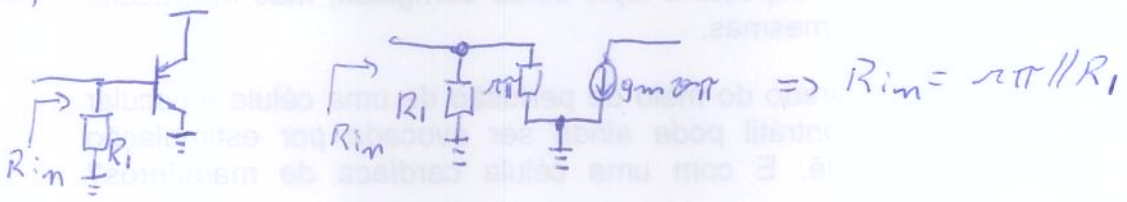
RAZAVI (5.5, 5.6, 5.9b, 5.13, 5.17, 5.38d, 5.47b, 5.52, 5.55, 5.58, 5.63, 5.68, 5.71, 5.72, 5.73)

CAP 5

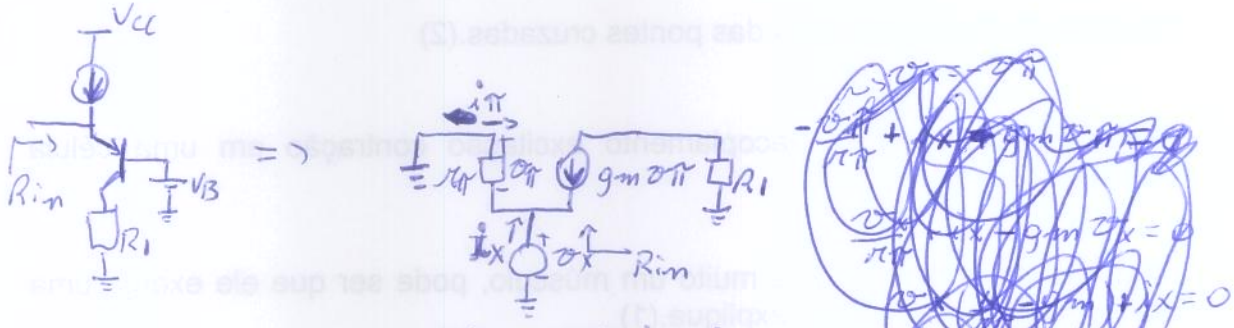
5.5 $V_A = \infty$, Z_{in}?

a)



$\Rightarrow R_{in} = r_\pi \parallel R_1$

b)



$i_\pi + g_m v_\pi + i_x = 0$

$\frac{v_\pi}{r_\pi} + g_m v_\pi + i_x = 0$

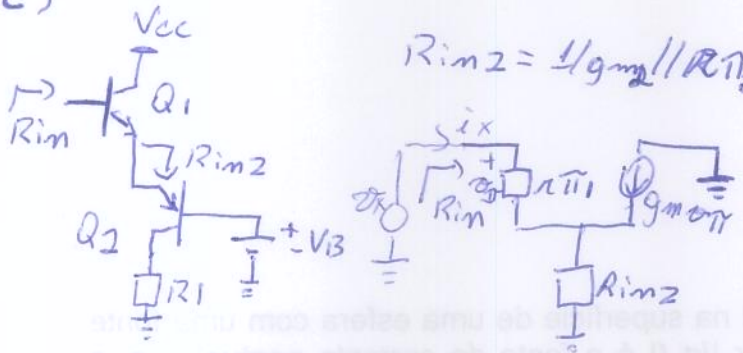
$v_\pi \cdot \left(\frac{1}{r_\pi} + g_m\right) = -i_x$

$-v_x$

$-v_x\left(\frac{1}{r_\pi} + g_m\right) = -i_x \Rightarrow R_{in} = \frac{v_x}{i_x} = \frac{1}{\left(g_{m1} + \frac{1}{r_\pi}\right)}$

$R_{in} = \frac{1}{g_m} \parallel r_\pi$

c)



