Bipolar Junction Transistors (BJTs) and Circuits

Common-Emitter (CE) Configuration:

The common-emitter configuration with npn and pnp transistors are indicated in Fig. 8-9. The external voltage source V_{BB} is used to forward bias the E-B junction and the external voltage source V_{CC} is used to reverse bias C-B junction. The magnitude of V_{CC} must be greater than V_{BB} to ensure the C-B junction remains reverse biased, since, as can be seen in the Fig. 8-9, $V_{CB} = V_{CC} - V_{BB}$.

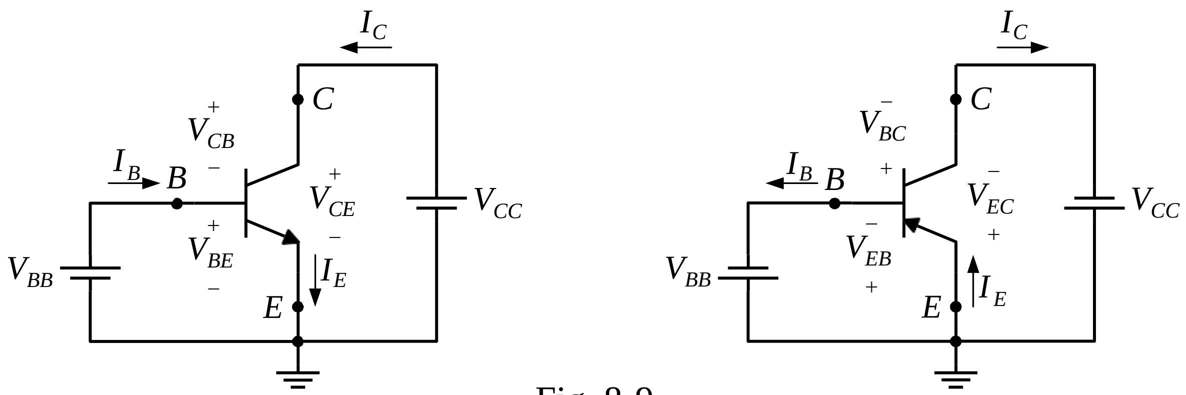

Fig. 8-9

From Eqs. [8.1] and [8.4], we obtain

$$I_C = \alpha\,(I_C + I_B) + I_{CBO}$$

Rearranging yields

$$I_C = \frac{\alpha I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha} \qquad [8.6]$$

From Fig. 8-10, Eq. [8.6] becomes

$$\boxed{I_{CEO} = \left.\frac{I_{CBO}}{1-\alpha}\right|_{I_B=0}} \qquad [8.7]$$

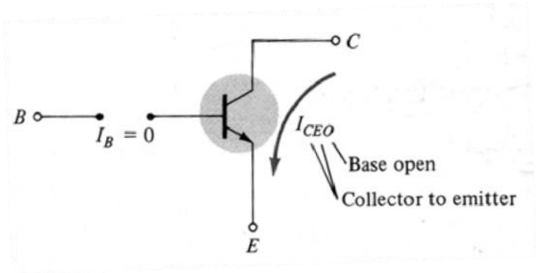

Fig. 8-10

In the dc mode the levels of I_C and I_B are related by a quantity called ***beta*** (β_{dc}) and defined by the following equation:

$$\boxed{\beta_{dc} = \frac{I_C}{I_B}} \qquad [8.8]$$

Where I_C and I_B are the levels of current at the point of operation. For practical devices the levels of β_{dc} typically ranges from about 50 to over 500, with most in the mid-range. On specification sheets β_{dc} is usually included as $\boldsymbol{h_{FE}}$ with *h* derived from an ac ***h****ybrid* equivalent circuit.

For ac situation an ac beta (β_{ac}) has been defined as follows:

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=const.} \qquad [8.9]$$

The formal name for β_{ac} is ***common-emitter***, ***forward-current***, ***amplification factor*** and on specification sheets β_{ac} is usually included as $\boldsymbol{h_{fe}}$.

