

FONAMENTI DI ELETTRONICA

Ingegneria Informatica – Corso in Teledidattica

AA 2006/2007 - Prof. Gaudenzio Meneghesso

TERZO HOMEWORK

ESERCIZIO

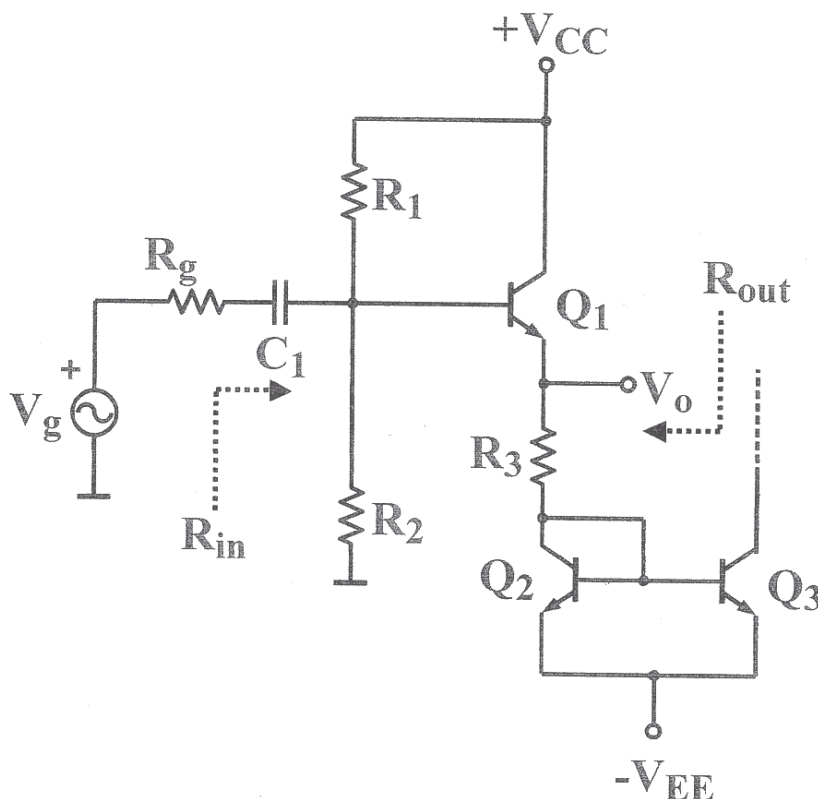
Il circuito riportato in figura rappresenta una parte di un amplificatore (il collettore di Q_3 è connesso ad una parte del circuito non mostrata in figura), i cui parametri sono i seguenti (a 25°C):

$$V_{CC} = V_{EE} = 15 \text{ V}, R_g = 10 \text{ k}\Omega, R_1 = 100 \text{ k}\Omega, R_2 = 22 \text{ k}\Omega, R_3 = 0.8 \text{ k}\Omega,$$

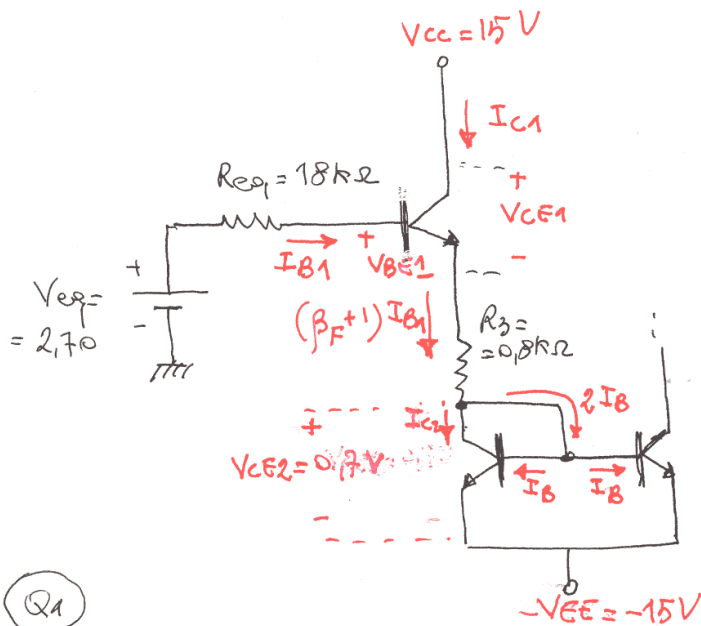
nnp BJT Q_1, Q_2, Q_3 : $V_{BE} = 0.7 \text{ V}$, $\beta_F = \beta_0 = 100$, Tensione di Early $V_A = 100 \text{ V}$

Determinare:

1. i punti di lavoro di Q_1 (V_{CE1} , I_{C1}) e Q_2 (V_{CE2} , I_{C2}) trascurando l'effetto Early;
2. il guadagno di tensione $A_V = V_o/V_g$ a centro banda (Considerando l'effetto Early);
3. la resistenza d'ingresso R_{in} indicata in figura;
4. la resistenza di uscita R_{out} indicata in figura.



