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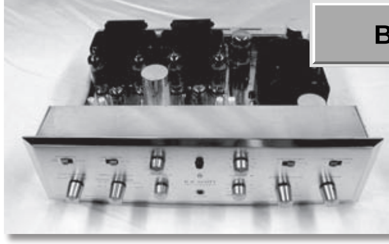


Renovating the Scott 222C Part 4: Listening & Measurements

By Charles Hansen

I connected my sources to the modified unit using the same tubes as in the original listening session, with my NHT satellites plugged into the 4Ω and then the 8Ω taps. The first listening session used the Direct input to the power amplifier (the "fourth" CW position on the input selector).

There was still a noticeable hum with my ear against the loudspeaker LF drivers that did not change with the loudness control setting. It was more pronounced in channel A (left), but was fortunately not noticeable from my listening position. The channel A power amplifier tubes, filter capacitor, and output transformer are farther from the power transformer than channel B, so any magnetic field pickup would seem more likely to affect channel B than channel A. Even the on-off power switch is closer to the channel B section of the loudness control.

Because the closest matched tubes were in channel B, I decided to swap the output tubes from left to right to see whether the higher hum level followed the unmatched tubes. Once I reset the bias for each tube, I again checked the hum level, which had not changed one iota. With no real objective reason to do so, I then swapped the 6U8 tubes with equally unsuccessful results—mystery still not solved!

I connected the CD player to the new Direct input and let the 222M run in for ½ hour, then began my listening session. I needed about 3 o'clock on the loudness control for a comfortable listening level. The Direct input is the purest configuration, without the steep high-pass input filter, the added preamp tubes, tone controls, and other response-altering circuitry.

I found the bass to be a bit weak, but with good definition, especially with an acoustic bass. The midrange was nicely presented while the highs were a bit rolled off. The soundstage was wide and the amplifier didn't lose definition with complex orchestration or massed chorals.

With only 13dB of gain available, I had to turn the loudness control almost all the way up for a comfortable listening level. I tried the 4Ω tap, which gave

FIGURE 42: Modified unit AC line inrush current.

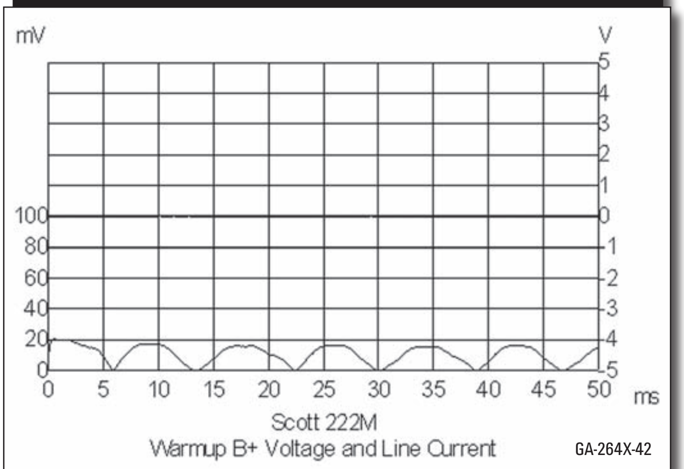


FIGURE 43: RIAA equalization response error.

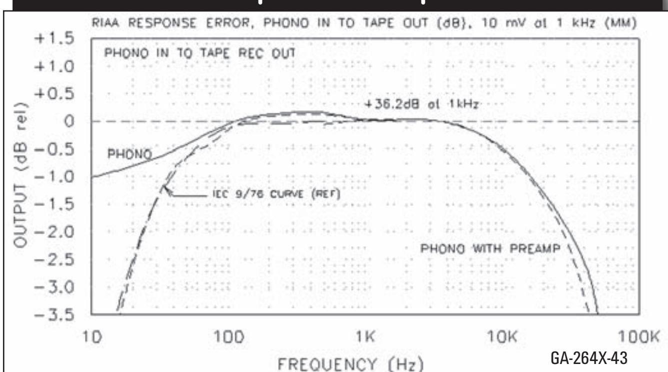


FIGURE 44: Phono section THD vs. frequency.

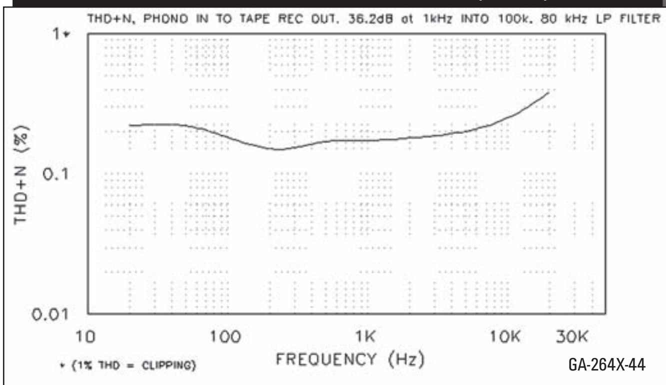
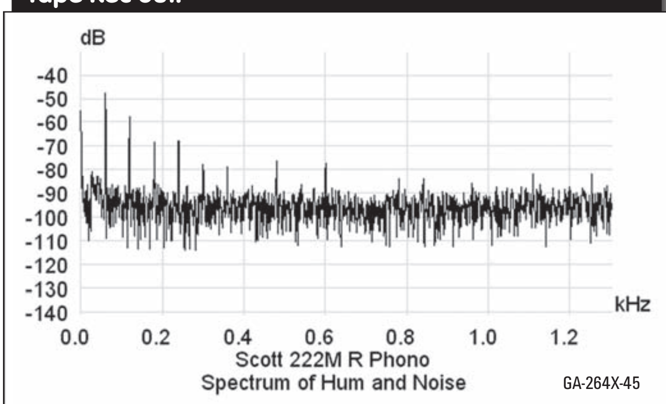


FIGURE 45: Spectrum of hum and noise, phono In to Tape Rec out.



a bit more volume with the 8Ω NHT SuperOnes, but the high frequencies were even more rolled off and took on a bit of edginess. Next, I connected the Center Channel output to the input of my subwoofer amplifier.

Fortunately, the hum was no more noticeable than that from the NHT satellites, so the Center Channel output was quite useful for this purpose. You may need to adjust the value of resistor R13 to provide a center channel signal level that is compatible with your own powered sub. The subwoofer level nicely tracked changes in the loudness control setting, although it was a bit overpowering at low levels with the Loudness switch turned on.

