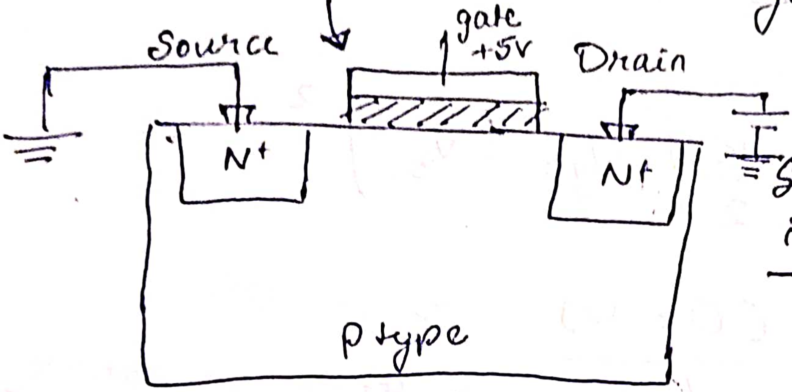
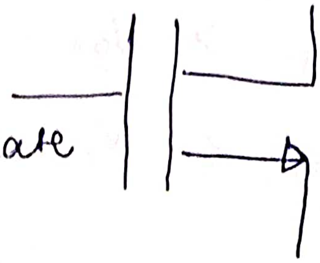
MOSFET

MOS → Metal oxide Semi-conductor

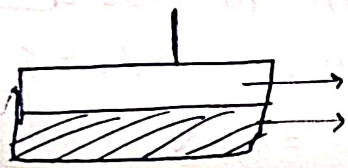
FET → field



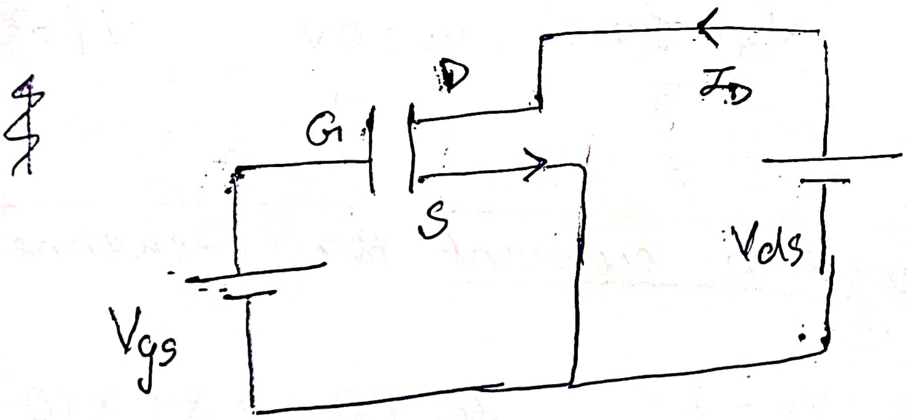


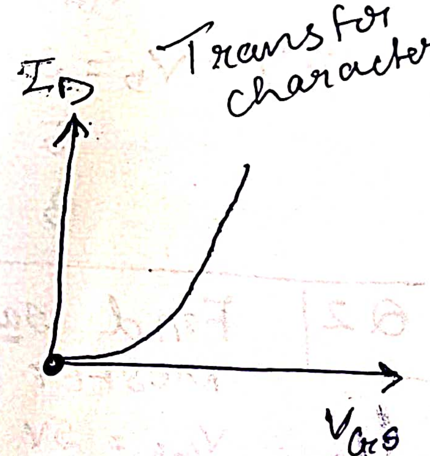
Source & Drain are interchangeable

Transistor : Transfer , resistor
Current flows without resistance between collector & emitter.

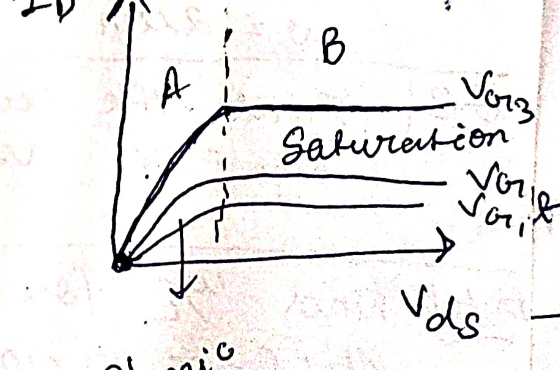


→ so that e⁻ don't go out through the metal.





$V_{G_1} < V_{G_2} < V_{G_3}$



Ohmic
used as resistor

Junction Transistor

11/10

if $V_{ds} \geq V_{gs} - V_t$: Saturation

$V_{ds} < V_{gs} - V_t$: Linear

- I_D (in saturation) $= \frac{K}{2}\left[V_{gs} - V_t\right]^2$

  $K = \frac{\mu_n C_{ox} W}{L}$ → W: width; L: length in source & drain

- I_D (in linear) $= \frac{K}{2}\left[2\left(V_{gs} - V_t\right)V_t - V_{ds}^2\right]$

Tut 6

Q1) Find the region of operation in N-MOSFET

(i) $V_D = 5V$ $V_G = 3V$ $V_S = 0V$ $V_T = 1V$

→ $V_{DS} = 5V$ $V_{GS} - V_t = 2V$

$V_{GS} = 3V$ $\therefore V_{DS} \geq V_{GS} - V_t$ ∴ Saturation

ii) $V_D = 3V$ $V_G = 1V$ $V_S = 0V$ $V_T = 0.5V$

V_D	V_G	V_S	V_T
3V	1V	0V	0.5V
5	3	1	2
3	5	1	0

Q.2) Find saturation current for n-channel MOSFET if

$V_{GS} = 5V$ $V_T = 1V$ $\mu_n C_{ox} = 89 \times 10^{-6}$

$W = 2\mu m$ $L = 1m$

Q.3) Find the current flowing through MOSFET

$V_{gs} = 5V$ $V_T = 1V$ $V_{ds} = 2V$ $\frac{\mu_n C_{ox} W}{L} = 110 \times 10^{-6}\ A/V^2$

Q.4) Find W/L for n-channel MOSFET whose $\mu_n C_{ox} = 110 \times 10^{-6}\ A/V^2$. For an $I_D = 1mA$, $V_{GS} = 3V$, $V_T = 0.5V$

