SUPERCHARGED SCIENCE

Unit 14: Electronics

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Appropriate for Grades:
5-12 (see notes on each project)
Duration: 10-50+ hours, depending on how many activities you do!

We're going to learn about one of my favorite topics. (No, it's not shooting off rockets—that's my other favorite.) You're going to learn about electronics. But before we dive into doing experiments, let's talk about what electronics actually is. First, start with the kind of electric circuits you made in Unit 10. These kinds of electric circuits use switches, motors, batteries, lights, and stuff like that. In this unit, we're going to build more complicated circuits that do far more that just turn stuff on and off. You'll get the chance to build burglar alarms, FM transmitters, and more.

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Key Vocabulary

If an **atom** has more electrons spinning in one direction than in the other, that atom has a magnetic field. Atoms are made of a core group of neutrons and protons, with an electron cloud circling the nucleus.

Capacitors are storage tanks for electrons. There are ceramic, electrolytic, and variable types of capacitors.

The proton has a positive **charge**, the neutron has no charge (neutron, neutral get it?), and the electron has a negative charge. These charges repel and attract one another kind of like magnets repel or attract. Like charges repel (push away) one another and unlike charges attract one another. Generally, things are neutrally charged. They aren't very positive or negative but rather have a balance of both.

The pieces we're going to use are electronic **components**, which are things like transistors, resistors, integrated circuits (IC) or chips, capacitors and lots more.

When electric current passes through a material, it does it by electrical **conduction**. There are different kinds of conduction, such as metallic conduction, where electrons flow through a conductor (like metal) and electrolysis, where charged atoms (called ions) flow through liquids. Metals are **conductors** not because electricity passes through them, but because they contain electrons that can move.

A **diode** is like a one-way valve for electricity. It lets current go through it one way but not the other. They have two leads, called the **anode** and the **cathode**.

Electrons technically don't orbit the core of an atom. They pop in and out of existence. Electrons do tend to stay at a certain distance from a nucleus. This area that the electron tends to stay in is called a shell. The electrons move so fast around the shell that the shell forms a balloon-like ball around the nucleus.

How much a capacitor stores is measured in units called **farads**. It turns out that a farad is really huge, so most capacitors are measured in **microfarads** (0.000001 farads) or **picofarads** (0.000000000001 farads).

A **field** is an area around an electrical, magnetic or gravitational source that will create a force on another electrical, magnetic or gravitational source that comes within the reach of the field. In fields, the closer something gets to the source of the field, the stronger the force of the field gets. This is called the inverse square law.

An **integrated circuit**, sometimes called an IC or a chip (as in computer chip) is a complete circuit that has been miniaturized and put into a small plastic block with wires coming out of it.

LED stands for **l**ight **e**mitting **d**iode.

A common type of programmable chip is called a **microprocessor**. These are the "brain" of a typical home computer. A cousin of the microprocessor is the **microcontroller**. A microcontroller is like a whole computer on a chip.

Diodes are commonly used to change AC current into DC current. These are called **rectifiers**.

Resistors are one of the most common electronics components. Their job is to resist the flow of electricity. Resistance is measured in **Ohms (Ω).**

A **schematic** is a simple line drawing of an electrical circuit.

Objects that are electrically charged can create a **temporary charge** on another object.

A **transformer** is a component that trades volts for amps and vice-versa.

A **transistor** is kind of like an electronic dimmer switch. Think of a light dimmer—you know, the kind that you might have on the lights in a room in your house or a friend's house. You turn a knob or slide a lever, and all the lights dim.

The way we measure energy in electrical circuits is using units called **Watts**. Watts = volts x amps.

Unit Description

Most people who learn about electronics start by studying the theory of how electric current flows through wires and other stuff that conducts electricity, which are called ***conductors***. Unfortunately this stuff is BORING! I mean, I can't stand it myself sometimes. So, we're going to start with what I call "Lego brick electronics". You're going to start by building cool things and then learn what each part of the circuit does, but we will not go into the minute details. You'll learn how to build circuits out of electronic "bricks" like you would build something out of Lego bricks. When you build with Legos, you don't need to design your own Lego bricks. You just focus on using them. Same thing here—you'll learn how to put pieces together to build circuits. Our pieces are electronic ***components***, which are things like transistors, resistors, integrated circuits (ICs) or chips, capacitors and lots more.

