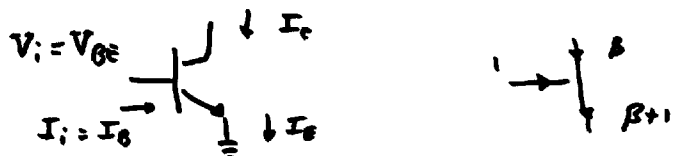


(1) $r_i \equiv \left. \frac{\partial I_i}{\partial V_i} \right|_{V_o}$



$$I_c = I_0 \exp\left(\frac{V_{BE}}{V_T}\right) \quad (\text{Ebers-Moll})$$

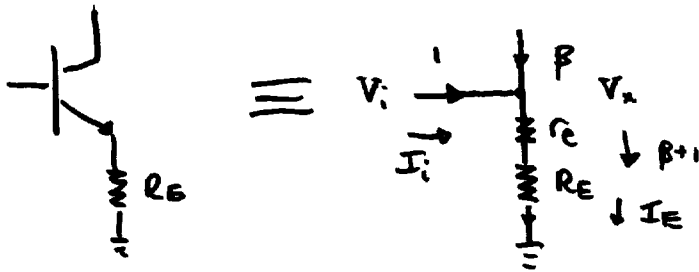
$$I_i = I_B = \frac{I_c}{\beta} = \frac{I_0}{\beta} \exp\left(\frac{V_{BE}}{V_T}\right) = \frac{I_0}{\beta} \exp\left(\frac{V_i}{V_T}\right)$$

$$\frac{\partial I_i}{\partial V_i} = \frac{1}{V_T} \cdot \frac{1}{\beta} \cdot I_0 \exp\left(\frac{V_i}{V_T}\right)$$

$$= \frac{I_c}{\beta V_T} = \frac{I_E}{(\beta+1)V_T} = \frac{1}{(\beta+1)} \cdot \frac{1}{r_e}$$

$$r_i = \left. \frac{\partial I_i}{\partial V_i} \right|_{V_o} = \frac{1}{\frac{1}{(\beta+1)} \cdot \frac{1}{r_e}} = (\beta+1) r_e = r_{\pi}$$

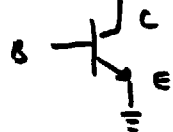
(2)



$$r_i \equiv \left. \frac{\partial I_i}{\partial V_i} \right|_{V_o}$$

$$\frac{\partial I_i}{\partial V_i} = \frac{\partial I_i}{\partial V_x} = \frac{\partial\left(\frac{1}{\beta+1} I_E\right)}{\partial V_x} = \frac{1}{\beta+1} \frac{\partial I_E}{\partial V_x} = \frac{1}{\beta+1} \cdot \frac{1}{r_e + R_E}$$

$$r_i = \left. \frac{\partial I_i}{\partial V_i} \right|_{V_o} = \left. \frac{1}{\frac{1}{\beta+1} \cdot \frac{1}{r_e + R_E}} \right|_{V_o} = (\beta+1)(r_e + R_E) = r_{\pi} + (\beta+1)R_E$$

③ $g_m \equiv \frac{\partial I_c}{\partial V_B}$  $V_{BE} = V_B$ (emissor e' terra)

Ebers-Moll : $I_c = I_0 \exp\left(\frac{V_{BE}}{V_T}\right)$

$$\frac{\partial I_c}{\partial V_{BE}} = \frac{I_0}{V_T} \exp\left(\frac{V_{BE}}{V_T}\right) = \frac{I_c}{V_T} = \frac{\beta}{\beta+1} \frac{I_E}{V_T}$$

$$= \frac{\beta}{\beta+1} \cdot \frac{1}{r_e} \approx \frac{1}{r_e}$$

④ $g_m = \frac{\partial I_0}{\partial V_i} = \frac{\partial \beta I_i}{\partial V_i} = \beta \frac{\partial I_i}{\partial V_i} = \beta / r_i$

$$= \frac{\beta}{\beta+1} \cdot \frac{1}{r_e + R_E} \approx \frac{1}{r_e + R_E}$$

⑤ $\frac{v_o}{v_i} = -g_m \cdot R_c = -\frac{R_c}{r_e + R_E}$

↑
AC Sinal !

$$\left[\frac{v_o}{v_i} = \frac{\partial V_o}{\partial V_i} = \frac{\partial (-R_c I_0)}{\partial V_i} = -R_c \frac{\partial I_0}{\partial V_i} = -R_c g_m \right]$$

a notar : usei a convençao maiúscula V para DC e minúscula v para sinal (AC)