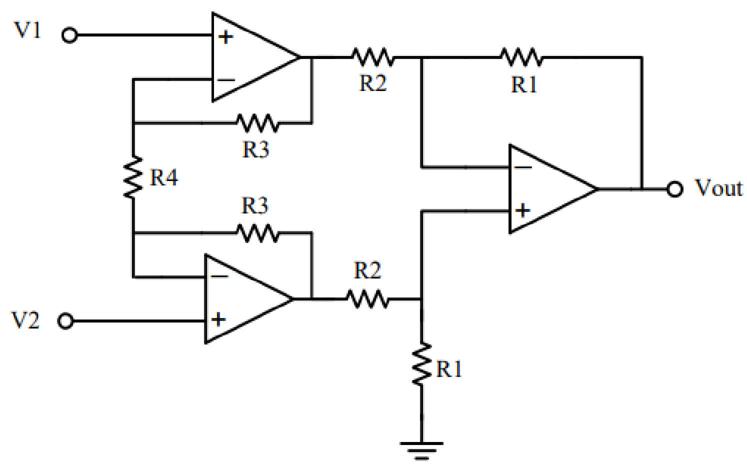
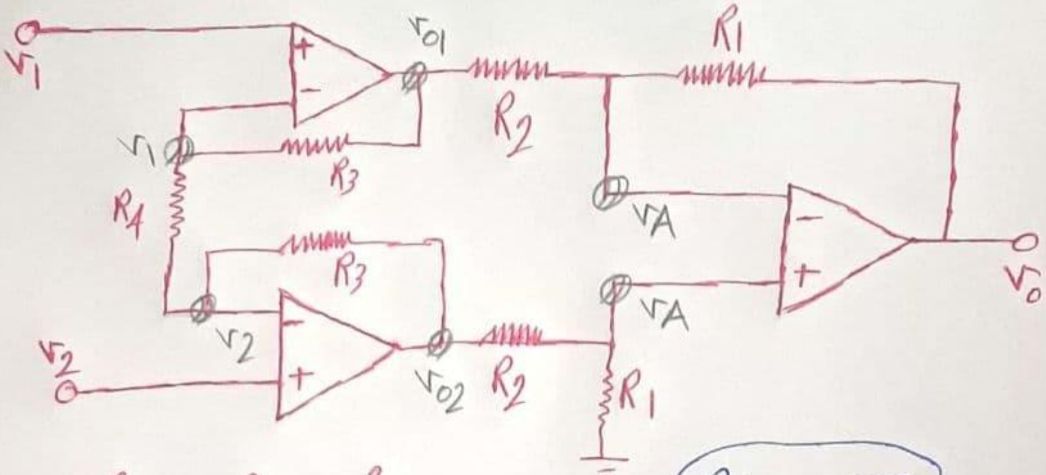
1- The configuration shown below is known as the "Instrumentation Amplifier" or "IA". Determine the output voltage in terms of the input voltages. How much is the input resistance seen from the input terminals (V1 and V2). Assume ideal op-amps.





$$\frac{v_o}{v_1 - v_2} = ? \qquad R_{in} = ?$$

$$R_{in} = \infty$$

$$KCL @ v_1 : \frac{v_1 - v_2}{R_4} + \frac{v_1 - v_{01}}{R_3} = 0$$

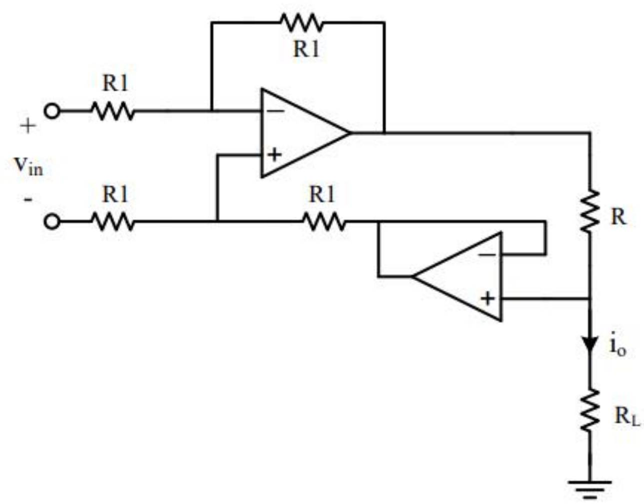
$$KCL @ v_2 : \frac{v_2 - v_1}{R_4} + \frac{v_2 - v_{02}}{R_3} = 0$$

