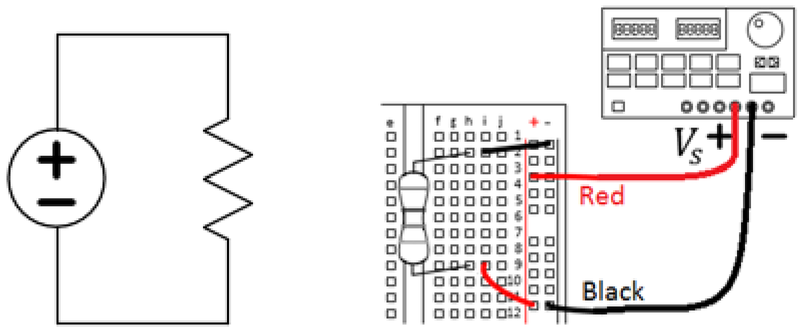
PreLab 1 Building Assignment

"Reading" a circuit schematic refers to the ability to predict the circuit's function and to reproduce a functional device using physcial components. A circuit schematic might be thought of as a blueprint for a circuit build. This is poor analogy, however, because a circuit schematic does not typically specificy the specific layout of components like a blueprint does. A better analogy is to think of a circuit schematic as a caracature of a real device. It simplifies realities into simpler symbols and simpler assumed mathematical models. It requires practice before the engineer can reliably take any circuit schematic and implement it in a clean, error-free prototype build. Figure 1 is an example of how different a circuit schematic may actually look from its implementation.



(a) (b)

Figure 1: An example: (a) A circuit schematic and (b) a physical diagram for the same circuit.

Circuit Build

In this exercise, we will systematically build a circuit while following a circuit schematic. While there is not a single way to map a schematic to a breadboard implementation, we will be very explicit in this build so that you can learn about methodologies and "best practices" that will aid in learning and trouble-shooting. Figure 2 shows the schematic of the circuit we will build.

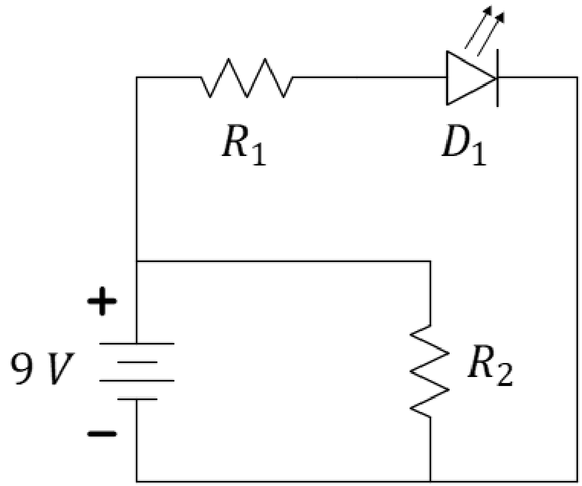


Figure 2: A circuit schematic to be implemented for Prelab 1 and brought to the first lab meeting.

In Figure 2, the symbol labeled $9\ V$ signifies a (multi-cell) battery, a voltage source admittedly short of “ideal”. You have a 9-volt battery in your kit (Figure 3) as well as the means for connecting it to your circuit. For the labeled resistors of Figure 2, let’s use $R_1 = R_2 = 1\ k\Omega$ so that these two resistors happen to have the same value of resistance. You can find these resistors by looking for the colored line patterns on the resistors in your kit (Figure 4); you are looking for paint stripes of brown, black, red, gold, in that order. More about how to interpret these colored lines will be provided later. The triangular symbol with arrows pointing away labeled D_1 is a light-emitting diode (LED). Let’s use a red-colored LED for this prelab exercise. Locate these materials in your kit to be ready to start your build.

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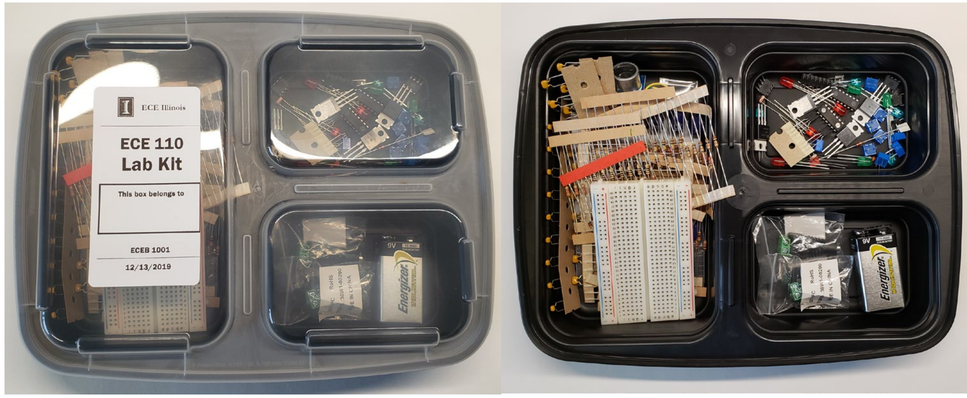

Figure 3: The ECE 110 Electronics Kit.

