Improving the Stax SRM-T1 Electrostatic Headphone Amplifier

Explore ways to improve the drive capability and the sound quality of the Stax SRM-T1, but be aware that the modifications involve potentially lethal high voltages so this is not the best project for a beginner.

Photo 1: The modified Stax SRM-T1 has increased drive capability and sound quality.

By
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Recently, I purchased a used Stax SRM-T1 electrostatic headphone amplifier "as-is." Now, I already had an amplifier—the SRX Plus described in an article I wrote for *audioXpress* in 2015. However, it never hurts to have a backup, and it came at an irresistibly low price, so I took a chance.

The T1 was first released in 1987, updated to the T1S with balanced XLR inputs in 1993, and to the T1W with extra switching facilities in 1994. It was reintroduced as the SRM-006t in 1999. All the T1 variants and the earlier SRM-006s have output sockets for both the standard 6-pin (230 V) and the Pro 5-pin (580 V) bias headphones, but the current SRM-006tII only has pro bias sockets.

In a visit to the Stax factory in 2012, it was reported that the T1 was used as a base amplifier for designing headphones until the late 2000s. However, that has recently changed. Headphone amplifier guru Kevin Gilmore commented that it "is actually a really good unit, but it uses 6FQ7s, which really cannot withstand the 600 V. So as it gets louder and louder, the sound becomes more restricted, and…the amount of high-frequency energy slowly disappears." The consensus is that it is somewhat underpowered for the more difficult to drive Stax headphones (e.g., my SR-007), sounding somewhat dark and lacking in detail, with flabby bass. The modifications I made on the Stax SRM-T1 (see **Photo 1**) are outlined in this article and will significantly increase its drive capability and sound quality. However, it involves potentially lethal high voltages and DIYers should proceed with caution.

Basic Design

The T1 is a hybrid amplifier with a DC-coupled topology from input to output, a differential FET input stage, balanced transistor intermediate amplification stages, a tube output stage, and overall feedback from the output stage back to the input (see **Figure 1**). The high voltage supply is unregulated, while the input stage has a Zener shunt regulated supply. All the modern Stax hybrid amplifiers share this topology, differing only in the output stage.

The output stage is a differential amplifier with the outputs taken off the tube plates. The T1 and the SRM-006 uses one dual triode 6CG7/6FQ7 tube per channel with 66 kΩ plate resistors and a B+ of 320 V. The limited edition SRM600 released in 2009 used one ECC99 tube per channel with 60 kΩ plate

