how to make a

fuzzbox

soldering your way to distortion

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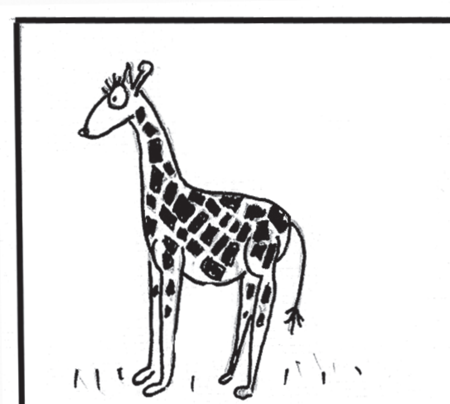
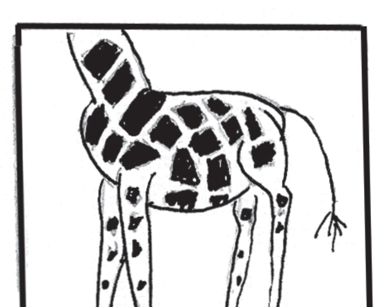
PHOTOGRAPHY BY ADAM COISH

IF YOU ARE asked to imagine the sound of an electric guitar, there's a good chance that the sound you hear in your head is not just an amplified guitar, but a *distorted* amplified guitar. The electric guitar dates back to the 1930s, but the fuzz sound that we often associate with it didn't really show up until the early '60s, when it was popularized by groups such as the Ventures and The Kinks. Initially, the effect was produced by overdriving a standard guitar amplifier, but there soon appeared on the market circuits that could produce the desired effect in a more controlled fashion. The fuzzbox, or distortion pedal, was born.

In essence, a fuzzbox is a small amplifier that is designed to be overdriven. Any amplifier has a certain amount of headroom: the output power that determines the level of signal that can be sent through the amp without the signal being clipped. Think of headroom as a piece of paper upon which you want to draw a picture of a giraffe. If you want to draw a giraffe, you must have a piece of paper tall enough to fit your giraffe's neck and head. If it is too short you will run out of room to draw the complete giraffe. In an amplifier, if the signal exceeds the headroom, its waveform will be clipped, just like the picture of the giraffe.



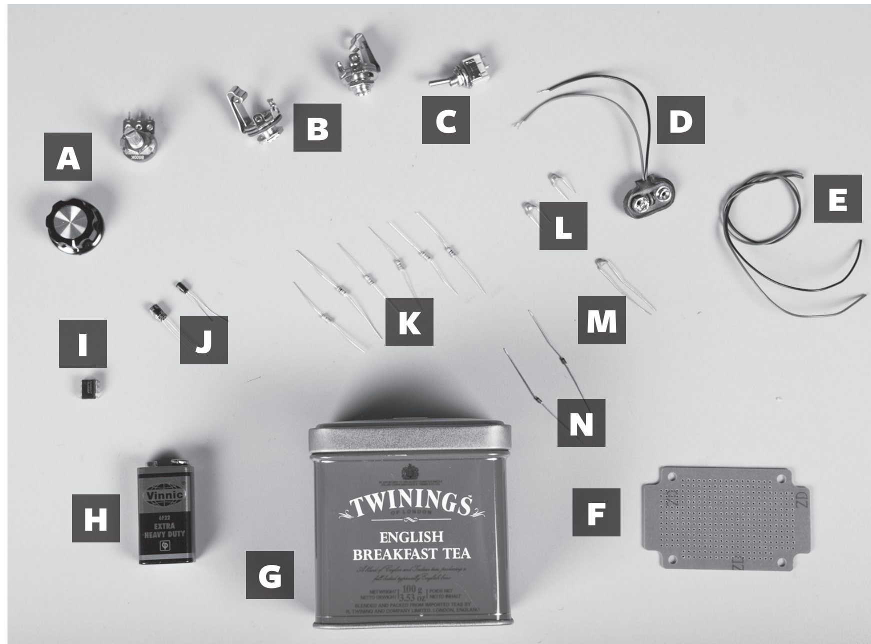


Distorting the shape of the waveform will change the sound: if we start with a smooth waveform and clip it, we wind up with a more complex, somewhat harsher sound. The clipping adds harmonics to the waveform, giving it a very different character from the original. If the clipping is severe enough, it will tend to flatten out the natural decay of the guitar's note, producing the well-known sustain effect heard in every psychedelic guitar solo.

