Tech corner – Your own PCBs, Part 1

It's been a long time since we've been able to hand-wire ½-watt resistors and wax-covered capacitors with a plumber's soldering iron. In this and the subsequent two articles, I'll cover how to create your own PCBs (printed-circuit boards) for minimal cost and no chemical mess. The results aren't perfect, but will be both sufficient and satisfying to the amateur experimenter. The software is easy to learn with a moderate level of electronics knowledge, and you won't spend hundreds of dollars.

I'm addressing this to new amateurs. If you want to set a breadboard experiment you found somewhere in hard fiber glass and copper, and you've never done this before, read on. When you're done, you'll even have extra copies to give to, or inflict on, friends. For less than $100 you can build a lasting monument to your own ingenuity.

I'm assuming you know how to read a circuit diagram, what the various components do, and what a lot of them look like. Your level of knowledge drives what you can build. We'll see that surface mount components aren't as scary as you might think and they're almost always cheaper than through-hole parts. Modern integrated circuits capture the capabilities of many transistors and passive components in a single package, reducing the size and complexity of your circuit. The op amps (operational amplifiers) used in my demonstration circuit have 26 (or more) transistors in a small package with eight pins, saving space and design time.

I'm giving an example of expressPCB, an ECAD (Electronic Computer-Aided Design) system for the beginner and those of us on a restricted budget. You design and layout your circuit, click order, give them your credit card number, and in a week or so, 3 small printed circuit boards arrive in the mail. Other tools such as ***kikad*** and ***Eagle*** are free but lack the start-to-finish workflow to ease the process.

If you have no electronics experience beyond that required to pass the FCC test, you should consider any of the beginning electronics books including those from the ARRL and all over the internet. These have many experiments, some of which you could consider for a first printed circuit board.

As a demonstration, I'm going to design and build a two-microphone mixer with variable band-pass filtering and gain stages. It's all analog, so no programming required; just turn it on. I'm probably going to make mistakes along the way, but that's part of the process.

How to get started

1. Download a copy of ***ExpressPCB***. Once you create a login, visit ***https://www.expresspcb.com/expresspcb-plus-pcblayout-software/*** and follow their directions. I'm assuming you have Windows 10 or 11. You'll need to give them an e-mail address. Spend some time with their tutorials and example PCBs.
2. Do you have an idea? You're going design and build a what? What sort of box are you going to put it in?
3. What are the main (largest, most expensive) components? A microprocessor? RF modules? Op amps? What connectors? Can you buy the components? Are they still being made or have the ones you're familiar with reached their end-of-life?
4. Sketch out the circuit on paper, grit your teeth and enter it into the schematic capture program.
5. Unless you're really sure of yourself, breadboard at least some of the circuit. If you're familiar with Ltspice you can substitute that.
6. Layout the components using the ExpressPCB Plus layout program. Make sure you have the right footprints for each component and that it all fits on the 3.x″ x 2.5″ board size.

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7. Connect the components with copper traces, and verify against the schematic. Pour the ground plane.
8. Add a silkscreen board name, test points, connector names, and whatever else there's room for.
9. Send to the board manufacturer with money, and purchase parts if you don't have them.
10. Solder things on, debug, add haywires as needed, declare success or repeat starting at step 5.
11. Make a pretty box and put your project in it.

In this *Microvolt* issue (Part 1) we'll cover steps 2 through 5 above.

The idea

I wanted to avoid digital circuitry, sticking to elementary analog; hence, a microphone mixer. Earlier, I attempted to connect a Kenwood desktop microphone to my TM-V71 transceiver - the mic's output just couldn't drive the modulation circuitry. Add to this that you may want two microphones of varying capabilities and remove background noise so you need a band-pass filter as well. This necessitates a number of potentiometers but I'm setting it up so some will remain unpopulated – if you don't need the bandpass filter, you can substitute fixed values for them.

I love 3D printing – I can design a box to fit the project, not buy a box and fit a project into it. The microphones will plug into the box, and the output into the transceiver. Be forewarned – there are many standards for PTT microphones, I'm not even going to attempt to fix that part of the circuit. But, I'm assuming an electret that needs a DC bias voltage to operate. Seeing as they can be less than a dollar, they're fairly common.

The parts

This design will use three **LM358 integrated circuit dual op amps** (operational amplifiers). These are common, inexpensive devices in a variety of packages. For ease of construction, I'm using the 8-pin DIP version with two amplifiers in each package. There is one op amp for each microphone channel and one for the last gain stage of which only half is used.

Adjustments are by potentiometers of various values and are connected to the circuit board with 0.1" headers. This allows you to select what kind to use - slides for a professional look or knobs for a classic look - or you can fix the values be soldering resistors on the pads provided. Note that knobs can be more expensive than the potentiometers themselves. A really fancy safety knob might set you back more than $500.

