element14
AN AVNET COMMUNITY

February 2020

Introduction to Circuits

Table of Contents

Bill of Materials

Product Name/Description	
Cardboard/Breadboard	3V incandescent screw base light bulbs and bases or a strand of old incandescent holiday or fairy lights.
All metal paperclips	Tape
Paper fastener brads	Needle nose pliers
AA batteries	Utility knife
Additional Options	
2 AA battery pack	20 gauge solid-core wire
Wire stripper	Multimeter (TENMA Handheld Digital)

Preface

We represent a Community of over 700,000 makers, professional engineers, electronics enthusiasts, and everyone in between. Since our beginnings in 2009, we've provided a place to discuss electronics, get help with your designs and projects, show off your skills by building and documenting a new prototype, and much more.

On our Community you can find Essentials courses that delve into the details of important electronics concepts, element14 Presents video tutorials that show you a project from start to finish, Design Challenges that follow a build from concept to prototype, and more. This eBook is focused on the fundamentals of circuits and their behavior, with an illustrated guide to building your own circuits with items you can find around the house. We hope you find this guide useful and enlightening, so happy reading!

element14 Community Team

Introduction to Circuits

If you are interested in electronics, building a simple circuit is perhaps the very first thing to do. Circuit fundamentals are key, as you advance your electronics knowledge and begin working with more complex circuits. Follow along with **Karen Corbeill** from **The Learning Circuit** as she builds a simple circuit, discusses the different types of circuits, adds switches and light bulbs, and more. Also, check out more episodes on a variety of topics **at: element14.com/TheLearningCircuit.**

CHAPTER 1
BUILDING A SIMPLE CIRCUIT

What is a Circuit?

Diving into electronics for the first time can be daunting. So let's talk basics: what is a circuit?

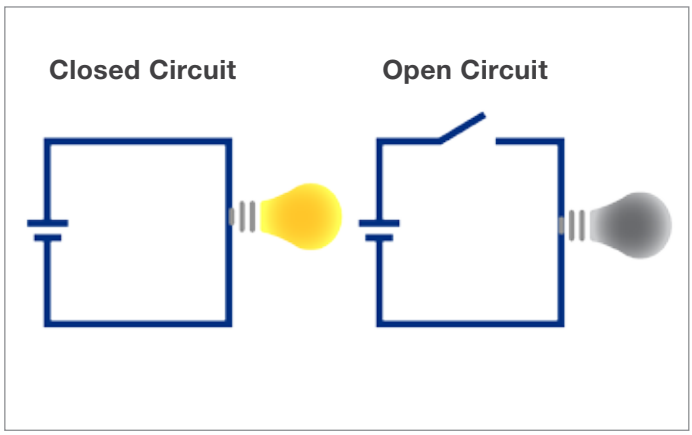
A circuit is a closed path through which an electric current can flow. We use circuits to send energy to turn things on, like the motor in a drill, the light bulb in a flashlight, and many more common devices.

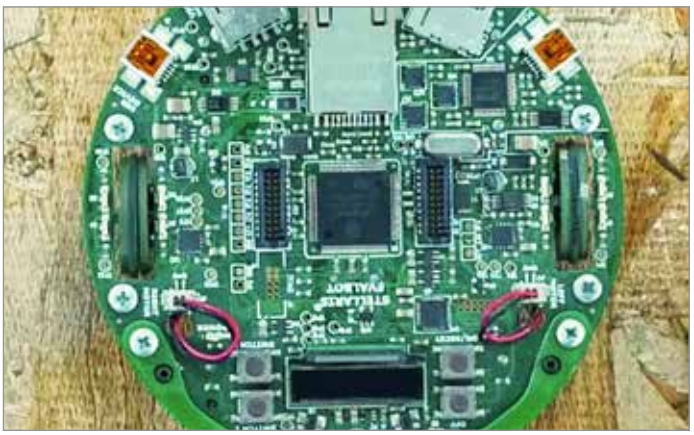
Closed and Open Circuits

A circuit can be closed, or open. If the circuit is closed, all of the components are connected and electric current can flow. If the circuit is open, then a connection is broken and the electric current cannot flow.

