



Physics 524
Survey of Instrumentation and Laboratory Techniques
2023

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Unit 4b: soldering and PCB assembly

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Goal for this unit

- Become more proficient at soldering
- Consider strategies for mounting printed circuit boards inside housings

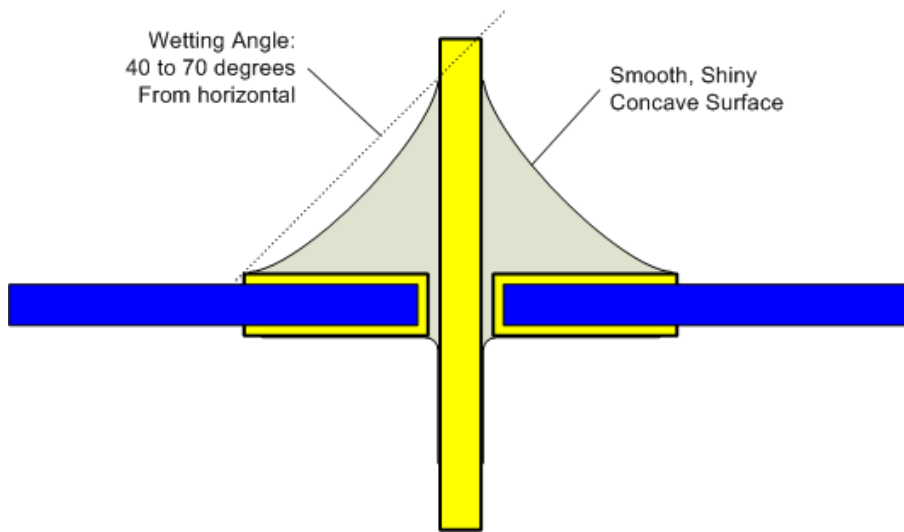
Introduction to soldering

Safety first:

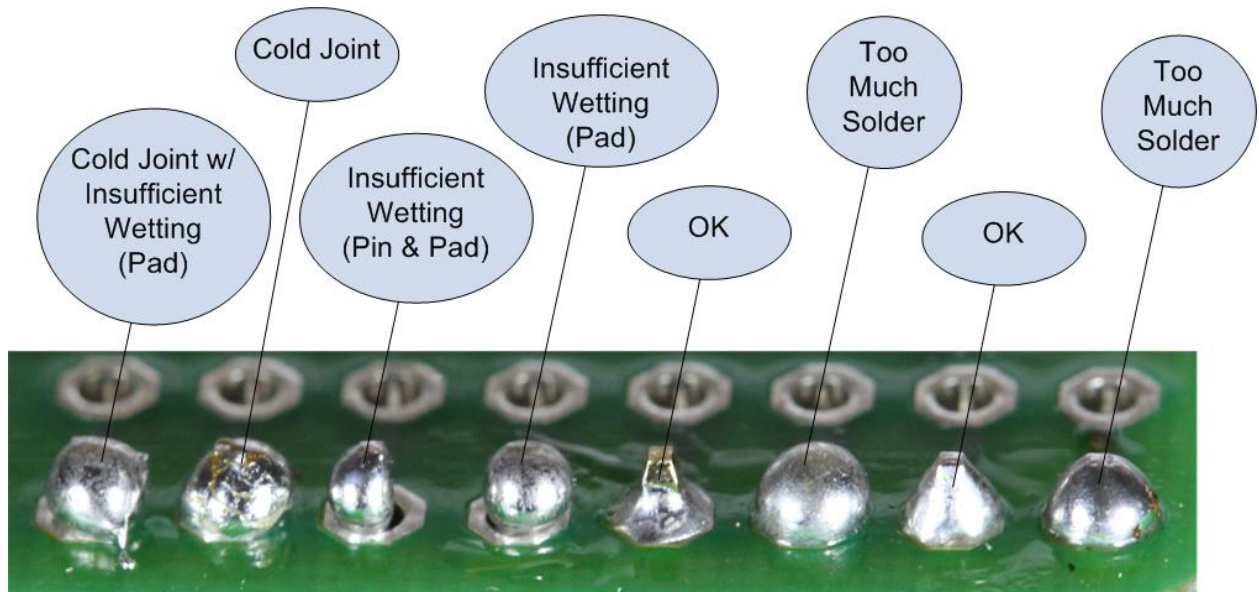
- always wear eye protection and a mask;
- run the USB-powered fan to disperse any airborne nasties;
- DO NOT BURN YOURSELF. Molten solder is very hot, and things you've soldered stay hot for a little while;
- Some solder alloys (including what we'll be using) contain lead, so always wash your hands when you are finished.