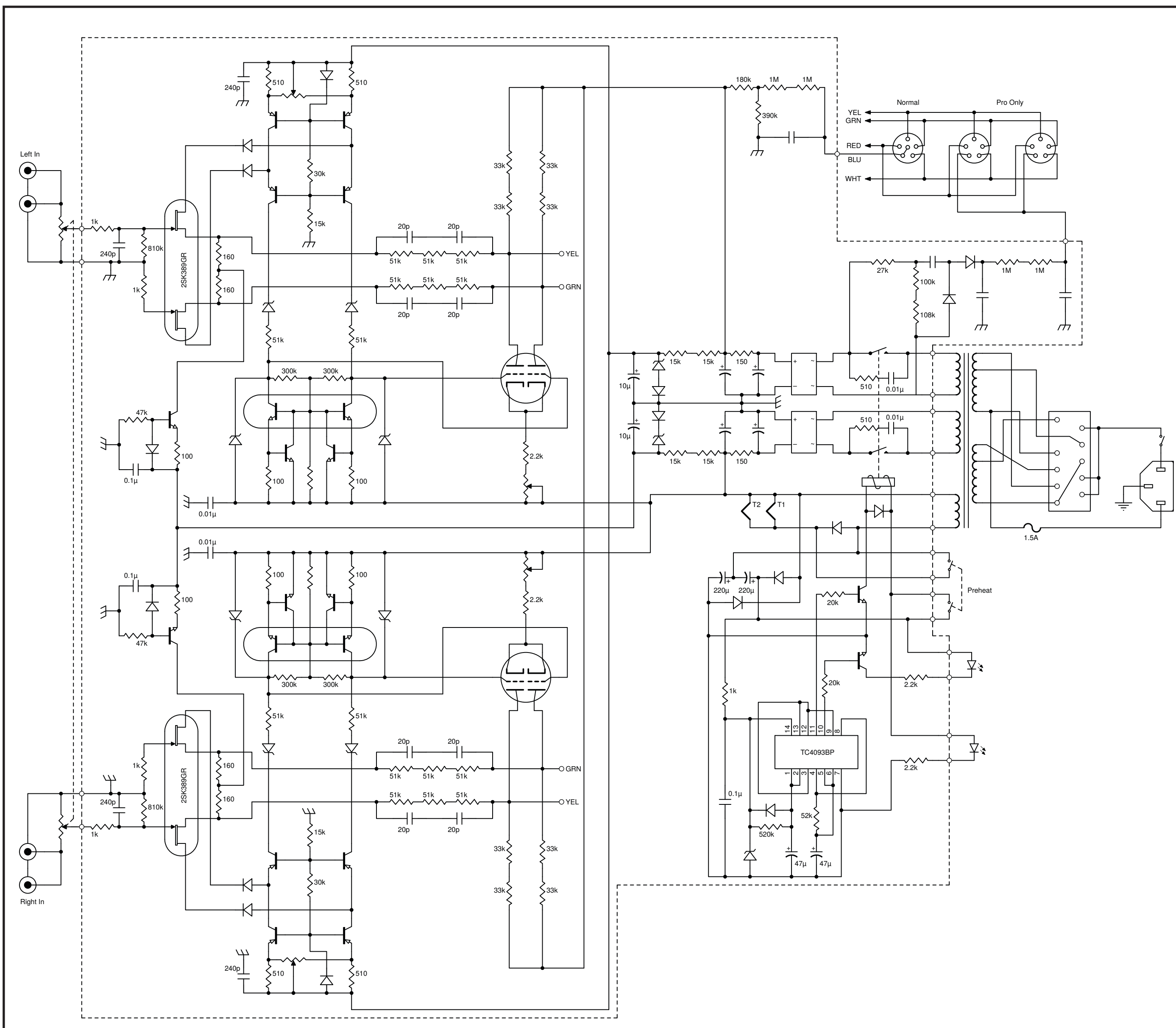

Figure 1: This is the schematic of the Stax T1 electrostatic headphone amplifier. The modifications are limited to the output stage, which is just to the left of middle.

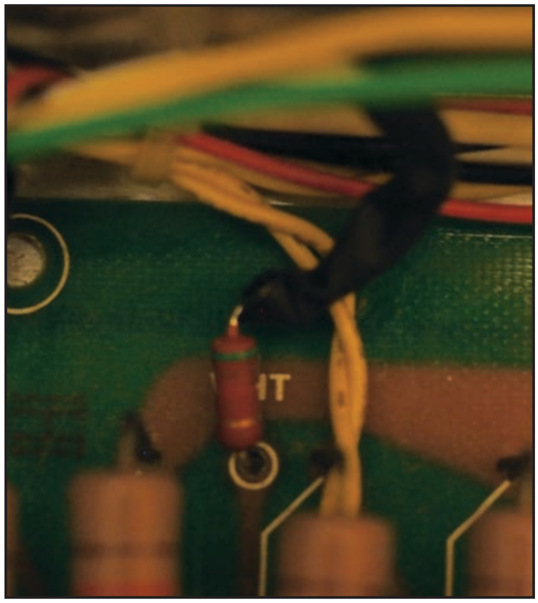

Photo 2: This is one of four output safety resistors installed on the circuit board.

resistors at a B+ of 350 V. The SRM-007tII, released concurrently with the SR-007 headphones, uses two 6CG7/6FQ7 output tubes per channel, with paralleled tube sections, driving 47 kΩ plate resistors at a B+ of 350 V.

Although the 6FQ7 tubes are run at close to maximum plate voltage, they are only at 55% of maximum power dissipation in the T1, which should result in long tube life. The output stage has two trimmers to adjust the offset and balance between the plate sections to get the output voltages to 0 V with respect to ground.