Clipping is usually not an all-or-nothing situation: there is hard clipping and soft clipping. In soft clipping the amplifier will begin to round out the edges of waveforms before going into hard clipping. Soft clipping produces a warmer, more pleasant sound—one of the reasons why many guitar amps are still made with vacuum tubes rather than transistors in the output stages. The tubes' clipping characteristics produce a much more desirable sound than the harsher sound of transistor amps. While only a few esoteric fuzz pedals use vacuum tubes, designers of fuzzboxes expend a great deal of effort to get a perfect soft-clipping sound, often sourcing vintage, hard-to-find transistors in order to achieve the desired effect.

These people would be appalled by what we are about to do. We're going to use an op-amp (operational amplifier), rather than individual transistors for the amplification stage. Op-amps are so named because they were originally intended for performing mathematical operations in analogue computers. In fact, every audio amplifier is a special-case analogue computer, which performs a mathematical operation on the input: multiplying it by the gain of the amplifier, and sending it to the output! The clipping characteristics of the op-amp are anything but soft, so we are going to use an old fuzzbox trick: a pair of diodes on the output to produce a soft-clipping curve. It's not going to sound like a tube amp, but it won't sound completely awful, and building it will cost less than a large latte.

set up



materials

[A] VR1, 500k-ohm logarithmic taper potentiometer (pot for short), with matching knob.

[B] 2 1/4" mono audio jacks.

[C] 1 SPST switch for power.

[D] 1 battery clip for a 9-volt battery.

[E] Insulated solid-core 24-gauge hookup wire and insulated stranded-core 24-gauge hookup wire.

[F] 1 small piece of circuit board.

[G] 1 tea-tin or similar tin box large enough to fit the circuit and to provide clearance for 1/4" jacks.

[H] 9-volt battery.

[I] IC1 TL072 op-amp. Be sure to get the 8-pin DIP version.

[J] C4, 100µF electrolytic capacitor and C5, 10µF electrolytic capacitor.

[K] 1 each of R1, 47k-ohm 1/4-watt resistor (coded with three bars: yellow, violet, orange), R2, R3, and R6, 10k-ohm 1/4-watt resistors (coded with three bars: brown, black, orange), R4, 4.7k-ohm 1/4-watt resistor (coded with three bars: yellow, violet, red), and R5, 33k-ohm 1/4-watt resistor (coded with three bars: orange, orange, orange).

[L] C1 and C3, 0.22µF capacitors.

[M] C2, 22pF capacitor. NB: Note the difference between microfarads (µF) and picofarads (pF).

[N] D1, D2, 1N914 general purpose diodes.

NOT PICTURED

Double-sided foam tape, duct tape, and some soft sponge foam for mounting the circuit and battery.

Rosin-core electronics solder (consider using the lead-free variety).

tools (NOT PICTURED)

Safety glasses or goggles.

Small wire cutters.

Wire strippers.

Needle-nose pliers.

Soldering iron, with a small tip, 40 watts or less.

1 helping hands tool.

Scissors.

Drill, with series of drill bits 1/16" to 3/8". A step bit such as a Unibit is best.

1 small metal file.

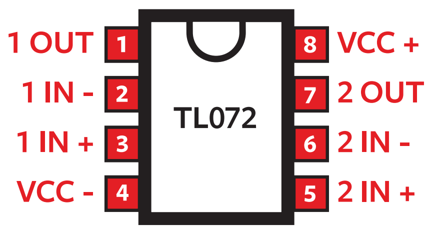
make it

time: a weekend **complexity:** difficult **cost:** ten dollars

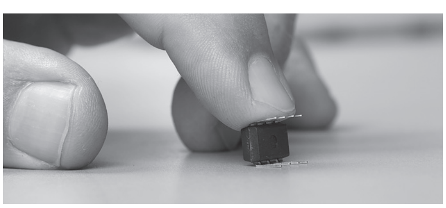
what you need to know: How to solder, plus basic electronic construction techniques, and the ability to read a schematic. You also need to be comfortable using a power drill.

1 mount IC1 chip to the circuit board

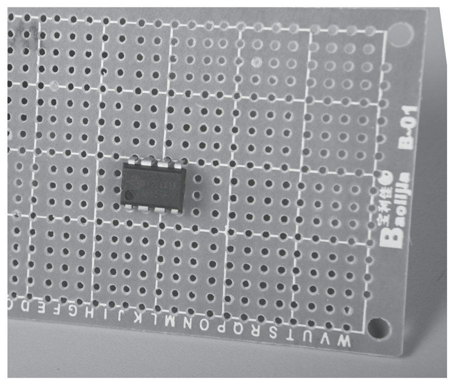
1a. Identify pin 1 of your IC1 chip. The key to identifying the pins is finding pin 1, which is to the left of the semicircular indentation at the end of the chip. The remaining pins are numbered 2 through 8 counterclockwise around the chip.



