Bipolar Junction Transistors

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Two Fundamental Types of Transistors

•Bipolar Junction Transistors (BJTs)

•Field Effect Transistors (FETs)

•The term **bipolar** refers to the use of both holes and electrons as carriers in the transistor structure.

BJT STRUCTURE

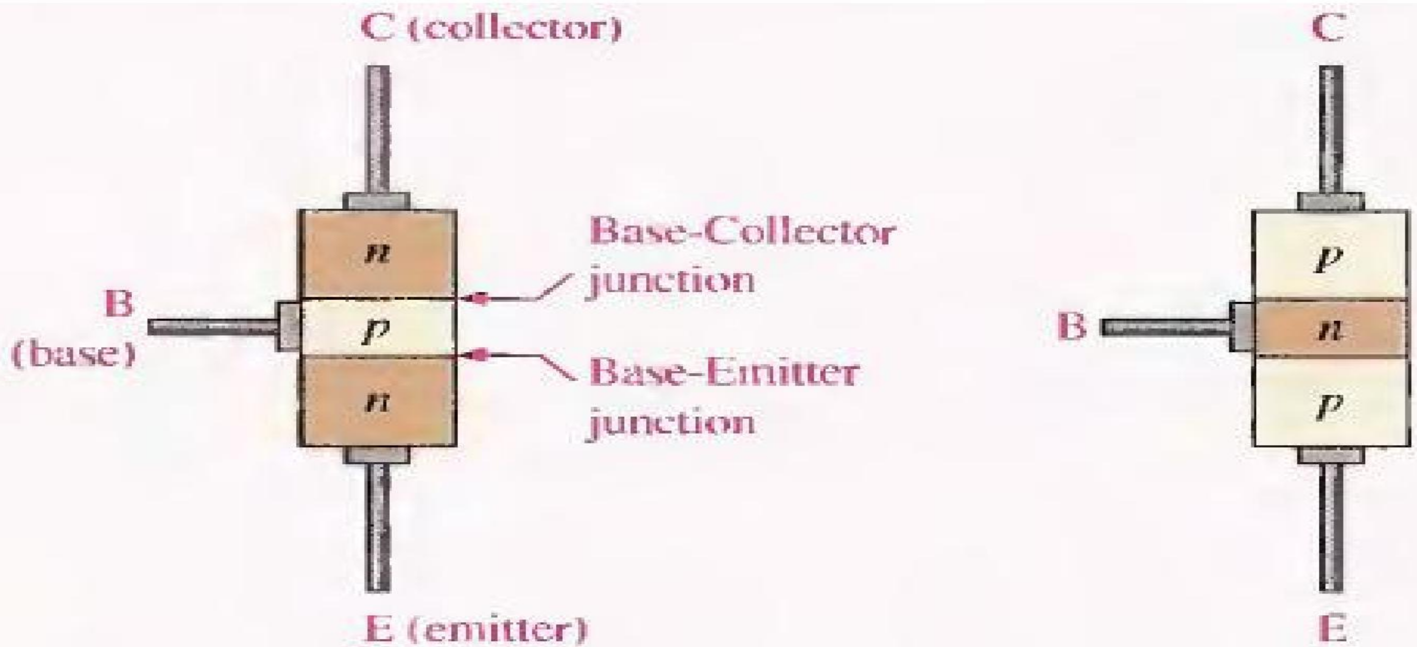
The **BJT (bipolar junction transistor)** is constructed with three doped semiconductor regions separated by two *pn* junctions, as shown in the epitaxial planar structure in Figure 4–1(a). The three regions are called **emitter**, **base**, and **collector**. Physical representations of the two types of BJTs are shown in Figure 4–1(b) and (c). One type consists of two *n* regions separated by a *p* region (*npn*), and the other type consists of two *p* regions separated by an *n* region (*pnp*).

The *pn* junction joining the base region and the emitter region is called the *base-emitter junction*. The *pn* junction joining the base region and the collector region is called the *base-collector junction*, as indicated in Figure 4–1(b). A wire lead connects to each of the three regions, as shown. These leads are labeled E, B, and C for emitter, base, and collector, respectively. The base region is lightly doped and very thin compared to the heavily doped emitter and the moderately doped collector regions. (The reason for this is discussed in the next section.)