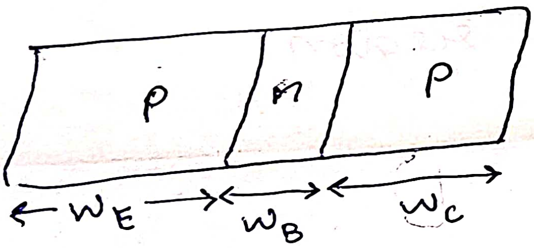
BJT | Bipolar Junction Transistor

11/10

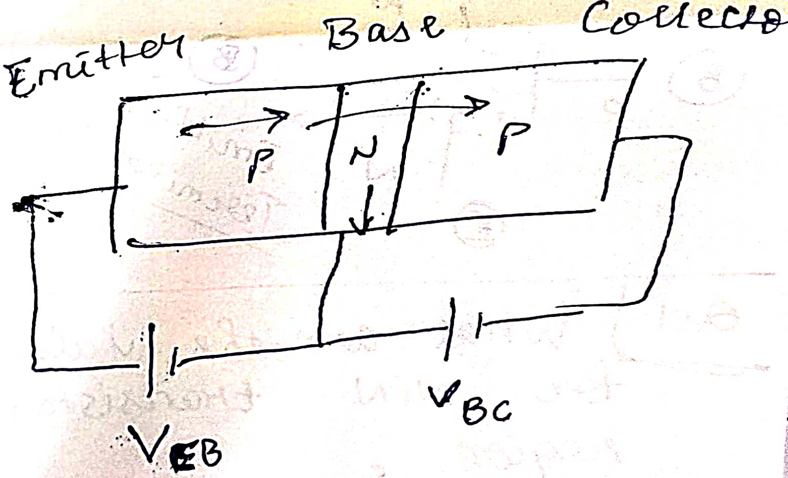
TRANSFER + RESISTOR

- BJT 1947
- (UJT) FET
  - JFET
  - MOSFET
    - Enhancement
    - Depleti

Not common current



$W_E \simeq W_C >> W_B$



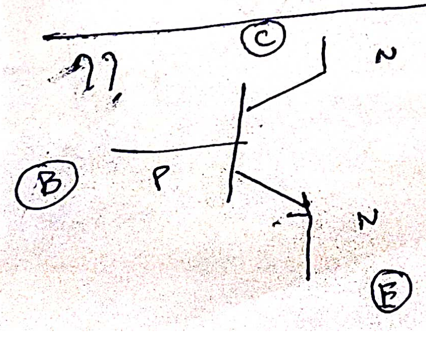
- Active Region –
  Input : Forward
  Output : Reverse

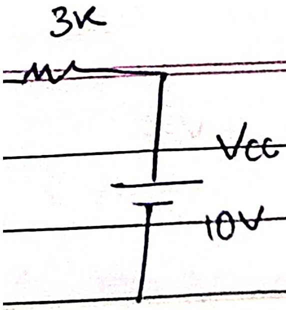
$$\boxed{I_E = I_B + I_C}$$

$$\alpha = \frac{I_C}{I_E}$$

$I_C = \alpha I_B + I_{leak}$

$I_{leak} \to I_{CBO}$ when input is open



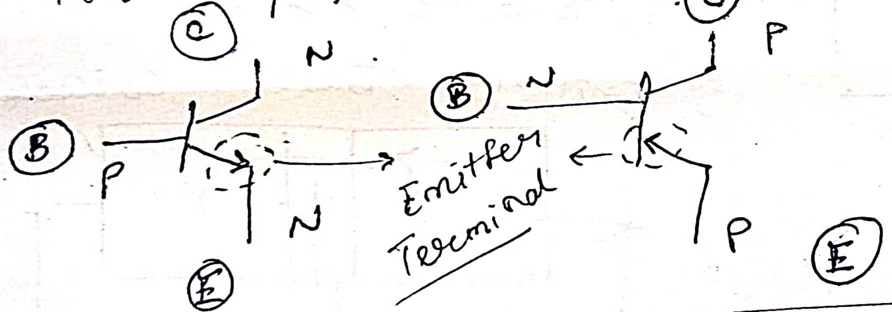


Q1)

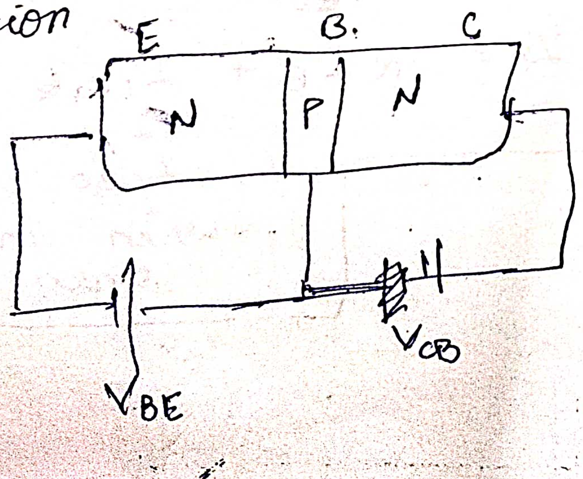
- **Operation Regions :**

Operation Region	Input Jn	Output Jn
Cut-off [DC]	Reverse	Forward / Reverse
Active	~~Forw~~ Forward	Reverse
Saturation [DC]	Forward	~~Reverse~~ Forward

- All logic gates are operated in cut-off or saturation.
- For amplification, active region



Q.1) What are the values of V_{BE} & V_{CB} for NPN transistor to be in an active region



$V_{BE} \rightarrow +ve$

$V_{CB} \rightarrow +ve$

5V Q] For PNP

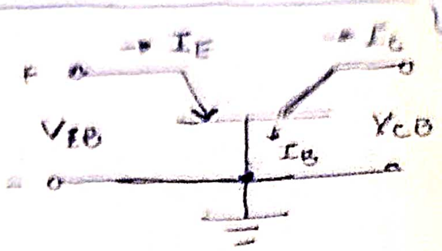
E 1mA

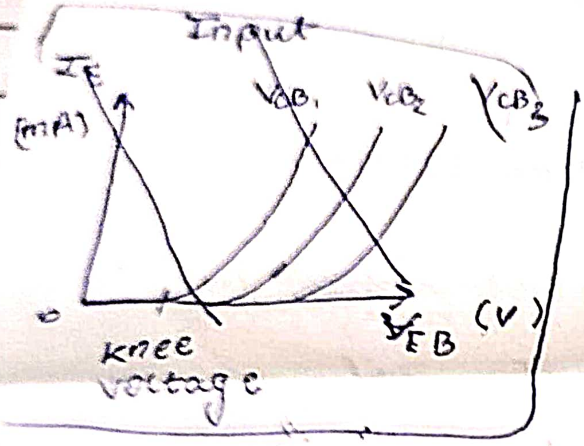
α 0.99

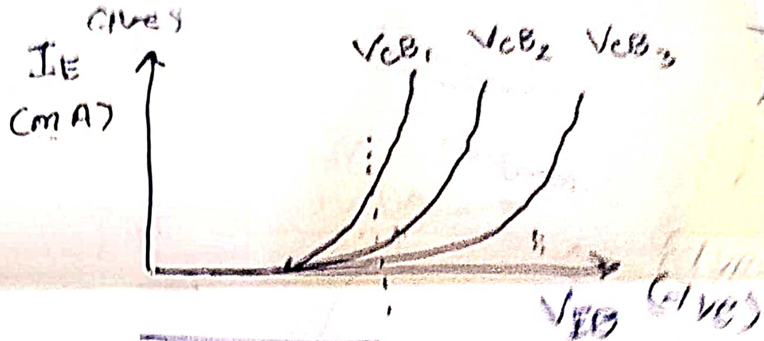
$\rightarrow I_C = 0.99mA$ $I_B = I_E - I_C = 0.01 mA$]

- Configurations

- CBC - Common Base config.



