**Maker Programs in Vermont Libraries: Spark a Culture of Innovation presents:**


Did you know you can build circuits with paper and conductive tape? Turn a paper fold into a switch? E-papercrafting is an accessible way to build circuits that add to paper projects of all kinds. Whether you are an origami aficionado or not, you will discover amazing ways to light up greeting cards, books, sculptures and anything made of paper.

## Workshop Objectives

During the course of this workshop, participants will:

- Use simple materials to build paper circuits.
- Learn to make a switch to turn a circuit on and off.
- Learn paper folding and manipulating techniques to create objects.

## Suggested Ages

8-16, especially if you have a few participants that know about origami.

## Next Generation Science Standards Addressed

- K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

For more information on NGSS, please visit http://www.nextgenscience.org

## Materials

To make circuits:
5mm cycling RGB and solid color LEDs
Copper tape
3v coin cell batteries
Binder clip
Metal paper clips
Metal brad paper fastener
Optional: sewable coin cell battery holders
Optional: circuit stickers
Optional: conductive ink

To make papercrafts:
Origami paper 6 “ x 6”
Construction paper
Bone paper folder
Pencil
Highlighter
Markers
Crayons
Glitter
Scissors
Origami tape (optional)

For inspiration:
Pull as many origami and papercraft books from your collection as you have room to display.

## Preparation

This session needs to be held in a location with plenty of table space.

Consider making tool kits for small groups of participants so that all the circuit-making materials are within easy reach. Something as simple as a shoebox with plastic cups holding the various tools and materials can be helpful.

Encourage reuse of conductive copper tape, especially in the experimentation part of the session.

You may want to have participants work in pairs during the experimentation part of the session as well. Again, this saves the copper tape and LEDs for projects later in the workshop.

Make a copy of the handout for each participant. The “Project Ideas” section of this module has links to a number of project sheets that can be used to create specific items. You may want to print a few of each out to share during the creativity studio time in the workshop.

## Safety

Goggles are optional for this activity.
If a battery or component gets warm or sparks or smokes, remove the battery.

## Optional materials

There are a number of optional materials listed for this project. Here is an explanation of some of them.

Sewable battery holder: The circuit experiments require a folded corner of the project to complete the circuit. A holder like this makes it possible to create flat circuits. Inexpensive and very useful.

Circuit pens: Conductive ink pens which allow you to draw the traces. Very useful but a bit pricey. See the Circuit Scribe at http://www.electroninks.com

Circuit stickers: Surface mounted LEDS and other components on stickers. Makes building paper circuits very easy. Quite expensive. See the Chibitronic stickers at http://store.chibitronics.com/collections/all

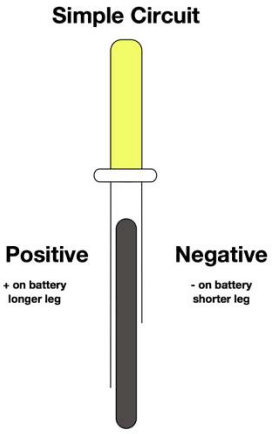
## How to run an e-Origami and e-Papercrafts session

### Experimenting with Paper Circuits

Begin by defining **circuit**: a closed path or loop around which an electric current flows.
For the circuits in this workshop participants will use a battery for the **power source** and LEDs (light emitting diodes which are very bright but low power lights) as the **output** component.
Explain that the components are **polarized**. A polarized component – a part with polarity marked as positive or negative (ground) – can only be connected to a circuit in one direction or the electricity will not flow around the circuit.

Examine the battery and an LED. Find the + and – on the battery. On the LED, the longer leg is positive. The shorter leg is negative.

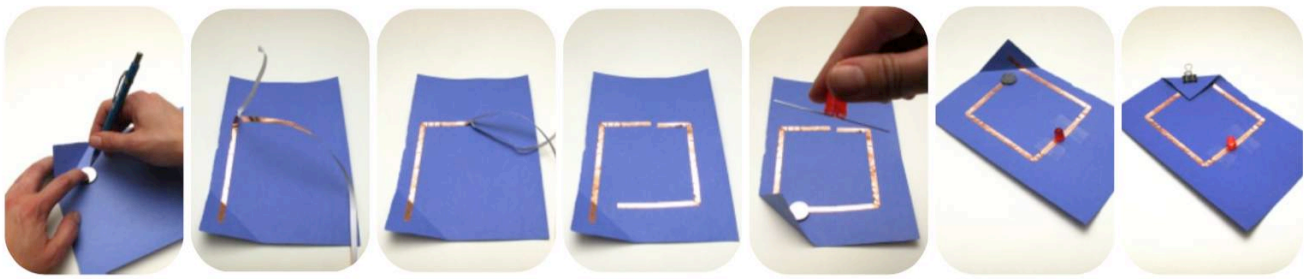
Begin by making the simplest circuit imaginable with these components. Simply hold the battery between the two legs of the LED and make contact. If the polarity is correct, the LED will light up. Reverse the battery and observe that if the polarity is reversed, nothing happens. Electricity will not flow.




