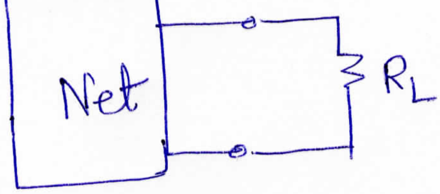
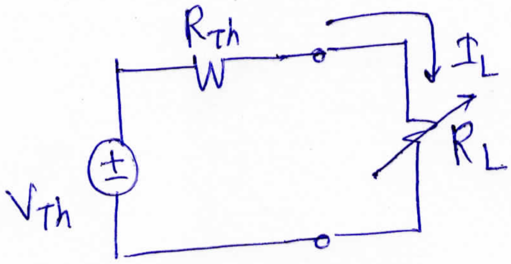
Maximum Power Transfer Theorem;



$\Rightarrow$



$$\Rightarrow I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

Power delivered to Load

$R_L = ?$

$$P_L = I_L^2 R_L$$

$$= \frac{V_{Th}^2 \, R_L}{(R_{Th} + R_L)^2}$$

$$\Rightarrow \frac{\partial P_L}{\partial R_L} = V_{Th}^2 \left[\frac{(R_{Th}+R_L)^2 \times 1 - R_L \times 2(R_{Th}+R_L) \times 1}{(R_{Th}+R_L)^4} \right]$$

$$= \frac{V_{Th}^2 \times (R_{Th}+R_L)\,[R_{Th}+R_L-2R_L]}{(R_{Th}+R_L)^4}$$

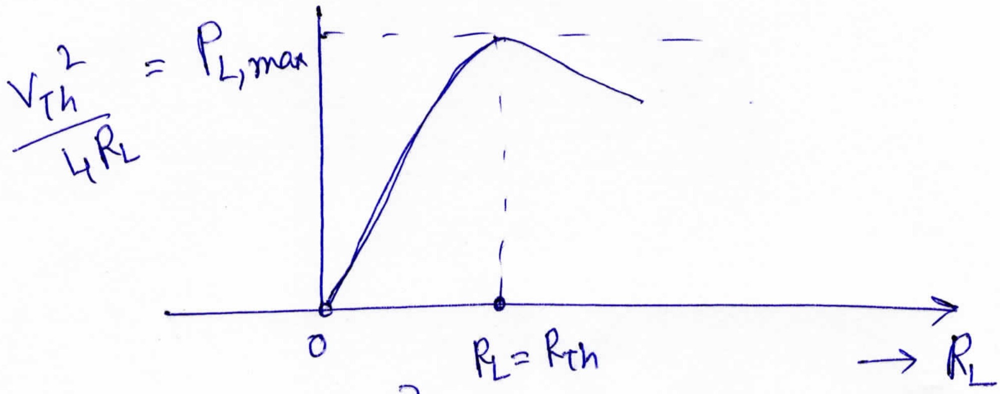
$$= \frac{V_{Th}^2 \,(R_{Th}-R_L)}{(R_{Th}+R_L)^3}$$

For maximum Power to the load

$$\frac{\partial P_L}{\partial R_L} = 0$$

$$\Rightarrow \quad R_{Th} - R_L = 0$$

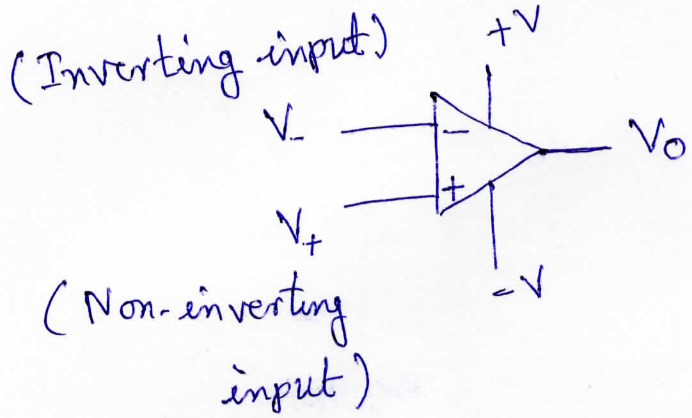
$$\Rightarrow \quad \boxed{R_L = R_{Th}}$$



$$P_L\Big|_{max} = \frac{V_{Th}^2 R_L}{(R_{Th}+R_L)^2}\Bigg|_{R_L = R_{Th}}$$

$$= \frac{V_{Th}^2}{4R_{Th}}$$

Operational Amplifier (OPAMP)



