



300+ PROJECTS

CLASSIC KITCLASS

BOOST STEM skills

BUILD light-activated systems

CREATE multi-alarm circuits



AGES 8+

REQUIRES 4 AA BATTERIES (NOT INCLUDED)



SNAP CIRCUITS

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Project Categories

PROJECT NUMBERS

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Snap Circuits® uses building blocks with snaps to assemble real electronic circuits. Each block has a function: switch, light, battery, different length wire blocks, and more! With this easy-to-follow project manual, simply snap together to create working circuits!

What is electricity? Nobody really knows. We only know how to produce it, understand its properties, and how to control it. Electricity is a form of energy that can give things the ability to move and work. Everything in the world around us is made of particles called protons, neutrons and electrons. These three tiny particles are found in everything around us. When the electrons move, they create electricity.

Important Safety Notes for Parents and Kids

- **Adult Supervision:** Because children's abilities vary so much, even with age groups, adults should exercise discretion as to which experiments are suitable and safe. Make sure your child reads and follows all of the relevant instructions and safety procedures, and keeps them at hand for reference.
- This product is intended for use by adults and children who have attained sufficient maturity to read and follow directions and warnings.
- Save the packaging and instructions. They contain important information.
- Never modify your parts, as doing so may disable important safety features in them, and could put your child at risk of injury
- ⚠ **Warning: Choking Hazard.** Small parts. Not for children under 3 years of age.
- ⚠ **Warning:** This product produces flashes that may trigger epilepsy in sensitized individuals.
- ⚠ **Warning: Shock Hazard.** Never connect Snap Circuits® to the electrical outlets in your home in any way!
- ⚠ **Warning:** Always check your wiring before turning on a circuit. Never leave a circuit unattended while the batteries are installed. Never connect additional batteries or any other power sources to your circuits.
- ⚠ **Warning: Moving parts.** Do not touch the fan or motor during operation. Do not lean over the motor. Keep hair away from moving parts.
- ⚠ **Caution:** Very warm lamp enclosure.
- ⚠ **Caution:** Very warm motor enclosure.
- Conforms to all applicable U.S. government requirements and CAN ICES-3 (B)/NMB-3 (B)

Installing batteries:

- Remove the safety cover from the battery holder (if your holder has one) with a screwdriver
- Insert two (2) 1.5V AA batteries (not included) in the holder. Be sure to orient the battery "+" as marked in the holder.
- Replace the cover (if your holder had one). When installing a battery, be sure the spring is compressed straight back, and not bent up, down, or to one side.
- Battery installation should be supervised by an adult.



Batteries:

x4



- Use only 1.5V AA type, alkaline batteries (not included).
- Insert batteries with correct polarity.
- Do not mix old and new batteries.
- Remove batteries when they are used up.
- Do not mix alkaline, standard (carbon-zinc), or rechargeable batteries.
- Do not connect batteries or battery holders in parallel.

- Do not short circuit the battery terminals.
- Never throw batteries in a fire or attempt to open its outer casing.
- Batteries are harmful if swallowed, so keep away from small children.
- Non-rechargeable batteries should not be recharged. Rechargeable batteries should only be charged under adult supervision, and should not be recharged while in the product.



Helpful Symbols

Look for these symbols throughout the manual:

GENERAL INFORMATION

- Definitions
- How it works

SNAP CIRCUITS

Technical information for using your parts.

ADULT ASSISTANCE REQUIRED

Get an adult to help with your build



Parts List

MODEL SC300

QTY.	ID	NAME	PART #
□ 1		Base Grid (11.0x7.7)	6SCBG
□ 3	1	1-snap wire	6SC01
□ 6	2	2-snap wire	6SC02
□ 3	3	3-snap wire	6SC03
□ 1	4	4-snap wire	6SC04
□ 1	5	5-snap wire	6SC05
□ 1	6	6-snap wire	6SC06
□ 1	A1	Antenna	6SCA1
□ 1	B1 B1B	2AA Battery holder	6SCB1
□ 1	C1	Capacitor 0.02μF	6SCC1
□ 1	C2	Capacitor 0.1μF	6SCC2
□ 1	C3	Capacitor 10μF	6SCC3
□ 1	C4	Capacitor 100μF	6SCC4
□ 1	C5	Capacitor 470μF	6SCC5
□ 1	CV	Variable Capacitor	6SCCV
□ 1	D8	Color LED	6SCD8
□ 1	D10	Red/Yellow LED	6SCD10
□ 1		Jumper Wire Black	6SCJ1
□ 1		Jumper Wire Red	6SCJ2
□ 1	L1	3V Lamp	6SCL1

QTY.	ID	NAME	PART #
□ 1	L2	6V Lamp	6SCL2
□ 1	M1	Motor	6SCM1
□ 1		Fan	6SCM1F
□ 1	Q1	PNP Transistor	6SCQ1
□ 1	Q2	NPN Transistor	6SCQ2
□ 1	Q4	Phototransistor	6SCQ4
□ 1	R1	Resistor 100Ω	6SCR1
□ 1	R2	Resistor 1kΩ	6SCR2
□ 1	R3	Resistor 5.1kΩ	6SCR3
□ 1	R4	Resistor 10kΩ	6SCR4
□ 1	R5	Resistor 100kΩ	6SCR5
□ 1	RV	Adjustable Resistor	6SCRV
□ 1	S1	Slide Switch	6SCS1
□ 1	S2	Press Switch	6SCS2
□ 1	SP	Speaker	6SCSP
□ 1	U2	Alarm IC	6SCU2
□ 1	U4	Power Amp IC	6SCU4
□ 1	U5	High Freq IC	6SCU5
□ 1	WC	Whistle Chip	6SCWC

IMPORTANT:

If any parts are missing or damaged, **do not return to retailer**. Email us at support@elenco.com, or order additional/replacement parts at elenco.com/replacement-parts

How to Use Snap Circuits®

Snap Circuits® uses building blocks with snaps to build the different electrical and electronic circuits in the projects. Each block has a function: there are switch blocks, lamp blocks, battery blocks, different length wire blocks, etc. These blocks are different colors and have numbers on them so that you can easily identify them. The circuit you will build is shown in color and with numbers, identifying the blocks that you will use and snap together to form a circuit.

For example:

This is the switch block which is green and has the marking **S2** on it as shown in the drawings. The drawing symbol may not match the actual switch part exactly.



This is a wire block which is blue and comes in different wire lengths. This one has the number **2**, **3**, **4**, **5**, or **6** on it depending on the length of the wire connection required.



This is a 1-snap wire that is used as a spacer or for interconnection between different layers.



Your battery holder is labeled **B1** or **B1B**. If yours is a B1B then it has a safety cover, remove it with a Phillips head screwdriver. Insert three (3) 1.5V "AA" batteries (not included) into the holder. Be sure to orient the battery "+" side as marked in the holder. Replace battery holder cover if yours had one.



B3B for EU

When installing a battery, be sure the spring is compressed straight back, and not bent up, down, or to one side. Battery installation should be supervised by an adult.

A large clear plastic base grid is included with this kit to help keep the circuit blocks properly spaced. You will see evenly spaced posts that the different blocks snap into.

You do not need this base to build your circuits, but it does help in keeping your circuit together neatly. The base has rows labeled A-G and columns labeled 1-10.

Next to each part in every circuit drawing is a small number in black. This tells you which level the component is placed at. Place all parts on level 1 first, then all of the parts on level 2, then all of the parts on level 3, etc.

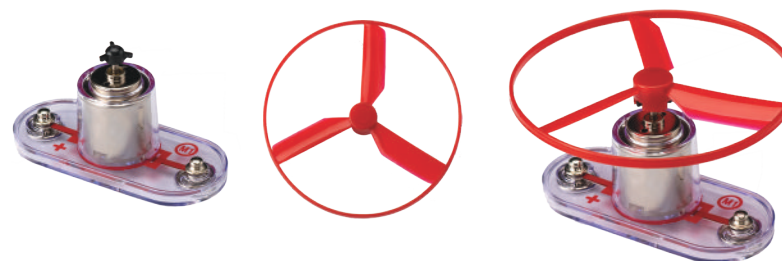
Some circuits use the jumper wires to make unusual connections. Just clip them to the metal snaps or as indicated.



B3 non EU



Usually when the motor **M1** is used, the fan will usually be placed on it. On top of the motor shaft is a black plastic piece (the motor top) with three little tabs. Lay the fan on the black piece so the slots in its bottom "fall into place" around the three tabs in the motor top. If not placed properly, the fan will fall off when the motor starts to spin.

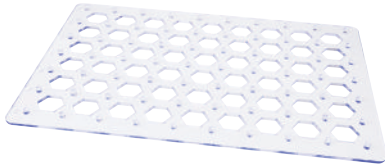


Note: While building circuits, be careful not to accidentally make a direct connection across the battery holder (a "short circuit"), as this may damage and/or quickly drain the batteries.

About Your Snap Circuits® Parts*

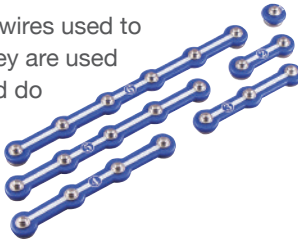
BASE GRID

The **base grid** is a platform for mounting parts and wires. It functions like the printed circuit boards used in most electronic products, or like how the walls are used for mounting the electrical wiring in your home.



SNAP WIRES & JUMPER WIRES

The **blue snap wires** are wires used to connect components. They are used to transport electricity and do not affect circuit performance. They come in different lengths to allow orderly arrangement of connections on the base grid.



The **red and black jumper wires** make flexible connections for times when using the snap wires would be difficult. They also are used to make connections off the base grid.



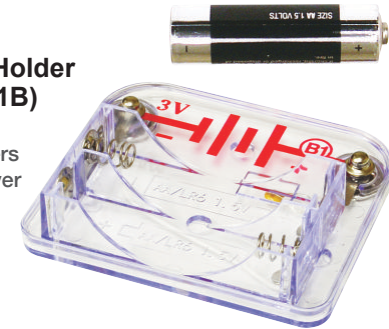
Wires transport electricity just like pipes are used to transport water. The colorful plastic coating protects them and prevents electricity from getting in or out.

BATTERY HOLDER

The **batteries (B1 or B1B)** produce an electrical voltage using a chemical reaction. This “voltage” can be thought of as electrical pressure, pushing electricity through a circuit just like a pump pushes water through pipes. This voltage is much lower and much safer than that used in your house wiring. Using more batteries increases the “pressure”, therefore, more electricity flows.

Battery Holder (B1 or B1B)

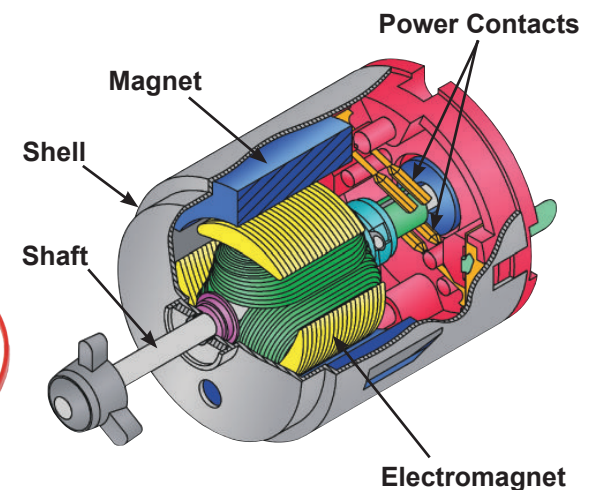
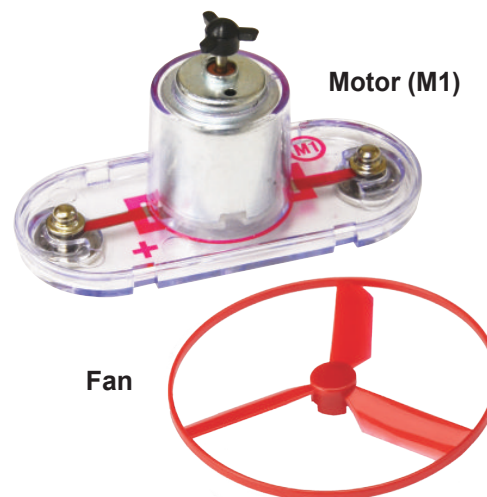
B1B holders have a cover



MOTOR

The **motor (M1)** converts electricity into mechanical motion. An electric current in the motor will turn the shaft and the motor blades, and the fan blade if it is on the motor.

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 repels 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.



*Part designs subject to change without notice.

About Your Snap Circuits® Parts

CAPACITORS

The **0.02 μ F, 0.1 μ F, 10 μ F, 100 μ F, and 470 μ F capacitors (C1, C2, C3, C4, & C5)** can store electrical pressure (voltage) for periods of time. This storage ability allows them to block stable voltage signals and pass changing ones. Capacitors are used for filtering and delay circuits. The whistle chip (WC) also acts like a 0.02 μ F capacitor in addition to its sound properties.

Capacitors
(C1, C2, C3,
C4, C5)



The **variable capacitor (CV)** can be adjusted from .00004 to .00022 μ F and is used in high frequency radio circuits for tuning.

Variable
Capacitor (VC)



TRANSISTORS

The **PNP & NPN transistors (Q1 & Q2)** are components that use a small electric current to control a large current, and are used in switching, amplifier, and buffering applications. They are easy to miniaturize, and are the main building blocks of integrated circuits including the microprocessor and memory circuits in computers.



PNP & NPN Transistors (Q1 & Q2)

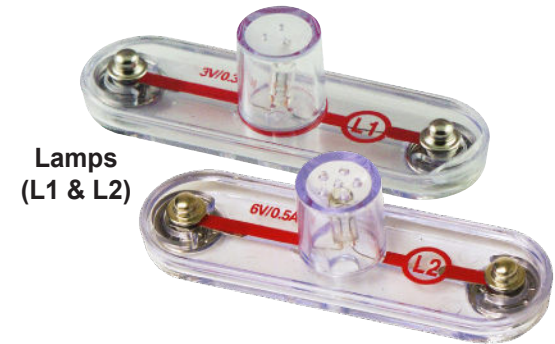
The **phototransistor (Q4)** is a transistor that uses light to control electric current.



Phototransistor (Q4)

LAMPS

A light bulb, such as in the **3V lamp (L1)** or **6V lamp (L2)**, contains a special thin high-resistance wire. When a lot of electricity flows through, this wire gets so hot it glows bright. Voltages above the bulb's rating can burn out the wire.



Lamps
(L1 & L2)

ANTENNA

The **antenna (A1)** contains a coil of wire wrapped around an iron bar. Although it has magnetic effects similar to those in the motor, those effects are tiny and may be ignored except at high frequencies (like in AM radio).

Antenna (A1)



About Your Snap Circuits® Parts

LEDs

The **color LED (D8)** and **red/yellow bicolor LED (D10)** are light emitting diodes, and may be thought of as a special one-way light bulbs. In the “forward” direction, (indicated by the “arrow” in the symbol) electricity flows if the voltage exceeds a turn-on threshold (about 1.5V for red, slightly higher for yellow, about 2.0V for green, and about 3.0V for blue); brightness then increases. The color LED contains red, green, and blue LEDs, with a micro-circuit controlling them. The red/yellow bicolor LED contains red & yellow LEDs in connected in opposite directions. A high current will burn out an LED, so the current must be limited by other components in the circuit (though your Snap Circuits® LEDs have internal resistors to protect against incorrect wiring). LEDs block electricity in the “reverse” direction.

LEDs
(D8 & D10)



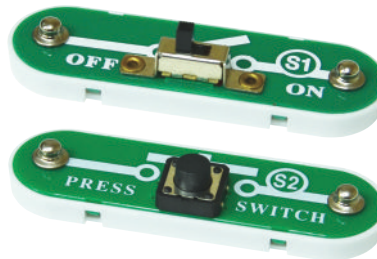
SPEAKER

The **speaker (SP)** converts electricity into sound by making mechanical vibrations. These vibrations create variations in air pressure, which travel across the room. You “hear” sound when your ears feel these air pressure variations.



SLIDE & PRESS SWITCHES

The **slide & press switches (S1 & S2)** connect (pressed or “ON”) or disconnect (not pressed or “OFF”) the wires in a circuit. When ON they have no effect on circuit performance. Switches turn on electricity just like a faucet turns on water from a pipe.



Slide Switch
(S1)

Press Switch
(S2)

WHISTLE CHIP

The **whistle chip (WC)** contains two thin plates. When an electrical signal 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 electrical signal applied across them is changing quickly, then the plates will vibrate. These vibrations create variations in air pressure that your ears feel just like sound from a speaker.

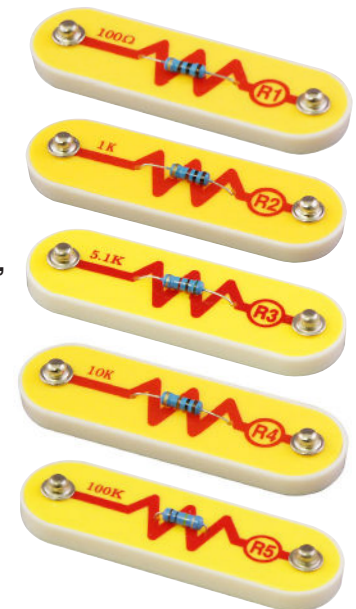
Whistle
Chip (WC)



RESISTORS

Resistors “resist” the flow of electricity and are used to control or limit the current in a circuit. This kit includes **100Ω (R1), 1kΩ (R2), 5.1kΩ (R3), 10kΩ (R4), and 100kΩ (R5)** resistors (“k” symbolizes 1,000, so R5 is really 100,000Ω). Materials like metal have very low resistance (<1Ω), while materials like paper, plastic, and air have near-infinite resistance. Increasing circuit resistance reduces the flow of electricity.

Resistors
(R1, R2, R3,
R4, & R5)



The **adjustable resistor (RV)** is a 50kΩ resistor but with a center tap that can be adjusted between 200Ω and 50kΩ.



Adjustable
Resistor (RV)

About Your Snap Circuits® Parts

ELECTRONIC MODULES

The **alarm IC (U2)** contains specialized sound-generation ICs and other supporting components (resistors, capacitors, and transistors) that are always needed with it. This was done to simplify the connections you need to make to use it. A schematic for it is available at www.elenco.com/FAQs.



Alarm IC

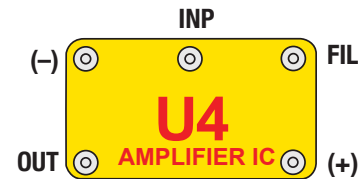
IN1, IN2, IN3: control inputs

(-): Power return to batteries

OUT: Output connection

Connect control inputs to (+) power to make five alarm sounds, see projects 2 for configurations.

The **power amplifier IC (U4)** is a module containing an integrated circuit amplifier and supporting components that are always needed with it. A description of it is given here for those interested:



Power Amplifier IC

(+): Power from batteries

(-): Power return to batteries

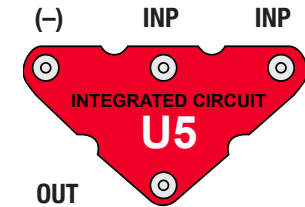
FIL: Filtered power from batteries

INP: Input connection

OUT: Output connection

See project 7 for example of connections.

The **high frequency IC (U5)** is a specialized amplifier used only in high frequency radio circuits. A description of it is given here for those interested:



High Frequency IC

INP: Input connection (2 points are same)

OUT: Output connection

(-): Power return to batteries

See project 7 for example of connections.

Introduction to Electricity

What is electricity?

Nobody really knows. We only know how to produce it, understand its properties, and how to control it. Electricity is the movement of sub-atomic charged particles (called electrons) through a material due to electrical pressure across the material, such as from a battery.

Power sources, such as batteries, push electricity through a circuit, like a pump pushes water through pipes. Wires carry electricity, like pipes carry water. Devices like LEDs, motors, and speakers use the energy in electricity to do things. Switches and transistors control the flow of electricity like valves and faucets control water. Resistors limit the flow of electricity.

The electrical pressure exerted by a battery or other power source is called **voltage** and is measured in **volts (V)**. Notice the “+” and “-” signs on the battery; these indicate which direction the battery will “pump” the 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)** or **milliamps (mA, 1/1000 of an ampere)**.

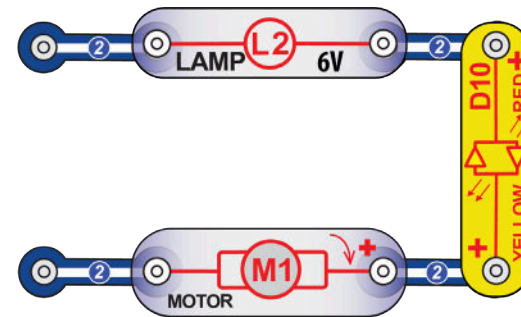
The “power” of electricity is a measure of how fast energy is moving through a wire. It is a combination of the voltage and current (Power = Voltage x Current). It is expressed in **watts (W)**.

The **resistance** of a component or circuit represents how much it resists the electrical pressure (voltage) and limits the flow of electric current. The relationship is Voltage = Current x Resistance. When the resistance increases, less current flows. Resistance is measured in **ohms (Ω)**, or **kilo ohms (k Ω , 1000 ohms)**.

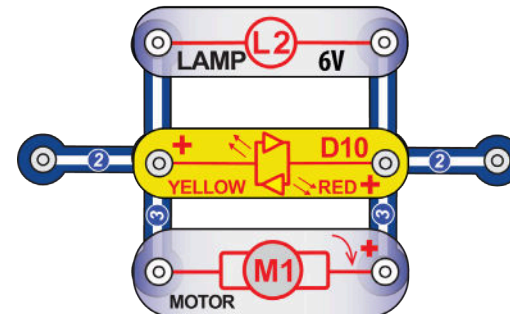
Nearly all of the electricity used in our world is produced at enormous generators driven by steam or water pressure. Wires are used to efficiently transport this energy to homes and businesses where it is used. Motors convert the electricity back into mechanical form to drive machinery and appliances. The most important aspect of electricity in our society 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.

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



Series Circuit



Parallel Circuit

Placing components in series increases the resistance; highest value dominates. Placing components in parallel decreases the resistance; lower value dominates.

The parts within these series and parallel sub-circuits may be arranged in different ways without changing what the circuit does. Large circuits are made of combinations of smaller series and parallel circuits.

DO's and DON'Ts of Building Circuits

After building the circuits in this booklet, you may wish to experiment on your own. Use the projects in this booklet as a guide, as many important design concepts are introduced throughout them. Every circuit will include a power source (the batteries), a resistance (which might be a resistor, capacitor, motor, integrated circuit, etc.), and wiring paths between them and back. **You must be careful not to create "short circuits" (very low-resistance paths across the batteries, see examples at right) as this will damage components and/or quickly drain your batteries.** Only connect the alarm IC (U2) and strobe IC (U23) using configurations given in the projects, incorrectly doing so may damage them. ELENCO® is not responsible for parts damaged due to incorrect wiring.

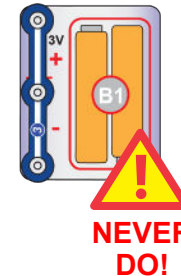
Here are some important guidelines:

ALWAYS	use eye protection when experimenting on your own.
ALWAYS	include at least one component that will limit the current through a circuit, such as the speaker, capacitors, ICs (which must be connected properly), motor, phototransistor, or resistors.
ALWAYS	use LEDs, transistors, and switches in conjunction with other components that will limit the current through them. Failure to do so will create a short circuit and/or damage those parts.
ALWAYS	connect capacitors so that the "+" side gets the higher voltage.
ALWAYS	disconnect your batteries immediately and check your wiring if something appears to be getting hot.
ALWAYS	check your wiring before turning on a circuit.
ALWAYS	connect the alarm IC (U2) and strobe IC (U23) using configurations given in the projects or as per the connection description on page 8.
NEVER	connect to an electrical outlet in your home in any way.
NEVER	leave a circuit unattended when it is turned on.
NEVER	touch the motor when it is spinning at high speed.

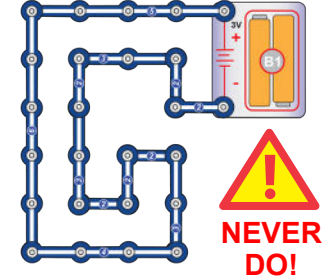
For all of the projects given in this book, the parts may be arranged in different ways without changing the circuit. For example, the order of parts connected in series or in parallel does not matter — what matters is how combinations of these sub-circuits are arranged together.

EXAMPLES OF SHORT CIRCUITS - NEVER MAKE THESE!

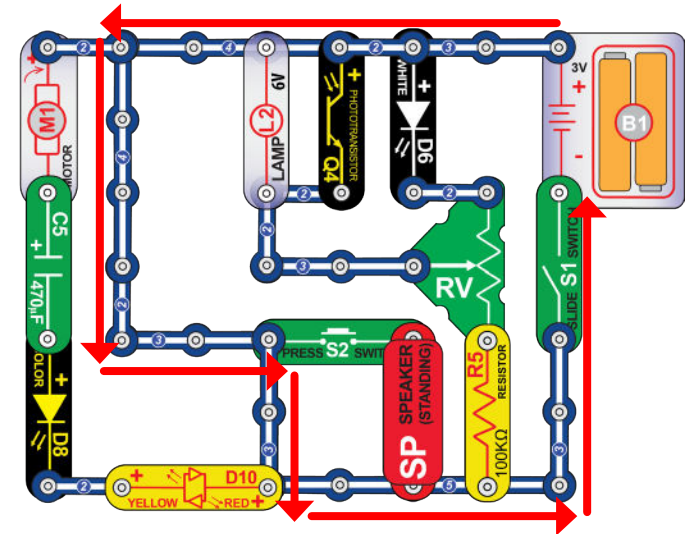
Placing a 3-snap wire directly across the batteries is a short circuit.



This is also a short circuit.



When the slide switch (S1) is turned on, this large circuit has a short circuit path (as shown by the arrows). The short circuit prevents any other portions of the circuit from ever working.



WARNING: SHOCK HAZARD

Never connect Snap Circuits® to the electrical outlets in your home in any way!



WARNING to Snap Circuits® owners:

Do not connect additional voltage sources from other sets, or you may damage your parts. Contact ELENCO® if you have questions or need guidance.

We want to hear about new circuits you create! If they are unique, we will post them with your name and the state you live in on our website at www.elenco.com/showcase. Send photos of your creations to info@elenco.com.

Elenco® provides a circuit designer so that you can make your own Snap Circuits® drawings. This Microsoft® Word document can be downloaded from www.elenco.com/for-makers.

Troubleshooting (Adult supervision recommended)

Basic Troubleshooting

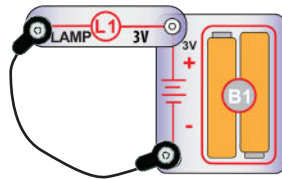
1. Most circuit problems are due to incorrect assembly, always double-check that your circuit exactly matches the drawing for it.
2. Be sure that parts with positive/negative markings are positioned as per the drawing.
3. Be sure that all connections are securely snapped.
4. Try replacing the batteries.

Elenco® is not responsible for parts damaged due to incorrect wiring.

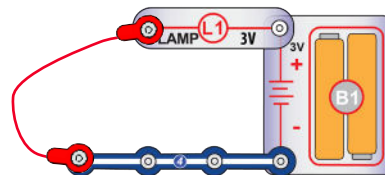
Advanced Troubleshooting

If you suspect you have damaged parts, you can follow this procedure to systematically determine which ones need replacing:

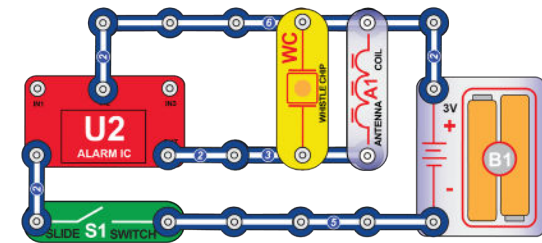
1. **3V lamp (L1), 6V lamp (L2), motor (M1), speaker (SP), color LED (D8), red/yellow LED (D10), and battery holder (B1):** Place batteries in holder. Place each lamp directly across the battery holder, each should light and L1 should be brighter. Place the color LED directly across the battery holder (LED + to battery +), it should light and be changing colors. Place the red/yellow LED directly across the battery holder in both directions, it should be red in one direction and yellow in the other. Place the motor (motor + to battery +), it should spin to the right at high speed. "Tap" the speaker across the battery holder contacts, you should hear static as it touches. If none work, then replace your batteries and repeat, if still bad then the battery holder is damaged.
2. **Jumper wires:** Use this mini-circuit to test each jumper wire, the lamp should light.



3. **Snap wires:** Use this mini-circuit to test each of the snap wires, one at a time. The lamp should light.

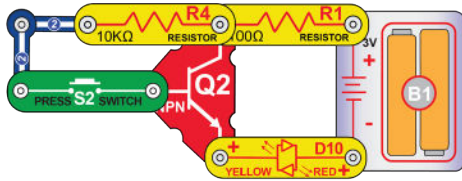


4. **Slide switch (S1) and Press switch (S2):** Build project 9, if the lamp (L1) doesn't light then the slide switch is bad. Replace the slide switch with the press switch to test it.
5. **100Ω (R1), 1KΩ (R2), 5.1KΩ (R3), and 10KΩ (R4) resistors:** Build project 10 except use the R1 resistor in place of the 3-snap wire. the color LED should light. Then replace the R1 resistor with R2, R3, and R4; the LED should light and the brightness decreases with the higher value resistors.
6. **Alarm IC (U2):** Build project 2, each should produce a different siren.
7. **Phototransistor (Q4):** Build project 28, shining bright light on Q4 should light the LED and covering Q4 should turn off the LED.
8. **Whistle chip (WC):** Build project 41, you should hear sound from the whistle chip.
9. **Antenna (A1):** Build the mini-circuit shown here, you should hear sound.

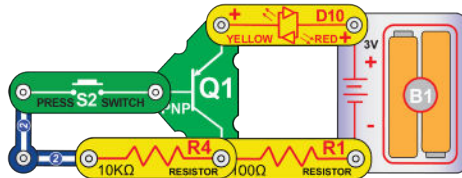


Advanced Troubleshooting (Adult supervision recommended)

- 10. NPN transistor (Q2):** Build the mini-circuit shown here. The LED (D10) should only be on if the press switch (S2) is pressed. If otherwise, then the NPN is damaged.



- 11. PNP transistor (Q1):** Build the mini-circuit shown here. The LED (D10) should only be on if the press switch (S2) is pressed. Otherwise, the PNP is damaged.



- 12. Adjustable resistor (RV):** Build project 37, RV's control lever should be able to turn on either LED.
- 13. 100KΩ resistor (R5) and 0.02μF (C1), 0.1μF (C2), and 10μF (C3) capacitors:** Build project 271, it makes sound unless the resistor is bad. Place the 0.02μF capacitor on top of the whistle chip (WC) and the sound changes (pitch is lower). Replace the 0.02μF with the 0.1μF and the pitch is even lower. Replace the 0.1μF with the 10μF and the circuit will "click" about once a second.
- 14. 100μF (C4) and 470μF (C5) capacitors:** Build project 173, press the press switch (S2) and turn on the slide switch (S1). The LED (D10) should be lit for about 15 seconds then go out (press the press switch again to reset this). Replace the 470μF with the 100μF and the LED is only lit for about 4 seconds now.
- 15. Power Amplifier IC (U4):** Build project 263, adjusting RV should change the sound.
- 16. Variable Capacitor (CV):** Build project 284 and place it near an AM radio, tune the radio and the capacitor to verify you hear the siren on your radio.
- 17. High Frequency IC (U5):** Build project 7 and adjust the variable capacitor (CV) and adjustable resistor (RV) until you hear a radio station.



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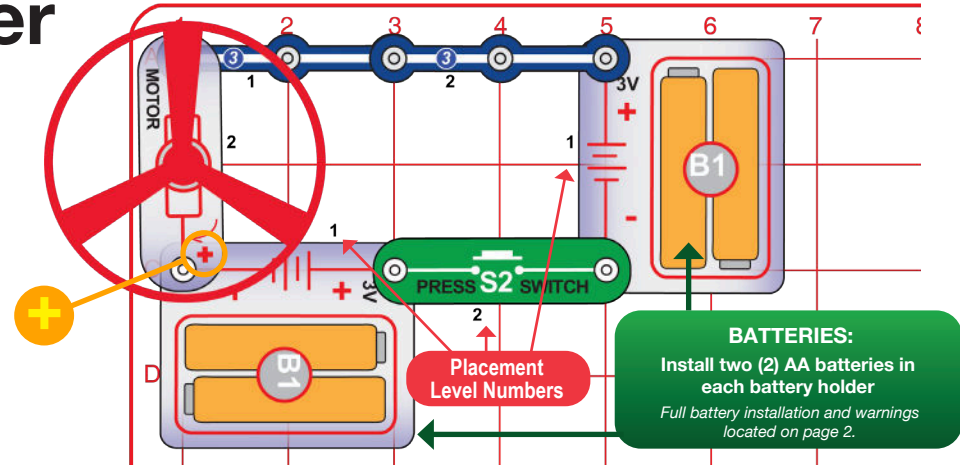
You may order additional/replacement parts at www.elenco.com/replacement-parts/

1. Introduction

PROJECT 1 Super Flying Saucer

Build the circuit shown on the right by placing all the parts with a **black 1** next to them on the board first. Then, place parts marked with a **2**. Install two (2) AA batteries (not included) into each **battery holder (B1)**. When installing a battery, be sure the spring is compressed straight back, and not bent up, down, or to one side. Battery installation should be supervised by an adult.

Push the **press switch (S2)** until the motor reaches full speed, then release it. The fan blade should rise and float through the air like a flying saucer. Be careful not to look directly down on fan blade when it is spinning. If the fan doesn't fly off, then press the switch several times rapidly when it is at full speed.



PROJECT 2 Siren

Build the circuit on the right. Turn on the **slide switch (S1)** and a siren sounds.

Part B: Machine Gun: Use the preceding circuit, but add a connection between the points marked B & C using a 1-snap wire and a 2-snap wire, or a jumper wire. Now it sounds like a machine gun.

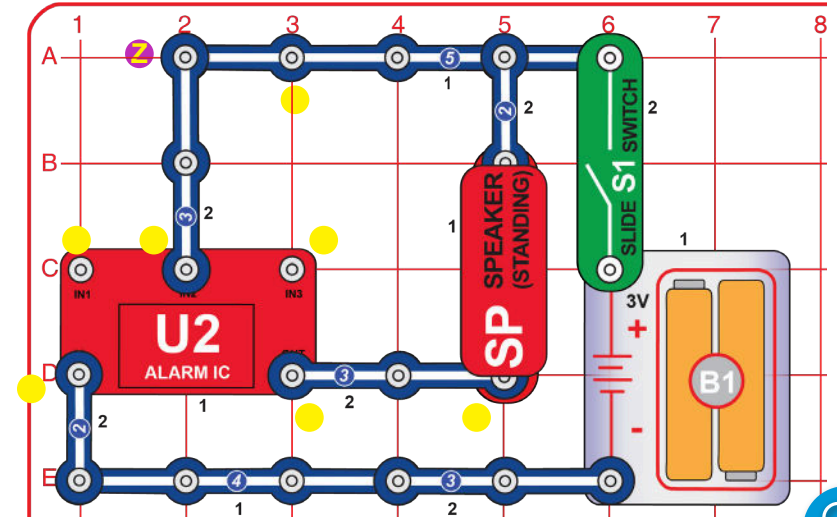
Part C: Fire Engine: Use the preceding circuit, but remove the connection between B & C, and add a connection between A & B. Now it sounds like a fire engine.

Part D: European Siren: Use the preceding circuit, but remove the connection between A & B, and add a connection between A & D. Now it sounds like a European siren.

Part E: Light Siren Changer: Use the project 2 circuit, but add the phototransistor (Q4, "+" on top) between Y & C. Cover and uncover the phototransistor to change the sound.

Part F: Light Siren: Use the project 2 circuit, but replace the 3-snap wire at Z & B with the phototransistor (Q4, "+" on top). A siren sounds when there is light on the phototransistor.

Part G: Softer Siren: Use any of the preceding circuits, but replace the 3-snap wire between E & F with the color LED (D8, "+" on left). The sound is not as loud, but LED does not light. If you flip the color LED so its "+" is on the right, the LED lights but you can barely hear the sound. A protection resistor inside D8 is causing most of the sound reduction.



The lower-right snap of the alarm IC (U2) is like an electrical gate, opening and closing quickly to let small bursts of electric current flow in. The bursts of electric current also flow through the speaker (which produces sound). The alarm IC produces different siren sounds by adjusting the pattern of current bursts through the speaker.

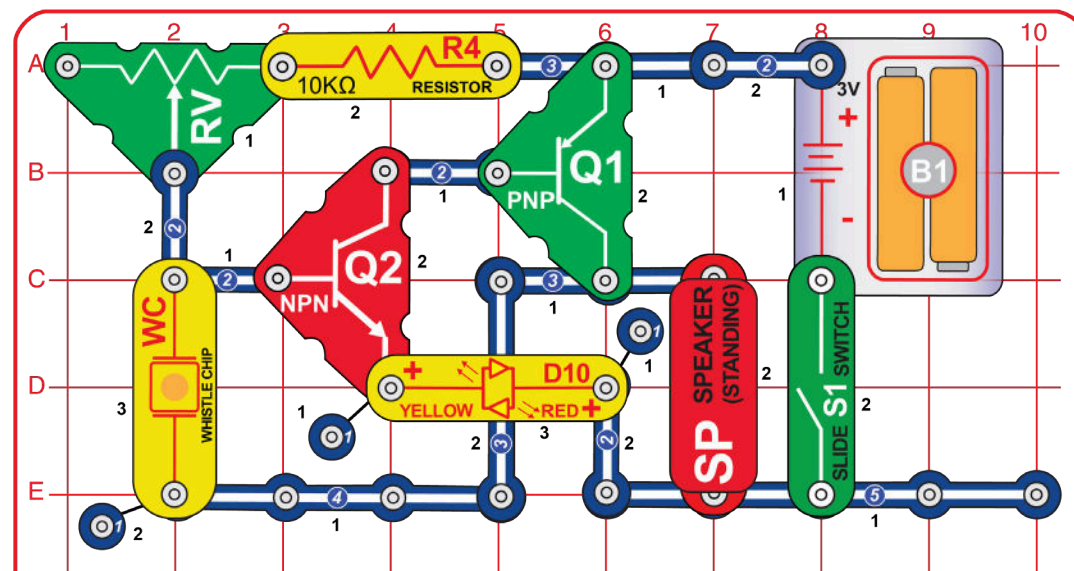
PROJECT 3 Adjustable Tone Generator

Turn on the **slide switch (S1)**. The speaker (SP) makes a tone and the red/yellow LED (D10) lights. Move the lever on the **adjustable resistor (RV)** to change the tone.

Part B: Place the 0.02 μ F capacitor (**C1**), 0.1 μ F capacitor (**C2**), or 10 μ F capacitor (**C3**) on top of the **whistle chip (WC)**. C1 and C2 lower the pitch of the tone, and C3 makes the sound beeping and the LED flashing.

Part C: Use any of the preceding circuits but replace the 10k Ω resistor (R4) with the **phototransistor (Q4, "+" on right)**. Change the tone by moving your hand up and down over the phototransistor to vary the amount of light on it. Using your hand, see if you can vary the sounds enough to make this circuit sound like an organ playing.

Part D: Use any of the preceding circuits but replace the red/yellow LED (D10) with the **color LED (D8, "+" on left)**.



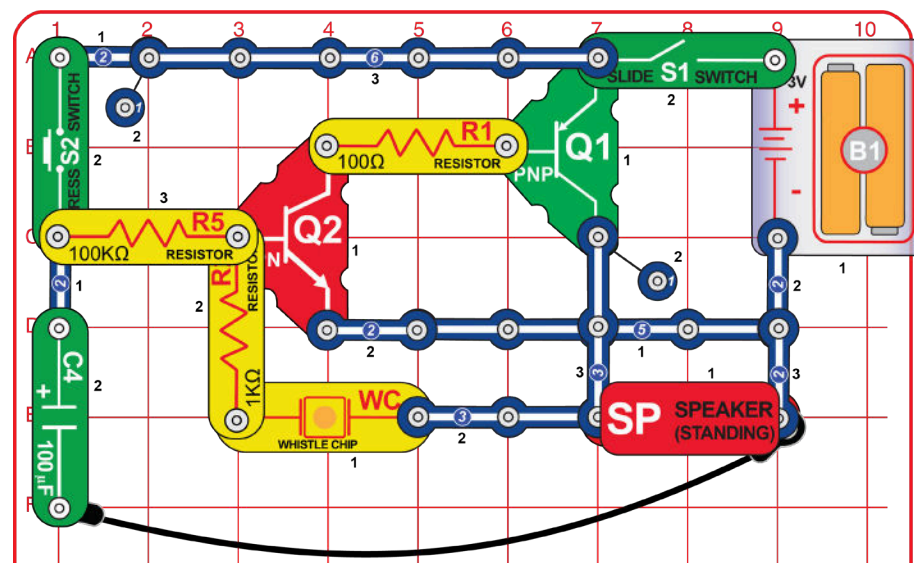
PROJECT 4 Lasting Doorbell

Build the circuit shown. Note that there is a 5-snap wire on layer 1 that is not connected to a 3-snap wire that runs over it on layer 3. Turn on the **slide switch (S1)**, then press and release the **press switch (S2)**. There is a doorbell sound that slowly fades away.

Part B: Place the 0.1 μ F capacitor (**C2**) or the 10 μ F capacitor (**C3**) on top of the **whistle chip (WC)**. Press and release the **press switch (S2)**. It makes a clicking sound for a while.

Part C: Use either of the preceding circuits, but replace the 100 μ F capacitor (C4) with the smaller 10 μ F capacitor (**C3**) or the larger 470 μ F capacitor (**C5**).

Part D: Use any of the preceding circuits, but replace the 100k Ω resistor (R5) with the smaller 10k Ω resistor (**R4**). See what happens.



When the press switch is pressed, the transistors (Q1 & Q2) are supplied with current for oscillation. At the same time, the 100 μ F capacitor (C4) gets charged. When the press switch is released, the capacitor discharges and keeps the oscillation going for a while.

PROJECT 5

Sound, Light, & Motor Stepper

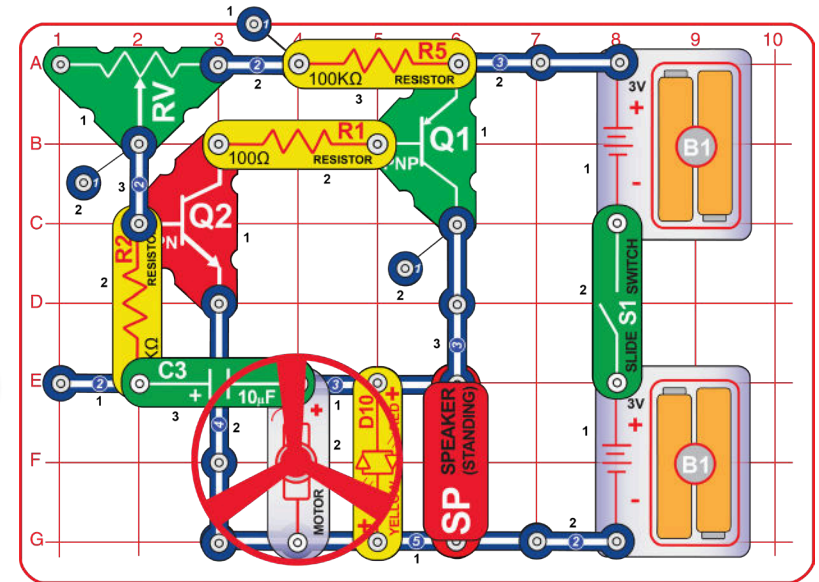
Turn on the **slide switch (S1)**. The circuit pulses once or twice a second, powering the speaker (SP), LED (D10), and motor (M1) in a short burst. Moving the lever on the **adjustable resistor (RV)** changes the rate.

Part B: Replace the 10 μ F capacitor (C3) with the larger 100 μ F capacitor (**C4**), or replace the 1k Ω resistor (R2) with the 5.1k Ω resistor (**R3**). See how the circuit performs differently now.

This circuit is an oscillator that turns on the transistors (Q1 & Q2), which turn on the speaker, LED, and motor for a short time, in a repeating cycle.

The transistors are off while the capacitor (C3) charges up through resistors RV and R5. Then the capacitor discharges in a burst that turns on the transistors, which activate the speaker, LED, and motor.

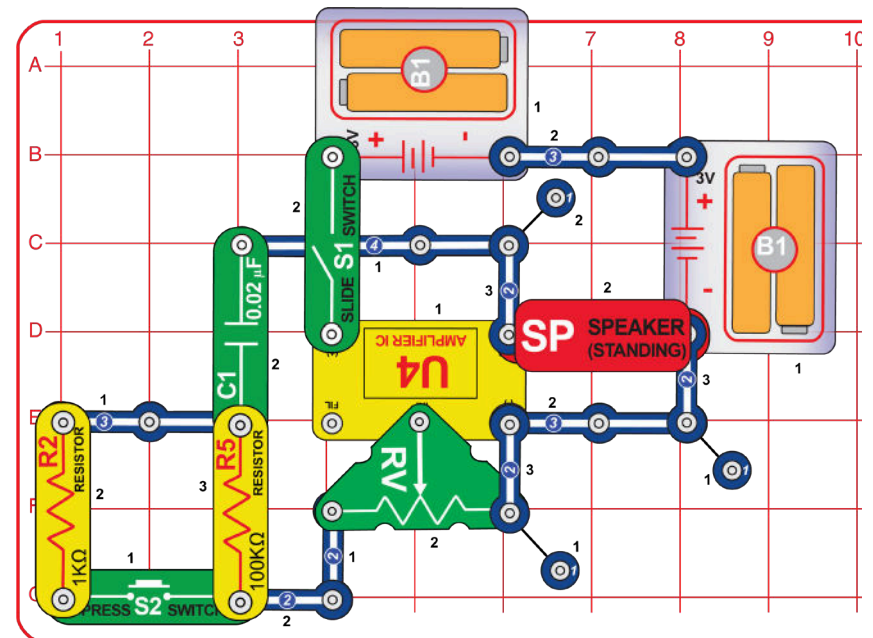
Changing the resistor or capacitor values changes the capacitor charging time, and a larger value for C3 or R2 keeps the action on longer.



PROJECT 6

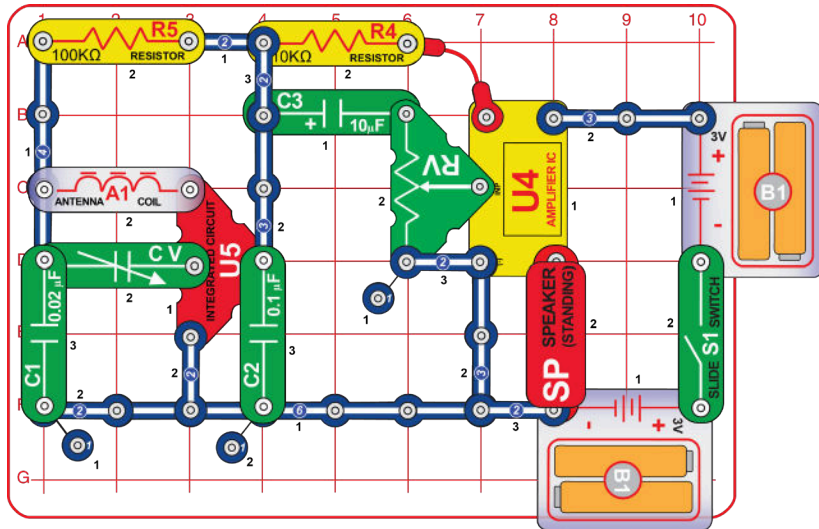
2-Tone Trombone

Modify the preceding circuit to be this one, which moves R2 and adds R5 and S2 on the lower left. Turn on the **slide switch (S1)** and the trombone should start playing. Push the **press switch (S2)** and move the lever on the adjustable resistor (RV) to change the tone. You can also replace capacitor C1 with **C2 or C3** ("+" on top), as done in the preceding circuit.



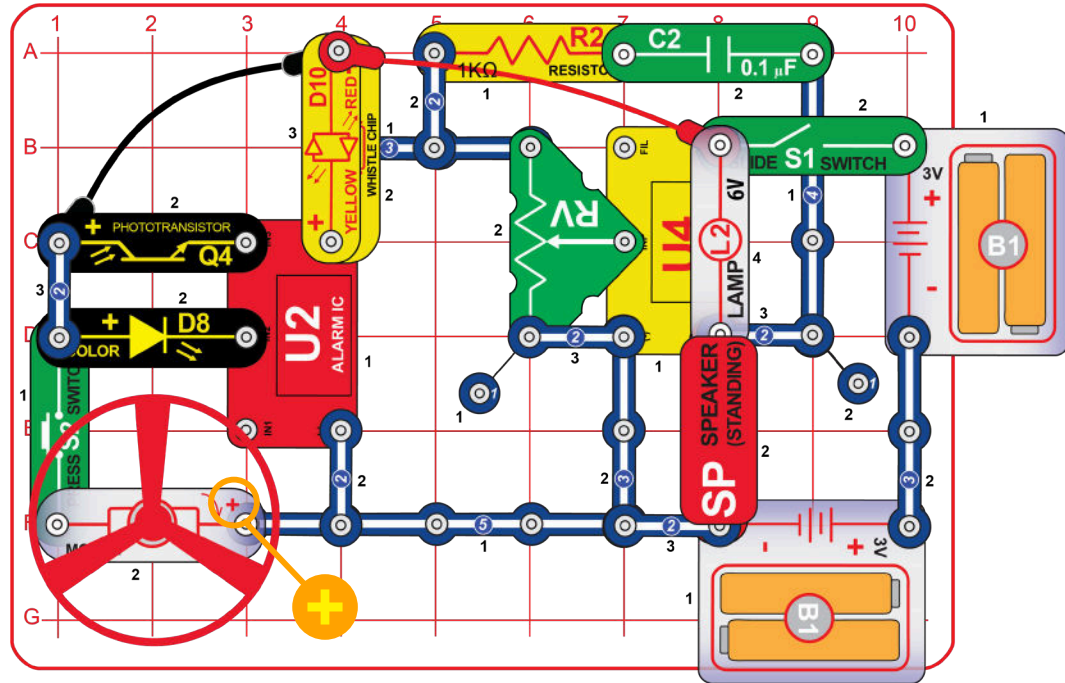
PROJECT 7 AM Radio

When you turn on the **slide switch (S1)**, the integrated circuit (U5) should amplify and detect the AM radio waves all around you. Tune the **variable capacitor (CV)** to hear a station. Set the **adjustable resistor (RV)** for best sound quality. The power amplifier IC (U4) amplifies the sound for the speaker (SP).



PROJECT 8 Super Circuit

Turn on the **slide switch (S1)**. The LEDs (D8 & D10) are flashing, the 6V lamp (L2) lights, and you hear machine gun and tone sounds. Move the lever on the **adjustable resistor (RV)** to change the tone sound. Completely cover the **phototransistor (Q4)** to change the machine gun sound to a siren. Push the **press switch (S2)** for a few seconds and release it to make the fan fly.



2. Basic Electric Circuits

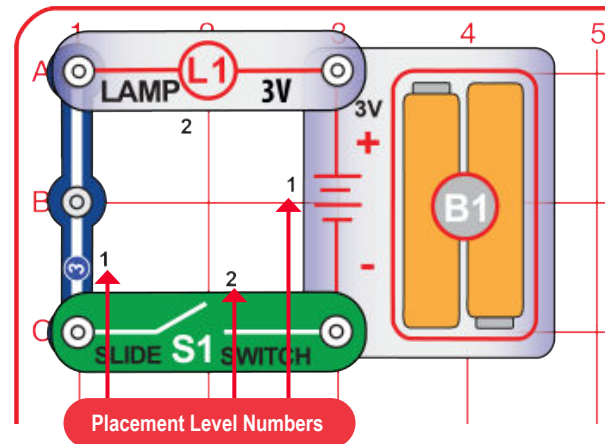
PROJECT 9 Electric Light

Snap Circuits® uses electronic blocks that snap onto a clear plastic grid to build different circuits. These blocks have different colors and numbers on them so that you can easily identify them.

Build the circuit shown on the right by placing all the parts with a **black 1** next to them on the board first. Then, assemble parts marked with a **2**. Install **two (2) AA batteries** (not included) into the **battery holder (B1)**. When installing a battery, be sure the spring is compressed straight back, and not bent up, down, or to one side. Battery installation should be supervised by an adult.

Turn on the **slide switch (S1)**, and the **lamp (L1)** lights.

When you turn on the slide switch, electricity flows from the batteries through the lamp and back to the battery through the switch. If the switch is off, the flow of electricity is blocked, and the lamp won't light.



Your battery holder has a cover.

Chemical energy from the batteries converts into electrical energy, traveling through wires to the lamp, then converts into light (and heat).

PROJECT 10 Color Light

Replace the **lamp (L1)** in the preceding circuit with the **color LED (D8)**. Turn on the **slide switch (S1)** and enjoy the light show from the **color LED (D8)**. For best effects dim the room lights.

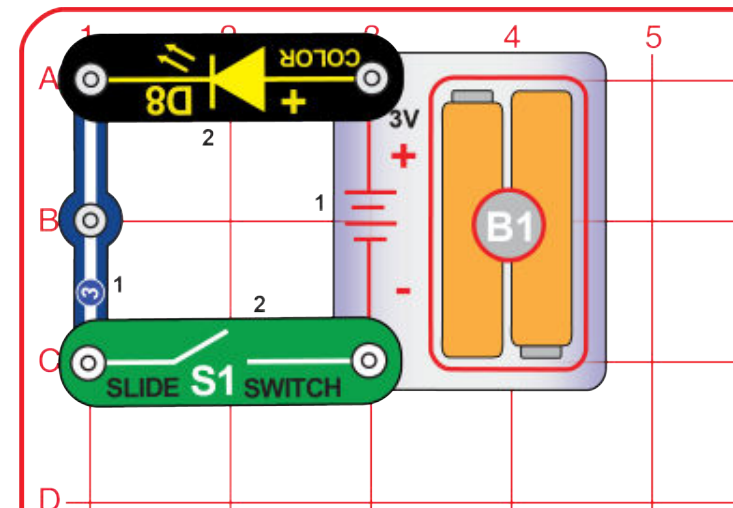
PROJECT 11 Red or Yellow Light

Use the same circuit, but replace the color LED with the red/yellow LED (D10), try it in both directions.

The color LED actually contains separate red, green, and blue lights, with a micro-circuit controlling them. The red/yellow LED has a red LED in one direction and a yellow LED in the other direction.

LEDs have a "+" side, because they only work in one direction. LEDs can be damaged by high current, so your color LED has an internal resistor to protect it.

LEDs are increasingly replacing incandescent lamps for room lighting because they are more efficient, using less electricity to make light.



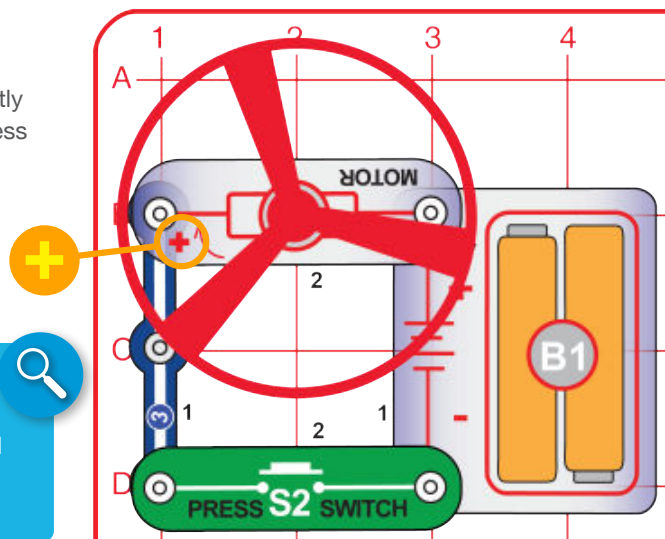
PROJECT 12 Flying Saucer

Build the circuit shown on the right. Push the **press switch (S2)** until the motor reaches full speed, then release it. The fan blade should rise and float through the air like a flying saucer. Be careful not to look directly down on fan blade when it is spinning. If the fan doesn't fly off, then press the switch several times rapidly when it is at full speed.

PROJECT 13 Fan

Use the same circuit, but reverse the position of the **motor (M1)**. Push the **press switch (S2)** to spin the motor and fan.

The air is being blown down through the blade and the motor rotation locks the fan on the shaft. When the motor is turned off, the blade unlocks from the shaft and is free to act as a propeller and fly through the air. If speed of rotation is too slow, the fan will remain on the motor shaft because it does not have enough lift to propel it.



In this circuit, the blade is blowing air upward; place your hand a short distance above the motor and you should be able to feel it.

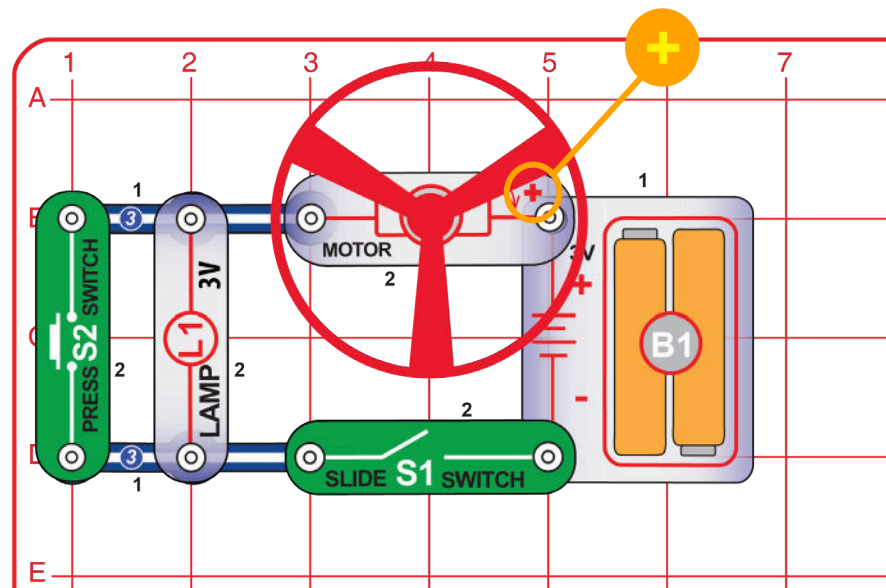
Chemical energy from the batteries was converted into electrical energy, traveled through wires to the motor, then was converted into mechanical motion in the motor. Motors like this one are used in battery powered equipment requiring rotary motion, such as a cordless drill, electric toothbrush, and toys. An electric motor is much easier to control than gas or diesel engines.

PROJECT 14 Two-Speed Fan

Turn on the **slide switch (S1)**; the motor (M1) spins the fan and the lamp (L1) lights. Push the **press switch (S2)** to bypass the lamp and increase the fan speed.

Swap the locations of the **lamp and motor** ("+" on top). Now pushing the press switch bypasses the motor and makes the lamp brighter.

When the lamp is on, the fan spins slower because the battery power is divided between the motor and lamp. Pushing S2 allows electricity to bypass the lamp, so all the battery power is available to the motor, so the fan spins faster.



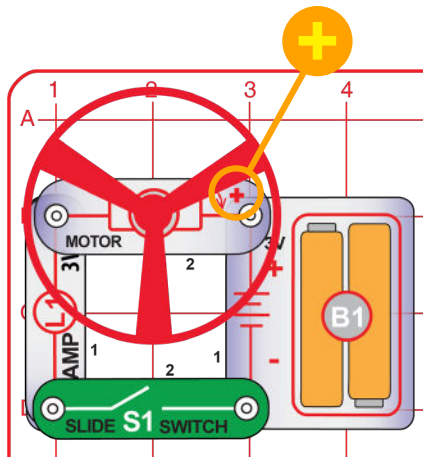
PROJECT 15

Lamp & Fan in Series

Build the circuit and turn on the **slide switch (S1)**. The **lamp (L1)** lights and the **motor (M1)** spins the fan. Notice how the lamp gets a little less bright as the motor speeds up.

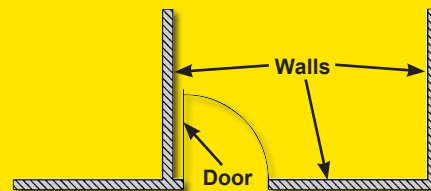
PROJECT 16 Light Dimmer

Use the preceding circuit, but **remove the fan** from the motor (M1). Turn on the **slide switch (S1)**, and watch how the **lamp (L1)** lights initially, but goes dark as the motor speeds up. Next, turn off the circuit and hold the motor top with your fingers so it can't spin, then turn on the switch and see how bright the lamp is.

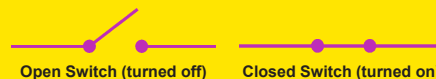


The faster the motor is spinning, the less electricity it needs. The more electricity flows, the brighter the lamp gets. The motor needs the most electricity when it starts up, making the lamp brightest. Without the fan, the motor can spin fast and needs little electricity, making the lamp dim.