This is a very simple circuit, but it is not good for much, because the light has to be directly touching the battery. Instead we need to use **conductive** materials to make a more complex circuit.

Make sure everyone (or every pair) has a half sheet of construction paper and some copper tape. Refer to the Basic Circuit directions on the handout. Have participants work to make a basic circuit.

**Basic Circuit**



Fold one corner of your paper. Trace a coin battery. This will be your on/off **switch**.

Electricity will flow through the **conductive** copper tape. Start the circuit at the corner, peeling off the backing as you go. The sticky part does not conduct electricity, so bend (don't cut) to make curves or corners. Leave a gap where the LED will go. Finish your circuit on the circle battery trace at the corner.

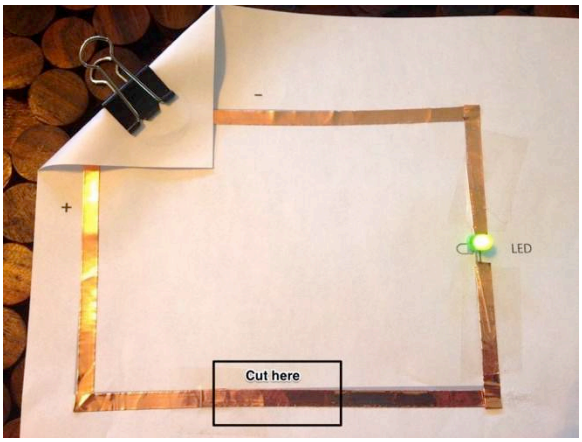
Bend out LED leads and tape each lead to one side of the circuit. Add battery and clip. No light? Flip over the battery.

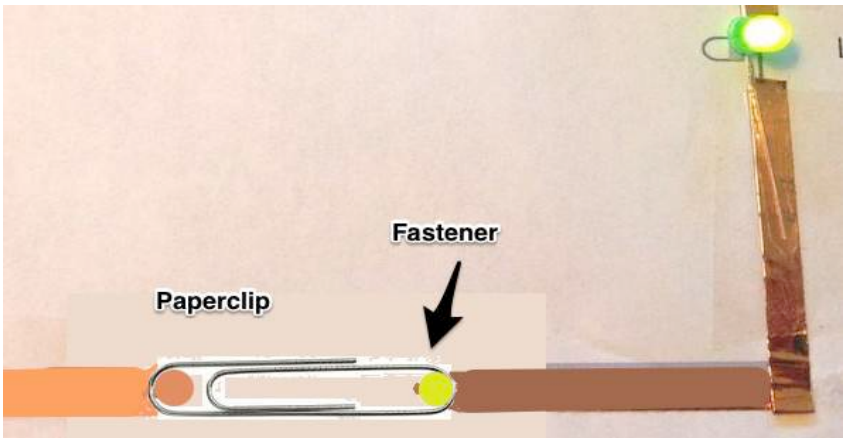
from Make:Paper Circuits, Make Magazine, 2014,
http://cdn.makezine.com/uploads/2014/07/papercircuits.pdf

Notice that this circuit has a **switch**: an **input** device to tell the electricity to flow or stop. The switch is the corner fold. In some circuits, this switch is not practical. The next task is to add a separate **switch** to the circuit. First, clip the corner with the battery with a binder clip to hold the battery against the **conductive traces**.

