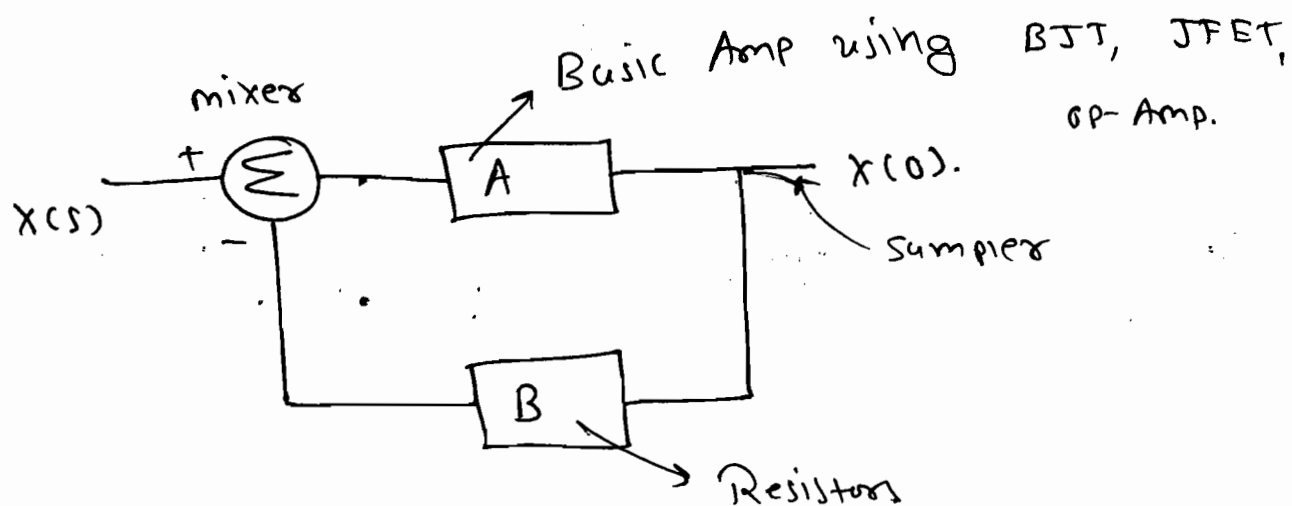


★ Feedback Amplifiers:



⇒ Gain with feedback,

$$\frac{X(0)}{X(s)} = A_F = \frac{A}{1 + AB}$$

→ If loop gain $AB \gg 1$.

↓

$$A_F = \frac{A}{AB} = \frac{1}{B}$$

⇒ B is designed with passive components which are predictable, stable and accurate. Hence, the Adv. of (-ve) feedback is to establish very accurate & stable gain.

⇒ Four types of Feedback:

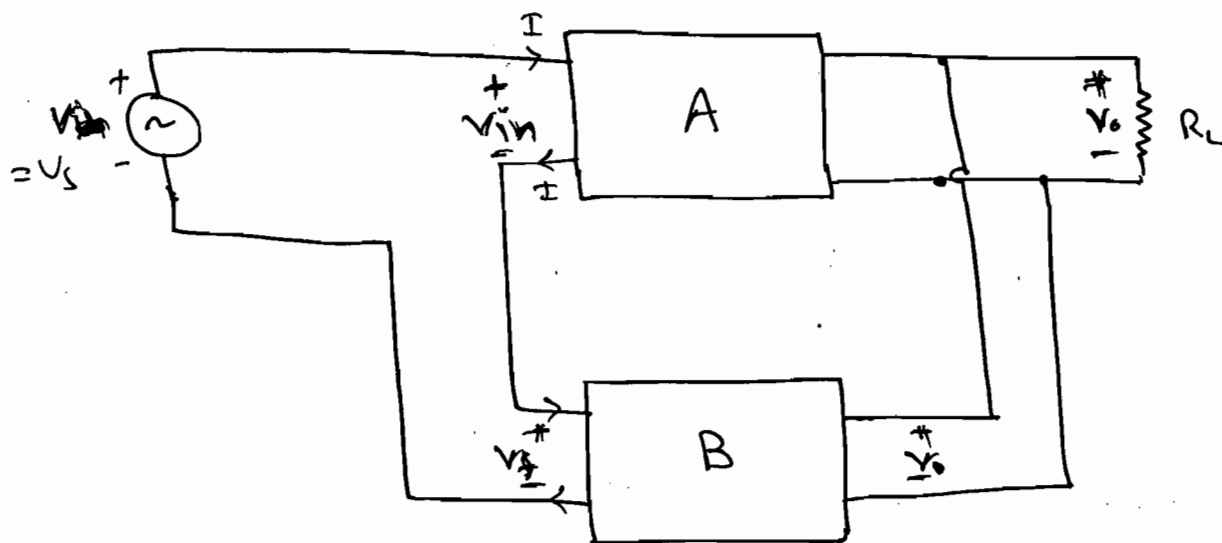
<u>Amp</u>	<u>R_{in}</u>	<u>R_o</u>	<u>Type of Feedback.</u>	
① Voltage	High	Low	ser. - shunt	(V/Vs)
② Current	Low	High	shunt - ser	(C/Cs)
③ Transconductance	High	High	ser - ser	(V/Cs)
④ Transresistance	Low	Low	sh - sh	(C/Cv).



Series-Shunt

Feedback:

(VCVS)



$$\therefore V_s - V_{in} - V_f = 0$$

$$\therefore V_{in} = V_s - V_f$$

negative feedback.

$$1) A = \frac{V_o}{V_{in}} = \frac{V_o}{V_s - V_f}$$

$$2) \beta = \frac{V_f}{V_o}$$

Voltage Control Voltage Source.

high V_{in} , Low V_o .

$$3) A_F = \frac{A}{1 + AB}$$

$$A_F = \frac{V_o}{V_s}$$

$$\therefore \frac{V_o}{V_s} = \frac{A}{1 + AB} = A_F$$

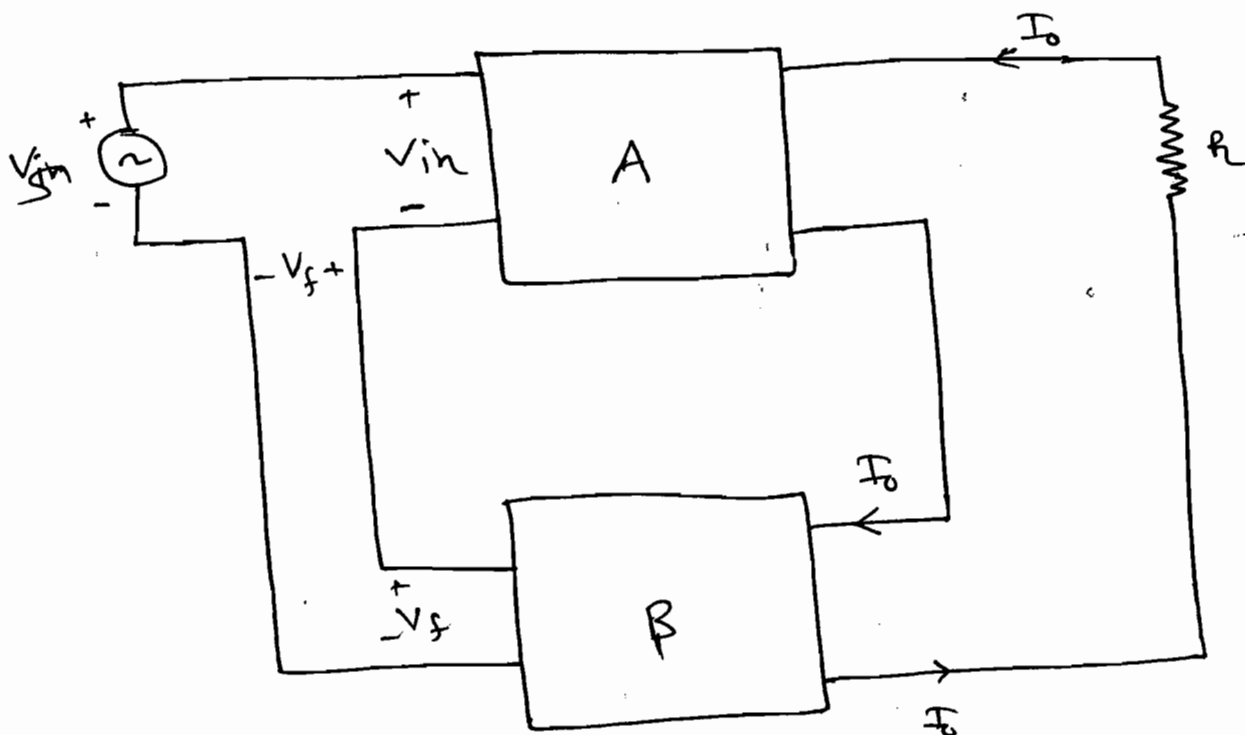
$$\therefore A = \frac{V_o}{V_s - V_f}$$

$$\therefore A = \frac{V_o}{V_s - \beta V_o}$$

$$\therefore AV_s - ABV_o = V_o$$

✓

* Series Series Feedback:
(V_{CCS}).



$$1) A = \frac{I_o}{V_{in}}$$

$$A = \frac{I_o}{V_s - V_f}$$

$$2) \beta = \frac{V_f}{I_o}$$

$$3) A_F = \frac{A}{1 + AB}$$

$\Rightarrow$ Voltage Control Current Source.

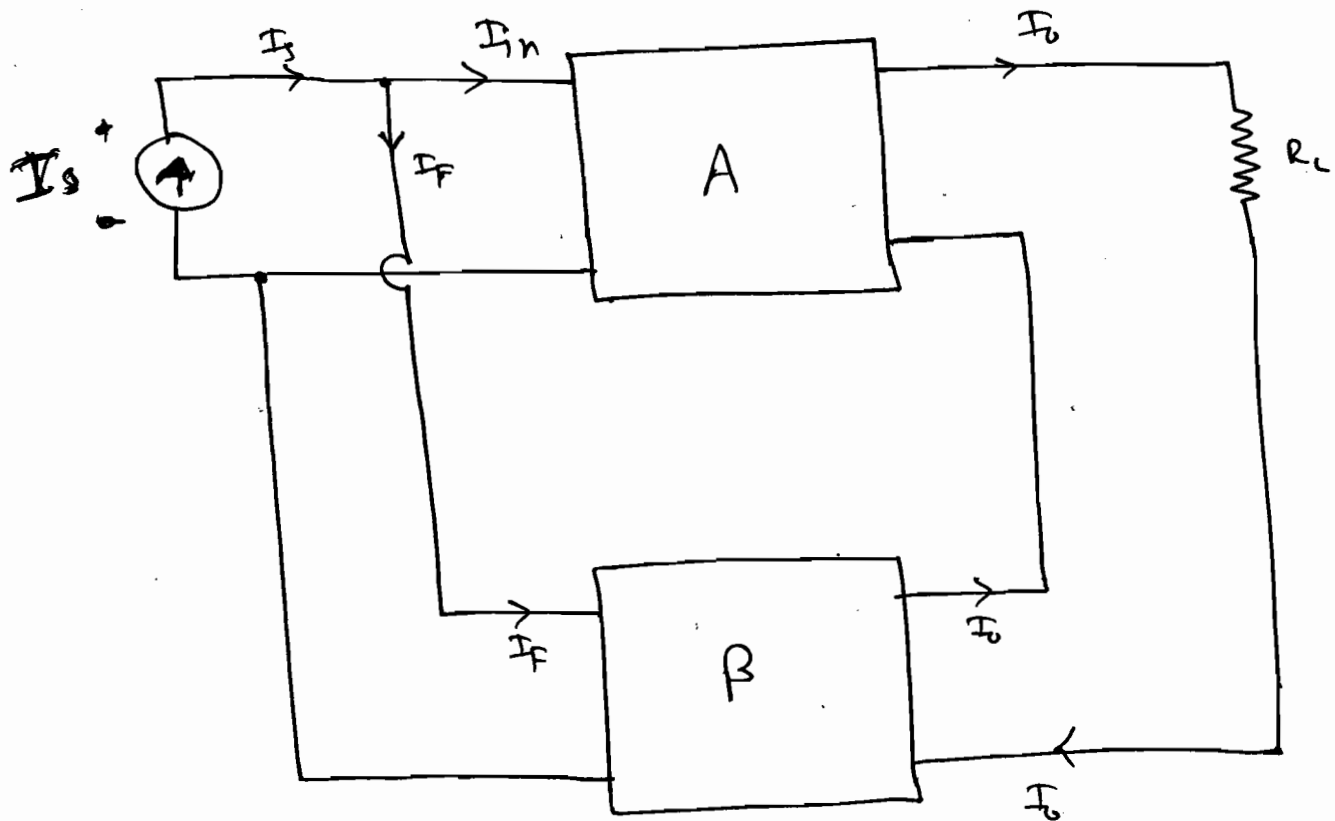
$V_{in} = \text{high}$

$V_o = \text{high}$.

$\Rightarrow$ Transconductance Amplifier.



Shunt - Series Feedback:



$$\therefore I_s = I_{in} + I_f.$$

$$\therefore I_{in} = I_s - I_f. \text{ Negative feedback.}$$

$$\therefore 1) A = \frac{I_o}{I_{in}} = \frac{I_o}{I_s - I_f}.$$

$$\therefore 2) \beta = \frac{I_f}{I_o}.$$

$\Rightarrow$ Current control current source.

$$3) A_F = \frac{A}{1 + A\beta}.$$

$\rightarrow V_{in} = \text{Low}$

$V_o = \text{High}$

$\rightarrow$ current amplifier.

→ Ex-1 Let, $I_S = 10 \mu A$, $I_O = 100 \mu A$.
 $I_F = 6 \mu A$, $A_f = ?$

$$\therefore A = \frac{I_O}{I_S - I_F} = \frac{\cancel{10 \mu A}}{10 \mu A - 6 \mu A}$$

$$\therefore A = \frac{100 \mu A}{4 \mu A}$$

$$A = \frac{100 \times 10^{-3}}{4 \times 10^{-6}}$$

$$\therefore A = 25 \times 10^3$$

$$\therefore \boxed{A = 25000}$$

$$\therefore \beta = I_F / I_O$$

$$\therefore \beta = \frac{6 \times 10^{-6}}{100 \times 10^{-3}}$$

$$\therefore \beta = 60 \mu$$

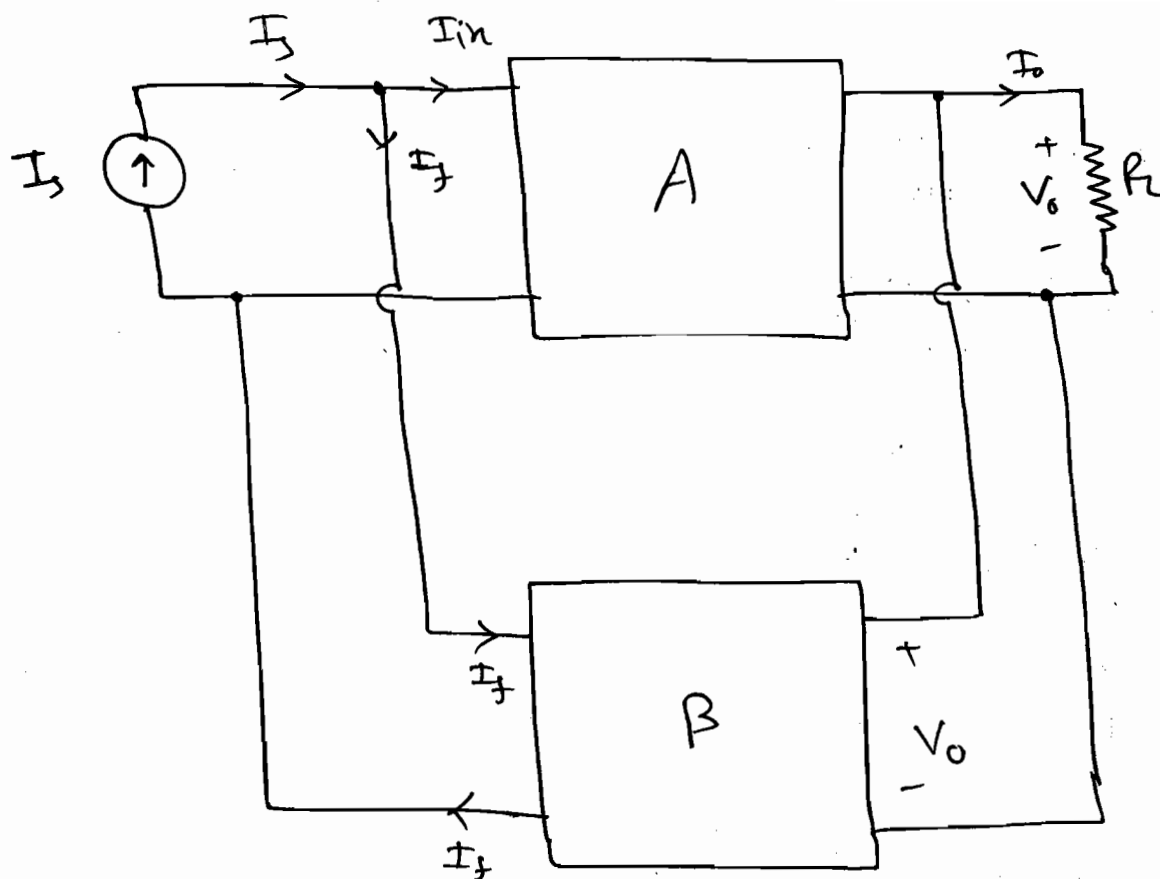
$$\therefore A_F = \frac{A}{1 + A\beta}$$

$$\therefore A_F = \frac{25000}{1 + (25000 \times 6 \times 10^{-5})}$$

$$\therefore \boxed{A_F = 10000}$$

☆ Trans Resistance Amplifier (CCVS).
 (Shunt - Shunt Feedback).

⇒



⇒ $I_{in} = I_s - I_f$.

∴ 1) $A = \frac{V_o}{I_{in}} = \frac{V_o}{I_s - I_f}$.

2) $\beta = I_f / V_o$.

3) $A_f = \frac{A}{1 + A\beta}$.

⇒ Current ~~Source~~ Control Voltage ~~Source~~ Source.

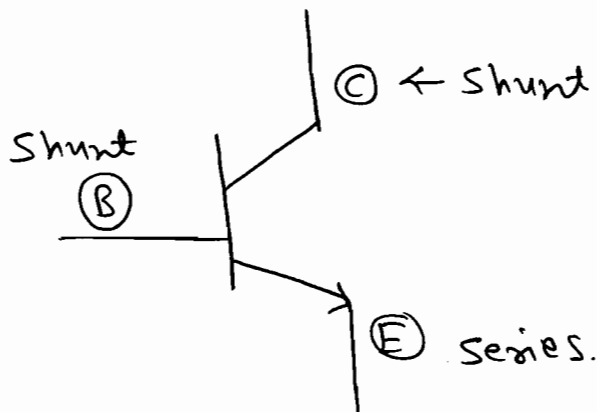
$V_{in} = \text{Low}, V_o = \text{Low}.$

(*)



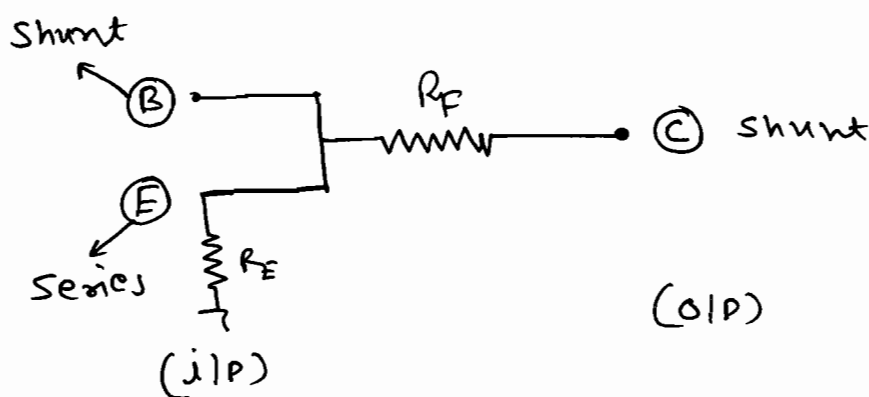
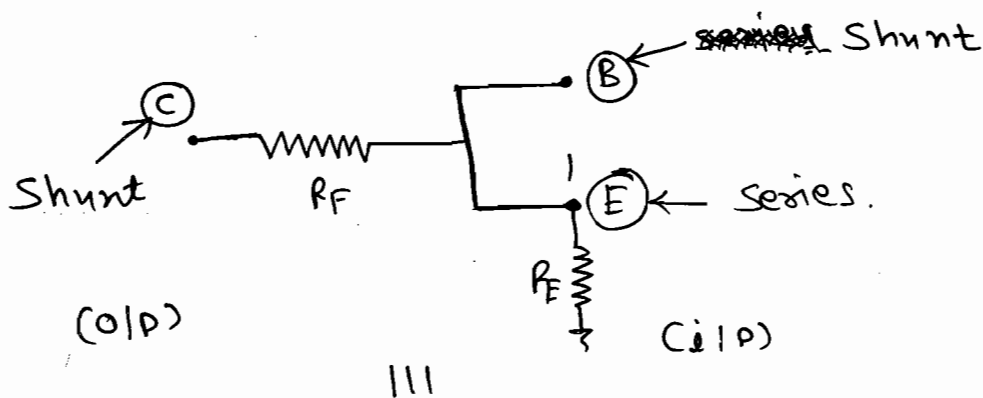
Techniques for Identifying Feedback and Type of Amplifiers.

(*)

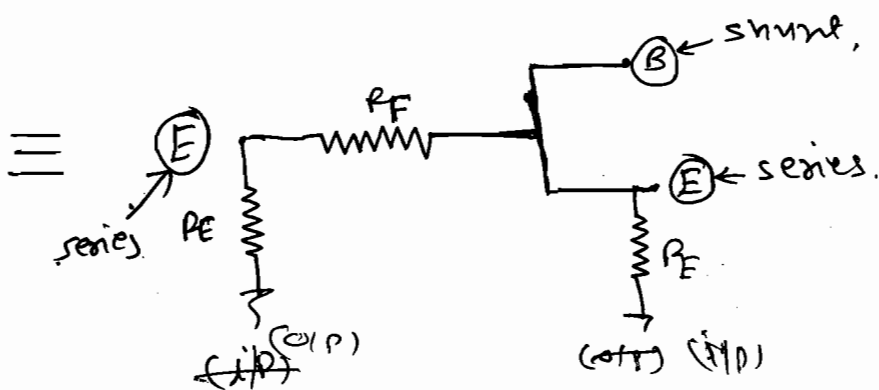
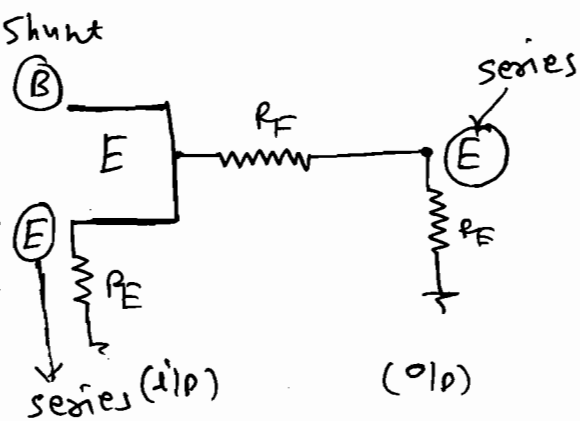


Most
IMP
concept

(*)



(*)



In words:

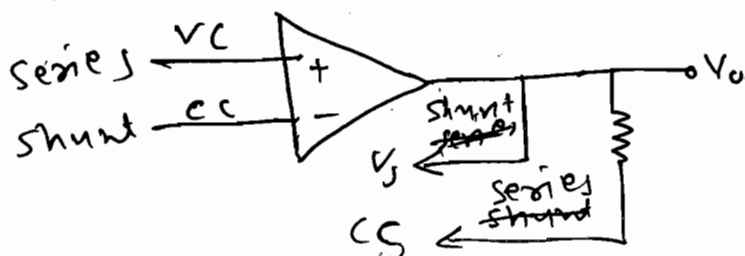
- ① ~~Series Shunt~~
 If we take ~~off~~ ^{feedback} from Collector along with R_F in series then it is shunt
 (or) Voltage Sampling.
- ② If we take feedback from Emitter in series with R_F then it is called series (or) Current Sampling. Don't forget R_E . There should be R_E .
- ③ Now, If taken feedback from o/p if it is connected to Base of i/p then it is called shunt mixing.
- ④ If taken feedback from o/p, it is connected to Emitter of i/p then it is called series mixing.

* Now,

Series - series } 1 stage, 3 stage.
 Shunt - shunt }

series - shunt } 2 stage, 2 stage.
 Shunt - series }

* OPAMP



① Series Shunt Feedback:

→ Series → $R_{in} = \text{high}$ → V_c
 Shunt → $R_o = \text{Low}$ → V_s → VCVS

VCVS
 ↓
 Voltage Series.

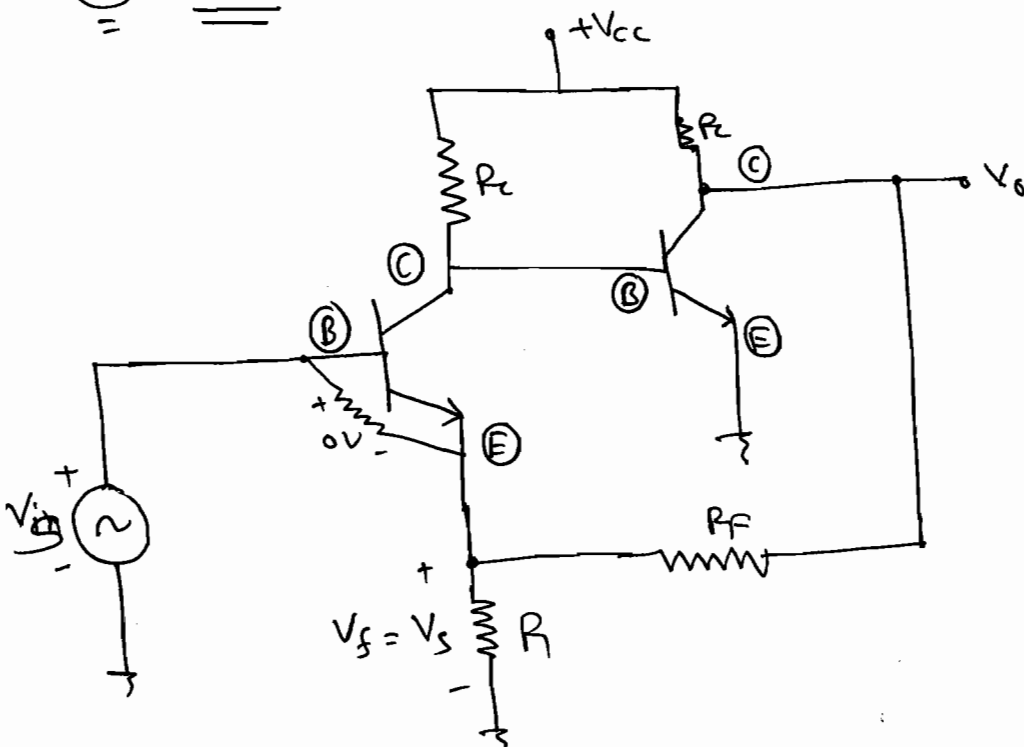
2 stage

→ Voltage Amplifier.

$$\therefore V_o = A_v V_s.$$

$$\therefore A_F = \frac{V_o}{V_s} \rightarrow \begin{array}{l} i/p = \text{Voltage form} \\ o/p = \text{Voltage form.} \end{array}$$

② BJT



$$\Rightarrow V_s = \frac{R_1}{R_1 + R_F} \cdot V_o.$$

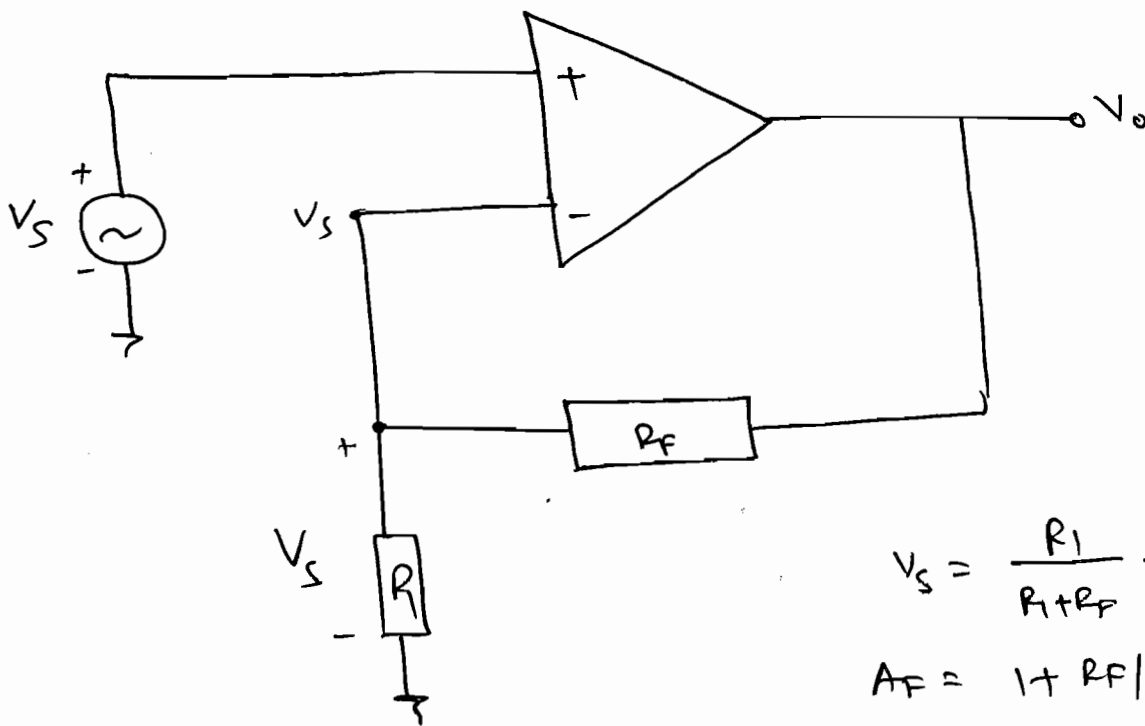
$$\Rightarrow A_F = \frac{V_o}{V_s} = \frac{R_1 + R_F}{R_1}.$$

$$\therefore A_F = \left(1 + \frac{R_F}{R}\right).$$

$$\therefore \beta = \frac{1}{A_F}.$$

$$\therefore \beta = \frac{R_1}{R + R_F}.$$

② OP-Amp:

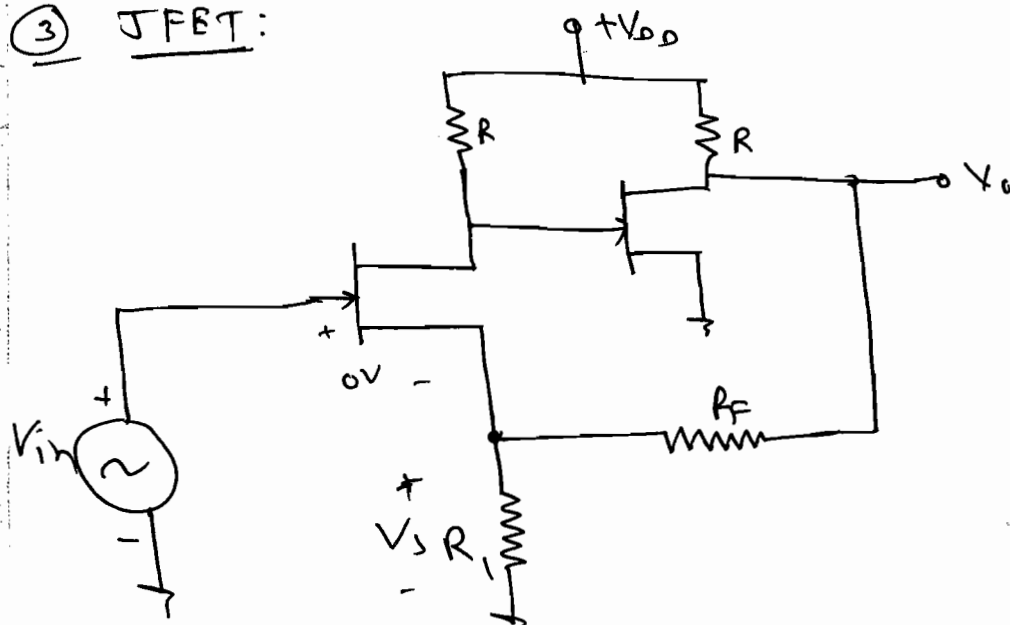


$$V_S = \frac{R_1}{R_1 + R_F} \cdot V_O$$

$$A_F = 1 + R_F/R$$

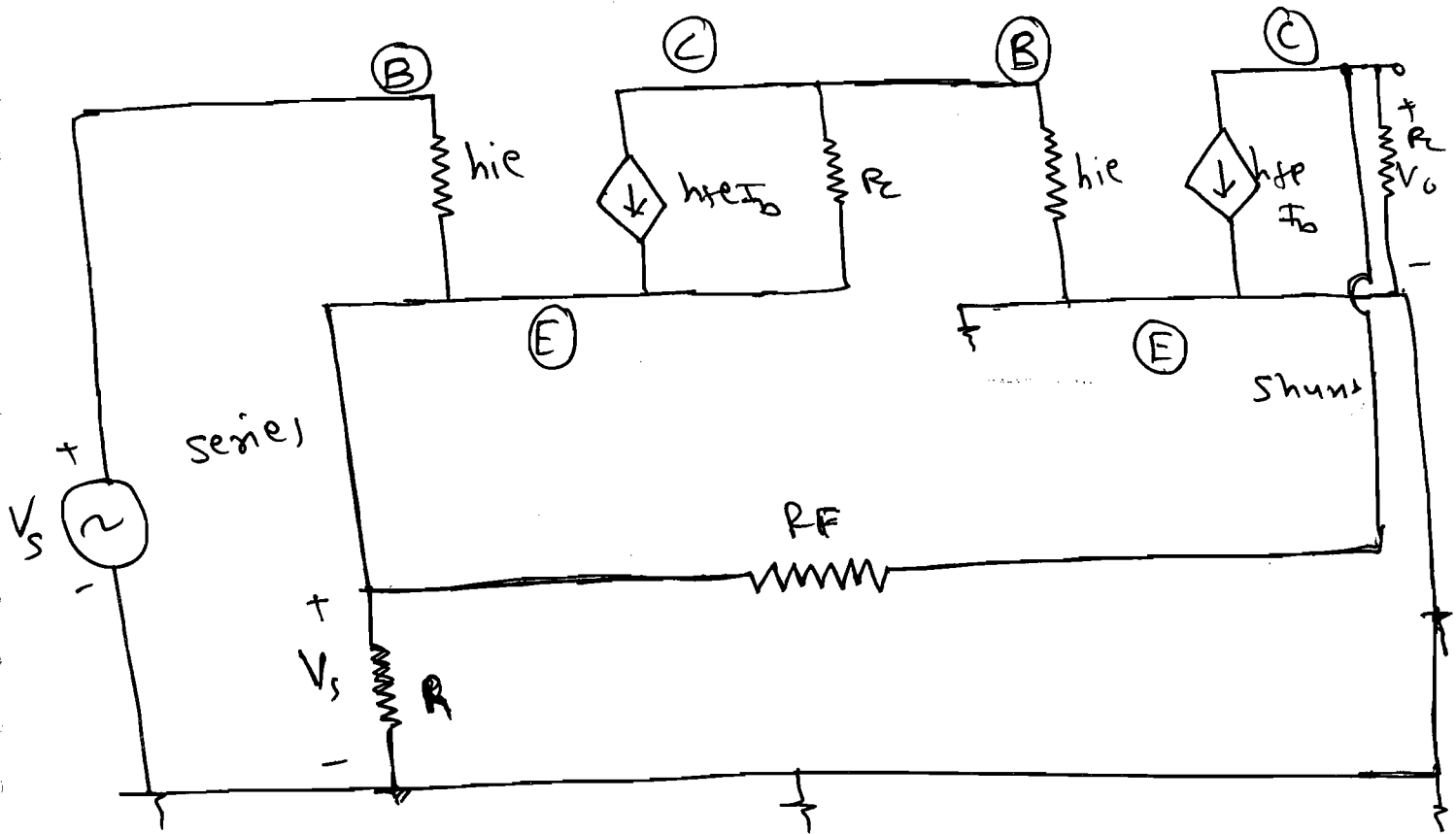
$$\beta = \frac{R_1}{R_1 + R_F}.$$

③ JFET:



* H-model

11



① Series-Shunt feedback

$$② A_F = 1 + \frac{R_F}{R_1} = \frac{V_o}{V_s}$$

$$③ \beta = \frac{1}{A_F}$$

$$\Rightarrow \beta = \frac{R_1}{R_1 + R_F}$$

④ Voltage Amplifier

⑤ Voltage Control Voltage Amplifier

⑥ Voltage series amplifier

$$⑦ R_{inF} = R_{in0} (1 + A\beta)$$

$$⑧ R_{oF} = \frac{R_{o0} (1 + A\beta)}{1 + A\beta}$$

② Shunt Shunt Feedback:

→ $R_{in} = \text{Low} \rightarrow CC$
 $R_o = \text{Low} \rightarrow VS$ } $CCVS$.

→ Shunt - Shunt

CC VS
 ↓

Voltage Shunt

1 stage

or

3 stage

→ TransResistance Amplifier.

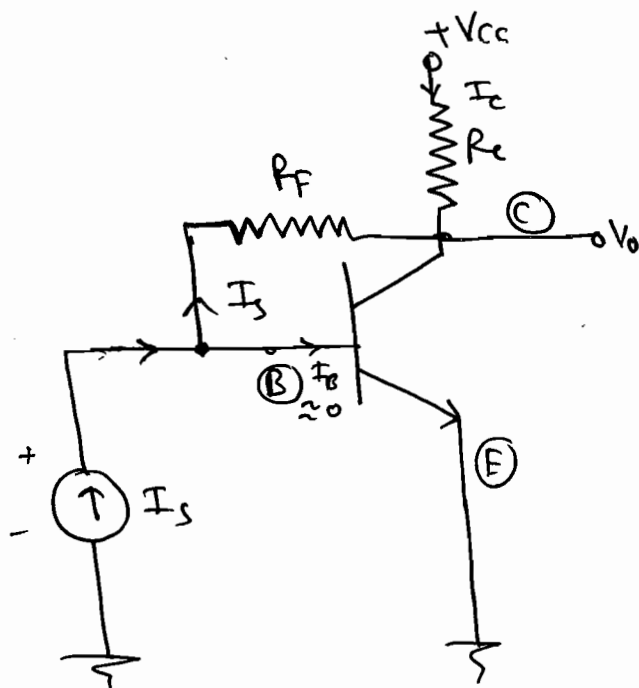
$$\therefore R_m = \frac{V_o}{I_s}$$

$$\therefore V_o = R_m \cdot I_s$$

→ i/p = Current form.

o/p = Voltage form.

① BJT:



$$I_C = I_o = -I_s$$

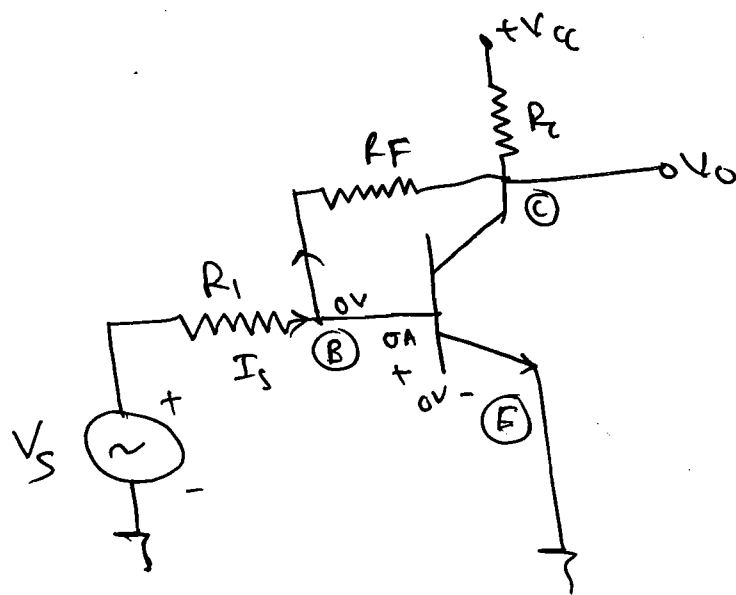
$$V_o = -I_s R_F$$

$$\therefore \boxed{\frac{V_o}{I_s} = -R_F}$$

$$\therefore A_F = \frac{V_o}{I_s} = -R_F$$

$$\therefore \boxed{\beta = \frac{1}{A_F} = -\frac{1}{R_F}}$$

⇒



$$I_s = \frac{V_s - 0V}{R_1}$$

$$\therefore V_s = I_s R_1$$

KCL,

$$\frac{V_s - 0}{R_1} = \frac{0 - V_o}{R_F}$$

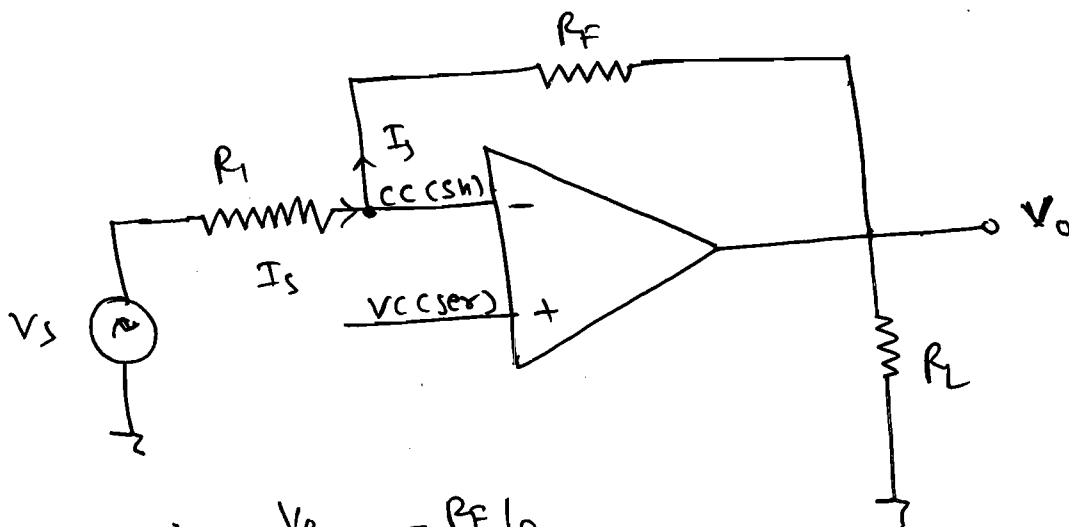
$$\therefore V_o = -\frac{R_F}{R_1} V_s$$

$$\therefore V_o = -\frac{R_F}{R_1} \cdot I_s \cdot R_1$$

$$\therefore \frac{V_o}{I_s} = A_F = -\frac{R_F}{R_1} =$$

$$\therefore \beta = \frac{1}{A_F} = -\frac{1}{R_F}$$

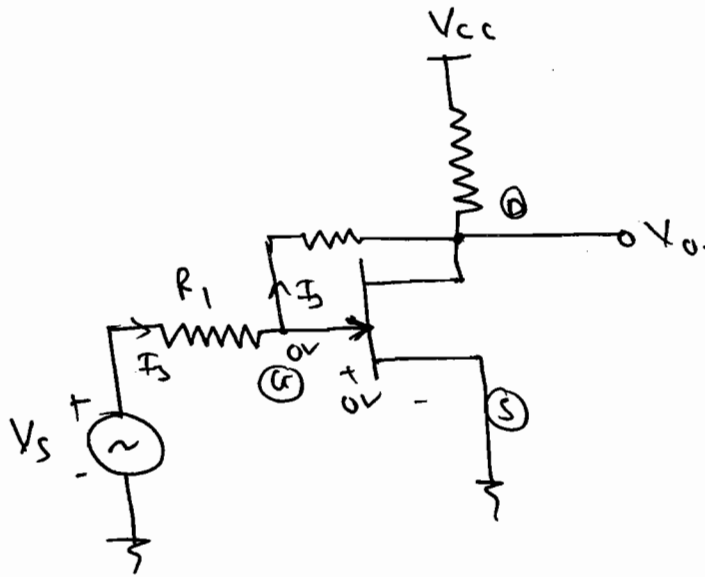
② OPAMP :



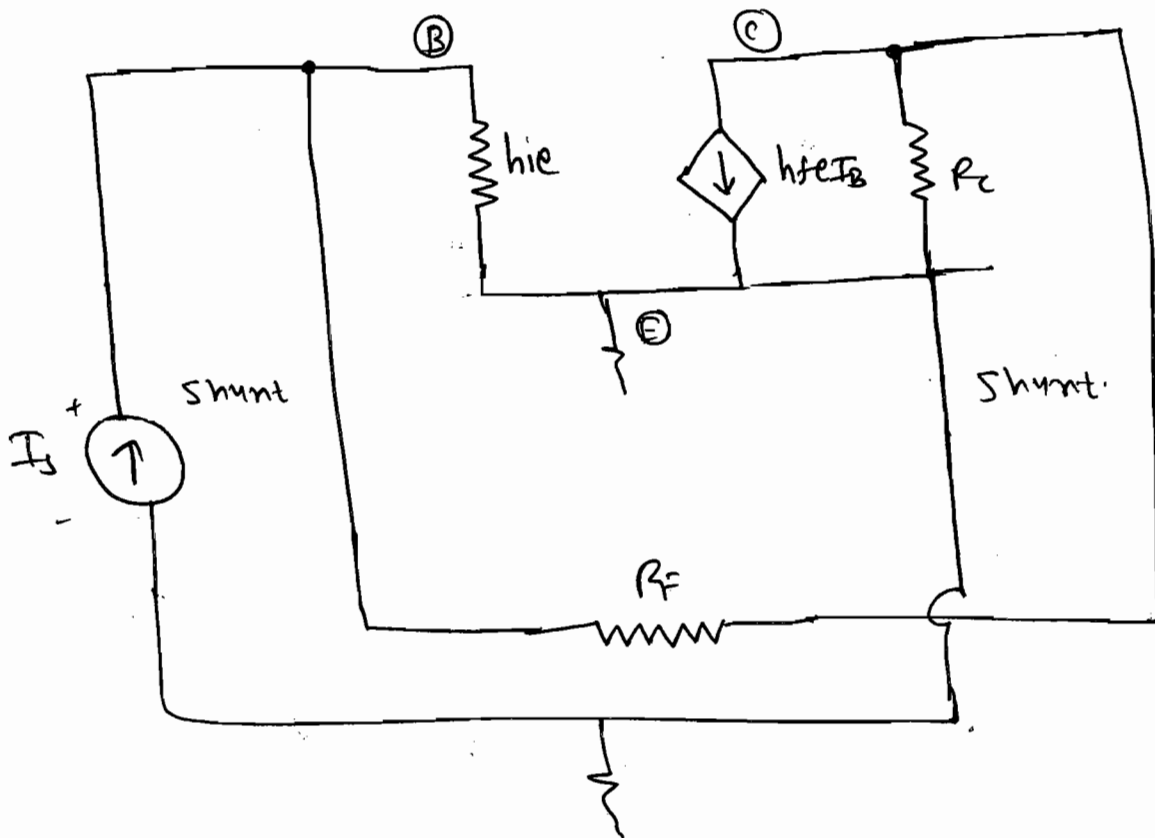
$$\therefore \frac{V_o}{V_s} = -\frac{R_F}{R_1}$$

$$\therefore \frac{V_o}{I_s} = -R_F = A_F \Rightarrow \beta = \frac{1}{A_F} = -\frac{1}{R_F}$$

③ JFET:



* H-Model:



① Shunt - Shunt

② $cc V_S$

③ $A_F = - \frac{R_F}{R_i}$

④ $\beta = \frac{1}{A_F} = -\frac{1}{R_F}$

⑤ Voltage Shunt.

⑥ Transconductance.

⑦ $R_{in_f} = \frac{R_{in}}{1+AB}$

⑧ $R_{of} = \frac{R_o}{1+AB}$

③ Series - series Feedback:

$$\begin{aligned} \rightarrow R_{in} = \text{high} \rightarrow V_C \\ R_o = \text{high} \rightarrow C_S \end{aligned} \left. \vphantom{\begin{aligned} \rightarrow R_{in} = \text{high} \rightarrow V_C \\ R_o = \text{high} \rightarrow C_S \end{aligned}} \right\} V_{CCS}$$

Voltage ^(series) Control current source.

V_{CCS}
↓
current series.

① stage
③ stage.

Trans Conductance amplifier.

$$\therefore g_m = \frac{I_o}{V_s}$$

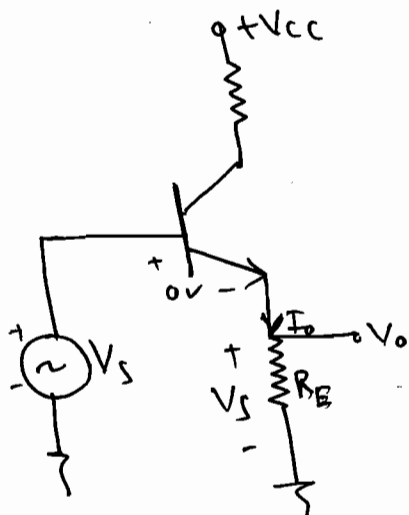
i/p = Voltage form.

o/p = current form.

$$\therefore I_o = g_m V_s$$

① BJT:

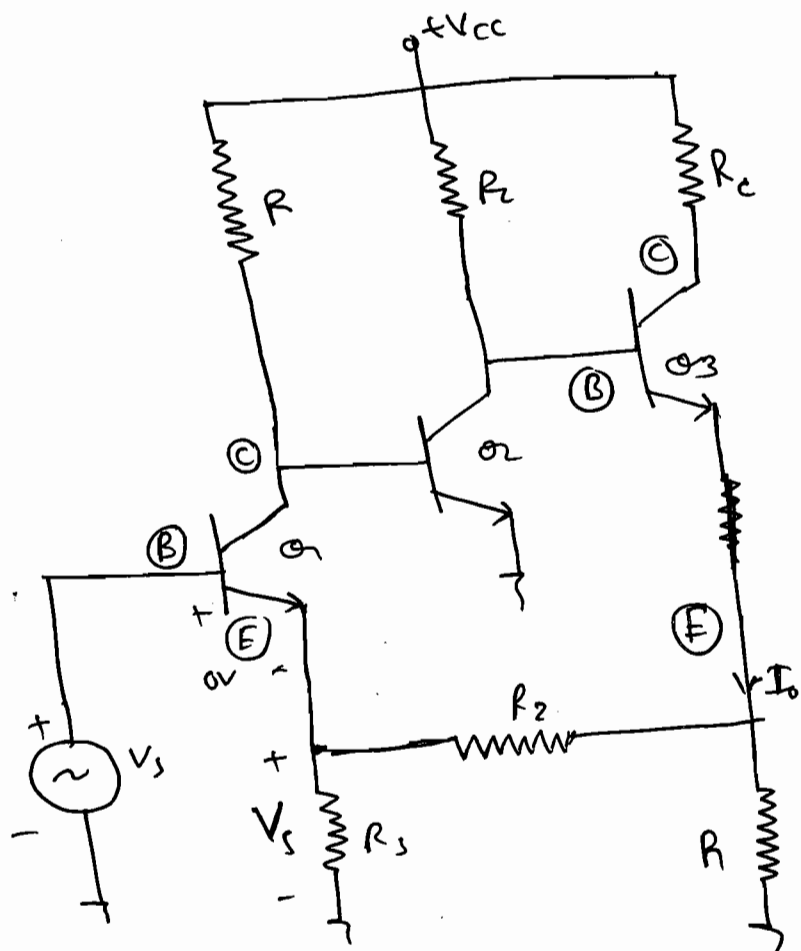
① single stage

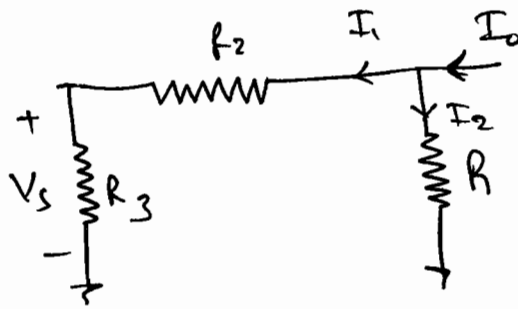


$$\therefore V_s = I_o \cdot R_E$$

$$\therefore I_o = \frac{V_s}{R_E}$$

② 3-stage





$$\therefore V_s = I_1 \cdot R_3$$

$$\text{Now, } I_1 = \frac{R_1}{R + R_2 + R_3} \cdot I_0$$

$$\therefore V_s = \frac{R_1 \cdot R_3}{R + R_2 + R_3} \cdot I_0$$

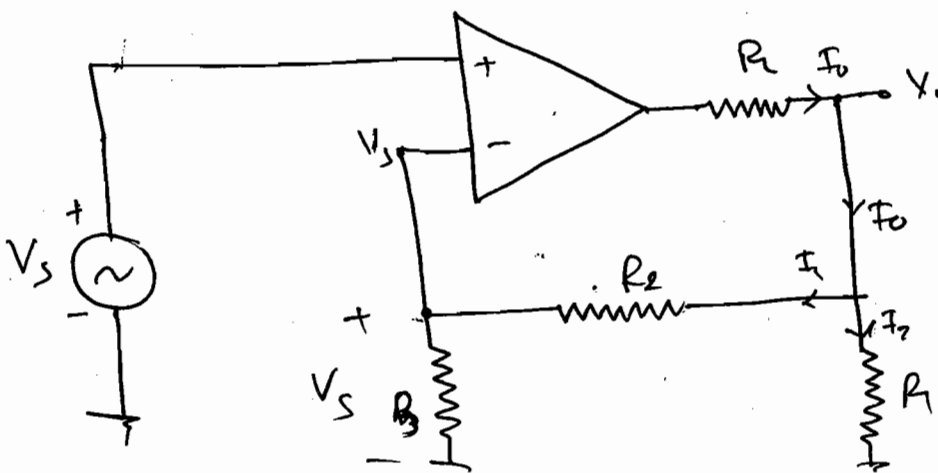
$$\therefore g_m = \frac{I_0}{V_s} = \frac{R_1 + R_2 + R_3}{R_1 \cdot R_3}$$

$$\therefore A_F = \frac{R_1 + R_2 + R_3}{R_1 \cdot R_3}$$

$$\beta = \frac{1}{A_F}$$

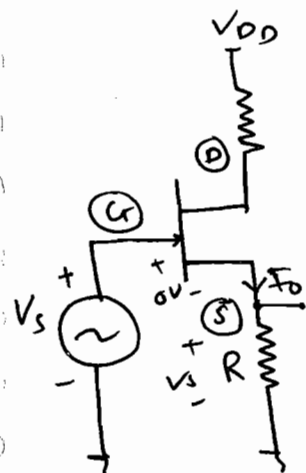
$$\therefore \beta = \frac{R_1 \cdot R_3}{R + R_2 + R_3}$$

② OP-Amp:



③ JFET:

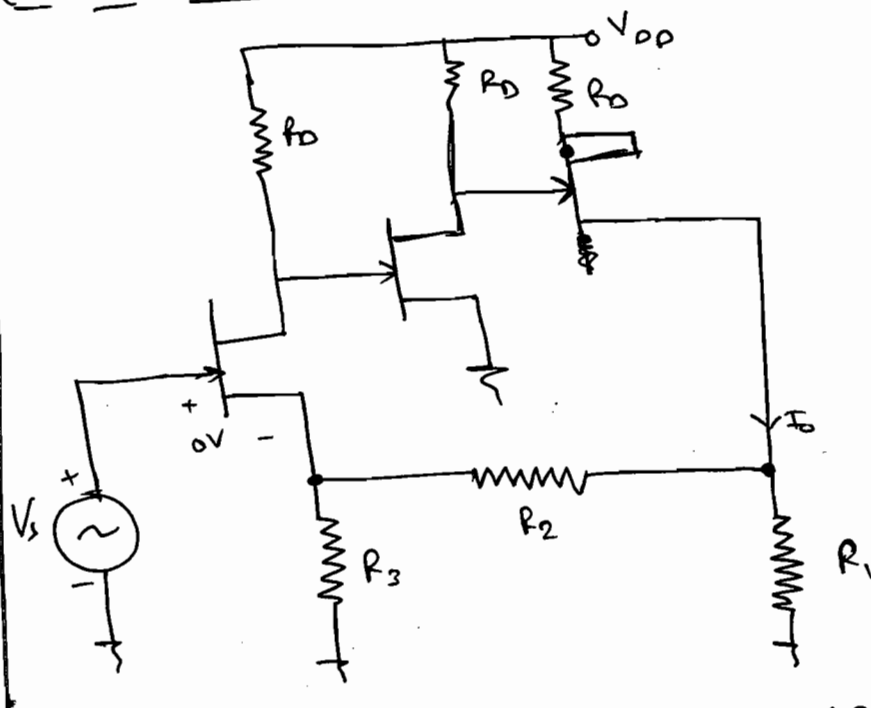
(1) Single Stage:



$$I_D = \frac{V_s}{R}$$

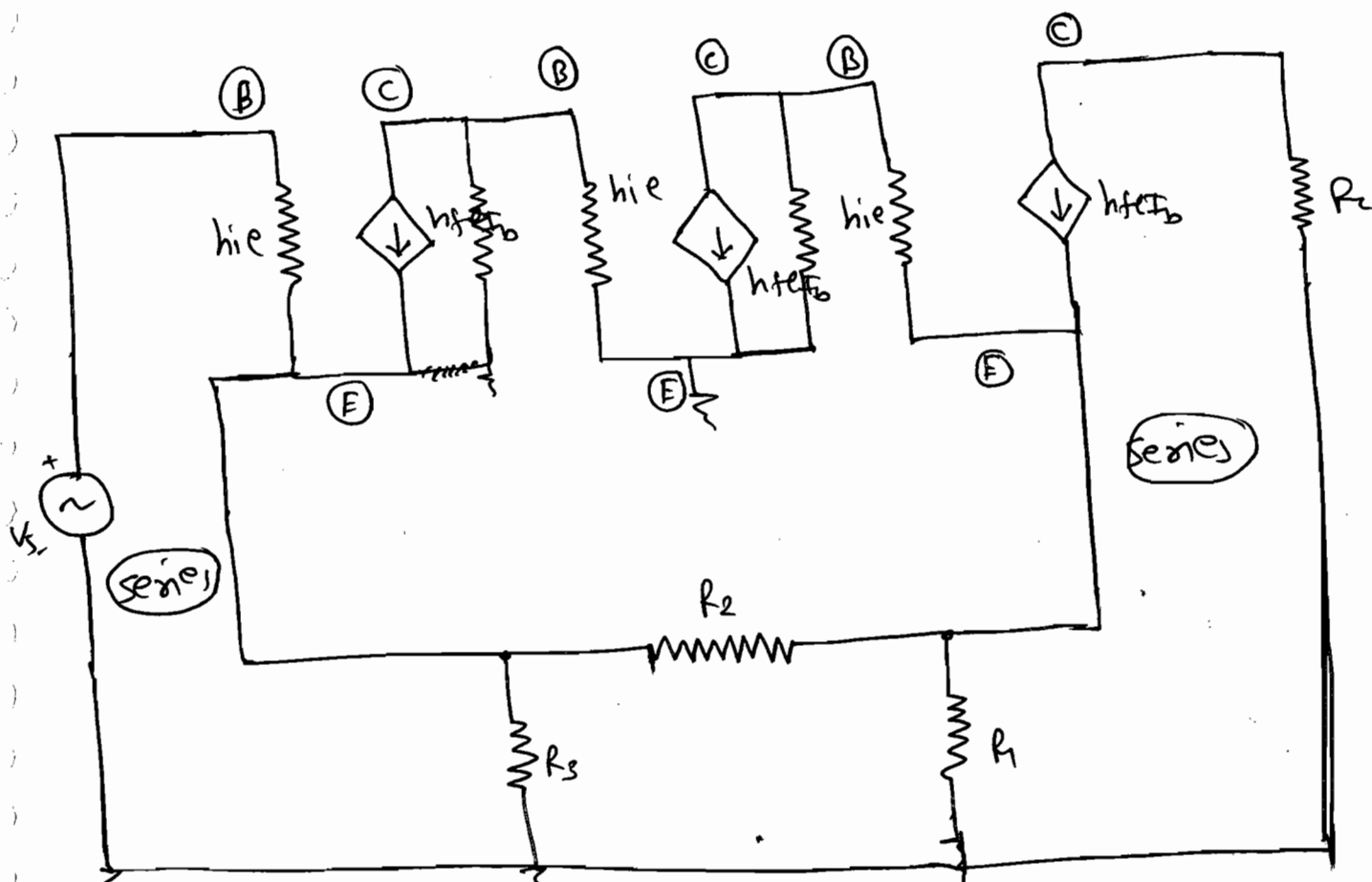
~ H-Model:

(2) 3-Stage:



⑦ $R_{inF} = R_{in}(1 + AB)$

⑧ $R_{oF} = R_o(1 + AB)$



① Series-series tlb

④ $\beta = 1/A_F$

⑥ Transresistance

② VCES

③ $A_F = \frac{R_1 R_2}{R + R_2 + R_3}$

⑤ current series ⑦ R

④ Shunt - series feedback:

→ $R_{in} = \text{Low} \rightarrow CC$
 $R_o = \text{high} \rightarrow CS$ } $CCCS.$

Current: Control current source.

Shunt - series

$CS \rightarrow CS$

↓
current shunt Amp.

2-stage

∴ Current Amplifier.

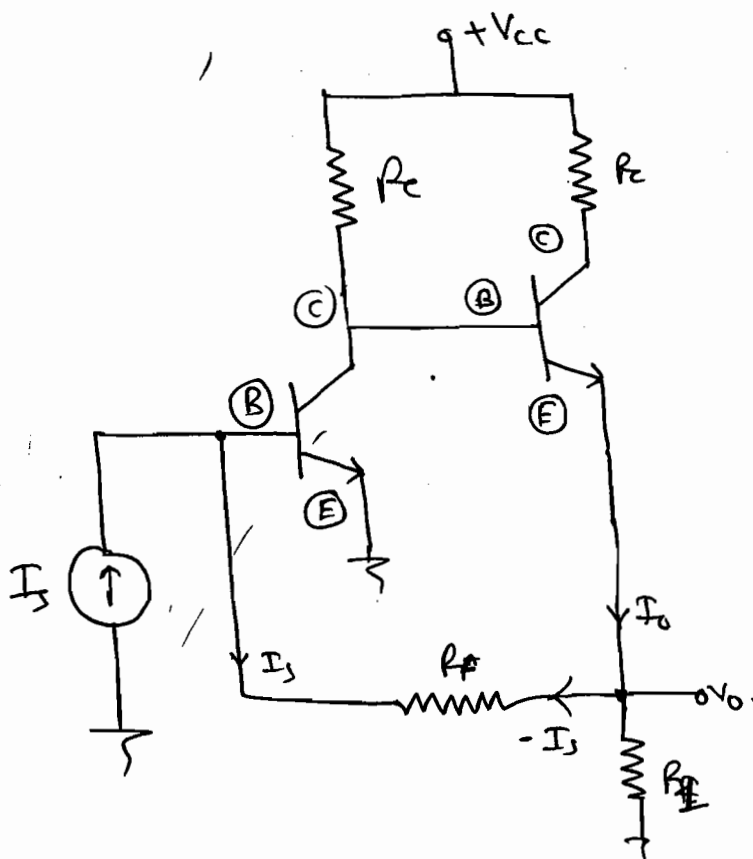
$$\therefore A_I = \frac{I_o}{I_s}$$

$$\therefore \boxed{I_o = A_I \cdot I_s}$$

i/p: current form.

o/p: current form.

① BJT:

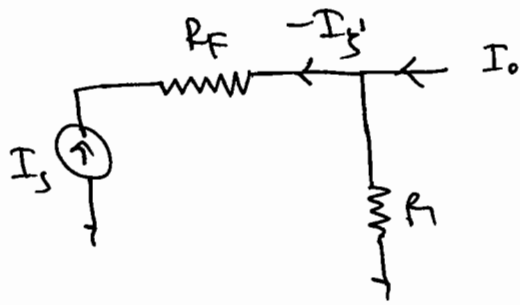


$$\therefore -I_s = \frac{R_1}{R_F + R_1} \cdot I_o$$

$$\therefore \frac{I_o}{I_s} = A_F = -\left(1 + \frac{R_F}{R_1}\right)$$

$$\boxed{A_F = -\left(1 + \frac{R_F}{R_1}\right)}$$

$$\boxed{\beta = -\frac{R_1}{R_1 + R_F}}$$

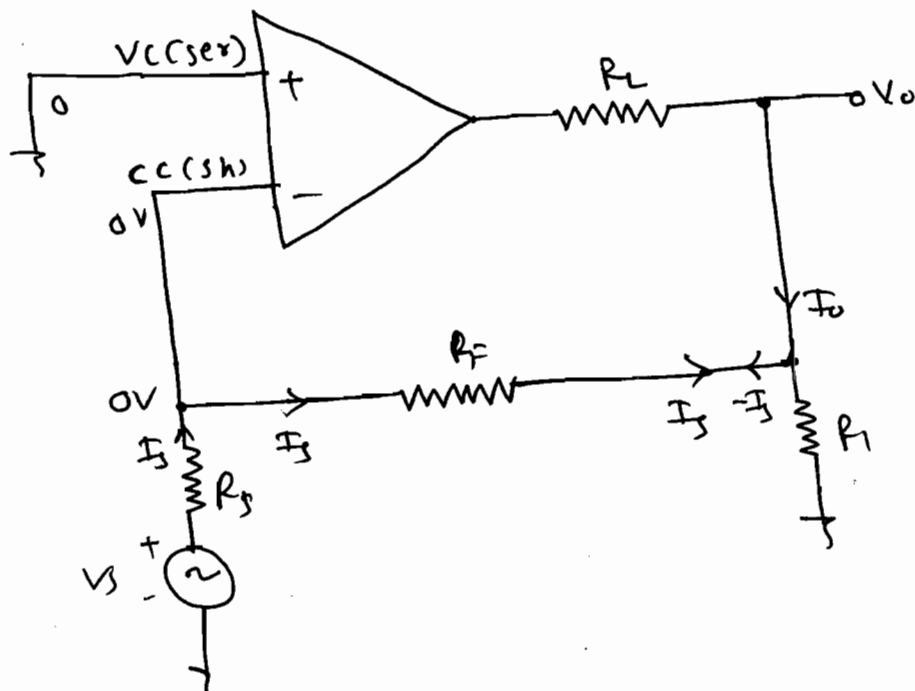


$$\therefore I_s = \frac{-R_1}{R_1 + R_F} I_o$$

$$\therefore A_F = -\left(1 + \frac{R_F}{R_1}\right) = \frac{I_o}{I_s}$$

$$\therefore \beta = \frac{1}{A_F} = -\frac{R_1}{R_1 + R_F}$$

② OP-Amp:



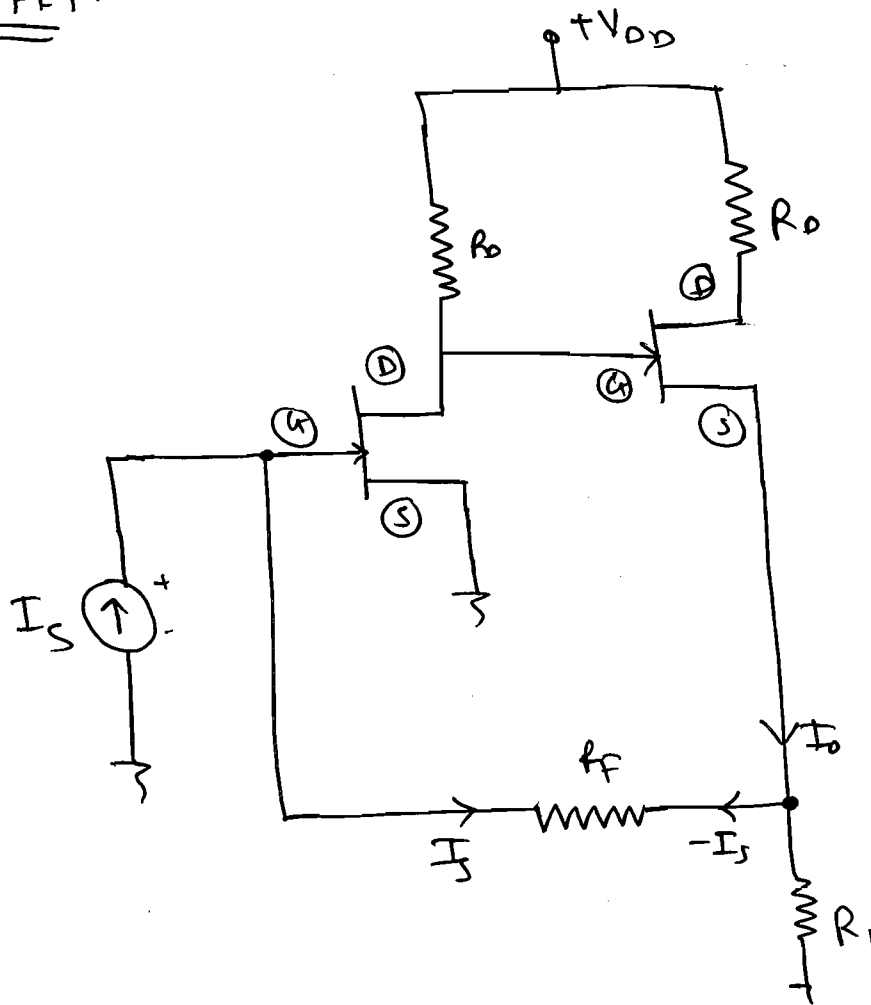
$$\therefore I_s = \frac{V_s - 0V}{R_s} = \frac{V_s}{R_s}$$

$$\therefore -I_s = \frac{R_1}{R_1 + R_F} \cdot I_o$$

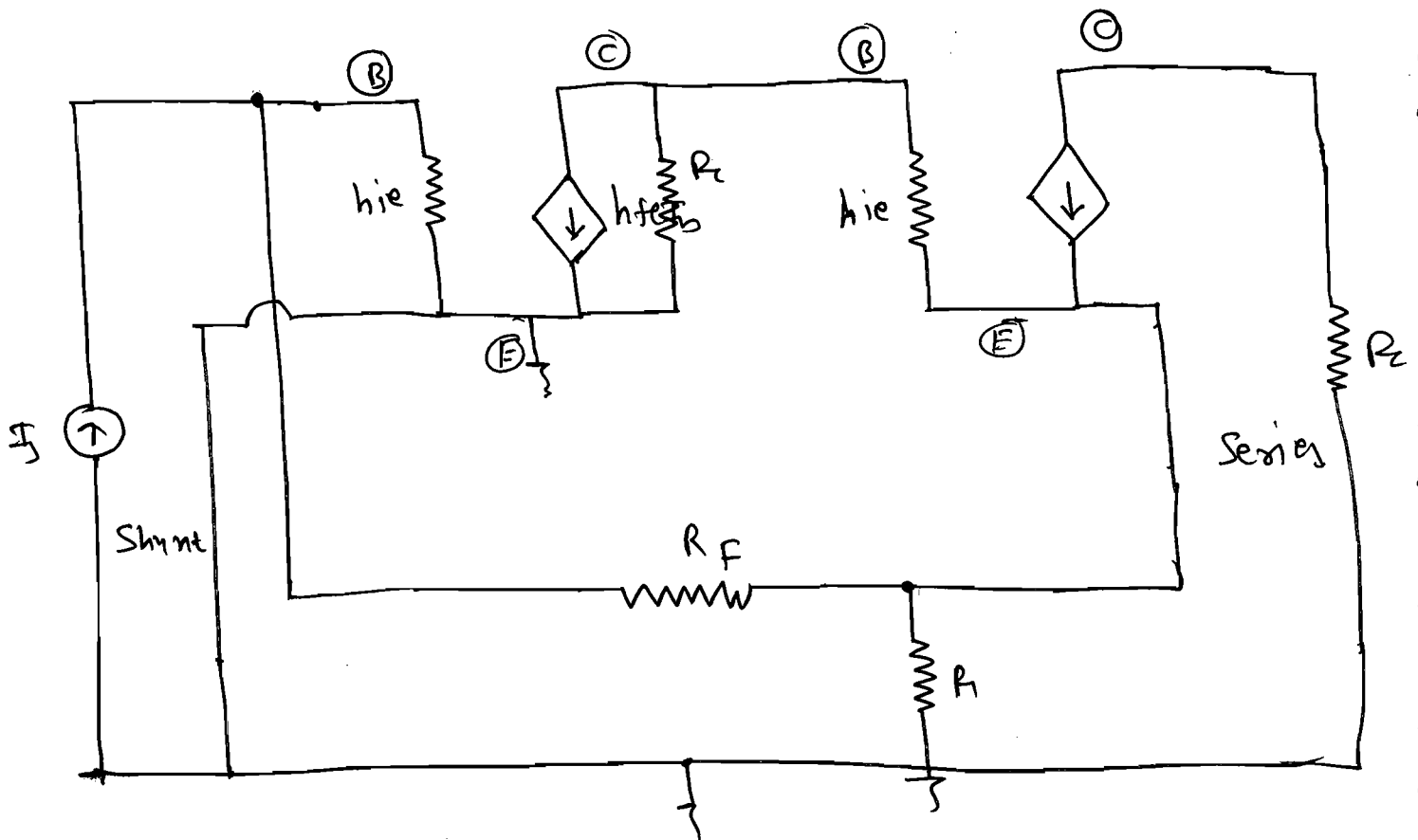
$$\therefore \frac{I_o}{I_s} = -\left(1 + \frac{R_F}{R_1}\right)$$

$$\therefore A_F = -\left(1 + \frac{R_F}{R_1}\right) \Rightarrow \beta = -\frac{R_1}{R_1 + R_F}$$

③ JFET:

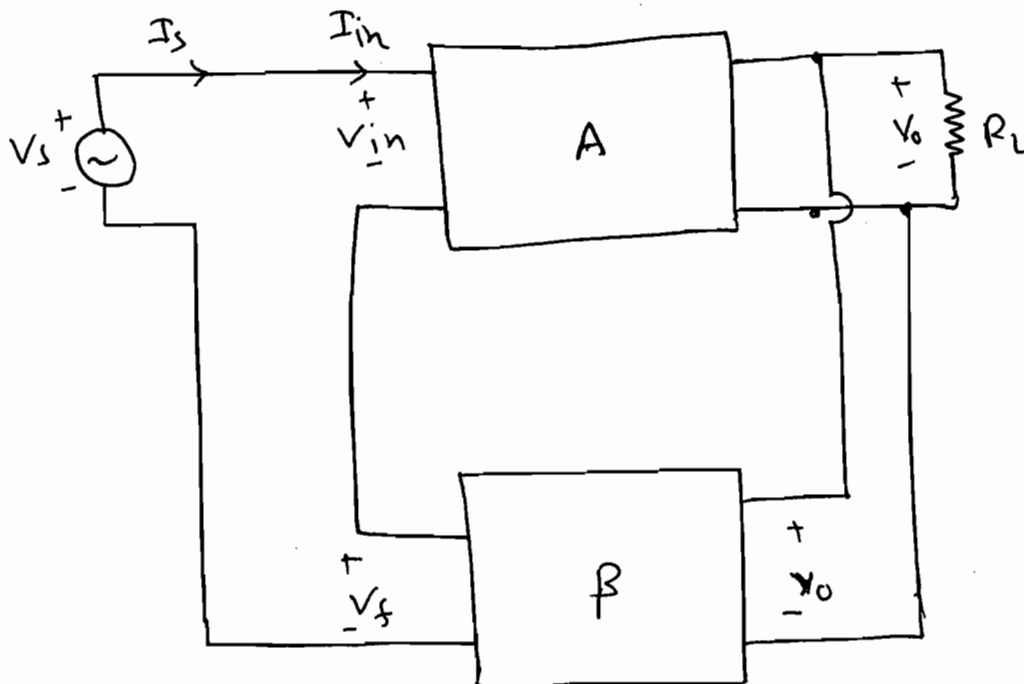


* H-Model:



- ① Shunt series A feedback.
- ② Current control current source.
- ③ Gain $A_F = \frac{I_o}{I_s} = -\left(1 + \frac{R_F}{R_1}\right)$
- ④ $\beta = \frac{1}{A_F} = -\frac{R_1}{R_1 + R_F}$.
- ⑤ current shunt
- ⑥ current Amplifier.
- ⑦ $R_{in_F} = \frac{R_{in}}{1 + AB}$.
- ⑧ $R_{o_F} = R_o (1 + AB)$.

* Input and output Resistance of feedback Amp:-



$$\rightarrow R_{in_{open}} = \frac{V_{in}}{I_{in}}$$

$$R_{in_F} = \frac{V_s}{I_s}$$

$$V_s = V_{in} + V_f$$

$$\therefore R_{inf} = \frac{V_{in} + V_f}{I_s} \quad \text{But } V_f = \beta V_o$$

$$\therefore R_{inf} = \frac{V_{in} + \beta V_o}{I_s} \quad , \quad \text{But } V_o = A V_{in}$$

$$\therefore R_{inf} = \frac{V_{in} + \beta A V_{in}}{I_{in}} \quad (\because I_{in} = I_s)$$

$$\therefore R_{inf} = \frac{V_{in}}{I_{in}} \cdot (1 + \beta A)$$

$$\therefore \boxed{R_{inf} = R_{in} (1 + \beta A)} \quad (\text{series})$$

similarly, $\boxed{R_{of} = \frac{R_o}{(1 + \beta A)}} \quad (\text{shunt})$

* Amp.	R_{inf}	R_{of}	
1) Ser-sh $\swarrow$ $V_c \quad V_s$	$R_{in}(1 + \beta A)$	$\frac{R_o}{1 + \beta A}$	Voltage-series [1] F.B.
2) Sh-ser $\swarrow$ $C_c - C_s$	$\frac{R_{in}}{1 + \beta A}$	$R_o(1 + \beta A)$	current-shunt [2] F.B.
3) Ser-ser $\swarrow$ $V_c - C_s$	$R_{in}(1 + \beta A)$	$R_o(1 + \beta A)$	Current-series [3] F.B.
4) Sh-sh $\swarrow$ $C_c - V_s$	$\frac{R_{in}}{1 + \beta A}$	$\frac{R_o}{1 + \beta A}$	Voltage-shunt [4] F.B.

$$* \quad A_F = \frac{A}{1+AB}$$

$$\therefore \frac{dA_F}{dA} = \frac{(1+AB)(1-A(B))}{(1+AB)^2}$$

$$\therefore \frac{dA_F}{dA} = \frac{1}{(1+AB)^2}$$

$$\therefore dA_F = \frac{dA}{(1+AB)^2}$$

$$\therefore \frac{dA_F}{A_F} = \frac{dA}{A_F(1+AB)^2}$$

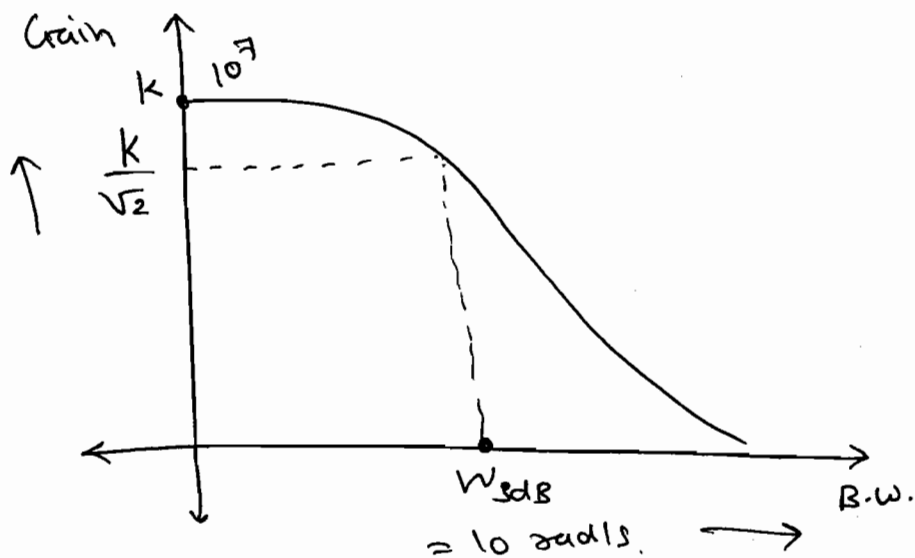
$$\therefore \frac{dA_F}{A_F} = \frac{dA}{\frac{A}{(1+AB)^2} \times (1+AB)^2}$$

$$\therefore \boxed{\frac{dA_F}{A_F} = \frac{\frac{dA}{A}}{1+AB}}$$

$$\therefore \boxed{\% \text{ Change in } A_F = \frac{\% \text{ Change in } A}{1+AB}}$$

→ "1+AB" is called desensitizing factor.

* BandWidth Extension:



$\Rightarrow$ open loop gain, $A = \frac{k}{1 + \frac{s}{W_{3dB}}}$

Where k is D.C. gain $= 10^6$ at $f=0$

$\therefore \text{Gain} \times \text{B.W.} = 10^6 \cdot 10 = 10^7$

$$A = \text{Gain} = \frac{k}{1 + \frac{j\omega}{W_{3dB}}}$$

* How to prove Gain $\times$ B.W. is Constant.

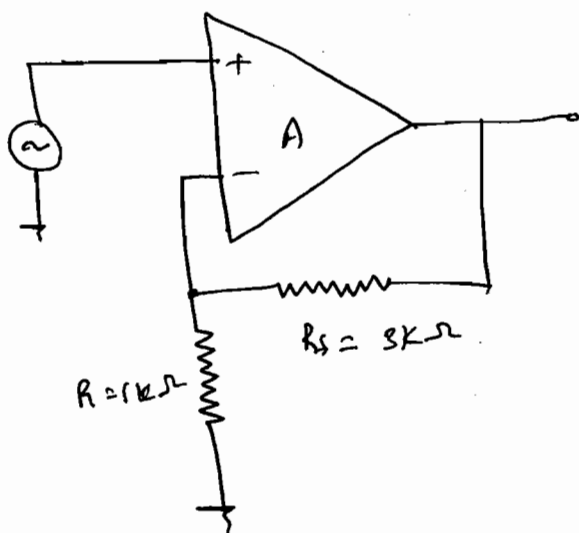
$\Rightarrow$ open loop gain

$$A = \frac{k}{1 + \frac{s}{W_{3dB}}}$$

$$\therefore A = \frac{10^6}{1 + s/10}$$

$$\& \beta = \frac{R_1}{R_1 + R_F}$$

$$\therefore \beta = \frac{1}{4}$$



Now, Closed loop gain

$$A_F = \frac{A}{1 + AB}$$

$$\therefore A_F = \frac{\frac{10^6}{1 + \frac{s}{10}}}{1 + \left(\frac{10^6}{1 + \frac{s}{10}} \right) \cdot 4}$$

$$A_F = \frac{4 \times 10^6}{4 \left(1 + \frac{s}{10} \right) + \frac{10^6}{4}}$$

But at high freq. $\frac{s}{10} = \frac{j\omega}{10} = \frac{j2\pi f}{10} \gg 1$

$$\begin{aligned} \therefore A_F &= \frac{4 \times 10^6}{\frac{4s}{10} + 10^6} \\ &= \frac{4}{1 + \frac{4(s)}{10^6}} \end{aligned}$$

$$\therefore A_F = \frac{4}{1 + \frac{s}{(10^7/4)}}$$

So, New gain $K=4$

$$BW = \frac{10^7}{4}$$

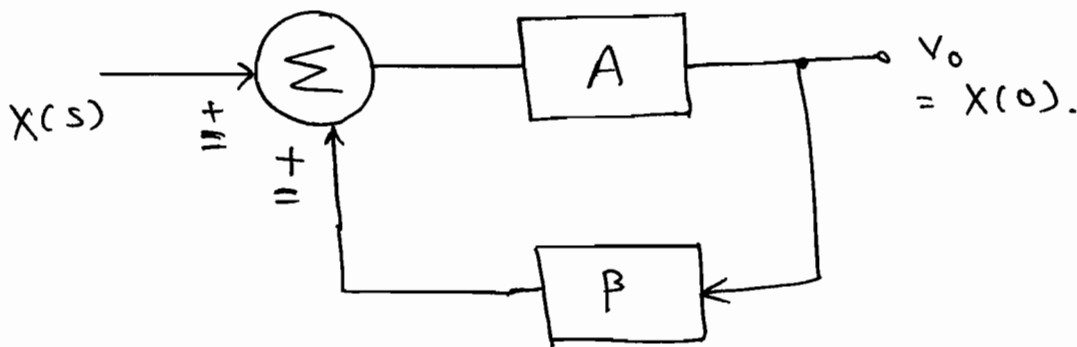
Before	After
open loop gain, A	closed loop gain, A_F
Gain = 10^6	new gain = 4.
B.W. = 10	B.W. = $10^7/4$.
Gain $\times$ B.W. = 10^7	Gain $\times$ B.W. = $10^7/4 \times 4 = 10^7$.

So, Gain, B.W. Products remains constant.

D: 25/7/2013

☆ Oscillators:

→ General Configuration of +ve feedback,



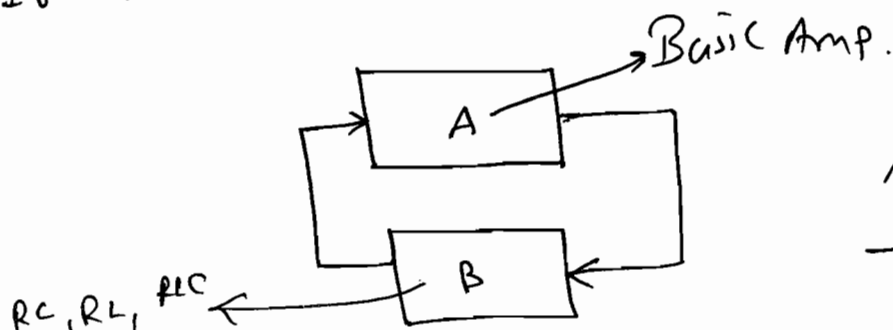
Gain with feedback.

$$\therefore \frac{X(0)}{X(s)} = \frac{A}{1-AB}$$

If $AB=1$ then $A_f = \infty$.

