Smart Switches

TCIPG

TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

MATERIALS
In the
SMART SWITCHES KIT

2 coin batteries (CR2032
Battery holder
Copper tape
Solar panels
Relay
Printed circuit board (PCB)
LED's (a few colors)

The color of the LED light depends on the type of semiconductor. Some LEDs have colored lenses and others have clear lenses. You may have to check the color of your LED using a battery.

Power engineering experts and educators from the Office for Mathematics, Science, and Technology Education (MSTE) and the Information Trust Institute (ITI) at the University of Illinois at Urbana-Champaign develop educational and outreach materials for the TCIPG project.

TCIPG EDUCATION

The Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) is a Department of Energy-funded project, with support from the Department of Homeland Security. The research team brings together experts from the University of Illinois at Urbana-Champaign, Dartmouth College, Cornell University, the University of California at Davis, and Washington State University.

Circuits with Copper Tape

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

Investigate circuits using copper tape, batteries and LEDs. Use the templates for your first circuits and then explore by adding more LEDs and copper tape traces.

How many LEDs can you light? Can you make a light-up card or art project?

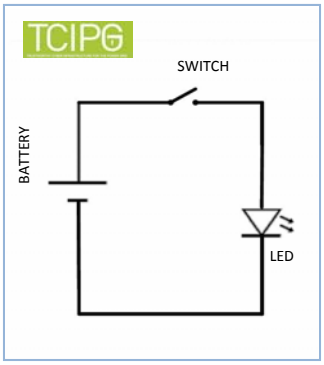
MATERIALS

coin battery (CR2032)

LED's (a few colors)

Copper tape

Circuit templates



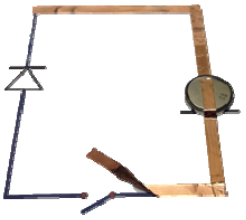
Getting Started:

Press copper tape on the circuit traces. Be sure to leave breaks in the tape for the LED, switch, and battery.

Using the Copper Tape

When tracing the circuit templates with tape, or creating your own circuit, try to turn corners without cutting the tape. When you need to join pieces of tape, be sure that the pieces overlap. Press the pieces firmly with your fingernail to ensure the best connection.

How to Put a Coin Cell Battery in the Circuit



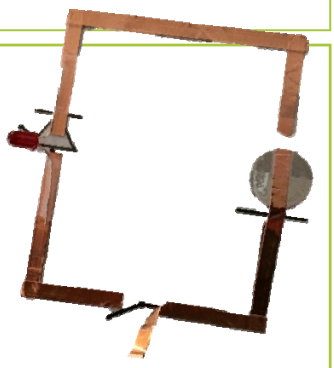
To put a battery into a circuit, both sides of the battery need to be a part of the conducting path. To do this, follow these steps:

- Create a break in the circuit.
- Place the battery on the copper tape right before the break. (The side of the battery with the words is the positive side).
- Extend the copper tape from the other side of the break so that it touches the top of the battery. Fold a small part of the end under so the shiny part of the tape shows on both sides.

Now both sides of the battery are in the circuit!

You can add a piece of transparent tape to reinforce the battery's connection and to keep it securely in place.

Troubleshooting Your Circuit



LEDs blink or don't stay lit

This is a connection issue! Firmly press down any corners where two pieces of tape meet. Double check that your battery is secured and that any switches in the circuit are closed. Add some transparent tape to your battery or to a switch to help keep it secure. Also be sure that the legs of your LEDs are touching the copper tape.

LEDs won't light

The most likely cause is that the LED is in the circuit in the wrong direction. Try reversing the direction of the LED in the circuit. If this still doesn't work, check the connections as described in the paragraph above.

Circuits Sampler

TCIPG

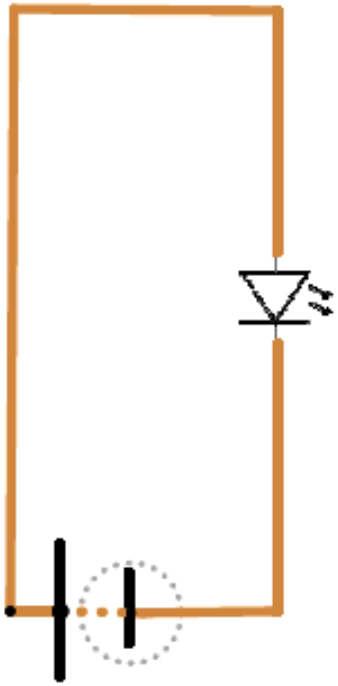
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

Materials -

copper tape
clear tape
LEDs
3V coin battery
scissors

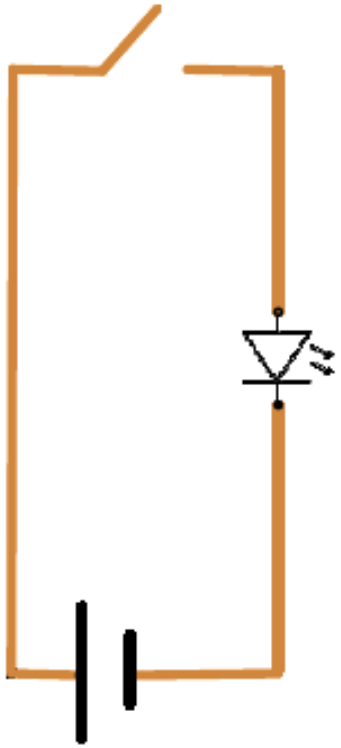
SIMPLE CIRCUIT

Trace the path of the circuit with copper tape, leaving breaks in the tape for the battery and LED. Both sides of the battery need to be a part of the conducting path. Place the battery on the copper tape right before the break. Extend the copper tape from the other side of the break so that it touches the top of the battery. Tape the LED and battery into the circuit.



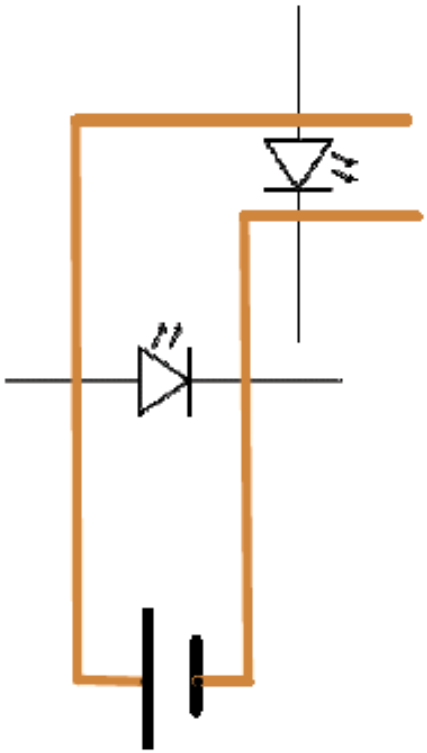
SIMPLE CIRCUIT
with a switch

Leave a small gap in the circuit for the switch. One side of the copper tape near the gap should be long enough to touch the other side plus an extra inch. Fold the long piece of tape under itself, covering up the adhesive for a half inch.

