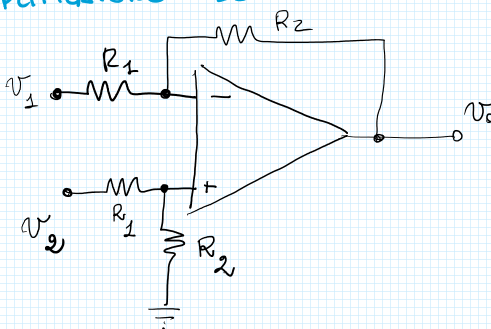
Amplificatore Operazionale: Amplificatore delle differenze, amplificatore per strumentazione, non idealita' dell'opamp.

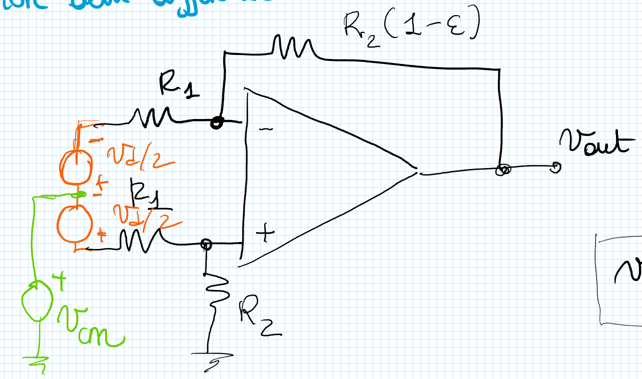
Monday, May 3, 2021 9:21 AM

AMPLIFICATORE DELLE DIFFERENZE



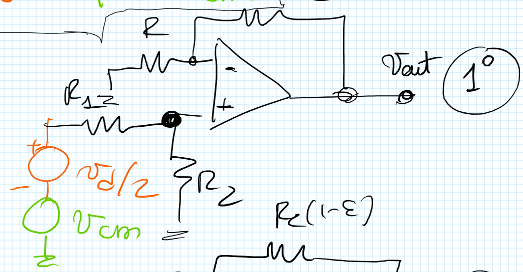
$$v_{out} = \frac{R_2}{R_1}(v_2 - v_1)$$

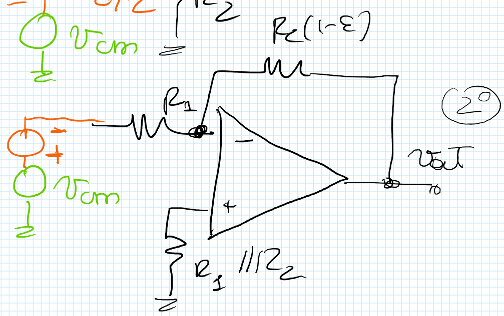
effetto del mismatch delle resistenze sul trasferimento dell'amplificatore delle differenze



$$v_2 - v_1 = v_d \qquad \frac{v_1 + v_2}{2} = v_{cm}$$

$$v_{out} = G_{dm}\, v_d + G_{cm}\, v_{cm}$$





$$v_{out} = \frac{R_2}{R_1+R_2}\left(1 + \frac{R_2(1-\varepsilon)}{R_1}\right)\left(\frac{v_d}{2} + v_{cm}\right) - \frac{R_2(1-\varepsilon)}{R_1}\left(v_{cm} - \frac{v_d}{2}\right) =$$

$$= \underbrace{\left[\frac{R_2}{R_1+R_2}\left(1 + \frac{R_2(1-\varepsilon)}{R_1}\right) - \frac{R_2(1-\varepsilon)}{R_1}\right]}_{G_{cm}} v_{cm} + \frac{v_d}{2}\underbrace{\left[\frac{R_2}{R_1+R_2}\left(1 + \frac{R_2(1-\varepsilon)}{R_1}\right) + \frac{R_2(1-\varepsilon)}{R_1}\right]}_{G_{dm}}$$

$$G_{cm} = \frac{R_2}{R_1+R_2} + \frac{R_2}{R_1}(1-\varepsilon)\frac{R_2}{R_1+R_2} - \frac{R_2}{R_1}(1-\varepsilon) =$$

$$= \frac{R_2}{R_1+R_2} + \frac{R_2}{R_1}(1-\varepsilon)\left[\frac{R_2}{R_1+R_2} - 1\right] = \frac{R_2}{R_1+R_2} + \frac{R_2}{R_1}(1-\varepsilon)\frac{-R_1}{R_1+R_2} =$$