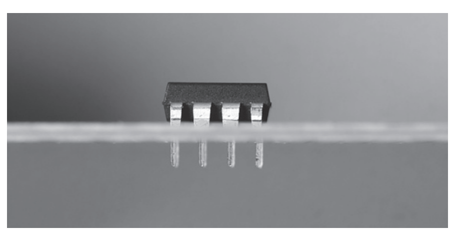
1b. Straighten the pins of the chip if they are not at right angles to the chip. Straighten them by slightly bending them on a flat surface, as shown.



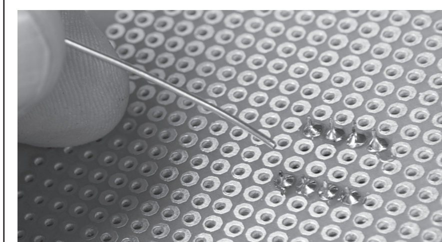
1c. Orient the chip on the circuit board, making sure that pin 1 is positioned to the lower left, as shown.



1d. You will solder and make connections on the underside of the board, so make sure all the pins of the chip go through the board, and are not bent underneath the chip. Don't force them.

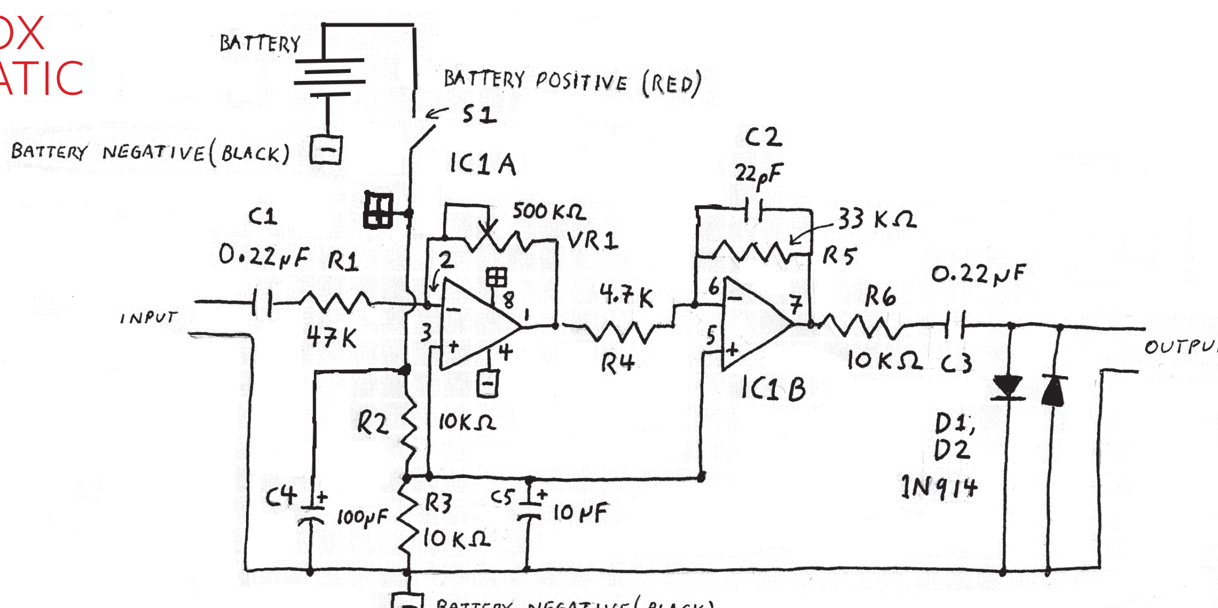


1e. Flip the board upside down and fix the chip in place by soldering all eight pins.



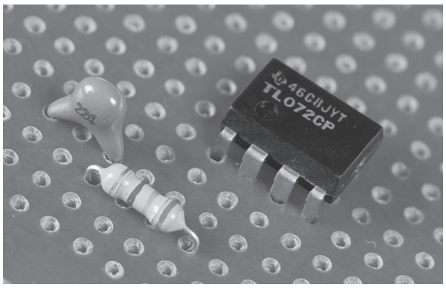
1f. Mark pin 1. On the underside of the board, with an indelible marker write 1 to keep the correct orientation when you're working on the circuit board. Note: Because this is a mirror image of the top of the board, the remaining pins are numbered 2 through 8 clockwise around the chip.

