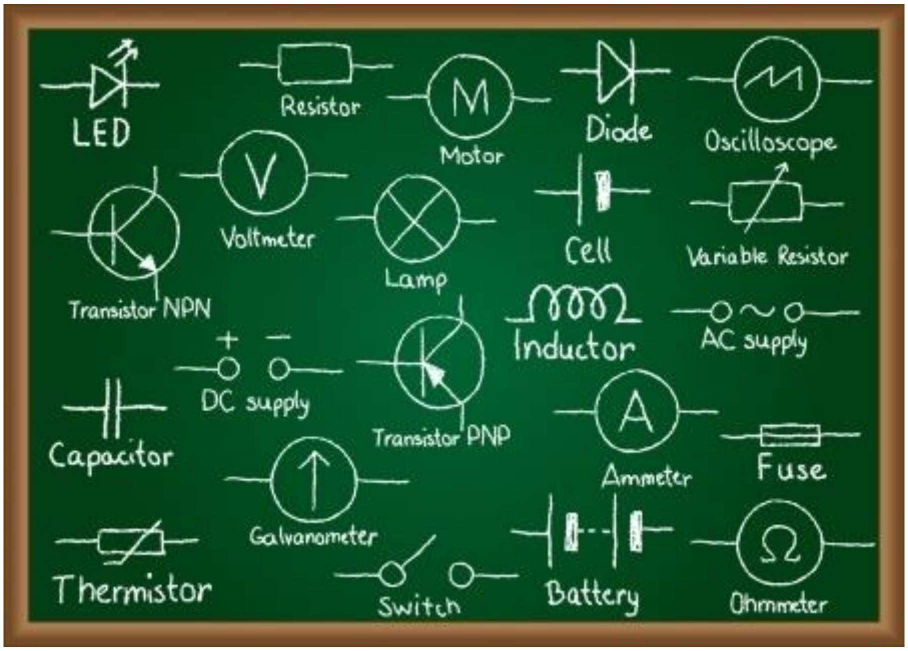
Electronic Engineering for Kids…



By Tyrome Williams

This basic electronics engineering guide was made by Building Dreams, an afterschool program in Omaha, NE in order to promote the curiosity and provide a supplement curriculum for children in the out-of-school setting. This print was made to be used as an open user guide or reference. Please distribute freely. If you have any questions or noticed something that needed to be corrected please feel free to contact me on Instructables.com under KID Hero.

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Contents

Electronic Engineering for kids.

Welcome to the exciting world of teaching STEM (Science, Technology, Engineering, and Math). Kids are naturally curious about how things work, and with a new trend in hardware companies creating open source hardware products, it's a great time to teach kids about electronics. But modern technology can seem too complex to even begin to understand. So where do you start?

<u>3 Different Methods of Teaching Electronics Engineering for Kids</u>

Start from the Beginning. Solderless breadboards are an easy way to begin. Another option is electronic dough which I will explain later. The third option is the hot glue method for students who haven't quite grasped the dexterity of the soldering gun.

The Basics of Electronic components

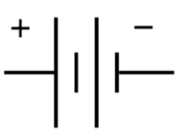
These are the most common components:

- Resistors
- Capacitors
- LEDs
- Transistors
- Inductors
- Integrated Circuits
- Diodes

General Symbols of Electronics

Lots of Batteries

Just as you would expect the battery is the power source for your electronic circuit. The electronic symbol shown belong commonly notates either the positive end or both the positive and negative end. Something else to look for is how many volts the power source has (ex. A square "9 volt battery" = 9 volts, while an "AA" battery has 1.5 volts). It's very important to know the voltage of the power source so you do not damage any of your electronic components when building.



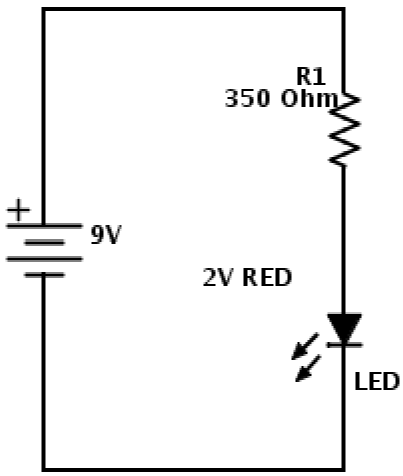
Common symbol for the battery.

Resistor

You use resistors to control the voltage and currents in your circuit. Think of them like a funnel. One side has a big end and the other a small end. It controls the flow of electricity allowed to come through so smaller electronics don't burn out or explode.

Common symbol for resistors commonly used in diagrams. The colored lines on an electrical circuit determines how much resistance the resistor provides. This is convenient especially when they can easily look alike.

****You use the resistor to control the voltages and the currents in your circuit.**



Example 1:

To the left is our example circuit diagram. We have a 9 volt power source powering a 2 volt LED light (down facing triangle with a line perpendicular to it). These LED's lights are very sensitive. If we hook the battery to the light without using a resistor (the squiggle labeled R1), the LED will burn out or pop and the light will never work again making us either very sad or very angry.

A Different Scenario

We're very thirsty and want to get a drink of ice cold glass of water, but our only water source is a high pressured fire hose.

When we turn on the fire hose, the water pressure will blast the cup right out of our hands or shatter it due to the force. The water **flow** is too strong, just like a high voltage battery or power source would do to low voltage circuits. It would destroy it. We need to use a funnel, a <u>valve</u> or <u>tank</u> to control the amount of water that coming from the source (just like a **resistor** in a circuit board), we could protect our components while still having a working circuit.

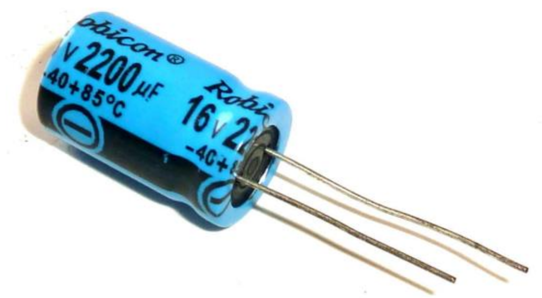
Note: The opening of a water bottle is just like a funnel. There's lots of water inside of the bottle, but the opening controls the flow (amount) of water able to come out. The neck of the bottle is our resistor.

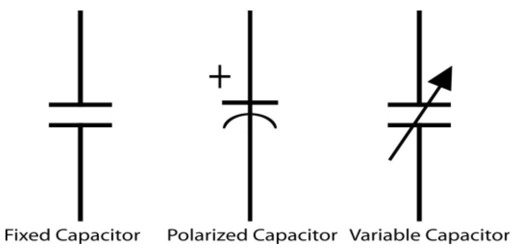
<u>Pipes carry water like wires carry electricity. Resistors limit the flow of Electricity, just like a control value on a pipe.</u>

Question: Why don't we just use the appropriate battery for the circuit we're building?

You could actually. However, when the size of your circuit grows, a small battery may not be able to power all of the components at once or be able to power them all for a long time. Think of a remote control car that only has a battery life of 10 seconds. This wouldn't make a very fun toy. Some components can run off of smaller batteries, however the battery life will quickly disappear. The other reason for using a different battery is you may only have a specific type (voltage) of battery available or that will fit for your use.

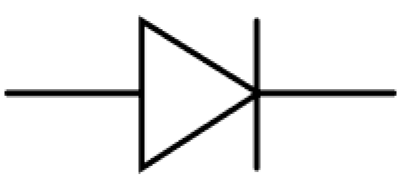
Capacitor





Symbol for a capacitor. Very similar to a battery. Think of a capacitor as a battery with very low capacity. You can charge and discharge it just like a battery. The capacitor is often used to introduce a time-delay in a circuit, however it has other uses. It's commonly used for removing noise, or making the supply voltage of a circuit more stable. There are many types of capacitors. They are commonly divided between polarized and non-polarized (fixed).

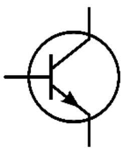
Diodes and Light Emitting Diode (LED)



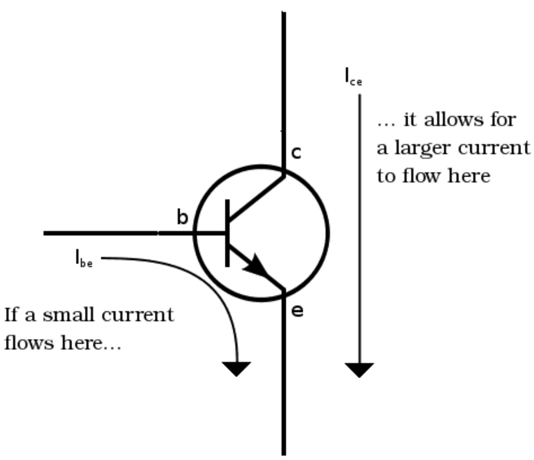
Electricity will always try to travel to the point of least resistance and to the closest ground possible. When you have an unexpected spark or ground in your electricity, this is called, “a short”. It may sound strange but electricity has the potential to travel backwards. Diodes work just like a “one-way street sign”, they only allow electricity to flow one way.

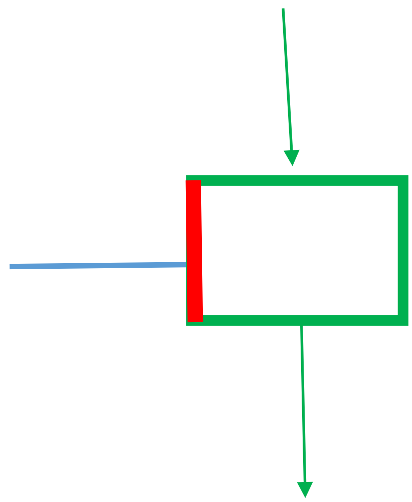
In the same manner, Light Emitting Diodes or LEDs, only allow for electricity to flow in one direction. This is also extremely helping in preventing accidently damage by hooking up the battery backwards. LED's are often used in computers, cell phones, cars, etc. A common LED in a cell phone would be the flash for the camera.

Transistor



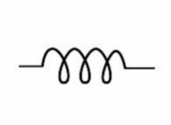
Symbol for transistors commonly used in diagrams. This is probably the hardest of the basic electronic components to explain to kids. **A simple way is to look at the transistor as a switch controlled by an electrical signal. It's like an electrical switch.** If you put about 0.7 volts between the base and the emitter, you turn it on.





Note: Just like a stop light at an intersection. If a stop light turns red for the blue line traffic on the left (this means power is on for the transistor), the traffic going south on the green line is clear (and can power whatever the connection to the bottom green wire powers). ****The top wire always has power, it's a matter of if that power is allowed to flow down through the circuit.**

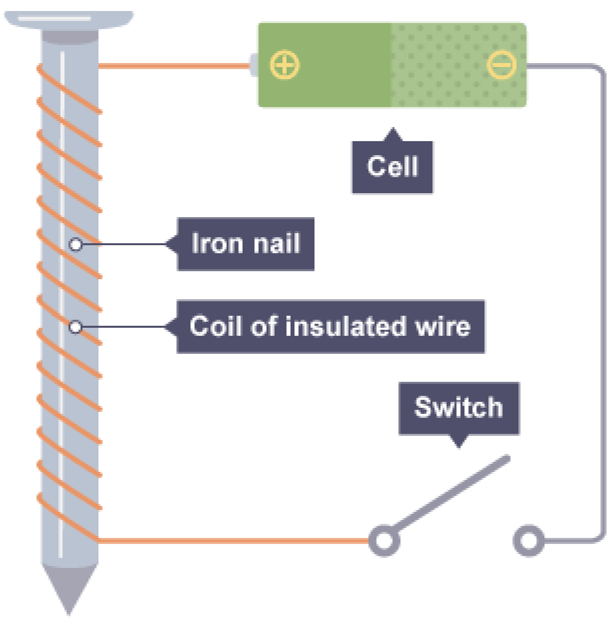
Inductor



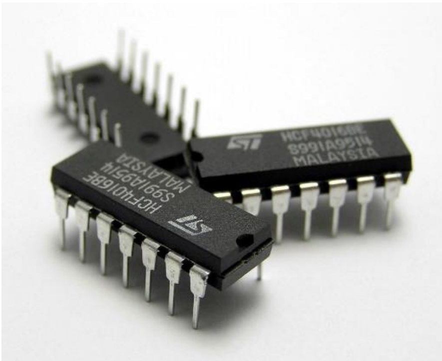
Symbol commonly used for an inductor. **It's just a coil of wire – and you can make one yourself by making some loops out of a wire.**

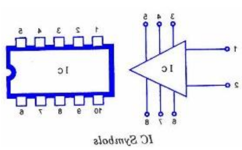
Sometimes they're wound around a metal core of some sort. They can be used as an electromagnet when a strong current is put through them. They can also be used as a filter.

Below: An example of an electromagnet circuit using wire, copper wire, galvanized nail, a battery, and a switch.