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

$$G_{dm} = \frac{R_2}{R_1}\left[1 - \frac{\varepsilon}{2}\frac{R_1+2R_2}{R_1+R_2}\right] \simeq \frac{R_2}{R_1}$$

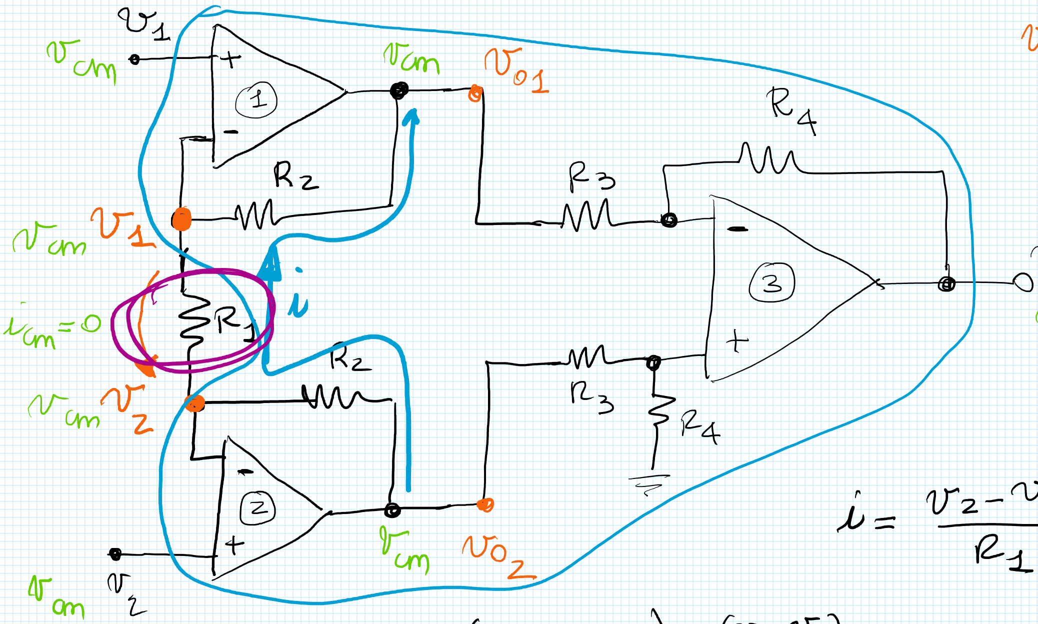
$$CMRR \triangleq \left|\frac{G_{dm}}{\dots}\right| = \left|\frac{\frac{R_2}{R_1}\left(1 - \frac{\varepsilon}{2}\frac{R_1+2R_2}{R_1+R_2}\right)}{\dots}\right| \; \left|\frac{1}{\dots}\,\frac{\frac{R_1+R_2-\frac{\varepsilon}{2}(R_1+2R_2)}{R_1+R_2}}{1}\,\frac{1}{\varepsilon}\right.$$

$$\mathrm{CMRR} \triangleq \left|\frac{G_{dm}}{G_{cm}}\right| = \left|\frac{\frac{R_2}{R_1}\left(1-\frac{\varepsilon}{2}\,\frac{R_1+2R_2}{R_1+R_2}\right)}{\frac{R_2}{R_1+R_2}\,\varepsilon}\right|$$

$$= \left(1+\frac{R_2}{R_1}\right)\frac{1}{\varepsilon} \xrightarrow[\varepsilon\to 0]{} \infty$$

