More BJTs

Example 1:

Consider an npn, $V_{BE}=0.7V$ at $I_C=1mA$. Find V_{BE} at $I_C=0.1mA$, and $10mA$.

$$I_C = I_S \cdot e^{V_{BE}/V_T}$$

$$\begin{cases} I_C = \beta I_B \\ \alpha I_E = I_C \\ I_E = I_B + I_C \end{cases} \Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}, \quad \beta = \frac{\alpha}{1-\alpha}}$$

$$\begin{cases} 1mA = I_S e^{0.7/25mV} \\ 0.1mA = I_S e^{V_{BE}/25mV} \end{cases}$$

$$\frac{1mA}{0.1mA} = \frac{I_S e^{0.7/25mV}}{I_S e^{V_{BE}/25mV}}$$

$$10 = e^{(0.7-V_{BE})/25mV}$$

$$\ln 10 = (0.7 - V_{BE})/25mV$$

Example 2:

npn BJT, $I_B = 14.46\ \mu A$, $I_E = 1.46\ mA$, $V_{BE} = 0.7V$

Calculate α, β, and I_S.

$\alpha I_E = I_C$

$$\alpha = \frac{I_C}{I_E} = \frac{I_E - I_B}{I_E} = \frac{1.46\ mA - 14.46\ \mu A}{1.46\ mA} = 0.99$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{0.01} = 99$$

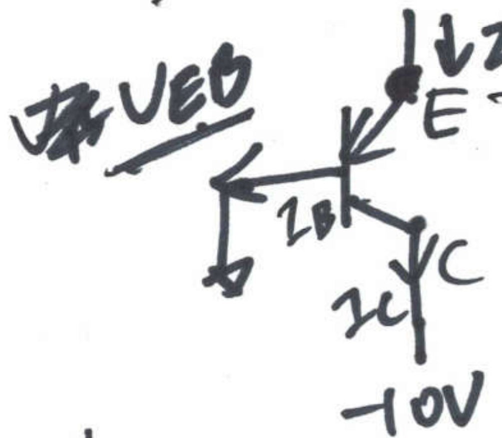
50 ~ 200

$$I_C = I_S \cdot e^{V_{BE}/V_T} \Rightarrow I_S = ~~\frac{e^{0.7/25mV}}{I_C} = \frac{e^{0.7/25mV}}{1.46mA - 14.46\mu A}~~ = \ldots$$

$$= \frac{I_C}{e^{0.7/25mV}}$$

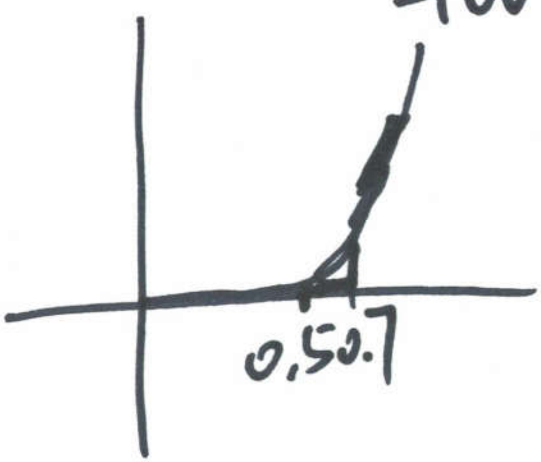
$$= 10^{-15}\ A$$

Example 3: PNP BJT



$\beta = 50$

$I_S = 10^{-14}$ A



V_E? I_B? I_C?