$R_{in2} = 1/g_{m2} \parallel R_{\pi 2}$

$v_x = v_{\pi_1} + \left(\frac{v_{\pi_1}}{r_{\pi_1}} + g_m v_{\pi_1}\right) \cdot R_{in2}$

$v_x = v_{\pi_1}\left[1 + \left(\frac{1}{r_{\pi_1}} + g_m\right) R_{in2}\right]$

$v_\pi = r_{\pi_1} \cdot i_x$

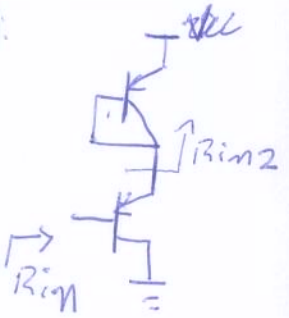
$v_x = r_{\pi_1} \cdot i_x \cdot \left[1 + \left(\frac{1}{r_{\pi_1}} + g_m\right) R_{in2}\right]$

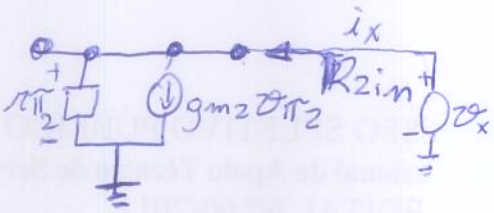
$R_{in} = \frac{v_x}{i_x} = r_{\pi_1}\left[\left(\frac{1}{r_{\pi_1}} + g_m\right) \cdot R_{in2}\right] = (1 + r_{\pi_1} g_m R_{in2})$ β_1

$R_{in} = \frac{v_x}{i_x} = r_{\pi_1}\left[1 + \left(\frac{1}{r_{\pi_1}} + g_m\right) R_{in2}\right] = r_{\pi_1} + \left(\frac{1}{r_{\pi_1}} + g_m\right) R_{in2}\, r_{\pi_1}$

$R_{in} = r_{\pi_1} + \left(1 + \underbrace{r_{\pi_1} g_{m1}}_{\beta}\right) R_{in2} \Rightarrow \boxed{R_{in} = r_{\pi_1} + (1+\beta) \cdot \left(\frac{1}{g_{m2}} \parallel r_{\pi 2}\right)}$

d)



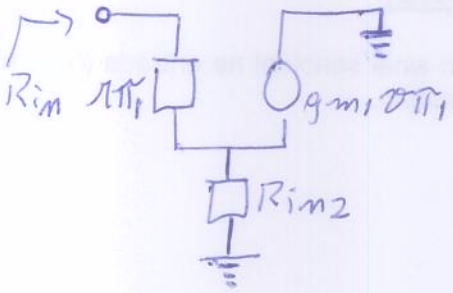


$$i_x = g_{m2} v_{\pi 2} + \frac{v_x}{r_{\pi 2}}$$

$$i_x = g_{m2} v_x + \frac{v_x}{r_{\pi 2}}$$

$$R_{in2} = \frac{v_x}{i_x} = \frac{1}{g_{m2} + \frac{1}{r_{\pi 2}}} = \boxed{\frac{1}{g_{m2}} \,//\, r_{\pi 2}}$$

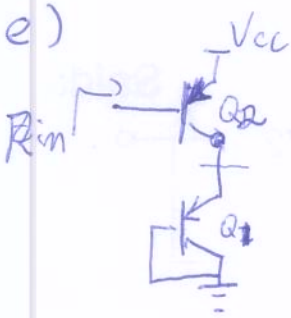
R_{in2}

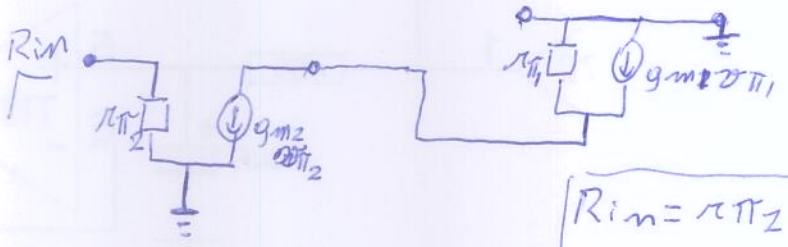


mesmo caso anterior

$$\boxed{R_{in} = r_{\pi 1} + (1+\beta) \cdot \left(\frac{1}{g_{m2}} \,//\, r_{\pi 2}\right)}$$

e)

