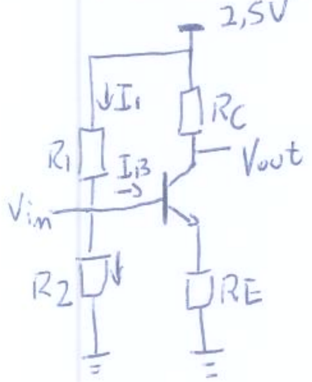
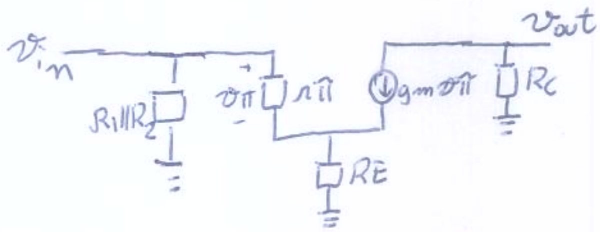
5.80




- $I_S = 6 \cdot 10^{-16} A$
- $V_A = \infty$
- $\beta = 100 \Rightarrow \alpha = 0{,}99$
- $V_{RE} = 300 mV$
- $I_1 \cong 10 \cdot I_B$
- $A_v = -5 \Rightarrow A_v = -2$
  ↳ Fazer
- $Z_{in} = 500 \Omega$

- Modelo de pequenos sinais




- $v_{out} = -R_C g_m v_\pi$
- $v_{in} = v_\pi + v_{RE} = v_\pi + \left(\frac{v_\pi}{r_\pi} + g_m v_\pi\right) \cdot RE$
- $v_{in} = v_\pi \left[1 + \left(\frac{1}{r_\pi} + g_m\right) RE\right]$, $\frac{1}{r_\pi} \to \frac{g_m}{\beta}$

- $$A_v = \frac{v_{out}}{v_{in}} = \frac{-R_C g_m}{1 + \left(\underbrace{\frac{g_m}{\beta} + g_m}_{\sim g_m}\right) RE} \Rightarrow A_v \cong \frac{-R_C g_m}{1 + g_m RE} \Rightarrow \boxed{A_v \cong \frac{-R_C}{\frac{1}{g_m} + RE}}$$

- obs: se $RE \gg \frac{1}{g_m} \Rightarrow \boxed{A_v \cong -\frac{R_C}{RE}}$

- $$i_{in} = \frac{v_{in}}{R_1 \| R_2} + \frac{v_\pi}{r_\pi} = \frac{v_\pi}{R_1 \| R_2}\left[1 + \left(\frac{1}{r_\pi} + g_m\right) RE\right] + \frac{v_\pi}{r_\pi}$$

- $$Z_{in} = \frac{v_{in}}{i_{in}} = \frac{1 + \left(\frac{1}{r_\pi} + g_m\right) RE}{\frac{1}{R_1 \| R_2} \cdot \left[1 + \left(\frac{1}{r_\pi} + g_m\right) RE\right] + \frac{1}{r_\pi}} \cong \frac{1 + g_m RE}{\frac{1}{R_1 \| R_2}\left[1 + g_m RE\right] + \frac{1}{r_\pi}}$$

$$Z_{in} \cong \frac{1}{\frac{1}{R_1 \| R_2} + \frac{1}{r_\pi}\left(\frac{1}{1 + g_m RE}\right)} \Rightarrow \boxed{Z_{in} \cong \frac{1}{\frac{1}{R_1 \| R_2} + \frac{1}{r_\pi + \beta RE}}}$$

$$Z_{in} = \frac{1}{\frac{1}{R_1 \| R_2} + \frac{1}{\frac{\beta}{g_m} + \beta RE}} \Rightarrow \boxed{Z_{in} \cong \frac{1}{\frac{1}{R_1 \| R_2} + \frac{1}{\beta\left(\frac{1}{g_m} + RE\right)}}}$$

- Condições de contorno

1-) $I_1 = I_2 \geq 10 I_B$

2-) $V_C > V_B$ (Região Ativa)

3-) $\begin{cases} \beta\left(\frac{1}{g_m} + R_E\right) > 500\Omega \\ \qquad\qquad \Rightarrow \text{Condição de } Z_{in} \\ R_1 // R_2 > 500\Omega \end{cases}$

- Utilizando 3

$$\beta\left(\frac{1}{g_m} + R_E\right) > 500 \Rightarrow \beta\left(\frac{V_T}{I_C} + \frac{V_E}{I_E}\right) > 500$$

$$\beta\left(\frac{V_T}{I_C} + \frac{V_E}{\alpha I_C}\right) > 500 \Rightarrow \beta\left(\frac{\alpha V_T + V_{BE}}{\alpha I_C}\right) > 500$$

$$500\alpha I_C < \beta(\alpha V_T + V_{BE}) \Rightarrow I_C < \frac{\beta}{500\alpha} \cdot (\alpha V_T + V_{BE})$$

$$\boxed{I_C < 0{,}0658_{\,\hookrightarrow A}} \text{ (A)}$$

- Utilizando 2

$$V_C > V_B \Rightarrow V_{CC} - R_C I_C > V_E + V_{BE} \Rightarrow V_{CC} - R_C I_C > V_E + V_T \ln \frac{I_C}{I_S}$$

$$\Rightarrow \cancel{V_{CC} - R_C I_C - V_E - V_T \ln \frac{I_C}{I_S} > 0}$$

$$-R_C I_C > -V_{CC} + V_E + V_T \ln \frac{I_C}{I_S}$$

$$\boxed{R_C < \frac{V_{CC} - V_E - V_T \ln(I_C/I_S)}{I_C}} \text{ (B)}$$

- $I_1 \cong I_2$

- $I_2 = \frac{V_B}{R_2} = \frac{V_E + V_{BE}}{R_2} \Rightarrow I_2 = \frac{V_E + V_{BE}}{R_2}$

