IN THIS CHAPTER

- Seeing electric current for what it really is
- Recognizing the power of electrons
- Using conductors to go with the flow (of electrons)
- Pushing electrons around with voltage
- Making the right connections with a circuit
- Controlling the destiny of electrons with electronic components
- Applying electrical energy to loads of things

Chapter 1

Introducing You to Electronics

If you're like most people, you probably have some idea about the topic of electronics. You've been up close and personal with lots of consumer electronics devices, such as smartphones, tablets, iPods, stereo equipment, personal computers, digital cameras, and televisions, but to you, they may seem like mysteriously magical boxes with buttons that respond to your every desire.

You know that underneath each sleek exterior lies an amazing assortment of tiny electronic parts connected in just the right way to make something happen. And now you want to understand how.

In this chapter, you find out that electrons moving in harmony through a conductor constitute electric current — and that controlling electric current is the basis of electronics. You discover what electric current really is and find out that you need voltage to keep the juice flowing. You also get an overview of some of the incredible things you can do with electronics.

Just What Is Electronics?

When you turn on a light in your home, you're connecting a source of electrical energy (usually supplied by your power company) to a light bulb in a complete path, known as an *electrical circuit.* If you add a dimmer or a timer to the light bulb circuit, you can *control* the operation of the light bulb in a more interesting way than just manually switching it on and off.

REMEMBER

Electrical systems use electric current to power things such as light bulbs and kitchen appliances. *Electronic systems* take this a step further: They *control* the current, switching it on and off, changing its fluctuations, direction, and timing in various ways to accomplish a variety of functions, from dimming a light bulb (see Figure 1-1), to flashing your holiday light display in sync with your favorite holiday tune, to communicating via satellites — and lots of other things. This control distinguishes electronic systems from electrical systems.

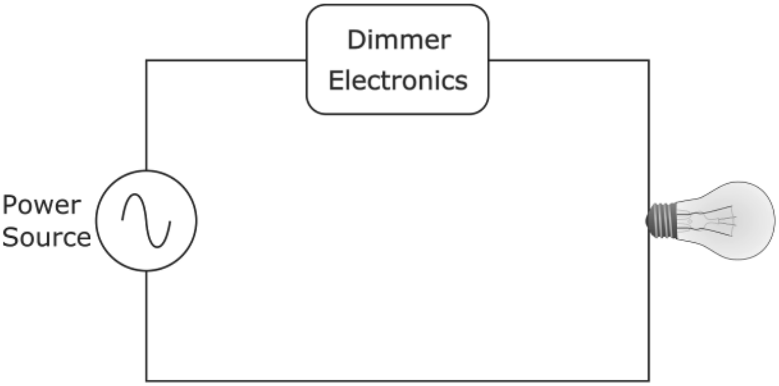

FIGURE 1-1: The dimmer electronics in this circuit control the flow of electric current to the light bulb.

The word *electronics* describes both the field of study that focuses on the control of electrical energy and the physical systems (including circuits, components, and interconnections) that implement this control of electrical energy.

To understand what it means to control electric current, first you need a good working sense of what electric current really is and how it powers things such as light bulbs, speakers, and motors.

WHAT IS ELECTRICITY?

The term *electricity* is ambiguous, often contradictory, and can lead to confusion, even among scientists and teachers. Generally speaking, electricity has to do with how certain types of particles in nature interact with each other when in close proximity.

Rather than rely on the term electricity as you explore the field of electronics, you're better off using other, more precise, terminology to describe all things electric. Here are some of them:

- **Electric charge:** A fundamental property of certain particles that describes how they interact with each other. There are two types of electric charges: positive and negative. Particles of the same type (positive-positive or negative-negative) repel each other, and particles of the opposite type (positive-negative) attract each other.
- **Electrical energy:** A form of energy caused by the behavior of electrically charged particles. This is what you pay your electric company to supply.
- **Electric current:** The movement, or flow, of electrically charged particles. This connotation of electricity is probably the one you are most familiar with and the one I focus on in this book.

Checking Out Electric Current

Electric current, sometimes known as electricity (see the sidebar "What is electricity?"), is the movement in the same direction of microscopically small, electrically charged particles called *electrons.* So where exactly do you find electrons, and how do they move around? You'll find the answers by taking a peek inside the atom.

Exploring an atom

Atoms are the basic building blocks of everything in the universe, whether natural or manmade. They're so tiny that you'd find millions of them in a single speck of dust. Every atom contains the following types of subatomic particles:

- **Protons** carry a positive electric charge and exist inside the *nucleus,* or center, of the atom.
- **Neutrons** have no electric charge, and exist along with protons inside the nucleus.