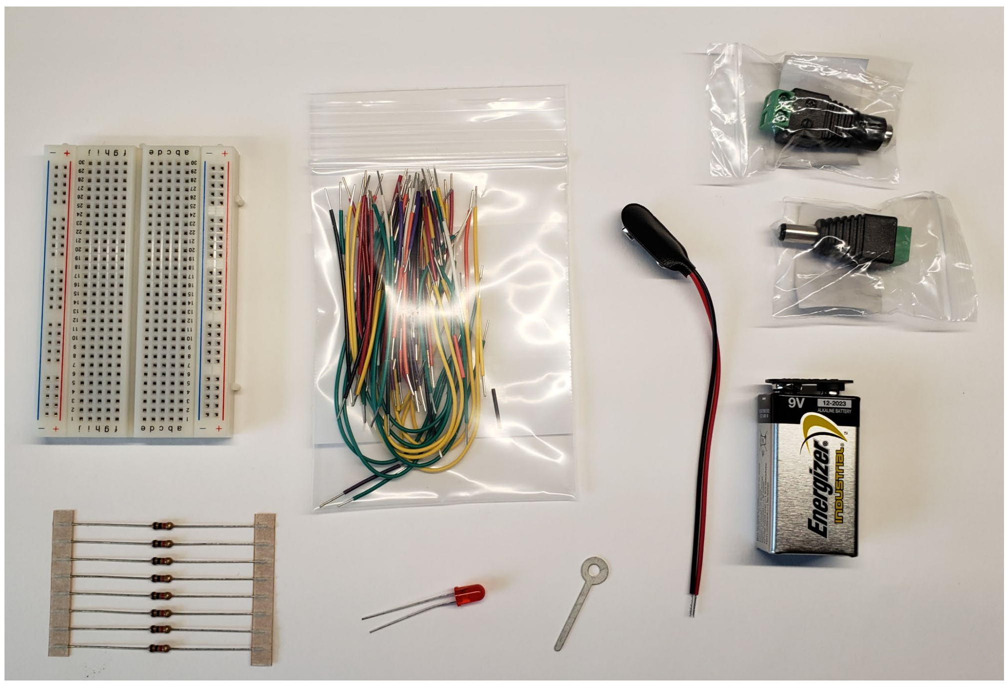

Figure 4: Parts needed for this procedure. The resistors are in the lower-left corner.

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Once you have found the parts of Figure 4, open the bag of wires and select a medium sized wire. Place this wire through the hole on the “ring terminal” and give it a few twists, essentially creating a kind of “key ring” for it. The ring terminal will be used in ECE 110 as a low-cost, light-duty screwdriver. The key ring will make it both easier to locate in your kit as well as easier to pick up from your table.

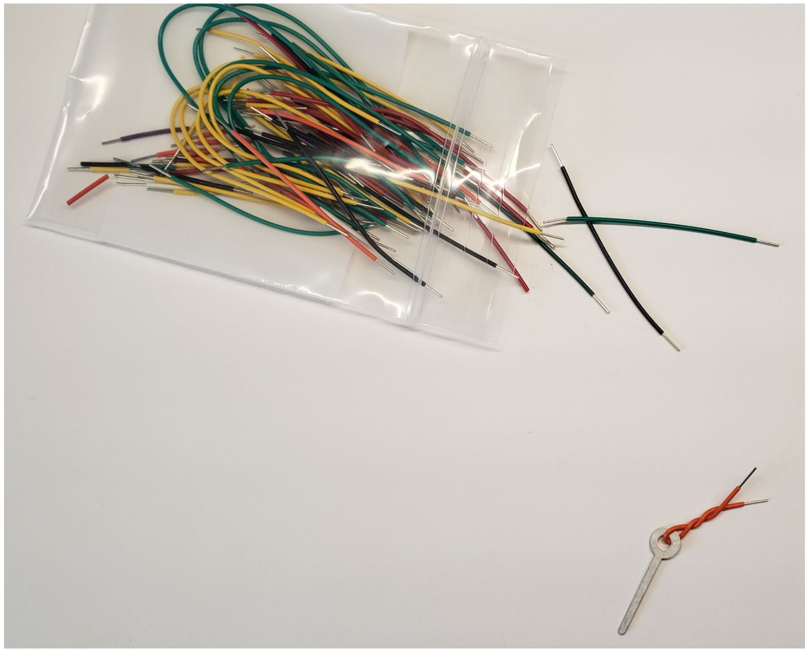

Figure 5: The wire bag and ring terminal to be used as a screwdriver.

Use the screwdriver to attach the 9-volt adaptor to the “barrel jack adapter” as shown in Figure 6. You may need to loosen the terminal screws on the barrel jack adapter by turning them counterclockwise until the wires will slide into the terminal space. Gently tighten the terminal connectors by turning the screws clockwise. Do not overtighten or you will bend your screwdriver. Be sure that the terminals are holding the bare wire and not the insulation on the wires. It is critical that you attach the red wire to the **positive** terminal and the black wire to the **negative** terminal.

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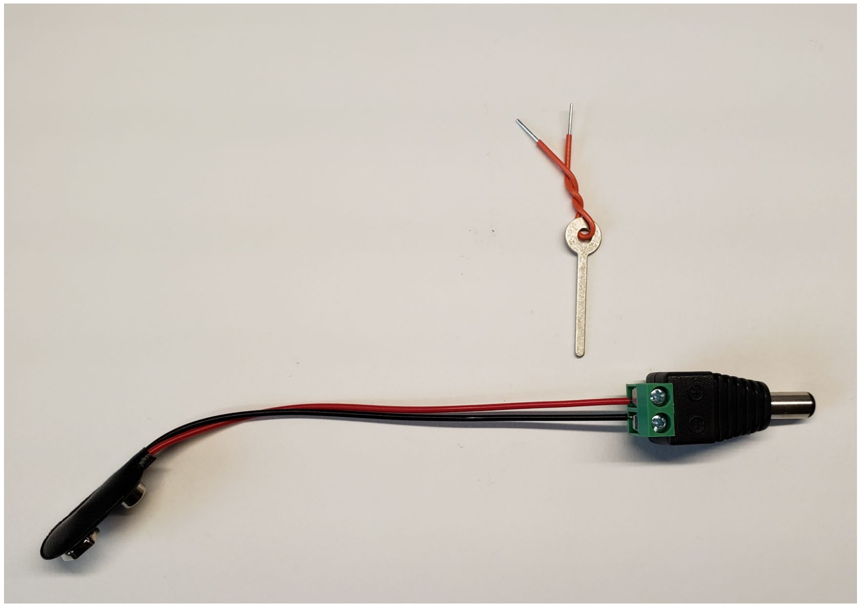

Figure 6: The assembled 9-volt-to-barrel adaptor.