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 simple 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:

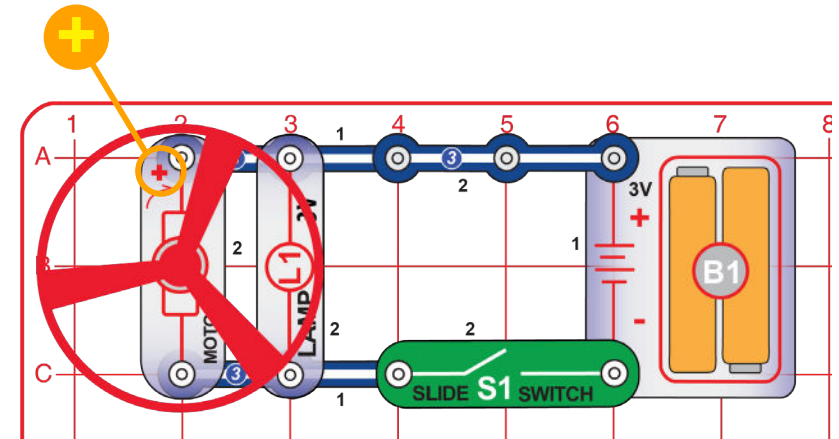


PROJECT 17

Lamp & Fan in Parallel

Build the circuit and turn on the **slide switch (S1)**. The **lamp (L1)** lights and the **motor (M1)** spins the fan.

Compare this circuit to the circuit in project 15, and also try removing the fan as done in project 8. Notice how the lamp brightness is not affected by the motor speed, and the motor starts a little faster.



Here the motor and lamp are connected in parallel. Each has its own path to the batteries, so they don’t affect each other.

An advantage of connecting parts in parallel is that if one of them burns out, the other will still work. The switch is connected in series with both the lamp and motor, so if it breaks, nothing will work. Electricity flows out of the batteries, through either the motor or lamp, then back to the batteries through the switch.

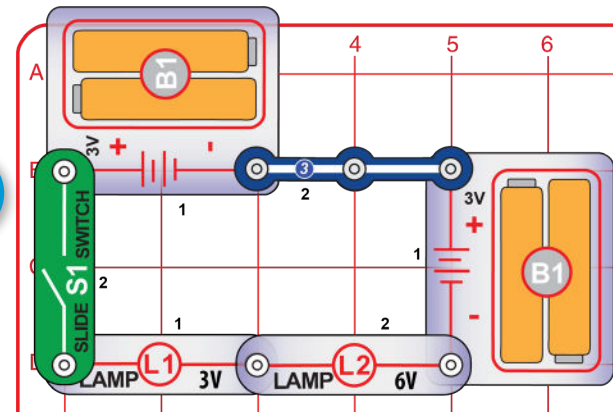
PROJECT 18 Fast Light, Slow Light

Turn on the **slide switch (S1)** to light the 3V lamp (L1) and the 6V lamp (L2). Notice that L1 turns on before L2, and that L1 is initially very bright but dims a little as L2 turns on—why?

PROJECT 19 Fast Light, Slow Light II

Replace one of the battery holders (B1) with a **3-snap wire**. Now L2 is much dimmer than L1, due to the difference in the lamp voltage ratings.

Incandescent bulbs like these make light by passing a big electric current through a special high-resistance wire, the filament. The high current heats up the filament, which gets so hot that it glows. L1 has a 3V bulb and L2 has a 6V bulb, and a dim bulb has less resistance than a bright one. L1 is designed for lower voltage than L2, so L1's filament heats up and glows more quickly than L2's. L2's resistance gradually increases as it turns on, lowering the current through L1.

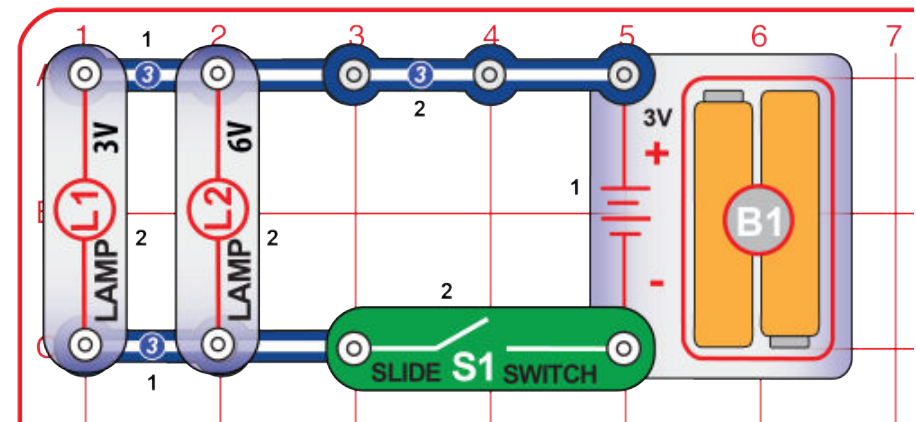


The two lamps and the switch are connected in series, so each affects the others. Being connected in series allows the switch to control both lamps, and makes wiring simpler. The disadvantage of connecting in series is that if one lamp burns out then neither will work.

PROJECT 20 Parallel Lamps

Turn on the **slide switch (S1)** to light the lamps (L1 & L2).

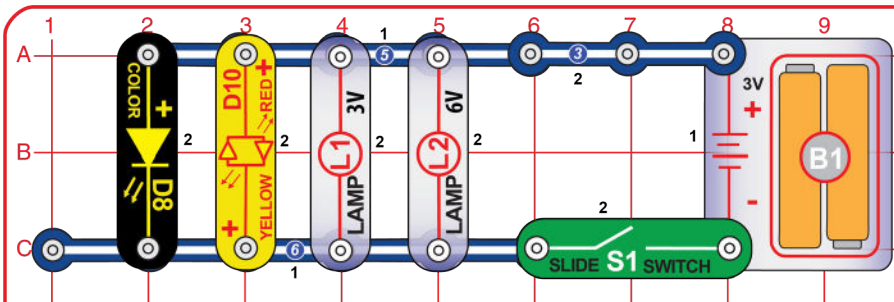
The two lamps are connected in parallel, so each has its own connection to the batteries and switch. If one lamp burns out then the other still lights. The 6V lamp (L2) is not at full brightness because it is rated for 6V and the battery voltage here is only 3V. If the battery voltage was increased to 6V then L2 would be brighter and the 3V lamp (L1) would burn out.



PROJECT 21

Parallel Lights

Turn on the **slide switch (S1)** to light the LEDs (D8 & D10) and lamps (L1 & L2). If you remove one of the LEDs or lamps, the others will not be affected.



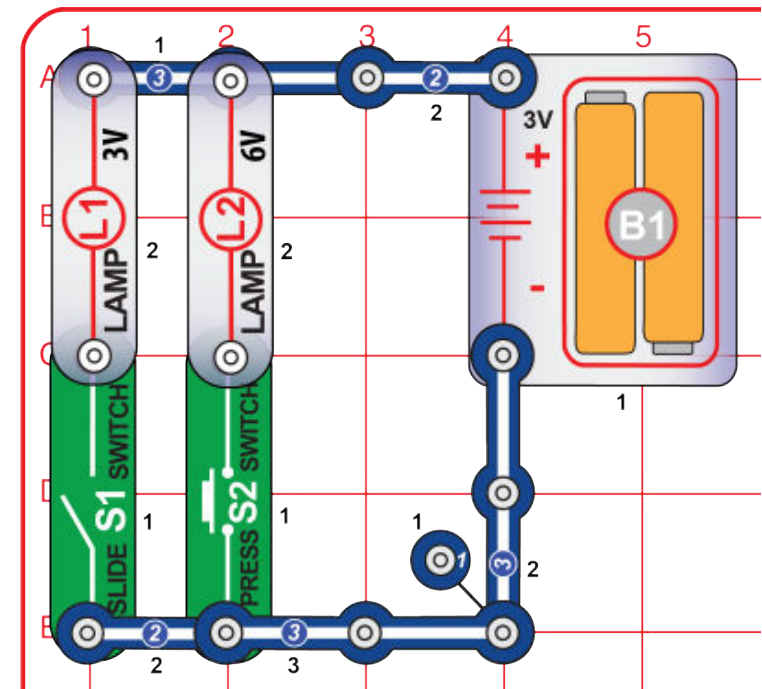
The LEDs and lamps are connected in parallel, so each has its own connection to the batteries and switch. If one light burns out then the other still lights. The slide switch (S1) is connected in series with all the LEDs and lamps, so it can control them all at once.

PROJECT 22

Independent Lamps

Turn on the **slide switch (S1)** to light the 3V lamp (L1), or push the **press switch (S2)** to light the 6V lamp (L2).

You can replace the 6V lamp with the **motor (M1, "+" on top)** and fan.

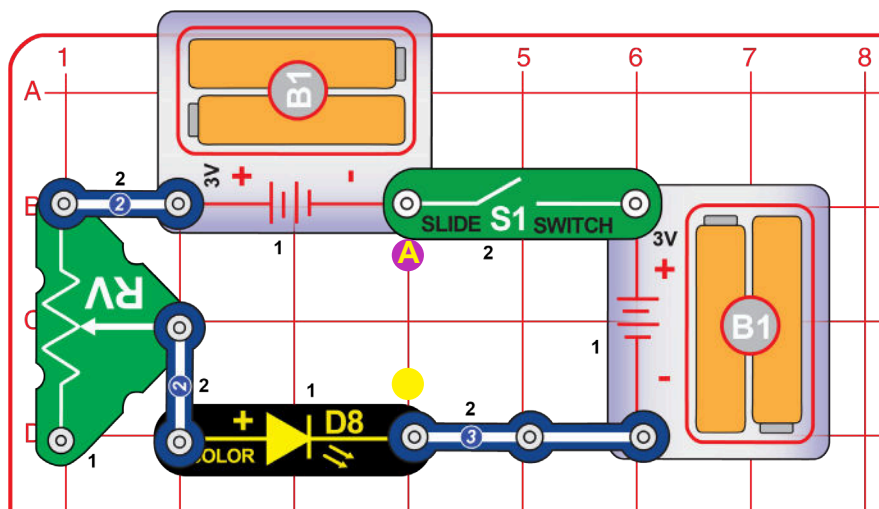


In project 12, the slide switch (S1) turned on both lamps. In this circuit each lamp has its own switch, so you can turn them on independently. In your home some switches will control several lights while others switches only control one light or appliance.

PROJECT 23

Brightness Control

Build the circuit and turn on the **slide switch (S1)**. Move the lever on the **adjustable resistor (RV)** to vary the brightness of the light from the color LED (D8).



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.

Resistors are used to control or limit the flow of electricity in a circuit. Higher resistor values reduce the flow of electricity in a circuit.

In this circuit, the adjustable resistor is used to adjust the LED brightness, to limit the current so the batteries last longer, and to protect the LED from being damaged by the batteries.

The adjustable resistor can be set for as low as 200Ω (when its lever is set to the top), or as high as $50,000\Omega$ ($50k\Omega$) when its lever is set to the bottom.

PROJECT 24 Resistors

Use the preceding circuit, but replace the 3-snap with one of the yellow **resistors** in this set (R1, R2, R3, R4, or R5). Observe how each changes the LED brightness at different settings for the adjustable resistor.



The R1 resistor (100Ω) will have little effect, since it will be dominated by the adjustable resistor. Resistor R5 ($100k\Omega$) is a high resistance, which greatly restricts the flow of electricity, so the LED will be very dim or off. Resistors R2 ($1k\Omega$), R3 ($5.1k\Omega$), and R4 ($10k\Omega$) will be in between those.

Though not directly in line, RV and the other resistor (or the 3-snap wire) are connected in a series circuit arrangement. When components are connected in series, the largest resistance dominates, since it will restrict electricity flow the most.

PROJECT 25 Resistors & LEDs

Use the two preceding circuits, but replace the color LED (D8) with the **red/yellow LED (D10)**, in positioned in either direction). Vary the adjustable resistor lever and change the yellow resistors to see how the LED light varies.

Next, replace the LED with the **6V lamp (L2)** or the **motor (M1)**. Notice that the lamp will not light and the motor will not spin at all, on any RV setting.

The lamp and motor need much more electricity to operate than LEDs do, so having RV or any of your other resistors in series with them restricts electric flow too much for them to function.

PROJECT 26 Low Power Brightness Control

Use the project 15 circuit but remove the slide switch (S1) and 3-snap wire, then place the **slide switch** between **points A & B**. Move the lever on the **adjustable resistor (RV)** to vary the brightness of the light from the color LED (D8). For best effects, do this in a dimly lit room. At some RV settings the LED will be very dim, and some of its colors may be totally off.

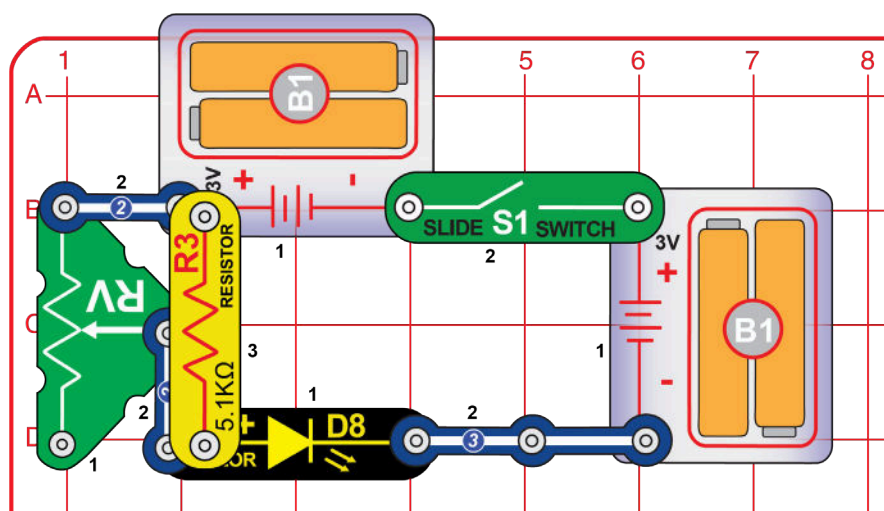
Replace the color LED (D8) with the **red/yellow LED (D10)**, in either direction). Vary the adjustable resistor lever to see how the light varies.

PROJECT 27

Brightness Control—Parallel

Use the project 15 circuit but add the **5.1kΩ resistor (R3)** on top of the 2-snap wire as shown. Move the lever on the **adjustable resistor (RV)** to vary the brightness of the light from the color LED (D8).

Replace the 5.1kΩ resistor with one of the other **resistors (R1, R2, R4, or R5)** and see how the LED brightness is affected at different RV settings.



The R1 resistor (100Ω) will have the most effect, since it is smaller than the lowest setting on the adjustable resistor. Resistor R5 (100kΩ) is a high resistance, which greatly restricts the flow of electricity, so will have little effect compared to RV. Resistors R2 (1kΩ), R3 (5.1kΩ), and R4 (10kΩ) will be in between those.

Here RV and the other resistor are connected in a parallel circuit arrangement. When components are connected in parallel, the smallest resistance dominates, since it will restrict electricity flow the least. Electricity looks for the easiest (lowest resistance) path through a circuit.

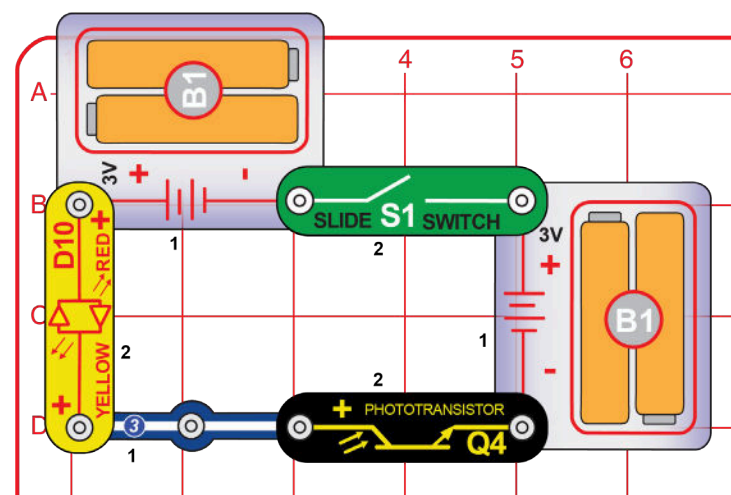
PROJECT 28

Light-Controlled Light

Turn on the **slide switch (S1)** and vary the amount of light shining on the phototransistor (Q4). The brighter the light on the phototransistor, the brighter the red/yellow LED (D10) should be. You can replace the phototransistor with one of the resistors to see what resistor value it is closest to.

PROJECT 29 Air Pressure-Controlled Light

Replace the phototransistor with the **microphone (X1)**. Blow on the microphone to change the LED brightness. You can replace the microphone with one of the resistors to see what resistor value it is closest to.



The phototransistor (Q4) uses light to control electric current. When more light shines on the phototransistor, the current flowing through it increases, making the LED glow more brightly. Parts like this are used in a number of ways that affect our lives. For example, you may have streetlights in your neighborhood that turn on when it starts getting dark and turn off in the morning.

The microphone is actually a resistor that changes in value when changes in air pressure (sounds or wind) apply pressure to its surface. Talking into the microphone will not change its resistance enough to have a noticeable effect on the LED brightness.

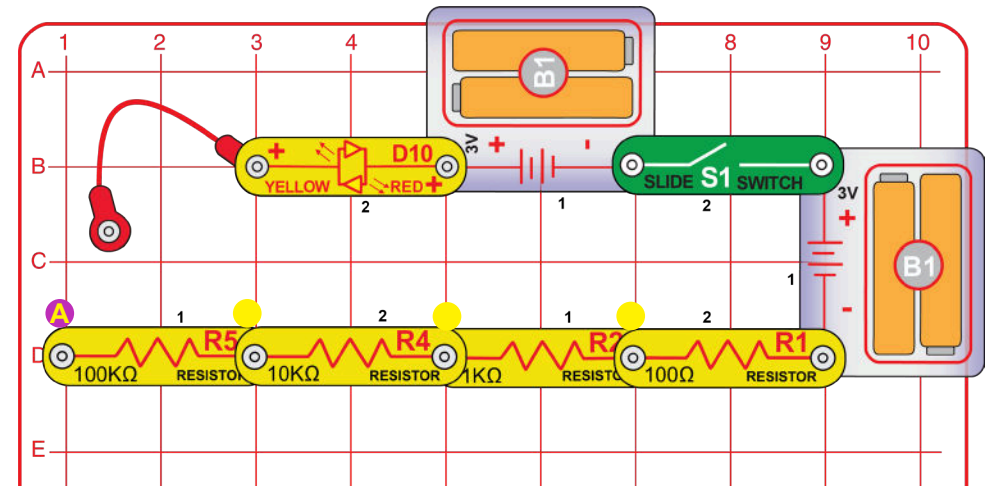
PROJECT 30 Resistor Row

Turn on the **slide switch (S1)** and connect the loose end of the red jumper wire to point **A**, then point **B**, then point **C**, then point **D**. The red/yellow LED (D10) will get brighter each time.

If you reverse the order of the resistors (so R1 is on the left, then R2, then R4, then R5), then the LED will be dim at all four points, because R5 will dominate.

When resistors are connected in series, the highest value dominates. Here the left resistor is the highest (100k Ω) and the right resistor is the lowest (100 Ω), so connecting to points A-D gets progressively brighter.

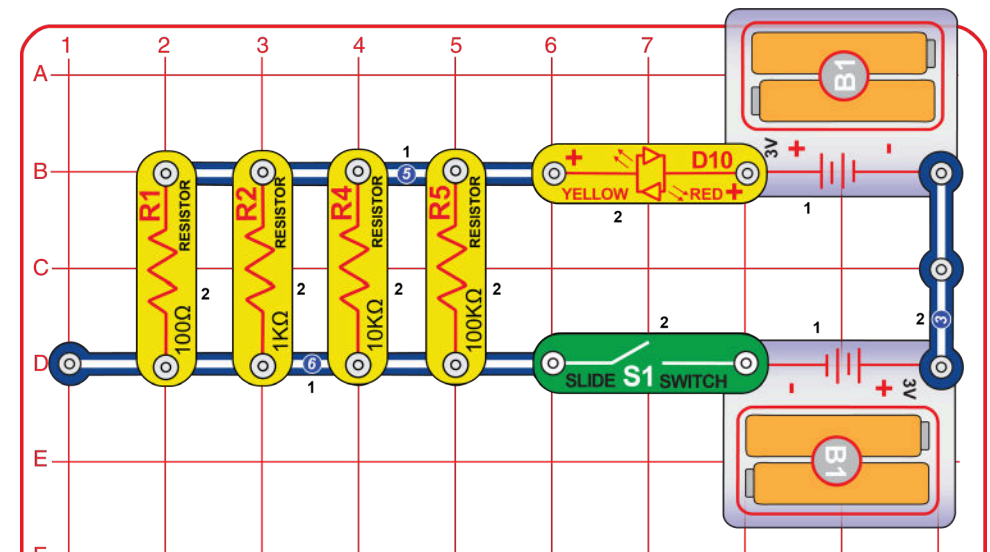
When you reverse the resistor order the right resistor is the highest, so it is always in the circuit, so the LED is always dim.



PROJECT 31 Resistor Array

Turn on the **slide switch (S1)**, the red/yellow LED (D10) is bright. Now remove **resistors (R1, R2, R4, or R5)** one at a time until one is left. See which resistor has the biggest effect on the LED brightness.

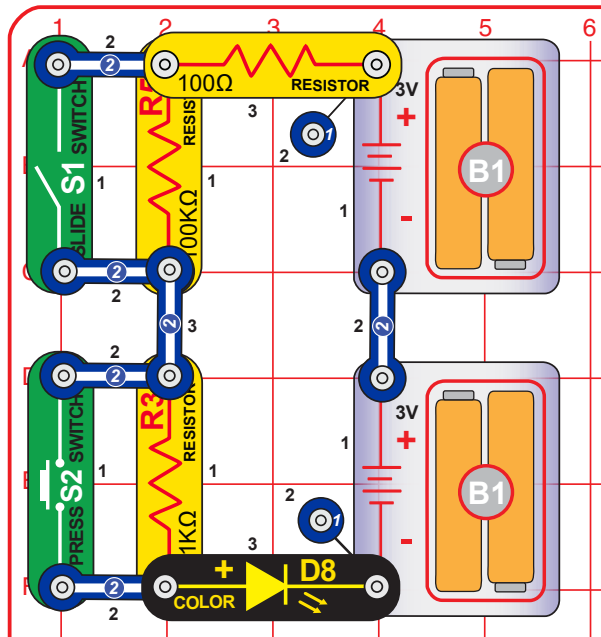
When resistors are connected in parallel, the smallest value dominates. Here the left resistor is the lowest (100 Ω) and the right resistor is the highest (100k Ω), so removing resistors from the left makes the LED dimmer but removing resistors from the right has little effect.



PROJECT 32

Current Controllers— Series

Build the circuit below. Turn on either or both **switches (S1 & S2)** and compare the white LED (D8) brightness.



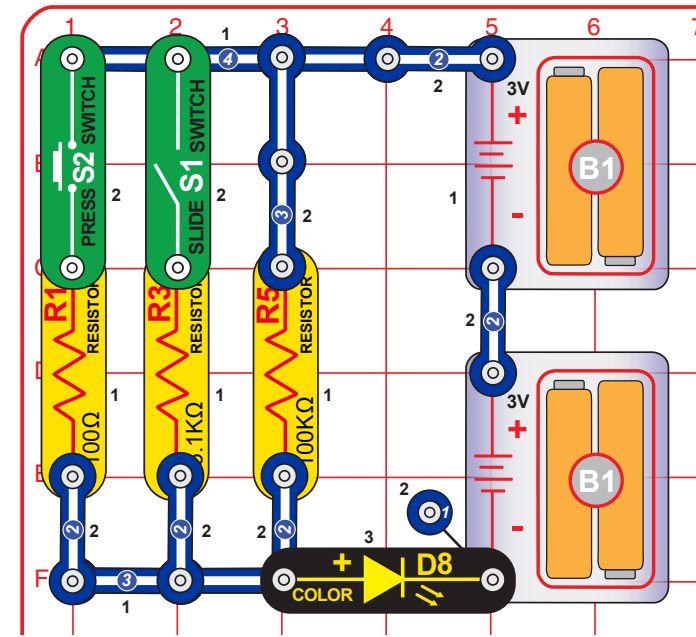
Resistors are used to control the amount of current through a circuit. Increasing the resistance decreases the current.

This circuit has the 100Ω resistor (R1), the 5.1kΩ resistor (R3), and the 100kΩ resistor (R5) arranged in series. The switches are used to bypass the larger resistors. The largest resistor controls the brightness in this arrangement.

PROJECT 33

Current Controllers— Parallel

Build the circuit below. Turn on either or both **switches (S1 & S2)** and compare the white LED (D8) brightness.

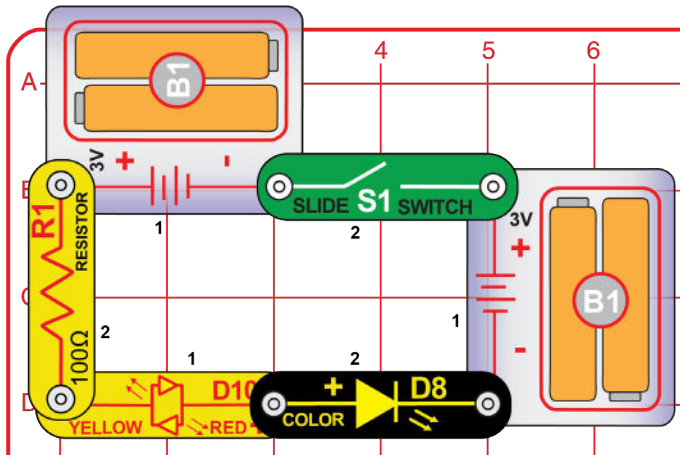


This circuit has the 100Ω resistor (R1), the 5.1kΩ resistor (R3), and the 100kΩ resistor (R5) arranged in parallel. The switches are used to disconnect the smaller resistors. The smallest resistor controls the brightness in this arrangement.

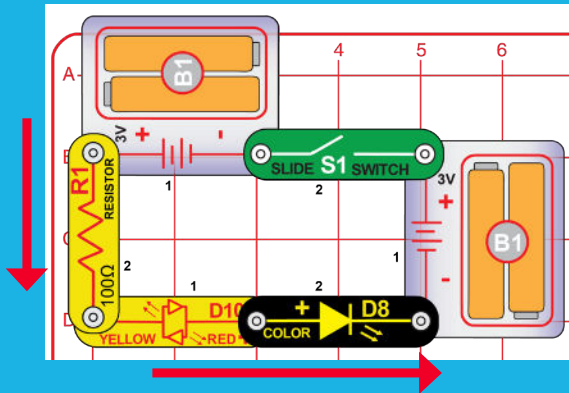
PROJECT 34

Dependent Lights

Build the circuit shown. Turn on the slide switch (S1). Both LEDs are blinking.



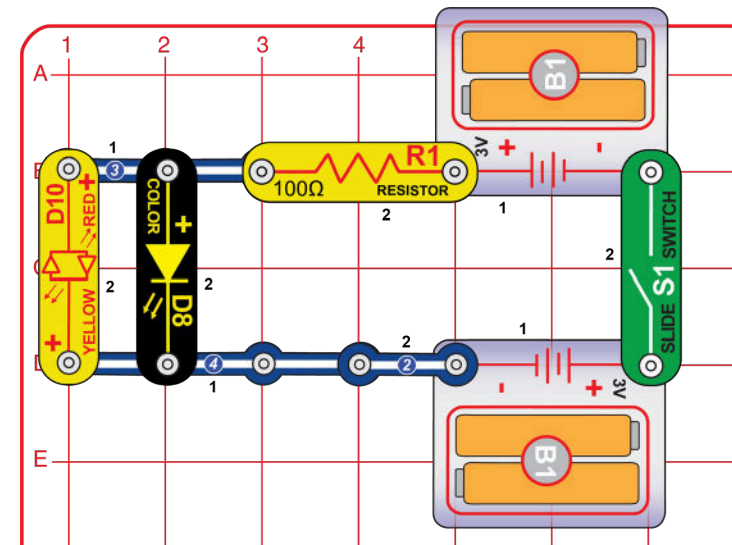
The two LEDs are connected in **SERIES**, and all the electric current from the batteries flows through each component in the circuit. Series circuits are simple to connect, and allow one component to easily control another (here the red/yellow LED blinking is controlled by the color LED's blinking).



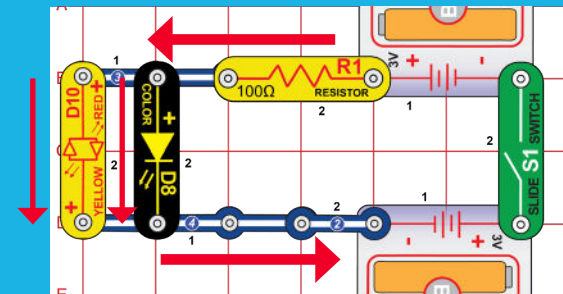
PROJECT 35

Independent Lights

Build the circuit shown. Turn on the slide switch (S1) to light the LEDs (D8 & D10). D8 is blinking but D10 is not.



Compare this circuit to the preceding circuit. This circuit has both LEDs connected in **PARALLEL**. Electric current from the batteries flows through the resistor (R1), then divides between the 2 LEDs, then re-combines and flows back into the batteries. Parallel circuits make components independent of each other but require more complex wiring.



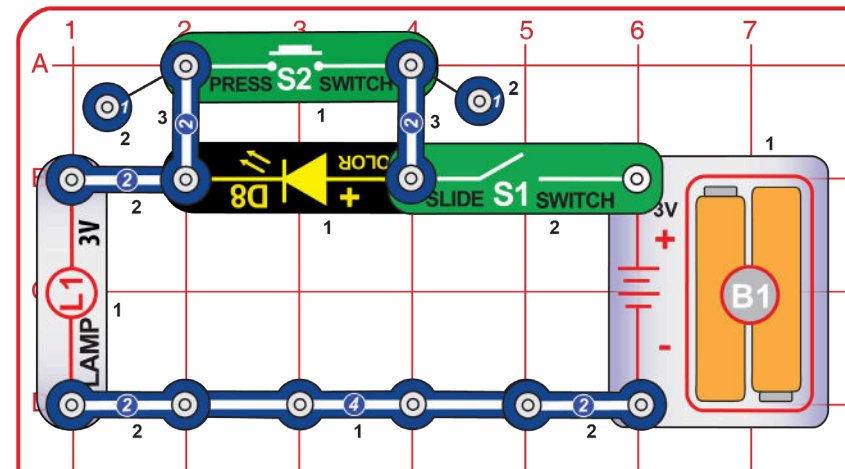
PROJECT 36 Power Shifter

Build the circuit shown on the right. When you turn on the **slide switch (S1)**, the color LED (D8) is on and the lamp (L1) is off.

Push the **press switch (S2)** to bypass the LED. The lamp turns on and the LED turns off. This shows how switches can be used to shift power between different devices.

The color LED has an internal resistor to protect it from overload. This resistor does not prevent the LED from lighting, but it limits the circuit current too much to allow the lamp to light.

If you swap the locations of the lamp and color LED (put LED "+" on top), then the LED will always be on, the lamp will always be off, and the press switch will have no effect.

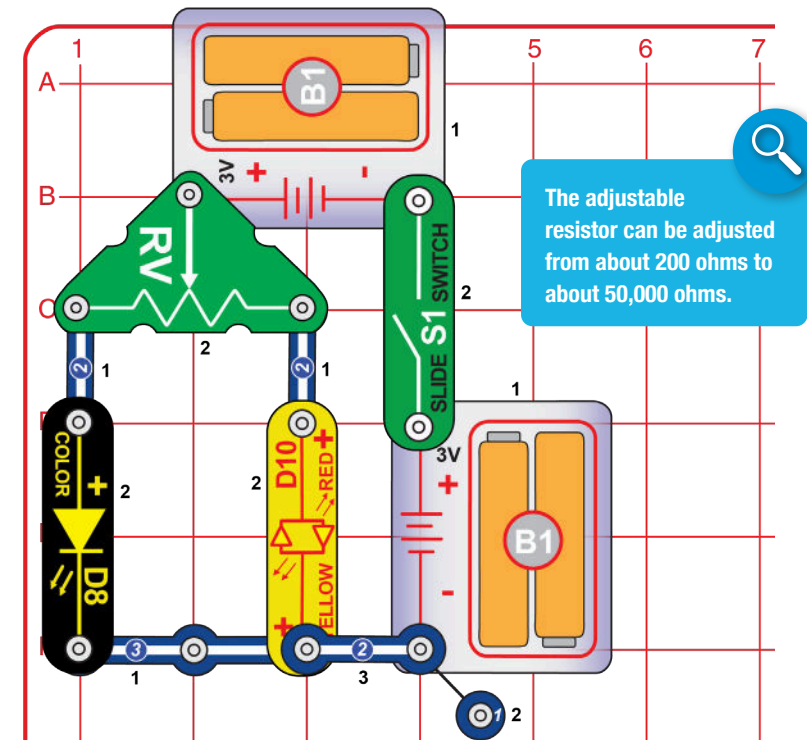


PROJECT 37

Resistance Director

Move the lever on the **adjustable resistor (RV)** across its range and watch the brightness of the color and red/yellow and LEDs (D8 & D10).

You can also replace one of the battery holders (B1) with a **3-snap wire**, and compare the LED brightnesses at lower voltage.

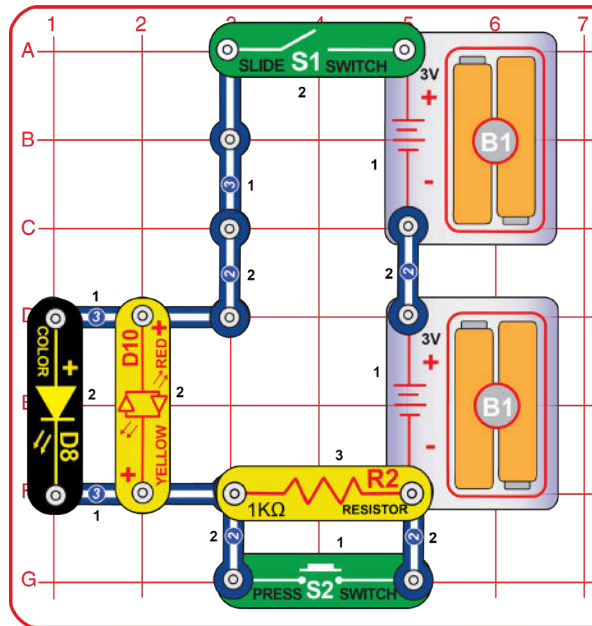


The adjustable resistor can be adjusted from about 200 ohms to about 50,000 ohms.

PROJECT 38

LEDs Together

Turn on the **slide switch (S1)**, and compare the brightness of the two LEDs. Then push the **press switch (S2)** to bypass the 1k Ω resistor (R2) and compare the LED brightness again. Flip the **red/yellow LED (D10)** around and compare yellow to red.



The voltage needed for an LED to turn on depends on the light color. Red and yellow light need the least, green needs more, but blue and white need the most. The color LED (D8) contains red, green, and blue LEDs.

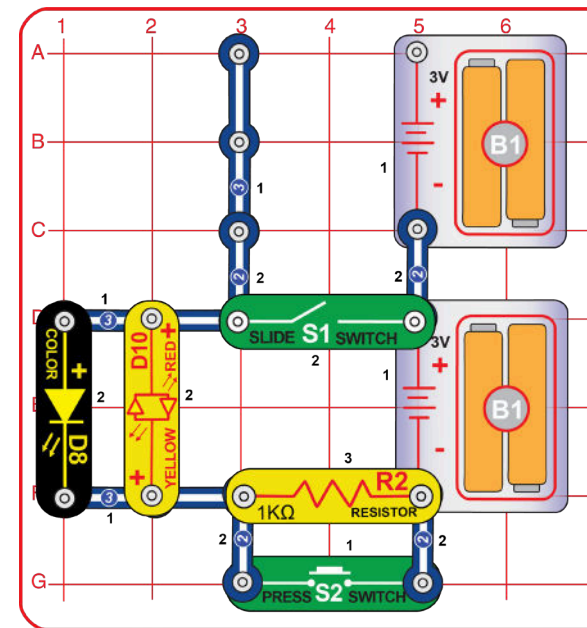
The R2 resistor reduces the voltage available to the LEDs. The LED brightness varies because some of the LED colors need more voltage than is available. Red color will dominate the other colors because it turns on more easily. Pressing S2 bypassed the R2 resistor and gives each LED the full battery voltage (note that each LED has an internal protection resistor that limits the current through it).

PROJECT 39

LEDs Together II

Modify the preceding circuit by moving the **slide switch (S1)** to the location shown here. Compare the brightness of the LEDs. Some LEDs may not turn on. Then push the **press switch (S2)** to bypass the 1k Ω resistor (R2) and compare the LED brightness again. Flip the **red/yellow LED (D10)** around and compare yellow to red.

Next, remove any of the LEDs and see how the brightness of the others changes.

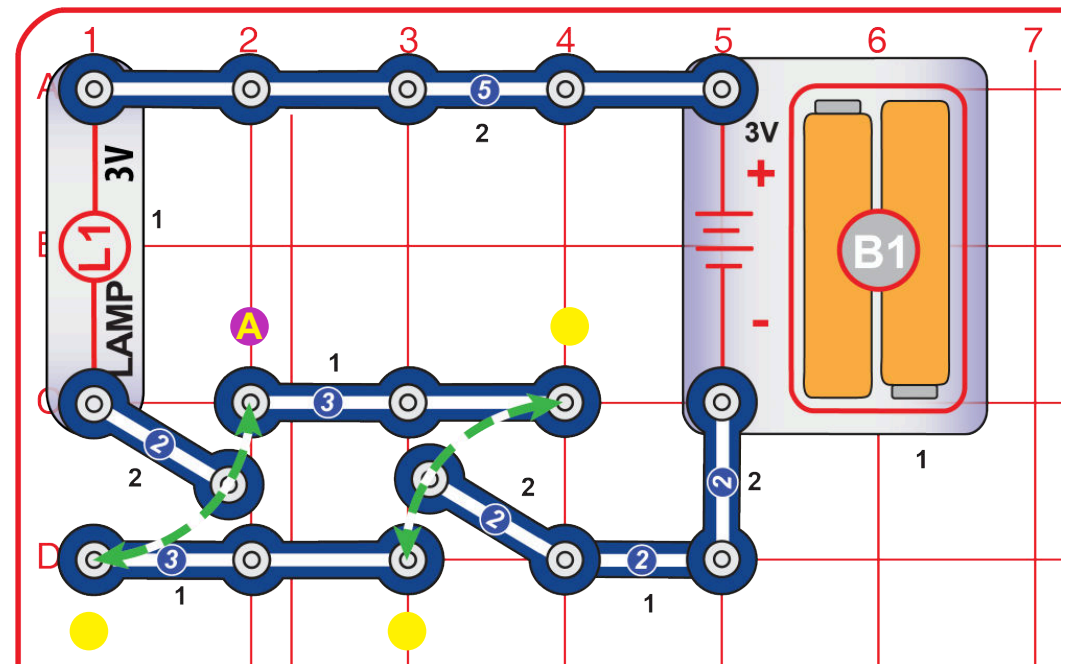


This circuit reduces the voltage to the circuit, because only one set of batteries is connected. The limited battery voltage is split between the R2 resistor and the LEDs. The remaining voltage across the LEDs is enough to activate the red color, but may not be enough to activate the other colors. With the reduced voltage, the red color will dominate even more than in the preceding circuit. Pressing S2 bypassed the R2 resistor and gives each LED the full battery voltage.

PROJECT 40

Two-way Light Switch

Build the circuit to the right. Note that two of the 2-snaps are left unconnected on one end because they will be used as switches in this project. If you connect the free ends of each of these 2-snaps both to the “high bar” or positions B in the figure or both to the “low bar” or positions A in the figure, the lamp (L1) lights. But if you connect the free end of one of the 2-snaps to the “high bar” and the free end of the other 2-snap to the “low bar”, then the lamp does not light.



3. Alarm IC Circuits

PROJECT 41

Soft Siren

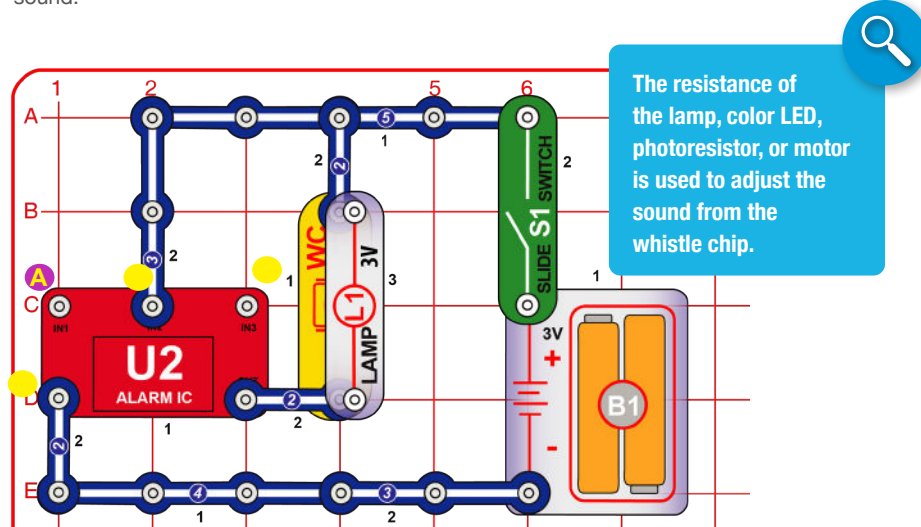
Turn on the **slide switch (S1)** and a siren sounds.

Part B: Use the preceding circuit, but add a connection between the points marked **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire.

Part C: Use either of the preceding circuits, but replace the lamp (L1) with the **color LED (D8 “+” on top)**. The sound changes a little as the color LED changes colors.

Part D: Use the projects 41 or 41B circuits, but replace the lamp (L1) with the **phototransistor (Q4 “+” on top)**. Vary the amount of light shining on the photoresistor to change the sound volume.

Part E: The fan speed changes as the sound changes, especially with the Machine Gun sound.



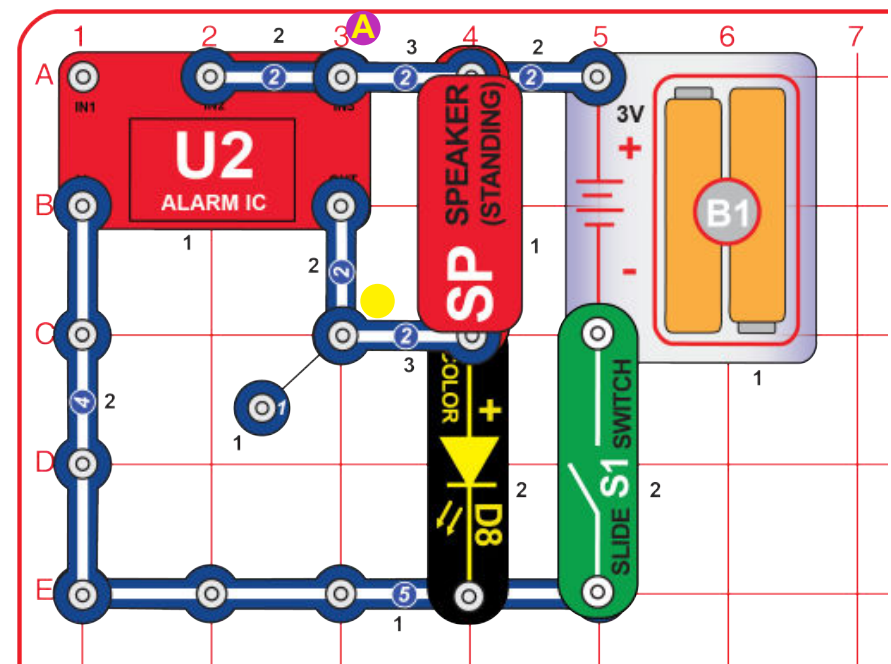
PROJECT 42

Machine Gun Buzz

Build the circuit shown below. Turn on the **slide switch (S1)** and you hear a machine gun and a buzzing sound, while the color LED (D8) is changing colors.

PROJECT 43 Double Flash Machine Gun

Use the preceding circuit, but add the **lamp (L1)** across the points marked A & B, on level 4.



PROJECT 44 Singing Siren

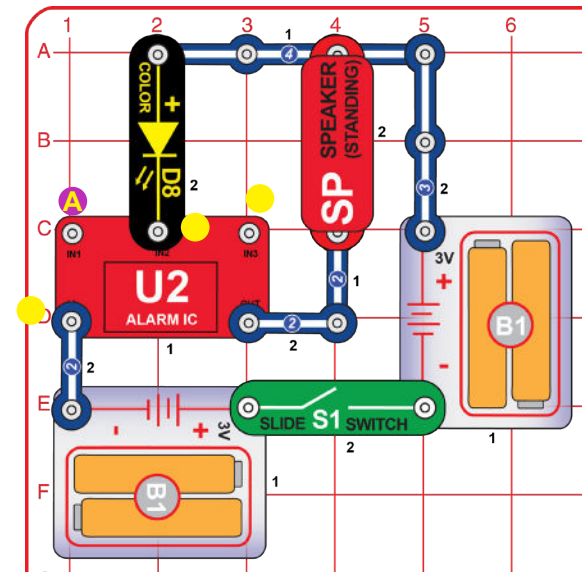
Build the circuit shown. Turn on the **slide switch (S1)** and listen to the sound.

PROJECT 45 Singing Siren II

Add a connection between the points marked **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire.

PROJECT 46 Singing Siren III

Use any of the preceding circuits but replace the speaker (SP) with the **whistle chip (WC)** and **red/yellow LED (D10)**, stacked together with the LED on top. The sound is different now.



Here the flashing pattern of the color LED (D8) varies the current to the alarm IC (U2), creating weird patterns in its sound.

PROJECT 47 Machine Gun Fan

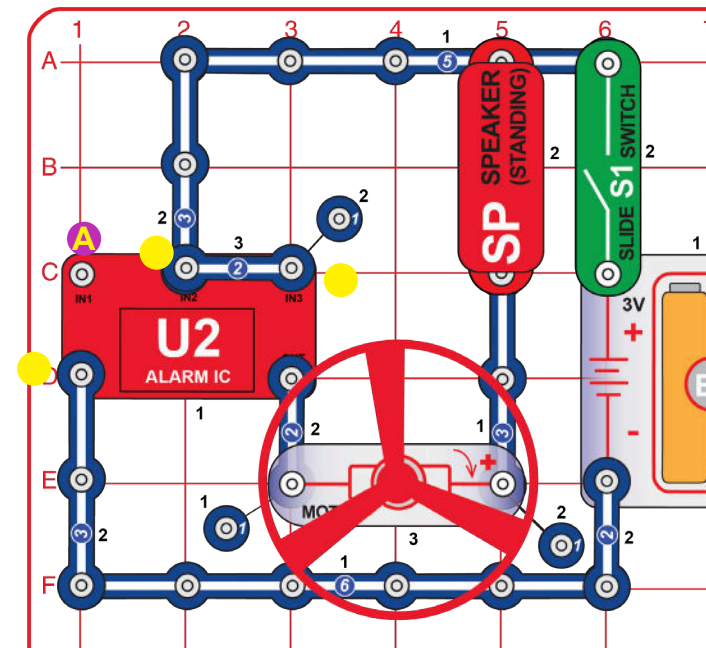
Turn on the **slide switch (S1)**. A machine gun sounds and the motor (M1) spins the fan in bursts. You may need to give the fan a push to get it started.

PROJECT 48 Siren Fan

Use the preceding circuit but remove the 2-snap wire and 1-snap wire that are across points C & D. Leave them off, or add them across points A & B or A & D.

PROJECT 49 Light Volume Control

Use any of the preceding circuits but replace the motor (M1) with the **phototransistor (Q4, "+" on right)**. Shine a bright light (like a flashlight) directly on the phototransistor to hear a machine gun sound, the sound will not be very loud.



PROJECT 50

Flashing Lights & Sound

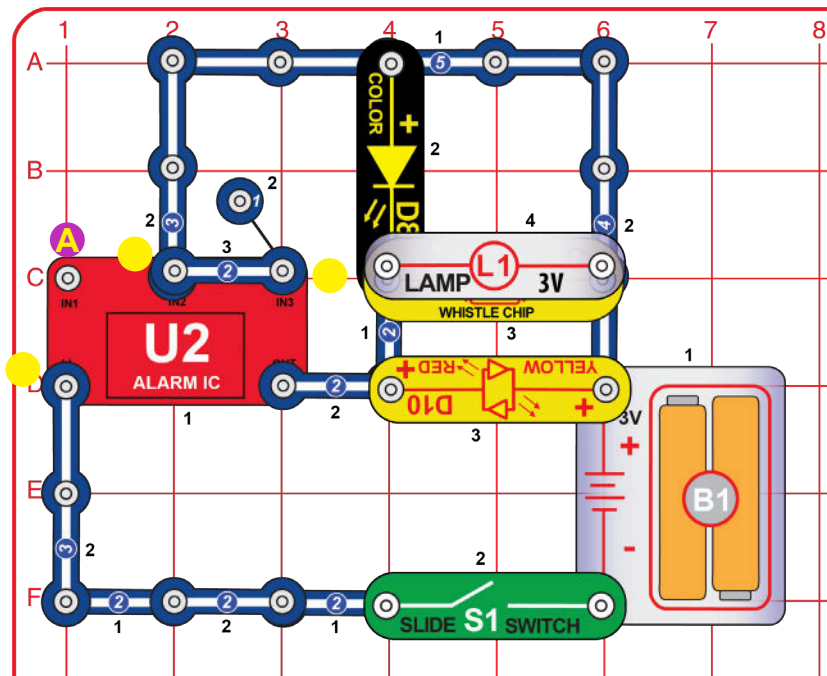
Build the circuit shown. Turn on the **slide switch (S1)**. A siren sounds and lights flash.

PROJECT 51 Flashing Lights & Sound II

Remove the 2-snap wire and 1-snap wire that are across points B & C. Leave them off, or add them across points A & B or C & D.

PROJECT 52 Flashing Lights & Sound III

Replace the whistle chip (WC) and 3V lamp (L1) with the **speaker (SP)**.



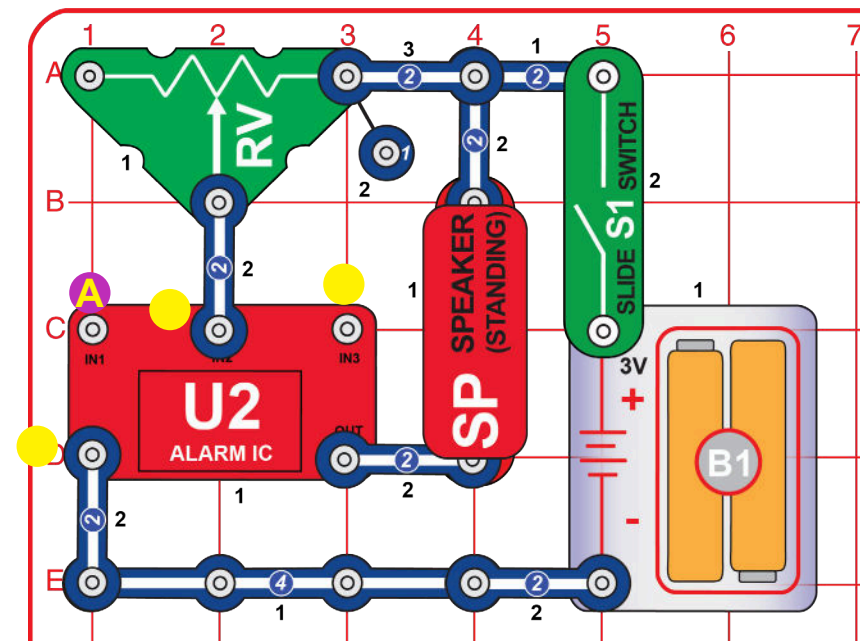
PROJECT 53

Accelerator

Build the circuit below. Set the lever on the **adjustable resistor (RV)** to the right and turn on the **slide switch (S1)**. A siren sounds. Slowly move RV's lever toward the left to slow down the sound. There will only be sound for a small part of RV's range.

PROJECT 54 Accelerator II

Add a connection across points **A & D**, **A & B**, or **B & C** using a 1-snap wire and a 2-snap wire, or a jumper wire.



The resistance of the adjustable resistor (RV) reduces the voltage to the alarm IC (U2), making it barely able to function. If the lever on RV is moved too far to the left then the alarm IC cannot function at all.

PROJECT 55 Adjusting Sound Level

Turn on the **slide switch (S1)** and adjust the sound volume using the lever on the **adjustable resistor (RV)**. You will only hear music for a small part of RV's range when the lever is set to the right side.

PROJECT 56 Adjusting Sound Level II

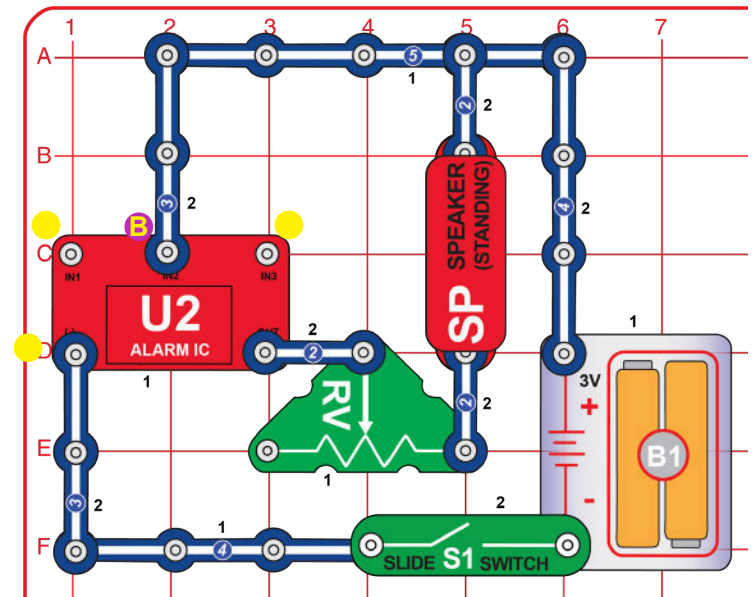
Remove RV and 2-snaps connecting it, and add the **100Ω resistor (R1)** between the alarm IC (U2) and speaker (SP). The sound is louder now, because R1 has less resistance than the lowest setting on RV.

Now replace R1 with a **3-snap wire**, so there is no resistance in series with the speaker. Notice how much louder the sound is now.

PROJECT 57 Adjusting Sound Level III

Use either of the preceding circuits but add a connection between the points marked **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire.

The adjustable resistor (RV) can be set from 200 to 50,000 ohms. The speaker's resistance is only 8 ohms, so placing RV in series with the speaker makes the sound much lower.

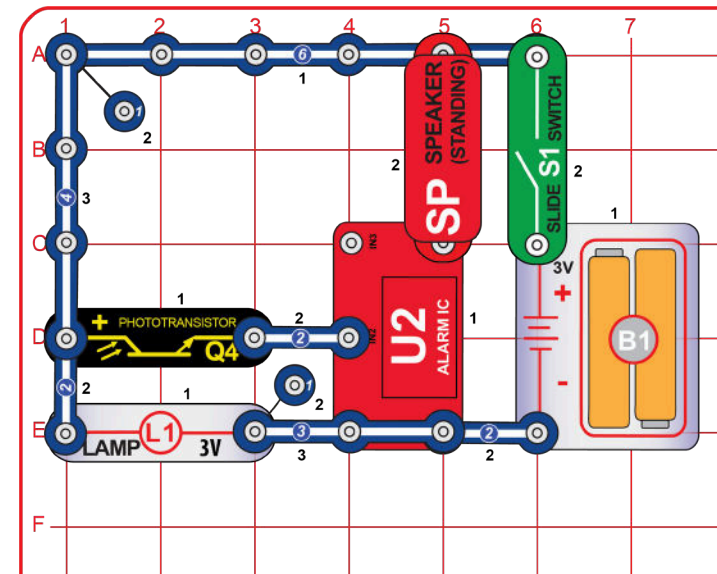


PROJECT 58 Reflection Detector

Build the circuit and place it where there won't be any room light hitting the phototransistor (Q4) (such as in a dark room or under a table), and then turn it on. The lamp (L1) will be bright, but there should be no sound. You may need to put a small piece of cardboard or your finger between the lamp and phototransistor to stop the sound.

Take a small mirror and hold it over the lamp and phototransistor. You should hear sound now. You have a reflection detector! You can also use a white piece of paper instead of a mirror, since white surfaces reflect light.

You can replace the speaker with the **red/yellow LED (D10)**, in either orientation). Now a reflection turns on the LED.



4. More Basic Circuits

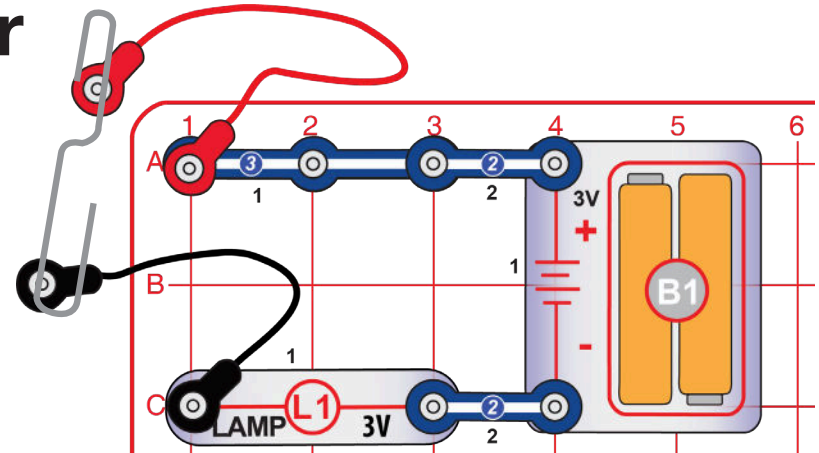
PROJECT 59 Conduction Detector

Build the circuit as shown. When you place a **metal paper clip** across the snaps on the red & black wires as shown in the drawing, current flows from the batteries (B1) through the paperclip, through the lamp (L1), and back to the battery. The paper clip completes the circuit and can current flow through the lamp.

Now replace the metal paperclip with other materials in your home, and see if the lamp lights. This circuit can be used to see if a material like plastic is a good conductor of electricity, or a poor conductor of it.

You may replace the lamp with the color LED (D8, “+” on left).

Materials that have low resistance to the flow of electricity are called **conductors**, and materials that have high electrical resistance are called **insulators**.

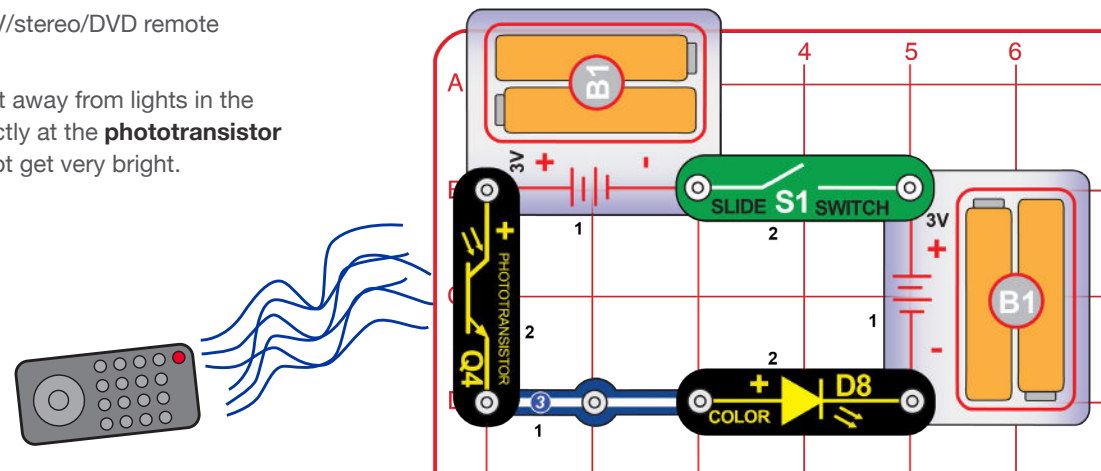


PROJECT 60 Infrared Controlled Light

You need an **infrared remote control** for this project, such as any TV/stereo/DVD remote control in your home.

Build the circuit and turn on the **slide switch (S1)**. Position the circuit away from lights in the room so that the color LED (D8) is off. Point your remote control directly at the **phototransistor (Q4)**, and press any button to turn on the color LED. The LED may not get very bright.

The phototransistor detects light, including infrared light that is invisible to the human eye.



PROJECT 61

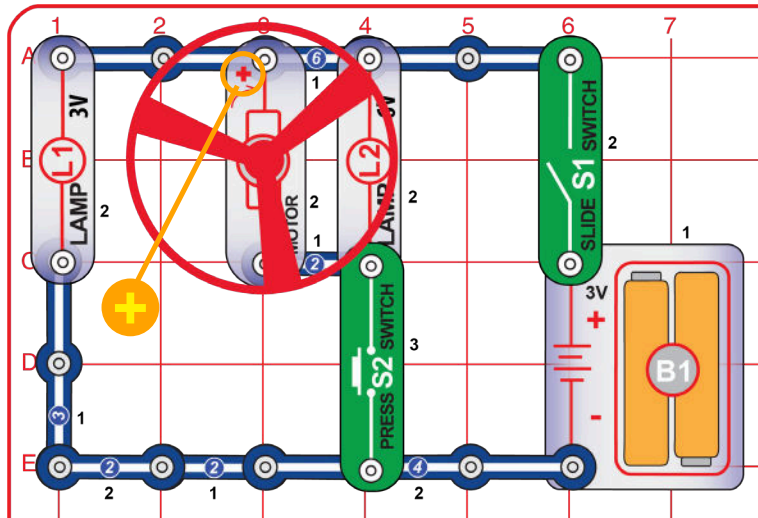
Battery Load

Build the circuit below. Turn on the **slide switch (S1)**, the 3V lamp (L1) lights. Push the **press switch (S2)** to spin the motor (M1) and light the 6V lamp (L2). Notice that L1 is dimmer when S2 is pressed.

Swap the 3V lamp with the **motor & fan**. Notice how the fan slows down a little when S2 is pressed.

