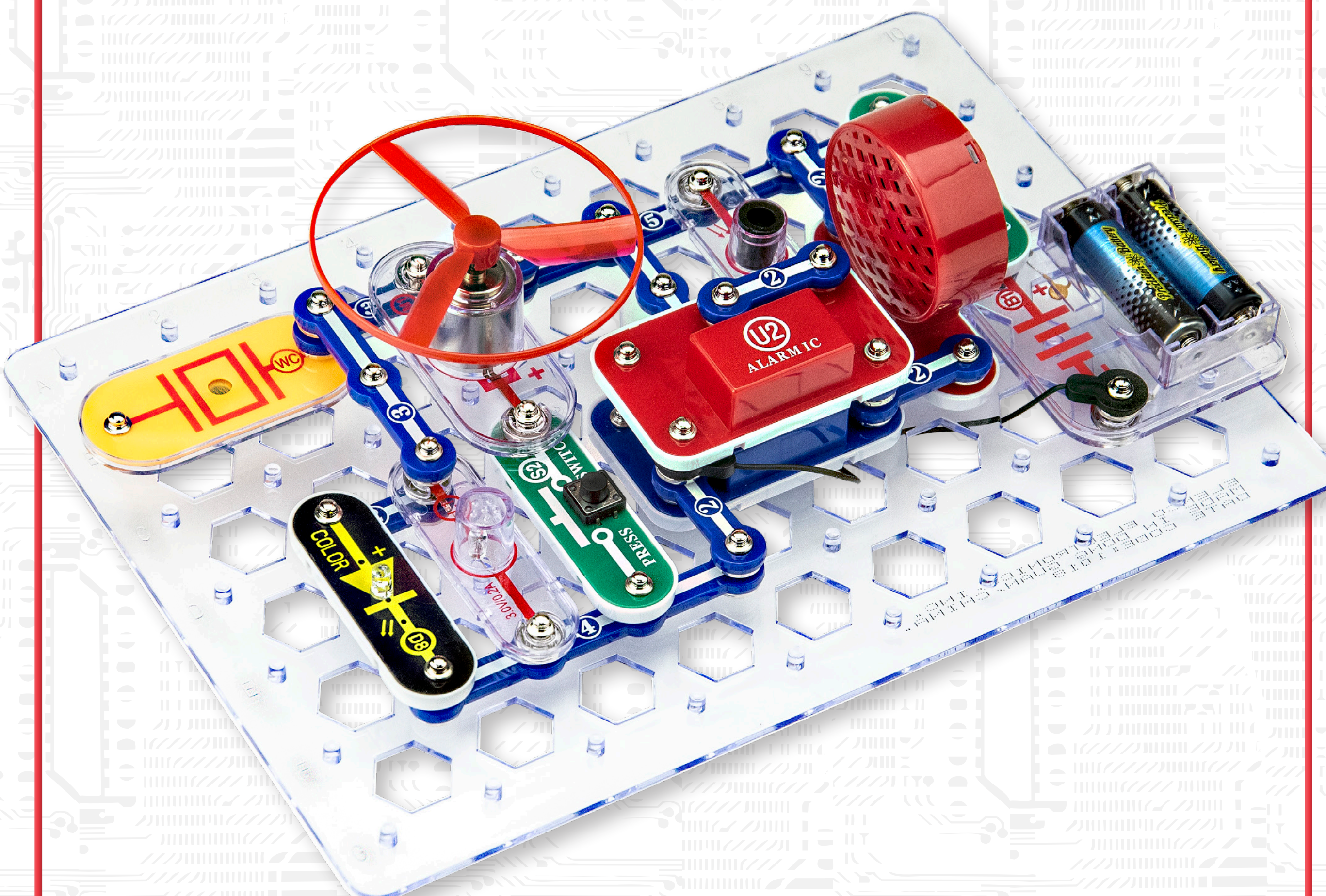
SNAP CIRCUITS®

Educational Training Program

STUDENT GUIDE

BASIC ELECTRICITY AND ELECTRONICS



Model SC-100R

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ELENCO®
Learn by doing.®

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THE SNAP CIRCUITS® PROJECT MANUALS

The Snap Circuits® project manual includes lots of useful information in addition to the projects themselves, as listed below. The project manual summarizes much of the lesson in the Student Guide while adding troubleshooting information.

Much of the text in all chapters is color-coded green and blue so that instructors can easily adapt the course based on the skills and interests of the students. The orange boxes are more advanced material while the brown boxes are considered additional/background material, either can generally be omitted without a significant impact on the course.

The Project Manual contains:

1. Parts List
2. How To Use It - brief description of how to make connections and understand the circuit drawings.
3. About Your Snap Circuits® Parts - brief description of what each component does.
3. Introduction to Electricity - brief description of the main terms and concepts in electricity.
4. DO's and DON'Ts of Building Circuits - brief but important guidelines for building circuits.
5. Basic & Advanced Troubleshooting - systematic testing procedure for identifying damaged parts.
6. Projects 1-71 in paper manual, or projects 72-130 in online manual.

PREFACE

This booklet is an introduction to the exciting world of electronics. Following the "Learn by Doing®" concept, electronics will be easy to understand by using Snap Circuits® to actually build circuits as you learn about them. This booklet emphasizes the practical applications of electronics, without bogging down in mathematics.

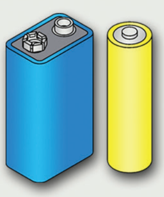
Why learn about electronics? Electronics plays an important and increasing role in our everyday lives, and so some basic knowledge of it is good for everyone. Learning about it teaches how to do scientific investigation, and the projects develop basic skills needed in today's world.

The first pages of the Snap Circuits® project manuals contain a brief description of the parts in Snap Circuits®, along with brief guidelines for building circuits.

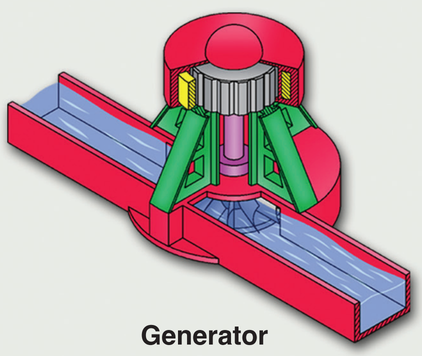
CHAPTER 1: BASIC COMPONENTS & CIRCUITS

Learn By Doing®

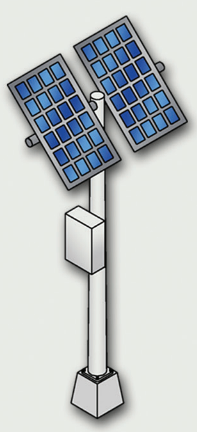
What is electricity? Nobody really knows. We only know how to produce it, understand its properties, and how to control it. It can be created by chemistry (batteries), magnetism (generators), light (solar cells), friction (rubbing a sweater), and pressure (piezoelectric crystals).



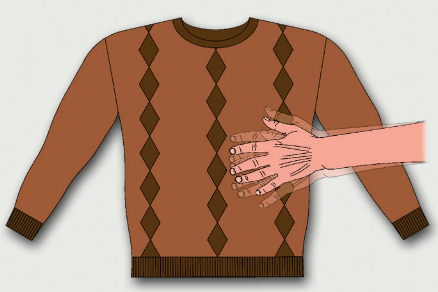
Batteries



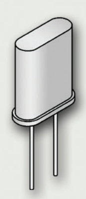
Generator



Solar Cells



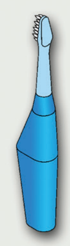
Rubbing a Sweater



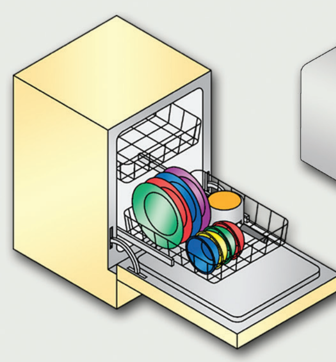
Piezoelectric Crystal

In this section you will learn about basic electrical components and circuits. By building circuits using Snap Circuits®, you will begin to understand the electrical world.

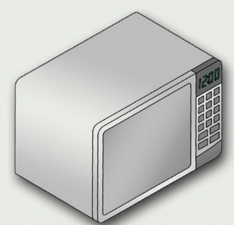
Electricity is energy that can be used to save us effort (electric toothbrushes and dishwashers), heat things (electric heaters and microwave ovens), make light (light bulbs), and send information (radio and television). But electricity can also be dangerous if abused (electric shock).



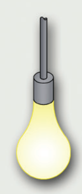
Electric Toothbrush



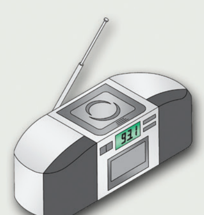
Dishwasher



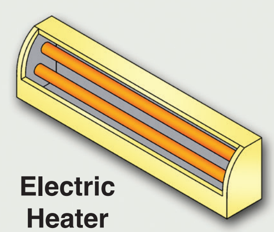
Microwave Oven



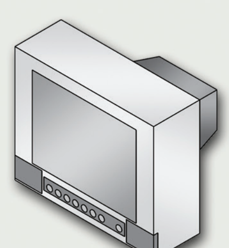
Light Bulb



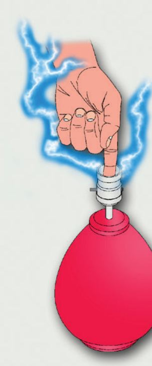
Radio



Electric Heater



Television



Electric Shock

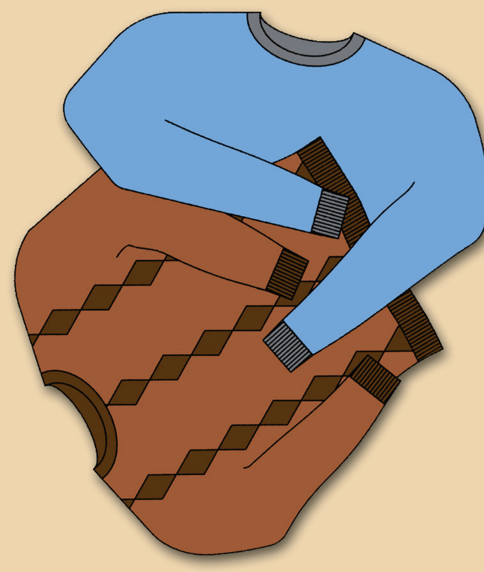
1-1 ELECTRICITY

The name electricity came from the Greek name for amber, the material in which electrical effects were first observed. What do you think of electricity as being? **Electricity** is one of the fundamental forces of nature. At its most basic level, it is an attraction and repulsion between sub-atomic (very, very, very, very tiny) particles within a material. This attraction/repulsion is referred to as an **electrical charge**; it is similar to and closely related to magnetism. These attractions/repulsions are extremely powerful but are so well balanced out at the sub-atomic level that they have almost no effect on our lives.

As an example, electrical attraction is about 1,000,000,000,000,000,000,000,000,000,000,000,000,000 times more powerful than gravity (gravity is what causes things to fall to the ground when you drop them). However electrical attraction is so completely balanced out that you don't notice it, while gravity effects are always apparent because they are not balanced out.

Gravity is actually the attraction between objects due to their weight (or technically, their mass). This effect is extremely small and can be ignored unless one of the objects is as big as a planet (like the earth). Gravity attraction never goes away and is seen every time you drop something. Electrical charge, though usually balanced out perfectly, can move around and change quickly.

For example, think about how two sweaters can cling to each other when you take them out of the dryer. This is due to an electric charge that has built up between them. There is also a gravity attraction between the sweaters, but it is always extremely small.



Electronics is the science of working with and controlling electricity. Many work-saving appliances like dishwashers, hairdryers, and drills are electrical but not electronic. Electronic products use electricity to control themselves, using parts like resistors, capacitors, and transistors. Electrical appliances are only controlled mechanically.

Most products you bring from your old house to your new house are electronic (such as TVs, computers, touch-tone phones, radios, most battery operated products), but not all (such as hairdryers, electric power tools).

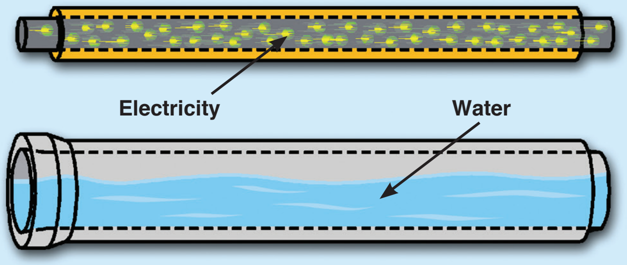
A good way to think of the difference between electrical and electronic products is to think about moving into a new house. Most products in the empty house are electrical (such as all the wiring and switches in the walls, rotary phones, dishwashers, electric ovens, air conditioners, most types of thermostats).

Electricity is the movement of sub-atomic particles (with their electrical charges) through a material due to an electrical charge outside the material. Electricity will be easier to understand if you think of the flow of electricity through circuits as water flowing through pipes.

1-2 WIRES

Wires can be thought of as large, smooth pipes that allow water to pass through easily. Wires are made of metals, usually copper, that offer very low resistance to the flow of electricity.

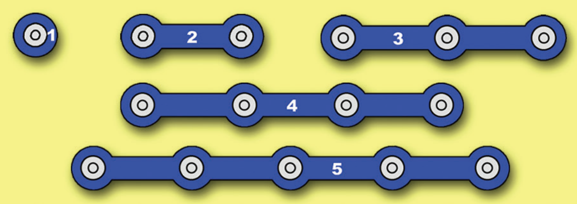
The **electric current** is a measure of how fast electricity is flowing in a wire, just as the water current describes how fast water is flowing in a pipe. It is expressed in **amperes** (A, named after Andre Ampere who studied the relationship between electricity and magnetism) or **milliamps** (mA, 1/1000 of an ampere).



With Snap Circuits the wires you will use have been shaped into snap wire strips, to make interconnection easy. These work the same as any other wires you might find in your house, since they are made of metal.

INTRODUCING NEW PARTS

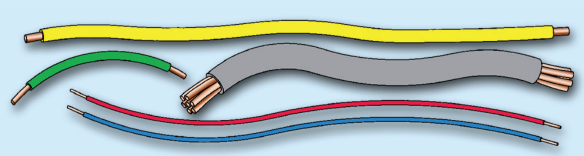
If you have the Snap Circuits® parts nearby then pull out the wires and look at them. They have numbers such as 2, 3, 4, or 5, depending on the length of the wire connection. There is also a 1-snap wire that is used as a spacer or for interconnection between different layers.



Wires can generally be as long as desired without affecting circuit performance, just as using garden hoses of different lengths has little effect on the water pressure as you water your garden. However there are cases where the length and size of a pipe does matter, such as in the water lines for your entire city or in an oil refinery. Similarly, wire length and size are important for electric power lines transporting electricity from a power plant in a remote area to a city, and in circuits used in radio or satellite communication.

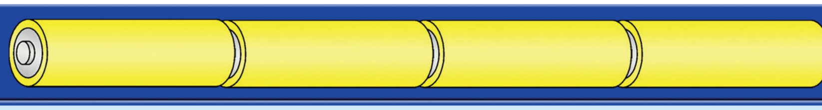
If you were to look inside an electronic device in your home (make sure it's not plugged in) you might see a lot of wires of different colors. The actual wires are all the same color of metal, but they have a protective covering over them. The colors are used to easily identify which wire is which during assembly and repair of the circuit.

The covering is also used to prevent different parts of a circuit from connecting accidentally.



Try to imagine the total length of wire used in all the products in your home!

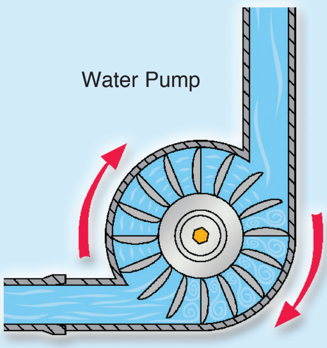
1-3 BATTERIES



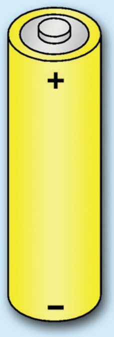
To make water flow through a pipe we need a pump. To make electricity flow through wires we use a battery. A battery creates an electrical charge across wires. It does this by using a chemical reaction and has the advantage of being simple, small, and portable.

Voltage is a measure of how strong the electric charge from your battery is, and is similar to the water pressure. It is expressed in volts (V, and named after Alessandro Volta who invented the battery in 1800). Notice the "+" and "–" signs on the battery. These indicate which direction the battery will "pump" the electricity, similar to how a water pump can only pump water in one direction.

Water Pump



Battery

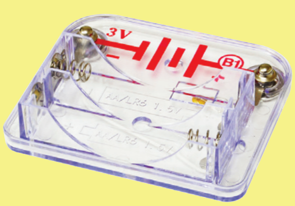


The 0V or "–" side of the battery is often referred to as "**ground**", since in house or building wiring it is connected to a rod in the ground as protection against lightning.

Battery power is much easier to use in electronics than the electricity that powers your home. This is because most electronic circuits only need a low voltage source to operate; all the electricity produced by your electric company comes at a higher voltage, which must be converted down. If a circuit is given too much voltage then its components will be damaged. It is like having the water in your faucet come out at higher pressure than you need, and it splashes all over the room. If water in a pipe is at too high of pressure then the pipe may burst. Batteries are selected to give your circuit just the voltage it needs.

INTRODUCING NEW PARTS

Your Snap Circuits® uses two 1.5V batteries in a holder (snap part B1, actual batteries are not included). Notice that just to the right of the battery holder pictured below is a symbol, the same symbol you see on the battery holder. Engineers are not very good at drawing pictures of their parts, so when engineers draw pictures of their circuits they use symbols like this to represent them.



