STEM ON A DIME

Introduction to Paper Circuits

Activity from SDSU Department of Electrical Engineering

Activity Updated November 2021

SKILL LEVEL

Age 8 - 18

KEY TERMS

Circuits, Simple Circuit, Parallel Circuit, LED, Closed Circuit, Open Circuit

EDUCATION STANDARDS

South Dakota Science:

- 4-PS3-2

TIME NEEDED

60 minutes

MATERIAL LIST

Materials needed per circuit:

- 2032 Coin Battery (3V)
- Five LEDs
- One Simple Circuit Template
- One Parallel Circuit Template
- Thank You Template

Materials to be shared by group:

- Pencil
- Scissors
- Copper Foil Tape (¼" adhesive)
- Scotch Tape
- Paper Clip or Binder Clip

EXPECTED LEARNER OUTCOMES

OBJECTIVE 1 – Youth will be able to describe how energy flows in a circuit.

OBJECTIVE 2 – Youth will construct a simple operating circuit.

OBJECTIVE 3 – Youth will be able to explain and troubleshoot circuits.

BACKGROUND

Through combining art and science, youth are encouraged to tap into both their creativity and their knowledge. The number of crafts that can be created with paper circuits are infinite; however, to get started, youth need to first be comfortable with the materials utilized, as well as the electricity concepts used in their creation. In this activity, youth will build a basic circuit, a parallel circuit and finally create a thank you card with a circuit.

An electrical circuit is the complete path of an electric current including the source of electrical energy. In a paper circuit this is most often comprised of a small coin battery, copper tape and lights. They may also be more complex and include items such as motors.

VOCABULARY

Circuit – The pathway that allows electricity to flow from the power source (out of the + side) to the item being powered (light, motor, etc.) and then back to the power source (into the – side).

Parallel Circuit – A circuit in which the electricity flows from the battery, into the items using the power simultaneously, and then back to the battery. Figure 2 in the Appendix.

LED (Light Emitting Diode) – A semiconductor diode which glows when voltage is applied. Unlike a traditional light bulb, an LED only allows electrical flow in one direction.

Semiconductor – a material that has a conductivity value falling between those of conductors (like metal) and insulators (like glass).

Diode – A one-way switch that allows current to easily flow in one direction but resists its flow in the opposite direction.

Leads – Every LED has two legs. These legs are called leads. The longer lead is generally the positive lead, while the shorter lead is generally the negative lead. This however is NOT always true as it is NOT an industry standard.

Terminals – The ends of a battery; one is always positive and one is always negative.

Closed Circuit – A circuit that is complete and allows electrical current to flow freely from one terminal of the battery to the other.

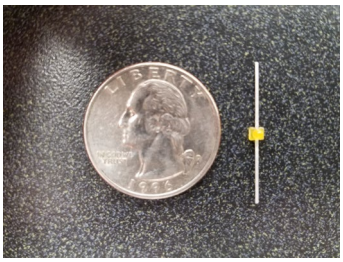
Open Circuit – A circuit that has a break or interruption in the continuity of the electrical currents path. This could be because a switch is off or a piece of the circuit (battery or light) is missing.

Short Circuit – A disruption of the electrical current within a circuit that causes the current to be diverged away from whatever it is supposed to be powering.

ACTIVITY PREPARATION

1. Gather the following materials for each youth:
   a. Coin Battery – You may choose to have one for each of the three circuits, or to have the youth utilize the same battery for all three circuits.
   b. LEDs (five total) – For ease of distributing these to youth, you may want to tape them to a small piece of paper, note card or something similar. For introductory purposes, a 5mm or 10mm LED will suffice; however, for intricate paper circuit designs or the thank you cards, you may want to consider a smaller LED, like a 1 mm LED. The LEDs can easily be purchased through Amazon.

5 mm LED



1 mm LED

   c. Copper Foil Tape – For ease of use, you may want to consider giving youth strips of the tape rather than the roll of tape itself. Youth may require assistance when it comes to removing the backing of the tape to apply it as this requires some dexterity. Also, practice caution when using the tape. The edges can be sharp and can cause cuts similar to a paper cut.
   d. Pencil – This will be utilized to punch the hole for the LED, so make sure it is sharp. If you have a hole punch capable of making these holes, use that instead.

e. Scissors – When selecting scissors consider both the safety and accessibility.

   i. Do you need safety scissors for the age group you are working with?
   ii. Do you have youth that need left-handed scissors?