PROJECT 62 Battery Load II

In the original circuit, replace the motor and 6V lamp with the **color LED (D8, "+" on top)** and **red/yellow LED (D10)**. Notice that the lamp brightness does not change when you push S2.



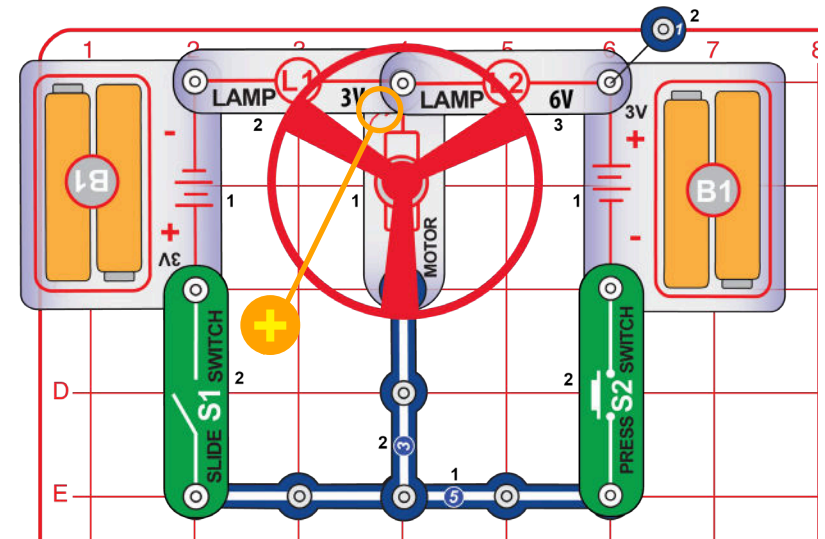
Pushing S2 turns on the motor and 6V lamp, increasing the amount of electrical current drawn from the batteries. Batteries produce electricity using a chemical reaction, but not all of the battery chemicals can react at once, so sometimes batteries cannot supply as much electricity as a circuit wants. When this happens, the batteries are overloaded and the voltage drops. This is why the lamp gets a little dimmer (or the fan slows down a little) when S2 is pressed. This effect is more noticeable when the batteries are weak.

LEDs need much less current than the lamps or motor, so adding them to the circuit with S2 has very little effect on the batteries, or the lamp brightness.

PROJECT 63

Motor Rotation

Push and release the **press switch (S2)** - the fan rotates clockwise. Turn on the **slide switch (S1)** - now the fan spins the other way. The positive (+) side of the battery is connected to the negative (-) side of the motor. The polarity on the motor determines which way it rotates.

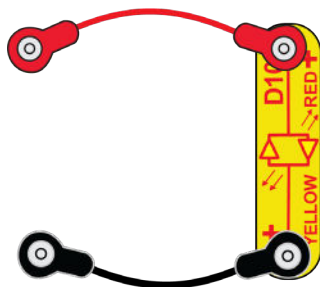


When you push the press switch you connect the positive (+) side of the right battery (B1) to the positive (+) side of the motor, and it spins clockwise. When you turn on the slide switch the positive (+) side of the left battery is connected to the negative (-) side of the motor, making it spin counter-clockwise. The polarity on the motor determines which way it rotates.

PROJECT 64

Battery Polarity Tester

Use this circuit to check the polarity of a battery (2V or higher). Connect the **red/yellow LED (D10)** to your battery using the red & black jumper wires. You can also connect them to your **B1** battery holder. If the positive (+) side of your battery is connected to the red wire then the red/yellow LED will be red, if the negative (-) side is connected to the red wire then the LED will be yellow.



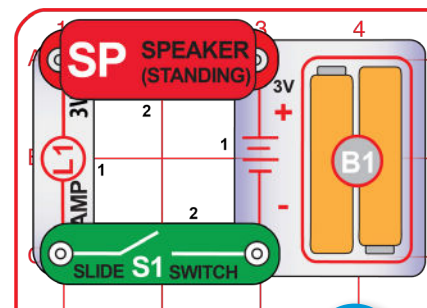
Usually this circuit will not check 1.5V batteries because the LED needs at least 1.5V to turn on, so the LED may be very dim or not light at all. Instead you can check a 1.5V battery by replacing the red/yellow LED (D10) with the 3V lamp (L1). If the lamp lights then the battery is working, but you cannot check battery polarity using the lamp.

PROJECT 65

Speaker and Lamp

Turn the **slide switch (S1)** on and off several times and listen closely to the speaker (SP). You hear static from the speaker when you first turn on the switch, but hear nothing after it is left on.

The speaker sound may be hard to hear over the switch contacts noise. To make the sound easier to hear, replace the slide switch with a **3-snap wire**, and gently touch one side onto the snap below it several times.



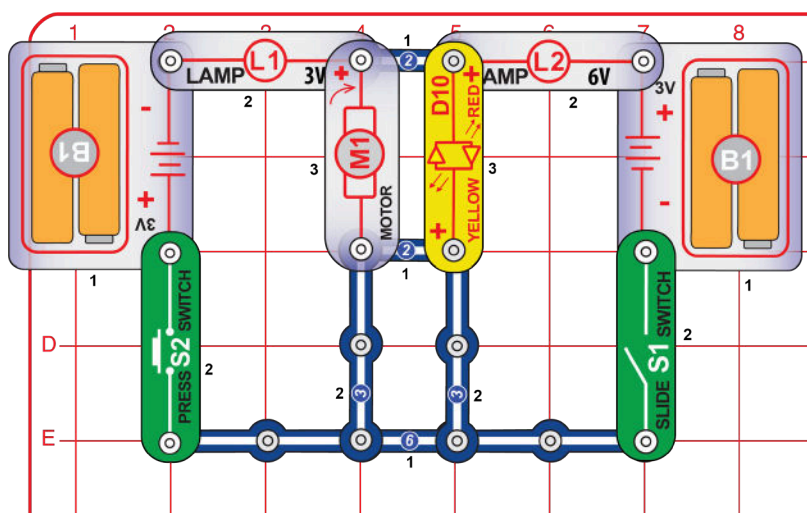
The speaker uses electromagnetism to create changes in air pressure, which your ears feel and interpret as sound. Think of the speaker as creating pressure waves in the air just like waves in a pool. You only see waves in the pool when you disturb the water, so the speaker only makes sound when the voltage changes.

PROJECT 66

LED Rotation Indicator

Do not place the fan onto the motor (M1). Turn the **slide switch (S1)** on. The motor rotates clockwise, and the red/yellow LED (D10) lights red. When you connect the positive (+) side of the battery (B1) to the positive (+) side of the motor, it spins clockwise. Turn the slide switch off and press the **press switch (S2)**. Now the fan spins the other way and the red/yellow LED lights yellow. The positive (+) side of the battery is connected to the negative (-) side of the motor. The polarity on the motor determines which way it rotates.

Now place the fan on the motor, and turn on **S1** or **S2** (not both). Now one of the lamps (L1 or L2) lights as the motor spins, but the LED is dim.



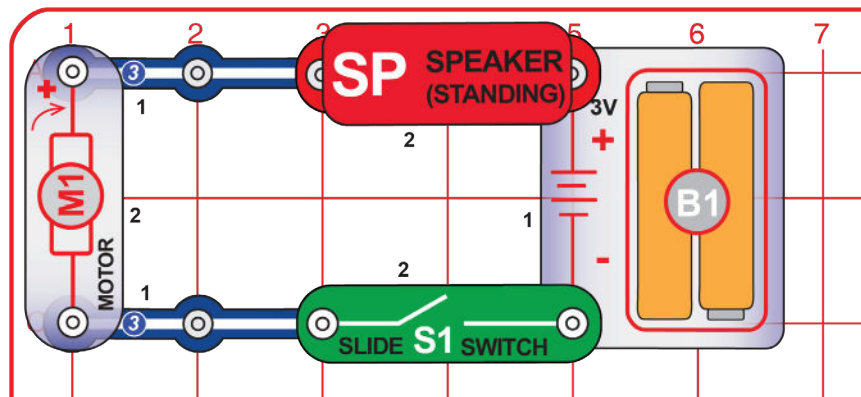
The motor needs a lot of current to spin the fan, but only a little current to spin without it. In this circuit, a lamp lights when the motor current is high, and an LED lights when the motor current is low. The lamps also prevent a short circuit if both switches are on.

PROJECT 67

Hear the Motor

Turn on the **slide switch (S1)**. If the shaft on the motor (M1) isn't spinning, then give it a push to get started. Listen to the motor.

You can also try this circuit with the fan on the motor.



Why does the motor make sound?

A motor uses magnetism to convert electrical energy into mechanical spinning motion. As the motor shaft spins around it connects/disconnects several sets of electrical contacts to give the best magnetic properties. As these contacts are switched, an electrical disturbance is created, which the speaker converts into sound.

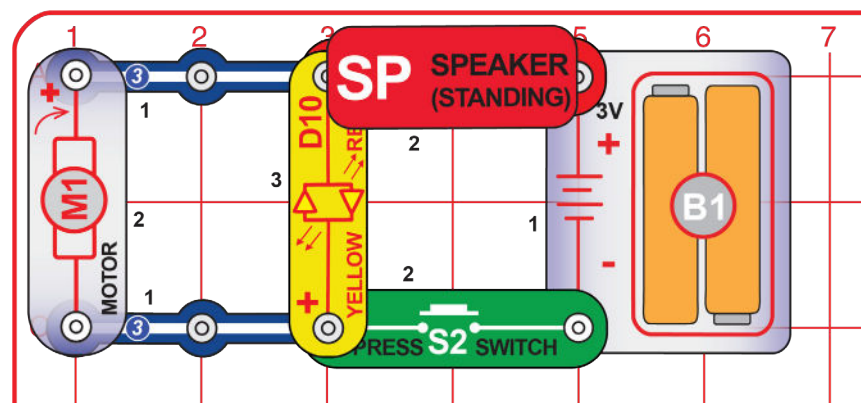
PROJECT 68

Motor Power

Build the circuit as shown, push the **press switch (S2)**, and look at the brightness of the red/yellow LED (D10). Try it three ways: with no fan on the motor, with the fan on the motor, and keeping the motor from spinning with your fingers. When the motor is spinning, you will hear noise from the speaker (SP).

PROJECT 69 More Motor Power

Use the preceding circuit but replace the red/yellow LED (D10) with the **color LED (D8)**, see how it compares to D10.



The color LED needs more electricity to light than the red/yellow LED. The motor "noise" that you hear on the speaker can also confuse the color LED and disrupt its color pattern.

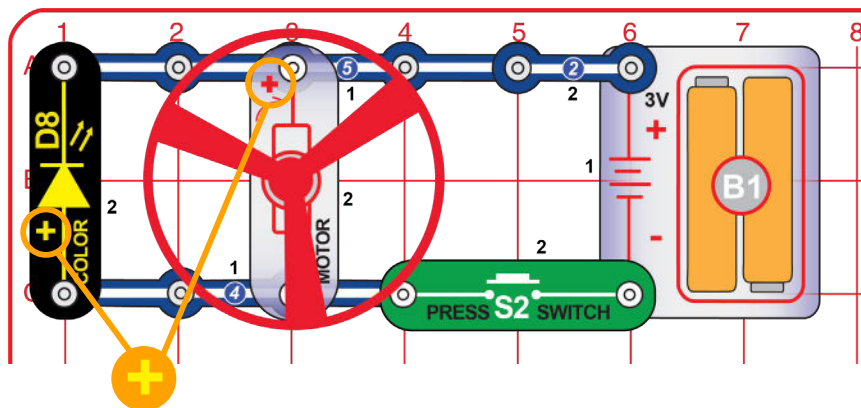
The motor needs a lot of electricity to start spinning, but needs less the faster it is spinning. When kept from spinning by your fingers, the motor sucks up all the electricity, leaving none to light the LED. With the fan on the motor, the LED gets enough electricity to light. When the motor is spinning without the fan, the LED gets lots of electricity and is bright.

PROJECT 70

Fan Storing Energy

Push the **press switch (S2)** for a few seconds and then watch the color LED (D8) as you release the press switch. The color LED lights briefly but only after the batteries (B1) are disconnected from the circuit.

If you reverse the motor direction, then the color LED will light the same way, but the fan may fly off after the LED lights.



PROJECT 71 Antenna Storing Energy

Replace the motor (M1) with the **antenna (A1)**. Push and release the **press switch (S2)** and watch the color LED (D8) as you release the switch. As with the motor, the color LED lights briefly but only after the batteries (B1) are disconnected from the circuit.

Do you know why the LED lights? It lights because the mechanical energy stored in the fan blade and the motor shaft make the motor act like a generator. When the press switch is released, this energy creates a brief current through the LED. If you remove the fan blade from the circuit then the LED will be dimmer, because the motor shaft alone does not store as much mechanical energy.

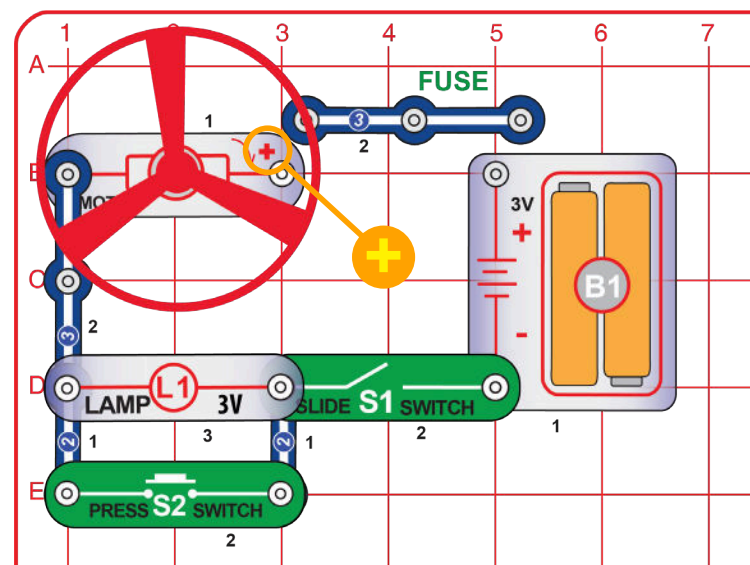
The antenna works differently from the motor because the antenna stores energy in a magnetic field. When S2 is released, this field creates a brief current through the color LED.

Note that the energy stored in a magnetic field acts like mechanical momentum, unlike capacitors which store energy as an electrical charge across a material. You can replace the antenna with any of the capacitors but the LED will not light. Energy stored in the magnetic fields of coils was called electrical momentum in the early days of electronics.

PROJECT 72

Fuse

Pretend the 3-snap wire marked fuse in the drawing on the left is a device that will open the circuit if too much current is taken from the battery. When you close the **slide switch (S1)**, current flows from the batteries through the slide switch (S1), the lamp (L1), motor (M1), and back to the battery (B1). When **press switch (S2)** is closed, the light is shorted and motor speed increases due to an increase in current to the motor. While still holding press switch (S2) down, remove the 3-snap wire marked fuse and notice how everything stops. Until the fuse is replaced, the open circuit path protects the electronic parts. If fuses did not exist, many parts could get hot and even start fires. Replace the 3-snap wire and the circuit should return to normal.



Many electronic products in your home have a fuse that will open when too much current is drawn. Can you name some?

PROJECT 73 Water Detector

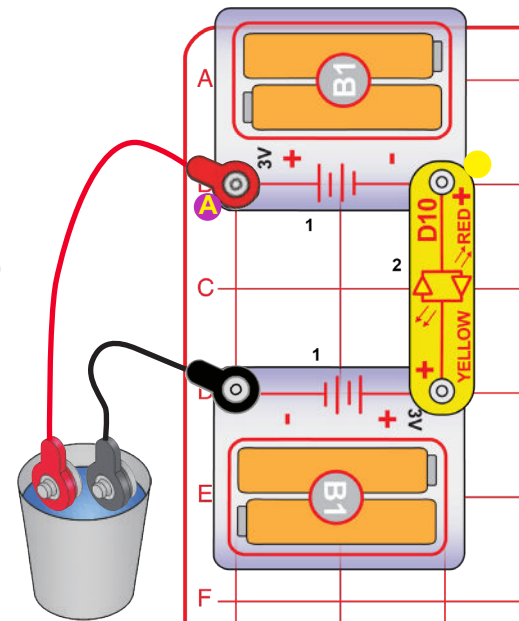
Build the circuit as shown, leaving the ends of the red & black jumper wires unconnected for now. The red/yellow LED (D10) should be off.

Place the loose ends of the red & black jumper wires into a **cup of water** (but not distilled water), without them touching each other. The LED should be on now, because water conducts electricity, completing this circuit. (You have detected water!)

Reduce the voltage by moving the end of the red jumper wire from point **A** to point **B**. The LED should be dimmer now.

Try dissolving some salt in the water or using different liquids, and see how the LED brightness changes. You can also replace the red/yellow LED with the **color LED (D8)**.

Don't drink any liquids used here.



Pure water (like distilled water) has very high resistance, but drinking water has impurities mixed in that increase the flow of electricity. Dissolving salt in water increases its electrical conductivity. Your body is mostly water, so it can conduct electricity.

PROJECT 74 Water Detector II

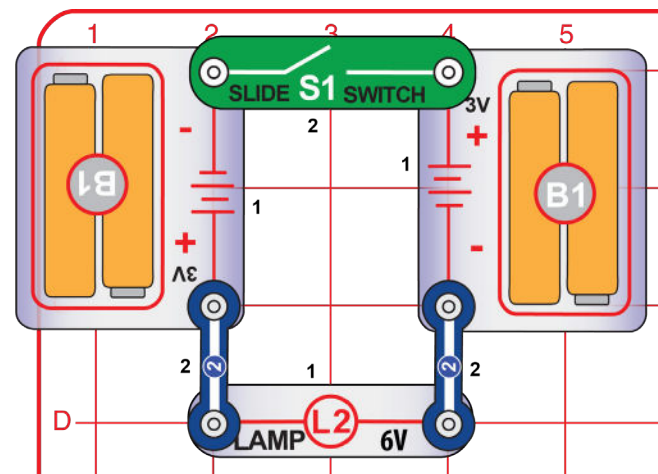
Use the same circuit, with the red jumper wire connected to point A. Instead of placing the red & black jumper wires in water, touch the metal part of each with your fingers, using your body to complete the circuit. Wet your fingers to get better electrical contact. The LED should be on, but brightness may vary.

PROJECT 75 Electric Heater

Turn on the **slide switch (S1)**, cover the holes in the top of the **6V lamp (L2)** with your finger, and wait. After a short time you should feel the lamp heating up.

Do not leave the circuit for two minutes because the lamp will be hot.

Incandescent light bulbs like L4 contain a special thin wire that gets so hot when electricity flows through it that it glows. Only about 5% of the electricity used in incandescent light bulbs is used to make light; the rest becomes heat, which is why you can feel the L4 lamp heat up when you cover its venting holes. Electric space heaters convert electricity to heat in a similar way to warm up a room.



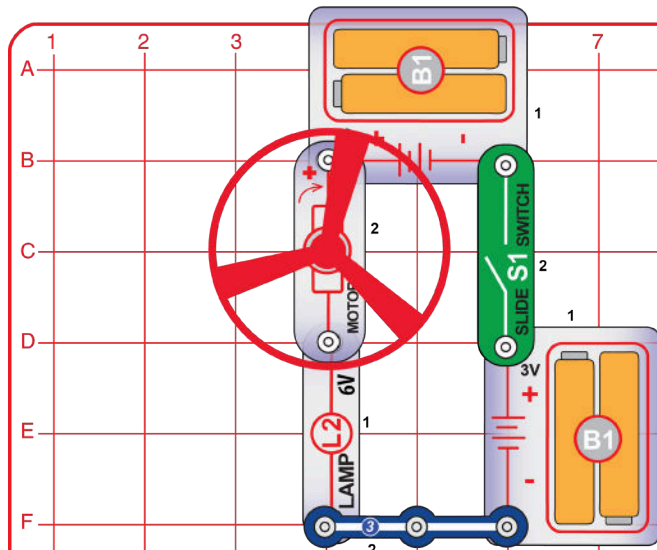
CAUTION: Very warm lamp enclosure.

PROJECT 76

Back EMF

Turn on the **slide switch (S1)**. The 6V lamp (L2) starts out bright, then dims a little as the motor speeds up.

Now turn off the slide switch, remove the fan, and turn the slide switch back on. The lamp may light dimly at first but then turns off.



The voltage from the batteries pushes an electric current through a coil in the motor, which spins the shaft using magnetism. But the spinning shaft also uses magnetism to produce a current in the coil, which opposes the current from the batteries.

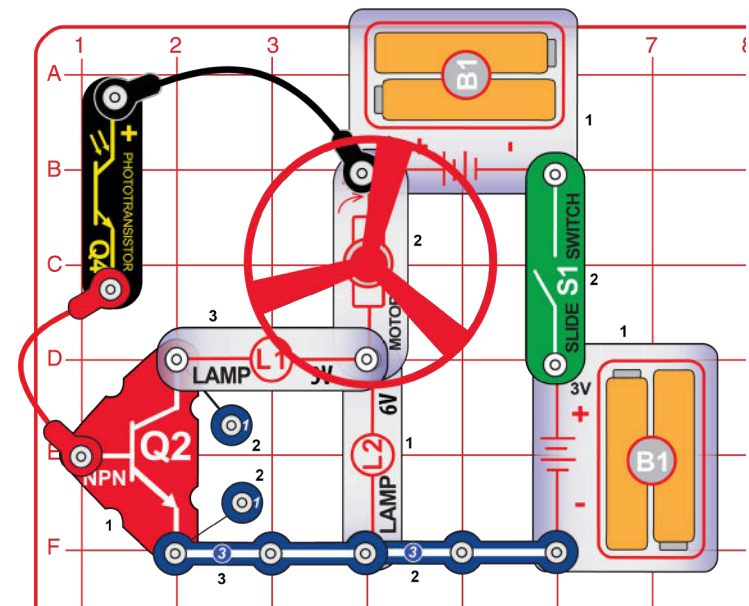
The result is that the motor has low resistance when the shaft isn't spinning fast, allowing a higher current to make the lamp bright. When the shaft is spinning really fast without the fan, the motor has high resistance, limiting the current and keeping the lamp dim.

The voltage/current produced by a motor when it is spinning is called its Back Electro-Motive-Force (Back EMF); this may be thought of as the motor's electrical resistance. The motor's Front Electro-Motive-Force is the force it exerts in trying to spin the shaft. This circuit demonstrates how the Back EMF increases and the overall current decreases as the motor speeds up.

PROJECT 77

Back EMF II

Expand the Back EMF circuit as shown. Turn on the **slide switch (S1)**, and hold the **phototransistor (Q4)** next to the **6V lamp (L2)** so the light shines on it. Watch how one or both of the lamps are bright at first, then get dimmer as the motor speeds up. By moving the phototransistor (Q4) next to or away from the 6V lamp, you should be able to change the motor speed. To slow the motor down even more, cover the phototransistor.



Holding the phototransistor next to the 6V lamp increases the current through the phototransistor, which turns on the NPN transistor (Q2), which makes the 3V lamp bright, which diverts motor current away from the 6V lamp and makes it dimmer, which reduces the amount of light shining on the phototransistor. So when the phototransistor is held next to the 6V lamp, the NPN transistor will try to keep the motor at a constant speed.

PROJECT 78

Electricity You Can Wear

Did you ever wonder why clothes cling together when they come out of the dryer? Did you ever hear a crackling sound when you take off a sweater? If the room is dark you might even see sparks. Have you ever felt a “zap” when you touch someone wearing a sweater on a dry day?

These effects are caused by electricity. We call this static electricity because the electrical charges are not moving, although pulling clothes apart sounds like static on a radio. When electricity is moving (usually through wires) to do something in another place, we call it an electric current.

Note: This project works best on a cold dry day. If the weather is humid, the water vapor in the air allows the static electric charge to dissipate, and this project may not work.

Clothes can cling together because electricity is all around us.



Find some clothes that cling together in the dryer, and try to uncling them.



The crackling noise you hear when taking off a sweater is static electricity. You may see sparks when taking one off in a dark room.



Rub a sweater (wool is best) and see how it clings to other clothes.

PROJECT 79

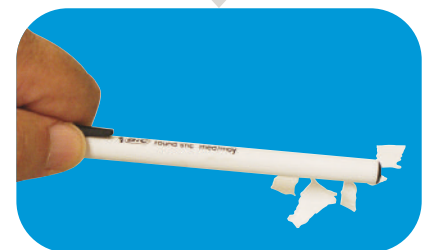
Electricity in Your Hair

You need a **comb (or a plastic ruler)** and some **paper** for this project. Rip up the paper into small pieces. Run the **comb through your hair several times** then **hold it near the paper pieces to pick them up**. You can also use a pen or plastic ruler, rub it on your clothes (wool works best).

Rubbing the comb through your hair pulls extremely tiny charged particles from your hair onto the comb. These give the comb a static electrical charge, which attracts the paper pieces.

Note: This project works best on a cold dry day. If the weather is humid, the water vapor in the air allows the static electric charge to dissipate, and this project may not work.

Notice how your hair can “stand up” or be attracted to the comb when the air is dry. Wetting your hair dissipates the static charge.



PROJECT 80

Bending Water

You need a **comb (or plastic ruler)** and a **water faucet** for this project. Run the **comb through your hair several times** then **hold it next to a slow, thin stream of water** from a faucet. The water will bend towards it. You can also use a plastic ruler. Rub it on your clothes (wool works best).

Rubbing the comb through your hair builds up a static electrical charge on it, which attracts the water.

Note: This project works best on a cold dry day. If the weather is humid, the water vapor in the air allows the static electric charge to dissipate, and this project may not work.



Static electricity was discovered more than 2,500 years ago when the Greek philosopher Thales noticed that when amber (a hard, clear, yellow-tinted material) is rubbed, light materials like feathers stick to it. Electricity is named after the Greek word for amber, which is electron.



PROJECT 81

Static Tricks

Electricity vs. Gravity:

Electricity is immensely 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's 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, you have seen how clothes can cling together in the dryer due to static electricity. There is also a gravity attraction between the sweaters, but it is always extremely small.

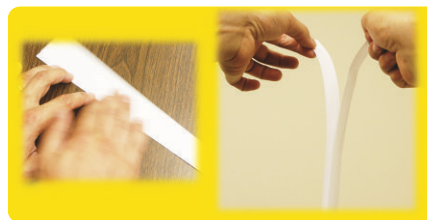
Note: This project works best on a cold dry day. If the weather is humid, the water vapor in the air allows the static electric charge to dissipate, and this project may not work.



If you have two balloons, rub them to a sweater and then hang the rubbed sides next to each other. They repel away. You could also use the balloons to pick up tiny pieces of paper.



Take a piece of newspaper or other thin paper and rub it vigorously with a sweater or pencil. It will stick to a wall.



Cut the paper into two long strips, rub them, then hang them next to each other. See if they attract or repel each other.



Electricity



Gravity

5. Capacitors

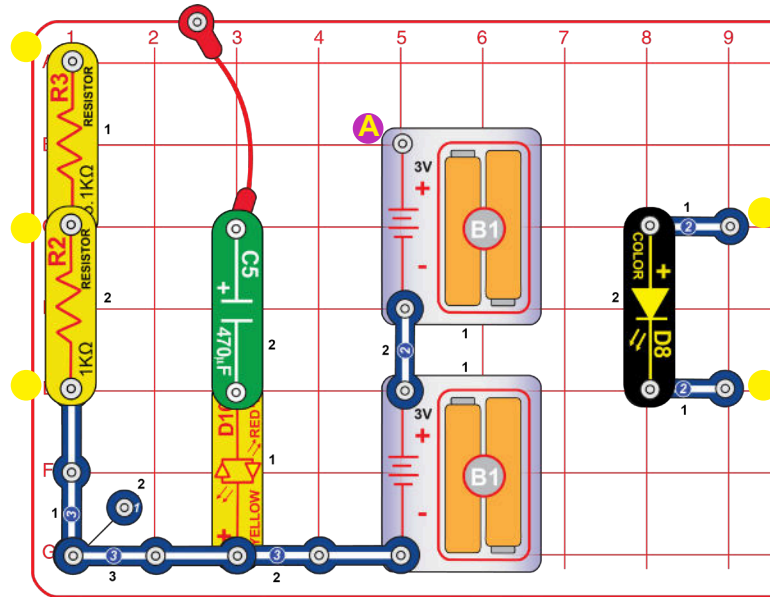
PROJECT 82 Mini Battery

Touch the loose end of the **red jumper wire** to point A. The red/yellow LED (D10) briefly lights red as batteries charge up the 470 μ F capacitor (C5). Now touch the loose end of the red wire to point B. The red/yellow LED briefly lights yellow as the capacitor discharges. Repeat touching the red wire to point A and then point B several times.

Instead of touching the red wire to point B to discharge the capacitor, touch it to point C or point D. The red/yellow LED stays on longer but does not get as bright.

Touch the red wire to point A to charge C5, then remove C5 from the circuit and place it across points E & F ("+" to E) to light the color LED (D8). Return C5 to the original circuit and repeat.

Replace C5 with the smaller 100 μ F capacitor (C4) or the much smaller 10 μ F capacitor (C3). The red/yellow LED goes out faster because the smaller capacitors charge and discharge faster.



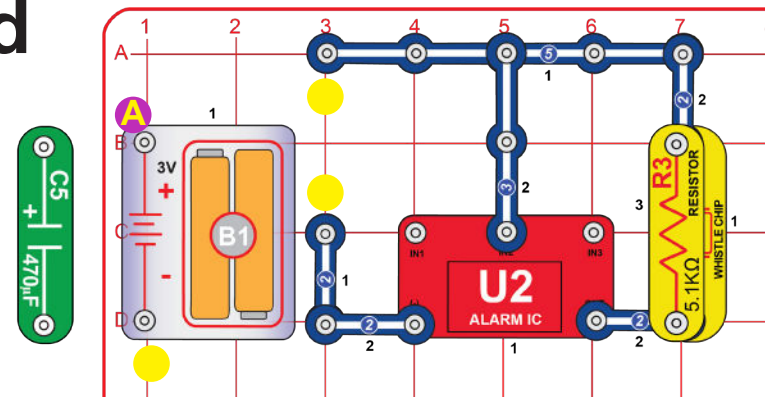
Capacitors are similar to tiny rechargeable batteries, but capacitors store energy in an electric field while batteries energy in chemical form. Although capacitors can't store as much electricity as batteries, capacitors can store and release electricity much faster than batteries. And, like a battery, a capacitor can store electricity for a long time. Notice that once C5 is charged, you can remove it from the main circuit and place it across the mini circuit containing D8.

Capacitors and rechargeable batteries are used in many devices in your home to store information, like the date or time, when the devices are turned off or when the power goes out in your home.

PROJECT 83 Mini Battery Sound

Touch the **470 μ F capacitor (C5)** across points A & B to charge it, then place it across points C & D to discharge it through the alarm IC (U2) circuit, which makes sound for a short time. Touch it across A & B, then across C & D several times.

Touching the capacitor across points A & B instantly charges it up from the batteries. Placing the capacitor across points C & D discharges it while powering the alarm IC circuit. The whistle chip (WC) is used here because it needs a lot less power to make sound than the speaker would.

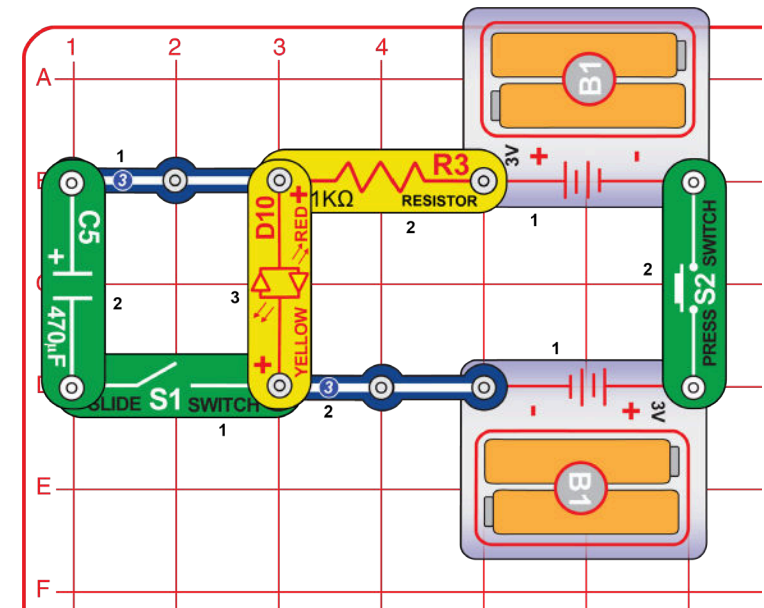


PROJECT 84 Slow Down a Circuit

Turn off the **slide switch (S1)**, then push and release the **press switch (S2)**. Notice the red/yellow LED (D10) turns on and off instantly.

Now turn on the slide switch and push the press switch again. Now the red/yellow LED turns on and off slowly.

When S1 is on, current through the 5.1k Ω resistor (R3) must charge up the 470 μ F capacitor (C5) before it can flow through the LED to turn it on. And when current through R3 stops because S2 was released, the stored charge in C5 discharges through the LED, keeping it on for a short time. So the capacitor delayed the change in the LED after S2 was pressed or released. Capacitors are often used to delay changes in circuits.



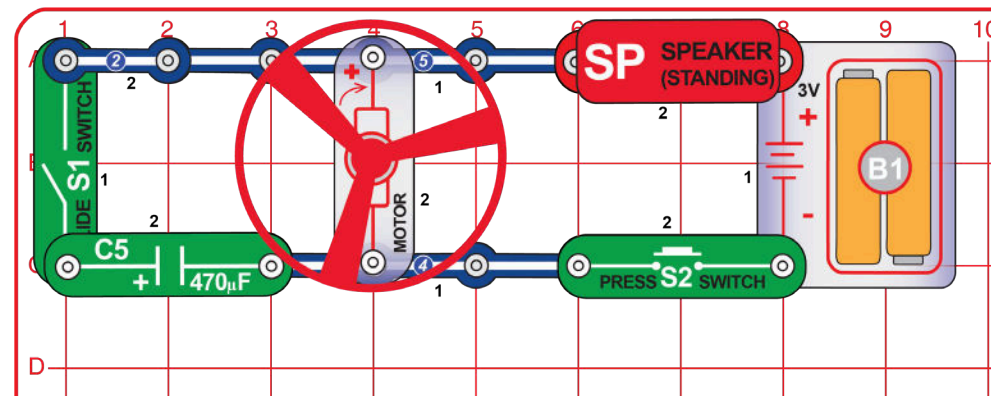
PROJECT 85 Quieting a Motor

Turn off the **slide switch (S1)**. Press the **press switch (S2)** and listen to the motor.

Now turn on the slide switch and push the press switch again. The fan spins just as fast, but the sound is not as loud.

If you replace the 470 μ F capacitor (C5) with one of the other capacitors in your set then the sound will not be changed as much.

As the motor shaft spins around it connects/disconnects several sets of electrical contacts. As these contacts are switched, an electrical disturbance is created, which the speaker converts into sound. Turning on the slide switch connects the 470 μ F capacitor (C5) across the motor, and the capacitor's electrical storage ability absorbs most of the motor's electrical disturbance and filters them out. Capacitors are often used to filter out undesired electrical disturbances.

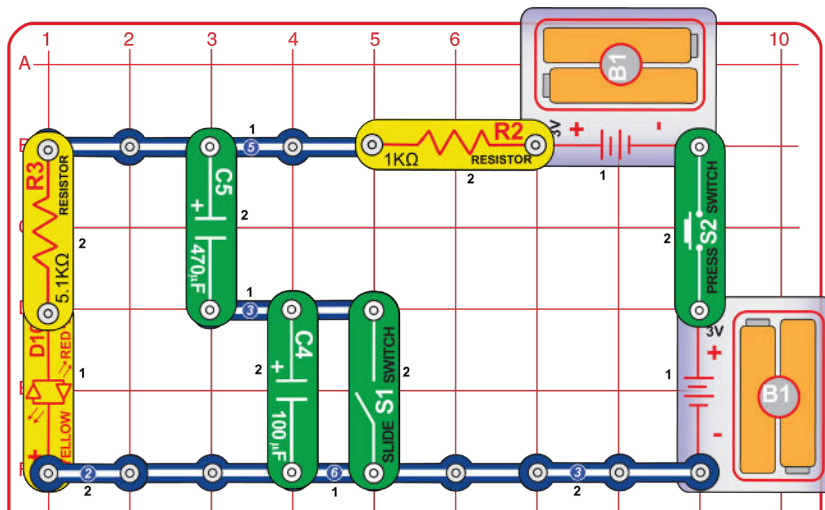


PROJECT 86

Capacitors in Series

Turn on the **slide switch (S1)**, then press and release the **press switch (S2)**. The red/yellow LED (D10) becomes bright when the 470 μ F capacitor charges up with the press switch on, then the LED slowly gets dim after you release the press switch.

Now turn off the slide switch. Repeat the test with the slide switch off; you'll notice the LED goes out much faster after you release the press switch.



PROJECT 87 Capacitors in Series II

Replace the 1k Ω resistor (R2) with the 100 Ω resistor (R1) and replace the 5.1k Ω resistor (R3) with the 1k Ω resistor (R2). The LED is brighter but goes out faster. You can also replace the red/yellow LED (D10) with the color LED (D8, “+” on top).

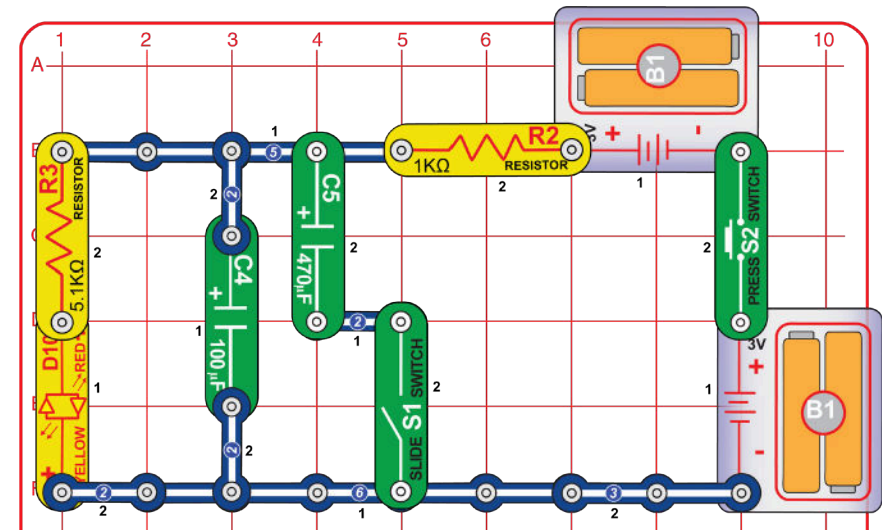
When S1 is off, the much smaller 100 μ F capacitor (C4) is in series with the 470 μ F and so reduces the total capacitance (electrical storage capacity), and they discharge much faster. Note that this is opposite to how resistors in series work.

PROJECT 88

Capacitors in Parallel

Turn off the **slide switch (S1)**, then press and release the **press switch (S2)**. The red/yellow LED (D10) becomes bright when the 100 μ F capacitor charges up with the press switch on, then the LED slowly gets dim after you release the press switch.

Now turn on the slide switch and repeat the test; you'll notice the LED goes out much slower after you release the press switch.



PROJECT 89 Capacitors in Parallel II

Replace the 1k Ω resistor (R2) with the 100 Ω resistor (R1) and replace the 5.1k Ω resistor (R3) with the 1k Ω resistor (R2). The LED is brighter but goes out faster. You can also replace the red/yellow LED (D10) with the color LED (D8, “+” on top).

When S1 is on, the much larger 470 μ F capacitor (C5) is now in parallel with the 100 μ F and so increases the total capacitance (electrical storage capacity), and they discharge much slower. Note that this is opposite to how resistors in parallel work.

PROJECT 90 Quick Fade Siren

Turn on the **slide switch (S1)**, you hear a siren that fades out in a few seconds. Push the **press switch (S2)** to re-start the sound.

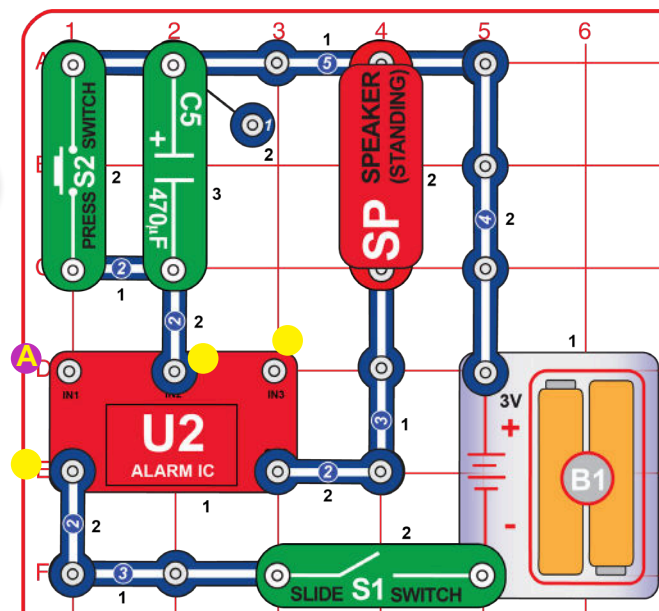
PROJECT 91 Quick Fade Siren II

Add a connection between points **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire. The sound is different now.

PROJECT 92 Quick Fade Siren IV

Replace the 470 μ F capacitor (C5) with the smaller 100 μ F capacitor (**C4**) or the much smaller 10 μ F capacitor (**C3**). The siren fades out faster.

Here the alarm IC (U2) is powered through the 470 μ F capacitor (C5), so the siren plays as C5 charges up. Once C5 is fully charged, current stops flowing through it, so U2 turns off. Pressing S2 discharges C5 and resets the circuit.



PROJECT 93 Storing Electricity

Turn the **slide switch (S1)** on and connect points **A & B** with a **2-snap wire**. The red/yellow LED (D10) will flash as the 470 μ F capacitor (C5) charges up with electricity. The electricity is now stored in the capacitor. Disconnect points A & B and connect points **B & C**. There will be a flash from the 6V lamp (L2). Connect points A & B and then B & C several times.

PROJECT 94 Storing Electricity II

Replace the lamp (L2) with the **color LED (D8, "+" on top)** or the motor (M1, "+" on top) and fan. The fan spins for a short time but the color LED lights for a while.

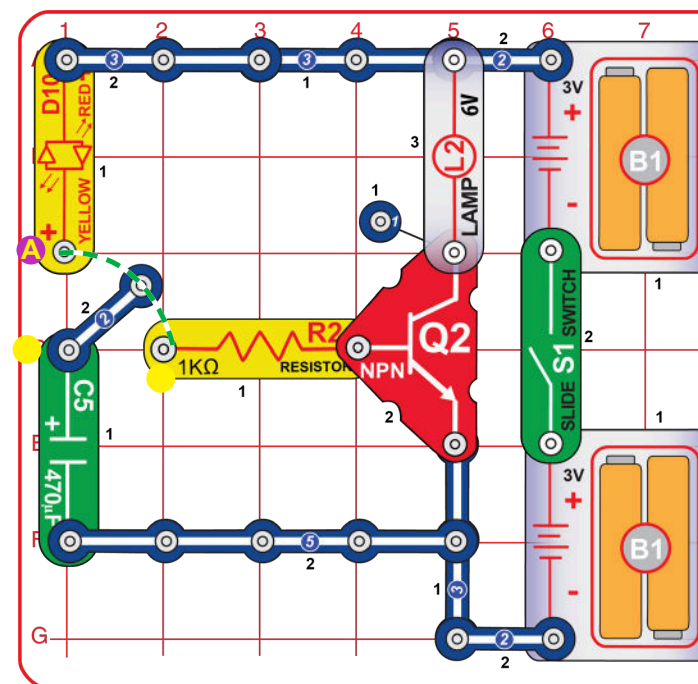
PROJECT 95 Storing Electricity III

Use any of the preceding circuits but replace the 1k Ω resistor (R2) with the smaller **100 Ω resistor (R1)**. The lamp/LED/motor goes out faster.

PROJECT 96 Storing Electricity IV

Replace the 470 μ F capacitor (C5) with the smaller **100 μ F capacitor (C4)**. The smaller capacitor charges up faster but also discharges faster.

The capacitor discharges through the resistor and NPN transistor (Q2), which controls the lamp. The lamp will go out after the capacitor discharges, because there is no more current to the transistor. Lowering the resistor and capacitor values speeds up the discharge time.



PROJECT 97

Slow Motor Speed Control

Build the circuit as shown, and do not place the fan on the motor. Set the lever on the **adjustable resistor (RV)** toward the 3-snap. Turn on the **slide switch (S1)** to start the **motor (M1)**. If the motor does not spin, then give it a push to get it started. Use the lever on the adjustable resistor to control the motor speed. If the motor does not spin even after giving it a push then replace your batteries.

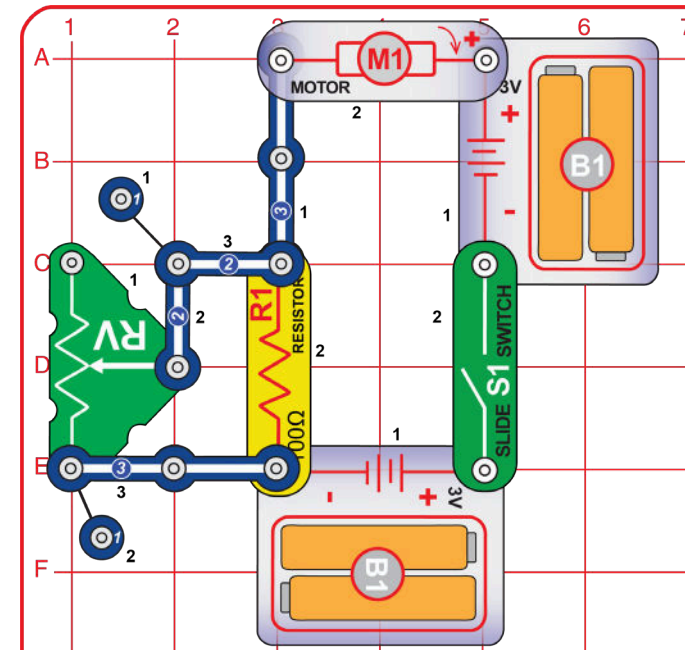
Turn off the switch and turn the motor shaft counter-clockwise with your fingers. Now turn the switch on try turning the motor counterclockwise; now it is harder because the circuit is trying to turn the motor clockwise at the same time.

PROJECT 98 Slow Motor Start Aid

Add the 470 μ F capacitor (C5) directly over the 100 Ω resistor (R1), "+" on top. The circuit works the same, but starts more easily.

The motor needs a lot of electricity to start spinning, but needs less the faster it is spinning. The resistors (R1 & RV) are limiting how much electricity flows, so the motor can barely spin.

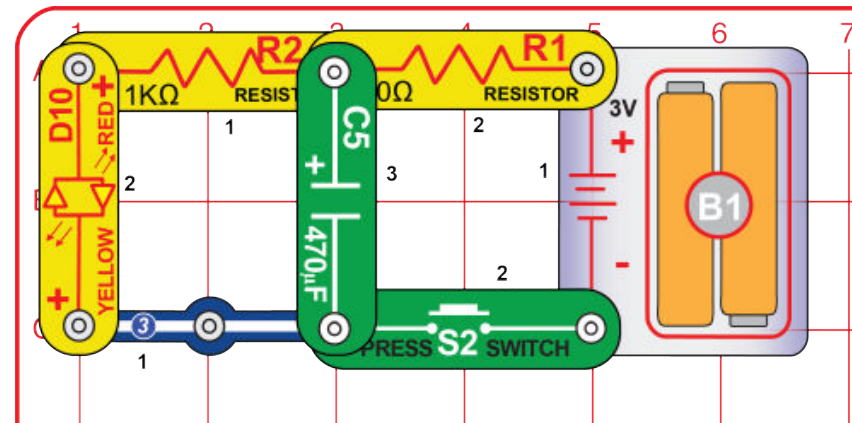
The capacitor allows a short surge of electricity to flow through it until it charges up. This short surge bypasses the higher resistance of the resistors, and helps the motor get going.



PROJECT 99 Slow Off Switch

Build the circuit and push the **press switch (S2)**. The LED (D10) turns off slowly after you release the switch.

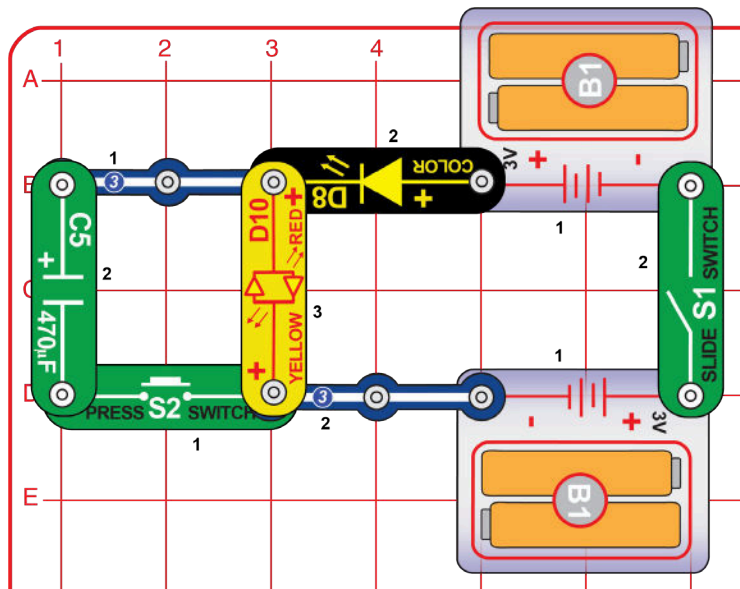
This delay in turning off the LED is caused by the 470 μ F capacitor (C5). Capacitors can store electricity and are used to delay changes in voltage. They can block unchanging voltages while passing fast-changing voltages.



PROJECT 100

Power Outage Helper

Turn on the **slide switch (S1)**, both LEDs (D8 & D10) are flashing. Push and hold the **press switch (S2)**, now the red/yellow LED gets dimmer but does not turn off.



As the color LED (D8) changes colors it briefly blocks current to the red/yellow LED (D10), so the red/yellow LED flashes in sync with the color LED.

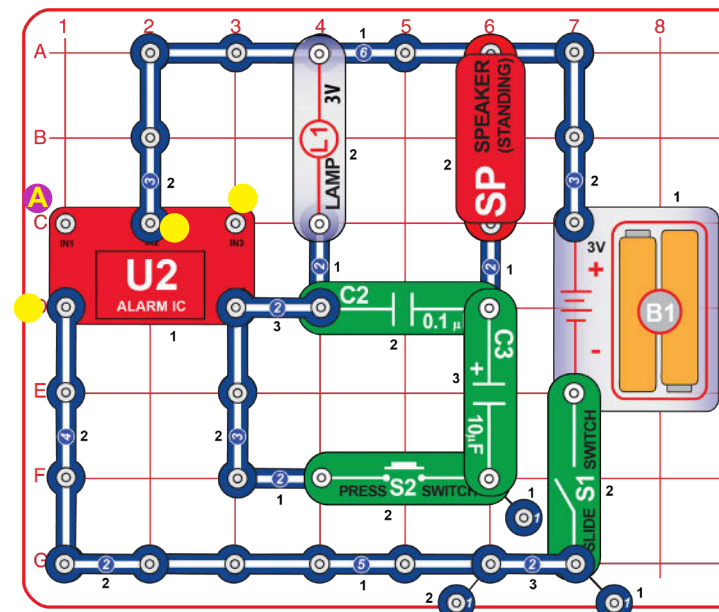
Pressing S2 places the 470mF capacitor (C5) across the red/yellow LED. The capacitor stores electricity, and uses it to help the red/yellow LED stay on when the color LED blocks the current to it.

PROJECT 101

Frequency Resistor—U2

Turn on the **slide switch (S1)**, the sound is not very loud. Push the **press switch (S2)** to make the sound louder.

Replace the 0.1μF capacitor (C2) with the **100Ω resistor (R1)** and replace the 10μF capacitor (C3) with the **10kΩ resistor (R4)**. Compare the sound volume with and without S2 pressed.



PROJECT 102 Frequency Resistor—U2 II

Make the sound different by adding a connection between points **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire.

Here capacitors and then resistors are connected in series with the speaker to change the sound volume. Notice that connecting the larger C3 capacitor in parallel with the smaller C2 capacitor makes the sound louder (indicating C3 has less resistance than C2), but connecting the larger R4 resistor in parallel with the smaller R1 resistor does not make the sound louder (indicating R4 has more resistance than R1).

Capacitors block constant or slow-changing (low frequency) signals, but pass fast-changing (high frequency) signals. Higher value capacitors have less resistance at any frequency than low value capacitors. A capacitor's resistance decreases as the frequency of the signal increases (this is not apparent here since all the sirens are similar in frequency); this is different from resistors, whose resistance is the same at all frequencies.

6. Transistors

PROJECT 103 NPN Amplifier

Turn on the **slide switch (S1)**. The red/yellow LED (D10) is dim but the color LED (D8) is bright.

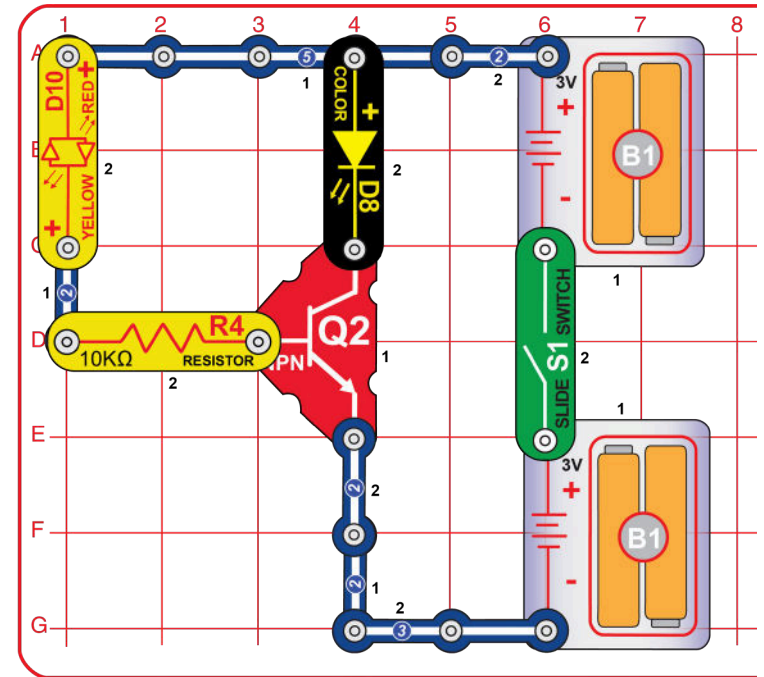
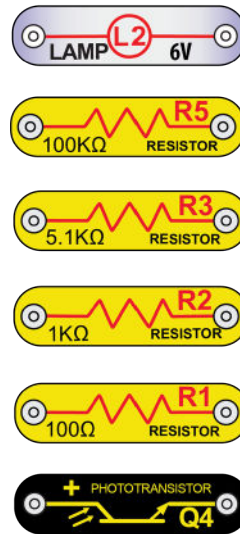
Part B: Remove either LED (D8 or D10) and see what happens to the other one.

Part C: In the original circuit, replace the 10k Ω resistor (R4) with the smaller 100 Ω resistor (R1) or the 1k Ω resistor (R2), or the larger 100k Ω resistor (R5). Compare the brightness of the LEDs.

Part D: In the original circuit, replace the 10k Ω resistor (R4) with the phototransistor (Q4, "+" on left). Vary the amount of light shining on the phototransistor. Compare the brightness of the LEDs.

Part E: In any of the preceding circuits, replace the color LED (D8) with the 6V lamp (L2). Compare the brightness of the red/yellow LED and lamp. Notice that the lamp only lights when the LED is very bright.

Part F: In the original circuit, replace the red/yellow LED with the 6V lamp and use each of the resistors (R1, R2, R3, R4, or R5). Notice that no matter which resistor is used, the lamp never lights and the color LED (D8) is always bright.



The NPN transistor (Q2) is a current amplifier, meaning it takes a small current and makes it larger. When a small current flows into Q2 through the left branch (through D10), a larger current will flow into Q2 through the right branch (with D8). Green arrows show the current flow. This is why the LED on the right side will be brighter than the LED on the left side. In fact, the current in the right branch can be as much as 100 times larger than the current in the left branch.

The left branch controls the right branch, so removing D10 turns off D8, but removing D8 does not affect D10.

A small electric current may be flowing through the left LED even when it appears to be off. This small current, when it pass through the NPN transistor (Q2) and gets amplified, can be enough to keep the right LED on.

The lamp needs much higher current to light than the LEDs (which are much more energy efficient), and will not light when placed in series with any of the resistors.



PROJECT 104 PNP Amplifier

These circuits are the opposite of projects in 103. Turn on the **slide switch (S1)**. The red/yellow LED (D10) is dim but the color LED (D8) is bright.

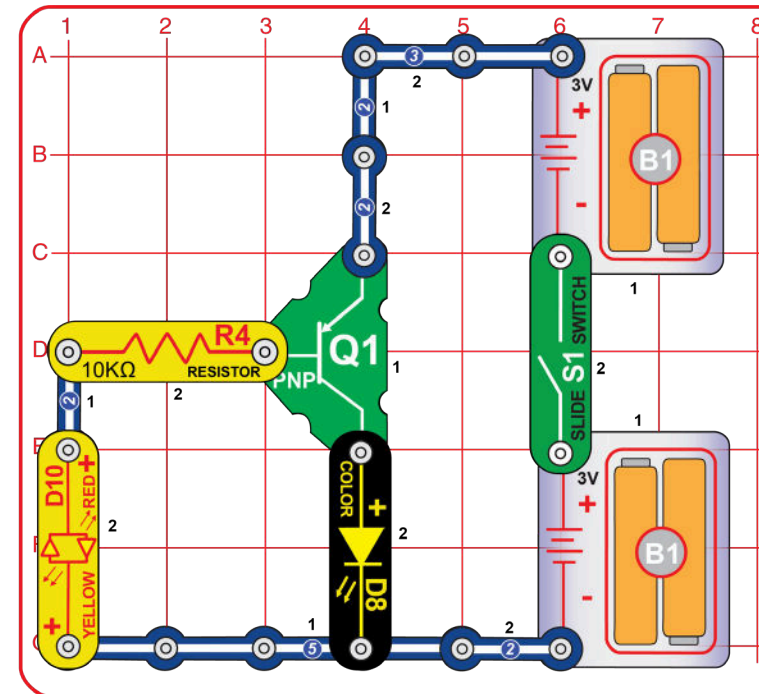
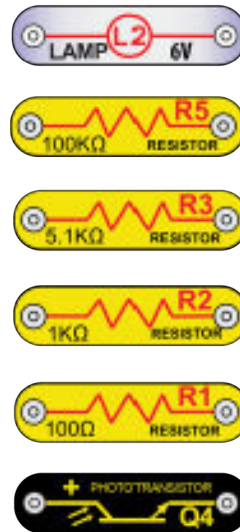
Part B: Remove either LED (D8 or D10) and see what happens to the other one.

Part C: In the original circuit, replace the 10kΩ resistor (R4) with the smaller 100Ω resistor (R1) or the 1kΩ resistor (R2), or the larger 100kΩ resistor (R5). Compare the brightness of the LEDs.

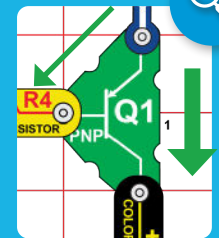
Part D: In the original circuit, replace the 10kΩ resistor (R4) with the phototransistor (Q4, “+” on right). vary the amount of light shining on the phototransistor. Compare the brightness of the LEDs. In any of the preceding circuits, replace the color LED (D8) with the 6V lamp (L2).

Part E: Compare the brightness of the red/yellow LED and lamp. Notice that the lamp only lights when the LED is very bright.

Part F: In the original circuit, replace the red/yellow LED with the 6V lamp and use each of the resistors (R1, R2, R3, R4, or R5). Notice that no matter which resistor is used, the lamp never lights and the color LED (D8) is always bright.



The PNP transistor (Q1) is just like the NPN transistor (Q2), except that currents flow in opposite directions. When a small current flows out of Q1 through the left branch (through D10), a larger current will flow out of Q1 through the right branch (with D8). Red arrows show the current flow.



PROJECT 105

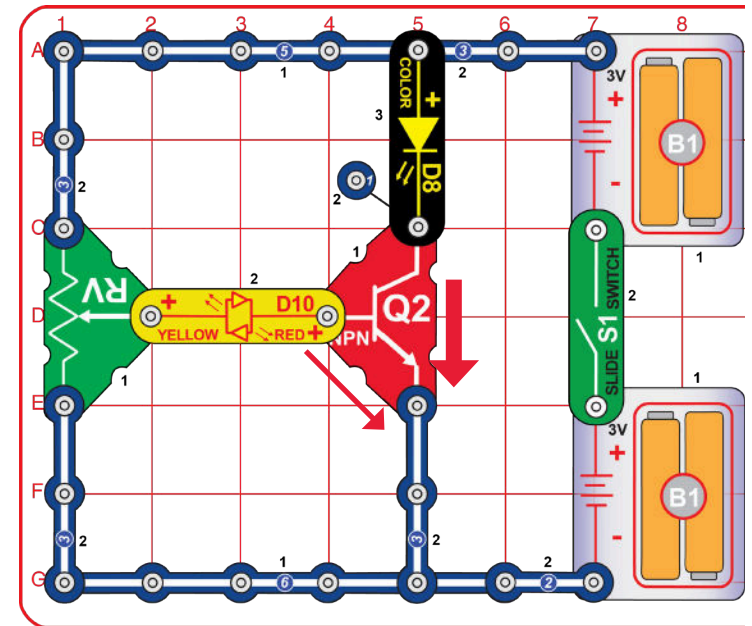
NPN Amplifier with RV

This project is similar to project 110. Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to make the LEDs (D8 & D10) light. Notice D8 is bright for a larger part of RV's range.