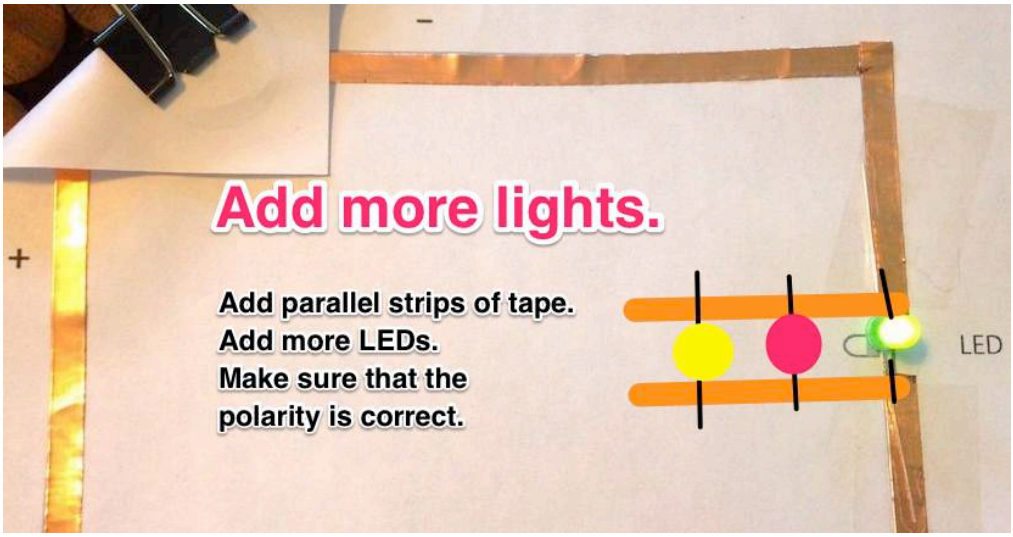
One way to make a switch: Get a metal paperclip and a paper fastener. Cut a piece out of the circuit that is slightly shorter than the paperclip. Put the metal fastener through the circuit on one side of the cutout. Use it to hold the paperclip against the copper tape. You can now swing the paperclip back and forth to open and close the circuit.  You can use it as a switch.

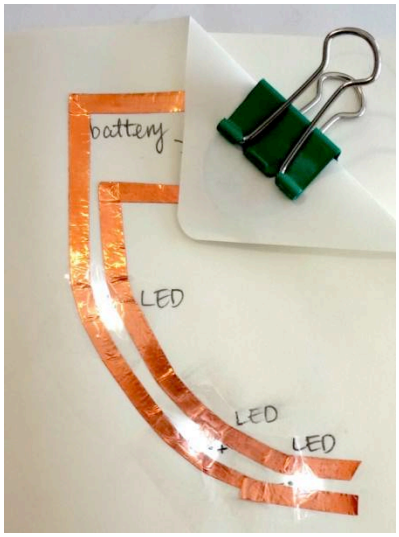
Alternatively, you could use any conductive material to make the switch, including a piece of copper tape.




So far there has just been one light in the circuit. Make a **parallel circuit** to light up more lights. Make two parallel strips of copper tape from the ends of the traces where the current LED is located. Fold the legs down on more LEDs and tape them into the circuit. Notice that the switch still works. The second image shows a completely new parallel circuit.



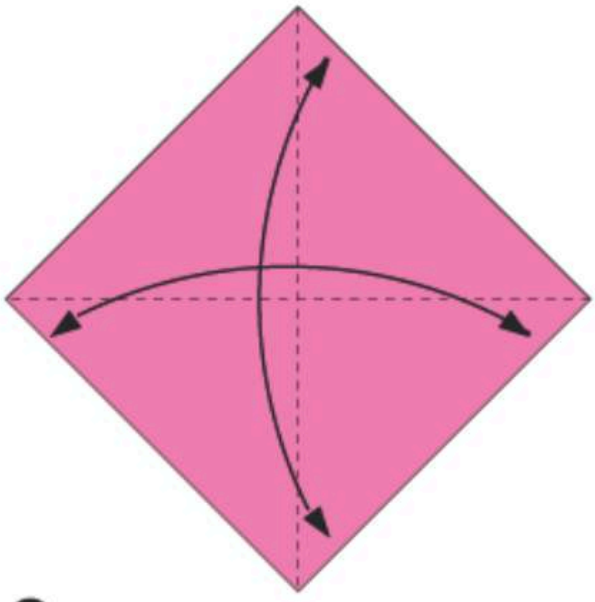




These are the basic circuits and switches used in e-Origami and papercrafts. Review what has been created so far, making sure that participants understand the basics.

