



# Build Your Own **STOMPBOX!**

| DIY DISTORTION BUILD GUIDE |

BY JOE GORE

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**BUILDING YOUR OWN STOMPBOXES IS EASIER THAN YOU MIGHT THINK.** This guide walks you through the process step by step.

When you've completed the project, you'll have a great-sounding DIY distortion pedal, but that's not all: You'll understand how most stompbox components work. You'll know how to select parts and customize circuits to get exactly the sounds you want. And you'll be in a fine position to build many other pedals using the circuit schematics readily available online.

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## PART 1: PREPARATIONS

### 1.01 About the *PG* distortion pedal

This project is a customized and modernized version of a simple but powerful distortion circuit that originally appeared in the Electra guitar, a 1980s axe with built-in effects. The guitar was never very popular, but the distortion circuit has inspired many modern boutique spin-offs. (Just Google the phrase “based on Electra distortion.”) Its tough, toothy crunch is a great alternative to the Tube Screamer-derived designs of most current distortion pedals. Compared to a Screamer, the Electra circuit is less compressed, less midrange-heavy, and more responsive to playing dynamics.

### 1.02 Project overview

This project is arranged in five parts. Part 1 covers preparations. In Part 2 you assemble the circuit on breadboard. In Part 3 you experiment with part options and choose your favorites. In Part 4 you solder components to a piece of circuit board, and in Part 5 you assemble everything inside an enclosure.

### 1.03 Tools you need

- Soldering iron (preferably 30 watts or more, but not a large gun-type iron)
- Lead-free solder
- A damp sponge
- A small electronics breadboard
- An assortment of jumper cables (you can make your own, but the prefab ones have metal tips that don't fray from repeated use)
- Wire stripper
- Wire cutter (most strippers have cutters, but you'll probably want a separate flush-edged tool for tight, close cuts)
- Needle-nose pliers
- Phillips-head screwdriver
- An adjustable wrench (or a wrench set)
- A digital multimeter with a continuity function (a “beeper”)—auto-ranging is a plus
- A small saw and vise for cutting perf board to size
- Double-sided foam tape
- An electric guitar, an amp, and two 1/4" instrument cables
- Optional: a “helping hand” vise to hold components steady while soldering
- Optional: a syringe-style de-soldering pump

### 1.04 Parts you need

Since this project involves choosing some parts to taste, not every part listed will be used in the final pedal. But since the parts in question are very inexpensive, I recommend rounding up everything so you can craft a pedal that best suits your style.

For the pedal:

- Five 1/4-watt metal-film resistors, values: 470R, 4.7K, 10K, 68K, 2.2M
- Four non-polarized capacitors: a 473 (sometimes called .047 $\mu$ F or 47n), a 683 (.068 $\mu$ F or 68n) and two units of 104 (.1 $\mu$ F or 100n). These can be polyester film, “box style,” or ceramic. Get small-format caps rated between 50 and 100 volts, not the large-format caps used in amps and other AC-powered devices
- One 16V 22 $\mu$ F electrolytic capacitor (this cap type is polarized)
- Three transistors: 2N5088, 2N5089, and 2N3904
- Eight diodes: two units each of 1N4001, 1N914, 1N34A, and red 3 mm LED



- Two 16 mm potentiometers (“pots”): A100K and C10K (substitute a B10K if you can’t find a C10K)
- A piece of perf board (perforated circuit board) at least 15 holes in width and seven in height (you’ll probably saw a standard-sized 45 mm x 45 mm piece in half)
- A 3PDT footswitch
- One 1/4" mono jack
- One 1/4" stereo jack
- One DC jack (I used the standard type with an internal nut for the photos in this guide, though you may find it easier to work with an external-nut model)
- One 5 mm LED (any color)
- One 5 mm LED bezel
- One battery snap
- One 9-volt battery
- Two knobs of your choice
- One 2" length of 1/8" heat-shrink tubing (you can substitute standard electrical tape)
- Hookup wire, preferably 24-gauge, stranded and pre-bonded (for visual clarity, it may help to use several contrasting colors, such as black, red, and white)
- One 1590B-size enclosure (order it pre-drilled for two knobs, footswitch, input, output, LED, and DC jack, or use a drill press to make your own holes)—or a larger enclosure if you like

Before we assemble the pedal, we’ll arrange and audition parts on electronic breadboard. For the benefit of those who already have breadboarding tools, I list the needed parts separately. If you’re a first-time builder with no parts, try to round up everything on this list too.

For breadboarding:

- A small electronics breadboard
- Two additional mono input jacks
- One additional battery snap
- One set of metal-tipped jumper cables
- Approximately 12" of additional hookup wire

### 1.05 Sourcing parts

Stompbox parts tend to fall into two categories: those you can get from large electronics supply houses, and those sold only by stompbox specialists. Large suppliers such as Mouser, Digi-Key, and Allied often have the lowest prices, but they don’t stock some of the essentials. Meanwhile, the specialized stompbox vendors often carry both specialized and non-specialized parts, and the convenience of one-stop shopping may compensate for slightly higher prices on small parts.

This isn’t a complete list of stompbox parts specialists—just three reliable U.S.-based vendors with fine reputations, listed in alphabetical order. I’ve had nothing but great service from all three businesses.

- Mammoth Electronics
- Pedal Parts Plus
- Small Bear Electronics

(Meanwhile, I hear good things about Germany’s Banzai Music from my friends in the E.U.)

Mammoth Electronics has created a preassembled kit with all the parts needed for this project. (*Premier Guitar* has no financial stake in the product—it's merely offered as a convenience.) The parts are good and the prices are competitive, but it's just one way to go. The kit includes all needed parts, but you must provide the tools. More info [here](#).

### 1.06 Soldering

If you've never soldered, it can be intimidating. And yes, it's possible to burn things, including yourself. But it's actually an easy procedure that quickly becomes second nature. If you've never soldered before, watch a few YouTube soldering tutorials.

Some basics:

- Don't touch the hot part.
- Don't leave a hot iron unattended.
- Work in a ventilated area. Even if you're using lead-free solder, it can't be healthy to inhale those fumes for hours!
- Wear eye protection.
- "Tin" the iron's tip by touching a bit of solder to it before starting.
- Keep a damp sponge or rag handy and swab the iron's tip frequently to keep it clean.
- Instead of touching solder to the iron's tip, try to heat the target component and melt the solder against the component. (But yeah, sometimes we cheat and quickly touch the solder to the iron for a fraction of a second to get it flowing.)
- A good solder joint is shiny, smooth, and shaped like a Hershey's Kiss. If it's dark, or sits on the surface like a water droplet, reapply the iron.
- If you make mistakes, it may help to have a syringe-type de-soldering tool. (You simply re-melt the solder, and then suck it up with the tool.)
- Consider using a "helping hands" vise to hold your components, leaving both hands free for work.

It's possible to complete this project with a bare-bones, pencil-type soldering iron, but it's far easier if you use a "soldering station" with adjustable temperature from a company such as Weller or Hakko. Simple hobbyist models start at around \$40, and fancier models go for about double that. But don't use big, high-wattage soldering guns—they're too powerful for fine electronics work.

### 1.07 Learning more and getting help

Chances are, you'll encounter a frustrating roadblock at some point, and sadly, we lack the resources to respond directly to every tech question. But you'll probably get good advice if you post your problems to the article's comments thread. Better yet, make the most of the online DIY community. Start out at the largest DIY forum, [diystompboxes](#). Another great resource is [freestompboxes.org](#).

Here are three fine "electronics for beginners" books

- *Getting Started in Electronics* by Forrest M. Mims III
- *Electronics for Dummies* by Cathleen Shamieh and Gordon McComb
- *Make: Electronics Book* by Charles Platt

It's impossible to keep track of all the great DIY stompbox blogs, though my two favorites are Beavis Audio Research and Gaussmarkov DIY Effects. Both sites are dormant, but they still include tons of great info and other resources.

### 1.08 Warnings, disclaimers, and general ass-covering

This project requires tools and techniques that can hurt you if you're not careful. Fortunately, it's pretty much impossible to electrocute yourself with 9-volt circuits like this one, but it's all too easy to cut or burn yourself.

When in doubt, step away from the bench and seek help. Don't touch things that are hot or sharp. Wear eye protection. Don't work when you're angry or stressed. Don't leave anything dangerous where kids or pets can find it. You know the drill—including the fact that you proceed at your own risk, and that neither I nor *Premier Guitar* can assume any responsibility for injury, property damage, or other unfortunate events that may occur while attempting this project. Be smart and careful, okay?

## PART 2: BREADBOARD THE CIRCUIT

In this section we'll assemble the circuit on breadboard before soldering together the components. Yeah, you *could* jump ahead to Part 3 and solder away—but this way, you'll gain a better understanding of how the components work. Also, you'll be auditioning different options from the get-go, resulting in a pedal fine-tuned to your taste. If you continue with DIY, the breadboard is a tool you'll use constantly.

Having said that, we *are* going to start with some soldering to assemble the wiring needed to route your guitar to and from the breadboard on its way to an amp.

### 2.01 Hi, jack!

Meet your basic mono audio jack—and our first soldering task (**Photo 1**).

On jacks of this type, the outermost lug (the one closest to the nut) carries the audio signal, while the inner one is soldered to ground.

Stereo jacks, which have a third lug sandwiched between these two, are most often used in guitar circuits as “kill switch” input jacks for battery-powered effects, so that there's no battery drain when nothing's plugged in. (We'll use one when we assemble the final pedal.) But for breadboarding purposes, we'll go with two mono jacks.

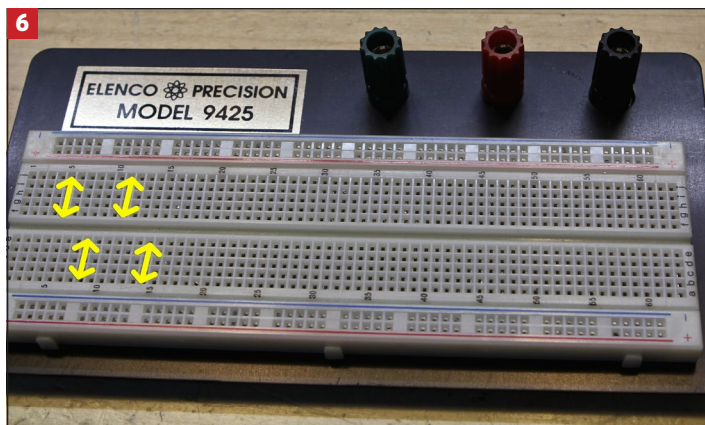
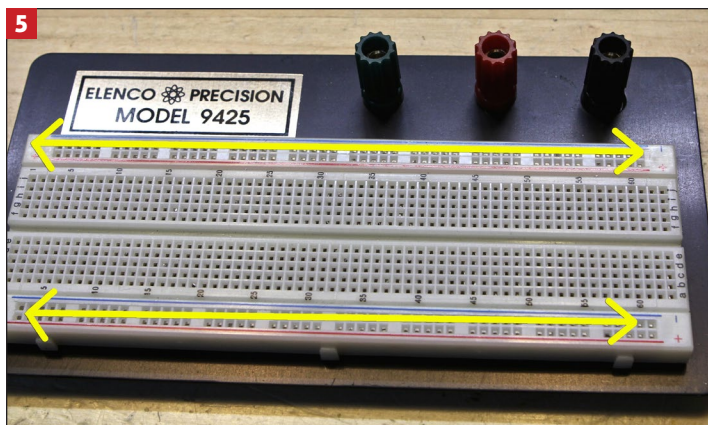
Strip 1/4" of insulation from a length of wire approximately 6" long. Thread it through the outer lug, pinning it in place with the tip of the hot iron (**Photo 2**). After a few moments, touch the solder to lug, next to, but not quite touching, the iron's tip. When the solder melts, remove the iron, and then let the solder set (it only takes a couple of seconds).

The solder joint should appear shiny and smooth (**Photo 3**). If it's dark or blobby, place the iron near the solder till it melts again.

As a visual aid, consider using black wire for the inner ground lug, and white for the outer audio lug. Solder both wires to the jack, and then solder wires to the second jack in the same way (**Photo 4**).







## 2.02 Meet the breadboard

Your breadboard may not look exactly like this, but the following comments probably apply.

The outermost lines of holes are connected lengthwise across the diameter of the breadboard. They're usually color-coded red and black, with red signifying battery power and black representing ground. Any component plugged into one of these "busses" is automatically connected to any other connected along the same parallel line (**Photo 5**).

The breadboard shown here has four busses. Some have more. Only two are needed for our purposes. Also, some breadboards split the long horizontal busses into two separate regions. If your breadboard has a physical gap midway along the bus, you may need to insert a jumper cable between the two regions to connect them.

The large area between the power and ground busses consists of many smaller, shorter busses oriented vertically, perpendicular to the longer busses (**Photo 6**). All the components get laid out here. Some will also connect to the horizontal power and ground busses. If you run out of holes on one of these short busses, you can use jumper cables to link multiple columns.

## 2.03 Meet the multimeter

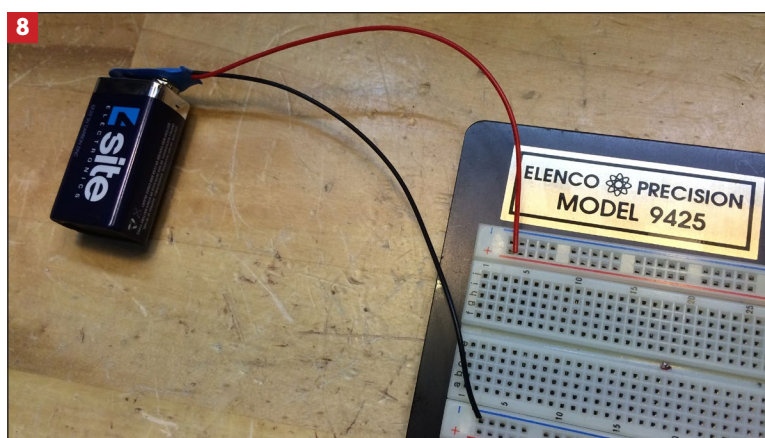
They call it a MULTImeter because it has several functions. First, we'll check the voltage of our 9-volt battery by setting the meter to its DC power function (it'll probably say "DCV"). Touch the red tip to the battery's positive (male) terminal and the black to the negative (female) terminal (**Photo 7**). If the battery is fresh, it'll probably read close to 9.5 volts.



## 2.04 Connect the power

Attach your battery snap, and connect the red wire to one of the red busses, and the black to one of the black. (The colors are just a visual aid—these busses are electronically identical.)

I could have connected the black wire to the black bus right next to the red one, but I used the one at the opposite side of the breadboard (**Photo 8**). This is because electronic schematics traditionally show power connections toward the top of the diagram and ground connections toward the bottom. Mirroring this arrangement makes it easier to transpose a circuit from a schematic to a breadboard.





## 2.05 Connect the audio

Plug the black ground wires from both audio jacks into the ground bus alongside the negative battery wire. Plug one of the white wires into the upper leftmost column, and the other into the lower leftmost column (**Photo 9**). They are not yet connected to each other.

Plug your guitar into the jack connected to the upper-left bus. Plug your amp into the jack connected to the lower bus. It's a good idea to tape stray cables to your work surface. This is going to get messy.