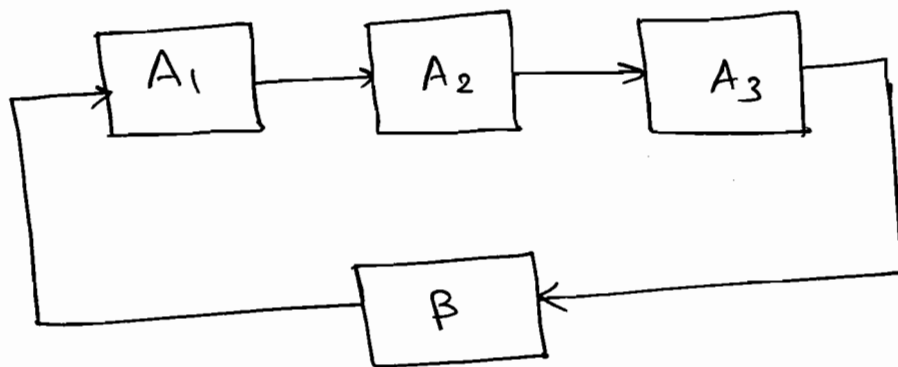
→ Infinite gain means with no input we can expect some O/P. In fact in an oscillator there is no input signal. Oscillator works on noise (or) kT transients.

→ If no input then,



loop gain = 1.

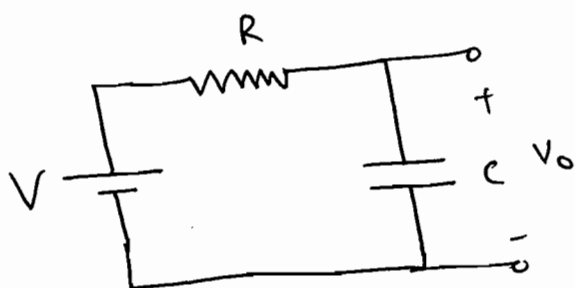
$$\rightarrow AB=1.$$



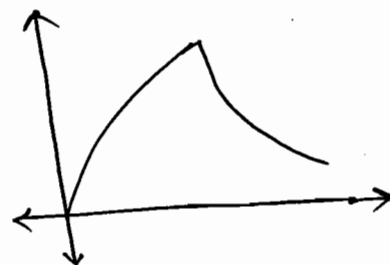
loop gain = 1.

$$\therefore A_1 \cdot A_2 \cdot A_3 \cdot \beta = 1.$$

*

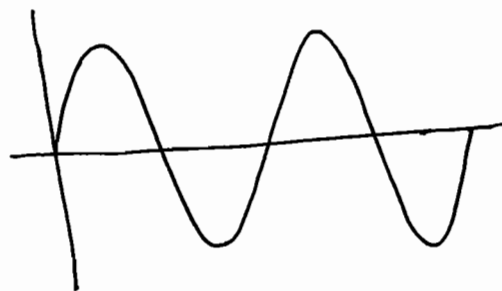
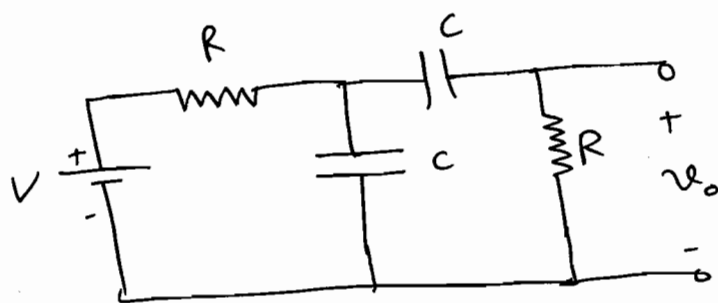


$\Rightarrow$



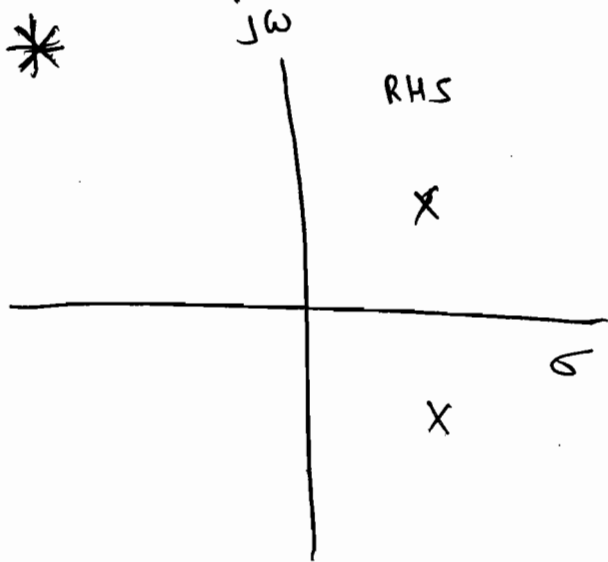
$$\frac{dy}{dx} + py = Q.$$

*



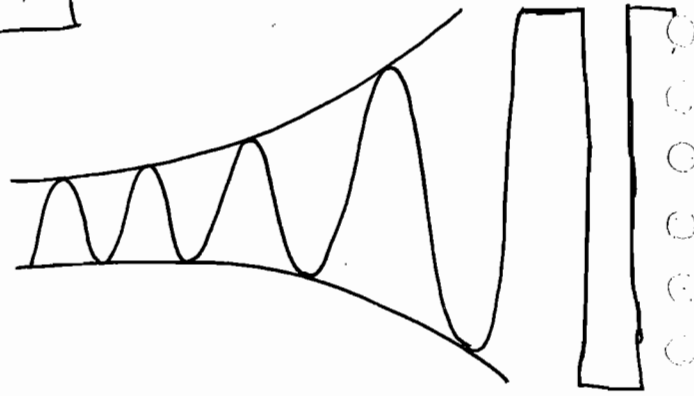
$$\frac{d^2y}{dx^2} + p \frac{dy}{dx} + Q = 0.$$

$\rightarrow$ If we eliminate the middle term of above eqⁿ then we can get sustain oscillation or perfect sine wave.



$$AB > 1$$

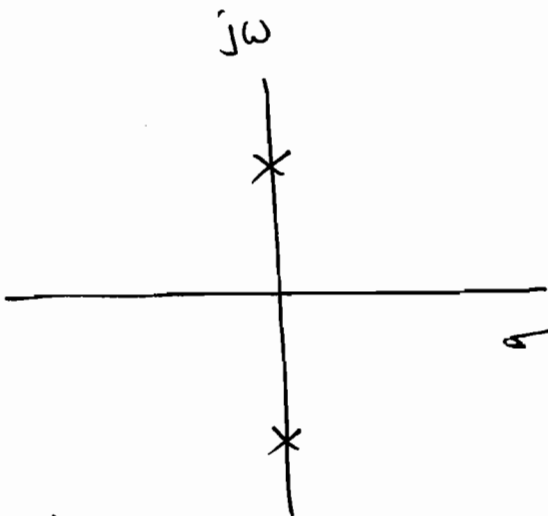
$\Rightarrow$



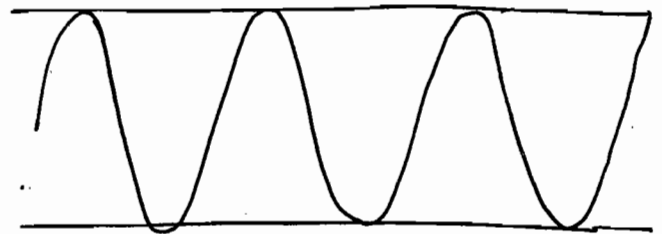
If we don't control the $AB > 1$ become multi-vibrator (square wave)

*

$$AB = 1$$



$\Rightarrow$

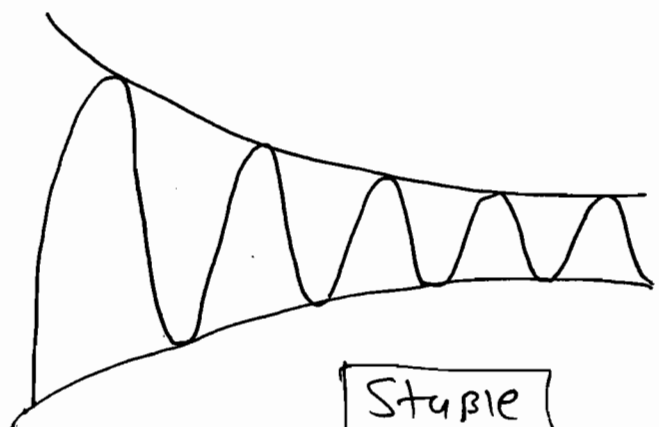
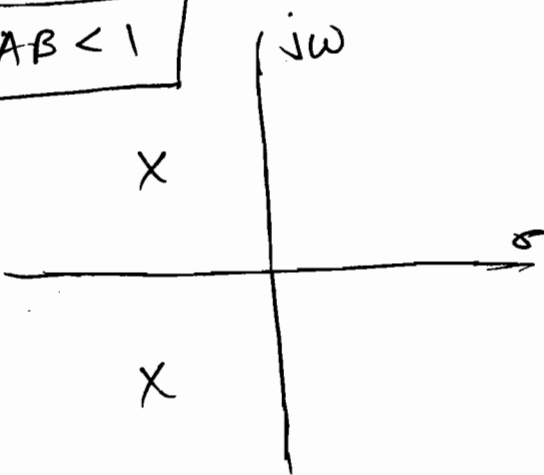


only at particular freq. gain is unity.

Conditionally Stable.

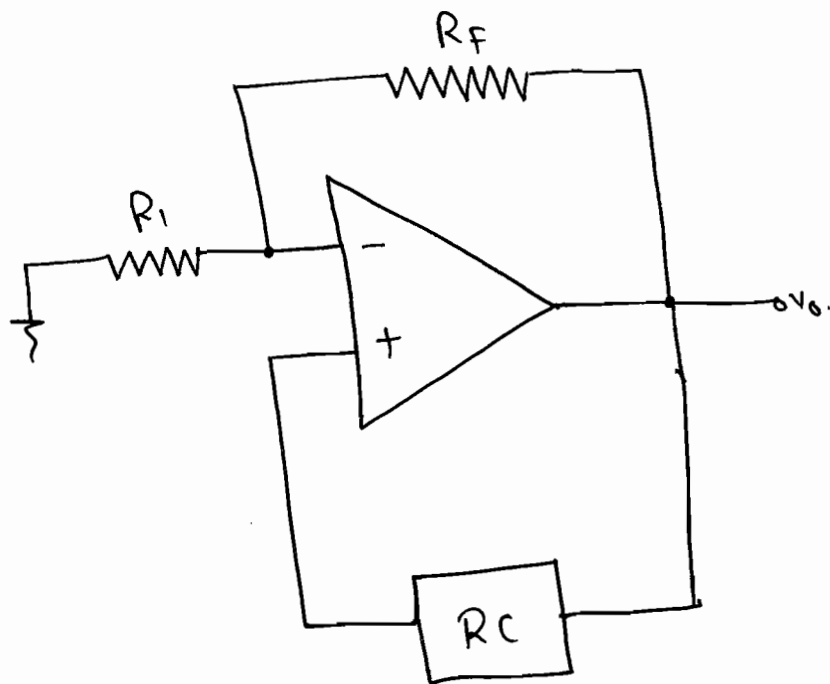
*

$$AB < 1$$



Stable

*



→ We have to move ~~poles~~ Right handside poles (Unstable) towards $j\omega$ axis so that the system become ~~un~~stable.

→ Now, If we decrease the R_f poles goes to left side of the plane and if we increase the R_f poles goes to Right hand side of the plane.

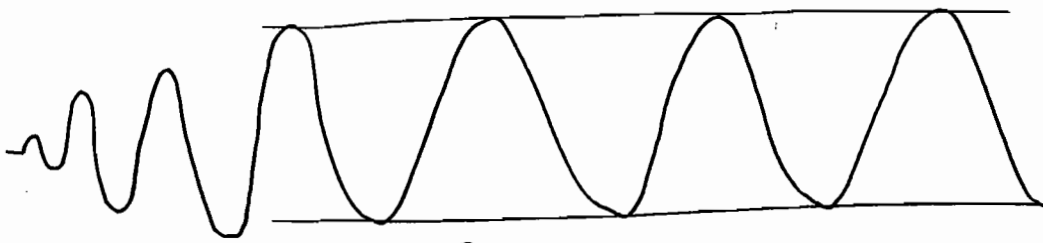
→ Let. $s = \sigma + j\omega$.

→ At the closed or Power supply,

Transient response

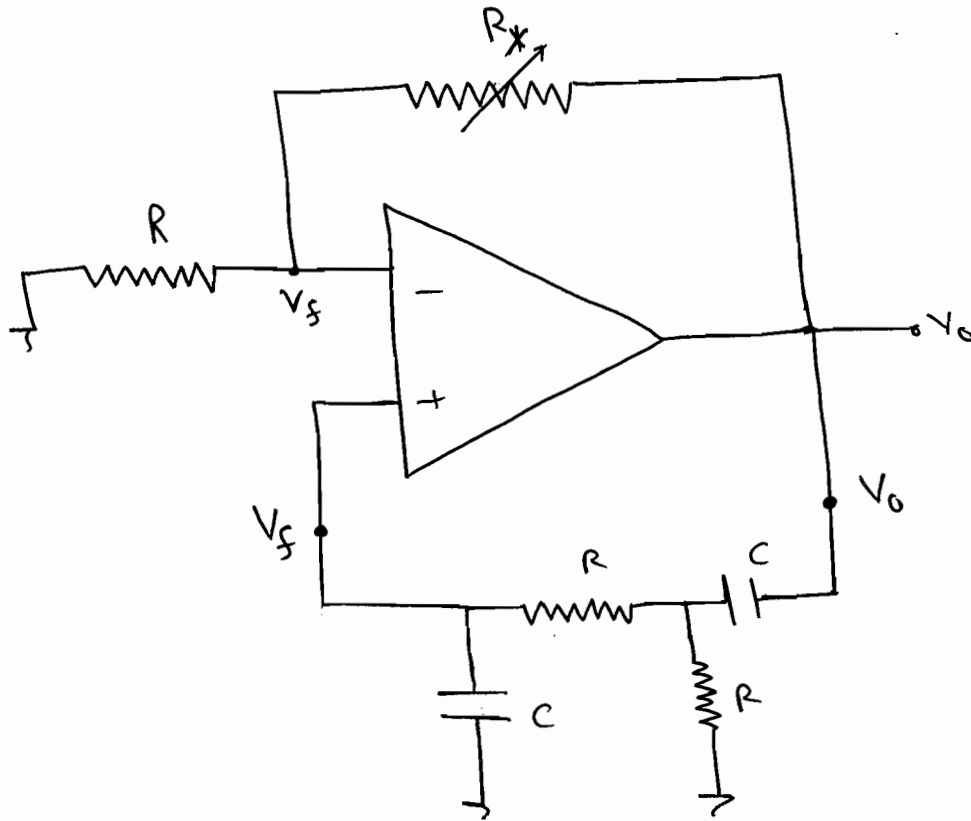
$$v_{ch} = e^{\sigma t} [e^{j\omega_0 t} + e^{-j\omega_0 t}]$$

$$v_{ch} = 2e^{\sigma t} \cos \omega_0 t$$



* Find the Value of Resistor R_x for sustained oscillations. Also find the freq. of this oscillations.

→



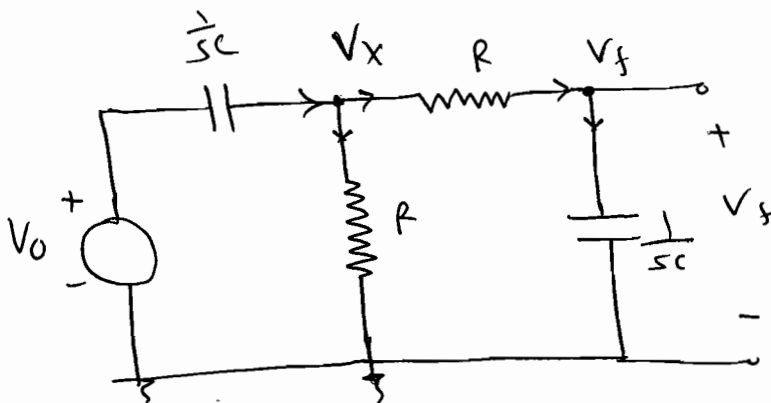
loop gain = 1.

$$A\beta = 1.$$

$$\textcircled{1} A_F = \frac{V_o}{V_f} \quad \textcircled{2} \beta = \frac{1}{A_F} = \frac{V_f}{V_o}.$$

→ Now,

$$A_F = \left(1 + \frac{R_x}{R}\right)$$



KCL,

$$\therefore \frac{V_o - V_x}{1/s_c} = \frac{V_x}{R} + \frac{V_x - V_f}{R}.$$

$$\therefore R s_c (V_o - V_x) = 2V_x - V_f.$$

$$\therefore R s_c V_o = (2 + R s_c) V_x - V_f.$$

$$\Rightarrow \frac{V_x - V_f}{R} = \frac{V_f}{s_c}.$$

$$\therefore V_x - V_f = R s_c V_f.$$

$$V_x = (1 + R s_c) V_f.$$

$$\therefore R s_c V_o = (2 + R s_c)(1 + R s_c) V_f - V_f.$$

$$\therefore R s_c V_o = (2 + 3R s_c + R^2 s_c^2 - 1) V_f.$$

$$\therefore R s_c V_o = (1 + 3R s_c + R^2 c^2 s^2) V_f.$$

$$\therefore \beta = \frac{V_f}{V_o} = \frac{1}{3 + R c s + \frac{1}{R c s}}.$$

$$s = j\omega$$

$$\therefore \beta = \frac{1}{3 + j(\omega R c - \frac{1}{\omega R c})}.$$

$$\text{Now, } A\beta = 1$$

$$A = \frac{1}{\beta}.$$

$$\therefore \left(1 + \frac{R_x}{R}\right) = 3 + j(\omega R c - \frac{1}{\omega R c}).$$

Compare real part,

$$\therefore 1 + \frac{R_x}{R} = 3$$

$$\therefore \boxed{R_x = 2R}$$

Compare imag. part.

$$\omega R c - \frac{1}{\omega R c} = 0.$$

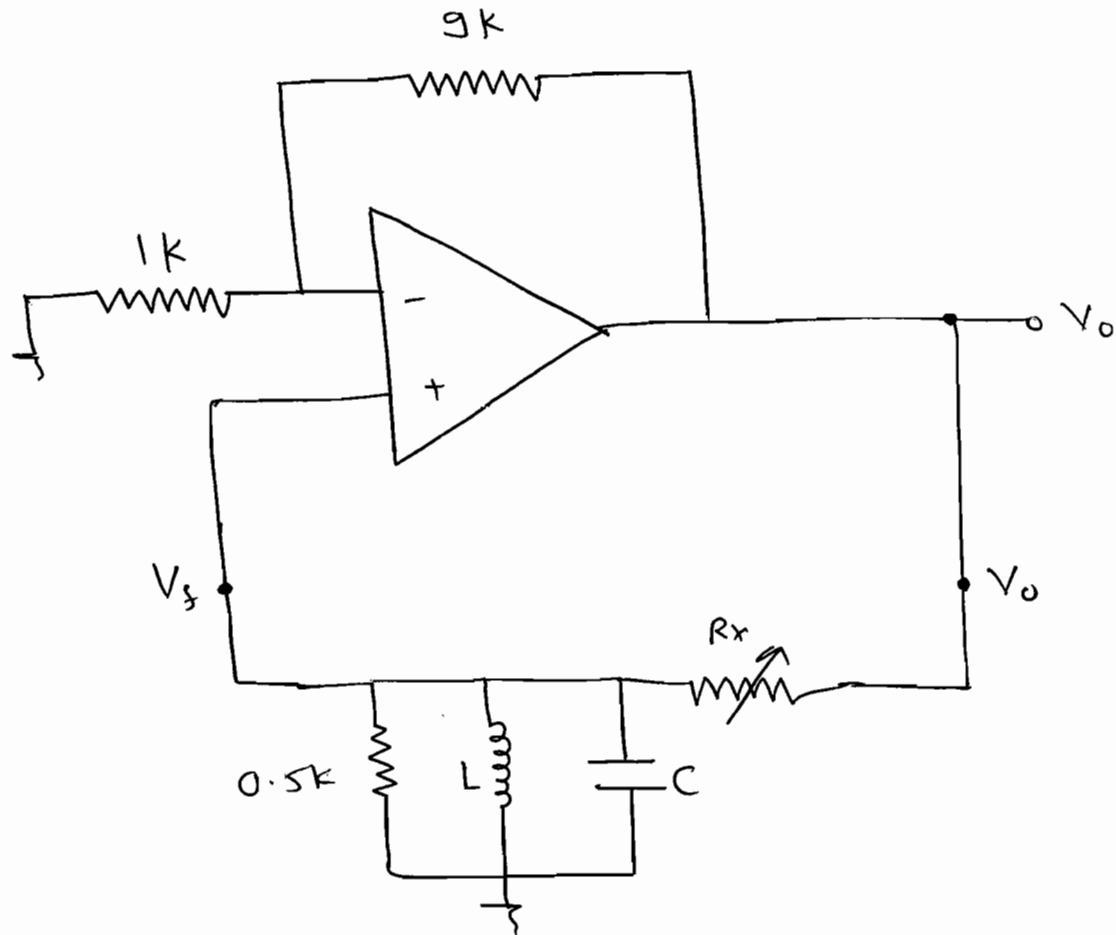
$$\omega^2 = \frac{1}{(R c)^2}.$$

$$\therefore \omega = \frac{1}{R c}.$$

$$\therefore R_x = 2R$$

$$f = \frac{1}{2\pi RC}$$

* Find the value of R_x to sustain oscillation.
Also find the freq. of this oscillator.



$$\Rightarrow \text{loop gain} = 1$$

$$A\beta = 1$$

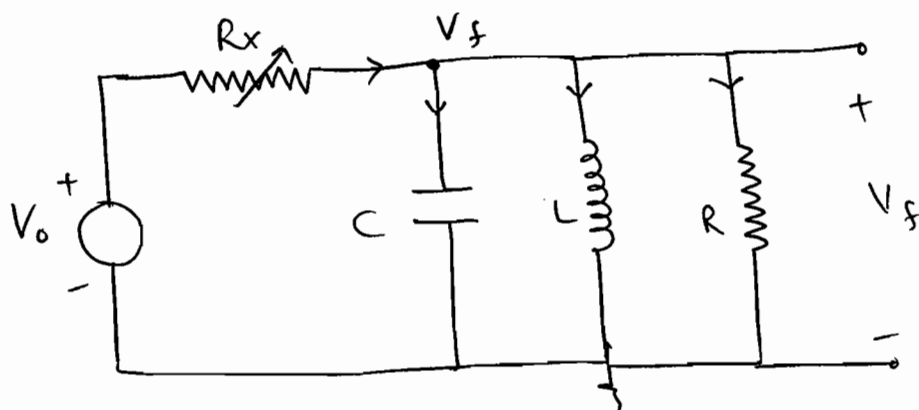
$$\textcircled{1} A_F = \frac{V_o}{V_f} \quad \textcircled{2} \beta = \frac{V_f}{V_o} = \frac{1}{A}$$

$$\therefore \rightarrow A_F = \left(1 + \frac{9K}{1K}\right) = 10$$

$$\therefore \boxed{A_F = 10}$$

Ans.





→ KCL,

$$\frac{V_0 - V_f}{R_x} = V_f \left(sC + \frac{1}{Ls} + \frac{1}{R} \right).$$

$$\therefore \frac{V_0}{R_x} = V_f \left(sC + \frac{1}{Ls} + \frac{1}{R} + \frac{1}{R_x} \right).$$

$$\therefore \beta = \frac{V_f}{V_0} = \frac{R_x}{R_x \left(sC + \frac{1}{Ls} + \frac{1}{R} + \frac{1}{R_x} \right)}$$

Now, $AB = 1$

$$A = \frac{1}{B}$$

$$\therefore 10 = \frac{\left(sC + \frac{1}{Ls} + \frac{1}{R} + \frac{1}{R_x} \right) R_x}{R_x}$$

$$s = j\omega$$

$$\therefore \frac{10}{R_x} = j\left(\omega C - \frac{1}{\omega L}\right) + \frac{1}{R} + \frac{1}{R_x}$$

Equate real part.

$$\therefore \frac{10}{R_x} = \frac{1}{R} + \frac{1}{R_x}$$

$$\therefore \frac{g}{R_x} = \frac{1}{R}$$

$$\therefore R_x = gR$$

$$\therefore R_x = g(0.5) \cdot k$$

$$\therefore R_x = 4.5 \text{ k}\Omega$$

$\therefore$ equate Imaginary part.

$$\therefore \omega C - \frac{1}{\omega L} = 0.$$

$$\omega^2 = \frac{1}{LC}.$$

$$\therefore \omega = \frac{1}{\sqrt{LC}}.$$

$$\therefore f = \frac{1}{2\pi\sqrt{LC}}$$

* Barkhausen Criteria:

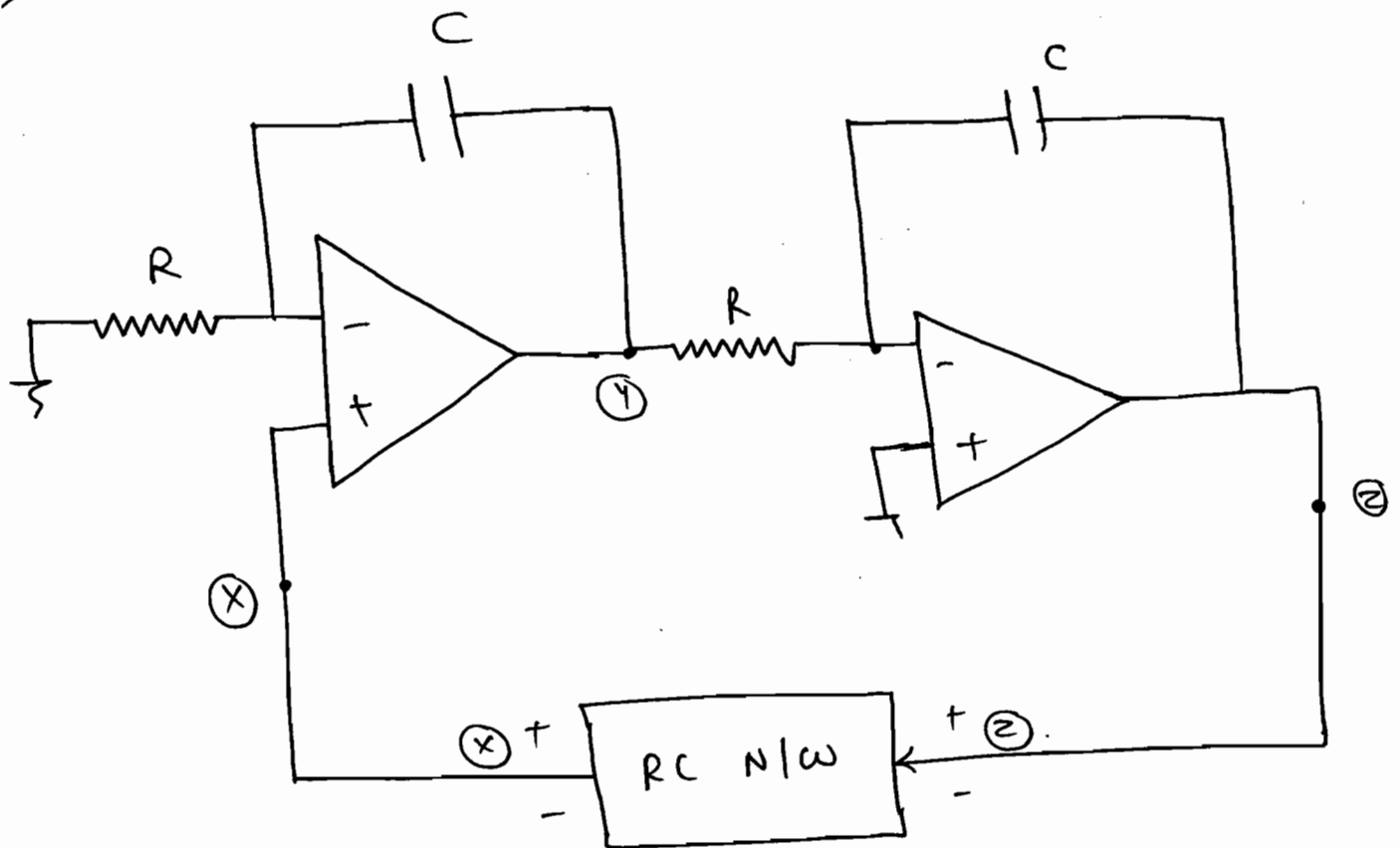
$$A\beta = 1 \angle 0^\circ \text{ or } 360^\circ$$

- ① Magnitude of loop gain is unity.
- ② phase angle of loop gain is 0° or 360° .

* Dr

* Design an RC N/w for Sustain oscillator 35
at a freq. $\omega = \frac{1}{RC}$.

$\Rightarrow$



$\rightarrow$ loop gain $AB = 1$.

$$\therefore \frac{Y}{X} \cdot \frac{Z}{Y} \cdot \frac{X}{Z} = 1.$$

$$\therefore \frac{Y}{X} = \left(1 + \frac{1}{sCR}\right).$$

$$\therefore \frac{Z}{Y} = \left(-\frac{1}{sCR}\right).$$

$$\text{So, } \left(1 + \frac{1}{sCR}\right) \left(-\frac{1}{sCR}\right) \cdot \left(\frac{Z}{Y} \cdot \frac{Y}{Z}\right) = 1.$$

$$\therefore -\frac{(sCR+1)}{(sCR)^2} \cdot \frac{X}{Z} = 1.$$

$$\therefore \frac{X}{Z} = -\frac{(sCR)^2}{1+sCR}.$$

$$\therefore \frac{X}{2} = - \frac{(SCR)^2}{1+SCR}$$

Now, $S = j\omega$.

$$\frac{X}{2} = \frac{\omega^2 R^2 C^2}{1+SCR}$$

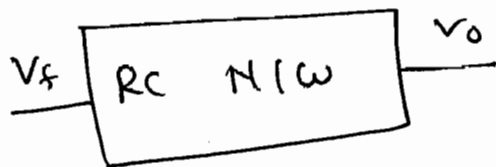
Put $\omega = \frac{1}{RC}$ in numerator.

$$\therefore \frac{X}{2} = \frac{1}{1+SCR}$$

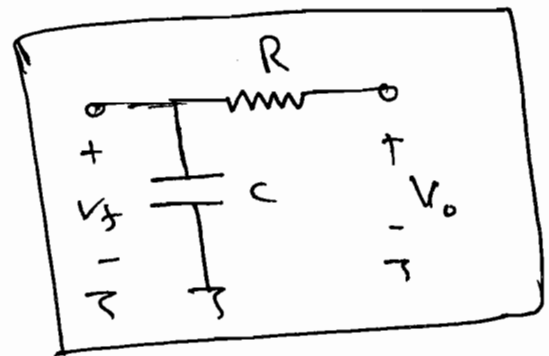
$$\therefore \boxed{\frac{X}{2} = \frac{\frac{1}{sC}}{R + \frac{1}{sC}}}$$

$$\therefore X = \left(\frac{\frac{1}{sC}}{\frac{1}{sC} + R} \right) 2$$

$$\therefore V_f = \left(\frac{\frac{1}{sC}}{R + \frac{1}{sC}} \right) V_o$$



$\Rightarrow$



loop gain = 1

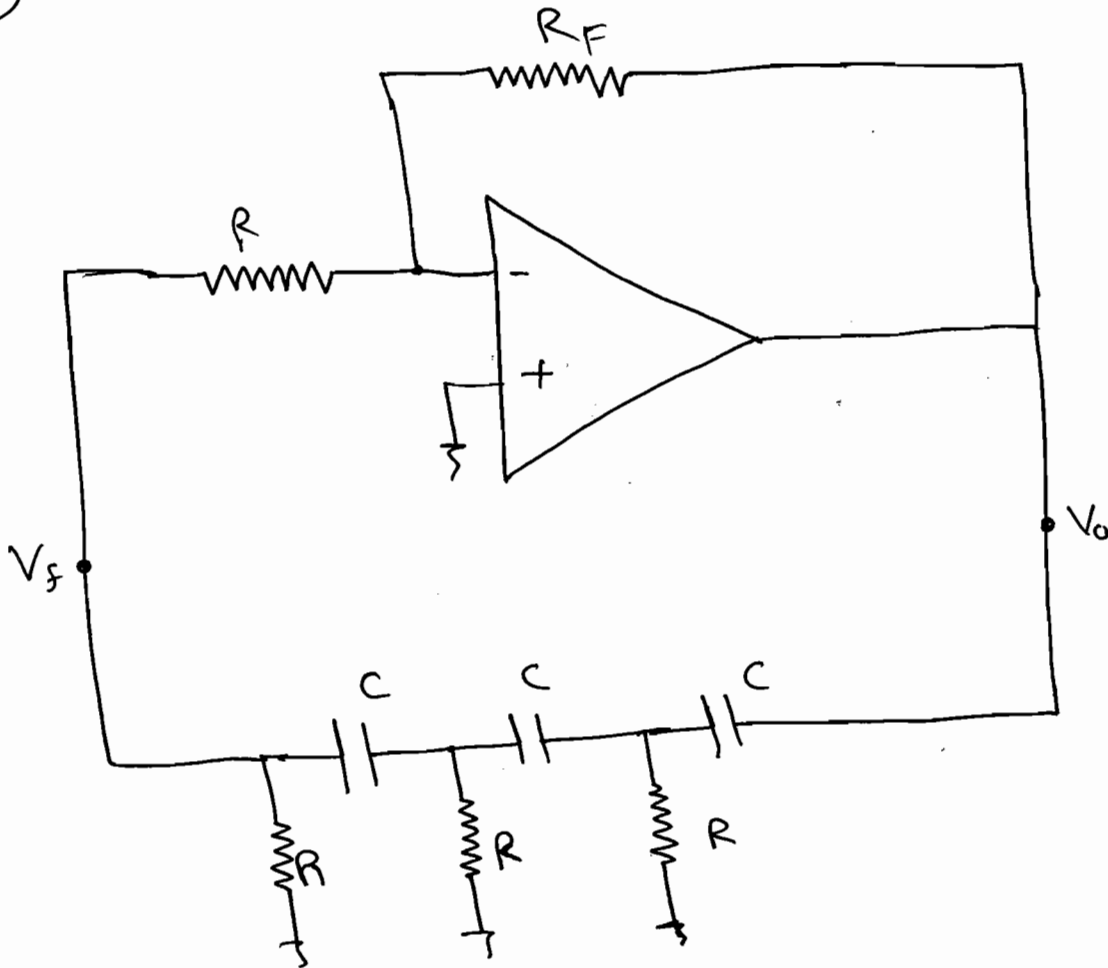
loop phase = 0°

So, it produces sine wave and it is nothing but Quadrature oscillator.

* Phase-shift Oscillator:

37

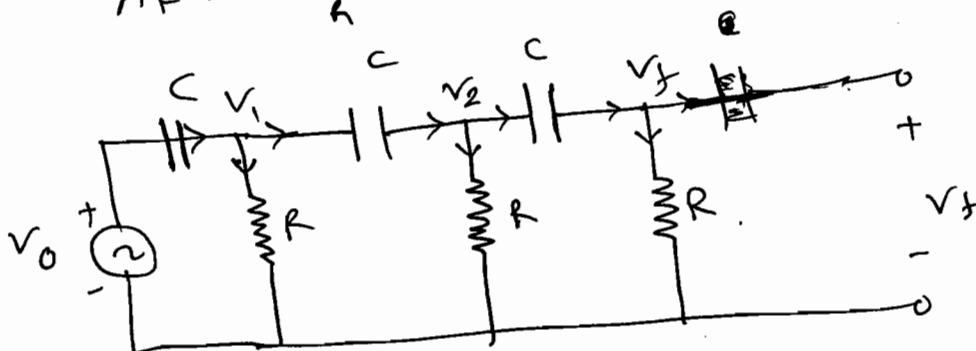
=>



* loop gain = 1.

$$A\beta = 1 \Rightarrow \beta = 1/A_F$$

$$A_F = -\frac{R_F}{R}$$



KCL

at node \$V_1\$,

$$\therefore sC(V_o - V_1) = \frac{V_1}{R} + sC(V_1 - V_2) \quad - (1)$$

$$\therefore sC(V_1 - V_2) = \frac{V_2}{R} + sC(V_2 - V_f) \quad - (2)$$

$$\therefore sC(V_2 - V_f) = \frac{V_f}{R} \quad - (3)$$

form - (3)

$$\therefore V_2 = \left(1 + \frac{1}{RSC}\right) V_f$$

put V_2 in - (2)

$$\therefore V_1 - V_2 = \frac{V_2}{RSC} + V_2 - V_f$$

$$\therefore V_1 = \left(2 + \frac{1}{RSC}\right) V_2 - V_f$$

$$\therefore V_1 = \left(2 + \frac{1}{RSC}\right) \left(1 + \frac{1}{RSC}\right) V_f - V_f$$

$$\therefore V_1 = \left(2 + \frac{3}{RSC} + \frac{1}{R^2 S^2 C^2} - 1\right) V_f$$

$$\therefore V_1 = \left(1 + \frac{3}{RSC} + \frac{1}{S^2 R^2 C^2}\right) V_f$$

Now, form - (1)

$$\therefore V_0 - V_1 = \frac{V_1}{RSC} + (V_1 - V_2)$$

$$\therefore V_0 = \left(2 + \frac{1}{RSC}\right) V_1 - V_2$$

$$\therefore V_0 = \left[\left(1 + \frac{3}{RSC} + \frac{1}{S^2 R^2 C^2}\right) \left(2 + \frac{1}{RSC}\right) - \left(1 + \frac{1}{RSC}\right) \right] V_f$$

$$\therefore V_0 = \left[2 + \frac{6}{RSC} + \frac{2}{S^2 R^2 C^2} + \frac{1}{RSC} + \frac{3}{R^2 S^2 C^2} + \frac{1}{R^3 C^3 S^3} - 1 - \frac{1}{RSC} \right] V_f$$

$$\therefore V_0 = \left[1 + \frac{5}{RSC} + \frac{5}{S^2 R^2 C^2} + \frac{1}{S^3 R^3 C^3} \right] V_f$$

$$\therefore \beta = \frac{V_f}{V_o}$$

$$\therefore \beta = \frac{s^3 R^3 C^3}{1 + s s C R + 6 s^2 R^2 C^2 + s^3 R^3 C^3}$$

Now, $A = \frac{1}{\beta}$

$$\therefore \left(-\frac{R_F}{R_1} \right) = \frac{1 + s s C R + 6 s^2 R^2 C^2 + s^3 R^3 C^3}{s^3 R^3 C^3}$$

$$\therefore -\frac{R_F}{R_1} = \frac{s = j\omega}{1 + j s \omega R - 6 \omega^2 R^2 C^2 - j \omega^3 R^3 C^3}$$

$$\therefore j \frac{R_F}{R_1} \times \omega^3 R^3 C^3 = (1 - 6 \omega^2 R^2 C^2) + j (s \omega R - \omega^3 R^3 C^3)$$

Compare ~~Real~~ ^{Imag.} ~~Real~~ part.

$$1 - 6 \omega^2 R^2 C^2 = 0$$

$$\omega^2 R^2 C^2 = 1/6$$

$$\therefore f = \frac{1}{2\pi R C \sqrt{6}}$$

Compare ~~Real~~ ^{Imag.} ~~Real~~ part.

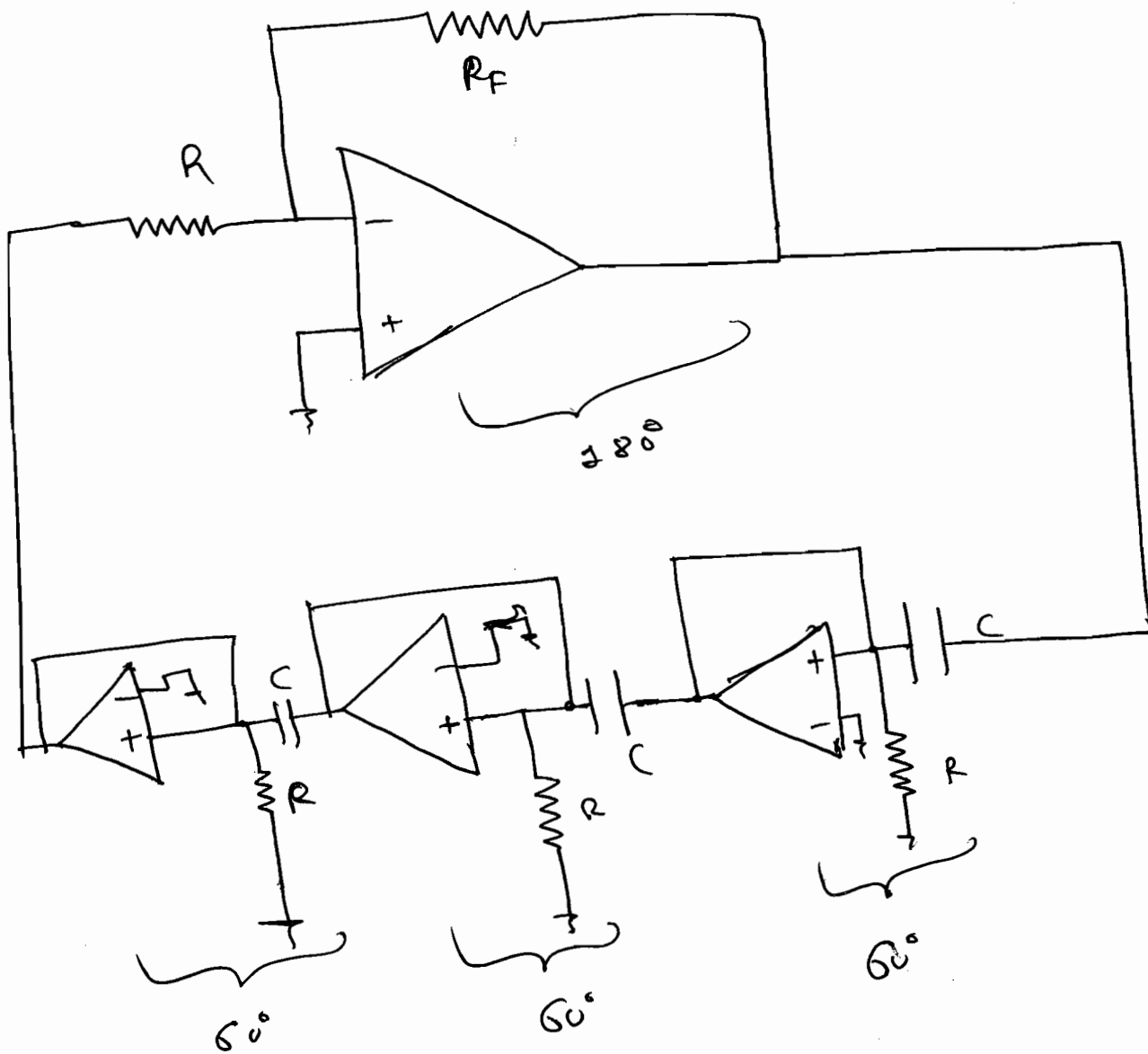
$$\therefore \frac{R_F}{R_1} \times \omega^3 R^3 C^3 = s \omega R - \omega^3 R^3 C^3$$

$$\therefore \frac{R_F}{R_1} \times \omega^2 R^2 C^2 = 5 - \omega^2 R^2 C^2$$

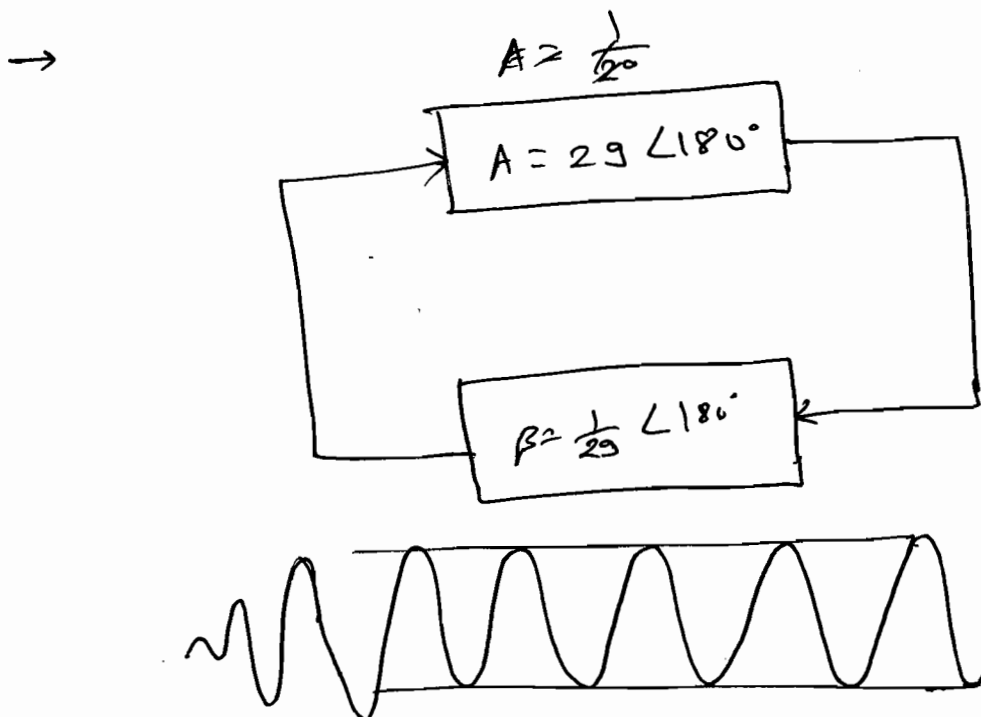
$$\therefore \frac{R_F}{R_1} = \frac{5}{\omega^2 R^2 C^2} - 1$$

$$\therefore R_F = (30 - 1) R_1 \Rightarrow \boxed{R_F = 29 R_1}$$

NOTE: phase shift oscillator

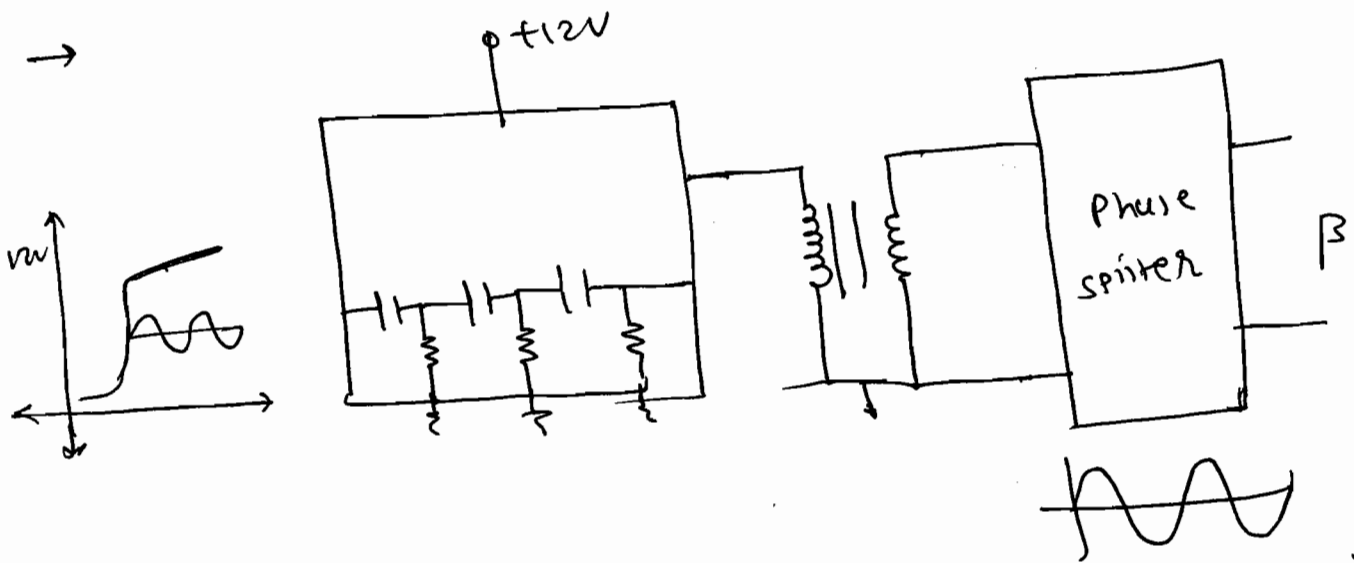


total loop phase = 360° or 0° .

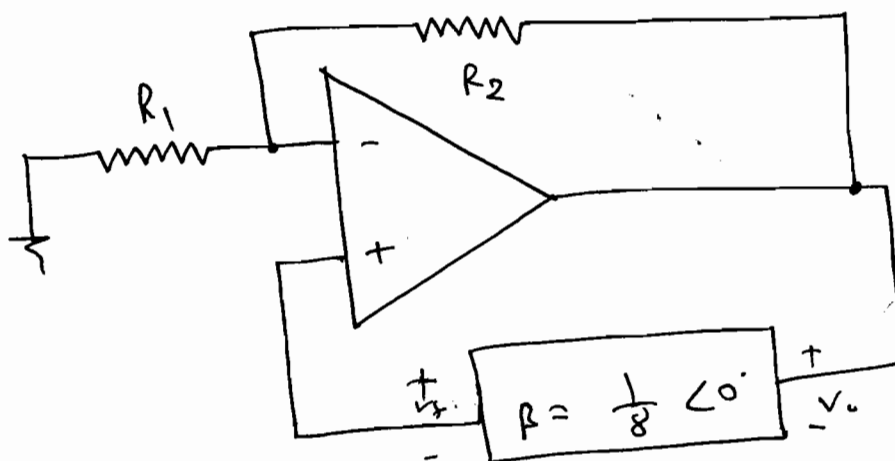


→ RC oscillator is used as a fixed audio⁴¹ freq. oscillator where as Weinbridge is a variable freq. audio freq. oscillator.

→ For high freq. of oscillations we go for wide-band amplifiers with LC network.



Ex-1 Find the Relation betⁿ R_1 & R_2 for sustained oscillation if $\beta = \frac{V_f}{V_o} = \frac{1}{8} \angle 0^\circ$.



$\therefore A = (1 + \frac{R_2}{R_1})$. Loop gain = 1 for sustained oscillation

$\therefore \beta = 1/8$. $\therefore A\beta = 1$.

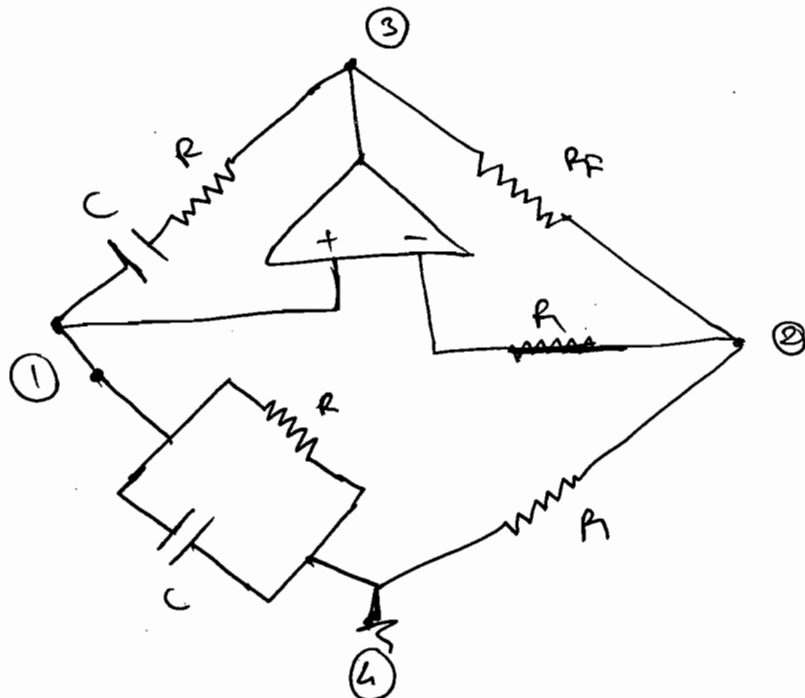
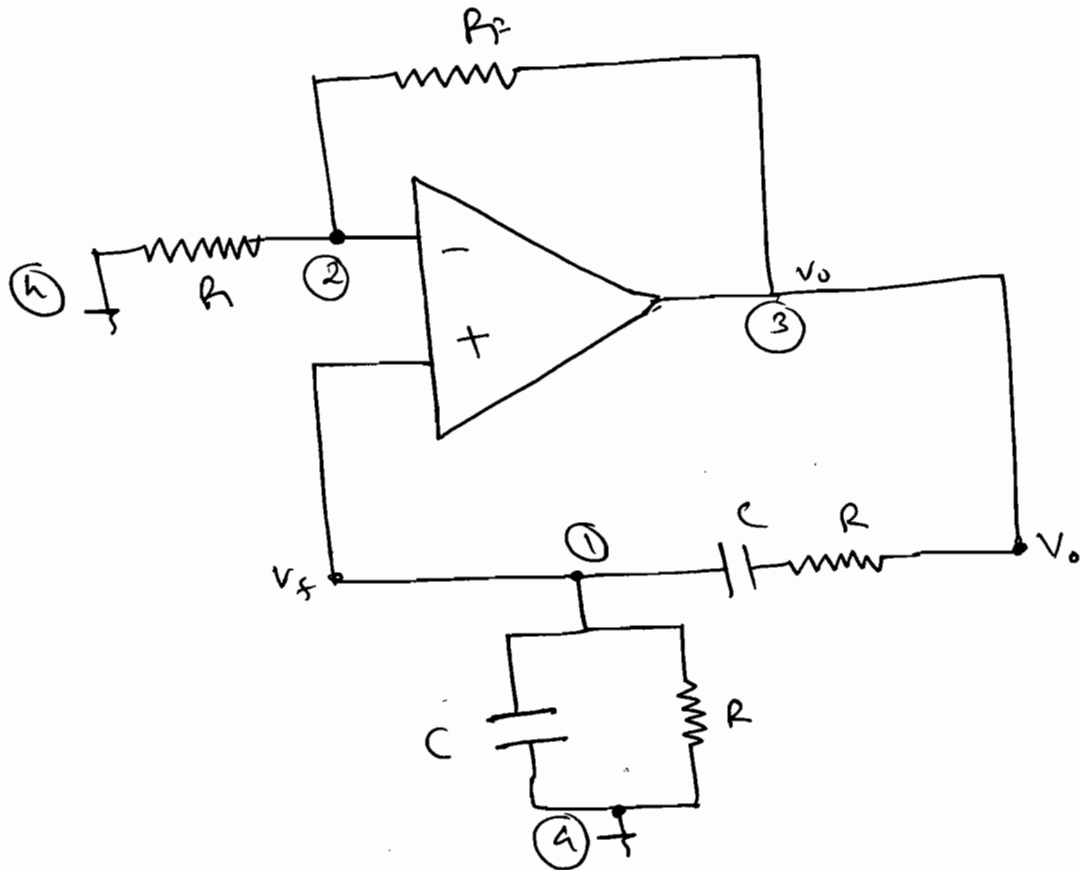
$$\therefore (1 + \frac{R_2}{R_1}) \frac{1}{8} = 1$$

$$\therefore \left(1 + \frac{R_2}{R_1}\right) = 8.$$

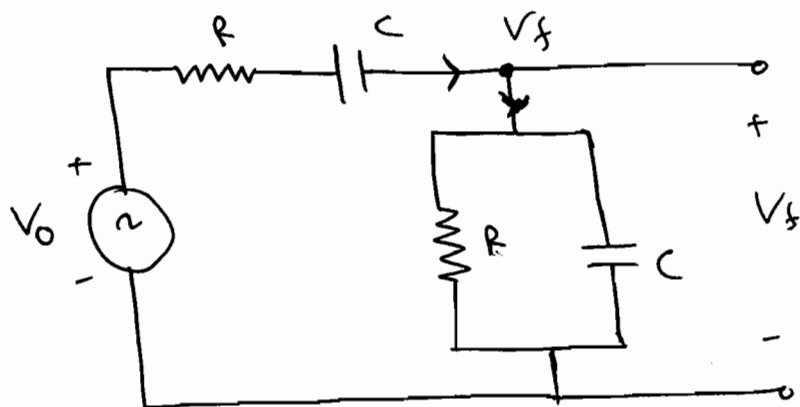
$$\therefore \left(1 + \frac{R_2}{R_1}\right) = 8$$

$$\therefore \boxed{R_2 = 7 R_1}$$

* Wein-Bridge oscillator:



$\Rightarrow$



$$\Rightarrow \frac{V_o - V_f}{R + \frac{1}{sC}} = \frac{V_f}{R} + sC V_f.$$

$$sC (V_o - V_f) = (1 + R s C) V_f \left[\frac{1}{R} + sC \right].$$

$$\therefore R s C (V_o - V_f) = V_f \left[(1 + R s C)^2 \right].$$

$$\therefore R s C (V_o - V_f) = V_f \left[1 + 2 R s C + s^2 R^2 C^2 \right].$$

$$\therefore V_o - V_f = V_f \left[2 + \frac{2}{R^2 s^2 C^2} + R s C \right].$$

$$\therefore V_o = \left[3 + \frac{1}{R^2 s^2 C^2} + R s C \right] V_f.$$

$$\therefore \frac{V_f}{V_o} = \beta = \left(\frac{1 + 3 R^2 s^2 C^2 + R^3 s^3 C^3}{R^2 s^2 C^2} \right)^{-1}.$$

$$\therefore A = \left(1 + \frac{R_F}{R} \right)$$

$$\therefore A = \frac{1}{\beta}.$$

$$\therefore 1 + \frac{R_F}{R} = \frac{R^2 s^2 C^2}{1 + 3 R^2 s^2 C^2 + R^3 s^3 C^3}.$$

$$\therefore 1 + 2 \frac{R_F}{R} \approx \frac{R^2 s^2 C^2}{1 + 3 R^2 s^2 C^2 + R^3 s^3 C^3}.$$

$$s = j\omega.$$

$$\beta = \frac{1}{3 + j(\omega RC - \frac{1}{\omega RC})}$$

$$\therefore A \cdot \beta = 1.$$

$$\therefore A = \frac{1}{\beta}$$

$$\therefore \left(1 + \frac{R_F}{R}\right) = 3 + j\left(\omega RC - \frac{1}{\omega RC}\right).$$

$\therefore$ ~~R_F~~ cancel real part,

$$\therefore \frac{R_F}{R} = 2.$$

$$\omega RC = \frac{1}{\omega RC}.$$

$$\therefore \boxed{R_F = 2R}$$

$$\therefore \omega^2 = \frac{1}{R^2 C^2}.$$

$$\therefore \omega = \frac{1}{RC}.$$

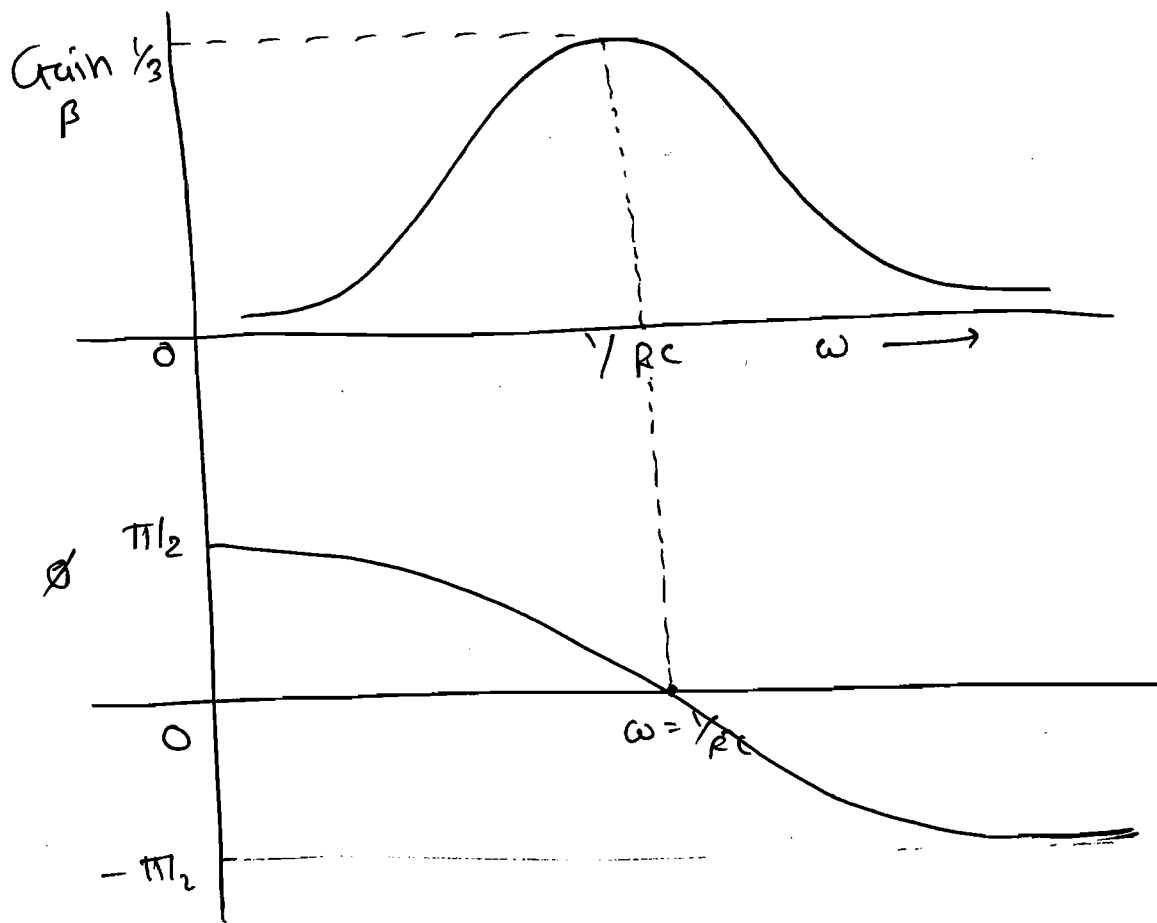
$$\therefore \boxed{f = \frac{1}{2\pi RC}}$$

Now, $\beta = \frac{1}{3 + j(\omega RC - \frac{1}{\omega RC})}$

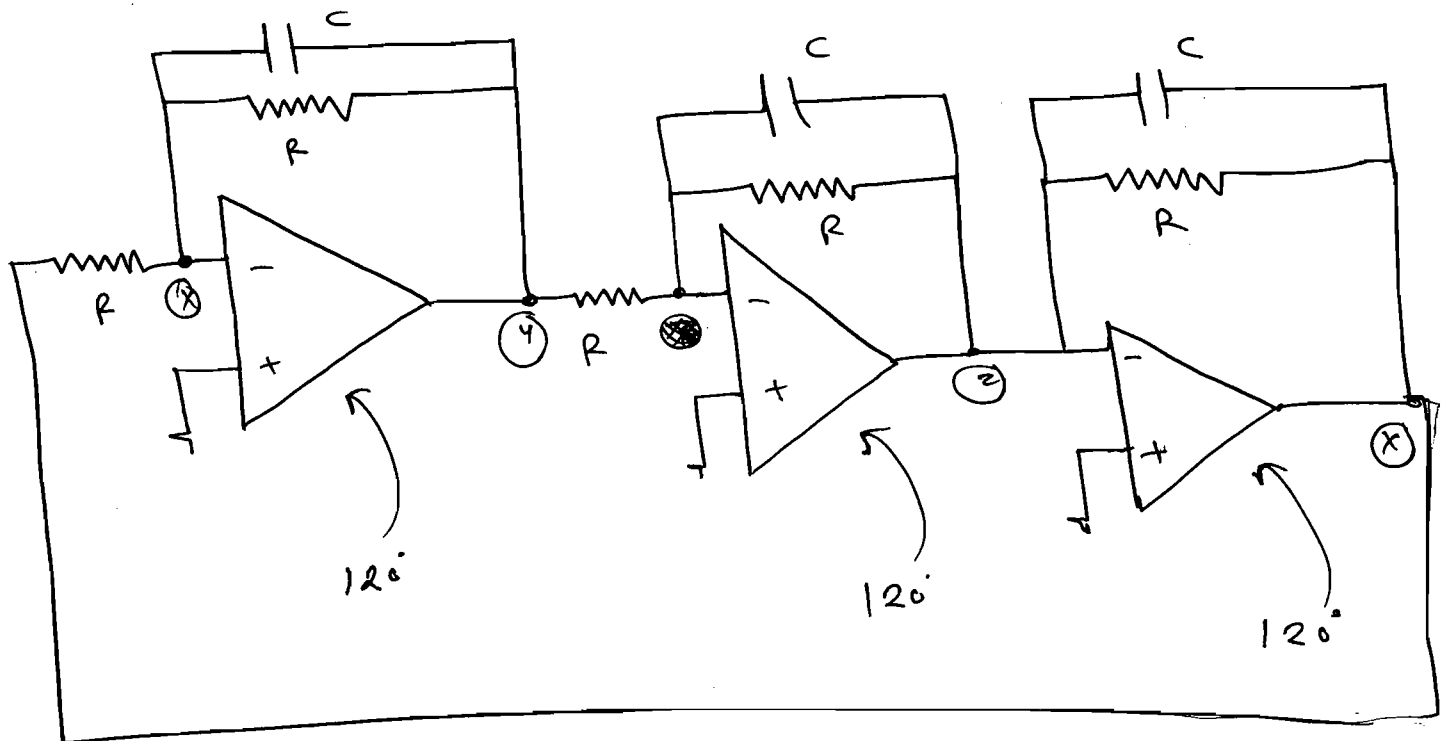
$$|\beta| = \frac{1}{\sqrt{9 + \left(\omega RC - \frac{1}{\omega RC}\right)^2}}$$

$$\therefore \angle \phi = -\tan^{-1} \left(\frac{\left(\omega RC - \frac{1}{\omega RC}\right)}{3} \right).$$

ω	$ \beta $	$\angle \phi$
0	∞	$+\pi/2$
$\frac{1}{RC}$	$\frac{1}{3}$	0
∞	0	$-\pi/2$



* 3-Phase Oscillator:



$\Rightarrow \text{Loop-gain} = 1.$

$\therefore \frac{y}{x} \cdot \frac{z}{y} \cdot \frac{x}{z} = 1.$

$\therefore \left(\frac{y}{x}\right)^3 = 1.$

$$\therefore \frac{Y}{X} = - \frac{R_F 11C}{R_1}$$

$\left(\frac{Y}{X}\right)^3 \neq \phi$ at high
freq. because also
at high freq.

$$\therefore \frac{Y}{X} = -\frac{1}{R_1} \left[\frac{R_F \times \frac{1}{sC}}{R_F + \frac{1}{sC}} \right]$$

$$\therefore \frac{Y}{X} = \frac{-(R_F/R_1)}{1 + sCR_F}$$

$$\therefore \left(\frac{Y}{X}\right)^3 = 1.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = (1 + sCR_F)^3.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 + s^3 C^3 R_F^3 + 3sCR_F + 3s^2 C^2 R_F^2.$$

$$s = j\omega.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 - j\omega^3 C^3 R_F^3 + j3\omega CR_F - 3\omega^2 C^2 R_F^2.$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 - 3\omega^2 C^2 R_F^2 - j(\omega^3 C^3 R_F^3 + j3\omega CR_F).$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = 1 - 3\omega^2 C^2 R_F^2$$

$\therefore$ cancel imag. part,

$$\therefore \omega^3 C^3 R_F^3 = 3\omega CR_F.$$

$$3 = \omega^2 C^2 R_F^2.$$

$$\therefore \omega^2 = \frac{3}{R_F^2 C^2}.$$

$$\therefore \boxed{f = \frac{\sqrt{3}}{2\pi R_F C}}.$$

Cancel Real part,

$$-\left(\frac{R_F}{R_1}\right)^3 = 1 - 3(3).$$

$$\therefore -\left(\frac{R_F}{R_1}\right)^3 = -8$$

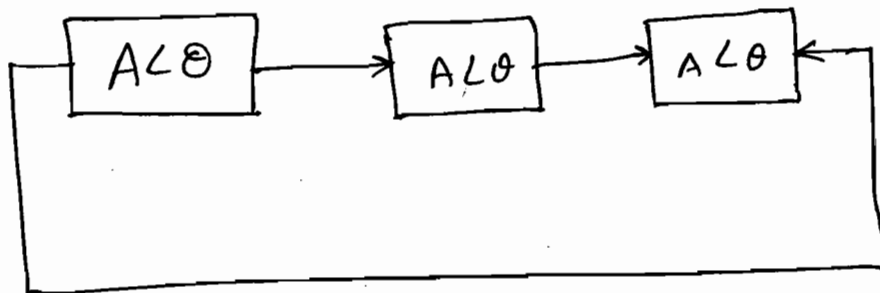
$$\left(\frac{R_F}{R_1}\right)^3 = 8.$$

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$$\therefore \frac{R_F}{R_1} = 2.$$

$$\therefore \boxed{R_F = 2R_1}$$

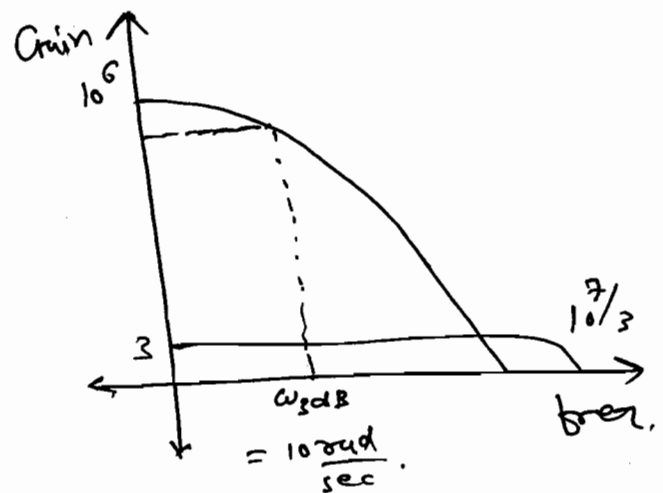
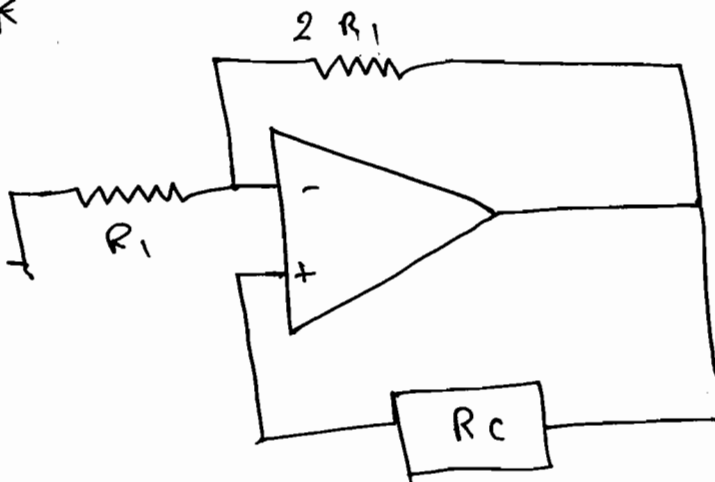
$$\rightarrow A^3 \angle 3\theta = 1 \angle 360^\circ.$$



$$3\theta = 360^\circ.$$

$$\therefore \boxed{\theta = 120^\circ}$$

*



$$\rightarrow \text{Gain} = \frac{10^6}{1 + \frac{s}{10}} = \frac{A_0}{1 + \frac{s}{\omega_{3dB}}}$$

$$\beta = \frac{R_1}{R_1 + R_F}$$

$$\boxed{\beta = 1/3}$$

$$\therefore A_F = \frac{A}{1 + A\beta}$$

$$\therefore A_F = \frac{\frac{10^6}{1 + \frac{s}{10}}}{1 + \frac{1}{3} \left(\frac{10^6}{1 + \frac{s}{10}} \right)}$$

$$\therefore A_F = \frac{3 \times 10^6}{3 + \frac{35}{10^6} + 10^6}$$

$$A_F = \frac{3}{1 + \frac{35}{10^6}}$$

$$\therefore A_F = \frac{3}{1 + \frac{5}{(10^3/3)}} = \frac{3}{1 + j\frac{3\omega}{10^3}}$$

Now, Phase of RC oscillator is

$$\phi = -\tan^{-1} \left[\frac{\omega^2 R^2 C^2 - 1}{3\omega RC} \right]$$

$$\text{let } x = \frac{\omega^2 R^2 C^2 - 1}{3\omega RC}$$

$$\therefore \frac{d\phi}{d\omega} = \frac{-1}{1+x^2} \cdot \frac{dx}{d\omega}$$

$$\therefore \frac{dx}{d\omega} = \frac{3\omega RC (2\omega R^2 C^2) - (\omega^2 R^2 C^2 - 1)(3RC)}{9\omega^2 R^2 C^2}$$

$$\therefore \frac{d\phi}{d\omega} = \frac{6\omega^2 R^3 C^3 - 3\omega^2 R^3 C^3 + 3RC}{9\omega^2 R^2 C^2}$$

$$\text{at } \omega = \frac{1}{RC}$$

$$\therefore \frac{d\phi}{d\omega} = \frac{2}{3\omega}$$

Now, Phase lag suffered by amp. is

$$(\phi) = -\tan^{-1} \left(\frac{3\omega}{10^3} \right) \approx \frac{3\omega}{10^3}$$

→ Phase lag is compensated by RC N.W.
at a rate $\frac{d\phi}{d\omega} = \frac{2}{3\omega}$

∴ Variation of freq.

$$d\omega = \frac{3\omega}{2} \cdot d\phi.$$

$$\therefore d\omega = \frac{3\omega}{2} \cdot \frac{3\omega}{10^7}.$$

$$\therefore d\omega = \frac{4.5\omega^2}{10^7}.$$

Now, at low freq say 1 kHz.

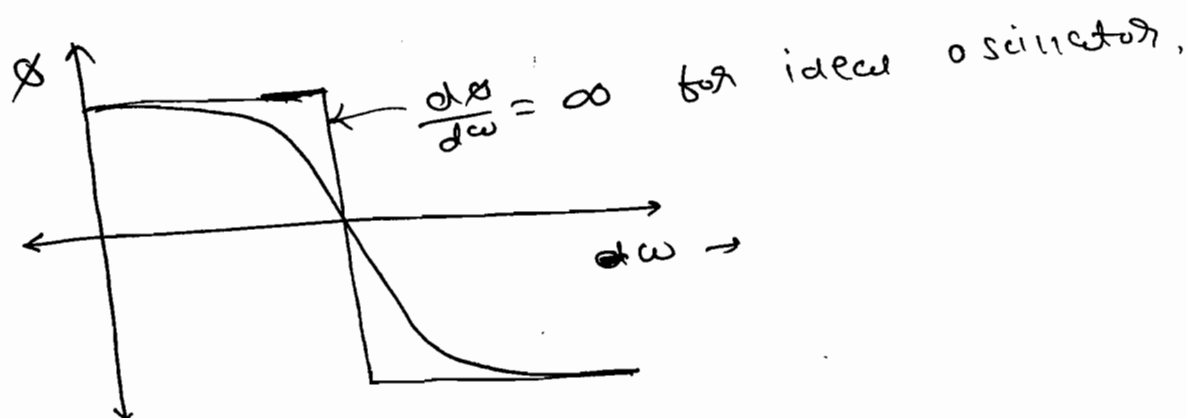
$$\therefore d\omega = \frac{4.5 \times 10^6}{10^7} = 0.45 \text{ rad/sec (stable).}$$

but at high freq say 100 kHz.

$$\therefore d\omega = \frac{4.5 \times 10^{10}}{10^7} = 4.5 \text{ K rad/sec} \\ = 4.5\% \text{ error.}$$

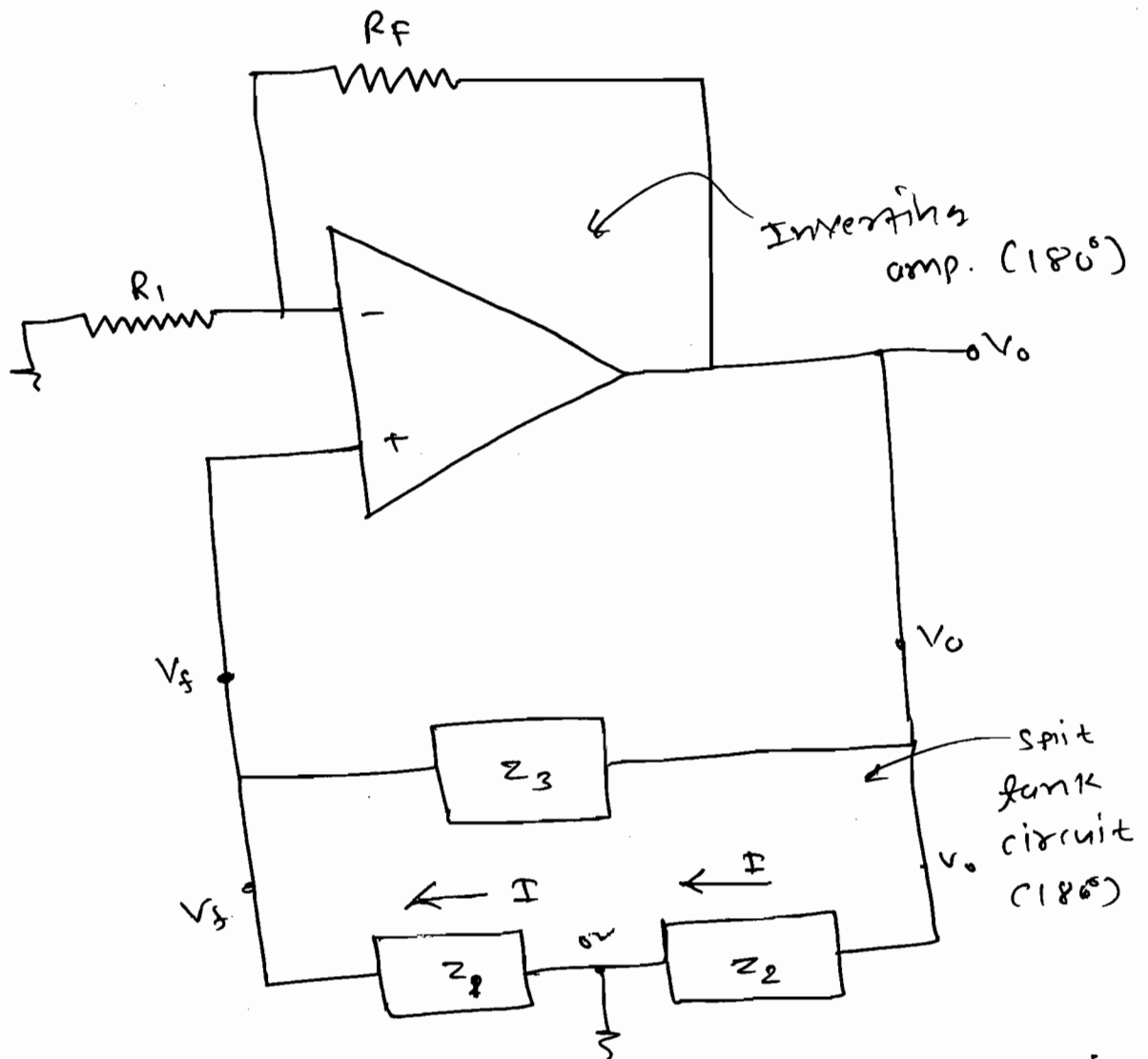
for good oscillator

$$\left| \frac{d\phi}{d\omega} \right| \neq \infty.$$

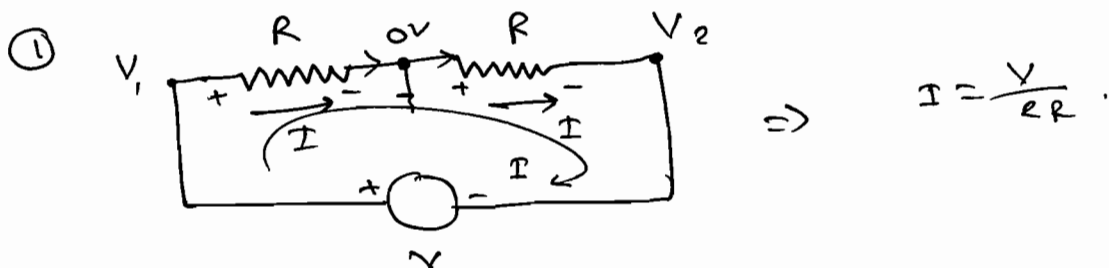


→ We conclude that RC NW Suber form this major disadvantage that their phase versus freq. response is very poor. For high freq. of 100 K rad/sec there is error of 4.5%. [i.e. 4.5 K rad/sec] - so we go for wide band amplifiers with LC network for high freq. of oscillation.

* General Configuration of LC oscillator:



→ Ground in middle we get 180° phase shift.



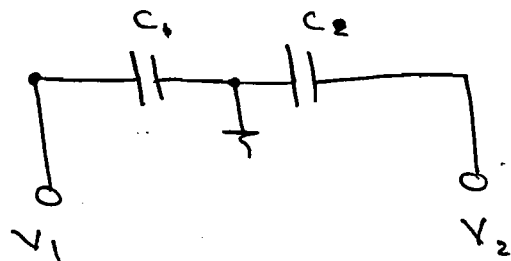
$$\therefore I = \frac{V_1 - 0}{R} = \frac{0 - V_2}{R}$$

$$\Rightarrow \boxed{V_1 = -V_2}$$



$$\Rightarrow \boxed{V_1 = -V_2}$$

③



$$\Rightarrow V_1 = -V_2$$

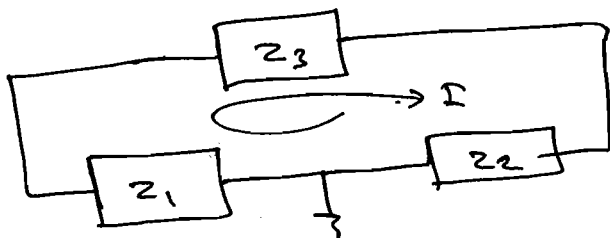
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$$\therefore I = \frac{V_0 - 0}{Z_2} = \frac{0 - V_f}{Z_1}$$

$$\therefore \boxed{\frac{V_f}{V_0} = -\frac{Z_1}{Z_2} = \beta} \quad \beta = \left| \frac{Z_1}{Z_2} \right| \angle 180^\circ$$

$$\Rightarrow A = \frac{1}{\beta} = -\frac{Z_2}{Z_1} = -\frac{R_F}{R}$$

$$\therefore \boxed{\frac{R_F}{R} = \frac{Z_2}{Z_1}}$$



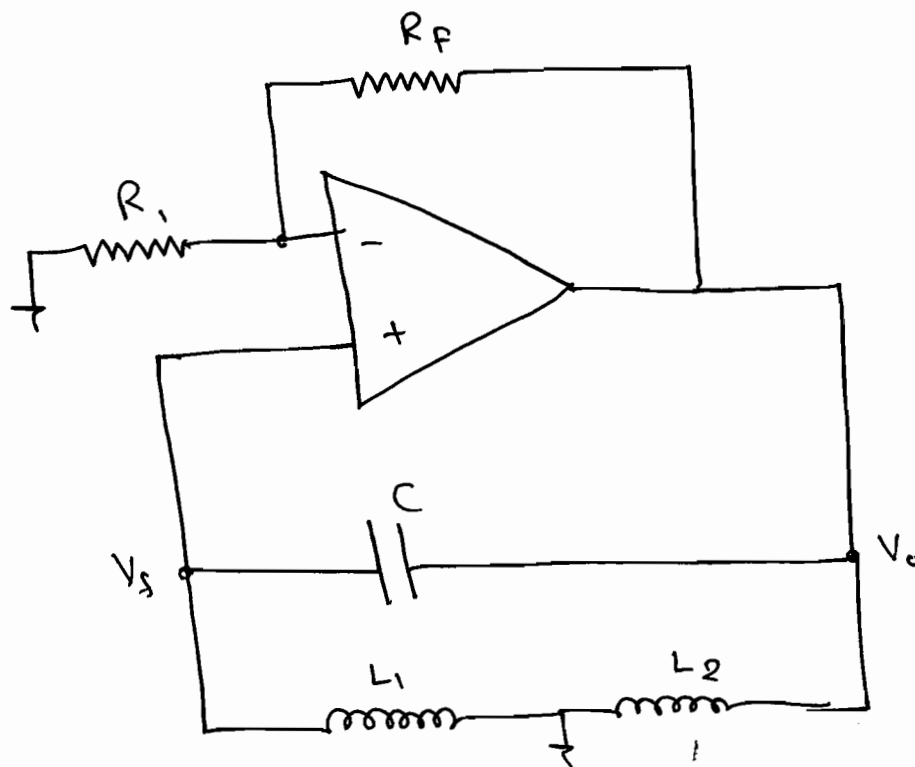
$$\therefore I (Z_1 + Z_2 + Z_3) = 0$$

$$\therefore \boxed{Z_1 + Z_2 + Z_3 = 0}$$

→ this is used for finding frequency.

* Hartley Oscillator:

→ Take $z_3 = C$, $z_1 = L_1$, $z_2 = L_2$.