FUZZ BOX SCHEMATIC

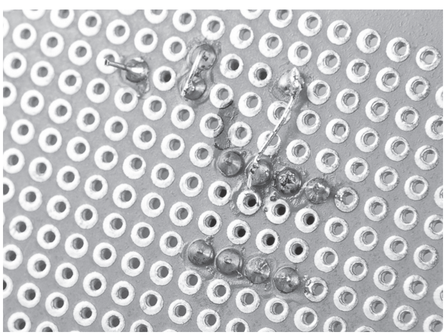


2 wire up the circuit

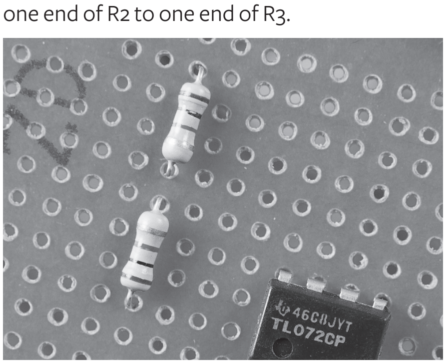
2a. Mount the C1, 0.22µF capacitor and R1, 47k-ohm resistor as shown.



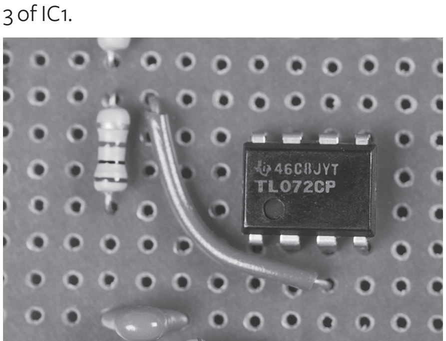
2b. Connect one side of C1 to R1, and the other side of R1 to pin 2 of IC1. The other side of C1 will be connected later. Note: Don't get R1, 47k-ohm, mixed up with R4, 4.7k-ohm.



2c. Mount R2 and R3 as shown and connect one end of R2 to one end of R3.



2d. Connect the junction of R2 and R3 to pin 3 of IC1.



GLOSSARY

Capacitor. A device that stores an electrical charge.

Capacitance. A measure of the amount of energy that a capacitor can store.

Chip. An informal name for an integrated circuit, a complex electronic circuit constructed on a tiny piece of silicon.

Circuit Board. A board, usually fiberglass, perforated with holes to mount components in.

DIP. Dual Inline Pin, which refers to the physical configuration or "package" of the chip.

Farad. A unit of capacitance, named after Michael Faraday.

Ground. The common point in a circuit to which all signals return.

Hertz. A measure of frequency, named after Heinrich Hertz. Previously called Cycles Per Second, or cps. The frequency A440, used as a tuning standard in Western music, is 440 Hertz.

Kilo. A prefix meaning 1000. One kilo ohm, usually written 1k-ohm, is 1000 ohms.

µ. The Greek letter *mu*, used as a prefix meaning *micro* or *1 millionth*. 0.1 µF is pronounced *point one microfarad*.

Ω. The Greek letter *omega*, used as an abbreviation for *ohm* and *ohms*.

Ohm. A unit of electrical resistance, named after Georg Ohm.

Op-amp. Operational amplifier, a simple yet versatile amplifier-on-a-chip.

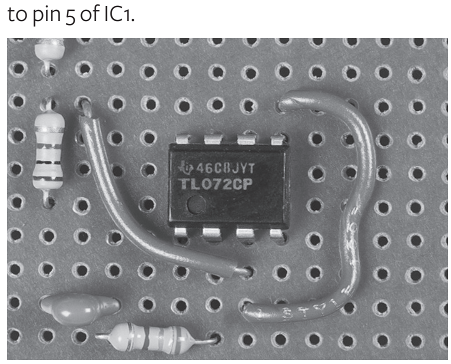
Pins. The electrical connections to a chip, also called *legs*.

Potentiometer. A variable resistor, often called a *pot* for short. The name is derived from an early use in circuits to measure electrical potential.

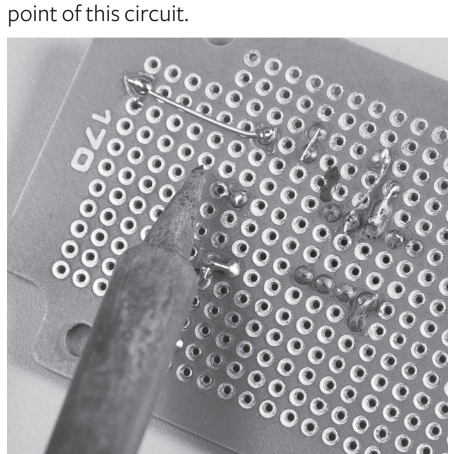
Resistor. A device that limits electrical current.

Wire Gauge. A system for specifying wire sizes. Smaller-diameter wires have larger gauge numbers.