Although you can't see electricity, you can certainly detect its effects—a buzzer sounding, a light flashing, a motor turning—all of these actions happen because of electricity, which is why electricity experiments are among the most frustrating. You can't always tell where the problem is in a circuit that refuses to work right.

We're going to outline the different electronic components (resistors, capacitors, diodes, transistors, etc.) so that you can get a better feel for how to use them in a circuit. While we're not going to spend time on *why* each of these parts work (which is a topic best reserved for college courses), we *are* going to tackle how to use them to get your circuit to do what you want. The steps to building several different electronics projects are outlined very carefully so you can really understand this incredible micro-world.

Electronics are used everywhere these days. Of course, we see them in TVs, stereos, computers, cell phones and iPods, but they're also a part of car keys and even mailing labels on boxes. They're used to explore the surface of Mars in space probes and give sight to blind people. All these things use transistors, resistors, chips and more—just what we'll be talking about in this unit. So, let's get started.

Objectives

Lesson 1: Breadboards

Prototyping & Experimenting

When you want to built an electronic circuit, you can certainly connect things together using clip leads like you did in other electronic circuits you have built, but most circuits need dozens of wires. If you can imagine trying to clip 50 clip leads to terminals without having a single one come off or touch another that it shouldn't, you'll probably guess this won't work very well. So, while we are doing our experiments, we use other ways to wire up circuits that are especially good.

Let's start with the breadboard. The breadboard lets you wire up circuits in a neat and organized way without soldering. They also make it easy to change or fix your circuit, add more ***components***, or replace parts if you damage them while experimenting (this happens semi-regularly when you're designing a new circuit).

By the end of this lesson, you will be able to

- Identify and describe how basic electronic components like resistors, capacitors, transistors, diodes, switches, relays (and more) work;
- Be able to follow an electronic schematic diagram to build a circuit;
- Learn how to 'breadboard' a circuit;
- Understand when and how to use series and parallel circuitry;
- Create really cool projects like audible light probes, flashing circuits, and light-detecting circuits as well as human-interactive circuits (like in the experiment called the Lie Detector);
- Hone your troubleshooting skills, which are *essential* if you're going to be a scientist of any kind.

Objectives

Lessons 2: Printed Circuit Boards

Printed circuit boards (PCB) is basically a piece of fiberglass with the “wires” stuck to the surface as flat pieces of copper. It makes it way easier to build a circuit than even using breadboards as long as you have the PCB for it (like if you buy a kit). Making your own PCBs is an involved process—it’s a lot of work to make one of them, but once you make one, it’s pretty easy to have 10 or 10,000 made. This is why they are used in nearly every electronic device you own these days.

In the videos for these experiments, you’ll learn how to solder, but I just want to mention again how important it is to be super careful with a soldering iron. I mean, think about it. It’s a sharp, pointy tool that operates at about 700° F (350° C). It can instantly cause severe burns and even catch things on fire.

Here are some basic soldering iron safety rules:

- If you’re done using it, unplug it immediately (don’t even leave it for a few minutes).
- If you’re not actively soldering something, put it back in its stand.
- ALWAYS use the stand for the soldering iron. Never lay it down somewhere else, even for a moment.

Do these things and you’ll be soldering safely for many years.

For this lesson, you’ll be assembling kits that you buy. Electronics kits are really popular, and there are probably tens of thousands of different types you can buy. You can get kits for everything from bike light flashers to home stereo systems to computers and robots. If you find you like building kits, it’s a great way to get into electronics.

I’ve selected these particular kits because they’re especially good quality, easy to build, and do cool things. It took me quite a while to pick the top kits out there. Many of the kits I went through before settling on the ones in the experiment section were either too difficult to build, had too many components, were made from low quality parts, or were impossible to make work after you built them. Often, electronic circuits require troubleshooting and tuning after you put them together (I'll show you how to do this in the videos), and many of the ones I tested required a seasoned technician to get them to work properly. But don't panic, I've already eliminated the pesky ones and have provided you with the ones you'll really enjoy building from start to finish.

These circuits are somewhat complicated, so I’ll describe the overall concept of how they work. Detailed descriptions for the police siren and the FM transmitter (along with their schematics) are in the instructions that come with them.

