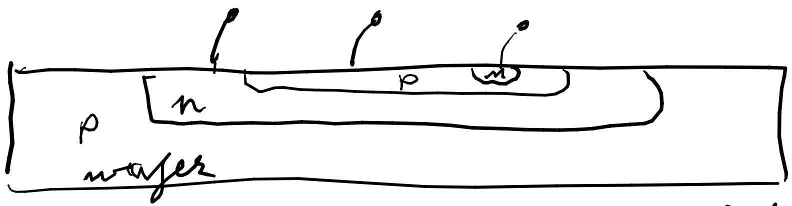
EE 303 H
09/12/13

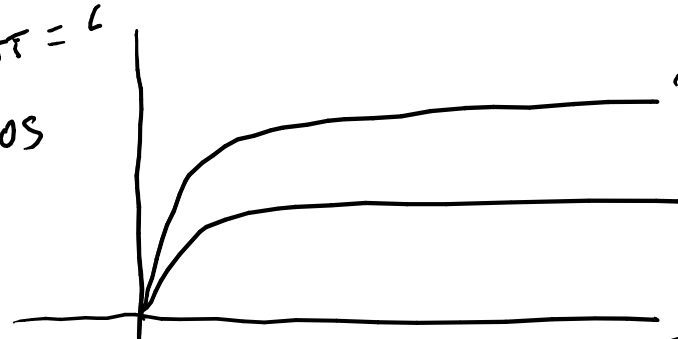
Note Title 9/7/2013



npn

to get pnp requires another diffusion

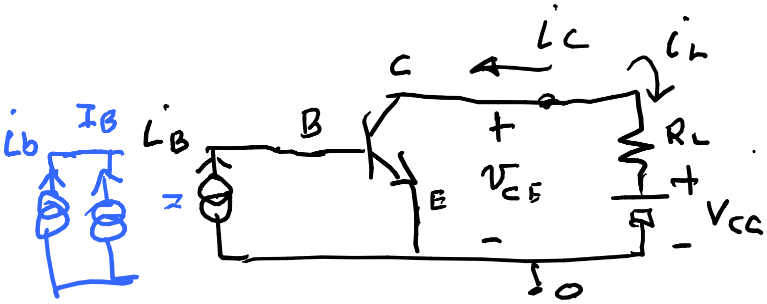
i_C for BJT $= i$
i_D for MOS

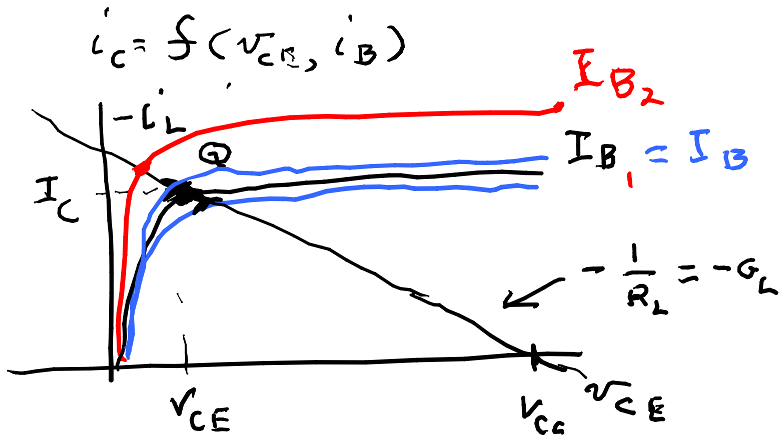


$x =$ BJT $\Rightarrow i_B$
MOS $\Rightarrow v_{GS}$

$v =$ BJT $\Rightarrow v_{CE}$
MOS $\Rightarrow v_{DS}$

$$i = f(v, x)$$





$$v_{CE} = R_L i_L + V_{CC}$$

$$i_C = -i_L$$

$$i_L = \frac{1}{R_L}(v_{CE} - V_{CC}) \Rightarrow -i_L = \frac{1}{R_L}(V_{CC} - v_{CE})$$

