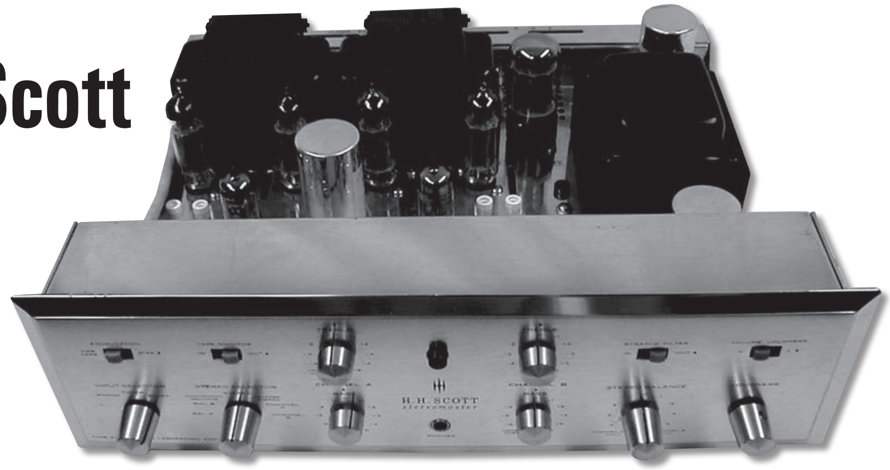
Renovating the Scott 222C, Part 3



By Charles Hansen

My replacement parts list, keyed to the schematics in **Figs. 33–36**, is shown in **Table 4.** Note that I changed the component designations from those used by Scott. They assigned left channel parts to digits 1-99 (example: C1), then the identical right channel parts by adding 100 (C101). The parts common to both channels had 200 series numbers. Mullard also used this system in their stereo amplifier designs.

I tried to work with this for a while, but found it totally (for me) counterintuitive. So I numbered my schematics 1-99 for the common parts, 100-199 for the left A channel, and 200-299 for the right B channel. Because there are no mechanical assembly drawings in the Operating Manual or lettered component numbers other than the tube ID label on the chassis bottom (which was going to need to be removed anyway), this was not a problem for me.

Parts cost for this renovation ran about $270, plus the cost of the original amplifier. The cost of a new Scott 222C in 1961 was $165 (if it appears this renovation was not exactly cost effective, think of the cost of a new 222C as $1031.25 in 2004 dollars).

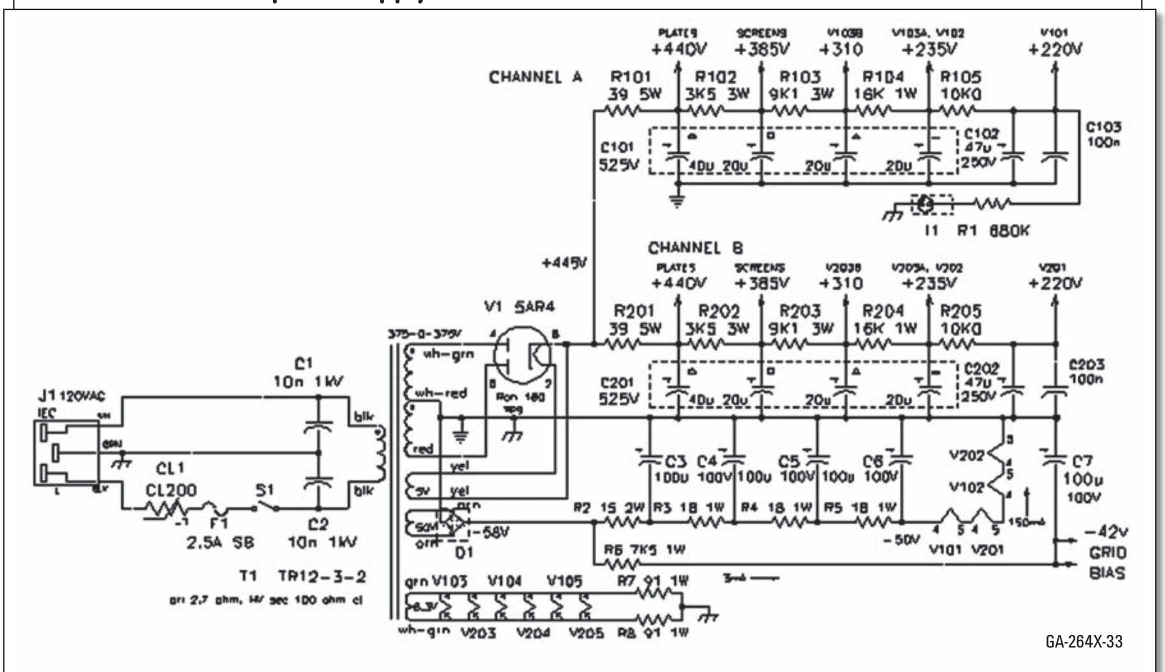
Scott engineers did a nice job in making mostly star connections for the grounds and power supplies. Decoupling caps are used from circuit ground to the chassis at the rear panel phono jacks and speaker terminals to help limit noise. Twisted pairs are used for AC and signal wiring, and the phono signals are shielded from the rear jacks to the front panel. The circuit ground connection to

TABLE 5: SUPPLY VOLTAGES FOR 7189 OUTPUT TUBE AMPLIFIERS.

Model	Power transformer	Power transformer HV winding	Vplate	Vscreen	Vphase inv	Vamp	Vpreamp	Vphono
222C	TR12-3-2	365-0-365	+420	+345*	+335	+300	+285	+220
222D	TR12-3-4	360-0-360	+410	+398	+315	+238	+238	+205
299A	TR12-3-1	365-0-365	+365	+295*	+280	+280	+230	+175
299B	TR12-3-1	350-0-350	+430	+360*	+320	+320	+225	+170

*a power resistor divider is used to derive the screen voltages in these three models.

FIGURE 33: Modified power supply.



the chassis is located at the phono preamp tubes.

The next order of business was to improve the power supply. There were four models of the Scott integrated amplifiers that used 7189 output tubes: the 222C, 222D, 299A, and 299B. The 222A and 222B used 6BQ5/EL84 tubes, while the later 299C and 299D used 7591 octal output tubes (schematics for the 299 series are also on the H. H. Scott website). Scott used four different power supply circuits with the four 7189 tube amplifiers. The differences are listed in **Table 5** (this is the DC voltage listed on the schematics at the filter caps, not the voltages measured at the tube sockets).

It appears that Scott was constantly revising the power supply for what was essentially the same amplifier design. Only the 299A appears to have kept the 7189 plate and screen voltages within the tube manual maximum limits. The 299B has even higher voltages than the 222C and 222D, although some sources list the 299B output tubes as 7189A. The Sams PhotoFact schematic for the 299B clearly calls for the 7189.

In the end I decided to design a fully dual-mono supply except for the 5AR4 rectifier tube (**Fig. 33**). Tube circuits have rather poor power-supply rejection unless you use constant-current sources or balanced differential stages, which was rare in the H.H. Scott era. I removed the old high voltage can capacitors (C201-C206, also including low voltage bypass caps C14 and C114), replacing them with a pair of modern CE Manufacturing 40μ/20μ/20μ/20μ twist-lock replacement cans with a higher 525V DC voltage rating. I had already replaced the selenium bridge with a 6A 200V silicon bridge rectifier during the initial power-up.

Because the 4 × 75μ/75V bias supply can cap was also worn out, I replaced it with four 100μ/100V discrete high-temperature (105° C) aluminum caps. I also used high-temperature aluminum caps for C105 and C205, the phono stage supply filters. I retained the stock neon power indicator lamp (the 222D and later amplifiers used a 6.3V filament lamp).

