Willow Revisited

A Design Celebrating the Enthusiasm and the Creativity of the Builder

In our December 2011 issue of *audioXpress*, we introduced readers to Willow, a "proof-of-concept" project. After four years of positive DIYer feedback, the Willow has been revised and updated.

By
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(United States)

It's funny how things go, Willow was a project that I never really expected to take off. What I had hoped for back then was that the DIY community would pick up on the design and build it into something that would fit specific requirements and tastes. From the correspondence I've received, many of you have done just that and much more than I ever expected. I can't relay how happy that makes me!

I was working on a different design when I got an email from a DIYer filled with enthusiasm and lots of questions about Willow so I decided to change tracks and revisit and update the design, especially now that the HA-5002 buffer is obsolete.

I wanted to keep the main amplifier circuit profile, but I also wanted to improve the power supply and the input to the buffer circuit. I especially wanted to make the amplifier as quiet as possible and have it be flexible so that those who want to avoid microcontrollers could still experiment with the design. After all, this is an amplifier for the DIY community and I enjoy seeing what can be done with my designs (see **Photo 1**).

The Buffer

The first issue I addressed in the revised design was the buffer. For this version, I chose the LM49600, which didn't have the open output problems of the HA-5002 that some builders experienced.

To keep the noise down, I redesigned the input bias circuit. First I used all low-noise regulators in the buffer power rails. Second, I used low-noise surface-mounted capacitors and resistors here, and throughout the design's audio section, to keep the signal path short and noise free. I also updated the buffer input using the negative 15 V rail to adjust the small final bias voltage, thus avoiding the variable carbon trim pots from the original design.

The change worked well. Although there was a slight difference between the two buffer biases, I could balance the offset between them to the point of only a few millivolts bias. You can individually bias each buffer by experimenting with the bias resistors and omit the negative 15 V variable resistor, but the benefit of the variable rail is that it's an easy fix if you check the bias voltages after a period of break in and need to tweak things.

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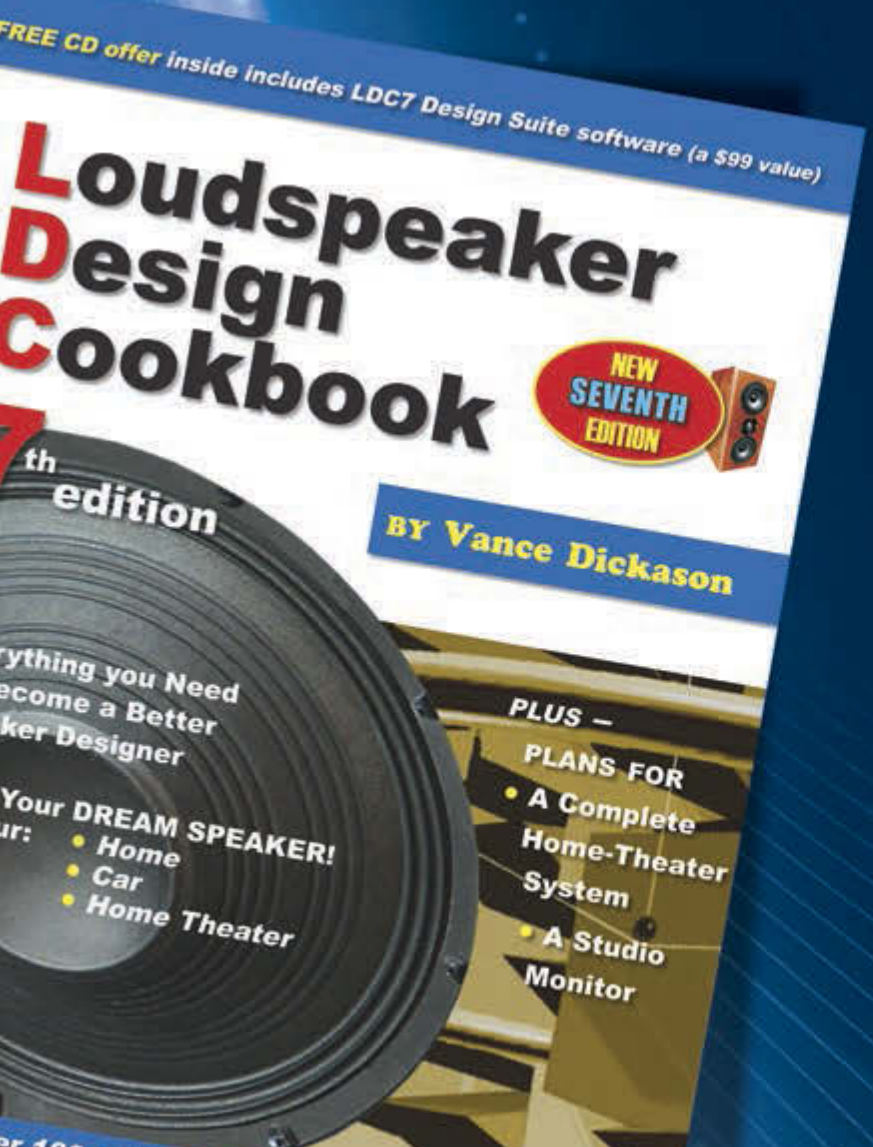

