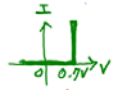
EE 101 Lecture #8 Jan 26, 2018

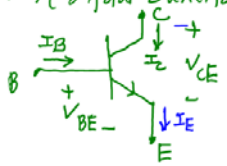
Qz3 on Jan 24(M), Qz2 returned today.

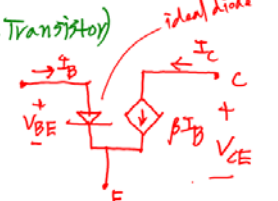
Move on Circuit Analysis

(Nodal Analysis – KCL
Loop/Mesh Analysis – KVL)



BJT (Bipolar Junction Transistor)





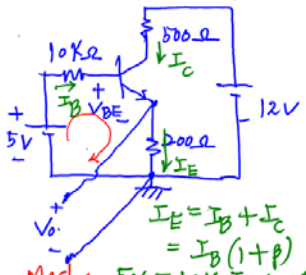
$I = I_B + I_C$

$= \frac{I_C}{\beta} + I_C = \left(\frac{\beta+1}{\beta}\right) I_C$, $I_C = \frac{\beta}{\beta+1} I_E = \alpha I_E$

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

DC equivalent model

Practice Problem 3.12



For $\beta = 100$

$V_{BE} = 0.7V$

Find V_o, V_{CE}

$I_E = I_B + I_C$

$= I_B(1+\beta)$, $V_o = 200\Omega \, I_B(101)$

Mesh: $5V = 10K\, I_B + 0.7 + 0.2K(101) I_B$

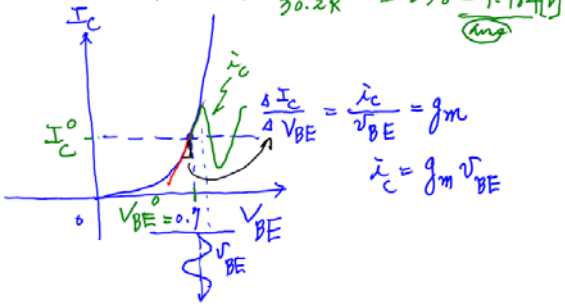
$I_B = \frac{5 - 0.7}{30.2K}$

$V_o = 0.2K(101)\frac{4.3}{30.2K} = \frac{20.2}{30.2} \times 4.3 = 2.876$ [V] (Ans)

$V_{CE} = 12 - 0.5K\, I_C - V_o$

$= 12 - 0.5K(100 I_B) - 2.876$

$= 12 - 50K \frac{4.3}{30.2K} - 2.876 = 1.984$ [V] (Ans)



At around the Bias Point V_{BE},

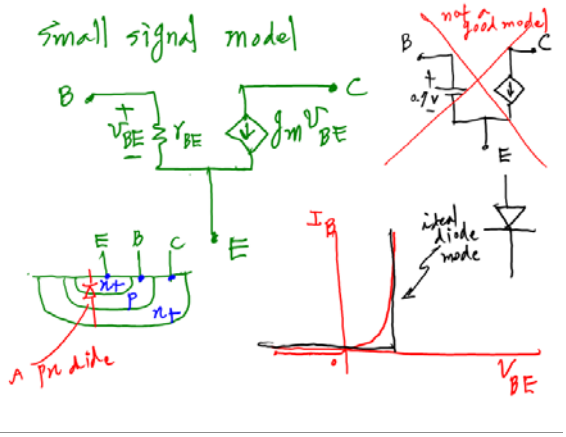
$f(V_{BE}^o + v_{BE}) = I_C^o + i_c$

$f(V_{BE}^o) + f'(V_{BE}) v_{BE} + f''(V_{BE})\frac{v_{BE}^2}{2!} + \cdots$

$I_C^o + i_c$

Thus $i_c = \underbrace{f'(V_{BE})}_{\text{slope at } V_{BE}} v_{BE} = g_m v_{BE} = i_c$

Small signal model



diode equation

$I_D = I_o\left(e^{\frac{V_D}{nV_T}} - 1\right)$

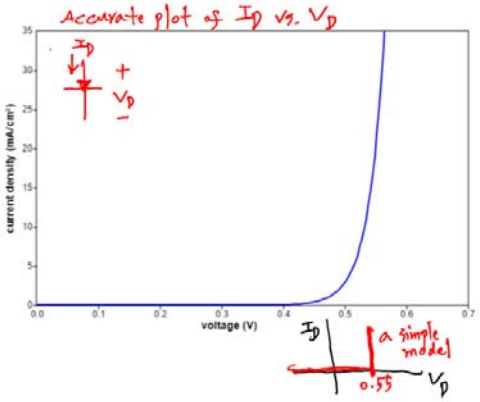
I_o = Saturation current = 10^{-14} [A]

$V_T = \frac{kT}{q} = \frac{1.38 \times 10^{-23}\ J/^\circ K \ (300^\circ K)}{1.6 \times 10^{-19}\ \text{Coulomb}}$

T = 300°K (room temp)

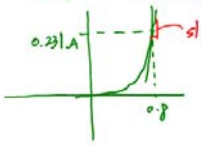
$= 0.026$ [V]

