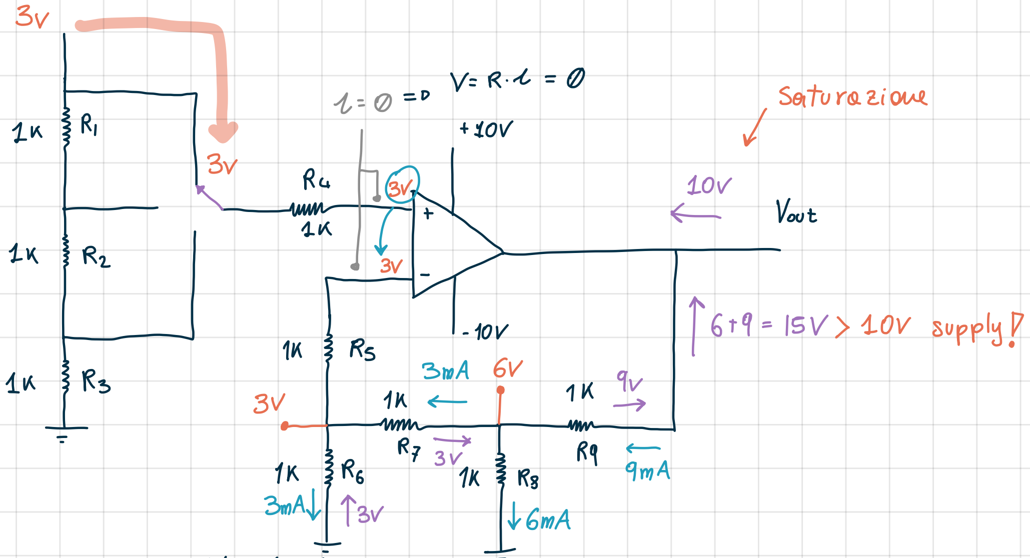
Es video youtube

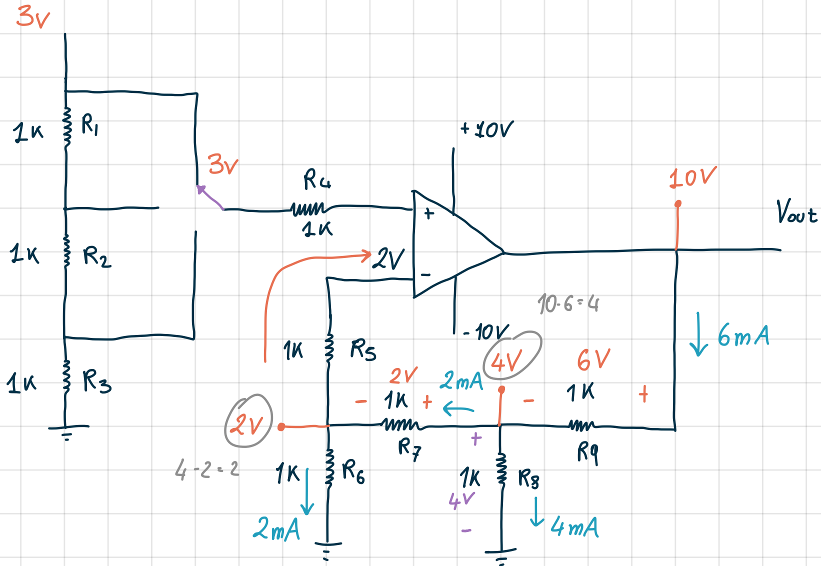


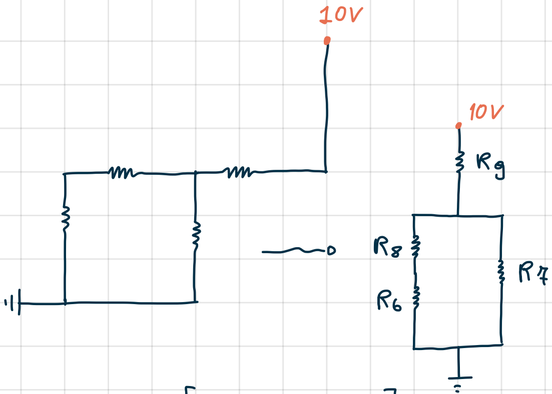
$V = R \cdot i$

$\Rightarrow i = \frac{3}{1K} = 3m$

$V_6 = 1K \cdot 3mA = 3V$ $\qquad$ $V_9 = 1K \cdot 9mA = 9V$

$i_8 = \frac{6V}{1K} = 6mA$



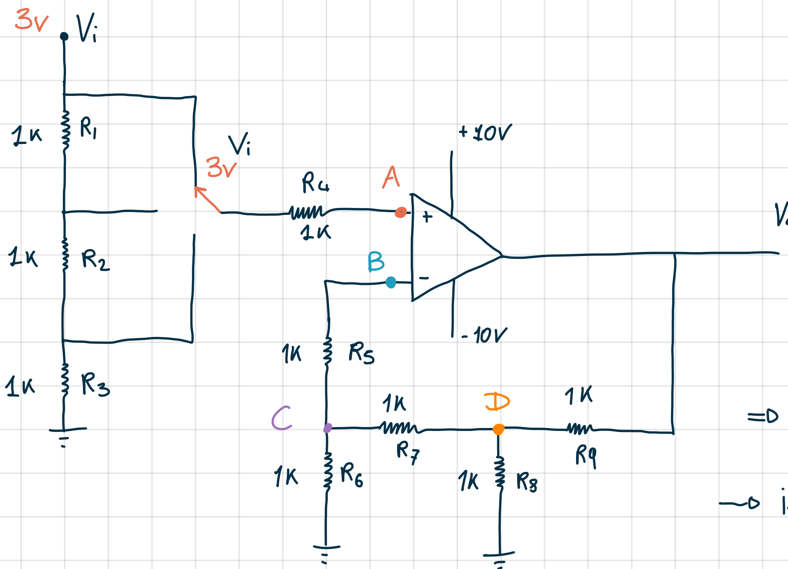


$V_9 = 6mA \cdot 1K = 6V$ $\qquad$ $V_7 = 2mA \cdot 1K = 2V$

$i_8 = \frac{4}{1K} = 4mA$

$R_{eq} = R_9 + \left[(R_8 + R_9) // R_7 \right]$

$= 1.666 K\Omega \Rightarrow i_9 = \frac{10}{R_{eq}} = \underline{6mA}$



$$V_{R_4} = R_4 \cdot i = \varnothing \Rightarrow V_A = V_i - \cancel{V_{R_4}}^{\,0} = V_i$$

$$\Rightarrow V_B = V_i \;, \quad V_{R_5} = R_5 \cdot i_5 = \varnothing \Rightarrow V_C = V_i$$

$$\rightarrow i_6 = \frac{V_C}{R_6} = \frac{V_i}{R_6} \checkmark$$

$$\Rightarrow \underbrace{i_7}_{} = i_6 = \frac{V_i}{R_6} \checkmark \rightarrow V_7 = \frac{R_7}{R_6} \cdot V_i \checkmark$$

