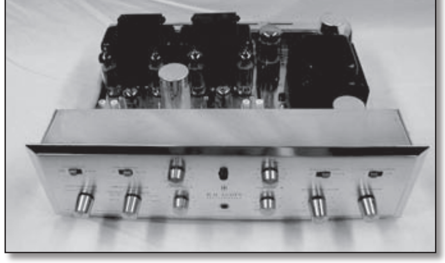


Renovating the Scott 222C Part 2: Modifications

By Charles Hansen

Back

I removed the tubes and stored them in boxes. If you don't have the original boxes, use plain white tube boxes (which you can obtain from Antique Electronic Supply) and write each tube type and its location in the chassis on the box. Wrap the boxes in bubble wrap. Bag and tag any parts and hardware you remove in the course of work and store them with any other components. Do not throw anything away until you again have a fully functional unit.

A number of websites list recommended changes to the Scott 222 series. The most common suggestions are:

- Replace all the ceramic-tube paper American Ceracaps with modern polypropylene film caps.
- Replace the selenium bias supply rectifier with a silicon rectifier (mandatory!)
- Update the output tube grid bias pot circuits to the 222D model.
- Replace the aluminum can capacitors with modern versions made by CE Manufacturing.
- Convert the output stages to ultralinear output transformers.
- Use modern speaker binding posts and phono jacks.
- Clean and polish the aluminum chassis.

If you would like to renovate or restore a Scott amplifier with 7189 output tubes, I suggest starting with the 222D. The 299A and 299B also used 7189 output tubes. None of the Scott products used ultralinear output transformers.

Scott made optional wood and metal cabinet covers available for its hi-fi equipment. In my view the heat captured by the cover could shorten the life of tubes and temperature sensitive components such as the electrolytic caps. If child safety is not an issue, I recommend running the amplifier without a cover.

DECONSTRUCTION

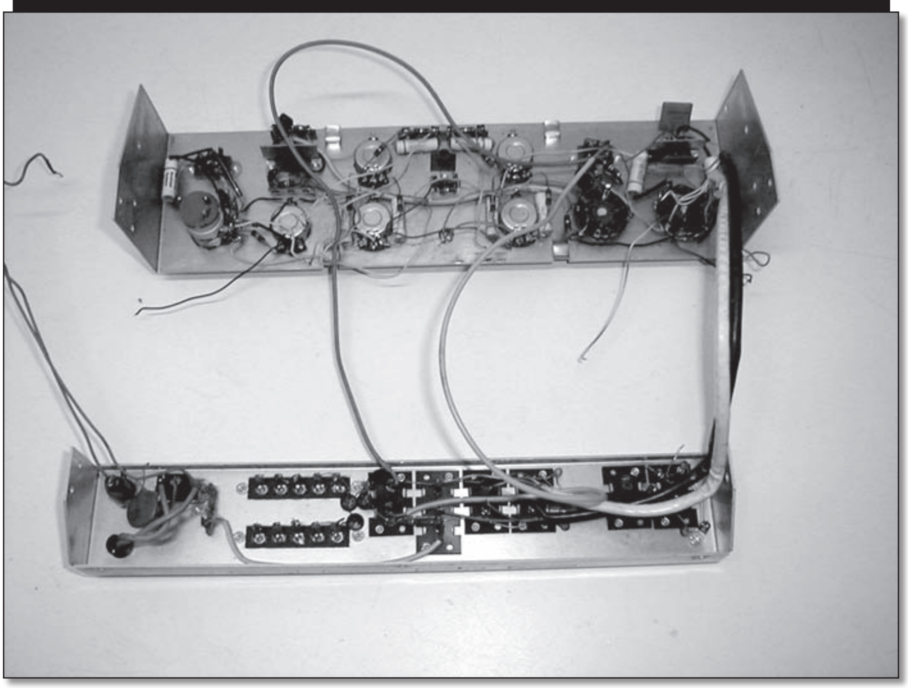
Because I would be replacing probably 95% of the components while making extensive modifications to the rear panel, I made "as received" drawings and took detailed photos of the component and wiring installation before doing anything else. I was able to find on eBay the construction manual for the LK-48, which is the Scott kit version of the 222. This was quite helpful in taking the 222C apart in the appropriate manner. I also took digital photos of every step in the modification to assist in documenting the changes.

