

# CIRCUIT BOARDS



Experimenting with batteries, bulbs, buzzers, switches, and other electrical components is a great way to start tinkering with circuits. Real parts mounted on sturdy wood blocks are designed for anyone to start creating electrical connections between everyday objects. From the basic elements you can deepen the experiments by adding potentiometers, double-pole double-throw switches (DPDT), motors, resistors, and other scrounged inputs and outputs that can do interesting and sometimes surprising things when connected. The set of circuit boards is not only a compelling way to work with electricity, but the parts can also be used in many other tinkering activities.

## BUILD IT!

Before you can start messing around with the activity, you need to assemble and build your own set of circuit boards. These can be used over and over as a stand-alone activity or in conjunction with other activities and tinkering explorations.

### Electrical Components:

You should gather these materials for each group of two to four people who will be using the boards at one time:

4 2x AA Battery Packs  
(3 volts total each)



8 AA batteries



8 Mini light bulbs



4 Single lights



4 Motors



1 Hand crank generator



24 Alligator clip wires



2 Buzzers



2 Double pole double throw switches



2 Potentiometers



1 Single pole single throw switch



1 Knife switch

the  
tinkering  
studio

## Parts and Tools for Construction:



## Other Things to Find:



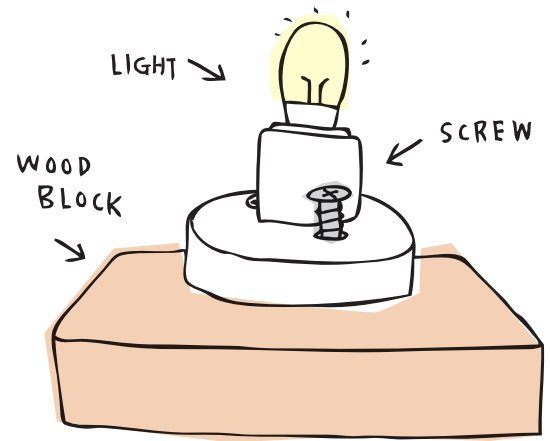
**TIP:** For safety we recommend only using direct current (DC) battery packs that are six volts or less.

# CONSTRUCTION GUIDE



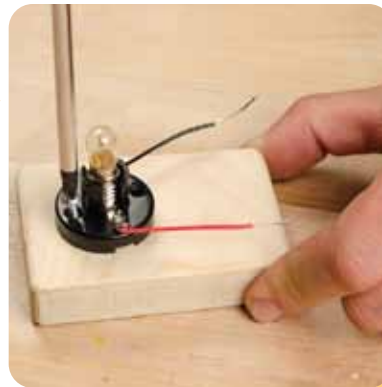
## Cutting the block bases:

Cut and sand blocks of wood (we use 1/2 in. (1.25 cm) pine because it is a softwood) that are two or three times larger than the part that will be mounted on it.



## Soldering and hot glue:

Solder the wire to the nails. Sometimes the nails can take a while to get hot enough to melt the solder, but be patient and give it time to work. We usually put a few drops of hot melt glue on the wires to help prevent them from breaking during use.



## Mounting the components:

Cut and strip short lengths of wire and attach the wires (when needed) to the electrical components. Mount the electrical components to the wood blocks with screws or zip ties. Drive nails into the wood blocks and wrap the loose end of stripped wire around them.