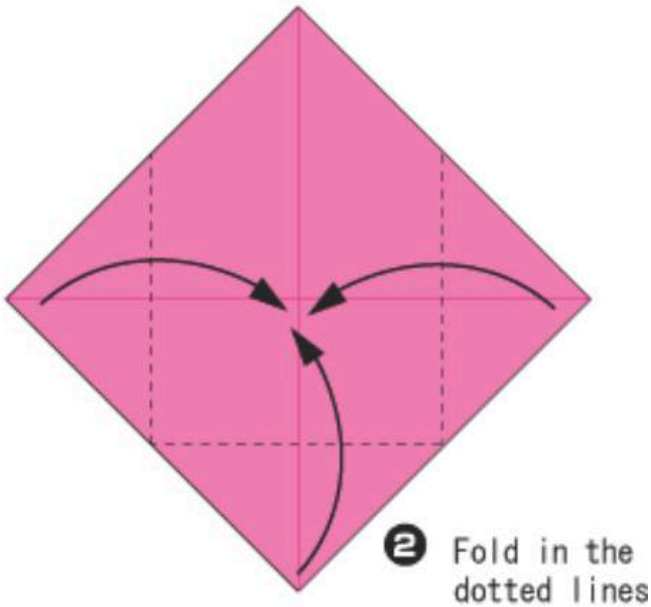
**Origami basics**

There are a wide variety of origami patterns available online and in books. This is a very simple project to show how origami and circuitry can be combined.

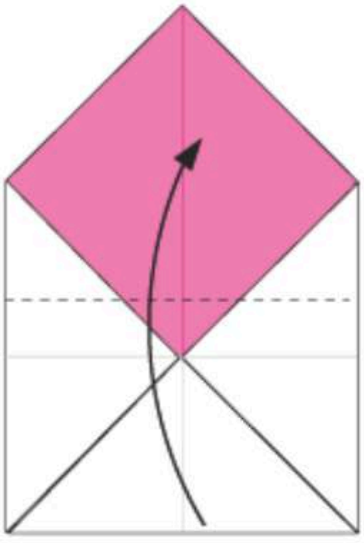
Use a piece of origami paper to fold a candle following the directions. Make each fold crisp and as straight as possible.