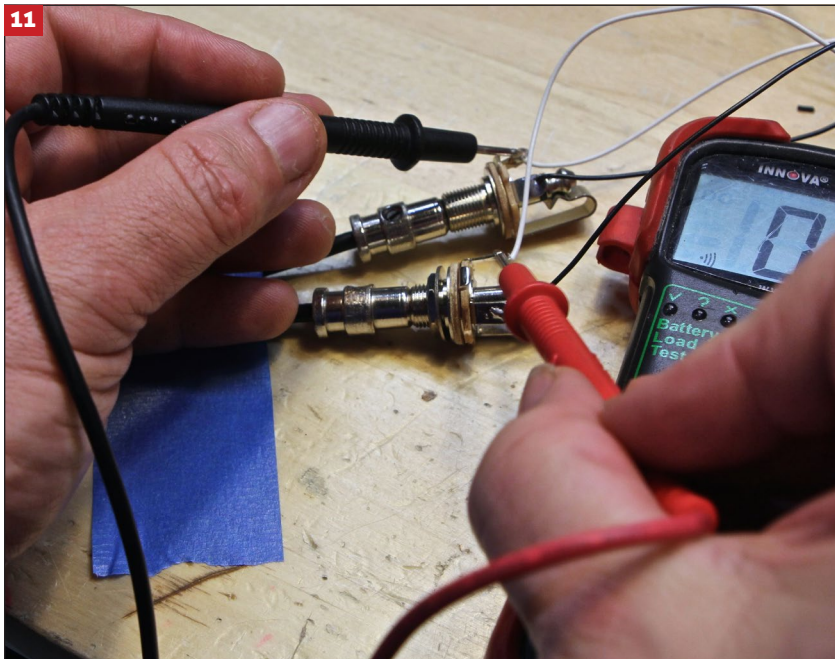
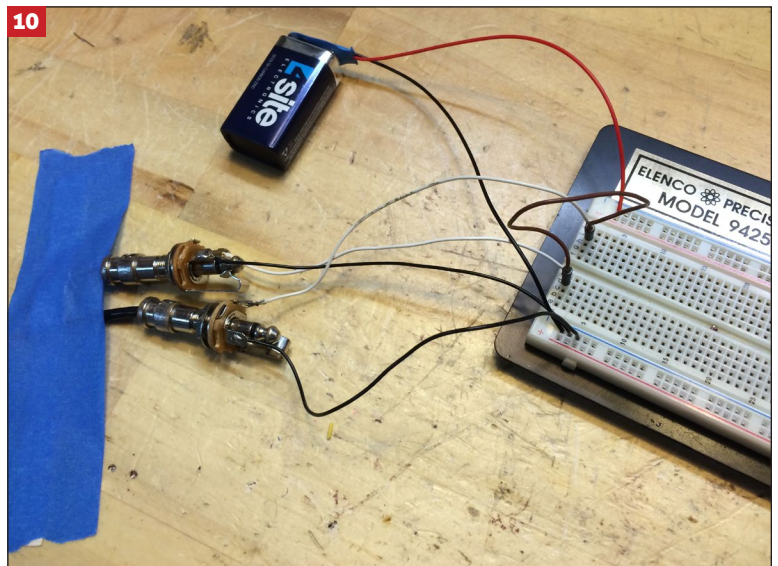
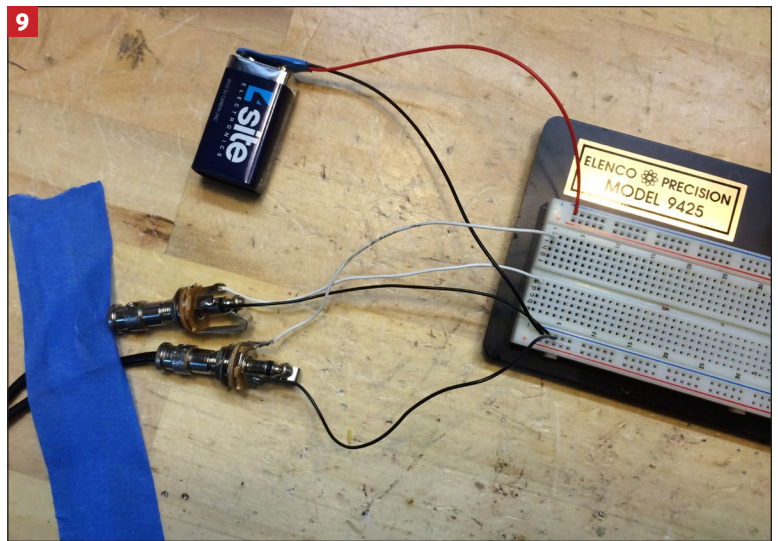
To hear guitar through this circuit, you must link the input and output. Connect one end of a short jumper cable to any hole on the input bus, and the other end to the output bus (**Photo 10**).

Turn on your amp. Do you hear your normal sound? Congrats! You've done a bunch of work and accomplished nothing! (Yet.)

Don't hear anything? Verify that your solder connections are solid. Triple-check that all wires are in the correct holes. Make sure your audio cables are good. (FYI, the battery isn't doing anything yet. You could disconnect it at this point and still hear your guitar.)

## 2.06 Troubleshooting with the multimeter

Set your multimeter to its "continuity" function. This is simply a beeper that sounds when you touch the test leads to two properly connected points within a circuit. (The function is often depicted on the meter with a speaker symbol.)

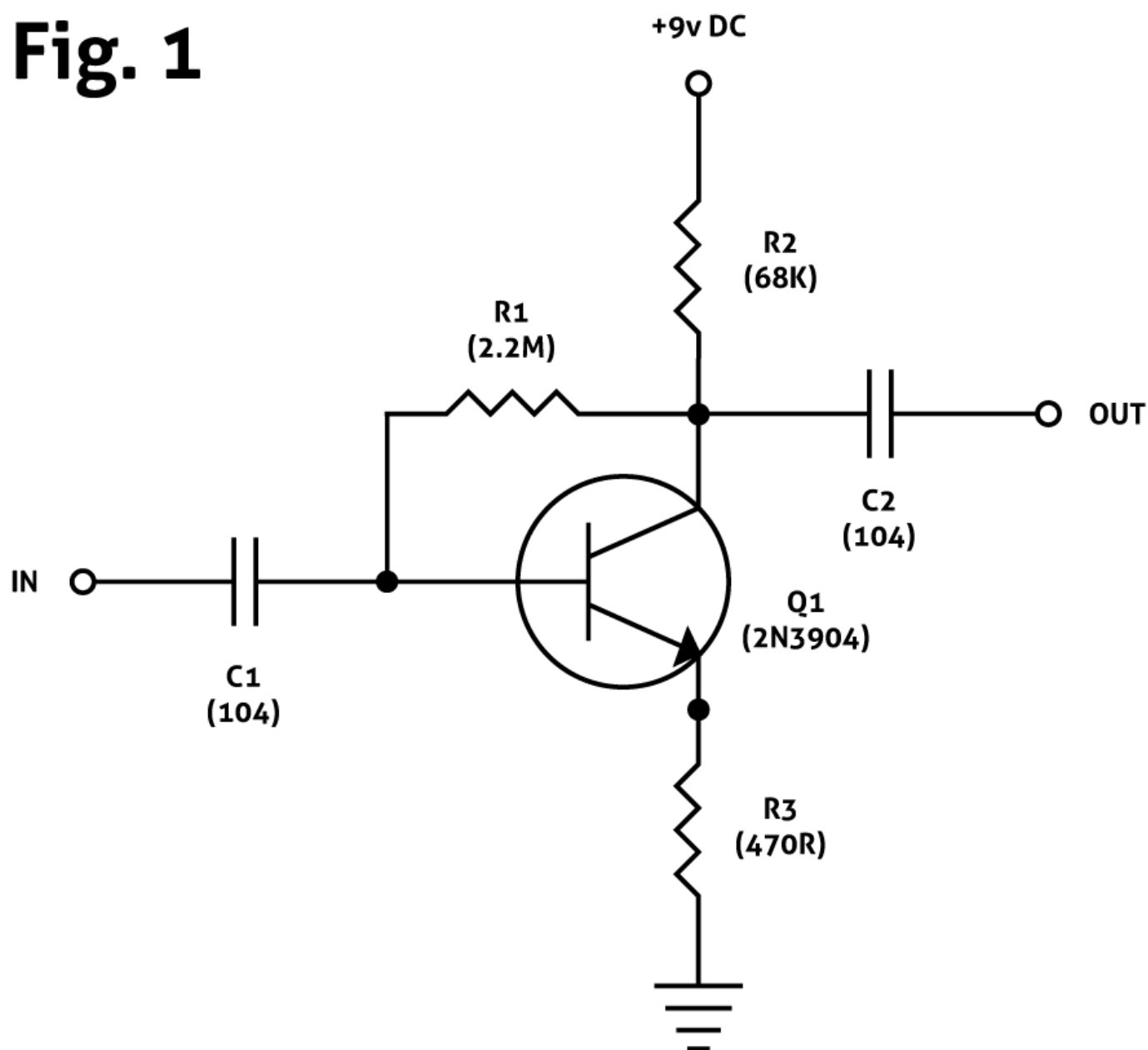


If you hear your guitar now (as you should), try touching the leads to the "hot" lugs of the two jacks (the ones with white wire).

If you hear guitar and a beep, you're awesome. If you hear guitar but no beep, you haven't set your meter properly, or didn't touch the right surfaces. If you hear a beep but no guitar, you have a bad cable, your amp isn't on, or your guitar's volume is turned down. If you hear no guitar and no beep, remove the wires and components from the breadboard and use the continuity function to test the individual pieces. For example, touch one lead to a jack lug, and the other to the end of the wire connected to it.

Get used to the view in **Photo 11**—you'll see it often. When you're done, remove the jumper cable from the breadboard.

# Fig. 1



## 2.07 Understanding schematics

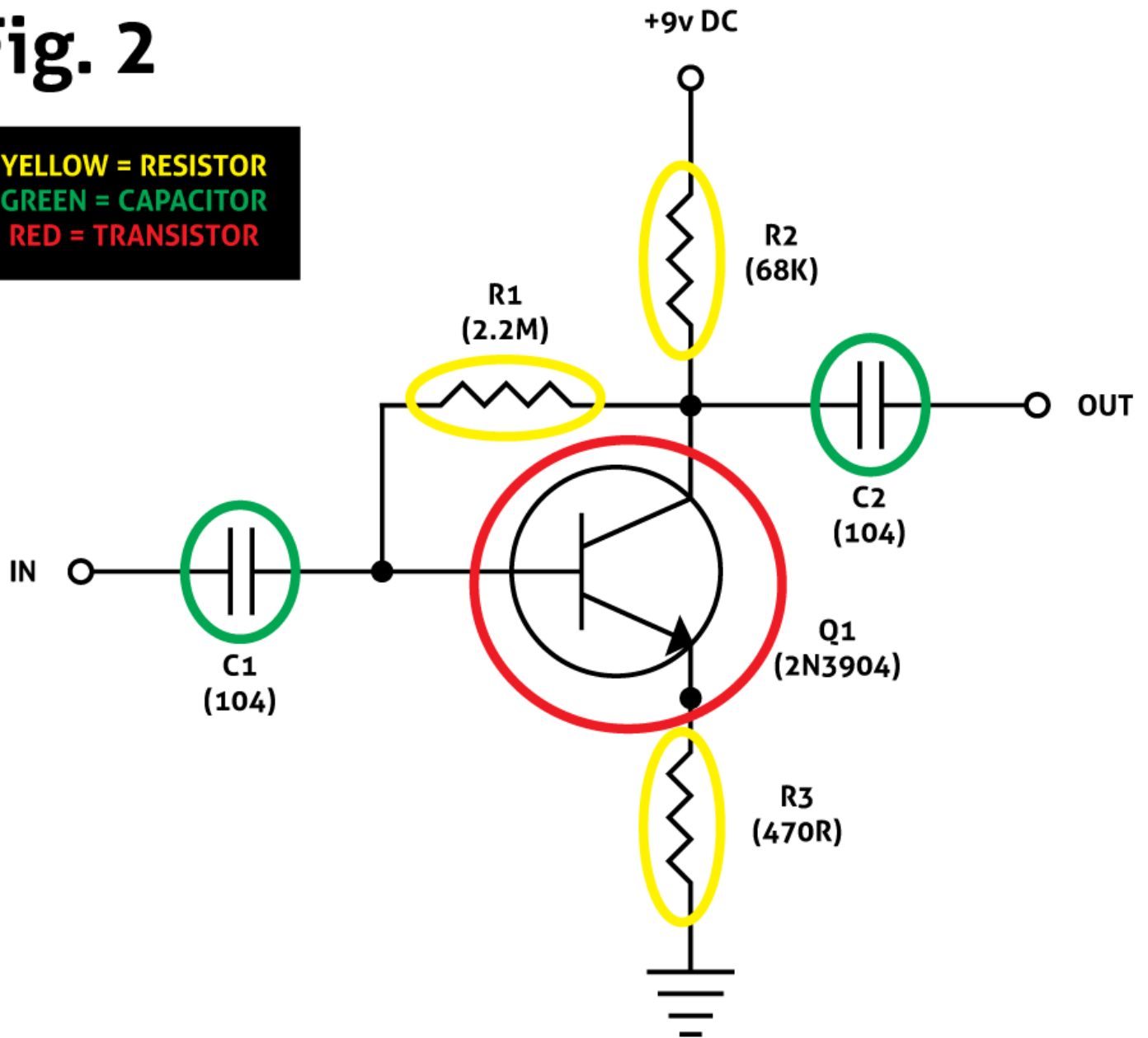
Here's the bare-bones schematic for this project (**Fig. 1**).

Schematics are graphic representations of circuits. They can be incredibly complicated, but this one's easy—you only need to learn a half-dozen symbols. (To learn more, Google “schematic symbols.”) Typically, audio input is shown on the left, and output on the right. Power appears at the top, and ground at the bottom.

The numbers in parentheses next to each component are the part values (for example, “104” or “68K”). The other numbers are just IDs for each component, which allows us to say things like, “If you hear too much bass, try replacing C1 with a 683 or 473.”

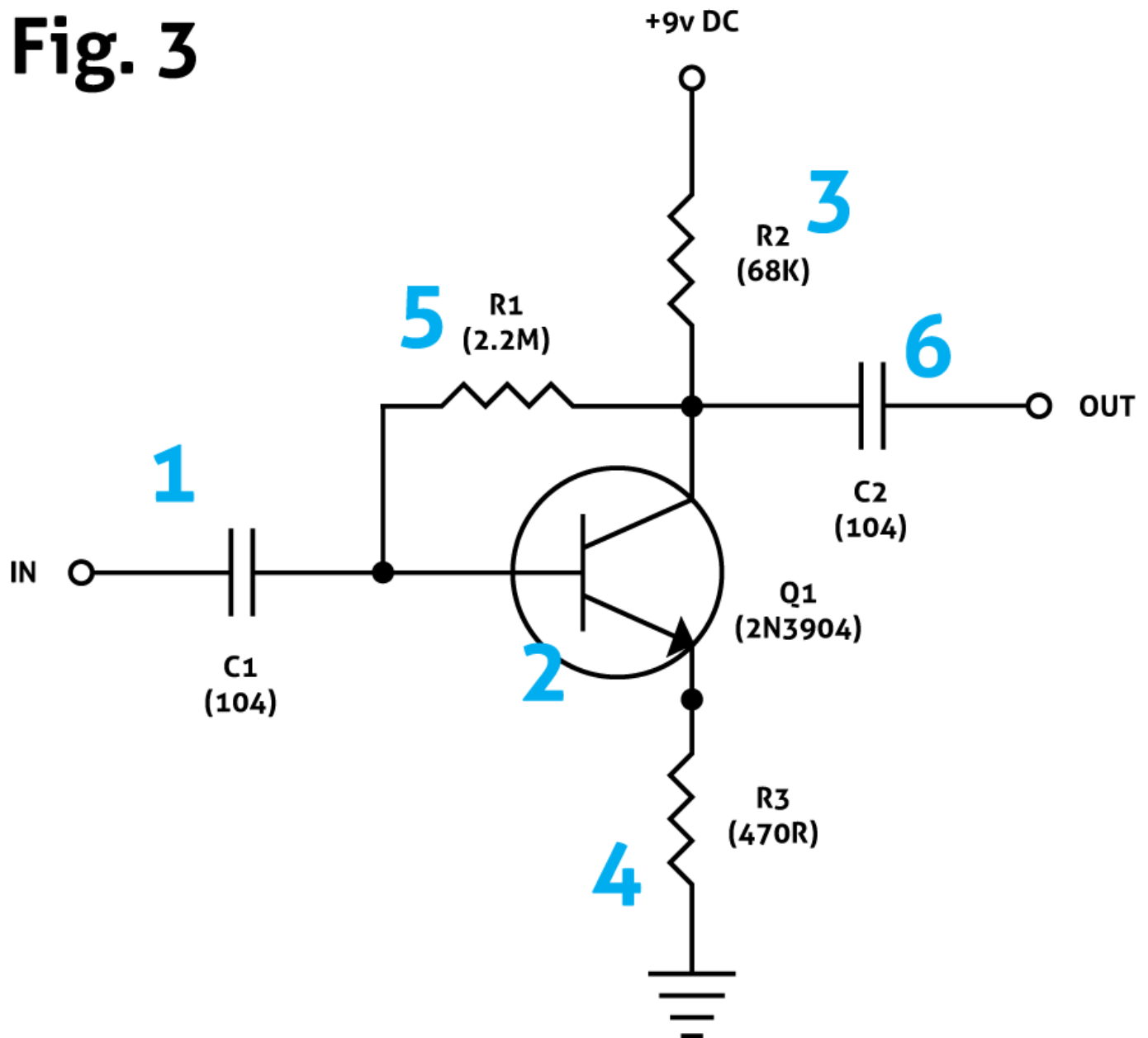
# Fig. 2

**YELLOW = RESISTOR**  
**GREEN = CAPACITOR**  
**RED = TRANSISTOR**



Notice that some symbols appear repeatedly. **Fig. 2** identifies them. The squiggly lines are resistors. The parallel lines denote capacitors. The circle thingy in the center is a transistor. And downward-pointing triangles represent a connection to ground.

# Fig. 3



What does what? **Fig. 3** explains the basics. To get you up and running with minimum theorizing, these explanations are greatly simplified. Check out the recommended reading from Part 1 for more info.

1. Guitar signal enters here. C1 acts as a filter. Smaller capacitors remove more lows.
2. The transistor amplifies your guitar signal—so much so that it distorts. Different transistors provide different amounts of gain.
3. The battery powers the transistor. R2 regulates the amount of current reaching the transistor.
4. R3 regulates the amount of current flowing from the transistor to ground. Lower values equal more gain.
5. R1 adds some current from the battery to the pre-transistor input signal.
6. C2 removes DC signal, preventing it from reaching your amp.



## 2.08 The transistor

In this circuit, the transistor works as an amplifier—so much so that it distorts. A lot!

We're going to audition three transistors in this circuit: a 2N3904, a 2N5088, and a 2N5089. All three are of the silicon BJT (bi-junction transistor) type. There are many other types.

