Al-Mustaqbal University / College of Engineering & Technology
Department (Communication Technical Engineering) 1
Class (First)
Subject (ELECTRONIC CIRCUITS) / Code (UOMU028022)
Lecturer (Prof.Dr.Haider J Abd)
2nd term – Lecture No. & Lecture Name (Lec2: transistor configurations)

Transistor Amplification Action:

The basic voltage-amplifying action of the CB configuration can now be described using the circuit of Fig. 8-8. The dc biasing does not appear in the figure since our interest will be limited to the ac response. For the CB configuration, the input resistance between the emitter and the base of a transistor will typically vary from 10 to 100 Ω, while the output resistance may vary from 100 kΩ to 1 MΩ. The difference in resistance is due to the forward-biased junction at the input (base to emitter) and the reverse-biased junction at the output (base to collector). Using effective values and a common value of 20 Ω for the input resistance, we find that

A **transistor amplifier** increases the strength of a weak input signal. It works by using a small input current or voltage at the **base** (in a bipolar junction transistor, BJT) to control a much larger current flowing from the **collector to the emitter**. This allows the transistor to act as a **current amplifier**, where a small input controls a large output. The power for amplification comes from an external **power supply**, not the input signal itself.

$I_i = V_i / R_i = 200mV / 20\Omega = 10mA$.

If we assume for the moment that

$\alpha_{ac} = 1$ ($I_c = I_e$),

$I_L = I_i = 10mA$

and $V_L = I_L R = (10mA)(5k\Omega) = 50V$.

The voltage amplification is

$A_v = V_L / V_i = 50V / 200mV = 250$.

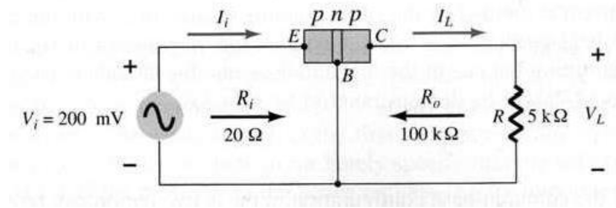

Fig. 8-8

Typical values of voltage amplification for the common-base configuration vary from 50 to 300. The current amplification (I_C/I_E) is always less than 1 for the CB configuration. This latter characteristic should be obvious since $I_C = \alpha I_E$ and α is always less than 1.

The basic amplifying action was produced by ***transferring*** a current I from a low-to a high-***resistance*** circuit. The combination of the two terms in italics results in the label transistor; that is, ***transfer*** + ***resistor*** → ***transistor***.

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, $V_{CB} = V_{CC} - V_{BB}$.

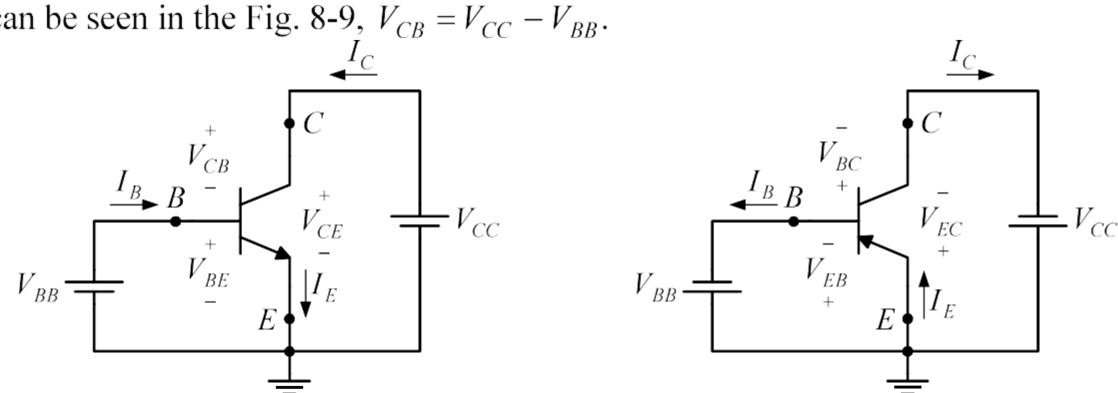

Fig. 8-9

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

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

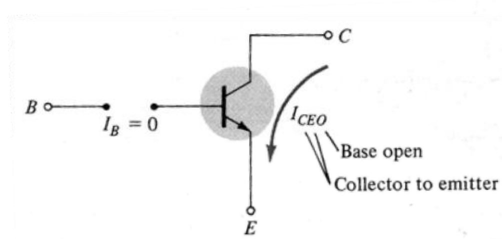

Fig. 8-10

Email (haider.jabber@uomus.edu.iq)

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:

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

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

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

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

$$\boxed{I_{CEO} \cong \beta I_{CBO}} \qquad [8.11]$$

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,

$$\boxed{I_C = \beta I_B + I_{CEO} \approx \beta I_B} \qquad [8.12]$$

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

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

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).