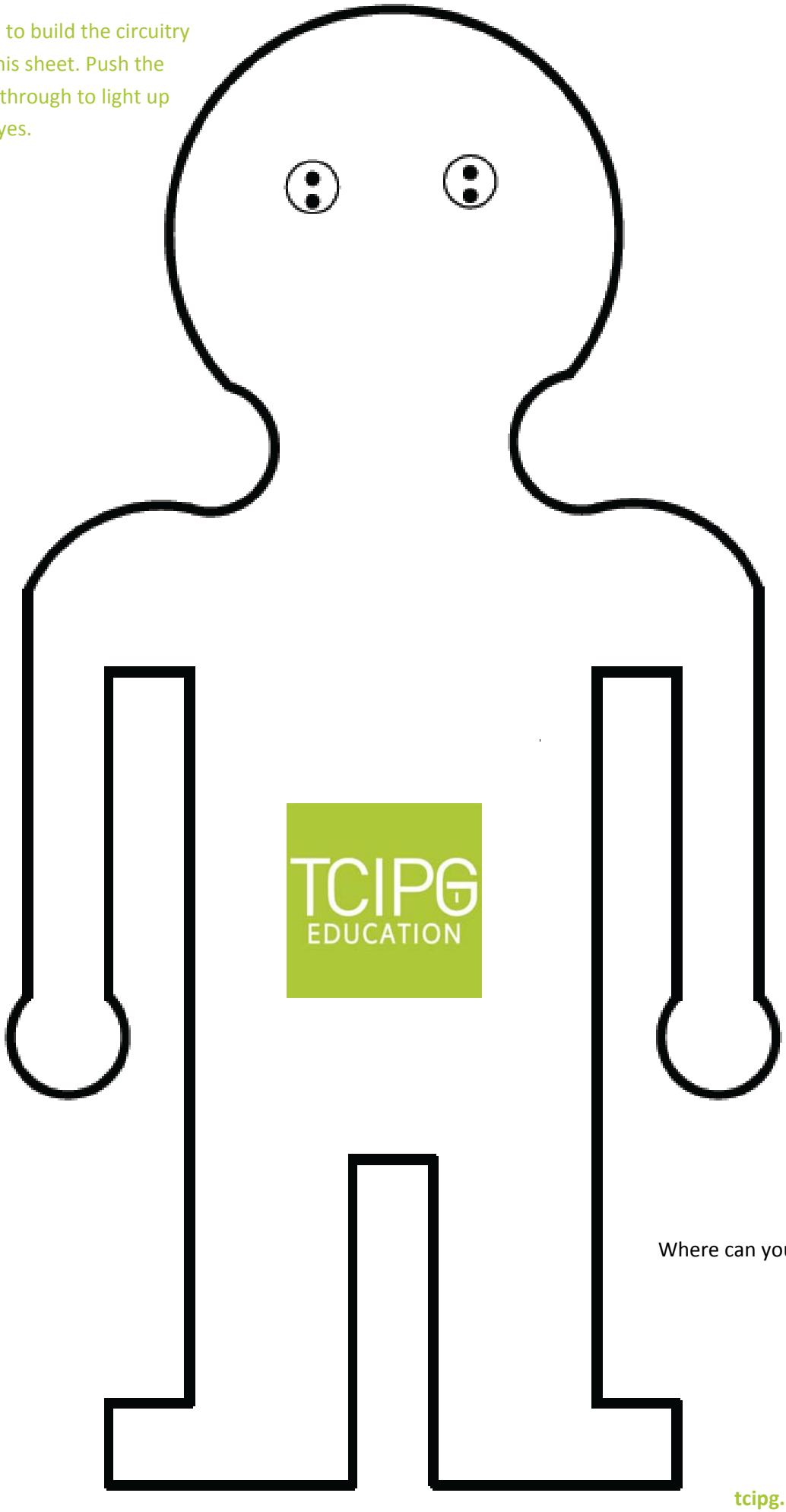


PARALLEL CIRCUIT

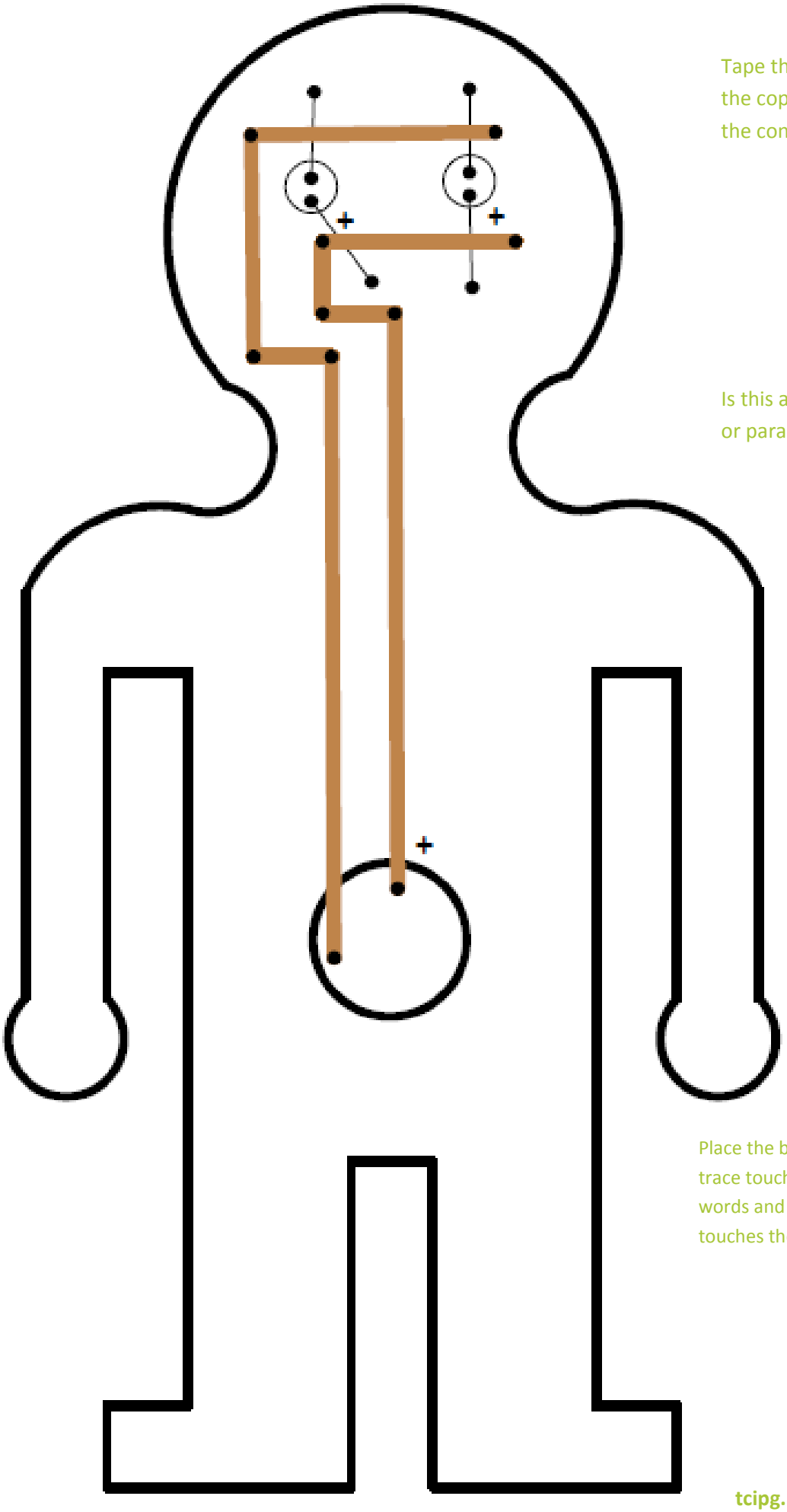
Use a parallel circuitto power two or more LEDs, . How can you add more LEDs?



