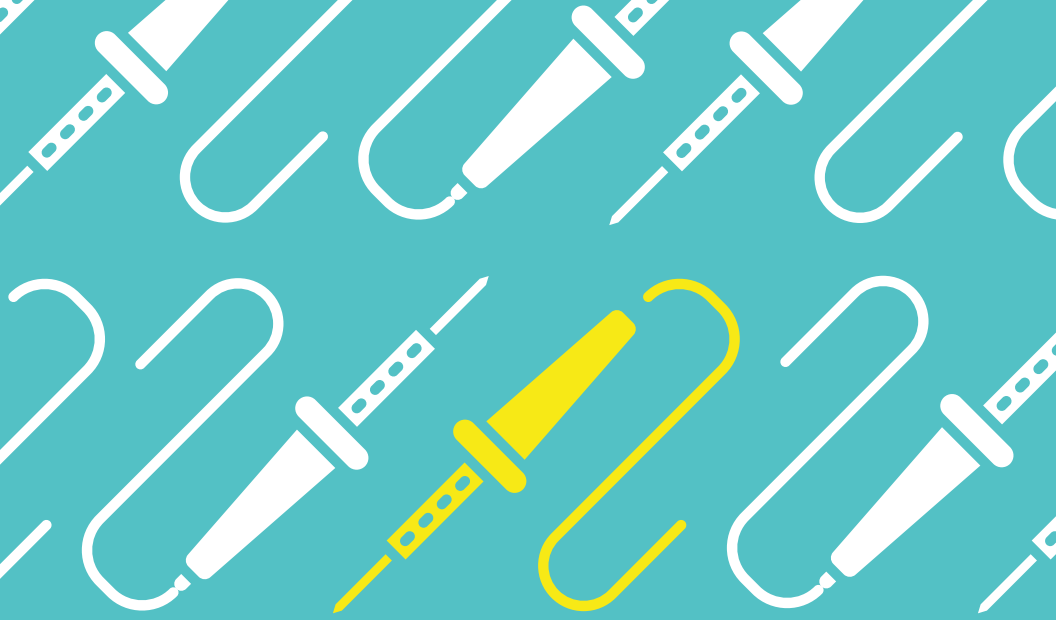


How To Solder

FOR DIY GUITAR PEDALS, SYNTH, AND OTHER HOBBY ELECTRONICS

Mark A. Stratman

MAS Effects

GLOSSARY

Bridge— or *Bridging*. An unintentional connection between adjacent points in your circuit. This is sometimes also called a *short*.

Flux — A chemical substance that prepares the metal surfaces to bond with the solder. Your solder should have a flux core.

Joint — or *Solder Joint*. A point at which two or more metals are joined together with solder.

Leads — Metal wires, lugs, or legs that extend from a component and are meant to be soldered to a PCB, wires, or other components.

Oxidation — Reaction of a metal surface with oxygen, resulting in a layer of a metal oxide that interferes with solder's ability to bond to it.

Pad — or *Solder Pad*. An exposed area of metal on a PCB onto which components are soldered. It may have a hole for surface mounted components, or no hole for surface mount.

PCB — Printed Circuit Board. A board, typically made of fiberglass, with copper pads, traces, and holes to electrically connect components together.

SMD — Surface Mount Devices. See "*Surface mount.*"

Solder — Filler metal that is melted and bonded to two or more other metal surfaces, allowing electricity to freely flow between them.

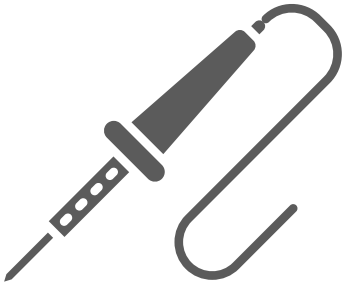
Surface mount — Mounting electrical components directly to the surface of the PCB. Common, related abbreviations: SMT (surface mount technology), SMD (surface mount devices).

Through-hole — Mounting components through holes in the PCB, and soldering their leads to the pad that surrounds the hole.

Tinning — Covering the tip of the soldering iron in a thin layer of fresh solder. This solder is critical, and is what conducts heat to your components and PCB.

How To Solder

For DIY Guitar Pedals, Synth, and Other Hobby Electronics



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PREFACE

While frequenting the various DIY guitar pedal forums, I've seen hundreds of failed projects due to bad soldering. Worse, since each was typically the builder's first pedal, there was a lot of disappointment and despair, not to mention wasted time and money.

Learning to solder is a critical first step in DIY electronics. You're probably eager to start building guitar pedals or other fun projects, but too many people ruin their first projects with bad soldering.

It's a heartbreaking and expensive lesson.

To help more people have an easier, gentler introduction to the hobby, I wrote this book and created the accompanying video and soldering practice kit. The kit is even included for free with every MAS Effects Beginner Pedal Kit.

When you finish this book (and/or video) and do the corresponding practice, you will be comfortable and proficient with a soldering iron and have a solid base of knowledge to be confident with any hobby electronics project.

I want you to succeed and have fun. This guide will show you how.

INTRODUCTION

What is soldering?

Soldering is bonding two or more separate metal pieces together with a filler metal, called solder.

It's important to note that word: "bonded."

You're not just melting solder over the joint. You are chemically modifying the surfaces of those metals to create a strong bond. Keeping this in mind will help you later when we consider good and bad solder joints.

WHO IS THIS FOR?

For absolute beginners

If you've never soldered before, this will walk you through all the basic knowledge and skills you will need to successfully solder components to build DIY guitar pedals or other hobby electronics.

It's recommended you go through this entire document and optionally the accompanying video to ensure your success.

For everyone else

Whatever your level of experience, this guide and the accompanying video can fill any gaps in your knowledge or clarify anything you're not confident in.

If you have the corresponding practice kit you can build a cute LED flashlight, and practice soldering 46+ joints before you get started building a pedal.

Feel free to skip the following chapter on tools if you're already geared-up.

ENHANCE YOUR EXPERIENCE

To help ensure your success, and make your journey into soldering even more enriching, here is a range of supplementary resources for you to use:

1. Practice kit

Reading this guide can prepare you to learn to solder, but only you, through practice, can become good at this hands-on skill.

The next page will show you the MAS Effects kit as well as alternative materials you can use for practice. Either way, the most important thing you need to do is solder many joints following the steps in "How to solder: Step by step" on page 22.

2. Accompanying videos

Visit `masfx.io` for the accompanying videos.

These videos provide step-by-step demonstrations of the techniques discussed in the text. Watching them can help you visualize and predict solder flow, see how the steps come together fluidly in real-time, and troubleshooting common issues.

3. Abbreviated guide

A web-based version of this guide is also available at `masfx.io`. At the bottom of the page you'll see buttons labeled *QUICK* and *COMPREHENSIVE*.

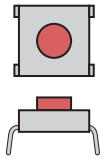
By selecting the *QUICK* version of the guide you can skip most of the "nice to know" information and focus on the core preparations and steps needed to successfully solder electronics projects.

TOOLS AND MATERIALS

We made a soldering practice kit to accompany this guide in hopes that everyone can have a successful and rewarding introduction to DIY electronics. We worked hard to make it inexpensive, convenient, and fun.

