Bipolar Junction Transistors (BJT)

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*, and the latter is called a *pnp transistor*.

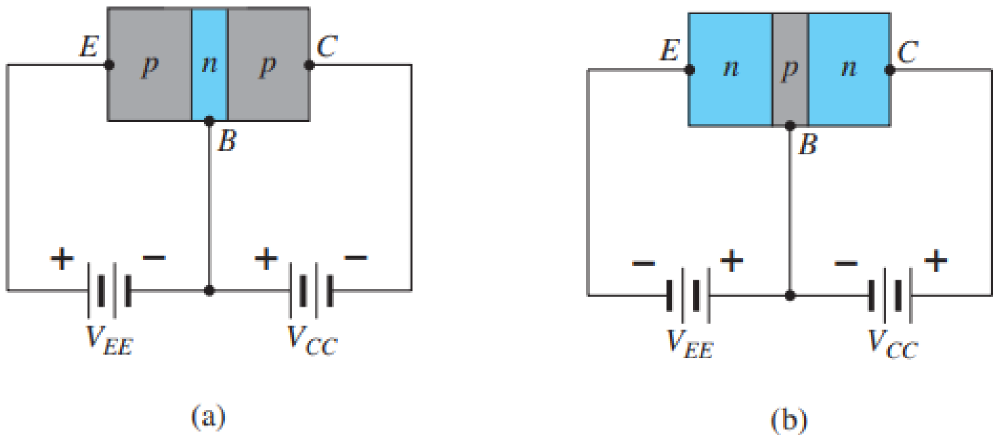
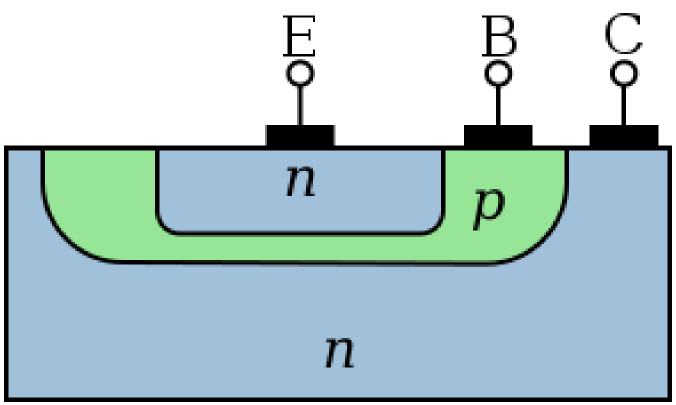
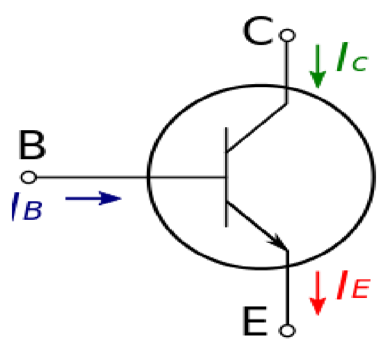


FIG. 3.3
Types of transistors: (a) pnp; (b) npn.



Simplified cross section of a planar *NPN* bipolar junction transistor



Bipolar Junction Transistors (BJT)

A terminal is connected to each of the three semiconductor regions of the transistor, with the terminals labeled **emitter** (E), **base** (B), and **collector** (C).

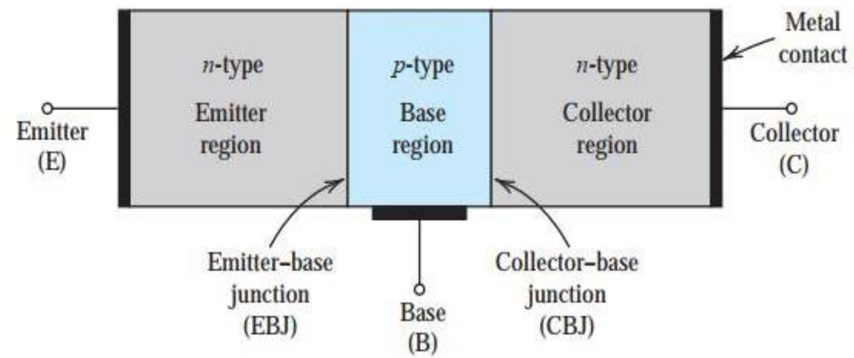


Figure 6.1 A simplified structure of the *npn* transistor.

The transistor consists of two *pn* junctions, the **emitter–base junction** (EBJ) and the **collector–base junction** (CBJ).