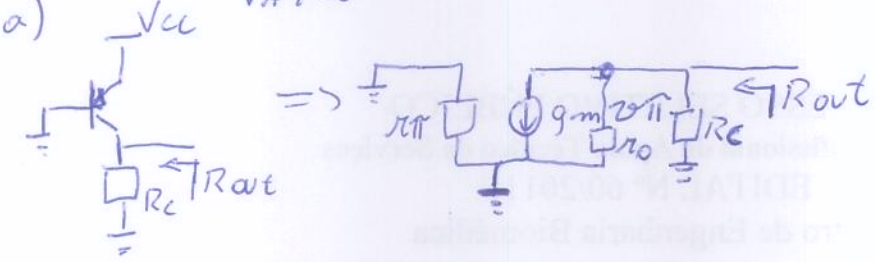




$$\boxed{R_{in} = r_{\pi 2}}$$

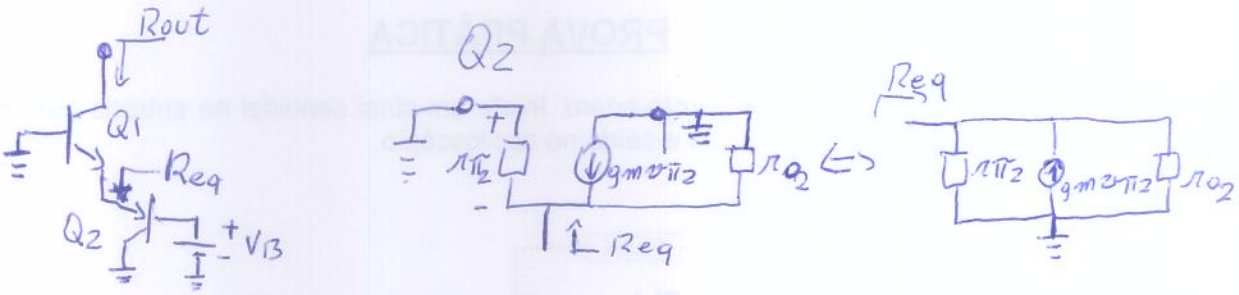
5.6

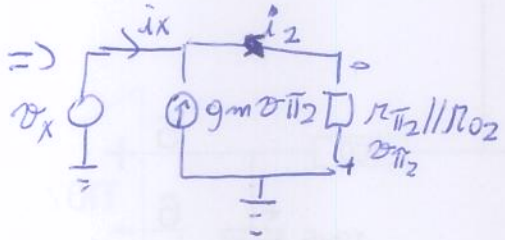
a) $V_A \neq \infty$



$R_{out} = R_c \| r_o$

b)