Some circuits use multiple transistors. In fact, the number of transistors is one of the defining properties of many boost/overdrive/distortion/fuzz circuits. (Fuzz Faces use two. Most Tone Benders use three. Big Muffs have four.) More isn't better—just different. Many great circuits use only one transistor. Examples include the mighty Dallas-Arbiter Rangemaster, the crispy-clean ZVEX Super Hard On, the Electro-Harmonix LPB-1 booster, and the Electra distortion circuit that inspired this project.

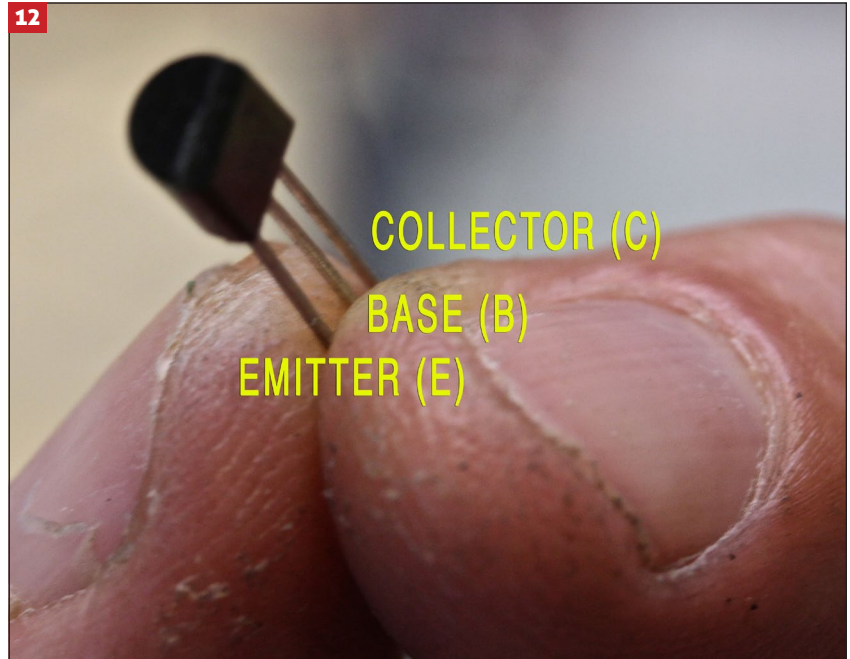
## 2.09 The ABCs of CBE

Transistors of this type have three terminals: the collector, base, and emitter, often abbreviated as C, B, and E (**Photo 12**).

The collector “collects” juice from the red power bus. Your guitar signal enters via the base. And the emitter connects to the ground bus. In most cases, there are other components between the C, B, and E pins and those destinations.

Confused? Sadly, it gets worse. The location of the C, B, and E pins can vary from one transistor type to another, even ones that appear identical! This pattern is called the “pinout.” Thankfully, the three transistors used in this project share the same pinout. With the plastic part toward you and the rounded side facing left, the pinout is C, B, E, from top to bottom.

It's easy to check a pinout online. For example, just Google “2N5088 pinout,” and you'll find your way to a manufacturer's spec sheet with the necessary info.

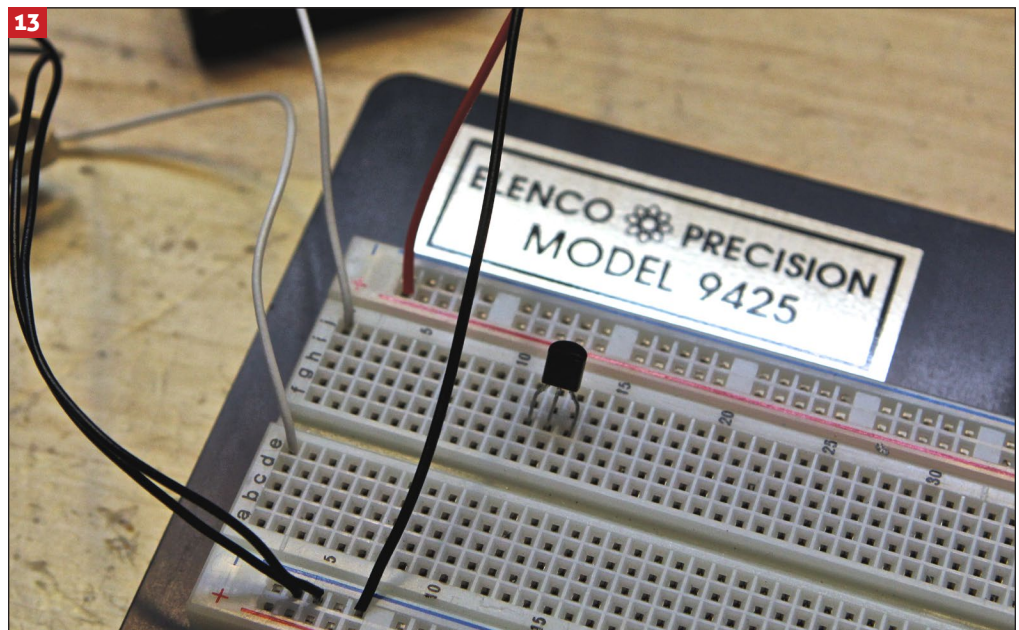


## 2.10 Place the transistor

Even though the transistor's terminals are shown top-to-bottom in the schematic, we must place the component sideways—otherwise, the three connections would be linked on the same bus.

The exact position on the breadboard doesn't matter. Anything like **Photo 13** works.

As positioned here, with the curved side facing up, the collector (C) is to the right, and the emitter (E) is to the left. Use the 2N3904 transistor to start. Later we'll audition the others.





### 2.11 Working with resistors

Resistors are not polarized, which means it doesn't matter which way you insert them.

There are three ways to measure the value of resistors:

1. Read the bag it came in. (My favorite technique.)
2. Memorize the resistor color codes. (My least-favorite technique.)
3. Use the multimeter's ohmmeter function, usually indicated by an omega symbol ( $\Omega$ ). Just touch the test leads to the two terminals. (If your multimeter doesn't have auto-ranging, you may have to manually adjust the range to get a reading.)

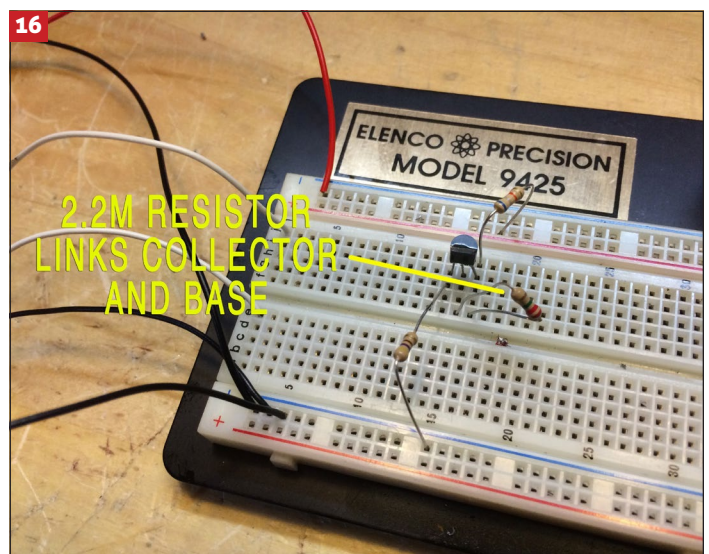
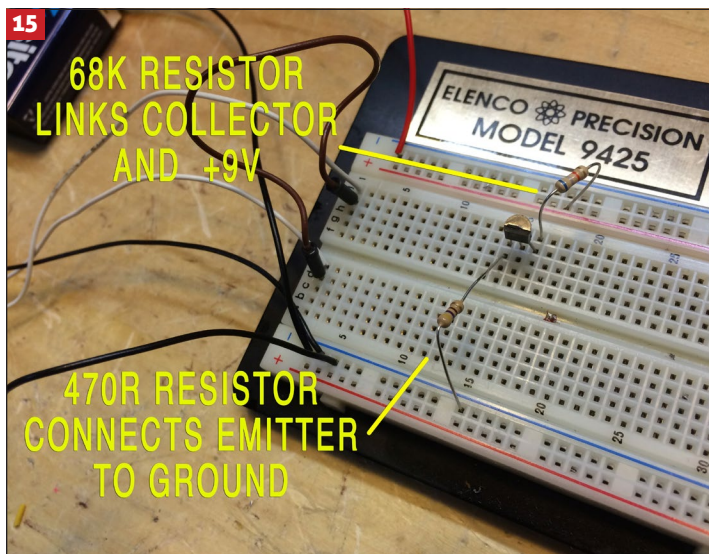
Do this if you ever get your parts mixed up.

To test resistors, you must remove them from the circuit, as shown in **Photo 14**. The values can vary by as much as 10%, so don't sweat it if, say, your 10K resistor reads 9.77K.

### 2.12 Place the resistors

Use the 68K resistor to connect the transistor's collector to battery power. Place one end of the resistor in the same bus as the collector, and the other end into the red 9-volt bus. Use the 470R resistor to connect the transistor's emitter to ground (**Photo 15**). (The "R" in the transistor's name means ohms. This 470R resistor is about half the value of a 1K, or 1,000-ohm, resistor.)

Place the 2.2M resistor between the transistor's collector and base (**Photo 16**). You now have two resistors connected to the collector.



### 2.13 Working with Capacitors

In some cases the orientation of the capacitor (or "cap") matters, but not with the caps we're about to use. The cap's value is important, but its material usually isn't. Mylar, ceramic, and box-type caps all work equally well here (**Photo 17**).



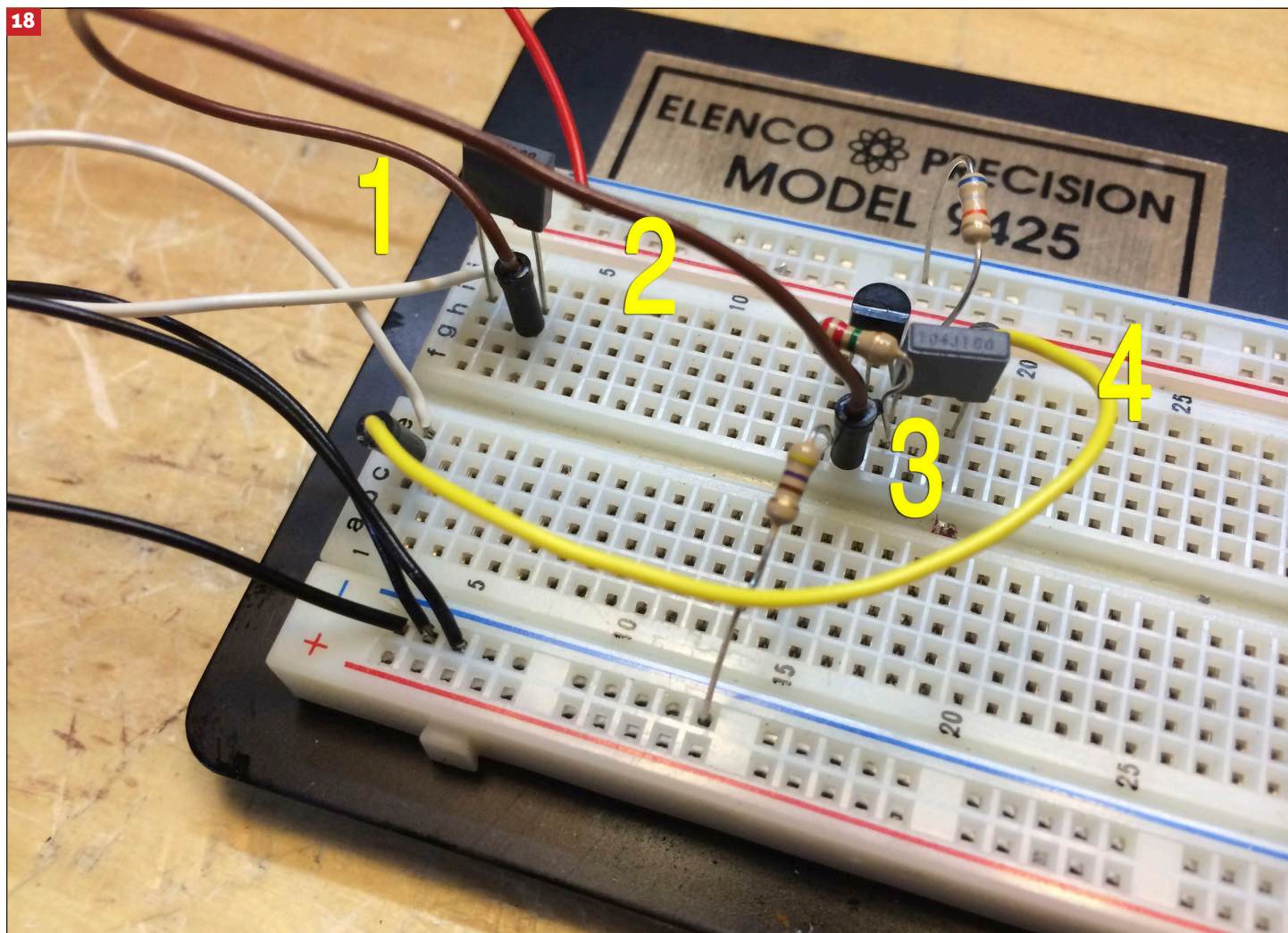
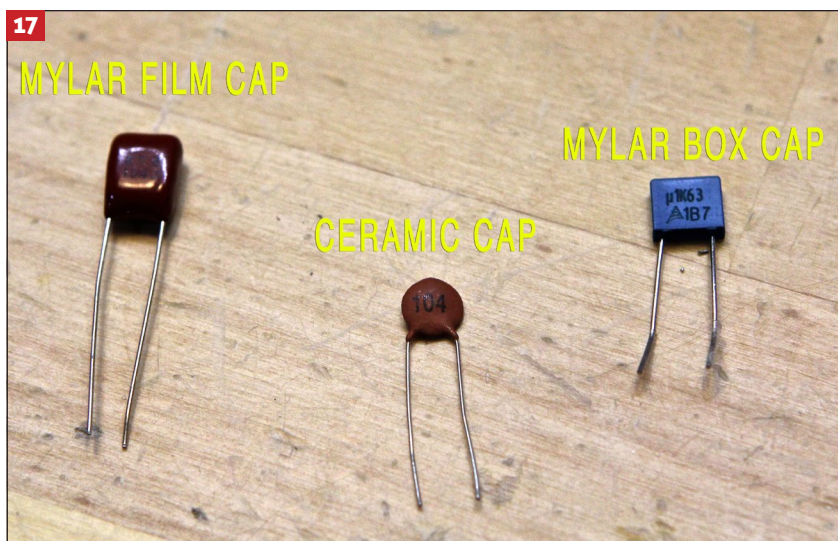
Cap values are printed on the component. But sadly, there are three different ways of denoting cap values. Here are the three ways of referring to the cap values used in this project:

1. 104 =  $.1\mu\text{F}$  = 100n
2. 683 =  $.068\mu\text{F}$  = 68n
3. 473 =  $.047\mu\text{F}$  = 47n

Google “capacitor values” for more info.

## 2.14 Place the input and output caps

Let's position the two 104 caps on the breadboard (Photo 18).



Place one leg of the input cap on the same bus as the guitar input (#1 in **Photo 18**). The second leg must connect to the transistor's base. We could probably do it without a jumper cable, but using one will give us more elbow room as the breadboard gets crowded (#2).

Place the output cap so one leg connects to the transistor's collector (#3). You now have four wires on the same vertical bus. Place the rightmost leg of the cap in an empty bus, and use another jumper to link it back to the output feeding your amp (#4).

## 2.15 Stand back!

Hope you had your amp turned down! You should now hear insanely loud guitar distortion. This is the circuit at maximum loudness. It's a loose, sloppy sound that we'll shape to taste in Part 3.

If you hear anything other than heavy-duty distortion, quadruple-check all connections (especially those confusing transistor pins). Compare your work to the schematic, and use the multimeter's continuity function to verify adjacent connections.

By the way, it's extremely rare for any of these components to fail. If the circuit doesn't work as expected, it's almost certainly due to human error. (One exception: Cheap jumper cables can be funky. Try swapping them out if necessary.)