- **Electrons** carry a negative electric charge and are located outside the nucleus in an *electron cloud.* Don't worry about exactly where the electrons of a particular atom are located. Just know that electrons whiz around outside the nucleus, and that some are closer to the nucleus than others.

The specific combination of protons, electrons, and neutrons in an atom defines the type of atom, and substances made up of just one type of atom are known as *elements*. (You may remember wrestling with the *Periodic Table of the Elements* way back in Chemistry class.) I show a simplistic representation of a helium atom in Figure 1-2 and one of a copper atom in Figure 1-3.

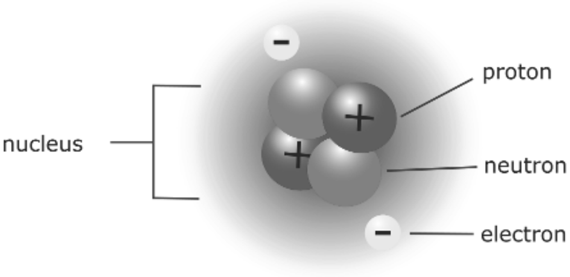

FIGURE 1-2: This helium atom consists of 2 protons and 2 neutrons in the nucleus with 2 electrons surrounding the nucleus.

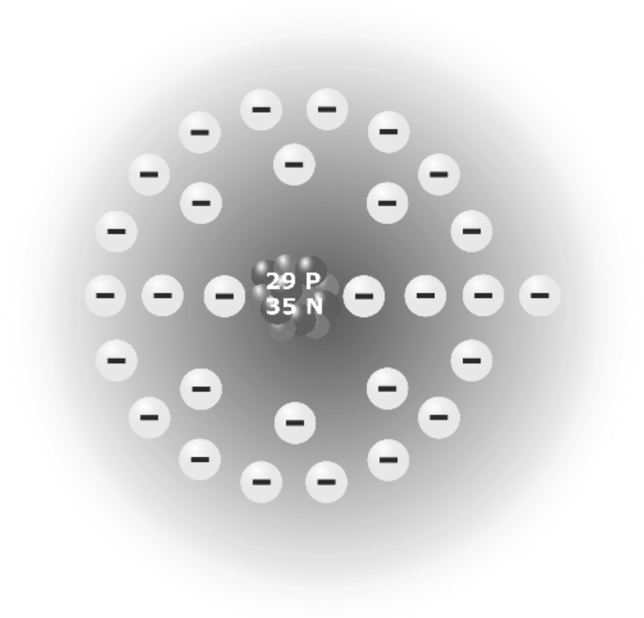

FIGURE 1-3: A copper atom consists of 29 protons, 35 neutrons, and 29 electrons.

Getting a charge out of protons and electrons

TECHNICAL STUFF

Electric charge is a property of certain particles, such as electrons, protons, and quarks (yes, quarks) that describes how they interact with each other. There are two different types of electric charge, somewhat arbitrarily named positive and negative (much like the four cardinal directions are named north, south, east, and west). In general, particles carrying the same type of charge repel each other, whereas particles carrying opposite charges attract each other. Within each atom, the protons inside the nucleus attract the electrons that are outside the nucleus.

TIP

You can experience a similar attraction/repulsion phenomenon with magnets. If you place the north pole of a bar magnet near the south pole of a second bar magnet, you'll find that the magnets attract each other. If, instead, you place the north pole of one magnet near the north pole of another magnet, you'll observe that the magnets repel each other. This mini-experiment gives you some idea of what happens with protons and electrons — without requiring you to split an atom!

Under normal circumstances, every atom has an equal number of protons and electrons, and the atom is said to be *electrically neutral.* (Note that the helium atom has 2 protons and 2 electrons and that the copper atom has 29 of each.) The attractive force between the protons and electrons acts like invisible glue, holding the atom together, in much the same way that the gravitational force of the Earth keeps the moon within sight.

The electrons closest to the nucleus are held to the atom with a stronger force than the electrons farther from the nucleus; some atoms hold on to their outer electrons with a vengeance, while others are a bit more lax. Just how tightly certain atoms hold on to their electrons turns out to be important when it comes to electricity.