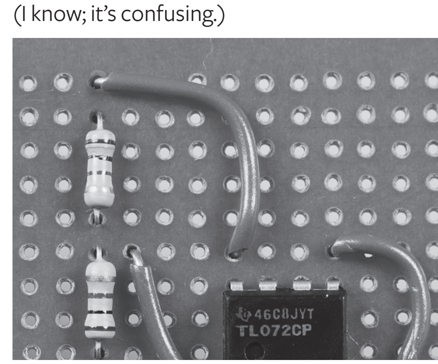
2e. Using a short piece of wire, connect pin 3 to pin 5 of IC1.



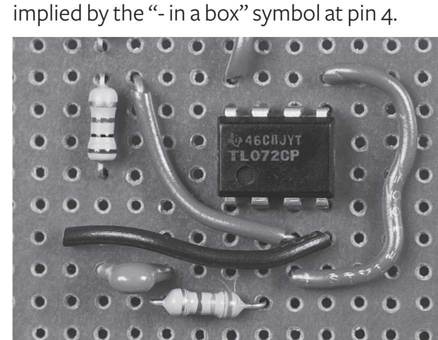
2f. Connect a short piece of hookup wire on the underside of the board as shown, from the bottom point of R3. This will be the ground point of this circuit.



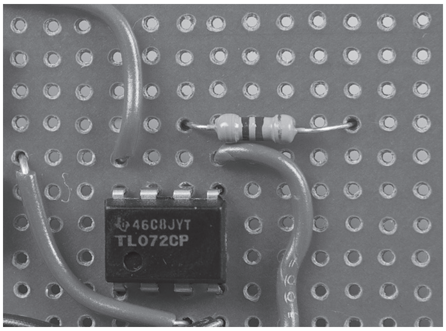
2g. Connect the free end of R2 with a short piece of wire to pin 8 of IC1. Note: This is implied, rather than directly shown on the schematic by the "+ in a box" symbol at pin 8. This is not the same as the + symbol at pin 3! (I know; it's confusing.)



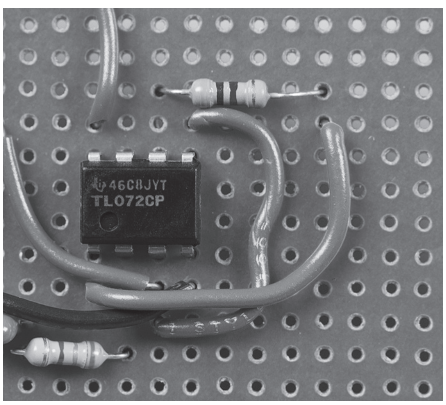
2h. Using a short piece of hookup wire, connect pin 4 of IC1 to the common ground point you made previously. Note: This is implied by the "- in a box" symbol at pin 4.



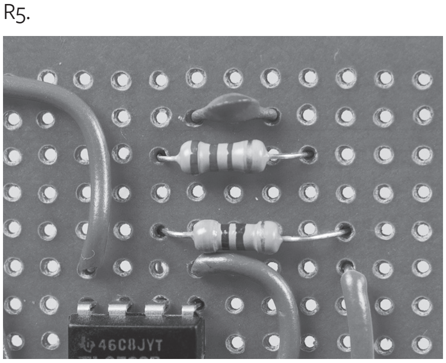
2i. Mount R4 as shown.



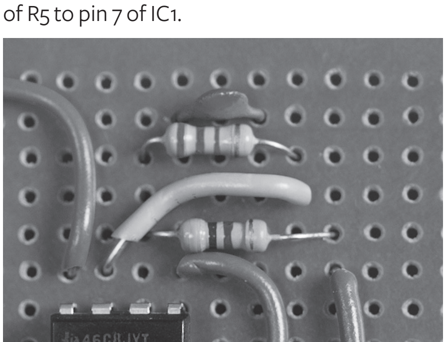
2j. Connect one end of R4 to pin 6 of IC1. Then, with a short piece of wire, connect the other end to pin 1.



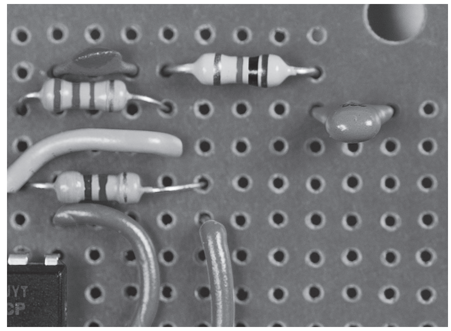
2k. Mount C2 and R5 as shown and connect each lead of C2 to the corresponding lead of R5.



2l. Connect one lead of R5 to pin 6 and, using a piece of hookup wire, connect the other lead of R5 to pin 7 of IC1.