## Inventing and testing new components:

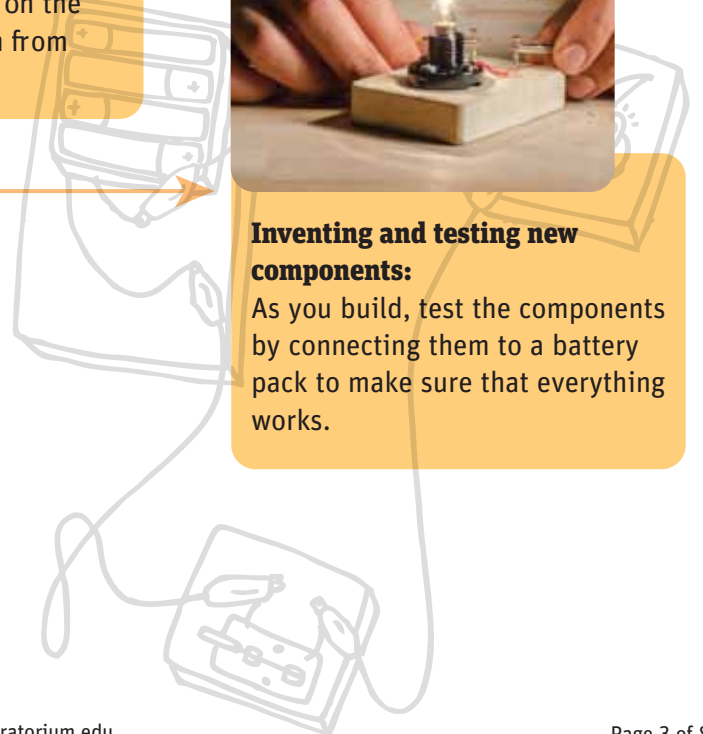
As you build, test the components by connecting them to a battery pack to make sure that everything works.

Keep a few extra wood blocks on hand to use for new or unusual electrical components that you might want to add to your circuit board collection.

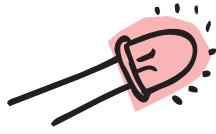
You can also make a few special boards for easy testing during experimenting:

**Wire tester**—this board can be used to see if a wire is broken.

**Battery tester**—this board can come in handy to identify a dead battery.



# TRY IT!



## Getting started:

The most important first step for the circuit board activity is to make sure that you have had some experience working with circuit boards as a learner yourself, in order to develop a basic understanding about what the components do and how you can get them to work.

## Getting started with others:

Offer each person or team a couple of wires with alligator clip leads, a battery block, and a light bulb block. Ask if they can figure out a way to connect the battery to the light bulb to make it light.

Once someone is successful at getting the light bulb to light, offer them a motor block and ask them if they could now try to connect the motor to the battery to make it turn.

When most of the group has had success with the light bulb and motor blocks, you could either introduce switches or more complicated components.

## Introducing Switches:

The goal for this pathway of investigation is to develop fluency with switches, potentiometers, conductive materials, and sensors that control the flow of current to the outputs motors, lights, buzzers.

Start by offering a third wire and a simple switch to incorporate into their simple circuit. Once there is some success with a simple switch controlling their simple



circuit, offer more complex and unusual switches to use. Try the electrical switches that you collected and constructed or use conductive materials like aluminum foil as switches.

## Introducing more complicated components:

The goal for this pathway of investigation is to develop fluency with the ways of connecting and testing a variety of electrical components. These include light bulbs, motors, buzzers, doorbells, mechanical toy parts, and anything else you might find to test. Start by challenging someone to connect a buzzer or doorbell after they have had success connecting the light bulb. Or offer the three-bulb block and ask for a solution where all of the lights can be powered by a single battery pack. All of the components have two

pins/nails that can be used to connect them to the two pins/nails on the battery. Sometimes switching the two wires from positive on the battery to negative on the battery will change the behavior of the component. Many components will only work when connected in one configuration.

Encourage a variety of explorations with the components, and ask everyone to share discoveries with one another as they explore.

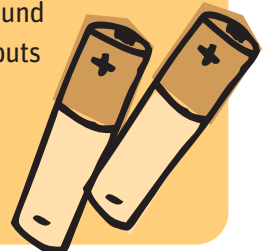
This activity does not always follow a step-by-step pattern and many participants discover interesting things through simply messing around with the components on their own. This activity might also result in a wire or battery pack getting hot if someone creates a short circuit (the battery is connected directly to itself). Keep an eye open for this and point it out in order to save precious battery life and prevent unexpected injury or component failure.

