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Wearables
Learner Guide

Have you ever worn a smart watch? A fitness band? Gloves that light-up? Wearables are electronic devices that we wear. Often, a wearable is functional, meaning it has sensors that measure information about the person wearing it. Sensors can track location, health data, and other information. Sometimes, a wearable is decorative, such as a name badge or character with light-emitting diode (LED) lights.

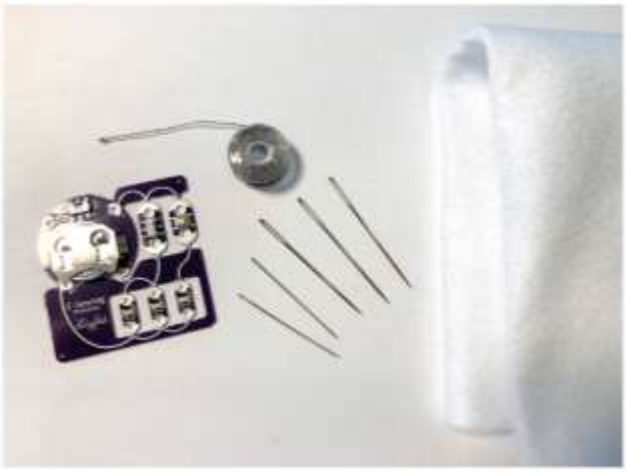
Today, you will make a decorative wearable, specifically a soft electronic patch that lights up. You will first design a patch on a piece of felt. The theme of the patch can be anything you want! Then, you will sew a circuit – a map that directs electricity around a group of electronics components – into your design.

Watch the Wearables Design video to find out about some other types of wearables, including a scrolling name badge and devices used to track people and equipment in a hospital.

Explore

Unbox and check out your components

1. It is now time for you to start making your own decorative, wearable device! Open the SparkFun E-Sewing box and look at your materials. You should have a large piece of felt, a bobbin of gray thread, a few needles, and a LilyPad ProtoSnap electronics circuit.
2. Pick up the LilyPad ProtoSnap electronics circuit and look at it closely. Identify the parts, called components, of the circuit:



a. On your circuit board, find the three white LED lights.
b. Find the slide switch and the button.
c. Find the battery holder and the CR2032 coin cell battery which provides the power to the circuit. Notice that the battery holder has its own on/off switch.
d. Use your finger to trace all the wires built into the circuit board.

3. Switch the battery to the ON position and experiment with the circuit to see how it works. The battery supplies the energy needed to run components such as LEDs, speakers, or motors. Electrical energy from the battery keeps looping around the circuit until the battery dies.
    a. Press and release the button.
    Which LED lights up?
    Which LED does the “wire” from the button connect to?
    b. Slide the small switch to ON.
    Which LEDs light up?
    Which LEDs does the “wire” from the small switch connect to?
    c. Leave the small switch on and press the button.
    Now which LEDs light up?
    Why do you think this happens?
    Slide the small switch to off.
4. Look at the plus (+) and minus (-) signs on the circuit.
    a. Which components have (+) and (-) signs on them?
    b. How are these components arranged? Does where the (+) and (-) signs are matter?

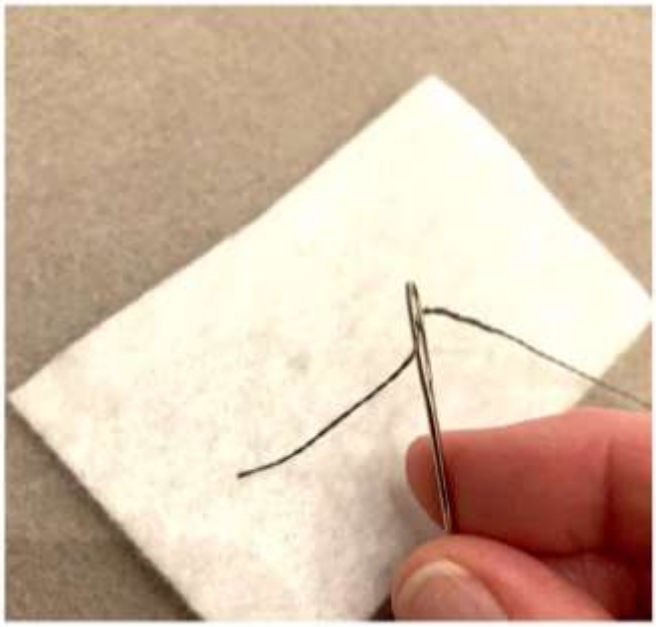
5. Unroll some thread from the bobbin and cut a piece approximately 12 inches long. The thread – made from stainless steel fiber – is conductive. This means that it acts like a wire. Conductive thread connects components in an electrical circuit. It carries the electric current from the battery to the components. Because it is soft and bendable, conductive thread works well in wearables that need to conform to the shape of the human body. Examine the thread closely.
    a. What does the thread look like?
    b. What does the thread feel like between your fingers?
    c. How difficult is it to cut, compared with normal thread or string?