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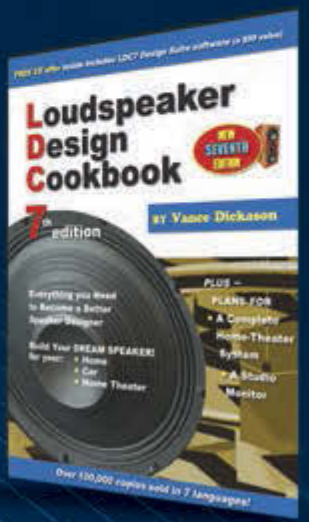

Photo 1: The revised Willow offers a unique cube design.

I liked the sound of the original JFETs so much that I kept that portion of the circuit true to the original design. What I tried to do was give you a basic layout that they could work from, but if you build this design as it stands, I think you'll find it is quite good.

The Power Supply

The power supply for the Willow's revised design is completely new (see **Figure 1**). I used all low noise regulators anywhere they were involved in the signal path. The other thing I did was take special care in balancing the input transformer. In past designs, I have simply showed different AC inputs leaving the choice up to the builder. The problem with that approach is that noise, especially hum, is tough to track down and keep out of circuits.

If you hear a hum that varies between left and right channels when you shut off your amplifier with your headphones on, then you very possibly have imbalances between the rails and the DC outputs.

Balancing the power supply, as I did here, eliminates those problems and keeps hum to a minimum. I laid out the circuit boards using a single point connecting the power supply and the auxiliary circuits (input relays, etc.) to the signal portion of the preamp itself.

The signal portion of the main board shown in **Photo 2** is basically contained in a small area of about 2" × 3" (50 mm to 75 mm). Very few