Objectives

Lesson 3: Basic Circuits

Exploring electronics can be a fun and rewarding experience. In workbook 1, we'll cover some basics of electronics as well as explore analog circuitry to get a better understanding of how analog circuits work.

We'll start our journey by learning about buzzers, light emitting diodes (LEDs), resistors, capacitors, and other electronic parts by building circuits that use these components. I hope you like to make noise because we are going to build a lot of circuits that generate all kinds of sounds.

Of course, building a circuit without understanding how the components work isn't as much fun, so we'll also take a close look at resistors and capacitors, along with other electronic components.

The 555 timer is a well known and respected timer IC that we'll be getting to know very well. We'll explore a lot of different ways to use the 555 timer by creating a lot of circuits that take advantage of the 555 timer's versatility.

Controlling voltage in a circuit is very important, so we'll explore voltage dividers as well as take a close look at voltage regulators.

Some other components we'll be building experiments with are

Operational Amplifiers (Op-Amp for short): An amplifier takes an input signal and boosts it so it can drive devices or components that require a higher strength signal. A good example of this is your stereo system. The signal going to the speakers is amplified so that the speakers can produce the sound.

Analog Comparator: An analog comparator compares two different voltages and produces an output based on those two inputs.

Electronics are a lot of fun, and understanding electronics will help you understand the world around you. So, enough talk, let's get started building some cool circuits!

Objectives

Lesson 4: Digital Circuits

Since the mid-1980s, digital electronics have slowly become an ever increasing part of our lives. Now you'd be hard pressed to find any device that doesn't use digital electronics. Digital electronics are in your TV, watch, computer, phone, car, kitchen appliances, and so much more. So, to help understand how digital electronics work, we'll be exploring them in a series of videos.

We are going to cover a lot of ground in workbook 2, beginning with learning about the basics of digital electronics. This will include learning what a bit is and what a high and low are. We will also learn about basic digital gates, among other topics.

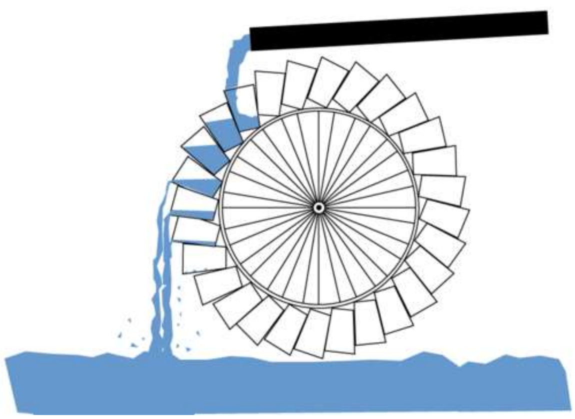
Next, we'll move on to building digital electronic circuits using both digital ICs and a few analog ICs along the way in order to learn about adding in binary, making cool sounds, digital memory, and bar graphs, among other things. We'll also be learning about 7 segment displays, how they work, and how to use them. There are so many neat and cool experiments. I know you are going to have a lot fun.

There's a lot of ground to cover and I know you are just as anxious to get started as I am, so I'll see you over at the electronics learning lab!

Textbook Reading

What is Electronics?

Electronics is all about how electricity flows through things like resistors, capacitors, transistors, ICs, and so on. Think of electricity like water flowing through a hose. Imagine you have a pump with the outlet of the pump going to a water wheel and the inlet coming from the basin under the water wheel.



The pump is like a battery, the hoses like wires, and the water wheel is like a light bulb, motor, or anything else that uses electricity. If we haven't decided what to hook up there yet, we sometimes just call it a ***device***. Now, as long as the pump is going, the water wheel turns. What would happen if you pinched the hose? The flow of water would stop and the water wheel would stop. This is what a switch does in a circuit—it stops the flow of electricity.

Just like the water coming out of a hose can spray out at different pressures and volumes, electricity also can spray out at different pressures and volumes. Imagine a small hose like a garden hose with your finger over the end so it sprays water really far. This water is coming out at high pressure, and maybe sprays 20 feet. Pressure in electronics is called ***voltage***.