Battery Holder (B1)

Battery Symbol

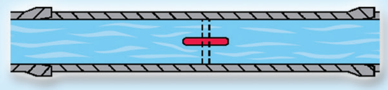
Batteries are made from materials like zinc and magnesium dioxide, electricity flows as these react with each other. As more material is used up by the reaction, the battery voltage is slowly reduced until eventually the circuit no longer functions and you have to replace the batteries. Some batteries, called rechargeable batteries (such as the batteries in your cell phone), allow you to reverse the chemical reaction using another electric source. That way the batteries can last through years of use.

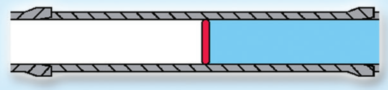
Challenge: *Try to count how many batteries are in your home*, your count will probably be low. Many products that use your house power also have batteries to retain clock or programmed information during brief power outages (such as computers and VCRs).

1-4 THE SWITCH

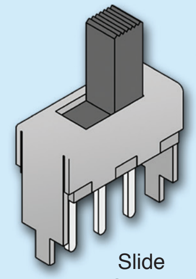
Since you don't want to waste water when you are not using it, you have a faucet or valve to turn the water on and off. Similarly, you use a switch to turn the electricity on and off in your circuit. A switch connects (the "closed" or "on" position) or disconnects (the "open" or "off" position) the wires in your circuit.

Closed Position





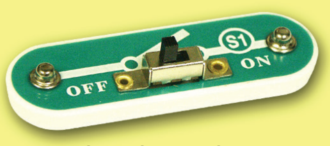
Open Position



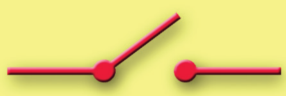
Slide Switch

INTRODUCING NEW PARTS

Just as the plumbing industry has a wide range of valves for different situations, there are many types of switches used in electronics. The type shown below is called a slide switch, because you slide it back and forth to turn it on and off. Snap Circuits® includes one of these (part S1), shown below. As with the battery, the slide switch is represented by a symbol, shown to its right. If you have the Snap Circuits® parts nearby, take out the switch and look at it.



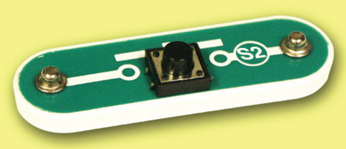
Slide Switch (S1)



Slide Switch Symbol

INTRODUCING NEW PARTS

Another type of switch is the press switch, and Snap Circuits® also includes one of these (part S2). When you press down the two pieces of metal touch, so electricity can flow. When you let go of it, the electricity stops. Its symbol is marked on the snap part, though on many professional electronics drawings both slide and press switches use the symbol for the slide switch because they really perform the same function.



Press Switch (S2)

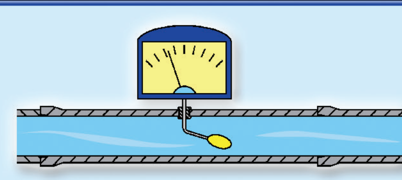
Press Switch Symbol

You can think of slide and press switches like the water faucet in your kitchen (which pours out water until you turn it off) and a water fountain in a school or movie theater (which only squirts out water as long as you are pressing the button).

Switches in modern electronics come in many diverse forms. Challenge: _Try to count how many are in your home or car_; you will be amazed. There are slide, press, membrane, rotary, push-button, and other switches controlling nearly everything.

1-5 THE LAMP

In a **lamp** electricity is converted into light, the brightness of the lamp increases as more electric current flows through it. You can think of a lamp as a water meter, since it is showing us how much current is flowing in a circuit just as a water meter shows how much water is flowing in a pipe.



Water Meter

INTRODUCING NEW PARTS

Snap Circuits® includes a lamp (part L1, shown below). If you have the parts with you, take it out and look at it.

3V Lamp (L1)

Just as there are different types of water meters to work with different pressures and volumes of water, there are also different lamps. Lamp L1 is a low-pressure meter, and works with voltages (electrical pressures) of up to 3V. Higher voltages than that will damage the bulb, so always make sure to use the correct lamp.

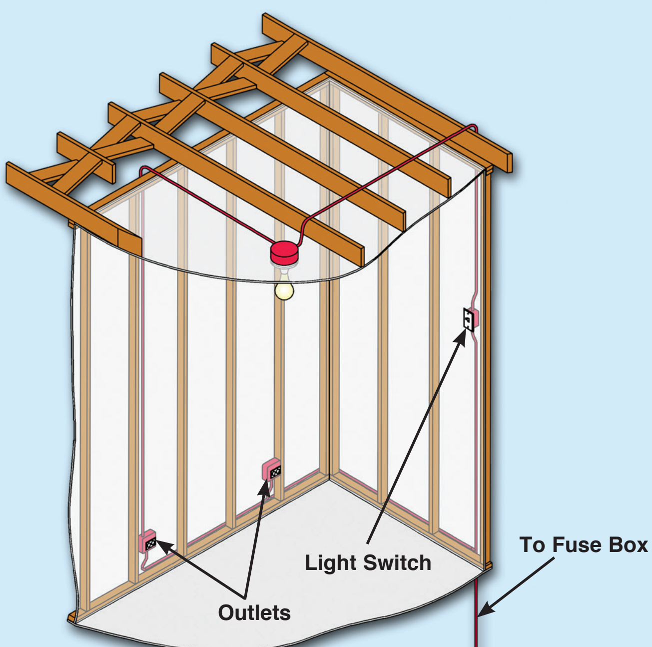
The electrical symbol for a lamp is shown here.

Lamp Symbol

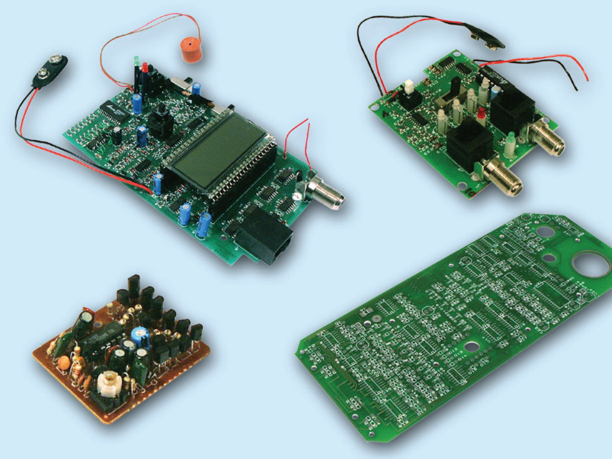
While occasionally lamps are used to indicate how much electricity is flowing in a circuit, they are mostly used to light our homes, businesses, and streets. Although scientists had been experimenting with electricity for years, the first practical use of electricity occurred when inventor Thomas Edison used it to light a bulb similar to these. For many years electricity was used almost exclusively for lighting. That has since changed. Now only a small percentage of the electricity produced in the United States is used for lighting with the rest going to a vast range of uses in everyday life that Edison would never have imagined.

1-6 THE BASE GRID

The water in your home flows through pipes mounted in the walls and floors of your home, and similarly the electricity in your house flows through wires mounted in the walls and ceilings of your home. But the wires in your walls take a lot of hard work to install and then can't be moved.



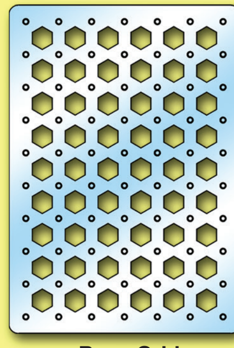
Most products that use electricity are small, easy to move, and easy to build. That is because they have almost all of their components and wires mounted on "circuit boards" such as these:



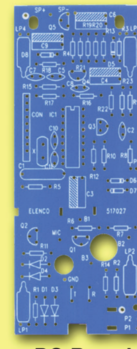
Boards like these are used in almost all electronic products, look inside any radio or computer and you will find them. Note that the "wires" connecting parts mounted on the circuit board are literally "printed" on the surface of the board; hence circuit boards all are called "printed circuit boards" or PCBs.

INTRODUCING NEW PARTS

In the same manner Snap Circuits® uses a clear plastic base grid with evenly spaced posts to mount the snap parts and wires and to keep them together neatly. It has rows labeled A-G and columns labeled 1-10 to easily identify points in your circuit. You don't need the base to build your circuits, but just try building one of the larger circuits without it! The base grid is shown here, next to a picture of a typical circuit industry board before parts are mounted.



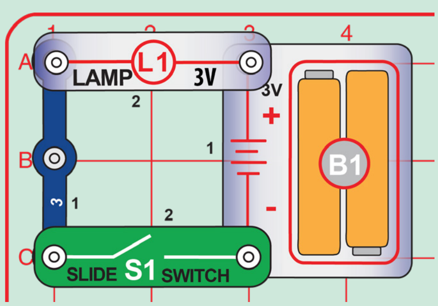
Base Grid

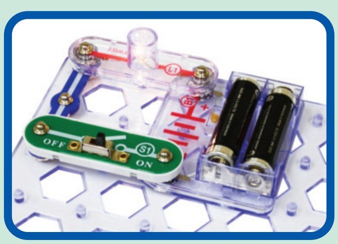


PC Board

EXPERIMENTS

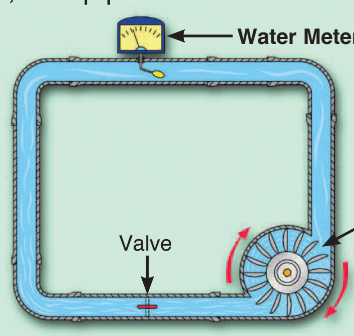
So far we've talked about wires, batteries, switches, lamps, and circuit boards; now it's time to put them together to form a circuit. Consider this circuit (which is project 1 on page 9 of the project manual):





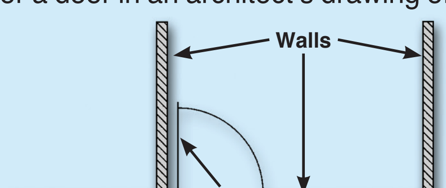
Turning on the switch turns on the lamp. This circuit is the same circuit used to turn on a lamp in your home. The only differences are the batteries are really power from the electric company, the lamp is larger and bright enough to light up the room, the switch is really a switch on the wall, and the snap wires are really wires in the wall and the cord to the lamp.

You can think of the electricity flowing through the battery, lamp, switch, and wires in the above circuit as if it were water flowing through a pump, water meter, valve, and pipes:

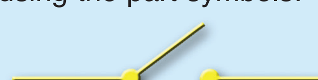


Note that each of the Snap Circuits® in the project manuals has a box ☐ next to it so that you can mark off the circuits as you build them.

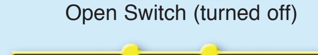
In electronics, the "on" position of a switch is also called the "closed" position. Similarly, the "off" position is also called the "open" position. This is because the symbol for a slide switch is similar to the symbol for a door in an architect's drawing of a room:



The electronics symbol for a slide switch should be thought of as a door to a circuit, which swings open when the switch is off. The "door" to the circuit is closed when the switch is on. This is shown here in drawings using the part symbols:



Open Switch (turned off)



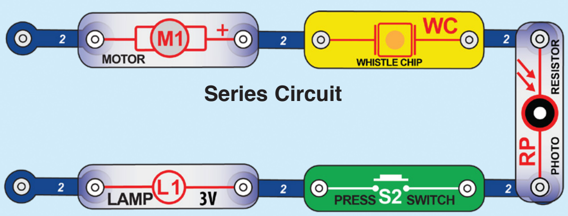
Closed Switch (turned on)

In case you haven't noticed, the batteries produce 3V and the lamp is also made for 3V. Note that the voltage rating of the batteries (1.5V from each battery) is actually the voltage they produce when the electric current flowing from them is low, as the circuit current increases the voltage produced by the batteries is reduced. Think again of the lamp as a water meter - the lamp is bright so there must be lots of current flowing, hence the voltage is lower. You can see from the water diagram that with only a pump, an open valve, and a meter there is nothing to slow down the water flow and the pump will move the water as fast as it can.

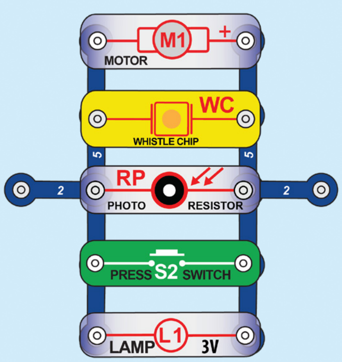
Why does the battery voltage drop as current increases? Remember that a battery produces electricity from a chemical reaction. Not only is there a limited amount of the chemicals in a small battery (batteries slowly get weaker as you use them), but also not all of the material can react together at the same time.

1-7 SERIES vs. PARALEL CIRCUITS

There are two ways of arranging parts in a circuit, in series or in parallel. Here are examples:

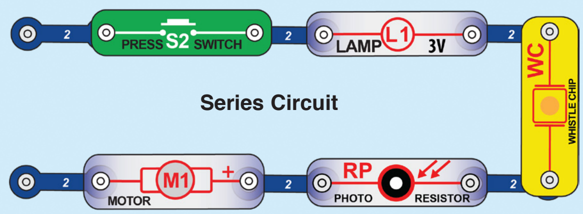


Series Circuit

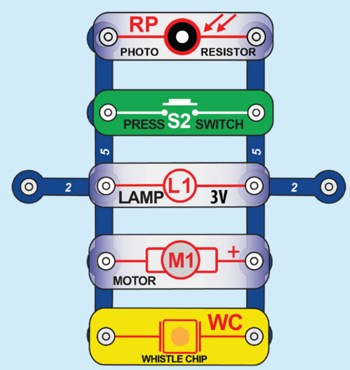


Parallel Circuit

The parts within these series and parallel sub-circuits may be arranged in different ways without changing what the circuit does. So these sub-circuits are the same as the ones on the left:

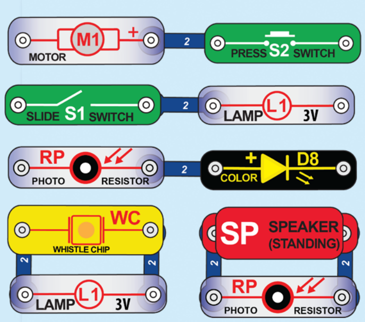


Series Circuit

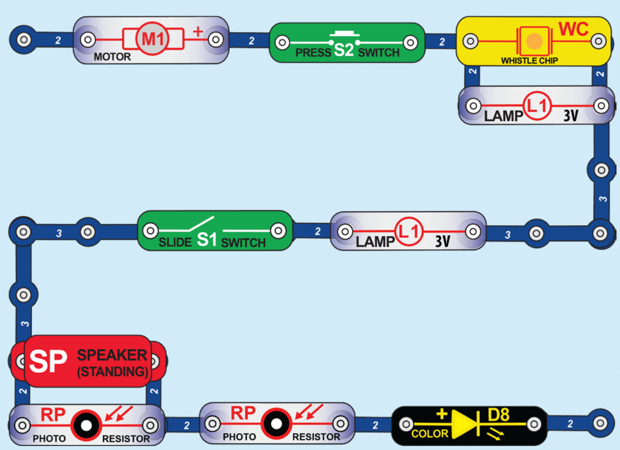


Parallel Circuit

Large circuits are made of combinations of smaller series and parallel circuits. For example, these small sub-circuits:

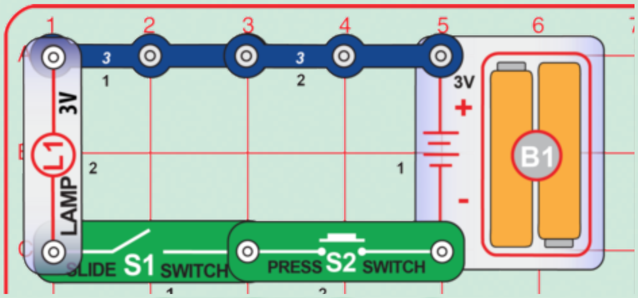


. . . may be combined into this larger circuit:



EXPERIMENTS

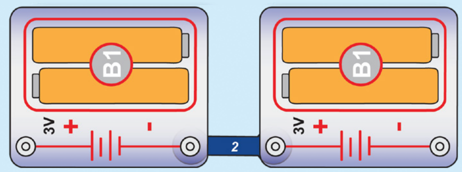
Consider this circuit (which is project 105):



If both switches are on, the lamp will light. If one switch is off then the lamp will be off, because the switches are in series.

If you connected several lamps in series then one switch would turn them all on or off. But if one of the bulbs was broken then none would light. Strings of inexpensive Christmas lights are wired in series; if one bulb is damaged then the entire string does not work.

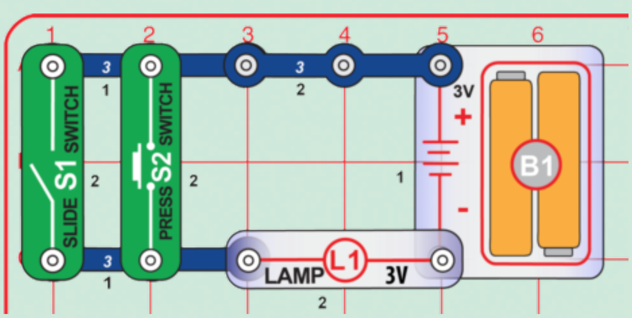
Note that battery holder B1 has two 1.5V batteries connected in series, these add together to produce 3V. If you had several battery holders, you could connect them in series to get higher voltages:



3V + 3V = 6V

EXPERIMENTS

Consider this circuit (which is project 104):



If either switch is on, the lamp will light. If one switch is off then the lamp will still be on, because the switches are in parallel.