i_7

$$\Rightarrow V_D = V_C + V_7 = V_i + \frac{R_7}{R_6} V_i = V_i\left(1 + \frac{R_7}{R_6}\right) \checkmark$$

$$\rightarrow i_8 = \frac{V_D}{R_8} = \frac{V_i}{R_8}\left(1 + \frac{R_7}{R_6}\right) \; i_8 \checkmark$$

$$\Rightarrow i_9 = i_8 + i_7 = \frac{V_i}{R_8}\left(1 + \frac{R_7}{R_6}\right) + \frac{V_i}{R_6} = V_i\left(\frac{1}{R_8} + \frac{R_7}{R_6 R_7} + \frac{1}{R_6}\right) \; i_9 \checkmark$$

$$V_9 = i_9 \cdot R_9 = R_9 V_i \left(\frac{1}{R_8} + \frac{R_7}{R_6 R_7} + \frac{1}{R_6}\right) \checkmark$$

Vout

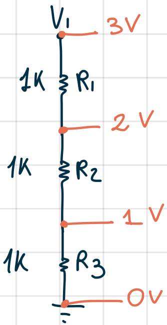
$$\Rightarrow V_{out} = V_9 + V_D = R_9 V_i \left(\frac{1}{R_8} + \frac{\cancel{R_7}}{R_6 \cancel{R_7}} + \frac{1}{R_6}\right) + V_i\left(1 + \frac{R_7}{R_6}\right) = V_i \left(\frac{R_9}{R_8} + \frac{R_9}{R_6} + \frac{R_9}{R_6} + 1 + \frac{R_7}{R_6}\right) \checkmark$$