→ ① $\beta = \frac{V_s}{V_o}$

② $\therefore z_1 + z_2 + z_3 = 0$

$$\therefore j\omega L_1 + j\omega L_2 + \frac{1}{j\omega C} = 0$$

$$j\omega (L_1 + L_2) = -\frac{1}{j\omega C}$$

$$\therefore \omega (L_1 + L_2) = \frac{1}{C}$$

$$\therefore \omega = \frac{1}{C (L_1 + L_2)}$$

$$\therefore f = \frac{1}{2\pi \sqrt{C L_{eq}}}$$

Where, $L_{eq} = L_1 + L_2$

$$\therefore \frac{R_F}{R_1} = \frac{z_2}{z_1}$$

$$\therefore \frac{R_F}{R_1} = \frac{j\omega L_2}{j\omega L_1}$$

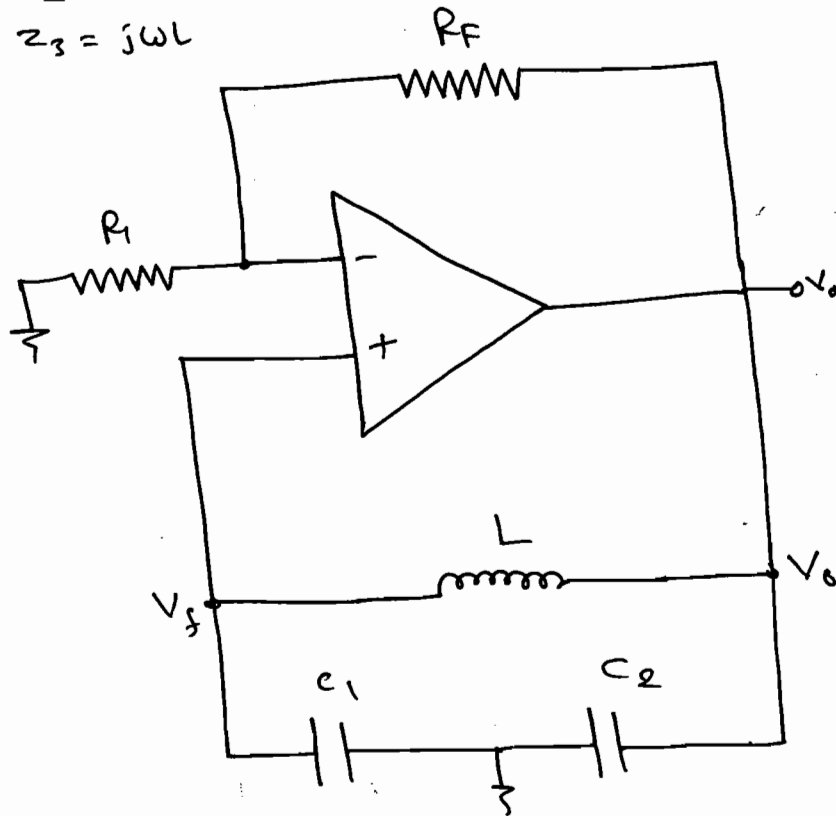
$\Rightarrow$

$$\boxed{\frac{R_F}{R_1} = \frac{L_2}{L_1}}$$

* Colpitts Oscillator

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$\Rightarrow$ Take $z_1 = R_1$
 $z_2 = \frac{1}{j\omega C_1}$
 $z_3 = j\omega L$



$\Rightarrow$ ① $z_1 + z_2 + z_3 = 0$

$$\therefore j\omega L + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2} = 0$$

$$\therefore \omega L = \frac{1}{\omega C_1} + \frac{1}{\omega C_2}$$

$$\therefore \omega^2 = \frac{1}{L \left[\frac{1}{C_1} + \frac{1}{C_2} \right]}$$

$$\therefore \omega = \frac{1}{\sqrt{L C_{eq}}}$$

$$\therefore f = \frac{1}{2\pi \sqrt{C_{eq} L}}$$

where $C_{eq} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$

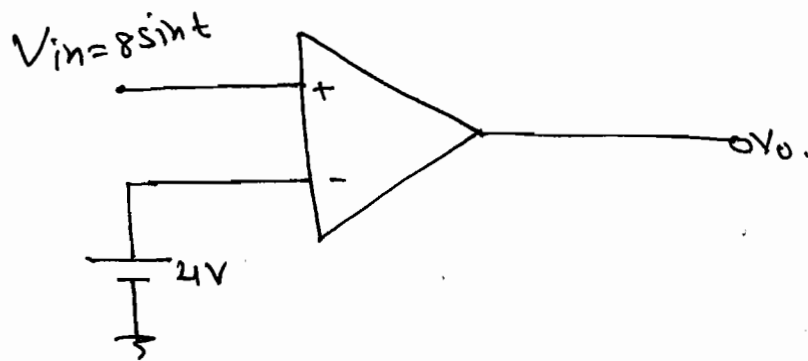
② $\frac{R_F}{R_1} = \frac{z_2}{z_1}$

$$\therefore \frac{R_F}{R_1} = \frac{\frac{1}{j\omega C_2}}{\frac{1}{j\omega C_1}} = \frac{C_1}{C_2} \Rightarrow$$

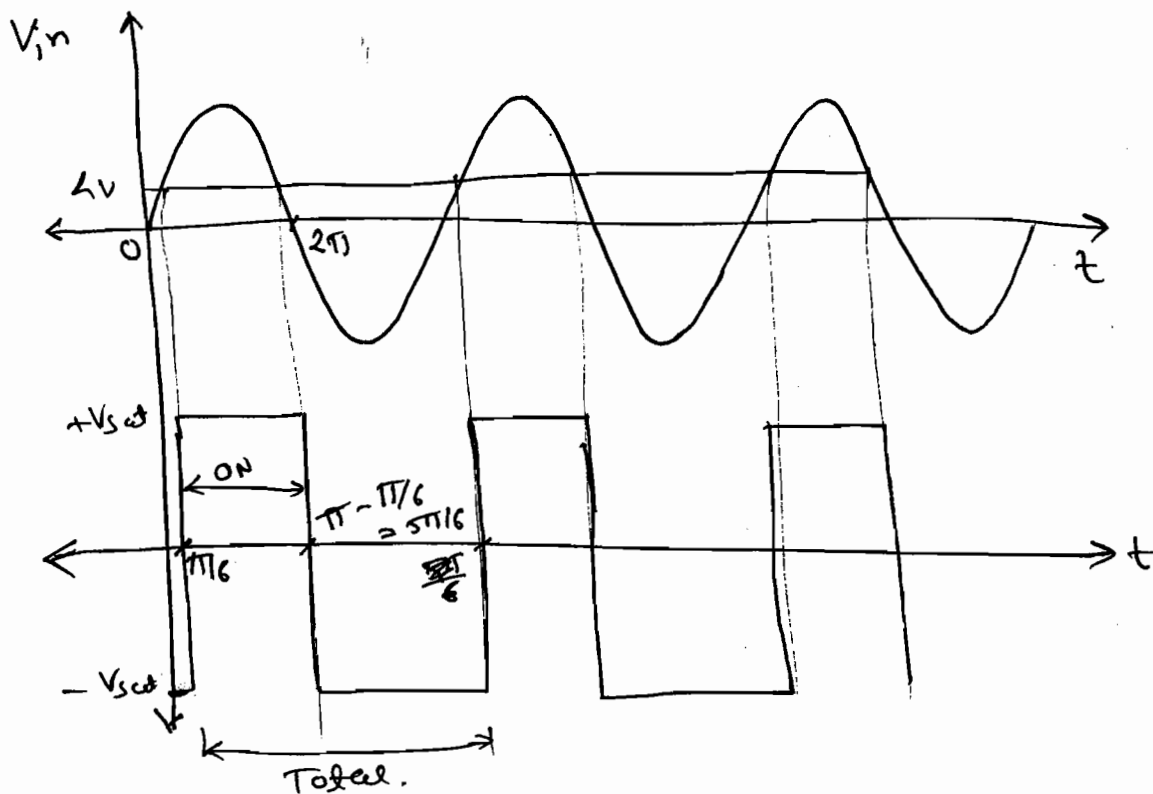
$$\boxed{\frac{R_F}{R_1} = \frac{C_1}{C_2}}$$

Ex-1 Calculate the duty cycle of the O/P of Comparators given.

Ans:



$$\therefore \begin{aligned} 8\sin t > 4 &\Rightarrow V_o = +V_{sat} \\ 8\sin t < 4 &\Rightarrow V_o = -V_{sat} \end{aligned}$$



$$8\sin t = 4$$

$$\therefore \sin t = \frac{1}{2} \Rightarrow t = \frac{\pi}{6}$$

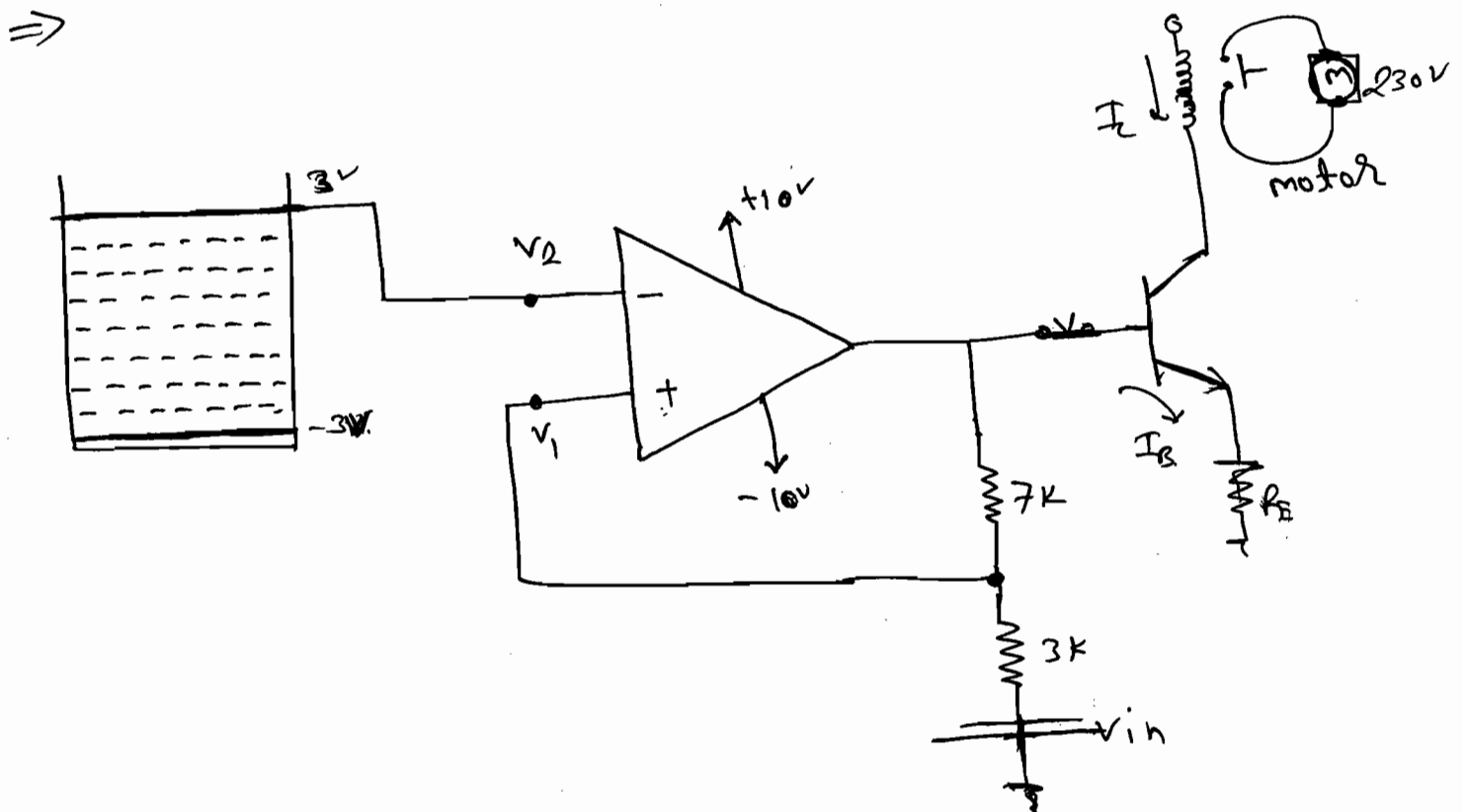
$$\therefore \text{Duty cycle} = \frac{T_{ON}}{T_{Total}}$$

$$= \frac{\frac{5\pi}{6} - \frac{\pi}{6}}{2\pi}$$

$$\therefore \text{Duty cycle} = \frac{1}{3}$$

* Schmitt trigger:

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→ Let, there is a overhead water tank which is automatically filled when it is empty by switching on the motor.

→ Let, there are two threshold voltage +3V which is ~~correspond~~ to indicate tank is full with water. and -3V which is indicate tank is empty.

→ Now, consider initial tank is empty, therefore we have to start motor. For To do so BJT should be on. for that output of OP-AMP is $+V_{sat}$.

⇒ So, we conclude that at initial voltage at V_2 is -3V. (tank is empty) and at

$V_1 = +3V$ (By voltage divider $V_1 = \frac{3}{10} \times 10 = 3V$).

→ Now, as motor on, tank will start to fill with water and corresponding voltage level also increase. (from $-3V$ to $+3V$). During this period voltage at V_0 is remain $+V_{sat}$ because ($V_1 > V_2$) and at V_1 voltage is still $+3V$.

→ Now, as soon as V_2 reaches to $+3V$ voltage $V_1 = V_2$ and $V_1 - V_2 = 0$ so $V_0 = -V_{sat}$, as soon as tank will totally filled with water $V_2 = +3V$. as water start to increase more, V_2 start to increase above $+3V$. Now, as $V_2 > +3V$, $V_1 - V_2 = -ve$ and output switch from $+V_{sat}$ to $-V_{sat}$. This thing switch off the BJT and it will in turn switch off the motor.

⇒ Now, $V_1 = -3V$ ($\because V_1 = \frac{3}{10} \times (-V_{sat}) = -3V$).
& $V_2 = +3V$.

⇒ Now, as the water in tank start to decrease V_1 also start to decrease, but $V_2 = +3V$ still and $V_0 = +V_{sat}$ still and motor is off still.

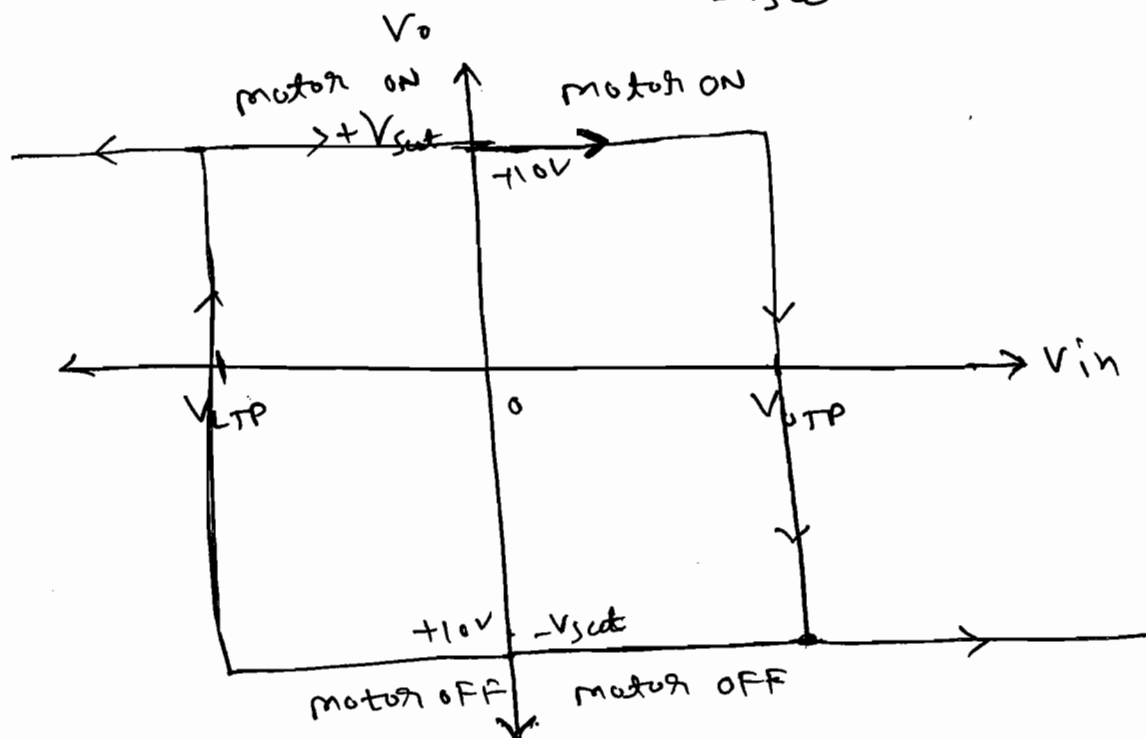
⇒ Now, when water tank is completely empty. $V_2 = -3V$, $V_1 = -3V$ but when water is below the $-3V$ i.e. $V_2 < -3V$. $\Rightarrow V_1 - V_2 = +ve$.

$\Rightarrow$ This will ~~change~~ V_o switch from $-V_{sat}$ to $+V_{sat}$. This will in turn on the motor and tank will again start to fill with water. at this state V_2 start increasing from $(-3 \text{ to } 3\text{V})$ and $V_1 = -3\text{V}$.

$\Rightarrow$ we can conclude that $+3\text{V}$ is V_{UTP} and -3V V_{LTP} .

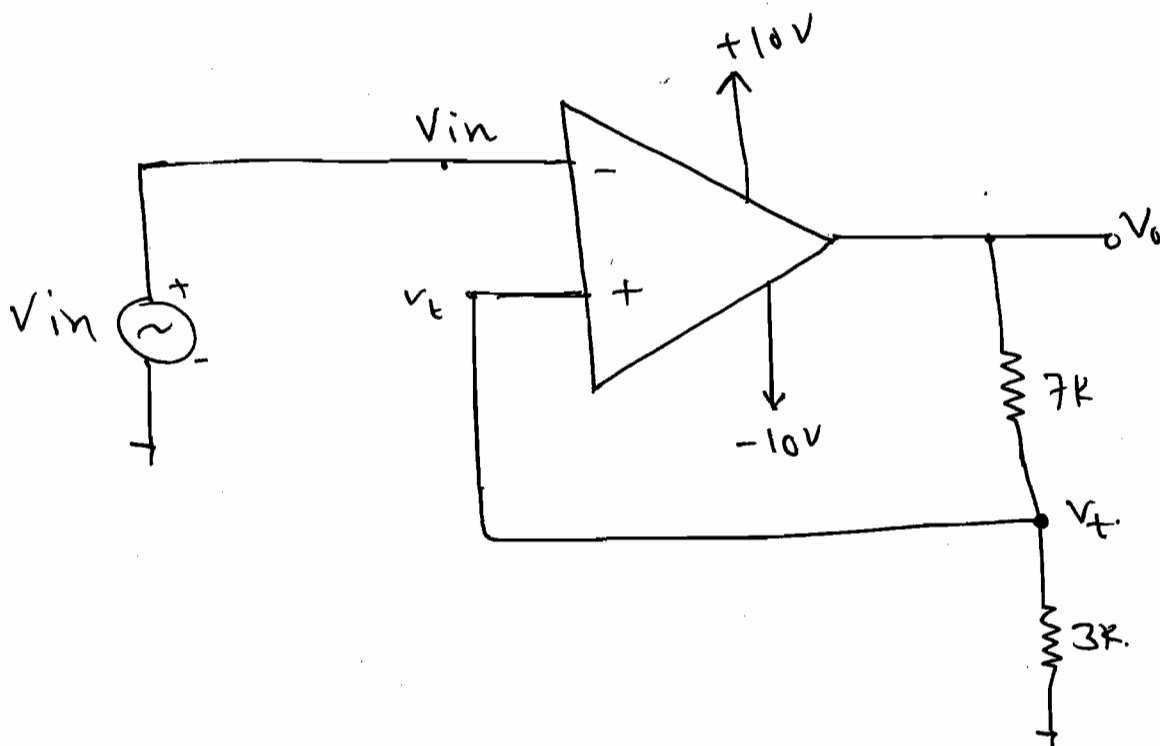
$\rightarrow$ when $V_{in} > V_{UTP}$ $\Rightarrow$ motor is on, as $V_{in} > 3\text{V}$ V_o switch from $-V_{sat}$ to $+V_{sat}$.

$\rightarrow$ when $V_{in} < V_{LTP}$ $\Rightarrow$ motor will OFF ^{as} and V_o switch from $+V_{sat}$ to $-V_{sat}$.

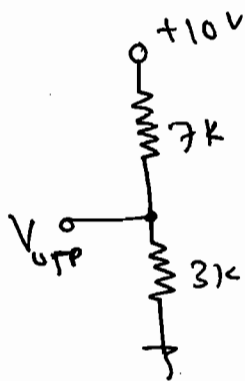


$\rightarrow$ when $V_{LTP} < V_{in} < V_{UTP} \Rightarrow V_o$ does not change its state. Hysteresis width = $V_{UTP} - V_{LTP}$

Ex-1 Calculate UTP & LTP and Hysteresis width.



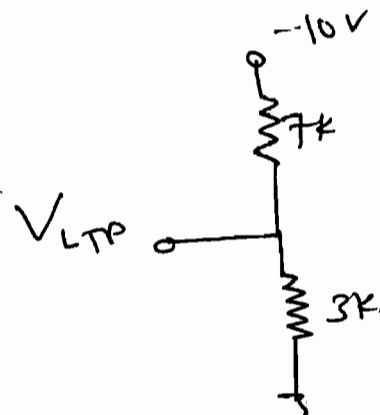
→ $V_t = V_{UTP}$ when $V_o = +10V$



$$V_{UTP} = \frac{V_o \times 3k}{10k}$$

$$\therefore \boxed{V_{UTP} = 3V}$$

→ $V_t = V_{LTP}$ when $V_o = -10V$



$$V_{LTP} = \frac{3}{10} \times (-10)$$

$$\boxed{V_{LTP} = -3V}$$

→ Hysteresis width:

$$HW = V_{UTP} - V_{LTP}$$

$$\therefore HW = 3 - (-3V)$$

$$\therefore \boxed{HW = 6V}$$

→ When $V_o = +V_{sat}$ $\frac{D_1 \text{ is on}}{D_2 \text{ is OFF}}$ and. 61

$$V_t = V_{UTP}$$

$$= \frac{8}{18} \times 124$$

$$V_E \approx V_{LE}$$

$$\boxed{V_{UTP} = 4V}$$

→ When $V_o = -V_{sat}$ $D_1 \text{ is OFF} \& D_2 \text{ is ON}$

$$\therefore V_t = V_{LTP}$$

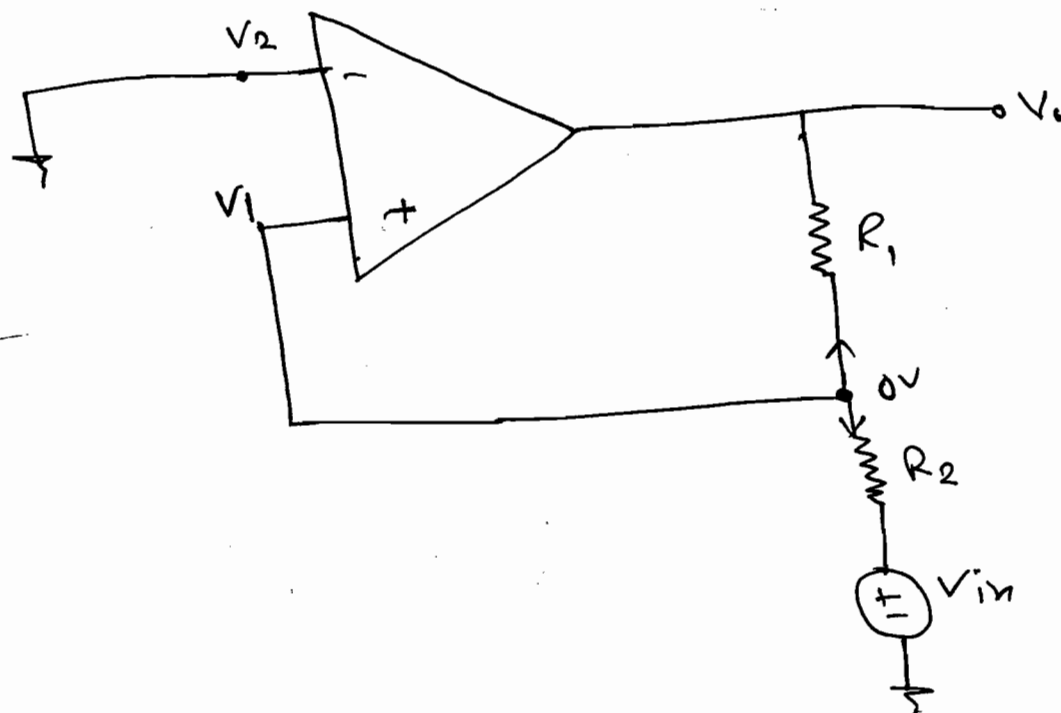
$$= \frac{6^2}{8} \times (12)4$$

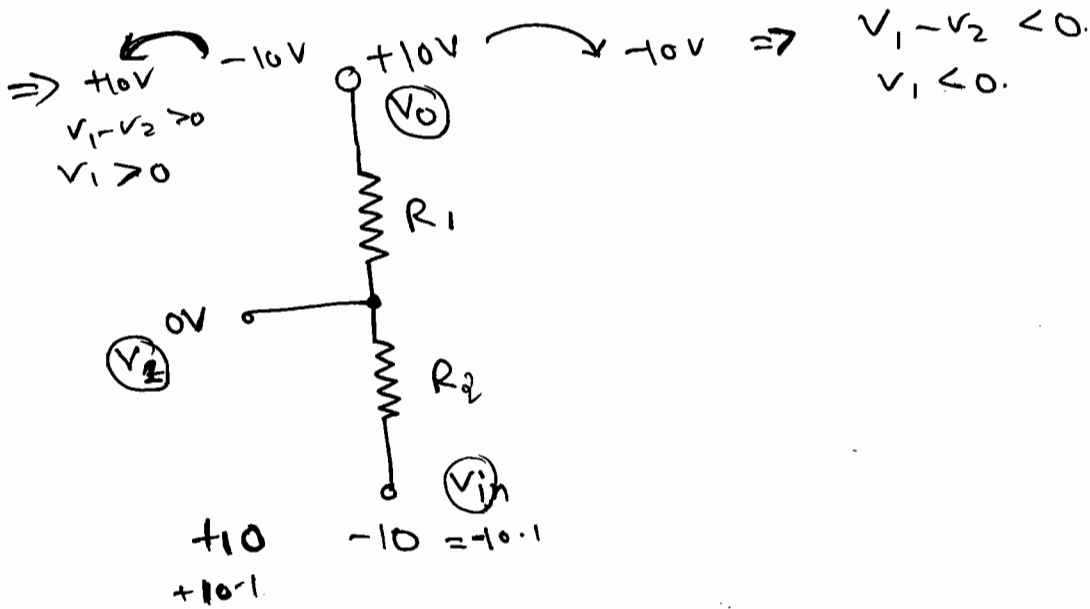
$$\therefore \boxed{V_{LTP} = -8V}$$

$$\therefore HW = V_{UTP} - V_{LTP}$$

$$\therefore HW = 4 - (-8) = 12V.$$

* Non-inverting Schmitt trigger:

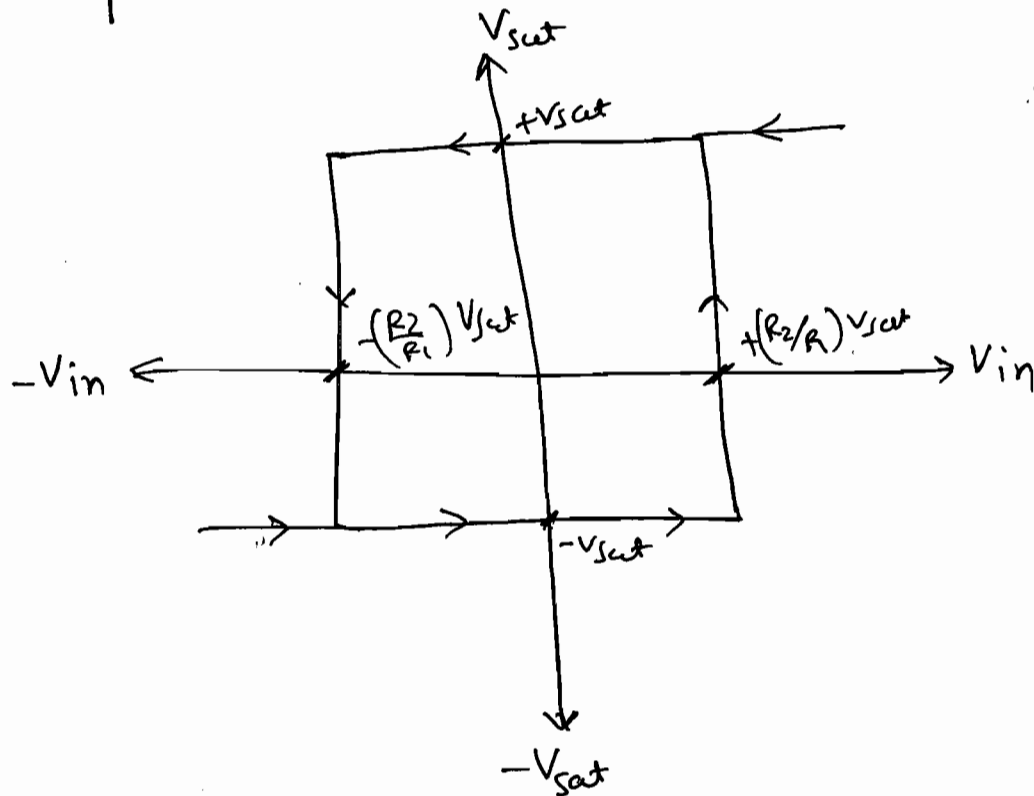




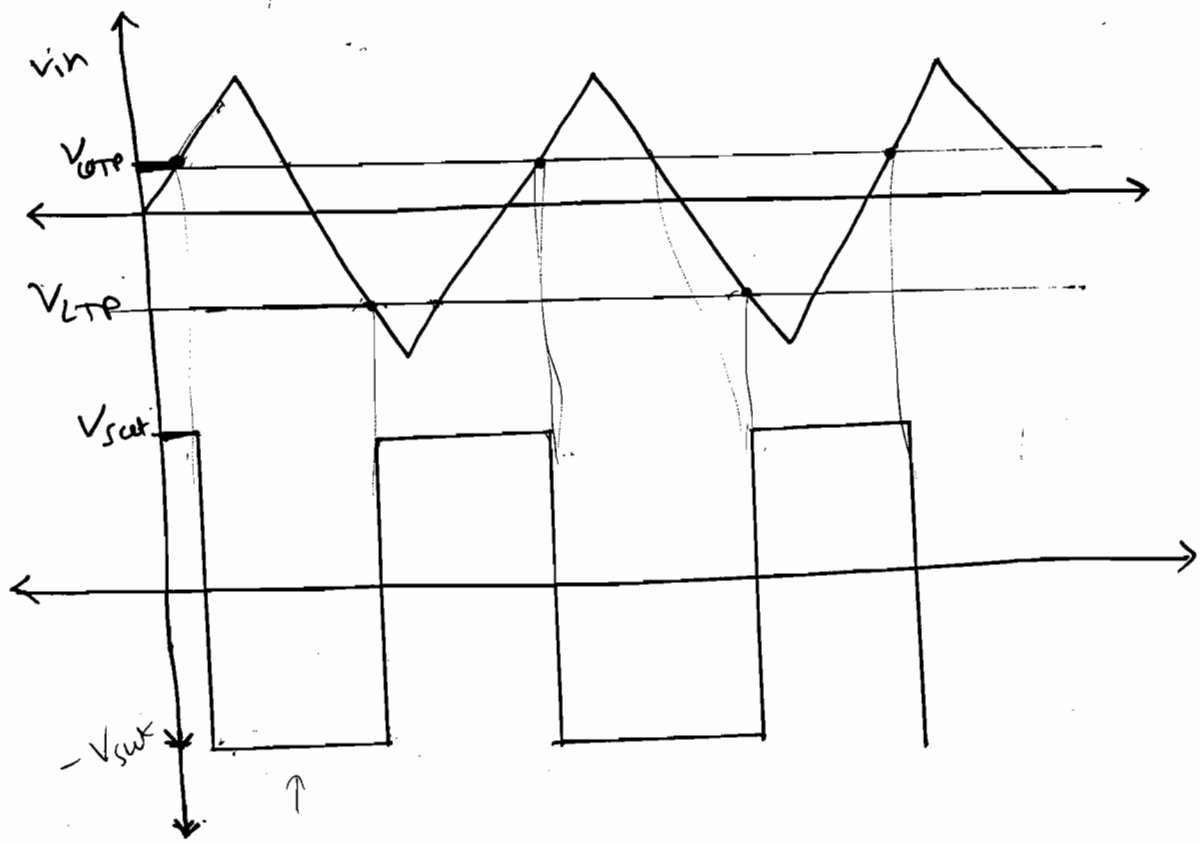
$$\therefore \frac{0 - V_0}{R_1} = \frac{V_{in} - 0}{R_2}$$

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

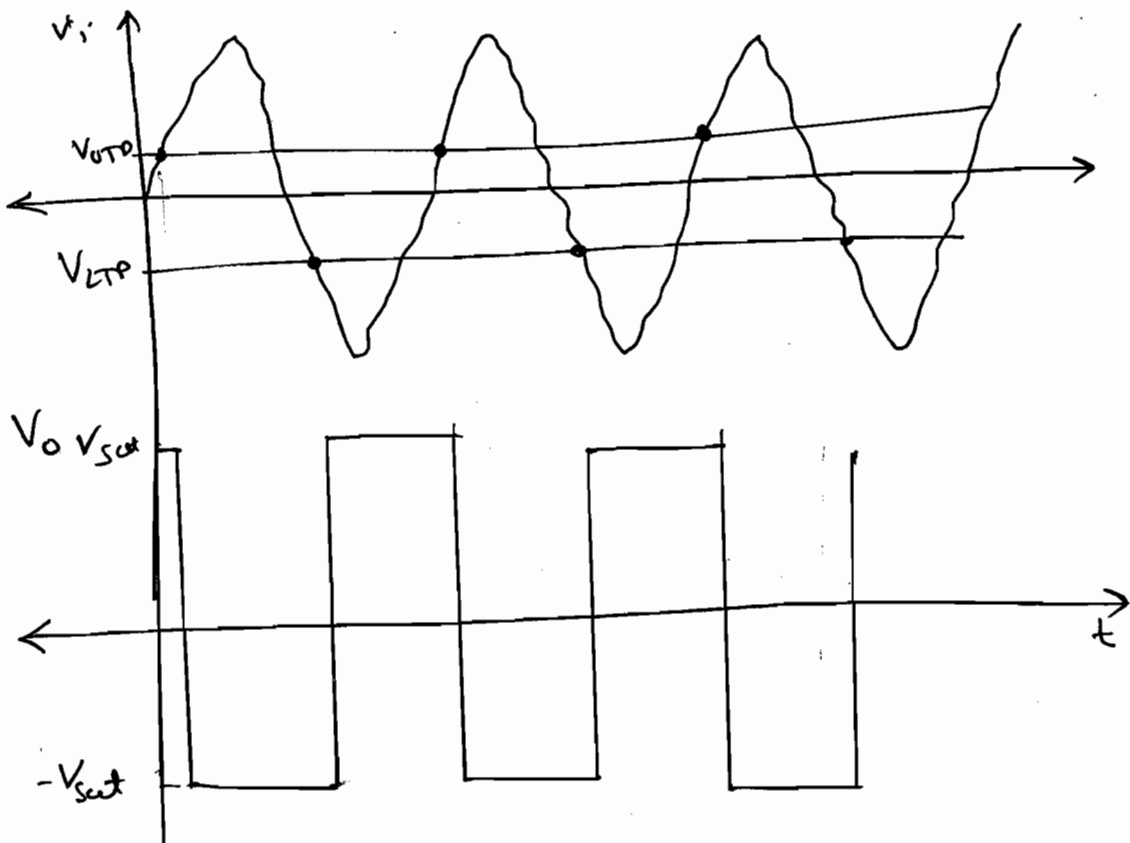
V_0	V_{in}
$+V_{sat}$	$< -\left(\frac{R_2}{R_1}\right) V_{sat}$ to switch V_0 from $+V_{sat}$ to $-V_{sat}$
$-V_{sat}$	$> \left(\frac{R_2}{R_1}\right) V_{sat}$ to switch V_0 from $-V_{sat}$ to $+V_{sat}$



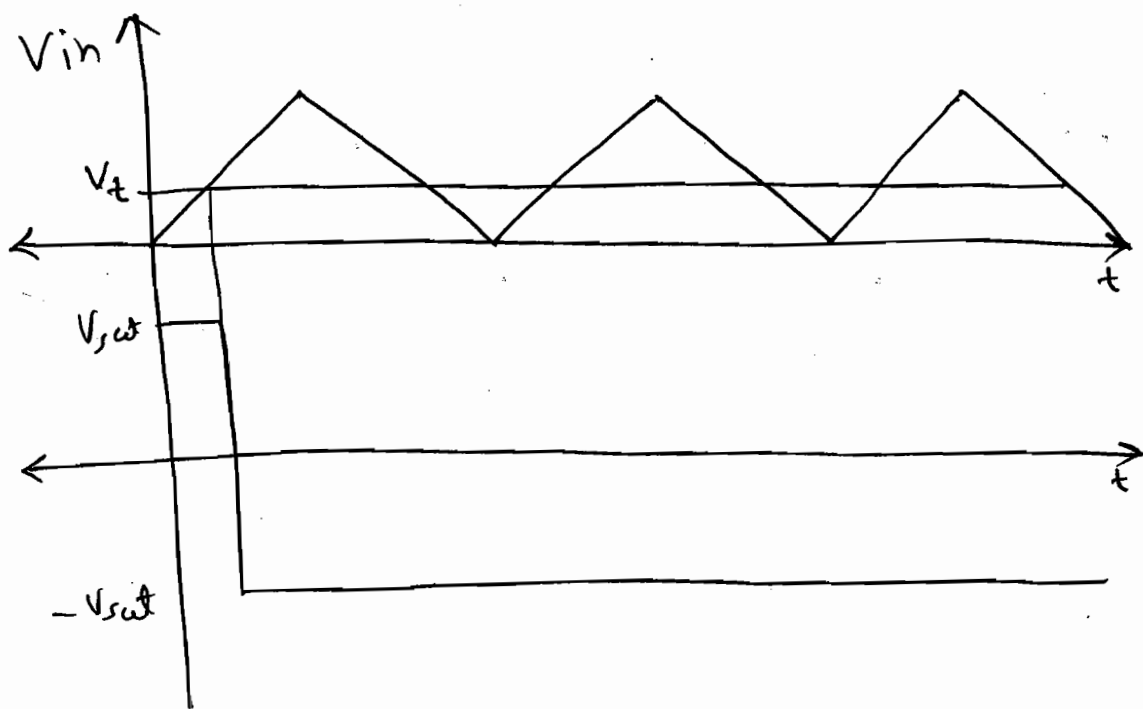
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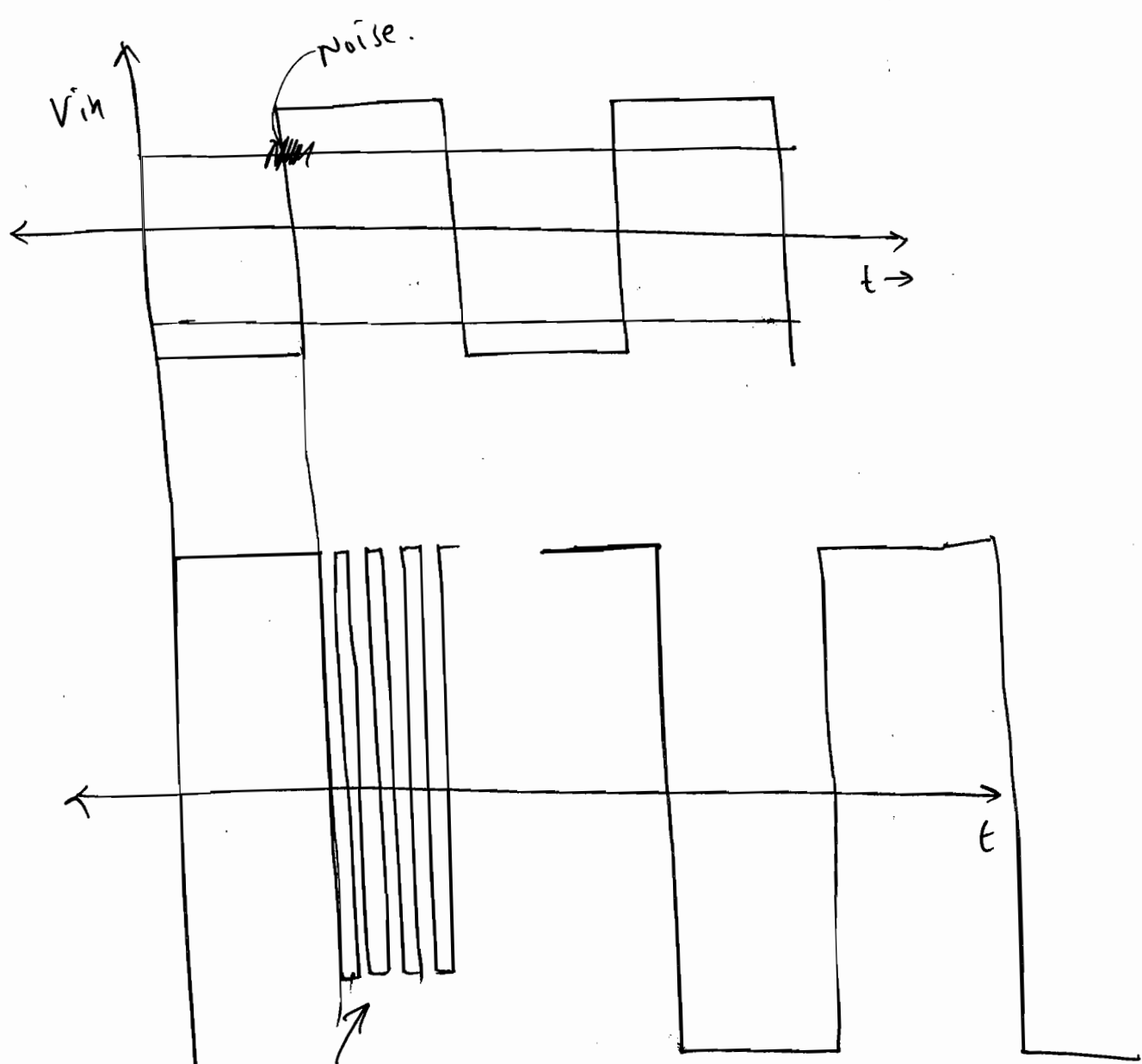
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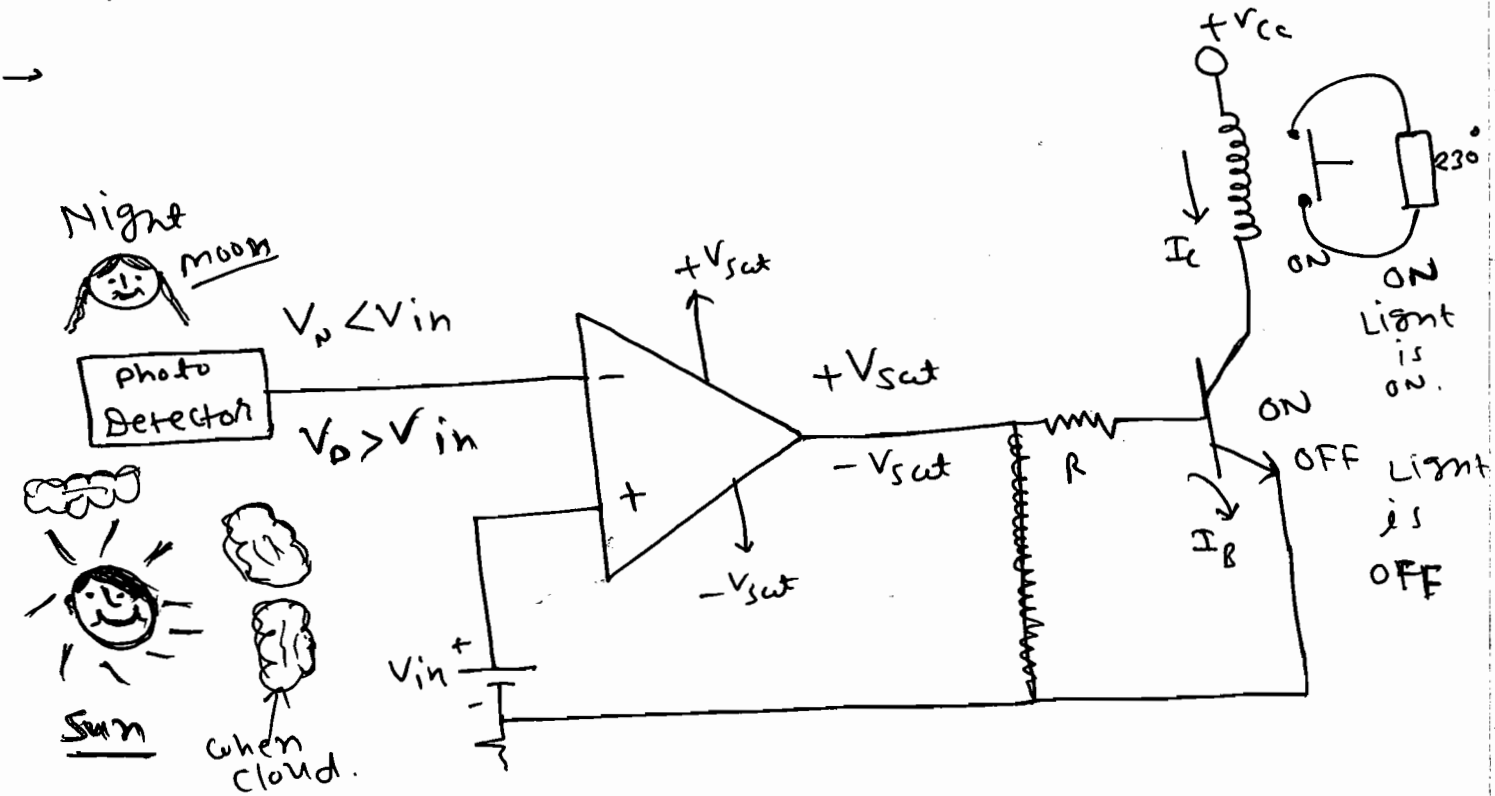
*



Comparator
O/P

Schmitt trigger
O/P.
Very high immune to noise.

* One more Application of Schmitt trigger: 65



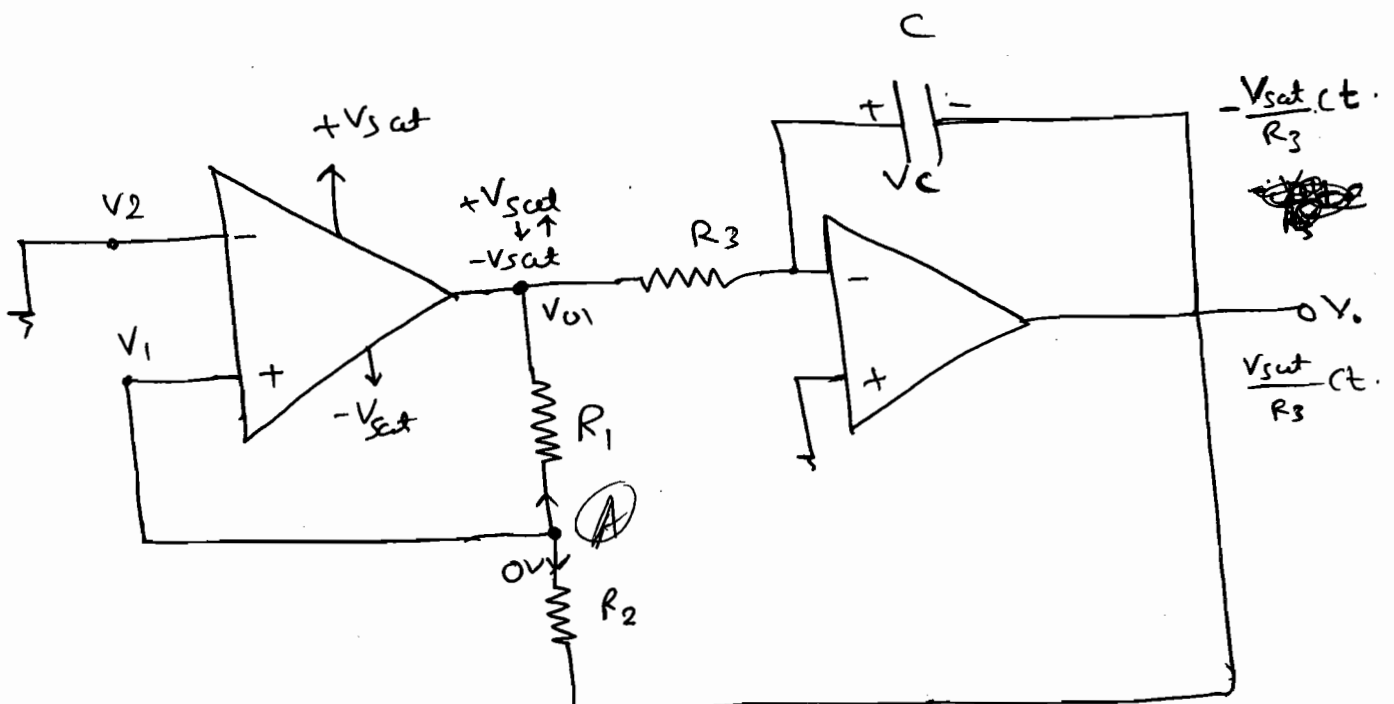
but

→ when cloud come $V_N < V_{in} < V_D$

$$V_N = V_{LTP}$$

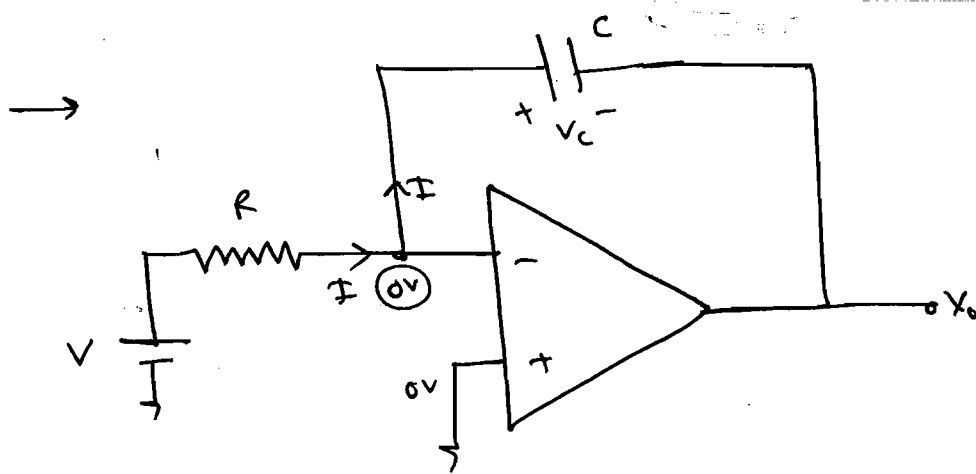
$$V_D = V_{LTP}$$

* Triangular Wave generator:



$$V_O < -\frac{R_2}{R} V_{sat}$$

$$V_O > \frac{R_2}{R} V_{sat}$$



$$\therefore I = V/R.$$

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

$$= \frac{1}{C} \int \frac{V}{R} dt$$

$$= \frac{V}{RC} \int dt$$

$$\therefore V_c = \left(\frac{V}{RC} \right) t.$$

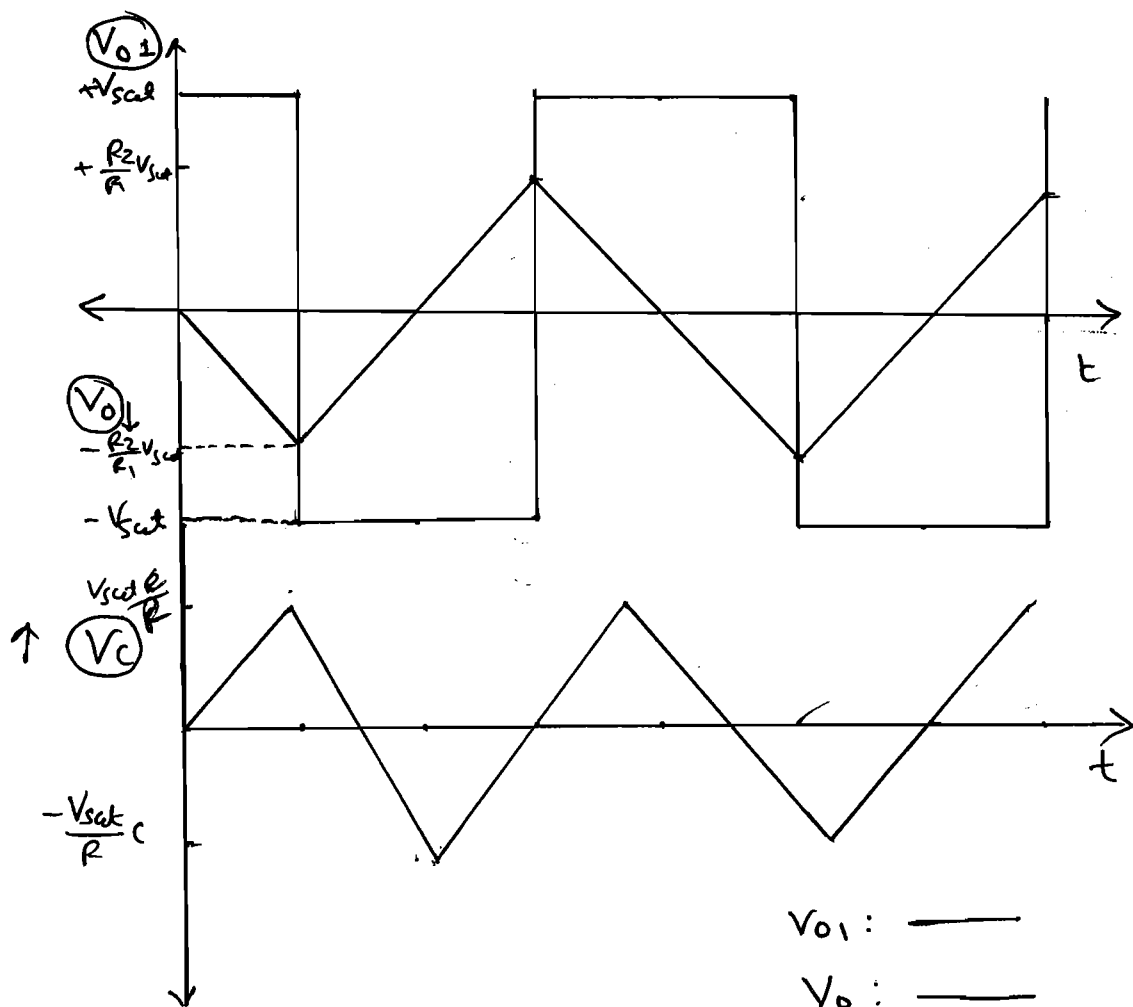
$$\therefore 0 - V_o = V_c.$$

$$\therefore \boxed{V_o = - \left(\frac{V}{RC} \right) t.}$$

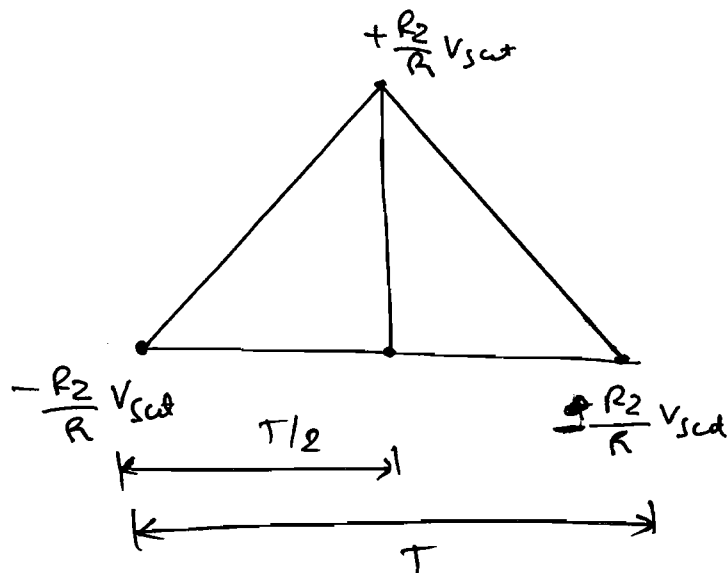
→ at node - (A).

$$\therefore \frac{0 - V_{o1}}{R_1} + \frac{0 - V_o}{R_2} = 0.$$

$$\therefore \boxed{V_o = - \left(\frac{R_2}{R_1} \right) V_{o1}.}$$

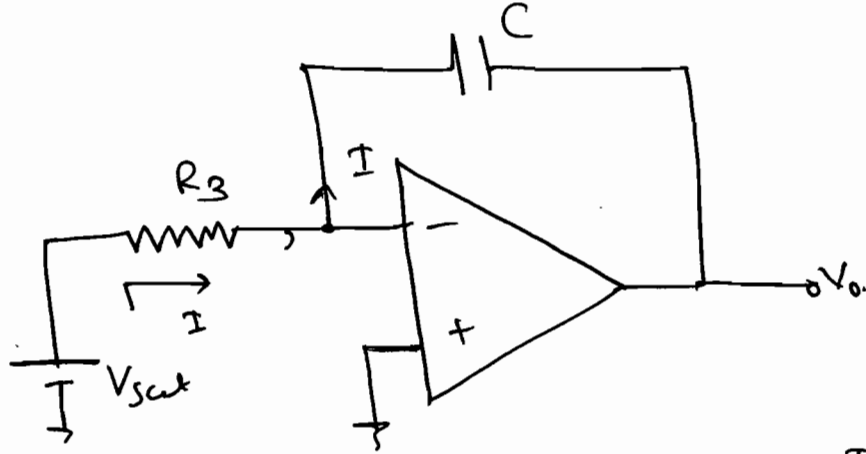


$V_{01} : \text{ ——— }$
 $V_0 : \text{ ——— }$
 $V_c : \text{ ——— }$



$$\therefore V_c(t) = V_c(0) + \frac{1}{C} \int I dt.$$

$$\therefore V_c(t) = -\frac{V_{sat}R_2}{R} + \frac{1}{C} \int I dt.$$



$$I = \frac{V_{sat}}{R_3}$$

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

$$\therefore V_c(t) = \frac{1}{C} \int \frac{V_{sat}}{R_3} \, dt$$

$$V_c(t) = \frac{V_{sat}}{R_3 C} \cdot t$$

$$\therefore V_c(t) = -\frac{R_2}{R_1} V_{sat} + \frac{V_{sat}}{R_3 C} \cdot t.$$

but at $t = T/2$, $V_c(t) = \frac{R_2}{R_1} V_{sat}$

$$\therefore \frac{R_2}{R_1} V_{sat} = -\frac{R_2}{R_1} V_{sat} + \frac{V_{sat}}{R_3 C} \cdot (T/2).$$

$$\therefore \frac{2R_2}{R_1} V_{sat} = \frac{V_{sat}}{R_3 C} \cdot (T/2)$$

$$T = \frac{4 R_2 R_3 C}{R_1}$$

$$f = \frac{R_1}{4 R_2 R_3 C}$$

If $R_1 = R_2 = R_3 = R$

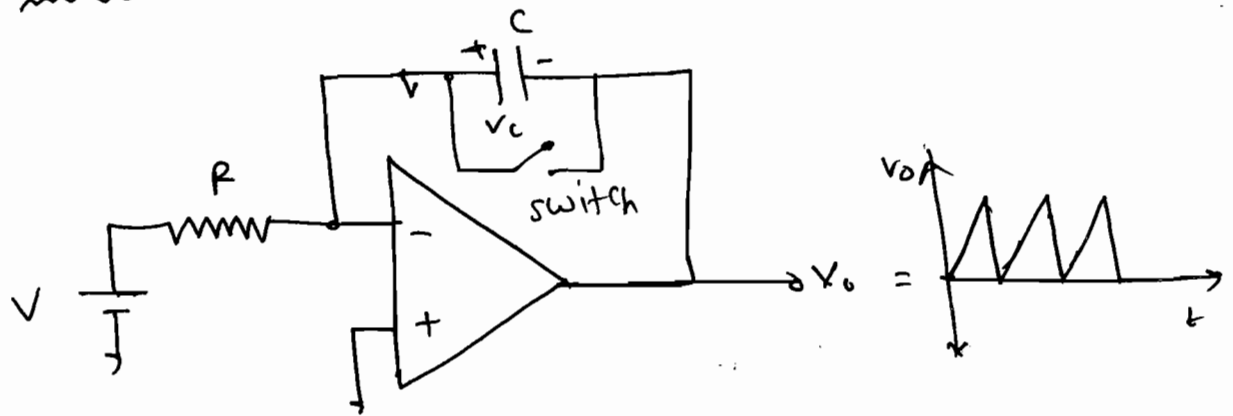
$$\therefore f = \frac{R}{4RC}$$

* Sweep circuits:

→ These are mainly two ways to generate Sweep (sawtooth) waveform:

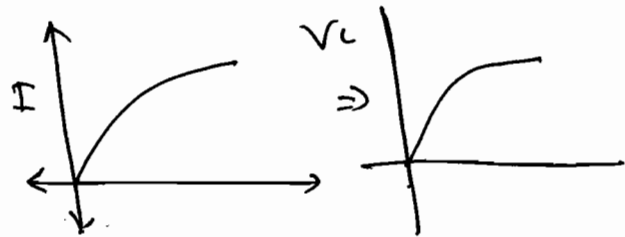
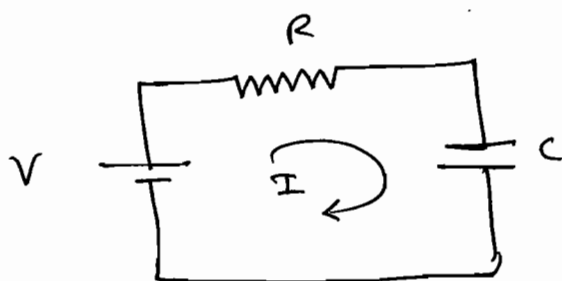
- ① Miller sweep circuit
- ② Boot strap sweep.

① Miller Sweep circuit:



② (Boot strap Sweep):

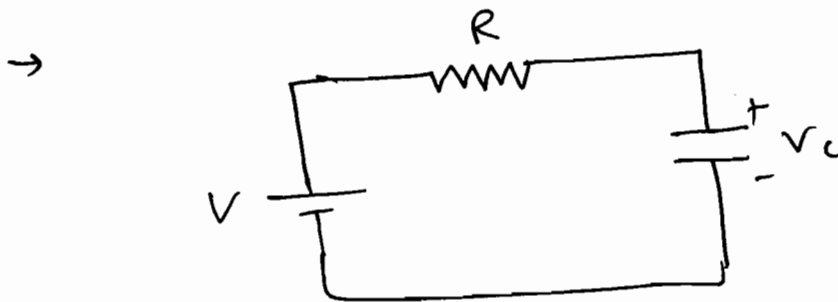
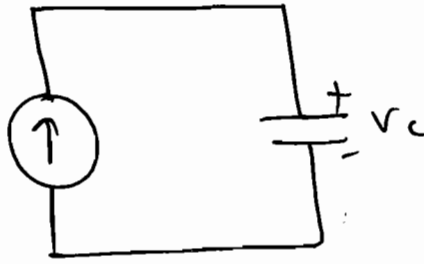
→ If current through a capacitor is exponential then capacitor charge is in exponential fashion.



$$\Rightarrow I_C = \frac{V}{R} e^{-t/RC}$$

$$V_c = \frac{1}{C} \int I_C dt$$

→ if V_c has to be linear I has to be constant



KVL, $-V + IR + V_c = 0.$

∴ we have to get $I = \text{constant} = V/R$
 To do so V_c should be V only.

By changing KVL,

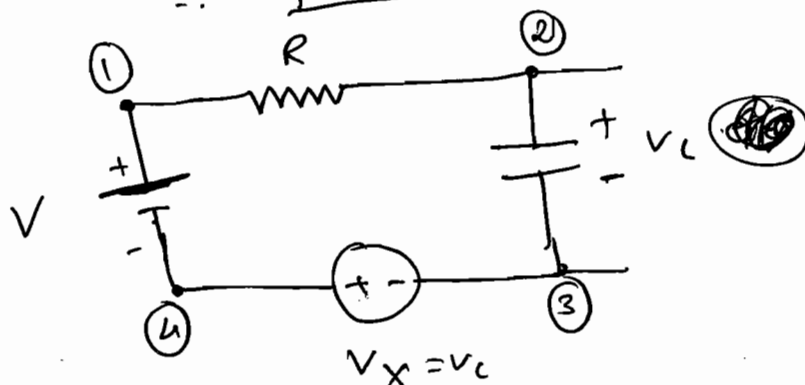
∴ $-V + IR + V_c - V_x = 0.$

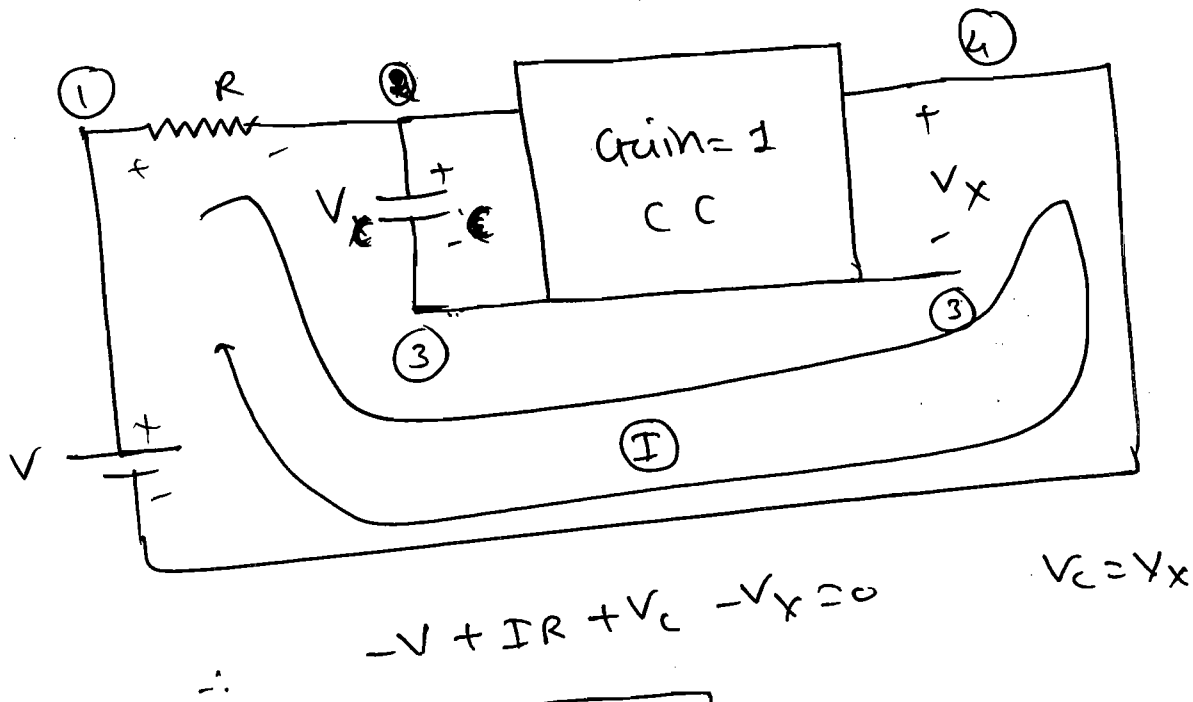
∴ $-V + IR + V_c - V_x = 0.$

$V_x = V_c$

$\Rightarrow \frac{V_c}{V_x} = 1.$

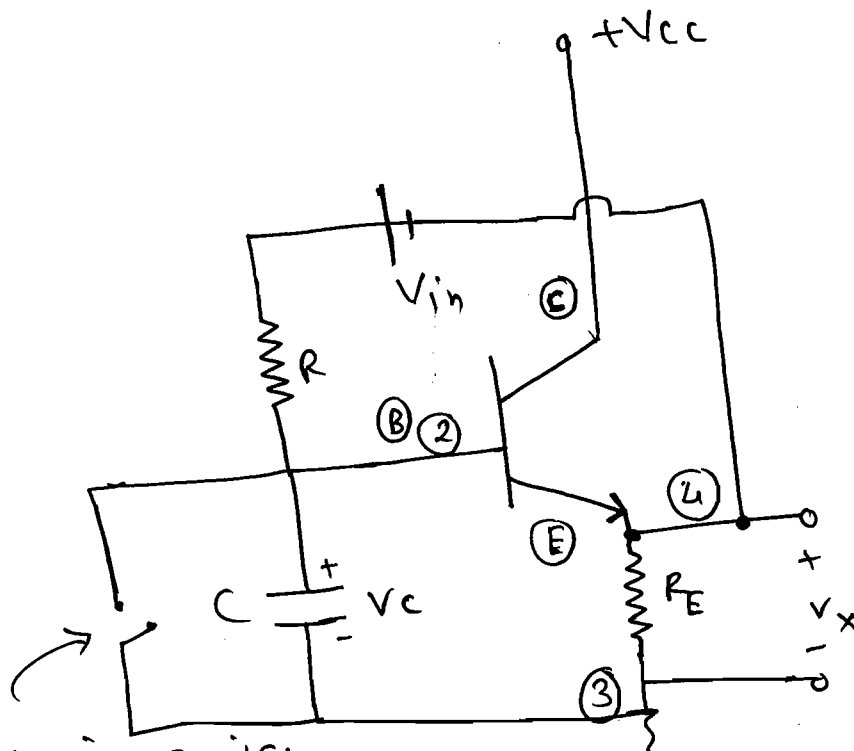
$I = V/R$





$$\Rightarrow I = V/R$$

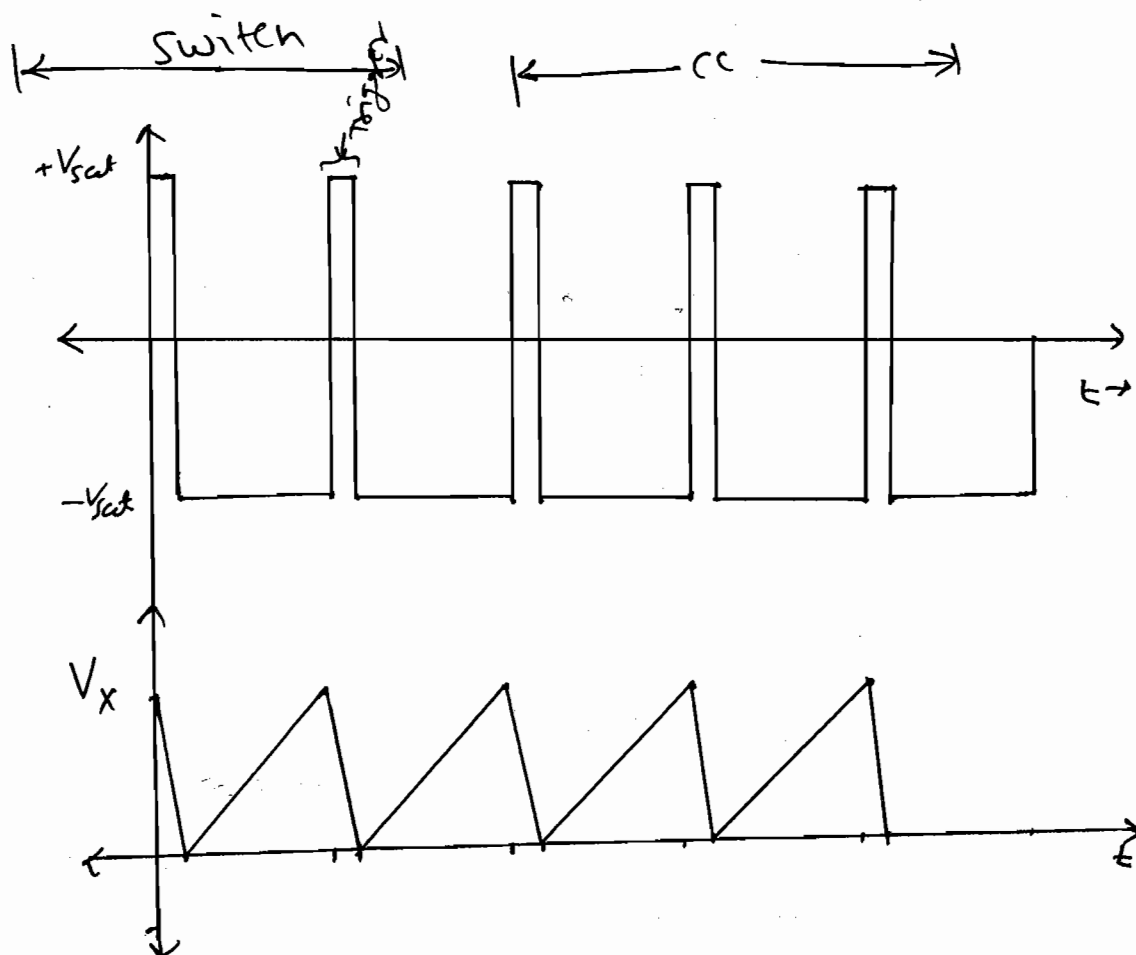
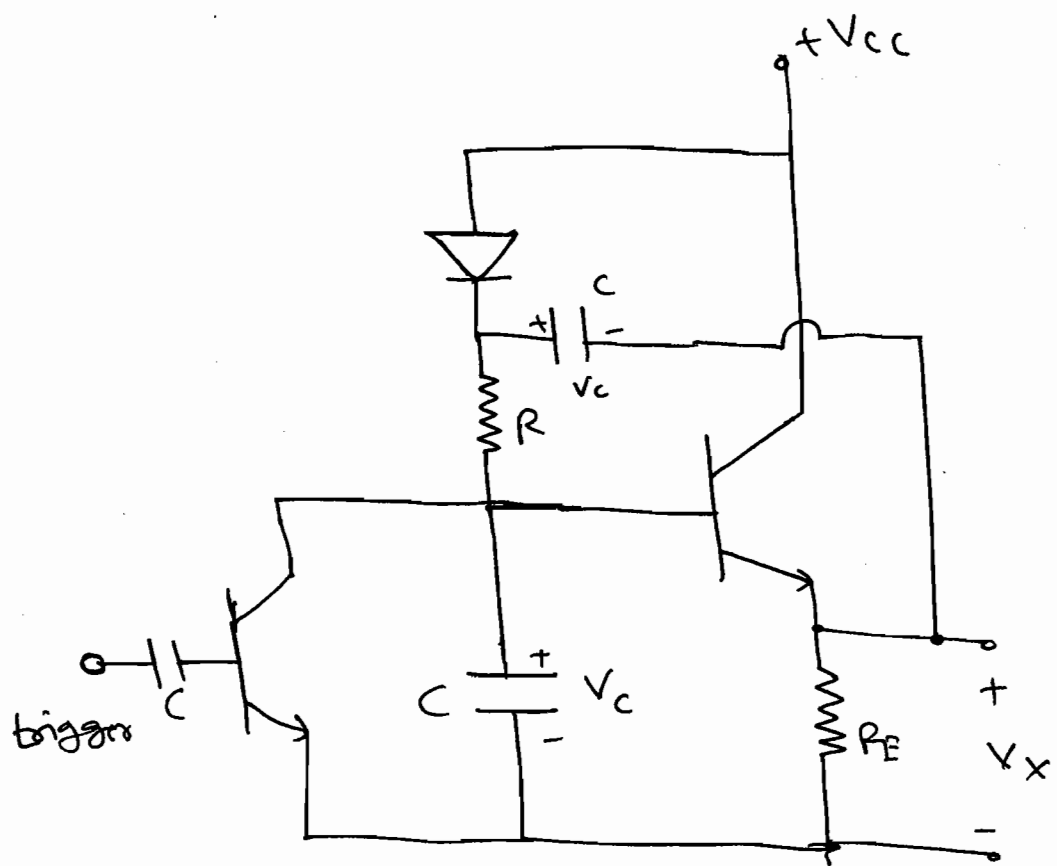
$\Rightarrow$



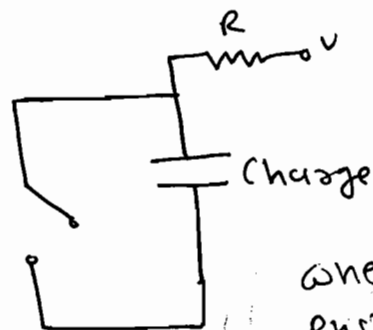
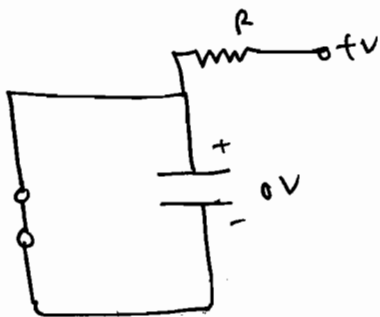
Electronic switch.

NOTE: Instead of two dc supply V_{cc} and V_{in} we can replace voltage source V_{in} with a capacitor. The charging time constant is far less as compared with discharging. Hence charge the

Capacitor through a Diode.



①

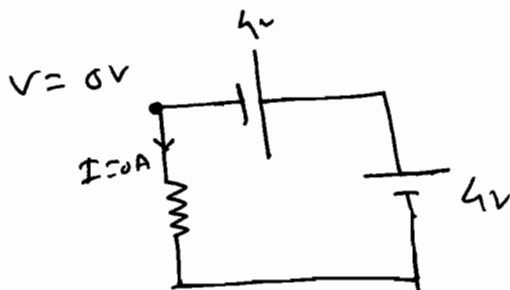


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Whenever we push trigger (or) push switch.

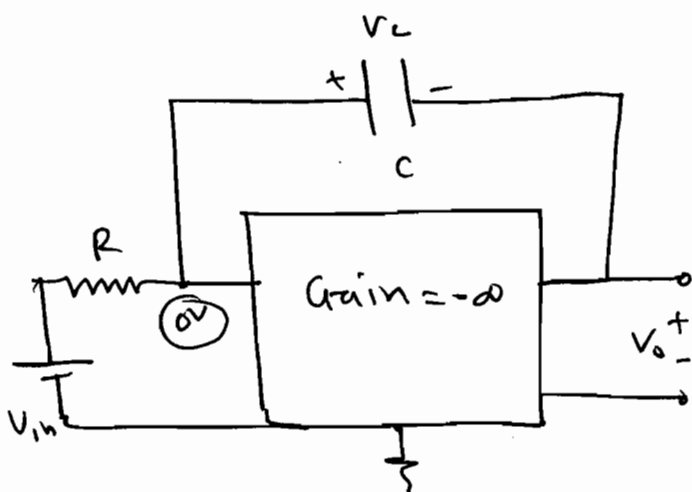
Capacitor discharge

known BJT that particular time.



(nullator (kt) ($V=0, I=0$).

Miller sweep

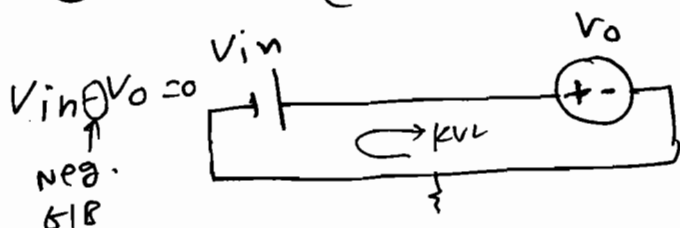


① Amp gain is very high.

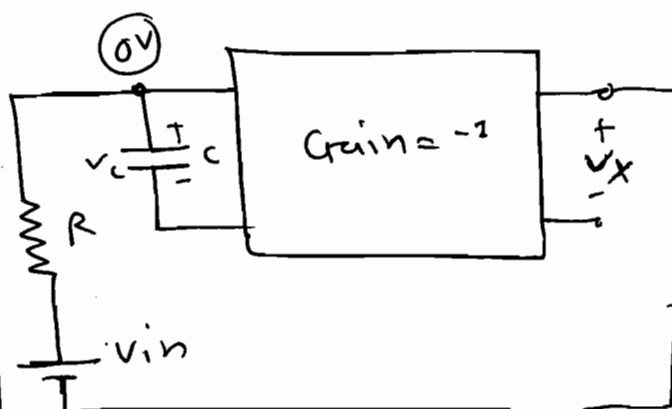
② Neg. feedback

③ $I = V/R$

④ $V_C = \left(\frac{V}{RC}\right)t$



Boot strap sweep

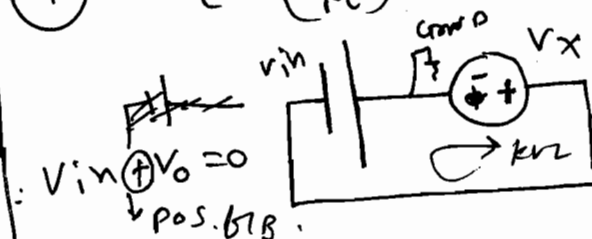


① Amp gain = 1

② Pos. feedback = 1.

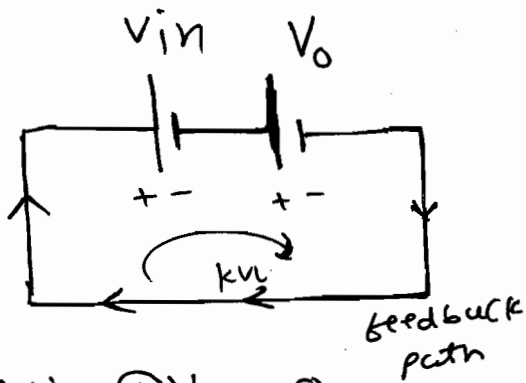
③ $I = V/R$

④ $V_C = \left(\frac{V}{RC}\right)t$



* Techniques for identifying type of feedback:

①



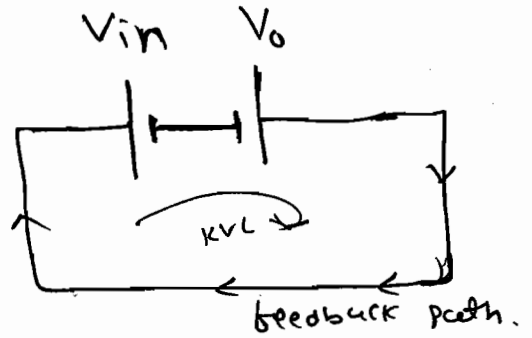
$$\therefore V_{in} + V_o = 0$$

↓
Positive feedback

→ If ^{(or) +ve} -ve terminal of OP is connected to the ^{(or) -ve} +ve terminal of IP then it is positive feedback

$$\begin{aligned} -ve &\rightarrow +ve \\ +ve &\rightarrow -ve \end{aligned}$$

②



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

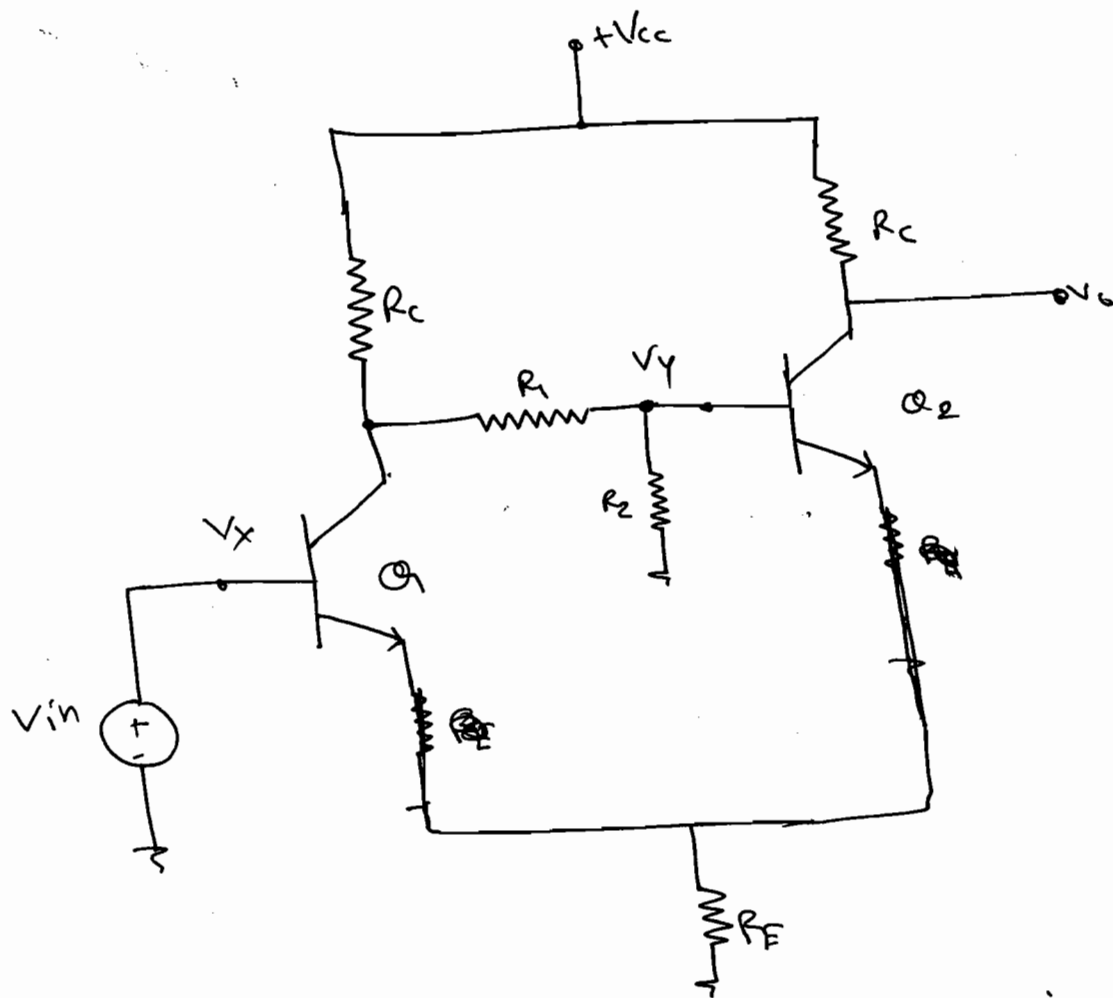
↓
negative feedback.

→ If +ve/-ve terminal of OP is connected to the +ve/-ve terminal of IP then it is called negative feedback.

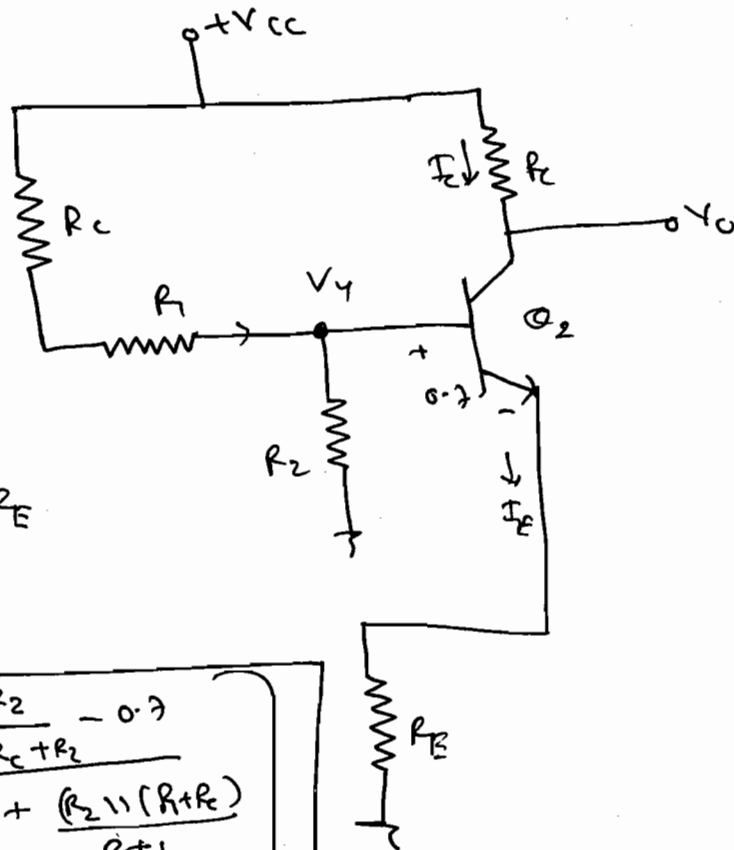
$$\begin{aligned} -ve &\rightarrow -ve \\ +ve &\rightarrow +ve \end{aligned}$$

☆ Schmitt Trigger using BJT:

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Case-1: $V_{in} = 0 \Rightarrow Q_1$ is OFF and Q_2 is ON.