In this circuit you could swap the locations of the switches with each other (because they are both in parallel) or the batteries with the lamp (they are both in series), but if you swap the lamp with one of the switches then the circuit will be different. All electric circuits are made up of combinations of series and parallel circuits, from simple ones like these to the most complex computers.

If you connected two lamps in parallel then if one is broken, the other would still work. Most of the lamps in your house are wired like this; if a bulb is broken on one lamps then the other lamps are not affected.

Batteries can also be placed in parallel. Placing two batteries in parallel allows them to last longer, or to supply more current at the same time.

Think of each battery as a storage tank that supplies water. If you put two in parallel, you can get more water (current), but the pressure (voltage) stays the same.

For all of the Snap Circuits® projects, the parts may be arranged in different ways without changing the circuit. The order of parts connected in series or in parallel does not matter - what matters is how combinations of these sub-circuits are arranged together. For example, in project 1 you may swap the locations of the switch and lamp without affecting the circuit operation in any way because they are connected in series.

The choice of whether to use a series or parallel configuration in a circuit depends on the application, but will usually be obvious. For example the overhead lights in the rooms of your home are all connected in parallel so that you can have light on in some rooms and off in others, but within each room the light and switch are connected in series so the switch can control the light.

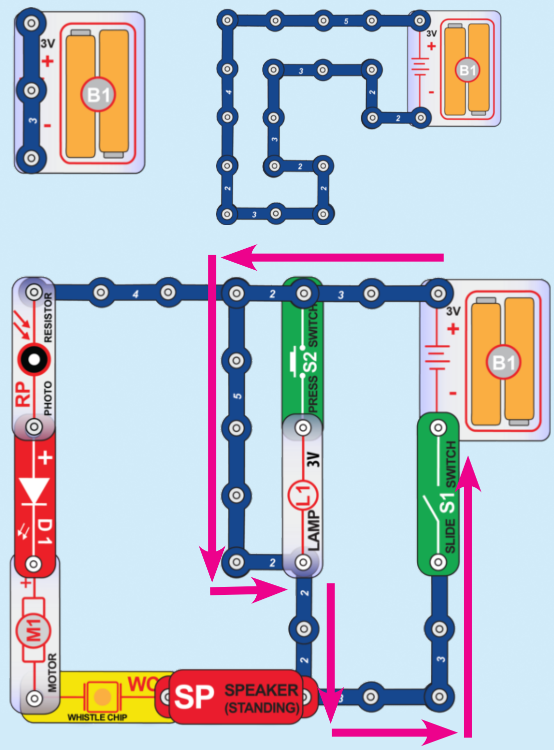
1-8 SHORT CIRCUITS

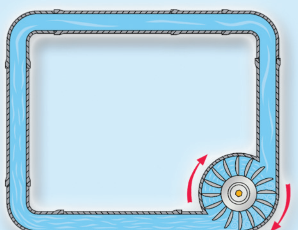
Every circuit will include a power source (the batteries), a resistance (which might be a resistor, lamp, motor, integrated circuit, etc.), and wiring paths between them and back. When wires from different parts of a circuit connect accidentally then we have a "**short circuit**". You've probably heard this term in the movies; it usually means trouble.

A short circuit is a wiring path that bypasses the circuit resistance, creating a **no-resistance path across the batteries. This will damage components and/or quickly drain your batteries.** Be careful not to make short circuits when building your circuits. Always check your wiring before turning on a circuit.

The name "short circuit" refers to how the current through the circuit bypasses (jumps around) other components in the circuit. It is the "easiest" path through the circuit, it is not always the "shortest".

Here are some examples:



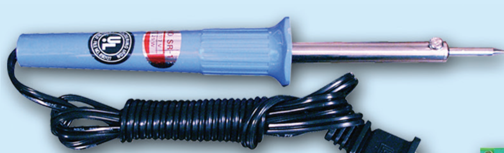


In a short circuit, there is nothing to limit the current in a circuit. However the chemical reaction in a battery cannot supply unlimited current, so the battery voltage drops to zero volts. This is called "overloading" the batteries. This overload produces heat and damages the batteries. Think of this as a pump pumping water in a loop as fast as it can until it burns out.

1-9 SOLDER

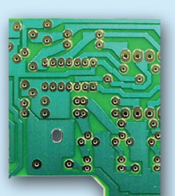
Solder is used to make electrical connections to components on a printed circuit board. It is a special metal made mostly of tin that melts at relatively low temperature (about 500°F). Solder is applied and melted around a joint where a connection is being made; it creates a solid bond between the metals.

The placement of parts onto circuit boards and the application of solder to connect and hold them in place are usually done automatically with special machines. In fact, the microprocessors used in modern computers are so finely designed that they are almost impossible to solder by hand.

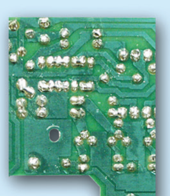


Soldering Iron

Solder



Before Soldering



After Soldering

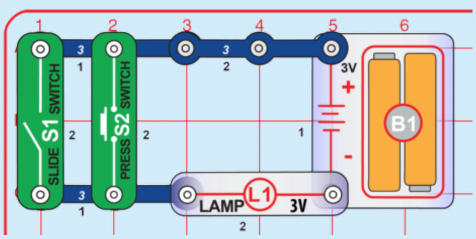
Soldering Machine

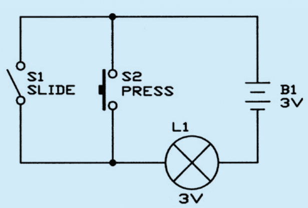
1-10 SCHEMATICS

The circuit diagrams in the Snap Circuits® manuals are easy to understand and build your circuits from. But what if you wanted to write down your own circuit? These diagrams are not very easy to draw. There are also many ways of building the same circuit. For example, you could use a jumper wire instead of a 2-snap wire.

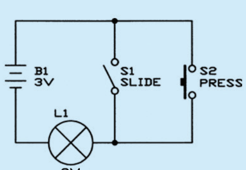
The Snap Circuit® diagrams give you more information than you really need. They tell you how to build it, when all you really need to know is how it will work. You can find your own way to build it.

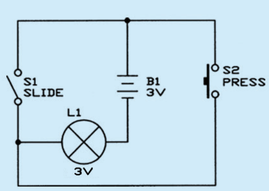
Notice the symbols marked on the parts. Those symbols are used in engineering circuit diagrams, which are called **schematics**. For example, Snap Circuits® project 104 is shown here with an engineering schematic for it:

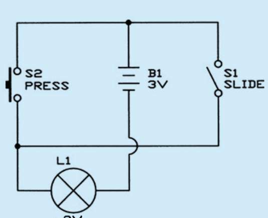




Schematics are easy to draw, and the part symbols used are international standards. Note that wires in a schematic are just lines, and can be as long as you like. Schematics are a flexible way of drawing circuits, and can be re-drawn in many different ways. For example, the above schematic could also be drawn as:

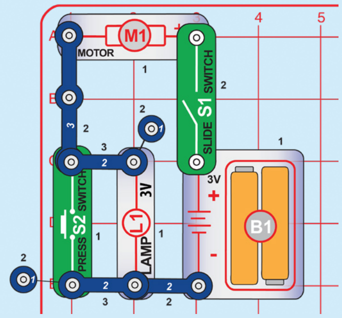


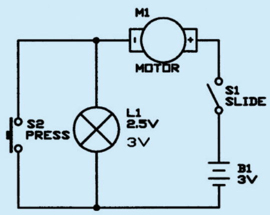


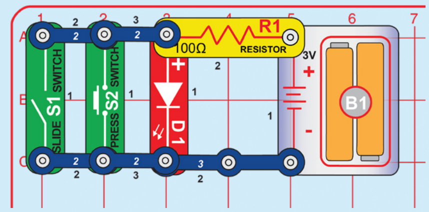


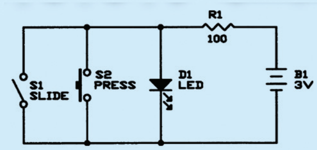
This represents two wires crossing over each other without connecting.

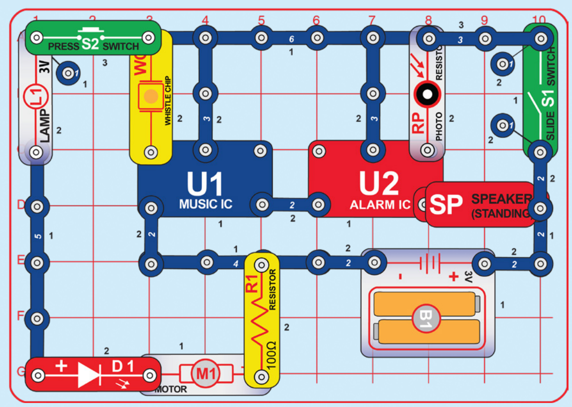
Here are some more schematic examples:

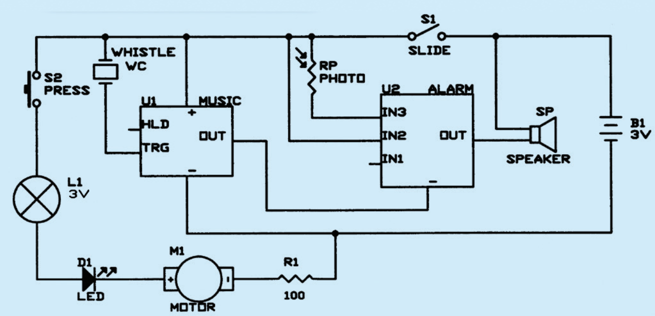












It is important to understand schematics, since many circuit designs are common and can be found in books. Almost all new circuits designed are similar to some circuit that already exists. Many products sold today come with schematics of their designs to assist in troubleshooting problems.

QUICK QUIZ

1. Draw a schematic for a circuit that consists of three lamps powered by a battery.
2. For each room in your home, make a schematic drawing showing how the lamps and switches controlling them are connected together.

SUMMARY

Summary of Chapter 1:

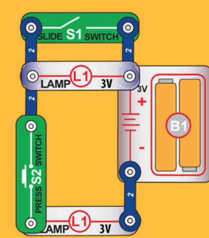
1. The electric current is a measure of how much electricity is flowing in a wire, and is expressed in Amperes.
2. The voltage is a measure of the electric pressure exerted into a wire or circuit by a battery or other power source, and is expressed in volts.
3. Switches are used to turn on or turn off the flow of electricity in a circuit.
4. A light bulb converts electricity into light.
5. Most electronic products have components mounted on circuit boards with the wires literally printed on the board surface.
6. Electrical circuits are all combinations of series and parallel configurations.
7. A short circuit is a no-resistance path across a power source, and causes damage to components and batteries.
8. Solder is a special metal that is melted to make solid electrical connections.
9. Schematics are engineering drawings of circuits using symbols.

QUIZ

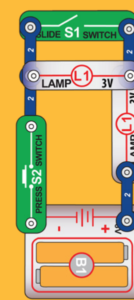
Chapter 1 Practice Problems

1. The flow of electricity is measured in ____________.
   A. gallons B. minutes C. amperes D. volts
2. To turn on a switch, you ____________ it.
   A. voltage B. open C. pressurize D. close
3. Three of the choices below are the same circuit with the parts arranged in different ways. Which choice is a different circuit?

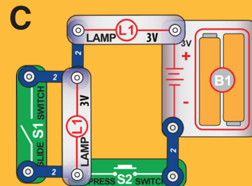
A



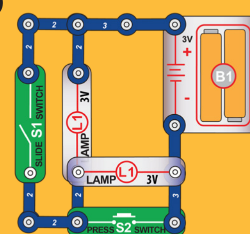
B



C

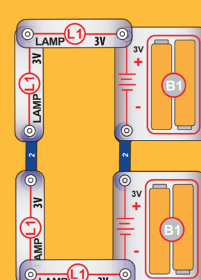


D

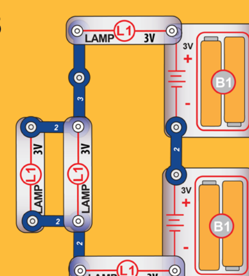


4. Which of these is a short circuit?

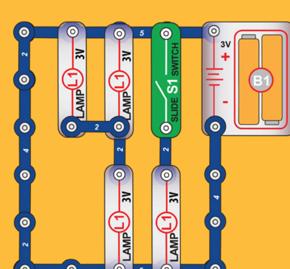
A



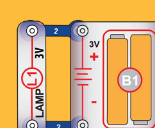
B



C



D

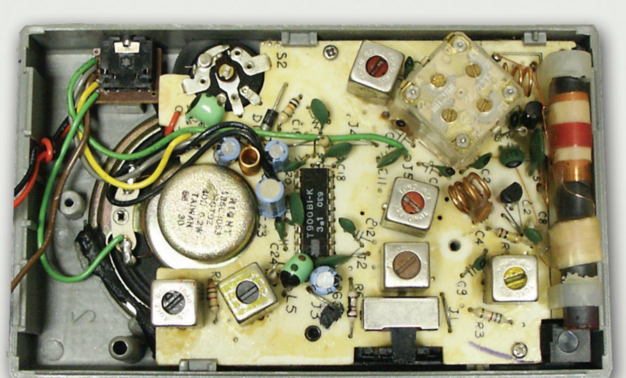


Answers: 1. C, 2. D, 3. D, 4. C

CHAPTER 2: MOTORS & ELECTRICITY

In this chapter you will learn about generators and motors. A generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion. This statement may not seem important to you but it is actually the foundation of our present society. Nearly all of the electricity used in our world is produced at enormous generators driven by steam or water pressure. Wires are used to efficiently transport this energy to homes and businesses where it is used. Motors convert the electricity back into mechanical form to drive machinery and appliances. **The most important aspect of electricity in our society** - more important than the benefits of the Internet - **is that it allows energy to be easily transported over distances.**

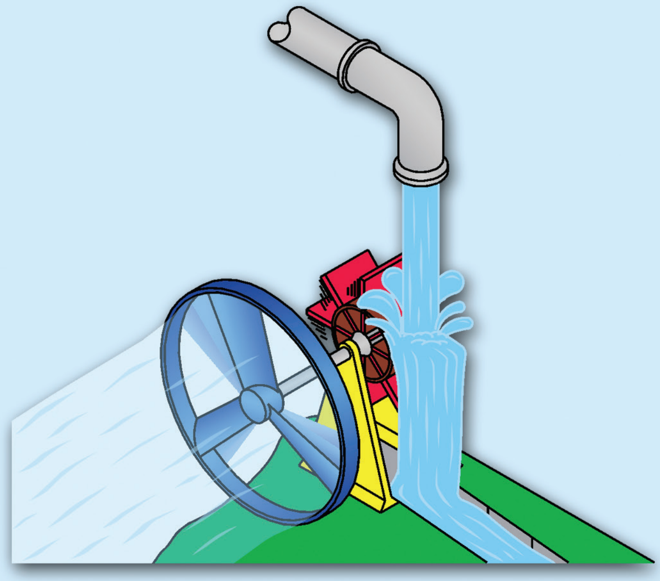
Note that "distances" includes not just large distances but also tiny distances. Try to imagine a plumbing structure of the same complexity as the circuitry inside a portable radio - it would have to be large because we can't make water pipes so small. Electricity allows complex designs to be made very small.



2-1 MOTORS

Water flowing under pressure in a pipe or a fast-moving stream can be used to turn a paddlewheel. If the paddlewheel was linked to a fan blade then you could use the water pressure to turn the fan, perhaps to cool yourself on a hot day. If the water was flowing very fast due to high pressure, then you could get the fan moving fast enough it might create a strong airflow like a propeller on a plane.

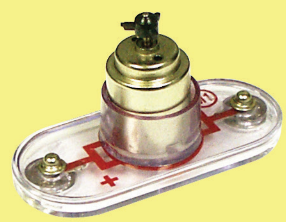
A similar thing happens in a motor, with electricity instead of water. A motor converts electricity into mechanical motion.



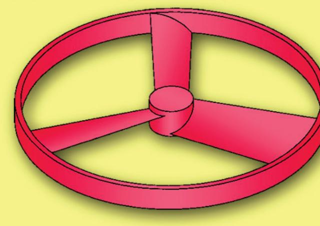
INTRODUCING NEW PARTS

Snap Circuits® includes one motor, shown here with its symbol. Snap Circuits® also includes a fan, which is used with the motor. An electric current in the motor will turn the shaft and the motor blades, and the fan blade if it is on the motor.

Motor Symbol

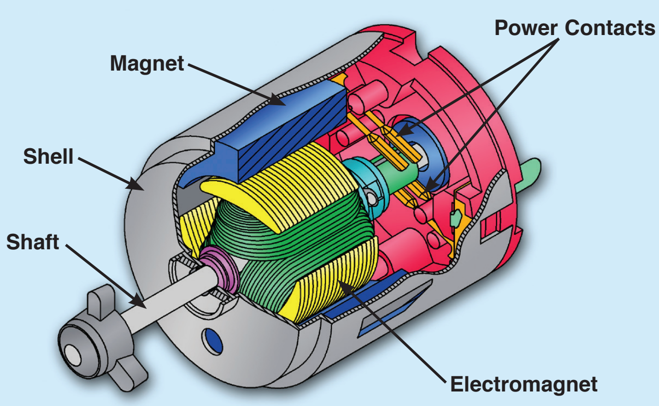


Motor (M1)



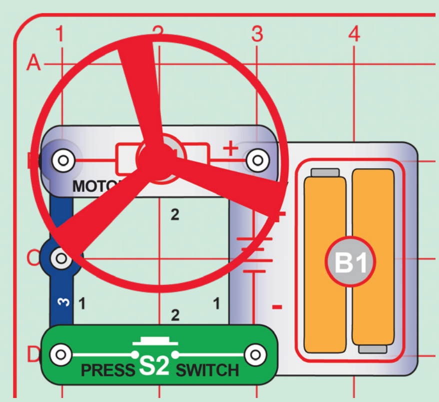
Fan Blade

How does electricity turn the shaft in the motor? The answer is magnetism. Electricity is closely related to magnetism, and an electric current flowing in a wire has a magnetic field similar to that of a very, very tiny magnet. Inside the motor is a coil of wire with many loops wrapped around metal plates. This is called an electromagnet. If a large electric current flows through the loops, it will turn ordinary metal into a magnet. The motor shell also has a magnet on it. When electricity flows through the electromagnet, it repells from the magnet on the motor shell and the shaft spins. If the fan is on the motor shaft then its blades will create airflow.