Bonus

$$A = \frac{V_o}{V_i} = \left(\frac{R_9}{R_8} + \frac{R_9}{R_6} + \frac{R_9}{R_6} + 1 + \frac{R_7}{R_6}\right) = 5$$

$$\sum_{i=1}^{9} R_i = 1K$$

VOLTAGE DROP



$R_{eq} = 3K \Rightarrow i = \frac{V_i}{R_{eq}} = \frac{3}{3K} = 1 \times 10^{-3}$

$\Rightarrow V_1 = 1K \cdot 1\,mA = 1V = V_2 = V_3$

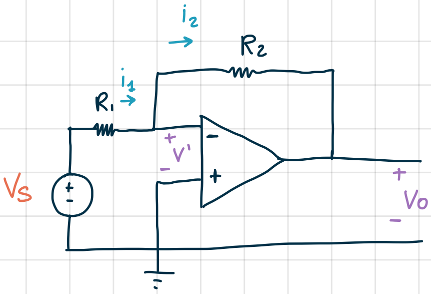
1. Trova corrente con Req
2. Trova la caduta di tensione per ogni resistore.

Esercizi dispense

Il trucco è quello di ricondursi sempre alle configurazioni studiate nella teoria:

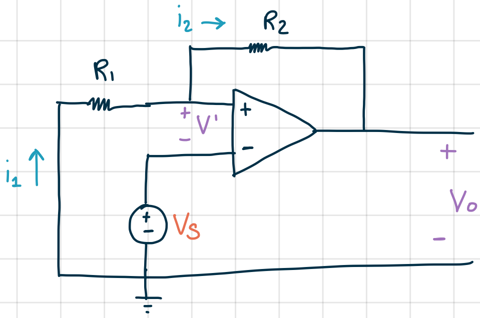
- **Invertente**
- **Non invertente**

INVERTENTE



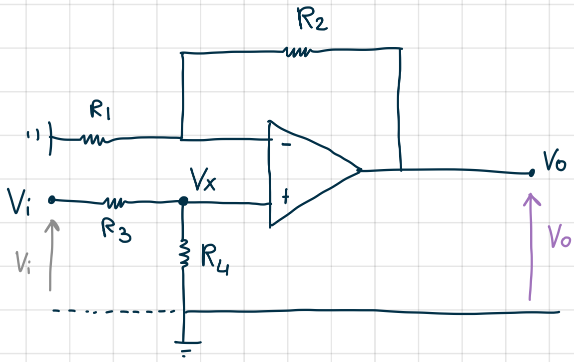
$$V_o = -\frac{R_2}{R_1} V_i$$

NON INVERTENTE



$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_i$$

ES 1



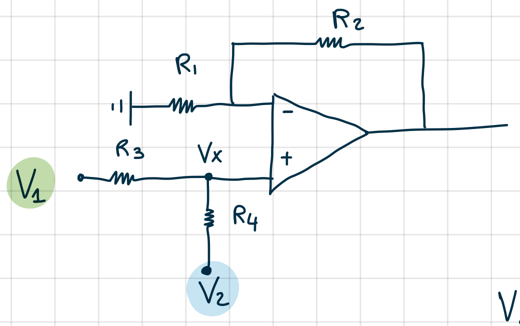
Siccome $V_o = \left(1 + \frac{R_2}{R_1}\right) V_x$

Trovo V_x $\rightarrow$ È proprio la caduta di tensione di R_4

$$\Rightarrow V_4 = V_i \frac{R_4}{R_3 + R_4} \Rightarrow \underline{V_o = \left(1 + \frac{R_2}{R_1}\right) \cdot V_i \frac{R_4}{R_3 + R_4}}$$

Ans

ES 2:



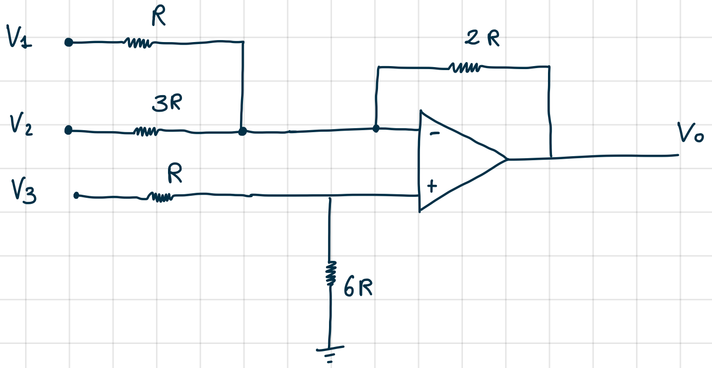
- Ci sono 2 INPUT $\Rightarrow$ SOVRAPPOSIZIONE

$$V_1: \quad V_x' = V_1 \cdot \frac{R_4}{R_3 + R_4} \Rightarrow \underline{V_o' = \left(1 + \frac{R_2}{R_1}\right) \cdot V_1 \frac{R_4}{R_3 + R_4}}$$