Here are some illustrations from Todd Moore (electrical engineer and UIUC physics staffer) about proper soldering joints.

The Proper Soldering Joint

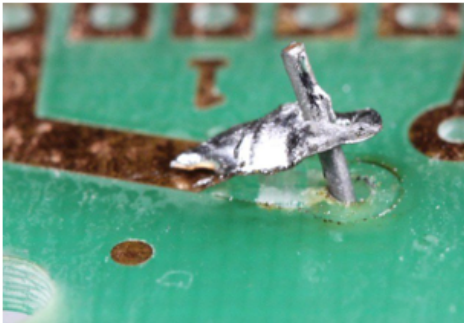
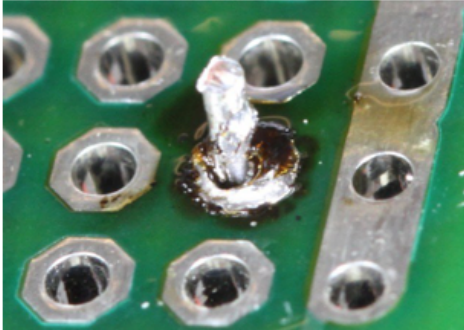


Types of Solder Joints

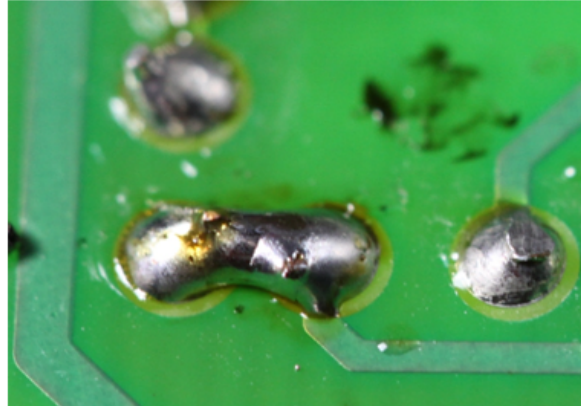


(NOT) the Proper Solder Joint

- Overheated Joint



- Solder Bridge



- Lifted Pad From Overheating or Desoldering

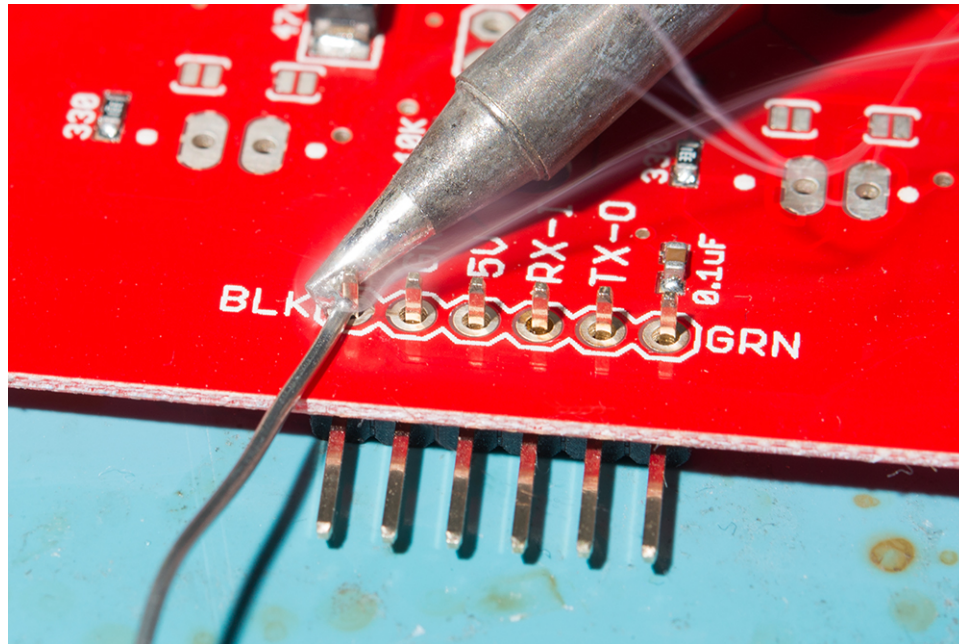
Now, Todd really knows his stuff, but my solder joints sometimes look more like his “too much solder” variants than what he identifies as “ideal.” Eh, OK.