## PART 3: CUSTOMIZE YOUR TONE

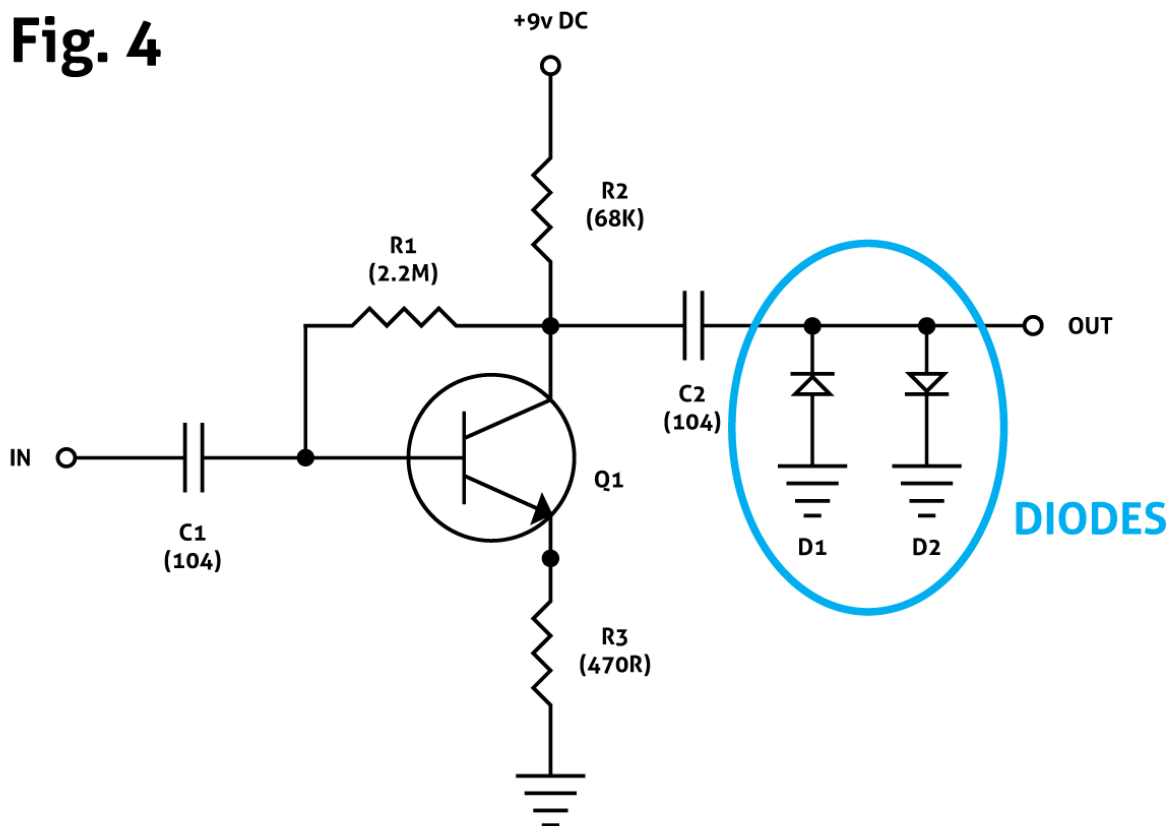
In this section we will:

- Modify the distortion sound with diodes
- Add a gain control
- Add a master volume control
- Start customizing the circuit to taste

### 3.01 Sculpting distortion

We've generated a loud, crude distortion sound. It's so loud that it can easily overwhelm your amp's input. When that happens, the tone is overly compressed and probably bass-heavy. So let's kick things *down* a notch.

The next schematic adds two new parts: the diodes indicated in **Fig. 4**.





### 3.02 Meet the diode

Diodes are components that transfer current in one direction, but block it in the opposite direction. That means that, unlike the resistors and caps we've used so far, their orientation *does* matter (in other words, they are polarized). Their positive terminals are called anodes and their negative terminals are called cathodes. The cathode is denoted by a band at one end of the component, and by the horizontal line in the schematic symbol (Fig. 5).

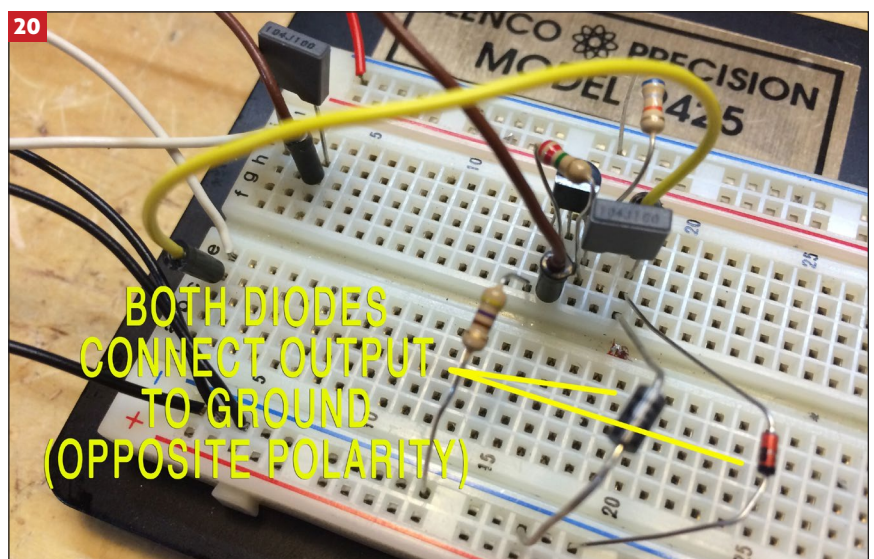
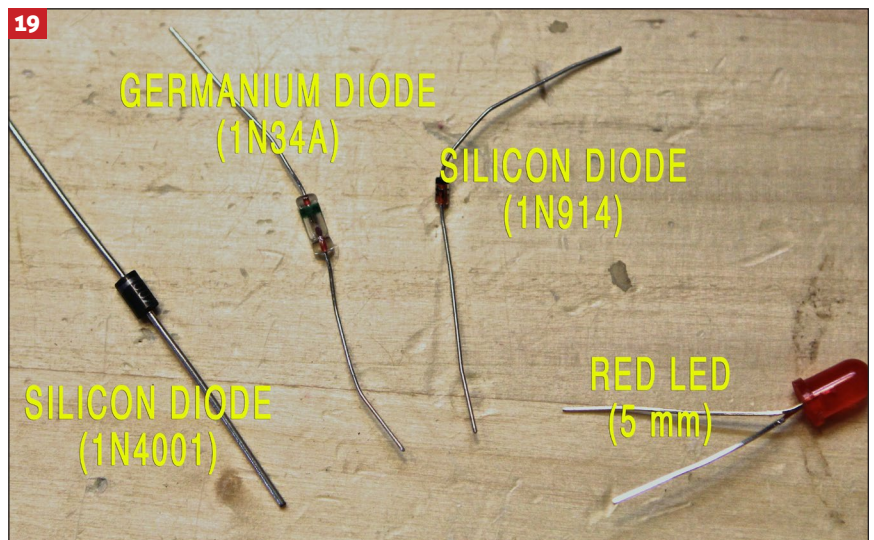
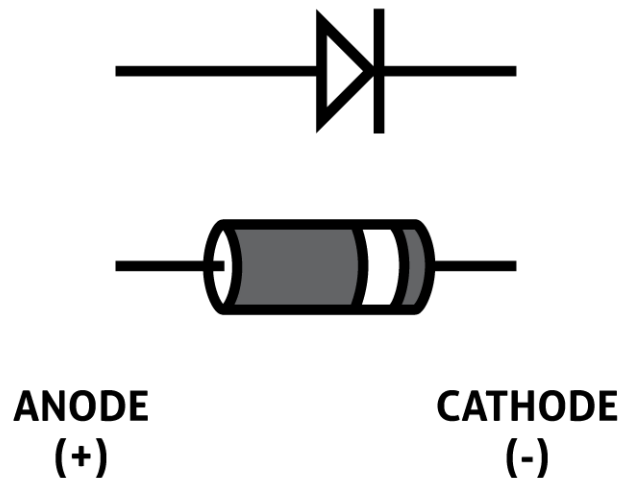
Diodes are often silicon, but can also be germanium. LEDs are diodes too. One leg of the LED is usually slightly longer than the other. This is the anode (positive side). When you add a pair of diodes between the audio signal and ground, oriented in opposite directions, the result is a distinctive type of distortion. Diodes are deployed this way in countless stompbox designs: primitive '60s pedals such as the Jordan Bosstone, '70s stompboxes such as the MXR Distortion+ and DOD 250, and *anything* related to the Ibanez Tube Screamer (which means something like 90% of today's overdrive pedals). Diodes are also partly responsible for the distortion sounds in many modern hard rock amps, such as Marshall JCM800s. (It's not only about the tubes!) Several common diode types appear in Photo 19.

### 3.03 Placing the diodes

Connect the anode of the 1N4001 diode and the cathode of the 1N914 diode to ground. Then press the other ends of both diodes into the same vertical bus where the right leg of C2 connects to the jumper wire going to your output (Photo 20).

You should hear a substantial decrease in volume. This is a good thing—believe me, the circuit will still have plenty of *oomph*. The distortion sounds more controlled, with a nice graininess. (It's okay if you prefer the tone without diodes—you can always build your pedal without them.) If you hear nothing, double-check the placement and orientation of the diodes. If they're not oriented in opposite directions, they'll kill the signal.

Fig. 5



### 3.04 Fun diode facts

Why two different diode types? Because different diodes provide different tones. In fact, you can pretty much use any common diodes in this circuit, so long as one is connected anode-to-ground, and the other cathode-to-ground. Try it yourself with any diodes you have around, including LEDs. (The lights won't glow, but you'll hear them!)

You're now doing what countless pedal designers have done: Experimenting with different diode combinations until you find one you love. Germanium diodes, such as the 1N34A, tend to sound a little warmer/tubbier than the silicon diodes we're starting with, and LEDs tend to be brighter and glassier. Just mix and match—there's no science to it. Actually, there is, but it's so boring and incomprehensible that it's probably better to just go crazy and have fun. That's how most of the experts do it. For many boutique builders, a new diode combination can inspire a whole new product.

One more wrinkle: You can use more than two diodes, so long as at least one is oriented in each direction. (Some refer to this as asymmetric distortion.) Try adding a third diode alongside these two, then try flipping it the other way. Then a fourth. Keep testing till you find something awesome. (The kit version of this project includes two each of four different diodes for just this purpose.) For now, I'm going with the 1N4001/1N914 pair.

### 3.05 Controlling the gain

The circuit is currently configured to extract near-maximum gain from the transistor. Now let's hear how it sounds with the gain dialed back.

The resistor connecting the transistor emitter to ground determines the amount of gain. The 470R resistor we used has a very low value, adding only a bit of resistance. If we add a higher-value resistor, there will be more resistance, and therefore less gain. If we were to replace the 470R resistor with, say, a 10K, the tone would clean up substantially. Now, you could experiment with different resistor values till you find your ideal sound, but there's a better way.

### 3.06 Meet the potentiometer

Potentiometers, or "pots," are simply adjustable resistors. The volume and tone pots in your guitar do their job by specifying how much current is allowed to flow to ground. The pot's value is the amount of resistance applied when the pot is turned all the way down.

If we replace the resistor between the emitter and ground with a 10K pot, we have a knob to dial in as much gain as we like.

The pot's three lugs are numbered in a standardized way (**Photo 21**). With the shaft facing you, lug 1 is on the left, lug 2 in the middle, and lug 3 on the right. But since you must flip the pot around to solder it, get in the habit of numbering the lugs with 3 on the left and 1 on the right. The full signal usually enters at lug 3. Lug 2 carries the variable signal, its output changing as you rotate the shaft. Sometimes one or more lugs are connected to ground.

### 3.07 Snip that tab thingy

While we're talking pots, use your wire cutter to snip the little tab that protrudes next to the pot shaft on both your pots (**Photo 22**). Otherwise they'll get in the way when we mount the parts in the enclosure.





### 3.08 Solder the pots

Strip about 1/4" of white wire and insert it through lug 3 of a C10K pot. Fold the wire over with your needle-nose pliers. Hold it in place with the tip of the iron, and then touch solder to the lug. Leave about 2 1/2" of wire attached to the pot lug. This task is easier with a helping-hand vise, as seen in **Photo 23**.

If you don't have a C10K pot, substitute the more common B10K. FYI, the letter at the beginning of a pot's name identifies its taper—how quickly it goes from higher to lower settings. A-series pots have a logarithmic curve and are often used as volume controls, as in this project. B-series pots are linear, and are used in most other instances. C-series pots are reverse logarithmic, and I've specified one here because it distributes gain settings more evenly across the pot's range. (If you ever encounter a pot on an amp or stompbox where all the cool sounds are clustered toward one end of the range, that means the designer probably should have used a pot whose name started with a different letter.)

Solder similar lengths of wire to all three lugs of both pots (**Photo 24**). Verify that none of the lug connections brush up against adjacent lugs. If necessary, trim the wire ends at the lugs with your clippers, and/or straighten bent lugs gently with your needle-nose pliers. (If I'd been cleverer, I'd have used black wire to visually differentiate the ground connections here.)

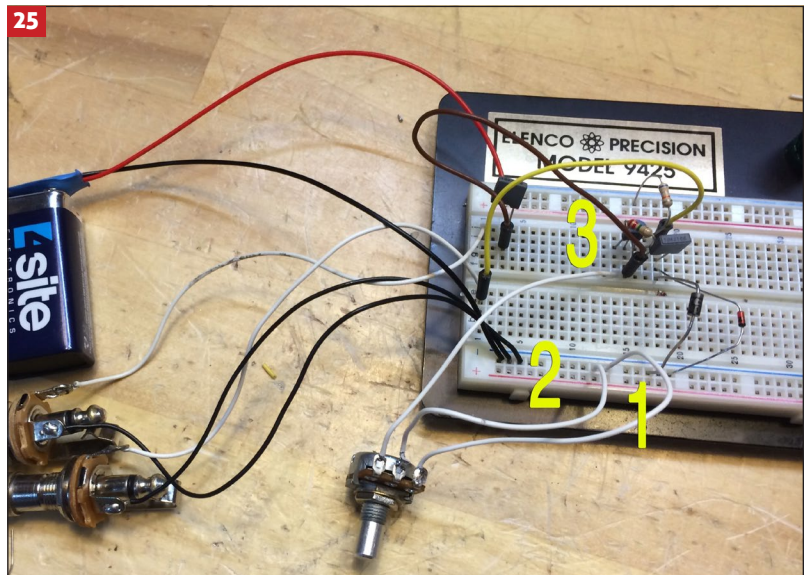
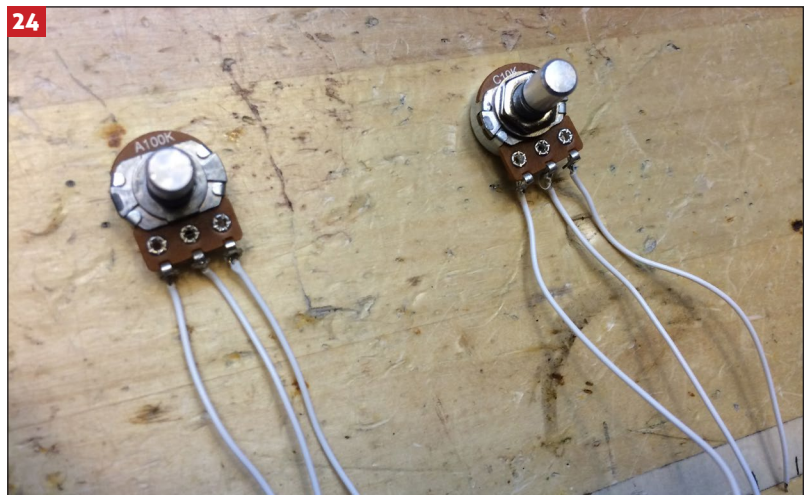
### 3.09 Place the gain pot

Remove the 470R resistor, and put the C10K pot where the resistor used to be. Connect lug 3's white wire to the transistor emitter, and the other two wires to ground (**Photo 25**). Since two lugs connect to the same destination, we might also have added a short wire between lugs 1 and 2, and then run a single wire to ground.

You should now have a working gain pot that sounds dirtier as you turn it clockwise. Useful tip: If a pot ever behaves opposite from how you want (for example, a volume control that gets quieter as you rotate it clockwise), you can correct it by reversing the wiring of lugs 1 and 3.

### 3.10 Super-cool resistor/pot trick

You can substitute a pot for almost any resistor. Sometimes it yields great results, and sometimes not. For example, you could try replacing our R2 resistor with, say, a 100K pot, but sadly, you won't hear



anything dramatic—it'll just crap out if the value gets too low. (The same goes for R1.) But in many other instances, you'll find cool variations this way.

Anytime you see a wacky pedal with a zillion knobs, chances are the designer simply replaced many fixed resistors with pots. That was the notion behind ZVEX's Fuzz Factory, the best-selling boutique pedal of all time—and still one of the coolest.

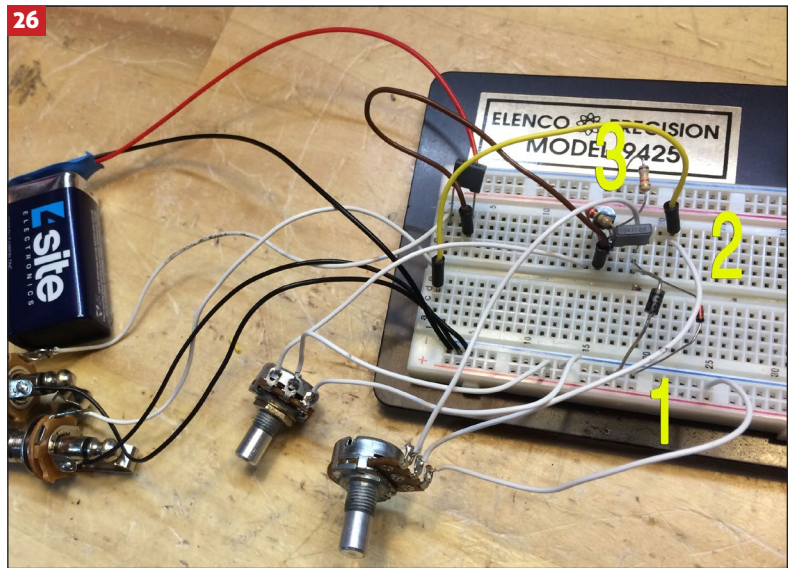
To find a perfect resistor value, temporarily replace it with a pot. Spin the shaft until the circuit sounds great. Remove the pot from the circuit, and measure its current resistance by setting your multimeter to “ $\Omega$ ” and touching the probes to lug 2 and to ground. Select the resistor value closest to that reading and pop it into the circuit.