$$20 \quad \frac{100}{5} = 400$$

AMPLIFICATORE PER STRUMENTAZIONE (INSTRUMENTATION AMPLIFIER) INA



$$v_2 - v_1 = v_d$$

$$\frac{v_1+v_2}{2} = v_{cm}$$

$$i = \frac{v_2 - v_1}{R_1}$$

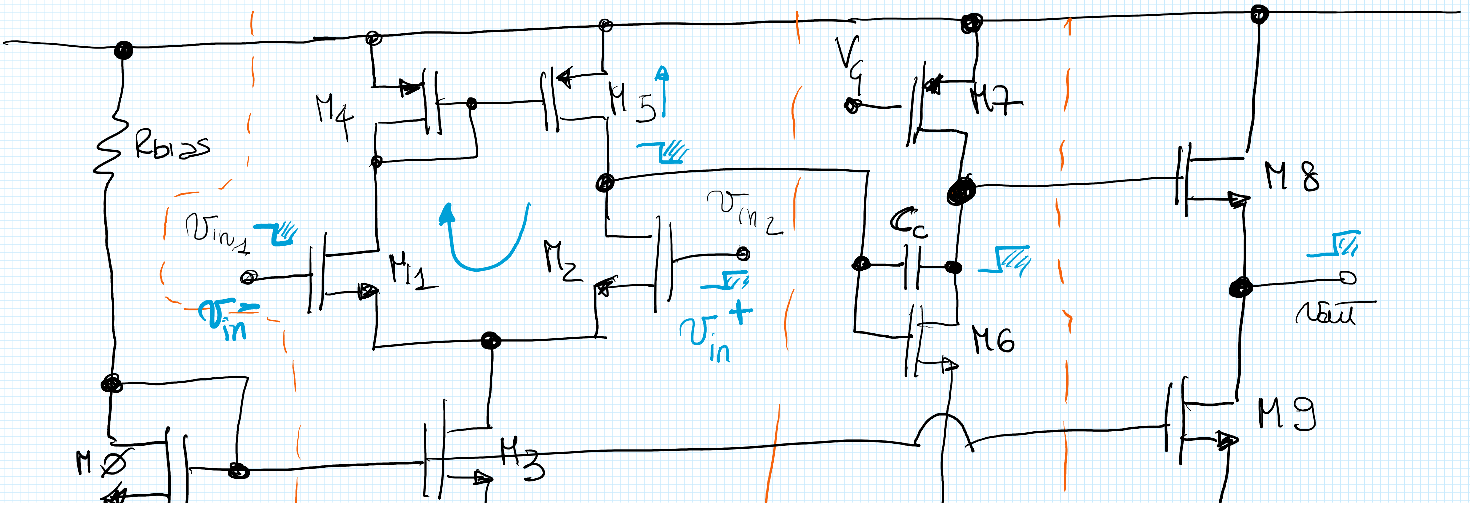
$$v_{o2} - v_{o1} = i\,(R_2+R_1+R_2) = \frac{(v_2-v_1)}{R_1}\,(R_1+2R_2)$$

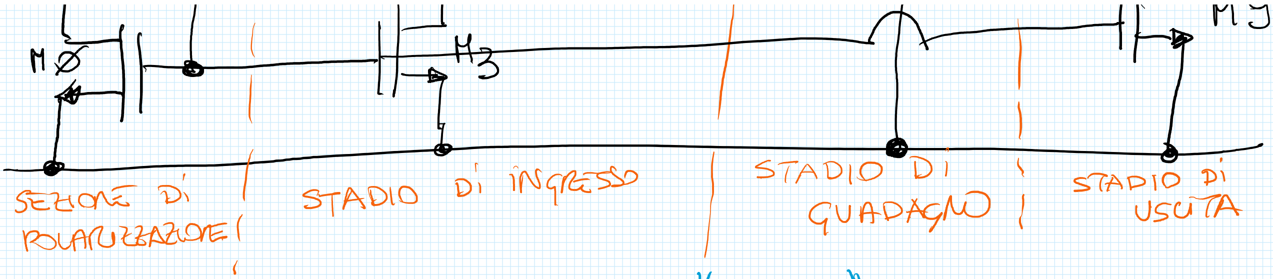
$$v_{out} = \frac{R_4}{R_3}\left(v_{o2}-v_{o1}\right) = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)(v_2-v_1)$$