SparkFun has a nice soldering tutorial and, like much of their instructional material, is covered by a CC BY-SA 4.0¹ license. Here’s the URL: <https://learn.sparkfun.com/tutorials/how-to-solder-through-hole-soldering/all>. Let me insert their tutorial here.

SparkFun tutorial: Introduction

Soldering is one of the most fundamental skills needed to dabble in the world of electronics. The two go together like peas and carrots. And, although it is possible to learn about and build electronics without needing to pick up a soldering iron, you’ll soon discover that a whole new world is opened with this one simple skill. We here at SparkFun believe that soldering should be a skill in everyone’s arsenal. In a world of increasing technological surroundings, we believe it is important that people everywhere be able to not only understand the technologies they use everyday but also be able to build, alter, and fix them as well. Soldering is one of many skills that will empower you to do just that.

¹ <https://creativecommons.org/licenses/by-sa/4.0/>.



In this tutorial we will go over the basics of **through-hole soldering** -- also known as plated through-hole soldering (PTH), discuss the tools needed, go over techniques for proper soldering, and show you where you can go from there. We will also discuss rework as it pertains to through-hole soldering and give you some tips and tricks that will make fixing any piece of electronics a breeze. This guide will be for beginners and experts alike. Whether you've never touched an iron before or are looking for a little refresher, this tutorial has a little something for everyone.

What is Solder?

Before learning how to solder, it's always wise to learn a little bit about solder, its history, and the terminology that will be used while discussing it.

Solder, as a word, can be used in two different ways. Solder, *the noun*, refers to the alloy (a substance composed of two or more metals) that typically comes as a long, thin wire in spools or tubes. Solder, *the verb*, means to join together two pieces of metal in what is called a **solder joint**. So, we solder with solder!



Solder wire sold as a [spool](#) (left) and in a [tube](#) (right). These come in both leaded and lead-free varieties.

Leaded vs. Lead-free Solder -- A Brief History

One of the most important things to be aware of when it comes to solder is that, traditionally, solder was composed of mostly lead (Pb), tin (Sn), and a few other trace metals. This solder is known as **leaded solder**. As it has come to be known, [lead is harmful to humans](#) and can lead to lead poisoning when exposed to large amounts. Unfortunately, lead is also a very useful metal, and it was chosen as the go-to metal for soldering because of its low melting point and ability to create great solder joints.

With the adverse effects of leaded soldering known, some key individuals and countries decided it was best to not use leaded solder anymore. In 2006, the European Union adopted the [Restriction of Hazardous Substances Directive \(RoHS\)](#). This directive, stated simply, restricts the use of leaded solder (amongst other materials) in electronics and electrical equipment. With that, the use of **lead-free solder** became the norm in electronics manufacturing.

Lead-free solder is very similar to its leaded counterpart, except, as the name states, it contains no lead. Instead it is made up of mostly tin and other trace metals, such as silver and copper. This solder is usually marked with the RoHS symbol to let potential buyers know it conforms to the standard.

Choosing the Right Solder for the Job

When it comes to manufacturing electronics, it's best to use lead-free solder to ensure the safety of your products. However, when it comes to you and your electronics, the choice of solder is yours to make. Many people still prefer the use of leaded solder on account of its superb ability to act as a joining agent. Still, others prefer safety over functionality and opt for the lead-free. SparkFun [sells both varieties](#) to allow individuals to make that choice for themselves.

Lead-free solder is not without its downfalls. As mentioned, lead was chosen because it performs the best in a situation such as soldering. When you take away the lead, you also take away some of the properties of solder that make it ideal for what it was intended -- joining two pieces of metal. One such property is the melting point. Tin has a higher melting point than lead resulting in more heat needed to achieve flow. And, although tin gets the job done, it sometimes needs a little help. Many lead-free solder variants have what's called a **flux core**. For now, just know that flux is a chemical agent that aids in the flowing of lead-free solder. While it is possible to use lead-free solder without flux, it makes it much easier to achieve the same effects as with leaded solder. Also, because of the added cost in making lead-free solder, it can sometimes be more expensive than leaded solder.

Aside from choosing leaded or lead-free solder, there are a number of other factors to consider when picking out solder. First, there are tons of other solder compositions out there aside from lead and tin. Check out the [Wikipedia solder page](#) for an extensive list of the different types. Second, solder comes in a variety of gauges, or widths. When working with small components, it's often better to use a very thin piece of solder -- the larger the number, the smaller the gauge. For large components, thicker wire is recommended. Last, solder comes in other forms besides wire. When getting into surface-mount soldering, you'll see that solder paste is the form of choice. However, since this is a through-hole soldering tutorial, solder paste will not be discussed in detail.

