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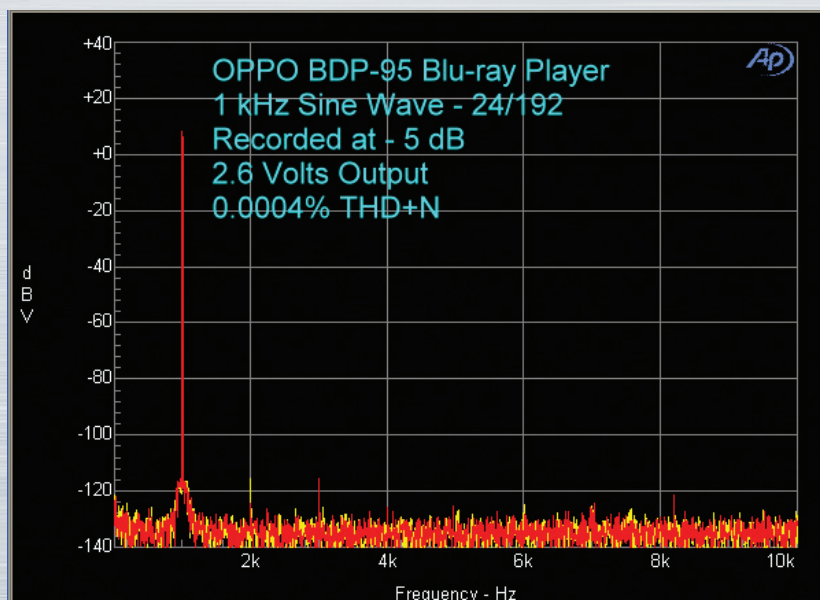




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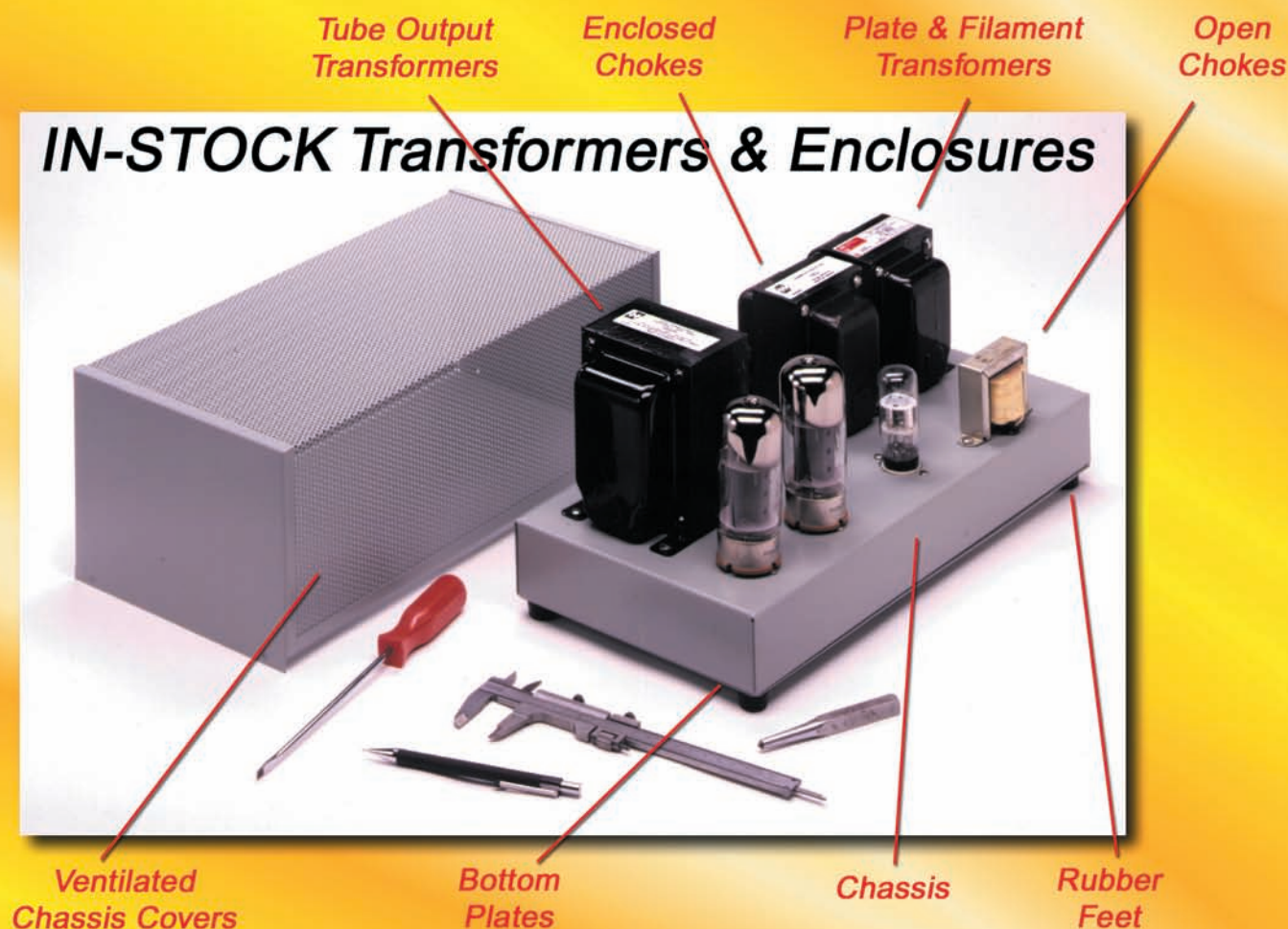
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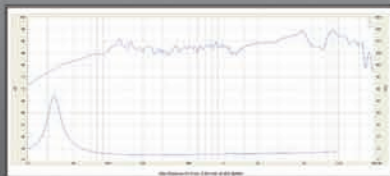
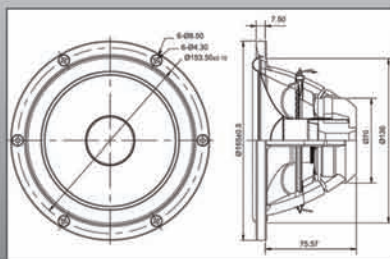
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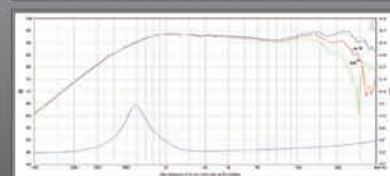
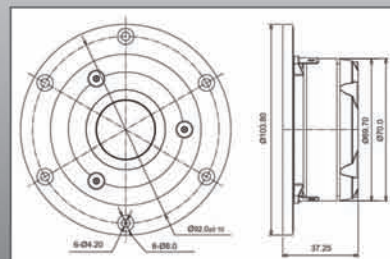
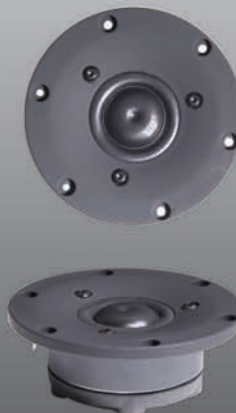
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Preliminary Data

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Voice coil inductance, Le	0.16 mH	Mechanical Q-factor, Qms	4.9
Effective piston area, Sd	119 cm ²	Electrical Q-factor, Qes	0.36
Voice coil diameter	35.5 mm	Total Q-factor, Qts	0.34
Voice coil height	17 mm	Moving mass incl. air, md	13.4 g
Air gap height	5 mm	Force factor, Bl	6.5 Tm
Linear coil travel (p-p)	12 mm	Equivalent volume, Vas	44.8 ltr
Magnetic flux density	1.17 T	Compliance, Cms	2.23 mm/N
Magnet weight (NEO)	0.13 kg	Mechanical loss, Rm	0.5 kg/s
Net weight	1.01 kg	Rated power handling	60 watt

The parameter are measured on drive units that are broken in

Specs :

Nominal Impedance	4 Ω	Free air resonance, Fs	590 Hz
DC resistance, Re	3.0 Ω	Sensitivity (2.83 V/1m)	93 dB
Voice coil inductance, Le	0.02 mH	Mechanical Q-factor, Qms	2.5
Effective piston area, Sd	9.6 m ²	Electrical Q-factor, Qes	1.5
Voice coil diameter	29.0 mm	Total Q-factor, Qts	0.9
Voice coil height	2.0 mm	Force factor, Bl	1.8 Tm
Air gap height	2.5 mm	Rated power handling*	100 Watt
Linear coil travel (p-p)	0.5 mm	Magnetic flux density	1.0 T
Moving mass incl. air, Mms	0.45 g	Magnet weight	0.22 kg
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The Solid-State Duo, Part 1

In this two-part article, the authors present two amplifiers capable of satisfying many users' power needs.

Because we are working on a digital-crossover system, which requires the use of as many amplifiers as frequency ranges and drivers, we started to look for suitable and reasonably priced DIY amplifiers. Our purpose was to design and construct a complete do-it-yourself audio system.

After many conversations about the affordable architectures and power re-

quests, we ended up choosing two uncommon amplifiers: the My Ref. rev. A and the Hypex UcD180. The former is based on the National LM3886 IC (www.national.com/mpf/LM/LM3886.html), whose smaller brother, the LM3875, is quite well known in the DIY world thanks to the Gainclone amplifier. The My Ref. amplifier described here is not another Gainclone,

but a completely different and smart implementation of the LM3886, where the "classic" voltage feedback amplifier concept evolves to a different step.

The latter is a class D amplifier from the Dutch company Hypex (www.hypex.nl), capable of a continuous power of 180W with a 4Ω load and a THD of 1%. The UcD180 is to be covered in the second part of this article.

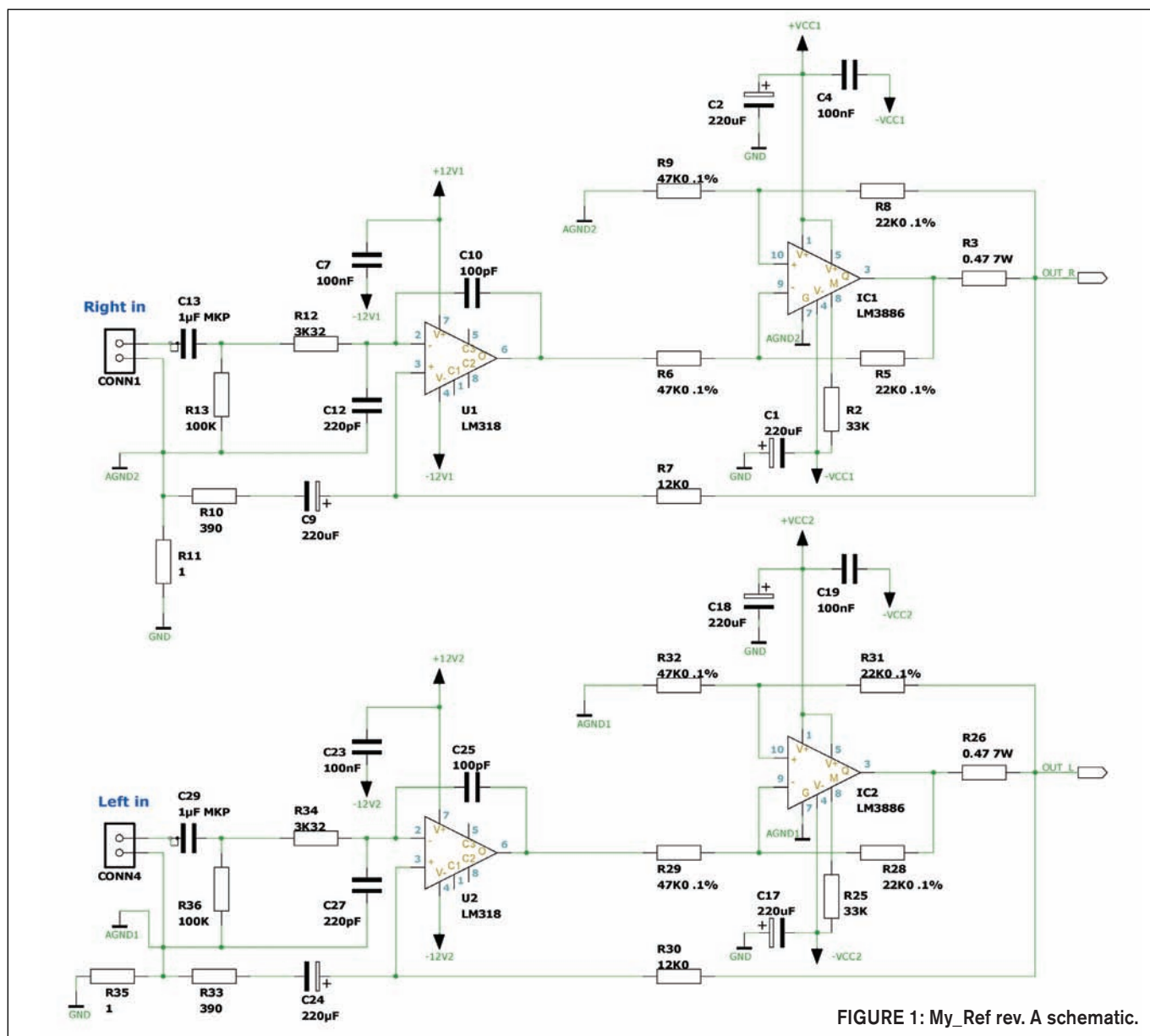


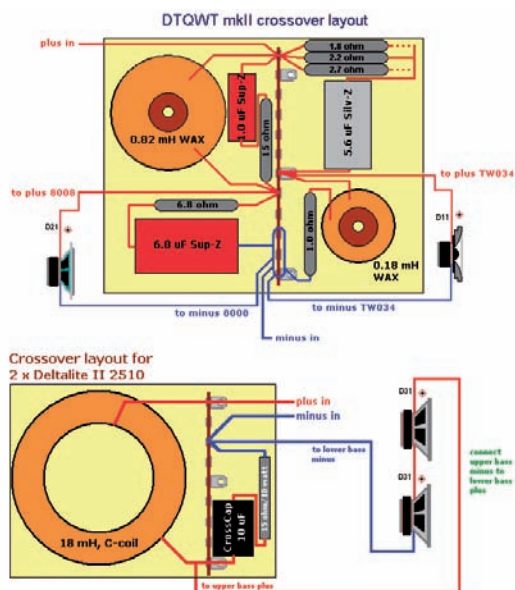
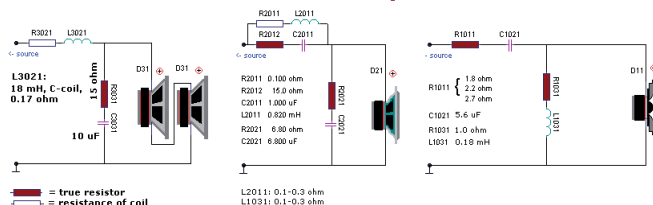
FIGURE 1: My_Ref rev. A schematic.