Refurbishment

Electrolytic capacitors deteriorate with time. Because the T1 is 24 to 30 years old, I recommend replacing all the electrolytic power supply capacitors before powering it up the first time. This is basic maintenance. There are four large high voltage power supply capacitors and six lower voltage caps. Since the 1990s, electrolytic capacitors have become smaller for the same capacitance, so the power supply can be improved by replacing the original capacitors with higher capacitance values, as long as the original voltage rating is maintained. This by itself may improve the sound simply by restoring the amplifier to factory specifications or better. The Parts List shows the original and the replacement values in my amplifier.

To avoid confusion, I removed and replaced the capacitors one at a time—be sure to install them in the same polarity. Then, power up and make sure it is working. It is always a good idea to confirm a unit is functioning before modifying it. After replacing the capacitors, my unit worked perfectly.

Modifications

My modifications are limited to the output stage, to improve safety and drive capability while decreasing distortion.

First, add 5.1 kΩ/500 V resistors between each tube plate and each output socket terminal. This can be done at the circuit board by desoldering the green, yellow, white, and red output wires from the circuit board to the sockets and interposing the resistor (see **Photo 2**). These safety resistors are present on all current Stax amplifiers to protect the headphones and the listener in the event of a catastrophic output stage failure.

Generally, amplifier output stages produce the most distortion because that is where the voltage and current variations are the greatest. Stax specifies the maximum output of the T1 as 300 VRMS at 1 kHz. With the SR-007 producing 100 dB with 100 VRMS at 1 kHz, the T1 should be able to drive them to 110 dB, which would be plenty loud. Although the sonic flaws of the T1 have been blamed on the relatively puny 6FQ7 output tubes, the most significant problem is the use of plate resistors in the output stage.

With plate resistors, any signal voltage requires a corresponding signal current to be consumed by the resistor, according to Ohm's law. Electrostatic headphones are inherently a high impedance load, but the plate resistors must be significantly lower in impedance in order to provide adequate signal current to drive the headphones.

As a result, the vast majority of the signal current is always wasted driving the plate resistors, while another fraction is consumed by the feedback resistors, with only a small percentage of the total current produced by the output tubes actually driving the headphones. Thus, at its specified maximum

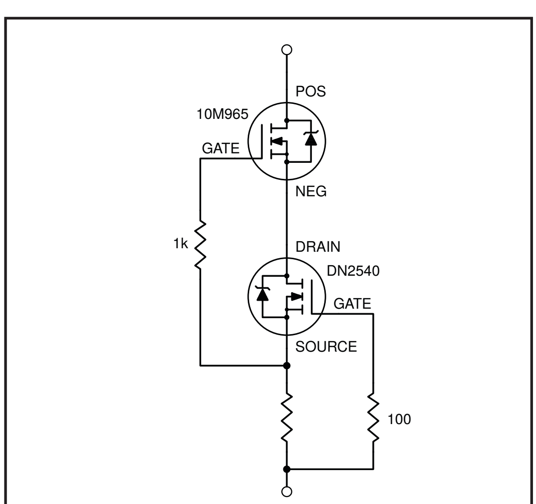

Figure 2: Here is the schematic of the cascode MOSFET constant current source (CCS). The unmarked resistor has to be chosen individually for each current source, or it can be replaced by a 261 Ω resistor plus a 100 Ω trimmer pot.

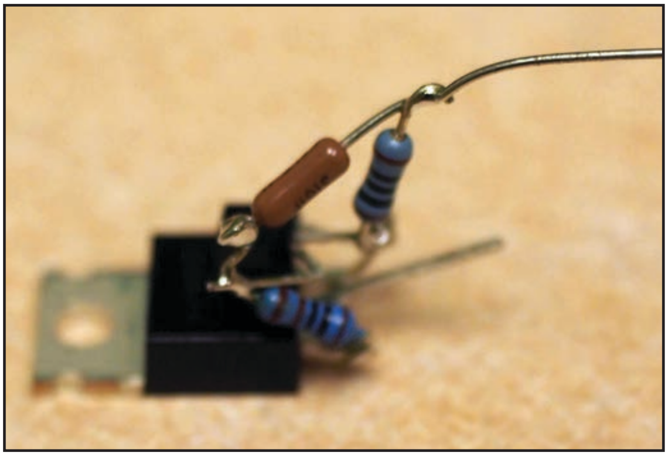

Photo 3: The constant current source (CCS) is hard wired—the blue resistors are the gate stop resistors and the brown resistor sets the current.