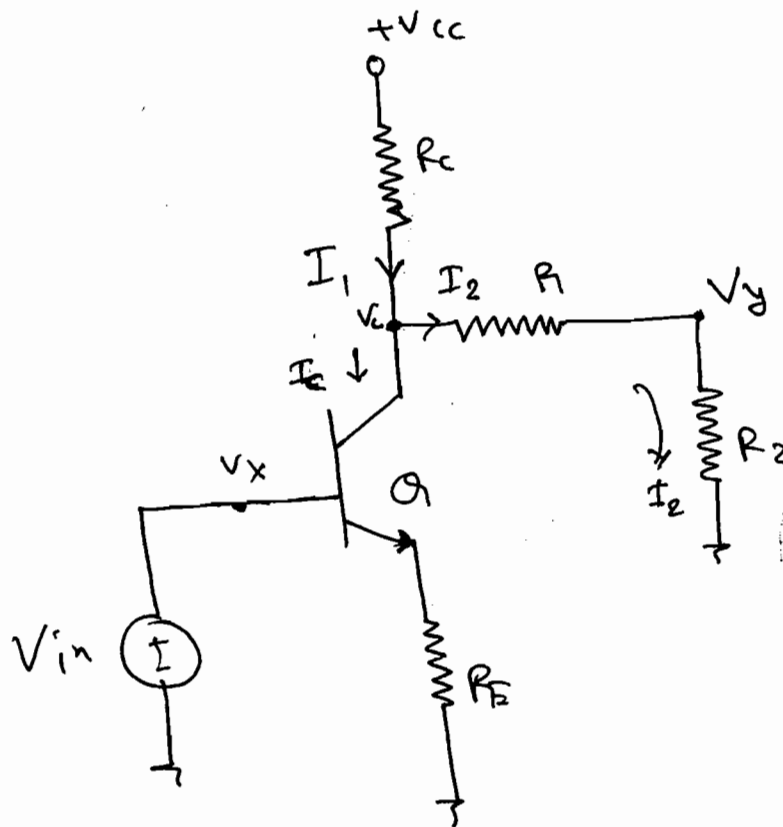
$$V_Y = 0.7 + I_E R_E$$

$$I_E \approx I_B$$

$$\therefore V_Y = 0.7 + R_E \left[\frac{\frac{V_{CC} R_2}{R_1 + R_C + R_2} - 0.7}{R_E + \frac{R_2 (R_1 + R_C)}{\beta + 1}} \right]$$

→ $V_{in} > V_y$ then Q_1 moves from OFF state to ON state.

Case - 2: $Q_1 = ON, Q_2 = OFF$



$$V_x = V_y.$$

$$\therefore I_1 = \frac{V_{CC} - V_c}{R_C}$$

$$\therefore V_y \cdot 0.7 + I_E R_E = V_y. \quad \therefore I_1 = \frac{V_{CC} - m V_y}{R_C}$$

$$\therefore V_y = \frac{R_2}{R_1 + R_2} V_c.$$

$$\therefore I_2 = \frac{V_y}{R_2}$$

$$V_c = \frac{R_1 + R_2}{R_2} V_y.$$

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

$$\therefore V_c = m V_y.$$

$$\therefore I_E \approx I_1$$

$$0.7 + I_{E1} R_E = V_y.$$

$$\therefore 0.7 + (I_1 - I_2) R_E = V_y.$$

$$\therefore 0.7 + R_E \left(\frac{V_{CC} - mV_y}{R_C} - \frac{V_y}{R_2} \right) = 0.7V_y. \quad 77$$

$$\therefore 0.7 + \frac{R_E V_{CC}}{R_C} = \left(1 + m \frac{R_E}{R_C} + \frac{R_E}{R_2} \right) V_y.$$

$$\therefore V_y = \frac{0.7 + \frac{R_E V_{CC}}{R_C}}{1 + m \frac{R_E}{R_C} + \frac{R_E}{R_2}}.$$

→ $V_{in} < V_y$ to switch on from ON state to OFF.

$$|HW| = V_{OTP} - V_{LTP}.$$

★ Multivibrators :

29/07/2013

→ It is the regenerative circuit where transistor either work in cut off or saturation and the op-amp at the saturation limit.

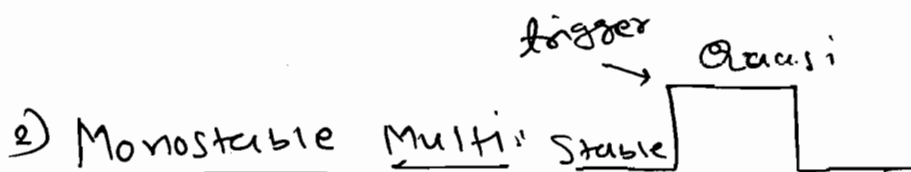
→ Based on the old state they are classified as:

1) Bistable Multi:



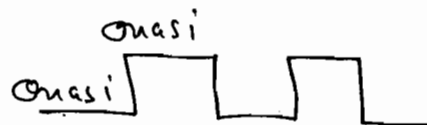
- 2 stable state
- Binary F/F
- eccless Jordan

2) Monostable Multi:



- 1 - stable state
- 1 - Quasi state
- one shot
- pulse generator.

3) Astable Multi:

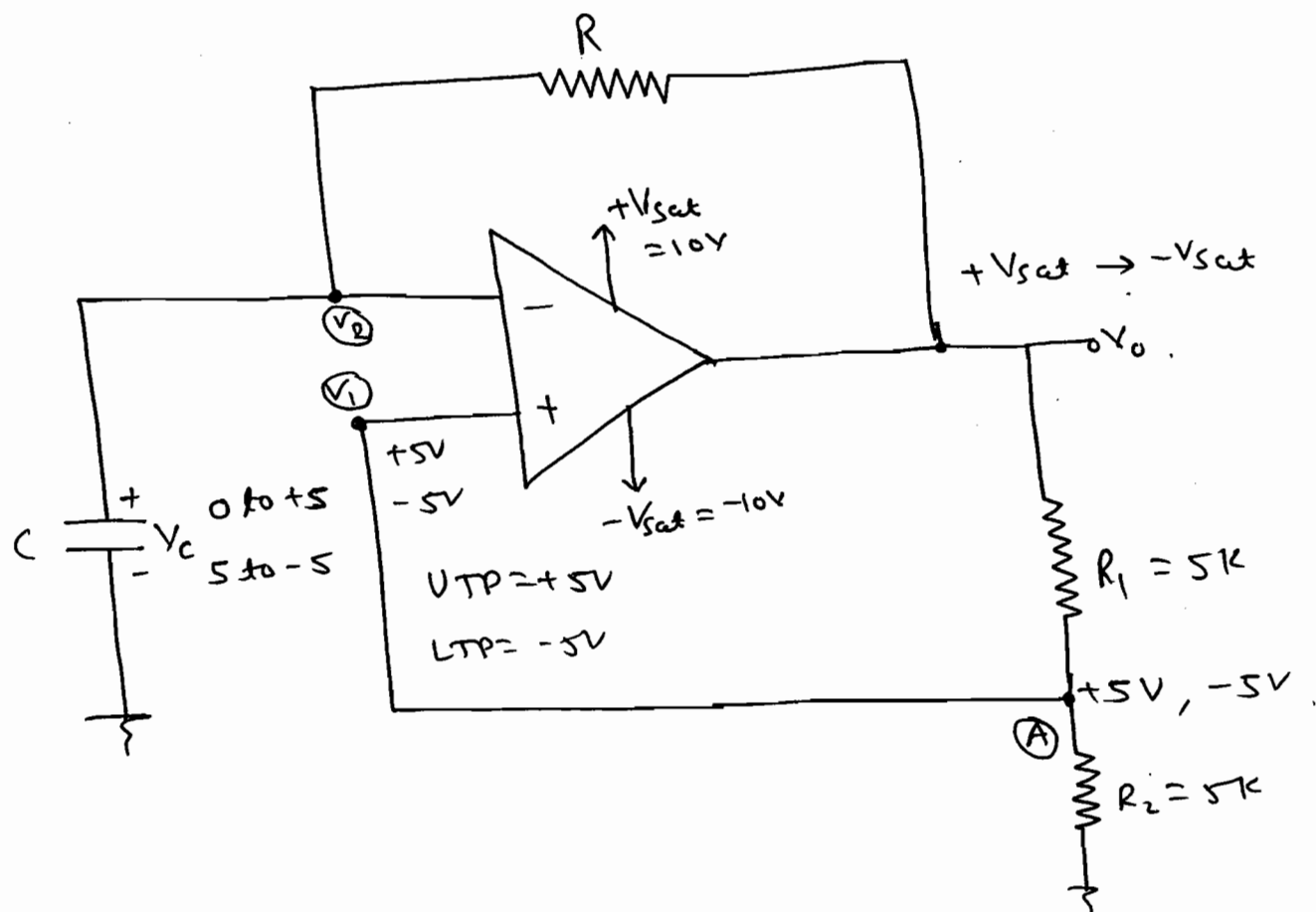


[No trigger required]

- Free running
- Square wave generator.

* Astable Multivibrator:

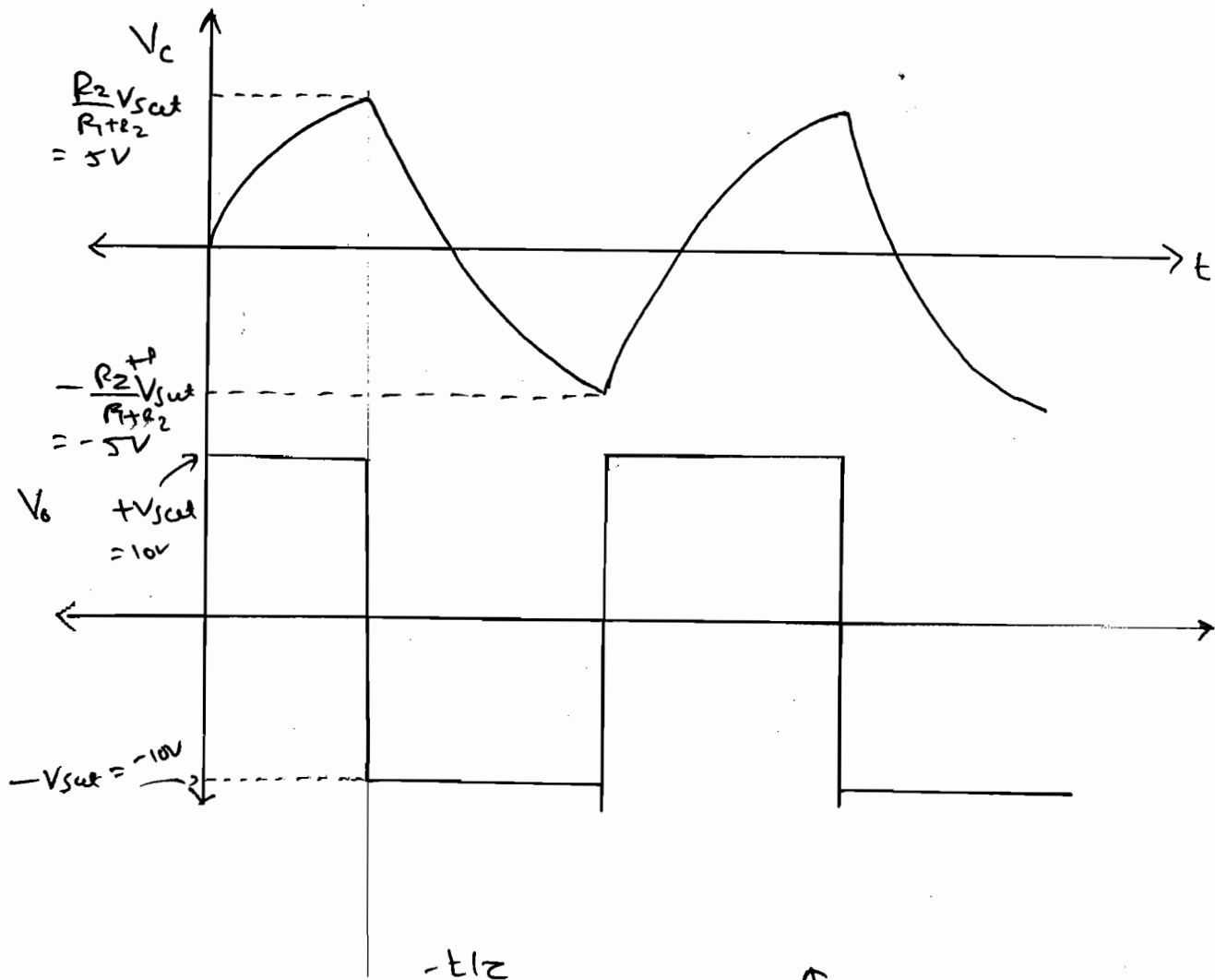
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operation:

- Let, assume initially o/p of op-Amp is V_{sat} . for simplicity take $R_1 = 5K$, $R_2 = 5K$. and $V_{sat} = 10V$.
- Now, By voltage divider voltage at $V_1 = +5V$ fixed.
- Now, As $V_0 = +V_{sat} = +10$. (capacitor C starts to charge and V_2 increase from 0 to $+V_{sat} = 10V$. But as soon as $V_2 \geq 5$, $V_2 > V_1$ and V_0 switch from $+V_{sat}$ to $-V_{sat}$. i.e when $V_2 > \frac{R_2}{R_1} V_{sat} \Rightarrow V_0$ switch from $+V_{sat}$ to $-V_{sat}$.
- $\Rightarrow$ Now, as $V_0 = -V_{sat} = -10V$. $\Rightarrow$ voltage at $V_1 = -5V$ (By voltage divider $-\frac{R_2}{R_1} V_{sat}$). and capacitor

Charges form $+5$ to $-V_{sat}$. But as $V_2 > -5$
 i.e. ~~the~~ when $V_2 > -\frac{R_2}{R_1+R_2} V_{sat}$ then $V_2 < V_1$
 and O/P switch form $-V_{sat}$ to $+V_{sat}$.
 and cycle repeat.



$$\rightarrow V_c(t) = A + B e^{-t/\tau}$$

$$\therefore \text{at } t=0$$

$$V_c(0) = A + B$$

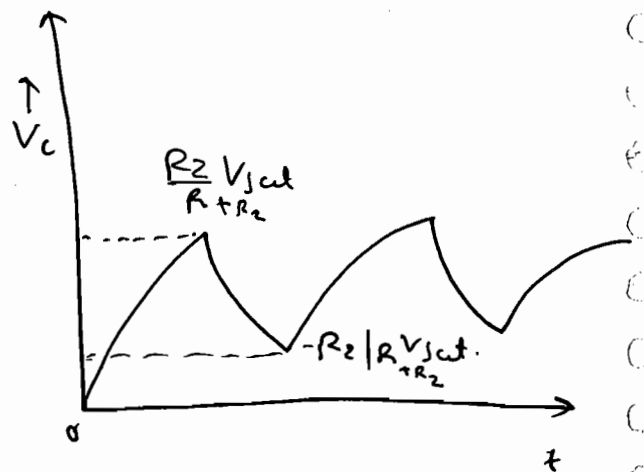
$$\text{at } t=\infty$$

$$\therefore \boxed{V_c(\infty) = A}$$

$$\therefore B = (A + B) - A$$

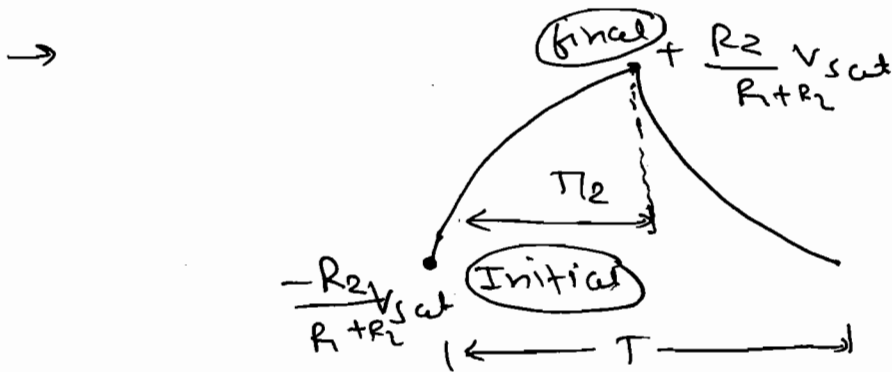
$$\therefore B = V_c(0) - V_c(\infty)$$

$$\therefore V_c(t) = [V_c(0) - V_c(\infty)] e^{-t/\tau} + V_c(\infty)$$



$$\Rightarrow V_c(t) = [V_c(0) - V_c(\infty)] e^{-t/\tau} + V_c(\infty).$$

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$$\Rightarrow V_c(t) = [V_c(0) - V_c(\infty)] e^{-t/\tau} + V_c(\infty).$$

$$\therefore V_c(t) = \left[-\frac{R_2 V_{sat}}{R_1 + R_2} - V_{sat} \right] e^{-t/\tau} + V_{sat}.$$

$$\text{At } t = T/2, \quad V_c(t) = \frac{R_2}{R_1 + R_2} V_{sat}.$$

$$\therefore \frac{R_2}{R_1 + R_2} V_{sat} - V_{sat} = \left[-\frac{R_2 V_{sat}}{R_1 + R_2} - V_{sat} \right] e^{-T/2\tau}.$$

$$\therefore \frac{R_2}{R_1 + R_2} - 1 = - \left[\frac{R_2}{R_1 + R_2} + 1 \right] e^{-T/2RC} \quad (\because \tau = RC).$$

$$\therefore \frac{R_1}{R_1 + R_2} = \frac{2R_2 + R_1}{R_1 + R_2} e^{-T/2RC}$$

$$\therefore e^{T/2RC} = \frac{2R_2 + R_1}{R_1}.$$

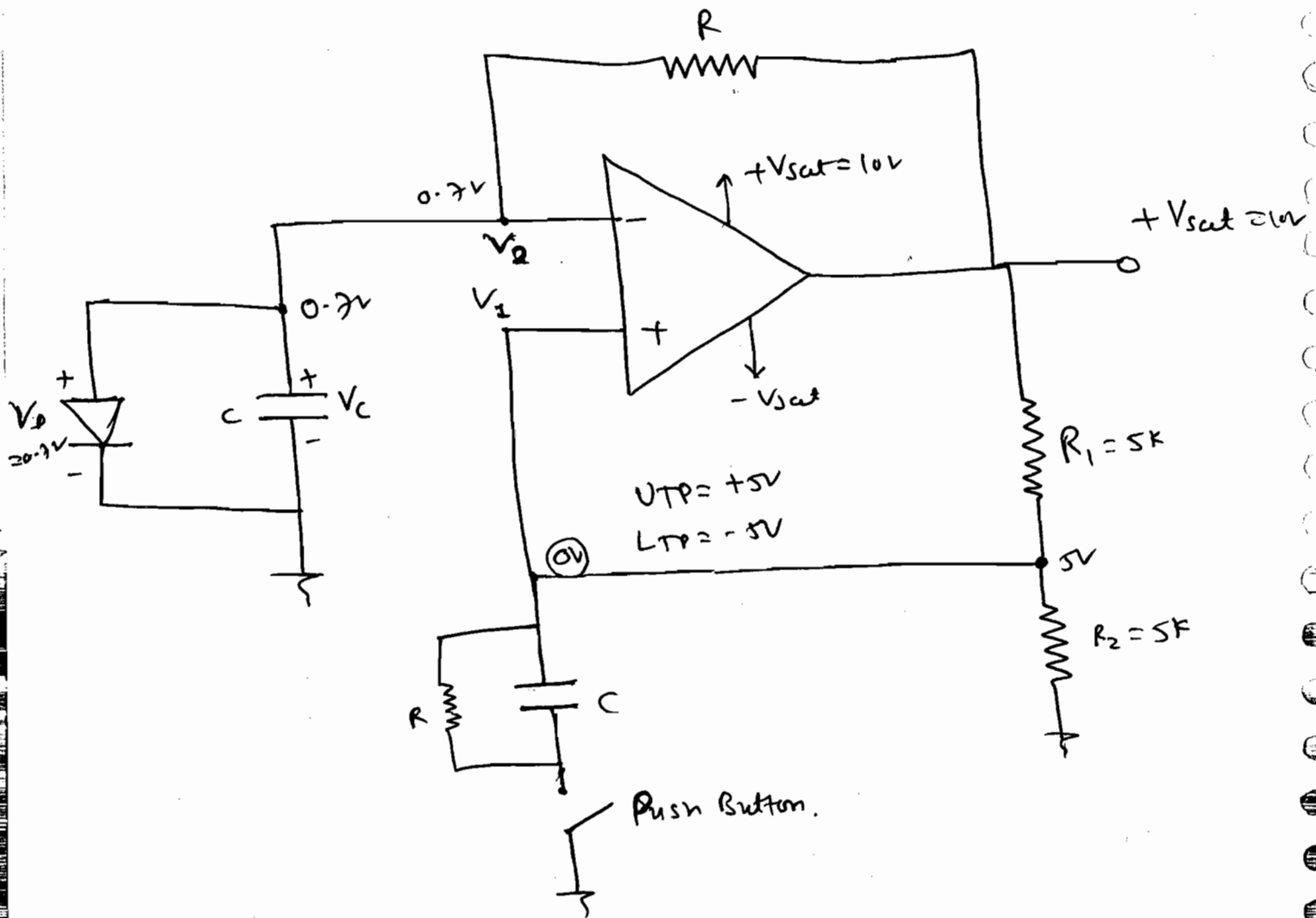
$$\therefore \frac{T}{2RC} = \ln \left(1 + \frac{2R_2}{R_1} \right)$$

$$\therefore T = 2RC \ln \left(1 + \frac{2R_2}{R_1} \right).$$

$$\therefore T = -2RC \ln \left[\frac{R_1}{R_1 + 2R_2} \right].$$

★ Monostable

Multivibrators



→ ~~Let~~ In order to understand operation of monostable multivibrator let's take one practical application:

→ Let, there is one coffee machine. In that there is one push button. Now, when customers want to a cup of coffee they have to push that button. Once the cup will full with the coffee, machine will automatically stop to give more coffee. and after that coffee machine will come in its initial state.

⇒ Now, another customer come do same thing to get a cup of coffee.

⇒ For this application we use monostable multivibrator. We can get monostable multi from Astable multi by making two changes as shown in figure with red mark.

⇒ Now, assume machine is in its initial state. i.e. O/P at OP-Amp $V_o = +V_{sat} = 10V$ therefore, voltage at $V_1 = +5V$ (By voltage divider rule).

→ Now, As $V_o = +V_{sat} = 10V$. Diode D is F.B. and voltage at $V_2 = 0.7V$.

⇒ Now, as $V_1 > V_2$ output stays $+V_{sat}$.

⇒ Now, one customer come and push the button to get a cup of coffee.

For this purpose (or) function we put a switch across V_1 along with tank circuit. i.e. we ~~connect~~ give a trigger.

⇒ As when customer press the button,

voltage at V_1 becomes 0V and

$V_1 < V_2$ and output switch from $+V_{sat}$

to $-V_{sat}$. As $V_o = -V_{sat}$, $V_1 = -5V$, diode is off (R.B.) and capacitor charge.

$0.7V$ to $-V_{sat}$ ($-5V$).

→ when cup is full coffee

→ when $V_2 > V_1$ i.e. $V_2 > -5$

→ When $V_2 < V_1$ i.e. $V_2 < -5$ then.

(Cup is full with coffee) then $V_1 - V_2 > 0$

and output switch from $-V_{sat}$ to $+V_{sat}$.

and machine will come into its initial state and stop to give more coffee.

→ As $V_0 = +V_{sat}$, $V_1 = +5V$ and $V_2 = V_C = 0.7V$
($\therefore$ Dis on).

→ Now, next customer will come and press the button to get coffee and cycle repeats.

$\Rightarrow$ During understanding the operation following two questions will arise in our mind.

Q-① Why should we put a tank RC ckt instead of giving direct ground?

Ans: Answer is simple.

→ If we give direct ground then

$$V = 0 \Rightarrow R = 0 \text{ and } I = V/R \Rightarrow I = V/0$$

$\Rightarrow I = \infty$. Therefore, very large current will flow by given direct ground.

→ Therefore the customer will get

bire instead of coffee (☹️).

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⇒ Now, we put RC tank circuit.

When $V_{sat} = +10V$, $V_1 = +5V$ and capacitor starts charging. When we push the button then capacitor will ground and discharge through a resistor slowly. and no large current will flow. Now, we get coffee instead of bire. (☹️).

Q-2 Why should we place a Diode across a capacitor in non-inverting terminal?

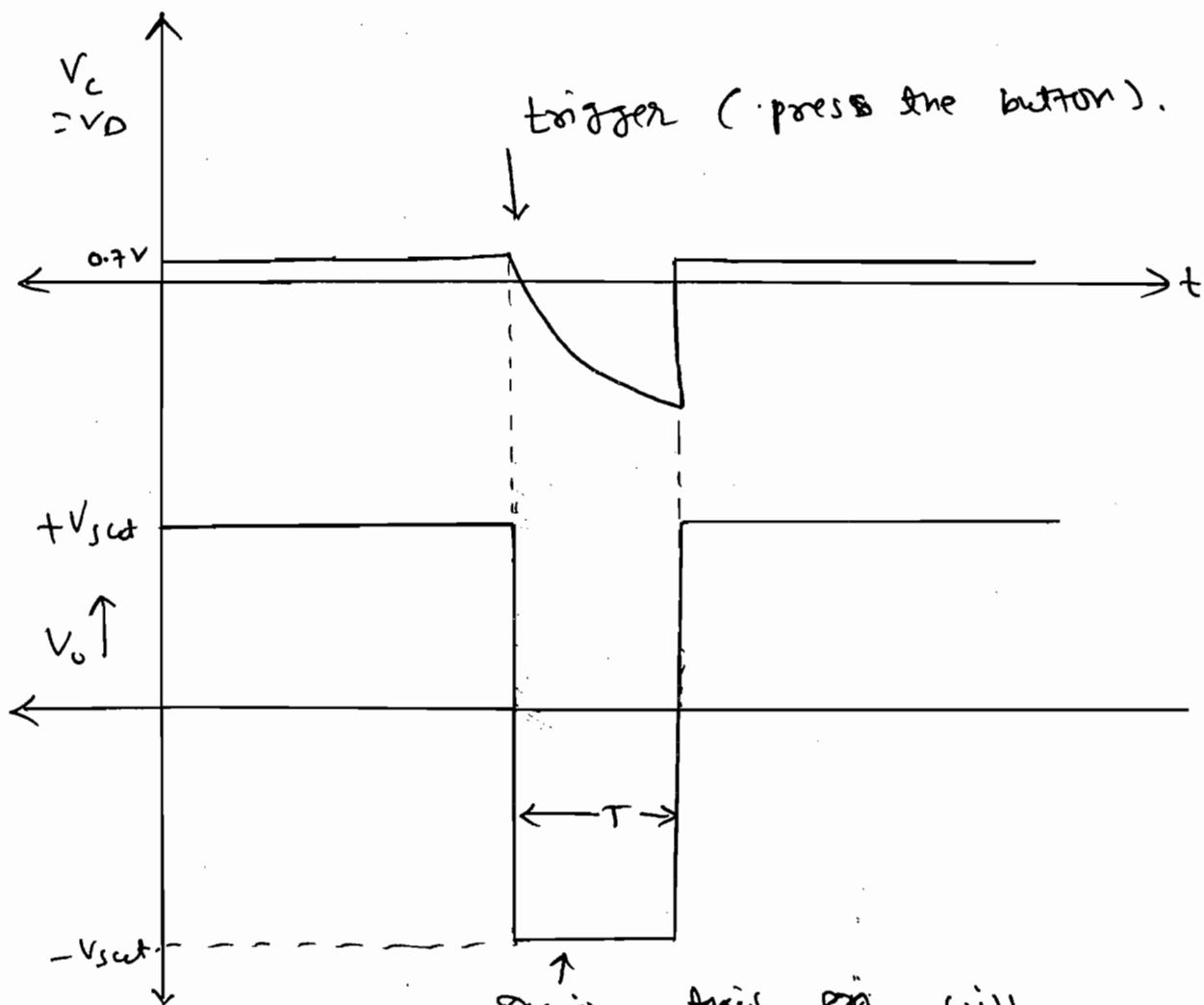
Ans: Answer of this question is also very simple.

→ If we don't put a Diode then following thing can be done.

When $V_{sat} = +10V$. Then capacitor charge from 0 to +5 V. one trigger is given.

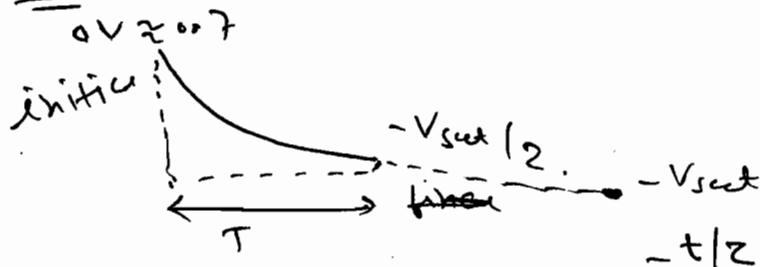
$V_1 = 0$ and $V_2 > V_1$ so, output switch from + V_{sat} to - V_{sat} and capacitor charge from +5 to -5. So, first customer will come and get coffee after that machine will stop. But as soon as V_2 exceed V_1 then $V_o = +V_{sat}$ to - V_{sat} and coffee will come again without pressing a button.

→ After one push, it becomes square wave generator. So, coffee will come after successive time. and second customer will be soaked that coffee is coming for a short period of time and then stop and then again come. The He ~~thought~~ will think that is there any ghost? 😊.



During this ~~on~~ will
After T time cup is full
with coffee and machine stop.

Time period:



$$V_c(t) = [V_c(0) - V_c(\infty)] e^{-t/\tau} + V_c(\infty).$$

$$\therefore V_c(t) = [0.7 + V_{sat}] \cdot e^{-t/\tau} - V_{sat}$$

$$\text{at } t = \tau, V_c(t) = -V_{sat}/2$$

$$\therefore -\frac{V_{sat}}{2} = [0.7 + V_{sat}] \cdot e^{-T/\tau} - V_{sat}$$

$$\text{take } 0.7 \approx 0.$$

$$\therefore \frac{V_{sat}}{2} = V_{sat} \cdot e^{-T/\tau}$$

$$\therefore e^{T/\tau} = 2$$

$$\therefore \frac{T}{\tau} = \ln 2$$

$$\therefore T = RC \ln 2$$

$$\therefore T = 0.69 RC$$

$$\boxed{\text{Pulse width } T = 0.69 RC}$$

→ i.e. How much coffee will fall into the cup is decided by pulse width $T = 0.69 RC$.

NOTE:

OP-AMP

+ve terminal for Voltage summing.

-ve terminal for current summing.

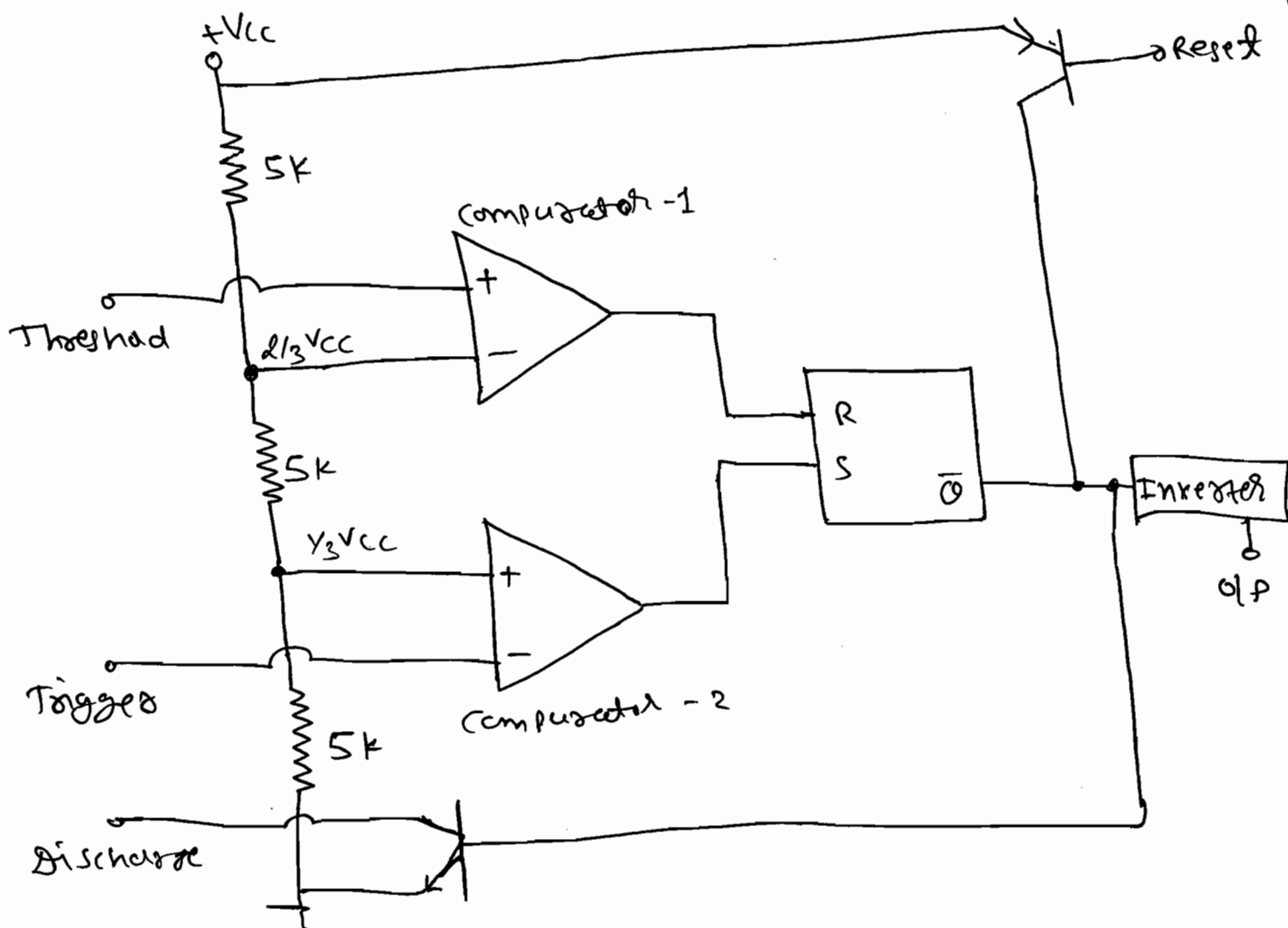
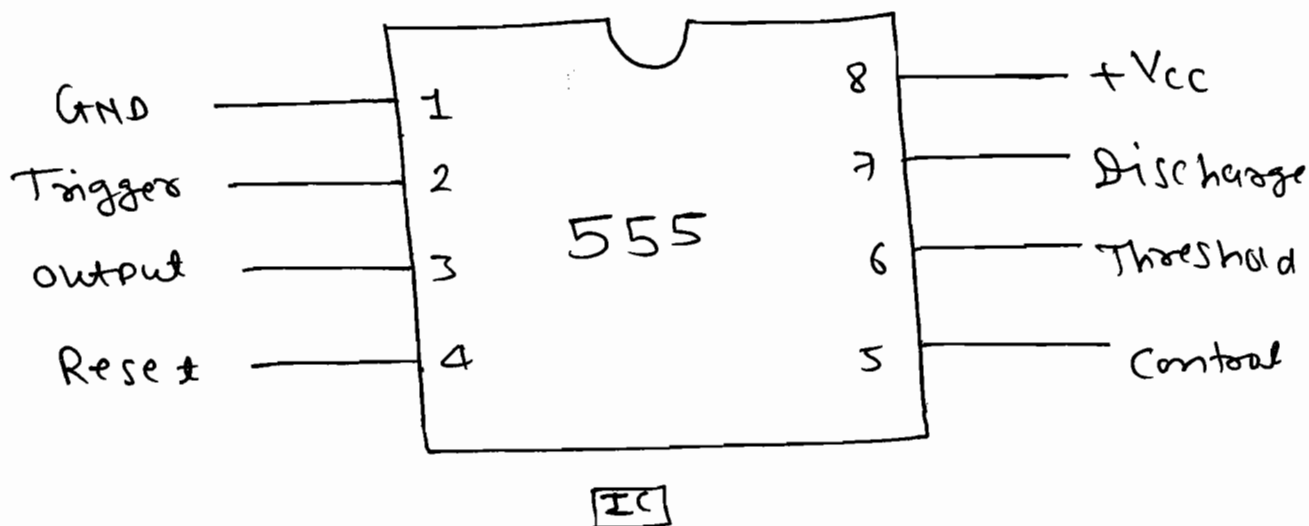
~~XXXXXXXXXX~~



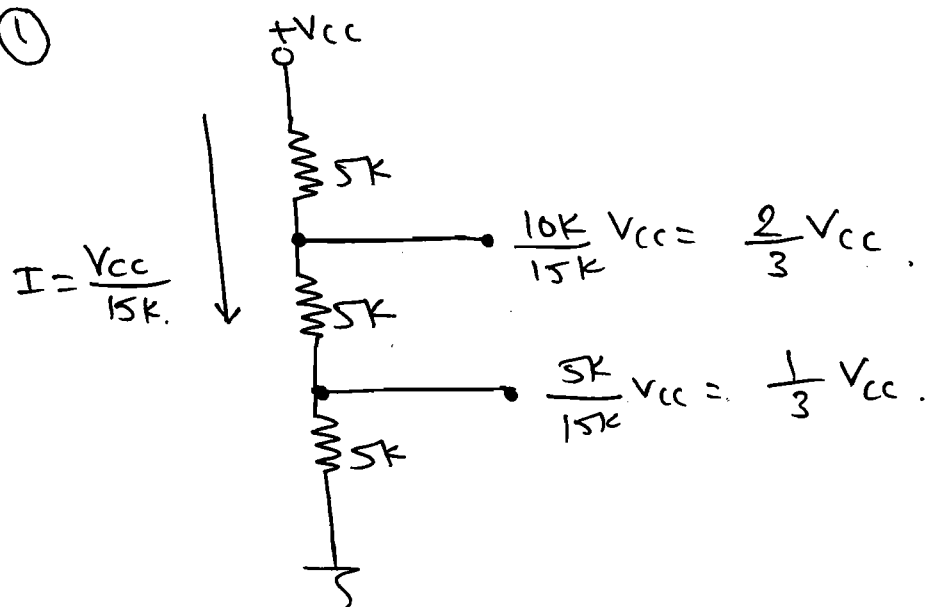
Multi Vibrators

Using 555 timer :-

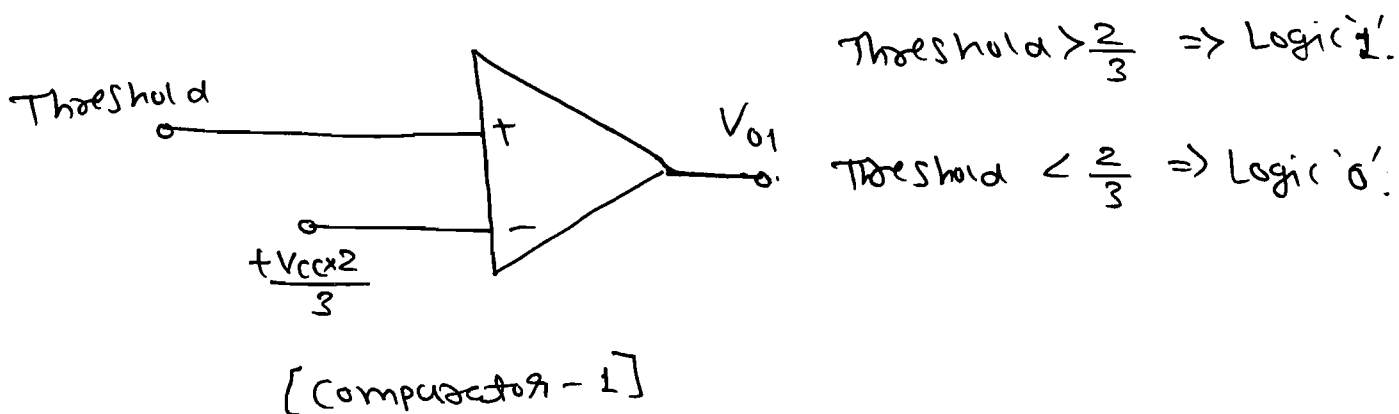
* 555 timer:



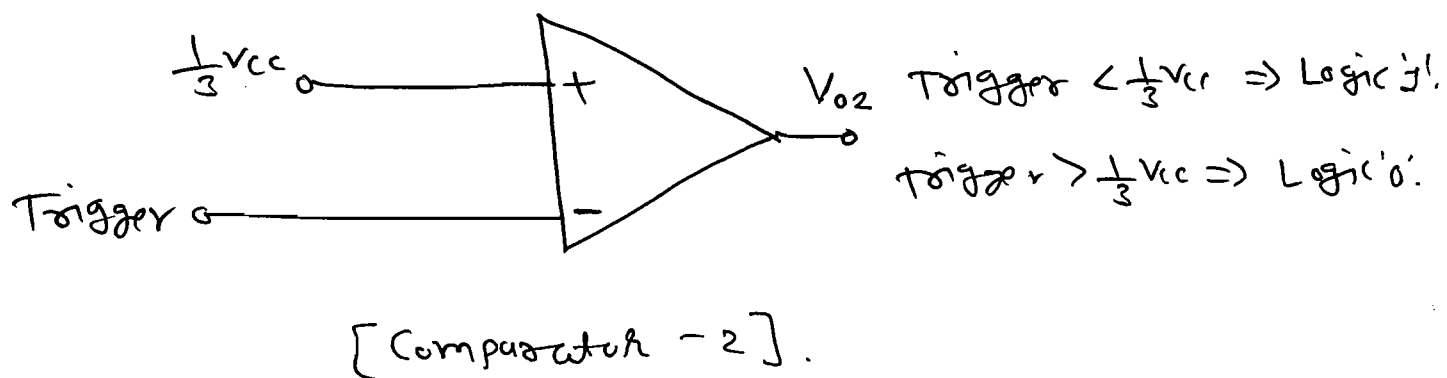
①



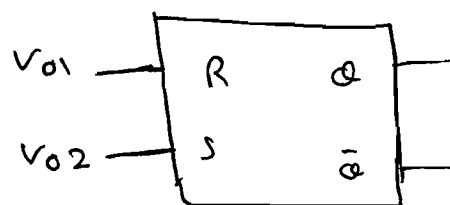
②



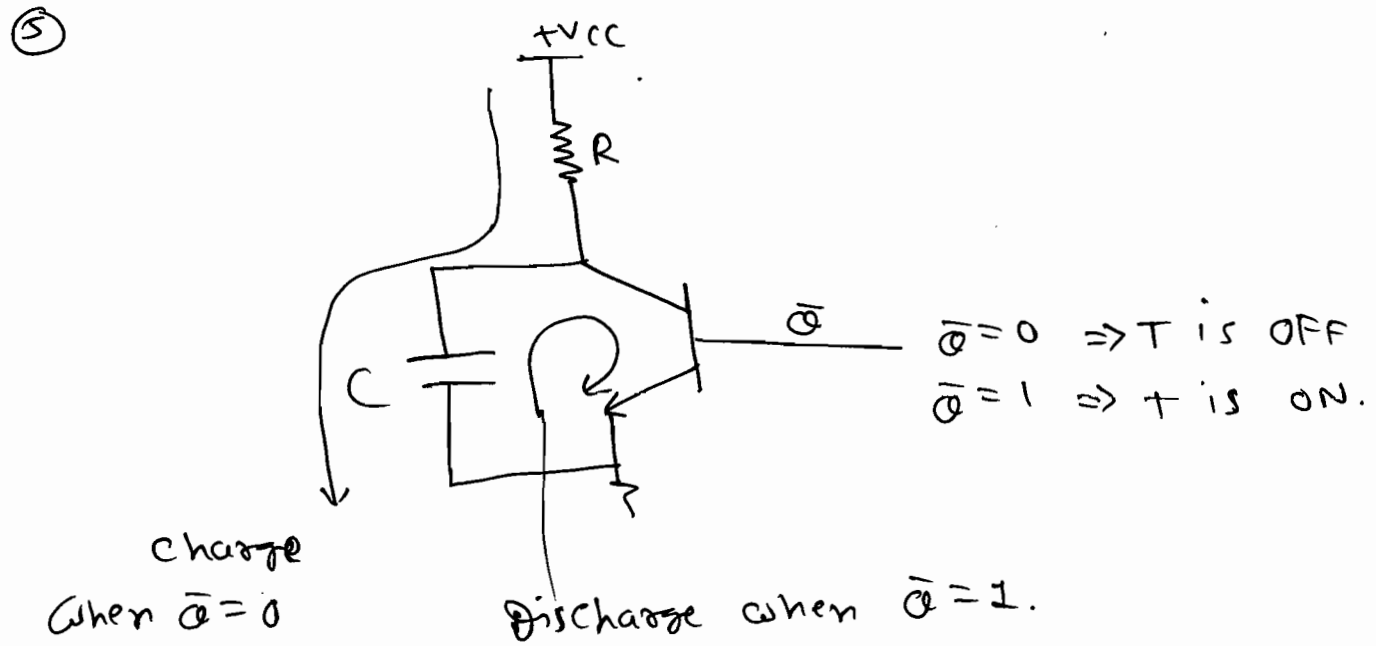
③



④

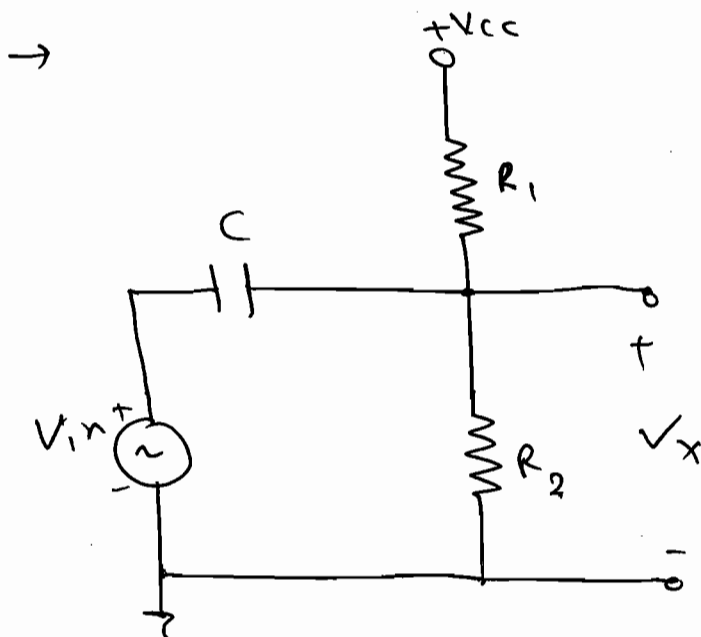
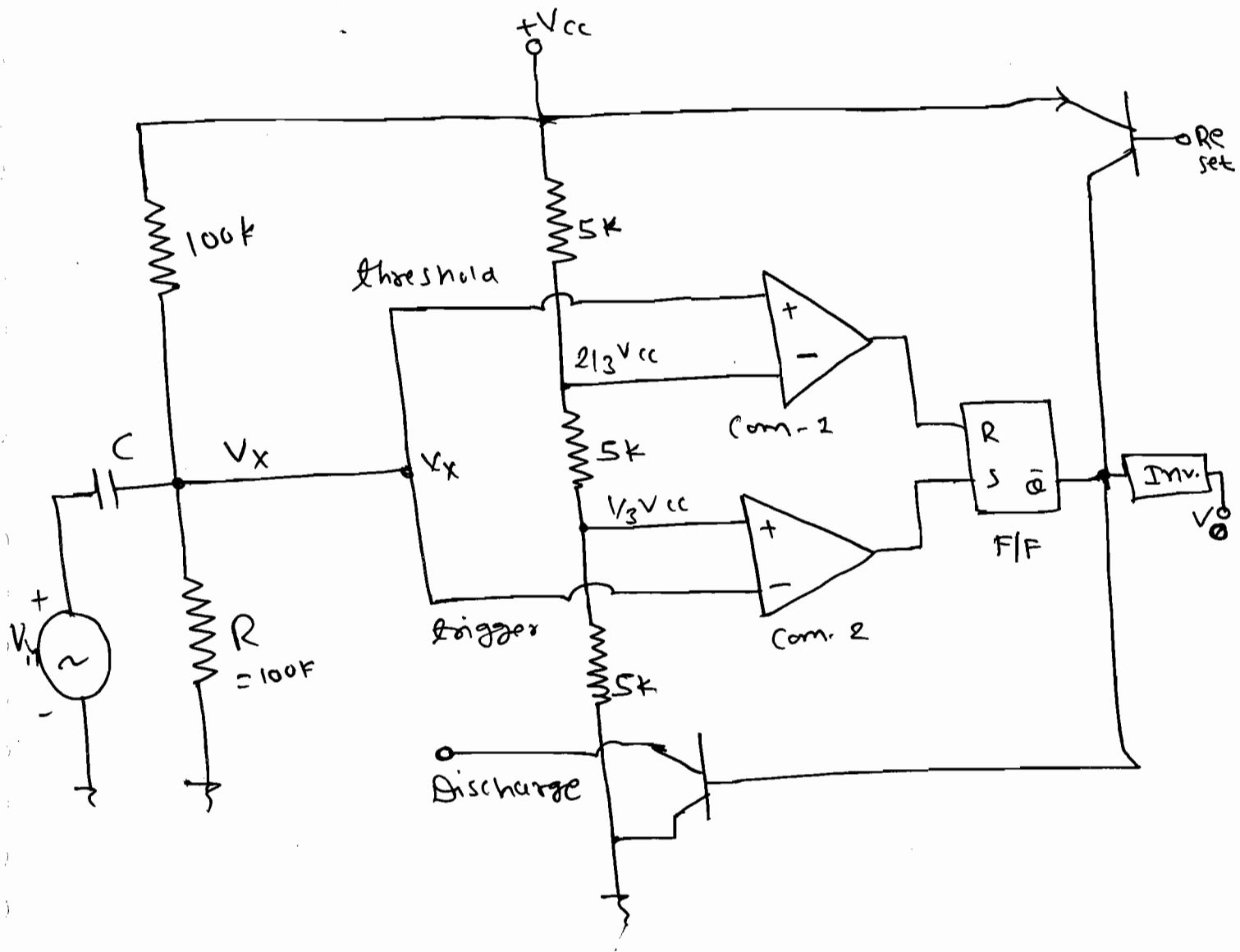


R	S	$\overline{Q}$	$0 P=Q$
0	0	previous	
0	1	0	1
1	0	1	0
1	1	Don't log.	



* Schmitt Trigger using 555 Timer:-

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$$V_x = \frac{R_2 V_{cc}}{R_1 + R_2} + V_{in}$$

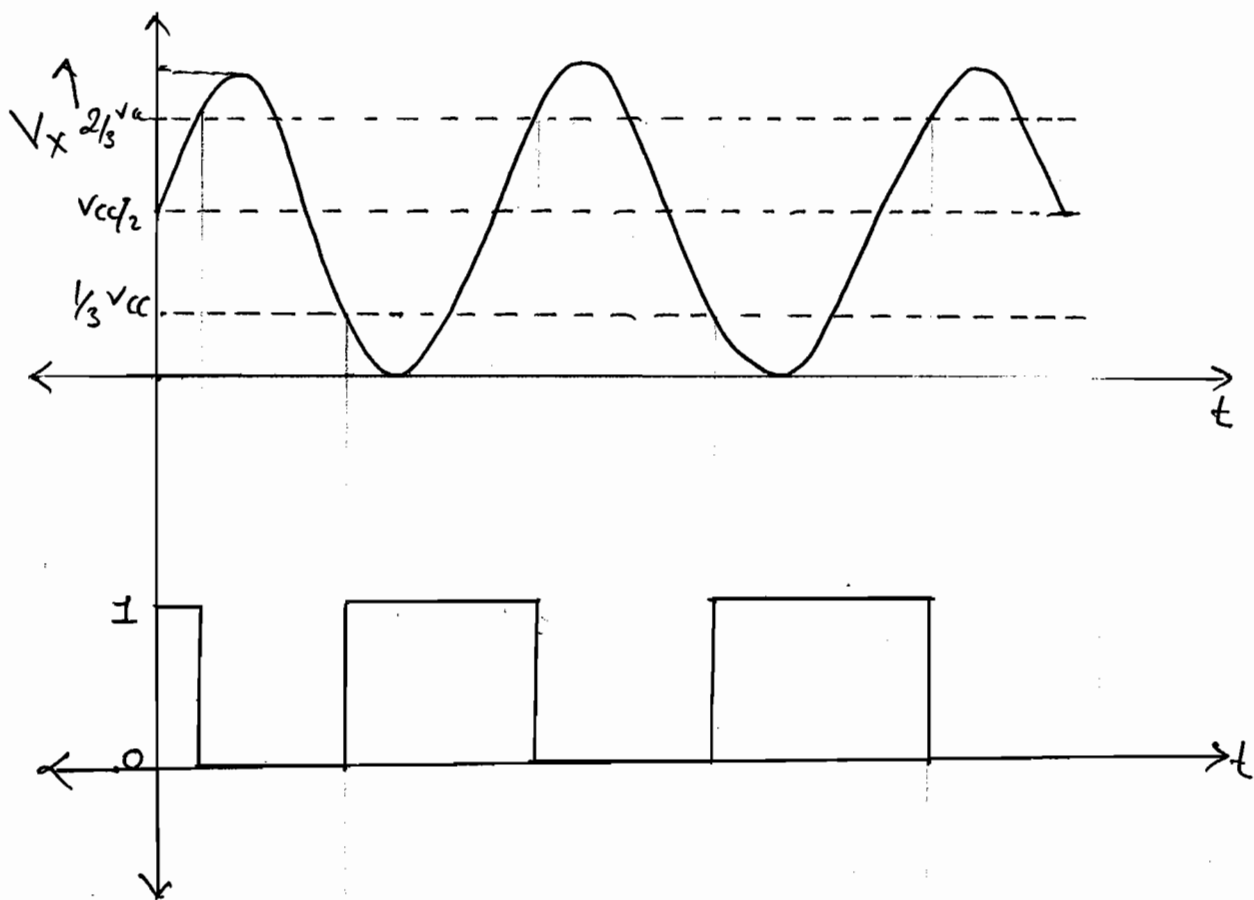
↑
DC picture.

↑
AC picture.

when $R_1 = R_2$

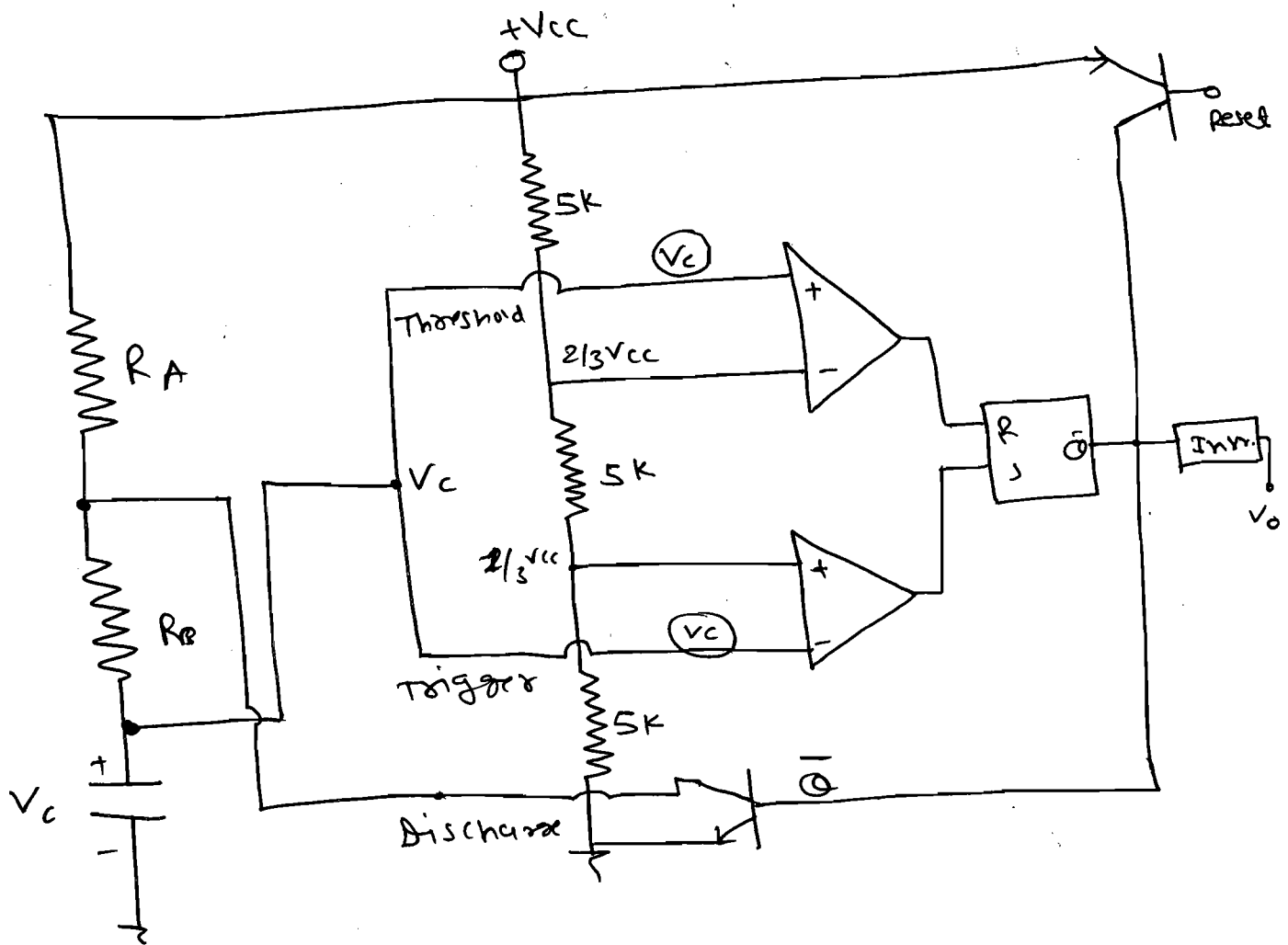
$$V_x = \frac{V_{cc}}{2} + V_{in}$$

	R	S	$\bar{Q}$	Q = 0 P
$V_X = 0$	0	1	0	1
$V_X = \frac{V_{CC}}{2}$	0	0	0	1 (previous)
threshold $> \frac{2}{3} V_{CC}$ $V_X > \frac{2}{3} V_{CC}$	1	0	1	0
$V_X = \frac{2}{3} V_{CC}$	0	0	1	0 (previous)
$V_X < \frac{1}{3} V_{CC}$ trigger $< \frac{1}{3} V_{CC}$	0	1	0	1



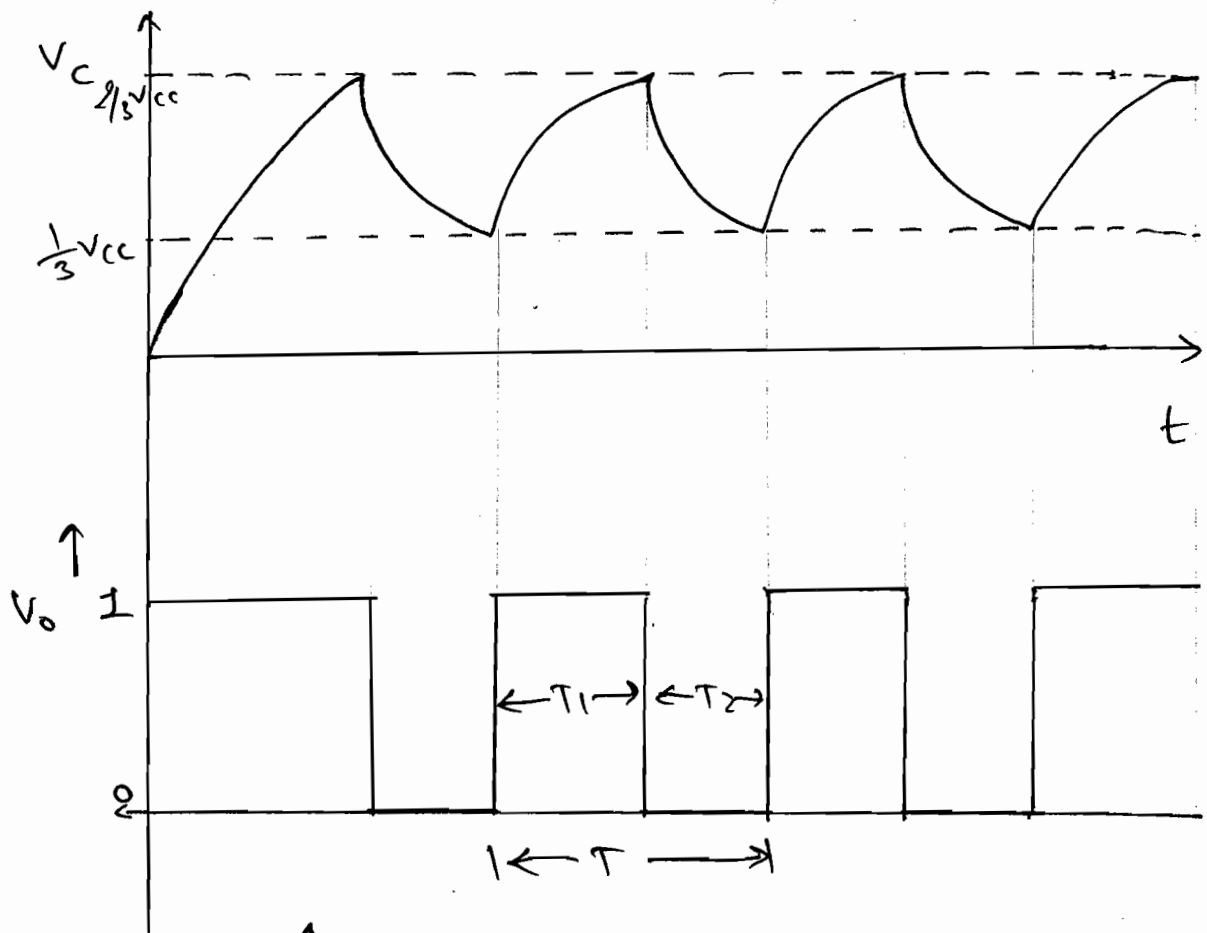
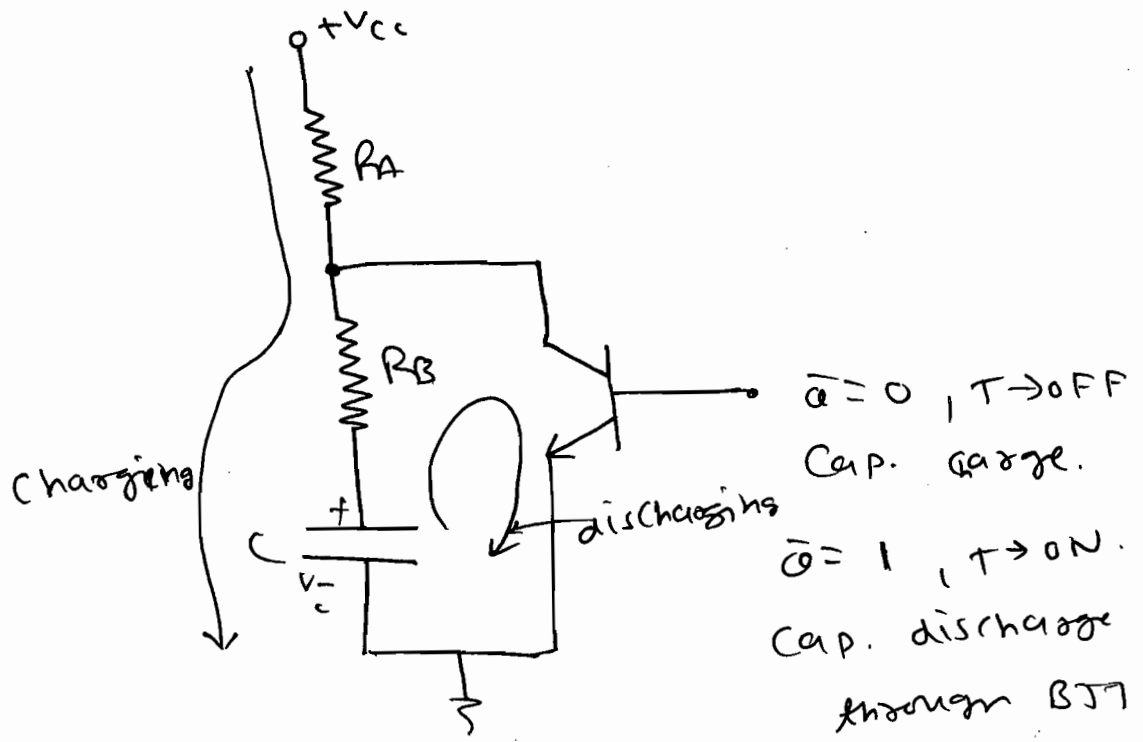
[Square wave].

* Astable Multivibrator using 555 timer: 93

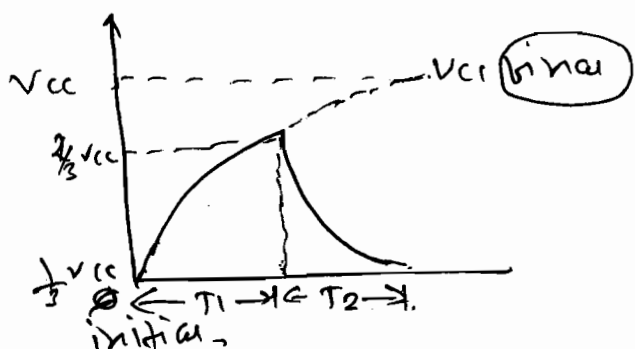


	R	S	$\bar{Q}$	Q	
$V_C = 0$	0	1	0	1	Transistor OFF, Capacitor charge.
$V_C > \frac{1}{3} V_{CC}$	0	0	0	1	Transistor OFF, Capacitor charge.
$V_C > \frac{2}{3} V_{CC}$	1	0	1	0	Transistor ON, Capacitor discharge.
$V_C < \frac{1}{3} V_{CC}$	0	1	0	1	Transistor OFF, Capacitor discharge.

⇒



*



$$V_c(t) = [V_{initial} - V_{final}]e^{-t/\tau} + V_{final}$$

$$\therefore V_c(t) = \left[\frac{1}{3} V_{cc} - V_{cc} \right] \cdot e^{-t/\tau} + V_{cc}.$$

$$\text{at } t = T_1 \quad V_c(t) = \frac{2}{3} V_{cc}.$$

$$\therefore \frac{2}{3} V_{cc} = -\frac{2}{3} V_{cc} \cdot e^{-T_1/\tau} + V_{cc}.$$

$$\therefore -\frac{1}{3} V_{cc} = -\frac{2}{3} V_{cc} \cdot e^{-T_1/\tau}$$

$$\therefore e^{-T_1/\tau} = \frac{1}{2}.$$

$$\therefore \frac{T_1}{RC} = \ln 2.$$

$$\therefore \boxed{T_1 = 0.69 RC.}$$

→ The charging time const. = $(R_A + R_B)C$.

∴ Similary discharging time const. = $R_B C$.

$$\therefore \boxed{T_1 = 0.69 (R_A + R_B)C.}$$

$$\therefore \boxed{T_2 = 0.69 R_B C.}$$

$$\therefore \text{Total } \boxed{T = T_1 + T_2.}$$

$$\text{Duty cycle} = \frac{T_{ON}}{T}$$

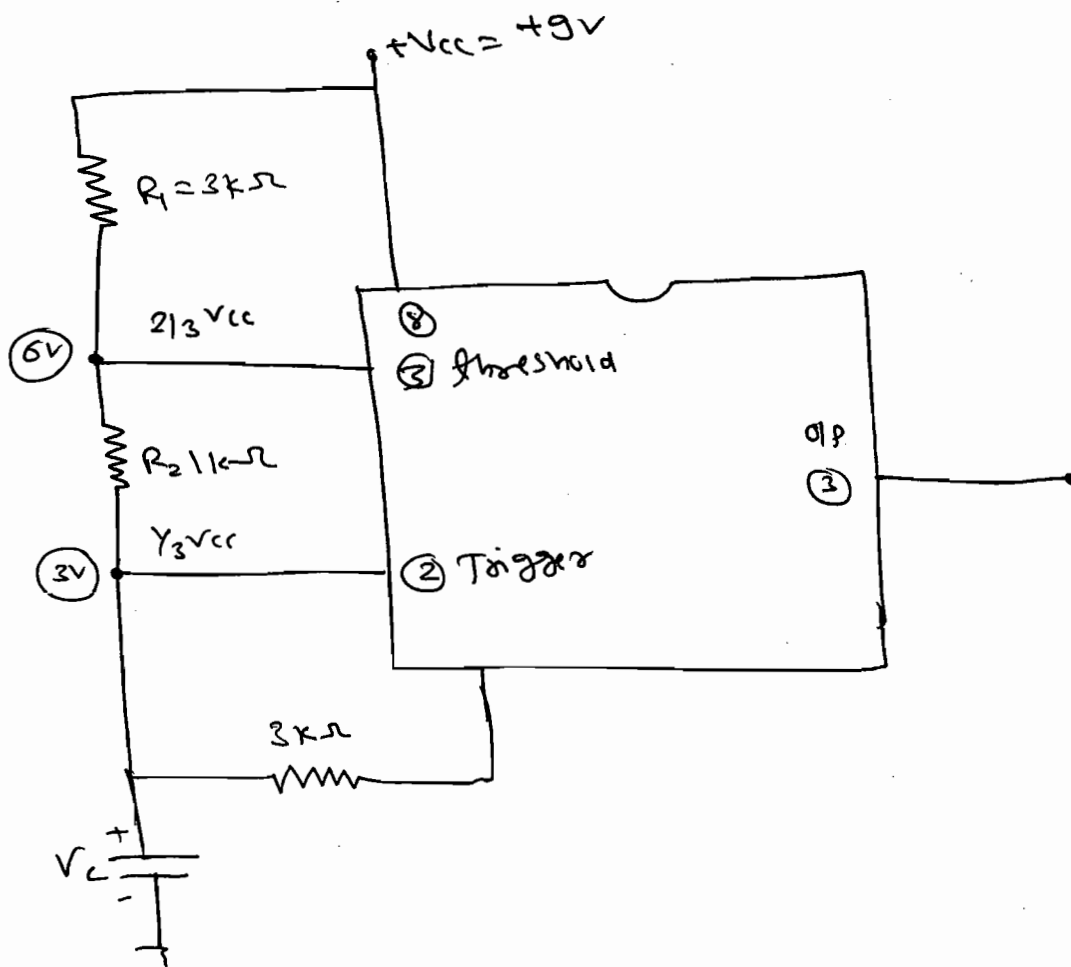
$$= \frac{0.69C(R_A + R_B)}{0.69C(R_A + 2R_B)}$$

$$\boxed{\text{Duty cycle} = \frac{R_A + R_B}{R_A + 2R_B}.$$

for 50% Duty cycle $R_A = 0 \Rightarrow D.C. = \frac{R_B}{2R_B} = 50\%.$

Ex-1 find the Range of Capacitor Voltage, V_C if the supply voltage is $+9V$ in the Astable multivibrator is given.

GATE:



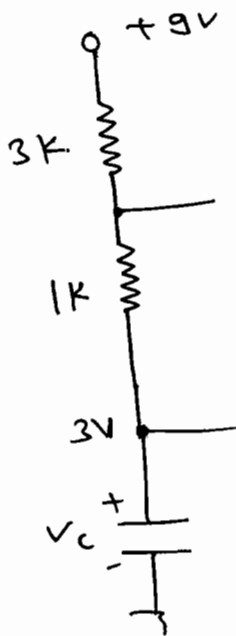
- (A) 3V to 6V.
 (B) 3V to 5V.
 (C) 3V to 4V.
 (D) None.

NOTE: A 555 timer change its states:

- ① when threshold just $> \frac{2}{3}V_{CC}$
 ② when trigger just $< \frac{1}{3}V_{CC}$.

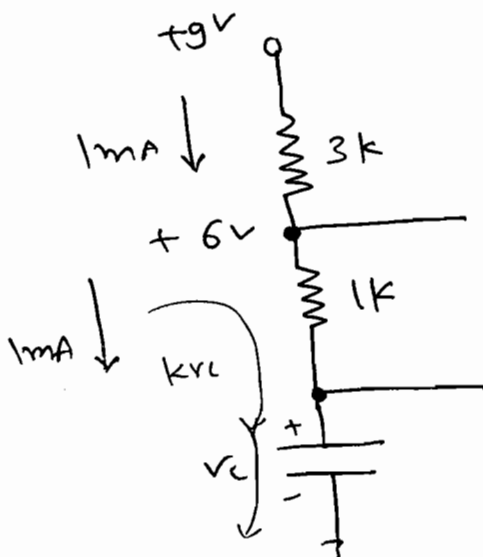
Solution:

① $V_{\text{trigger}} = \frac{1}{3}V_{CC} = 3V.$



$$\text{So, } V_c = 3V$$

② $V_{\text{threshold}} = \frac{2}{3} V_{cc} = \frac{2}{3} \times 9 = 6V.$



$$I = \frac{9 - 6}{3K} = 1mA$$

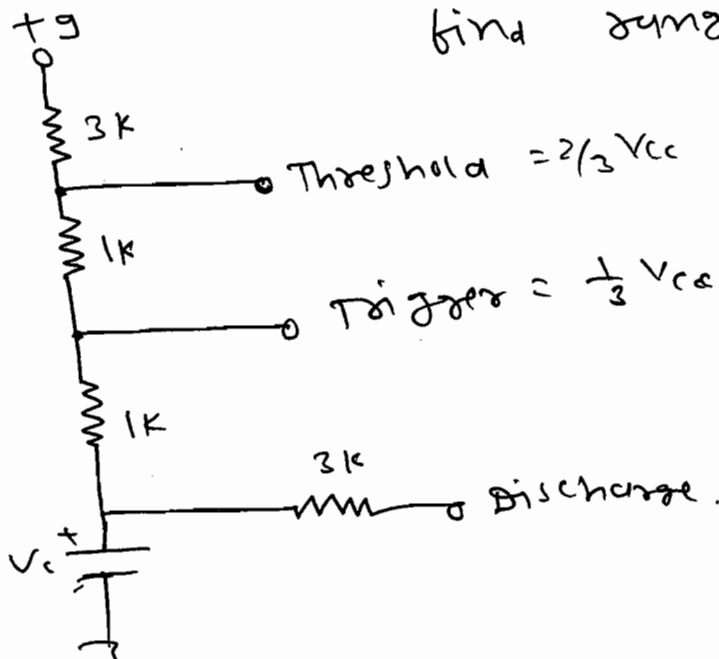
$$+6 - (1mA \times 1K) - V_c = 0$$

$$\therefore V_c = +5V$$

So, range of V_c is $3V \text{ to } 5V$

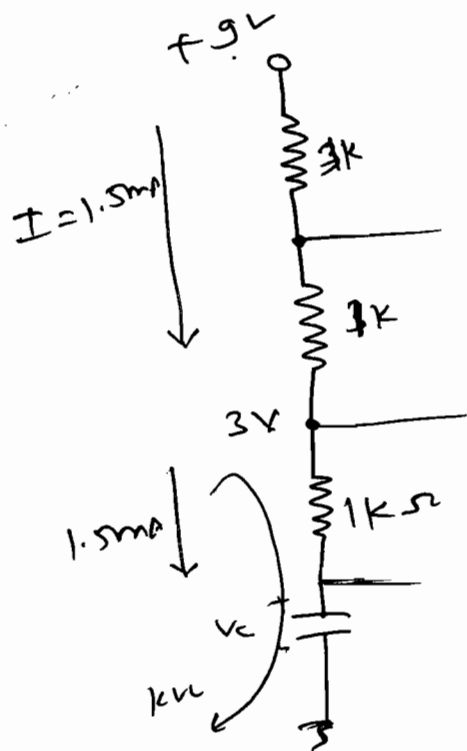
Ex-2

find range of V_c .



Ans:

① Trigger = $\frac{1}{3} V_{CC} = \frac{9}{3} = 3V$.



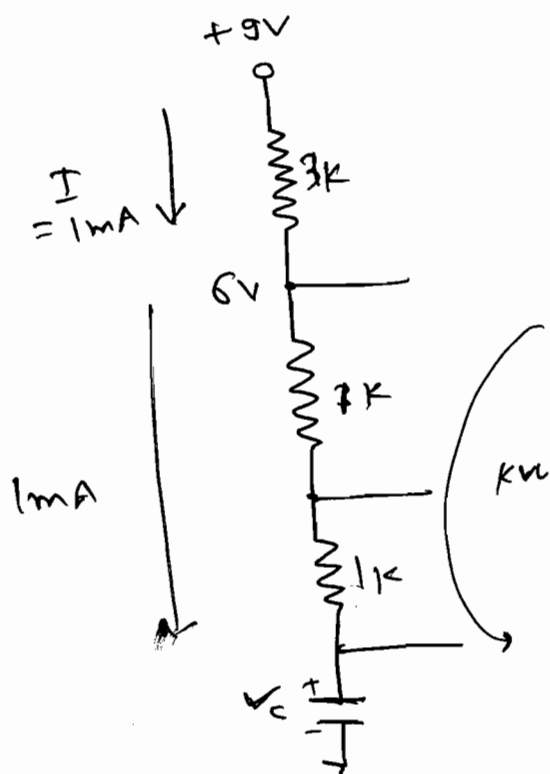
$$I = \frac{9-3}{(3+1)k} = \frac{6}{4}$$

$$I = 1.5mA$$

$$\therefore 3V - (1.5 \times 1) - V_c = 0$$

$$\therefore V_c = 1.5V$$

② Threshold = $\frac{2}{3} V_{CC} = \frac{2}{3} \times 9 = 6V$.

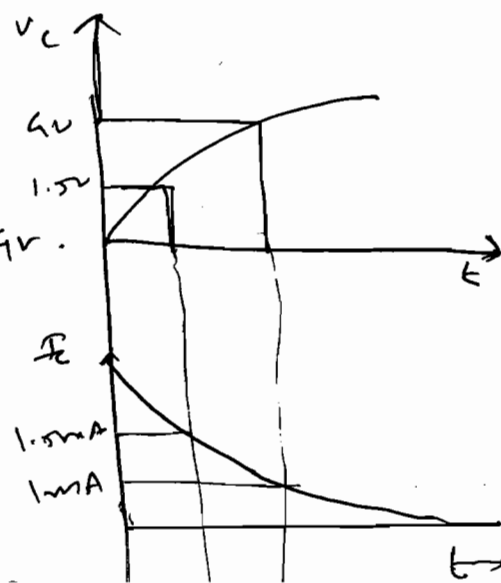


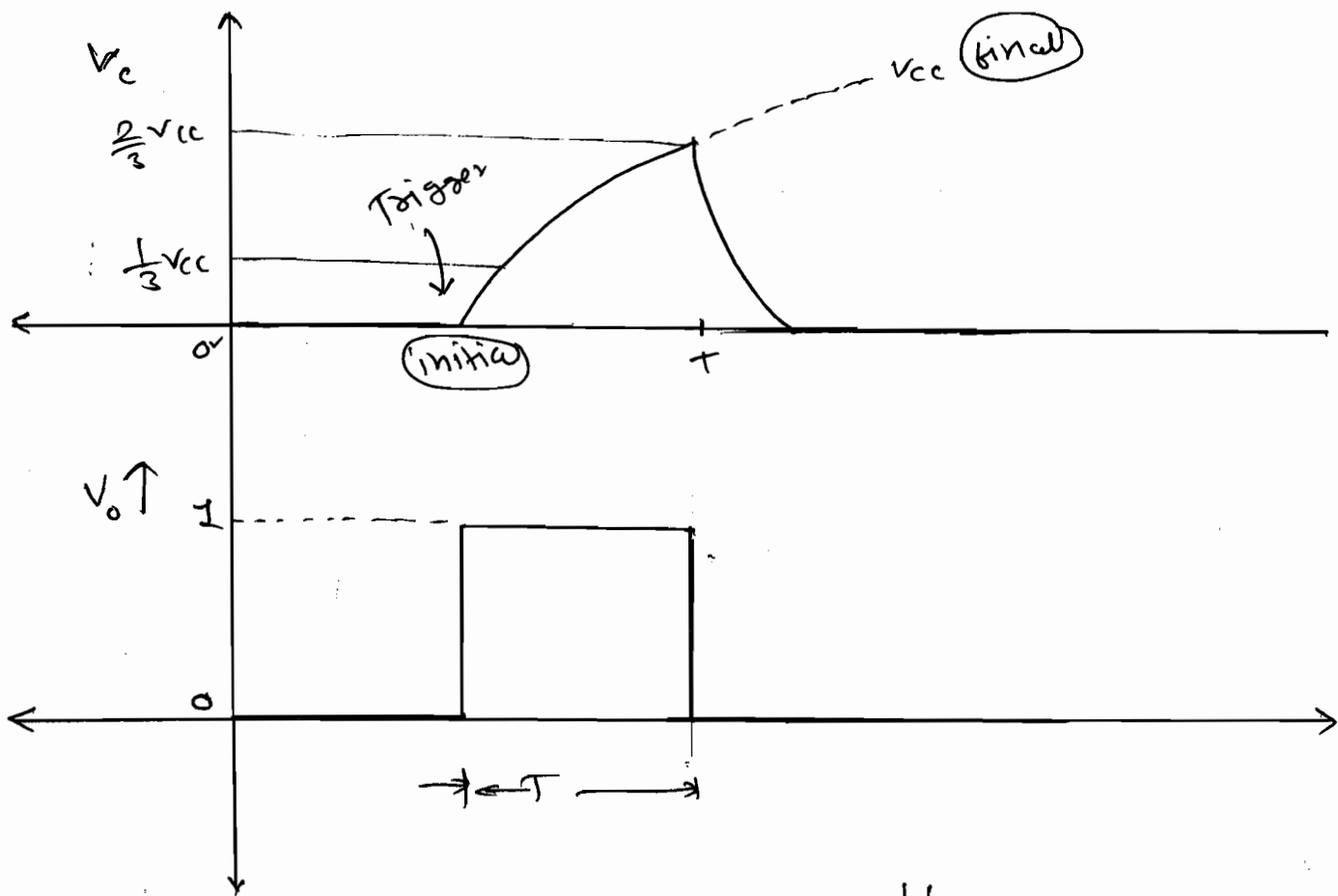
$$I = \frac{9-6}{1k} = 1mA$$

$$6 - (1 \times 1) - V_c = 0$$

$$V_c = 4V$$

So, range of V_c is 1.5 to 4V.





$$\rightarrow V_c(t) = [V_{c(\text{initial})} - V_{c(\text{final})}] \cdot e^{-t/\tau} + V_{c(\text{final})}$$

$$V_c(t) = \left[0 - \frac{2}{3}V_{cc} \right] \cdot e^{-t/\tau} + V_{cc}$$

$$\therefore V_c(t) = [0 - V_{cc}] \cdot e^{-t/\tau} + V_{cc} [1 - e^{-t/\tau}]$$

$$\text{at } t = T, \quad V_c(t) = \frac{2}{3}V_{cc}$$

$$\therefore \frac{2}{3}V_{cc} = V_{cc} [1 - e^{-T/\tau}]$$

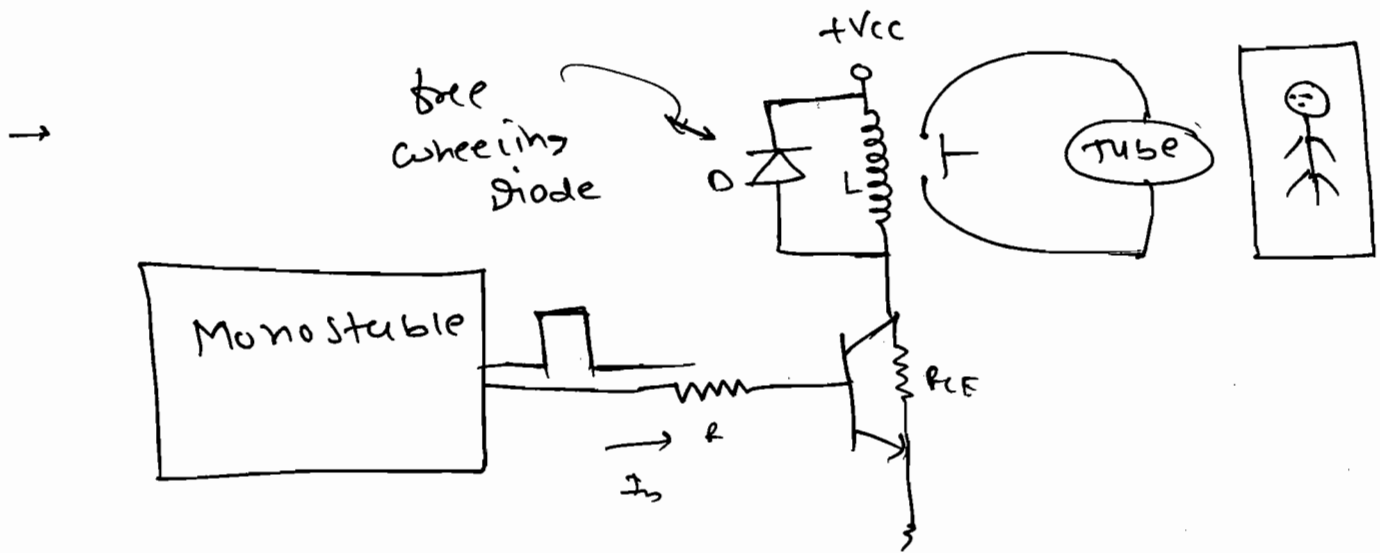
$$e^{-T/\tau} = 1 - \frac{2}{3}$$

$$e^{-T/\tau} = \frac{1}{3}$$

$$\therefore \boxed{T = 1.1RC}$$

* Application of Monostable multivibrator.

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⇒ never Open inductor never Short Capacitor directly.