$$KCL @ v_{A-} : \frac{v_A - v_{01}}{R_2} + \frac{v_A - v_o}{R_1} = 0$$

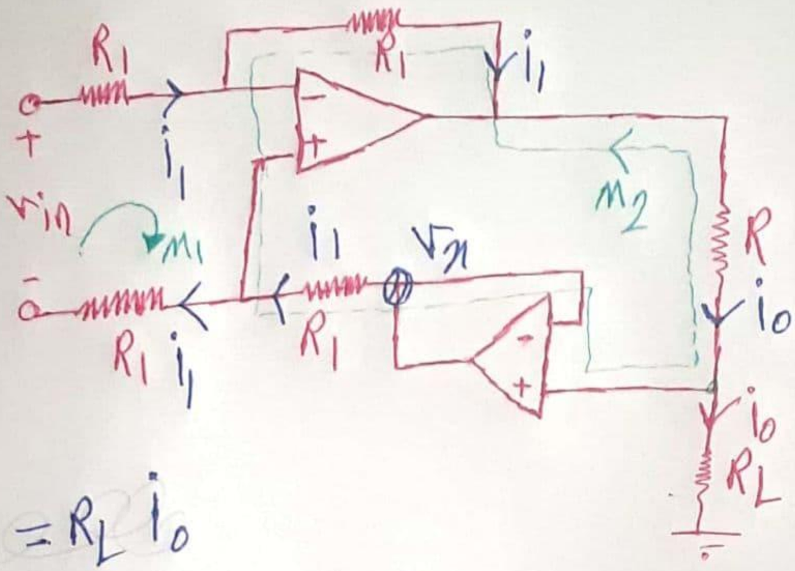
$$v_{A+} : v_A = \frac{R_1 v_{02}}{R_1 + R_2}$$

$$\longrightarrow \frac{v_o}{v_1 - v_2} = -\left[\frac{R_1 R_3 \left(\frac{1}{R_3} + \frac{1}{R_4}\right)}{R_2} + \frac{R_1 R_3}{R_2 R_4}\right]$$

2- Calculate the output current (i_o) in the following circuit. The op-amps are supposed to be ideal one.