In light of the high inrush current (**Fig. 2**), I added a CL200 inrush current limiter, which is a negative temperature coefficient (NTC) thermistor whose resistance is initially high but decreases as its temperature rises due to the current flow through it.

The CL200 is rated for 25Ω (cold) and 1.7 Arms. At 5W/channel output this device dissipates almost 1.2W, so it requires good ventilation to extract all the heat it produces. I positioned it directly under the large hole in the chassis vacated by tubular resistor R212.

The 222C output tube screen supply used 1K2 10W series resistor R213 from the HV filter caps to the four screen grids, and shunt 4K 7W tubular resistor R212 to ground. These two resistors dissipate almost 20W by themselves. The tubular shunt resistor needed to be mounted above the chassis. The 299A and 299B also used shunt resistors for the screen supply, although with higher resistances that didn't waste as many watts. The screen supply for the 222D is more energy efficient, using a higher resistance series-dropping resistor between the plate and screen filter caps with no shunt resistor, and 1K series resistors to each pair of screen grids.

With my dual mono supply, I am using individual screen resistors for each of the four screen grids. I suspect the high voltage winding on the 222D transformer actually had less than 360-0-360V AC. Without R212 the plate voltage in my modified supply rose to +457V DC, while the 222D schematic lists it as +410.

One side of the 6.3V AC filament winding was grounded in the original 222C. I used two 91Ω resistors, R7 and R8, with their center-point grounded for improved hum rejection in the power amplifier section. This also restored the heater supply to 6.3V with the higher 120V line voltage. The Scott amplifiers were designed back when the nominal AC line voltage was 117V AC. I also selected R2 so the heater voltage for the four series 12AX7s was the correct value (50.4V DC) at 2W/channel output and 120V AC line voltage.

I decided to completely change the phono preamp circuit (**Fig. 34**) because it was not very accurate with respect to the specified RIAA equalization curve. A SPICE simulation of the original circuit showed this to be the case, even with the original specified values. I removed the 100K resistors in series with the MAG HI inputs and used these two jack positions for a fourth input selector position, this one directly to the top of the power amplifier loudness control through a coupling capacitor. I used a new Electroswitch D4C0406N four-pole six-position rotary switch for this purpose. The added position is clockwise from the Extra input and is unmarked on my faceplate.

I removed the RIAA/NAB EQ modules from the Equalization switch and abandoned the slide switch in place. Ditto for the Scratch Filter switch. The Tape Monitor switch uses the original slide switch.

The modified phono stage uses standard high voltage polypropylene and ceramic NP0 caps. I needed to maintain flat response at low frequencies because of the steep rolloff of the preamp input high-pass filter. I settled on a higher +220V DC for the phono stage after playing around with the SPICE circuit simulation program to ensure I had sufficient headroom using this value of B+ voltage and adequate power supply isolation from the rest of the amplifier.

Incidentally, after measuring the actual no-load current draw for all the various stages, SPICE proved to be a quick way to determine the optimum series step-down resistors for the whole power-supply design. The unknown is the ripple current in the high voltage filter caps, and SPICE accounts for this quite nicely. It also showed that the ESR and ESL of those older electrolytic capacitors must have been horribly high if the original schematic voltages were correct.

The preamp/tone control circuit (**Fig. 35**) is derived from the Scott 222D and the 299D integrated amplifiers. It may appear that you can remove quite a few of the components near the 222C Scratch Filter, but this is not the case. You can combine C9 and C10 into a single value (I used 56pF), but C8, R14, C9, C10, R15, C11, R16, R17, C12,

FIGURE 34: Modified phono stage.

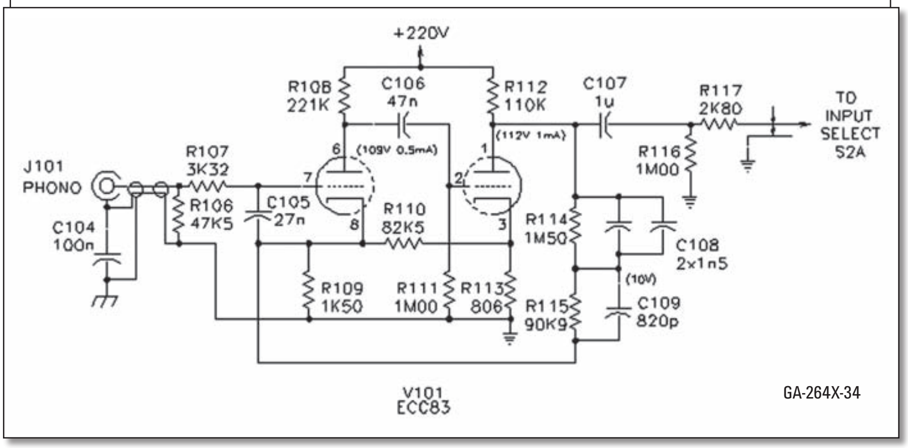
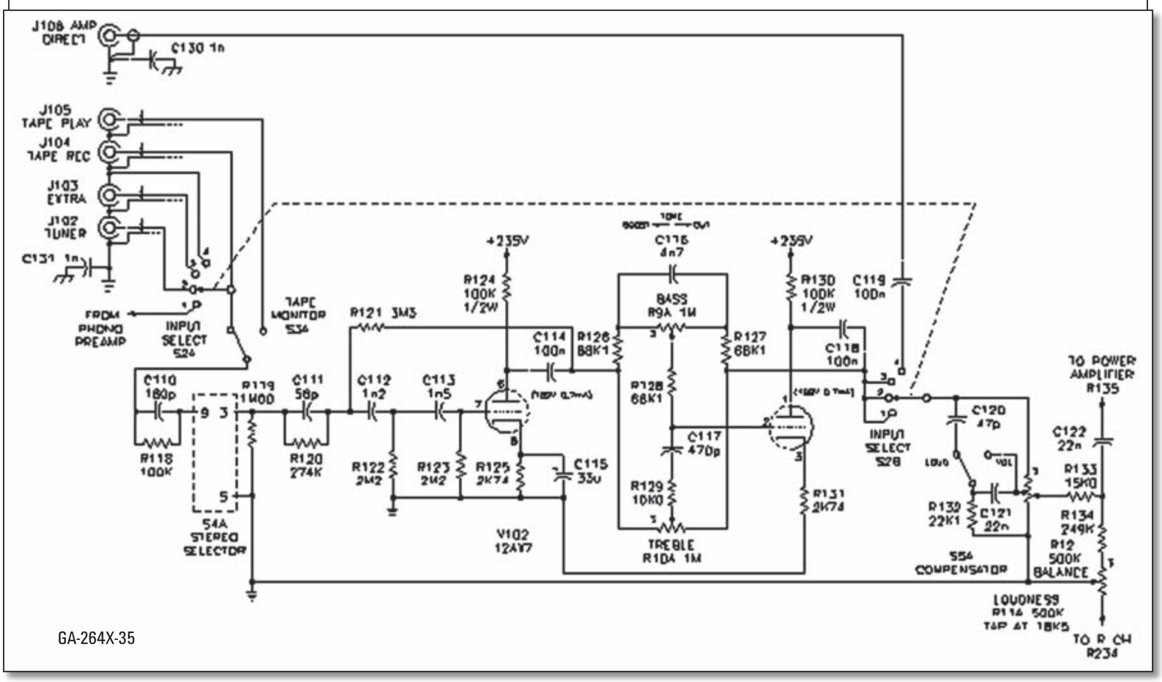


FIGURE 35: Modified preamp and tone controls.