$\alpha I_E = I_C$

$I_C = \frac{\beta}{1+\beta} \cdot 2mA = \frac{50}{51} \cdot 2mA$

$= 1.96 mA$

$I_B = I_E - I_C = 2mA - 1.96mA$

$= 0.04 mA$

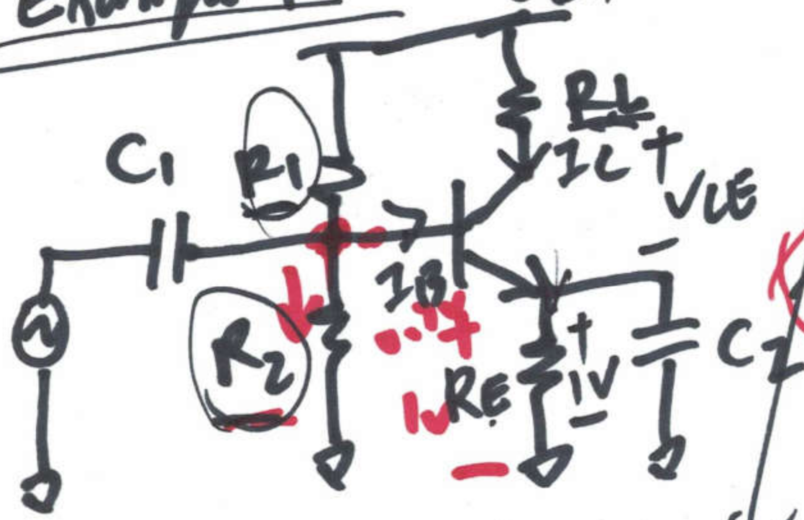
$V_E = V_{EB}$

$I_C = I_S \cdot e^{V_{EB}/V_T} \Rightarrow \frac{I_C}{I_S} = e^{V_{EB}/V_T}$

$\Rightarrow \ln \frac{I_C}{I_S} = \frac{V_{EB}}{V_T}$

$V_{EB} = V_E = V_T \cdot \ln \frac{I_C}{I_S}$

Example 4:



Quiescent Point (Q point)

I_C, I_B, V_{BE}

V_{CE}.

when $V_{CE}=0$ V.

$$I_C = \frac{V_{CC}-V_{RE}}{R_L}$$

If $R_L = 1.2\,K\Omega$

$V_{CC} = 12V$, $V_{RE} = 1V$,

$\beta = 100$.

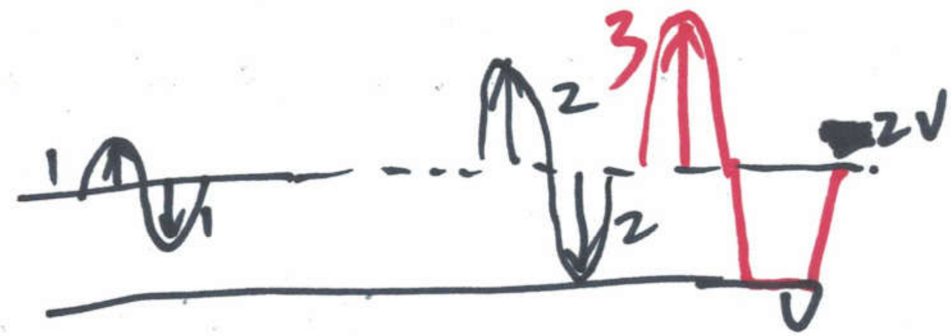
$I_{R2} = 10 I_B$

$$I_{Cmax} = \frac{V_{CC} - V_{RE}}{R_L} = \frac{12-1}{1.2K}$$

$= 9.2\,mA$

$$I_{CQ} = \frac{I_{Cmax}}{2} = 4.6\,mA$$

5



$I_{BQ} = \frac{I_{CQ}}{\beta} = 46\,\mu A$

$I_{R2} = 10 I_B = 10 \cdot 46\,\mu A = 460\,\mu A$

$V_B = V_{R2} = 1.7V$

$R_2 = \frac{V_{R2}}{I_{R2}} = \frac{1.7V}{460\,\mu A} = 3.71\,K\Omega$

$I_{R1} = 10 I_B + I_B = 11 I_B = 11 \cdot 46\,\mu A = 460\,\mu A + 46\,\mu A = 506\,\mu A$

$R_1 = \frac{V_{CC} - V_B}{I_{R1}} = \frac{12V - 1.7V}{506\,\mu A} = 20.45\,K\Omega$

$I_E = I_C + I_B = \beta I_B + I_B = I_C + \frac{I_C}{\beta} = (1 + \frac{1}{\beta}) I_C$