The mixer needs positive and negative voltages which you must also supply through a 3-pin header. This could be anything from two 1.5-volt AAA batteries to two 9-volt batteries or something fancier of your own design. I've avoided buck/boost and switching power supplies to avoid electrical noise. If you want an LED to indicate the device is on, you're on your own.

The audio connectors are problematic. If your microphone has an RJ-11 connector, a screw-on 3.5-mm (3- or 4-wire) plug, or ¼″ plug, these need to be part of the box and not the circuit board. In addition, the PTT function of most radio microphones is connected outside the circuit board.

The circuit

The circuit was entered with the ***expressSCH*** program. You select parts from a library, add their values, maybe their footprint, and a part number for a BOM (bill of materials), though you only need the type.

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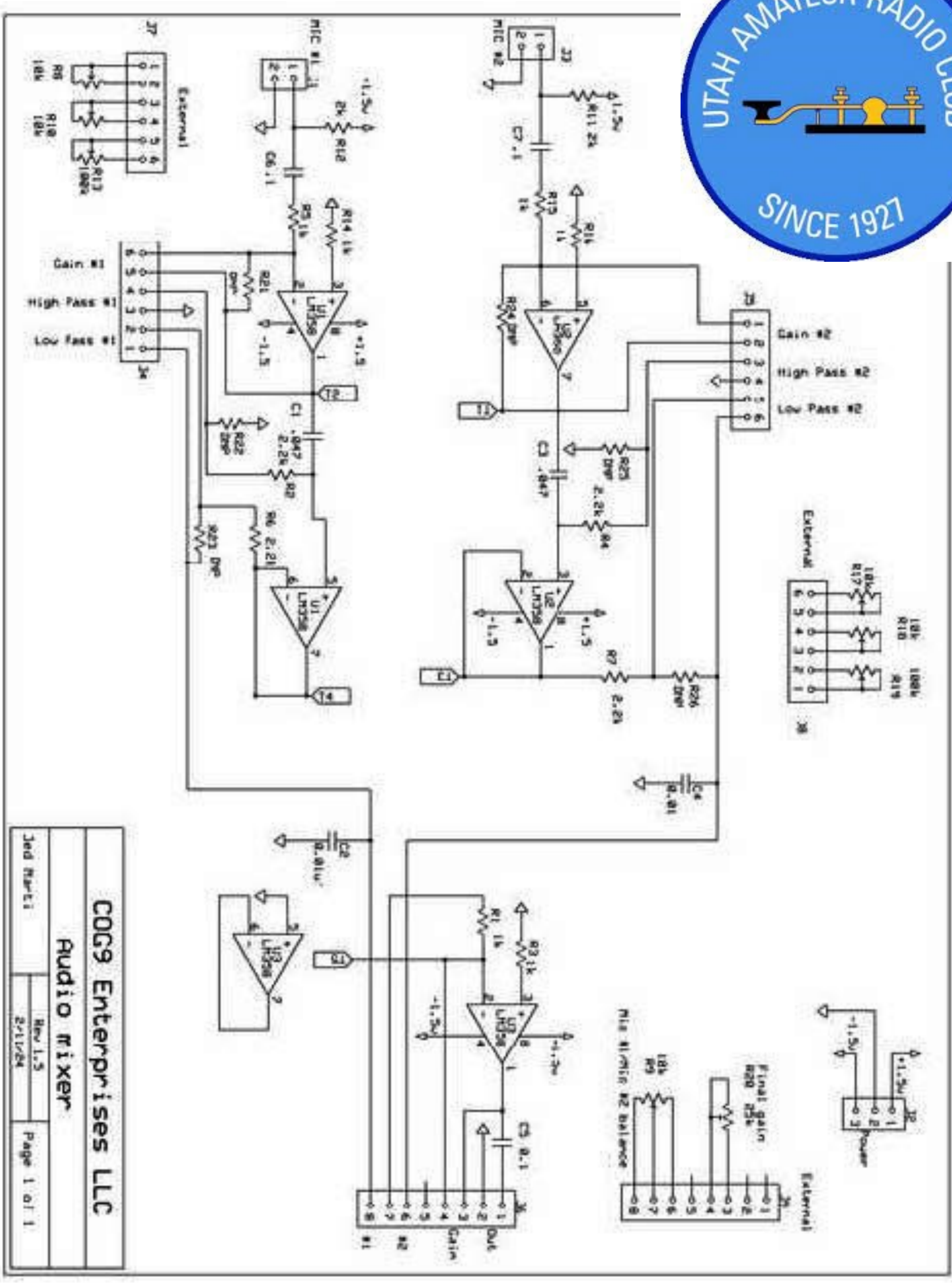

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The mixer has input sections for multiple electret microphones. Each section has an amplification stage and a filter stage. These are then passed to a final amplifier with a balance potentiometer to select either microphone or both. All connections to potentiometers, microphones and power are made through 0.1″ headers.