Now imagine that you had a really big pipe, and lots of water was coming out of it, but it was flowing slowly—just kind of pouring out the end. The water is coming out at low pressure, but at a high volume or amount. In other words, lots of gallons of water are coming out, but the water only travels a foot or two through the air as it dumps out of the pipe. The volume of water is equivalent to electrical ***current*** (measured in ***amps***) in electricity. Now, imagine a big pipe with a lot of pressure—there is lots of gallons coming out and it sprays for 20 feet. This is like high voltage AND high current (a deadly combination if you touch it).

So, voltage is electrical pressure and current (amps) is electrical volume. Together they determine how much total ***energy*** is following through a wire. For example, if I have 12 volts at one amp flowing through a circuit, that contains a certain amount of energy (the ability to do work). If I have 12 volts at 2 amps, I have twice as much energy. The way we measure energy in electrical circuits is using units called ***Watts***. (Watts = volts x amps). We'll talk more about this soon. For now, just know this is true.

We use abbreviations for common words in electronics. Here are a few to keep in mind:

V = volts

I = amps or current (Don't ask why it's "I" and not "A"—engineers are funny that way)

W = Watts

Okay, so that's the basic idea of electricity. If it's not perfectly clear yet, don't worry. Re-read this after you've built some circuits, and it will make more sense.

I mentioned earlier that we have power sources like batteries (or ***power supplies***). We also have "devices" that do something when you put electricity into them. And you know about switches (which are like valves for water). There are other types of components, too. Let's take a look at some of them.

Power Supplies

A power supply is simply a source of voltage and current. It is usually either a battery (or battery pack) or something that can plug into the wall (often called an AC adapter or wall transformer).

Facts to know about power supplies:

- Any given circuit or "device" uses a certain amount of volts and amps. Your power supply must provide the right number of volts for the circuit and *at least* as many amps as it needs. So…
- The volts required by the circuit *must* equal the volts provided by the power supply (not more, not less).
- The amps required by the circuit must be equal to *or less than* the number of amps the power supply can provide.

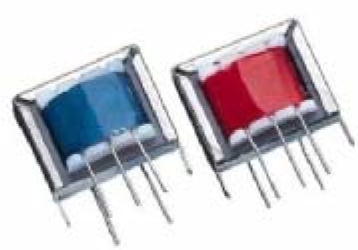
For example, if I have a 12 volt light bulb that uses 1 amp, I *must* connect it to a 12 volt power supply. But that power supply could provide 1 amp, 10 amps or even 1000 amps, and the lamp would work fine. But, if the power supply only provided half of an amp, then we'd have a problem (the light wouldn't light up and it could damage the power supply).

Transformers

A transformer is a component that trades volts for amps and vice-versa. If I put 100 volts at 1 amp into a transformer, it might put out 10 volts at 10 amps.

Input volts x amps = output volts x amps.

Remember, volts x amps = Watts



How many times a transformer multiplies or divides voltage depends on what the transformer is designed for.

Resistors

Resistors are one of the most common electronics components. Their job is to resist the flow of electricity. They are kind of like having a valve in the middle of a hose and closing it part way. It will reduce the volume of water that flows. Resistors reduce the amount of current that flows through a circuit (they turn the current that they don't let through into heat, so sometimes they get warm). Engineers and geeks say they "limit current".

A resistor has two ***leads***, or wires, connecting to it. It has no ***polarity*** (its leads can be connected either way) and it is what's called a ***passive*** component. This means it doesn't need any extra electricity connected to it to do its job (a computer chip, for example, is not passive. You have to connect power to it, as well as the circuit you want it to work in).

If you take a volt meter and connect one probe to each side of a resistor in an operating circuit, you'll get a voltage reading. This means that the resistor is "using" some of the current that's going through it. It's not really using it up, but it is converting the electricity into heat, so it can't be used as electricity anymore.

Resistors affect current according to something called Ohm's law. I'll mention it here because anyone who's an engineer would get upset if I didn't. But I'm not going to explain it in detail. Here it is:

$V = I \times R$

(volts = amps x resistance)

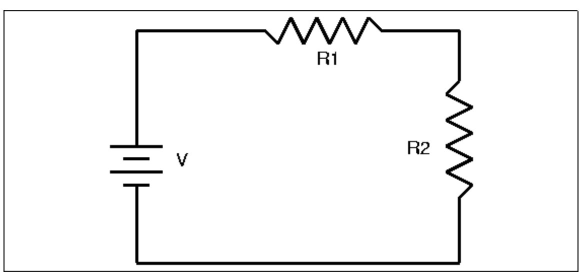
Resistance is measured in units called ***Ohms***.

