Bipolar Junction Transistors (BJTs) and Circuits

Basic Construction:

The transistor is a three-layer semiconductor device consisting of either two n- and one p-type layers of material is called an npn transistor or two p- and one n-type layers of material 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, 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 (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.

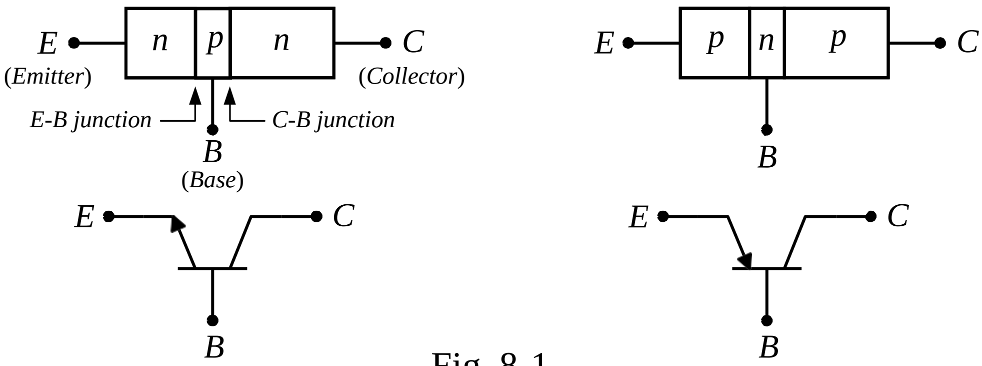

Fig. 8-1

The abbreviation BJT, from (bipolar junction transistor). The term bipolar reflects the fact that holes and electrons participate in the injection process into the oppositely polarized material.

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

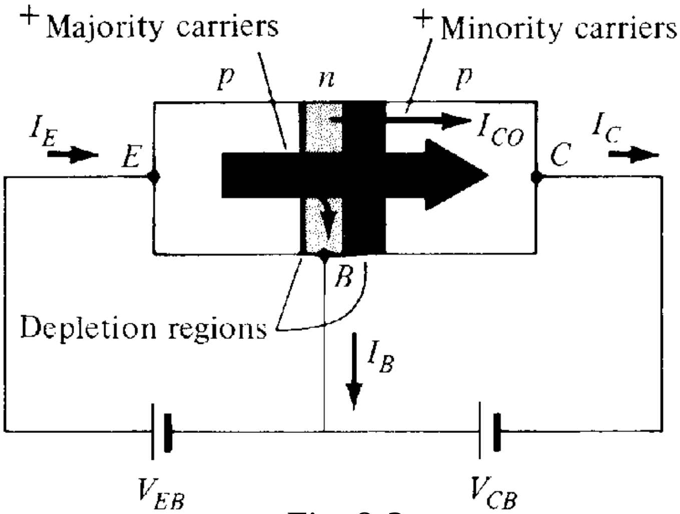

Fig. 8-2

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.

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 I_{CO} (I_C current with emitter terminal Open). The collector current, therefore, is determined in total by Eq. [8.2].

$$I_C = I_{C\,\text{majority}} + I_{CO\,\text{minority}} \qquad [8.2]$$

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.

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