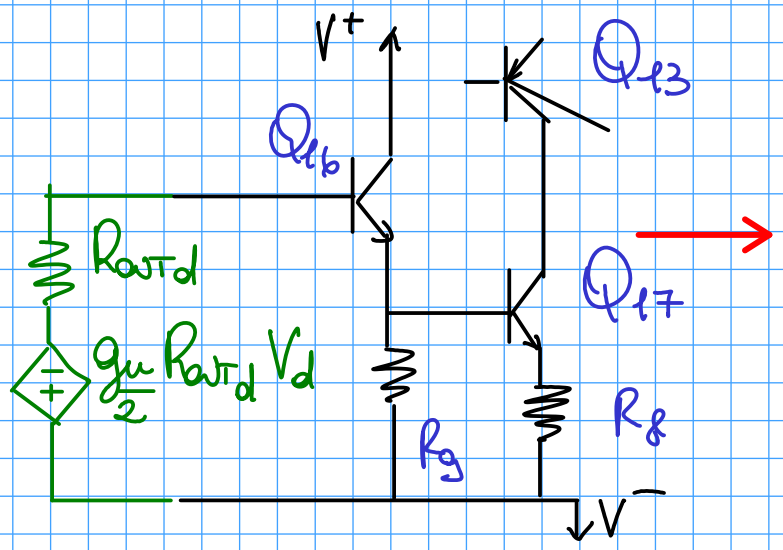
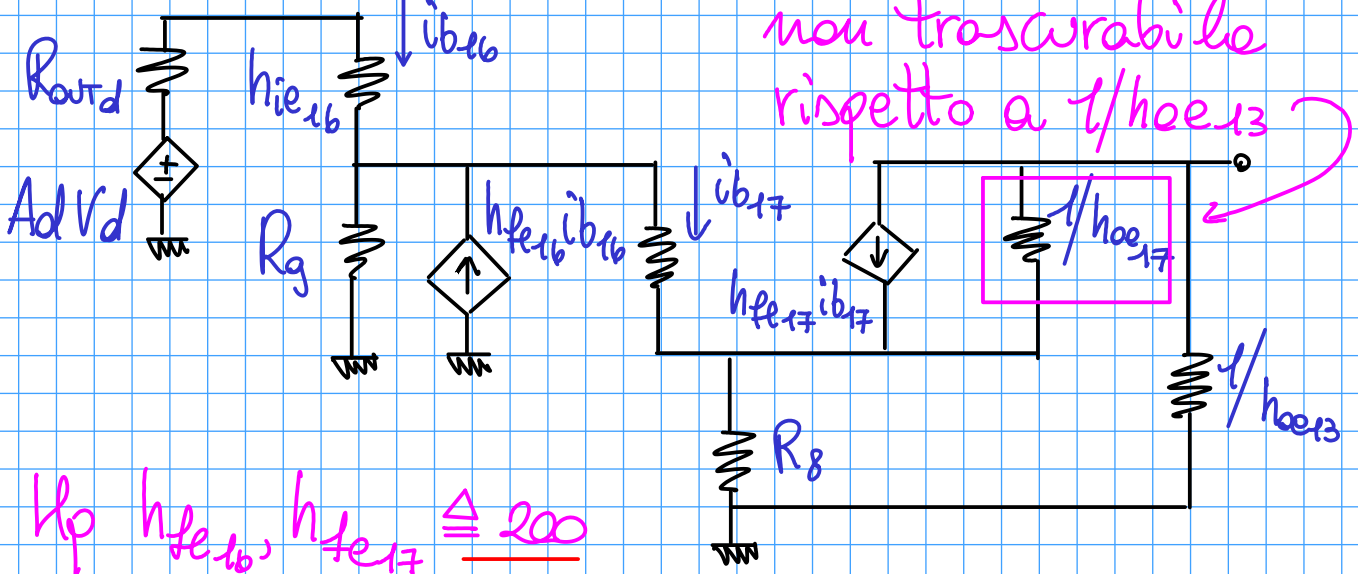
Stadio di guadagno