Gather some additional items

As you work, these additional items help to design and make your wearable patch:

- Ruler or measuring tape,
- Pencil,
- Scissors,
- Scraps of felt,
- Fabric glue,
- Permanent markers, and
- Googly eyes (optional)

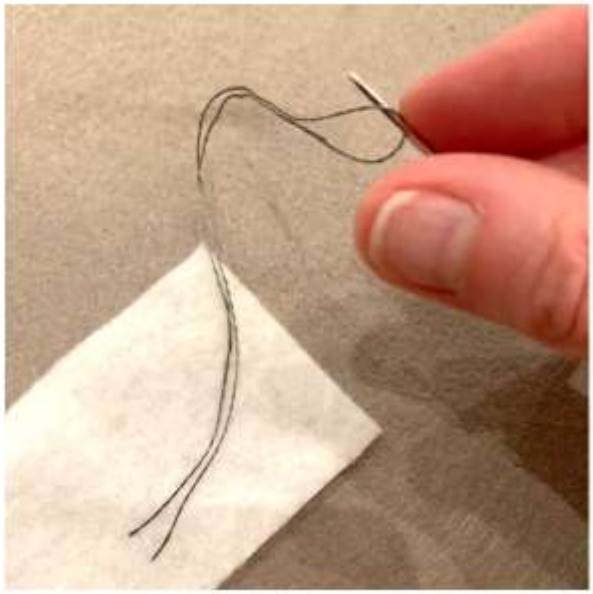
Practice stitching

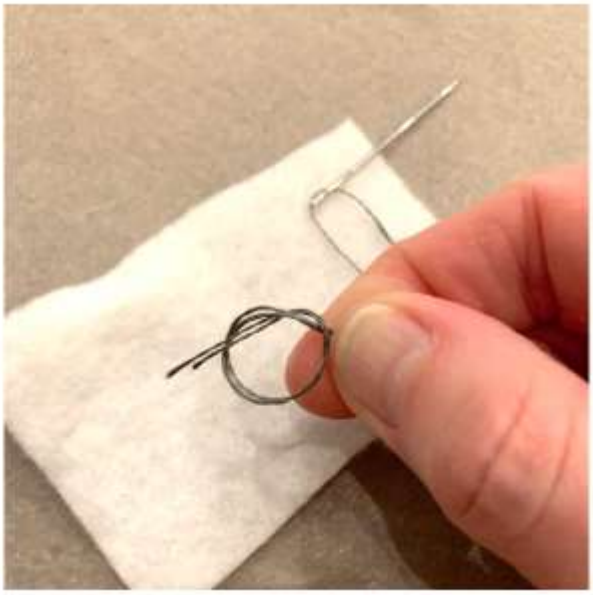


1. Choose a needle from the set included in the kit and thread it with the conductive thread. Then pull the thread so that the length hanging from each side is equal.

Note: For those new to e-sewing, picking a needle with a larger hole, called the eye, makes threading the needle easier. But be careful, picking one too large makes it near impossible to poke the needle through fabric.

2. Place the ends side-by-side and then loop them into a circle and pull the ends through the loop to make a knot. The knot will hold the thread secure in the felt as you sew.





3. Cut a small rectangle-shaped piece of felt, approximately 1 by 2 inches in size. Poke the needle through the felt, then space a quarter-inch over and push it back through the felt. This makes one stitch. Continue moving the needle in and out of the felt a few times.

4. To close the line of stitches, called a seam, make a knot by forming a loop with the thread and then pulling the needle through the loop. Repeat this process two or three times to create a secure knot. This is the practice of tying off. Cut the thread near the knot, leaving about a one-eighth tail.

Create

Design Your Patch

Electrical engineers and wearables designers rely on the design process to do their work. It is an organized way of planning and conducting design projects. In the design process you perform the following steps:

Ask questions to understand what the user needs or wants.

Explore possible ideas which may satisfy the user's needs or wants.

Model one or more ideas by drawing possible designs and/or prototyping designs.

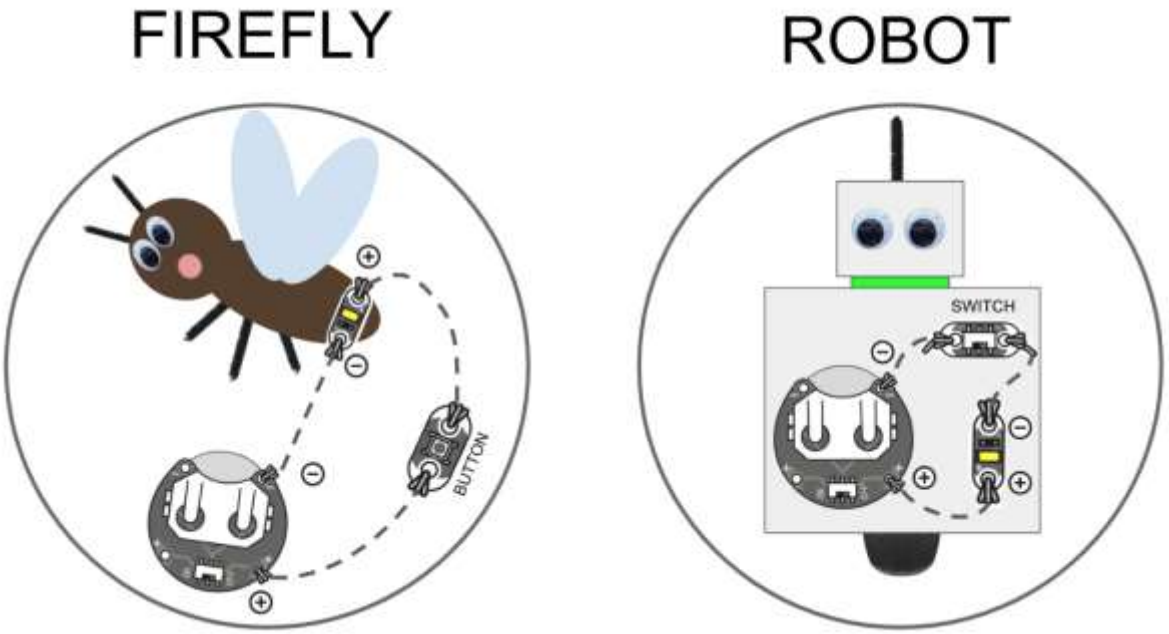
Evaluate your designs by determining how well they solve the needs or wants of the user.