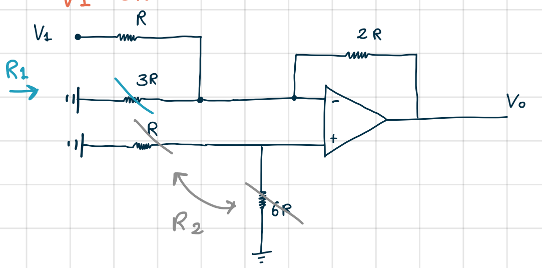
$$V_2: \quad V_x'' = V_2 \cdot \frac{R_3}{R_3 + R_4} \Rightarrow V_o'' = \left(1 + \frac{R_2}{R_1}\right) \cdot V_2 \cdot \frac{R_3}{R_3 + R_4}$$

$$\Rightarrow V_o = V_o' + V_o'' = \underbrace{\left(1 + \frac{R_2}{R_1}\right)\left[V_1 \frac{R_3}{R_3 + R_4} + V_2 \frac{R_4}{R_3 + R_4}\right]}_{\text{OUT}}$$

ES 3



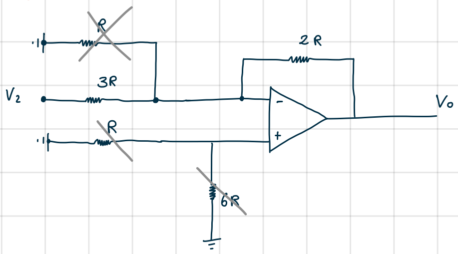
V_1 ON



$$\left.\begin{array}{l} R_1 = \text{NON C'E' CORRENTE} \\ R_2 = \text{NON C'E' CORRENTE} \end{array}\right\} \Rightarrow V_o = -\frac{R_2}{R_1} \cdot V_i \Rightarrow V' = -\frac{2R}{R} \cdot V_1 = -2V_1$$

V'

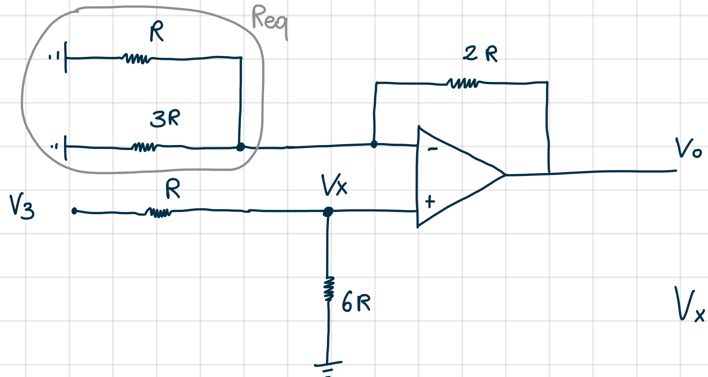
V_2 ON



$$V_o' = -\frac{2R}{3R} V_2 = -\frac{2}{3} V_2$$

V_o''

V_3 ON



$$Req = R \,//\, 3R = \frac{R \cdot 3R}{R + 3R} = \frac{3R^2}{4R} = \frac{3}{4} R$$

Req

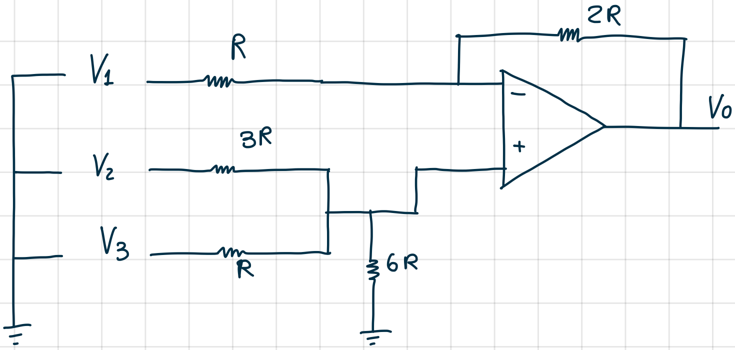
$$\rightsquigarrow V_o''' = \left(1 + \frac{2R}{Req}\right) V_x$$