GUADAGNO DIFFERENZIALE

$$G_{dm} \triangleq \frac{v_{out}}{v_2 - v_1} = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)$$

STRUTTURA INTERNA DELL'AMPLIFICATORE OPERAZIONALE



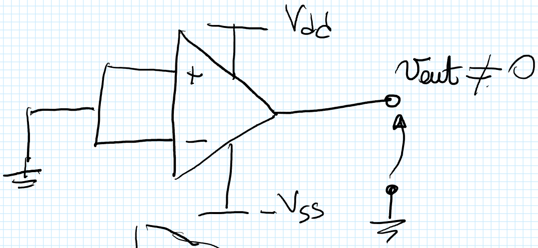


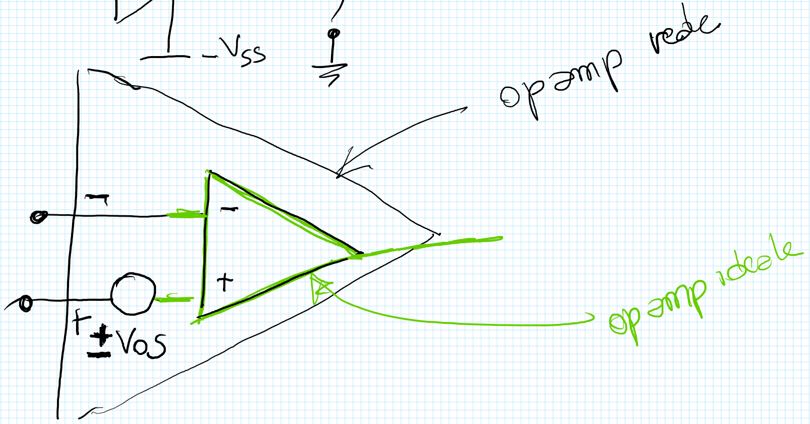
L'AMPLIFICATORE OPERAZIONALE "REALE"

★ TENSIONE DI OFFSET (V_{OS})