Use copper tape to build the circuitry on the back of this sheet. Push the legs of the LEDs through to light up Robot TCIPG's eyes.



Where can you add another LED?



Tape the legs of the LEDs to the copper traces to make the connections secure.

Is this an example of a series or parallel circuit?

Place the battery so the positive trace touches the side with the words and the negative trace touches the other side

Use LEDs to light up the antennae and abdomen lights of the Firefly.

Tape your circuit on the back.

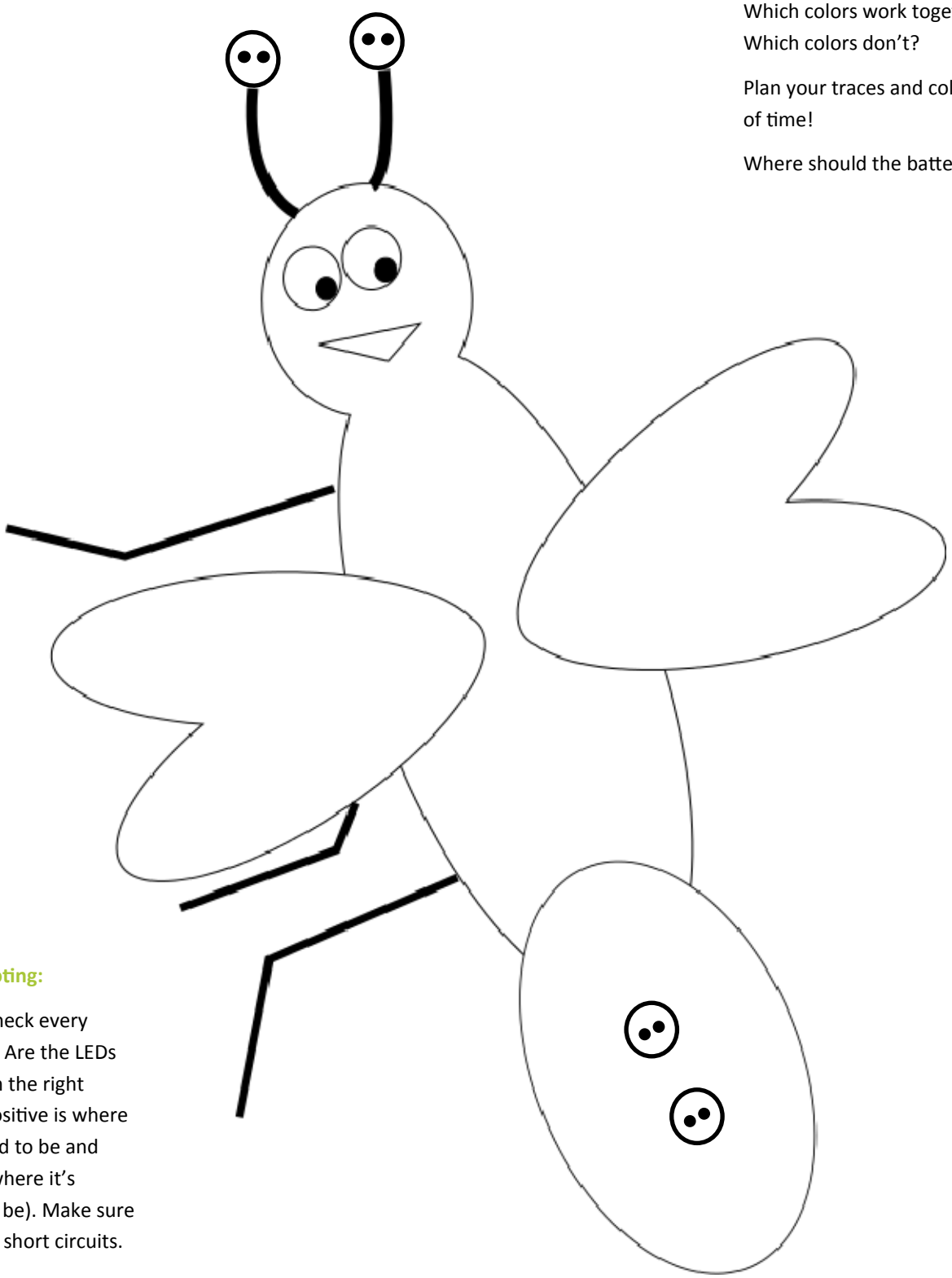
Questions to consider:

Should the LEDs be connected in series or parallel?

Which colors work together? Which colors don't?