1) POLARIZZAZIONE



$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{100 \cdot 22}{100 + 22} \approx 18 \text{ k}\Omega$$

$$V_{eq} = V_{cc} \cdot \frac{R_2}{R_1 + R_2} = \frac{15 \cdot 22}{100 + 22} \approx 2.70 \text{ V}$$

$$V_{eq} - (V_{CE2} + (-V_{EE})) - V_{BE1} = R_{eq} I_{B1} + R_3 (\beta_F + 1) I_{B1}$$

$$I_{B1} = \frac{V_{eq} - (V_{CE2} + (-V_{EE})) - V_{BE1}}{R_{eq} + (\beta_F + 1) I_{B1} R_3}$$

$$= \frac{2.7 - (0.7 - 15) - 0.7}{18 + (100 + 1) \cdot 0.8} \approx 0.165 \text{ mA} = 165 \mu\text{A}$$

$$I_{C1} = \beta_F I_{B1} = 100 \cdot 0.165 = 16.5 \text{ mA}$$

$$V_{CE1} = V_{cc} - (V_{CE2} + (-V_{EE})) - R_3 (\beta_F + 1) I_{B1}$$

$$= 15 - (0.7 + (-15)) - 0.8 (100 + 1) \cdot 0.165 \approx 15.97 \text{ V}$$

Q2

$$(\beta_F + 1) I_{B1} = I_{C2} + 2 I_B = I_{C2} + 2 \frac{I_{C2}}{\beta_F} = \frac{\beta_F + 2}{\beta_F} I_{C2}$$

$$I_{C2} = \frac{\beta_F}{\beta_F + 2} \cdot (\beta_F + 1) I_{B1} = \frac{100}{100 + 2} (100 + 1) 0.165 = 16.34 \text{ mA}$$

$$V_{CE2} = V_{BE2} = 0.7 \text{ V}$$

PICCOLI SEGNALI

Q1

$$g_{m1} = \frac{I_{C1}}{V_T} = \frac{16.5}{25 \cdot 10^{-3}} = 660 \frac{\text{mA}}{\text{V}}$$

$$r_{\pi 1} = \frac{\beta_0}{g_{m1}} = \frac{100}{660} \approx 151 \Omega$$

$$r_{o1} = \frac{V_{CE1} + V_A}{I_{C1}} = \frac{15.97 + 100}{16.5} \approx 7 \text{ k}\Omega$$