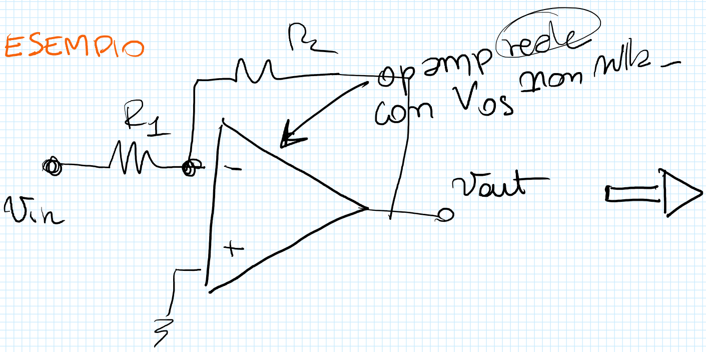
typ 1mV ÷ 5mV

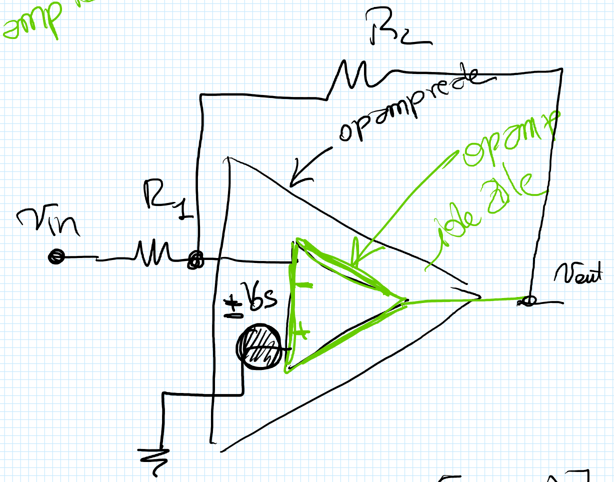
$$V_{OS} = \frac{V_{out}}{A_0}$$





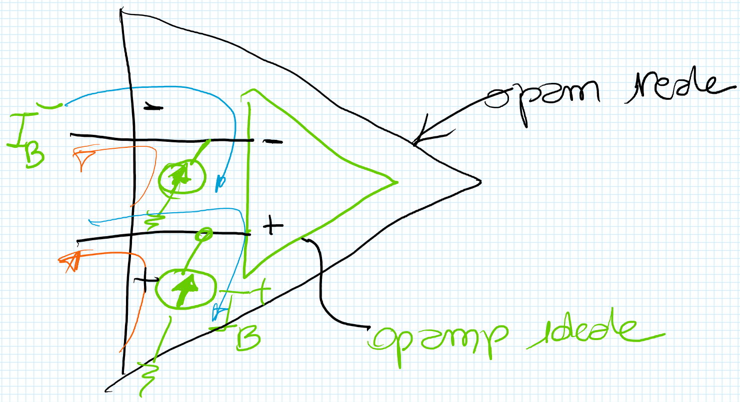
ESEMPIO





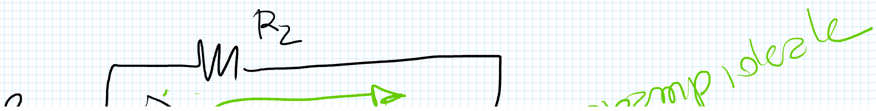
$$V_{out} = -\frac{R_2}{R_1} V_{in} \pm V_{OS} \left[1 + \frac{R_2}{R_1}\right]$$

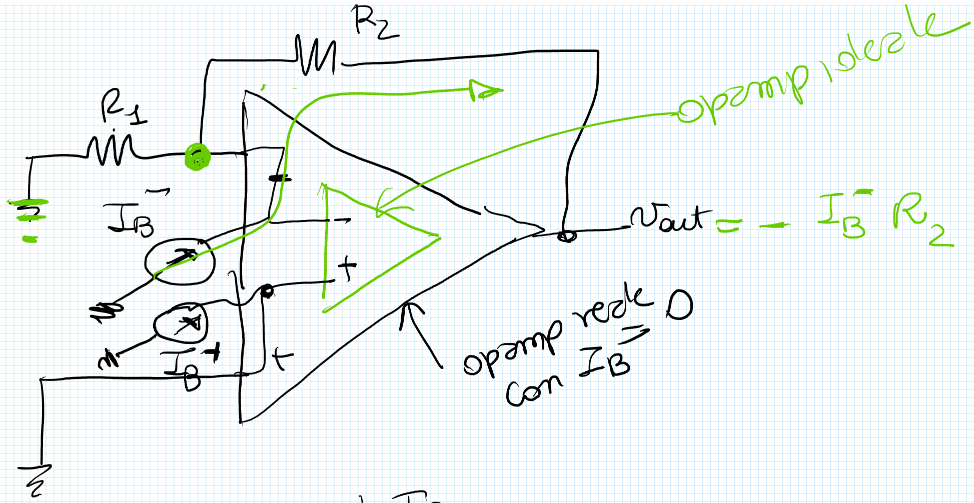
★ CORRENTI DI POLARIZZAZIONE (BIAS CURRENT O CORRENTI DI BIAS)