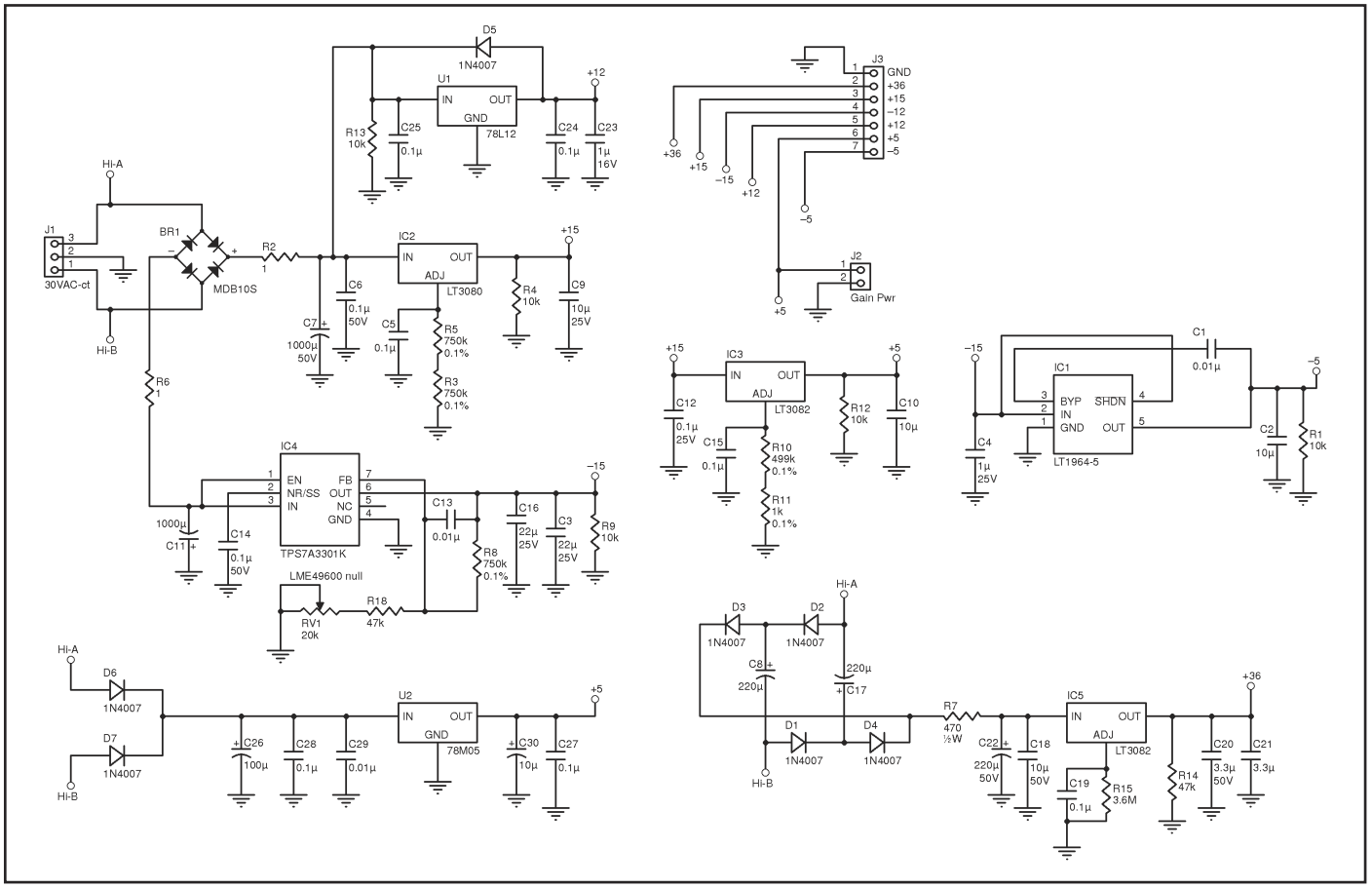

Figure 1: The revised Willow has a completely new power supply.

amplifiers have such short paths. I carefully chose each component for its audio excellence.

Low noise and compactness make a final design that rivals many high-end commercial units in a package the DIYer can build. **Photo 3** shows the 250 kHz square wave output. (The upper trace is the amplifier. The lower trace is the source.)

The Silent Microcontroller

I took special care to shut off the gain microcontroller. It goes to sleep after the level is set and displayed. The AD5282 digital 50 kΩ pot has only the I²C leads (SCL, SDA) on the amplifier board. The microcontroller and the three digit LED display are on their own board mounted to the front panel (see **Figure 2**). The display comes on for a few seconds to show which one of the possible 256 levels has been selected (see **Photo 4**). Then, it shuts off so it emits the lowest noise possible.