Next I tried the Extra input, which adds the preamp section with its filters and tone controls. With 26dB of available gain, I needed only half the loudness control setting for the same acoustic level as the Direct input. This was fortunate because the two stages of preamp gain add more hum that varies with the loudness control. The deepest bass was noticeably weaker than the Direct input, no doubt caused by the steep LF input filter. The midrange and highs were quite nice, with only a bit less soundstage width. I could bring the highs back up to a satisfying level with just a slight adjustment to the treble controls.

With the subwoofer connected to the Center Channel again, the bass was acceptable down to the open-string E_3 (41Hz), but lacked bass slam with a 5-string electric bass, whose A_3 reaches down to 22.5Hz. The preamp HP filter actually accentuates the 2nd harmonic, which is already dominant over the fundamental on the electric bass.[10] This also made some well-recorded acoustic bass music sound even richer.

My final test was to connect my turntable to the Phono input. There was a noticeable low-frequency thump when I selected Phono on the input selector. The hum level was no higher than that of the Extra input with the loudness control set for the same output level at 1kHz, but there was noticeably higher hiss. I replaced the phono preamp tubes with Mullard ECC83s, with only a marginal reduction in the hiss level. Adding tube shields did not help (which is fine with me since I suspect they shorten tube life).

I played a mix from my collection of jazz and classical LPs. Even with the softest sections of classical chorals and orchestration, hum and hiss was not really objectionable from my listening position. The phono section provided a deep and wide sound stage with bass performance equivalent to the Extra input.

The cannons in the finale of Tchaikovsky's *1812 Overture* didn't suffer too much from the HP filter and all those coupling capacitors, and the hum was much lower than with the 222C as I received it. I was quite impressed, in

FIGURE 46: Extra input frequency response.

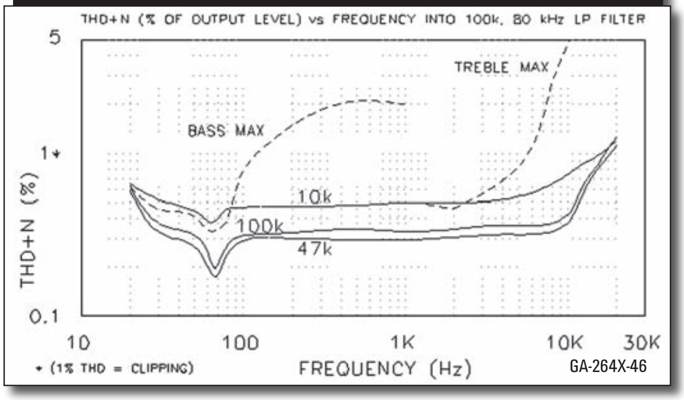
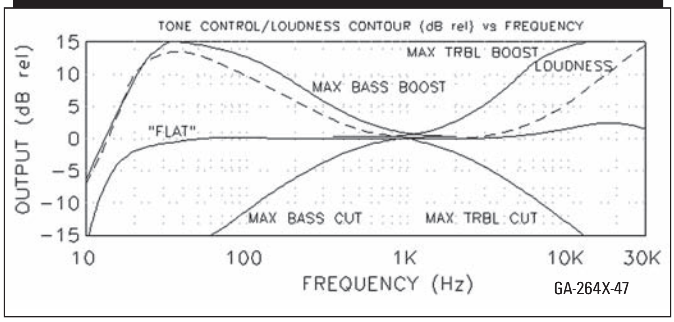


FIGURE 47: Tone control modifications to frequency response.



fact, with the midrange and low treble performance. This is a very usable phono stage.

The preamp section, with its hum, noise, and limited bass, is still the weak link in this project. The power amplifier and phono sections are much improved over the original, but still not in a class with the modern tube amplifiers I have auditioned and tested.

MEASUREMENTS—MODIFIED UNIT

Figure 42 shows the modified amplifier AC line inrush current recorded with the 100:1 ratio current transformer. The 1Ω CT secondary burden is again processed by the precision full-wave rectifier op-amp circuit, with a scaling factor of 10mV/amp.

The initial magnetizing inrush (first half-cycle) is now only 2.1A peak. I took several traces with a cool-down period between each one, and the peak current never varied. The inrush current half-cycles are also uniform, without the 3rd harmonic content or asymmetry from operation on a minor hysteresis loop that would suggest a DC component was impressed on the transformer.

The Phono input impedances were both 47k5. The phono stage output impedances measured at the Tape Rec output jacks had decreased to 7k3 (A) and 7k7 (B) at 1kHz, including series 2k80

FIGURE 48: Extra input/preamp THD+N vs. frequency.

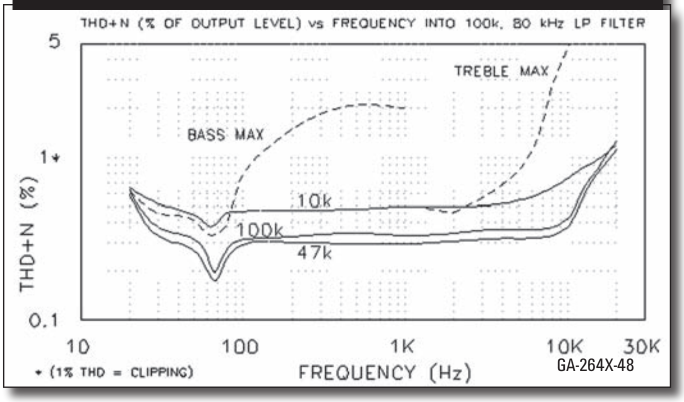


FIGURE 49: Extra input/preamp THD+N vs. output voltage.

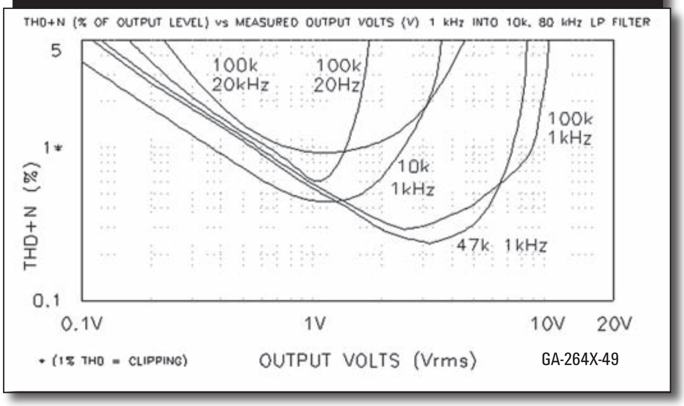


FIGURE 50: Extra input residual distortion, 1kHz 2V 100k.