5 NOV

riporto stadio di ingresso con equivalente di Thevenin



circuito alle variazioni



non trascurabile rispetto a $1/h_{oe_{13}}$

Hp $h_{fe_{16}}, h_{fe_{17}} \triangleq 200$

$$h_{ie_{16}} \cong r'_{be_{16}} = \frac{V_T}{I_{C_{16}}} h_{fe_{16}}$$

$$I_{C_{16}} = I_{300} \beta_T = 117\,\mu A \cdot 120 = 14\,\mu A$$

$$h_{ie_{16}} = 371\,K\Omega$$

$$h_{ie_{17}} = \frac{V_T}{I_{C_{17}}} h_{fe_{17}} = 8{,}67\,K\Omega$$

$$I_{C_{17}} = 115\,\mu A$$

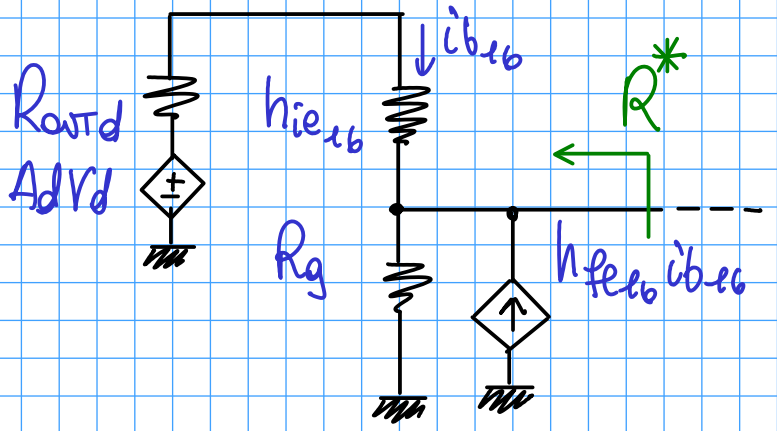
⚠ calcolata considerando solo stadio ingresso ($R_{in_{16}} \to \infty$)

con $A_d = -\frac{g_m}{2} R_{out} V_d = -1104$

$R_{out_d} = 6{,}04\,M\Omega$

stadio differenziale ingresso

guadagno Q_{16} con carico R_g, come se Q_{17} fosse interdetto



$$A_{V_{16}} = \frac{(h_{fe_{16}}+1) R_g \, i b_{16}}{A_d V_d}$$

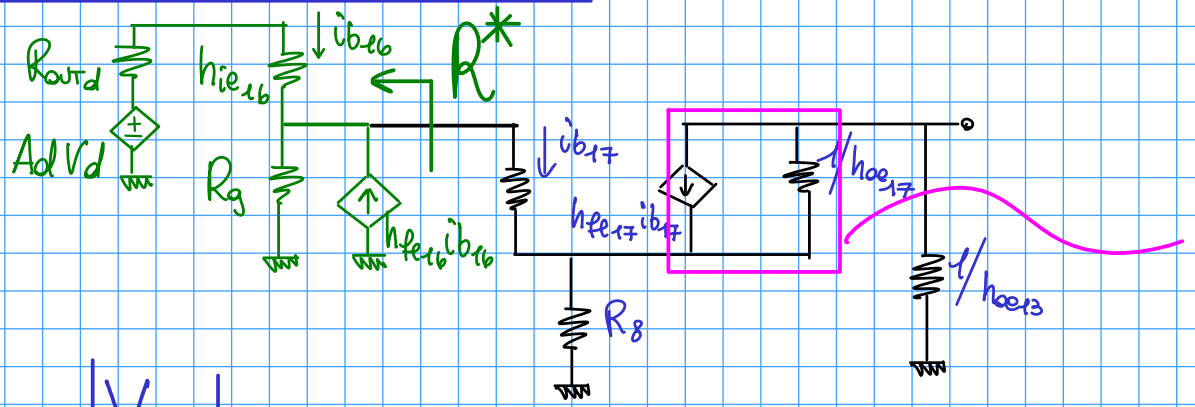
$$i b_{16} = - \frac{A_d V_d}{R_{out_d} + (h_{fe_{16}}+1) R_g + h_{ie_{16}}}$$

riunisco:

$$A_{V_{16}} = - \frac{(h_{fe_{16}}+1) R_g}{R_{out_d} + h_{ie_{16}} + (h_{fe_{16}}+1) R_g} = -0,61 \rightarrow \boxed{A_{V_{16}} = -0,61}$$

$$R^* = R_g \,/\!/\, \frac{h_{ie_{16}} + R_{out_{16}}}{h_{fe_{16}} + 1} = 19,5 \; K\Omega$$