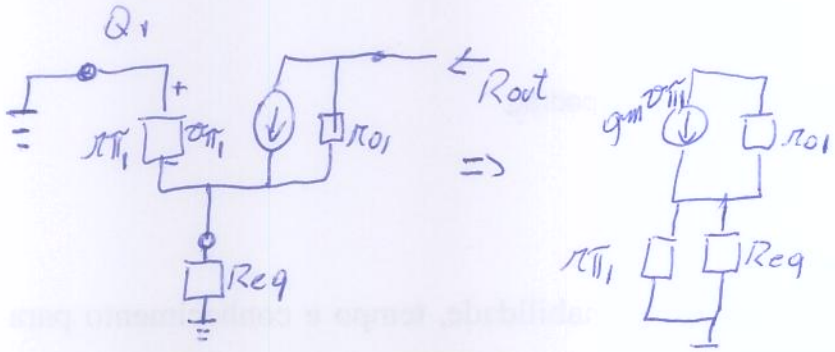
$i_x + g_m v_{\pi 2} + i_2 = 0$

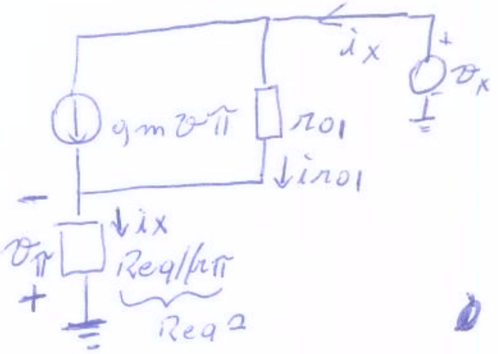
$i_x + g_m v_{\pi 2} + \frac{v_{\pi 2}}{r_{\pi 2} \| r_{o2}} = 0$

$i_x = -v_{\pi 2}\left(g_m + \frac{1}{r_{\pi 2} \| r_{o2}}\right)$, $v_{\pi 2} = v_x$

$i_x = v_x\left(g_m + \frac{1}{r_{o2} \| r_{\pi 2}}\right)$

$\Rightarrow \frac{v_x}{i_x} = \boxed{R_{eq} = \frac{1}{g_{m2}} \| r_{\pi 2} \| r_{o2}}$





$i_x = g_{m1} v_\pi + i_{r o1}$

$$\begin{cases} i_x = g_{m1} v_\pi + \dfrac{v_x + v_{\pi1}}{r_{o1}} \\ i_x = -\dfrac{v_\pi}{R_{eq2}} \Rightarrow v_\pi = -i_x r_{\pi1} \end{cases}$$

~~$i_x = -\frac{i_x r_\pi g_{m1}}{R_{eq2}} + \frac{v_x - i_x R_{eq2}}{r_{o1}}$~~

~~$i_x = -i_x \frac{R_{eq}}{R_{eq2}} g_{m1} + \frac{v_x}{r_{o1}} - i_x \frac{R_{eq2}}{r_{o1}} \Rightarrow i_x (1 + \ldots$~~

$$i_x = -g_{m1} i_x R_{eq2} + \frac{v_x - i_x R_{eq2}}{r_{o1}}$$

$$i_x = -g_{m1} i_x R_{eq2} + \frac{v_x}{r_o} - i_x \frac{R_{eq2}}{r_o}$$

$$i_x \cdot \left(g_{m1} R_{eq2} + \frac{R_{eq2}}{r_{o1}} + 1\right) = \frac{v_x}{r_{o1}}$$

$$R_{out} = \frac{v_x}{i_x} = r_{o1} \cdot \left(1 + R_{eq2} \cdot \left(g_{m1} + \frac{1}{r_{o1}}\right)\right)$$

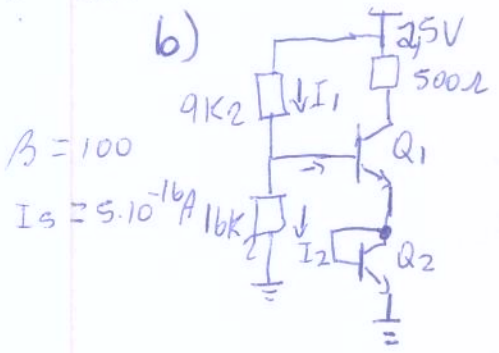
$$R_{out} = r_{o1} + r_{o1} R_{eq2} \left(g_{m1} + \frac{1}{r_o}\right)$$

$$R_{out} = r_{o1} + R_{eq2} \cdot \left(g_{m1} r_{o1} + 1\right)$$

$$\boxed{R_{out} = r_{o1} + (1 + g_{m1} r_{o1})\, r_{\pi1} // \frac{1}{g_{m2}} // r_{\pi2} // r_{o2}}$$

5.9

b)



