4A
3V	2A
5V	0A





* Differentiator:

$\Rightarrow$



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

$$\frac{V_o}{V_{in}} = -\frac{R_F}{(1/s_c)} = -(RC) \frac{dV_i}{dt}$$

$$V_o = -(RC) \frac{dV_i}{dt}$$

$$\therefore V_i = V_{oc} + V_m \sin \omega t$$

$$\therefore V_i = 1 + 1 \sin \frac{2\pi}{T} t$$

$$V_i = 1 + \sin \frac{2\pi}{1\text{ms}} t.$$

$$\boxed{V_i = 1 + \sin 200\pi t}$$

$$\therefore V_o = (-RC) \cdot \frac{dV_i}{dt}$$

$$= (-100 \times 10^{-8}) \times \cos 200\pi t (200\pi)$$

$$\therefore V_o = -0.628 \cos 200\pi t.$$

$$t=0$$

$$\therefore V_o = -0.628.$$

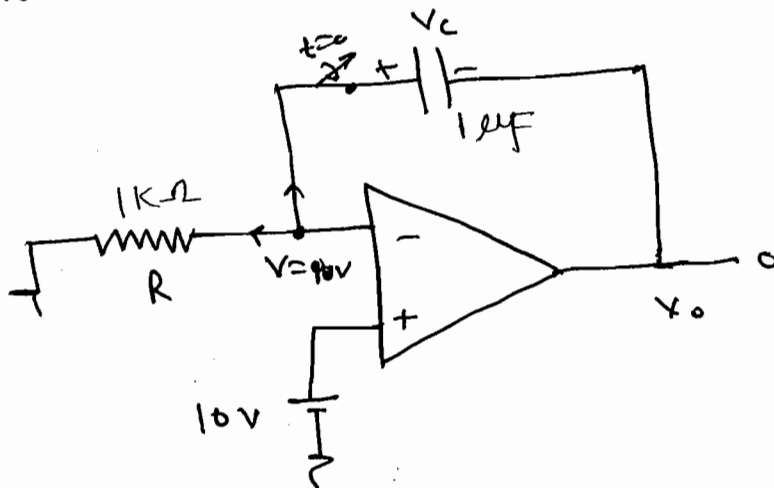
$$\therefore 2\pi \times T = 200\pi$$

$$2T = 200$$

$$\therefore T = 10^2$$

$$\boxed{T = 10\text{ms.}}$$

Ex-1 Find the Capacitor Voltage at $t = 0.5\text{ms}$ if Switched is closed at $t = 0$. Assume Capacitor initially uncharged.



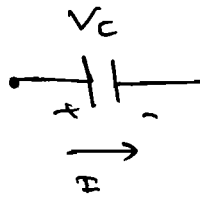
$$\therefore \frac{V_c > 0}{k} \Rightarrow V_c \rightarrow V_c$$

$$\therefore V_c = V_0 = 0.$$

$$\therefore 10 = V_c = V_0 = 0.$$

$$\therefore$$

$$\therefore I = \frac{0 - 10}{1k}$$



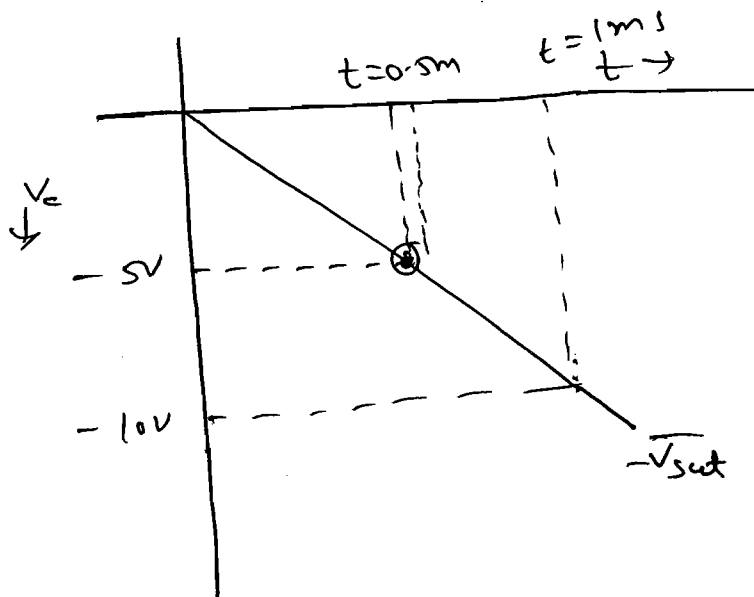
$$\therefore \boxed{I = -10mA}$$

$$\therefore V_c = \frac{1}{C} \int_0^{0.5} I dt$$

$$= \frac{-10 \times 10^{-3}}{1 \times 10^{-6}} \times [t]_0^{0.5ms}$$

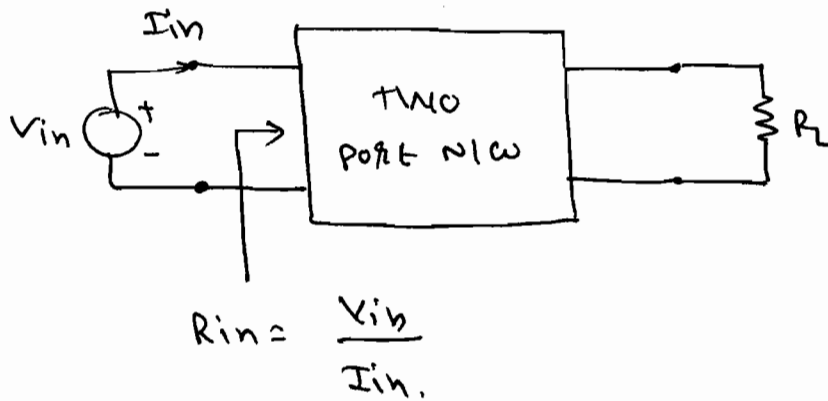
$$\therefore V_c = -5V.$$

$$\therefore \boxed{V_c = -5V}$$

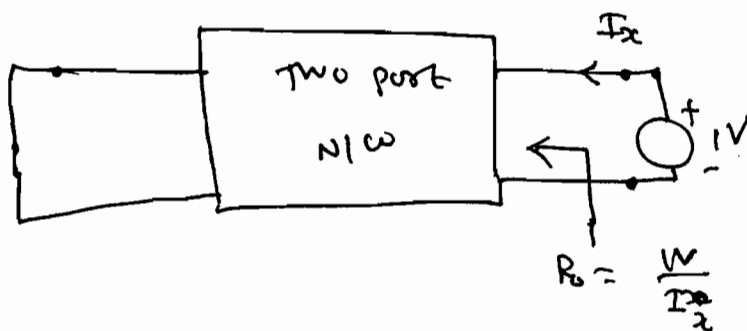


* Input and output Resistance of an amplifier using op-amp.

① Input Resistance:



② Output Resistance:



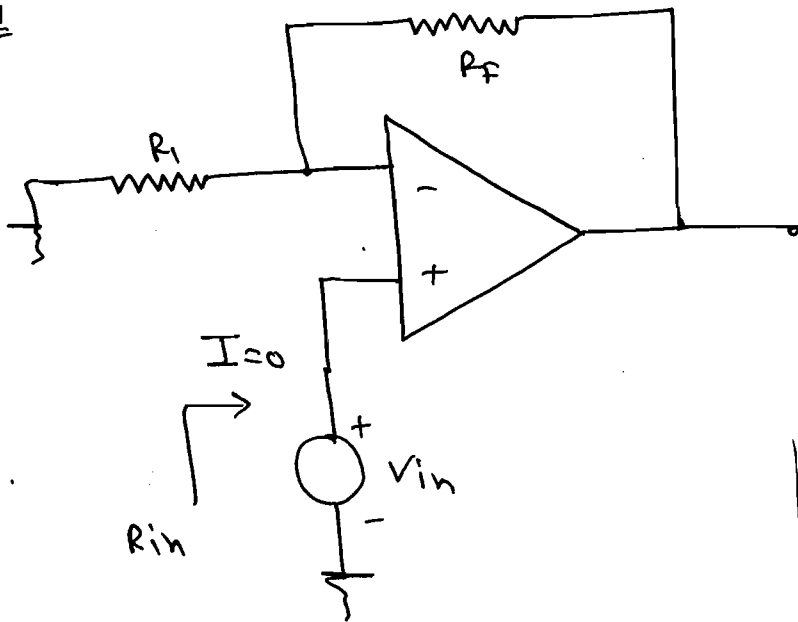
① OC R_L

② SC V_{in}

③ Connect $1V$ source to o/p terminals

$$R_o = \frac{1V}{I_{sc}}$$

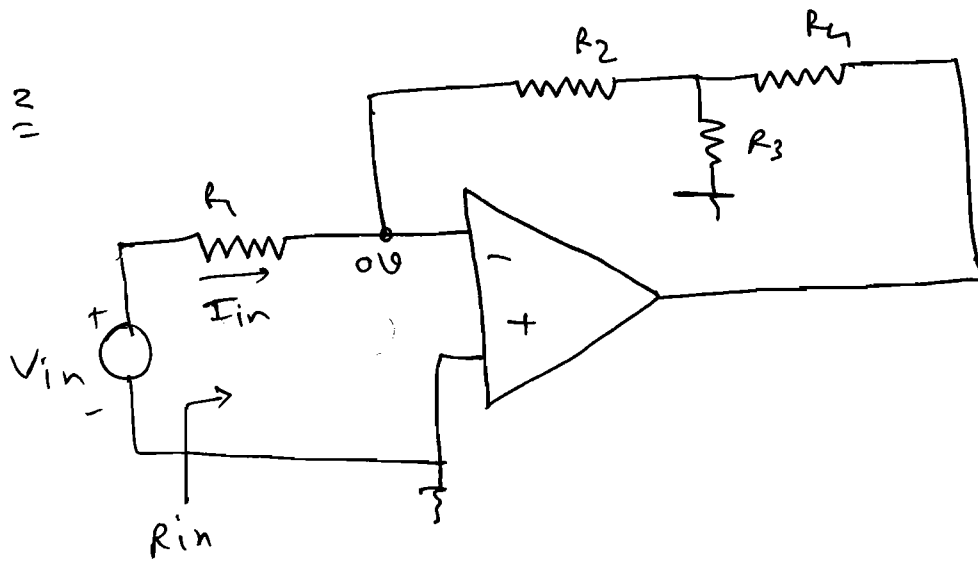
*
= Ex-1
=



$$\therefore R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{0}$$

$$\therefore \boxed{R_{in} = \infty}$$

Ex-2
=

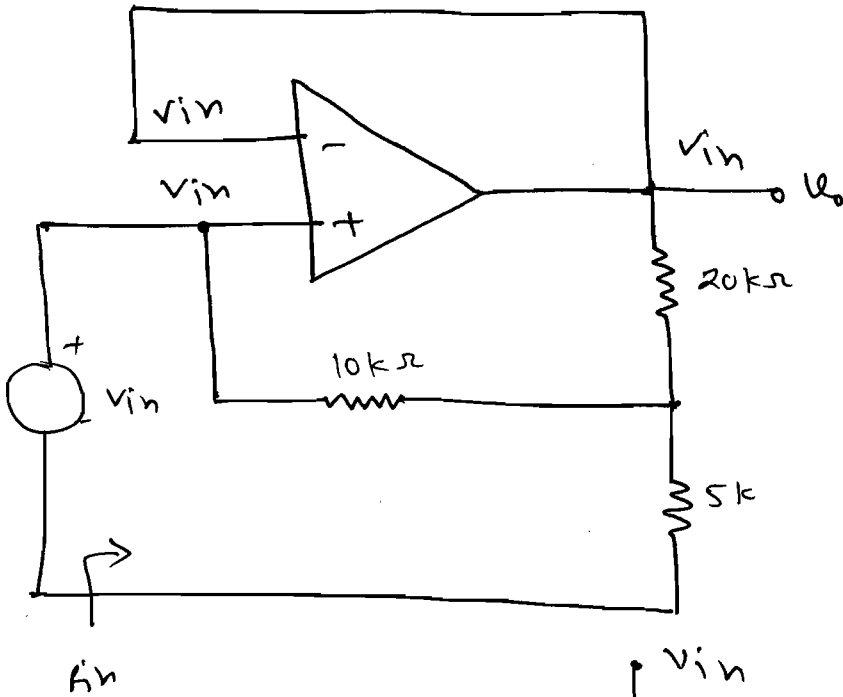


$$I_{in} = \frac{V_{in} - 0}{R_1}$$

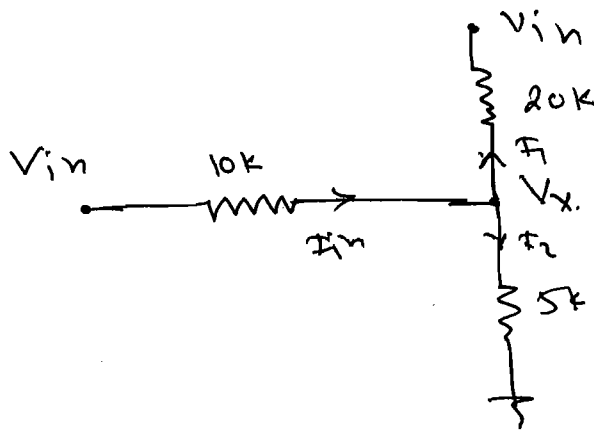
$$\therefore R_{in} = \frac{V_{in}}{I_{in}}$$

$$\therefore \boxed{R_{in} = R_1}$$

Ex-3



Ans:



By KCL

$$\therefore I_{in} = I_1 + I_2$$

$$\therefore \frac{V_{in} - V_x}{10} = \frac{V_x - V_{in}}{20} + \frac{V_x}{5}$$

$$\therefore 2(V_{in} - V_x) = V_x - V_{in} + 4V_x$$

$$\therefore 7V_x = 3V_{in}$$

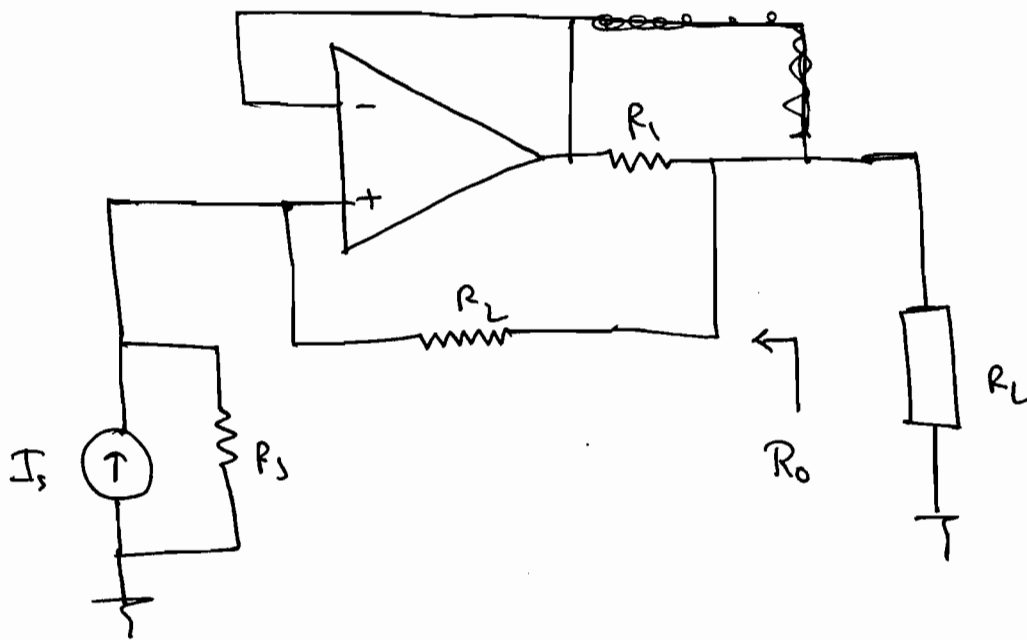
$$\therefore \boxed{V_x = \frac{3V_{in}}{7}}$$

Now, $I_{in} = \frac{V_{in} - V_x}{10}$

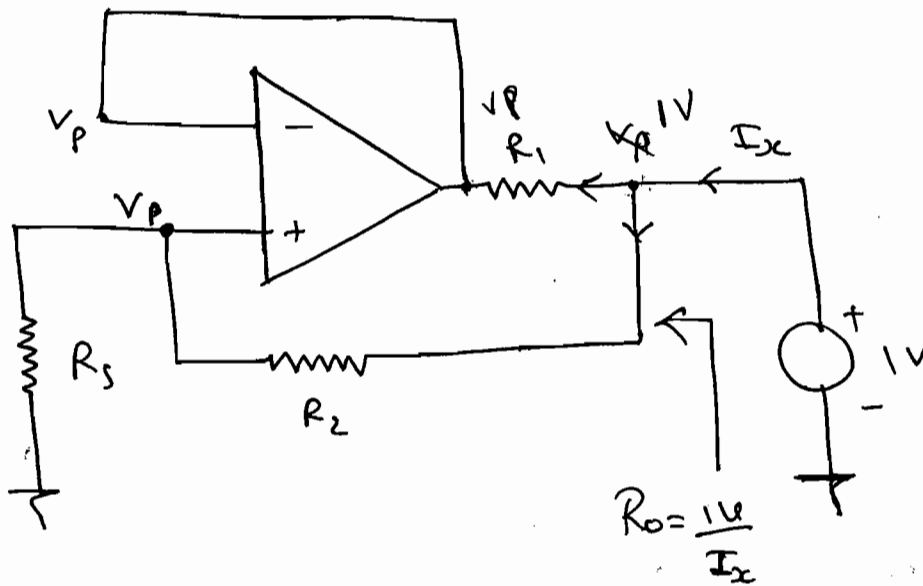
$$\therefore I_{in} = \frac{V_{in} - \frac{3}{7}V_{in}}{10}$$

$$\therefore I_{in} = \frac{4}{70} V_{in}$$

$$\therefore R_{in} = \frac{V_{in}}{I_{in}} = \frac{70}{4} \text{ k}\Omega$$



|||



$$\rightarrow V_p = \frac{R_s (1)}{R_s + R_2} \Rightarrow 1 - V_p = \frac{R_2}{R_2 + R_1}$$

$$I_x = \frac{1 - V_p}{R_1} + \frac{1 - V_p}{R_2}$$

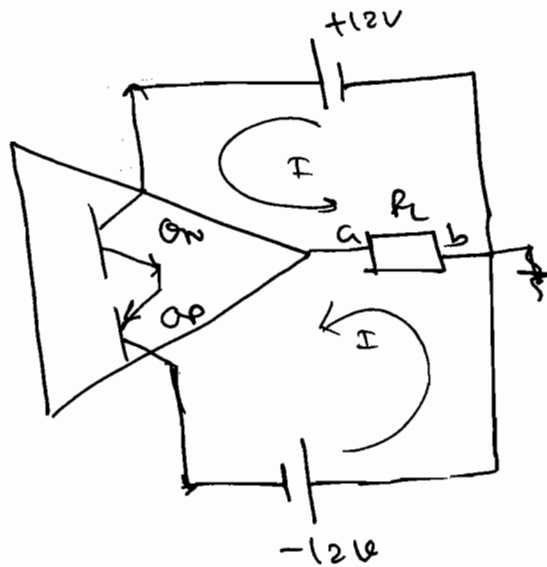
$$\therefore I_x = (1 - V_p) \left[\frac{1}{R_1} + \frac{1}{R_2} \right]$$

$$\therefore I_x = \left[\frac{R_2}{R_2 + R_s} \right] \left[\frac{R_1 + R_2}{R_1 R_2} \right]$$

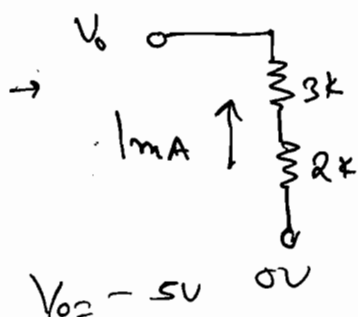
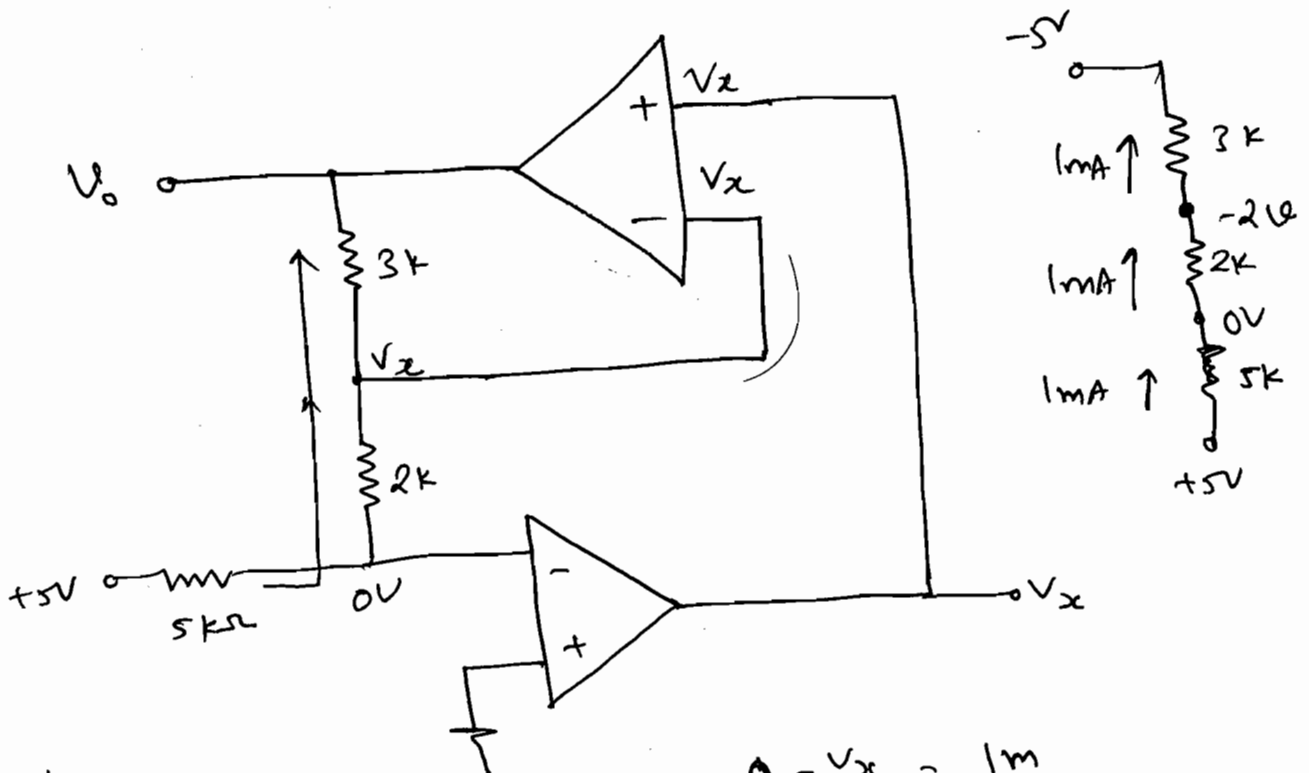
$$\therefore R_o = \frac{1}{I_{sc}}$$

$$R_o = \frac{R_2 + R_3}{1 + \frac{R_2}{R_1}}$$

*



*

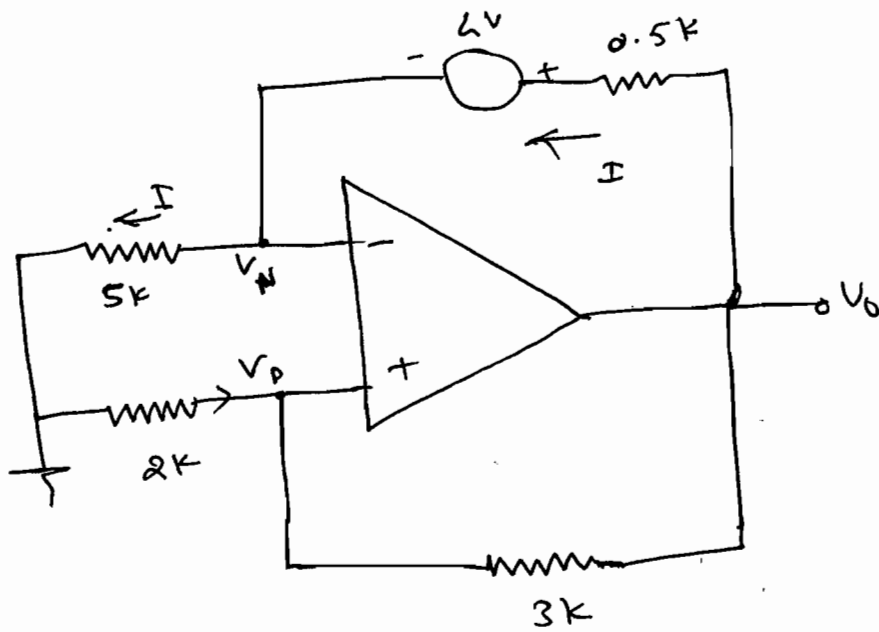


$$\therefore \frac{0 - V_x}{2k} = 1m$$

$$\therefore \boxed{V_x = -2V}$$

Ex-2

35



$$\rightarrow V_P = \frac{2}{5} V_O.$$

$$V_N = V_P = \frac{2}{5} V_O.$$

$$\therefore \frac{0 - V_N}{5} = \frac{V_N + 4 - V_O}{0.5}.$$

$$\therefore -\frac{2V_O}{25} = 2\left(\frac{2}{5}V_O + 4 - V_O\right).$$

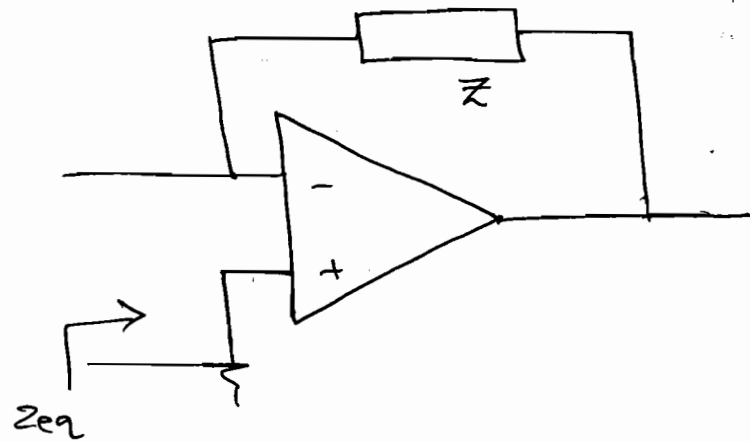
$$\therefore -\frac{V_O}{255} = \frac{2V_O + 20 - 25V_O}{5}$$

$$\therefore -V_O = 10V_O + 100 - 25V_O.$$

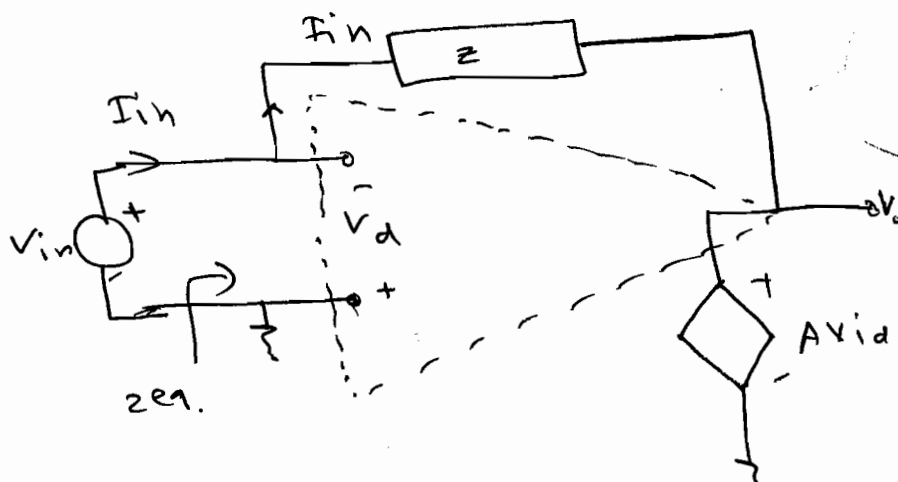
$$\therefore 14V_O = 100$$

$$\therefore \boxed{V_O = \frac{50}{7} \text{ V.}}$$

* Miller's effect:



|||



$$\rightarrow V_{in} - Z I_{in} - A_{vid} V_d = 0$$

$$\therefore I_{in} = \frac{V_{in} - A_{vid} V_d}{Z}$$

But, $-V_{id} - V_d = 0$
 $\therefore V_d = V_{in}$

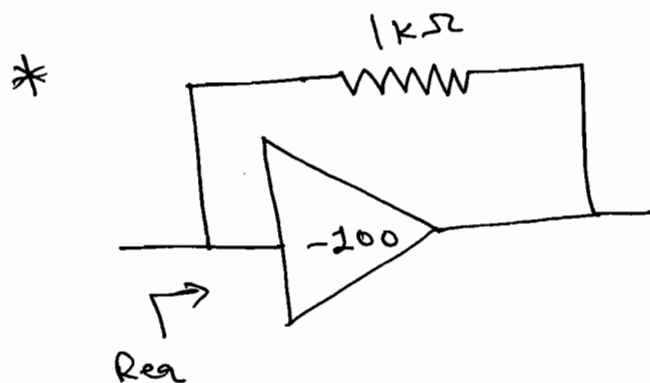
$$\therefore I_{in} = \frac{V_{in} + A_{vid} V_{in}}{Z}$$

$$\therefore Z_{eq} = \frac{V_{in}}{I_{in}} = \frac{Z}{1+A}$$

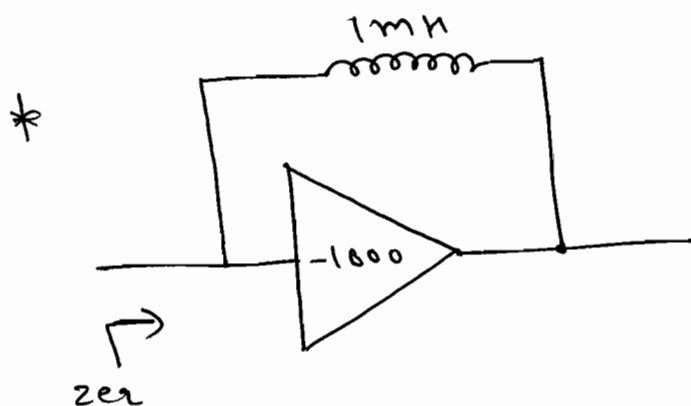
NOTE: Miller's effect is seen only for $\therefore$ 37
inverting amplifier.

e.g. / CE amplifier suppress form Miller's effect.

- There is no Miller's effect for CB and CC amplifier.



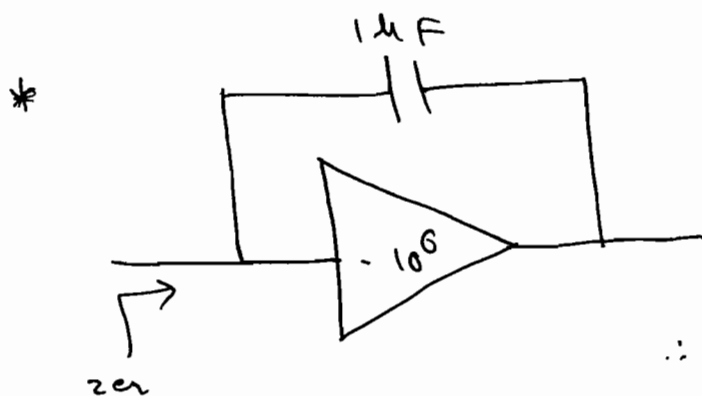
$$\therefore Z_{ea} = \frac{Z}{1+A} = \frac{1k}{1+200} = \frac{1000}{201} \approx 10\Omega$$



$$\therefore Z_{ea} = \frac{Z}{1+A} = \frac{j\omega L}{1+1000} = \frac{SL}{1+1000}$$

$$\therefore S L_{ea} = \frac{SL}{1+1000}$$

$$\therefore L_{ea} = \frac{1000}{1+1000} = 1mH$$



$$Z_{ea} = \frac{Z}{1+A}$$

$$\therefore \frac{1}{SC_{ea}} = \frac{1}{SC_{ea}} = \frac{1}{SC_{ea}}$$

$$\therefore C_{ea} = \frac{C(1+A)}{1}$$

$$\therefore C_{ea} = \frac{10^{-6}}{10^6}$$

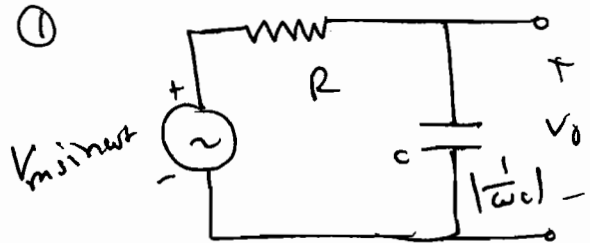
$$C_{ea} = 10^{-12} F$$

$$C_{ea} = 1pF$$

$$\therefore C_{ea} = (1+A)C$$

Miller's multiplication

①



$$\tau = RC$$

$$\tau = R_m C$$

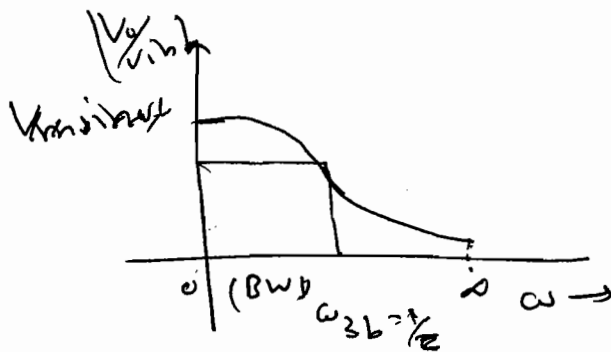
$$\therefore \left| \frac{1}{2\pi f RC} \right|$$

as $f \rightarrow \text{high}$ $\left| \frac{1}{2\pi f RC} \right| \rightarrow 0$ so S.C.

$$\text{So, } V_o = 0.$$

$f \rightarrow \text{Low}$ $\left| \frac{1}{2\pi f RC} \right| \rightarrow \infty$ so O.C.

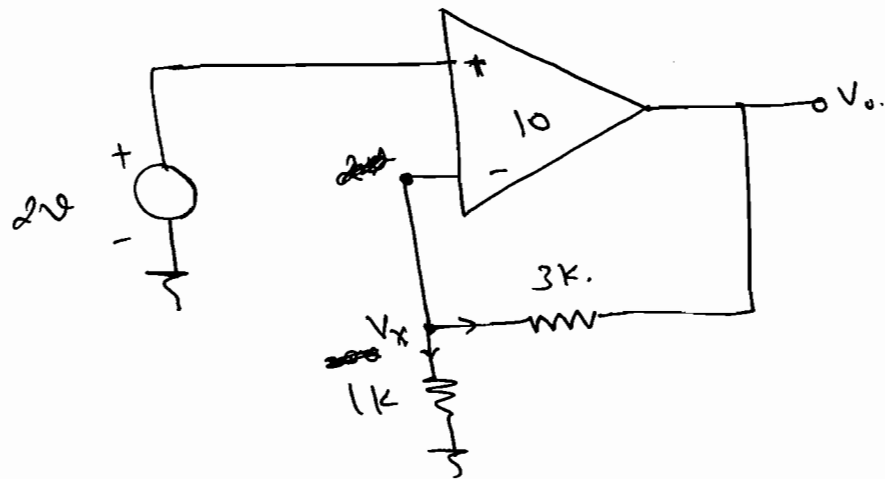
$$\therefore \text{So, } V_o = \sin wt.$$



$$\therefore BW = \frac{1}{\tau} = \frac{1}{RC}$$

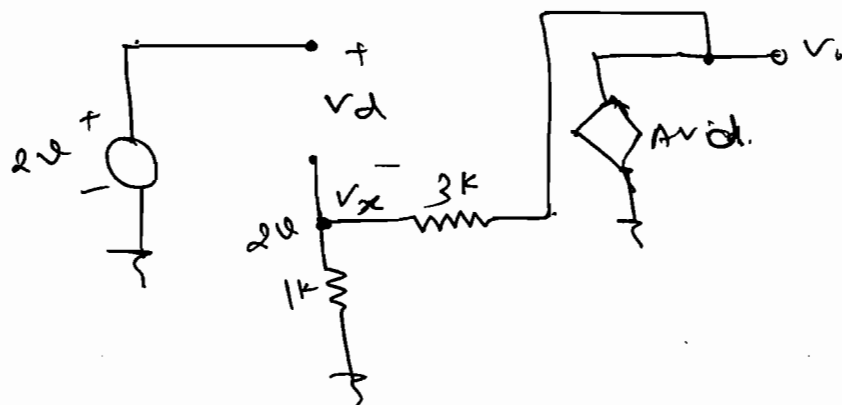
$$\therefore C_{eq} \uparrow \Rightarrow \tau \uparrow \Rightarrow BW \downarrow$$

Ex-1



$A_{OL} = 10$ find $V_o = ?$

III



$$\therefore V_x = V_o \left(\frac{1}{4} \right).$$

$$\therefore V_o = 10V_d.$$

$$\text{and } V_d = 2 - V_x$$

$$\therefore V_d = 2 - \left(\frac{V_o}{4} \right).$$

$$\therefore V_o = 20 - \frac{5V_o}{2}.$$

$$\therefore \frac{7V_o}{2} = 20$$

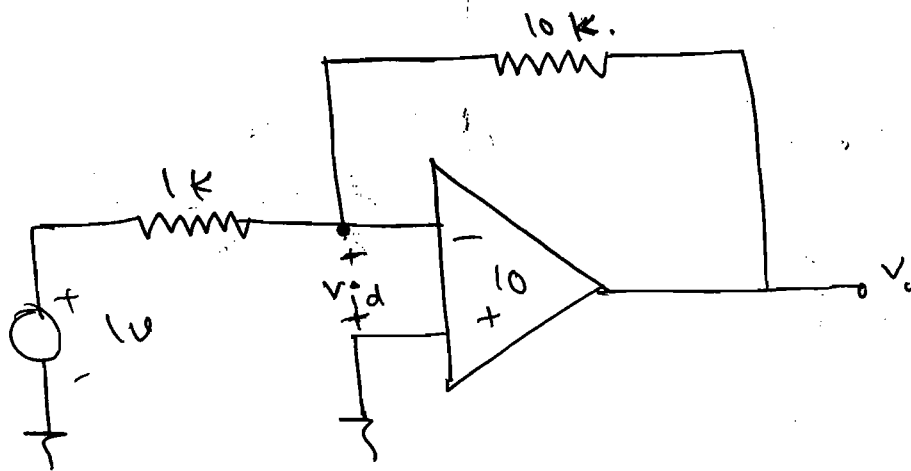
$$\therefore \boxed{V_o = \frac{40}{7} \text{ V}}$$

$$\therefore A_v = \frac{V_o}{2V}.$$

$$\therefore \boxed{A_v = \frac{20}{7}}, A_{OL} = 10.$$

Ex 2

Find V_o . $A_{OL} = 10$.



$$\frac{1 + V_{id}}{1k} = \frac{-V_{id} - V_o}{10k}$$

$$\therefore V_o = A_{OL} V_{id}$$

$$\therefore V_o = 10 V_{id}$$

$$\therefore \frac{1 + \frac{V_o}{10}}{1k} = \frac{-\frac{V_o}{10} - V_o}{10}$$

$$\therefore 10 + V_o = \frac{-V_o - 10V_o}{10}$$

$$\therefore 100 + 10V_o = -V_o - 10V_o$$

$$V_o = 100V$$

$$100 + V_o = -V_o - 10V_o$$

$$\boxed{V_o = -10}$$

$$\therefore 100 + 10V_o = -V_o - 10V_o$$

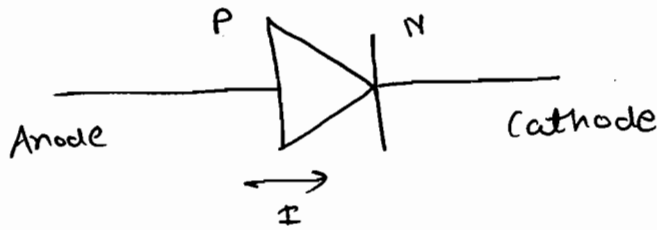
$$\frac{100}{21} = -V_o$$

$$\boxed{V_o = -4.76V}$$

$$21 \overline{) 100} \\ \underline{84} \\ 160 \\ \underline{147} \\ 130$$

★ Diode Applications:

41



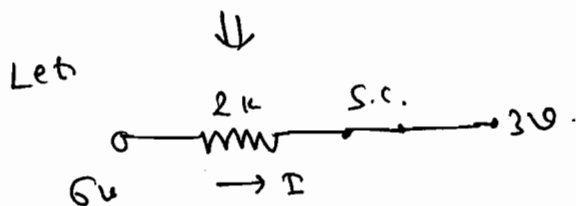
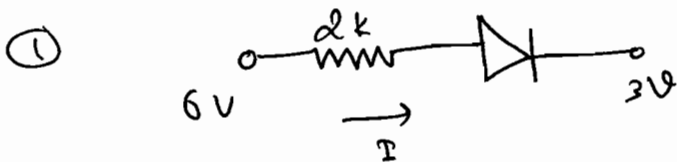
→ A diode is forward bias when anode is more +ve than cathode.



piece-wise
Linear model.

if $I = +ve \rightarrow$ F.B.
 $I = -ve \rightarrow$ R.B.
 But I never $-ve$ so
 $I = 0 \Rightarrow$ R.B.

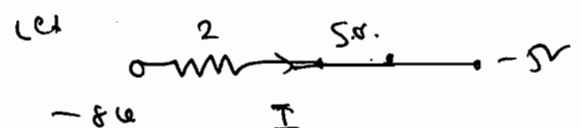
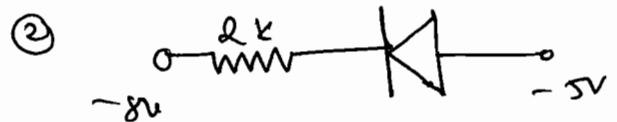
Ex -1 Check whether Diode is F.B. or not.
 also find the value of current flow:



$$I = \frac{6-3}{2}$$

$$I = 1.5 \text{ mA}$$

so, **F.B.**



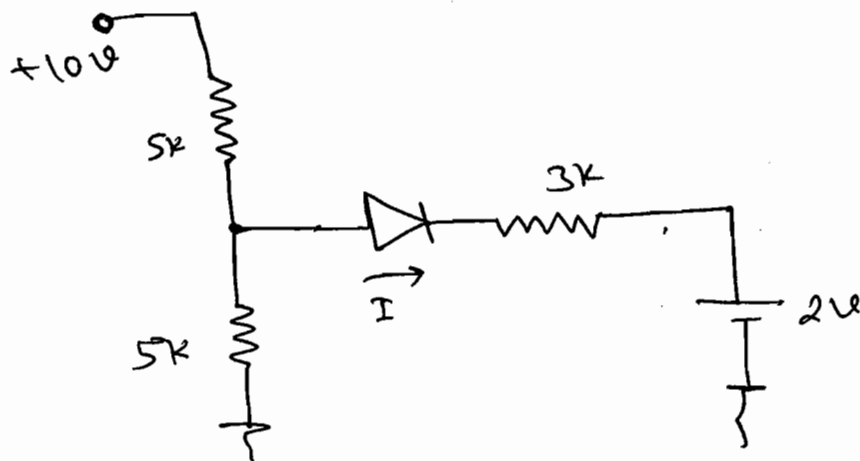
$$I = \frac{-8 - (-5)}{2}$$

$$I = -1.5 \text{ mA}$$

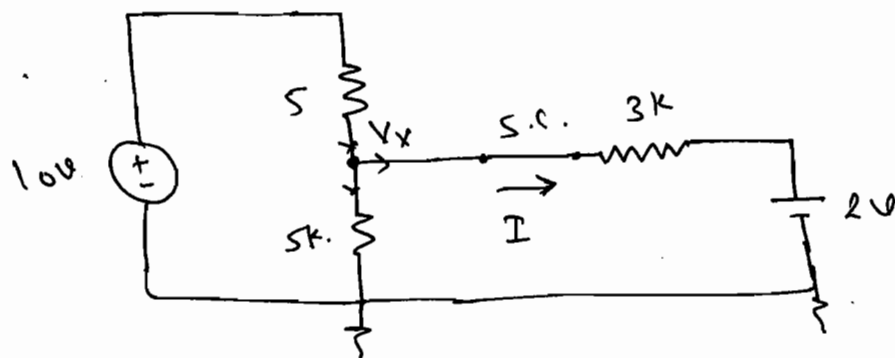
so, **R.B.**

and **~~I = 0~~**

Ex-3



↓



$$\therefore \frac{10 - V_x}{5} = \frac{V_x}{5} + \frac{V_x - 2}{3}$$

$$\therefore 2 - \frac{V_x}{5} = \frac{V_x}{5} + \frac{V_x}{3} - \frac{2}{3}$$

$$2 + \frac{2}{3} = \frac{2V_x}{5} + \frac{V_x}{3}$$

$$\therefore \frac{8}{3} = \frac{5V_x + 5V_x}{15}$$

$$\boxed{V_x = \frac{40}{11} = V_x}$$

$$\therefore I = \frac{V_x - 2}{3k}$$

$$\therefore I = \frac{\frac{40}{11} - 2}{3k}$$

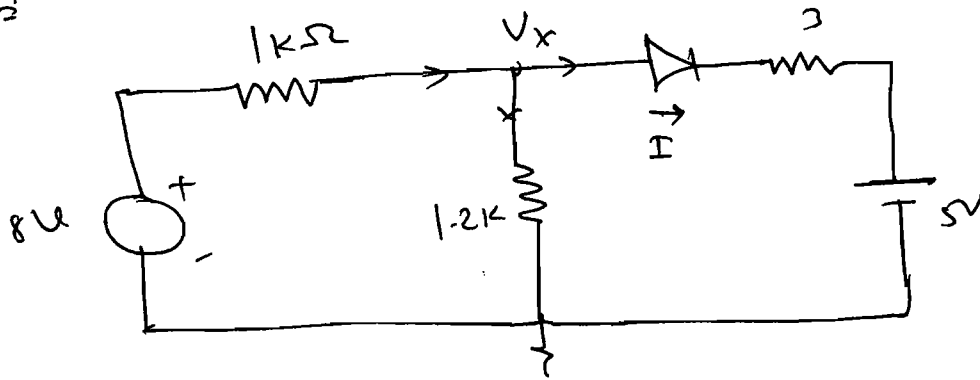
$$I = \frac{18}{3}$$

$$\therefore \boxed{I = \frac{6}{11} \text{ mA}}$$

S, A.B.

Ex 4

43



$$\rightarrow \frac{8 - V_x}{1} = \frac{V_x}{1.2} + I \cdot \frac{V_x - 5}{3}$$

$$\therefore 8 - V_x = \frac{5V_x}{6} + \frac{V_x}{3} - 5/3$$

$$\therefore 8 + \frac{5}{3} = \frac{7V_x}{6} + V_x$$

$$= \frac{29}{3} = \frac{13V_x}{6}$$

$$\therefore \boxed{\frac{58}{13} = V_x}$$

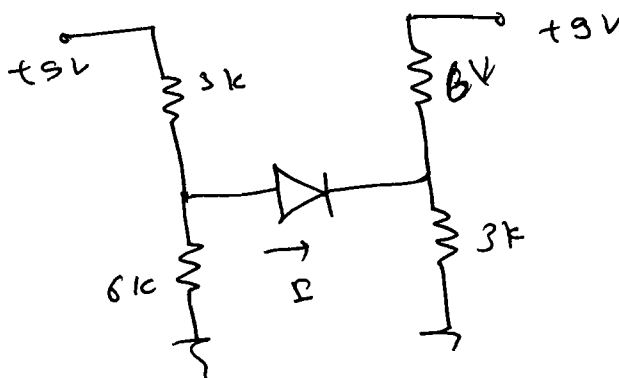
$$\therefore I = \frac{V_x - 5}{3k}$$

$$\therefore I = \frac{\frac{58}{13} - 5}{3k}$$

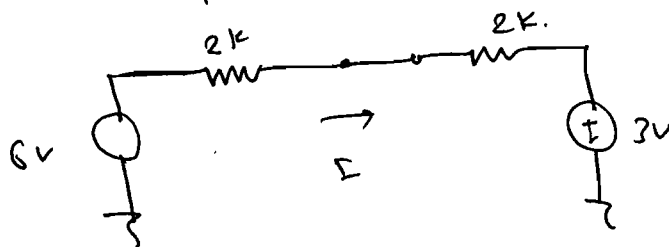
$$\therefore \boxed{I = \frac{-7}{39} \text{ mA}}$$

So, R.B. $\boxed{I = 0}$

Ex 5



=

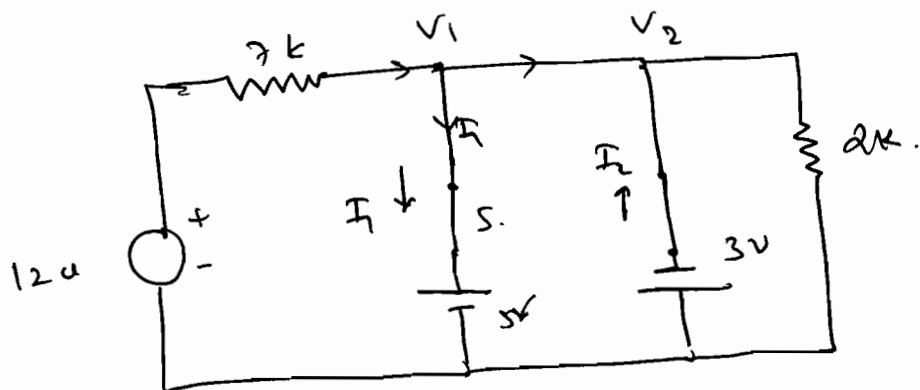
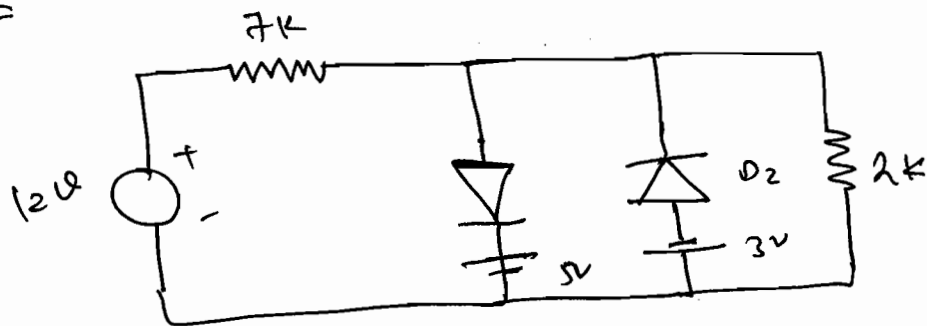


$$I = \frac{6-3}{4}$$

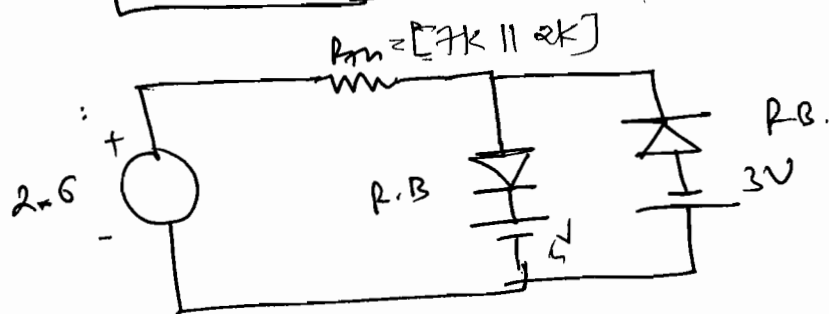
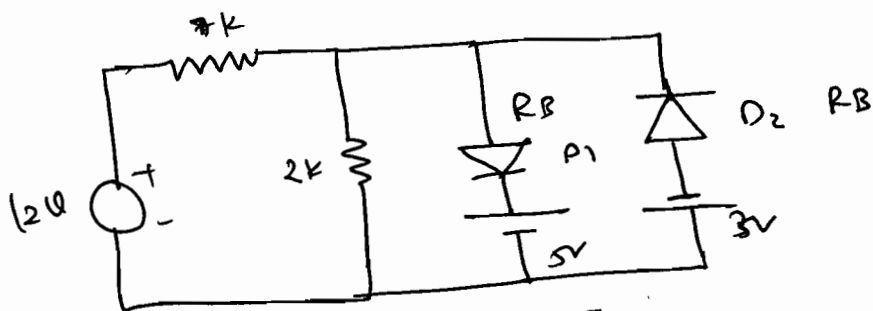
$$I = 3/4$$

$$I = 0.75 \text{ mA}$$

Ex 2

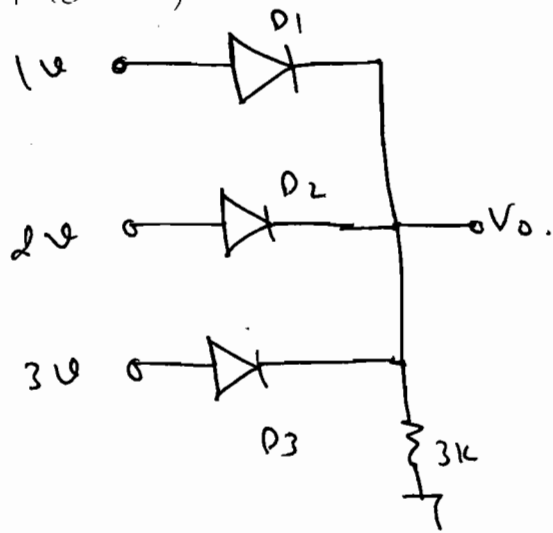


→ $\frac{V_2 - V_1}{A} = \frac{V_1 - 5}{I_1}$



Both are R.B.

Ex-1 Find V_o , Diode is ideal

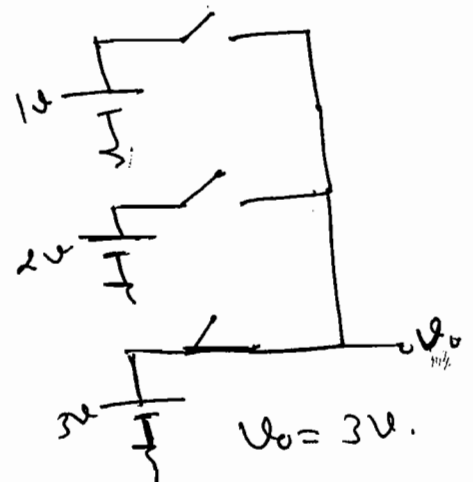
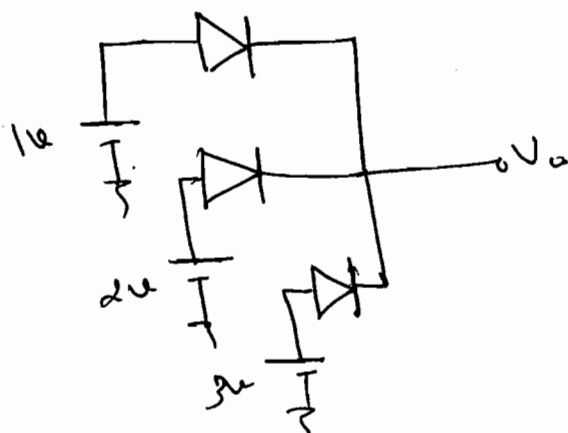


45

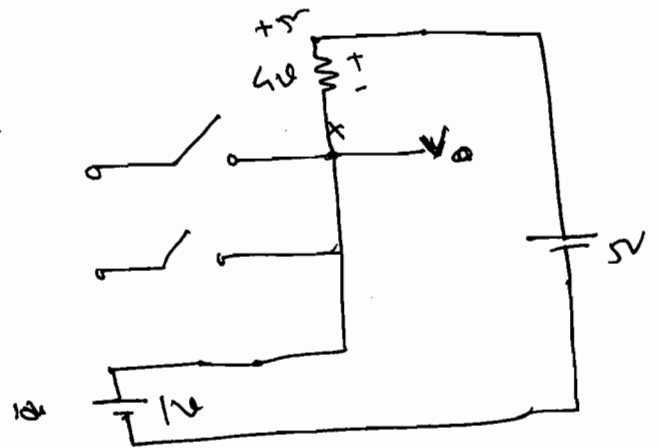
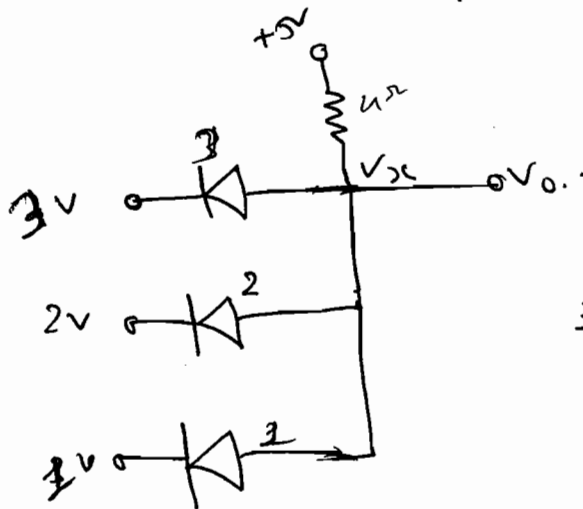
$$I_a = I_s e^{V_o / V_T} \quad \text{Exp operation}$$

$$V_o = V_T \ln \left[\frac{I_o}{I_s} \right] \quad \text{Log operation}$$

→ ① $V_o =$

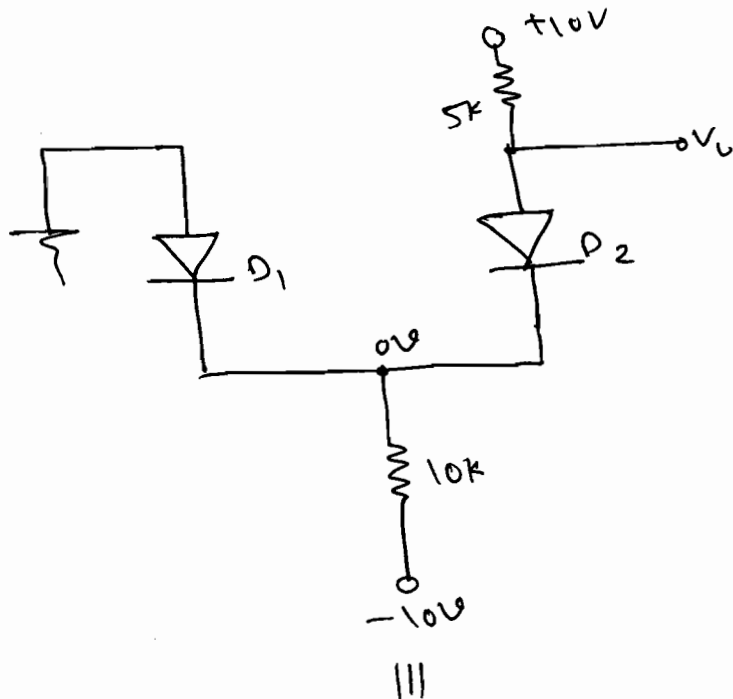


Ex-2

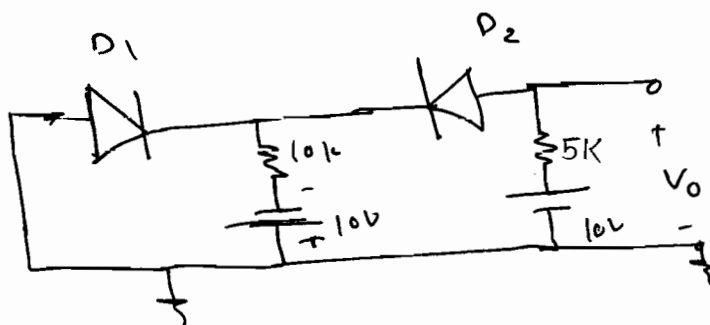


→ 3V Diode experiences more potential difference
 so, it is on and D_2 D_3 is off.
 and $V_o = 3V$.

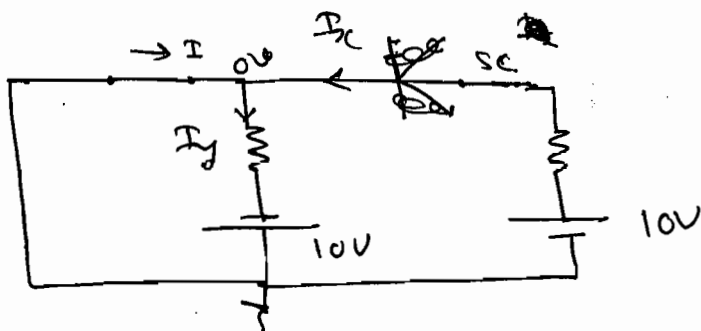
Ex-2



⇒



Ans: Let Test - D_1

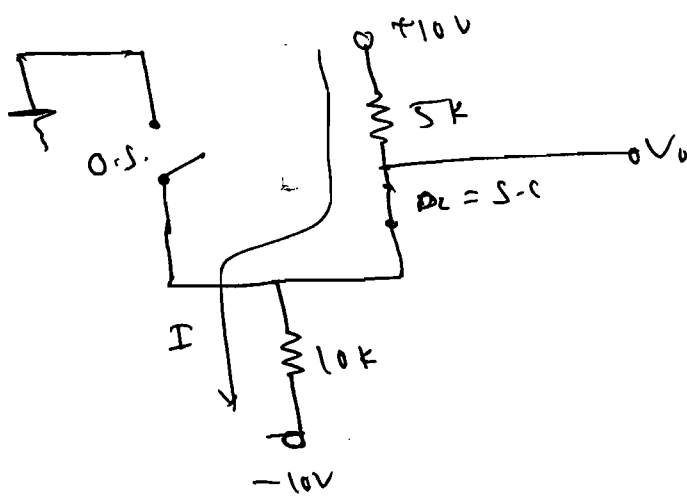


$$\therefore I = I_y - I_x.$$

$$I = \frac{0 - (-10)}{10K} - \left[\frac{10 - 0}{5K} \right].$$

$$\therefore I = -1mA \text{ (Neg).}$$

$\therefore$ Diode D_1 is in RB.



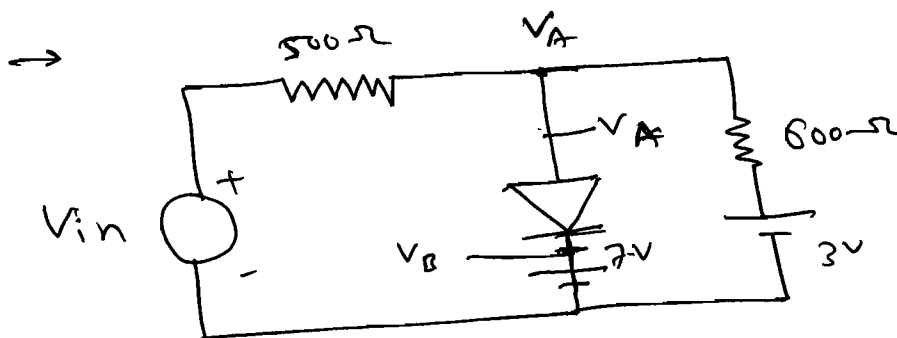
$$\therefore I = \frac{10 - (-10)}{15}$$

$$I = \frac{20}{15}$$

$$\therefore I = \frac{4}{3} = 1.33 \text{ mA}$$

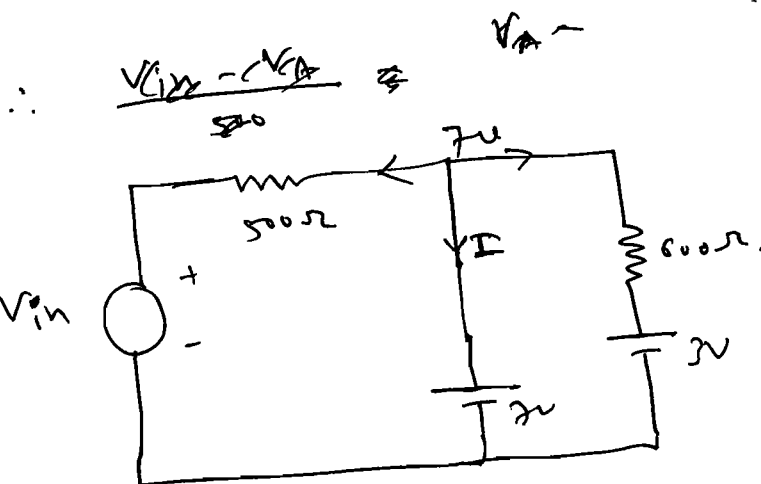
$\therefore S_{01}, D_2$ (i) F-B.

Ex 2 Find the minimum voltage V_{in} for Diode to be FB.



for F-B.

$$\therefore V_A - V_B > 0$$



$$\therefore V_{in} = 10.33 \text{ for } I = 0$$

$\therefore$ so Diode D_1 is in FB when $I > 0$.

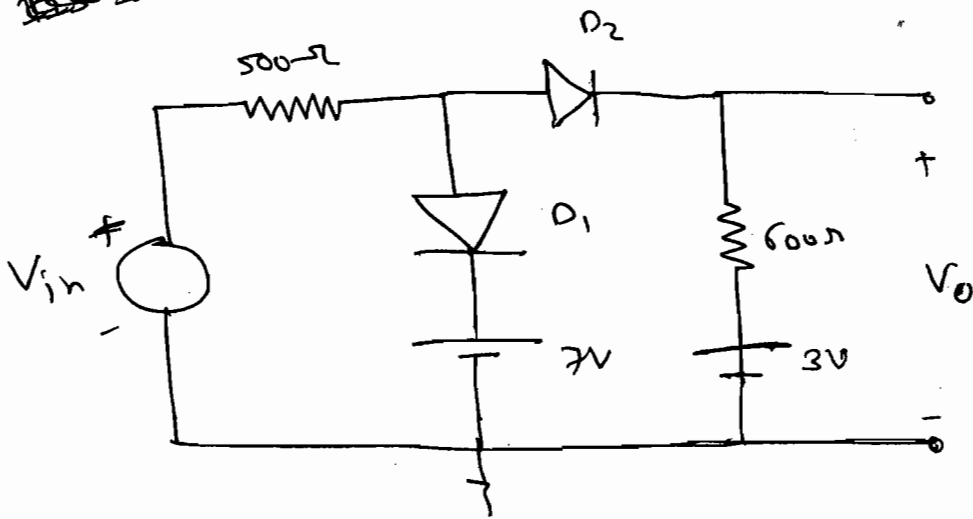
$$\rightarrow V_{in} > 10.33 \text{ V}$$

$$\frac{7 - V_{in}}{500} + I + \frac{7 - 3}{600} = 0$$

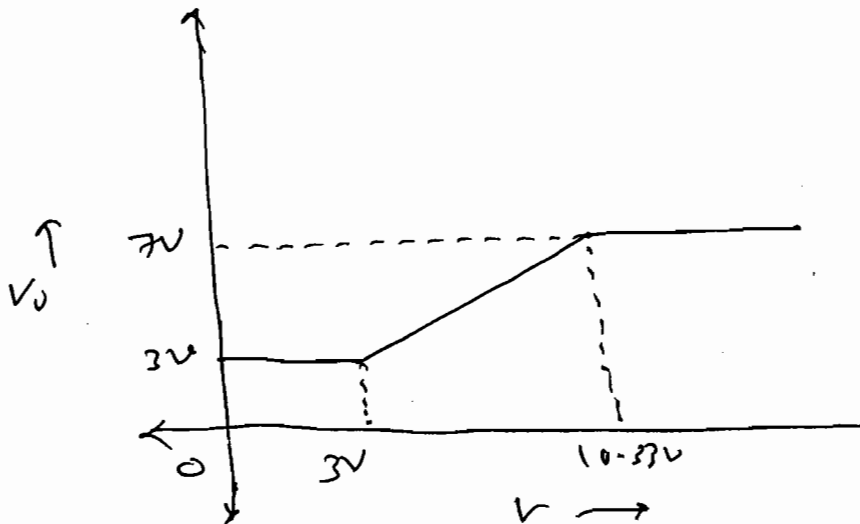
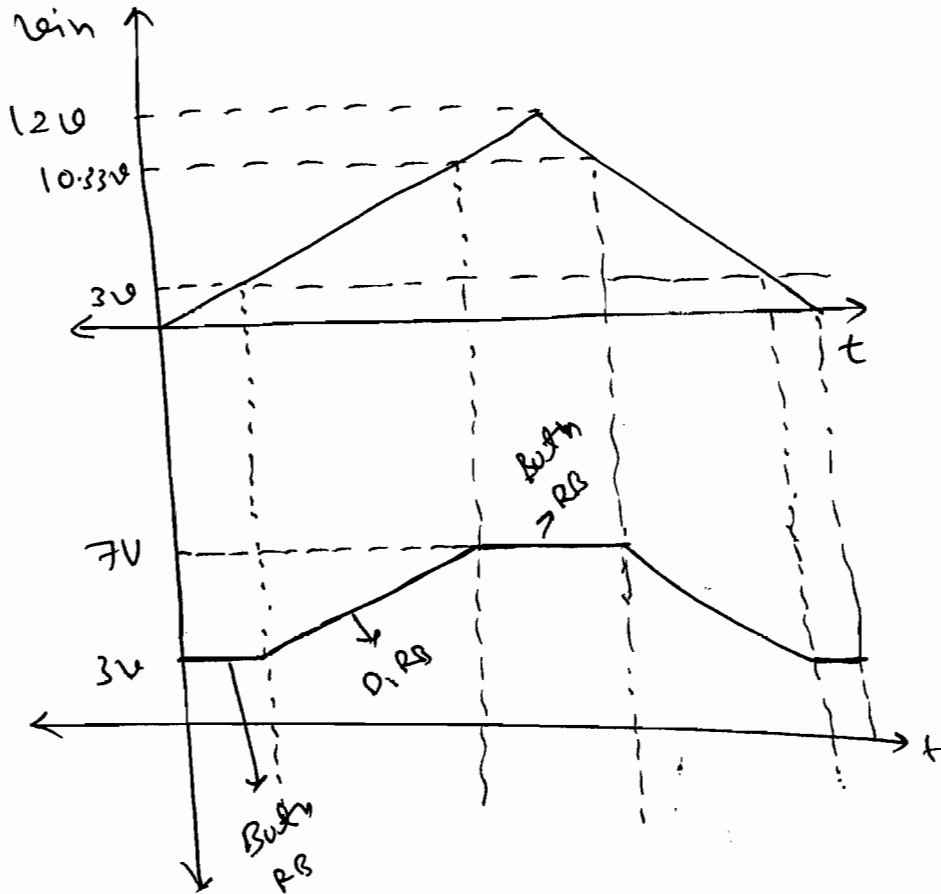
Sub $I = 0$

$$\therefore \frac{7 - V_{in}}{500} + \frac{7 - 3}{600} = 0$$

Ex-1
~~1500~~ 1500 Ω DSC



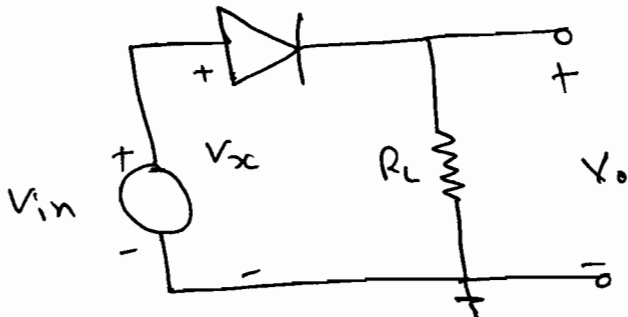
Ans:



★ Clippers or Clipping Circuits: [Limiters] 49

→ Clipper is a circuit which cuts the portion of the required waveform.