(a) Basic epitaxial planar structure

FIGURE 4–1

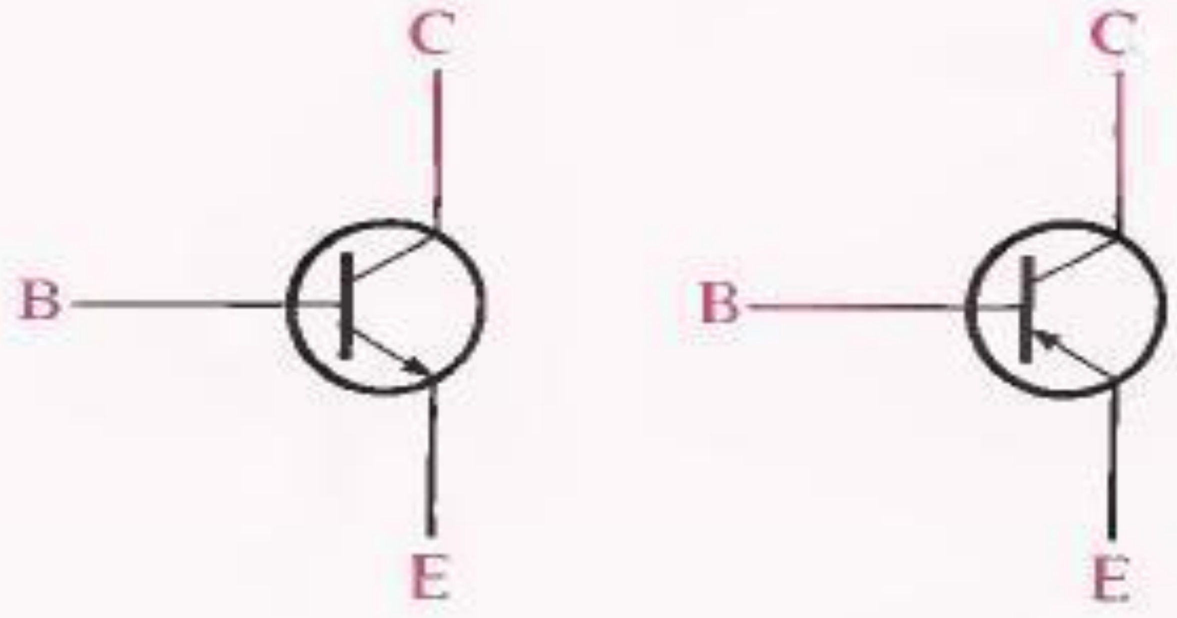
Basic BJT construction.