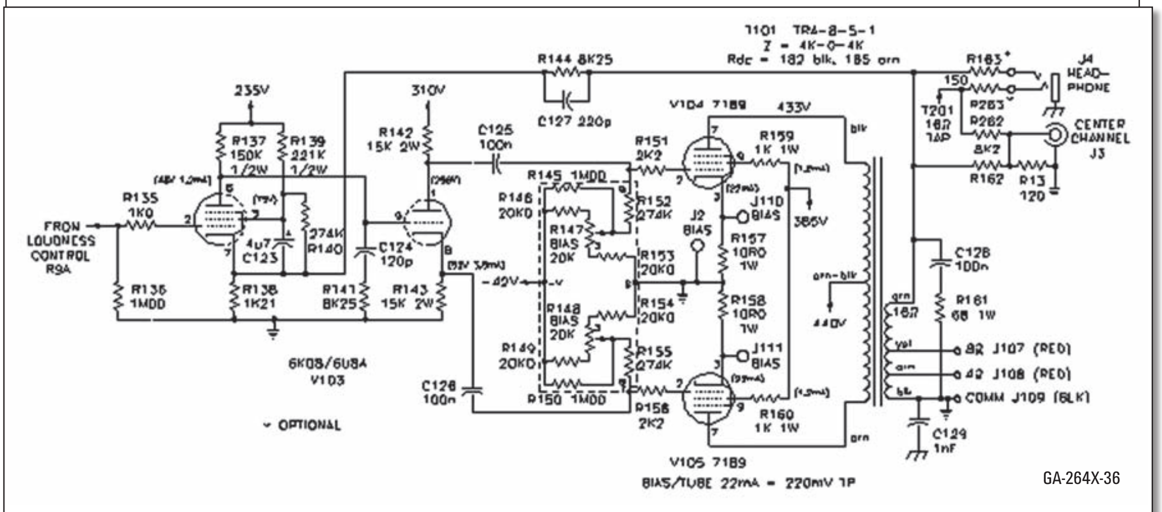
and C13, along with V2-A, form the sharp cutoff (-12dB) HP filter. The 222C Service Bulletin in my Operating Manual says it "is designed to prevent overload of the output stage and the loudspeaker due to subsonic rumble frequencies and record eccentricities."

Because the filter remains engaged during Tuner or Extra input operation, it may also be designed to prevent saturation of the output transformers at low frequencies, although my tests of the output transformers make this less likely. A test of the modified unit at the direct input to the amplifier, which bypasses the HP filter, will determine whether this is true. I decided to incorporate the input filter for now. It is easier to remove parts later than try to make room for additional parts after all the wiring is finished.

The tapped tone control pots were intermittent and very noisy and needed replacing, so I redesigned the circuit to increase the capacitor values and decrease the resistances. I reduced the Balance control to 500k and added two 249k resistors to each leg to reduce its authority. The Stereo Selector switch allows the selection of either A or B input mono, so having that capability in the balance control was redundant. This allowed me to reduce the value of R133 (old R31) to 15k for less noise.

The power amplifier section is largely unchanged (**Fig. 36**). The part values around V103 are from the 222D.

FIGURE 36: Modified power amplifier.



I added 10Ω cathode resistors to each output tube, which now has its own individual 20k bias adjust pot, and tip jacks to easily measure the output tube bias current. Because the idle current for each output tube is 22mA, each 10Ω resistor dissipates only about 5mW. I used carbon composition resistors for the grid stoppers for their higher surge ratings in case of a grid failure. There is little current through them, so noise is not really an issue.

I did not reconnect the headphone jack, only left it in place to fill the hole in the front panel. If you want a functioning headphone jack, you can use the original 222C circuit, or the simpler one I show on the schematic that uses R163 and R263 to supply the signals from the 16Ω taps. In the latter case, you will need to disconnect your speakers and substitute load resistors when you want to use headphones. I did retain the center channel output for use with my subwoofer amp (the 222D also has a center channel speaker-level output).

Because I have the capability of matching transconductance (Gm) and plate resistance (Rp) at any given value of bias current using an Audiomatica Sofia tube curve tracer, I did not include an AC bias adjust pot in my modified 222C. The Sofia is no longer in production, but Jim Hagerman makes a fine tube curve tracer, the VacuTrace[8].

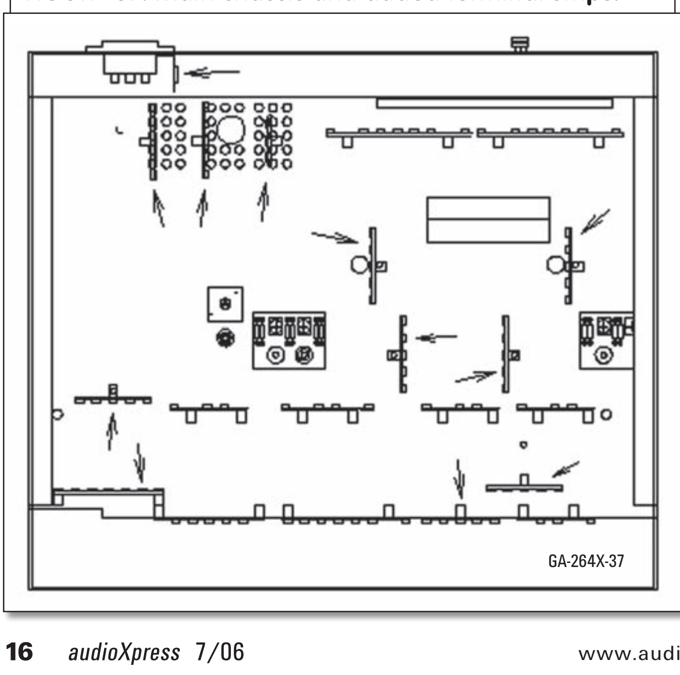
The output stage and output transformer are mainly responsible for the distortion characteristic. An ideal push-pull amplifier will cancel all even harmonics. You already know from **Fig. 30** that the output transformers have a small even harmonic content due to the winding imbalances.

The second harmonic can also occur if there is an imbalance in the bias current between the push-pull pair. A large imbalance can cause momentary saturation of the output transformer on each swing of the AC output voltage. Higher orders of even harmonics are produced if the dynamic characteristics of the output tubes vary significantly from each other.

If you want to use unmatched tubes, setting the DC bias to 22mA in each tube will still leave you with the dynamic unbalance caused mainly by differences in tube transconductance. This can lead to higher levels of even-order harmonic distortion (some may even find this sonically desirable). You can compensate for this by adding an AC bias adjust pot in series or in parallel with R142/R242. With the pot centered, the total resistance should still equal 15k. I don't know how much adjustment range will be needed, but if the pot resistance is not optimal you risk drawing too much current in the phase inverter with the pot at its minimum setting.

In order to provide a center channel output signal that is compatible with my subwoofer power amplifier, I adjusted the value of resistor R13 to provide a center channel output signal level equal to the Direct input signal level when the loudness control is set for unity gain.

FIGURE 37: Main chassis and added terminal strips.