The AD5282 is on the amp board, in close proximity to the capacitors and the JFETS in keeping with short signal paths. All the control electronics are on the front panel where they don't lengthen the signal path. All this careful attention to circuit layout, along with component choices, pays off in a dead-quiet amplifier and minimum signal path lengths. Even the headphones have a relay that shuts off the leads to them by a front panel switch when not in use.

Looking at the PCB top trace, the red copper pour is the signal ground and the bottom blue is power supply ground (**see Figure 3**). A jumper from J3 to J4 on the amplifier board connects the two at this single location only. The red top copper show just how small the actual amplifier is with only the leads from the inputs outside the pour itself. The inputs have their own copper pour (bottom blue on the top edge of the board). The power board bottom copper (**see Figure 4**) shows how I ran the low noise ground plane.

Figure 5 shows the revised schematic for the updated Willow design. Portions of the circuit isolated in red dotted line boxes are not in the circuit. I made a small board for the LED circuit and mounted it to the top of the acrylic case, each LED is associated with an input. I used an SMLW56RGB1W1 tricolor LED for this application emitting a red, blue, and green light. The fourth input is a combination of the three (white light). The diode area in red is for those who want to use the buffers in other designs, tubes for example. It holds the input to the buffers at a safe level, we do not need it in this circuit.

The AD5282 is quite a chip, it contains all low-noise metal film resistors and is so superior to

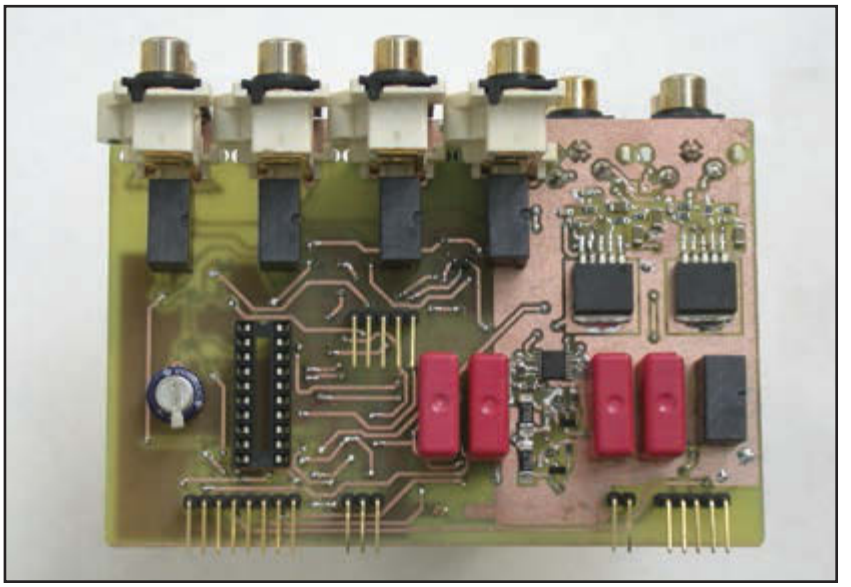

Photo 2: The signal portion of the main board is basically contained in a very small area.