$-V \leq V_0 \leq +V$

IC → 741

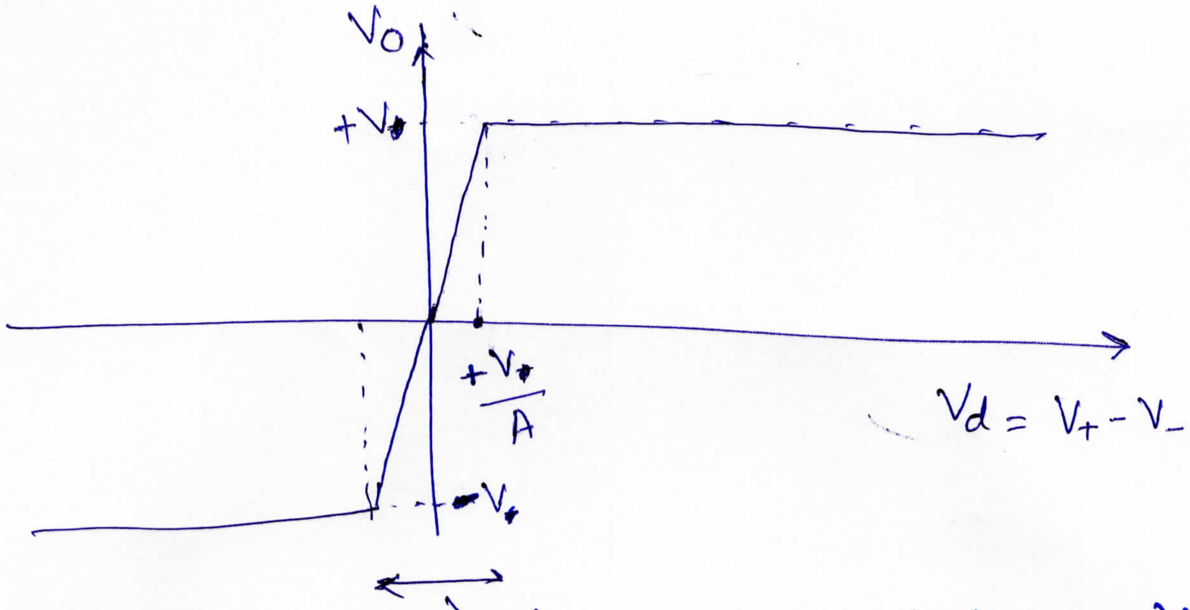
- High gain differential amplifier
- $A \rightarrow$ voltage gain (large)

$A \rightarrow 10^6$

$$\Rightarrow \quad V_0 = A(V_+ - V_-)$$

Applications :-

1. Voltage Amplifier
2. Math. operations → Addition, Sub., Multiplication, Log, Integration, Differentiation.
3. To design oscillator (Square wave)



linear Zone $\longrightarrow -\frac{V}{A} \leq V_d \leq \frac{V}{A}$

- Op-Amp is used with -ve feedback

$\downarrow$

Adv. $\rightarrow$ System Stability $\uparrow$

Disadv. $\rightarrow$ gain $\downarrow$

$$\boxed{-V_o \leq V_o \leq +V_o}$$

$\Rightarrow$ $V_o = A(V_+ - V_-)$

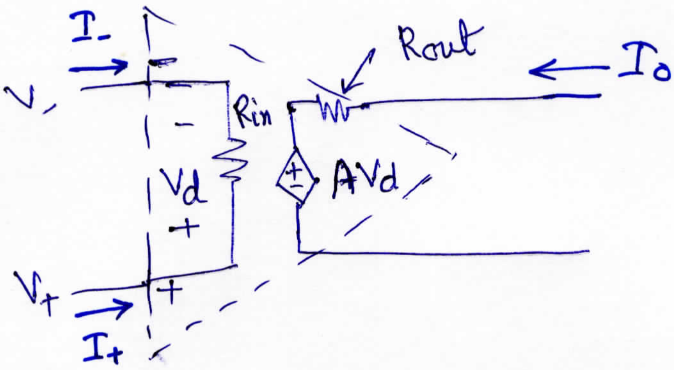
$\downarrow$

finite

$\Rightarrow$ $V_+ - V_- = \frac{V_o}{A} \simeq 0$

$\Rightarrow$ $\boxed{V_+ \simeq V_-}$

practical Op-Amp



$R_{in} \longrightarrow M\Omega \Rightarrow I_+ , I_1 \rightarrow$ (low)

$R_{out} \longrightarrow \Omega \longrightarrow I_o$

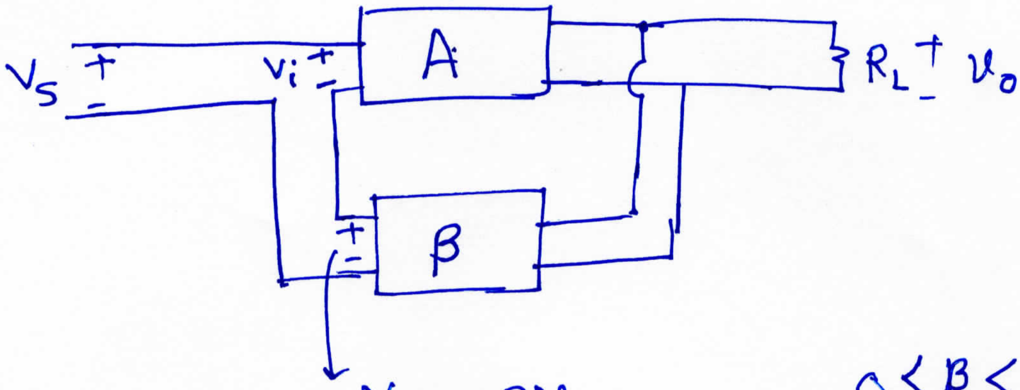
$A \longrightarrow 10^6$

ideal Op-Amp :