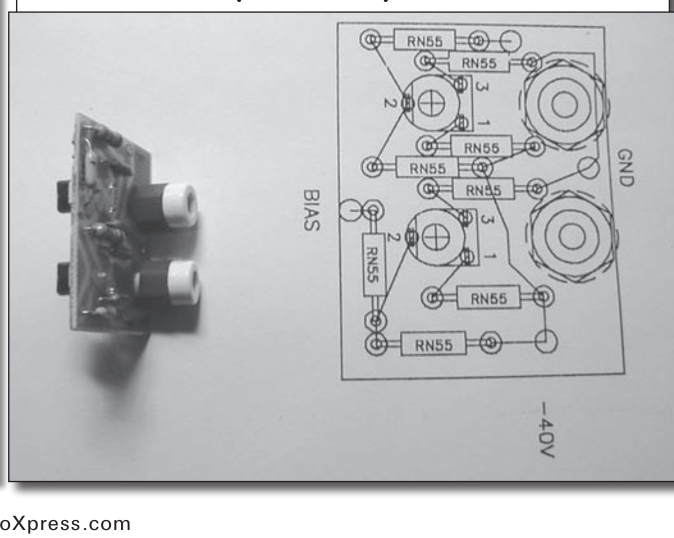
REBUILDING

Before I fired up the soldering iron, I made a new set of wiring drawings using the LK-48 ScottKit manual as a guide. Because of all my circuit changes, I needed to add 11 more terminal strips on the main chassis (indicated by the arrows in **Fig. 37**) and one on the rear chassis near the IEC receptacle. I installed the new terminal strips and tube sockets using 6-32 stainless steel hardware (available from Digi-Key). Stainless will not have a galvanic reaction with the aluminum chassis if moisture is present, as could occur with zinc-plated hardware. The original hardware was cadmium plated and after all those years the plating had started to turn to a yellow-green powder (cadmium is one of the environmentally undesirable heavy metals, and cadmium plating is being banned under the European Cadmium Directive 91/338/EEC).

I wanted to place the RIAA EQ network as close to the phono preamp tubes as possible, so I lost the use of the front panel RIAA/NAB switch as terminal points. I also decided not to use the scratch filter switch for some of the low-pass input filter components.

I must marvel at the wiring layout of the original 222C. The Scott engineers and designers crammed quite a lot of circuitry into their products, and most of the H. H. Scott line used just one chassis size. I left the old can capacitor C207-C210 in place but did not make connections to the positive terminals. I did use its ground terminals as grounding points

PHOTO 8: Bias adjust board layout detail.



for discrete replacement caps C3-C7.

Do yourself a favor and pre-tin any new old stock (NOS) items such as tube sockets, terminal strips, and so on. Make sure they take solder properly before you install them in the chassis. The original wire was solid core PVC wire, which is susceptible to melting with a solder iron. I used Teflon insulated wire, which is readily available on eBay in convenient 50′ lengths, for all my re-wiring, and I followed the original 222C wire colors as closely as possible.

Before making the bias adjust boards, I made a preliminary CAD parts layout to find the minimum size I needed. Then I located a space near the output tubes where the boards could fit. Since the bias adjust pots and pin jacks needed to fit through new holes in the chassis, I made a chassis drill jig from ⅛″ aluminum so the hole locations would be accurate. This is important because the pot adjusters cannot bind in the holes.

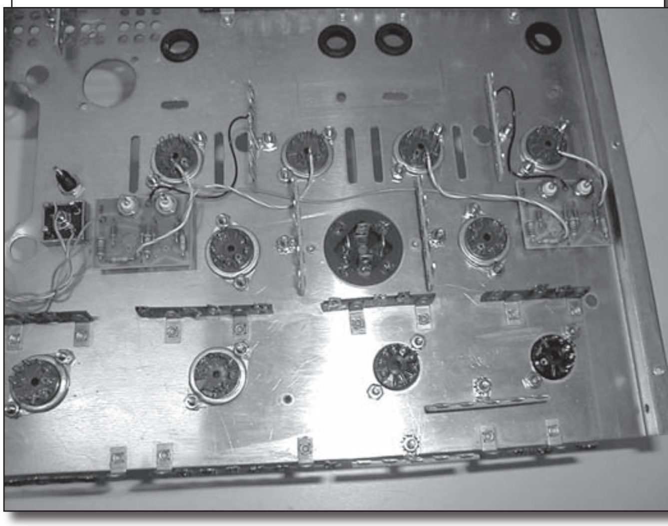
I routed the tracks for the two bias adjust boards with my Dremel router. The track layout and one of the finished boards is shown in **Photo 8**. Each board has two adjust pots with pin jacks that allow the mV drop across the 10Ω output tube cathode resistors to be monitored and adjusted from the top.

I added plastic spacers that allow the pin jacks to do double duty as circuit board mounting studs. These spacers bring the two bias adjust pots to the ideal height in their holes in the chassis. I first used the chassis drill jig to exactly locate the pots on the boards and soldered them in place. The installation of the boards in the main chassis is shown in **Photo 9**, while a close-up of a board installation is shown in **Photo 10**.

The new tone control and balance pots have slightly smaller metric bushings so they no longer self-center in the old mounting holes. I had to fit the front plate on and adjust each pot by trial and error until it was centered. The anti-rotation tabs are also on the opposite side, so the pot terminals are upside down from the originals. This doesn't affect the wiring at all.

I drilled a new anti-rotation hole for the input selector rotary switch because it didn't line up with the old one. The

PHOTO 9: Bias adjust boards installed in chassis.



second deck of this switch and the deck mounting screws came very close to one of the original terminal strips on the main chassis when I test-fitted the front chassis before I began wiring. I used a belt sander to grind down the length of the two rear deck spacer bushings to 7⁄32″ (same as the front deck spacers) and cut eight threads from the two 1-⅜ × 4-40 deck mounting screws to allow the switch to fit properly without interference. The rewired front panel is shown in **Photo 11**, with the original wiring drawing from the LK-48 manual. I didn't wire the headphone jack, as I mentioned earlier.

Once I removed the riveted input jacks and their insulated spacers, I reused the outer phenolic insulators for the new rear panel phono jacks. The original jacks were more closely spaced than in today's units, as was pretty much standard for the time. RCA plugs were quite small and didn't have threaded outer shells. The shield braid was fitted over and soldered to the ground shell.

As a result, most modern phono plugs won't fit the close spacing without the A and B channel plug shells hitting each other. I considered a custom fiberglass jack insulator, but the cutouts in the rear panel sheet metal preclude any closer spacing. I had to use small metric Deltron gold jacks (available from Mouser) to fit the available space. The holes in the Scott insulators are actually too big for the Deltron jack body, but the included gold flat washer works fine.

There is a problem inside the chassis because the included ground lug is too small and pulls through the insulator hole. I solved this by using a fiber shoulder washer at the rear of each jack. These washers are only available in inch sizes, so I had to bore the ¼″ ID of each washer to 7mm with a reamer to allow the threaded jack body to pass through the shoulder washer.

The good news is that holes in the original phenolic insulators were large enough to allow me to space the jacks for each channel further apart than the originals. Now modern sleeved interconnects will just fit without the plug shells touching. The phenolic insulators and fiber washers provide the only mechanical support for the new jacks, so they flex a bit when I plug in a pair of interconnects.

I also test-fitted the rear panel before doing any wiring to be sure the new gold speaker binding posts would not hit the main chassis. The rewired rear panel (**Photo 12**) is again shown with the original LK-48 drawing for that panel.

The original 222C used "mike lapel" wire (an insulated wire and a bare wire running in parallel inside black vinyl

PHOTO 10: Bias adjust board installation closeup.

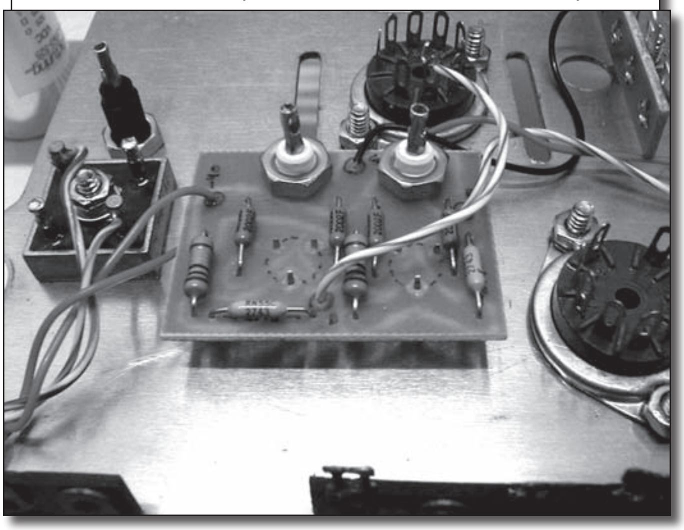


PHOTO 12: Rewired rear panel.