→ Inductor never allow Sudden Change in Current and Capacitor never allow Sudden Change voltage.

→ Now, as pulse comes transistor is on over a period T which is on the X-ray machine and we will get X-Ray.

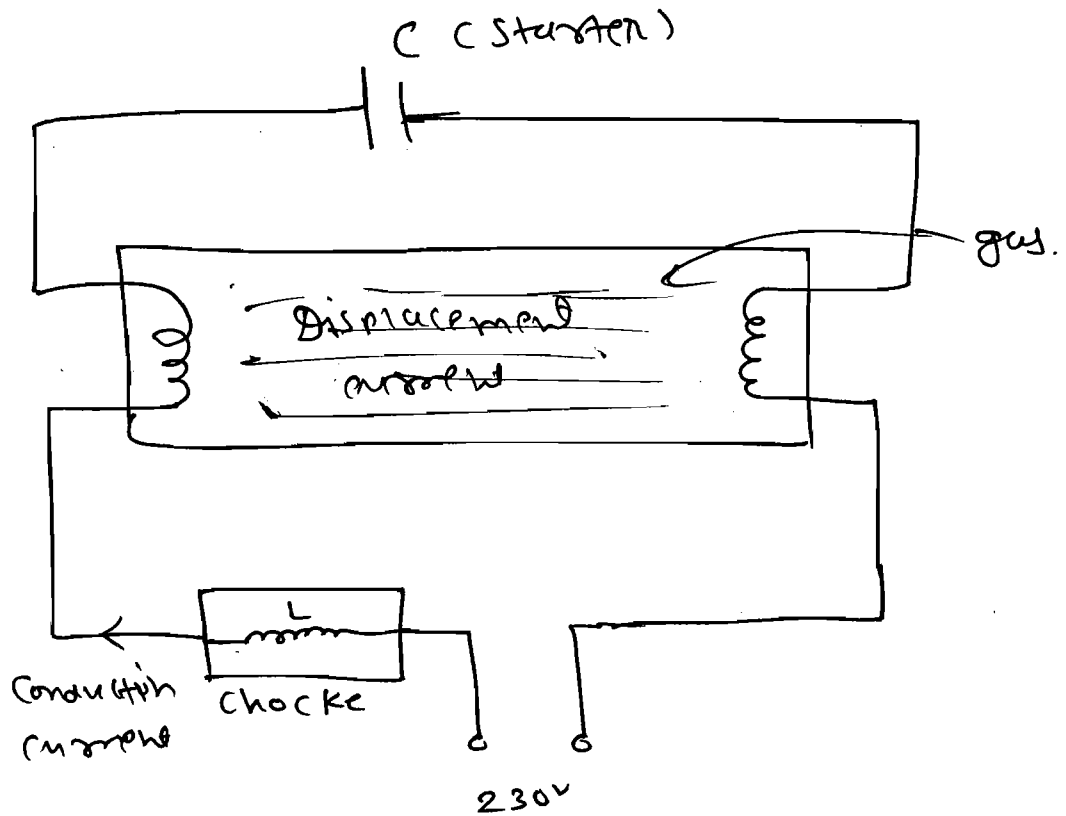
→ But when pulse fall from high to Low transistor is off and o.c. Therefore inductor current has no path to flow and generate a very large voltage.

$$V = L \frac{di}{dt} = \frac{1 \times 10^{-3} \times 1m}{10^{-9}} = 1000V. \text{ This voltage}$$

will damage the transistor every time. If diode is not put across the inductor.

→ Reverse Diode provide a closed loop to flow inductor current. And Diode is called free wheeling diode.

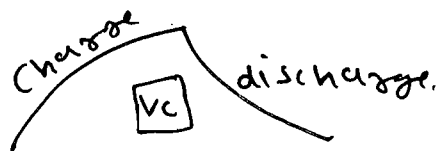
* Tubelight



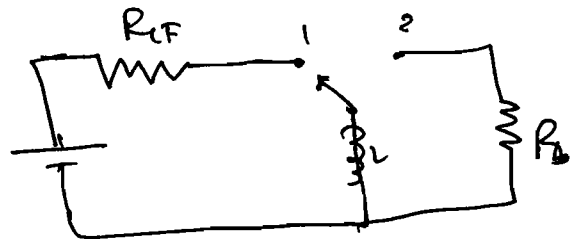
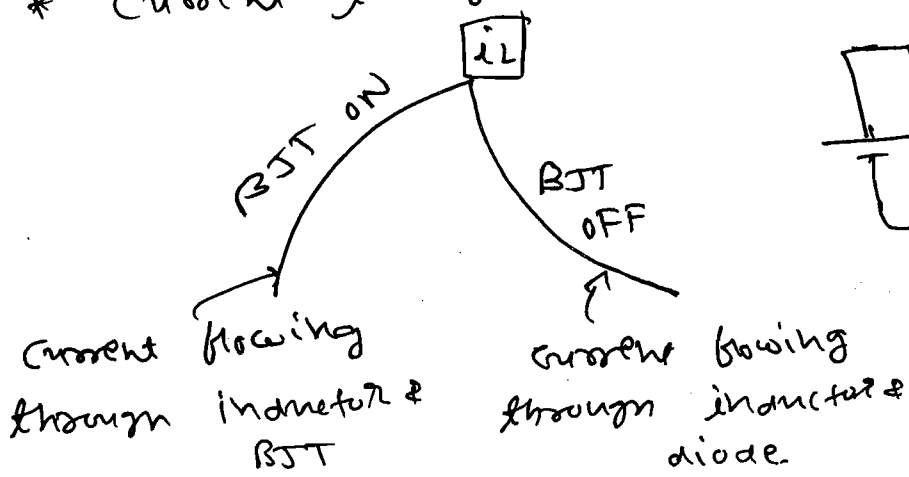
→ When capacitor o.c. then induction ~~current~~ voltage is very high. which is provided to gas inside the tube and light will be ~~on~~ blow.

→ capacitor is starter and inductor is choke.

* Voltage across Capacitor:



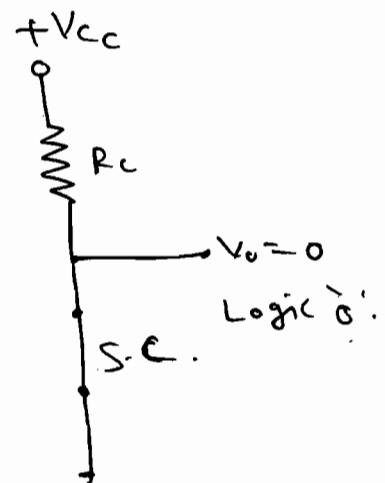
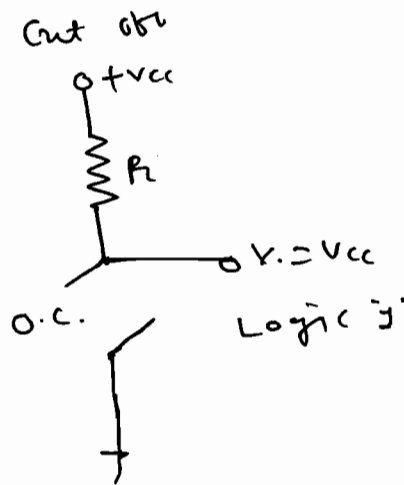
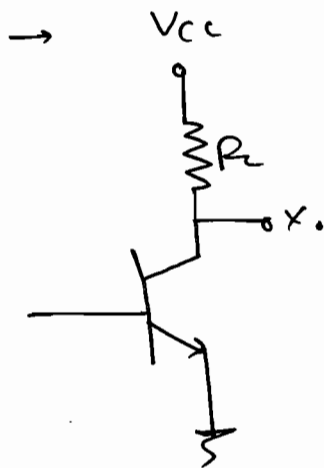
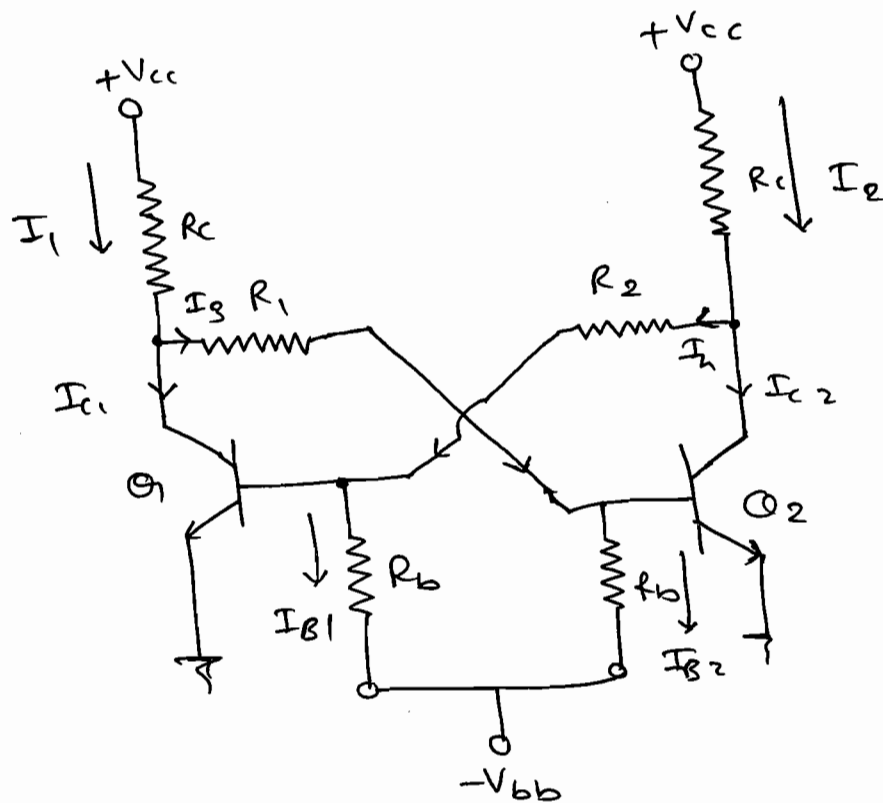
* Current through inductor.



★ Multivibrators Using BJT:

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① Bistable multivibrators:



$$\rightarrow I_1 = 1.000012 \text{ mA}$$

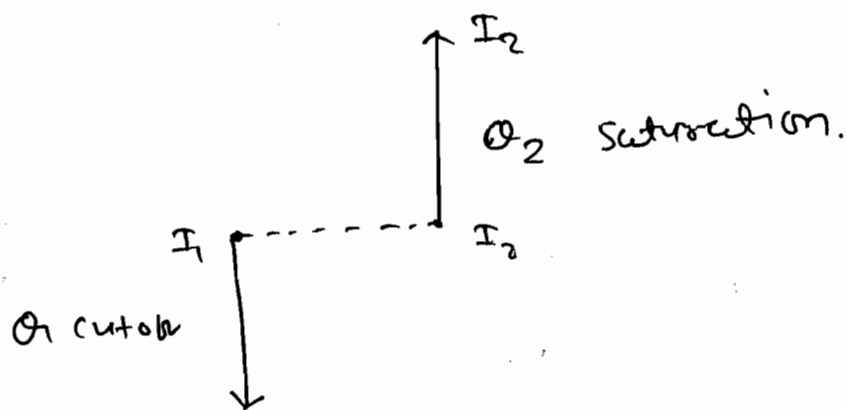
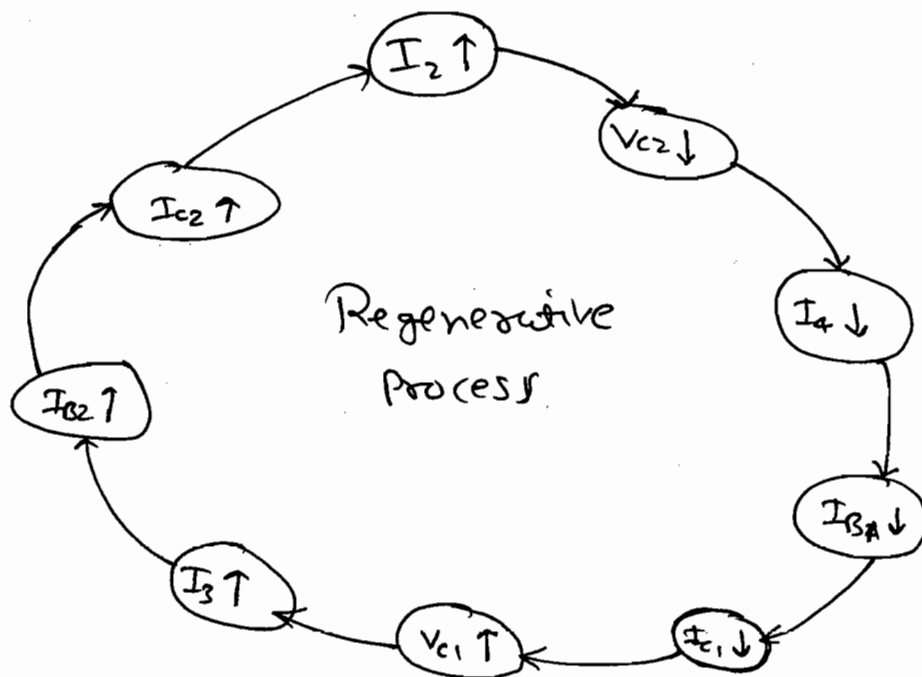
$$I_2 = 1.000013 \text{ mA}$$

$$I_2 > I_1$$

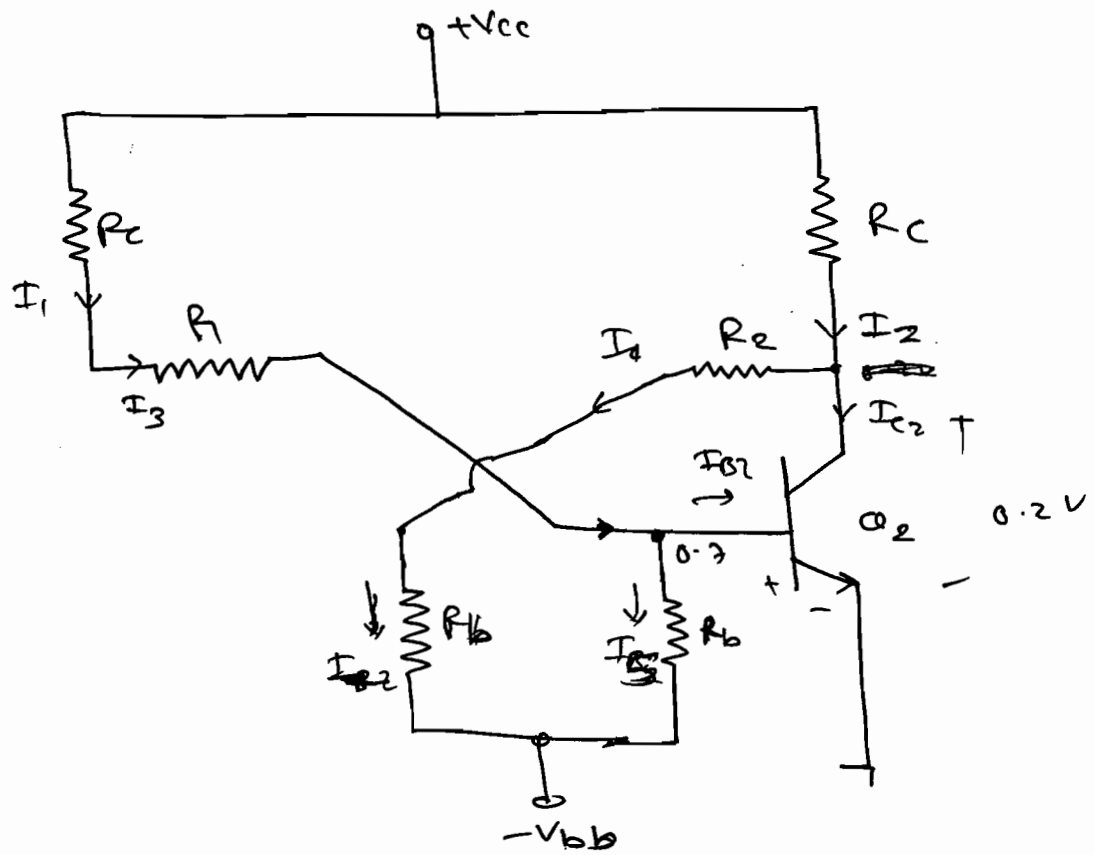
$$\therefore V_{c2} = V_{cc} - I_2 R_c \rightarrow V_{c1} = V_{cc} - I_1 R_c$$

∴ Let us assume,

$$V_{C2} = V_{CC} - I_2 R_C < V_{C1} = V_{CC} - I_1 R_C.$$



* Calculate the node voltages and branch current if Q₁ is in cutoff and Q₂ is in saturation.



$$\rightarrow I_{B2} = I_1 - I_3$$

$$I_{C2} = I_2 - I_4$$

$$\therefore I_1 = I_3 = \frac{V_{CC} - 0.7}{R_C + R}$$

$$\therefore I_2 = \frac{V_{CC} - 0.2}{R_C}$$

$$\therefore I_{B1} = I_{B2} = \frac{V_{C2} - (-V_{bb})}{R_B + R_1}$$

$$\text{But } I_5 = \frac{0.7 + V_{bb}}{R_B}$$

$\rightarrow Q_2$ is in saturation So,

$$\beta_{force} < \beta_{active}$$

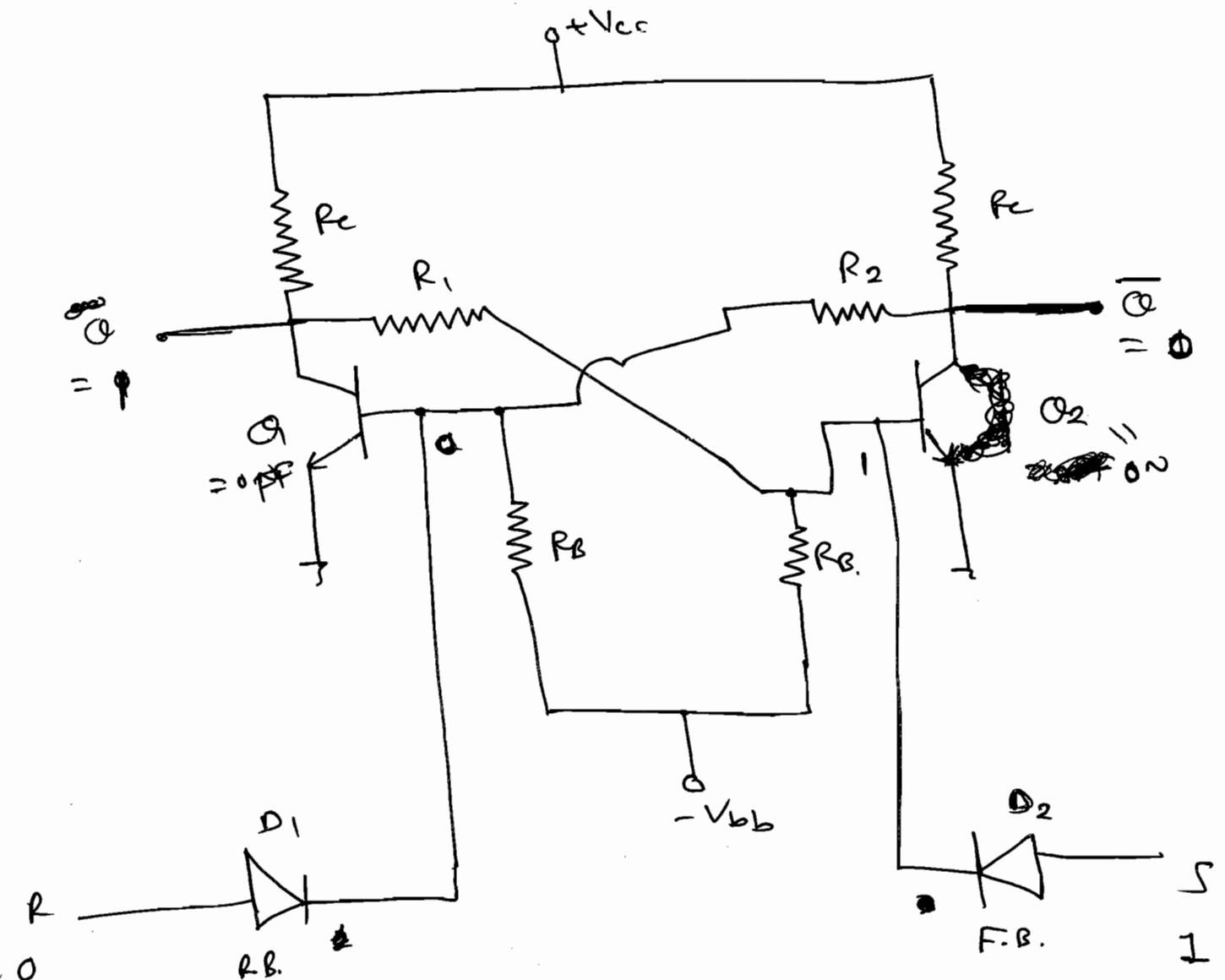
$$\therefore \left| \frac{I_{C2}}{I_{B2}} \right| < \beta_{active}$$

$$\left| \frac{I_2 - I_4}{I_1 - I_3} \right| < \beta_{\text{active}}$$

* TWO TYPES of Triggering & Bistable circuits:

- ① Asymmetrical triggering
- ② Symmetrical triggering.

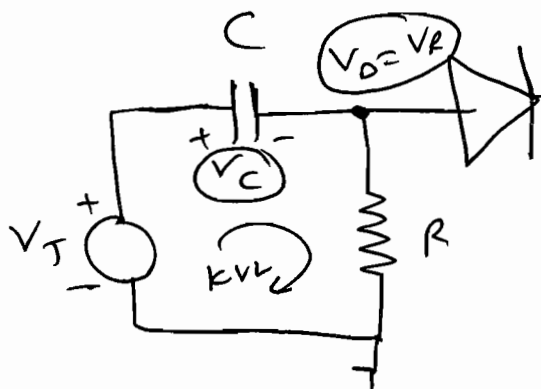
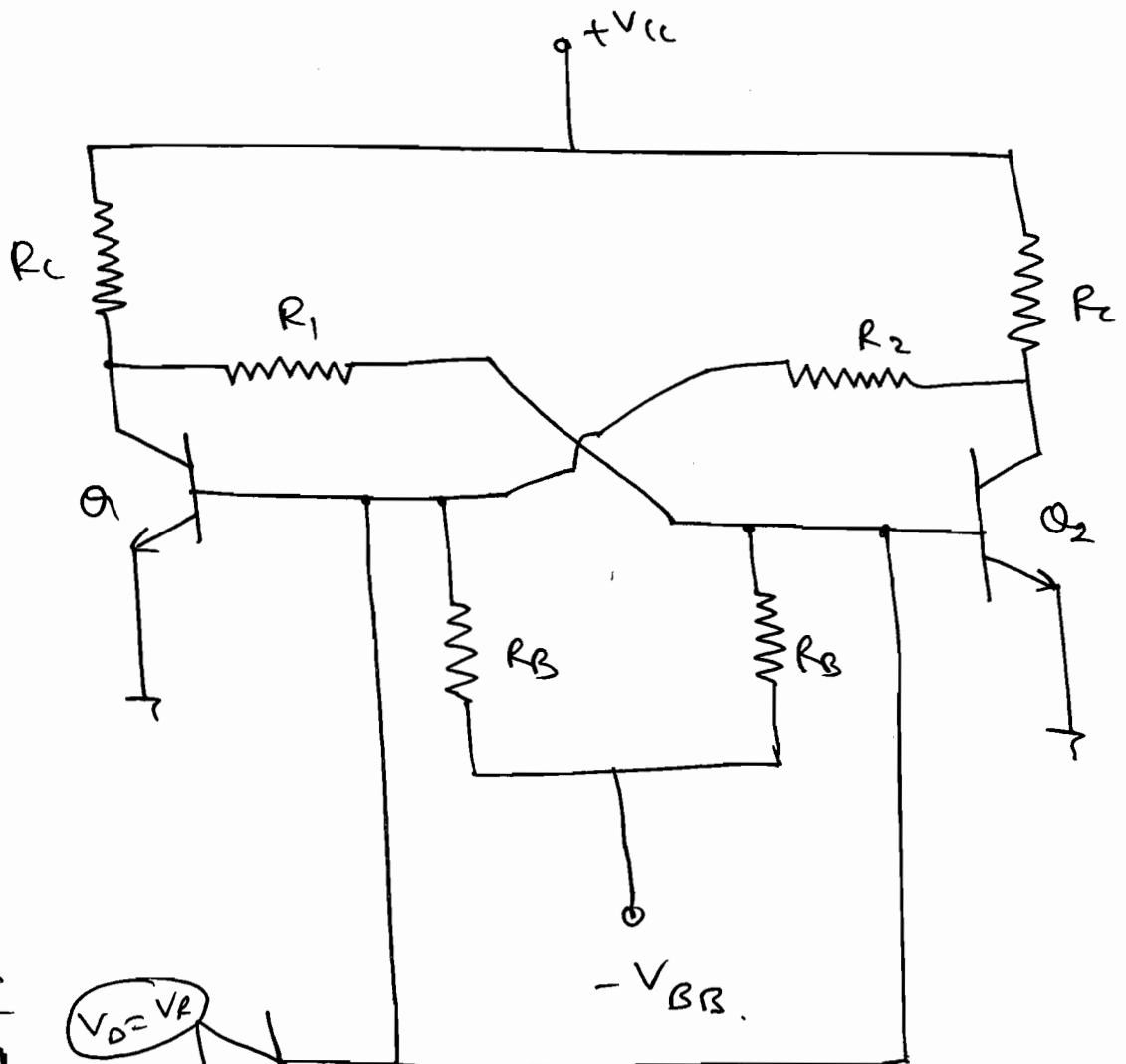
* RS Flip flop using BJT:



R	S	$\bar{Q}$	Q	D_1	D_2	T_1	T_2
0	0	Previous			Previous		
0	1	0	1	R.B.	F.B.	OFF	ON
1	0	1	0	F.B.	R.B.	ON	OFF
1	1	Don't try.		-	-	-	-

* Edge Trigger^{FF} using BJT:

⇒

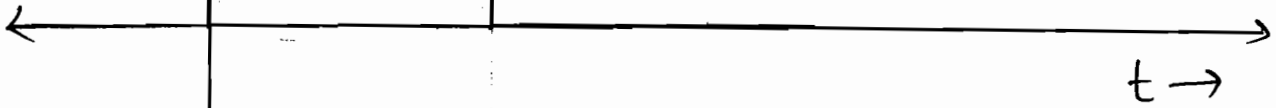


$$\therefore V_T - V_C - V_D = 0$$

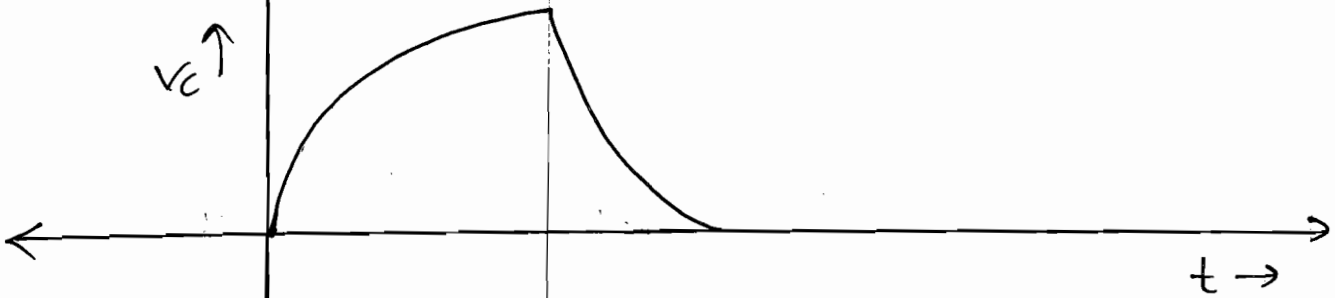
$$\therefore \boxed{V_D = V_T - V_C}$$

V_T
 $V_T \uparrow$

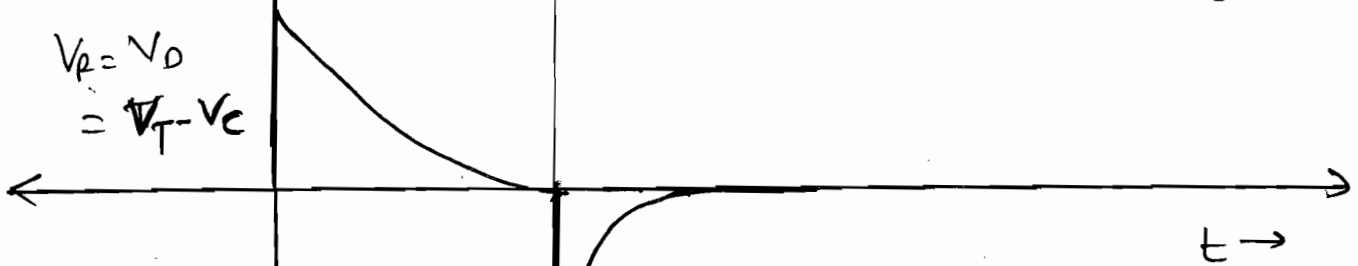
$$RC \ll T$$

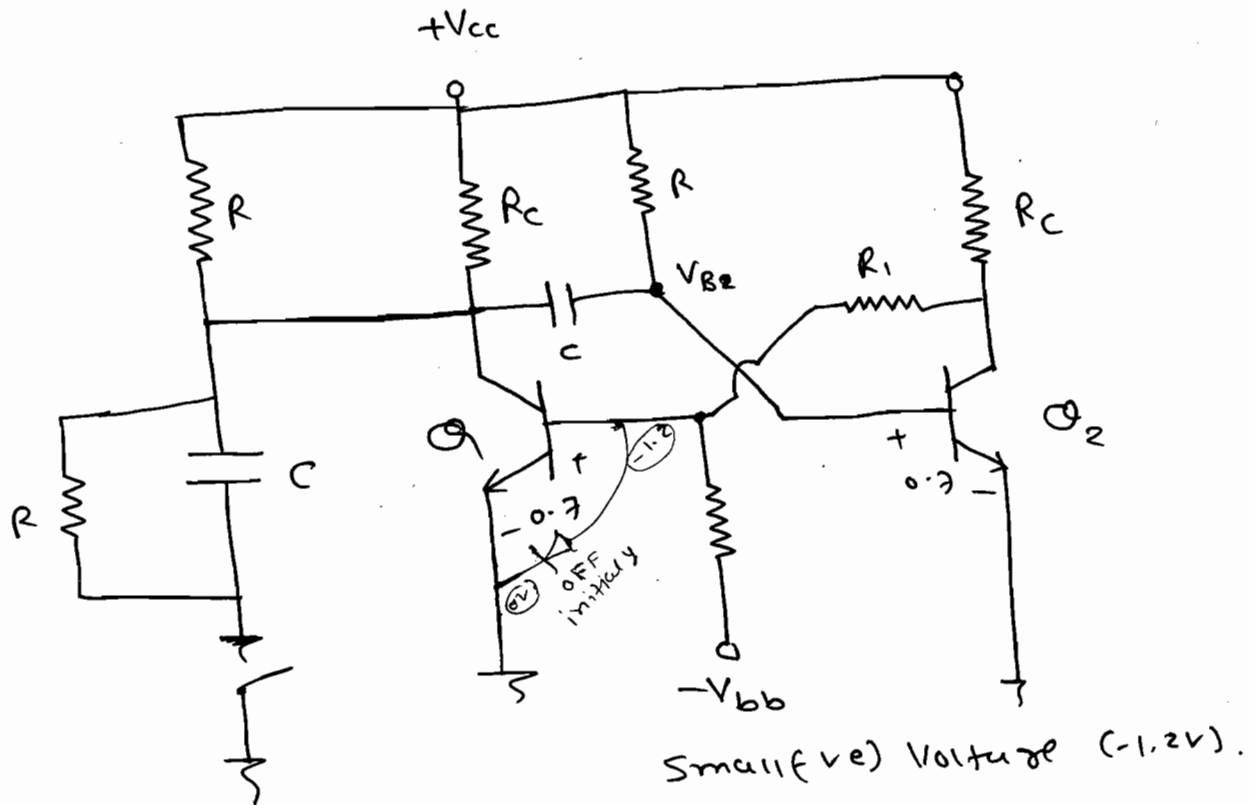


$V_C \uparrow$

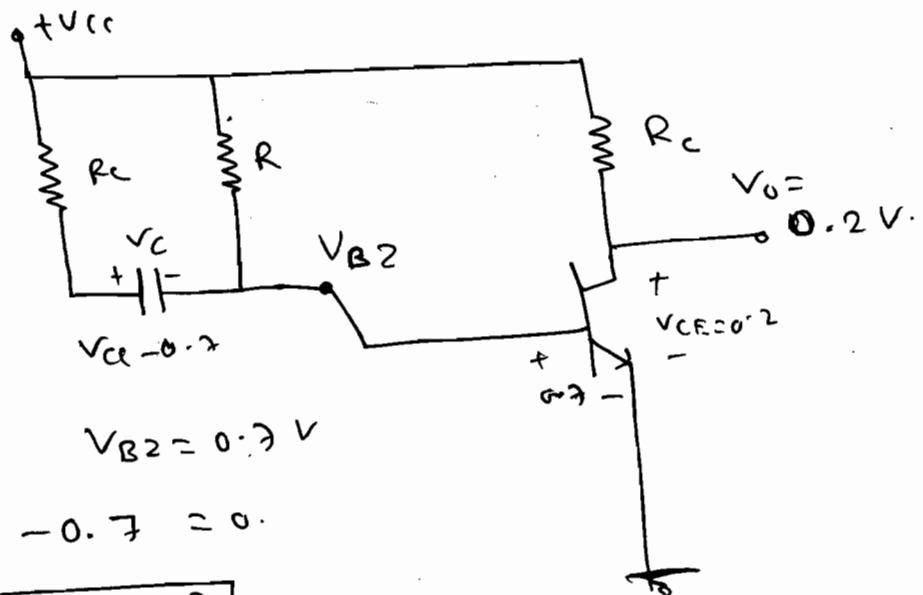


$$V_R = V_D = V_T - V_C$$





$\Rightarrow$ Consider initially Q_1 is OFF because of Small negative voltage ($-V_{bb}$).



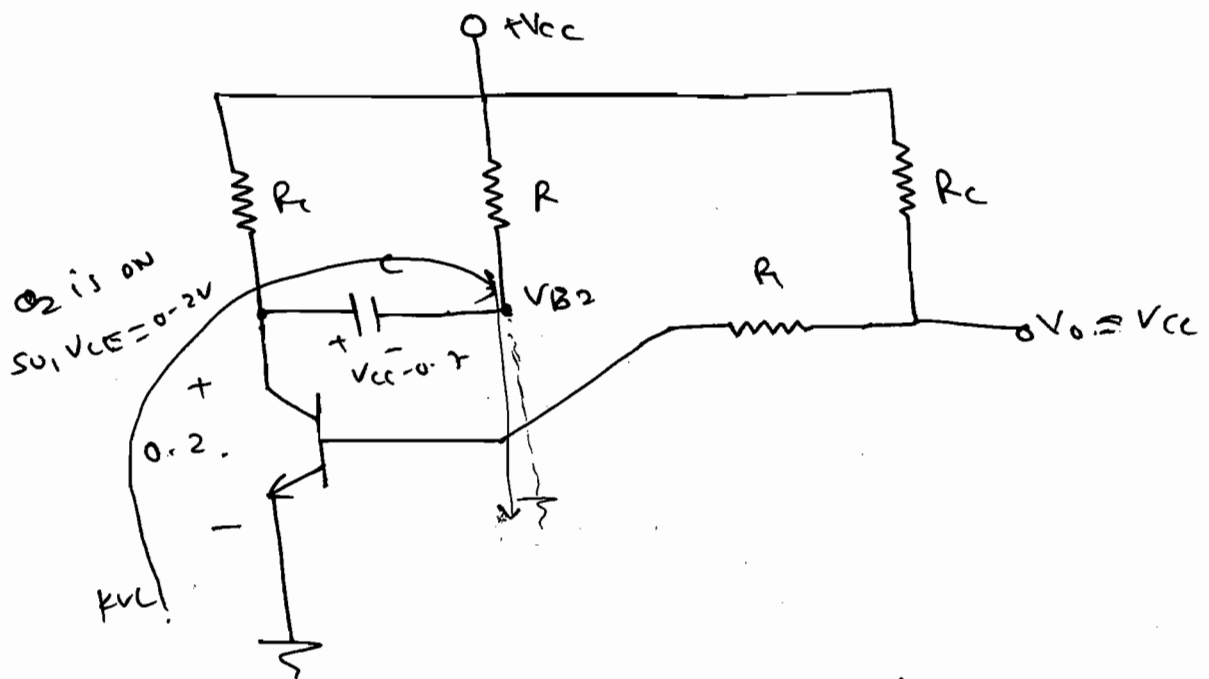
$\Rightarrow$ By KVL, $V_{B2} = 0.7V$

$$\therefore V_{cc} - V_c - 0.7 = 0$$

$$\therefore \boxed{V_c = V_{cc} - 0.7}$$

$\Rightarrow$ So, Capacitor charges to $V_{cc} - 0.7V$.

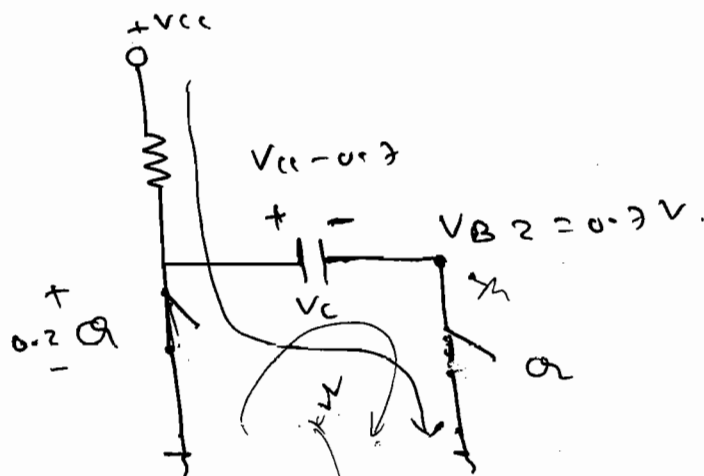
$\Rightarrow$ let us give an external trigger for a short duration, within no time Q_2 is OFF. and Q_1 is ON.



By KVL, $+0.2 - V_{CC} + 0.7 - V_{B2} = 0$.

$$\therefore V_{B2} = 0.9 - V_{CC}$$

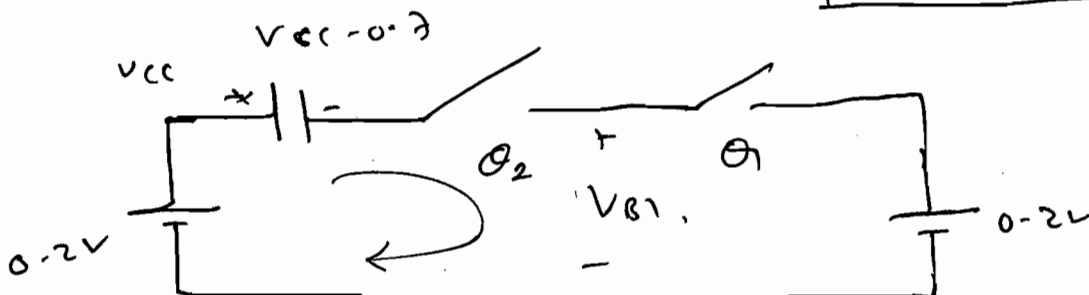
$$V_{B2} = -(V_{CC} - 0.9)V$$

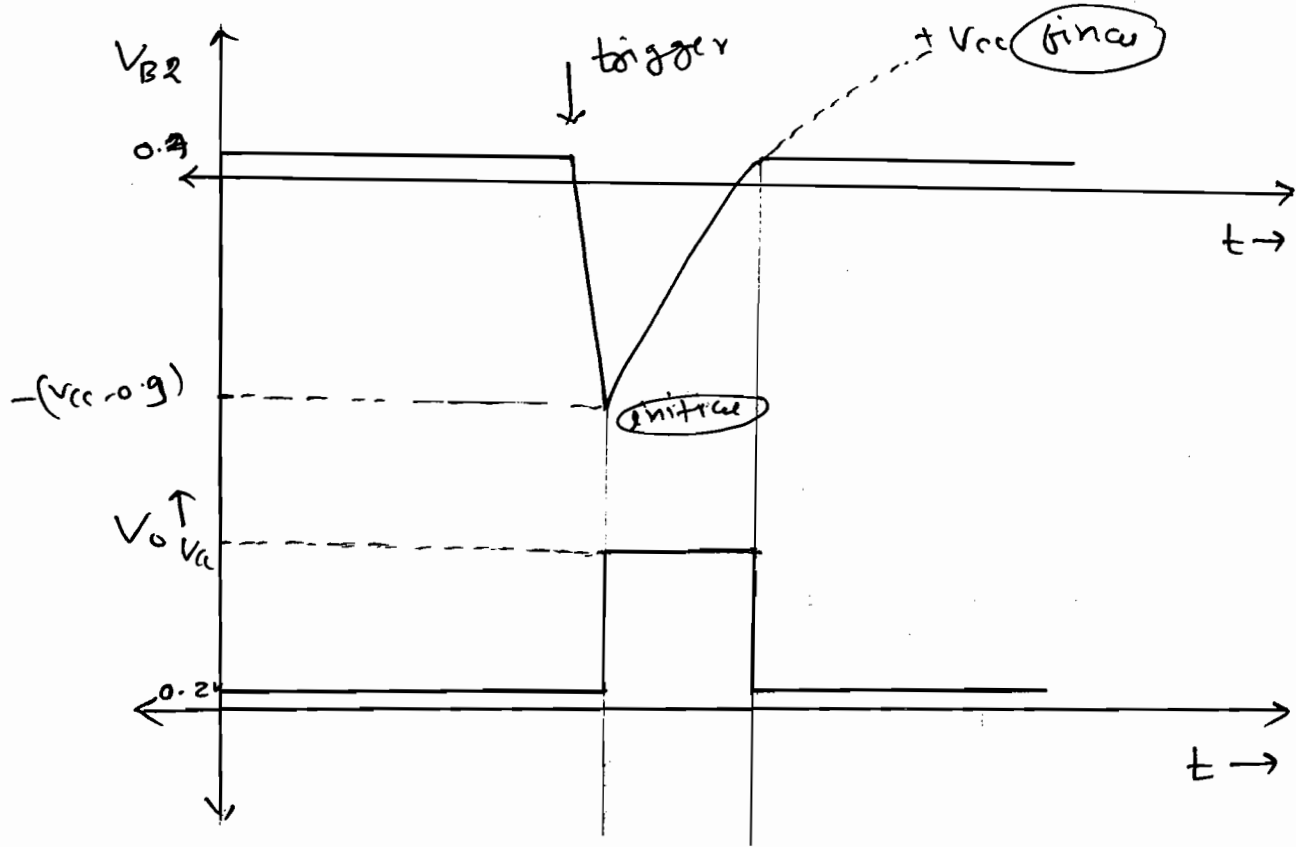


$\rightarrow \phi_1 = OFF \quad \phi_2 = ON \Rightarrow V_C = V_{CC} - 0.7$

$\rightarrow \phi_1 = ON \quad \phi_2 = OFF \Rightarrow 0.2 - V_{CC} + 0.7 - V_{B2} = 0$

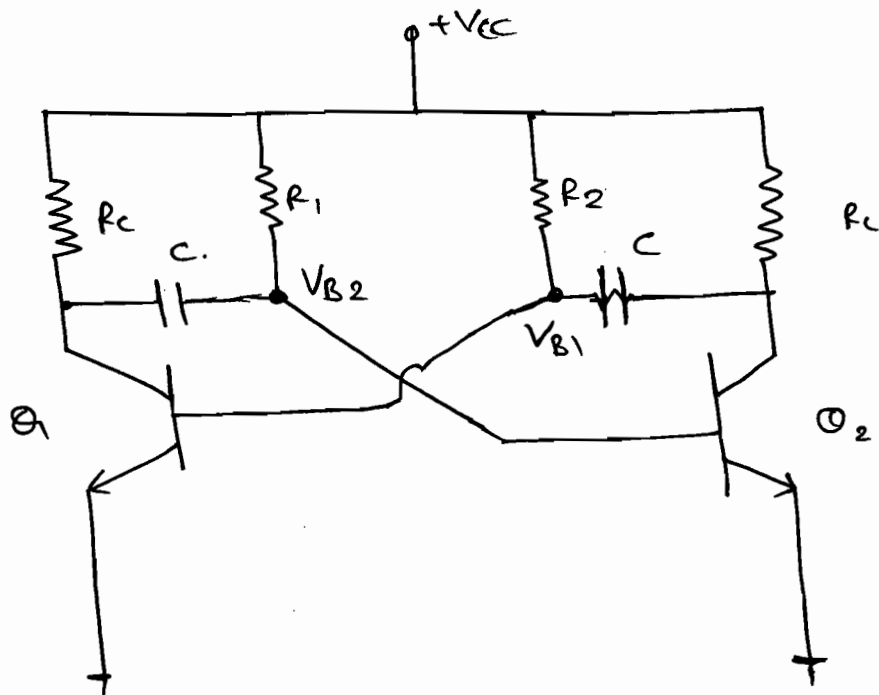
$$V_{B2} = -(V_{CC} - 0.9)V$$





* Astable Multivibrator: using BJT.

*

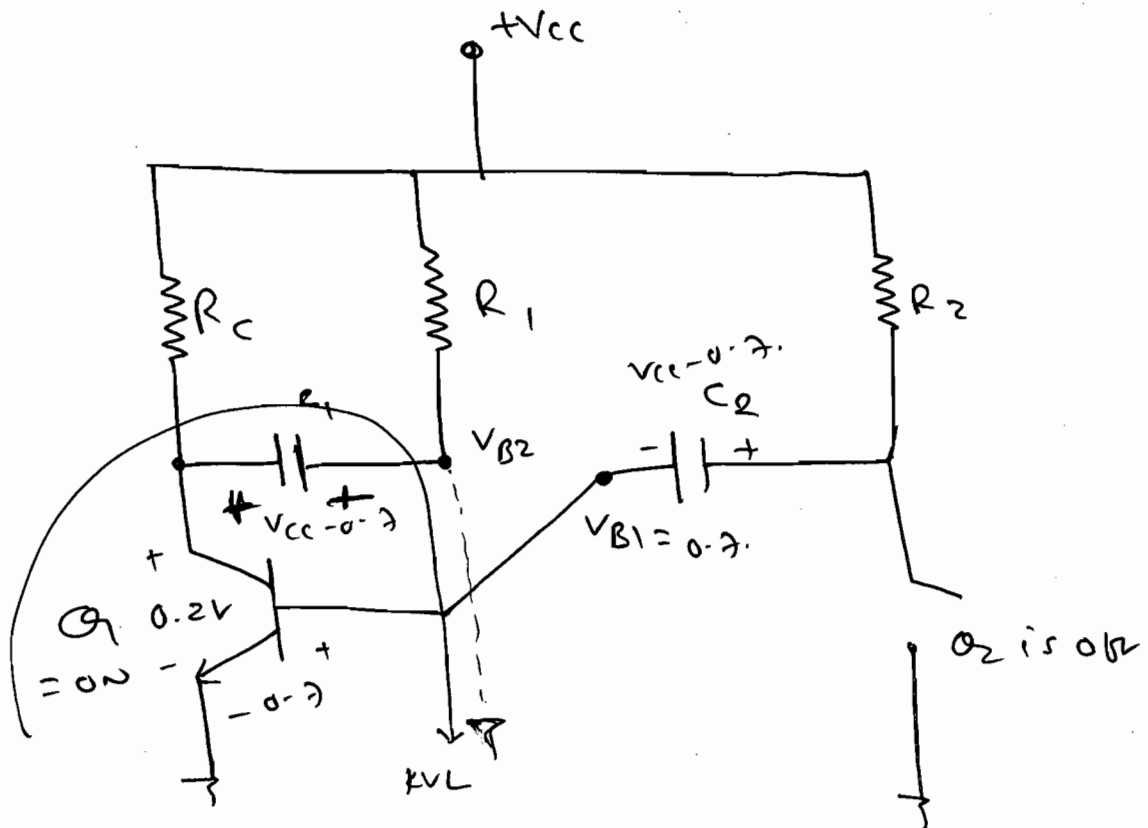


$\Rightarrow$ we will take 2 case:

① Q_1 is ON, Q_2 is OFF.

② Q_1 is OFF, Q_2 is ON.

case-(i)
 Let us, $Q_1 = ON$, $Q_2 = OFF$.



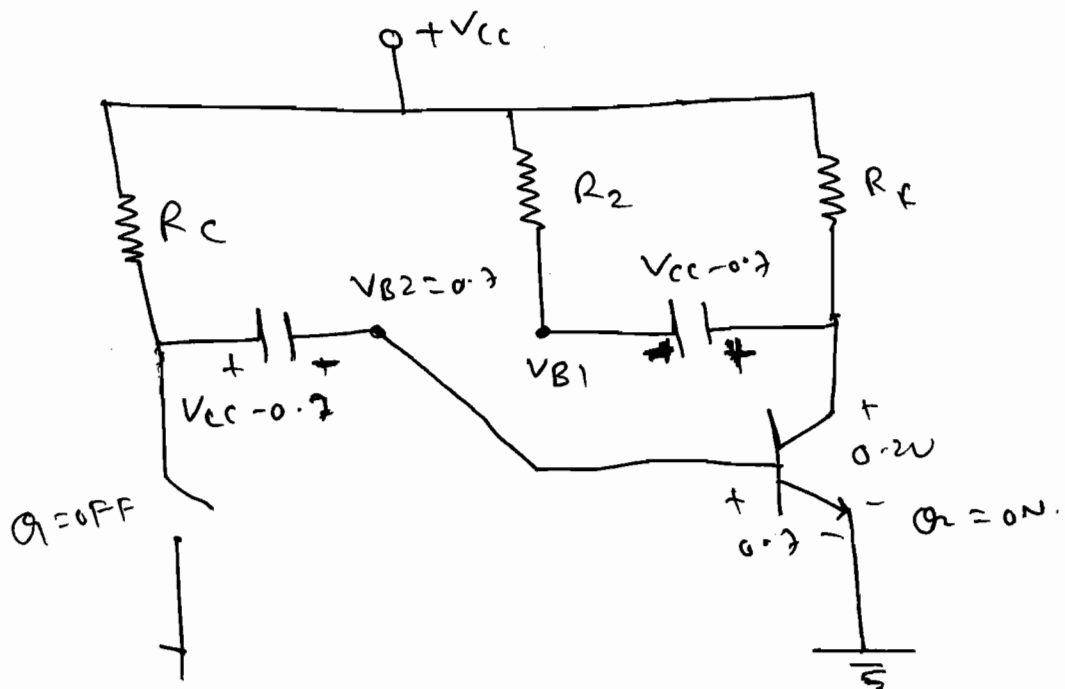
$$\therefore V_{B1} = 0.7.$$

$$\therefore 02 - V_{CC} + 0.7 - V_{B2} = 0$$

$$\therefore V_{B2} = -(V_{CC} - 0.7). \text{ towards } V_{CC}$$

C_2 charges to $V_{CC} - 0.7V$.

case-(ii)
 =



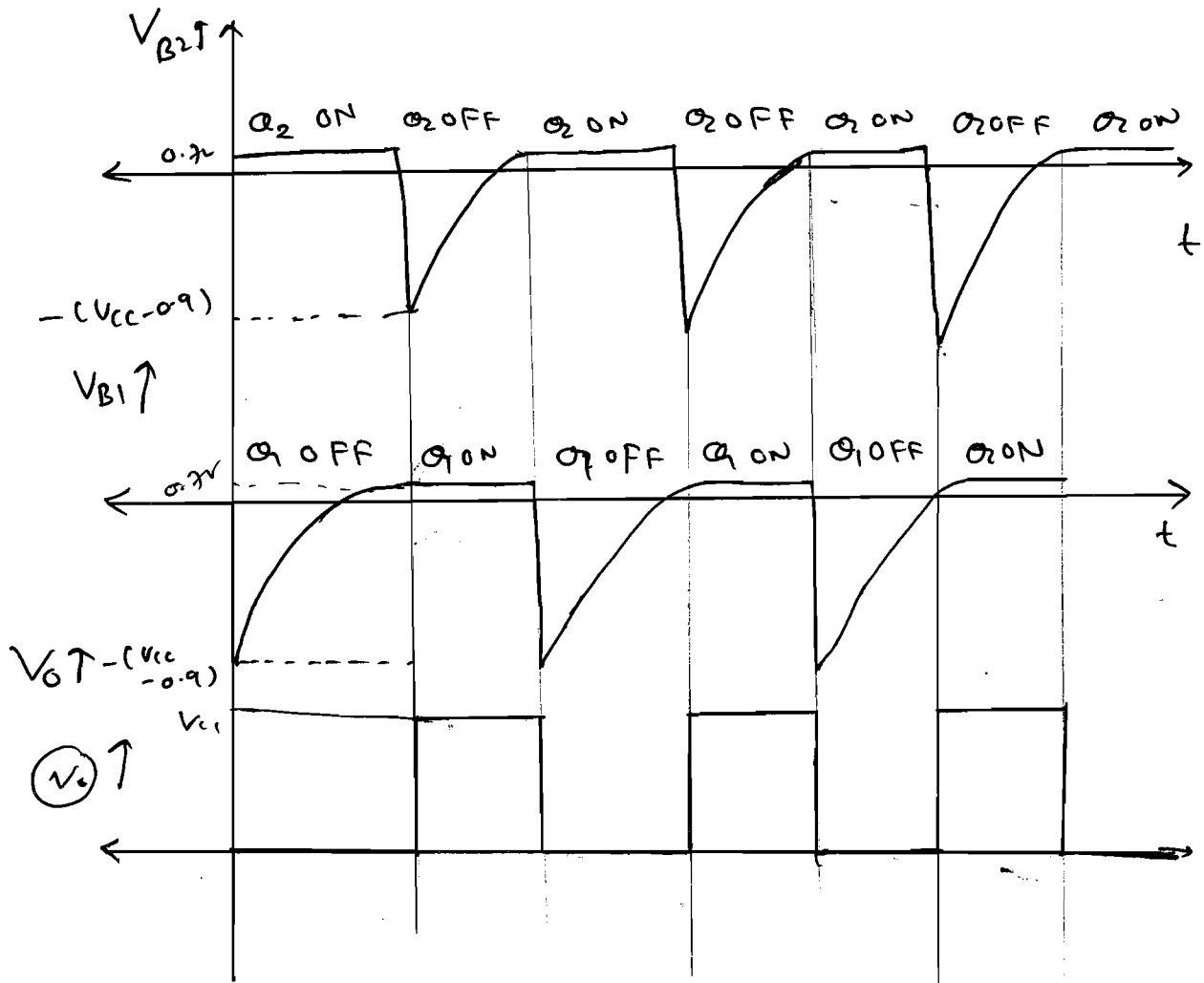
$$Q_2 = \text{OFF}, \quad Q_1 = \text{ON}.$$

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$$\therefore V_{B2} = 0.7V$$

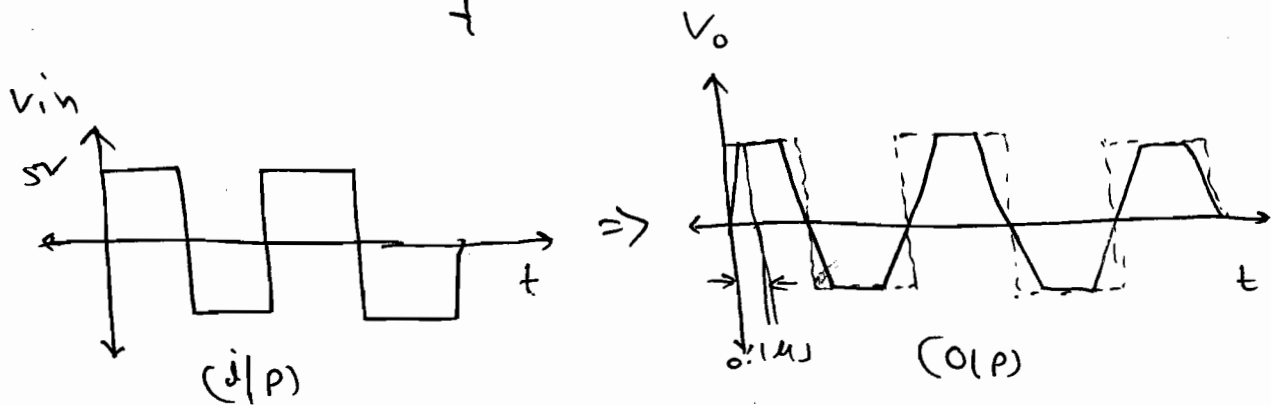
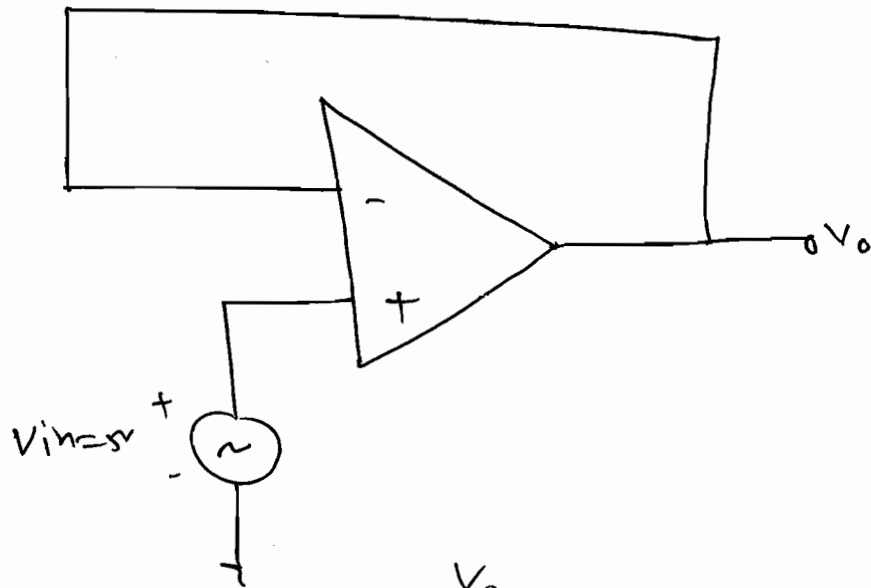
C_1 Charges to $V_{CC} - 0.7V$.

$\therefore V_{B1}$ goes from $-(V_{CC} - 0.9)$ to V_{CC}



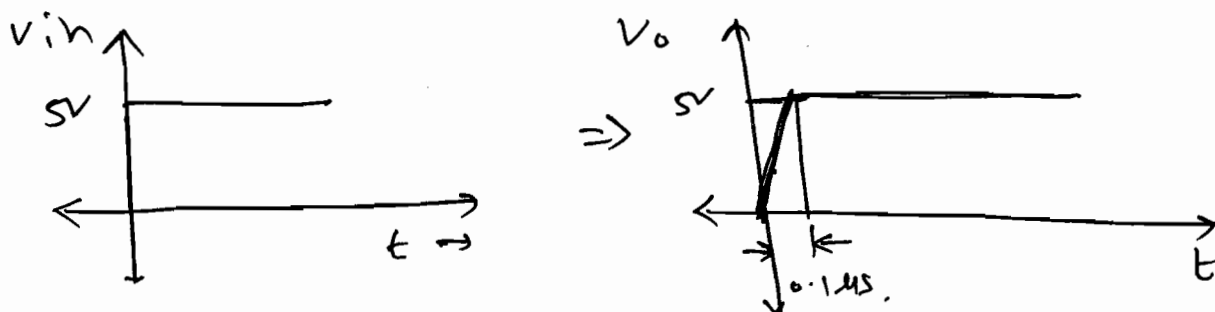
* Slew rate of an OP-Amp:-

→ It is the maximum rate of change of output voltage for all possible input voltage.



$$\therefore \text{Slew rate} = \frac{5V}{0.1\mu sec} = 50 V/\mu sec.$$

→ Step signal is a test signal to measure slew rate of an OP-Amp.



→ What is (SR) signal.

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$$\rightarrow V_o = V_m \sin \omega t.$$

$$\therefore \frac{dV_o}{dt} = \omega V_m \cos \omega t.$$

$$\therefore \left| \frac{dV_o}{dt} \right|_{\max} = \omega V_m.$$

$$\therefore \text{Slew Rate} = (SR) = \left| \frac{dV_o}{dt} \right|_{\max} = \omega V_m.$$

$$\therefore \boxed{SR = 2\pi f_{\max} \cdot V_{\max}.$$

Ex-(1): An op-amp has a slewwate of $1V/\mu s$. with gain of 40 dB . If this amplifier has to faithfully amplify sinusoidal signals from 0 to 20 kHz without any distortion. What must be the max. input signal level.

Ans:

$$|SR| = 2\pi f_{\max} \times V_{\max}.$$

$$\therefore V_{\max} = \frac{SR}{2\pi f_{\max}}.$$

$$= \frac{1}{2 \times \pi \times 20 \times 10^3 \times 10^{-6}}.$$

$$\therefore V_{\max} = \frac{1000}{40\pi}$$

$$\therefore \boxed{V_{\max} = 7.95V}$$

$$\rightarrow \text{Gain}_{dB} = 20 \log \left| \frac{V_{omax}}{V_{imax}} \right|.$$

$$\therefore 40 = 20 \log \left| \frac{7.95}{V_{imax}} \right|.$$

$$\therefore 100 = \frac{7.95}{V_{imax}}.$$

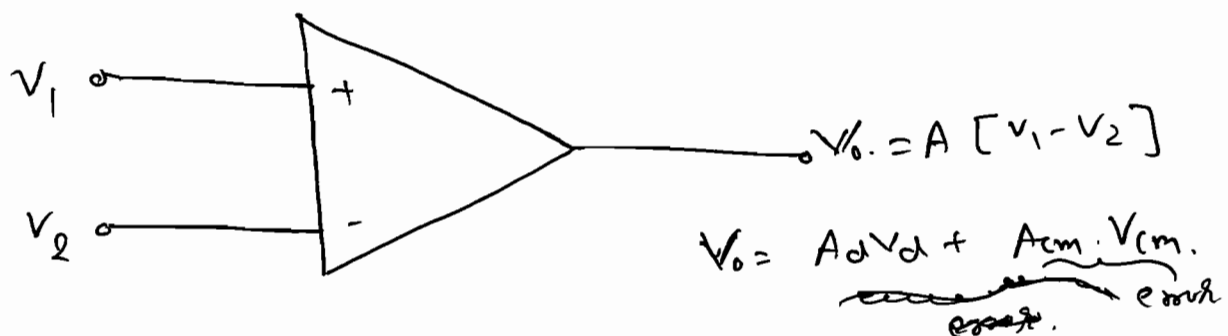
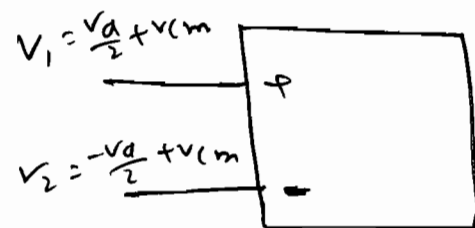
$$\therefore \boxed{V_{imax} = 79.5 \text{ mV.}}$$

★ CMRR: Common Mode Rejection Ratio:

→ It is a Ratio of differential mode gain to the Common mode gain.

$$\boxed{\text{CMRR} = \left| \frac{A_d}{A_{cm}} \right|}$$

Ideally $\boxed{A_{cm} = 0}$
 $\& \boxed{\text{CMRR} = \infty}$



$$\rightarrow V_0 = A(V_1 - V_2).$$

$$V_0 = A_d V_d + A_{cm} V_{cm}.$$

$$\therefore V_o = A_d V_d \left[1 + \frac{A_{cm} \cdot V_{cm}}{A_d \cdot V_d} \right]$$

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$\therefore$ in worst case $V_{cm} = V_d$.

$$\therefore V_o = A_d V_d \left[1 + \frac{A_{cm}}{A_d} \right]$$

But $CMRR = \left| \frac{A_d}{A_{cm}} \right|$

$\therefore V_o = A_d V_d \left[1 + \frac{1}{CMRR} \right]$

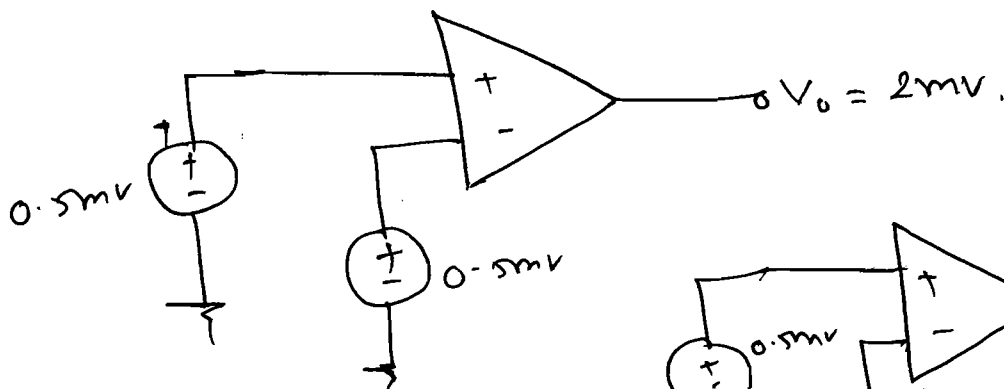
$$\therefore CMRR = \left| \frac{A_d}{A_{cm}} \right|$$

$$\therefore CMRR_{dB} = 20 \log \frac{A_d}{A_{cm}}$$

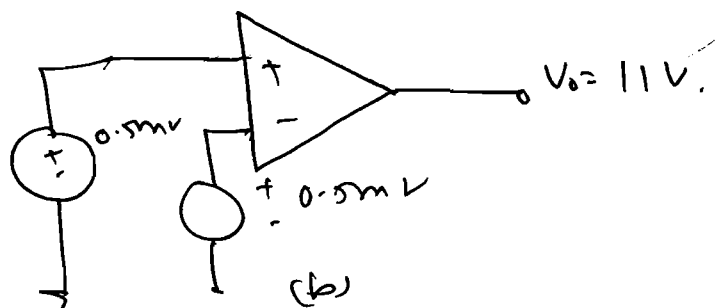
$$\frac{A_d}{A_{cm}} = 10^{\frac{CMRR_{dB}}{20}}$$

$$\therefore V_o = A_d V_d \left[1 + \frac{1}{10^{\frac{CMRR_{dB}}{20}}} \right] \rightarrow \text{error} < 0.1\%$$

Ex-1 Calculate CMRR.



(a)



(b)

Ans: $A_d = \frac{V_o}{V_d} = \frac{11V}{0.5m - (-0.5m)}$

$\therefore A_d = \frac{11}{1 \times 10^{-3}}$

$\therefore A_d = 11000$

from - figure - a

$\Rightarrow A_{cm} = \frac{V_o}{V_{cm}}$

$A_{cm} = \frac{2mV}{0.5mV} = 4.$

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

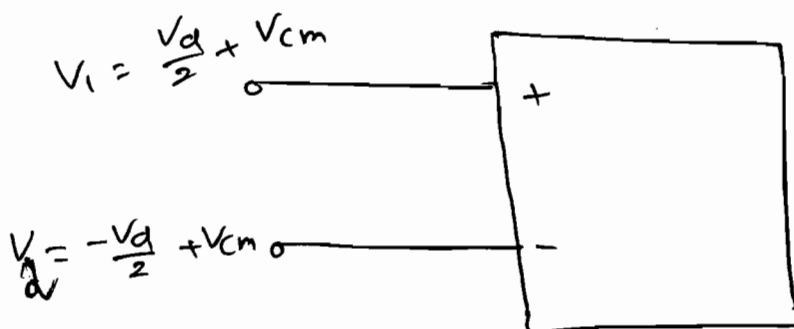
$\therefore CMRR = \frac{11000}{4} = 2750$

$\therefore CMRR_{dB} = 20 \log \left| \frac{A_d}{A_{cm}} \right|$

$= 20 \log \left| \frac{11000}{4} \right|$

$\therefore CMRR = 68.7 \text{ dB}$

*



$V_d = V_1 - V_2$
 $V_{cm} = \frac{V_1 + V_2}{2}$

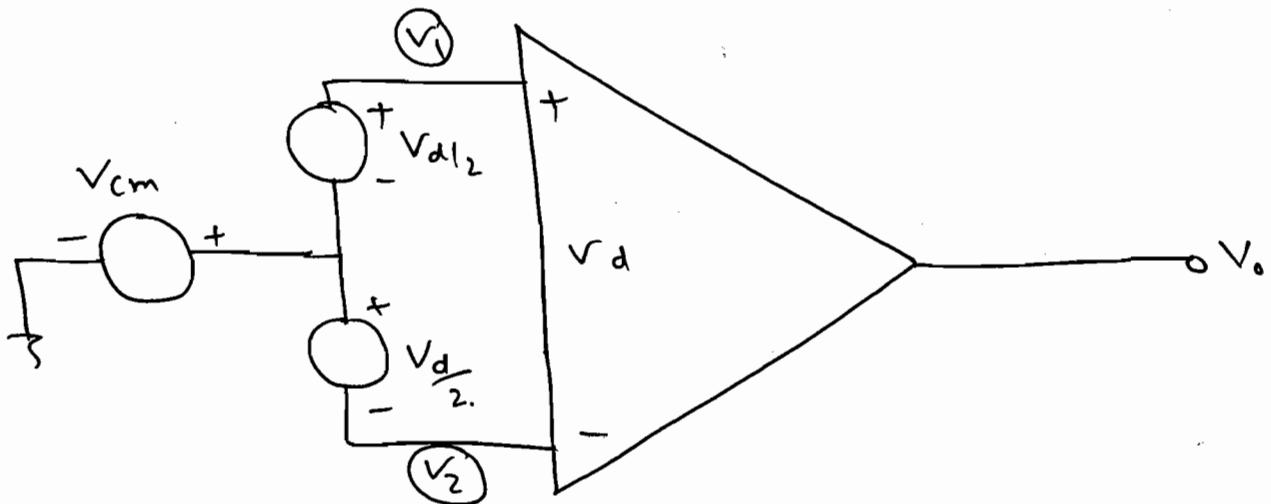
$$\rightarrow V_1 = \frac{V_1}{2} + \frac{V_2}{2} + \frac{V_1}{2} - \frac{V_2}{2}$$

$$V_1 = V_{cm} + \frac{V_d}{2}$$

$$\rightarrow V_2 = \frac{V_2}{2} + \frac{V_1}{2} + \frac{V_2}{2} - \frac{V_1}{2}$$

$$V_2 = V_{cm} + \left(-\frac{V_d}{2}\right)$$

$$\therefore V_2 = V_{cm} - \frac{V_d}{2}$$



* Superposition:

$$V_o = A_d V_d + A_{cm} V_{cm}$$

$$V_o = A_1 V_1 + A_2 V_2$$

$$\therefore \textcircled{1} \quad V_2 = 0, \quad V_1 \text{ apply.}$$

$$\therefore V_o = A_1 V_1 \big|_{V_2=0} \Rightarrow A_1 = \frac{V_o}{V_1}$$

$$\textcircled{2} \quad V_1 = 0, \quad V_2 \text{ apply.}$$

$$\therefore V_o = A_2 V_2 \big|_{V_1=0} \Rightarrow A_2 = \frac{V_o}{V_2}$$

$$\therefore V_o = A_d V_d \big|_{v_{cm}=0} + A_{cm} V_{cm} \big|_{v_d=0}$$

$$= A_1 V_1 \big|_{v_2=0} + A_2 V_2 \big|_{v_1=0}$$

$$\therefore A_d = \frac{A_1 - A_2}{2}$$

* $A_{cm} = A_1 + A_2$

$\therefore$ * $CMRR = \frac{A_d}{A_{cm}}$

$\therefore$ * $CMRR = \frac{A_1 - A_2}{2(A_1 + A_2)}$

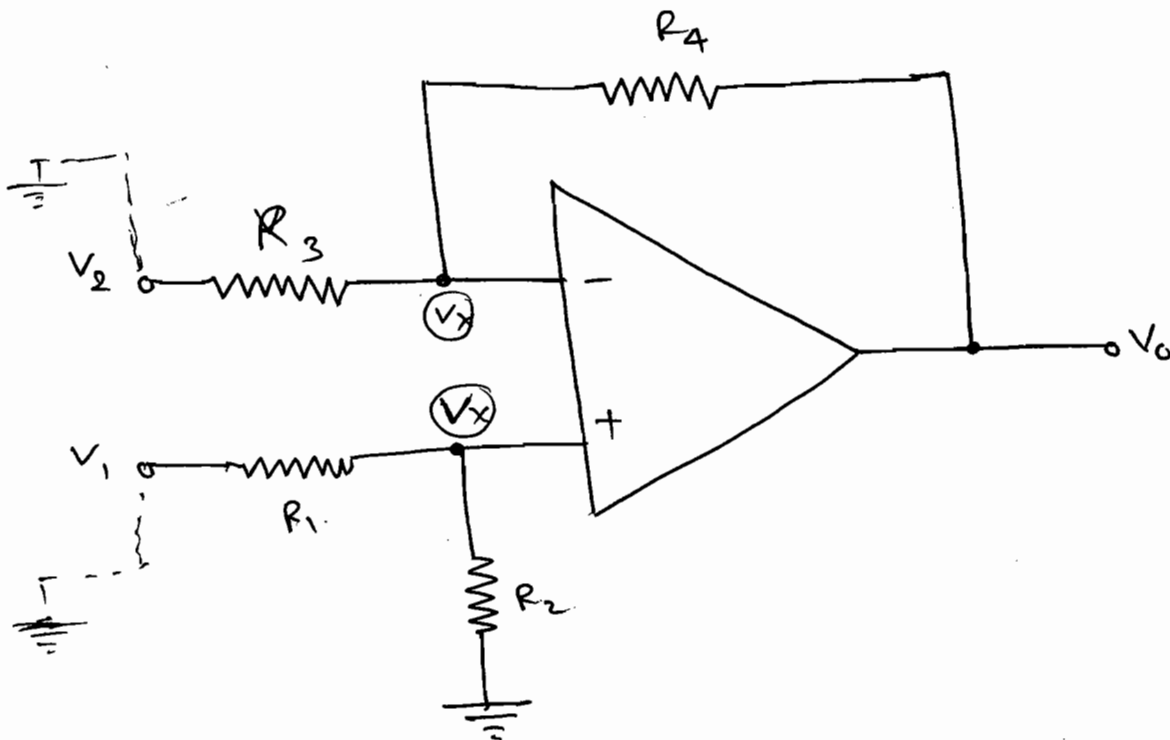
$$A_{cm} = \frac{2A_1 \cdot A_2}{A_1 + A_2}$$

$$A_d = \frac{A_1 \cdot A_2}{A_2 - A_1}$$

$$CMRR = \frac{A_1 + A_2}{2(A_2 - A_1)}$$

★ CMRR of Difference Amplifier:-

⇒



→ By superposition

$$\therefore A_1 = \frac{V_o}{V_1} \big|_{v_2=0}, \quad A_2 = \frac{V_o}{V_2} \big|_{v_1=0}$$

-(i) When $V_2 = 0$.

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$$\therefore V_x = \left(\frac{R_2}{R_1 + R_2} \right) V_1.$$

$$\therefore V_o = \left(1 + \frac{R_4}{R_3} \right) V_x.$$

$$\therefore V_o = \left(1 + \frac{R_4}{R_3} \right) \times \left(\frac{R_2}{R_1 + R_2} \right) V_1.$$

$$\therefore A_1 = \frac{V_o}{V_1} = \frac{(R_3 + R_4) R_2}{R_3 (R_1 + R_2)}.$$

(ii) When $V_1 = 0$.

$$\therefore V_o = - \left(\frac{R_4}{R_3} \right) V_2.$$

$$\Rightarrow A_2 = \frac{V_o}{V_2} = \frac{\cancel{A_1} - A_2}{2(\cancel{A_1} + \cancel{A_2})} = - \frac{R_4}{R_3}$$

$\Rightarrow$ CMRR = ∞ when $A_{cm} = 0 = A_1 + A_2 = 0$.

$$\therefore A_1 = -A_2.$$

$$CMRR = \frac{A_1 - A_2}{2(A_1 + A_2)}.$$

$$\therefore \frac{R_4}{R_3} = \frac{(R_3 + R_4) R_2}{R_3 (R_1 + R_2)}$$

$$\therefore \frac{R_1 + R_2}{R_2} = \frac{R_3 + R_4}{R_4}.$$

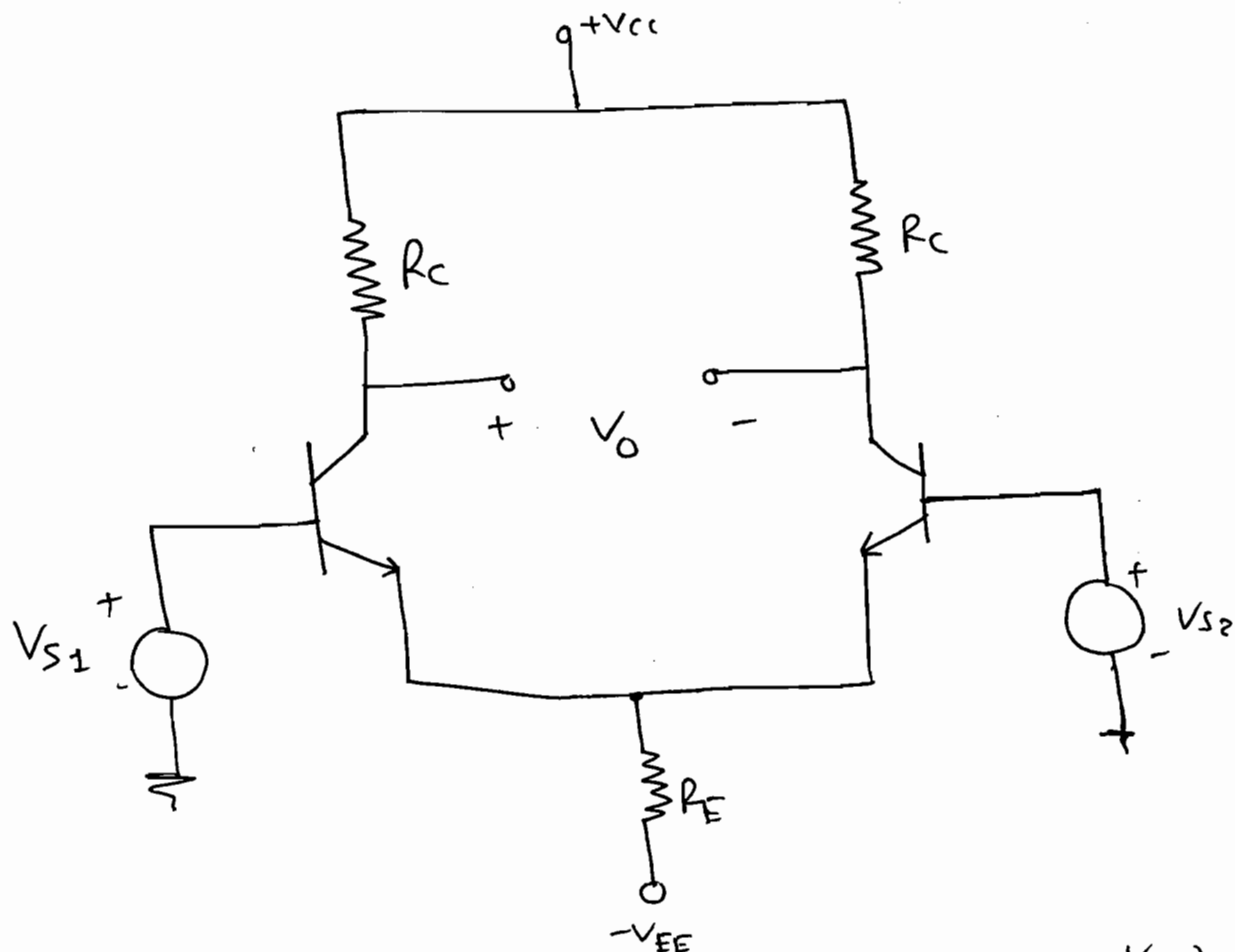
$$\therefore 1 + \frac{R_1}{R_2} = 1 + \frac{R_3}{R_4}.$$

$$\therefore \boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

★ CMRR

For a Differential

Amplifier:



$$V_O = K (V_{S1} - V_{S2})$$

$$V_O = K_1 V_{S1} - K_2 V_{S2}$$

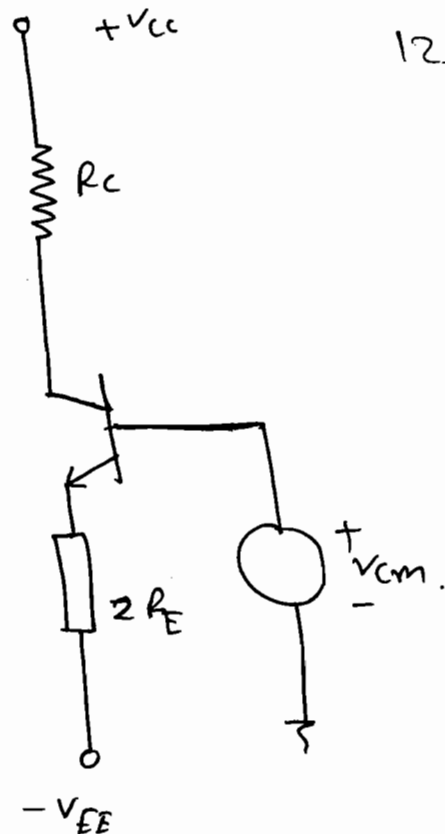
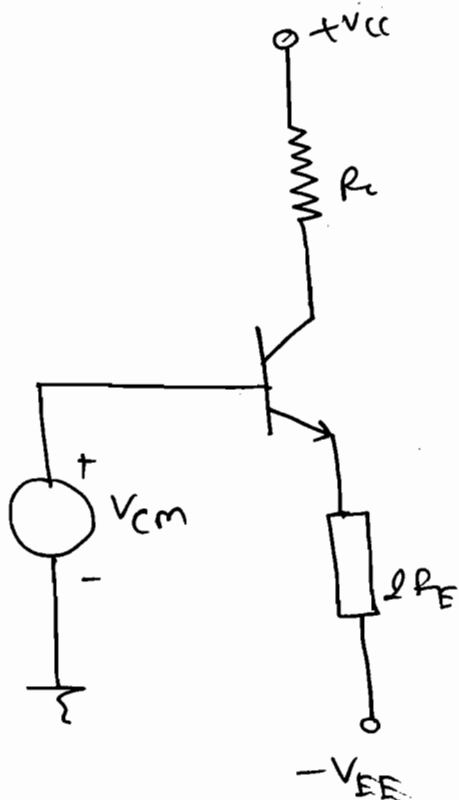
$$\therefore \Rightarrow V_O = -g_m R_C [V_{S1} - V_{S2}]$$

$\Rightarrow$ Differential

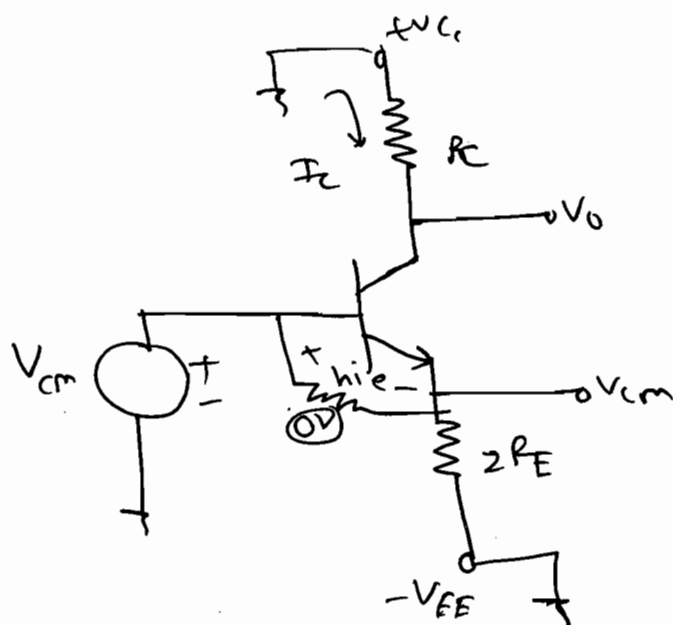
$$\text{gain} = A_d = \frac{V_O}{V_d} = \frac{V_O}{V_{S1} - V_{S2}} = -g_m R_C$$

$\rightarrow$ If $V_{S1} = V_{S2}$, $V_O = 0$, this is under the assumption that both transistors have the same AC char. which is not possible. Hence we go for ~~single~~ ^{single} ended Analysis to make the individual gains as low as possible such that the difference can still be zero due to common signals.