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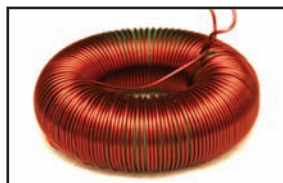
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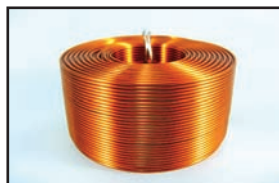
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This article also describes a simple and cheap soft-start circuit, a “four ears” listening comparison of the two amplifiers and how they performed at our bench lab.

MY_REF REV. A

This open source project was designed by the Italian Mauro Penasa, and premiered in the diyAudio Forum (www.diyaudio.com) in March 2005. The interest aroused by the My Ref. amp was enormous! With the thread counts totaling more than 300 pages.

Figures 1 and 2 show, respectively, the amplification circuit and the power supply with a speaker protection section. From the schematic you notice that the My Ref. has a high open loop gain, and quite a lot of NFB applied in a particular manner since the output stage is a transconductance one. These are all uncommon features in modern audio amplifiers. Moreover, the Italian designer of this project has studied Graham Maynard’s reverse-driven measurements (Maynard published various articles on this subject in the magazine EW, between 2004-2005).

By this test, you can see the DUT damping factor amplitude and phase changes in the audio spectrum. Both Maynard and Penasa found a correlation between the reverse-driven measurement and the sonic result. Their conclusion was that an amplifier with an almost flat damping factor amplitude, as well as a phase without big rotations, ensures a clean and balanced sound. If you are interested in the topic, you can read more about it on Mauro’s home page: www.webalice.it/mauro.penasa/index.html.

The My ref. amplifier plays music very well, given that more than a thousand of them have been built worldwide. There wouldn’t be that much interest from the DIY community if this project’s musicality or electronic circuit were lacking.

My Ref. comes in three flavors (revisions), with the A and C versions the most popular. This article uses the first revision (A). In this version Penasa wanted to reproduce the sound of a single-stage class A amplifier, such as the JLH 10W or the Aleph, while the rev. C is a different amplifier rather than

an upgrade from rev. A.

You can switch from one revision to the other just by substituting a few components, using the same PCB (**Figs. 3-4**). As you can see, we used a single face Eurocard. If you are interested in the Gerber files of the PCB, you can download them from Mauro’s home page. He suggests that, to make the PCB, you use 70µm (2 oz.) of copper, or solder the PCB traces, to maximize the current flow.

This PCB has “all on board,” so you just need to add a cabinet, a transformer, a switch, and a main fuse to get it ready to rock. The components list is in **Table 1**, the parts suppliers are Farnell (www.farnell.com), Distrelec (www.distrelec.com), and RS-Components (www.rs-components.com).

The specifications are:

- Frequency response: 2Hz-70kHz
- Rated power output (8Ω): 40W RMS
- Rated power output (4Ω): 56W RMS
- Damping factor (8Ω): > 200
- S/N ratio (600Ω): > 96dB un-weighted

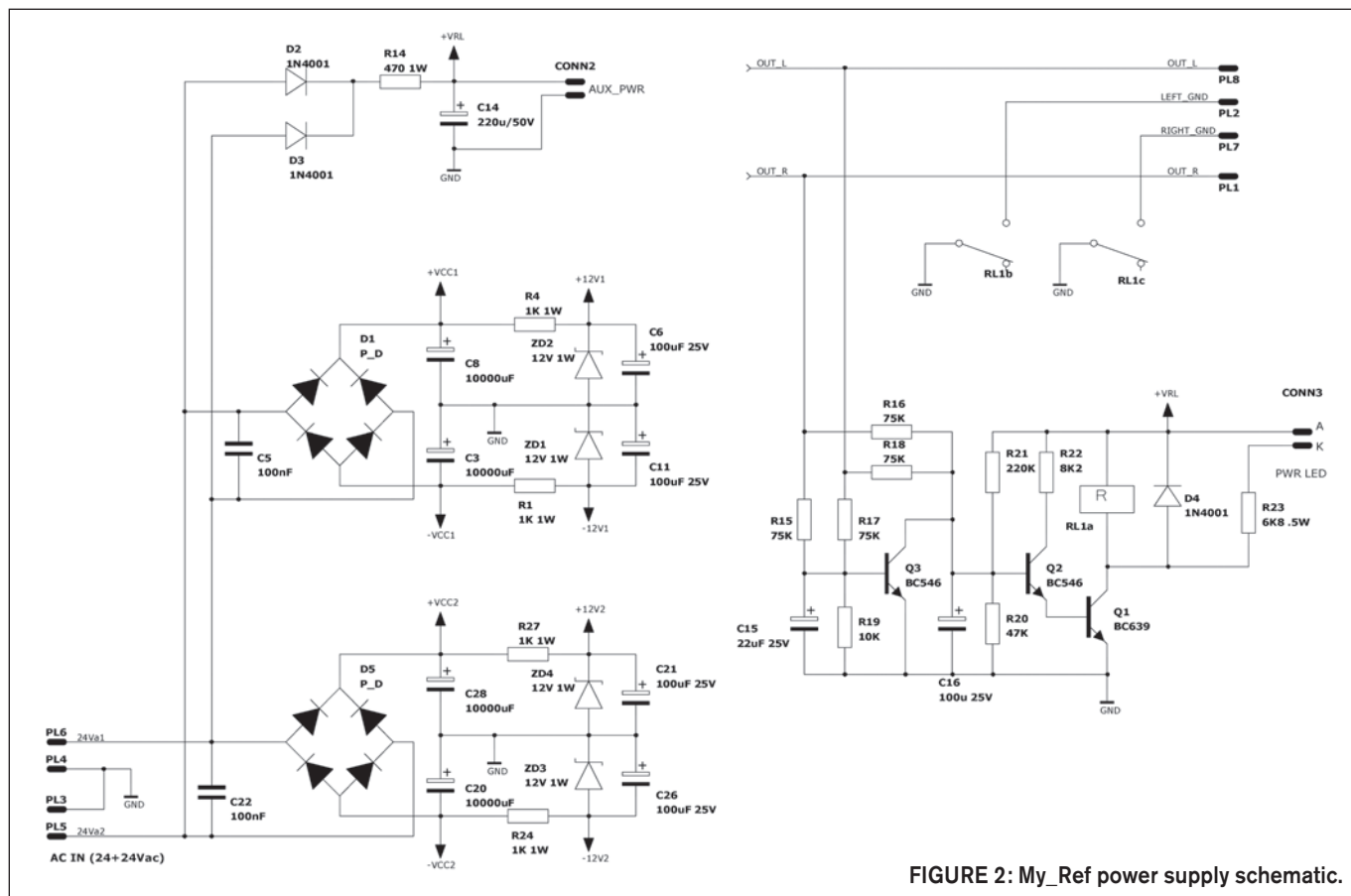


FIGURE 2: My_Ref power supply schematic.

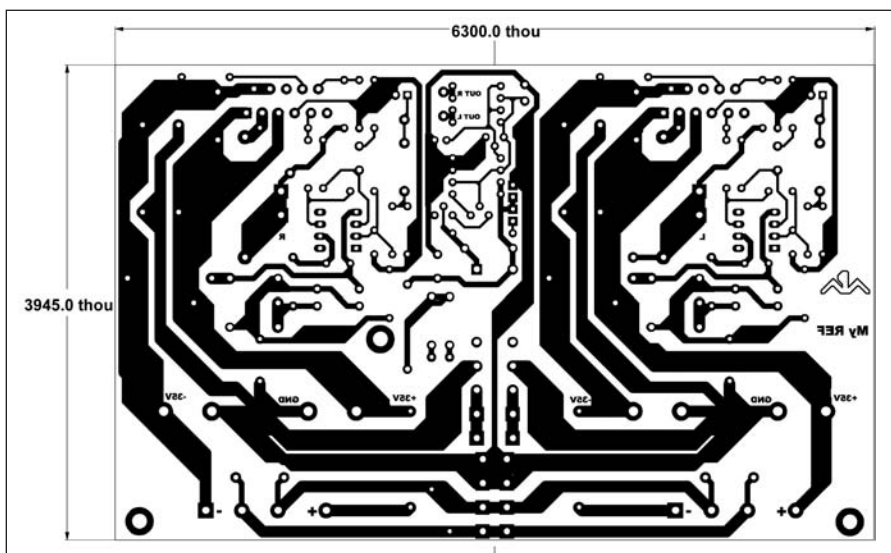


Figure 3: PCB solder side. Actual dimensions: 100 × 160mm.

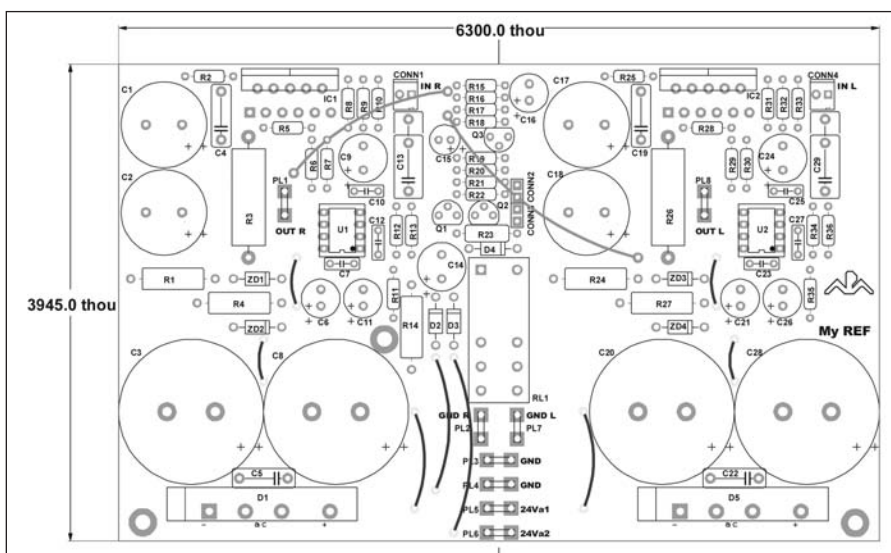


Figure 4: PCB component side.

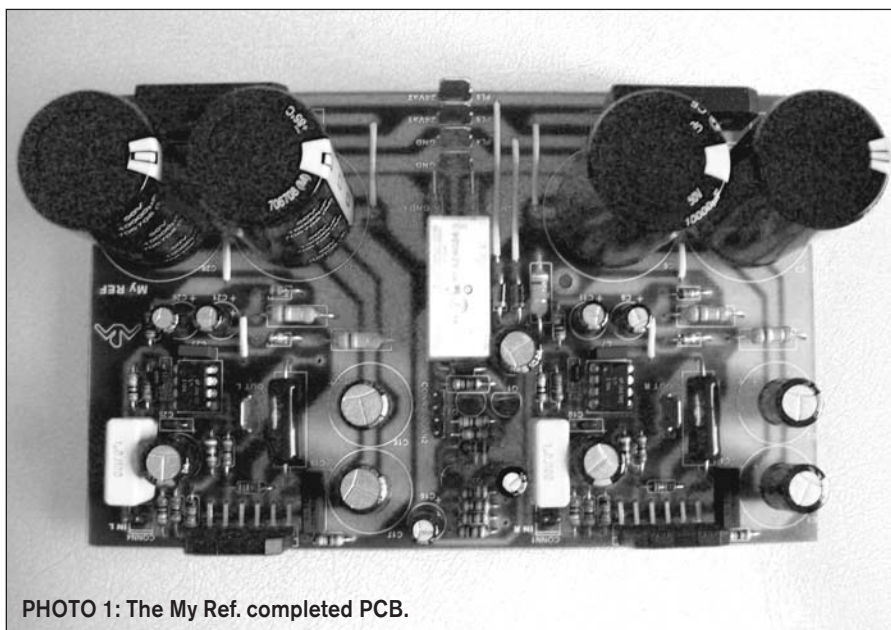


PHOTO 1: The My Ref. completed PCB.

- THD (20Hz-20kHz, 1-40W, 8Ω)
< 0.05%

CONSTRUCTION

We started soldering the PCB components, beginning with the smaller ones: first jumpers, resistors, diodes, the DIP8 socket for LM318N, then capacitors, faston, relay, leaving the four big electrolytic caps, the bridges and the power ICs for last. To increase the heat dissipation, it's important to solder the power resistors (R3, R26, R1, R4, R14, R24, R27) and the zener diodes (ZD1-2-3-4) about 5mm from the PCB. To achieve this, place a small piece of plastic (or paper, or foam) between the component to be soldered and the PCB. Once you solder the part, you can slide off the thickness. The finished PCB is shown in **Photo 1**.