$$V_x = V_3 \cdot \frac{6R}{6R + R} = V_3 \frac{6R}{7R} = \frac{6}{7} V_3$$

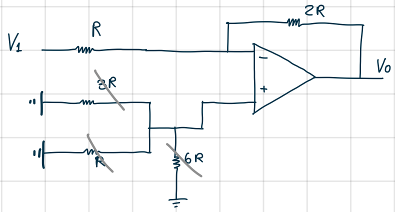
V_x

$$\Rightarrow V_o''' = \left(1 + \frac{2\cancel{R}}{3\cancel{R}} \cdot 4\right) \cdot \frac{6}{7} V_3 = \left(1 + \frac{8}{3}\right) \cdot \frac{6}{7} V_3 = \frac{22}{7} V_3 \Rightarrow gain = \frac{22}{7} \cong \pi \cong 3.4$$

ES 5



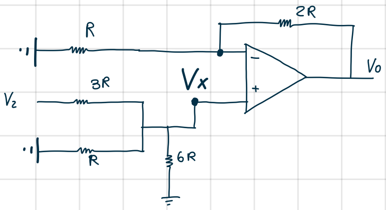
V1 ON

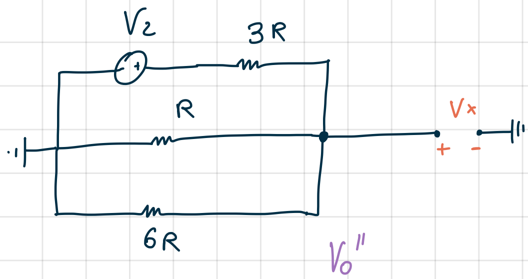


$$V_o' = -\frac{2R}{R} V_1 = -2V_1$$

V_o'

V2 ON





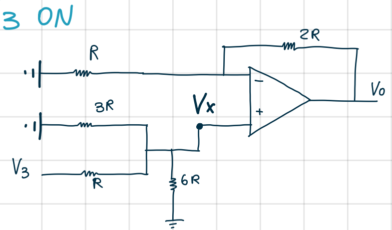
$$\Rightarrow R_{eq} = 3R + (R /\!/ 6R)$$
$$= 3R + \frac{6R^{\cancel{2}}}{7\cancel{R}}$$
$$= 3R + \frac{6}{7}R = \frac{27}{7}R \simeq 3.85$$

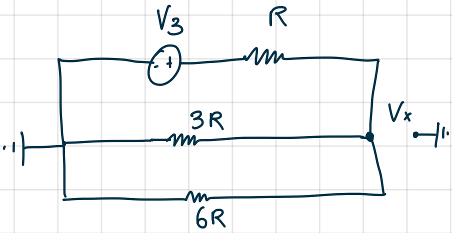
$$\Rightarrow V_x = V_{R/\!/6R} = V_2 \cdot \frac{\frac{6}{7}R}{\frac{6}{7}R + 3R} = \frac{2}{9}V_2 \Rightarrow V_o'' = \left(1 + \frac{2R}{R}\right) \cdot \frac{2}{9} V_2$$

V_o''

ovvero: $V_o'' = \left(1 + \frac{2R}{R}\right) \cdot \frac{R_{/\!/}}{R_{/\!/} + 3R} V_2$

V3 ON





$$V_x = V_3 \cdot \frac{R_{/\!/}}{R_{/\!/} + R}$$

con $R_{/\!/} = \frac{3R \cdot 6R}{3R + 6R} = \frac{\cancel{18}^{2} R}{\cancel{9}} = 2R$ ($R_{/\!/}$)

$$\leadsto V_x = V_3 \frac{2R}{2R + R} = V_3 \frac{2R}{3R} = \frac{2}{3} V_3$$

V_x

$$\Rightarrow V_o''' = \left(1 + \frac{2R}{R}\right) \cdot \frac{2}{3} V_3 = 2V_3 \Rightarrow A''' = 2$$

V_o'''