$$I_B = \frac{I_B^+ + I_B^-}{2}$$ CORRENTE DI BIAS

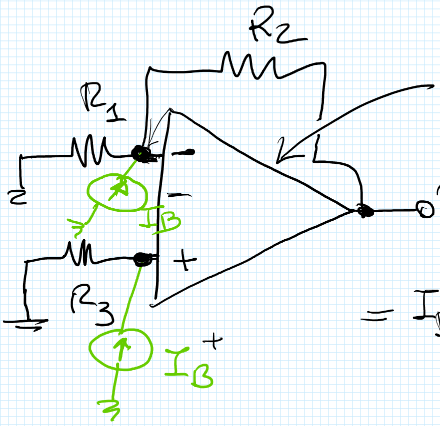
$$I_{OS} = \left| I_B^+ - I_B^- \right|$$ OFFSET DELLE CORRENTI DI BIAS





I_B^+ non dà contributo

Compensazione delle correnti di bias



opamp ~~reale~~ ideale

$$V_{out} = I_B^+ R_3 \left(1+\frac{R_2}{R_1}\right) - I_B^- R_2 = I_B \underbrace{\left[R_3\left(1+\frac{R_2}{R_1}\right) - R_2\right]}_{=0}$$

$I_B = |I_B^+| = |I_B^-|$

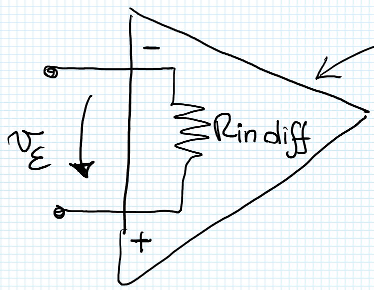
$$R_3 \frac{R_1+R_2}{R_1} - R_2 = 0$$

$$R_3 R_1 + R_3 R_2 = R_1 R_2$$

$$R_3 (R_1 + R_2) = R_1 R_2$$

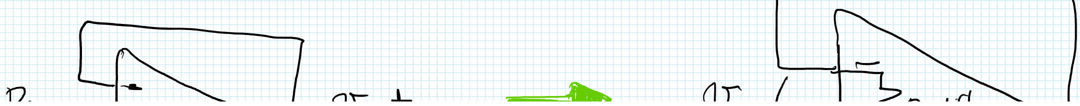
$$R_3 = R_1 /\!/ R_2$$

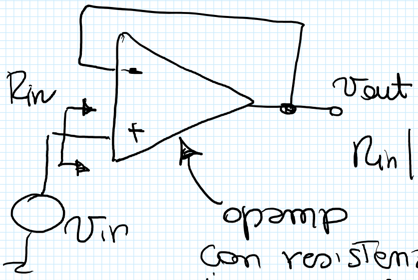
★ RESISTENZA DI INGRESSO FINITA



opamp reale con resistenza di ingresso finita

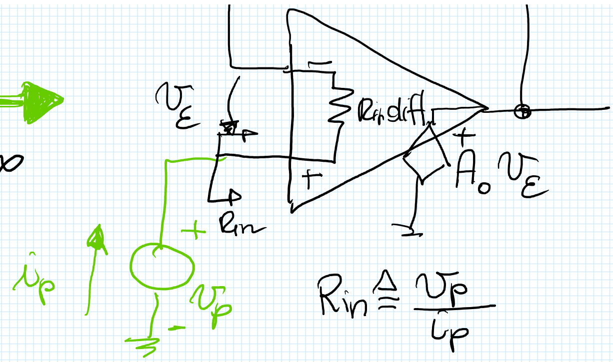
Calcolo della resistenza di ingresso di un buffer