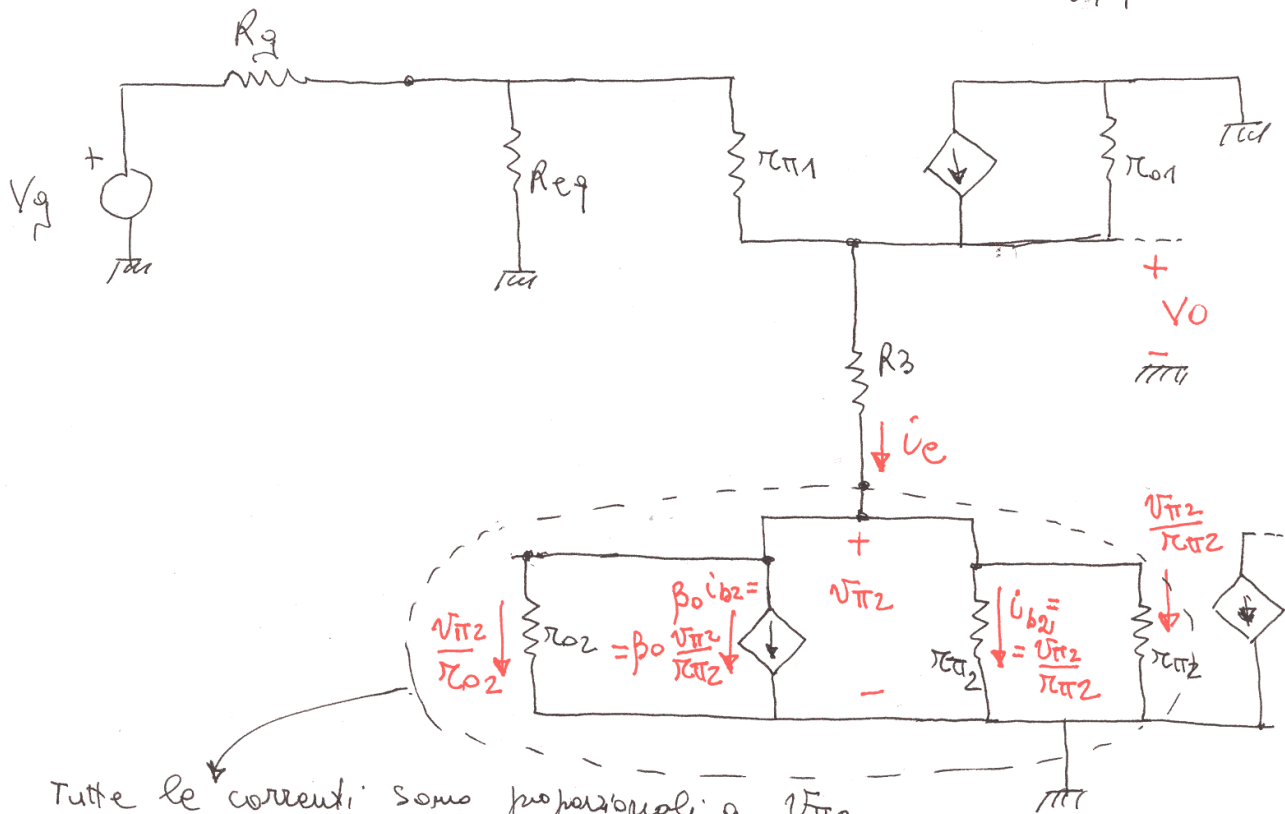
Q2

$$g_{m2} = \frac{I_{C2}}{V_T} = \frac{16.34}{25 \cdot 10^{-3}} = 654 \frac{\text{mA}}{\text{V}}$$

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$$r_{\pi 2} = \frac{\beta_0}{g_{m2}} = \frac{100}{634} \approx 158 \Omega$$

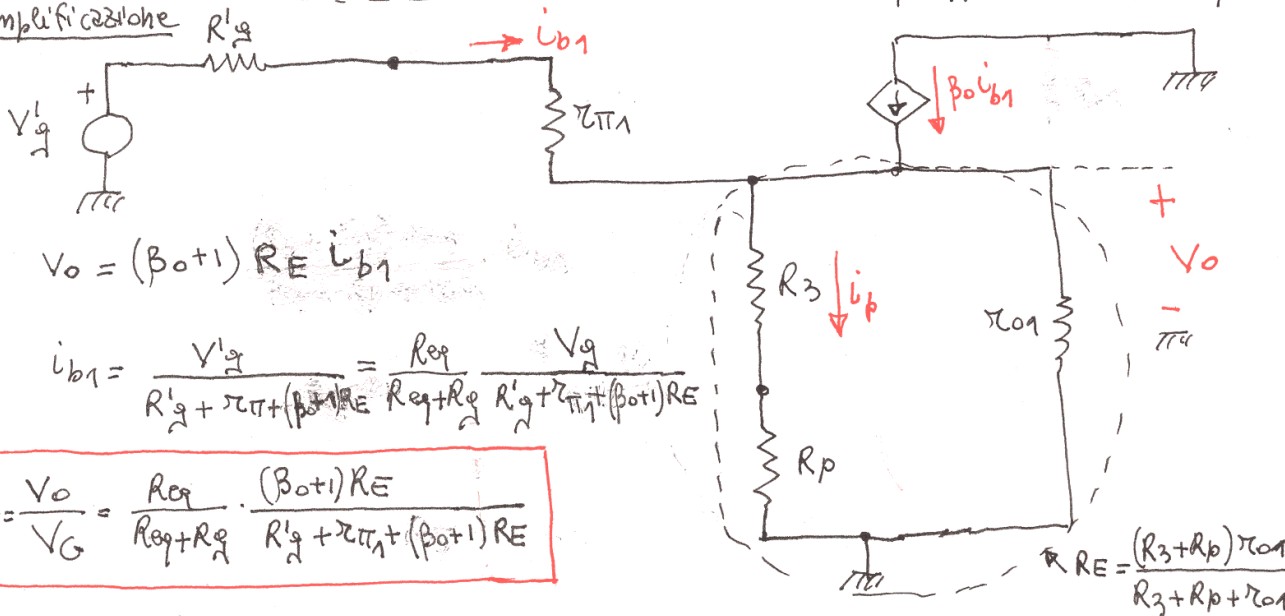
$$r_{o2} = \frac{V_{CE2} + V_A}{I_{C2}} = \frac{0.7 + 100}{16.34} \approx 6.16 \text{ k}\Omega$$