$R_{in} \rightarrow \infty$

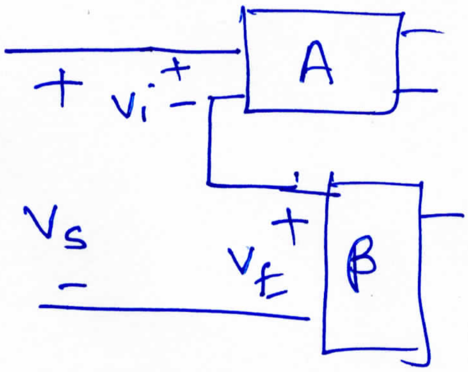
$R_{out} \rightarrow 0$

$A \rightarrow \infty$



$V_f = \beta v_o$

$0 < \beta \leq 1$



$$V_s = V_i + V_f$$

$$\Rightarrow \quad V_i = V_s - V_f$$

$$v_o = A V_i = A(V_s - V_f)$$

$$= A V_s - A V_f$$

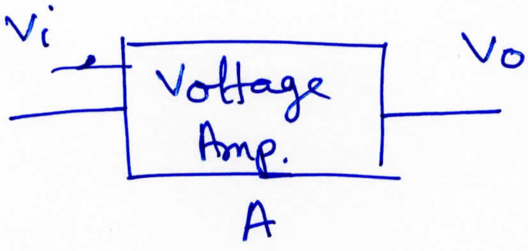
$$= A V_s - A(\beta V_o)$$

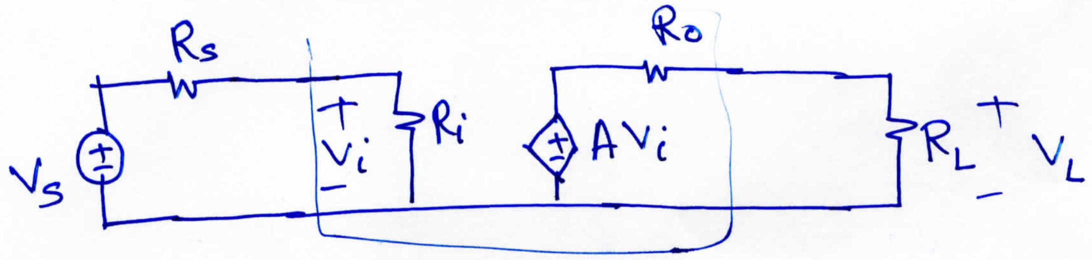
$$\Rightarrow \quad V_o + A\beta V_o = A V_s$$

$$\Rightarrow \quad V_o(1 + A\beta) = A V_s$$

$$\Rightarrow \quad \frac{V_o}{V_s} = \frac{A}{1+A\beta} = A_f < A$$

A → large $\quad A_f \simeq \frac{\cancel{A}}{\cancel{A}\beta} = \frac{1}{\beta}$





$$\frac{V_L}{V_s} = ?$$

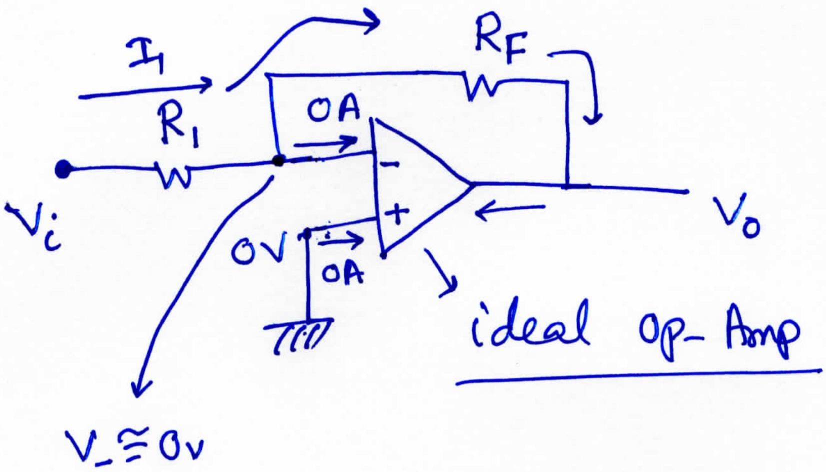
$$V_i = \frac{R_i}{R_s + R_i} \times V_s$$

$$\Rightarrow \quad V_L = \frac{R_L}{R_o + R_L} \times A V_i$$

$$\frac{V_L}{V_s} = \left(\frac{R_L}{R_o + R_L}\right) \times \left(\frac{R_i}{R_s + R_i}\right) \times A \quad < A$$

$$\begin{cases} R_i \gg R_s \\ R_o \ll R_L \end{cases}$$

1) Inverting Amplifier



KCL

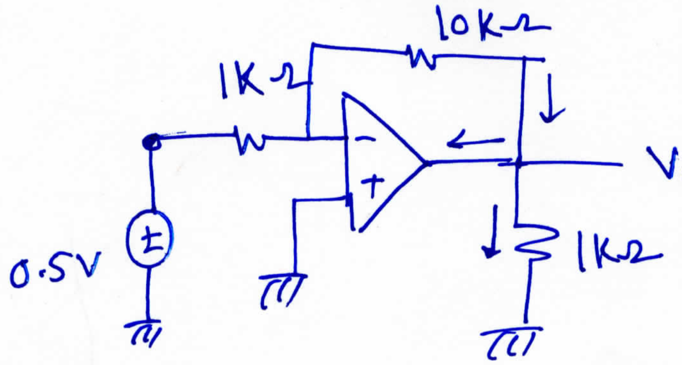
$$\frac{0 - V_i}{R_1} + \frac{0 - V_o}{R_F} = 0$$