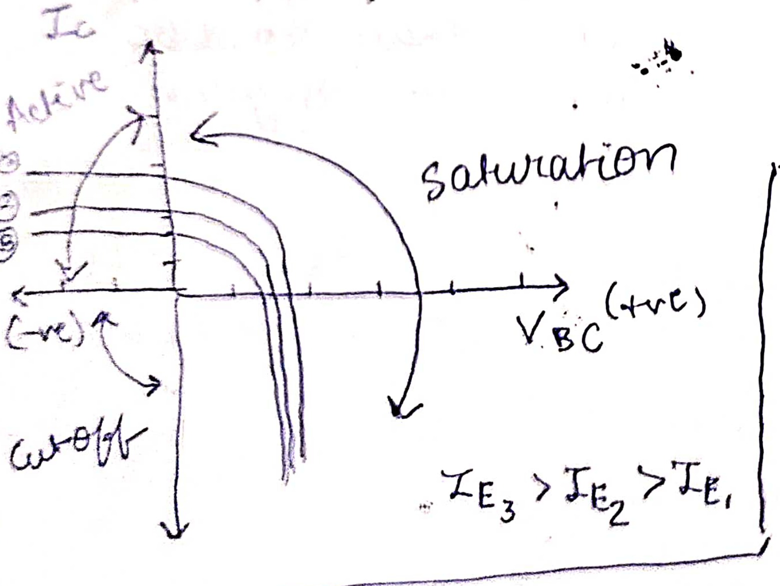


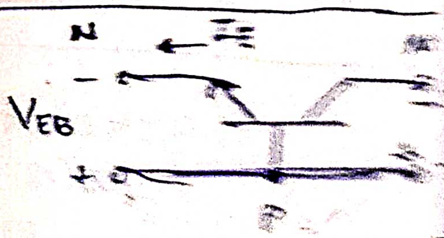


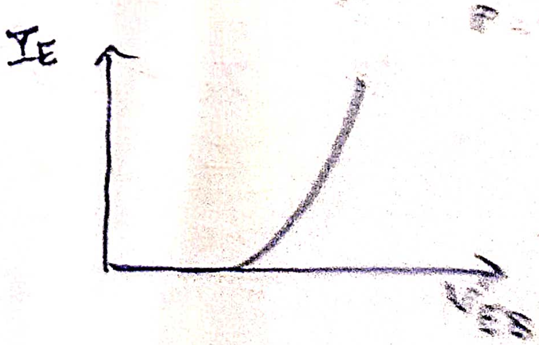
INPUT

I-V Characteristics

PNP CBC





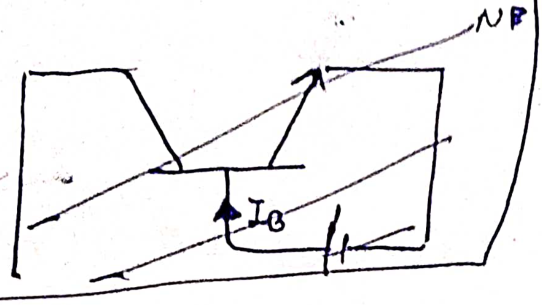


BJT

RC L ↑

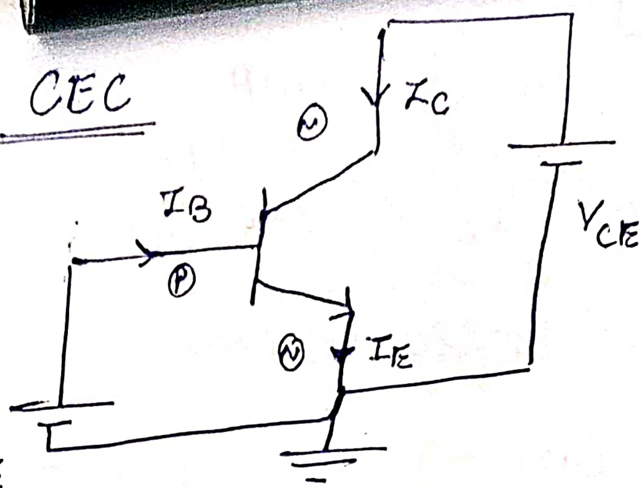
Integrator

Differentiator

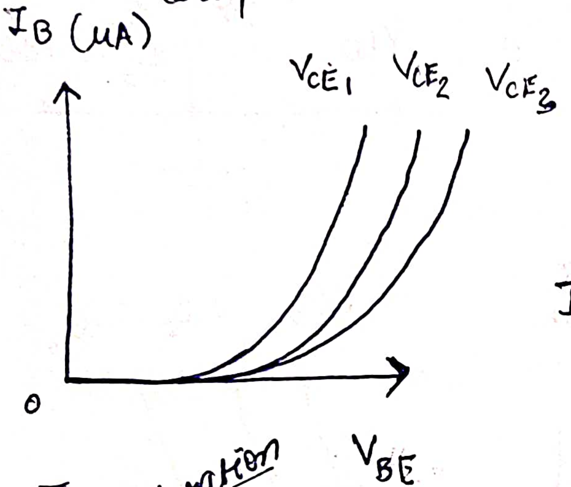


Input: forward
Output: reverse

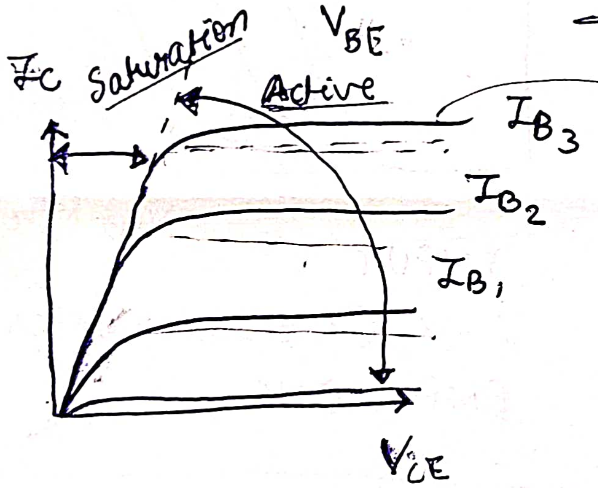
CEC



V_{BE}
[Input voltage]