EXPERIMENTS

Consider this circuit (which is project 5):



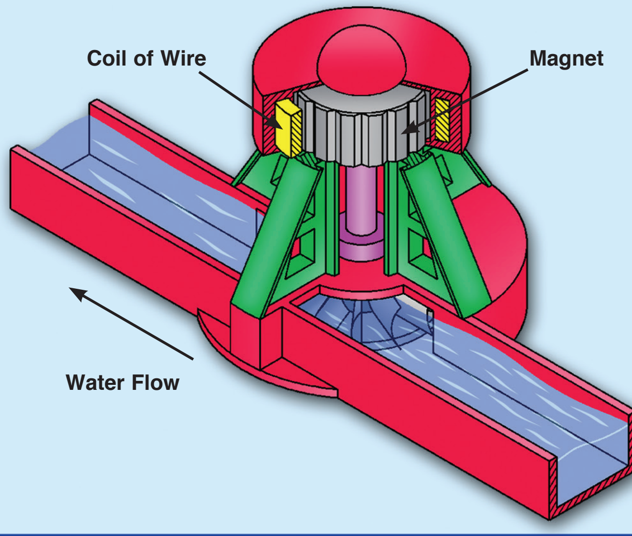
When the switch is on, current flows from the batteries through the motor making it spin. The fan blades will force air to move past the motor. Be careful not to touch the motor or fan when it is spinning at high speed.

Motors are used in all electric powered equipment requiring rotary motion, such as a cordless drill, electric toothbrush, and toy trains. An electric motor is much easier to control than gas or diesel engines.

The electromagnetic effect described above also works in reverse - spinning a magnet next to a coil of wire will produce an electric current in that wire. This is what happens in a **generator**, which uses mechanical motion to create electricity. In an electric power plant, high-pressure water (from a dam) or steam (heated by burning oil or coal) is used to spin a paddlewheel linked to magnets. The magnets create an electric current in a coil of wire, which is used to power our cities.

In theory, you could connect your Snap Circuits® motor directly to the 3V lamp and spin the fan blade with your fingers to light the lamp. In reality, it would be impossible for you to spin the motor fast enough to produce enough current to get even a glimmer of light from the lamp.

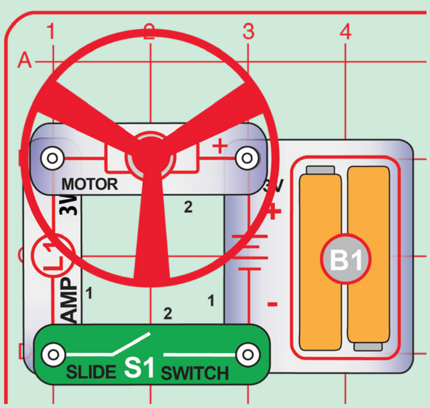
To summarize, **a generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion**.



2-2 MOTOR CIRCUITS

EXPERIMENTS

Consider this circuit (which is project 41):

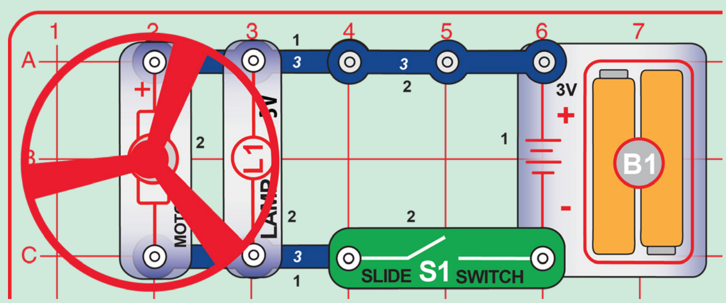


If the switch is on, the lamp will light and the fan will spin. If the lamp or the motor is broken then neither will work, because they are in series.

Since the lamp and motor are in series, the voltage from the batteries will get divided between them. In this circuit more of the voltage will be used at the lamp than at the motor.

If the fan was not on the motor then the motor would spin much faster but the lamp would not be as bright. The motor needs more voltage to spin faster, so there is less voltage available to light the lamp.

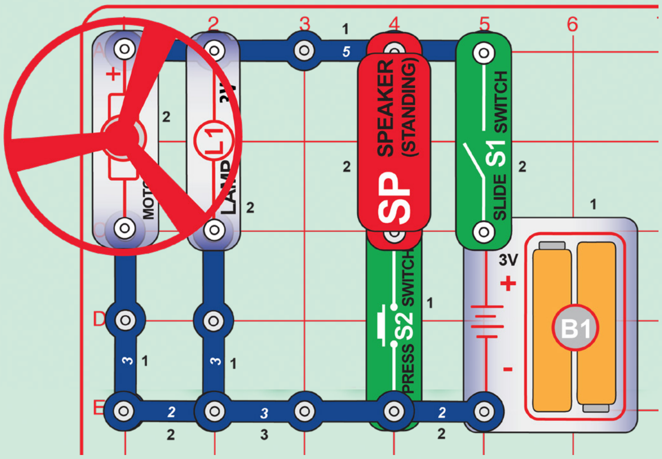
Consider this circuit (which is project 43):



If the switch is on, the lamp will light and the fan will spin. If the lamp or the motor is broken then the other will still work, because they are connected in parallel. Since the lamp and motor are in parallel, the full voltage from the batteries would be applied to both. So the fan would spin faster than for the circuit in project 41, which divided the battery voltage between the lamp and motor.

EXPERIMENTS

Now consider this circuit (which adds the speaker to project 43):



In this circuit the lamp will not be at full brightness, even though the full battery voltage is applied to it. Do you know why? Remember that as the circuit current increases, the voltage produced by a battery is reduced. The motor draws a high current, very high when it first starts up with the fan on. The chemical reaction in the batteries can't supply such a high current, so the battery voltage (electrical pressure) drops.

If your instructor has a meter to measure voltage, ask him to measure the battery voltage with the slide switch on and off. You would see the voltage drop when the switch is on.

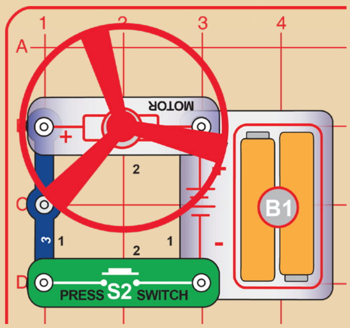
Push the press switch (S2) to add the speaker to the circuit and increase the circuit current even more. This will make the lamp less bright.

Take the fan off the motor and turn on the switch again. The lamp will be brighter now. It doesn't take as much current to spin the motor without the fan, so the battery voltage doesn't drop much.

You know that the AA batteries used to power your Snap Circuits have + and – markings on them, called **polarity** markings. The chemical reaction in the batteries only makes the electric current flow in one direction. To make the current flow in the other direction you just reverse the batteries (all batteries in the same circuit must be reversed). The motor also has + and – markings, because if the direction of current flow through is reversed than the motor will spin in the opposite direction (reversing the electric current reverses the magnetic field generated, which reverses the direction the shaft spins). The lamp, switch, and wires have no such + and – markings on them because they work the same regardless of which way the current is flowing.

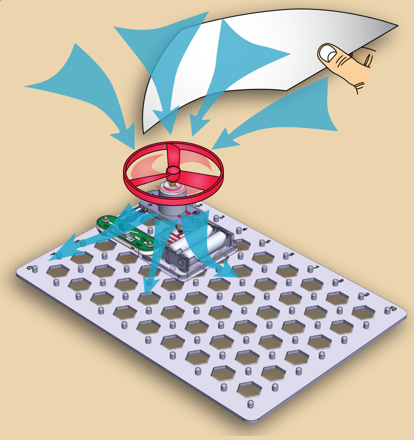
EXPERIMENTS

Consider this circuit (which is project 4):



If the switch is turned off when the motor is spinning at full speed, the fan will rise into the air. Be careful not to touch the motor or fan while it is spinning at high speed. In this circuit the fan blades suck in air and push it down to the table.

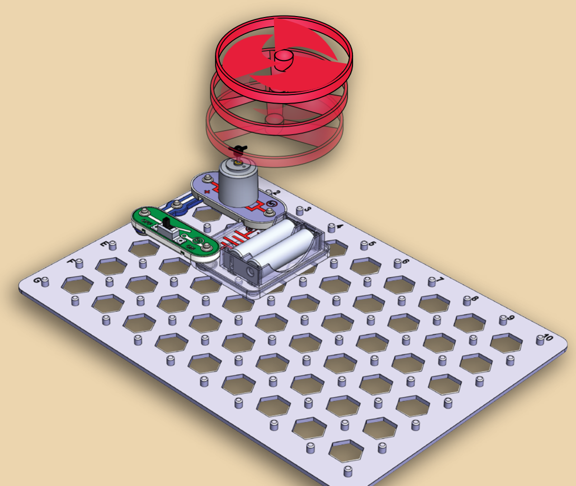
If you hold a sheet of paper above the fan, you will see it get sucked toward the fan.



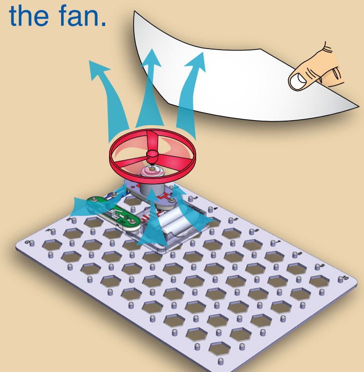
How does the fan rise? Think first about how you swim. When your arms or legs push water behind you, your body moves ahead. A similar effect occurs in a helicopter - the spinning blades push air down, and create an upward force on the blades. If the blades are spinning fast enough, the upward force will be strong enough to lift the helicopter off the ground.

While the switch is on, the motor rotation locks the fan on the motor shaft. The fan does not spin fast enough to lift the entire circuit off the ground. Sometimes there may be enough lift to make the base grid hover around the table like a puck on an air hockey table.

When the motor is turned off, the fan unlocks from the shaft. The fan rises into the air like a helicopter, since it is no longer held down by the weight of the full circuit.

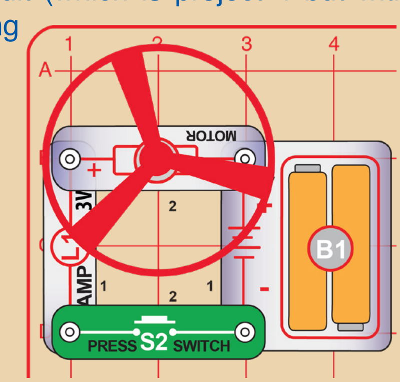


If the motor polarity were reversed (+ on the right, as in project 5), the fan would never fly. The fan blades are sucking in air around the motor and pushing it straight up. If you hold a sheet of paper above the fan, you will see it get pushed up and away from the fan.



EXPERIMENTS

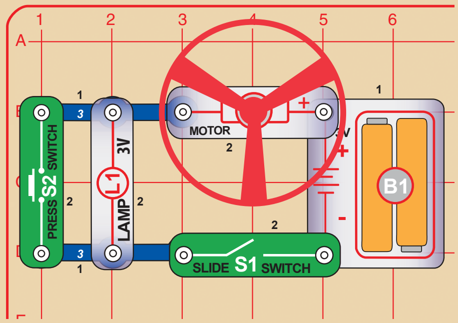
Consider this circuit (which is project 4 but with lamp (L1) replacing the 3-snap wire):



By placing the lamp in series with the motor, the voltage at the motor is reduced. The motor speed will be reduced, so the fan will probably not fly off.

EXPERIMENTS

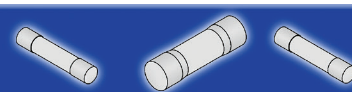
Consider this circuit (which is project 87):



If the slide switch (S1) is on, the fan spins and the lamp lights. If the press switch (S2) is also on, then the fan will spin faster but the lamp will be off. In this case, the full battery voltage is applied to the motor, instead of being divided between the motor and lamp.

This is one way of controlling the speed of a fan. Commercial fans do not use this method because the lamp produces heat and wastes energy. Commercial fans change the amount of voltage applied to the motor using other methods.

2-3 FUSES

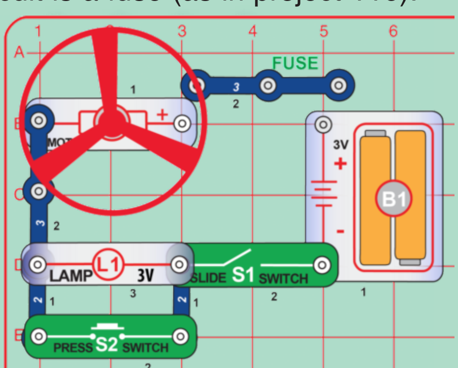


Occasionally electronic products/components break due to people using them incorrectly, accidents, natural storms, bad design, or component failures. Often the problem is a short circuit, which results in an excessively high current flow. This high current can overheat components in the product enough to damage them, make them explode, or start a fire.

A **fuse** is usually a special wire that breaks ("blows") when too much current flows through it. A "blown fuse" shuts down the product before anything can overheat or cause a fire. Although a "**blown fuse**" prevents the product from working, fuses are easy to replace.

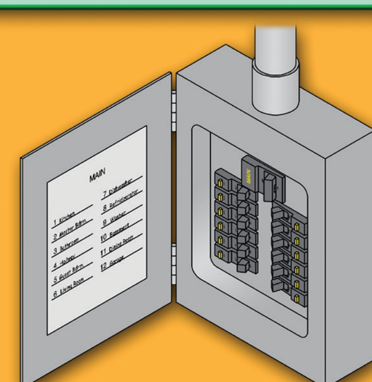
EXPERIMENTS

Imagine that one of the 2-snap wires in the previous circuit is a fuse (as in project 116):



If the circuit is operating properly then the "fuse" acts as a 2-snap wire. However if the motor breaks and suddenly becomes a short circuit while both switches are on, then there will be nothing to limit the current in the circuit. A very high current will flow from the batteries, and would damage them if it continues. This excessively high current will "blow" the fuse, creating an open circuit just like turning off the slide switch would do. This will protect the batteries from damage. The motor can then be repaired and the fuse replaced.

Fuses are very important and most electronic products have one. Products using electricity supplied by the electric company are usually required to have them because the high voltages and currents available here can cause severe damage and fires. Small battery-powered products usually do not have fuses because the batteries in them are not powerful enough to cause harm.



While many fuses must be replaced when blown, flipping a switch can reset some types. Every home has an electrical box of such fuses, to isolate any problems in one room from the rest of the house and your neighbors. But these fuses protecting your home take a much higher current to "blow" them than a fuse used in a radio.

2-4 YOUR ELECTRIC COMPANY

Batteries are widely used because they are easy-to-use, safe, and portable. For example, Snap Circuits® can be used on a camping trip in a remote wilderness as long as you have batteries. You can even take along spare batteries because they are small and easy to carry.

What if you wanted to take a microwave oven on the camping trip? A microwave oven uses a lot of electricity, so the batteries for it would be large, heavy, expensive, and wouldn't last long. Heavy, high-power products like microwave ovens are not moved often.

Only a tiny portion of the electricity used in our world comes from batteries. The rest is produced at enormous electric power plants, operated by your local electric company. The electricity from these power plants is available at the electrical outlets in the walls of your home. The cost of electricity from the electric company is much less than the cost of electricity from batteries.

The voltage of the electricity supplied by the electric company is 120V, much higher than the voltage of the batteries in Snap Circuits®. This is available at each of the electrical outlets in your home. The current available is very large, since it must power products like dishwashers and TVs.

A "**blackout**" occurs when part of a city is cut off from the power plants supplying it with electricity. The city will appear "black" from the air at night, since there are no electric lights on. This is usually due to accidents or storms, but is also done to confuse attacking bombers in war.

A "**brownout**" occurs when power plants cannot supply enough current to a city during high demand, and must reduce the voltage below 120V. This sometimes occurs on hot days in summer when everyone is using their air conditioners.

Our lives are much easier and more fun by having such power available by simply plugging into an electrical outlet. This amount of electricity is also very dangerous, and it will kill anyone who abuses it. While accidents involving electricity are rare, they kill people every year. **Never put anything into an electrical outlet except an electrical plug.** Battery-powered products are safe, since small batteries are too weak to hurt people.

The protective plastic around the wires to plug in a lamp are all that protects you from the full power of electricity. Damaged electrical cords should always be unplugged and repaired. Remember that electricity travels through water, so don't use electric products while taking a bath (battery-powered products are fine).

