Tutorial 8 Bipolar junction transistor
(*Basic concept*)

Question 1

A BJT has I_C=1 mA and I_B=10 uA. What are I_E, $ß_F$ and α_F?

Solution:

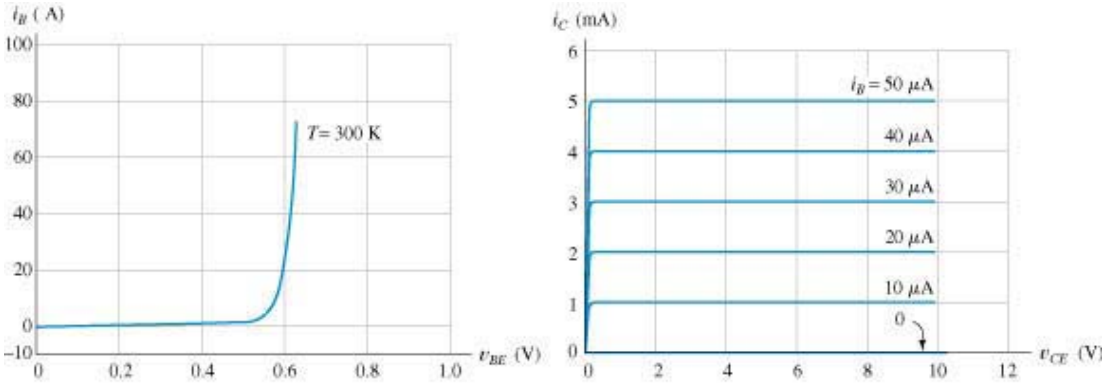
$$I_E = I_C + I_B = 1\text{mA} + 10\,\mu\text{A} = 1.01\text{mA}$$

$$\beta_F = \frac{I_C}{I_B} = \frac{1\text{mA}}{10\,\mu\text{A}} = 100$$

$$\alpha_F = \frac{I_C}{I_E} = \frac{1\text{mA}}{1.01\text{mA}} = 0.9901$$

Question 2

Using Device Curves of a bipolar junction transistor to determine its α and β.



(a) Input characteristic (b) Output characteristics

Solution:

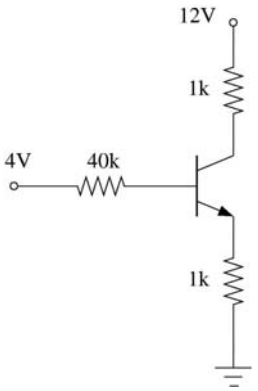
For example:
at v_{CE}=4 V and i_B=30 μA; i_C=3 mA;

$$\beta = \frac{i_C}{i_B} = \frac{3\ mA}{30\ \mu A} = 100$$

$$\alpha = \frac{\beta}{\beta + 1} = 0.99$$

Question 3

Compute transistor parameters I_B, I_C, V_{BE}, V_{CE} (Si BJT with β = 100).



Solution:

$$\text{BE-KVL}: \quad 4 = 40\times10^3\, i_B + v_{BE} + 10^3\, i_E$$

$$\text{CE-KVL}: \quad 12 = 10^3\, i_C + v_{CE} + 10^3\, i_E$$

$$\text{Assume Cut-off}: \quad i_B = 0,\ i_C = 0 \ \text{and}\ v_{BE} < V_{D0} = 0.7\ \text{V}$$

$$i_E = i_B + i_C = 0$$

$$\text{BE-KVL}: \quad 4 = 40\times10^3\times0 + v_{BE} + 10^3\times0 \rightarrow v_{BE} = 4\ \text{V}$$

$$v_{BE} = 4\ \text{V} > V_{D0} = 0.7\ \text{V} \rightarrow \text{Assumption incorrect}$$

Because BE-KVL depends on i_E (there is a resistor in the emitter circuit), i_B would depend on the state of transistor (active or saturation)e

$$\text{BE-KVL}: \quad 4 = 40\times10^3\, i_B + v_{BE} + 10^3\, i_E$$

$$\text{CE-KVL}: \quad 12 = 10^3\, i_C + v_{CE} + 10^3\, i_E$$

$$\text{Assume Active}: \quad i_C = \beta\, i_B \ \text{and}\ v_{CE} \geq V_{D0} = 0.7\ \text{V}$$

$$\text{BE ON}: \ v_{BE} = V_{D0} = 0.7\ \text{V} \ \text{and}\ i_B \geq 0$$

$$i_E = i_B + i_C = (\beta+1)\, i_B = 101 i_B$$

$$\text{BE-KVL}: \quad 4 = 40\times10^3\, i_B + v_{BE} + 10^3\times101\, i_B$$

$$4 = (40+101)\times10^3\, i_B + 0.7 \rightarrow i_B = 23.4\ \mu\text{A}$$

$$i_C = \beta\, i_B = 100\times23.4\times10^{-6} = 2.34\ \text{mA}$$

$$i_E = i_B + i_C = 2.36\ \text{mA}$$

$$\text{CE-KVL}: \ 12 = 10^3\times2.34\times10^{-3} + v_{CE} + 10^3\times2.36\times10^{-3} \rightarrow v_{CE} = 7.3\ \text{V}$$

$$v_{CE} = 7.3\ \text{V} > V_{D0} = 0.7\ \text{V} \rightarrow \text{Assumption correct}$$

It is a very good approximation to set $i_E \approx i_C$ in the active mode!