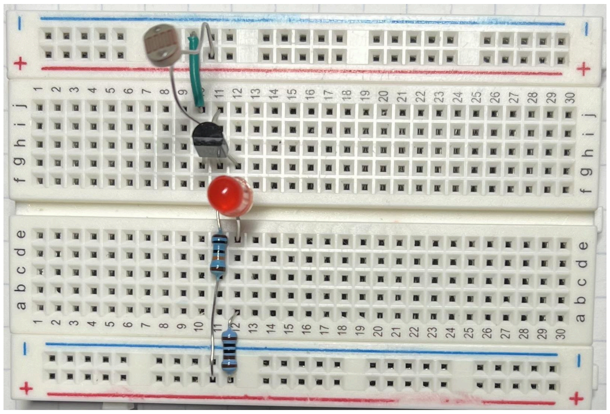
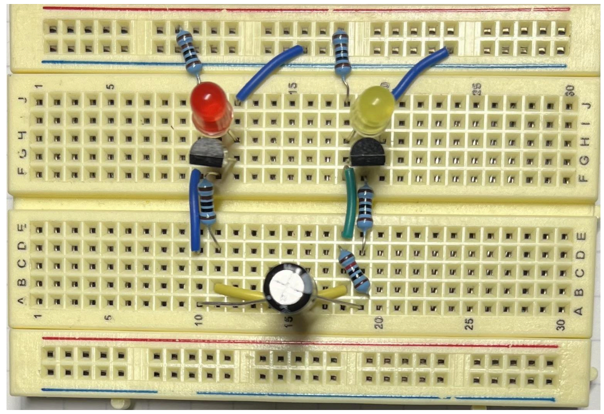
MAKING WAVES with radio

FACILITATOR GUIDE
Transistors





Learning Objectives

1. Understand how a basic circuit controls current with a mechanical switch.
2. Observe how an LED turns on when the circuit is complete.

Activity Goals

This activity includes five parts designed to help students become familiar with the breadboard and explore how basic electronic components work together:

- In Part A, students build a simple circuit to turn on a light.
- Part B introduces a switch to control the flow of electricity.
- In Part C, students use a photoresistor to create a light-sensitive circuit.
- Part D builds on this by integrating a transistor and a photoresistor to turn a light on or off depending on how much light is present.
- Finally, in Part E, students create a blinking light circuit using transistors and a capacitor.

This sequence of activities is intended to introduce students to breadboarding and help them recognize and use essential electronic components, including resistors, capacitors, transistors, photoresistors, and LEDs.

Materials

Part A: Simple circuit
- Breadboard
- 3V battery
- 1 LED
- 1 100Ω resistor
- 1 1KΩ resistor
- 1 10KΩ resistor
- 1 100KΩ resistor
- wires

Part B: On/Off Circuit
- Breadboard
- 3V battery
- 1 LED
- 1 tactile button (switch)
- 1 100Ω resistor
- Wires

Part C: Light-sensitive Circuit
- Breadboard
- 3V battery
- 1 LED
- 1 Photoresistor (LDR)
- Wires

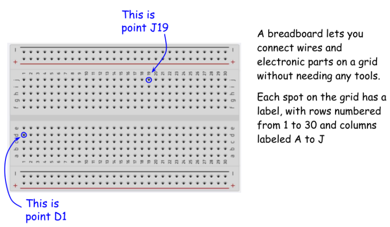
Part D: Smart Light-sensitive Circuit
- Breadboard
- 3V battery
- 1 LED
- 1 Photoresistor (LDR)
- Wires
- 1 1KΩ resistor
- 1 100KΩ resistor
- 1 NPN Transistor (2N2222)