*

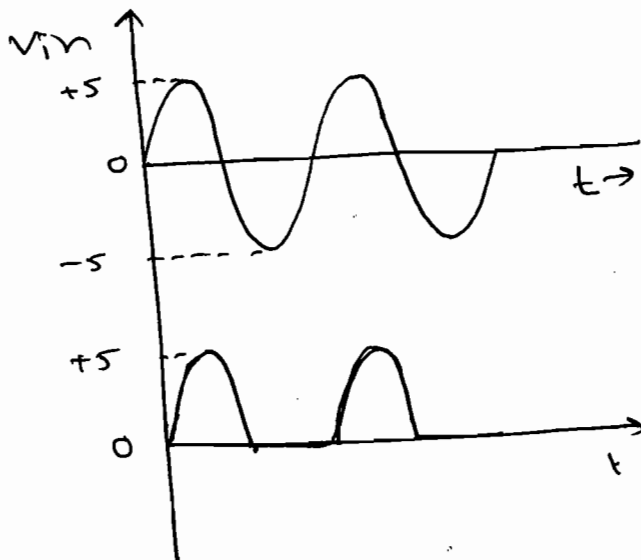


$$\therefore V_x = V_{in}$$

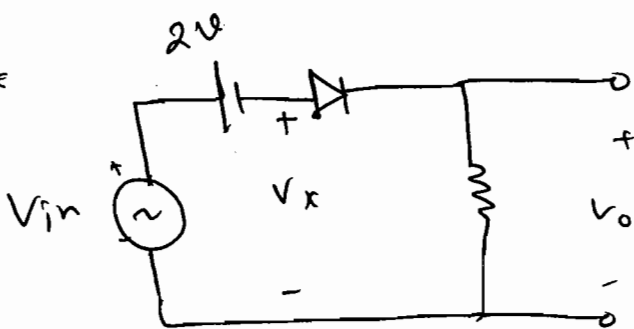
$$\therefore V_{in} \text{ range: } -5 \text{ to } +5$$

$$V_x \text{ range: } -5 \text{ to } +5$$

$$V_o \text{ range: } 0 \text{ to } +5$$



*

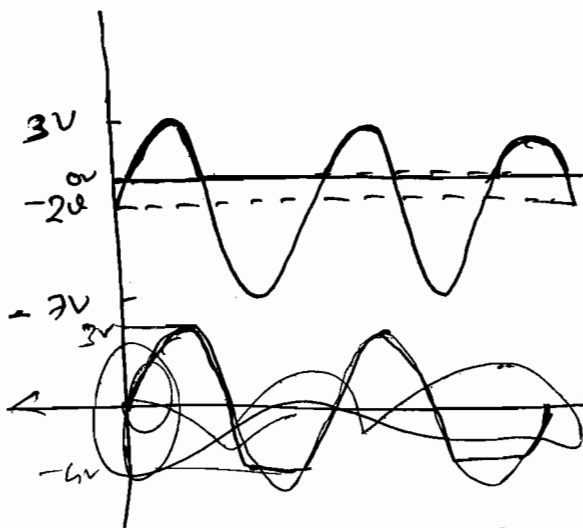


$$\therefore V_x = V_{in} - 2V$$

$$\therefore V_{in} \text{ range: } -5 \text{ to } +5V$$

$$V_x \text{ range: } -7 \text{ to } 3V$$

$$V_o \text{ range: } 0 \text{ to } 3V$$



$$\therefore V_o = V_{in} - 2V$$

$$V_{in} > V_A - V_B$$

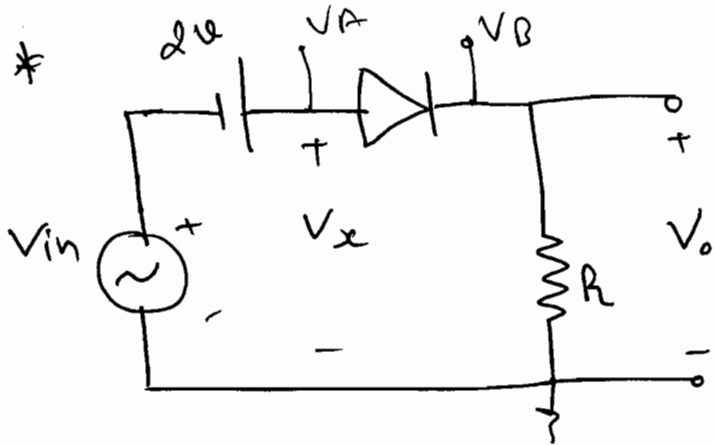
$$V_{in} > -2 - 0$$

$$V_{in} > -2 \rightarrow \text{F.B.}$$

$$-2 < V_{in} < 5 \rightarrow \text{F.B.}$$

$$V_o = V_{in} - 2$$

$$-4 < V_o < +3$$

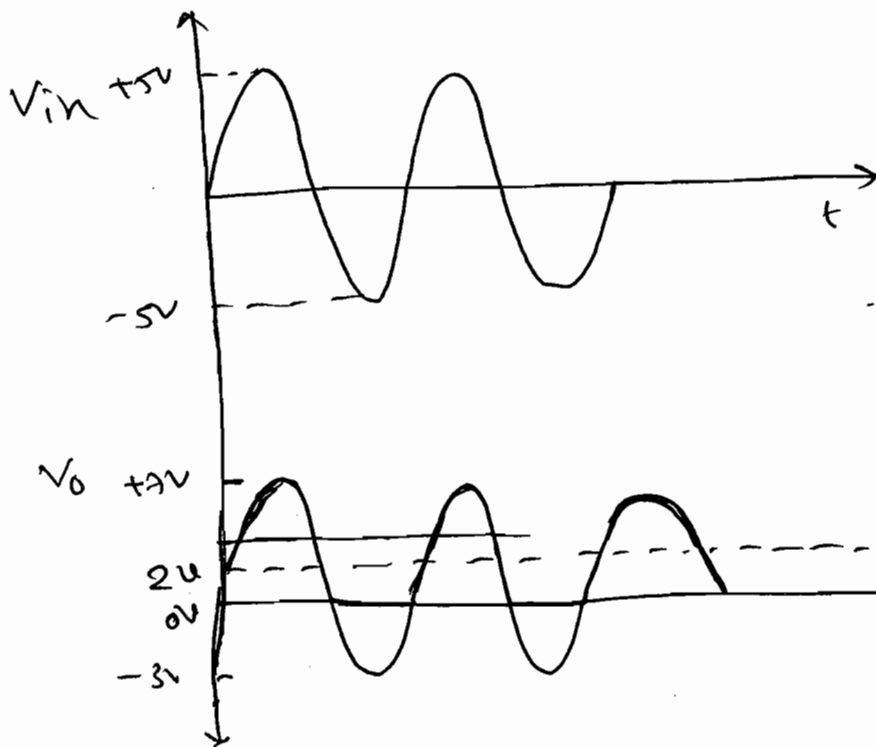


$$V_x = V_{in} + 2$$

V_{in} range: -5 to $+5$ V

V_x range: -3 to $+7$ V

V_o range: 0 to 7 V



$$V_{in} > V_A - V_B$$

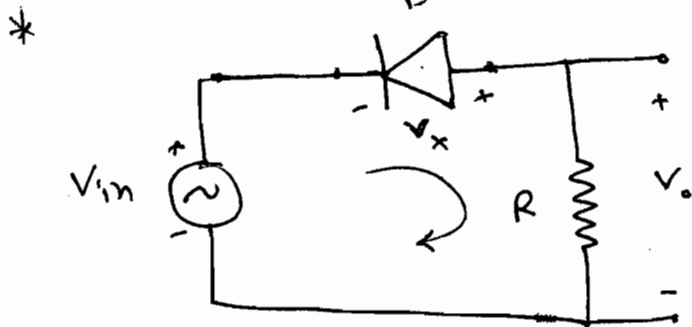
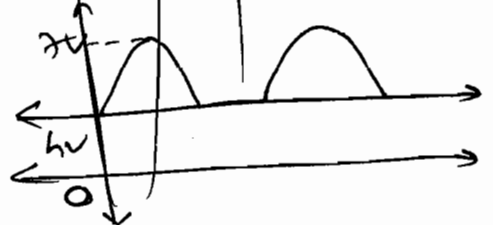
$$V_{in} > 2 - 0$$

$$V_{in} > 2 \rightarrow \text{F.B.}$$

$$2 < V_{in} < 5 \rightarrow \text{F.B.}$$

$$V_o = V_{in} + 2 \text{ V}$$

$$\therefore 0 < V_o < 7 \text{ V}$$



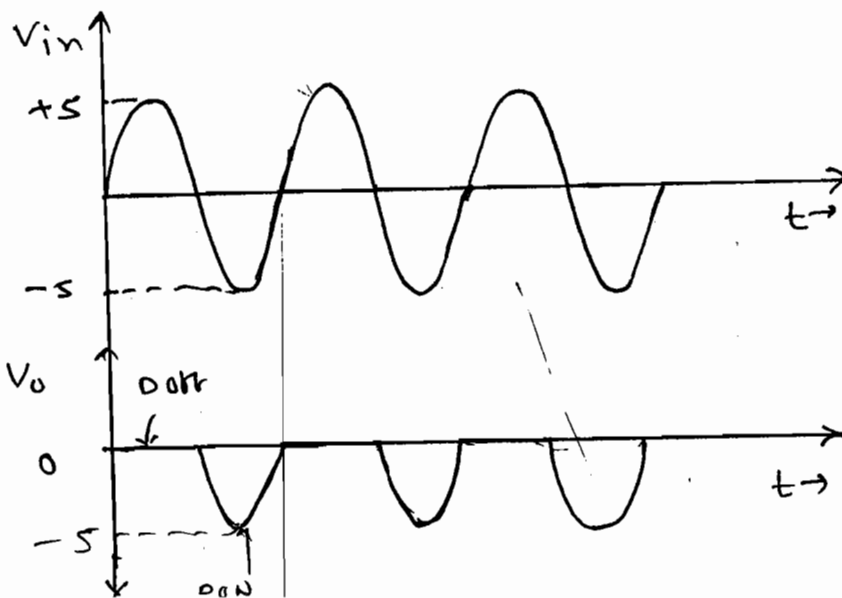
$$V_{in} + V_x = 0$$

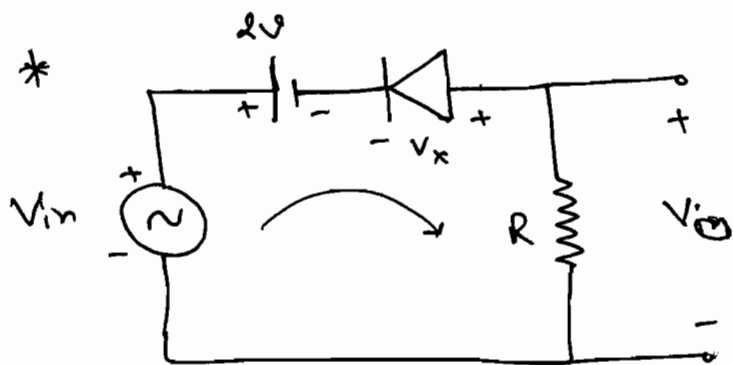
$$\therefore V_x = -V_{in}$$

V_{in} range: -5 to $+5$

V_x range: 5 to -5

V_o range: 0 to -5





$$V_{in} - 2 + V_x = 0 \quad S1$$

$$\therefore V_x = 2 - V_{in}$$

$$\therefore V_{in} \text{ range: } -5 \text{ to } +5 \text{ V}$$

$$V_x \text{ Range: } 7 \text{ to } -3$$

$$V_o \text{ Range: } 0 \text{ to } 3$$

$$-7 \text{ to } 0$$

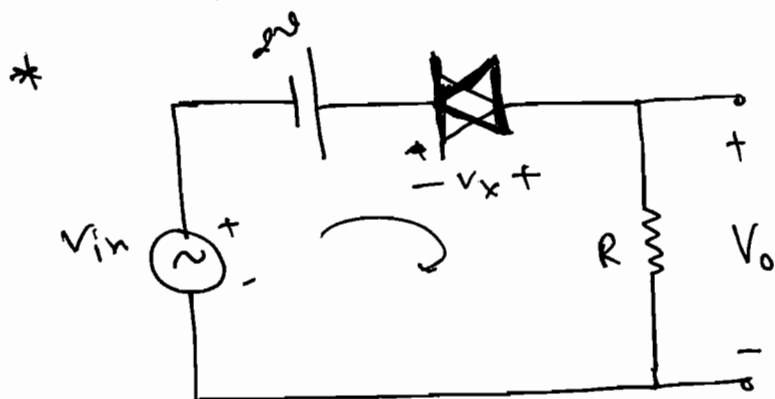
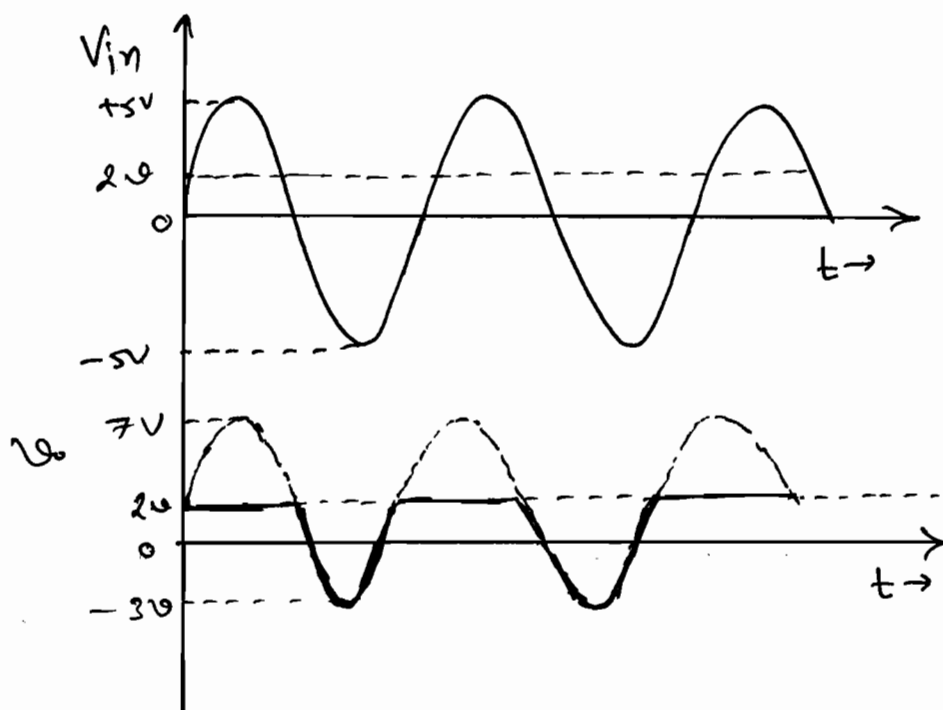
$$V_x > 0$$

$$2 - V_{in} > 0$$

$$V_{in} < 2 \text{ V}$$

for F.O.

-



$$V_{in} + 2 + V_x = 0$$

$$\therefore V_x = -V_{in} - 2$$

$$V_x \text{ range: } 3 \text{ to } -7 \text{ V}$$

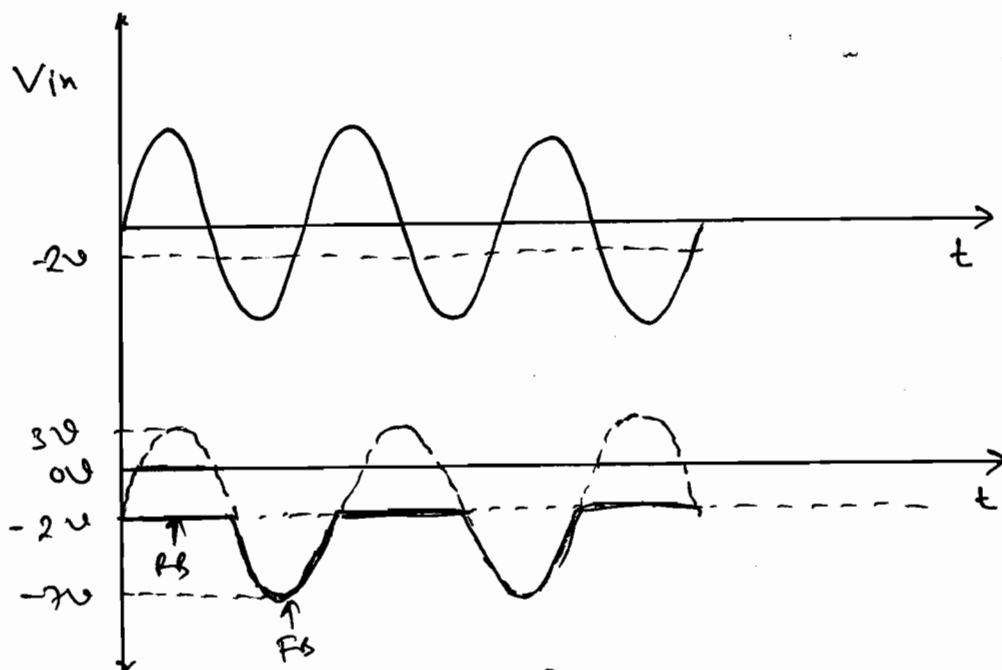
$$V_o \text{ range: } 0 \text{ to } -7 \text{ V}$$

$$V_x > 0$$

$$-V_{in} - 2 > 0$$

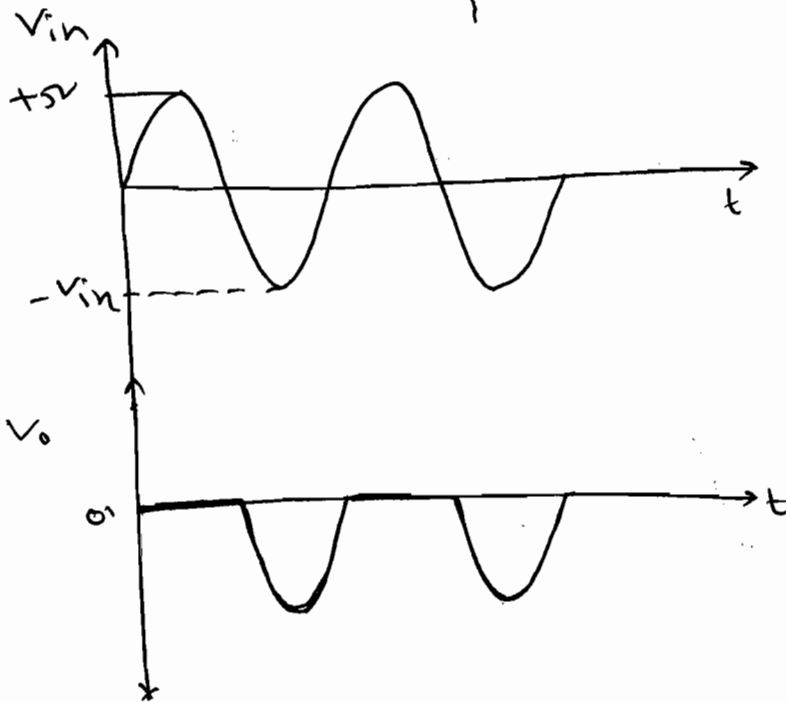
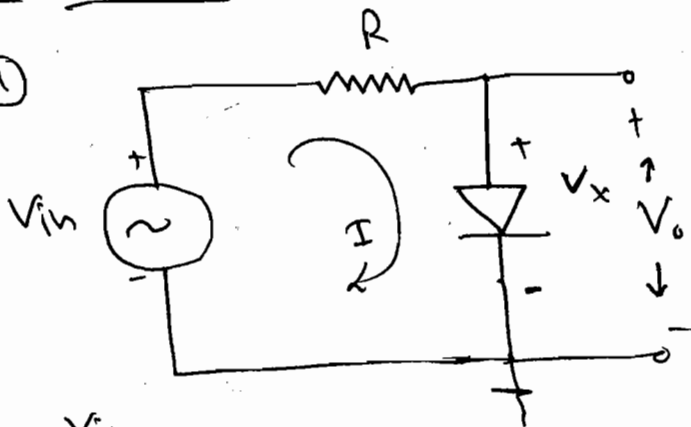
$$V_{in} < -2 \text{ V}$$

$$V_o = 0 \text{ to } -3 \text{ V}$$



* Sketchen V_o .

①



$$V_{in} - V_x = 0$$

$$\therefore V_x = V_{in}$$

$$\therefore V_{in} \text{ range: } -5 \text{ to } +5$$

$$V_x \text{ range: } -5 \text{ to } +5$$

$$V_o \text{ range: } -5 \text{ to } 0$$

F..

$$F.B \quad I > 0$$

$$\therefore I = \frac{V_{in} - 0}{R}$$

$$I = \frac{V_{in}}{R} > 0$$

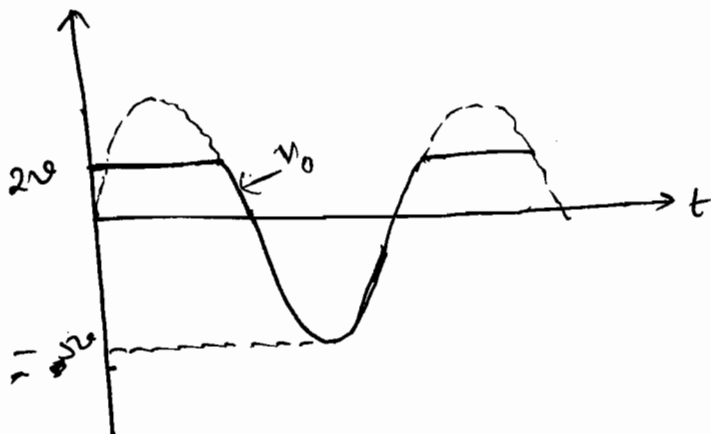
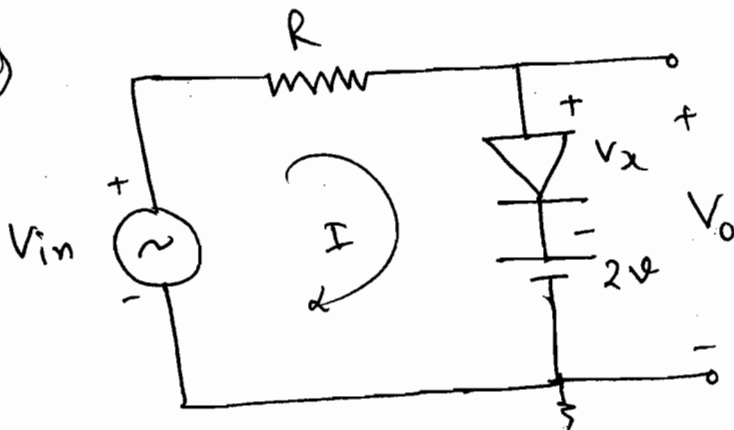
$$\therefore \boxed{V_{in} > 0} \text{ F.B.}$$

$$V_{in} \leq 0 \text{ R.B.}$$

$$\therefore V_o = V_{in}, \quad V_{in} \geq 0$$

$$V_o = 0, \quad V_{in} < 0$$

②



$$I = \frac{V_{in} - 2}{R} > 0$$

$$\therefore \boxed{V_{in} > 2V} \rightarrow \text{F.B.}$$

$$\text{R.B. } \boxed{V_{in} \leq 2V} \rightarrow V_o = 2V$$

$$V_o = V_{in} - 2$$

$$V_o = -5 - 2$$

$$V_{in} > 2V$$

$\Downarrow$

F.B.

$$V_o = 2V$$

$\rightarrow$ F.B.
(S.C.)

$$V_{in} < 2V$$

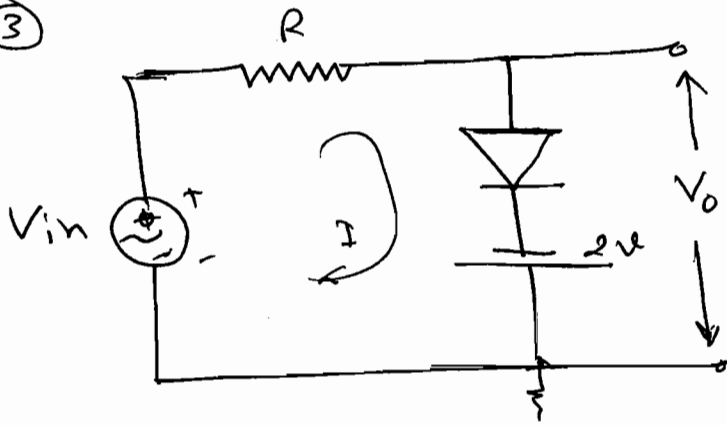
$\Downarrow$

R.B.

$$V_o = V_{in}$$

$\rightarrow$ R.B.
(O.C.)

③



$$I = \frac{V_{in} + 2}{R}$$

for F.B. $I > 0$

$$\therefore \frac{V_{in} + 2}{R} > 0$$

$$\boxed{V_{in} > -2} \rightarrow \text{F.B.}$$

S.C.

↓

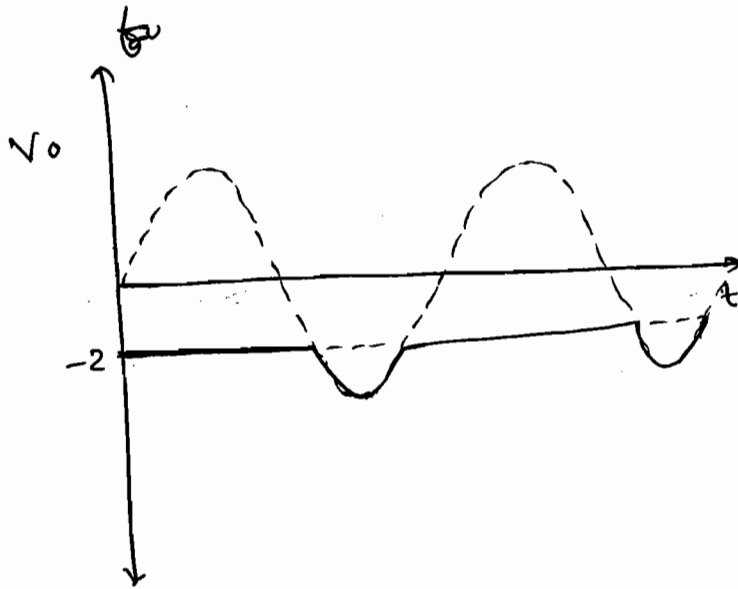
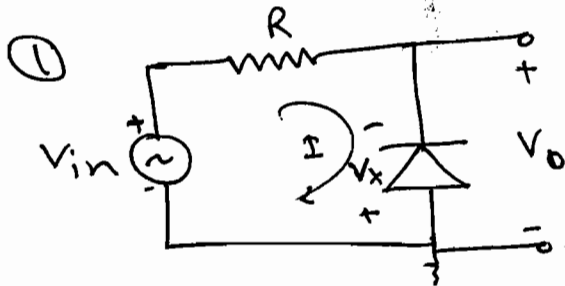
$$V_o = -2V$$

for R.B. $I \leq 0$

$$\therefore \boxed{V_{in} \leq -2}$$

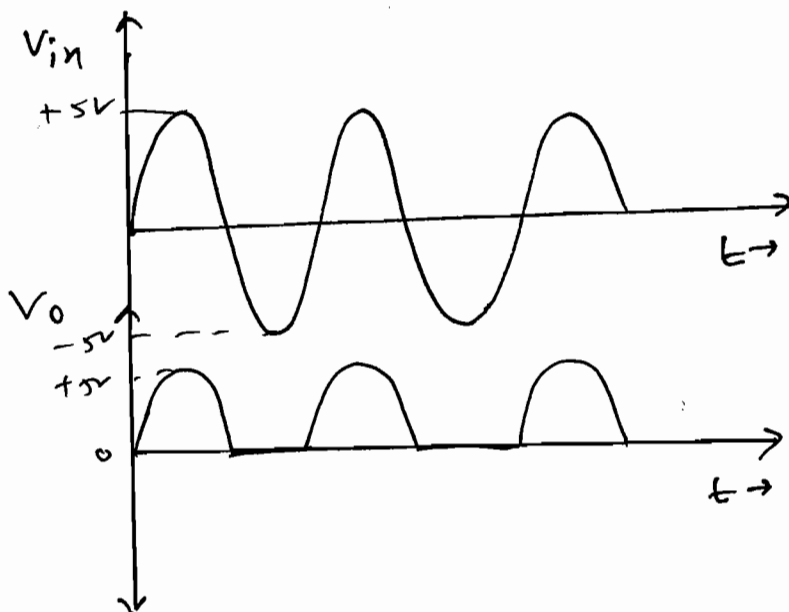
O.S.

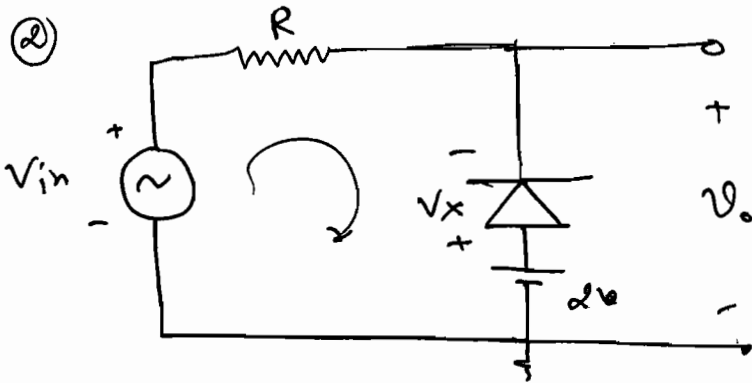
$$V_o = V_{in}$$

* Sketch V_o :

$$V_{in} + V_x = 0$$

$$\therefore V_x = -V_{in}$$

 V_{in} range: -5 to $+5$ V_x range: $+5$ to -5 V_o range: 0 to $+5$, -5 to 0 .



$$V_{in} + V_x - 2V = 0$$

$$\therefore V_x = 2 - V_{in}$$

$$\therefore V_{in} \text{ range: } -5 \text{ to } 5V$$

$$V_x \text{ range: } 7 \text{ to } -3V$$

$$V_o \text{ range: } 7 \text{ to } 0V$$

$$V_x > 0 \rightarrow \text{F.B.}$$

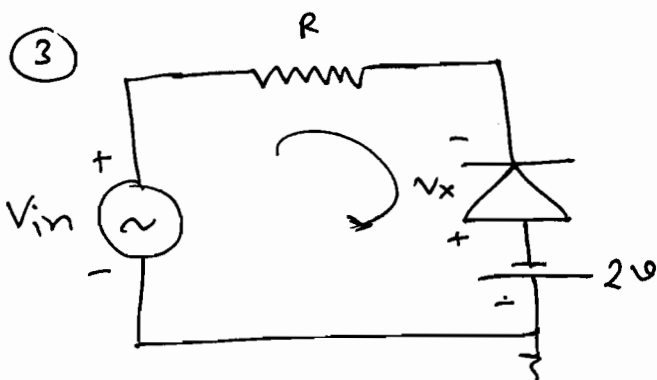
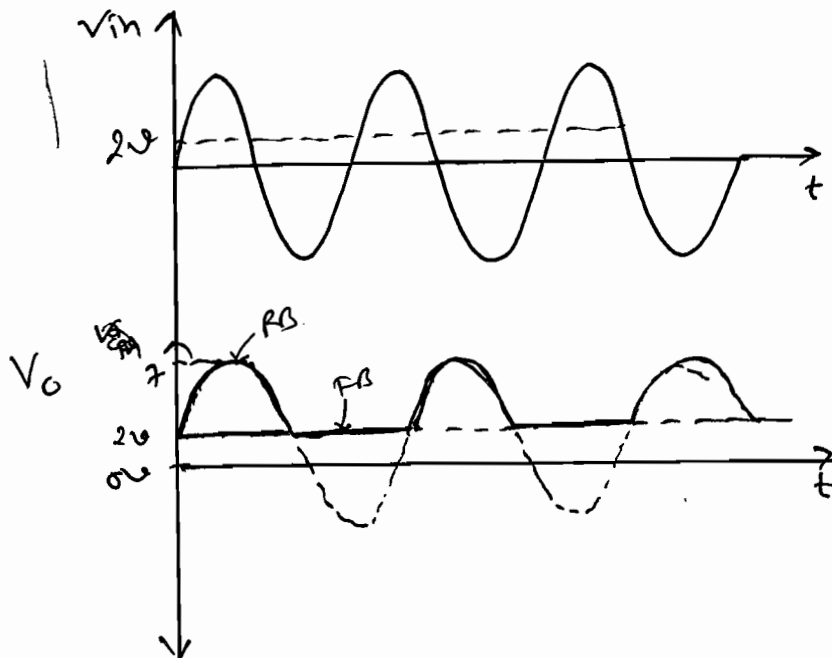
$$2 - V_{in} > 0$$

$$\boxed{V_{in} < 2V}$$

$$V_o = 2V$$

$$V_{in} \geq 2V \rightarrow \text{R.B.}$$

$$V_o = V_{in}$$



$$V_{in} + V_x + 2V = 0$$

$$\therefore V_x = -2 - V_{in}$$

$$V_{in} \text{ range: } -5 \text{ to } 5V$$

$$V_x \text{ range: } +3 \text{ to } -7V$$

$$V_o \text{ range: } +3 \text{ to } 0V$$

$$V_x > 0 \rightarrow \text{F.B.}$$

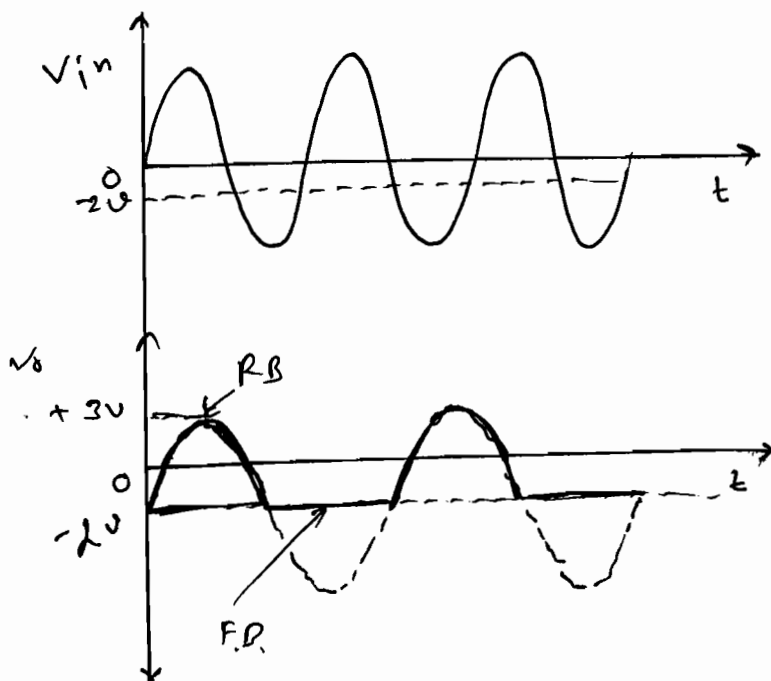
$$-2 - V_{in} > 0$$

$$\boxed{V_{in} < -2V} \rightarrow \text{F.B.}$$

$$\boxed{V_o = -2V}$$

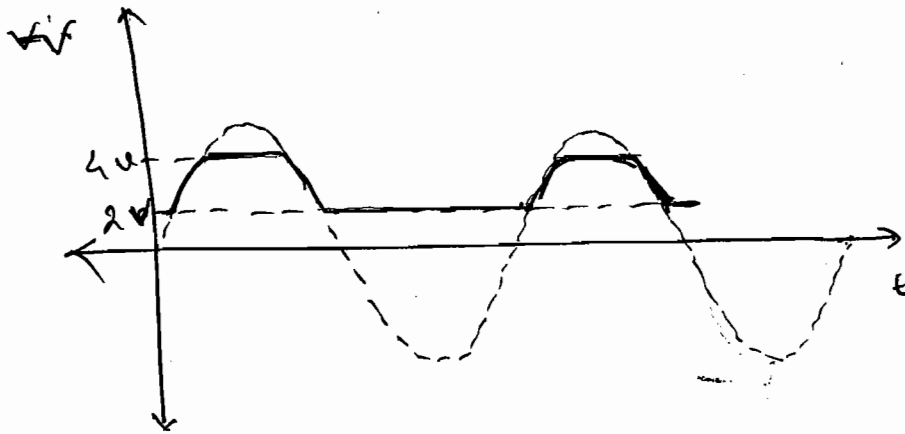
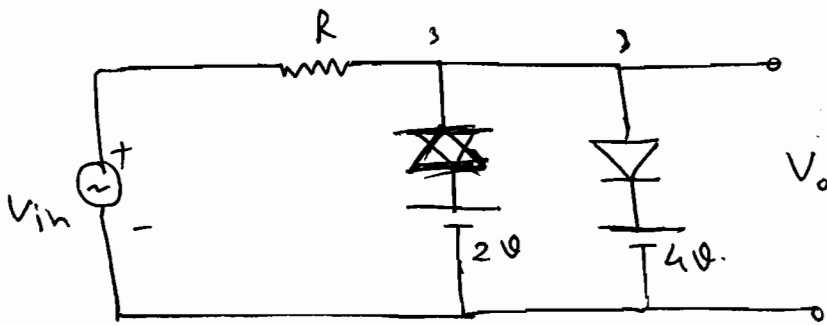
$$V_{in} \geq -2V \rightarrow \text{R.B.}$$

$$V_o = V_{in}$$

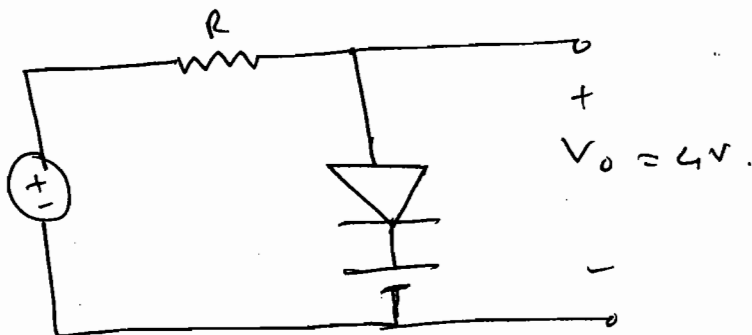


* Design a double bias clipper / slicer

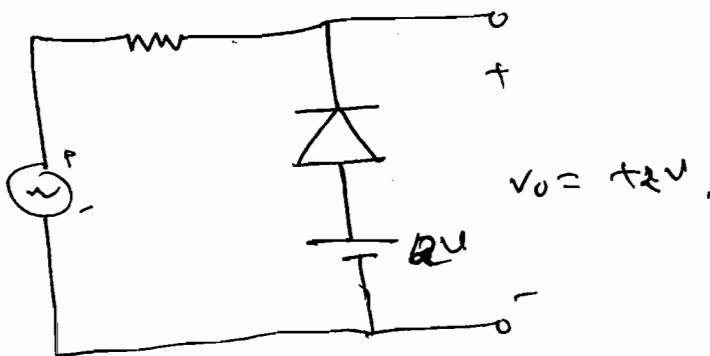
55



① Case-1: $V_{in} > 4 \rightarrow V_o = +4V.$



② Case-2: $V_{in} < 2 \rightarrow V_o = +2V.$

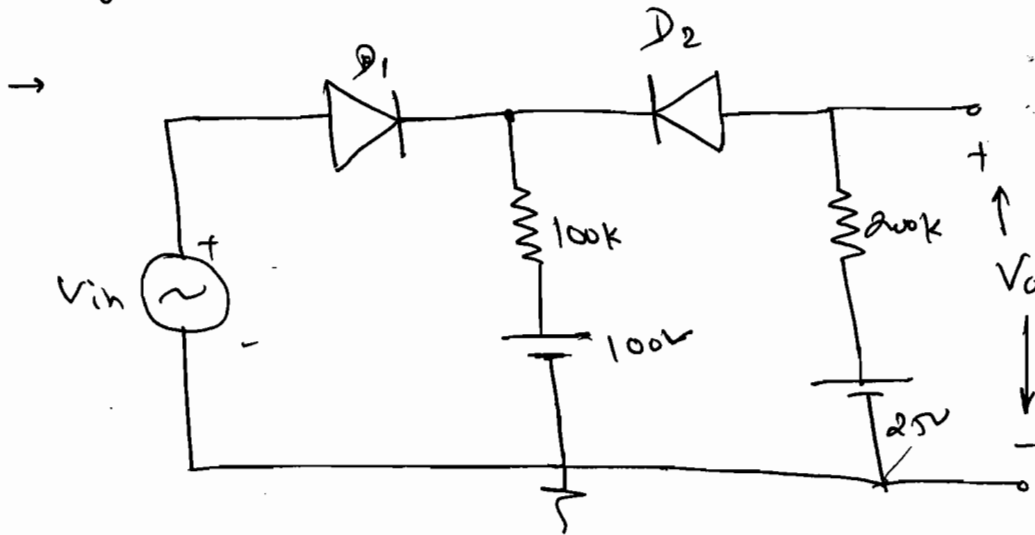


Case-3 $2 \leq V_{in} \leq 4.$

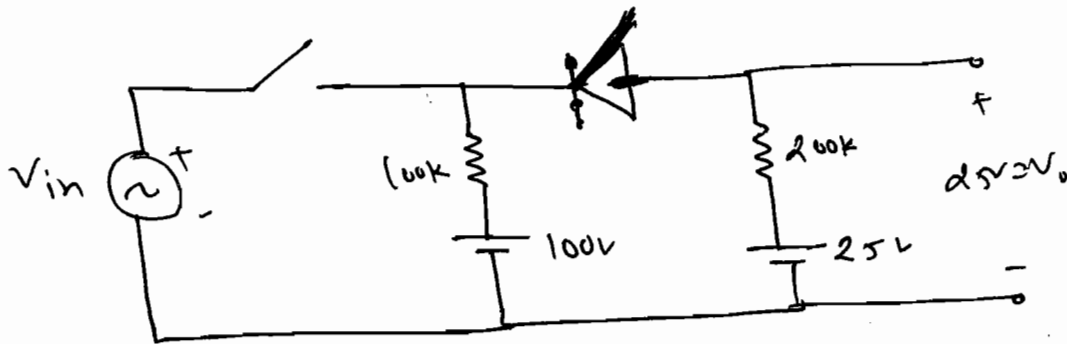
Both $\textcircled{R_1}$

$V_o = V_{in}.$

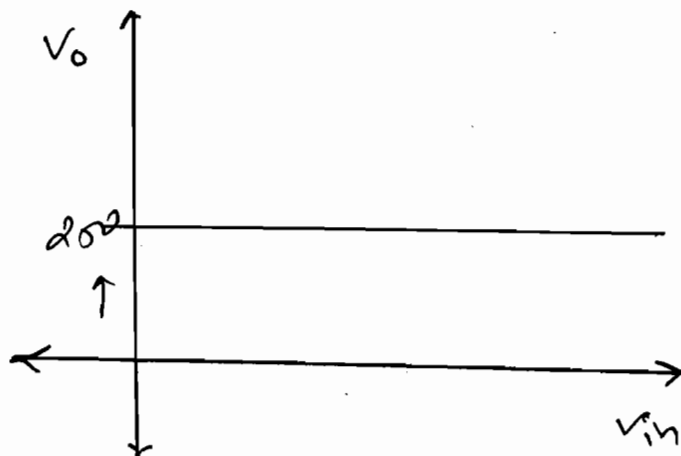
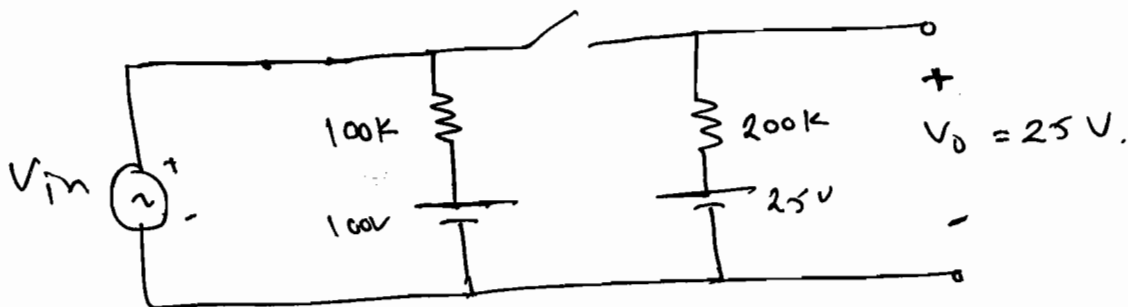
* Sketch the Transfer Characteristics of the circuit for V_{in} varies from 0 to 150V.



→ Case: (1) $V_{in} = 0V$, so $D1$ & $D2$ off.



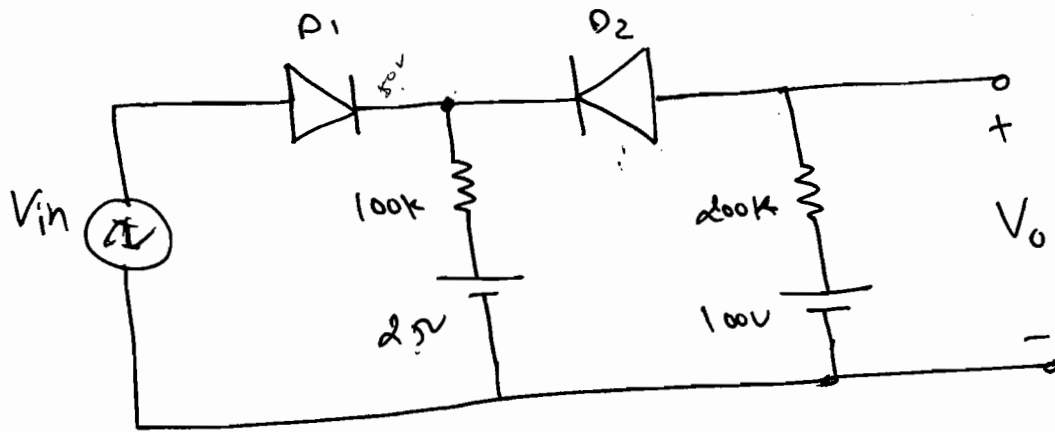
Case- (2) $V_{in} \geq 100V$



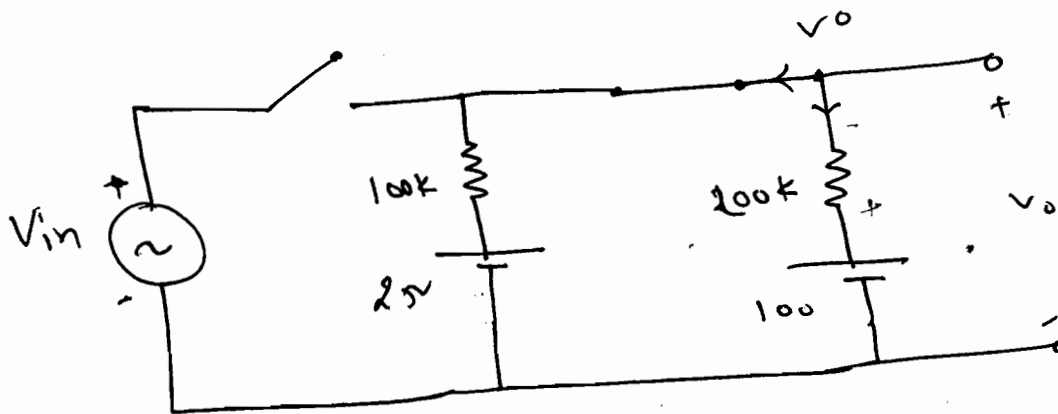
Transfer Characteristic.

* Sketch Transfer Char.

57



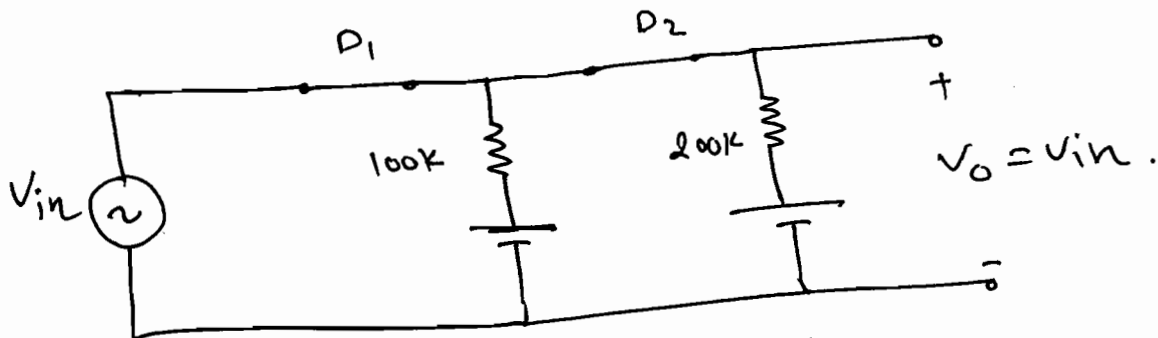
→ Case (i): $V_{in} = 0$, $D_1 = \text{off}$, $D_2 = \text{on}$.



KCL, $\frac{V_o - 25}{100} + \frac{V_o - 100}{200} = 0$

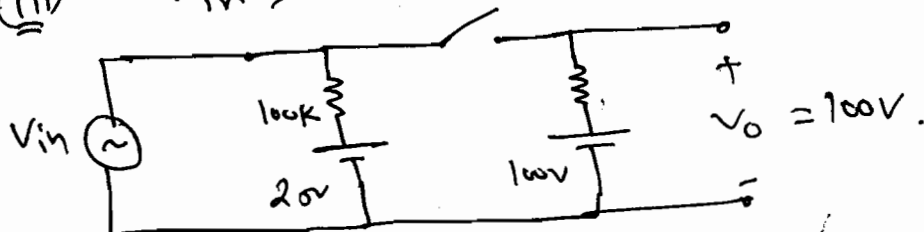
$\therefore V_o = 50 \text{ V}$

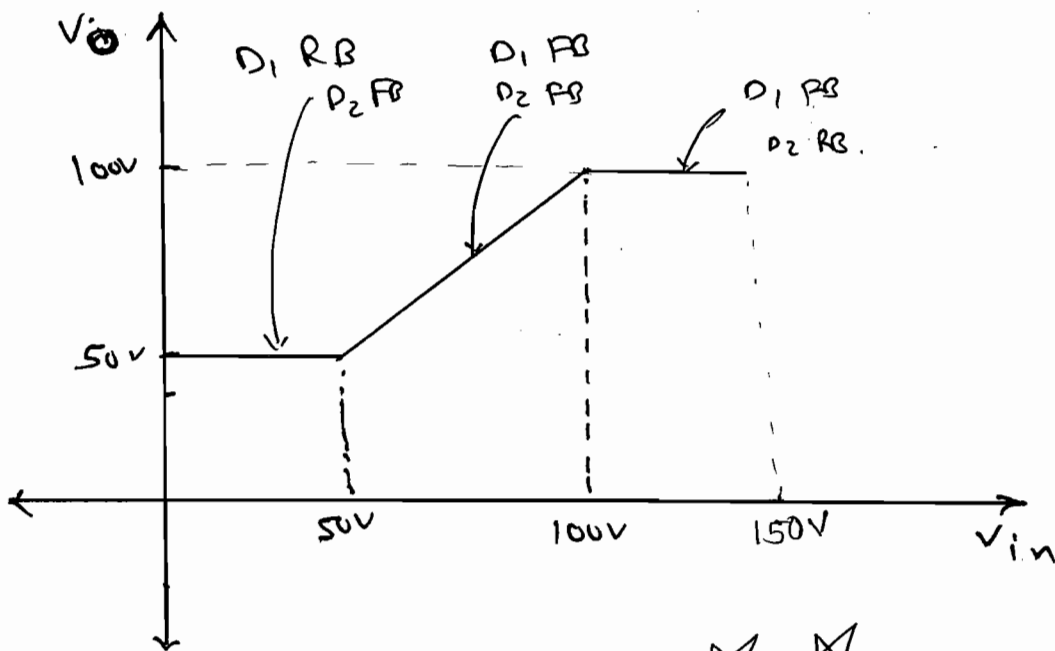
→ Case (ii) $100 \text{ V} \geq V_{in} > 50 \text{ V}$, $D_1 = \text{on}$, $D_2 = \text{on}$.



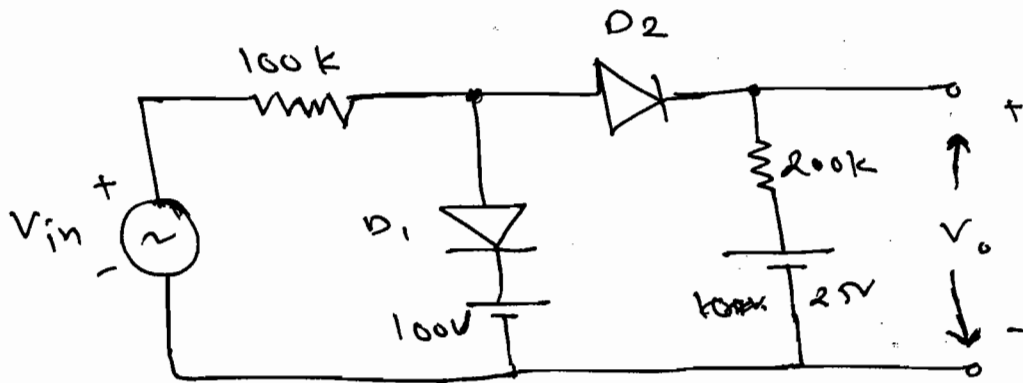
$V_o = V_{in}$

→ Case (iii) $V_{in} > 100 \text{ V}$.

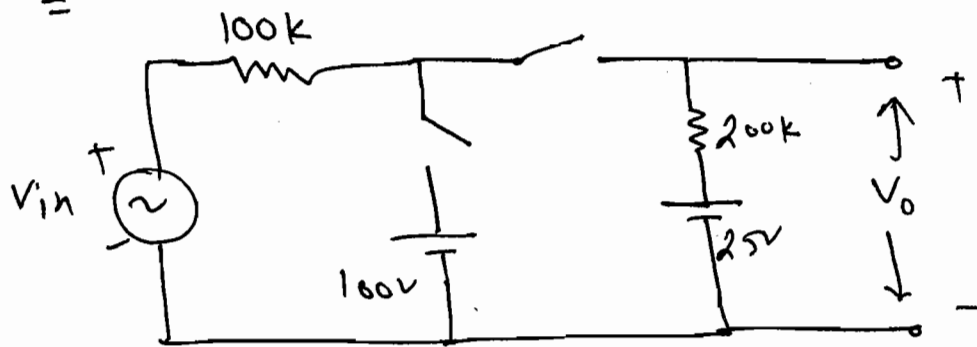




* Sketch transfer char:

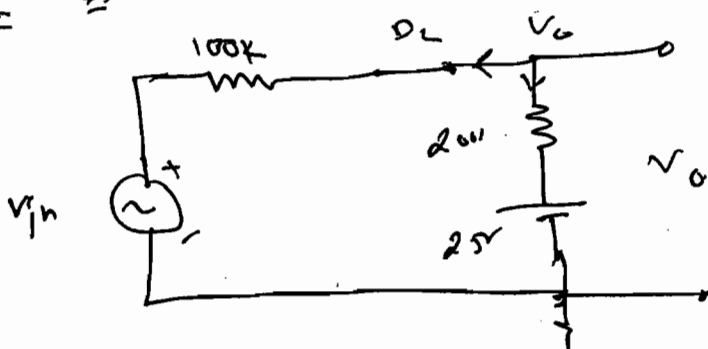


Case (i) $V_{in} = 0$, $D_1 = OFF$, $D_2 = OFF$



$$V_o = 25V$$

Case (ii) $V_{in} \geq 25V$, $D_1 = OFF$, $D_2 = ON$



$$\therefore \frac{V_o - V_{in}}{100} + \frac{V_o - 25}{200} = 0.$$

$$\therefore 2V_o - 2V_{in} + V_o - 25 = 0.$$

$$\therefore 3V_o = 2V_{in} + 25.$$

$$\therefore V_o = \frac{2}{3} V_{in} + \frac{25}{3}.$$

Now, max value of $V_o = 100V$.

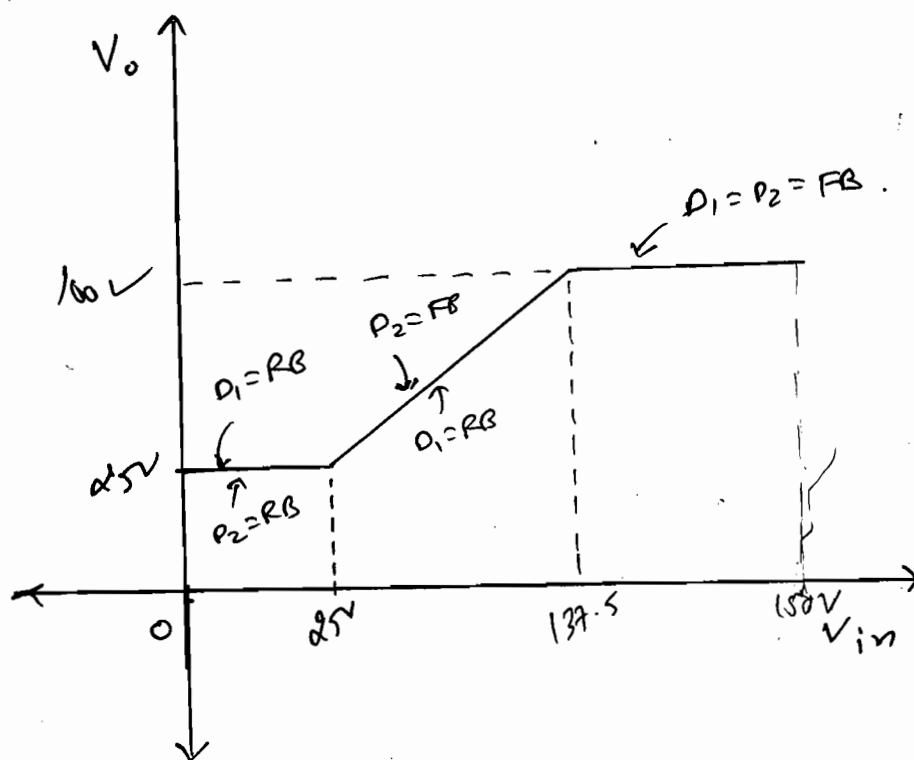
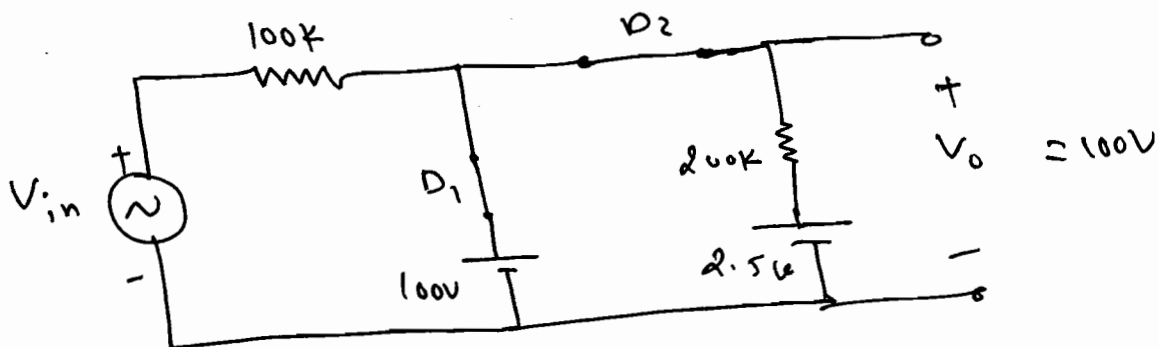
$$\therefore 100 = \frac{2}{3} V_{in} + \frac{25}{3}.$$

$$\therefore \frac{300 - 25}{2} = V_{in}$$

$$\therefore V_{in} = 137.5V. \Rightarrow V_o = 100V.$$

Case-(iii)

= When $V_{in} > 137.5$. $D_1 = ON, D_2 = ON$.

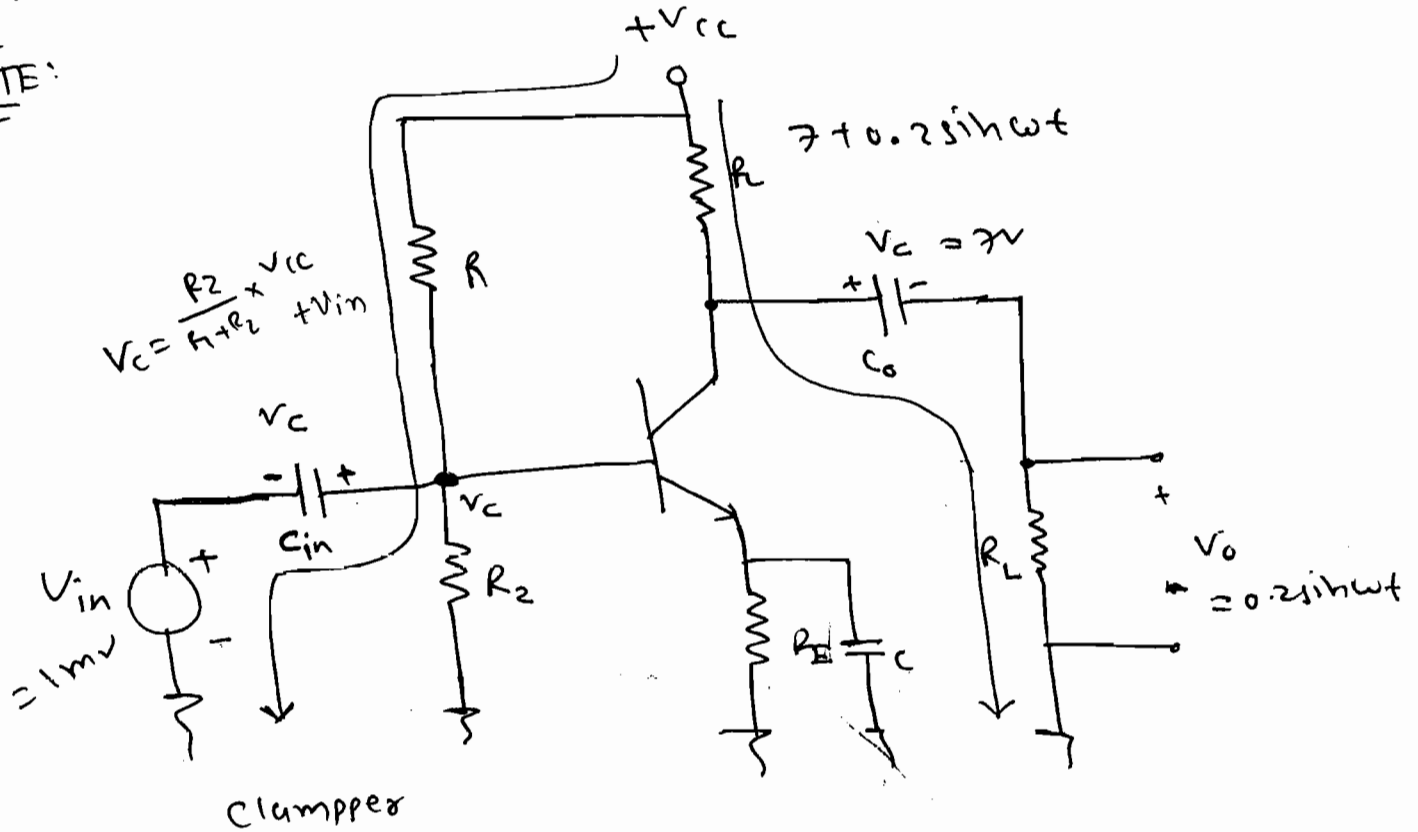


★ Clamping circuits or Clamper:

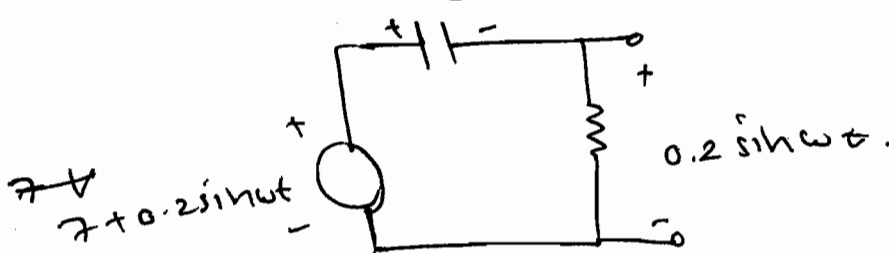
→ Clamper is a circuit that adds DC to the given input wave form.

→ Also called DC Restorer.

Imp Note:



→ ① for V_o $V_c = 7V$

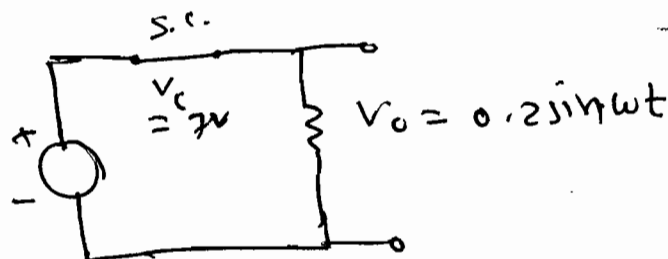
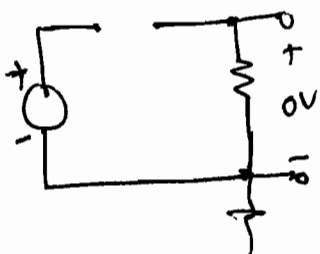


$$Z = \left| \frac{1}{\omega C} \right| \Omega$$

(D.C.) $\omega = 0 \Rightarrow Z = \infty$
O.C.

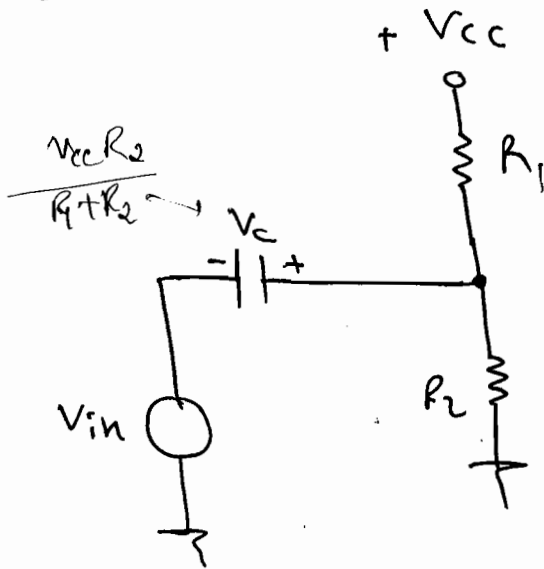
(A.C.) $\omega = \infty \Rightarrow Z = 0$
S.C.

DC	AC
$\omega = 0$ $Z = \infty$ O.C.	$\omega = \infty$ $Z = 0$ S.C.



→ So, at o/p Capacitor is used to block DC Component and allow AC Component.

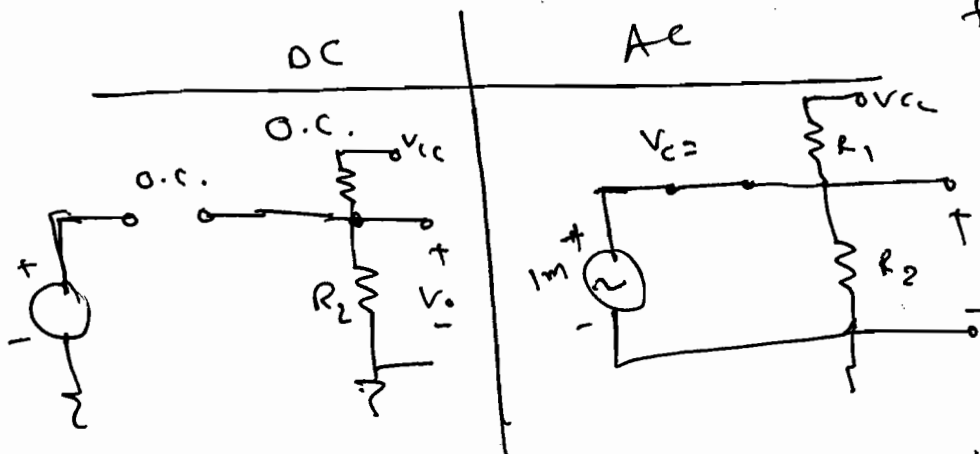
② At i/p:



* If we don't use capacitor C_i then very small input voltage available and therefore the device is in cut off region.