(b) *npn*

(c) *pnp*

Schematic symbols for the NPN and PNP bipolar junction transistors



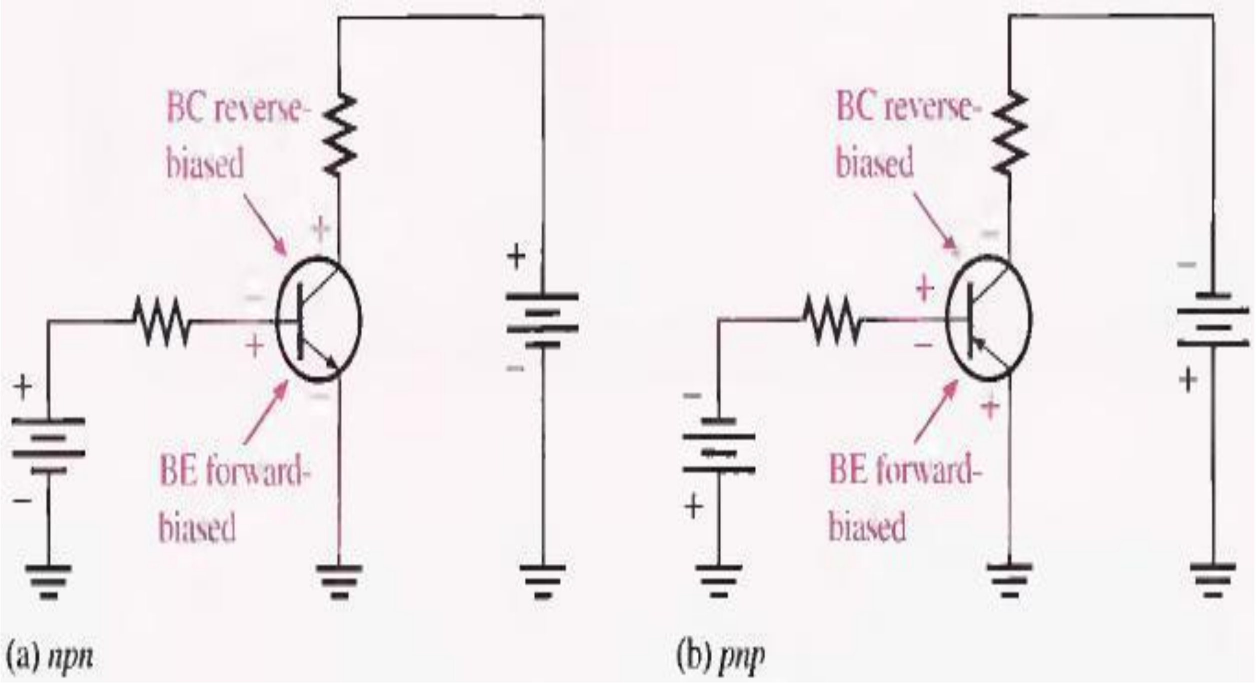
(a) *npn* (b) *pnp*

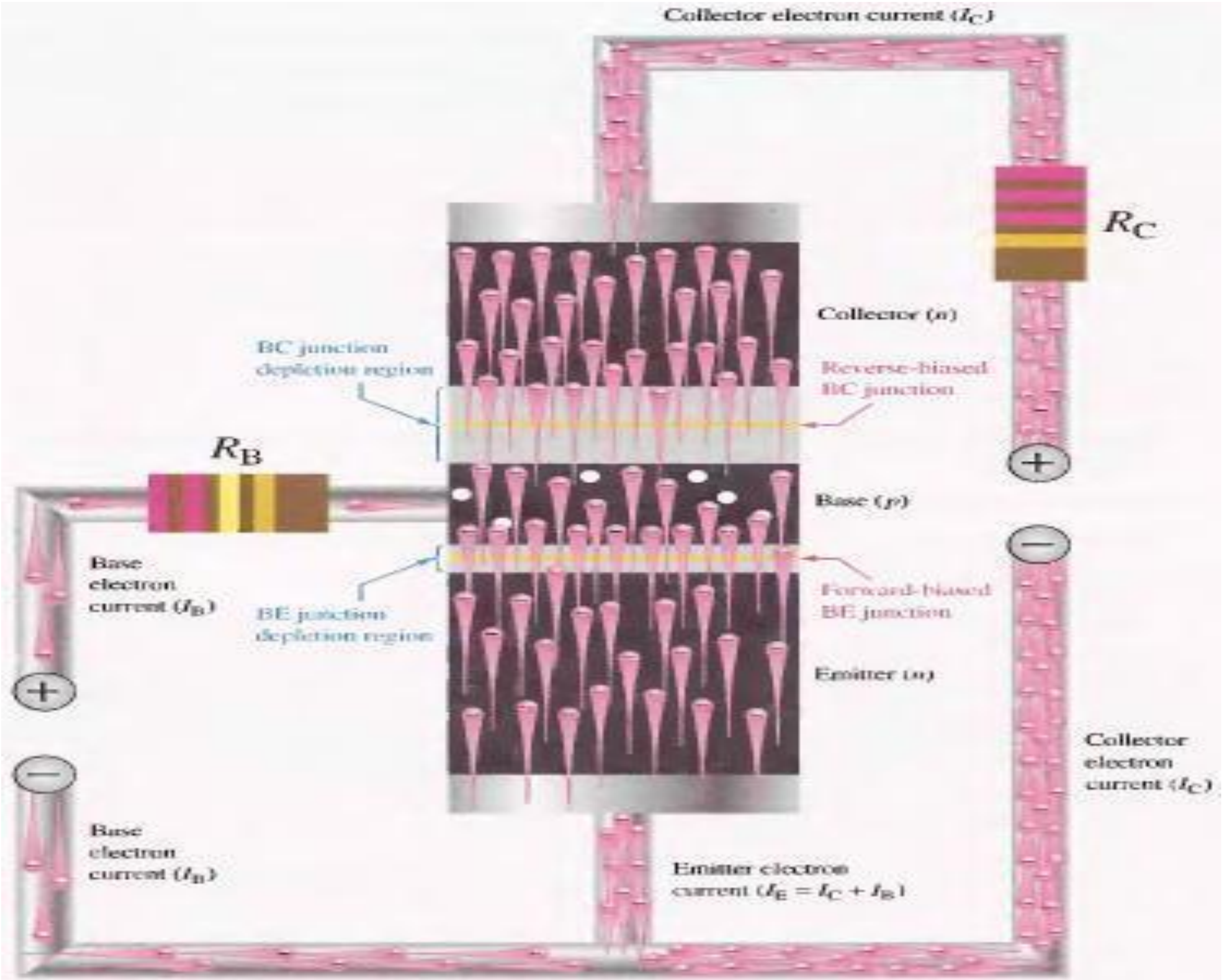
BASIC TRANSISTOR OPERATION

•In order for the transistor to operate properly as an amplifier, the two pn junctions must be correctly biased with external dc voltages.