### 3.11 Add the volume pot

We've almost finished our circuit! All we need is a master volume control.

Connect lug 1 of your A100K pot to the ground bus (#1 in **Photo 26**). Place the wire from lug 2 in an empty bus near the output capacitor. Remove the jumper wire that connects the right leg of C2 to the output, and plug it into the same bus as the lug 2 wire (#2). Plug the wire from lug 3 (#3) into the same bus as the right leg of C2 and the diodes. You should now have a working volume control.

The updated schematic in **Fig. 6** adds the two pots. The pot symbol looks like a resistor with an inward-pointing arrow. The topmost junction is lug 3, and the lowest junction is ground. The arrow represents lug 2. The gain pot here has two lugs to ground, indicated by the bent arrow. Meanwhile, since no volume pot lugs are connected to each other, the lug 2 arrow doesn't bend toward lug 1.

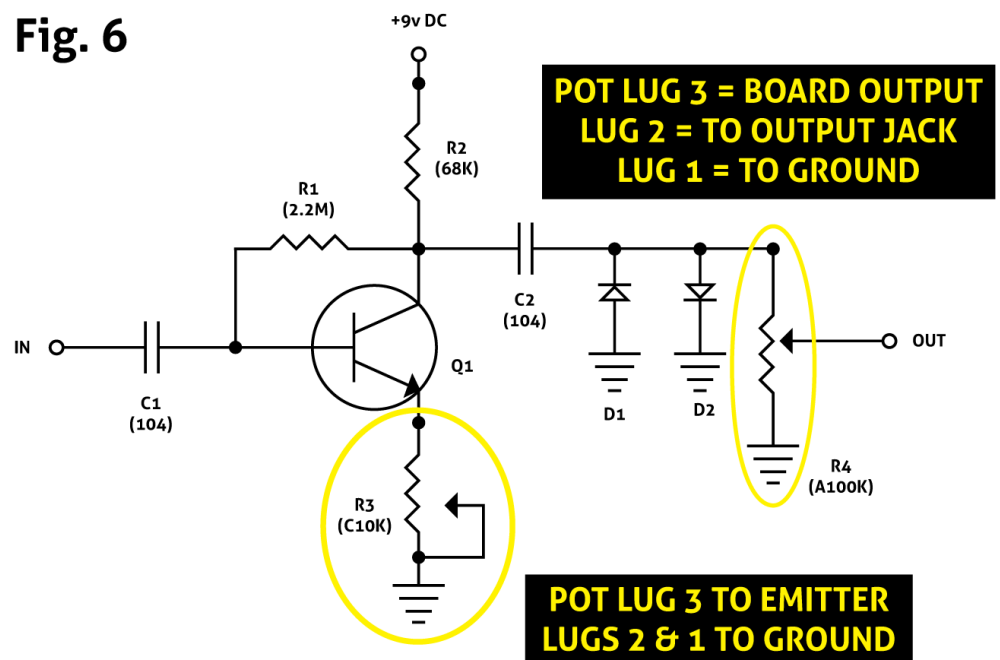


### 3.12 Try some mods!

The circuit should sound pretty darn good at this point—but that doesn't mean you can't make it better. Try these variations:

- The circuit is quite fat-sounding—maybe *too* fat. You can tighten it (at the expense of some gain and low end) by lowering the value of C1 from 104 to 683. (Yes, that is a smaller value, for reasons that will become clear if you Google “capacitor values.”) You might even go down to a 473. (The kit version of this project includes these alternate cap values.)

**Fig. 6**





- Replace the 2N3904 transistor with a relatively high-gain 2N5088. You should hear more distortion overall. Now try an even higher-gain 2N5089. Pick your favorite.
- Experiment further with various diode pairs (or trios, or quartets). You may find a new favorite recipe now that we've added a gain control, or if you changed any components in the preceding steps.

See the beauty of the breadboard now? It's great to be able to refine a circuit without soldering and de-soldering.

### 3.13 Food for Thought

Yeah, this is a simple circuit, but you're already doing what most big-name boutique builders do: tinkering with an extant circuit till you find something cool. This often boils down to nudging components up and down in value until you dig the result. For example, the three cap values we auditioned for C1 are common adjacent values. We might also have tried a *larger* cap for more bass, such as a 154 or a 224. (Not a bad idea if you think you might enjoy this effect on bass guitar.) Same when we tried out transistors of varying gain. We also altered the circuit when we added or subtracted diodes and replaced resistors with pots.

Remember, you don't have to go with the circuit as depicted in the Fig. 6 schematic. Maybe you like it better without any diodes. Maybe you don't want a gain control—you might prefer one "magic" value for R3, and just a single master volume knob.

The takeaway: You can design to taste right from the start. This will become even truer when you start working with switches. Can't decide which value you like best for C1? Choose two or three values, and make them switchable. Or switch between two different transistors. Or various diode combinations.

Once you've found your favorite recipe, jot it down. Now all we need to do is mount your components on a piece of circuit board, and then mount the board in an enclosure.

## PART 4: ASSEMBLE YOUR CIRCUIT BOARD

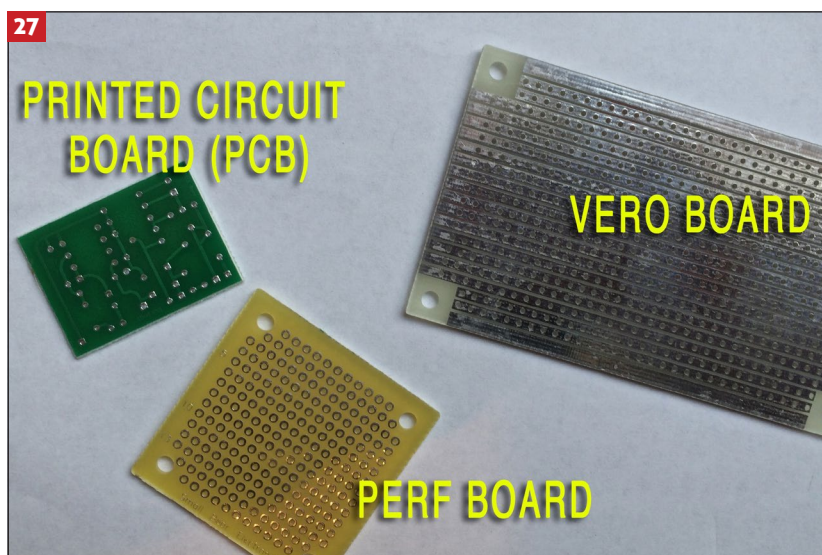
In this section we'll transfer the circuit—or whatever variation you've concocted—to a small piece of perf board before mounting it in an enclosure.

### 4.01 PCB, perf board, and vero board

Most stompboxes (and most non-boutique amps) are assembled on printed circuit board (PCB). A PCB is a piece of layered fiberboard or plastic in which all the components are connected by internal conductive traces. You just solder the components into the designated holes, and all the connections are made.

Commercial stompbox kits usually come with a PCB and a bag of parts. It's definitely faster and easier to build this way. (It's also surprisingly easy to make your own PCBs, but that's a lesson for another day.) Another alternative is vero board, which features horizontal rows of pre-connected holes, much like on a breadboard.

But we're going to assemble everything on perf board, which has rows of copper-lined holes, none of them pre-connected. We'll make all connections manually on the reverse side of the board. It's a cumbersome technique, but it has advantages: You'll develop more of an understanding of how circuits work, and in the future, you'll find it easy to turn a schematic into a pedal. **Photo 27** shows the three circuit board types.



#### 4.02 Cutting the perf board to size

Perf board comes in multiple sizes. To accommodate the components for this project and fit the whole shebang into an enclosure, you need a piece about 7 holes in height and 15 holes in width. It's okay if it's a little larger, but not *too* much. Just check whether it fits into your enclosure before proceeding. (If you're working with the 45 mm perf board square that comes with the project kit, just cut in half.) It may help to mark the intended cut with a felt pen. A small saw and vise will get the job done (**Photo 28**). I don't need to tell you to be careful with sharp tools, do I?

#### 4.03 Create a positive bus

We're going to wire our board with positive and negative busses, just like your breadboard. Remember, wires and components are inserted from the top side of the board—*not* the side on which the copper is most visible. That's where the soldering happens.

Strip a couple of inches from a piece of red wire. Insert it through the rightmost holes of the top row, and then draw it back out through the leftmost hole. Pull it fairly tight (**Photo 29**). Snip off any extra.

Flip the board over and solder the two ends of the wire into place. Don't solder between these points yet. We'll be weaving several components through and around this wire (**Photo 30**).

Use wire lengths of 5" or 6" here and elsewhere in this section. We'll trim them shorter when we insert the perf board into the enclosure, but you'll want that much length when we test the assembly in your breadboard.

#### 4.04 Create a negative bus

Repeat what you just did, this time on the bottom edge of the perf board, and using black wire (**Photo 31**).

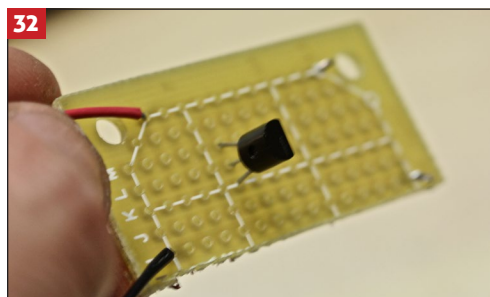
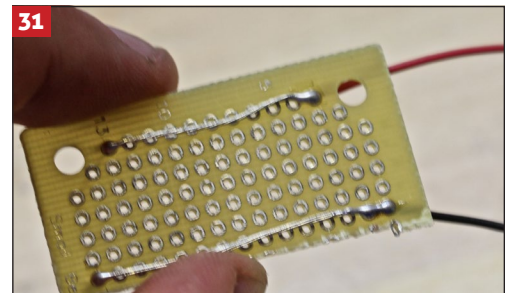
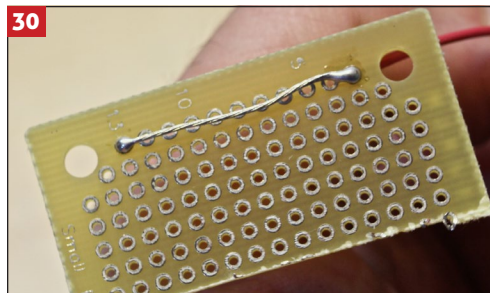
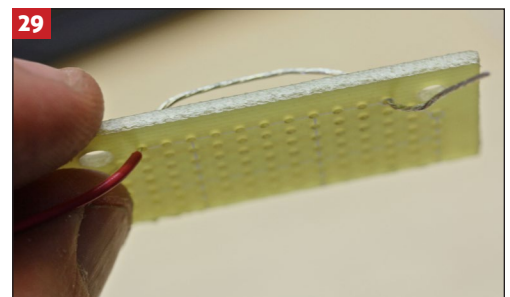
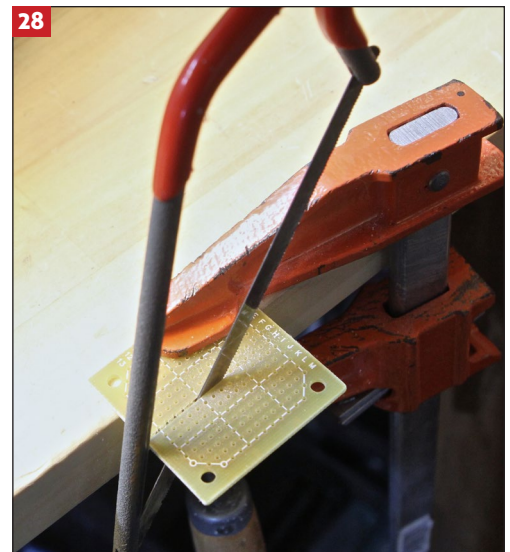
#### 4.05 Insert the transistor

Insert your transistor of choice near the midpoint of the board. Assuming it's a 2N3904, 2N5088, or 2N5089, the curved side should face left (**Photo 32**).

Why start at the center of the circuit rather than, say, working from left to right? It's often a good idea to start where the greatest number of components and wires intersect. But the exact sequence isn't fixed. You'll figure out what works best for you.

#### 4.06 Add R1 and R2

Bend R1, the 2.2M resistor, into a "u" shape and insert it alongside the transistor. (Remember, it doesn't matter which end is which.) Place the resistor directly adjacent to the transistor (**Photo 33**) so that one leg is in the same horizontal row as the transistor's collector (uppermost pin), and the other leg is in the same row as the transistor's base (middle pin).





Whenever possible, insert wires and components so that all points that connect are on the same row. These rows aren't pre-connected like on your breadboard, but trust me, this practice makes it easier to maintain your bearings when you solder.

Now insert R2, the 68K resistor linking the transistor's collector (topmost pin) to the positive bus. Now one end of each resistor should reside in the same horizontal row as the collector (**Photo 34**).

Flip over the board. Solder the topmost end of R2 to the positive bus. (Remember, you can always verify the connection using your multimeter's continuity function.) Snip off the extra wire (**Photo 35**).

As we proceed, try to trim the nest of soldered wires close to the surface so the board fits into the enclosure, resting on the back side of the pots.

Soon we'll solder together the adjacent components in the horizontal row—but not just yet.

#### 4.07 Add C1 and C2

Now let's add the caps  
(**Photo 36**). For C1, use your breadboard favorite. Cap 2 is a 104. Cap 1 should reside on the same horizontal row as the transistor's base (middle pin). C2 should be on the same row as the transistor's collector (top pin).

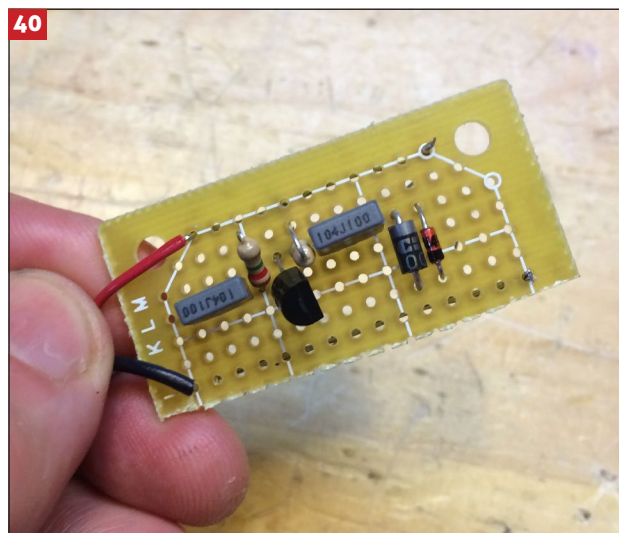
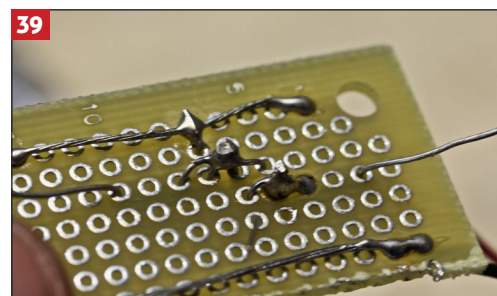
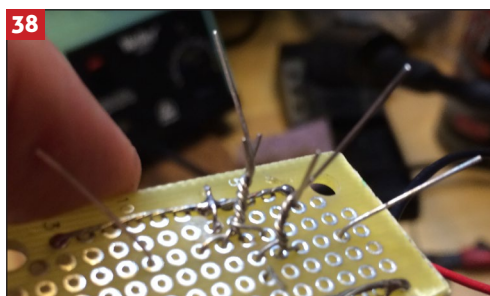
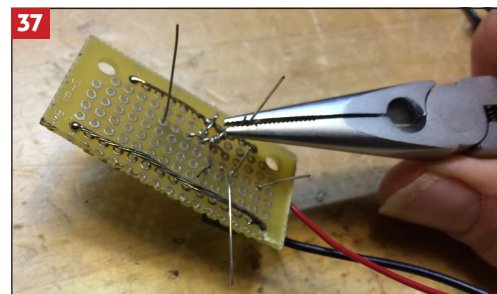
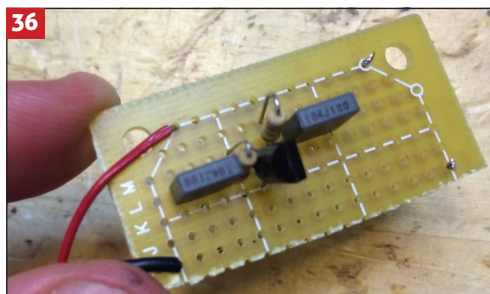
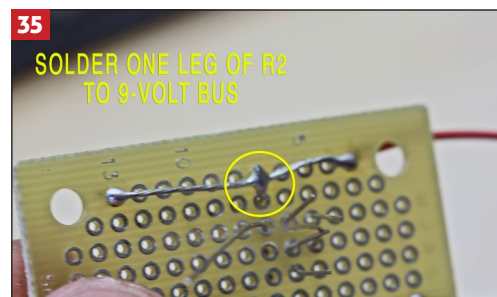
Now let's sort out the mess of wires. Flip the board over. Using your needle-nose pliers, twist together the wires located on adjacent holes on the same row (**Photo 37**). Specifically, connect one end each of R1 and R2 to the transistor's collector (top pin) and the nearest side of C2 (four wires total).