Identifying conductors and insulators

Materials (such as copper, silver, aluminum, and other metals) containing loosely bound outer electrons are called *electrical conductors,* or simply *conductors*. Copper is a good conductor because it contains a single loosely bound electron in the outermost reaches of its electron cloud. Materials that tend to keep their electrons close to home are classified as *electrical insulators.* Air, glass, paper, and plastic are good insulators, as are the rubber-like polymers that are used to insulate electrical wires.

In conductors, the outer electrons of each atom are bound so loosely that many of them break free and jump around from atom to atom. These free electrons are like sheep grazing on a hillside: They drift around aimlessly but don't move very far or in any particular direction. But if you give these free electrons a bit of a push in one direction, they will quickly get organized and move together in the direction of the push.

Mobilizing electrons to create current

REMEMBER

Electric current (often called electricity) is the displacement of a large number of electrons in the same direction through a conductor when an external force (or push) is applied. That external force is known as *voltage* (which I describe in the next section, "Understanding Voltage").

This flow of electric current appears to happen instantaneously. That's because each free electron — from one end of a conductor to the other — begins to move more or less immediately, jumping from one atom to the next. So each atom simultaneously *loses* one of its electrons to a neighboring atom and *gains* an electron from another neighbor. The result of this cascade of jumping electrons is what we observe as electric current.

Think of a bucket brigade: You have a line of people, each holding a bucket of water, with a person at one end filling an empty bucket with water, and a person at the other end dumping a full bucket out. On command, each person passes his bucket to his neighbor on the right, and accepts a bucket from his neighbor on the left. Although each bucket moves just a short distance (from one person to the next), it appears as if a bucket of water is being transported from one end of the line to the other. Likewise, with electric current, as each electron displaces the one in front of it along a conductive path, it appears as if the electrons are moving nearly instantaneously from one end of the conductor to the other. (See Figure 1-4.)

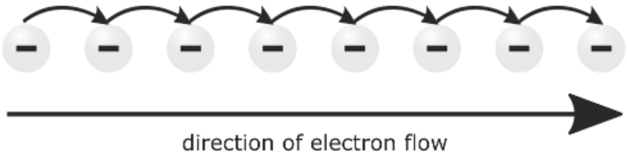

FIGURE 1-4: Electron flow through a conductor is analogous to a bucket brigade.

REMEMBER

The strength of an electric current is defined by how many charge carriers (usually electrons) pass a fixed point in one second, and is measured in units called *amperes,* or *amps* (abbreviated as A). One ampere is defined to be 6,241,000,000,000,000,000 electrons per second. (A more concise way to express this quantity, using scientific notation, is 6.241×10^{18}.) Measuring electric current is analogous to measuring water flow in gallons per minute or liters per second, for instance. The symbol *I* is used to represent the strength of an electric current. (It may help to think of *I* as representing the intensity of the current.)

EXPERIENCING ELECTRICITY

You can personally experience the flow of electrons by shuffling your feet across a carpet on a dry day and touching a doorknob; that zap you feel (and the spark you may see) is the result of electrically charged particles jumping from your fingertip to the doorknob, a form of electricity known as static electricity. *Static electricity* is an accumulation of electrically charged particles that remain static (unmoving) until drawn to a bunch of oppositely charged particles.

Lightning is another example of static electricity (but not one you want to experience personally), with charged particles traveling from one cloud to another or from a cloud to the ground. The energy resulting from the movement of these charged particles causes the air surrounding the charges to rapidly heat up to nearly 20,000 Celsius — lighting the air and creating an audible shock wave better known as thunder.

If you can get enough charged particles to move around and can control their movement, you can use the resulting electrical energy to power light bulbs and other things.

You may hear the term *coulomb* (pronounced "cool-ome") used to describe the magnitude of the charge carried by 6,241,000,000,000,000,000 electrons. A coulomb is related to an amp in that one coulomb is the amount of charge carried by one amp of current in one second. Coulombs are nice to know about, but amps are what you really need to understand because moving charge, or current, is at the heart of electronics.

A typical refrigerator draws about 3–5 amps of current, and a toaster draws roughly 9 amps. That's a whole lot of electrons at once, much more than are typically found in electronic circuits, where you're more likely to see current measured in milliamps (abbreviated mA). A *milliamp* is one one-thousandth of an amp, or 0.001 amp. (In scientific notation, a milliamp is 1×10^{-3} amp.)

Understanding Voltage

Electric current is the flow of negatively charged electrons through a conductor when a force is applied. But just what is the force that provokes the electrons to move in harmony? What commands the electronic bucket brigade?