If you don't already have a MAS Effects Soldering Practice Kit, get one at: `masfx.io/practice`

PRACTICE KIT CONTENTS



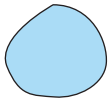
Buttons (3)

SPST momentary
single pole, single throw

LEDs (3)

Light emitting diodes

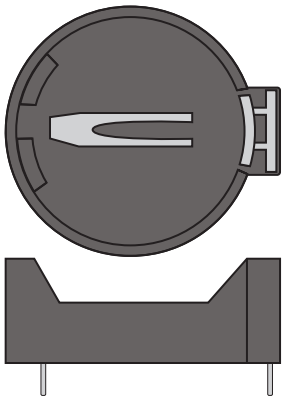
Blue putty



Holds your PCB or secures components in place while you solder

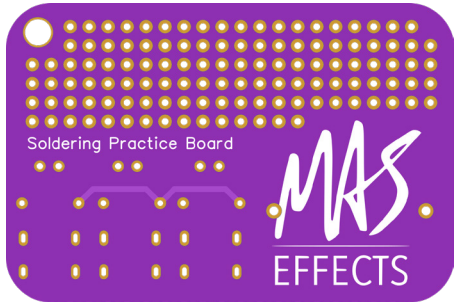
Resistors (13)

470Ω
yellow, violet, black, black, brown



Battery holder (1)

for CR2025 or CR2032 coin batteries



PCB (1)

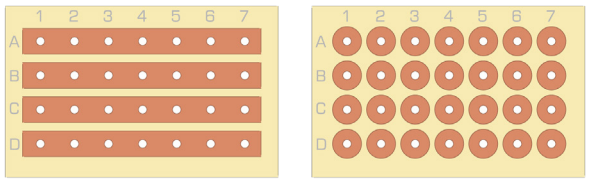
Printed circuit board

(ALTERNATIVE) DIY PRACTICE KIT

You don't need the MAS Effects practice kit to use this guide. With the exception of the flashlight project, you can follow along and do all the same practice by using "stripboard," "veroboard," or "perfboard" prototyping boards.

These are fiberglass boards, similar to a PCB, with a grid of holes. Stripboard, also known as veroboard, has copper strips connecting adjacent holes. Perfboard has individual, unconnected copper pads on its holes.

In addition to the prototyping board, you will need components or wires to solder to it. Resistors, diodes, capacitors, or any other through-hole component should work great. You can also use solid core wire, approximately 22 to 28 gauge (AWG).



Stripboard

Perfboard

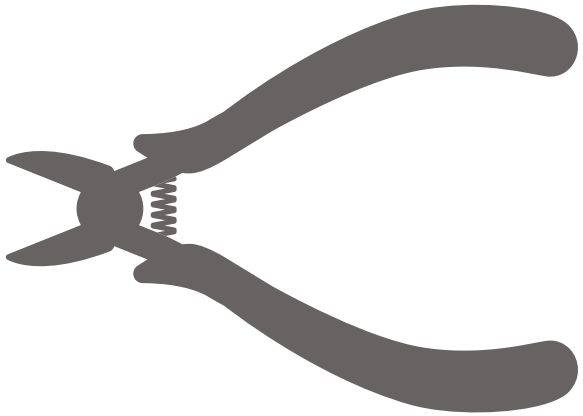
REQUIRED TOOLS

Soldering iron

A soldering iron and solder are the main tools you'll need. We discuss recommendations in the following pages. In short: buy an inexpensive iron from a marketplace (Amazon, Ali, Ebay, etc). It'll get you through a handful of pedals before you decide whether it's worth upgrading. The quality won't make a difference if you're using good techniques.

DO NOT get an L-shaped one that looks like a gun, or one meant for plumbing work. You need the style shown here, with removable tips.

Flush cutters



Or *diagonal cutters*, or *side cutters*, or *wire cutters*. These are for snipping the excess leads after soldering.

Sponge

A damp (not soaked!) cellulose kitchen sponge will work great for keeping your soldering iron tip clean. To determine if it's suitable, make sure it's the type that gets hard when it dries. That's a pretty good indication it's cellulose. Bath sponges that are always soft, however, aren't going to work and will melt.

Another popular option is a brass soldering sponge. These are made of tiny strips of brass that don't thermally shock your iron tip the way a damp sponge does, so it doesn't experience as much temperature drop. Usually in practice it's not a big deal, so don't worry about it yet. Plus the brass sponges tend to leave little balls of solder on your tip which can be annoying.

And finally, a folded pile of damp paper towels can work great in a pinch, too.

OPTIONAL TOOLS

- **Eye protection**: This is only "optional" insomuch as you can assemble a pedal without it. But you shouldn't. Bits of solder can fly a couple feet or more, and clipped leads from components can go flying as well.
- **Blue putty**, included with the MAS Effects practice kit, is useful to stick the circuit board to the table, or to hold pieces in place while you solder. It lasts forever, so save it for your future DIY pedal builds. Specialized tools like "helping hands" (alligator clips on adjustable arms), a vice, or whatever else you have on hand could be used instead.
- **Needle nose pliers** to bend leads and pull them through the circuit board more easily.
- **Wire strippers**: The simplest, most affordable ones you can find will be great. You don't need these for the MAS Effects practice kit or beginner kit, but future projects may require them.
- **Small fan** to blow flux fumes away from your face or a soldering fan with attached carbon filter to draw fumes in
- **Multimeter**: Any inexpensive multimeter can be useful when troubleshooting. Use it to check for continuity between points in the circuit, as well as measure voltages.
- **Solder sucker pump**: if you mistakenly place a component in the wrong spot then remove it, the hole will be plugged with solder. A solder sucker is the best tool to clear it out, but as we'll see later in this guide, you don't usually need to clear the hole to replace most components.
- **Flux**: Your solder should have a flux core, and that is enough for most soldering. In some rare or advanced situations, additional flux can be helpful. A syringe of flux gel is quite versatile, but you can also get flux pens, bottles, and other packages.

GET GEARED UP FOR ABOUT $15

My philosophy

If you go online and ask people who are deep in the DIY pedals hobby what you need to get started in pedal building, you'll end up with a $400 shopping cart. People are more than happy to spend YOUR money for you.

Further, they'll also endlessly list things they've acquired over many years and dozens or hundreds of projects, as well as stuff that has marginal or niche utility. If you're building a first - and possibly only! - pedal then their needs clearly don't match yours.

> "People are more than happy to spend YOUR money for you."

You'll also hear the old adage to "buy the best tool you can afford." This makes a lot of sense if you're going to use it often, but for something you use once or twice, or even occasionally, it's terrible advice.

Instead, I say this:

- Get just enough tooling to get the job done. Avoid "nice to have" tools, or those for occasional use.
- Purchase the cheapest tools you can find. If you don't already have them and need them for other projects, don't invest yet! Cheap ones will easily last 10+ pedal builds, which is more than enough time to assess your interest.
- If you keep going in the DIY pedal building hobby, you'll slowly upgrade and add to your tool collection as you go. You'll also only end up with things you care about, not what somebody else told you they needed.

ALTERNATE APPROACH:

If budget constraints aren't a concern for you, or you know you want to use your soldering iron many times, get a reliable one to start with.

