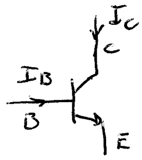
ELECTRÓNICA 1 – AULA 9

TRANSISTORES BJT. MODELOS DE PEQUENO SINAL. CONFIGURAÇÕES BÁSICAS. EMISSOR COMUM. COLECTOR COMUM. BASE COMUM.

Modelos de pequeno sinal

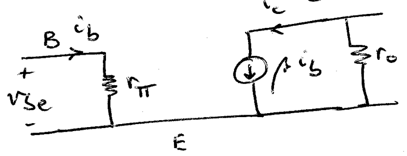


$$I_B = I_S \, e^{v_{BE}/V_T} \left(1 + \frac{1}{V_E} v_{CE}\right)$$

com $V_T = \frac{k_B T}{q} \simeq 25 \text{ mV}$

$$I_C = \beta I_B = \beta I_S \, e^{v_{BE}/V_T} \left(1 + \frac{1}{V_E} v_{CE}\right)$$

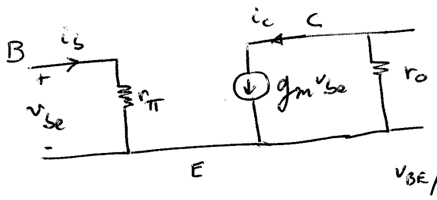
modelos π



$$A_I = \frac{\partial I_C}{\partial I_B} = \beta$$

$$\frac{1}{r_\pi} = \left.\frac{\partial I_B}{\partial v_{BE}}\right|_{v_{BE} = V_{BE\phi}} = \frac{1}{V_T} I_S \, e^{v_{BE}/V_T} = \frac{I_B}{V_T} = \frac{1}{\beta} \frac{I_C}{V_T}$$

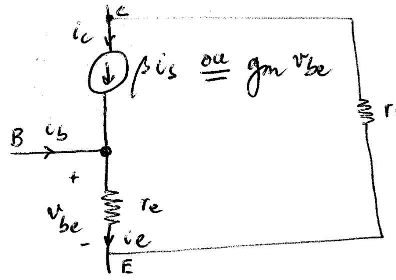
$$r_\pi = \beta \frac{V_T}{I_C}$$



$$g_m = \left.\frac{\partial I_C}{\partial v_{BE}}\right|_{v_{BE} = V_{BE\phi}} = \frac{1}{V_T} \beta I_S \, e^{v_{BE}/V_T} = \frac{I_C}{V_T}$$

$$\frac{1}{r_o} = \frac{\partial I_C}{\partial v_{CE}} \simeq \frac{I_C}{V_E}$$

modelo T



$$\frac{1}{r_e} = \left.\frac{\partial I_E}{\partial v_{BE}}\right|_{v_{BE}=V_{BEQ}}$$

