Al-Mustaqbal University / College of Engineering & Technology
Department (Communication Technical Engineering)
Class (First)
Subject (ELECTRONIC CIRCUITS) /
Code (UOMU028022) Lecturer
(Prof.Dr.Haider J Abd)
2nd term – Lecture No. & Lecture Name (Lec1: Bipolar junction transistor)

Bipolar Junction Transistors (BJTs)

Basic Construction:

The transistor is a three-layer semiconductor device consisting of either two n- and one p-type layers of material or two p- and one n-type layers of material. The former is called an npn transistor, while the latter is called a pnp transistor. Both (with symbols) are shown in Fig. 8-1. The middle region of each transistor type is called the base (B) of the transistor. Of the remaining two regions, one is called emitter (E) and the other is called the collector (C) of the transistor. For each transistor type, a junction is created at each of the two boundaries where the material changes from one type to the other. Therefore, there are two junctions: emitter-base (E-B) junction and collector-base (C-B) junction. The outer layers of the transistor are heavily doped semiconductor materials having widths much greater than those of the sandwiched p- or n-type material. The doping of the sandwiched layer is also considerably less than that of the outer layers (typically 10:1 or less). This lower doping level decreases the conductivity (increases the resistance) of this material by limiting the number of "free" carriers.

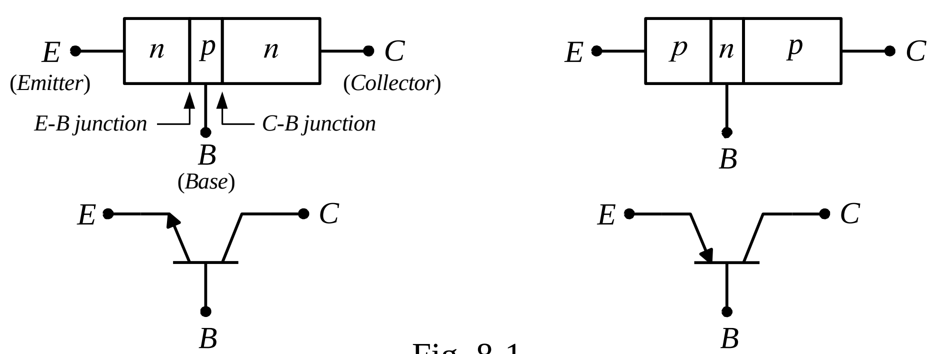

Fig. 8-1

The dc biasing is necessary to establish the proper region of operation for ac amplification or switching purposes. Table 8-1 shows the transistor operation regions and the purpose with respect to the biasing of the E-B and C-B junctions.

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Table 8-1

Operation region		Purpose	Junctions biasing	
			E-B junction bias	**C-B junction bias**
1	Active region	Amplification	Forward-biased	Reverse-biased
2	Cutoff region	Switching	Reverse-biased	Reverse-biased
3	Saturation region		Forward-biased	Forward-biased

The abbreviation BJT, from bipolar junction transistor, is often applied to this three-terminal device. The term bipolar reflects the fact that holes and electrons participate in the injection process into the oppositely polarized material. If only one carrier is employed (electron or hole), it is considered a unipolar device. Such a device is the field-effect transistor (FET).

Active Region Operation:

The basic operation of the transistor will now be described using the pnp transistor of Fig. 8-2. The operation of the npn transistor is exactly the same if the roles played by the electron and hole are interchanged. When the E-B junction is forward-biased, a large number of majority carriers will diffuse across the forward-biased p-n junction into the n-type material (base). Since the base is very thin and has a low conductivity (lightly doping), a very small number of these carriers will take this path of high resistance to the base terminal. The larger number of these majority carriers will diffuse across the reverse-biased C-B junction into the p-type material (collector).

The reason for the relative ease with which the majority carriers can cross the reverse-biased C-B junction is easily understood if we consider that for the reverse-biased diode the injected majority carriers will appear as minority carriers in the n-type base region material. Combining this with the fact that all the minority carriers in the depletion region will cross the reverse-biased junction of a diode accounts for the flow indicated in Fig. 8-2.