output of 300 VRMS, 6.4 mA peak current is required to drive the plate resistors, plus another 2.8 mA for the feedback resistors, a total of 9.3 mA. With a standing current of 9.7 mA, 0.5 to 3 mA at most remains for the headphones. If you're wondering how 9.7 mA minus 9.2 mA equals 3 mA, remember that electrostatic headphones somewhat resemble a capacitor so the current drive to the headphones can be up to 90° out of phase. No output device sounds its best when it is strained to the limit. If we eliminate the current burned up in the plate resistors, the drive capability, distortion, and sound quality should be improved.

The solution is to replace the plate resistors with a good constant current load. This decouples the signal current and

Parts List

Power supply (original values in parentheses)

4 – 330 (100) µf/400 V electrolytic capacitors
2 – 33 (10) µf/50 V electrolytic capacitors
2 – 47 µf/35 V electrolytic capacitors
2 – 270 (220) µf/10 V electrolytic capacitors

Output section (both channels)

Resistors (0.25 W unless otherwise specified)
4 – 100 Ω gate stop resistor
4 – 300 Ω approximate (current setting resistor, see text, adjust value to get 4.9 mA) or 261 Ω resistor plus 100 Ω trimmer pot
4 – 1 kΩ gate stop resistor
4 – 5.1kΩ/2 W/500 V resistor (safety resistors for the output stage)

Active devices

4 – 10M90s TO220 FET current source
4 – DN4250 N-channel MOSFET

Other

1- finned heatsink approx. 4″ × 2.5″ × 1″
4 – high voltage ceramic TO220 insulator
Heatsink compound
4 - 4-40 ½″ screws for mounting the 10M90S FET
4 - #4 Isolating washer
4 – 4-40 1″ standoffs
4 – 4-40 3/8″ screws for mounting heatsink standoff to side wall

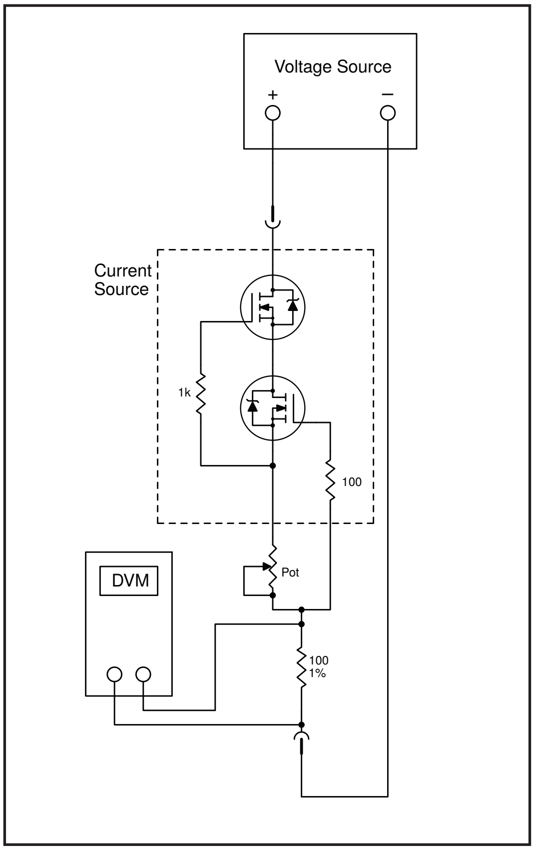

Figure 3: The testing jig is used to determine the source resistor for the DN2540 to set the current.

voltage, enabling the output tube to swing its entire voltage amplitude without consuming any appreciable signal current, thus relieving the strain on the output tubes. Constant current output loads are used in a number of electrostatic amplifier designs including Stax's contemporary solid-state designs.

High voltage N-channel MOSFETs make excellent constant current loads. You can read about MOSFET CCSs and loads in Walt Jung's *audioXpress* articles (see Resources). Cascoded constant current loads using MOSFETs provide excellent performance with only two MOSFETs and three resistors.