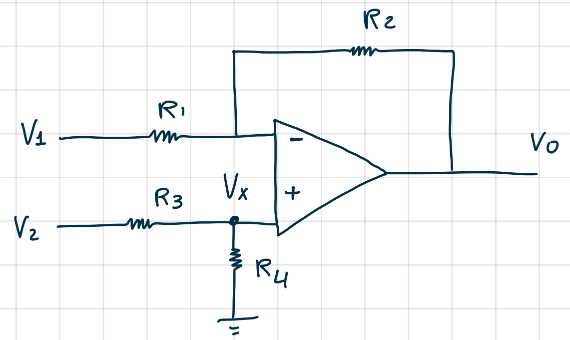
$$V_o = V_o' + V_o'' + V_o'''$$

ES 5

Q: Dimensionare R_1, R_2, R_3, R_4 affinché

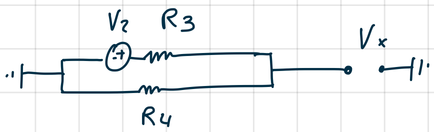
$V_o = 2(V_2 - V_1)$ ovvero $A = 2$

(1) Risolvo



$V_o' \to V_1$ ON $\Rightarrow$ $V_o' = -\dfrac{R_2}{R_1} V_1$ V_o'

$V_o'' \to V_2$ ON $\Rightarrow$ $V_o'' = \left(1 + \dfrac{R_2}{R_1}\right) \cdot V_x$ con V_x :



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

$$\to V_o'' = \left(1 + \frac{R_2}{R_1}\right) \cdot \frac{R_4}{R_3 + R_4} V_2$$

Risolvo il sys: $V_o = 2(V_2 - V_1) \Rightarrow \begin{cases} V_o'(V_1) = -2V_1 \\ V_o''(V_2) = 2V_2 \end{cases}$

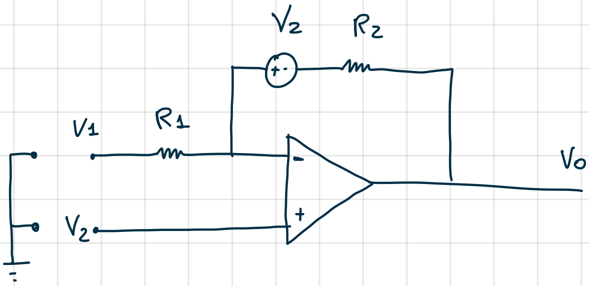
$$\begin{cases} +\dfrac{R_2}{R_1} \cancel{V_1} = +2\cancel{V_1} \Rightarrow \dfrac{R_2}{R_1} = 2 \leadsto R_2 = 2R_1 \\ V_o'' = \underbrace{\left(1 + \dfrac{R_2}{R_1}\right)}_{3} \cdot \dfrac{\cancel{R_4}}{\cancel{R_4}\left(\dfrac{R_3}{R_4} + 1\right)} \cancel{V_2} = 2\cancel{V_2} \to \dfrac{3}{1 + \dfrac{R_3}{R_4}} = 2 \to 3 = 2\left(1 + \dfrac{R_3}{R_4}\right) \end{cases}$$

$$\to 3 = 2 + \frac{2R_3}{R_4} \to \frac{R_3}{R_4} = \frac{1}{2}$$

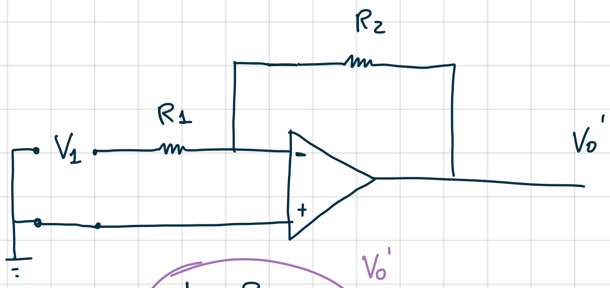
quindi $\dfrac{R_2}{R_1} = 2 \Rightarrow \dfrac{R_1}{R_2} = \dfrac{R_3}{R_4} = \dfrac{1}{2}$ Ans

ES 6

IMPO



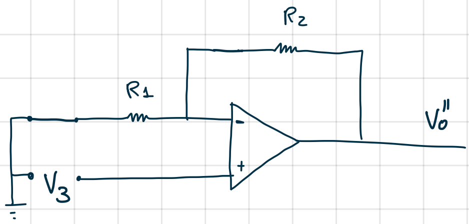
V_1 ON



$$\rightarrow V_0' = -\frac{R_2}{R_1} V_1$$

V_0'

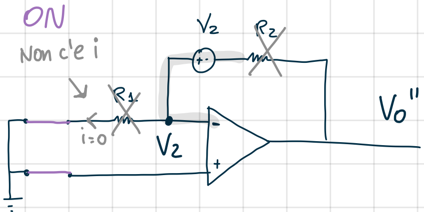
V_3 ON



$$V_0'' = \left(1 + \frac{R_2}{R_3}\right) \cdot V_3$$

V_0''