To dissipate the power IC generated heat, the author suggests a 1° C/W heatsink. However, we decided on a different way. We used a cabinet, the GX288 by HiFi 2000 (www.hifi2000.it), capable of dissipating the heat through its aluminum panels (the laterals are extruded). Moreover, we placed a small heatsink, the Fischer Elektronik SK68/75, between the LM3886 and the GX288 back panel. We applied thermal grease between the parts to increase the heat transfer, while 3MA type screws block the IC to the heatsink, and this one to the GX288 back panel. **Photo 2** illustrates the results.

We recommend you solder the IC at the very end, so that you are sure of the proper coupling between IC heatsink, and cabinet. Also double-check—after blocking the three parts—for aluminum residue, which can cause undesirable shorts on the PCB. We used the plastic insulated LM3886, which has the TF suffix. In case you decide to use the uninsulated kind, be sure to use a gasket isolation kit.

Once the amplifier PCB and its heatsink are firmly placed inside the cabinet, it's time to take care of the power transformer, using an M6 screw to affix it to a 3mm thick rectangular piece of Bakelite. A neoprene foil between the transformer and the Bakelite decouples the parts. In **Photo 3** you can see that the Bakelite is glued to the

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cabinet lateral caves (we recommend gluing only after having verified that the amplifier is working).

Start the cabling, beginning with the IEC power connector visible in **Photo 4**. There is an X2 class 275V AC capacitor connected to the neutral and phase whose aim is to suppress RFI (radio frequency interference). Be sure to insulate the exposed capacitor terminals as well as to glue it firmly. Always keep in mind the danger involved in working

with AC line voltage!

A cable (A) connects the power connector ground terminal to the case. Because our back panel is anodized aluminum, we had to rip off the surface to obtain a proper contact. The other two cables starting from the IEC connector go to the double pole power switch, located in the front panel (**Photo 5**). A 10nF X2 class 275V AC capacitor on each pole of the switch has the function of arc suppression to preserve, in

the long run, the switch contact from discontinuous current flow. Because the used power switch is illuminated, we didn't take advantage of the My Ref. available light connections.

If you prefer, you can directly connect a LED to CONN3 to acknowledge a "speaker-on" status, or to CONN2 for a "power-on" condition. In this last case, you must place a 6.8k Ω ½W resistor in series with the LED. The lighting "status" can be

PHOTO 2: Heatsinks and back panel of my ref. amp.



Photo 3: Sheet of bakelite glued to the case to support the transformer



Photo 4: Power line and signal cabling

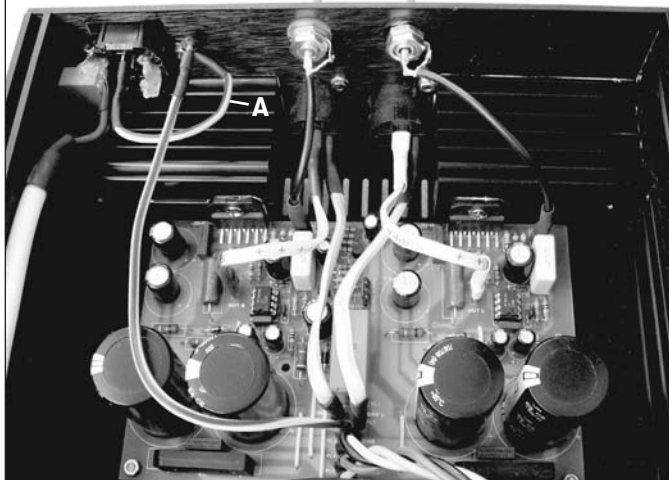


Photo 5: Switch cabling view.



Photo 6: Completed amplifier internal view.

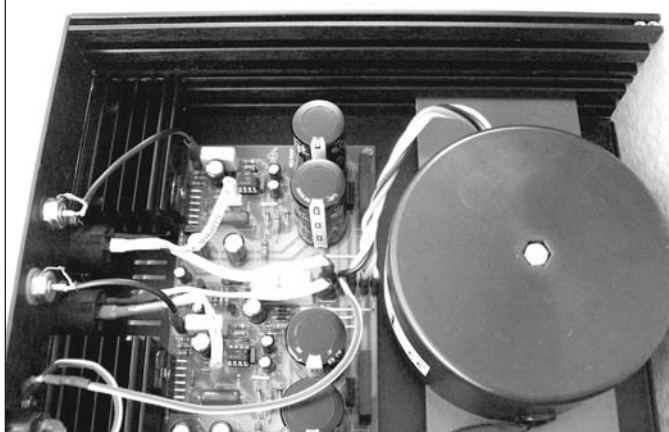
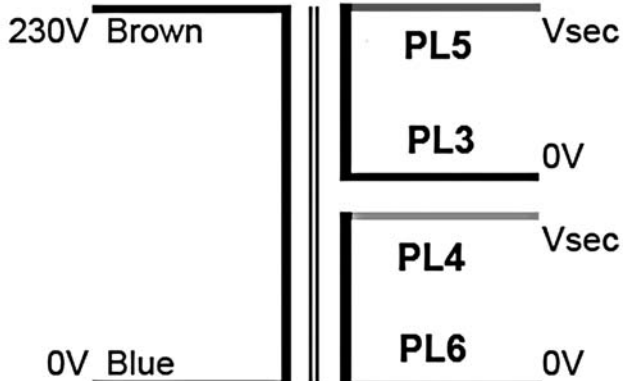


Figure 5: Transformer secondary cabling.



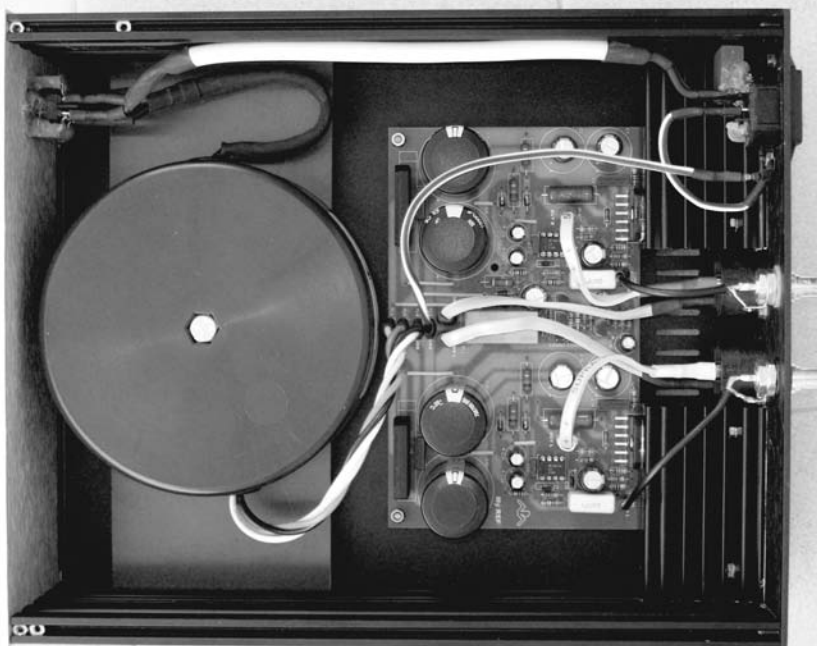


PHOTO 7: Inside the My ref. amp.

easily achieved with one bicolor LED. The other two poles of the power switch go to the transformer mains, keeping the phase cable correctly connected. Usually a dot on the transformer indicates where to connect the power line phase.

The four cables of the transformer secondary are twisted together to reduce interferences, and are connected to the PCB (PL3 to PL6) through faston. Depending on the chosen transformer, check for the proper match. We used the Multicom (alias Norotel) FE225/25, with the red cable inserted in PL5, orange in PL6, black in PL3, and the yellow one inserted in PL4 (Photo 6 and Fig. 5). Be sure to

compensate for the PCB bending while inserting the faston. From Photo 6 you can notice that a cable comes out from PL3 and goes to the chassis; this is the PSU ground to earth link.

The last cables to connect are the input/output audio signal, as depicted in Photo 4. Place the input cables—we used the RG174 type—away from high current components such as the output cables, the power supply cables, and the LM3886. Apply the same precaution to the panel input socket, placing them away from the IEC connector, output sockets, and LM3886. The output negative cables—the ones from PL2-7—run parallel to each other in an attempt to

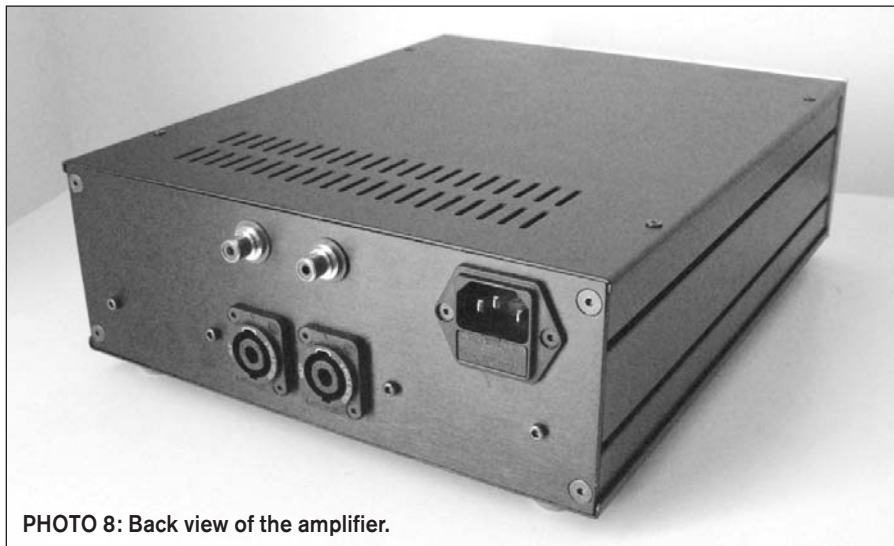


PHOTO 8: Back view of the amplifier.

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reduce the channel's diaphony.

The completed amplifier is visible in **Photo 7 and 8**. To increase the natural convective heat transfer through the cabinet upper and lower panel holes, we used rubber feet taller than those that come with the GX288.

INITIAL STARTUP

Once you've assembled your project, you're no doubt in a hurry to turn it on. But first, spend some time doing a final inspection. Take a look at the board to see whether everything is properly connected, and double-check the power supply filter capacitors proper polarity and the wiring of the AC line. Next, use a multimeter to verify that the LM3886T is isolated from the case, as well as that the input RCA cold terminal is not linked to the chassis.

Now place the ohmmeter terminals between PL3-4 and the case. You must see a short. Between the negative input RCA and PL3-4 you should read 1Ω —that is the value of R11-35—while you should read 2Ω between the two RCA negatives. Screw in the top panel and connect the line power cable to the IEC connector.

Turn on the main switch for just a few seconds, during which you should hear the relay acting. If no smoke/smell occurs, you are ready to turn the amp on again and measure each channel output DC offset. 20mV is the safe limit, measured with the signal input closed with a 600Ω resistor. If everything sounds good, turn it off, connect some cheap speakers to the My Ref. and start playing some music.

[See *aX Digital* (p.31) for measurements of the amp's performance. *aX Digital* is available to all subscribers. Simply send your e-mail address to Sharon at custserv@audioXpress.com]

CONCLUSION

The price to build this power amp is a bargain—\$300, placing it as a best buy product. To get the most out of the My_Ref rev. A, we suggest you use an active preamplifier instead of a passive one, which might cause an unwanted high-frequency response rolloff. In part 2, we will illustrate how this amplifier performed when playing music. *aX*

TABLE 1: Parts list

Reference	Description	Farnell P/N	RS-comp. P/N	Distrelec P/N
R1, R4, R24, R27	1K, 1W, 5%		131-839	712177
R2, R25	33K, 1/4W, 1%		148-859	714136
R3, R26	0.47, 7W, 5%, Wire Wound, Low ESL, 20 x 10 mm		159-297	721120
R5, R8, R28, R31	22K, 1/4W, 0.1%			710430
R6, R9, R29, R32	47K, 1/4W, 0.1%			710434
R7, R30	12K, 1/4W, 1%		148-758	714123
R10, R33	390, 1/4W, 1%		148-405	714079
R11, R35	1, 1/4W, 1%		150-565	714000
R12, R34	3320, 1/4W, 1%		477-8088	
R13, R36	100K, 1/4W, 1%		148-972	714148
R14	470, 1W, 5%		131-817	712169
R15, R16, R17, R18	75K, 1/4W, 1%		148-944	714145
R19	10K, 1/4W, 1%		148-736	714115
R20	47K, 1/4W, 1%		148-893	714140
R21	220K, 1/4W, 1%		149-060	714165
R22	8200, 1/4W, 1%		148-714	714113
R23	6800, 1/2W, 1%		149-795	714111
D1, D5	Diode Rectifier, Fagor B250 C5000/3300			602271
D2, D3, D4	Diode, 1N4001		628-8931	603560
ZD1, ZD2, ZD3, ZD4	Zener diode, 12V, 1W, BZX85C-12		812-487	
Q1	BC639		545-2276	610378
Q2, Q3	BC546		544-9292	610356
U1, U2	LM318N, DIL8, only National			640727
IC1, IC2	LM3886T or LM3886TF	9493603	827-079	641215
RL1	Relay, 24Vdc, 8A, 250V, 2 pole		198-6911	402608
C1, C2, C17, C18	Elec. Cap. 220 microF, 50V, low ESR, diam. 18 mm	1219481	526-1660	801852
C3, C8, C20, C28	Elec. Cap. 10000 microF, 40V, snap in, diam. 30 mm	1165579	339-6887	
C4, C5, C19, C22	MKT Cap. 100 nanoF, 100V, P 10, 43 x 133 mm		487-9787	820457
C6, C11, C16, C21, C26	Elec. Cap. 100 microF, 25V, diam. 8 mm	1219466	526-1430	801844
C7, C23	MKT Cap. 100 nanoF, 50V, P 5, 25 x 75 mm Or Ceramic COG		312-1469	820408
C9, C14, C24	Elec. Cap. 220 microF, 50V, diam. 10 mm	1219481	526-1660	801852
C10, C25	MKT Cap. 100 picoF, 50V, P 5, 25 x 75 mm Or Ceramic COG		211-4971	831575
C12, C27	MKT Cap. 220 picoF, 50V, P 5, 25 x 75 mm Or Ceramic COG		538-1225	831577
C13, C29	MKC Cap. 1 microF, 63V, P 10-15, 62 x 184 mm Or MKI or MKP or FKP			820370
C15	Elec. Cap. 22 microF, 25V, diam. 6.3 mm	8812993	228-6723	801808
PL1 to PL8	Faston, male, PCB mount., 6.3 mm		534-834	450280
CONN1 to CONN4	Molex, male, 2 poles or Pin Header	1360130	547-3239	114620
Transformer	Toroidal, encapsulated, Sec. 25+25 Vac, 225 VA	9531971	223-8831	
X2 Cap. 10 nanoF, 275V			616-7698	820729
Switch, illuminated, DPST		1082460		
Power Inlet IEC, fused, with 1A slow fuse		145358		110251
X2 Cap. 0.33F micro, 275V			441-9650	820745
Heathsinks, Fischer Elektronik SK 68/75				650204
Neutrix Speakon, 2 poles		3104400	2508451169	
Case Hi-Fi 2000 GX288 - http://www.hifi2000.it/				

Lilliputian Amplifiers

These SE and push-pull beauties are the latest in this author's love affair with tubes.