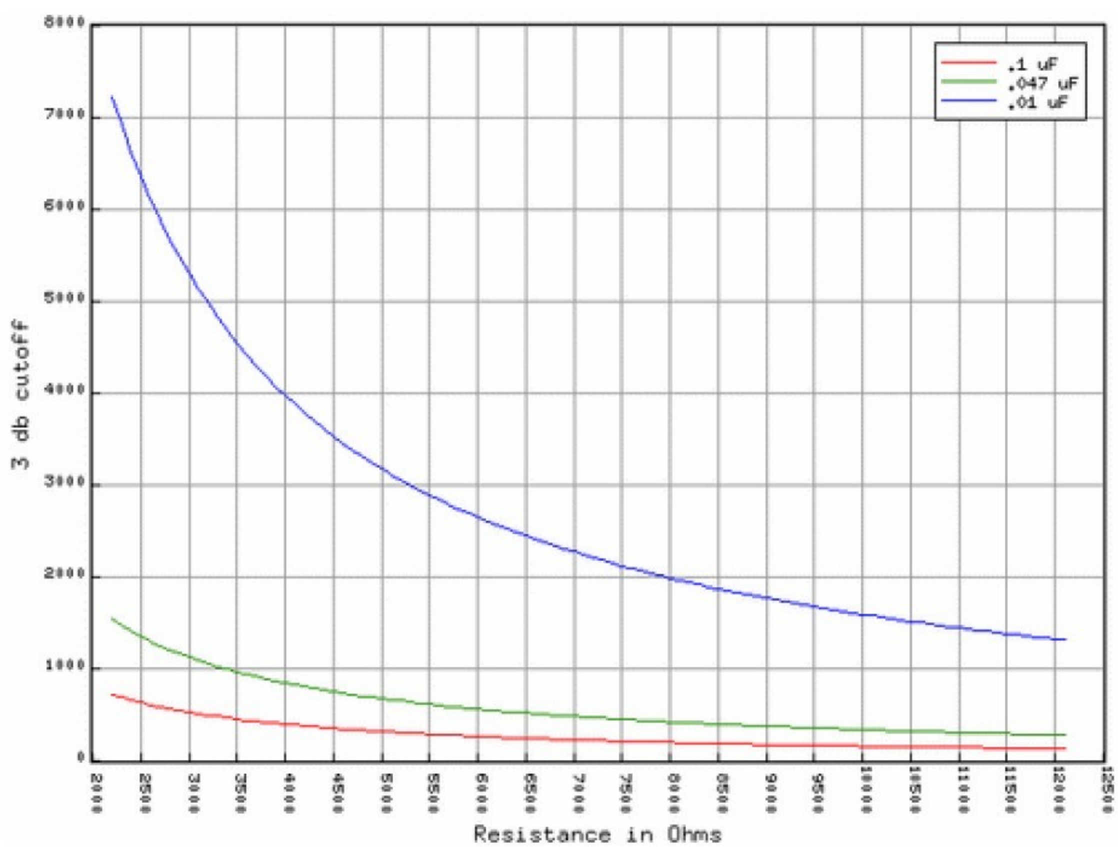
Starting from the microphone (J1), the electret bias resistor R12 provides a DC bias that is removed from the first state amplifier by capacitor C6. This stage has a gain of

$$\frac{R13}{R5} = \frac{R13}{1000}$$

If R13 is set to its full 100-kΩ value, the gain is 100, though this may well saturate on a big signal. If you want unity gain, you don't need a pot, and you can populate R21 with a 1-kΩ resistor instead. The filter is a passive band-pass using only resistors and capacitors. A –3 dB cutoff frequency is calculated by

$$f = \frac{1}{2\pi RC}$$

with C in farads. The high-pass filter combination of C1 and R2 + R10 has the green curve in the following plot. At the smallest value for R10, signals below 1540 Hz disappear and at its highest value, and signals below 280 Hz are attenuated. The low-pass filter combination of C2, R6 + R8 has a 3 dB cutoff at 7.23 kHz at the lowest resistance and 1.3 kHz cutoff at the maximum resistance. You can play with the resistance and capacitance values to adjust how wide of a range you want.



