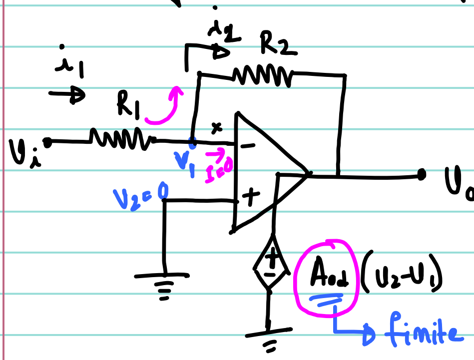
Lec-26

Inverting Amplifier having finite A_{od}



Assuming, input resistance is infinite

$$i_1 = \frac{V_i - V_1}{R_1}$$

$$i_2 = \frac{V_1 - V_o}{R_2}$$

$$V_o = A_{od}(\cancel{V_2}^{\,0} - V_1)$$

$$V_1 = \frac{-V_o}{A_{od}}$$

$$i_1 = i_2$$

$$\frac{V_i - V_1}{R_1} = \frac{V_1 - V_o}{R_2}$$

$$\therefore \frac{V_i + V_o/A_d}{R_1} = \frac{-\frac{V_o}{A_{od}} - V_o}{R_2}$$

$$\frac{V_o}{V_i} = \frac{-R_2}{R_1\left[1 + \left(1 + \frac{R_2}{R_1}\right)\frac{1}{A_{od}}\right]} = A_v$$

fixed for this case
$R_2 = 10R_1$

$A_{od} = 100$, $\frac{V_o}{V_i} = -9.001$

$A_{od} = 1000$, $\frac{V_o}{V_i} = -9.89$

$A_{od} = 10{,}000$, $\frac{V_o}{V_i} = -9.99$

Ideal op-Amp

$A_{od} \to \infty$

$$\frac{V_o}{V_i} = -\frac{R_2}{R_1}$$

$\boxed{R_2 = 10R_1}$

$$\frac{V_o}{V_i} = -10$$

$$\text{Gain} = -\frac{R_2}{R_1}$$

gain = -100

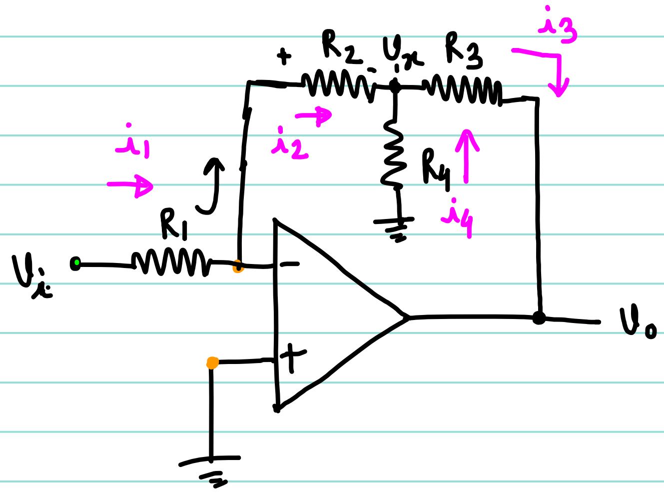
; $\boxed{R_1 = 50k\Omega}$

$R_2 = 5000k\Omega$

$R_2 = 5M\Omega$

op-Amp is Ideal
input resistance → ∞
$A_{od} \to \infty$.

Inverting Amplifier with T-Network



$$\frac{v_x - v_o}{R_3} = i_3 = i_2 + i_4$$

$$i_1 = \frac{v_i - 0}{R_1} = \frac{v_i}{R_1} = i_2 \quad ; \quad v_x = 0 - i_2 R_2 = -\frac{v_i}{R_1} \cdot R_2 = -v_i \times \frac{R_2}{R_1}$$

$$i_4 = \frac{0 - v_x}{R_4} = -\frac{v_x}{R_4}$$

$$i_2 + i_4 = i_3$$

$$-\frac{v_x}{R_2} - \frac{v_x}{R_4} = \frac{v_x - v_o}{R_3}$$

$$-\frac{v_x}{R_2} - \frac{v_x}{R_4} - \frac{v_x}{R_3} = -\frac{v_o}{R_3}$$

$$v_o = R_3 \times \left(-\frac{R_2}{R_1} v_i\right)\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)$$