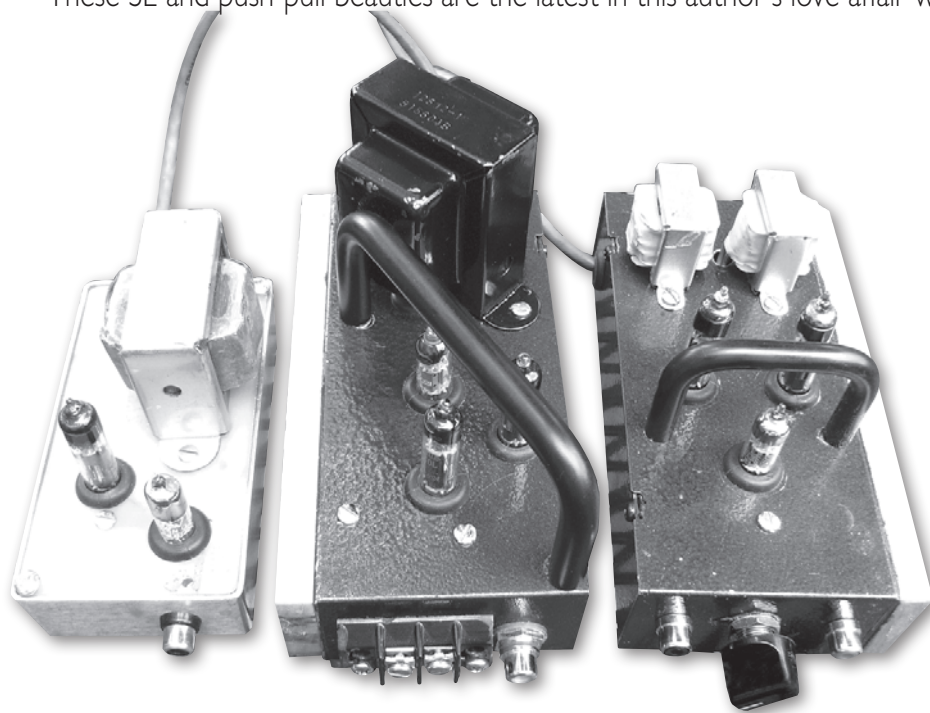


PHOTO 1: Three amps featuring mini tubes.

I love tubes!

I spend much of my free time building tube amps and rebuilding/restoring tube audio equipment in general. I have built amps ranging from 2-3W to 120W. Many of the construction articles in *audioXpress* have been the starting point for hours of fun. I have dozens of amps using a variety of tubes such as 6B4, 6V6, 6L6, EL34, 6AQ5, 6BQ8, 7591, KT88, 6550, and even the Compactron 6T10.

[The Author provides an interesting history of—and his experiences with—subminiature tubes. See *aX Digital*, p. 33. *aX Digital* is available to all subscribers. Simply send your e-mail address to Sharon at custserv@audioxpress.com]

DESIGN PLANS

Because I had collected a number of catalogs and datasheets for these tubes which included design data and sample circuits, it seemed reasonable to just start from the ground up, and use my

experience and some of the information found on the web. My intent was to build a single-ended amp and then a push-pull version.

I also intend at some point to build a headphone amp and maybe even a DC operated one using 6088 pentodes. I recently bought a few of the round type, but very small, a type used in a radio-sones, that is rated at several watts, but was designed for high power for only ten hours. I plan to test this at a lower output and see how long I can get it to live in a headphone amp.

The power supply for these two different amplifiers is very similar, and you can actually use the same one for both SE and PP amps. The major difference is that the SE power supply uses a choke for additional filtering. You can refer to many earlier articles on fine-tuning power supplies and using what you have on hand. The parts list includes a Hammond Power transformer available from Antique Electronic Supply. You could also use

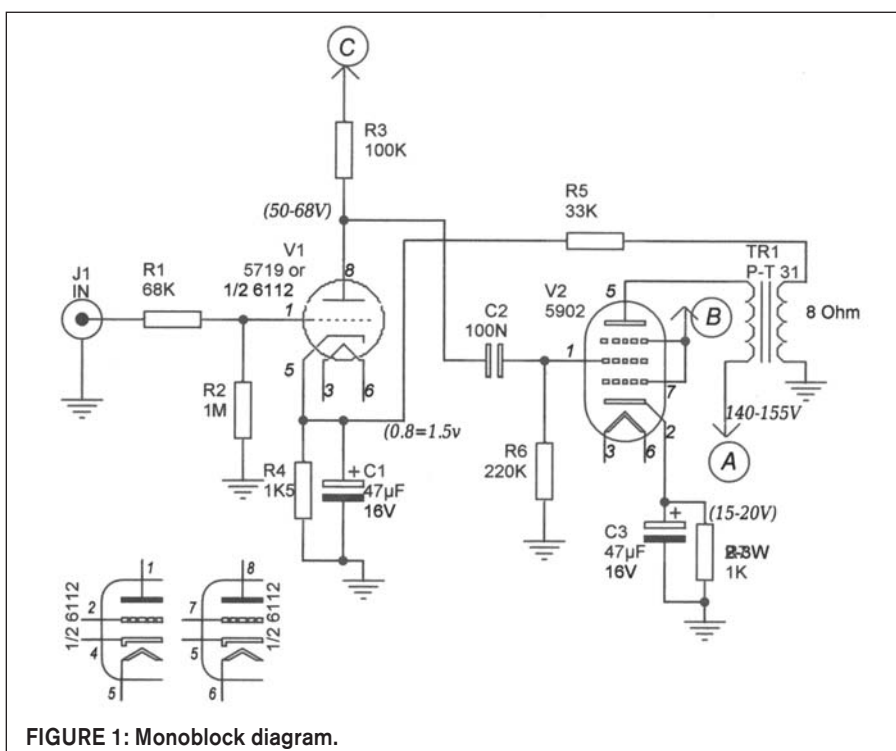
a small isolation transformer for the high voltage (120:120) and a small transformer for the filaments.

For the amplifiers in this article I am using the 5902 Power Pentode tube, which was specifically designed for audio use. It has a 6.3V filament drawing 450mA and is rated for 165V on the plates and 155 on the grids. The plate dissipation of this tube is 4W and the grid is 1W. These are pretty impressive numbers for a tube that is roughly 3/8" diameter and less than 2" long.

The driver tube I am using in the first amp (monoblocks) is a 5719 hi mu triode designed for low-level audio applications. It, too, has a maximum plate voltage of 165V with a plate dissipation of 1.1W. The heater draws 150mA. This tube is also available in a dual triode as a 6112, which I used in the stereo SE version (Fig. 1).

I needed to find some output transformers. Because this started out as an experiment, my first criterion was "inexpensive." My first search was AES, where I found the P-T31 SE 8W 5K primary 8Ω sec (100Hz-18kHz). This is a very inexpensive transformer, and, as it turns out, it works great here. If you want to build an amplifier with a lower frequency range rolloff, you could also use the Hammond P-T125ASE or P-T125A from AES, although they are considerably more expensive.

The auto bias setup for this amplifier is where one of the design issues typically seems to occur. The datasheets on this tube list 270Ω as the appropriate cathode resistor, but I have seen these as high as 1.8K. I settled on a 1K 3W silicon power resistor, which gives me 15-20V on the cathode, depending on individual tubes. You will notice a wide range of voltages on the schematics, which is due



to what seems to be a wide variation in different manufacturers' tubes and your potential power supply voltages.

SE CONSTRUCTION

The circuit is very straightforward and quite simple. The biggest difficulty I had was trying to find the best way to mount and connect the tubes into the circuit. On my original breadboard, I drilled small holes in some solid fiberglass circuit board, ran the leads through, and connected them on terminal strips. This didn't turn out to be satisfactory, so I tried grommets, with the tubes pushed through and then the leads connected

to terminal strips (**Photo 2**). This has worked pretty well, except when I overheated a couple of tubes during testing and melted some grommets.

The filament leads are generally on pins 3 and 6 (at least on the tubes I have used to date). Once you slide the tubes into the grommet and start to lay out your wiring, it is a good idea to try to route the filament leads far from the grids on the input tube (pin 1 on 5719 and 2 and 7 on the 6112). The schematic of the power supply (**Fig. 2**) for this first amp uses a choke, with separate decoupled voltage for the pentode connection and separate decoupled

driver tube voltage. For 2-5902s and 2-5719s (or one 6112) you will need a filament current of 1200mA and well under 100mA of high voltage current at between 120 to 150V. If you don't have anything that will work, AES has a Hammond transformer (P-T262F) that supplies 120V at 140mA and 6.3V at 1.5A.

I used 7-pin tube sockets for the umbilical cords because I had some 7-pin plugs from the surplus store and found some covers to glue on them. You may use whatever connector type you can find, such as Molex™ type, or build the complete amplifier and power supply on a single chassis (**Fig. 2**). Please observe safety practice and do not have exposed connections with a potential high voltage presence exposed.

I used some really small photoflash electrolytic capacitors in the power supply. They are 100 μ F 330V units. I am not sure what type of life they will have, but they were very inexpensive and extremely compact for their value. Feel free to use standard caps with a value of 47 μ F or better, if you don't feel comfortable with the photoflash caps.

When you complete your wiring, connect a 5-6k Ω 10W resistor between ground and the HV output to load the supply down and power it up. A high voltage output between 160 and 200V is fine.

When fine-tuning your supply, it is extremely important to let all caps discharge before you make any changes. Even though I have a bleeder resistor on the supply, I will still connect a 1K 2W



resistor across each capacitor positive and ground terminals. (Many years ago I made up a resistor like this with insulated clip leads and I use it all the time.)

If your voltage is a little low, you can add capacitance before the choke (see schematic option). If your voltage is a little high, you can add a 5-10W resistor between A and Y. Start with a 1.5K and repeat the process above to fine-tune. Try to keep the value of R1 around 10K because this isolates the grid and plate supplies. If your transformer has a center tap on the 6.3V winding, you can eliminate R3 and R4 ground reference resistors (**Photo 3**).

My initial design used midpoints in factory datasheets recommendations, and I adjusted these to fine-tune. Feel free to adjust the value of the 5719 plate resistor to achieve around 65V on the plate. The cathode voltage of about 1.5 seems to be pretty close. As I mentioned earlier, the cathode resistor of the 5902 of 1K gives a cathode voltage of 15-20V. I have tried to generally keep it at about 20V. The cathode is connected to pins 2, 4, and 8 internally, so you can cut off whichever two aren't convenient for you to use. Use a small side cutter and cut very close to the glass. (Be sure you are cutting off the right leads—the old

adage of measure twice and cut once also applies here!)

With all of these amplifiers you can vary the power tube cathode resistor to change auto bias setting and how much power it will produce. I have used between 270Ω and 1kΩ during my experimenting. I noticed no hum with this design, although this may be due to the rolloff of the output transformers.

The chassis for these monoblocks were cast aluminum Velleman G106, which are $4\frac{1}{2} \times 2\frac{1}{2} \times 1$. I cut some military glass board to replace the metal tops. After trying this I would just drill the metal top and have a complete metal case.

I liberally use Teflon tubing to cover leads of the tubes and components. I always tend to start at the output and work my way forward, adding terminal strips as needed. This is just my habit, do whatever works for you. You can even build the complete amp and power supply on a single chassis, but be sure to observe good layout practices.