# TAKE IT FURTHER

- Organize a conductive scavenger hunt using a light bulb, battery pack, and two wires that can be connected to different objects to test their conductivity. Try making switches out of tinfoil, metal flatware, bottle caps, dental fillings, and other electrically conductive things (just be careful to not connect the two wires to another battery or external power source—that could be dangerous)

- Build a test-kit for discovering interesting inputs and outputs. Having a battery block and a couple of wires handy when you are dissecting unused electronic items, household appliances, or mechanical toys will help you to identify and test the motors, switches, sensors, and other parts that you find. Bring your test-kit to surplus stores, electronics shops, and even craft supply stores to find unusual new things to use with your circuit board set.

- Incorporate individual circuit board components into other construction-based or tinkering activities. For example, you might use the battery packs and light bulbs in an explorations about kinetic light play, or integrate the found inputs and outputs into the chain reaction activity.



# EDUCATOR ADDENDUM

## **A note on our philosophy:**

*The Tinkering Studio is based on a constructivist theory of learning, which asserts that knowledge is not simply transmitted from teacher to learner but actively constructed by the mind of the learner. Constructionism suggests that learners are more likely to make new ideas while actively engaged in making an external artifact. The Tinkering Studio supports the construction of knowledge within the context of building personally meaningful artifacts. We design opportunities for people to “think with their hands” in order to construct meaning and understanding.*

## **Activity Design** (decisions and designs that support a tinkering experience)



*Tinkering Studio activities and investigations are designed to encourage learners to complexify their thinking over time. The variety of materials and variables available for experimentation allow learners to enter at a point where they are comfortable starting, and then alter and refine their designs as they develop new ideas. Tinkering activities are often fun, whimsical, inspired, and surprising.*



The circuit board activity is one that allows for learners to choose their own pathway as they develop an understanding about the electrical components and test out the connections between them. This often leads to multiple pathways and discoveries being made by learners of all ages and backgrounds. Our goal is not to “teach” specific things about circuits, but to allow a first-hand understanding to develop over time.

Because there is a variety of more and less complex parts, learners of many different experience levels are able to find something to start with. This means beginners can start with quick success, yet complexify as ideas progress.



Trial and error is a key part of the circuit board activity. This is especially important in order to test assumptions and understanding later on. Batteries sometimes get hot when wires are crossed and bulbs sometimes burn out, but these are real and important outcomes of the ideas that many people have while exploring.

The nails, boards, and electrical components are a mixture of familiar and unfamiliar objects. Unfamiliar electrical components seem less intimidating when connected to a pine board with steel nails. Almost everything is visible, so the learner can actually trace the wires to figure out how things are connected.

There are no instructions and no pre-conceived “right” way to connect something at the start. The electrical components will either work or not, and allowing learners to connect something the “wrong” way is almost as useful as connecting something the “right” way. We are often surprised and delighted by the variety of ways that people use the circuit board components, and we wouldn’t want to do anything to design the possibility for discovery out of the activity.



## **Environment** (the elements of the space that support tinkering)

*In the Tinkering Studio there are many things that we keep in mind when setting up an environment for a successful tinkering activity.*

*Since learners often work with us for an extended period of time, we try to create a warm and welcoming workspace with comfortable seating, sturdy worktables, and good lighting. We often display exhibits or examples from past projects and current activities throughout the space to seed ideas and provide an introduction to what is happening that day. Materials are easily accessible and in close proximity to the tinkerers. We often work at large, communal activity stations to enable cross-talk and invite collaboration between participants, allowing them to look to each other for answers and solutions.*



When creating an environment for exploring circuit boards, you'll want to prepare a place for everyone to explore the components together, in ways that allow each learner to share their discoveries (and frustrations) with the rest of the group. Sitting across from one another at a comfortable table will go a long way in this regard.