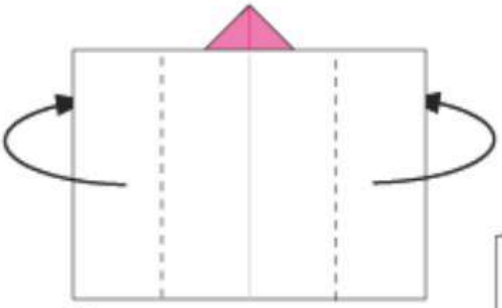
❶ Fold to make creases and fold back



❷ Fold in the dotted lines



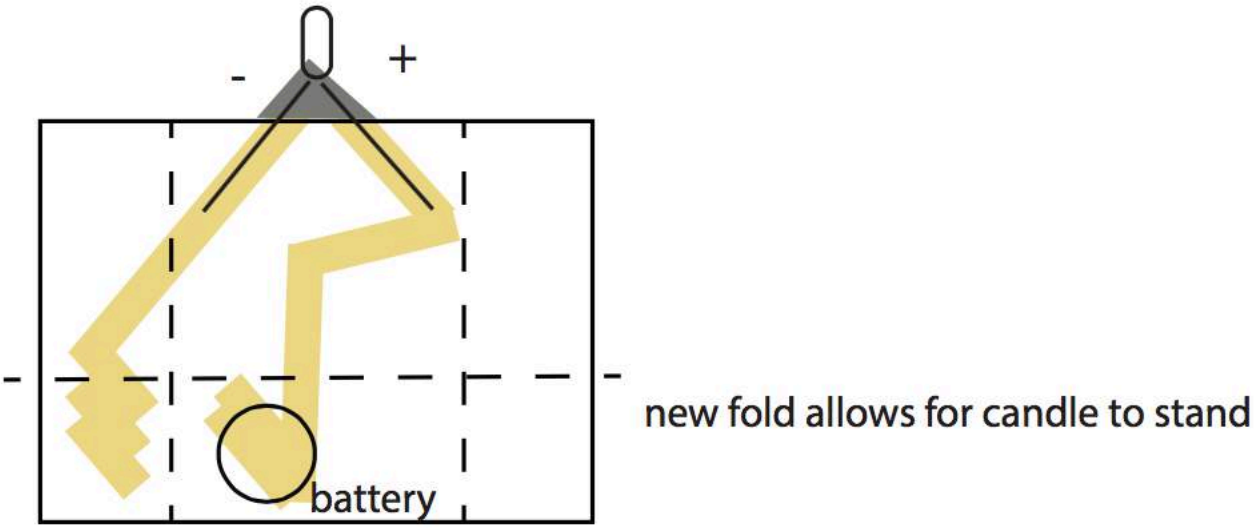
❸ Fold in the dotted line



❹ Fold backward in the dotted line

❺ Finished

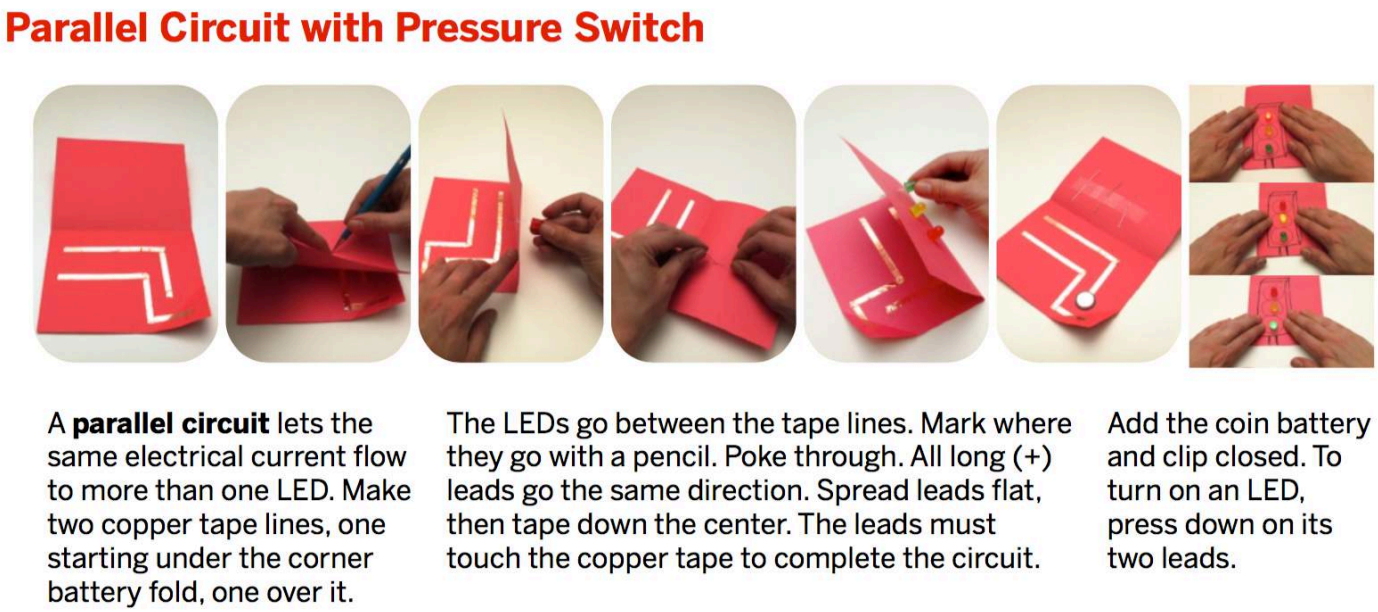
Then unfold the shape and add the circuit. The LED will be the candle flame. The circuit needs to meet under a fold so that the positive and negative traces touch the battery correctly. There is more than one way to do this, but here is a possible circuit:




Refold the circuit and admire your candle!

**Creativity Studio Time**

For the remainder of the session, allow participants to work on paper and circuits projects that interest them. Some may have origami patterns they want to illuminate; others may want to make cards using their new circuitry skills. On the handout, there are instructions for a stoplight using a parallel circuit:




from Make:Paper Circuits, Make Magazine, 2014,
http://cdn.makezine.com/uploads/2014/07/papercircuits.pdf

This is a good starting point for participants who are not sure where to start. Prior to the workshop, you may want to print out some of the following projects to have as examples for individuals who need inspiration. In all, copper tape can be used if other materials are mentioned.