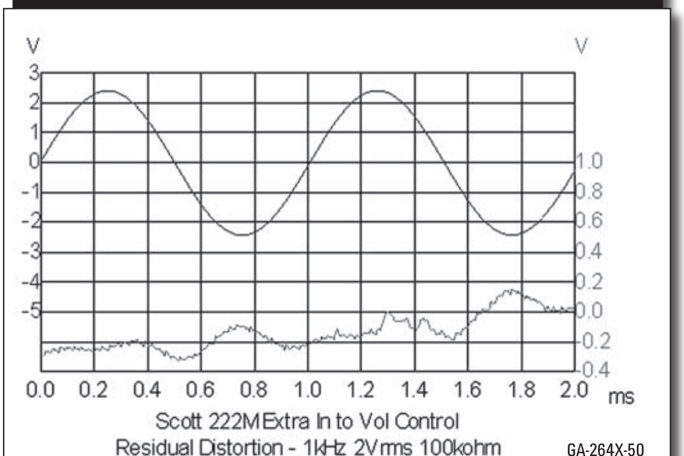


FIGURE 51: Extra input spectrum of 50Hz, 2V 100k.

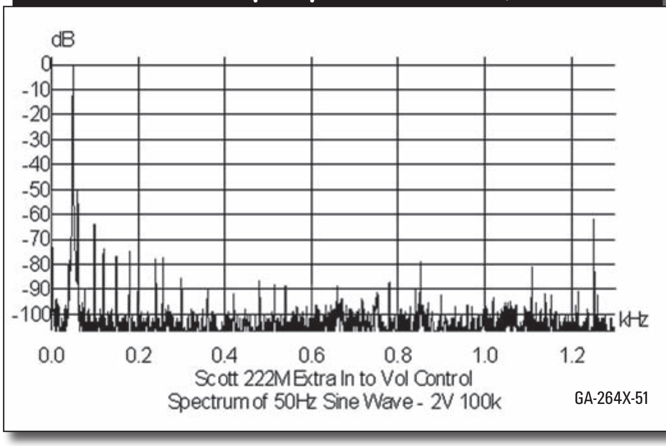


FIGURE 52: Extra input spectrum of 1kHz, 2V 100k.

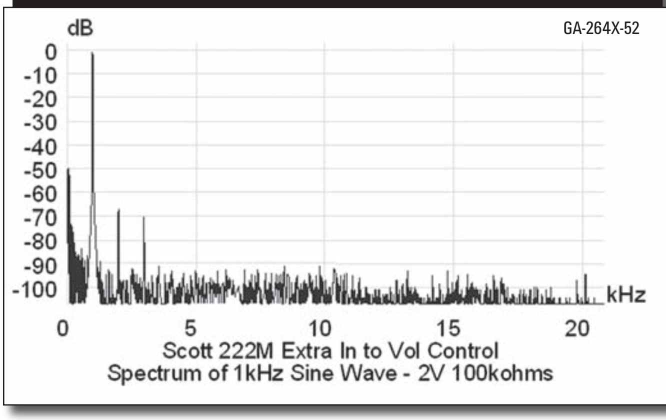
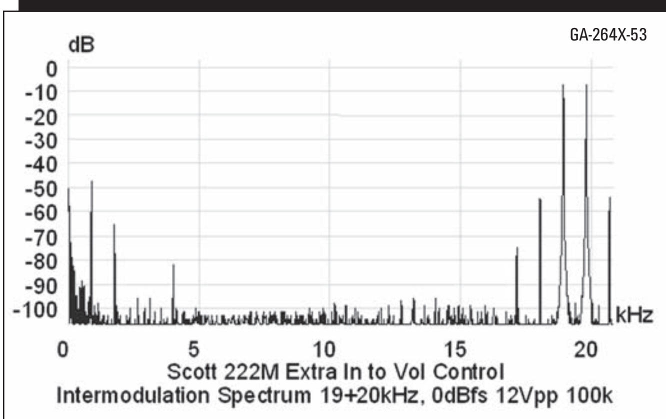


FIGURE 53: Extra input spectrum of 19kHz + 20kHz intermodulation signal.



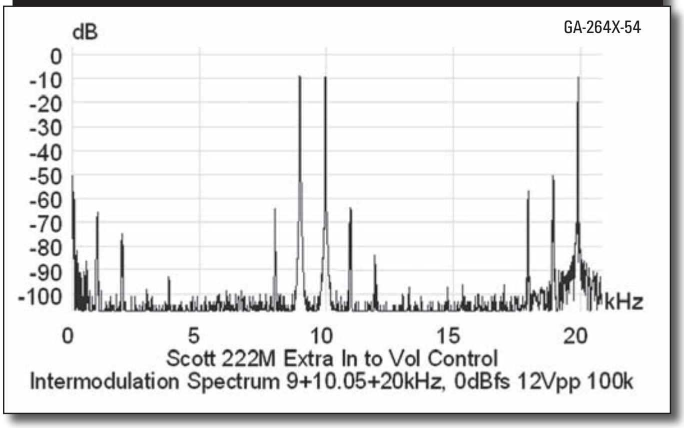


FIGURE 54: Extra input spectrum of 9kHz + 10.05kHz + 20kHz intermodulation signal.

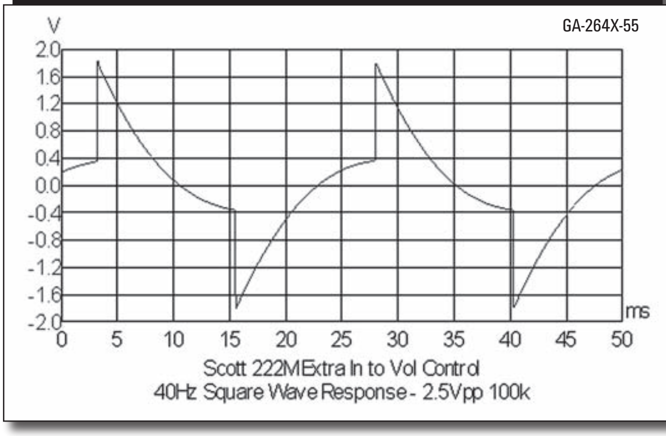


FIGURE 55: Extra input 40Hz square wave response, 100k.

resistors R117 and R217.

I again made frequency response measurements with a test signal level into my inverse RIAA network that produces 10mV at 1kHz at the Phono input jack. Gain at 1kHz, 10mV input improved from 32dB to 36.2dB, which is closer to the ideal 40dB.