Input characteristics of NPN transister in CEC



Not ~~vertical~~ but horizontal

$I_{B_3} > I_{B_2} > I_{B_1}$

* Output is higher in CEC than in CBC in ACTIVE region

$$\text{Current gain} = \frac{I_{out}}{I_{in}} = \frac{I_C}{I_B}$$

$I_E = I_C + I_B$

$I_C = \alpha I_E + I_{CBO}$

$$\Rightarrow I_C = I_C\alpha + I_B\alpha + I_{CBO}$$

$$\frac{I_C}{I_B}(1-\alpha) = \alpha + \frac{I_{CBO}}{I_B}$$

$$\Rightarrow \boxed{\frac{I_C}{I_B} = \frac{\alpha}{1-\alpha} + \frac{1}{1-\alpha}\cdot\frac{I_{CBO}}{I_B}}$$

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

~~$\alpha = \frac{I_C}{I_E}$~~

$\beta - \beta\alpha = \alpha$

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

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

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

Leakage curr is > in CEC

Q1) $I_E = 2mA$ $\alpha = 0.995$ reverse sat. $I = 100nA$ at $T = 25°C$ determine remaining current & 'β' at 75°C

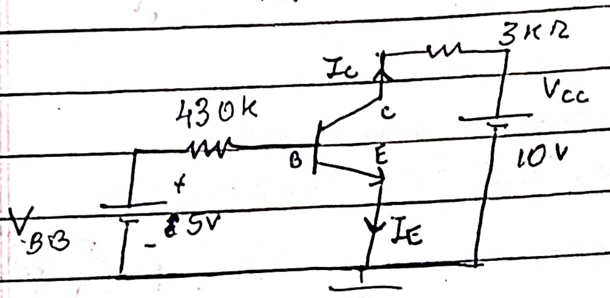
$\rightarrow$ $I_{CBO} = 100nA \times \underbrace{2\times2\times2\times2\times2}_{5\ times} = 3200nA$ $\because$ $\frac{25° - 75°}{10} = 5$

$I_C = 0.995(2mA) + 3.2\mu A$

$I_C = 1.99 + 0.0032 = \underline{1.9932\ mA}$ $I_B = .00\cancel{68}68$ $= 6\cancel{8}.8\ \mu A$

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.995}{1.995} = \frac{I_C}{I_B} = \frac{1.9932}{0.0068}$

Q.



$\beta = 200$

$V_{BE} = 0.7V$

[Ignore leakage current]

[if β not given $\beta = 100$]

For a given Si transistor Determine all the currents of transistor & operating region. [if $V_{CE} = 0.2V$]

$\rightarrow$ ~~I_{BB}~~ $V_{BB} - I_B(430K\Omega) - V_{BE} = 0$

$I_B = \frac{5 - 0.7}{430K\Omega} \quad \frac{4.3}{4.3\times10^5} = \underline{\cancel{20}\ 10\ \mu A}$

True only in active region $\rightarrow$ $\beta = \frac{I_C}{I_B} = 200$ $I_C = \cancel{20\ \mu A}\ 2mA$

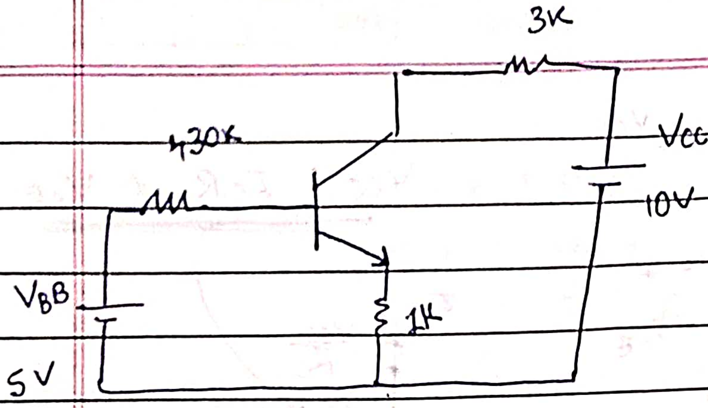
$\alpha = \frac{\beta}{1+\beta} = \frac{200}{201}$ $I_E = 2mA + 10\mu A$

$\boxed{I_E = 2.01\ mA}$

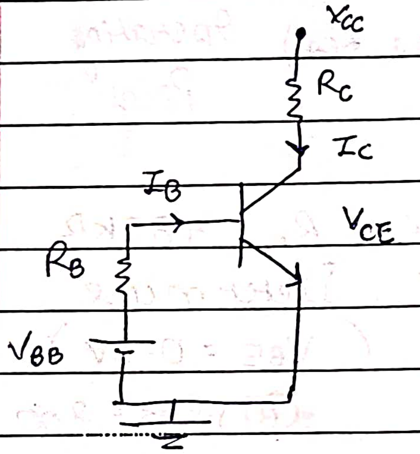
~~$V_{CC} - I_C R_C - V_{CE} = 0$~~

$V_{CC} - I_C R_C - V_{CE} = 0$ from this if $V_{CE} > 0.2V$

$V_{CE} = 10 - 2mA(3K\Omega) = \underline{4V}$ this active region



$\cancel{I_B = I_C\beta}$ $\beta = \dfrac{I_C}{I_B}$ [in active region]