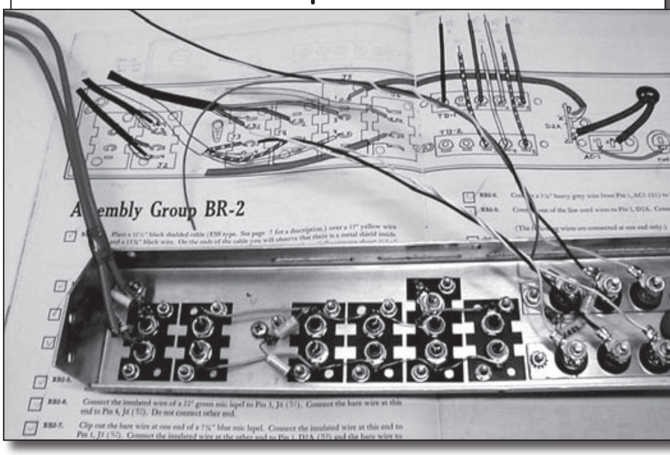


PHOTO 11: Rewired front panel.

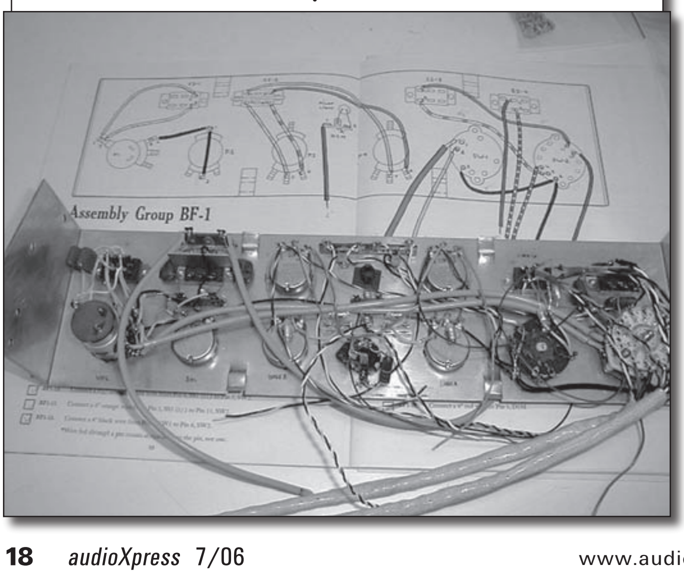
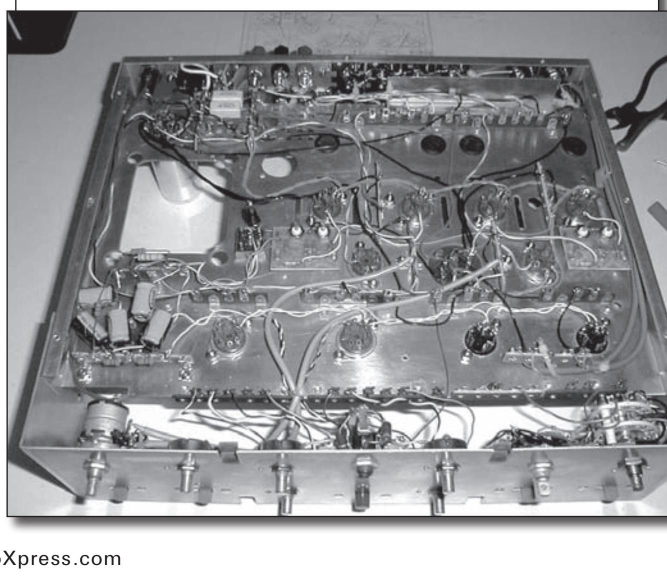


PHOTO 13: Front and rear panels installed to main chassis.



sleeving) for some of the line-level signals on the front panel. The wiring from the line-level input jacks on the back routed all the line-level signals for each channel together inside one piece of "conductive vinyl," which is sleeving with a conductive material inside which surrounded the hookup wire. I replaced these with twisted pairs running inside high temperature Varflex sleeving. The mag phono inputs originally used "ESS conductive cable," a hollow vinyl tube with a spiral metal shield inside. I used conventional twisted-shielded pairs here.

Photo 13 shows the modified front and rear panels re-installed and interconnected to the main chassis. The new resistors and five green filter caps for the output tube bias supply and the DC supply for the four 12AX7 tubes are installed at the lower right.

Photo 14 shows a bottom view of the chassis with all the wiring completed, just prior to the transformers being installed on the main chassis. I dressed the wiring with nylon wire ties where necessary.

Photo 15 shows the bottom of the modified 222C with the transformers installed. Although there are more parts

PHOTO 14: Main chassis bottom view with all wiring completed.

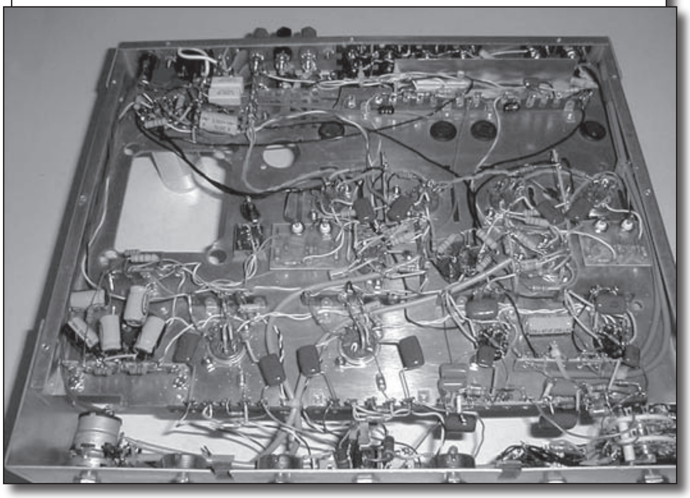
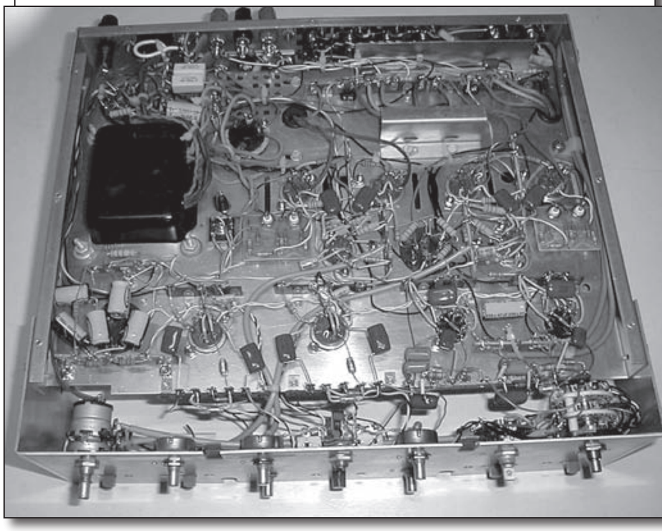


PHOTO 15: Bottom view with transformers installed.



than in the original unit, modern passive components are smaller and have thinner leads and higher maximum temperature ratings. This leads to a lower parts density, which will improve the cooling.

POWER UP THE UNIT—CAREFULLY!

