MINT-TIN AMP
Pocket amplifier punches up headphones.

By Warren Young

Headphone amps make portable listening good and loud. Commercial audiophile models can cost $200+, or you can build a great-sounding amp inside a mint tin for around $30, following Chu Moy's popular design. Powered by a 9-volt battery, this amp drives high-impedance headphones to thunderous volumes from even weak sources.

To make one, you need an op-amp chip (like the TI/Burr-Brown OPA132), capacitors, resistors, an LED, and a small prototyping board, plus optional knobs, switches, and other bits, all easily obtained. And, of course, you also need a pocket-sized box, like a Penguin or Altoids tin. See the website listed at the end for a full parts list, along with layout diagrams and more detailed instructions.

Prepare the Protoboard
Start with a small prototyping board such as RadioShack's model #276-150 — anything that has at least 12 rows of holes and fits into your case. Larger protoboards can be cut down to size with an X-Acto knife. Then solder nine jumper wires as shown in Fig. 1 on page 133.

The jumpers lower down along the edges are what I call "M-jumpers." They tie three two-hole pads together to form a single pad with three free holes. You can make these by taking a one-inch piece of stiff wire, folding it in half, pinching the kink tight with pliers, and then bowing the two ends over. You may also need pliers to stuff the thick middle bit into the

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hole. Some people make the same connection by threading "S-jumpers" through to the other side, but this makes the jump less visible.

**Build the Power Supply**

Solder in the capacitors, and use them to orient everything else. Make sure you put the legs in the right holes — the jumpers you placed previously dictate the path of current flow, so there's no room for "creativity" now. All the electrolytic capacitors are polarized, so you must orient them properly. If one leg is shorter than the other, the short one is negative, and there should also be a stripe or other mark on the negative side.

Now solder the LED and the current-limiting resistor. As with the capacitors, the short/negative leg of the LED should lead to the negative side of the power supply, with resistors in series in between. If you're mounting the LED on the lid of the mint tin, solder the resistor close to the board and cover the joint with heat-shrink tubing. That way, its legs won't flex and snap from repeated openings of the case (see Fig. 1).

On the underside of the board, solder two 2-inch hookup wires to each side of the third row, in the holes marked V+ and V- (for voltage) in Fig. 1. Leave the other ends dangling loose, but don't let them touch while power is applied.

Now figure out a temporary way to add power to the board. For example, you can solder a 9V battery clip's leads into the holes marked "Batt +" and "Batt -". This only needs to work until you start working on the case.

To test the power, set your meter to DC volts, apply power to the board, and measure from the signal ground ("Ground" in the diagram) to the hookup wires going to the V+ and V- holes. With a fresh 9V battery, you should see about +4.5V DC and -4.5V DC at each capacitor, respectively, and their magnitudes should be nearly identical. If you're off by more than a tenth of a volt, check the wiring and look for solder bridges, wayward drips of solder shorting out to neighboring nodes. Fix any problems and unplug the power supply before continuing.

**Add the Amplifier**

Solder the IC socket to the board with the notch away from the power supply. Leave one or two rows of holes between it and the power supply caps; use two rows if your caps are exceptionally large. Insert the op-amp into the socket. While placing the other components, refer to the pinout diagram on the op-amp's datasheet.

Next, add all the resistors (see Fig. 2). Notice in the photo on page 135 that I used jumpers in place of R5. I almost never install these resistors; they're there to quiet the low-level hiss that you hear with some low-impedance headphones. If you hear a low hiss at normal volume with the audio source disconnected, you can try adding two 47 to 100Ω resistors in the R5 positions. But don't do this otherwise because it will raise the amp's output impedance, inhibiting control over the headphones.

For the remaining resistors, I add them in matched pairs: for each resistor in the left channel, I use my ohmmeter to find another that measures as close to identical as possible for the right channel. I haven't scientifically studied whether this really helps, but it's easy and quick, so why not? It's one less thing to blame if the final product's sound has flaws.

Now add the input capacitors (C2). These aren't polar like the electrolytic power supply caps, so you can orient them any way you like. Axial capacitors are easiest to fit into tight spaces, but most caps can be made to work with a bit of creative lead bending.

Next, take the hookup wires coming from the V+ and V- points in the power supply area and run them to pins 4 and 8 of the op-amp, the chip's V+ and V- points. I recommend you do this on the bottom side of the board, since you'll be adding more wires to the top later. The more wires you can put on the bottom, the cleaner the top side of the finished amp will be, facilitating any repairs and tweaks later.

Finally, add test points at R.out and L.out, and also at R.in and L.in if an alligator clip can't attach to the input capacitor leads directly (see Fig. 2). I use half-inch pieces of stiff wire, usually clippings from resistor and capacitor legs, bent in an upside-down "U". These are temporary, used only for the signal test, the next step.

**Test the Amp**

Now you're ready to see if you have an amplifier yet or not! Apply power to the board, and let it sit a bit. Then, carefully touch the op-amp and
MINI-CMOY POCKET AMP WIRING DIAGRAM

Fig. 1 Add power supply.

Fig. 2 Add amplifier section.

Fig. 3 Add panel components, enclose, and enjoy!

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all the resistors’ bodies to make sure nothing is overheating. You shouldn’t feel any heat at all; if you do, unplug the power and find out what’s going wrong.