$$R_p = \frac{V_{\pi 2}}{i_e} = \frac{V_{\pi 2}}{\frac{V_{\pi 2}}{r_{o2}} + \beta_0 \frac{V_{\pi 2}}{r_{\pi 2}} + \frac{V_{\pi 2}}{r_{\pi 2}} + \frac{V_{\pi 2}}{r_{\pi 2}}} = \frac{1}{\frac{1}{r_{o2}} + \frac{\beta_0}{r_{\pi 2}} + \frac{2}{r_{\pi 2}}}$$

$$= \frac{1}{\frac{1}{6,16} + \frac{100}{158} + \frac{2}{158}} \approx 1,55 \, \Omega$$

2) Amplificazione $R'_g = \frac{R_g R_{eq}}{R_g + R_{eq}}$ (T. Thev) $V'_g = V_g \frac{R_{eq}}{R_{eq} + R_g}$ $R'_g = \frac{R_g R_{eq}}{R_g + R_{eq}}$



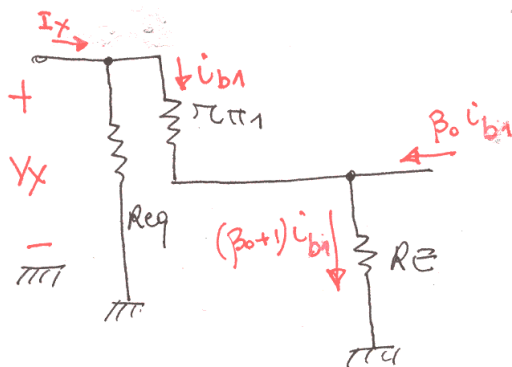
$$R_E = \frac{(R_3 + R_P) r_{o1}}{R_3 + R_P + r_{o1}} = \frac{(800 + 1,55) \cdot 7000}{800 + 1,55 + 7000} \approx 719 \, \Omega \quad 4/4$$

$$R'_g = \frac{R_g \cdot R_{eq}}{R_g + R_{eq}} = \frac{10 \cdot 18}{10 + 18} \approx 6,43 \, k\Omega$$

$$A_v = \frac{V_o}{V_g} = \frac{R_{eq}}{R_{eq} + R_g} \cdot \frac{(\beta_0 + 1) R_E}{R'_g + r_{\pi 1} + (\beta_0 + 1) R_E} = \frac{18}{18 + 10} \cdot \frac{(100 + 1) \cdot 0,719}{6,43 + 0,151 + 0,719 \cdot 101}$$

$$= 0,589$$

3) Resistenza di ingresso

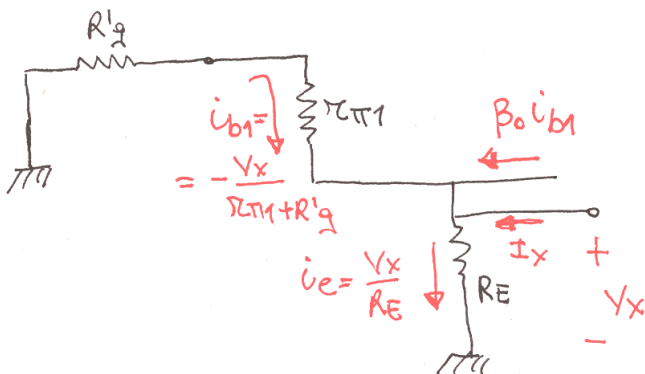


$$R_{in} = \frac{V_x}{I_x} = r_{\pi 1} + R_E (\beta_0 + 1) \parallel R_{eq}$$

$$= \frac{(0,151 + 0,719 \cdot 101) \cdot 18}{0,151 + 0,719 \cdot 101 + 18}$$

$$= 14,43 \, k\Omega$$

4) Resistenza di uscita



$$R_{out} = \frac{V_x}{I_x}$$

$$= \frac{V_x}{\frac{V_x}{R_E} - \left(-\frac{V_x}{r_{\pi 1} + R'_g} \right) (\beta_0 + 1)}$$

$$= \frac{1}{\frac{1}{R_E} + \frac{1}{r_{\pi 1} + R'_g}}$$

$$R_{out} = \frac{R_E (r_{\pi 1} + R'_g)}{(\beta_0 + 1) R_E + r_{\pi 1} + R'_g} = \frac{0,719 (0,151 + 6,43)}{(100 + 1) \cdot 0,719 + 0,151 + 6,43}$$

$$= 59,74 \, \Omega$$