Now use the screwdriver to attach a red and a black wire to the complementary barrel “jack” as shown in Figure 7. Again, attach the red wire to the positive terminal and the black wire to the negative terminal. Note that using two different length wires will reduce the likelihood of accidentally shorting your battery (Figure 8).

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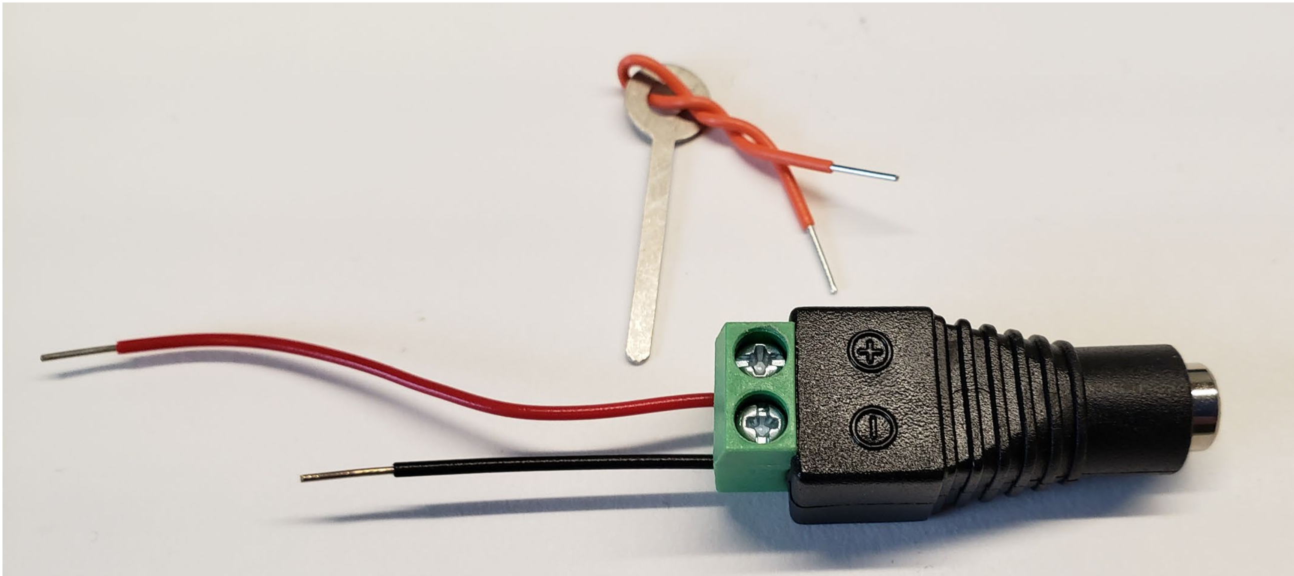

Figure 7: Assembled barrel-to-wire adaptor.

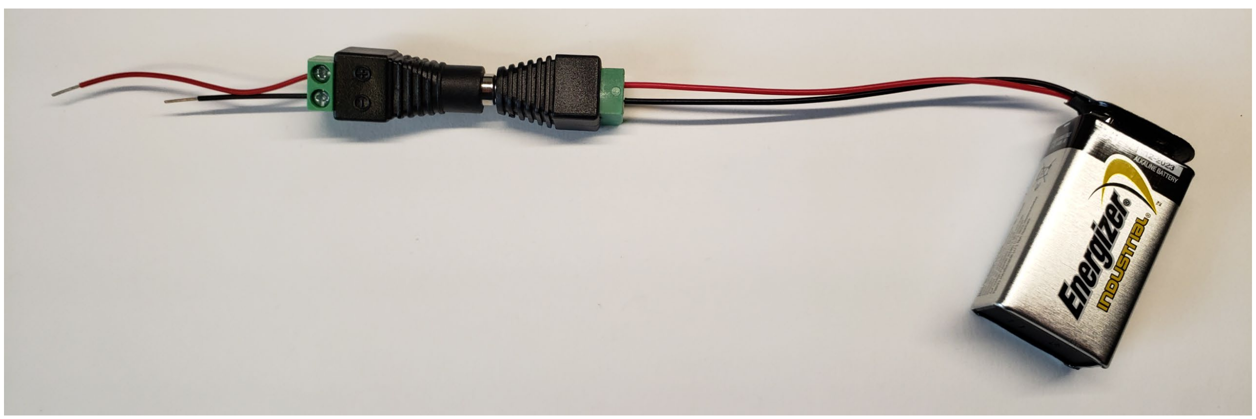

Figure 8: A 9-volt battery prepared for breadboard usage.

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You can now attach the 9-volt battery to your breadboard's "power rails" as shown in Figure 9. The red and blue lines on your breadboard outline the available spaces now connected to the positive and negative sides of your battery, respectively.