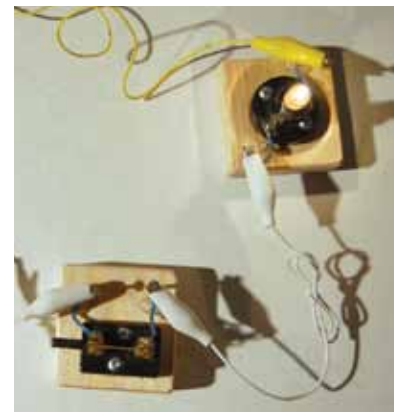
This type of seating arrangement also allows the teacher to be more of a facilitator, walking around and checking in on people, rather than being the focus of attention.

We often add images and videos of beautiful and compelling circuit-based things to the environment as a way to support learners to “think differently” about electricity. And we place unusual and inspiring objects throughout the room so that facilitators or teachers can interact with learners using even more unusual things like mechanical relays, telephone dials, or other found objects begging to be connected.

## **Facilitation** (the things we say and do to support learning through tinkering)

*Facilitation is a way of teaching in which you support the learner's own investigations, questions, and ideas within the framework of an activity. In the Tinkering Studio, we strive to practice a kind of facilitation that respects the individual path of the learner. As facilitators, we watch and wait until the right moment to jump in and offer a hint, a material, or a new way of looking at a problem. As educators, we allow learners to feel frustration and encounter moments of failure as they work with real materials to try to solve their own challenges.*

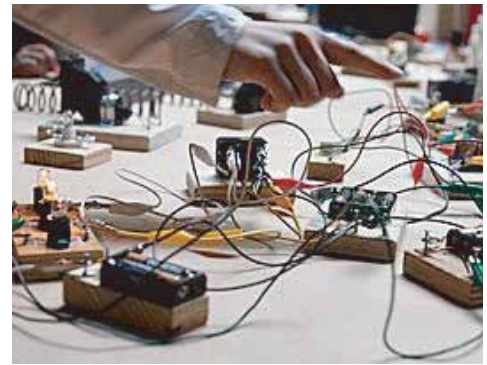
*There are many ways that the facilitator can influence the interactions with participants in an activity. We help people get started with the activity by giving a quick sense of the goals. We invite them into the space and introduce the materials and tools they might use. We spark interest and sustain learner's engagement by asking questions about their work and responding to their answers. We support multiple outcomes of the activity and are open to the possibility of new ideas, different solutions, and changing goals of the individual learners. We try to practice a style of facilitation in which we are not teachers who transmit knowledge to passive learners, but rather are guides and co-learners on a path to understanding.*



For circuit boards, we tend to facilitate in three ways depending on where the learner is in their investigations. Early on, we facilitate learners to begin playing with the materials by asking simple questions like “can you make something work by attaching a battery pack to it with the wires”? Getting people started in this way will indicate to the facilitator their level of confidence and ability. It is a great way to get a sense of what they might already know.

### Things that you might say and do at this stage:

- “Have you ever completed a circuit like this before?”
- If stuck and something isn’t working you might ask them to trace the wires to make sure there is a complete pathway (circuit) for the electricity.
- Learners sometimes get complicated quickly, so one thing we offer is a suggestion to simplify. Clear a larger space to carefully look at the connections and expectations.
- Sometimes things don’t work because a wire is broken or a battery is dead. Suggesting to participants that they check these things early in their investigations will go a long way in helping them later on.
- Let people make simple discoveries for themselves, and allow learners the opportunity to be proud of small steps when getting things to work.



In the middle stage of facilitation, we spend some time keeping people going. Helping get unstuck, or offering more complex or diverse challenges with the materials on the table. We might follow up a successful light bulb connection to a simple switch by offering a more complex switch (DPDT or a potentiometer), or we might ask if they could light three bulbs at the same time, using more wires and the solution they came up with to light a single bulb.