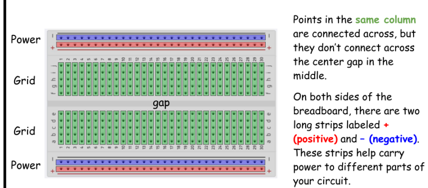
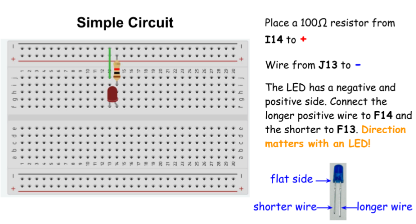
Part E: Blinking Lights
- Breadboard
- 3V battery
- 2 LED (preferably of different colors)
- Wires
- 4 1KΩ resistor
- 1 100µF capacitor
- 1 10µF capacitor
- 2 NPN Transistor (2N2222)

Advance Preparation

- Test all the circuits before the activity. Look at the troubleshooting section for additional guidance.
- Check the accompanying slides. Tweak them as necessary to provide the support you think your learners will need.

Activity Procedure

<table>
<tr><th>Slide</th><th>Description of Activity and Key Takeaways</th></tr>
<tr><td>Part A
Simple Circuit</td><td>Note: Before starting this activity, make sure students are familiar with the basic idea of a circuit. It's helpful to use the <u>PhET Circuit Construction Kit</u> simulation and have students build a simple circuit with a battery and a lightbulb. This gives them a visual understanding of how electric current flows and sets a foundation for the hands-on breadboard work.</td></tr>
<tr><td></td><td>Introduce the breadboard and show students how to identify the name of each point on the grid.

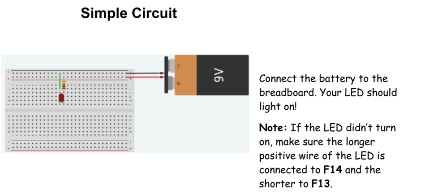
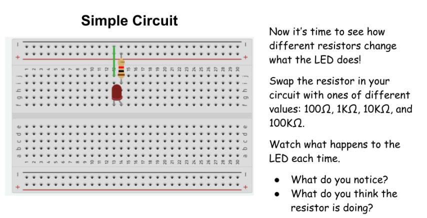
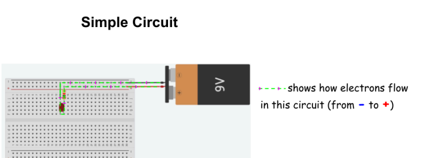
Note: The instructions students will follow to build these circuits use the names of the breadboard points for easy identification.</td></tr>
<tr><td></td><td>Describe the main parts of the breadboard, including how rows are connected internally and how the power rails work.</td></tr>
<tr><td></td><td>Distribute materials to each student or small group.

Note: Provide only the 100Ω resistor at this point, as students will be challenged to try other resistor values later in the activity.

Use the instructional slide to guide students step by step as they build the first circuit together.

Direct attention to the LED and ask students to observe and identify the long wire (anode), short wire (cathode), and the flat side of the LED.

Emphasize that direction matters when connecting an LED in a circuit, and that reversing it will prevent it from lighting up.</td></tr>
</table>

	Instruct learners to connect the battery to the breadboard. ***Note:*** *Walk around to check student setups. Common issues include reversed polarity, loose wire connections, or not fully pressing wires into the breadboard. If the circuit doesn't work later, this is the first place to check!*
	Challenge students to explore how resistor values affect the LED. Ask them to swap the resistor in their circuit with 100Ω, 1KΩ, 10KΩ, and 100KΩ resistors and observe what happens. ***Note:*** *At this point, students do not need to know how to read resistor color bands. It's perfectly fine if they can simply recognize and distinguish the two main resistors used in this activity: the 1KΩ and the 10KΩ. You can label or group them ahead of time to make this easier.* Discuss student observations using the slide prompts. Look for students to notice that some resistors make the LED brighter or dimmer. Highlight that higher resistance allows less current to flow, which makes the LED dimmer. Encourage students to use their own words to describe what the resistor is doing. Suggestion: Use the [PhET Circuit Construction Kit] simulation to help students visualize how resistors slow down the flow of electrons in a circuit.
	Use the slide diagram to show how electrons flow through the circuit. Visualizing the flow helps students connect what they observed (changes in brightness) to what's happening inside the wires. It reinforces the idea that resistors slow down the flow of electrons, which affects how much energy reaches the LED.