$i_o = ?$



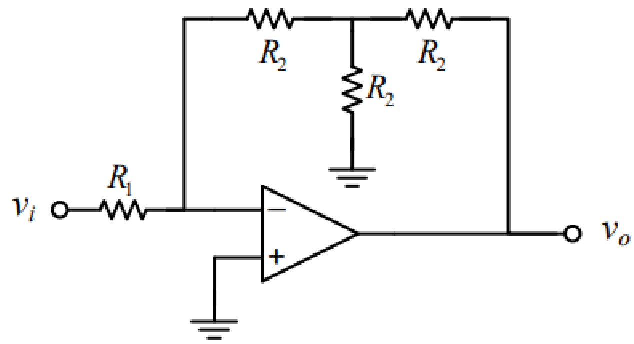
$v_x = R_L i_o$

$$KVL\ @m_1:\ i_1 = -\frac{v_{in}}{2R_1}$$

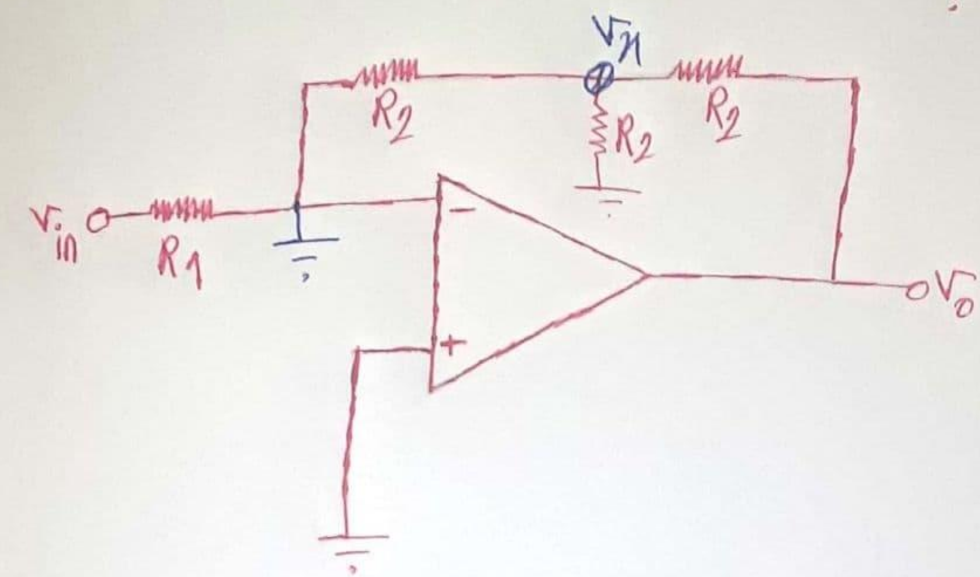
$$KVL\ @m_2:\ -R i_o - R_1 i_1 - R_1 i_1 = 0 \rightarrow i_o = -\frac{2R_1 i_1}{R}$$

$$i_o = -\frac{v_{in}}{R}$$

3- Determine the voltage gain $\frac{v_o}{v_i}$ in the following circuit. Assume that the op-amp is ideal.



? = Av | 3



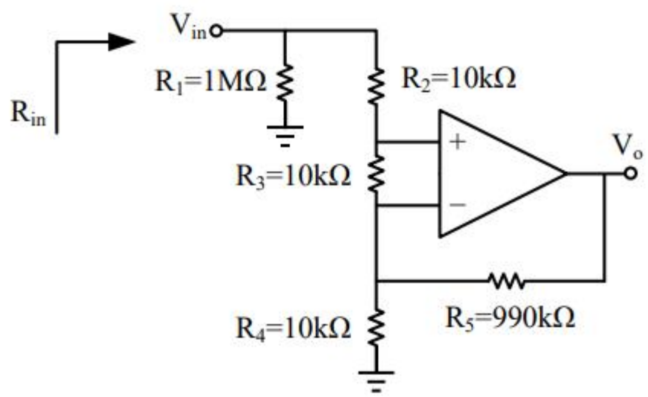
$$\text{kcl @ } \text{ground}: \quad \frac{v_{in}}{R_1} = \frac{-v_x}{R_2} \longrightarrow v_x = \frac{-R_2}{R_1} v_{in}$$

$$\text{kcl @ } v_x: \quad \frac{v_x}{R_2} + \frac{v_x}{R_2} = \frac{v_o - v_x}{R_2}$$