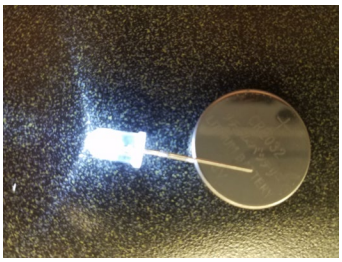
f. Circuit Templates – These are included in Appendix A. Be sure that it is printed single-sided.
g. Thank You Template – This is included in Appendix A. Be sure that this is printed double-sided to allow for it to be used as a card. If you so choose, it can be printed on cardstock or on the Avery 3265 half-fold greeting card template.

2. Consider the age and capabilities of your youth as well as the amount of time you have for this activity.
   a. Smaller LEDs may be more difficult for younger youth to manage.
   b. Copper tape can be challenging and even frustrating for younger youth. You may want to have extra adult hands, or older youth who can help younger youth with peeling tape and applying it.

3. To simplify the facilitation of the activity, consider packaging the materials for each group together in a small container or Ziploc bag.

ACTIVITY INSTRUCTIONS

1. Introduction to LEDs
   a. Based on youth background knowledge, you may want to provide some insight on what a circuit is.
   b. Instruct them that they will be creating a circuit utilizing one of the LEDs and the battery and ask if they can identify how these two objects can create a circuit. (You may want to talk about conductors and insulators here depending on youth interest. For more information on this topic, see the STEM on a Dime Robo Art lesson.)
   c. Have the youth try and make these simple circuits with their LEDs. They will place one lead on either side of the battery and hold in place.



      i. Do some of the LEDs light up while others don't? Have youth compare their set ups. If one LED lights up and the other doesn't, can they identify what is different? Are the long and short leads on different terminals of the battery?
      ii. After a few moments of letting them compare and try to identify the differences, have them share back what they noticed. Most likely they will note that the one lead (depending on your LEDs this will be the longer lead) needs to be on the positive terminal while the other should be on the negative terminal.
   d. Provide the definition of an LED and diode to solidify what they have discovered about the LEDs.

2. Simple Circuit
   a. Apply the copper tape to all of the grey lines on the Simple Circuit template – leaving a gap for the LED. It is best to maintain a continuous strip of copper tape to ensure connectivity.
      i. To make square corners when using a continuous strip, fold the copper back at a 45-degree angle away from the direction you are moving (Image 2). Then make a crease and fold the tape back at 180 degrees and continue to apply to the template (Image 3).

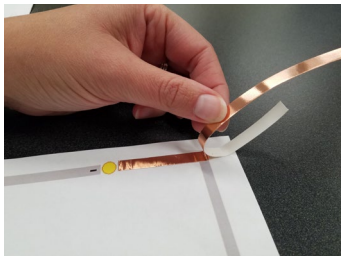
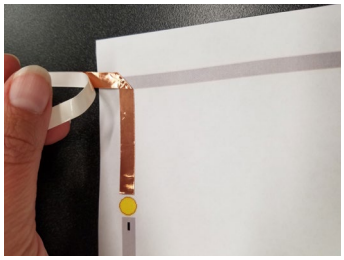
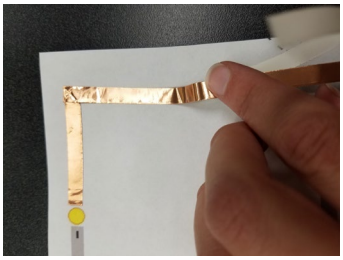
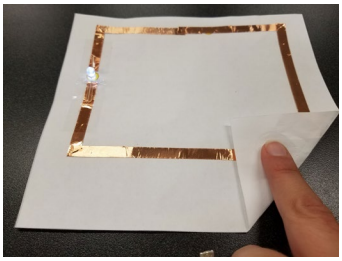
		

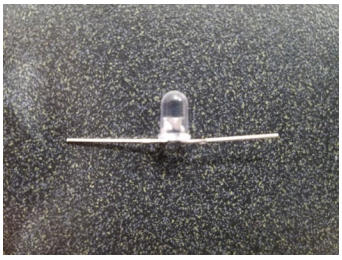
Image 1	Image 2	Image 3

ii. If the tape is pre-cut into strips, be sure that the strips overlap and securely adhere to one another at the corners.