Many objects we use every day contain circuits and circuit boards.

Here is an example of a circuit board. It contains many circuits that each have their own function. One circuit might have a button that turns on a light bulb. Another might have a microchip that tells a motor when and how fast to turn. But circuits aren't always complicated.





Building a Simple Circuit

We can make simple circuits with a light bulb, a power source, and a few wires.

To build the first circuit you will need:

- Some cardboard
- All metal paperclips
- Paper fastener brads
- One AA battery - 1.5 volts
- Needle nose pliers
- A 3V incandescent screw base light bulb and base, or a strand of old incandescent holiday or fairy lights
- Tape
- A utility knife

(If using a strand of lights, cut off one bulb, leaving wires on either side. Strip the ends of the wire, removing the wire covering so that the metal wire inside is exposed).

Circuits typically use wires or circuit traces to send electricity and signals along the circuit.

For the project circuit, use the paperclips and fasteners in place of wires and traces. The paperclips need to be metal and have no coating. They need to be conductive, so that electricity will flow through them wherever they touch.

For this project, a battery will be the power source. Batteries have a positive and a negative terminal. Some components only work in one orientation, so it's important to note which way your battery is hooked up. One AA battery supplies 1.5V of power. When choosing a light bulb, you want to choose one that is rated for low voltage. If the bulb is rated for 2 or 3V, it should still work with one battery.

Light Bulbs vs LEDs

For this project, I prefer to use incandescent bulbs because they're less sensitive to voltages.

If this light bulb is rated for 3V, it will still turn on and glow dimly at a lower voltage, and it can handle a higher voltage before burning out.

Now let's talk about LEDs:

Sizes: LEDs come in different sizes. The most common you see are 3mm, 5mm, and 10mm.

Voltages: LEDs are more sensitive to voltage than incandescent bulbs.

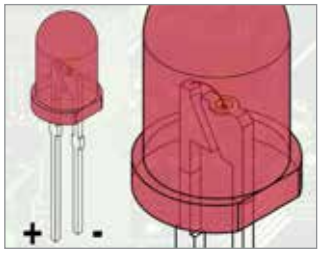
LEDs are usually rated for between 1.5 and 5V, depending on the color. You can find that information in the product description, or on the data sheet for the LED.

If fed the wrong voltage, the LED could either burn out or not turn on at all, which can be frustrating because you don't know whether your circuit is wrong or broken.

Polarity: LED stands for Light Emitting Diode. A diode is an electrical component that has polarity, meaning it only allows electricity to flow through in one direction. An LED will not work if it is hooked up backwards.

With incandescent light bulbs, the orientation of the positive and negative terminals doesn't matter, unlike LEDs.

You can identify the negative side of an LED a few different ways. Sometimes, the negative side is flat. Usually the negative lead is shorter. And lastly, if you look inside the LED the larger side is the negative side.



CHAPTER 2

ASSEMBLING THE CIRCUIT

Step 1: First, tape the battery to the card/breadboard near the bottom.

Step 2: Take two paperclips to add to either side of the battery to act as wires to conduct the electricity. (Read step 3 before this step).

Use a pair of needle nose pliers to bend one end up at a 90 degree angle, then put it right against the battery and push a fastener right at the end to hold it in place.

Next, push the bent up part of the paperclip tightly against one end of the battery.

Insert a metal brad into the end to hold the paperclip in place. This works best if you push the paperclip tight against the battery and insert the fastener as close to the end as possible. This will keep the paperclip from wiggling and the battery from falling out.

Repeat on the other end of the battery so that it is trapped between two bent paperclips that are held down by metal brads.

Step 3: One more paperclip will be added to each brad. This may be easier to do during step 2, or after as its own step, and can hook the paperclips around the brads afterwards. Do what works easiest for you.

Step 4: Place the light bulb base on the cardboard above the battery.