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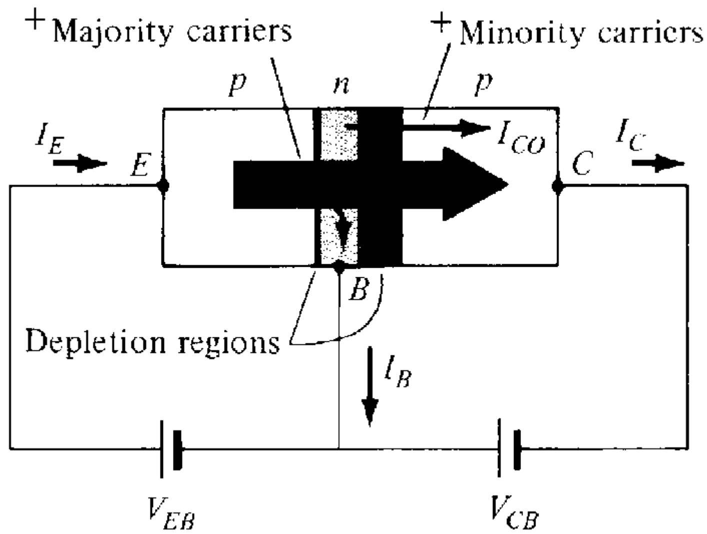

Fig. 8-2

Applying Kirchhoff's current law to the transistor of Fig. 8-2, we obtain

$$\boxed{I_E = I_C + I_B} \qquad [8.1]$$

The collector current, however, is comprised of two components: the majority and minority carriers as indicated in Fig. 8-2. The minority-current component is called the leakage current and is given the symbol ICO (IC current with emitter terminal Open). The collector current, therefore, is determined in total by Eq. [8.2].

IC = IC majority + ICO minority [8.2]

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Common-Base (CB) Configuration:

The common-base configuration with npn and pnp transistors are indicated in Fig. 8-3. The common-base terminology is derived from the fact that the base is common to both input and output sides of the configuration. In addition, the base is usually terminal closest to, or at, the ground potential.

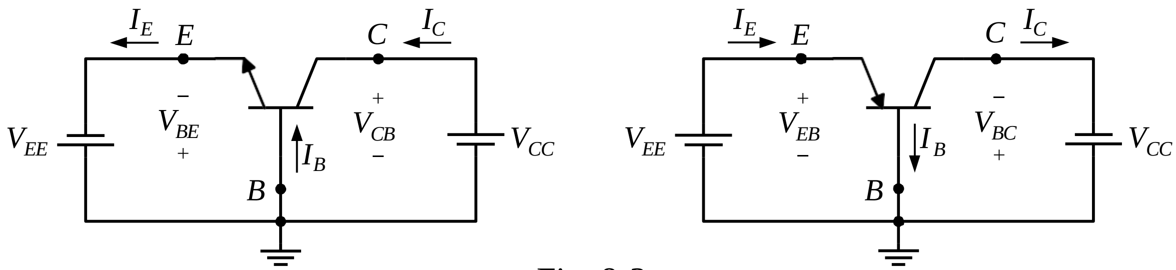

Fig. 8-3

In the dc mode the levels of IC and IE due to the majority carriers are related by a quantity called alpha (αdc) and defined by the following equation:

$$\boxed{\alpha_{dc} = \frac{I_C}{I_E}} \qquad [8.3]$$

Where I_C and I_E are the levels of current at the point of operation and $\alpha_{dc} \approx 1$, or for practical devices: $0.900 \leq \alpha_{dc} \leq 0.998$.