Integrated Circuit





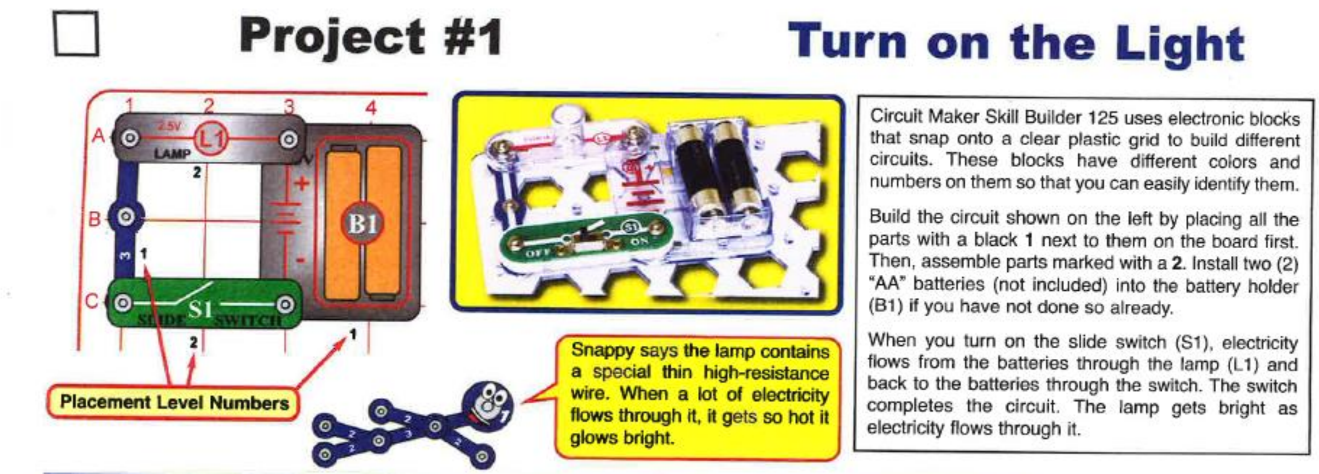
Common symbol for an integrated circuit. An Integrated Circuit (IC) consists of many basic electronic components. It's nothing mysterious or magical.

****It's just an electronic circuit that has been shrunk to fit inside a chip.** It could be an amplifier, it could be a microprocessor, and it could be a USB to serial converter… It could be anything!

Building Circuits with Kids

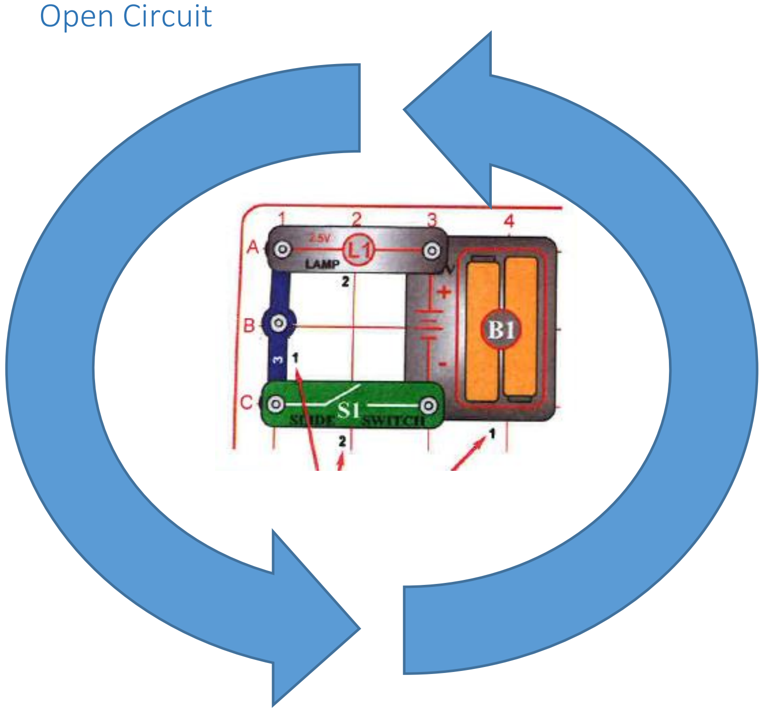
Snap Circuits, activity kits are a great way to introduce circuits to kids. The instructions have kid friendly pictures and are easy to explain what is going on. In the picture to the left, students at Jackson Elementary experiment with building some of their first circuits. Let's look at a simple circuit from the SNAP Circuits 125 piece kit.

On page 11 of the instruction manual, "Project 1" (See below) is the first project that the students will be introduced to. The plastic grid is labeled similar to the Raster Method. 'X' is labeled 1~10, and 'Y' is labeled A ~ J. The piece placement isn't critical until the circuits get so big that students may run out of space.



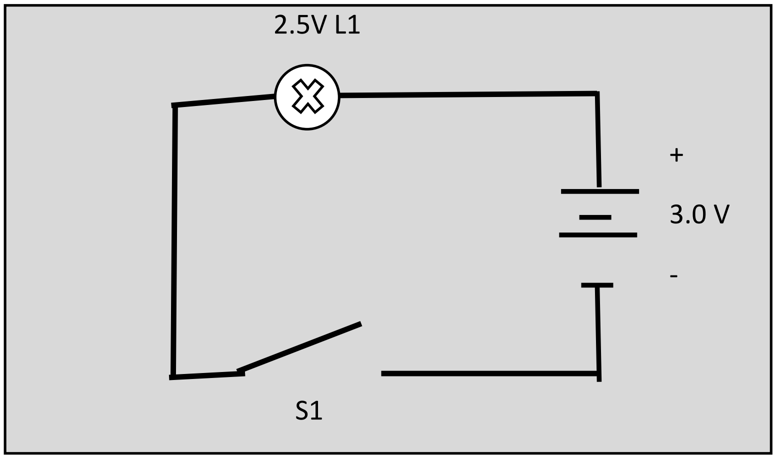
Let's review this circuit. In "Project 1" above, the circuit has four pieces. The battery (B1), the lamp (L1), the sliding on-off switch (S1), and a number 3 section blue wire piece. The most critical part when doing this first project with kids is for them first to build a basic working circuit and then ask them, **"What kind of shape is our circuit forming?"** The common answers will be a square or rectangle. The main point you need to students to learn is a circuit will always have a start (power in) and an end (ground point).

Open Circuit



The circuit begins from the positive end of the battery. It goes through the lamp to the blue 3-section of wire, to the switch, and then finally to the ground (or negative side) of the battery). The lesson you really want to drive home is, "if the ground is not connected on the circuit **(C3 or any point in-between)**, the circuit will never work." You can demonstrate this by disconnecting the right side of the slide switch from the negative side of the battery (at C3). When you turn on the switch, the light does not turn on. The circuit must be complete. When a circuit is not complete, this is called an open circuit. An easy way to think of this is when you turn a light switch off, you are creating a break in the circuit. This break in the circuit turns the lights off.

Project 1 can be built in different ways as well. You can swap the positioning of the lamp with the switch, the lamp with the wire or the wire with the switch. The orientation does not affect the function of the circuit. Here is the same circuit drawn in a diagram instead of an illustration.



Can you make sense of it? The circle with the 'x' in the center is the lamp (L1). Its voltage is notated that it needs 2.5 volts to run. We are running a 3 volt system, so the lamp will have sufficient power and be safe. If we were running a stronger power source (ex. 9v, 12v, etc.) we would need to use a resistor. Else the lamp may burn up, or explode. The battery is labeled with how many volts it has. An 'AA battery' has 1.5 volts. Since this circuit uses two in a series, it has a total of 3.0 volts. The "S1" at the bottom is the sliding switch. Notice how the line has a break away from the main line. This means that the line can be manually broken or put back together, just like a sliding switch operates. Having students manually draw the circuit diagrams after they understand how to build them will reiterate what they've learned and help them remember.

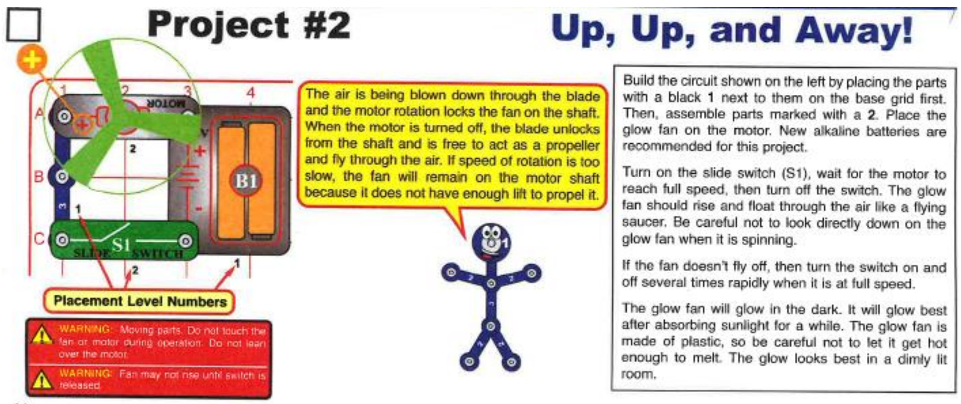
Learn by experimenting

Have the students begin going through the book an practice the projects. In the beginning phase, I recommend students skip "Project 3". They are liable to get frustrated if they do not gain experience using the Snap Circuit project first.

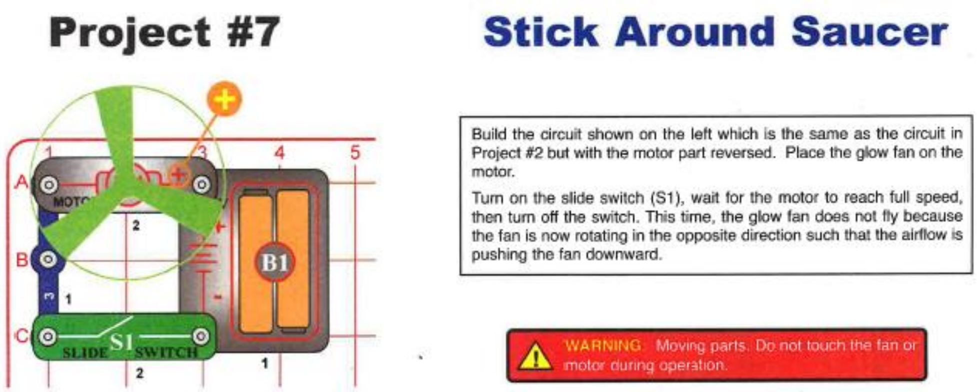
The Cool Characteristics of Motors!

Project 2 and **Project 7** are great projects to explain the property of motors. This is especially important when the students begin building the George the Robot Bug.

First have the students build the circuit in Project 2 – Up, Up, and Away. You should have the kids note two things when building. Make sure the positive end of the motor is facing the top left corner (A1) and that the propeller will fly after the motor hits max speed when turned off.



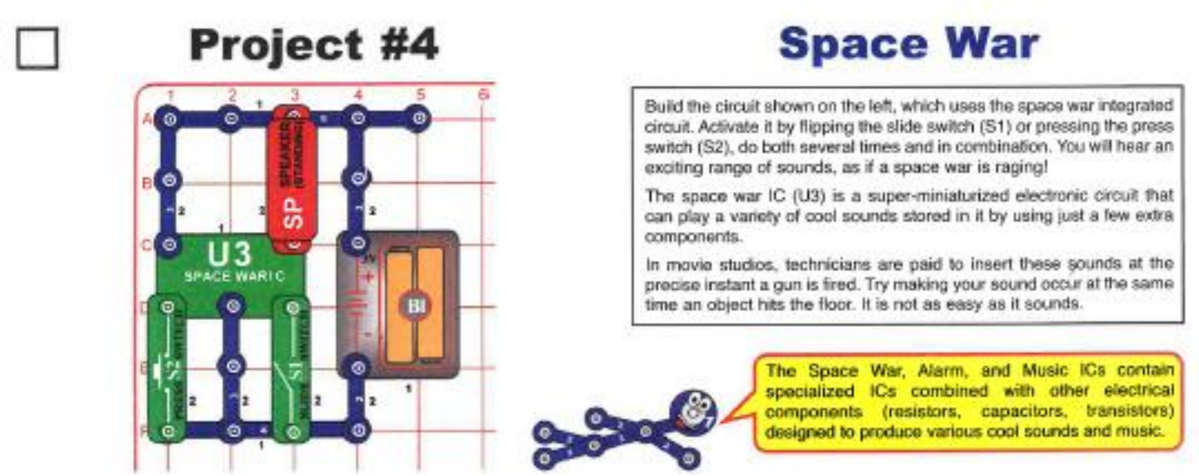
Now have them build Project 7 – Stick Around Saucer. The only modification the students will need to make is to rotate the motor 180 degrees, putting the positive end on the top right corner (A3) instead of the top left (A1).



Now ask the students, "What did we observe? What was different?" First, the propeller did not fly in "Project 7". Secondly, is that the propeller is now spinning in reverse. **A motor special because it can run clockwise or counter clock wise depending upon which side is powered by the positive electrical source.** This is extremely important for building the ***George, Bug Robot Project***. If the electric motors are connected backwards, George will be permanently running backwards (if both motors are reverse) or in circles (if one motor is forward and the other is reverse).

Project 4: Integrated Circuits – Space War

Project 4 - Space War (on page 12) is the first basic project students will use an Integrated Circuit (IC) to build. **U3 Space War IC** is made up of tinier circuits that tells the speakers what kind of sound effect to make.



☐ **Project #4** **Space War**

Build the circuit shown on the left, which uses the space war integrated circuit. Activate it by flipping the slide switch (S1) or pressing the press switch (S2), do both several times and in combination. You will hear an exciting range of sounds, as if a space war is raging!

The space war IC (U3) is a super-miniaturized electronic circuit that can play a variety of cool sounds stored in it by using just a few extra components.