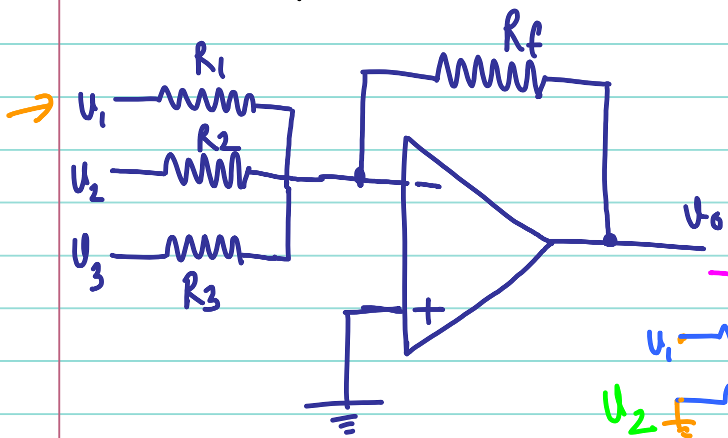
gain → $$\frac{v_o}{v_i} = -\frac{R_2}{R_1}\left(1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}\right)$$

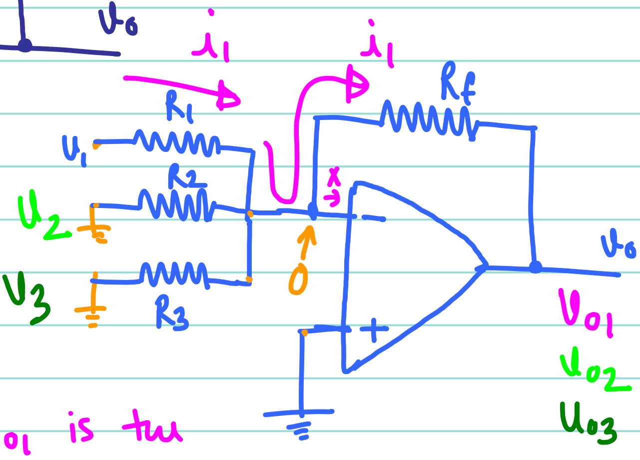
$\boxed{-100}$

$R_1 = 50\ k\Omega$
$R_2 = R_3 = 390\ k\Omega$
$R_4 = 33\ k\Omega$

$$\frac{v_o}{v_i} = -107.78$$

Summing Amplifier:





$V_{01} = -i_1 R_f$

$\rightarrow V_{01} = -\frac{R_f}{R_1} \cdot V_1$; V_{01} is the o/p for i/p V_1

$V_{03} \longrightarrow V_3$ $\qquad$ $V_{02} \rightarrow V_2$

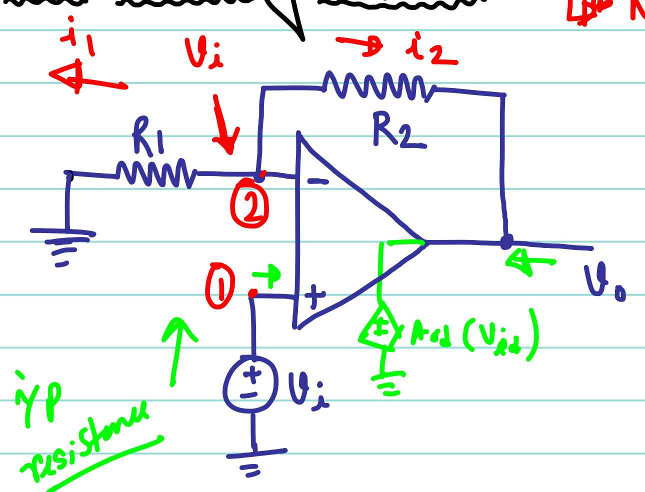
$\rightarrow V_{02} = -\frac{R_f}{R_2} V_2$ $\qquad$ $\rightarrow V_{03} = -\frac{R_f}{R_3} \cdot V_3$.

$$\text{Total o/p} = V_{01} + V_{02} + V_{03} = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right)$$

$\underline{R_1 = R_2 = R_3}$, $\quad \text{Total o/p} = -\frac{R_f}{R_1}\left(\underline{V_1 + V_2 + V_3}\right)$

Non-Inverting Amplifier:

↳ Node ① and ② are virtually shorted.