Resistors look like candy-striped hot dogs. Their job is to limit current to keep sensitive electronics from being overloaded. If you break open a resistor, you'll find a pile of graphite. If you have a digital multimeter, draw a line on a sheet of paper with a graphite pencil and place one probe near the end of the line. You can measure the change in resistance along the line with your other multimeter probe!

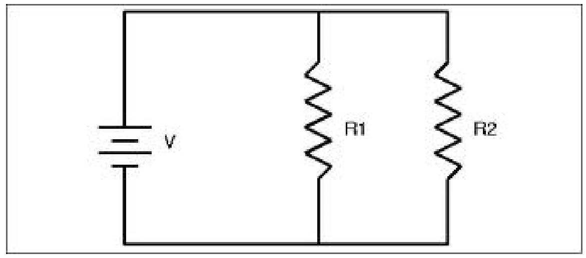
Okay, you can look it up to learn more about it if you want, but for now, we're just going to keep in mind that resistors reduce current. If you hook up a couple of them in a circuit called a voltage divider, they can reduce voltage too.

A couple of useful resistor factoids you should know:

Two resistors connected in ***series*** add their resistances together. So if I have a 100 Ohm resistor and a 50 Ohm resistor and connect them in series, I'll get 150 Ohms.



If I connect two resistors in parallel, it actually *decreases* their total resistance.



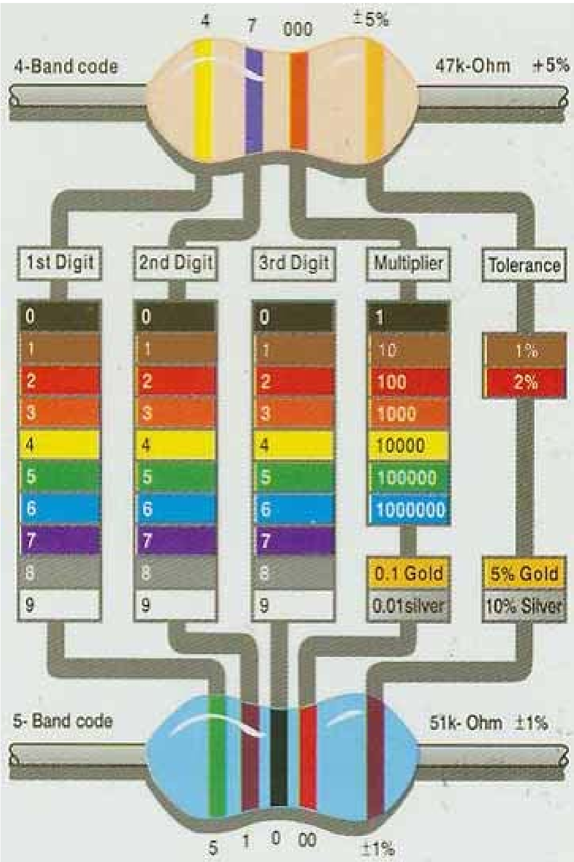
There's an equation for calculating it (called the parallel resistance formula). But the general idea is that half the current goes through each one. So, if you connected two 100 Ohm resistors in parallel, you would end up with the equivalent of a 50-Ohm resistor.

The last thing to know about resistors is how to determine their **value** (how many Ohms they are). For whatever reason, instead of printing numbers on them like most other electronic components, they put colored stripes on them. So, we compare the stripes to a color code chart, and it tells us how many Ohms a resistor is.

Most resistors have 4 colored stripes on them. Here's what each one means:

- The first band gives the first digit.
- The second band gives the second digit.
- The third band indicates the number of zeros.
- The fourth band is used to show the tolerance of the resistor.

See below to access a reference sheet so you can tell which resistor is which.



By the way, there are these cool things called variable resistors. These are resistors that you can change the value of by turning a knob.

Capacitors

A capacitor is like a water storage tank. You can pump water into it, and then you can use whatever you've put in when you need it. However, most capacitors get filled up or "charged" within a fraction of a second, and discharged just as quickly.

