6-1 The Unbiased Transistor

A transistor has three doped regions, as shown in Fig. 6-1. The bottom region is called the **emitter**, the middle region is the **base**, and the top region is the **collector**. In an actual transistor, the base region is much thinner as compared to the collector and emitter regions. The transistor of Fig. 6-1 is an *npn device* because there is a *p* region between two *n* regions. Recall that the majority carriers are free electrons in *n*-type material and holes in *p*-type material.

Transistors are also manufactured as *pnp* devices. A *pnp* transistor has an *n* region between two *p* regions. To avoid confusion between the *npn* and the *pnp* transistors, our early discussions will focus on the *npn* transistor.

GOOD TO KNOW

During the afternoon of December 23, 1947, Walter H. Brattain and John Bardeen demonstrated the amplifying action of the *first* transistor at the Bell Telephone Laboratories. The first transistor was called a *point-contact transistor*, which was the predecessor to the junction transistor invented by Schockley.

Doping Levels

In Fig. 6-1, the emitter is heavily doped. On the other hand, the base is lightly doped. The doping level of the collector is intermediate, between the heavy doping of the emitter and the light doping of the base. The collector is physically the largest of the three regions.

Emitter and Collector Diodes

The transistor of Fig. 6-1 has two junctions: one between the emitter and the base, and another between the collector and the base. Because of this, a transistor is like two back-to-back diodes. The lower diode is called the *emitter-base diode*, or simply the **emitter diode**. The upper diode is called the *collector-base diode*, or the **collector diode**.

GOOD TO KNOW

The transistor in Fig. 6-1 is sometimes referred to as a *bipolar junction transistor*, or *BJT*. However, most people in the electronics industry still use the word *transistor*, with the understanding that a bipolar junction transistor is meant.

Before and After Diffusion

Figure 6-1 shows the transistor regions before diffusion has occurred. As discussed in Chap. 2, free electrons in the *n* region will diffuse across the junction and recombine with the holes in the *p* region. Visualize the free electrons in each *n* region crossing the junction and recombining with holes.

The result is two depletion layers, as shown in Fig. 6-2. For each of these depletion layers, the barrier potential is approximately 0.7 V at 25°C for a silicon transistor (0.3 V at 25°C for a germanium transistor). As before, we emphasize silicon devices because they are now more widely used than germanium devices.

Figure 6-1 Structure of a transistor.

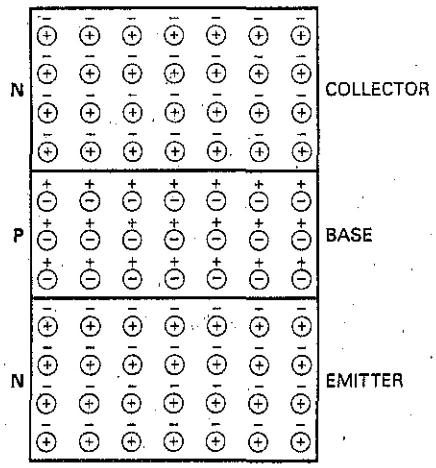
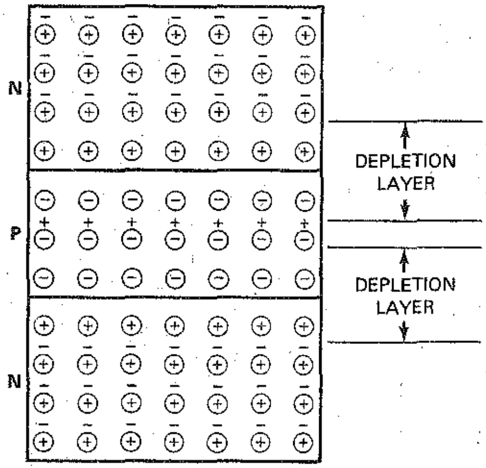


Figure 6-2 Depletion layers.



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.