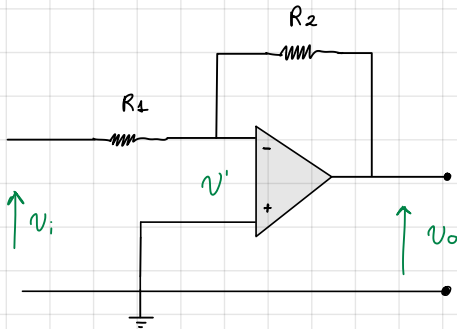


- **Proporzionale**
- **Integrale**
- **Derivativo**

PROPORZIONALE

$$U(t) = K_p \cdot e(t) \Leftrightarrow U(s) = K_p \cdot E(s)$$

$$\Rightarrow G(s) = \frac{U(s)}{E(s)} = K_p$$

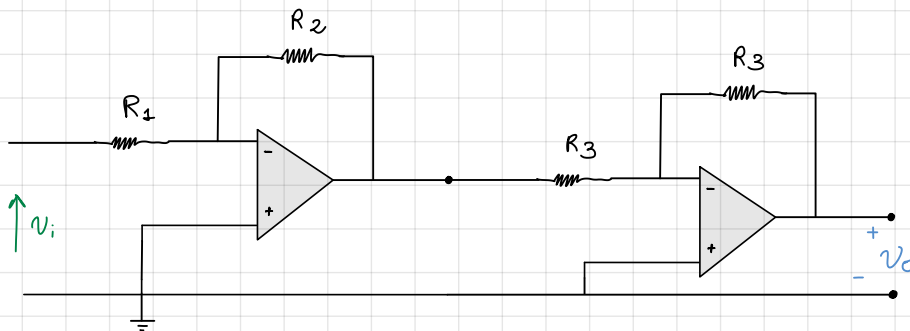


dal metodo delle impedenze: $V_o = -\frac{Z_2}{Z_1} V_i$

ma se abbiamo solo resistenze $Z_1 = R_1$, $Z_2 = R_2$

$$\Rightarrow V_o = -\frac{R_2}{R_1} V_i \quad \text{e se } R_2 = R_1 \rightarrow \underline{V_o = -V_i}$$

\Rightarrow Ci bastano due circuiti in serie:



$$\Rightarrow V_o = K_p \cdot V_i$$

con $K_p = \frac{R_2}{R_1}$

ES: Voglio $K_p = 3$ ed ho $R_1 = 4 \Omega$

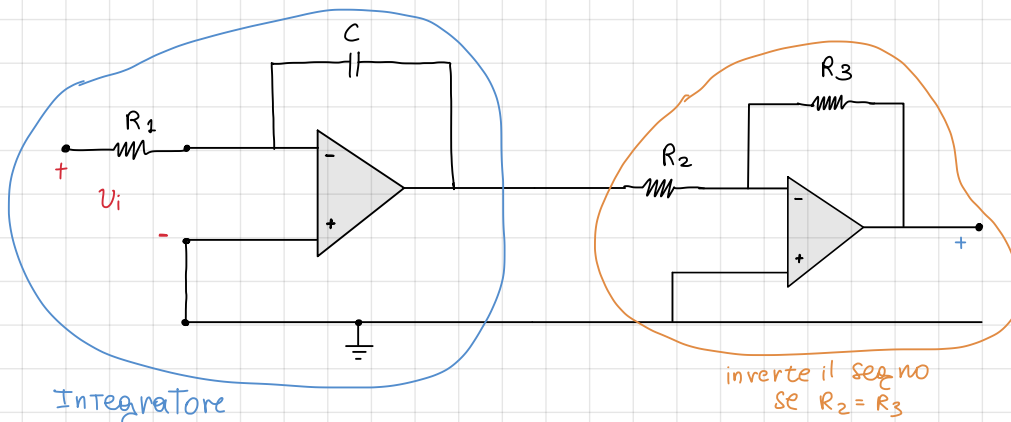
$$\Rightarrow K_p = \frac{R_2}{R_1} = 3 \Rightarrow \frac{R_2}{4} = 3 \Rightarrow \underline{R_2 = 12 \Omega}$$

Se non prendo $R_3 = R_4 \rightarrow K_p = \frac{R_4}{R_3} \cdot \frac{R_2}{R_1}$

INTEGRATORE

$$U(t) = K_i \int_0^t e(t) dt \Leftrightarrow U(s) = \frac{K_i}{s} E(s) \Rightarrow G(s) = \frac{K_i}{s}$$