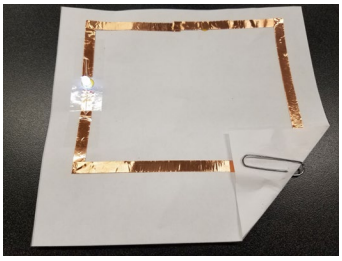
b. Score the corner where indicated by the dashed line, and fold it at a 45-degree angle.



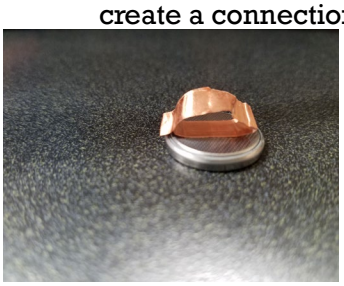
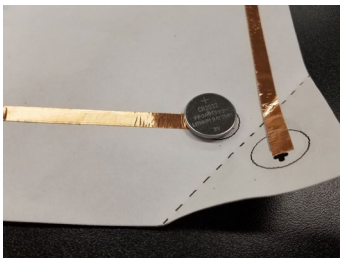
c. Mount the LEDs to the copper tape using clear tape.
   i. Be certain that you know which lead is positive and which is negative, so that they are inserted in the correct direction. This will vary from LED to LED; however in most cases the long leg is the positive and goes on the positive side of the copper tape and the short leg is the negative and goes on the negative side of the copper tape. You can test this prior to attaching them by using the battery.
   ii. Bend the leads of the LED to 90 degrees and tape them securely ensuring that as much of the lead as possible is contacting the copper tape.



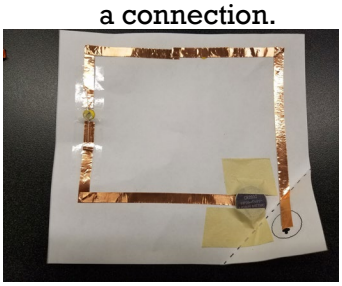
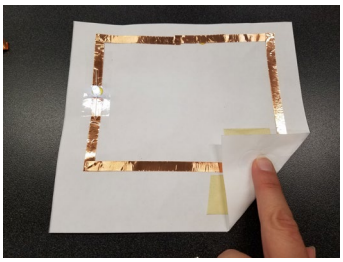
d. Attach the battery to the circuit.
   i. Place the battery on the copper tape making sure that the negative terminal is facing down.
   ii. When the corner of the paper is folded, the positive terminal should connect with the copper tape completing the circle and lighting the LED.
   iii. Secure your battery to the circuit. However, you will not want your circuit continuously closed (light on) or you will use up your battery. Consider the following options for securing your battery.
      1. Use your hands to hold the battery in place. Fold the paper to create contact with the copper tape and battery. Then use a paperclip to hold in place. *Note that to open the circuit the paperclip will need to be removed.



2. Fold copper tape to create two adhesive sides. Then use it to adhere the negative terminal of the battery to the circuit. *Note this circuit will remain open (off) until the corner is folded to create a connection.

3. Use tape to tape the battery to the circuit. You will need to use caution with this method as the tape can create a barrier between the battery and the copper tape. You want the copper tape to touch the battery! *Note this circuit will remain open (off) until the corner is folded to create a connection.

e. Troubleshoot circuit. If your light is not working, follow the steps in Appendix B to troubleshoot the possible errors.
f. Reflection:
   i. Can youth describe the energy flow in the circuit?
      1. What does the energy flow through? (Copper tape, LED, conductive materials)
      2. What were some of the challenges with building the circuit?
         a. Did they have to troubleshoot problems? What were they?

3. Parallel Circuit
   a. Apply the copper tape to all of the grey lines on the Parallel Circuit template – leaving a gap for the LED. It is best to maintain a continuous strip of copper tape to ensure connectivity.
      i. To make square corners, fold the copper back at a 45-degree angle away from the direction you are moving. Then make a crease and fold the tape back at 180 degrees and continue to apply to the template.
         1. If the tape is pre-cut into strips, be sure that the strips overlap and securely adhere to one another at the corners.
   b. Score the corner where indicated by the dashed line, and fold it at a 45-degree angle.
   c. Mount the LEDs to the copper tape using clear tape.
      i. Be certain that you know which lead is positive and which is negative, so that they are inserted in the correct direction. This will vary from LED to LED; however in most cases the long leg is the positive and goes on the positive side of the copper tape and the short leg is the negative and goes on the negative side of the copper tape. You can test this prior to attaching them by using the battery.
      ii. Bend the leads of the LED to 90 degrees and tape them securely ensuring that as much of the lead as possible is contacting the copper tape.