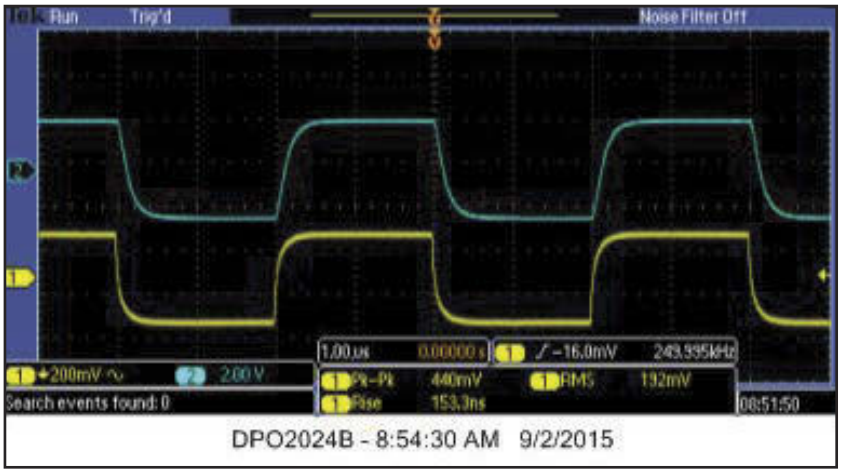

Photo 3: This is the 250 kHz square wave output for our revised Willow.

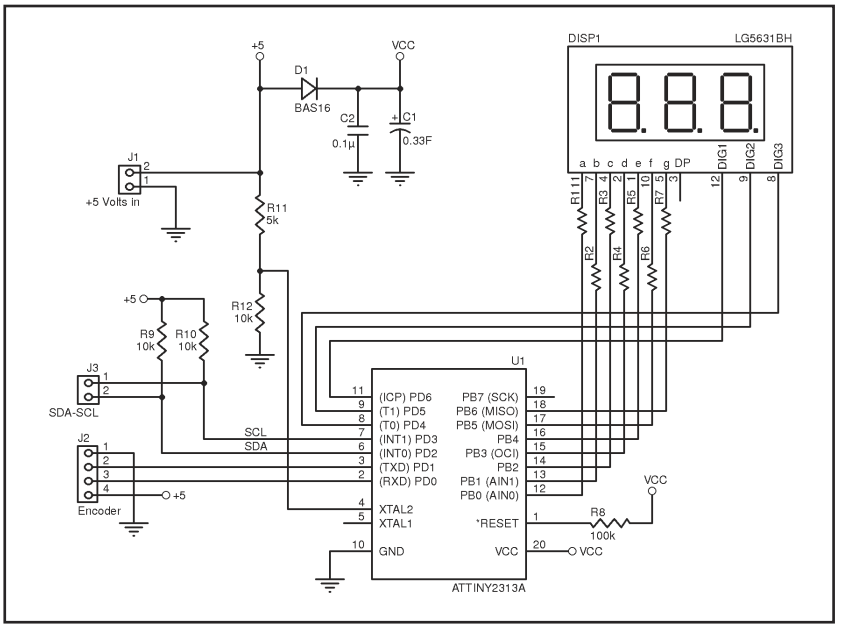

Figure 2: This is the gain display for the Willow's updated design. A new revised schematic is also available in the Supplementary Material.

Photo 4: The display comes on for a few seconds to show which one of the possible 256 levels has been selected.

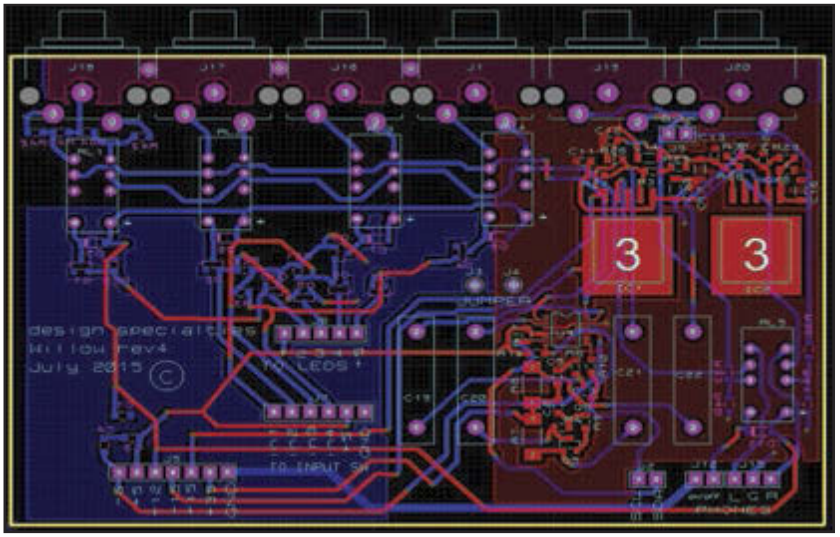

Figure 3: Looking at the PCB top trace, the red copper pour is the signal ground and the bottom blue is power supply ground.