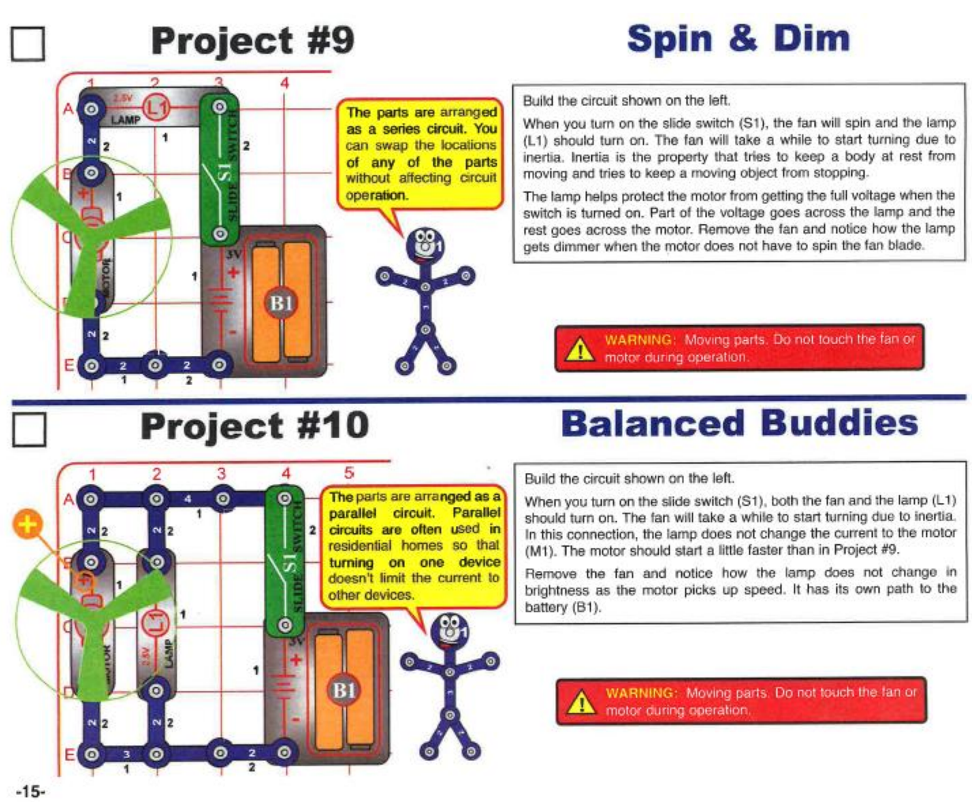
In movie studios, technicians are paid to insert these sounds at the precise instant a gun is fired. Try making your sound occur at the same time an object hits the floor. It is not as easy as it sounds.

The Space War, Alarm, and Music ICs contain specialized ICs combined with other electrical components (resistors, capacitors, transistors) designed to produce various cool sounds and music.

In this circuit, S1 (the sliding switch) is the on-off button. S2 is an over-ride button for making a grenade sound effect.

Doing Two Things at Once – Series & Parallel

Project 9 and project 10 are circuits you should have the students try. They introduce the students to building circuits that do two things at once. In these lessons, students understand how the robot needs to be wired if they want it to operate properly.



☐ **Project #9** **Spin & Dim**

The parts are arranged as a series circuit. You can swap the locations of any of the parts without affecting circuit operation.

Build the circuit shown on the left.

When you turn on the slide switch (S1), the fan will spin and the lamp (L1) should turn on. The fan will take a while to start turning due to inertia. Inertia is the property that tries to keep a body at rest from moving and tries to keep a moving object from stopping.

The lamp helps protect the motor from getting the full voltage when the switch is turned on. Part of the voltage goes across the lamp and the rest goes across the motor. Remove the fan and notice how the lamp gets dimmer when the motor does not have to spin the fan blade.

WARNING: Moving parts. Do not touch the fan or motor during operation.

☐ **Project #10** **Balanced Buddies**

The parts are arranged as a parallel circuit. Parallel circuits are often used in residential homes so that turning on one device doesn't limit the current to other devices.

Build the circuit shown on the left.

When you turn on the slide switch (S1), both the fan and the lamp (L1) should turn on. The fan will take a while to start turning due to inertia. In this connection, the lamp does not change the current to the motor (M1). The motor should start a little faster than in Project #9.

Remove the fan and notice how the lamp does not change in brightness as the motor picks up speed. It has its own path to the battery (B1).

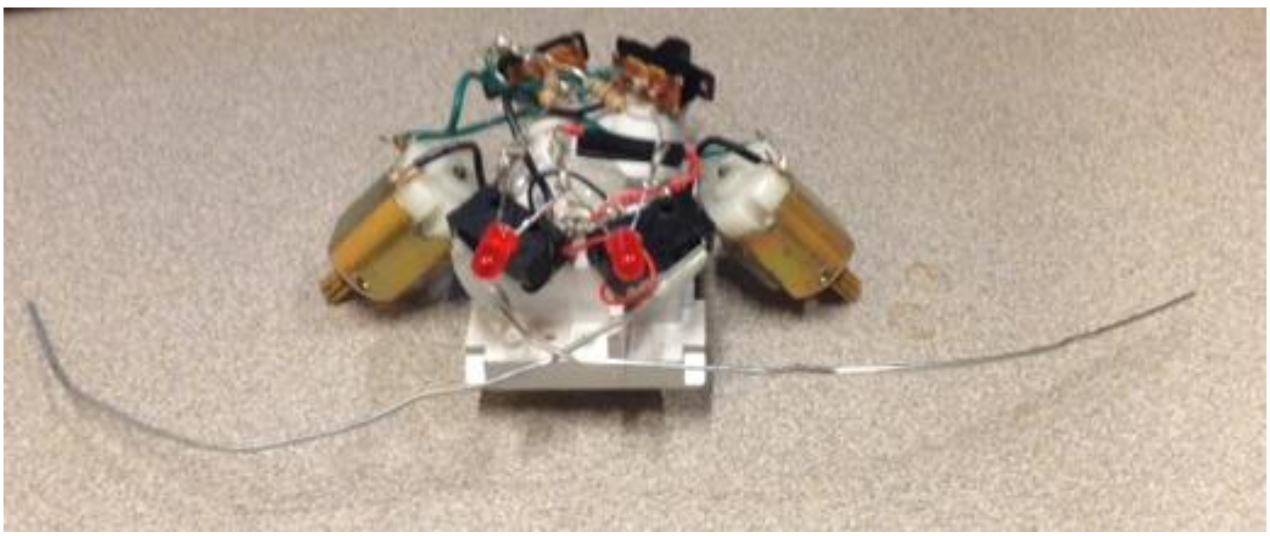
WARNING: Moving parts. Do not touch the fan or motor during operation.

-15-

The key difference between the two projects that students will discover on Project 9, the light will be dimmer and the fan will spin more slowly than on Project 10. **In Project 9, the motor and the light are hooked up in a series** (dazzy-chained one device after the other), compared to **Project 10 they are set up in parallel** (there is a separate power line that goes to the motor and goes to the light bulb). This makes sure that the power isn't limited by the other device before going into the next device that requires power. This is extremely important to know because the bug robot will have two LED eyes and two motors as feet. While they will have separate power, they will sometimes be operated at the same time.

Note: In a **series circuit**, the current through each of the components is the same, and the voltage across the **circuit** is the sum of the voltages across each component. In a **parallel circuit**, the voltage across each of the components is the same, and the total current is the sum of the currents through each component.

George, the Scuttle Bug Robot



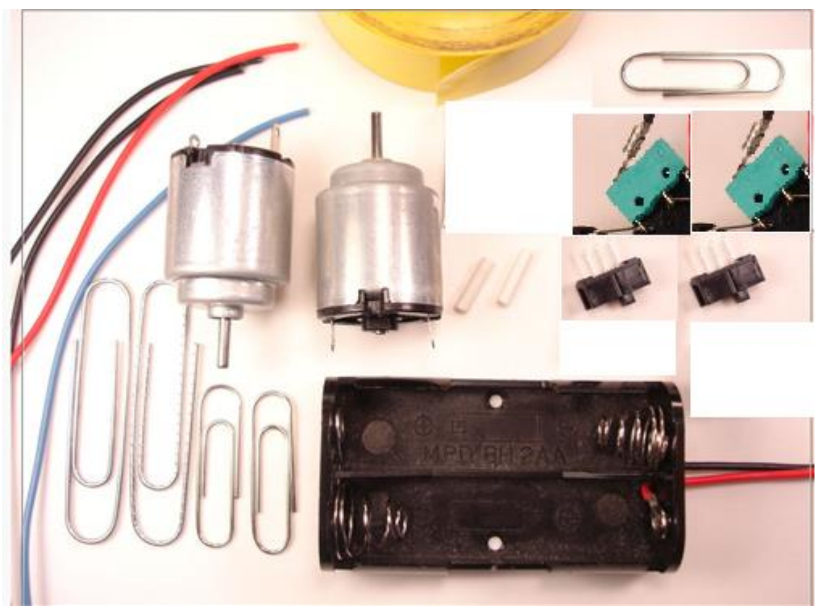
Now for the exciting ordeal. Students will be able to build their first robot build out of reclaimed or brand new parts. The biggest challenge with this project is making sure you use the correct components. Assembly is the easy part. He is not the cutest robot in the world but he will create lots of excitement during your program. The parts list follows on the next page. However, the highlights of his design are his illuminating eyes (2x LEDs) his antenna which detect obstructions, and his dual motors which allow him run quickly across the floor.

Parts list for George.

Description	Qty	
AA battery holder	KEYSTONE 2463	1
SPDT switches	MX-90-C-02 Micro Switch 1P2T 1A	2
SPST switches	Slide Switch 1P2T Through Hole 0.5A 50VDC	2
Large Paper Clips	1 small box (need 5 paperclips for 1 robot)	1
Motors	1.5-3v Brushed DC Toy Motor	2
On/Off switch	Push button latching ON/OFF DPDT 0.5A 50VDC 8X8MM	2
Hook Up Wire (2')	22 AWG - Any color 2'	1
LEDs	5 MM Through hole LED- Any color	3
Heat shrink tubbing 2" (2 sizes)	1/16 diamater & 3/32 Heat shrink tubing	2
Batteries	AA Alkaline batteries	2
Bottle Caps	1" diameter	2
Resistors	68 Ohm 1/4 watt	1
	Total part count	2
		27

While the list above seems like a lot (27 pieces), when you look at the picture blow, it doesn't seem as intimidating.

Illustration of parts needed:



Tools Needed:

Wire strippers

Needle nose pliers

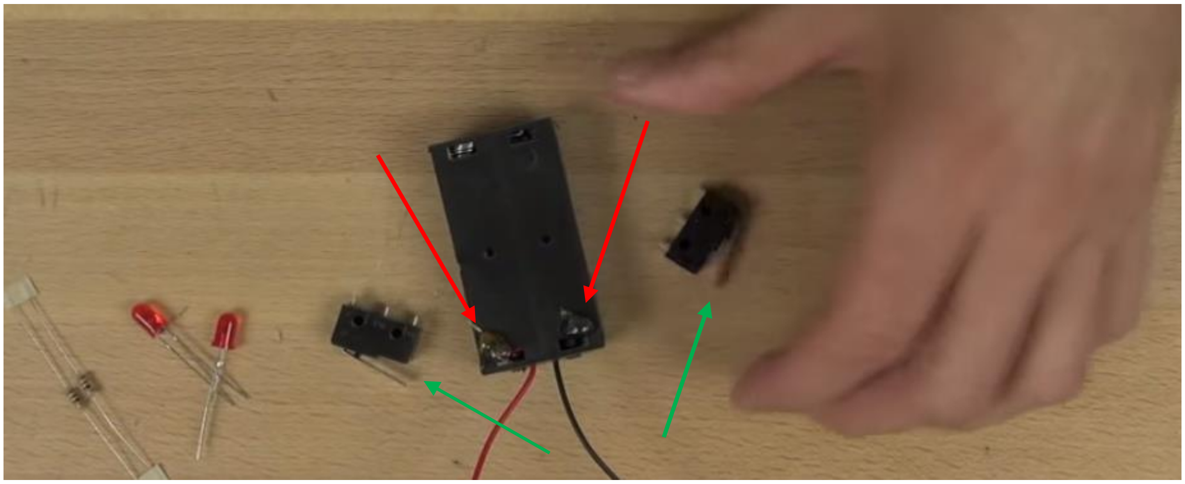
Hot glue gun with glue sticks

STEP 1: Attach the SPDT switches

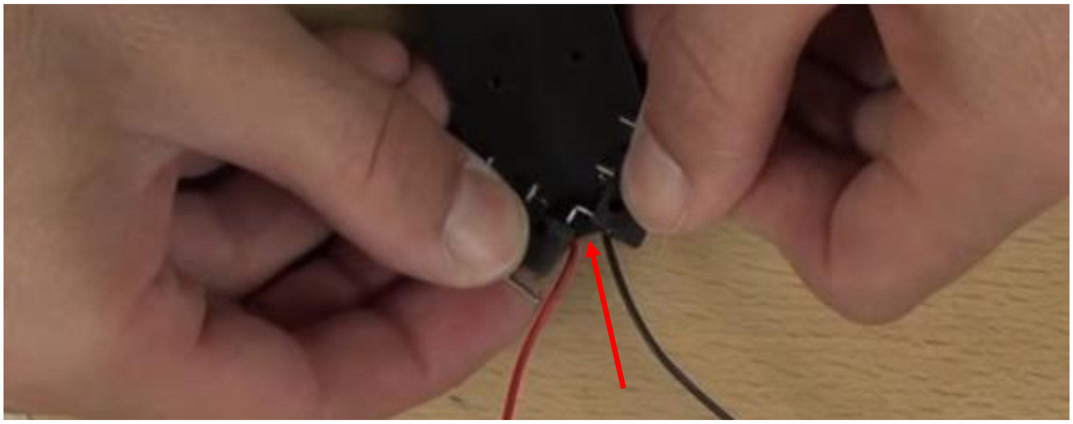
It's in your favor to read STEP one completely before beginning. "**SPDT"** means single pull double throw. It means there is one switch that can activate one of two circuits that could be potentially be installed. For example, power is always hook up to the "C prong". When you throw the switch, it either supplies power to 'A' or 'B'.

