Note Title 9/15/2014

EE 303H
09/16/14

BJT fig. 6.3, p354 = npn, fig. 6.10, p.364 = pnp

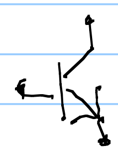
large signal fig 6.5, p. 358, T model, small signal, p.410

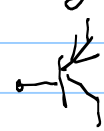
bias, Ex. 6.10, p. 390

(Spice) characteristics, p. 372, fig. 6.17

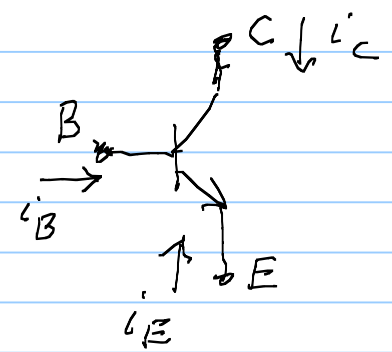
CE amp, p. 427, fig 6.50

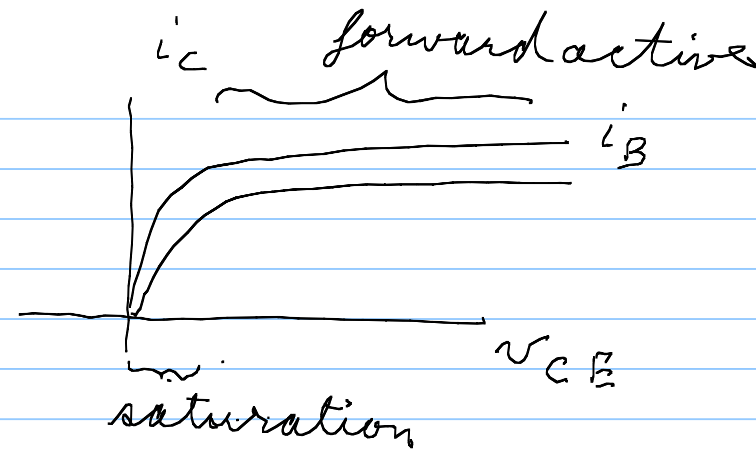
BJT = bipolar junction transistors

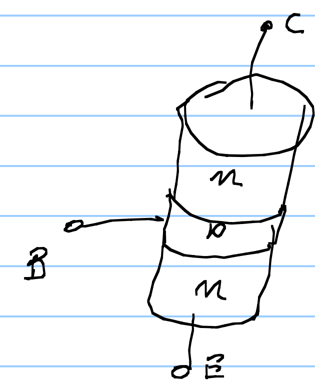




npn



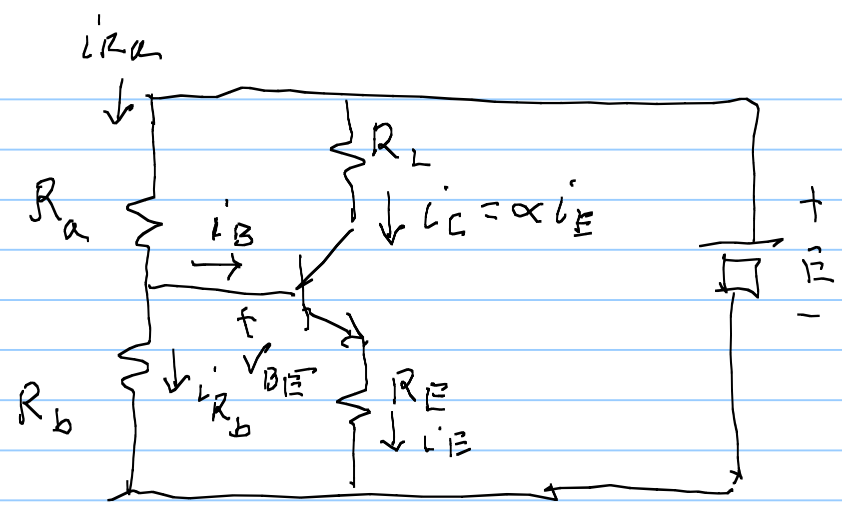


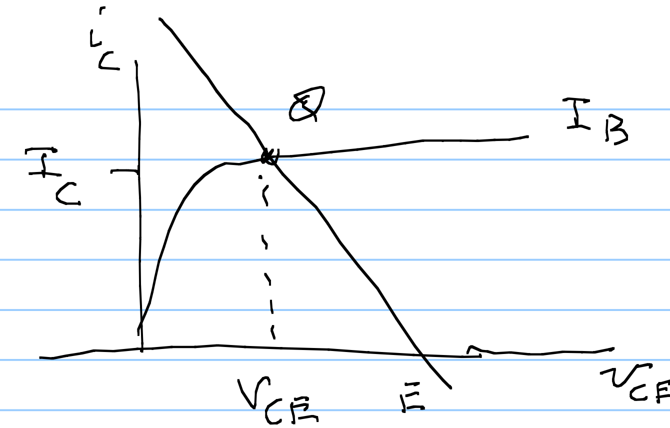


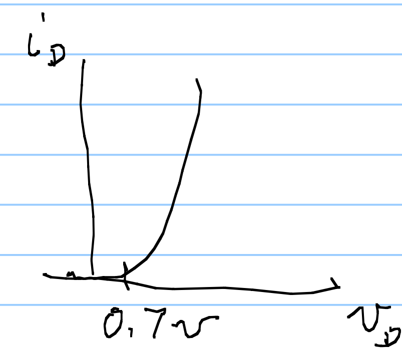
$i_C \approx \beta i_B$ $\quad$ β large

$i_C = -\alpha i_E$

we back bias C-B diode
& forward bias B-E diode







$i_C + i_E + i_B = 0$ by KCL

$i_C = \beta i_B \Rightarrow (\beta+1) i_B \simeq -i_E$

$\Rightarrow (\beta+1)\frac{1}{\beta} i_C = -i_E$