Soldering Irons

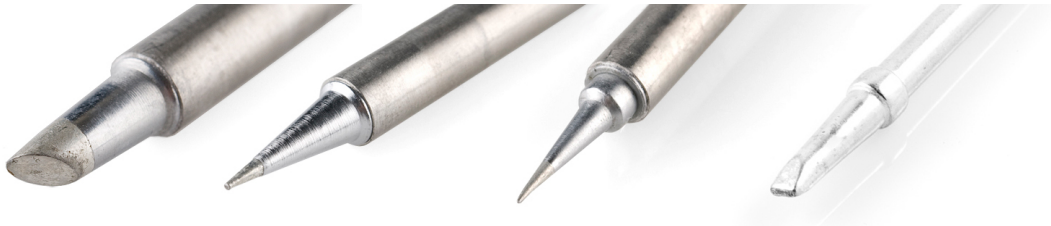
There are many tools that aid in soldering, but none are more important than the [soldering iron](#). If nothing else, you need at least an iron and some solder to accomplish the task at hand. Soldering irons come in a variety of from factors and range from simple to complex, but they all function roughly the same. Here, we'll discuss the parts of an iron and the different types of irons.



Soldering Iron Anatomy

Here are the basic parts that make up a soldering iron.

- **Soldering Tips** - No iron is complete without an iron tip. The tip is the part of the iron that heats up and allows solder to flow around the two components being joined. Although solder will stick to the tip when applied, a common misconception is that the tip transfers the solder. The tip actually transfers heat, raising the temperature of the metal components to the melting point of the solder, and the solder melts accordingly. Most irons give you the option to change your tip, should you need to replace an old tip or if you need to switch to a different style of tip. Tips come in a variety of sizes and shapes to accommodate any component.



Several types of tips. From left to right, the bevel tip (aka hoof tip), two conical tips with varying widths, and the chisel tip.

Changing the tip is a simple process that consists of either unscrewing the wand or simply pushing in and pulling out the tip.



Tip: The efficiency of the heat transferred from the tip to the joint is dependent on the the size of the soldering iron tip that you are using. Usually, you want to have a soldering tip that is about

the same width as the soldering pad you are soldering to. For more information, check out [this article by Hakko](#).

- **Wand** - The wand is the part of the iron that holds the tip. This is also the part that is handled by the user. Wands are usually made of a variety of insulating materials (such as rubber) to prevent the heat of the tip from transferring to the outside of the wand, but they also house wires and metal contacts that transfer heat from the base or outlet to the tip. This dual role of heating and preventing burns makes a high quality wand much appreciated.

Two varieties of wands. Notice how the tips screw into the wand allowing for interchangeability. Some wands have tips that simply push in and pull out without any attaching mechanism.

Some irons consist of just a wand that plugs into a wall outlet. These irons are as simple as they come, and they do not have any controls to vary the temperature. In these irons, the heating element is built directly into the wand.



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A [simple soldering iron](#) that consists of just the wand. Some of these irons do not offer interchangeable tips.

- **Base** - The base of the soldering iron is the control box that allows the adjusting of temperatures. The wand attaches to the base and receives its heat from the electronics inside. There are analog bases, which have a dial that controls the temperature, and there are digital bases, which have buttons to set the temperature and a display that tells you the current temperature. Some bases even have extra features such as heat profiles that allow you to quickly change the amount of heat provided to the tip for soldering a variety of components.



Two variations of a soldering iron base. On the left, a digital base, complete with control buttons and a digital display. On the right, an analog base that uses a dial to control the temperature.

The base typically comprises a large transformer and several other control electronics that safely allow you to vary the heat of your tip.



The insides of a soldering iron base

- **Stand (Cradle)** - The iron stand (often referred to as a cradle) is what houses the iron when it is not in use. The stand may seem trivial, but leaving an unattended iron laying around on your desk or workbench is a potential hazard: it could burn you, or, worse, it could burn your desk and start a fire. Again, they can be as simple as a [metal stand](#), or they can be complex, offering an auto-shutoff feature that reduces the temperature of the tip when the wand is placed in the cradle. This helps prevent the wearing of your tip over time.



