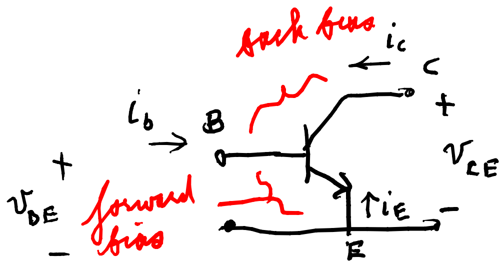
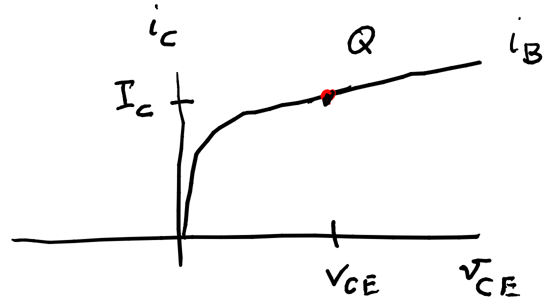
BJT, small signal π-equivalent

EE 303
02/26/08

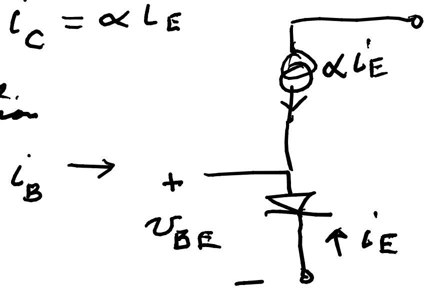
p. 448 = basic
457 with r_o
p. 487 = hybrid-π, high frequency

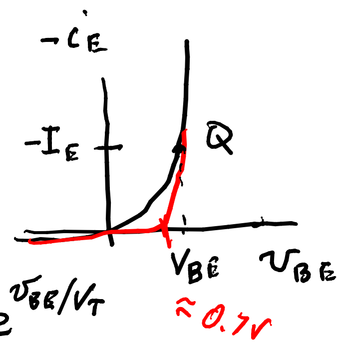




$-i_C = \alpha i_E$

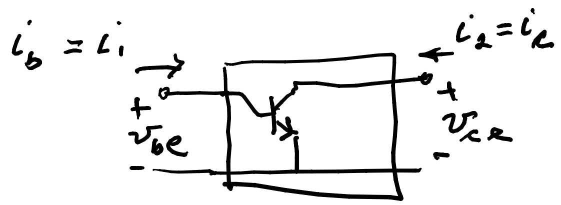
BE junction





Equation: $-i_E = I_{SE}(e^{v_{BE}/V_T} - 1) \approx I_{SE} e^{v_{BE}/V_T}$

$$\frac{\partial(-i_E)}{\partial v_{BE}} = \frac{I_{SE}}{V_T} e^{v_{BE}/V_T} = -\frac{I_E}{V_T}$$



$i_E + i_B + i_C = 0$

$-i_C = \alpha i_E$

$i_B = -i_E - i_C$

$= -i_E + \alpha i_E$

$-i_E = \frac{i_B}{1-\alpha}$; $i_C = \beta i_B$

$$\frac{\partial(-i_E)}{\partial v_{BE}} = -\frac{I_E}{V_T} = \frac{I_B}{(1-\alpha)V_T} = g_m$$

$$= \frac{I_C}{\alpha V_T}$$

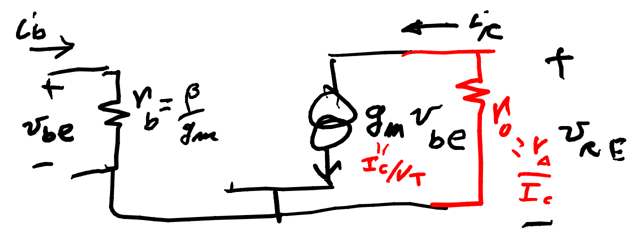
$i_B = +\frac{1}{\alpha} i_C - i_C$

$= (\frac{1}{\alpha} - 1) i_C = \frac{1-\alpha}{\alpha} i_C \Rightarrow i_C = \frac{\alpha}{1-\alpha} i_B$; $\beta = \frac{\alpha}{1-\alpha}$

For transfer: want $\left.\frac{\partial i_C}{\partial v_{BE}}\right|_Q = -\frac{\partial \alpha i_E}{\partial v_{BE}} = \alpha \frac{\partial(-i_E)}{\partial v_{BE}} = \alpha \cdot \frac{I_C}{\alpha V_T} = \frac{I_C}{V_T}$