d. Attach the battery to the circuit.
    i. Place the cell battery on top of the copper tape making sure that the negative terminal is facing down.
    ii. When the corner of the paper is folded, the positive terminal should connect with the copper tape completing the circle and lighting the LED.
    iii. Secure your battery to the circuit.
e. Troubleshoot circuit. If your light is not working, follow the steps in Appendix B to troubleshoot the possible errors.
f. Reflection
    iv. Can youth describe the energy flow in the circuit?
        4. How does this circuit differ from the first circuit? (number of LEDs, parallel strips of copper tape, etc.)
    v. What were some of the challenges with building the circuit?
        1. Did they have to troubleshoot problems? What were they?

4. Light Up Thank You
    a. Apply the copper tape to all of the traced lines. It is best to maintain a continuous strip of copper tape to ensure connectivity.
        i. To make square corners, fold the copper at a 45-degree angle away from the direction you are moving. Then make a crease and fold the tape back at 180 degrees and continue to apply to the template.
        ii. If the tape is pre-cut into strips, be sure that the strips securely adhere to one another at the corners.
    b. Score the corner where indicated by the dashed line, and fold it at a 45-degree angle.
    c. Punch holes to mount the LEDs, so that they are peeking through the card and appear around the words 'Just a note to say thank you so much.'
    d. Mount the LEDs to the copper tape using clear tape.
        i. Bend the leads of the LED to 90 degrees and tape them securely.
        ii. Be certain that you know which lead is positive and which is negative. The negative terminal should point towards the bottom circuit. How to tell the positive lead from negative lead will vary from LED to LED; however in most cases the long leg is the positive and goes on the positive side of the copper tape and the short leg is the negative and goes on the negative side of the copper tape. If you are using smaller flat LEDs for this circuit, there may be a small metal plate on the back of the LED to help you identify the directionality. You can test this prior to attaching them by using the battery.
    e. Attach the battery to the circuit.
        i. Place the cell battery on top of the copper tape making sure that the negative terminal is facing down.
        ii. When the corner of the paper is folded, the positive terminal should connect with the copper tape completing the circle and lighting the LED.
        iii. Secure your battery to the circuit.
    f. Reflection
        i. Can youth describe the energy flow in the circuit?
            1. Which circuit is this one most like, the simple circuit (the first one) or the parallel circuit (the second one)?
        ii. What were some of the challenges with building the circuit?
            1. Did they have to troubleshoot problems? What were they?
        iii. How might they expand upon what they have learned? What additional projects would they like to try adding circuits to?

EXTENDED LEARNING

Once youth have the basics of building a paper circuit mastered, they can begin creating various works of art with built-in circuits. Consider some of the ideas shared by the following sources:

Maker Ed (https://makered.org/resources/curriculum-ideas-integration-paper-circuits-three-ways/)

Makerspaces.com (https://www.makerspaces.com/wp-content/uploads/2017/10/Paper-Circuits-For-Makerspaces-Ebook.pdf)

These ideas and skills can be further developed through the exploration of other electricity-based STEM on a Dime lessons like Basic Bread Boards, Circuit Bugs and Glowing Chromatography Flowers.

You may also want to check out the 4-H Junk Drawer Robotics Curriculum (https://4-h.org/parents/curriculum/robotics/) and the Scribbling Machine from the Exploratorium (https://www.exploratorium.edu/sites/default/files/pdfs/scribbling_machines.pdf)

Youth may also want to further explore the South Dakota 4-H Electricity Project (https://extension.sdstate.edu/4-h-electricity-project).