Figure 43 shows the RIAA equalization error relative to 36.2dB (the line labeled PHONO), with 1kHz the 0dB point. The RIAA accuracy varied –1dB to +0.15dB from 11Hz to 17kHz, and –3dB to +0.15dB from under 10Hz to 48kHz. When measured at the output of the preamp section at the top of the loudness control, it again closely follows the IEC 9/76 LF rolloff curve shown in the curved dotted line. The two channels varied from each other by only 0.2dB (not shown).

The input overload for visible output clipping now exceeded the RIAA requirements across the board before hitting 1% THD. It was 52.6mV at 20Hz (5.42mV required), 208mV at 1kHz (50mV required), and a greatly improved 1042mV at 20kHz (477.5mV required).

The THD+N from the Phono input to the Tape Rec output is shown in **Fig. 44**, relative to 10mV input at 1kHz. Recall that it was immeasurably high due to the excessive hum level in the as-received 222C.

A spectrum of the improved hum and noise from the Phono input to the Tape Rec output is shown in **Fig. 45**. The 60Hz component has been reduced from –26dB (5%) to –48dB (0.4%), while the noise floor dropped from about –70dB to about –95dB. I think a major portion of this improvement is due to the power supply modifications and the replacement filter caps.

The input impedance at the Extra and Tuner inputs was 918k. Hum and noise at the top of the volume control with the inputs terminated at 600Ω was 3.4mV (A) and 2.7mV (B) for –55dB and –57dB. The A-weighted values were 0.45mV and 0.14mV, or –73dB and –83dB, respectively. This shows the noise performance of the preamp A channel to be worse than the B channel. Switching preamp tubes between the two channels did not materially alter the readings.

Loudness control tracking between the two channels with a 0.5V input signal favored left channel A throughout the rotation. Its worst divergence was at about 11 o'clock (1.6dB), decreasing to about 0.6dB until 1 o'clock, and then increasing again to just over 1dB from 2 o'clock to the maximum. Crosstalk was identical from L to R and R to L, at about -39dB referred to 0.5V RMS input from 1kHz to 20kHz. This result is dominated by noise.

The preamp output impedance (at the top of the loudness control) was 700Ω at 20Hz, 560Ω at 1kHz, and 630Ω at 20kHz.

The frequency response of the preamp section, from the Extra input to the top of the loudness control, is shown in **Fig. 46**. The graph is normalized to the +13dB available gain, with 0dB at 1kHz and 100k load. This graph differs from the preamp response graph of the original unit in **Fig. 6** (Part 1) in that regard.

Note that the SPICE-predicted response based on the 222D schematic is not as good as the actual response of the modified unit. The HF response peak drops off above 20kHz, while the 222C response and

FIGURE 56: Extra input 1kHz square wave response, 100k.

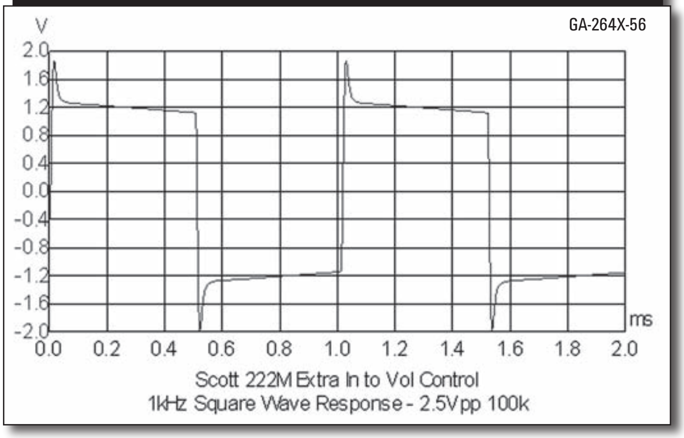


FIGURE 57: Extra input 10kHz square wave response, 100k.

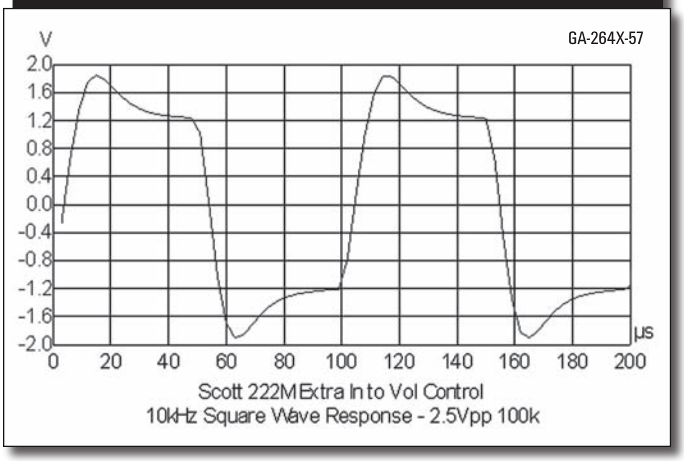


FIGURE 58: Power amplifier frequency response.

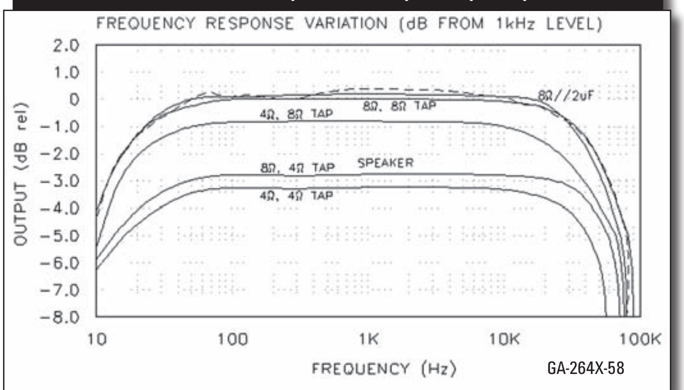


FIGURE 59: Power amplifier frequency and phase response, 8Ω, 3% THD.

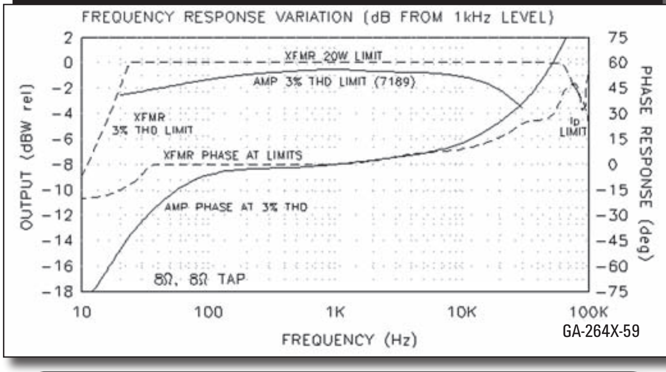


FIGURE 60: Power amplifier THD+N vs. frequency.