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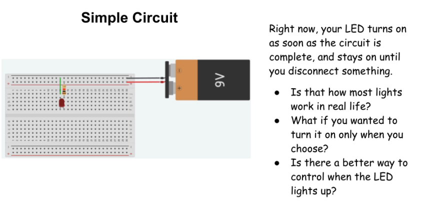
<td>
</td>
<td>Use this slide to prompt students to think about control in circuits. Encourage them to connect this to real-life examples, like light switches at home. Look for students to recognize that most lights have a switch, and that adding one to the circuit would let them decide when the LED turns on or off.</td>
</tr>
<tr>
<td>Part B
On/Off Circuit</td>
<td>Mention that in the next part of the activity, they will get a chance to add a switch to the circuit to turn the LED on and off.</td>
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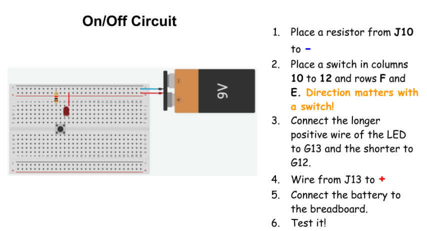
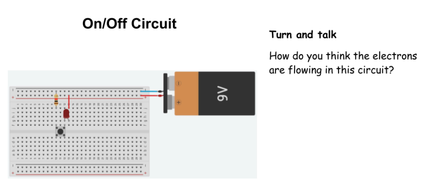
<tr>
<td>
</td>
<td>Distribute materials to each student or small group.

Use the instructional slide to guide students step by step as they build the second circuit together.

Emphasize that direction matters when connecting a switch in a circuit

Ask students to test their circuit. They should see the LED turn on when the button is pressed and turn off when it’s released.</td>
</tr>
<tr>
<td>
</td>
<td>Ask students to turn and talk using the slide prompt:

How do you think the electrons are flowing in this circuit?

After a minute or two of discussion, invite volunteers to come to the board and draw or explain how they think electrons are moving through the circuit.

Look for students to recognize that electrons flow from the negative side of the battery, through the switch, through the LED, and back to the positive side.</td>
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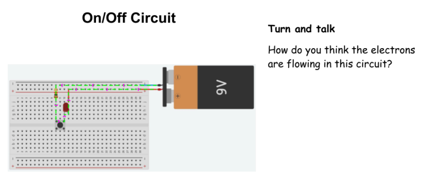
<td>
</td>
<td>Use the slide to show students how electrons are flowing.</td>
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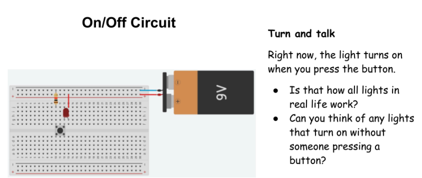
<td>
</td>
<td>Use the slide prompt to spark curiosity about automatic circuits:

Right now, the light turns on when you press the button.
Is that how all lights in real life work?
Can you think of any lights that turn on without someone pressing a button?
Encourage students to think of real-life examples like night lights, motion-activated lights, or refrigerator lights. The goal is to build the need for a circuit that responds to the environment without human input, setting up the next activity with the photoresistor.</td>
</tr>
<tr>
<td>Part C
Light-sensitive Circuit</td>
<td>Mention that some circuits have special sensors that can help them control when something turns on or off. Let students know they'll now build a circuit that uses a photoresistor to control the LED based on how much light is present.</td>
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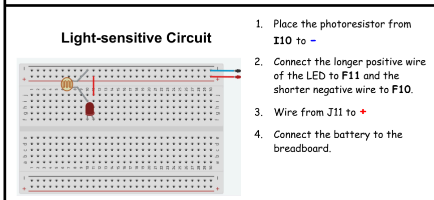
<td>
</td>
<td>Distribute materials to each student or small group.