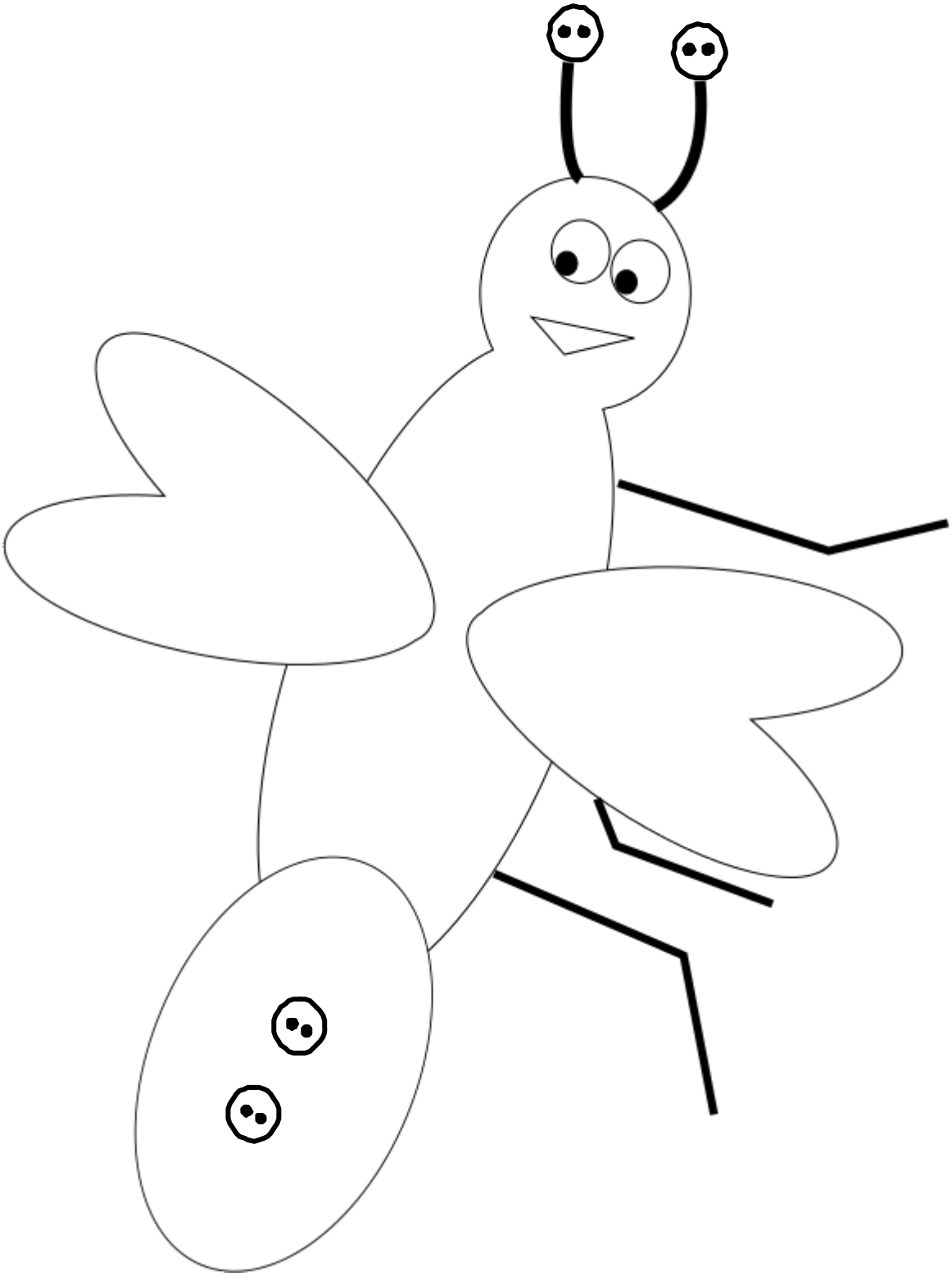
Plan your traces and colors ahead of time!

Where should the battery go?



Troubleshooting:

Be sure to check every connection! Are the LEDs connected in the right direction (positive is where it is supposed to be and negative is where it's supposed to be). Make sure there are no short circuits.



Logic Gates

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

Sometimes electric circuits use switches to make decisions. These are called *logic gates*. The gate receives one or more inputs and produces one output. Each input and each output is either ***off*** or ***on*** (***0*** or ***1***, ***low voltage*** or ***high voltage***).

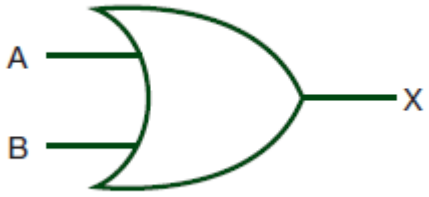
Different types of logic gates perform different logical functions. Often, we use truth tables to help us interpret logic gates.

OR gates and **AND gates** are examples of common basic logic gates.

OR gate

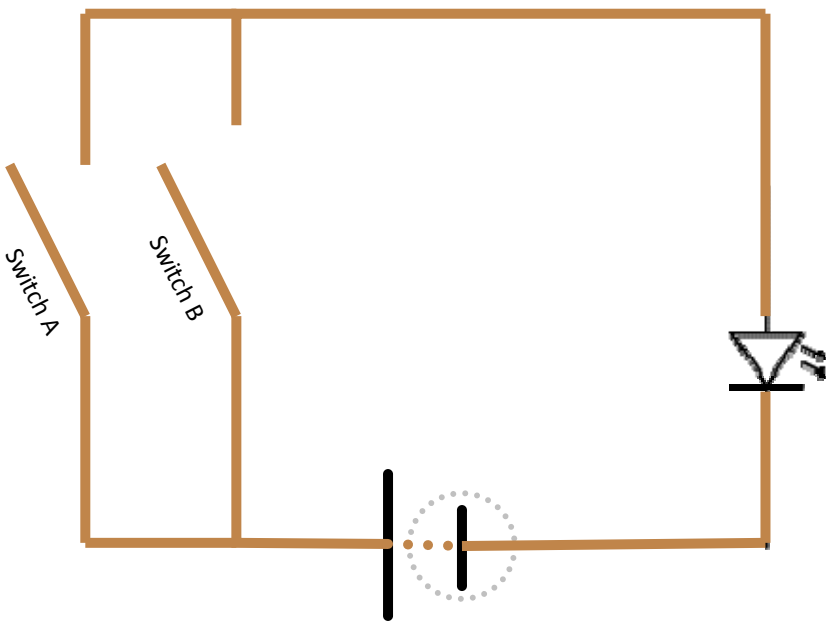
Use copper tape, a battery, and an LED to build the circuit below.
Open and close switches A and B and observe the LED to complete the truth table.

When does this gate output an ***on*** decision? Test the combinations of switches that cause the LED to light. Mark ***0*** in the table when the LED is off and ***1*** when the LED is on.



OR gate symbol

A lamp in a room that can be controlled by two separate switches uses an OR gate.



