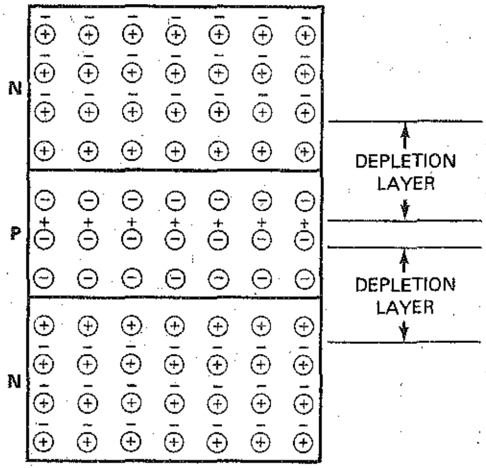
Figure 6-2 Depletion layers.



6-2 The Biased Transistor

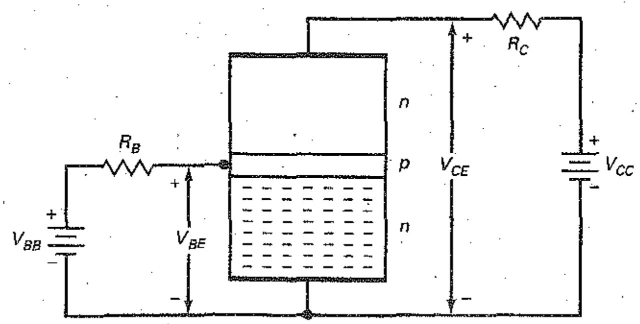
An unbiased transistor is like two back-to-back diodes. Each diode has a barrier potential of approximately 0.7 V. When you connect external voltage sources to the transistor, you will get currents through the different parts of the transistor.

Emitter Electrons

Figure 6-3 shows a biased transistor. The minus signs represent free electrons. The heavily doped emitter has the following job: to emit or inject its free electrons into the base. The lightly doped base also has a well-defined purpose: to pass emitter-injected electrons on to the collector. The collector is so named because it collects or gathers most of the electrons from the base.

Figure 6-3 is the usual way to bias a transistor. The left source V_{BB} of Fig. 6-3 forward-biases the emitter diode, and the right source V_{CC} reverse-biases the collector diode. Although other biasing methods are possible, forward-biasing the emitter diode and reverse-biasing the collector diode produce the most useful results.

Figure 6-3 Biased transistor.



GOOD TO KNOW

In a transistor, the emitter-base depletion layer is narrower than the collector-base depletion layer. The reason can be attributed to the different doping levels of the emitter and collector regions. With much heavier doping in the emitter region, the penetration into the *n* material is minimal because of the availability of many more free electrons. However, on the collector side, fewer free electrons are available and the depletion layer must penetrate more deeply in order to set up the barrier potential.

Base Electrons

At the instant that forward bias is applied to the emitter diode of Fig. 6-3, the electrons in the emitter have not yet entered the base region. If V_{BB} is greater than the emitter-base barrier potential in Fig. 6-3, emitter electrons will enter the base region, as shown in Fig. 6-4. Theoretically, these free electrons can flow in either of two directions. First, they can flow to the left and out of the base, passing through R_B on the way to the positive source terminal. Second, the free electrons can flow into the collector.

Which way will the free electrons go? Most will continue on to the collector. Why? Two reasons: the base is *lightly doped* and *very thin*. The light doping means that the free electrons have a long lifetime in the base region. The very thin base means that the free electrons have only a short distance to go to reach the collector. For these two reasons, almost all the emitter-injected electrons pass through the base to the collector.

Only a few free electrons will recombine with holes in the lightly doped base of Fig. 6-4. Then, as valence electrons, they will flow through the base resistor to the positive side of the V_{BB} supply.

Collector Electrons

Almost all the free electrons go into the collector, as shown in Fig. 6-5. Once they are in the collector, they feel the attraction of the V_{CC} source voltage. Because of this, the free electrons flow through the collector and through R_C until they reach the positive terminal of the collector supply voltage.

Figure 6-4 Emitter injects free electrons into base.

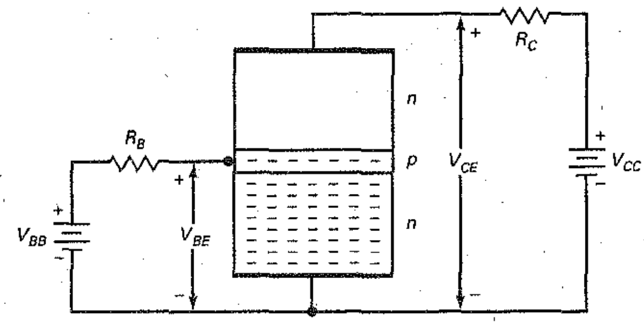
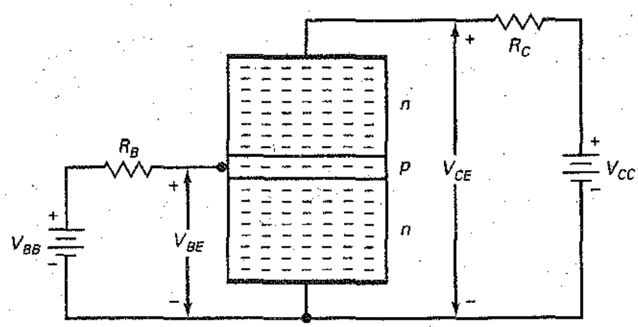


Figure 6-5 Free electrons from base flow into collector.



Example 6-3

A transistor has a collector current of 2 mA. If the current gain is 135, what is the base current?

SOLUTION Divide the collector current by the current gain to get:

$$I_B = \frac{2\text{ mA}}{135} = 14.8\ \mu\text{A}$$

PRACTICE PROBLEM 6-3 If $I_C = 10$ mA in Example 6-3, find the transistor's base current.

6-4 The CE Connection

There are three useful ways to connect a transistor: with a CE (common emitter), a CC (common collector), or a CB (common base). The CC and CB connections are discussed in later chapters. In this chapter, we will focus on the CE connection because it is the most widely used.

Common Emitter

In Fig. 6-7*a*, the common or ground side of each voltage source is connected to the emitter. Because of this, the circuit is called a **common emitter (CE)** connection. The circuit has two loops. The left loop is the base loop, and the right loop is the collector loop.

Figure 6-7 CE connection. (*a*) Basic circuit; (*b*) circuit with grounds.