$$\Rightarrow -\frac{V_i}{R_1} = \frac{V_o}{R_F}$$

$$\Rightarrow V_o = -\frac{R_F}{R_1} V_i$$

$$\Rightarrow \boxed{\frac{V_o}{V_i} = -\frac{R_F}{R_1}}$$

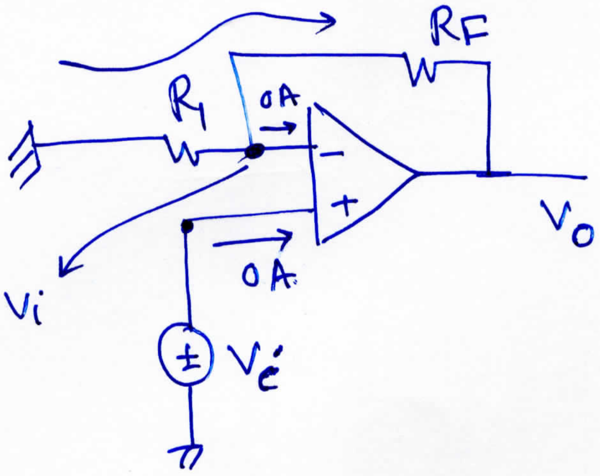
ex



$$V_o = -\frac{10}{1} \times 0.5$$

$$= -5V$$

2) Non-inverting Amp.



KCL

$$\frac{V_i - 0}{R_1} + \frac{V_i - V_0}{R_F} = 0$$

$$\Rightarrow \frac{V_i}{R_1} + \frac{V_i}{R_F} - \frac{V_0}{R_F} = 0$$

$$\Rightarrow \frac{V_0}{R_F} = V_i\left[\frac{1}{R_1} + \frac{1}{R_F}\right]$$

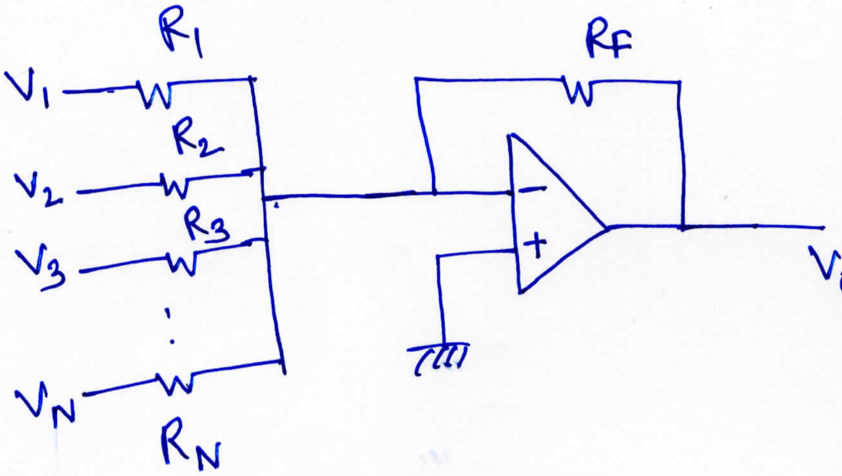
$$V_0 = V_i\left[\frac{1}{R_1} + \frac{1}{R_F}\right] \times R_F$$

$$= \left(1 + \frac{R_F}{R_1}\right) V_i$$

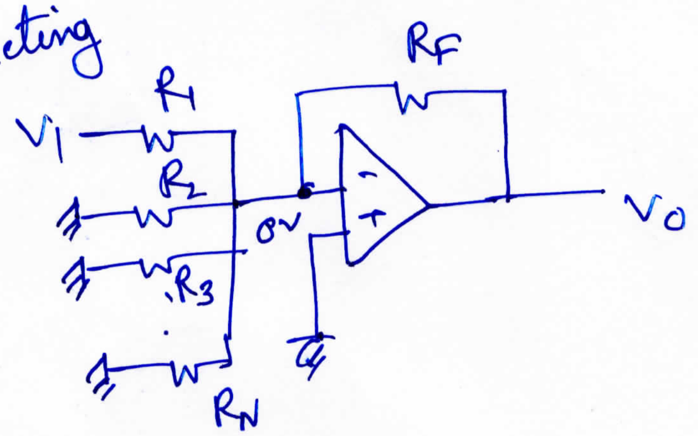
$$\Rightarrow \boxed{\frac{V_0}{V_i} = 1 + \frac{R_F}{R_1}}$$

3) Summing Amplifier or Adder

a) Inverting type:



V_1 is acting



$$V_{o,1} = -\frac{R_F}{R_1} V_1$$

$$\vdots$$

$$V_{o,N} = -\frac{R_F}{R_N} V_N$$

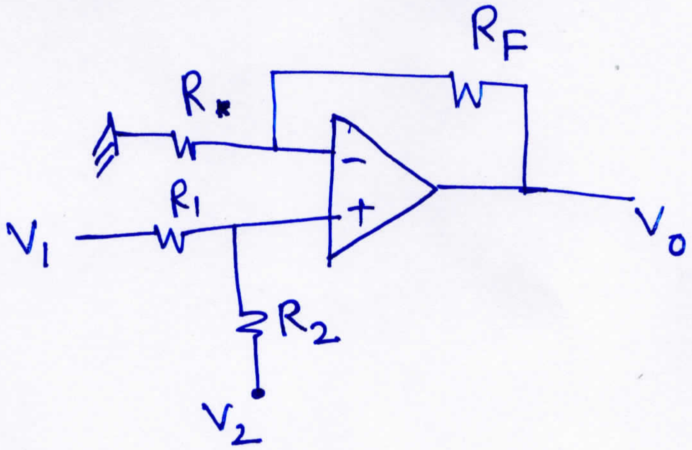
$$V_o = -\frac{R_F}{R_1} V_1 - \frac{R_F}{R_2} V_2 - \frac{R_F}{R_3} V_3 - \cdots - \frac{R_F}{R_N} V_N$$

$$= (-R_F) \times \sum_{i=1}^{N} \frac{V_i}{R_i}$$

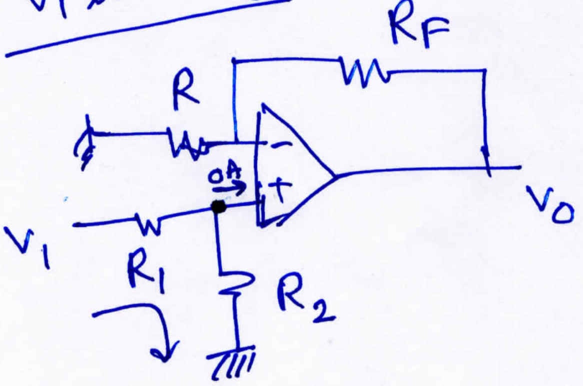
when $R_1 = R_2 = R_3 = \cdots = R_N = R$

$$\Rightarrow V_o = \left(-\frac{R_F}{R}\right) \times \sum_{i=1}^{N} V_i$$

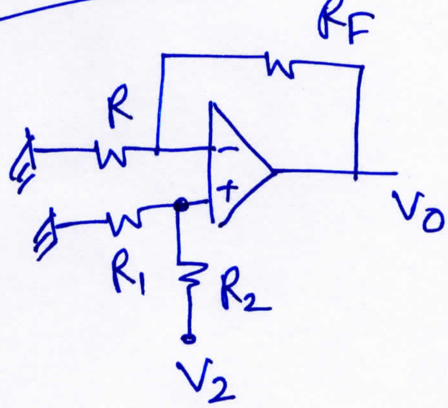
b) Non-inverting type



V_1 is acting

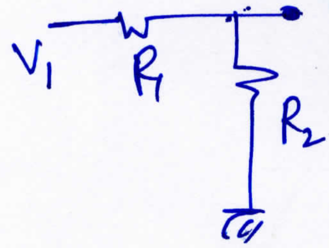


V_2 is acting



$$V_{o,1} = \left(1 + \frac{R_F}{R}\right) \times \left(\frac{R_2}{R_1 + R_2}\right) \times V_1$$

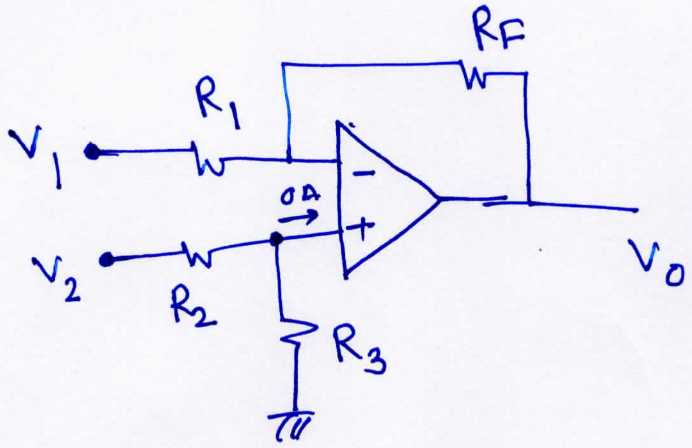
$$V_{o,2} = \left(1 + \frac{R_F}{R}\right) \times \left(\frac{R_1}{R_1 + R_2}\right) \times V_2$$



$$\left(\frac{R_2}{R_1 + R_2}\right) \times V_1$$

$$\Rightarrow \quad V_o = \frac{\left(1 + \frac{R_F}{R}\right)}{(R_1 + R_2)} \times \left[R_2 V_1 + R_1 V_2 \right]$$

4) Difference Amplifier



$$V_0 = K(V_2 - V_1)$$

$$V_0 = \left(-\frac{R_F}{R_1}\right) \times V_1 + \left(1 + \frac{R_F}{R_1}\right) \times \left(\frac{R_3}{R_2 + R_3}\right) \times V_2$$