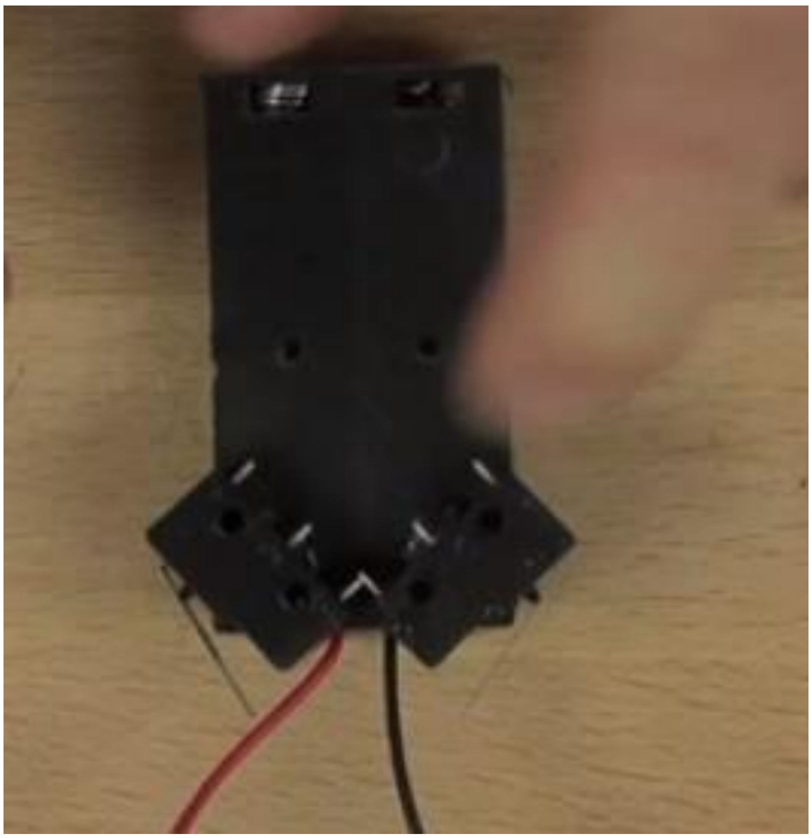
Install the switches.

First attach the SPDT switches onto the back side of the battery holder.



Grab the battery holder and your 2x SPDT switches. The switches are black with silver tabs. You want the two metal tabs to be facing inwards (green arrows) when you glue them onto the back side of the battery holder. These are also glued onto the same end as the positive and negative wires. Squeeze some hot glue on the back side near the end closest to these wires (red arrows) and mount the SPDT switches at a 90 degrees from each other. The prongs should be nearly touching each other as seen below.





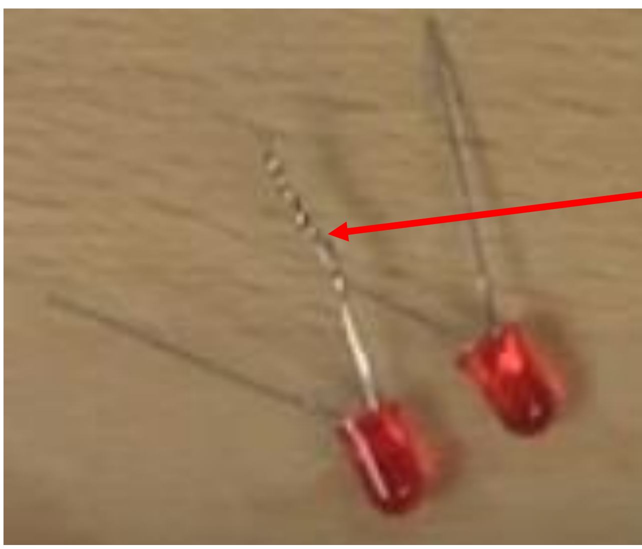
Note: The SPDT switches are now mounted. Review their orientation carefully. The switches are positioned 90 degrees from each other. The metal clips pointing inward and the first end prong on the bottom should nearly be touching the other.

STEP 2A: Setting up Parallel LED Eyes

Step 2 is one of the longer steps for this project. As explained in the "Diodes & LEDs" section on page 5, the LEDs you will be using in this project are single direction polarity. The best way to determine which side is positive and negative if it is a polarized LED is to look at the legs that come off the bottom of the light. **One leg is slightly longer than the other. The longer of the two legs is the positive end.** If you review the picture of the white LED light bulb to the right. The leg on the right side is slightly longer than the other; making it the positive end.

Connect Two LEDs Together

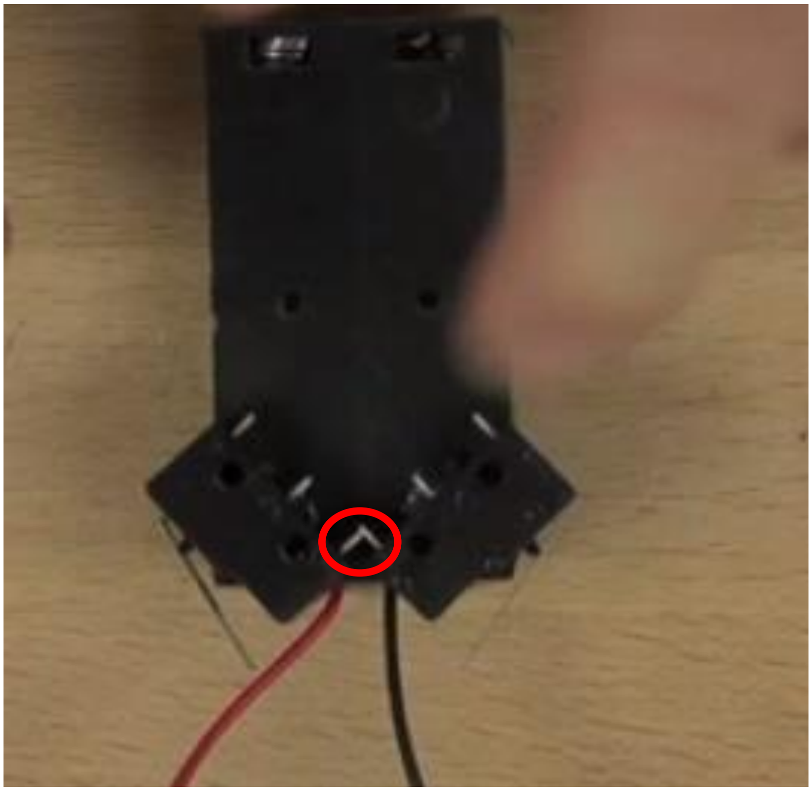
Take two color LEDs of your choice and bend the shorter legs out away from the longer leg (leave the longer legs straight). With the two individual longer legs of each LED you are going to twist them together, like in the picture below. The metal legs near the plastic bulb can be fragile so make sure you are only twisting the metal legs and not near the root by the plastic. You could unintentionally snap off the leg.



Note: Positive terminal legs are twisted together in center. You've just installed two LED's in parallel. Awesome job!

Install Parallel Power Wire

This part is a little tricky but necessary. On page 12 "Doing Two Things at Once", it was explained how to wire circuits in a series or parallel. In this circuit we will wire the LED's and motors in parallel. We want the voltage across each component to be the same.



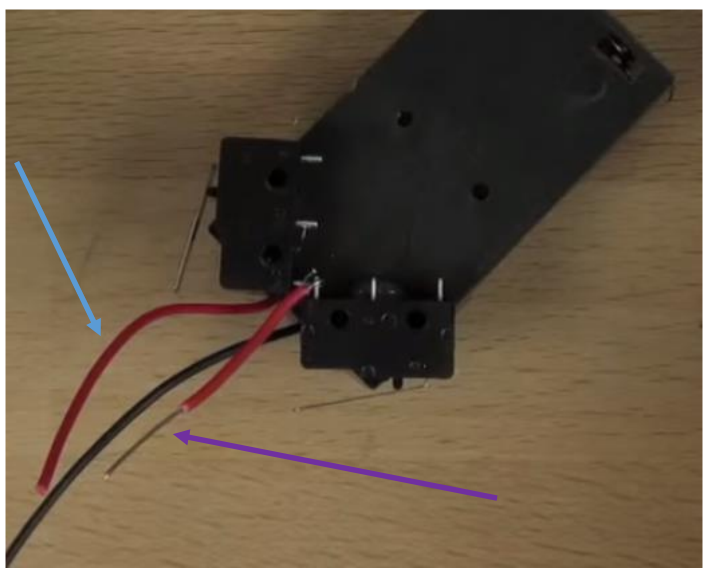
Find the red circle in the picture to the left. You will first need to install a new red wire by slipping it through the both pins on the two SPDT switches we installed on the back battery box from Step 1.

<u>Strip the Wires and then Start Connecting</u>

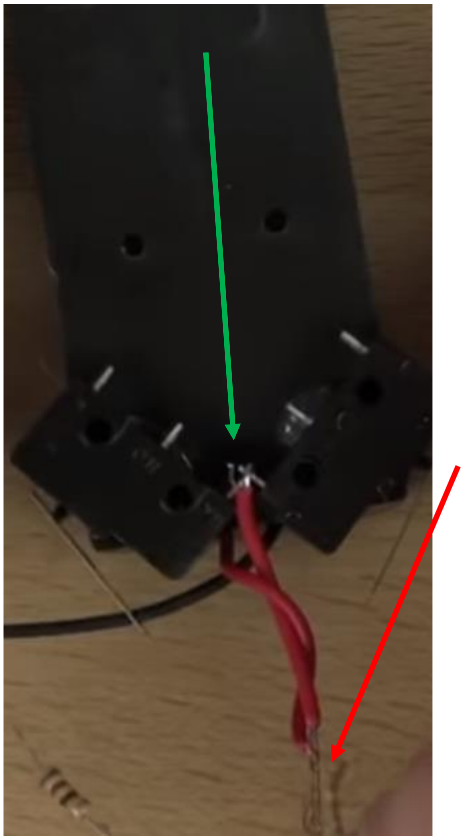
Using a pair of wire strippers strip back a section of wire to bend into a tiny 'J'. Then insert the wire through the holes of the pins circled above. It will look something like this.

Strip the wire on the opposite end of the wire you just installed giving you about an inch of expose wire as seen in the picture to the left.

You will now strip the red wire coming from the battery box and then twist that wire with the end of the new red wire you just installed. In the picture to the right, you can see the new wire installed on center terminals of SPDT switches just prior to connecting it with the red wire from the battery box.



Inspect your Work



Take a break from the activity and inspect students work and assist those who need help. Inserting the "J" hook wire end into the two SPDT switches may be the most difficult part for those who have low finger coordination or patience.

<u>Summary of Work Completed:</u>

The positive wire from the battery holder should now be connected (twisted together) to the new red wire you just installed. That new wire was looped through the end terminals of the two SPDT switches that were mounted on the back side of the battery box from part one (green arrow).

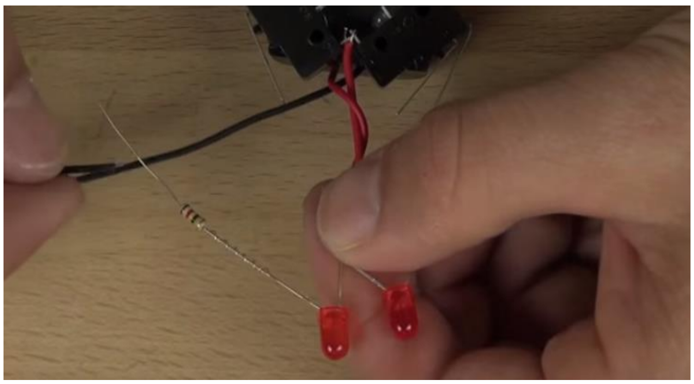
When all the students have caught up. You are now almost ready to finish the LED eyes.

Step 2B: Installing the LED Eyes

The circuit is now starting to get larger. In this part, you will install resistors on the negative ends of the LED eyes and attach the positive end of the LED eyes to the power wire on the battery box you just created in Step 2A.

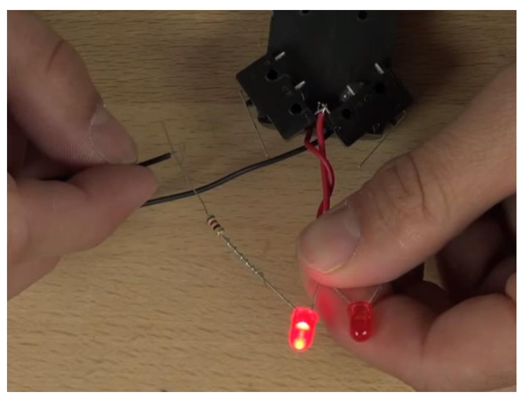
Putting on the Resistors

Note: Attach one resistor to each end of the negative ends of the LEDs. We know that the center metal prong that connects the LEDs is the positive end. This means, you will be attaching one resistor to the left and one resistor to the right.



