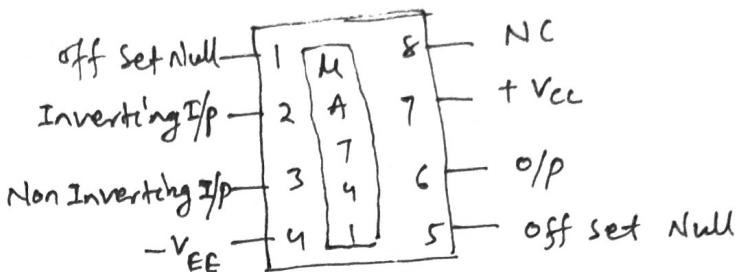
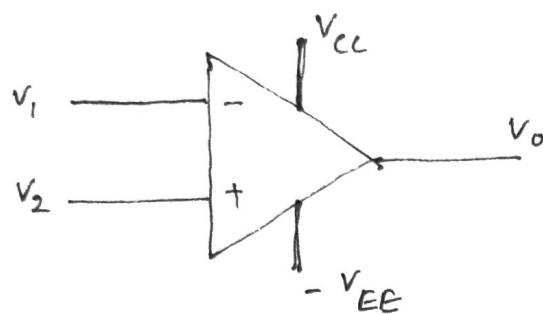


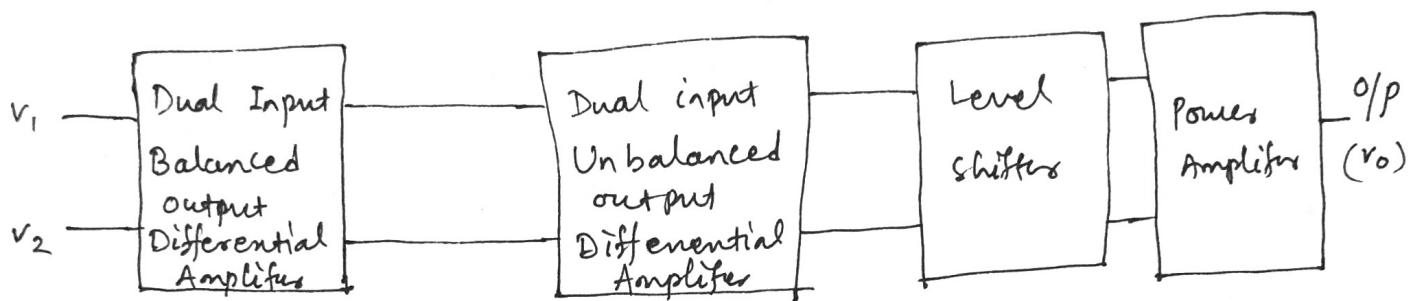
CHAPTER - 8

OPERATIONAL AMPLIFIERS

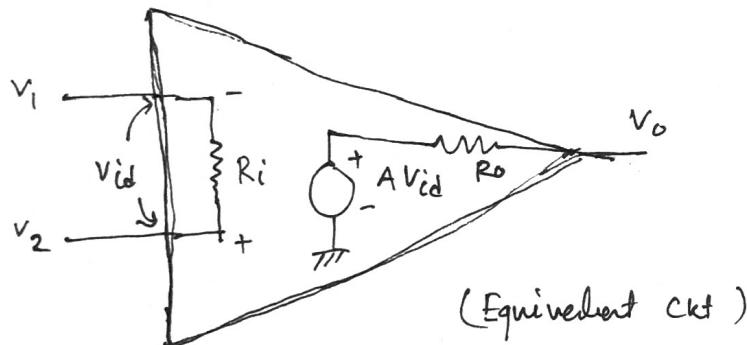
1.



2.



3.

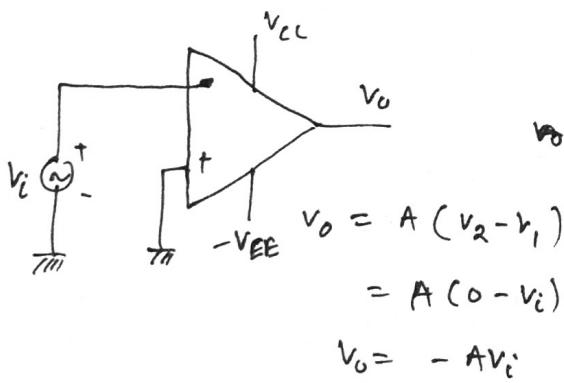


$$v_o = A v_{id}$$

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

<u>Ideal</u>	<u>Practical</u>
$R_i \rightarrow \infty \Omega$	$10^6 \Omega$
$R_o \rightarrow 0 \Omega$	$10^2 \Omega$
$A \rightarrow \infty$	$10^6 \Omega$