I removed the front and rear subchassis sections (**Photo 5**) from the main chassis, and then removed all the chassis-mounted parts that I was going to replace. Make certain you de-solder in a well-ventilated location. The highly reactive solder fluxes used back then, as well as the fine dust accumulated over time, are none too friendly to your lungs. I use a muffin fan equipped with a charcoal filter for an indoor air purifier.

Switches, sockets, can capacitor insulators, speaker terminals, and jacks are all riveted to the sheet metal, so these rivets will need to be drilled out with a 5/32 drill if you need to replace any of the parts. You can use 6-32 screws, nuts, and lock washers to replace the rivets.

I stripped most of the wiring and components from the main chassis, except the tube sockets, terminal strips, and the three transformers. This was an incredibly tedious job made moreso by the propensity of the dedicated ladies of Maynard who wired the 222Cs to wrap every wire and component lead around the various terminal connections far in excess of the 180° necessary for a good mechanical connection. Most were wrapped at least 360°, and in some instances as much as 720°! And the tail ends were tucked tightly against each terminal so it wasn't easy to unwrap. It

PHOTO 5: Front and rear sub-chassis removed.



meant days of careful struggling with soldering and de-soldering irons, diagonal cutters, and needlenose pliers to prevent breaking off or overheating a terminal on the custom terminal strips that Scott used.

In the end, after breaking a few tube socket lugs, I decided to replace all the 9-pin sockets. Time and temperature had made the copper lugs brittle and beyond saving. I removed the three can capacitors by carefully untwisting the can lugs, and left the insulated mounts in place because they were in good condition. The main chassis—after stripping all the parts but before removing the transformers and doing any cleaning—is shown in **Photo 6**.

I removed the pots and rotary switches from the front sub-chassis for cleaning. The slide switch actuators are color-matched to the gold front panel, so I decided to try to save them by cleaning them with Caig Deoxit. The loudness control is a custom item, so my goal was to save it if possible as well.

The back half consists of a 500k pot tapped at 18k5, with an attached push-pull switch. This section is soldered to the rear of the front tapped 500k pot section and interconnected with a custom shaft to operate the whole stereo assembly. The later Scott 299/LK-72 used a separate slide power switch, making the upgrade to a new dual pot very easy. Note that Noble and Alps do not

PHOTO 6: Main chassis after removing parts and wiring.

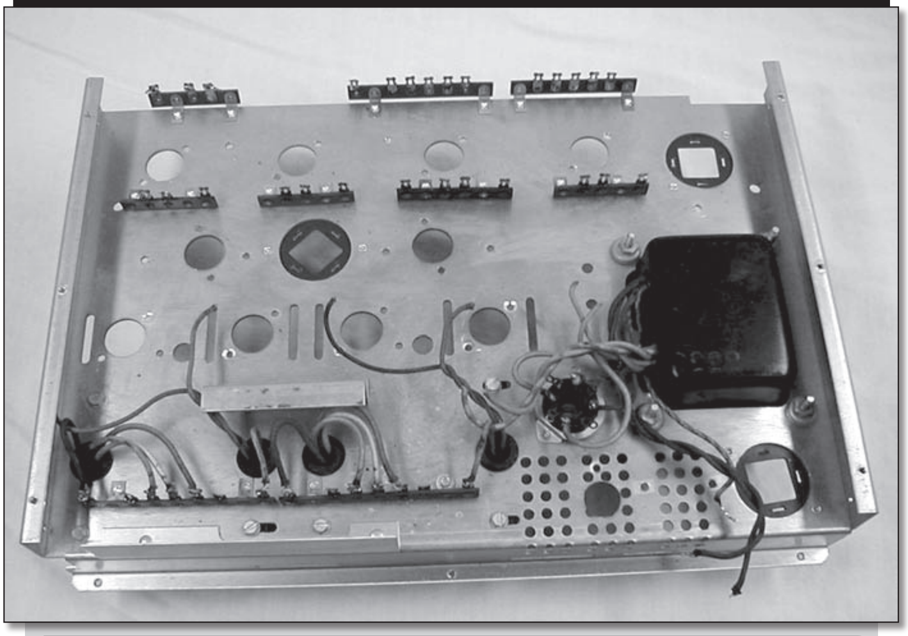
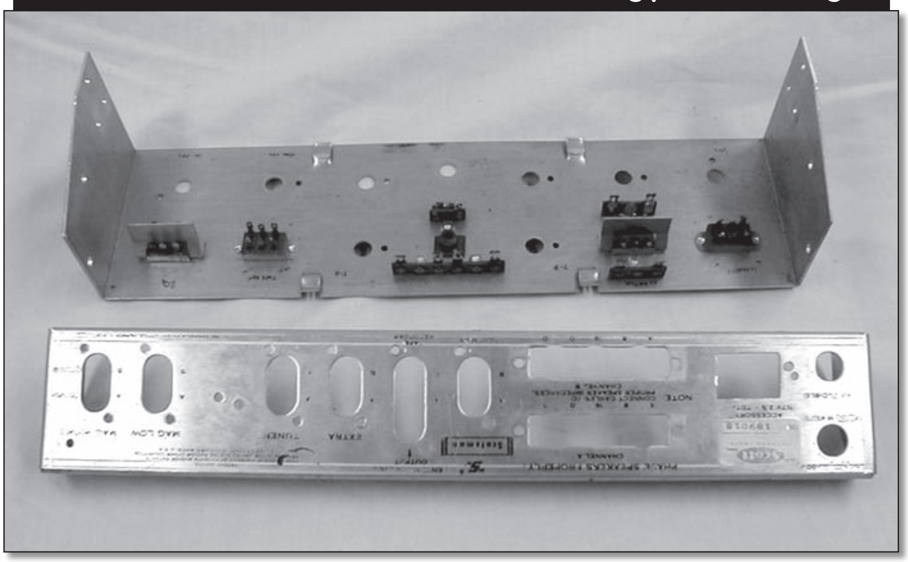