Step 5: Add paperclips and brads to continue the "wiring" to connect the battery "wires" to the base of the light bulb.

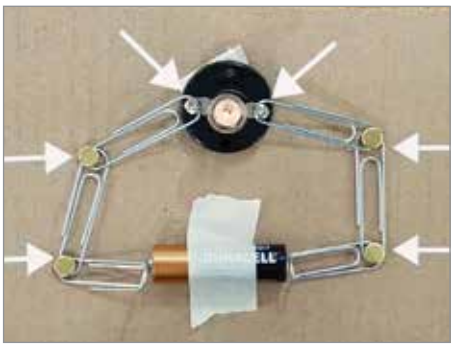
Once you figure out where the light needs to be for the paperclips to reach, tape the light in place.

Step 6: Loop the paperclip around the screws on the light, or wrap the wires around a fastener and insert that to hold the paperclip down.

If you use a light from a strand, tape the wires down and hook the wires to the end of a paperclip. Add tape or a brad to keep it secure.

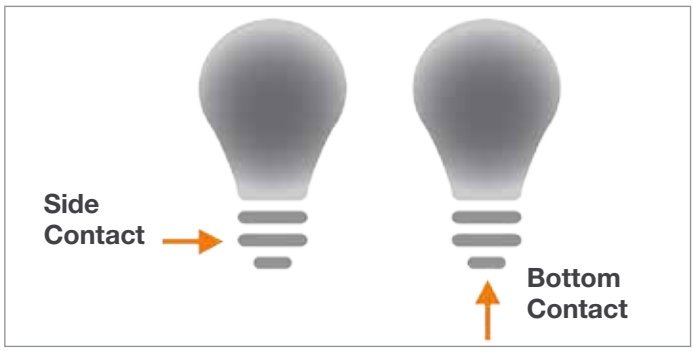
That's it! The circuit is made. If everything is hooked up right, the light should turn on.

If the light doesn't turn on, here are some places to look to troubleshoot the problem:



Check all your connections and make sure that the metal stays touching metal when not being held. If not, bend it more, or try adding tape.

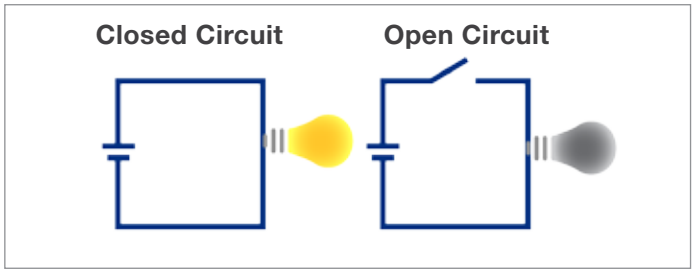
If your circuit still doesn't work, take a look at your light bulb. Look at the inside of the bulb at the filament. Remember how we talked about open and closed circuits? If the filament is broken, the electricity cannot flow across it. Replace the bulb with one that has the filament intact.



Lastly, make sure your light bulb is screwed all the way in. The screw threads are one contact of the bulb, while the bottom is the other contact. Both have to be touching the socket for the circuit to work.