$$\frac{1}{r_e} = \frac{1}{V_T}(\beta+1) I_S \, e^{V_{BE}/V_T}$$

$$\frac{1}{r_e} = \frac{I_E}{V_T} = \frac{\beta+1}{\beta}\,\frac{I_C}{V_T}$$

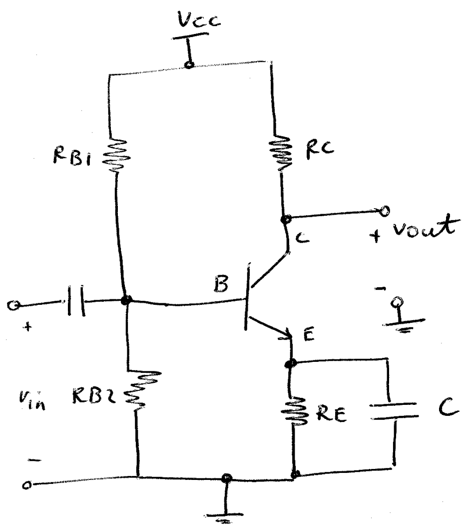
notar que

$$r_e = \frac{1}{(\beta+1)}\, r_\pi$$

notar que

$$g_m = \frac{\beta}{r_\pi} \simeq \frac{1}{r_e}$$

CONFIGURAÇÃO DE EMISSOR COMUM

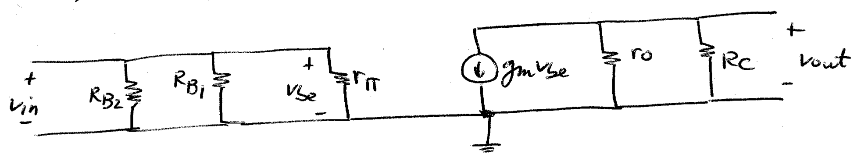


modelo de pequeno sinal

a) com condensador C

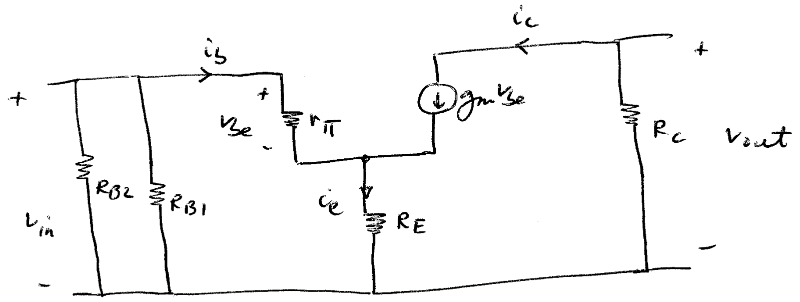
tal que $|Z_C| = \frac{1}{2\pi f C} \simeq 0$

a) com condensador



$$A_v = \frac{v_{out}}{v_{in}} = \frac{-g_m v_{be}\,(r_o \parallel R_C)}{v_{be}} = -g_m\,(r_o \parallel R_C) \simeq -g_m R_C$$

b) sem condensador e <u>ignorando r_o</u>



$$v_{out} = -R_C\, g_m v_{be}$$

$$v_{in} = v_{be} + R_E\, i_e$$

mas $\quad i_e = i_b + i_c = \frac{v_{be}}{r_\pi} + g_m v_{be}$

logo

$$v_{in} = v_{be} + R_E\left(\frac{1}{r_\pi} + g_m\right) v_{be}$$

$$v_{in} = \left(1 + \frac{R_E}{r_\pi} + g_m R_E\right) v_{be}$$

logo $\quad A_v = \frac{v_{out}}{v_{in}} = -\frac{R_C\, g_m}{1 + \frac{R_E}{r_\pi} + g_m R_E} \simeq -\frac{R_C}{R_E}$

Resistência de entrada

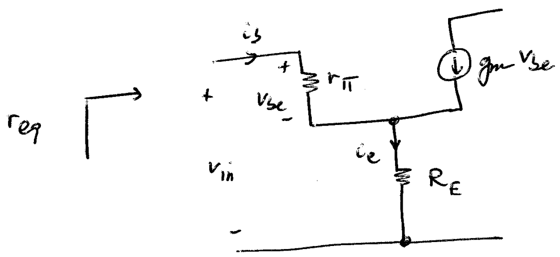
$$R_{in} = \frac{v_{in}}{i_{in}}$$

a) com condensador

$$R_{in} = R_{B2} \,\|\, R_{B1} \,\|\, r_\pi \simeq r_\pi$$

b) sem condensador

$$R_{in} = R_{B2} \,\|\, R_{B1} \,\|\, r_{eq}$$



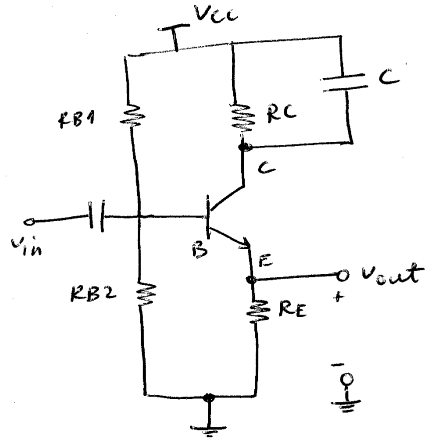
$$r_{eq} = \frac{v_{in}}{i_b} = \frac{v_{be} + R_E\, i_e}{i_b} = \frac{r_\pi i_b + R_E (g_m r_\pi i_b + i_b)}{i_b}$$

$$r_{eq} = r_\pi + R_E\, g_m r_\pi + R_E = r_\pi + (1 + g_m r_\pi) R_E$$

Resistência de saída

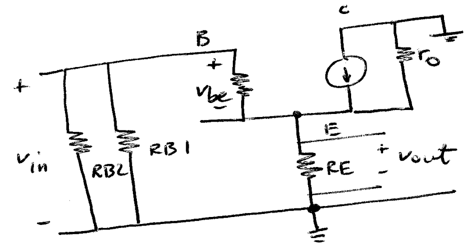
$$R_{out} = \frac{v_{out}}{i_{out}} = r_o \,\|\, R_C \simeq R_C$$