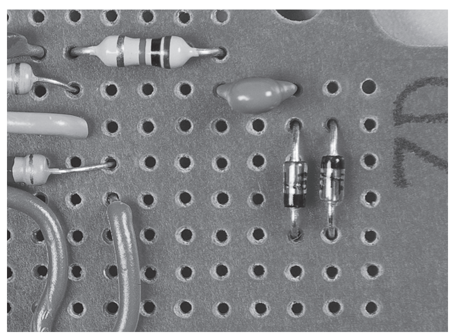


2m. Mount R6 and C3 as shown.

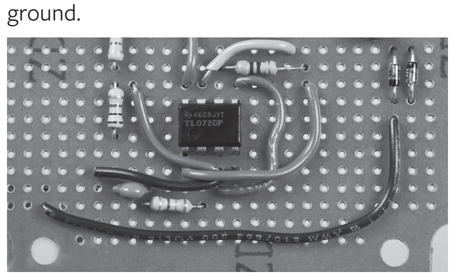


2n. Connect one end of R6 to pin 7 of IC1, and the other end of R6 to C3.

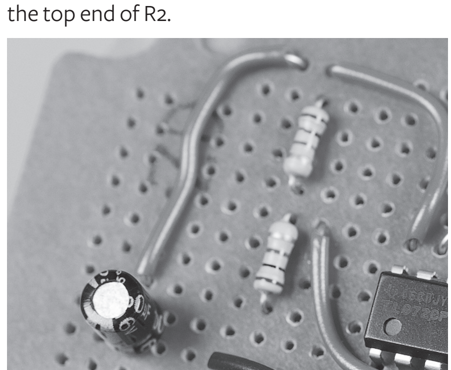
2o. Mount the diodes, D1 and D2 as shown. Make sure the stripes are oriented opposite to each other. Connect D1, D2, and the free end of C3 together.



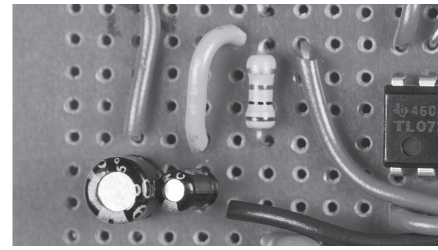
2p. Connect the other ends of D1 and D2 together and connect this to the circuit ground.



2q. Mount C4, noting the polarity of the leads. Connect the negative (-) lead to the circuit ground. Connect the positive (+) lead to the top end of R2.

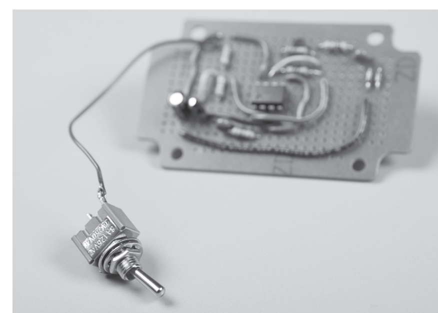


2r. Mount C5 connecting the (-) lead to the ground and the (+) lead to the junction of R2 and R3.

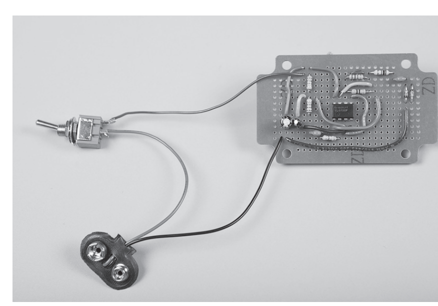


3 mount jacks, switches, and pot to the circuit

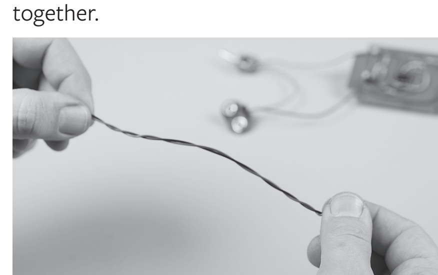
3a. Take a piece of stranded hookup wire and connect one side of switch S1 to the junction of R2 and C4.



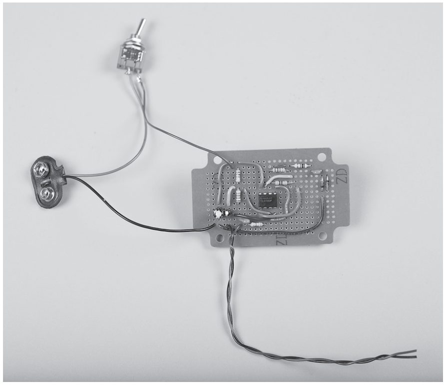
3b. Connect the black lead of the 9V battery clip to the circuit ground. Connect the red wire of the 9V battery clip to the free side of the S1 switch.