$\Rightarrow$



$\Rightarrow$ For AC analysis.



negative h_{ie}
 $\Rightarrow h_{ie} = 0$

$$\therefore V_{cm} = V_E \neq V_{R_E}$$

$$\therefore V_o = -I_c R_c$$

$$\therefore I_c = I_E = \frac{V_E}{2R_E} = \frac{V_{cm}}{2R_E}$$

$$\therefore V_o = -\frac{V_{cm}}{2R_E} \cdot R_c$$

$$\therefore \frac{V_o}{V_{cm}} = -\frac{R_c}{2R_E}$$

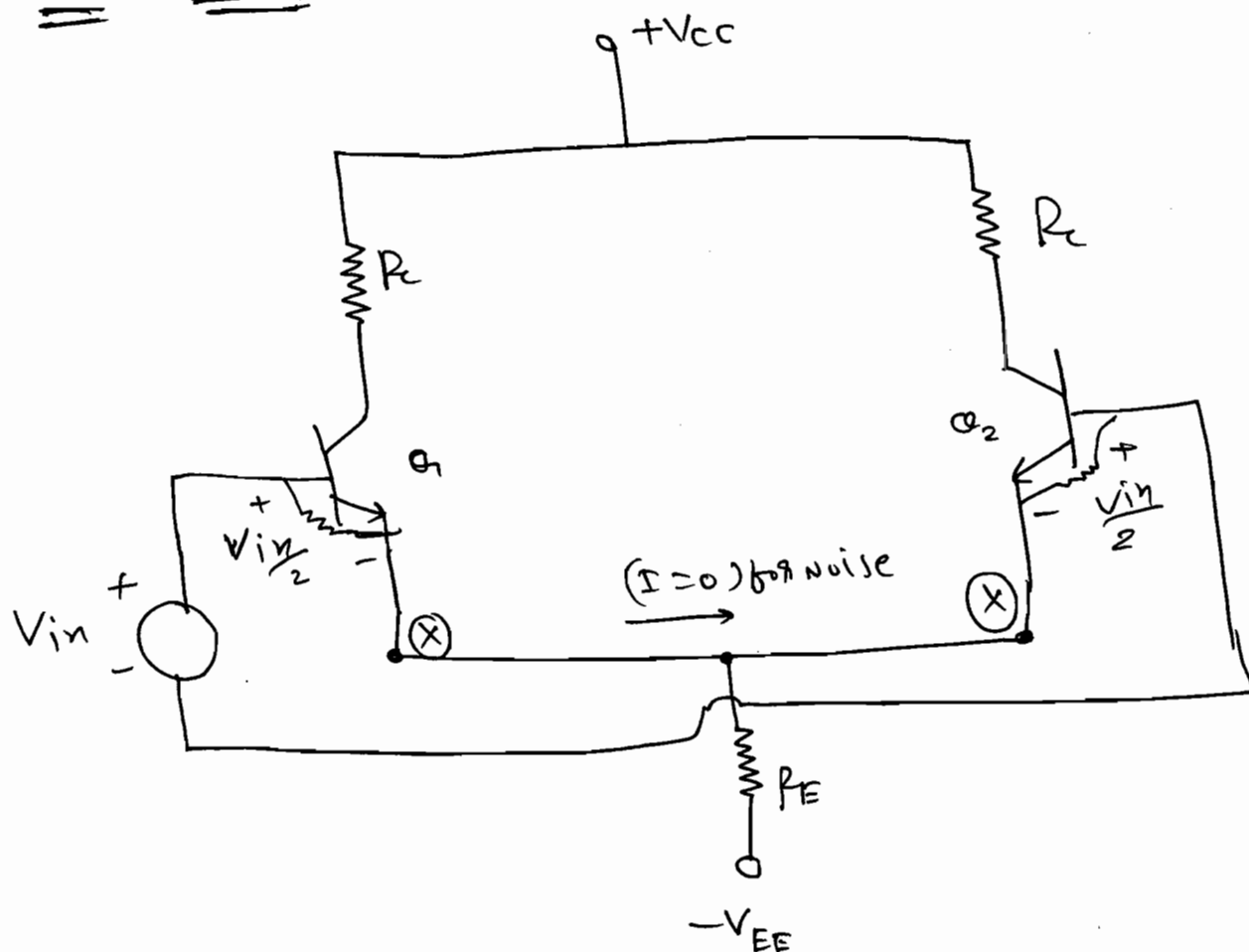
$$A_{cm} \text{ (half-kt)} = - \frac{R_c}{2R_E}$$

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

$$= \frac{- \frac{g_m R_c}{2}}{-R_c / 2R_E}$$

$$\therefore CMRR = + g_m R_E$$

→ CMRR can be improved by increasing R_E hence replace R_E with a constant current source (or) current mirror. Current mirrors offers large o/p impedance improving CMRR.



→ Input at Q_1 : V_1 $= \frac{V_{in}}{2} + N.$

→ Input at Q_2 : V_2 $= -\frac{V_{in}}{2} + N.$

⇒ Change in input signal at Q_1 & Q_2 are ~~same~~ different (i.e. 180 phase shift i.e. $\frac{V_{in}}{2}$ & $-\frac{V_{in}}{2}$).

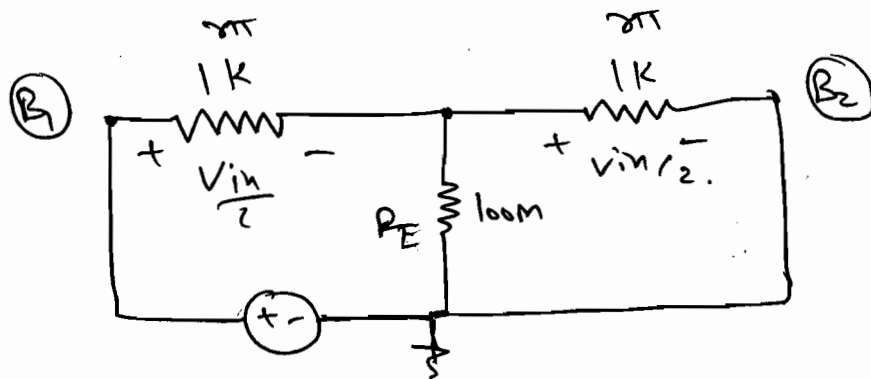
But change in the noise is same at input at Q_1 & Q_2 .

① Now, there are no noise.

∴ Change in the signal is different.

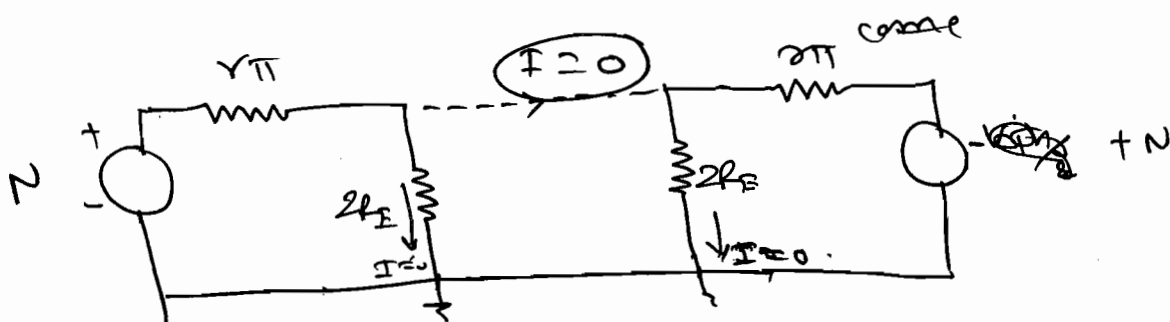
hence voltage at ~~both~~ node (X) are different i.e. $V_{in}/2$ & $-V_{in}/2$.

for A.C.



→ R_E is very large. So, it is treated at o.c. and R_E is dummy when there is no noise.

② But, Now as noise enters into the signal then change in the noise at both input are same. therefore voltage at (X) & (X) are same due to noise. ~~Structure split into two part when noise~~
i.e.



⇒ So, noise at both end nailed to the ground through R_E . i.e. noise are get cancelled out.

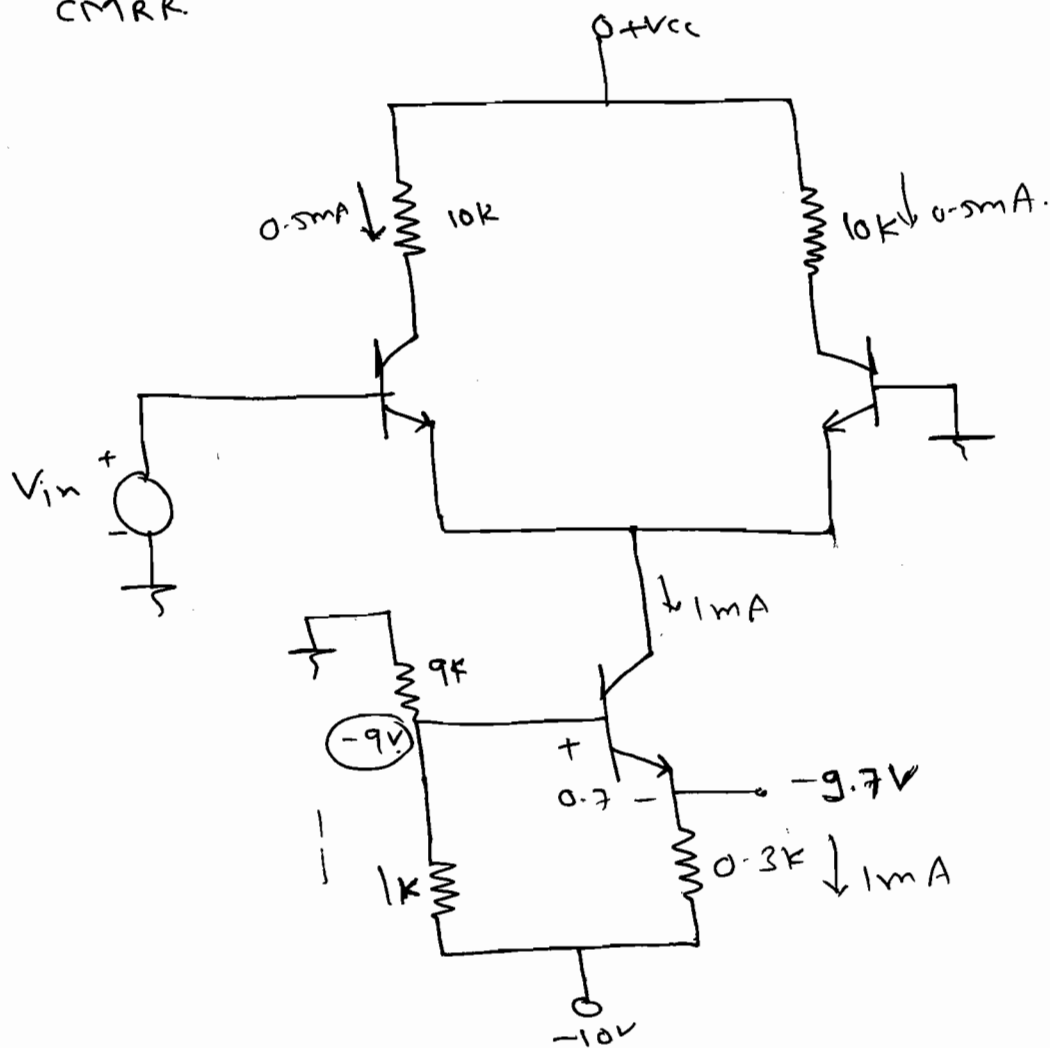
* Beauty of Differential Amplifier

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⇒ As the desired signal is coming then it act as double ended structure.

⇒ But as soon as Noise come, it split into two parts nicely, for noise and noises are nulled to ground through R_E .

Ex-1 A Common mode gain is 0.001, calculate CMRR.



$$\rightarrow A_d = \frac{g_m R_c}{2}$$

$$A_d = \frac{\frac{1}{50} \times 10k}{2} = -100$$

$$g_m = \frac{I_{CQ}}{\beta V_T}$$

$$= \frac{0.5m}{25m} = \frac{1}{50}$$

$$CMRR = \left| \frac{A_d}{A_{cm}} \right|$$

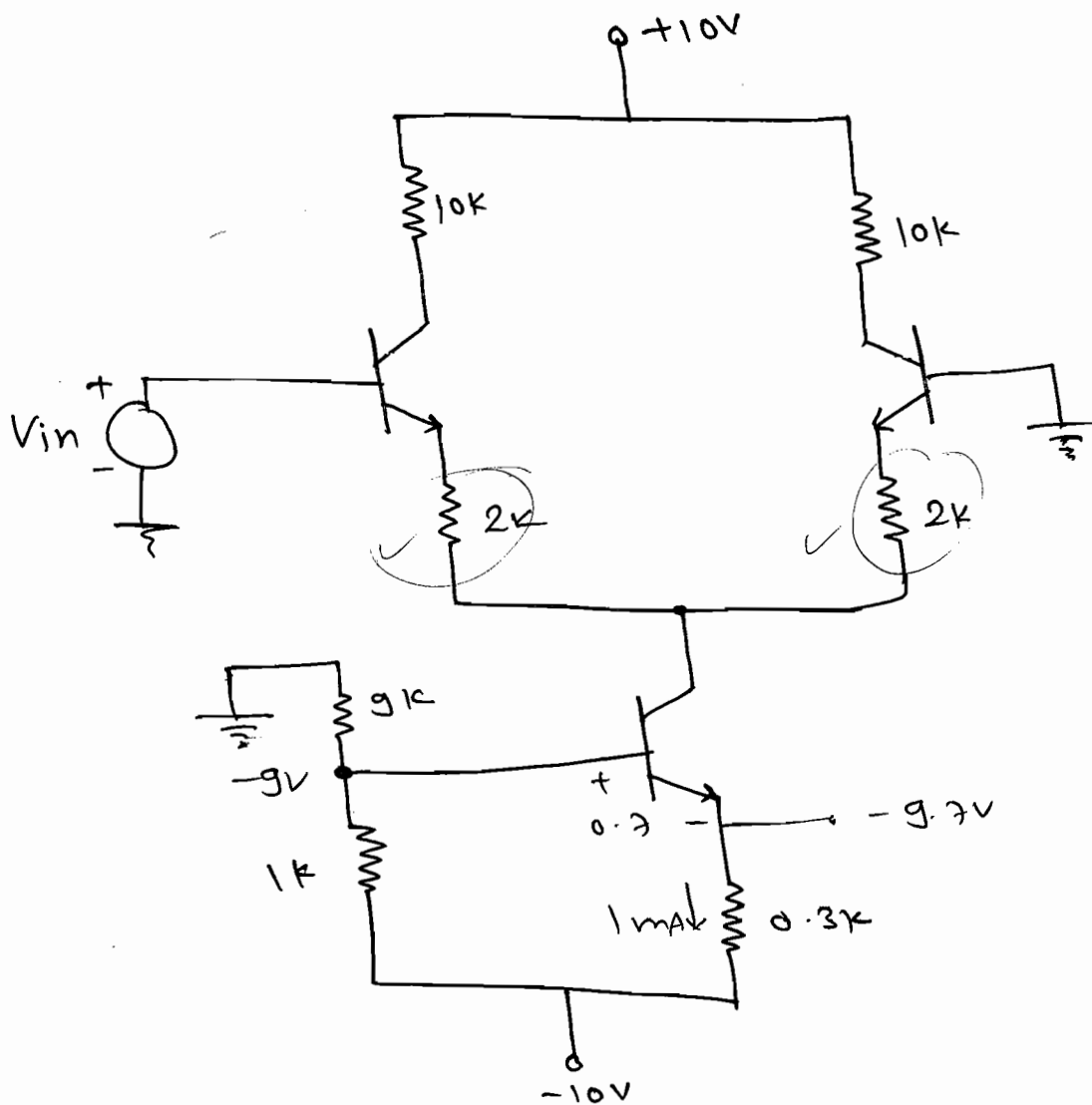
$$= \left| \frac{100}{0.01} \right|$$

$$\therefore CMRR = 10^5$$

$$\therefore CMRR_{dB} = 20 \log 10^5 = 100 \text{ dB}$$

$$\therefore CMRR = 100 \text{ dB}$$

Ex-2 Find CMRR:



given $A_{cm} = 0.001$.

$$A_d = -\frac{R_c}{R_E}$$

But CMRR is calculated for half CKT.

$$\therefore A_d = \frac{-R_c}{\frac{2R_E}{2}} = \frac{-10k}{\frac{1k}{2}} = -20$$

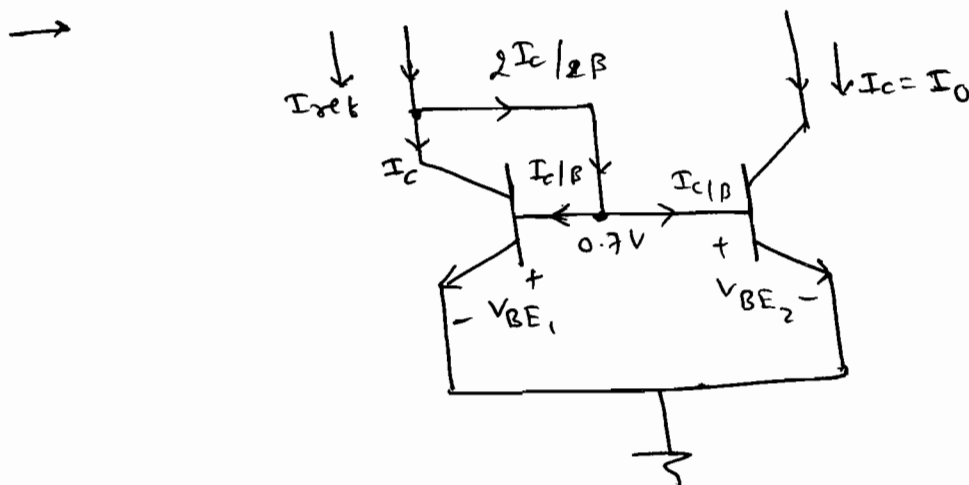
$$\therefore CMRR = \left| \frac{2.5}{0.001} \right| = 2500.$$

$$\therefore CMRR = 20 \log_{10} 2500$$

$$\therefore \boxed{CMRR = 67.96 \text{ dB}}$$



Current Mirror:



By KCL,

$$I_{ref} = I_c + \frac{2I_c}{2\beta}$$

$$I_{ref} = I_c \left[1 + \frac{2}{2\beta} \right]$$

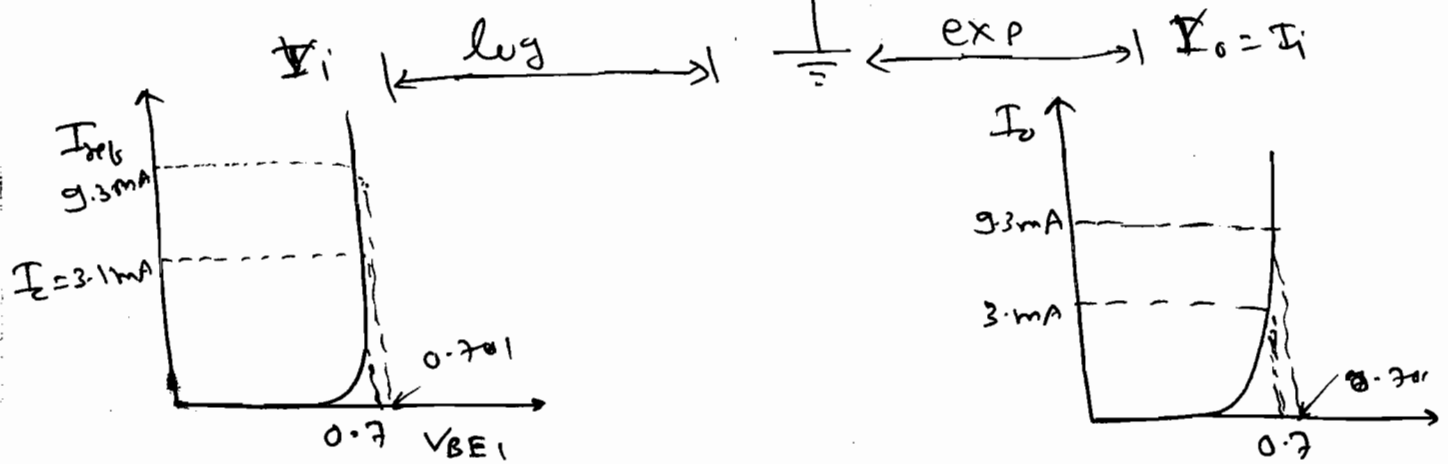
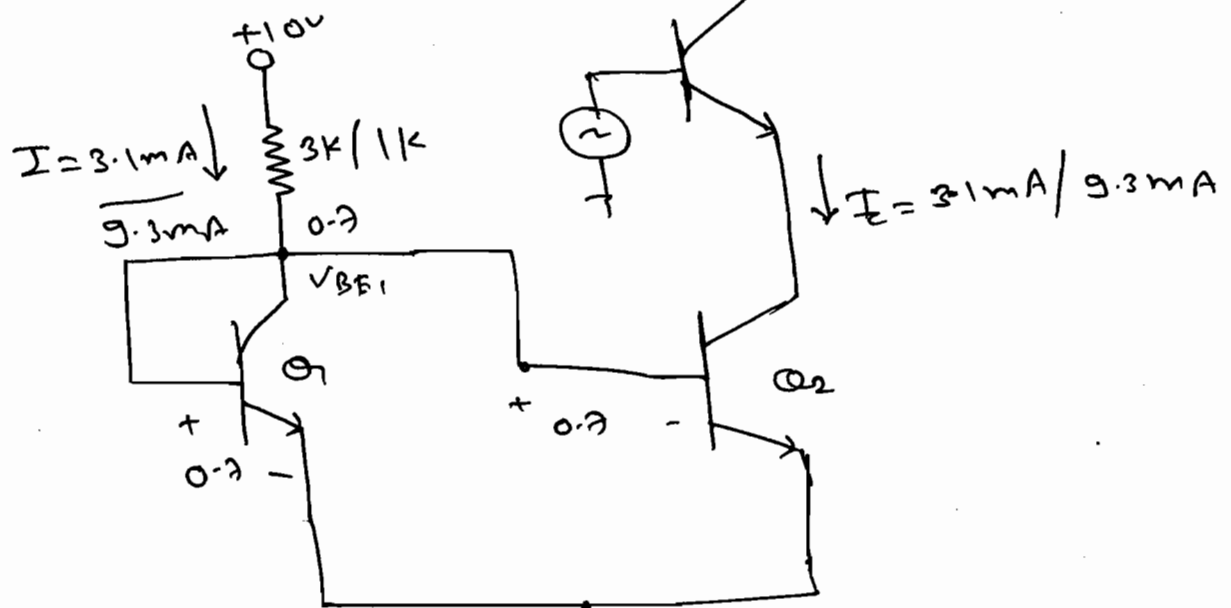
$$\therefore I_{ref} = I_o \left[1 + \frac{2}{2\beta} \right]$$

if β is very large.

$$\therefore \boxed{I_{ref} \approx I_o}$$

By giving I_{ref} we can control or set I_o .

→ Redesign the current mirror:



NOTE: If current changes the voltage it is log operation, and if voltage changes the current it is exponential operation.

$$\rightarrow I_C = I_S \cdot e^{\frac{V_{BE}}{V_T}}$$

$$\therefore V_{BE1} = V_T \log\left(\frac{I_{C1}}{I_S}\right) \quad (\log).$$

$$\therefore \text{But } V_{BE1} = V_{BE2}.$$

$$V_{BE2}/V_T.$$

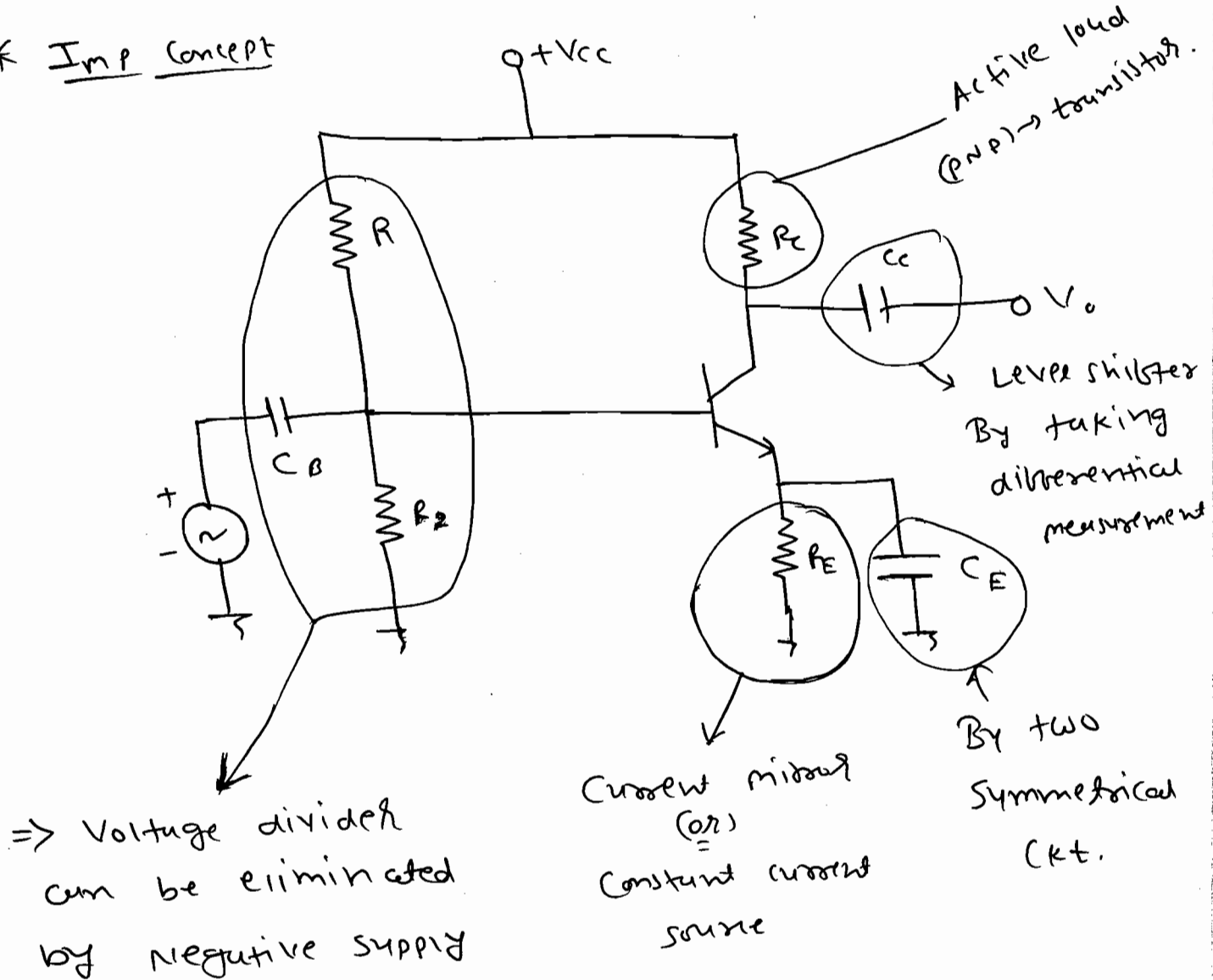
$$\therefore I_{C2} = I_S \cdot e$$

$$\therefore I_{C2} = I_S \cdot e^{\frac{V_{BE1}}{V_T}}$$

$$\therefore \boxed{I_{C2} = I_{C1}}$$

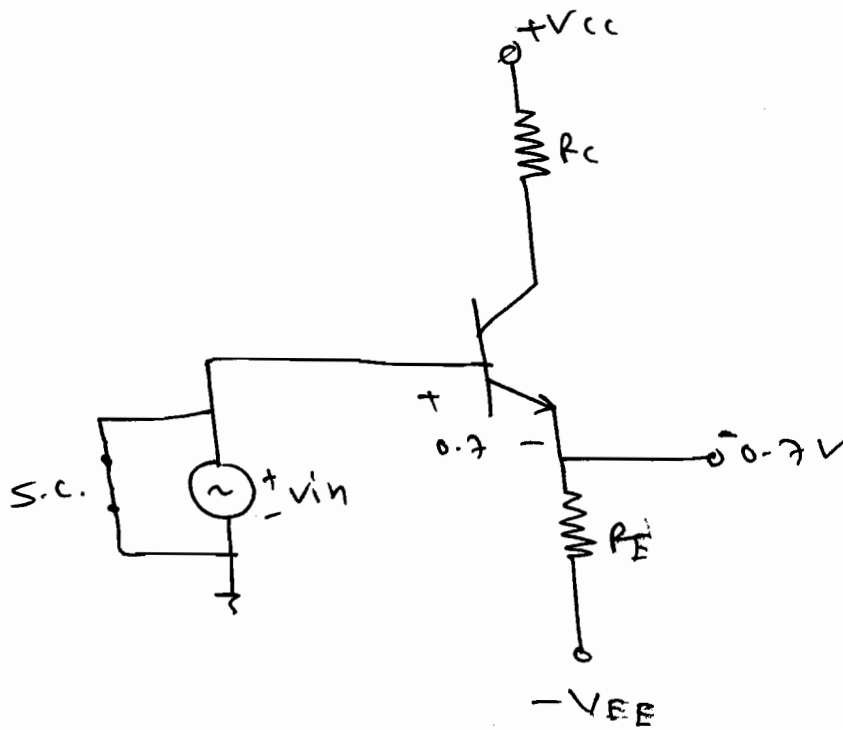
This current mirror:

* Imp Concept



(1) Eliminate Voltage divider By negative Supply.

De



$$\therefore I_{C_{DC}} = \frac{-0.7 - (-V_{EE})}{R_E}$$

$$I_{C_{DC}} = \frac{V_{EE} - 0.7}{R_E}$$

$$\therefore I_{C_{DC}} = \frac{V_{EE} - V_{BE}}{R_E}$$

By voltage divider

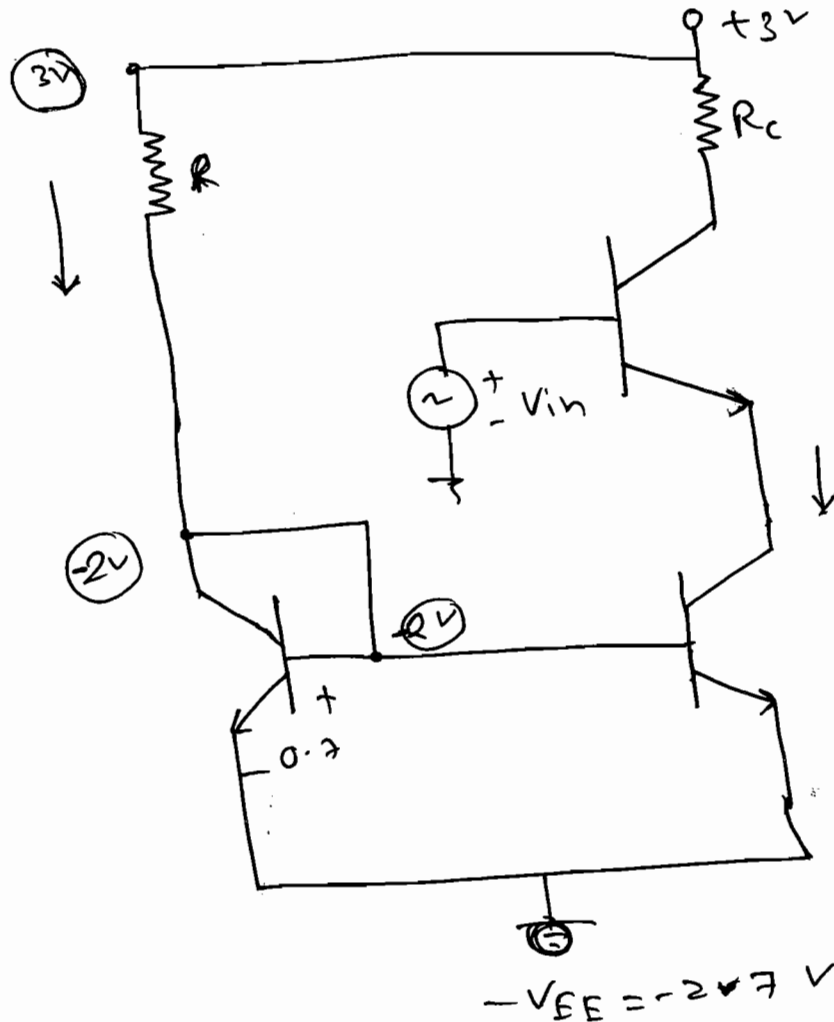
$$I_{C_{DC}} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

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

(2) We have to replace R_E by constant current source.

→ In absence of R_E we can bias BJT with proper choice of R .

→ R_E can be replaced by current mirror as shown in figure



We want
SMA

This can be
achieve by
choosing R .

→ Required current SMA.

$$\therefore \text{SMA} = \frac{3 - (-2V)}{R}$$

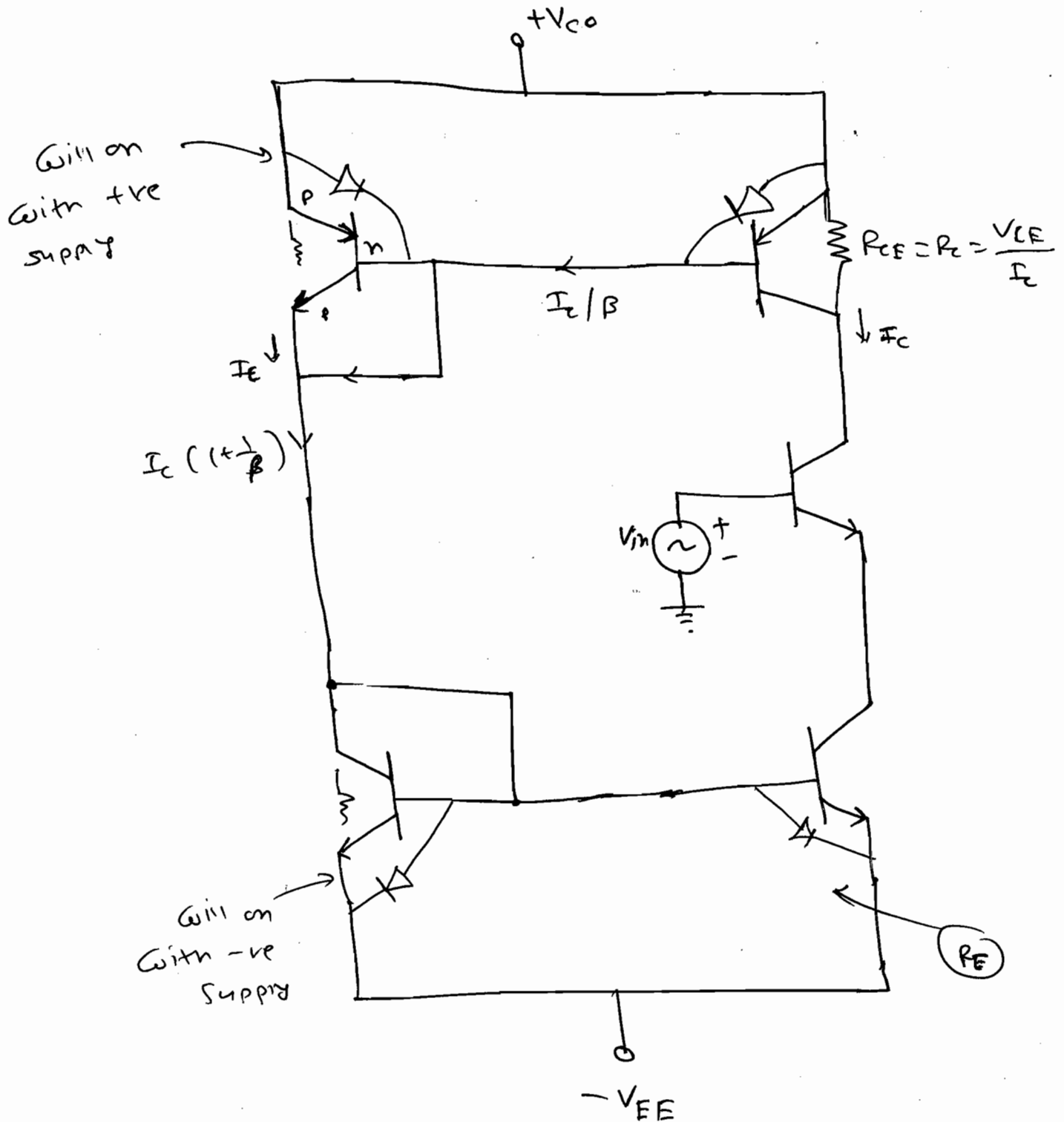
$$\therefore R = \frac{5}{\text{SMA}}$$

$$\therefore \boxed{R = 1k\Omega}$$

→ So, till now we replace R_1, R_2 , and C_E by negative supply ($-V_{EE}$) and R_E by current mirror.

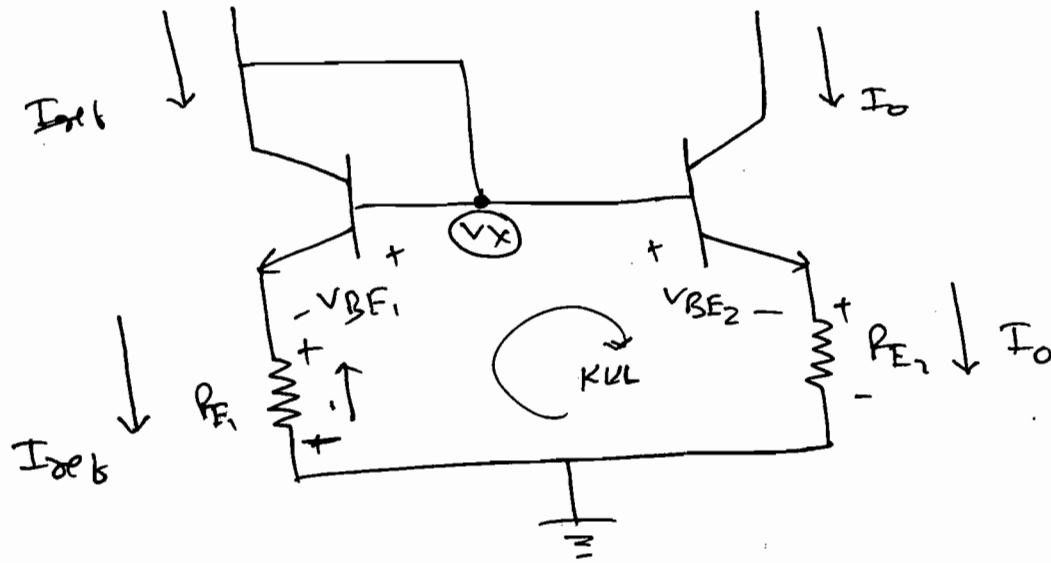
③ Now, we can replace R_c by PNP Transistor.

→ BJT is acting as a Resistor with constant I_B in current mirror.



* Current ^{mirror} Emitter Degeneration Resistors 135

⇒



$$\rightarrow V_x = V_{BE1} + I_{ref} R_{E1} = V_{BE2} + I_O R_{E2}$$

But if $V_{BE1} = V_{BE2}$

$$\therefore I_{ref} R_{E1} = I_O R_{E2}$$

Ideally

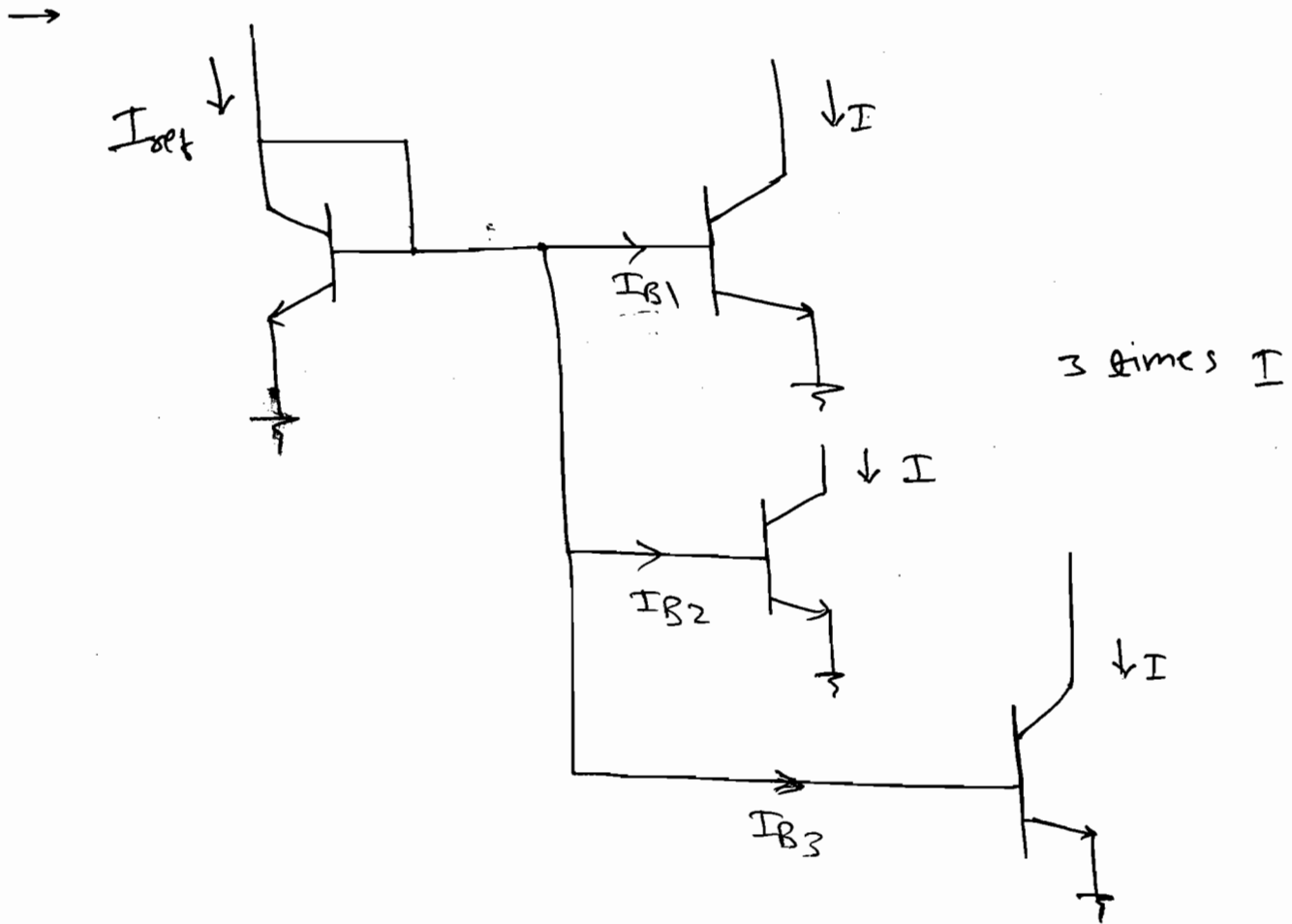
$$V_{BE1} = 0.700 \text{ V}$$

$$V_{BE2} = 0.701 \text{ V}$$

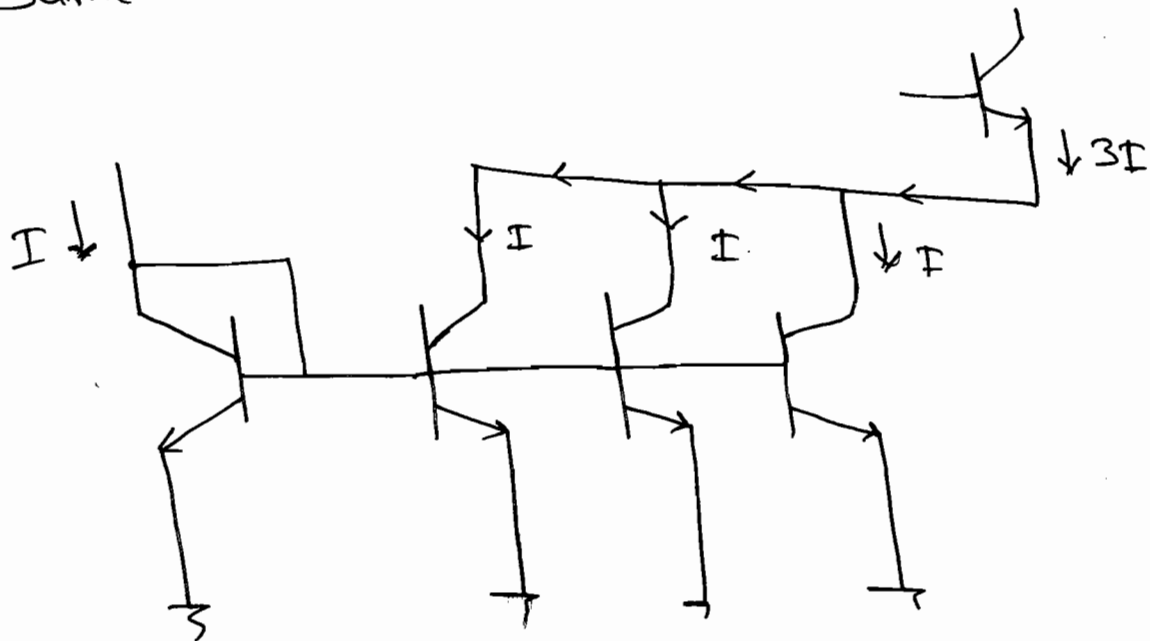
$$\therefore \boxed{\frac{I_O}{I_{ref}} = \frac{R_{E1}}{R_{E2}}}$$

→ By choosing proper resistor we can adjust I_O .

☆ Current Source in Parallel :-



→ Same circuit can be represented as follow:



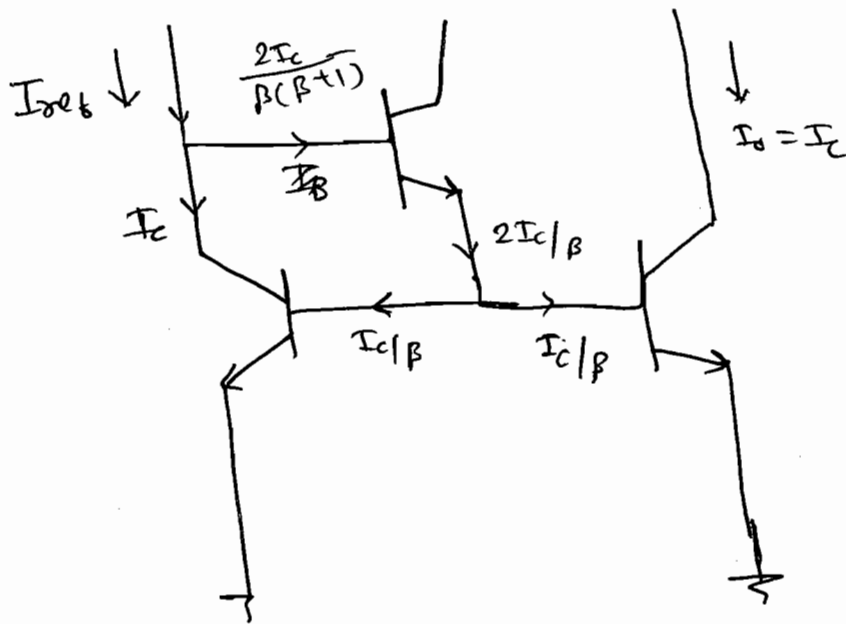
→ Ideal output Resistance should be ∞ .

$r_o \approx \infty$.

→ But as we connect current source in parallel o/p resistance will decrease.

Disadvantage:

- The output Resistance decreases when current sources are connected in parallel.
- The load on I_{ref} has increase to supply base currents to all the parallel transistors.
- To decrease the load on I_{ref} . let us include transistor Q_3 in the current mirror.



$$\rightarrow I_{ref} = \frac{2I_C}{\beta(\beta+1)} + I_C.$$

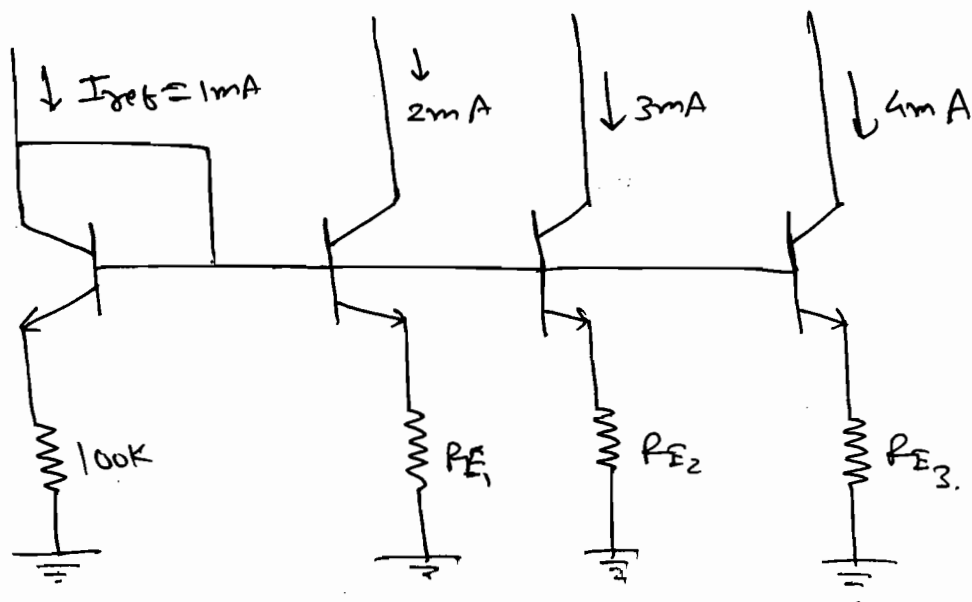
$$I_{ref} = I_C \left[1 + \frac{2}{\beta^2 + \beta} \right]$$

$$\therefore I_{ref} = I_O \left[1 + \frac{2}{\beta^2 + \beta} \right]$$

→ I_b β is very large.

$$\therefore I_{\text{ref}} \approx I_0$$

Ex-1 Find R_{E1} , R_{E2} , R_{E3} ?



$$\therefore I_{\text{ref}} \times 100k = R_{E1} \times 2m$$

$$\therefore 1m \times 100k = R_{E1} \times 2m$$

$$\boxed{R_{E1} = 50k}$$

$$\therefore R_{E2} = \frac{1m \times 100k}{3mA}$$

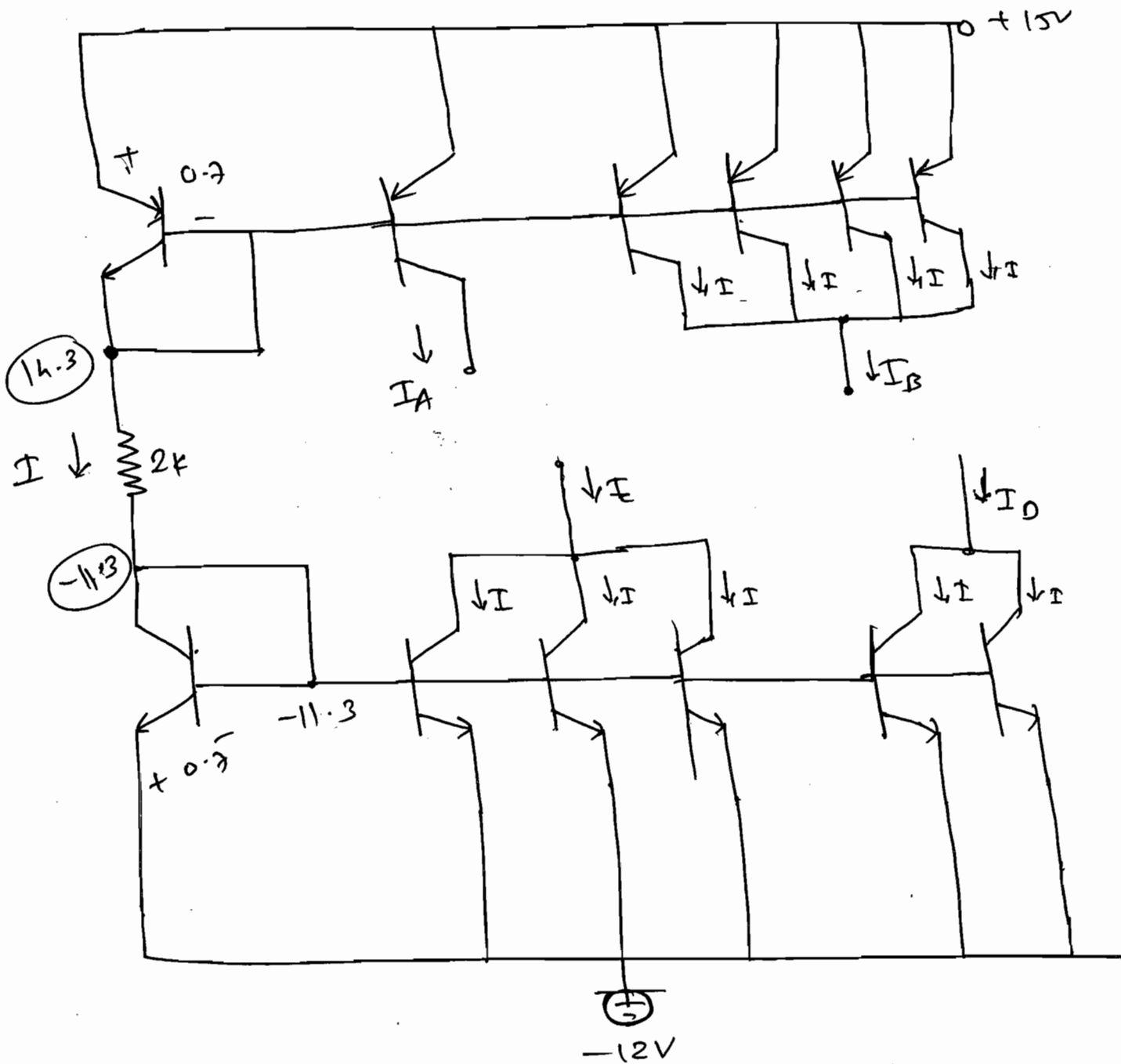
$$\therefore \boxed{R_{E2} = 33.333 \text{ k}\Omega}$$

$$\therefore R_{E3} = \frac{1m \times 100k}{4m}$$

$$\therefore \boxed{R_{E3} = 25 \text{ k}\Omega}$$

Ex-2 Calculate I_A, I_B, I_C, I_D .

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$$\Rightarrow I_A = I$$

$$I_B = 4I$$

$$I_C = 3I$$

$$I_D = 2I$$

$$I = \frac{14.3 + 11.3}{2k} \text{ mA}$$

$$I = 12.8 \text{ mA}$$

$$I_A = 12.8 \text{ mA}$$

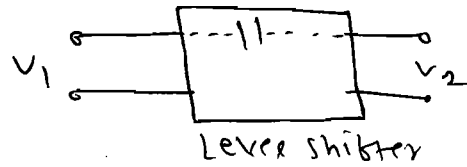
$$I_B = 12.8 \times 4 = 51.2 \text{ mA}$$

$$I_C = 3I = 12.8 \times 3 = 38.4 \text{ mA}$$

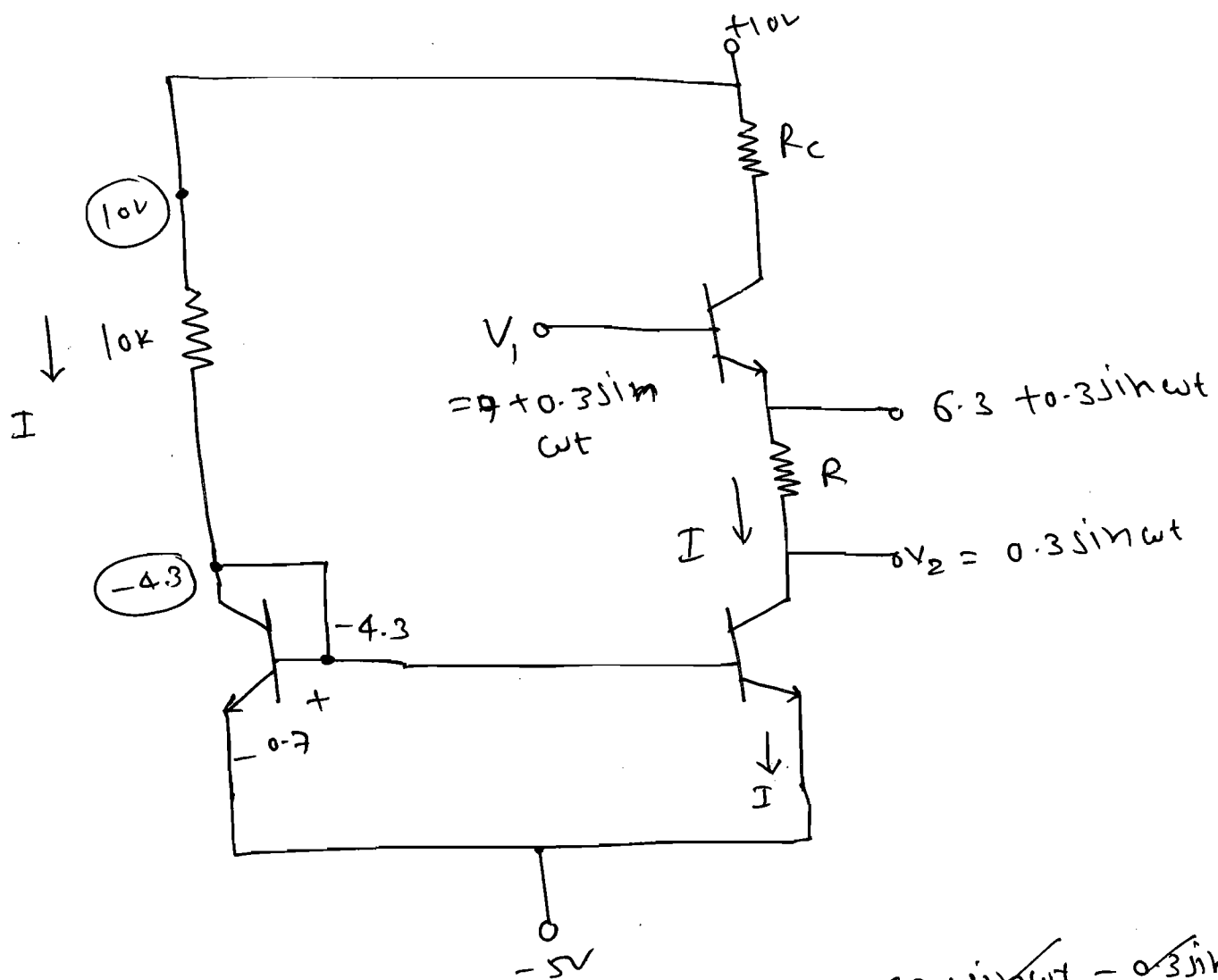
$$I_D = 2I = 25.6 \text{ mA}$$

* The Purpose of the alp capacitor:
is to block Dc and allow Ac signal.

$\Rightarrow$ Dc can be BLOCK With circuit Called
level shifter.



Ex: Find the value of R if, $V_1 = 9.7 + 0.3 \sin \omega t$
and $V_2 = 0.3 \sin \omega t$.



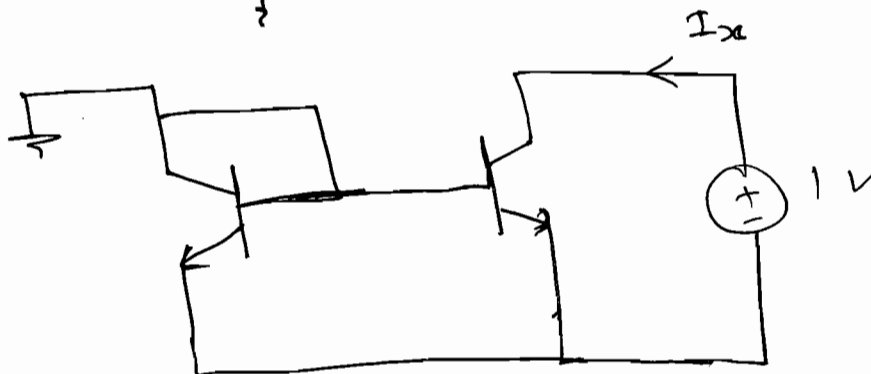
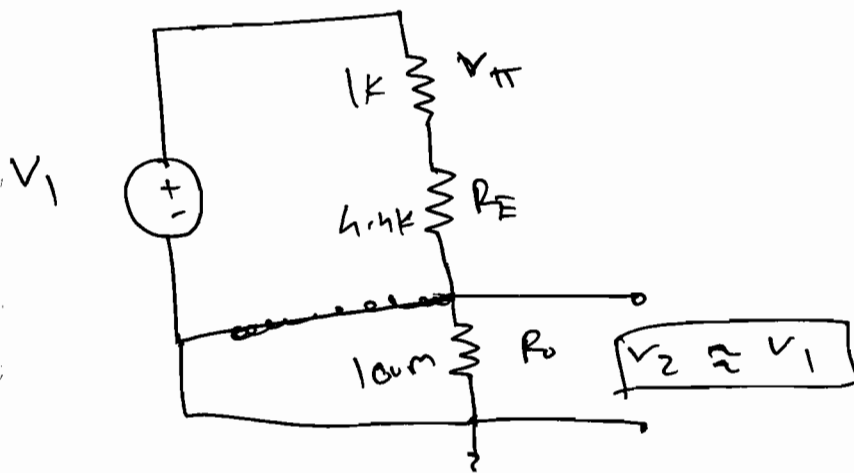
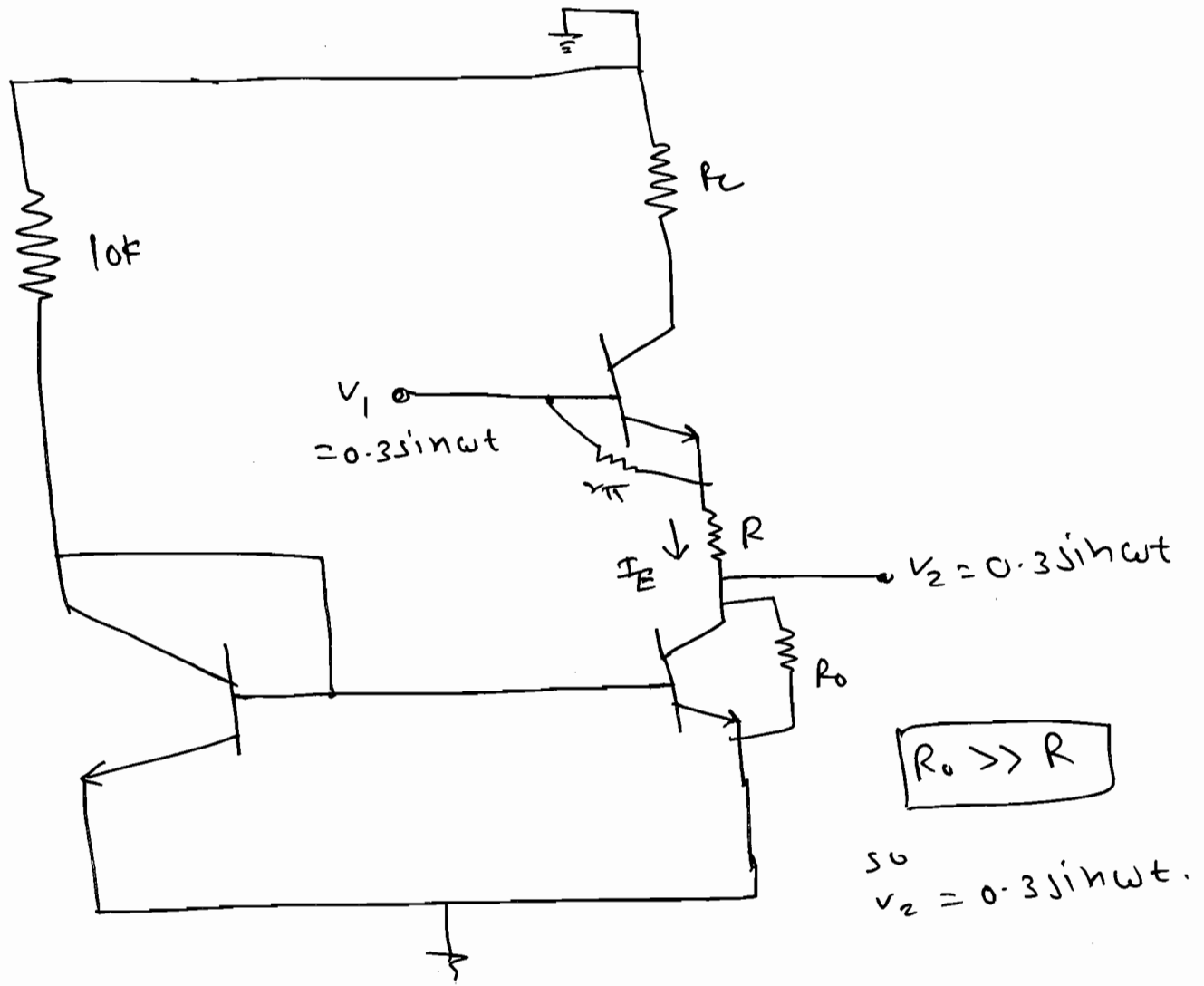
$$I = \frac{10 + 4.3}{10k}$$

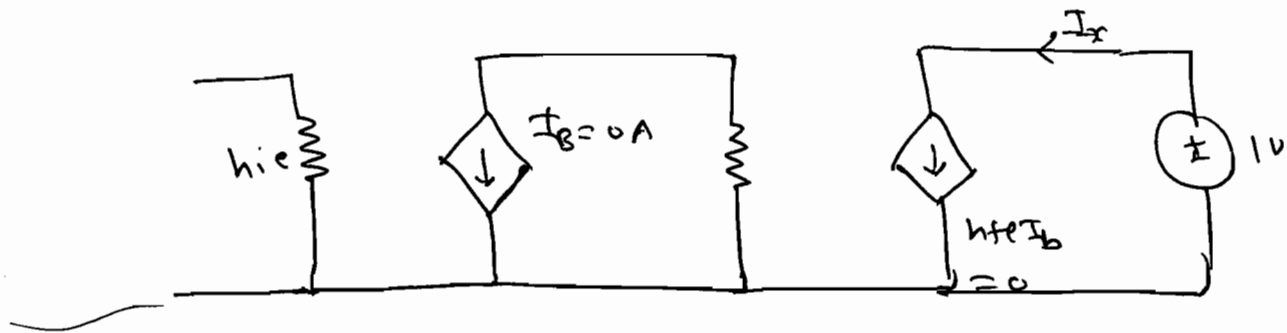
$$I = 1.43 \text{ mA}$$

$$I = \frac{9.7 + 0.3 \sin \omega t - 0.3 \sin \omega t}{R}$$

$$R = \frac{9.7}{1.43}$$

$$R = 4.4 \text{ k}\Omega$$





$$\Rightarrow Z_o = \frac{1V}{I_x}$$

$$Z_o = \frac{1V}{0}$$

$$Z_o = \infty$$

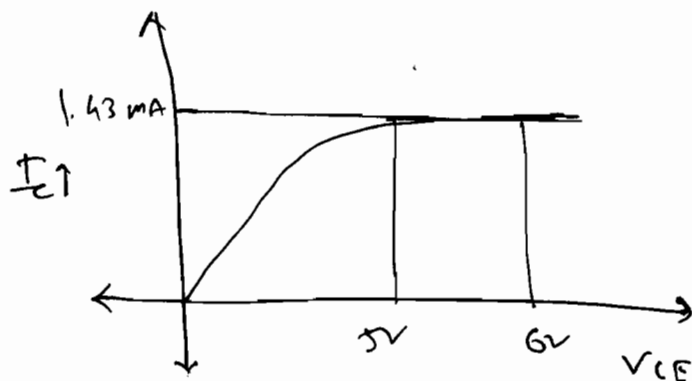
→ By BJT we can choose Resistor
from 0 (sat) to ∞ (cut off) by choosing
operating point. and it has variable
nature because it is non-linear

$$R_E = 100 \text{ m}\Omega$$

$$I_{E_{dc}} = 1 \text{ mA}$$

$$\Rightarrow \min V_{CC} = R_E I_{E_{dc}} = R_E I_E$$

$$V_{CC} = 100 \text{ mV} \rightarrow \text{undesirable.}$$



$$R_{DC} = \frac{5}{1.43 \text{ m}}$$

$$R_{DC} = 3.49 \text{ k}\Omega$$

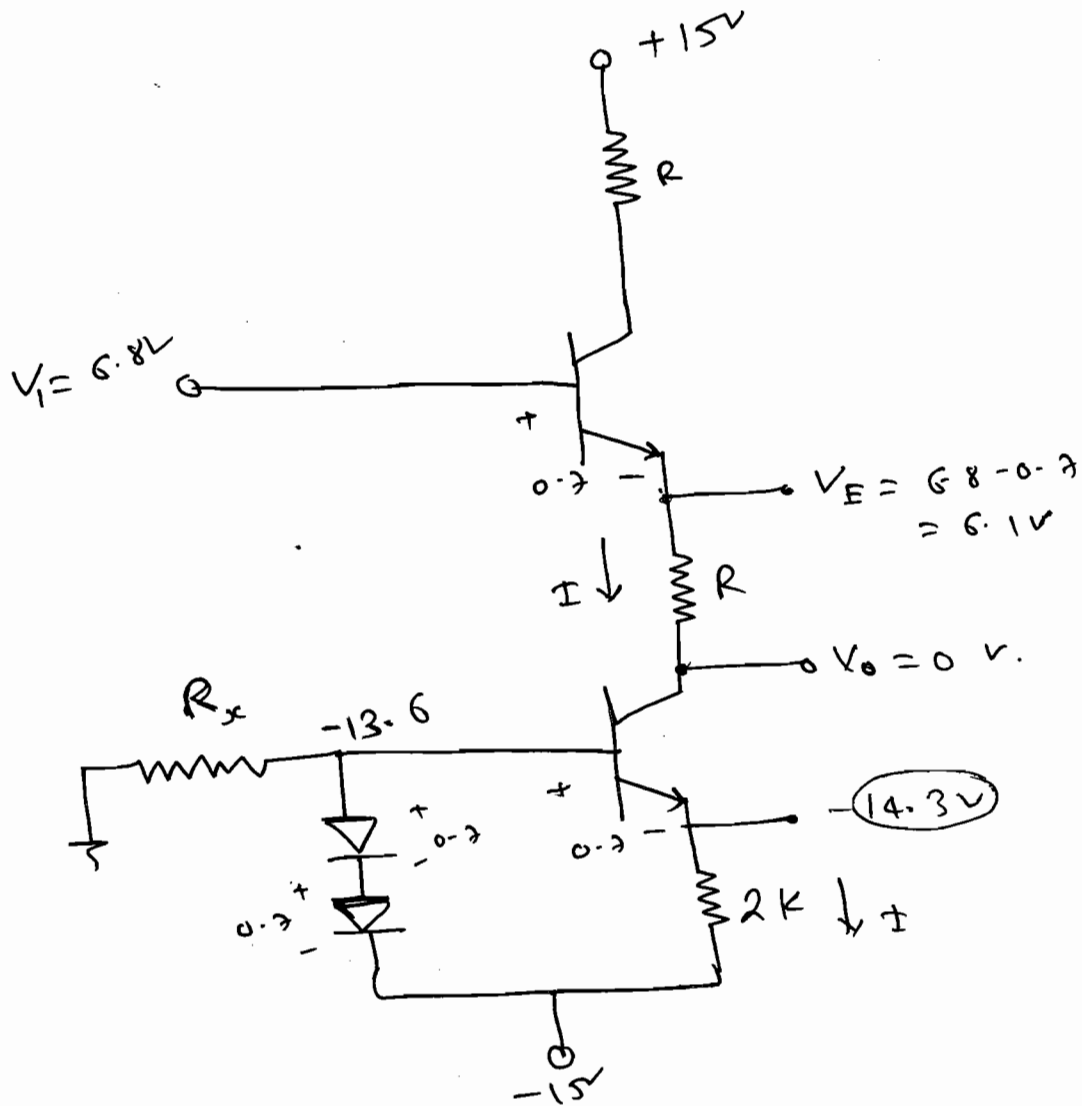
↓
DC resistance.

$$R_{AC} = \frac{\Delta V_{CE}}{\Delta I_E} = \frac{6-5}{1.43-1.43} = \frac{1}{0} = R_o = \infty.$$

AC Resistance

$$R_{AC} = \infty.$$

Ex: Find the value of R for DC level shift
of 6.8V.



$$I = \frac{-14.3 + 15}{2k}$$

$$I = \frac{6.1 - 0}{R}$$

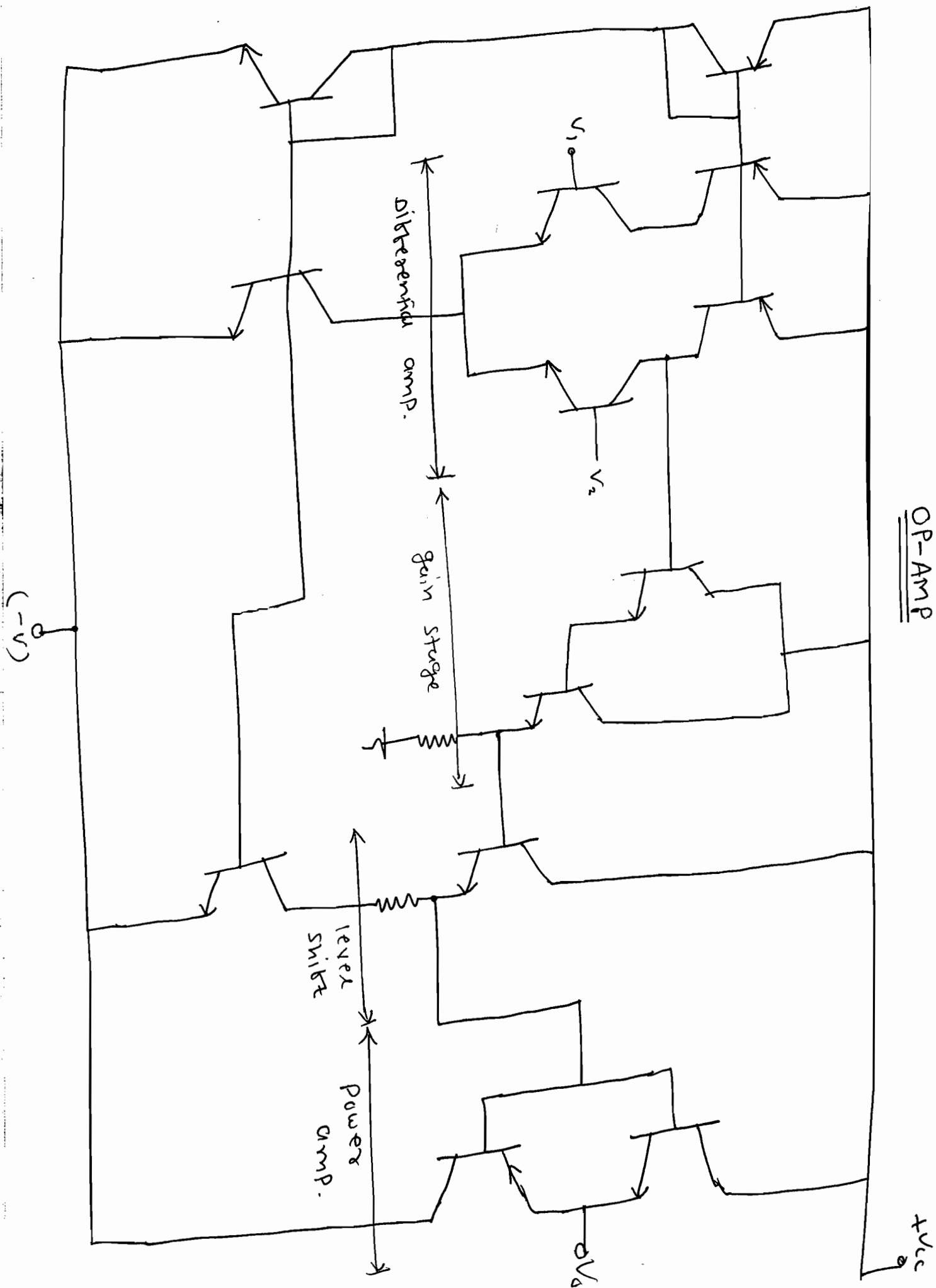
$$I = \frac{0.7}{2k}$$

$$\frac{6.1}{R} = \frac{0.7}{2k}$$

$\therefore R =$

$$\therefore R = 17.43mA$$

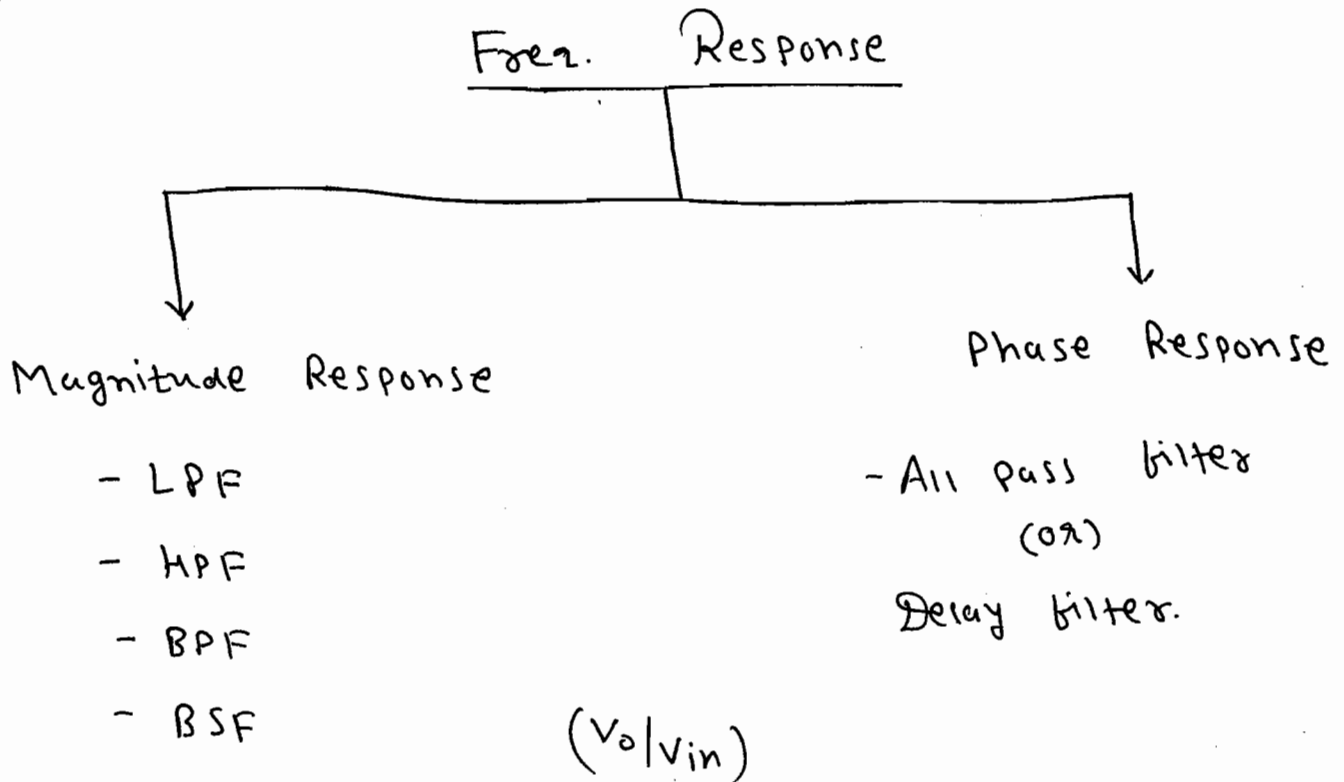
OP-AMP



* Frequency Response:

145

⇒



⇒

1. LPF $\Rightarrow \frac{K}{1+s\tau}$

2. HPF $\Rightarrow \frac{Ks}{1+s\tau}$

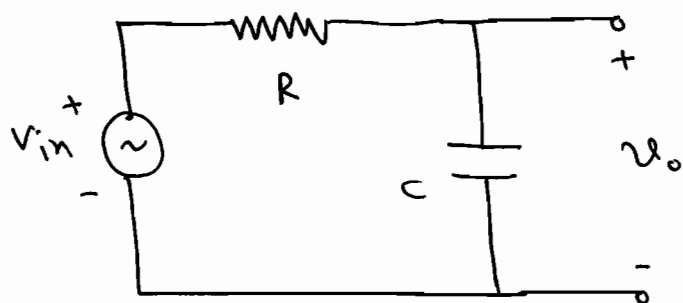
3. BPF $\Rightarrow \frac{Ks}{s^2 + 2\xi\omega_0 s + \omega_0^2}$

4. BSF $\Rightarrow \frac{K[s^2 + \omega_0^2]}{s^2 + 2\xi\omega_0 s + \omega_0^2}$

5. All Pass filter $\Rightarrow \frac{s-a}{s+a}$

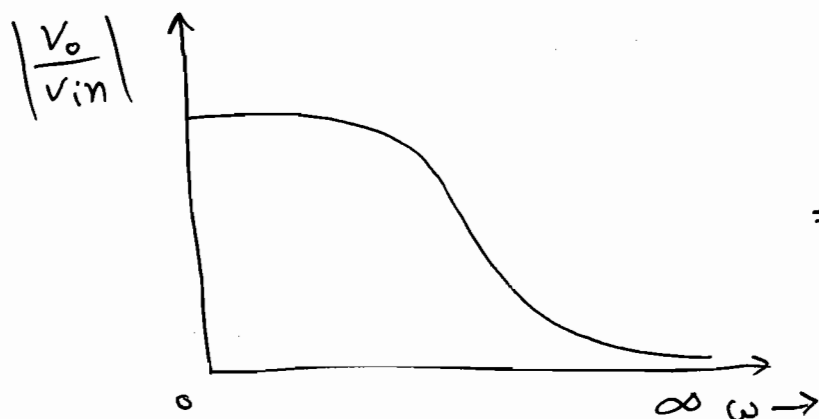
* Recognize the type of filter:

☆



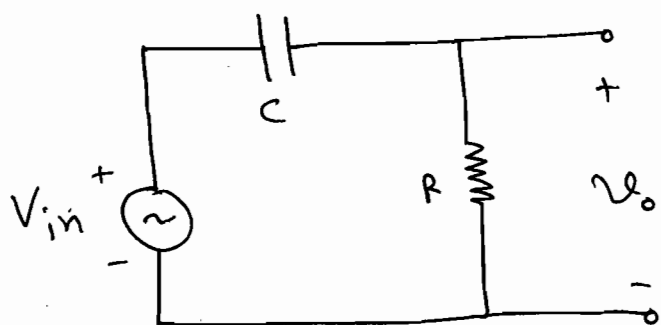
⇒

	$\omega = 0$	$\omega = \infty$
Cap ($\frac{1}{\omega C}$)	(O.S.)	(S.C.)
Inductor (ωL)	(S.C.)	(O.C.)



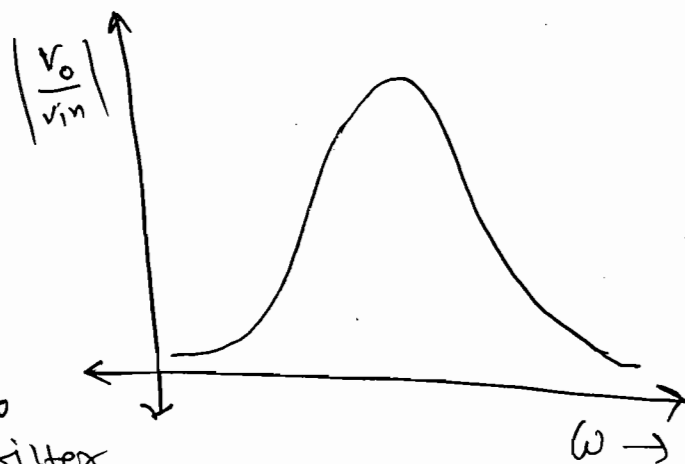
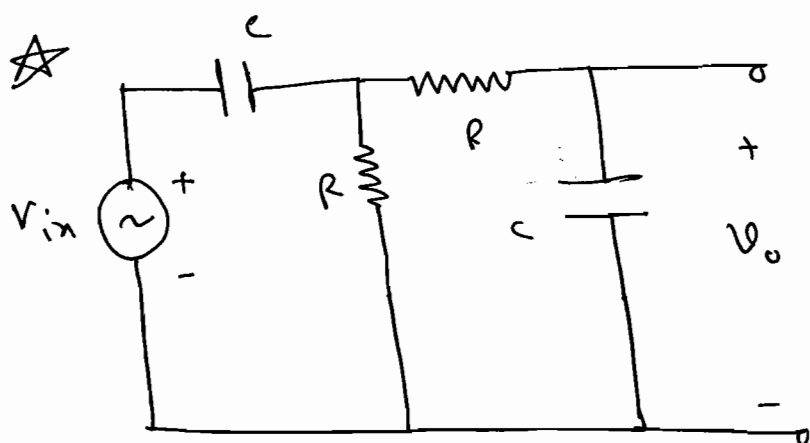
⇒ Low Pass filter.

☆



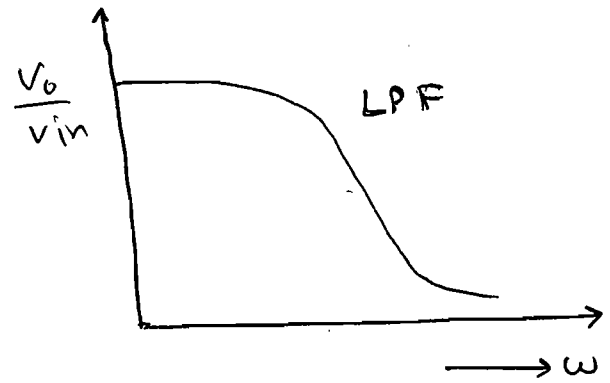
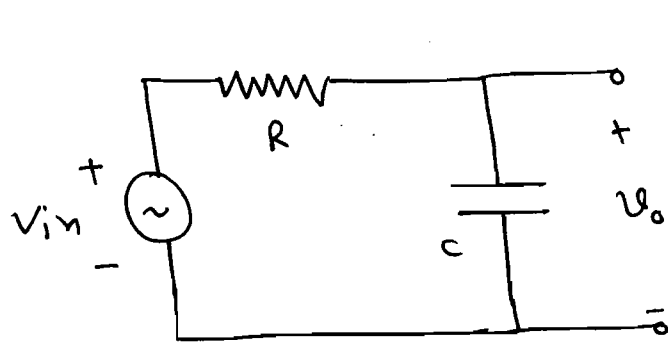
High pass filter

☆



Band Pass filter

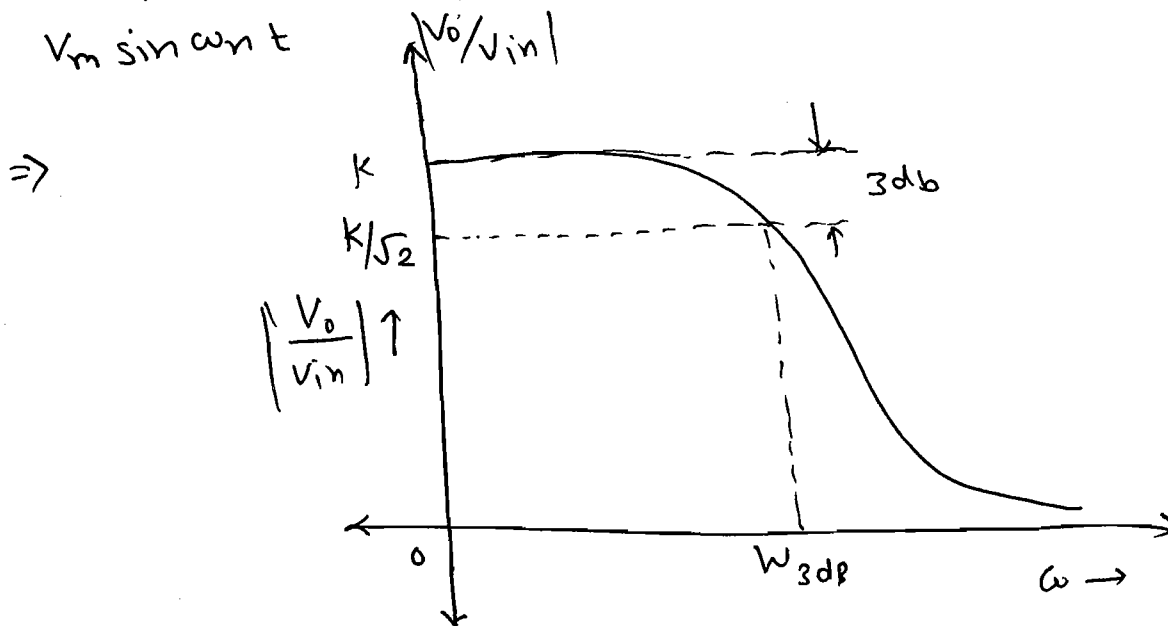
⇒ Here we are interested in the 2nd parameter. 147



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

$$= V_m \sin \omega t$$

$$V_m \sin \omega t$$



$$\Rightarrow \text{LPF: } \left| \frac{V_o}{V_{in}} \right| = \frac{K}{1 + j\omega\tau} = \left| \frac{K}{1 + j\omega\tau} \right|$$

$$= \frac{K}{\sqrt{1 + \omega^2\tau^2}}$$

At $\omega = \omega_{3dB}$ gain reduced to $K/\sqrt{2}$.