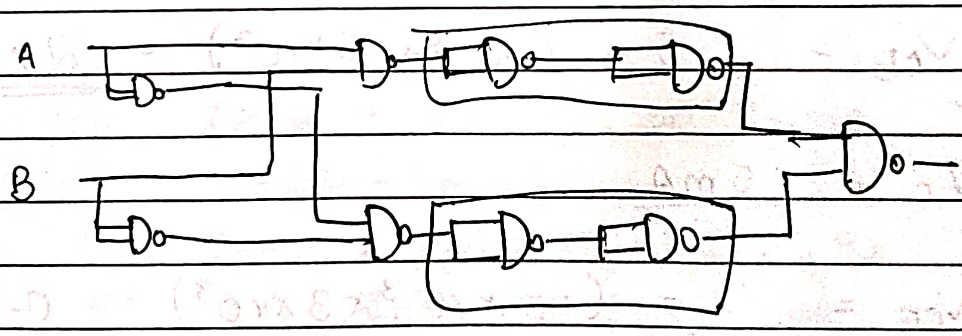
$V_{CC} - I_C R_C - V_{CE} = 0$

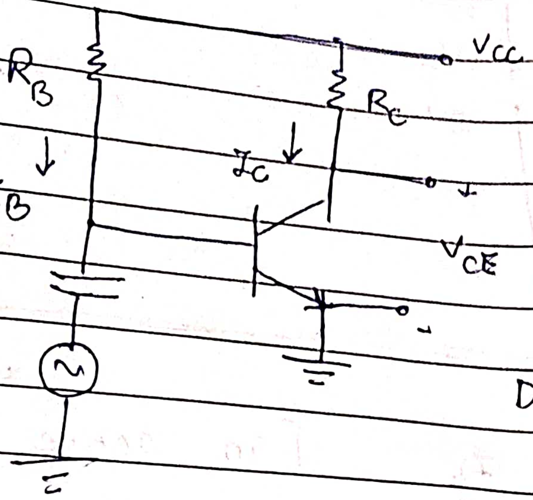
$V_{BB} - I_B R_B - V_{BE} = 0$
↓
0.2V

$\cancel{I_E R_E +}\ V_{CC} - I_C R_C - V_{CE} - I_{E} R_E = 0$

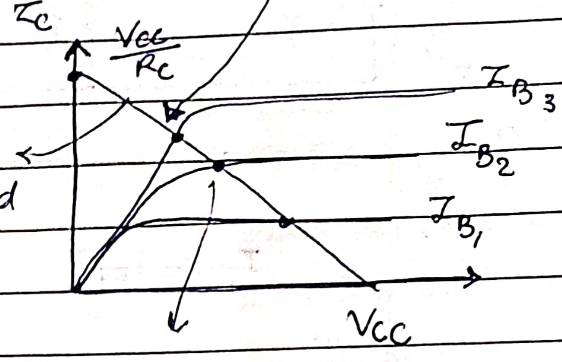
$I_E R_E + V_{BB} - I_B R_B - V_{BE} = 0$

In linear saturation region $I_E \approx I_C$ ∵ $\alpha \approx 1$





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



(V_{CEQ}, I_{CQ}) Operating Point

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

For the given fixed bias $R_B = 430\,k\Omega$ and R_C is $3\,k\Omega$, V_{CC} is $5\,V$. Determine operating points for ($V_{BE} = 0.7V$)
(i) $\beta = 100$ (ii) $\beta = 150$ (iii) $\beta = 200$

→ (i) $I_B = \frac{5-0.7}{430} \times 10^{-3} = \frac{43}{4300} \times 10^{-3} = 10^{-5}$

$= 0.01\ mA$

$I_C = \beta I_B = 1mA$

$V_{CE} = 5 - (10^{-3} \times 3\times10^{3}) = 2V$

(ii) $I_C = 1.5\,mA$

$V_{CE} = 5 - (1.5\times10^{-3}\times 3\times10^{3}) = 0.5\,V$

(iii) $I_C = 2mA$

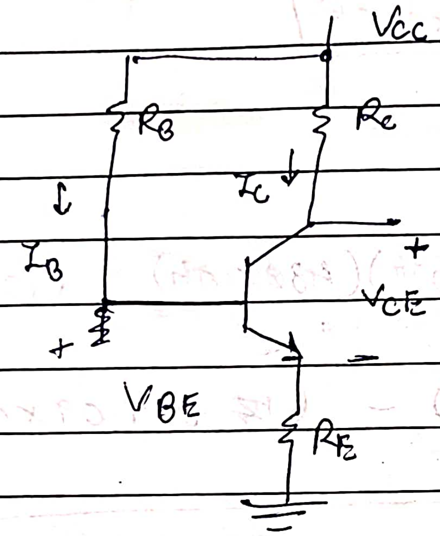
$V_{CE} = -1\,V$ [Transistor in saturation]

$\therefore V_{CE} = 0.2V$

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

$0.2 = 5 - I_C\, 3k\Omega$

$I_C = \frac{4.8 \times 10^{-3}}{3} = \underline{1.6\,mA}$



SELF BIAS

- ↑ high cost.
- ↑ Power losses

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

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

$I_E \rightarrow (1+\beta) I_B$

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

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

Q. $R_C = 2k\Omega$, $R_E = 1k\Omega$, $R_B = 430k\Omega$, $V_{CC} = 5V$

→ i) $\beta = 100$

$V_{CC} = \cancel{I_C R_C} + V_{CE} + (1+\beta) I_B R_E$

$\cancel{I_B = V_{CC} - V_{BE}}$

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

$0 = I_C R_C - I_B R_B + V_{CE} - V_{BE}$

$\Rightarrow 0 = I_C R_C - I_B R_B + V_{CC} - I_C (R_C + R_E) - V_{BE}$

$0 = V_{CC} - I_B R_B$

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

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

$V_{CC} - I_B R_B - V_{BE} - (1+\beta) I_B R_E = 0$

$\Rightarrow V_{CC} - I_B R_B - V_{BE} = \dfrac{4.3}{430\,k\Omega + (100)\,1\,k\Omega}$

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

$\boxed{I_B = 8.09 \times 10^{-6}}$

$\boxed{I_C = 8.09 \times 10^{-4}}$

$V_{CE} = V_{CC} - (8.09 \times 10^{-4})(430 \times 10^3) - (101)(8.09 \times 10^{-6})(1\,k\Omega)$