CALCOLO GUADAGNO Q_{17}

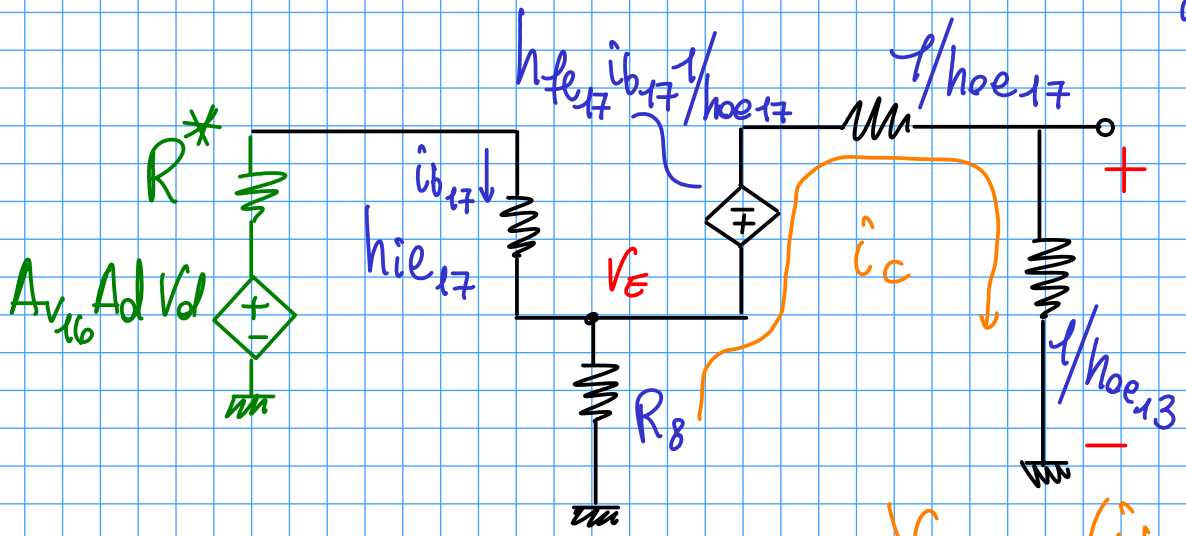


$R^* = 19{,}5\ K\Omega$

equivalente di thevenin stadio Q_{17}

$$1/h_{oe_{17}} = \frac{|V_{A_n}|}{I_{C_{17}}} = \frac{100\ V}{600\ \mu A} = 166{,}67\ K\Omega$$

$$1/h_{oe_{16}} = 83{,}33\ K\Omega$$



$$\begin{cases} i_C = \dfrac{V_E - h_{fe_{17}} i_{b_{17}} 1/h_{oe_{17}}}{1/h_{oe_{17}} + 1/h_{oe_{16}}} & (1) \\ i_{b_{17}} = \dfrac{A_{V_1} A_d V_d - V_E}{R^* + h_{ie_{17}}} & (2) \end{cases}$$

$$V_E = (i_{b_{17}} - i_C) R_8 \quad (3)$$

$$V_4 = \frac{i_C}{h_{oe}}$$

sostituisco V_E a ①

$$i_c = \frac{R_8 i_{b_{17}} - h_{fe_{17}} i_{b_{17}} 1/h_{oe_{17}}}{1/h_{oe_{17}} + 1/h_{oe_{16}} + R_8}$$

sostituisco in i_c in ③

$$V_E = (i_{b_{17}} - i_c) R_8 = i_{b_{17}} \left(1 + \frac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{16}} + R_8}\right) R_8$$