Rather than just turn on the AC line voltage, I decided to take it one deliberate step at a time for safety sake. First I did a point-to-point resistance check and a visual inspection of all the solder joints and the parts and wiring clearances around any high voltage locations. Without any tubes in the unit, I connected a 30V DC power supply to pin 2 of the 5AR4 rectifier socket. Then I connected a fixed resistor from each tube socket plate to cathode and plate to screen pin in turn and made sure there was 30V DC at each plate and screen, a small voltage at each cathode, and no voltage at each control grid.

Next, I repeated these tests with a high voltage supply, slowly increasing the voltage while looking for any evidence of high voltage breakdown. This also made sure the electrolytic filter capacitor charge currents were not excessive the first time they had voltage applied. I installed all the tubes except the HV rectifier and used a Variac to slowly increase the AC line voltage.

I measured the 6.3V AC heater voltage and made sure all the tubes were lit. I measured the 50V DC across the four 12AX7 preamp tube heaters and the -40V DC output tube grid bias voltage. I set the four grid bias pots fully counterclockwise (maximum grid cutoff).

Only when all these tests were successful did I install the HV rectifier tube and begin operational tests. I connected shorting plugs to the EXTRA input, turned the loudness to zero, connected 8Ω load resistors to the 8Ω output binding posts, and plugged in the AC cord. The inrush current limiter prevented the bright heater flare-up that was so noticeable in the original amplifier, especially in the series 12AX7s.

The Scott 222C, 222D, and LK-48 family of amplifiers called for a total output tube pair bias current of 44mA, or 22mA per tube. (The 7189 data sheet calls for an idle current of 15mA per tube.) I set the bias for each output tube to Scott's recommended 22mA (220mV

TABLE 4: PARTS LIST.

Symbol	Value	Description	Vendor	Part no.
C1, C2	10nF 1kV	ceramic Y5P	Mouser	140-102P9-103k
C3-C7	100µ 100V	aluminum 105c	Mouser	140-HTRL100V100
C101, C202	40µ/20µ/20µ/20µ at 525V	aluminum FP	AES	C-EC40-20X3-525
C102, C202	47µF 250V 10%	aluminum 105C	Mouser	140-HTRL250V47
C103, C203	100nF 250V 10%	polypropylene	Mouser	1429-2104
C104, C128, C204, C228	100nF 100V 10%	polypropylene	Mouser	1429-1104
C105, C205	27nF 100V 10%	polypropylene	Mouser	1429-1273
C106, C206	47nF 250V 10%	polypropylene	Mouser	1429-2473
C107, C207	1µF 250V 10%	polypropylene	Mouser	1429-2105
C108A, C108B, C208A, C208B	1n5 600V 5%	polypropylene	Mouser	715P15256JD3
C109, C209	820pF 50V 5%	polystyrene axial	Mouser	23PS182
C110, C210	180pF 50V 5%	polystyrene axial	Mouser	23PS118
C111, C211	56pF 500V 5%	ceramic NBP	Mouser	140-50N5-560J
C112, C212	1200pF 50V 5%	polystyrene axial	Mouser	23PS212
C113, C213	1500pF 50V 5%	polystyrene axial	Mouser	23PS215
C114, C118, C119, C125, C126, C214, C218, C219, C225, C226	100nF 400V 10%	polypropylene	Mouser	1429-4104
C115, C215	33µF 25V 20%	aluminum 105C	Mouser	140-HTRL25V33
C116, C216	4700pF 50V 5%	polystyrene radial	Mouser	23PW247
C117, C217	470pF 50V 5%	polystyrene axial	Mouser	23PS147
C120, C220	47pF 500V 5%	ceramic NPO	Mouser	140-50N5-470J
C121, C122, C221, C222	22n 250V 10%	polypropylene	Mouser	1431-2223k
C123, C223	4µ7 160V	aluminum 105C	Mouser	140-HTRL160V4.7
C124, C224	120pF 500V 5% silver mica		Mouser	5982-15-500V120
C127, C227	220pF 500V 5% silver mica		Mouser	5982-15-500V220
CL1	250 1.7A	CL200 inrush current limiter	Mouser	527-CL200
D1	6A 200V	diode bridge	Mouser	583-RS603
F1	2.5A slo-blo	fuse 3AG		re-use
J1		IEC receptacle		
J2		tip jacks, bias voltage (B1k)	Mouser	530-105-0803-001
J3		phono jack, gold (wht)	Mouser	161-1005
J101-J106		phono jack, gold (blk)	Mouser	432-0100
J107, J108, J207, J208		speaker post, gold (red)	AES	S-H266R
J109, J209		speaker post, gold (blk)	AES	S-H266B
J110, J111,J210, J211		tip jacks, bias voltage (red)	Mouser	530-105-0802-001
J201-J206		phono jack, gold (red)	Mouser	432-0500
R1		680k 1W 10% carbon composition		re-use
R2	15 1W 5%	metal oxide	Mouser	261-15
R3-R5	18 1W 5%	metal oxide	Mouser	261-18
R6	7k5 2W 5%	metal oxide	Mouser	262-7.5k
R7, R8	91 1W 5%	metal oxide	Mouser	261-91
R9A, R9B,R10A, R10B	1M pot, linear (bass, treble)	carbon	Mouser	31VA601
R11	500k pot, dual tapped at 18k5 (loudness) w/sw	carbon	Mouser	re-use
R12	500k pot, linear (balance)	carbon	Mouser	31VA505
R13	120 ¼W 5%	carbon film	Mouser	291-120
R101, R201	39 5W 10%	wirewound	Mouser	280-CR5-39
R102, R202	3k5 3W 5%	wirewound	Mouser	588-23J-3.5k
R103, R203	9k1 3W 5%	wirewound	Mouser	588-23J-9.1k
R104, R204	16k 1W 5%	metal oxide	Mouser	261-16k
R105, R205	10k0 ½W 1%	metal film	Mouser	273-10.0k
R106, R206	47k5 ¼W 1%	metal film	Mouser	271-47.5k
R107, R207	3k32 ¼W 1%	metal film	Mouser	271-3.32k
R108, R208	22k ¼W 1%	metal film	Mouser	271-221k
R109, R209	1k50 ¼W 1%	metal film	Mouser	271-1.5k
R110, R210	82k5 ¼W 1%	metal film	Mouser	271-82.5k
R111, R116, R119, R136, R145, R150, R211, R216, R219, R236, R245, R250	1M00 ¼W 1%	metal film	Mouser	271-1.0M
R112, R212	110k ¼W 1%	metal film	Mouser	271-110k
R113, R213	806 ¼W 1%	metal film	Mouser	271-806
R114, R214	1M50 ¼W 1%	metal film	Mouser	271-1.5M
R115, R215	90k9 ¼W 1%	metal film	Mouser	271-90.9k
R117, R217	2k80 ¼W 1%	metal film	Mouser	271-2.8k
R129, R229	10k0 ¼W 1%	metal film	Mouser	271-10k
R118, R218	100k ¼W 1%	metal film	Mouser	271-100k
R120, R140, R152, R155, R220, R240, R252, R255	274k ¼W 1%	metal film	Mouser	271-274k
R121, R221	3M3 ¼W 5%	carbon film	Mouser	291-3.3M
R122, R123, R222, R223	2M2 ¼W 5%	carbon film	Mouser	291-2.2M
R124, R130, R214, R230	100k ½W 1%	metal film	Mouser	273-100k
R125, R131, R225, R231	2k744 ¼W 1%	metal film	Mouser	271-2.74k