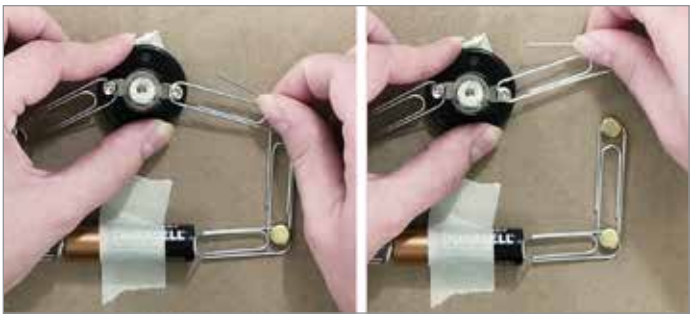
CHAPTER 3
ADDING A SWITCH

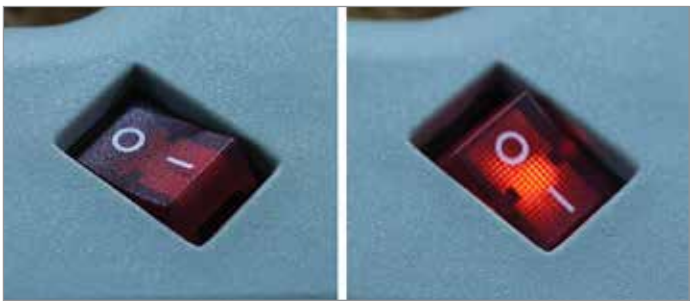
The circuit you just built is closed. To be able to open the circuit, there needs to be a break in the circle. This can be done by adding a switch.



The best part is that nothing needs to be added to make this happen. Any break in the circle will open the circuit, causing the light to turn off.

To make the switch, loosen one of the paperclips so it just touches the top of one of its fasteners. It can swivel and becomes a switch that can easily move to open or close the circuit.





A Note About Commercial Switches

If you take a look at switches you can find on commercial products, you'll often find that there is a line on one side and a circle on the other. The line represents a closed circuit. When the switch is in this position, the circuit is closed, so the switch is in the On position. When the switch is in the position by the circle representing an open circuit, the switch is off.

CHAPTER 4
ADDING MORE LIGHTS

In this step, you'll add another light to the circuit and will need a few more materials:

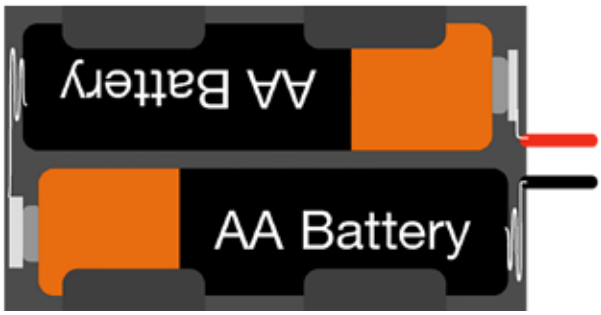
- 1 AA battery
- Light bulb and holder

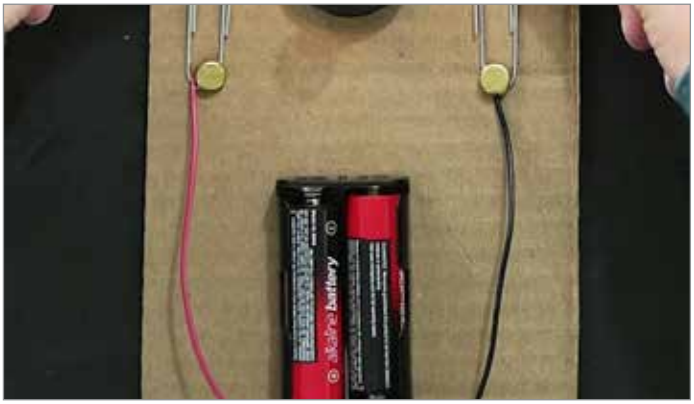
Additional Options:

- 2 AA battery pack
- 20 gauge solid-core wire
- Wire stripper
- Multimeter

The current circuit uses one AA battery at 1.5V. To add more lights, a higher voltage is needed to make the circuit work. Add a second battery in series to get 3V.

You can try putting two batteries end-to-end and continue using the paperclips, or you can swap in a battery pack. If going this route, strip enough of the plastic insulation off the end of the wires to wrap them around the metal fasteners.

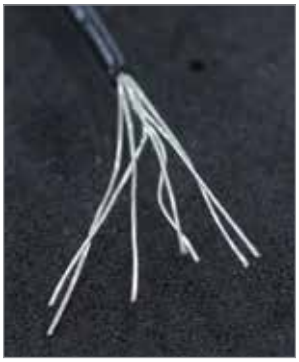




A Note About Wire

Rather than using paperclips, it may be easier to use some wire, so let's go over some things that are helpful to know about wire.