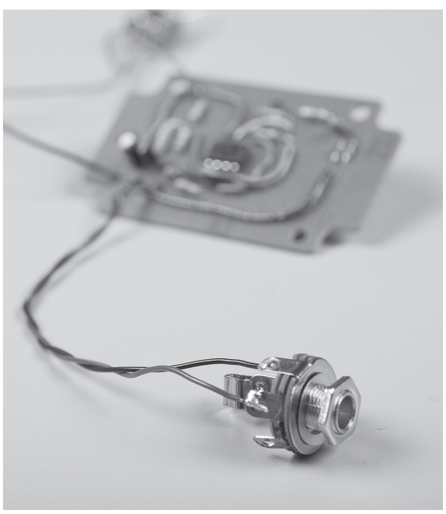
3c. Take two different-coloured pieces of stranded hookup wire and twist them together.



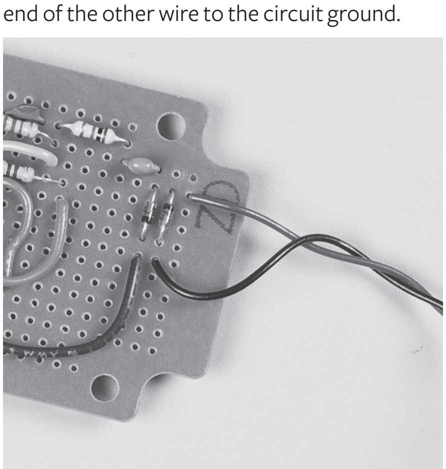
3d. Connect one wire of this pair to the free end of C1 and the same end of the other wire to the circuit ground.



3e. Take the free ends of the two wires and connect the one from C1 to the "tip" contact of the input jack, then connect the one from the circuit ground to the ground terminal of the input jack.



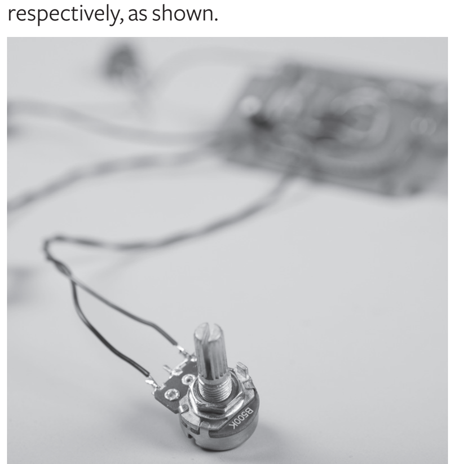
3f. Take another pair of different-coloured pieces of stranded hookup wire and twist them together. Connect one wire of this pair to the junction of D1, D2, and C3, and connect same end of the other wire to the circuit ground.



3g. Take the free ends of the two wires and connect the one from the circuit junction to the "tip" contact of the output jack, then connect the one from the circuit ground to the ground terminal of the output jack.

3h. Place the potentiometer on a flat surface and position it with the shaft pointing up and the terminals pointing toward you then connect a short piece of hookup wire between the left-hand terminal, and the centre terminal.

3i. Take another pair of different-coloured pieces of stranded hookup wire and twist them together. Connect one wire of this pair to pin 2 of IC1, and connect the same end of the other wire to pin 1 of IC1. Take the free ends of the two wires and connect them to the left and right terminals of the potentiometer respectively, as shown.



4 mount the components

4a. Using a power drill, and starting with the smallest bit you have, drill two 3/8" holes into each side of the tin, one for the input jack and one for the output jack. Deburr the edges of the drilled hole with a metal file. Make sure the box is big enough to allow clearance for the plugs when they are inserted.

4b. Using a power drill, again starting with the smallest bit you have, drill two 1/4" holes into the front of the tin, one for the potentiometer and one for the switch. Switches normally require 1/4" mounting holes, but measure your switch to check. Vacuum the metal shavings out of the tin to ensure that no short circuits occur.

4c. Use a couple of layers of duct tape to insulate the inside of the tin. You will later attach the board to it with double-sided tape, but only after you've tested the circuit.

4d. Mount the switches and jacks from the inside of the tin and tighten all nuts.

TROUBLESHOOTING

If the circuit doesn't work, or produces only a loud hum, disconnect the battery!