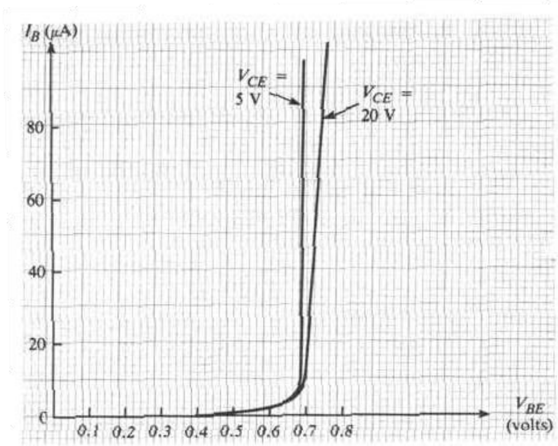

Fig. 8-11

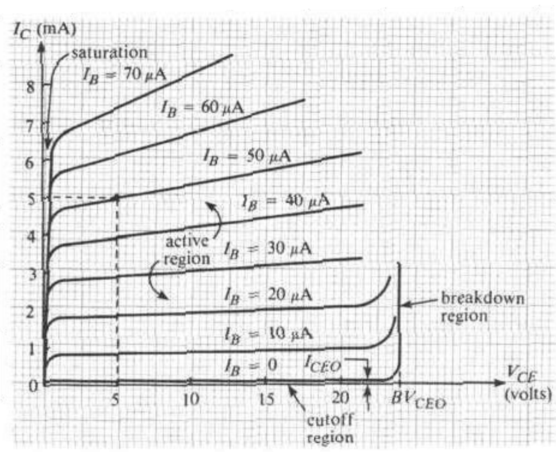

Fig. 8-12

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.

- ◀ 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 $\alpha \cong 1$, $I_E \approx I_C$).

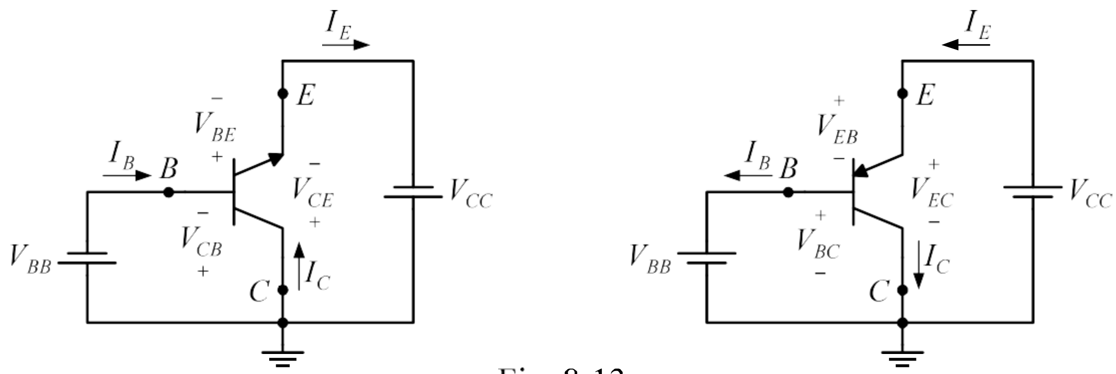

Fig. 8-13

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.

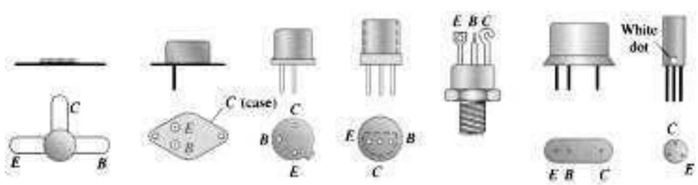

Fig. 8-14

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.
   i. Find β and I_{CEO}.
   ii. Find its (exact) collector current (I_C) when I_B = 30 µA.
   iii. Find the approximate collector current, neglecting leakage current.