There are lots of great options available depending on your budget and preferences, so stop by our forum and get some personalized recommendations: `masfx.io/forum`

Quick recommendation

Buy an inexpensive kit with soldering iron and accessories. Supplement with additional supplies or tools if needed.

When the tip is worn out, replace with a brand-name tip.

Choosing tools

Go on your favorite marketplace site (e.g. Amazon, Ebay, Ali, etc) and search for "SOLDERING IRON KIT."

For approximately $15 USD you should be able to get

- Soldering iron with power adjustment and removable tips
- Stand to hold the iron
- Flush cutters
- Solder
- Desoldering pump and other optional tools

There are endless variations on these kits, with more or fewer items in them. Look carefully at the list and be sure to get each of required items, or supplement it with additional purchases.

Common soldering iron package. Perfect for trying the hobby on a minimal budget.

Although the tips that come with it will wear out extremely quickly, a kit with both a conical and a chisel tip (ignore the other shapes for now) will give you an opportunity to try both and see if you have a preference.

When the time comes to replace the tip, get one from a reputable brand. For example, all the irons like the one pictured above can use a Hakko T18 tip. The Hakko tips cost nearly $10 but will last significantly longer than the cheaper ones.

More details? Or get started?

If you're happy with a kit, skip to "Prepare to solder" on page 16.

If you'd rather gear up piece by piece, or learn more details about solder and irons, continue on to the next page.

SOLDERING IRONS: GOOD VS. CHEAP

The internet will tell you to go out and buy a Hakko FX-888D ($105) and don't waste your time with the $8 soldering iron. If you can confidently predict you're going to build dozens of pedals, I'll agree.

If, on the other hand, you're going to build only a few pedals, or aren't yet certain you'll enjoy this hobby, you probably don't need more than the most basic tool.

But to be sure, let's articulate the differences between the $8 and $100+ soldering irons:

An Anecdote

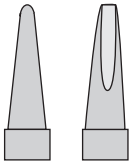
When my old, name-brand iron broke down, I bought and used one of those cheap irons exclusively and excessively for over a year until it finally failed. I actually replaced it with the same one and used it for a while longer before finally switched back to a quality iron.

I'm certain if you follow this guide and learn to solder, and tin your tip, you will be able to build many pedals with an $8 iron before you feel the need to upgrade.

	$8 iron	$105 iron	Will I regret the cheaper one?
Initial heating time	Slower (~2 min).	Fast (~30 sec).	Not for occasional use; just turn it on to preheat while you prepare other things.
Temperature stability	Temperature drops a bit when heat is applied to the PCB.	Temperature remains fairly consistent.	It won't make much difference for guitar pedal PCBs, but it may require a bit more patience when soldering a pad connected to a large plane of copper. If you follow this guide and learn to recognize a good solder joint, and don't apply excessive heat, you won't have any problems. If you don't learn how to properly to solder first, however, it'll be easier to burn the pads off the circuit board.
Temperature accuracy	The dial, if it has one, controls power. The temperature setting is an approximation.	Sets exact temperature fairly precisely.	No, it doesn't matter for guitar pedals or most hobby electronics.
Life span	Will last approximately 1 year of heavy, frequent use, or much longer with occasional use.	Will last forever.	If you're certain you will use it very often, then you should skip the cheap iron. For gauging your interest or for occasional use, it'll last much longer than a starter iron needs to and you will get plenty of value out of it.
Tip quality	Includes cheap tips which don't last very long.	Includes quality tips which last longer.	Not if you get one like pictured on the previous page, which can take Hakko T18 tips. After building a few pedals and you're having trouble tinning your iron, just get a brand-name replacement tip.

Tips for Tips: That last row is worth repeating: eventually you should replace the included tips with Hakko T18 tips. They will last much longer.

CHOOSING A TIP FOR YOUR IRON



Conical and chisel tips

Choose a conical pencil-shaped tip or a chisel tip. These will work well for all guitar pedal parts. They're even suitable for SMD (surface mount devices) if you ever get to that, though it's outside the scope of what we'll learn with this guide.

The tip needs to be large enough to simultaneously heat both the part being soldered and the pad on the circuit board, but not so large you inadvertently heat other pads or components.

Use whatever came with your iron. If you eventually, after many hours of use, find it will no longer tin properly - more on that later - then replace it with a name-brand, high-quality tip.

I prefer a Hakko T18-D16 chisel type (1.6mm wide tip), or sometimes the T18-B conical with a 0.5mm radius.

CHOOSING SOLDER

If you bought a kit that came with solder, use it! However, if you need to buy solder, or for future reference, here are some basic considerations.

Leaded vs. lead-free:

Leaded solder is MUCH easier to work with than lead-free. An entire article could be written about this topic, but it can be summarized with this: *lead-free solder has the potential to cause you far more headaches with very few benefits.*

I strongly recommend using leaded solder until you have learned the fundamentals and feel confident in your soldering ability. Your chances of success with lead-free solder, as a beginner, are greatly diminished. Even after you're highly proficient at soldering you should probably continue using leaded solder. The failure rate of lead-free solder joints over time is much higher, and it is simply less reliable.

Lead-free solder is widely used for commercial products due to environmental concerns. Countless tons of consumer electronics eventually pollute the Earth, so lead-free solder can help reduce contamination.

Switch to lead-free solder when your projects are being manufactured and assembled by professional PCB fabricators.

Quick recommendations

Solder:

- Leaded
- 60/40 to 63/37 (*approximate*) tin/lead ratio
- 0.31" or 0.32" or 0.8mm (*approximate*) diameter
- "No Clean" flux core

Tip for soldering iron:

- Hakko T18-D16 (1.6mm wide chisel)

Leaded solder safety:

People often think the fumes that rise while soldering have lead in them, but they do not. The fumes are from flux, and they are equally (if not more) harmful in lead-free solder. We'll touch on this soon, but for now the biggest safety consideration when working with leaded solder is to WASH YOUR HANDS to remove any traces of lead when you are finished. Refrain from touching your face, eating, or touching other people until you wash your hands.

If you are soldering on a sensitive surface like a kitchen table, lay down newspapers to protect it from tiny bits of solder that will splash and clean the surface well when you are done.

Tin/lead ratio:

Leaded solder is made from a mixture of tin and lead, and is available in a variety of ratios.

60/40 or 63/37 are the most popular for DIY electronics, and the difference between them is negligible. Choose whichever is cheaper or more readily available.

Width of solder wire

0.031 or 0.032" (~ 0.8mm) is a good multi-purpose size.

Smaller can be used as well, but you'll have to push far more solder wire into each joint. I keep a roll of 0.6mm for SMD work, but probably wouldn't use solder narrower than this.

Solder larger than 0.032" should be avoided since it makes it easy to quickly add too much solder to joints.

Flux

Flux is a chemical substance that prepares the metal surfaces to bond with the solder. It is critical for soldering because it removes and prevents layers of oxidation on your component and PCB pad so the solder can properly bond to the metal.

Without it you would have unreliable solder joints.

Flux core solder (required)

Solder used for electronics like DIY pedals should always have a flux core. Most solder you find for electronics is suitable. Avoid plumbing solder, though.

For the majority of soldering, the flux inside your solder wire will be sufficient.