Part B: Replace the color LED (D8) with the **6V lamp (L2)**. The lamp is only on for a small part of RV's range.

Part C: Replace the lamp with the **motor (M1, "+" on top)** and fan. The fan only spins for a small part of RV's range.

Transistors, such as the NPN transistor (Q2), can amplify electric currents. In this circuit, the adjustable resistor controls a small current going to the transistor through the red/yellow LED. The transistor uses this small current to control a larger current through the color LED. At some RV settings, the control current is too small to light the red/yellow LED, but the transistor-amplified current is large enough to light the color LED. The lamp and motor require higher current to operate than the color LED, so only work for a smaller part of RV's range.



PROJECT 106

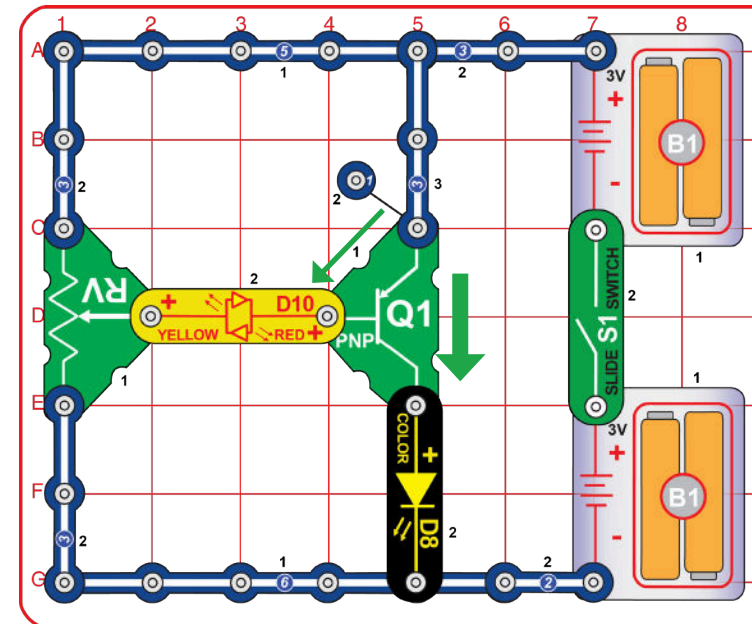
PNP Amplifier with RV

This circuit is similar to project 103, and is the opposite of project 104. Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to make the LEDs (D8 & D10) light. As in project 116, D8 is bright for a larger part of RV's range. But here the transistor control current through the red/yellow LED flows out of the PNP transistor (Q1), making D10 red instead of yellow. Also, the LEDs are bright when RV is set to the bottom instead of the top.

Part B: Replace the color LED (D8) with the **6V lamp (L2)**. The lamp is only on for a small part of RV's range.

Part C: Replace the lamp with the **motor (M1, "+" on top)** and fan. The fan only spins for a small part of RV's range.

Current flow through a PNP transistor is opposite that through an NPN transistor, as indicated by the arrows on Q1 and Q2.



PROJECT 107 NPN Emitter—Lamp

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to make the 3V lamp (L1) light. The lamp will only light for a small part of RV's range.

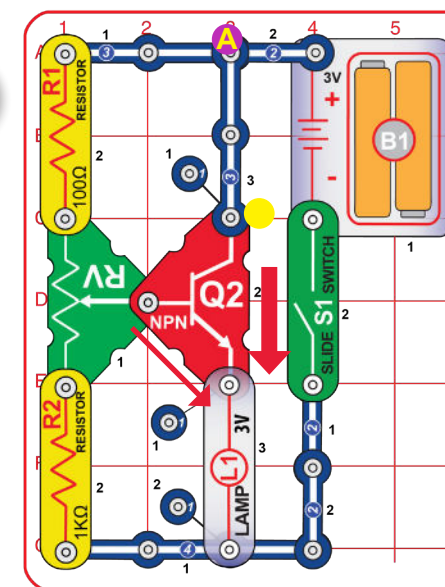
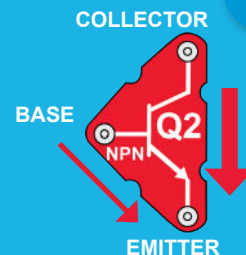
Now swap L1 with the 3-snap wire across points **A** & **B**. Notice L1 is brighter now.

PROJECT 108 NPN Emitter—Motor

Replace the lamp with the **motor (M1, "+" on top)** and fan. Place the motor in the original lamp position and across points **A** & **B**. The fan only spins for a small part of RV's range. Notice the fan spins faster when the motor is across points A & B.

In an NPN transistor, a small current flows into the snap connected to RV, this is called the **BASE** of the transistor. The small current flowing from RV into the base produces an amplified current flowing into the snap connected to the 3-snap wire, which is called the **COLLECTOR** of the transistor. The base and collector currents combine and exit through the snap connected to L1, which is called the **EMITTER** of the transistor.

The lamp is brighter when it is connected to the transistor's collector (across points A & B), because when connected to the emitter the lamp's resistance reduces the current into the base, and so reduces the current to be amplified. Connecting the lamp to the transistor's collector makes a better amplifier, but connecting it to the transistor's emitter is useful as a buffer between circuits.



PROJECT 109 PNP Emitter—Lamp

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to make the 3V lamp (L1) light. The lamp will only light for a small part of RV's range.

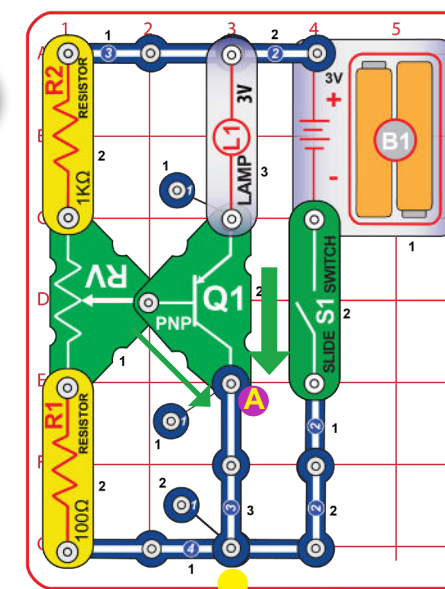
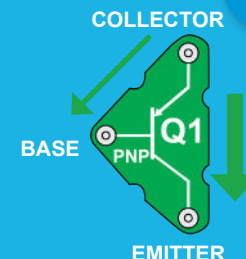
Now swap L1 with the 3-snap wire across points **A** & **B**. Notice L1 is brighter now.

PROJECT 110 PNP Emitter—Motor

Replace the lamp with the **motor (M1, "+" on top)** and fan. Place the motor in the original lamp position and across points A & B. The fan only spins for a small part of RV's range. Notice the fan spins faster when the motor is across points A & B.

In a PNP transistor, a small current flows out of the snap connected to RV, this is called the **BASE** of the transistor. The small current flowing into RV from the base produces an amplified current flowing out of the snap connected to the 3-snap wire, which is called the **COLLECTOR** of the transistor. The base and collector currents enter together through the snap connected to L1, which is called the **EMITTER** of the transistor.

The lamp is brighter when it is connected to the transistor's collector (across points A & B), because when connected to the emitter the lamp's resistance reduces the current from the base, and so reduces the current to be amplified. Connecting the lamp to the transistor's collector makes a better amplifier, but connecting it to the transistor's emitter is useful as a buffer between circuits.

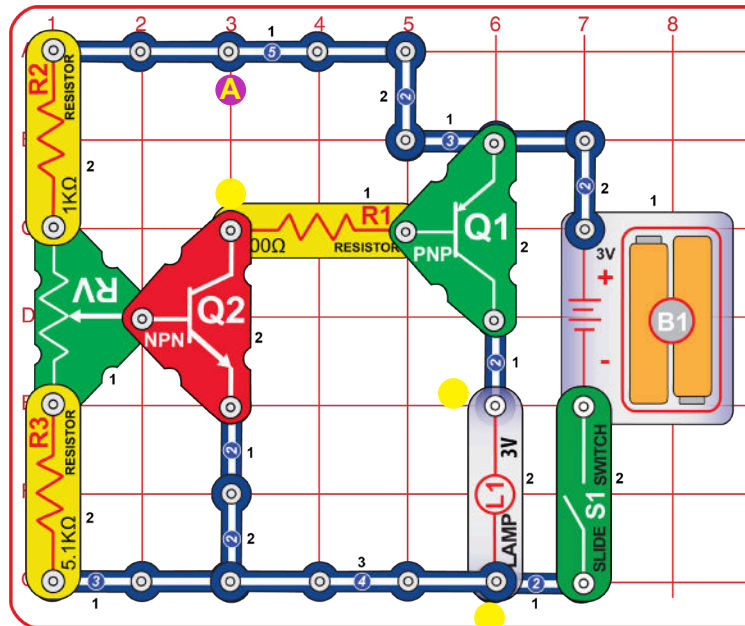


PROJECT 111

Two Transistor Amplifier

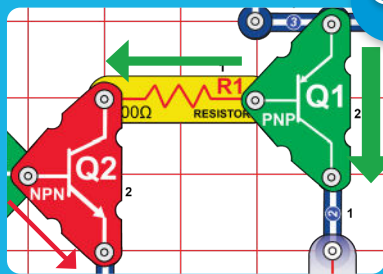
This circuit combines two transistors to make a super amplifier. Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to make the 3V lamp (L1) light. Notice that the lamp lights for most of RV's range.

Now move the lamp to be across points A & B, which removes the PNP transistor (Q1) from the circuit. Move the lever on RV to light the lamp. Notice that now the lamp only lights for a small part of RV's range.



With the lamp across points A & B, the current through RV is amplified by the NPN transistor (Q2) to make the lamp light, but only for a small part of RV's range.

With the lamp in the original circuit (across points C & D), the current through RV is amplified by both the NPN transistor (Q2) and the PNP transistor (Q1), making the lamp light for most of RV's range.



PROJECT 112

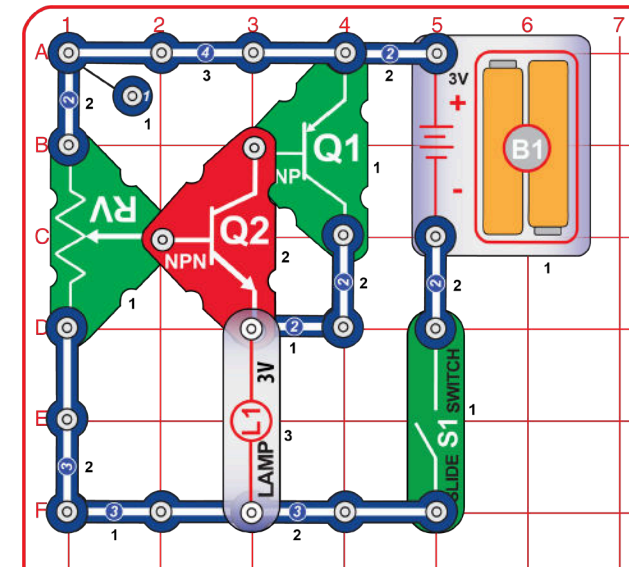
Lamp Brightness Control

Build the circuit shown. This is a variation of the preceding circuit, it has less transistor amplification but uses less parts. Turn on the slide switch (S1) and move the lever on the adjustable resistor (RV) to make the 3V lamp (L1) light.

PROJECT 113

Lamp Brightness Control II

Replace the 3V lamp with the **color LED (D8, "+" on top)** or the motor (M1, "+" on top) and fan. Turn on the slide switch (S1) and move the lever on the adjustable resistor (RV) to make the LED (D8) light or motor (M1) spin.



PROJECT 114

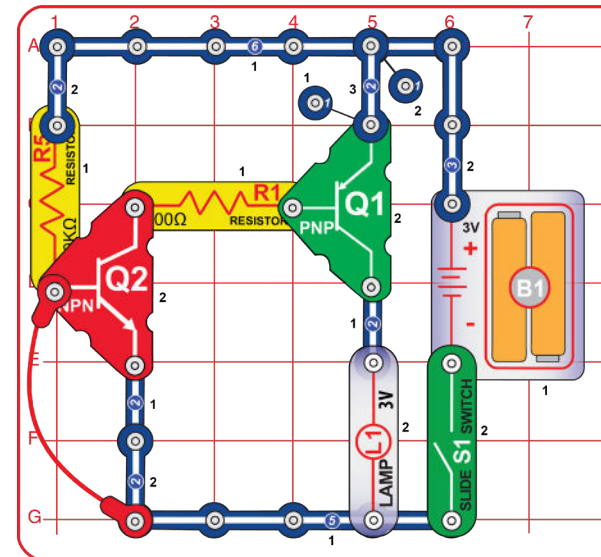
Two-Transistor Light Alarm

Turn on the **slide switch (S1)**. Nothing happens. Disconnect the red jumper and the 3V lamp (L1) turns on.

PROJECT 115 Two-Transistor Light Alarm II

Replace the 3V lamp with the **color LED (D8, “+” on top)** or the **motor (M1, “+” on top)** and fan. Disconnect the red wire to light the LED or spin the fan.

You can replace the red jumper wire with a longer wire and run it across a doorway to signal an alarm when someone enters.



PROJECT 116

One-Transistor Light Alarm

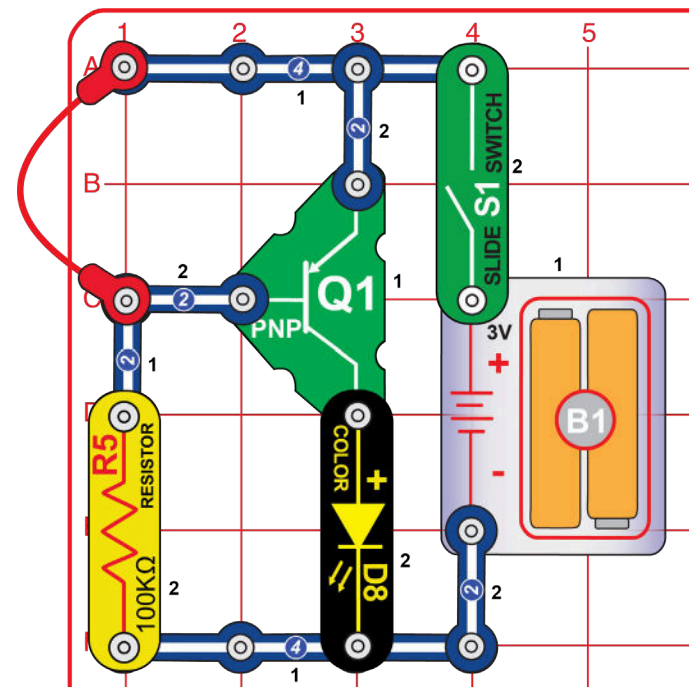
Turn on the **slide switch (S1)**. Nothing happens. Disconnect the red jumper and the color LED (D8) turns on. You can replace the color LED with the **red/yellow LED (D10, in either direction)**.

PROJECT 117 One-Transistor Light Alarm II

Replace the color LED with the **3V lamp (L1)**, and disconnect the red wire. Nothing happens. Now replace the 100kΩ resistor (R5) with the smaller 100Ω resistor (R1) or 1kΩ resistor (R2), then disconnect the red wire to light the lamp. You can replace the 3V lamp with the motor (M1, “+” on top) and fan.

You can replace the red jumper wire with a longer wire and run it across a doorway to signal an alarm when someone enters.

This circuit is similar to project 114, but 114 has two transistors while this circuit only has one. With the 100kΩ resistor in the circuit, the transistor-amplified is enough to light the LED but not the lamp. Using the smaller R1 or R2 resistor lets the circuit turn on the lamp, but makes more current flow when the red wire is connected, and so drains the batteries faster when the alarm is not activated.

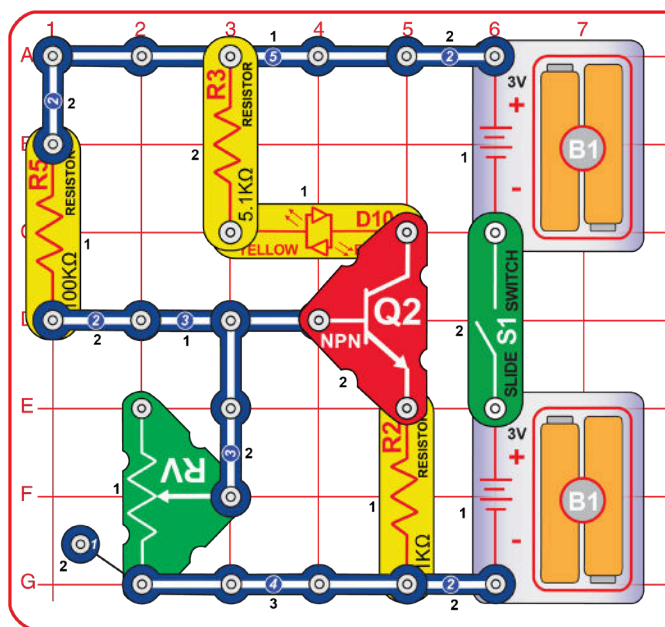


PROJECT 118

Standard Transistor Circuit

Turn on the **slide switch (S1)** and move the **adjustable resistor (RV)** control lever across its range. When the lever is all the way down the red/yellow LED (D10) will be off, as you move the lever up it will come on and reach full brightness.

You can reverse the red/yellow LED, or replace it with the color LED (D8, "+" on left).



This circuit is considered the standard transistor configuration for amplifiers. The adjustable resistor control will normally be set so that the LED is at half brightness, since this minimizes distortion of the signal being amplified.

PROJECT 119

Flasher Control

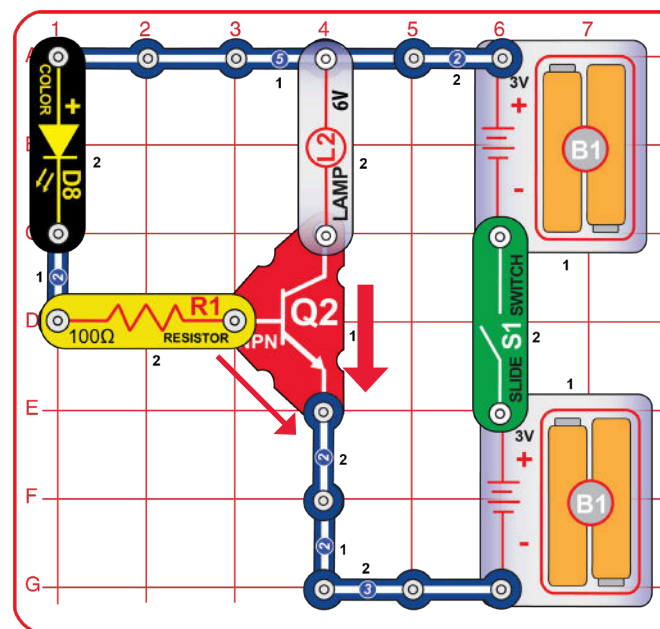
Turn on the **slide switch (S1)**. The 6V lamp (L2) flashes in sync with the color LED (D8).

Part B: Remove either the color LED or the lamp and see what happens to the other one.

Part C: Replace the lamp with the red/yellow LED (D10, in either direction). The red/yellow LED stays on and does not flash.

Part D: In the original circuit, replace the 100Ω resistor (R1) with the 1kΩ resistor (R2) or the 5.1kΩ resistor (R3). The lamp is dimmer or does not light.

Part E: In the original circuit, remove the 6V lamp and replace the 100Ω resistor with it. Notice the color LED lights but the lamp does not.



In part E, placing the lamp in series with the color LED does not light the lamp, because the lamp needs high current to light, and color LED restricts the current too much.

The main circuit uses the NPN transistor (Q2) to amplify the current through the color LED. This allows a small current through the color LED to control a larger current through the lamp, and make the lamp flash in sync with the color LED. Transistors allow low-current parts to control high current parts.

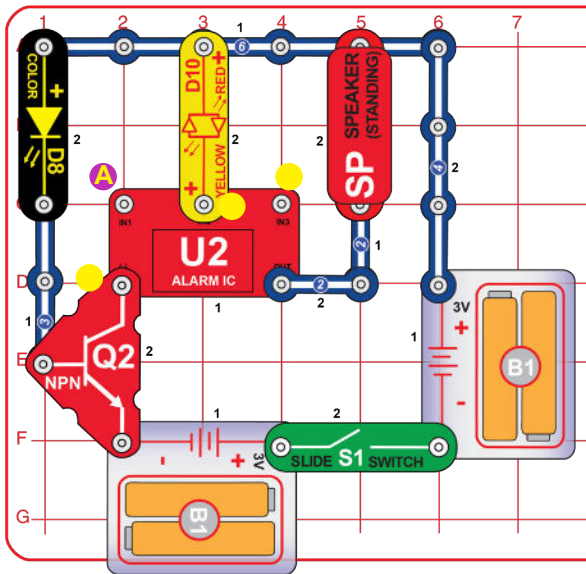
Changing the 100Ω resistor to the larger 1kΩ or 5.1kΩ resistor reduces the control current to the transistor, so the transistor-amplified current is not enough to make the lamp bright.

The current through the color LED drops when it changes colors (turning the lamp off) but some current is still flowing. So when you replace the lamp with the red/yellow LED in part C, the red/yellow LED does not flash because there is always enough current to keep it bright.

PROJECT 120

Funky Blink Sirens

Turn on the **slide switch (S1)**. A siren plays in a strange pattern.



Part B: Use the preceding circuit, but connect points **A & B**, **B & C**, or **A & D** using a jumper wire.

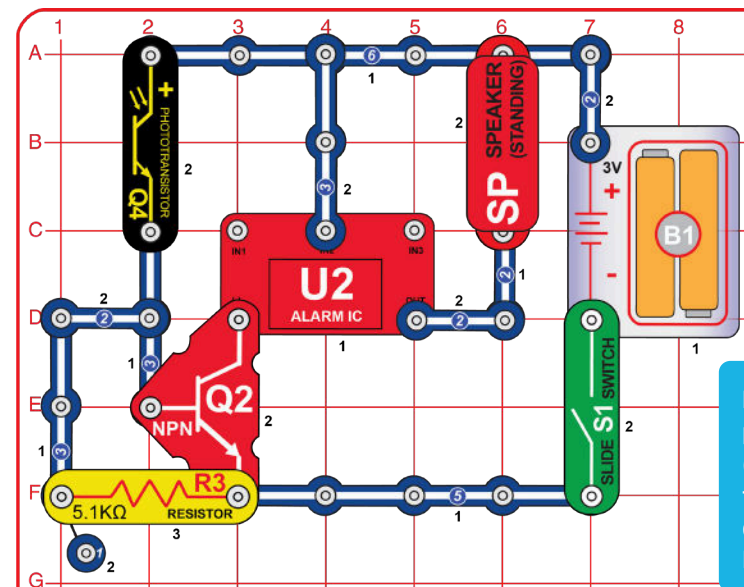
Part C : Use either of the preceding circuits, but replace the speaker (SP) with the **whistle chip (WC)** and **6V lamp (L2)**, stacked together.

The color LED's (D8) changing pattern turns the NPN transistor (Q2) on and off, which disrupts power to the alarm IC (U2), which changes the sound from the speaker (SP).

PROJECT 121

Light-Controlled Sirens

Turn on the **slide switch (S1)**. Vary the amount of light shining on the **phototransistor (Q4)** to change the sound volume. With bright light the siren will be loud, with dim light the siren will be distorted, and in darkness there will be no sound.



Here the phototransistor (Q4) uses the NPN transistor (Q2) to control the alarm IC (U2).

Part B: Remove the **5.1kΩ resistor (R3)** to make the sound louder in dimmer light, or replace it with the **1kΩ resistor (R2)** to make the sound only turn on in very bright light. (The resistor diverts some current from the phototransistor to keep the circuit from being too sensitive to light.)

Part C: In the original circuit, swap the locations of **Q4** and **R3** (for Q4, put "+" on left). Now the light control is opposite.

Part D: In any of the preceding circuits, connect points **A & B**, **B & C**, or **A & D** using a jumper wire. Or replace the alarm IC (U2) with the music IC (U1). Or replace the speaker (SP) with the whistle chip (WC) and red/yellow LED (D10), stacked together.

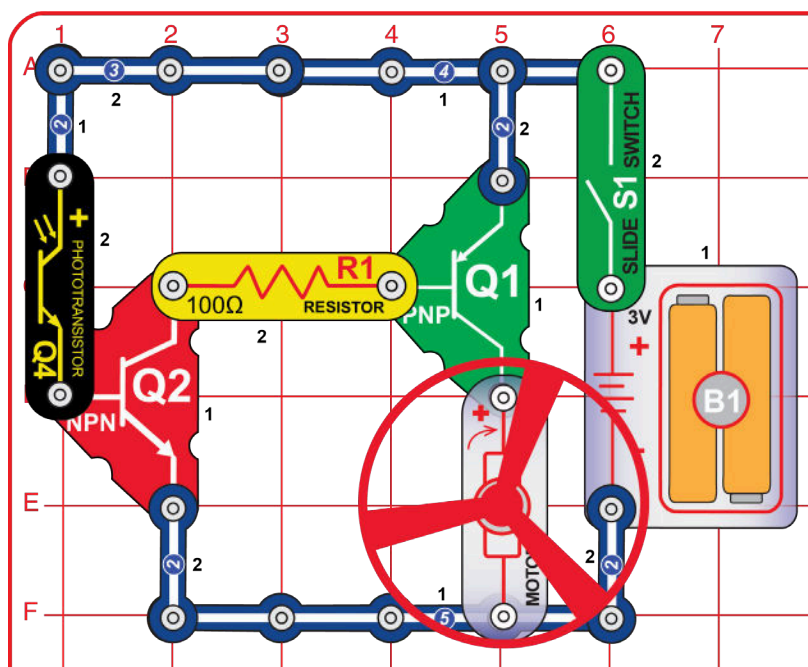
PROJECT 122

Light-Activated Fan

Turn on the **slide switch (S1)**. Cover and uncover the **phototransistor (Q4)** to make the fan start and stop.

PROJECT 123 Light-Activated Flying Saucer

Cover the phototransistor (Q4) and then turn on the **slide switch (S1)**. Uncover the phototransistor to launch the fan.



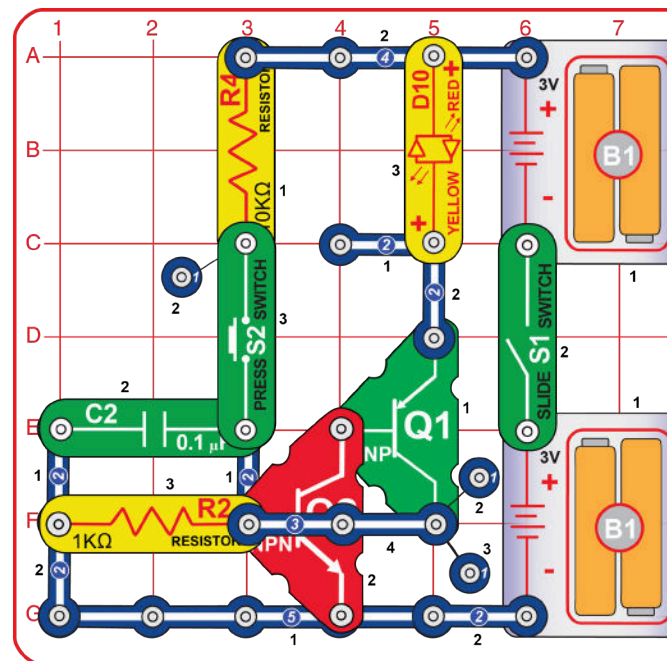
PROJECT 124

Silicon-Controlled Rectifier (SCR)

Turn on the **slide switch (S1)**—nothing happens. Now push the **press switch (S2)**—the LED (D10) comes on and stays on. The LED stays on until you turn off S1. The circuit remembers that you pressed S2.

You can replace the red/yellow LED (D10) with the **6V lamp (L2)** or the **motor (M1, “+” on top)** and fan.

If you replace D10 with the color LED (D8) then D8 only lights briefly after you press S2.



Here the two transistors (Q1 & Q2) are connected together to act as an electronic device called an SCR (Silicon Controlled Rectifier). An SCR is a three-pin device that once its base is triggered (in this case by pressing S2), remains on until the current flow through it stops.

D8 only lights briefly because it stops the current for a moment when it changes colors, and that turns off the SCR.

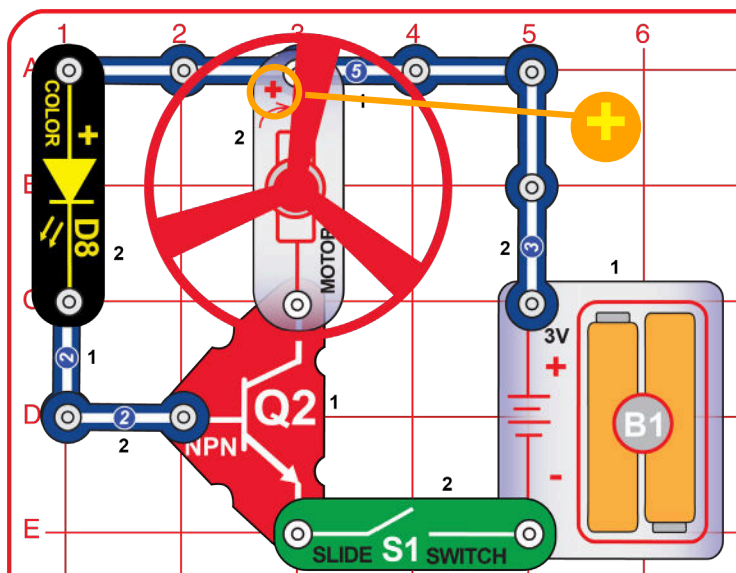
PROJECT 125

LED Spinner

Turn on the **slide switch (S1)**. The fan speed changes as the color LED (D8) changes colors.

Part B: Replace the motor (M1) with **red/yellow LED (D10)**. The LED lights but does not flash like D8 does.

Part C: Replace the motor or D10 with the **3V lamp (L1)**. The lamp will light dimly or not at all.



The color LED cannot control the motor directly, due to the LED's internal protection resistor limiting the current too much for the motor to function. This circuit uses the NPN transistor (Q2) to amplify the LED current enough for the LED to control the motor. The LED's blinking pattern changes the current to the motor, which changes the fan speed.

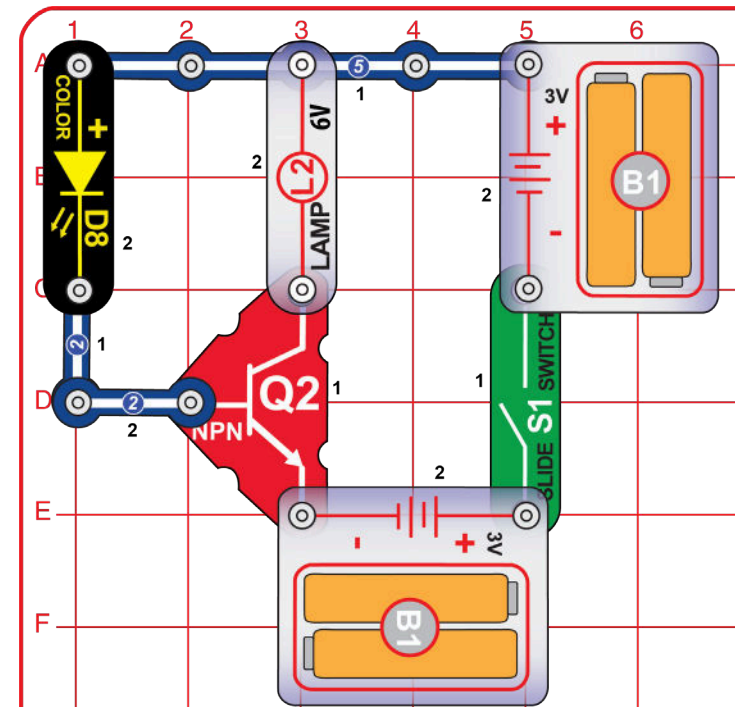
When the color LED changes colors the current through it changes but does not fall to zero. This small current, amplified by the transistor, is enough to keep the second LED (D2, D6, or D10) on continuously.

When the lamp is used in place of the motor, the average current from the color LED is too low to make the lamp bright, even when amplified by the transistor.

PROJECT 126

Blinking Two

Turn on the **slide switch (S1)**. The 6V lamp (L2) blinks as the color LED (D8) changes colors.



In the preceding circuit the color LED (D8) could not make the lamp bright. The circuit adds a second set of batteries to increase the current. Now the changing color LED current, amplified by the Q2 transistor, is enough for the 6V lamp to be bright and blinking.

PROJECT 127 Transistor Diodes

Build the circuit as shown, leaving one end of the red jumper wire unconnected for now. Turn on the **slide switch (S1)**. The red/yellow LED (D1) appears to be off, but may be very dimly lit.

Connect the loose end of the red jumper wire to the point labeled **B**, to bypass PNP transistor (Q1). The LED lights now.

Now move the end of the red jumper wire from point B to point **A**, to also bypass the NPN transistor (Q2). The LED is brighter now.

PROJECT 128 Transistor Diodes II

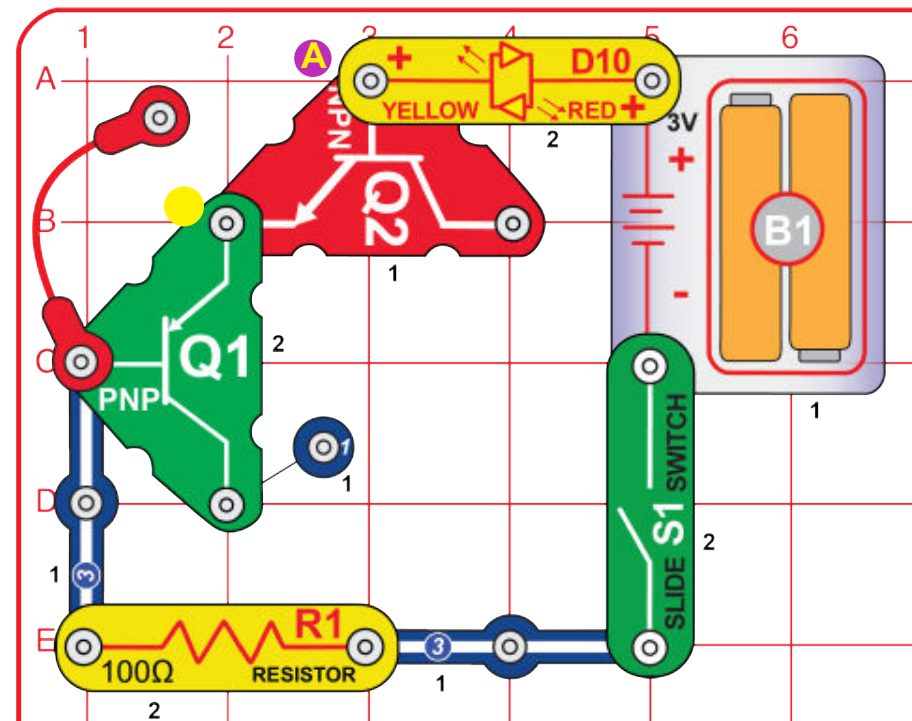
Replace the red/yellow LED with the **color LED (D8, "+" on the right)**. Check the color LED brightness with the red jumper wire connected to point A, point B, and not connected.

PROJECT 129 Transistor Diodes III

Replace the color LED with a **3-snap wire** and replace the 100Ω resistor (R1) with the **3V lamp (L1)**. Check the lamp brightness with the red jumper wire connected to point A, point B, and not connected.

PROJECT 130 Transistor Diodes IV

Replace the lamp with the **motor (M1, "+" on left)** and fan. Notice the fan speed with the red jumper wire connected to point A, point B, and not connected.



The base-emitter junction of the PNP and NPN transistors (the 2 snaps with the white arrow between them) acts as a diode. A diode is like a one-way switch, but with a turn-on voltage (about 0.7V) that must be overcome before any current can flow. LEDs (light emitting diodes, your D8 and D10 parts) are diodes but have a higher turn-on voltage (1.5V - 3V, depending on color) and emit light.

With the red/yellow LED, initially the LED is off (or very dim), because the total turn-on voltages for the LED and 2 transistors are about the same as the 3V battery voltage. When one or both of the transistors are bypassed with the red jumper wire, the turn-on voltages are exceeded and current flows, limited by the R1 resistor and D10's internal protection resistor.

With the color LED, red, green, and blue are bright when the red jumper wire connects to point A. With the red wire to point B, you see red and green but not blue, because blue has a higher turn-on voltage than red and green. With the red wire unconnected, you may see a dim red, because red has the lowest turn-on voltage.

With the lamp, having one or both transistors unbypassed lowers the voltage to the lamp, making it dimmer. Note that the transistors have a turn-on voltage to overcome but otherwise have low resistance, so the lamp can light even though it needs much higher current than LEDs.

The motor performance here is similar to the lamp, so having one or both transistors unbypassed reduces the fan speed.

PROJECT 131 Transistor Diodes 6V

Use the **project 127** circuit, but add a second battery holder as shown. Turn on the **slide switch (S1)** and view the red/yellow LED (D1) brightness with the red jumper wire connected to point A, point B, and unconnected.

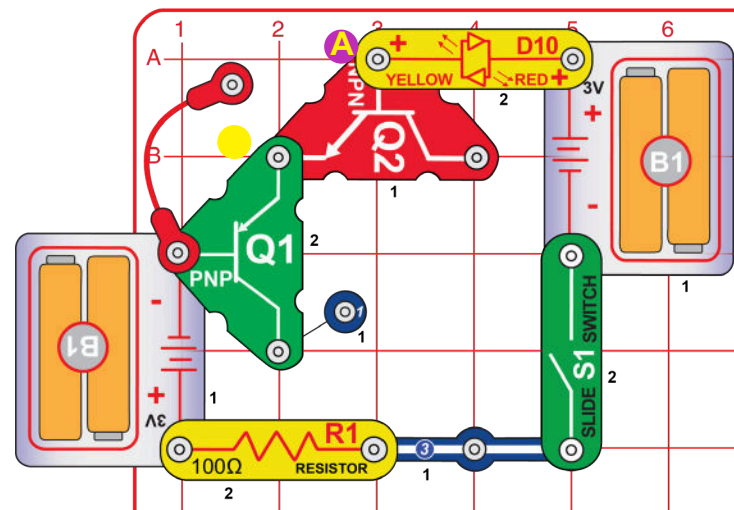
PROJECT 132 Transistor Diodes 6V II

Replace the red/yellow LED with the **color LED (D8)**. Check the color LED brightness with the red jumper wire connected to point A, point B, and not connected.

PROJECT 133 Transistor Diodes 6V III

Replace the color LED with the **6V lamp (L2)** and replace the 100Ω resistor (R1) with a **3-snap wire**. Check the lamp brightness with the red jumper wire connected to point A, point B, and not connected.

Now the battery voltage is 6V, so the transistor turn-on voltages have less effect, so the red wire location has only a small effect on LED brightness.



PROJECT 134 **Flasher Siren Control**

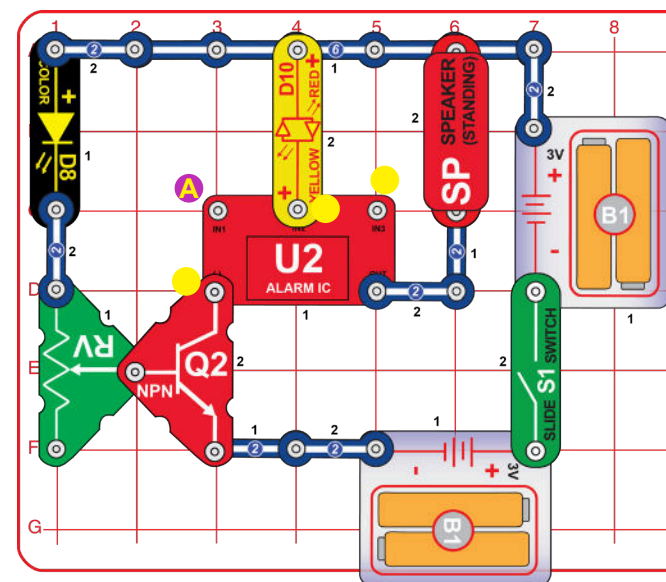
Turn on the slide switch (S1) and move the lever on the adjustable resistor (RV) around to vary the sound.

Part B: Use the preceding circuit, but replace the speaker (SP) with the whistle chip (WC) and 100Ω resistor (R1), stacked together with R1 on top.

Part C: Use any of the preceding circuits, but add a connection between the points marked A & B, B & C, or A & D using a 1-snap wire and a 2-snap wire, or a jumper wire. Adjust the sound using the lever on RV for each.

Part D: Use any of the preceding circuits but replace the color LED (D8) with the phototransistor (Q4, “+” on top). Cover and uncover the phototransistor to change the sound.

Here the flashing pattern of the color LED (D8) controls the NPN transistor (Q2), which then varies the current out of the alarm IC, causing the sound to vary in funky ways.

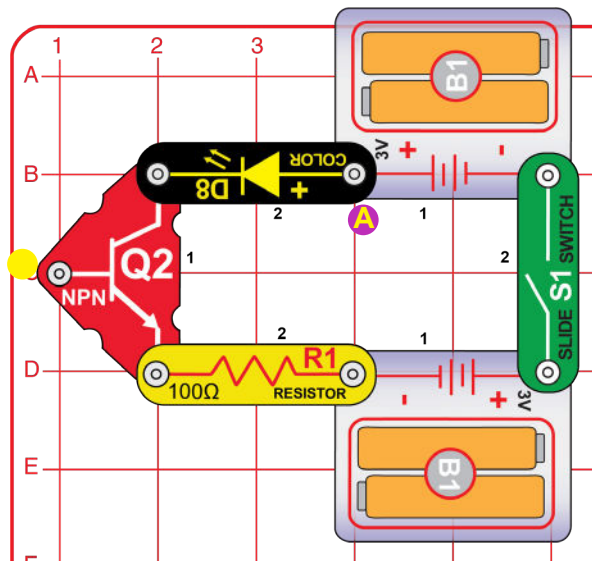


PROJECT 135

Two-Finger Touch Light

Build the circuit below. You're probably wondering how it can work, since one of the points on the NPN transistor (Q2) is unconnected. It can't, but there is another component that isn't shown. That component is you.

Touch points **A & B** with your fingers. The color LED (D8) may be dimly lit. The problem is your fingers aren't making a good enough electrical contact with the metal. Wet your fingers with water or saliva and touch the points again. The LED should be very bright now.



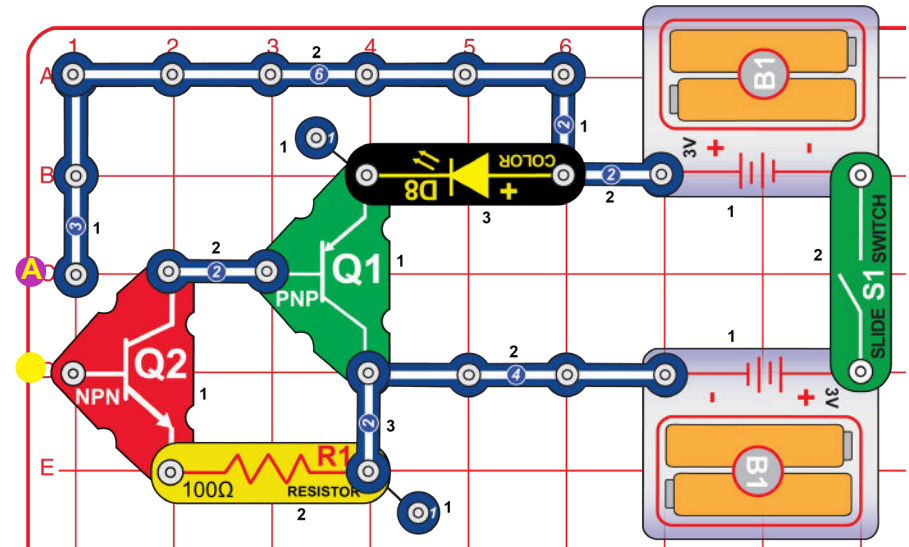
Your body has some electrical conductivity, so touching points A & B produces a current into the NPN transistor (Q2), which is amplified enough to light the LED.

Think of this circuit as a touch lamp since when you touch it, the LED lights. You may have seen such a lamp in the store or already have one in your home.

PROJECT 136

One-Finger Touch Light

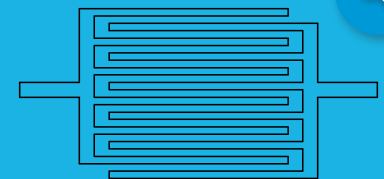
This circuit improves the preceding one by making the touch points closer together, and adding a second transistor to make it more sensitive. Turn on the **slide switch (S1)** and touch one finger across points **A & B**, the color LED (D8) lights. If the LED is not bright then wet your finger to get better electrical contact.



PROJECT 137 One-Finger Touch Light II

This circuit should be sensitive enough to turn on an incandescent lamp, so replace the color LED (D8) with the **6V lamp (L2)**. Touch one or two fingers across points **A & B** as before, but you will probably have to wet your fingers to get good enough contact to light the lamp.

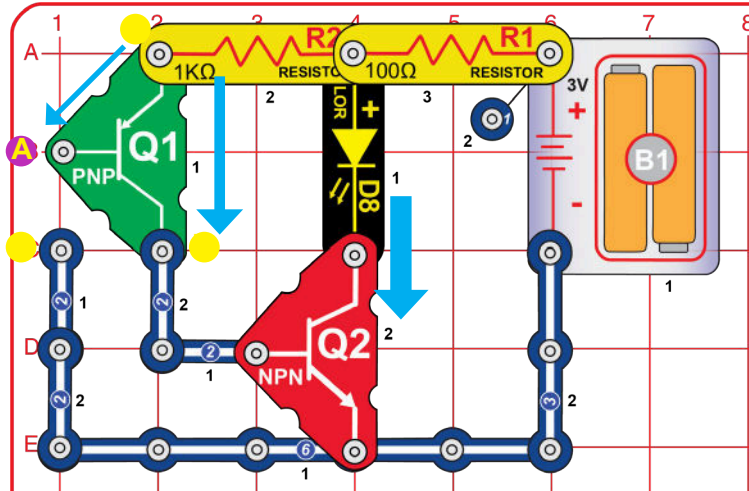
To make it easier for one finger to touch the two contacts, touch lamps or other touch devices will have the metal contacts interwoven as shown on the right and will also be more sensitive so that you don't have to wet your finger to make good contact.



PROJECT 138

Another Touch Light

Place one or two fingers across the snaps labeled **A & B**.
The color LED (D8) turns on.



This circuit has no on/off switch, but no electricity flows from the batteries because the transistors (Q1 & Q2) are off. Placing your finger across points **A & B** allows a tiny current to flow out of transistor Q1, which is amplified first by transistor Q1 and then by transistor Q2. The amplified current through Q2 turns on the color LED. The blue arrows show the current flow.

PROJECT 139 Another Touch Light II

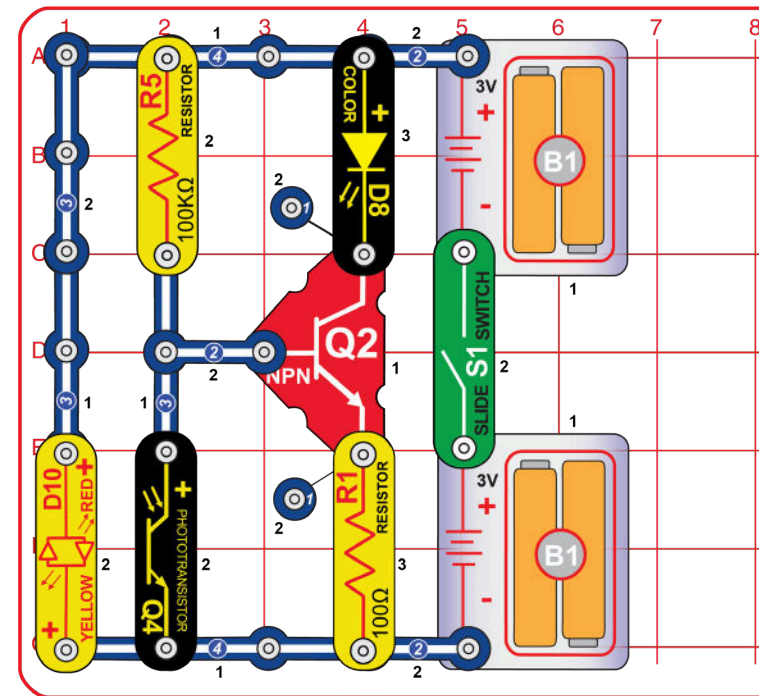
Now place your fingers across points **C & D**. The color LED may light dimly. Notice that the LED is brighter when you press harder on the snaps. Next, wet your fingers and place them across points C & D again - the LED should be brighter now. You can replace the color LED (D8) with the red/yellow LED (D10, in either direction).

Pressing harder on the snaps or wetting your fingers helps your body get better electrical contact, basically to overcome “contact resistance” between the surfaces. The contacts in your S1 and S2 switches also have some contact resistance, but it is very low and is not noticeable in your circuits.

PROJECT 140

Mail Notifying System

Turn on the **slide switch (S1)**. If there is light on the phototransistor (Q4) then the color LED (D8) will not light. Cover the phototransistor and now the color LED lights.



A simple mail notifying system can be made using this circuit. Install the phototransistor and the red/yellow LED (D10) inside the mailbox facing or next to each other, so that arriving mail would be placed between them. Place the color LED outside the mailbox. When there is mail, the light between the red/yellow LED and phototransistor is blocked, and the color LED turns on.

PROJECT 141

Water Alarm

Build the circuit shown, but initially **leave the red & black jumper wires outside the cup.** Turn on the **slide switch (S1)**; nothing happens. Place the red & black wires into a cup of water (without letting the metal on them touch each other) and an alarm sounds! You can also place the wires into a small puddle of water on a table.

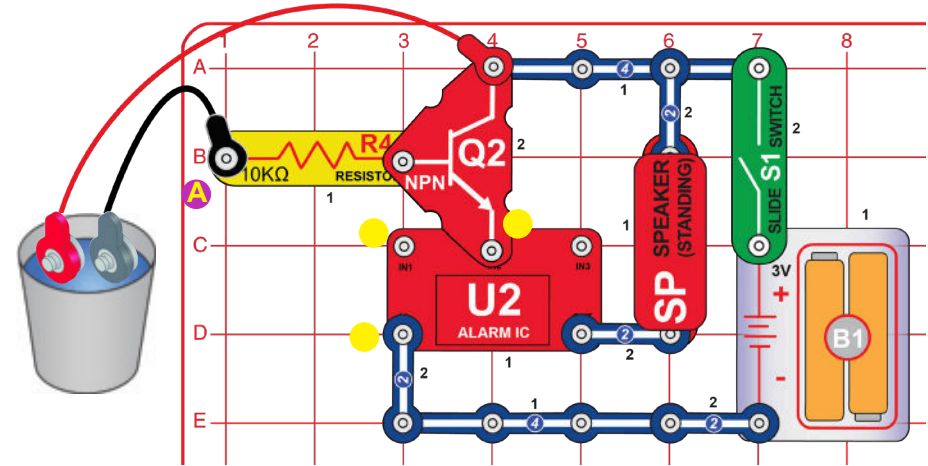
You could use longer wires and lay them on your basement floor, if your basement floods during a storm, then this circuit will sound an alarm.

Part B: Move the end of the black jumper wire from point **A** to point **C**, to bypass the NPN transistor (Q2). Notice the alarm sound is weaker and not as sensitive now.

Part C: Add salt to the water and the tone of the alarm is louder and faster, telling you that salt is in the water you detected.

Part D: Use any of the preceding arrangements, but add a connection between points **B & C** or **B & D**. The siren sound is different now.

Don't drink any water used here.



Normal tap water has some electrical resistance, but much less than air. Adding salt to water lowers its resistance.

This project uses water to connect the alarm IC (U2). With the black wire connected to point C, water allows enough current to flow to turn on the alarm IC, but barely. Connecting the black wire to point A uses the NPN transistor (Q2) to amplify the current through the water, making it much easier to power the alarm IC.

PROJECT 142

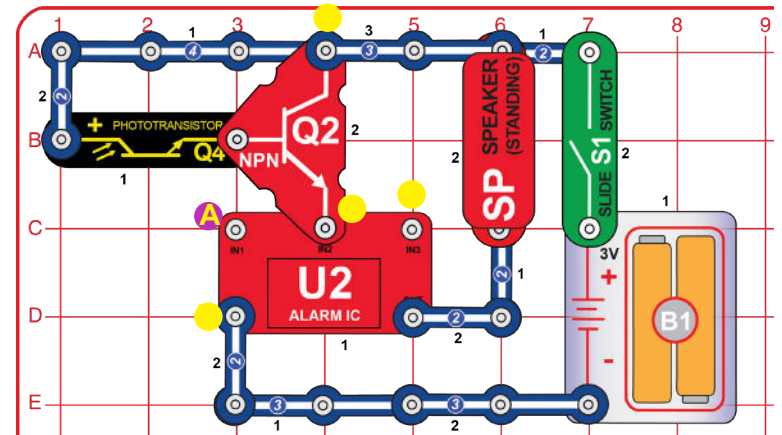
High-Sensitivity Light Alarm

Turn on the **slide switch (S1)**. If there is light then an alarm sounds. Try covering the **phototransistor (Q4)** to make the alarm stop - it may not. Take the circuit into a very dark room and the alarm turns off.

Remove the phototransistor and NPN transistor (Q2), then place the phototransistor across points **X & B** ("+" to X). Now it takes more light to turn on the alarm.

PROJECT 143 High-Sensitivity Light Alarm II

Change the siren by making a connection between points **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire. Or you can replace the speaker (SP) with the **whistle chip (WC)** and **red/yellow LED (D10)**, stacked together.



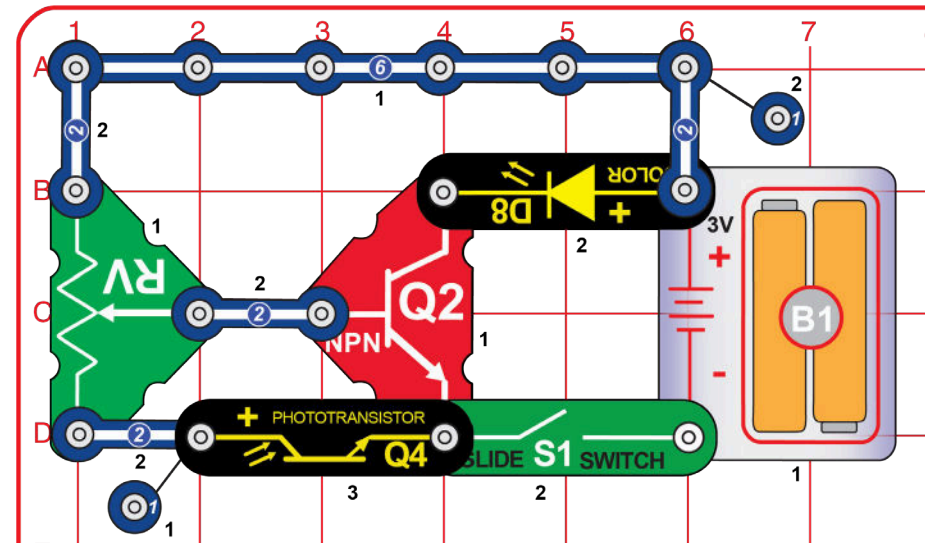
The circuit is much more sensitive to light when the NPN transistor is used (compared to the phototransistor alone), because it amplifies the current through the phototransistor.

PROJECT 144

Motion Detector

Build the circuit to the right, and set the **adjustable resistor (RV)** to the center position. Turn on the **slide switch (S1)**—the color LED (D8) lights. Now, move the lever on the **adjustable resistor (RV)** down until the LED just turns off. The circuit is ready. Wave your hand over the **phototransistor (Q4)** and the LED turns on, having detected the motion of your hand. You can set the circuit so the phototransistor faces a hallway, and detects when someone passes by.

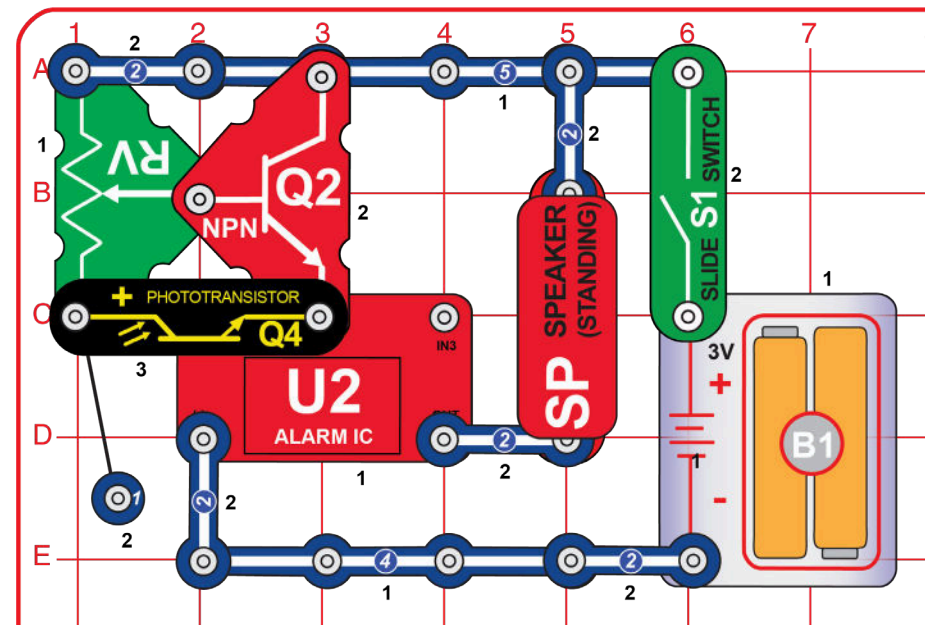
This circuit detects motion by sensing when something has obstructed the room light shining on the phototransistor. When the amount of light shining on the phototransistor changes, the phototransistor's resistance changes, changing the current to the NPN transistor (Q2), which turns on the color LED.



PROJECT 145

Motion Detector II

Build the circuit to the right, and set the **adjustable resistor (RV)** to the center position. Turn on the **slide switch (S1)** and a siren will sound. Now, move the lever on the **adjustable resistor (RV)** down until the siren just turns off. The circuit is ready. Wave your hand over the phototransistor (Q4) and the siren sounds, having detected the motion of your hand. You can set the circuit so the phototransistor faces a hallway, and detects when someone passes by.



PROJECT 146

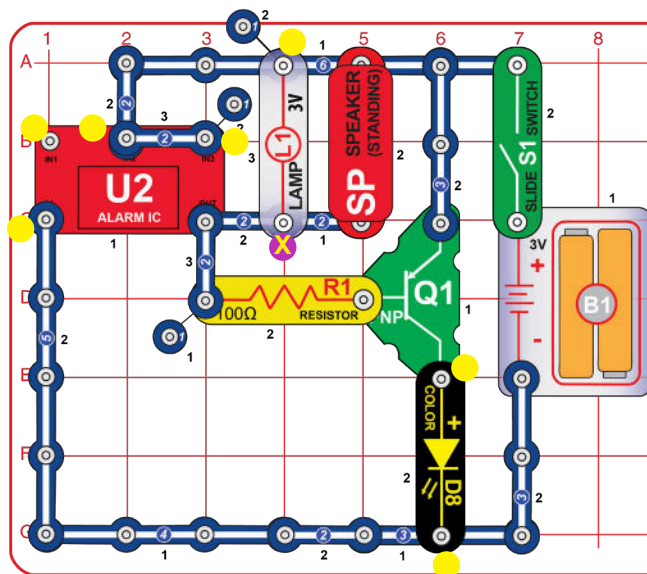
Transistor Buffer

Turn on the **slide switch (S1)**. Lights flash and you hear a machine gun sound. Remove the **speaker (SP)** and notice that the 3V lamp (L1) gets brighter. Remove the lamp and notice that the speaker gets louder.

Next, move the color LED to points **W & X** (“+” to W) and move the lamp to points **Y & Z**. Observe that: the LED color pattern is different when it is at W & X unless you remove the speaker, the lamp is brighter at Y & Z, and removing the LED from W & X does not make the speaker louder.

PROJECT 147 Transistor Buffer II

Change the sound and light pattern by removing the 2-snap wire and 1-snap wire that are across points B & C. Leave them off, or add them across points A & B or C & D.



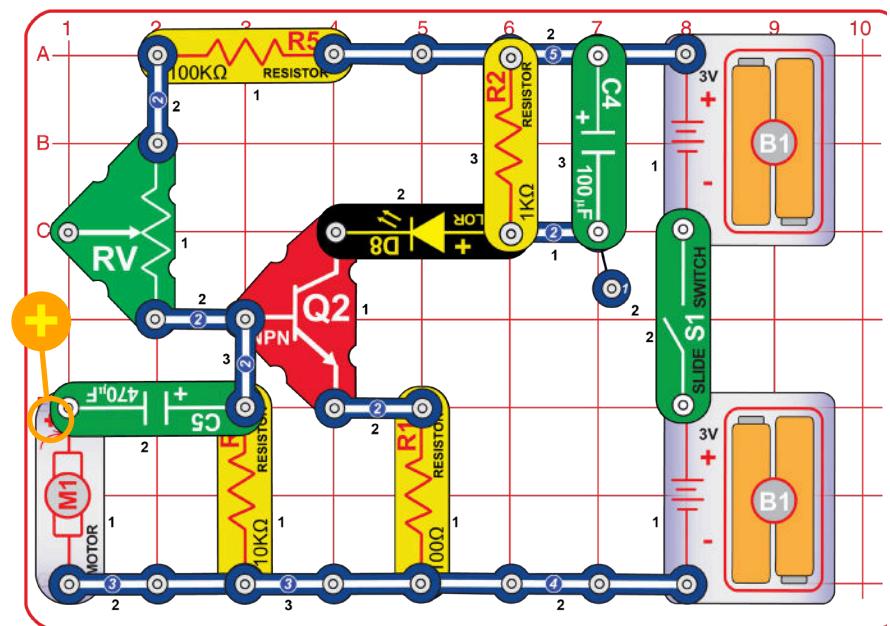
When the lamp or color LED are at points W & X (next to the speaker), the speaker disrupts the lamp and LED, and the lamp lowers the speaker volume. Basically they are bothering each other. When the lamp and LED are at points Y & Z, the PNP transistor (Q1) acts as a buffer, isolating them from the speaker.