Different types of iron cradles. Notice some allow for a regular sponge while others hold a brass sponge.

- **Brass Sponge** - As you solder, your tip will tend to **oxidize**, which means it will turn black and not want to accept solder. Especially with lead-free solder, there are impurities in the solder that tend to build up on the tip of your iron, which causes this oxidization. This is where the sponge comes in. Every so often you should give your tip a good cleaning by wiping off this build-up. Traditionally, an actual wet sponge was used to accomplish this. However, using a wet sponge can drastically reduce the lifespan of your tip. By wiping your tip on a cool, wet sponge, the tip tends to expand and contract from the change in temperature. This expansion and contraction will wear out your tip and can sometime cause a hole to develop in the side of the tip. Once a tip has a hole, it is no good for soldering. Thus, brass sponges have become the standard for tip cleaning. Brass sponges pull the excess solder from your tip while allowing the tip to maintain its current heat level. If you do not have a brass sponge, a regular sponge is better than nothing.



A [brass sponge](#). If your iron stand doesn't have a spot for a brass sponge, you can get [one](#) with its own base.

Soldering Accessories

Now that you know the ins and outs of a soldering iron, it's time to discuss the other tools that will aid you on your soldering adventure.

Solder Wick

- **Solder Wick** - The eraser to soldering's pencil. When dealing with issues such as jumpers or the removal of parts (desoldering), solder wick comes in very handy. Solder wick -- aka desoldering braid -- is comprised of thin copper wire braided together. Solder is soaked (wicked) up by the copper allowing you to ["erase" extra globs of solder](#).



Tip Tinner

- **Tip Tinner** - A chemical paste used to clean the tip of your soldering iron. It is composed of a mild acid that helps remove baked on residue (like when you accidentally melt your tip on a component) and helps prevent oxidation (the nasty black stuff) that accumulates on your soldering tip when not in use.



Solder Vacuum (Solder Sucker)

- **Solder Vacuum (Solder Sucker)** - A great tool for removing solder left behind in through-holes when desoldering components. We'll go over how to use this tool a little later in the tutorial.

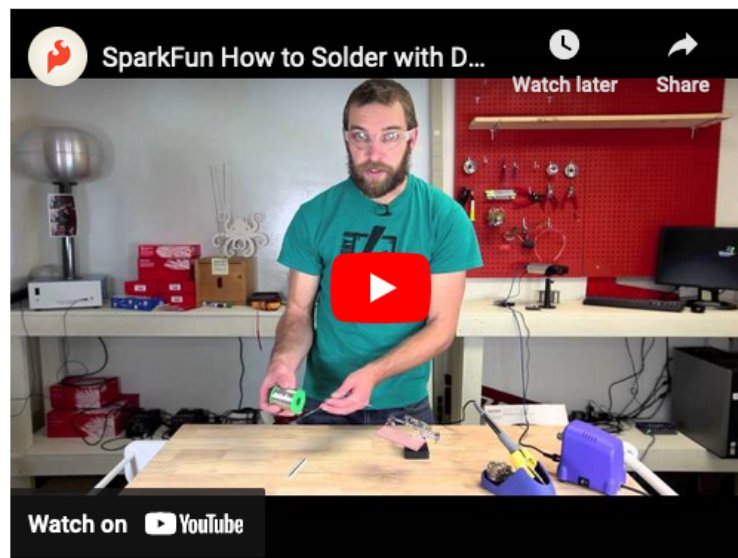


Silicone Soldering Mat

- [Insulated Silicone Soldering Mat](#) - Protect your desktop and keep it clean with a silicone soldering mat. (The picture is uninformative!)

Soldering Your First Component

Let's put all these tools into action. This first video will go over the basics of soldering your first component -- headers! (Sparkfun video: <https://youtu.be/f95i88OSWB4>)