$= 5 - (347.87) - (817.09 \times 10^{-3})$

$\overline{A \cdot B}$

$(\overline{A+B})$

$(\overline{A} \cdot B)$

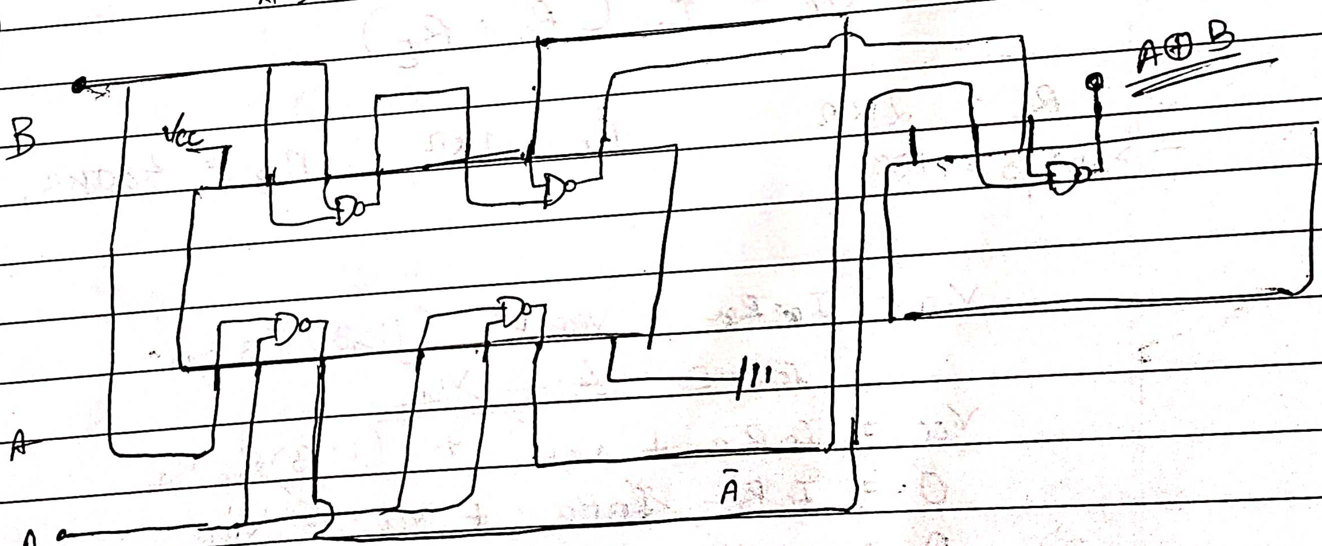
$A+\overline{B}$

$(A+B) \cdot (\overline{A}+\overline{B}) = A\overline{B} + \overline{A}B$

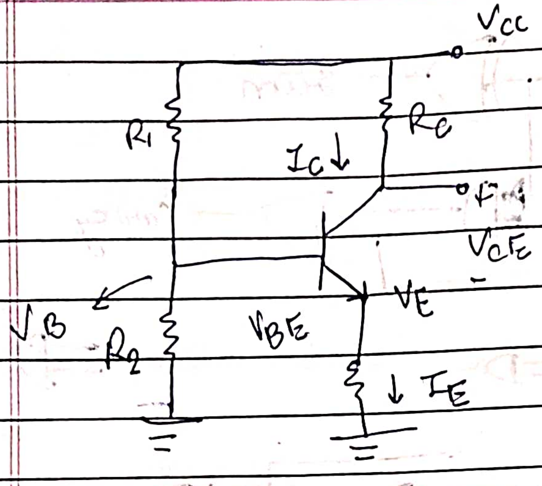
$\overline{A \cdot B}$

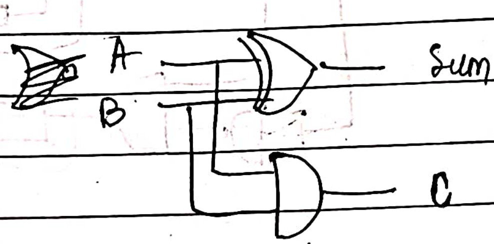
~~$AB + \overline{A}\overline{B}$~~

~~$AB + \overline{A}\overline{B} +$~~



$(\overline{A}+B) \cdot (A+\overline{B}) = A\overline{A} + \overline{A}\overline{B}$

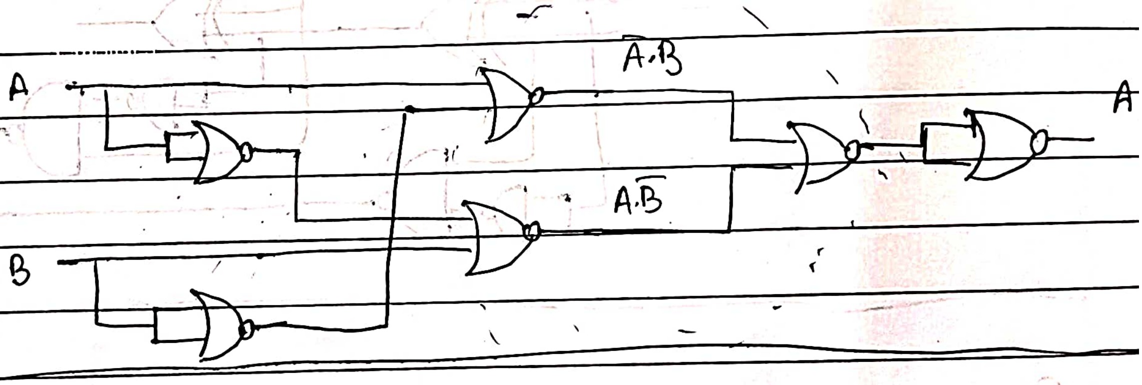




$A \cdot \overline{B} + \overline{A} \cdot B$

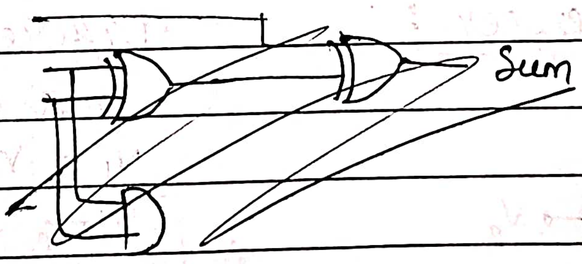
$\left(\overline{A+B}\right) \quad \overline{A} \cdot B$