V_2 ON

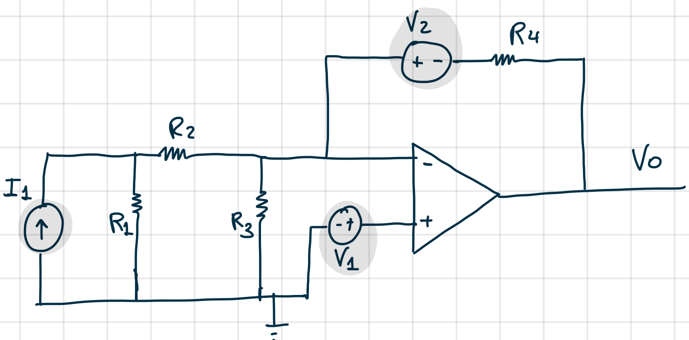


$$V_0''' = -\frac{R_2}{R_1} V_2 = -V_2$$

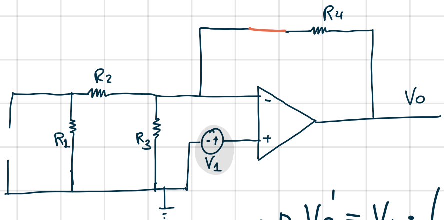
V_0'''

$$\Rightarrow V_0 = V_0' + V_0'' + V_0'''$$

ES 7



V_1 ON



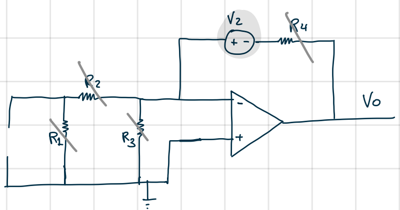
$$V_0 = V_1 \cdot \left(1 + \frac{R_2}{\hat{R}_1}\right)$$

$$\hat{R}_1 = R_3 // R_2 + R_1 = \frac{R_3 (R_2 + R_1)}{R_1 + R_2 + R_3}$$

$$\rightarrow V_0' = V_1 \cdot \left(1 + \frac{R_4}{R_3 // R_2 + R_1}\right)$$

V_0'

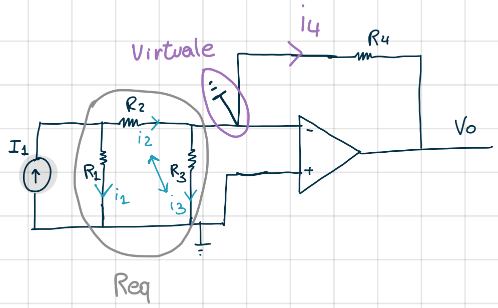
V_2 ON



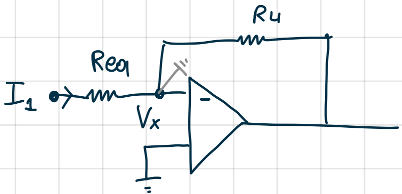
$$\rightarrow V_0'' = -V_2$$

V_0''

I_1 ON



$$Req = R_1 // R_2 + R_3$$



$$i_2 = I_1 \cdot \frac{R_1}{R_1 + R_2}$$

$\Rightarrow$ Siccome V_0 è la ddp tra V_0 e gnd, e visto che $i_2 = i_4$

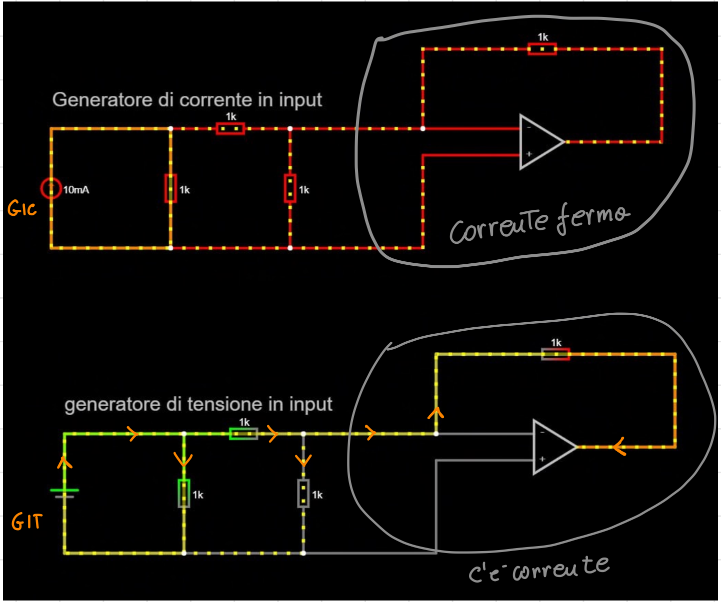
$$\rightarrow V_0 = R_4 \cdot i_4 = -\frac{R_1 R_4}{R_2 + R_1} \cdot I_1$$