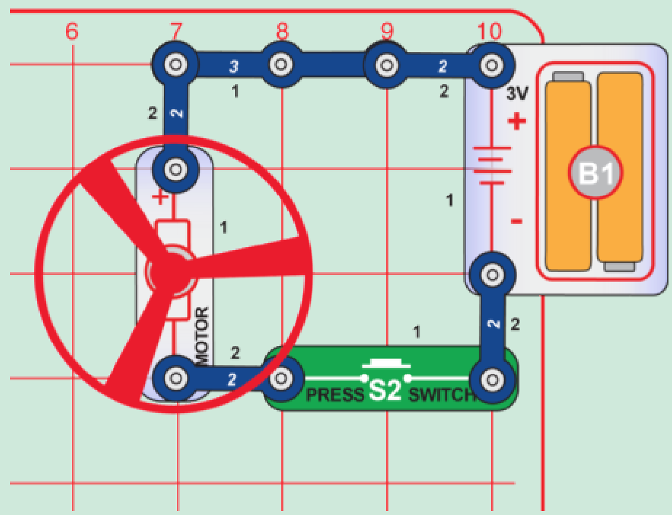
Your home has fuses that automatically turn off the electricity in your home if there is an electrical problem, such as a short circuit. These fuses prevent electrical problems in your home from affecting your neighbors, but they do not protect you.

The electricity supplied to your home and school by your local electric company is not a constant voltage like that from a battery. It averages about 120V but is constantly changing, due to the design of the generators that produce it. This is not a problem, since all equipment that uses it accounts for this change.

An electrical signal that is changing is called an **alternating current**, or **AC**. Because of this, the power from the electric company is also called AC power. An electrical signal that is constant and unchanging is called a **direct current**, or **DC**. The power from a battery is also called DC power.

EXPERIMENTS

For a demonstration of this, consider this simple circuit (which is projects 109-110):



Make a paper disc with lines on it like the one shown here (a sample for cutout is on the last page of the projects 72+ online manual). Tape it to the fan blade and place it on the motor. Place this circuit under a white fluorescent light in your home or school (don’t use an ordinary incandescent lamp). As the speed changes you will notice the white lines first seem to move in one direction then they start moving in another direction.

Do you know why it does this? The reason is because the lights are blinking 60 times a second and the changing speed of the motor is acting like a strobe light to catch the motion at certain speeds. To prove this, go into a dark room and try the same test with a flashlight. The light from a flashlight is constant, so you won’t see this effect and will always see the lines move in the same direction.

The fluorescent lights are blinking because they use the AC power from the electric company. A flashlight uses DC power from batteries.

Note: Some new fluorescent lights use an electronic ballast and they also produce a constant light.

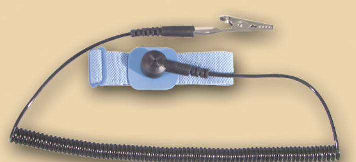
2-5 STATIC ELECTRICITY

You may have noticed that sometimes you can get an electric “zap” in your home or school, how clothes stick together when you take them out of the dryer, or when taking off a wool sweater on a dry day. Occasionally differences in electrical charge build up between things, called static electricity. The things, which might include your body, are storing electrical charge. They might store a very small amount of electrical charge at high voltage. This is just like a cloud storing electrical charge before a thunderstorm.

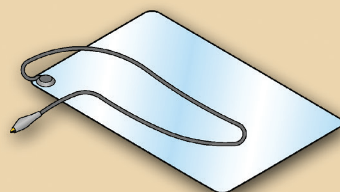
The name “static” is used to describe the electrical charge build-up because the charge is not moving around to disperse. “Static cling” refers to how clothes sometimes cling to each other in the dryer, due to static electricity. Static electricity in the atmosphere causes the “static” (erratic noises) you hear on your AM radio when reception is poor.

Static “zaps” occur when an electrical current flows to equalize the charge difference. Though the voltage might be high, the current is small and the duration is short. The actual “zap” occurs because the voltage is high enough to “jump” across a high-resistance material (usually air), making a small spark as it happens.

Though the “zap” might sting you briefly, these effects do not harm people. However, these static zaps can damage some types of sensitive electronic components and electronics manufacturers have to protect against it. Such protection includes static wrist straps, conductive floor matting, and humidity control. The parts in Snap Circuits® will not be damaged by static.



Anti-Static Wrist Strap



Anti-Static Floor Mat

Anti-Static Ankle Strap

In the same way, clouds can build up a static electrical charge. This charge might become very large, and it is spread out over the enormous volume of the clouds. Lightning occurs when this electrical charge discharges into the ground, and can be very destructive. Lightning is looking for the lowest-resistance path from the clouds to the ground.

Do you know why you often “see” lightning before you “hear” it? It is because light travels faster than sound.

Since people have less resistance than air, standing in an open field during a thunderstorm is very dangerous. Houses and other buildings have “**lightning rods**” to protect them, which are metal bars from the roof into the ground. Their purpose is to encourage lightning to go through the rods to the ground, instead of going through the house to the ground.

Large aircraft can build up a large electrical charge during a long flight. A wire similar to a lightning rod is usually connected to an aircraft shortly after landing, as a precaution against static zap.

Static Electricity Example:
Comb your hair vigorously with a plastic comb and hold the comb near some little (1cm x 1cm) scraps of paper to pick them up OR tilt the comb near a slow, steady stream of water from a faucet and see how the water bends towards it.

QUICK QUIZ ¿ ? ¿

1. List all the products in your home that use an electric motor.
2. Name some examples of static electricity.

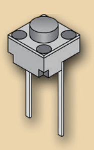
2-6 TYPES OF LAMPS

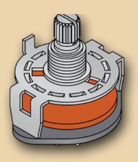
The lamps in Snap Circuits® are **incandescent** type, the same as the larger lamps in your home. The bulbs contain a special high-resistance wire, called the **filament**. When an electric current passes through it the wire gets so hot that it glows. Heat is also produced, and the glass bulb prevents the filament from reacting with oxygen in the air and burning. When the voltage rating of an incandescent bulb is exceeded, the filament gets so hot it burns out. Filaments are usually made of tungsten, since ordinary copper would melt.

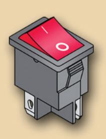
The **fluorescent** light bulbs that come in white 4 ft. tubes are the standard room lights for offices and schools. They pass electric current through a gas, usually neon. This gas emits light as the electricity passes through it, similar to how a tungsten wire does. Although larger and more expensive than ordinary incandescent lamps, they are more efficient at converting electricity into light.

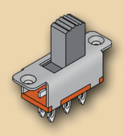
The difference in heat produced between incandescent and fluorescent light bulbs might surprise you. Find a fluorescent bulb and feel the heat coming off it; you won't feel much. Find an incandescent lamp THAT HAS BEEN OFF FOR A WHILE and turn it on. Feel the heat it produces; it soon becomes too hot to touch. Only about 5% of the electricity used by incandescent bulbs is converted into light. Without the more efficient fluorescent bulbs, our society of office buildings might have been much different.

2-7 TYPES OF SWITCHES


Push Button

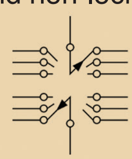

Rotary

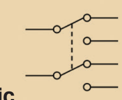

Rocker


Slide

The slide and press switches included in Snap Circuits® are simple switches, more complex types are also available. Switches come in almost every shape and size imaginable. There are membrane, rocker, rotary, DIP, locking, and non-locking types just to name a few.

Very often, a single switch is used to make many different connections. The combinations of connections for a switch are indicated in the symbol for it. Here are some examples:


Rotary Switch Schematic


Slide Switch Schematic

2-8 ELECTRICIANS

There are many different ways of using electricity, so there are many types of people who work directly with it. The main categories are electricians and engineers/technicians. Although many people think of these as being the same career, they are actually very different. They attend different schools, use different tools, and work in different places.

Electricians are the people who install electrical wiring into homes and businesses. Electricians deliver the electricity to your home to be used. It takes a lot more electricity to operate everything in a building than to operate a computer or radio, so safety is very important and the equipment they use can handle high levels of voltage and current. Buildings are not easy to re-wire, so the wiring must be reliable and safe for many years.

Electricians are trained in union and trade schools. Local government licenses them because buildings must be wired as per strict local building codes to be sure they will be safe even after many years.

Electrical/electronics engineers and technicians design and develop products that will use the electricity that electricians have brought to them. Voltages and currents are much lower and safer, but circuits can be much more complex (like computers) and technologies change quickly. Electronic products are mass-produced in factories, unlike building wiring which must be installed in the building. Engineers are trained in colleges and technicians are trained in trade schools. Government does not regulate them but products must meet industry safety standards.

SUMMARY

Summary of Chapter 2:

1. An electric current flowing in a wire has a magnetic field.

2. A generator uses mechanical motion to create electricity and a motor uses electricity to create mechanical motion.

3. A fuse is a special wire that breaks when an excessively high current flows through it, used for safety.

4. Electrical outlets are 120V, and can supply enough current to kill people.

5. An electrical current that is changing is called an alternating current (AC). An electrical signal that is constant and unchanging is called a direct current (DC). The electricity in homes is AC power.

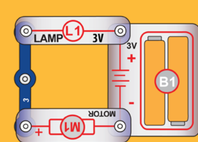
6. Static electricity can cause clothes to stick together. Lightning occurs when static electricity in clouds discharges into the ground.

7. Only a small amount of the electricity used by light bulbs is converted into light, the rest becomes heat.

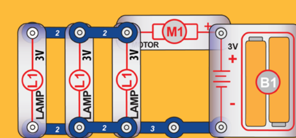
QUIZ

Chapter 2 Practice Problems

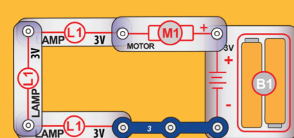
1. Fuses are needed for all of the following reasons except:
   A. They improve circuit performance.
   B. To prevent an electrical problem from starting a fire.
   C. To limit the current in a circuit.
   D. People don't always use products correctly.
2. All of the following are caused by static electricity except:
   A. Lightning
   B. Erratic noises interrupting music on your AM radio.
   C. Clothes sticking together in the dryer.
   D. Blackouts
3. Which circuit will spin the fan the fastest? Which will spin fan the slowest?



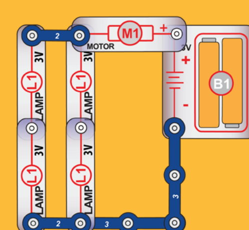
A



B

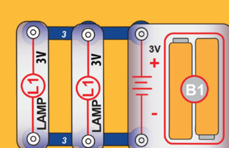


C

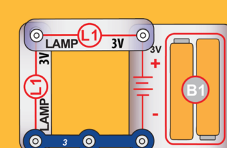


D

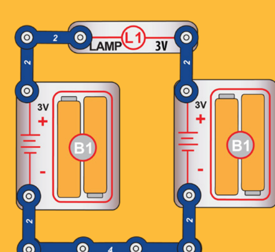
4. Which circuit will make the lamp the brightest?



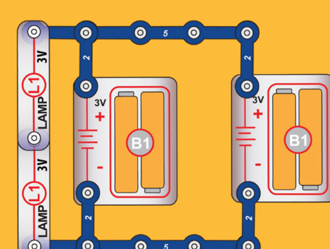
A



B



C



D

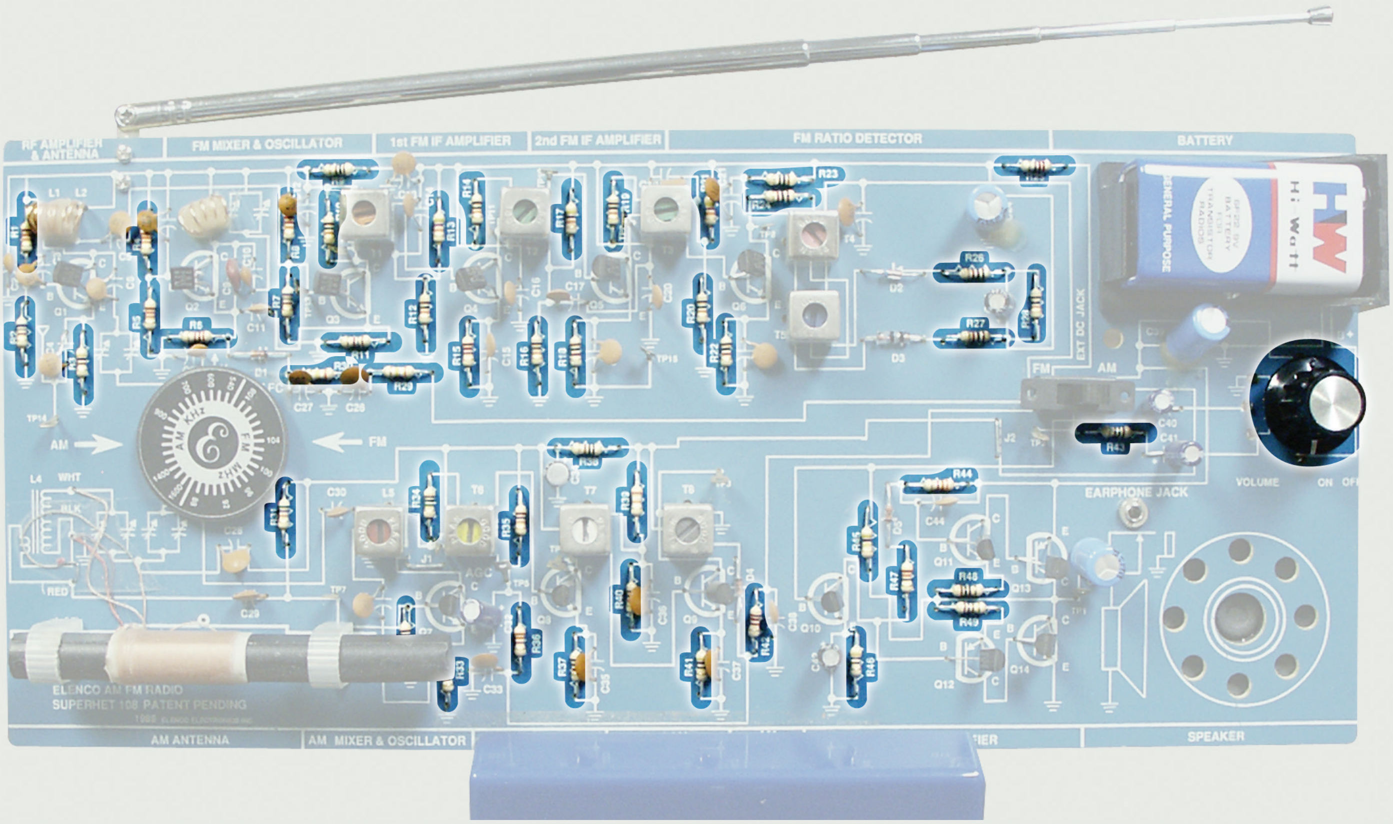
Answers: 1. A, 2. D, 3. B/C, 4. A

CHAPTER 3: RESISTANCE

All of the circuits and components studied in chapters 1 and 2 are commonly used by electricians, though the actual parts used will be for much higher voltages and currents than the Snap Circuits® parts representing them. Electricians are concerned with getting the electricity to where it will be used as efficiently as possible, without wasting energy.

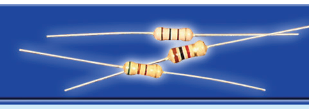
In consumer products like toys, radios, and computers, electronics engineers and technicians want to control how it is used.

In this chapter you will learn about resistors, which are used to limit and control the flow of electricity. As an example of how important resistors are in electronics, consider a typical AM/FM radio:



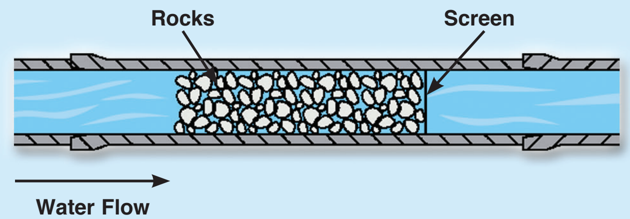
This radio contains 50 resistors, which are highlighted. The radio needs every one to operate properly. Televisions contain hundreds of resistors, and computers contain even more.

3-1 RESISTORS



Why is the water pipe that goes to your kitchen faucet smaller than the one that comes into your house from the water company? And why is it much smaller than the main water line that supplies water to your entire town? The reason is that you don't need so much water. The pipe size limits the water flow to what you actually need.

Electricity works in a similar manner, except that wires have so little resistance that they would have to be very, very thin to limit the flow of electricity. They would be hard to handle and break easily. But the water flow through a large pipe could also be limited by filling a section of the pipe with rocks (a thin screen would keep the rocks from falling over), which would slow the flow of water but not stop it.



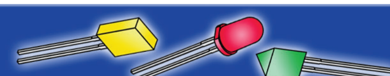
Resistors are like rocks for electricity, they control or limit how much electric current flows. The resistance, expressed in **ohms** (Ω, named after George Ohm) or kilohms (KΩ, 1000 ohms) is a measure of how much a resistor resists the flow of electricity.

To increase the water flow through a pipe you can increase the water pressure or use less rocks. To increase the electric current in a circuit you can increase the voltage or use a lower value resistor.

This set does not include a separate resistor part but other Snap Circuits® sets may have them. Resistors typically look like this:

The symbol for the resistor is this squiggly line:

3-2 LEDS



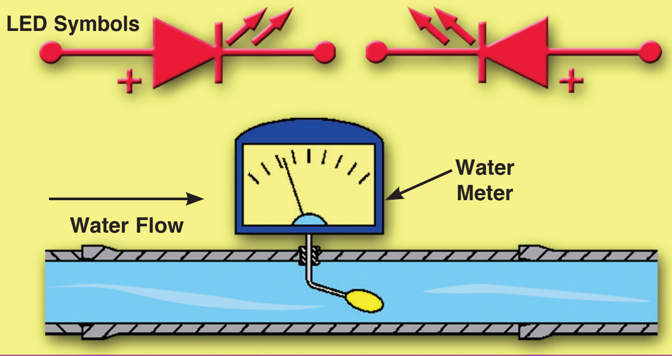
The Snap Circuits® lamp you have (part L1) needs a high current to be bright, and can be thought of as a high current meter since its brightness is an indication of how much current is flowing in a circuit. Even a very small resistor would limit the current so much that the lamp would not light at all. So you need a low current meter.