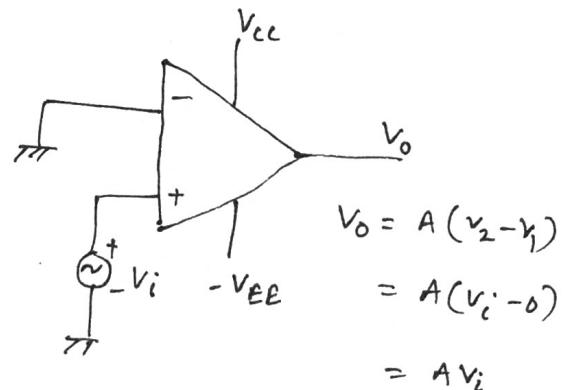
4.



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

$$= A (0 - v_i)$$

$$V_o = -A v_i$$



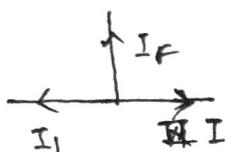
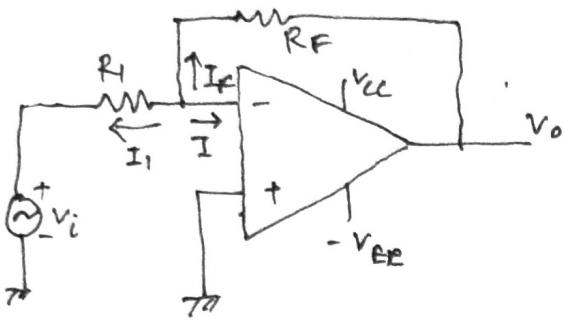
$$V_o = A (v_2 - v_1)$$

$$= A (v_i - 0)$$

$$= A v_i$$

(open loop configuration)

5. Close Loop Inverting Amplifier



Apply NODAL Analysis

$$I_1 + I_f + I = 0$$

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

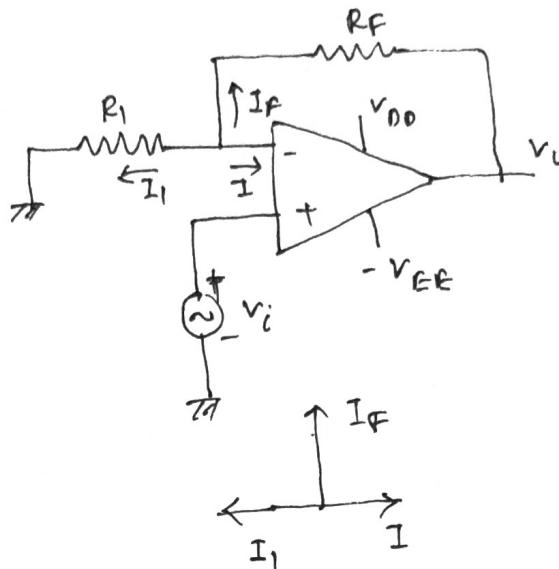
$$\Rightarrow \frac{-v_i}{R_1} + \frac{-v_o}{R_F} = 0$$

$$\Rightarrow \frac{-v_o}{R_F} = \frac{v_i}{R_1}$$

$$\Rightarrow \boxed{v_o = -\frac{R_F}{R_1} v_i}$$

$$\Rightarrow v_o = A \times v_i$$

Close Loop Non Inverting Amplifier



Apply NODAL Analysis

$$I_1 + I_f + I = 0$$

$$\frac{v_i - 0}{R_1} + \frac{v_i - v_o}{R_F} + I = 0$$

$$\Rightarrow \frac{v_i}{R_1} + \frac{v_i - v_o}{R_F} - \frac{v_o}{R_F} + 0 = 0$$