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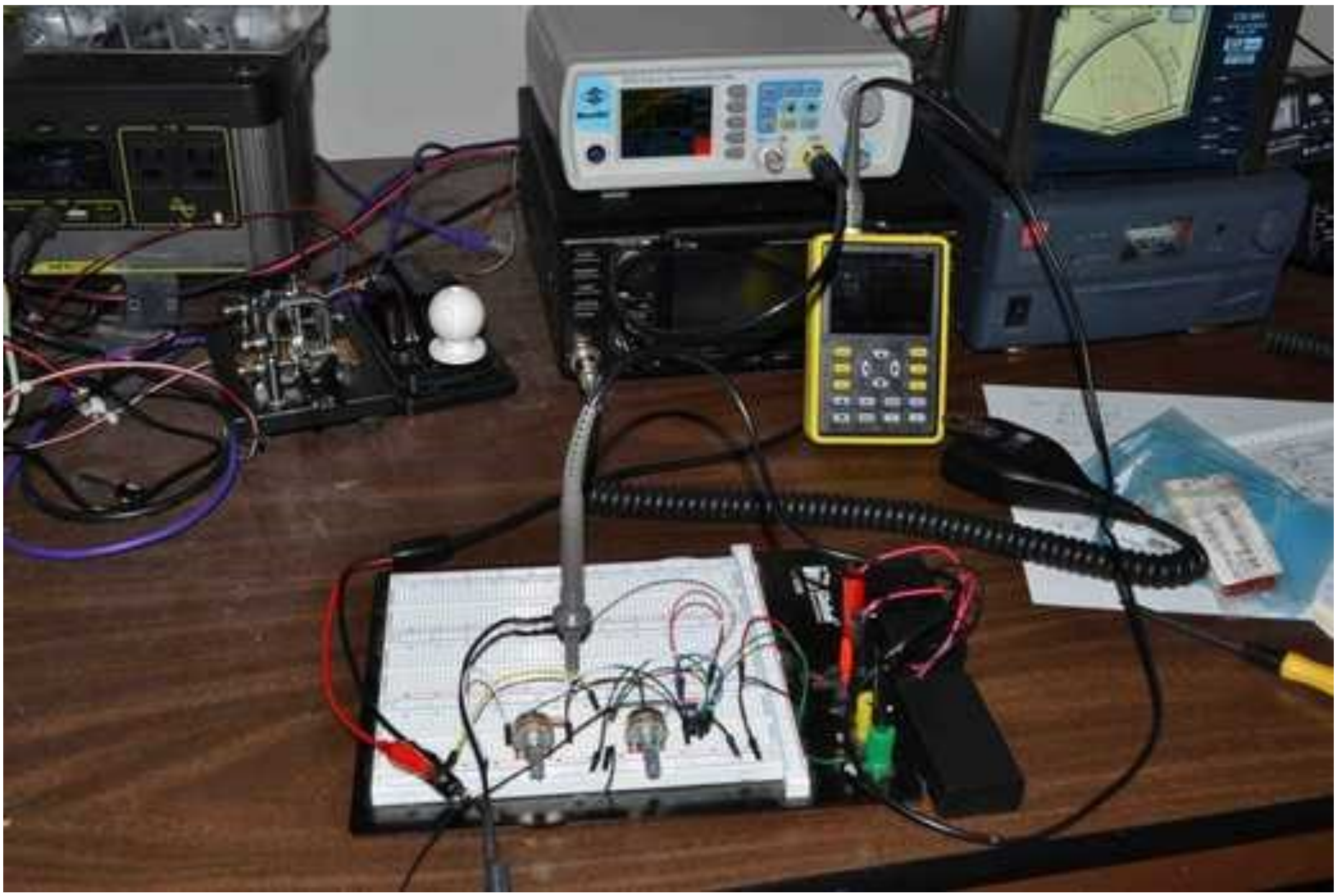
The final amplifier stage selects between the two microphones with R9, a 10-kΩ potentiometer. A final gain stage from R20 can fixed to unity by putting a 1-kΩ resistor between pins 3 and 4 on J6. Test points are included on operational amplifier outputs.

Breadboard and circuit capture

Shown is the first amplifier stage and the RC filter stage. I powered it with two, two-cell 1.5-volt alkaline battery holders giving ±3 volts. I used a sweep signal generator and battery-powered oscilloscope to test the band-pass filter and then a PTT microphone from a defunct Xeigu transceiver to test the first stage amplifier.



Some warnings

Running under Windows 11, the capture program has some difficulties. If you make some components your favorites and close the schematic you're working on, when you start next time, the component names are missing the first letter and don't work. If you're used to a commercial system like Altium, you'll find this somewhat slow. There's little help for checking circuit consistency, though it will check for unconnected pins.

Next month

Board layout and ordering parts.

Jed Marti KI7NNP