There are two basic types of wires—solid and stranded.



Stranded wire is flexible, but the ends can be difficult to manage without soldering.

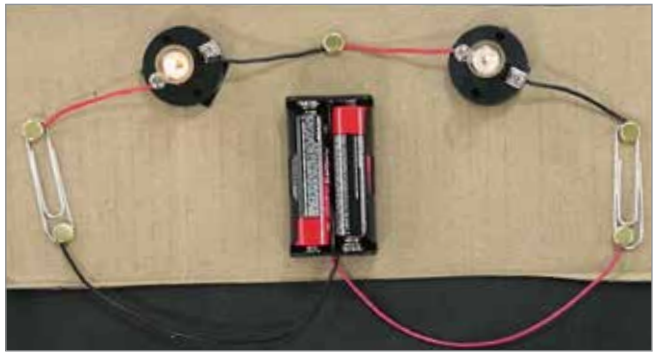
Solid-core wire is stiff yet moldable. However, with too much bending back and forth it can break.

For this project, use solid wire. Its stiffness will help it stay attached better.

Make sure you use a wire with an appropriate gauge (thickness). A 20 gauge wire works well for this project, but anything between 18-24 gauge could also work.

CHAPTER 5
SERIES & PARALLEL CIRCUITS

When using two light bulbs in a circuit, they can be placed in a series or parallel. In a series circuit, all components are connected so there is only one path through which the current can flow. In a parallel circuit, there are multiple paths through which the current can flow through the bulbs.



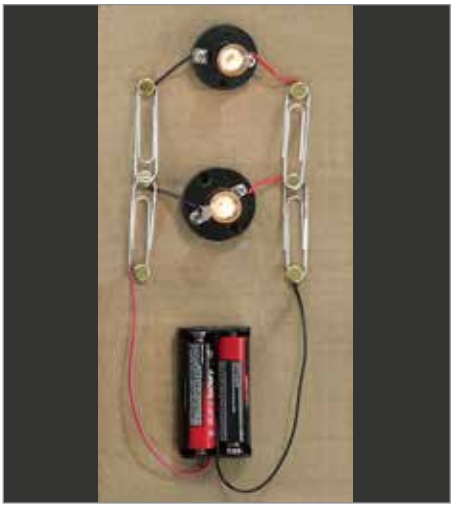
Making a Series Circuit

To set up two light bulbs in a series circuit, one battery wire connects to one side of a bulb. The other side of this light

bulb is connected to the second light bulb. Finally, the other side of the second light bulb is connected back to the second battery wire.

Look closely at the bulbs. One is dimmer than the other. Why do you think this circuit has one light dimmer than the other?

Making a Parallel Circuit



The original circuit has one battery and one light bulb. The new circuit has two batteries and one light bulb.

The two circuits are the same, except one has an additional battery. The electricity flows in a circle to turn the light bulb on. It is still a series circuit.

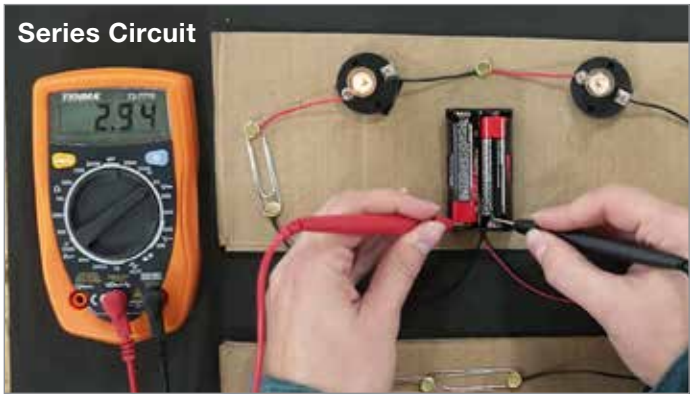
Now add one light bulb to the circuit. One battery wire connects to one side of both bulbs. The other battery wire connects to the other sides of both bulbs. These two bulbs are in parallel. If you look closely at each light bulb, they appear to be the same brightness. Why do you think the light bulbs in a parallel circuit have the same brightness?