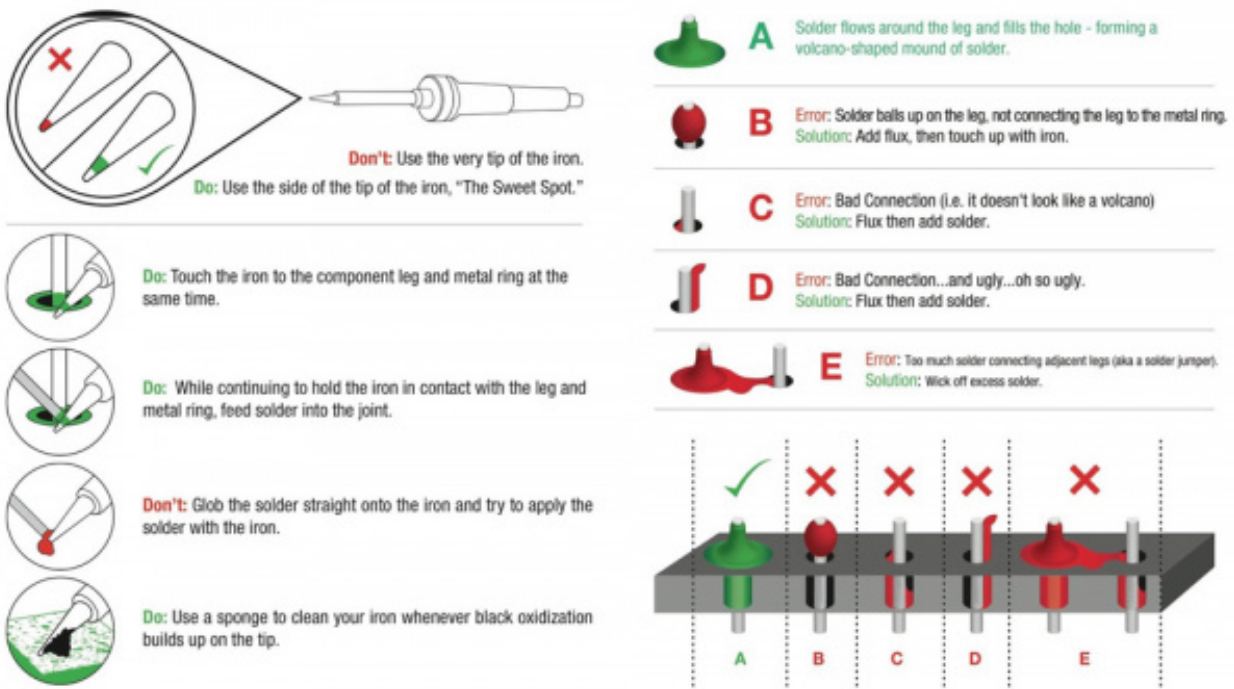


Recap

It's really that easy! Follow Dave's simple rules to make every solder connection a good one.

- Be cautious when handling hot irons
- Use third hands or vices to hold boards while you solder
- Set your iron at a good medium heat (325-375 degrees C)
- If you see smoke coming from your solder, turn down the heat
- Tin your tip with solder before each connection to help prep the joint
- Use the side of the tip (aka the sweet spot), not the very tip of the iron
- Heat both the pad and the part you want to solder evenly and at the same time
- Pull the solder away, then the iron
- A good solder joint should look like a volcano or Hersey kiss, not a ball or clump

We've also put together this diagram to help you better understand what makes a good solder joint.



When you are finished, tin the tip to increase its life before turning your soldering iron off.

See <https://learn.sparkfun.com/tutorials/how-to-solder-through-hole-soldering/all#tips-and-tricks> for a few tips from SparkFun.

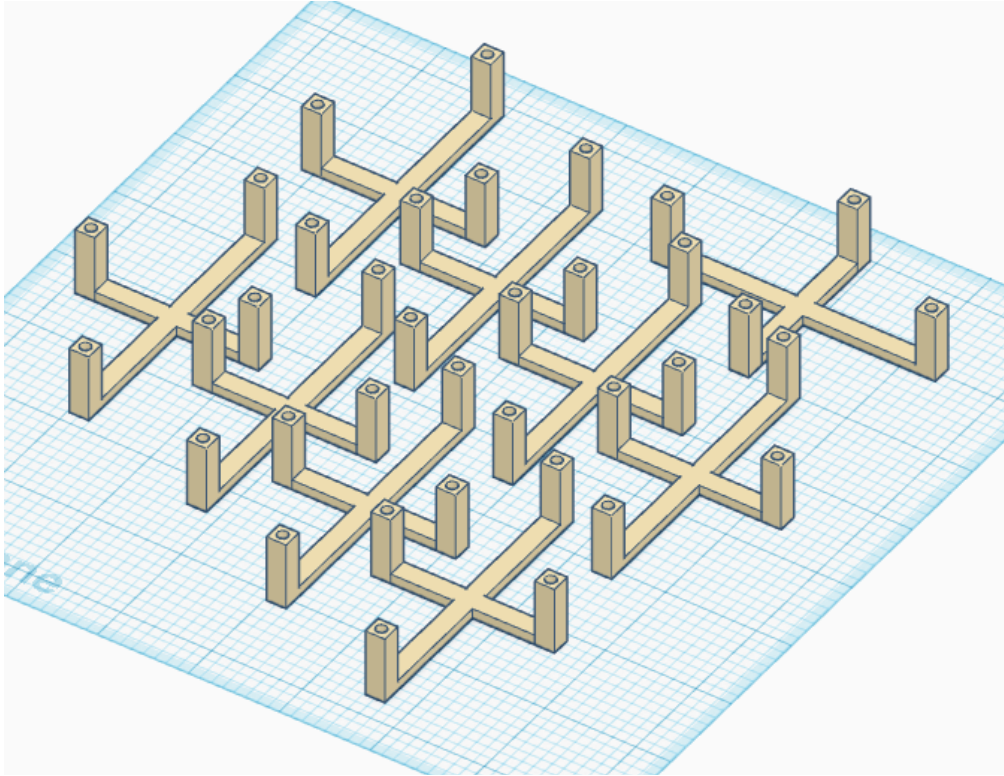
Some of mine, which we'll go over in class:

- Using painter's blue masking tape to hold components steady while soldering
- How to align a header to be perpendicular to a PCB

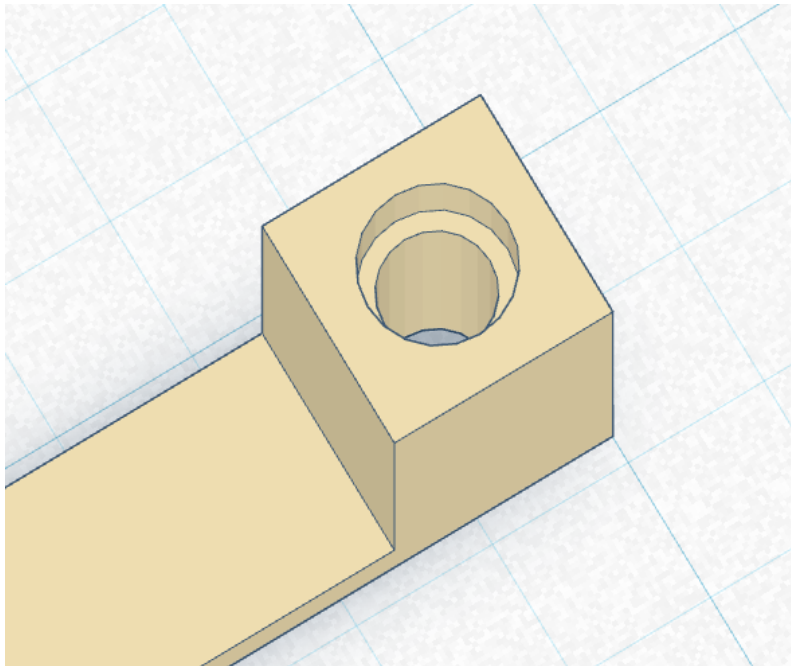
Mounting PCBs in 3D printed cases

Take a look at my Tinkercad design “protoboard_cradle9.” It’s here:

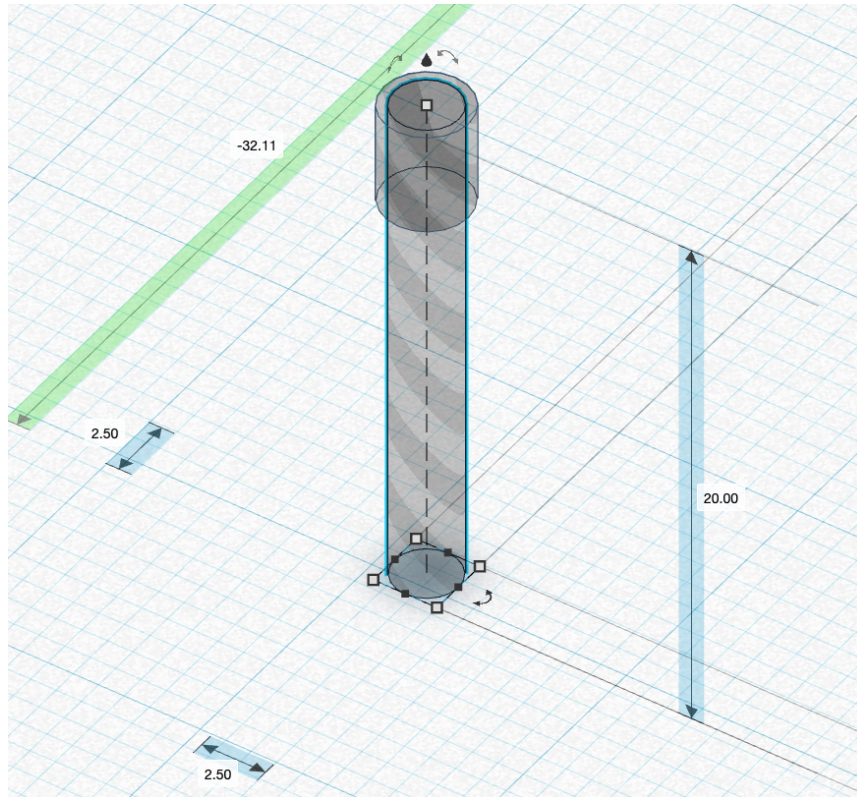
<https://www.tinkercad.com/things/giNdAVoatk2> .