$$i_C = -\frac{\beta}{\beta+1} \cdot i_E = -\alpha i_E \, ; \qquad \alpha = \frac{\beta}{1+\beta} \quad \text{if } \beta = 100 \Rightarrow \alpha = \frac{100}{101} \approx 0.98$$

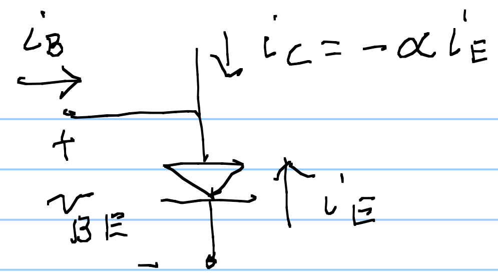
Biasing: need to find the R's under constraints

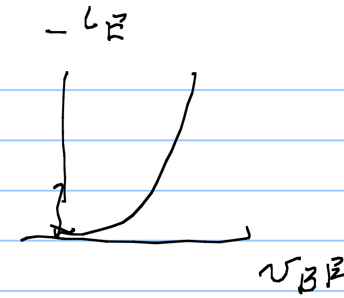
1st look at small signals

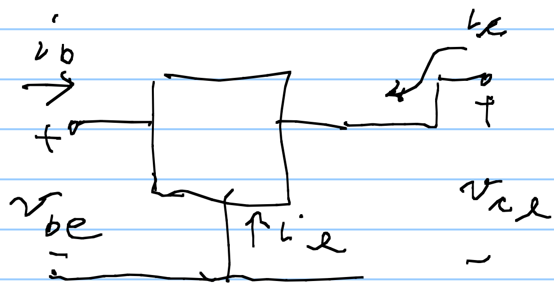
$$i_C = f(v_{CE}, i_B) = \underbrace{I_C}_{= f(V_{CE}, I_B)} + \left.\frac{\partial f}{\partial v_{CE}}\right|_Q \underbrace{(v_{CE} - V_{CE})}_{= v_{ce}} + \left.\frac{\partial f}{\partial i_B}\right|_Q \underbrace{(i_B - I_B)}_{i_b} + \underbrace{\cdots}_{\text{drop}}$$

$$i_c = i_C - I_C = g_0 \cdot v_{ce} + \beta \cdot i_b$$

base to emitter







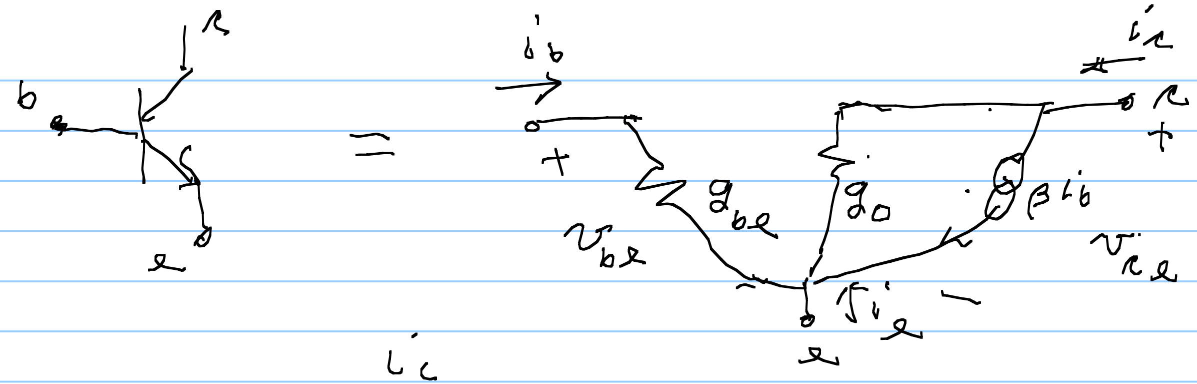
$$i_B = \frac{1}{\beta} i_C = -\frac{\alpha}{\beta} i_E \quad \text{but } \alpha = \frac{\beta}{\beta+1}$$