PHOTO 7: Front and rear sub-chassis after removing parts and wiring.



offer their volume control pots with a resistance greater than 250k, so the high end pots may not be an option unless you do a more extensive redesign.

The RIAA/NAB equalization components are contained in a four-wire ceramic-potted module (Scott p/n 1346248). They are shown as C3, C4, R3, R4, and R5 (for channel A) on the 222C schematic. It was not until the 299D/LK-72 that this module was shown on the schematics with its actual pinouts. There it is called the PEC (potted equalization circuit?) 222ER, and the 222 was the first Scott model in which these devices were used.

One of my modules was a red 222ER; the other was a tan 222E. The capacitance and resistance values read at least 14% higher than those shown on the schematic.

I removed everything from the rear sub-chassis in preparation for installing an IEC power receptacle, modern jacks, and binding posts. Because I was only bringing out the 4Ω and 8Ω taps, I had to re-letter the rear panel in that area, as well as where the Mag Low input jack was located. The remaining lettering was readable, but not in great shape, so I needed to decide whether I was going to re-letter the entire panel. **Photo 7** shows the front and rear sub-chassis with parts and wiring removed.

The rear sub-chassis here shows the cutout for the IEC receptacle and the modifications to accept the gold five-way binding posts. The slot for the speaker terminals is ½″ high. The binding post mounting insulators are 9⁄16″ high, so I had to file small half-circles in the top and bottom of the slot so the insulators could bottom against the drilled adapter plate I was making. The half-circles also allowed the binding posts to center themselves in the openings. I also needed to locate a spot for a turntable ground connection post, which my 222C did not originally have.

I removed all the tin-plated phono jacks by carefully bending their tabs. Then I drilled out the rivets, saving the outer phenolic insulators for re-use when I replaced the phono jacks with modern gold-plated jacks. The old jacks were vertically spaced less than ½″ apart, so I'll need to address the problem of clearance for the larger shells of modern enclosed phono plugs.

With all the components removed, I measured the capacitance, dielectric absorption (DA), dissipation factor, equivalent series resistance (ESR), and leakage current of the three multi-section electrolytic can filter caps with a Sencore LC102 Auto-Z capacitor-inductor analyzer. Now this may be pure coincidence, but the dielectric absorption (DA) grew worse and the leakage current became higher in the same order that the six 20µF 450V capacitor sections were connected from the plate down to the phono preamp (i.e., C206 75µA leakage, C205 100µA, C204 260µA, C203 1.2mA, C202 1.5mA, then C201 at 11.7mA). All of these 450V sections had good ESR readings, however.

The two 25µF 25V sections (C14, C114) had very high ESR and DA, and the leakage of C114 was very high at 2.5mA. The four 75µF 75V sections all had DA readings above 77%, and their leakage current was higher than 35mA. Note that in every instance the capacitance was within specification. The lesson here is that capacitance readings alone will not identify a bad electrolytic capacitor.