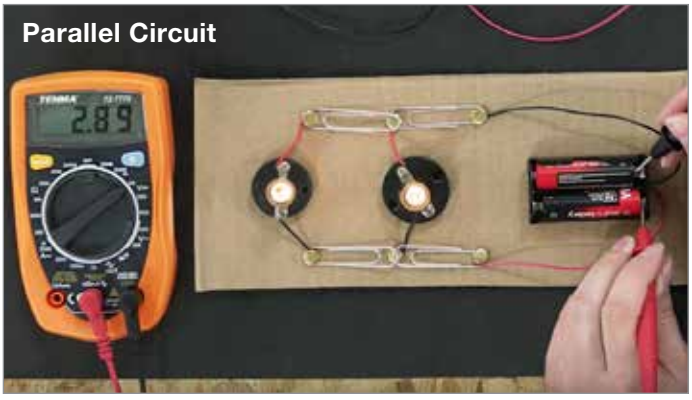
Comparing Series & Parallel Circuits

In the series circuit, the light bulbs share the same path. This means they have the same current flowing through them. Depending on the light bulb resistance and voltage drop, one light bulb could be brighter or dimmer than the other. You can use a multimeter to measure the voltage.

In the parallel circuit, each light bulb has its own path for current to flow. They effectively both have access to the full voltage of the batteries, so both light bulbs have the same brightness.

In a series circuit, the sum of the voltages across each light bulb should equal the battery source voltage. In a parallel circuit, the voltage across each light bulb should equal battery source voltage.





A Note About Voltages

While we can plan circuits and often use the ideal values, in real circuits the numbers are often a little different. Batteries are not always exactly their rated value (1.5V, 3V, 9V, etc.). Some batteries have a higher voltage when brand new, and as they are used, the voltage slowly drops.

The paperclips being used in these circuits have a level of resistance that can also decrease the amount of voltage available from the batteries. A small amount of voltage is lost in the form of heat in the paperclips, so the voltage across the lights may be slightly less.

CHAPTER 6

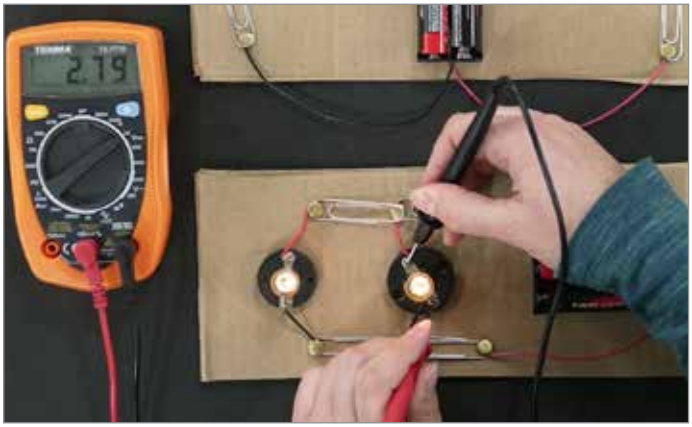
LIGHT BULB VOLTAGES IN A CIRCUIT

Light Bulb Voltages in a Series Circuit

Here I measured the light bulbs in the series circuit. The first light bulb is slightly more than half the voltage of the battery pack. The second light is slightly less than half the voltage of the battery pack. While the voltages across the lights are similar, they still both only get approximately half the voltage of the battery pack.