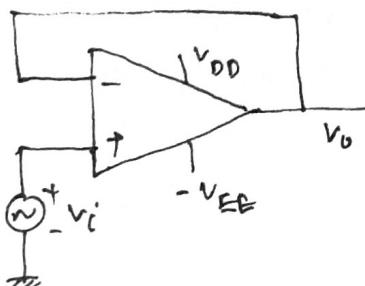
$$\Rightarrow v_i \left(\frac{1}{R_1} + \frac{1}{R_F} \right) = \frac{v_o}{R_F}$$

$$\Rightarrow v_i R_F \left(\frac{1}{R_1} + \frac{1}{R_F} \right) = v_o$$

$$\Rightarrow \boxed{v_o = \left(\frac{R_F}{R_1} + 1 \right) v_i}$$

$$\Rightarrow v_o = A v_i$$

6. Voltage Follower

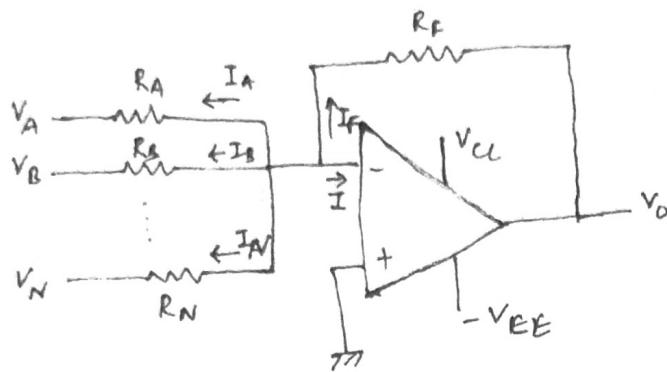


We know

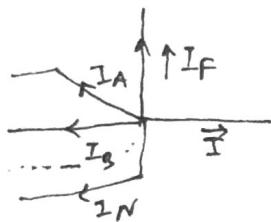
$$\begin{aligned} v_o &= \left(\frac{R_F}{R_1} + 1 \right) v_i \\ &= \left(\frac{0}{R_1} + 1 \right) v_i \end{aligned}$$

$$\boxed{v_o = v_i}$$

7. Adder or Summing Amplifier



Apply NODAL ANALYSIS



$$I_A + I_B + \dots + I_N + I_F + I = 0$$

$$\Rightarrow \frac{0 - V_A}{R_A} + \frac{0 - V_B}{R_B} + \dots + \frac{0 - V_N}{R_N} + \frac{0 - V_O}{R_F} + 0 = 0$$

$$\Rightarrow -\frac{V_A}{R_A} - \frac{V_B}{R_B} - \dots - \frac{V_N}{R_N} + \frac{-V_O}{R_F} = 0$$

$$\begin{aligned} \Rightarrow V_O &= +R_F \left(-\frac{V_A}{R_A} - \frac{V_B}{R_B} - \dots - \frac{V_N}{R_N} \right) \\ &= \cancel{+R_F} - R_F \left(\frac{V_A}{R_A} + \frac{V_B}{R_B} + \dots + \frac{V_N}{R_N} \right) \end{aligned}$$

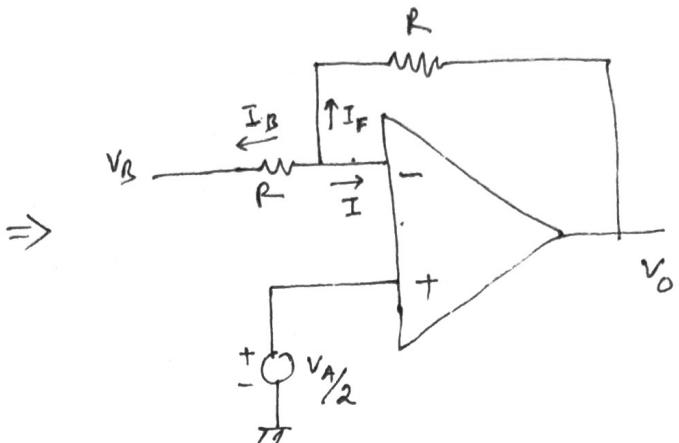
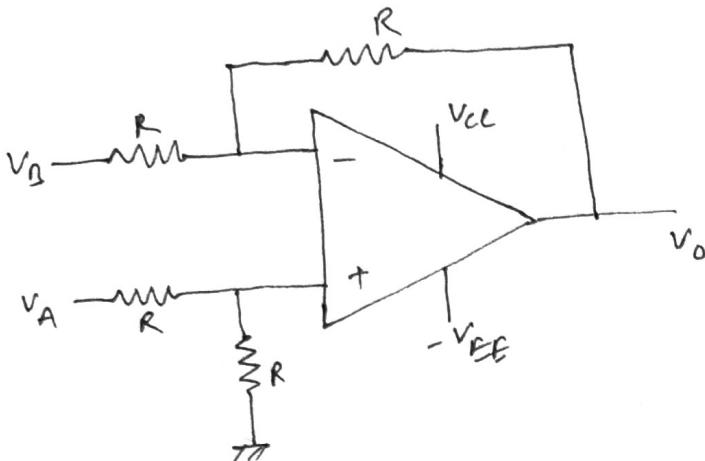
$$\text{If } R_F = R_A = R_B = \dots = R_N$$