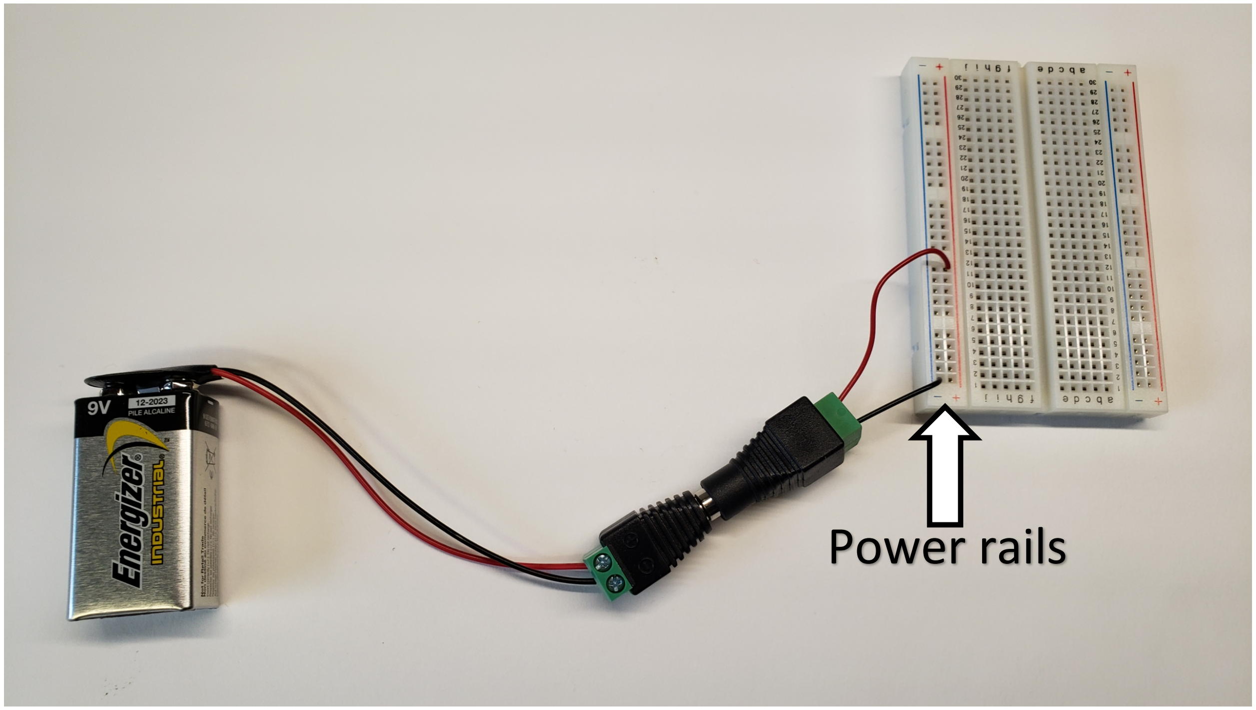

Figure 9: Attaching the battery to the breadboard's "power rails."

On your circuit schematic, you might consider color-coding your nodes so that they are easier to identify while building your circuit. In Figure 10, the ***nodes*** corresponding to the positive and negative sides of the battery have been highlighted with red and black colors.

What is a node? The answer might not be as simple as you might think. First, you need to understand that our circuit schematics are actually based on something called "lumped circuit models". This means that all the interesting stuff has been lumped into circuit symbols representing real-life devices (dry cell batteries, carbon-composition resistors, silicon LEDs, etc.) but with behavior modeled by a simpler math. These lumped components are joined by what we call **nodes** which may be thought of as wires with no resistance. However, it is faulty to think of them as physical wires as nodes don't necessarily represent how the

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connections between elements might be accomplished. In Figure 10, the red node, for instance, is available along the entire power rail while the circuit schematic fails to imply anything about this.

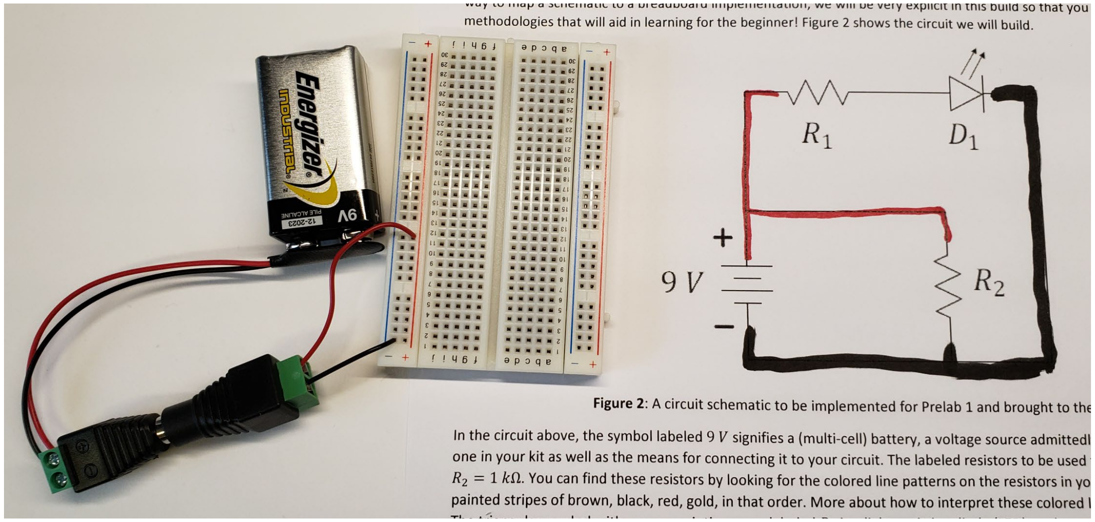

Figure 10: Using color coding to identify elements connected to nodes.

But enough about the abstract nature of schematics, let's get back to the build! Disconnect your battery by separating the barrel connection. The red and blue power rails represent the battery for the remainder of our build (see Figure 10). Removing the battery reduces the potential for catastrophic failure due to mis-wiring of our circuit. By "catastrophic", we mean failure of a device caused by, say, short circuiting your battery.