Explain your final design to your user.

You can use this process to design and make your wearable patch, including the artistic design and the circuit you will build. You will make the artistic design by gluing felt or drawing with permanent markers onto the patch. You will make the circuit by sewing it onto your patch. Remember that a circuit is a group of electronics components connected with wire. In a wearable soft circuit, the wire is a "sewable" thread that lets electricity flow through it. The components you will use are a battery, one LED light, and a switch or button to turn the circuit on and off.

Design your patch by following the Design Process:

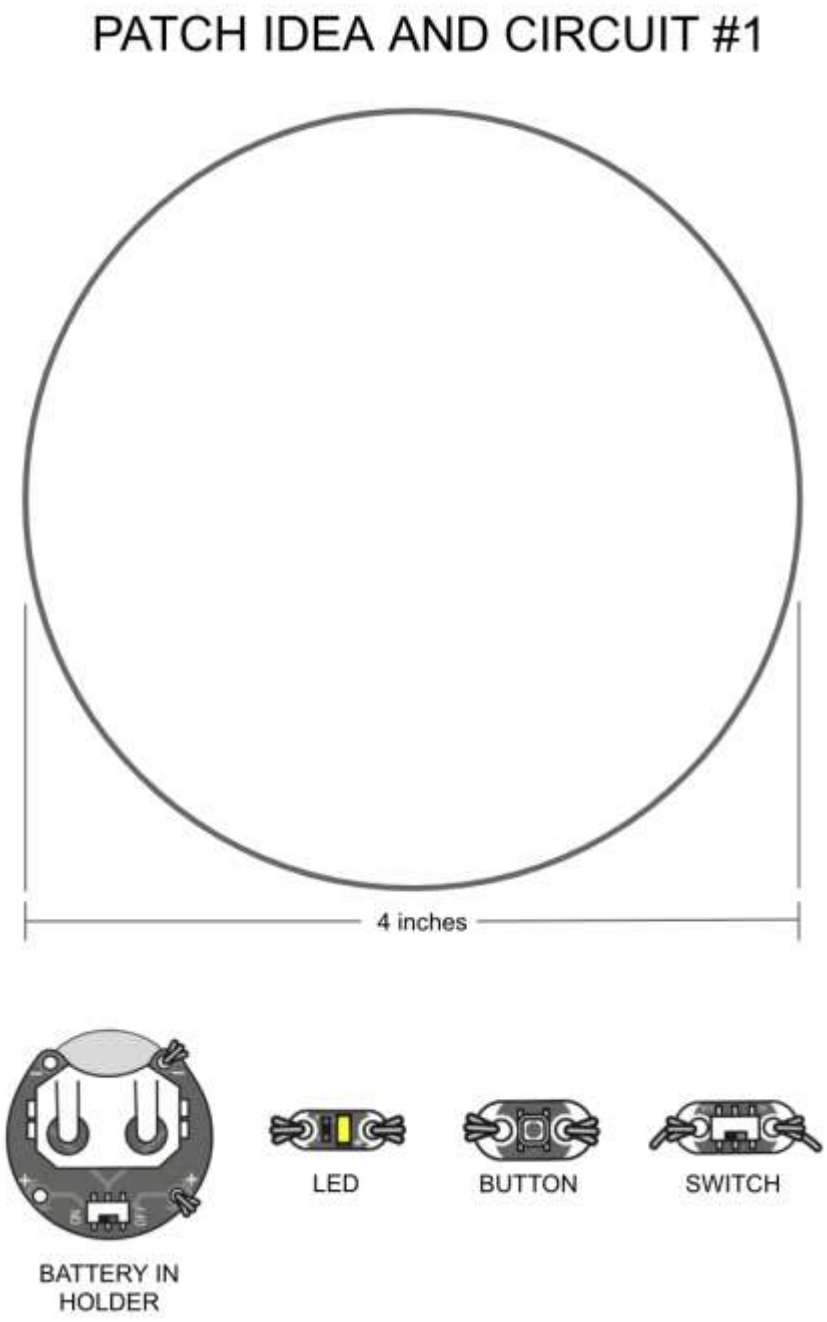
5. What interests or hobbies do you have that might be fun to feature as a theme on a wearable patch?
6. Explore example designs to help clarify how to transform a theme for a patch into a circuit. Here are two designs. Each features a simple character and circuit with one LED light. Note that the design carefully popped the components out of the LilyPad ProtoSnap board and positioned them ready to sew into a circuit on the patch.



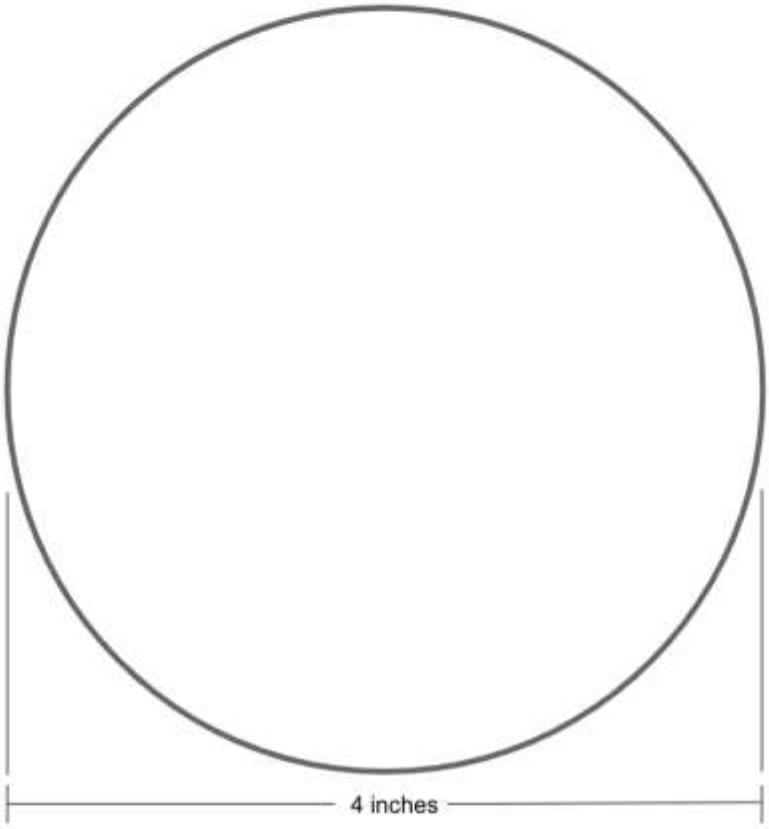
The firefly patch includes a button to turn on the LED, while the robot patch includes a switch to turn on the LED. Each patch has a battery and conductive thread, stitched to make a complete loop through the components. The circuit is on the front of each patch. The function of the design determines the use of either a button or switch on each patch The firefly design has a button, because a firefly only sometimes flashes its light as a warning to predators. (Curiously, a real firefly uses an electrochemical process to produce light.) The robot design has a switch to turn on its light and leave it on for longer time periods.