I use a portable CD player for testing since they have volume controls, useful when you’re testing a circuit without a volume control. Turn the player’s volume all the way down and start it playing.

Hook the source into the circuit. There is no one right way to do this, but I use six alligator jumpers and a mini-to-mini audio jack cable. I plug the cable into the player’s headphone out and connect three jumpers to the other end. For ¼” and ¼” stereo mini plugs, the tip carries the left channel, the “ring” further down is the right, and the long remainder, the “sleeve,” is the ground. I clip one jumper to each of these, and then clip the other ends to the corresponding test points and across the ground jumper on the board, as shown above.

Then I use the other three alligator jumpers to tie my amp’s output points to a pair of cheap headphones. Don’t use your $200 cans for first tests — if something’s hooked up wrong, you can blow your cans’ drivers out.

With the headphones sitting on the table, slowly turn up the volume on the player until you can hear some sound out of the headphones. Put them on now and adjust the volume. If you get good sound, you’re done! You might listen for a while longer and try to stress the amp a bit, but basically, you hooked the amp up right the first try. Once you’re satisfied that the amp circuit is behaving properly, try your good headphones with the amp. Sometimes efficient, cheapie ‘phones will work fine, but the higher load of big, audiophile headphones causes problems.

Amps that don’t work right exhibit different symptoms. With some, you’ll hear nothing at all, or the sound will be faint or scratchy, even with the player volume turned up. Others sound fine at very low volumes, but distort when louder. And in some cases, the amp plays for a short while, but then stops. This last case comes from the op-amp shutting down; op-amps often have power-protection circuitry, which is triggered by various wiring faults.

Troubleshooting is difficult, and I can’t cover it deeply here. But the main things to check are that all the connections to ground are solid, and that
Alligator jumpers all hooked up for testing. From music source (I use a CD player) and headphones. Be sure to use a cheap pair of headphones, because an improperly wired circuit can destroy the headphone's drivers.

You don't have signals or power going to ground when they shouldn't. Check all connections with your meter; sometimes a connection will look right but have high resistance, in which case it needs to be re-soldered.

If your wiring fully checks out, try adding a second battery temporarily, in series with the first. If that cleans the sound up, your circuit or op-amp are marginal. You can either keep on using extra voltage and build for two batteries or try to improve your implementation. See the article, "Basic Troubleshooting for Headphone Amplifiers," at tangensoft.net/audio/trouble.html for more advice.

Set Up the Enclosure
With the amplifier board built and tested, you can decide where on the case you want to place the panel components — the volume control, power switch, LED, and I/O jacks. To minimize the tangle of hookup wire, the exterior ports for these components should be positioned close to where they hook up on the board. Beyond that, it's your aesthetic judgment. Once you have your layout, drill the necessary holes and set it all up with the board in the case and the panel components fastened into their holes, but not connected to the board. This ensures that everything's going to fit before you start soldering again.

Add the Panel Components
When wiring the panel components into the circuit, add them one at a time, and retest the circuit after each. If you connect all the components at once and then have a problem, troubleshooting becomes very difficult. Also, be sure to test each component on its own, out in the air, and then again once it's fastened in place. This identifies weak wires, bad chassis grounding, and other issues. I've built several amps that worked fine when the panel components were still flopping around on their hookup wires, but failed once the amp was batten down within its case. Fig. 3 on page 133 shows where all the panel components (the switch, LED, in and out jacks, and volume control potentiometer) hook up to the PC board. First, I hook up the LED and the power switch to the power supply. Once these are working, I add the input and output jacks, remembering the standard stereo plug tip/ring/sleeve ordering.
The completed amp. Unless you want to build it in a day, including the time to get the parts, there's little reason to get RadioShack parts; the big mail-order houses have everything RadioShack has and more, with cheaper prices and better quality. I highly suggest you mail order everything you can, if you can stand waiting a week for the parts to arrive.

I described above. I connect and test each one at a time, and use extra-long wires for the inputs. That way, it's easy to splice in the potentiometer, which is the next and final step. The potentiometer has six pins, three in a row for each channel. The middle pin, the "wiper," connects to the circuit board's input capacitor, at L.in or R.in on the diagram. The pins on either side of the wiper connect to the input jack and to ground. If you want volume to increase as you turn the knob clockwise, the ground usually needs to connect to the pin that's on the left, as you face the knob with the pins pointing downward. But it's best to determine the pin arrangement by checking the component's datasheet or testing with an ohmmeter; lowering the resistance between the side pin and the wiper means turning the volume up. If you reverse these connections, the amp will work fine, but the volume knob will operate in the wrong direction.

That's it — now you've got an amp! You can enhance it with various tweaks described on the website, including tuning the gain, adding a DC power jack, using different caps and resistors, and improving the virtual ground circuit.

For the full project tutorial site, including a parts list, background articles and other references, and more detailed instructions, visit makezine.com/04/headphoneamp.

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Silly Putty's been around for 50 years, and in that time it's become an international toy classic. Now you can purchase a 5-pound block of the original Silly Putty at www.make.com/category.asp?NAV=PUTTY. The block comes in a box; no plastic eggs included. There's also a Bouncing Putty Mailing List at www.make.com. Both, with instructions on how to get 100 pounds of Dow Corning's Coral Putty at bulkputty.org/ordering/DocPrint.