Understand, though, that once you melt the solder the flux burns off. If you are reworking a joint is often a good idea to add fresh solder in order to get more flux.

Additional flux (optional)

In some circumstances it helps to have additional flux you can apply to the parts you are working on. For example, if you are working on surface mount devices (SMD), which are typically very small, it is often useful to apply solder directly from the tip of the iron. When the solder melts and adheres to the tip, though, the flux is burned off. Because of this you will need to first add additional flux to the work pieces.

Additional flux can come in a variety of formats:

- Gel in a syringe: my favorite. It's easy to apply, sticks to the intended surface, and is tacky and can hold surface mount parts in place
- Liquid in a pen or bottle
- Paste

Flux types

Rosin flux

An aggressive flux that will work well for most situations, including older, moderately oxidized parts. However it leaves a thick, dark residue that must be cleaned with isopropyl alcohol (rubbing alcohol). Stronger mixes, e.g. 91%, make the job easier

No clean flux

This is the least aggressive, and leaves less residue on the circuit board so it's often not cleaned off. This is my preferred type.

Unless you're working on old parts that are in rough shape, it's perfectly adequate. It is generally safe to leave on the PCB, as the "no clean" name implies, so it can save you time if that's important to you.

However, if you'd like to clean it, use isopropyl alcohol just like with rosin core

Water soluble flux [not recommended]

As the name implies it is cleaned with water, so care must be taken when using water-sensitive components. This is also a very aggressive flux. Because of various problems water causes in your circuit (e.g. from minerals and oxide), I don't recommend using this flux.

PREPARE TO SOLDER

PROTECT YOURSELF (AND YOUR TABLE)

Protect your eyes

Tiny bits of solder will sometimes fly from your work piece, so keep your eyes covered with glasses. If you're not careful you may also send sharp metal cutoffs flying when clipping them after soldering. Wear eye protection at all times.

Protect your lungs (flux fumes)

The fumes that rise while soldering - though they don't contain lead, as many people believe - are still hazardous to your health if you breath them frequently.

If you're working in a well ventilated area, use a fan to blow them away from your face.

Alternatively, especially if your area isn't as well ventilated, you can use a fan with a carbon filter to suck the fumes into the filter and away from your face. You can tape a carbon filter to a computer case fan, or search for "soldering fan" in your favorite marketplace.

Protect Your Table

Unless you're working on a rough workbench that you don't mind damaging, put down some newspapers and cover at least 60cm (~2 ft) in each direction. Little balls of solder will sometimes go flying when you're making a solder joint.

SOLDERING TEMPERATURE: 315°C TO 375°C

If your soldering iron has a temperature setting or a power dial that shows approximate temperature, set it to between 315°C (600°F) and 375°C (700°F). If it is not adjustable, then don't worry about the temperature as long as it's a pencil type soldering iron for electronics, and NOT a gun shaped one.

Ideally you'll work at a higher temperature and solder the joints very quickly. Until you gain this ability, though, start on the lower end of the range to give yourself a little more time and leeway. As your skills improve and you speed up, increase the temperature to allow you to work more quickly.

How important is a specific temperature?

It's not, mostly*.

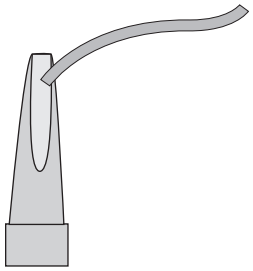
You want the iron hot enough so it can heat the component and pad, and the solder melts when contacting the component and pad (not the iron). You want to minimize the amount of time the component and pad are subjected to high heat, as well.

A good rule of thumb is:

- Quicker speed, higher temperatures
- Slower speed, lower temperatures

** This applies if, and only if, you learn good technique by following this guide. If, on the other hand, you take unreasonably long to form your joints you will absolutely destroy components and lift pads off the PCB.*

TINNING: THE KEY TO EASY SOLDERING



You need to keep a thin layer of solder on your tip at all times. This is called *tinning*. Without it you won't be able to transfer heat to your solder joint.

As soon as your soldering iron heats up, the tip is going to tend to oxidize. When this happens it won't accept solder. To clean it off, wipe it against your damp sponge. Now, immediately apply solder to the tip.

Your tip is tinned once a shiny layer of solder has flowed across it. This is one of the most important things to ensure success. You want to keep your tip tinned at all times. This will help dramatically increase its useful lifetime, too.

Tips for tips

- Clean and tin every few joints while using it
- Clean and tin the tip immediately after turning on your soldering iron.
- Keep the tip protected by putting a large amount of solder on it any time you'll be setting it down for more than a few seconds. Wipe it gently when you pick it up again, optionally adding more solder if needed.

> "You need to keep a thin layer of solder on your tip at all times."

Tinning steps

1. Wipe both sides of the tip

2. Quickly, immediately apply solder

3. Repeat until the tip is shiny

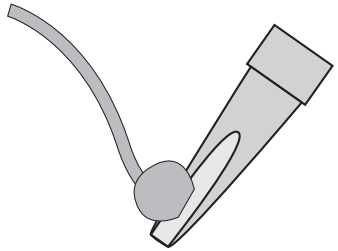
Re-tin

While soldering, clean and tin the tip every few joints

TROUBLESHOOTING: TIP WON'T TIN?

If the solder still doesn't flow over and coat the tip with a layer of shiny solder, clean it again. Repeat as needed. If after several times you're not making any progress, it may be time to replace the tip. Remember, a quality, brand-name tip is worth the extra cost and will last much longer.

Alternatively you can use a special tip tinning product, or a jar of flux which will work more aggressively to remove oxidation. Do not use "tip tinner" products for routine maintenance, though, as it's usually abrasive. Instead use it to get a little more life out of an already-damaged tip.



Problem: The solder balls up and doesn't flow across the tip

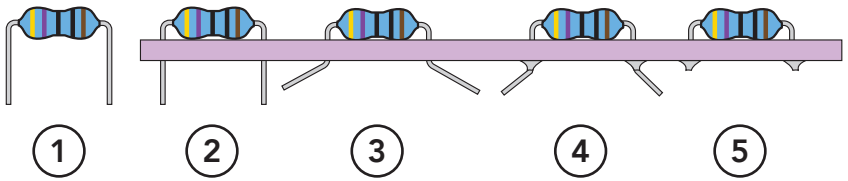
HOW TO SOLDER

QUICK OVERVIEW

Soldering a through-hole component

Let's take a brief look at the entire process of how to solder a through-hole component, i.e., one with leads that go through holes in the PCB, as opposed to surface mount devices which rest on solid pads.

We will cover surface mount soldering later since that will build upon the fundamental skills were learn here.



Don't solder yet.

Let's first preview the steps

1 Bend the leads (if needed)

Axial components, i.e., those with leads coming from opposite sides of its body, need their leads bent before fitting into the PCB. Bend the leads at a right angle.

Radial components, i.e., those with leads on the same side of the body won't require this.

2 Insert into PCB

Put the leads through the holes in the PCB

3 Secure

Flip the PCB over and bend the leads outward slightly. This will hold the resistor in place while you solder.

Use blue putty to stick the PCB to the table.

4 Solder

Heat both the component lead and the PCB pad simultaneously, then melt solder (and the flux in its core) into the joint, bonding the three metals together.