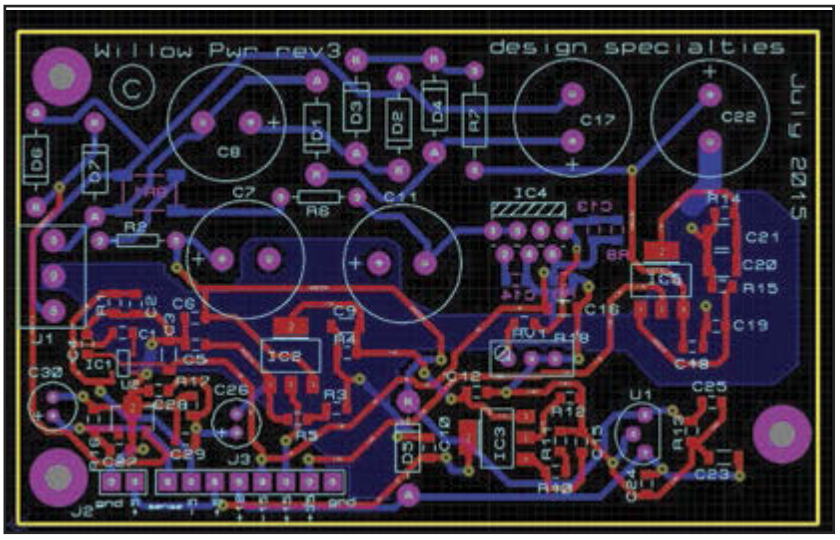

Figure 4: The power board bottom copper shows how I ran the low noise ground plane.

carbon pots that I do think it makes a difference. Using it keeps the signal path tight and completely carbon free.

You certainly can use switched pots with ganged resistors here. I find the better ones overly expensive, but this is your amplifier and I understand how you may prefer different components. The problem is that ganged and carbon pots either sit off the main amplifier board or take up a lot of room on it, which introduces noise along with contacts that degrade over time.

Chips such as the PGA2311 are built around op-amps. I avoid those as they influence my design and ability to contour circuits to my specific liking. Also the PGA2311 is not in the same league as the AD5282 series of chips. The AD pots are that much better.

Project Files

To download additional material and files, visit http://audioxpress.com/page/audioXpress-Supplementary-Material.html.

Resources

Design Specialties, www.dsgnspec.com.

R. Nance Dee, "The Willow Preamp: A High Slew Rate JFET Amplifier," *audioXpress*, December 2011. Available online http://audioxpress.com/article/The-Willow-Pre-amp-A-high-slew-rate-JFET-amplifier.html.

Sources

AD5282 Potentiometer
Analog Devices, Inc. | www.analog.com

SMLW56RGB1W1 Tricolor LEDs
ROHM Semiconductor | www.rohm.com

LM49600 Audio buffer
Texas Instruments, Inc. | www.ti.com

About the Author

Robert Nance Dee is a retired electronics engineer. He received his BS from the State University of NY, where he was nominated for the Chancellor's Award for Student Excellence. He has worked on large frame military computers and has several medical instrument patents. He enjoys electronics, mechanics, clock and watch making and precision machining. He and his wife Nancy live in the Western Catskill Mountains of NY where he is presently restoring a massive E. Howard Tower Clock in the Delhi, NY village square.