- $I_1 = \frac{V_{CC}}{R_2 + R_1}$

- $\frac{V_E + V_{BE}}{R_2} = \frac{V_{CC}}{R_2 + R_1} \Rightarrow R_2 [V_{CC} - (V_E + V_{BE})] = R_1 (V_E + V_{BE})$

$$\bullet\ R_1 = R_2 \cdot \frac{[V_{CC} - (V_E + V_{BE})]}{(V_E + V_{BE})}$$

- $Z_{in} = 500\Omega \Rightarrow R_1 // R_2 // R_{eq} = 500\Omega$

$\underset{R_{eq} = \beta(\frac{1}{g_m} + R_E)}{}$ $\Rightarrow$ $\boxed{R_{eq} = \frac{\beta}{I_C}(V_T + V_E)}$

$$\frac{1}{R_1//R_2} = \frac{1}{500} - \frac{1}{R_{eq}} \Rightarrow \frac{1}{R_1//R_2} = \frac{1}{500} - \frac{I_C}{\beta(V_T + V_E)}$$

$$\frac{R_1 + R_2}{R_1 R_2} = \frac{\beta(V_T + V_E) - 500 I_C}{500\beta(V_T + V_E)}$$

$$\frac{\cancel{R_2}\frac{[V_{CC} - (V_E + V_{BE})]}{V_E + V_{BE}} + \cancel{R_2}^{1}}{R_2^{\cancel{2}} \cdot \frac{[V_{CC} - (V_E + V_{BE})]}{V_E + V_{BE}}} = \frac{\beta(V_T + V_E) - 500 I_C}{500\beta(V_T + V_E)}$$

$$500\beta(V_T + V_E) \cdot \left(\frac{V_{CC} - (V_E + V_{BE})}{V_E + V_{BE}} + 1\right) = R_2 \frac{[V_{CC} - (V_E + V_{BE})]}{V_E + V_{BE}} \cdot [\beta(V_T + V_E) - 500 I_C]$$

$$500\beta(V_T + V_E) \cdot \left(\frac{V_{CC} - \cancel{(V_E + V_{BE})} + \cancel{(V_E + V_{BE})}}{\cancel{V_E + V_{BE}}}\right) = R_2 \frac{[V_{CC} - (V_E + V_{BE})]}{\cancel{V_E + V_{BE}}} \cdot [\beta(V_T + V_E) - 500 I_C]$$

$$R_2 = \frac{500\beta(V_T + V_E) \cdot V_{CC}}{[V_{CC} - (V_E + \underset{\downarrow\ V_T \ln \frac{I_C}{I_S}}{V_{BE}})][\beta(V_T + V_E) - 500 I_C]}$$

• $I_2 = \frac{V_B}{R_2} = \frac{V_E + V_{BE}}{R_2}$

$$\boxed{I_2 = (V_E + V_{BE}) \cdot \frac{[V_{CC} - (V_E + V_{BE})] \cdot [\beta (V_T + V_E) - 500 I_C]}{500 \beta (V_T + V_E) \cdot V_{CC}}}$$

• $I_2 > 0{,}1\, I_C$

$$\frac{\left(V_E + V_T \log \frac{I_C}{I_S}\right) \cdot \left[V_{CC} - \left(V_E + V_T \log \frac{I_C}{I_S}\right)\right] \cdot [\beta (V_T + V_E) - 500 I_C]}{500 \beta (V_T + V_E) \cdot V_{CC}} - 0{,}1 I_C > 0$$

$I_{C\,máx} = 0{,}0\cancel{333}\ 189\ A$

• ~~Escolho $I_C = 0{,}02\ A$~~

• ~~$V_{BE} = 0{,}8096$~~
• ~~$V_B = 1{,}1096$~~ ~~OK~~
• ~~$V_C = 1{,}8539\ V$~~
• ~~$R_C = \cancel{64{,}6200}\ 32{,}303\ \Omega$~~
• ~~$R_E = 14{,}8515\ \Omega$~~
• ~~$g_m = 0{,}7692$~~
• ~~$A_V = 2$~~
• ~~$R_2 =$~~

• Escolho $I_C = 0{,}015$, pois $R_2 > 500\Omega$ e $R_C$ e $R_{eq}$ variam pouco com $I_C$.

• $V_{BE} = 0{,}8021\ V$
• $R_C = 43{,}0706\ \Omega$
• $g_m = 0{,}57695$
• $R_E = 19{,}8020\ \Omega$
• $I_1 \cong I_2 = 0{,}0020 > 0{,}1\, I_C$ → OK

• $a_v = 2$
• $V_B = 1{,}1021\ V$
• $V_C = 1{,}8539\ V$ OK
• $R_2 = 540{,}7906$

• $R_1 = 1{,}5997 \cdot 10^4\ \Omega$
• $R_{eq} = 2{,}1733 \cdot 10^3\ \Omega$
• $Z_{in} = 421{,}62\ \Omega$ → devido a aproximação $I_1 \cong I_2$