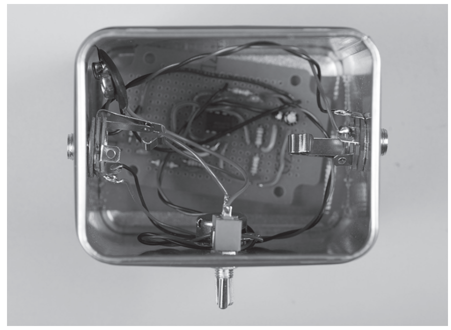
1. Make sure you are using a fresh battery.

2. Check to see if the chip is hot.
Be careful. Touch it quickly, as if you were testing an iron. If it's hot, two things are possible:
- The power to the chip is wired backwards.
- One of the outputs—pin 1 or pin 7—is short-circuited.

3. Check for other errors.
If the chip is not hot, but the circuit does not work, check if:
- One or both of the electrolytic capacitors is wired backwards.
- The jacks, potentiometer, and/or switches are wired incorrectly.
- All connections are secure, especially the "implied" power connections.

4. Check for correct voltages.
If you have a voltmeter, check that there is approximately 4.5 volts DC at pins 3 and 5, as well as at pins 1 and 7. There should be no DC (0 Volts) at the input and output. These voltages are measured with respect to the negative battery lead. There should be 9 volts at pin 8, and 0 volts at pin 4.

4e. Place the circuit board at the bottom of the tin and place a piece of foam, cut to size, on top of the circuit. Connect the battery to the battery holder and place the battery on top of the foam. Cut some foam pieces to hold the battery in place, and attach them to the tin with double-sided tape.



4f. Turn the potentiometer fully counterclockwise and attach the knob so that the pointer is in the seven-o'clock position. Note: You may need a small screwdriver or hex-key to secure the knob to the potentiometer shaft.

5 test your circuit

5a. Turn the fuzzbox on.

5b. Turn the volume on your guitar amp all the way down and plug the output of the fuzzbox into the input of your amp.

5c. Plug your instrument into the fuzzbox, and turn up the volume on your amp slightly. Note: Since the circuit has a fair bit of gain, the setting you use will be lower than what you normally use with your instrument alone.

5d. Turn up the potentiometer on the fuzzbox about a quarter of the way, and play your instrument.

5e. Adjust the potentiometer for the desired amount of distortion. You can also use the volume knob on your instrument to control the level to the fuzzbox, and therefore the amount of distortion.

5f. If you hear nothing, or hear only a hum or noise, disconnect the battery immediately, and proceed to the troubleshooting section of this article (see box). Note: With the increased gain of this circuit, it may be possible to overdrive your amplifier. While this may produce some great (and very loud) additional distortion, some amplifiers are more tolerant of this sort of thing than are others—as are some neighbours.

how it works

THE TL072 CHIP has two op-amps in it. Our fuzzbox uses both of them, cascaded in two stages. Op-amp theory can get quite complicated, so we are going to go light on the details.

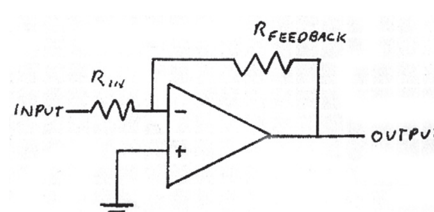
An op-amp has three terminals: a *non-inverting input* (marked + on the diagram), an *inverting input,* (marked – on the diagram), and an *output*.

There are several ways of using these inputs and outputs; we will use a configuration called an *inverting amplifier*. The output of the inverting amp is essentially a mirror image of the input, multiplied by the gain of the circuit. An op-amp has the almost magical quality of providing, theoretically, an infinite gain, so we have to bring it back down to realistic levels, using negative feedback by taking some of the output and feeding it back into the inverting input. As shown in the following illustration of the inverting amplifier, the gain is calculated thus: Gain equals $R_{feedback}$ divided by R_{input}.

The value of R_{input} also sets the input impedance of the circuit, which is the load that is "seen" by the source. In our case, we've set the impedance to work with the output from an electric guitar, which likes to "see" a relatively high impedance.

In our circuit, the signal passes through C1, which blocks the direct current from going back to the source, and into R1, which sets the input impedance and helps determine the gain of the first stage, in combination with VR1, the potentiometer, which is the feedback resistor. The gain is variable, from zero to a little over ten: 500k-ohm divided by 47k-ohm equals 10.6.

R2, R3, C4, and C5 do not affect the signal, but are part of the power supply for the circuit.



Inverting op-amp schematic

R4 is the input resistor for the second stage and, with R5 sets, the gain, which is fixed at about seven (33k-ohm divided by 4.7k-ohm)

C2 provides a high-frequency bypass, so that the circuit is less likely to go into oscillation—or pick up radio stations. Thus, the total gain of the circuit is around seventy.

R6 and C3 couple the output to the two diodes, which provide the soft-clipping action.