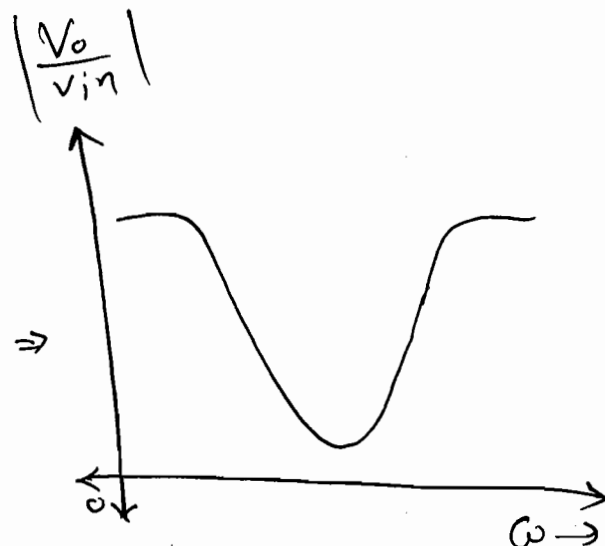
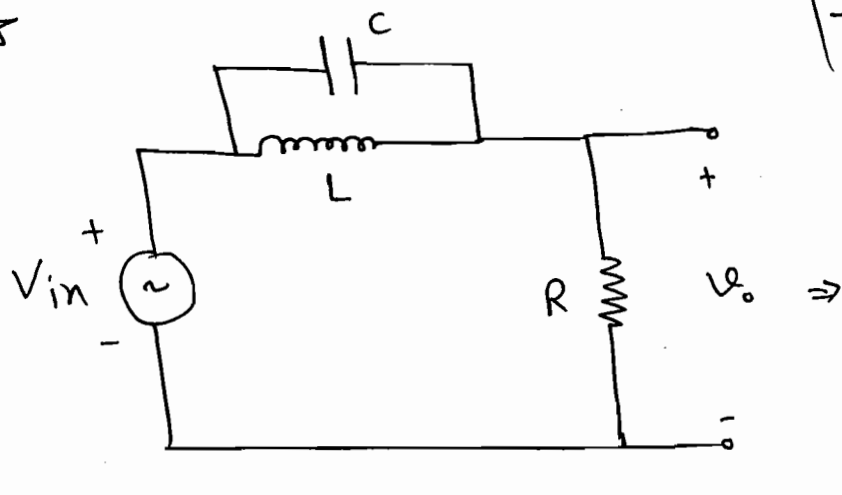
$$\therefore \frac{K}{\sqrt{2}} = \frac{K}{\sqrt{1 + (\omega_{3dB}\tau)^2}}$$

$$\therefore 1 + \omega_{3dB}^2 \tau^2 = 2$$

$$\therefore \omega_{3dB}^2 = \frac{1}{\tau^2}$$

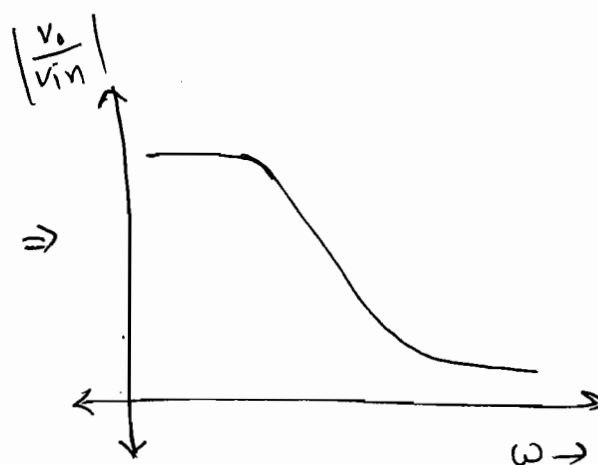
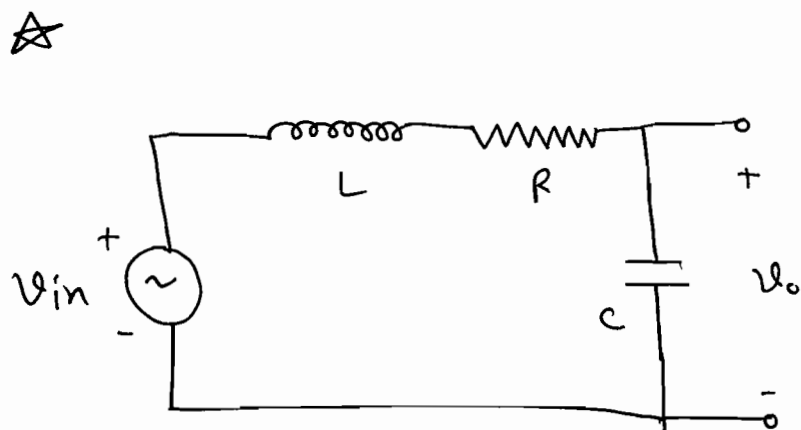
$$\omega_{3db} = \frac{1}{2}$$

☆



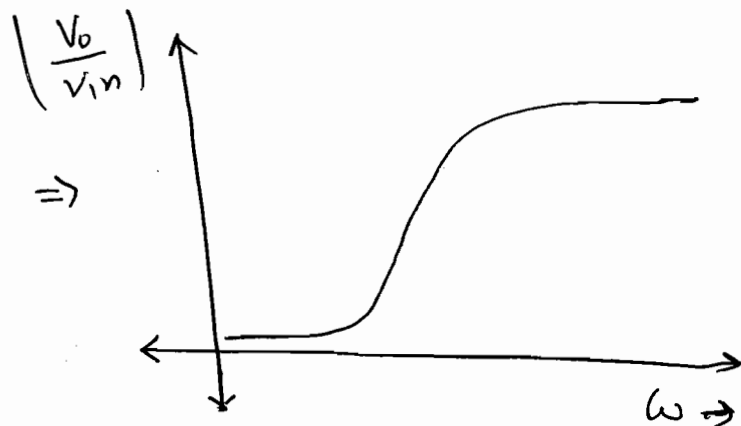
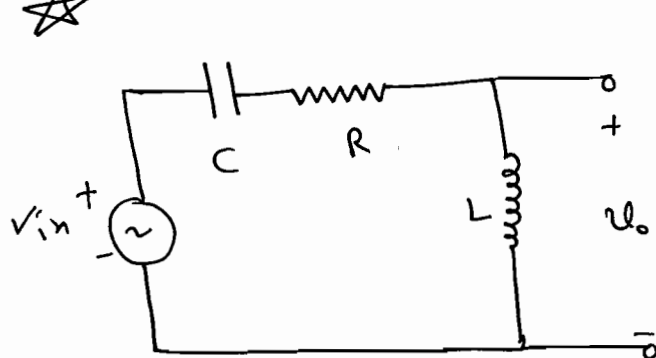
Band stop filter:

☆



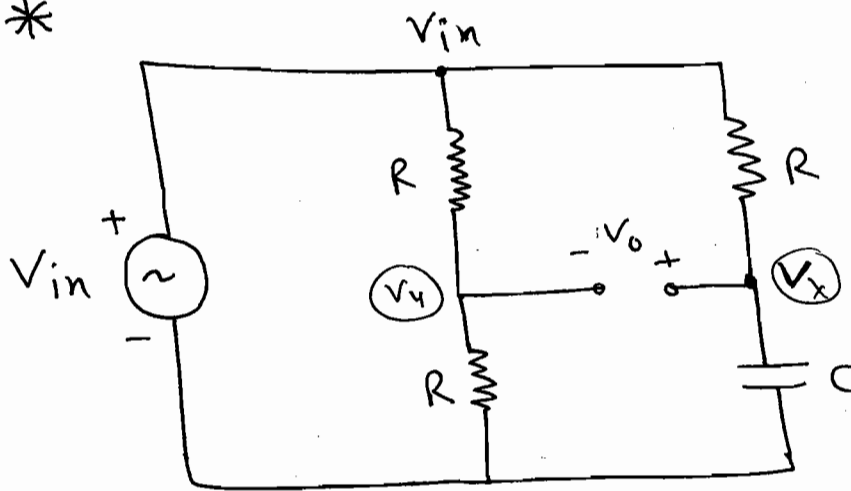
Low Pass filter:

☆



High pass filter:

*



$$\Rightarrow V_o = V_x - V_y.$$

$$V_x = \left(\frac{\frac{1}{sC}}{R + \frac{1}{sC}} \right) V_{in} = \frac{V_{in}}{1 + sCR}$$

$$V_y = \left(\frac{R}{R + R} \right) V_{in} = \frac{V_{in}}{2}.$$

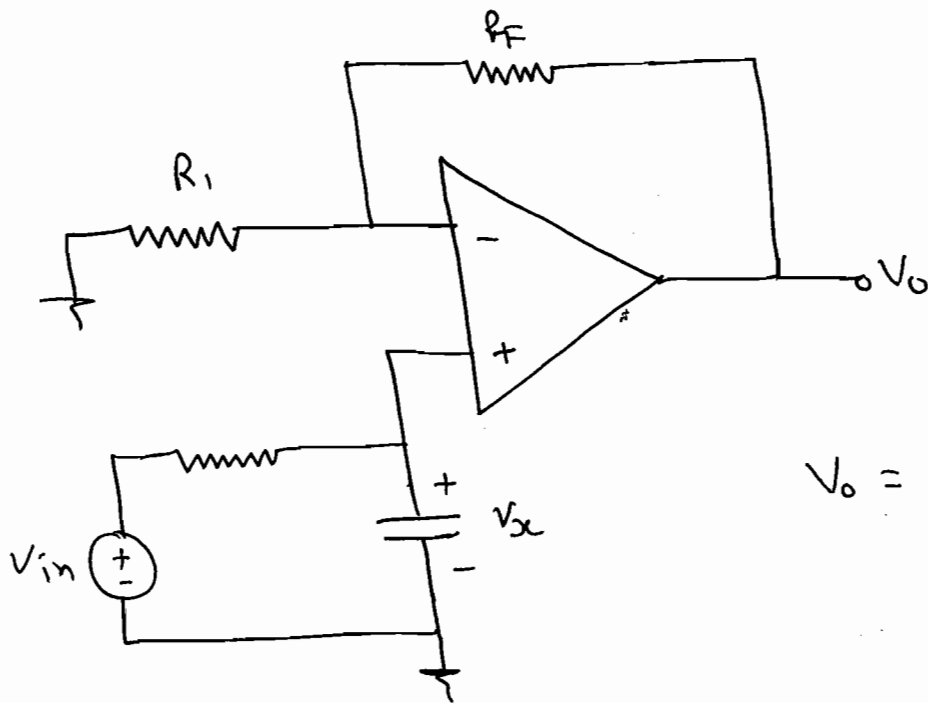
$$\therefore V_o = V_{in} \left[\frac{1}{1 + sCR} - \frac{1}{2} \right].$$

$$V_o = V_{in} \left[\frac{2 - 1 - sCR}{2C(1 + sCR)} \right]$$

$$\therefore \frac{V_o}{V_{in}} = \frac{1 - sCR}{2 + 2sCR} = \frac{s - a}{s + a} \text{ form.}$$

All pass filter.

*



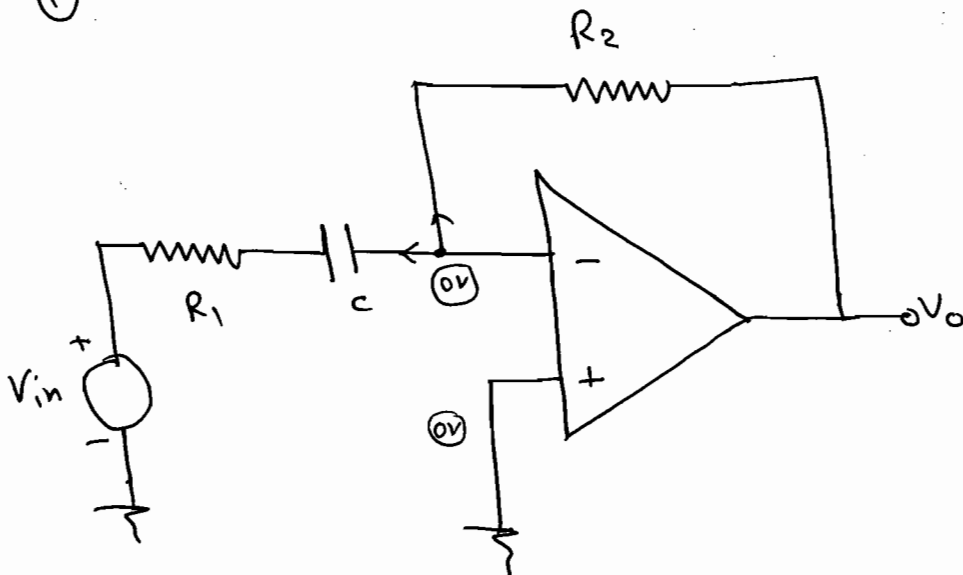
$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_x$$

⇒ Use the Passive Components at high freq. (R, L, C 's).

⇒ OPamp can not work at high freq.
OPamp itself is a lowpass filter.
Because of Restricted by Gain BW Product.

★ Recognize the type of the filter also
find the transfer fn V_o/V_{in} .

①



⇒ By NDA,

$$\frac{0 - V_0}{R_2} + \frac{0 - V_{in}}{R_1 + \frac{1}{sC}} = 0.$$

$$\therefore \frac{V_0}{R_2} = - \frac{V_{in} \times sC}{1 + R_1 sC}.$$

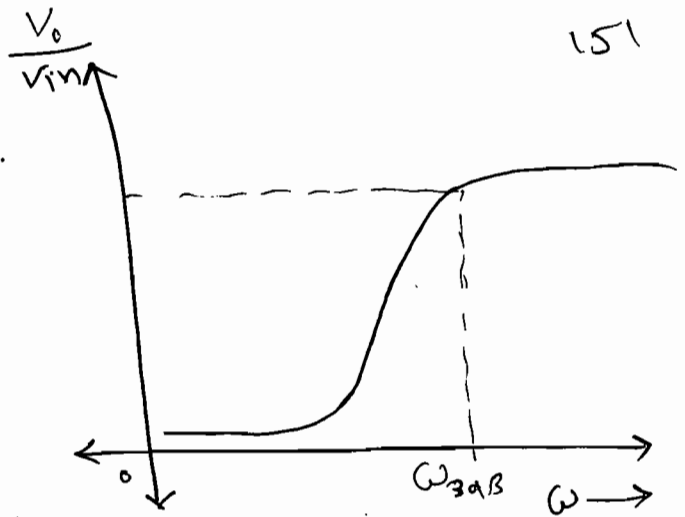
$$\therefore \frac{V_0}{V_{in}} = - \frac{R_2 sC}{1 + R_1 sC}.$$

$$\therefore \left| \frac{V_0}{V_{in}} \right| = \left| \frac{R_2 sC}{1 + sC R_1} \right| = \frac{KS}{1 + sT}$$

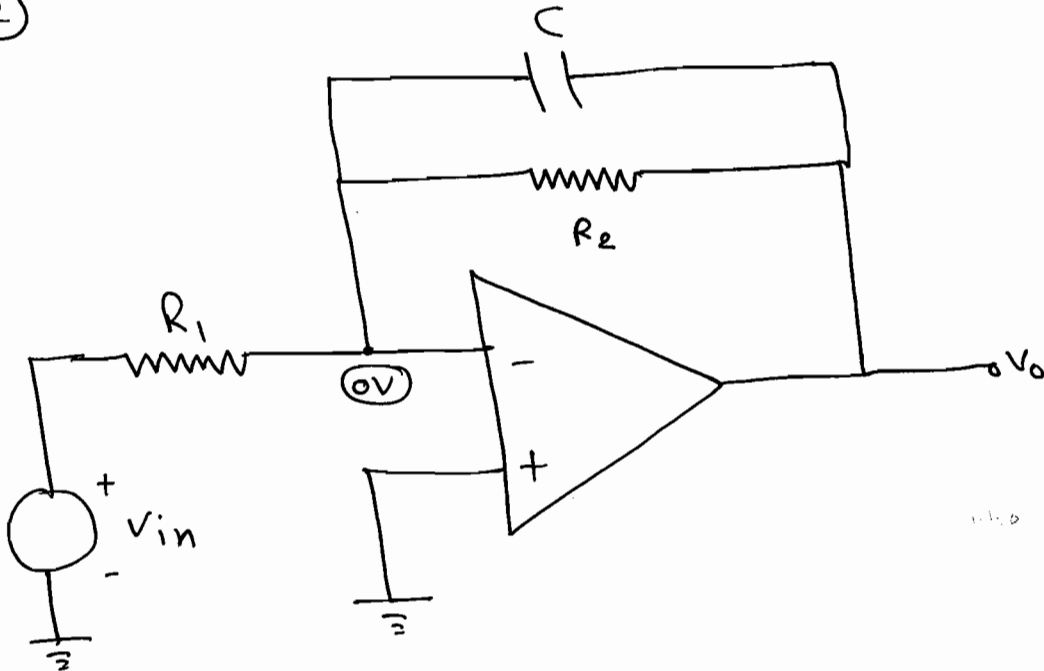
$$\Downarrow$$

$$\omega_{3dB} = \frac{1}{T} = \frac{1}{R_1 C}$$

So, High pass filter.



(2)



$$\Rightarrow \frac{0 - V_{in}}{R_1} + \frac{0 - V_0}{C \parallel R_2} = 0.$$

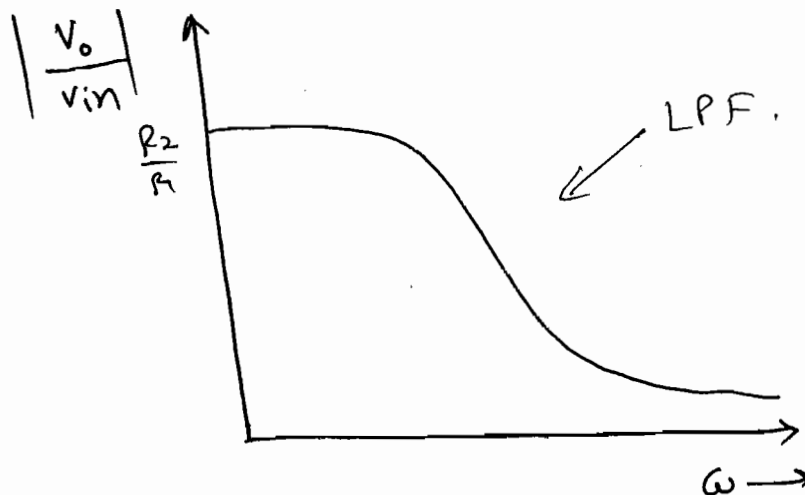
$$\therefore \frac{-V_0}{\frac{R_2 C}{R_2 + C}} = \frac{V_{in}}{R_1}$$

$$\therefore \frac{V_o}{V_{in}} = \frac{R_2 C}{R_1 (R_2 + R_2)} \\ = \frac{R_2 / sC}{R_1 (R_2 + \frac{1}{sC})}$$

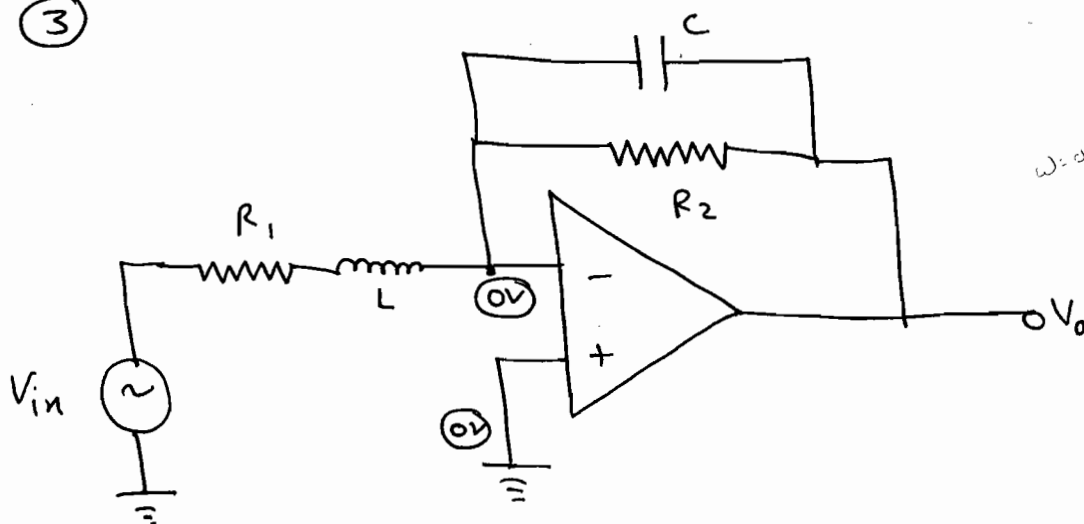
$$\therefore \frac{V_o}{V_{in}} = \frac{R_2}{R_1 (1 + sCR_2)} = \frac{K}{1 + s\tau}$$

So, Low Pass filter.

$$\omega_{3dB} = \frac{1}{\tau} = \frac{1}{R_2 C}$$



(3)



$\omega = 0 \rightarrow s = 0 \rightarrow C \rightarrow P-S.F$

By NDA,

$$\frac{0 - V_{in}}{R_1 + sL} + \frac{0 - V_o}{R_2 \parallel \frac{1}{sC}} = 0$$

$$\therefore \frac{V_{in}}{R_1 + sL} = -V_o \left[\frac{R_2 + \frac{1}{sC}}{R_2 \parallel sC} \right]$$

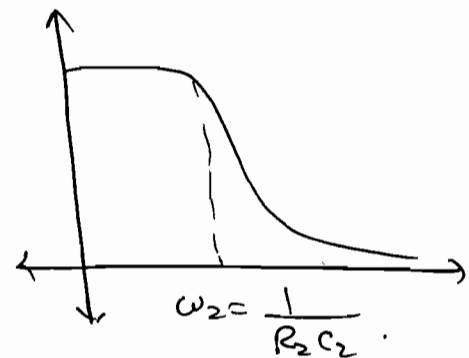
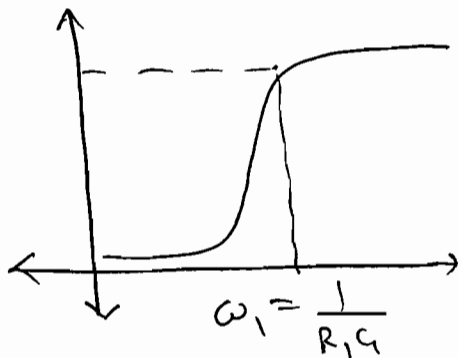
$$\therefore \frac{V_{in}}{R_1 + sL} = -V_o \left[\frac{1 + R_2 sC}{R_2} \right]$$

$$\therefore \frac{V_o}{V_{in}} = - \frac{R_2}{(R_1 + sL)(1 + R_2 sC)}$$

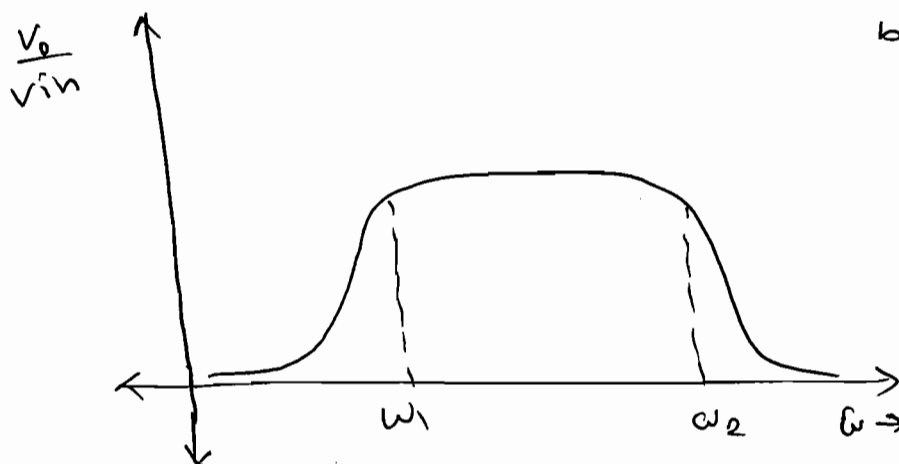
$$\therefore \frac{V_o}{V_{in}} = - \frac{R_2}{R_1 + R_1 R_2 sC + sL + R_2 LC s^2}$$

$$\frac{V_o}{V_{in}} = \frac{-\frac{1}{LC}}{s^2 + \left(\frac{R_1 R_2 C + L}{R_2 LC} \right) s + \frac{R_1}{R_2 LC}}$$

$$\frac{V_o}{V_{in}} = \frac{-R_2/R_1}{(1 + sCR_2)(1 + \frac{sL}{R_1})}$$



$\Rightarrow$ For Band pass filter ; $\omega_2 > \omega_1$
 $\Rightarrow$ otherwise it will be Band stop filter.



$$Z_2 = \frac{R_2}{1 + R_2 C s} \quad , \quad Z_1 = R_1 + sL$$

$$\left| \frac{V_o}{v_{in}} \right| = \left| \frac{Z_2}{Z_1} \right|$$

$$= \frac{R_2 / R_1}{(1 + sCR_2) \left(1 + \frac{sL}{R_1} \right)}$$

$$= \frac{K}{(1 + sT_1) (1 + sT_2)}$$

$$T_1 = R_2 C$$

$$T_2 = L / R_1$$

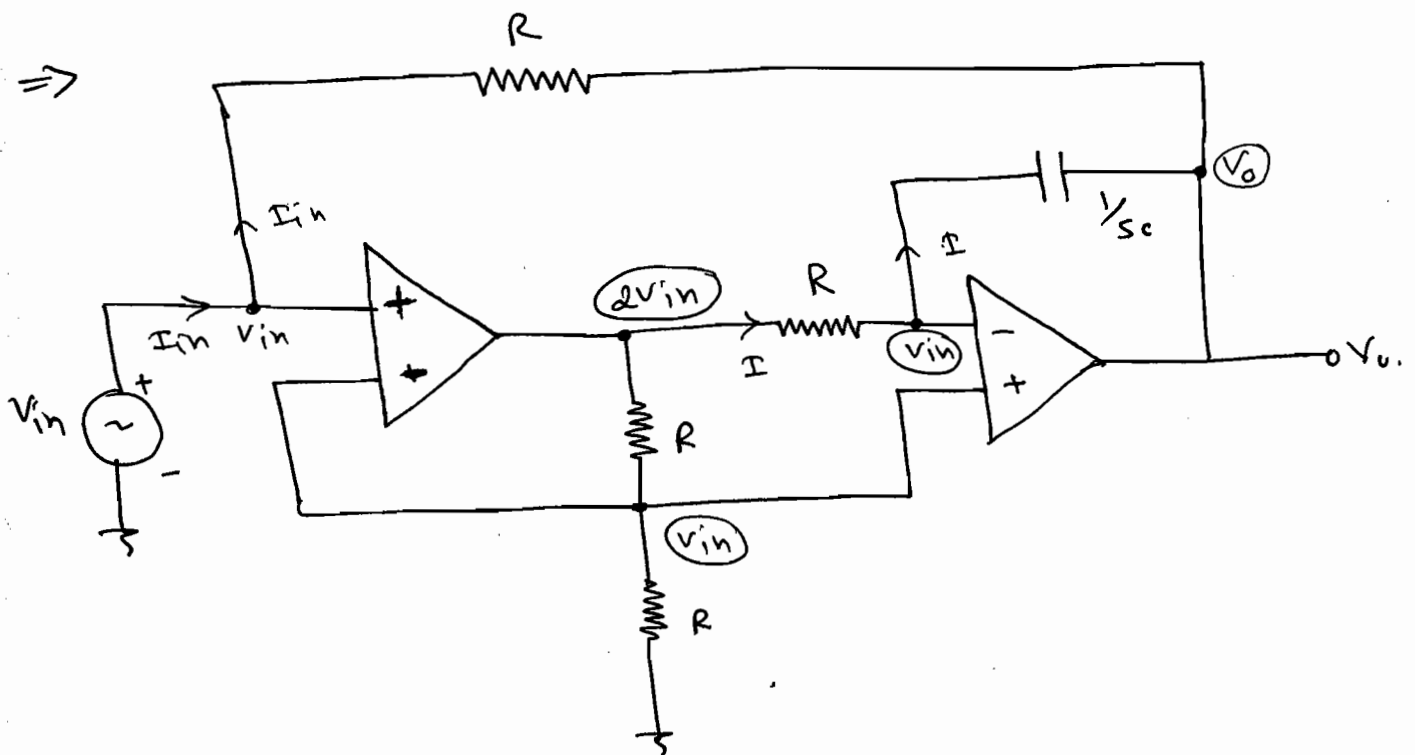
$\Rightarrow$ 2nd order LPF

* Simulation of Inductor [Circuit] 155

$$\Rightarrow \tau = RC = \frac{L}{R}.$$

$$\Rightarrow L = CR^2.$$

$$\frac{V_{in}}{I_{in}} = Z_{in} = SL = SCR^2.$$



$$\Rightarrow I = \frac{2V_{in} - V_{in}}{R} = \frac{V_{in}}{R}.$$

$$\rightarrow V_{in} - V_o = I \left(\frac{1}{s_c} \right).$$

$$\therefore V_{in} - V_o = \frac{V_{in}}{R} \cdot \left(\frac{1}{s_c} \right).$$

$$\therefore V_o = V_{in} - V_{in} \left(\frac{1}{s_c R} \right).$$

$$\Rightarrow I_{in} = \frac{V_{in} - V_o}{R}$$

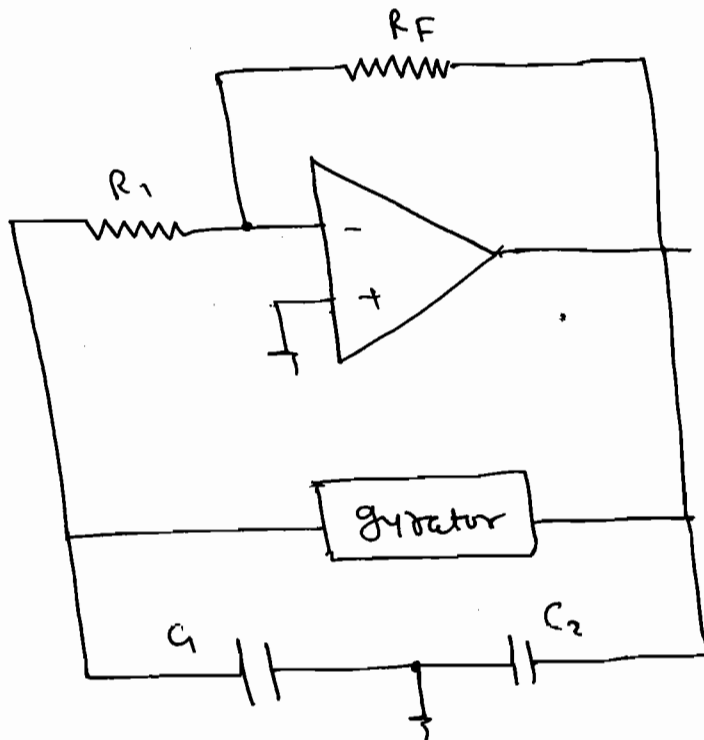
$$I_{in} = \frac{V_{in} - V_{in} + V_{in} \left(\frac{1}{s_c R} \right)}{R}$$

$$\therefore I_{in} = V_{in} \left(\frac{1}{sCR^2} \right)$$

$$\therefore \frac{V_{in}}{I_{in}} = Z_{in} = sCR^2 = sLeq$$

$$\therefore \boxed{L = CR^2}$$

* Colpitt's oscillator:

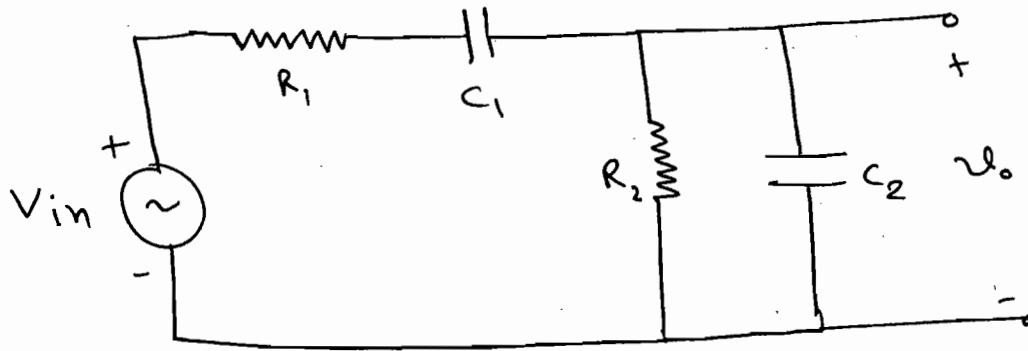


$$\Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$$

$$\therefore f = \frac{1}{2\pi\sqrt{R^2C^2}}$$

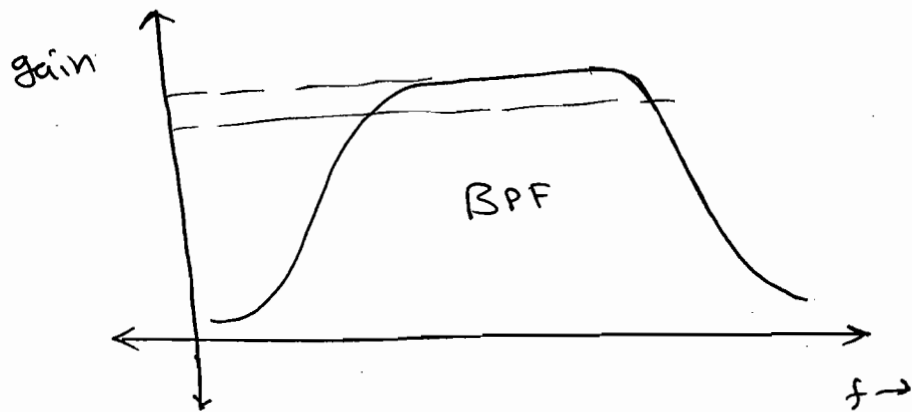
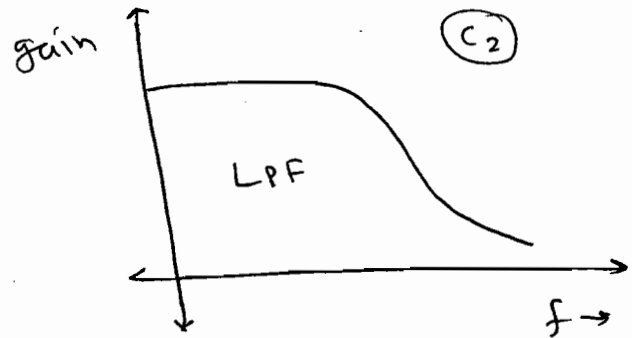
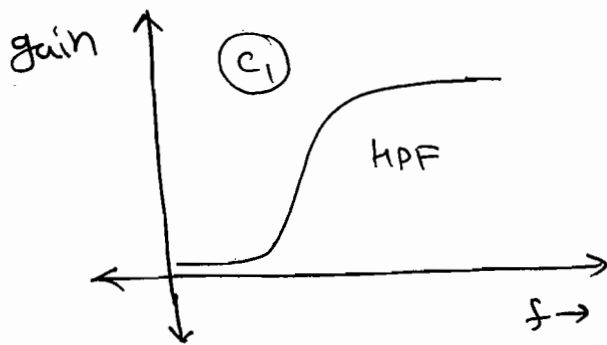
$$\boxed{f = \frac{1}{2\pi RC}}$$

*

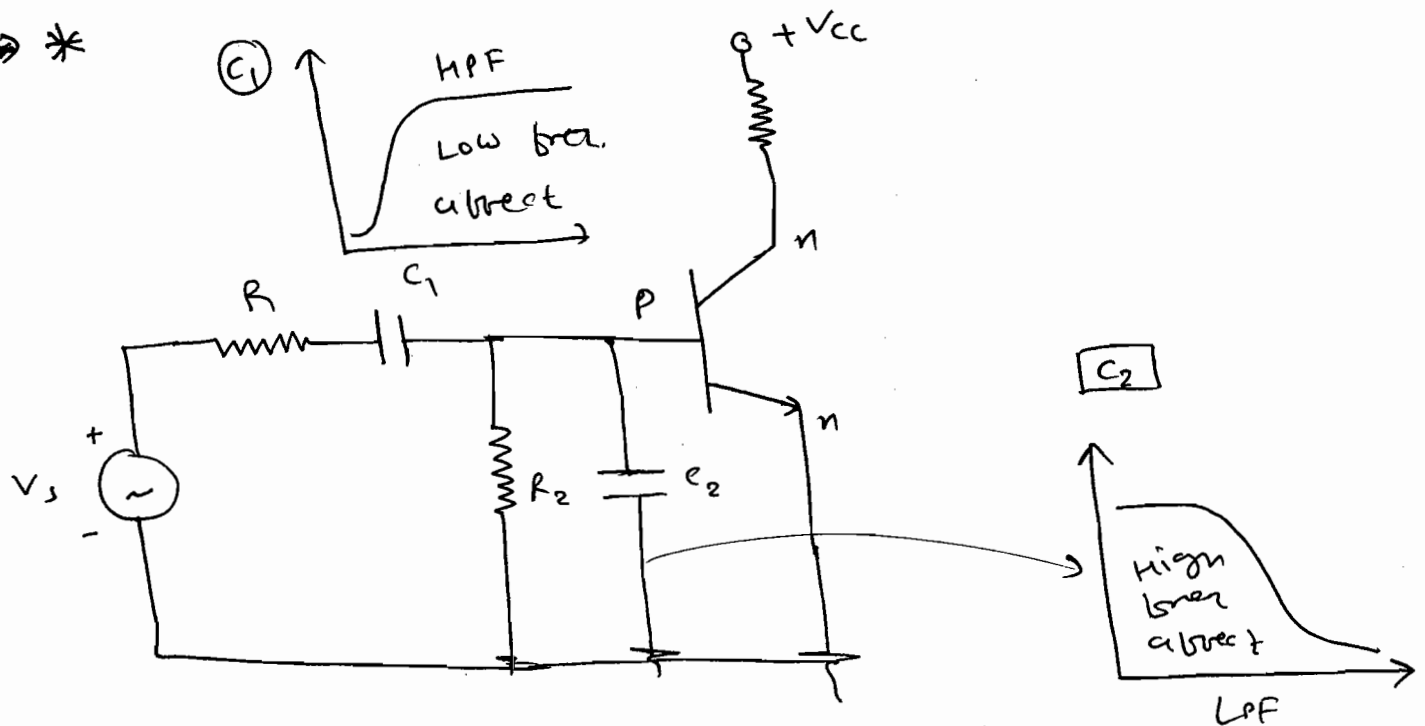


(B NW of Wein bridge oscillator).

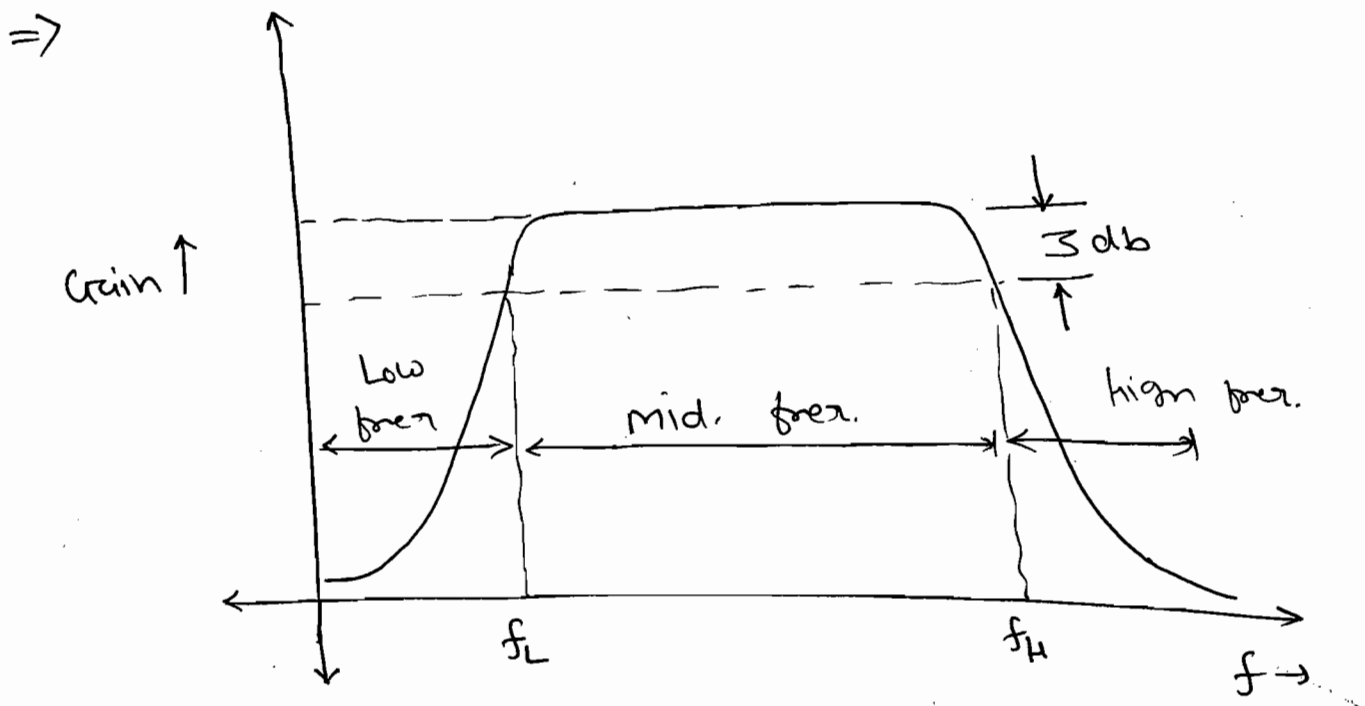
⇒



⇒ *



$\Rightarrow$ Frequency response of a Common emitter Amplifier is a BPF. The terms that affect low freq. gain are constant over a high freq. range. Similarly, the terms that affect high freq. gain are constant over low freq. Hence, low and high freq. analysis are two independent problems.



$\Rightarrow$

Coupling and
bypass cap.

Parasitic and
Load capacitor

1. Low freq.

Consider

Better
Open

2. mid freq.

Short

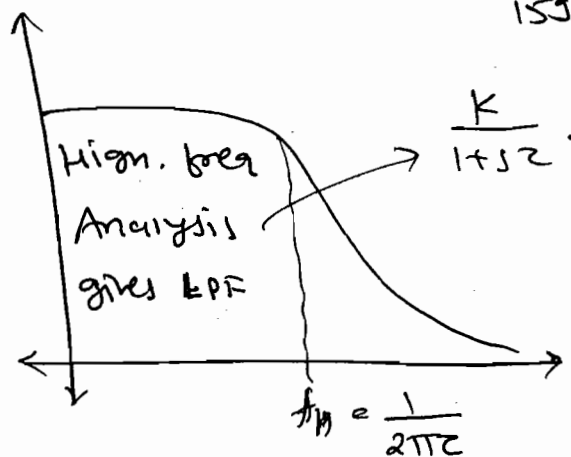
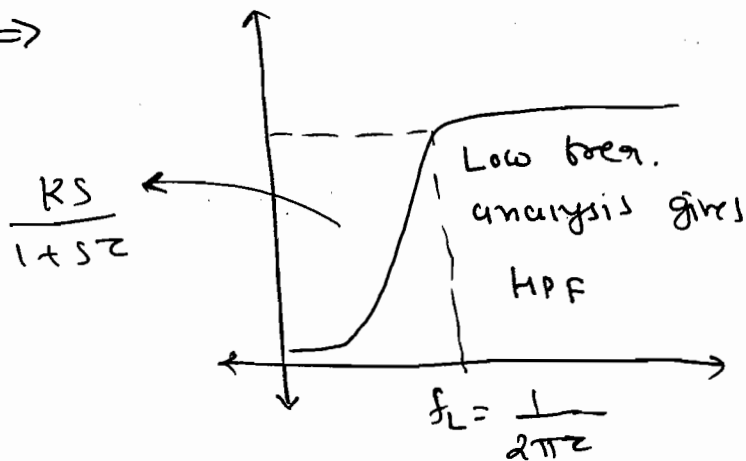
Open

3. High freq.

Better
Short

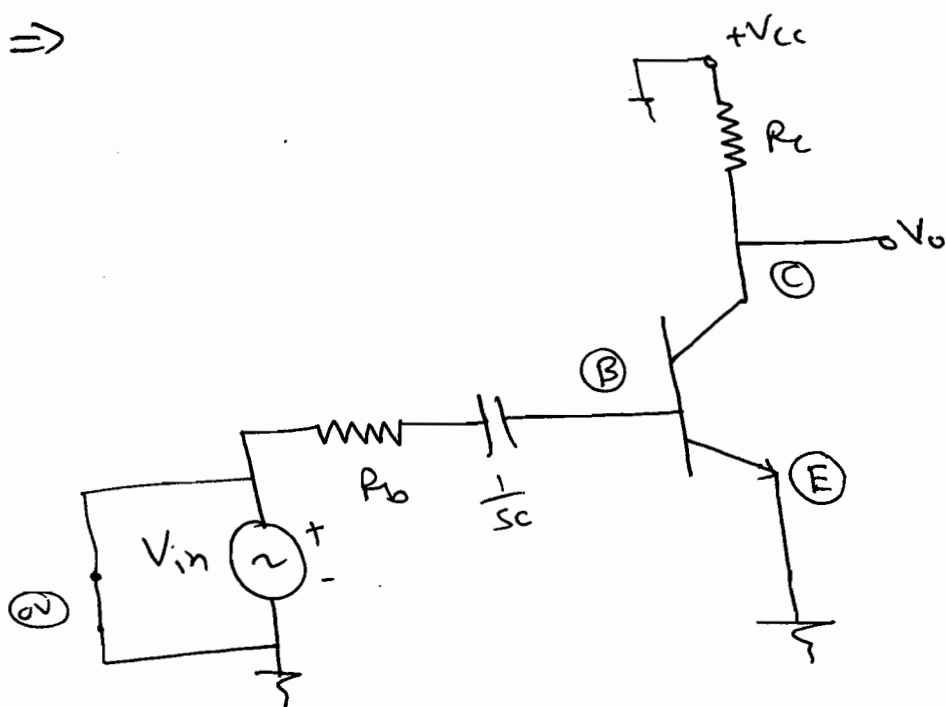
Consider

⇒



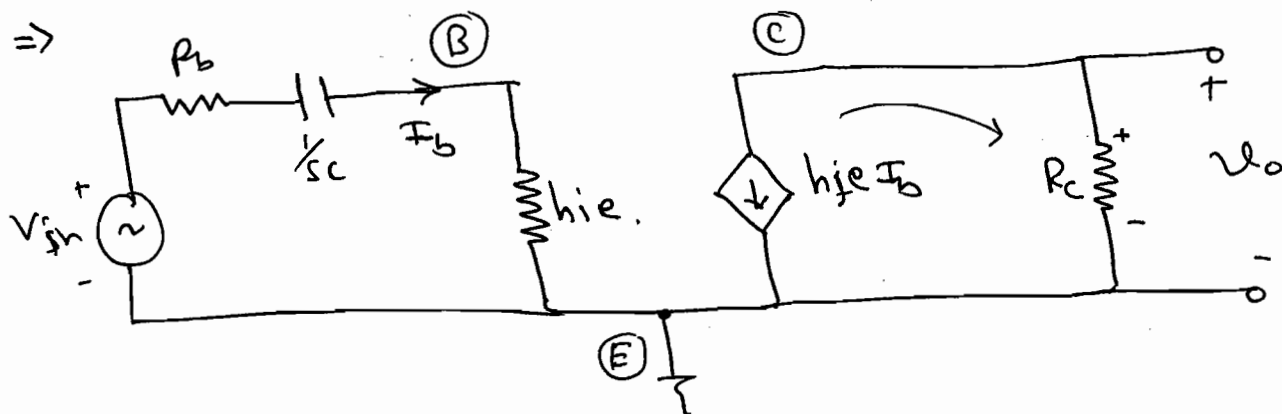
* Effect of Coupling Capacitor on Low freq. Response:

⇒



	$s=0$	$s=\infty$
LPF	Gain	0
HPF	0	Gain

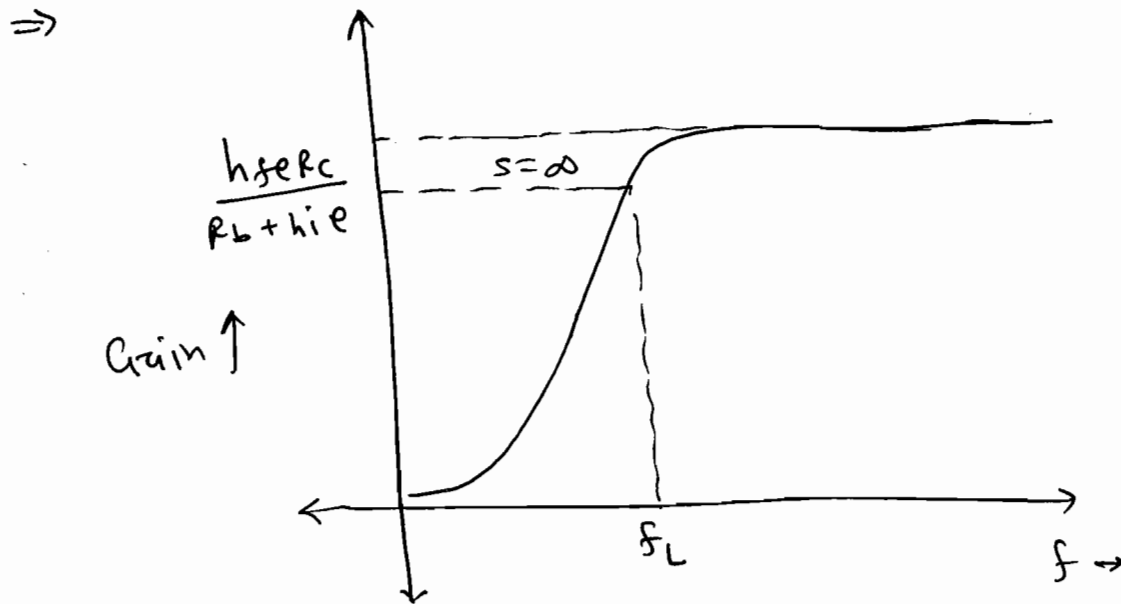
⇒



⇒ $V_o = -h_{fe} \cdot R_C \cdot I_B$ — (1)

$$\Rightarrow V_{in} = I_b \left[R_b + h_{ie} + \frac{1}{sC} \right] \quad - (2)$$

$$\left| \frac{V_o}{V_{in}} \right| = \frac{[h_{fe} R_c] s}{1 + sC [R_b + h_{ie}]} = \frac{Ks}{1 + s\tau} \quad \boxed{\text{HPF}}$$



$$\Rightarrow \omega_L = \frac{1}{\tau}$$

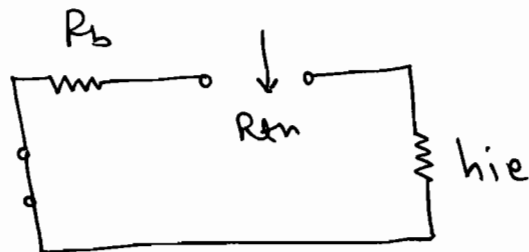
$$f_L = \frac{1}{2\pi\tau}$$

$$\therefore f_L = \frac{1}{2\pi [R_b + h_{ie}] C}$$

(OR)

$$\Rightarrow \tau = R_{th} \cdot C$$

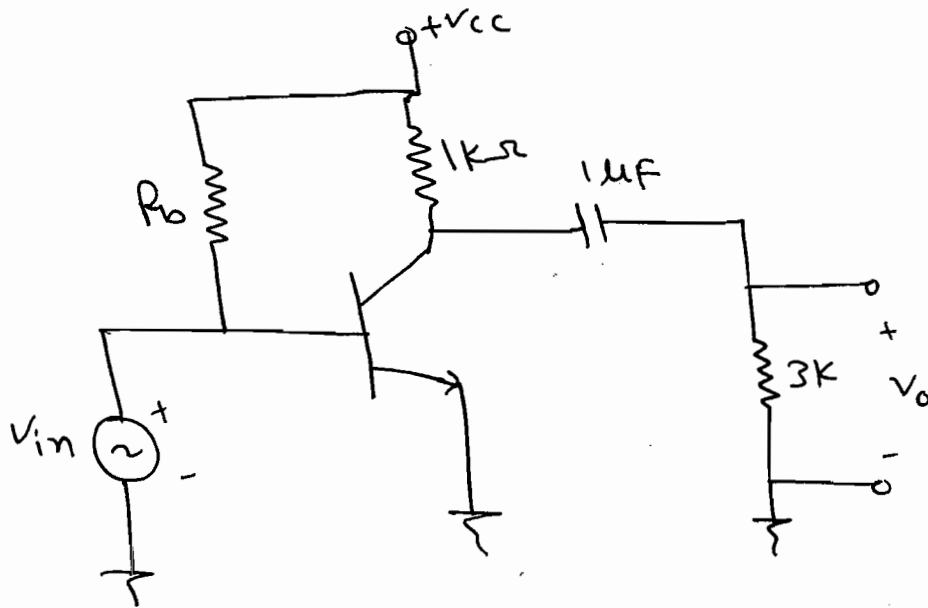
$$\tau = [R_b + h_{ie}] C$$



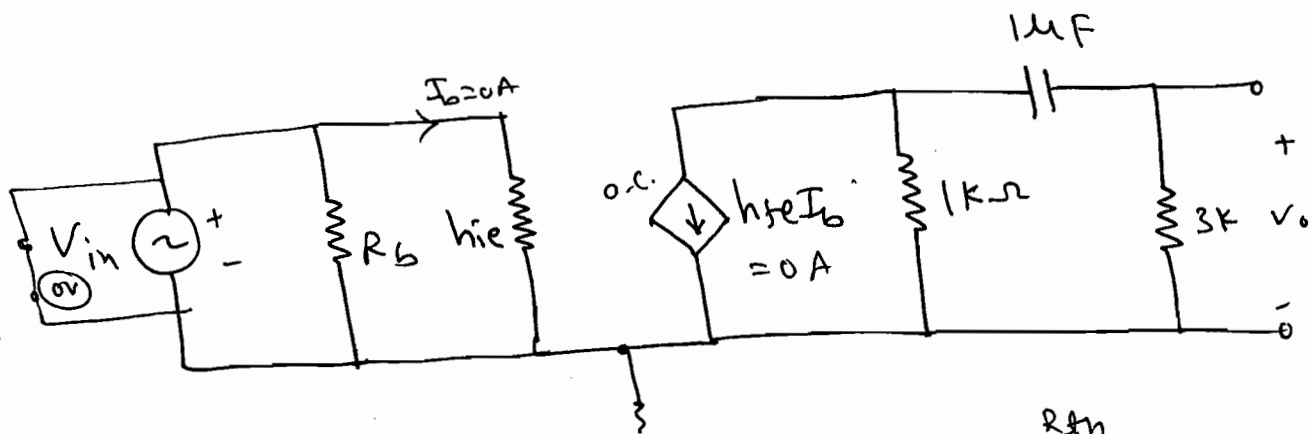
$$\therefore f_L = \frac{1}{2\pi\tau} = \frac{1}{2\pi [R_b + h_{ie}] C}$$

Ex-1 Find the cut-off freq. due to an o/p 1G1 Capacitor given.

⇒



Ans:



$$\tau = R_{th} \cdot C$$

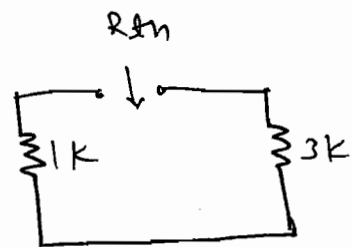
$$\therefore \tau = 4k \cdot 1\mu F$$

$$\tau = 4 \times 10^{-3} \text{ sec}$$

$$\therefore \omega_{3dB} \quad f_L = \frac{1}{2\pi\tau}$$

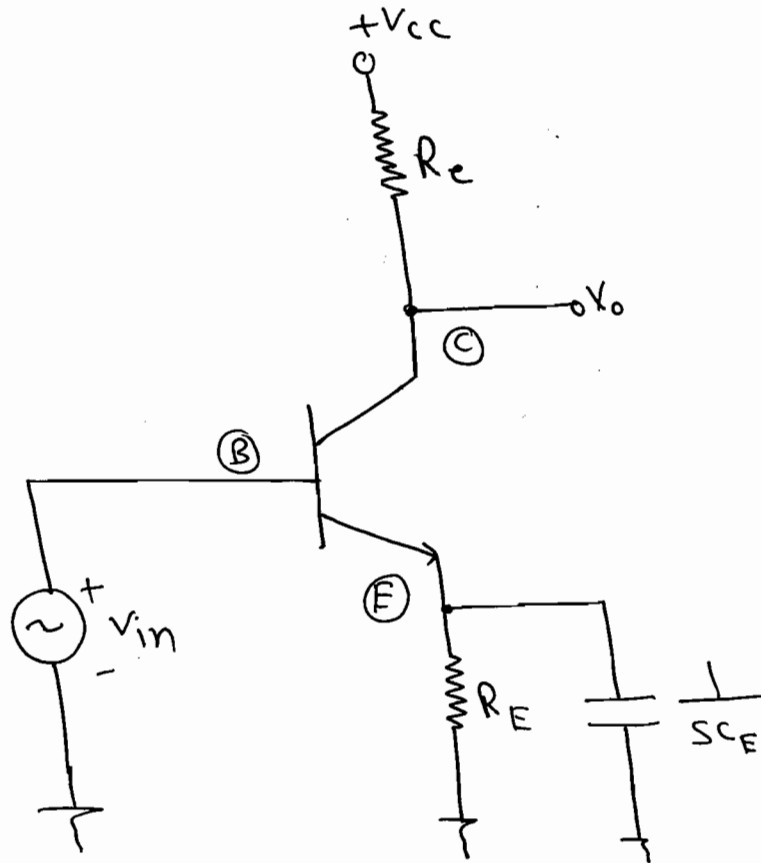
$$\therefore f_L = \frac{1}{2\pi \times 4 \times 10^{-3}}$$

$$\therefore f_L = \frac{1000}{8\pi} \text{ Hz}$$

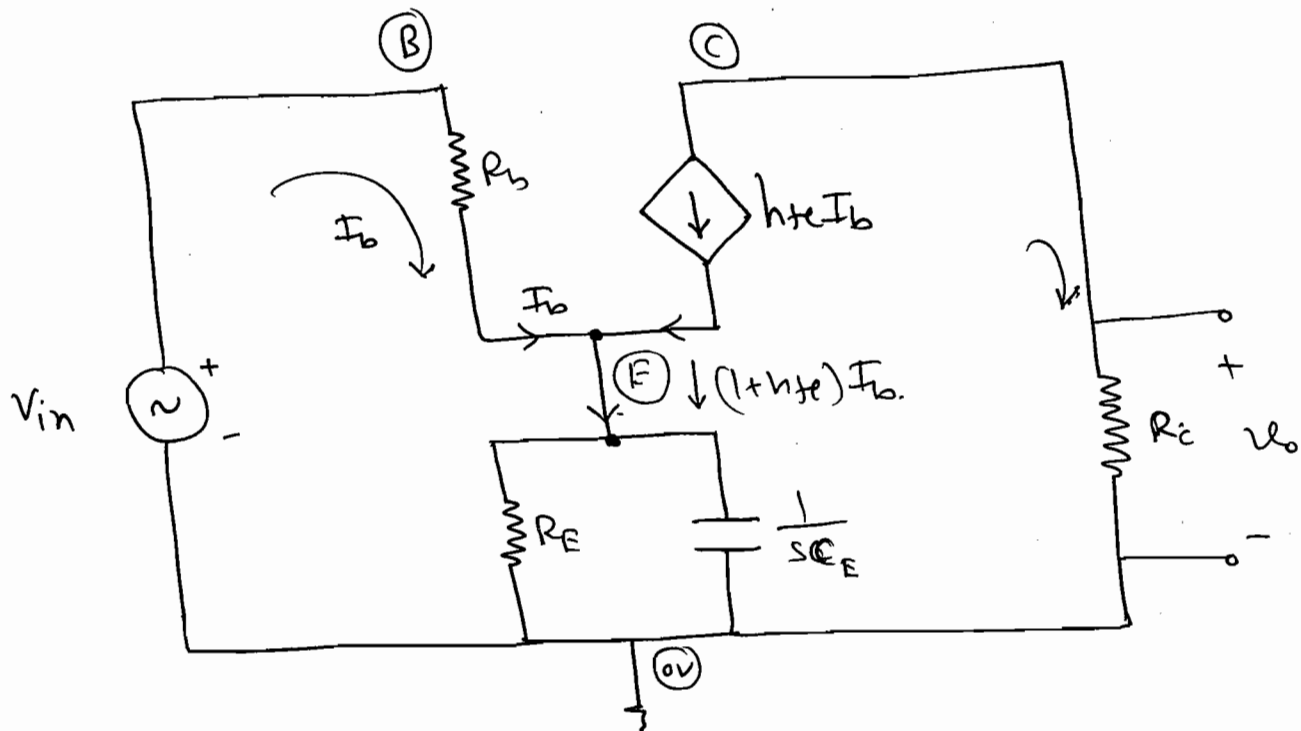


* Effect of Bypass Capacitor on Low freq. Response.

⇒



⇒



$$\rightarrow V_o = -h_{fe} \cdot I_b \cdot R_c. \quad - (1)$$

$$V_{in} = R_b I_b + (1+h_{fe}) I_b \left[\frac{R_E}{1+R_E \cdot sC_E} \right]. \quad - (2)$$

$$\therefore \left| \frac{V_o}{V_{in}} \right| = \frac{(h_{fe} \cdot R_c) [1 + s C_E R_E]}{h_{ie} + (1 + h_{fe}) R_E + s C_E R_E h_{ie}}$$

$$\therefore \left| \frac{V_o}{V_{in}} \right| = \frac{h_{fe} \cdot R_c}{h_{ie} + (1 + h_{fe}) R_E} \cdot \left[\frac{1 + s C_E R_E}{1 + s \frac{C_E R_E \cdot h_{ie}}{h_{ie} + (1 + h_{fe}) R_E}} \right]$$

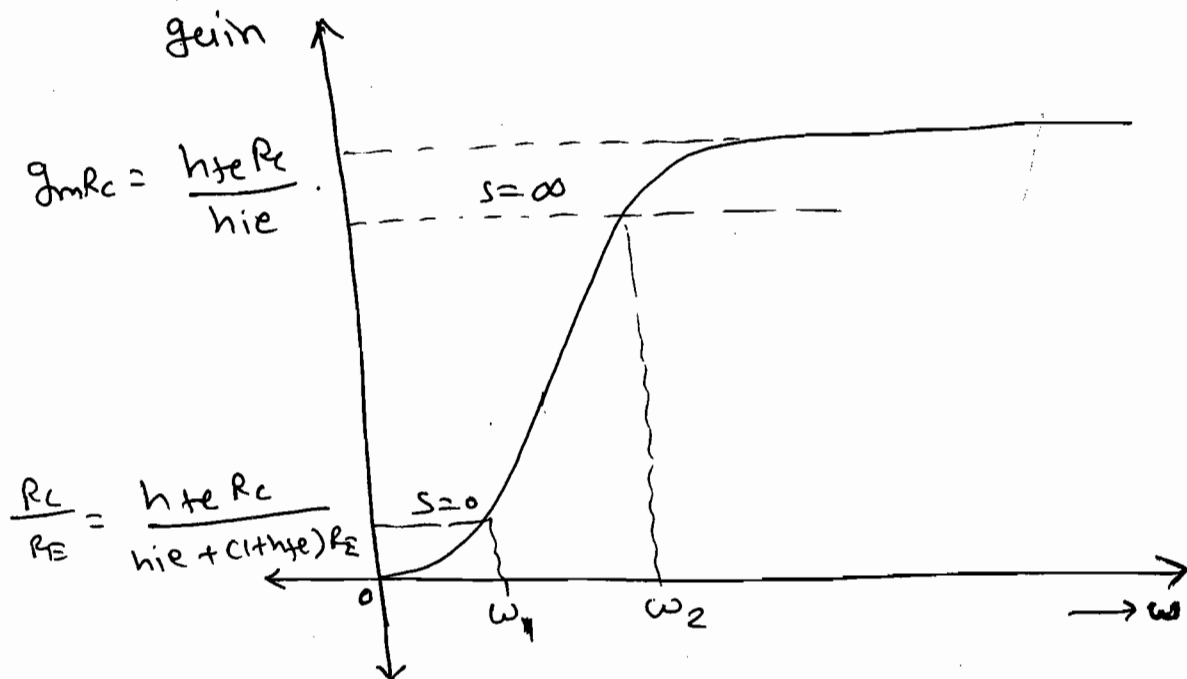
$$\left| \frac{V_o}{V_{in}} \right| = \frac{K [1 + s \tau_1]}{1 + s \tau_2}$$

$$\therefore \omega_1 = \frac{1}{\tau_1} = \frac{1}{R_E C_E}$$

$$\omega_2 = \frac{1}{\tau_2} = \frac{h_{ie} + (1 + h_{fe}) R_E}{C_E R_E \cdot h_{ie}}$$

$$\boxed{\omega_2 > \omega_1}$$

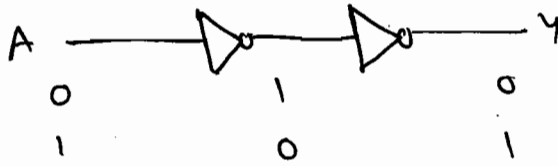
$\Rightarrow$



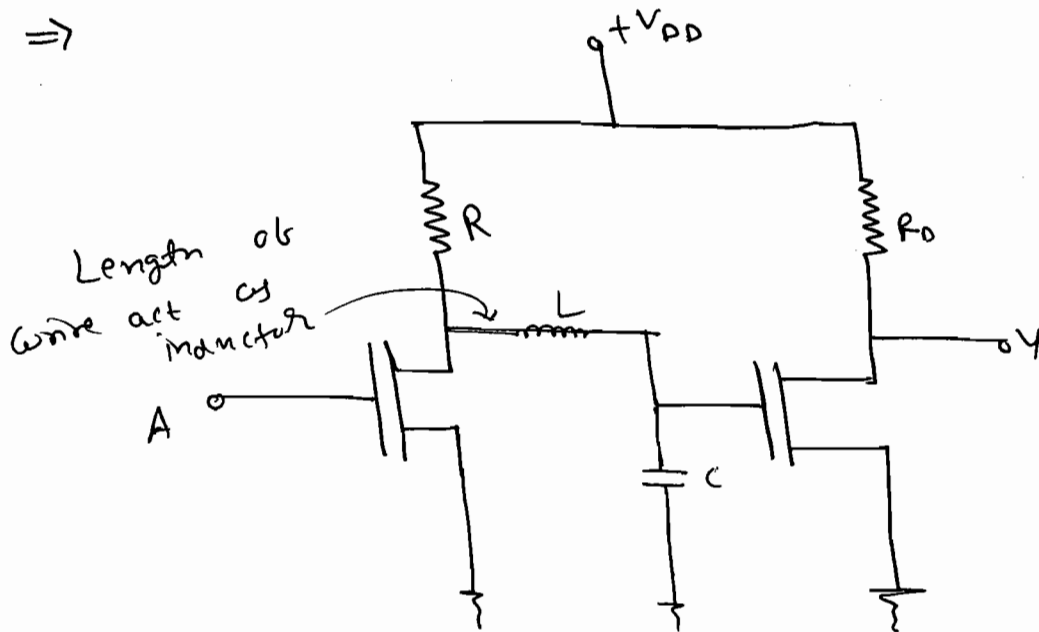
$$\begin{aligned} \Rightarrow B_w &= f_H - f_L \\ &= 1\text{M} - 40\text{Hz} \\ &= 1\text{M} \end{aligned}$$

$$B_w \approx f_H$$

* High freq. Analysis:

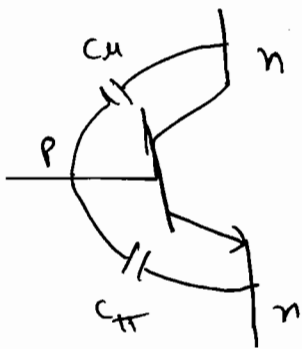


⇒



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

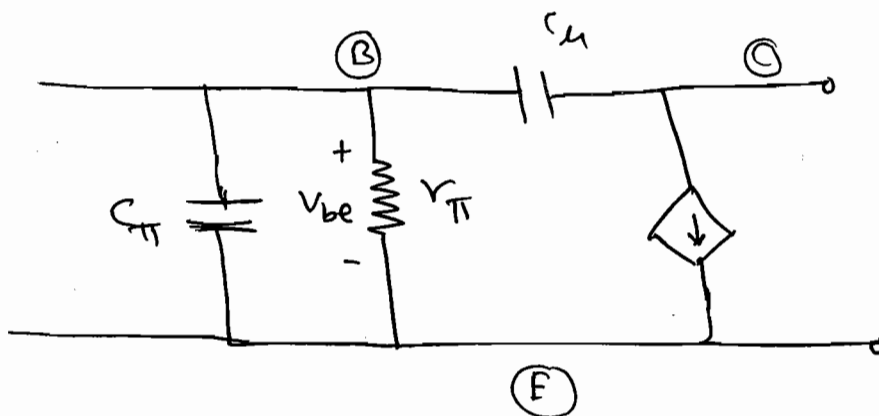
$$S.R. = \frac{dV_c}{dt} = I/C$$



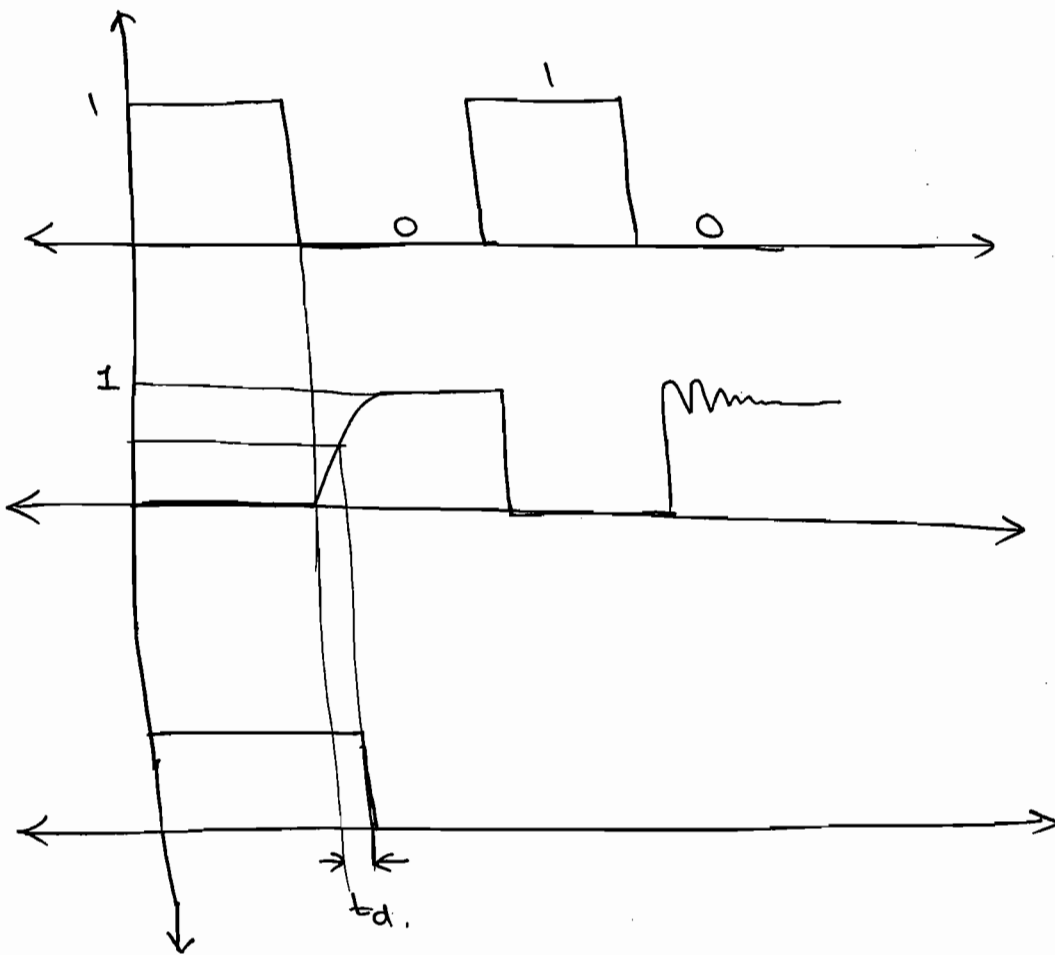
$C_\pi \rightarrow$ forward biased diffusion cap. (3 pF)

$C_\mu \Rightarrow$ Reverse biased cap. (0.01 pF)

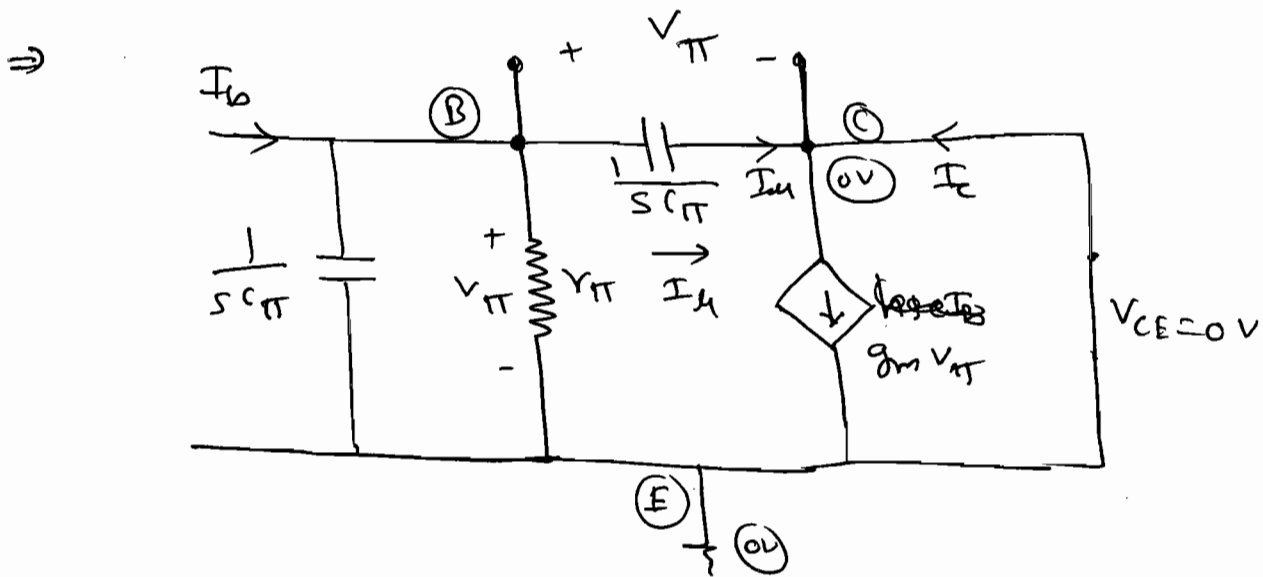
⇒



Simplified high freq. model.



* Calculation of Unity gain freq. & 3db Bandwidth from Short circuit current gain β (or) h_{fe} .



$$\Rightarrow I_c = h_{fe} I_b + h_{oe} V_{ce}$$

$$\beta = h_{fe} = \frac{I_c}{I_b} \bigg|_{V_{ce}=0}$$

(sc forward current gain)

By KCL, $I_{\mu} + I_c = g_m V_{\pi}$

$\therefore V_{\pi} [sC_{\mu}] + I_c = g_m V_{\pi}$

$\therefore I_c = [g_m - sC_{\mu}] V_{\pi}$
↘ neglect

$\Rightarrow I_c = g_m V_{\pi} \quad \text{--- (1)}$

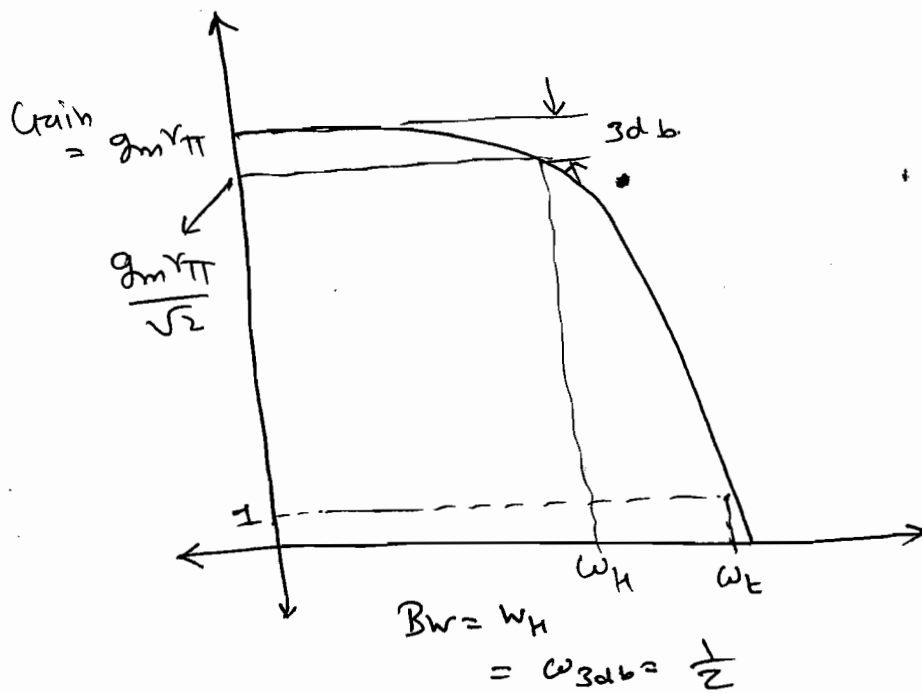
$\rightarrow I_b = V_{\pi} [sC_{\pi}] + \frac{V_{\pi}}{r_{\pi}} + V_{\pi} [sC_{\mu}]$

$I_b = V_{\pi} \left[\frac{1}{r_{\pi}} + s[C_{\pi} + C_{\mu}] \right]$

$\therefore \left| \frac{I_c}{I_b} \right| = \frac{g_m \cdot r_{\pi}}{1 + s r_{\pi} [C_{\pi} + C_{\mu}]} = \frac{K}{1 + s z}$

$= \frac{\beta_0}{1 + s r_{\pi} [C_{\pi} + C_{\mu}]}$

$\Rightarrow$



$\omega_c = gain \cdot BW$

$$* \text{Gain}(k) = g_m r_{\pi}$$

167

$$* \text{3db BW} = \frac{1}{2\pi\tau}$$

$$= \frac{1}{2\pi r_{\pi} [C_{\pi} + C_{\mu}]}$$

$$* \text{Gain. BW} = \frac{g_m}{2\pi [C_{\pi} + C_{\mu}]}$$

$\Rightarrow$ Defining the unity gain freq. is the freq. at which gain falls down to '1'. (ω_t).

$$\left| \frac{I_c}{I_b} \right| = \frac{g_m r_{\pi}}{\sqrt{1 + [\omega r_{\pi} (C_{\pi} + C_{\mu})]^2}}$$

$$\Rightarrow \text{At } \omega = \omega_t \Rightarrow \left| \frac{I_c}{I_b} \right| = 1.$$

$$1 = \frac{g_m \cdot r_{\pi}}{\omega_t r_{\pi} [C_{\pi} + C_{\mu}]}$$

$$\therefore \omega_t = \frac{g_m}{C_{\pi} + C_{\mu}}$$

$$\Rightarrow C_{\pi} + C_{\mu} = \frac{g_m}{2\pi f_t}$$

$$\therefore \boxed{f_t = \frac{g_m}{2\pi [C_{\pi} + C_{\mu}]}}$$

$$\Rightarrow \boxed{C_{\pi} = \frac{g_m}{2\pi f_t}}$$

$$\Rightarrow \boxed{\begin{array}{l} f_t = K \cdot f_{3db} \\ \text{unity gain} \\ \text{freq.} = \text{Gain. BW.} \end{array}}$$

Ex-1 An op-amp has unity gain ber. of 200 MHz with a gain of 80 dB. Find the 3dB BW.