PROJECT 148

Motor Speed Detector

Turn on the **slide switch (S1)**, nothing will happen. It is a motor speed detector, and the motor isn't moving. Watch the color LED (D8) and give the black motor top (on M1) a good spin **CLOCKWISE** with your fingers (don't use the fan blade); you should see a flash of light. The faster you spin the motor, the brighter the flash will be. As a game, see who can make the brightest flash. The adjustable resistor (RV) is used here.

If you spin the motor top in the opposite direction (counter-clockwise) then it won't flash at all, because the electricity it produces flows in the wrong direction and won't activate the NPN transistor (Q2) that controls the color LED.



Here the motor is used as a generator. Spinning the motor shaft with your fingers produces a small electrical voltage, which is amplified by the NPN transistor (Q2) to light the color LED.

PROJECT 149 Automatic Street Lamp

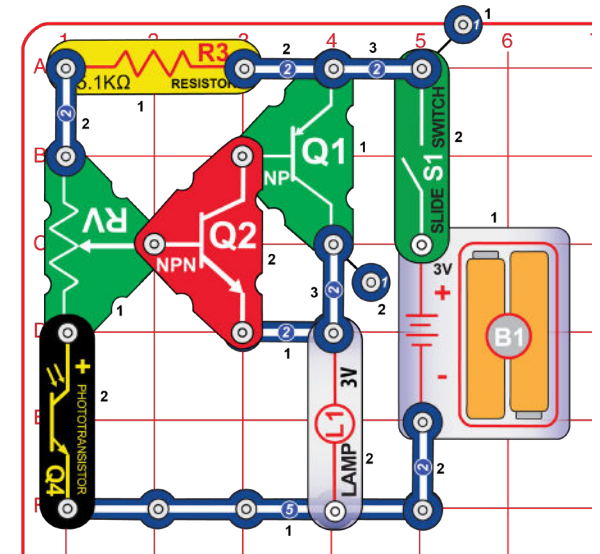
Turn on the **slide switch (S1)** and set the **adjustable resistor (RV)** so the 3V lamp (L1) just lights. Slowly cover the **phototransistor (Q4)** and the lamp brightens. If you place more light on the phototransistor the light dims.

You can replace the 3V lamp with one of the more energy-efficient **LEDs (D8 or D10, “+” on top for D8)**.

PROJECT 150 Electric Fan Stopped by Light

Replace the 3V lamp with the **motor (M1, “+” on top)** and fan. Turn on the **slide switch (S1)** and set the **adjustable resistor (RV)** control so the motor (M1) just starts spinning. Slowly cover the **phototransistor (Q4)** and the motor spins faster. Placing more light on the phototransistor slows the motor.

This is an automatic street lamp that you can turn on by a certain darkness and turn off by a certain brightness. This type of circuit is installed on many outside lights to turn them off during daytime when they are not needed, to save electricity. They come on at night for safety.



PROJECT 151 Photo Transistor Control

Build the circuit and turn on the **slide switch (S1)**. The red/yellow LED (D10) will be on and the fan will spin if there is bright enough light on the phototransistor (Q4); cover the **phototransistor** to turn them off. You can also replace D10 or the motor/fans with the **color LED (D8)** or the **3V lamp (L1)**.

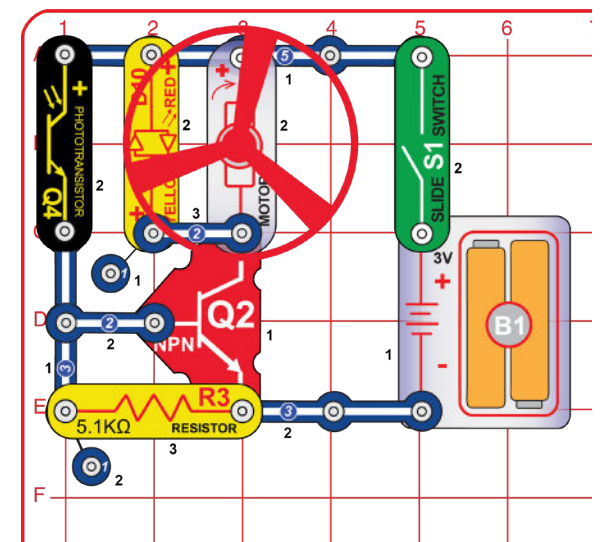
PROJECT 152 Photo Transistor Control II

Remove the 5.1kΩ resistor (R3), and see how its sensitivity to light changes. The resistor diverts some current from the phototransistor to keep the circuit from being too sensitive to light.

PROJECT 153 Photo Transistor Control III

In the original circuit, swap the locations of **Q4** and **R3** (for Q4, put “+” on left). Now the light control is opposite.

In this project, the phototransistor is able to control other devices (like the LED and motor) much more easily than project 28 (Light Controlled Light). This is because the NPN transistor (Q2) is used to amplify (or increase) the current, enabling the small current that passes through the phototransistor to control the much larger electric current that passes through the LED and motor.



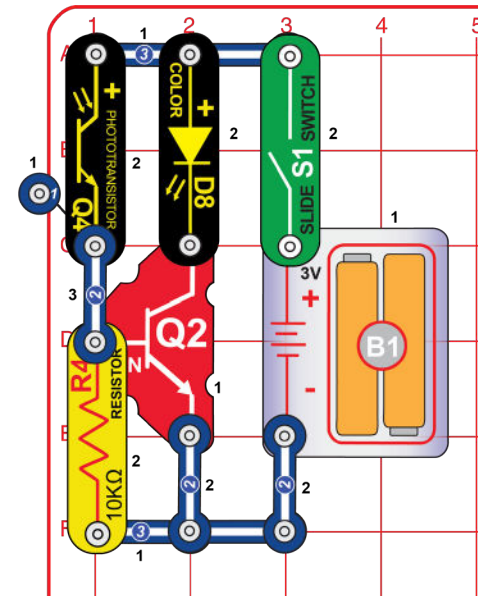
PROJECT 154 NPN Light Control

Build the circuit as shown and turn on the **slide switch (S1)**. The color LED (D8) is on when there is light on the phototransistor (Q4). Shine light on or cover the **phototransistor** to turn the color LED on or off.

Part B: Replace the 10kΩ resistor (R4) with the **100kΩ resistor (R5)** to make the color LED (D8) turn on with less light on Q4, or with the **1kΩ resistor (R2)** to make it less sensitive.

Part C: Replace the color LED (D8) with the **3V lamp (L1)**. The circuit is less sensitive to light now.

Part D: Swap the locations of the **phototransistor (Q4)** and **10kΩ resistor (R4)**. Now the color LED turns on when the room is dark or you cover the phototransistor. If the LED turns on too easily then replace R4 with R5 to reduce the sensitivity. If the LED does not turn on easily enough then replace **R4** with **R2** to increase the sensitivity.



The phototransistor's resistance decreases as more light shines on it. Current through the phototransistor is amplified by transistor Q2 to turn on the color LED. The lamp requires more current to light, so requires more light on the phototransistor. The R4 resistor diverts some of the phototransistor current away from the transistor, so is used to adjust the circuit's sensitivity to light.

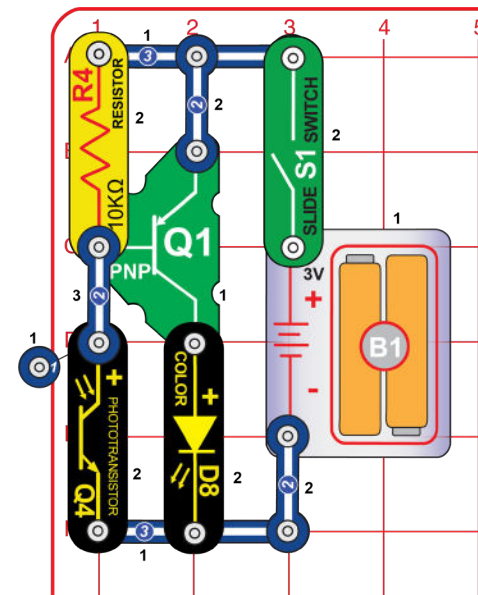
PROJECT 155 PNP Light Control

This circuit is the opposite of project 181. Turn on the **slide switch (S1)**. The color LED (D8) is on when there is light on the phototransistor (Q4). Shine light on or cover the **phototransistor** to turn the color LED on or off.

Part B: Replace the 10kΩ resistor (R4) with the **100kΩ resistor (R5)** to make the color LED (D8) turn on with less light on Q4, or with the **1kΩ resistor (R2)** to make it less sensitive.

Part C: Replace the color LED (D8) with the **3V lamp (L1)**. The circuit is less sensitive to light now.

Part D: Swap the locations of the **phototransistor (Q4)** and **10kΩ resistor (R4)**. Now the color LED turns on when the room is dark or you cover the phototransistor. If the LED turns on too easily then replace **R4** with **R5** to reduce the sensitivity. If the LED does not turn on easily enough then replace **R4** with **R2** to increase the sensitivity.

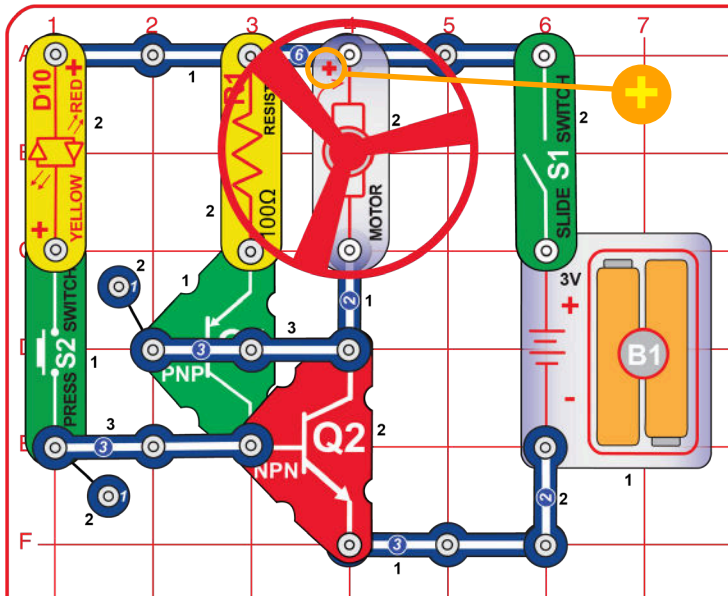


The phototransistor's resistance decreases as more light shines on it. Current through the phototransistor is amplified by transistor Q1 to turn on the color LED. The lamp requires more current to light, so requires more light on the phototransistor. The R4 resistor diverts some of the phototransistor current away from the transistor, so is used to adjust the circuit's sensitivity to light.

PROJECT 156

Thyristor with Motor

Turn on the **slide switch (S1)**. Nothing happens. Push and release the **press switch (S2)**; the red/yellow LED (D10) flashes, turning on the PNP and NPN transistors (Q1 & Q2), which turn on the motor (M1) and fan. The motor will continue to run until you turn off the slide switch.



PROJECT 157 Thyristor with Motor II

Replace the motor (M1) with the **lamp (L1)** or **color LED (D8)**. The circuit works the same way.

Transistors Q1 and Q2 act as a thyristor bistable switch, conducting electricity when their gate (the left side of Q2) is triggered (by pressing S2), and continuing to conduct until the circuit is turned off.

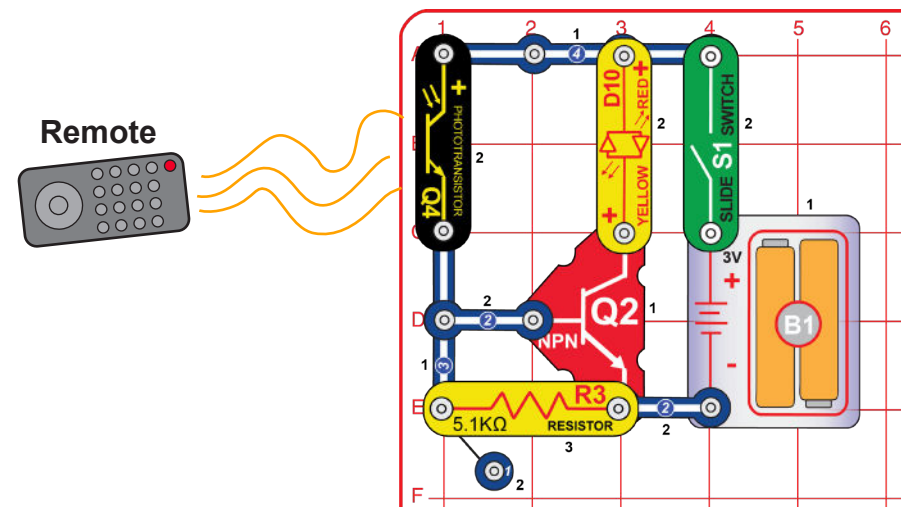
PROJECT 158

IR Control

You need an **infrared remote control** for this project, such as any TV/stereo/DVD remote control in your home.

Turn on the **slide switch (S1)** and position the circuit away from lights in the room so that the red/yellow LED (D10) is off. Point your remote control directly into the **phototransistor (Q4)**, and press any button to turn on the LED.

Note that when the phototransistor (Q4) is activated by room lights the LED is on continuously, and when the phototransistor is activated by your infrared remote control the LED will be blinking.



The phototransistor detects light, including infrared light that is invisible to the human eye. The LED blinks even if you press the remote control continuously, because the signal that is coming from your remote control is a stream of infrared light bursts. Each burst of infrared light causes a burst of current to flow through the LED, making it blink.

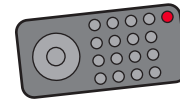
PROJECT 159 Photo Infrared Detector

You need an **infrared remote control** for this project, such as any TV/stereo/ DVD remote control in your home.

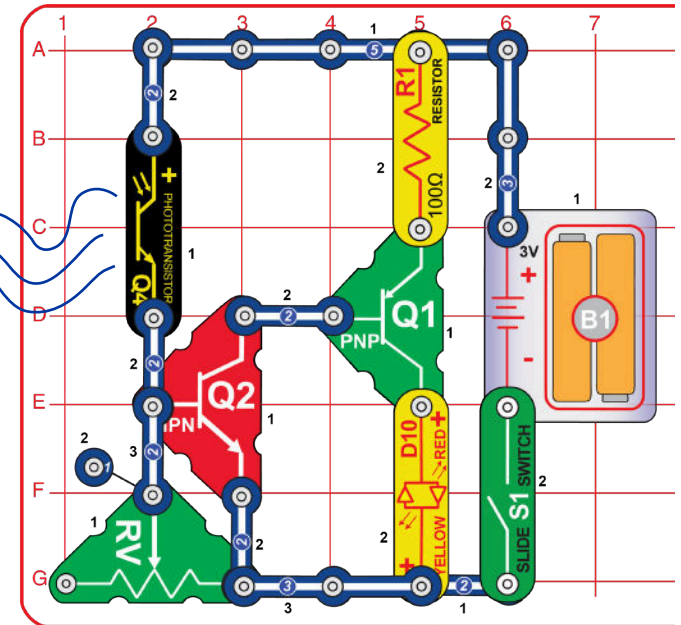
Build the circuit and turn on the **slide switch (S1)**. Set the lever on the **adjustable resistor (RV)** so the red/yellow LED (D10) just turns off; this is easier in a dimly lit room. Point your remote control directly into the mounting base on Q4, and press any button to activate the LED.

Note that when the phototransistor (Q4) is activated by room lights the LED is on continuously, and when the phototransistor is activated by your infrared remote control the LED will be blinking.

Remote



The phototransistor can detect light, and infrared light is light. The adjustable resistor adjusts for the room light, so that the additional light from the infrared remote control will turn on the LED.

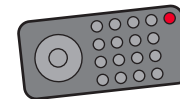


PROJECT 160 Audio Infrared Detector

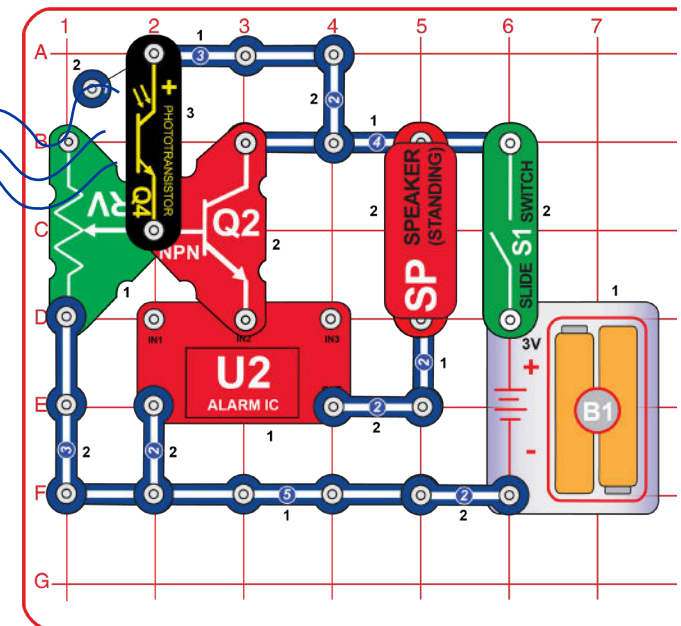
You need an **infrared remote control** for this project, such as any TV/stereo/ DVD remote control in your home.

Build the circuit and turn on the **slide switch (S1)**. Set the lever on the **adjustable resistor (RV)** so the sound just turns off; this is easier in a dimly lit room. Point your remote control directly into the mounting base on Q4, and press any button to hear a siren.

Remote



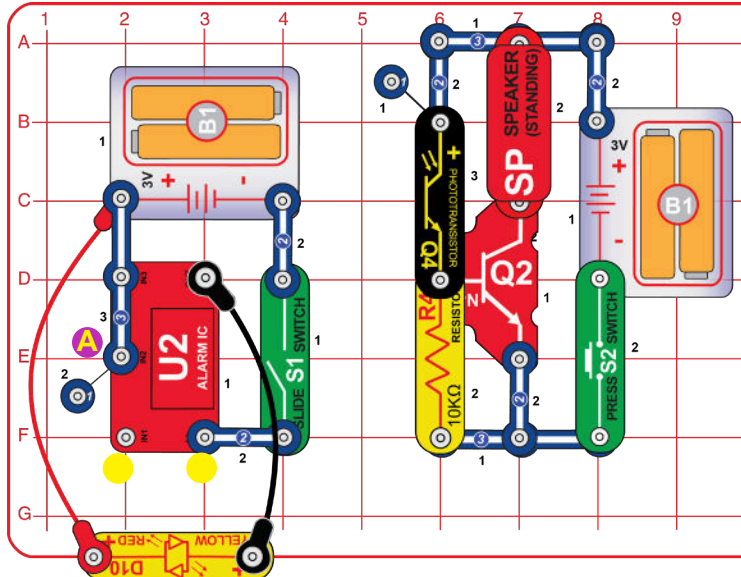
The phototransistor can detect light, and infrared light is light. The adjustable resistor adjusts for the room light, so that the additional light from the infrared remote control will turn on the siren.



PROJECT 161

Sound by Light

Turn on the **slide switch (S1)** and hold the **red/yellow LED (D10)** just above the **phototransistor (Q4)** and pointing towards it. Now push the **press switch (S2)** to hear a siren. The sound stops if you move the LED away from the phototransistor.



PROJECT 162 Sound by Light II

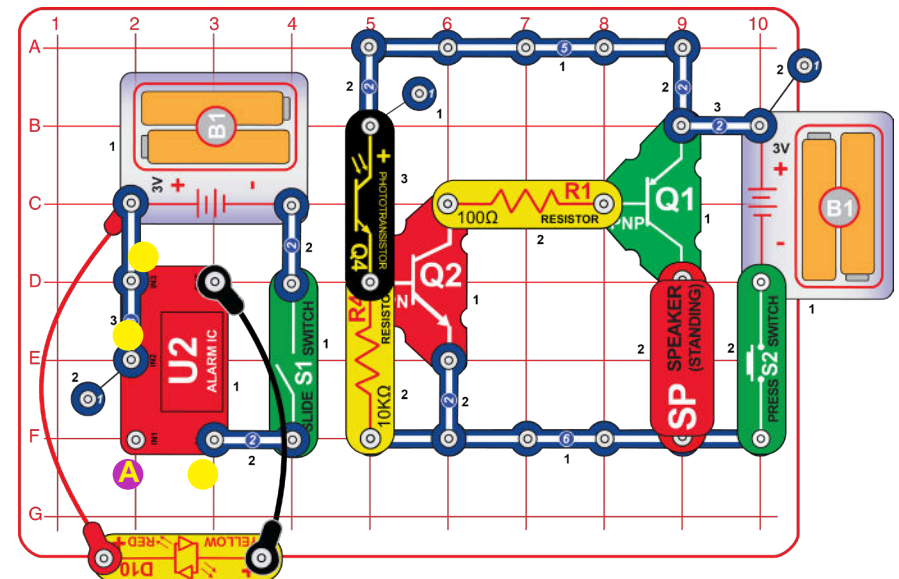
Change the sound by making a connection across point **A & B** or **B & C** using a 1-snap wire and a 2-snap wire.

The left and right circuits are not electrically connected. The left circuit makes the red/yellow LED flash a pattern from the alarm IC (U2). The right circuit detects the LED's light pattern with the phototransistor, then amplifies it with the NPN transistor (Q2) so it can be heard on the speaker (SP).

PROJECT 163

Two Transistor Sound by Light

This project is just like the preceding one, but adds a second transistor. It works the same way except that the red/yellow LED (D10) does not need to be as close to the phototransistor (Q4) for the siren to play on the speaker.



7. Transistor-Capacitor Timing Circuits

PROJECT 164

Adjustable Time Delay Lamp

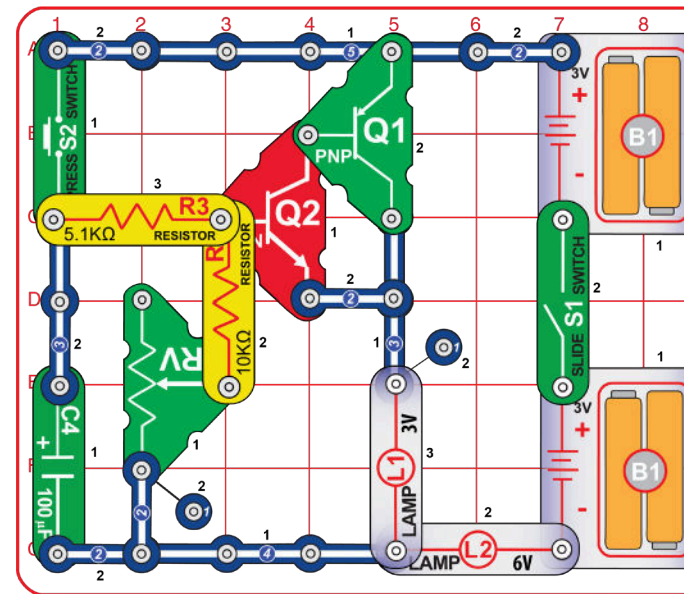
Turn on the **slide switch (S1)** and press the **press switch (S2)**. The lamps stay on for a while after you release the press switch. You can change the delay time using the **adjustable resistor (RV)**.

PROJECT 165 Adjustable Time Delay Fan

Replace the lamp (L1) with the **motor (M1, “+” on top)** and fan. Turn on the **slide switch (S1)** and press the **press switch (S2)**. The fan stays on for a while after you release the press switch. You can change the delay time with the **adjustable resistor (RV)**.

PROJECT 166 Adjustable Time Delay Lamp II

In either of the preceding circuits, replace the 100 μ F capacitor (C4) with the **470 μ F capacitor (C5)** or **10 μ F capacitor (C3)** to increase or decrease the delay. If you remove the capacitor then the lamps turn off as soon as you release the press switch.



Pressing S2 turns on the transistors (Q1 & Q2) and lamps, and charges the 100 μ F capacitor (C4). When S2 is released the capacitor discharges through the resistors and Q2 transistor, which keeps the lamps on for a while.

PROJECT 167 3V Adjustable Time Delay Lamp

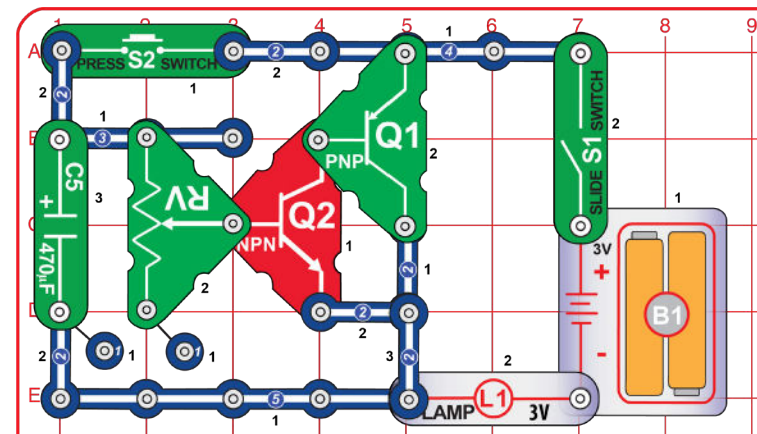
This circuit is similar to project 197. Turn on the **slide switch (S1)** and press the **press switch (S2)**. The lamps stay on for a while after you release the press switch. You can change the delay time using the **adjustable resistor (RV)**.

PROJECT 168 3V Adjustable Time Delay Fan

Replace the lamp (L1) with the **motor (M1, “+” on left)** and fan. Turn on the **slide switch (S1)** and press the **press switch (S2)**. The fan stays on for a while after you release the press switch. You can change the delay time with the **adjustable resistor (RV)**.

PROJECT 169 3V Adjustable Time Delay Lamp II

In either of the preceding circuits, replace the 470 μ F capacitor (C5) with the **100 μ F capacitor (C4)** to decrease the delay. If you remove the capacitor then the lamps turn off as soon as you release the press switch.

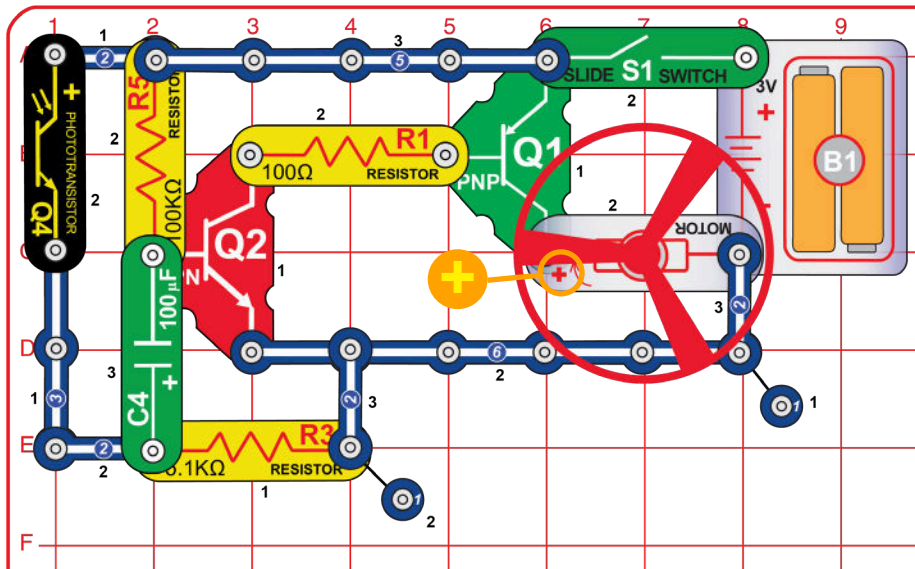


PROJECT 170

Start-Stop Delay

Turn on the **slide switch (S1)**, the fan starts spinning. As you move your hand over the **phototransistor (Q4)**, the fan slows. Now cover the phototransistor to block the light. The fan slows down. In a few seconds the fan speeds up again.

If you replace the 100 μ F capacitor (C4) with the **10 μ F capacitor (C3)** then covering the phototransistor will slow down the fan but it may not stop.



PROJECT 171 Start-Stop Delay II

With either C3 or C4 in the circuit, replace the motor (M1) and fan with the **3V lamp (L1)**. Now covering the phototransistor turns off the lamp for a time.

When light shines on the phototransistor current flows through it to charge capacitor C4, and current flows through resistor R5 to turn on the transistors (Q1 & Q2) and motor.

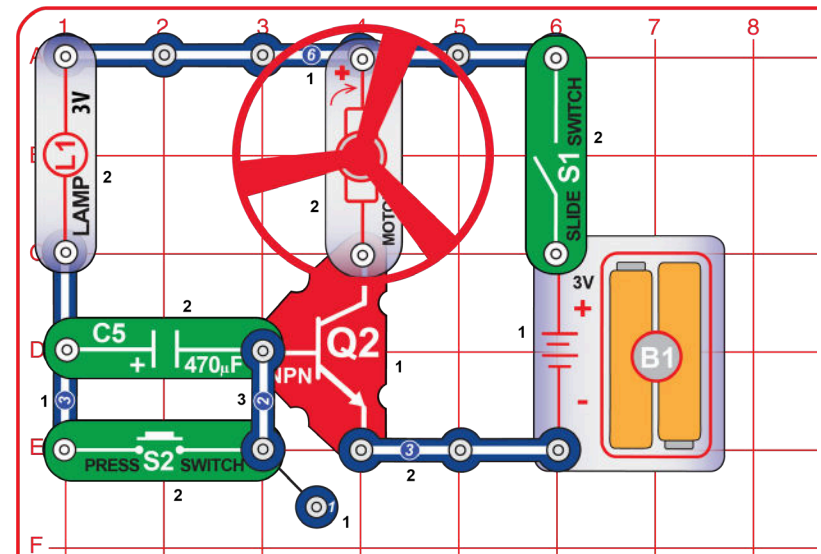
When the phototransistor is covered, the voltage across the capacitor is reversed, so current through R5 is diverted from the transistors (turning off them and the motor) for a while to charge C4 from the other side.

PROJECT 172

Short Spin

Place the **fan** on the **motor** and turn on the **slide switch (S1)**. The motor spins briefly as the 470 μ F capacitor (C5) charges up. Turn off the slide switch (S1) and then push the **press switch (S2)** to discharge the capacitor and reset the circuit.

You can bypass the capacitor by pushing the press switch while the slide switch is on. This lets the motor spin at full speed and also lights the lamp.



Here the capacitor is used to only let the fan spin for a short time.

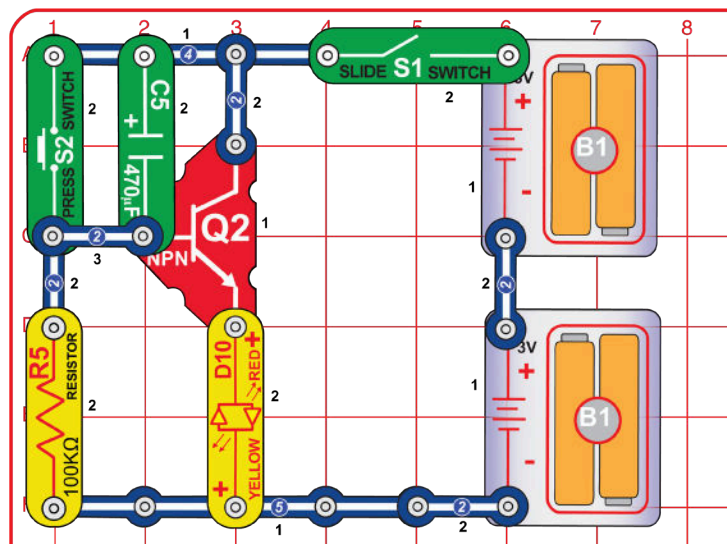
PROJECT 173

Auto-Off Night-Light

When you turn on the **slide switch (S1)** the first time the red/yellow LED (D10) will come on and very slowly get dimmer and dimmer. If you turn the **slide switch (S1)** off and back on after the light goes out it will NOT come on again. Push and release the **press switch (S2)** to reset the timer and let the LED come on again.

To make the LED stay on longer, remove the 100kΩ resistor (R50). To make the LED turn off faster, replace the 470μF capacitor (C5) with the smaller **100μF capacitor (C4)** or the much smaller **10μF capacitor (C3)**, or replace the 100kΩ resistor with the smaller **10kΩ resistor (R4)**.

You can replace the red/yellow LED (D10) with the **color LED (D8)**. You could also replace D10 with the **6V lamp (L2)**, but the lamp would go out very quickly.



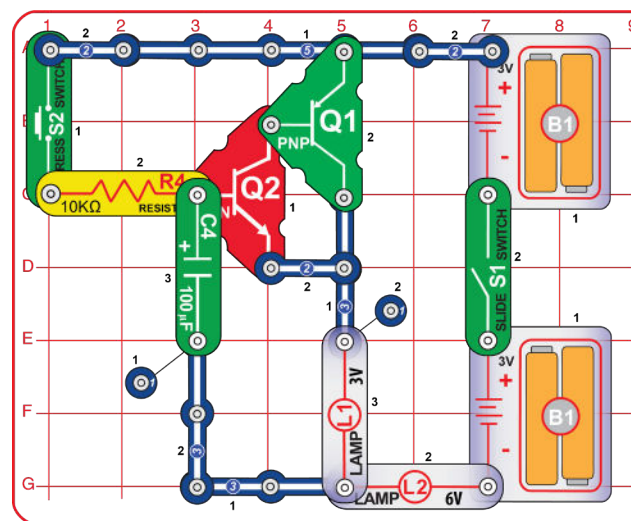
The LED is on while the 470μF capacitor (C5) is charging up, then the LED stays off until the capacitor has been discharged. Pushing the press switch (S2) instantly discharges the capacitor. Lowering the value of R5 or C5 decreases the capacitor charge time. The ability of capacitors to store electricity makes them very useful in timing and delay circuits.

This circuit would make a good night light. It would allow you to get into bed, and then it would go out. No further current is taken from the batteries, so it will not drain them even if left on all night.

PROJECT 174

Delayed Action Lamp

Turn on the **slide switch (S1)** and press the **press switch (S2)**. The lamps (L1 & L2) turn on slowly, but stay on for a while after you release the press switch.



Pushing S2 charges capacitor C4 through resistor R4, then the capacitor discharges through the NPN transistor Q2 and the 3V lamp (L1). The transistors (Q1 & Q2) amplify the small capacitor discharge current enough to light the lamp.

PROJECT 175 Delayed Action Fan

Replace the lamp (L1) with the **motor (M1)**, positive (+) side up. Be sure to put on the fan. Turn on the **slide switch (S1)** and press the **press switch (S2)**. The fan turns on slowly but stays on for a while after you release the press switch.

PROJECT 176 Delayed Action Lamp II

Use either of the preceding circuits, but replace the 100μF capacitor (C4) with the smaller **10μF capacitor (C3)** or the larger **470μF capacitor (C5)**.

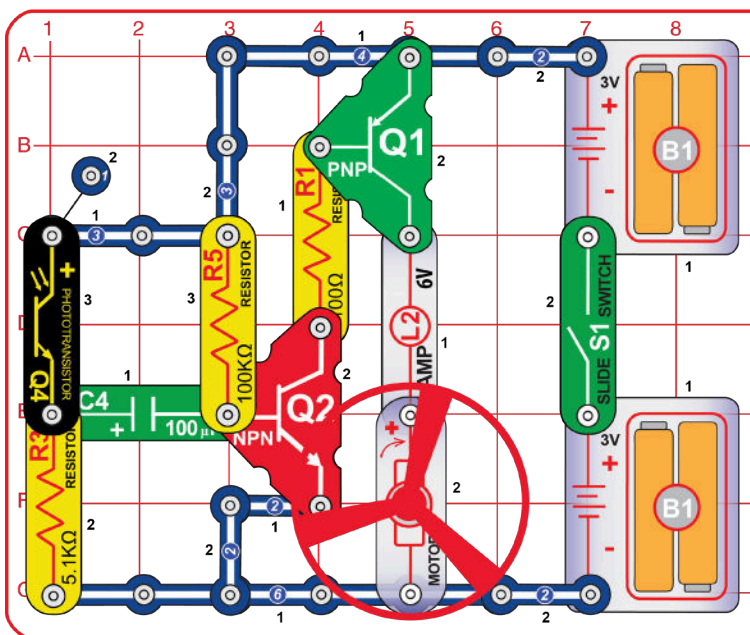
PROJECT 177 Delayed Action LEDs

Use the original circuit, but replace the 3V lamp (L1) with the **color LED (D8, "+" on top)** and replace the 6V lamp (L2) with the **red/yellow LED (D10, in either direction)**. The LEDs stay on much longer than the lamps, because they need less current. You can replace C4 with C2 or C3 to make the LEDs turn off faster.

PROJECT 178

Dark Interrupter

Turn on the **slide switch (S1)** and shine light on the **phototransistor (Q4)**. The motor (M1) and fan spin, and the 6V lamp (L2) lights. Move your hand over the **phototransistor**. The motor and lamp get slower & dimmer or turn off. After a few seconds the motor and lamp speed up & brighten again.



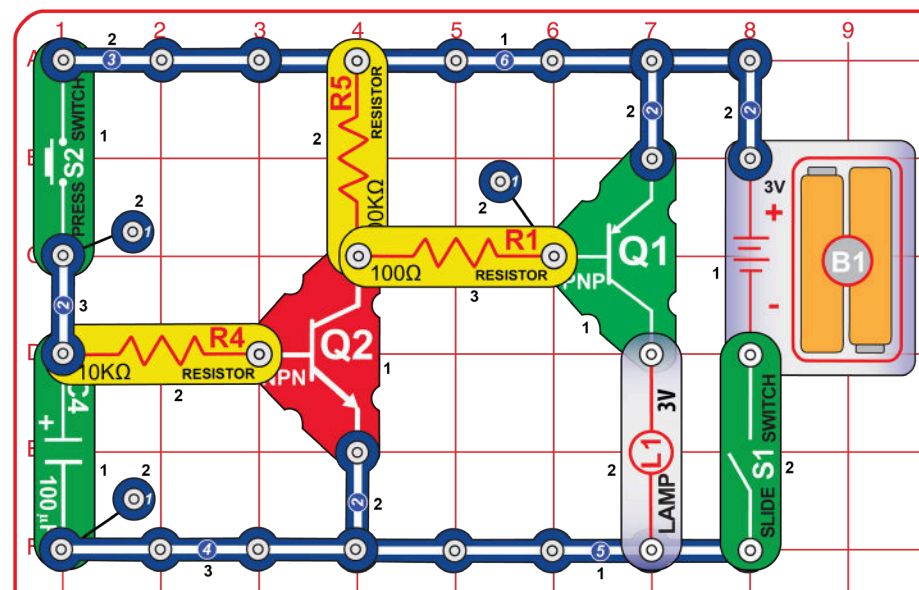
Current through the 100kΩ resistor (R5) turns on the transistors (Q1 & Q2), which turn on the motor and lamp. Blocking light to the phototransistor changes the voltage across the 100μF capacitor (C4). This diverts current from R5 into C4 and away from the transistors, turning off the transistors, motor, and lamp. After a few seconds the voltage across C4 stabilizes, so current from R5 returns to the transistors, and the motor and lamp turn back on.

PROJECT 179

Watch Light

Turn on the **slide switch (S1)** and push the **press switch (S2)**. The 3V lamp (L1) stays on for a few seconds after you release the press switch.

You can replace resistor R4 with **R2** or **R3**, and capacitor C4 with **C3** or **C5**. Lower values make the lamp turn off faster, higher values keep the lamp on longer.



PROJECT 180 Delayed Bedside Fan

Replace the 3V lamp (L1) with the **motor (M1**, “+” side up) and fan. Turn on **S1** and push **S2**. The fan stays on for a while after you release the press switch. This could have a longer delay and be near your bed, to turn off after you fall asleep.

Pressing S2 instantly charges up capacitor C4, then C4 slowly discharges through resistor R4 and transistor Q2, which turns on transistor Q1 and the lamp. Once C4 is discharged, the transistors and lamp turn off until you press S2 again.

A miniature version of a circuit like this might be in your wristwatch - when you press a light button on the watch to read the time in the dark, a light comes on but automatically turns off after a few seconds to avoid draining the battery.

PROJECT 181 Lazy Fan

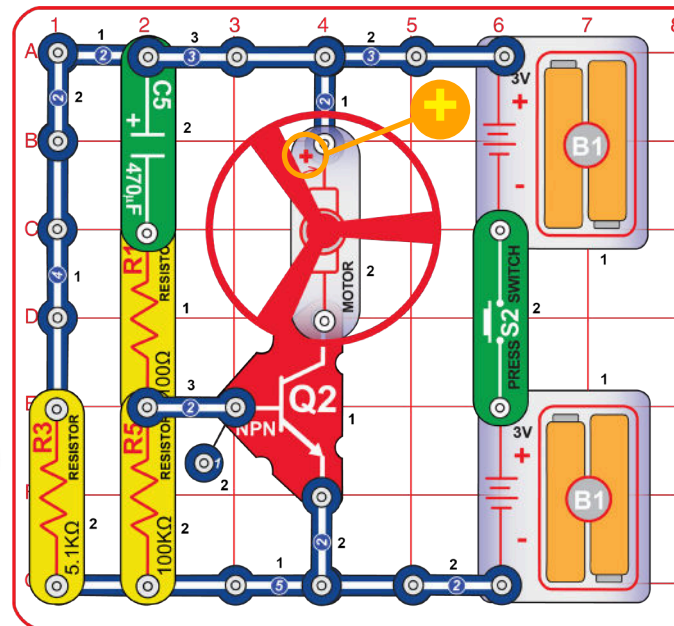
Push the **press switch (S2)** and the fan spins for a few turns. Wait a few seconds for the circuit to reset, then press **S2** again and the fan will make a few more turns.

Replace the 470 μ F capacitor (C5) with the smaller **100 μ F capacitor (C4)**. Now the fan does not spin as much but the circuit resets faster.

PROJECT 182 Lazy Fan II

Using either capacitor, replace the motor (M1) with the **6V lamp (L2)**. Now pressing S2 creates brief flash of light. Next, replace the lamp with the **color LED (D8, "+" on top)**. The LED stays on longer and the circuit recharges faster.

When you push the switch, current flows through the 470 μ F capacitor (C5), charging it while turning on the NPN transistor (Q2) and motor. Once C5 is charged, current stops flowing through it and the circuit shuts off. When the switch is not pressed, C5 discharges through the 5.1k Ω resistor (R3), resetting the circuit.

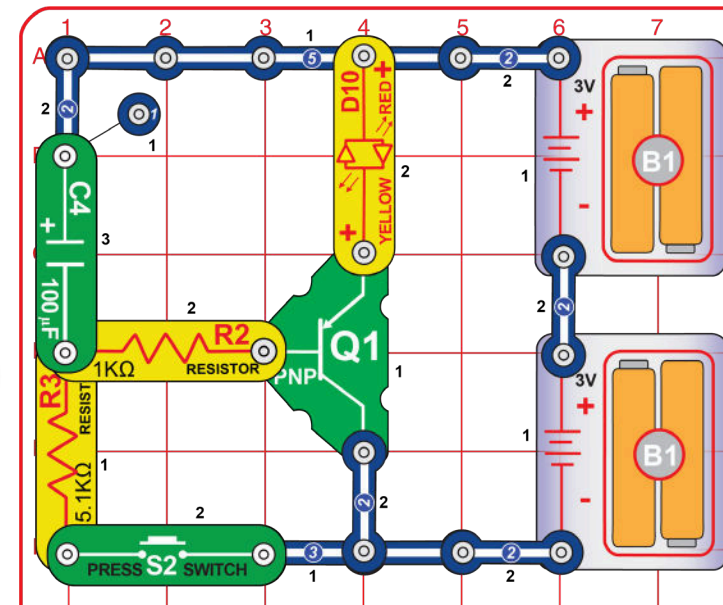


PROJECT 183 Light Dimmer

Push the **press switch (S2)**. At first nothing happens. Press S2 for about a second and the red/yellow LED (D10) turns on. The LED stays on for a while after you release S2, slowly dimming. Press S2 again to re-light the LED. You can replace the red/yellow LED with the **color LED (D8, "+" on top)**.

Replace the 100 μ F capacitor (C4) with the smaller **10 μ F capacitor (C3)**, now the LED turns on faster but also goes out faster. If you use the much smaller **C1** or **C2** capacitor then the LED turns on and off almost instantly. If you use the larger **C5** capacitor then the LED turns on and off more slowly than with C4.

When you push switch S2, at first current flows through capacitor C4, resistor R3, and the switch to charge C4, and no current flows through transistor Q1 or LED D10. As C4 becomes charged the current through it drops off, and current starts flowing through the transistor and resistor R2 to R3 and S2, turning on the LED. When S2 is released, current through Q1 and R2 flows through C4 (instead of R3 & S2), discharging it. The LED stays on until C4 is discharged.



PROJECT 184

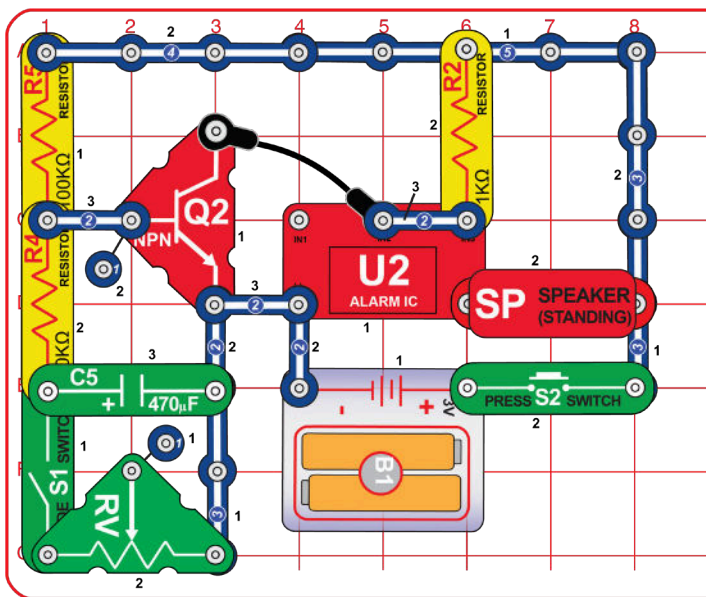
Laser Gun with Limited Shots

Turn off the **slide switch (S1)** and push the **press switch (S2)**. A machine gun sounds while you press S2, but stops after a short time. Wait a few seconds for the circuit to reset, then press S2 again and the machine gun will work again.

Now turn on the slide switch and press S2 again. The sound plays longer and the circuit resets faster.

Replace the 470 μ F capacitor (C5) with the smaller **100 μ F capacitor (C4)**. Now the sound does not play as long but the circuit resets faster.

The adjustable resistor (RV) is used here as a fixed resistor (of 50k Ω), so moving its lever has no effect.

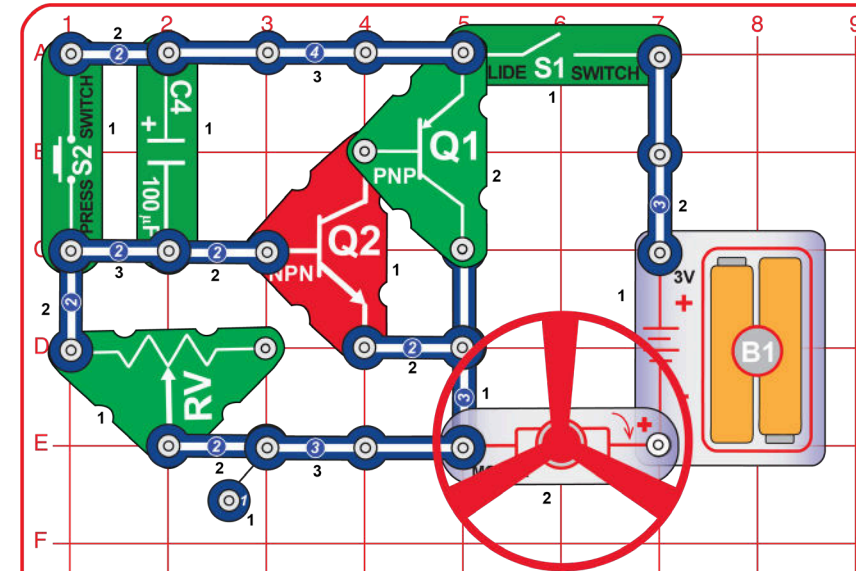


The sound plays while capacitor C5 is charging, then stops until C5 is discharged. Turning on the slide switch connects the adjustable resistor (RV) across the capacitor, allowing it to discharge faster.

PROJECT 185

Motor Delay Fan

Set the **adjustable resistor (RV)** lever to the far right. Turn the **slide switch (S1)** on and then push the **press switch (S2)** once. The fan will spin for a while and then stop. Now set the resistor lever to the far left and push the press switch again. The fan only spins for a short time now.



PROJECT 186 Motor Delay Fan II

Replace the 100 μ F capacitor (C4) with the smaller **10 μ F capacitor (C3)** to make the fan turn off faster or replace it with the larger **470 μ F capacitor (C5)** to make the fan stay on longer. You can also replace the motor (M1) and fan with the **3V lamp (L1)**.

When S2 is pressed, current flows through S2 to turn on the transistors (Q1 & Q2) and spin the fan. Pressing S2 also discharges the 100 μ F capacitor (C4). When S2 is released, the capacitor begins discharging and supplies control current to keep the transistors and fan on. The transistors act like a switch connecting the motor to the batteries. When the capacitor is fully discharged, the transistors turn off and the fan stops. The adjustable resistor controls how fast the capacitor discharges; the more resistance, the longer the discharge time.

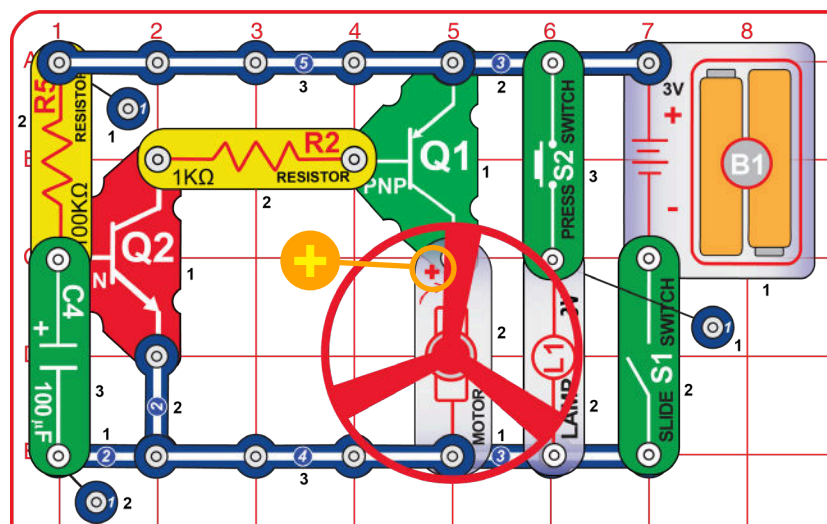
PROJECT 187

Delayed Start Fan

Turn on the **slide switch (S1)**—nothing happens. After a few seconds delay the fan spins. Push the **press switch (S2)**, the 3V lamp (L1) lights and the fan slows down a little.

Replace the lamp with the **red/yellow LED (D10)**, in either direction). Pressing S2 lights the LED but does not affect the fan speed.

Replace the 100 μ F capacitor (C4) with the larger **470 μ F capacitor (C5)**. Now the fan start-up delay is much longer.



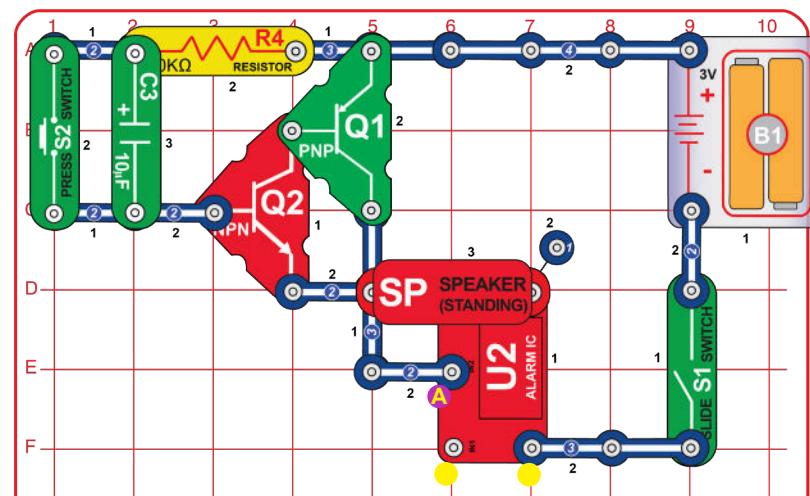
When you turn on the circuit, current flows through the 100k Ω resistor (R5) to charge up the 100 μ F capacitor (C4). Once C4 is charged, current from R5 flows to the transistors (Q1 & Q2) where it is amplified enough to power the motor (M1). The start-up delay is determined by R5 and C4; increasing these values makes the delay longer.

Turning on the lamp increases the current load on the batteries, lowering their voltage a little and so slowing the motor (especially if the batteries are weak). The red/yellow LED uses much less current than the lamp, so does not effect the batteries.

PROJECT 188

Transistor Fading Siren

Turn on the **slide switch (S1)**, then press and release the **press switch (S2)**. You hear a siren that slowly fades away and eventually goes off.



PROJECT 189 Transistor Fading Siren II

Connect points **A & B** or **B & C** using a jumper wire. The siren is different now.

PROJECT 190 Transistor Fading Siren III

Replace the 10 μ F capacitor (C3) with the **100 μ F capacitor (C4)** or **0.1 μ F capacitor (C2)** to greatly slow down or speed up the fading.

When you turn on the circuit, current flows through the 10k Ω resistor (R4), charging the 10 μ F capacitor (C3) and turning on the transistors (Q1 & Q2), which control the alarm IC (U2). Once C3 is charged, current stops flowing to the transistors and the siren shuts off. Pressing S2 discharges the capacitor and resets the circuit.

PROJECT 191 Alarm Timer

Turn on the **slide switch (S1)**. An alarm may sound briefly and the 3V lamp (L1) brightens. Push the **press switch (S2)** and the alarm sounds. Release the press switch; the alarm still sounds for a while and then the lamp lights.

PROJECT 192 Alarm Timer II

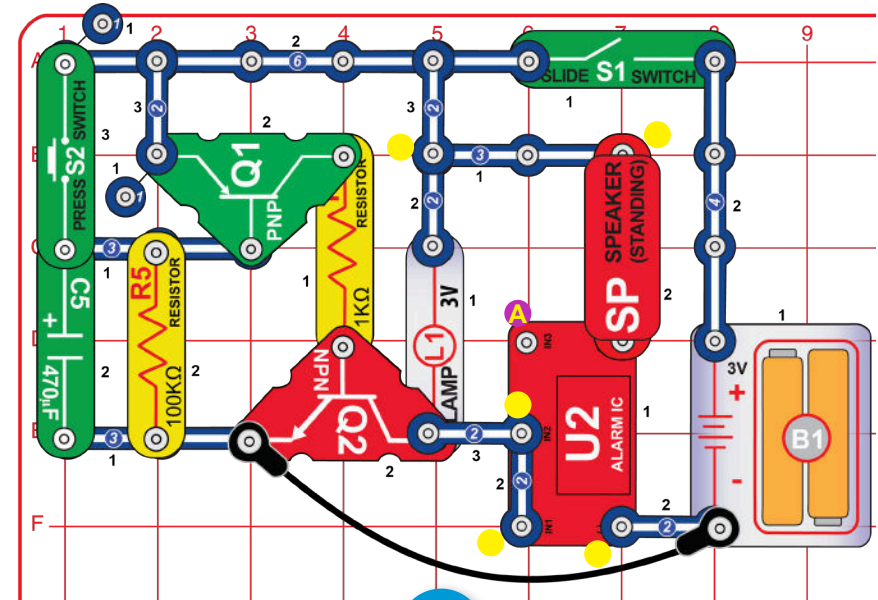
Remove the 2-snap wire that is across points B & C and place it across points **A & B**, or replace it with a 1-snap at point **B**, or replace it with a 1-snap at point **B** and a 2-snap across points **C & D**. The siren is different now.

PROJECT 193 Alarm Timer III

Replace capacitor C5 and resistor R5 with these combinations: **R5 & C3**, **R4 & C4**, and **R4 & C5**.

PROJECT 194 Alarm Timer IV

Replace the 3-snap wire across points X & Y with the **100Ω resistor (R1)**, or replace the speaker (SP) with the **whistle chip (WC)** and color LED (D8, "+" on top) stacked together.



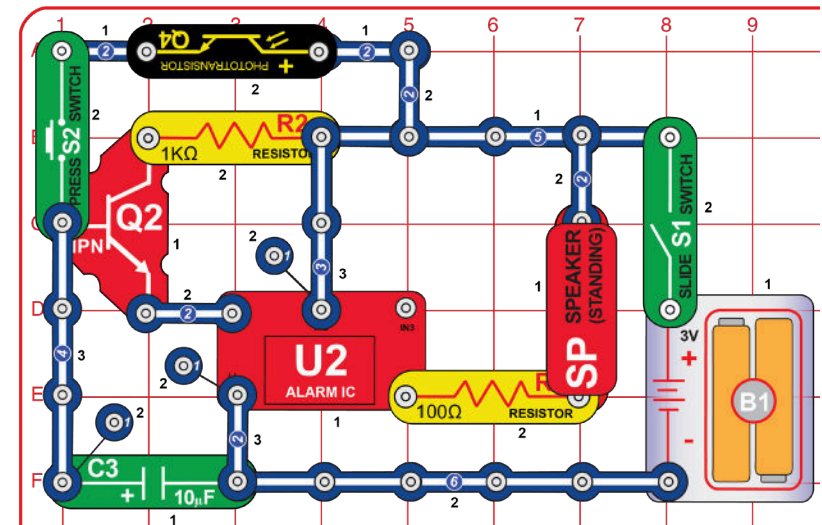
Pressing S2 instantly charges up the 470μF capacitor (C5). When C5 is charged, its voltage keeps the transistors (Q1 & Q2) off, and the alarm IC (U2) and LED are turned on by a small current through the 3V lamp (L1). When S2 is released, C5 discharges through resistor R5, keeping the transistors off and the alarm IC & LED on for a while. C5's voltage drops as it is discharged, turning the transistors on, which turns on the lamp and turns off the alarm IC & LED. The capacitor discharge time is determined by the values for C5 and R5.

PROJECT 195 Slow Siren Changer

Turn on the **slide switch (S1)** and you hear a siren sound. Now hold down the **press switch (S2)** until the sound becomes a fire engine sound. If there is bright light on the phototransistor then the delay will be only a few seconds.

Release the press switch and after a while the sound will be a siren again.

Pressing S2 charges up the 10μF capacitor (C3) through the phototransistor, and changes the sound by turning on the NPN transistor (Q2). When S2 is released capacitor C3 discharges through transistor Q2, keeping it (and the fire engine sound) on for a little while.



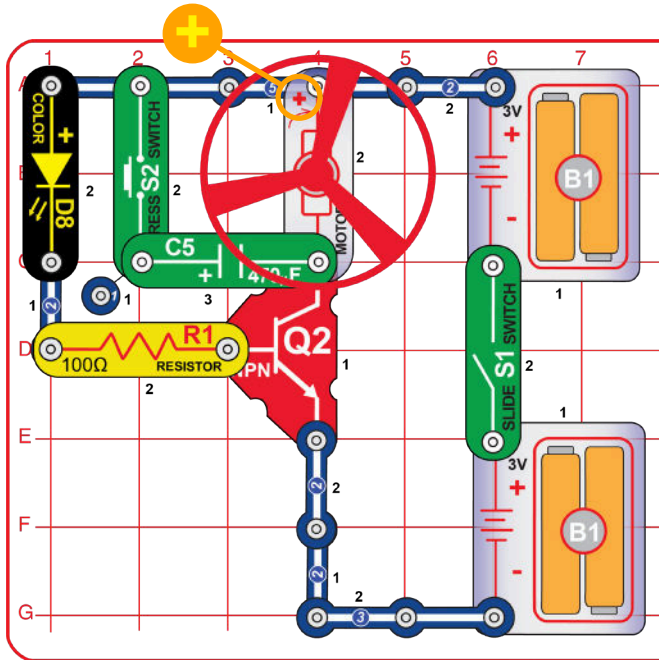
PROJECT 196

Flasher Motor Control

Turn on the **slide switch (S1)**. The fan spins and the color LED (D8) lights, but the color LED may not be flashing.

Push the **press switch (S2)** to connect the 470 μ F capacitor (C5) across the motor (M1). Now the color LED is flashing and the fan is changing speed.

Replace the 100 Ω resistor (R1) with the **1k Ω resistor (R2)** or the **5.1k Ω resistor (R3)** to reduce the fan speed.



Here current through the color LED is amplified by the NPN transistor (Q2) to control the motor.

The motor produces electrical pulses as it spins, and these pulses can confuse the color LED. Pressing S2 connects the 470 μ F capacitor across the motor's electrical pulses, so the color LED can change colors. The current through the color LED drops as it changes colors, reducing the current to the motor in bursts, which change the fan speed. Capacitors are very useful for filtering out circuit disturbances.