invertente

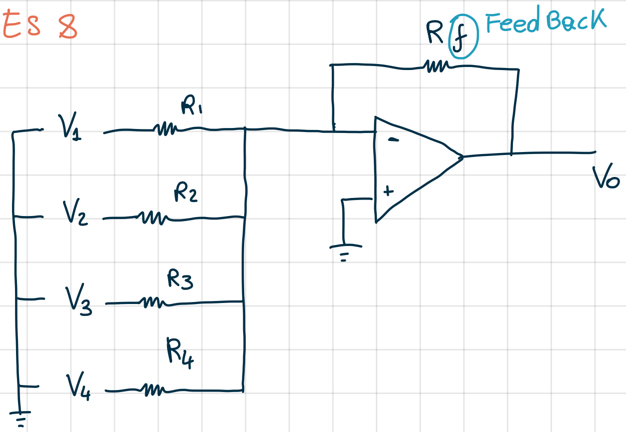
CONSIDERAZIONI

Gli opamps sono progettati in modo che **la differenza di potenziale degli input sia zero**; quindi se in input non c'è un **forzamento** (di tensione) L'amplificatore tenderà a non far scorrere corrente, non solo all'interno egli input, ma anche nel ramo di feedback.

D'altro canto, invece, se posizioniamo un generatore di **tensione** in input, ci sarà una corrente che fluisce all'interno dell'opamp.

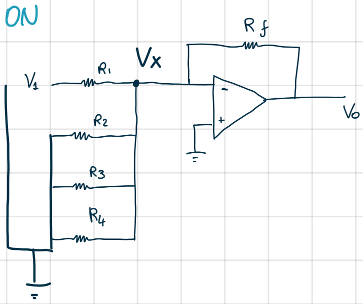


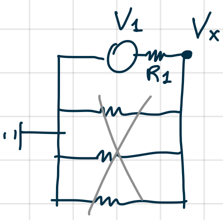
Es 8



Q: Scegliere R_1, R_2, R_3, R_4 Tali che l'uscita sia $V_o = -V_1 - 2V_2 - 4V_3 - 8V_4$

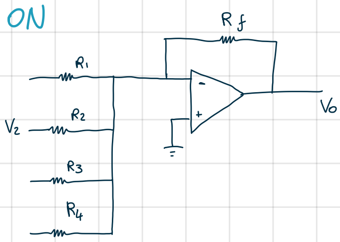
V_1 ON

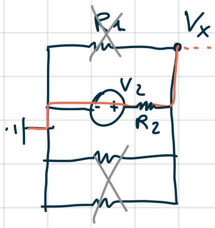




$V_x = V_1 \Rightarrow \boxed{V_0' = -\frac{R_f}{R_1} V_1}$ V_0'

V_2 ON





$V_x = V_2 \Rightarrow$ la corrente circola solo sulla resistenza in serie al gen acceso.

$\Rightarrow \boxed{V_0'' = -\frac{R_f}{R_2} V_2}$ V_0''

$\Rightarrow \boxed{V_0''' = -\frac{R_f}{R_3} V_3}$, $\boxed{V_0'''' = -\frac{R_f}{R_4} V_4}$

$$\Rightarrow \text{Sys} \rightarrow \begin{cases} V_0' = -V_1 \\ V_0'' = -2V_2 \\ V_0''' = -4V_3 \\ V_0'''' = -8V_4 \end{cases} \Rightarrow \begin{cases} +\frac{R_f}{R_1} = +1 \\ +\frac{R_f}{R_2} = +2 \\ +\frac{R_f}{R_3} = +4 \\ +\frac{R_f}{R_4} = +8 \end{cases} \Rightarrow \begin{cases} R_1 = R_f \\ R_2 = \frac{1}{2} R_f \\ R_3 = \frac{1}{4} R_f \\ R_4 = \frac{1}{8} R_f \end{cases}$$

Ans