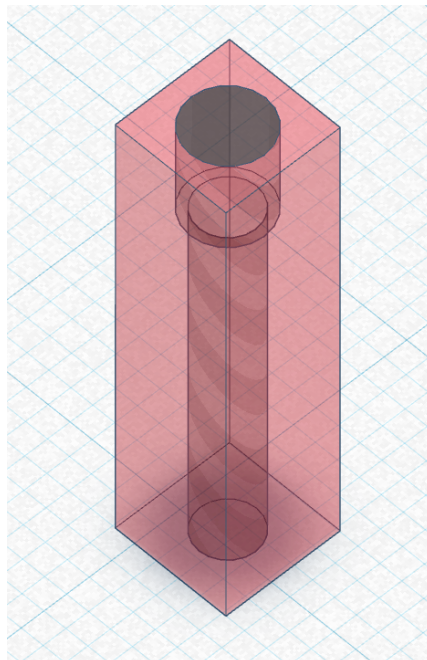
Let me enlarge the view of one of the posts for you.



The wider section of the hole is meant to accommodate a knurled brass insert that's threaded for an M2 (metric) screw. Here's the hole: it's 20 mm tall, with the diameter of the narrower portion set to 2.5 mm. The wider portion is 4 mm long and 3.3 mm in diameter.



When I center the hole in a 5 mm square post, I get this:



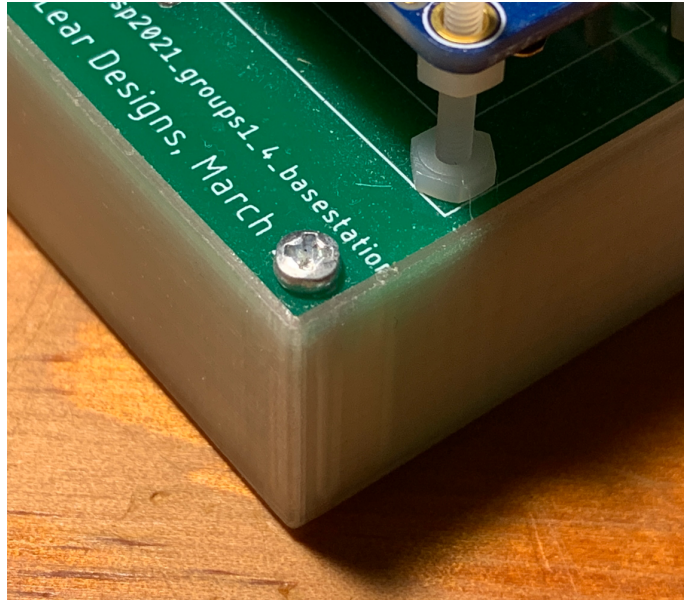
Here's a link to a single post with this geometry:

<https://www.tinkercad.com/things/dacZrGhbNLP> . Note that you may need to adjust the diameter of the wider section of the hole slightly to get the size just right: you'll want to press-fit the insert, perhaps squeezing it in a vise, or hammering it into place.

A standard M2 screw is 2 mm in nominal diameter, with a distance between threads of 0.4 mm. One common way of referring to it is as an "M2-25" screw, meaning it is a metric 2mm diameter screw with 25 threads per cm. Here's a photo.



Since the PCBs I have fabricated by JLCPCB are about 1.6 mm thick, an 8 mm long M2 screw works nicely to hold them in place. Here's an example:



Homework

None, but please finish getting your projects breadboarded!