Next, connect the other end of R1 to the transistor's base (middle pin) and the nearest side of C1 (three wires total). The outermost legs of C1 and C2 and the transistor's emitter (bottom pin) aren't connected to anything yet (**Photo 38**).

Solder each "bundle" of wires close to the holes, and then snip off the extra wire (**Photo 39**).

#### 4.08 Add the diodes

Add your preferred diode set. Double-check their orientation. At least one must have the cathode (banded) end toward the negative bus, and at least one must be oriented in reverse (**Photo 40**). If you prefer more than two diodes, place additional ones alongside the first two with their legs inserted into the same horizontal rows.



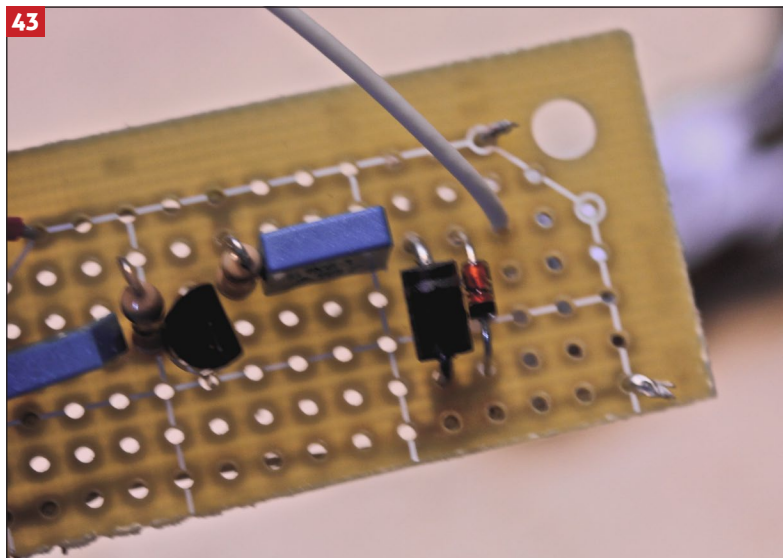
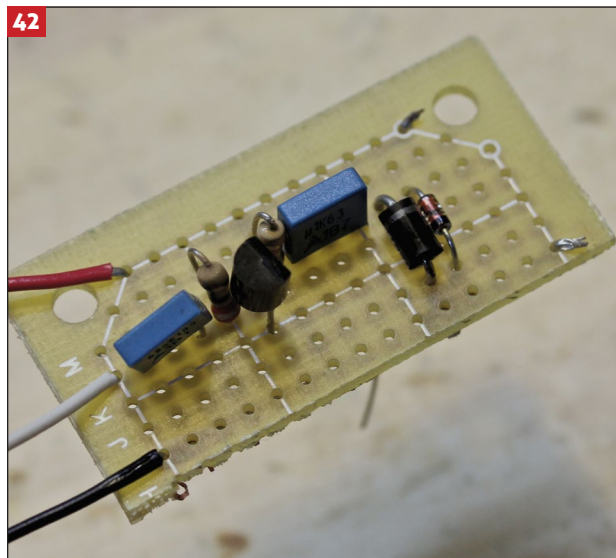
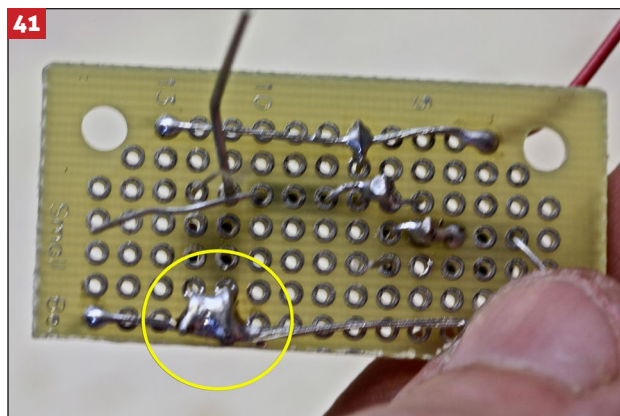


Solder one leg of each diode to ground (**Photo 41**). Meanwhile, the other leg of each diode and the outermost leg of C2 should be on the same row in consecutive holes—but don't solder them yet.

#### 4.09 Add input and output wires

Strip about an inch of insulation from a length of white wire, and insert it alongside the outermost leg of C1 (**Photo 42**). Turn the board over and twist the two wires together. Solder and snip.

Do the same with the output wire (**Photo 43**). Twine it with the uppermost legs of your diodes and the outermost leg of C2 (four wires total—five if you're using three diodes). Solder and snip.



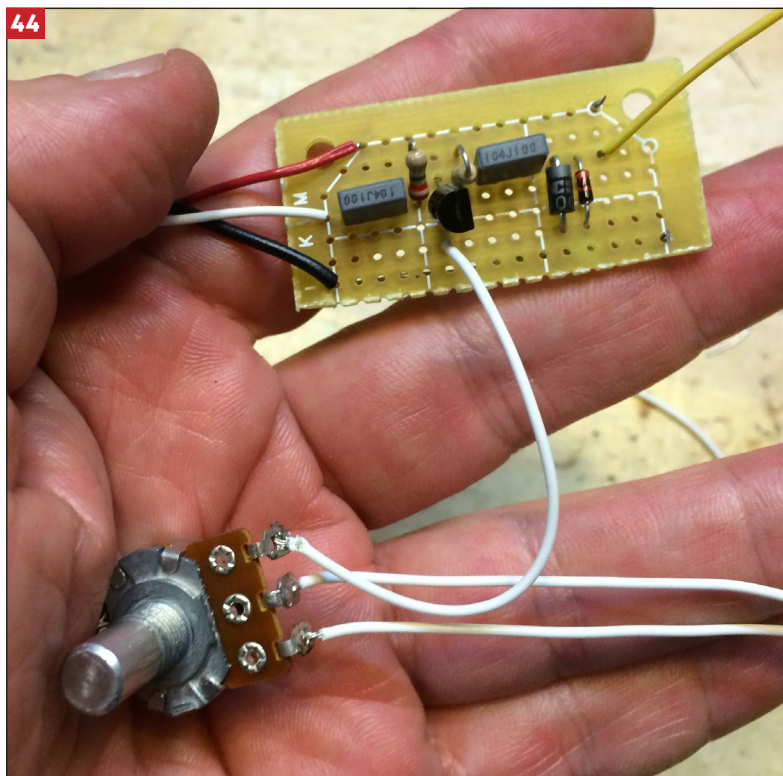
#### 4.10 Connect the gain pot

Trim the wires connected to the C10 gain pot to about 3" and strip about half an inch of insulation from each wire. Insert the wire connected to lug 3 alongside the transistor's lowest pin, the emitter (**Photo 44**). Turn the board over and twist the two wires together. Solder and snip.

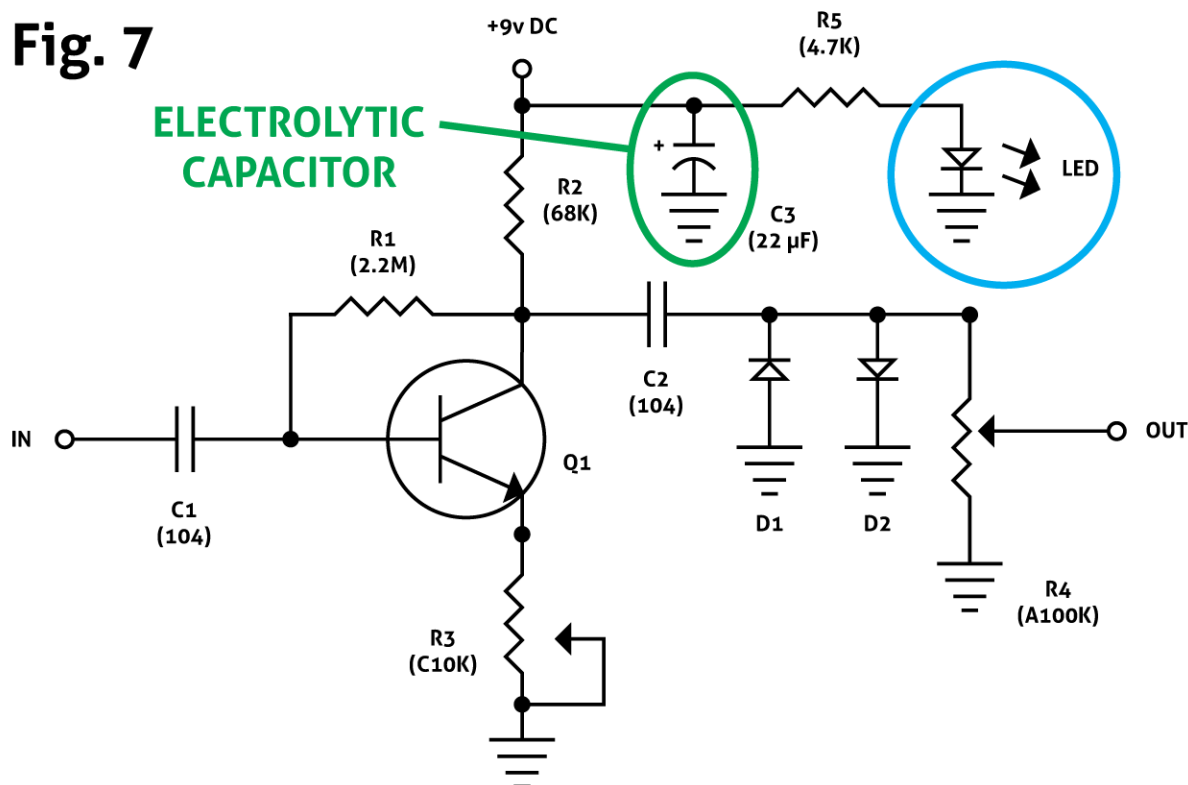
Insert the wires connected to lugs 1 and 2 of the C10K pot alongside your ground bus (**Photo 45**). Flip the board over. Solder the two wires to the ground bus. Snip.

Just two more parts before boxing the thing: a resistor to protect our power LED-to-be, and a large capacitor to filter the power supply and minimize noise. Neither affects the tone of the circuit. Our final schematic (**Fig. 7**) includes the new parts.

The 22 $\mu$ F electrolytic capacitor filters out noise. Electrolytic caps are polarized, and their symbol, a modified version of the simpler cap symbol, shows their positive/negative orientation. R5 protects the



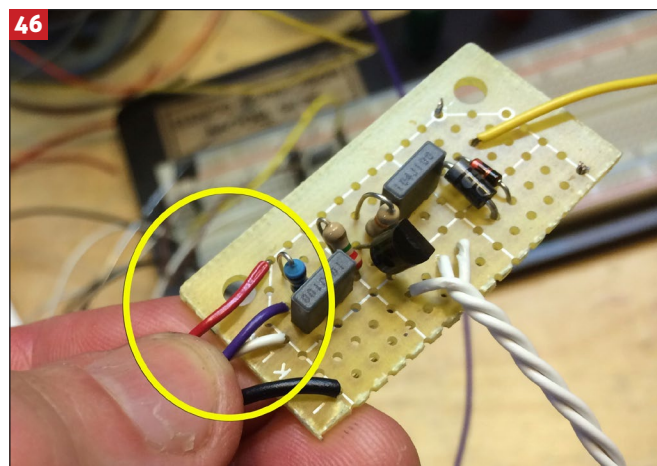
**Fig. 7**



LED—if you wire its positive end directly to the 9-volt bus, the LED will fry in seconds. The LED symbol is like the diode symbol, but with added arrows to represent emanating light.

#### 4.11 Add R5 (LED protection)

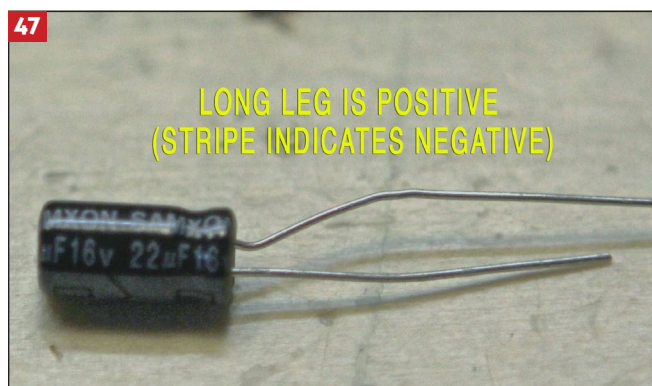
Insert a 4.7K resistor (R5) above C1 (**Photo 46**). Strip about an inch of insulation from a new length of wire and insert it alongside the resistor. Flip the board over and twine the new wire around one leg of the resistor. Solder and snip. Solder the other leg of R5 to the positive bus. The new wire will eventually connect to the positive leg of our power-indicator LED.



#### 4.12 Add C3

The longer leg of C3 is positive, while a contrary-colored band on the cap indicates the negative leg (**Photo 47**).

Insert the 22μF electrolytic cap toward the left edge of the perf board with the positive leg toward the top (**Photo 48**). Flip





the board over and bend the capacitor's legs so that the long wire touches the positive bus and the short one touches the negative bus. Solder and snip.

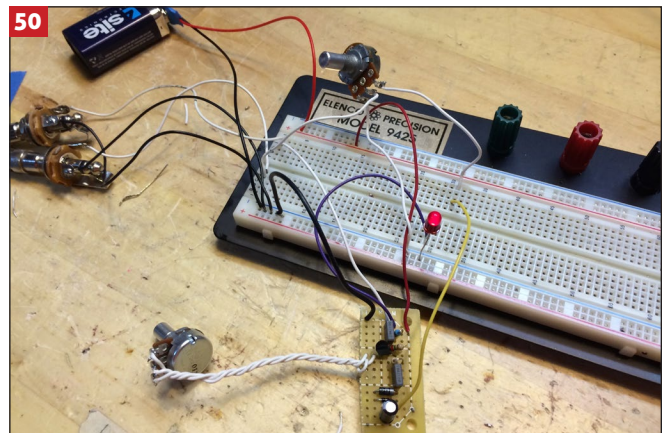
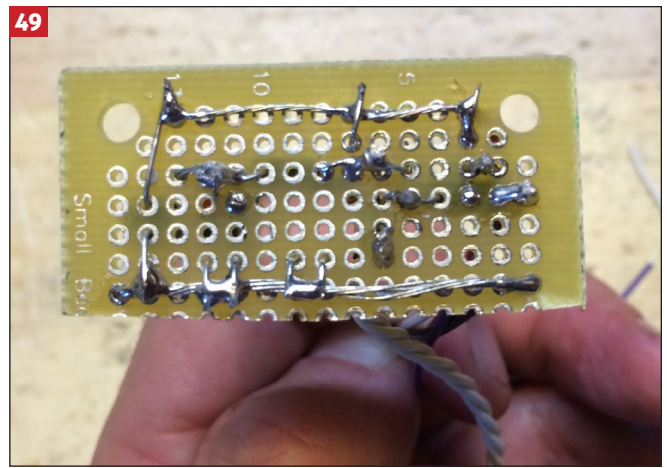
Inspect the rear of the board again (**Photo 49**). Verify the integrity of the solder joints. (A magnifying glass helps.) Make sure nothing's touching that shouldn't be touching (verify with your continuity meter). Check that no wires or solder clumps protrude too far above the board's surface.

#### 4.13 Have a listen!

Let's plug back into your breadboard and see if it goes! Connect the red wire to the positive bus, the black wire to the negative, the input wire to the input jack, and the output wire to the output jack. It should sound the same as your breadboarded version.

Connect an LED as well. Plug its short leg into the negative bus, and connect its long leg to the wire you just connected to R5. The LED should illuminate.

Add your A100K volume knob. Disconnect the perf board's output wire from the output jack and connect it to the wire extending from lug 3 of the pot. Connect lug 2 to the output jack, and lug 1 to ground (**Photo 50**).



## PART 5: BOX IT UP!

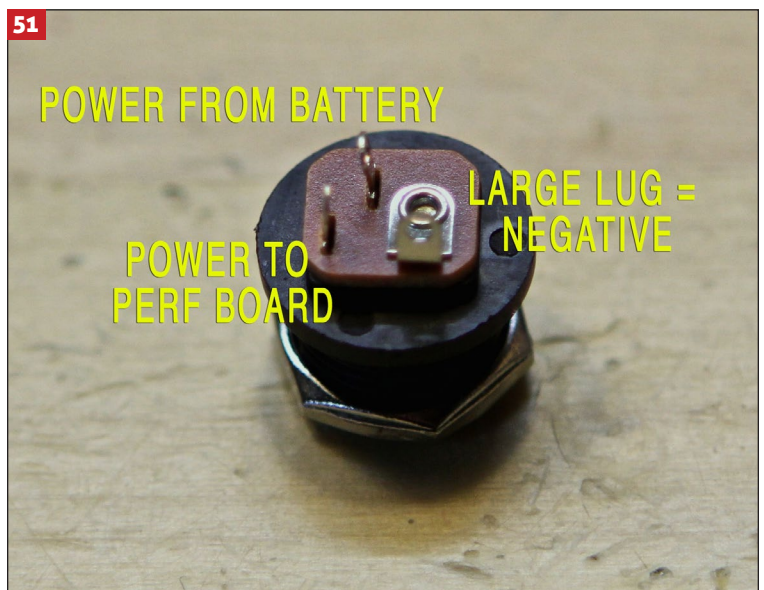
Circuit boards vary, but they tend to get boxed in a standard way. The techniques in the section apply to most stompboxes you're likely to build.