**Project ideas for creativity studio time and to learn more**

Marvelous tutorial from the Exploratorium, definitely worth downloading:
http://tinkering.exploratorium.edu/sites/default/files/Instructions/paper_circuits.pdf

From Kithub—great, easy to follow handouts:

- Expressive artwork https://kithub.cc/wp-content/uploads/2015/01/ExpressiveArt.jpg
- Popup Greeting Card https://kithub.cc/wp-content/uploads/2015/01/LEDPopUpCard.jpg
- Interactive friendship bracelets https://kithub.cc/wp-content/uploads/2015/01/Bracelets.jpg

Paper circuit robot card http://www.enrichscience.com/2014/09/paper-circuit-cards/

From the Sparkfun website—more complicated tutorials:

- Light up holiday cards https://learn.sparkfun.com/tutorials/let-it-glow-holiday-cards
- Advanced: e-origami flowers https://learn.sparkfun.com/tutorials/origami-paper-circuits

One of the first e-Origami projects published:
Evil Mad Scientist's e-Origami cube light http://www.evilmadscientist.com/2008/paper-circuitry-at-home-electric-origami/

Origami instruction sheets

- Make an origami box: http://www.origami-fun.com/support-files/origami-box-print.pdf
- Make an origami crane: http://www.origami-fun.com/support-files/origami-crane-print.pdf

**Closing sharing session**

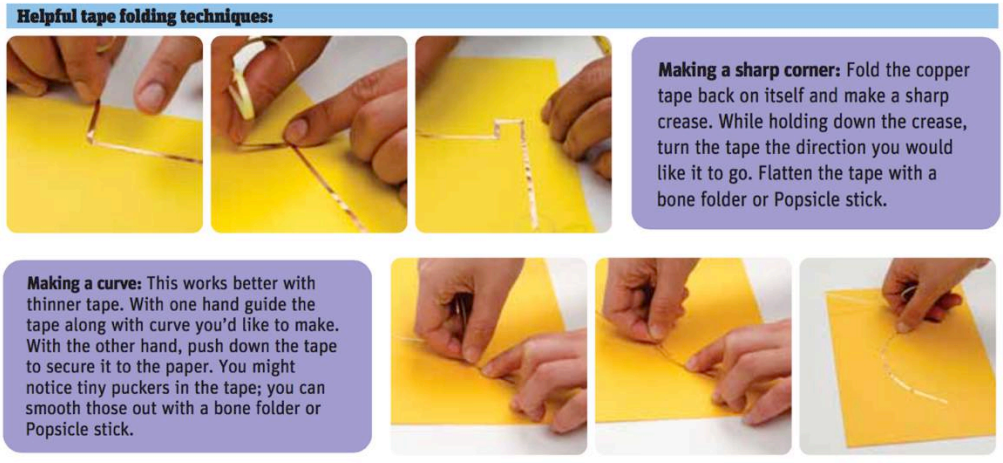
Leave time at the end of the workshop for sharing. It helps if there is a dark place where participants can display their works of art. Admire both the art and the circuitry, along with all the learning that has happened.

## Troubleshooting

Make sure that in all the excitement of paper folding, conductive traces don't touch in unexpected places. This can short out circuits.

Some participants have difficulty working with the copper tape. Here are some tips from the Exploratorium Tinkering Studio. This is also included on the participant handout.

The best way to determine how to make a circuit is to fold the paper, unfold it and them plot the circuit design.



## Vocabulary

**Circuit:** a closed path or loop around which an electric current flows
**Power source:** item that introduces energy into circuit (like a battery)
**Input:** a device (button, switch, etc.) that feeds data to a microprocessor chip
**Output:** a device that sends data to a user (light, sound, movement, etc.)
Polarized: a part with polarity marked as positive or negative (ground)
**Switch**: a mechanical device used to turn a current on or off in an electric circuit
**LED**: light emitting diode
**Short circuit**: an electrical circuit that allows a current to travel along an unintended path, often where essentially no resistance is encountered
**Conductive trace**: a path for current to run through a circuit (thread, paint, tape, wire) •
**Conductive**: a substance that allows electric current to pass through it
**Parallel circuit:** a circuit constructed with each component having its own loop back to the energy source

**The Maker Programs in Vermont Libraries: Spark a Culture of Innovation grant was made possible by the following organizations:**

**Grant Sponsor**

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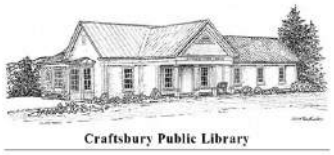


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