I took this one over to my friend Larry's house and we hooked it up to some JBL 100s in his shop. He was very impressed and loved how "cute" it was; he was even more amazed by the sound of the amplifier. (Might make a good

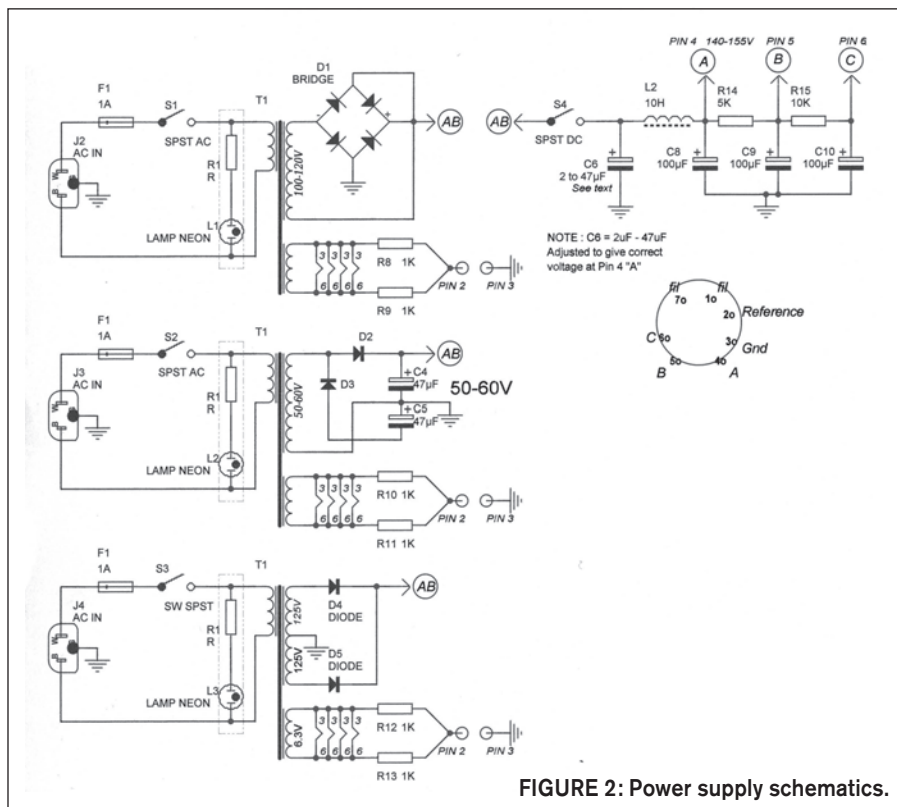
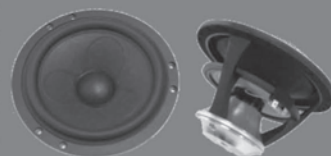


FIGURE 2: Power supply schematics.



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PHOTO 4: Completed pair of monoblocks.

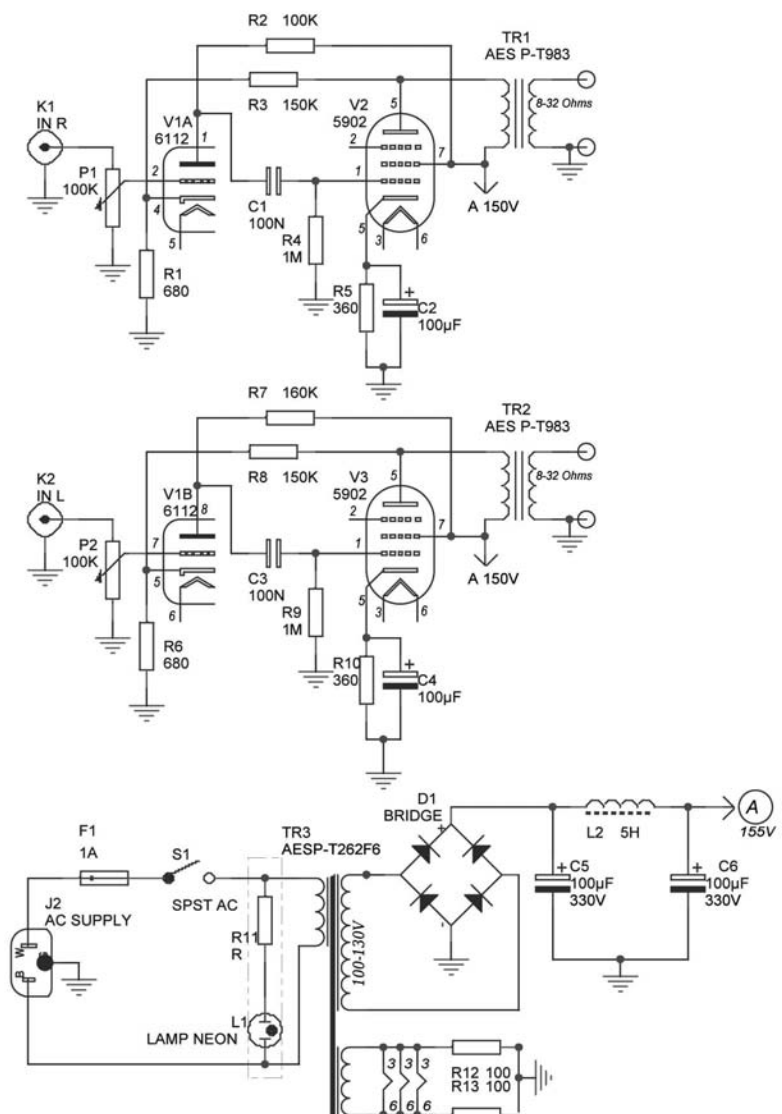


FIGURE 3: Stereo amp and power supply schematic.

project for the office or bedroom.) I played with this amplifier extensively in my shop hooked up to a set of Dynaco A-10s and I thought it really sounded wonderful, in spite of the rolloff below 100Hz. In my shop I usually listen to FM stations with a Van Alstine modified FM 5. With some better quality (more expensive) SE transformers, you probably could get much lower solid bass, but I am fine with the way they turned out (Photo 4).

I also built the SE stereo version shown earlier, with AES PT-983s output transformers. I really wanted to see how small I could go. These turned out really well, but the wiring was pretty tight. The amplifier circuit (Fig. 3) is simplified, as well as the power supply. I built these on some surplus video processor chassis that were stripped, painted with antique gray finish and then cut some Tiger wood sides (to cover excess holes).

PUSH-PULL AMPLIFIER

The next amplifier I built was a push-pull pentode mode set of monoblocks (Photo 5). I like the sound of pentode-connected amplifiers, even though they generally require a more complicated power supply (companies such as Fisher and Harman-Kardon can't be too wrong). You can use the Hammond power transformer specified above. The power supply is pretty much the same

(Fig. 4), although I didn't use a choke in this one. As I said earlier, everything is the same except for the decoupling resistor values.

The circuit (Fig. 5) is also a very standard push-pull power amp, which uses two 5902 pentode outputs tubes and a medium mu 6021 dual triode, with the first triode as an amplifier and the second as the phase inverter.

One of the keys to keeping these amps small is to use 200V coupling caps (a little hard to find; I bought some in a surplus store) and relative low voltage electrolytic caps specified in the parts list. You can eliminate the first coupling cap if you aren't worried about DC blocking. I used some surplus CATV chassis for the monoblocks and a regular BUD case for the power supply (rack handles to protect these little tubes come from the surplus shop, too). If you thought the SE ones were tight to work on, you really are going to enjoy this one! You could use the Velleman again, but it will be tight (Photo 6).

The output transformers I bought on eBay were from some German tape player amplifier. The seller said they were about 6K center tapped and they worked very well. I don't know the rolloff, but they produce substantial bass. You could probably use some Hammond universal outputs (P-T125A or C) and play around with the impedance taps to maximize the



PHOTO 5: Push-pull amplifier.

7052PH

Phantom Powered Measurement Mic System

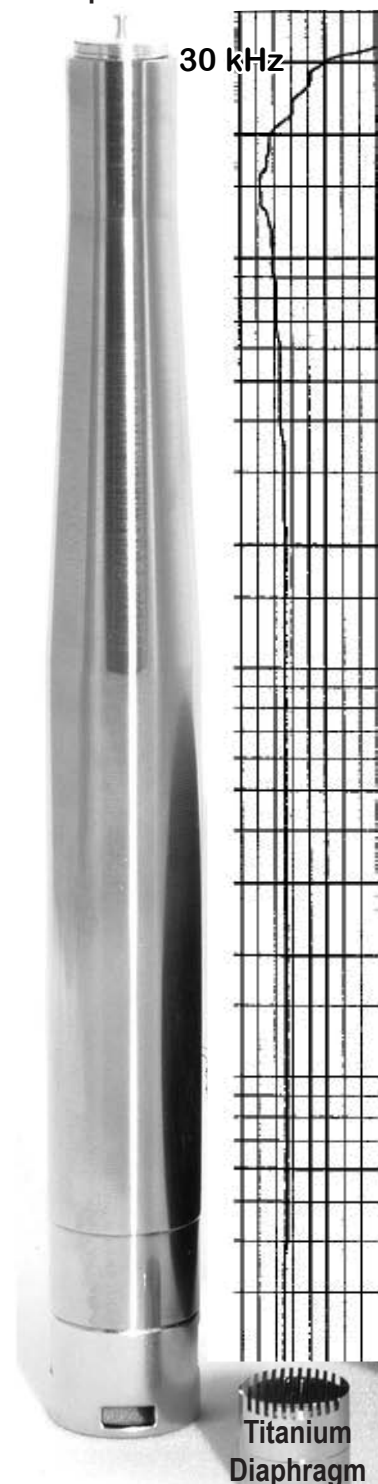
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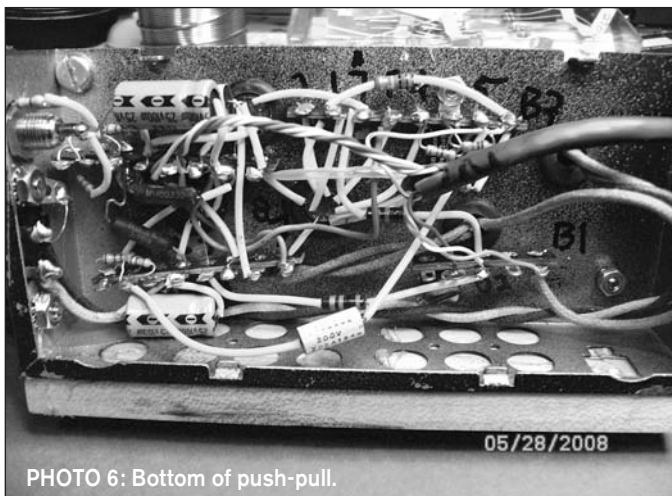


PHOTO 6: Bottom of push-pull.

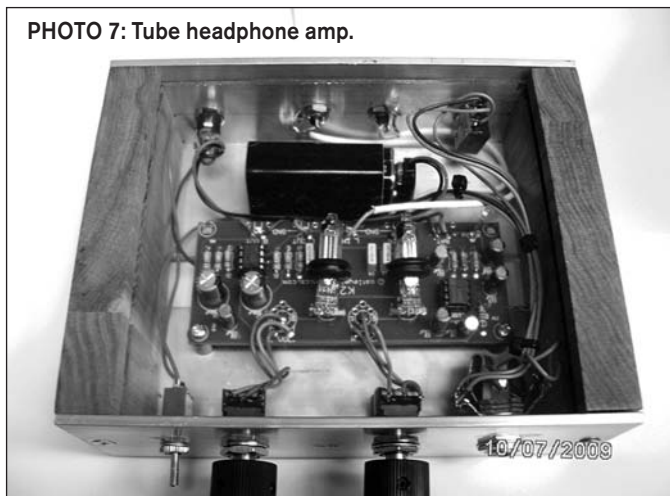


PHOTO 7: Tube headphone amp.

power and sound.

If you want to eliminate the umbilical cables and connectors, you can build the whole amp on a suitable size chassis. The main reason I elected not to do this for the first ones was to have just one power supply for all of these. The other reason was to keep the amps very small; you can generally hide the power

supply and impress your friends with the size of the amps.

NOTES ON BUILDING

You can change the cathode resistor (680Ω) of the first preamp section to modify the gain of the amplifier, to achieve the drive signal for full output. This value worked for me, on one chan-

nel, but I needed to change it a little bit on the other channel to balance them.

Also, you may need to lower or raise the value of the 100K plate resistor on the same tube section depending on the power transformer you use. I try to get 65-75V on the plate.

So how did these sound and where do we go from here? I found this to be an extremely pleasant experience and I think the amplifiers turned out very well. They are certainly unique. Everyone who has seen them says the same thing, "Boy those are cute! How do they sound?" This is usually followed by "Can you build me some?"

Just before I submitted this article, I saw a DIYAudio forum blog on a subminiature tube/MOSFET headphone amp/preamp. I ordered one and built it (Oakley electronics, www.oakleyelectronics.com). It is a very nice kit; you supply the appropriate case and jacks and you have a really nice headphone amp (and can be used as a preamp also for feeding your MP3 into a tube amp). It uses two pentodes (flattened subminiature tubes) operating in triode mode, driving a high quality headphone op amp, and does it all with a 9V battery. I tried it with several different headphones and input sources, and it really improves the sound of my iPod (Photo 7).

If I can be of any assistance to anyone interested in building any of these, please contact me at Tuninfork@aol.com. Keep your eyes open for some more subminiature stuff coming down the road. I just got a small DC to DC converter that can produce up to 150V, and it may be perfect for a battery-operated portable headphone amplifier. *aX*

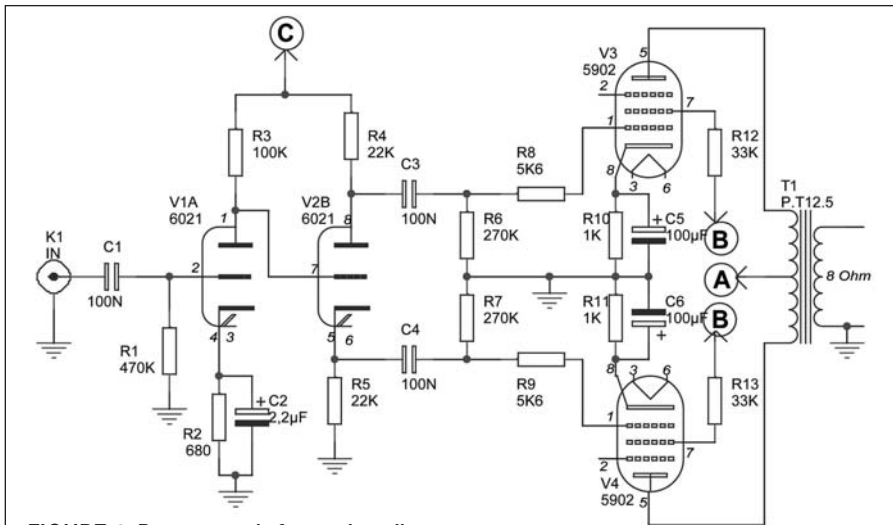


FIGURE 4: Power supply for push-pull amp.