Push the solder into the pad and the component, NOT the iron.

Ensure your soldering iron's tip is well tinned! This is the key to transferring heat.

We'll break this step down further on the following page.

5 Trim

Hold the leads and use your cutters to snip the excess free. If you don't hold them while cutting they will fly and create a dangerous safety hazard, particularly for your eyes.

Cut the lead, not the solder. You should have a small dome remaining on the PCB.

Keep these clippings for additional soldering practice!

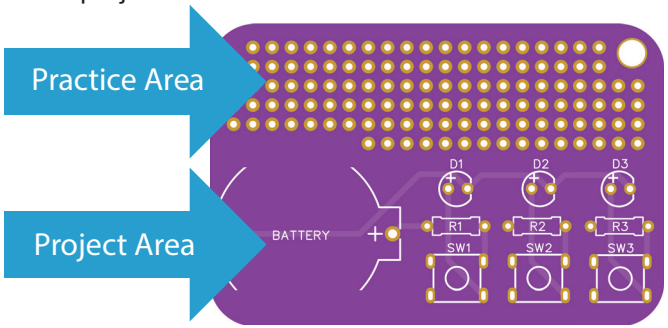
HOW TO SOLDER: STEP BY STEP

Now that you've seen how to solder at a glance, let's take a closer look at some of the steps and you can try it for yourself.

Get ready

If you're using the MAS Effects practice kit, grab the PCB and resistors. The PCB is divided into two areas:

- **Practice area** where you can solder resistors and the extra cutoff leads to learn, experiment, and perfect your technique.
- **Project area** where you will make a flashlight later. Set aside 3 resistors for this project!



MAS Effects Soldering Practice Kit

Otherwise if you don't have the practice kit, get a perfboard or veroboard and resistors, other components, or solid core wire to solder to it.

Steps 1 – 3

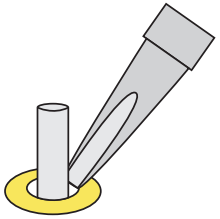
Referring to the previous page: Bend the leads (if needed), insert into PCB, then bend the leads again to secure the component to the PCB. Use some blue putty to stick the PCB to the table and let's get ready to solder.

Step 4A: Clean and tin your tip

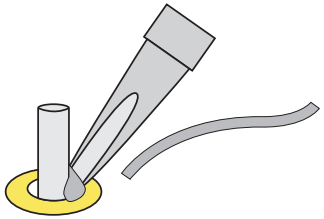
In order to get a proper bond, both the component lead and the PCB pad need to be heated, and the only good way to transfer the heat is with a well-tinned soldering iron tip that's wet with solder.

Take a moment now to clean and tin your tip again, and add a bit more solder.

Step 4B: Heat joint



Touch the pad and component lead: Press the tip against the lead and the pad on the PCB. Use a bit of pressure, but don't strain yourself. If you find the PCB moves too easily, look for something to secure it. I like to use blue putty, but get creative and use whatever you can find.

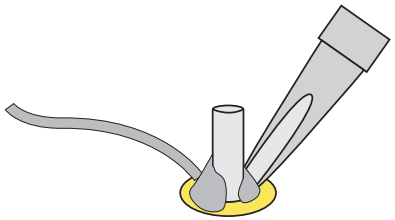


Transfer heat: Add a bit of solder between the tip, pad, and the component if it's not already fairly wet. This little bit of solder will act as a bridge to let the heat flow from the iron's tip to the pad and the component.

Time check

At this point no more than **1-2 seconds** should have passed with heat applied. If it's been longer, remove the iron and let the PCB and component cool. Take this opportunity to clean and tin your tip again.

Step 4C: Apply solder



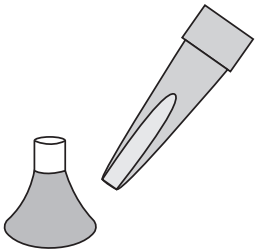
Start adding solder from the other side. The component's lead and the pad should be melting the solder, NOT your iron's tip.

If you feel any resistance, or the solder isn't being pulled across the pad and up lead, it's not hot enough. Reassess and make sure you have wet solder on the tip, and that it's touching both the pad and the component. If so, let it heat for up to 1 or 2 more seconds to see if the resistance disappears.

Otherwise clean your tip, tin it again, then try heating and adding solder again.

Step 4C: Apply solder (continued)

Finish adding solder: If there's no resistance and the solder is flowing, keep pushing solder into the joint until you have a concave mountain as shown here. Notice how the solder has completely covered the pad and has been drawn up the lead.



Time check

2-5 seconds should have passed since you first applied heat.

If you're taking longer than 5 seconds, STOP. Let the solder and component cool, then reapply heat and finish your joint

Step 4D: Cool and Check

Don't let anything move while the solder joint cools (3-6 seconds). If the component's lead moves while it's cooling, the solder won't properly bond to it and you'll have what's called a "disturbed" or "cold joint" that doesn't conduct electricity properly. Luckily this is easily fixed by reheating the solder and "reflowing" the joint.

Do not blow on it or otherwise try to speed up the cooling, either.

To check your joint, first make sure it has a concave mountain shape. It should be smooth and relatively shiny, but if it's not, try reheating the joint to reflow it.

If you're still having trouble getting your joint to look like the picture above, don't worry! In the following pages we'll diagnose and solve bad solder joints. Feel free to skip ahead.

VIDEO: SEE IT IN ACTION

Visit **masfx.io** to watch how these steps come together in real-time, and how the soldering process should look.

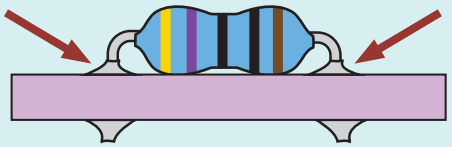
Plated through-hole pads

Through-hole pads often have a metal plating which lines the inside of holes, connecting the two sides of the board. It will typically be present if there are solder pads on both sides of the board.

This plating tends to draw solder into the hole. If your PCB has these, as does the one in the MAS Effects practice kit, you should see a little bit of solder coming out of the side of the board with the resistor's body.

If there's no solder on the lead near its body, you may not have used enough solder. On the other hand, you may have used too much solder if you see an excessive amount of solder, e.g., enough to reach the body of the resistor.

Perfboards and veroboards will not usually be two-sided, and therefore won't usually have plated through-holes. If you're using one of these, don't expect to see solder on the other side of the board.



Step 4E: Clean and tin your tip (again!)

Clean and tin the tip again before you set it down. If you're going to be leaving your soldering iron for a while, add extra solder to the tip to keep it protected from oxidation.

Step 5: Clip the leads

Wear safety glasses! Clipping leads often sends them flying unpredictably.

Hold one or two leads with one hand, and use your cutters to clip them free with the other hand. Holding them will not only greatly increase your safety, but will also make cleanup easier.

Clip the lead, but not the solder. You'll have a little mound of solder on the circuit board like the picture above; It shouldn't be flush.

Save the clipped leads for additional practice when you run out of resistors.

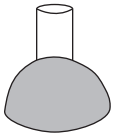
GOOD AND BAD SOLDER JOINTS

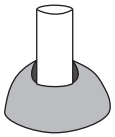
Problem:

None. This looks great! Notice how the solder curves as it was drawn up the component lead and out across the PCB pad.