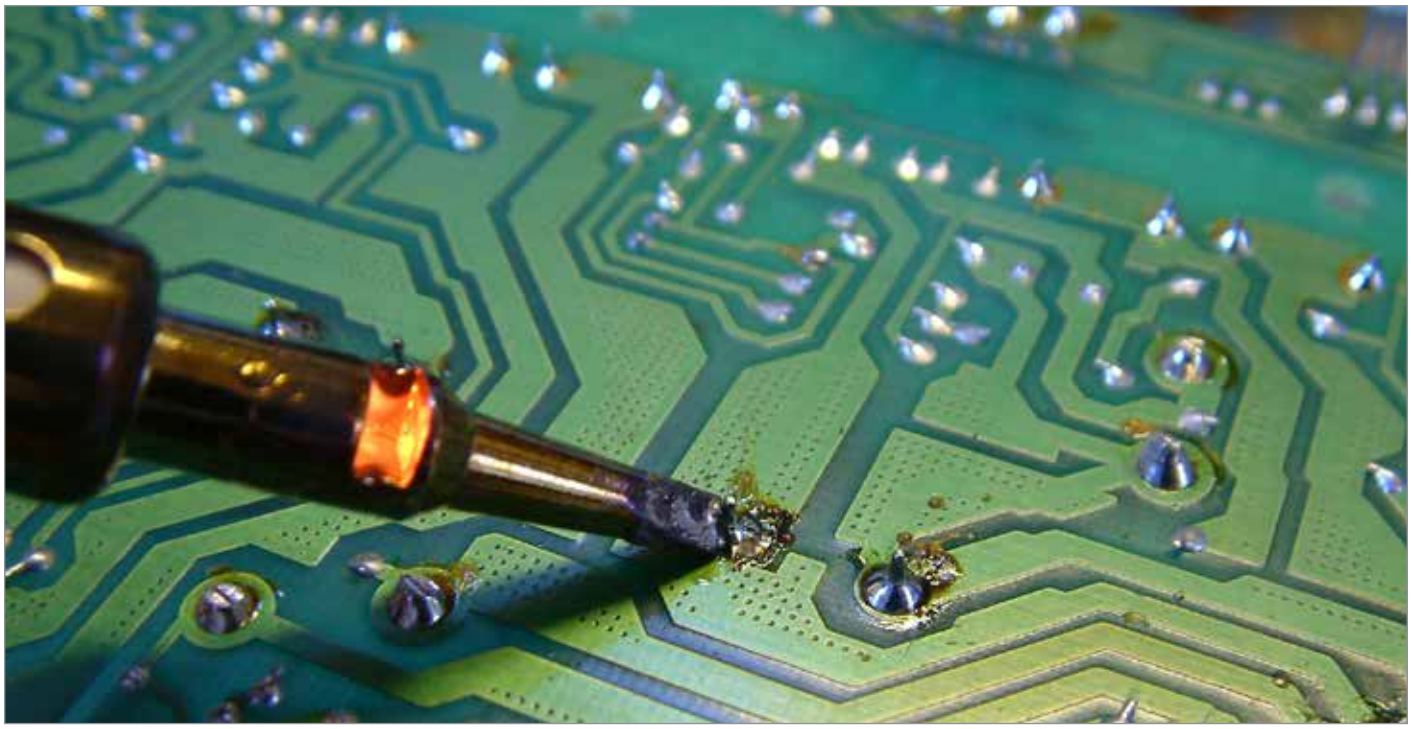
Light Bulb Voltages in a Parallel Circuit

Here you can see I measured that the voltage across the first light bulb is slightly lower than the voltage of the battery pack. The second light has slightly lower voltage than that. The voltages of the battery pack and both lights are all fairly equal.



Challenge

The parallel lights both have access to the full voltage of the battery, while the series lights share the voltage of the battery pack. Do you think both battery packs will last the same amount of time? Will one battery pack die sooner than the other?