•For a transistor to work as an amplifier, the base-emitter (BE) junction is forward-biased and the base-collector (Be) junction is reverse-biased.

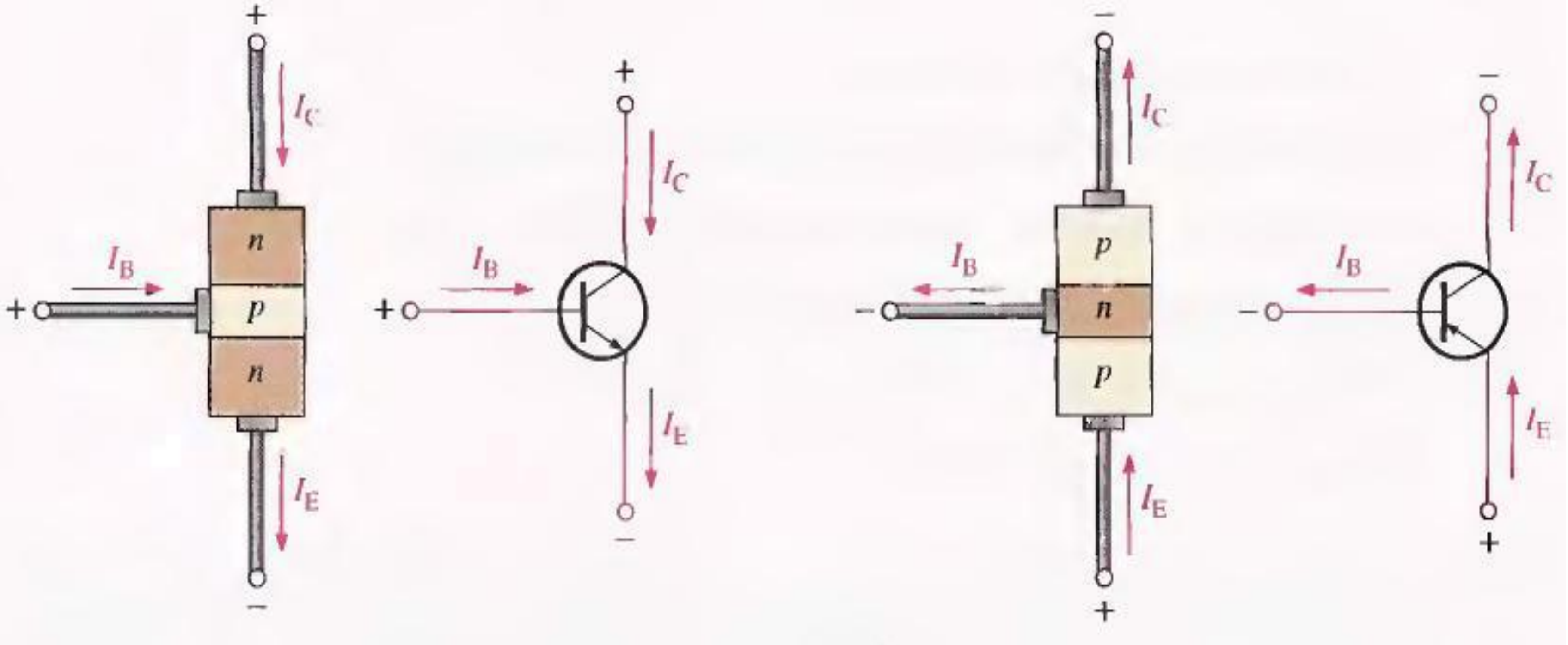
•In this section, we use the npn transistor for illustration. The operation of the pnp is the same as for the npn except that the roles of the electrons and holes, the bias voltage polarities, and the current directions are all reversed.