sostituisco "nuova" V_E in ② → e ricavo $i_{b_{17}}$

$$i_{b_{17}} (R^* + h_{ie_{17}}) = A_{V_{16}} A_d V_d - V_E$$

$$i_{b_{17}} = \frac{A_{V_{16}} A_d V_d}{h_{ie_{17}} + R^* + R_8 + R_8 \dfrac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{13}} + R_8}}$$

a questo punto sostituisco $i_{b_{17}}$ nella 1ª

$$i_c = \frac{A_{v_{16}} A_d V_d \dfrac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{13}} + R_8}}{h_{ie_{17}} + R^* + R_8 + R_8 \dfrac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{13}} + R_8}}$$

quindi, per concludere:

con $V_u = \dfrac{i_c}{h_{oe_{13}}}$

$$\frac{V_u}{V_d} = \frac{\dfrac{A_{v_{16}} A_d}{h_{oe_{13}}} \dfrac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{13}} + R_8}}{h_{ie_{17}} + R^* + R_8 + R_8 \dfrac{h_{fe_{17}} 1/h_{oe_{17}} - R_8}{1/h_{oe_{17}} + 1/h_{oe_{13}} + R_8}}$$

($<\emptyset$ sul primo termine, $<\emptyset$ sul secondo)

~ 180.000 !

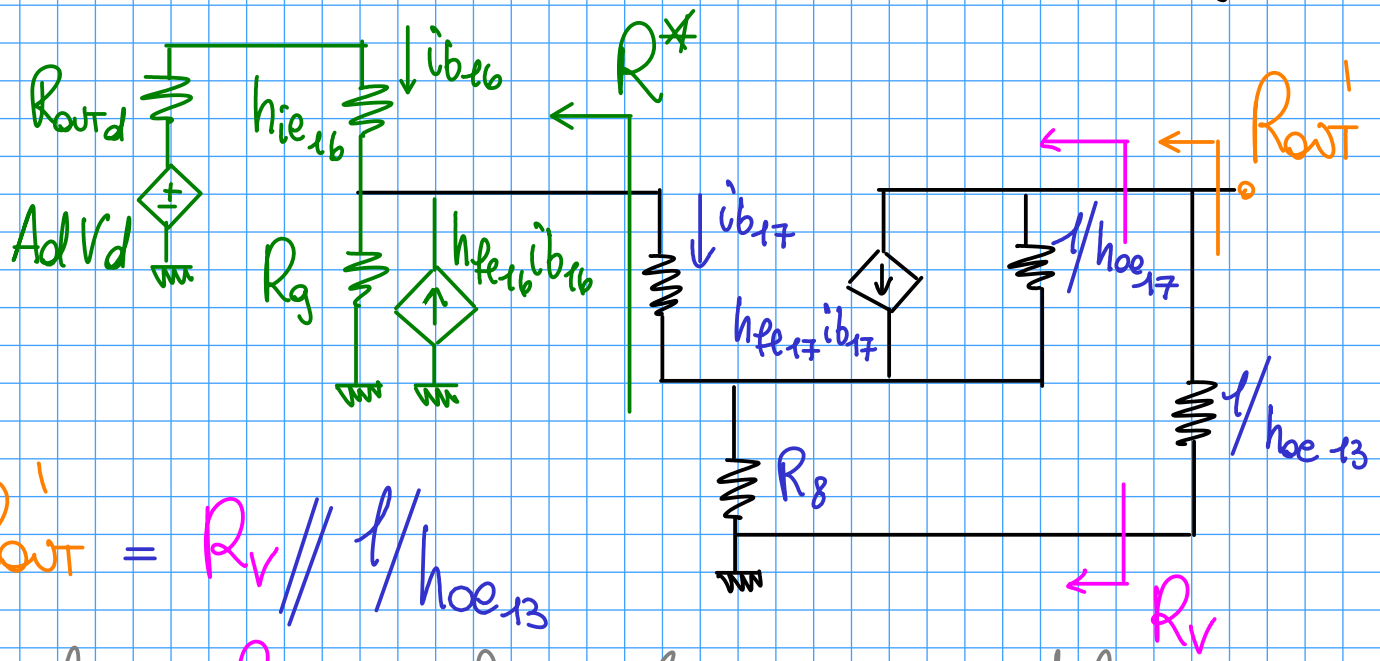
guadagno complessivo (ingresso + guadagno)