Light Emitting Diodes (LEDs) may be thought of as one-way, low-current meters. Like light bulbs, their brightness increases as the current through them is increased. But they are made from different materials and so have other characteristics. They are more sensitive than light bulbs and become bright at much smaller currents, but will be damaged by high currents (which is why they are normally used with resistors or other parts to limit the current). They can be made to produce specific colors of light, usually red, green, blue, or yellow. They also completely block current flow in one direction.

INTRODUCING NEW PARTS

Snap Circuits® includes a color changing LED. The arrow in the symbol of the part includes which direction it allows current to flow in (referred to as the forward direction):

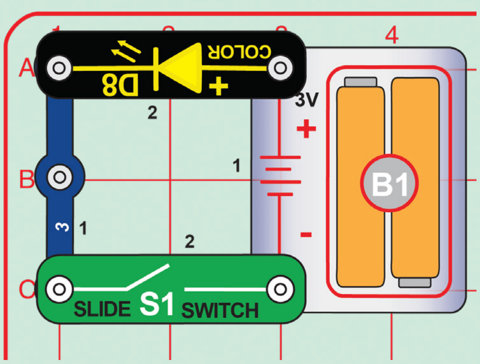
Color LED (D8)



The color LED (D8) is not a normal LED, and is actually separate red, green, and blue LEDs with a microcircuit controlling them. High currents can damage LEDs so a resistor (usually 330 ohms) has been added inside the D8 module to protect the color LED from accidental mis-wiring (such as placing the D8 part directly across the battery holder). Also, the red/green/blue LEDs of the color LED block current in the reverse direction, but the microcircuit controlling them acts as a voltage drop when connected in reverse, so when the D8 part is connected backwards the LED will be off but some current can still flow (limited by the LED protection resistor).

EXPERIMENTS

Consider this simple circuit (which is project 2):

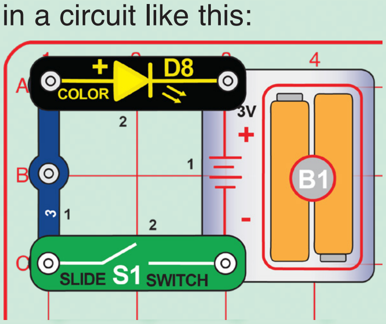


If the switch is on, the LED (D8) will light. The LED is just like a lamp here, except that it would not be as bright and would use less battery power. Also, an LED appears much brighter when viewed from above than from the side. LEDs concentrate most of their light in one direction, unlike a light bulb which emits light nearly equally in all directions.

If the 3-snap wire was replaced by a resistor component (or the color LED's internal protection resistor value was increased), the LED would become much dimmer.

EXPERIMENTS

What would happen if the LED position were reversed, in a circuit like this:



The LED does not light when connected in reverse.

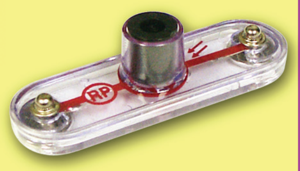
1-4 THE SWITCH

Some materials, such as Cadmium Sulfide, change their resistance when light shines on them. Electronic parts made with these light-sensitive materials are called photoresistors. Their resistance decreases as the light becomes brighter.

INTRODUCING NEW PARTS

Snap Circuits® includes one photoresistor. Its resistance value changes from nearly infinite in total darkness to about 1KΩ when bright light shines directly on it. Note that a black plastic case partially shields the Cadmium Sulfide part.

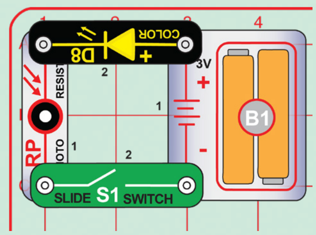
Photoresistor (RP)



Photoresistor Symbol

EXPERIMENTS

Consider this circuit (which is project 3):

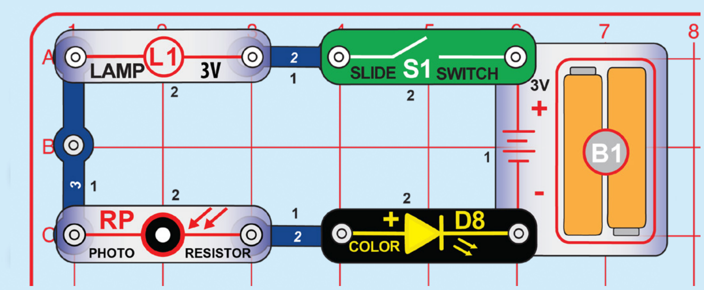


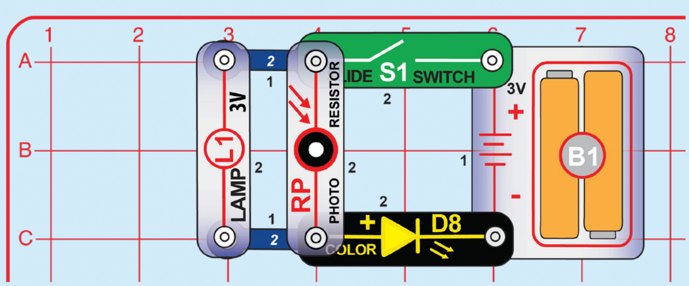
The brightness of the LED depends on how much light shines directly on the photoresistor. If the photoresistor is held next to a flashlight or other bright light, then the LED will light. It may be dim, so wrap your hand around it to see it better.

Photoresistors are used in applications such as streetlamps, which come on as it gets dark due to night or a severe storm.

3-4 RESISTORS IN SERIES & PARALLEL

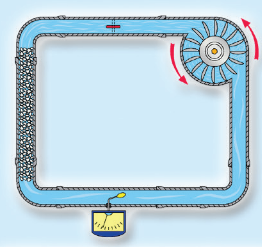
Consider these two mini-circuits:

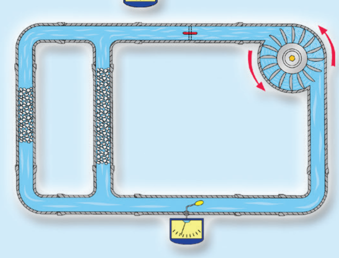




The first circuit has the lamp and photoresistor in series, the second circuit has them in parallel. Which circuit will make the LED brighter? (The lamp is used here as a low value resistor, and will not light in either circuit due to the color LED's internal protection resistor limiting the current too much.)

Just think of the resistors as rock piles slowing down the flow of water in a pipe:





From the water diagrams, it should be easy to see that the circuit with the resistors in parallel will have the brighter LED. You can build these mini-circuits with your Snap Circuits® parts to prove this.

Placing resistors in series increases the total resistance, and so decreases the current to the LED. Resistors in series add together. **Placing resistors in parallel decreases the total resistance**, and so increases the current to the LED.

Advanced students can compute the total resistance as follows:

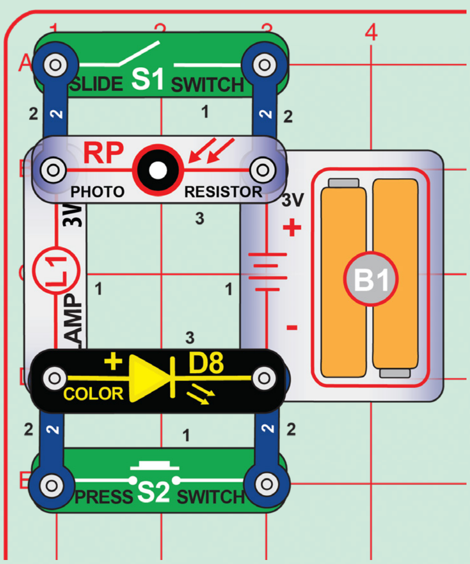
$$R_{series} = R1 + R2 + R3 + \ldots$$

$$\frac{1}{R_{parallel}} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots$$

The total series resistance is greater than the biggest resistor, and the total parallel resistance is smaller than the smallest resistor.

EXPERIMENTS

As a review, consider this mini-circuit. Make sure there is a bright light shining on the photoresistor (RP).



If the slide switch (S1) is on then the color LED will be on and the lamp off, the color LED's internal protection resistor limits the current. Turning off the slide switch places the photoresistor in series and the LED becomes very dim. If both switches are on, the resistances of the photoresistor and color LED are bypassed, allowing a higher circuit current and the lamp lights.

You've learned that when you increase resistance in a circuit, less current flows (making an LED dimmer). This relationship between voltage, current, and resistance is the most important one in electronics. It is known as **Ohm's Law** (after George Ohm who discovered it in 1828):

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

The most basic rules for analyzing circuits as known as **Kirchhoff's Laws** (known after Gustav Kirchhoff, who stated them in 1847):

1. The total voltages driving a circuit must equal the voltage drops within it.
2. All current flowing into a point must flow out of it.

The "**power**" of electricity is a measure of how much energy is moving through a wire. It is expressed in **Watts** (W, after James Watt for his work with engines). It is a combination of the electrical voltage (pressure) and current:

Power = Voltage x Current

OR

$$\text{Power} = \frac{\text{Voltage x Voltage}}{\text{Resistance}}$$

3-5 RESISTANCE

Just what is Resistance? Take your hands and rub them together very fast. Your hands should feel warm. The friction between your hands converts your effort into heat. **Resistance** is the electrical friction between an electric current and the material it is flowing through; it is the loss of energy from sub-atomic particles as they move through the material.

You can also compare resistors to the friction with the ground when you walk. If there is too much friction (like two feet of snow) you have to go very slow or get stuck. If there is too little friction (like ice) then you have no control and will slip and fall.

Resistors are made from carbon and can be constructed with different resistive values, such as the five parts included in Snap Circuits®. If a large amount of current is passed through a resistor then it will become warm due to the electrical friction. Resistors get warm because they exert control by wasting power as heat. Light bulbs use a small piece of a highly resistive material called tungsten. Enough current is passed through this tungsten to heat it until it glows white hot, producing light.

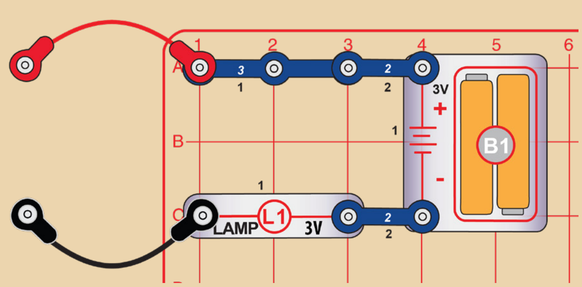
Electric stoves and heaters use resistors to change electricity into heat.

Metal wires have some electrical resistance, but it is very low (less than 1Ω per foot) and can be ignored in almost all circuits. Materials, such as metals, which have low resistance are called **conductors**. The best conductor material known is silver, but it is too expensive to be widely used. Copper is second best, and it is used in most wires and printed circuit boards in the electronics industry.

Materials such as paper, plastic, and air have extremely high values of resistance and are called *insulators*.

EXPERIMENTS

You can use Snap Circuits® to test whether materials are conductors or insulators. Consider this simple circuit (which is project 28):



Touch the loose ends of the red & black jumper wires to any material. If the lamp is bright then the material is a conductor, if the lamp is off then it is an insulator.

LEDs are made from materials called **semiconductors**, so-called because they have more resistance than metal conductors but less than insulators. Most semiconductors are made of Silicon but Gallium Arsenide is usually used in LEDs. Their key advantage is that their resistance can be changed by the operating conditions to be very high or very low. Transistors (current amplifiers) are made from semiconductor materials, and are the basic building blocks for computers and memory circuits.

Nearly all electricity produced eventually becomes heat. All currents flowing through resistors produce heat in them. Light from a lamp or TV produces heat in whatever it shines on. All the circuits in a computer produce heat, and most computers have vents to get this heat out.

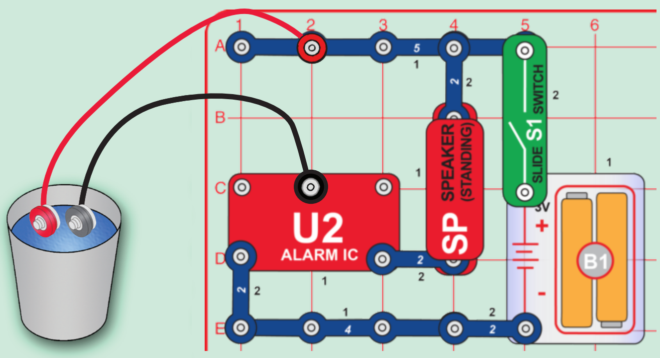
QUICK QUIZ

Draw a schematic for a circuit using a battery set, an LED, a resistor, a slide switch, and a lamp. The resistor must be used to limit the current through the LED. The lamp must be on at all times, but you must be able to turn off the LED.

3-6 RESISTANCE OF WATER

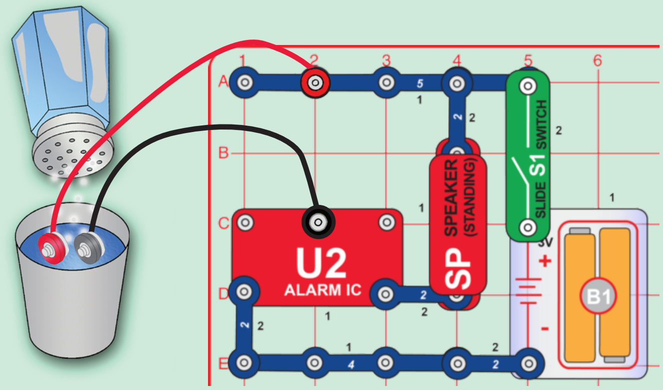
EXPERIMENTS

Consider this circuit (which is project 34):



If the loose ends of the jumper wires are placed into a cup of water, an alarm will sound. The circuit can be used as a water detector. The tone depends on your local water supply. If more water were added to the cup, the tone would change slightly.

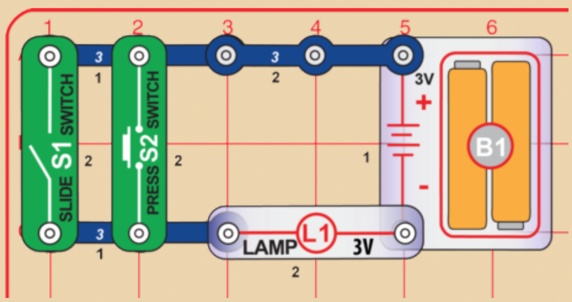
Pure water (like distilled water) has very high resistance, but drinking water has impurities mixed in that lower the resistance. What would happen if salt was added to the cup and dissolved in the water?



Dissolving salt in water decreases the resistance of the water, so the tone of the alarm is louder and faster. It could be used as a salt-water detector.

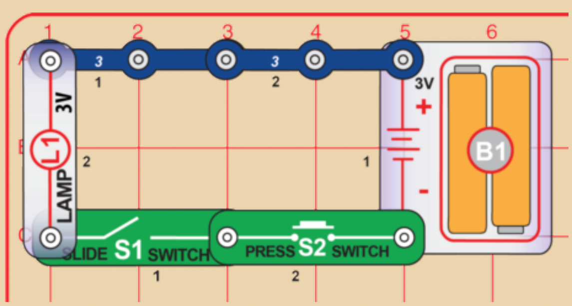
EXPERIMENTS

Consider this circuit (which is project 104):



If the slide switch OR the press switch is on, the lamp lights up. This is called an OR circuit. While this may seem very simple and boring, it represents an important concept in electronics. Two switches like this may be used to turn on a light in your house. You could also have more than two switches and the circuit would function the same way.

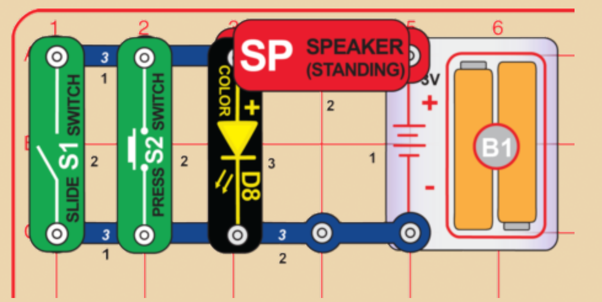
Now consider this circuit (which is project 105):



If the slide switch AND the press switch are on, the lamp lights up. This is called an AND circuit. Two switches like this may be used to turn on the same light in your house, the room switch and the master switch in the electrical box.

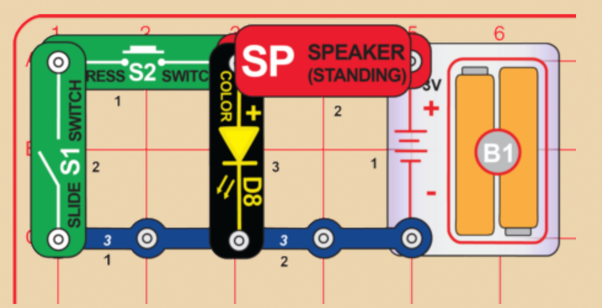
AND and OR circuits are the basic building blocks of today's computers, though transistors are used instead of switches and lights. Combinations of AND and OR circuits are used to add and multiply numbers together.

Now consider this circuit (which is project 106):



This circuit is the counter-part to the OR circuit, the LED lights in the opposite combinations of that circuit. Engineers called it a NOR circuit (short for "NOT this OR that").