Now we can continue our circuit construction by focusing on a single "loop", that is a path through the circuit that starts at one node and then returns to the same node. In Figure 11, we will focus on loop 1 that goes from, say, the black node at the negative side of the battery, through the battery to the red node and then through R_2 before returning to the black node. Since the red and black nodes are already physically represented on our breadboard, all that remains to complete this loop is to add R_2 to the circuit between the red and black nodes.

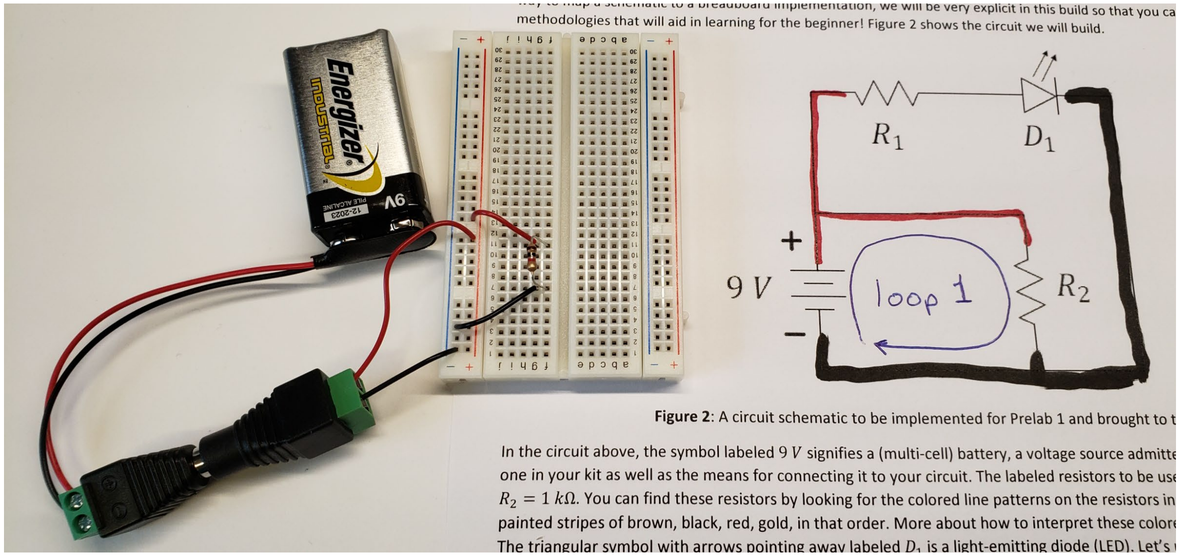

Figure 11: Defining a loop for implementation on the breadboard.

Locate the $1\ k\Omega$ resistors in your kit and remove one for use as R_2. These resistors will easily pull from the ribbon, however you may wish to cut one free (see Figure 12) to avoid any residual glue that could affect getting a good connection in the breadboard. The wires (leads) of the resistor are thin enough to be cut by an ordinary scissors.

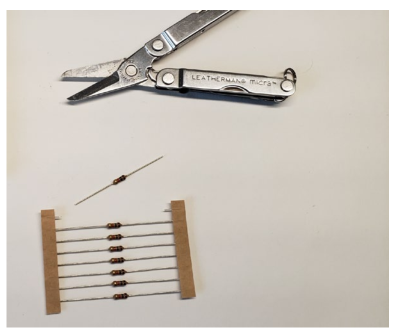

Figure 12: Remove a resistor by pulling or cutting it free of the ribbon.

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Now, we’ll add the resistor to the circuit. In Figure 13, you can see that a red wire was used to <u>extend</u> the “red node” to another location on the breadboard and a black wire similarly extends the black node. The resistor is then placed on the breadboard in available holes on those two rows of the breadboard completing loop 1. The battery is shown connected in Figure 13, but it is appropriate not to have it connected until the circuit is complete.

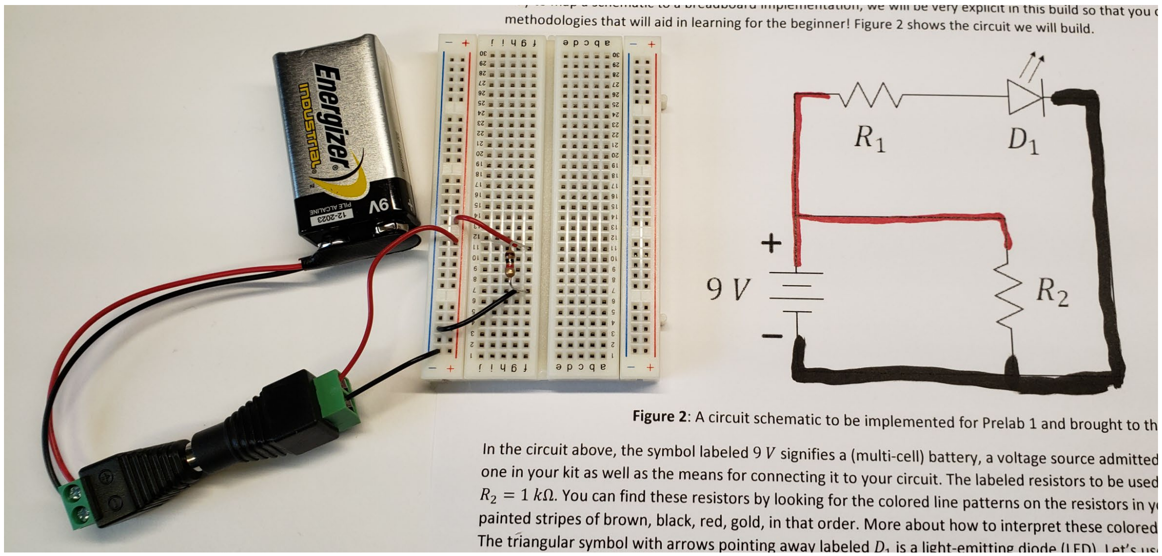

Figure 13: Completion of the loop containing R_2.