$$V_O = -R_F \left(\frac{V_A}{R_F} + \frac{V_B}{R_F} + \dots + \frac{V_N}{R_F} \right)$$

$$= -\frac{R_F}{R_F} (V_A + V_B + \dots + V_N)$$

$$V_O = -(V_A + V_B + \dots + V_N)$$

8. Subtractor



Apply NODAL Analysis

$$I_B + I_F + I = 0$$

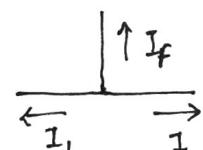
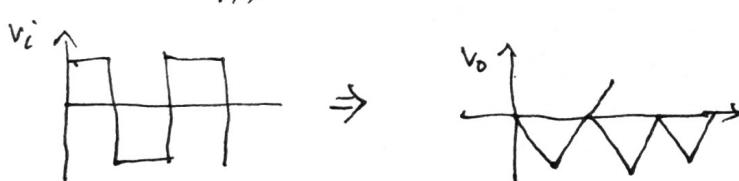
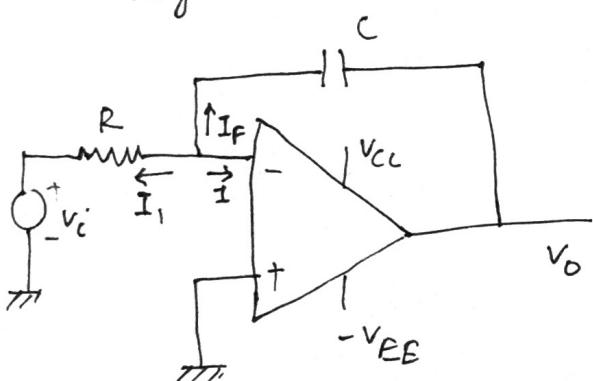
$$\Rightarrow \frac{\frac{V_A}{2} - V_B}{R} + \frac{\frac{V_A}{2} - V_O}{R} + I = 0$$

$$\Rightarrow \frac{\frac{V_A}{2} - V_B + \frac{V_A}{2} - V_O}{R} + 0 = 0$$

$$\Rightarrow \frac{V_A}{2} + \frac{V_A}{2} - V_B - V_O = 0$$

$$\Rightarrow V_A - V_B = V_O \Rightarrow \boxed{V_O = V_A - V_B}$$

9. Integrator



Apply NODAL Analysis

$$I_B + I_F + I = 0$$

$$\frac{0 - V_i}{R} + \frac{d(0 - V_O)}{dt} \times C + 0 = 0$$

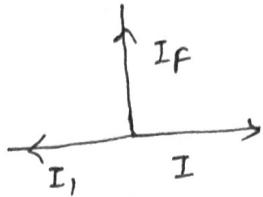
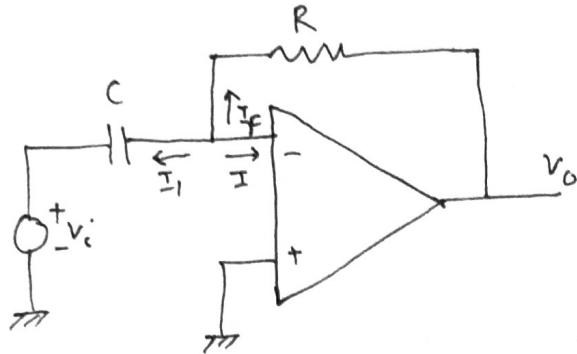
$$-\frac{V_i}{R} + C \frac{d(-V_O)}{dt} = 0$$

$$\Rightarrow -C \frac{dV_O}{dt} = \frac{V_i}{R}$$

$$\Rightarrow dV_O = -\frac{V_i}{RC} dt$$

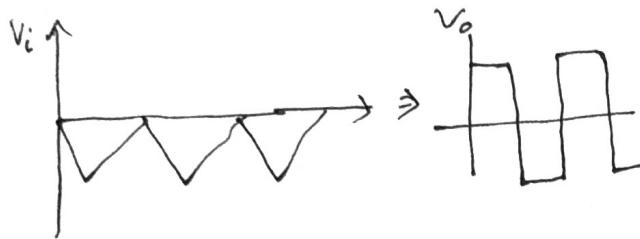
$$\Rightarrow V_O = -\frac{1}{RC} \int V_i dt$$