Let the force be with you

REMEMBER

The force that pushes electrons along is technically called an *electromotive force* (abbreviated *EMF* or *E*), but it is more commonly known as *voltage* (abbreviated *V*). You measure voltage by using units called (conveniently) *volts* (abbreviated V). Apply enough voltage to a conductor, provide a complete path through which an electric charge can move, and the free electrons in the conductor's atoms will move in the same direction, like sheep being herded into a pen — only much faster.

TIP

Think of voltage as electric pressure. In much the way water pressure pushes water through pipes and valves, voltage pushes electrons through conductors. The higher the water pressure, the stronger the push. The higher the voltage, the stronger the electric current that flows through a conductor.

Why voltage needs to be different

A *voltage* is simply a difference in electrical charge between two points. In a battery, negatively charged atoms (atoms with an abundance of electrons) build up on one of two metal plates, and positively charged atoms (atoms with a dearth of electrons) build up on the other metal plate, creating a voltage across the plates. (See Figure 1-5.) If you provide a conductive path between the metal plates, you enable excess electrons to travel from one plate to the other, and current will flow in an effort to neutralize the charges. The electromotive force that compels current to flow when the circuit is completed is created by the difference between charges at the battery terminals. (You discover more about how batteries work in the later section "Getting direct current from a battery.")

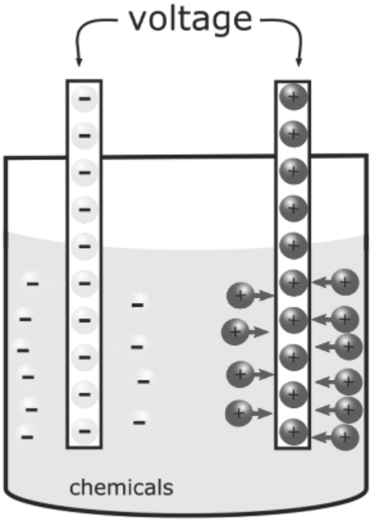

FIGURE 1-5: A difference in charge between metal plates in a battery creates a voltage.

You may also hear the terms *potential difference, voltage potential, potential drop,* or *voltage drop* used to describe voltage. The word *potential* refers to the possibility that a current may flow if you complete the circuit, and the words *drop* and *difference* both refer to the difference in charge that creates the voltage. You read more about this in Chapter 3.

Putting Electrical Energy to Work

Ben Franklin was one of the first people to observe and experiment with electricity, and he came up with many of the terms and concepts (for instance, *current*) we know and love today. Contrary to popular belief, Franklin didn't actually hold the key at the end of his kite string during that storm in 1752. (If he had, he wouldn't have been around for the American Revolution.) He may have performed that experiment, but not by holding the key.

Franklin knew that electricity was both dangerous and powerful, and his work had people wondering whether there was a way to use the power of electricity for practical applications. Scientists such as Michael Faraday, Thomas Edison, and others took Franklin's work further and figured out ways to harness electrical energy and put it to good use.

WARNING

As you begin to get excited about harnessing electrical energy, remember that over 250 years ago, Ben Franklin knew enough to be careful around the electrical forces of nature — and so should you. Even tiny amounts of electric current can be dangerous — even fatal — if you're not careful. In Chapter 13, I explain more about the harm that current can inflict and the precautions you can (and must) take to stay safe when working with electronics.

In this section, I explain how electrons transport energy — and how that energy can be applied to make things, such as light bulbs and motors, work.

Tapping into electrical energy

As electrons travel through a conductor, they transport energy from one end of the conductor to the other. Because like charges repel, each electron exerts a non-contact repulsive force on the electron next to it, pushing that electron along through the conductor. As a result, electrical energy is propagated through the conductor.

If you can transport that energy to an object that allows work to be done on it, such as a light bulb, a motor, or a loudspeaker, you can put that energy to good use. The electrical energy carried by the electrons is absorbed by the object and transformed into another form of energy, such as light, heat, or motion. That's how you make the bulb glow, rotate the motor shaft, or cause the diaphragm of the speaker to vibrate and create sound.

TIP

Because you can't see gobs of flowing electrons, try thinking about water to help make sense out of harnessing electrical energy. A single drop of water can't do much on its own, but get a whole group of water drops to work in unison, funnel them through a conduit, direct the flow of water toward an object (for example, a waterwheel), and you can put the resulting energy to good use. Just as millions of drops of water moving in the same direction constitute a current, millions of electrons moving in the same direction make an electric current. In fact, Benjamin Franklin came up with the idea that electricity acts like a fluid and has similar properties, such as current and pressure.