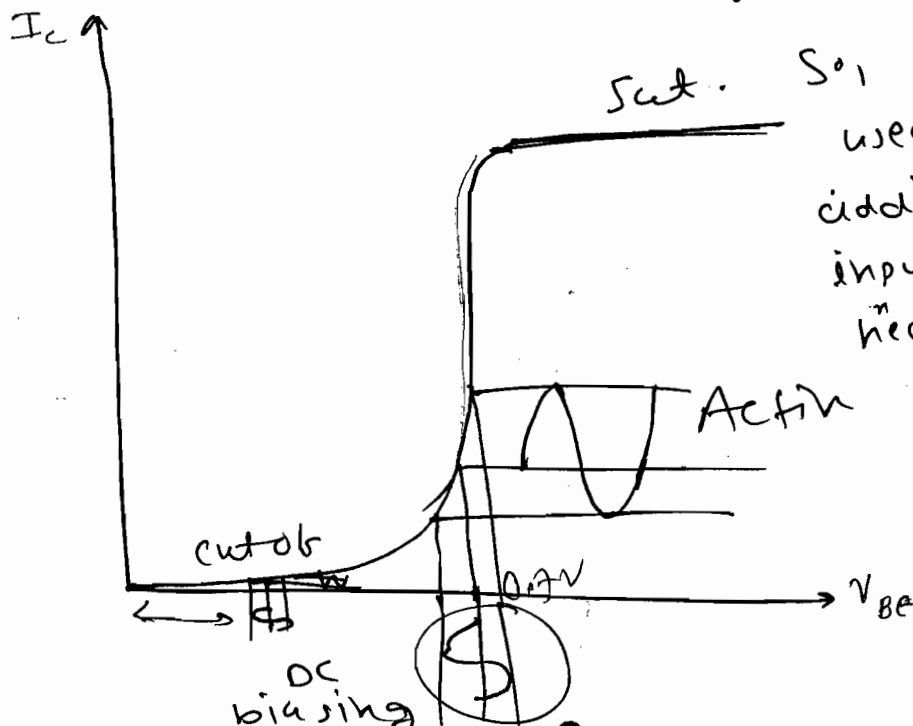
→ Now, because of capacitor it store the DC voltage and

this DC voltage are used Add to the input so that DC biasing $V_{in} = V_{C_i} = V_o$ point shift from small value to large value so that the device will come into active region.



$$\therefore V_o = \frac{R_2}{R_1 + R_2} \times V_{cc}$$

Biasing:
Adding some DC.



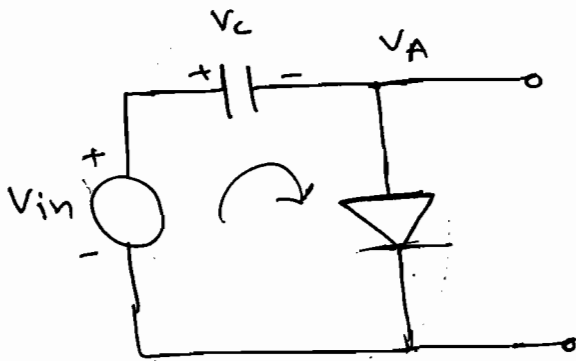
Sat. So, capacitor is used for the adding dc to input and here act as clamped.

★ Two Simple Steps to draw the Clamped
Output:

(i) Find the Capacitor Voltage V_C in its
Steady state.

(ii) Replace diode with open switch and
draw the output waveform.

Ex-1

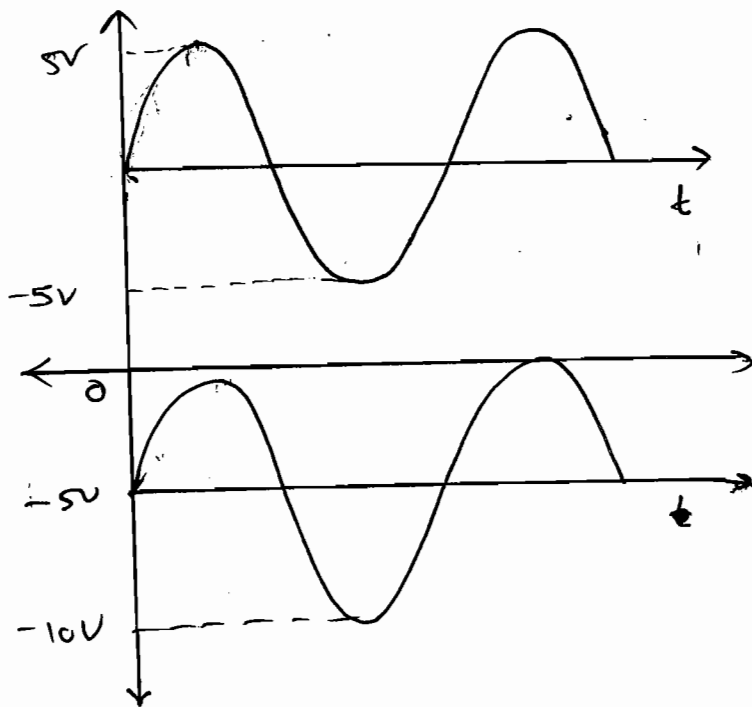


$$V_A = V_{in} - V_C$$

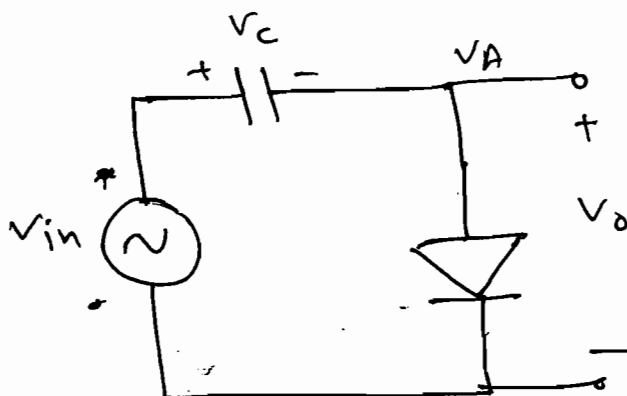
$$V_A = V_{in} - 5 \quad V_C = +5V$$

$$V_{in} \text{ range: } -5 \text{ to } +5$$

$$V_A \text{ range: } -10 \text{ to } 0V \text{ (neg.)}$$



Ex-2

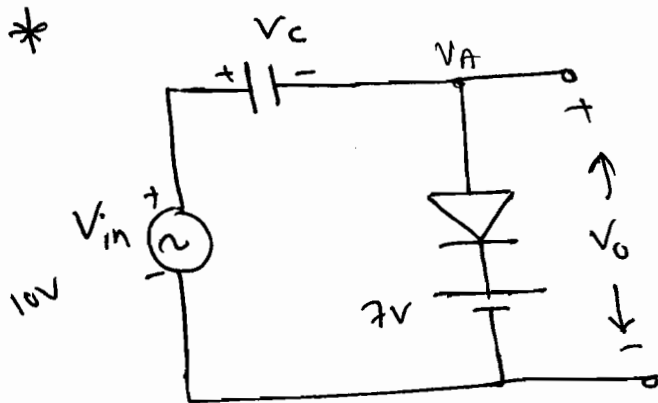
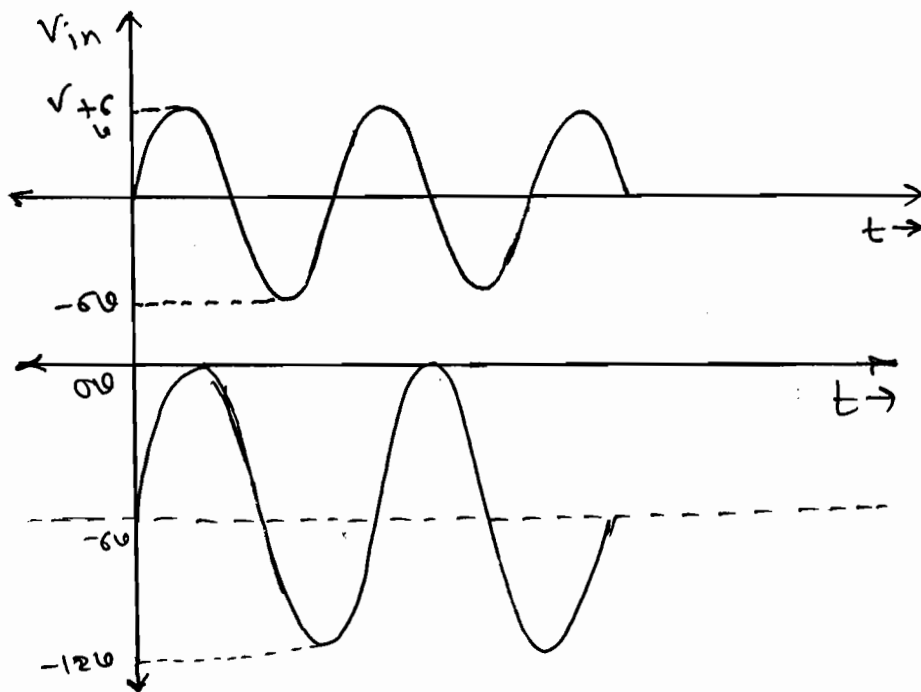


$$V_C = 6V$$

$$V_A = V_{in} - 6$$

$$V_{in} \text{ range: } -6 \text{ to } +6V$$

$$V_O \text{ range: } -12 \text{ to } 0V$$



~~XXXXXXXXXX~~

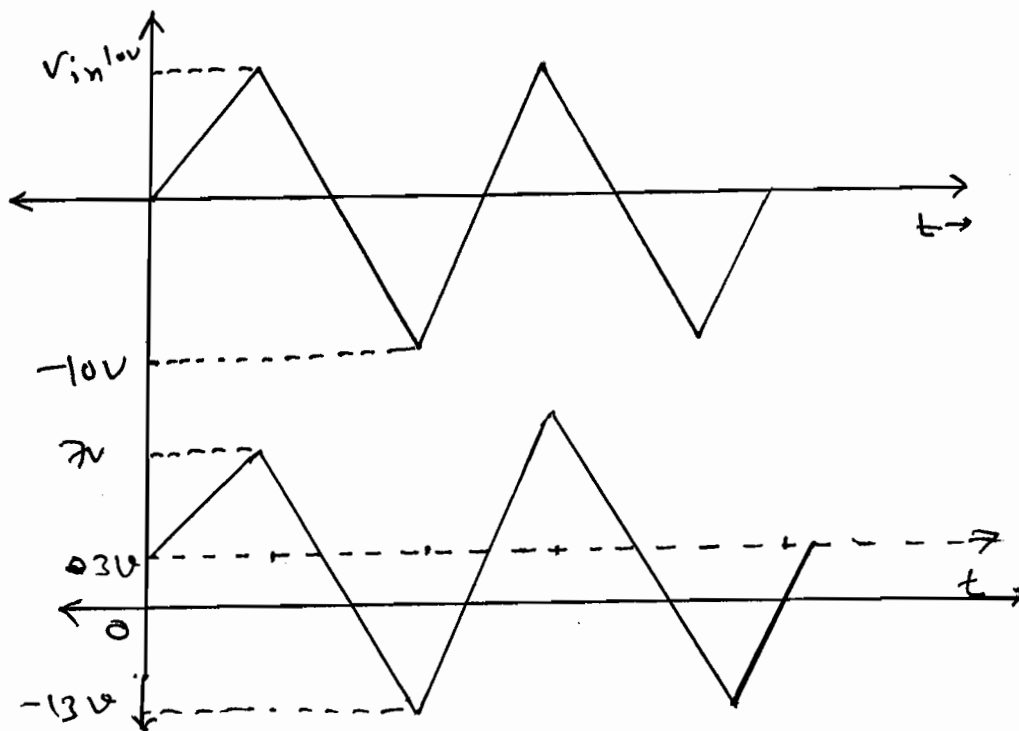
$$10 - V_C - 7 = 0$$

$$V_C = 3V$$

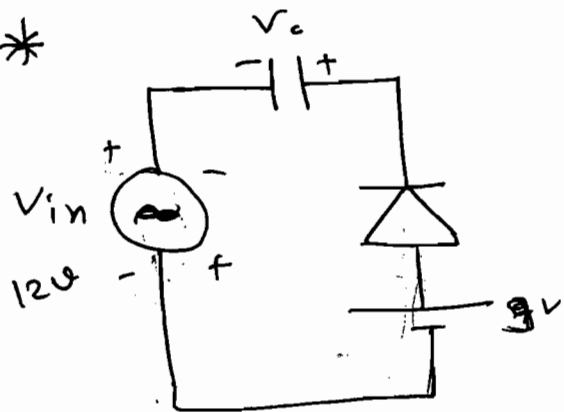
V_{in} Range: -5 to $+5$.

$$V_o = V_{in} - 3V$$

V_o range: 7 to $-13V$.



*



$$V_{in} + V_c - 9 = 0.$$

$$\therefore \text{KVL}$$

$$\therefore +12 - V_c + 9 = 0$$

$$-12 + V_c - 9 = 0$$

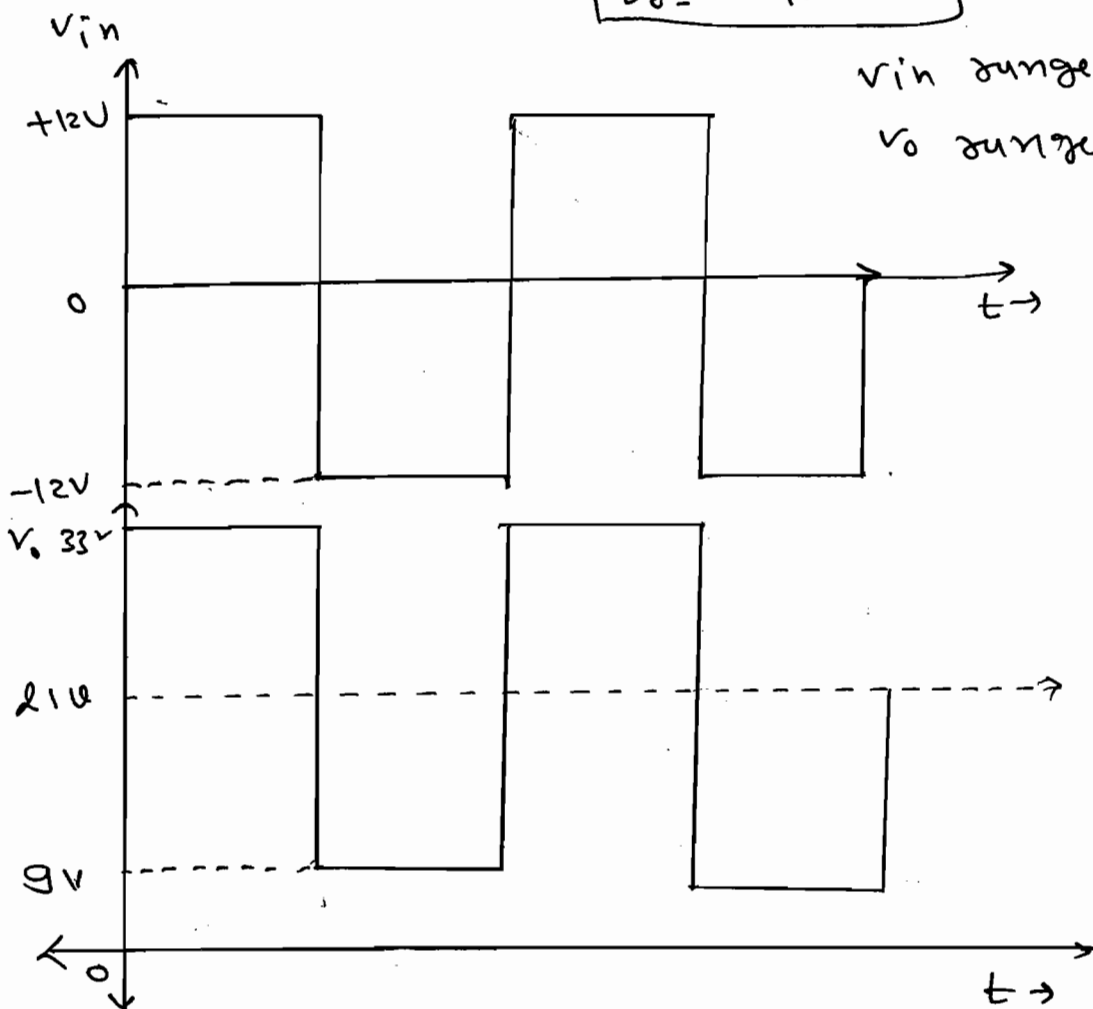
$$V_c = 21V$$

$$V_o = V_{in} + V_c$$

$$V_o = V_{in} + 21.$$

V_{in} range: -12 to 12

V_o range: 9 to 33.



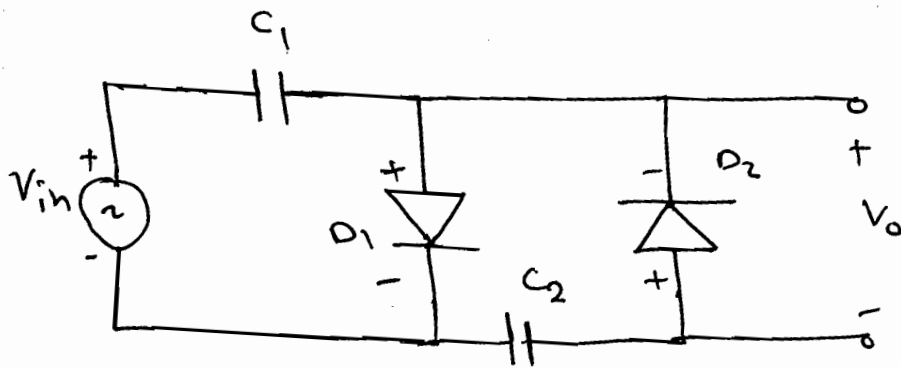
★ Voltage Multiplier:

65

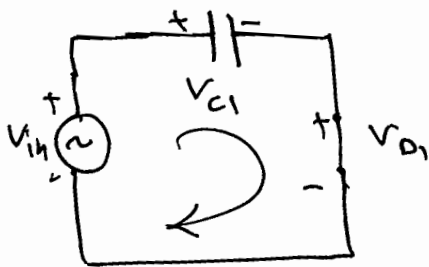
$$\rightarrow V_{in} = V_m \sin \omega t \text{ (Ac)}$$

$$V_o = n V_m \text{ (dc)} \quad n = 2, 3, 4, \dots$$

* Double:



$\Rightarrow$ During +ve cycle



$$2. V_{in} - V_{C1} = 0 \text{ V}$$

$$\therefore V_{C1} = 6 \text{ V}$$

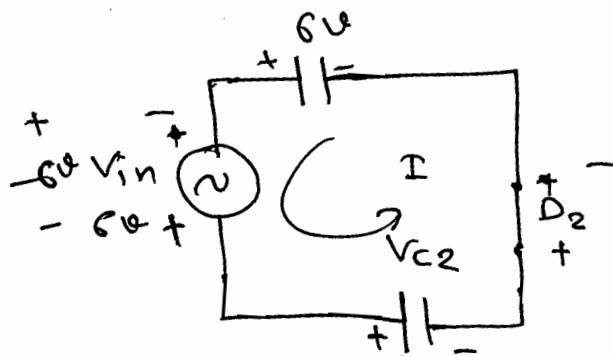
$$\therefore V_{in} - 6 \text{ V} - V_{o1} = 0 \text{ [when } V_{o1} \text{ is R.B.]}$$

$$\therefore V_{o1} = V_{in} - 6 \text{ V}$$

$$V_{in} \text{ range: } -6 \text{ to } +6$$

$$V_{o1} \text{ range: } -12 \text{ to } 0 \text{ V}$$

$\Rightarrow$ During -ve cycle.



$$\therefore V_{in} - V_{C2} + 6 = 0$$

$$V_{C2} = V_{in} + 6$$

$$\therefore V_{C2} = 6 + 6 = 12 \text{ V}$$

$$V_{C2} = 12 \text{ V}$$

$$\therefore V_{in} - 6 + V_{o2} + V_{C2} = 0$$

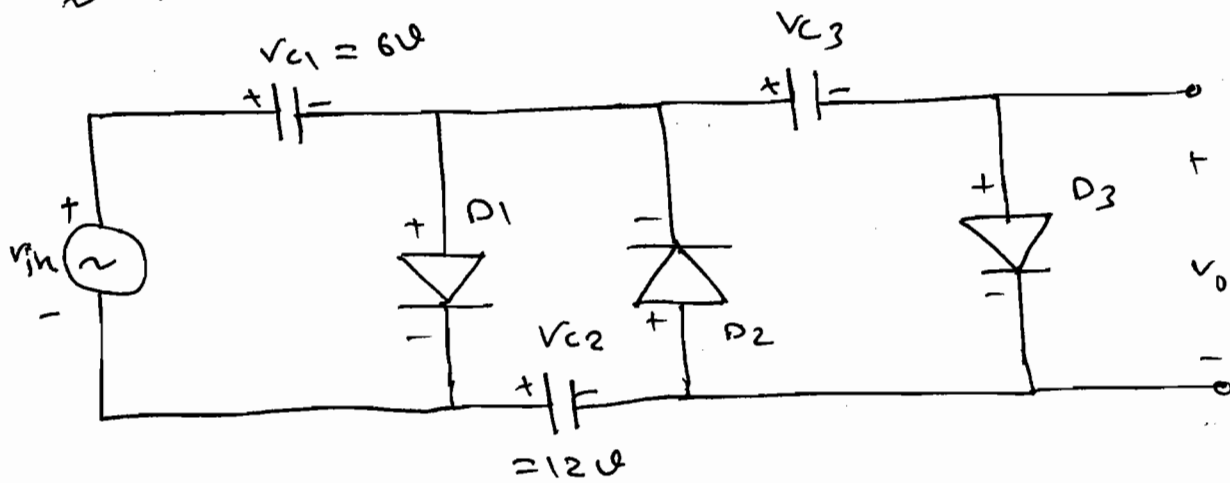
$$\therefore V_{in} - 6 + V_{o2} + 12 = 0$$

$$\therefore V_{o2} = -(V_{in} + 6) \text{ V}$$

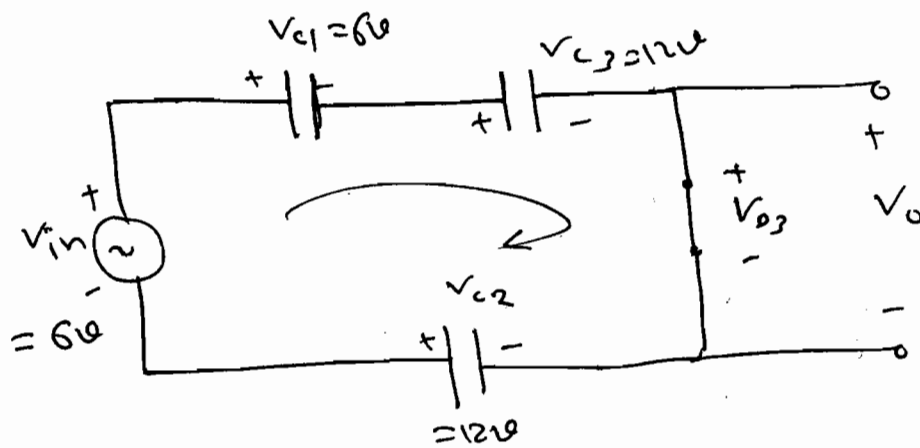
$$V_{in} \text{ range: } -6 \text{ to } +6 \text{ V}$$

$$V_{o2} \text{ range: } 0 \text{ to } -12 \text{ V}$$

* Voltage Tripler:



→ Now again in second positive cycle,



$$\therefore V_{in} - V_{C1} - V_{C3} + V_{C2} = 0$$

$$\therefore 6 - 6 - V_{C3} + 12 = 0$$

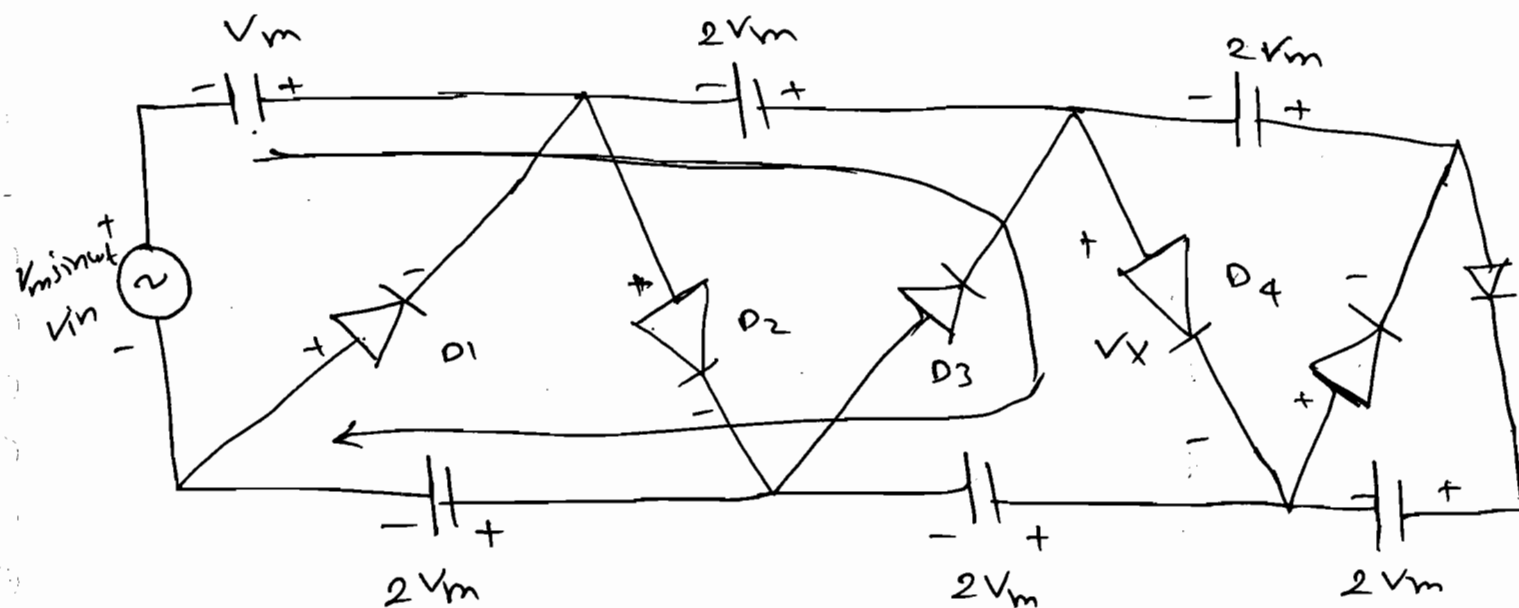
$$\therefore \boxed{V_{C3} = 12V}$$

$$\therefore V_{in} - V_{C1} - V_{C3} + V_{D3} + V_{C2} = 0$$

$$\therefore V_{in} - 6 - 12V + V_{D3} + 12V = 0$$

$$\therefore \boxed{V_{D3} = V_{in} - 6V}$$

So, Capacitor can charge up to only Voltage range of input.

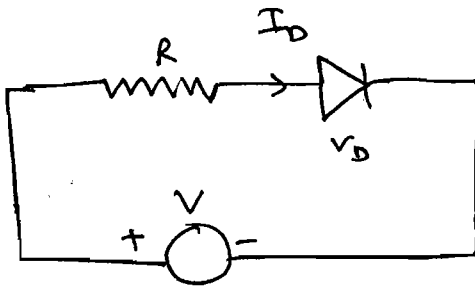


$$\therefore -V_{in} + V_m + 2V_m - V_x - 2V_m - 2V_m = 0$$

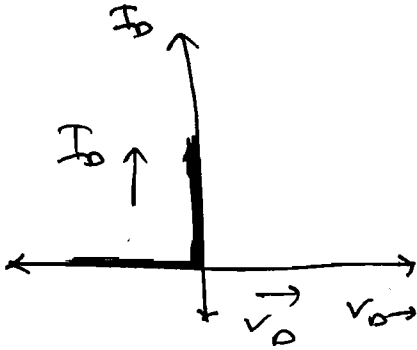
$$\therefore \boxed{V_x = V_{in} - V_m.}$$

D: 09/07/2013

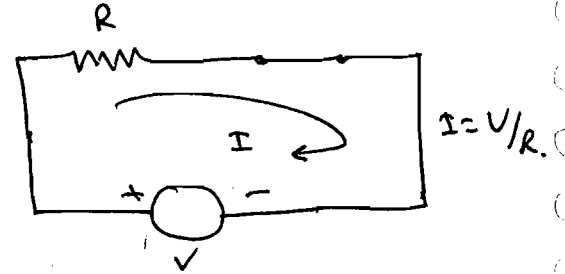
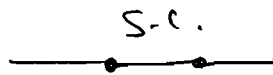
*



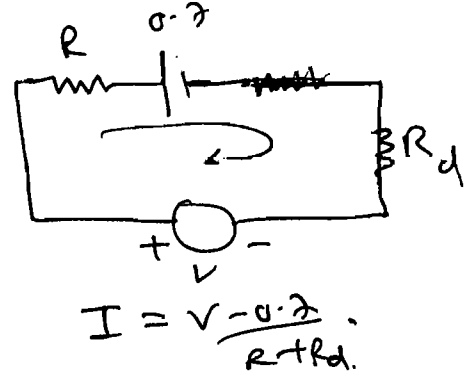
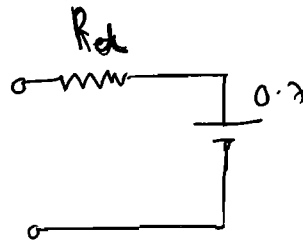
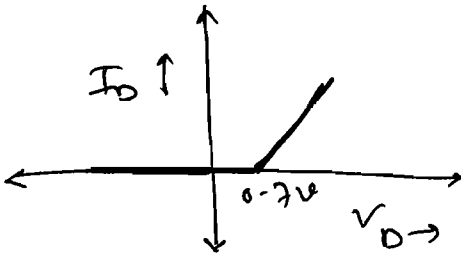
→



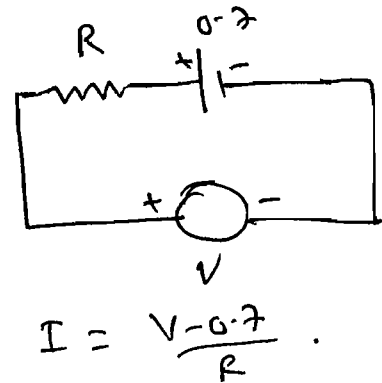
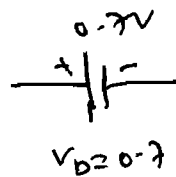
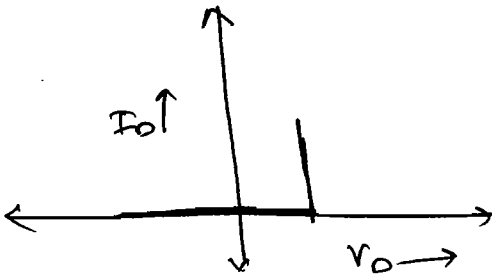
Model



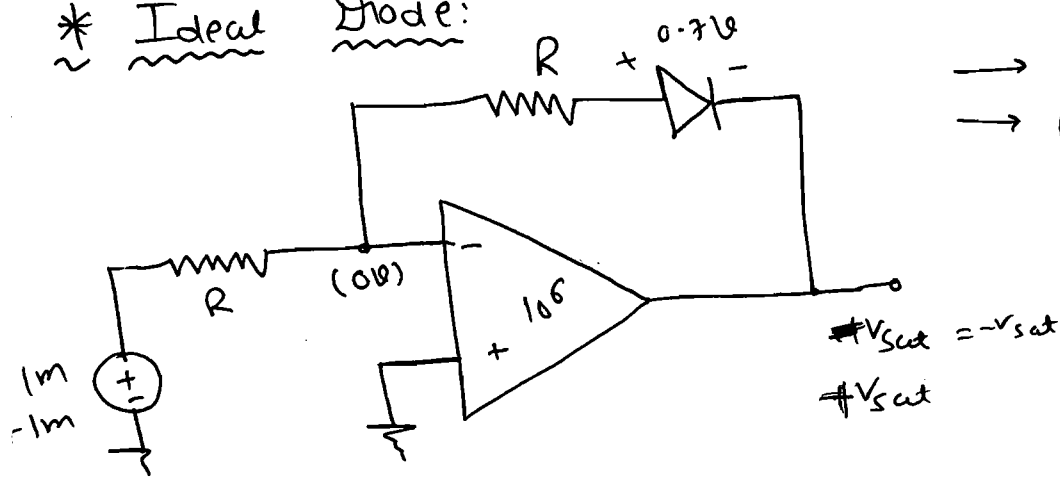
→



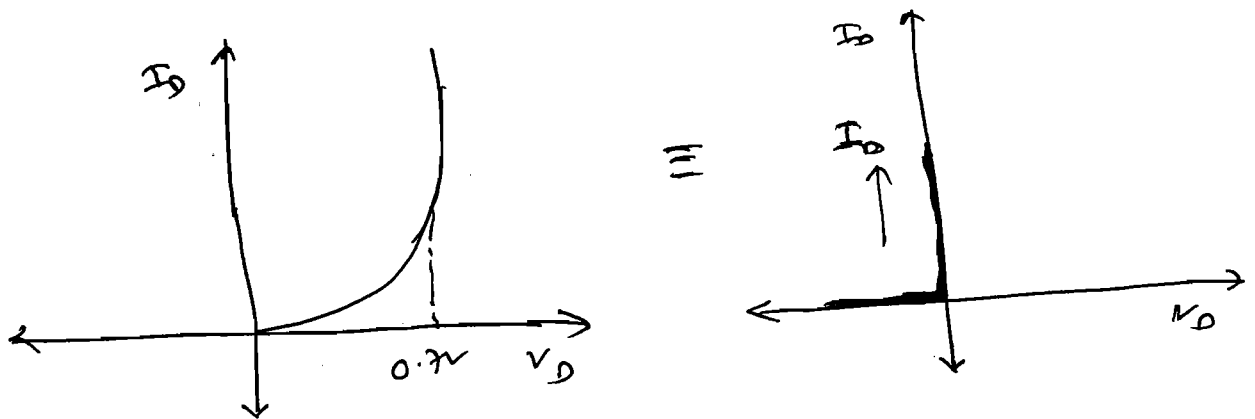
→



* Ideal Diode: 69



→ Super diode
→ Precision diode.



→ When diode is F.B. the OP-AMP is in close loop configuration.

→ But at initial stage input voltage is very small so diode is off for a very small time. and op-amp is in open loop configuration. So OLP is $V_o = A V_d$

$$\therefore V_o = 10^6 \times (1\text{mV}) \approx 1000\text{V}$$

But, V_o never exceed $\pm V_{sat}$ So.

$$\therefore V_o = -V_{sat} \quad (\because \text{inverting amp.})$$

Now, this $-V_{sat}$ make diode F.B. and OP-AMP is now in close loop configuration.

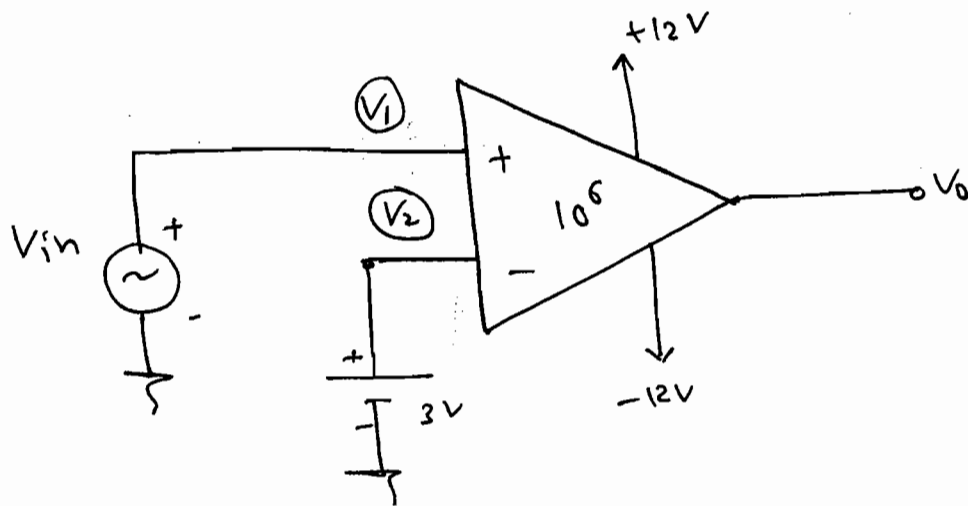
→ So, within a no time. diode will be in F.B. Condition i.e. $\frac{0.7}{10^6}$ V required to turn on the diode instead of 0.7 V.

So, for $\pm 1V$, diode will be on and it is look like a ideal diode. as shown in figure.

Note:

- Virtual ground concept apply only when ~~open~~ OP-Amp is in its ^{negative} close loop (negative feedback) configuration.
- When the diode is on then apply virtual ground concept.
- When the diode is off i.e. o.c. then OP-Amp is in open loop OP-Amp.
- ~~When~~ Can not apply virtual ground concept in the feedback also.
- When diode or BJT are driven by OP-Amp then Chua is changing to ideal diode.
- Diode and BJT can be driven by OP-Amp.
- OP-Amp is driver.

* Open loop configuration: (Comparator). 71



$$\rightarrow V_0 = A [V_1 - V_2].$$

$$\therefore V_0 = A [V_{in} - 3].$$

Case-(i) When $V_{in} > 3 \Rightarrow V_{in} - 3$ is positive.

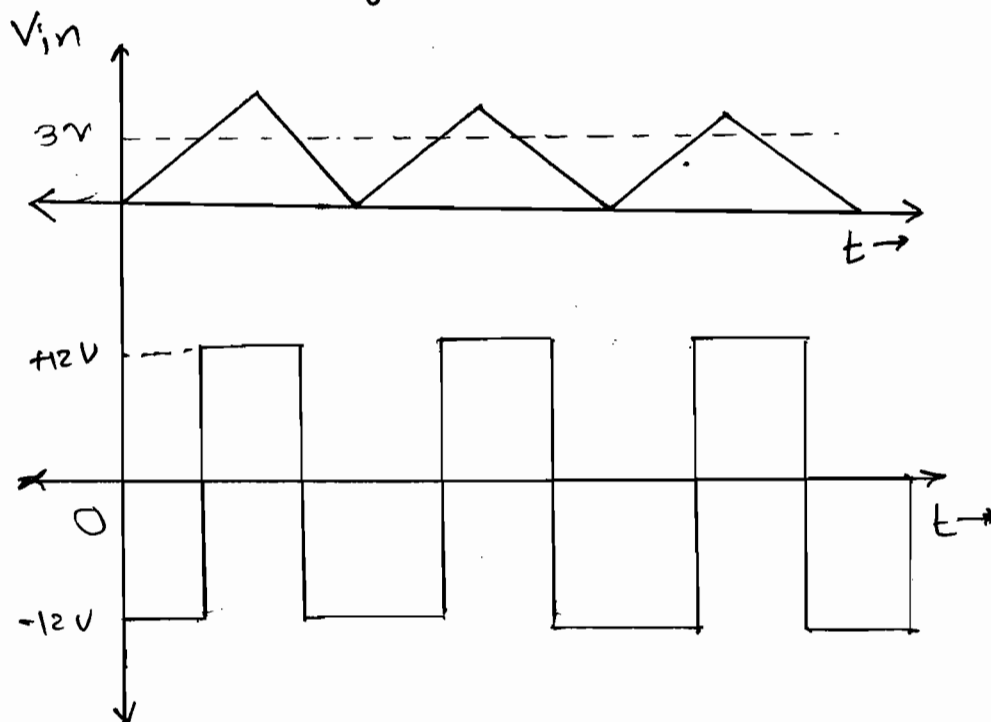
$$\rightarrow V_0 = 10^6 [\text{small pos}].$$

$$V_0 = +V_{sat} = +12V.$$

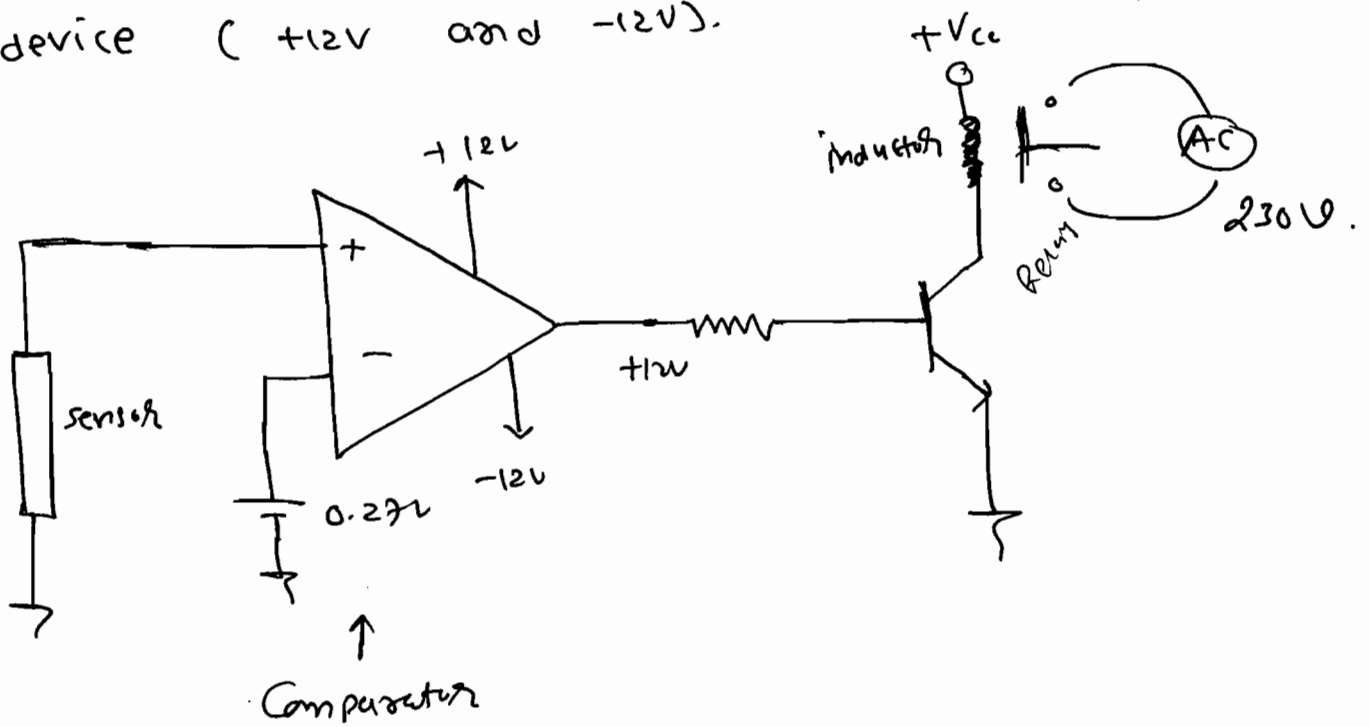
Case-(ii) When $V_{in} < 3 \Rightarrow V_{in} - 3$ is negative

$$\rightarrow V_0 = 10^6 [\text{small neg}]$$

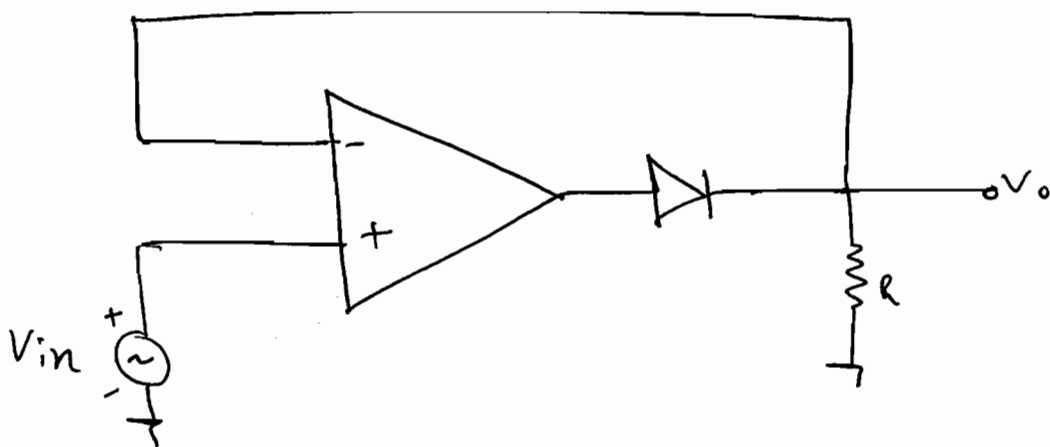
$$V_0 = -V_{sat} = -12V.$$



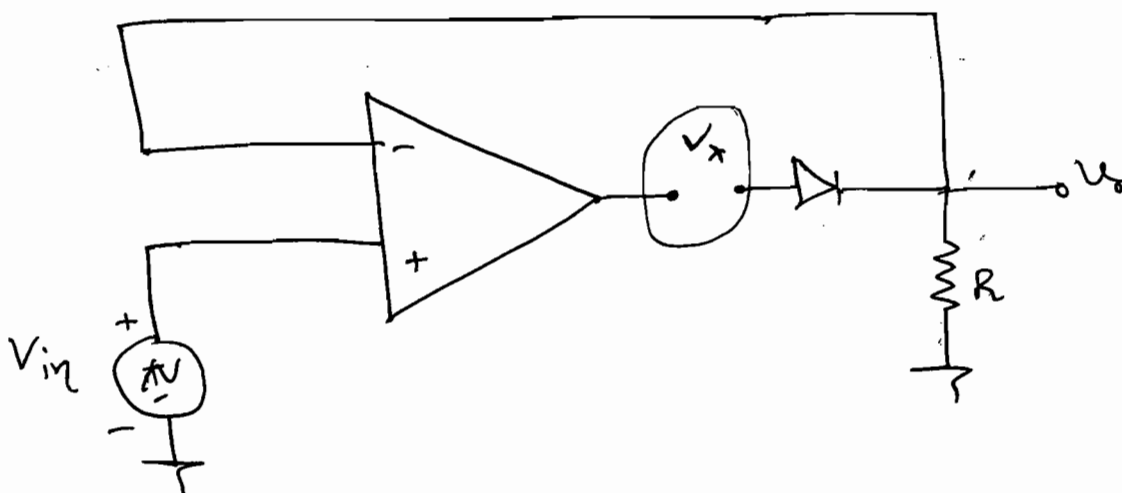
→ It is used for switching purpose for external device (+12V and -12V).



* Precision diode (Ideal Diode).



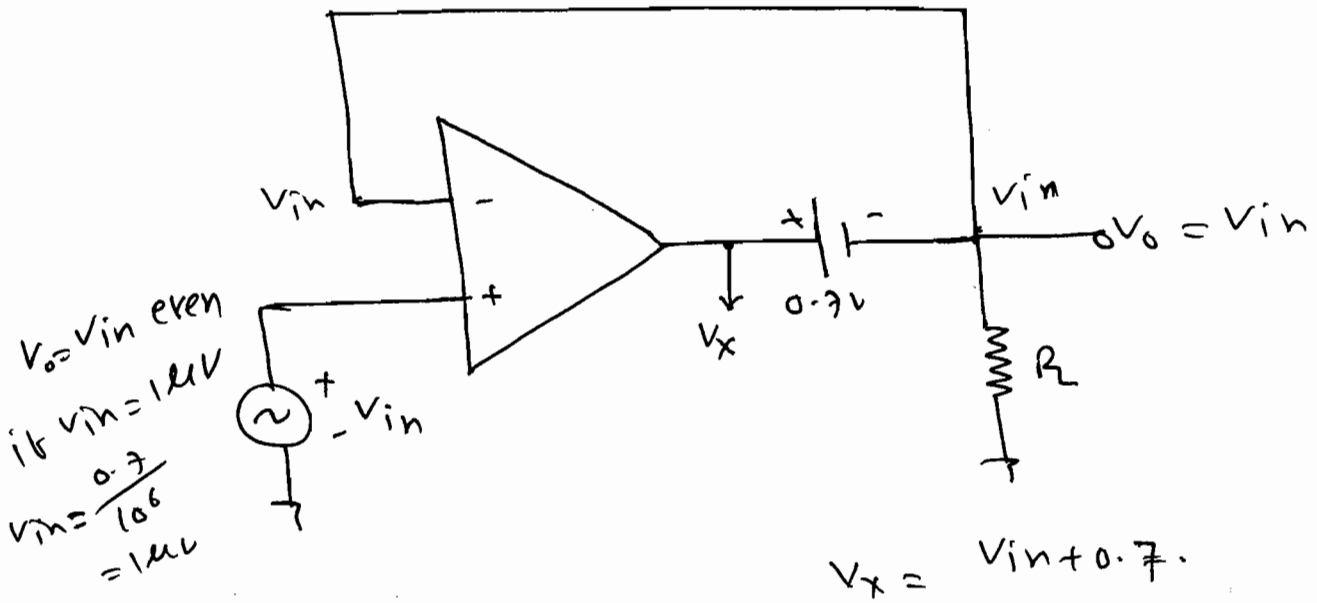
III



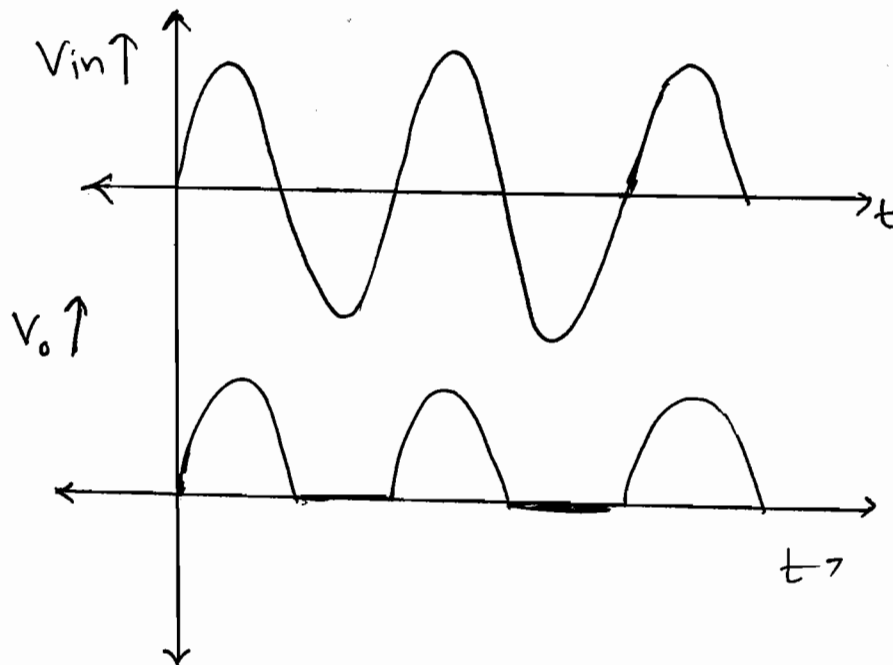
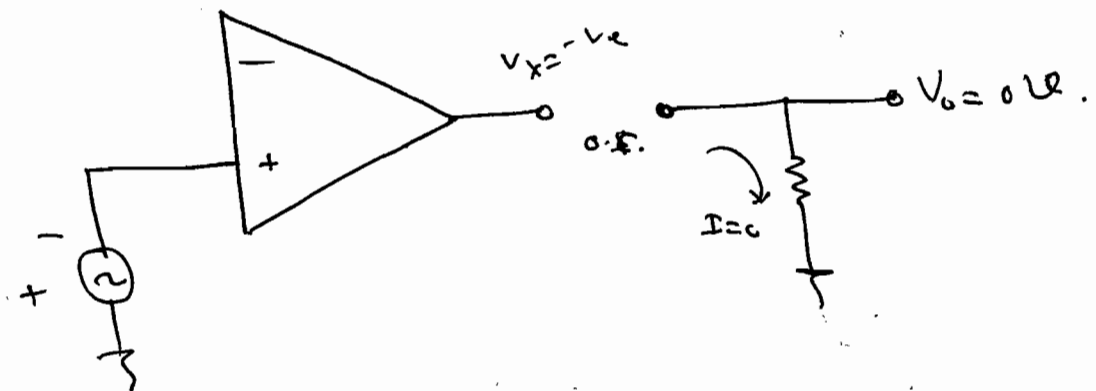
Case-1 When $V_{in} > 0 \Rightarrow V_x$ is pos.

73

$\downarrow$
Diode is F.B. (neg. F.B.).



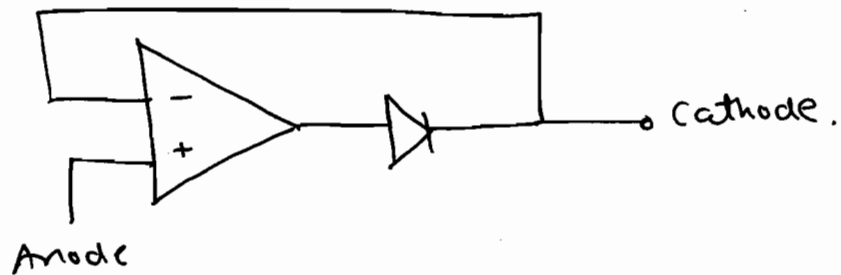
Case-(ii) $V_{in} < 0 \rightarrow V_x$ is neg $\rightarrow$ Diode is R.B.



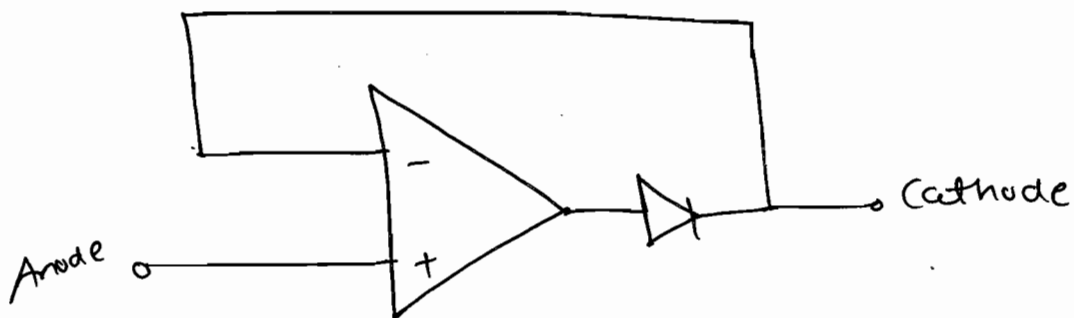
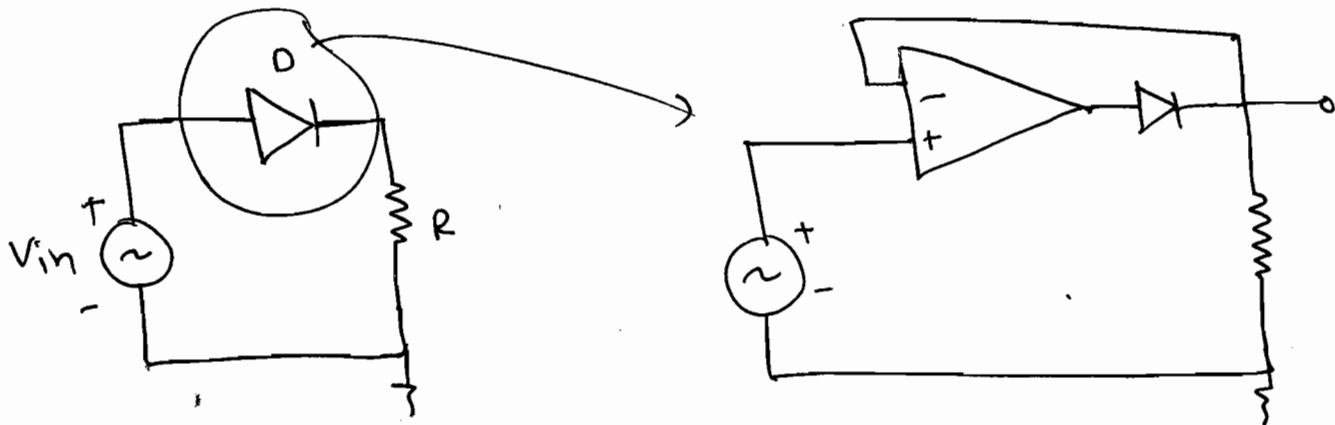
Half Wave
Rectifier.

NOTE: This circuit rectifies all voltage V_{in} slightly greater than $\frac{0.7}{A_{OL}} \approx \frac{0.7}{10^5} \approx 1 \mu V$.

*



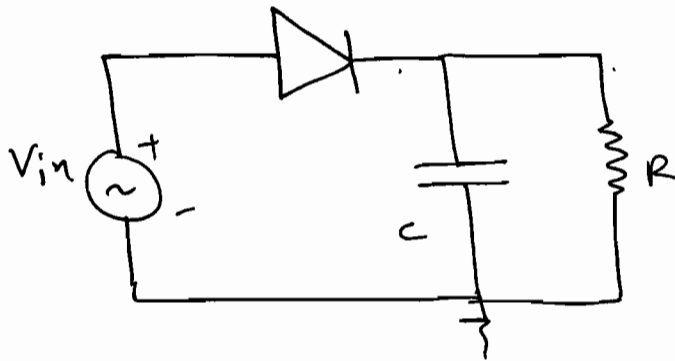
(ideal diode)



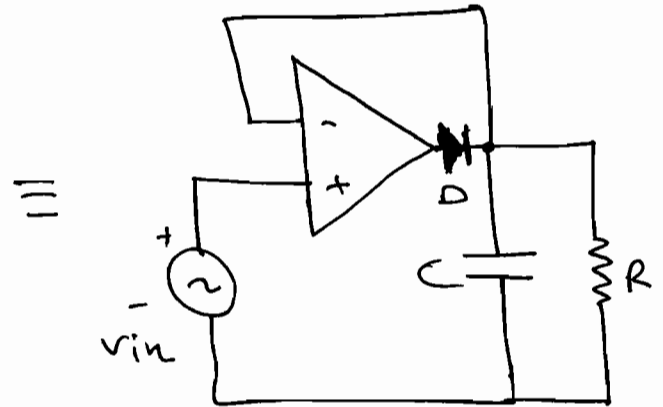
Ideal diode = op-amp + Diode.

* Peak detector (envelope detector)

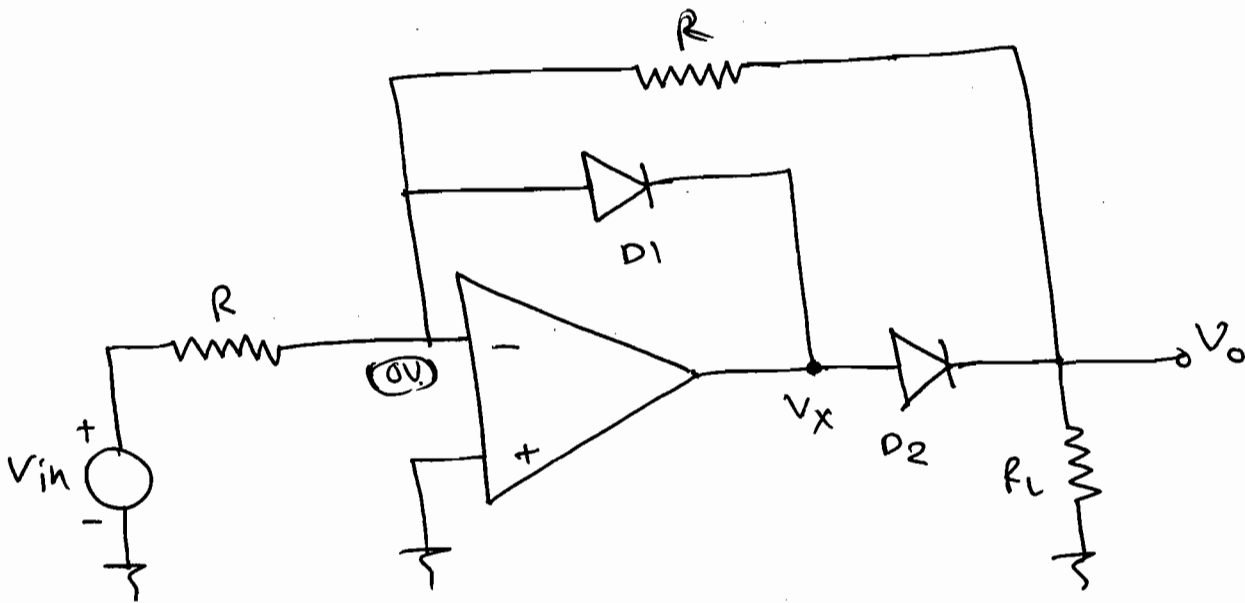
→ All Buffers have current gain.



it wait fill
0.7V



* Improved Half Wave Rectifier:



Case-(1) :

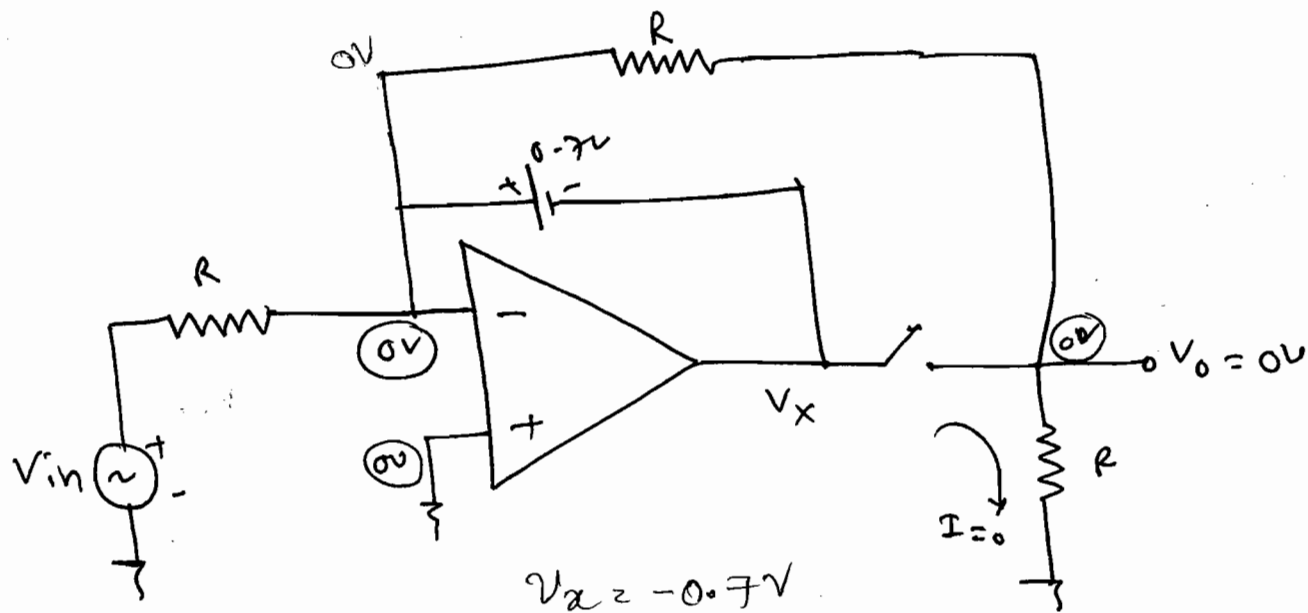
When

$$V_{in} = +ve$$

$$V_x = -ve.$$

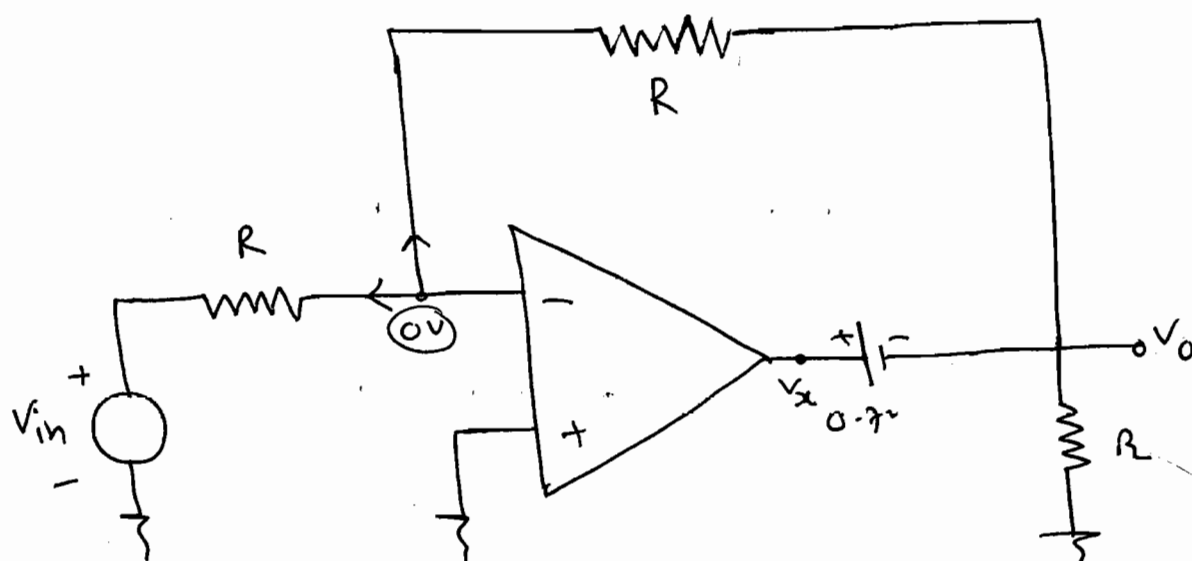
So, $D_1 \rightarrow F.B.$

$D_2 \rightarrow R.B.$



Case - 2

$$\left. \begin{array}{l} V_{in} \Rightarrow -ve \\ V_x \Rightarrow +ve \end{array} \right\} \begin{array}{l} D_1 \text{ RB} \\ D_2 \text{ FB} \end{array}$$