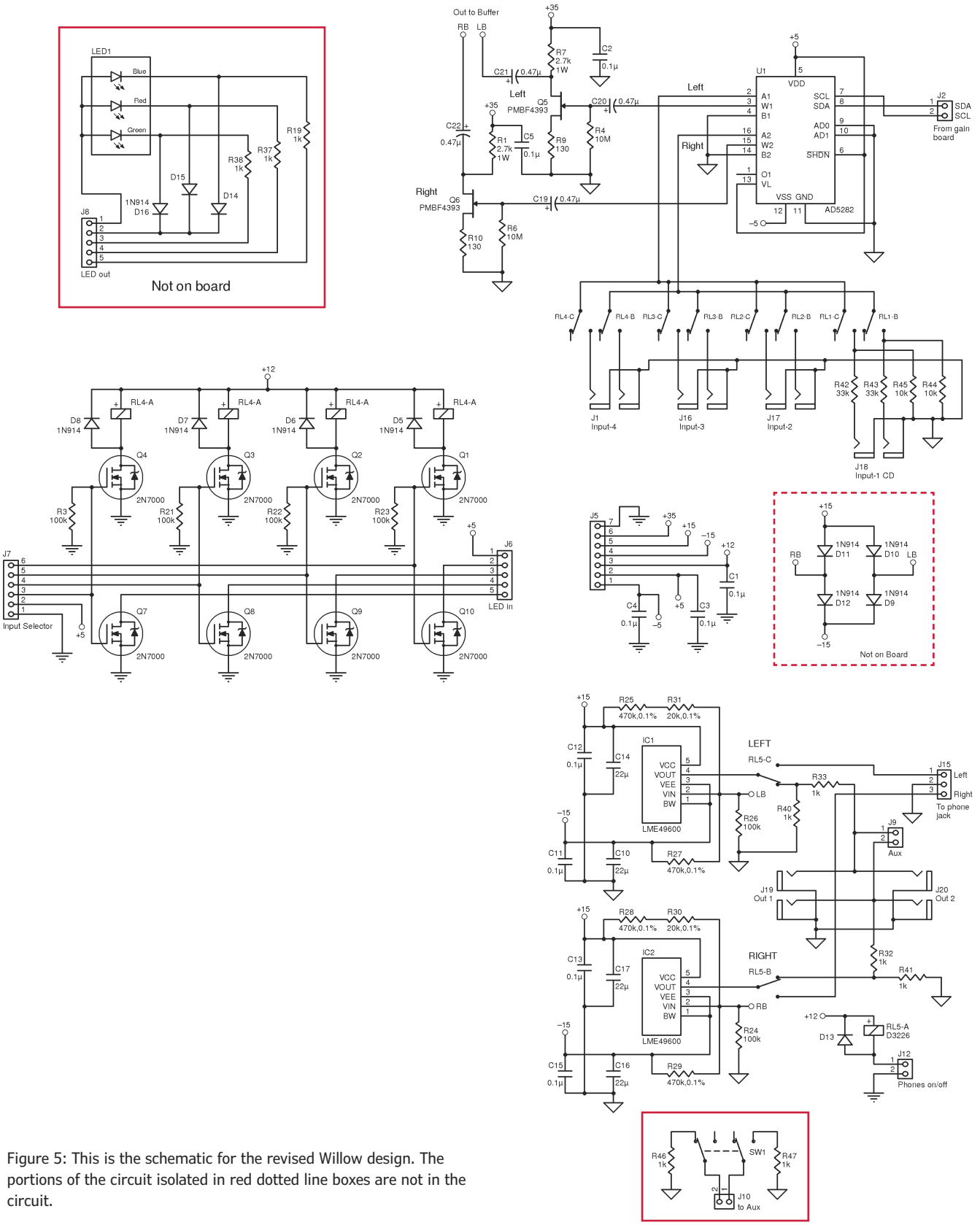

Figure 5: This is the schematic for the revised Willow design. The portions of the circuit isolated in red dotted line boxes are not in the circuit.