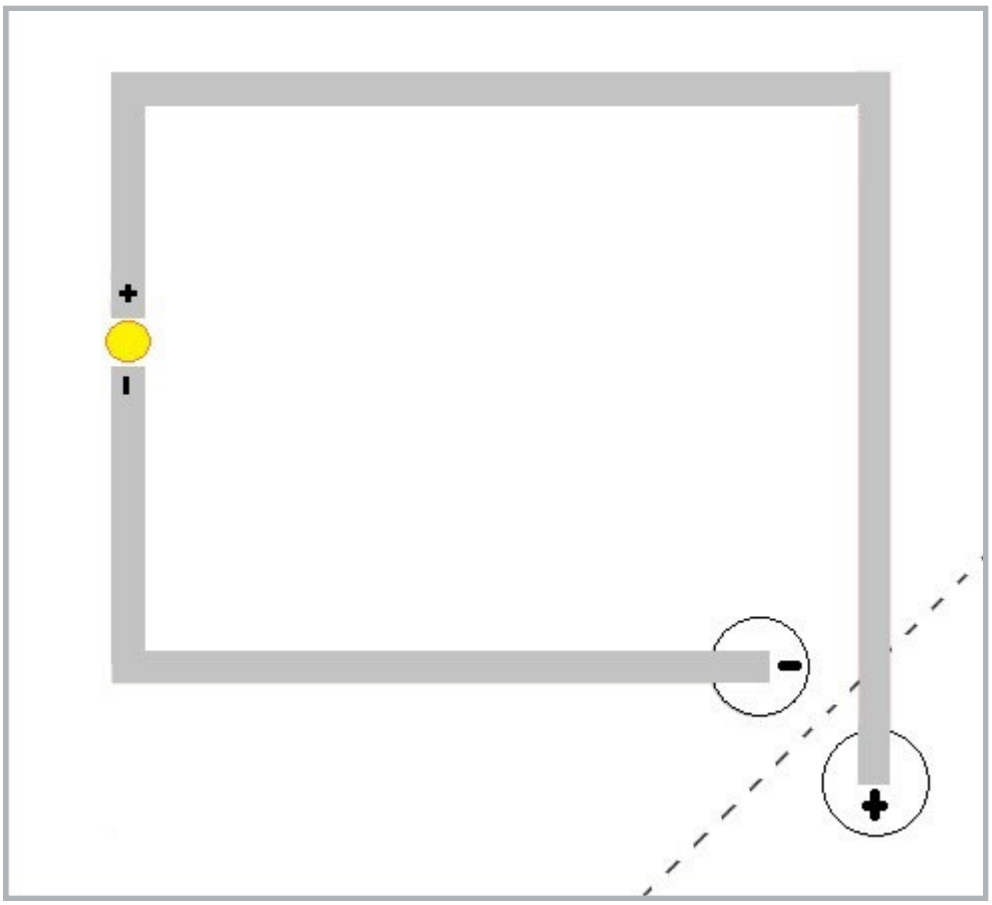


FIGURE 1: Simple Series Circuit

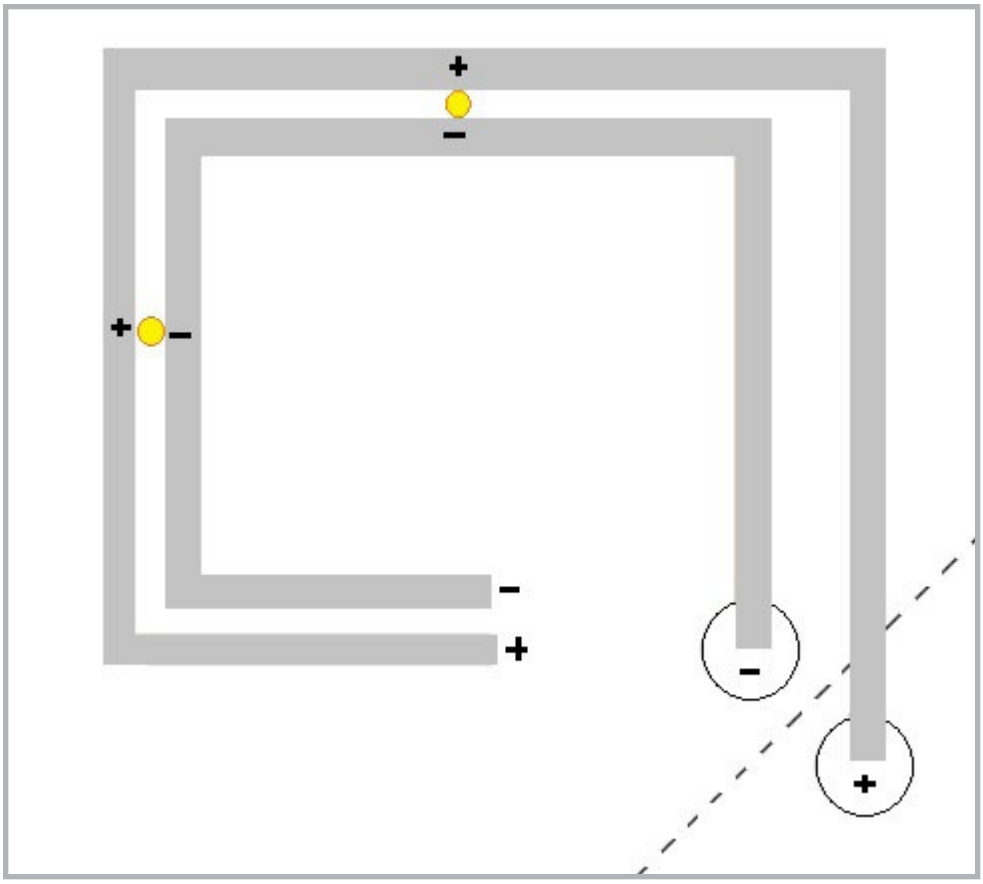
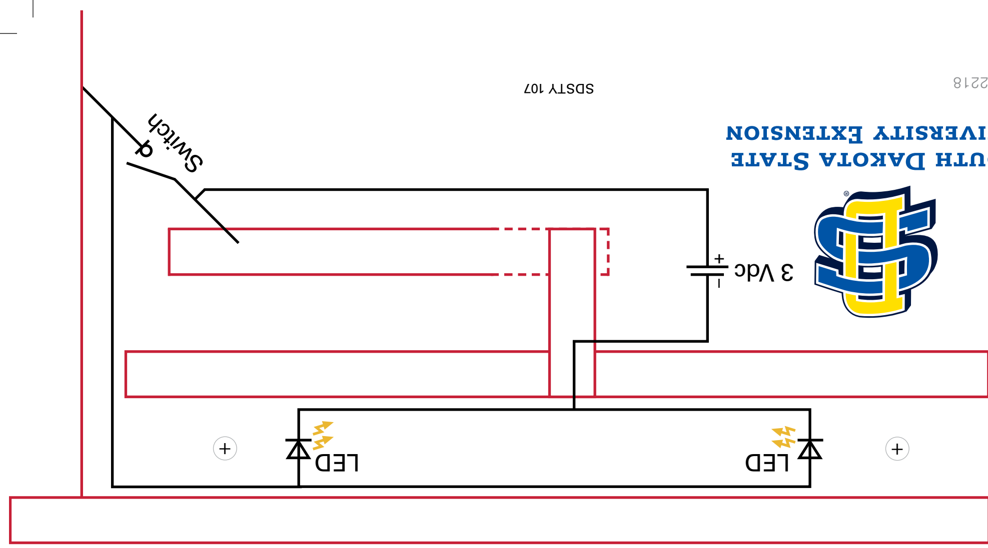


FIGURE 2: Parallel Circuit

MC-02218
SDSTY 107

South Dakota State University Extension



Thank You!

Just a note to say
thank you so much.

FOLD BACK
TO HERE

APPENDIX B TROUBLESHOOTING

When building paper circuits, it isn't uncommon for issues to arise and for the circuit not to work. There are several different factors that play into this. Read through the list below to try and correct the problem.

1. Make sure that your battery and LED are functioning.
   a. Place the negative lead of the LED onto the negative terminal of the battery, and the positive lead of the LED onto the positive terminal of the battery. The LED should light. If it does not, that means one or both are not working. Try a different battery. If the LED lights, you had a bad battery, if the LED does not, you may have a bad LED. Try a different LED.
2. Make sure that the negative lead of the LED is on the copper leading to the negative terminal of the battery, and the positive to the positive terminal. NOT all LEDs are created equal and even though the long lead is generally the positive, this may not be the case.
3. Make sure that the leads of the LED are making contact with the copper tape. If there is anything obstructing this contact they will not light.
4. Make sure that the battery is making solid contact with the copper tape.
5. If your tape is not continuous, be sure that the pieces are overlapping and secure contact has been made between pieces. Even the slightest disruption of contact can cause the circuit to open.
6. Check for wrinkles or tears in the copper tape. Wrinkles may cause a disruption in the current flow, so be sure the tape is securely adhered to the paper.
7. Check for shorts in the circuit. Any time the negative and positive portions of the circuit cross paths, it can cause it to short out. This could happen between copper tape, LED legs or both.