10. Differentiators :-



Apply NODAL ANALYSIS

$$I_1 + I_f + I = 0$$



$$C \times \frac{d(0 - V_i)}{dt} + \frac{0 - V_o}{R} + 0 = 0$$

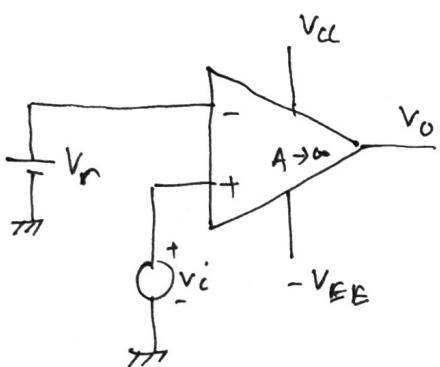
$$\Rightarrow -C \frac{dV_i}{dt} - \frac{V_o}{R} = 0$$

$$\Rightarrow -\frac{V_o}{R} = C \frac{dV_i}{dt}$$

$$\Rightarrow V_o = -RC \frac{dV_i}{dt}$$

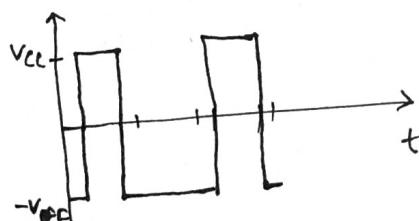
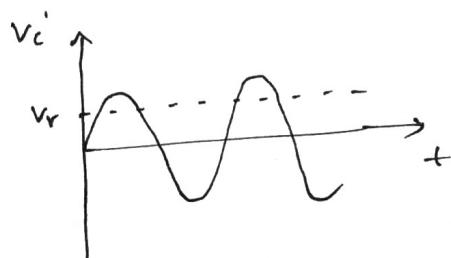
11. Comparator

→ Non-Inverting Comparator with the reference voltage



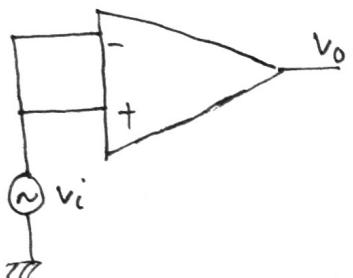
we know

$$V_o = A(V_i - V_r)$$

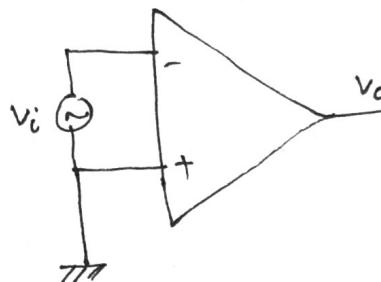


12. CMRR (Common Mode Rejection Ratio) :-

$$CMRR = \frac{A_d}{A_c} \rightarrow \begin{array}{l} \text{Differential gain} \\ \text{Common mode gain} \end{array}$$



common Mode configuration



Differential Mode

$$A_c = \frac{V_o}{V_i}$$

$$A_d = \frac{V_o}{-V_i}$$

NOTE

→ For Ideal OPAMP $CMRR \rightarrow \infty$

→ CMRR is ability of OPAMP to reject common mode signal.

13. slew Rate :-

$$SR = \left[\frac{dV_o}{dt} \right]_{\max}$$

$$\text{Ex} \rightarrow V_o = V_m \sin \omega t$$

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

$$SR = \left. \frac{dV_o}{dt} \right|_{\max} = V_m \omega = 2\pi f V_m$$

NOTE

→ For Ideal OPAMP $S.R \rightarrow \infty$, MA741 : $SR = 0.5 \text{ V}/\mu\text{sec}$

→ Slew Rate of OPAMP is Maximum rate of change of Output Voltage