7. Model your first patch idea and circuit on the template below. Then draw your second idea. Note that the patch is about 4 inches in diameter. Be sure to include the following items on each model drawing:
   - Battery in its holder, 1 inch in diameter;
   - One LED light, half-inch long – position the positive (+) side of the LED toward the positive (+) side of the battery;
   - One button or switch, half-inch long; and

- Complete the circuit by sketching the conductive thread connecting the components in a loop. Do not cross the wire over itself!



PATCH IDEA AND CIRCUIT #2



BATTERY IN HOLDER

LED

BUTTON

SWITCH

8. Evaluate your two models using the decision matrix chart.

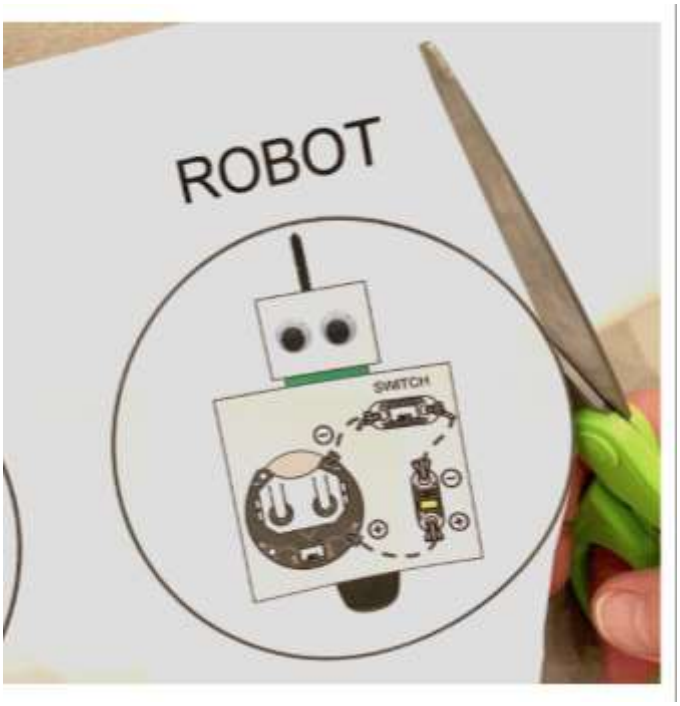
Question	Design Idea #1	Design Idea #2
	Yes	Yes
Does the design show a character or scene you like?		
Did you choose a switch or button based on the function of the patch?		
Did you draw the components the correct size to ensure they will fit on the patch?		
Did you make sure that the (+) and (-) symbols (representing the flow of electrical current in the circuit) align correctly?		
Did you draw a loop of thread, making sure it did not cross over itself?		

9. Explain your example designs to another person. Show your model drawings and describe how you transformed a theme into the final product, with the circuit included.

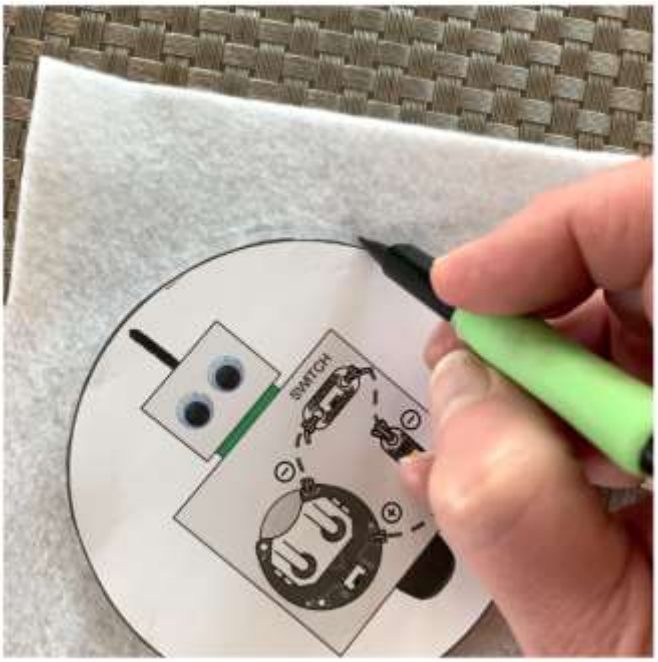
Now that you understand the basics of the LilyPad ProtoSnap circuit and how to use the Design Process, it is time to create your own wearable soft circuit patch! Work through each of the following sections to complete your patch.