Sfrutto che $Z_C = \frac{1}{sC}$ e che $V_o = -\frac{Z_2}{Z_1} V_i$ Pongo $Z_2 = Z_C$ e $Z_1 = R_1$



$$V_o = \frac{1}{R_1 C s} \cdot \frac{R_3}{R_2} V_i$$

$$= \left(\frac{1}{s} \right) \cdot \left(\frac{R_3}{R_1 R_2 C} \right) V_i$$

integratore K_i

PROPORZIONALE INTEGRALE

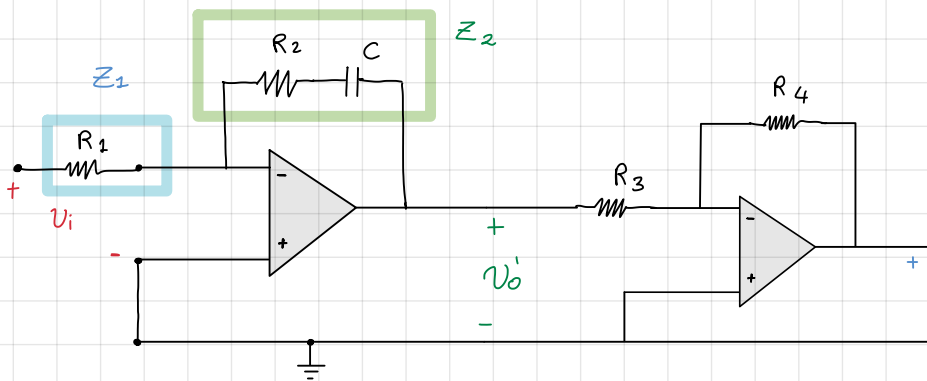
$$U(t) = k_p \cdot e(t) + k_i \int_0^t e(t) dt \quad \text{C.I.} = 0 \quad \Leftrightarrow \quad U(s) = k_p E(s) + k_i \cdot \frac{E(s)}{s}$$

$$= E(s) \left[k_p + \frac{k_i}{s} \right]$$

$$\Rightarrow G(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s}$$

mi serve $k_p + \frac{k_i}{s}$ e so realizzarli singolarmente.

-> Si come Z_1 (serie) $Z_2 = Z_1 + Z_2$



$$Z_2 = R_2 + \frac{1}{Cs} = \frac{R_2 Cs + 1}{Cs}, \quad Z_1 = R_1 \quad \Rightarrow \quad V_0' = - \frac{\frac{R_2 Cs + 1}{Cs}}{R_1} = - \frac{R_2 Cs + 1}{R_1 Cs}$$

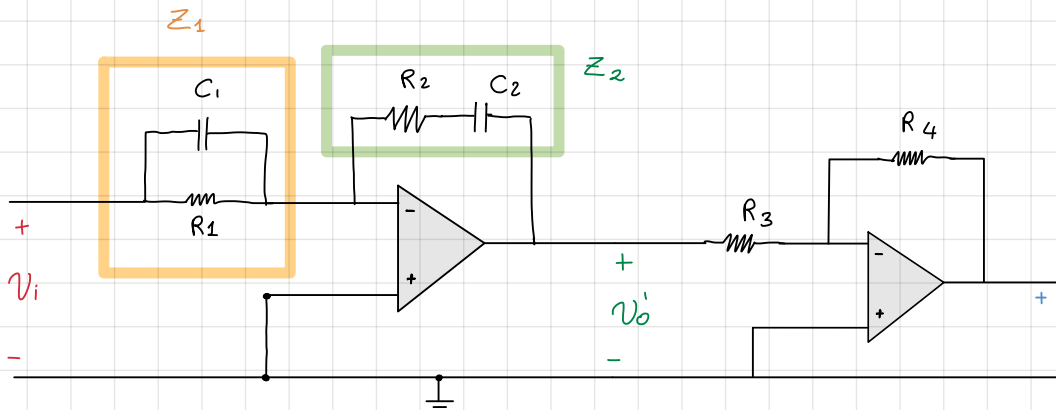
$$\Rightarrow V_0 = \frac{R_4}{R_3} \cdot \frac{R_2 Cs + 1}{R_1 Cs} = \frac{R_4}{R_3} \left[\frac{R_2 Cs}{R_1 Cs} + \frac{1}{R_1 Cs} \right] = \frac{R_4}{R_3} \left[\frac{R_2}{R_1} + \frac{1}{R_1 Cs} \right]$$

Integrazione

PROPORZIONALE INTEGRALE DERIVATIVO

$$U(t) = k_p \cdot e(t) + k_i \int_0^t e(t) dt + k_d \cdot \frac{de(t)}{dt} \Rightarrow U(s) = k_p E(s) + k_i \cdot \frac{E(s)}{s} + k_d s E(s)$$

$$\Rightarrow G(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s} + s k_d$$



$$V_0 = \frac{R_4}{R_3} \frac{R_2}{R_1} \frac{(R_1 C_1 s + 1)(R_2 C_2 s + 1)}{R_2 C s} V_i$$