R126, R127, R128, R227, R228	68k1 ¼W 1%	metal film	Mouser	271-68.1k
R132, R232	22k1 ¼W 1%	metal film	Mouser	271-22.1k
R133, R233	150k ½W 1%	metal film	Mouser	273-150k
R134, R234	249k ¼W 1%	metal film	Mouser	271-249k
R135, R235	1k00 ¼W 1%	metal film	Mouser	271-1k
R137, R237	15k0 ¼W 1%	metal film	Mouser	271-15k
R138, R238	1k21 ¼W 1%	metal film	Mouser	271-1.21k
R139, R239	221k ½W 1%	metal film	Mouser	273-221k
R141, R144, R241, R244	8k25 ¼W 1%	metal film	Mouser	271-8.25k
R142, R143, R242, R243	15k 2W 5%	metal oxide	Mouser	262-15k
R146, R149, R153, R154, R246, R249, R253, R254	20k0 ¼W 1% metal film	Mouser	271-20k	
R147, R148,	20k 1W trimpot	cermet trimpot	Mouser	652-3306F-1-203
R247, R248				
R157, R158,	10 1W 5%	metal oxide	Mouser	261-10
R257, R258				
R159, R160,	1k 1W 5%	metal oxide	Mouser	261-1.0k
R259, R260				
R161, R261	68 1W 5%	metal oxide	Mouser	261-68
R162, R262	8k2 ¼W 5%	carbon film	Mouser	291-8.2k
R163, R263	150 ½W 5%	carbon film	Mouser	293-150
S2	input select sw	Electroswitch 4P 6 pos, D4C0406	Newark	22F611
S3	tape monitor sw	2P2T slide		
S4	stereo selector sw			re-use
T1		TR 12-3-2 power transformer		re-use
T101, T201		TR 8-5-1 output transformer		re-use
V1		GZ34/5AR4 FW rectifier		
V101, V102		12AX7 dual hi-mu triode	Raytheon	
V201, V202		ECC83/12AX7 dual hi-mu triode	Raytheon	
V103, V203		6U8/GH8 triode-pentode	RCA	
V104, V105, V204, V205	7189 beam power pentode	Telefunken	re-use	
		1⅜″ diameter can cap insulators (2)	AES	S-H120
		sockets, (6) 9-pin, shield bse (6U8)	AES	P-ST9-700
		sockets, (4) 9-pin (7189)	AES	P-ST9-511
		socket, (1) octal (5AR4)	AES	P-ST8-807
		extruded shoulder washers (13)	Digi-Key	SC1145-ND
		Terminal strip, (1) 2-lug, 1 ground	AES	P-0201H
		Terminal strips, (6) 5-lug, 1 ground	AES	P-0501H

across the 10Ω cathode resistors) and let the 222C operate while I continued to check bias current for 30 minutes. The 7189 bias drifted ±4mA and showed some interaction between the adjustments for each pair. I settled on 20mA and accepted a couple milliamps of upward drift.

Next I measured the ripple on the 7189 plate and screen supply voltages (see **Photo 16** at 5V/cm plate and 1V/cm screen). While the plate supply ripple is now down to 3Vp-p, I believed there was still too much ripple on the

PHOTO 16: AC ripple voltage at the plate and screen grid, initial test of redesigned 222C.

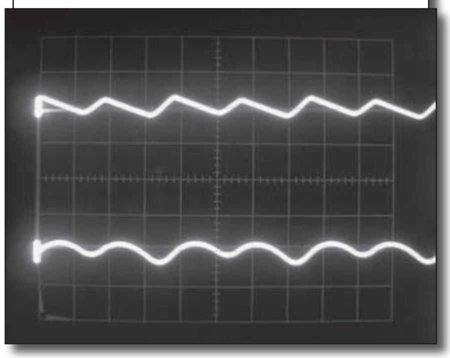
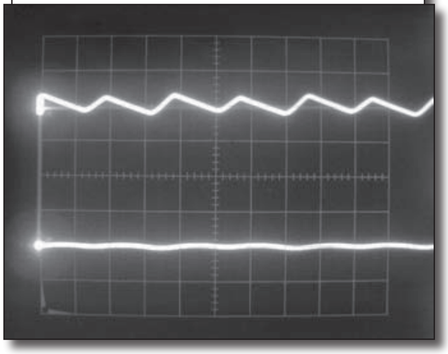


PHOTO 17: AC ripple voltage at the plate and screen grid, final design.



screens. I increased R102/R202 from 560Ω, which I originally scaled from the 222D values, to 3k5. While this reduced the screen grid ripple, the cascade effect on the other supplies made them too low.

Back to SPICE to adjust each series resistor to restore the proper B+ values to all the other tubes. The final values are those shown in **Fig. 33**. **Photo 17** shows the AC ripple voltage at the 7189 plate and screen grid with this final design of the dual mono power supply.

I again reset the output tube bias to 22mA, and after a half-hour the zero signal plate voltage supply measured +445V DC, with +440V DC at the plates. Reducing the line voltage to the 117V AC in use at the time the 222C was designed produced a still-high +432V DC at the plates. Short of rewinding the HV secondary on the power transformer, or purchasing a suitable replacement, I didn't have much recourse except to live with it.

The zero signal plate dissipation is now 9.7W versus 8.8W with the specified 400V DC plate voltage (see the two diagonal dashed lines in **Fig. 38**). While the plate voltage is 10% above the maximum, this is still less than the rated 12W plate dissipation for a 7189. I don't want to add more series resistance between the rectifier and the plate supply as regulation will suffer. Fortunately, the voltage and current swings along the linear load line in a Class AB1 push-pull circuit take the dynamic plate dissipation away from the constant power parabola in the plate curves.

Without any active voltage regulators the power supply voltages vary with both AC line voltage and with output power. The variations with line voltage at 1kHz 1W/channel output are shown in **Fig. 39**. The variation with 1kHz output power at a fixed AC line voltage of 120V AC is shown in **Fig. 40**. I have also thrown in a graph of amplifier efficiency versus output power in **Fig. 41** for your edification. At normal listening levels the efficiency of my modified 222C is about 3%. Raising all those cathodes to their thermionic operating temperatures is not free, and the 222C consumes 42W to do so.

I applied a 1kHz 0.5V RMS sine wave to the Extra Input and adjusted the loudness for 2W/channel. I let the amplifier run in for 30 minutes sitting on its bottom plate, then tipped the unit on its side and measured component temperatures with an Extech 42530 infrared non-contact digital thermometer. This unit has a laser pointer that pinpoints the component being measured. The hottest components (other than the

FIGURE 38: Plate curves, load line, and power dissipation.

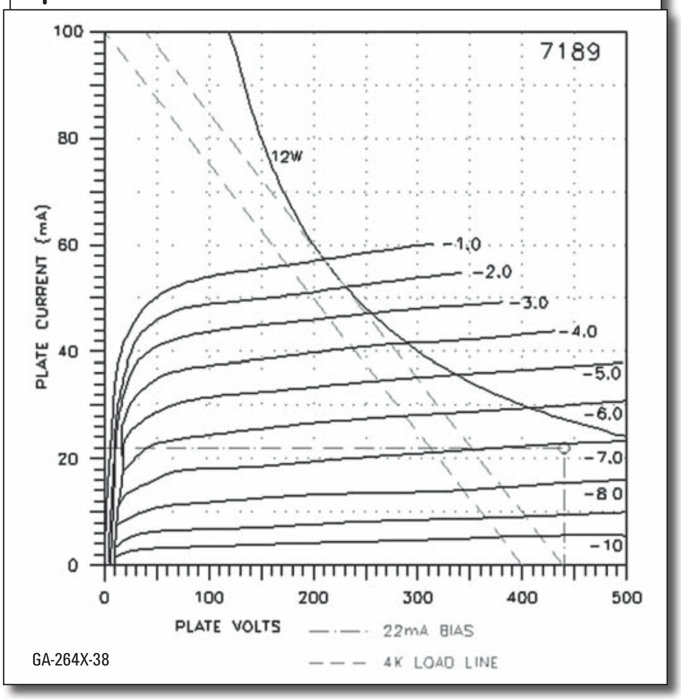


FIGURE 39: Variation of DC supply voltages with AC line voltage.