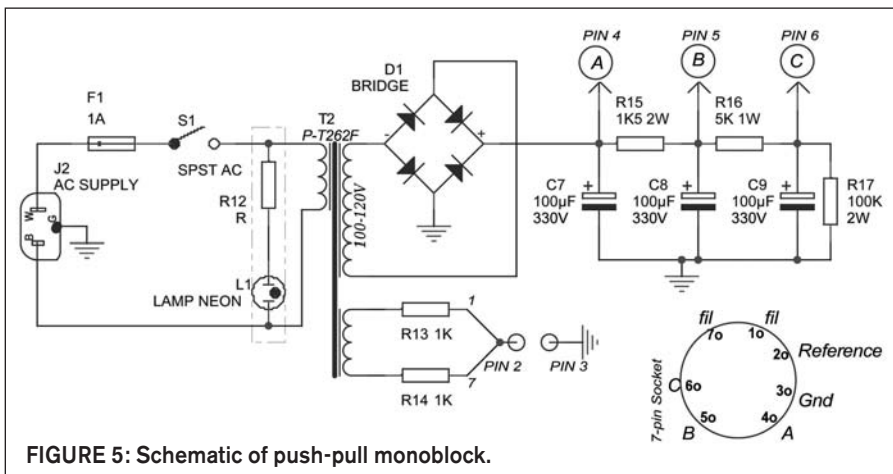


FIGURE 5: Schematic of push-pull monoblock.

PARTS LIST FOR MONOBLOCK SE AMPLIFIER (STEREO PAIR)

2- 68K ¼W resistors
 2- 1MΩ ¼W resistors
 2- 100K ½W resistors
 2- 1.5K ¼W resistors
 2- 220K ¼W resistors
 2- 1K 2W resistors
 2- .1μF (100nF) 200-400V film caps
 4- 47mF 16V electrolytic capacitors
 2- 4-5K SE output transformers (AES P-T31, see text)

2- 5719 high mu triode (or 1- 6112 dual if you are going to build both amps on the same chassis)

Miscellaneous

2- power connectors (jacks and plugs) and CAT 5 cable
 2- RCA input jacks
 2- output connectors (barrier strips or banana jacks—whatever you want)
 2- Velleman cast aluminum enclosure (G106) 115 × 65 × 30
 3/8 inside diameter grommets
 Teflon sleeving
 Assorted terminal strips
 Hook up wire

POWER SUPPLY

Power transformer (see text) or AES Hammond P-T262F6

200V 1A diodes or bridge (depending on the power supply configuration you choose. If using the above transformer use a bridge)

10H choke AES Hammond P-T158M
 5K 2W resistor
 10K 2W resistor
 3- 100mF 330V photo flash electrolytic capacitors (Electronic Goldmine)

1kΩ 2W resistors
 1- 100K 1W resistor

Miscellaneous

AC cord
 1A fuse and holder
 Neon AC indicator
 SPST switch
 1- Suitable enclosure 5" × 4" × 3" BUD
Parts list for Stereo SE amp is not shown

PUSH-PULL STEREO AMPLIFIER (FOR BOTH CHANNELS)

2- 470kΩ ¼W resistors
 2- 680Ω ¼W resistors (see text)
 2- 100K ¼W resistors (see text)
 4- 22kΩ ¼W resistors
 4- 220K ¼W resistors
 4- 5.6kΩ ¼W resistors
 2- 33K ½W resistors
 4- 1K 2W silicon resistors

6- .1μF (100nF) 200V film capacitors
 2- 2.2mF 10V electrolytic capacitors
 4- 100mF 35V electrolytic
 2-6021 medium mu dual diode subminiature tubes
 4- 5902 pentode beam power subminiature tubes
 2- Output transformers (see text) AES P-T125A, P-T125C, or P-T291
 2- RCA input jacks
 2- output connectors (your choice)
 2- Power connector, umbilical cable or chassis large enough for both amps and power supply
 Chassis of your choice

POWER SUPPLY

1- Power transformer AES P-T262F
 1- Power switch
 1- 1 amp fuse and fuse holder
 1- Neon AC indicator
 1- 200V 1A bridge rectifier
 2- 1kΩ 1W resistors
 1- 100K 1W resistor
 1- 1.5K 2W resistor
 1- 5K 1W resistor
 3- 100mF 200-330V electrolytic capacitors (I used small 330V photoflash ones from Electronic Goldmine)
 1 or 2 suitable chassis (depending on how you want to build)
 Power connectors and umbilical cable (your choice)

SOURCES FOR PARTS AND ADDITIONAL INFORMATION

Antique Electronic Supply (AES) www.tubesandmore.com
 Electronic Goldmine www.goldmine-elec.com
 Subminiature Tubes- Jon- <http://stores.ebay.com/Townsend-Tube-works>
 Subminiature Tubes sockets- Chris -1103xo@sbcglobal.net

Tube Data and collector data:

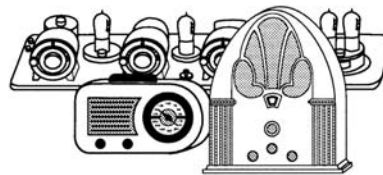
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www.zvexamps.com
www.musicsynthesizer.com
www.dogstar.dantimax.dk/tubestuff/gallery4.htm
www.pw2.netcom
www.wps.com/archives/tube-datasheets
 Franks Electron Pages
www.tubedata.info/history.html
www.vintageradio.me.uk

ADDITIONAL REFERENCES

Essential Characteristics- GE Tube Manual 1973 addition
 Sylvania Gold Brand Premium Subminiature Tubes-NP71 Brochure
 Raytheon Reliable Subminiature Tubes Catalog 3rd edition DL-Q-7101

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PHOTO 1: The front panel of the NuForce Icon HDP contains a volume control, input selector, and a 1/4" stereo headphone jack.

NuForce, an audio company based in California with manufacturing facilities in Taiwan, was founded in 2005 and has become a leader in audiophile-quality amplifiers based on proprietary switching technology. More recently, they have expanded into portable and desktop audio products, including the Icon HDP reviewed here (**Photo 1**). They also manufacture headphones, loudspeakers, a music server, CD player, preamp, multichannel amplifier, and cables. The Icon HDP combines a Digital-to-Analog converter, preamplifier, and headphone amp into one very small package, measuring $6 \times 4\frac{1}{2} \times 1"$.

The Icon HDP has only two knobs—a volume control and a selector switch. The front panel has a tri-colored LED to indicate the selected input: blue for USB digital, white for S/PDIF digital, and red for the stereo analog inputs. There's no digital lock light, which can make troubleshooting a bit more difficult.

The 1/4" headphone jack is also located on the front, but all other connections are made on the rear panel, including the power supply, analog and digital inputs, and analog outputs (**Photo 2**). The analog output connectors are audiophile-quality gold-plated Teflon-insulated RCA jacks, but the analog inputs and S/PDIF digital input are PC-mount types.

NuForce also includes a dual-purpose 3.5mm stereo phone jack. The analog contacts are in parallel with the analog RCA connectors, for connection of portable music devices. You should never connect the RCA and 3.5mm inputs at the same time—it's one or the other. There's also

an S/PDIF optical receptor in the rear of the 3.5mm connector, for connection of a TOSLINK digital cable using the supplied adaptor. As with the analog connection, it's either TOSLINK optical or S/PDIF coax, not both at once.

The Toslink and S/PDIF inputs accept data streams up to 192kHz/24-bit. The highest sampling rate accepted by the USB-2 input is 96kHz. The Icon HDP is supplied with an outboard AC power supply, power cord, USB cable, 1/4" to 3.5mm headphone adapter, and a Toslink to 3.5mm optical adapter (**Photo 3**).

INTERNAL DETAILS

NuForce has packed a surprising amount of sophisticated circuitry into the Icon HDP's small enclosure. The HDP has two circuit boards—analogue and digital—with the digital board piggy-backed onto the larger analogue board (**Photo 4**). The Icon HDP uses an AKM Semiconductor AK4113VF input receiver, which can switch up to six inputs, and includes a low-jitter PLL. The digital board is marked "96kHz 24-bit USB Codec" and contains proprietary NuForce chips for digital decoding and D/A conversion. The decoder chip feeds an I²S bus to the quad DAC chip, which operates in true differential mode for each stereo channel. NuForce notes that this same D/A converter chip is used in their flagship CDP-8 DAC.

Analog circuitry is based on National Semiconductor's LM49860 dual op amps. These high-performance chips are specifically designed for audio applications, with a slew rate of 20V/μS, input noise density of 2.7nV/√Hz, and THD of 0.00003% into 600Ω loads. I applaud

NuForce for avoiding the dated 5532, which is still found in products far more expensive than the Icon HDP.

The analog circuitry is DC-coupled except for a single film capacitor at each analog input. The headphone output is driven with NuForce's proprietary HPA10W01 headphone amplifier module. NuForce notes that the analog circuitry in the HDP is similar to that used in their high-end P-8S preamp. The volume control and selector switch are high-quality parts, better than I'd expect at this price.

The Icon HDP comes with an outboard desktop AC adapter made by Li Tone Electronics, a Taiwan-based company with manufacturing in mainland China. This 24W switching-mode power supply is the model LTE24E-S3-1, and is rated at 15V out at 1.6A. The Icon HDP probably doesn't draw anything close to 1.6A—my power supply was cool even after several hours of operation. I suspect that NuForce deliberately overrated the supply to prevent dynamic current limiting.

The DC power input on the Icon HDP appears well-filtered with both capacitors and a toroidal inductor. NuForce has separated the analog and digital supply regulation inside the HDP. The digital supply is regulated with a 5V, three-terminal regulator. The analog supply is isolated with NuForce's own "audio grade" NH15 DC-to-DC converter, which converts the single-polarity DC input into dual-polarity $\pm 12V$ rails for the analog circuitry.

NuForce has a series of spectral distortion measurements available for downloading on their website. These include 400Hz THD and 19kHz+20kHz IM measurements on the Icon HDP and 22 competing products, most costing many times more than the HDP. The Icon HDP stacks up extremely well against products made by—among others—Musical Fidelity, Perreaux, Esoteric, Lexicon, and PS Audio—and, in many cases, the NuForce offers superior measured performance. The measurements speak well for NuForce's digital design expertise.

THE SOUND

For the ultimate listening test of the DAC/preamp combination, I connected the Icon HDP into my main stereo system, feeding the coax S/PDIF output from my NAD M55 player to the HDP,

and connecting the HDP's outputs directly to my Monarchy SE-100 Deluxe MK2 power amplifiers (which feed a pair of ACI Sapphire III/Sub-1 loudspeaker systems). The HDP replaced both my custom-built preamp and PS Audio Digital Link III D/A converter; a tall order to say the least!

My first reaction to the sound was how punchy and dynamic it was, especially for something so small, with necessarily basic internal power supplies. The bass was especially impressive—not as powerful in the nether regions as my reference DAC and preamp, but with surprising weight and impact nonetheless. Left-right imaging

was quite precise, if somewhat narrower than my reference, but front-to-back depth was rather vague. Inner detail was surprisingly good, lessened only by some roughness and graininess in the upper midrange and treble region.

Indeed, the biggest limitation in performance was the lack of ultimate smoothness and detail in the treble. Overall, however, the Icon HDP provided a surprisingly musical and pleasant listening experience. The evenings I spent with the HDP in my main system were both enjoyable and satisfying, and I was continually impressed by how well something so small and so affordable could perform.

As a headphone amplifier, the Icon



PHOTO 2: The rear panel of the HDP includes analog input and output jacks, USB, S/PDIF and optical digital inputs, and the power supply connector.

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A black NuForce Icon uDAC2 device is shown at an angle. A US quarter coin is placed next to it for scale. The device has a volume knob and several ports on its side.

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HDP performed impressively with my AKG K701 headphones. The punchy, dynamic qualities of the HDP when used as a DAC/preamp are retained when driving headphones. Indeed, the HDP easily drove my AKGs, which have a nominal impedance of 62Ω, with no sense of strain whatsoever. NuForce's headphone amplifier module can provide much higher output current than unbuffered IC op-amp-based headphone amps, and will deliver 4.5V RMS into a 16Ω load before clipping (op-amp-based headphone amplifiers are usually comfortable driving loads of 40Ω or higher).

NuForce notes that the HDP can drive in-ear monitors (IEMs, sometimes called "ear buds"), which often have impedances as low as 16Ω. The one caveat is that low-Z, high-sensitivity IEMs may allow you to hear the HDP's noise floor. The HDP was optimized for higher-Z headphones, where this will normally not be a problem. I never heard the HDP's noise floor with my AKG K701s.

The sound field with my AKGs is spacious and detailed, and never becomes fatiguing even during lengthy listening sessions. If you need a headphone amplifier better than the HDP, you'll need to spend a great deal more. The HDP will provide a worthwhile upgrade over the built-in, op-amp-based headphone amplifiers typically included with integrated amplifiers, digital players, and personal computers.

COMPUTER APPLICATION

For many audiophiles, the Icon HDP will find a permanent home in a high-performance computer audio playback system, using the USB connection. Surely, the ultimate DAC/preamp for this application is the Benchmark DAC-1 USB, which Chuck Hansen and I reviewed in *aX* in January 2009. That reference-quality product quickly became an indispensable part of my computer-based digital audio editing system at work. But, its \$1295 price tag puts it out of the reach of many home computer/audio enthusiasts.

At \$459, the Icon HDP shouldn't be expected to offer the same level of transparency and refinement as the Benchmark, and it doesn't. What it does offer is a significant improvement over most computer sound cards. The Icon HDP easily outperforms the Creative Labs Audigy 2 that came with my Dell Dimension 4600 (running Windows XP Pro). In my home computer system, the Icon HDP feeds an Adcom GFA-5200 power amplifier and a pair of Madisound Speaker Components' Sledgling loudspeakers.