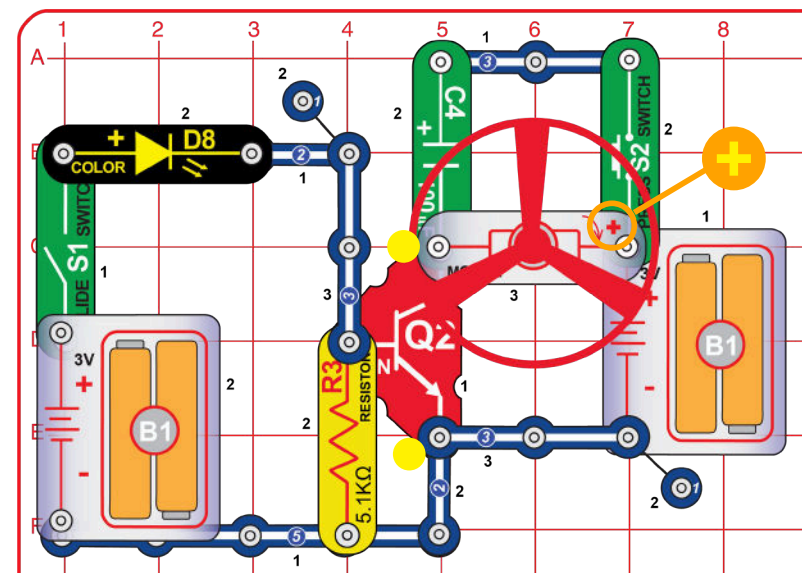
PROJECT 197

Funny Speed Motor

Build the circuit as shown and turn on the **slide switch (S1)**. The color LED (D8) is blinking and the motor (M1) spins at different speeds. Try this circuit with the fan on the motor, and without the fan.

If the color LED (D8) does not flash with its normal pattern, then push the **press switch (S2)** and hold it down.

If desired add the **red/yellow LED (D10)** across points **A & B** (in either direction). This adds another blinking light.



In this circuit the color LED is powered by one set of batteries, and the motor is powered by different set. This was done because the motor produces electrical pulses as it spins, and these pulses can confuse the color LED. Pushing S2 adds the 100 μ F capacitor to help filter out the motor pulses.

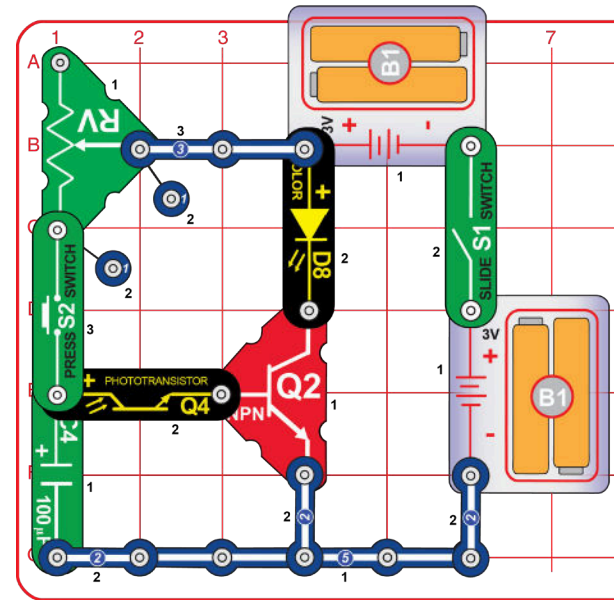
The motor is controlled by the color LED using the transistor (Q2). If you remove the color LED from the circuit then the motor will not spin.

PROJECT 198 Photo Control

Turn on the **slide switch (S1)**, and push the **press switch (S2)** until the color LED (D8) is brightest. The color LED will light for a while and then slowly turn off. The brighter the light on the **phototransistor (Q4)**, the shorter the color LED stays on. The lever on the **adjustable resistor (RV)** controls how quickly the color LED gets bright when S2 is pressed.

PROJECT 199 Photo Control II

Replace the 100 μ F capacitor (C4) with the smaller **10 μ F capacitor (C3)** to make the color LED turn on and off faster, or with the larger **470 μ F capacitor (C5)** to make the LED turn on and off much more slowly. You can also replace the color LED with the **red/yellow LED (D10)**.



Pressing S2 charges capacitor C4 through the adjustable resistor. When S2 is released, the capacitor discharges through the phototransistor and NPN transistor (Q2). The transistor controls the color LED, so current from the capacitor keeps the LED on after S2 is released.

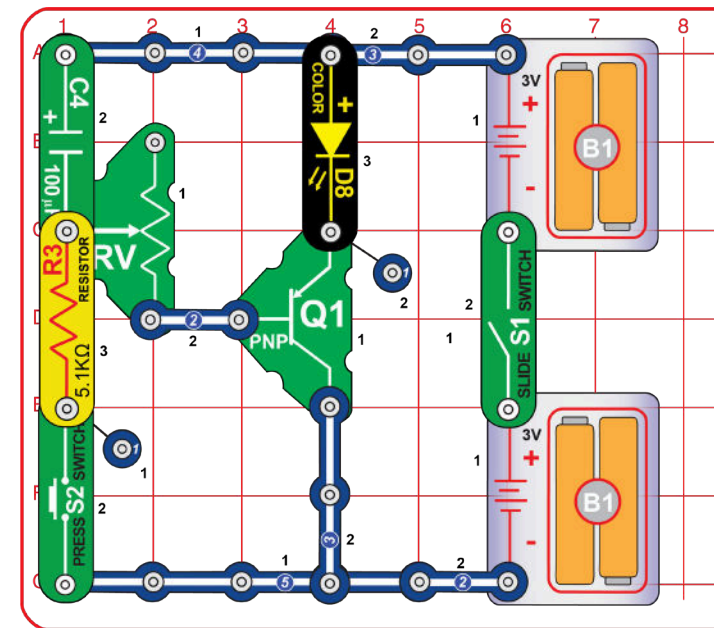
PROJECT 200 Slow On, Slower Off

Turn on the **slide switch (S1)**, nothing happens. Now push the **press switch (S2)** and hold it down. The color LED (D8) takes a few seconds to turn on, then will very slowly get dim after S2 is released. The adjustable resistor (RV) controls the shut-off time.

PROJECT 201 Slow On, Slower Off II

Replace the 100 μ F capacitor (C4) with the **smaller 10 μ F capacitor (C3)** to make the color LED turn on and off faster, or with the larger **470 μ F capacitor (C5)** to make the LED turn on and off much more slowly. You can also replace the color LED with the **red/yellow LED (D10)**.

The 100 μ F capacitor (C4) controls the color LED through the PNP transistor (Q1). Pressing S2 quickly charges up the capacitor through resistor R3, and releasing S2 allows the capacitor to slowly discharge through RV and the transistor.



8. Transistor Oscillators

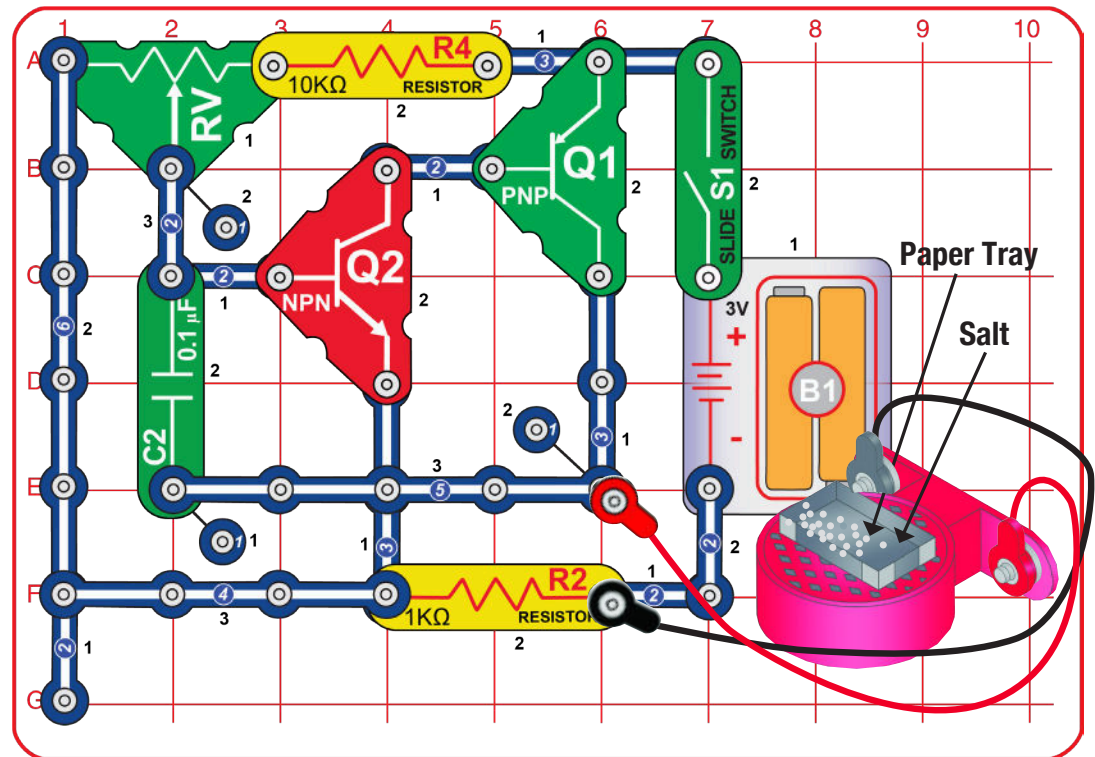
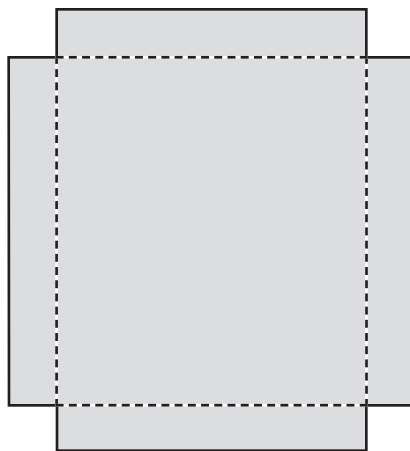
PROJECT 202 Sound Wave Magic

Build the circuit shown on the left and connect the **speaker (SP)** using the two (2) jumper wires. Then, lay the speaker on a flat hard surface.

Setup: Use some paper and scissors to cut out a rectangular pattern. Use the one shown below as a guide. Use colored paper if available. Fold at the points shown. Scotch tape the corners so the tray has no cracks at the corners. Place the tray over the speaker and sprinkle a small amount of white table salt in the tray. There should be enough salt to cover the bottom with a little space between each salt grain.

Sound Magic: Turn on the circuit by turning on the **slide switch (S1)**. Adjust the **adjustable resistor (RV)** for different pitches and watch the salt particles. Particles that bounce high are directly over the vibrating paper and ones that do not move are in the nodes where the paper is not vibrating. Eventually, all the salt will move to the areas that have no vibration, and stay there. Change the position of the tray and the material used to create different patterns due to the sound. Try sugar and coffee creamer, for example, to see if they move differently due to the sound waves.

Sample Cut-out Pattern



PROJECT 203 Motor Oscillator

Turn on the **slide switch (S1)**, about once a second the lamp (L2) flashes and the fan spins in a short burst. Moving the control lever on the **adjustable resistor (RV)** makes these occur more or less often. This works with the fan on or off the motor.

PROJECT 204 Motor Oscillator II

Replace the 100 μ F capacitor (C4) with the larger 470 μ F capacitor (C5). Now the circuit activates less often, but the lamp flash is brighter and the motor turns farther.

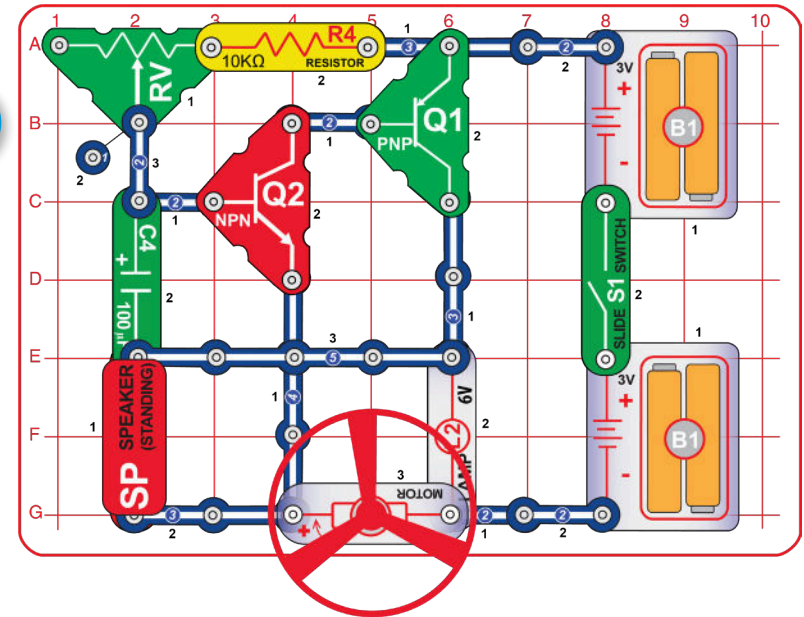
PROJECT 205 Motor Oscillator III

Now replace the 470 μ F capacitor (C5) with the smaller 10 μ F capacitor (C3). Now the circuit activates more frequently, but the lamp may be too dim to see and the motor barely moves.

This circuit is an oscillator that turns on the transistors (Q1 & Q2, which control the lamp and motor for a short time, in a repeating cycle.

The transistors are off while the capacitor (C4) charges up through resistors RV and R4. Then the capacitor discharges in a burst that turns on the transistors, which light the lamp and turn the motor.

Changing the resistor or capacitor values changes the capacitor charging time, and a larger capacitor keeps the lamp and motor on longer.



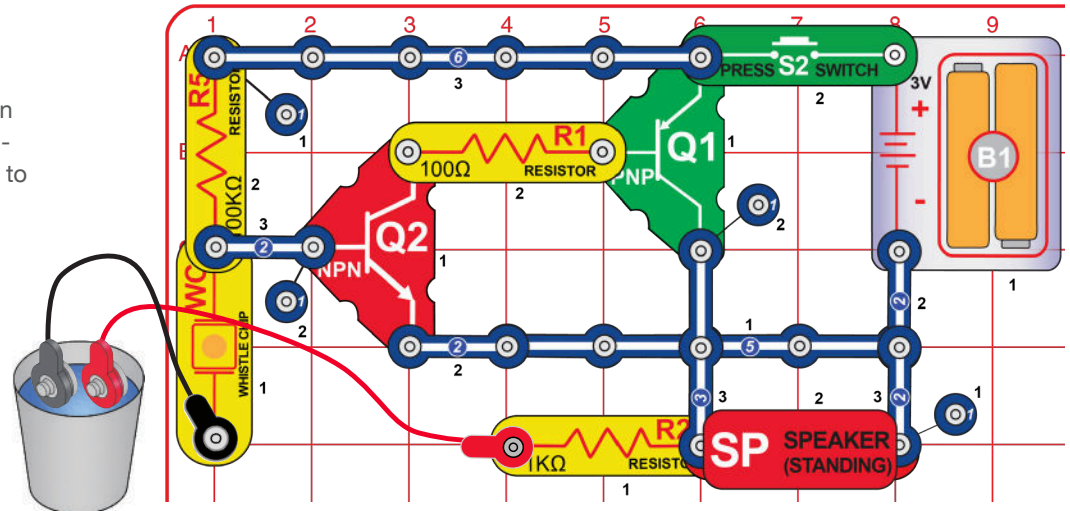
PROJECT 206 Water Tester

Build the circuit shown, and place the loose ends of the **red & black jumper** in an empty cup (without them touching each other). Press the **press switch (S2)** - nothing happens. Add some water to the cup and an alarm will sound. Add salt to the water and the tone changes.

You can also test different liquids and see what tone they produce.

Don't drink any water used here.

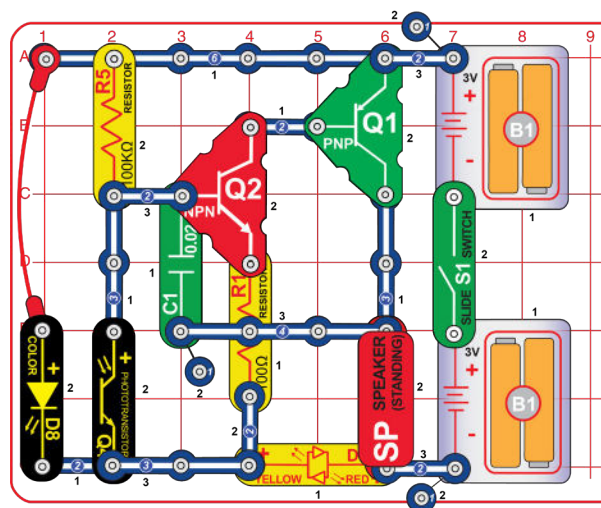
This circuit uses water to complete an oscillator circuit. When you add salt to the water its resistance changes, which changes the tone of oscillation.



PROJECT 207

Funky Sound Oscillator

Turn on the **slide switch (S1)**. Cover the **phototransistor (Q4)**, but without blocking light from the color LED (D8) to it. Listen to the sounds.



Varying the amount of light shining on the phototransistor changes the phototransistor's resistance, which changes the frequency of oscillation. The color LED's changing pattern changes the light to the phototransistor, so changes the sound.

PROJECT 208 Funky Sound Oscillator II

Remove the color LED and replace the **red/yellow LED (D10)** with it (put the color LED's "+" on left). The sound is different now.

PROJECT 209 Funky Sound Oscillator III

With any of the preceding circuits, place the 0.1μF capacitor (C2), 10μF capacitor (C3), or **whistle chip (WC)** directly over the 0.02μF capacitor (C1). The circuit works the same way, but the sound is different now.

PROJECT 210 Funky Sound Oscillator IV

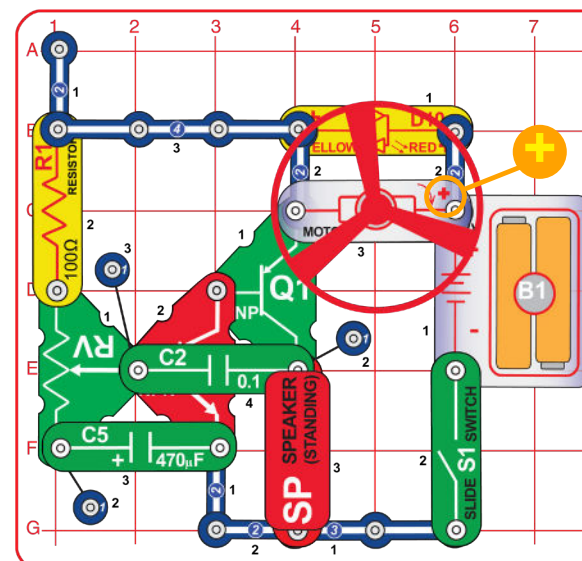
With any of the preceding circuits, replace the speaker (SP) with the **6V lamp (L2)**. The lamp twinkles as D8 changes colors, though there is no sound.

PROJECT 211

Screaming Fan

Turn on the **slide switch (S1)** and move the setting on the **adjustable resistor (RV)** across its range. You hear screaming sounds, the red/yellow LED (D10) lights, and the fan spins.

Notice the color of the red/yellow LED—the red side is toward the batteries so it should be red, but it may look orange. Try the LED in both directions.



This circuit is an oscillator that is continuously switching the motor (M1) and LED on and off. When the motor is switched off its mechanical motion briefly generates a voltage across the LED but in the opposite direction. So when the oscillator is on the LED lights red and when the oscillator is off the LED lights yellow, but the LED color changes so fast that it looks like a mix of red and yellow (orange). The resistors (R1 & RV) and C2 capacitor change the oscillation frequency.

PROJECT 212 Screaming Fan II

Replace the 0.1μF capacitor (C2) with the smaller 0.02μF capacitor (C1).

PROJECT 213 Screaming Fan III

Replace the 0.1μF capacitor (C2) with the larger 10μF capacitor (C3) or 100μF capacitor (C4), "+" on either side. Set **RV** to mid-range to make the fan spin in bursts.

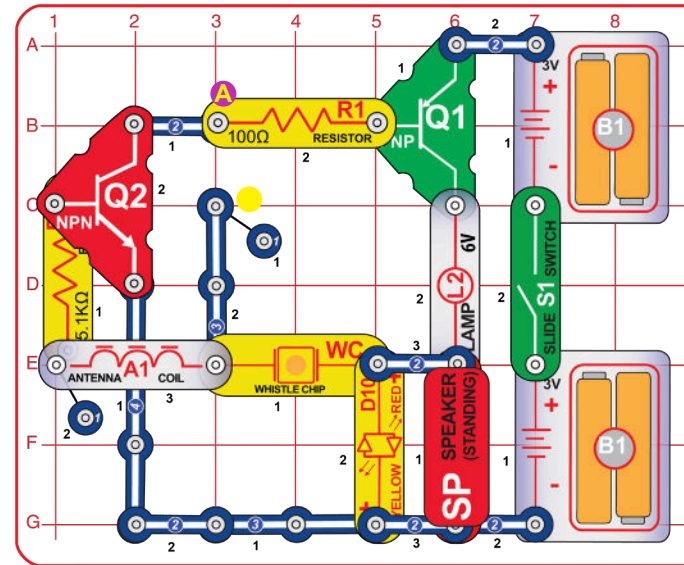
PROJECT 214 Screaming Fan IV

In any of the preceding circuits, replace the 100Ω resistor (R1) with the **phototransistor (Q4)**, "+" on top), and wave your hand over it.

PROJECT 215 Lie Detector

Turn on the **slide switch (S1)** and place your finger across points **A & B**. The speaker (SP) will output a tone and the red/yellow LED (D10) will flash at the same frequency. Your finger acts as a resistor connecting points A & B. When a person is lying, one thing the body starts to do is sweat. The sweat makes the finger a better conductor by reducing its resistance.

Lightly wet your finger and place it across points **A & B** again. Both the output tone and LED flashing frequency increase, and the lamp (L2) may begin to light. If your finger is wet enough, then the lamp will be bright and the sound stops - indicating you are a big liar! Now change the wetness of your finger by drying it and see how it affects the circuit. This is the same principle used in lie detectors that are sold commercially.



This circuit is an oscillator, but it must have a high resistance between points A & B. As the resistance drops, the frequency of the tone increases. If the resistance drops too much then the circuit stops oscillating.

PROJECT 216 Hissing Foghorn

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)**. Sometimes it will make a foghorn sound, sometimes it will make a hissing sound, and sometimes it will make no sound at all.

PROJECT 217 Hissing Foghorn II

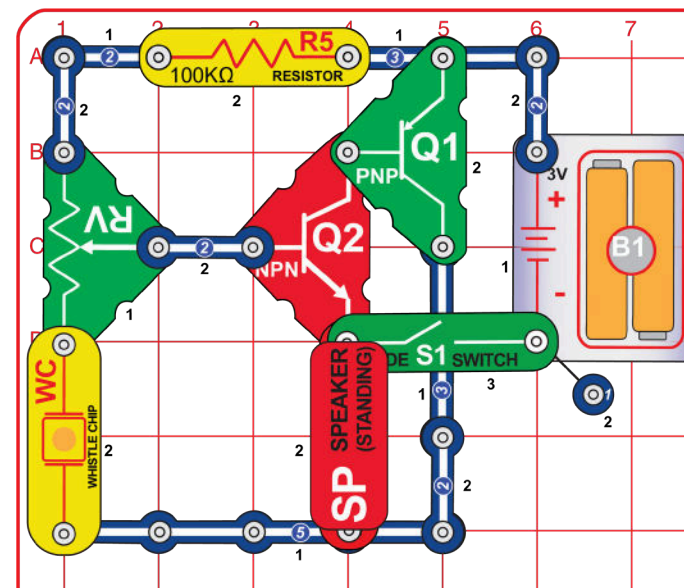
Replace the 100kΩ resistor (R5) with the **phototransistor (Q4, "+" on right)**. Move the **adjustable resistor (RV)** lever until you hear hissing sounds, and then shield the phototransistor and you hear clicking sounds.

PROJECT 218 Hissing Foghorn III

Remove the phototransistor (Q4) from the circuit and instead touch your fingers across the snaps where it had been connected while moving the **adjustable resistor (RV)** lever. You hear a clicking that sounds like the engine sound in auto-racing video games.

PROJECT 219 Hissing Foghorn IV

Put the 100kΩ resistor (R5) back in the circuit and place the 0.1μF capacitor (C2) or the 10μF capacitor (C3, "+" on top) on top of the **whistle chip (WC)**. Or use the 10kΩ resistor (R4) instead of the 100kΩ resistor.



This circuit is an oscillator. The resistors (R5, & RV) and the capacitance of the whistle chip change the oscillation frequency; reducing their values increases the pitch of the sound. The circuit will not oscillate at all component values.

PROJECT 220 Whiner

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)**. It makes a loud, annoying whine sound. The color LED (D8) appears to be on, but it is actually flashing at a very fast rate.

PROJECT 221 Lower Pitch Whiner

Place the 0.02 μ F capacitor (**C1**) above the **whistle chip (WC)** and vary the **adjustable resistor (RV)** again. The frequency (or pitch) of the whine has been reduced by the added capacitance.

PROJECT 222 Hummer

Now place the 0.1 μ F capacitor (**C2**) above the **whistle chip (WC)** and vary the **adjustable resistor (RV)** again. The frequency (or pitch) of the whine has been reduced by the greater added capacitance and it sounds more like a hum now.

PROJECT 223 Adjustable Metronome

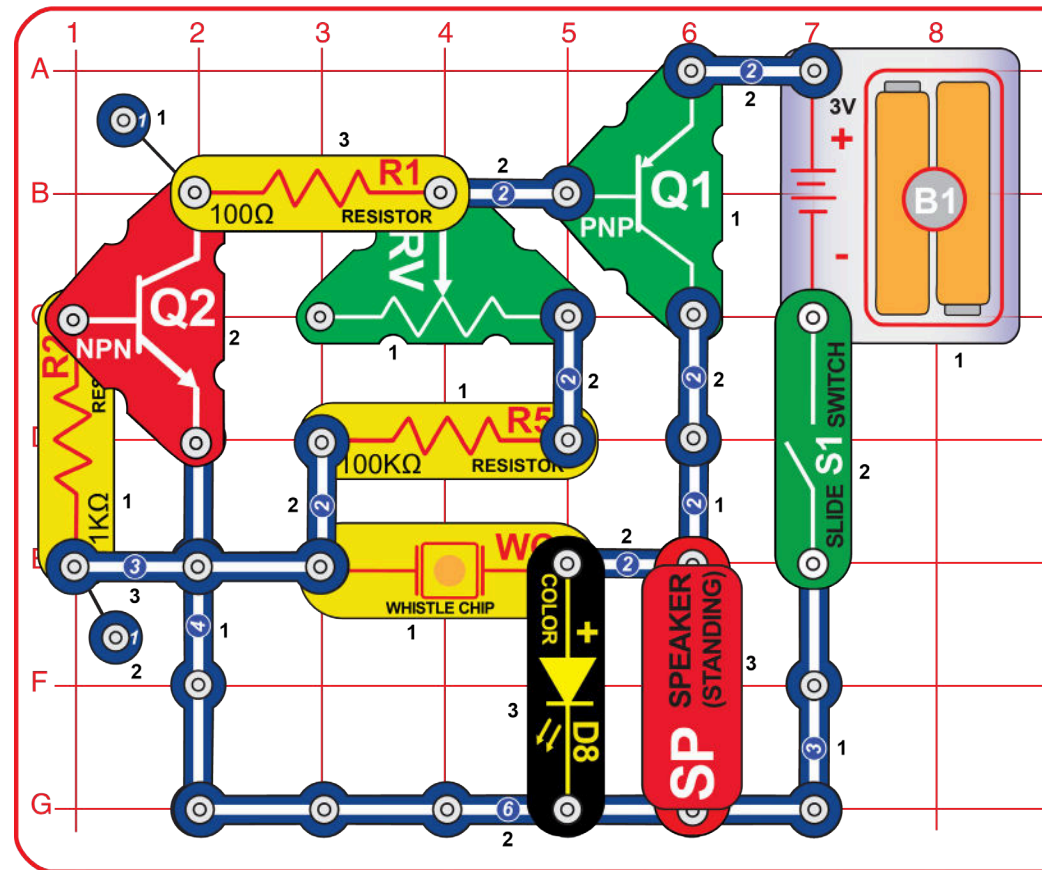
Now place the 10 μ F capacitor (**C3**, "+" side on right) above the **whistle chip (WC)** and vary the **adjustable resistor (RV)** again. There is no hum now but instead there is a click and a flash of light repeating about once a second, like the "beat" of a sound. It is like a metronome, which is used to keep time for the rhythm of a song.

PROJECT 224 Quiet Flasher

Leave the 10 μ F capacitor (C3) connected but replace the speaker (SP) with the **3V lamp (L1)**.

PROJECT 225 Experimental Whiner

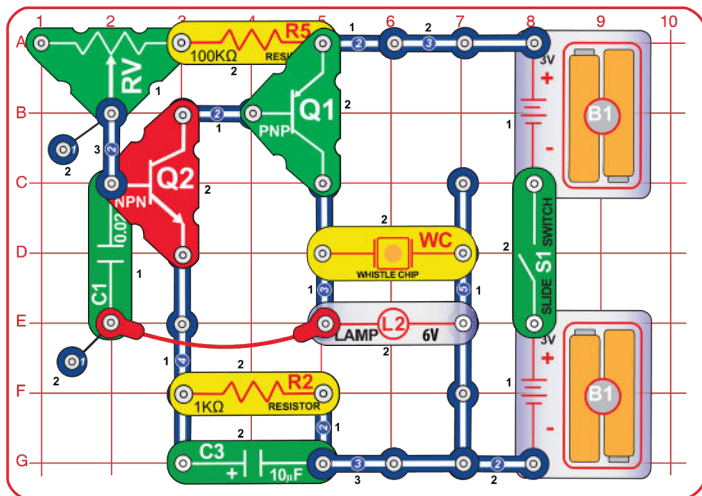
Experiment with replacing R2 and R5 with **different resistor values**, or replace the color LED (D8) with the **red/yellow LED (D10)**, in either direction).



This circuit is an oscillator. The resistors (R2, R5, & RV) and the capacitance of the whistle chip change the oscillation frequency; reducing their values increases the pitch of the sound. The circuit may not oscillate at all component values.

PROJECT 226 Pitch

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)**. The frequency or pitch of the sound is changed.



PROJECT 227 Pitch II

Place the 0.1μF capacitor (**C2**) or the 10μF capacitor (**C3**, "+" on top) on top of the 0.02μF capacitor (**C1**); notice how the sound has changed.

PROJECT 228 Pitch III

Use any of the preceding circuits and replace the 100kΩ resistor (**R5**) with the **phototransistor (Q4)**. Wave your hand up and down over the phototransistor to change the sound. Changing the light on the phototransistor changes the circuit resistance just like varying the adjustable resistance does.

PROJECT 229 Pitch IV

Replace the 100kΩ resistor (**R5**) with the smaller **10kΩ resistor (R4)**.

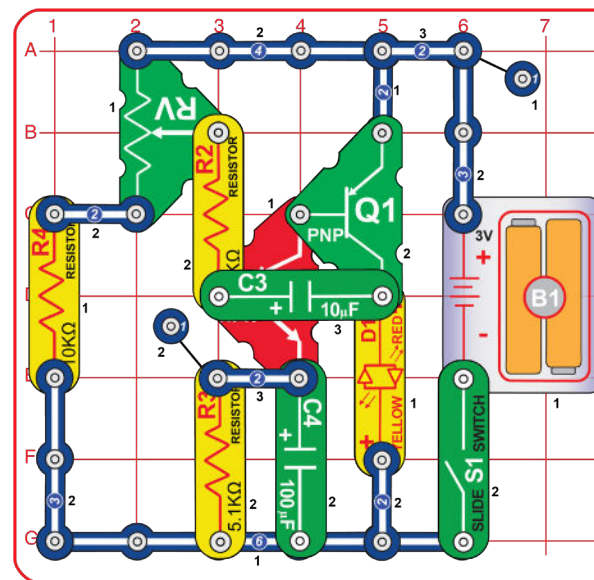
This circuit is an oscillator. The resistors (**R5**, & **RV**) and capacitor (**C1**) change the oscillation frequency; reducing their values increases the frequency of the sound. The circuit may not oscillate at all component values.

Pitch is the musical profession's word for frequency. If you've had music lessons, you may remember the music scale using chords such as A3, F5, and D2 to express the pitch of a sound. Electronics prefers the term frequency, as in when you adjust the frequency on your radio.

PROJECT 230

Oscillator 0.5–30Hz

Set the **adjustable resistor (RV)** to the bottom position and then turn on the **slide switch (S1)**. The red/yellow LED (**D10**) will start flashing at a frequency of 0.5Hz (once every two seconds). Slowly adjust the adjustable resistor and the LED flashes faster. As the frequency increases, the LED flashes faster. Eventually, the LED flashes so fast, it looks like it is on all of the time.



This circuit is an oscillator. The resistors (**R4**, & **RV**) and capacitor (**C3**) change the oscillation frequency; reducing their values increases the frequency of the sound. The circuit may not oscillate at all component values.

PROJECT 231 Sound Pulse Oscillator

Connect a single snap under the **speaker (SP)** and then connect it across the LED (on level 4). Turn the **slide switch (S1)** on and now you can hear the oscillator. Adjust the **adjustable resistor (RV)** to hear the different frequencies. Now you can hear and see the frequencies. Note: You may not hear sounds at all settings of the adjustable resistor.

PROJECT 232 Oscillator 0.5–30Hz II

Replace the 10μF capacitor (**C3**) with the smaller 0.02μF capacitor (**C1**) or the 0.1μF capacitor (**C2**). Now the sound is a tone, not beeping.

PROJECT 233

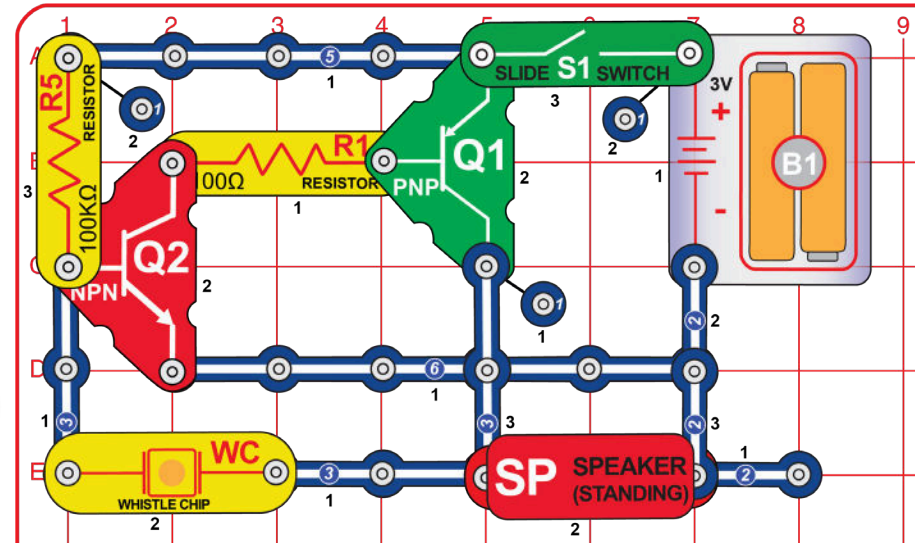
Tone Generator

Turn on the **slide switch (S1)**. You hear a high-frequency tone.

PROJECT 234 Tone Generator II

Place the 0.02 μ F capacitor (**C1**) on top of the **whistle chip (WC)**. Next replace C1 with the 0.1 μ F capacitor (**C2**), then replace C2 with the 10 μ F capacitor (**C3**). The pitch of the sound is lower with each value, and with C3 is a beeping sound.

This circuit is an oscillator. Resistor R5 turns on the transistors (Q1 & Q2), which are amplifiers. The output of the transistor amplifiers is fed back to their input through the whistle chip to be re-amplified, creating oscillation. Stacking capacitors on top of the whistle chip reduces the oscillation frequency.



PROJECT 235

More Tone Generator

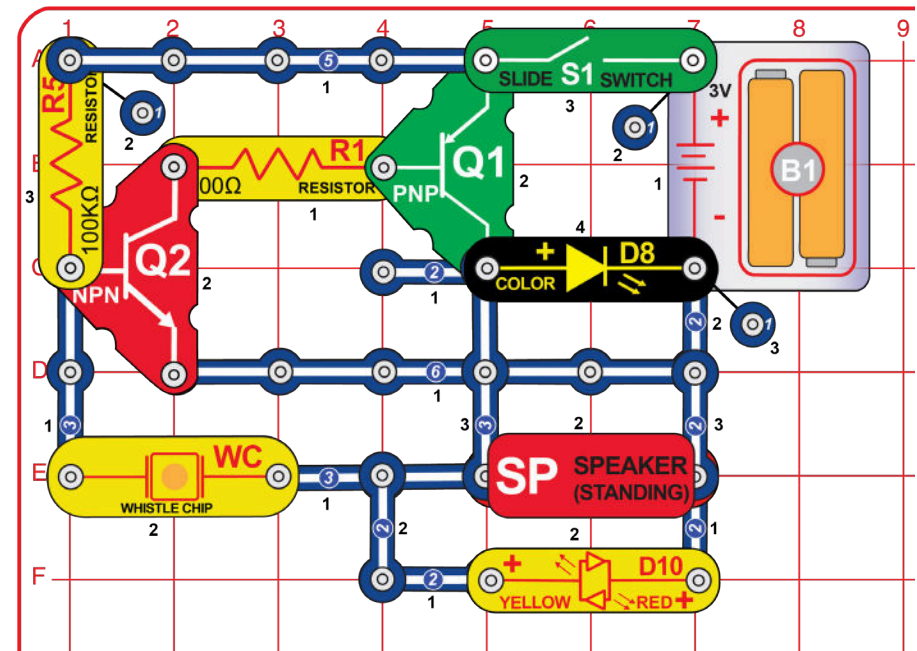
This circuit is similar to project 271, but adds some LEDs. Turn on the **slide switch (S1)**. You hear a tone, and the LEDs (D8 & D10) are dimly lit. The LEDs are actually blinking at a very fast rate.

PROJECT 236 More Tone Generator II

Place the 0.02 μ F capacitor (**C1**) or the 0.1 μ F capacitor (**C2**) on top of the **whistle chip (WC)**. The pitch of the tone is lower now.

PROJECT 237 More Tone Generator III

Now place the 10 μ F capacitor (**C3**) on top of the **whistle chip (WC)**. You hear a clicking sound as the LEDs blink about once a second.



PROJECT 238 Another Tone Generator

Turn on the **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** to change the tone. The circuit may not make sound at all RV settings.

PROJECT 239 Another Tone Generator II

Replace the slide switch with the **press switch (S2)**. Press and release S2 to create long and short tones. You can use this circuit to practice sending messages by Morse Code using the code chart in project 346.

PROJECT 240 Ghost Shriek Machine

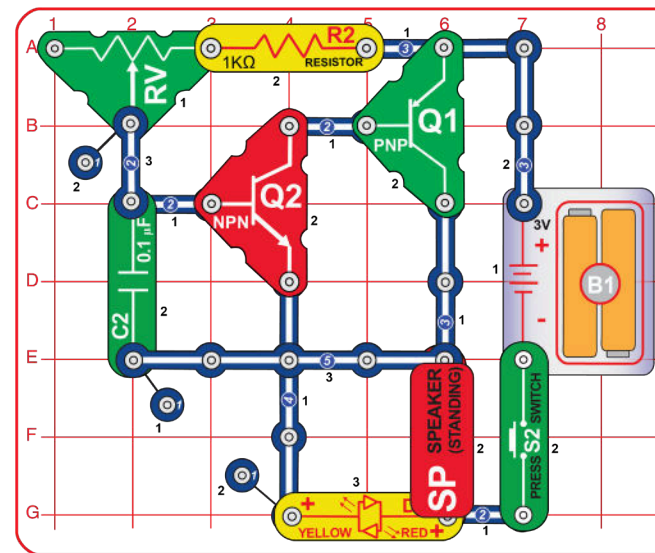
Use the original circuit but replace the 1k Ω resistor (R2) with the 10k Ω resistor (**R4**) and replace the 0.1 μ F capacitor (C2) with the **whistle chip (WC)**. Adjust the lever on **RV** for a ghost like sound.

PROJECT 241 Dog Whistle

Now replace the 10k Ω resistor with the 100 Ω resistor (**R1**). The pitch of the sound is even higher now. If you do not hear sound, then the circuit may be making sound waves at a frequency too high for your ears to hear. But your dog may hear it, because dogs can hear higher frequencies than people can.

PROJECT 242 Another Tone Generator III

Use any of the preceding circuits but replace the red/yellow LED (D10) with the **color LED (D8)**. The sound is different now.



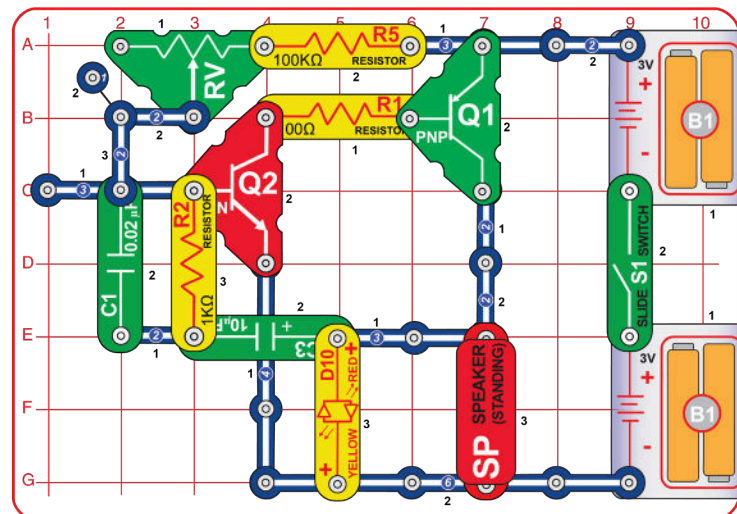
This circuit is another oscillator. The resistors (RV & R2) turn on the transistors (Q1 & Q2), which are amplifiers. The output of the transistor amplifiers is fed back to their input through capacitor C2 to be re-amplified, creating oscillation. The oscillation frequency is controlled by the resistors and capacitor.

PROJECT 243 Blink & Beep

Set the **adjustable resistor (RV)** to the far left and turn on the **slide switch (S1)**. The LED (D10) lights and the speaker (SP) sounds once per second. Adjusting **RV** to the right increases the rate.

Remove the 1k Ω resistor (**R2**) to change the sound from beeping to a whine.

This circuit is also an oscillator. R5 and RV determine the transistor current, and C3 and R2 provide the feedback for oscillation to occur; changing their values affects the oscillation frequency. Removing resistor R2 places the small capacitor C1 in series with the larger C3, so C1 will dominate, and increase the oscillation frequency.



PROJECT 244 Buzzing in the Dark

This circuit makes a high-frequency screaming sound when light shines on the **phototransistor (Q4)**, and makes a buzzing sound when you shield the phototransistor.

Place the 0.1 μ F capacitor (**C2**) on top of the **whistle chip (WC)** to lower the pitch of the tone, or use the 10 μ F capacitor (**C3**) to make a beeping sound.

PROJECT 245 Touch Buzzer

Remove the phototransistor (Q4) and instead touch your fingers across where it used to be (points labeled **A & B**) to hear a cute buzzing sound. The circuit works because of the resistance in your body. If you put back the photoresistor and partially cover it, you should be able to make the same resistance your body did, and get the same sound.

PROJECT 246 High-Frequency Touch Buzzer

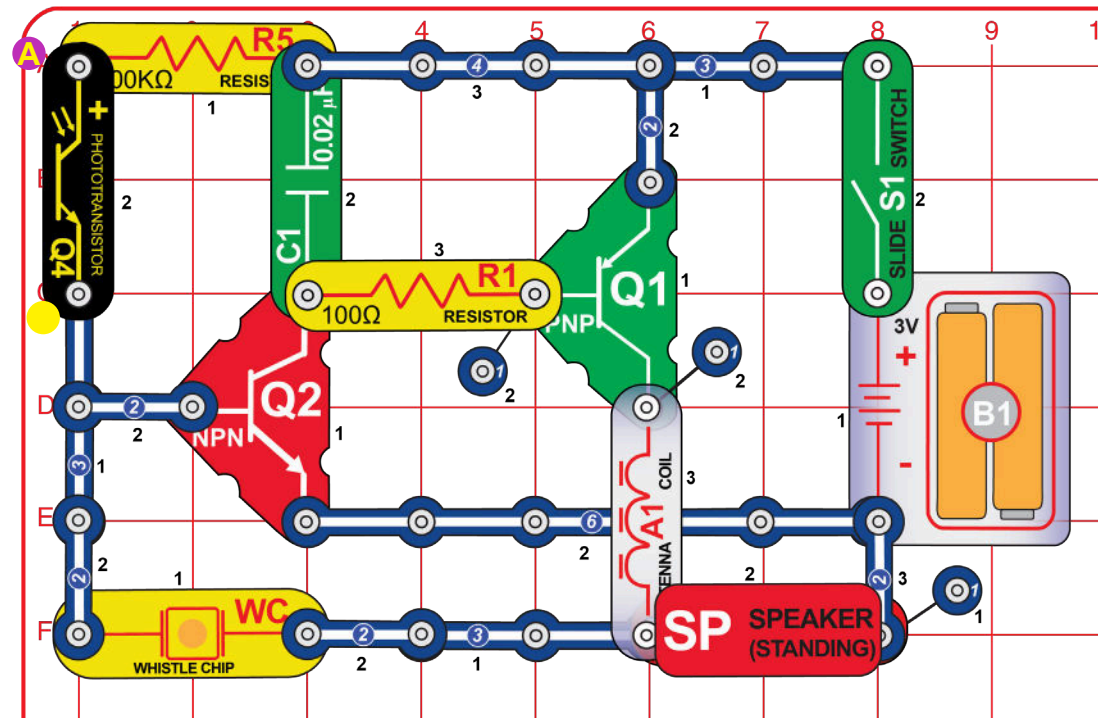
Replace the speaker (SP) with the **3V lamp (L1)**. Now touching your fingers between points **A & B** creates a quieter but more pleasant buzzing sound from the whistle chip (WC).

PROJECT 247 High-Frequency Water Buzzer

Now connect two (2) **jumper**s to points **A & B**, and place the loose ends into a **cup of water**. The sound will not be much different now, because your body is mostly water and so the circuit resistance has not changed much.

PROJECT 248 Mosquito

Place the **phototransistor (Q4)** back into the circuit. Now the buzz sounds like a mosquito.

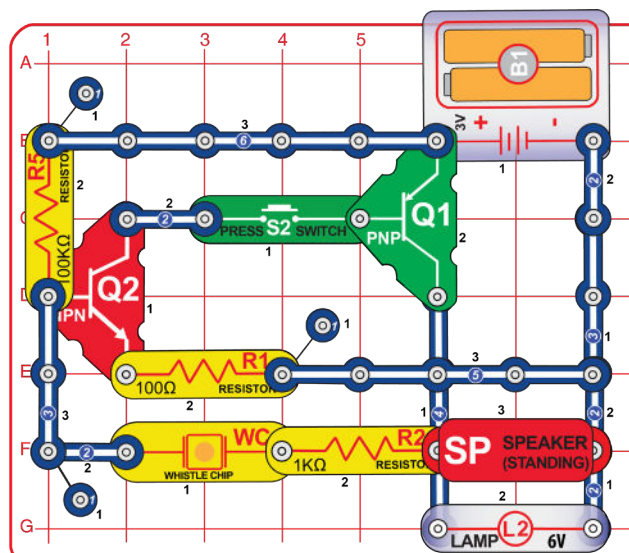


This circuit is an oscillator. Resistor R5 and the phototransistor set the control current to the transistors (Q1 & Q2), which are amplifiers. The output of the transistor amplifiers is fed back to their input through the whistle chip to be re-amplified, creating oscillation. Stacking capacitors on top of the whistle chip reduces the oscillation frequency. Covering the phototransistor increases its resistance, reducing the control current to the transistor amplifiers.

PROJECT 249

High Pitch Bell

Build the circuit shown and push the **press switch (S2)**. The circuit oscillates, and generates the sound of a high pitch bell.



This circuit is also an oscillator. Adding a capacitor over the whistle chip reduces the oscillation frequency. Changing the values of the resistors (R1, R2, & R5) also changes the frequency of the sound but may cause the circuit to stop oscillating or make sound at a frequency you cannot hear.

PROJECT 250 Steamboat Whistle

Use the preceding circuit, but connect the 0.02μF capacitor (C1) across the **whistle chip (WC)**, on level 3. Push the **press switch (S2)**. The circuit now generates the sound of a steamboat.

PROJECT 251 Steamship

Use the preceding circuit but replace the 0.02μF capacitor (C1) with the 0.1μF capacitor (C2). Push the **press switch (S2)**. The circuit now generates the sound of a steamship.

PROJECT 252 Dot-Dot-Dot

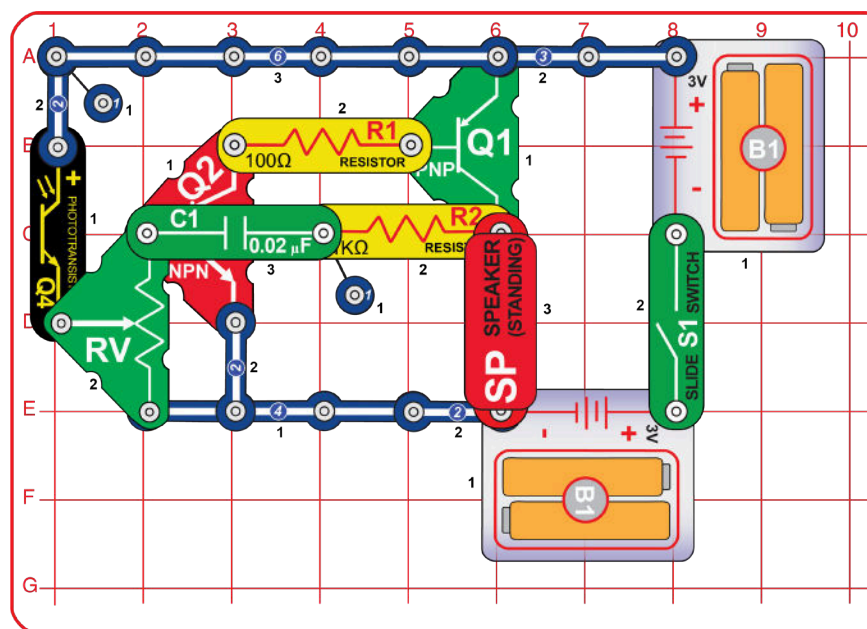
Use the preceding circuit but replace the 0.1μF capacitor (C2) with the 10μF capacitor (C3). Push the **press switch (S2)**. The circuit now generates a beeping sound.

PROJECT 253

Light Oscillator

Set the **adjustable resistor (RV)** to the middle position and then turn on the **slide switch (S1)**. Wave your hand over the **phototransistor (Q4)** and the sound changes. You can adjust the sensitivity by moving the **RV** lever to a different position.

You can change the range of tones by replacing the 0.02μF capacitor (C1) with one of the other **capacitors**, or by replacing the 1kΩ resistor (R2) with one of the other **resistors**, but the circuit will not make sound for all combinations.



This circuit is also an oscillator. Q4 and RV determine the transistor current, and C1 and R2 provide the feedback for oscillation to occur; changing their values affects the oscillation frequency.

PROJECT 254 High-Power Buzzer

Turn on the **slide switch (S1)**. Move the lever on the **adjustable resistor (RV)** to vary the pitch of the buzzing sound. The motor (M1) and fan may not spin.

PROJECT 255 Buzz Fan

Use the preceding circuit, but place the 5.1k Ω resistor (**R3**) directly over the 100k Ω resistor (**R5**) using a 1-snap. The pitch of the tone is higher now, and the fan spins.

PROJECT 256 Photo Buzzer

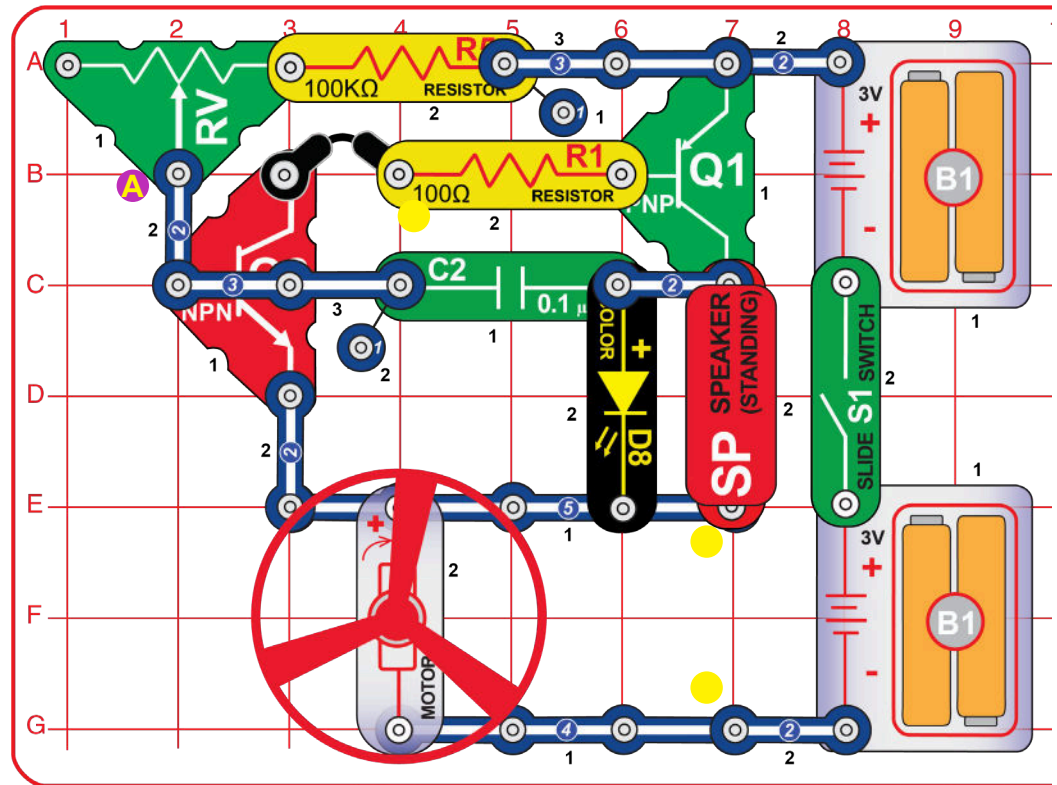
Use any of the preceding circuits, but add the **phototransistor (Q4, "+" on right)** across points **A & B**. Shine a bright light on the **phototransistor** to change the sound, while also moving the lever on **RV**.

PROJECT 256 Step Beeper

Use any of the preceding circuits, but place the 10 μ F capacitor (**C3**) or the 100 μ F capacitor (**C4**) on top of the 0.1 μ F capacitor (**C2**), with the "+" to the right. The motor will move in small bursts, with long intervals or almost continuously, depending on the resistors and phototransistor. Next, replace the color LED (D8) with the **red/yellow LED (D10)**. See how the circuit works now.

PROJECT 258 Wacky Buzzer

Repeat projects 254-256 but add the 100 μ F capacitor (**C4**) across points marked **C & D** ("+" to C). The motor may not spin but the sound is different. The sound may not be very loud.



This circuit is also another oscillator, but the current passes through the motor before returning to the batteries. The resistors and capacitors determine the frequency of the sound.

9. Power Amplifier Circuits

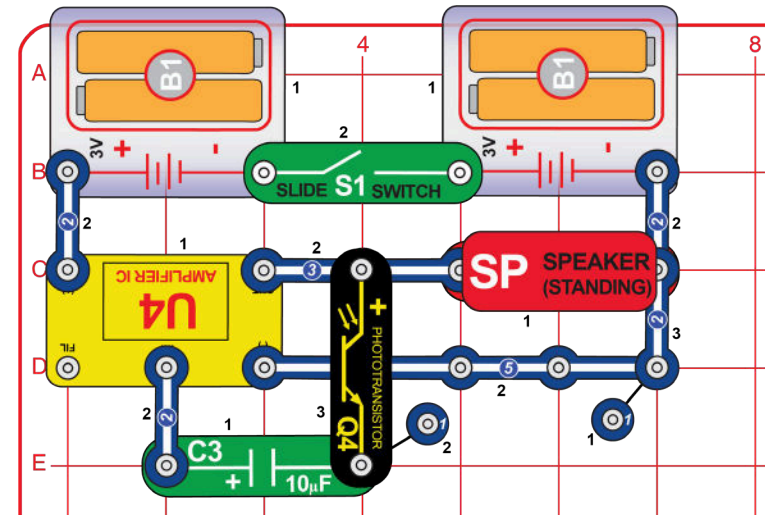
PROJECT 259 Ticking Screecher

Build the circuit as shown, and turn on the **slide switch (S1)**. Vary the amount of light to the **phototransistor (Q4)** by partially covering it with your hand. You can make screeching sounds by allowing just a little light to reach the photoresistor.

PROJECT 260 Ticking Screecher II

Replace the 10 μ F capacitor (C3) with a **3-snap wire** or any of the other capacitors (**C1, C2, C4, or C5**). The sound is a little different now.

Here the output of the power amplifier IC (U4) is fed back to its input through the phototransistor and capacitor, creating an oscillation that you hear on the speaker (SP). Changing the light on Q4 changes its resistance, and so changes the oscillation signal.



PROJECT 261

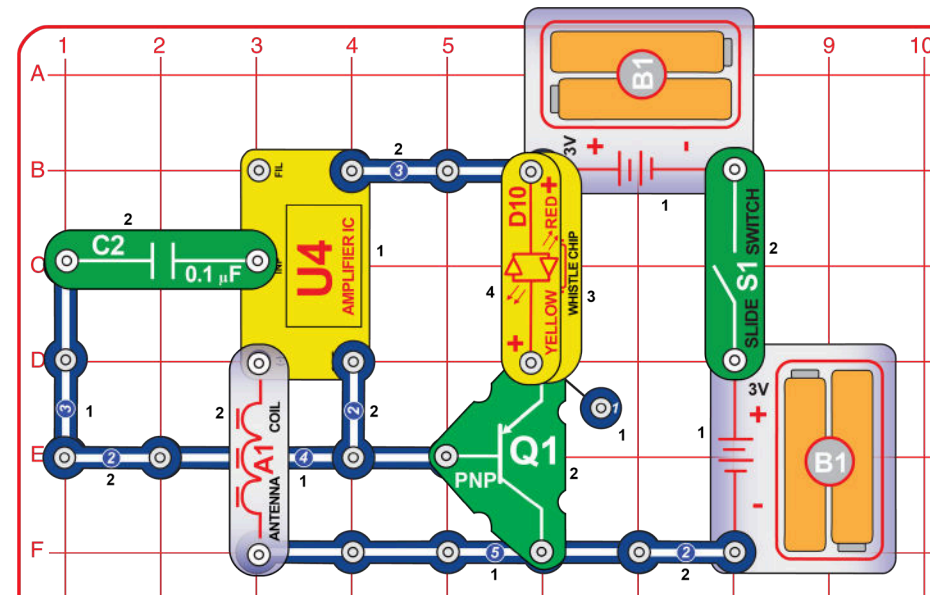
Twice-Amplified Oscillator

Turn on the **slide switch (S1)**. The red/yellow LED (D10) is blinking and you hear a beeping sound.

PROJECT 262 Sound, Light, & Motor Stepper

Replace the 0.1 μ F capacitor (C2) with the 0.02 μ F capacitor (**C1**). The sound is different now. The red/yellow LED may appear to be on continuously but is actually flashing very quickly.

The output of the power amplifier IC (U4) is fed back to its input through the 0.1 μ F capacitor (C2), producing oscillation. U4 is one amplifier and the PNP transistor (Q1) is the other amplifier. The antenna (A1) is just used as a 3-snap wire.

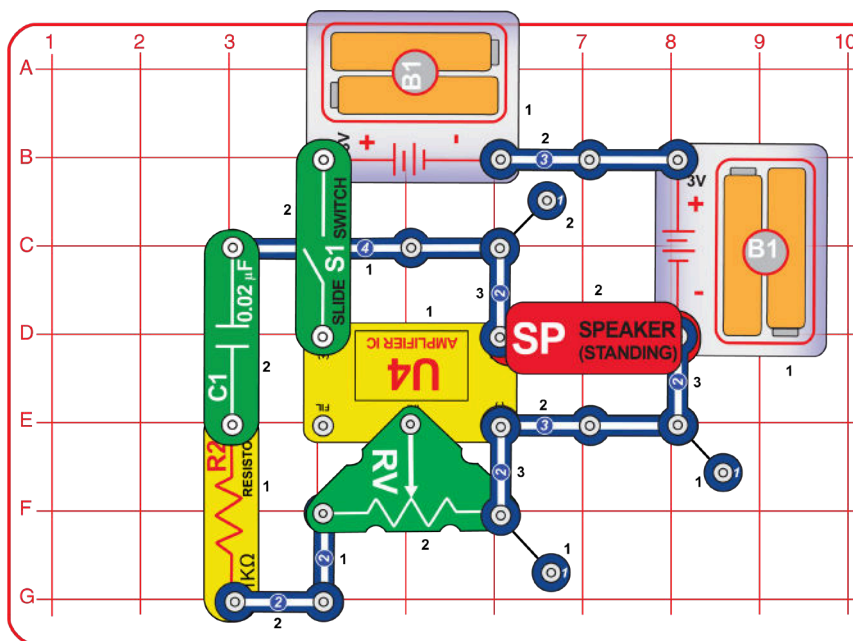


PROJECT 263

Trombone

Turn on the **slide switch (S1)** and the trombone should start playing. To change the pitch of the note, simply slide the lever on the **adjustable resistor (RV)** back and forth.