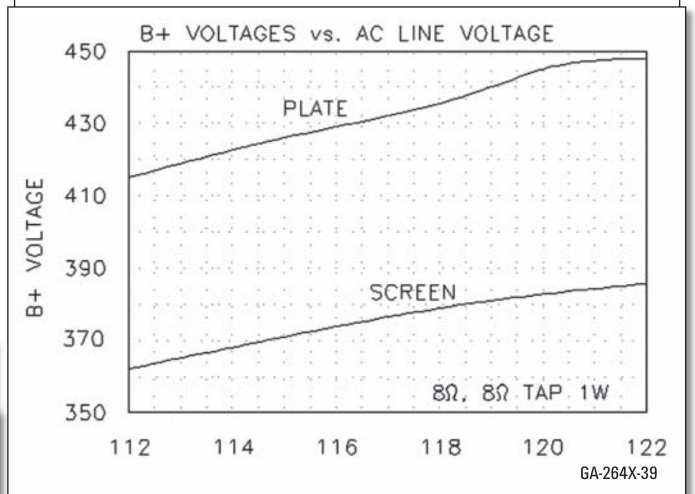
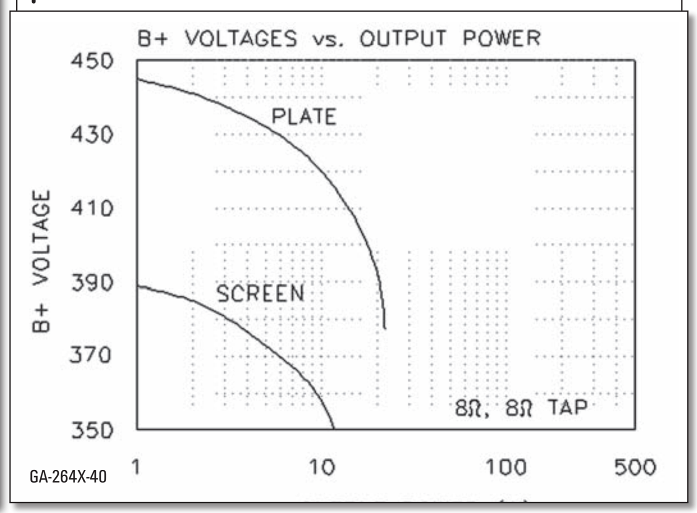


FIGURE 40: Variation of DC supply voltages with output power.



tubes) and their temperatures are listed in **Table 6**. Finally, I ruggedized the larger discrete aluminum caps to the chassis with RTV, and then installed the bottom cover and the front panel.

The front and rear of the completed unit are shown in **Photos 18** and **19**. **Photo 20** shows a top view with the four bias white adjust jacks and blue pots near the two outside output tubes. The black common bias jack is to the right near the power transformer. I used clear label tape to label the tube types on the top of the chassis, and to label the inputs and outputs on the top of the rear chassis. The latter makes it easy to identify the connections from the front of the unit.

The output tubes in **Photos 18-20** are Russian-made "6п14п" (translates in English to 6p14p—see the Sidebar in part 4 for comparison tests with the 7189).

TABLE 6: HOTTEST COMPONENT TEMPERATURES.

Component	Max Temp °C
CL1	75
R103/R203	60
Chassis at V1	60
R101/R201	50
R102/R202	50
R104/R204	48
T1	41
D1	36

FIGURE 41: Amplifier efficiency vs. output power.

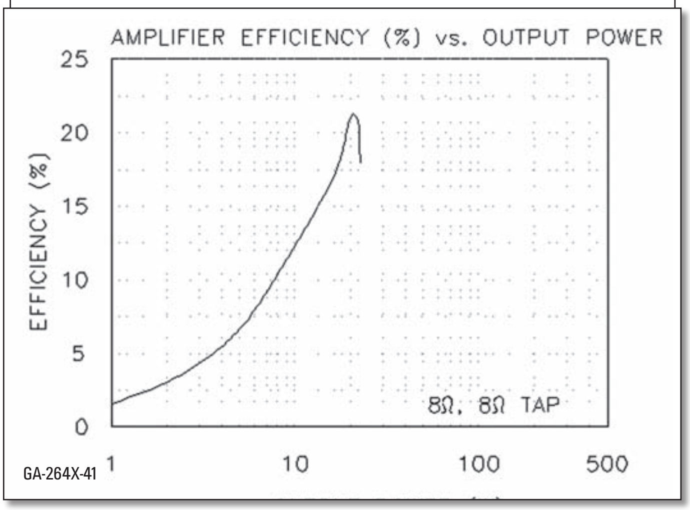
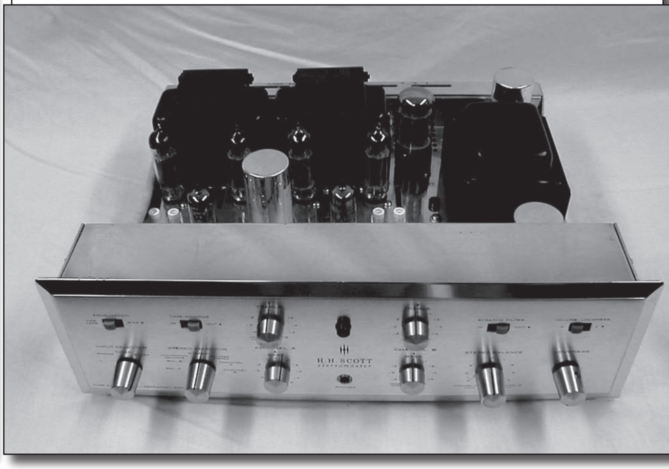


PHOTO 18: Front view of completed unit.



Next month, I'll wrap up this extensive restoration project with a listening audition and a look at the responses of the modified amp. *aX*

References

8. "Product Review, The VacuTrace," Charles Hansen, *audioXpress*, pp. 56–63, Feb. '02 (The article shows plate curve traces both with the Sofia and the VacuTrace).

9. *Tube Lore*; L. Sibley; Sept. 1996, with supplements 1997, 2002; Chernay Printing.

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www.tubesandmore.com

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701 Brooks Ave. South
Thief River Falls, MN 56701-0677
1-800-344-4539
www.digikey.com

Mouser Electronics
958 N. Main
Mansfield, TX 76063-4827
1-800-346-6873
www.mouser.com

Newark Electronics
Chicago, IL 60640
1-800-263-9275
www.newark.com

PHOTO 19: Rear view of completed unit.

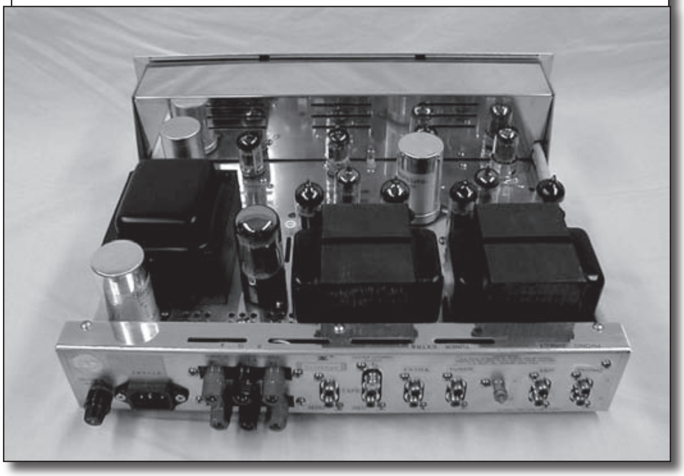

PHOTO 20: Top view of completed unit.