Capacitors are used for lots of different things. They can be part of a "filter" circuit that removes unwanted electrical "blips" or signals. For example, radios use capacitors. You see, a radio initially doesn't receive just one FM radio station. No, it receives ALL the stations in your area at once. Then it has a filter circuit using capacitors to filter out all of the stations except the one that you have the radio tuned to.

Capacitors are also used to let AC current pass through them but not DC (if you don't know about AC and DC, that's okay for now).

How much a capacitor stores is measured in units called farads. It turns out that a farad is really huge, so most capacitors are measured in ***microfarads*** (0.000001 farads) or ***picofarads*** (0.000000000001 farads).

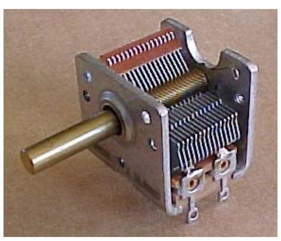
Capacitors come in lots of shapes and sizes. Here are some common ones:

- Ceramic capacitors are small in size and value, ranging from pico farads to 1 µF. They are not polarized so

either end can go to ground.

- Electrolytic capacitors look like small cylinders and range in value from 1 µF to several farads. Polarized, cathode must go to ground. Cathode is assigned with a minus sign on case. Value is usually written on case.

- Variable capacitors are also called tuning capacitors. They have very small capacitance values, between 100pF and 500pF (100pF = 0.0001µF). They have knobs that can change their value.



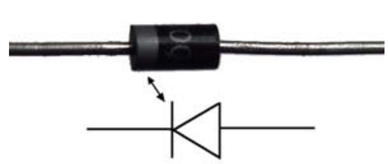
Okay, so now you know that capacitors are storage tanks for electrons. You can actually make a simple capacitor by sandwiching a piece of waxed paper between two smaller sheets of aluminum foil. By touching a battery contact to each side of the foil, you are charging the capacitor. (The metal foil stores the electrons.)

When you charge a capacitor, the minus side is charged with electrons right away. (You can slow this process down by adding a resistor.) If you leave the capacitor charged with electrons, it will slowly leak until the two plates have the same charge. You can discharge a capacitor quickly by touching the plates (or wires) together, and if you add a resistor, it will also slow the discharge process down. When you use capacitors, you'll be charging and discharging them quickly in your circuit.

Diodes

A diode is like a one-way valve for electricity. It lets current go through it one way but not the other. They have two leads, called the ***anode*** and the ***cathode***.

If you put positive voltage in the anode, it will go through to the cathode. But if you put positive voltage in the cathode, nothing will come out the anode. As an aside, a diode will slightly reduce the voltage that you put in the anode (usually by 0.7 volts).



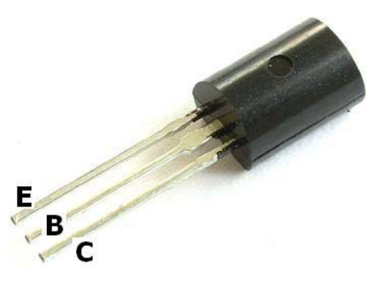
Diodes are commonly used to change AC current into DC current. These are called ***rectifiers***. Another common use is in radio receivers for transforming the AC radio signal into a signal that can be turned into audio that we can hear.

There are different types of diodes, but they all share this one-way valve characteristic. One special kind of diode is the LED. These are the colored (or white) "lights" that are used on so many things these days. They are diodes that have been specially designed to emit light of a certain color when you put electricity through them. They have polarity because they need to be connected just like any other diode. We generally just use them to make light, but they still only let current through one way. We'll be doing a bunch of experiments with LEDs, so just know that they come in many different sizes and colors.

Sometimes we put LEDs in shapes to make numbers or letters on digital displays, like on a digital clock. If your clock lights up in color, it's probably an LED display (black on grey are liquid crystal displays (LCDs), not LED).

Transistors

The transistor is a small electronic component that has radically changed your life. It has made most of the electronic items we use today (like computers, cell phones, etc.) possible.



A transistor is kind of like an electronic dimmer switch. Think of a light dimmer—you know, the kind that you might have on the lights in a room in your house or at a friend's house. You turn a knob or slide a lever, and all the lights dim.