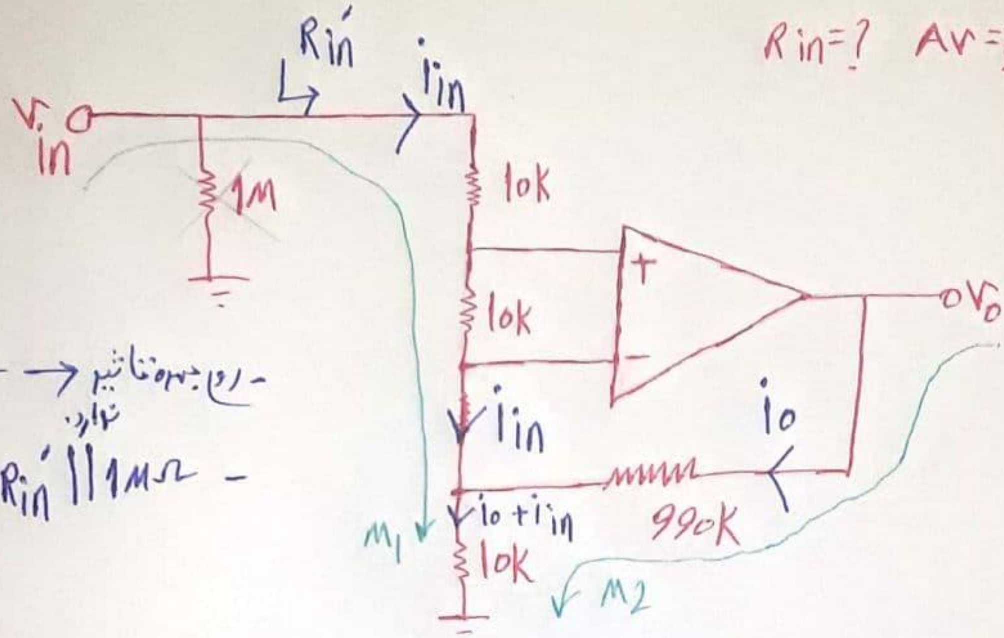
$$v_x = \frac{v_o}{3}$$

$$\frac{v_o}{3} = -\frac{R_2}{R_1} v_{in} \longrightarrow Av = -3\frac{R_2}{R_1}$$

4- Calculate the input resistance and the voltage gain of the following structure. The op-amp is ideal.



$R_{in} = ?$ $A_v = ?$ 14



$1M\Omega \rightarrow$ روی جریان تاثیر ندارد -

$R_{in} = R'_{in} \,||\, 1M\Omega$ -

$KVL @ M_1 :\ -v_{in} + 20 i_{in} + 10 i_o + 10 i_{in} = 0 \rightarrow$

$v_{in} = 30 i_{in} + 10 i_o$ (*) $\qquad i_{in} = 0$

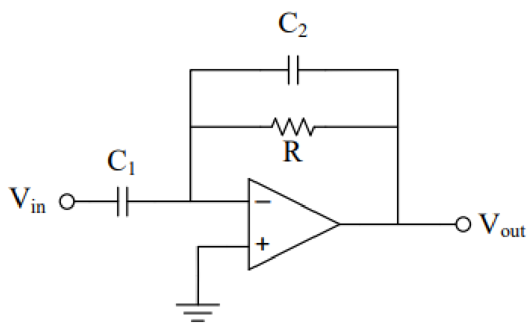
$\frac{v_{in}}{i_{in}} = \infty = R'_{in} \qquad R_{in} = 1M\Omega \,||\, \infty \Rightarrow$

$R_{in} = 1M\Omega$

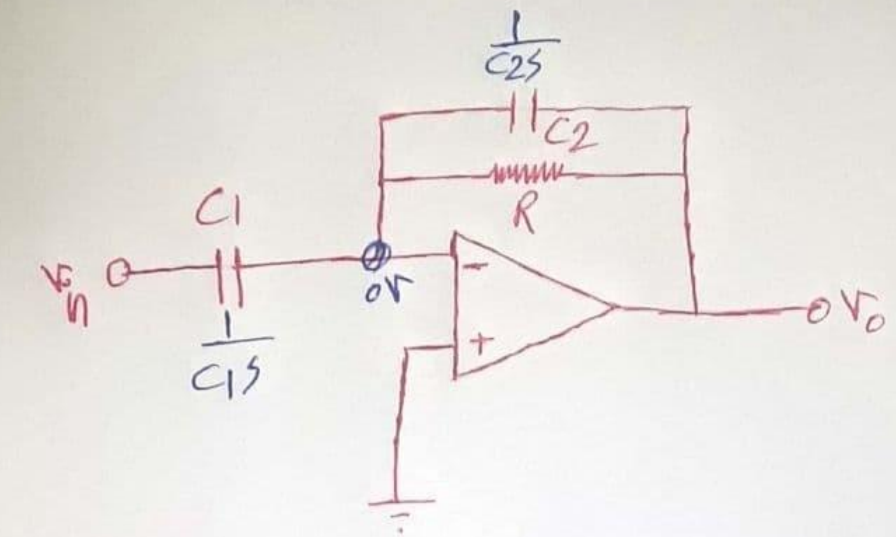
$KVL @ M_2 :\ -v_o + 990 i_o + 10 i_o + 10 i_{in} = 0 \rightarrow i_o = \frac{v_o}{1000}$