Use the instructional slide to guide students step by step as they build the second circuit together.</td>
</tr>
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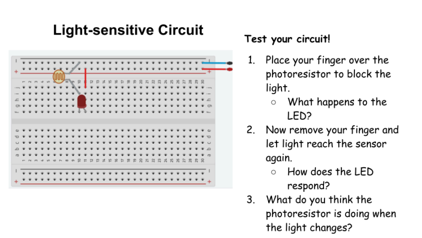
<td>
</td>
<td>Encourage learners to test the circuit by placing and removing their finger over the photoresistor. Look for students to observe that covering the photoresistor blocks light and causes the LED to turn off, while uncovering it allows light in and turns the LED on.

Prompt students to explain why this might be happening using what they know about how the circuit works.</td>
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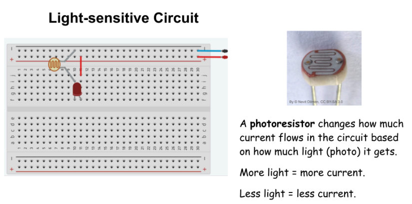

</td>
<td>Use the slide image to describe how the photoresistor works.</td>
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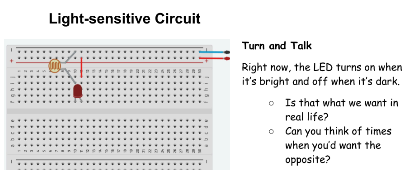

</td>
<td>Ask students to turn and talk with the slide prompts:
Right now, the LED turns on when it's bright and off when it's dark.

Is that what we want in real life?
Can you think of times when you'd want the opposite?

Use this prompt to help students recognize a mismatch between their circuit and how many real-world lights work. Encourage them to think of examples like night lights or streetlights, which turn on when it gets dark. This sets up the need to redesign the circuit so it turns the LED on in the dark instead of the light.</td>
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<tr>
<td>Part D
Smart Light-sensitive Circuit</td>
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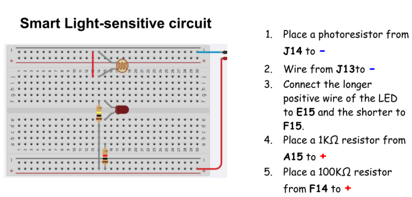

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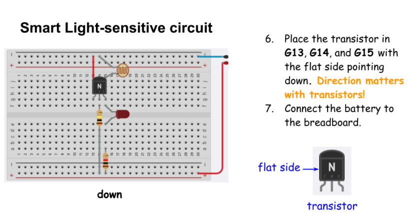

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<td>Use the instructional slide to guide students step by step as they build the second circuit together.

Emphasize that direction matters when connecting a transistor in a circuit</td>
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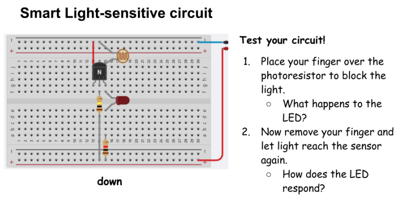
<td>
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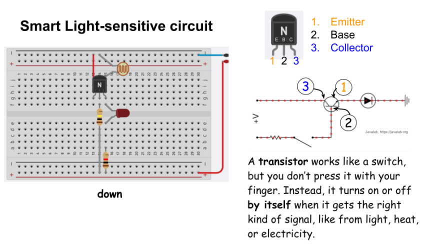
<td>
</td>
<td>Use the slide images to describe how the transistor works. The slide text provides a simple overview of the transistor as a switch that controls the flow of current.

