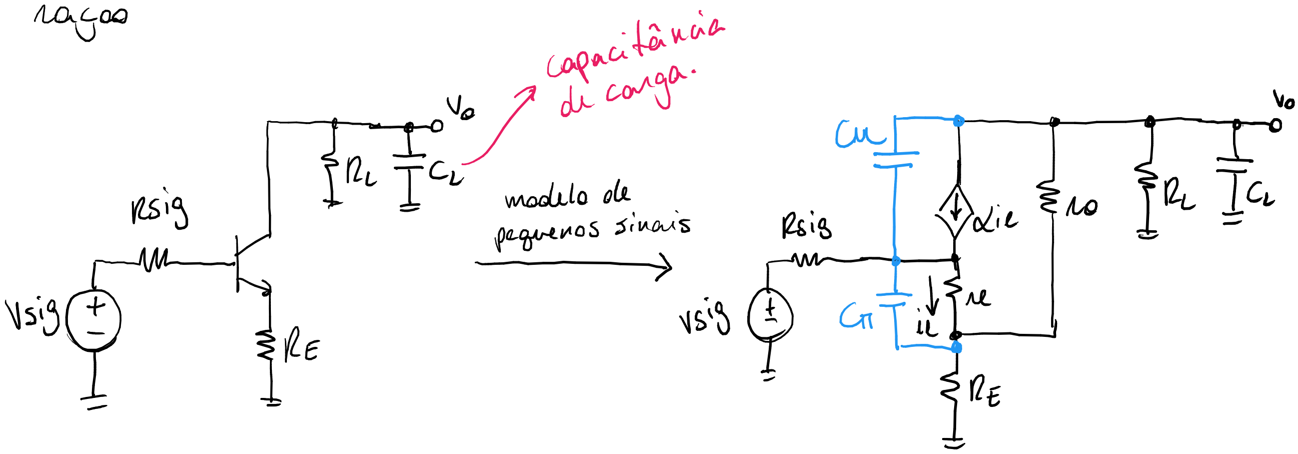
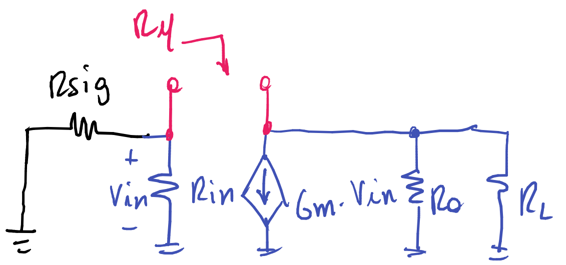
- CEA - Nota de aula → Resposta em frequência do CE com degeneração



↳ A análise da resposta em frequência deve ser feita avaliando as constantes de tempo percebidas pelos capacitores C_μ, C_π e C_L.

- <u>Análise C_μ</u>

↳ P/ esta análise, consideramos o seguinte modelo de pequenos sinais

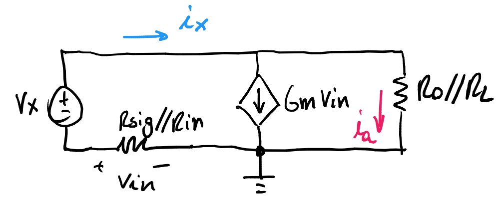


onde: $R_{in} \cong (\beta+1)(r_e + R_E)$

$G_m \cong \dfrac{1}{r_e + R_E}$

$R_o \cong r_o + R_E // r_\pi + g_m r_o (R_E // r_\pi)$

<u>Redesenhando</u>:



<u>Pela LKC</u>:

$i_x = G_m V_{in} + i_a$

↳ $i_a = \dfrac{V_x + V_{in}}{R_o // R_L}$

↳ $V_{in} = -i_x (R_{sig} // R_{in})$

- Assim:

$$i_x = G_m\left(-i_x \cdot R_{sig}//R_{in}\right) + \frac{V_x - R_{sig}//R_{in} \cdot i_x}{R_o // R_L}$$

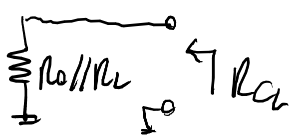
$$i_x \left(1 + G_m R_{sig}//R_{in} + \frac{R_{sig}//R_{in}}{R_o//R_L}\right) = \frac{V_x}{R_o//R_L}$$

$$i_x \left[\frac{R_o//R_L + R_{sig}//R_{in}\left(1 + G_m \cdot R_o//R_L\right)}{R_o//R_L}\right] = \frac{V_x}{R_o//R_L}$$

$$\boxed{R_\mu = \frac{V_x}{i_x} = R_o//R_L + R_{sig}//R_{in}\left(1 + G_m R_o//R_L\right)}$$

- <u>Análise de C_L</u>

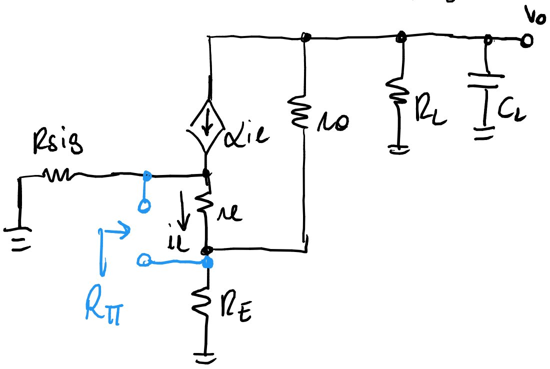
↳ Modelo →



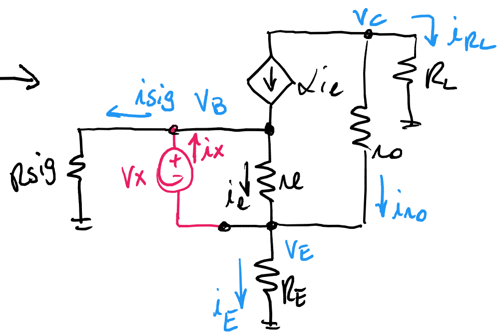
$$\boxed{R_{CL} = R_o // R_L}$$

• Análise C_π

↳ O modelo de pequenos sinais utilizado é o seguinte:



→ Redesenhando



onde:

$$\begin{cases} i_e = V_x / r_e \\ i_{sig} = V_B / R_{sig} \\ i_E = V_E / R_E \\ i_{R_L} = V_C / R_L \\ i_{ro} = \dfrac{V_C - V_E}{r_o} \end{cases}$$

→ **Pela LKC**

$$\begin{cases} i_x = i_{sig} + i_e - \alpha i_e = i_{sig} + i_e(1-\alpha) \\ i_e + i_{ro} = i_E \\ \alpha i_e + i_{ro} + i_{R_L} = 0 \end{cases}$$

Além disso, $V_x = V_B - V_E$

$$\begin{cases} i_x = \dfrac{V_B}{R_{sig}} + \dfrac{V_x}{r_e}(1-\alpha) \\ \dfrac{V_x}{r_e} + \dfrac{V_C - V_E}{r_o} = \dfrac{V_E}{R_E} \\ \alpha\left(\dfrac{V_x}{r_e}\right) + \dfrac{V_C - V_E}{r_o} + \dfrac{V_C}{R_L} = 0 \\ V_x = V_B - V_E \end{cases} \Longrightarrow \begin{cases} i_x = V_x\left[\dfrac{1}{R_{sig}} + \dfrac{1}{r_e}(1-\alpha)\right] - \dfrac{V_E}{R_{sig}} \\ V_C = V_E\left(\dfrac{r_o}{R_E} + 1\right) - V_x \dfrac{r_o}{r_e} \\ V_E = \dfrac{\alpha r_o}{r_e} V_x + V_C\left(1 + \dfrac{r_o}{R_L}\right) \end{cases}$$

obs: $\dfrac{\alpha}{r_e} = g_m$

• Assim,

$$V_E = g_m r_o V_x + \left(\frac{R_L + r_o}{R_L}\right)\left[V_E\left(\frac{r_o + R_E}{R_E}\right) - V_x \frac{r_o}{r_e}\right]$$

$$V_E\left(1 - \frac{(R_L + r_o)}{R_L}\left(\frac{r_o + R_E}{R_E}\right)\right) = V_x\left(g_m r_o - \frac{r_o}{r_e}\left(\frac{R_L + r_o}{R_L}\right)\right)$$

$$V_E\left(\frac{\cancel{R_L R_E} - R_L r_o - \cancel{R_L R_E} - r_o^2 - R_E r_o}{R_L R_E}\right) = V_x\left(\frac{g_m r_o r_e R_L - R_L r_o - r_o^2}{r_e R_L}\right)$$

$$V_E\left[\frac{-\cancel{r_o}}{\cancel{R_L} R_E}\left(R_L + R_E + r_o\right)\right] = V_x \cdot \frac{\cancel{r_o}}{r_e \cancel{R_L}}\left(g_m r_e R_L - R_L - r_o\right)$$

$$V_E = V_x \cdot \frac{R_E}{r_e}\left[\frac{R_L + r_o - g_m r_e R_L}{R_L + R_E + r_o}\right]$$

• Com isso,

$$i_x = V_x\left[\frac{1}{R_{sig}} + \frac{1}{r_e}(1-\alpha)\right] - \frac{V_x R_E}{R_{sig} r_e}\left[\frac{R_L + r_o - g_m r_e R_L}{R_L + R_E + r_o}\right]$$

$\therefore$ $g_m r_e = \alpha$; $1 - \alpha = \dfrac{1}{\beta + 1}$ // $r_e(\beta + 1) = r_\pi$

→ Continuando

$$i_x = V_x\left[\frac{1}{R_{sig}} + \frac{1}{r_e}(1-\alpha)\right] - \frac{V_x R_E}{R_{sig}\, r_e}\left[\frac{R_L + r_o - g_m r_e R_L}{R_L + R_E + r_o}\right]$$

$$i_x = V_x\left[\frac{1}{R_{sig}} + \frac{1}{r_\pi}\right] - V_x\,\frac{R_E}{R_{sig}\, r_e}\left[\frac{R_L/(\beta+1) + r_o}{R_L + R_E + r_o}\right]$$

$$\frac{i_x}{V_x} = \frac{r_\pi + R_{sig}}{R_{sig}\, r_\pi} - \frac{R_E}{R_{sig}\, r_\pi (R_L + R_E + r_o)}\Big(R_L + r_o(\beta+1)\Big)$$

$$\frac{i_x}{V_x} = \frac{(r_\pi + R_{sig})(R_L + R_E + r_o) - R_E\big(R_L + r_o(\beta+1)\big)}{R_{sig}\, r_\pi\, (R_L + R_E + r_o)}$$

Finalmente:

$$R_\pi = \frac{V_x}{i_x} = \frac{R_{sig}\, r_\pi\, (R_L + R_E + r_o)}{(r_\pi + R_{sig})(R_L + R_E + r_o) - R_E\big(R_L + r_o(\beta+1)\big)}$$