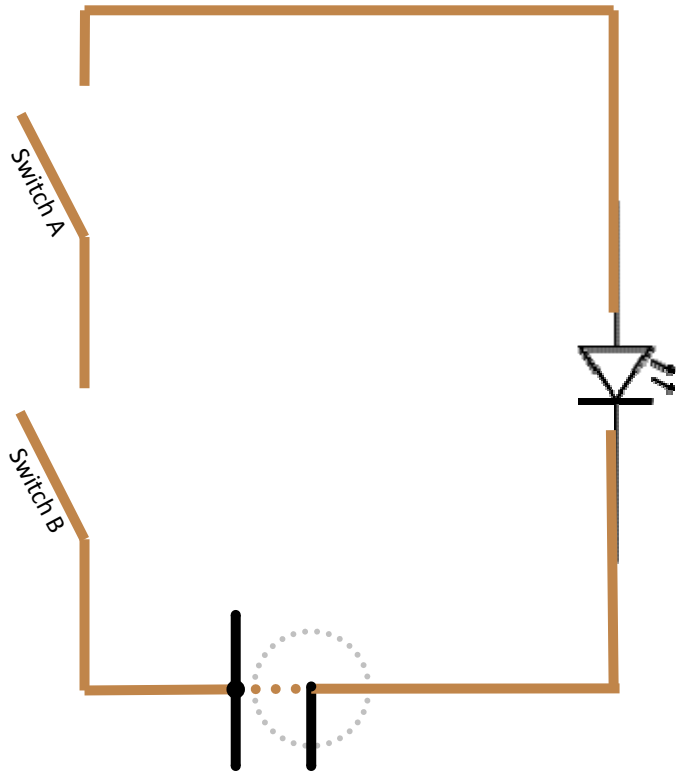
	Switch A IN	**Switch B** IN	**LED** OUT
Both switches A and B off	0	0	
Switches A on, B off	1	0	
Switches A off, B on	0	1	
Both switches A and B on	1	1	

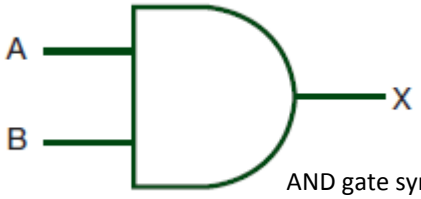
Logic Gates

AND gate

Use copper tape, a battery, and an LED to build the circuit below. Open and close switches A and B and observe the LED to complete the truth table.

When does this gate output an ***on*** decision? Test the combinations of switches that cause the LED to light. Mark ***0*** in the table when the LED is off and ***1*** when the LED is on.





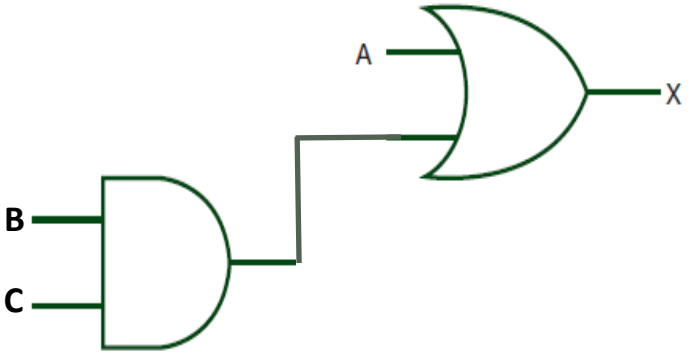
AND gate symbol

	Switch A IN	**Switch B** IN	**LED** OUT
Both switches A and B off	0	0	
Switches A on, B off	1	0	
Switches A off, B on	0	1	
Both switches A and B on	1	1	

Logic Gates

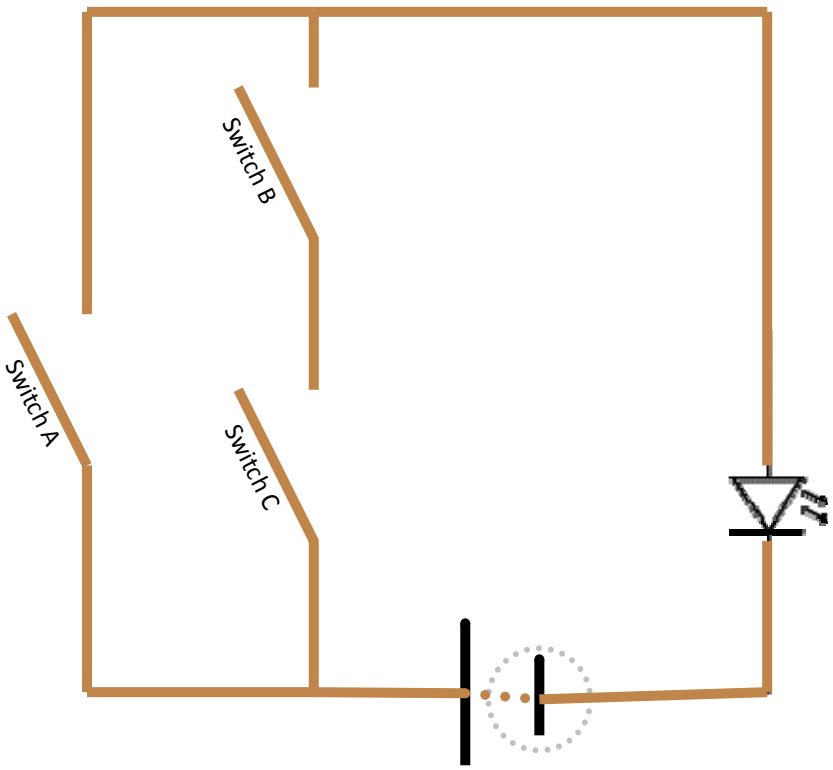
TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

Logic gates can be combined together to produce more **complex logic circuits or networks.** This network has three inputs and eight possible outputs.



Use copper tape, a battery, and an LED to build the circuit below. Open and close switches A and B and observe the LED to complete the truth table.

When does this gate output an ***on*** decision? Test the combinations of switches that cause the LED to light. Mark ***0*** in the table when the LED is off and ***1*** when the LED is on. When might this type of logic circuit be used?