I repeated the tests with the two CP Manufacturing replacement can caps, which were within spec for every measured parameter. The date code was 2004 for these caps.

Many of the carbon composition resistors were well outside their 10% tolerances (carbon comp resistors change value with temperature, age, and humid-

FIGURE 26: Scott 222C output transformer frequency and phase response.

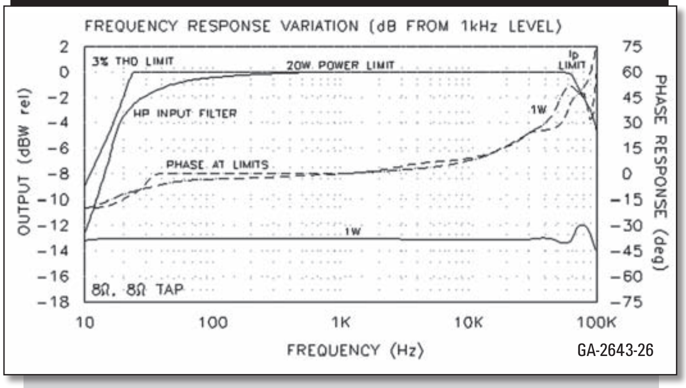


FIGURE 27: Output transformer test setup.

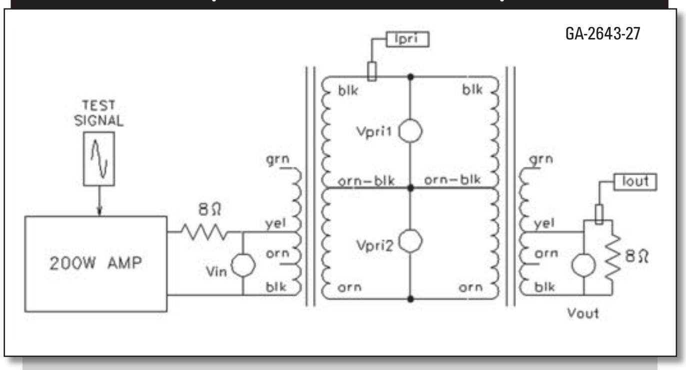
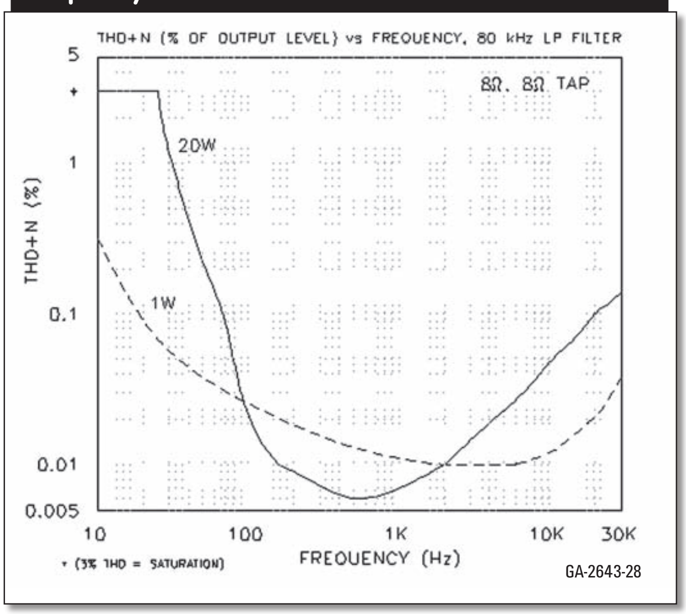


FIGURE 28: Scott 222C output transformer THD vs. frequency.



ity). The large white tubular 8k resistor mounted on the top of the chassis showed evidence of overheating once I removed the cement wirewound resistors below it. The cement was cracked at one terminal, and both terminals were rusty.

When I stripped back the leads on all three transformers to get fresh copper, I found the copper on all the leads had turned green. I carefully removed the oxide coating down to bare copper and re-tinned all the leads.

LUMPS OF IRON

The design of fixed-frequency power transformers is fairly straightforward. They use 12-mil thick silicon steel laminations for 60Hz or 14-mil for 50/60Hz designs (aerospace 400Hz transformers use 4-mil laminations). The silicon content increases the electrical resistivity of the steel and limits eddy current losses. Carlite insulation is used on the surface of the steel to keep the eddy currents from flowing across the lamination stack.