But where does the original energy — the thing that starts the electrons moving in the first place — come from? It comes from a *source* of electrical energy, such as a battery. (I discuss electrical energy sources in the section "Supplying Electrical Energy," in this chapter.)

Working electrons deliver power

To electrons delivering energy to a light bulb or other device, the word *work* has real physical meaning. *Work* is a measure of the energy consumed by the device over some time when a force (voltage) is applied to a bunch of electrons in the device. The more electrons you push, and the harder you push them, the more electrical energy is available and the more work can be done (for instance, the brighter the light, or the faster the motor rotation).

REMEMBER

Power (abbreviated *P*) is the total energy consumed in doing work over some period of time, and it is measured in *watts* (abbreviated *W*). Power is calculated by multiplying the force (voltage) by the strength of the electron flow (current):

$$power = voltage \times current$$

$$\text{or}$$

$$P = V \times I$$

The power equation is one of a handful of equations that you should really pay attention to because of its importance in keeping you from blowing things up. Every electronic part, or *component,* has its limits when it comes to how much power it can handle. If you energize too many electrons in a given component, you'll generate a lot of heat energy and you might fry that part. Many electronic components come with maximum power ratings so you can avoid getting into a heated situation. I remind you about the importance of power considerations in later chapters when I discuss specific components and their power ratings, as well as how to use the power equation to ensure that you protect your parts.

Using Circuits to Make Sure Electrons Arrive at Their Destination

Electric current doesn't flow just anywhere. (If it did, you'd be getting shocked all the time.) Electrons flow only if you provide a closed conductive path, known as an *electrical circuit*, or simply a *circuit*, for them to move through, and initiate the flow with a battery or other source of electrical energy.

As shown in Figure 1-6, every circuit needs at least three basic things to ensure that electrons get energized and deliver their energy to something that needs work done:

- **Source of electrical energy:** The *source* provides the voltage, or force, that nudges the electrons through the circuit. You may also hear the terms *electrical source, power source, voltage source,* and *energy source* used to describe a source of electrical energy.
- **Load:** The *load* is something that absorbs electrical energy in a circuit (for instance, a light bulb, a speaker, or a refrigerator). Think of the load as the destination for the electrical energy.
- **Path:** A conductive *path* provides a conduit for electrons to flow between the source and the load. Copper and other conductors are commonly formed into wire to provide this path.

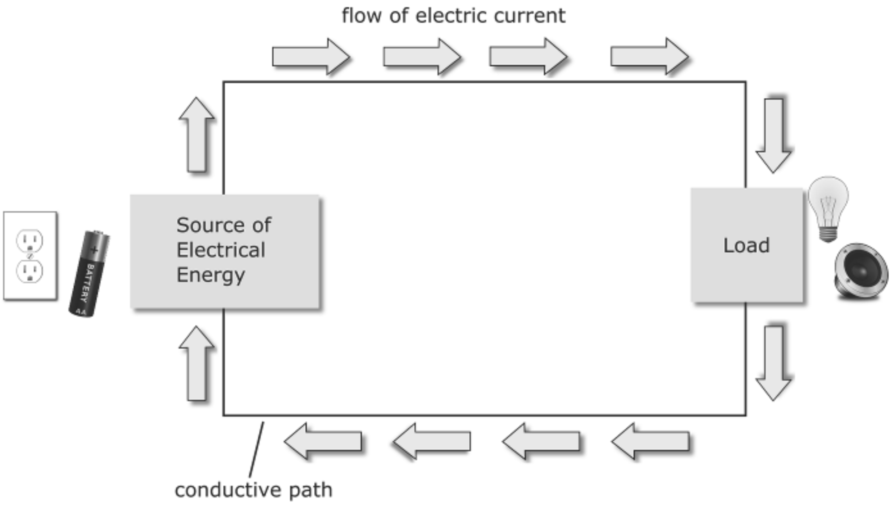

FIGURE 1-6: A simple circuit consisting of a power source, a load, and a path for electric current.

An electric current starts with a push from the source and flows through the wire path to the load, where electrical energy makes something happen (such as light being emitted) and then back to the other side of the source. Most often, other electronic parts are also connected throughout the circuit to control the flow of current.

TECHNICAL STUFF

If you simply provide a conductive path in a closed loop that contains a power source but no light bulb, speaker, or other external load, you still have a circuit and current will flow. In this case, the role of the load is played by the resistance of the wire and the internal resistance of the battery, which transfer the electrical energy into heat energy. (You find out about resistance in Chapter 5.) Without an external load to absorb some of the electrical energy, the heat energy can melt the insulation around a wire or cause an explosion or release of dangerous chemicals from a battery. In Chapter 3, I explain more about this type of circuit, which is known as a *short circuit*.