$R_{in}|_{ideale} \to \infty$

opamp con resistenza di ingresso finita



$$R_{in} \triangleq \frac{v_p}{i_p}$$

RESISTENZA VISTA A RETROAZ. SPENTA $(A_0=0)$

$$R_{in} = R_{in}^{0} \left(1 - G_{loop}^{*}\right)$$

$$v_\varepsilon = v_p - A_0 v_\varepsilon$$

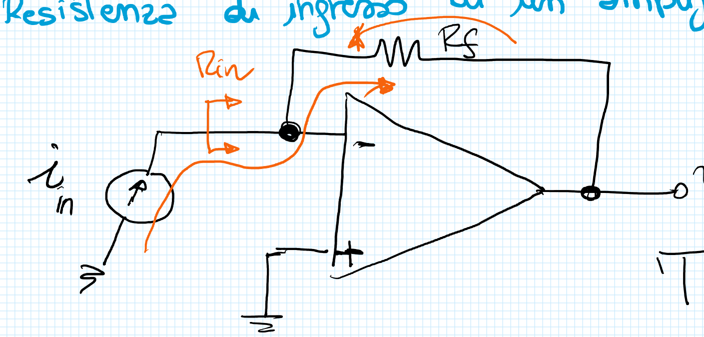
$$\hookrightarrow v_p = v_\varepsilon (1 + A_0) \Rightarrow v_\varepsilon = \frac{v_p}{1+A_0}$$

$$i_p = \frac{v_\varepsilon}{R_{in\,diff}} = \frac{v_p}{(1+A_0) R_{in\,diff}}$$

$$R_{in} \triangleq \frac{v_p}{i_p} = \frac{v_p}{\frac{v_p}{(1+A_0) R_{in\,diff}}} =$$

$$= \frac{R_{in\,diff}\,(1+A_0)}{[1-(-A_0)]}$$

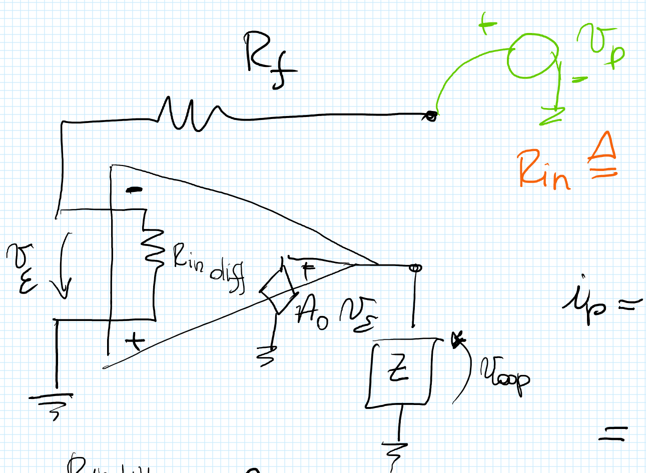
Resistenza di ingresso di un amplificatore a transimpedenza



$$v_{out} = -i_{in} R_f$$

$$T \triangleq \frac{v_{out}}{i_{in}} = -R_f$$

$$R_{in}|_{ideale} = 0$$



$$R_{in} \triangleq \frac{v_p}{i_p}$$

$$i_p = \frac{v_p}{R_{in\,diff}} + \frac{v_p - A_0 v_\varepsilon}{R_f} =$$

$$= \frac{v_p}{R_{in\,diff}} + \frac{v_p (1 + A_0)}{R_f} =$$

$$= v_p \left[\frac{1}{R_{in\,diff}} + \frac{(1+A_0)}{R_f}\right]$$

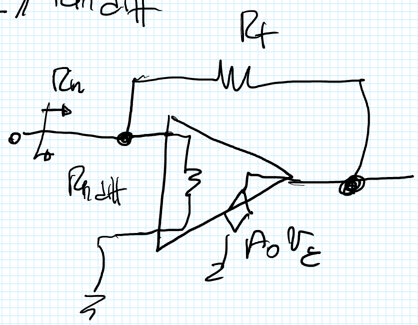
$$G_{loop} \triangleq -\frac{R_{in\,diff}}{R_{in\,diff} + R_f} A_0$$

$$R_{in\,diff} + R_f \qquad = v_p \left[\frac{\;}{R_{in\,diff}} + \frac{\;}{R_f} \right]$$

$$R_{in} \triangleq \frac{v_p}{v_p \left[\frac{1}{R_{in\,diff}} + \frac{(1+A_0)}{R_f} \right]} = R_{in\,diff} \,/\!/\, \frac{R_f}{1+A_0} =$$