Output transformer design is an art and science of compromises[7]. An output transformer is used to match the high impedance of the output tubes to the relatively low impedance of the loudspeaker over a wide frequency range. It consists of two electrical windings—a primary with NP turns and a secondary with NS turns—coupled by a magnetic core. The primary winding is divided into two mirror-image sections to minimize the leakage inductance. The secondary may consist of multiple parallel windings that are interleaved within the primary.

Most push-pull output transformers use 14-mil 3% silicon steel E-I laminations, although early designs used as much as 4% silicon content. These thicker laminations are cheaper and easier to stack, but the core losses are greater at high frequency than with thinner laminations. For instance, the core loss for 14-mil 3% silicon steel at a fixed flux density of 3kgauss is only 0.015W/lb at 20Hz, but rises to a whopping 50W/lb at 5kHz.

Fortunately, power amplifiers are operated with as flat a frequency response as possible, and with a fixed output voltage the flux density decreases in direct proportion to frequency. Still, the core losses increase exponentially with frequency, so the flux density must be kept much lower than that of the power transformer. This, as well as the requirement for low frequency response, requires a lot of iron.

This is the reason that the power transformer, which handles hundreds of watts, is not much bigger than the output transformer. The power transformer is designed for 16kgauss at the AC line frequency, while the output transformer operates with a flux density of only 1.2 kgauss at 1kHz. Extra margin is added for the higher order harmonics that produce exponentially higher core losses.

The source and load impedances affect the performance of an output transformer. In the real world these impedances may also change with frequency. The transformer primary winding resistance should be low compared to the source impedance (generally less than 5% of the primary impedance at 1kHz). At low frequencies the leakage reactance and winding capacitance are very low and distortion occurs due to the non-sinusoidal magnetizing current, which is mainly 3rd harmonic.

In order to avoid saturation, the open-circuit inductance should be as large as possible. This requires a large core area that, along with power rating, directly determines the volume of the transformer. Output transformers are also operated at low flux densities, well below the knee of the saturation curve, to minimize their contribution to distortion. High open-circuit inductance also requires a large number of primary turns, because inductance is proportional to the core area and the square of the number of winding turns. However, the more turns in the primary, the greater the winding resistance and distributed capacitance that ends up reducing the high-frequency response.

This high-frequency response is determined by the leakage inductance, winding resistance and capacitance, and the source and load impedances. The resonant frequency defined by the LC leakage inductance and winding capacitance should be as high as possible because the response is relatively flat up to this frequency, and has a second-order rolloff (-12dB/octave) above resonance. Good input and output impedance matching is necessary in order to limit distortion and high-frequency peaking. Because the LC circuit introduces phase shift that can eventually reach 180º, feedback amplifiers require careful design in order to avoid peaking, underdamped ringing, or even oscillation. The high-frequency rolloff of the feedback network must be well below that of the output transformer, because feedback cannot be used to extend frequency response.

Ed Dell told me that Scott wound all their own transformers. The Scott TRA-8-5 comprises a total of 160 E-I lamination pairs of 14-mil silicon steel with Carlite C10 organic insulation finish (newer transformers might use C5 organic/inorganic finish). I wanted to check the frequency response of the TRA-8-5-1 output transformers to see whether I could extend the amplifier LF response a bit.

For my own information, I measured the winding resistances, the open-circuit primary inductance, the leakage inductance of each winding, and the primary-secondary capacitance. Without knowing the core area, I could not model the transformer core saturation, so I could not really predict the LF response rolloff. The next task was to run some tests, and to measure the actual saturation characteristics.

At no load, the primary exciting current was 1.5mA at 145V RMS 60Hz, driving one half of the total center-tapped primary winding. **A note of caution**: You should not operate vacuum tube amplifiers without a load. The high reflected secondary resistance can react with parasitic capacitance to cause ringing that may impress voltages across the output transformer windings that exceed their voltage rating. Similarly, operating into an output short-circuit could draw too much current from the output tubes.

OUTPUT TRANSFORMER MEASUREMENTS

Figure 26 shows the frequency and phase response of the Scott TRA-8-5-1 output transformer driving one 8Ω secondary with a 200W power amplifier through a series tap-matching 8Ω resistor. The two primaries are interconnected, and the output of the second transformer has a tap-matching 8Ω load resistor (**Fig. 27**). I measured the transformer current with a Tek A6302 hall-effect current probe and AM 503 current probe amplifier.