stadio di guadagno $\longrightarrow$ invertente

nota guadagno netto stadio $\longrightarrow A_{dor} = \dfrac{V_u}{A_d V_d} = \dfrac{180000}{-1104} = \boxed{-163}$

trascurando la $1/h_{oe_{17}}$ si sarebbe commesso un errore del 33%!

Resistenza di uscita dello stadio di guadagno (Q_{16}–Q_{17})



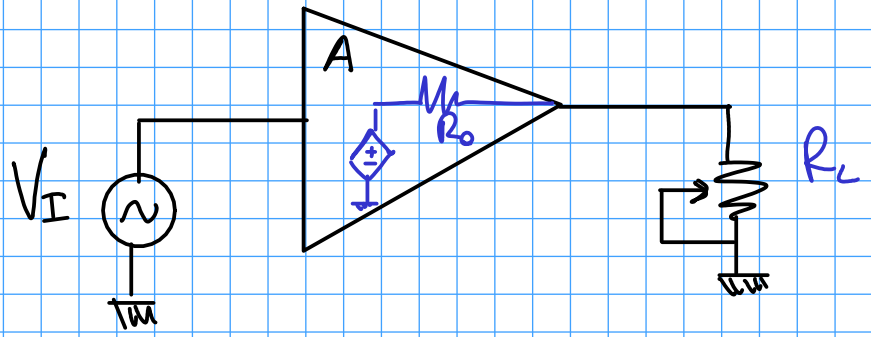
$$R_{OUT}' = R_V \,//\, 1/h_{oe_{13}}$$

sviluppo R_V con formula arcana sublime

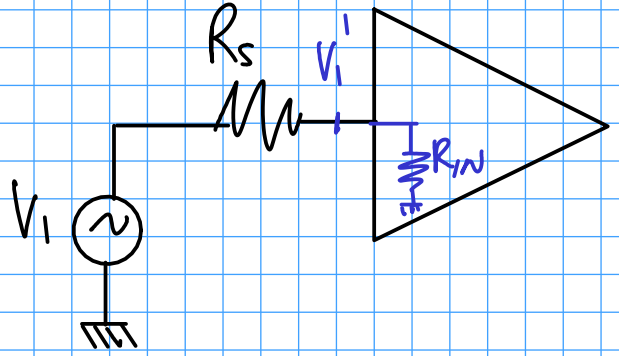
$$R_o \cong \left[\frac{h_{fe} R_E}{h_{ie} + R_x + R_E} + 1 \right] \frac{1}{h_{oe}}$$

$$R_{OUT}' = \frac{1}{h_{oe_{13}}} \,//\, \left[\frac{1}{h_{oe_{17}}} \left(1 + \frac{R_8 h_{fe}}{R_8 + h_{ie_{17}} + R^*} \right) \right] = 64{,}46\ K\Omega$$

COME MISURO PRATICAMENTE Z_{IN} E Z_{OUT} DI UN AMPLIFICATORE?



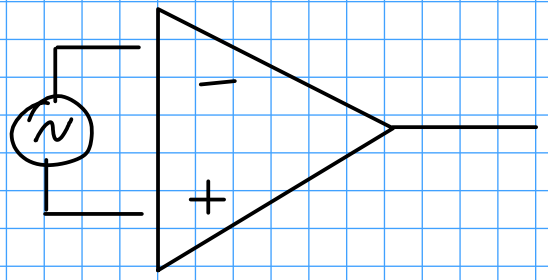
$$V_u = A V_I \frac{R_L}{R_o + R_L} \longrightarrow R_o$$



