Chapter 1

What Is Electronics and What Can It Do for You?

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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)
- Making the right connections with a circuit
- Controlling the destiny of electrons with electronic components
- Applying electrical energy to loads of things

If you're like most people, you probably have some idea about what electronics is. You've been up close and personal with lots of so-called "consumer electronics" devices, such as 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 components connected together 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 constitute electric current — and that controlling electric current is the basis of electronics. You take a look at what electric current really is and what you need to keep the juice flowing. You also get an overview of some of the 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 simply switching it on and off.

Electrical systems, such as the circuits in your house, use pure, unadulterated electric current to power things like light bulbs. *Electronic systems* take this a step further: They *control* the current, changing its fluctuations, direction, and timing in various ways in order to accomplish a variety of functions, from dimming a light bulb to communicating with satellites (and lots of other things). (See Figure 1-1.) It is this control that distinguishes electronic systems from electrical systems.

To understand how electronics involves the control of electric current, first you need a good working sense of what electric current really is and how it powers things like light bulbs.

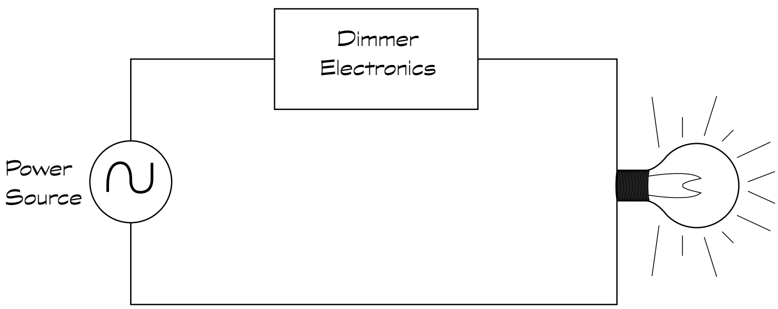

Figure 1-1: The dimmer electronics in this circuit control the flow of electric current to the light bulb.

What is electricity?

The simple truth about electricity is that it is not so simple. The term "electricity" is ambiguous, often contradictory, and can lead to great confusion, even among scientists and teachers.

Generally speaking, "electricity" has do with how certain types of particles found in nature interact with each other when a bunch of them are hanging around in the same general area.

Rather than talk about electricity, you're better off using other, more precise, terminology to describe all things electric. Here are some of them:

- **Electric charge:** A fundamental (that means don't question it) property of certain particles that describes how they interact with each other. There are two types: positive and negative. Particles of the same type (positive or negative) repel each other, while particles of the opposite type 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 flow of electrically charged particles. This is probably the connotation of electricity you are most familiar with, and the one we focus on in this chapter.

So, if you're just bantering around the water cooler, it's okay to use the word electricity to describe the stuff that powers your favorite gaming system, but if you throw that word around carelessly among learned physics types, you might just repel them.

Checking Out Electric Current

Electric current, sometimes known as electricity (see the sidebar "What is electricity?"), is the flow of teeny tiny 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.

Getting a charge out of electrons

Atoms are the basic building blocks of everything in the universe, whether natural or manmade. They're so tiny, you'd find millions of them in a single speck of dust, so you can imagine how many there are in your average sumo wrestler. Electrons can be found in every single atom in the universe, living outside the atom's center, or *nucleus.* All electrons carry a negative electric charge and are attracted to other tiny particles called *protons,* which carry a positive electric charge and exist inside the nucleus.

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 flavors of electric charge, somewhat arbitrarily named "positive" and "negative" (okay, you really could call them "Moe" and "Larry" or "north" and "south" instead, but those names are already taken). In general, particles carrying the same type of charge repel each other, whereas particles carrying different charges attract each other. That's why electrons and protons find each other so attractive.

Under normal circumstances, there are an equal number of protons and electrons in each atom, and the atom is said to be *electrically neutral.* The attractive force between the protons and electrons acts like invisible glue, holding the atomic particles 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.

Mobilizing electrons in conductors

Materials (such as air or plastic) that like to keep their electrons close to home are called *insulators.* Materials, such as copper, aluminum, and other metals, that contain loosely bound outer electrons are called *conductors.*

In metals, the outer electrons are bound so loosely, many of them break free and wander around among the metal atoms. 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 gladly move in the direction of the push. *Electric current* (often called electricity) is the movement *en masse* of electrons through a conductor when an external force (or push) is applied.