Transfer your design onto the white felt

10. Cut out the circle showing the paper design you want to use for your patch. This design will be your template.



11. Place your template on the white felt. Use a pencil to carefully trace around the circle onto the felt. Remove the paper template.



12. Cut out the white felt circle. This will become your patch.

Layout your scrap felt and circuit components

13. If you are using scraps of felt, cut those out and position them on the felt. Do not glue them down yet!

14. Lay each decorative component you will use onto the patch.

15. Carefully pop the electrical components you need out of the ProtoSnap board. (Place the remaining ProtoSnap board and any unused components in the red SnapFun box.) Position all decorative and electronic components according to your plan shown on the design template.

16. Check your design to make sure your arrangement matches your paper design template. It is very important that you place the positive (+) side of the LED toward the positive (+) side of the battery.

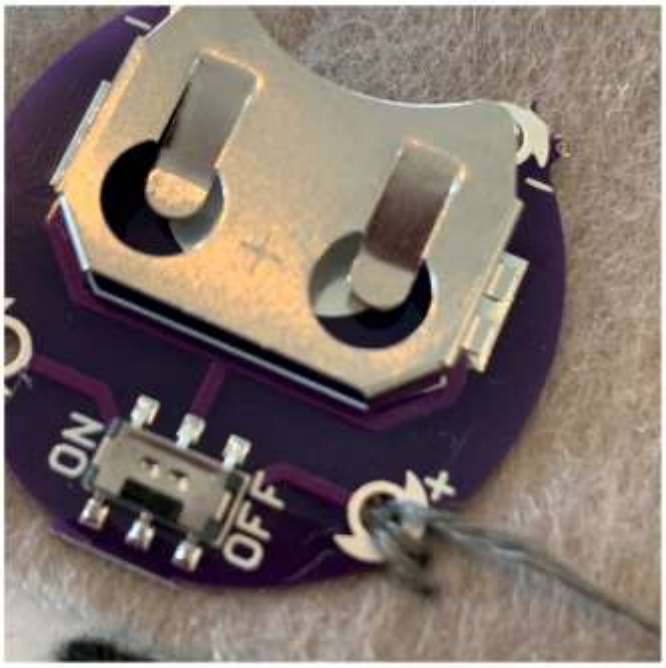
Attach your artistic design

17. If you are using scraps for felt for your design, attach them to your patch with a few small dots of fabric glue. Avoid using glue in areas where you will stitch conductive thread. Give the glue a few minutes to dry. (If instead, you are using permanent markers, color your design onto the patch according to your design plan.)

Stitch your circuit design

18. Remove the coin cell from the battery holder.
19. Thread the needle with approximately 18 inches of thread. Make sure an even quantity is hanging down on each side of the needle. Knot the ends of the thread.

20. Hold the battery holder against the felt. Stitch a few loops through the (+) terminal to firmly attach the battery holder to the felt.



21. Continue stitching a seam until you reach the next component.

22. Hold the next component against the felt. Stitch a few loops through one end of the component to firmly attach it to the felt.

Remember, when you attach an LED, you must ensure the (+) side is close to the (+) side of the battery holder.

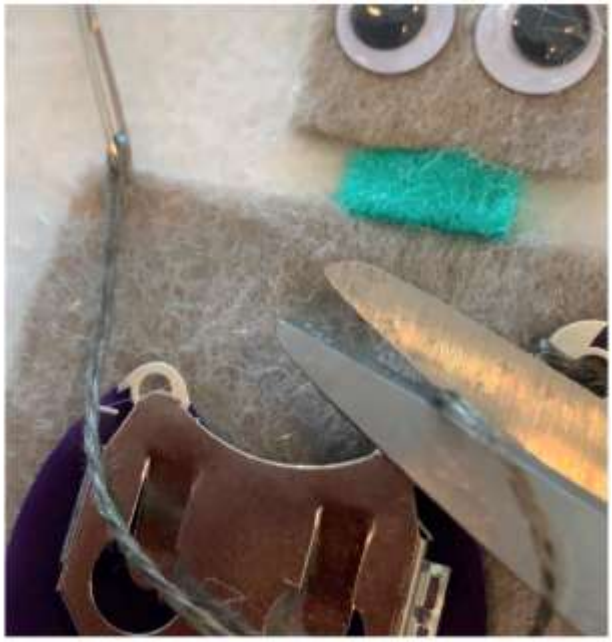
23. After attaching a component, tie off the thread and then cut it, leaving a small tail.

Before continuing, if your length of thread becomes too short to work with, remove the thread from the needle. Cut a new length of thread around 18” in length, rethread and knot the needle.

24. Repeat the process of threading the needle, knotting the thread, stitching, attaching a component, and cutting the thread until you reach the negative (-) terminal of the battery holder.

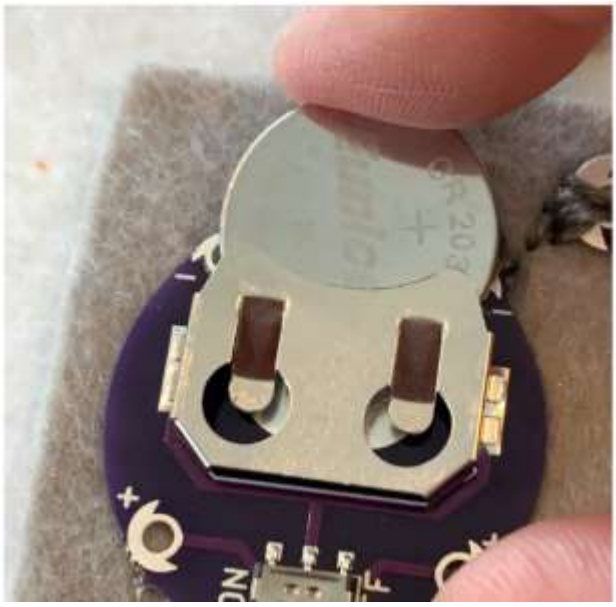


25. Stitch a few loops to attach the (-) terminal of the battery holder to the felt. Then cut the thread to leave a tiny tail.