$I_{E1} = I_{E2}$

$\Rightarrow I_{C1} = I_{C2} \Rightarrow \begin{cases} V_{BE1} = V_{BE2} \\ I_{B1} = I_{B2} \end{cases}$

$$I_{B1} = I_1 - I_2 = \frac{V_{CC} - 2V_{BE}}{9.10^3} - \frac{2V_{BE}}{16.10^3}$$

$$I_{C1} = \beta I_{B1} = \beta \cdot \left(\frac{V_{CC} - 2V_{BE}}{9.10^3} - \frac{2V_{BE}}{16.10^3} \right)$$

$$I_{C1} = \beta \cdot \left(\frac{V_{CC} - 2V_T \ln I_C/I_S}{9.10^3} - \frac{2V_T \ln I_C/I_S}{16.10^3} \right)$$

$$I_{C1} - \beta \left(\frac{V_{CC} - 2V_T \ln I_C/I_S}{9.10^3} - \frac{2V_T \ln I_C/I_S}{16.10^3} \right) = \emptyset$$

$$I_{C1} - \frac{\beta V_{CC}}{9.10^3} + \frac{2\beta V_T \ln(I_C/I_S)}{9.10^3} + \frac{2\beta V_T \ln I_C/I_S}{16.10^3} = 0$$

$$I_C - \frac{\beta V_{CC}}{9.10^3} + \frac{18}{} \frac{32\beta V_T \ln I_C/I_S + 18\beta V_T \ln I_C/I_S}{9.16.10^6} = \emptyset$$

$$I_C - \frac{\beta V_{CC}}{9.10^3} + \frac{50\beta V_T \ln I_C/I_S}{9.16.10^6} = \emptyset$$

⇓ Calculo numérico

$$\boxed{I_C \tilde{=} 1{,}72\,mA}$$

$V_{BE} \tilde{=} V_{BE1} = V_{BE2} = V_T \ln I_C/I_S \Rightarrow V_{BE} = 751\,mV$

$V_{CE2} = V_{BE} \tilde{=} 751\,mV$

$V_{CE1} = 2{,}5 - 500 I_C - V_{CE2} \Rightarrow V_{CE1} = 840\,mV$

$V_{B1} \tilde{=} 2 . V_{BE} = 1{,}502\,V$

$V_{C1} = 2{,}5 - 500 I_C = 1{,}64\,V$ $\Rightarrow V_{C1} > V_{B1} \Rightarrow Q_1$ modo Activo

Q_2 próximo a saturação

5.9 b) Resolução iterativa

① $V_{BE} = 0,7$

$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right) \Rightarrow I_C = 2,4633 \cdot 10^{-4} A$

$I_B = \frac{V_{CC} - 2V_{BE}}{9 \cdot 10^3} - \frac{2V_{BE}}{16 \cdot 10^3} \Rightarrow I_B = 3,4722 \cdot 10^{-5} A$

② $I_C = \beta I_B = 3,4722 \cdot 10^{-3} A$

$V_{BE} = V_T \ln \frac{I_C}{I_S} = 0,7688 V$

$I_B = 1,0836 \cdot 10^{-5} A$

③ $I_C = 1,0836 \cdot 10^{-3} A$

$V_{BE} = 0,7385 V$

$I_B = 2,1349 \cdot 10^{-5} A$

④ $I_C = 2,1349 \cdot 10^{-3}$

$V_{BE} = 0,7561 V$

$I_B = 1,5227 \cdot 10^{-5}$

⑤ $I_C = 1,5227 \cdot 10^{-3}$

$V_{BE} = 0,7474$

$I_B = 1,8278 \cdot 10^{-5}$

⑥ $I_C = 1,8278 \cdot 10^{-5}$

$V_{BE} = 0,7521$

$I_B = 1,6629 \cdot 10^{-5}$

⑦ $I_C = 1,66 \cdot 10^{-3}$

$V_{BE} = 0,7497 V$

$I_B = 1,7482 \cdot 10^{-5}$

⑧ $I_C = 1,7482 \cdot 10^{-3} A$

$V_{BE} = 0,7497 V$

$I_B = 1,7482 \cdot 10^{-5} A$