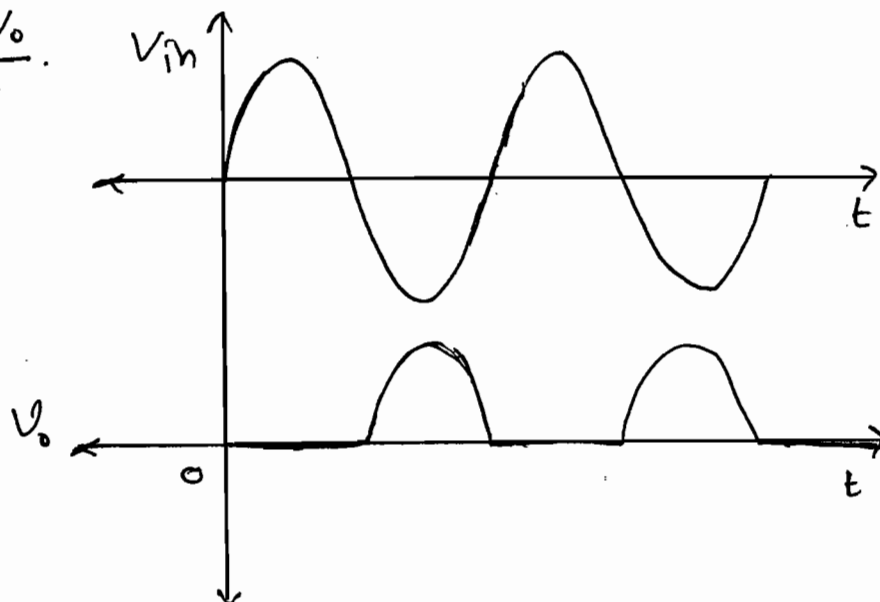


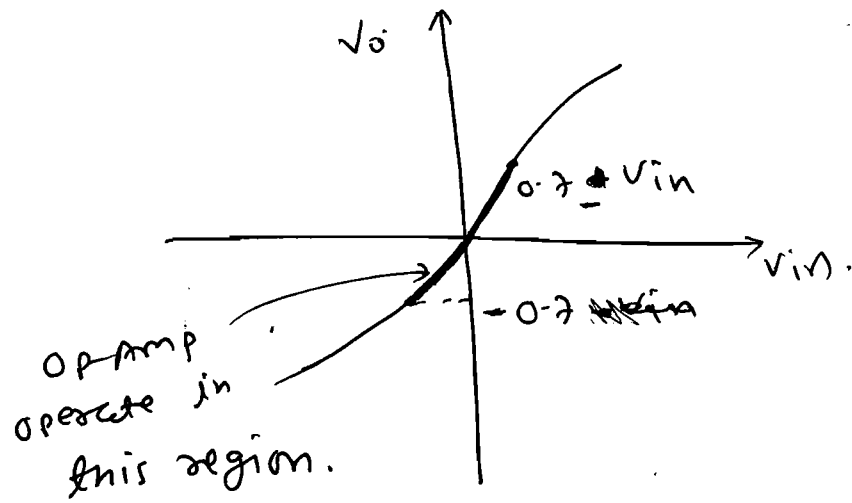
$$\frac{0 - V_{in}}{R} = \frac{0 - V_o}{R}$$

$$\therefore \boxed{V_o = -V_{in}}$$

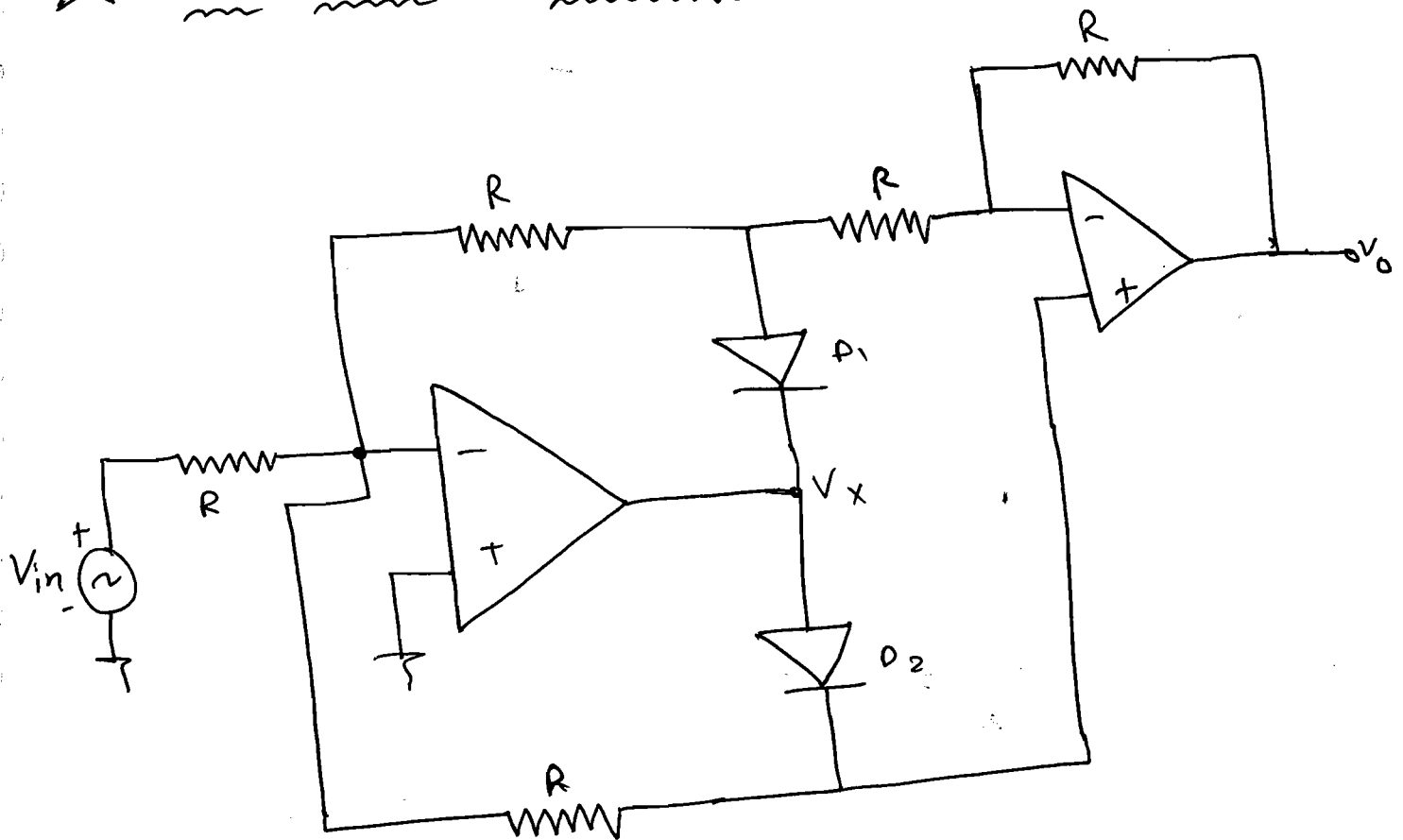
$$\therefore V_x = 0.7 + V_o$$

$$\therefore \boxed{V_x = 0.7 + V_{in}}$$



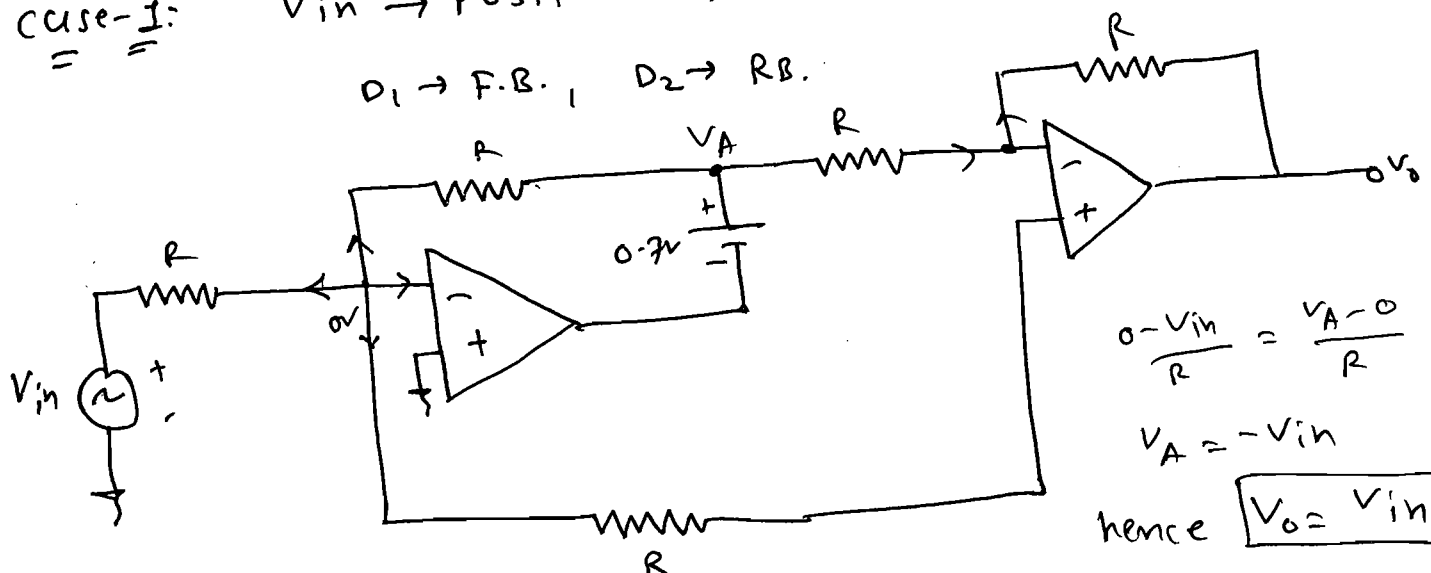


★ Full Wave Rectifier:



Case-I: $V_{in} \rightarrow \text{Positive} \Rightarrow V_x \Rightarrow -ve$

$D_1 \rightarrow \text{F.B.}, D_2 \rightarrow \text{R.B.}$



$$\frac{0 - V_{in}}{R} = \frac{V_A - 0}{R}$$

$$V_A = -V_{in}$$

hence $V_o = V_{in}$

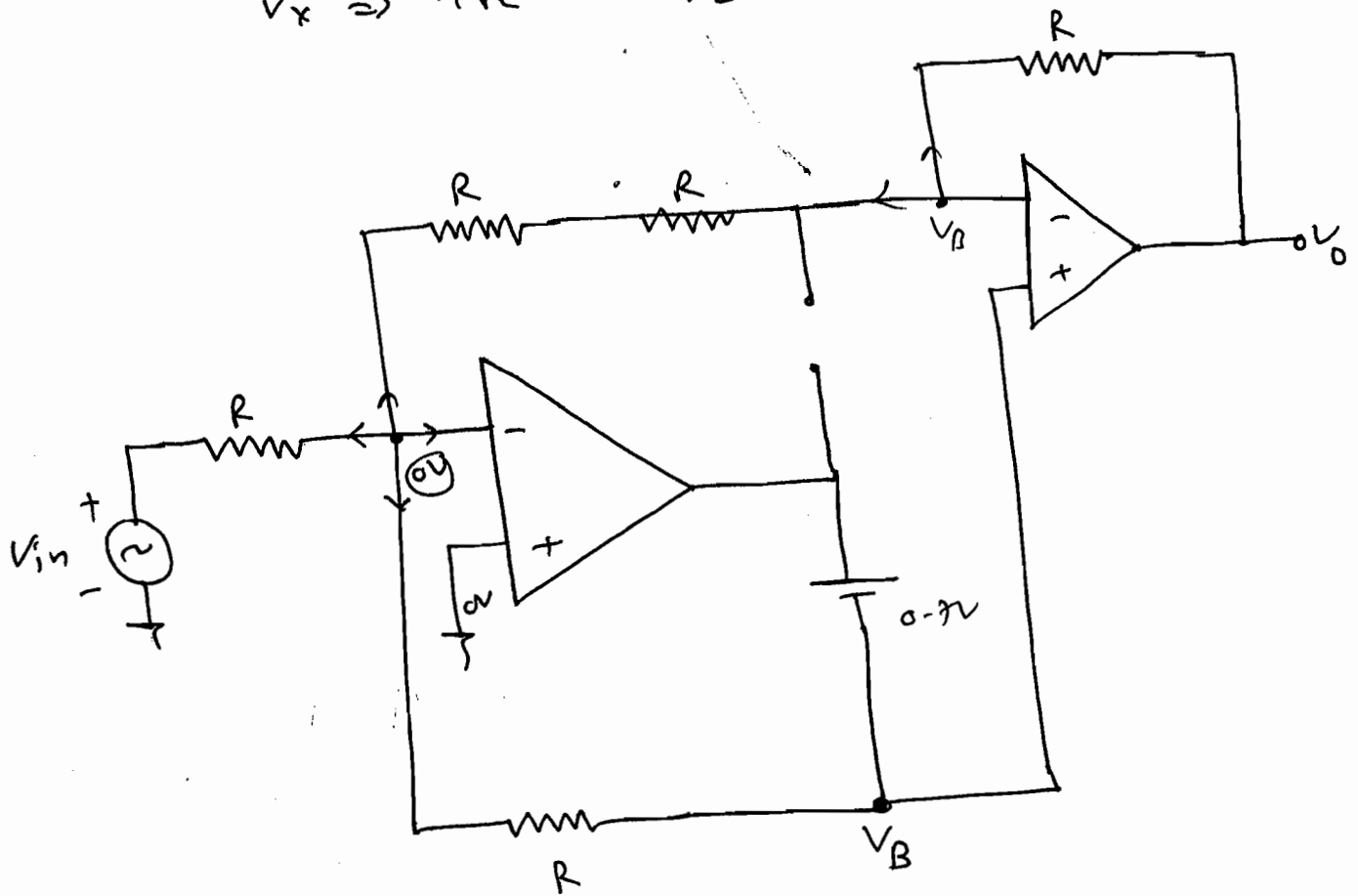
Case- 2:

$$V_{in} \Rightarrow -ve$$

$$V_x \Rightarrow +ve$$

$$D_1 = 0V$$

$$D_2 = 0V$$



$$\rightarrow \frac{0 - V_{in}}{R} + \frac{0 - V_B}{2R} + \frac{0 - V_B}{R} = 0.$$

$$\therefore -2V_{in} - V_B - 2V_B = 0$$

$$\therefore V_B = -\frac{2}{3} V_{in}.$$

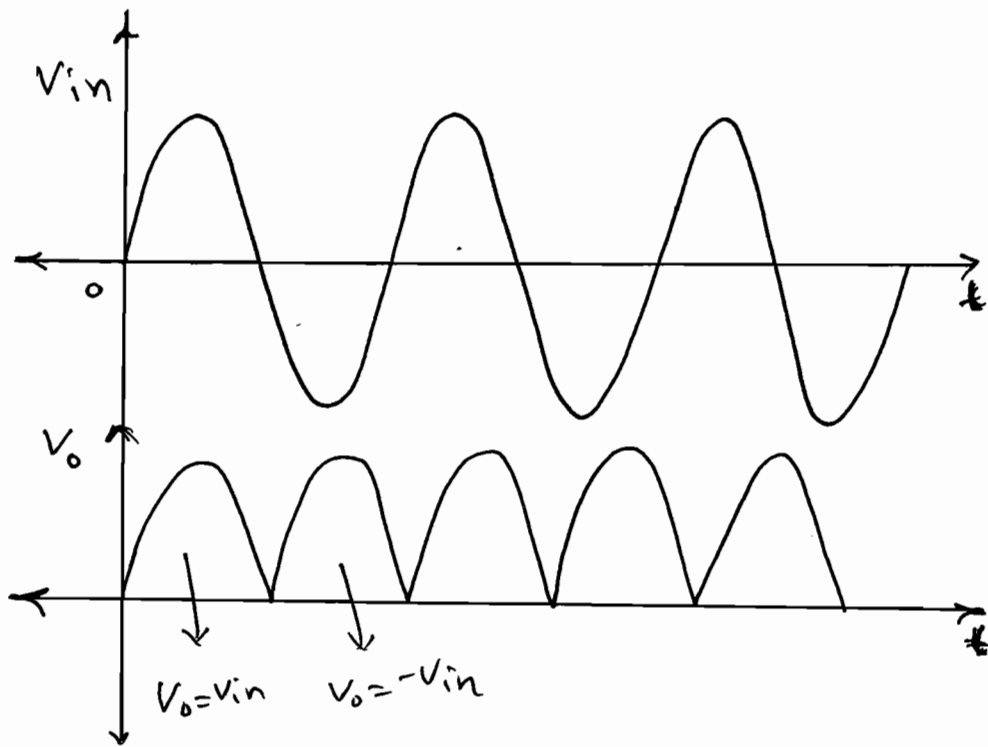
$$\rightarrow \frac{V_B - 0}{2R} + \frac{V_B - V_0}{R} = 0.$$

$$\therefore \frac{V_B}{2R} + \frac{V_B}{R} - \frac{V_0}{R} = 0.$$

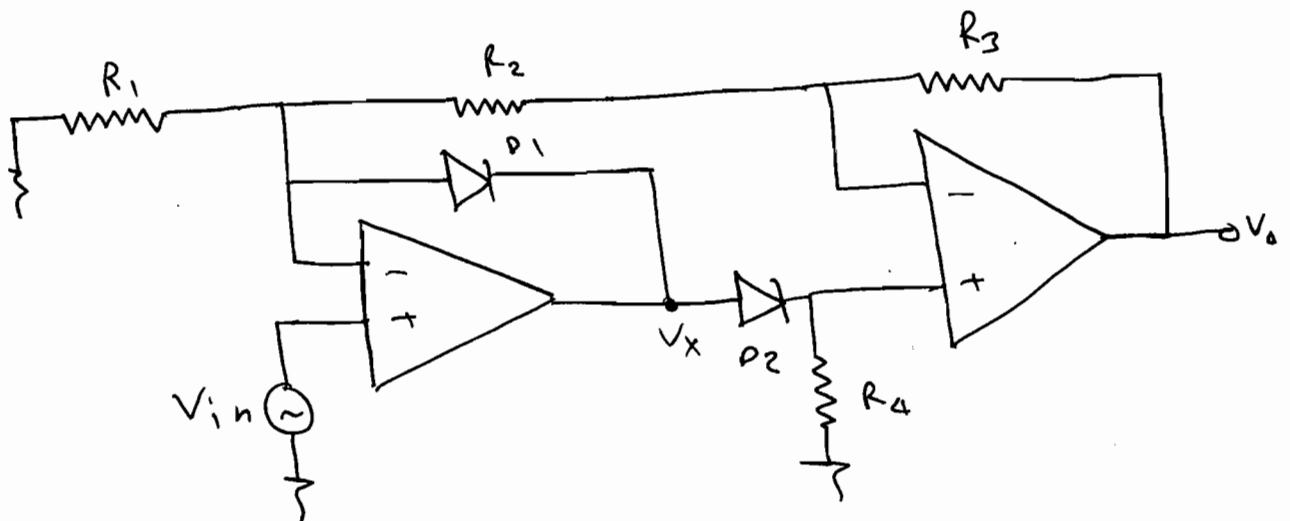
$$\therefore V_0 = \frac{3}{2} V_B.$$

$$\therefore V_0 = \frac{3}{2} \left(-\frac{2}{3} V_{in} \right)$$

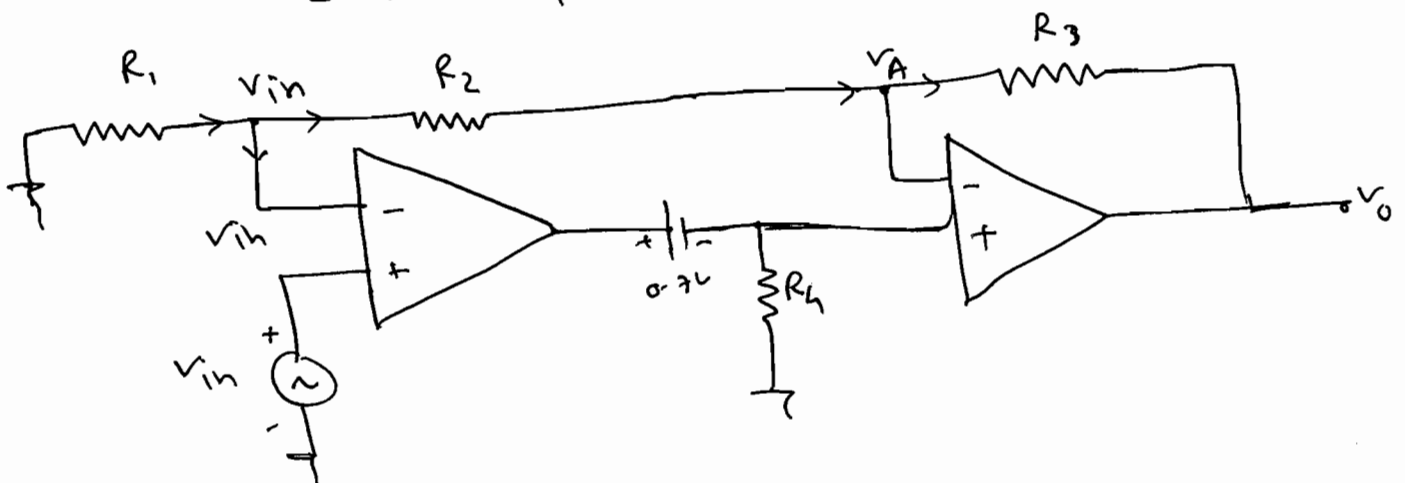
$$\therefore \boxed{V_0 = -V_{in}}$$



Ex-1 Find V_o if $V_{in} = +ve$ & $V_{in} = -ve$.



Ans: (i) When $V_{in} = +ve \Rightarrow V_x = +ve$.
 D_2 is FB, $D_1 \rightarrow RB$.



$$\frac{0 - V_{in}}{R_1} = \frac{V_{in} - V_A}{R_2}$$

$$\frac{V_A}{R_2} = \frac{V_{in}}{R_2} + \frac{V_{in}}{R_1} \quad - (1)$$

$$\frac{V_{in} - V_A}{R_2} = \frac{V_A - V_0}{R_3}$$

$$\therefore \frac{V_{in}}{R_2} = \frac{V_A}{R_2} + \frac{V_A}{R_3} - \frac{V_0}{R_3}$$

$$\therefore V_A \left[\frac{R_2 + R_3}{R_2 \cdot R_3} \right] = \frac{V_{in}}{R_2} + \frac{V_0}{R_3}$$

x

$$\therefore V_A = \left[\frac{V_{in}}{R_2} + \frac{V_0}{R_3} \right] \times \frac{R_2 \cdot R_3}{R_2 + R_3} \quad - (2)$$

$\therefore$ Put (2) in (1)

$$\frac{R_3}{R_2 + R_3} \left[\frac{V_{in}}{R_2} + \frac{V_0}{R_3} \right] = \frac{V_{in}}{R_2} \left[\frac{R_1 + R_2}{R_2 \cdot R_3} \right]$$

$$\therefore \frac{R_3}{R_2(R_2 + R_3)} V_{in} + \frac{V_0}{R_2 + R_3} = V_{in} \left[\frac{R_1 + R_2}{R_2 \cdot R_3} \right]$$

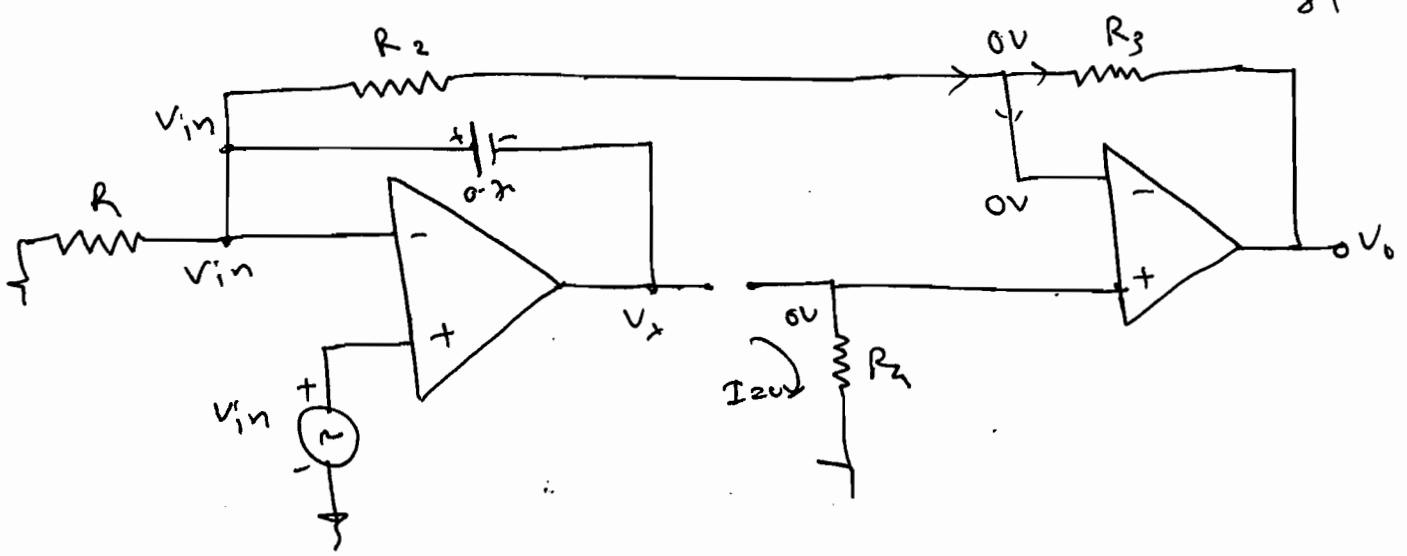
$$\frac{0 - V_{in}}{R_1} = \frac{V_{in} - V_0}{R_2 + R_3}$$

$$\therefore \frac{-V_{in}(R_2 + R_3)}{R_1} = \frac{R_1(V_{in}) - R_1 V_0}{R_2 + R_3}$$

$$\therefore R_1 V_0 = V_{in}(R_1 + R_2 + R_3)$$

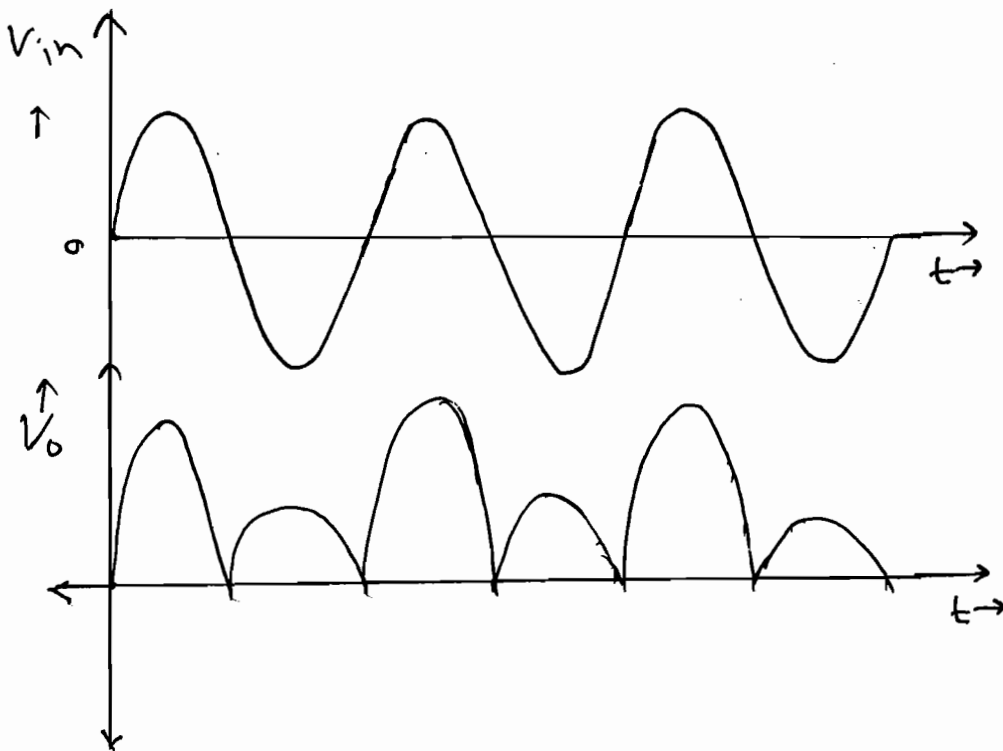
$$\therefore \boxed{V_0 = \frac{R_1 + R_2 + R_3}{R_1} V_{in}}$$

- ② when $V_{in} = -V_e$
 $V_x \Rightarrow +V_e$
 $R_2 \rightarrow I.B.$
 $R_1 \rightarrow F.B.$

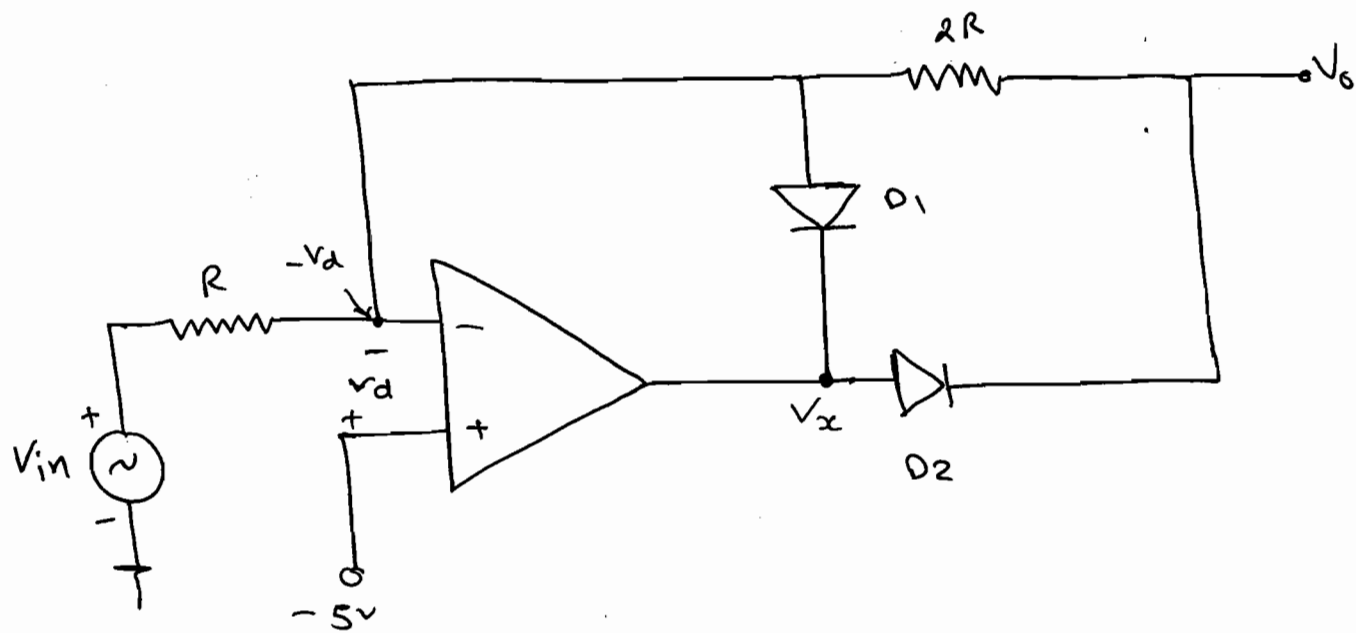


$$\therefore \frac{V_{in} - 0}{R_2} = \frac{0 - V_o}{R_3}$$

$$\therefore \boxed{\frac{V_o}{V_{in}} = -\left(\frac{R_3}{R_2}\right)} \Rightarrow V_o = -\left(\frac{R_3}{R_2}\right)V_{in}$$



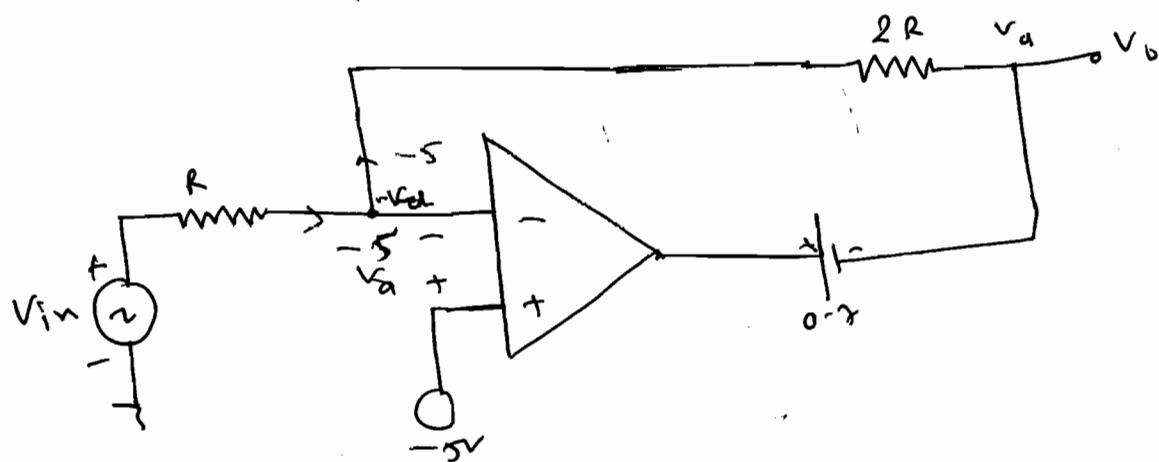
Ex-2



Ans: Case-(i) $V_d > 0$, $V_d = -V_{in} - 5 > 0$
 $V_{in} < -5V$.

$$V_d > 0 \Rightarrow V_x = +ve.$$

$\therefore D_1 \rightarrow R.B. \quad D_2 \rightarrow F.B.$



$$\therefore \frac{V_{in} - (-V_d)}{R} = \frac{-V_d - V_o}{2R} \quad V_d = 5$$

$$\therefore 2V_{in} + 2V_d = -V_d - V_o$$

$$3V_d = -V_o - 2V_{in}$$

$$15 = -V_o - 2V_{in}$$

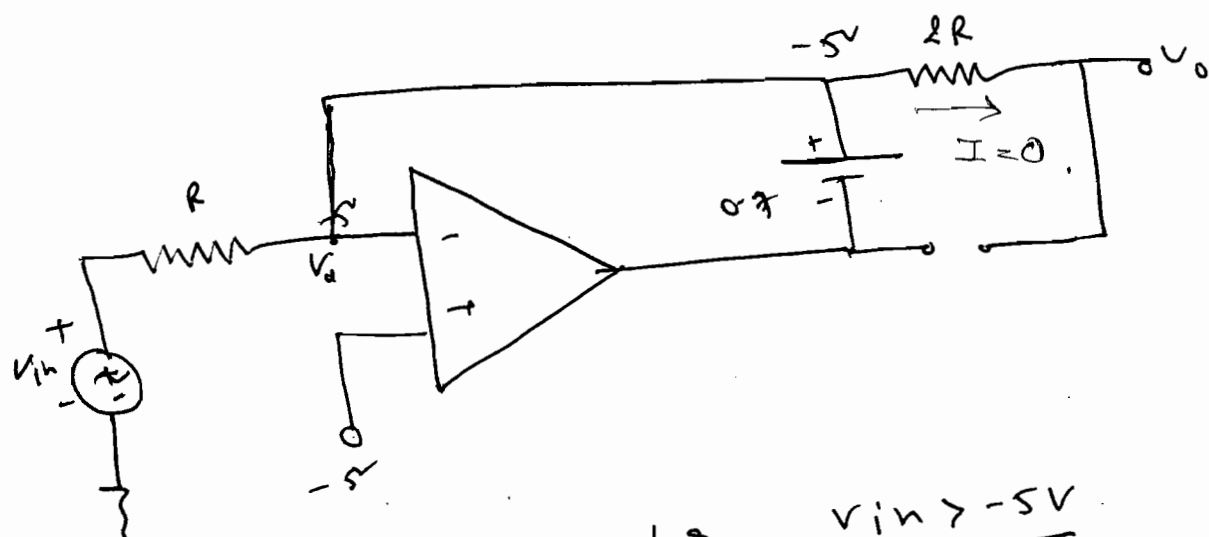
$$\therefore \boxed{V_o = -(15 + 2V_{in})}$$

for $V_{in} < -5$.

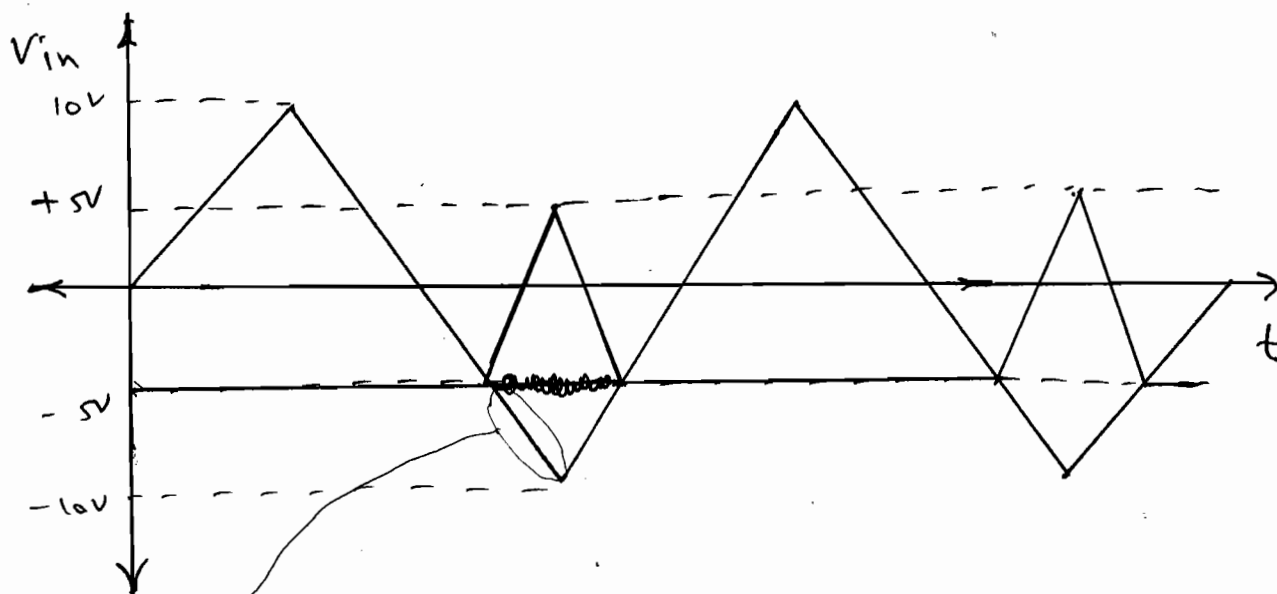
②

$V_{in} > -5 \Rightarrow$
 $2V_d < 0$
 $D_1 = R.B.$
 $D_2 = R.B.$

$$V_x = -ve$$



So, $V_0 = -5V$ for $V_{in} > -5V$

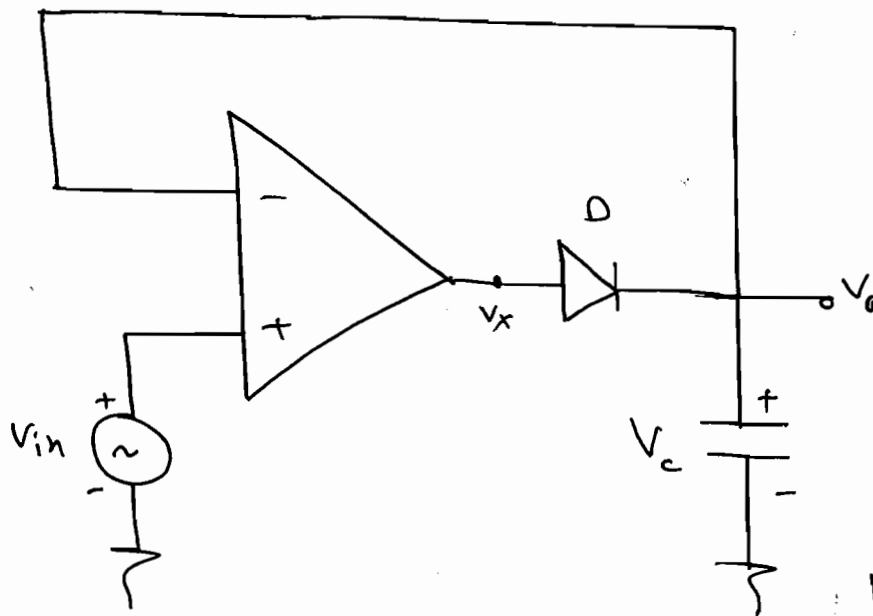


$V_{in} < -5 \rightarrow$

V_{in}	$V_0 = -(2V_{in} + 5)$
-5	-5
-6	-3
-7	-1
-8	+1
-9	+3
-10	+5

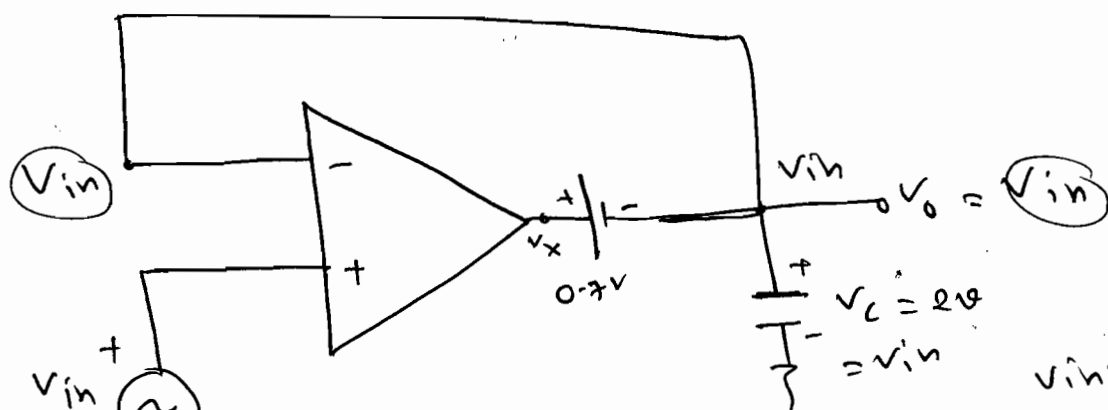
* Peak Detector:

⇒



$$V_x = V_{in} + V_c$$

⇒ Case (1): When $V_{in} > V_c$. V_x is +ve.
 $D \rightarrow$ F.B.



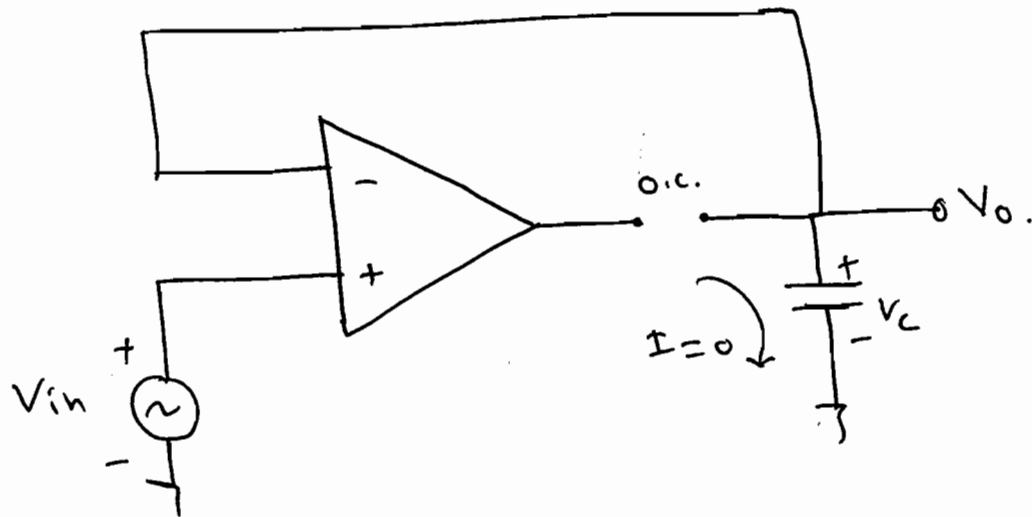
$$V_o = V_{in}$$

Capacitor charges to new value
 $V_{in} > V_c$ i.e. 3V.

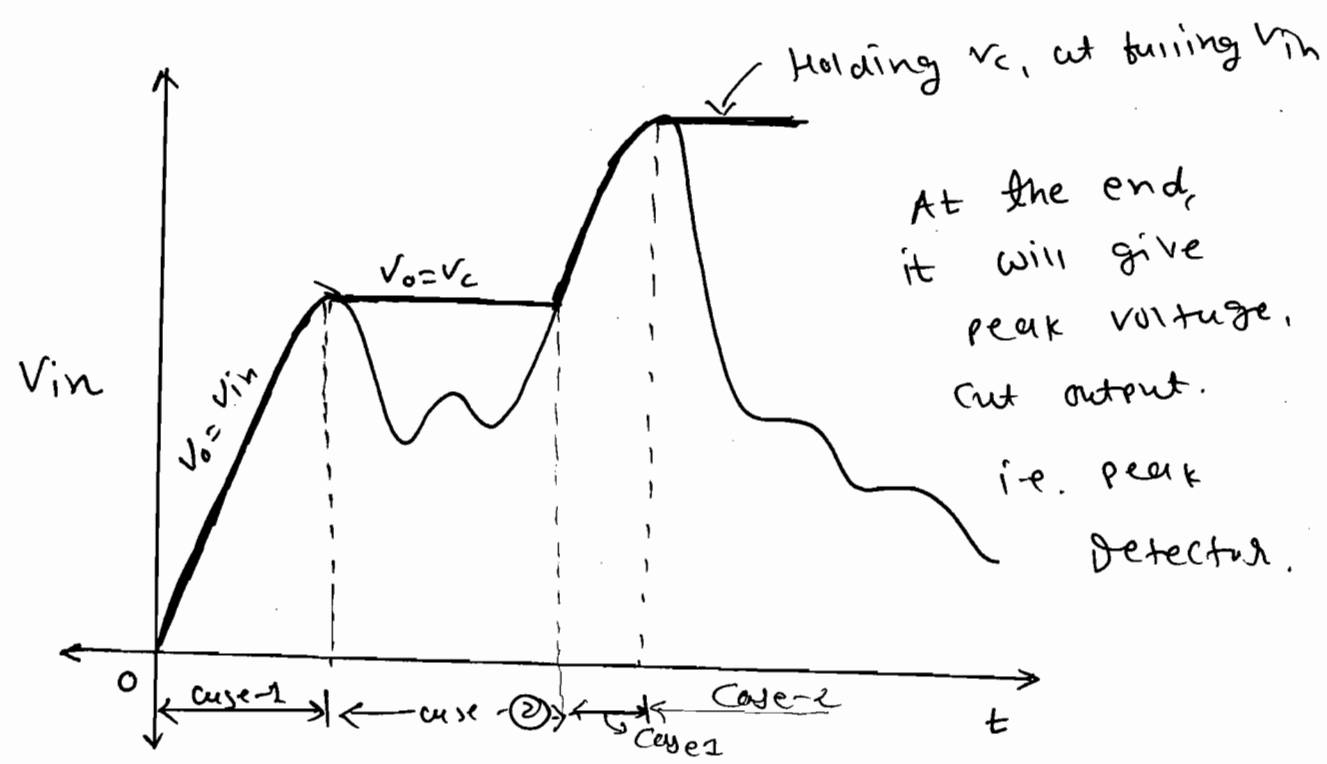
Case-2: When $V_{in} < V_c$.

$\therefore D \rightarrow$ R.B. ($\because V_x = -ve$).

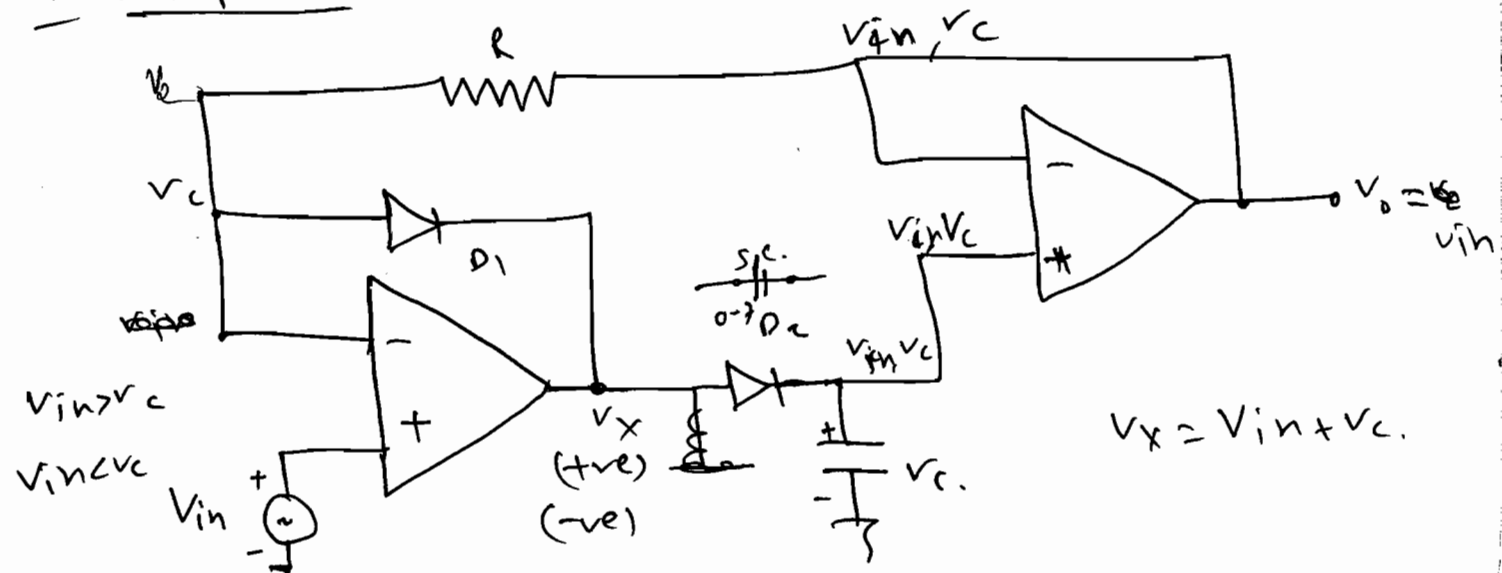
diode $\rightarrow$ R.B.



So, $V_o = V_c$ until $V_{in} > V_c$.



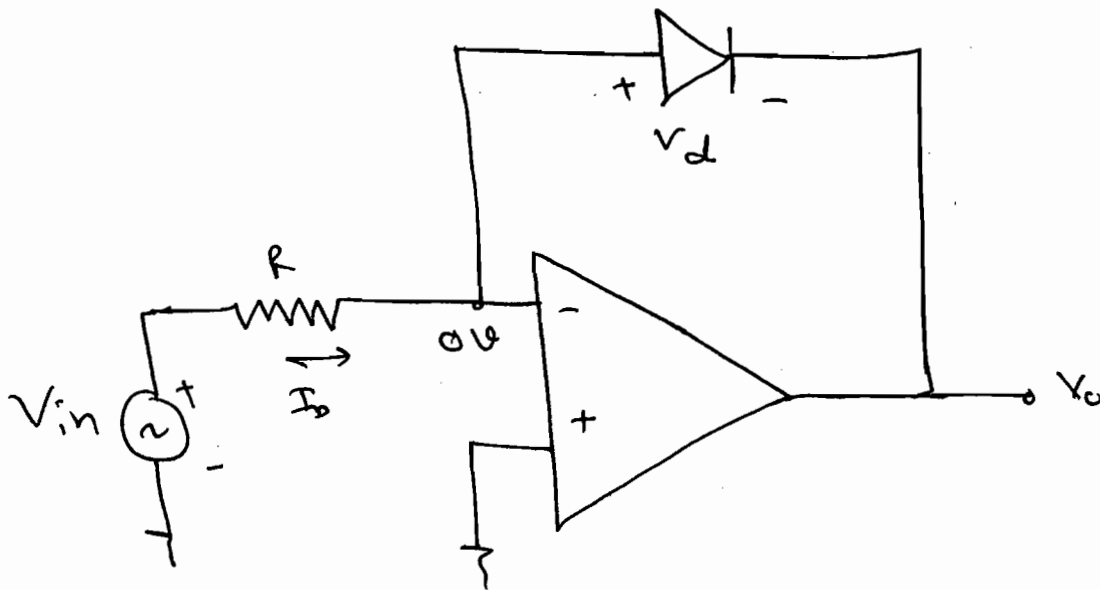
* Improved peak Detector:



★ Log Amplifier:

$$I_d = I_s e^{\frac{V_d}{V_T}}$$

$$V_d = V_T \ln \left(\frac{I_d}{I_s} \right)$$



$$0 - V_o = V_d$$

$$\boxed{V_D = -V_o}$$

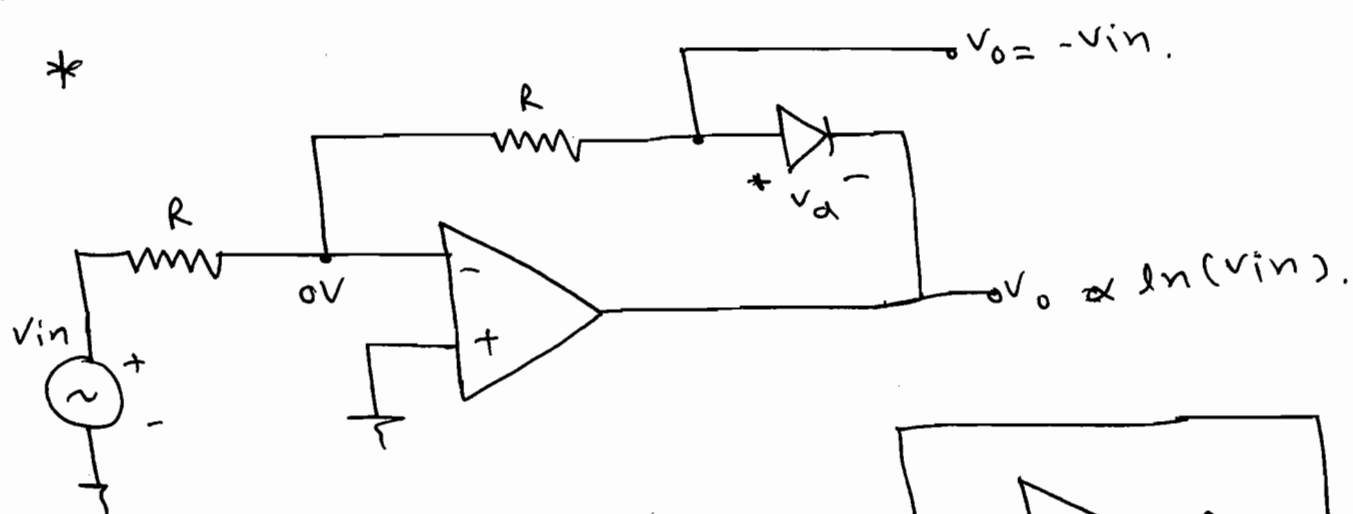
$$\therefore I_D = \frac{V_{in} - 0}{R}$$

$$I_D = \frac{V_{in}}{R}$$

Now, $V_d = V_T \ln \left(\frac{I_D}{I_s} \right)$

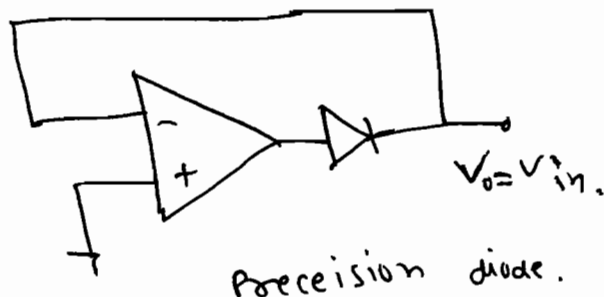
$$\therefore V_o = -V_T \ln \left[\frac{V_{in}}{R I_s} \right]$$

$$\boxed{V_o \propto \ln(V_{in})}$$



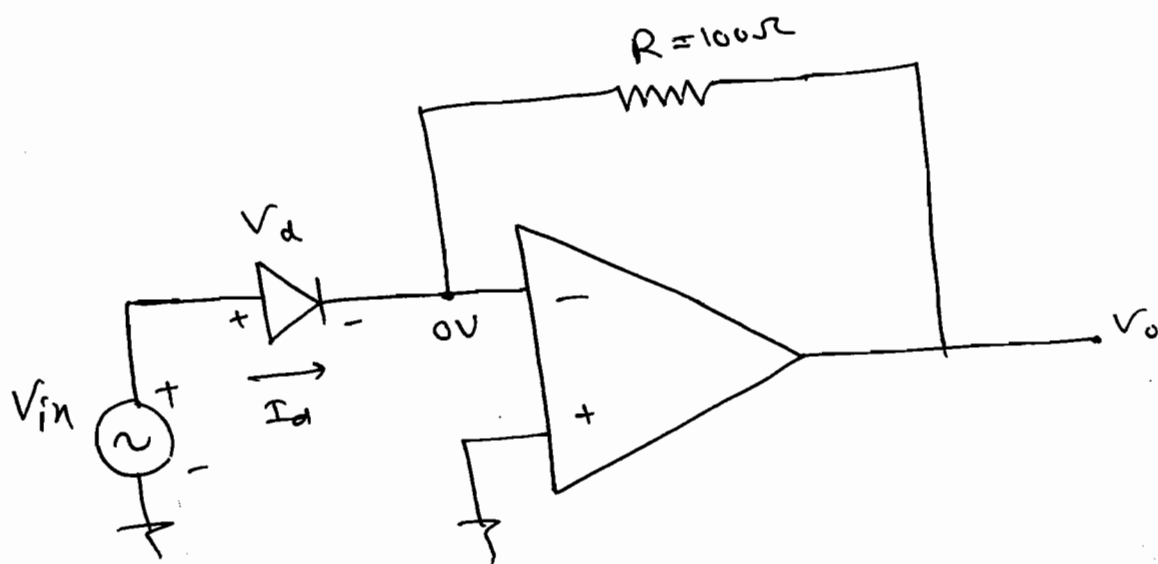
$$\frac{0 - V_{in}}{R} + \frac{0 - V_o}{R} = 0.$$

$$\therefore \boxed{V_o = -V_{in}}.$$



→ If we involve V_d in op then it is log operation otherwise precision diode.

Exponential Amplifier:



$$\therefore I_d = \frac{0 - V_o}{R}.$$

$$\therefore V_o = -R I_d \quad V_o / V_e.$$

$$\therefore V_o = -R I_s e^{V_{in}/V_t}$$

$$\therefore V_o = -R I_s e^{V_{in}/V_t}$$

But $V_d = V_{in}$

$$\boxed{V_o \propto e^{V_{in}}}$$

Now $\eta = 1$, $V_t = 25 \text{ mV}$, $I_s = 10^{-13} \text{ A}$, $V_{ih} = 0.6 \text{ V}$

$$\therefore V_0 = -100 \times 10^{-13} \left[e^{\frac{0.68}{25 \times 10^{-3}}} \right]$$

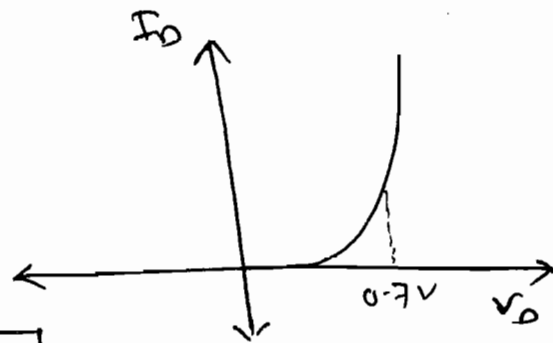
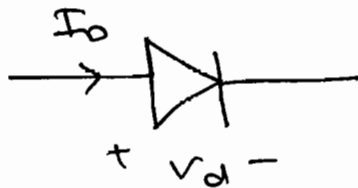
$$\therefore \boxed{V_0 = -6.5 \text{ V}}$$

★ Small Signal Analysis:-

→ Amp is linear operation.

→ Nonlinear devices are as follow:

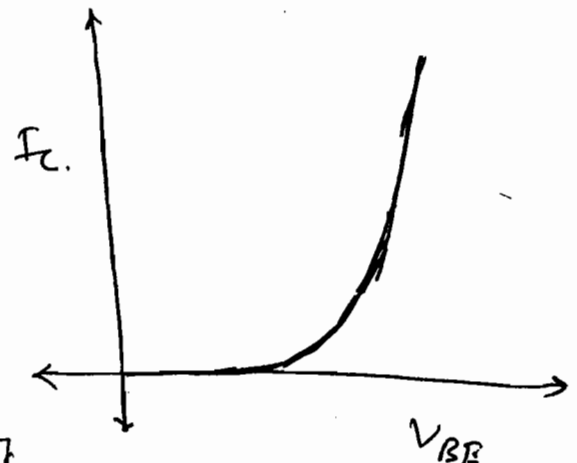
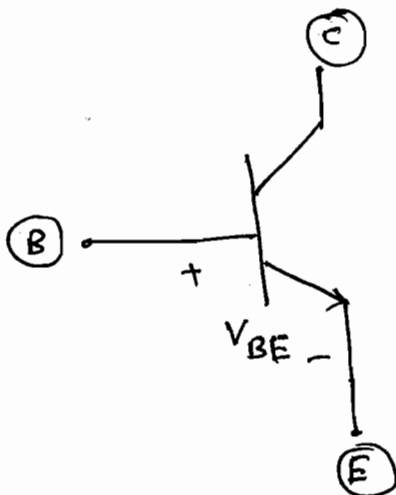
(1) Diode:



$$\boxed{I_D = I_s \cdot e^{V_D/V_t}}$$

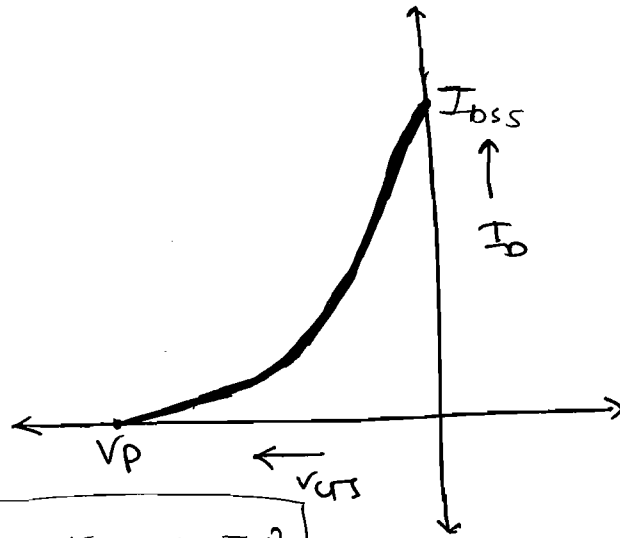
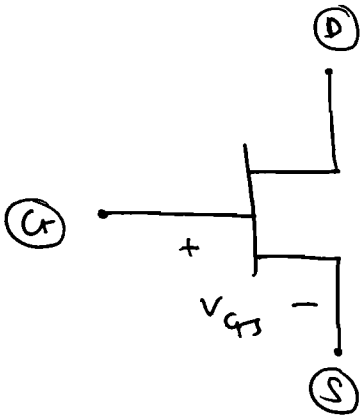
(2)

BJT:



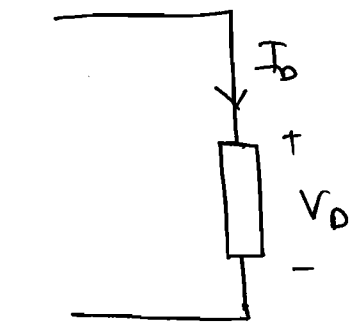
$$\boxed{I_C = I_s \cdot e^{V_{BE}/V_t}}$$

③ FET:

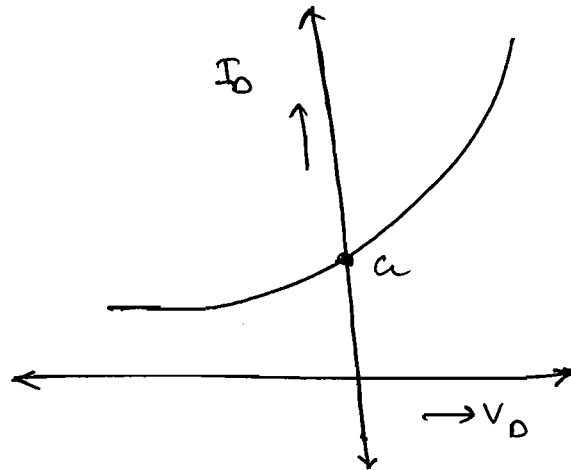


$$I_D = I_{DSS} \left[1 - \frac{V_{GS}}{V_P} \right]^2$$

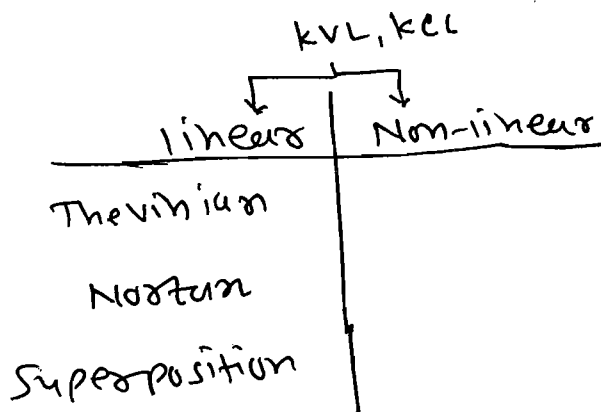
*



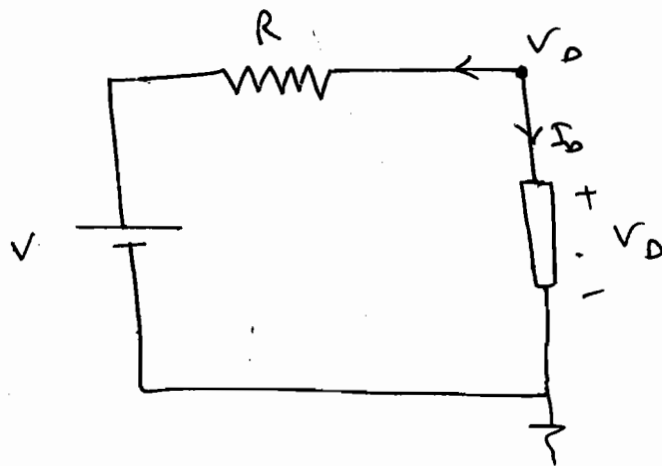
$$I_D = I_S e^{bV_D}$$



*



* Dc Analysis:



KCL, $\frac{V_D - V}{R} + I_D = 0$ ①

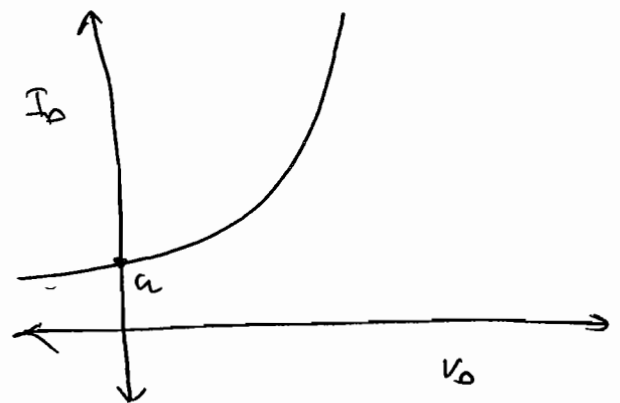
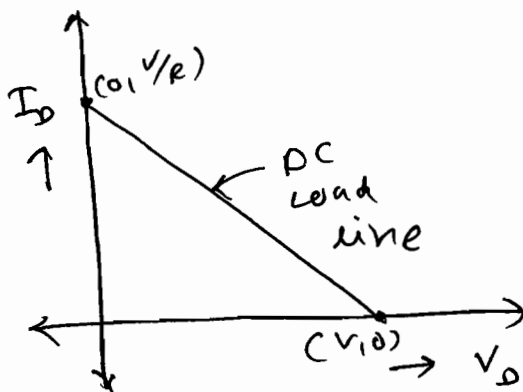
Now, $I_D = \frac{V_D}{R}$ or bV_D

$$\therefore \frac{V_D - V}{R} + bV_D = 0$$

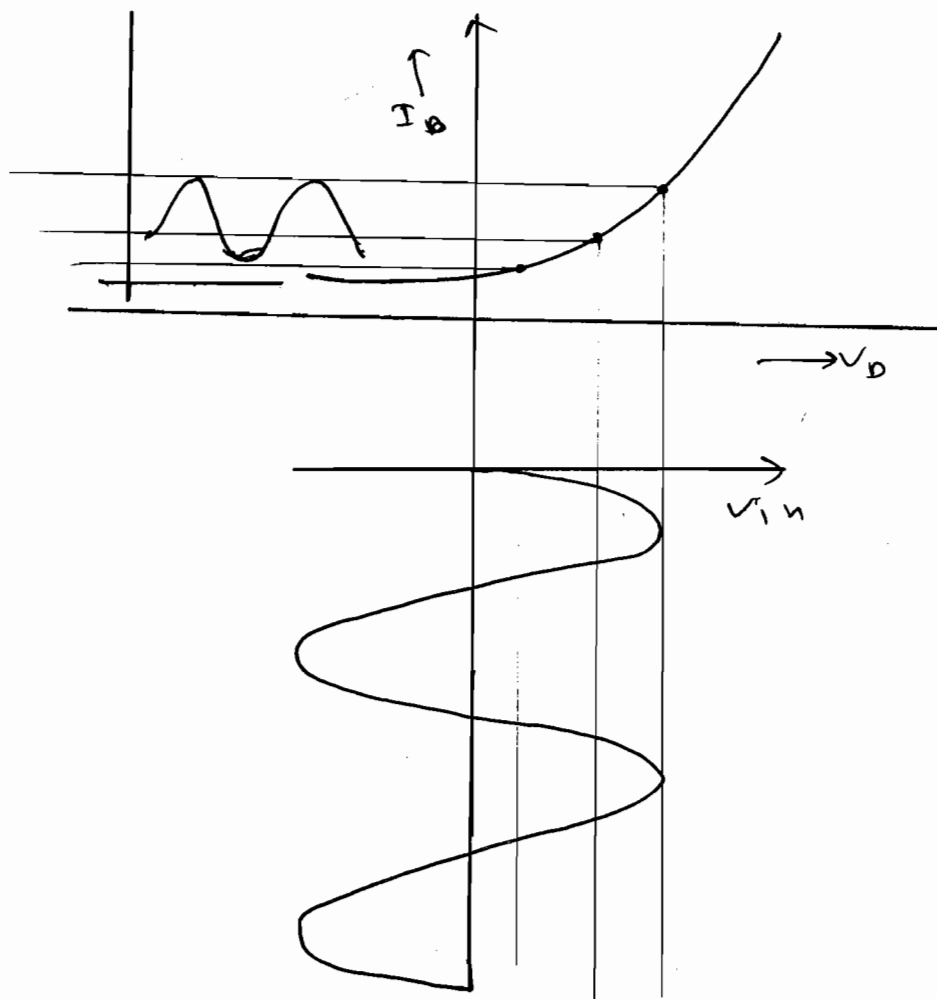
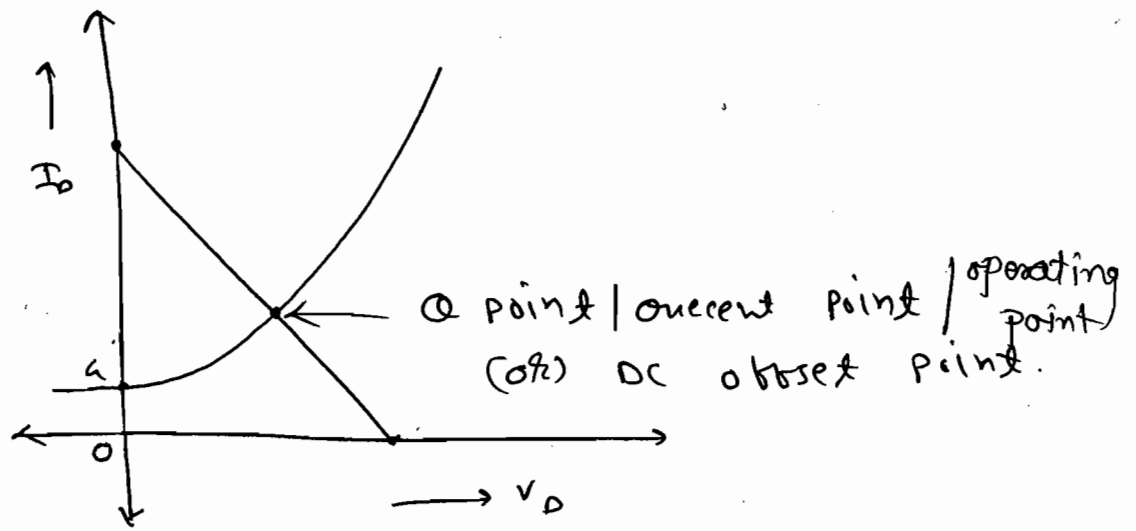
Solve by ① trial and error.

② Iteration [Numerical method].