Supplying Electrical Energy

If you take a copper wire and arrange it in a closed loop by twisting the ends together, do you think the free electrons will flow? Well, the electrons might dance around a bit, because they're so easy to move. But unless a force pushes the electrons one way or another, you won't get current to flow.

Think about the motion of water that is just sitting in a closed pipe: The water isn't going to go whooshing through the pipe on its own. You need to introduce a force, a pressure differential, to deliver the energy needed to get a current flowing through the pipe.

Likewise, every circuit needs a source of electrical energy to get the electrons flowing. Batteries and solar cells are common sources; the electrical energy available at your wall outlets may come from one of many different sources supplied by your power company. But what exactly is a source of electrical energy? How do you "conjure up" electrical energy?

REMEMBER

Electrical energy isn't created from scratch. (That would go against a fundamental law of physics called the conservation of energy, which states that energy can neither be created nor destroyed.) It is generated by converting another form of energy (for instance, mechanical, chemical, heat, or light) into electrical energy. Exactly how electrical energy is generated by your favorite source turns out to be important because different sources produce different types of electric current. The two different types are

- **Direct current (DC):** A steady flow of electrons in one direction, with very little variation in the strength of the current. Cells (commonly known as batteries) produce DC and most electronic circuits use DC.
- **Alternating current (AC):** A fluctuating flow of electrons that changes direction periodically. Power companies supply AC to your electrical outlets.

Getting direct current from a battery

A battery converts chemical energy into electrical energy through a process called an *electrochemical reaction.* When two different metals are immersed in certain chemicals, the metal atoms react with the chemical atoms to produce charged atoms, known as *ions*. As you see in Figure 1-7, negative ions build up on one metal plate, known as an *electrode,* while positive ions build up on the other electrode. The difference in charge across the two electrodes creates a voltage. That voltage is the force that electrons need to push them around a circuit.

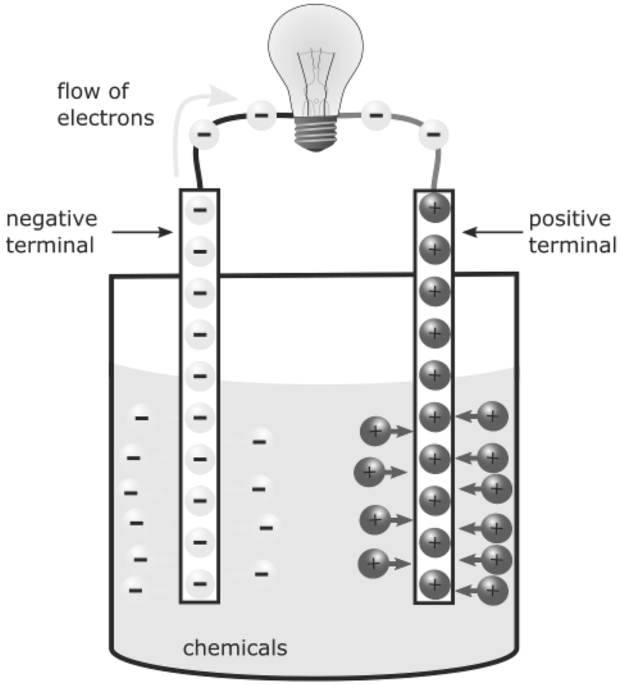

FIGURE 1-7: Direct current (DC) generated by a battery.

You might think that the oppositely charged ions would move towards each other inside the battery, because opposite charges attract, but the chemicals inside the battery act as a barrier to prevent this from happening.

To use a battery in a circuit, you connect one side of your load — for instance, a light bulb — to the negative terminal and the other side of your load to the positive terminal. (A *terminal* is just a piece of metal connected to an electrode to which you can hook up wires.) You've created a path that allows the charges to move, and electrons flow from the negative terminal, through the circuit, to the positive terminal. As they pass through the wire filament of the light bulb, some of the electrical energy supplied by the battery is converted to light and heat, causing the filament to glow and get warm.

The electrons keep flowing as long as the battery is connected in a circuit and the electrochemical reactions continue to take place. As the chemicals become depleted, fewer reactions take place, and the battery's voltage starts to drop. Eventually, the battery can no longer generate electrical energy, and we say that the battery is flat or dead.