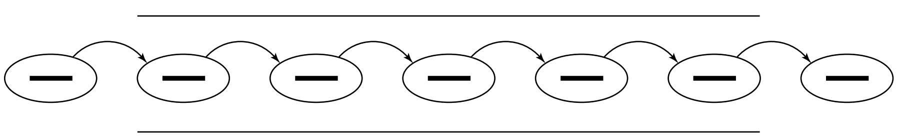

Figure 1-2: Electron flow through a conductor is analogous to a bucket brigade.

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.

Think of a bucket brigade: You've got 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 left, and accepts a bucket from his neighbor on the right, as in a bucket brigade. 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 1-2.)

Electric current is a realm of tiny things that sometimes interact in huge quantities, so it needs its own units of measurement. A *coulomb,* for example, is defined as the charge carried by 6.24 x 10^{18} (that's 624 followed by 16 zeros) electrons. If a coulomb of charge moves past a point within a second, we say that the strength of the electric current is *one ampere,* or one amp (abbreviated as 1 A). That's a whole lot of electrons at once, much more than are typically found in electronic systems. There you're more likely to see current measured in *milliamps* (mA). A milliamp is one one-thousandth of an amp.

Giving electrons a nudge

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?

The force that pushes electrons along is known as *voltage,* and it is measured in units called *volts* (abbreviated V). Apply enough voltage to a conductor, and the free electrons within it will move together in the same direction, like sheep begin herded into a pen — only much faster.

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 pressure, the stronger the push — so the higher the voltage, the stronger the electric current that flows through a conductor.

You may also hear the terms *potential difference, voltage potential, potential drop,* or *voltage drop* used to describe voltage. Try not to let these different terms confuse you. There's more about this in Chapter 2.

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. When charged particles move around, they release energy (hence the zaps and the sparks).

If you can get enough charged particles to move around, and you can harness the energy they release, you can use that energy to power light bulbs and other things.

Harnessing Electrical Energy to Do 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 got people wondering whether there was a way to use the power of electricity for practical applications. Scientists like Michael Faraday, Thomas Edison, and others took Franklin's work a bit 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, take note of the scary-looking Warning icon to the left, and 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 quite dangerous — even fatal — if the circumstances are right (or wrong). In Chapter 9, we explain more about the harm current can inflict and the precautions you can (and must) take to stay safe when working with electronics. But for now, consider this a warning!

In this section, we explore how electrons transport energy — and how that energy can be applied to make things 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 mechanical energy. That's how you make the filament glow, rotate the motor shaft, or cause the diaphragm of the speaker to vibrate.

TIP

Because you can't see — and you don't necessarily want to touch — 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 to help (or hurt) anyone, 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 water 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 he probably would have cautioned you against drinking it).

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 (we discuss electrical energy sources in Chapter 2).

Making 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 only flow if you provide a closed conductive path, or *circuit,* for them to move through, and initiate the flow with a battery or other source of electrical energy. Copper and other conductors are commonly formed into wire to provide a path for the flow of free electrons, so you can direct electrical energy to a light bulb or other object that will use it. Just as with pipes and water, the wider the wire, the more freely the electrons flow.

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). The total energy consumed in doing work over some period of time is known as *power* and is measured in *watts.* Power is calculated by multiplying the force (voltage) by the strength of the electron flow (current):

$$\text{Power} = \text{voltage} \times \text{current}$$

Power calculations are really important in electronics, because they help you understand just how much energy electronic parts are willing (and able) to handle without complaining. If you energize too many electrons in the same electronic part, you'll generate a lot of heat energy and you might fry that part. Many electronic parts come with maximum power ratings so you can avoid getting into a heated situation. We remind you about this in later chapters when we discuss specific components and their power ratings.