Solution:

Keep practicing until all your joints look like this.



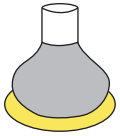


Problem:

Solder bonded to the pad, but not the lead. Notice solder doesn't curve toward the lead, but instead curves outward. There may or may not be a gap.

Solution:

Reflow the joint by applying heat until you see the solder flow both up the lead and across the pad. Make sure you heat the pad and the lead.

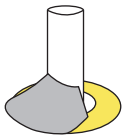


Problem:

Solder bonded to the lead, but not the pad.

Solution:

Reflow the joint by applying heat until you see the solder flow both up the lead and across the pad. Make sure you heat the pad and the lead.

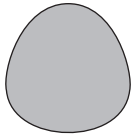


Problem:

Not enough solder.

Solution:

Reheat the joint and push more solder into it.



Problem:

Too much solder.

Solution:

This isn't necessarily a problem, but sometimes it masks the issue where the solder bonded to the lead but not the pad.

To be safe, clean your soldering iron tip really well but don't tin it, then immediately reheat the joint pressing firmly on the PCB's solder pad. This will do two things: 1. Ensure you flow the solder over the PCB pad, and 2. Pull some of the solder off the joint onto your tip

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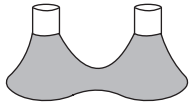


Problem:

Solder bridge: solder has connected two pads, sometimes by bridging the pads themselves, or sometimes by bridging the two adjacent leads.

Solution:

Clean your iron tip really well and reheat the solder between the two pads. Let solder flow onto your iron. If it doesn't disconnect on the first try, clean the tip and try again. It may take a few tries, each time pulling a bit more solder off the joint.

If you have any flux paste, it will help (optional).

Alternatively you can use desoldering tools like a pump or a braid, but these are almost never necessary.

COMMON MISTAKES TO AVOID

Don't burn the pad off the PCB!

Unlike most bad solder joints, this cannot be easily fixed. Apply heat for no more than a few seconds. If your joint isn't forming well, back off and let it cool before trying again. Too much heat can damage the PCB and cause the copper pad to lift off, disconnecting your component from the rest of the circuit. We'll talk a bit more about this in the chapter on "When things go wrong" on page 30.

Don't transfer solder with the tip!*

Sometimes people try to apply solder to the iron, then from the iron to the joint. The problem with this is that the flux in the solder will have already burnt off by the time you try to transfer the solder. The flux is critical for getting a good joint because it removes layers of oxidation that would otherwise prevent a good bond. Instead you push solder into the heated joint directly using the solder wire, allowing the flux to activate where you need it.

*Caveat: There's actually a valid soldering technique for surface mount devices called "drag soldering", in which you'll load up the tip with solder and transfer it to the pads and component leads. This technique requires additional flux applied to the joint. It's a bit more advanced than we're ready for, yet, but you can find some resources in "Surface mount devices (SMD)" on page 40.

Don't let the joint move while cooling!

This was mentioned before, but is worth repeating. The solder will not bond properly to the metal if it moves while cooling, leaving you with an unreliable connection. If you think it may have moved while cooling, reheat the joint to reflow it.

PRACTICE AND EXPERIMENT

Solder more joints, but this time don't apply heat for long enough, or only heat the resistor lead, or only heat the pad. Experiment to see what happens.

Solder all the resistors to the circuit board and learn to recognize when the solder...

- is flowing freely, and when you feel resistance because it's not yet hot enough
- has flowed across the pad
- has flowed up the resistor lead

Or in short, learn to recognize what a good solder joint looks and feels like.

After you've soldered all the resistors, use the clipped leads to get even more practice if you still aren't fully comfortable. Still want more practice? Order another practice kit and use the code MOREPRACTICE at checkout for half off. We want you to feel 100% ready before tackling your next electronics project.

Now go to `masfx.io/forum` and post some pics! Whether you're feeling confident and want to show off, or not so sure: We want to see! If you have any doubts, show us your solder joints and we'll help you figure out where to go from here.

> "Learn to recognize what a good solder joint looks **AND FEELS** like"

FINISHING UP AND CLEANING UP

1. Clean and tin your tip! I bet you guessed this step by now. Put some extra solder on it then turn off your iron.
2. Clean the flux off your PCB. This will appear as brown spots near the solder joints. If you have a "no clean" flux this step may be optional, depending how messy it looks. Use isopropyl alcohol (rubbing alcohol) for regular rosin flux, and a toothbrush to scrub away the flux.
3. WASH YOUR HANDS. Remove any traces of lead before handling food, or touching your face or other people.

WHEN THINGS GO WRONG

SEEKING HELP

The following pages cover common problems and how to fix them.

If those don't help, though, head over to `masfx.io/forum` to post pictures of your build and a brief description of the trouble you're having. This is the preferred and quickest way to get your problem resolved.

Other DIY pedal communities such as `reddit.com/r/diypedals`, `diystompboxes.com`, or freestompboxes.org are great too, but you'll need to provide them with additional context like a schematic and links to the build docs.

Finally, if none of that works for you, send an email to `mark@mas-effects.com`.

PROBLEM: BAD SOLDER JOINTS

Most bad solder joints can be fixed easily by applying more heat to reflow the joint. Clean and tin your soldering iron, then touch the joint and watch the solder flow over the pad and the component, about 1-3 seconds, then let it cool.

If necessary, you may need to add additional solder when heating.

Refer back to "Good and bad solder joints" on page 26 for more details. If you're not sure about yours, feel free to post a picture on our support forum to get some feedback.

PROBLEM: BURNT OR LIFTED PAD

The copper pad may lift off the PCB if you apply heat for too long (e.g., more than 4 seconds), or don't let the PCB cool down long enough before reheating a joint. This causes a disconnect between the component and the rest of the circuit.

This is one of the trickier problems to solve so take great care not to overheat your joints!

When this happens it's rarely worth the trouble to attempt a direct fix. Instead, a simple and more reliable workaround - though still tricky sometimes, especially for a beginner - is to forego using the pad and instead run a wire directly from the component to another place on the circuit board.

Start by visually following the copper traces on both sides of the board from your broken pad to see where they lead. The traces will be covered by a colored solder mask (like an epoxy) but you can still see them if you look carefully.

Any of the other solder joints to which these traces lead may be used. Solder a wire from your component to this other joint to work around the broken pad.

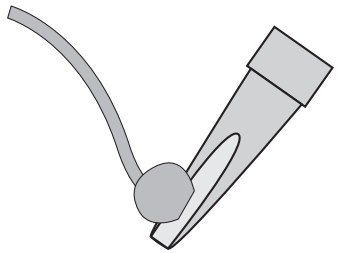
Ask for help: Since the specifics may vary from repair to repair, visit the support forum and post pictures to get detailed advice if this happens to you.

PROBLEM: TIP WON'T TIN

Solder Balls Up and Falls

If your soldering iron's tip won't accept solder, it needs to be cleaned or replaced. Wipe it firmly on a damp sponge then immediately try to coat it with solder. If it doesn't work, try again.

If after several times you're not making any progress, it may be time to replace the tip. Alternatively you can use a special tip tinning product, or a jar of flux which will work more aggressively to remove oxidation.