Note: The position of the base, collector, and emitter is not the same on all transistors. For example, on the BC547, the emitter is on the right when the flat side is facing you. On the 2N2222, the emitter is on the left. Always check the datasheet or diagram before connecting.</td>
</tr>
<tr>
<td>Part E
Blinking Lights</td>
<td>Now that students understand how a transistor can act like a switch, this is a great moment to show how we can use it to build more complex circuits. Let them know they'll explore how transistors, when combined with other components, can control circuits in more interesting and useful ways, like making lights blink automatically.</td>
</tr>
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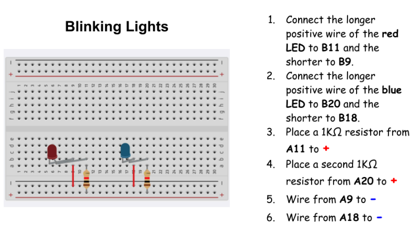
<td>
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<td></td>
<td>Use the instructional slide to guide students step by step as they build the second circuit together.

Emphasize that direction matters when connecting a transistor in a circuit.

Note: While some capacitors can be connected in either direction, the capacitor used in this activity is an electrolytic capacitor, which is polarized. If it's connected backward, it can be damaged or even fail.</td>
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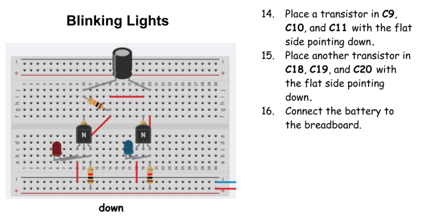
<td>
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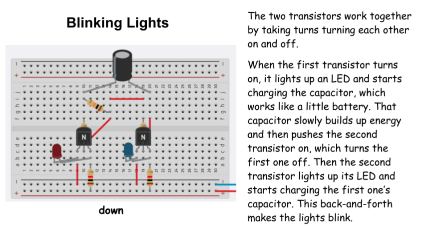
<td>
</td>
<td>Use the slide image to describe how the transistors and the capacitor in the circuit work together to make the LED blink.</td>
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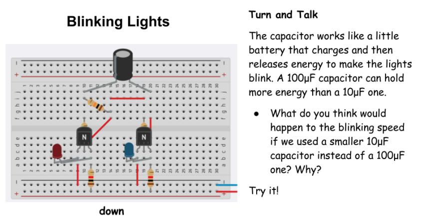
<td>
</td>
<td>Remind them that the capacitor works like a little battery that charges and releases energy to make the lights blink. Ask learners what they think would happen to the blinking speed if we used a smaller 10µF capacitor instead of a 100µF one?

Look for students to reason that a smaller capacitor charges and discharges faster, making the lights blink more quickly.

Provide a 10µF capacitor and encourage them to test their predictions.</td>
</tr>
</table>

Troubleshooting

Use the following checklist to help you diagnose when a circuit is not working as expected.

- Current flow - Check that there is a path for current to flow away and back to the power supply/battery. Use your finger to trace the circuit from a + of your battery through each component.
- Connectors - Check that the connectors are fully seated in the breadboard and they are using conductive material/wires.
- Power - check that there is enough voltage to power the circuit. (e.g. check if the batteries are old or new using a multimeter. Place the multimeter leads across the ends of the battery.)
- Parts - Check that the parts match the suggested parts above. For example, check that the resistance for the resistors is not so high that it stops the current from flowing. (Any changes in R, I, or V will affect the circuit. Check V=IxR or recommended parts list.)

- Polarity and direction: some parts only work in a circuit when placed in a certain direction. Check the +/- .

Notes to the Presenter

Working with small groups:

- Allow each group to build and test the blinking circuit independently.
- Circulate among groups to offer support and ask guiding questions.
- Provide resistor and capacitor options at a central “supply station” to promote student choice and experimentation.
- Encourage groups to share discoveries informally with other groups or post quick notes/predictions on a shared class board.

Working with large/class groups:

- Use shared reflection time (e.g., class discussion or class board responses) to make group learning visible. These prompts can help you engage students with each other’s ideas:
    - *Can someone build on what [Student A] just said?*
    - *Does anyone have a different explanation or design that worked?*
    - *Why do you think your group’s circuit blinked faster than theirs?*
    - *Can someone explain your group’s design to someone from another group?*
    - *Let’s pause for a second. What patterns are we seeing across groups?*
    - *Can anyone rephrase [Student B]’s idea in their own words?*

Supporting equitable participation

- Pair verbal instructions with clear visual diagrams (project breadboard layout and wiring steps).
- Demonstrate each step physically while describing it aloud.
- Use gestures or labeled visuals to reinforce terms like “LED,” “resistor,” “current,” “flow,” etc.
- Offer pre-stripped wires or pre-assembled circuit components if fine motor skills are a barrier.
- Pair students strategically for mutual support, especially when one peer has strong verbal or hands-on skills.