If there's a break in the path (an *open circuit*), electrons stop flowing — and the metal atoms in the wire quickly settle down to a peaceful, electrically neutral existence. Picture a gallon of water flowing through an open pipe. The water will flow for a short time, but then stop when all the water exits the pipe. If you pump water through a closed pipe system, the water will continue to flow as long as you keep forcing it to move. To keep the electrons flowing, you need to connect everything together in one big happy *electrical circuit.* As shown in Figure 1-3, every circuit needs at least three basic things to ensure that electrons get energized and deliver their energy to something that needs work done:

- **A *source* of electrical energy:** The source provides the 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. We discuss sources of electrical energy in Chapter 2.
- **A *load:*** The load is something that absorbs electrical energy in a circuit (for instance, a light bulb or a speaker). Think of the load as the destination for the electrical energy.
- **A *path:*** A conductive path provides a conduit for electrons to flow between the source and the load.

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 — emitting light, for instance.

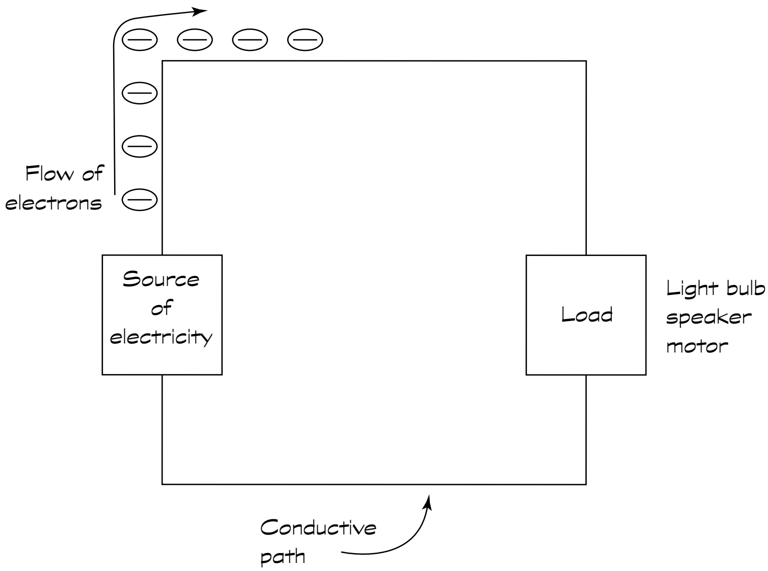

Figure 1-3: A circuit consists of a power source, a load, and a path for electric current.

Oh, the Things Electrons Can Do (Once You Put Their Minds to It)!

Imagine applying an 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 (well, certain music anyway). There's so much more you can do with electric current once you know how to control the flow of electrons.

Electronics is all about using specialized devices known as *electronic components* (for example, resistors, capacitors, inductors, and transistors, which we discuss in Chapters 3, 4, 5, and 6, respectively) to control current (also known as the flow of electrons) in such a way that a specific function is performed.

Simple electronic devices use a few components to control current flow. The dimmer switch that controls current flowing into a light bulb is one such example. But most electronic systems are a lot more complicated than that; they connect lots of individual components together in one or more circuits to achieve their ultimate goal. The nice thing is that you once 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 electrons 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, and the job of the electronic components within 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 the one wedged in your La-Z-Boy recliner, emit infrared light when you press a button, and the specific pattern of the emitted light acts as a sort of code to the device you are controlling, telling it what to do.

The inside surface of the tube in a cathode-ray tube (CRT) TV set (are there any still around?) is coated with phosphors that glow when struck by electron beams within the tube. The electronic circuits within the TV set control the direction and intensity of the electron beams, thus controlling the pattern painted across the TV screen — which is the image you see. Enlightening, isn't it?

Sensing and alarming

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

Controlling motion

A common use of electronics is to control the on/off activity and speed of motors. By attaching various objects — for instance, wheels, airplane flaps, or your good-for-nothing brother-in-law — 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.

Solving problems (a.k.a. computing)

In much the same way that the ancients (those living long ago, not your great-grandparents) 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 they are crunching numbers!) If you have your decoder ring handy, you can translate the resulting pattern into an actual number (or you can just let the display electronics do that for you).

Communicating

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 transmission), convert 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 within the message into the sound of your friend's voice (via a speaker).

Data-communication systems, which you use every time you shop online, use electronics to convert your materialistic desires into shopping orders — and (usually) extract money from your bank account.