The top curve in **Fig. 26** is the frequency response at the three limits of transformer operation. Between 10Hz and 25Hz the power handling capability of the output transformer was limited by LF saturation, which I held to a fixed 3% THD. From 25Hz to 50kHz the transformer was capable of its full 20W output power rating with no noticeable temperature rise. Beyond 50kHz the primary current requirement was held to the 72mA plate current limit I set for the 7189 output tubes.

Just below the "limit" curve at low frequency is the equivalent response of the steep preamp input high-pass filter. The two dashed middle curves represent

FIGURE 29: Scott 222C output transformer 20Hz distortion residual at 3% THD.

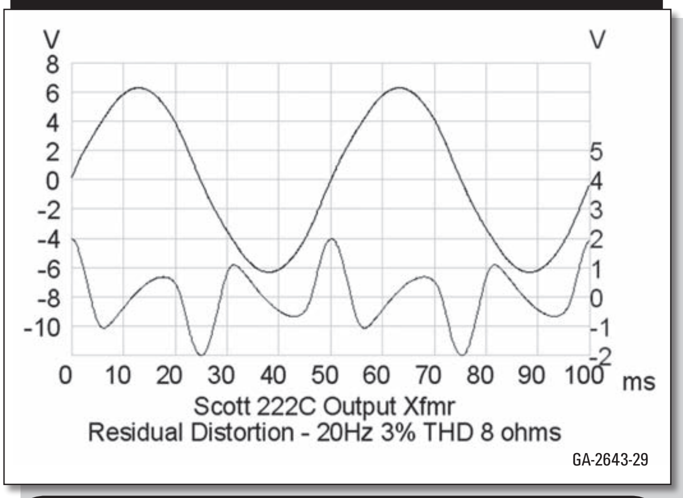


FIGURE 31: Scott 222C output transformer 1kHz spectrum at 1W.

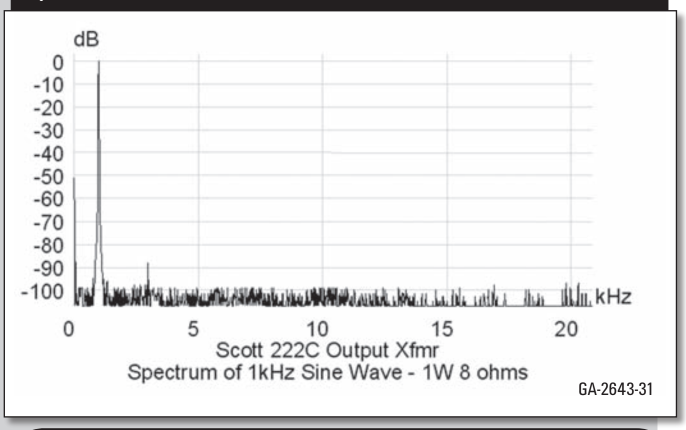


FIGURE 30: Scott 222C output transformer 20Hz spectrum at 3% THD.

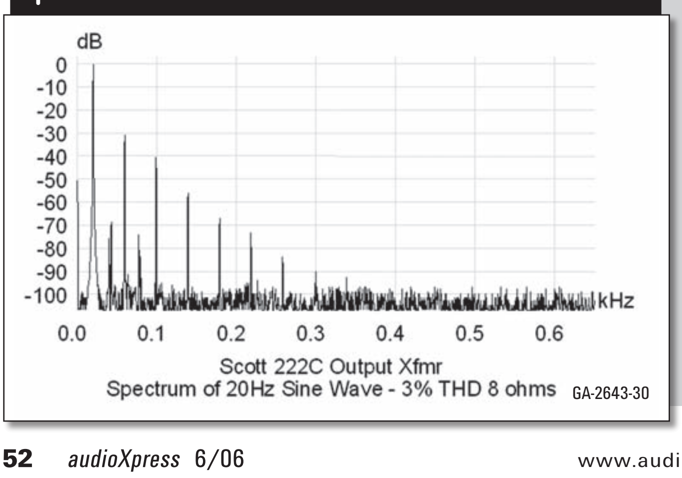
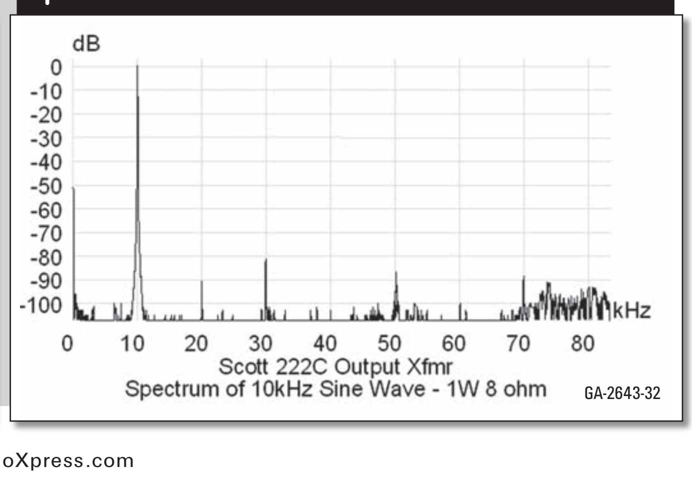


