Why it Matters

Transistors and Integrated Circuits

A computer motherboard is a multi-layered collection of integrated circuits containing millions of transistors and other circuit elements.

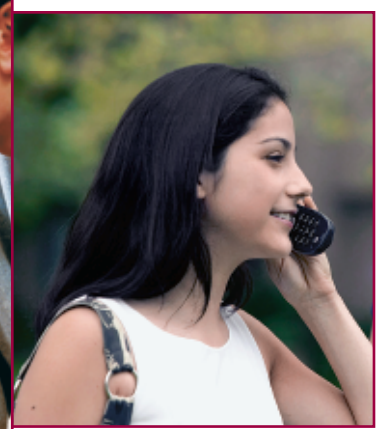
In the chapter "Electrical Energy and Current," you learned about a class of materials called *semiconductors,* which have properties between those of insulators and conductors. Semiconductors play many important roles in today's world, as they are the foundation of circuits found in virtually every electronic device.

Most commercial semiconductors are made primarily of either silicon or germanium. The conductive properties of semiconductors can be enhanced by adding impurities to the base material in a process called *doping.* Depending on how a semiconductor is doped, it can be either an n-type semiconductor or a p-type semiconductor. N-type semiconductors carry negative charges (in the form of electrons), and p-type semiconductors carry positive charges. The positive charges in a p-type semiconductor are not actually positively charged particles. They are "holes" created by the absence of electrons.

The most interesting and useful properties of semiconductors emerge when more than one type of semiconductor is used in a device. One such device is a *diode,* which is made by placing a p-type semiconductor next to an n-type semiconductor. The junction where the two types meet is called a *p-n junction.* A diode has almost infinite resistance in one direction and nearly zero resistance in the other direction. One useful application of diodes is the conversion of alternating current to direct current.

A *transistor* is a device that contains three layers of semiconductors. Transistors can be either *pnp transistors* or *npn transistors,* depending on the order of the layers.

A transistor is like two diodes placed back-to-back. You might think this would mean that no current exists in a transistor, as there is infinite resistance at one or the other of the p-n junctions. However, if a small voltage is applied to the middle layer of the transistor, the p-n junctions are altered in such a way that a large amount of current can be in the transistor. As a result, transistors can be used as switches, allowing a small current to turn a larger current on or off. Transistor-based switches are the building blocks of computers. A single switch turned on or off can represent a binary digit, or *bit,* which is always either a one or a zero.



An *integrated circuit* is a collection of transistors, diodes, capacitors, and resistors embedded in a single piece of silicon, known as a *chip.* Much of the rapid progress in the computer and electronics industries in the past few decades has been a result of improvements in semiconductor technologies. These improvements allow smaller and smaller transistors and other circuit elements to be placed on chips. A typical computer motherboard, such as the one shown here, contains several integrated circuits, each one containing several million transistors.