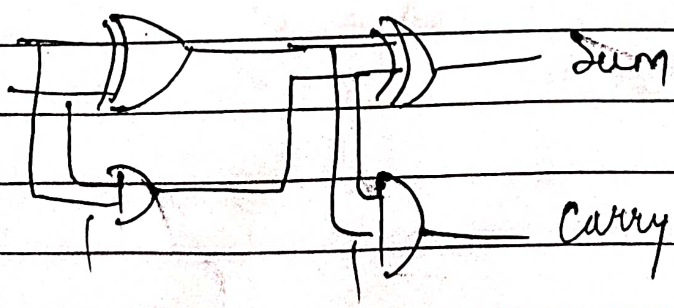
$A \cdot \overline{B} + \overline{A} B$

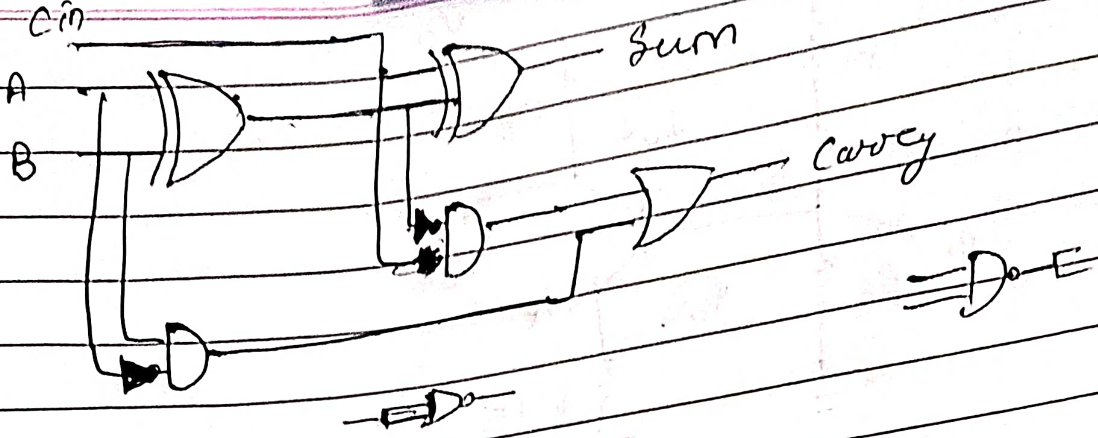


$\left(\overline{A+B}\right)$

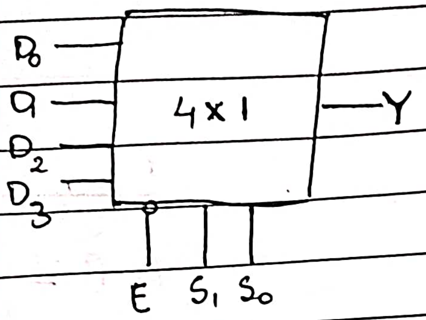
$\overline{A} \cdot B$

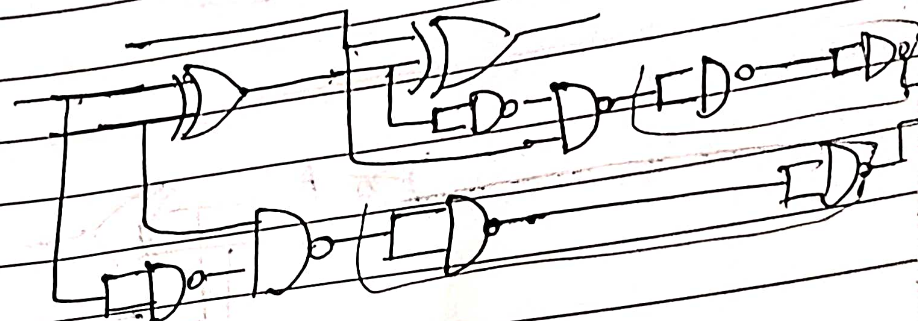


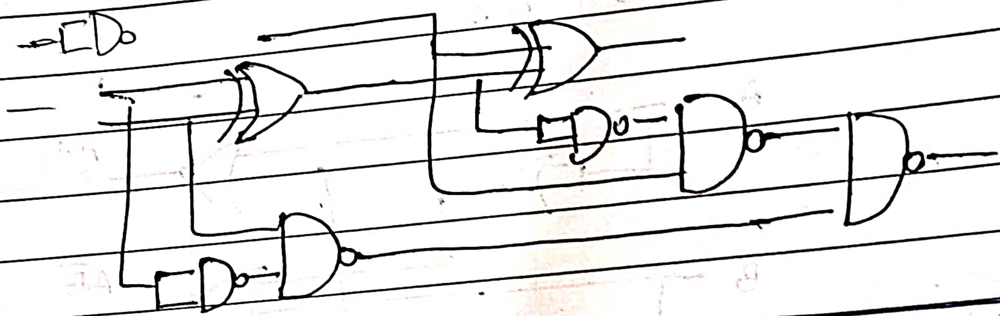




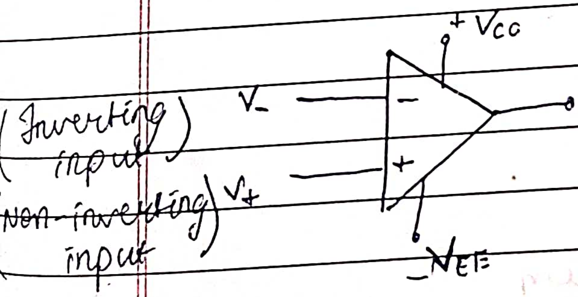
74153







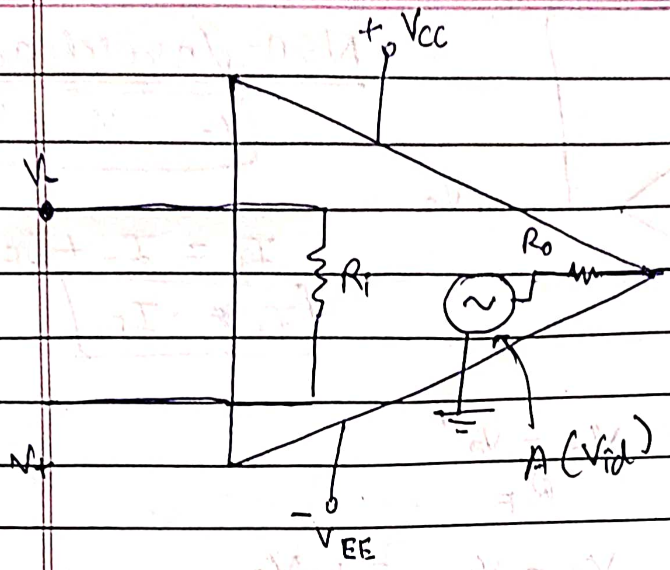
- Operational Amplifier :



Differential amplifier
(Noise cancellation)

$V_1 - V_2$

$$\left[\begin{array}{l} V_1 + V_n - (V_2 + V_n) \\ V_1 - V_2 \end{array}\right]$$