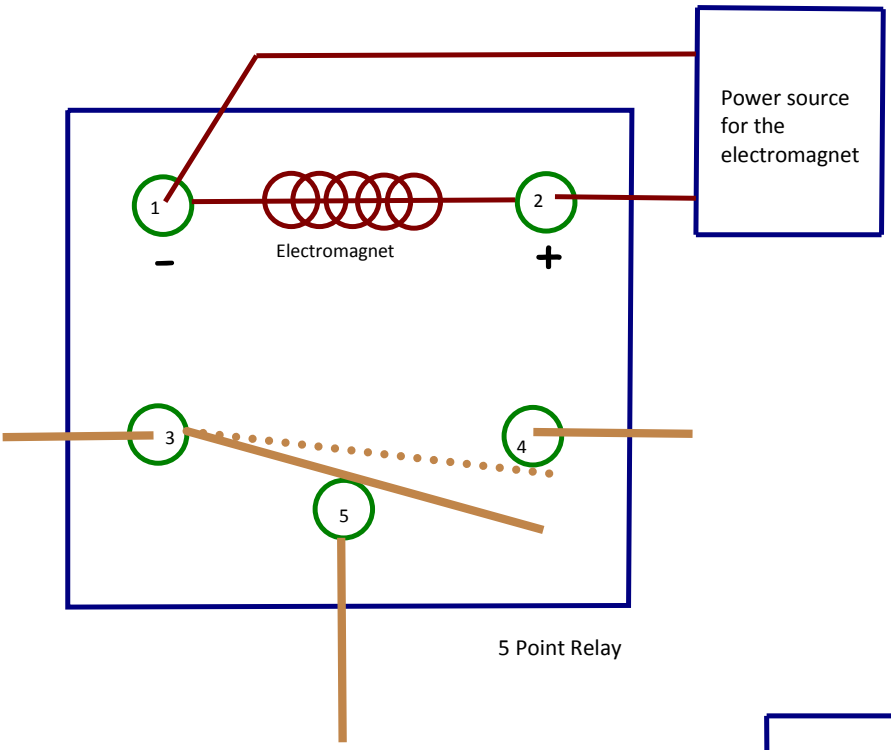


	Switch *A* IN	**Switch *B* IN**	**Switch *C* IN**	**LED OUT**
All switches *A*, *B*, and *C* off	0	0	0	
Switches *A* on, *B* and *C* off	1	0	0	
Switches *A* off, *B* and *C* on	0	1	1	
Switches *A* and *B* on, *C* off	1	1	0	
Switches *A* and *C* on, *B* off	1	0	1	
Switches *B* on, *A* and *C* off	0	1	0	
Switches *C* on, *A* and *B* off	0	0	1	
All switches *A*, *B*, and *C* on	1	1	1	

Relays

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

A **relay** is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch.

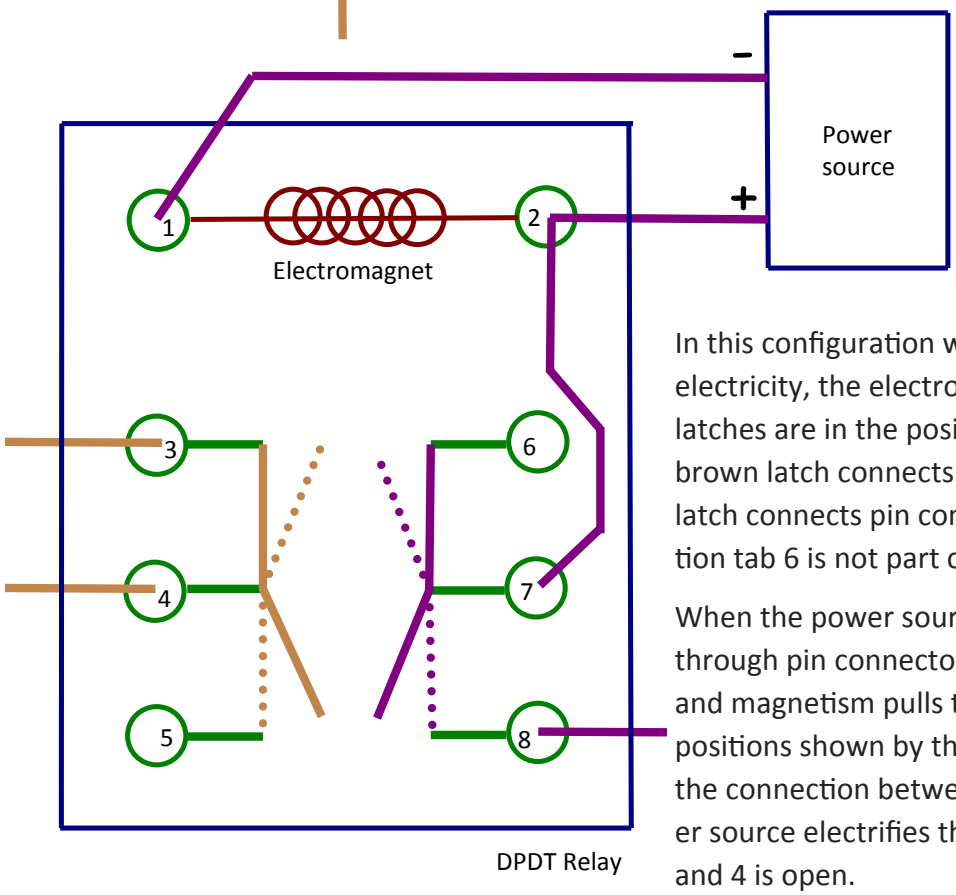


5 Point Relay

This 5 point relay uses one power source to provide electricity to the electromagnet that controls the switch but other separate power sources to produce electricity for the rest of the circuitry (not shown here).

In this configuration when the power source is not providing electricity, the electromagnet is off and pin connector 3 is connected to pin connector 5.

When the power source does provide electricity to the circuit through pin connectors 1 and 2, the electromagnet turns on and magnetism pulls the switch to make the connection between 3 and 4.