Problem: The solder balls up and doesn't flow across the tip

PROBLEM: COMPONENT PLACED IN THE WRONG SPOT

If you misplace a component you need to remove the wrong one, then replace it with the correct one.

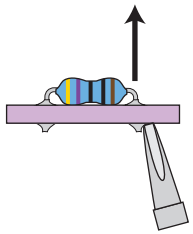
STEP 1: Removing a component

To remove a component we need to heat up the solder, then pull the lead(s) free. The specific technique will vary depending on the type of component, how many leads it has, and how far apart they are spaced.

Start by cleaning and tinning your soldering iron tip, then put some extra solder on it.

Method: Removing one lead at a time

Resistors, diodes, and other axial components (those with 2 leads coming from opposite sides) are easiest to remove one lead at a time.

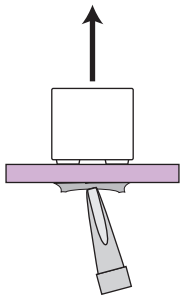


Heat and pull one side

Use the blob of solder to heat up one of the solder joints while pulling the component from the other side. Be careful not to burn your fingers! Repeat for the other side.

Method: Removing two or more leads at a time

For radial components with leads on the same side, you may have trouble trying to pull only one lead out. Instead you may need to heat up all the pads simultaneously to pull the entire component out.



Heat all joints and pull entire component

Here are three of the many ways you can do this:

1. Use a large blob of solder to heat all the joints of the component. This works well with capacitors, LEDs, and other components with tightly spaced leads.
2. Use a hot air gun if you have one. This is especially effective for components with more than 2 or 3 leads.
3. Use a wire or lead cutoff to create a heat bridge between the solder joints. Add solder to attach it to each joint, then apply heat for a few seconds to melt all the joints simultaneously.

Additional methods for removing a component

You can usually remove a component using one of the two methods already described. From time-to-time, particularly when desoldering components with 3 or more leads, it will be helpful to know a few additional techniques.

Method: Hybrid approach

I like to think of this as the "teeter totter" approach. Heat one side and pull it a bit, leaving the component at an angle. Heat the other side and pull it a bit, straightening it out and lifting it further from the PCB.

Repeat this a few times and eventually your component is free, or you have enough of its leads exposed that you can safely clip them while leaving enough to re-solder later.

This method works well for potentiometers if you heat two of its leads simultaneously. i.e., left and center, then right and center. Repeat.

Method: Clearing all solder

You can use a solder sucker, a braided solder wick, or a combination of both to remove the solder from the joint in order to free the component.

I don't recommend this method on PCBs with plated through holes (i.e. metal walls on the holes). Even when the majority of the solder is removed, the leads will remain bonded to the holes and cause you more trouble than it's worth.

Method: Destroy the component then remove one lead at a time

If you don't have a hot air gun, and the component has several leads or more, you may find it very difficult to heat enough joints simultaneously to pull the component away from the PCB. In some of these cases you may find it easiest to simply clip the leads off the component, remove its body, then heat and remove the leads one at a time.

PROBLEM: COMPONENT PLACED IN THE WRONG SPOT (CONT.)

STEP 2: Replacing a component

After removing the incorrect component, you'll need to replace it with the correct one. The thing that makes this tricky is the pad is probably filled with solder.

Method: Replacing without clearing holes (recommended)

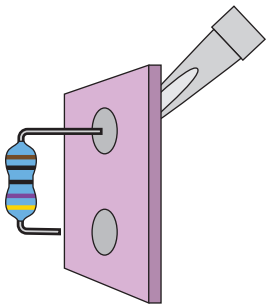
For individual wires, or components with only two leads, you do not usually need to clear the solder out of the holes.

Secure the PCB sideways at a right angle from the table so you can access both sides. Use blue putty to hold it, or have a friend help you if needed. Heat the pad from one side while pushing the component through the other. Do the same for the other pad.

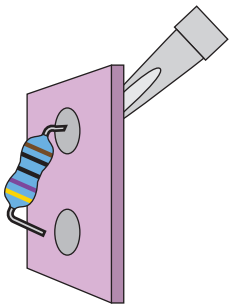
You may need to trim the other lead fairly short to make it easier to insert.

After the component is in place, reheat each joint and add a bit more solder to add flux and ensure a good bond.

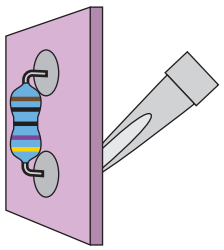
Trim the leads.



Trim one of the leads, then heat one pad



Push lead through



Heat other pad and push lead through

Method: Clearing solder from holes

Here are a few of the countless ways to clear solder from a hole:

Option 1: If you have a desoldering pump, you can clean out the pad first. Press in the plunger on your pump. Secure the PCB at a right angle. Heat the pad on one side, place the pump over the other, then push the button to suck solder out of the hole. You may need to do this a few times. When you have the hole cleared out you can insert the correct component and solder it.

Option 2: You can try heating the solder then poking something through the hole such as a toothpick or mechanical pencil tip.

Option 3: You can also use a solder wick, which is made of braided copper wires, along with flux to remove solder. Apply flux to the braid, set it over the hole, then press your soldering iron tip into the braid to heat it up. The solder will begin to transfer to the braid. Slowly drag the braid across and off the hole and it should hopefully be clear of solder.

Option 4: Finally you can also heat up the solder then smack the PCB against the table to let momentum pull the solder from the hole.

PROBLEM: ANYTHING ELSE!

If you're having any other problems and would like help, head over to our support forum at:

masfx.io/forum

FLASHLIGHT PROJECT

Now that you feel comfortable soldering, you can make 3 mini flashlights with just a few components. If you don't have one, you can pick up a kit at `masfx.io/practice`.

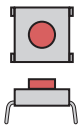
Not yet confident in your soldering? Take some clippings from your resistor leads and practice more solder joints. If you want one or more additional practice kits, visit `masfx.io/practice` and use code *MOREPRACTICE* at checkout to get half off. You're getting this at-cost because it's really important that you have good solder joints before moving on to your next project.

GATHER PARTS

You'll need a CR2025 or CR2032 coin battery to power this (not included), as well as the included parts:

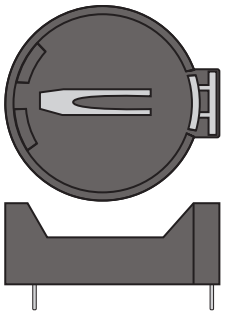
- 3 resistors
- 3 momentary buttons, SPST (single pole, single throw)
- 3 LEDs
- Coin battery holder

resistors (3)



buttons (3)

LEDs (3)



battery holder

SOLDERING BUTTONS

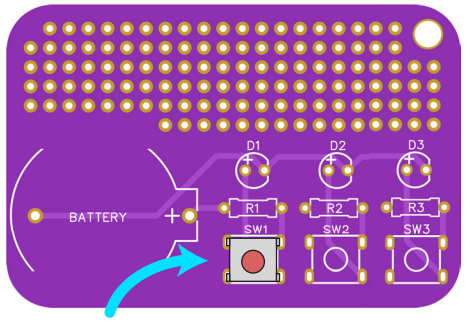
Locate the 3 buttons and squeeze their legs gently to bend them at a right angle to the body. This is optional, and will help keep the button from falling off the PCB before you solder it.