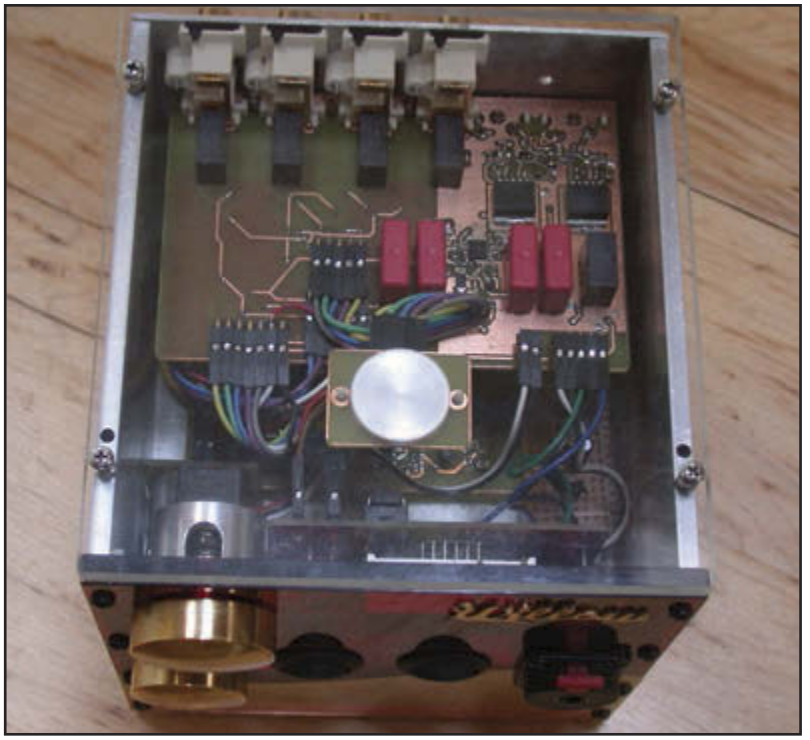

Photo 5: Space is efficiently utilized in this tight cube design.

The Case

I also built a new case for this preamplifier. The most efficient utilization of space is a cube (see **Photo 4** and **Photo 5**). This one has added benefits. The power transformer is located in the bottom of the case. It is separated from the power board (next tier up) by a metal shield above it and the metal surrounding it.

The front panel incorporates a metal lower plate of brass and copper and an acrylic upper plate in red to enhance the display's three digits and still surround the transformer with a metal shield. The main board occupies the highest location in the case, completely isolating it from the transformer. There is a ground from the main board at the outputs to the case itself. The three-legged mains line also has its ground leg going to the case. The power supply board has no grounds to the case and a single-point ground to the main board, again, at pins "J3" and "J4" of the main board.

The specs for this amplifier should include a gain of 20.7 dB with the distortion and noise at less than 0.15%. This means the amplifier should be noise free. Mine is dead quiet with the inputs shorted—no hissing or low frequency hums. In fact, I can't tell whether the amplifier is on or off using headphones.

The bills of material (BOMs) are included in the Supplementary Material on the *audioXpress* website, which will enable you to build Willow using the same components used in this design. But, I encourage you to experiment on your own.

Redesign Final Remarks

Any design has trade-offs but what is gained here I find worth it. There's no reason you can't incorporate the updates with the original design if you so desire, nothing is etched in stone.

I won't go into verbose nonsense on the sound, I'll let the builders and listeners decide for themselves if these changes make a better sounding amplifier. I will say that if you like tube amps give this a try. It has a smoothness but with great detail. Do the changes make a better overall amplifier? Yes, I believe very much so. I could give you a lot of specs but what does that really mean and how does it equate to sound, musicality, or the sheer joy of building something that rivals many amplifiers regardless of price?

Author's Note: I have updated the gain display board and added a new bill of materials (BOM). They can be found in the Supplementary Material section of the audioXpress *website and on my website.*