Returning our attention to the circuit schematic, we see that there are two more components not yet accounted for on our breadboard implementation, R_1 and D_1. There is also a third node that connects these two elements. In Figure 14, we have color-coded that node in green.

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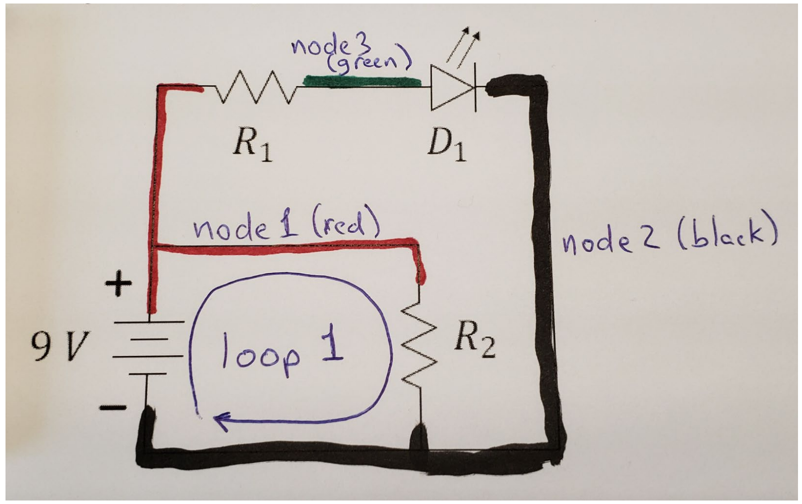

Figure 13: Identifying a third node on our schematic.

Now, we form another loop. See Figure 14. Loop 2 starts at the black node, goes through the battery to the red node, through R_1 to the green node, and through D_1 back to the black node. This second loop has touched all the remaining elements of our circuit. Once loop 2 has been mapped to the breadboard, our circuit will be complete.

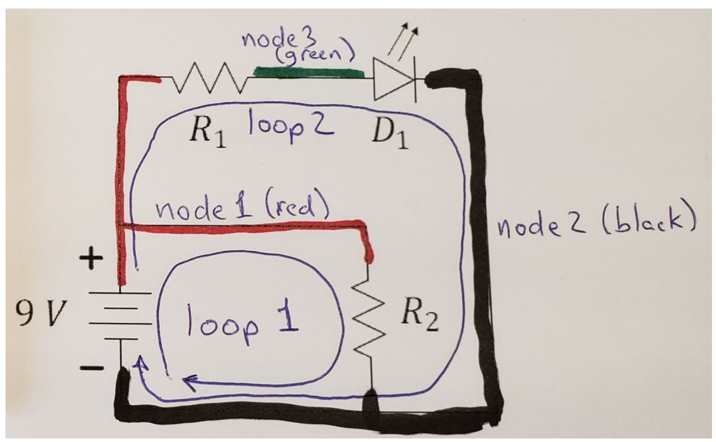

Figure 14: A second loop has touched all the remaining elements.

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In consideration of the LED, we need to realize that this diode, like all diodes, is directional and will only work as intended when placed in the right orientation. Close inspection of the LED will reveal that one of its leads is slightly longer than the other. The shorter lead will need to be placed towards the negative side of the battery (the black node) as shown in Figure 15.

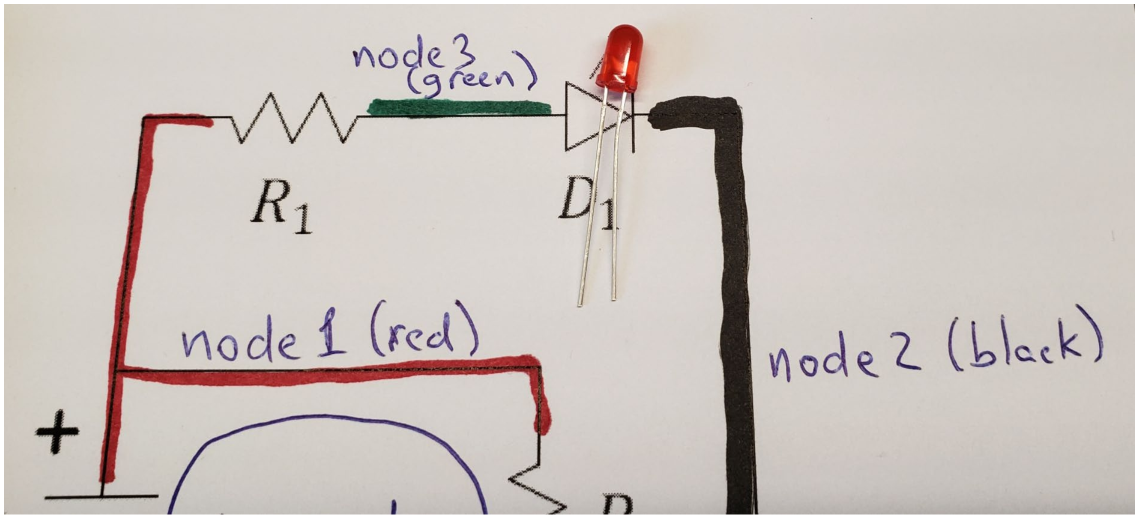

Figure 15: The shorter LED lead (wire) needs to be placed towards the negative side of the battery.

Bending the longer lead into a "dog leg" can help you identify it more quickly and help you place it properly into the circuit. Just remember that the dog lifts its leg to pee on the top of the hydrant and you will remember that the longer leg of the LED needs to be raised to the higher voltage to be illuminated. See Figure 16.