The measured DC impedance of the constant current loads in this modification is more than 150 MΩ, so each output tube will swing the full voltage output of the amplifier while consuming less than 3 µA—less than 0.1% of the standing current. The constant current load sets the operating conditions of the output stage, but is practically invisible to the output tube—all it sees is the headphones and feedback resistors. At the stock T1's same 300 VRMS maximum specified output, 2.8 mA peak current is consumed by the feedback resistors, leaving 6.8 mA to 9.2 mA of standing current available to drive the headphones, much better than the stock output stage. In other words, using constant current loads has converted an amplifier for driving plate resistors into an amplifier for driving headphones.

With a B+ voltage of 320 V and a plate resistance of 66 kΩ, the standing current for each tube section is 4.9 mA. This will be the nominal value for our current load. Each current load dissipates over 1.5 W, so a heatsink is mandatory.

The schematic of the current load is shown in **Figure 2** and is identical to the current loads used in the SRX Plus. The DN2540 MOSFET alone makes a decent current load with an impedance of a few hundred kilohms. It sits between the gate and the source of the 10M90S MOSFET, which swings the voltage. The gate-to-source voltage of the 10M90S stays relatively constant with large voltage swings, largely isolating the DN2540 from overall voltage variations, resulting in a much higher impedance for the cascode pair. Gate stop resistors on both MOSFETs prevent ultrasonic oscillations, and the source resistor of the DN2540 sets the current. It can be built as a simple hard-wired module (see **Photo 3**).

DN2540s can vary, so the source resistor has to be individually chosen for each current load. I used a simple jig with a voltage source, a variable pot as the current setting resistance, a 100 Ω sense resistor and a digital multimeter (DMM) to measure the current (see **Figure 3**). I adjusted the pot to get 0.49 V across the sense resistor, then measured the pot resistance, soldered in the closest 1% resistor,

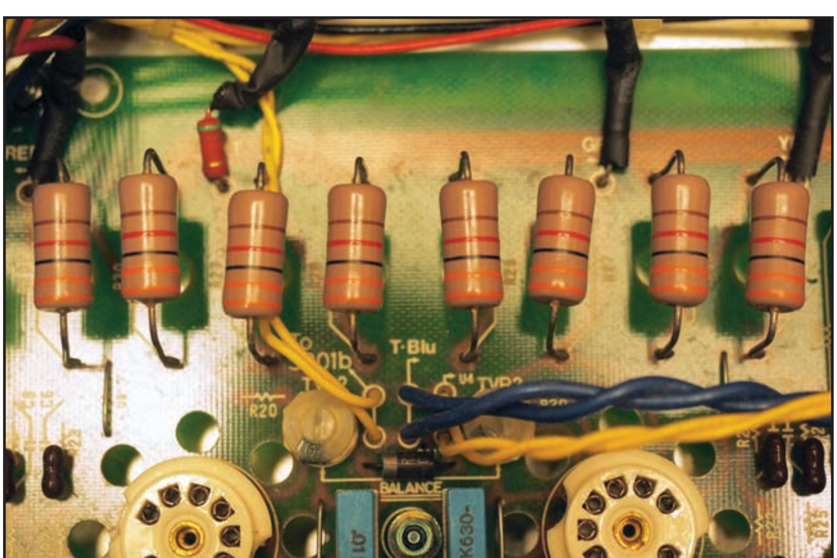

Photo 4: These eight plate resistors will be replaced by four current sources.

and confirmed the current measurement again. For my four current loads, the current set resistor varied between 270 Ω and 340 Ω.

If you don't want to mess with hardwiring an individual resistor for each current load, you can build all four current loads on a piece of perf board, using a 261 Ω resistor plus 100 Ω trimmer pot on the DN2540 source terminal. Use the jig to adjust the pot to set the current to the proper value, and attach the perf board and 10M90S FETs to the heatsink.

Due to the high impedance, the value measured at 15 to 20 V will be the same as at 320 V in circuit. The current loads are mounted on a heatsink with a high voltage ceramic TO220 insulator. There are two wires coming from each current load. The wire coming from the 10M90S will go to B+, and the wire coming from the DN2540 source resistor will go to the plate of a 6CG7/6FQ7 tube section.