By turning the slide switch on and off and moving the slider on RV you will be able to play a song much like a trombone player makes music. The switch represents air going through the trombone, and the adjustable resistor control is the same as a trombone slider bar. The circuit may be silent at some positions of RV.



PROJECT 264 Trombone II

Replace the 0.02µF capacitor (C1) with the 0.1µF capacitor (C2) or the 10µF capacitor (C3, “+” on bottom). The sound is different now. With C3, by sliding RV’s lever up and down you should be able to make the sound of a race car engine as it’s motor speeds up and slows down.

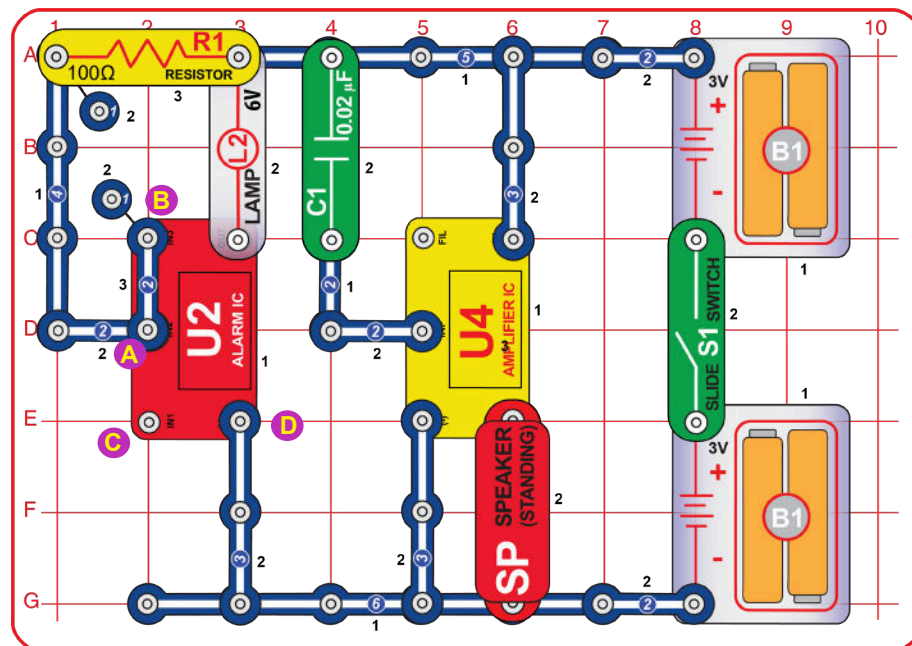
Here the output of the power amplifier IC (U4) is fed back to its input through the resistors (R2 & RV) and 0.02µF capacitor (C1), creating an oscillation that you hear on the speaker (SP). Changing the resistor or capacitor values changes the oscillation signal.

PROJECT 265

Ripple Amplifier

Turn on the **slide switch (S1)**. The 6V lamp (L2) flashes and you hear a machine gun sound. You can change the sound by removing the 1-snap wire and 2-snap wire at point **B**, or moving them to be between points **A & C** or **C & D**.

Here the alarm IC (U2) creates an electrical signal representing siren or machine gun sounds, which are amplified by the power amplifier IC (U4), then played on the speaker (SP). But notice U3’s output (its upper right snap) is not connected to U4’s input (its left-middle snap). So how is the space war electrical signal getting to the power amplifier IC and speaker?



The electrical signal created by the alarm IC flashes the 6V lamp, and the high lamp current turning on and off creates a disturbance or “ripple” on the voltage from the batteries. This ripple enters the power amplifier IC through the 0.02µF capacitor (C1) and gets amplified, then is heard on the speaker.

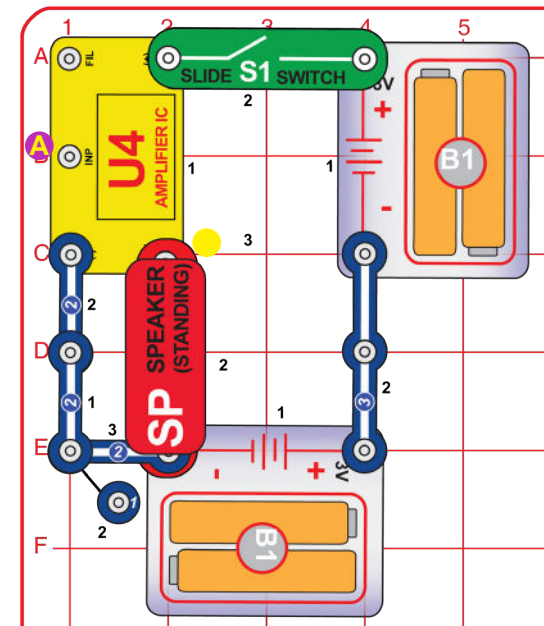
If you replace the 6V lamp with a lower current device like one of the LEDs or resistors then the space war sounds will not be as loud or may not be heard at all.

PROJECT 266

Power Amplifier

Turn on the **slide switch (S1)**. There will probably be no sound. Touch point **A** with your finger and you should hear static. If you do not hear anything, listen closely and wet your finger that touches point **X**. High frequency clicks or static should be coming from speaker (SP) indicating that the amplifier is powered on and ready to amplify signals.

The circuit may make sound on its own (without you touching it), due to self-oscillation. Do not worry, this is normal with high gain amplifiers like this. The sound should still change when you touch point A.



The power amplifier IC (U4) amplifies signals at its input snap (point A). Placing your finger on point A makes your body act as an antenna to pick up electrical signals in the air, to be amplified by U4. Touching points A & B uses your body's electrical resistance to make a feedback path between U4's input and output, making it oscillate. Changing the position of your fingers or pressing harder changes your connected resistance enough to change the oscillation sound.

PROJECT 267 Feedback Kazoo

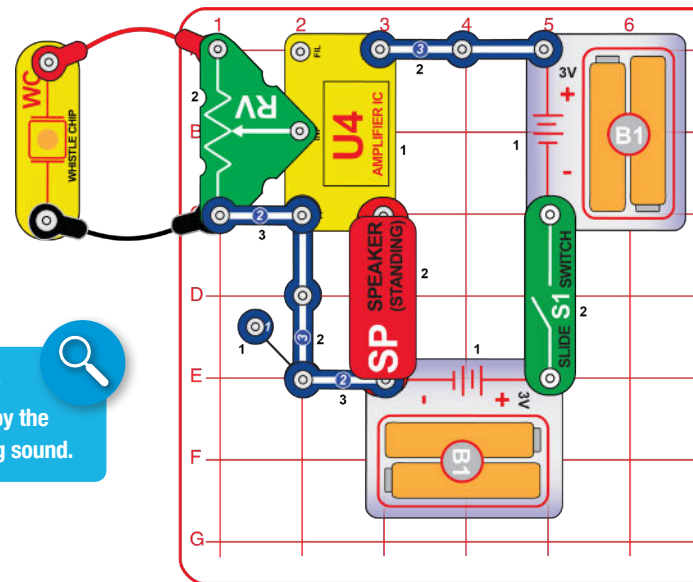
Use the same circuit but now place one finger on point **A** and another finger on point **B**. The sound should be much louder now, because you just provided a feedback path to make the amplifier into an oscillator. You may even be able to change the pitch of the oscillation sound by pressing harder on the snaps. This is the principle used to make an electronic kazoo. If you practice and learn the amount of pressure required to make each note, you may even be able to play a few songs.

PROJECT 268

Whistle Audio Amplifier

Set the **adjustable resistor (RV)** to mid-range and turn on the **slide switch (S1)**. Hold the **whistle chip (WC)** away from the **speaker (SP)**. Tap or blow on the whistle chip and hear it on the speaker. If the circuit just makes a loud whining sound then move RV's lever down to lower the volume.

Blowing or tapping on the whistle chip creates a tiny voltage in it, which is amplified by the power amplifier IC (U4) and then heard on the speaker. Sometimes sound from the speaker is picked up by the whistle chip, creating a feedback loop that makes the circuit self-oscillate in a continuous whining sound.



PROJECT 269

Siren Amplifier

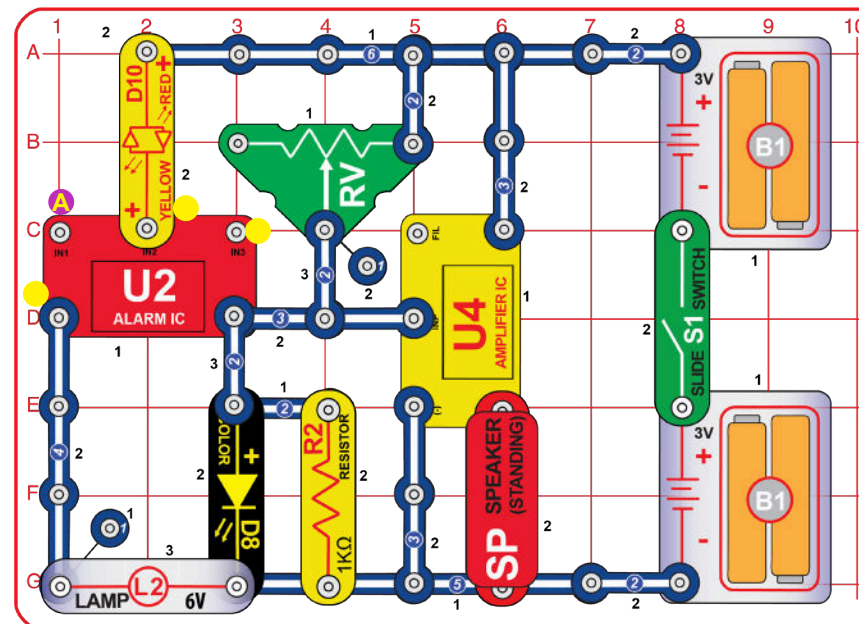
The **slide switch (S1)** and move the lever on the **adjustable resistor (RV)** around. You hear a siren on the speaker (SP) which is not affected by RV, but the color LED (D8) only lights when RV's lever is on the right. The red/yellow LED (D10) and 6V lamp (L2) will not light.

PROJECT 270 Siren Amplifier II

Replace the color LED with each of the capacitors (**C1, C2, C3, C4, or C5**) and move **RV's** lever back and forth. Notice how the sound changes for each capacitor.

PROJECT 314 Siren Amplifier III

With each of the preceding circuits, add a connection between points labeled **A & B, B & C, or A & D** using a jumper wire. The siren is different now.



Here the resistors (RV & R2) are used to reduce the signal from the alarm IC (U2) to the power amplifier IC (U4). When RV is set to the right, U2's output signal is not reduced, indicated by the color LED being bright. Moving RV's lever to the left reduces the signal to U4, indicated by the color LED being off. Notice that even though the LED turns off as RV's lever is moved to the left, the sound stays loud - because U4 is amplifying the signal from U2 (up to U4's maximum output volume). Nearly all toys that make sound use a power amplifier of some sort.

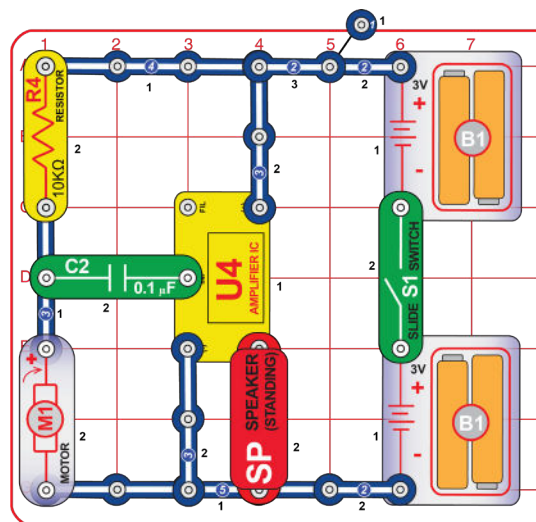
A capacitor's electric storage ability gives it lower resistance to fast-changing signals than to constant or slow-changing signals. When the color LED is replaced by a capacitor, RV and the capacitor act as a filter on U2's signal to U4. Increasing RV's resistance (by moving RV's lever to the left) or increasing the capacitor value reduce the signal to U4. Notice that RV's lever reduces the sound slightly with C1, reduces it a lot with C3, and you barely hear any sound with C5.

PROJECT 272

Old-Style Typewriter

Turn on the **slide switch (S1)**, nothing will happen. Spin the **motor top (on M1)** slowly with your fingers (don't use the fan blade). You will hear a clicking that sounds like an old-time manual typewriter keystrokes. Spin the motor faster and the clicking speeds up accordingly.

This circuit works the same if you spin the motor in either direction.



By spinning the motor with your fingers, the physical effort you exert is converted into electricity. In electric power plants, steam is used to spin large motors like this, and the electricity produced is used to run everything in your town.

PROJECT 273

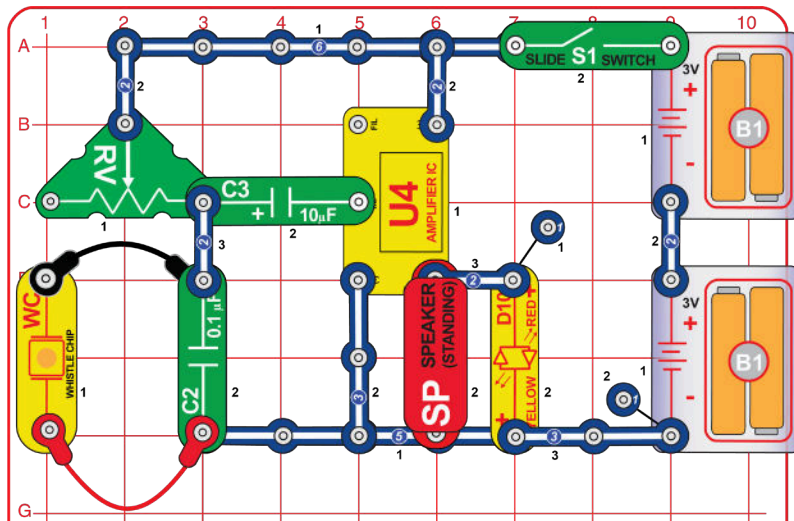
Pressure Alarm

Connect two **jumper wires** to the **whistle chip (WC)** as shown. Set the **adjustable resistor (RV)** lever to the far left and turn on the **slide switch (S1)**. There should be no sound from the speaker (SP) and the LED (D1) should be off. Tap the center of the whistle chip. The speaker sounds and the LED lights (you may have to put your ear next to the speaker to hear the sound, and the LED may only light dimly).

Place a small object in the center of the **whistle chip**. When you remove the object the speaker and LED are activated. In alarm systems, a siren would sound to indicate the object has been removed.

PROJECT 274 Pressure Alarm II

Place the **color LED (D8)** directly over the whistle chip, LED "+" on the black jumper snap. Turn on the **slide switch (S1)** and adjust the **adjustable resistor (RV)** lever to change the light and sound.

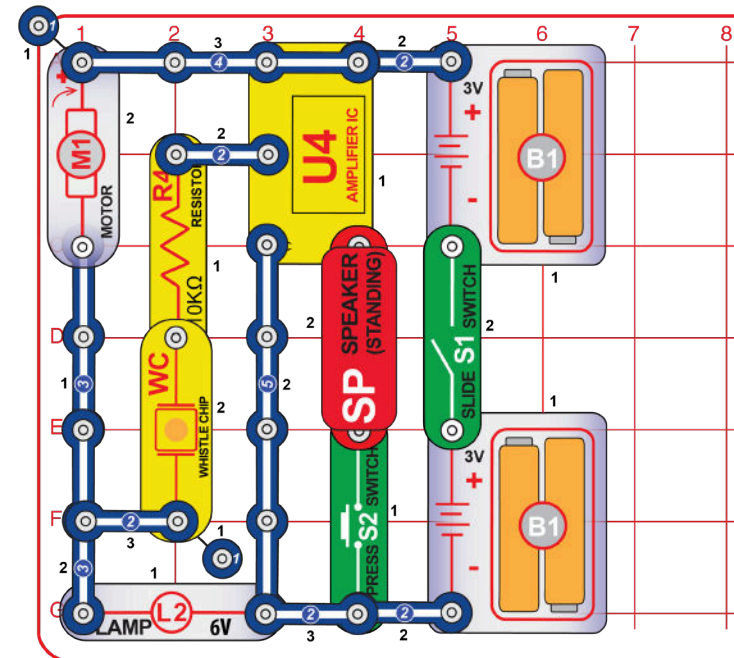


The whistle chip has a piezocrystal between two metal plates. Sound waves or other changes in air pressure cause the plates to vibrate and produce a small voltage. The voltage is amplified by the power amplifier IC (U4), which drives the speaker and LED.

PROJECT 275

Motor Sounder

Turn on the **slide switch (S1)**. The motor (M1) shaft spins. Now push the **press switch (S2)**, and you hear sound from the speaker (SP). Try this with and without the fan on the motor, and notice the difference.

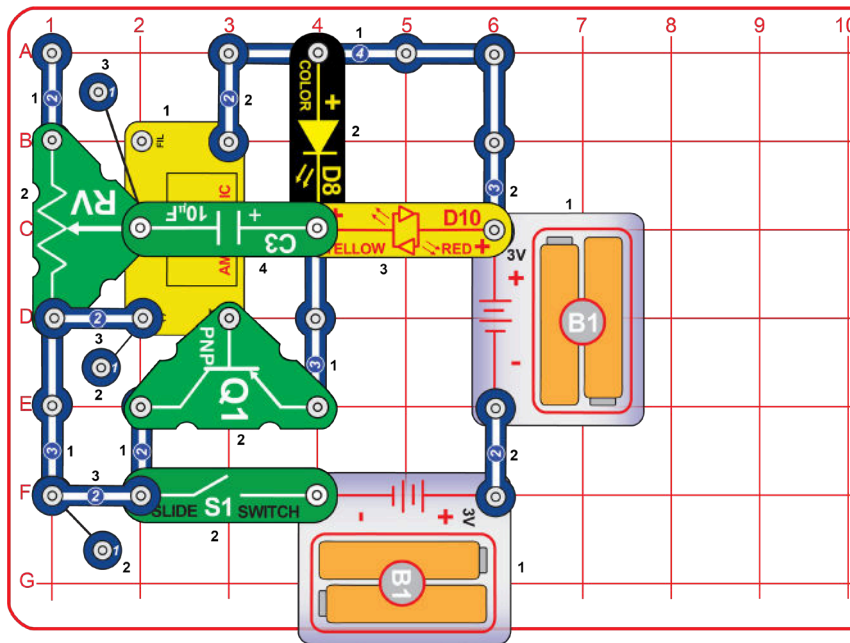


As the motor shaft spins it switches contacts, producing electrical pulses. The pulses are amplified by the power amplifier IC (U4) and heard on the speaker.

PROJECT 276

LED Flasher

Set the **adjustable resistor (RV)** to the top position and then turn on the **slide switch (S1)**. The LED's (D1 & D2) flash about once per second. As you adjust RV's knob down, the LED's flash faster. When RV is at the bottom, the LED's turn off.



This circuit is an oscillator. The flash rate is controlled by RV and C3.

PROJECT 277

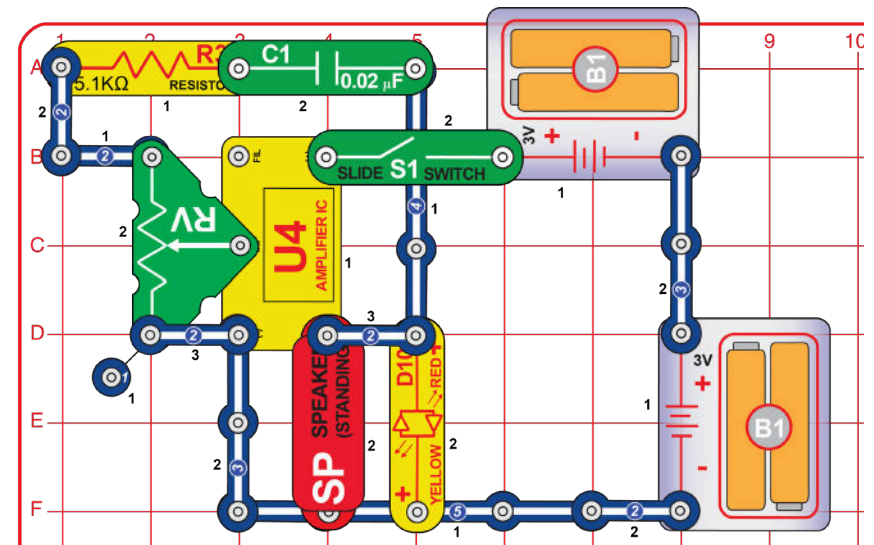
Bicolor Trombone

This circuit is similar to project 306, but adds the red/yellow bicolor LED (D10). Turn on the **slide switch (S1)** and the trombone should start playing. To change the pitch of the note, simply slide the lever on the **adjustable resistor (RV)** back and forth.

Look closely at the red/yellow LED, you see it is a mix of red and yellow, or orange. Moving RV's lever may vary the mix of red and yellow.

PROJECT 278 Bicolor Trombone

Replace the 0.02µF capacitor (C1) with the 0.1µF capacitor (C2) or the 10µF capacitor (C3, "+" on right). The sound is different now, and the mix of red/yellow may be different.



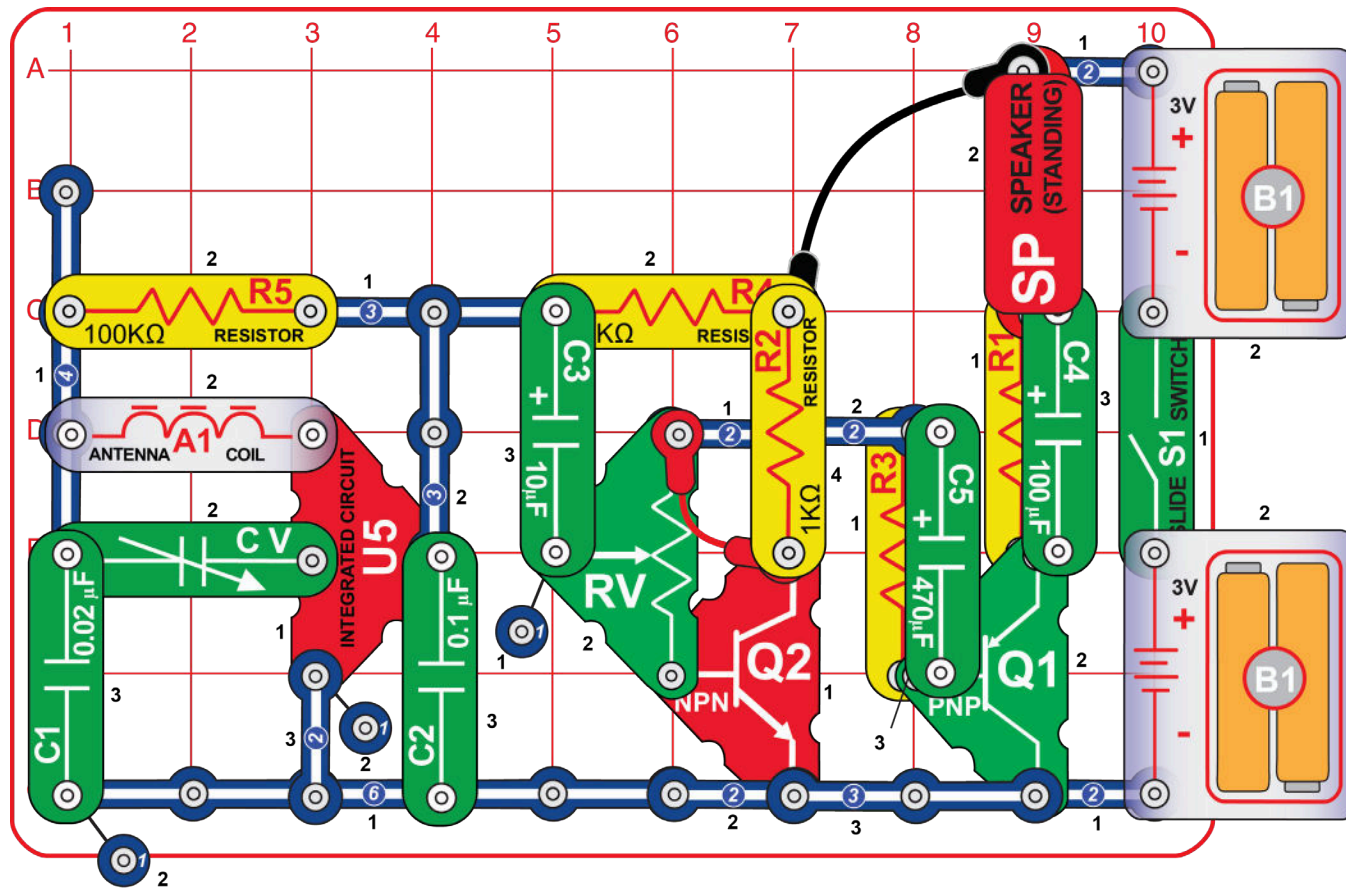
Here the output of the power amplifier IC (U4) is fed back to its input through the resistors (R2 & RV) and 0.02µF capacitor (C1), creating an oscillation that you hear on the speaker (SP). Changing the resistor or capacitor values changes the oscillation signal.

10. Radio Circuits

PROJECT 279

AM Radio with Transistors

This circuit is like project 7 but uses a transistor circuit to amplify the sound instead of the power amplifier IC (U4). Turn on the **slide switch (S1)**, tune the **variable capacitor (CV)** to a station, and set the **adjustable resistor (RV)** for the best sound. The sound will not be very loud.

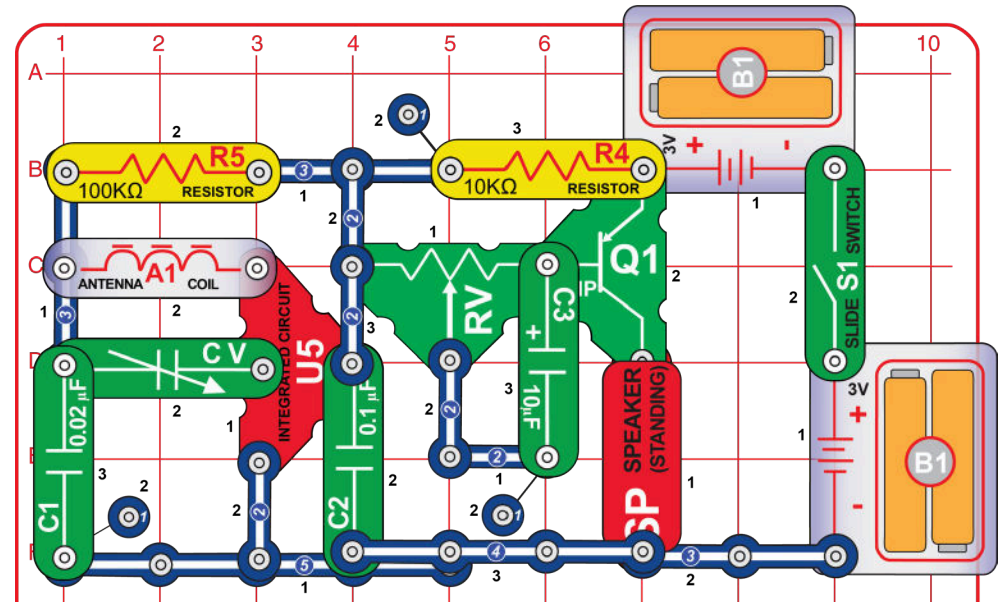


PROJECT 280

One-Transistor AM Radio

This circuit is like project 7 but only uses one transistor. Turn on the **slide switch (S1)**, tune the **variable capacitor (CV)** to a station, and set the **adjustable resistor (RV)** lever to the left. The sound will not be very loud. Compare the sound to project 7.

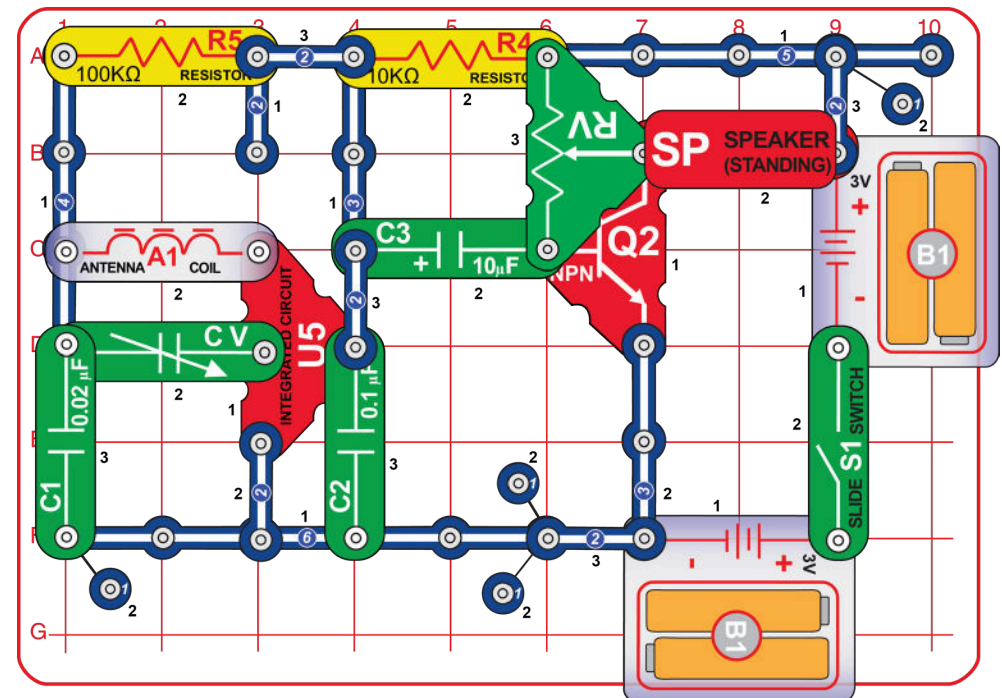
This circuit only uses one transistor to amplify the sound, so is not as loud as the other AM radio circuits.



PROJECT 281

One-Transistor AM Radio II

This circuit is like project 280 but uses a different transistor arrangement. Turn on the **slide switch (S1)**, tune the **variable capacitor (CV)** to a station, and set the **adjustable resistor (RV)** lever for the best sound. The sound will not be very loud. Compare the sound to project 326.

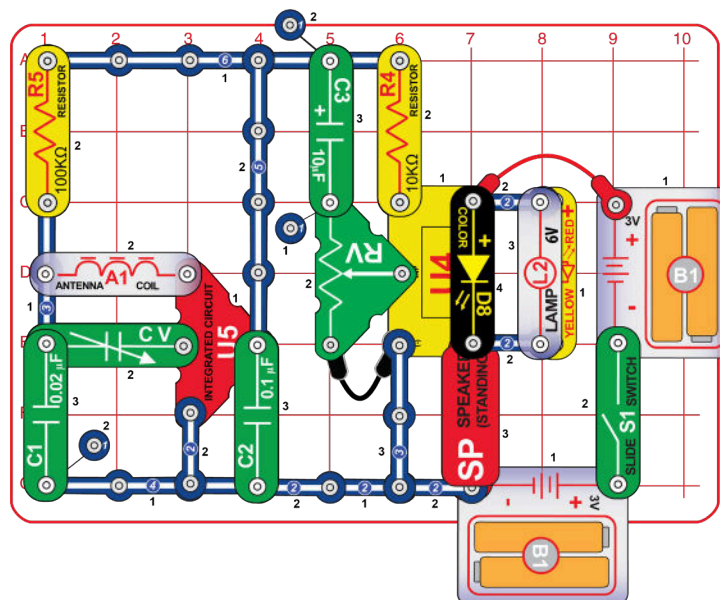


PROJECT 282

AM Radio with Lights

Turn on the **slide switch (S1)**, tune the **variable capacitor (CV)** to a station, and set the **adjustable resistor (RV)** lever for the best sound. The LEDs (D8 & D10) and 6V lamp (L2) flicker a little with the sound.

The LEDs and lamp are connected to the speaker (SP). When the speaker sound changes due to different sound on the radio, it changes the current through the LEDs and lamp, making them flicker.



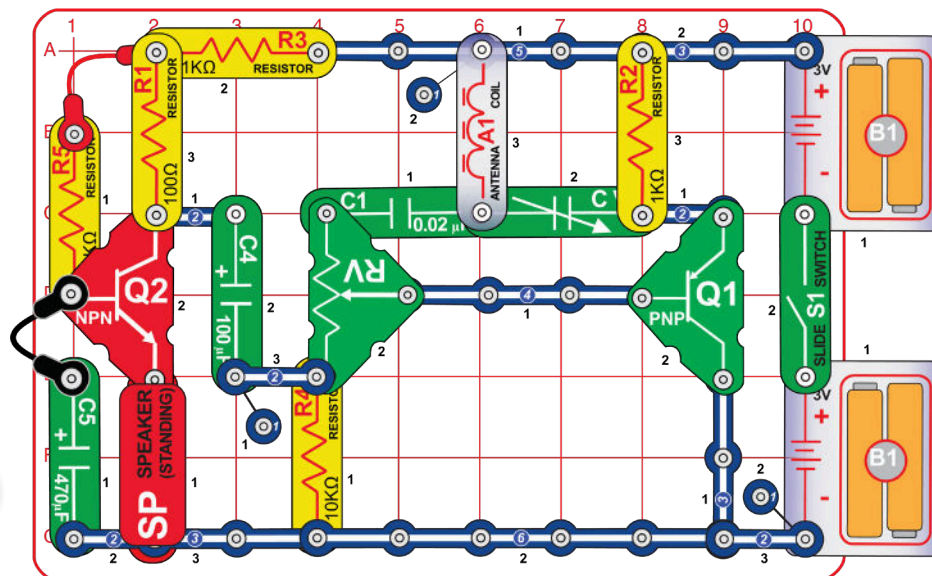
PROJECT 283

Radio Announcer

You need an **AM radio** for this project. Build the circuit shown but do not turn on the **slide switch (S1)**. Place it within a foot of your AM radio and tune the radio frequency to the middle of the AM band (around 1000 kHz), where no other station is transmitting. Turn the volume up so you can hear the static. Set the adjustable resistor (RV) control to the middle setting. Turn on the slide switch and slowly tune the adjustable capacitor (CV) until the static on the radio becomes quiet. You may hear a whistle as you approach the proper tuning. In some cases you may also need to set the adjustable resistor slightly off-center.

When the radio static is gone, tap on the **speaker (SP)** with your finger and you should hear the sound of tapping on the radio. Now talk loudly into the speaker (used here as a microphone) and you will hear your voice on the radio. Set the adjustable resistor for best sound quality at the radio.

The speaker is used here as a microphone, your voice/tapping is filtered and used to adjust a radio frequency oscillator, which creates radio waves in the air through the antenna (A1). The variable capacitor (CV) tunes the oscillator frequency.

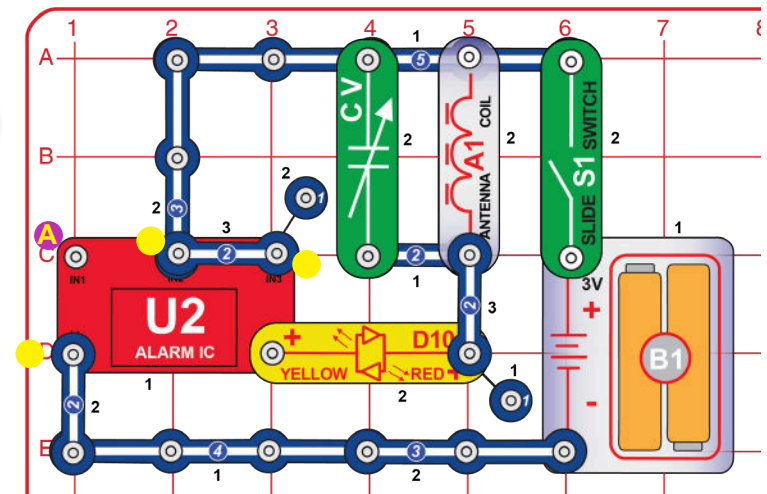


PROJECT 284 Siren Radio Station

Place the circuit next to an **AM radio**. Tune the radio so no stations are heard and turn on the **slide switch (S1)**. You should hear the alarm IC (U2) sound on the radio. The red/yellow LED (D10) should also be on. Adjust the **variable capacitor (CV)** for the best sound.

You can replace the red/yellow LED with the **3V lamp (L1)**.

The alarm IC output moves current through the variable capacitor (CV) and antenna (A1), causing the antenna to radio waves through the air. The frequency of the radio waves is set by CV, which tunes to the AM radio broadcast range. The LED limits the current through the antenna, and is also an indicator that the circuit is working.

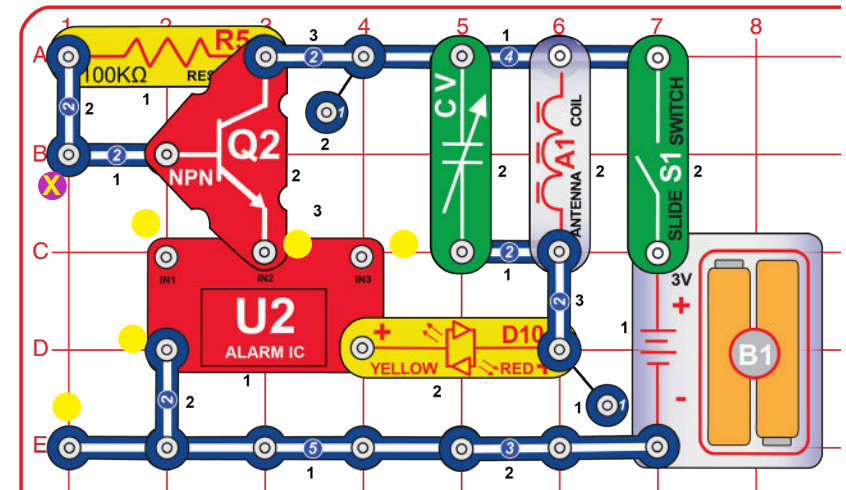


PROJECT 286 Radio Music Alarm

You need an **AM radio** for this project. **Build the circuit** on the right and turn on the **slide switch (S1)**. Place it next to your AM radio and tune the radio frequency to where no other station is transmitting. Then, tune the **adjustable capacitor (CV)** until your siren sounds best on the radio. Now connect a jumper wire between **X** and **Y** on the drawing, the music stops.

If you remove the jumper now, the siren will play indicating your alarm wire has been triggered. You could use a longer wire and wrap it around a bike, and use it as a burglar alarm!

You can replace the red/yellow LED with the **3V lamp (L1)**.



The alarm IC output moves current through the variable capacitor (CV) and antenna (A1), causing the antenna to radio waves through the air. The frequency of the radio waves is set by CV, which tunes to the AM radio broadcast range. The lamp limits the current through the antenna, and is also an indicator that the circuit is working. The NPN transistor (Q2) controls power to the music IC, so it can be controlled by the phototransistor or an alarm wire.

PROJECT 287 Daylight Alarm

Remove the jumper wire. Replace the 100kΩ resistor (R5) with the **phototransistor (Q4)**. Now your AM radio will play a siren as long as there is light in the room.

PROJECT 288 Night Radio

Put the 100kΩ resistor back in as before and instead connect the **phototransistor** between **X** & **Y** ("+" to X) using a jumper wire. Now your radio plays a siren when it is dark.

PROJECT 289 Radio Music Alarm II

To change the siren sound in any of the preceding circuits, connect points **A & B**, **B & C**, or **A & D** using a jumper wire.

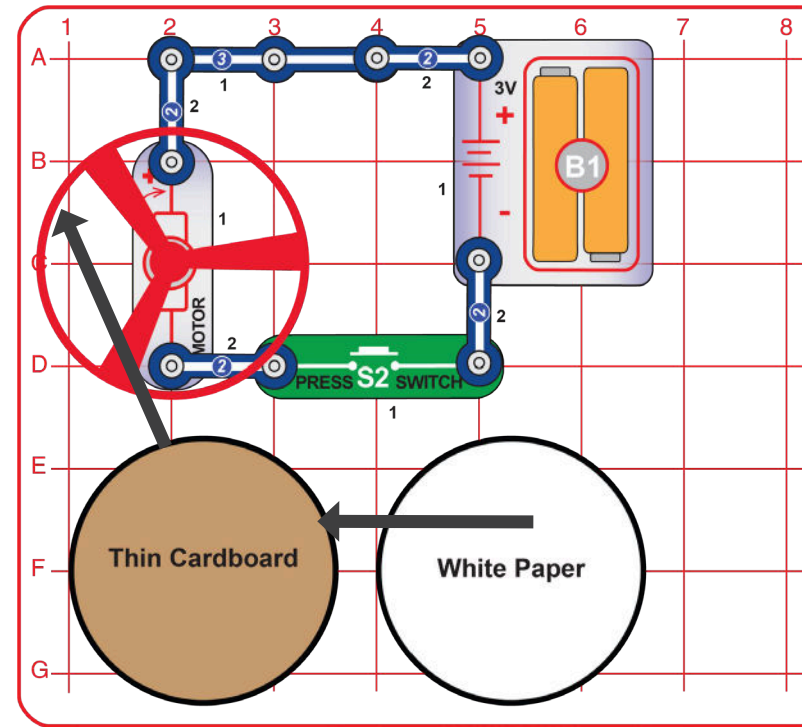
11. Other Fun Circuits

PROJECT 290 Spin Draw

Setup: Cut out a circular piece of thin cardboard from the back of an old spiral notebook or note pad. Use the fan blade as a guide. Place the fan on the cardboard and trace around it with a pencil or pen. Cut the cardboard out with scissors and tape it to the fan blade. Do the same thing with a piece of white paper, but tape the paper on top of the cardboard so it can be removed easily later.

Drawing: To make a ring drawing obtain some thin and thick marking pens as drawing tools. Spin the paper by pressing and holding **press switch (S2)** down. Press the marker on the paper to form rings. To make spiral drawings, release press switch (S2) and as the motor approaches a slow speed move the marker from the inside outward quickly.

Change the colors often and avoid using too much black to get hypnotic effects. Another method is to make colorful shapes on the disc then spin the disc and watch them blend into each other. When certain speeds are reached under fluorescent lights without electronic ballasts, the strobe principle shown in another project will produce strange effects and backward movement. Make a wheel with different colored spokes to see this strange effect. Adding more spokes and removing spokes will give different effects at different motor speeds.



PROJECT 291

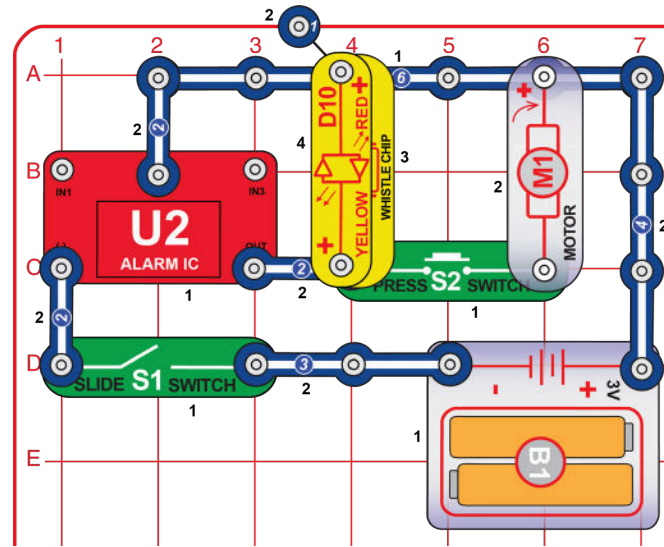
Motor Color Changer

Turn on the **slide switch (S1)**. A siren is heard, and the red/yellow LED (D10) is red.

Now push the **press switch (S2)** to connect the **motor (M1)** across the LED. Notice that the red/yellow LED is now orange (instead of red). Why? You can try this with or without the fan on the motor.

PROJECT 292 Motor Color Changer II

Change the sound by adding a connection across points **A & B**, **B & C**, or **A & D** using a 1-snap wire and a 2-snap wire, or a jumper wire.



The red/yellow LED may appear to be on, but is actually being turned on and off by the alarm IC (U2) at a very fast rate.

When you add the motor across the LED by pressing S2, the motor is also being turned on and off by the alarm IC (U2) at a very fast rate. When the alarm IC turns off the motor the spinning energy of the motor shaft acts as a generator, producing a voltage in the opposite direction across the LED, which makes the red/yellow LED turn yellow. So when U2 turns on the LED it is red, but when U2 turns off the LED the motor makes it yellow, and red and yellow blend into the orange color you see.

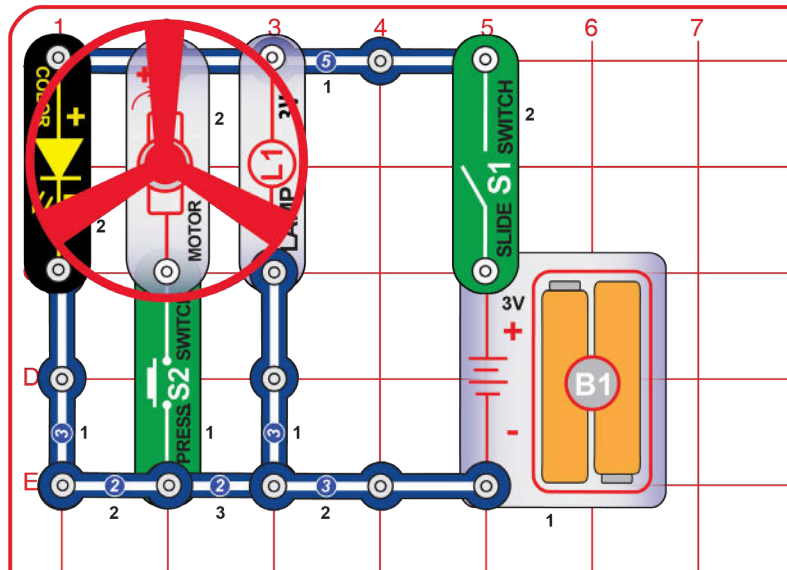
PROJECT 293

Light Spots

Turn on the **slide switch (S1)**; the lamp (L1) and color LED (D8) are on. Notice how the color LED is changing colors.

Now push the **press switch (S2)** to spin the motor and fan. Notice how the color LED color pattern has changed. You can try this with or without the fan on the motor.

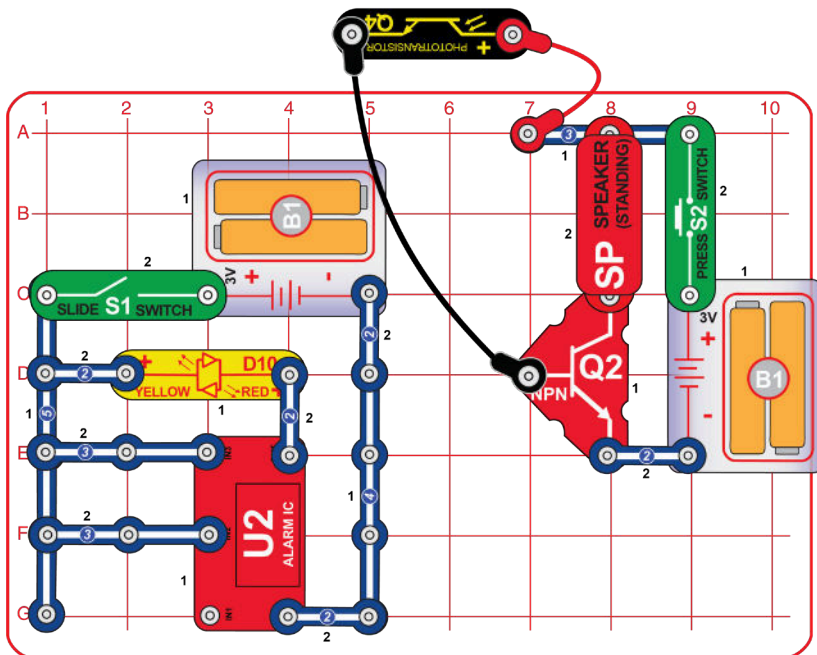
The motor produces electrical “noise” as it spins, which can confuse the color-changing circuit in the color LED. The lamp is just a simple light bulb, and is not affected by the motor.



PROJECT 294

Optical Transmitter & Receiver

Build the circuit shown. Connect the **phototransistor (Q4)** to the circuit using the red & black jumper wires. Place the phototransistor upside down over the red/yellow LED (D10), so the LED goes into the phototransistor. Turn on both switches (hold down the **press switch (S2)** button). Music plays on the speaker, even though the two parts of the circuit are not electrically connected.

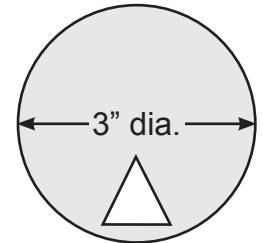


The left circuit, with the LED and alarm IC (U2) creates a music signal and transmits it as light. The right circuit, with the phototransistor and speaker, receives the light signal and converts it back to music. Here the phototransistor has to be on top of the LED for this to work, but better communication systems (such as fiber optic cables), can transmit information over enormous distances at very high speeds.

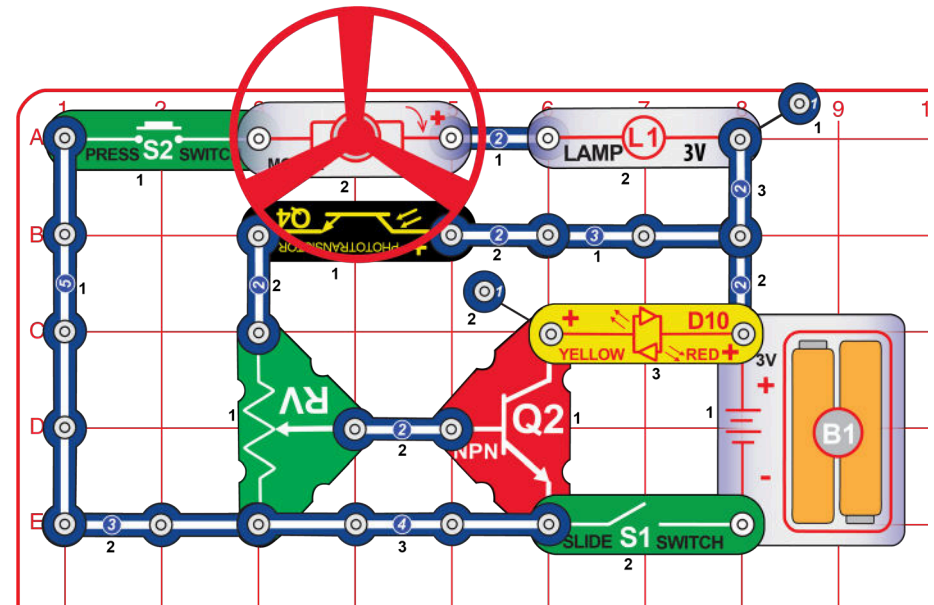
PROJECT 295

Fan Modulator

Using the fan as a stencil, draw and cut a **3" circle** out of a piece of paper. Then, cut a small triangle in it as shown. Tape the circle onto the **fan** and then place it on the **motor (M1)**. Place the circuit in a dimly lit room, shine a flashlight from above the fan towards the **phototransistor (Q4)** but not through the triangle cutout. Turn on the **slide switch (S1)** and set the lever on the adjustable resistor (RV) so that the red/yellow LED (D10) barely turns off. Now push the **press switch (S2)** to spin the fan and light the lamp (L1).



As the triangle opening moves over the phototransistor (Q4), more light strikes it. The brightness of the LED changes, making the LED blinking.

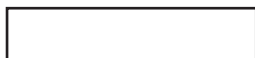


As the triangle opening moves over the phototransistor the brightness of the LED changes, or is modulated. As in AM or FM radio, modulation uses one signal to modify the amplitude or frequency of another signal.

PROJECT 296

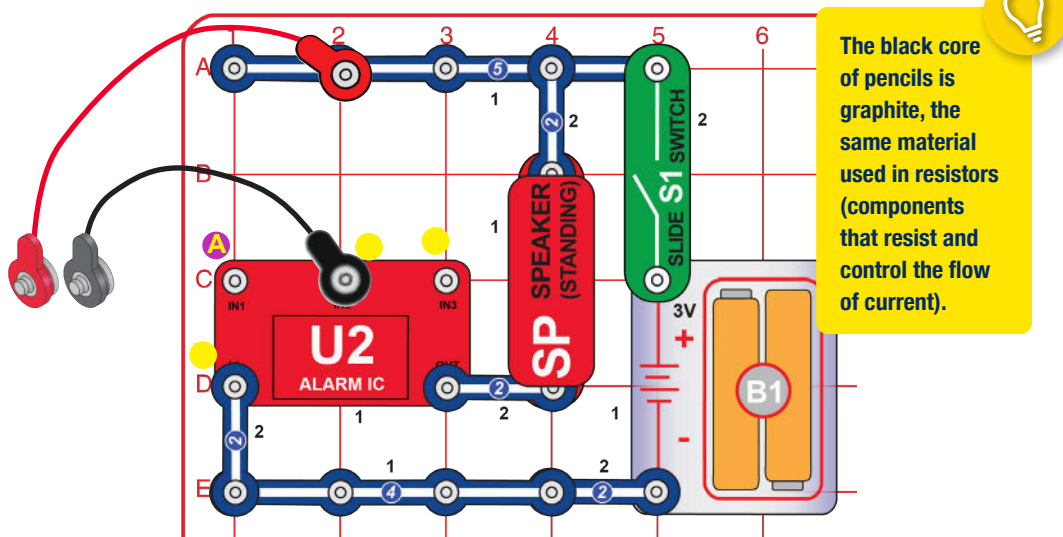
Pencil Alarm

Build the circuit shown and connect the two jumpers to it, leave the loose ends of the jumpers unconnected for now. There is one more part you need and you are going to draw it. Take a pencil (No. 2 is best but other types will also work). **Sharpen it** and fill in the shape below. You will get better results if you place a hard, flat surface directly beneath this page while you are drawing. **Press hard** (but **don't rip the paper**), and fill in the shape several times to be sure you have a **thick, even layer of pencil lead**.



Turn on the **slide switch (S1)** and take the loose ends of the jumpers, press them to the shape and move them around over the drawing. If you don't hear any sound then move the ends closer together and move over the drawing, add another layer of pencil lead, or put a drop of water on the jumper ends to get better contact.

Now you can draw your own shapes and see what kinds of sounds you can make.



PROJECT 297 Pencil Sirens

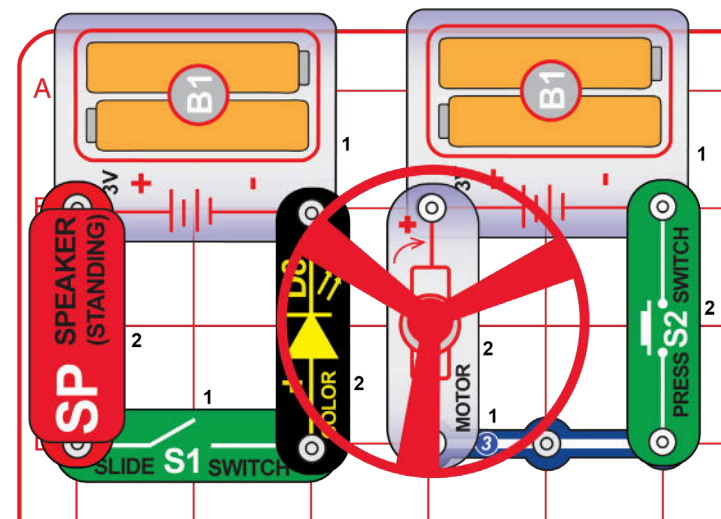
Use the preceding circuit, but connect points **A & B**, **B & C**, or **A & D** using a 2-snap wire and a 1-snap wire.

PROJECT 298

Little Red Circle

Turn on the **slide switch (S1)**. Place the circuit in a dark room and push the **press switch (S2)** to spin the fan. The color LED (D8) lights up the spinning fan with a red spot.

Replace the color LED (D8) with the **red/yellow LED (D10)**, in either direction). Now there is no red spot on the fan.



The color LED lights up the fan with a red circle while the red/yellow LED does not, because the color LED shines light most of its light out at a narrower beam, while the red/yellow LED shines light out in all directions.

The circuit with the color LED is not electrically connected to the circuit with the motor. This was done because the motor produces electrical pulses as it spins, and these pulses can confuse the color LED.

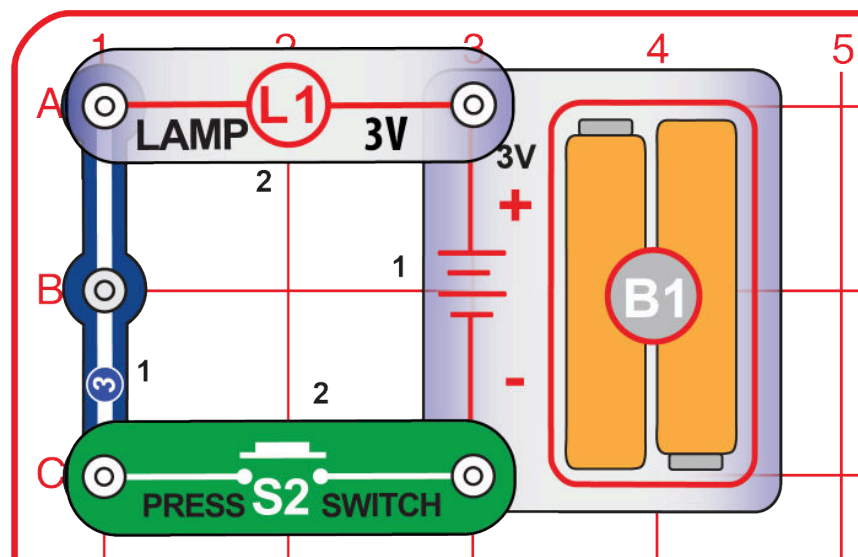
PROJECT 299

Morse Code

This simple circuit can be used for communication. Press the **press switch (S2)** in long and short bursts to make a pattern of light flashes representing the dots and dashes shown in the Morse Code table below. You can use Morse Code and this circuit to send secret messages to some friends in the room without others knowing what you're saying.

If you have a strong flashlight or searchlight then you can send messages to friends far away at night. During World War II Navy ships sometimes communicated by flashing Morse Code messages between ships using searchlights (because radio transmissions might reveal their presence to the enemy).

Years ago, Native Americans sent messages to other tribes using smoke signals and a special code.



Morse Code

The forerunner of today's telephone system was the telegraph, which was widely used in the latter half of the 19th century. It only had two states—on or off (that is, transmitting or not transmitting), and could not send the range of frequencies contained in human voices or music. A code was developed to send information over long distances using this system and a sequence of dots and dashes (short or long transmit bursts). It was named Morse Code after its inventor. It was also used extensively in the early days of radio communications, though it isn't in wide use today. It is sometimes referred to in Hollywood movies, especially Westerns. Modern fiber optics communications systems send data across the country using similar coding systems, but at much higher speeds.

A	. _	N	_ .	Period	
B	_ . . .	O	_ _ _ _	Comma	
C	_ . . .	P	. _ . .	Question	
D	_ . .	Q	_ . _ .	1	. _ _ _
E	. _ .	R	. _ .	2	. . _ _
F		S	. . .	3	. . . _
G	_ . .	T	_ .	4	
H		U	. . .	5	
I	. .	V		6	
J	. _ _ _	W	. _ .	7	
K	_ . .	X	_ . .	8	. _ . .
L		Y	_ . .	9	. _ . .
M	_ _	Z	_ . .	0	_ _ _ _

PROJECT 300

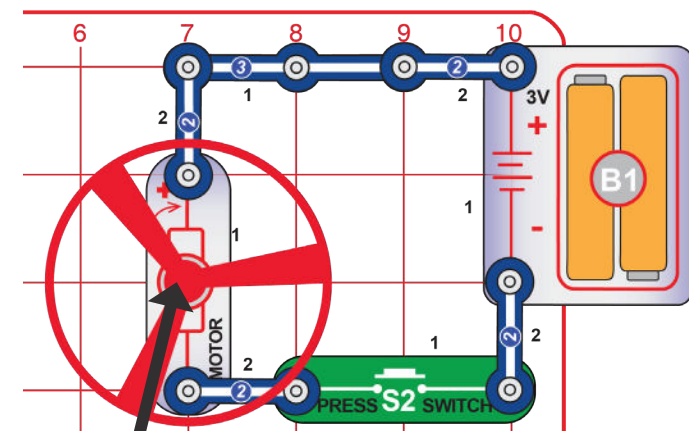
Spinning Rings

Setup: Cut out the **colorful disc** on the following page (shown below). Using tape, attach the disc with the colorful side up on the top of the **fan blade**. Place the blade on the **motor** as shown.

When the **press switch (S2)** is pressed, the arcs will turn into colored rings with a black background. Notice how the color drops in brightness when it is stretched to make a complete circle.

PROJECT 301 Strobe House Lights

This requires a fluorescent light with a T12 bulb (1.5" diameter) that runs on normal house current. Place the Spinning Rings circuit under the fluorescent light. Start the disc spinning and release the **press switch (S2)**. As the speed changes you will notice the white lines first seem to move in one direction then they start moving in another direction.



This effect is because the lights are blinking 120 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, try the same test with a flashlight. The light from a flashlight is constant and if all other lights are out, you will not see the effect that looks like a helicopter blade in a movie. This does not work with newer fluorescent lights, because they use an electronic ballast and produce a constant light.