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 $I_C / \alpha = I_C + I_C / \beta$ and dividing both sides of the equation by I_C will result in $1/\alpha = 1 + 1/\beta$ or $\beta = \alpha\beta + \alpha = (\beta + 1)\alpha$ so that

$$\alpha = \frac{\beta}{\beta + 1} \quad \text{or} \quad \beta = \frac{\alpha}{1-\alpha} \qquad [8.10]$$

In addition, recall that $I_{CEO} = I_{CBO} /(1-\alpha)$ but using an equivalence of $1/(1-\alpha) = \beta + 1$ derived from the above, we find that

$$I_{CEO} = (\beta + 1) I_{CBO} \qquad [8.11]$$

Beta is particularly important parameter because it provides a direct link between current levels of the input and output circuits for CE configuration. That is,

$$I_C = \beta I_B \qquad [8.12]$$

and since $I_E = I_C \quad I_B = \beta I_B + I_B$ we have

$$I_E = (\beta + 1) I_B \qquad [8.13]$$

The input (base) characteristics for the CE configuration are a plot of the base (input) current (I_B) versus the base-to-emitter (input) voltage (V_{BE}) for a range of values of collector-to-emitter (output) voltage (V_{CE}) as shown in Fig. 8-11. Note that I_B increases as V_{CE} decreases, for a fixed value of V_{BE}. A large value of V_{CE} results in a large reverse bias of the C-B junction, which widens the depletion region and makes the base smaller. When the base is smaller, there are fewer recombinations of injected minority carriers and there is a corresponding reduction in base current (I_B).

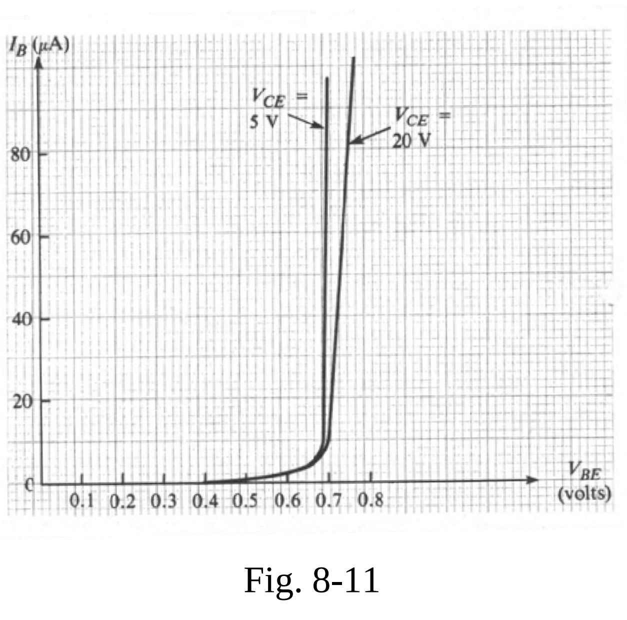

Fig. 8-11

The output (collector) characteristics for CE configuration are a plot of the collector (output) current (I_C) versus collector-to-emitter (output) voltage (V_{CE}) for a range of values of base (input) current (I_B) as shown in Fig. 8-12. The collector characteristics have three basic region of interest, as indicated in Fig. 8-12, the active, cutoff, and saturation regions.

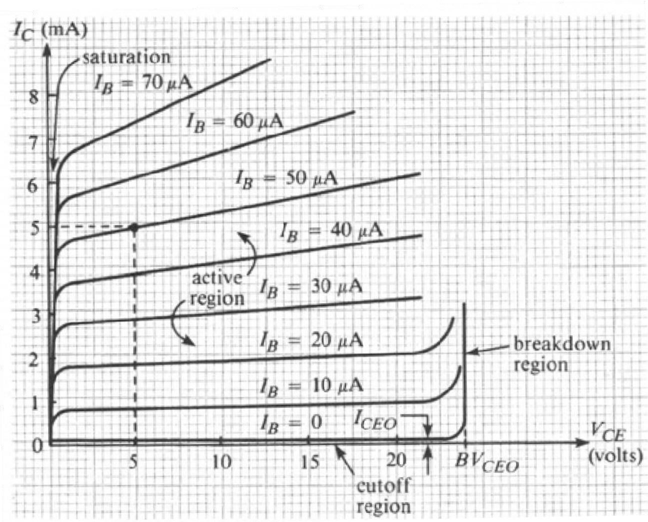

Fig. 8-12

Active region: $I_B > 0$ and $I_C = \beta I_B$.
Cutoff region: $I_B = 0$ and $I_C = I_{CEO}$.
Saturation region: $V_{CE} \approx 0$ and $I_{B(sat.)} = I_{C\,(sat.)} / \beta$.