I also like the ability to adjust the playback volume without using the Windows volume control, which is annoying because there's no way to make it sit on top of your application (the Sound Forge 10 Pro digital editor, in my case). Even if the volume control is open, you must



PHOTO 3: The Icon HDP is supplied with a USB cable, AC adapter, power cord, plus 1/4" to 3.5mm headphone adapter, and a Toslink to 3.5mm optical adapter.

first click on the task bar, and then drag the fader. Once you're back to editing, the volume control disappears. I find it much more convenient to adjust the playback volume on an outboard DAC/preamp¹.

I'm not fond of switching-mode power supplies in high-performance audio equipment, and I suspected that the switching AC adapter might be a limiting factor in the Icon HDP's performance. Indeed, NuForce's website notes an optional linear supply for the HDP, though it's not available as of this writing. NuForce's Jason Lin explained that the linear supply—still under development—will also include a 192kHz/24-bit USB to S/PDIF converter, to help isolate the HDP from noise generated inside the computer. The supply will also contain a custom-designed R-core transformer (a description of this type of transformer—ideal for audio applications—can be found on the website of its developer, Kitamura Kiden, <http://www.kitamura-kiden.co.jp/english/index.html>).

Many years ago, I described a 12V outboard supply that I designed for the Audio Alchemy Digital Transmission Interface, and later used with other outboard sample-rate converters/jitter suppressors used in my system². I modified one of these supplies to provide +15V to the Icon HDP. My own linear supply produced a wider and more precise soundstage, deeper bass, and a reduction in the grain and texture in the treble. Overall, the sonic presentation is richer and warmer with the linear supply. When NuForce's own linear supply becomes available, it should be a worthwhile upgrade.

CONCLUSION

The NuForce Icon HDP is a remarkable device, combining three fine products—DAC, preamp, and headphone amp—into one compact enclosure. The USB input makes it ideal for a computer audio installation, and the fine sonic qualities of the preamp and headphone amplifier will surely appeal to anyone in need of high performance in a small, affordable package. NuForce has several other items in their Icon line, including the ultra-compact uDAC-2 DAC/preamp/headphone amp priced at \$129. It's hard to imagine an audiophile who

couldn't find a use for one of these high-value products. Highly recommended!

REFERENCES

1. For a replacement Windows volume control that can sit on top of your application, I recommend Code Sector Software's Audio Sliders, www.codesector.com.
2. Galo, Gary A. "Ask TAA—DTI Update" *The Audio Amateur*, 4/1994, p. 40. For 15V DC output, simply change R2 to 10.5k and use a transformer with a 15V AC secondary. *ax*



PHOTO 4: The Icon HDP circuitry is housed on two circuit boards, with the smaller digital board piggybacked onto the main analog board. The volume control and selector switch are high-quality parts.

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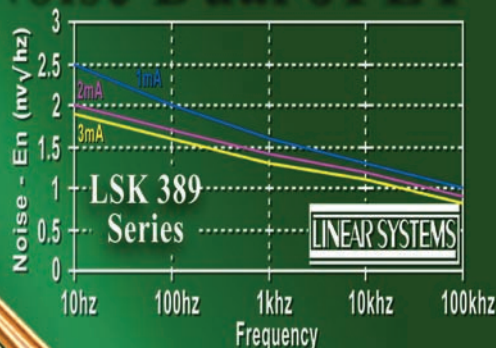
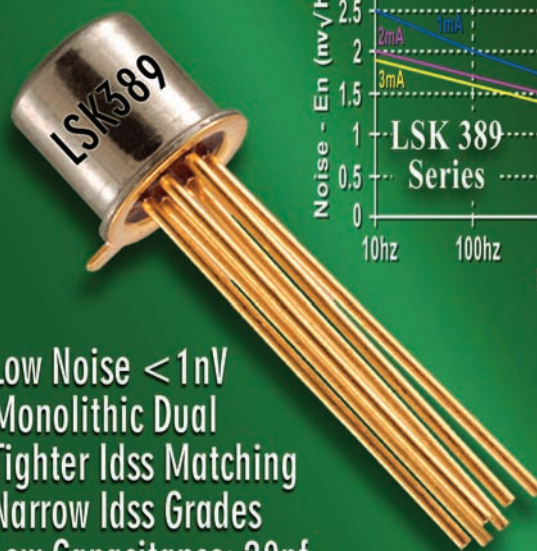
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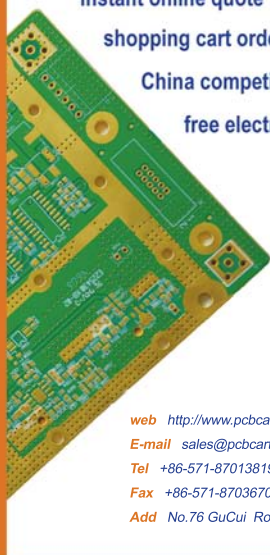
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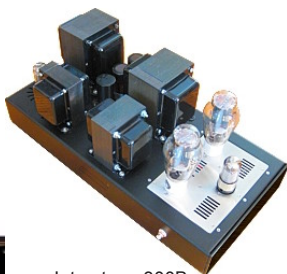
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Contributors

Claudio Negro ("The Solid-State Duo, Pt. 1," p. 6) is a retired commercial airplane pilot, and has been interested in speaker building since the age of 13 when he built a zero offset three-way speaker with a self-made tweeter acoustic lens. He also became interested in electronics, building a mixer based on a Radford preamp and Marantz MM pre-schematics, with separate PSU enclosure. In 1985 he was classified sixth in an Italian magazine DIY speaker contest, after which he took a long break from DIY audio. In recent years he published a tutorial on Speaker Workshop and various articles in *audioXpress*. His other interests are listening and playing hard rock music, photography, computers, and online car racing.

Valerio Russo ("The Solid-State Duo, Pt. 1," p. 6) is an Italian DIYer whose interest in music blossomed since childhood, when he started playing piano. Growing up, he developed an interest in mechanics and computing; he also had some racing engineering experience with two-stroke engines. His passion for music and engineering led to a particular interest in speaker building, especially home, without disregarding electronics. He is working on a three-way speaker, and applying his mechanical studies to low-frequency nonlinear behavior, as well as the amplifier-speaker interaction. He is a recent graduate in Mechanical Engineering in Naples.

Bruce Brown ("Lilliputian Amplifiers," p. 16) is a registered pharmacist who works in the medical research area for a major pharmaceutical company. He has been experimenting with electronics for over 35 years, remaining actively interested in electronics, building kits, and "home brew" audio. Online auctions have stimulated new interests. He has just recently become interested in restoring vintage audio equipment and writing articles to assist other hobbyists. He can be reached at Tuninfork@aol.com.

Gary Galo (Review: NuForce Icon HDP—Headphone Amp, DAC Converter, Preamp, p. 23) is Audio Engineer at The Crane School of Music, SUNY Potsdam, where he also teaches courses in music literature. A contributor to AAC since 1982, he has authored over 230 articles and reviews on audio technology, music, and recordings.

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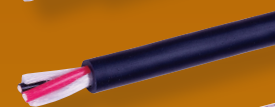


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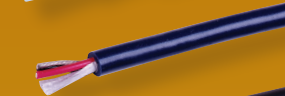
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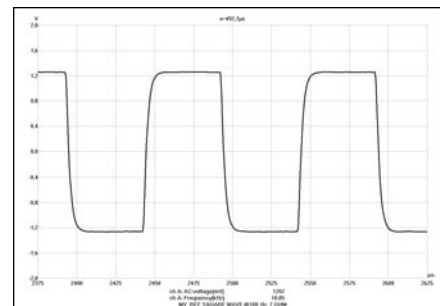
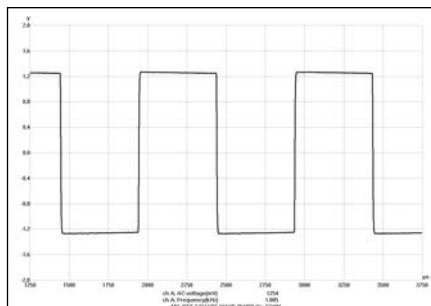
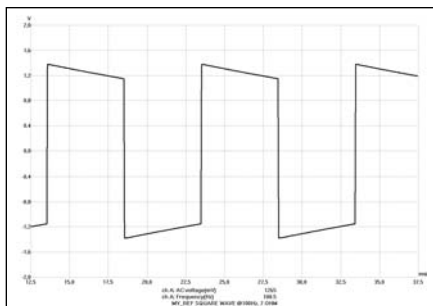
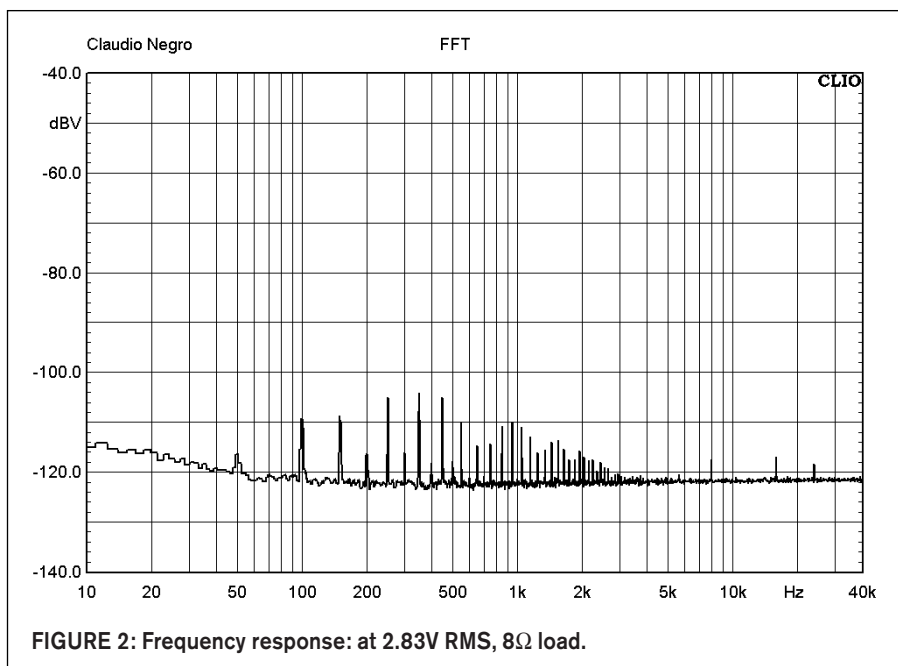
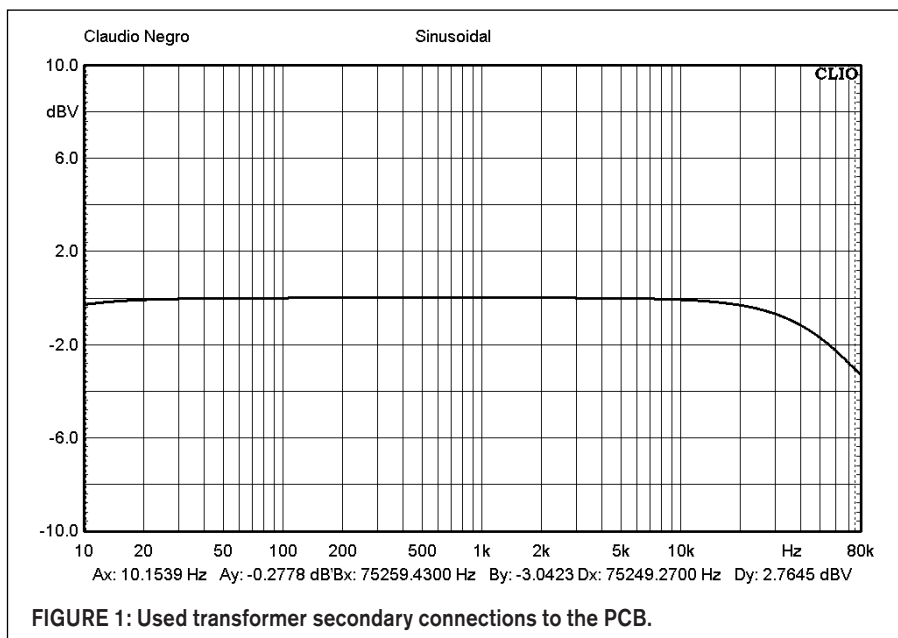


The Solid-State Duo, Part 1

Measurements

Performance results of the My-Ref amp (from p. 6).

The test setup included the Audiomatica Clio 10, Picotech 212/3 oscilloscope, and Protek B8011 function generator. The output DC offset was 12.8mV for the right channel and 11.6mV for the left one. The input impedance at 1kHz resulted in 74150Ω , while the output damping factor referred to 8Ω was equal to 265 at 1kHz.



The frequency response in Fig. 1 shows a 0.3dB deviation from 10 to 20kHz, with the -3dB frequency located at 75kHz. The measured noise spectrum is below 110dBV, as in Fig. 2. We then fed the amplifier with a square wave at 100-1k-10kHz, using a 7Ω load. The results are shown in Figs. 3-5.

Next we fueled the amplifier with a 1kHz wave to see what happens just before clipping. Figure 6 shows the FFT with a load of 8Ω and an output of 47W.