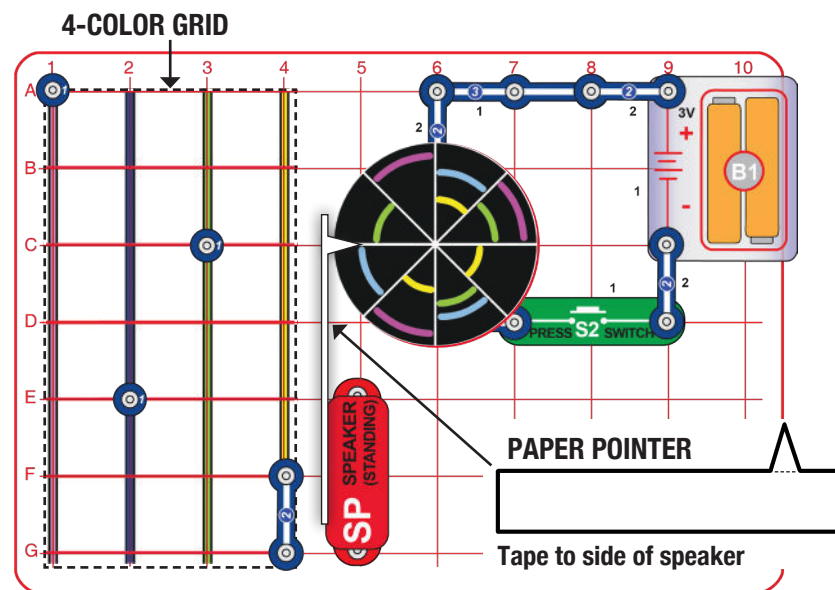
PROJECT 302

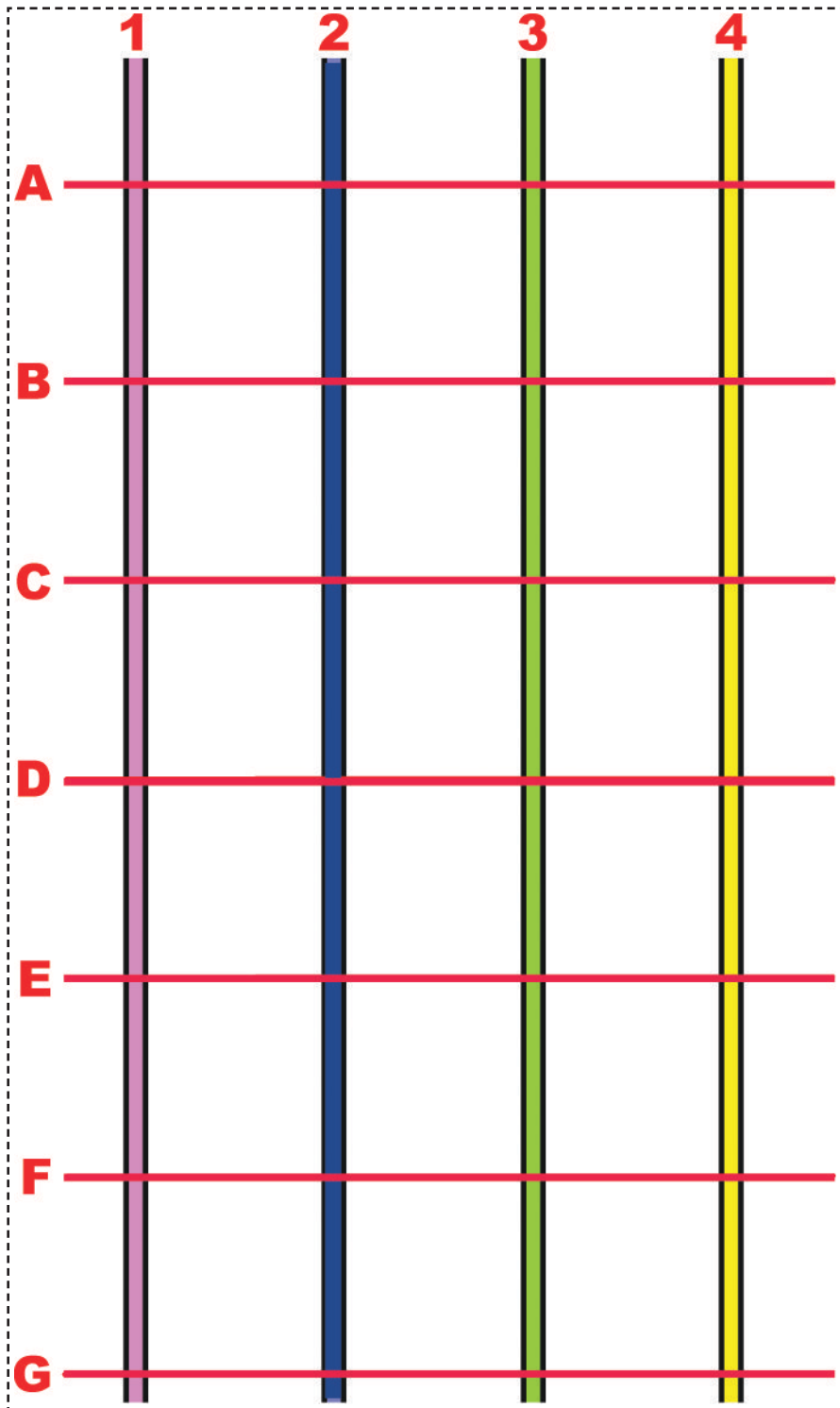
Race Game

Modify the preceding project by adding the **speaker (SP)** and a paper pointer (template found on the next page), shown below. Cut the pointer out and tape it to the side of the speaker—high enough so the pointer will be above the colorful disc. Fold the triangle on the pointer so it points to the disc.

Setup: Cut out the 4-color grid from the following page and place it under the base as shown on the left. Each player picks a color (or two colors if only 2 people are playing) and places a single snap on row G. The purple player goes in column 1, the blue player in column 2, the green player in column 3, and the yellow player in column 4. Spin the wheel by closing the **press switch (S2)**. The first single color wedge that the pointer points to is the first player to start. You only have three 1-snaps, so use a 2-snap if you have four players.

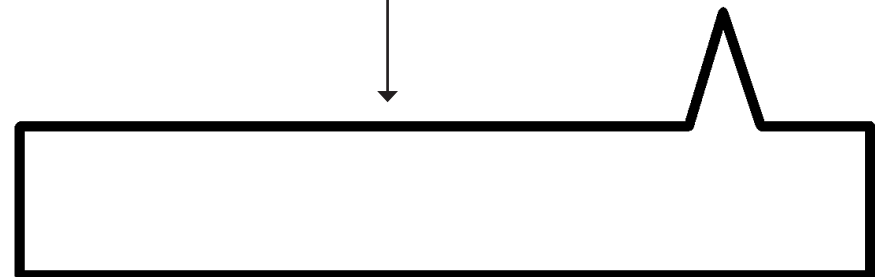
Play: Each player gets a turn to press the press switch. They release the press switch and when the pointer points to a wedge, the players that match the colors on the wedge get to move up one space. If the pointer stops between two colors (as shown below) then the players on each side of the line get to move up two spaces. The first player to reach the top row (A) wins. If two players reach the top row at the same time they must both drop down to row "D" and play continues.





FOR PROJECT 300

← **FOR PROJECT 302**



PROJECT 303 Mind Reader Game

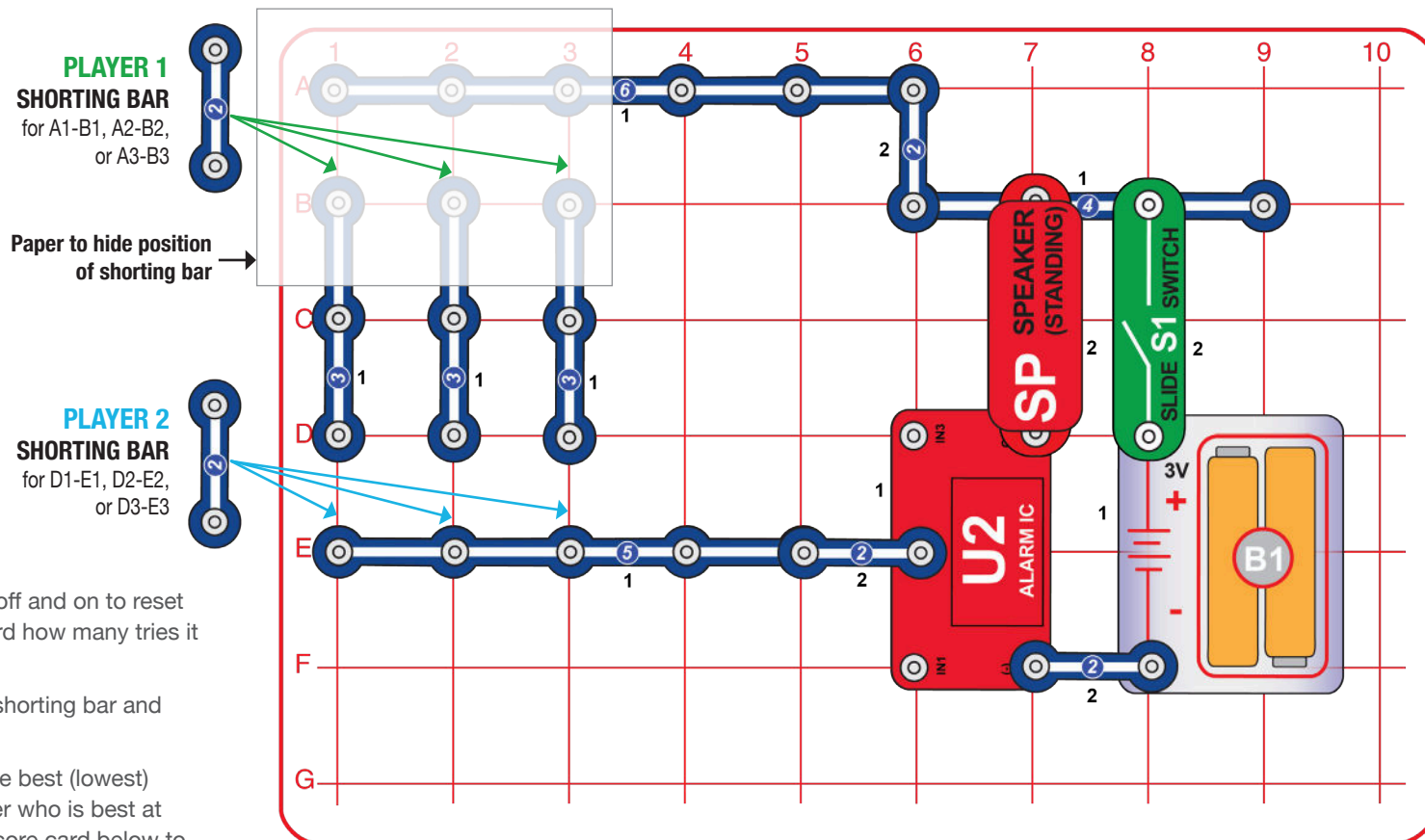
Build the circuit to the right. It uses two 2-snap wires as “shorting bars.”

Setup: Player 1 sets the target by placing a 2-snap shorting bar across base grid locations A1-B1, A2-B2, or A3-B3, and covering it with a sheet of paper. Player 2 must NOT know where the shorting bar is located under the paper. Turn on the **slide switch (S1)**.

The object is for Player 2 to guess the location by placing the other 2-snap shorting bar across base grid locations D1-E1, D2-E2, or D3-E3. If Player 2 places their 2-snap shorting bar at the correct position, the sounds played indicates a “hit”. They keep guessing until they get a hit. After each hit, remove the 2-snap shorting bar and slide the switch off and on to reset the sound. If you are keeping score, record how many tries it takes to get a hit.

Player 2 then sets up the hidden 2-snap shorting bar and player 1 tries their luck.

Play multiple rounds and see who gets the best (lowest) overall score. The winner will be the player who is best at reading their opponent’s mind. Use the score card below to determine the winner.



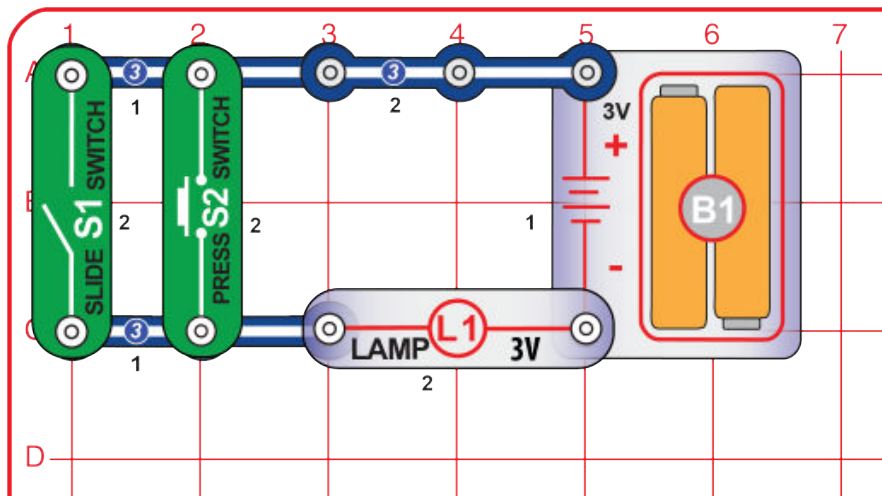
Part B, Quiet Zone Game: Player 1 places three 2-snap shorting bars across base grid locations A1-B1, A2-B2, or A3-B3, and player 2 tries to guess which of D1-E1, D2-E2, or D3-E3 will NOT make sound.

Round #	1	2	3	4	5	6	7	8	9	10	Total
Player 1	—	—	—	—	—	—	—	—	—	—	—
Player 2	—	—	—	—	—	—	—	—	—	—	—

PROJECT 304

This OR That

Build the circuit shown. Notice that if you turn on the **slide switch (S1)** OR press the **press switch (S2)** the lamp (L1) lights up. There is no partially lit state here, the lamp is either totally on or totally off. 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, or they might be two sensors at a railroad crossing used to start the ding-ding sound and lower the gate. You could also have more than two switches and the circuit would function the same way.

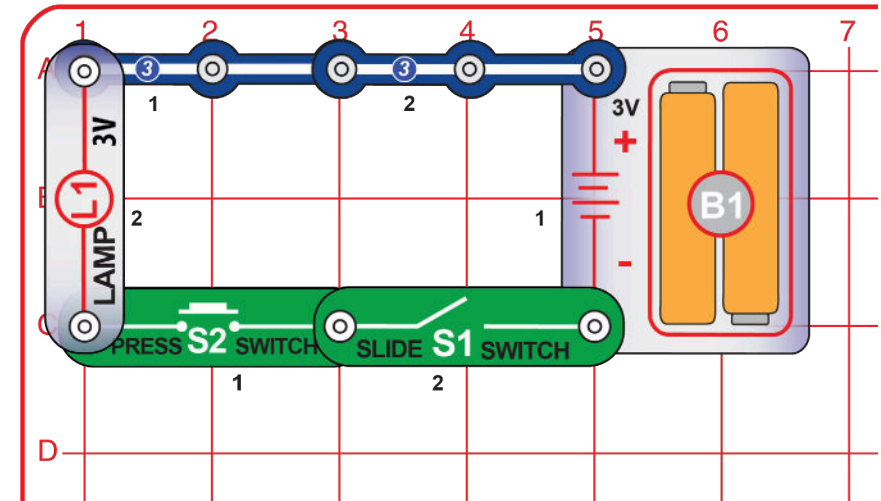


This circuit is commonly called an OR gate. OR gates are used in digital logic circuits to perform logical additions. When one of the inputs is high (one of the switches is on) the output is high (LED on). The output will only be low (LED off) if both inputs are low (both switches are off).

PROJECT 305

This AND That

Build the circuit shown. Notice that if you turn on the **slide switch (S1)** AND press the **press switch (S2)** the lamp (L1) lights up. Once again, there is no partially lit state here, the lamp is either totally on or totally off. 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. You could also have more than two switches and the circuit would function the same way.

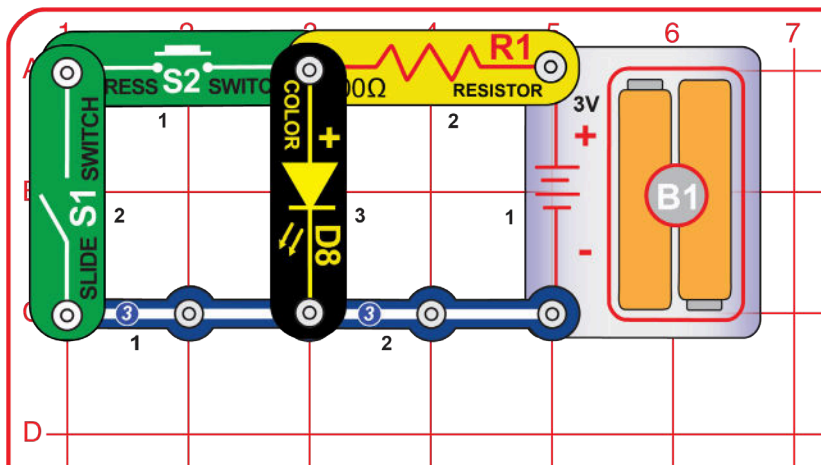


This circuit is commonly called an AND gate. AND gates are used in digital logic circuits to perform logical multiplies. When one of the inputs is low (one of the switches is off) the output is low (lamp off). The output will only be high (lamp on) if both inputs are high (both switches are on). Combinations of AND and OR circuits are used to add and multiply numbers together in modern computers. These circuits are made of tiny transistors in massive integrated circuits.

PROJECT 306

NOT This AND That

Build the circuit below and test the combinations of the **slide switch (S1)** and **press switch (S2)**. If you compare it to the AND circuit in Project 351, you can see the color LED (D8) lights in the opposite combinations of when the lamp lit in that circuit. Hence, we refer to it as 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. Like the OR, AND, and NOR, NAND and NOT are important building blocks in computers. Disassemble the circuit when finished to avoid draining your batteries.

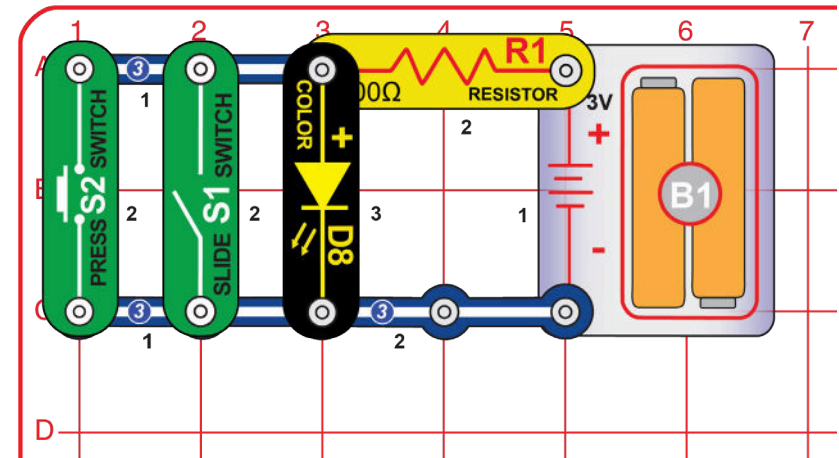


This circuit is commonly called a NAND gate. NAND gates are used in digital logic circuits to perform an inverted logical multiply. When one of the inputs is low (one of the switches is off) the output is high (LED on). The output will only be low (LED off) if both inputs are high (both switches are on).

PROJECT 307

Neither This NOR That

Build the circuit and test the combinations of the **slide switch (S1)** and **press switch (S2)**. If you compare it to the OR circuit in Project 352, you can see the color LED (D8) lights in the opposite combinations of when the lamp lit in that circuit. Hence, we refer to it as a NOR circuit (short for “NOT this OR that”). Like the OR and AND, it is an important building block in computers. Disassemble the circuit when finished to avoid draining your batteries.



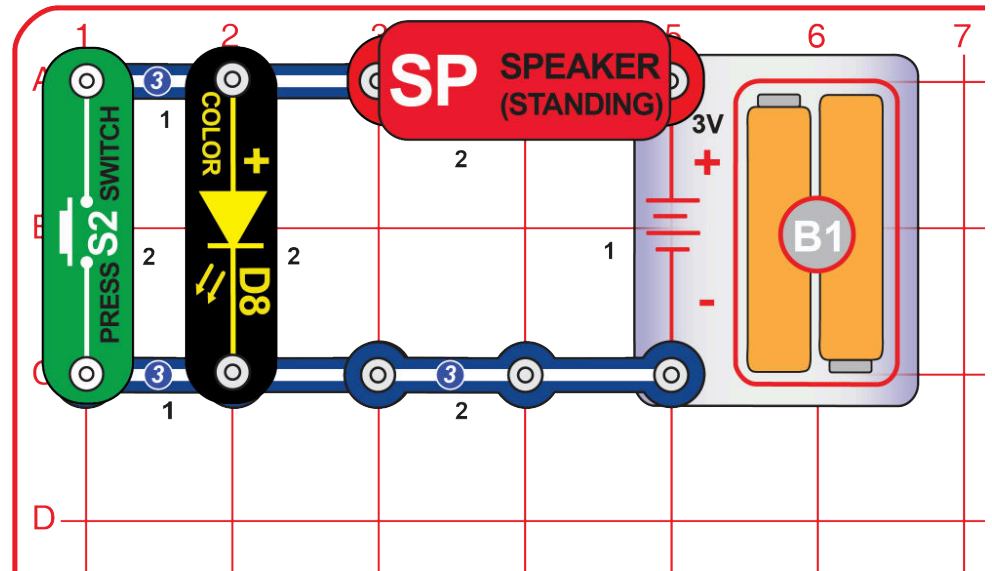
This circuit is commonly called a NOR gate. NOR gates are used in digital logic circuits to perform an inverted logical add. When one of the inputs is high (one of the switches is on) the output is low (LED off). The output will only be high (LED on) if both inputs are low (both switches are off).

PROJECT 308 NOT Circuit

Build the circuit shown. Notice that when the **press switch (S2)** is pressed, the color LED (D8) goes off. This is an example of an inverter circuit, or NOT gate. Whenever the input is high (switch is on), the output is low (LED is off) and whenever the input is low (switch is off) the output is high (LED is on). Ignore any sound coming from the speaker (SP). Disassemble the circuit when finished to avoid draining your batteries.

Although this circuit seems simple, inverters or NOT gates are very important in digital logic circuits.

The speaker is used here to load the batteries, so there will not be a short circuit when S2 is pressed. The speaker will make a little noise as the color LED changes the circuit current as it changes colors.



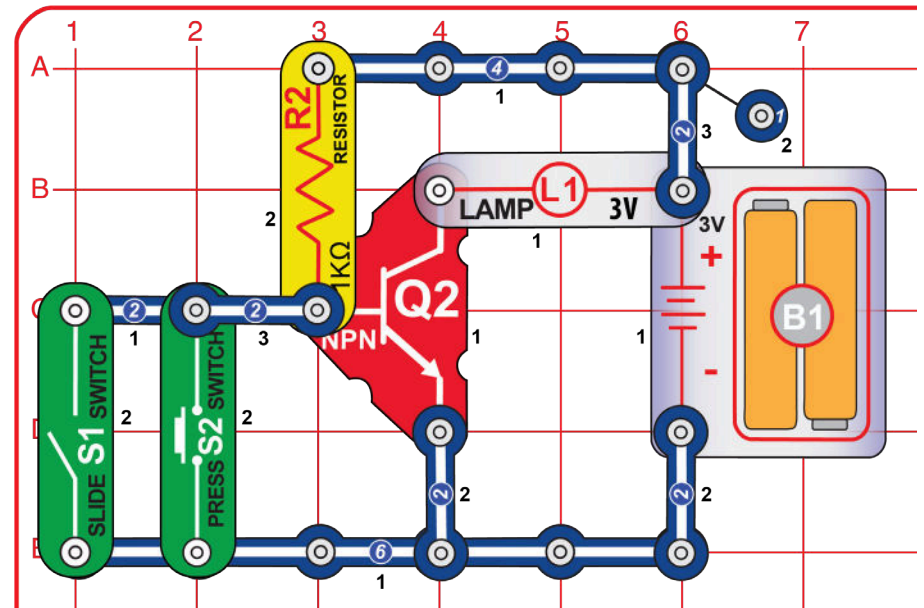
PROJECT 309 Lamp NOR Gate

Build the circuit on the right and test the combinations of the **slide switch (S1)** and **press switch (S2)**. You will find that the lamp (L1) is on when neither the **slide switch (S1)** NOR the press switch (S2) are on. This is referred to as an NOR gate in electronics and is important in computer logic.

Example: If neither condition X NOR condition Y are true, then execute instruction Z.

Disassemble the circuit when finished to avoid draining your batteries.

This circuit is a NOR gate light the preceding one, but uses a transistor (Q2) to control a lamp.



PROJECT 310

Cup & String Communication

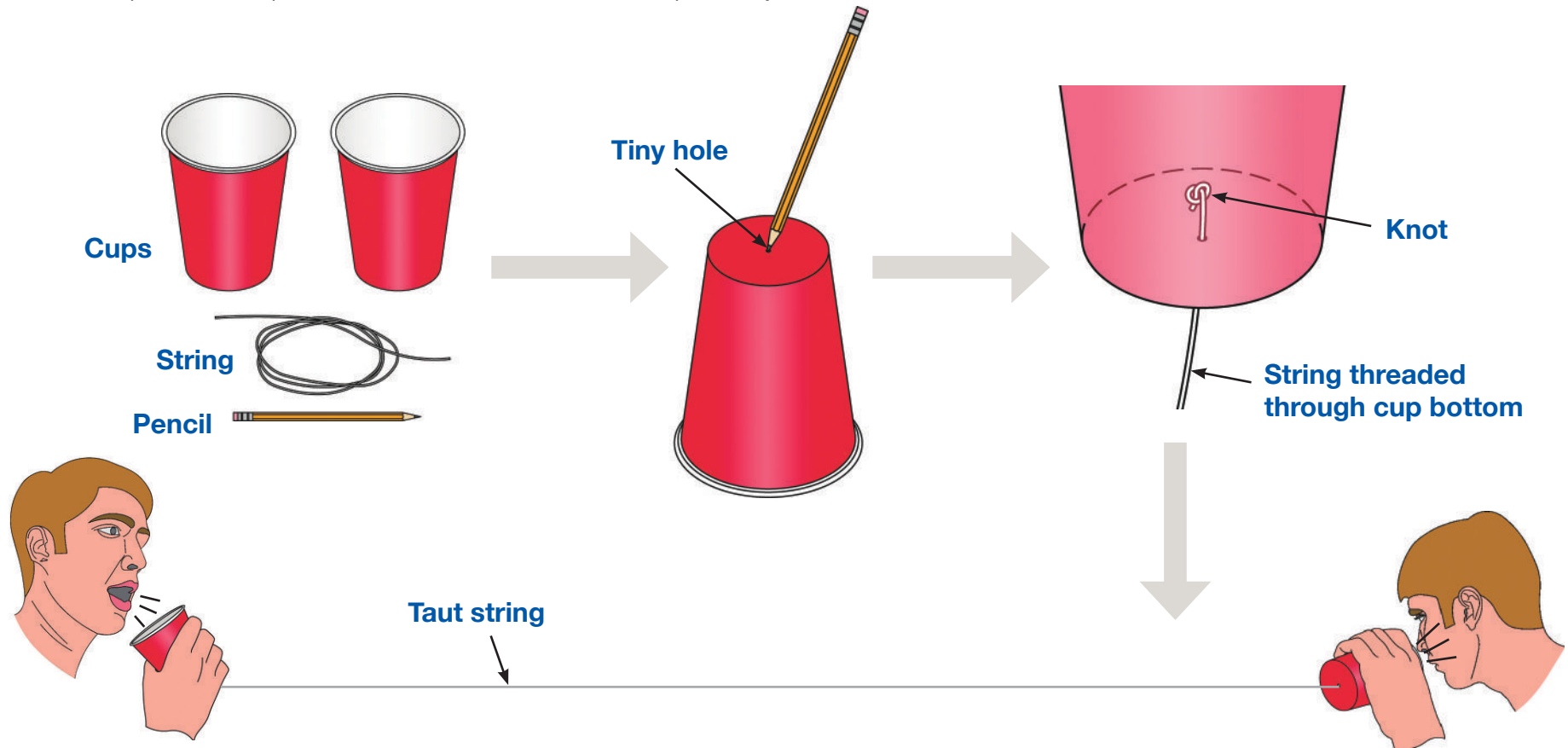
Light, radio signals, and sound all travel through air like waves travel through water. To help you understand how they are like waves, you can make a cup & string telephone. This common trick requires some household materials (not included with this kit): two large plastic or paper cups, some non-stretchable thread or kite string, and a sharp pencil. Adult supervision is recommended.

Take the cups and punch a tiny hole in the center of the bottom of each with a sharp pencil (or something similar). Take a piece of string (use between 25 and 100 feet) and thread each end through each hole. Either knot or tape the string so it can't go back through the hole when the string is stretched. With two people, have each person take one of the cups and walk apart until the string is tight. The key is to make the string tight, so it's best to keep it in a straight line. Now, if one person talks into one of the cups, the second person should be able to hear what the first person says.

How it works:

When you talk into the cup, the cup bottom vibrates back and forth from your sound waves. The vibrations travel through the string by pulling the string back and forth, and then make the bottom of the second cup vibrate just like the first cup did, producing sound waves that the listener can hear. If the string is tight, the received sound waves will be just like the ones sent, and the listener hears what the talker said.

Telephones work the same way, except that electric current replaces the string. In radio, the changing current from a microphone is used to encode electromagnetic waves sent through the air, then decoded in a listening receiver.



12. See the Signals

PROJECT 311 Test Your Hearing

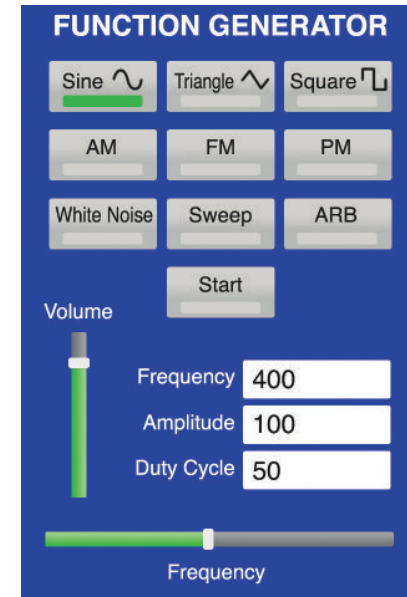
This project requires a smart phone with an internet connection, so you can download a free app. Find and download a “**function generator**” app that can generate sine and square signals. Visit the Snap Circuits® Classic product page at shop.elenco.com/consumers/snap-circuits-classic.html to find a few suggestions.

Set the app for “**Sine**” function (for a single tone), start it, and vary the frequency across the available range. Listen to the sound directly on your smart phone. Set the volume control on your smart phone so that the sound is at a comfortable level for middle frequencies.

See what range of frequency you can hear. Notice that the sound is loud at middle frequencies, but low (or no sound at all) at low or high frequency. There are two reasons for this:

1. Your hearing ability depends on frequency. Most people can hear frequencies in the range of 20 Hz to 20,000 Hz, but much better in the middle of this range than at the low or high ends of it. As you get older you don’t hear higher frequencies as well, so use the same circuit to see what range of frequency your grandparents can hear.
2. Your speaker’s ability to produce sound depends on frequency, and it may not perform as well at low or high frequency. Speakers are only designed to produce sound in the range that we can hear.

Part B: Set the frequency on the function generator app to just below what you can hear, then change the function from “Sine” to “**Square**” function (for a tone with lots of overtones). You should be able to hear it now, because a signal with overtones has some energy at higher frequencies, which should be within your hearing range.



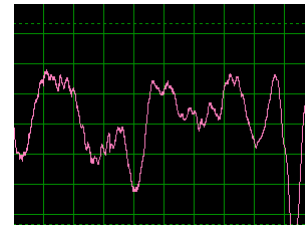
PROJECT 312 See the Sound

This project requires a smart phone with an internet connection, so you can download a free app. Find and download an “**oscilloscope**” app that lets your smart phone act as an oscilloscope. Visit the Snap Circuits® Classic product page at shop.elenco.com/consumers/snap-circuits-classic.html to find a few suggestions.

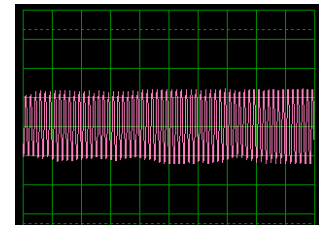
An oscilloscope is an instrument that engineers use to actually look at electrical signals. Constant tones are especially interesting to look at, because they are repetitive and actually look like a wave.

Start the app and talk into the smart phone’s microphone, and watch your voice on the screen. Try making a single tone at different frequencies, or whistling, or snapping your fingers. Try not to blow into the microphone while you talk into it.

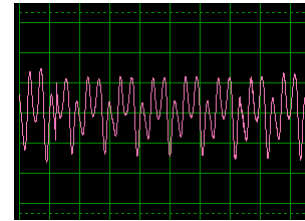
Your waveforms should resemble those at right but will not match, due to differences in time and amplitude settings in the app, microphone sensitivity, how far you are from microphone, and other sounds in the room.



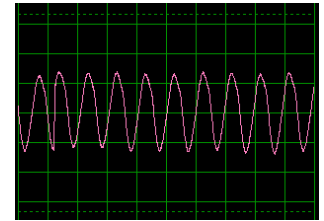
Blowing into microphone



Whistling into microphone



Ahhhhhh sound



Humming into microphone

Part B, See the Spectrum:

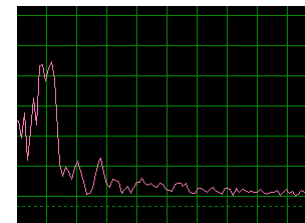
Find and download a “**spectrum analyzer**” app that lets your smart phone view the frequency spectrum of a signal, some oscilloscope apps include this on the same screen. Visit the Snap Circuits® Classic product page at shop.elenco.com/consumers/snap-circuits-classic.html to find a few suggestions.

A spectrum analyzer is an instrument that engineers use to look at the frequency content of electrical signals, and shows which frequencies have the most energy. A pure tone will have all its energy at a single frequency, while a tone with overtones will have the most energy at the main tone, but also have energy at multiples of the main tone. A complex sound will have its energy spread across many frequencies.

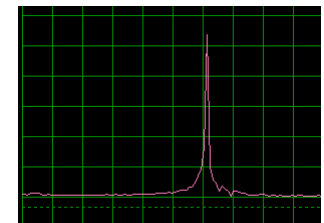
Spectrum analyzers usually show data as a chart of energy content versus frequency. Energy is usually shown in dB (decibels), a logarithmic measurement, so the strongest frequencies have much more energy than the weak ones shown. There is always a “noise floor” of background noise, which can make weak signals difficult to observe.

Start the app and talk into the smart phone’s microphone, and watch the frequency content of your voice on the screen. Try making a single tone at different frequencies, or whistling. Your waveforms should resemble those at right but will not match, due to differences in time and amplitude settings in the app, microphone sensitivity, how far you are from microphone, and other sounds in the room.

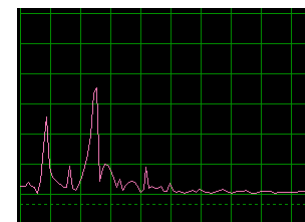
These spectrum analyzer pictures correspond to the oscilloscope pictures above them. Notice the spectrums for the hum and whistle have only a single big peak. Smooth, well-rounded, and repetitive waveforms (as viewed on an oscilloscope app) have nearly all of their energy at a specific frequency like for the hum. A tone, siren, and most music have a series of mathematically-related peaks, while “random” waveforms (like from blowing into the microphone or several people talking at the same time) have a frequency “blob” instead of distinct peaks. Most women have higher-frequency voices than most men, and so their frequency peaks are further to the right on your display.



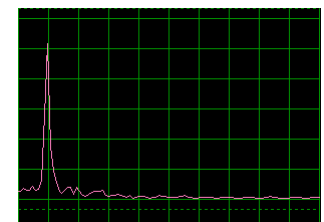
Blowing into microphone



Whistling into microphone



Ahhhhhh sound

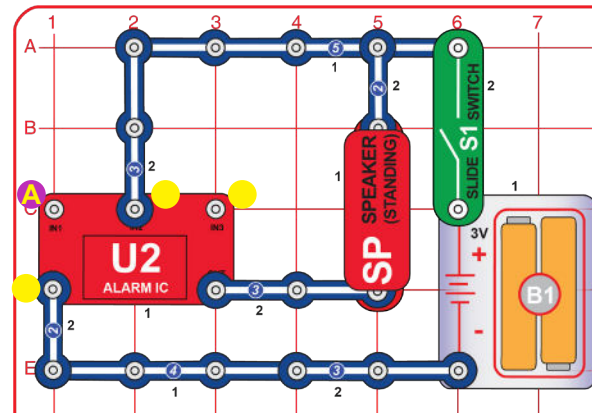


Humming into microphone

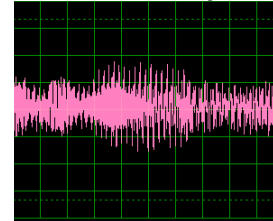
PROJECT 313 See the Sirens

Rebuild project 2 (Siren). Open the **oscilloscope** and/or **spectrum analyzer apps** you downloaded to your smart phone in project 313 and hold your smart phone near the **speaker (SP)**. Turn on the **slide switch (S1)** and look at the oscilloscope and spectrum analyzer waveforms for the siren sound.

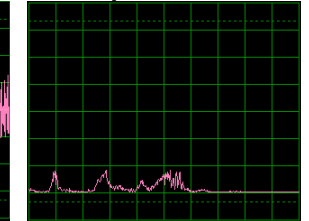
The oscilloscope and spectrum analyzer waveforms are constantly changing. This is because the siren sound you hear is not a continuous tone but instead is constantly changing frequency, and it spends more time at some frequencies than at others. Some oscilloscope and spectrum analyzer apps may allow you to zoom in on part of the waveform to see it in more detail.



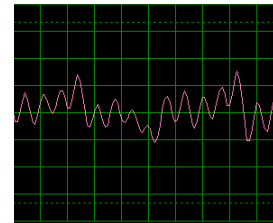
Siren - oscilloscope



Siren - spectrum

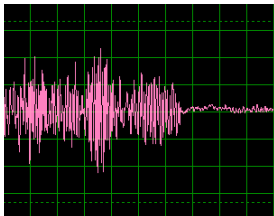


Siren - oscilloscope, zoomed in horizontally

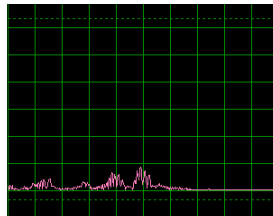


Part B, Machine Gun: Add a connection between the points marked **B & C** using a 1-snap wire and a 2-snap wire, or a jumper wire. The sound shuts off between bursts.

Machine Gun - Oscilloscope

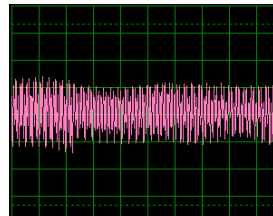


Machine Gun - Spectrum

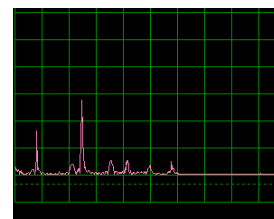
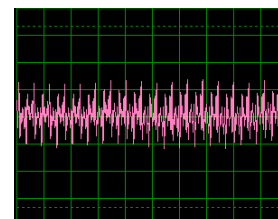
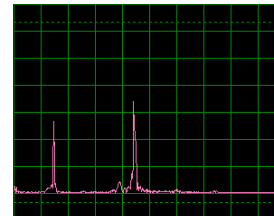


Part C, Fire Engine: Remove the connection between **B & C**, and add a connection between **A & B**. The waveform slowly rises and falls in pitch, and gives a clear spectrum that slowly rises and falls in frequency.

Fire Engine - Oscilloscope

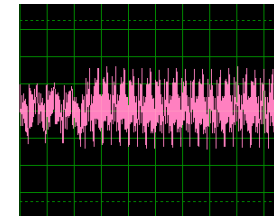


Fire Engine - Spectrum

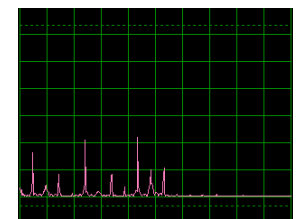
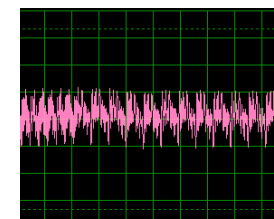
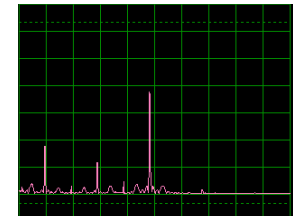


Part D, European Siren: Remove the connection between **A & B**, and add a connection between **A & D**. The signal alternates between two frequencies.

European Siren - Oscilloscope



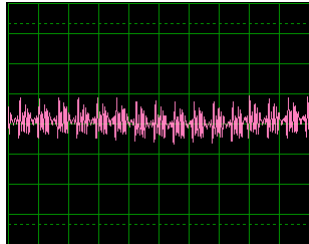
European Siren - Spectrum



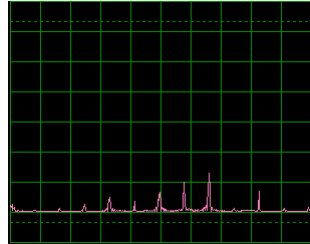
PROJECT 314 See the Tone Generator

Rebuild project 233 (Tone Generator). Open the **oscilloscope** and/or **spectrum analyzer** apps you downloaded to your smart phone in project 359 and hold your smart phone near the **speaker (SP)**. Turn on the **slide switch (S1)** and look at the oscilloscope and spectrum analyzer waveforms for the tone sound.

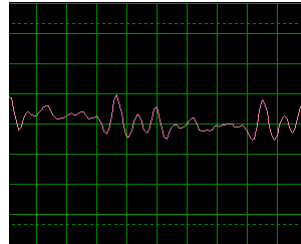
The tone waveform is actually a repetitive burst, and the spectrum has energy at a number of frequencies. Some oscilloscope and spectrum analyzer apps may allow you to zoom in on part of the waveform to see it in more detail.



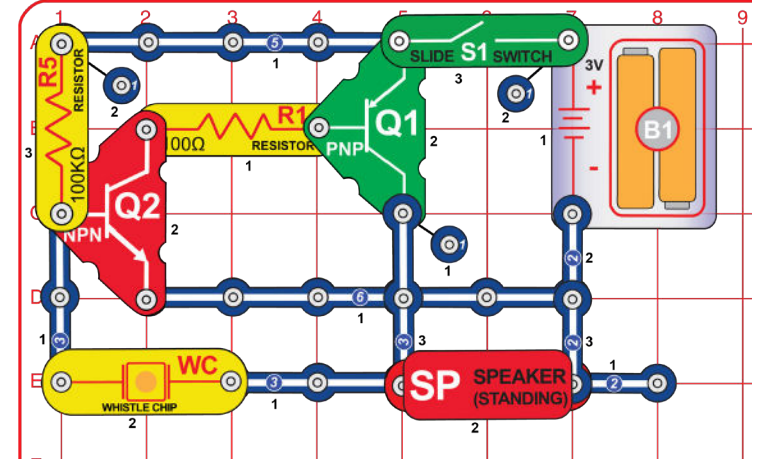
Tone Generator -
Oscilloscope



Tone Generator -
Spectrum



Oscilloscope,
zoomed in horizontally

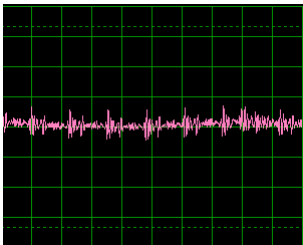


Part B: Place the 0.02μF capacitor (**C1**) on top of the **whistle chip (WC)**. The bursts in the waveform are spread out more, and frequency spectrum is lower.

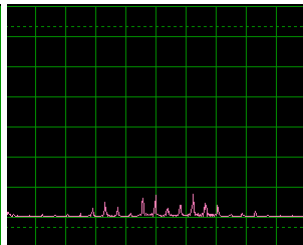
Part C: Replace C1 with the 0.1μF capacitor (**C2**). Now the waveform is a series of short bursts.

Part D: Now replace C2 with the 10μF capacitor (**C3**). Now the waveform is an occasional short burst.

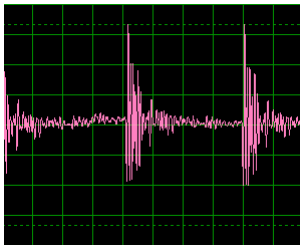
C1 - Oscilloscope



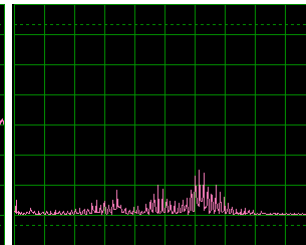
C1 - Spectrum



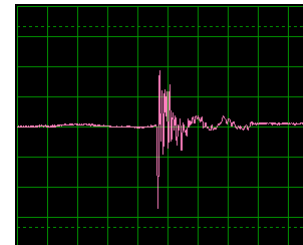
C2 - Oscilloscope



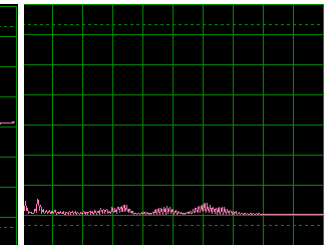
C2 - Spectrum



C3 - Oscilloscope



C3 - Spectrum



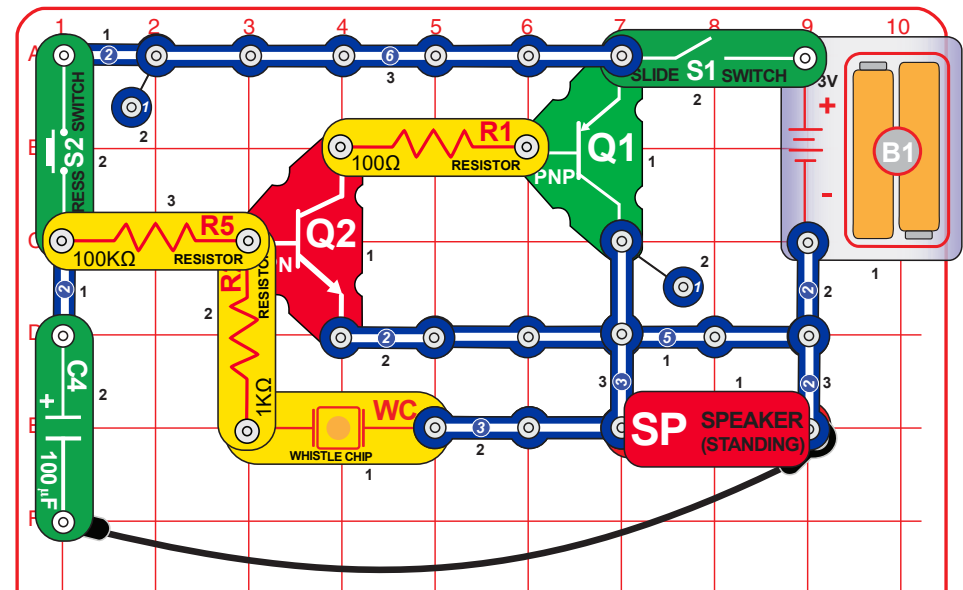
PROJECT 315

See the Lasting Doorbell

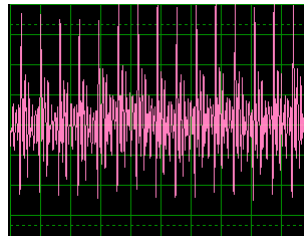
Rebuild project 4 (Lasting Doorbell). Open the **oscilloscope** and/or **spectrum analyzer** apps you downloaded to your smart phone in project 359 and hold your smart phone near the **speaker (SP)**. Turn on the **slide switch (S1)**, push the **press switch (S2)**, and look at the oscilloscope and spectrum analyzer waveforms for the sound as it slowly fades away.

In oscilloscope mode you see repetitive pulses that slowly spread out. In spectrum analyzer mode you see the energy is spread among many specific frequencies, and those are slowly moving to the left (getting lower in frequency) as the sound fades away.

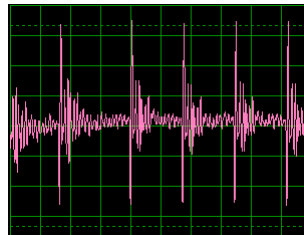
See how the waveforms change with these variants: Place the $0.1\mu\text{F}$ capacitor (**C2**) or the $10\mu\text{F}$ capacitor (**C3**) on top of the **whistle chip (WC)**. Replace the $100\mu\text{F}$ capacitor (**C4**) with the smaller $10\mu\text{F}$ capacitor (**C3**) or the larger $470\mu\text{F}$ capacitor (**C5**). Replace the $100\text{k}\Omega$ resistor (**R5**) with the smaller $10\text{k}\Omega$ resistor (**R4**).



Sample waveform -
Oscilloscope

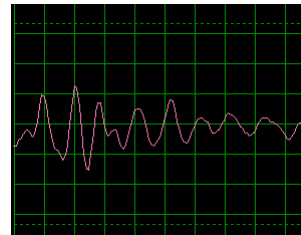
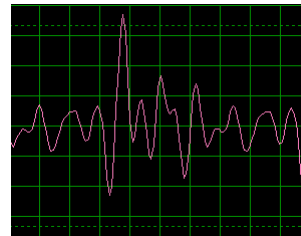


Just after pressing S2:

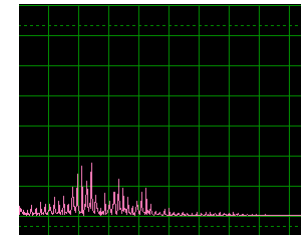
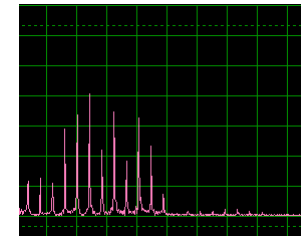


A while after pressing S2:

Sample waveform -
Oscilloscope, zoomed in horizontally



Sample waveform -
Spectrum



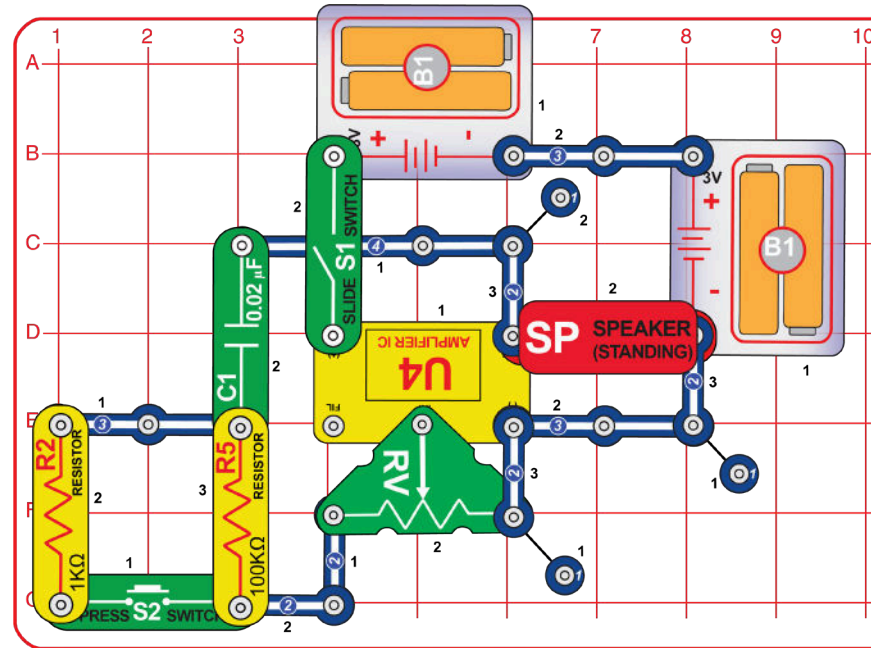
PROJECT 316

See the Trombone

Rebuild project 6 (2-Tone Trombone). Open the oscilloscope and/or spectrum analyzer apps you downloaded to your smart phone in project 359 and hold your smart phone near the speaker (SP). Turn on the **slide switch (S1)** and look at the oscilloscope and spectrum analyzer waveforms for the trombone sound as you vary it using the lever on the adjustable resistor (RV), with and without the **press switch (S2)** pressed. The circuit may be silent at some positions of RV.

The oscilloscope waveform is complex, and the spectrum shows the energy spread across many specific frequencies.

You can replace the 0.02 μ F capacitor (C1) with the 0.1 μ F capacitor (C2) or the 10 μ F capacitor (C3, "+" on right) and see how the waveforms change.

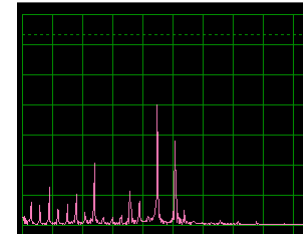
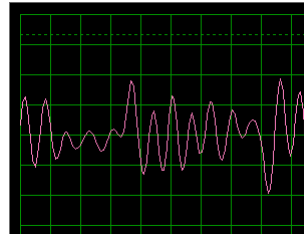
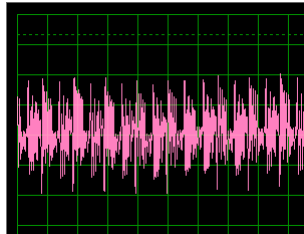


Sample waveform -
Oscilloscope

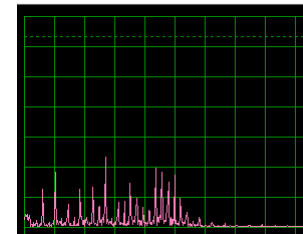
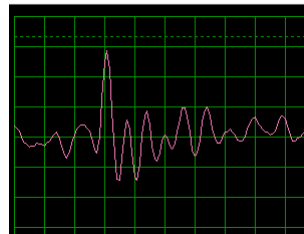
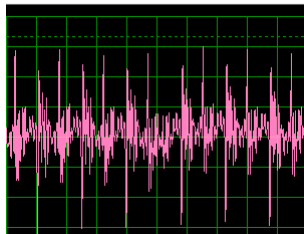
Sample waveform -
Oscilloscope, zoomed in horizontally

Sample waveform -
Spectrum

S2 pressed:



S2 not pressed:



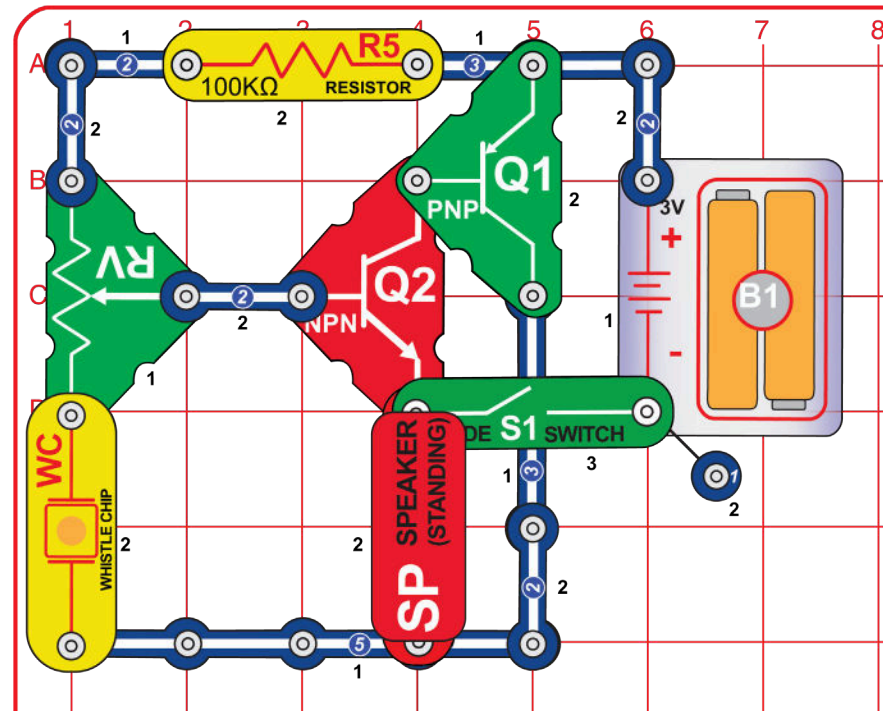
PROJECT 317

See the Hissing Foghorn

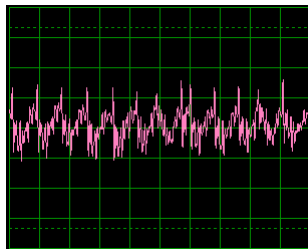
Rebuild project 216 (Hissing Foghorn). Open the **oscilloscope** and/or **spectrum analyzer** apps you downloaded to your smart phone in project 359 and hold your smart phone near the **speaker (SP)**. Turn on the **slide switch (S1)** and look at the oscilloscope and spectrum analyzer waveforms for the sound as you vary it using the lever on the adjustable resistor (RV). The circuit may be silent at some positions of RV.

The oscilloscope waveform is complex, and the spectrum shows some energy concentrated at a particular frequency (the peak in the spectrum) and some energy spread across many specific frequencies.

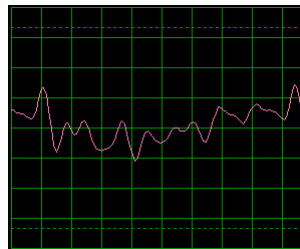
You can place the 0.1 μ F capacitor (**C2**) or the 10 μ F capacitor (**C3**, "+" on top) on top of the **whistle chip (WC)** and see how the waveforms change. Or use the 10k Ω resistor (**R4**) instead of the 100k Ω resistor.



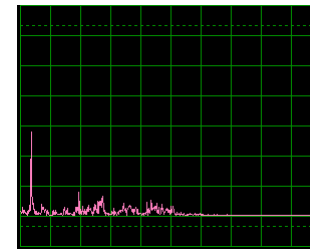
Sample waveform -
Oscilloscope



Sample waveform -
Oscilloscope, zoomed in horizontally



Sample waveform -
Spectrum

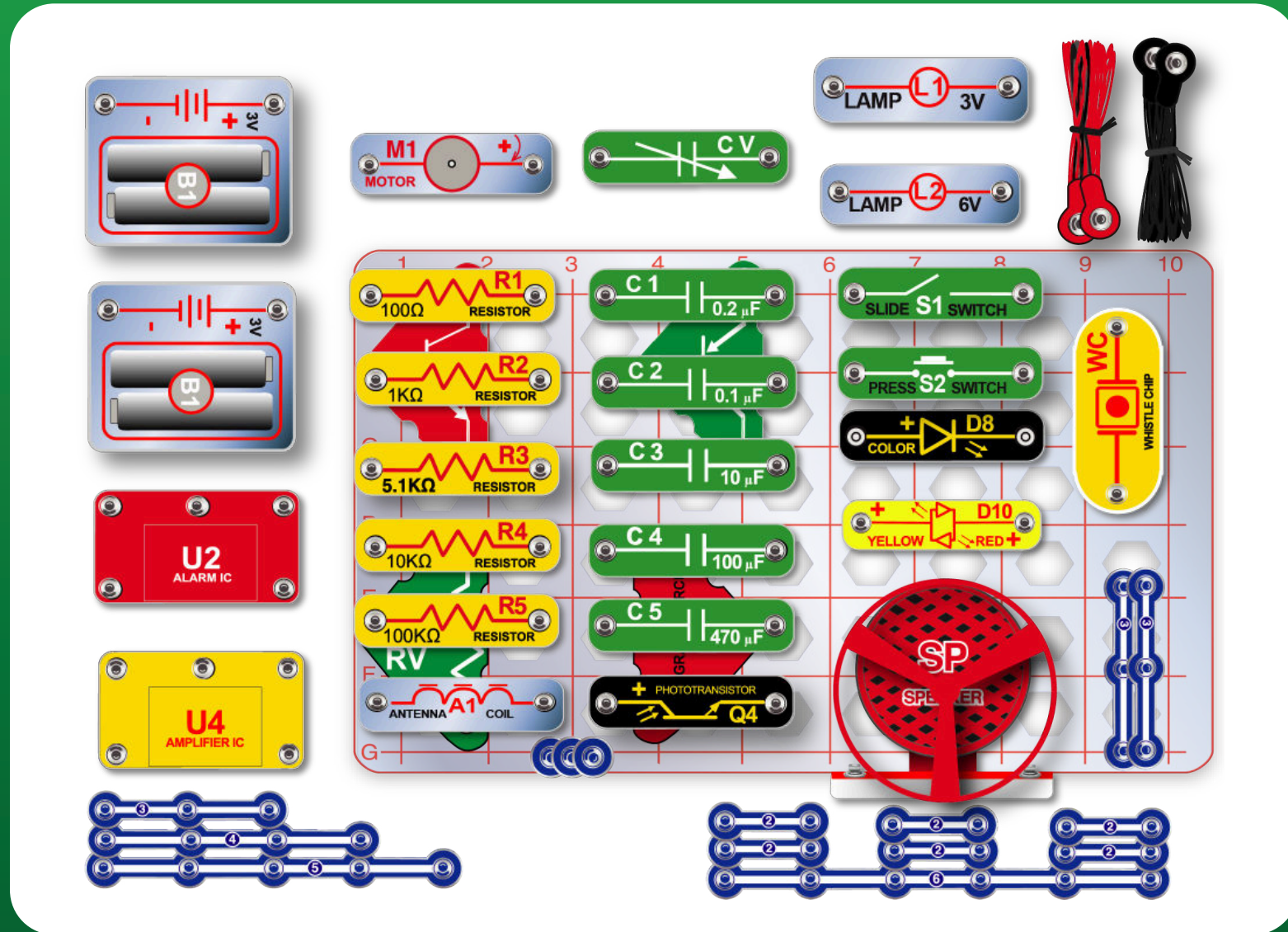


See the Screaming Fan

The oscilloscope waveform is complex, and the spectrum shows some energy concentrated at a particular frequency (the peak in the spectrum) but most energy spread across many specific frequencies.

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📞 (800) 533-2441

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🌐 elenco.com