$\xrightarrow{*} v_{in} = \frac{v_o}{100} \rightarrow A_v = 100$

5- Determine the transfer function of the following circuit and prove that it acts like a filtering circuit. Specify the type of the filter. Assume ideal op-amp.



5



$$KCL\ @-op: C_1 s\, v_{in} = -v_o/R - C_2 s\, v_o \rightarrow$$

$$\frac{v_o}{v_{in}} = -\frac{C_1 s}{\frac{1}{R} + C_2 s} \rightarrow H(s) = \frac{v_o}{v_{in}}(s) = \frac{-RC_1 s}{1+RC_2 s}$$

$$s=0 \rightarrow H(s=0)=0 \qquad s\rightarrow\infty \rightarrow H(s)\Big|_{s\rightarrow\infty} = -\frac{C_1}{C_2} \rightarrow$$ فیلتر بالاگذر

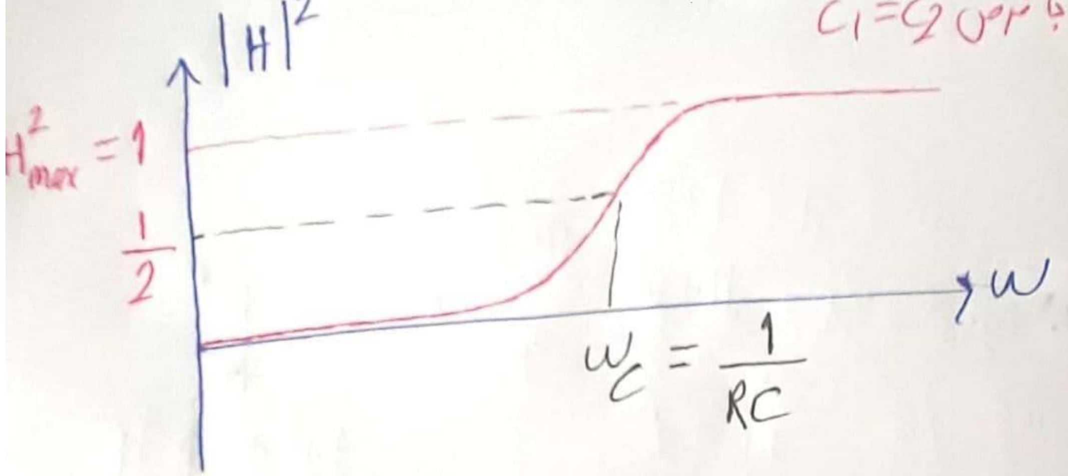
$$H(jw) = \frac{-R_1C_1 jw}{1+RC_2 jw} \rightarrow |H| = \frac{R_1 C_1 w}{\sqrt{1+(RC_2 w)^2}}$$

$$|H|^2_{(w)} = \frac{(RC_1 w)^2}{1+(RC_2 w)^2} \rightarrow \text{if}\{C_1=C_2\} \rightarrow H_{max}=1$$

$$\frac{(RCw_c)^2}{1+(RC_2 w_c)^2} = \frac{1}{2} \rightarrow 2(RCw_c)^2 = 1+(RCw_c)^2$$