Because the electrons move in only one direction (from the negative terminal, through the circuit, to the positive terminal), the electric current generated by a battery is DC. The AAA-, AA-, C-, and D-size batteries you can buy almost anywhere each generate about 1.5 volts — regardless of size. The difference in size among those batteries has to do with how much current can be drawn from them. The larger the battery, the more current can be drawn, and the longer it will last. Larger batteries can handle heavier loads, which is just a way of saying they can produce more power (remember, power = voltage × current), so they can do more work.

TIP

Technically speaking, an individual battery isn't really a battery (that is, a group of units working together); it's a *cell* (one of those units). If you connect several cells together, as you often do in many types of flashlights and children's toys, *then* you've created a battery. The battery in your car is made up of six cells, each generating 2 to 2.1 volts, connected together to produce 12 to 12.6 volts total.

Using alternating current from a power plant

When you plug a light into an electrical outlet in your home, you're using electrical energy that originated at a generating plant. Generating plants process natural resources — such as water, coal, oil, natural gas, or uranium — through several steps to produce electrical energy. Electrical energy is said to be a *secondary* energy source because it's generated through the conversion of a primary energy source.

The electric current generated by power plants fluctuates, or changes direction, at a regular rate known as the *frequency*. In the United States and Canada, that rate is 60 times per second, or 60 hertz (abbreviated Hz), but in most European countries, AC is generated at 50 Hz. The electricity supplied by your average wall outlet is said to be 120 volts AC (or 120 VAC), which just means it's alternating current at 120 volts.

TIP

Heaters, lamps, hair dryers, and electric razors are among the electrical devices that use 120 volts AC directly; clothes dryers, which require more power, use 240 volts AC directly from a special wall outlet. If your hair dryer uses 60 Hz power, and you're visiting a country that uses 50 Hz power, you'll need a *power converter* to get the frequency you need from your host country.

Tablets, computers, cellphones, and other electronic devices require a steady DC supply, so if you're using AC to supply an electronic device or circuit, you'll need to convert AC to DC. *Regulated power supplies,* also known as *AC-to-DC adapters,* or *AC adapters,* don't actually *supply* power: They convert AC to DC and are commonly included with electronic devices when purchased. Think of your cellphone charger; this little device essentially converts AC power into DC power that the battery in your cellphone uses to charge itself back up.

Transforming light into electricity

Solar cells, also known as *photovoltaic cells,* produce a small voltage when you shine light on them. They are made from *semiconductors,* which are materials that are somewhere between conductors and insulators in terms of their willingness to give up their electrons. (I discuss semiconductors in detail in Chapter 9.) The amount of voltage produced by a solar cell is fairly constant, no matter how much light you shine on it — but the *strength* of the current you can draw depends on the intensity of the light: The brighter the light, the higher the strength of the available current (that is, until you reach the solar cell's maximum output, at which point no more current can be drawn).

Solar cells have wires attached to two terminals for conducting electrons through circuits, so you can power your calculator or the garden lights that frame your walkway. You may have seen arrays of solar cells used to power calculators (see Figure 1-8), emergency road signs, call boxes, or lights in parking lots, but you probably haven't seen the large solar-cell arrays used to power satellites (not from close up, anyway).

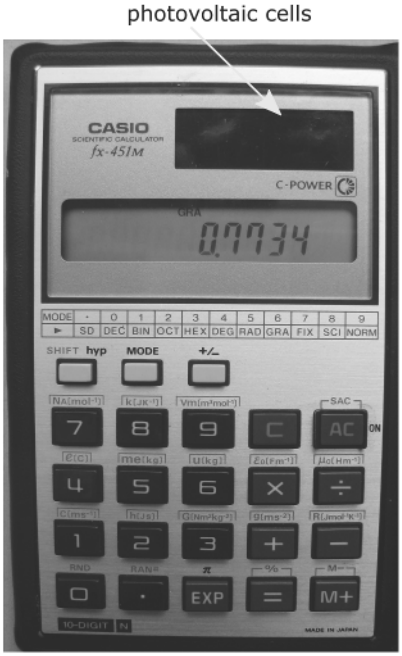

FIGURE 1-8: This calculator is powered by photovoltaic cells.

Solar panels are becoming increasingly popular for supplying electrical power to homes and businesses. If you scour the Internet, you'll find lots of information on how you can make your own solar panels — for just a couple of hundred dollars and a willingness to try. You can read more about this topic in *Solar Power Your Home For Dummies*, 2nd Edition, by Rik DeGunther (Wiley Publishing, Inc.).