IC741

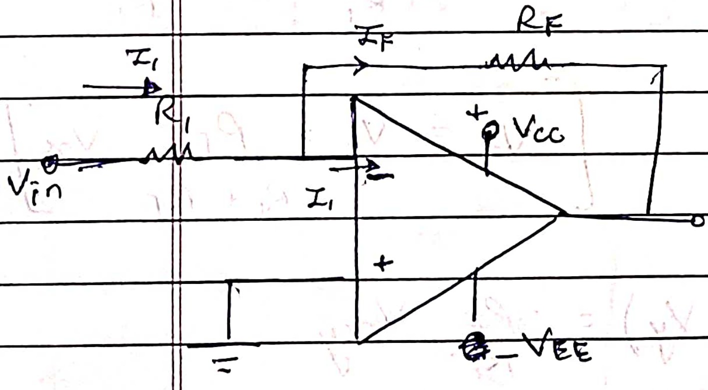
$$\boxed{V_0 = A V_{id} - I_0 R_0}$$

Characteristics of Ideal OP Amp -

1. R_i tends to infinite (in MΩ order)
2. R_0 tends to zero (kΩ)
3. Open loop gain A is ∞ [2×10^5]

Conclusion -

1) $I_+ = I_- = 0$
2) $V_0 = A V_{id}$
3) $V_+ = V_-$ [∵ $A \to \infty$



$$\boxed{I_1 = I_{-} + I_F}$$

$$\boxed{\therefore I_1 = I_{-}}$$

$$\frac{V_{in} - V_{-}}{R_1} = \frac{V_{-} - V_0}{R_F}$$

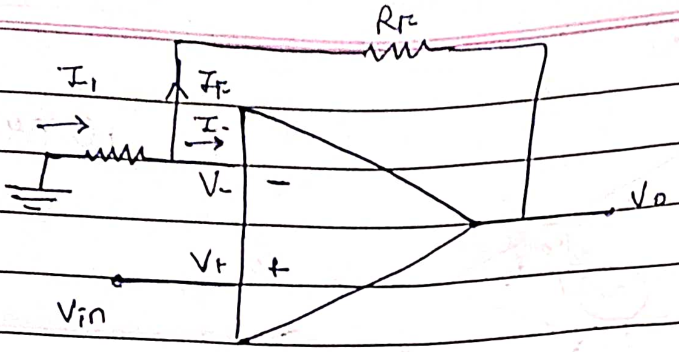
$V_- = V_+ = 0$

$$\frac{V_0}{V_{in}} = A_F = -\frac{R_F}{R_1}$$

Inverting Amplier

Date

Non-Inverting



$$\boxed{V_- = V_+ = V_{in}}$$

$$I_1 = I_- + I_F$$

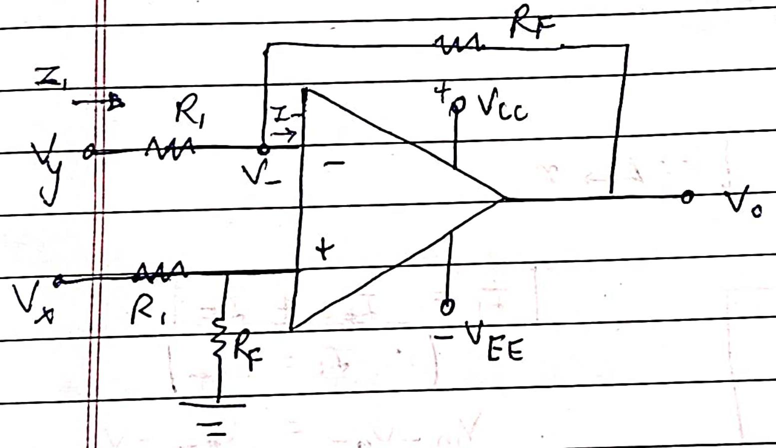
$$\boxed{I_1 = I_F}$$

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

$$\frac{-R_F}{R_1} = \frac{V_{in} - V_o}{V_{in}} = 1 - \frac{V_o}{V_{in}}$$

$$\boxed{1 + \frac{R_F}{R_1} = \frac{V_o}{V_{in}}}$$

- Differential Amplifier



$$I_1 = I_- + I_F$$

$$\boxed{I_1 = I_F}$$

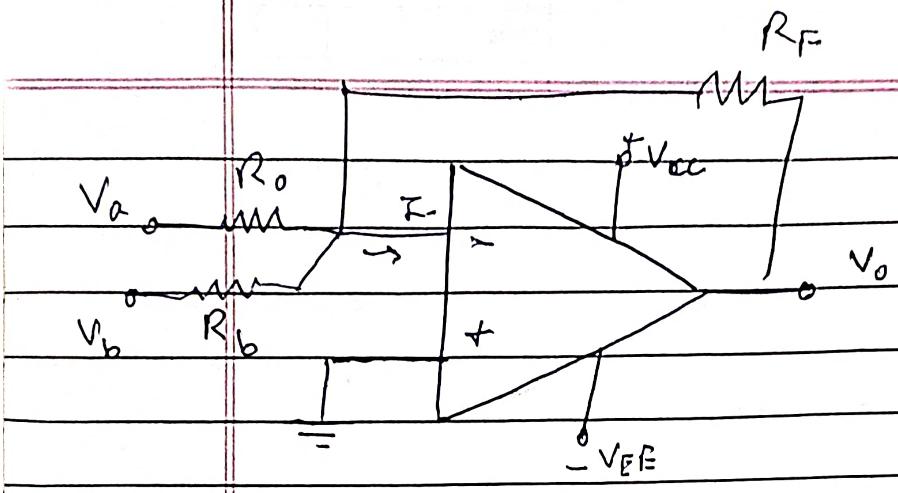
$$\frac{V_y - V_-}{R_1} = \frac{V_- - V_o}{R_F}$$

$$\left[V_- = V_+ = \frac{R_F}{R_1 + R_F} V_x \right]$$

$$V_o = \frac{R_F}{R_1}(V_x - V_y) = \frac{R_F}{R_1} V_{xy}$$

[if all resistors are same then $V_o = V_x - V_y$]

Subtracting circuit.



$$\frac{V_a}{R_a} + \frac{V_b}{R_b} = \frac{-V_o}{R_F}$$

$$V_o = -\left[\frac{R_F V_a}{R_a} + \frac{V_b R_F}{R_b}\right]$$

<u>Case I</u> :

$R_F = R_a = 2R_b$

$V_o = -(V_a + 2V_b)$ Scaling Amplifier

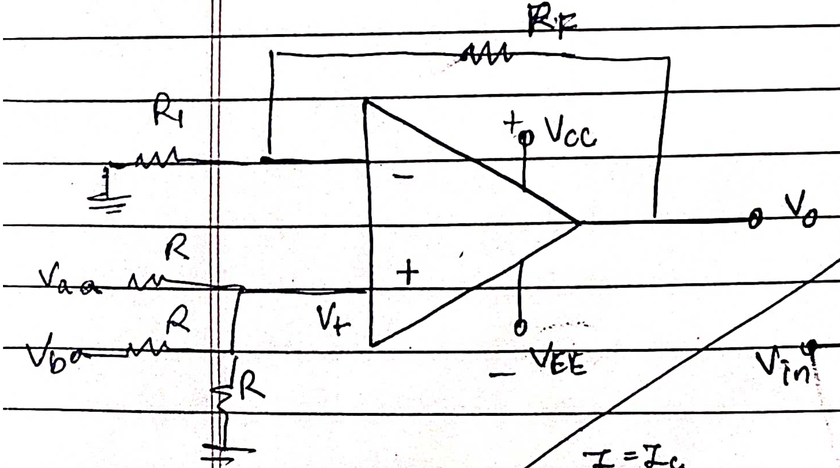
<u>Case II</u> :

$R_F = R_a = R_b$

$\therefore V_o = -(V_a + V_b)$ Summing circuit

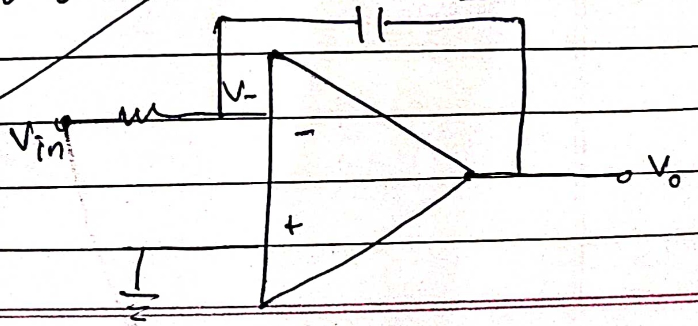
<u>Case III</u> : $2R_F = R_a = R_b$

$\therefore V_o = -\left(\frac{V_a + V_b}{2}\right)$ Averaging



$V_o = ?$

Summing
Averaging
<u>Integrator</u>



$I = I_c$

$$\frac{V_{in}}{R} = -C\frac{dV_o}{dt}$$

$$V_o = \frac{-1}{RC}\int V_{in}\, dv$$

Interchange R & C