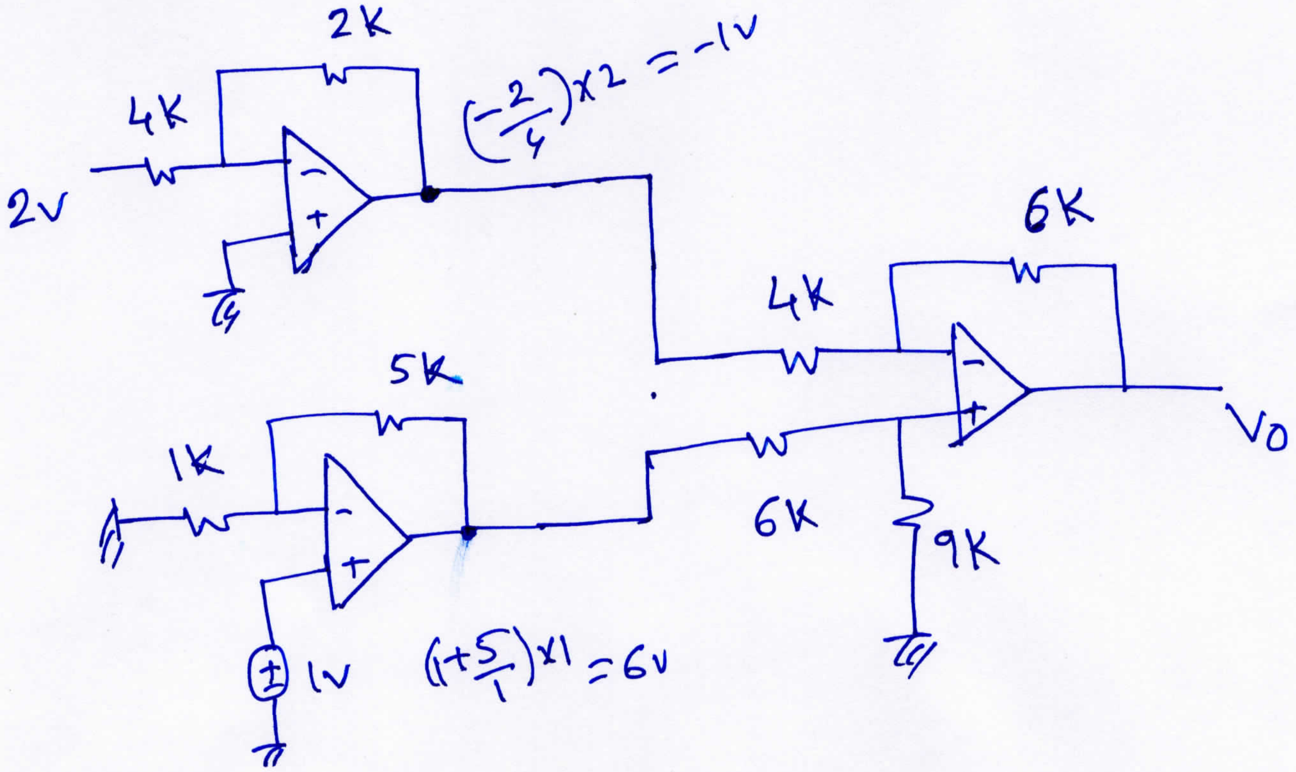
$$= -\frac{R_F}{R_1} \times V_1 + \frac{\frac{R_F}{R_1} \times \left(1 + \frac{R_1}{R_F}\right)}{\left(1 + \frac{R_2}{R_3}\right)} \times V_2$$

when $\frac{R_1}{R_F} = \frac{R_2}{R_3}$

$$\Rightarrow V_0 = -\frac{R_F}{R_1}(V_1) + \frac{R_F}{R_1} \times V_2$$

$$\boxed{V_0 = \frac{R_F}{R_1}(V_2 - V_1)}$$

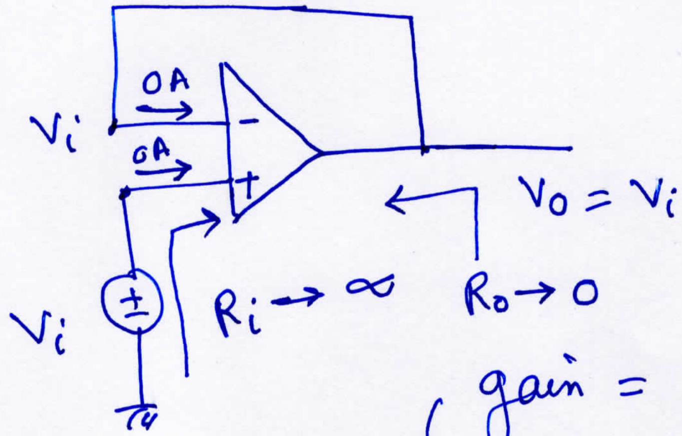
ex



$$V_o = \frac{\cancel{6}^{\,3}}{\cancel{4}_{\,2}} \times (6 - (-1))$$

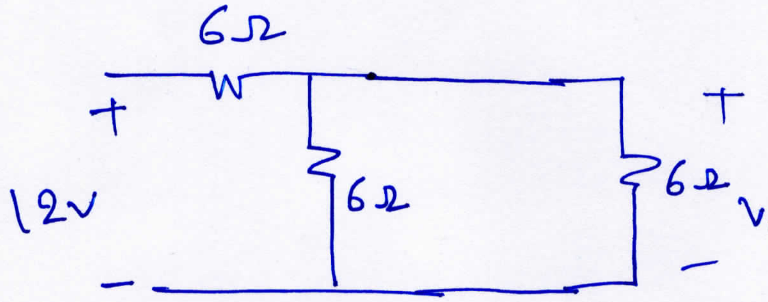
$$= \frac{21}{2} = \underline{\underline{10.5\,V}}$$