Remember, things that are connected to the outlets or wall switches in your house run on 120 volts if you live in the USA, or 220 volts in many other countries. So, you're controlling 120 volts (or 240 volts) by turning a single small knob. Now, imagine that instead of you turning that knob, you wired up a motor (like you did in the Electricity Unit) to a 3 volt battery pack and attached the motor to the dimmer knob so the motor would turn it. This way, you could make a motor running on 3 volts control a 120 volt light. This is basically what a transistor does. It takes a small voltage (or current) and uses it to control a larger one.

Transistors are commonly used in amplifiers (think stereo or iPod) and switches. As a matter of fact, the computer you're reading this on probably has *millions* of transistors in it. They are used in amplifiers to make voltages higher which translates to louder sounds when we run a transistor to a speaker.

When transistors are used as switches, we can have one switch control another or even dozens of other ones, each performing a different function, or maybe going to long chains of even more transistor switches. We can even link lots of them together to solve complex problems.

We're not going to go into the details of how to design transistor circuits, but rather we want to understand that they are commonly used as either amplifiers or switches. Once you start building some experiments and looking at their ***schematic*** diagrams, you'll get a better idea of how they are used.

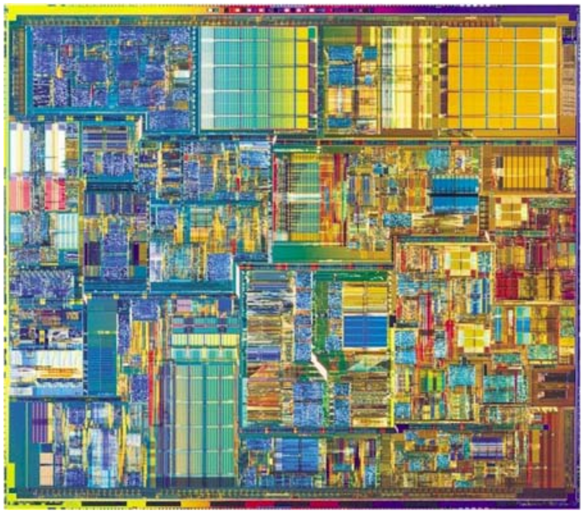
Transistors come in all sizes, and some things that look like transistors really aren't transistors at all! The ones we are going to use have three leads and tiny writing on the flat side (like the one shown here). Each lead has a specific name and job, and we're going to use two transistors (the NPN and PNP) that look alike, but the wiring is different. The three wires on the transistors each have their own name: an emitter (E), base (B), and collector (C). We'll go over in the video which wire lead does which job.

Okay, so now you know that transistors are like a valve in your circuit—they allow electricity to flow up one lead and down the other when the valve is open. When the valve is closed, there's no flow of electricity. Transistors are also one of the most sensitive components we're going to be using. If you solder them too much, the heat will destroy the fragile circuitry inside (we'll be soldering in a later lesson), so using a heat sink is highly recommended. The leads themselves are easy to break, so if you need to bend one, be sure to do it away from the head so it doesn't separate from the body. And if you live somewhere that's dry enough to be plagued by static electricity, sometimes the zap from your own static charge build-up is enough to fry one of these.

Integrated Circuits

An integrated circuit, sometimes called an IC or a chip (as in computer chip) is a complete circuit that has been miniaturized and put into a small plastic block with wires coming out of it. Most chips are just 5 to 20 mm long and wide. They come in different shapes, and have different numbers of wires (called leads) coming out of them.

The thing to remember is that there isn't just one kind of IC. Since they are complete circuits (with transistors, capacitors, resistors, diodes, etc.) they can do anything that a full-sized circuit can do. A typical computer chip these days will have hundreds of thousands, if not millions, of transistors, resistors, transistors, etc. on it. The image below is what the Pentium 4 chip looks like on the inside.



It's a square piece of crystallized silicon containing millions of tiny transistors connected by *very* tiny wires.

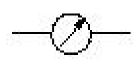
In one of our experiments, a chip will run a clock. In other projects, a chip might be the heart of a telephone. It all depends on what the chip was designed for. Some chips store information that is put into them. A flash drive or SD card is an example of an IC. Other chips can change their function by being programmed by a computer. These programmable chips get plugged into a computer, have software uploaded to them, and then they do something different. For example, the chip that is used to scroll the digital display of the clock you'll build in this unit could be re-programmed to control an automatic coffee maker or guide a small robot to follow a line drawn on a sheet of paper.