Common-Collector (CC) Configuration:

The third and final transistor configuration is the common-collector configuration, shown in Fig. 8-13 with npn and pnp transistors. The CC configuration is used primarily for impedance-matching purposes since it has a high input impedance and low output impedance, opposite to that which is true of the common-base and common-emitter configurations.

From a design viewpoint, there is no need for a set of common-collector characteristics to choose the circuit parameters. The circuit can be designed using the common-emitter characteristics. For all practical purposes, the output characteristics of the CC configuration are the same as for the CE configuration. For the CC configuration the output characteristics are a plot of emitter (output) current (I_E) versus collector-to-emitter (output) voltage (V_{CE}), for a range of values of base (input) current (I_B). The output current, therefore, is the same for both the common-emitter and common-collector characteristics. There is an almost unnoticeable change in the vertical scale of I_C of the common-emitter characteristics if I_C is replaced by I_E for the common-collector characteristics (since $\alpha \cong 1$, $I_E \approx I_C$).

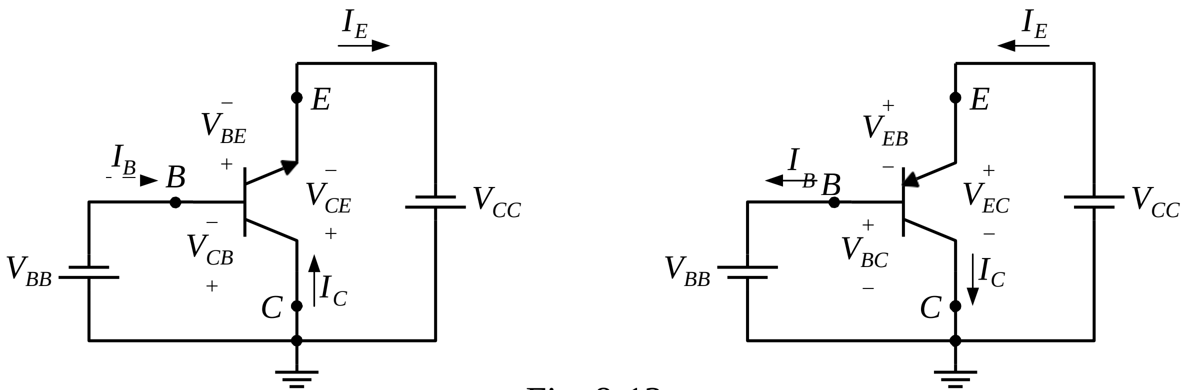

Fig. 8-13

Transistor Casing and Terminal Identification:

Whenever possible, the transistor casing will have some marking to indicate which leads are connected to the emitter, collector, or base of a transistor. A few of the methods commonly used are indicated in Fig. 8-14.

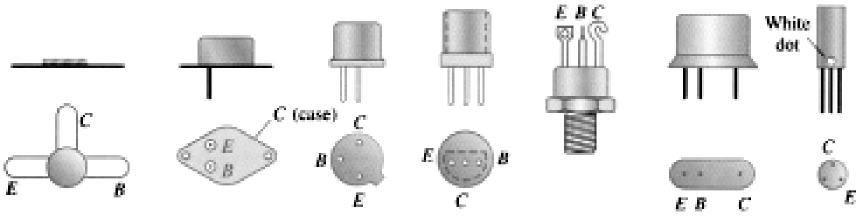

Fig. 8-14

Exercises:

1. Given an α_{dc} of 0.998, determine I_C if I_E = 4 mA.
2. Determine α_{dc} if I_E = 2.8 mA and I_B = 20 µA.
3. Find I_E if I_B = 40 µA and α_{dc} is 0.98.
4. Given that α_{dc} = 0.987, determine the corresponding value of β.
5. Given β_{dc} = 120, determine the corresponding value of α.
6. Given that β_{dc} = 180 and I_C = 2.0 mA, find I_E and I_B.
7. A transistor has I_{CBO} = 48 nA and α = 0.992, find β and I_{CEO}.