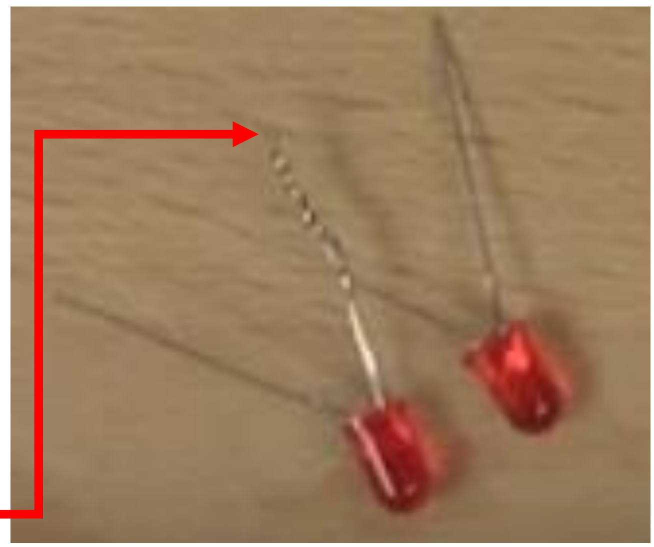
Note: In the picture on the left, you can see one resistor attached to the negative prong on one LED. You will do the same with the other side.

Once both resistors have been installed on the LEDs, it's time to test the LED light bulbs. Touch the positive wire from the battery after installing 2x AA batteries in your battery box and then touch the negative wire (black wire) from the battery box to one end of the resistors. One of your lights should illuminate. Now test the others side. If your lights don't light up, don't freak out. One of several things could have occurred. The first possibility, check your connections and make sure everything is touching. If a circuit isn't complete (closed circuit), the LED lights won't illuminate. The second possibility if only one light is lighting up, you either connected a negative end to a positive end or one of your LED's is bad. It would be best to check them individually if you are having issues.



Finally, Installing the Eyes

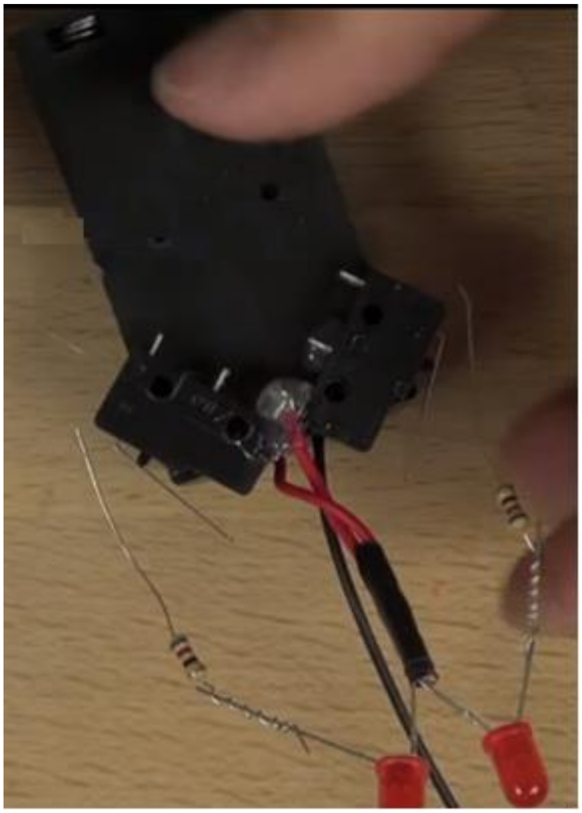
You are ready to finally mount the eyes. Basically, you will attach the red wire pair from the battery box (in the picture on the left below) to the twisted positive ends (in the center) of the LED pair you created. You will attach these two together by twisting them and then use some hot glue, solder, or electrical tape to make sure the connections hold in place.



Ex 2-1: Paired twisted red wire from battery box.

Ex. 2-2: Paired twisted LED in the center is attached to the red wires in Ex. 2-1.

Step 2 Complete

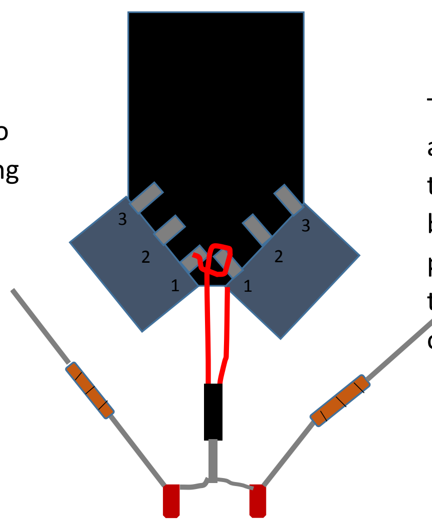


You're officially done with Step 2. Your robot should now look something like this, with the LED's mounted to the positive wire pair from the battery (soldered, hot glued, or wrapped with electrical tape) with the resistors hanging off each side of the LED's.

The opposing ends of the transistors have not been permanently connected yet. Once we add some additional wiring, the ground connection for the resistors will be ready.

STEP 3: Main Body Wiring

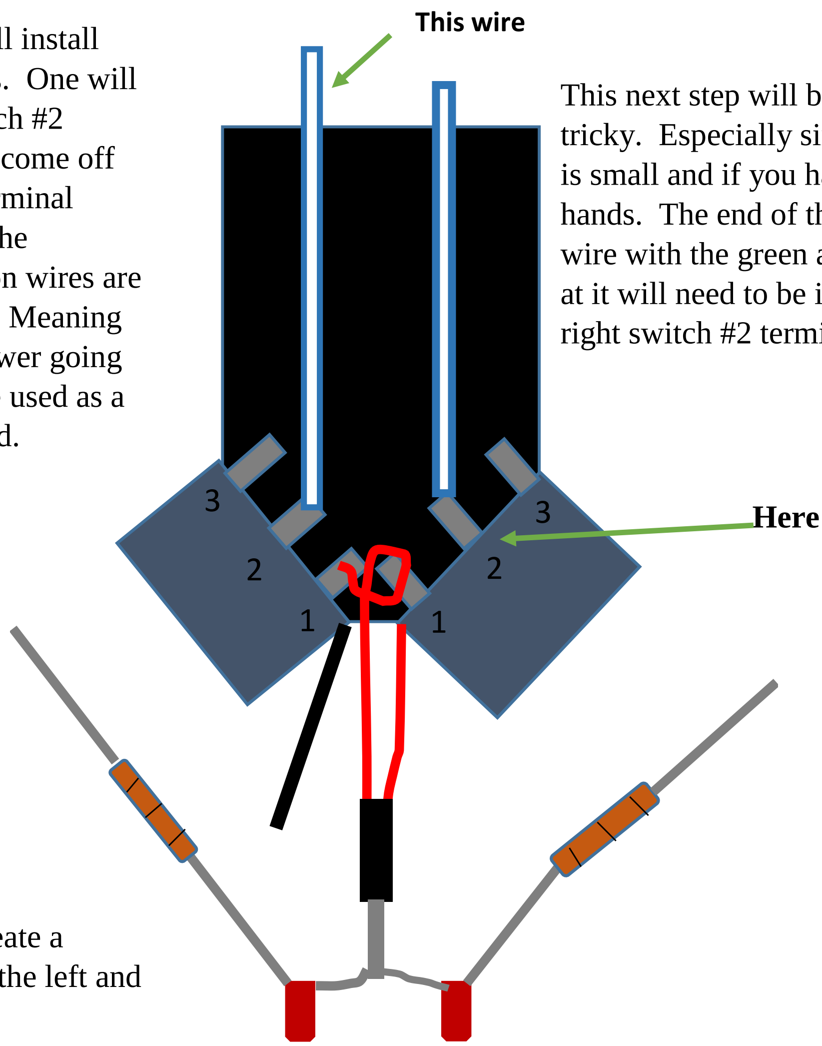
The figure to the right is the current wiring set up that you've completed. On the SPDT switches (blue boxes), the silver terminal blocks are numbers #1, #2, & #3 respectively on the left and right to make sense of the main body wiring that needs to be completed.



Terminal block # 1 on the left and right have been wired together and then meet at the battery box red power wire. This pair leads into the LED lights and then splits individually with their own separate resistor.

Main Body Common wire

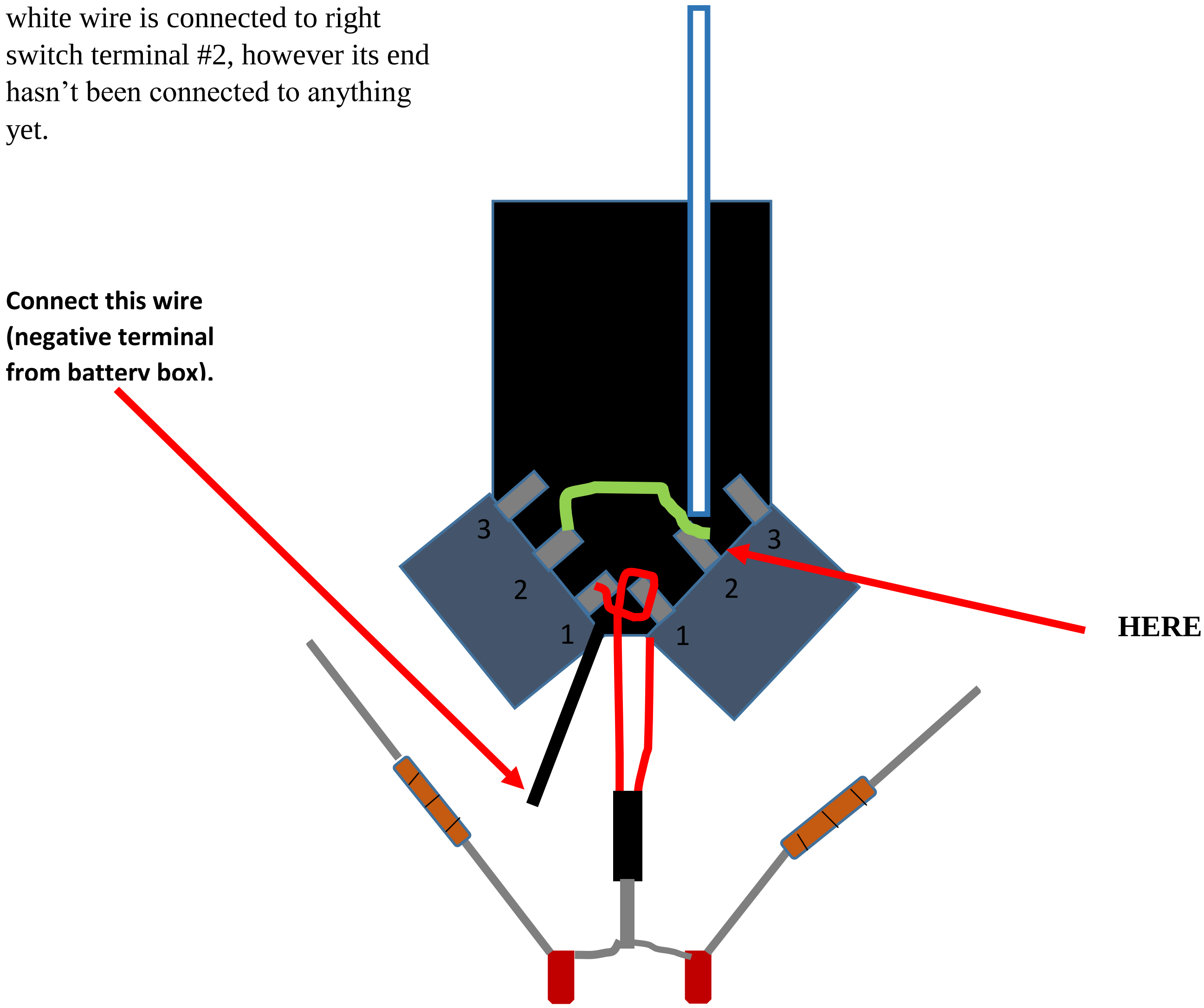
For the next step you will install two separate white wires. One will come off of the left switch #2 prong and the other will come off of the right switch #2 terminal block. These wires are the common wires. Common wires are neutral or ground wires. Meaning sometimes they have power going through them and can be used as a power source or a ground.



This next step will be slightly tricky. Especially since our robot is small and if you have larger hands. The end of the left white wire with the green arrow pointing at it will need to be installed to the right switch #2 terminal block.

This white wire will create a common wire between the left and the right.

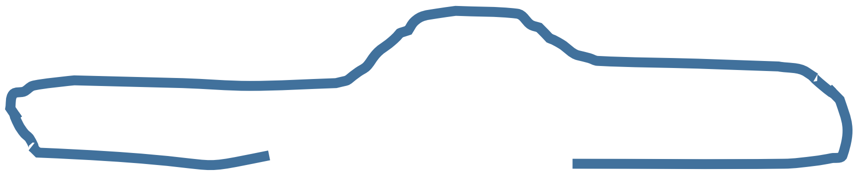
Seen below, the white wire connection (although notated in the color green for visibility purposes), which we made from the left switch, terminal #2 to the right switch, terminal #2. A secondary white wire is connected to right switch terminal #2, however its end hasn't been connected to anything yet.