$$i_1 = \frac{V_i}{R_1} \quad ; \quad i_2 = \frac{V_i - V_o}{R_2}$$

$$i_1 = -i_2 \,, \quad \frac{V_i}{R_1} = \frac{V_o - V_i}{R_2} \;;$$

$$V_i R_2 = V_o R_1 - V_i R_1$$

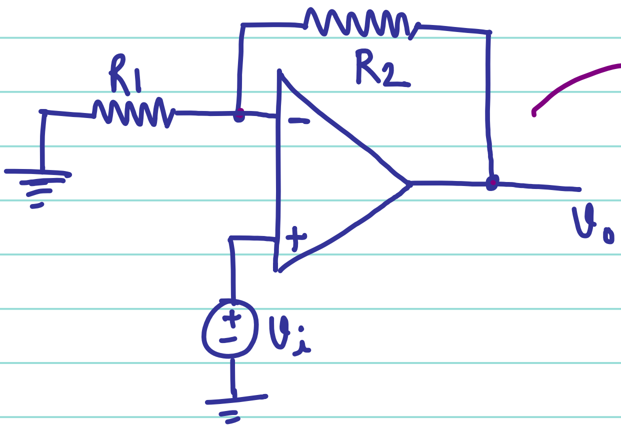
$$\text{gain} = \frac{V_o}{V_i} = \frac{R_2 + R_1}{R_1} = \left(1 + \frac{R_2}{R_1}\right) \quad \text{Always} \geq 1$$

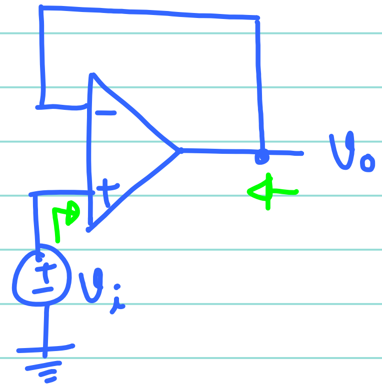
positive

i/p resistance → ∞

o/p " → 0.

Voltage Follower / Buffer :





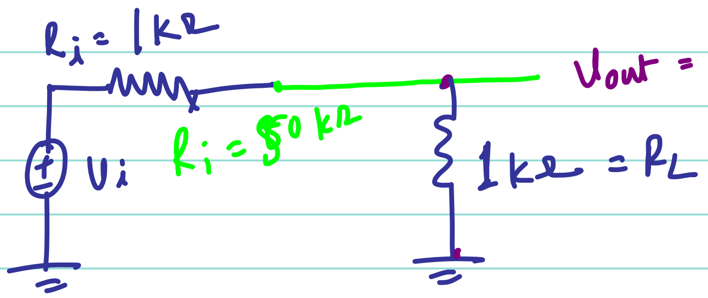
gain = $1 + \frac{R_2}{(R_1)}$

- i/p resistance → ∞
- o/p " = 0

; if, $R_2 = 0$, $R_1 \to$ any value

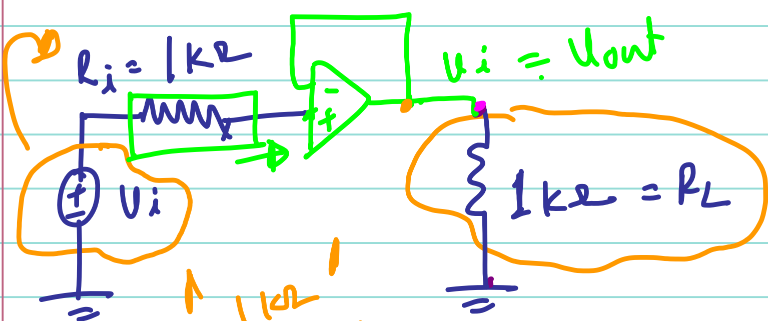
Say, $R_1 \to \infty$, if, R_2 is finite