Content Background

Transistors are foundational to modern electronics. They function as electrically controlled switches or amplifiers, allowing a small input current to control a larger current flowing through a circuit. In NPN bipolar junction transistors (BJTs), when a small current enters the base terminal, it allows a larger current to flow from the collector to the emitter. This ability to regulate current makes transistors essential for building logic circuits, amplifiers, and automated systems. They are a core component in everything from digital computers to light-sensitive devices.

Another important concept in the activity is the use of resistors, which are components that limit the flow of electric current. Resistance is measured in ohms (Ω), and varying the resistance in a circuit can affect how much current reaches components like LEDs. A higher resistance means less current and a dimmer LED, while a lower resistance allows more current to pass through. This relationship gives students an entry point into understanding how engineers use component values to control and fine-tune circuit behavior.

Capacitors are also introduced, serving as energy storage devices that charge and discharge over time. When current flows into a capacitor, it builds up an electric field and stores energy. Once it's fully charged, it can release that energy into the circuit. This charging and discharging behavior introduces timing into a circuit, enabling phenomena like blinking lights or delayed responses. The size of a capacitor, measured in microfarads (μF), determines how much energy it can store and how quickly it charges or discharges.

Photoresistors, or light-dependent resistors (LDRs), change their resistance depending on the amount of light they receive. In bright conditions, their resistance drops, allowing more current to flow; in darkness, their resistance increases, limiting the flow of current. This light-sensitive behavior makes them ideal for use in automatic lighting systems, such as night lights or solar garden lights. When combined with a transistor, a photoresistor can effectively control a circuit based on environmental light levels.

List of Terms Related to this Activity

Note: *The following terms are written in student-friendly language to support understanding during the activity. These are not meant to be frontloaded or introduced all at once. Instead, aim to develop these terms gradually through discussion, hands-on experience, and reflection as they naturally come up in the context of the circuit-building work. Where possible, co-construct definitions with students based on what they observe and discover.*

Circuit: A path that electricity flows through. If the path is complete, the electricity can move and power things like lights.

Current: The movement of electric charge (like tiny particles called electrons) through a circuit. It's what actually flows and makes devices work.

Resistor: A part that slows down the flow of electricity. It's used to control how much current flows to things like LEDs so they don't get too much power.

Resistance (Ω): A way to measure how much something resists or slows down the flow of electricity. Higher resistance means less current gets through.

LED (Light Emitting Diode): A small light that turns on when electricity flows through it the correct way. LEDs only work in one direction.

Polarity: The direction that electricity flows in a component. Some parts, like LEDs and certain capacitors, only work if they are connected the right way.

Transistor: A part that acts like an electronic switch. It can turn things on or off in a circuit by using a small amount of electricity to control a larger flow.

Base: The part of the transistor that controls whether it turns on or off. It only takes a little bit of electricity here to switch the transistor.

Collector: The part of the transistor where the electricity enters when it's turned on.

Emitter: The part of the transistor where the electricity exits when it's turned on.

Capacitor: A part that stores small amounts of electricity and then releases it. It's like a tiny battery and is used for things like timing in blinking circuits.

Microfarad (µF): A unit used to measure how much electricity a capacitor can hold. Bigger numbers mean the capacitor stores more energy.

Photoresistor (LDR): A resistor that changes based on light. In bright light, it lets more electricity flow. In the dark, it lets less flow.

Breadboard: A reusable board for building circuits without needing to solder. You plug wires and components into the holes to connect them.

Voltage: The push or pressure that makes electricity move through a circuit. It's what gets the current flowing.

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