### Things that you might say and do at this stage:

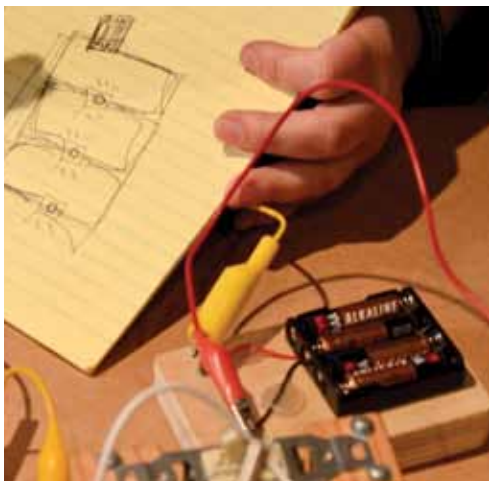
- Ask specifically what they are trying to do (if something isn’t working), and ask them to show you how they have already completed a circuit like it with these materials. This way you can get a sense of how the learner is thinking about things.
- Sometimes a learner might make something work, but unintentionally. You might check this by asking them to apply the same wiring to another component.
- Allowing people to get stuck is important, and doing what you can to linger in that moment before you step in and “help” might go a long way toward developing confidence in the learner. Don’t wait too long, however, because we don’t want people to give up. This takes practice.
- Do what you can to offer suggestions along the lines of their current ideas. Try to resist offering YOUR solution to THEIR problem.

Different facilitation strategies happen much later in someone’s investigation cycle, and they often include supporting the development of more creative uses of the electrical parts (using a mechanical toy to create an automatic switch for example).

Later stage facilitation is also an opportunity to work out some of the misconceptions learners might have about electricity, or the lingering ideas about series and parallel circuits.

### Things that you might say and do at this stage:

- Offer a challenge that is a little bit tricky. For example, ask them, “Can you make three lights turn on by wiring them three different ways?” (This is a way to explore parallel and series circuits.)
- Try sharing new ideas in non-verbal ways. For example, construct an interesting circuit or contraption next to them to see if/how they are able to observe and understand what you have done. Then you can talk about it with them.
- Ask if a learner might be willing to step in and help out someone else at the table. This is a good idea to allow them to put their new understanding to work, but be careful that they don’t take over someone else’s investigation.



# RELATED TINKERING ACTIVITIES

**Toy Take-Apart:** Collect discarded mechanical stuffed toys and dissect them to find battery packs, switches, sensors, and motor-driven mechanical elements similar to the parts used for circuit boards. You can use the circuit board components to test the things that you find inside, and some of these parts can even become new circuit board blocks.

<http://tinkering.exploratorium.edu/toy-take-apart>

**Sewn Circuits:** Explore a variety of circuits by experimenting with conductive thread, sew-on battery packs, and LEDs. Creating a unique soft electronic patch or wearable object is a great way to build on the basic understanding of electricity that you can develop with circuit boards. Additionally, circuit boards can be used to troubleshoot or plan out ideas while experimenting with these new materials.

<http://tinkering.exploratorium.edu/paper-circuits>

**Paper Circuits:** Paper circuits is another exploration of electrical circuits inspired by artist Jie Qi that incorporates traditional paper-folding techniques into electronic projects. In this activity, you can use copper tape, surface mount LEDs, and watch batteries to bring a greeting card or piece of origami to life. As in the circuit board activity, participants build understanding of circuits as solutions to problems that come up as they engage with materials.

<http://tinkering.exploratorium.edu/sewn-circuits>



## ARTIST CONNECTIONS

*(inspiring connections to the Circuit Boards activity)*



**Shih Chieh (“CJ”) Huang** creates technological life forms out of computer fans, digital screens, night-lights, and other electronic components that he has scrounged over the years. These electronic life forms mimic natural biology as they drift and move gracefully in rhythm with lights and video screens turning on and off in unusual patterns.

<http://www.messymix.com>

**Jay Silver** and **Eric Rosenbaum** invented a computer interface board called Makey Makey. This invention allows anything that can conduct electricity (bananas, metal forks, cups of milk) to act as an input device on your computer. The Makey Makey board allows experimentation with a variety of inputs to control one-button computer games, musical keyboard simulations, or other programs that you design yourself.

<http://www.makeymakey.com>