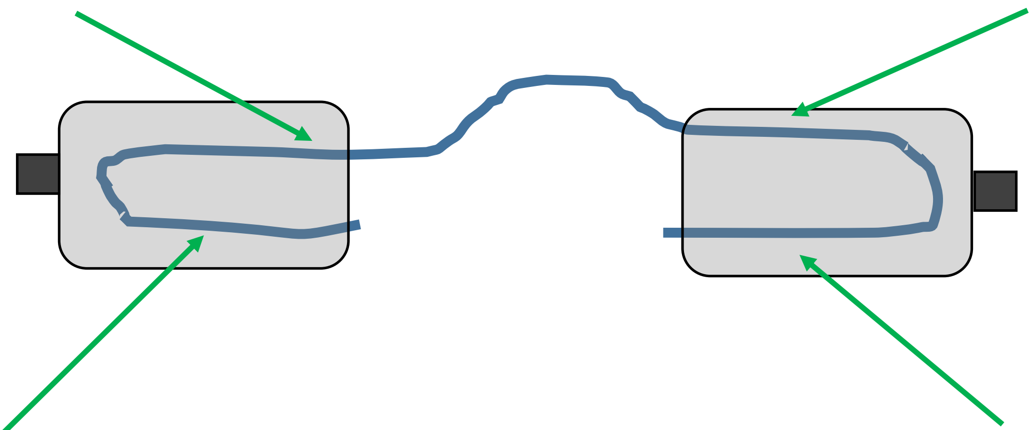
Now we are going to install the negative wire coming from the battery box to right switch, terminal #2. If you review the illustration above, the wire is notated with a red arrow. You can either thread this wire through the eye or twist it to a wire that is already threaded to achieve conductivity.

Step 4: Mounting the Motors

We will now prepare the motor mount system which will drive the robot. The motor mount is made from one giant paper clip. You will first take your paper clip and try your best to make it as straight as possible. Once you have done that, you will need to bend it similar to this formation (below).



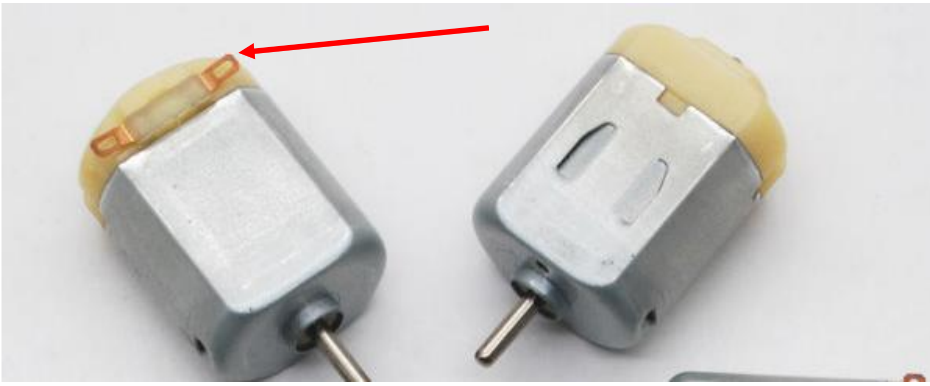
By bending the paperclip into this formation, the bump shape in the center allows you to be able to angle the motors better after mounting to achieve faster or slower sleeps. The little dog ears on both ends allow you to properly mount the motors while contacting 2 surfaces (two pieces of the wire paper flip (areas are noted with green arrows).



Attention: When mounting your motor, if your electronic terminals on your motor are on the flat side, you will want to mount your paperclip on the opposite side of your mounts. If your electronic terminals are on top in middle just make sure they are in position for you to reach them later. It's about accessibility. Don't mount your motor in a position where you cannot thread a wire later on. Here is two examples of what your motor may look like.

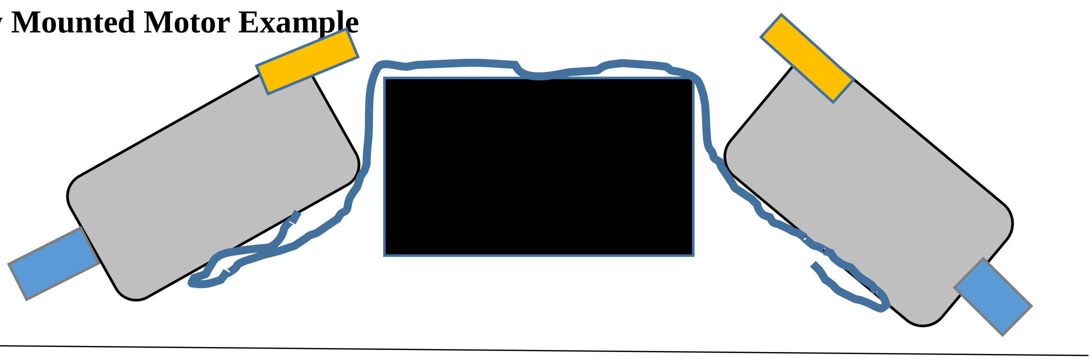
Motor electronic terminal examples

Side mounted Terminals on motor



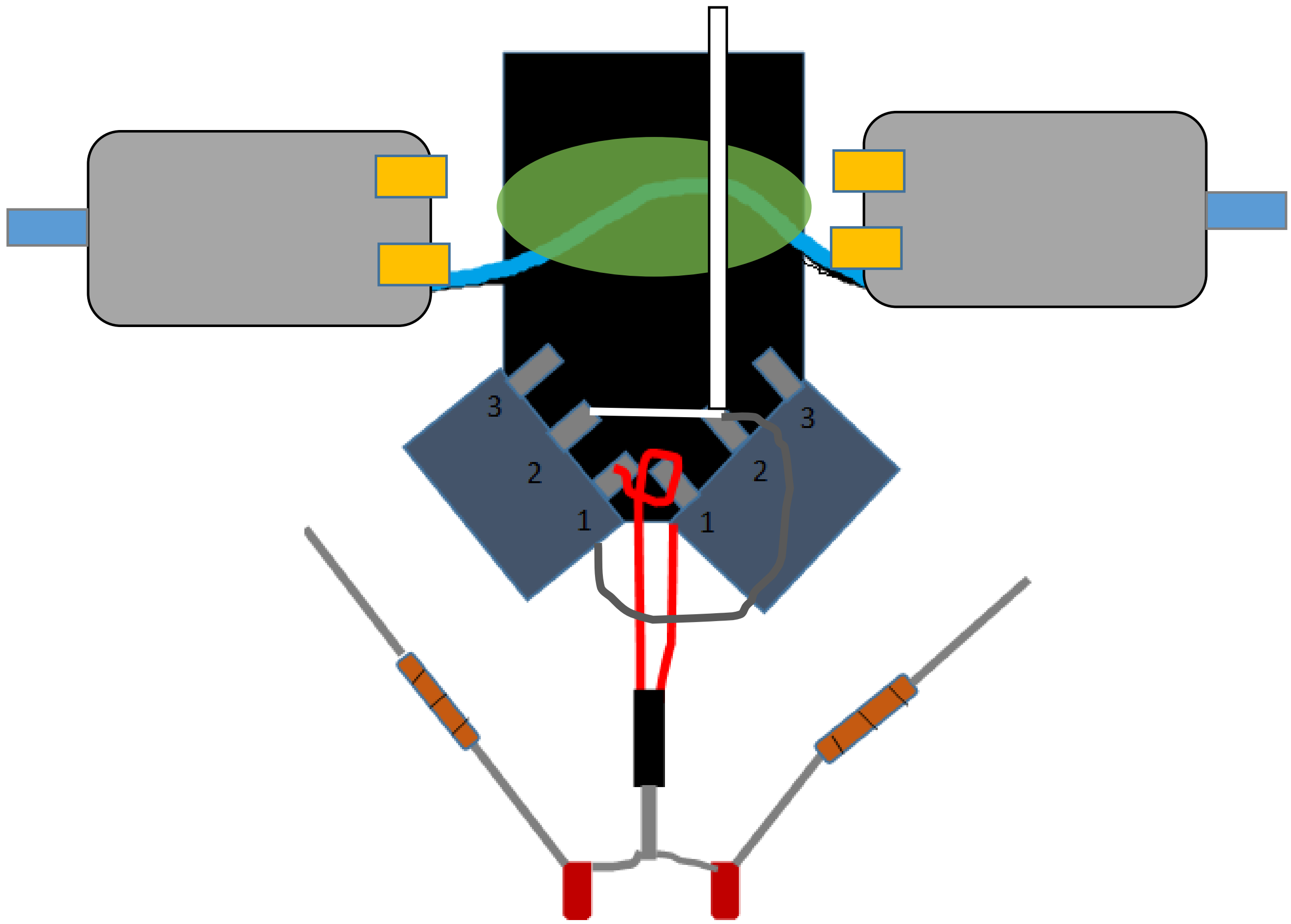
Top mounted terminals on motor

Front View Mounted Motor Example



Step 4B: Attaching your Motor Mount and Motors

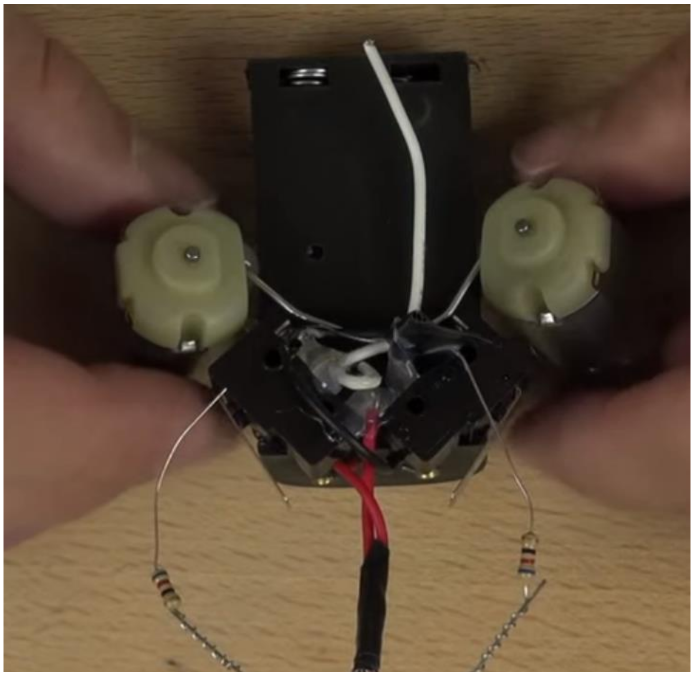
Top View



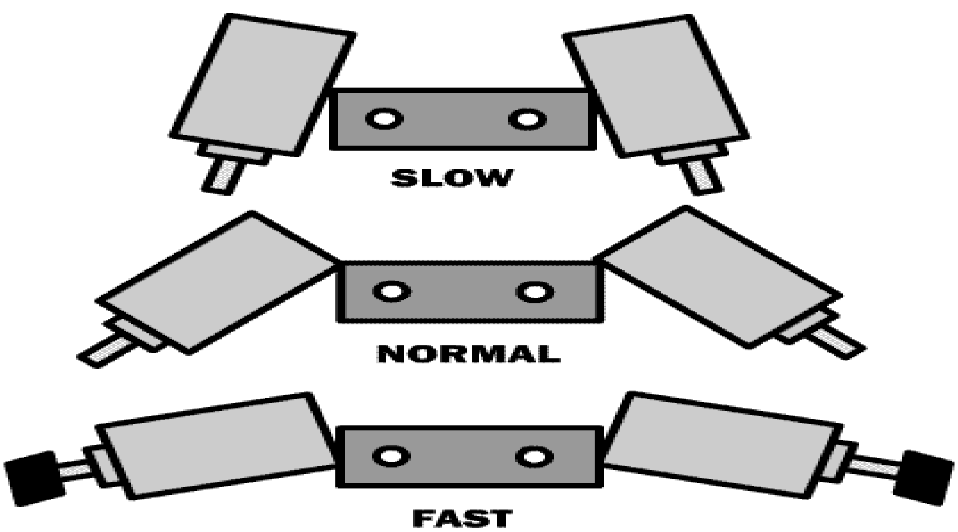
Attach your motor mount to the back side of your battery holder by using hot glue in the transparent green oval area as noted in the illustration above. It's important to make sure the paperclip mount is firmly held in place until the glue dries so your motors will be firmly secured. If you haven't already, attach your motors to the paperclip mount with the electronic terminals facing the opposite side of the paper clip or in an accessible area for wires to be installed later. Also beware not to accidently glue the mount on top of the white wire coming from right switch, terminal #2.

Step 4 Complete

Take a moment to review your project and give yourself and other students a pat on the back. George is growing up and should look something like this.