Each current load replaces two 33 kΩ plate resistors. These are the eight large resistors that are sitting in a row, elevated off the circuit board (see **Photo 4**).

Out of the 16 terminals for the plate resistors, identify which eight terminals will be used by looking at the back side of the circuit board. Four of the resistors are connected together—these are the B+ terminals and will be connected to the wires going to the 10M90S positive lead. Four of the resistors will have terminals connecting to the green, yellow, red, or white wires going the output socket. These are the plate terminals and will be connected to

About the Author

James Lin became interested in DIY audio by reading *The Audio Amateur*. He has written modification articles for *The Audio Amateur, Speaker Builder*, *Glass Audio*, and *audioXpress*. He recently retired from the Veterans Administration in Albuquerque, NM.

Resources

W. Jung, "Performance Current Regulators Revisited," *audioXpress*, April 2009.

——, "Sources 101, Audio Current Regulator Tests for High Performance: Part 1 and Part 2," *audioXpress*, April and May, 2007, www.audioxpress.com/article/Sources-101-Audio-Current-Regulator-Tests-for-High-Performance-Full-Article.

J. Lin, "The SRX Plus Hybrid Amplifier: Part 1 and Part 2," *audioXpress*, November and December 2015.

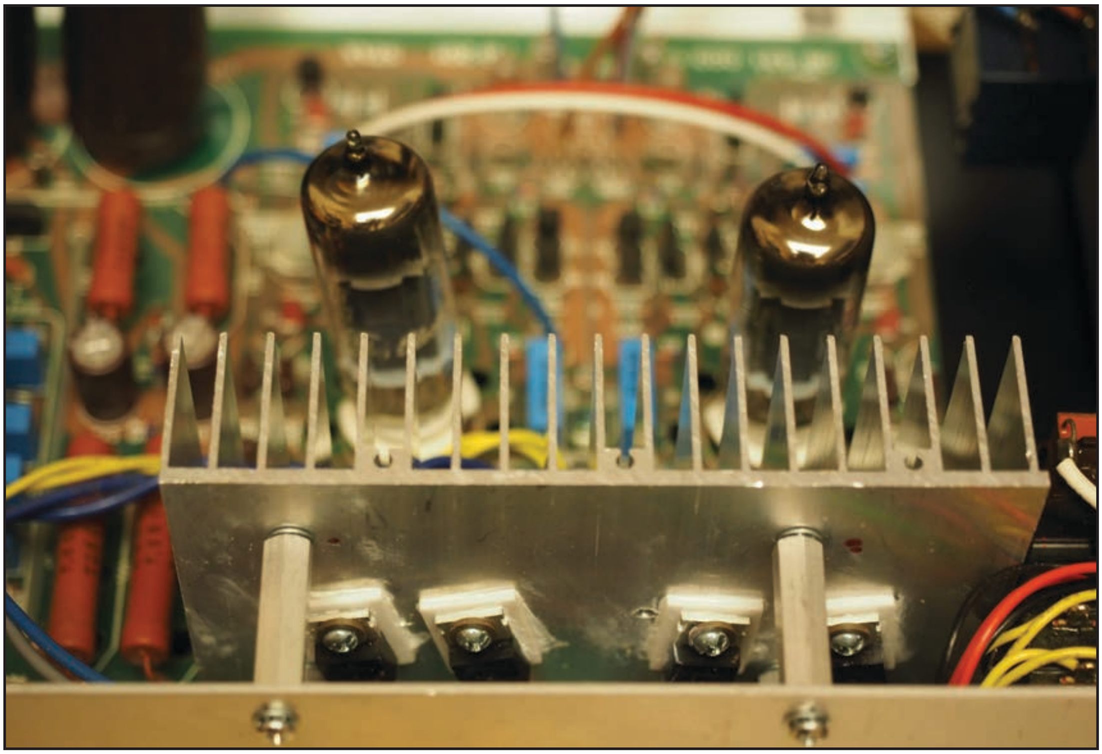

Photo 5: The heatsink with constant current sources in place of the plate resistors.

the source resistor of the DN2540. The other eight terminals connect between pairs of plate resistors and will not be used.