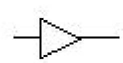
A common type of programmable chip is called a ***microprocessor***. These are the "brain" of a typical home computer. A cousin of the microprocessor is the ***microcontroller***. A microcontroller is like a whole computer on a chip. I won't go into the details here, but know that they are used in just about every electronic device these days that has to do much more than just turn on and off a simple circuit.

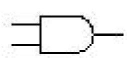
Schematics

A schematic is a simple line-drawing of an electrical circuit. It makes it easy to draw a circuit without having to draw actual pictures of each part. A wire is simply a line. A motor is a circle with an "M" in it (lots easier than trying to draw a picture of a motor). Take a look at the schematic symbols below, as well as the sample circuit to get an idea.

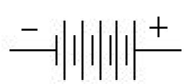
Here's a list of the symbols you're going to see in the schematics in this unit:


An ammeter is used to measure the current that is flowing.

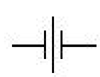

An amplifier is used to amplify the signal.


And a gate contains two binary values as input

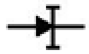

An antenna is used to catch the signal.



A battery-DC current has its value in volts (e.g. 9 volt battery).

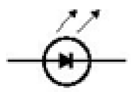

A capacitor is a type of storage storing current.


A circuit breaker, as the name says, divides the circuit.

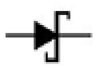


A diode stops the current flow in one direction.

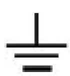
A diode type 2 stops the current flow in one direction.



A diode-type light, also called LED, is used for emitting light.

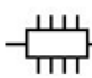


A diode-Schottky is a semiconductor diode with a low forward voltage

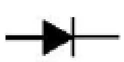


To earth ground is to throw away additional current to the earth.

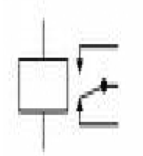
An exclusive OR is a type of OR gate only.



An integrated circuit contains thousands of transistors within it.



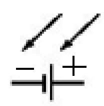
A rectifier-electrical device converts alternating current (AC) to direct current (DC).



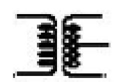
A relay-electrical switch opens and closes under the control of another electrical circuit.

A rheostat is a two-terminal variable resistor.

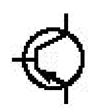
A resistor is a two-terminal electronic component that opposes an electric current by producing a voltage drop between its terminals in proportion to the current.



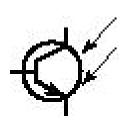
A solar cell is used to generate solar energy.



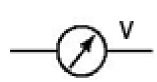
A transformer transforms high AC To low AC and vice versa.



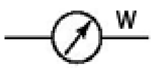
The arrow in the PNP transistor symbol is on the emitter leg.



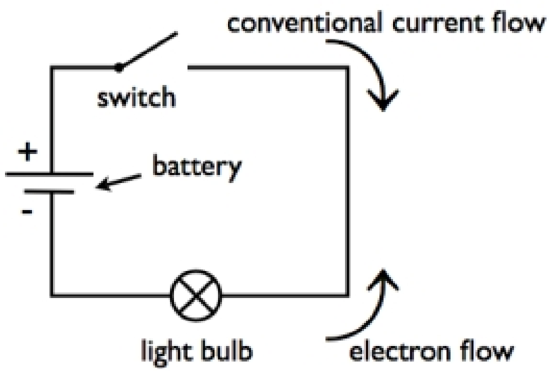
An NPN transistor is formed by introducing a thin region of P-type semiconductor.



A voltmeter is used to measure volts.



A wattmeter is used to measure watts (i.e. power).



In this schematic, the battery, switch and LED are connected so the LED will light up when the switch is turned on. Just spend a minute looking at this schematic until it makes sense to you. Then try drawing one yourself of another circuit you've built.

Note that the current flows from the plus side of the battery to the minus. That's the way you'll find it written in textbooks. However, you might find it written up somewhere that the flow of electrons is in the opposite direction, and that's true. However, the rest of the world uses the plus-to-minus convention. So remember: **current flows from plus to minus.**