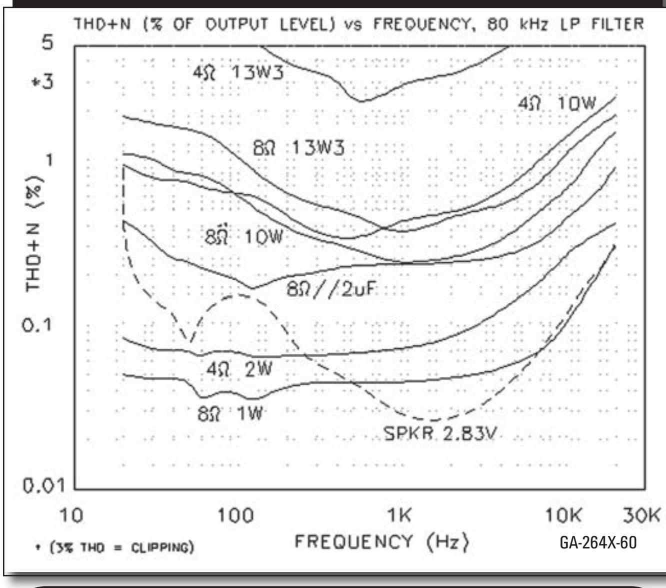


FIGURE 61: Power amplifier THD+N vs. output power.

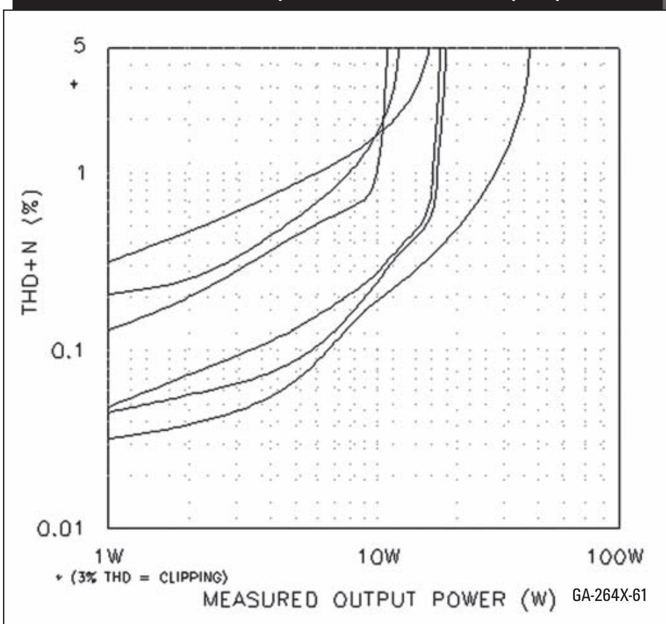


FIGURE 62: Residual distortion, 1kHz 8Ω load.

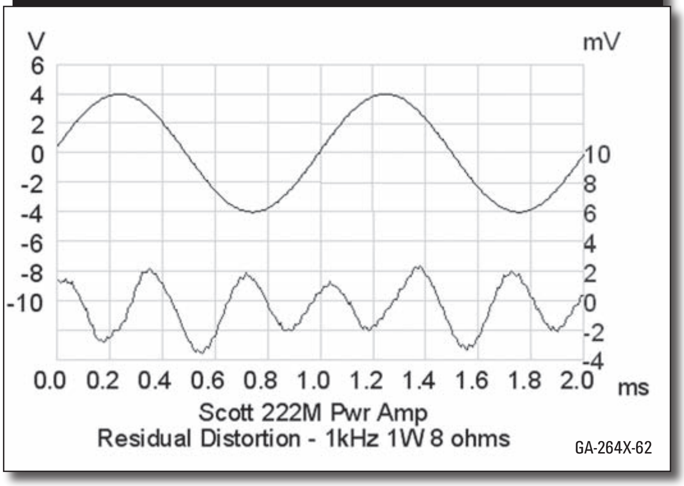
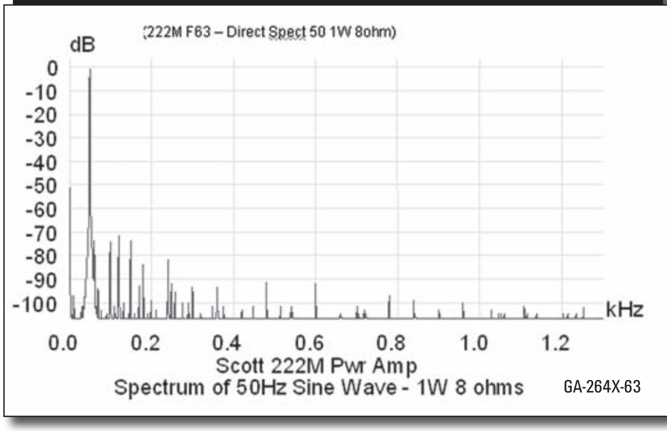


FIGURE 63: Spectrum of 50Hz 1W sine wave, 8Ω load.



the predicted SPICE response continue to rise. I show the actual response at both 100k (the input impedance of my test equipment) and 47k loads. The load impedance is higher in the actual circuit, which is one reason why SPICE predicted a higher 17.5dB gain.

The range of response modification by the tone controls is shown in **Fig. 47**. The loudness contour curve (dashed line) shows more of a peak at each end than the earlier 222C tests in **Fig. 7**, but that may be due to the difficulty of setting the loudness control at exactly the same 9 o'clock point. The revised tone control circuitry also has a bit more authority at the cut end of their settings.

Figure 48 shows the THD+N versus Frequency for the modified preamp section from the Extra input to the top of the loudness control. The solid lines are with the bass and treble controls set flat. The dashed lines are with the bass and then the treble control set to maximum. The hum notch out at 60Hz is quite a bit smaller than in **Fig. 8** (Part 1), showing the improvement in the power supply.

Note that the distortion with a 47k load is lower than that of the 100k load. I also show a 10k load distortion line for information. The preamp load actually connects directly to the volume control with no external connection available. This load impedance will vary from 500k at the minimum loudness control setting to about 250k at the maximum loudness control setting (assuming the balance control is centered).