Now consider this circuit (which is project 107):

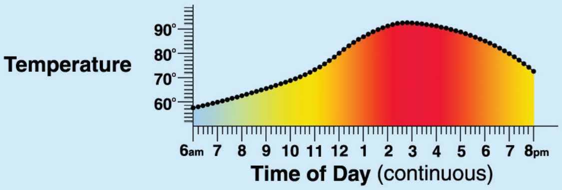


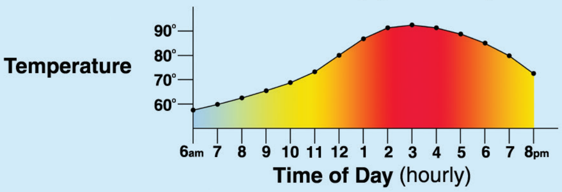
This circuit is the counter-part to the AND circuit, the LED lights in the opposite combinations of that circuit. It is called a NAND circuit (short for "NOT this AND that"). This circuit can also have more or less than two inputs, though when it only has one input it is referred to as a NOT circuit.

OR, AND, NOR, NAND and NOT circuits are all important building blocks in modern computers.

3-8 DIGITAL ELECTRONICS

Suppose you wanted to keep a record of how the temperature outside was changing throughout the day. You could use a thermometer to measure it, and watch it continuously or just check it every hour and write it down. Your results might look something like this:

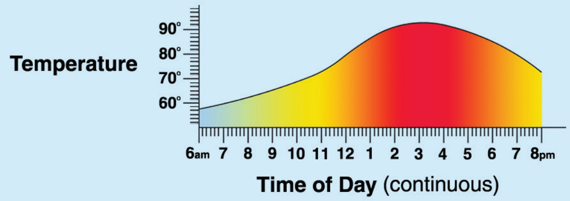


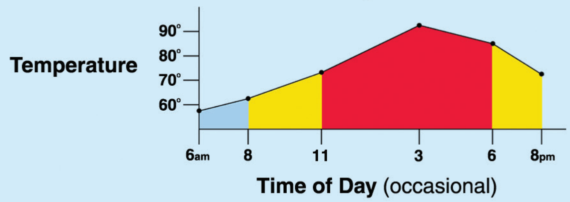


Checking it once an hour gave you a very good record of how the temperature was changing throughout the day, with much less effort than watching it all day long.

Digital electronics uses a series of numbers to represent an electrical signal. If your thermometer was electronic it might increase an output voltage as the temperature increased. It would be hard to store what that voltage was throughout the day, but easy to measure it and store it as a series of numbers. The series of numbers could be converted back into a continuous voltage later.

The accuracy of your digital representation depends on how accurately and how often you measured the original voltage. For example, you could get a better or worse representation of your temperature:





Sometimes it is easier to process information as a digital series of numbers (computers), and sometimes it is easier to use a continuously changing voltage (AM radios). Many products use both methods on the same information but at different times. The disadvantage of digital systems is that they are more complex since they have to store and process all the numbers. The advantages are that IC technology makes it inexpensive to store and process information, and digital systems are more protected from interference.

Computers store numbers in memory using vast arrays of transistors that are switched on or off. The OR, AND, NOR, NAND, and NOT gates are actually made up of transistors. These gates are used to add and multiply large numbers in tiny pieces to form the processing functions in computers.

SUMMARY

Summary of Chapter 3:

1. Resistors are used to limit and control the current in a circuit.

2. Resistance is a measure of how much something opposes the flow of electricity in a circuit, and is expressed in ohms.

3. Light emitting diodes (LEDs) are one-way, low-current light bulbs.

4. Placing resistors in series increases the total resistance. Placing resistors in parallel decreases the total resistance.

5. In a circuit, the current equals the voltage divided by the resistance. This is known as Ohm's Law.

6. Power measures how much energy is moving through a circuit, it equals the voltage multiplied by the current and is expressed in Watts.

7. Materials which have very low resistance are called conductors. Materials which have very high values of resistance and are called insulators.

8. Photoresistors change their resistance when light shines on them.

9. All currents flowing through resistors produce heat in them.

10. OR, AND, NOR, NAND and NOT circuits are basic building blocks of computers.

11. Digital electronics uses numbers to represent an electronic signal. The accuracy of the digital representation depends on how accurately and how often the original signal was measured.

12. Computers store numbers using arrays of transistors that are switched on or off.

QUIZ

Chapter 3 Practice Problems

1. The following are characteristics of an LED except:
   A. They block current flow in one direction.
   B. They get brighter as current increases.
   C. They can handle very high currents.
   D. They can emit different colors of light.

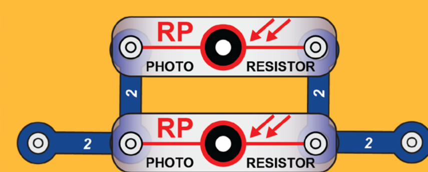
2. To increase the current through a circuit, you . . .
   A. Increase the resistance.
   B. Decrease the watts.
   C. Increase the ohms.
   D. Increase the voltage.

3. Which of these sub-circuits will have the lowest resistance? Which will have the highest resistance?

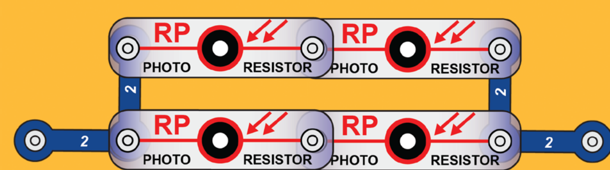
A

B

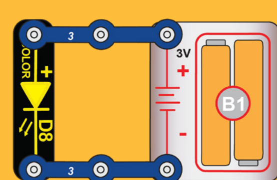
C



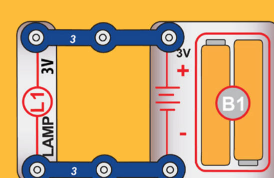
D



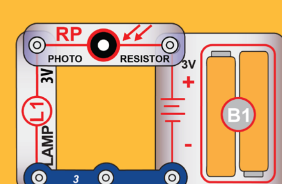
4. Which circuit will be the brightest?



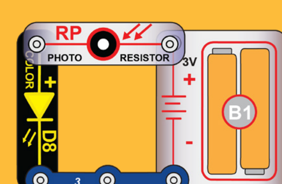
A



B



C



D

Answers: 1. C, 2. D, 3. C/B, 4. A

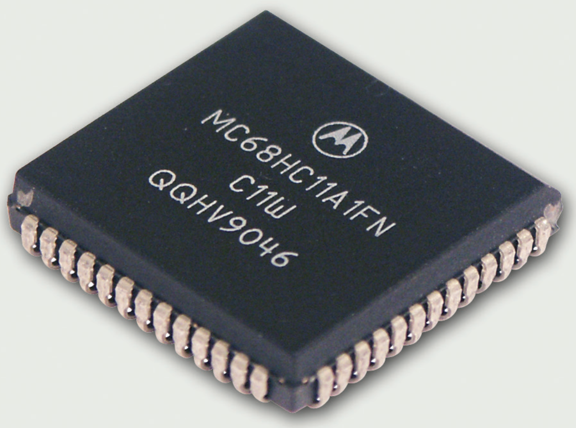
CHAPTER 4: ELECTRONIC SOUND & INTEGRATED CIRCUITS

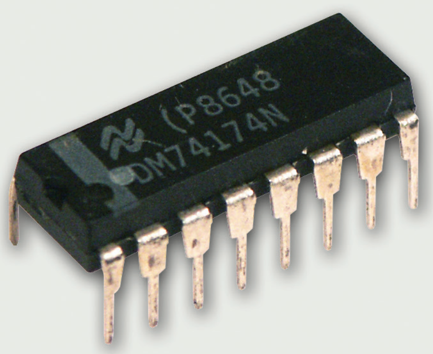
Learn By Doing®

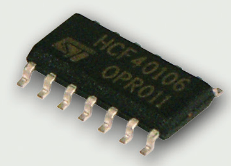
A key advantage of semiconductors is that several transistors can be manufactured on a single piece of silicon. This led to the development of Integrated Circuit (IC) technology around 1960. In ICs, careful control of complex manufacturing processes has enabled entire circuits consisting of transistors, diodes, resistors, and capacitors to be constructed on a silicon base. IC manufacturing is so specialized that particles of dust can render parts useless.

Many thousands of parts now fit into an area smaller than your fingernail. In fact, some ICs used in computers now have more than a million transistors on them, and a drawing of everything on them would be huge. Spectacular improvements in cost, size, and reliability have been achieved as a result.

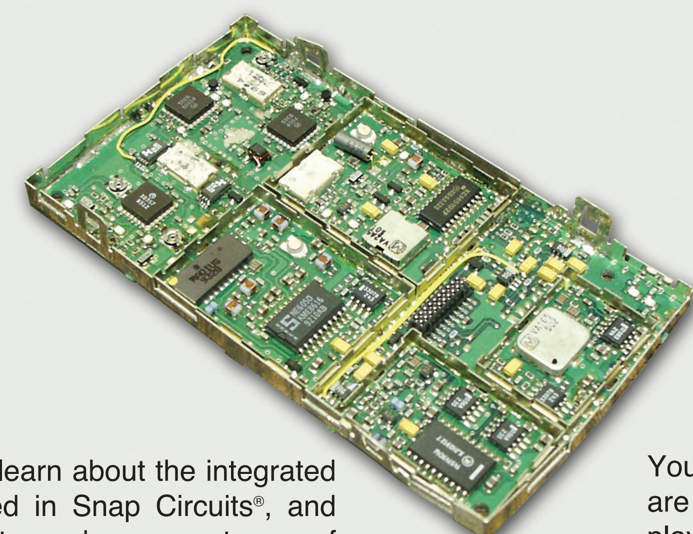
Further research led to the development of microprocessor ICs, which can do many different tasks based on programming that can be easily changed. The leader of Intel Corporation once boasted that the speed of the newest microprocessors doubled every eighteen months. This came to be known as Moore's Law, and held true for more than a decade.







Integrated circuits are used in everything from simple electronic toys to the most advanced computers. Many technologies would not have been possible without them. A cellular phone, for example, is an extremely complex device that has been so miniaturized with ICs that it fits in your hand.



In this chapter you will learn about the integrated circuit modules included in Snap Circuits®, and have the opportunity to make many types of circuits using them. But first you will learn about electronic sound.

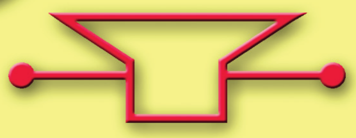
Your electronic stereo and radio are powered by electricity and play music, so how does electricity make sound? In this chapter you will find out.

4-1 ELECTRONIC SOUND

INTRODUCING NEW PARTS

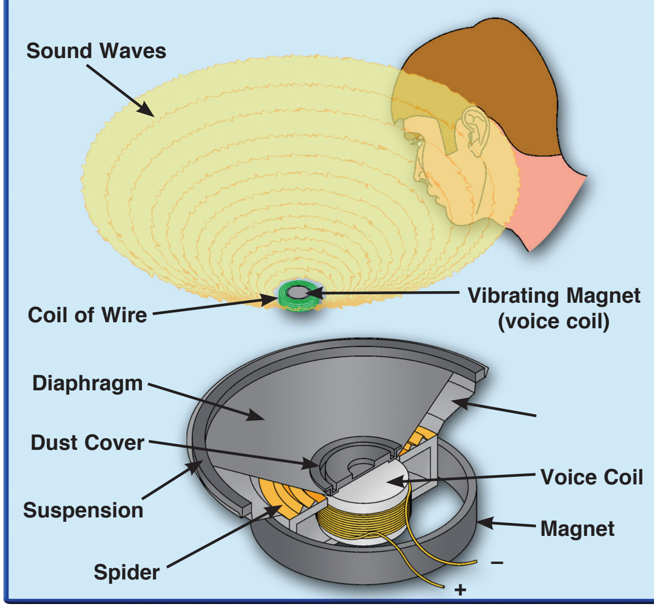
Snap Circuits® includes a speaker:

Speaker (SP)



Speaker Symbol

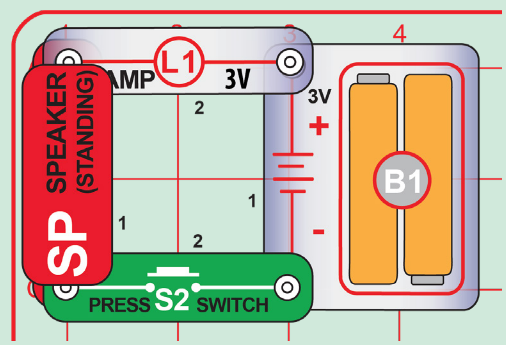
A **speaker** converts electricity into sound. It does this by using the energy of a changing electrical signal to create mechanical vibrations (using a coil and magnet similar to that in the motor). These vibrations create variations in air pressure, called sound waves, which travel across the room. You "hear" sound when your ears feel these air pressure variations.

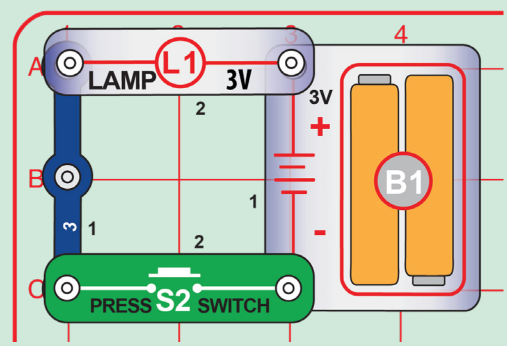


A speaker can only create sound from a CHANGING electrical signal, for unchanging electrical signals it acts like an 8Ω resistor. (An unchanging signal does not cause the magnet in the speaker to move, so no sound waves are created).

EXPERIMENTS

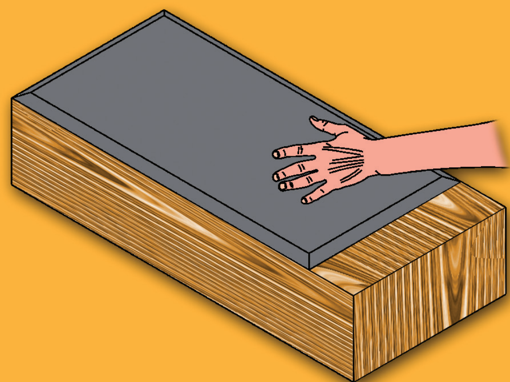
For example, compare these two mini-circuits:



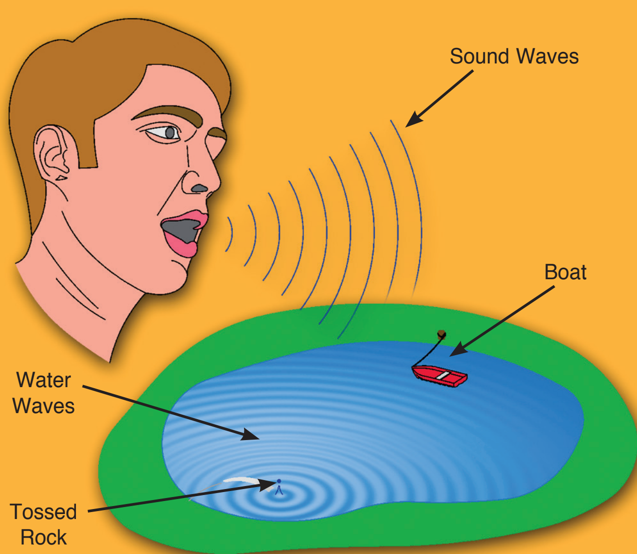


When you press or release the press switch, you hear static from the speaker. When you hold the press switch down, the speaker is silent and the lamp is not as bright as the circuit without it.

What is Sound? **Sound** is a variation in air pressure created by a mechanical vibration. For a demonstration of this, lay one of your stereo speakers on the floor, place your hand on it, and turn up the volume. You should feel the speaker vibrate. Now place a piece of paper on the speaker; if the volume is loud enough, you will see the paper vibrate.



You can compare sound waves from your voice to waves in a pond. When you speak the movements in your mouth create sound waves just as tossing a rock into the pond creates water waves. Sound waves travel through air as water waves travel across the pond. If someone is nearby then their ears will feel the pressure variations caused by your sound waves just as a small boat at the other side of the pond will feel the water waves. When you say a word you create a sound wave with energy at various frequencies, just as tossing a handful of various-sized rocks into the pond will create a complicated water wave pattern.



Nearly all sound waves have their energy spread unevenly across a range of frequencies.

Frequency measures how fast something repeats. It is expressed in **Hertz** (Hz, named after Heinrich Hertz for his work in electromagnetism). The range of frequencies that can be heard by the human ear is approximately 16 to 16,000 Hz, and is referred to as the **audio** range.

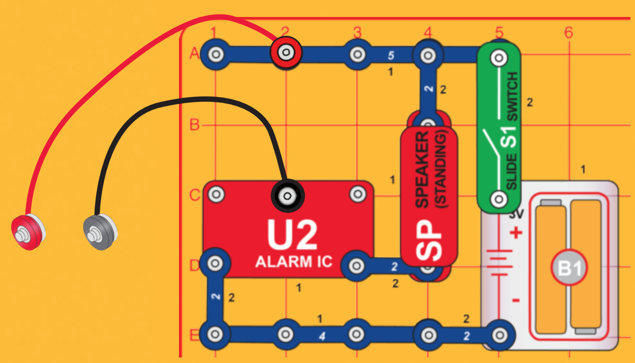
What is Music? Music is when sounds occur in an orderly and controlled manner forming a pattern with their energy concentrated at specific frequencies, usually pleasant to listen to. Noise is when the sounds occur in an irregular manner with their energy spread across a wide range of frequencies, usually annoying to hear (static on a radio is a good example). Notice how some people refer to music that they don't like as noise.