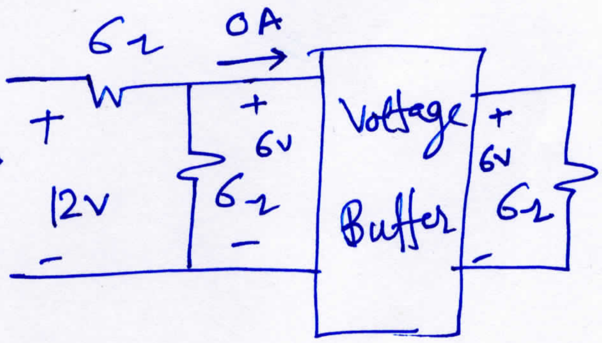
5) Voltage follower or Voltage Buffer :-



$$\begin{cases} \text{gain} = \dfrac{V_o}{V_i} = 1 \\ R_i = \infty \\ R_o = 0 \end{cases}$$

- It reduces loading effect

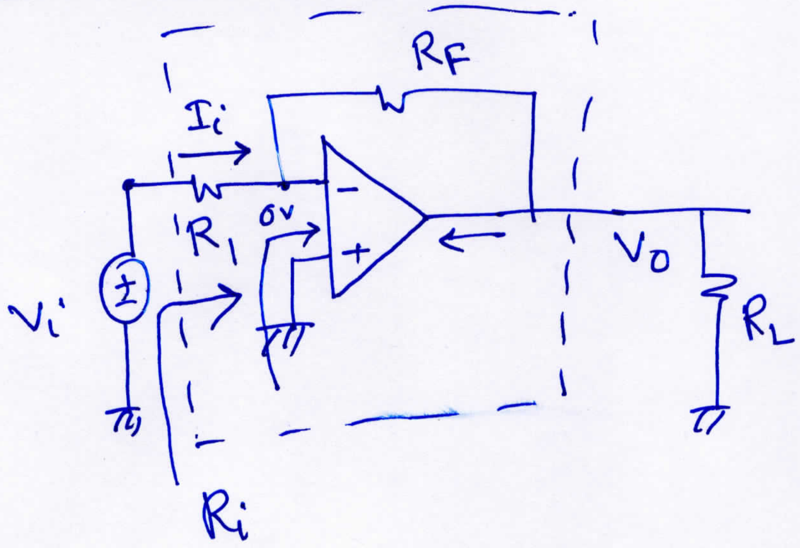




$$V_o = \frac{3}{6+3} \times 12 = 4V$$

Input impedence

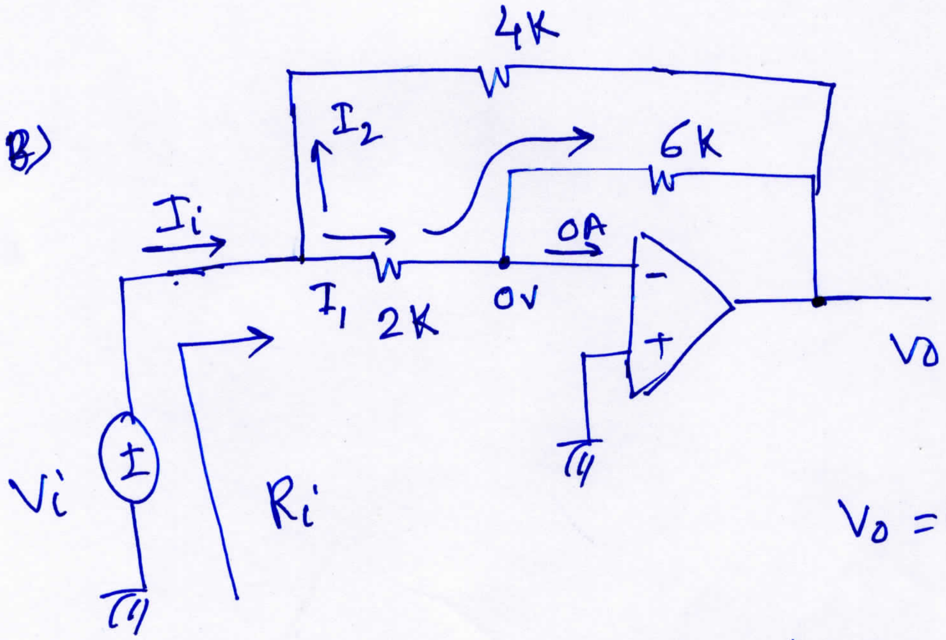
A)



$$I_i = \frac{V_i - 0}{R_1} = \frac{V_i}{R_1}$$

$$\Rightarrow R_i = \frac{V_i}{I_i} = R_1$$

B)