The THD+N versus output voltage is shown in **Fig. 49** at 20Hz, 1kHz, and 20kHz with a 100k load. Curves for 47k and 10k loads are also included at 1kHz, again only for information. Again the distortion for the 47k load is lower than the 100k load until the output voltage exceeds 6V RMS. The downward slopes of the noise content of THD+N are dominant until the output exceeds 1V RMS or more, where the distortion component takes over on the upward slopes.

The preamp residual distortion for 1kHz from Extra input to the top of the loudness control is shown in **Fig. 50**. The output sine wave is at the top while the distortion residual signal after the distortion test set notch filter is the bottom trace. The residual shows mainly a third harmonic dominated by noise. The trace is gradually rising from left to right, which shows it is modulating the hum from the lower frequency AC line.

You can see the preamp intermodulation of the AC line 60Hz with the 50Hz test sine wave in the spectrum in **Fig. 51**.

I applied the 2V RMS test signal to the Extra input and monitored the spectrum at the top of the loudness control. Hum pickup in the circuit produced 60Hz at –50dB (0.32%). Nonlinearities in the preamplifier produced IM products at 70Hz and 80Hz, and AC line harmonics out through 480Hz. There is one unexplained –52dB spike at 1250Hz. The noise floor is low at -106dB.

Repeating the spectrum with a 1kHz 2V RMS input signal produced the results shown in **Fig. 52**. Here the only harmonics are the 2nd and 3rd at about –70dB, with the power line harmonics shown grouped below the 1kHz fundamental.

Figure 53 shows the output spectrum reproducing a 12Vpp combined 19kHz + 20kHz CCIF IMD signal into 100k. The 1kHz IMD product is –47dB (0.079%) and the 18kHz and 21kHz products are –55dB (0.035%). There are also products at 2kHz, 4kHz, and 17kHz. Taken all together the products equal 0.51%.

Repeating the test with a multi-tone IMD signal (9kHz + 10.05kHz + 20kHz, **Fig. 54**) produced odd and even order IM products spaced about 1kHz apart with a total calculated value of 0.32%. The multi-tone IMD is more representative of music than a sine wave test signal.

The 2.5 Vpp square wave at the Extra input at 40Hz showed a significant amount of tilt and leading phase shift (**Fig. 55**) as a result of the steep HP filter in the preamp section. The 1kHz square wave (**Fig. 56**) has a peak at the leading edge, possibly coinciding with the slight rise in frequency response at 20kHz in **Fig. 46**. This response peak is more obvious in **Fig. 57**, where it exactly splits the two halves of the top of the 10kHz square wave.

The final batch of figures shows the tests done on the Direct input to the power amplifier section, where the test signals are applied to the top of the loudness control. **Figure 58** shows the frequency response of the power amplifier with various loads, with 0dB representing 2.83V RMS at 1kHz across 8Ω at the 8Ω tap. Both channels were driven for all these tests. The loudspeaker response is shown with a dashed line. I made measurements for the loudspeaker load with my NHT SuperOne satellites at the end of 6′ of 12-gage Monster cable.

Figure 59 compares the frequency and phase response of the power amplifier section of the modified 222C at 3% THD with the transformer limits that were established earlier and shown in **Fig. 26** (Part 2). The output load is 8Ω at the 8Ω tap. The maximum power over the audio band (solid line) is below the transformer power limit (dashed line) down to 18Hz.

At that point, the amplifier LF rolloff pretty much follows the transformer 3% THD limit line. This tells me the steep HP filter in the preamp was there to roll off the phono response to prevent LF record warp from getting through to the speakers of the day, and not to prevent saturation of the output transformer.

FIGURE 64: Spectrum of 50Hz 4V sine wave, speaker load.

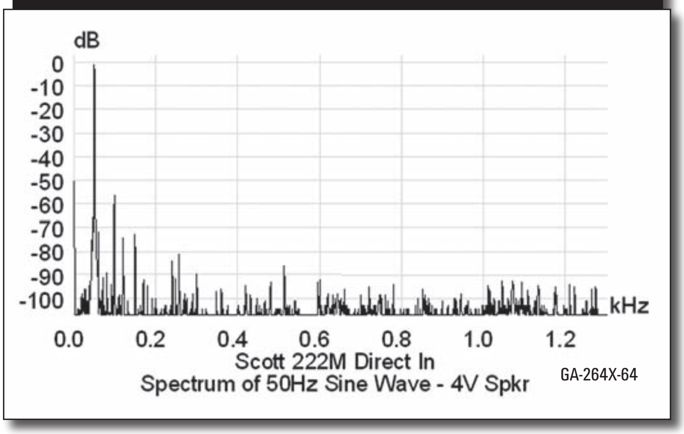


FIGURE 66: Spectrum of 19kHz + 20kHz intermodulation signal.

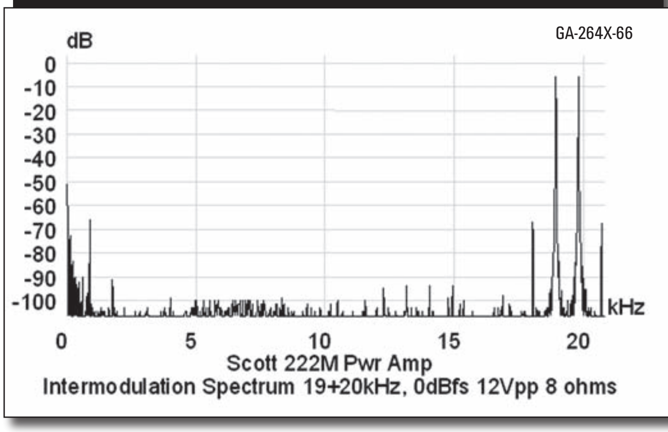


FIGURE 65: Spectrum of 50Hz 5W sine wave, 8Ω load.

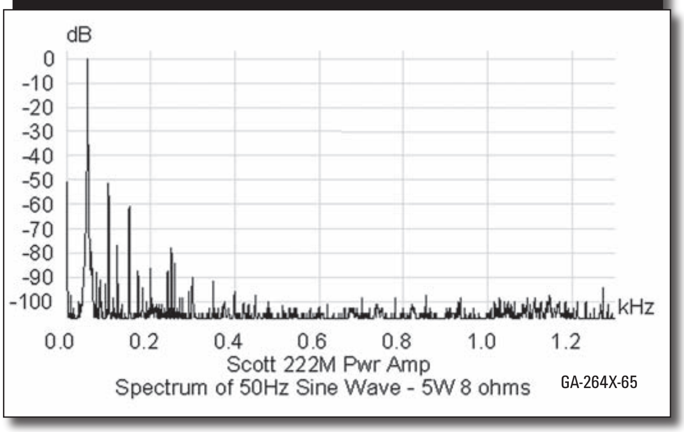


FIGURE 67: Spectrum of 9kHz + 10.05kHz + 20kHz intermodulation signal.