$$= \frac{R_{in\,diff} \cdot \frac{R_f}{1+A_0}}{R_{in\,diff} + \frac{R_f}{1+A_0}} = \frac{R_{in\,diff} \cdot R_f}{R_f + R_{in\,diff} + R_{in\,diff} A_0} =$$

$$= \underbrace{\frac{R_{in\,diff} \cdot R_f}{(R_{in\,diff} + R_f)}}_{R_f /\!/ R_{in\,diff}} \cdot \frac{1}{1 - \left(- \frac{R_{in\,diff}}{R_{in\,diff} + R_f} A_0 \right)} = \boxed{\frac{R_{in}^0}{1 - G_{loop}^*}}$$



METODO DI CALCOLO DELLA RESISTENZA IN CIRCUITO RETROAZIONATO

1. Quanto vale la resistenza ideale? (nelle hp di G_{loop} infinito)

$R \to \infty$	$R \to 0$
• La retroazione sta controllando la corrente nel ramo	• La retroazione sta controllando la tensione del nodo

2. Applico un opportuno generatore di prova

• gen. di tensione	• gen di corrente

3. Calcolo la resistenza vista A RETROAZIONE SPENTA $(A_0 = 0)$ (R^0)

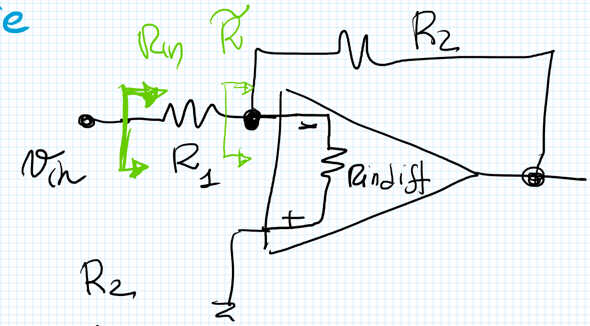
4. Calcolo il G_{loop}^* della configurazione con il gen. di prova

5. La resistenza vista è data:

$$R = R^0 \left(1 - G_{loop}^*\right) \qquad \Bigg| \qquad R = \frac{R^0}{1 - G_{loop}^*}$$

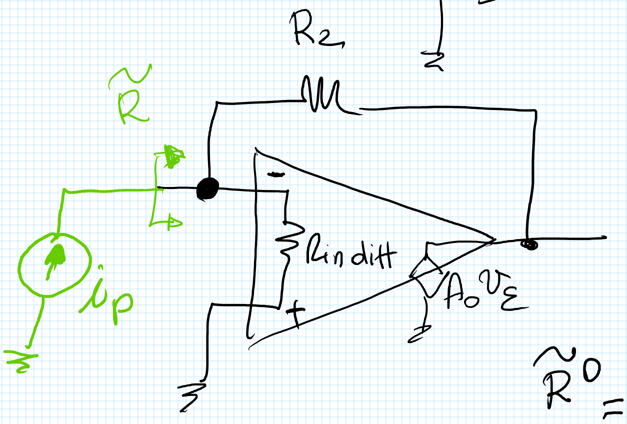
$$R = R^0 \left(1 - G^*_{loop}\right) \quad \Big| \quad R = \frac{\quad}{1 - G_{loop}^*}$$

Calcolo la resistenza di ingresso di una configurazione invertente



$$R_{in}\Big|_{ideale} = R_1 + 0$$

$$R_{in} = R_1 + \tilde{R}$$



$$\tilde{R}\Big|_{ideale} \to 0$$

$$\tilde{R} = \frac{\tilde{R}^0}{1 - G^*_{loop}}$$

$$\tilde{R}^0 = R_{in\,diff} \,//\, R_2$$

$$G^*_{loop} = -\frac{R_{in\,diff}}{R_{in\,diff} + R_2} A_0$$