Using symbols to represent energy sources

Figure 1-9 shows the symbols commonly used to represent different energy sources in circuit diagrams, or *schematics*.

In the battery symbol (see Figure 1-9, left), the plus sign signifies the positive terminal (sometimes called the *cathode*); the minus sign signifies the negative terminal (or the *anode*). Usually the battery's voltage is shown alongside the symbol. The sine wave in the symbol for an AC voltage source (see Figure 1-9, center) is a reminder that the voltage varies up and down. In the symbol for a photovoltaic cell (see Figure 1-9, right), the two arrows pointing towards the battery symbol signify light energy.

FIGURE 1-9: Circuit symbols for a battery (left), AC power source (center), and photovoltaic cell (right).

Marveling at What Electrons Can Do

Imagine applying a constant electric current to a pair of speakers without using anything to control, or "shape," the current. What would you hear? Guaranteed it wouldn't be music! By using the proper combination of electronics assembled in just the right way, you can control the way each speaker diaphragm vibrates, producing recognizable sounds such as speech or music. There's so much more you can do with electric current when you know how to control the flow of electrons.

REMEMBER

Electronics is all about using specialized devices known as *electronic components* (for example, switches, resistors, capacitors, inductors, and transistors) to control current (also known as the flow of electrons) in such a way that a specific function is performed.

The nice thing is that you after you understand how a few individual electronic components work and how to apply some basic principles, you can begin to understand and build interesting electronic circuits.

This section provides just a sampling of the sorts of things you can do by controlling electric current with electronic circuits.

Creating good vibrations

Electronic components in your iPod, car stereo, and other audio systems convert electrical energy into sound energy. In each case, the system's speakers are the load, or destination, for electrical energy. The job of the electronic components in the system is to "shape" the current flowing to the speakers so that the diaphragm within each speaker moves in such a way as to reproduce the original sound.

Seeing is believing

In visual systems, electronic components control the timing and intensity of light emissions. Many remote-control devices, such as your TV remote, emit infrared light (which is not visible) when you press a button, and the specific pattern of the emitted light acts as a sort of code that is understood by the device you are controlling. A circuit in your TV detects the infrared light and, in effect, decodes the instructions sent by the remote.

A flat-screen liquid crystal display (LCD) or plasma TV consists of millions of tiny picture elements, or *pixels,* each of which is a red, blue, or green light that can be switched on or off electronically. The electronic circuits in the TV control the timing and on/off state of each pixel, thus controlling the pattern painted across the TV screen, which is the image you see.

Sensing and alarming

Electronics can be used also to make something happen in response to a specific level or absence of light, heat, sound, or motion. Electronic *sensors* generate or change an electrical current in response to a stimulus. Microphones, motion detectors, temperature sensors, humidity sensors, and light sensors can be used to trigger other electronic components to perform some action, such as activating an automatic door opener, sounding an alarm, or switching a sprinkler system on or off.

Controlling motion

A common use of electronics is to control the on/off activity and speed of motors. By connecting various objects — for instance, wheels, airplane flaps, or fan blades — to motors, you can use electronics to control their motion. Such electronics can be found in robotic systems, aircraft, spacecraft, elevators, and lots of other places.

Computing

In much the same way that the ancients used the abacus to perform arithmetic operations, so you use electronic calculators and computers to perform computations. With the abacus, beads were used to represent numbers, and calculations were performed by manipulating those beads. In computing systems, patterns of stored electrical energy are used to represent numbers, letters, and other information, and computations are performed by manipulating those patterns using electronic components. (Of course, the worker-bee electrons inside have no idea that they are crunching numbers!) The result of a computation is stored as a new pattern of electrical energy and often directed to special circuits designed to display the result on a monitor or other screen.

Voice, video, and data communications

Electronic circuits in your cellphone work together to convert the sound of your voice into an electrical pattern, manipulate the pattern (to compress and encode it for efficient, secure transmission), transform it into a radio signal, and send it out through the air to a communication tower. Other electronic circuits in your handset detect incoming messages from the tower, decode the messages, and convert an electrical pattern in the message into sound (through a speaker) or a text or video message (through your phone's display).

Data communication systems use electronics to transmit information encoded in electrical patterns between two or more endpoints. When you shop online, your order is transmitted by sending an electrical pattern from your data communication device (such as a laptop, smartphone, or tablet) over the Internet to a communication system operated by a vendor. With a little help from electronic components, you can get electrons to convert your materialistic desires into shopping orders — and charge the order to your credit card.