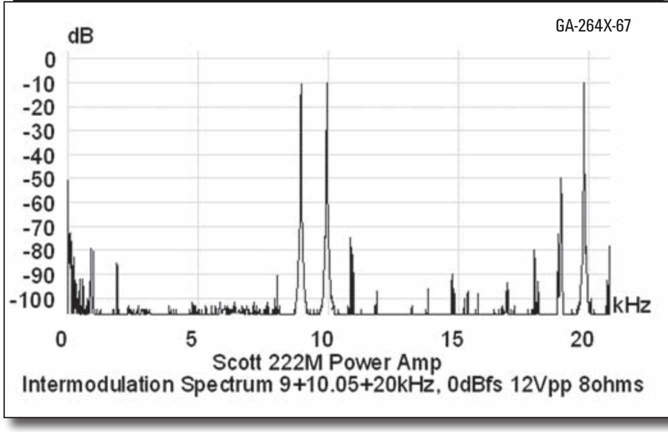


FIGURE 68: 40Hz square wave response, 8Ω.

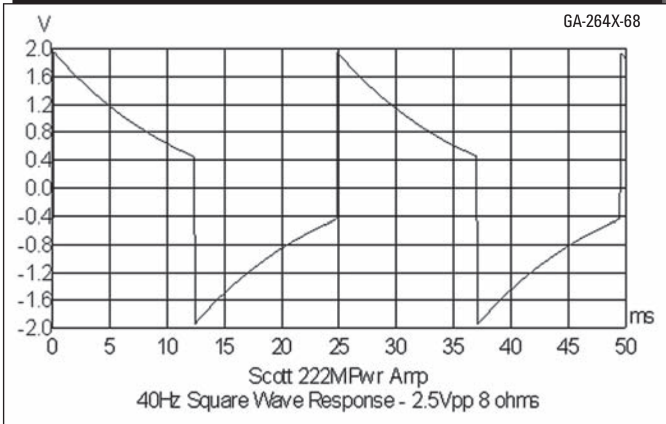


FIGURE 69: 1kHz square wave response, 8Ω.

C127/C227 (**Fig. 36**, Part 3) provide the dominant feedback pole to roll off the HF response below the limits of the output transformer.

Because the amplifier high and low frequency rolloff is faster than the inherent rolloff of the transformer, the rate of change in the amplifier phase response is proportionally higher.

The power amplifier THD+N versus frequency is shown in **Fig. 60** with the loads indicated on the graph. Note the large excursions in distortion with the speaker load as the amplifier responds to changes in speaker impedance with frequency. The dips in response at 60Hz and 120Hz at 8Ω 1W are at much lower dB levels than with the preamp section in **Fig. 48**, indicating there is much less hum to notch out in the power amplifier. The distortion only exceeds 3% in portions of the 13.3W curve into a 4Ω load.

Figure 61 shows the amplifier THD+N increase as the output power is pushed higher by increasing the input signal, with the loudness control at maximum clockwise rotation. Both channels are driven. The loads from bottom to top at 1W are 8Ω at the 4Ω tap, 8Ω at the 8Ω tap, 4Ω at the 4Ω tap, 4Ω at the 8Ω tap, the preceding all at 1kHz; then 8Ω at the 8Ω tap at 20Hz and 8Ω at the 8Ω tap at 20kHz.

The residual distortion in **Fig. 62** shows mainly the third harmonic with some noise. The test signal is 1kHz at 1W into 8Ω at the 8Ω tap.

The spectrum of a 50Hz sine wave producing 1W into 8Ω (8Ω tap) in **Fig. 63** shows the harmonics and AC line intermodulation products all below –70dB, with a low noise floor. Replacing the 8Ω load with the loudspeaker in **Fig. 64** produces an increase in the second harmonic and a bit more complexity in the noise floor. Increasing the output power to 5W (**Fig. 65**) increases the percentage of all the harmonics but leaves the AC line product levels lower than they were at 1W.

Next, I applied my two intermodulation test signals. The CCIF 19 + 20kHz IMD spectrum is shown in **Fig. 66**, at 12Vpp into 8Ω. While the 1kHz, 18kHz, and 19kHz products are all at –68dB (0.04%), there are no other multiples of 1kHz above –92dB. This is a much better result than in **Fig. 53** with the preamp.

Switching the IM test generator to the multi-tone signal produced an overall lower level of IMD products (**Fig. 67**), except for the 18.95kHz product that remains at –50dB. The total calculated value of the even and odd order products is 0.103%.

The next series of tests are all responses to square waves at the Direct input to the power amplifier. I adjusted the output for 2.5Vpp into the 8Ω load at the 8Ω tap. **Figure 68** shows the response to a 40Hz square wave. It shows only moderate tilt when compared with the response of the preamp in **Fig. 55**.

The 1kHz square wave in **Fig. 69** is just about perfect. Increasing the square wave frequency to 10kHz (**Fig. 70**) produced a waveform with no peaking and a slight rolloff of the edges. When a 2µF capacitor is switched across the 8Ω load, the response is little changed (**Fig. 71**).

Crosstalk performance for each of the sections of the modified 222C is shown in **Table 7**. A summary of the modified 222C test data versus the original specifications is shown in **Table 8**.

EPILOGUE

While work on this unit may be finished for now, I still want to do some more testing and modifications. I'm fairly pleased with most of the modifications to the 222C, and I learned quite a bit along the way. The hum and noise remaining after all the modifications to my power supply points to the reasons why modern tube amplifiers use voltage regulators in the B+ circuits for all the voltages below that of the output tubes.

The power-supply rejection of single-stage amplifiers is not very good. Most modern push-pull amplifiers also use ultralinear (UL) output transformers. Dennis Colin made an interesting comparison of KT88 plate curves for triode, 70% UL, 43% UL, and pentode output stage topologies in a letter to *audio-*

FIGURE 70: 10kHz square wave response, 8Ω.