* Graphical:

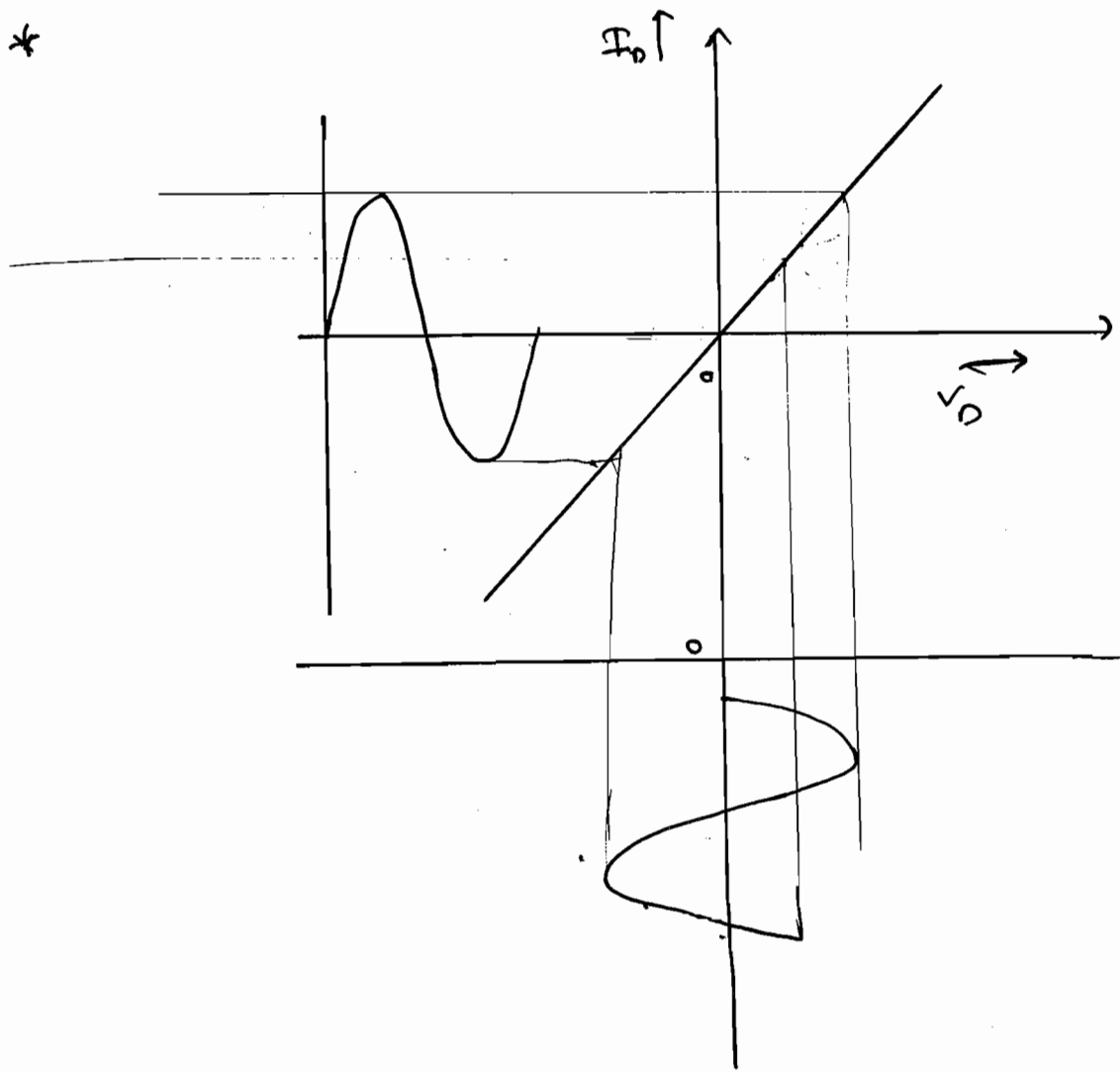


V_D	I_D
V	0
0	V/R

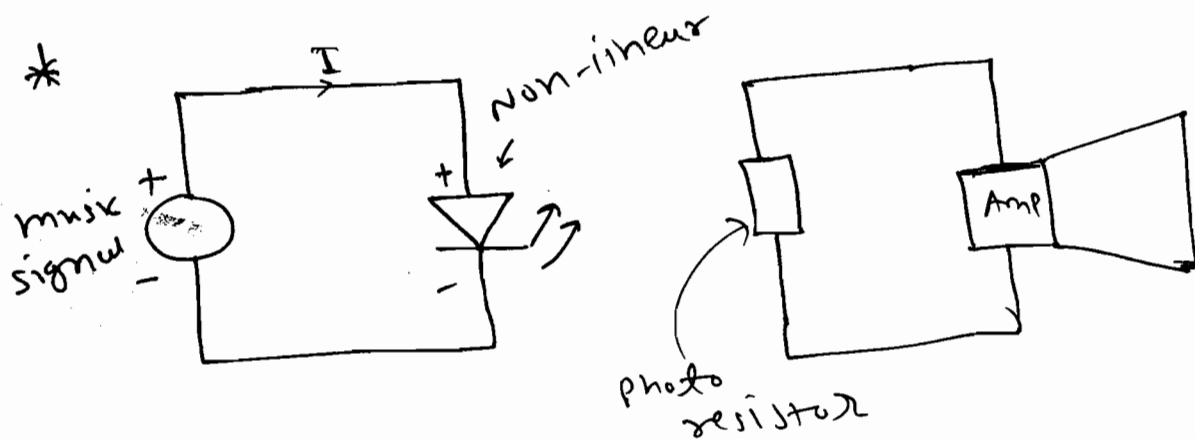


→ In order to get same shape at output, the characteristic must be linear. So, BJT, and MOS are active devices but they are non-linear devices and they do not give the same shape as input if the input signal is very large. So, some solution is required.

*



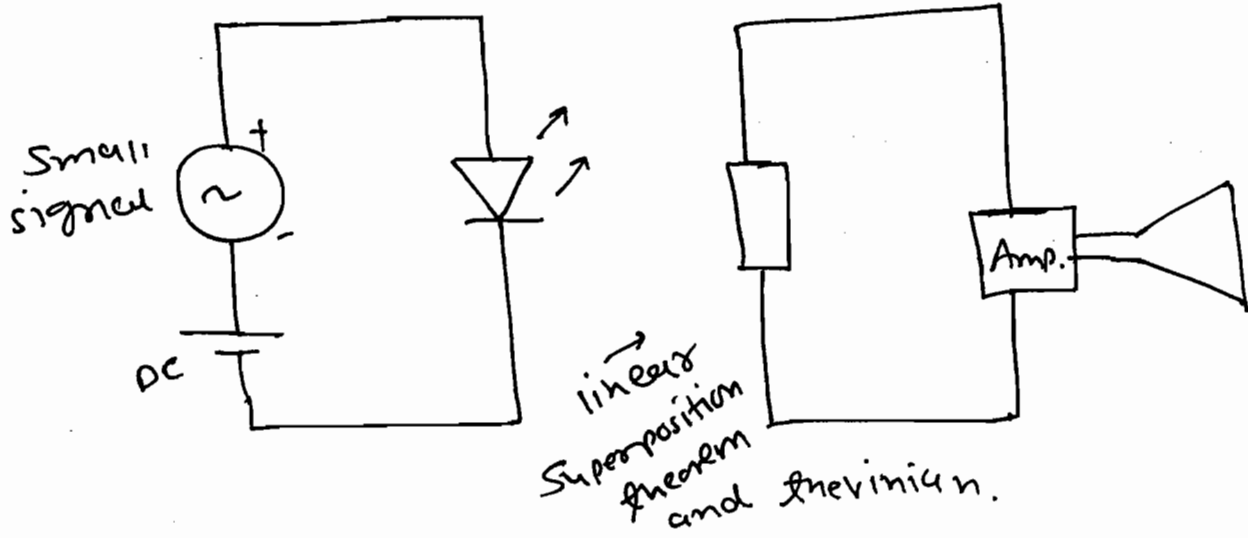
*



→ In order to get same shape of input at output (Amplified), Amp should follow the same shape of photo resistor and in order to do this photo resistor should follow shape available at LED and LED should follow

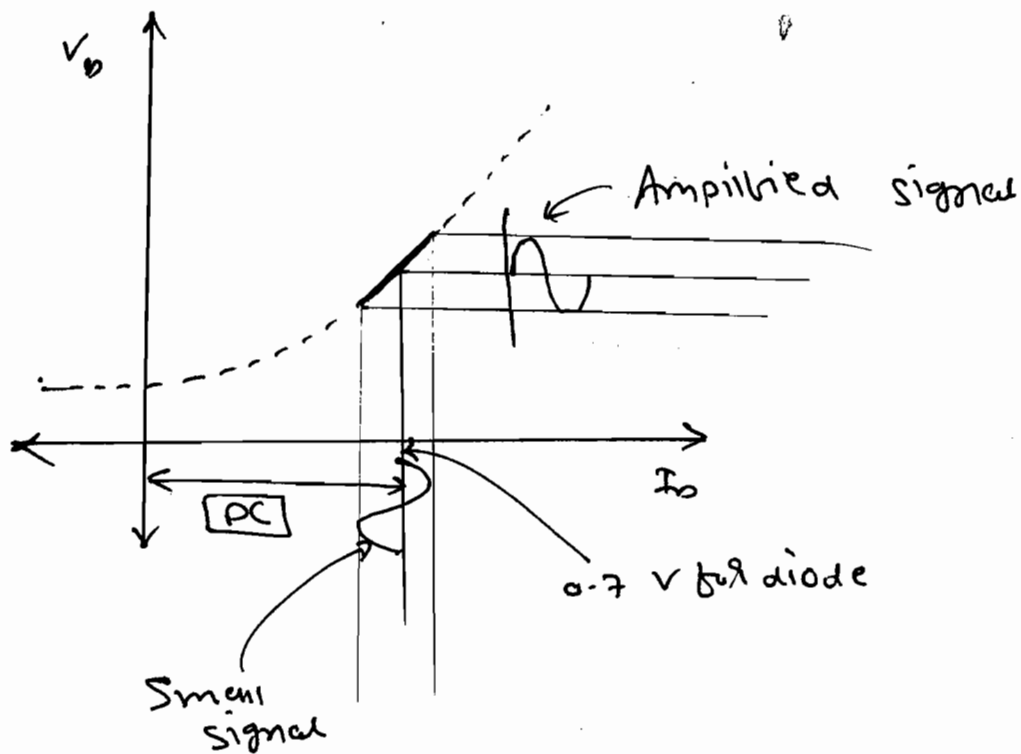
input shape

→ so, this is the linear operation then o/p is same as the input.



adding dc = biasing.

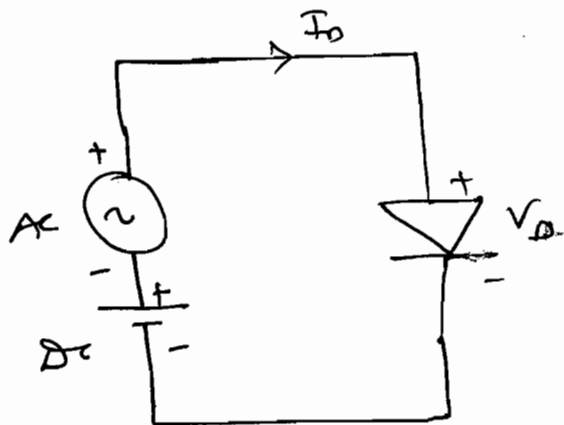
→ Now, All devices has same shape^{or} voltage which is at input.



★ Small Signal Analysis :

- 1) Add DC
- 2) keep the signal small.
- 3) non linear $\Rightarrow$ linear.

* Small Signal Analysis of Diode:



$$V_{D\text{total}} = V_{D\text{DC}} + V_{D\text{AC}}$$

$$I_{D\text{total}} = I_{D\text{DC}} + I_{D\text{AC}}$$

$$\rightarrow I_D = I_S e^{V_D/V_T}$$

$$I_{D\text{DC}} = I_S e^{V_{D\text{DC}}/V_T} \quad \text{--- ①}$$

$$I_{D\text{total}} = I_S e^{V_{D\text{total}}/V_T}$$

$$= I_S \cdot e^{\frac{V_{D\text{DC}} + V_{D\text{AC}}}{V_T}}$$

$$\therefore I_{D\text{total}} = I_S \cdot e^{\frac{V_{D\text{DC}}}{V_T}} \cdot e^{\frac{V_{D\text{AC}}}{V_T}} = I_{D\text{DC}} \cdot e^{\frac{V_{D\text{AC}}}{V_T}}$$

$$\therefore I_{D\text{total}} = I_{D\text{DC}} \left[1 + \frac{V_{D\text{AC}}}{V_T} \right] \quad \leftarrow e^{\frac{V_{D\text{AC}}}{V_T}} \approx 1 + \frac{V_{D\text{AC}}}{V_T}$$

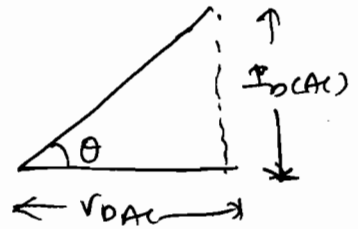
$$\therefore \cancel{I_{D\text{DC}}} + I_{D\text{AC}} = \cancel{I_{D\text{DC}}} + I_{D\text{DC}} \cdot \frac{V_{D\text{AC}}}{V_T}$$

$$I_{D_{AC}} = I_{D_{DC}} \cdot \frac{V_{D_{AC}}}{V_t}$$

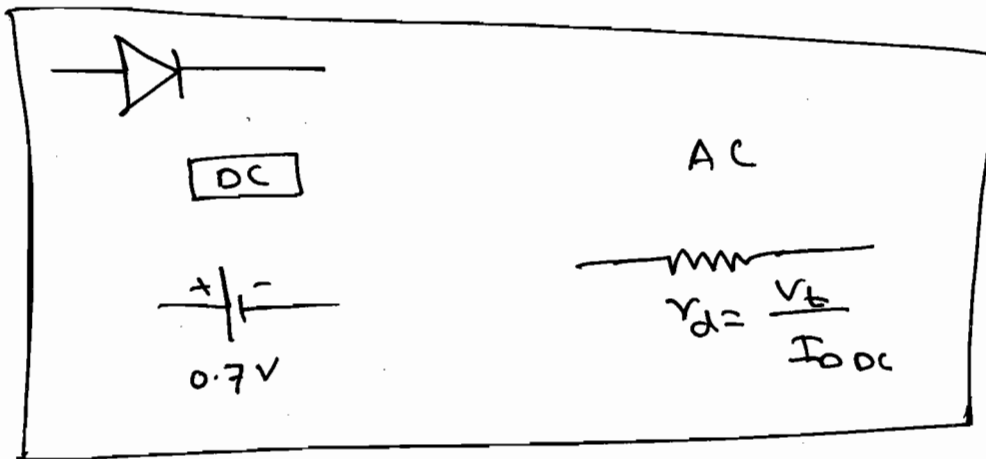
→ Diode Resistance,

$$(r_d) = \frac{V_{D_{AC}}}{I_{D_{AC}}} = \frac{V_t}{I_{D_{DC}}} = \text{const.}$$

$$\therefore V_d = \frac{V_t}{I_D}$$



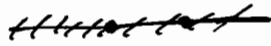
Diode work
as a linear
device.



~~DC ($\omega = 0$)~~

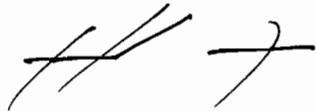
~~AC ($\omega = \text{high}$)~~

1. Resistor



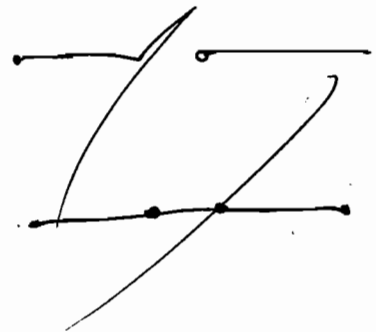
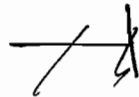
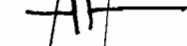
2. Inductor

ωL



3. Capacitor

$\frac{1}{\omega C}$



1. Resistor



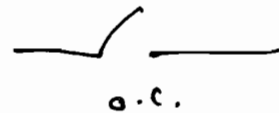
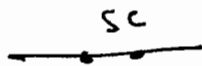
DC
($\omega = 0$)



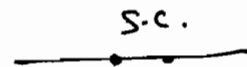
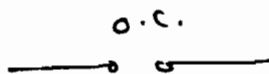
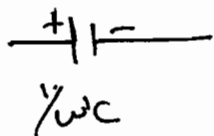
AC
($\omega = \text{high}$)



2. Inductor

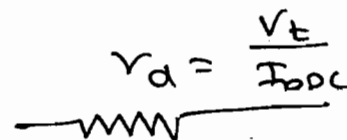
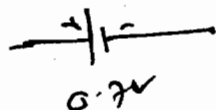


3. Capacitor

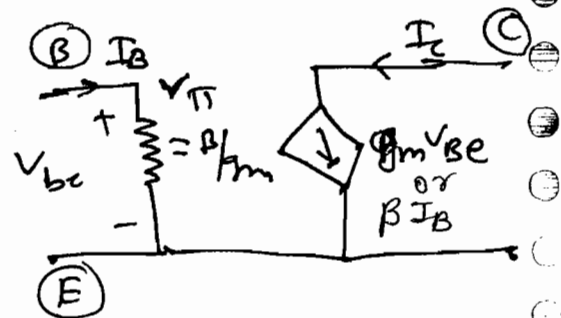
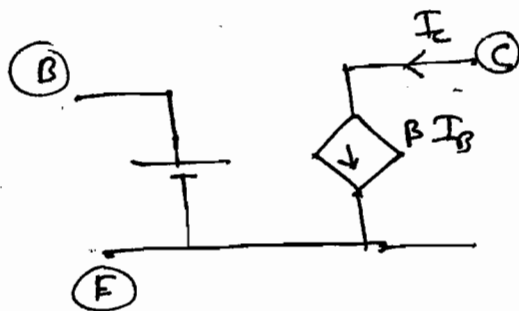
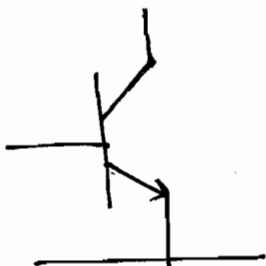


4. Diode

(small signal)



5. BJT



$$I_C = g_m V_{be}$$

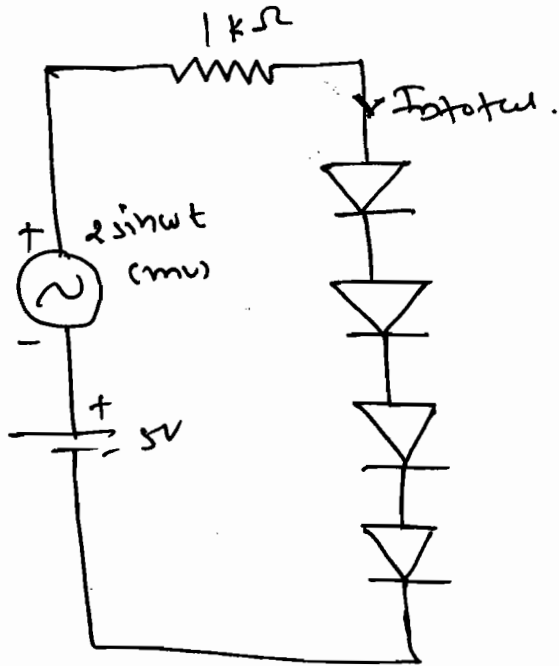
$$V_{be} = I_B r_{\pi}$$

$$\therefore V_{\pi} = \frac{V_{be}}{I_B} = \frac{I_C}{g_m \times I_B}$$

$$I_C = \beta I_B$$

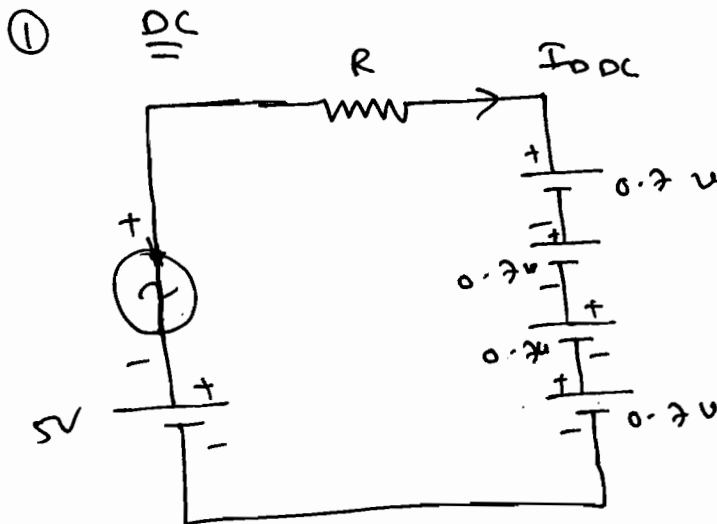
$$\therefore V_{\pi} = \beta / g_m$$

★ Find the total Diode current i_t . 97
 $V_t = 25 \text{ mV}$ and forward drop $V_D = 0.7 \text{ volts}$.



NOTE:

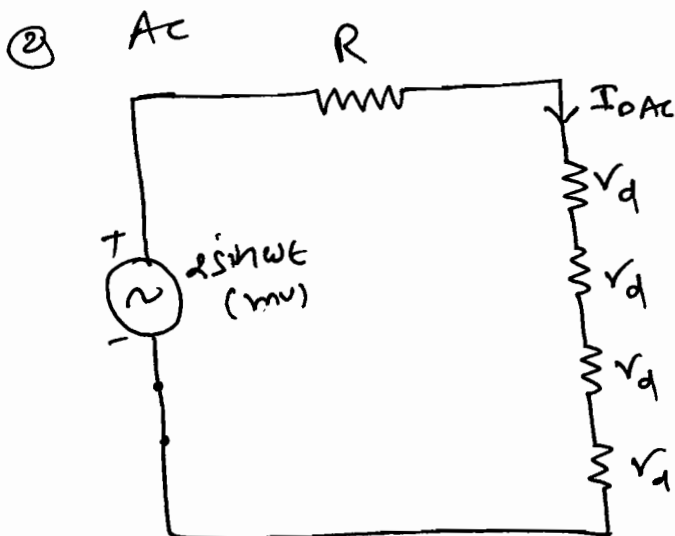
- (i) Diode is 2 terminal / nonlinear / passive device.
- (ii) BJT is 3 terminal / nonlinear / active device.



$$I_{D DC} = \frac{5 - (4 \times 0.7)}{1k}$$

$$I_{D DC} = 5 - 2.8 \text{ mA}$$

$$I_{D DC} = 2.2 \text{ mA}$$



$$r_d = \frac{V_t}{I_{D DC}}$$

$$r_d = \frac{25}{2.2} = 11.36 \Omega$$

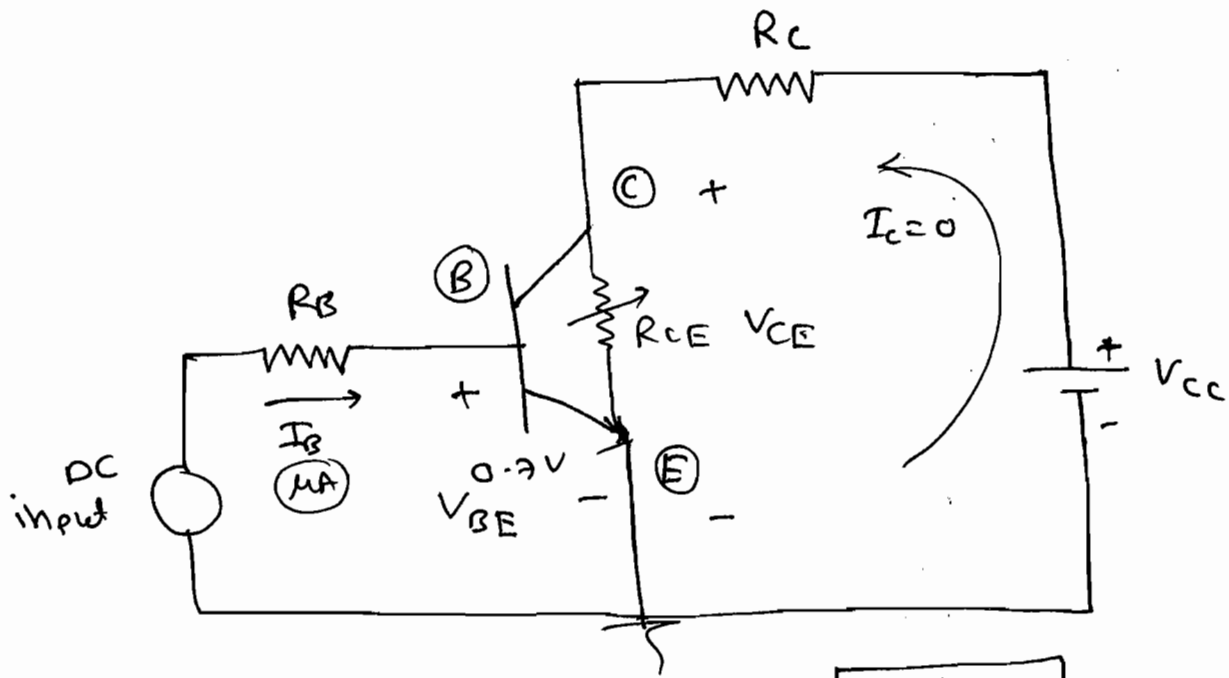
$$I_{D AC} = \frac{2 \sin \omega t}{4(11.36) + 1k}$$

$$I_{D AC} = 1.913 \sin \omega t \text{ mA}$$

$$I_{D AC} = 1.913 \sin \omega t \text{ mA}$$

$$I_{D total} = I_{D DC} + I_{D AC} = 2.2 + 1.913 \sin \omega t \text{ mA}$$

★ BJT and its region of operation:

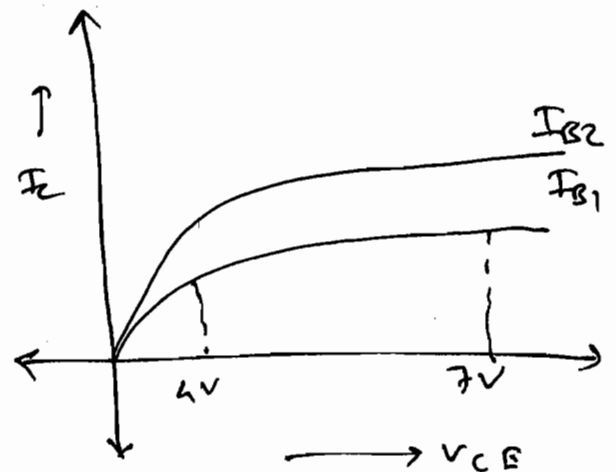


→ I_C is control by I_B from input side.

$$\therefore I_C = \frac{V_{CC}}{R_C + R_{LE}} = 0 \text{ cut off}$$

V_{CC}	I_C	V_{CE}	$R_{LE} = \frac{V_{CE}}{I_C}$
5	1m	4V	4K
6	1m	5V	5K
7	1m	6V	6K
8	1m	7V	7K

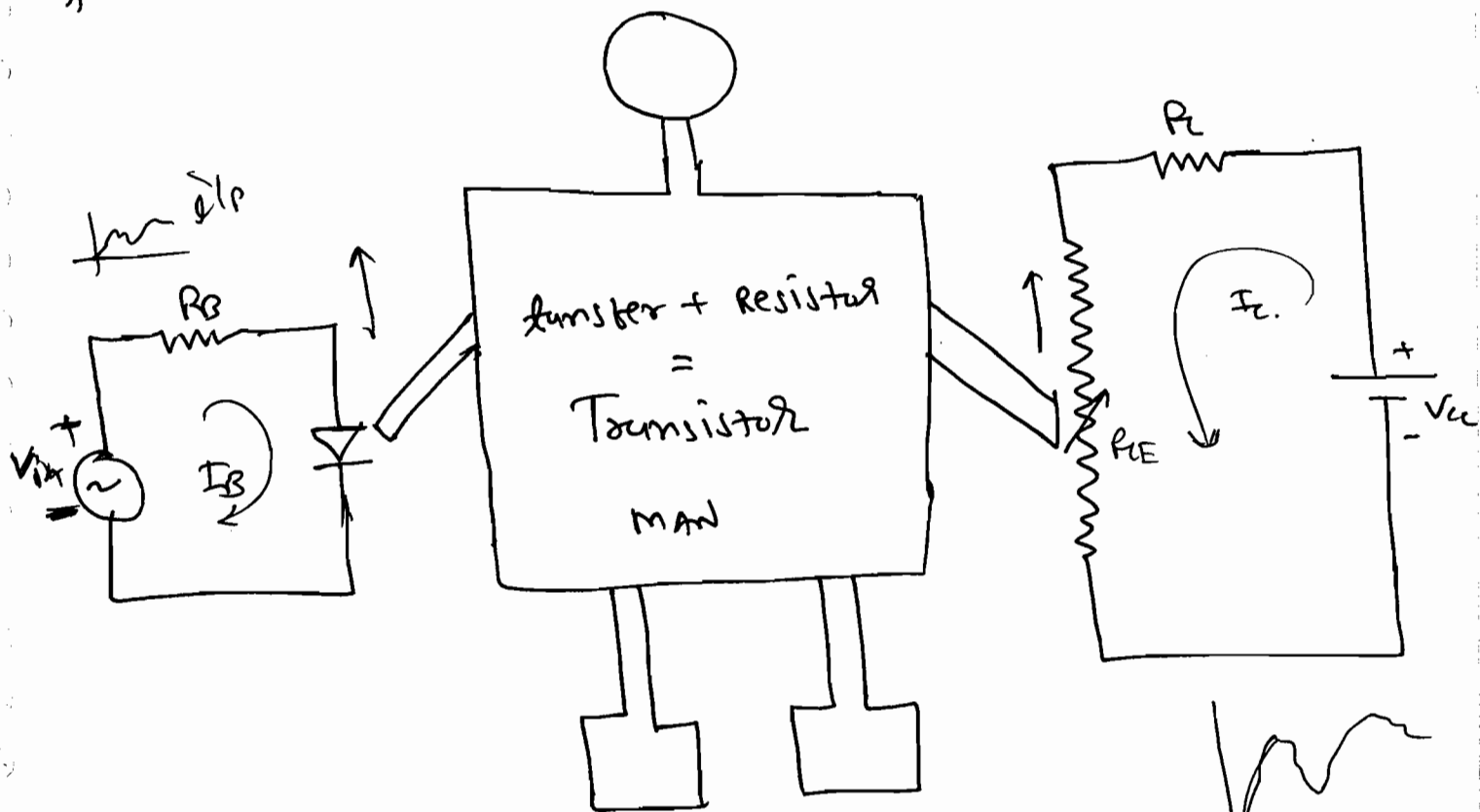
$R_C = 1K$



→ I_C is only change when I_B or R_B will change.

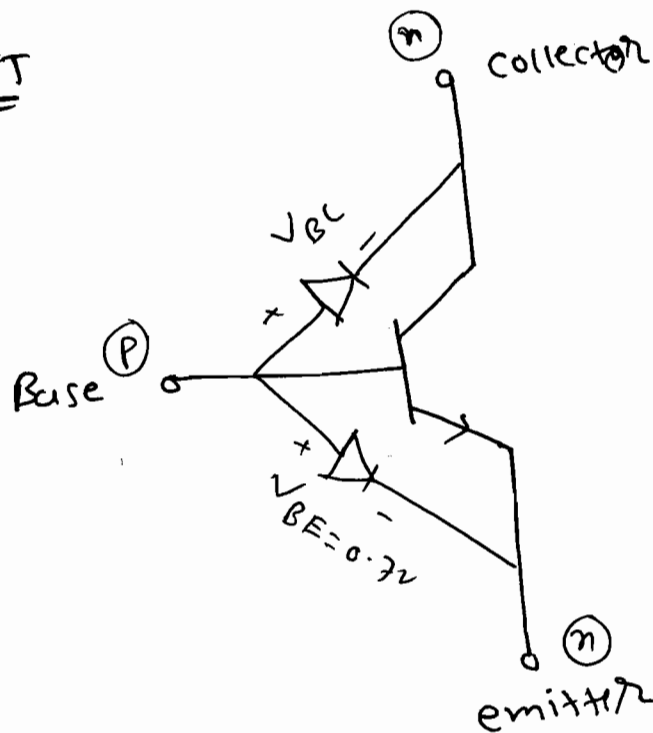
→ So, BJT is current control current source device.

*



$$\begin{array}{l}
 I_B \quad I_B \uparrow \Rightarrow R_{CE} \downarrow \Rightarrow I_E \uparrow \\
 I_B \quad I_B \downarrow \Rightarrow R_{CE} \uparrow \Rightarrow I_E \downarrow
 \end{array}$$

BJT

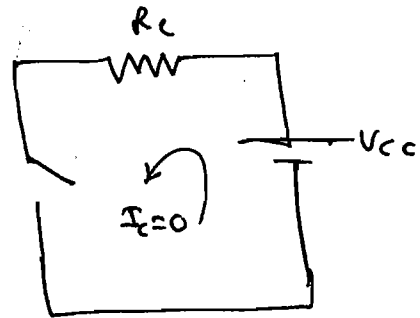
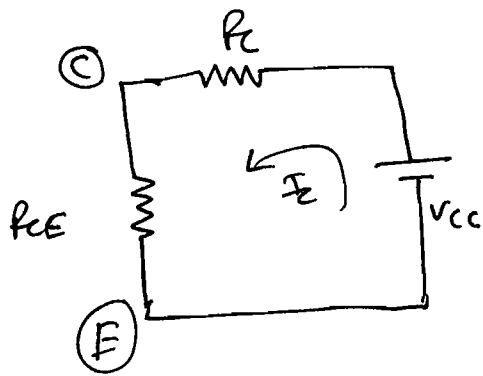
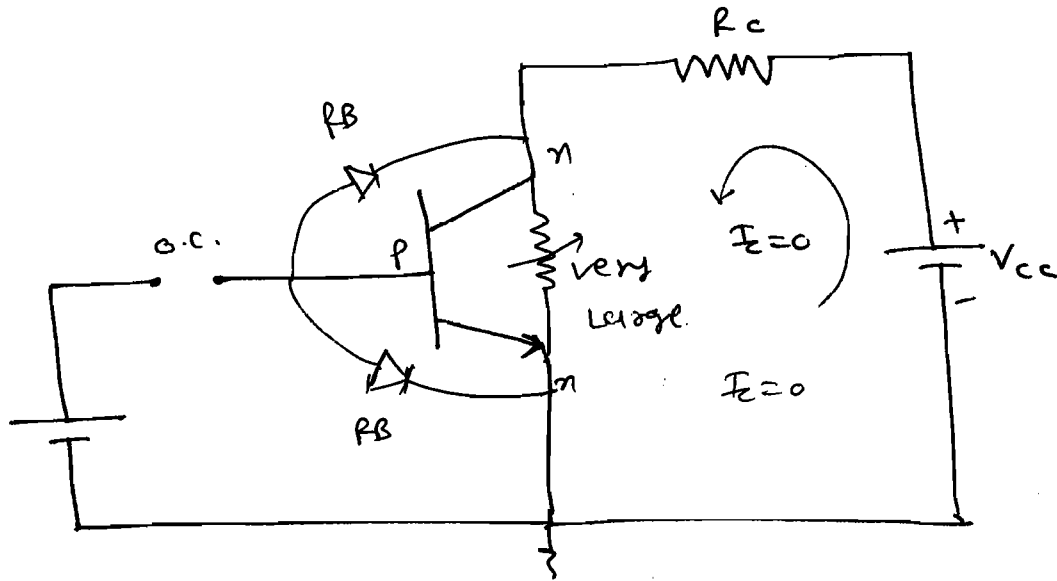


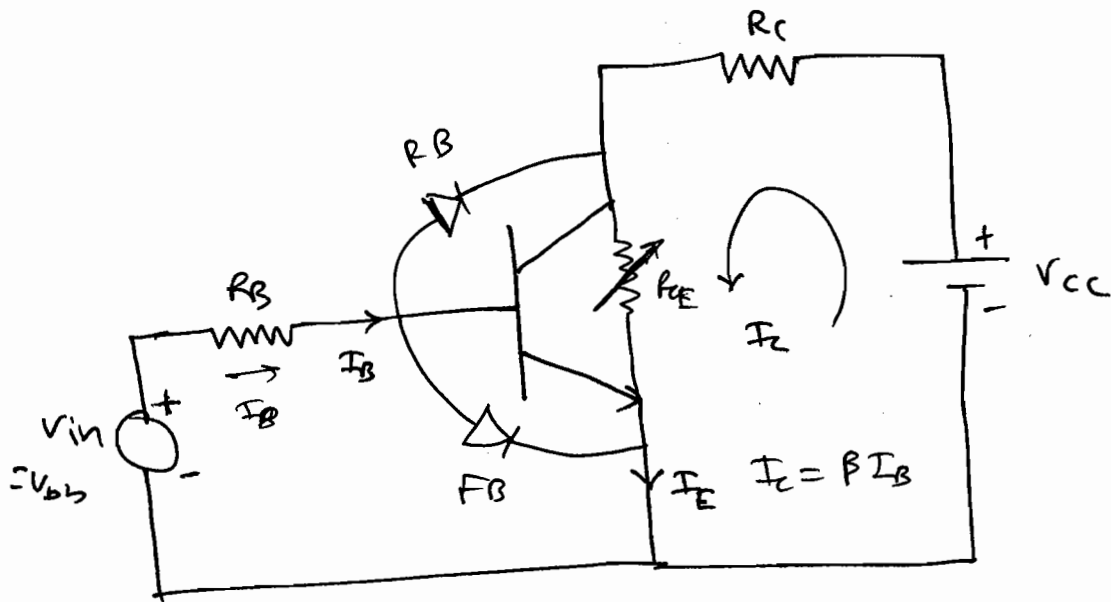
BJT is a controlled OFF switch which is controlled from input side.

*

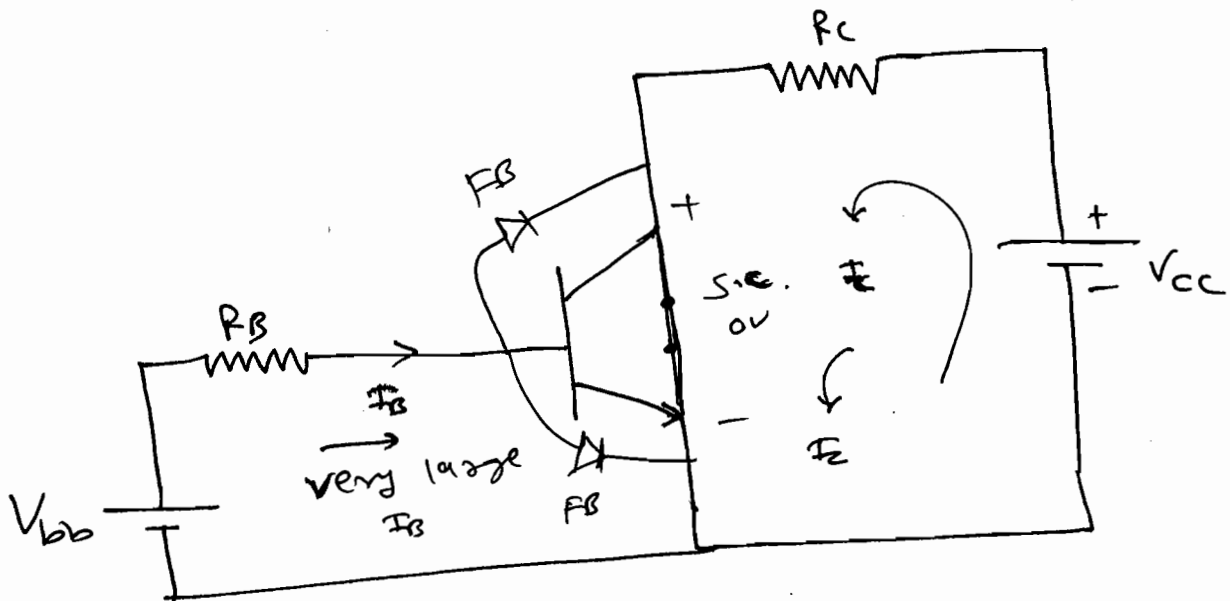
	Emitter-Base Junction	Collector-Base Junction
1. Cut off	$V_{BE} < 0.6 \text{ V}$ RB	$V_{BC} < 0.6 \text{ V}$ RB
2. Inverse Active	$V_{BE} < 0.6 \text{ V}$ RB	$V_{BC} > 0.6 \text{ V}$ (FB)
3. Active	$V_{BE} \geq 0.6 \text{ V}$ (FB)	$V_{BC} < 0.6 \text{ V}$ RB
4. Saturation	$V_{BE} \geq 0.6 \text{ V}$ (FB)	$V_{BC} \geq 0.6 \text{ V}$ (FB)

1. Cut-off:





3. Saturation:



$$|I_B| > |I_{B_{active}}|$$

I_B is very large
 $\Downarrow$
 No effect on I_C .

$$\therefore |I_B| > \left| \frac{I_C}{\beta_{active}} \right|$$

Resistance $\Rightarrow$ BJT

$$\therefore \beta_{active} > \left| \frac{I_C}{I_B} \right|$$

α Cut off 0 Saturation

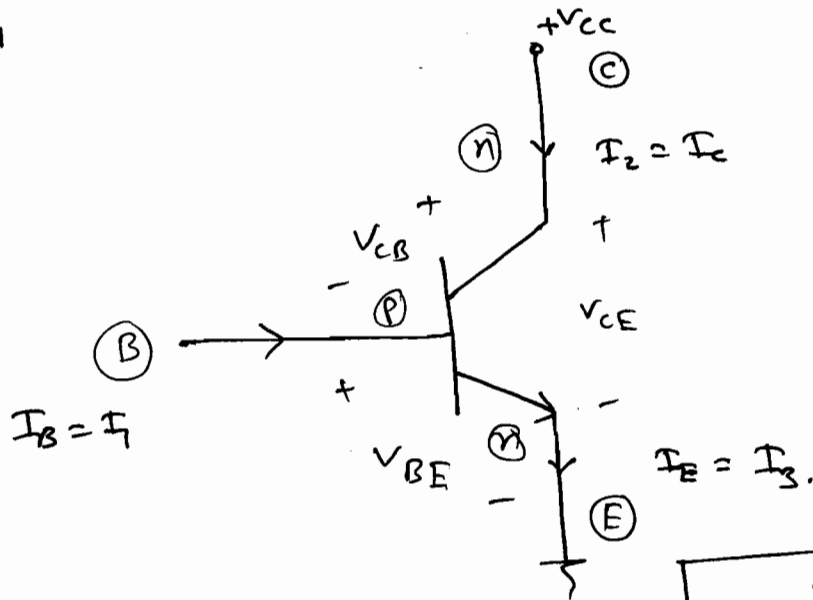
Active region for Amp.

Cut off region for Switching.

$$\therefore \boxed{\beta_{forced} < \beta_{active}}$$

* Solving BJT Problem:

① NPN



KCL, $I_1 + I_2 = I_3$.

$\therefore I_E = I_B + I_C$.

KVB, $-V_{BE} - V_{CB} + V_{CE} = 0$.

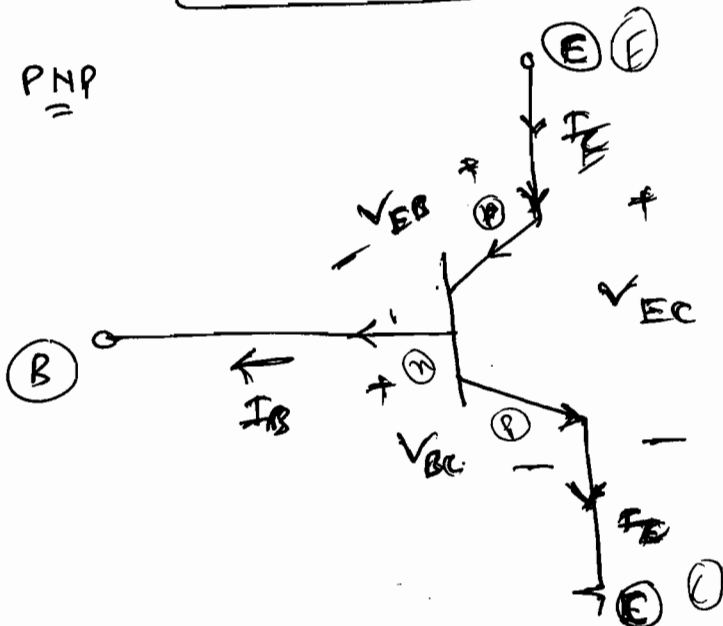
$\therefore V_{CE} = V_{BE} + V_{CB}$.

For npn
 $V_{BE} \rightarrow$ Forward
 Active CB $\rightarrow$ Reverse
 it is
 $V_{CE} > 0.2V$

PNP,

CB $\Rightarrow$ forward.
 BE $\Rightarrow$ Reverse.
 $V_{EC} > 0.2$.

② PNP

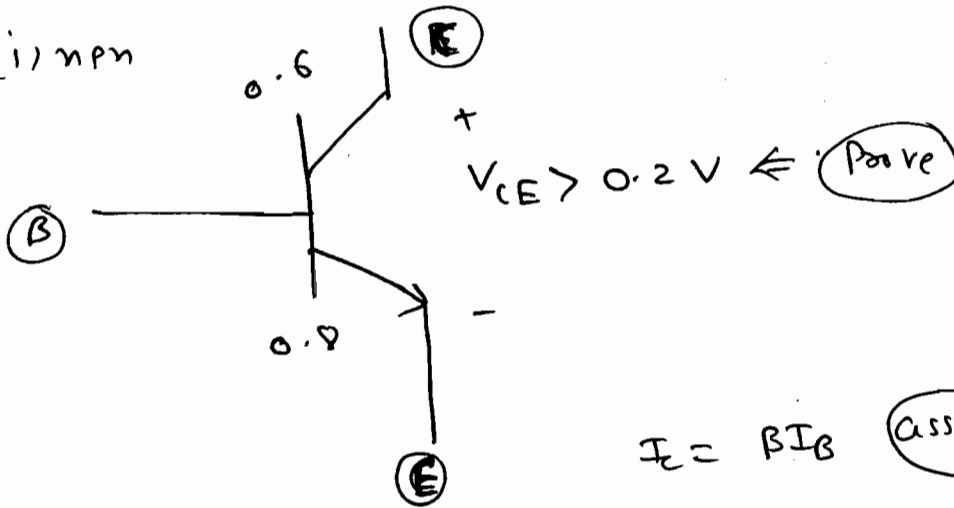


KVL,

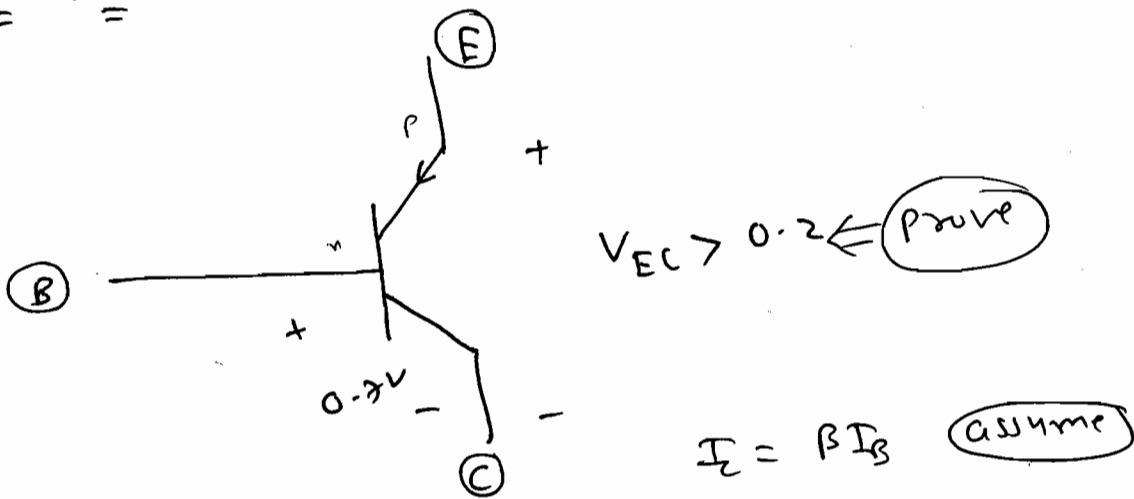
$V_{BC} + V_{EB} - V_{EC} = 0$

① Active Condition:

(i) npn

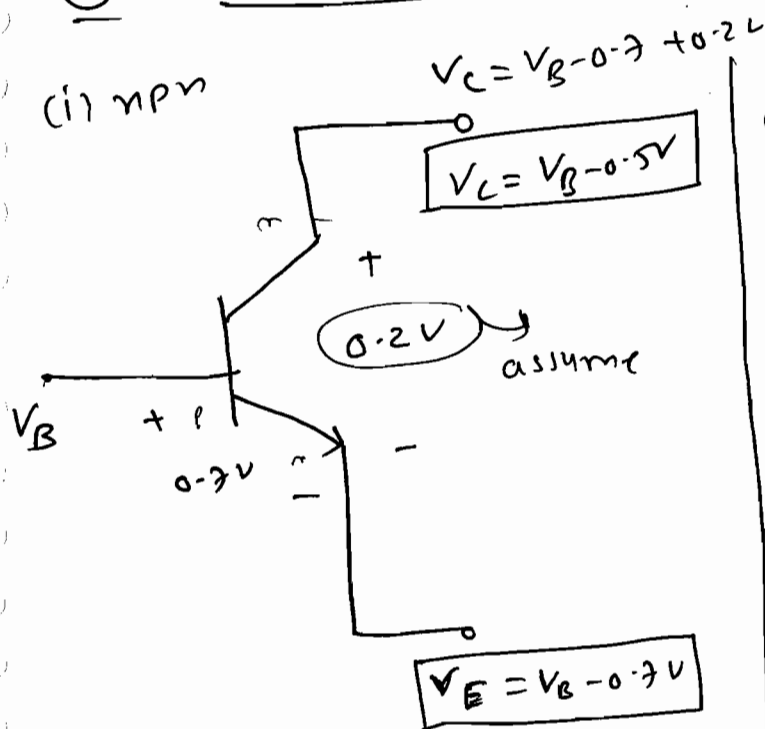


(ii) pnp:

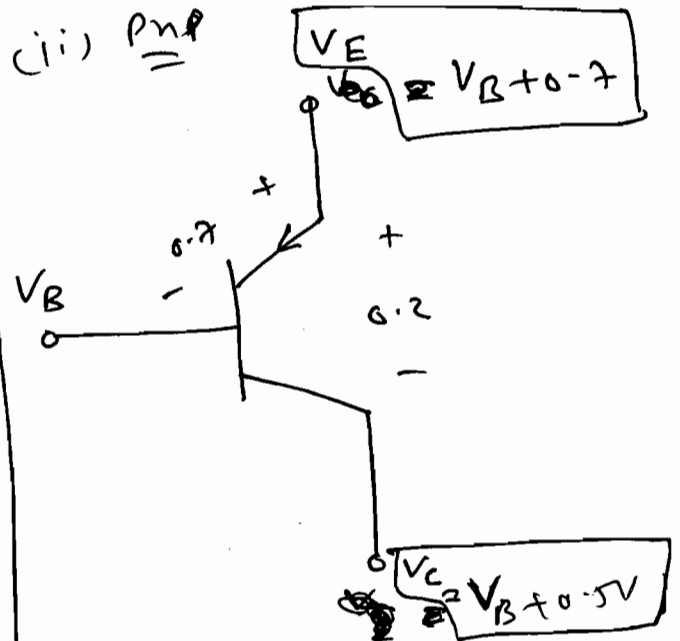


② Saturation Condition:

(i) npn

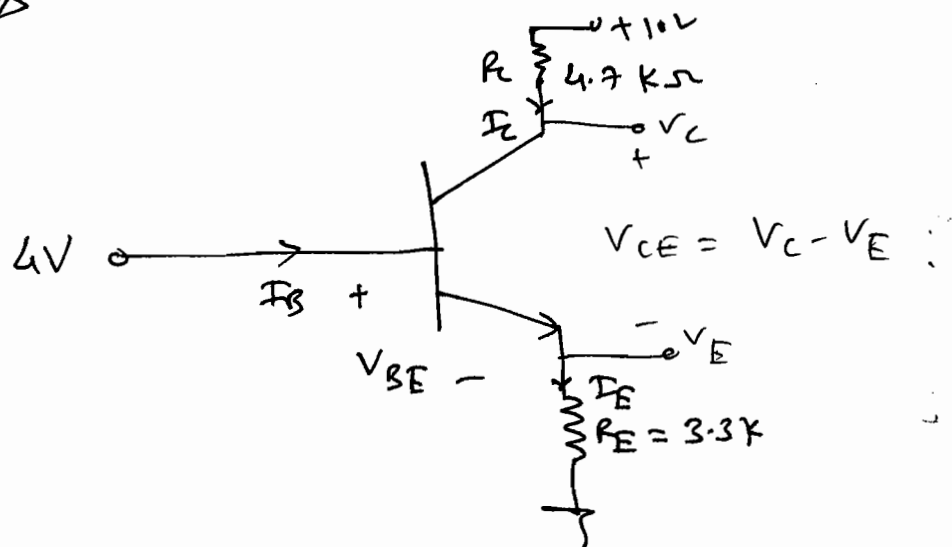


(ii) pnp



Prove $\beta_{forced} < \beta_{active}$

Ex-1 Find All mode Voltage and Branch current. take $\beta = 100$.



Ans:-

$$V_E = 4 - V_{BE}$$

$$\therefore V_E = 4 - 0.7$$

$$V_E = 3.3 \text{ V}$$

$$\therefore I_E = \frac{V_E}{R_E}$$

$$\therefore I_E = \frac{3.3}{3.3 \text{ k}}$$

$$I_E = 1 \text{ mA}$$

$$\therefore I_E = I_C + I_B$$

$$\therefore I_E = \beta I_B + I_B$$

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

$$I_C = \beta I_B$$

$$\therefore \frac{I_C}{I_E} = \frac{\beta}{\beta + 1}$$

$$I_c = \frac{\beta}{\beta + 1} \cdot I_E$$

$$\therefore I_c = \frac{100}{101} \cdot 1 \text{ mA}$$

$$\therefore \boxed{I_c = 0.9909 \text{ mA}}$$

$$\begin{aligned} \rightarrow V_c &= 10 - I_c R_c \\ &= 10 - (0.9909 \text{ mA}) \times (4.7 \times 1000) \end{aligned}$$

$$\therefore \boxed{V_c = 5.346 \text{ V}}$$

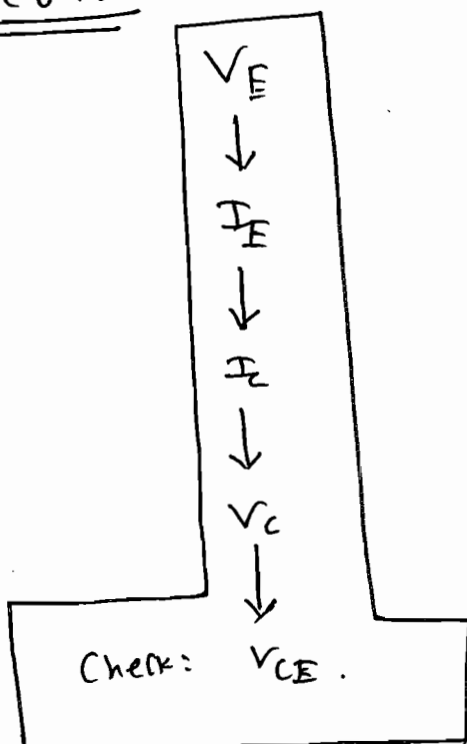
$$\therefore V_{CE} = V_c - V_E \quad (\because \text{nPN})$$

$$\therefore V_{CE} = 5.346 - 3.3$$

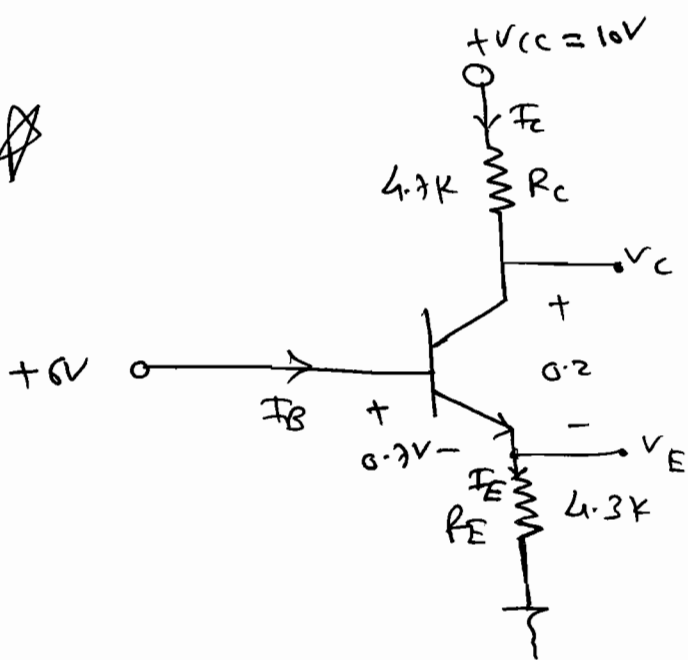
$$\boxed{V_{CE} = 2.046} > 0$$

So, transistor is in active condition.

Procedure:



Ex-2



Ans:

$$V_E = 6 - 0.7V$$

$$V_E = 5.3V$$

$$\therefore I_E = \frac{V_E}{R_E} = \frac{5.3}{4.3}$$

$$\therefore I_E = 1.2325 \text{ mA}$$

$$\therefore I_C = \frac{\beta}{\beta + 1} I_E$$

$$\therefore I_C = \frac{100}{101} \times 1.2325 \text{ mA}$$

$$\therefore I_C = 1.2203 \text{ mA}$$

$$\therefore V_C = 10V - I_C R_C$$

$$= 10 - (1.2203 \text{ mA} \times 4.7K)$$

$$\therefore V_C = 4.26V$$

$$\therefore V_{CE} = V_C - V_E = 4.26 - 5.3 < 0.2$$

$$\therefore V_{CE} < 0.2$$

So, transistor is not in active.

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Now, Let, $V_{CE} = 0.2$. and we will find β_{forced} .

$$\therefore V_E = 6 - V_{BE}$$

$$\therefore V_E = 6 - 0.7 = 5.3V.$$

$$\therefore \boxed{V_E = 5.3V.}$$

$$\therefore V_{CE} = 0.2$$

$$\therefore V_C - V_E = 0.2.$$

$$\therefore \boxed{V_C = 5.5V.}$$

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

$$\therefore I_C = \frac{10 - 5.5}{4.7}$$

$$\therefore \boxed{I_C = 0.957mA}$$

$$I_E = \frac{V_E}{R_E}$$

$$I_E = 1.2325.$$

$$\therefore I_B = I_E - I_C$$

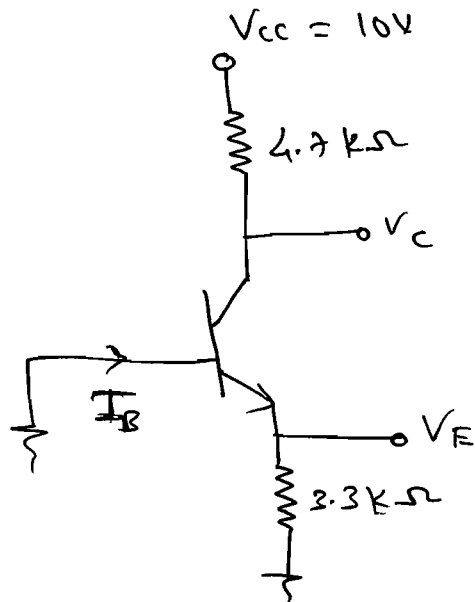
$$\boxed{I_B = 0.275mA}$$

$$\therefore \beta_{forced} = \frac{I_C}{I_B}$$

$$\boxed{\beta_{forced} = 3.473 < \beta_{active}.}$$

So, transistor is in saturation region.

Ex 3



Ans:

$$V_E = 0$$

$$I_E = 0$$

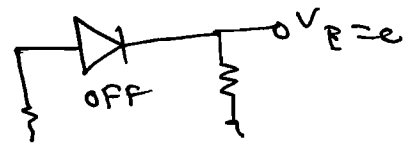
$$I_C = 0$$

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

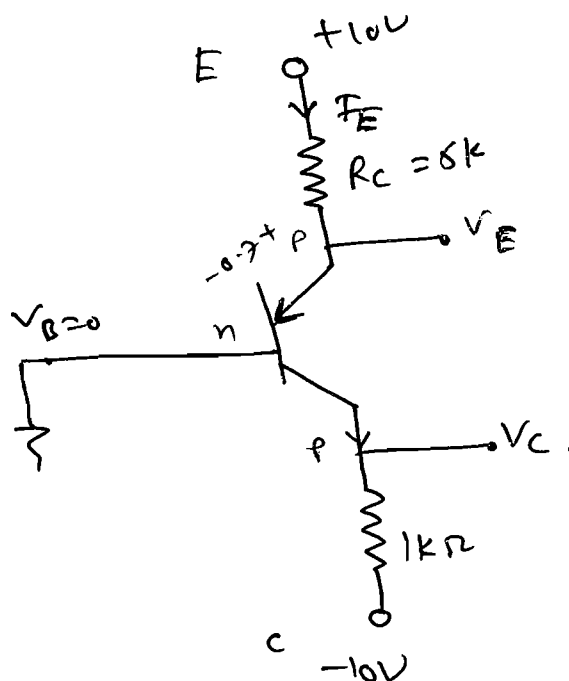
$$\therefore V_C = V_{CC} = 10V$$

$$\therefore \boxed{V_C = 10V.}$$

So, transistor is in cutoff.



Ex 4



$$\therefore V_E = V_B + V_{BE}$$

$$\therefore V_E = 0 + 0.7 \text{ V}$$

$$\boxed{V_E = 0.7 \text{ V}}$$

$$\therefore I_E = \frac{10 - 0.7}{5 \text{ k}}$$

$$\therefore \boxed{I_E = 1.86 \text{ mA}}$$

$$\therefore I_C = \frac{\beta}{\beta + 1} \times I_E$$

$$\therefore I_C = \frac{100}{101} \times 1.86$$

$$\therefore \boxed{I_C = 1.84 \text{ mA}}$$

$$\therefore V_C = I_C R_C - 10 \text{ V}$$

$$V_C = (1.84) - 10 \text{ V}$$

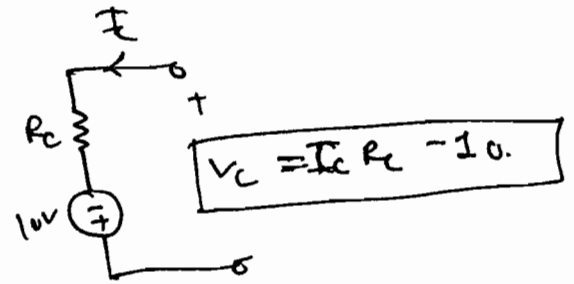
$$\therefore \boxed{V_C = -8.16 \text{ V}}$$

$$V_{EC} = V_E - V_C$$

$$\therefore V_{EC} = 0.7 - (-8.6)$$

$$\therefore V_{EC} = 8.76 > 0.2 \text{ V}$$

So, in active region.

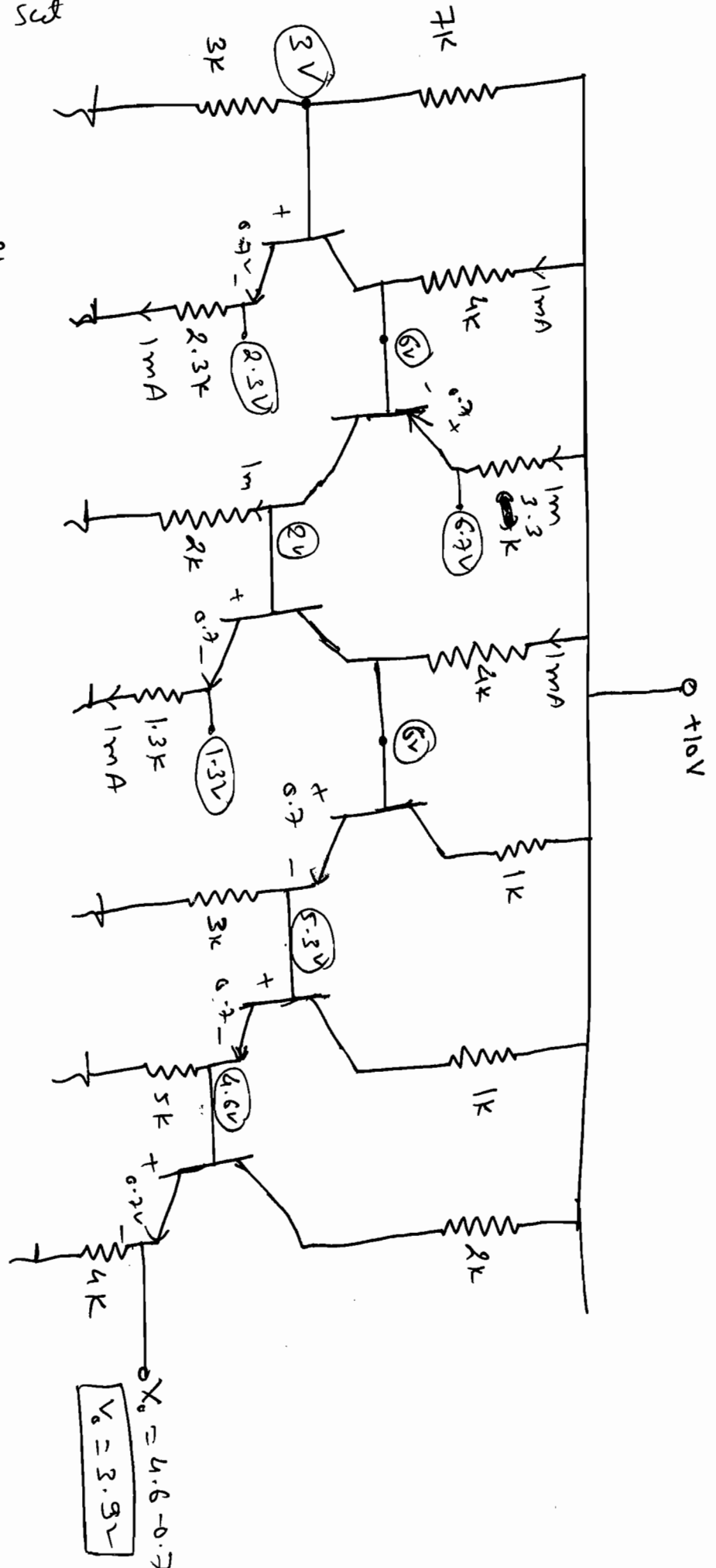


* To make BJT form
~~set~~ active to set
 following two ways
 can be applicable:

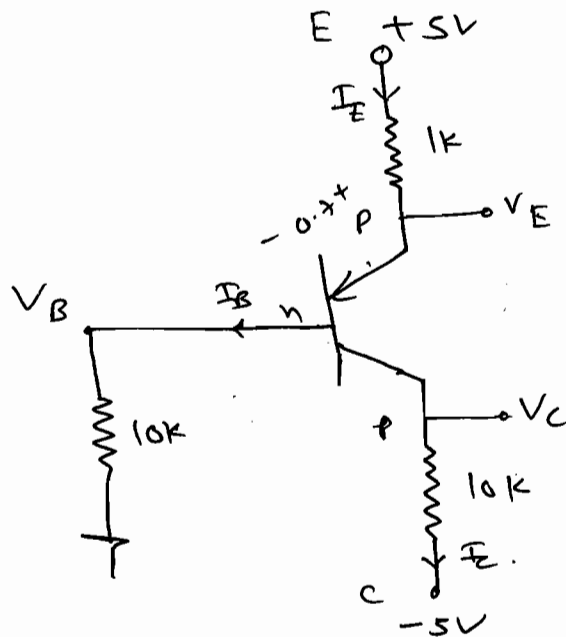
(1) $\downarrow R_c$
 $\textcircled{I_C} = \beta_{\text{forced}} < \beta_{\text{active}}$
 $\uparrow \textcircled{I_B}$ $V_{BB} \uparrow$

→ (i) I_C should be
~~decrease~~ and
 it can be active
 by increasing
 value of R_c :
 $R_c \gg \text{Large}$.

(ii) By increasing
 V_{BB} I_B can
 be increased
 which in turn
 reduce the
 β_{forced} .



Ex-4 Calculate the All node voltages and branch current $\beta=100$ and it is in saturation. III



$$V_{EC} = 0.2V$$

$$V_E = V_B + 0.7V$$

$$V_C = V_E - V_{EC}$$

$$\therefore V_C = V_B + 0.7 - 0.2$$

$$V_C = V_B + 0.5V$$

$$\rightarrow I_E = I_B + I_C$$

$$\therefore \frac{5 - V_E}{1k} = \frac{V_B}{10k} + \frac{V_C + 5V}{10k}$$

$$\therefore 10(5 - V_B - 0.7) = V_B + V_B + 5 + 0.5$$

$$\therefore 50 - 10V_B - 7 = 2V_B + 5.5$$

$$\therefore 12V_B = 37.5$$

$$\therefore V_B = 3.125V$$

$$\therefore I_B = \frac{V_B}{R_B} = \frac{3.125}{10k} = 0.3125mA$$

$$\therefore I_E = \frac{3.125 + 5 + 0.5}{10} = 0.86mA$$

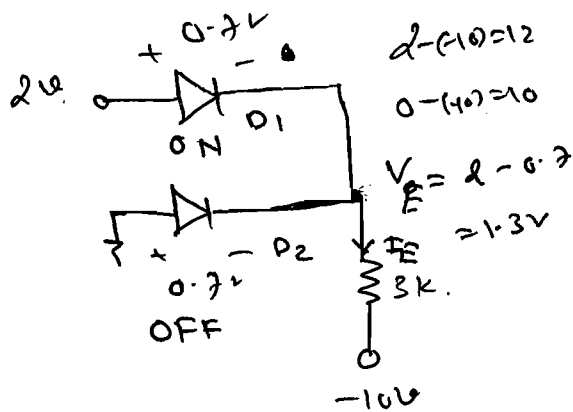
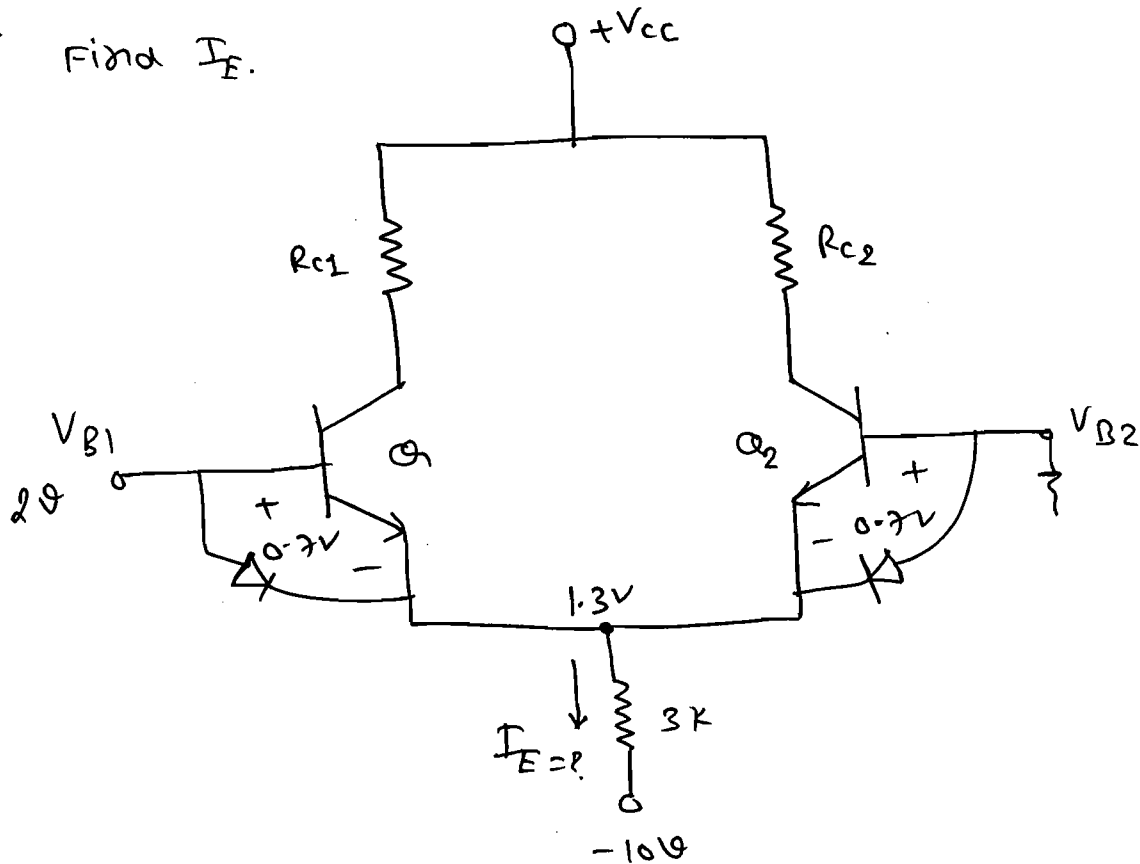
$$\therefore \beta_{forced} = \frac{0.86}{0.3125} = 2.752 < \beta_{active}$$

So, it is in sat.

$$I_E = I_C + I_B = 1.1725mA$$

$$I_E = 1.1725mA$$

Ex-5 Find I_E .