Test your circuit and admire your handiwork

26. Place the coin cell battery into the battery holder. The side with the writing on it should be facing you. Slide the battery switch to the ON position.
27. Press the button or slide the switch in your circuit to ON. Your LED should light! If it does not light, troubleshoot your circuit. Common mistakes include turning the LED the wrong direction, crossing wires, or not securely stitching wires to components.



Connect

Throughout this project, you have been working as an electrical engineer and a wearables designer. Career electrical engineers work on many types of projects such as designing circuits for electronics devices, miniaturizing new components like batteries, and developing new ways to produce and transmit power for use in cities and homes.

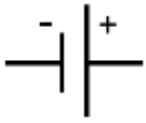
Wearables designers are often researchers or entrepreneurs who see a need and invent an entirely new product to meet that need. For example, Purdue University has developed a contact lens that can monitor medical conditions and deliver medications. A company called Waverly Labs has invented earbud translators that allow people speaking different languages to converse. And a dance group, called iLuminate, competed in America's Got Talent, performing in black body suits covered in electroluminescent wire and LEDs.

Can you imagine other ways in which electronic wearables can meet a want or a need? Continue learning and, one day, you may invent the next amazing wearable!

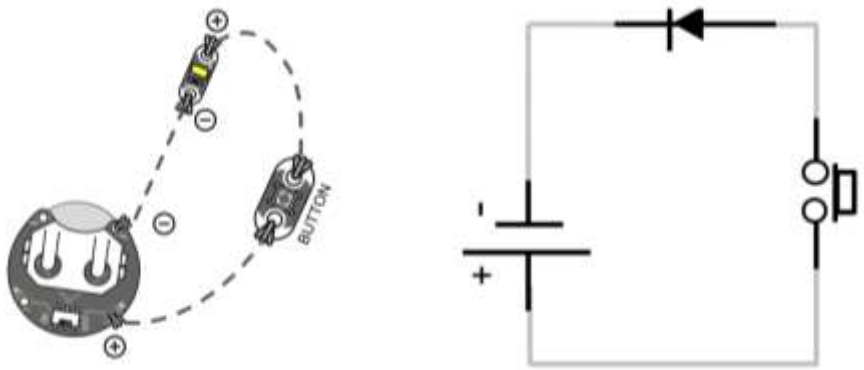
Extend

Draw schematics

Instead of drawing a picture of the actual circuit they are designing, electrical engineers draw a special diagram called a **schematic** to represent all the components and their wiring. A schematic diagram uses a symbol for each component as a sort of shorthand. Here are some symbols you might see in a schematic diagram:

	LED
	switch
	battery
	wire
	button

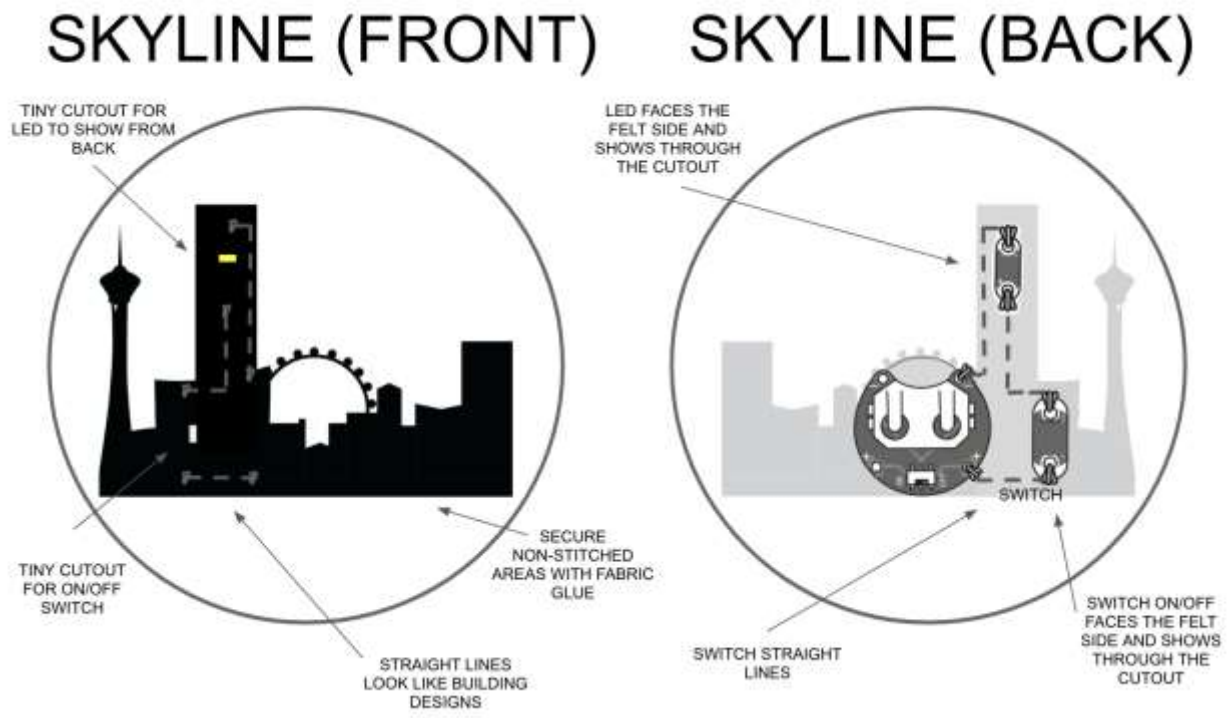
Here is an example of how an electrical engineer would represent a simple circuit (like the one on the firefly patch) as a schematic diagram:



Try drawing a schematic for the design you used in your patch!