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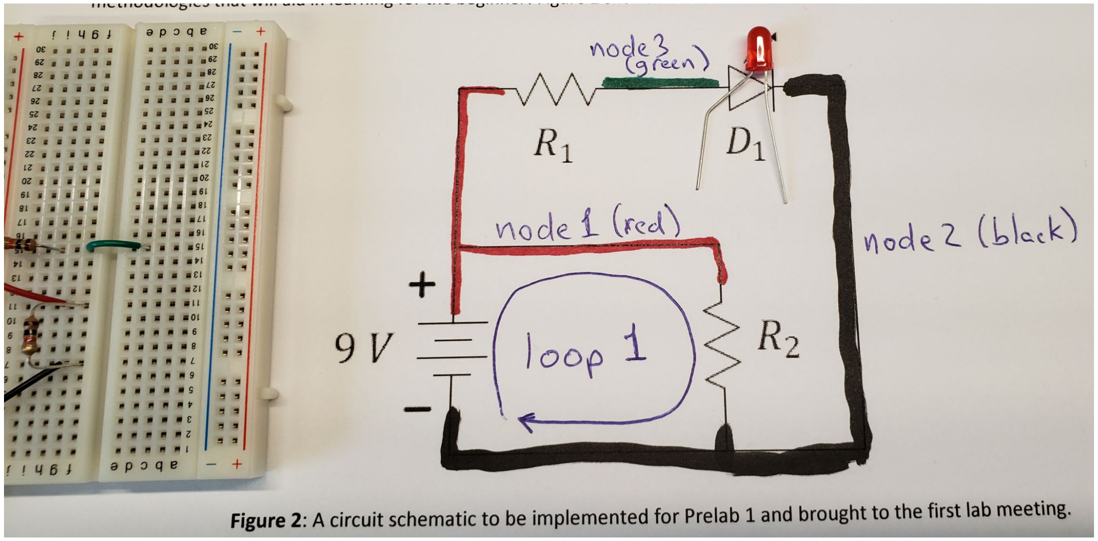


Figure 16: A dog leg can help you remember how to insert a directional element like the LED.

In implementing loop 2, we again note that the battery is already present and the black and red nodes are already implemented by the power rails. In this implementation of Figure 17, we have chosen to connect R_1 directly to the red power rail and into an isolated region of the breadboard. In another location on that same row, we used a green wire (representative of the green node) to extend the green node across the center of the board (normally, the row is not connected through the center). Now, we have added the LED from the green node to another isolated position in the breadboard and then used another black wire to complete the connection to the negative end of the battery. Reinsertion of the battery should cause the LED to illuminate.

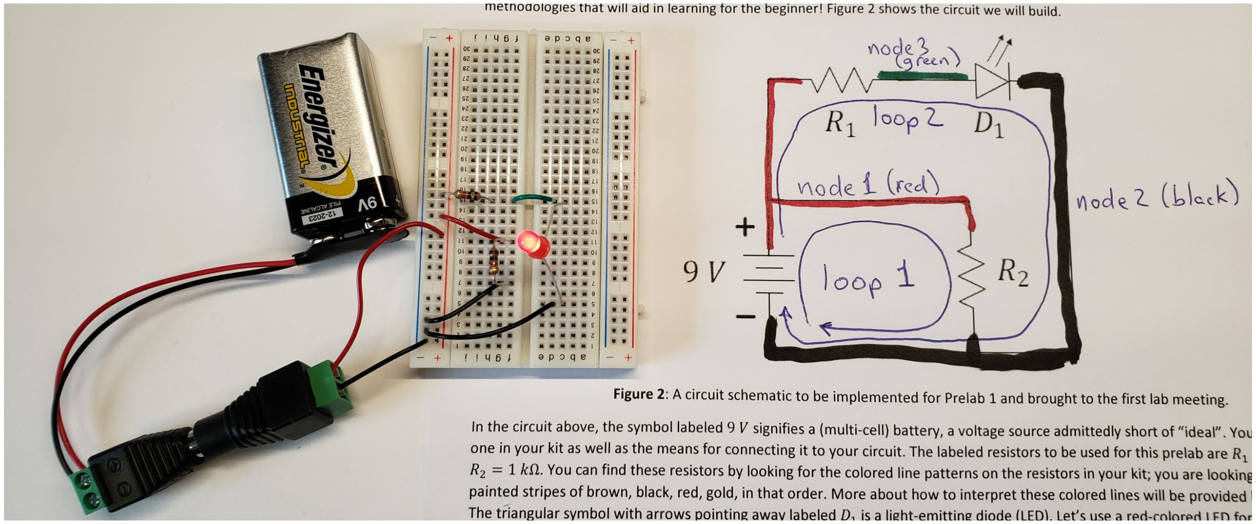
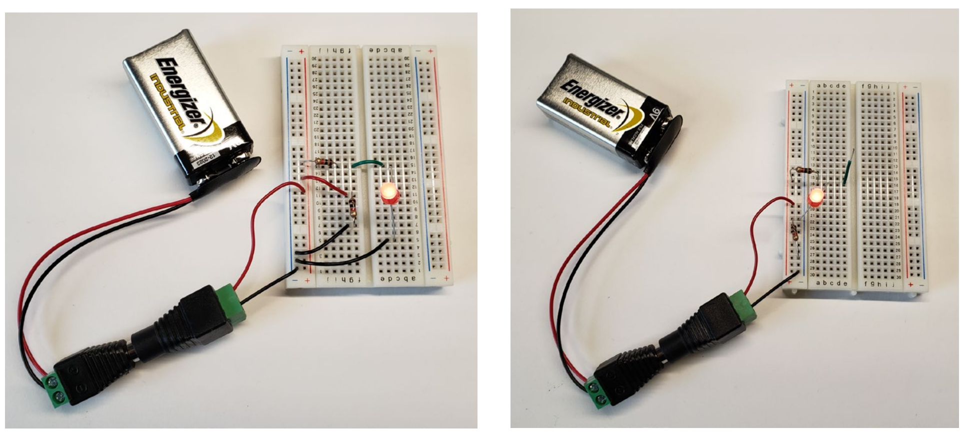


Figure 17: Completing the circuit build.