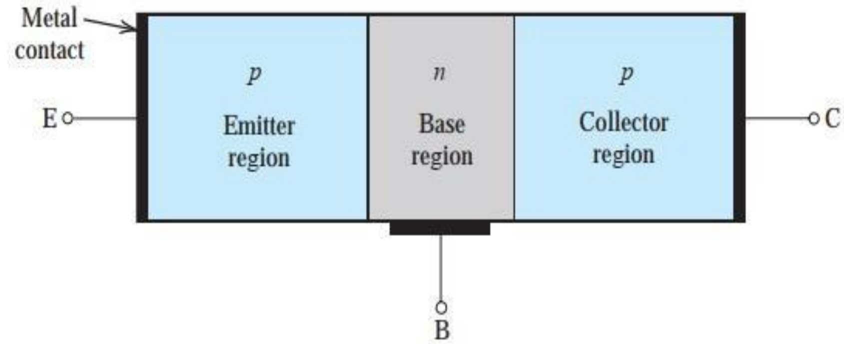


Figure 6.2 A simplified structure of the *pnp* transistor.

Bipolar Junction Transistors (BJT)

Depending on the bias condition (forward or reverse) of each of these junctions, different modes of operation of the BJT are obtained, as shown in Table 6.1. The **active mode** is the one used if the transistor is to operate as an **amplifier. Switching** applications (e.g., logic circuits) utilize both the **cutoff mode** and the **saturation mode**.

Table 6.1 BJT Modes of Operation

Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

Bipolar Junction Transistors (BJT)

Operation of the *npn* Transistor in the Active Mode

Of the three modes of operation of the BJT, the active mode is the most important. Therefore, we begin our study of the BJT by considering its physical operation in the active mode. This situation is illustrated in Fig. 6.3 for the *npn* transistor.

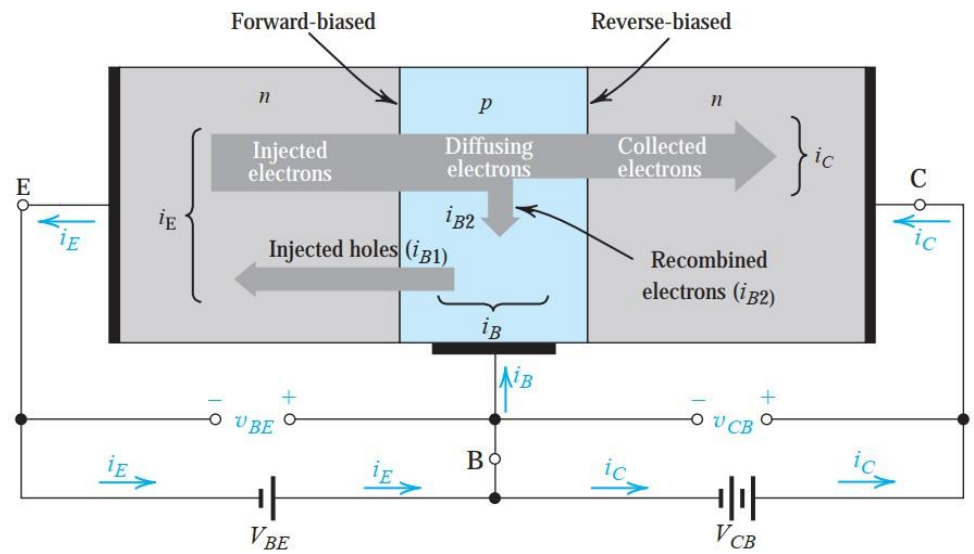


Figure 6.3 Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

Two external voltage sources (shown as batteries) are used to establish the required bias conditions for active-mode operation.

Bipolar Junction Transistors (BJT)

The Collector Current,

$$i_C = I_S e^{v_{BE}/V_T}$$

The base current,

$$i_B = \frac{i_C}{\beta}$$

where β is a transistor parameter. For modern npn transistors, β is in the range 50 to 200, but it can be as high as 1000 for special devices. For reasons that will become clear later, the parameter β is called the **common-emitter current gain**.

The collector current,

$$i_C = \alpha i_E$$

α is a constant (for a particular transistor) that is less than but very close to unity. For instance, if β = 100, then α 0.99. α is called the **common-base current gain**

Bipolar Junction Transistors (BJT)

Relation between α and β

The Emitter Current,

$$i_E = i_c + i_B$$

$$\Rightarrow i_E = i_c + \frac{i_C}{\beta}$$

$$\Rightarrow i_E = i_c \left(\frac{1+\beta}{\beta}\right)$$

$$\Rightarrow \frac{i_E}{i_C} = \left(\frac{1+\beta}{\beta}\right)$$

$$\therefore \boldsymbol{\alpha} = \frac{\boldsymbol{\beta}}{\mathbf{1}+\boldsymbol{\beta}}$$

And,

$$\alpha + \alpha\beta = \beta$$

$$\Rightarrow \alpha = \beta - \alpha\beta$$

$$\Rightarrow \alpha = \beta(1 - \alpha)$$

$$\therefore \boldsymbol{\beta} = \frac{\boldsymbol{\alpha}}{\mathbf{1}-\boldsymbol{\alpha}}$$