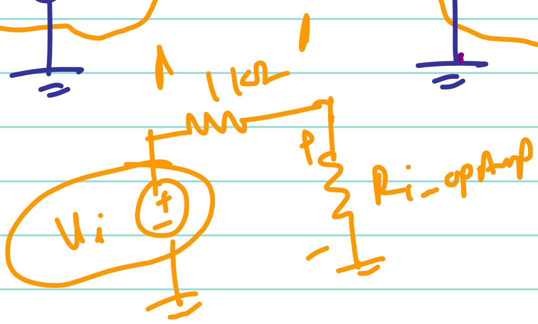
→ gain = 1 ; $R_2 = 0$



$V_{out} = \frac{1}{1+1} \cdot V_i = \frac{V_i}{2}$

$V_{out} = \frac{1}{51} V_i$





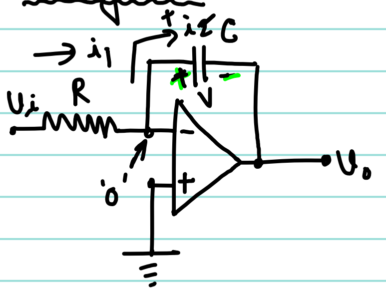
Loading effect

$Q = CV$

$\frac{dQ}{dt} = C\frac{dV}{dt}$

$I = C\frac{dV}{dt}$

Integrator: V_c



$i_1 = \frac{V_i}{R}$ $\qquad V_0 = -V$

$i_2 = C\frac{dV}{dt} = -C\frac{dV_0}{dt}$

$i_2 = i_1$

$\frac{V_i}{R} = -C\frac{dV_0}{dt}$

'C' was discharged initially

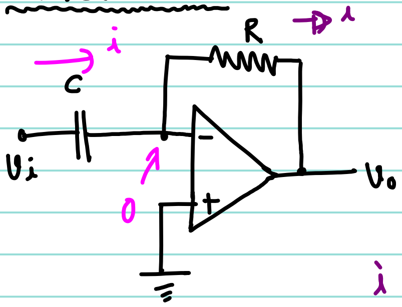
$\boxed{V_0 = -\frac{1}{RC}\int V_i\,dt}$

if, capacitor was charged initially by a voltage V_c then,

$V_0 = -V_c - \frac{1}{RC}\int V_i\,dt.$

sign depends on the polarity

Differentiator:

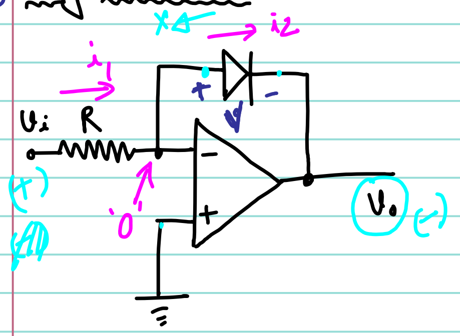


$i = C\frac{dV_i}{dt}$

$V_0 = 0 - iR = -RC\frac{dV_i}{dt}$

$\rightarrow V_0 = -RC\frac{dV_i}{dt}$

Log Ampifier:



$$i_1 = \frac{V_i}{R}$$

$$i_2 = I_s\left[\exp\left(\frac{V}{V_T}\right) - 1\right]$$

$$\left[V_0 = -V\right]$$

$$i_2 = I_s\left[\exp\left(-\frac{V_0}{V_T}\right) - 1\right]$$

$$i_1 = i_2$$

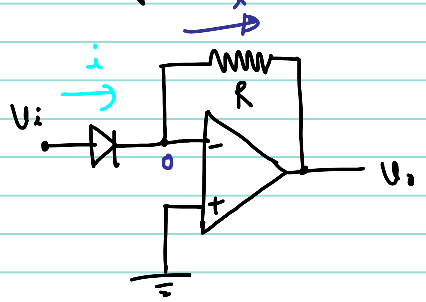
$$\frac{V_i}{R} = I_s\left[\exp\left(\frac{-V_0}{V_T}\right) - 1\right]$$

$|V_0| > 3V_T$
neglect '-1' term

$$\frac{V_i}{R} = I_s \exp\left(-\frac{V_0}{V_T}\right)$$

$$V_0 = -V_T \ln\left(\frac{V_i}{I_s R}\right)$$

Anti-log Amplifier:



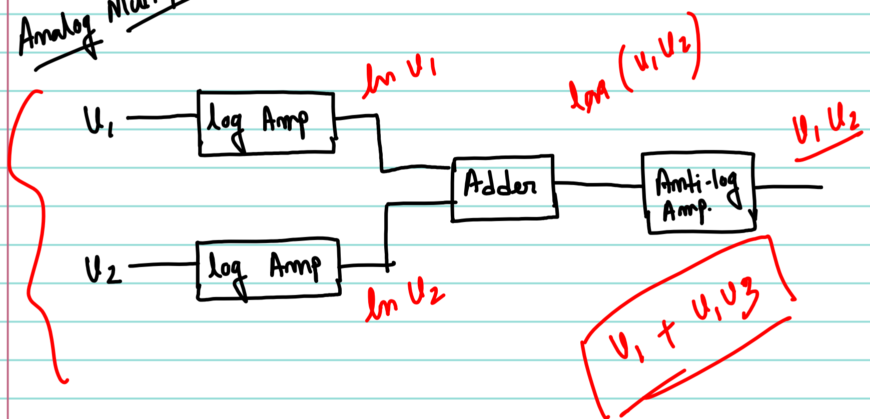
$$i = I_s \exp\left(\frac{V_i}{V_T}\right)$$