Ans:

$$G_{\text{dB}} = 20 \log G_{\text{ain}}$$

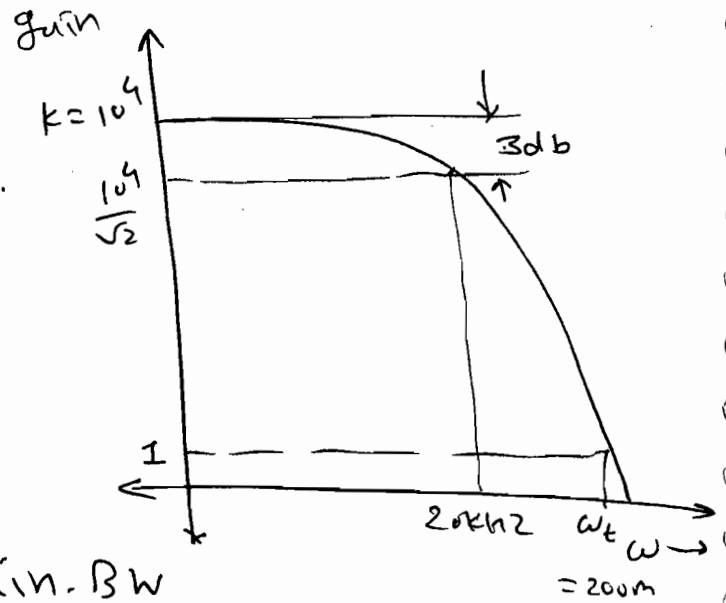
$$80 = 20 \log G_{\text{ain}}$$

$$G_{\text{ain}} = 10^4$$

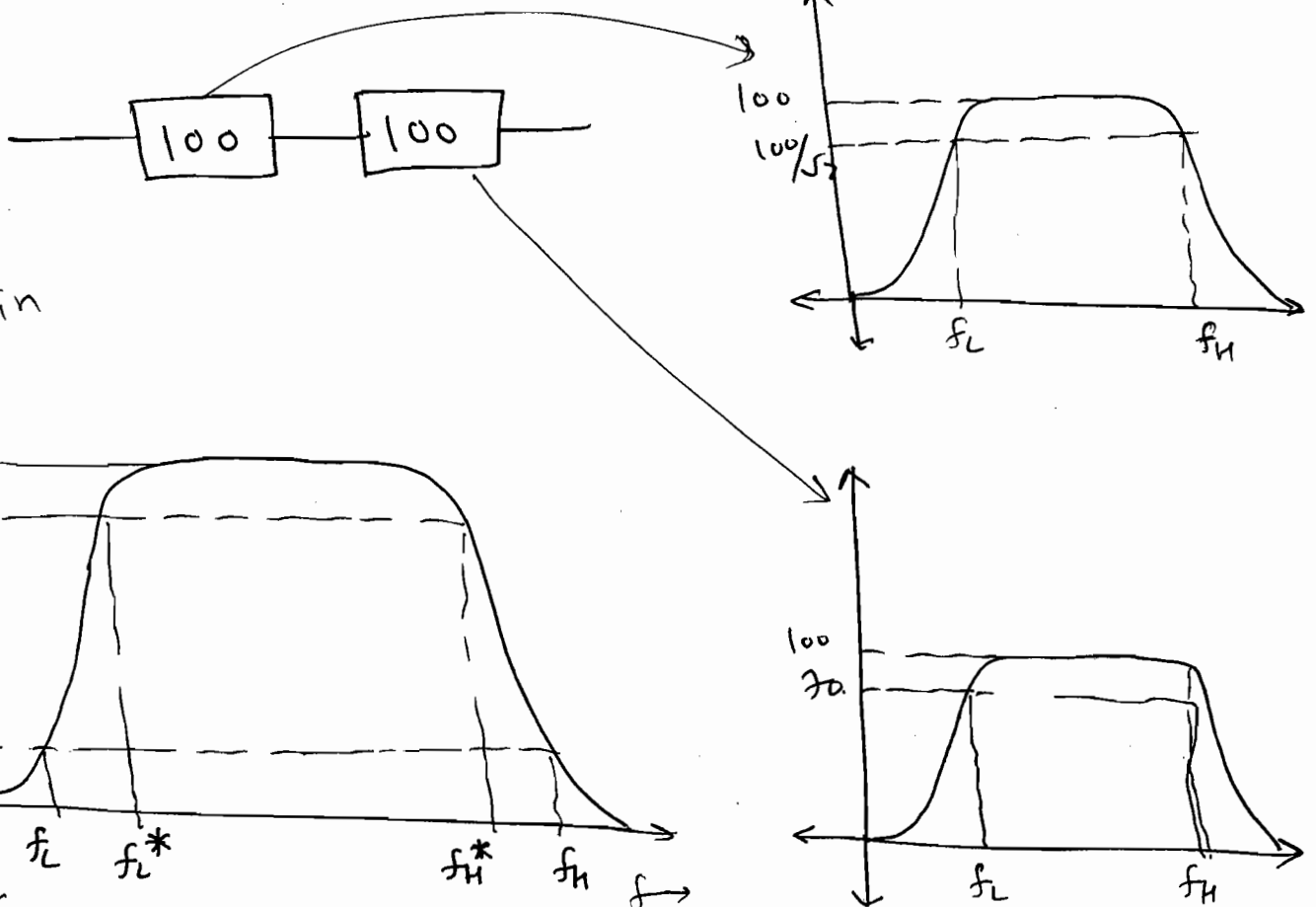
$$\rightarrow \text{unity gain ber.} = G_{\text{ain}} \cdot \text{BW}$$

$$200 \times 10^6 = 10^4 \times \text{BW}$$

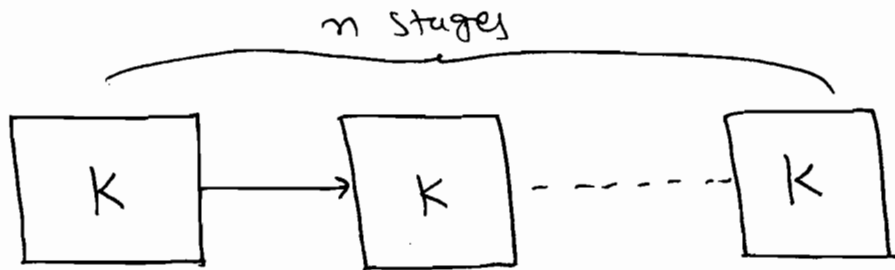
$$\therefore \boxed{\text{BW} = 20 \text{ kHz}}$$



*



⇒



⇒ LPF $\frac{K}{1+s^2} = \frac{K}{1+\frac{s}{\omega_{3dB}}} = \left| \frac{K}{1+j\frac{\omega}{\omega_{3dB}}} \right|^2 = \frac{K}{\sqrt{1+\left(\frac{\omega}{\omega_{3dB}}\right)^2}}$

for single stage $\frac{K}{\sqrt{1+\left(\frac{\omega}{\omega_{3dB}}\right)^2}} = \frac{K}{\sqrt{2}}$

for n stages.

$$\left[\frac{K}{\sqrt{1+\left(\frac{\omega}{\omega_{3dB}}\right)^2}} \right]^n = \frac{K^n}{\sqrt{2}}$$

$W_{H_{total}} = W_H \sqrt{2^{\frac{1}{n}} - 1}$
$W_{L_{total}} = \frac{W_L}{\sqrt{2^{\frac{1}{n}} - 1}}$

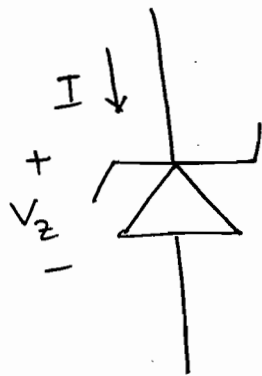
→ for n=2

$$W_{H_{total}} = 0.6 W_H$$

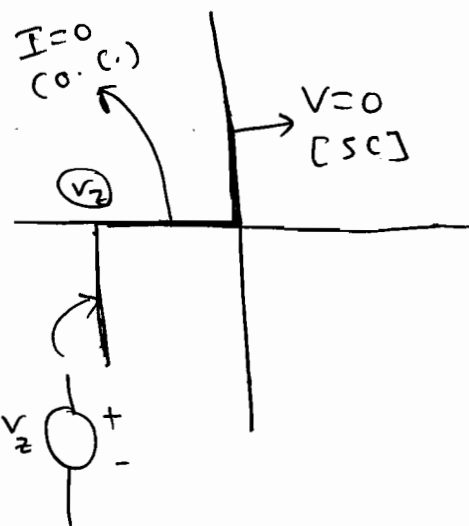
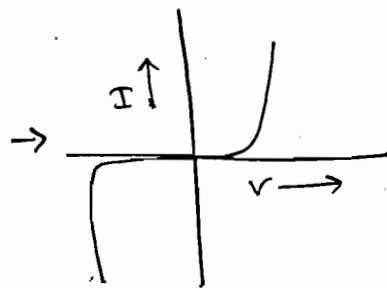
$$W_{L_{total}} = 1.55 W_L$$

★ Voltage Regulators:

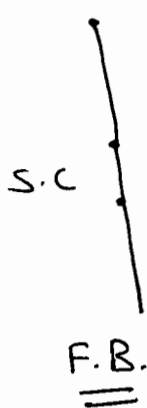
⇒



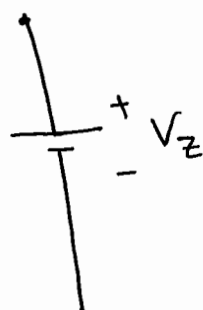
Zener Diode



⇒



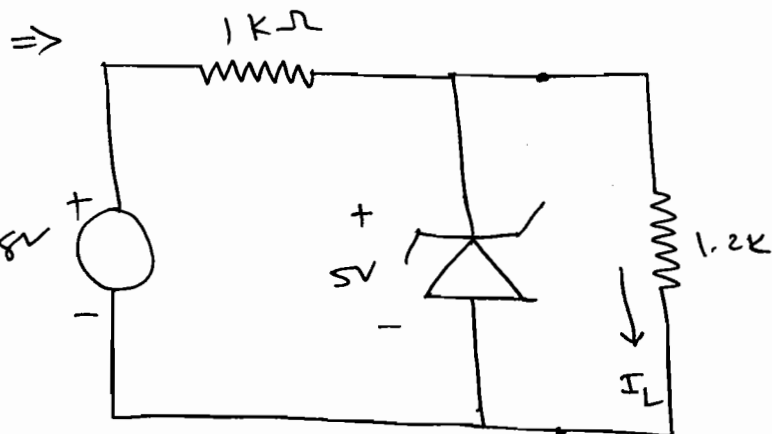
When Zener is not in breakdown



Zener is in breakdown

RB

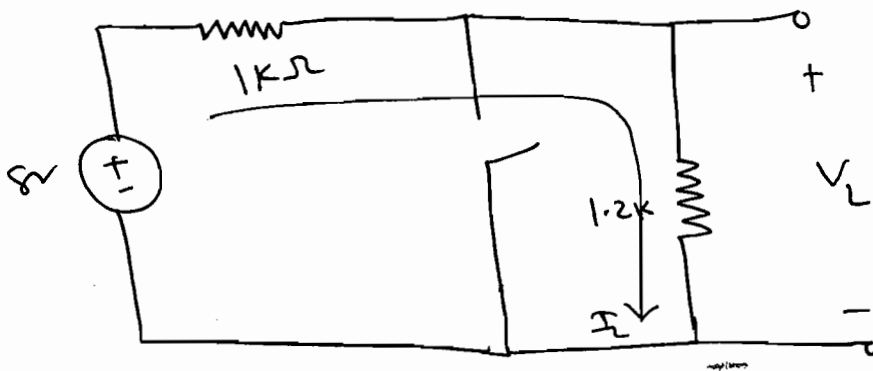
⇒ Zener as a Voltage Regulator:



⇒ First open k/t the Zener and calculate the terminal voltage, i.e. check whether Zener

is in breakdown or not.

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$$V_L = \frac{1.2k}{2.2k} \times 8$$

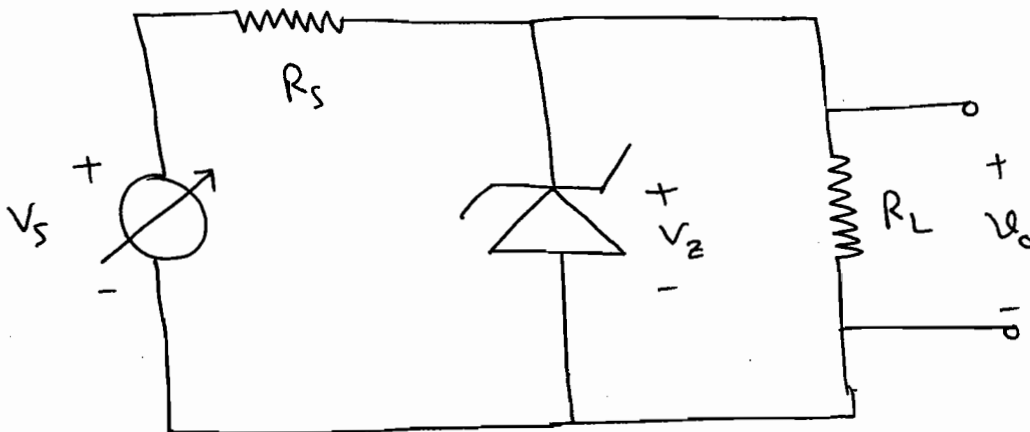
$$= 4.3V < V_Z$$

$\Rightarrow$ Zener is not in breakdown.

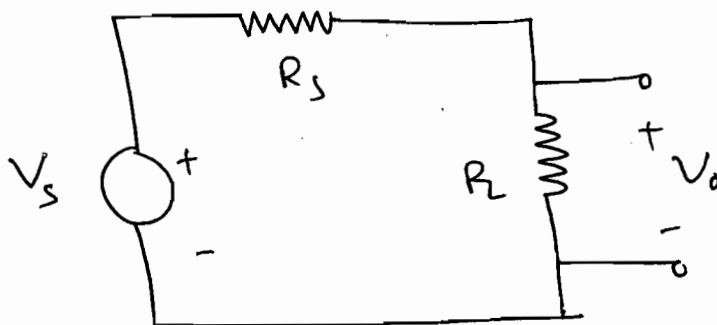
$$\therefore I_L = \frac{8}{2.2k}$$

$$\therefore I_L = 3.64 \text{ mA}$$

*



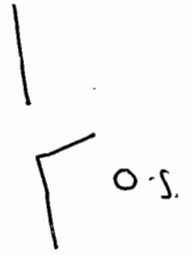
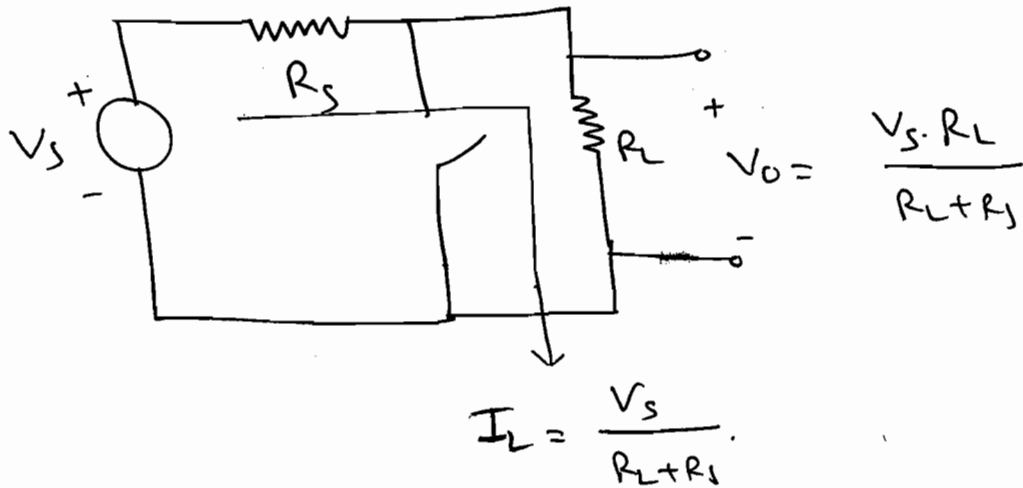
$\Downarrow$



$$V_o = \left(\frac{R_L}{R_L + R_S} \right) \times V_S$$

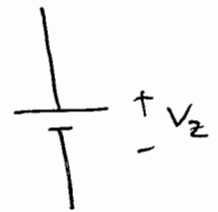
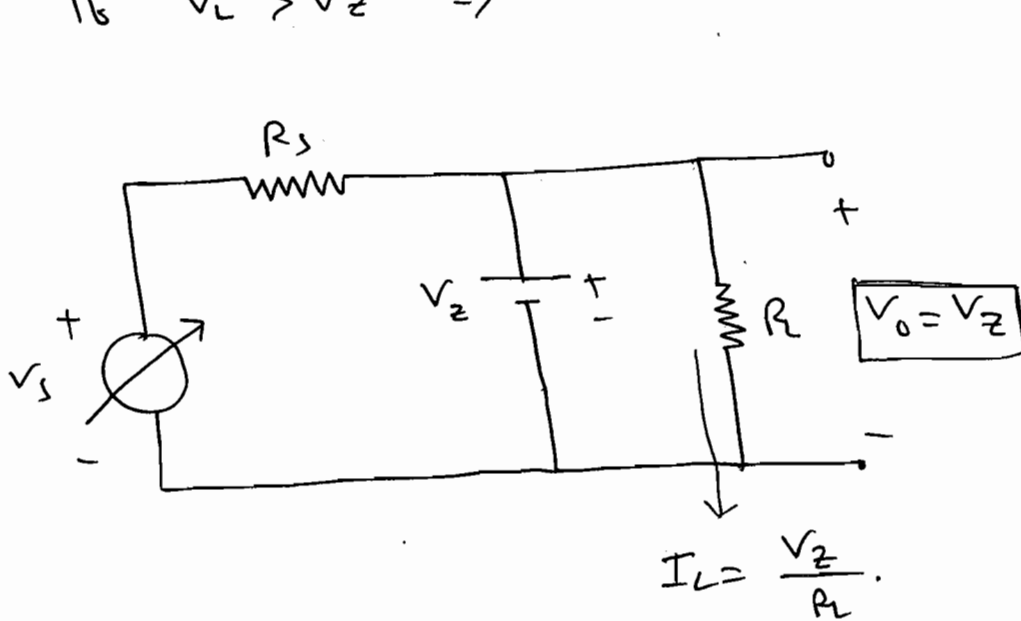
Case-i)

$\Rightarrow$ if $V_L < V_Z \Rightarrow$ Zener is not in Breakdown.

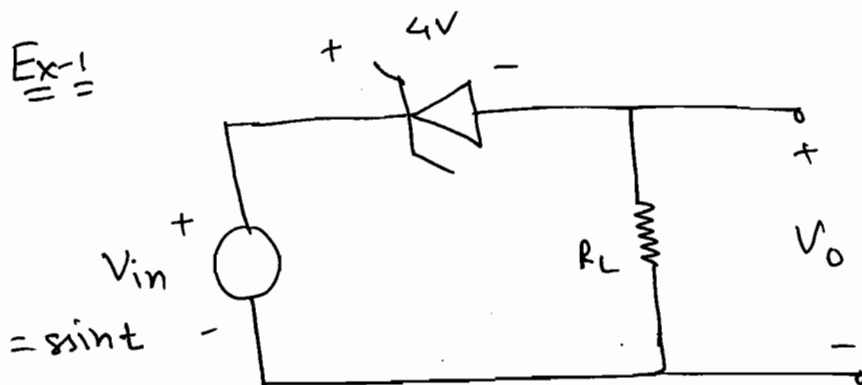


Case-ii

$\Rightarrow$ if $V_L > V_Z \Rightarrow$ Zener is in breakdown.

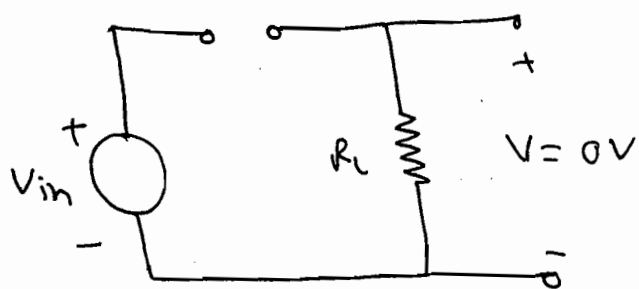


Ex-1



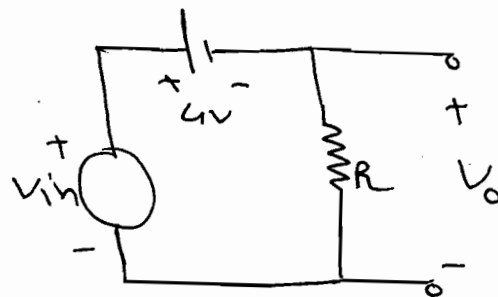
Sketch the output waveform V_O .

(i) $0 \leq V_{in} \leq 4V$



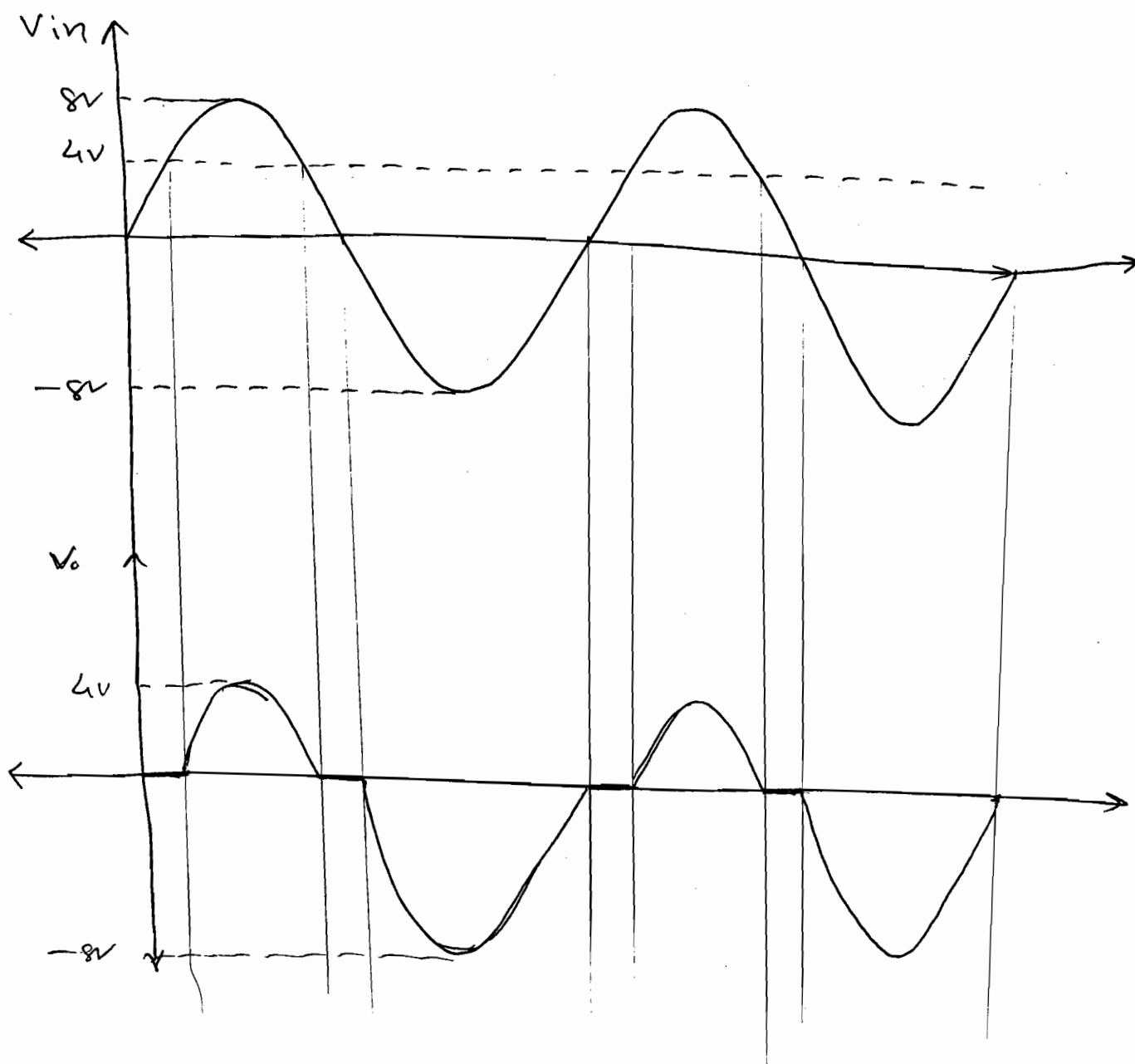
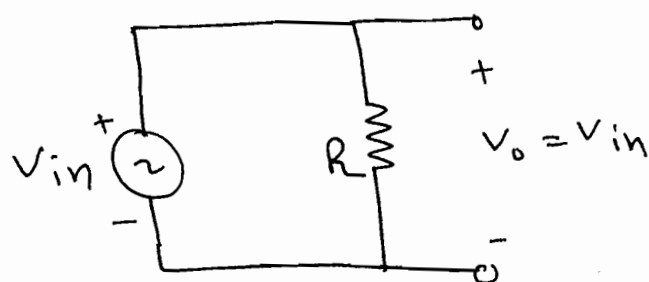
(ii) $4 \leq V_{in} \leq 8V$

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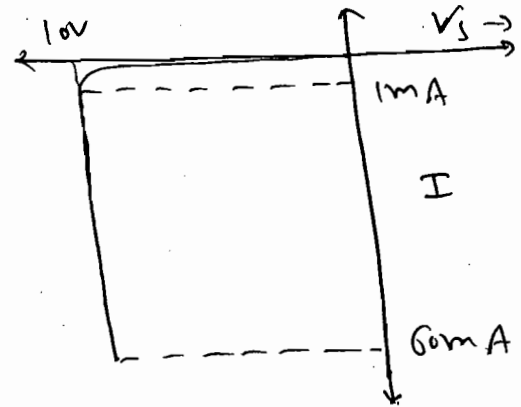
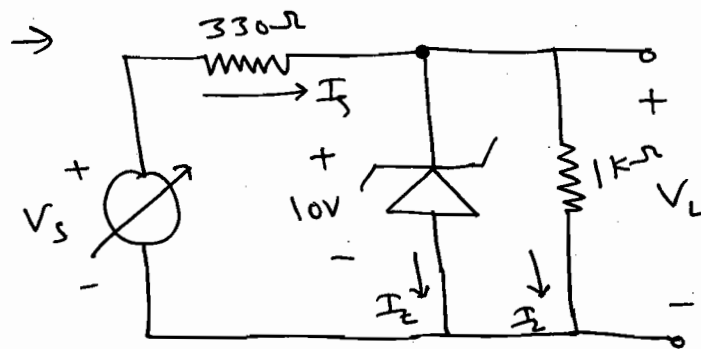


$V_o = V_{in} - 4$

(iii) neg cycle:



Ex-1 Find the Range of Voltage Source V_s to which the zener is satisfactory on it the minimum current is 1mA and the maximum current zener can safely handle a 60mA .



Ans: $V_z = 10\text{V}$,

$$I_s = I_z + I_L$$

$$\frac{V_s - 10}{330} = I_s$$

$$\therefore V_s = 10 + 330 \cdot I_s$$

$$\begin{aligned} V_s \uparrow \\ I_s \uparrow \\ &= (I_z + I_L) \\ &\quad \downarrow \\ &\quad \text{const} \end{aligned}$$

① $I_z = 1\text{mA}$

$$\therefore I_L = \frac{10}{1k} = 10\text{mA}$$

$$\therefore I_s = 1\text{mA} + 10\text{mA} = 11\text{mA}$$

$$\therefore V_s = 10 + (330 \times 11\text{mA})$$

$$V_s = 13.3\text{V}$$

② $I_z = 60\text{mA}$

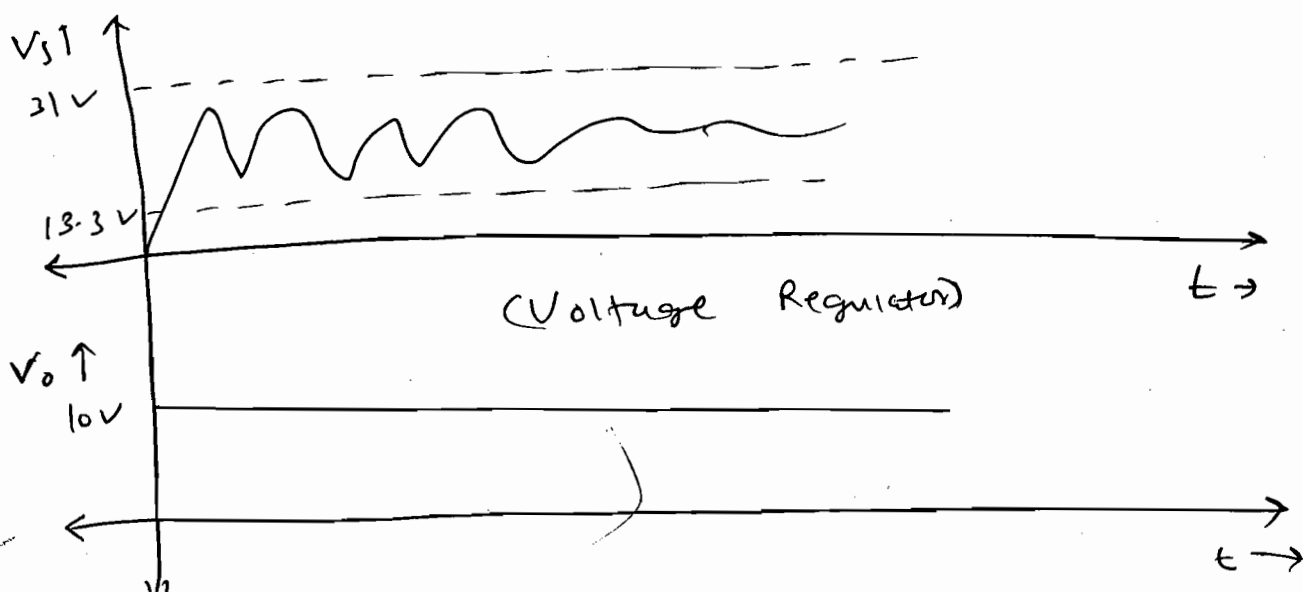
$$\therefore I_s = 10\text{mA} + 60\text{mA} = 70\text{mA}$$

$$\therefore V_s = 10 + (330 \times 70\text{mA})$$

$$V_s = 33.1\text{V}$$

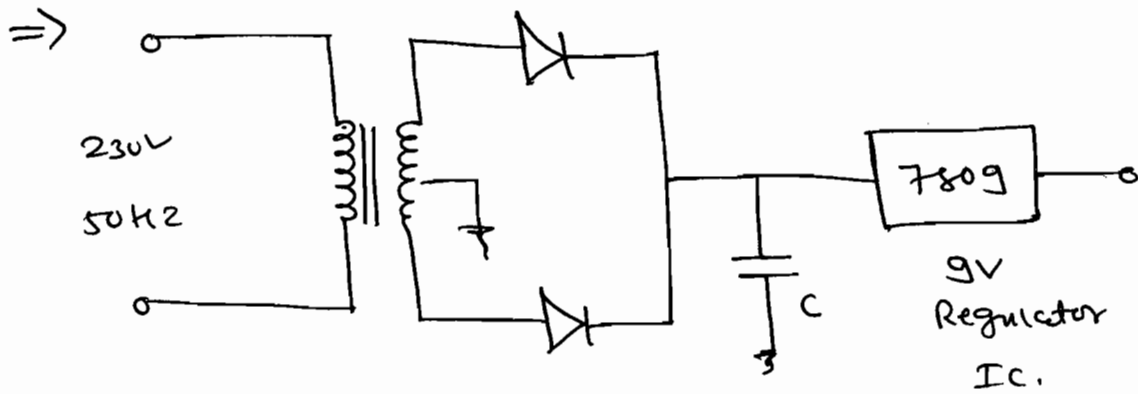
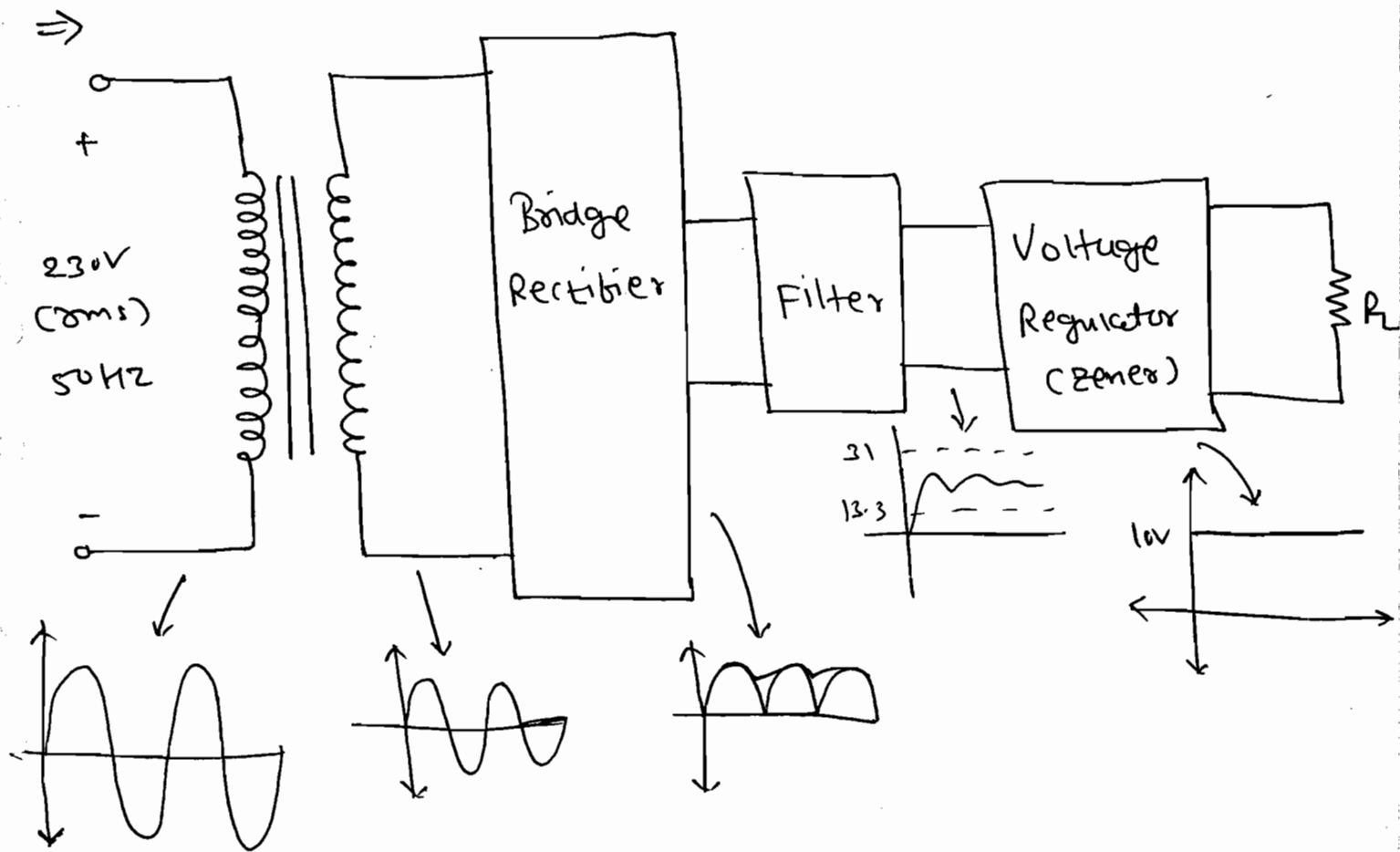
So, V_o range

$$V_o = 13.3\text{V to } 31\text{V}$$



★ Simplify Block Diagram of a DC Power Supply.

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7809 → 9V

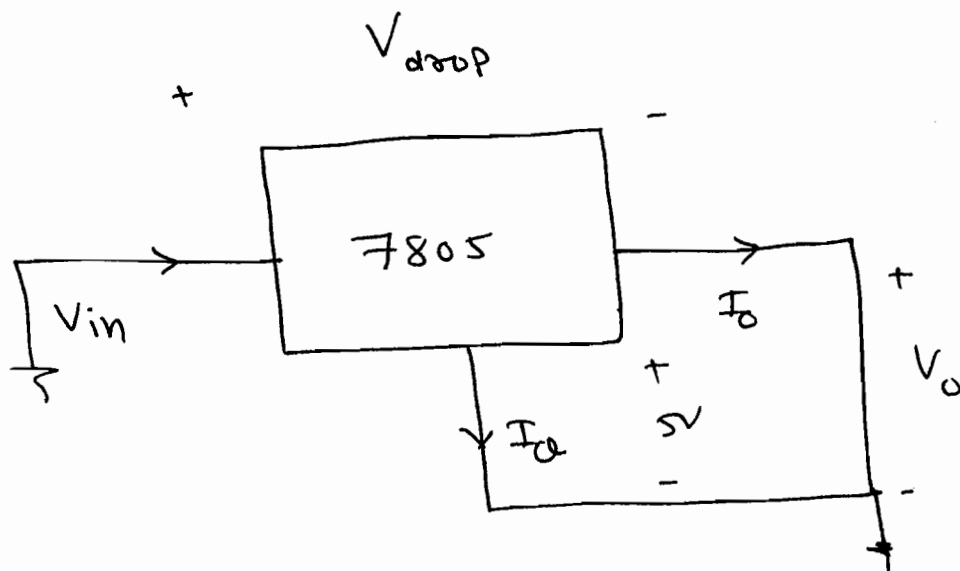
7810 → 10V

7812 → 12V

7909 → -9V

7910 → -10V

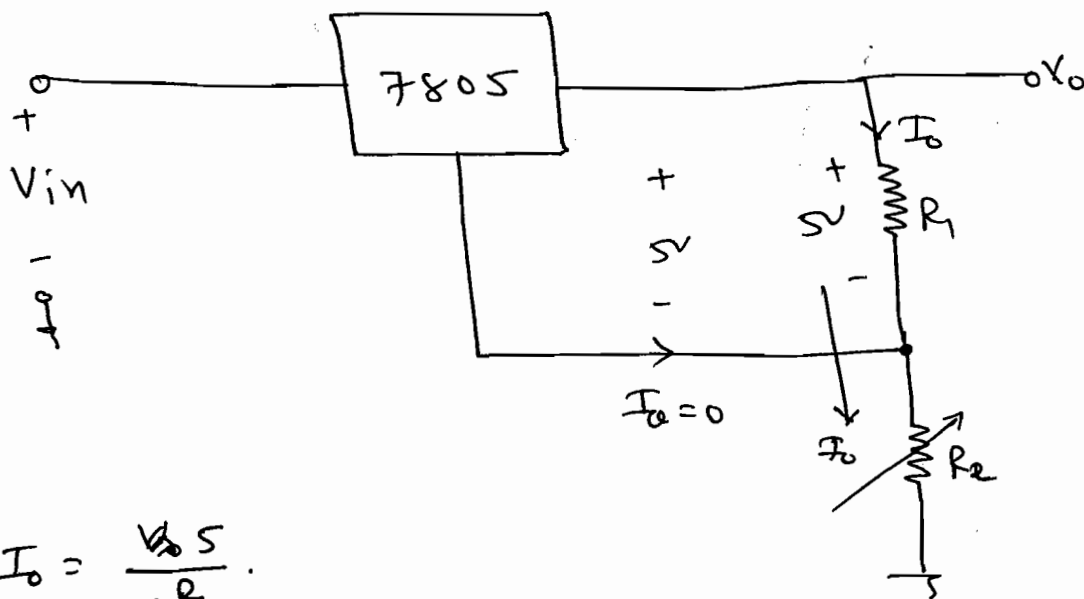
*



$$\Rightarrow \underline{KCL}, \quad I_{in} = I_a + I_o.$$

$$\Rightarrow \underline{KVL}, \quad V_{in} = V_{drop} + V_o.$$

* Increase the Voltage range of 7805 from 5V to 12V (neglect the quiescent current I_a and the drop across the IC is 2V).



$$\rightarrow I_o = \frac{V_{o5}}{R_1}.$$

$$\therefore V_o = I_o (R_1 + R_2).$$

$$\therefore V_0 = \frac{5}{R_1} \left(R_1 + \frac{R_2}{10} \right)$$

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$$\therefore V_0 = \left(1 + \frac{R_2}{R_1} \right) 5$$

let, $R_1 = 1 \text{ k}\Omega$.

V_0 range: 5 to 12 V

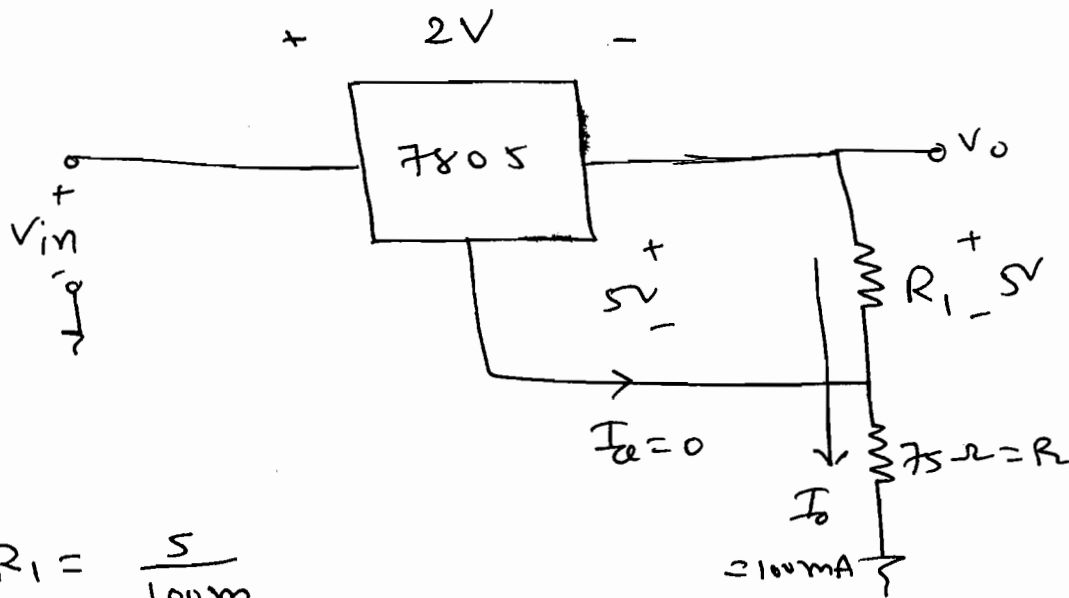
R_2 range: 0Ω to $1.4 \text{ k}\Omega$

IES

Ex-1

Design a 7805 for a 75Ω load drawing a current of 100mA . A drop across the IC is 2V and neglect the quiescent current.

Ans:



$$\therefore R_1 = \frac{5}{100\text{m}}$$

$$\therefore \boxed{R_1 = 50\Omega}$$

$$\therefore V_{in\min} = 12.5 + 2\text{V}$$

$$= V_0 + V_{\text{drop}}$$

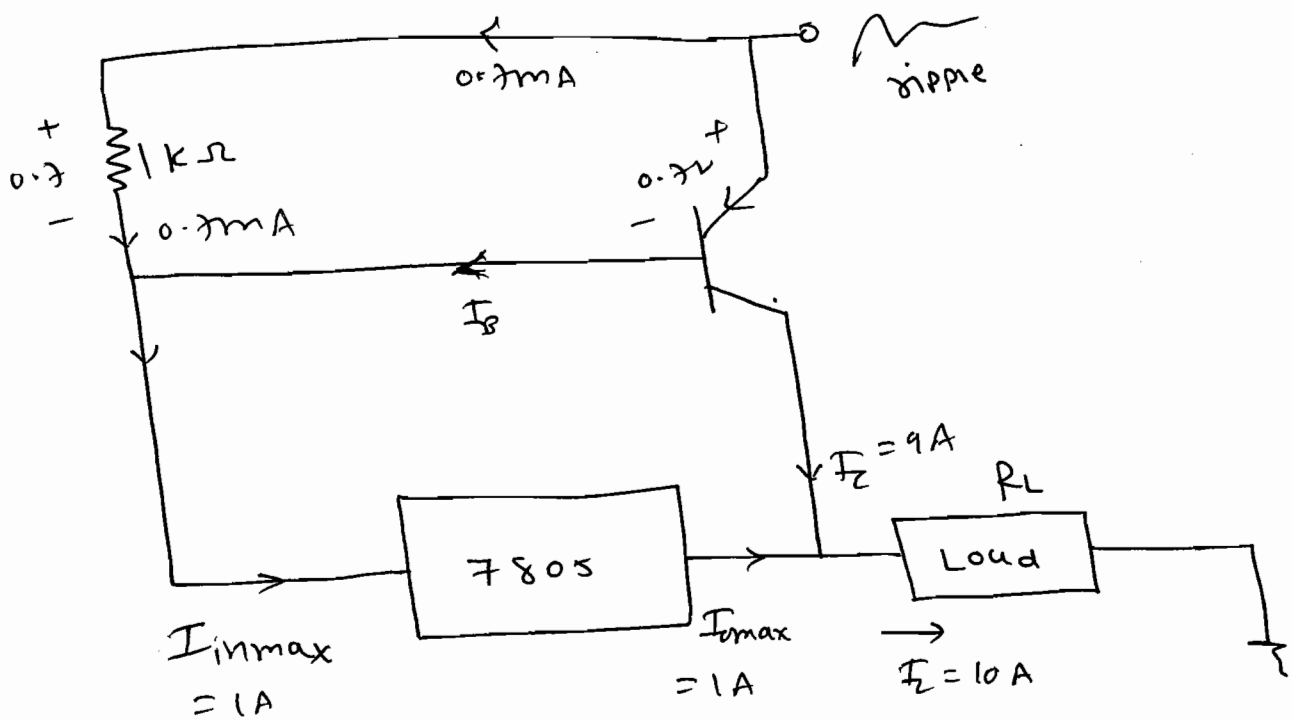
$$\therefore V_0 = I_0 (R_1 + R_2)$$

$$\therefore V_0 = 100\text{m} (125)$$

$$\boxed{V_0 = 12.5\text{V}}$$

$$\therefore \boxed{V_{in\min} = 14.5\text{V}}$$

* Increasing Current range of Voltage regulator:



$$\Rightarrow I_{inmax} = 0.7mA + I_B$$

$$\rightarrow I_B \approx I_{inmax} = 1A$$

$$I_Z = I_{Omax} + I_L$$

$$I_Z = \beta I_B + I_{Omax}$$

$$\therefore I_Z = \beta I_{in} + I_{Omax}$$

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

$$\therefore I_{Omax} = 1A$$

$$\therefore \beta = 9 \Rightarrow$$

$$I_Z = (9 + 1) I_B$$

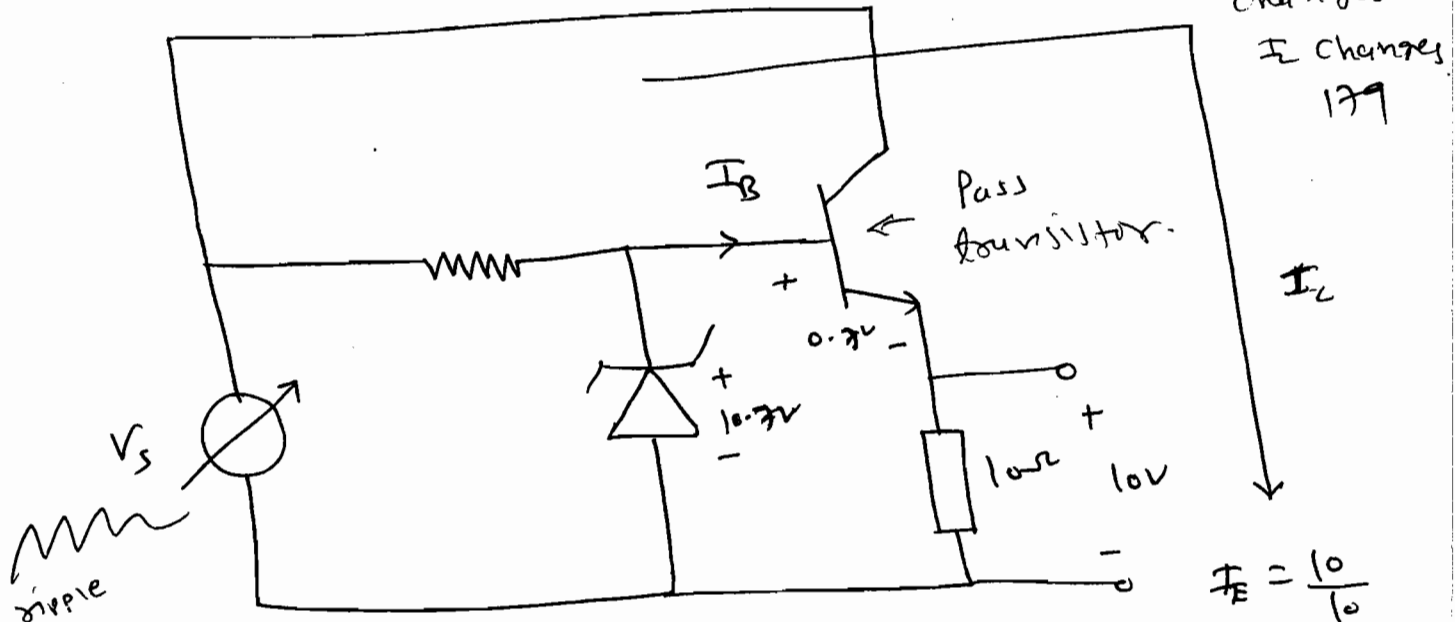
$$I_Z = 10A$$

Disadvantages:

- (i) 0.7V drop across transistor
- (ii) If we want different output voltage we have to change the zener diode.

$$I_B \approx I_{in}$$

*

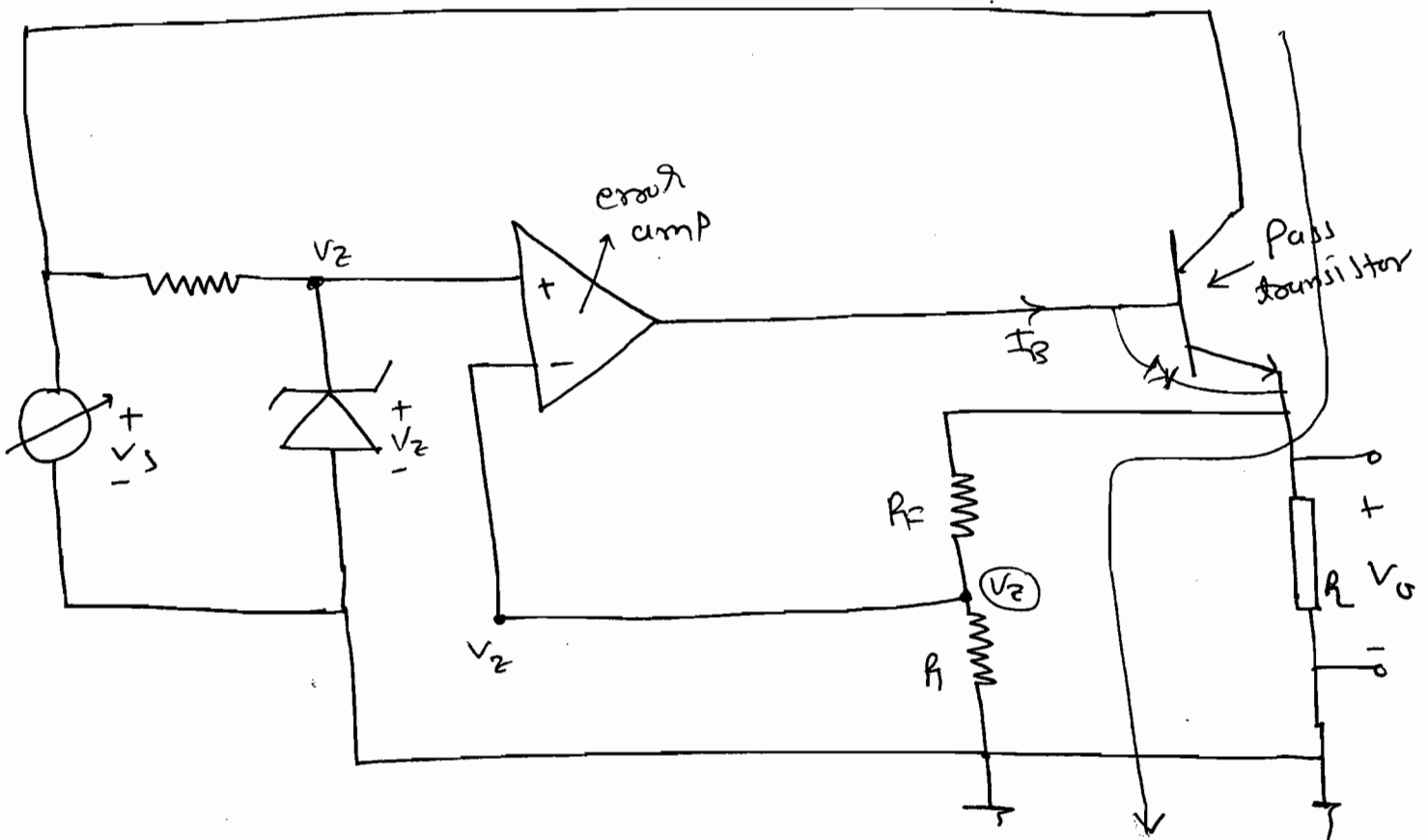


$$I_E = \frac{I_O}{10}$$

$$I_E = 1A$$

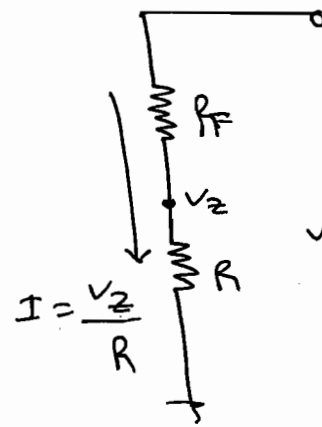
Increasing the current range

* Increase Voltage range of Zener by error Amp. along with increase current range by Pass transistor.



$$\Rightarrow \frac{V_z - V_o}{R_F} + \frac{V_z}{R} = 0$$

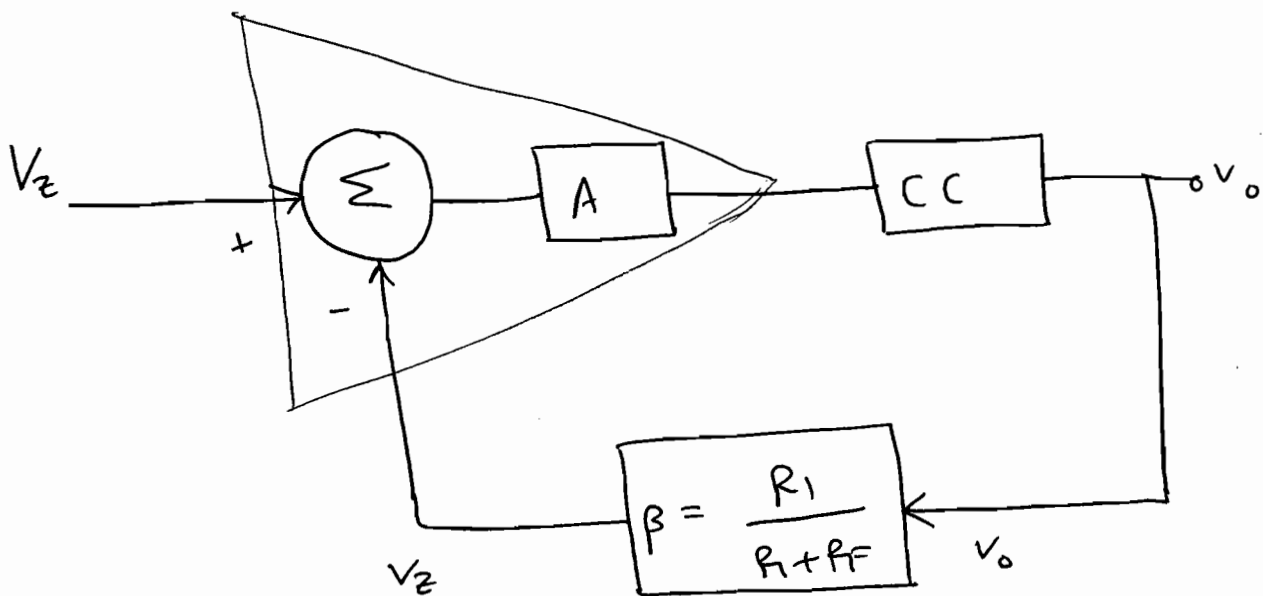
$$\therefore V_o = \left(1 + \frac{R_F}{R}\right) V_z$$



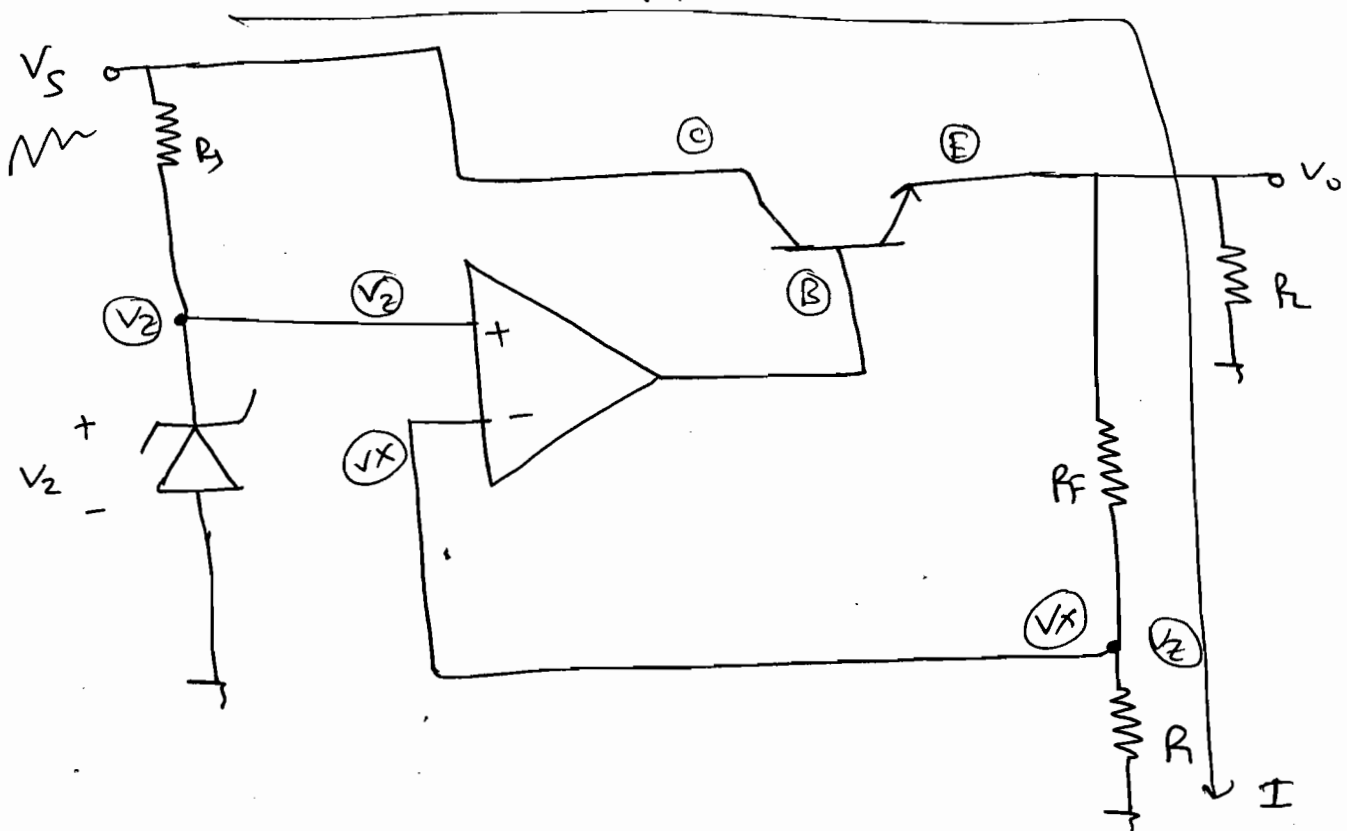
$$V_o = I(R_F + R)$$

$$V_o = \frac{V_z}{R}(R_F + R)$$

* General Configuration:



III



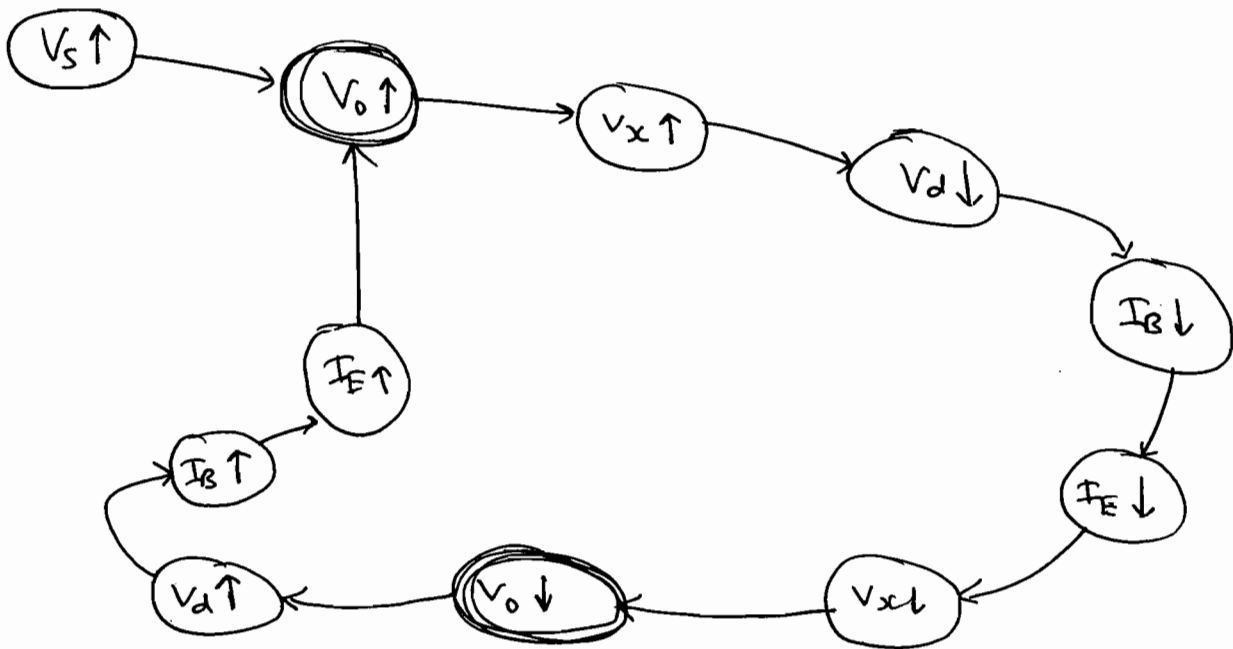
$$\Rightarrow I = \frac{V_Z}{R}$$

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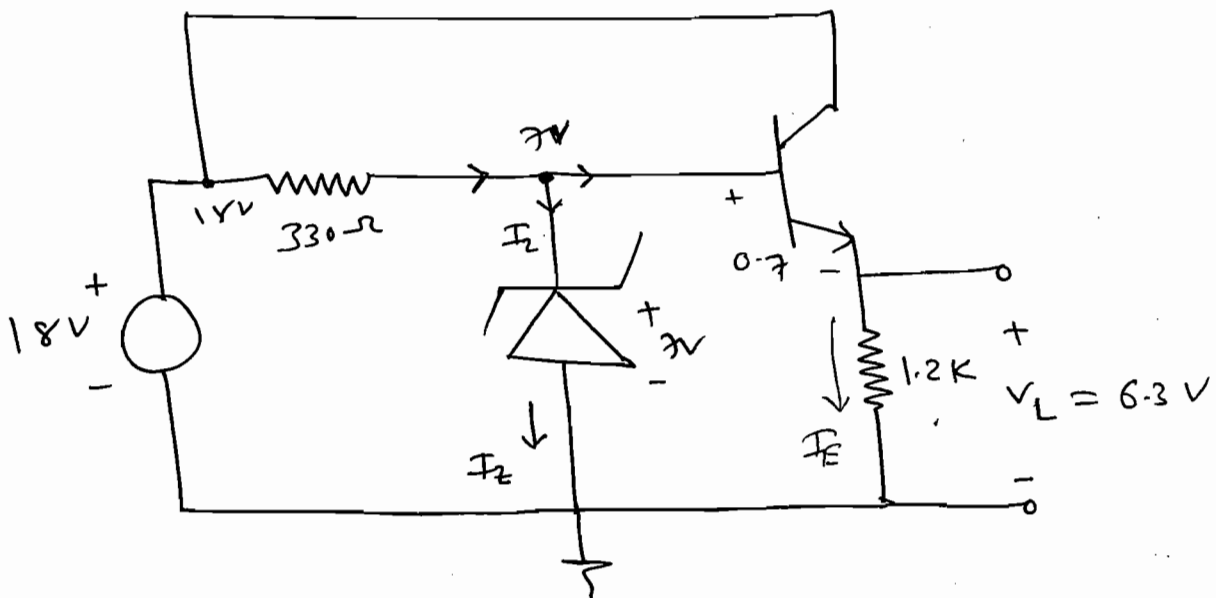
$$\therefore V_o = I (R_1 + R_F)$$

$$\therefore V_o = \frac{V_Z}{R} (R + R_F)$$

$$\therefore V_o = V_Z \left(1 + \frac{R_F}{R} \right)$$



Ex-1 Given $\beta = 100$. Calculate the Zener current I_Z .



Ans:

$$I_E = \frac{V_E}{R_E} = \frac{6.3}{1.2k}$$

$$I_E = 5.25 \text{ mA}$$

$$\beta/2 \quad I_B = \frac{I_E}{(\beta+1)}$$

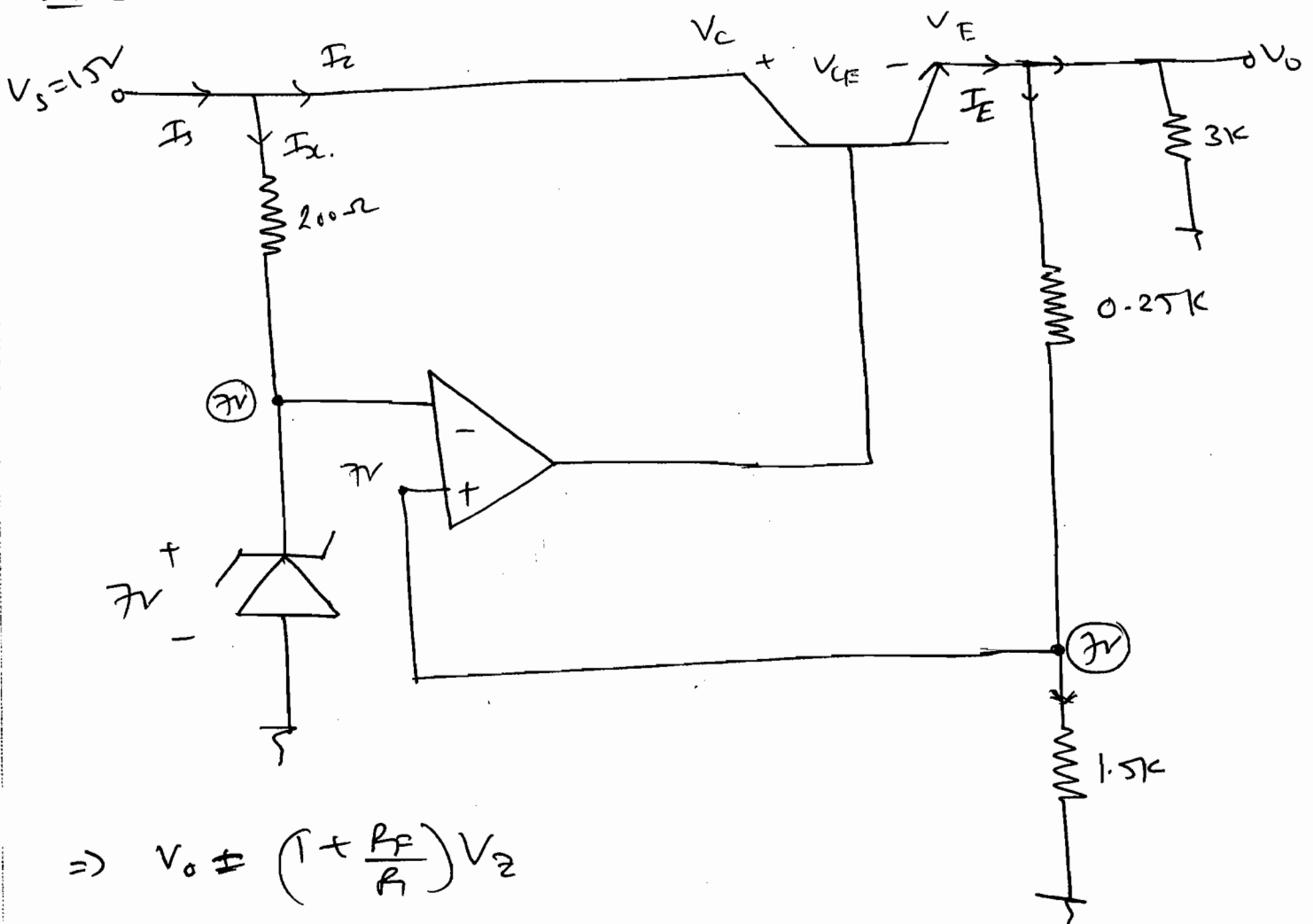
$$I_B = 51.94 \mu\text{A}$$

By KVL, NDA

$$\frac{18-7}{330} = I_Z + I_B$$

$$\therefore I_Z = 33.28 \text{ mA}$$

Ex-1 Calculate the Power dissipation if $\beta=100$.



$$\Rightarrow V_O = \left(1 + \frac{R_F}{R_1}\right) V_Z$$

$$\Rightarrow V_0 = \left(1 + \frac{0.25}{1.25}\right) 7$$

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$$\boxed{V_0 = 8.4 \text{ V} \approx V_E}$$

$$I_S = \frac{15 - 7}{200} + I_E$$

By NDA

$$I_E = \frac{V_0}{1.75 \text{ K}} + \frac{V_0}{3 \text{ K}}$$

$$\rightarrow \boxed{I_S = 47.52 \text{ mA}}$$

$$\therefore I_E = \frac{8.4}{1.75 \text{ K}} + \frac{8.4}{3 \text{ K}}$$

$$\rightarrow \boxed{V_C = 15 \text{ V}}$$

$$\therefore I_E = 7.6 \text{ mA}$$

$$I_C = \left(\frac{\beta}{\beta + 1}\right) I_E$$

$$\therefore \boxed{I_E = 7.5247}$$

$\therefore$ Power dissipation

$$P_D = V_{CE} \times I_E$$

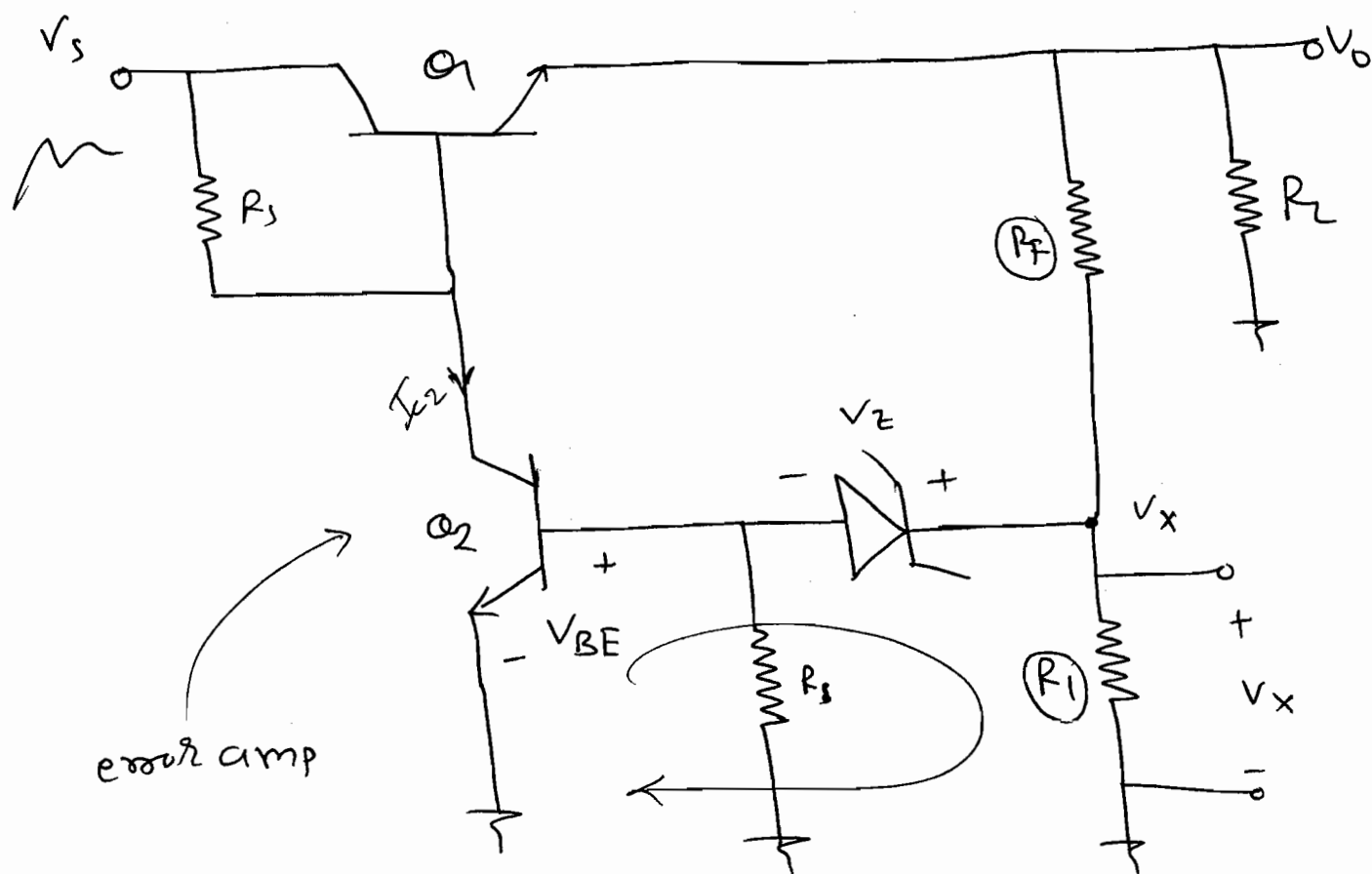
$$= (V_C - V_E) \times I_E$$

$$= (15 - 8.4) \times 7.5247$$

$$\rightarrow \boxed{P_D = 49.66 \text{ mW}}$$

* Error Amplifier using BJT:

⇒

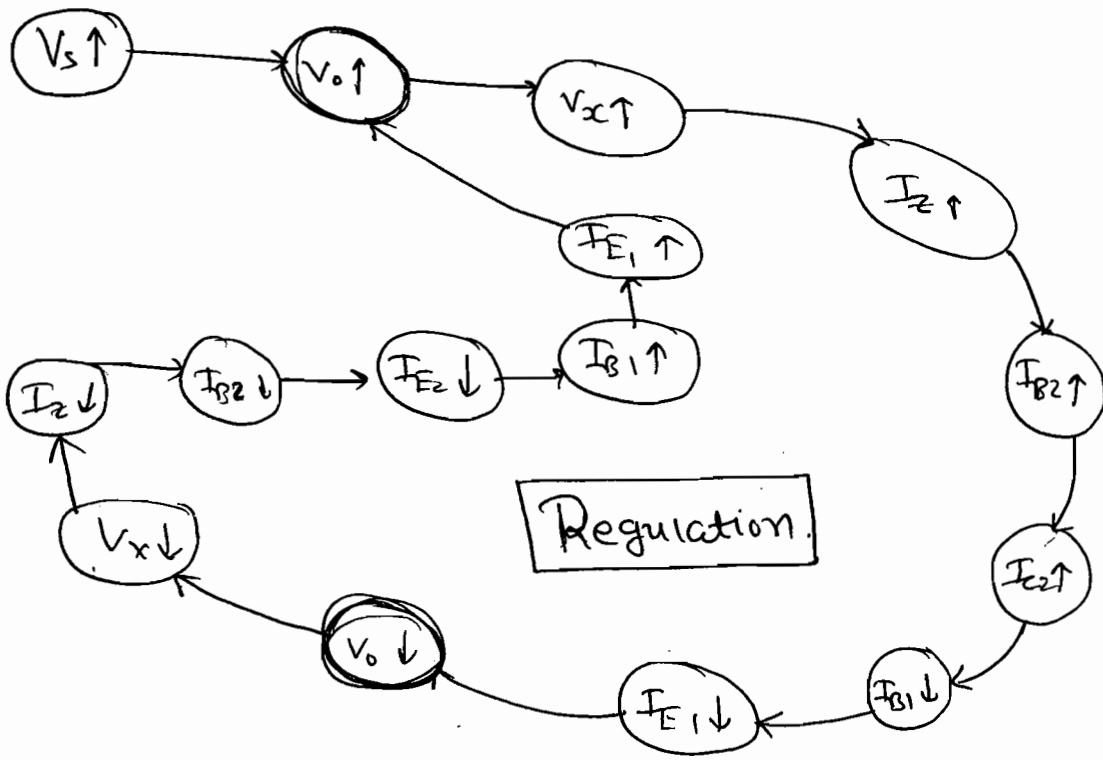


$$\therefore V_x = \left(\frac{R_1}{R_1 + R_F} \right) V_o.$$

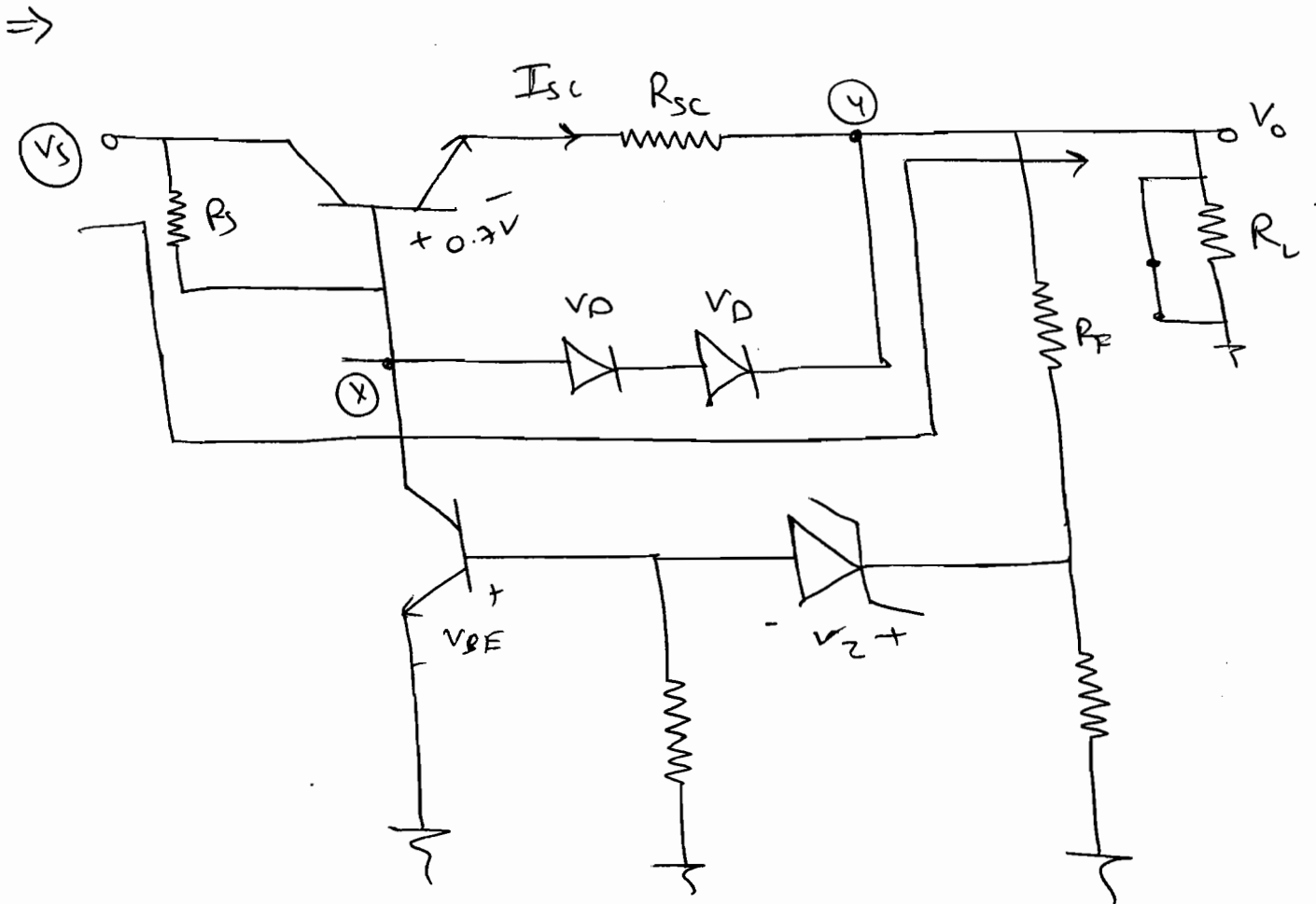
By KVL $V_{BE} + V_Z = V_x.$

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

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



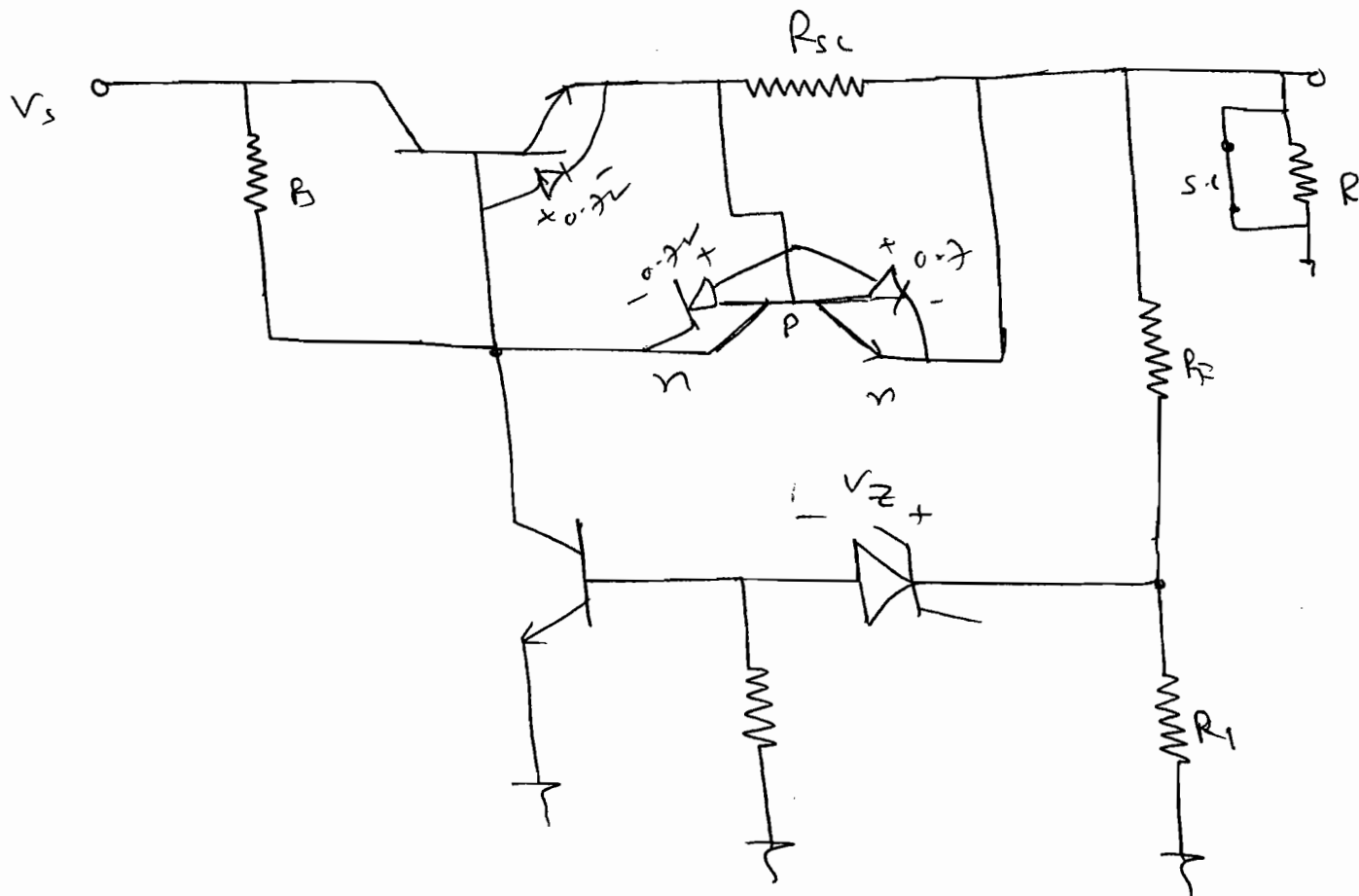
* Short circuit Protection of Voltage Regulator:



$$\Rightarrow V_{xy} = 0.7 + I_{sc} \cdot R_{sc} = V_D + V_D.$$

$$\therefore R_{sc} = \frac{0.7}{I_{sc}}.$$

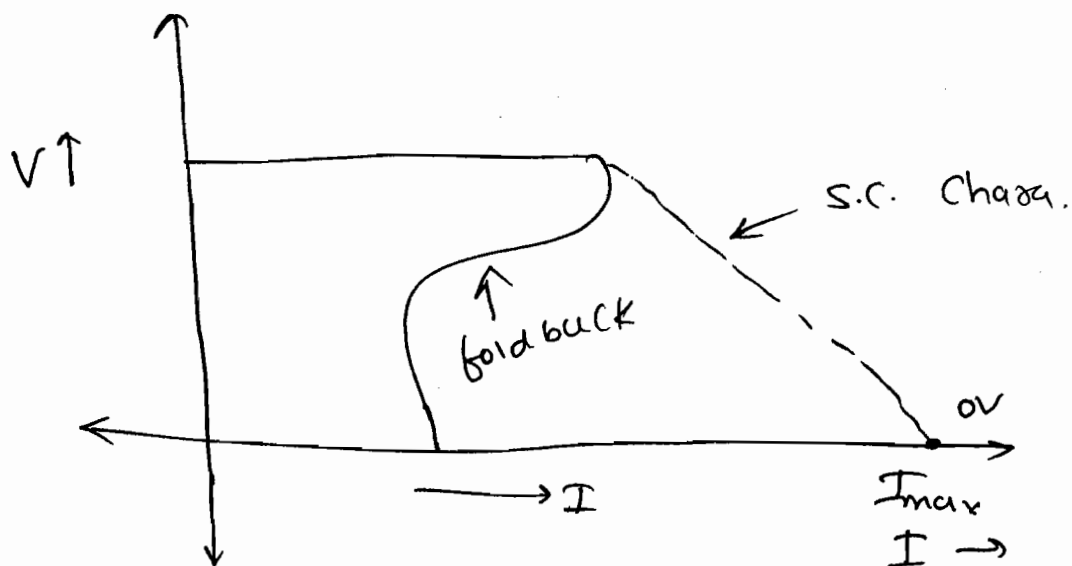
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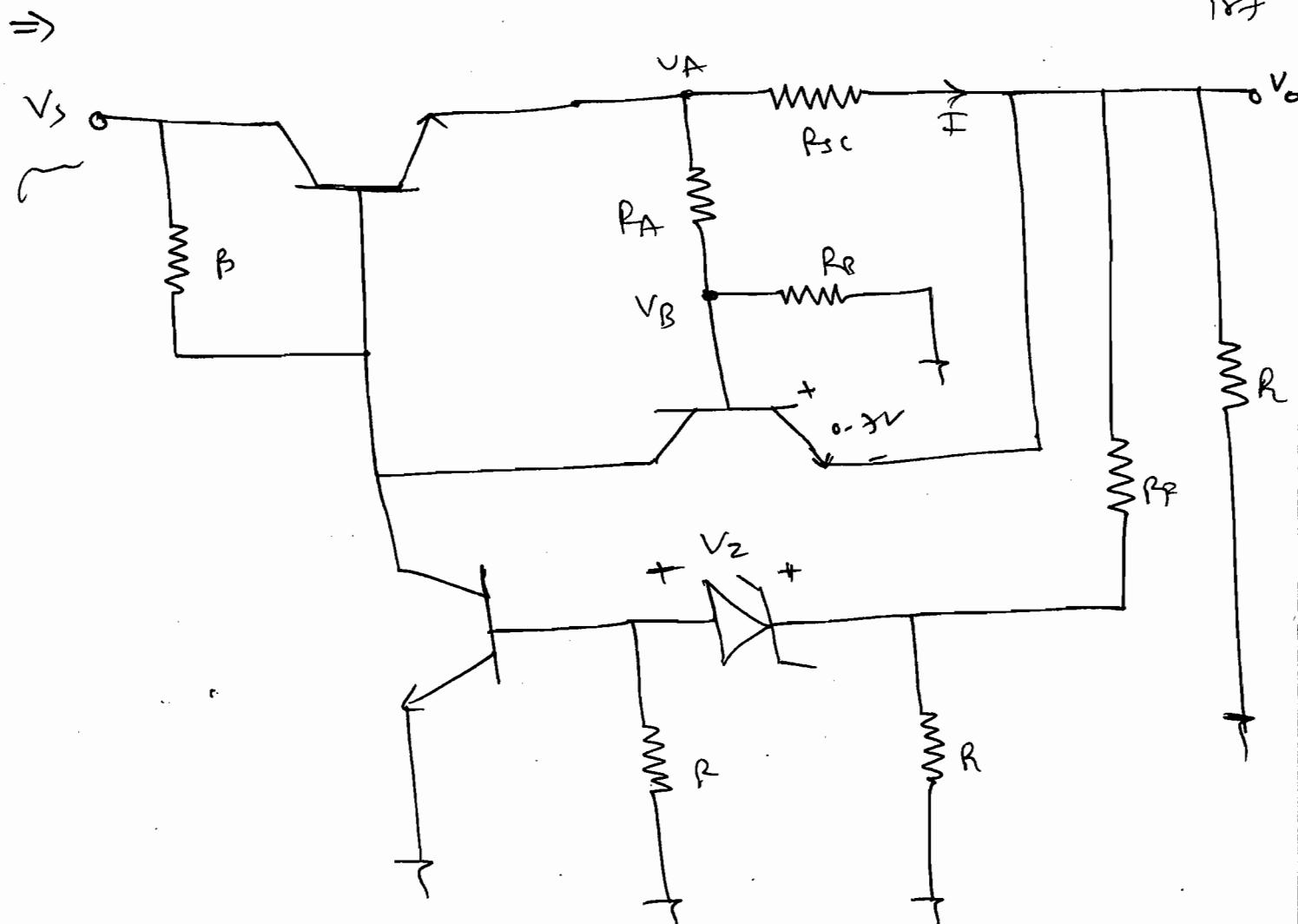


$\Rightarrow$ * Foldback Current limiting of Voltage

Regulators:

$\Rightarrow$





$$\Rightarrow V_B = \left(\frac{R_B}{R_A + R_B} \right) V_A = 0.7 + V_0$$

$$\Rightarrow V_A = \left(1 + \frac{R_A}{R_B} \right) V_B$$

$$\rightarrow V_A = I R_L + V_0 = \left(1 + \frac{R_A}{R_B} \right) (0.7 + V_0)$$

$$\therefore I_{nos} = \frac{\left(1 + \frac{R_A}{R_B} \right) (0.7 + V_0) - V_0}{R_L}$$

During S.C. $V_0 = 0V$.

$$\therefore I_{sc} = I = \left(1 + \frac{R_A}{R_B}\right) 0.7.$$

$$I_{sc} < I_{nom.}$$

*