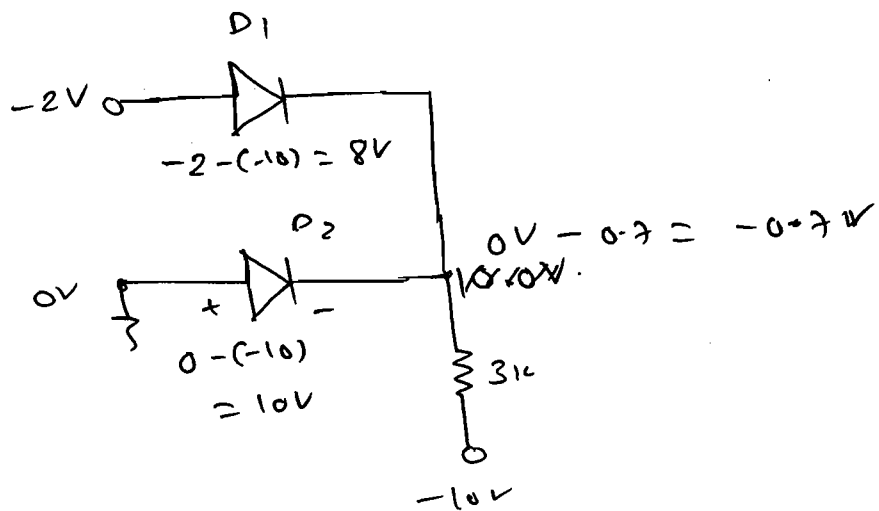
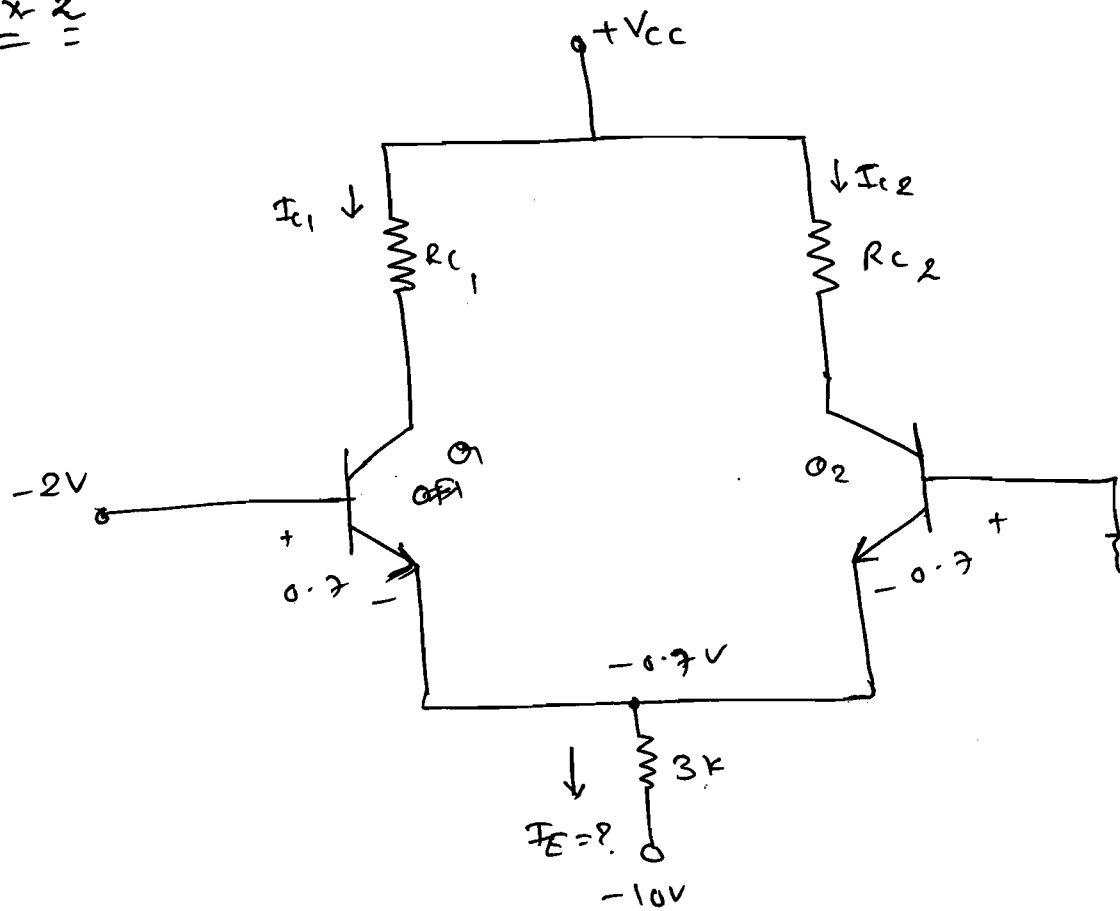
D_1 is on because it experiences more potential difference.

$$\rightarrow \therefore I_E = \frac{1.3 - (-10)}{3k}$$

$$I_E = 3.76mA$$

→ Diode in BJT can be on by either
 ✓ Voltage divider or ^{giving} + negative supply.

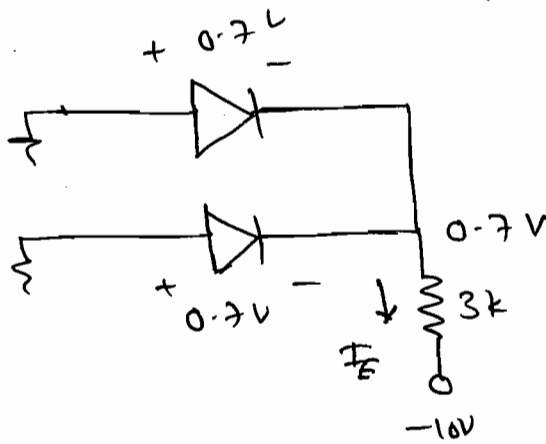
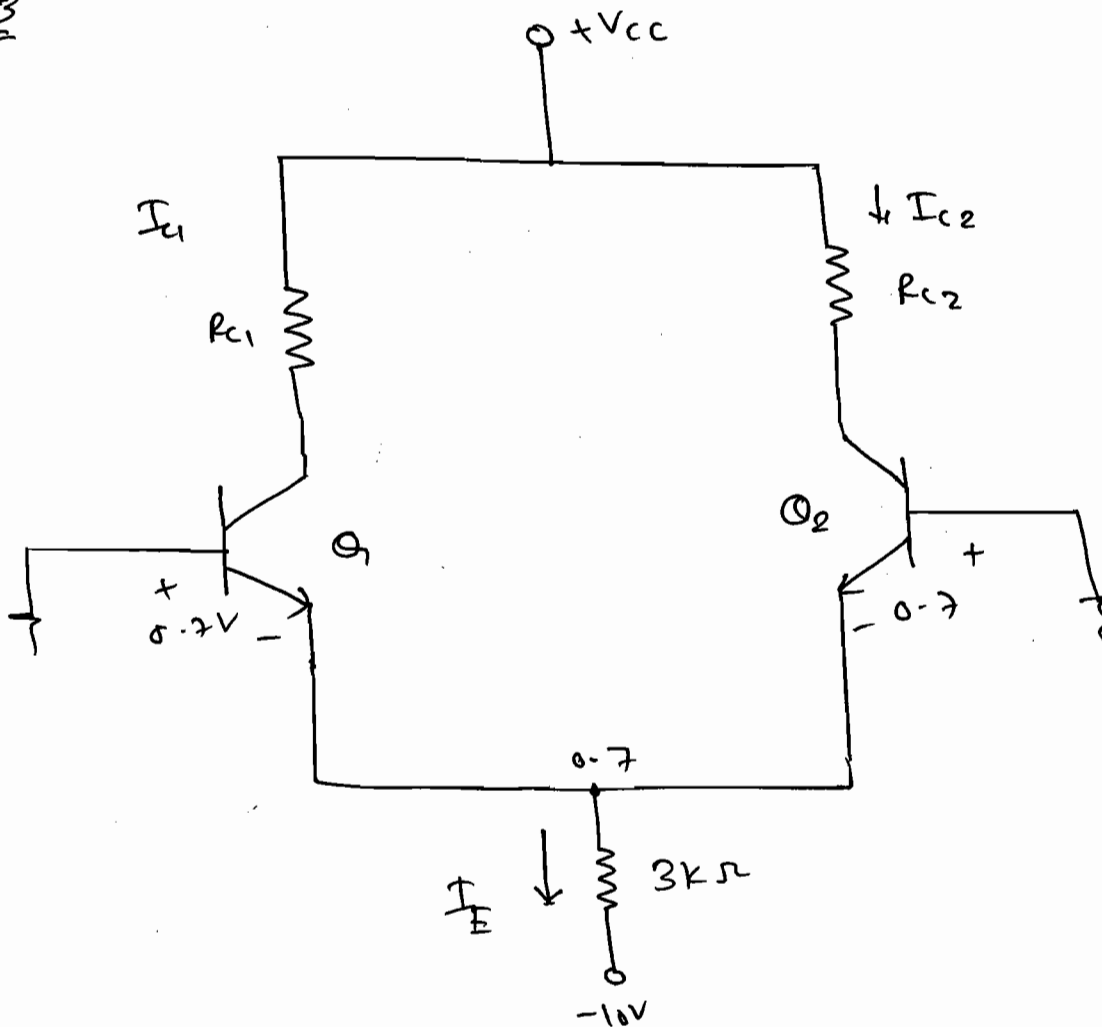
Ex 2



$$\therefore I_E = \frac{-0.7 - (-10)}{3k}$$

$$\therefore \boxed{I_E = 3.1mA.}$$

Ex 3



$$\therefore I_E = \frac{0.7 - (-10)}{3k} = \frac{10.7}{3k} = 3.567 \text{ mA}$$

$$I_{C1} = I_{C2} = I_E$$

$$\therefore dI_E = I_E$$

$$\therefore I_{C1} = I_{C2} = I_E / 2$$

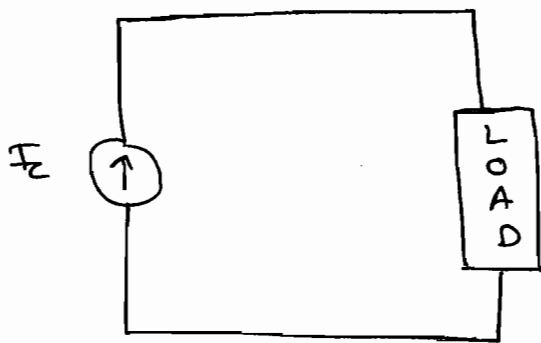
$$\therefore \boxed{I_{C1} = I_{C2} = 1.78 \text{ mA}}$$

★ Biasing a BJT:

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→ The purpose of biasing is to switch on the BJT to work in active region such that the dc collector current remain constant independent of β , Temp. and load variations.

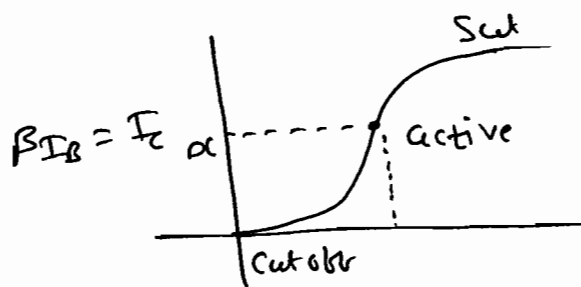
→



$$I_c \neq f(\beta, \text{temp}, \text{Load})$$

$$\therefore I_c \neq f(\beta, V_{be}, V_{ce})$$

① β (with R_E).



If β change the $I_c = \beta I_B$ changes.

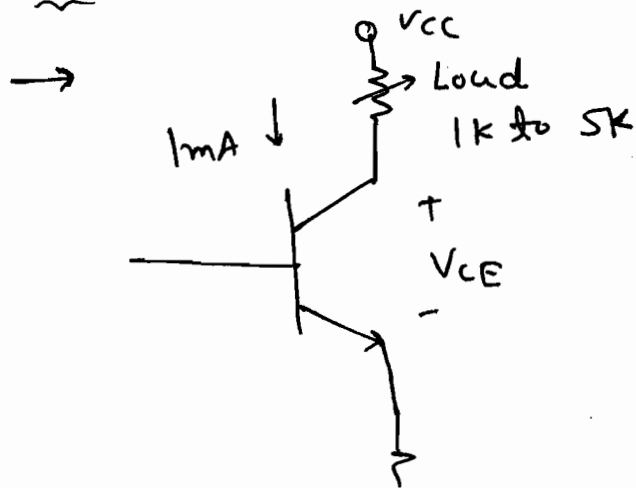
② Temperature:

$$\rightarrow V_{BE} = -2.5 \text{ mV}/^\circ\text{C}$$

→ If temp. changes $\Rightarrow V_{BE}$ changes.

this will change I_B and ^{will} turn in change the I_c .

③ Load Variations:



$$V_{CE} = V_C - V_E.$$

$$\therefore V_{CE} = V_{CC} - I_C R_C - V_E$$

$$\therefore I_C = \frac{V_{CC} - V_{CE} - V_E}{R_C}$$

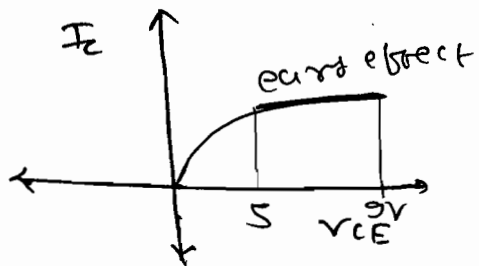
if R_C changes

↓

V_{CE} changes

↓

I_C will change.

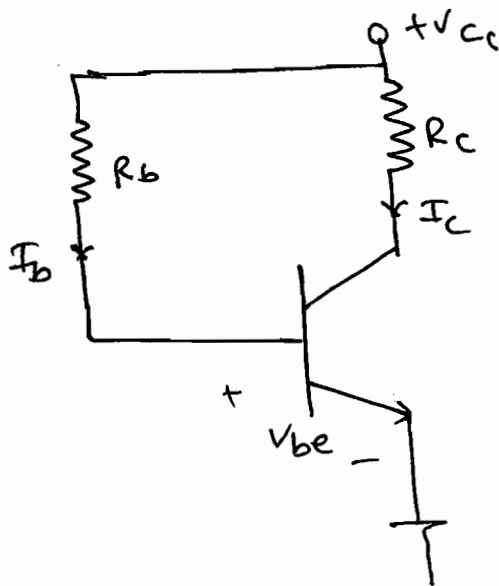


→ In order to rid this problem we should make constant current source.

① Fixed Bias / Fixed Base bias:

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→



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

$$V_{BE} \approx \text{const.}$$

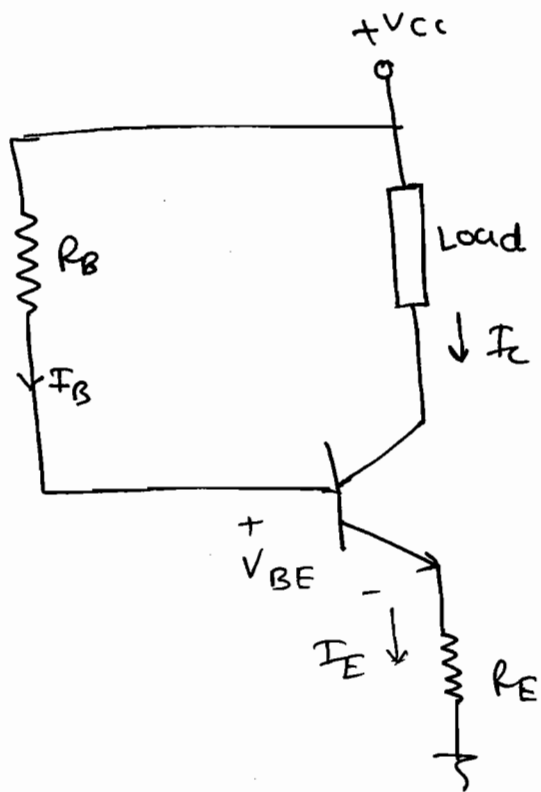
$$R_B \approx \text{const.}$$

$$\therefore I_B = \text{const.}$$

$$\therefore I_E = \beta I_B = \beta \left[\frac{V_{CC} - V_{BE}}{R_B} \right]$$

→ β changes from 50 to 250 for the different specimens of the given transistor type. any ckt which depend on a particular value of β is a bad ckt.

Without R_E	With R_E
$I_C = \beta I_B$	$I_C = \beta I_B$
$I_B = K = \text{const.}$	$I_E = K = \text{const.}$
$I_E = \beta I_B$	$\therefore I_B = I_C / K$



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

$$\text{And } I_E = (\beta + 1) I_B.$$

$$\rightarrow I_B = I_E / (\beta + 1).$$

$$\therefore V_{CC} - V_{BE} = \left(\frac{R_B}{\beta + 1} + R_E \right) I_E.$$

$$\therefore I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_B}{\beta + 1}}.$$

Now, choose $R_E \gg \frac{R_B}{\beta + 1}$

$$\therefore I_E \approx I_{DC} = \frac{V_{CC} - V_{BE}}{R_E}.$$

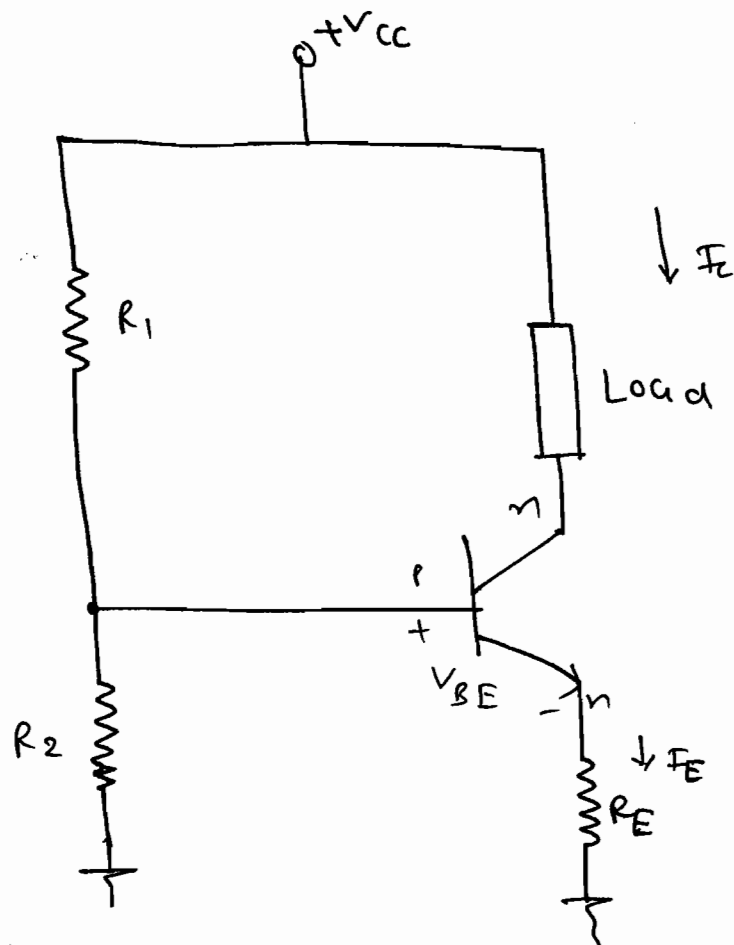
② Voltage divider bias (or)

Self bias (or)

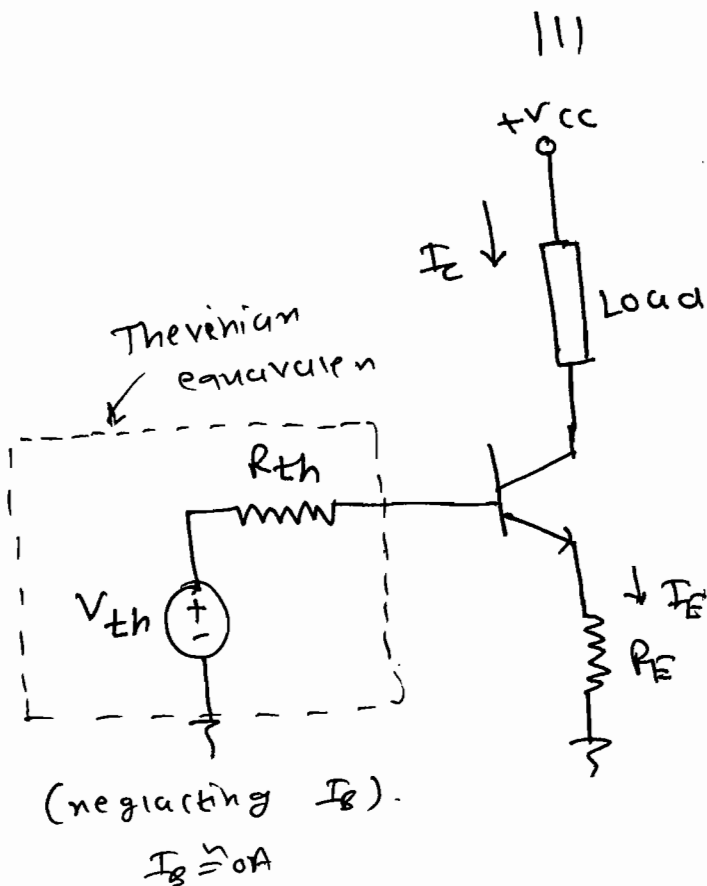
Universal bias.

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⇒



→



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

$$R_{th} = \frac{R_1 \cdot R_2}{R_1 + R_2} = R_1 || R_2$$

$$\rightarrow V_{th} - V_{BE} - I_B R_B - I_E R_E = 0.$$

$$\therefore I_B = \frac{I_E}{\beta + 1}.$$

$$\therefore I_E \left[\frac{R_B}{\beta + 1} + R_E \right] = V_{th} - V_{BE}.$$

$$\therefore I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_B}{\beta + 1}} \approx I_{E,DC}$$

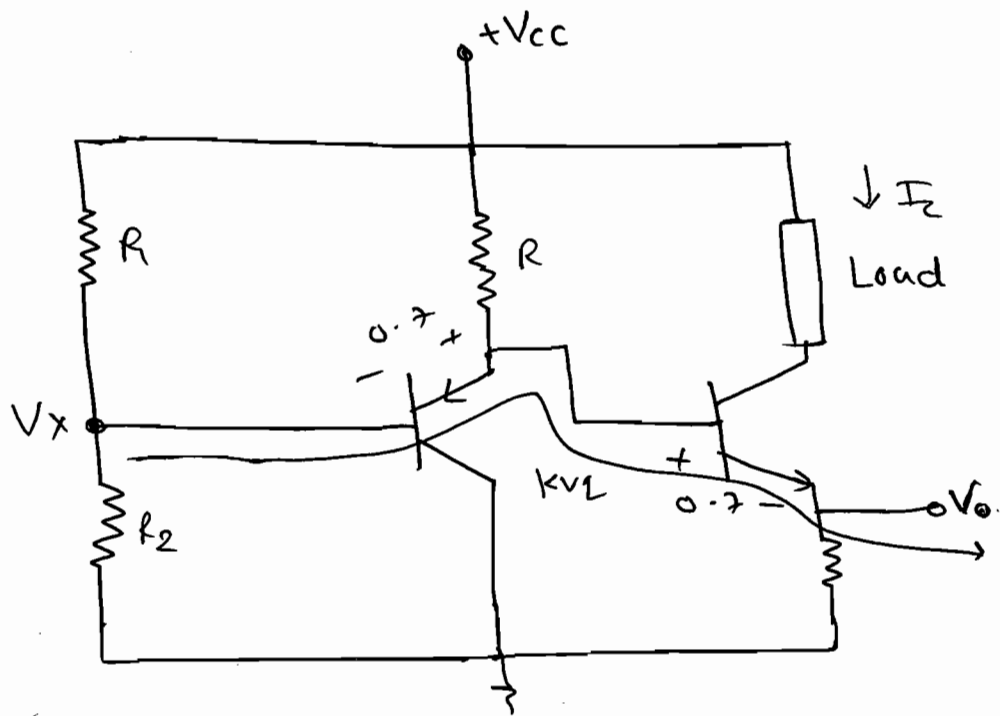
$$R_E \gg \frac{R_{th}}{\beta + 1}.$$

$$\therefore R_E \gg \left(\frac{R_1 \cdot R_2}{R_1 + R_2} \right) \times \frac{1}{\beta + 1}.$$

$$\therefore I_{E,DC} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

Ex-1

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$$\rightarrow V_X = \frac{V_{CC} R_2}{R_1 + R_2}$$

$$\therefore V_X + 0.7 - 0.7 - V_O = 0$$

$$\therefore V_X = V_O = V_E$$

$$\therefore V_E = V_O = \frac{V_{CC} R_2}{R_1 + R_2} \quad \text{--- (1)}$$

$$\therefore I_C = I_E = \frac{V_E}{R_E}$$

$$\therefore I_C = \frac{\frac{V_{CC} R_2}{R_1 + R_2}}{R_E}$$

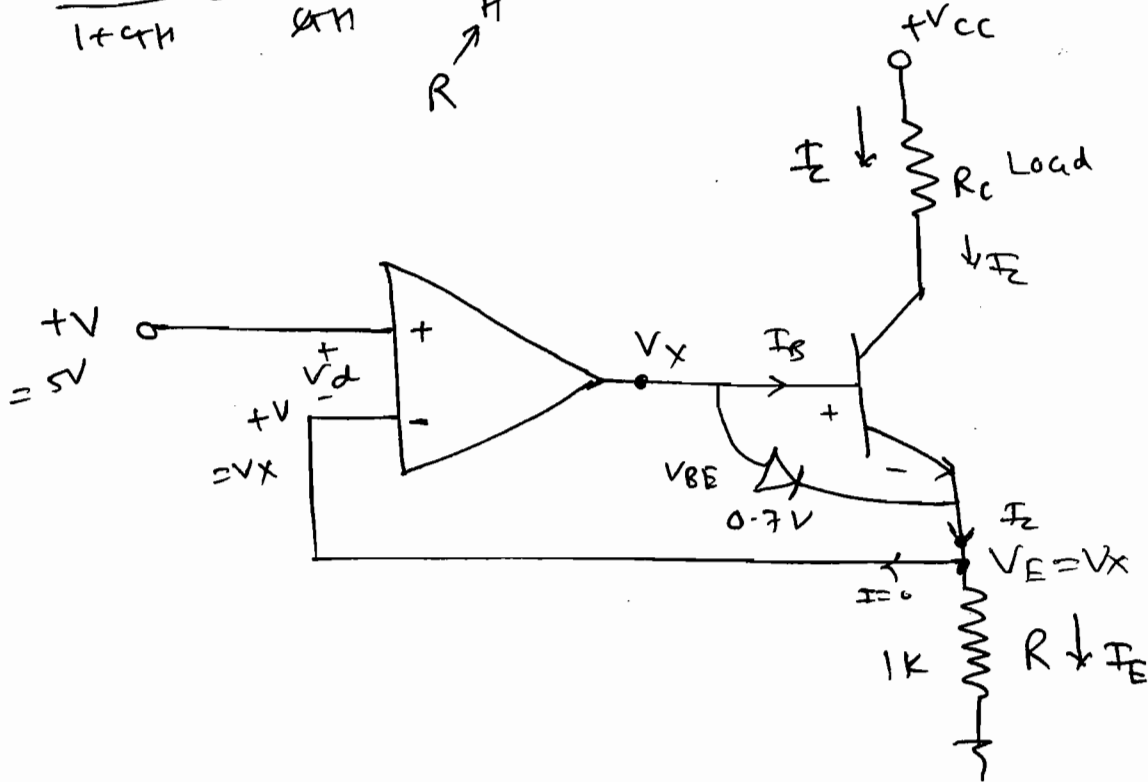
$$\therefore I_C = \frac{V_{CC} R_2}{(R_1 + R_2) R_E} = V/R$$

NOTE: Designing a current source with op-Amp in -ve feedback will totally eliminate the problem of drift.

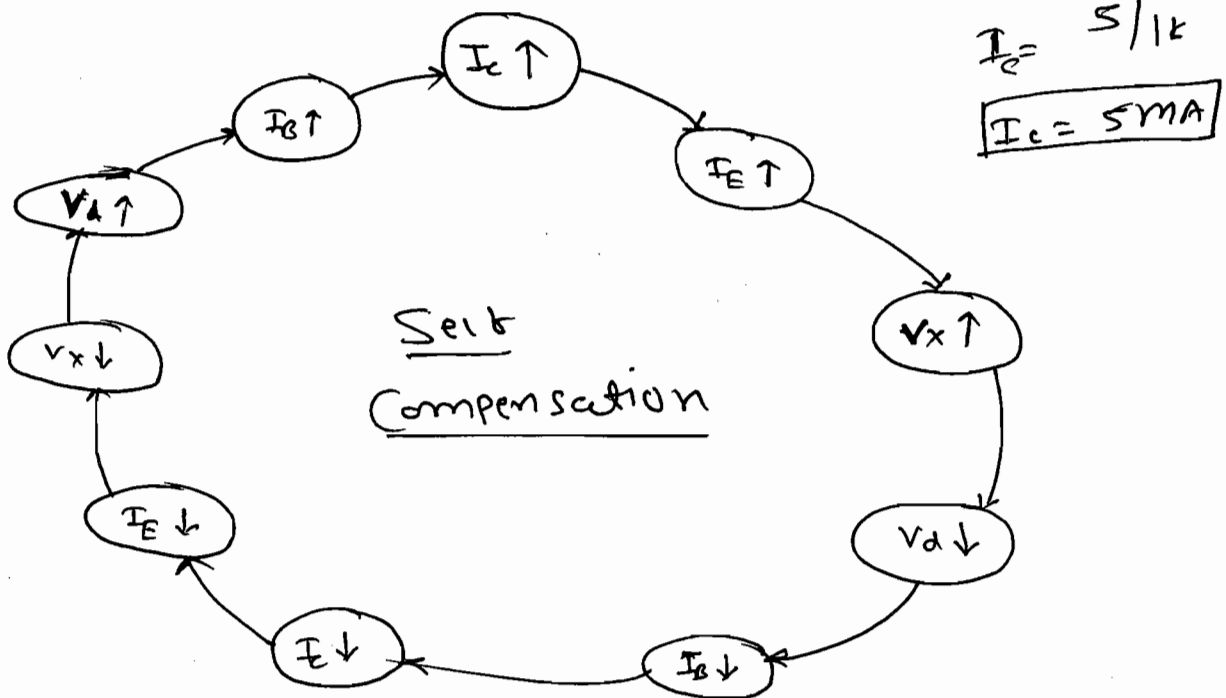
*

$$\frac{G}{1+GH} = \frac{G}{GH} = \frac{1}{H}$$

$R \nearrow H$



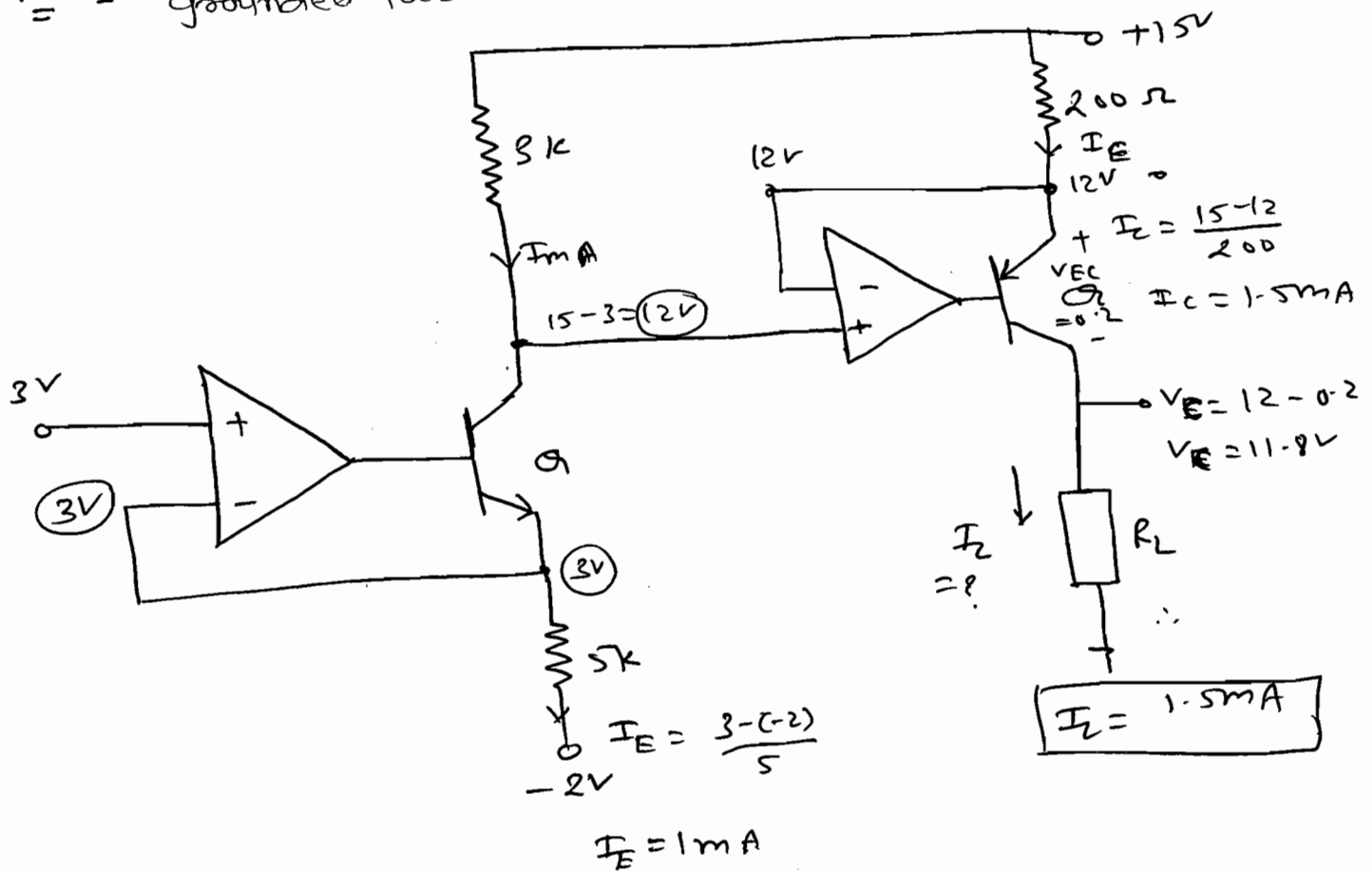
⇒



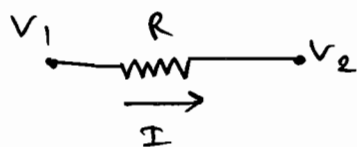
→ Temp. changes but all parameters stable because of -ve feed back mechanism which is provided by non-inverting op-Amp.

Voltage programmable Current Source with grounded load.

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* NOTE:



$\Rightarrow$

$$I = \frac{V_1 - V_2}{R}$$

$$V_2 = V_1 - IR$$

→ find the minimum value of R_L for the BJT to be in Sat. with $V_{EC} = 0.2$.

$$\therefore V_E = 12\text{V}$$

$$V_{EC} = 0.2\text{V}$$

$$\therefore V_E - V_C = 0.2$$

$$\therefore V_C = 12 - 0.2 = 11.8\text{V}$$

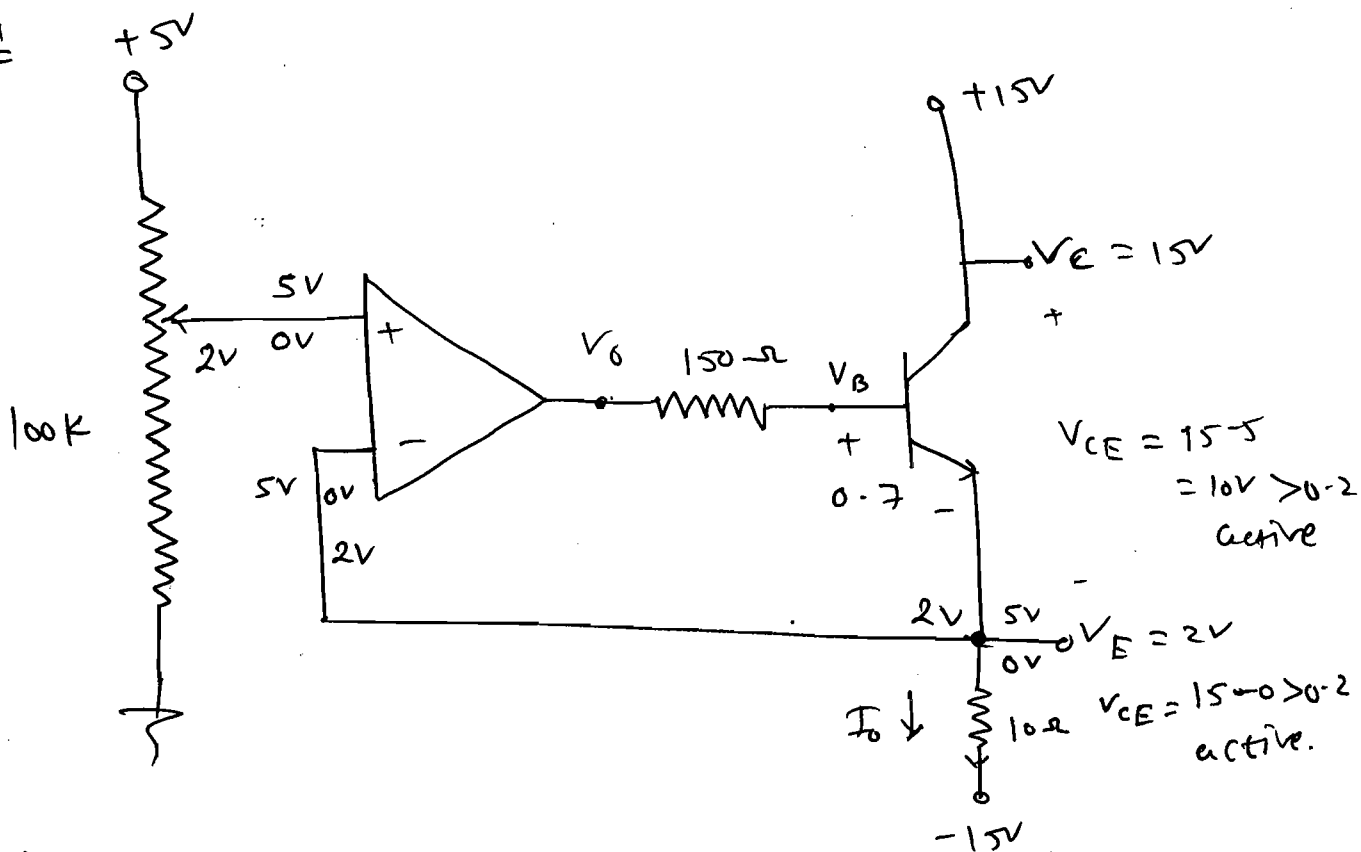
$$\therefore R_C = \frac{V_C}{I_C}$$

$$\therefore R_{L\min} = \frac{11.8}{1.5\text{mA}}$$

$$\therefore R_{L\min} = 786\Omega$$

hm

Ex-1



Find

- Check the region of operation.
- If $V_{in} = 2V$ then find V_o & I_o .

Ans: (a) possible value of V_{in} is ± 5 & 0 .

for both the value transistor is active region as shown in ckt.

(b) Now, $V_{in} = 2V$

$$\therefore V_E = 2V.$$

$$\therefore I_o = \frac{2 - (-15)}{10}$$

$$\therefore \boxed{I_o = 1.7A}$$

$$\therefore V_B - 0.7 = 2V$$

$$\therefore \boxed{V_o = 2.7V}$$

$$\therefore \frac{V_o - V_B}{150} = I_B$$

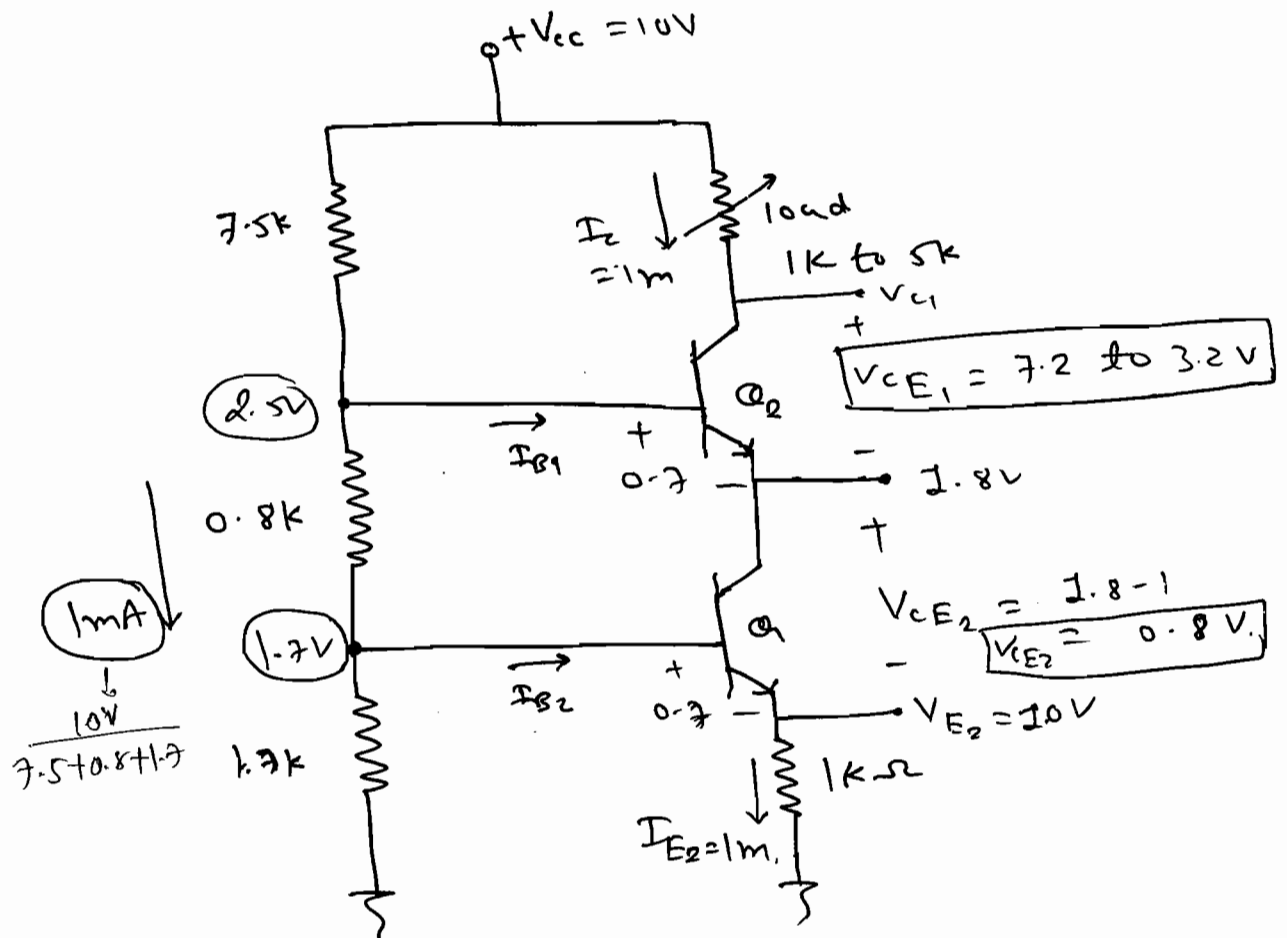
$$\therefore \frac{V_o - V_B}{150} = \frac{I_E}{\beta + 1}$$

$$\therefore V_o - 2.7 = \frac{150 \times 1.7}{101}$$

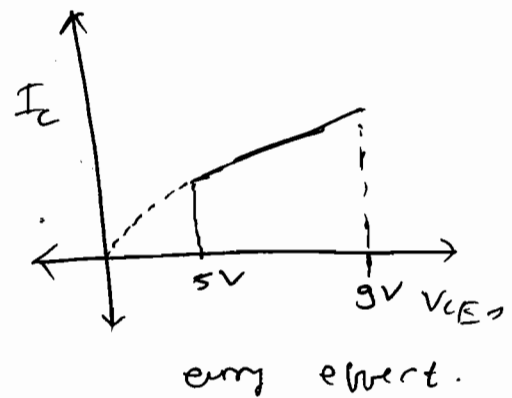
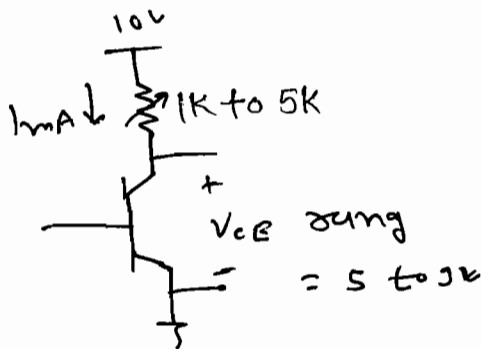
$$\boxed{V_o = 5.224V}$$

★ Cascade Current Source for Improved Stability on Load Variations. 125

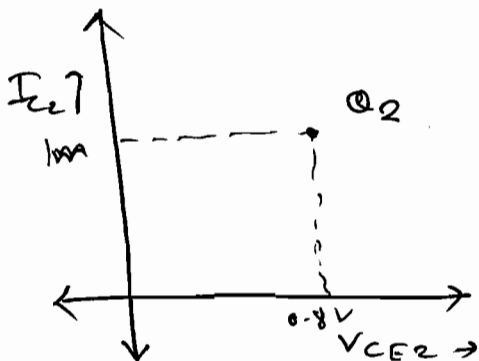
⇒



→

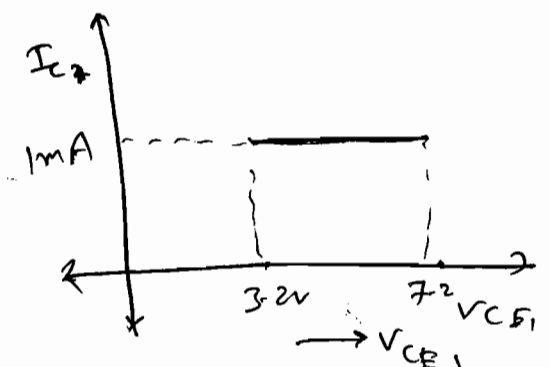


→



[for Q_2]

→

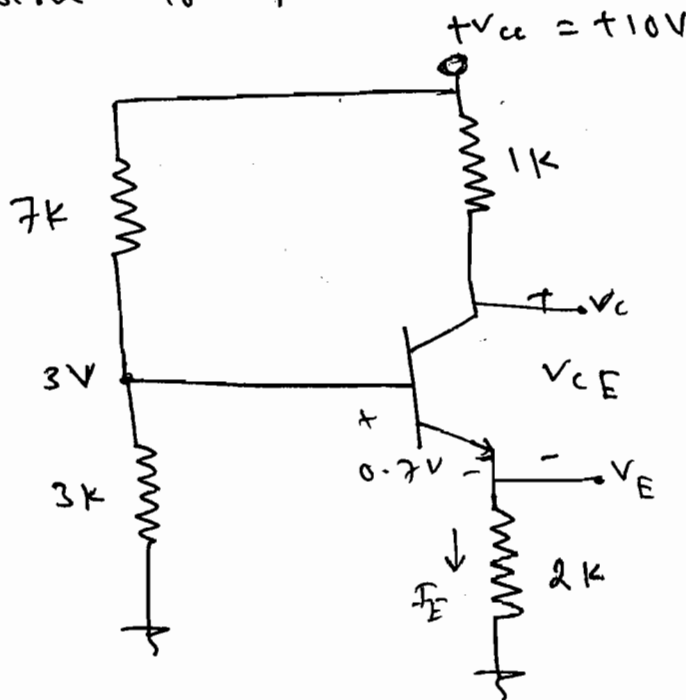


$$R_o = \frac{1}{Slope} = \frac{1}{0} = \infty$$

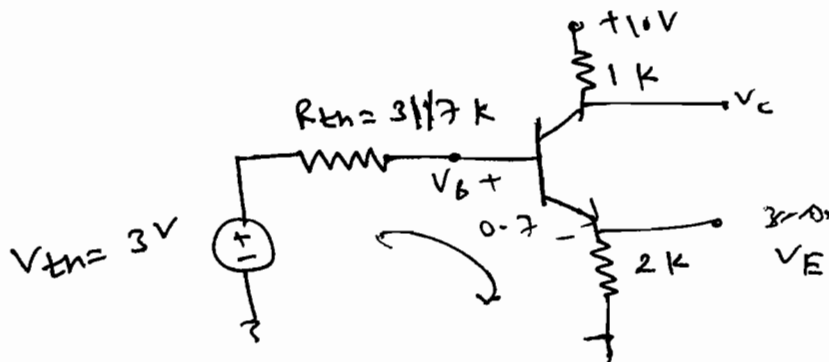
ideal current source

load	V_{CE2}	V_{CE1}	I_C
1K	0.8	7.2 V	1mA
2K	0.8	6.2 V	1mA
3K	0.8	5.2 V	1mA
4K	0.8	4.2 V	1mA
5K	0.8	3.2 V	1mA

Ex-1 Calculate all node voltages and Branch current if $\beta = 100$.



Ans:



$$\rightarrow V_{th} - \frac{I_E}{\beta + 1} R_{th} - V_{BE} - I_E R_E = 0$$

$$\therefore I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta + 1}}$$

$$R_{th} = \frac{3 \times 7}{10}$$

$$R_{th} = 2.1 \text{ K}\Omega$$

$$\therefore I_E = \frac{3 - 0.7}{2 + \frac{2.1}{101}}$$

$$I_E = \frac{2.3}{2.02}$$

$$\therefore I_E = 1.14 \text{ mA} \quad \checkmark$$

$$\therefore I_C = \frac{\beta}{\beta+1} \times I_E.$$

$$\therefore I_C = \frac{100}{101} \times 1.14 \text{ mA}$$

$$\therefore I_C = 1.127 \text{ mA} \quad \checkmark$$

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

$$\therefore V_C = 10 - (1.127 \times 1 \text{ k}).$$

$$\therefore V_C = 8.87 \text{ V} \quad *$$

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

$$V_E = I_E R_E.$$

$$I_B = 11.29 \text{ } \mu\text{A} \quad \checkmark$$

$$\therefore V_E = 2.28 \text{ V} \quad *$$

$$\therefore \frac{V_{CC} - V_B}{2.1 \text{ k}} = I_B.$$

$$\therefore 3 - V_B = 11.29 \times 10^{-6} \times 2.1 \text{ k}$$

$$\therefore 3 - V_B = 0.024.$$

$$\therefore V_B = 2.976 \text{ V} \quad *$$

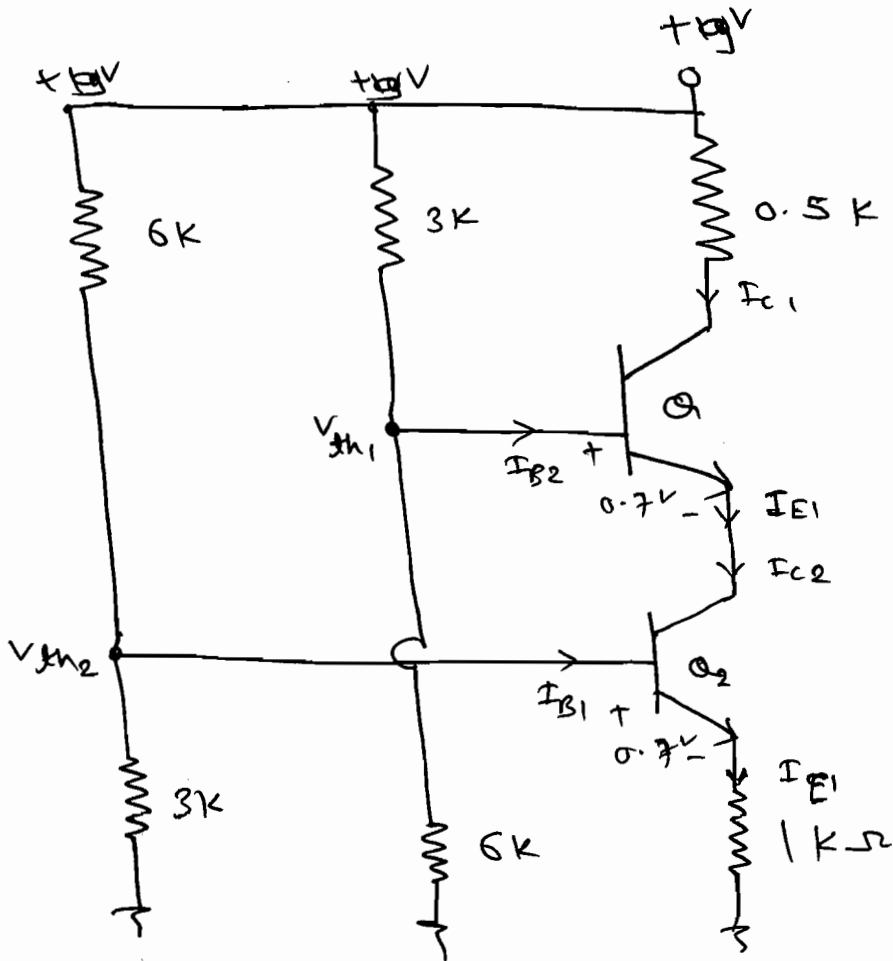
$$V_{CE} = V_C - V_E$$

$$\therefore V_{CE} = 8.87 - 2.28$$

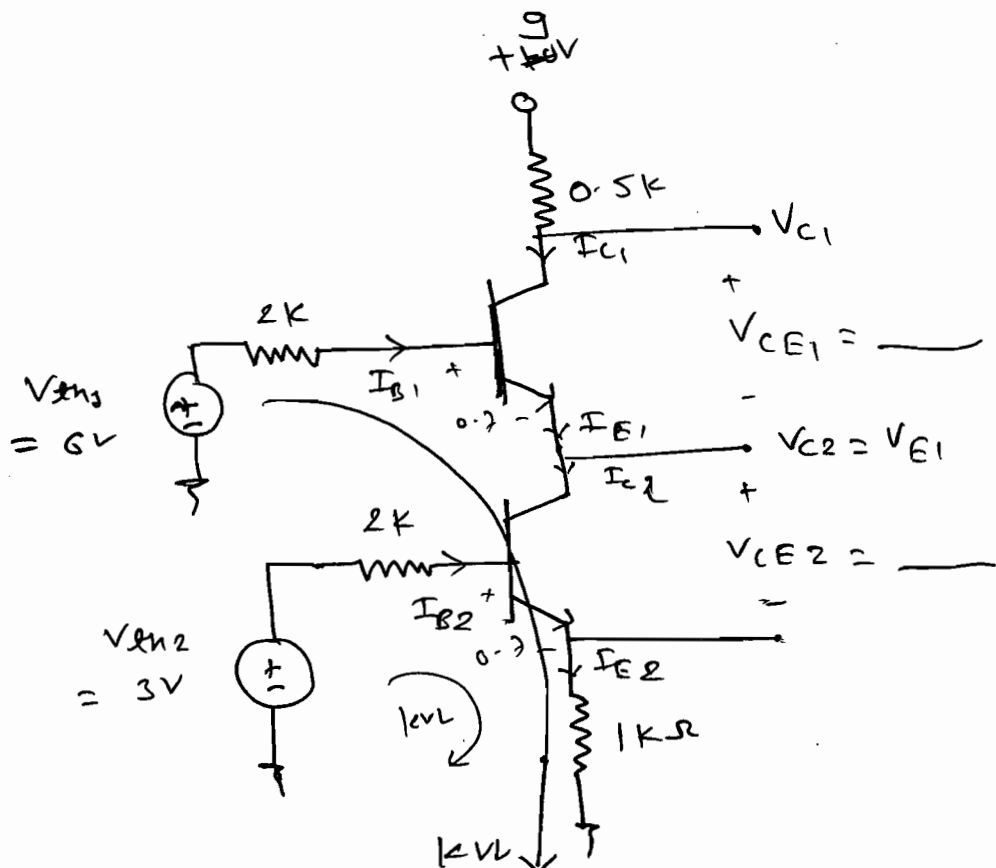
$$\therefore V_{CE} = 6.59 \text{ V} \quad *$$

Ex-2 Calculate the all the Node Voltages and Branch currents.

⇒



Ans:



$$I_{E2} = \frac{V_{th2} - V_{BE2}}{R_E + \frac{R_{th1}}{\beta + 1}}$$

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$$R_{th1} = \frac{3 \times 6}{9}$$

$$R_{th1} = 2 \text{ K.}$$

$$\therefore I_{E2} = \frac{3 - 0.7}{1 + \frac{2}{101}}$$

$$V_{th1} = \frac{3}{8} \times 8$$

$$V_{th1} = 3 \text{ V.}$$

$$\therefore \boxed{I_{E2} = 2.255 \text{ mA}} \quad \checkmark$$

$$\therefore I_{C2} = \frac{\beta}{\beta + 1} \times I_{E2}$$

$$\therefore I_{C2} = \frac{100}{101} \times 2.255$$

$$\therefore \boxed{I_{C2} = 2.23 \text{ mA}} \quad \checkmark$$

$$\therefore I_{B2} = \frac{I_{E2}}{\beta + 1}$$

$$\therefore \boxed{I_{B2} = 22.33 \text{ } \mu\text{A.}} \quad \checkmark$$

$$\therefore I_{E1} = I_{C2}$$

$$\therefore \boxed{I_{E1} = 2.23 \text{ mA.}} \quad \checkmark$$

$$\therefore I_{C1} = \frac{\beta}{\beta + 1} \times I_{E1}$$

$$\therefore I_{C1} = \frac{100}{101} \times 2.23$$

$$\therefore \boxed{I_{C1} = 2.21 \text{ mA.}} \quad \checkmark$$

$$\therefore I_{B1} = \frac{I_{E1}}{\beta + 1} \quad \therefore \boxed{I_{B1} = 22.08 \text{ } \mu\text{A.}} \quad \checkmark$$

$$\therefore V_{E2} = I_{E2} \times R_{E2}$$

$$\therefore V_{E2} = 2.255 \times 1$$

$$\therefore \boxed{V_{E2} = 2.255 \text{ V}} \star$$

$$\therefore V_{C1} = 9 - I_{C1} R_{C1}$$

$$\therefore V_{C1} = 9 - (2.21 \times 0.5)$$

$$\therefore \boxed{V_{C1} = 7.895 \text{ V}} \star$$

$$\therefore V_{th1} - I_{B1} R_{th1} - 0.7 - V_{CE2} - I_{E2} R_{E2} = 0$$

$$\therefore V_{CE2} = 6 - (0.02208 \times 2) - 0.7 - (2.255 \times 1)$$

$$\therefore \boxed{V_{CE2} = 3 \text{ V}} \star$$

$$\therefore V_{CE2} = V_{C2} - V_{E2}$$

$$\therefore V_{C2} = 3 + 2.255$$

$$\therefore \boxed{V_{C2} = 5.255 \text{ V}} \star$$

$$\therefore V_{E1} = V_{C2}$$

$$\therefore \boxed{V_{E1} = 5.255 \text{ V}} \star$$

$$\therefore V_{CE1} = V_{C1} - V_{E1}$$

$$\therefore V_{CE1} = 7.895 - 5.255$$

$$\therefore \boxed{V_{CE1} = 2.64 \text{ V}} \star$$

$$V_{B1} = \frac{V_{th1} - V_{B1}}{R_{th1}} = I_{B1}$$

$$\therefore V_{B1} = V_{th1} - I_{B1} R_{th1}$$

$$\therefore V_{B1} = 6 - (0.02208 \times 2)$$

$$\boxed{V_{B1} = 5.9558 \text{ V}} \star$$

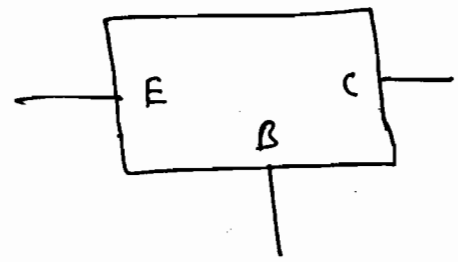
$$V_{B2} = V_{th2} - I_{B2} R_{th2}$$

$$\therefore \boxed{V_{B2} = 2.955 \text{ V}} \star$$

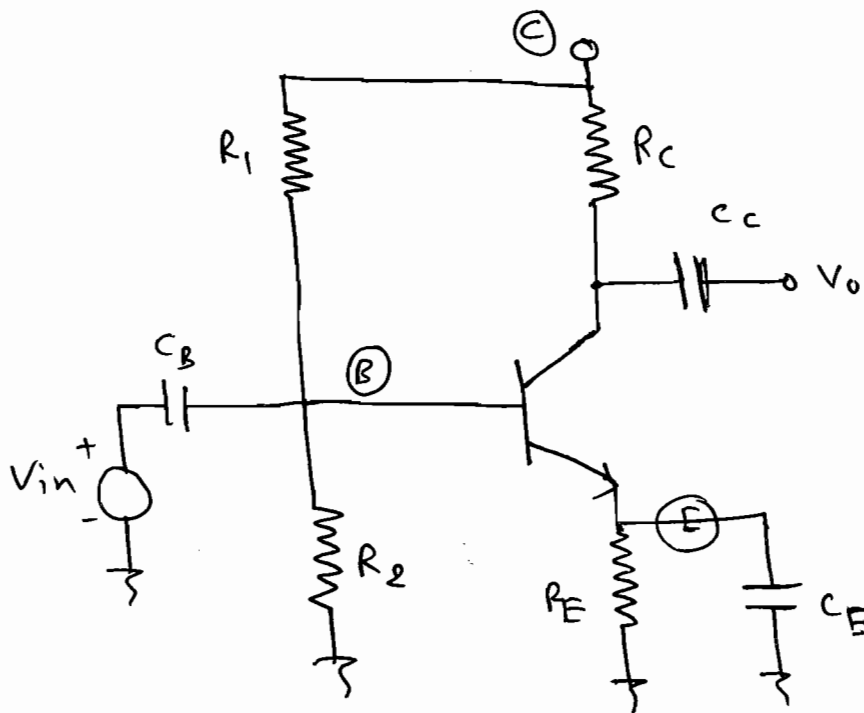
★ Configuration of BJT:

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- 1) Common Emitter
- 2) Common Base
- 3) Common Collector



① Common Emitter:



$$Z_{in} = 1 \text{ k}\Omega$$

$$Z_o = 50 \text{ k}\Omega$$

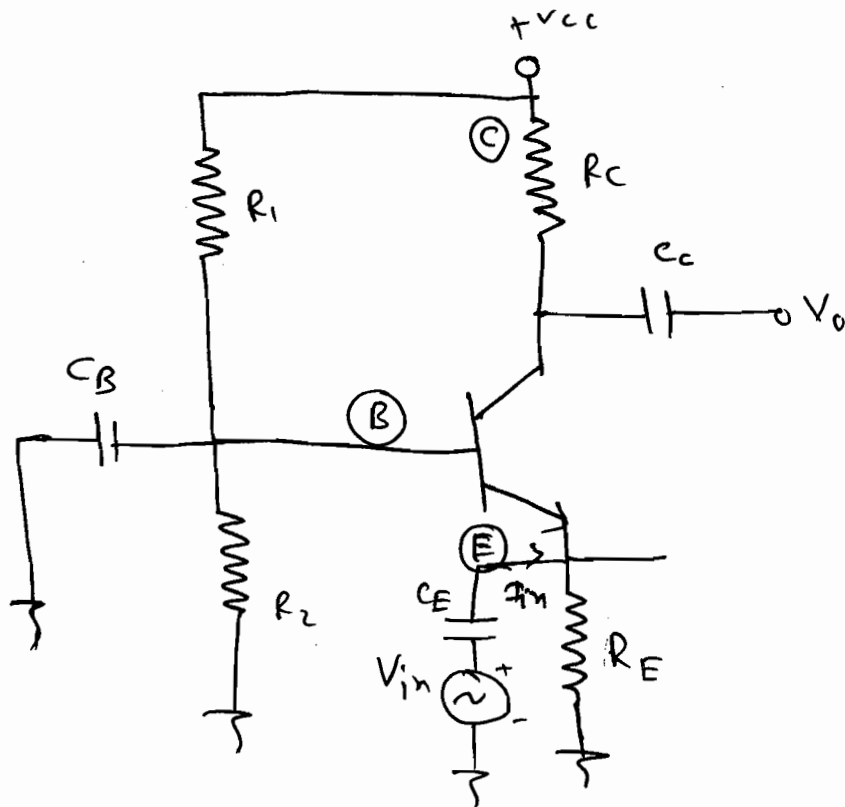
$$A_v = -200$$

$$A_i = -100$$

$$A_p = A_v A_i$$

Very high power gain.

② Common Base:



$$Z_{in} = \frac{V_{in}}{R_{in}} = 30 \Omega \Rightarrow CC$$

$$\therefore Z_o = 1 M\Omega \Rightarrow CS$$

$$\therefore CB \Rightarrow CCCS.$$

$$\rightarrow A_I = 1 \Rightarrow \underline{\text{Current Buffer}}$$

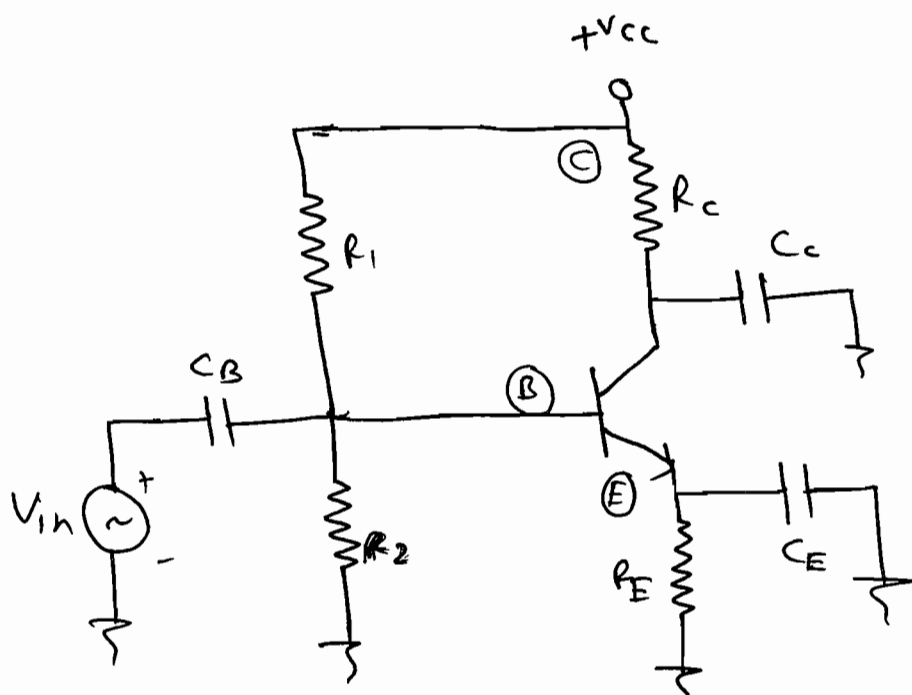
$$\therefore A_V = \infty$$

$$\therefore A_P = A_V \cdot A_I$$

$$A_P = \infty.$$

(3) Common Collector:

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$$Z_{in} = g_m \Omega (V_C).$$

$$Z_o = 8 \Omega (V_S).$$

$$C_C \rightarrow V_C V_S$$

$$A_V = 1 \rightarrow \text{voltage Buffer}$$

$$A_I = 100.$$

$$\therefore A_P = A_V \cdot A_I$$

$$\therefore A_P \cong A_I$$

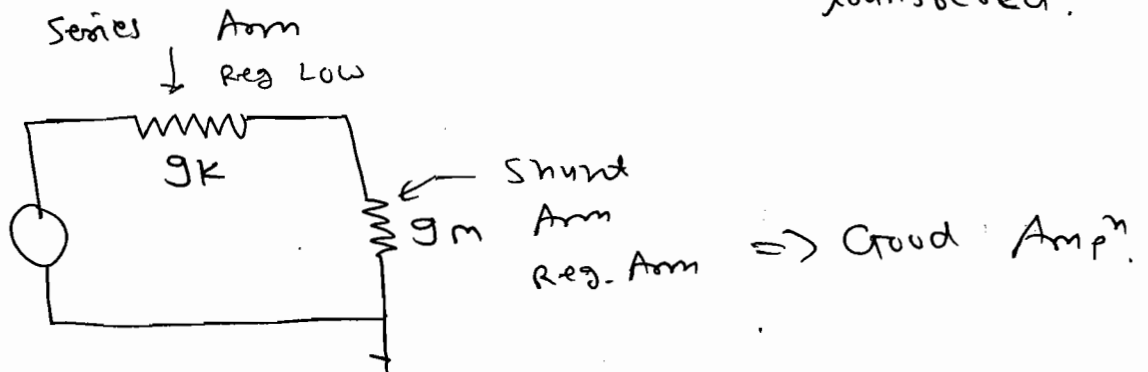
* Input impedance is found for Impedance matching.