Another way to think of this is that the ear tries to estimate the next sounds it will hear. Music with a beat, a rhythm, and familiar instruments can be thought of as very predictable, so we find it pleasant to listen to. Notice also that we always prefer familiar songs to music that we are hearing for the first time. Sudden, loud, unpredictable sounds (such as gunfire, a glass breaking, or an alarm clock) are very unnerving and unpleasant. Most electronic speech processing systems being developed use some form of speech prediction filters.

The musical world's equivalent to frequency is pitch. The higher the frequency, the higher the pitch of the sound. Frequencies above 3000 Hz can be considered to provide treble tone. Frequencies about 300 Hz and below provide bass tone. Loudness (the musical term) or amplitude (the electronics term) is increased by simply sending more electrical power to the speaker.

EXPERIMENTS

Build the circuit shown here (which is project 34 but without the cup of water).



You need one more part, and you are going to draw it. Take a pencil (No. 2 lead is best), SHARPEN IT, and fill in a shape like this:

Place a hard, flat surface beneath the paper you draw on. Press HARD and fill in the shape several times to get a thick, even layer pencil lead. Turn on the switch and press the loose ends of the jumpers to the drawing, move them around over it. The alarm sound will be faster if the ends are closer together in the shape. If you don't hear any sound, add another layer of lead or put a drop of water on the jumper ends to get better contact.

You can draw your own shapes and see what kinds of sounds you can make. Wash your hands when finished.

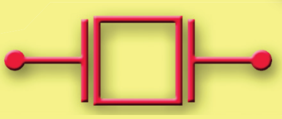
Actually, pencils aren't made out of lead anymore (although they are still called "lead pencils"). The "lead" in pencils is really a form of carbon, the same material that resistors are made of. So the drawings you just made should act just like the resistors in Snap Circuits®.

4-2 THE WHISTLE CHIP

The whistle chip contains two thin plates separated by a special high resistance material. When a voltage is applied across them they will stretch slightly in an effort to separate (like two magnets opposing each other), when the signal is removed they come back together. If the voltage is changing quickly, then the plates will vibrate. These vibrations create variations in air pressure that your ears feel, just like sound from speaker.

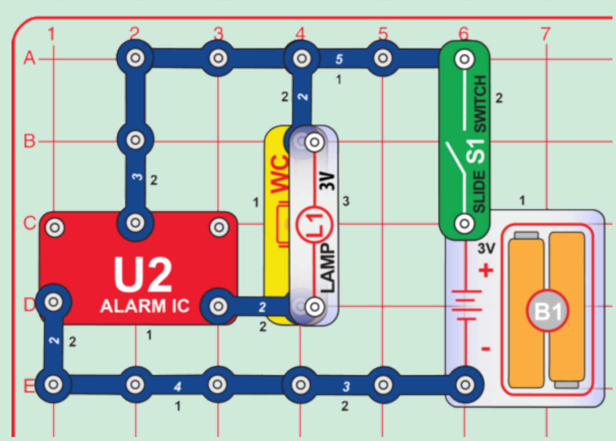
INTRODUCING NEW PARTS

Whistle Chip (WC)



Whistle Chip Symbol

EXPERIMENTS



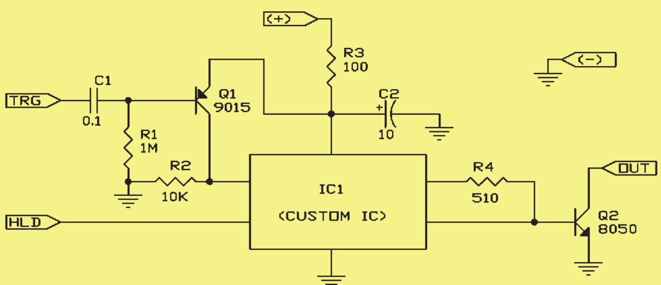
This circuit (which is project 29) demonstrates how the whistle chip makes sound, just turn on the switch to hear an alarm. You may change the sound pattern as per project 30.

4-3 THE ICs IN SNAP CIRCUITS®

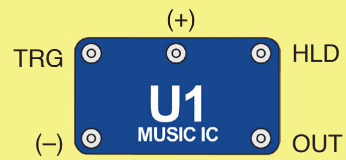
Although Snap Circuits® includes several parts that are called integrated circuits, they are actually modules containing a number of parts. The modules contain specialized sound-generation and amplifier ICs and other supporting components (resistors, capacitors, and transistors) that are always needed with them. This was done to simplify the connections you need to make to use them.

INTRODUCING NEW PARTS

The **music IC** module contains sound-generation ICs and supporting components. It can play one or more musical tunes that are recorded in it. Its actual schematic is complex and looks like this:



Its Snap Circuits® connections are like this:



Music IC:

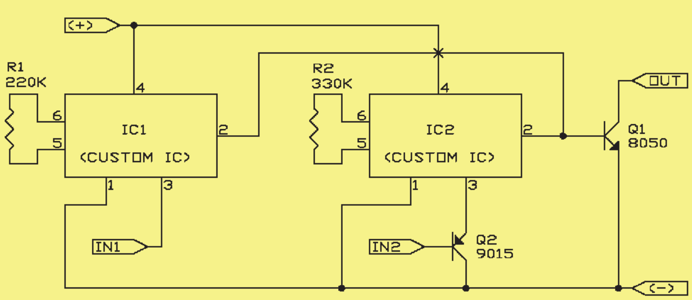
(+) - power from batteries
(–) - power return to batteries
OUT - output connection
HLD - hold control input
TRG - trigger control input

Music for ~20 sec on power-up, then hold HLD to (+) power or touch TRG to (+) power to resume music.

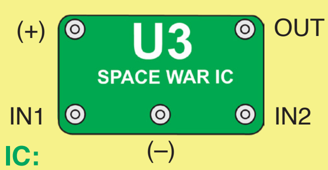
This module has two different control inputs. The OUT connection pulls current into the module (not out of it), usually from a speaker. This current is adjusted to make the music. Snap Circuits® projects 8 and 15 show how to connect this part and what it can do.

INTRODUCING NEW PARTS

The **space war IC** module contains sound-generation ICs and supporting components. It can make several siren sounds. Its actual schematic looks like this:



Its Snap Circuits® connections are like this:



Space War IC:

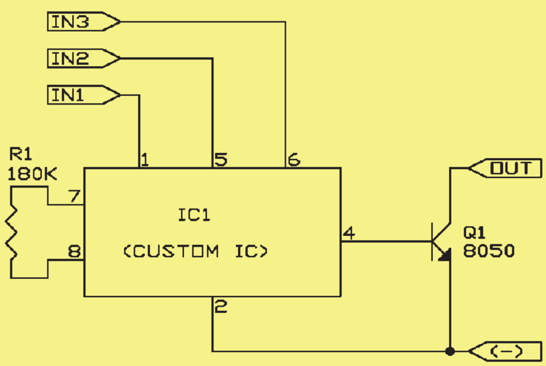
(+) - power from batteries
(–) - power return to batteries
OUT - output connection
IN1, IN2 - control inputs

Connect each control input to (–) power to sequence through 8 sounds.

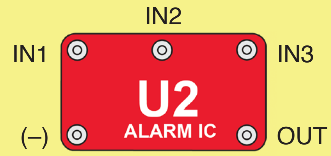
This module has two control inputs that can be stepped through 8 sounds. The OUT connection pulls current into the module (not out of it), usually from a speaker. This current is adjusted to make the space war sounds. Snap Circuits® project 6 shows how to connect this part and what it can do.

INTRODUCING NEW PARTS

The **alarm IC** module contains a sound-generation IC and supporting components. It can make several siren sounds. Its actual schematic looks like this:



Its Snap Circuits® connections are like this:



Alarm IC:

IN1, IN2, IN3 - control inputs
(–) - power return to batteries
OUT - output connection

Connect control inputs to (+) power to make four alarm sounds.

This module has three control inputs, and can make four siren sounds. The OUT connection pulls current into the module (not out of it), usually from a speaker. This current is adjusted to make the siren sounds. Snap Circuits® projects 21-24 in your manual show how to connect this part and what it can do.

QUICK QUIZ

1. Select an electronic product in your home and guess how many ICs are inside it. Then (with the power disconnected from it) open it and look to see how many there are.

4-4 INTEGRATED CIRCUIT PROJECTS

Integrated circuits are used in most electronic products; there are probably more than a thousand throughout your home. The range and uses of ICs available is hard to imagine.

Although Snap Circuits® contains only five IC modules, more than half of the projects use at least one. There are many more examples of using the parts described in the preceding chapters, such as the whistle chip and photoresistor. Here is a short description of each, the project manuals explain them in more detail:

Suggested Projects: 6, 8, 15, 21, 40, 46, and 66.

Projects 6-7:	These are the standard circuits for using the space war IC.
Projects 8-10:	These are the standard circuits for using the music IC.
Projects 11-14:	Use the music IC with the whistle chip instead of the speaker.
Project 15:	Uses the music IC as a doorbell.
Projects 16-20:	Use the space war IC with the whistle chip instead of the speaker.
Projects 21-27:	These are the standard circuits for using the alarm IC.
Projects 29-33:	Use the alarm IC with the whistle chip instead of the speaker.
Projects 34-35:	Make a water alarm using the alarm IC.
Projects 36-39:	Combine the sound effects of all 3 ICs.
Project 40:	Use the music IC to control the space war IC.
Projects 44-47:	Use the music IC to control the alarm IC.
Projects 48-51:	Combine the sound effects of the music and alarm ICs.
Projects 52-53:	Combine the sound effects of the alarm and space war ICs.
Projects 55-56:	Combine the sound effects of the music and space war ICs.
Projects 57-58:	Use the music IC to control the alarm IC.
Projects 59-62:	Combine the sound effects of the alarm and space war ICs.
Projects 63-65:	Use the alarm IC to control the space war IC.
Projects 66-68:	Use the alarm IC to control the music IC.
Projects 69-70:	Combine the sound effects of the music and alarm ICs.
Projects 72-76:	Combine the sound effects of all 3 ICs.
Projects 78-83:	Combine the sound effects of the music and alarm ICs.
Projects 84-86:	Use the space war IC to control the alarm IC.
Project 88:	The space war IC uses the photoresistor to detect reflections from a lamp.
Projects 89-90:	The music IC uses the photoresistor to detect reflections from a lamp.
Projects 91-94:	Use the alarm IC to control the space war IC.
Projects 96-98:	Use the music IC to control the alarm IC.
Projects 99-100:	Use the space war IC to control the motor.
Projects 101-102:	The music IC controls an LED.
Projects 113-114:	The alarm IC controls the speaker and lights.
Project 115:	Use the space war IC in a mind reading game.

Projects 117-118:	Use water to control the space war IC.
Projects 119-121:	Use the music IC to control the space war IC.
Projects 122-123:	Use the music IC to control a light.
Projects 124-125:	You draw an activator for the alarm IC.

SUMMARY

Summary of Chapter 4:

1. A speaker uses a changing electrical signal to make variations in air pressure.
2. All sounds are variations in air pressure that your ears feel.
3. Frequency measures how fast something occurs, and is expressed in Hertz.
4. Audio refers to the range of frequencies that can be heard by human ears.
5. Integrated Circuits are miniature circuits with many transistors, resistors, capacitors, and wires all made on a semiconductor base.
6. The ICs in Snap Circuits® are modules containing specialized integrated circuits and supporting parts that are always needed with them.

QUIZ

Chapter 4 Practice Problems

1. Which of the following has the highest frequency?
   - A. A stoplight repeating its green-yellow-red cycle.
   - B. The minutes hand on a clock passing twelve o'clock.
   - C. Your birthday.
   - D. The wipers sweeping across the windshield of a car while driving in the rain.

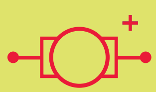
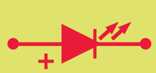
2. The following parts can be built into an integrated circuit except:
   - A. Diodes
   - B. Switches
   - C. Resistors
   - D. Transistors

3. Which of these electrical products is least likely to have an integrated circuit in it?
   - A. Lamp
   - B. Garage door opener
   - C. Car
   - D. Radio

4. Which of the following are advantages of integrated circuits?
   - A. Size
   - B. Reliability
   - C. Cost
   - D. All of the above

Answers: 1. D, 2. B, 3. A, 4. D

SUMMARY OF COMPONENTS

Schematic Symbol	Part	Function	Qty. in SC-100R
	Wire	Connection of other components.	Various
	Battery	Produce electrical voltage using a chemical reaction.	1
	Switch	Connects or disconnects parts in a circuit.	2
	Lamp	Make light from electricity.	1
—	Printed Circuit Board	Used for mounting and connection of components.	0
—	Solder	Special metal that is melted to make solid electrical connections.	None
	Motor	Make mechanical motion from electricity.	1
—	Fuse	Used to shut off a circuit when excessive current is drawn.	0
	Resistor	Limits and controls the flow of electricity in a circuit.	0
	Photo Resistor	Light-sensitive resistor.	1
	LED	A one-way, low-current lamp.	1
	Speaker	Make sound from electricity, has low resistance.	1
	Whistle Chip	Make sound from electricity, has high resistance.	1

SUMMARY OF COMPONENTS

Schematic Symbol	Part	Function	Qty. in SC-100R
–	Music IC	Module to make musical sounds.	1
–	Alarm IC	Module to make alarm sounds.	1
–	Space War IC	Module to make space war sounds.	1

DEFINITION OF TERMS (also see Summary of Components 43-44)

AC Common abbreviation for alternating current.

Alternating Current A current that is constantly changing.

Ampere (A) The unit of measure for electric current.

Amplify To make larger.

Amplitude Strength or level of something.

Analogy A similarity in some ways.

Audio Electrical energy representing voice or music that can be heard by human ears.

Battery A device which uses a chemical reaction to create an electric charge across a material.

Blackout When part of a city is cut off from the power plants supplying it with electricity.

Circuit An arrangement of electrical components to do something.

Clockwise In the direction in which the hands of a clock rotate.

Coil A wire that is wound in a spiral.

Color Code A method for marking resistors using colored bands.

Conductor A material that has low electrical resistance.

Counter-Clockwise Opposite the direction in which the hands of a clock rotate.

Current A measure of how fast electricity is flowing in a wire or how fast water is flowing in a pipe.

DC Common abbreviation for direct current.

Digital Circuit A wide range of circuits in which all inputs and outputs have only two states, such as high/low.

Digital Electronics Using a series of numbers to represent an electrical signal.

Diode An electronic device that allows current to flow in only one direction.

Direct Current A current that is constant and not changing.

Electric Charge An electrical attraction/ repulsion between materials.

Electrical Power A measure of how much energy is moving in a wire.

Electricity An attraction and repulsion between sub-atomic particles within a material.

Electromagnetic Involving both electrical and magnetic effects.

Electronics The science of electricity and its applications.

Filament A high-resistance wire used in incandescent light bulbs.

Fluorescent Lamp A lamp that creates light using a glowing gas.

Frequency The rate at which something repeats.

Friction The rubbing of one object against another that generates heat.

Fuse A device used to shut off a circuit when excessive current is drawn.

Gallium Arsenide A chemical element that is used as a semiconductor.

Generator A device which uses steam or water pressure to move a magnet near a wire, creating an electric current in the wire.

Ground A common term for the 0V or "–" side of a battery or generator.

Incandescent Lamp A lamp that creates light using a material that is heated until it glows.

Insulator A material that has high electrical resistance.

Integrated Circuit A type of circuit in which transistors, diodes, resistors, and capacitors are all constructed on a semiconductor base.

Kilo—(K) A prefix used in the metric system. It means a thousand of something.

LED Common abbreviation for light emitting diode.

DEFINITION OF TERMS (also see Summary of Components 43-44)

Light Emitting Diode A diode made from gallium arsenide that has a turn-on energy so high that light is generated when current flows through it.

Lightning A discharge of static electricity between a cloud and the ground.

Lightning Rod A metal rod between the roof and ground, used to protect houses from lightning.

Magnetic Field The region of magnetic attraction or repulsion around a magnet or an AC current.

Magnetism A force of attraction between certain metals. Electric currents also have magnetic properties.

Mili (m) A prefix used in the metric system. It means a thousandth (0.001) of something.

Modulation Methods used for encoding signals with information.

Motor A device which converts electricity into mechanical motion.

Ohm's Law The relationship between voltage, current, and resistance.

Ohm, (Ω) The unit of measure for resistance.

Parallel Circuit When several electrical components are connected between the same points in the circuit.

Pitch The musical term for frequency.

Polarity Markings indicating which direction a device is positioned in, usually (+) and (–).

Printed Circuit Board A board used for mounting electrical components. Components are connected using metal traces "printed" on the board instead of wires.

Resistance The electrical friction between an electric current and the material it is flowing through.

Resistor Components used to control the flow of electricity in a circuit.

Schematic A drawing of an electrical circuit that uses symbols for all the components.

Semiconductor A material that has more resistance than conductors but less than insulators. It is used to construct diodes, transistors, and integrated circuits.

Series Circuit When electrical components are connected one after the other.

Short Circuit When wires from different parts of a circuit (or different circuits) connect accidentally.

Solder A tin-lead metal that becomes a liquid when heated to above 500°F. It makes a strong mounting that can withstand shocks.

Speaker A device which converts electrical energy into sound.

Static Electricity A naturally occurring build-up of electrical charge between materials, usually at high voltage.

Switch A device to connect ("closed" or "on") or disconnect ("open" or "off") wires in an electric circuit.

Transformer A device which uses coils to change the AC voltage and current (increasing one while decreasing the other).

Transistor An electronic device that uses a small amount of current to control a large amount of current.

Tungsten A highly resistive material used in light bulbs.

Voltage A measure of how strong an electric charge difference between materials is.

Volts (V) The unit of measure for voltage.

Watt (W) The unit measure for electrical power.

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150 Carpenter Avenue
Wheeling, IL 60090
(847) 541-3800 | elenco.com
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