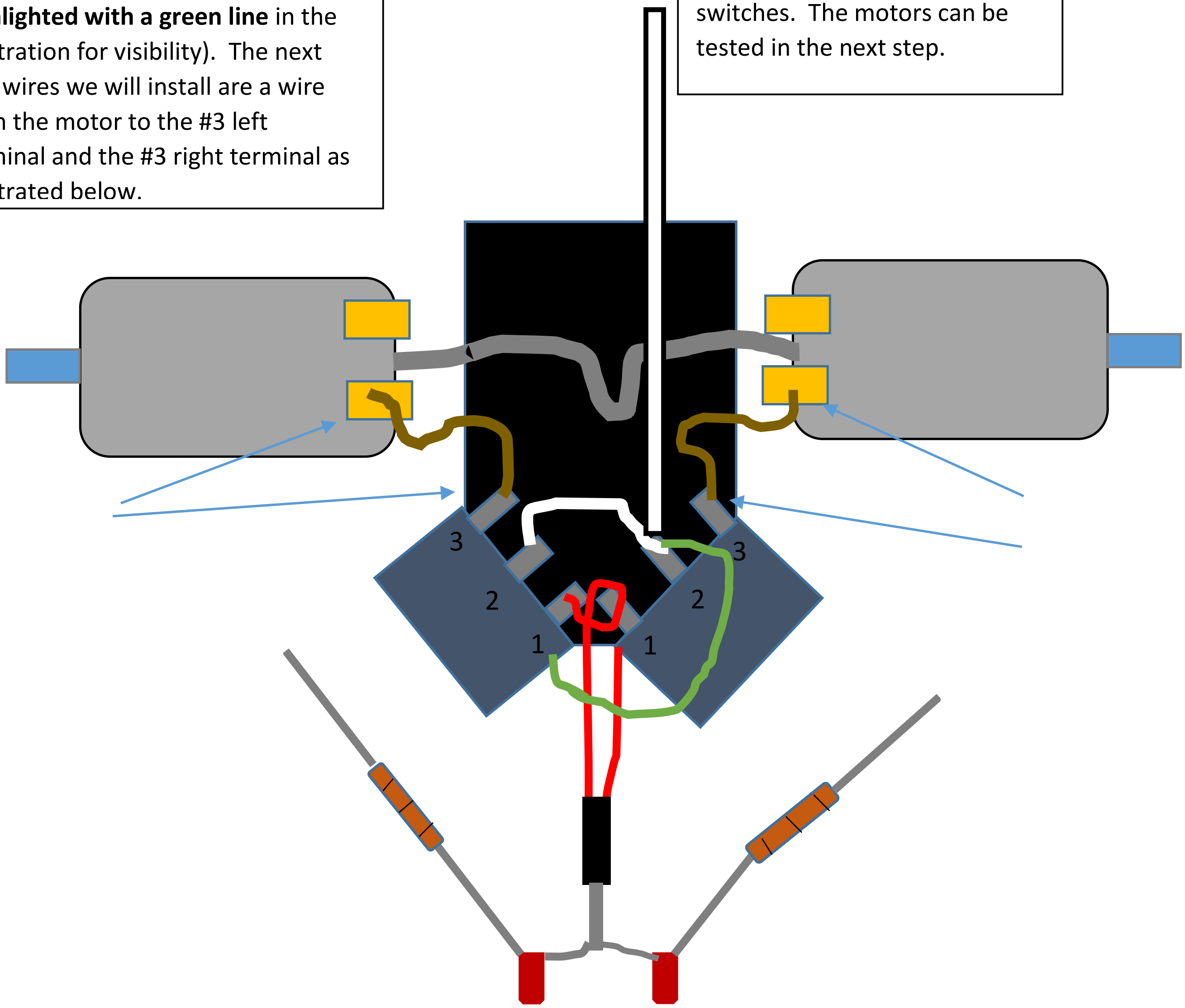
Notice how the motors are mounted more vertically than in the example illustration on the prior page? The more vertical your motors, the slower your robot will crawl along. If you want a faster moving robot, you need to angle your motors similar to the illustration below.



Step 5: Wiring the Electric motors.

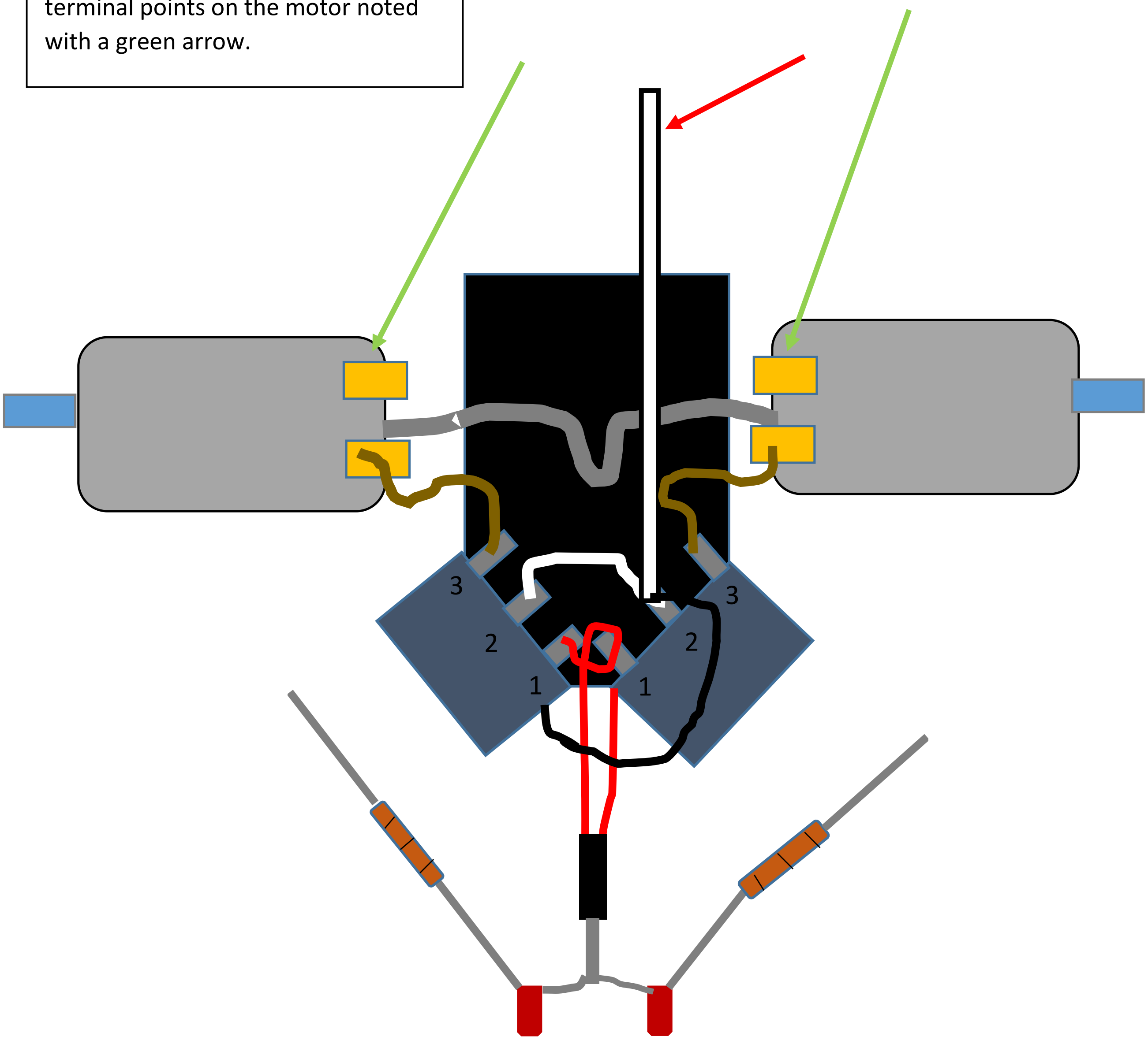
The black ground wire from battery box has just been connected to the right switch #2 terminal (**black wire is highlighted with a green line** in the illustration for visibility). The next two wires we will install are a wire from the motor to the #3 left terminal and the #3 right terminal as illustrated below.

NOTE: This wiring set up puts power to the motors using common wires through the switches. The motors can be tested in the next step.



Step 5B: Testing the Motors

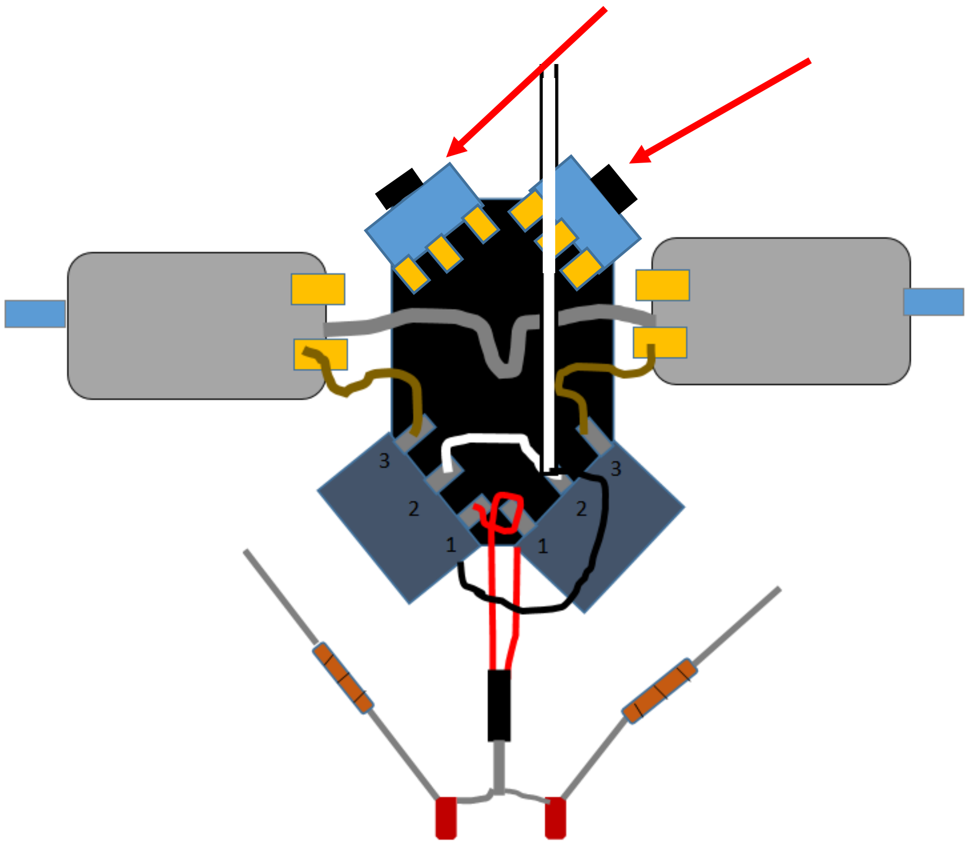
Let's make sure the motors work. We will test our circuit by touching the white wire noted with a red arrow (below) to either of the available terminal points on the motor noted with a green arrow.



Did you hear the motor spin? Do you have batteries installed? Still nothing? If not, return to earlier steps to make sure your wiring is correct.

Step 6: Mounting the Switches

Mount the left and right on-off switches on the side opposite of the LED eyes using hot glue to glue it to the battery holder. The toggles for the switches will face the back with the terminal prongs towards the center to make the wiring easier later one. Remove your 'AA batteries' if you haven't done so before **Step 8.** The next step will be the final step and has the required wiring to complete. We are removing the batteries to avoid a short or to prevent the batteries from dying if the antennas are pressed.

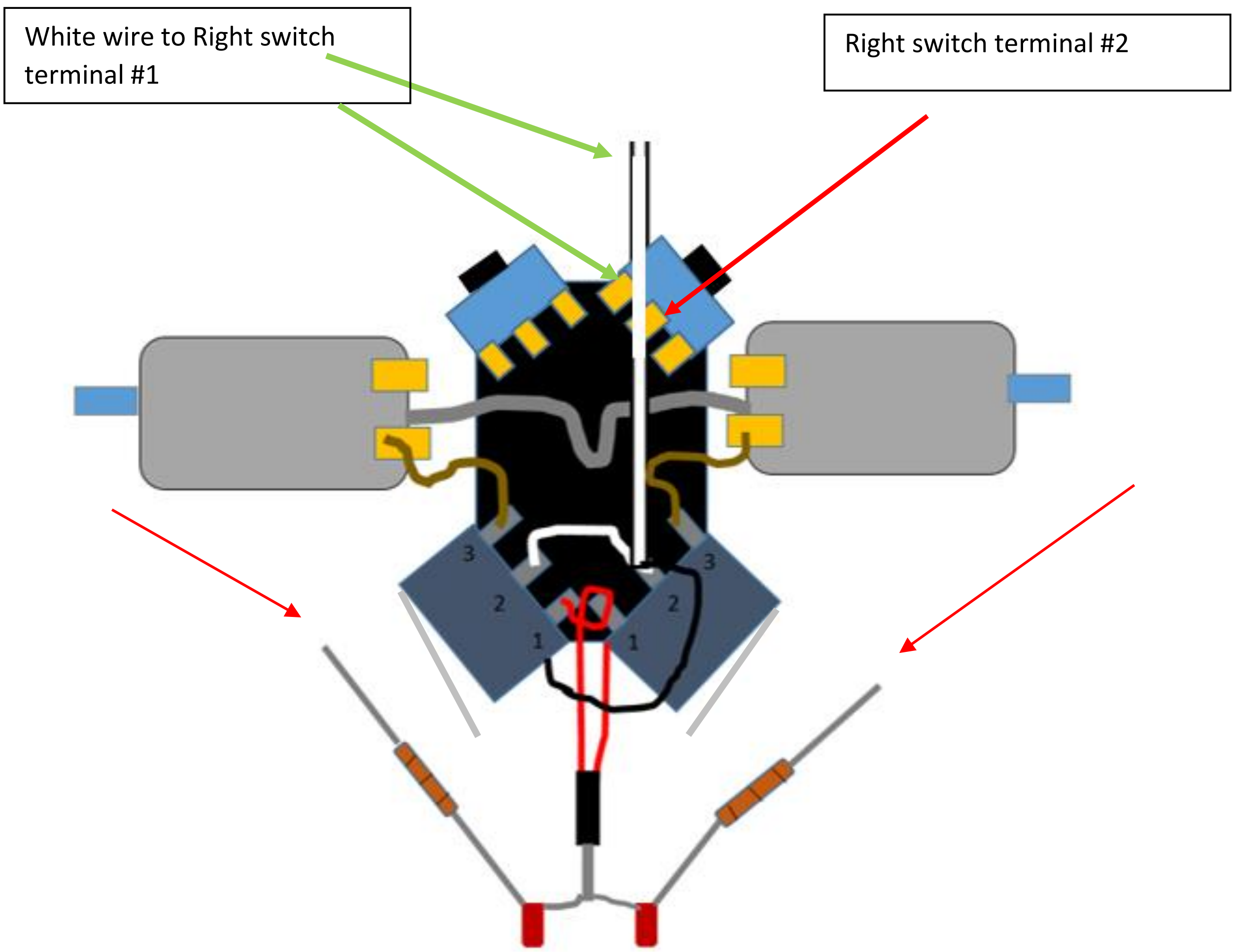


Make sure you can reach all of the terminals on the on-off switches so you can wire them in the next step. Double check all of your work and you can take a moment if everything tested correctly to hot glue all connected wires into place.