$$(RC\omega_c)^2 = 1 \rightarrow \omega_c = \frac{1}{RC}$$

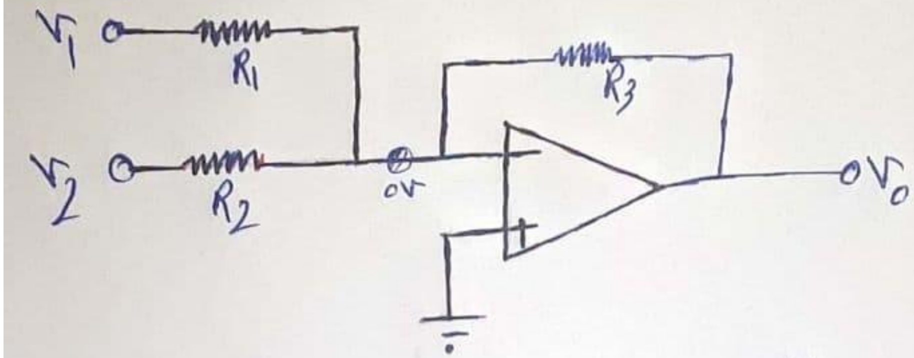
با فرض $C_1 = C_2$



6- Design a circuit which its output voltage is according to the following relation. V_1 and V_2 are the input voltages.

$$V_{out} = 4 \times V_1 + 3 \times V_2$$

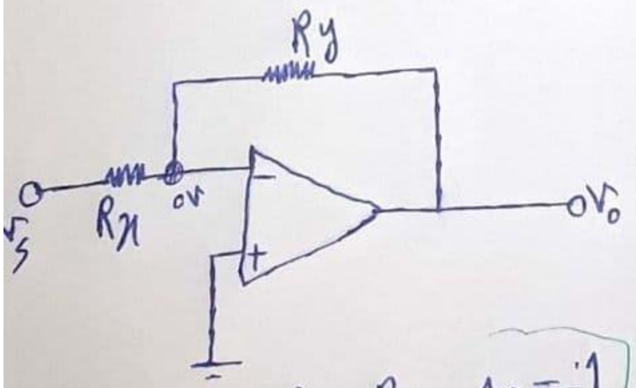
$V_{out} = 4V_1 + 3V_2$ -6



$$KCL @ 0V: \frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_0}{R_3} \longrightarrow$$

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

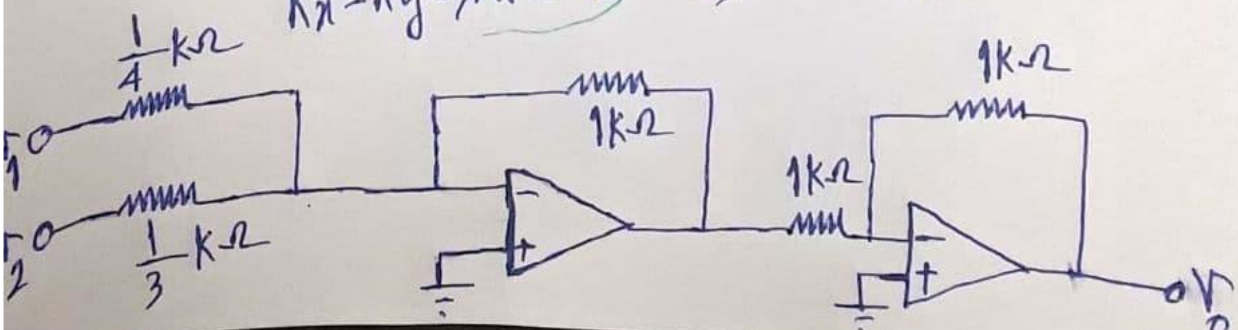
$$\frac{R_3}{R_1} = 4 \qquad \frac{R_3}{R_2} = 3 \qquad \left\{ \begin{array}{l} R_3 = 1\,k\Omega \\ R_1 = \frac{1}{4}\,k\Omega \\ R_2 = \frac{1}{3}\,k\Omega \end{array} \right.$$



$$KCl: \frac{V_s}{R_x} = \frac{-V_0}{R_y}$$

$$\frac{V_0}{V_s} = -\frac{R_y}{R_x} \qquad R_x = R_y = 1k$$

$R_x = R_y \rightarrow A_v = -1$



7- Design a circuit which solves the following differential equation.