* Output Resistance is found for Maximum power transfer.

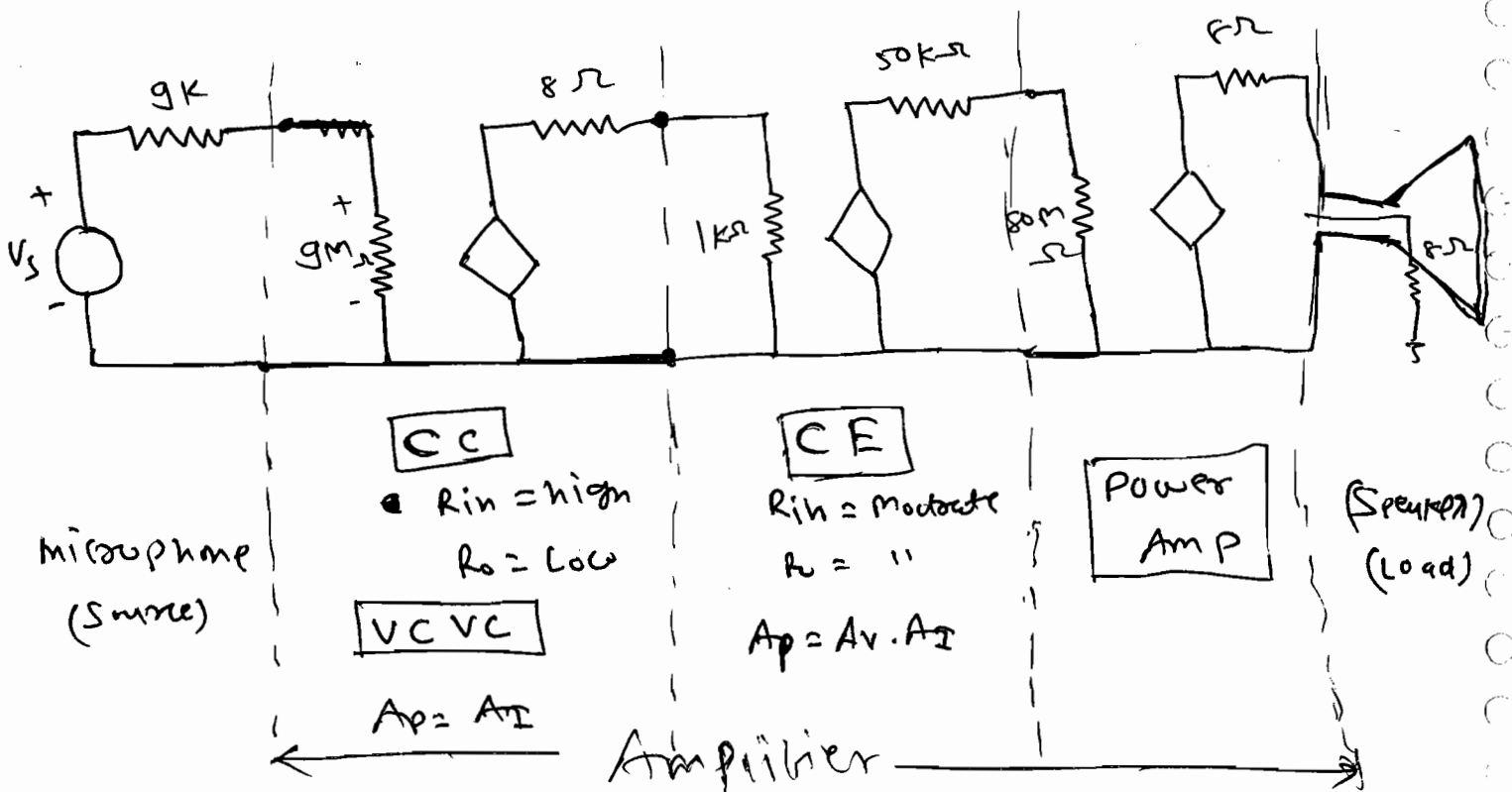
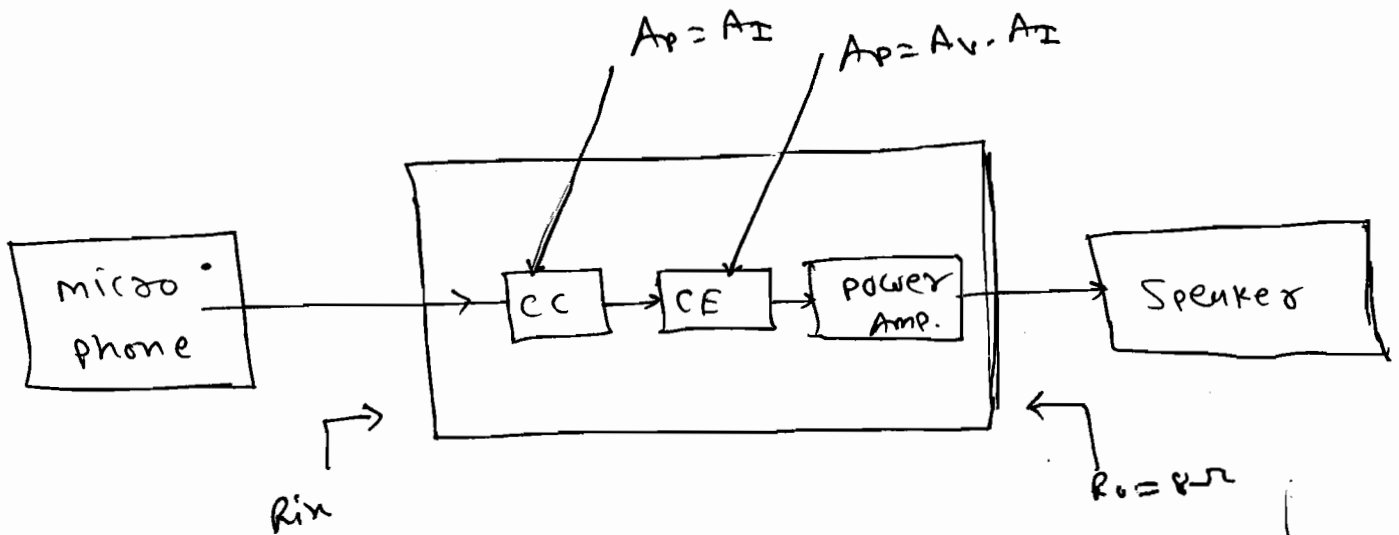
If OIP Resistance = Load Resistance



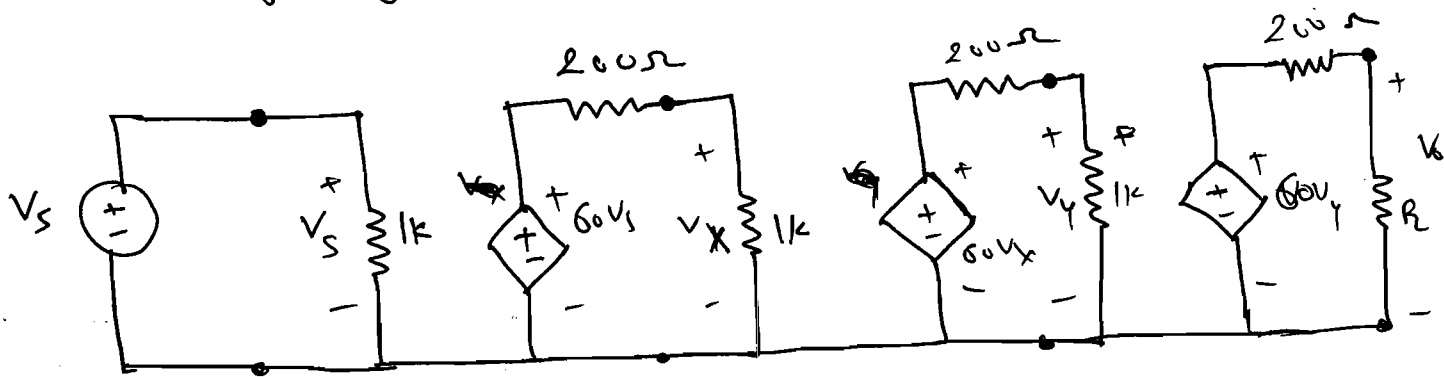
Maximum power can be transferred.



*



Ex: (1) An Amp has an input Resistor of 135
 $1\text{ k}\Omega$, o/p Resistor $= 200\Omega$. It and
 open loop Voltage gain $A_o = 50$. It is
 similar Stages cascaded with a load
 Resistor $R_L = 2.2\text{ k}\Omega$. Find the over all
 Voltage gain.



$$\therefore A_v = \frac{V_o}{V_s} = \frac{V_o}{V_y} \times \frac{V_y}{V_x} \times \frac{V_x}{V_s}$$

$$\therefore V_x = \frac{50 V_s \times 1\text{ k}}{200\Omega + 1\text{ k}}$$

$$\therefore \boxed{V_x = 50 \cdot V_s}$$

$$\therefore \boxed{\frac{V_x}{V_s} = 50}$$

$$\therefore V_y = \frac{50 V_x \times 1000}{1200}$$

$$\therefore \boxed{\frac{V_y}{V_x} = 50}$$

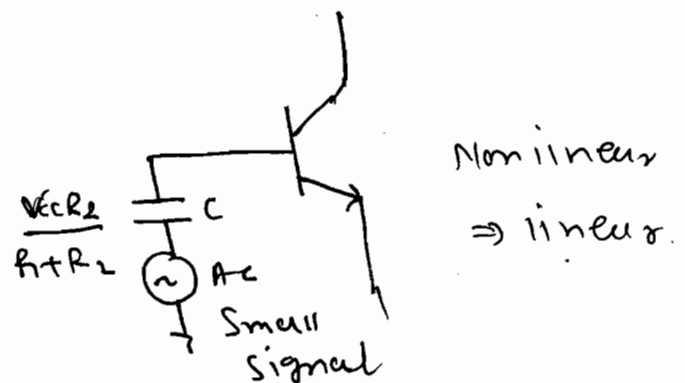
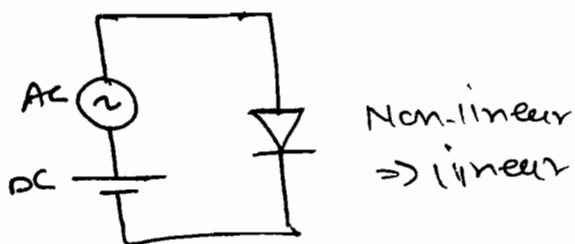
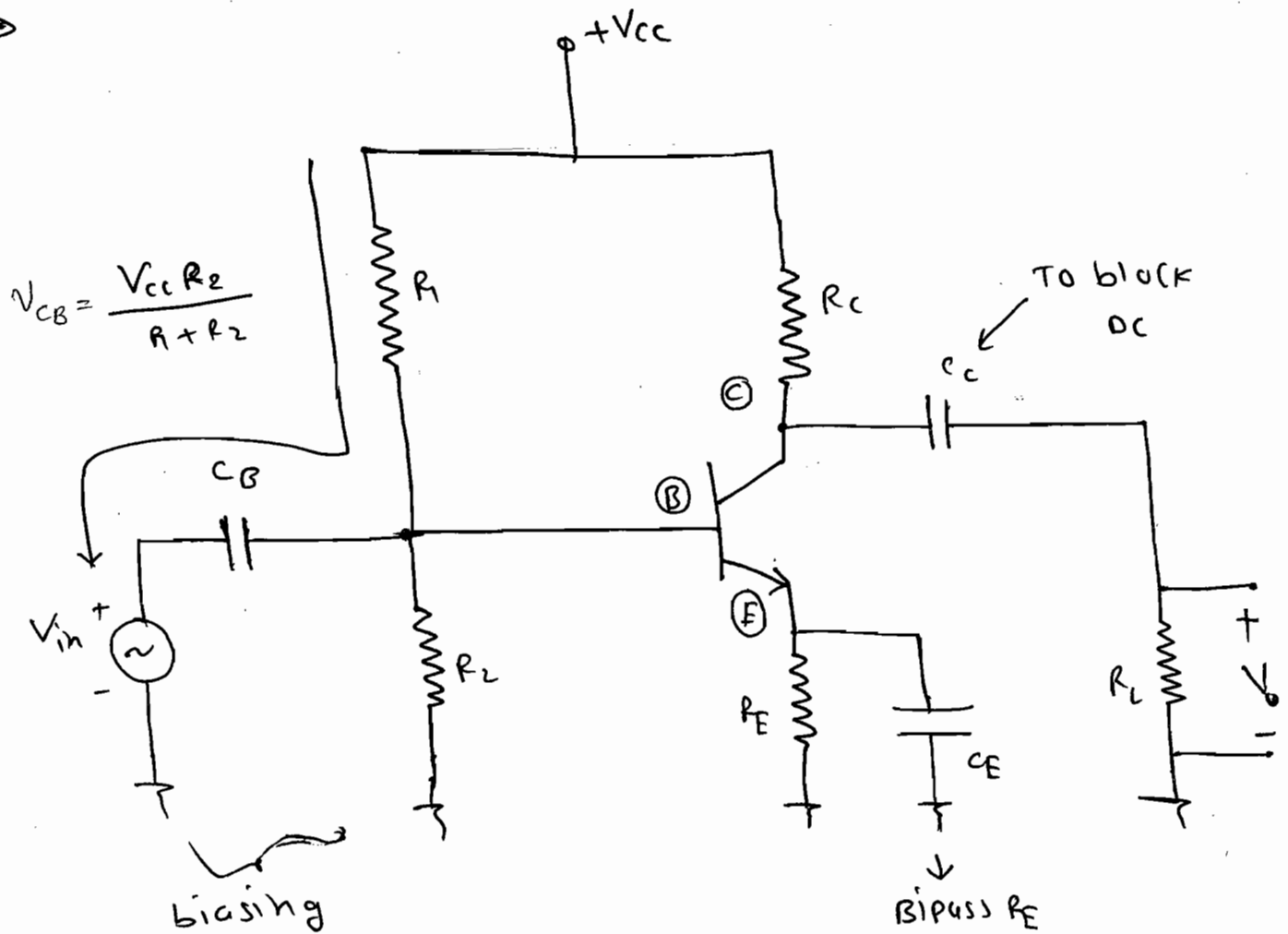
$$\therefore V_o = \frac{50 V_y \times 2200}{2400}$$

$$\boxed{\frac{V_o}{V_y} = 55}$$

$$\therefore A_v = 55 \times 50 \times 50$$

$$\boxed{A_v = 1.375 \times 10^5}$$

★ Small Signal Analysis of BJT:-



→ If load connected to V_{CC} it is called floating load and it is R_C coupled ckt.

→ If load is connected to ground then it is called grounded load and called Direct coupled ckt.

* Purpose of each capacitor:

→ ① $C_B \rightarrow$ for DC biasing.

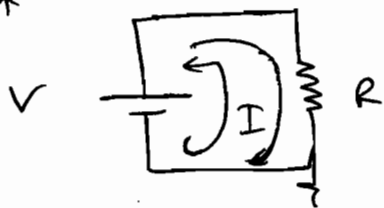
② $C_E \rightarrow$ to block DC and allow AC in V_o .

③ $C_E \rightarrow$ Bypass C_E .

→ (i) C_E behaves as open circuit for DC signal and it allows R_E to play its role in establishing β independent DC collector current. ($I_{C_{DC}}$).

(ii) C_E behaves as short circuit for AC signal eliminating the gain Reducing emitter Resistor.

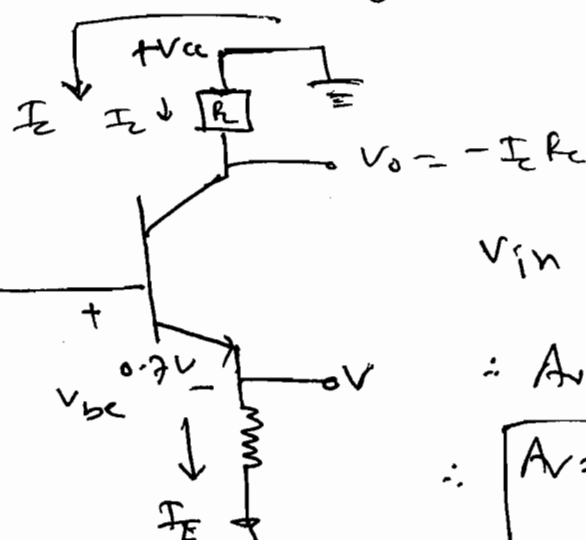
*



→ Going to ground $V = IR$

→ Coming from ground $V = -IR$.

CE ~~Amplifier~~ BJT gives 180° Phase Shift
as we get V_o in V_{in}



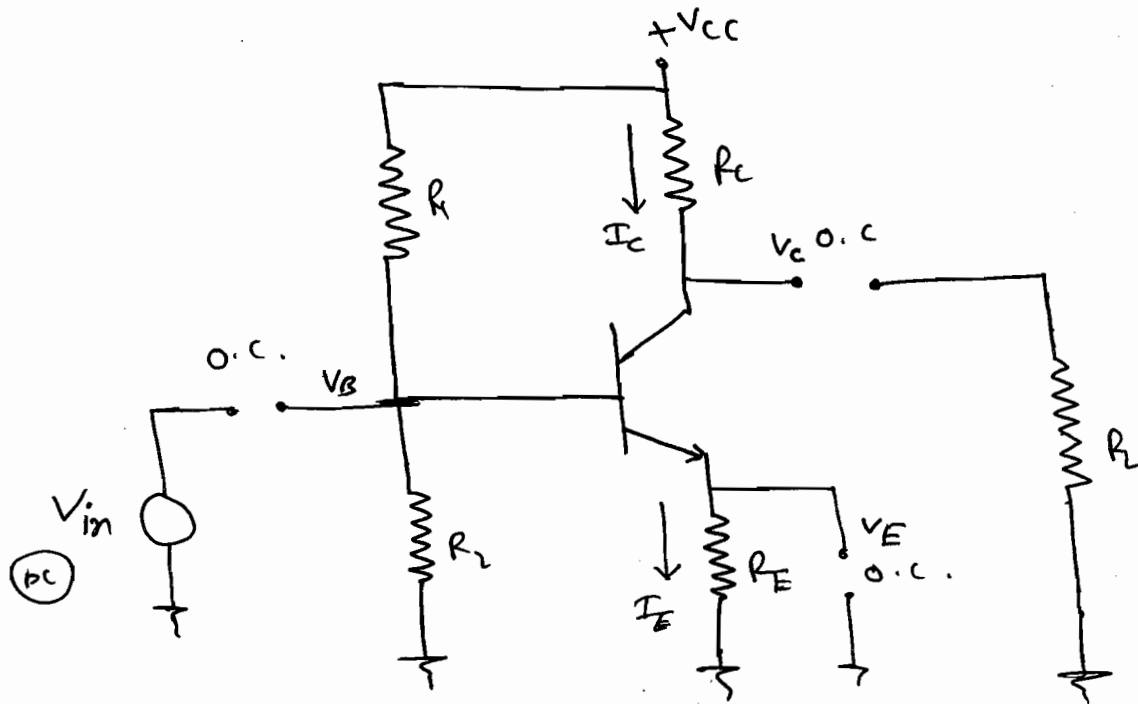
$$V_{in} = V_{be} + I_E R_E$$

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

$$\therefore A_v = \frac{-I_E R_E}{V_{be} + I_E R_E}$$

① Dc picture:

→ open circuit the all capacitor.
After that it is self bias.



$$\therefore V_{c_{dc}} = V_{cc} - I_{c_{dc}} R_c$$

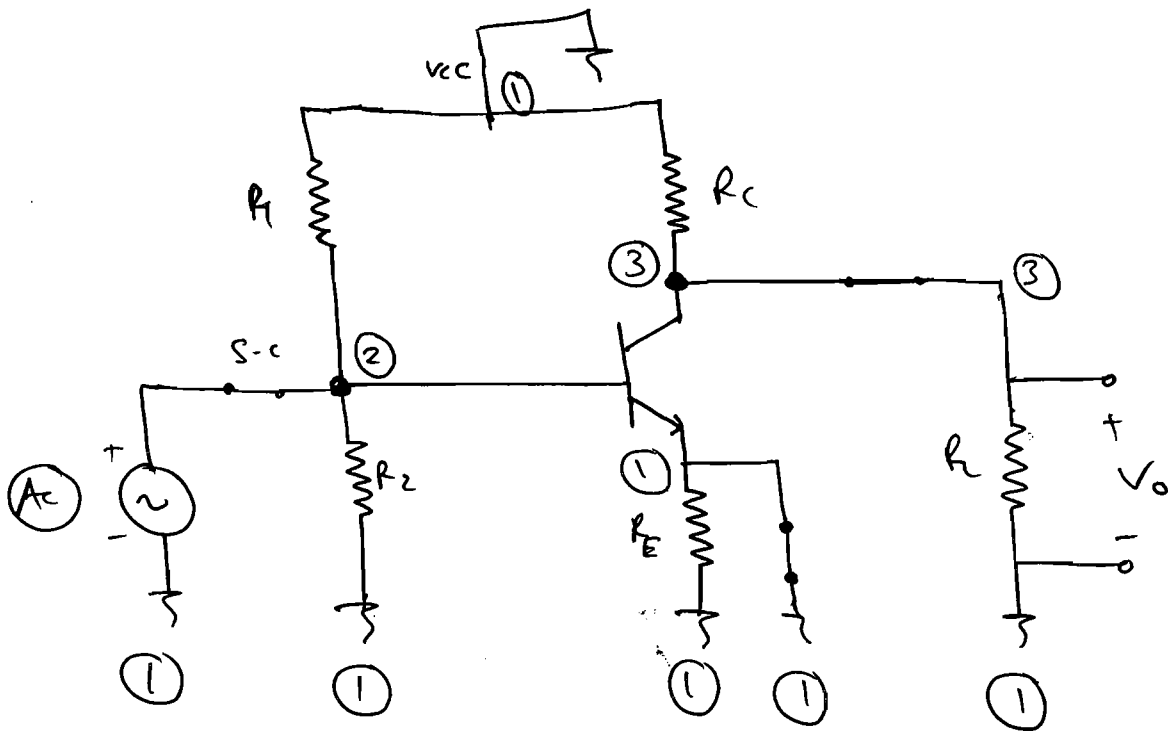
$$\therefore V_{c_{dc}} = V_{cc} - \left[\frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 || R_2}{\beta + 1}} \right] \cdot R_c$$

$$\rightarrow I_{c_{dc}} = I_E = \frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 || R_2}{\beta + 1}}$$

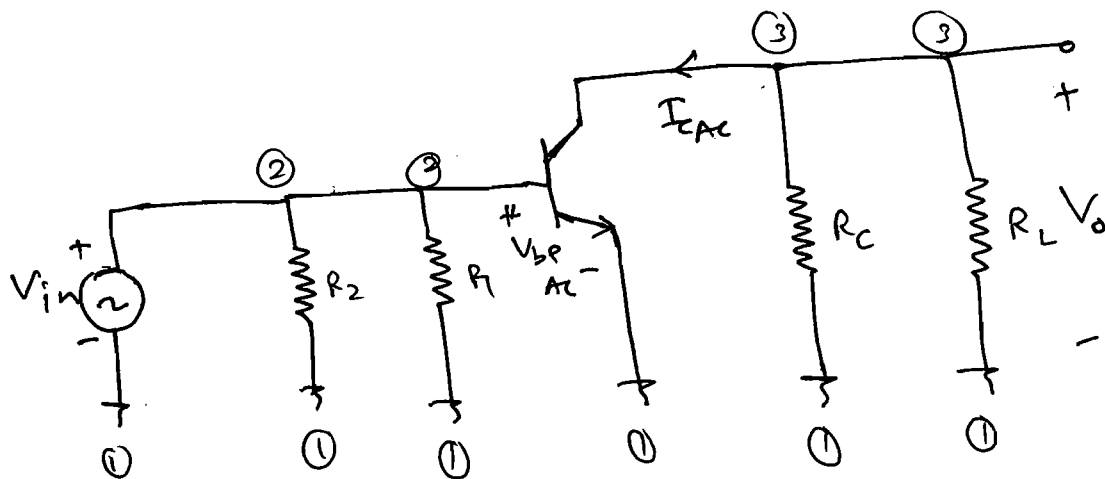
(2) Ac Picture:

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→ Short cts all the capacitors and DC supply i.e. V_{cc} .



⇓



$$\therefore V_o = -I_{cAc} (R_C \parallel R_L).$$

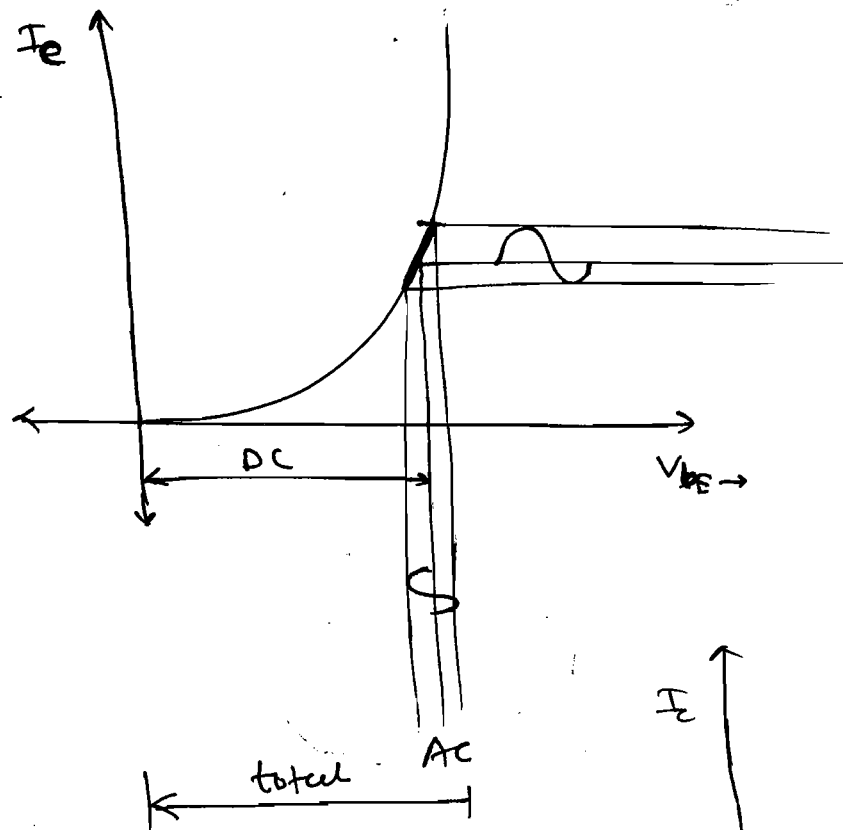
$$\therefore V_{in} = V_{be_{Ac}}.$$

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

$$A_v = \frac{-I_{c(Ac)}}{V_{be(Ac)}} [R_c || R_L]$$

$$\therefore A_v = -g_m [R_c || R_L]$$

$$\rightarrow I_c = I_s \cdot e^{V_{be}/V_t}$$



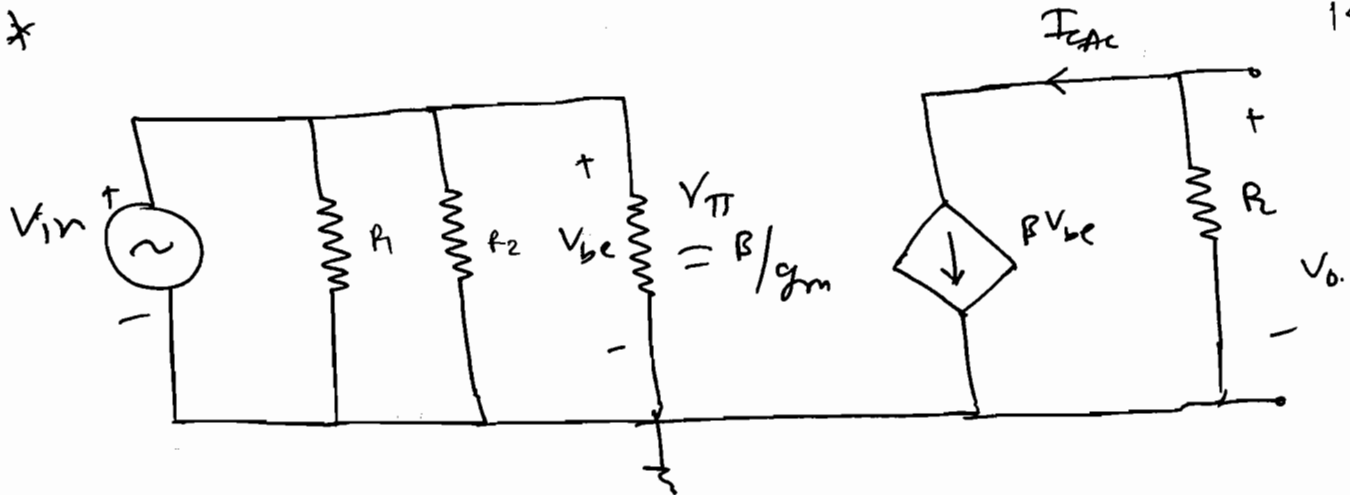
$$g_m = \frac{dI_c}{dV_{be}} \cdot \frac{V_{be}/V_t}{V_t}$$

$$= I_s \cdot e \cdot \frac{1}{V_t}$$

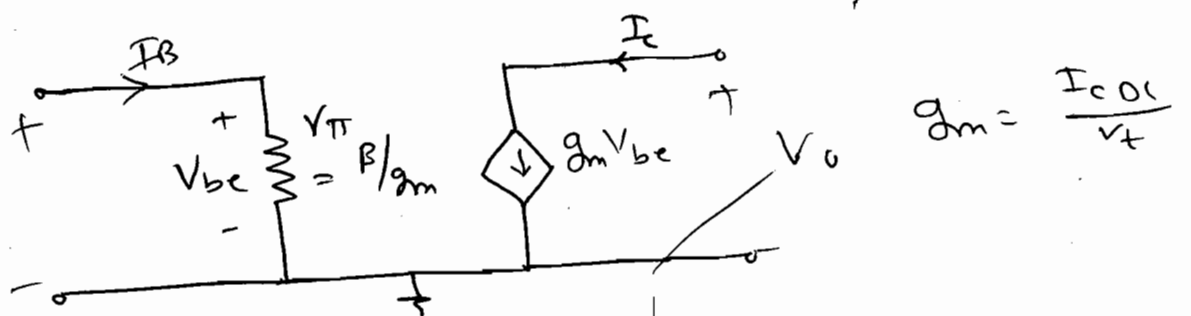
where

$$g_m = \frac{I_{c(Ac)}}{V_t}$$

$$\therefore g_m = \frac{I_c \cdot DC}{V_t}$$



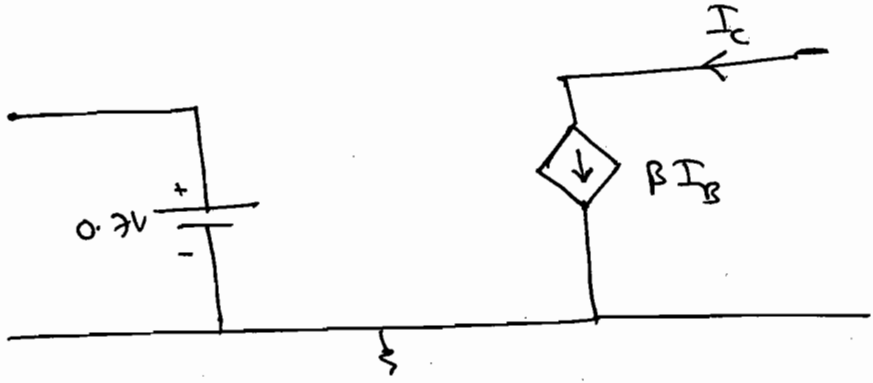
* AC model



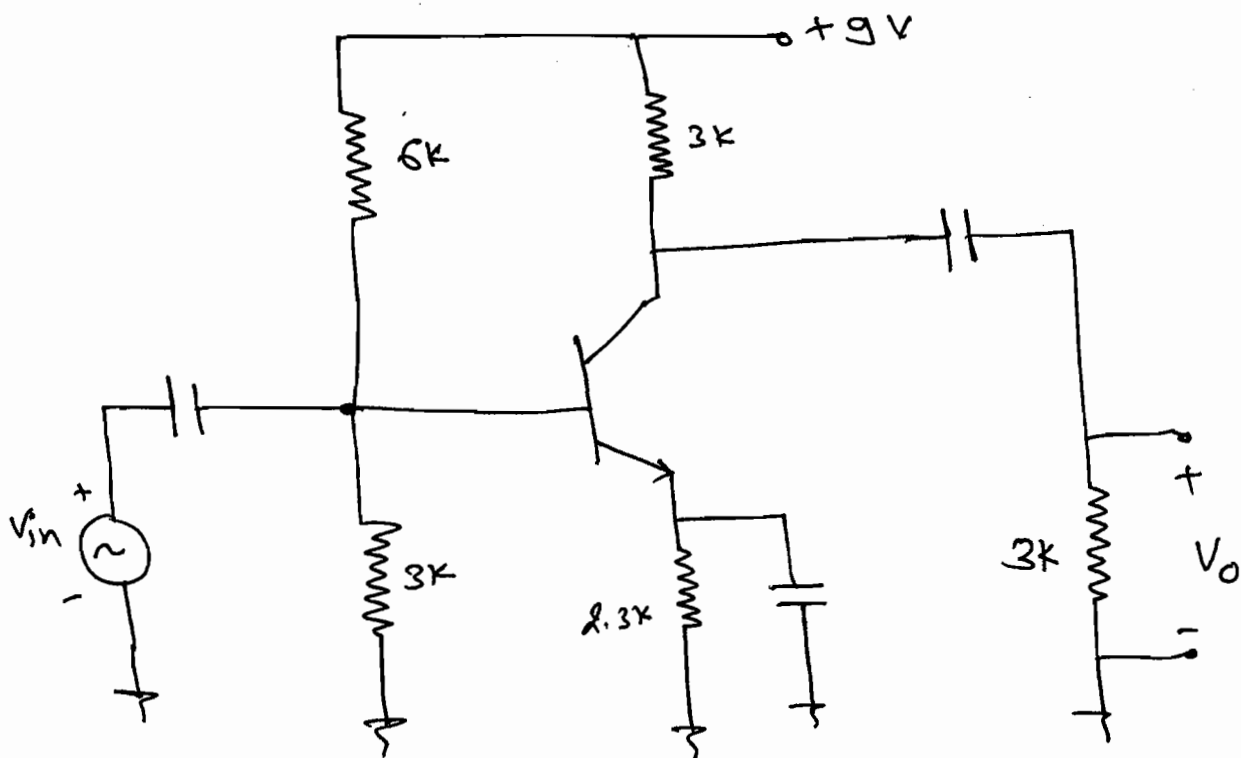
$$g_m = \frac{I_{CQ}}{V_T}$$

r_π = Base to emitter resistance

* Dc model



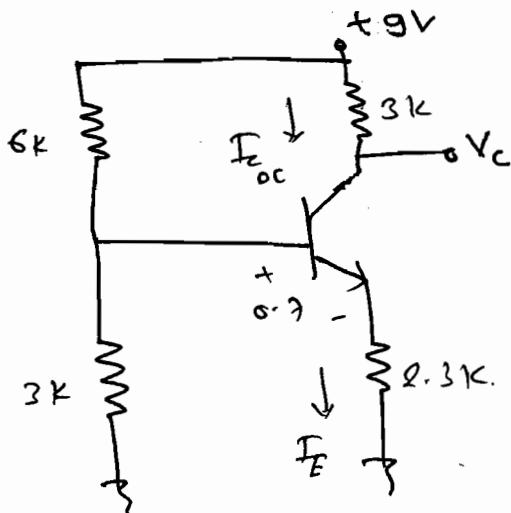
Ex-1 Find the voltage gain V_o/V_{in} if β is very large.



Ans:

① DC picture:

a.c. the capacitor



$$\therefore V_{th} = 3V, \quad R_{th} = 2k.$$

$$\therefore I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta + 1}}$$

$$\therefore I_E = \frac{3 - 0.7}{2.3 + 0} \quad (\because \beta \gg \text{very large})$$

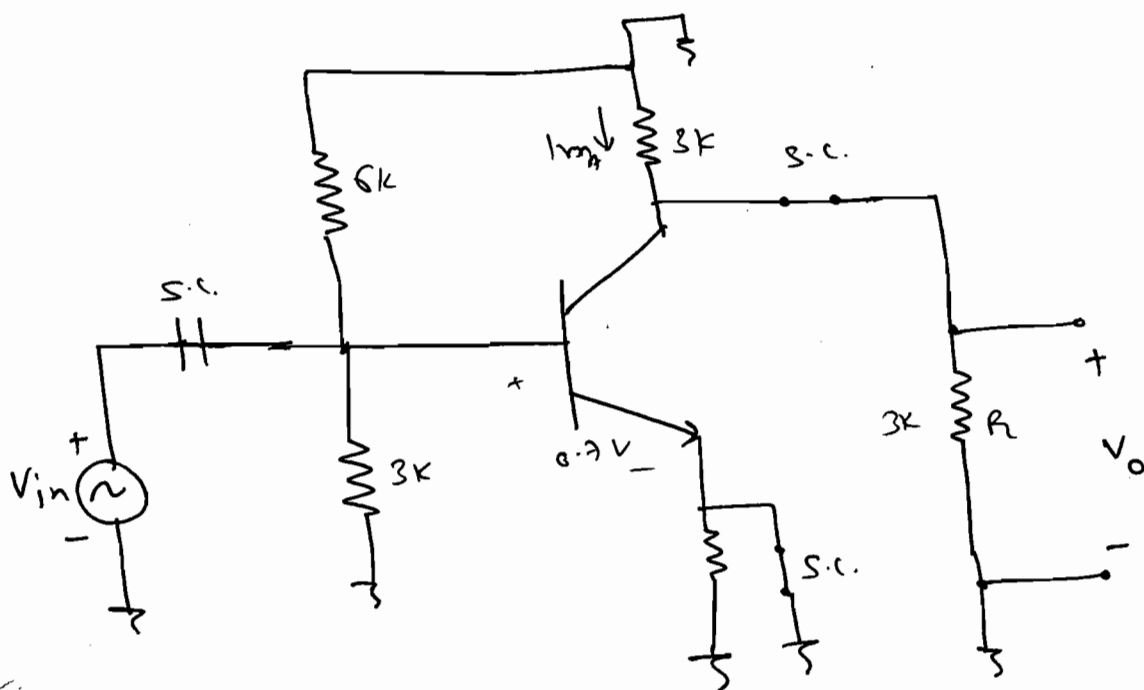
$$\therefore \boxed{I_E = 1 \text{ mA}}$$

$$\therefore I_{C_{DC}} = \frac{\beta}{\beta+1} \cdot I_E = I_E \quad (\because \beta \text{ is very large})$$

$$\therefore \boxed{I_{C_{DC}} = 1 \text{ mA}}$$

→ ② Ac picture

S.C. Capacitors and Dc sources.



III



$$\therefore \frac{V_o}{V_{in}} = -g_m (R_C \parallel R_L)$$

$$g_m = \frac{I_{C_{DC}}}{V_T}$$

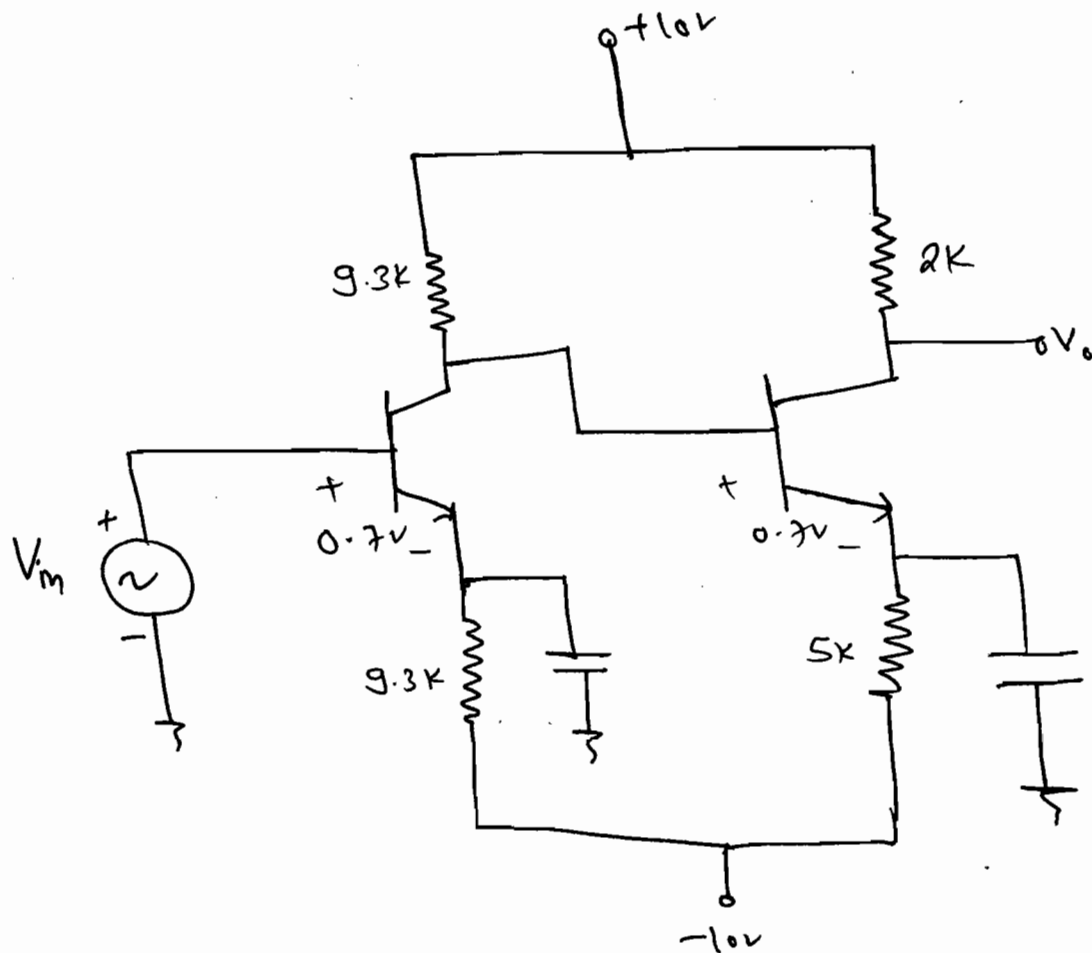
$$g_m = \frac{1 \text{ mA}}{25 \text{ mV}} = 0.04$$

$$\therefore \frac{V_o}{V_{in}} = -0.04 [1.5 \text{ k}]$$

$$\frac{V_o}{V_{in}} = -\frac{1}{25} \times 1500 = -60$$

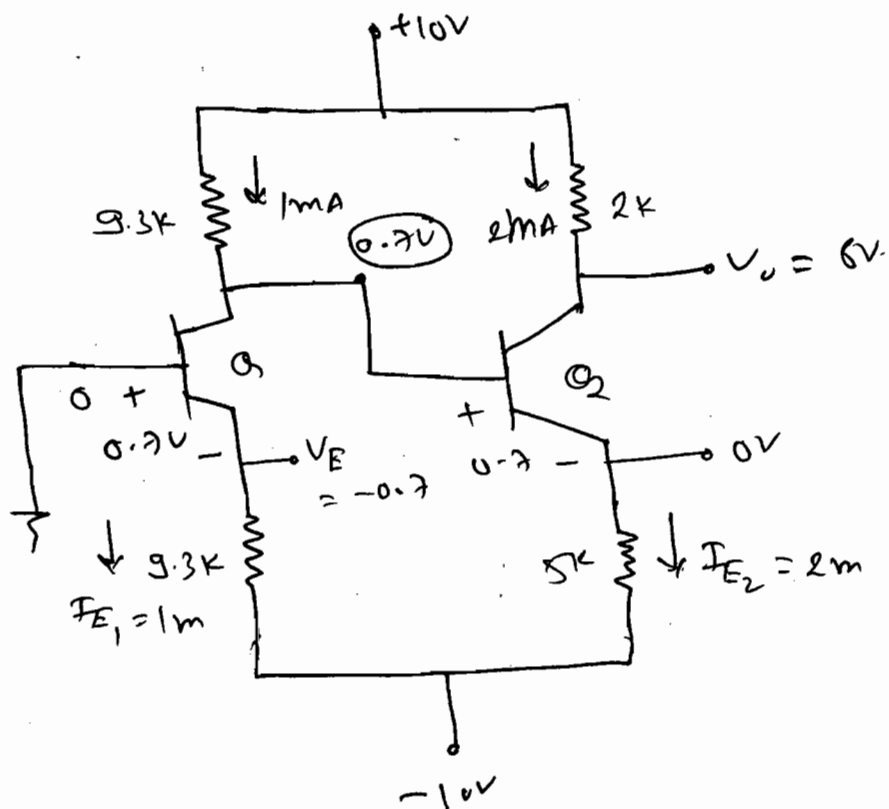
$$\therefore \boxed{\frac{V_o}{V_{in}} = -60}$$

Ex-2 Find V_o :



Ans:

① Dc picture.



$$\therefore V_{E1} = 0 - 0.7$$

$$V_{E1} = -0.7V$$

$$\rightarrow I_{E1} = \frac{-0.7 - (-10)}{9.3k}$$

$$= \frac{9.3}{9.3k}$$

$$\therefore I_{E1} = 1m$$

$$\therefore I_{C1} = 1m$$

$$\therefore V_{C1} = 10 - (9.3 \times 1)$$

$$V_{C1} = 0.7V$$

$$\therefore V_{E2} = 0.7 - 0.7 = 0V$$

$$\therefore I_{E2} = \frac{V_{E2} - (-10)}{5k}$$

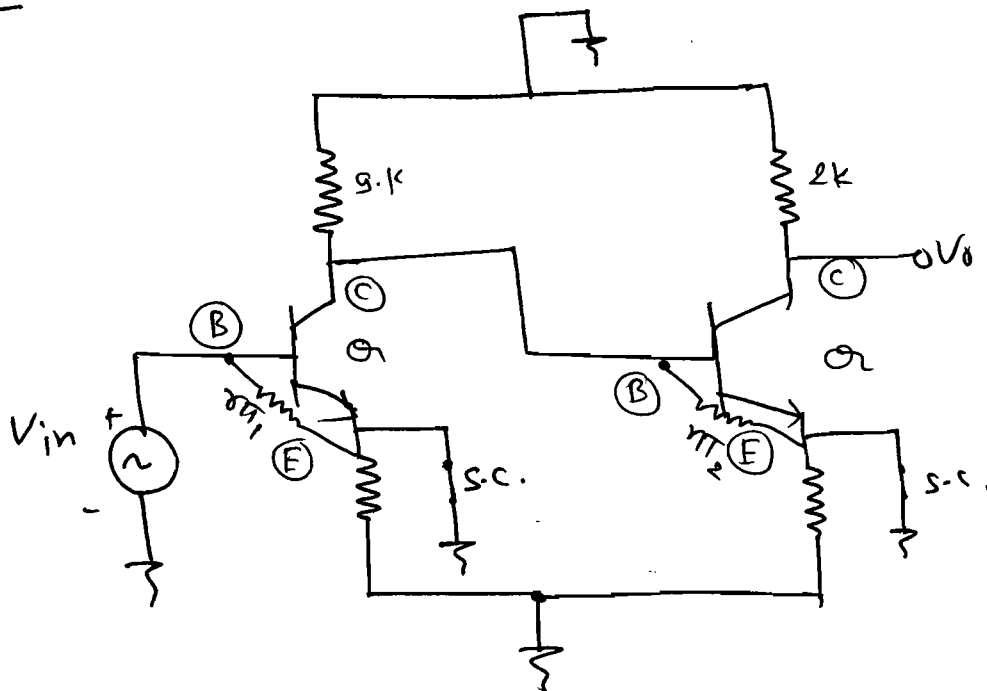
$$I_{E2} = 2mA$$

$$\therefore I_{C2} = 2mA$$

$$\therefore V_0 = 10 - (2 \times 2)$$

$$V_0 = 6V$$

② Ac picture:



Q₁

$$g_{m1} = \frac{I_{CQ1}}{V_T}$$

$$g_{m1} = \frac{1\text{m}}{25\text{m}}$$

$$g_{m1} = \frac{1}{25}$$

$$V_{\pi1} = \beta / g_{m1}$$

$$V_{\pi1} = \frac{100}{1/25}$$

$$V_{\pi1} = 2.5\text{K}\Omega$$

Q₂

$$g_{m2} = \frac{I_{CQ2}}{V_T}$$

$$= \frac{2\text{m}}{25\text{m}}$$

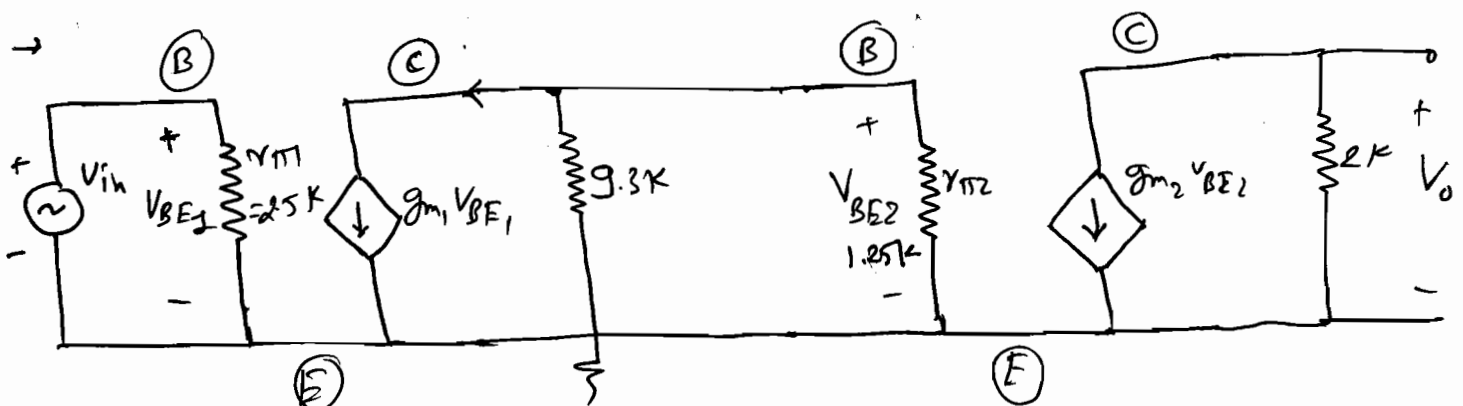
$$g_{m2} = \frac{2}{25}$$

$$V_{\pi2} = \beta / g_{m2}$$

$$V_{\pi2} = 100 / (2/25)$$

$$V_{\pi2} = 1.25\text{K}\Omega$$

Now,

(Q₁)(Q₂)

$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_{BE2}} \times \frac{V_{BE2}}{V_{BE1}}$$

$$\therefore V_{BE2} = -g_{m1} \cdot V_{BE1} \cdot (1.25k \parallel 9.3k).$$

$$\therefore \frac{V_{BE2}}{V_{BE1}} = -g_{m1} (1.25k \parallel 9.3k).$$

$$\therefore V_o = -g_{m2} V_{BE2} (2k).$$

$$\begin{aligned} \therefore \frac{V_o}{V_{in}} &= -g_{m2} (2k) \times -g_{m1} (1.25k \parallel 9.3k). \\ &= \frac{2}{25} \times \frac{1}{25} \times (2000) (\end{aligned}$$

$$\therefore \frac{V_o}{V_{in}} = A_v = 7052.$$

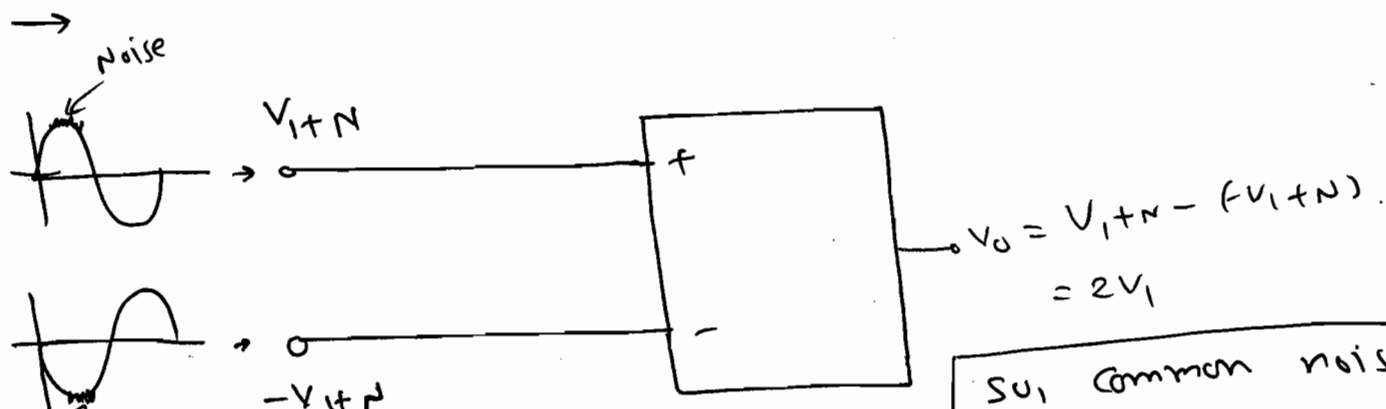
$$\text{Now, } V_o = 7052 \times V_{in}$$

$$\text{But } V_{in} = V_{BE1} = 0.7$$

$$\therefore V_o = 7052 \times V_{BE1} = 7052 \times 0.7$$

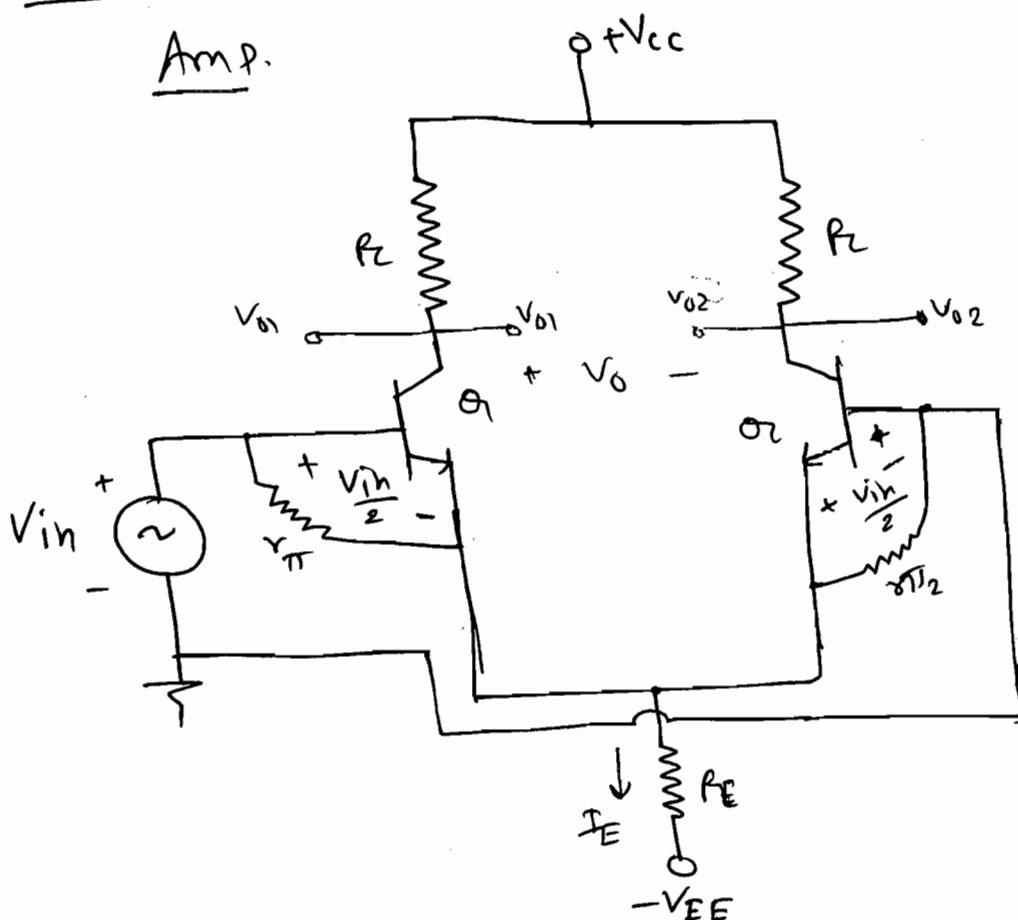
$$\therefore \boxed{V_o = 4936.5V}$$

★ Differential Amplifier:



So, Common noise gets cancelled out at output by taking differential measurement.

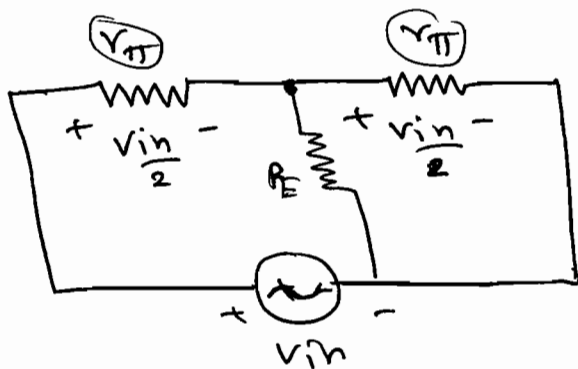
Direct Coupled Amp.



→ For DC analysis we will get $I_{C1\ DC}$ & $I_{C2\ DC}$.

Now, For Ac.

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→ Here, $R_E \gg r_{\pi}$ ($\because R_E$ is in $m\Omega$ and r_{π} is in $k\Omega$).

So, $R_E \parallel r_{\pi} \approx r_{\pi}$

So, R_E is shunted by r_{π} (dynamic resistance) as $R_E \gg r_{\pi}$.

Now, $V_{o1} = -I_{C_{DC1}} \cdot R_C$

$$\frac{I_C}{V_{BE}} = -g_m$$

$$\therefore V_{o1} = -g_m R_C (V_{BE1})$$

$$\therefore V_{o1} = -g_m R_C \left(\frac{V_{in}}{2} \right)$$

$\because V_{BE1} = \frac{V_{in}}{2}$
see fig.).

Similarly

$$\therefore V_{o2} = -g_m R_C \left(-\frac{V_{in}}{2} \right) \quad (\because V_{BE2} = -\frac{V_{in}}{2})$$

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

$$= -g_m R_C \left(\frac{V_{in}}{2} - \left(-\frac{V_{in}}{2} \right) \right)$$

$$\therefore \boxed{V_o = -g_m R_C V_{in}}$$

So, $\boxed{A_v = \frac{V_o}{V_{in}} = -g_m R_C} = A_d \leftarrow \text{gain of diff amp}$

* CE Amplifier suffers from all common problem. (Noise, drift etc).

→ Diff. Amplifier eliminates such kinds of all these problem.

→ CE amplifier practically never used.

NOTE:

→ Differential Amplifier is a Basic Building Block of Analog IC design.

→ Need for voltage divider and coupling capacitor to bias the BJT is eliminated in differential amplifier with -ve supply.

→ The need for the Bypass Capacitor is eliminated in a differential amplifier with two symmetrical structure (or) with a two symmetrical circuit.

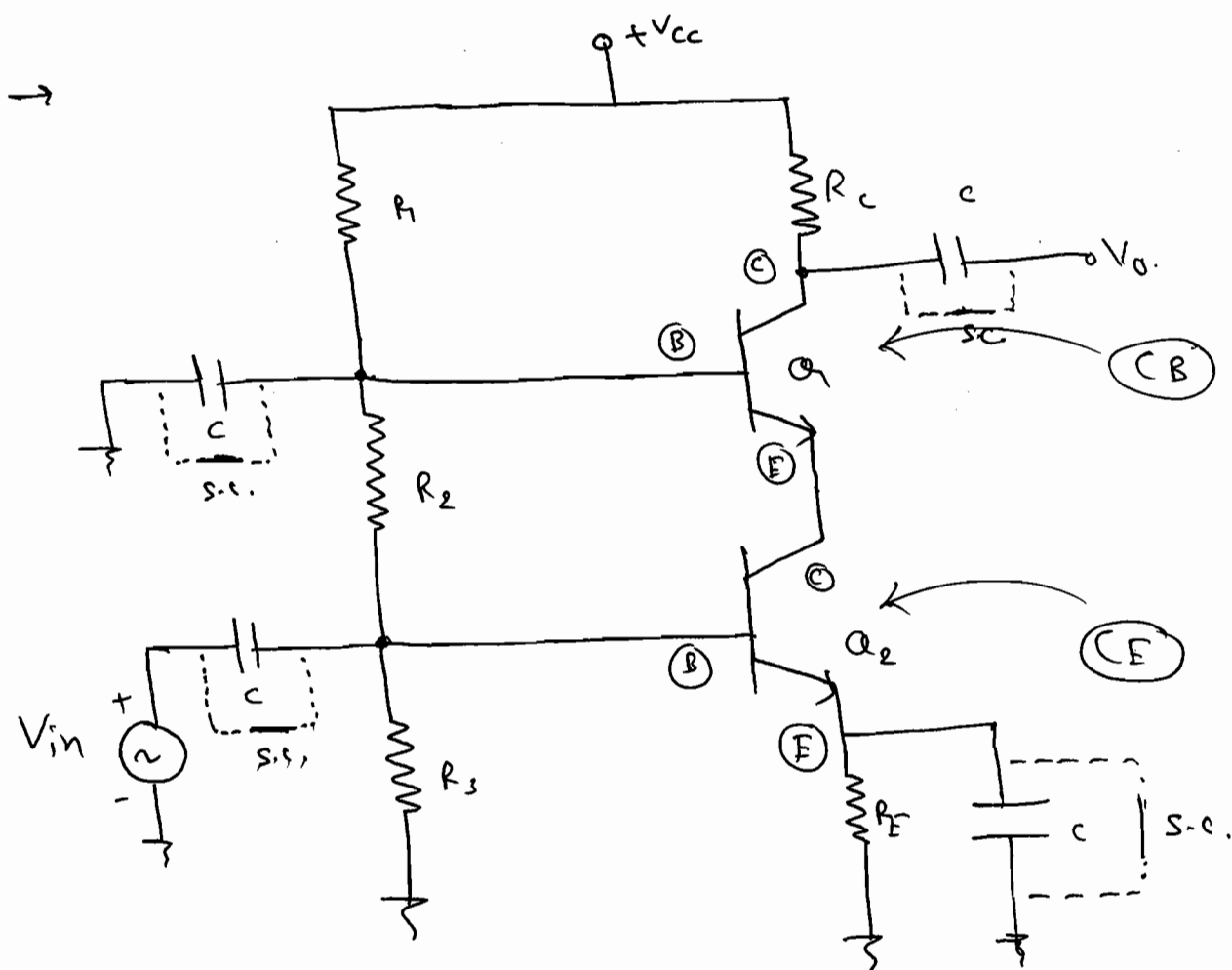
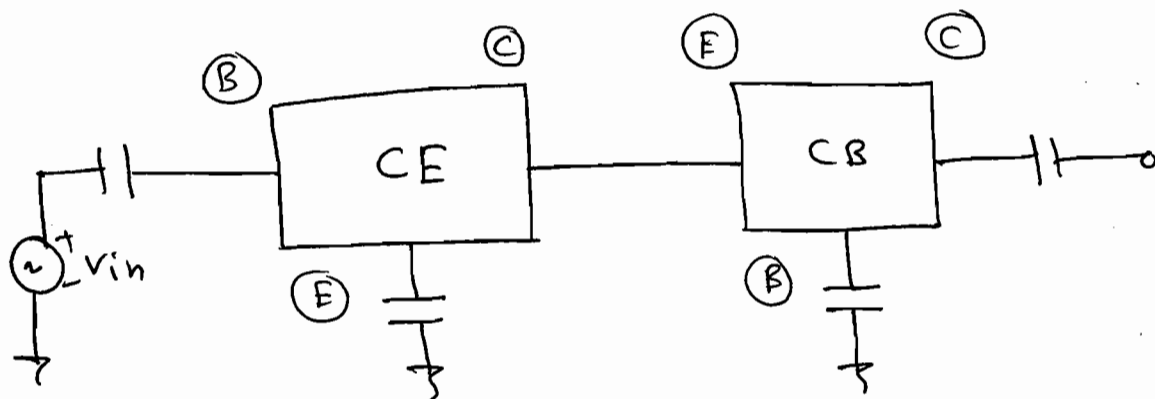
→ O/P Capacitor is eliminated by differential measurement.

→ The input capacitor is eliminated by negative supply.

→ Capacitor has to be eliminated because it takes more space in circuits and the solution of this problem is differential amplifier.

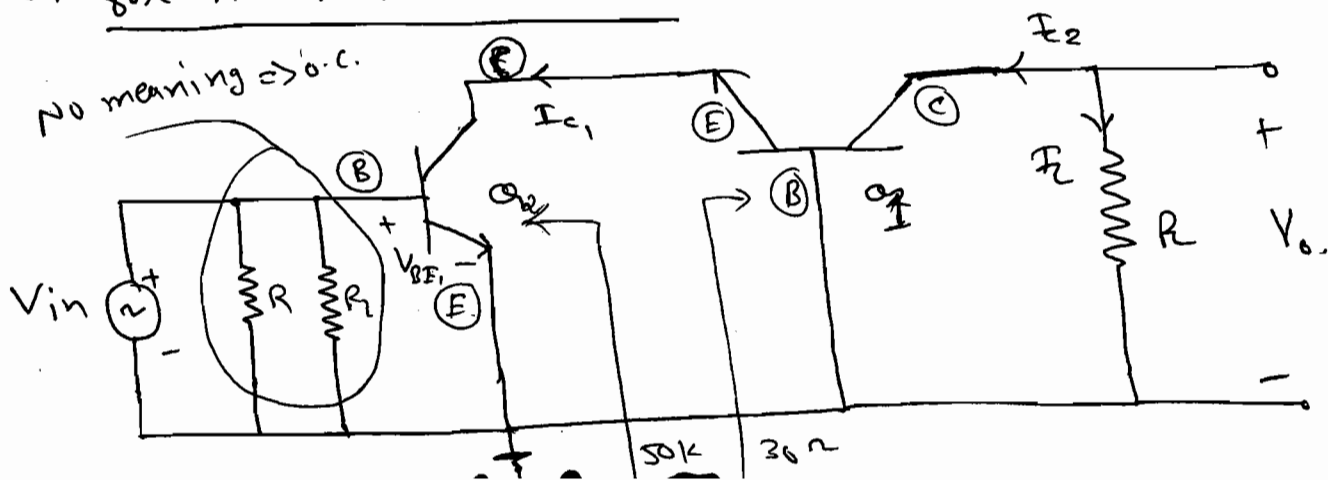
★ Cascode Amplifier: [Wide Band Structure] 151

See sujal's NLSJ note.



→ for AC picture s.c. C

No meaning $\Rightarrow$ o.c.



$$\rightarrow g_m = \frac{I_{C(AC)}}{V_{BE(AC)}}$$

$$\therefore V_{in} = V_{BE(AC)} \quad I_E = -I_C$$

$$\therefore V_o = I_C R_C$$

$$V_o = -I_C R_C = -I_{C(AC)} R_C$$

$$\therefore A_V = \frac{V_o}{V_{in}} = \frac{-I_{C(AC)} \cdot R_C}{V_{BE(AC)}}$$

$$\therefore \boxed{A_V = -g_m \cdot R_C}$$

$$\rightarrow B_W = \frac{1}{R_C} \quad , \quad \text{Time Constant} = R_C$$

$C_{eq} \uparrow$ (Miller effect)

$R \downarrow$ (Cross) impedance mismatches.

$\rightarrow$ one way to improve B_W is by giving -ve feedback but -ve feedback reduced the gain.

$\rightarrow$ But in ~~the~~ Cascode Amplifier B_W is increased without Reducing gain.

$\rightarrow$ Cascode: Connection of (C) or CE to the (B) or (CB) is called

$\rightarrow$ Cascode: o/p of one stage is connected to the i/p of another stage.