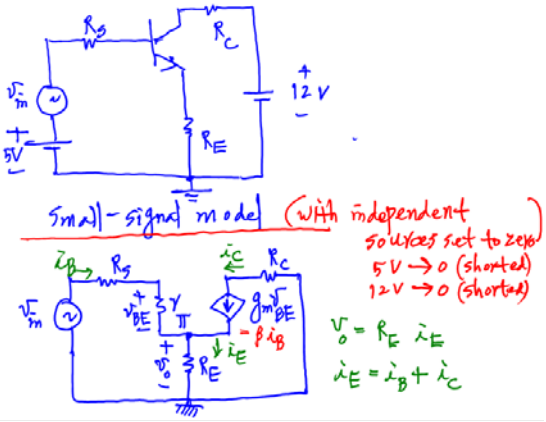
Accurate plot of I_D vs. V_D



V_D [V]	I_D [A]
0.3	10^{-9}
0.7	0.005
0.8	0.231
0.801	0.240
0.9	10.796

$\frac{\Delta I}{\Delta V} = g_m \left(\text{at } V_D = 0.8\right) = \frac{0.009}{0.001} = 9\,S$

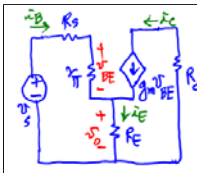




small-signal model (with independent sources set to zero)
5 V → 0 (shorted)
12 V → 0 (shorted)

$v_o = R_E\, i_E$

$i_E = i_B + i_C$



$v_o = R_E\, i_E$

$= R_E\left(i_B + g_m r_\pi\, i_B\right)$ (β)

$\left(v_{be} = r_\pi i_B\right)$

$= R_E (1+\beta)\, i_B$

also $v_s = R_S\, i_B + r_\pi\, i_B + v_o$

$= \left[R_S + r_\pi + R_E(1+\beta)\right] i_B$

$\Rightarrow i_B = \frac{v_s}{R_S + r_\pi + R_E(1+\beta)}$

& $v_o = R_E(1+\beta)\, i_B$

$= v_s \frac{R_E(1+\beta)}{R_S + r_\pi + R_E(1+\beta)} = v_o$

$R_E(1+\beta)$ is an equivalent resistance seen by i_B !

$$i_B = \frac{v_{in}}{R_S\left[1 + R_E(1+g_m r_\pi)\right]}$$

$$\Rightarrow v_o = R_E(1+g_m r_\pi)\frac{v_{in}}{R_S\left[1+\frac{R_E}{R_S}(1+g_m r_\pi)\right]}$$

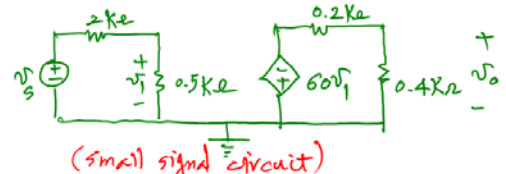
$$= v_{in}\frac{R_E(1+g_m r_\pi)}{R_S + R_E(1+g_m r_\pi)}$$

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

$R_S = 10\,K$, $R_E = 0.2K$, $g_m r_\pi = \beta = 100$

$$v_o = v_{in}\frac{1}{\left[1 + \frac{10K}{0.2K(1+100)}\right]} = \frac{v_{in}}{1.5}$$

Related Problem 3.87



(small signal circuit)

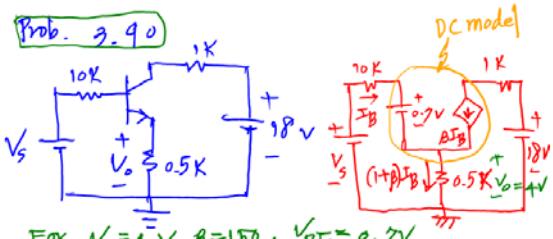
$$v_1 = \frac{0.5K}{2K\Omega + 0.5K\Omega} v_s$$

$$v_o = -60 v_1 \frac{0.4K}{0.2K + 0.4K\Omega}$$

$$= -60\frac{0.4}{2.4}\left[\frac{1}{5} v_s\right] = -2 v_s$$

ans

Prob. 3.90



DC model

For $V_o = 4$ V, $\beta = 150$, $V_{BE} = 0.7$V

Find V_s

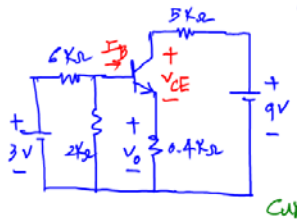
Solution $V_s = 10K\, I_B + 0.7 + 4V$

$I_E = \frac{4}{0.5K} = 8\,mA = (1+\beta) I_B$

$I_B = 8\,mA/151$

$\Rightarrow V_s = 10K(8\,mA/151) + 4.7 = \frac{80}{151} + 4.7 = 5.23$ Ans.

Prob 3.91



For $\beta = 200$, $V_{BE} = 0.7$V

Find I_B and V_{CE}, V_o

solution

$\frac{V_o}{0.4K} = I_B(1+200)$

Current through 2Kꭥ resistor

$I_{2K} = \frac{0.7 + V_o}{2K}$

current through 6Kꭥ is

$I_{6K} = I_B + I_{2K}$

KVL: $3V = 6K \cdot I_{6K} + 0.7 + V_o$

where $I_{6K} = \frac{V_o}{0.4K(201)} + \frac{0.7+V_o}{2K}$ } solve for

$V_o = 49$ mV