$$V_i' = V \frac{R_{IN}}{R_{IN} + R_s} \longrightarrow \text{TROVO } R_{IN}$$

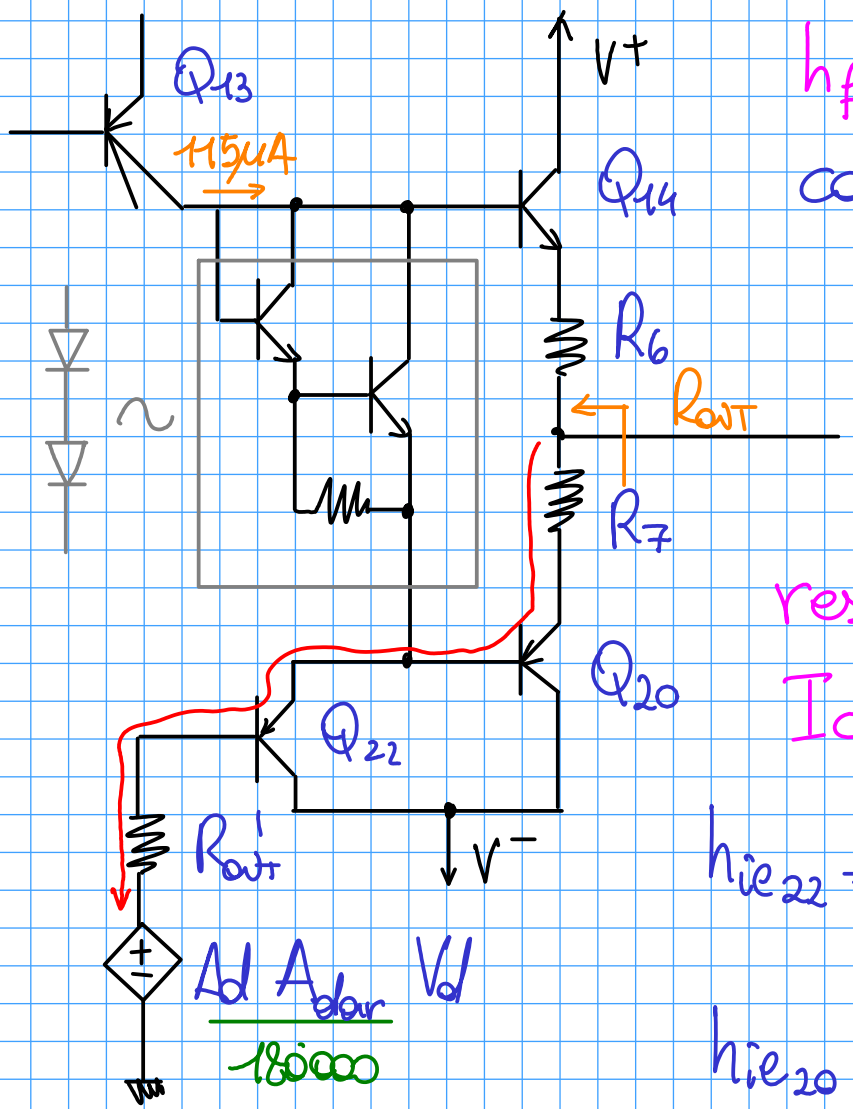
V_i' ↑ MISURATA

NEL CASO UTILIZZO UN OPERAZIONALE



stadio di uscita

Hp simmetria attorno all'uscita
(ipotesi "quasi" vera)



$h_{fe20}, h_{fe22} = 120$

calcoliamo la resistenza di uscita

$$R_{OUT} = R_7 + \frac{h_{ie20} + \frac{h_{ie22} + R'_{OUT}}{h_{fe22} + 1}}{h_{fe20} + 1}$$

restano da calcolare h_{ie20}, h_{ie22}

$I_{C13} \approx I_{C22} = 115\,\mu A$ trascuro i_{b14}, i_{b20}

$$h_{ie22} = \frac{V_T}{I_{C22}} h_{fe22} = 27{,}13\,K\Omega$$

$h_{ie20} = 3{,}12\,K\Omega$

$R_7 = 27\,\Omega$

schema fornito indica 22Ω, ma calcoli professore utilizzano $R_6 = R_7 = 22\,\Omega$

$$R_{OUT} = 59\,\Omega$$