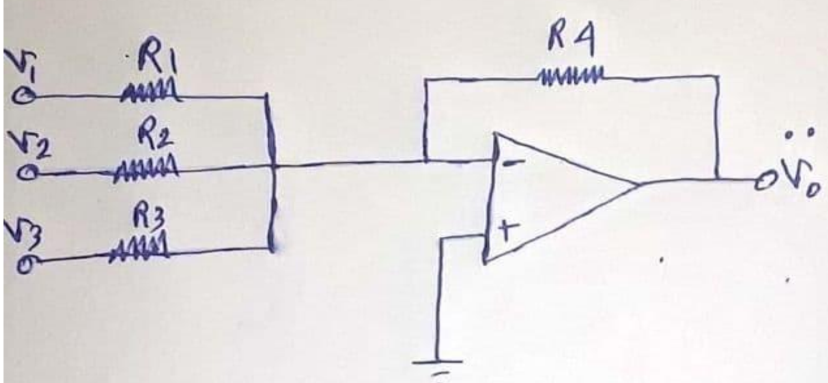
$$\frac{d^2 v}{dt^2} = -20\frac{dv}{dt} - 100\, v + 25\text{ V}$$

-7

$\ddot{V}_o = -20\dot{V}_o - 100 V_o + 25V$

خروجي

مقدار DC



$$\ddot{V}_o = -\left(\frac{R4}{R_1}V_1 + \frac{R4}{R_2}V_2 + \frac{R4}{R_3}V_3\right)$$

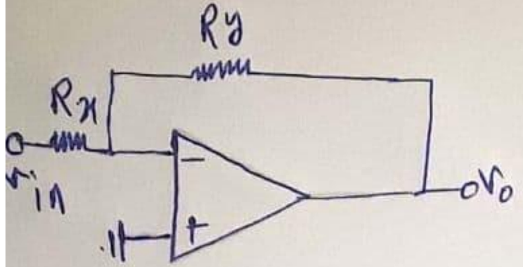
$\frac{R4}{R_1} = 1$ $\quad V_1 = -25V \quad V_2 = V_o$

$\frac{R4}{R_2} = 100 \quad \frac{R4}{R_3} = 20 \quad V_3 = \dot{V}_o$

$R4 = 100k\Omega \rightarrow R_1 = 100k\Omega$

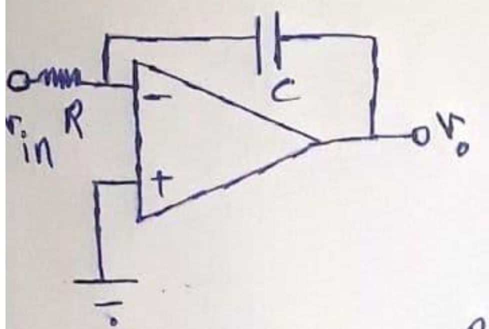
$\rightarrow R_2 = 1k\Omega$

$\rightarrow R_3 = 5k\Omega$



$$\frac{v_o}{v_{in}} = -\frac{R_y}{R_x}$$

$$R_x = R_y = 1K \longrightarrow \frac{v_o}{v_{in}} = -1$$



$$KCL @ -op: \frac{V_o}{v_{in}} = \frac{-1}{RCS}$$

$$\xrightarrow{L^{-1}} v_o(t) = \frac{-1}{RC}\int v_{in}\,dt$$

$$\left.\begin{matrix} R = 10k\Omega \\ C = 0.1mF \end{matrix}\right\} \longrightarrow v_o(t) = -\int v_{in}\,dt$$