I like using small 1590B-sized enclosures like the ones pictured here. If you want a little more working room, go with the slightly larger and deeper 125B size. You can buy pre-drilled and pre-painted enclosures from such online vendors as Mammoth Electronics and Pedal Parts Plus. If you're enough of a workbench stud to own a drill press, you can make your own holes, though it helps to use an Irwin-style stepped drill bit. You can find drilling templates online: Just Google "1590B drilling template" or "125B drilling template."

#### 5.01 The DC jack

The DC jack lets you power your pedal with a standard Boss-style power supply. Most DC jacks attach via a nut inside the enclosure, though you can also get ones with external nuts (**Photo 51**), which lets you solder the jack before screwing it into the enclosure, and remove all the electronics from an enclosure without any de-soldering should you want to transplant an effect into a new box. Make sure you know which jack type you have before soldering!

If your DC jack is the inside-screw type, install it in the enclosure before completing the following steps.





Start with the negative connection: Solder two wires into the large negative terminal: the black wire from the battery snap, and a second wire that will connect to the middle lug of the stereo (three-lug) input jack (**Photo 52**). If your enclosure has a side-mounted DC jack next to the output jack, three inches or so should do for the second wire. If the DC jack is next to the input jack, you only need about an inch. Make it longer if either the input jack or DC jack are top-mounted.

Connect the red wire from the battery snap to the DC jack's middle terminal (**Photo 53**), the one nearest the negative terminal. (We'll eventually connect the power wire from the perf board to the third terminal.) Wired this way, the effect runs on battery power when no adapter is connected. When you plug in, the adapter jack breaks the connection to the battery, conserving juice.

### 5.02 The LED assembly

The hardware that holds the LED is called a bezel. You don't always need one—sometimes the LED hole is sized for the bare bulb. **Photo 54** shows a common bezel type, sized for a standard 5mm LED. You can use any color LED you like, or opt for a smaller 3mm LED. We'll soon be soldering wires to the LED's legs, so thread them through whatever plastic retainer comes with your bezel.

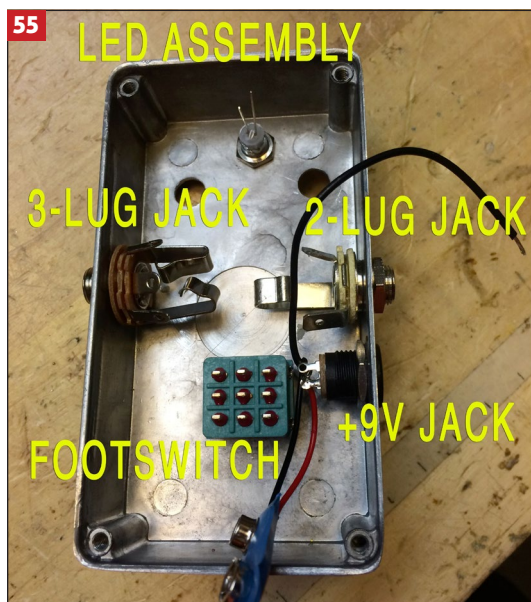
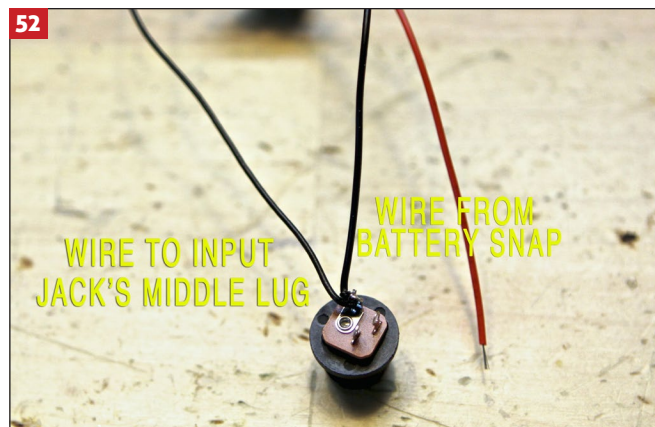
### 5.03 Install the hardware

Mount all the hardware inside the enclosure. From this rear view, the stereo (three-lug) input jack goes on the left, and the mono (two-lug) output jack goes on the right (**Photo 55**). It's your call whether to use the large plastic washer that comes with most footswitches. You may have to finesse the position of the jacks relative to the footswitch.

### 5.04 Wiring the LED

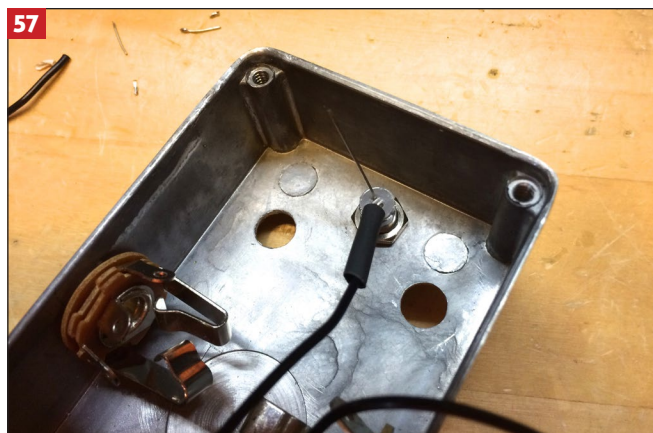
Cut a length of black wire long enough to reach from the LED to the footswitch. Strip one end and twine it around the LED's negative leg (the *shorter* leg). Solder them together (**Photo 56**).

It's a good idea to apply a bit of heat-shrink tubing here to prevent these wires from shorting out, especially since the





perf board is going to rest atop these connections. Snip off a 1" length of 1/8"-diameter tubing and work it over the solder joint. Carefully apply a match, lighter, or heat gun for a few seconds until the tubing shrinks, sealing the connection (**Photo 57**). If you don't have heat-shrink tubing, a bit of electrical tape will do. Some builders also like applying heat-shrink to the jack and pot connection.



### 5.05 The stereo input jack

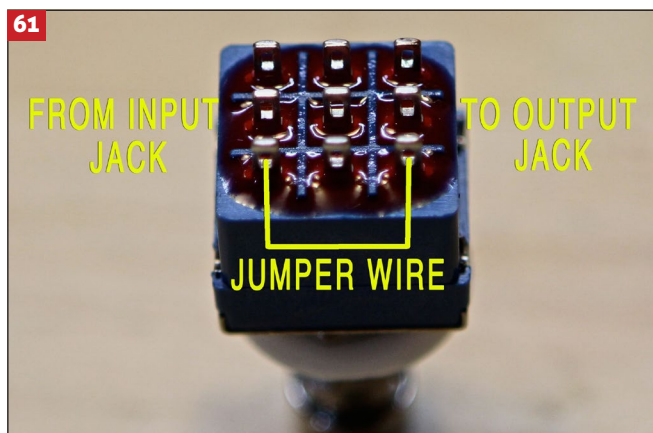
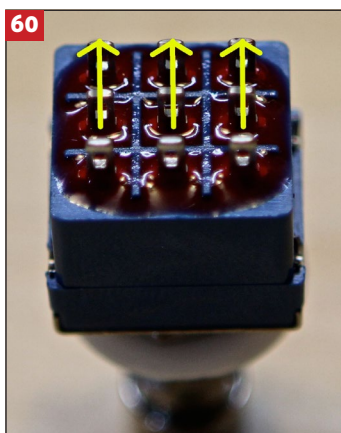
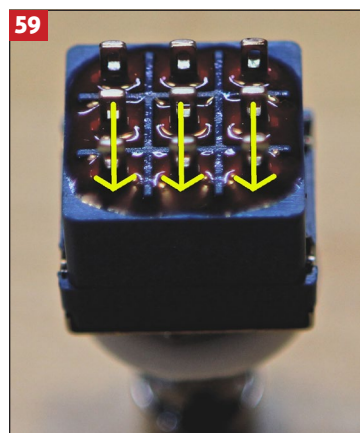
It's called a stereo jack because it has three terminals capable of carrying two audio signals, but we're not configuring it that way. Instead, we'll use two lugs for ground connections (**Photo 58**). When a plug is inserted, the inner and middle lugs are linked, so the battery's negative terminal is grounded, and current flows. When the plug is removed, the battery's connection to ground is broken, and there's no battery drain. Clever!



### 5.06 The 3PDT Footswitch

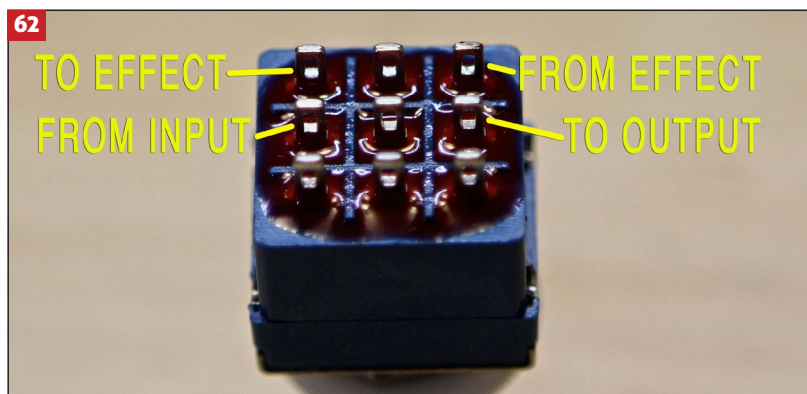
3PDT stands for "triple pole/double throw," which means it's actually *three* switches, each with two possible positions (on and off). When the switch is off, the three middle lugs are linked to the three bottom lugs (**Photo 59**). When the switch is on, the middle lugs are connected to the three upper lugs (**Photo 60**).

We'll connect a jumper wire between the lower-left and lower-



right lugs, so that when the footswitch is off, signal flows from the input jack through the jumper to the output jack, bypassing the effect (**Photo 61**). When the footswitch is on, the signal from the input jack is routed into the perf board via the upper-left lug. The effected sound returns at the upper-right lug (via the volume pot, in this case), before exiting to the output jack (**Photo 62**).

Meanwhile, the middle column of lugs handles LED switching. The center lug connects to ground,

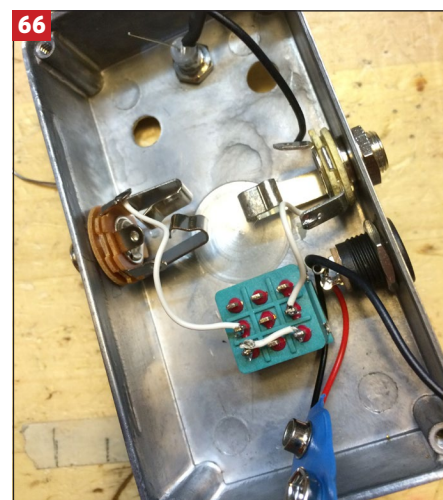
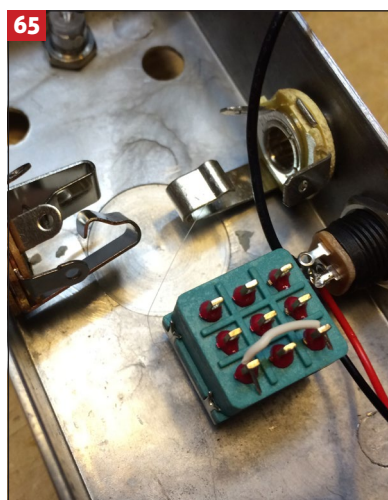
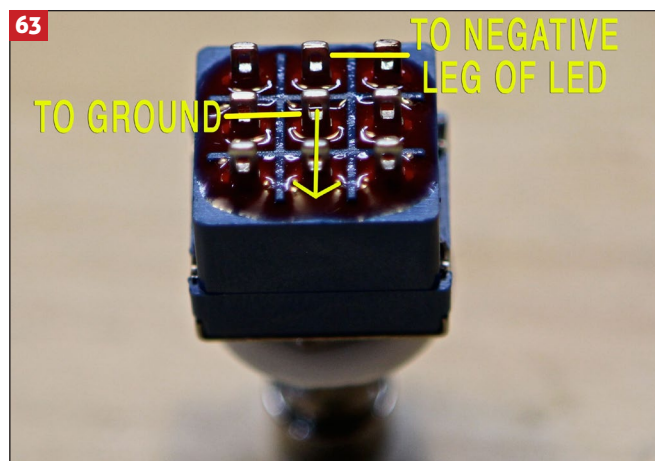




and the top-middle one to the LED's negative terminal. When the switch is off, the LED is ungrounded, so it stays dark (**Photo 63**). In the on position, it glows (**Photo 64**). (FYI, there are other ways to wire the footswitch, but I like this method because it's the easiest to visualize.)

Solder a short length of insulated wire between the lower-left and lower right lugs (**Photo 65**). Don't let bare wire touch the lower-middle lug (which will remain empty).

Add an input wire from the outermost lug of the input jack to the left-middle footswitch lug. Add an output wire from the right-middle footswitch lug to the outermost lug of the output jack (**Photo 66**).



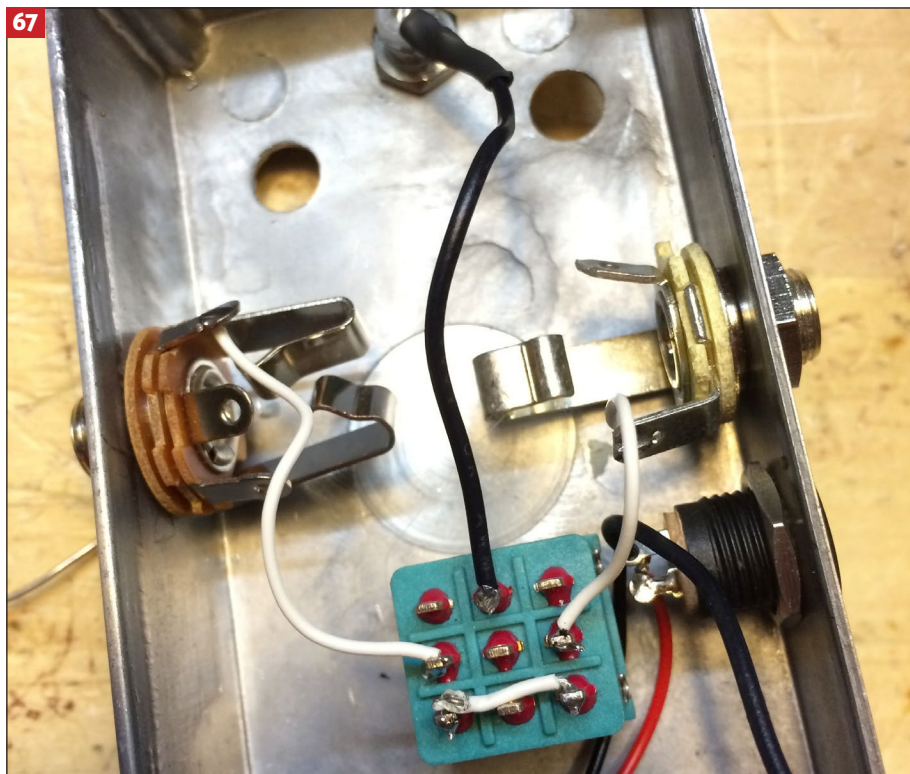
Connect the wire from the LED's negative leg to the upper-middle footswitch lug (**Photo 67**). Leave enough slack so the wire can be pressed against the enclosure, allowing room for the perf board.

### 5.07 Install the volume pot

We soldered wires to all three lugs of the volume pot for breadboarding purposes. But now, unsolder the wire from lug 3. We're going to replace it with the perf board's output wire.

Screw in your A100K volume pot. It can go in either hole, but remember that the orientation is reversed when the pedal is right side up.

This is the last stage in the circuit, trimming the effect volume before it returns to the footswitch. Connect the wire from





the pot's middle lug to the upper-right footswitch jack (**Photo 68**). We'll connect the remaining volume pot wire to ground in a bit.