Step 7: Finish up the Wiring

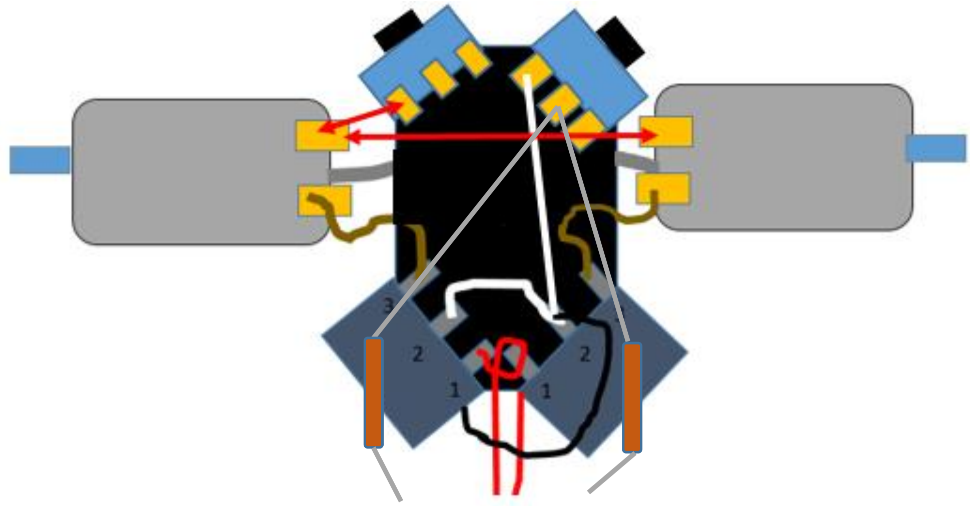
Step 7A: Connect the White Wire and Resistors

The white wire that's been hanging around for a while will be connected to right switch terminal #1. Now, locate the two resistors that are coming off of each LED eye. You want to twist the ends of the resistors together and then connect a wire from both resistors to right switch terminal #2 as indicated below.



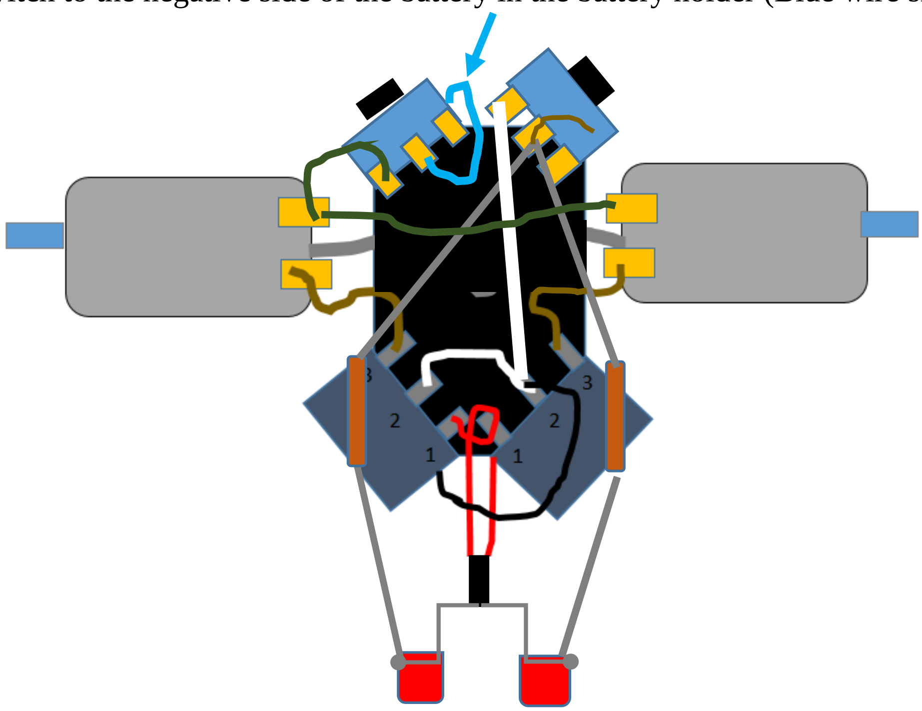
Step 7B: Connecting the Switches and Motors

Now it's time to connect the motors together and then wire them to the switches. Use green wires for the following as not to confuse it with everything else. The red arrows indicate the required connection.



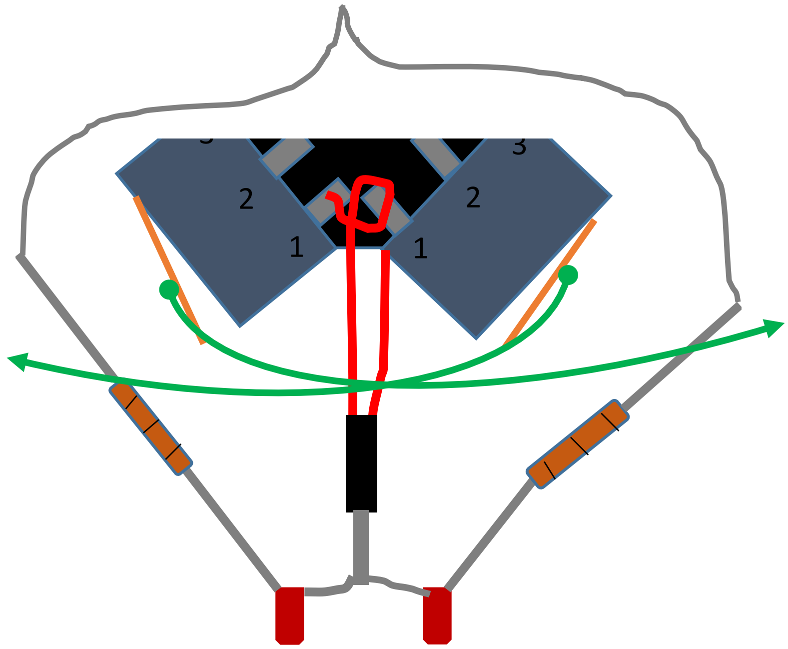
Step 7C: Complete Wiring Complete

Finish connecting the wires as displayed and then connect a ground wire from the left switch to the negative side of the battery in the battery holder (Blue wire shown below).



Step 8: Mounting the Antenna

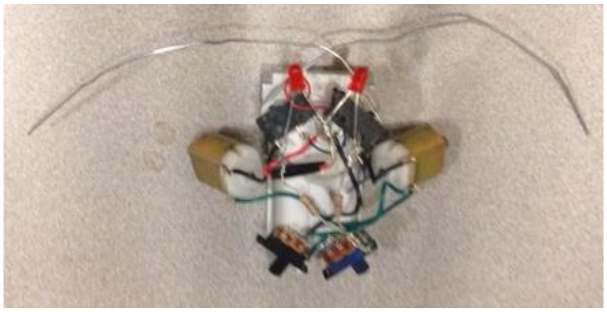
Take two large paperclips and straighten them as much as possible. These paperclips will become add-on sensors for wall and obstruction detection (a.k.a. bug antenna). Now put a slight arc in each paper clip and then hot glue the antenna to crisscross to the opposing side. You will glue these onto the metal tabs on the SPDT switches. In the illustration below, the orange lines represent the metal tables on the SPDT switches. The green lines represent a bent paper clip mounted as an antenna.



Now test the antenna and the switches. There must be enough glue on the paper clips so the antenna will not come off if the paper clip presses against a wall or a hard object. The switch also must fully compress and depress. Be certain not to glue the switch into place (open or closed), else the robot will not function.

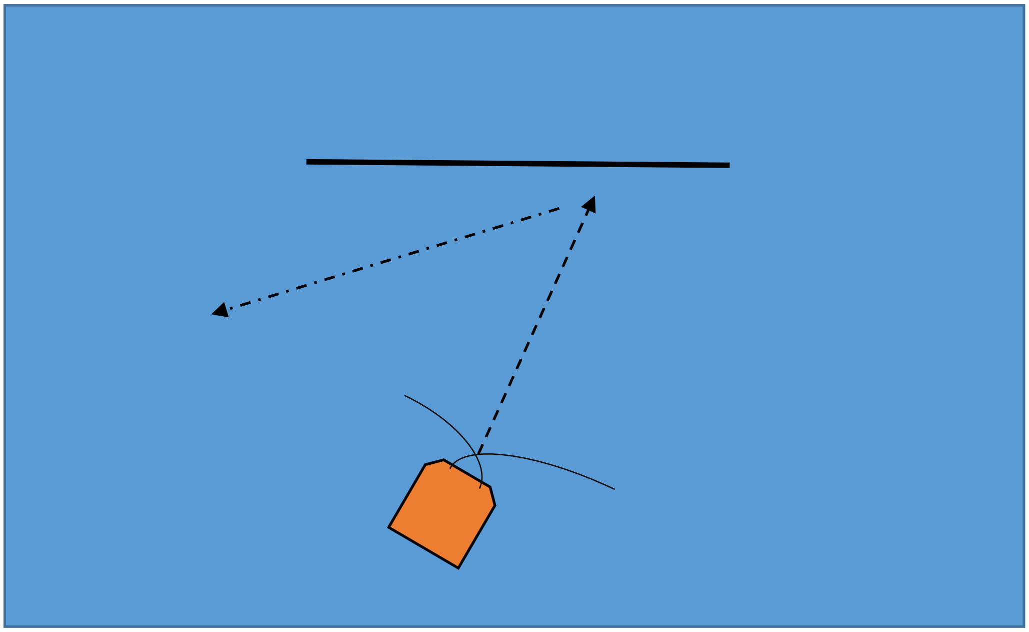
Step 9: Beta Test and Experiment

The way George works is when his antenna strikes an object, the SPDT switch is depressed and he will turn (switch depressed will activate opposing side motor to go in reverse.



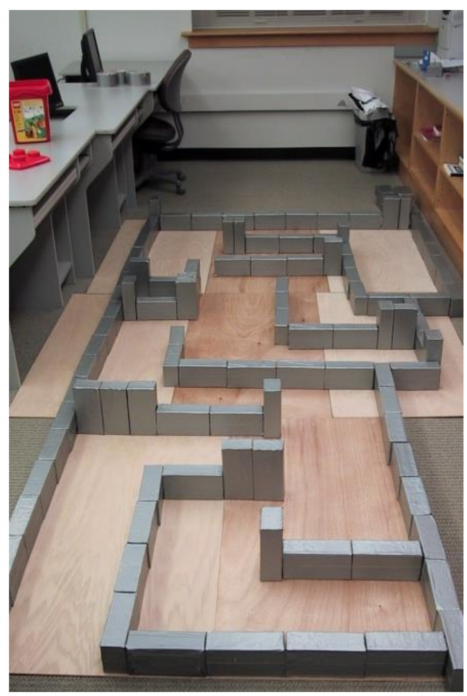
Example:

If the left antenna is depressed, right SPDT is activated since antenna are crisscross. The right SPDT switch will cause the left motor to go in reverse, meaning George will turn to the left. In the example picture, the dashed line displays the assumed route George will run if his left antenna strikes the wall first when approaching a wall. **Important:** You'll want his antenna bent in such a manner that either one antenna can be compressed or the other, else he will run in an infinitely straight line.



Experiment:

1) Build an obstacle course for each student to have their George robot run through. Use a stop watch to see who has the best time. The obstacle course can be a small maze made out of 2x4's, cardboard, or any type of solid surface that the robot can detect. The walls need to be constructed firm, and have a definitive start and end point.



2) Observe what kind of problems or challenges arise. Were sharp turns too difficult for the robot to find its way? How could this or other problems be avoided? How can we improve our robot based on the problems that we discovered?
3) Customize George. I have seen students put on bug, snail, and turtle shells made from bowls and other plastics. I have seen snakes, cats, mice, and all sorts of decorations. Making the antenna as whiskers of a cat. I lot of materials used for decorating can be found at a hobby or thrift store.

Now experiment and have fun with the kids.

I appreciate you taking the time to share this curriculum with your students. If you have any questions, comments, or concerns please share so we can improve upon this handout and make it better for our students.