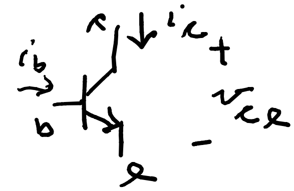
i_B = total $= I_B + i_b$ usually assume $|i_b|$ small $<< I_B$

I_B = bias

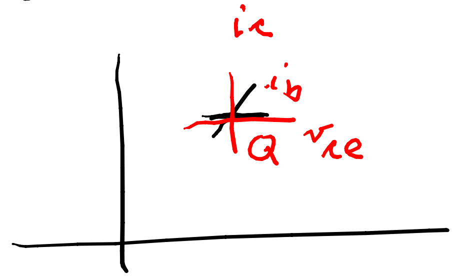
i_b = signal

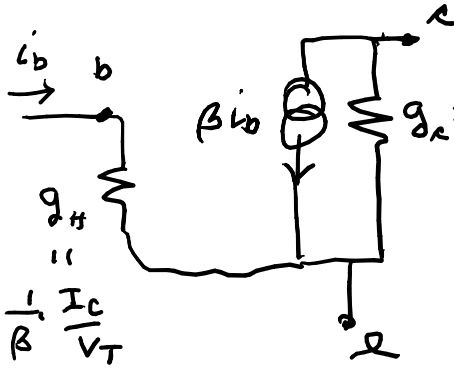
$$i_C = f(v_{CE}, i_B) = \underbrace{f(V_{CE}, I_B)}_{= I_C} + \left.\frac{\partial f}{\partial v_{CE}}\right|_Q \underbrace{(v_{CE} - V_{CE})}_{= v_{ce}} + \left.\frac{\partial f}{\partial i_B}\right|_Q \underbrace{(i_B - I_B)}_{= i_b} + \cdots$$

$$\underbrace{i_c - I_c = i_c \doteq \frac{\partial i_c}{\partial v_{CE}}\Big|_Q \cdot v_{ce} + \frac{\partial i_c}{\partial i_B}\Big|_Q \cdot i_b}$$



$$i_c = g_c \cdot v_{ce} + \beta \cdot i_b$$

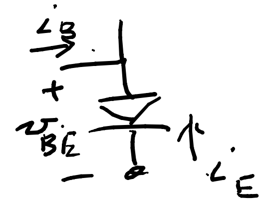




$$g_c = \frac{I_C}{V_A} = \frac{\Delta i_c}{\Delta v_{CE}}\Big|_Q$$

small signal π equivalent circuit

The B to E is forward biased here.



$$-i_E = I_S(e^{v_{BE}/V_T} - 1)$$

$$-\frac{\partial i_E}{\partial v_{BE}}\Big|_Q = \frac{I_S}{V_T} \cdot e^{v_{BE}/V_T}\Big|_Q \approx \frac{I_S(e^{v_{BE}/V_T} - 1)}{V_T}\Big|_Q = \frac{-I_E}{V_T} = -g_{be} = -g_d$$

$$i_c = \beta i_B = -\alpha i_E \Rightarrow i_B = -\frac{\alpha}{\beta} i_E \Rightarrow i_b = -\frac{\alpha}{\beta}(-g_d) v_{be} = g_\pi v_{be}$$

$$i_b = -\frac{\alpha}{\beta} i_e$$

$$i_b = g_\pi v_{be}$$

$$\frac{\alpha}{\beta} = \frac{\alpha}{\frac{\alpha}{1-\alpha}} = 1-\alpha$$

$$g_\pi = \frac{\beta}{\beta+1} \times \frac{1}{\beta} \cdot (g_d) = \frac{-I_E}{V_T} \cdot \frac{1}{\beta+1}$$

$$= \frac{\alpha}{\beta} \cdot \frac{-I_E}{V_T} = \frac{I_C}{\beta V_T}$$

$$\beta = \frac{\alpha}{1-\alpha} \Rightarrow \beta - \alpha\beta = \alpha$$

$$\Rightarrow \beta = \alpha(\beta+1)$$

$$\Rightarrow \alpha = \beta/(\beta+1)$$

but $I_C = -\alpha I_E$

$$I_E = -\frac{1}{\alpha} I_C$$

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