$-i_C = \alpha i_E$

$$g_m = \left.\frac{\partial i_C}{\partial v_{BE}}\right|_Q = \frac{I_C}{V_T}$$

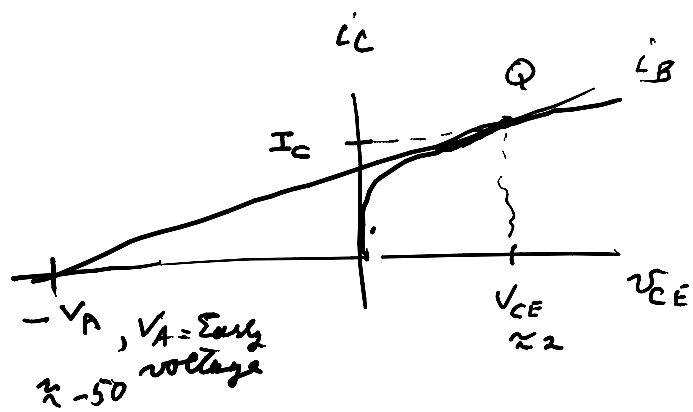


$$g_{be} = \left.\frac{\partial i_b}{\partial v_{BE}}\right|_Q = (1-\alpha)\left.\frac{\partial(-i_E)}{\partial v_{BE}}\right|_Q = \frac{1-\alpha}{\alpha}\frac{I_C}{V_T}$$

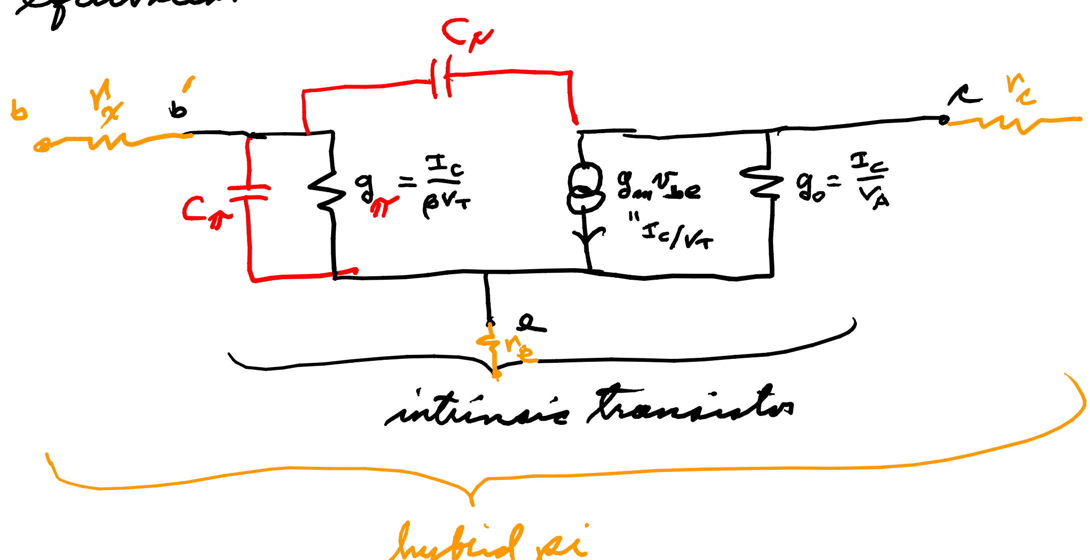
$$= \frac{I_C}{\beta V_T} = \frac{g_m}{\beta}$$

$$g_o = \left.\frac{\partial i_C}{\partial v_{CE}}\right|_Q = \frac{I_C}{+V_A + V_{CE}}$$

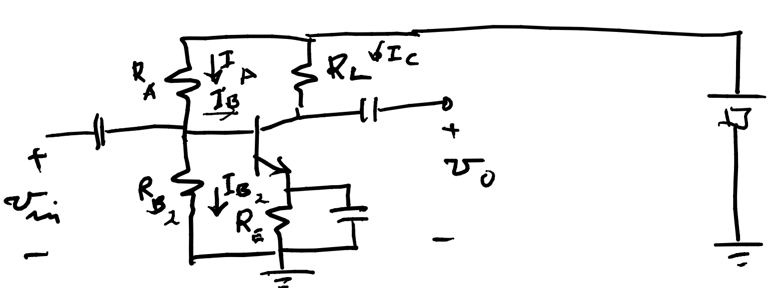
$$\approx +\frac{I_C}{V_A}$$



$\Longrightarrow$ π equivalent



To use we need to bias, i.e. set the Q point:



$$\frac{v_o}{v_i} = -g_m R_L = -\frac{I_C}{V_T}\cdot R_L$$