$$V_o = \left(-\frac{6}{2}\right) V_i = -3V_i$$

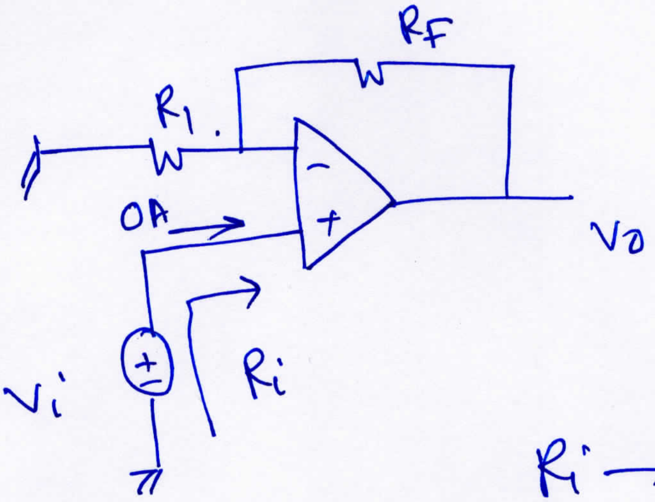
$$I_1 = \frac{V_i}{2 \times 10^3}$$

$$\Rightarrow I_2 = \frac{V_i - V_o}{4 \times 10^3} = \frac{V_i + 3V_i}{4 \times 10^3} = \frac{V_i}{10^3}$$

$$\Rightarrow I_i = I_1 + I_2 = \frac{(1.5) \times V_i}{10^3}$$

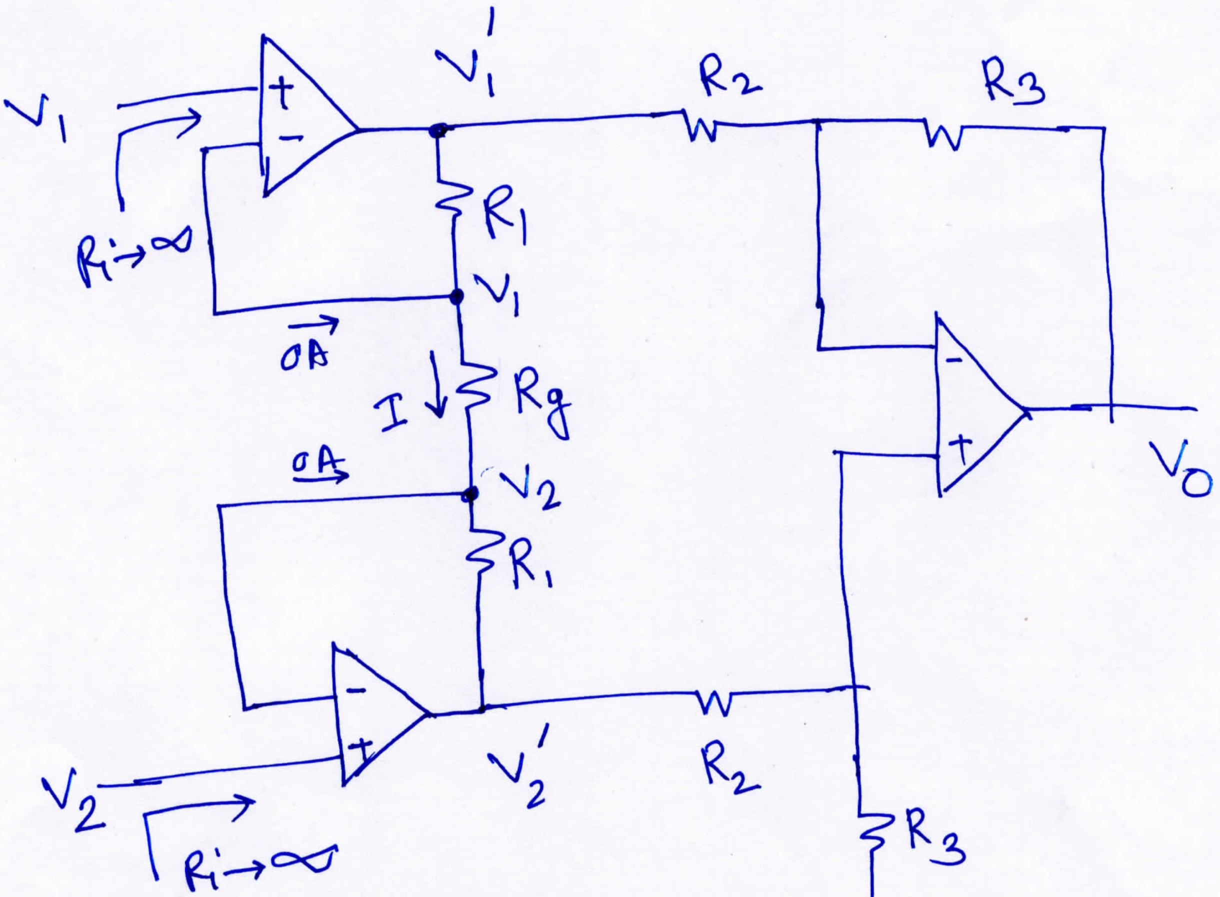
So, $R_i = \frac{V_i}{I_i} = 10^3/1.5 = \frac{2}{3}\, k\Omega$

(3)



$R_i \to \infty$

6) Instrumentation Amplifier



$$I = \frac{V_1 - V_2}{R_g} = \frac{V_1' - V_2'}{2R_1 + R_g}$$

$$\Rightarrow V_1' - V_2' = \left(\frac{2R_1 + R_g}{R_g}\right) \times (V_1 - V_2)$$

Again;

$$V_0 = \frac{R_3}{R_2}\left(V_2' - V_1'\right)$$

$$\boxed{V_0 = \frac{R_3}{R_2} \times \left(1 + \frac{2R_1}{R_g}\right)\left(V_2 - V_1\right)}$$