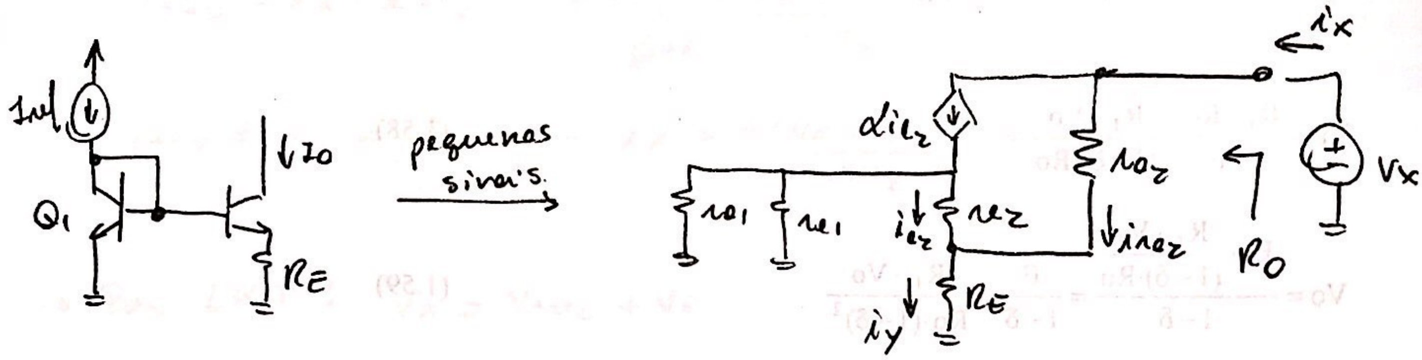
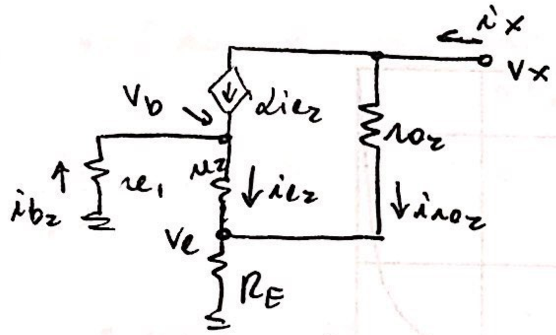
→ Espelho de Widlar → Cálculo de R_o



Como $r_{o1} >> r_{e1} \rightarrow r_{o1} // r_{e1} \cong r_{e1}$



$\rightarrow i_x = \alpha i_{e2} + i_{ro2}$

$$\frac{V_e}{R_E} = i_{e2} + i_{ro2}$$

$$(1) \quad \frac{V_e}{R_E} = i_{e2} + i_x - \alpha i_{e2} = i_x + (1-\alpha) i_{e2}$$

$$i_{e2} = \frac{V_b - V_e}{r_{e2}} \longrightarrow V_b = -i_{b2} r_{e1} = -\frac{i_{e2} r_{e1}}{\beta+1}$$

$$i_{e2} = -\frac{i_{e2} r_{e1}}{(\beta+1) r_{e2}} - \frac{V_e}{r_{e2}} \longrightarrow (\beta+1) r_{e2} = r_{\pi 2}$$

$$i_{e2}\left(1 + \frac{r_{e1}}{r_{\pi 2}}\right) = -\frac{V_e}{r_{e2}}$$

$$(2) \quad i_{e2} = \frac{-r_{\pi 2}}{r_{\pi 2} + r_{e1}} \cdot \frac{V_e}{r_{e2}} = \frac{-(\beta+1)}{r_{\pi 2} + r_{e1}} \cdot V_e$$

→ Substituindo (2) em (1)

$$\frac{V_e}{R_E} = i_x + (1-\alpha) \cdot \frac{-(\beta+1)}{r_{\pi 2} + r_{e1}} \cdot V_e \longrightarrow 1 - \alpha = 1 - \frac{\beta}{\beta+1} = \frac{1}{\beta+1}$$

$$\frac{V_e}{R_E} = i_x - \frac{V_e}{r_{\pi 2} + r_{e1}} \longrightarrow V_e\left(\frac{1}{R_E} + \frac{1}{r_{\pi 2} + r_{e1}}\right) = i_x$$

- Como $r_{\pi 2} >> r_{e1}$, pois $\beta >> 1$

$$V_e \underbrace{\left(\frac{1}{R_E} + \frac{1}{r_{\pi 2}}\right)}_{\frac{1}{R_E // r_{\pi 2}}} = i_x \longrightarrow \boxed{V_e = i_x (R_E // r_{\pi 2})}$$

• Continuando

$$i_{ro_2} = i_x - \alpha i_{e_2} = i_x - \frac{\beta}{\cancel{\beta+1}} \left(\frac{-\cancel{(\beta+1)}}{r_{\pi_2}} V_e \right)$$

$$i_{ro_2} \cong i_x + \frac{\beta}{r_{\pi_2}} V_e = i_x + \frac{\beta (R_E // r_{\pi_2})}{r_{\pi_2}} i_x$$

→ Por LKT: $V_x = V_{ro_2} + V_e$

$$V_x \cong r_{o_2} \cdot i_{ro_2} + (R_E // r_{\pi_2}) i_x$$

$$V_x \cong r_{o_2} i_x + \frac{r_{o_2} \beta (R_E // r_{\pi_2})}{r_{\pi_2}} i_x + R_E // r_{\pi_2} i_x$$

$$\frac{V_x}{i_x} = R_o \cong (R_E // r_{\pi_2}) + r_o + \frac{\beta r_{o_2} (R_E // r_{\pi_2})}{r_{\pi_2}}$$

• mas, $r_{\pi_2} = \frac{V_T}{I_B} = \frac{\beta V_T}{I_C}$ e $\frac{I_C}{V_T} = g_m$

logo, $r_{\pi_2} = \frac{\beta}{g_m}$

→ Assim:

$$R_o \cong (R_E // r_{\pi_2}) + r_o + g_m r_{o_2} (R_E // r_{\pi_2})$$

se $g_m r_{o_2} \gg 1$ → $\boxed{R_o \cong g_m r_{o_2} (R_E // r_{\pi_2})}$

ou $R_o \cong (r_{o_2} + g_m r_{o_2} (R_E // r_{\pi_2}))$

$$= (1 + g_m (R_E // r_{\pi_2})) r_{o_2}$$