Thapar University, Patiala

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Course Code: UEC 301; Course Name: Analog Electronics

B. Tech, ECE (III-Sem), "Tutorial Sheet No. - 2"

Solution

Q1.

A relationship can be developed between β and α using the basic relationships introduced thus far. Using $\beta = I_C/I_B$, we have $I_B = I_C/\beta$, and from $\alpha = I_C/I_E$ we have $I_E = I_C/\alpha$. Substituting into

$$I_E = I_C + I_B$$

we have

$$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

and dividing both sides of the equation by I_C results in

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

or

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

so that

$$\boxed{\alpha = \frac{\beta}{\beta + 1}} \qquad \textbf{(3.12)}$$

or

$$\boxed{\beta = \frac{\alpha}{1 - \alpha}} \qquad \textbf{(3.13)}$$

In addition, recall that

$$I_{CEO} = \frac{I_{CBO}}{1 - \alpha}$$

but using an equivalence of

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

derived from the above, we find that

$$I_{CEO} = (\beta + 1)I_{CBO}$$

or

$$\boxed{I_{CEO} \cong \beta I_{CBO}} \qquad \textbf{(3.14)}$$

Q2.

Solution *a.* Since the base is forward-biased, the transistor is not cut off. Hence it must be either in its active region or in saturation. Assume that the transistor operates in the active region. From KVL applied to the base circuit of Fig.

Dr. Hardeep Singh, Dr. Sanjay Kumar, Dr. Vinay Kumar, Dr. Hem Dutt Joshi, 5-12*a* (with I_B expressed in milliamperes), we have

$$-5 + 200\,I_B + V_{BE} = 0$$

As noted above, a reasonable value for V_{BE} is 0.7 V in the action region, and hence

$$I_B = \frac{5 - 0.7}{200} = 0.0215 \text{ mA}$$

Since $I_{CO} \ll I_B$, then $I_C \approx \beta I_B = 2.15$ mA.

We must now justify our assumption that the transistor is in the active region, by verifying that the collector junction is reverse-biased. From KVL applied to the collector circuit we obtain

$$-10 + 3\,I_C + V_{CB} + V_{BE} = 0$$

or

$$V_{CB} = -(3)(2.15) + 10 - 0.7 = +2.85 \text{ V}$$

For an *n-p-n* device a positive value of V_{CB} represents a reverse-biased collector junction, and hence the transistor is indeed in its active region.

Note that I_B and I_C in the active region are independent of the collector circuit resistance R_c. Hence, if R_c is increased sufficiently above 3 K, then V_{CB} changes from a positive to a negative value, indicating that the transistor is no longer in its active region. The method of calculating I_B and I_C when the transistor is in saturation is given in Sec. 5-9.

b. The current in the emitter resistor of Fig. 5-12*b* is

$$I_B + I_C \approx I_B + \beta I_B = 101\,I_B,$$

assuming $I_{CO} \ll I_B$. Applying KVL to the base circuit yields

$$-5 + 200 I_B + 0.7 + (2)(101\,I_B) = 0$$

or

$$I_B = 0.0107 \text{ mA} \qquad I_C = 100\,I_B = 1.07 \text{ mA}$$

Note that $I_{CO} = 2 \times 10^{-5}$ mA $\ll I_B$, as assumed.

To check for active circuit operation, we calculate V_{CB}. Thus

$$V_{CB} = -3I_C + 10 - (2)(101\,I_B) - 0.65$$

$$= -(3)(1.07) + 10 - (2)(101)(0.0107) - 0.7 = +3.93 \text{ V}$$

Since V_{CB} is positive, this (*n-p-n*) transistor is in its active region.

Q3.

$$I_{B_Q} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega} = \mathbf{47.08\ \mu A}$$

$$I_{C_Q} = \beta I_{BQ} = (50)(47.08\ \mu\text{A}) = \mathbf{2.35\ mA}$$

$$V_{CE_Q} = V_{CC} - I_C R_C$$
$$= 12\text{ V} - (2.35\text{ mA})(2.2\text{ k}\Omega)$$
$$= \mathbf{6.83\ V}$$

$V_B = V_{BE} = \mathbf{0.7\ V}$
$V_C = V_{CE} = \mathbf{6.83\ V}$
Using double-subscript notation yields

$$V_{BC} = V_B - V_C = 0.7\ \text{V} - 6.83\ \text{V} = \mathbf{-6.13\ V}$$