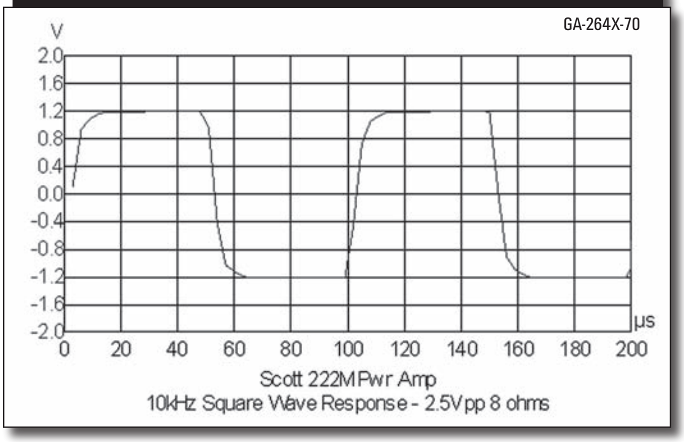
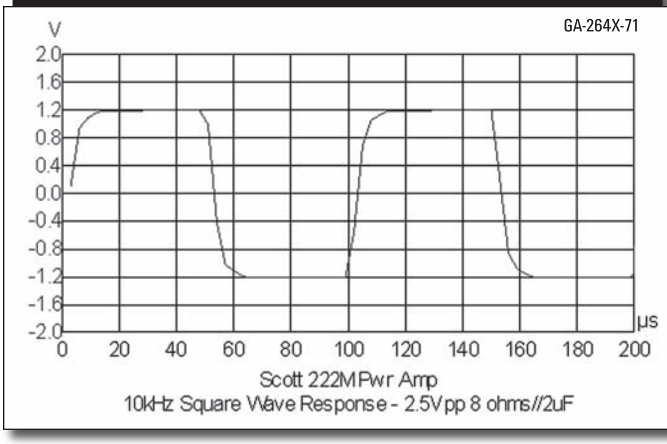


FIGURE 71: 10kHz square wave response, 8Ω//2µF.



Xpress, (Aug. '05, p. 60).

I'll try to find some reasonably priced 7189A output tubes and compare them with the 7189 and 6n14n types. I may remove or modify the preamp input high-pass filter because it does not seem to be necessary to prevent output transformer saturation. There is an undesirable HF peak in the preamp frequency response that I may be able to eliminate with a small compensation cap from the plate coupling cap output to the grid of one or both tubes. And the hum and crosstalk performance of the preamp are inferior to both the phono section and the power amplifier.

I hope this article encourages you to look at the vintage tube hi-fi gear, much of which is available on eBay. I found an average of two pages of listings each for many vintage manufacturers: Scott, Fisher, Pilot, Eico, Heathkit, and so on. The Japanese manufacturers also produced tube hi-fi equipment towards the end of the era.

It is important to find equipment that is in good cosmetic condition with good transformers. Understandably, this will cost you more money. If the unit is operating, all well and good, but remember that I replaced most of the electronic parts in my unit. If you want do a more faithful restoration, the condition of switches, potentiometers, and the other mechanical items that are no longer available takes on more importance. **aX**

TABLE 7: CROSSTALK PERFORMANCE.

	Phono dB		Preamp dB		Amp dB	
Freq	**L to R**	**R to L**	**L to R**	**R to L**	**L to R**	**R to L**
100			–58	–57	–65	–52
1k			–52	–44	–65	–52
10k	–44	–54	–40	–39	–64	–52
20k			–39	–38	–61	–52

TABLE 8: MEASURED PERFORMANCE (CHANNEL B, MODIFIED 222C).

Parameter	HH Scott Specifications	Measured Results, Unmodified
Max power output, 1000 cycles	Music waveforms - 24Wpc Steady state – 20Wpc	No specified test method 17.8Wpc, 8Ω at 8Ω tap
Total Harmonic Distortion	0.8% rated power, 1000 cycles	3% THD, 17.8W, 1kHz, 8Ω 0.8% THD, 10W, 1kHz, 8Ω
Frequency Response, 20W steady-state, 1.5% THD	20 to 20,000 cycles*	18Hz – 30kHz (8Ω relative to 10W), 1.5% THD
Max usable power output, 20 cycles	Music waveforms – 28Wpc Steady state – 24Wpc	No specified test method 11.1W, 3% THD, 8Ω at 8Ω tap
Power Bandwidth at 1.5% distortion (IHF method)	Below 19 cycles to above 20,000 cycles (test equipment limits)*	20Hz – 30kHz (8Ω relative to 10W), 1.5% THD
Intermodulation distortion	Below 0.5%	0.045% CCIF 8Ω
Signal for rated output at 1 kc		
NAB (NARTB) tape	3.0mV	Circuit Removed
RIAA (MAG LOW)	3.0mV	19.5mV RMS
RIAA (MAG HIGH)	9.0mV	Circuit Removed
Tuner, Extra and Tape Playback	0.50V	0.67V 10W 8Ω
Hum and noise		
High level inputs	80dB below rated power	–53dB ref 10W
Low level inputs	10 microvolts equivalent	No specified test method
Scratch Filter	Above 5 kc	Circuit Removed
Treble boost, treble cut, 10 kc	15 dB ± 2dB	14dB boost, –13dB cut
Bass boost, treble cut, 50 cycles	15 dB ± 2dB	15dB boost, –17dB cut
Input Impedance		
Low level (MAG LOW)	47kΩ	47k51
High level (MAG HIGH)	150kΩ	Circuit Removed
High level inputs	500kΩ	918kΩ
Output loads		N/A
Tape load resistance	200kΩ minimum	
Tape out cable capacitance	200pF maximum	
Line voltage range	105–125V, 50-60 cycles	Optimized for 120V AC
Power Consumption, 60 cycles	170W	174W max, 132W at 2Wpc 8Ω
Damping Factor	N/S	4.7 4Ω, 6.3 8Ω; 1kHz
Input Overload, Mag Low		
20Hz		52.6mV RMS
1kHz		208mV RMS
20kHz	N/S	1042mV RMS
Gain, 1kHz, Mag Low	N/S	10mVin produces 646mVout, or 36.2dB
RIAA Accuracy	N/S	–3.0/+0.15dB
S/N, A-Wtd, Ref 5mVin	N/S	–64dB (phono), –73dB (Extra)
Crosstalk, 10kHz	N/S	–44dB (phono), –38dB (Extra)

** Sharp cutoff filter (12dB or sharper per octave) becomes fully operative below 20 cycles.*

References

10. "Modifying Peavey's TKO 80 Bass Amp, Part 1," Hansen, C., Koonce, GR; *audioXpress*, pp. 16-27, 67, Oct '03; "Part 2," Hansen, C., Koonce, GR; *audioXpress*, pp. 40-49, Nov '03.

Next time...

I will wrap up this series in next month's issue with a look at tube specifications and alternatives you can use in the Scott 222C. I audition and measure the performance of these tubes.