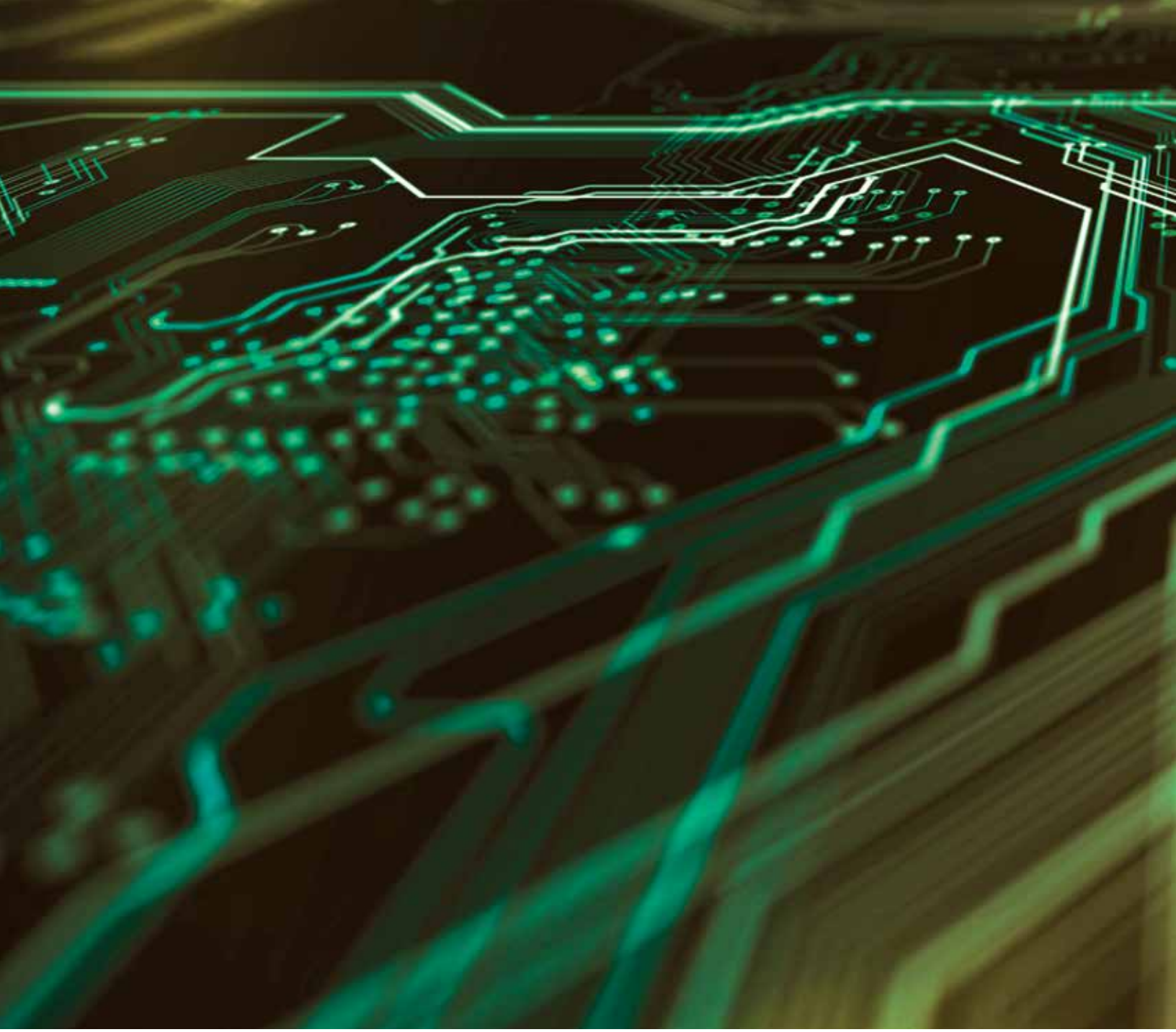
EXPLORE MORE!

Now that you know about open and closed, series and parallel circuits, take what you know and experiment! Try adding a switch to a circuit with multiple lights. Try adding more lights to your circuit and see what happens. Remember that we had to add a battery when we added a second light. In your experimentation, be mindful of the voltages that your lights require. Try to add enough that your lights will all turn on, but not too much to burn them out.

Good luck, and happy learning!

Check out our website on **The Learning Circuit** to watch more episodes on circuits and build your knowledge. You can also share your own projects, ask questions of our members, and suggest topics for future episodes.

THE LEARNING CIRCUIT



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