Collector electron current (I_C)
R_C
Collector (n)
BC junction depletion region
Reverse-biased BC junction
R_B
Base (p)
Base electron current (I_B)
BE junction depletion region
Forward-biased BE junction
Emitter (n)
Collector electron current (I_C)
Base electron current (I_B)
Emitter electron current ($I_E = I_C + I_B$)

TRANSISTOR CURRENTS

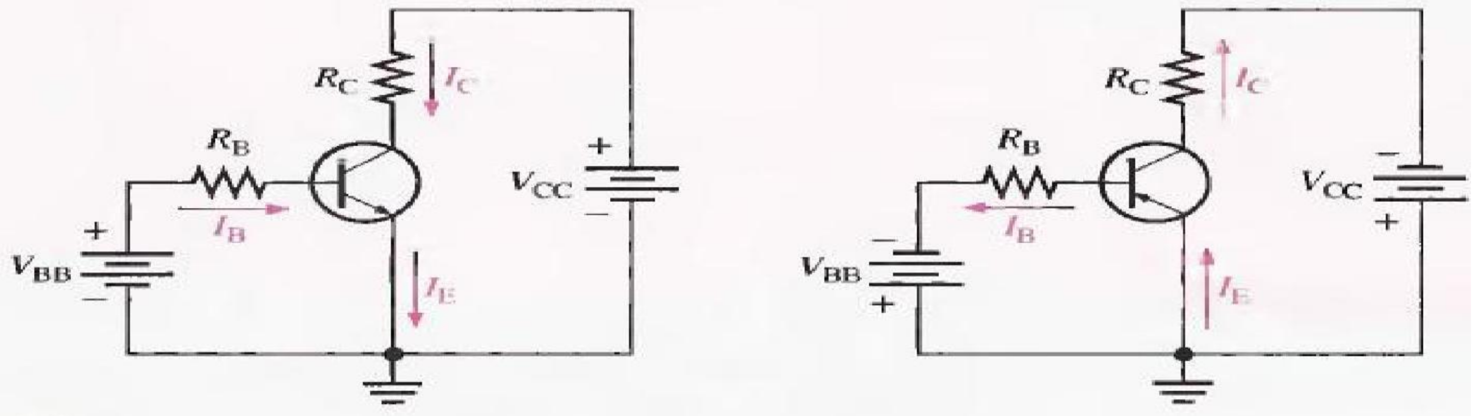


(a) *npn* (b) *pnp*

These diagrams show that the emitter current (I_E) is the sum of the collector current (I_C) and the base current (I_B), expressed as follows:

$$I_E = I_C + I_B$$

As mentioned before, I_B is very small compared to I_E or I_C. The capital-letter subscripts indicate dc values.



(a) *npn* (b) *pnp*

DC Beta (β_{DC}) and DC Alpha (α_{DC})

The ratio of the dc collector current (I_C) to the dc base current (I_B) is the dc **beta** (β_{DC}), which is the dc current gain of a transistor.

$$\beta_{DC} = \frac{I_C}{I_B}$$

Typical values of β_{DC} range from less than 20 to 200 or higher. β_{DC} is usually designated as an equivalent hybrid (h) parameter, h_{FE}, on transistor data sheets. h-parameters are covered in Chapter 6. All you need to know now is that

$$h_{FE} = \beta_{DC}$$

The ratio of the dc collector current (I_C) to the dc emitter current (I_E) is the dc **alpha** (α_{DC}). The alpha is a less-used parameter than beta in transistor circuits.

$$\alpha_{DC} = \frac{I_C}{I_E}$$

Typically, values of α_{DC} range from 0.95 to 0.99 or greater, but α_{DC} is always less than 1. The reason is that I_C is always slightly less than I_E by the amount of I_B. For example, if I_E = 100 mA and I_B = 1 mA, then I_C = 99 mA and α_{DC} = 0.99.

Current & Voltage Analysis

I_B: dc base current

I_E: dc emitter current

I_C: dc collector current

V_{BE}: dc voltage at base with respect to emitter

V_{CB}: dc voltage at collector with respect to base

V_{CE}: dc voltage at collector with respect to emitter