Since alpha is defined solely for the majority carriers and from Fig. 8-4, Eq. [8.2] becomes

$$\boxed{I_C = \alpha I_E + I_{CBO}} \qquad [8.4]$$

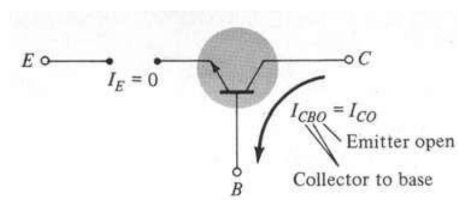

Fig. 8-4

The input (emitter) characteristics for a CB configuration are a plot of the emitter (input) current (I_E) versus the base-to-emitter (input) voltage (V_{BE}) for a rage of values of the collector-to-base (output) voltage (V_{CB}) as shown in Fig. 8-5. Since, the exact shape of this I_E-V_{BE} carve will depend on the reverse-biasing output voltage, V_{CB}. The reason for this dependency is that the grater the value of V_{CB}, the more readily minority carriers in the base are swept through the C-B junction. The increase in emitter-to-collector current resulting from an increase in V_{CB} means the emitter current will be greater for a given value of base-to-emitter voltage (V_{BE}).

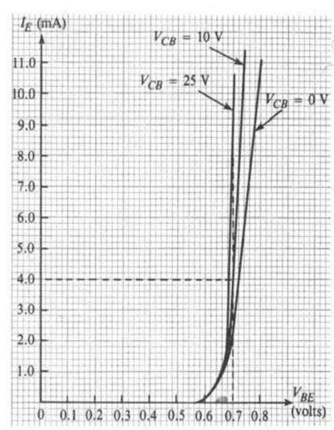

Fig. 8-5

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The output (collector) characteristics for CB configuration will be a plot of the collector (output) current (I_C) versus collector-to-base (output) voltage (V_{CB}) for a range of values of emitter (input) current (I_E) as shown in Fig. 8-6. The collector characteristics have three basic region of interest, as indicated in Fig. 8-6, the active, cutoff, and saturation regions.

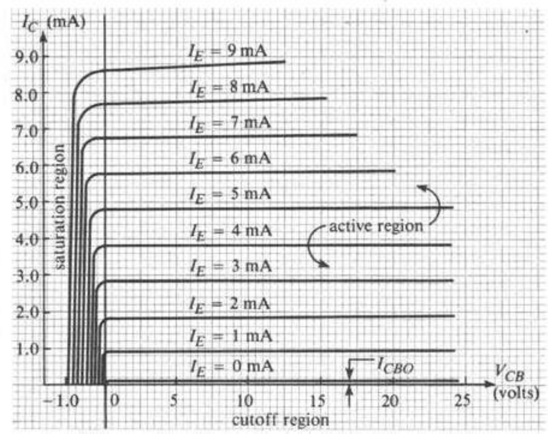

Fig. 8-6

Active region:

VCB > 0 and IC $=\alpha$IE .

Cutoff region:

IE = 0 and IC $=$ ICBO .

Saturation region:

$V_{CB} < 0$ and $I_{C(sat.)} \approx$ IE

For ac situations where the point of operation moves on the characteristic carve, an ac alpha (αac) is defined by

$$\boxed{\alpha_{ac} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}=const.}} \qquad [8.5]$$

The ac alpha is formally called the ***common-base***, ***short-circuit***, ***amplification factor***, and for most situations the magnitudes of α_{ac} and α_{dc} are quite close, permitting the use of the magnitude of one for other.

Fig. 8-7 shows how the common-base output characteristics appear when the effects of breakdown are included. Note the sudden upward swing of each curve at a large value of V_{CB}. The collector-to-base breakdown voltage when $I_E = 0$ (emitter open) is designed BV_{CBO}.

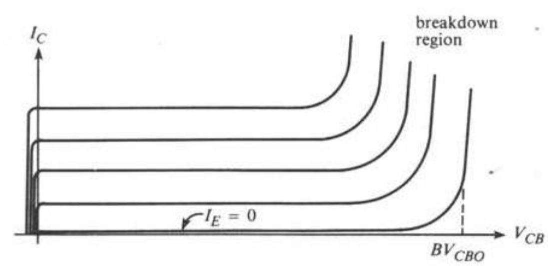

Fig. 8-7