FIGURE 32: Scott 222C output transformer 10kHz spectrum at 1W.



the phase shift between the primary and secondary, first at the “limit” conditions, and then the smoother curve at a fixed 2.83V RMS (1W) into 8Ω. Phase shift in the output transformer does not by itself introduce significant output distortion.

The bottom curve is the transformer frequency response with a fixed 2.83V RMS output into the 8Ω load resistor. Note the peak in response and corresponding changes in phase shift, at about 80kHz due to the increasing winding capacitance. The amplifier response is deliberately rolled off below this frequency to avoid potential instability problems (see **Fig. 10** in Part 1).

Figure 28 shows the THD versus frequency for the output transformer driven by the test setup in **Fig. 27**. Again, I limited the low-frequency output power to the 3% distortion point where the transformer begins to saturate. This graph is limited to 30kHz, but with the LP filter turned off in the distortion test set, the THD began to drop again above 50kHz. This may be due to the increasing high-pass filter effect of the winding capacitance. The THD at 1W is shown as a dashed line.

The output transformer distortion residual for 1W into 8Ω at 20Hz is shown in **Fig. 29**, where I held the distortion to my 3% limit. The upper waveform is the amplifier output signal, and the lower waveform is the monitor output (after the THD test set notch filter), not to scale. This distortion residual signal is predominantly third harmonic as expected. The spectrum of this waveform is shown in **Fig. 30**.

Note that in addition to the smoothly decreasing series of odd harmonics, the 2nd and 4th are also present, albeit at low levels. This indicates a small unbalance in the primary windings of less than 0.03%.

The spectrums for 1kHz and 10kHz at 1W into 8Ω are shown in **Figs. 31** and **32**. At 1kHz the THD+N measures 0.011%, and only the 3rd harmonic is present above the noise floor. In **Fig. 32** there are more odd harmonics present even though the THD+N is still a very low 0.012%. The burst of noise near 75kHz is due to the switching power supply in the computer connected to the digital storage oscilloscope.

The test data for the TRA-8-5-1 output transformer shows it is quite capable of wideband low-distortion operation.

CLEANUP AND REPAINTING

With all the components removed from the chassis, I used car wash powder and water to remove all the dirt, flux, and corrosion from the four aluminum chassis sections. Some of the lettering on the rear panel—already in bad shape—came off with just this mild cleaning. Because I needed to re-letter some areas of the rear panel anyway, I decided to remove all the factory lettering, including the large NOTICE from the top of the front panel informing the owner of how to contact the factory for warranty service. I resorted to steam and a plastic scraper to remove the metal cal, then paint thinner to remove the residual glue.

Next I used Meguiars Mag and Aluminum Polish to clean and brighten all the visible areas of bare aluminum. In some cases, I used Bon-Ami first to remove scratches, followed by the Mag and Aluminum Polish. I didn’t waste time polishing the inside of the chassis, the front surface of the front chassis (it is covered by the face plate), or the bottom panel.

With the transformers removed, I masked the wires and laminations, and sanded and repainted the transformer end bells and mounting hardware with semi-gloss black enamel. I decided against painting the laminations because at high power the laminations vibrate at twice the electrical frequency, which in my experience eventually causes the paint to flake off. There are special varnishes and epoxies made for this purpose, but they use industrial processes that are beyond the capability of the hobbyist.

Next issue I will detail the changes I made to the schematics and power up the revised unit for listening tests. aX

REFERENCE

7. *Electronic Transformers and Circuits, 3rd Edition*, 1988; R. Lee, L. Wilson, C. Carter, Chapter 5 “Amplifier Transformers”; Wiley ISBN 0-471-81976-X.