$\alpha I_E = I_C$

$= \frac{\beta}{1+\beta} \cdot I_C$

$I_E = \frac{1}{\alpha} \cdot I_C = \frac{1+\beta}{\beta} \cdot I_C = \frac{101}{100} \cdot 4.6\,mA = 4.63\,mA$

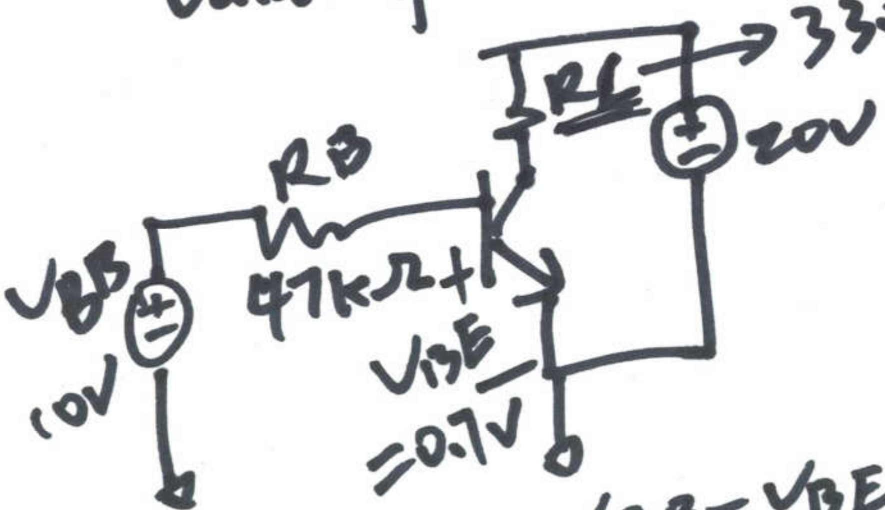
$R_E = \frac{1V}{I_E} = \frac{1V}{4.63\,mA} = 216\,\Omega$

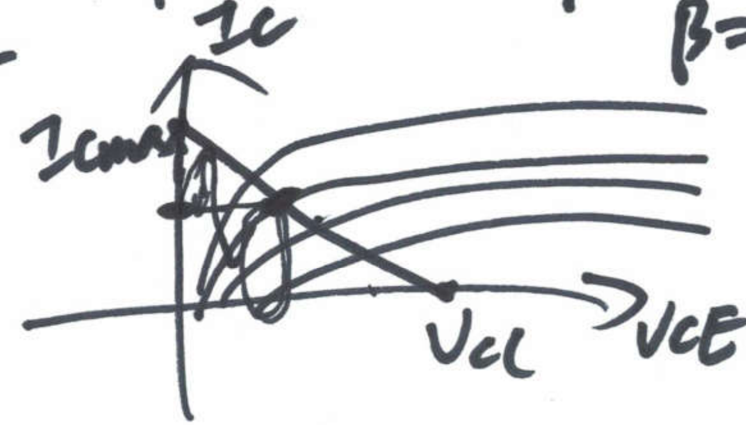
In conclusion, $R_1 = 20\,K\Omega$, $R_2 = 3.7\,K\Omega$, $R_L = 1.2\,K\Omega$

$R_E = 216\,\Omega$

Example 5:

Determine the Q-point and find the maximum peak value of the Base current for linear operation. $\beta = 200$.





$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{10V - 0.7V}{47K} = 198\,\mu A = I_{BQ}$$

$$I_C = \beta \cdot I_B = 200 \cdot 198\,\mu A = 39.6\,mA = I_{CQ}$$

$$I_{cmax} = \frac{20 - 0}{R_L} = \frac{20V}{330\Omega} = 60.6\,mA$$

39.6 mA is closer to the I_{cmax},

so the peak $I_{c_p} = 60.6\,mA - 39.6\,mA = 21\,mA$

$$I_{Bp} = \frac{I_{Cp}}{\beta} = \frac{21\ mA}{200} = \ldots$$