* Advantages:

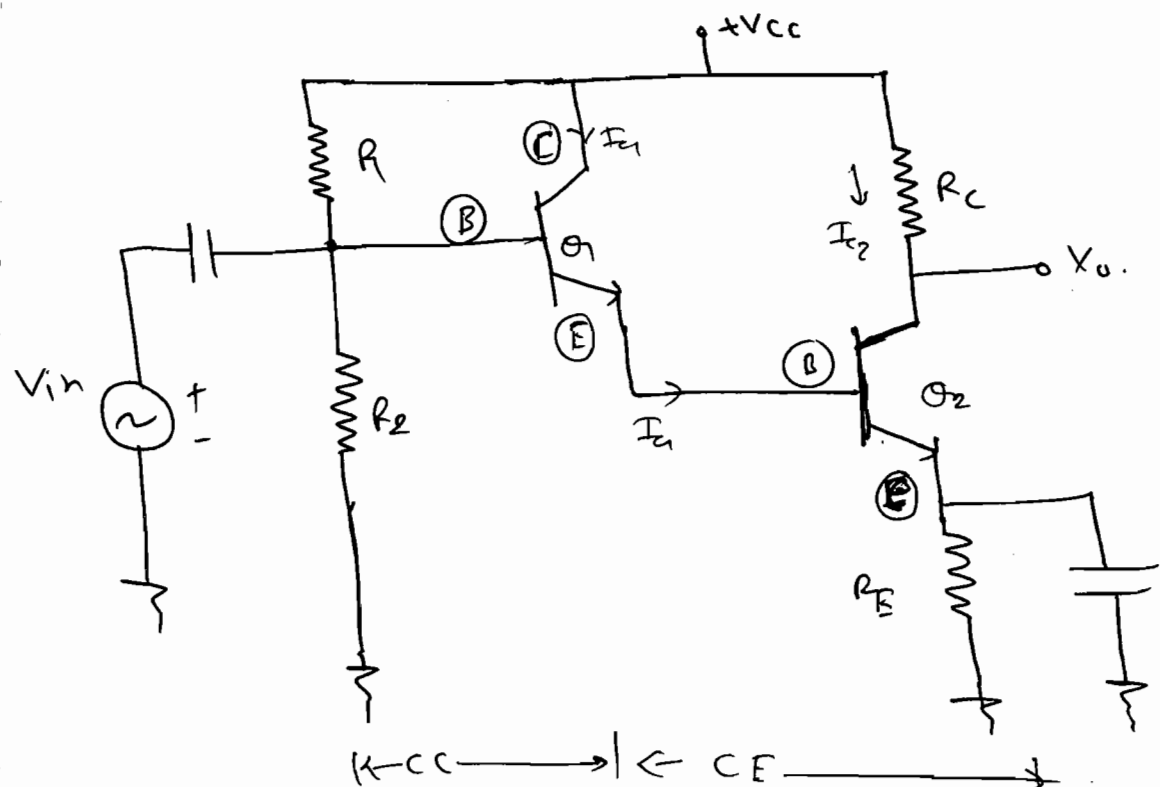
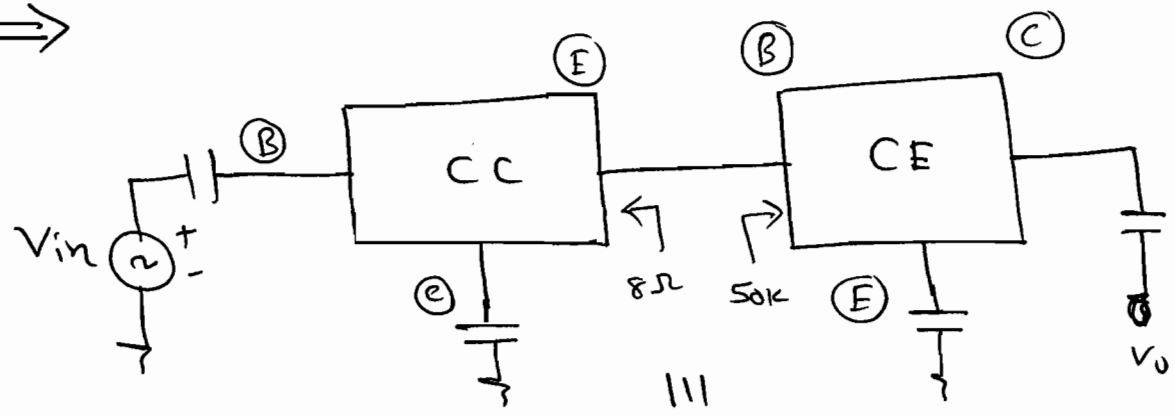
→ wider BW.

→ The overall transconductance of cascode Amp = the larger transconductance of Common Emitter amplifier.

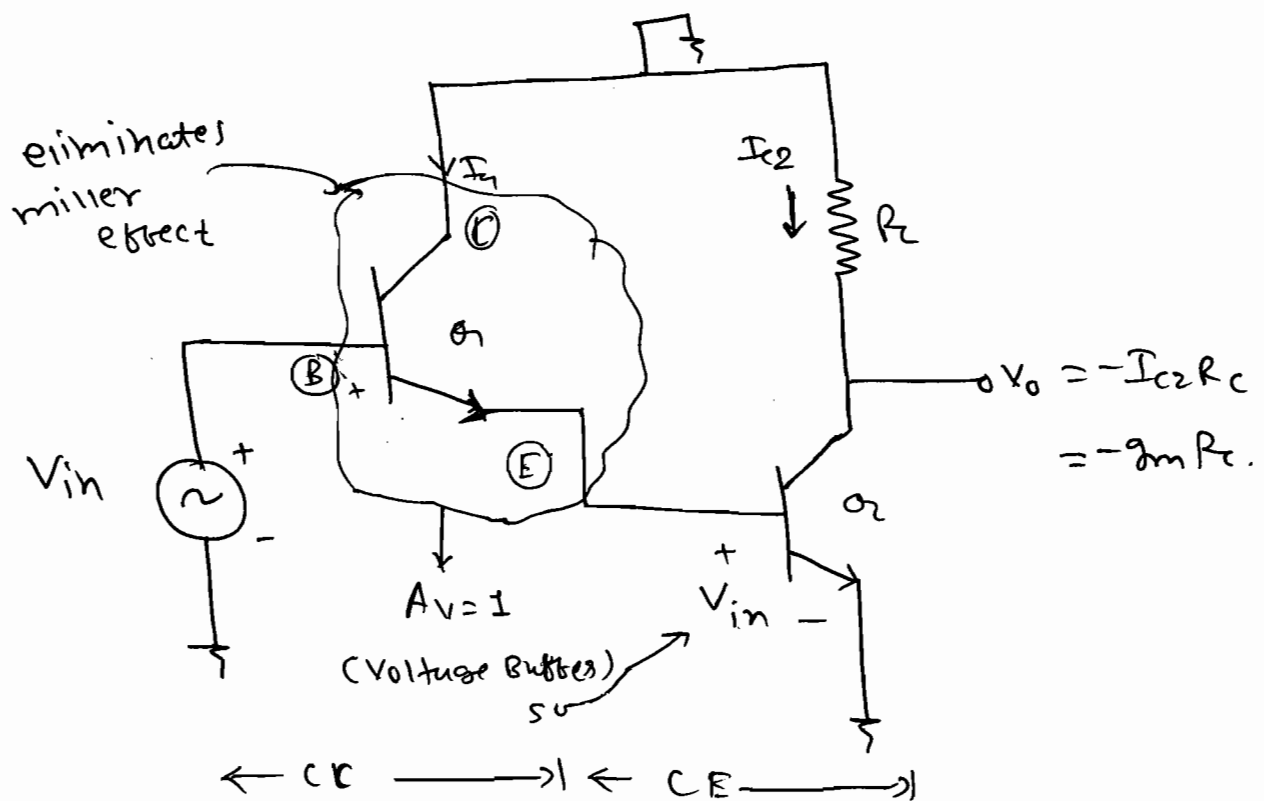
→ Large Output Impedence.

* Common Collector With Common Emitter.
[wide Band Structure].

⇒



→ Ac Picture:



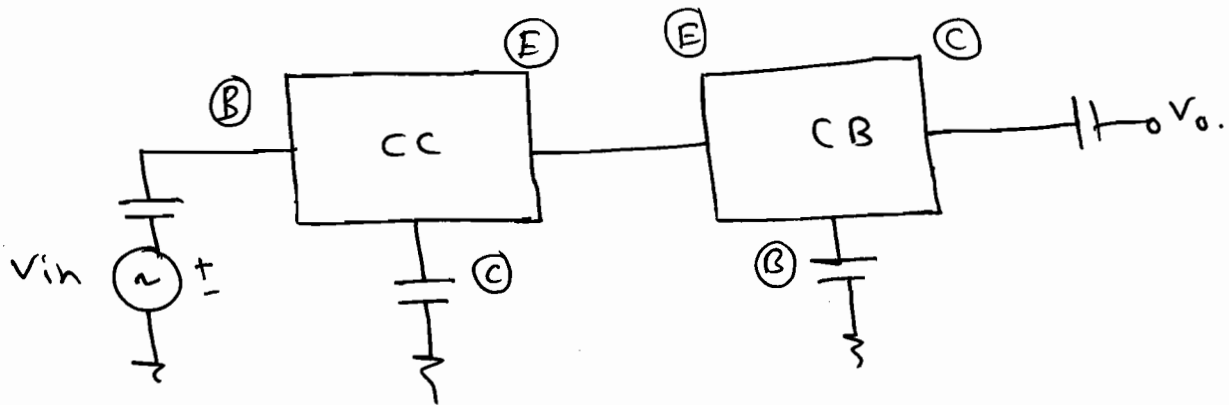
→ Current Buffer at O/P ($A_I = 1$) (O/P)
 Voltage Buffer at i/p ($A_V = 1$) is put
 in order to avoid miller's effect.

→ The overall transconductance is g_m
 and voltage gain,

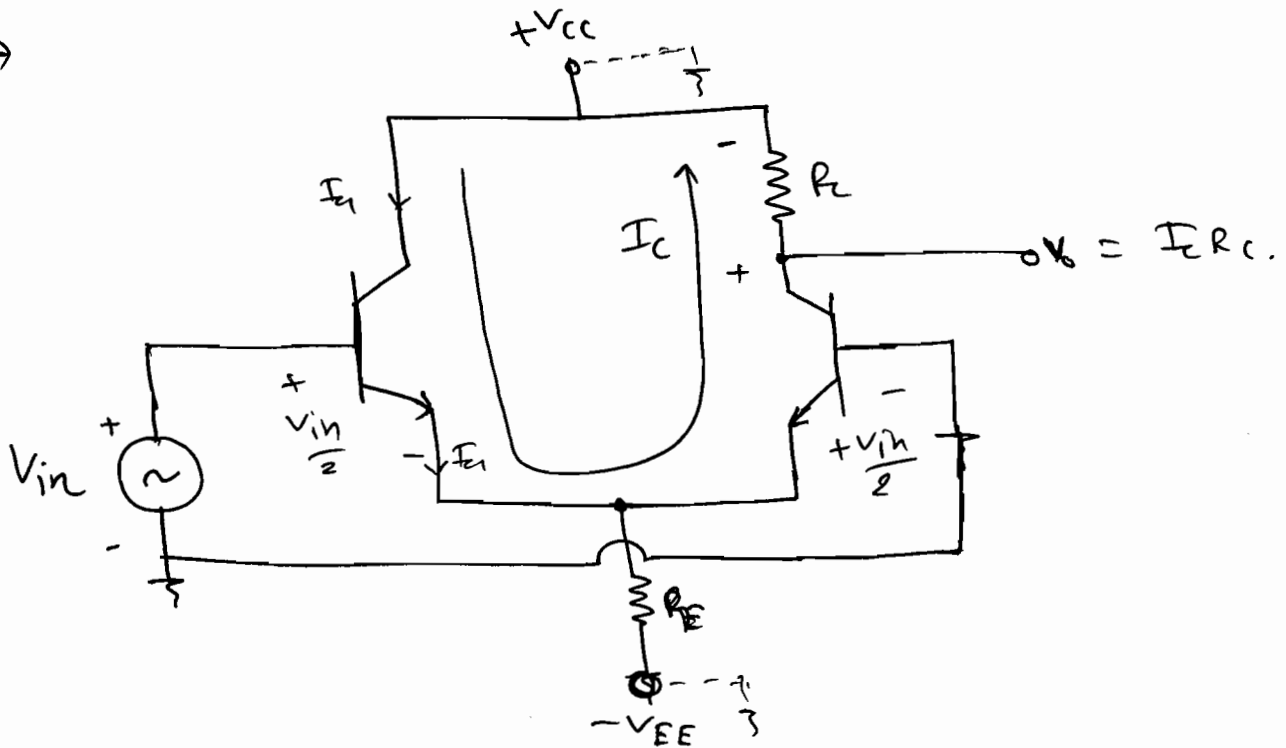
$$\therefore A_V = -g_m R_C$$

* Common Collector with Common Base:⁵

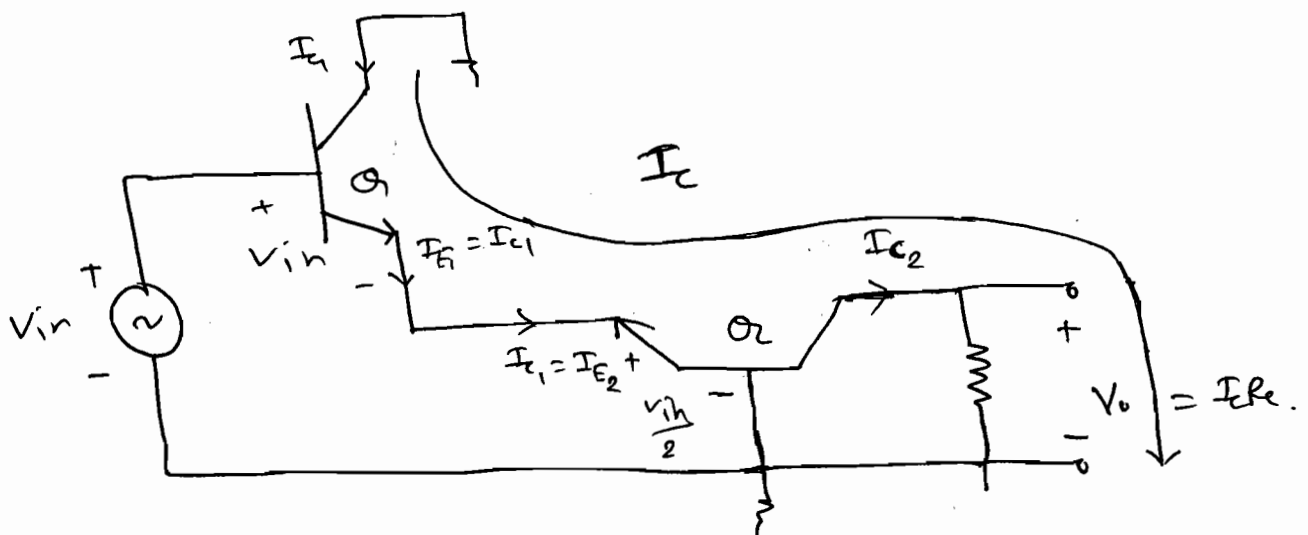
→



→



→



→ $V_o = I_C R_C$

$$\therefore g_m = \frac{I_c(Ac)}{V_{BE}(Ac)}$$

$$V_{BE} = \frac{V_{in}}{2}$$

$$\therefore g_m = \frac{I_c(Ac)}{V_{in}/2}$$

$$\therefore \frac{g_m}{2} = \frac{I_c(Ac)}{V_{in}}$$

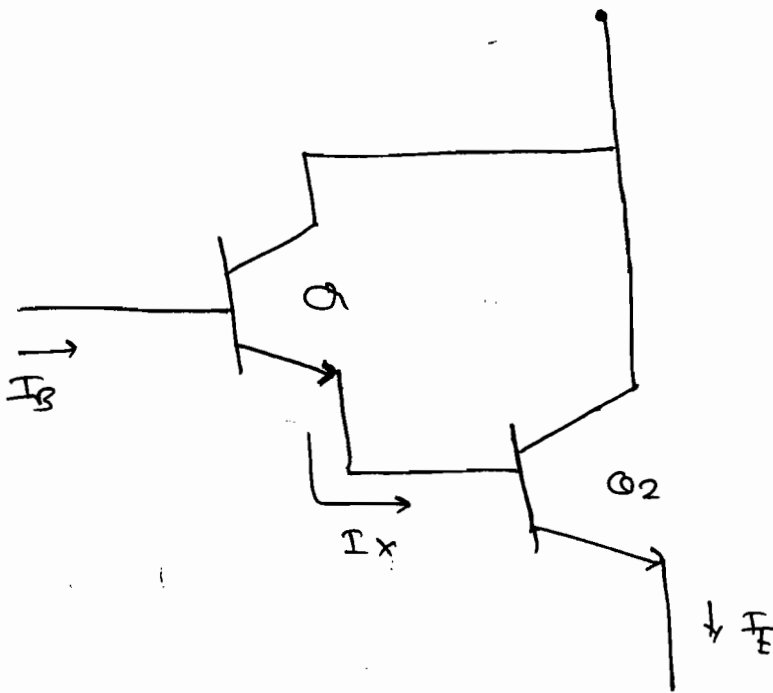
$$\therefore A_v = \frac{V_o}{V_{in}} = \frac{I_c \cdot R_c}{V_{in}}$$

$$\therefore A_v = + \frac{g_m}{2} \cdot R_c$$

★ Darlington Transistor Pair:

→ Advantages:

High Current gain,
High i/p impedance.



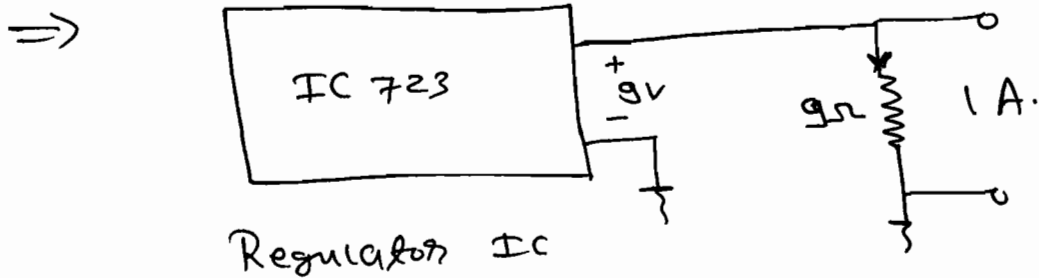
$$\rightarrow I_E = (\beta + 1) I_B.$$

$$\text{But } I_E = (\beta + 1) I_B.$$

$$\text{So, } I_E = (\beta + 1)^2 I_B.$$

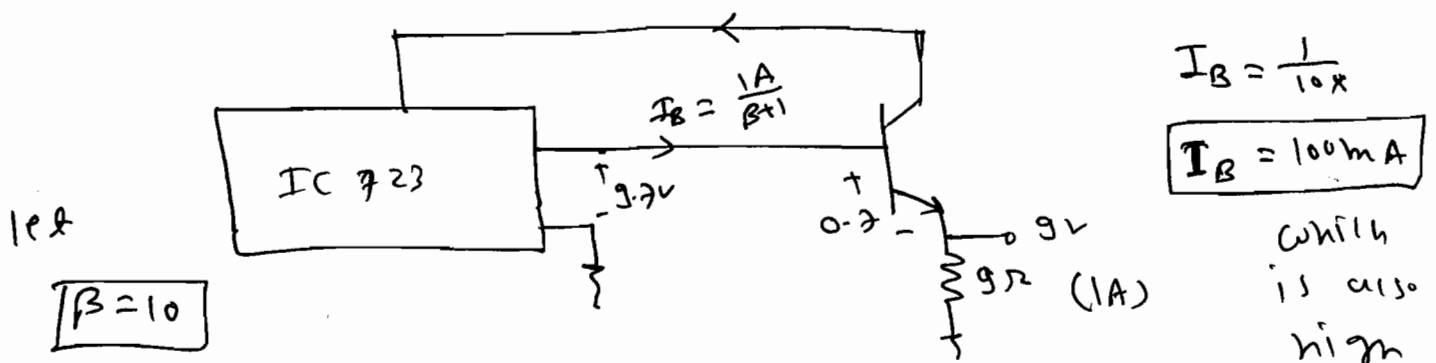
$\rightarrow$ To deal with worst load, darlington pair used.

let, 9Ω load

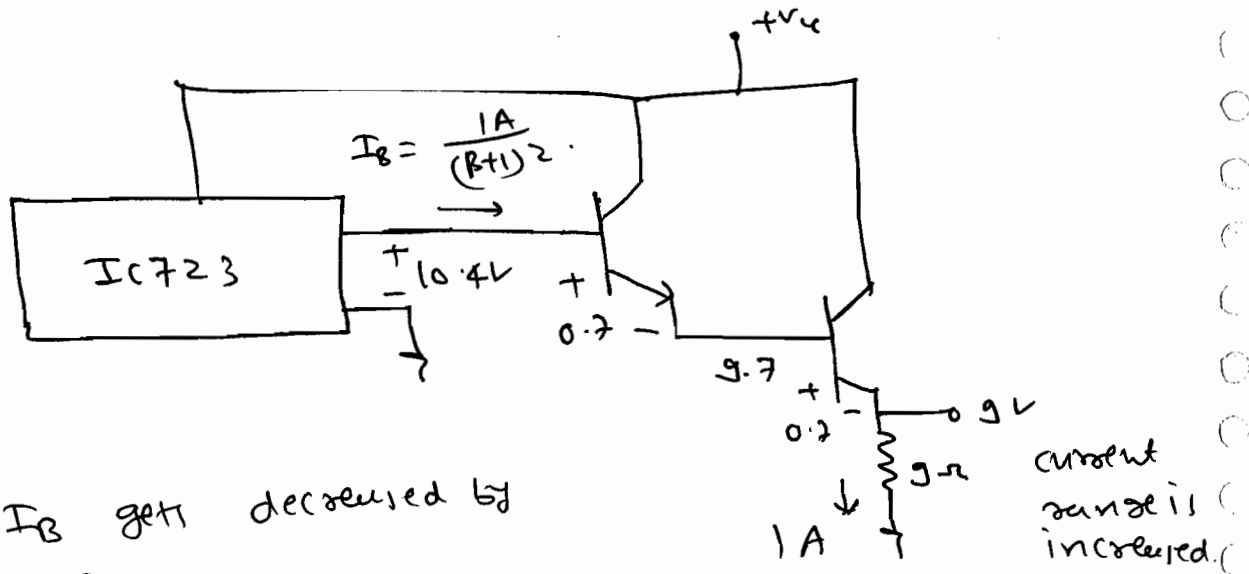


$\rightarrow$ Here, Voltage at I_E is, $9V$ and load is connected which is 9Ω . So, current flowing through the ckt is $1A$ which is too high for the IC723. because IC723 can handle maximum current upto $100mA$. and I_E gets burn.

$\rightarrow$ Now, Put transistor as shown in figure.



Now, use Darlington pair of Transistor.



→ I_B gets decreased by $(\beta + 1)^2$

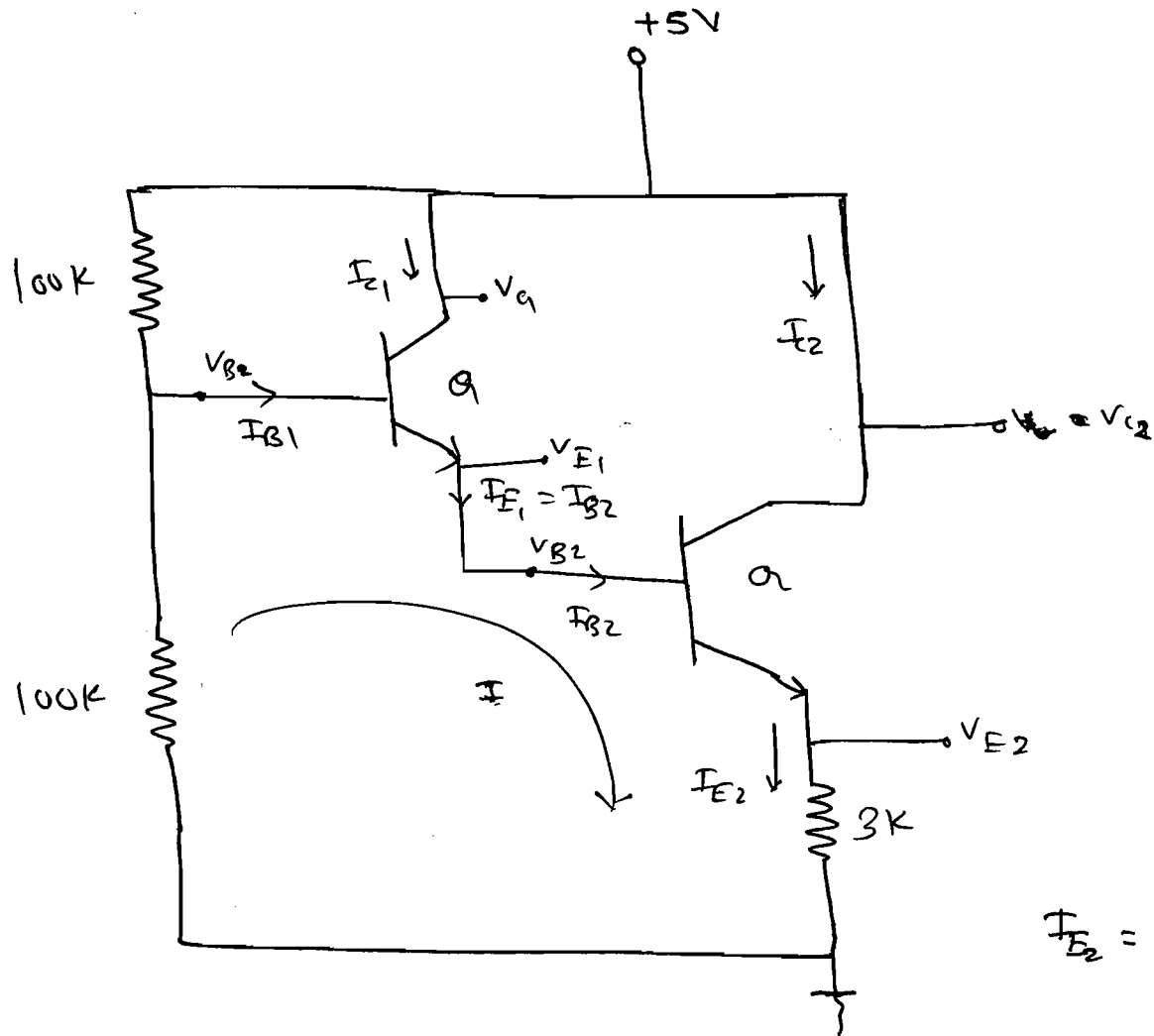
$$\therefore I_B = \frac{1}{100}$$

$$\therefore \boxed{I_B = 10 \text{ mA}}$$

→ Now, IC can driven by darlington pair of transistor.

→ Now, In order to produce 9V across the 9.7 ohm load 1A current is available because of darlington pair even if current flowing through IC is 10mA. The required current gain (10mA to 1A) is provided by darlington pair.

Ex-1 Calculate node Voltage and Branch current.
 take $\beta = 75$.



$$I_{E2} = \frac{I_{B2}}{\beta + 1}$$

$$\rightarrow V_{th} = \frac{100}{200} \times 5 = 2.5V. \quad R_{th} = 50K$$

$$\therefore V_{th} - I_{B1} R_{th} - V_{BE} - V_{BE} - I_{E2} R_{E2} = 0.$$

$$\therefore \text{Now, } I_{E2} = \frac{I_{B2}}{(\beta + 1)}$$

$$\text{But } I_{B2} = \frac{I_{B1}}{(\beta + 1)}$$

$$\therefore I_{E2} = \frac{I_{B1}}{(\beta + 1)^2}$$

$$\therefore I_{E2} = \frac{V_{th} - 2V_{BE}}{R_E + \frac{R_{th}}{(\beta + 1)^2}}$$

$$\therefore I_{E2} = \frac{2.5 - 1.4}{3000 + \frac{50000}{(76)^2}}$$

$$\therefore I_{E2} = 0.366 \text{ mA}$$

$$\therefore I_{C2} = \frac{\beta}{\beta + 1} \times I_{E2}$$

$$\therefore I_{C2} = \frac{75}{76} \times 0.366$$

$$I_{C2} = 0.361 \text{ mA}$$

$$\therefore I_{B2} = I_{E2} - I_{C2}$$

$$\therefore I_{B2} = 4.815 \mu\text{A}$$

$$\therefore I_{E1} = 4.815 \mu\text{A}$$

$$\therefore I_{C1} = \frac{75}{76} \times 4.815$$

$$\therefore I_{C1} = 4.75 \mu\text{A}$$

$$\therefore I_{B1} = 63.35 \text{ nA}$$

$$\therefore V_{B1} = V_{th} - I_{B1} \cdot R_{th}$$

$$\therefore V_{B1} = 2.5 - (63.35 \times 10^{-9} \times 50 \times 10^3)$$

$$V_{B1} = 2.5 - 0.003167$$

$$\therefore V_{B1} = 2.496 \text{ V}$$

$$V_{C1} = 5 \text{ V}$$

$$V_{C2} = 5 \text{ V}$$

$$V_{E1} = V_{B1} - 0.7$$

$$\therefore V_{E1} = 1.796 \text{ V}$$

$$\therefore V_{E2} = I_{E2} \times R_E$$

$$\therefore V_{E2} = 0.36 \times (3).$$

$$\therefore \boxed{V_{E2} = 1.098 \text{ V}}$$

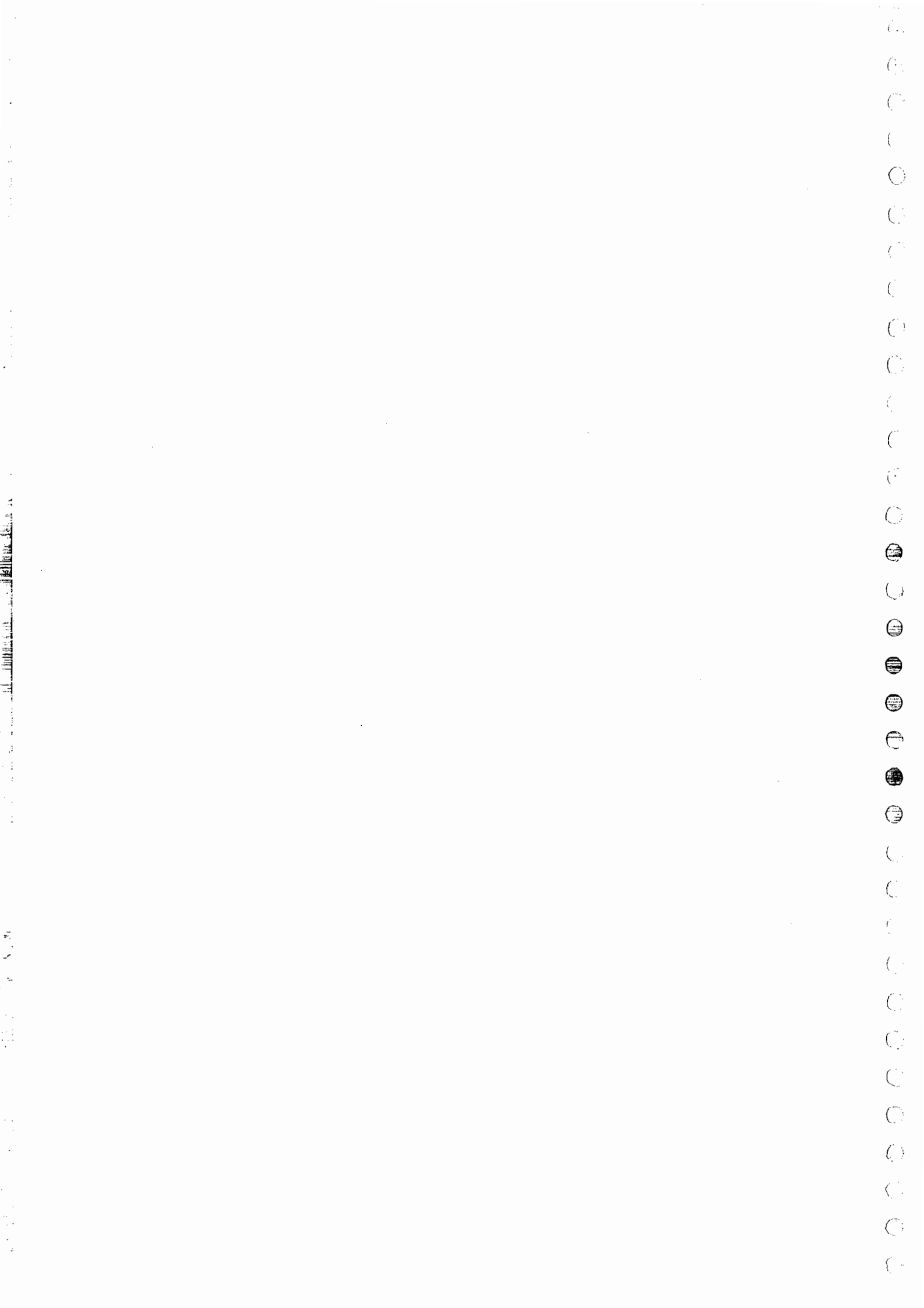
$$\therefore V_{CE1} = V_{C1} - V_{E1} \\ = 5 - 1.796$$

$$\therefore \boxed{V_{CE1} = 3.204}$$

$$\therefore V_{CE2} = V_{CE1} + 0.7$$

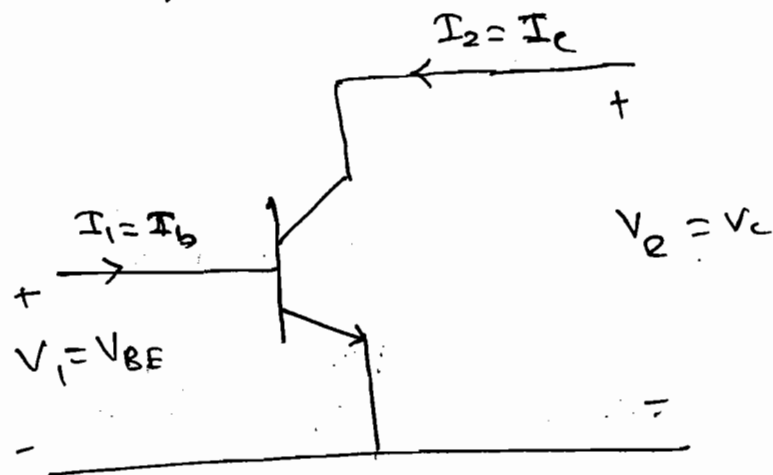
$$\therefore V_{CE2} = 3.204 + 0.7$$

$$\therefore \boxed{V_{CE2} = 3.904 \text{ V}}$$



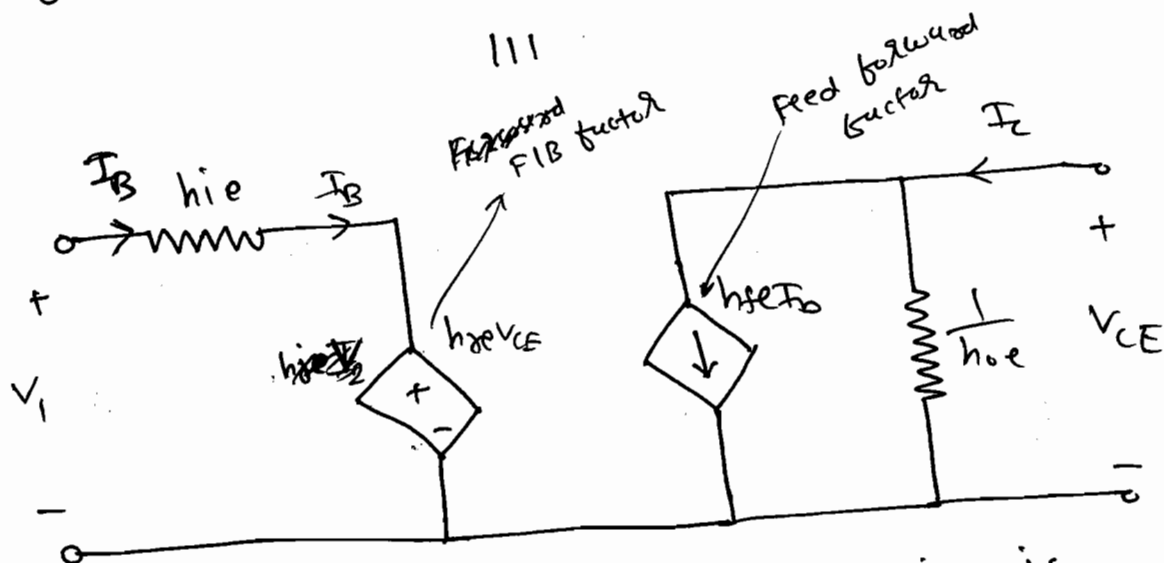
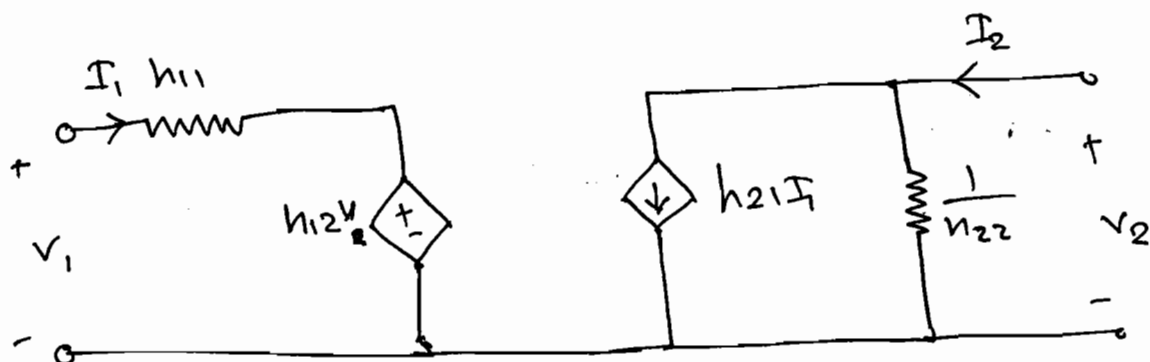
★ Hybrid Model:

13



$\rightarrow V_1 = h_{11} I_1 + h_{12} V_2$ (KVL, Khevenian)
 $I_2 = h_{21} I_1 + h_{22} V_2$ (KCL, Norton).

let, $V_1 = V_{BE}$, $V_2 = V_{CE}$ $h_{11} = h_{ie}$, $h_{12} = h_{re}$
 $I_1 = I_B$, $I_2 = I_C$ $h_{21} = h_{fe}$, $h_{22} = h_{oe}$

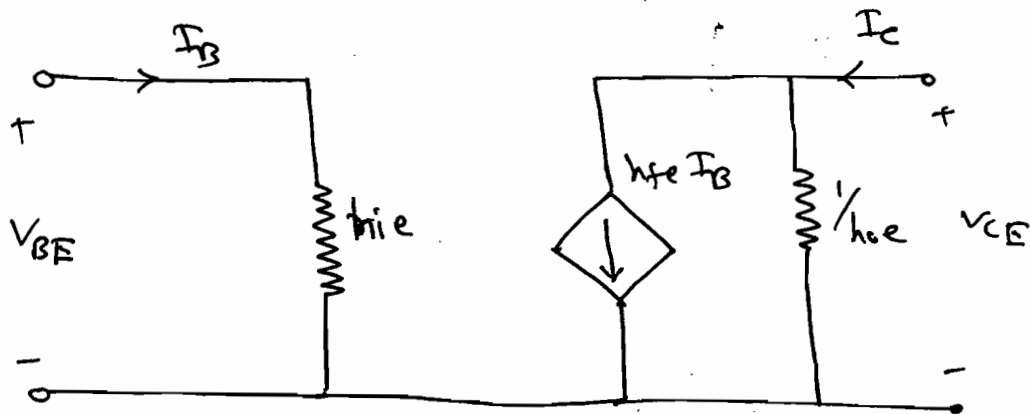


Where, $h_{11} = h_{ie}$
 $h_{21} = h_{fe}$

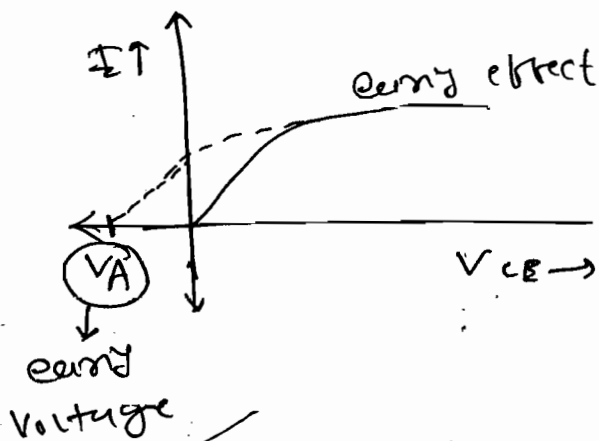
$h_{12} = h_{re}$
 $h_{22} = h_{oe}$

This is H model of Transistor.

2!
 → as the $h_{re} = 10^{-12}$ and $h_{fe} = 100$.
 We can neglect h_{re} and the ckt will be.



Now, $h_{oe} = \frac{I_C}{V_{CE}}$

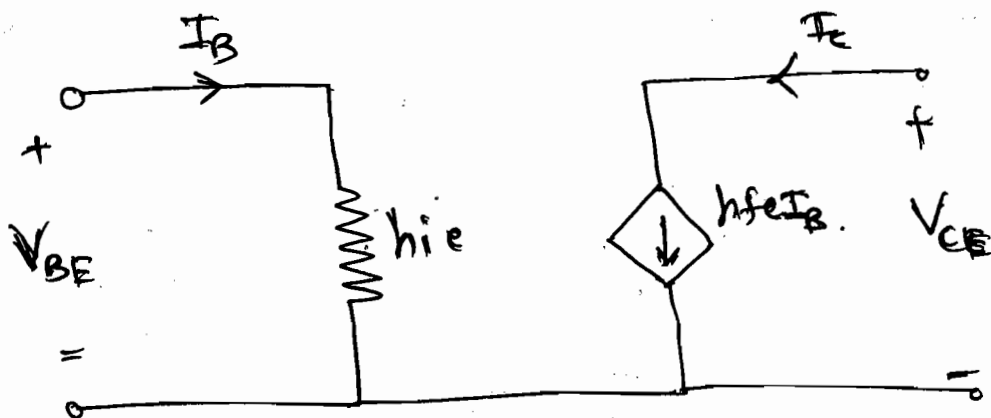


$\frac{1}{R_C} = \frac{I_C}{V_{CE}} = \frac{1}{\text{slope}}$

$R_{CE} \rightarrow \infty$
 $h_{oe} \rightarrow 0$

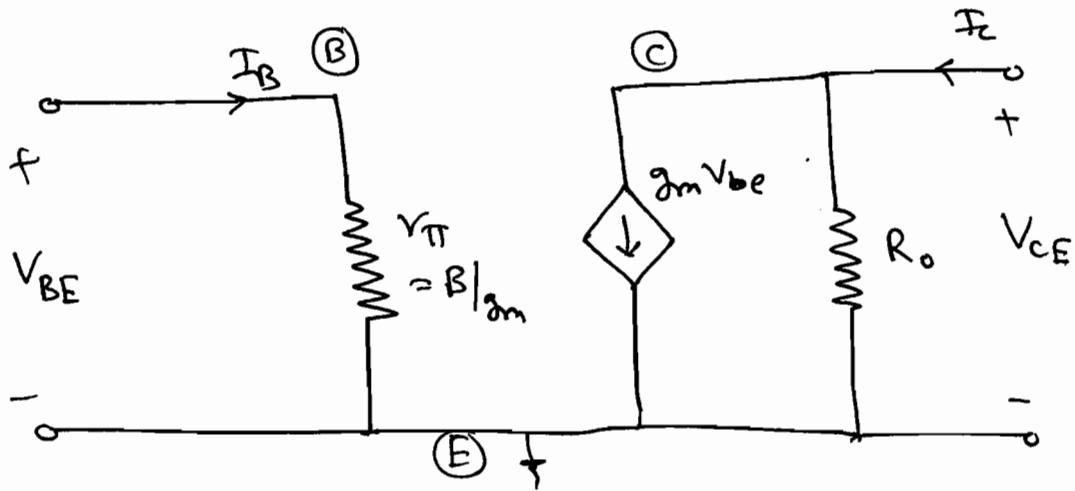
$h_{oe} = 0$

So final H-model is as below:



* π Model is seeing from base.

15



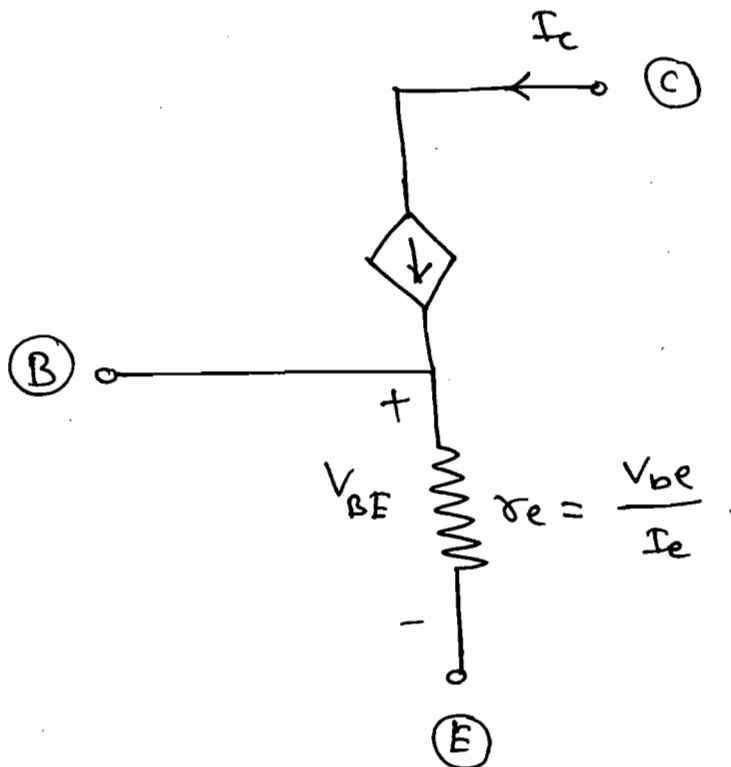
$\Rightarrow$ 1) $r_{\pi} = h_{ie} = \beta / g_m$.

2) $h_{fe} = \beta$

3) $R_o = \frac{1}{h_{oe}} = \frac{V_A}{I_{C_{OC}}}$.

$$g_m = \frac{h_{fe}}{h_{ie}}$$

* T-Model:



gain

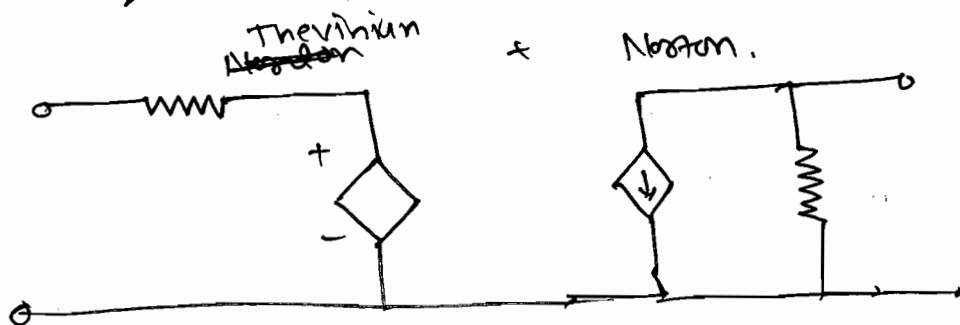
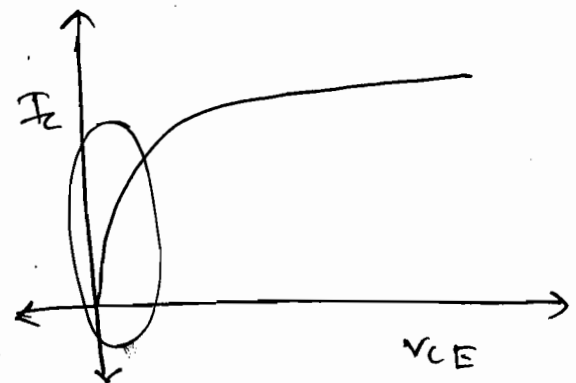
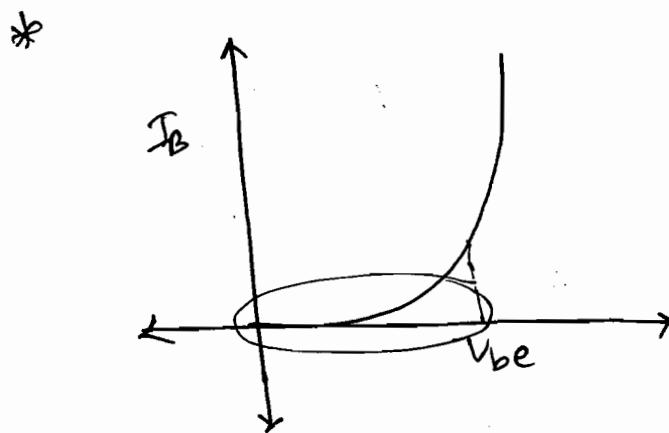
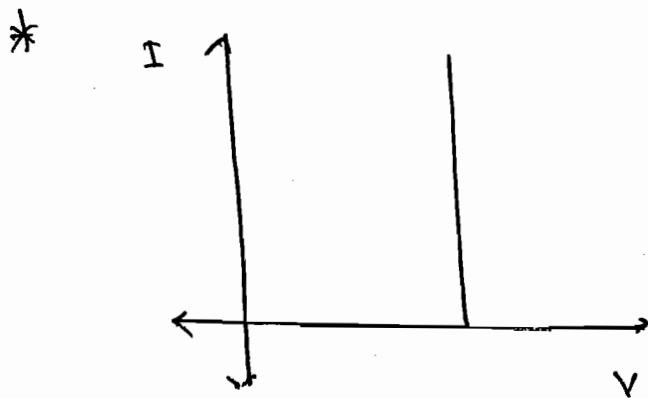
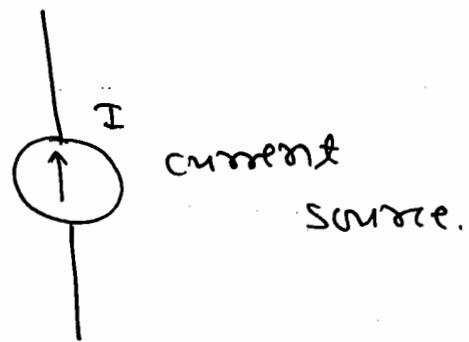
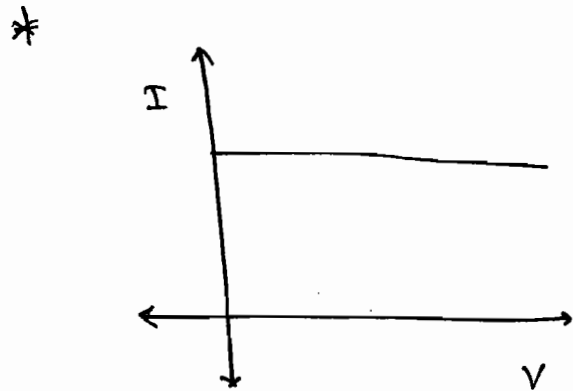
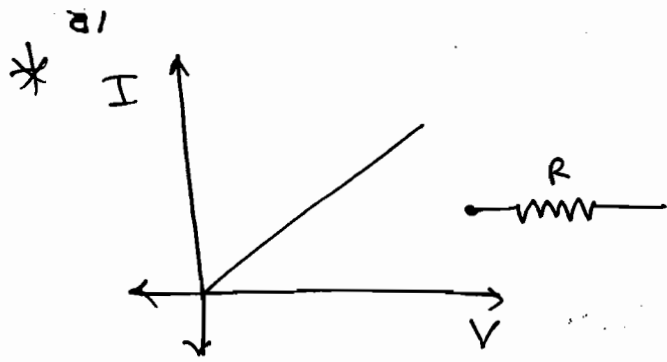
$$\frac{V_o}{V_{in}} = -g_m R_c$$

$$\therefore A = -\frac{h_{fe}}{h_{ie}} \cdot R_c$$

$$\therefore r_e = \frac{V_{be}}{I_e} = \frac{V_{be}}{I_C}$$

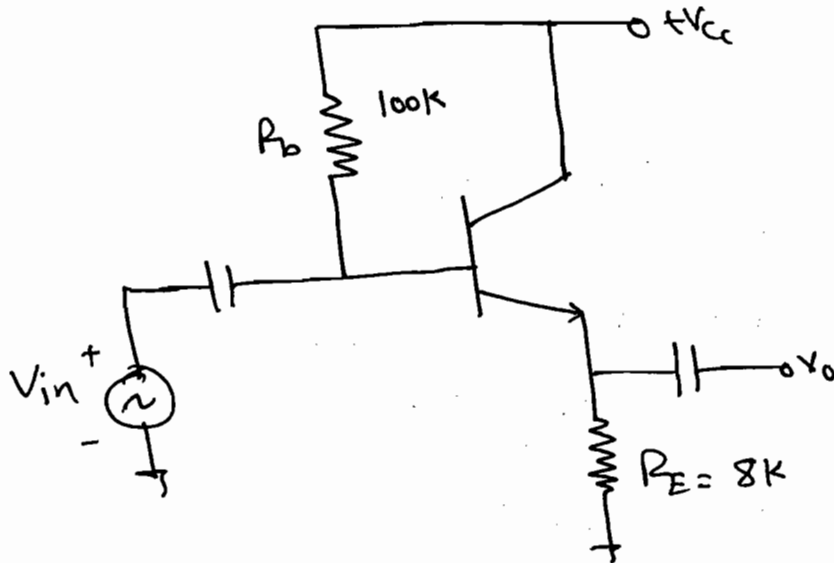
$$\therefore r_e = \frac{1}{g_m}$$

← T model is seeing through emitter.
 $\Downarrow$
 to find operating point.

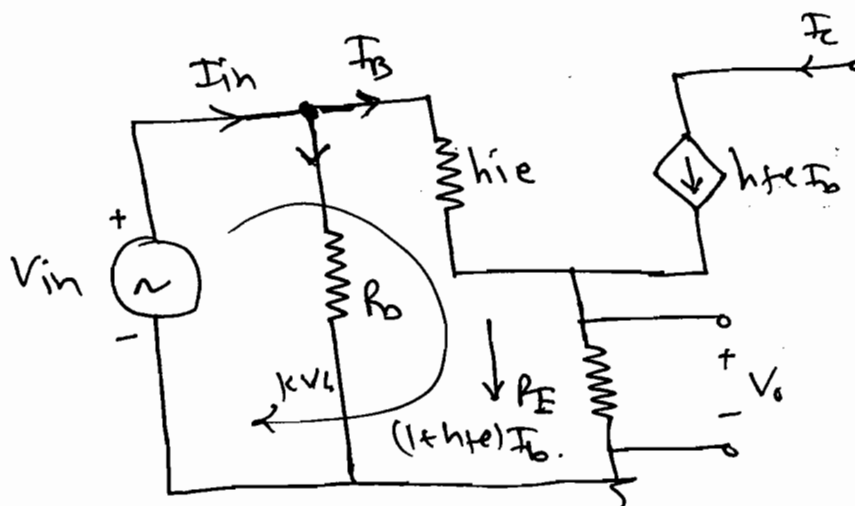
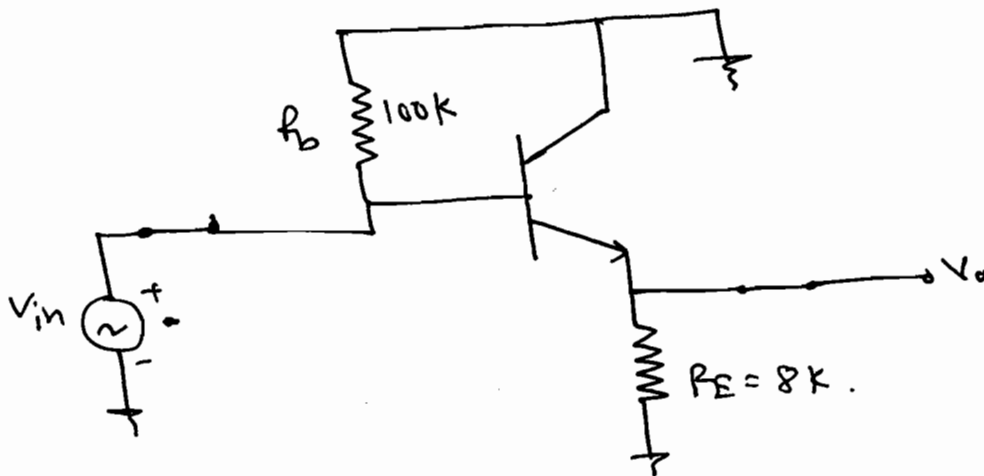


Ex-1 For emitter follower circuit given
 Calculate input impedance, o/p impedance
 and voltage gain. $h_{ie} = 1k$, $h_{fe} = 100$.

Ans:



→ Ac picture:



7.1

$$V_o = (1 + h_{fe}) I_B R_E$$

$$\therefore V_{in} - I_B h_{ie} - (1 + h_{fe}) I_B R_E = 0$$

$$\therefore V_{in} = I_B [h_{ie} + R_E (1 + h_{fe})]$$

$$\therefore \text{Voltage gain} = A_v = \frac{V_o}{V_{in}}$$

$$\therefore A_v = \frac{R_E (1 + h_{fe})}{h_{ie} + R_E (1 + h_{fe})}$$

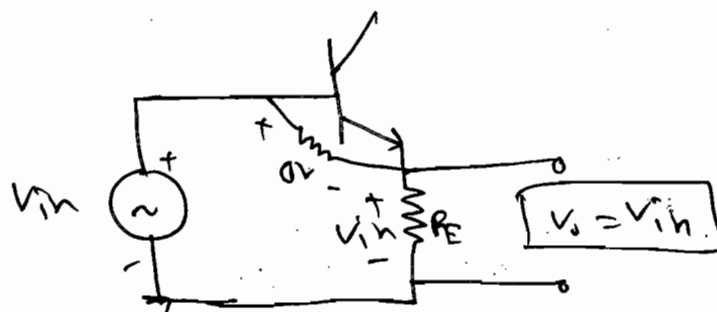
$$\therefore A_v = \frac{8000 (1 + 100)}{1000 + 8000 (1 + 100)}$$

$$\therefore A_v = 0.99876$$

We can neglect h_{ie} at the beginning and

$$\therefore A_v = \frac{R_E (1 + h_{fe})}{R_E (1 + h_{fe})}$$

$$A_v \approx 1 \text{ so, emitter follower}$$



$$\therefore Z_{in} = \frac{V_{in}}{I_{in}}$$

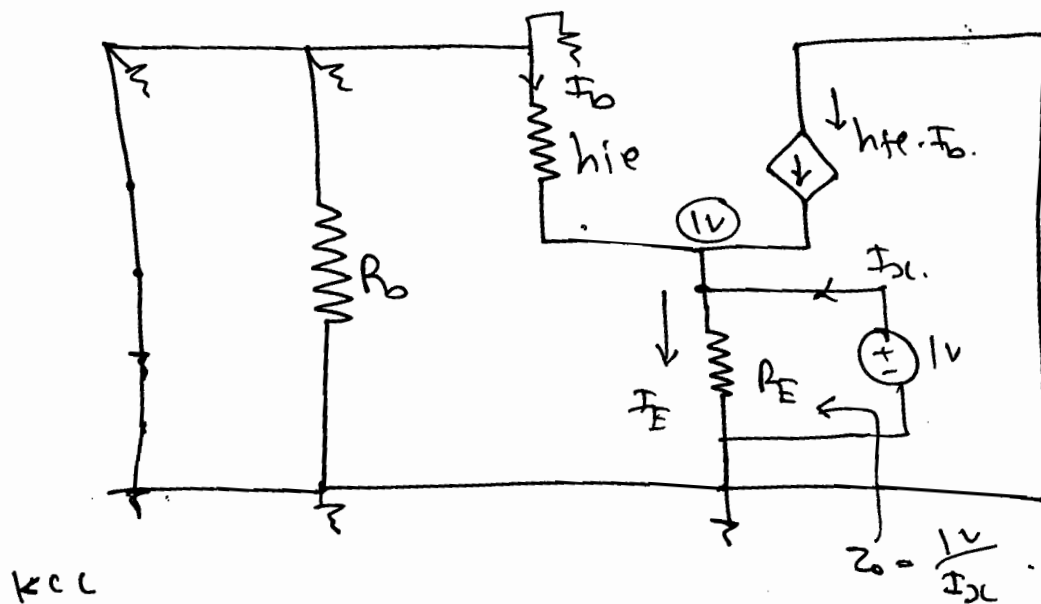
$$\therefore I_{in} = I_B + \frac{V_{in}}{R_B}$$

$$\therefore I_{in} = \frac{V_{in}}{R_b} + \frac{V_{in}}{h_{ie} + (1+h_{fe})R_E}$$

$$\therefore \frac{V_{in}}{I_{in}} = \frac{1}{\frac{1}{R_b} + \frac{1}{[h_{ie} + (1+h_{fe})R_E]}}$$

$$\therefore Z_{in} = R_b \parallel [h_{ie} + (1+h_{fe})R_E].$$

→ Now, finding o/p impedance.



$$\therefore I_b + I_x + I_E = I_E.$$

$$\therefore \frac{0-1V}{h_{ie}} + I_x + h_{fe} \cdot \left(-\frac{1}{h_{ie}}\right) = \cancel{\left(-\frac{1}{h_{ie}}\right)} \cdot \frac{1V}{R_E}.$$

$$\therefore (1+h_{fe}) \left(-\frac{1}{h_{ie}}\right) + I_x = \frac{1}{R_E}.$$

$$\therefore I_x = \frac{1}{R_E} + \frac{1+h_{fe}}{h_{ie}}.$$

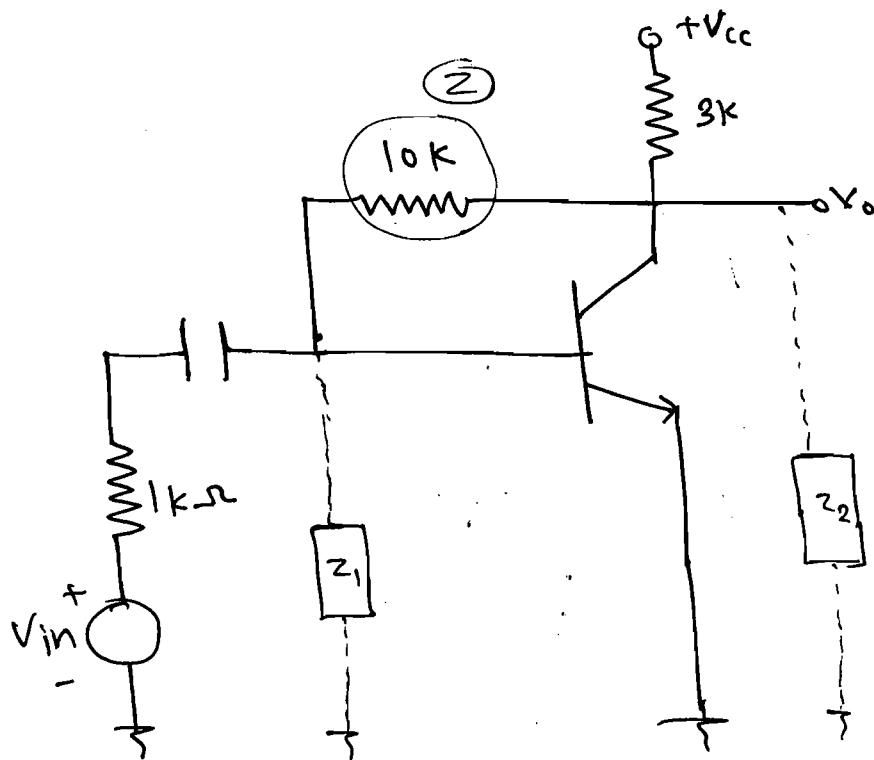
$$\therefore Z_o = \frac{1V}{I_x}.$$

$$\therefore Z_o = \frac{1}{\frac{1}{R_E} + \frac{1+h_{fe}}{h_{ie}}}.$$

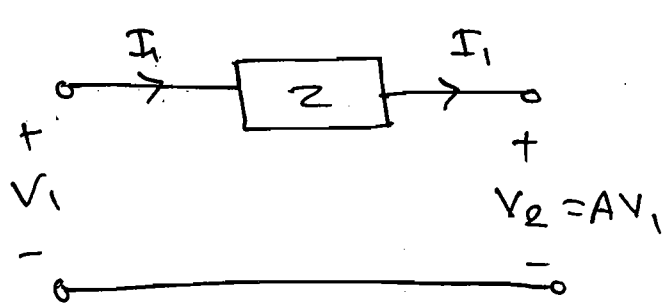
$$\therefore Z_o = R_E \parallel \frac{h_{ie}}{1+h_{fe}}$$

GATE, IFS

Ex-2 Using the miller's theorem find the voltage gain V_o/V_{in} if $h_{ie} = 1k$, $h_{fe} = 100$.



Ans: * Miller's theorem:



$$V_2 = AV_1$$

$$\rightarrow I_1 = \frac{V_1 - V_2}{Z}$$

$$I_1 = \frac{V_1 - 0}{Z_1}$$

$$\therefore \frac{V_1 - V_2}{Z} = \frac{V_1 - 0}{Z_1}$$

$$\text{but } V_2 = AV_1$$

$$\therefore \frac{V_1 - AV_1}{z} = \frac{V_1}{z_1}$$

$$\therefore V_1 \frac{(1-A)}{z} = \frac{V_1}{z_1}$$

$$\therefore \boxed{z_1 = \frac{z}{1-A}}$$

Similarly, $I_1 = \frac{V_1 - V_2}{z} = \frac{0 - V_2}{z_2}$

$\therefore V_1 \neq AV_1$ But $V_2 = AV_1$
 $\Rightarrow V_1 = V_2/A$

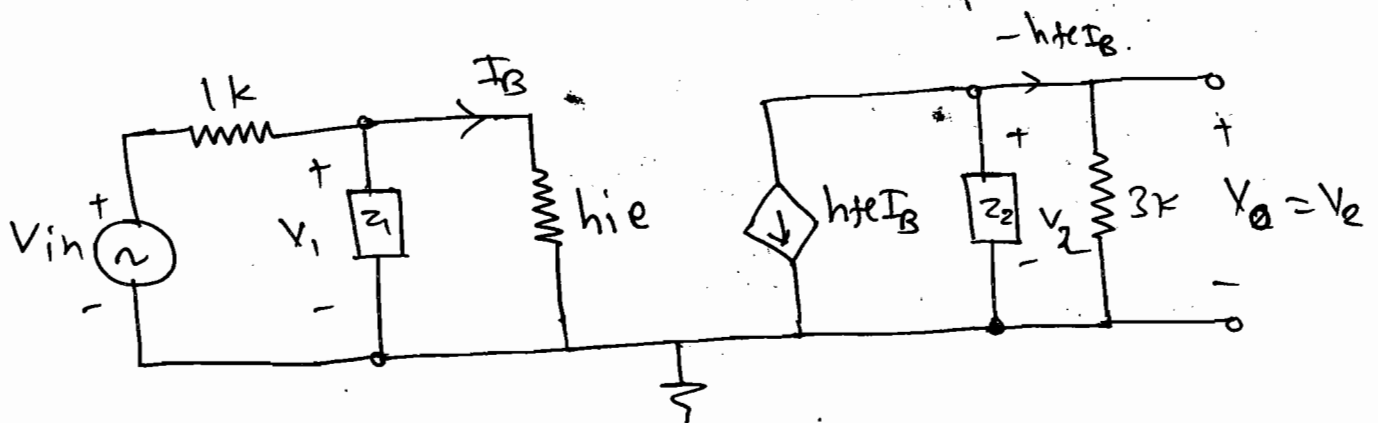
$$\therefore \frac{\frac{V_2}{A} - V_2}{z} = \frac{-V_2}{z_2}$$

$$\therefore \frac{V_2 \left(\frac{1}{A} - 1 \right)}{z} = \frac{-V_2}{z_2}$$

$$\therefore z_2 = \frac{z}{1 - \frac{1}{A}}$$

$$\therefore \boxed{z_2 = \frac{zA}{A-1}}$$

Now, Ac picture,



$$z_1 = \frac{10k}{1-A}$$

$$A = \frac{V_2}{V_1} = \frac{V_o}{V_i}$$

$$z_2 = \frac{10kA}{A-1}$$

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

$$\therefore V_o = -h_{fe} I_B \cdot [3K || z_2]$$

$$\therefore V_i = I_B h_{ie}$$

$$V_i = I_B (2K)$$

$$\therefore A = \frac{V_o}{V_i} = \frac{-h_{fe} [3K || z_2]}{h_{ie}}$$

$$\therefore A = \frac{2000}{100 \left[\frac{1}{3000} + \frac{1}{10000} \right]}$$

$$\therefore A = \frac{-190}{1000} \left[\frac{1}{\frac{1}{3000} + \frac{1}{10000}} \right]$$

$$\therefore +10A = \frac{-1}{\frac{1}{3000} + \frac{1}{10000A}}$$

$$\therefore 10A \left[\frac{1}{3000} + \frac{1}{10000A} \right] = -1$$

$$\therefore 10A \left[\frac{1}{3000} + \frac{A-1}{10000A} \right] = -1$$

$$\therefore \frac{10A}{3} + \frac{A(A-1)}{1} = -1000$$

$$\therefore 10A + 3A(A-1) = -3000A$$

$$\therefore \cancel{3A^2} - 3A + 10A + 3000A = 0$$

$$\therefore \cancel{3A^2} + 7A + 3000A = 0$$

$$\therefore 13A - 3 = -3000$$

$$13A = -2997$$

$$\therefore \boxed{A = -230.54}$$

$$\therefore Z_1 = \frac{10000}{1-A}$$

$$Z_2 =$$

$$\therefore Z_1 = \frac{10000}{232}$$

$$Z_1 = 43.10 \Omega$$

$$Z_2 = \frac{10k \times A}{A-1} = 10k$$

$$\therefore Z_2 = 10k$$

KCL

$$\therefore \frac{V_{in} - V_1}{1k} = \frac{V_1}{Z_1} + \frac{V_1}{1k}$$

$$\therefore V_1 \left[\frac{1}{1000} + \frac{1}{43.2} + \frac{1}{1000} \right] = \frac{V_{in}}{1000}$$

$$\therefore V_1 [2 + 23.20] = V_{in}$$

$$\therefore \frac{V_1}{V_{in}} = \frac{1}{25.20}$$

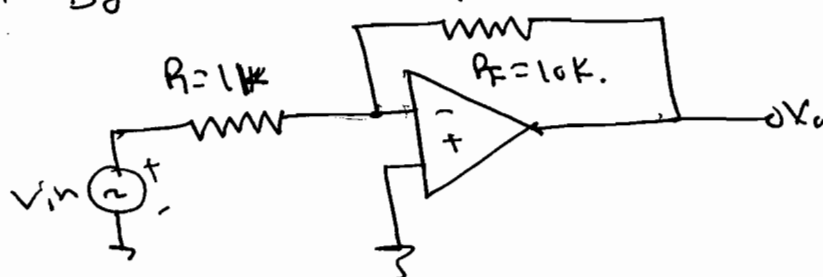
$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_1} \cdot \frac{V_1}{V_{in}}$$

$$= (-232) \times \left(\frac{1}{25.20} \right)$$

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

$$\therefore A = -9.2$$

Now, By inspection we can do it easily.



$$\therefore V_o = -R_F/R \cdot V_{in}$$

$$\therefore \frac{V_o}{V_{in}} = A_v \approx -10$$

*