DPDT Relay

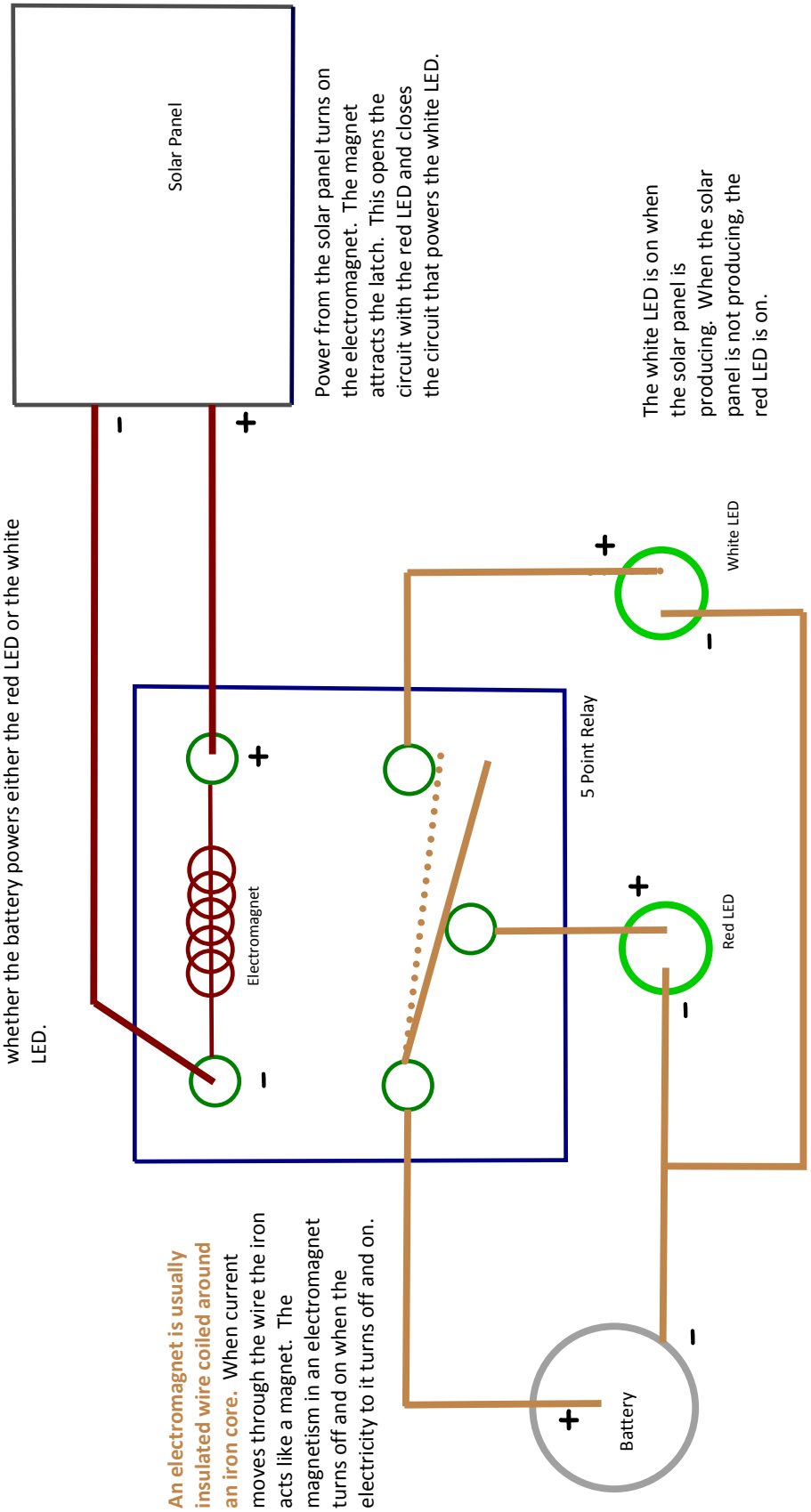
This DPDT relay uses one power source to provide electricity to power the electromagnet that controls the switch. The same power source also produces electricity for the rest of the purple circuitry (only part of it is shown).

In this configuration when the power source is **not** providing electricity, the electromagnet is off and the purple and brown latches are in the positions shown by the solid lines. The brown latch connects pin connectors 3 and 4. (The purple latch connects pin connectors 6 and 7, but in this configuration tab 6 is not part of any circuit.)

When the power source **does** provide electricity to the circuit through pin connectors 1 and 2, the electromagnet turns on and magnetism pulls the purple and brown latches into the positions shown by the dotted lines. The purple latch closes the connection between pin connectors 7 and 8 and the power source electrifies that circuit. The connection between 3 and 4 is open.

Relays

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID



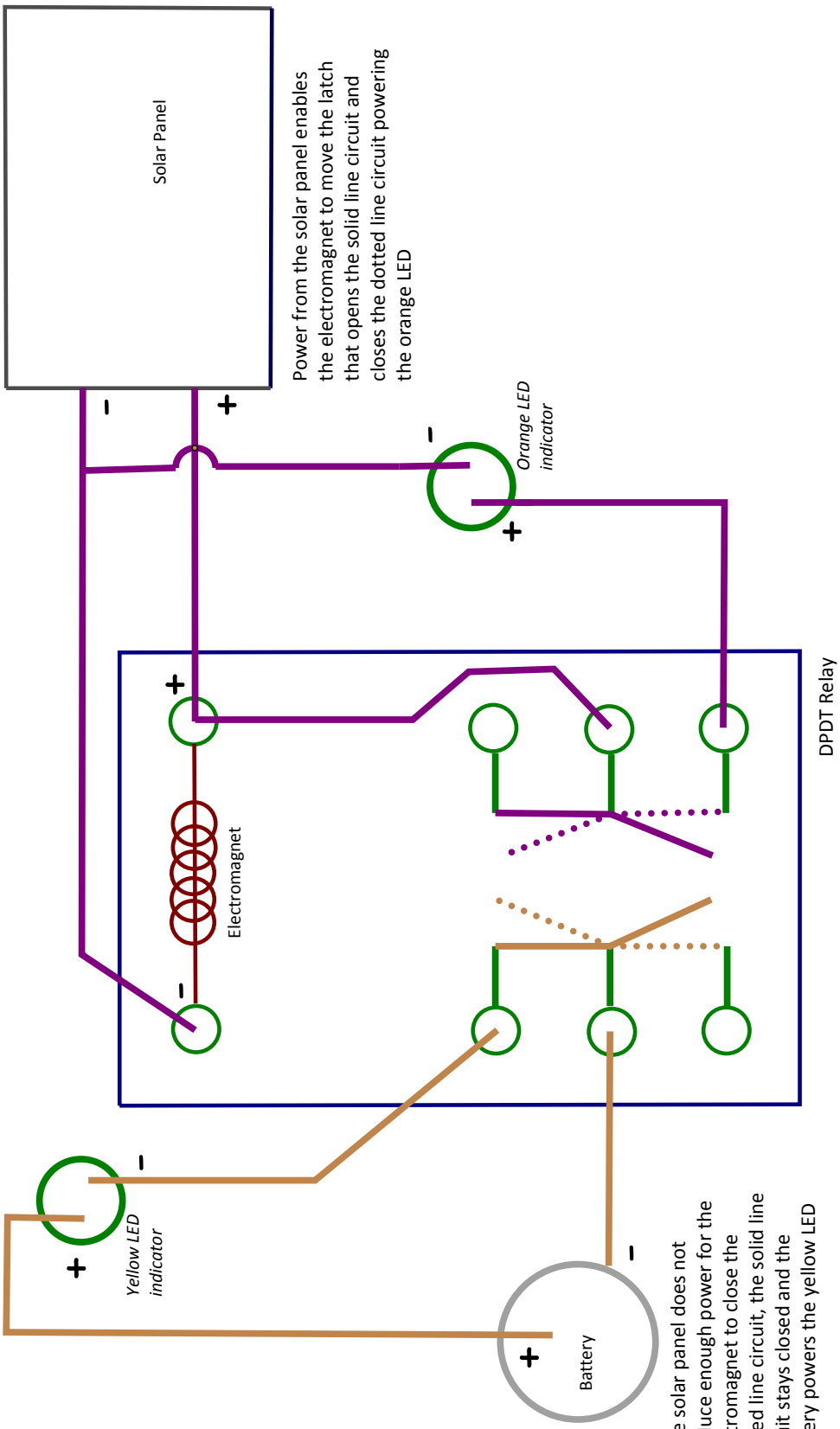
A relay is a switch controlled by electric current. This relay uses solar power to activate the electromagnet. Whether the solar panel produces electricity determines whether the battery powers either the red LED or the white LED.