CONFIGURAÇÃO DE COLECTOR COMUM

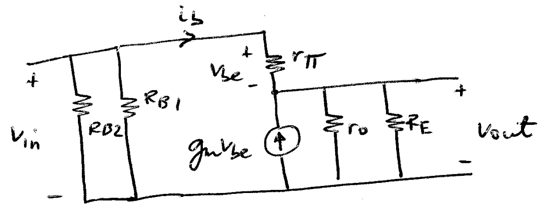


modelo de pequeno sinal

a) com condensador C



circuito equivalente



$$v_{out} = (r_o \| R_E)\,(g_m v_{be} + i_b)$$

$$v_{out} = (r_o \| R_E)\left(g_m v_{be} + \frac{v_{be}}{r_\pi}\right)$$

$$v_{out} = (r_o \| R_E)\left(g_m + \frac{1}{r_\pi}\right) v_{be}$$

mas $v_{in} = v_{be} + v_{out}$ logo $v_{be} = v_{in} - v_{out}$

substituindo

$$v_{out} = (r_o \| R_E)\left(g_m + \frac{1}{r_\pi}\right)(v_{in} - v_{out})$$

$$A_V = \frac{(r_o \| R_E)\left(g_m + \frac{1}{r_\pi}\right)}{1 + (r_o \| R_E)\left(g_m + \frac{1}{r_\pi}\right)}$$

mas $r_\pi = \dfrac{V_T}{I_B}$

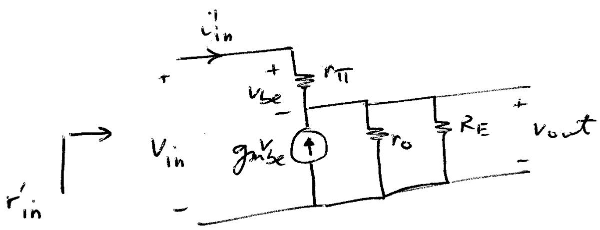
$$g_m = \frac{I_C}{V_T} = \beta \frac{I_B}{V_T} = \frac{\beta}{r_\pi}$$

logo

$$A_V \simeq \frac{g_m R_E}{1 + g_m R_E} \simeq 1 \quad \text{(mas menor que 1)}$$

resistência de entrada

$$R_{in} = \frac{v_{in}}{i_{in}} = R_{B1} \,\|\, R_{B2} \,\|\, r'_{in}$$

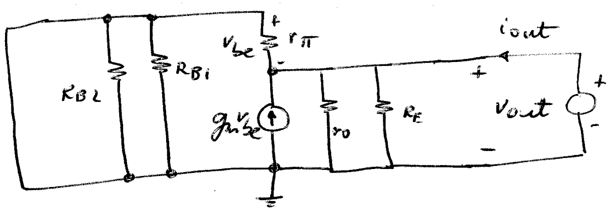


$$\begin{aligned} v_{in} &= v_{be} + v_{out} \\ &= r_\pi i'_{in} + (g_m v_{be} + i'_{in})(r_o \,\|\, R_E) \\ &= r_\pi i'_{in} + (g_m r_\pi i'_{in} + i'_{in})(r_o \,\|\, R_E) \end{aligned}$$

$$r'_{in} = \frac{v_{in}}{i'_{in}} = r_\pi + (1 + g_m r_\pi)(r_o \,\|\, R_E)$$

$$r'_{in} \simeq (g_m R_E)\, r_\pi$$

resistência de saída



$$R_{out} = \frac{v_{out}}{i_{out}} = \left(\frac{1}{g_m} \parallel r_\pi \parallel r_o \parallel R_E \right)$$

$$R_{out} \simeq \frac{1}{g_m}$$