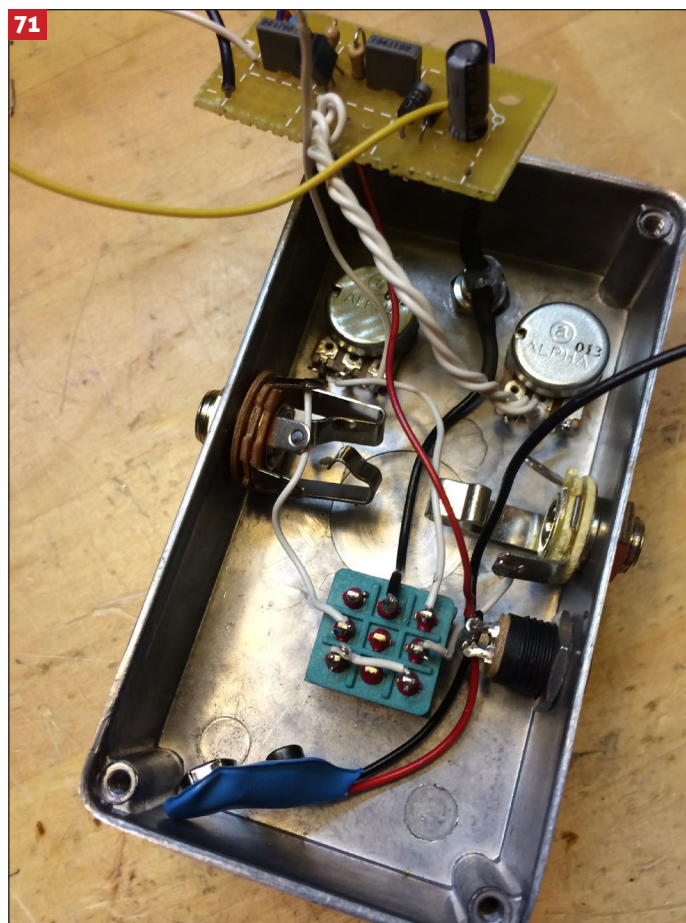
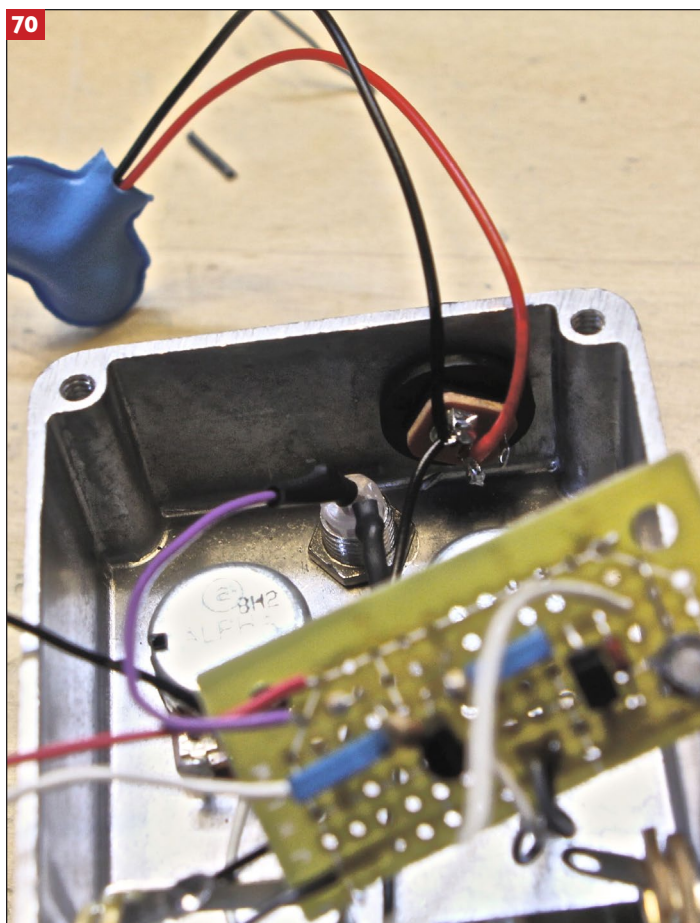
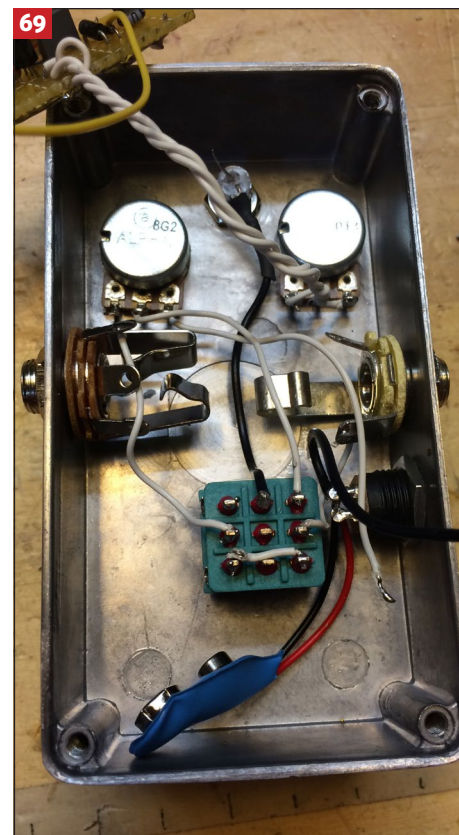
#### 5.08 Install the gain pot

Screw in the C10K gain pot. All three terminals should already be wired to the perf board. Organize the mess of wires as best you can, weaving the battery snap down toward the area below the footswitch, where the battery will reside (**Photo 69**).

#### 5.09 Connect the power and LED

Connect the wire from the 4.7K LED-protection resistor (it's purple here) to the positive (longer) leg of the LED. Apply heat-shrink tubing or electrical tape (**Photo 70**).

Solder the red power wire from the perf board to the unused lug of the DC power jack—the one furthest from the large negative jack (**Photo 71**).





### 5.10 Connect the effect input and output

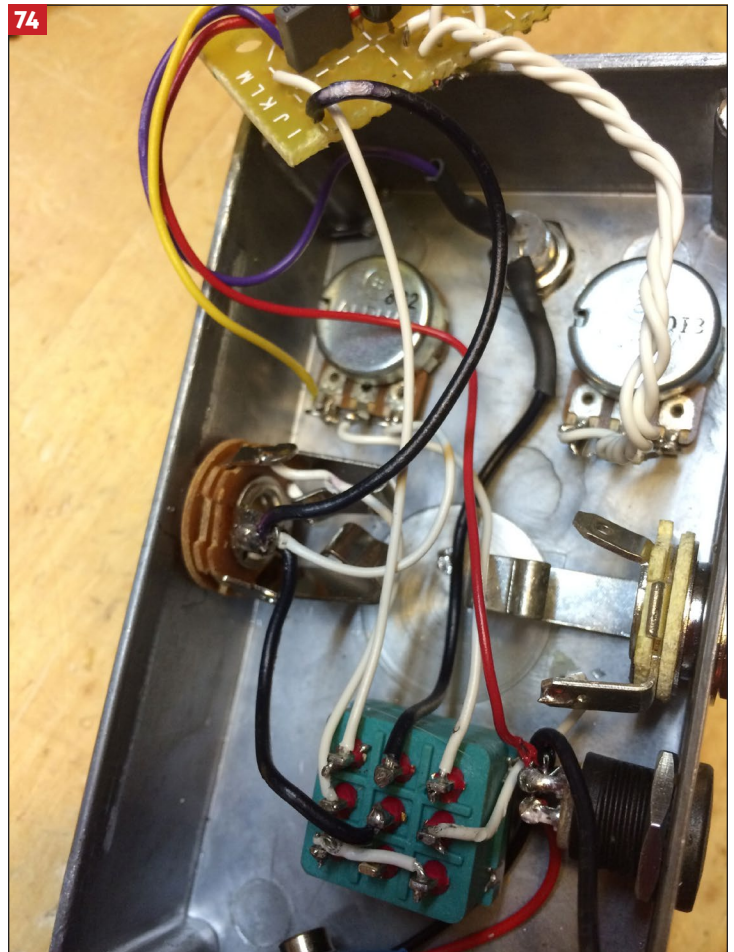
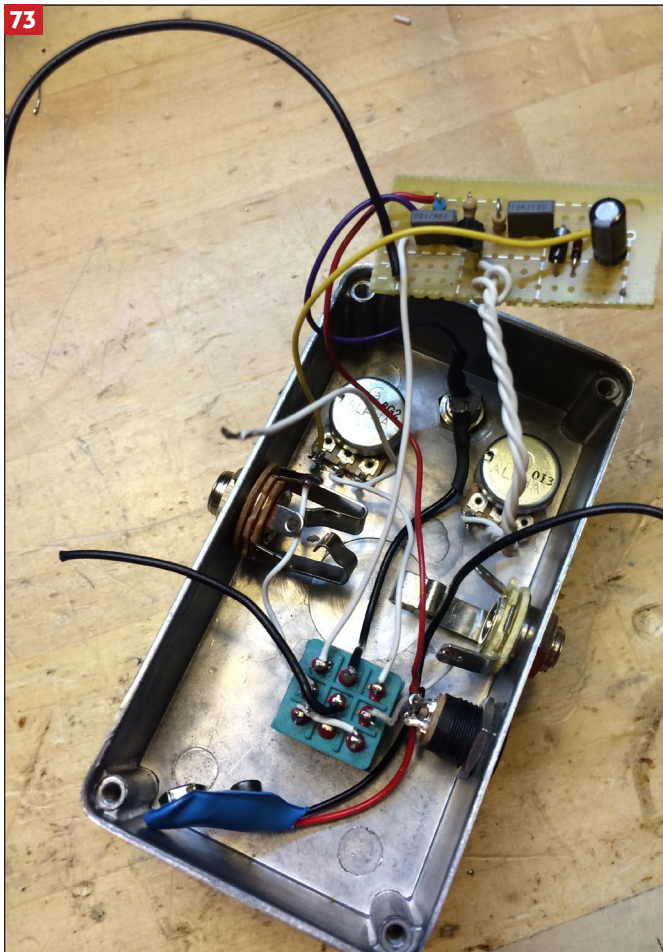
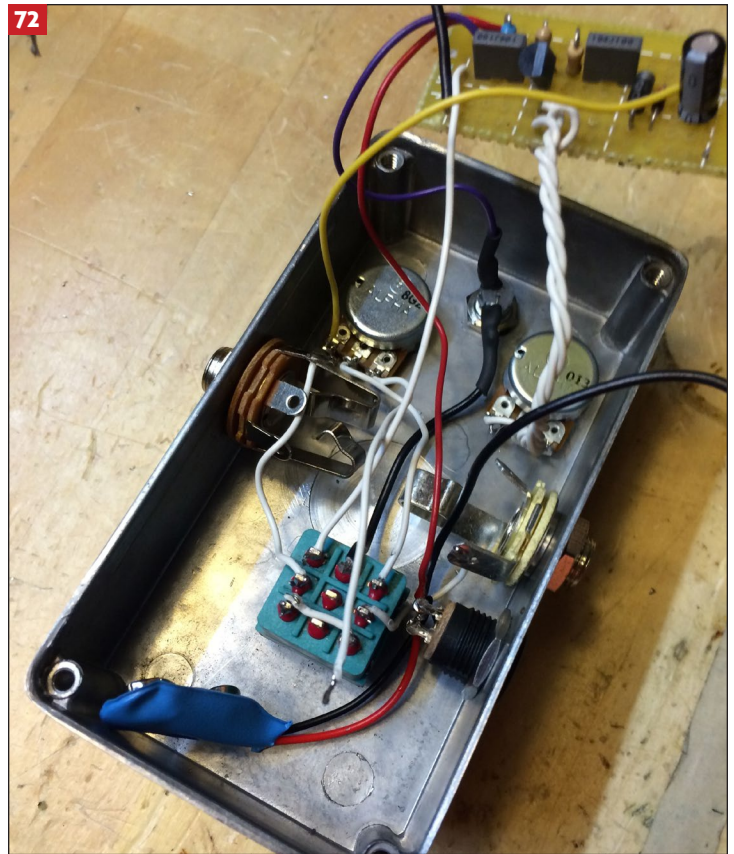
Solder the output wire from the perf board to now-vacant lug 3 of the A100K volume pot. Solder the perf board's input wire to the footswitch's upper-left lug (**Photo 72**).

### 5.11 The ground connections

All ground wires in a circuit must be linked for the circuit to function, though it doesn't matter exactly *where* they connect. I recommend uniting them at the input jack's inner lug because it's a big, easy-to-solder hole. You must connect *three* wires here: the black ground wire from the perf board, the black ground wire from the A100K volume pot, and a third short wire connecting this input jack lug to the footswitch's center lug (to complete the LED ground connection).

Cut a short length of black wire and solder one end to the footswitch's top-center lug (**Photo 73**).

Connect the other end of this wire to the footswitch's inner lug, along with the ground wire from the perf board and the wire from the volume pot's lug 3. (If I'd been more on the ball, I'd have used black wire here as a visual aid.) Solder them all together (**Photo 74**).





Finally, solder the wire from the DC jack's negative lug to the center lug of the input jack (**Photo 75**).

### 5.12 Cross your fingers!

Before we fasten everything down, test your work. Plug in the pedal. (Remember, with the top of the pedal facing you, your guitar goes into the right jack.) When you click the footswitch, the LED should illuminate, and you should sound awesome.

If only the light or the effect is working, recheck the relevant connections. Verify that you connected everything to the correct lugs, especially on that tricky input jack. If you have no light and no awesome sound, confirm that you hear your guitar when the pedal is bypassed. If not, it's probably a bad ground connection—especially if the effect worked when you tested the assembled perf board on the breadboard.

### 5.13 Attach the perf board

Fasten the perf board to the back of the pots with a short length of double-sided foam tape (**Photo 76**). (A double layer may adhere better.) This keeps the components in place and prevents perf board components from shorting out against the pots.

### 5.14 Arrange the wires

You can use a small cable tie (**Photo 77**) to organize the wires—especially if you've inadvertently made some of them longer than necessary.

Check again that everything works. If so, screw down the enclosure's back plate and check once more. (Sometimes a short appears only after you screw on the back plate, especially if the components are tightly packed.) You can apply additional foam tape to the inside of the back plate if needed.

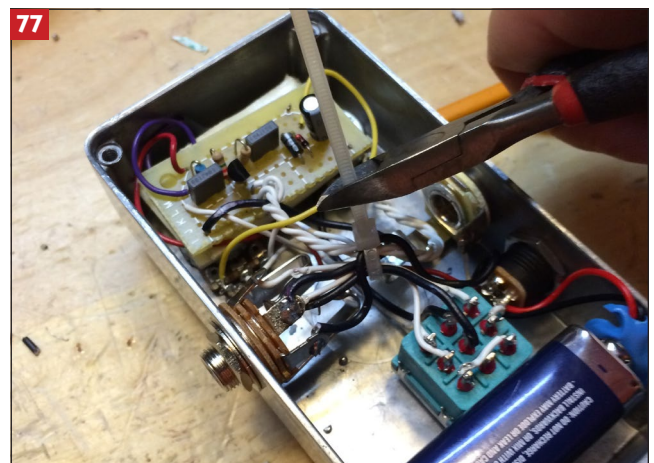
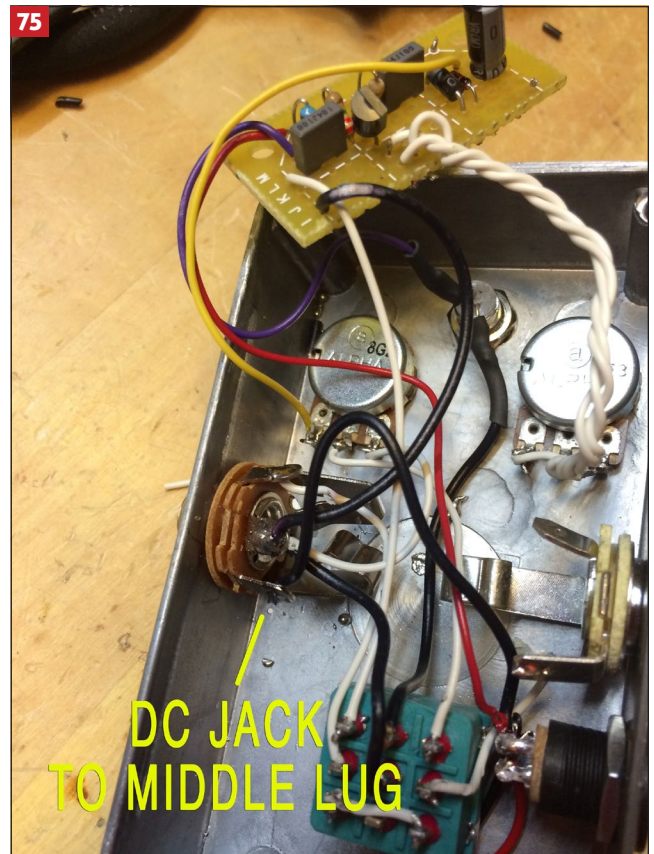
Give the pedal a shake. Does the battery rattle around? If so, slip a bit of packing foam between the battery and the bottom edge of the enclosure.

Attach your knobs of choice, and you're done. Maybe.

### 5.15 What if it doesn't work?

Don't panic. Unless you're very talented, something *always* goes wrong. It's not uncommon to spend more time troubleshooting than building, especially for new builders. Just return to the last step where things worked as expected, and re-check each subsequent step. Use your multimeter's beeper to verify connections, starting with anything that connects to ground.

If you've been working all day at this, give it a rest and try again tomorrow. That's probably the last thing you want to hear, but time and again, I've found that revisiting a project with fresh eyes lets me instantly spot problems I couldn't see the day before.





## WHAT'S YOUR NEXT PROJECT?

That's up to you! You could try a Fuzz Face using old-school germanium transistors. Or maybe a Tube Screamer spinoff using an IC (integrated circuit), the one common component we didn't use in this project. Your second build will be easier than your first, and your third will be easier still.

Whatever you choose, don't be afraid to customize the circuit to taste using the techniques covered here. You may be a beginning builder, but you probably have definite likes and dislikes when it comes to guitar tone. Trust your taste and follow your ear! 🎸