Place one of the buttons into the SW1, SW2, or SW3 spots on the PCB.

No need to worry about orientation, one direction simply won't fit, and for the other you can safely rotate it 180° since it is symmetric and has no polarity.

Turn the PCB over, ensuring the button doesn't fall out. If it does, bend the legs more, or hold the button in place with blue putty, tape, or just use pressure against the table.

Solder its 4 legs to the PCB, then repeat with the other two buttons.



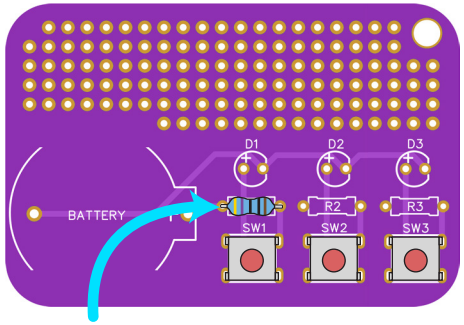
Squeeze legs for tighter fit, then insert and solder 3 buttons

SOLDERING RESISTORS

Like the button, the resistor is also symmetric; It has no polarity, so you can insert it into the PCB in either direction.

Insert one of the resistors into the R1, R2, or R3 spots and solder it into place just as you did in the practice area.

Repeat with the other two resistors.



Solder each of the 3 resistors to the PCB

SOLDERING LIGHT EMITTING DIODES (LEDS)

Orientation matters for LEDs. They have a polarity. Current only flows through LEDs in one direction.

The longer lead, called an anode, goes on the positive side which is marked with a "+" on the PCB.

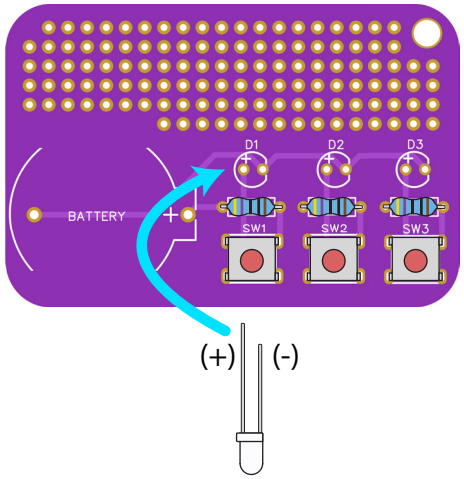
The shorter lead, called a cathode, goes on the negative side which is indicated on the PCB with a flat section of the LED outline. If you look closely at the LED itself, you'll find it also has a flat side which is useful for determining the polarity if its leads have been clipped.

Insert the LED into the D1, D2, or D3 spots on the PCB.

Bend its leads outward slightly to hold it in place, just as you did with the resistors.

Solder it into place, taking care not to overheat it. LEDs are a type of diode, and diodes are more susceptible to damage from heat than resistors.

Repeat with the other two LEDs.



Solder each of the 3 LEDs, paying attention to polarity

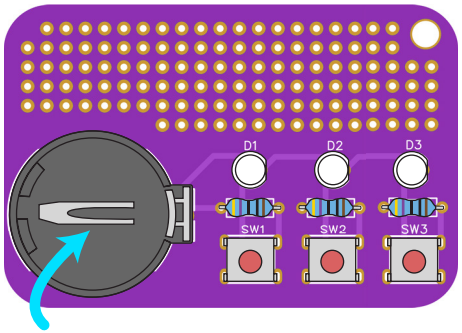
SOLDERING BATTERY HOLDER

Locate your battery holder and ensure the metal fork is in place in the center, as shown in this illustration. It may have fallen out in your component bag. If necessary, press it back into place.

Insert the battery holder into the PCB, matching its outline to the outline on the circuit board.

Carefully turn it over and let gravity hold it in place. Alternatively you may use putty, tape, or any creative means you'd like to ensure it stays still while soldering.

Solder its two pins.



Reattach metal fork, if needed, then install and solder battery holder to the PCB

COMPLETING YOUR FLASHLIGHT

Find a CR2025 or CR2032 battery (not included) and install it flat (+) side up.

Now press the buttons and bask in the glow of your success! Head on over to `masfx.io/forum` to share your completed project, or to ask questions if you ran into any problems.

Curious how it works?

Visit masfx.io to read *How Pedals Work: Conceptual Basics for the Absolute Beginner.* Early in that book, it will you walk you through this exact circuit to learn how the flashlight works.

If you continue you'll also learn the most common building blocks for guitar pedals and how they work together to make boost, distortion, and fuzz effects.

WHAT'S NEXT?

Congratulations on learning how to solder! You've come a long way, and now that you've got a grip on soldering basics, it's time to get started on some fun projects.

DIY PEDALS

There's a good chance this is what brought you here, and now you're equipped to take on some of the MANY options for building DIY pedals:

- Complete kits, such as the Beginner Pedal Kit and Digital Pedal Kit from MAS Effects, or the many options from Aion FX.
- Buy a pre-fabricated PCB and source your own parts. Popular and reliable vendors include: PedalPCB, Aion FX, and Madbean Pedals.
- Create your circuit board from scratch using stripboard, perfboard, or etching copper clad.

There many fantastic DIY pedal building communities filled with people who will help you get the most out of this hobby, so if you're not sure where to start, visit our forum and we'll help you find what you're looking for.

SURFACE MOUNT DEVICES (SMD)

Most DIY pedals use through-hole components like the ones we practiced with. Outside of hobby use and a few niche industries, though, they're becoming increasingly rare. Most electronics utilize surface mount devices instead.

As the name implies, they mount directly to the surface of the PCB rather than through a hole. They also tend to be smaller, in general. These two factors present additional challenges for soldering these components by hand. In production they're placed and soldered by machines.

Nevertheless, you can learn to solder them fairly quickly without any special tools.

Visit `masfx.io/smd` to see a couple of videos showing you how. Perhaps later we'll put together a shorter consolidated guide and/or video. Leave your feedback in the forum.

For DIY pedals this can be a useful skill to learn since certain components, such as the popular FV-1 digital signal processor, are only available in surface mount packages. Other components, like JFETs and other transistors, are increasingly rare and expensive in through-hole packages, making it far more practical to buy SMDs.

DIGITAL PROJECTS

If digital signal processing (DSP), microcontrollers, or other digital electronics interest you, there are countless options available to explore.

Shape audio signals with DSP code running on an FV-1, a relatively simple and purpose-built processor for audio. Alternatively you can dive into DSP on a more general-purpose processor and utilize a wide variety of tools.

For controlling screens, integrating MIDI, and other digital interfaces, simple and inexpensive microcontrollers such as AVR (ATTiny, ATMega) and PIC are very popular. Far more powerful and featureful options are frequently used, too, such the STM32 family.

HAVE FUN!

Whatever you decide to do next, I hope you have fun and grow. Remember, the key to mastering any skill is practice and persistence. Don't be afraid to experiment, make mistakes, and learn from them.

Happy soldering!

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Visit **masfx.io** for:
- Videos to accompany this book
- Practice kits
- *Ultimate Beginner Pedal* kits, book and videos
- *How Pedals Work* book