Design on the front and back

You may prefer to hide the electronic components of your wearable. Here is a design that demonstrates this technique. The following patch features a city skyline scene.



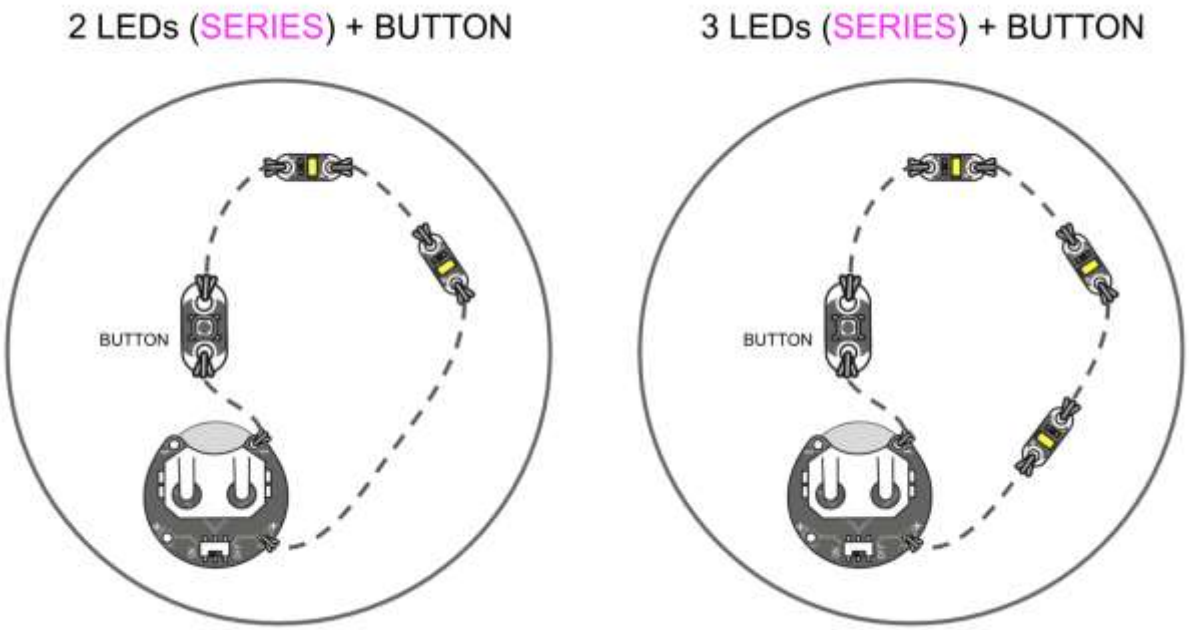
The artistic design is cut out of black felt and glued to the front of the patch, and the circuit is stitched onto the back of the patch. The cut holes allow the LED to shine through and make the switch to be accessible from the front of the patch.

Try creating your own front and back design!

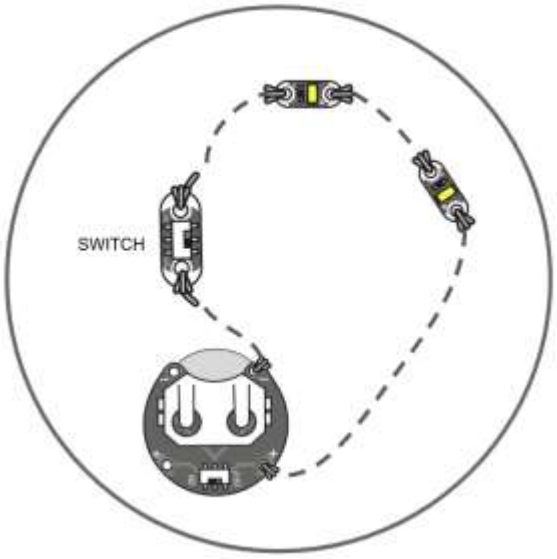
Designing with multiple LEDs

As you gain more experience with designing circuits and stitching soft circuits, you will want to use more components. For example, you may want to use all the LEDs in the ProtoSnap kit. Here are some ways in which you can use 2 LEDs and 3 LEDs in a circuit.

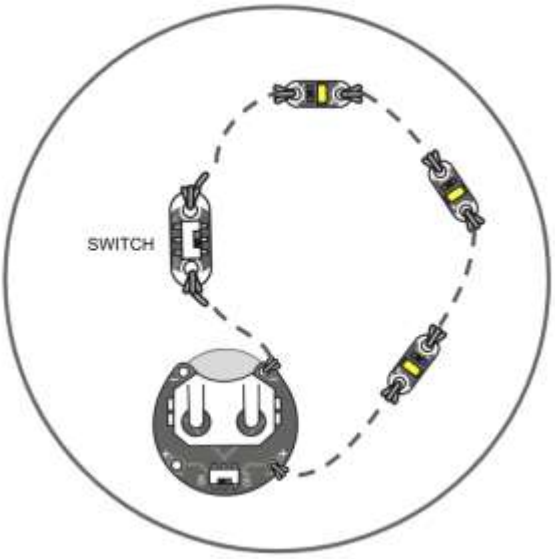
Arrange LEDs in a series which connects them in a single loop. This requires the least stitching. However, the voltage of the battery splits over the multiple LEDs which decreases the brightness of each LED. Here are some arrangements of multiple LEDs stitched in series.