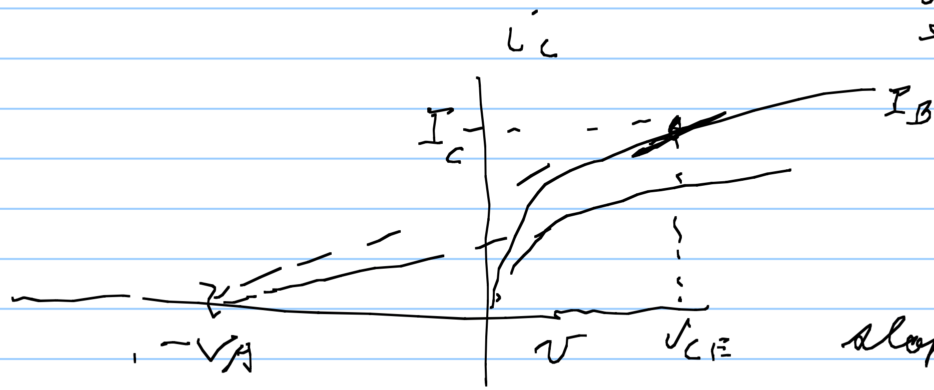
$$i_B = -\frac{\beta/(1+\beta)}{\beta} i_E = -\frac{1}{1+\beta}, \quad i_E \approx -\frac{1}{\beta} i_E$$

$$= \frac{i_C}{\alpha} = -i_E = I_S\left(e^{v_{BE}/V_T} - 1\right) \approx I_S e^{v_{BE}/V_T} \approx \frac{i_C}{\alpha} \Rightarrow -i_e = \frac{I_C}{\alpha V_T} v_{be}$$

$$g_d = \frac{-I_E}{V_T} = +\frac{I_C}{\alpha V_T} \approx \frac{I_C}{V_T} \approx \beta\, I_B/V_T \quad \Rightarrow i_b = g_{be} v_{be} = -\frac{\alpha}{\beta} i_e$$

as seen at the base $\Rightarrow i_b = \frac{\alpha}{\beta} \cdot \frac{I_C}{\alpha V_T} \cdot v_{be} = g_{be} v_{be} \Rightarrow g_{be} = g_\pi = \frac{I_C}{\beta V_T} = \frac{g_m}{\beta}$





$\frac{\partial i_c}{v_{CE}}$

slope = $\frac{I_C}{V_{CE} + V_A} \approx \frac{I_C}{V_A}$

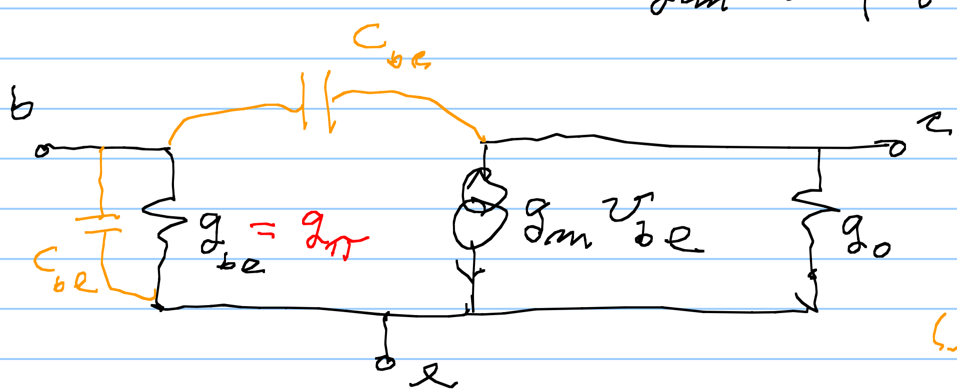
$g_o = \frac{I_C}{V_{CE} + V_A}$

V_A = Early voltage

but $i_b = g_{be} \cdot v_{be} \Rightarrow \beta i_b = \beta g_{be} \cdot v_{be} \Rightarrow i_b = g_{be} v_{be}$

$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\; i_c = \beta g_{be} v_{be} = g_m v_{be}$

$g_m = \beta g_{be} \Rightarrow g_{be} = \dfrac{g_m}{\beta} = \dfrac{I_C}{\beta V_T}$



$= \pi$ equivalent circuit

(hybrid π with 0 lead resistances)

$C_{be} > C_{bc}$

$r_\pi = 1/g_\pi = \beta/g_m$; $g_m = \dfrac{I_C}{V_T} \Rightarrow g_\pi = \dfrac{I_C}{\beta V_T}$

if $I_C = 1\,mA \Rightarrow g_m = \frac{10^{-3}}{26 \times 10^{-3}} = \frac{1}{26}\,\mho$

$I_B = I_C/\beta$ if $\beta = 100 \Rightarrow I_B = 10^{-5}\,A = 10\,\mu A$

$\Downarrow$

current gain = 100