An electromagnet is usually insulated wire coiled around an iron core. When current moves through the wire the iron acts like a magnet. The magnetism in an electromagnet turns off and on when the electricity to it turns off and on.

Relays

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

This diagram shows how the relay on the TCIPG Education Relay Breakout Board works.
When the solar panel is not producing electricity the electromagnet is off and the purple and brown latches are in the positions shown by the solid lines.
When the solar panel is producing electricity the electromagnet is on. The magnet pulls the latches into the positions shown by the dottled lines.



Smart Switches

TCIPG
TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

Smart switches can be found in many places throughout the electric grid. Protection relays protect the power grid when an outage is detected. The device is designed to break the circuit if part of the grid is damaged. For example, if a tree falls on a power line a relay will quickly detect a fault, which in turn flips a switch to stop power from flowing down the fallen line. Once the fault is repaired, the relay can switch the power line back to normal operation.

Smart switches can also automatically transfer the flow of power so outages may affect smaller areas and power outages occur for shorter periods of time.

Energy Storage

Power utilities currently must generate electricity just when the users need it, but researchers are experimenting with large scale energy storage systems. Some hydroelectric power plants pump water uphill to a storage reservoir when energy demand is low and then allow it to flow downhill through a turbine/generator when demand is higher. Batteries are a familiar example of energy storage, but the batteries you use at home store a very small amount of energy. Newer larger batteries have been developed for use in electric vehicles, and systems of large batteries are in use in a few places. Researchers are also investigating other forms of storage including compressed air storage and flywheel storage.

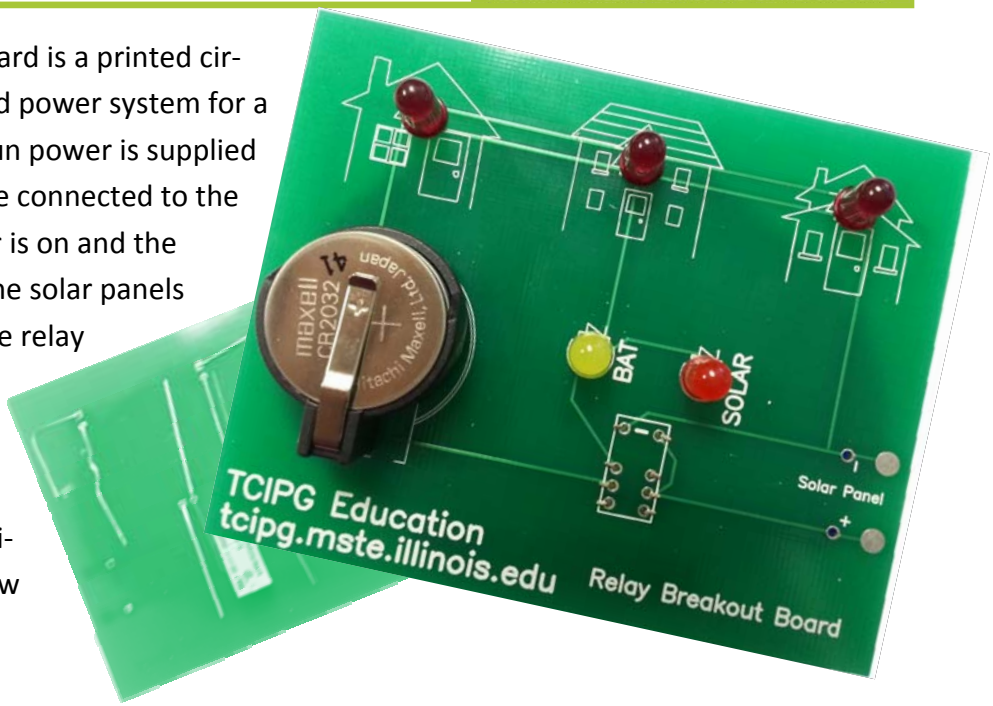
Xtreme Power's Dynamic Power Resource at First Wind's Kahuku Wind project on Oahu. (Photo: Business Wire) See a video about energy storage here http://www.xtremepower.com/about-energy-storage/why-storage.php

TCIPG Education

Relay Breakout Board

TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID

The TCIPG Education Relay Breakout Board is a printed circuit board (PCB) that models a simplified power system for a small neighborhood. When sufficient sun power is supplied by the solar panels (or any power source connected to the solar panel inputs), the orange indicator is on and the houses are solar powered. But, when the solar panels are not producing enough electricity, the relay switches to allow the coin cell batteries to power the houses and the yellow indicator is on.



Compare the traces on the PCB to the diagrams on the previous pages to see how the relay is managing the power source.

Assembling the breakout board

- Push the legs of the red LEDs through the connecting pin holes near the houses. Insert the longer (positive) leg through the round hole and the shorter (negative) leg through the square hole at each house.
- Insert a yellow LED to indicate when the battery is powering the system and an orange LED to indicate when the solar panel is providing electricity.
- Pull the legs through and bend away from each other. Use clear tape or solder to hold in place.
- Insert the relay into the PCB from the back. Line the pins up with the holes and without bending the pins push through to the front. Then bend the pins away from the center. The electromagnet and the switches that move when the magnet is on are inside the relay box.

- Put two batteries in the battery holder. The printed sides of the batteries should both face up. Push the battery pins through the battery connecting pin holes. Be sure the positive pin is in the positive through hole.
- The battery power should light the yellow battery indicator LED and the three red LEDs at the houses.
- Attach the solar panel. Depending on the type of solar panel and the sun conditions you may need to connect more than one solar panel to generate enough electricity to power the electromagnet and the three houses. You may be able to hear the relay click when the electromagnet pulls the latches. If you hear the click and the orange solar indicator lights, the solar panel is producing. The solar panel produces best in bright sunlight. You may need to add another solar panel if conditions are not sunny enough.

Visit the TCIPG Education website for more trouble shooting suggestions.