While the completed build is functional, we might also recognize that it could have been made using fewer wires and less space.



(a) (b)

Figure 18: (a) The first build and (b) a cleaner version.

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Figure 19 shows a close-up view of the cleaner circuit using less space and fewer wires. Notice that the green wire was left in the circuit to serve as a flag noting the location of the green node. It serves no function, but flags can make debugging easier by speeding your interpretation of the breadboard and mapping it back to your schematic!

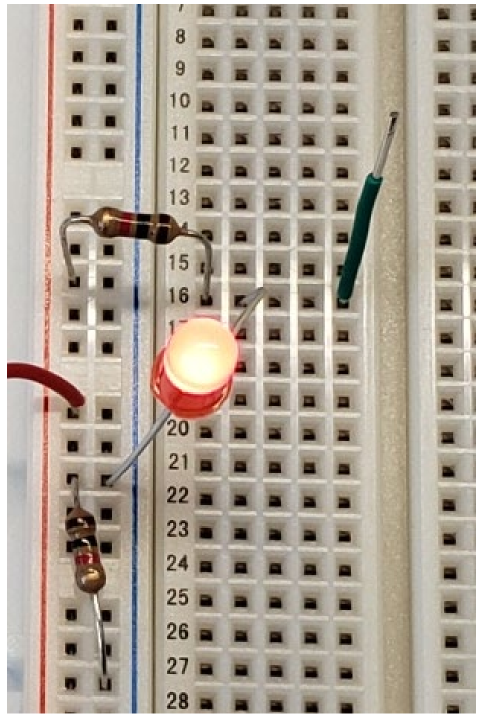

Figure 19: A close-up view of Figure 19 (b).

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As a final note, we should mention that circuit schematics are not unique either. Note how Figure 22 is the exact same circuit implementation as that of Figure 2. To confirm this, just note that the two loops used to construct your circuit are identical here.

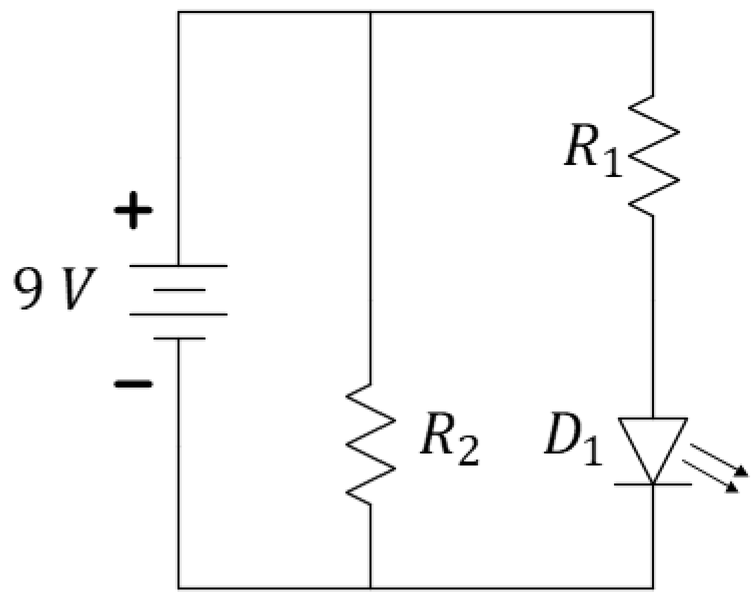

Figure 22: An alternate circuit schematic matching the circuit you built today.

Finally, it is time to put your kit away and save your circuit for grading at the next lab meeting. You will want to

- Disconnect your battery. Leaving it attached will likely drain it dead after some amount of time.
- Place your battery in its own compartment to limit the possibility of accidental shorts. A short-circuited battery can easily overhead and possibly ignite! (Figure 20)
- Place your completed circuit into the electronics kit where it is least likely to be distorted by the transport in your backpack.
- Put the lid on correctly so that wires and other devices cannot migrate into the battery compartment. (Figure 21)

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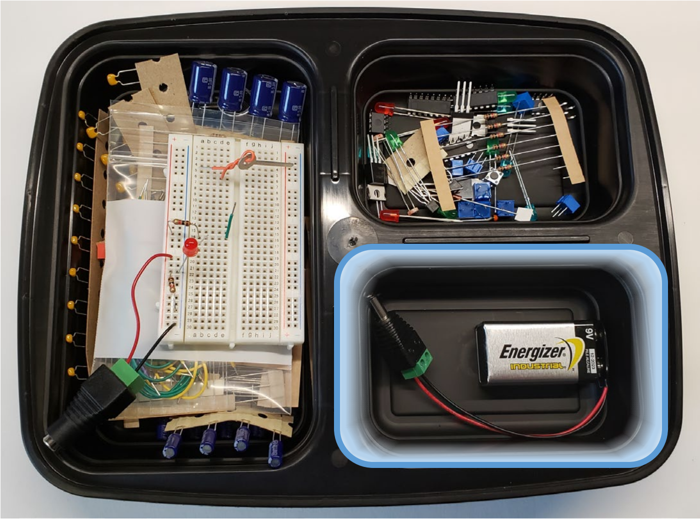

Figure 20: Give the battery its own compartment to avoid short-circuits and fire!

Figure 21: Place the lid so that the compartments are covered properly and wires and devices cannot migrate between compartments.