Remove all eight resistors to clear a space to mount the heatsink, insert the wires from each current load into the appropriate terminals, mount the heatsink to the adjacent side wall with standoffs, and then solder the wires in place on the circuit board (see **Photo 5**).

When you plug in the amplifier and turn it on, you will need to adjust the output voltages to zero. This is checked by inserting a DC voltage probe into the appropriate output terminals on the headphone socket in front (see **Photo 6**). There is a ground terminal at the back of the chassis that you can use as a reference point.

There are two adjustment pots for each channel. The right channel is closest to the front panel and the left channel is behind it. TVR1 (offset) adjusts the voltage between the positive and negative outputs of the channel. TVR2 (balance) adjusts both output voltages up or down in tandem to bias the tubes and is located close to the output tubes. Use a plastic handled screwdriver to make any needed adjustments. First adjust TVR1 by putting your probes in the + and – terminals of the same channel and adjust to 0 V, then remove one of the probes and attach it to the ground terminal to adjust the balance control close to zero. Then do the same for the other channel.

The offset adjustment is somewhat finicky, so go slow. The offset is pretty stable after the first few minutes, but the balance will change as the amplifier warms up. I do a preliminary adjustment after 5 to 10 minutes, then put the cover on and allow the amp to warm up to steady state for an hour or so, and readjust. Adjust the output voltages as close to zero as possible, but it doesn't pay to be too compulsive about it, as there will be some variation with warm up, with changes in line voltage, and as the tubes age. Stax specifies offset and balance voltages within ±15 V of each other or zero.

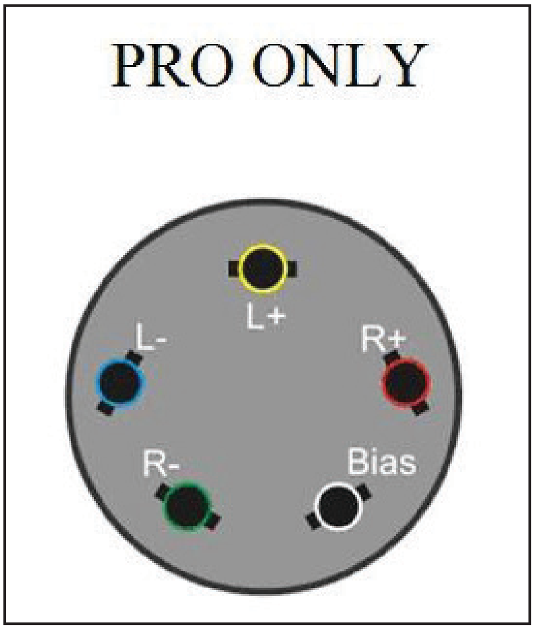

Photo 6: Diagram of the Stax output socket, from the front side

I had problems getting one channel zeroed due to a faulty pot and tube socket. Once they were replaced, the adjustments went smoothly. With the amplifier warmed up, the heatsink temperature was around 55° to 60°C.

Once the output voltages are adjusted, you can close up the unit, attach the source and the headphones, and enjoy!

Other Changes

The safety resistors and current loads are by far the most important improvements for this amplifier. Some modifiers have also replaced the inputs with better quality RCA jacks and upgraded the input wiring and the volume control.

The volume control is a 50 kΩ Alps RK27 with two sections (four sections in later models, which allow balanced inputs) and concentric shafts to adjust the volume independently in each channel. The knobs pull off. The front part of the volume knob is connected to the smaller concentric shaft, and the rear part to the larger shaft. They are friction linked, enabling it to act as a volume control when they are turned together, and as a balance control by holding the rear knob and independently turning the front part. If you decide to replace it, you will lose the balance function and need to replace the volume knob itself, so there are pluses and minuses to that modification.

Conclusion

These modifications can be done to any T1, T1S, or 006T. In the T1W, a heatsink mount will need to be devised. These modifications should be able to be adapted to the SRM-600 and SRM-007T with appropriate size current loads and heatsinks, but I have not actually done this.

So, how does it sound? Compared to a stock unit, the modified T1 retains the character of the original but sounds cleaner, clearer, more neutral, and more powerful with better bass punch and control, particularly as you crank up the volume.

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