2 LEDs (SERIES) + SWITCH

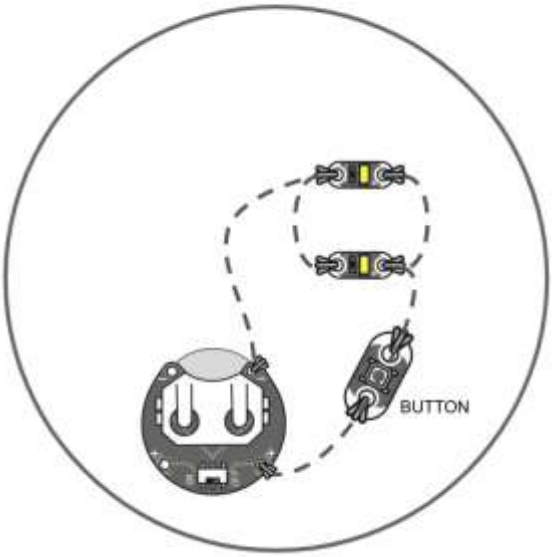


3 LEDs (SERIES) + SWITCH

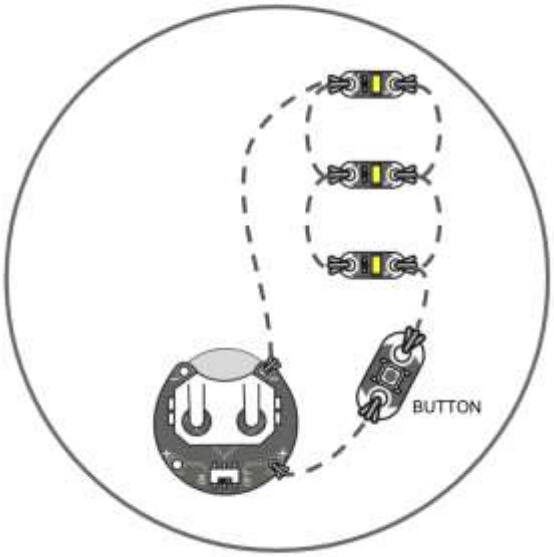


Another option – arrange LEDs in **parallel**. This means that the (+) sides all connect in a chain to the (+) side of the battery, and the (-) sides all connect in a chain to the (-) side of the battery. This requires more stitching than a series arrangement – but the voltage of each LED battery is the same as the battery voltage so all LEDs shine with equal brightness as a single LED. See some arrangements of multiple LEDs stitched in parallel below.

2 LEDs (PARALLEL) + BUTTON

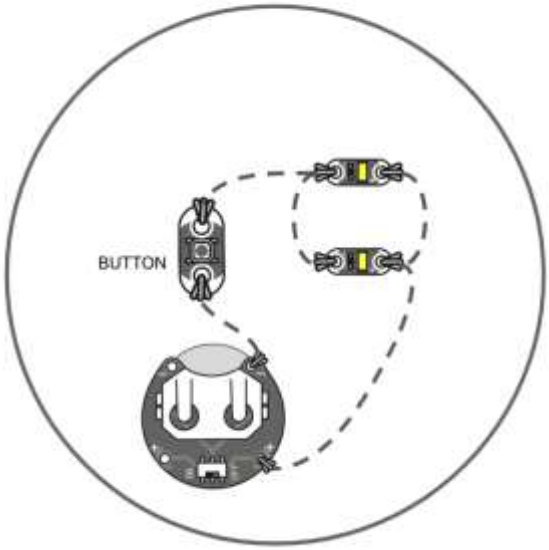


3 LEDs (PARALLEL) + BUTTON



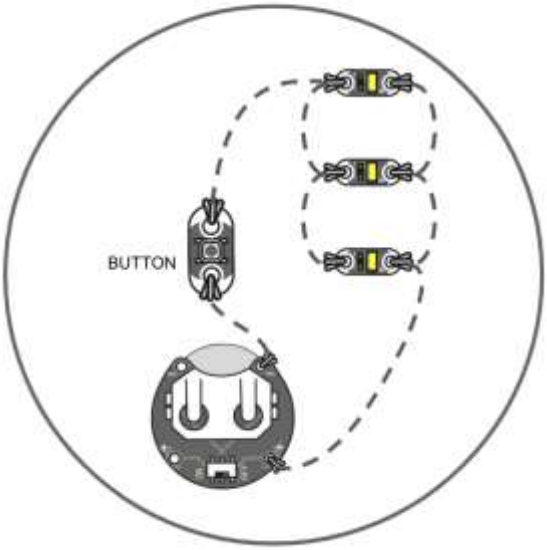
2 LEDs (PARALLEL) + BUTTON

Different placement of button

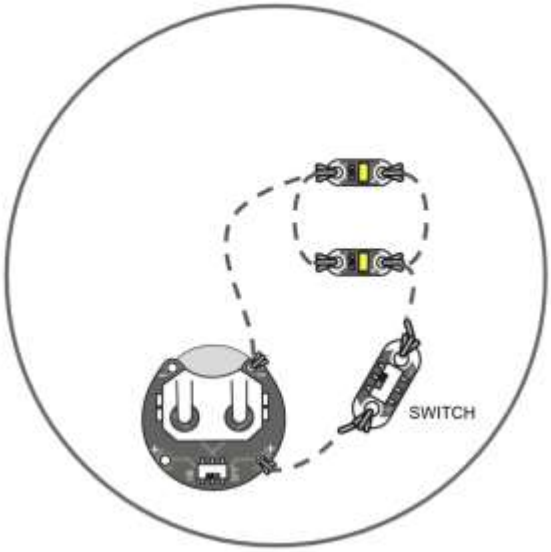


3 LEDs (PARALLEL) + BUTTON

Different placement of button



2 LEDs (PARALLEL) + SWITCH



3 LEDs (PARALLEL) + SWITCH