$$V_0 = -iR$$

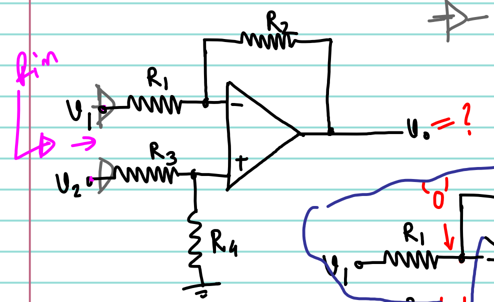
$$V_0 = -I_s R \exp\left(\frac{V_i}{V_T}\right)$$

$$V_0 \propto \exp\left(\frac{V_i}{V_T}\right)$$

Analog Multipliers:

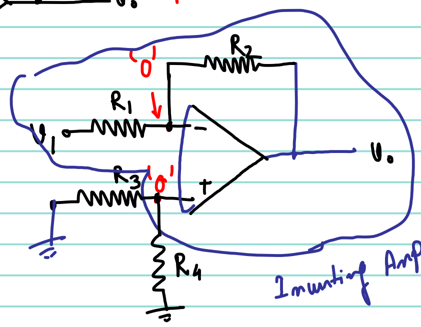


Difference Amplifier:



Superposition

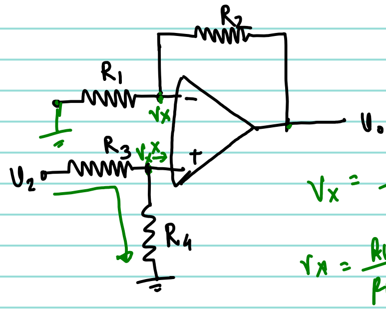
when, V_1 is active



Inverting Amp.

$$V_{o_1} = -\frac{R_2}{R_1} V_1$$

when, V_2 is active



$$V_x = \frac{R_4}{R_3+R_4} \cdot V_2$$

$$V_x = \frac{R_1}{R_1+R_2} \cdot V_o$$

$$\Rightarrow V_{o_2} = \left(1+\frac{R_2}{R_1}\right) V_x = \left(1+\frac{R_2}{R_1}\right) \frac{R_4}{R_3+R_4} V_2$$

Total o/p $V_o = V_{o1} + V_{o2}$

$$V_o = V_2 \left(\frac{R_4}{R_3+R_4}\right)\left(\frac{R_1+R_2}{R_1}\right) - \frac{R_2}{R_1} V_1$$

$$V_o = V_2\left(\frac{R_4}{R_3+R_4}\right) \cdot \left(\frac{R_3+R_4}{R_3}\right) - \frac{R_2}{R_1} V_1$$

$$V_2 \cdot \frac{R_4}{R_3} - \frac{R_2}{R_1} V_1$$

$$\frac{R_2}{R_1} V_2 - \frac{R_2}{R_1} V_1$$

$$V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

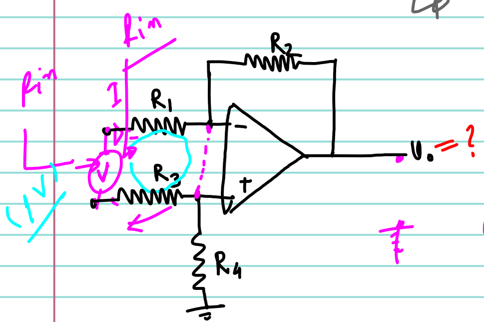
$$\Rightarrow \boxed{\frac{R_4}{R_3} = \frac{R_2}{R_1}} \; ; \; V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

$$1 + \frac{R_4}{R_3} = \frac{R_2}{R_1} + 1 \qquad \frac{R_3+R_4}{R_3} = \left(\frac{R_2+R_1}{R_1}\right)$$

$$\Rightarrow V = I R_1 + I R_3$$

$$\frac{V}{I} = R_1 + R_3$$

input resistance



$$= (R_1 + R_3)$$