Using the Clio linearity and distortion analysis, we ended the My Ref. lab test with the last three measurements: THD vs. power (Fig. 7) and the IMD vs. power (Fig. 8), loading the amplifier with the usual 4 and 8Ω, while Fig. 9 shows THD vs. frequency at 1-10-48W, with an 8Ω load. *ax*

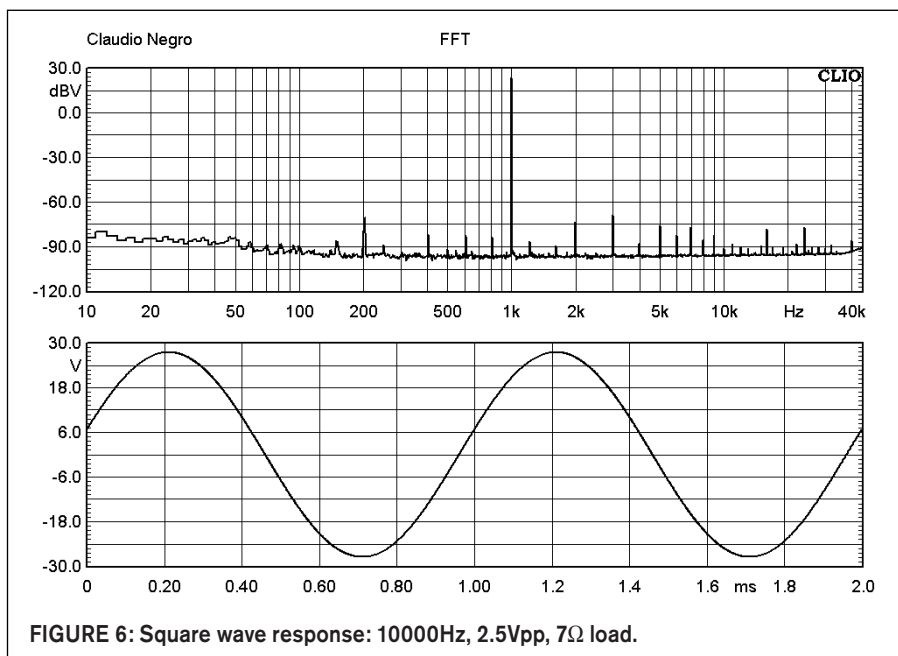


FIGURE 6: Square wave response: 10000Hz, 2.5Vpp, 7Ω load.

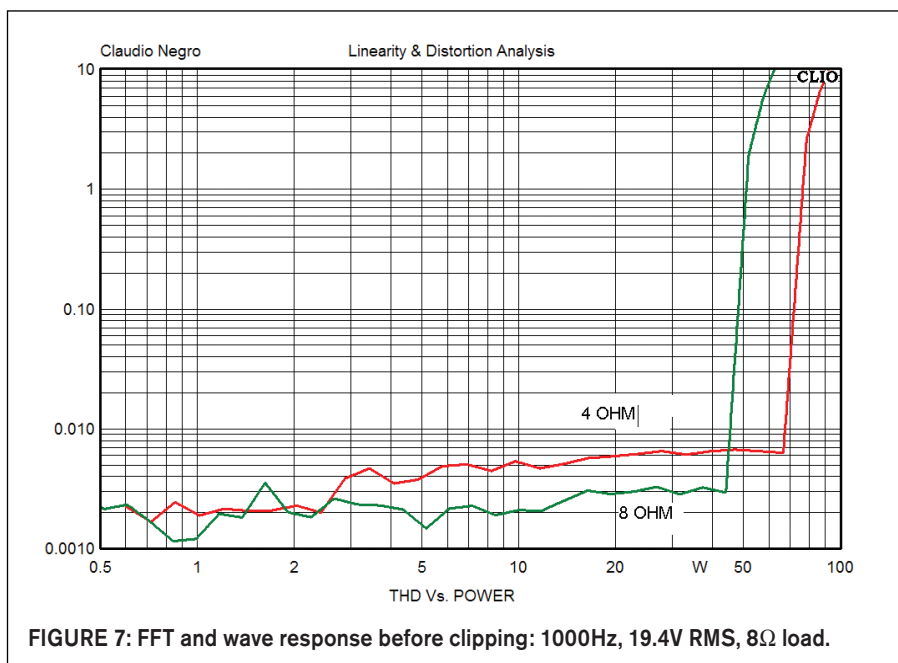


FIGURE 7: THD vs. power, 4 and 8Ω load.

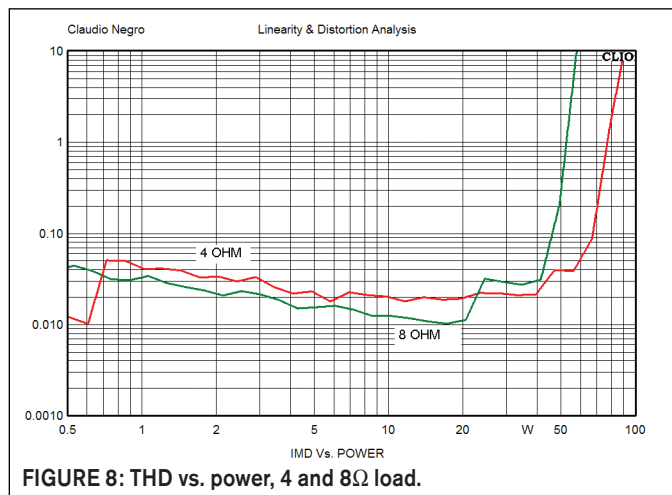


FIGURE 8: THD vs. power, 4 and 8Ω load.

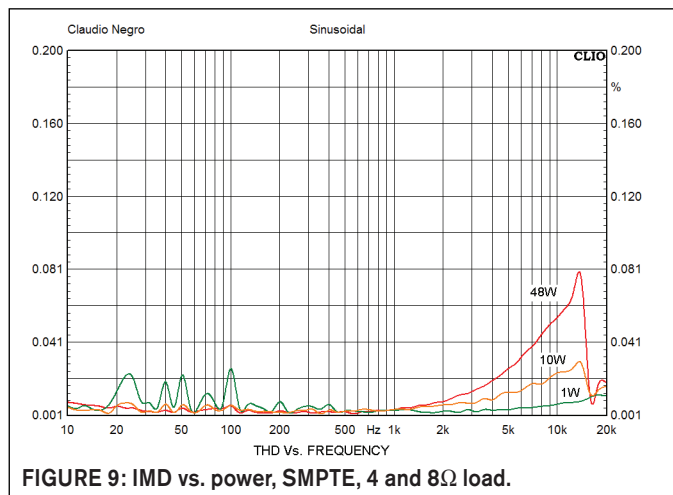


FIGURE 9: IMD vs. power, SMPTE, 4 and 8Ω load.

Lilliputian Amplifiers continued

A brief history of submini tubes.

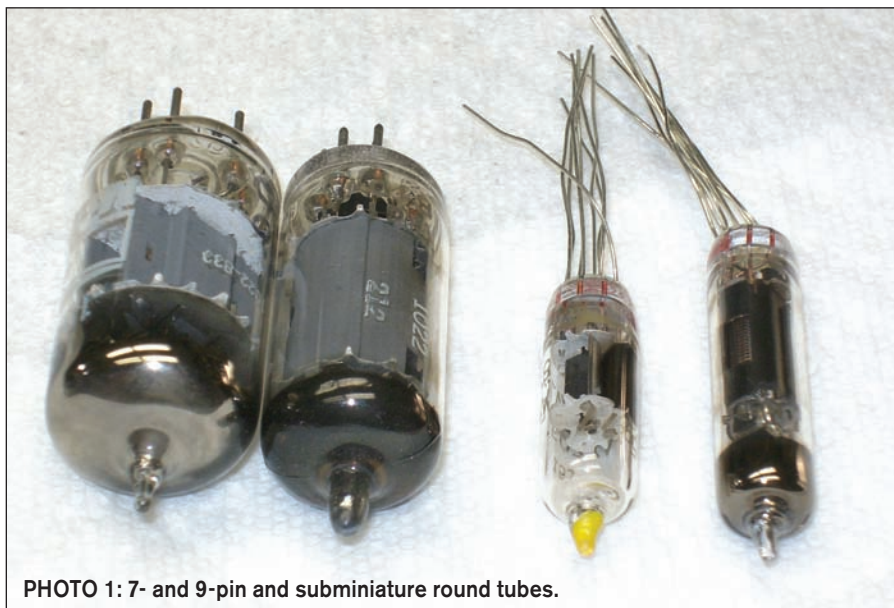


PHOTO 1: 7- and 9-pin and subminiature round tubes.

The commercial development of tubes generally starts with 4-pin tubes and ends with miniature 7- and 9-pin varieties. There has been little interest in Compactrons, until a few recent articles (*audioXpress* May 2008 and *Nuts and Volts* August 2004). These interesting tubes combine several different type tubes in one envelope, and were considered by many to be the last hurrah for tubes. This was shared with the subminiature tube (also referred to as the “pencil”). Recently a large number of these were released from government surplus, and there are many types being sold online.

These tubes were developed in the late 40s and early 50s and were targeted for military use. They are one-half to one-third the diameter of 7-pin tubes and have flying leads. The first series tubes were round and the later were

flattened slightly.

From the number of sales and data brochures I have collected from Raytheon, Sylvania, and RCA, there were a few commercial radios using them (usually in combination with transistors—more on this later). Most of the major radio companies from the 50s made portable AM radios using these tubes. Many years ago Antique Electronic Supply even sold a kit for building a subminiature tube AM radio. (If anyone has the schematic or instructions, I would like a copy—AES didn’t keep a copy in their files.)

The original subminiature tubes were “proximity fuses” developed to help explode charges fired at buzz bombs launched by Germany in WWII (I have no way of verifying this). It is claimed that Raytheon was the first developer. There is a great deal of confusion concerning the use of these

tubes, as one highly acclaimed radio collector claims that 1955 was the last time these tubes were used commercially, but I have several sales catalogs and brochures dated in the late 50s that contradict this.

The most recent brochure I have is dated 1958 and states “Raytheon Subminiature tubes with **Reliability** + answer the urgent need for tubes meeting extreme reliability requirement of guided missiles and other critical applications. The new line of Raytheon tubes is the outcome of a two-year program of development covering every phase of tube manufacturing and sponsored by the Bureau of Ordnance, US Navy.”

The brochure further states, “Improvements in these tubes include:

- reduced vibration output
- superior uniformity
- reduced microphonics
- controlled operation time
- tightened limits
- great resistance to shock and fatigue

These tubes were designed to meet increased specs by increasing the mechanical strength and a simplified design eliminates complex assembly and welding requirements.”

Women were the primary manufacturing crew as evidenced by statements such as, “a significant result of these new techniques is the 2 girl team for tube assembly, instead of the conventional assembly line of 12-15.”

One of the “sales sheets” I have says, “At your Command for all military applications approved miniature

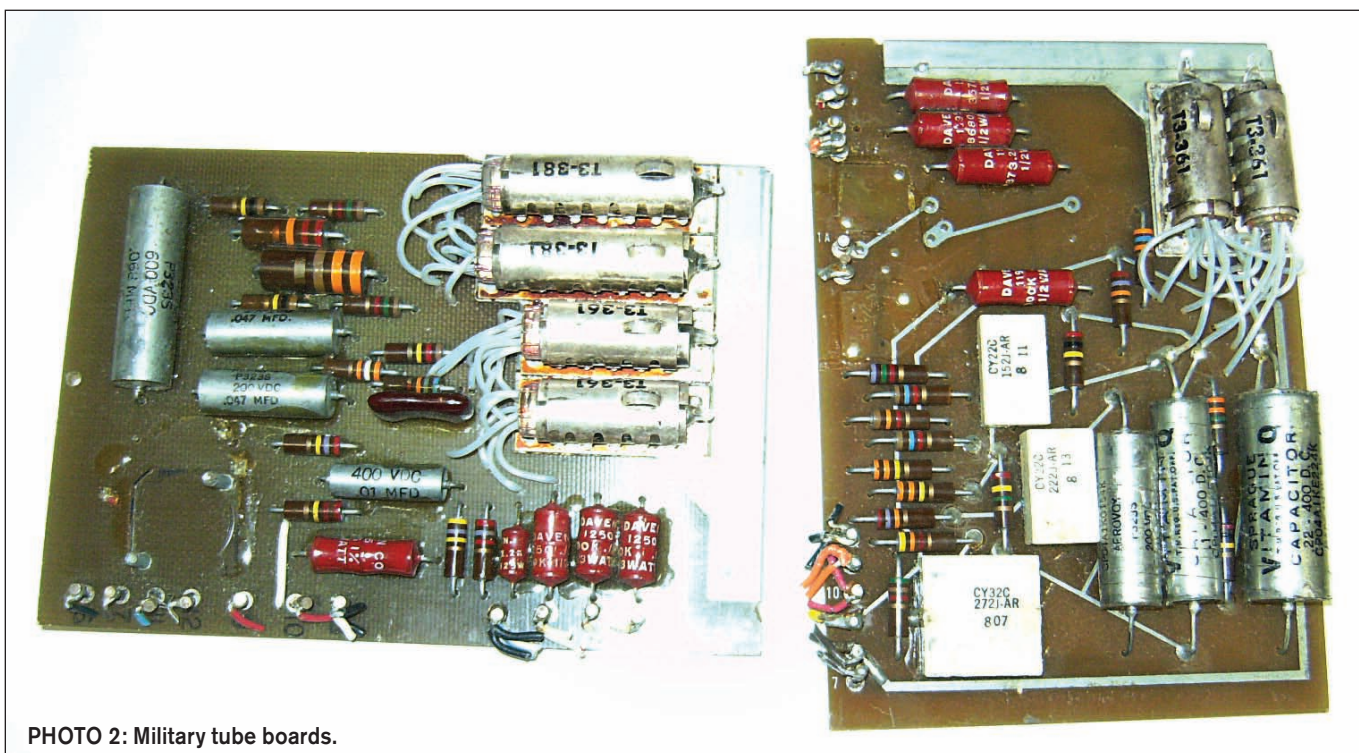


PHOTO 2: Military tube boards.

and subminiature tubes for guided missiles, computer use, communications, radar and radiation measurement instruments as well as other military applications.” (Photo 1 shows some examples of tubes used for military applications). All the datasheets I have found indicate that they meet mil spec (MIL-E-1), which states impact acceleration of 450Gm, unified acceleration of 1000Gm, bulb temp of 220° C, and a working altitude of 80,000’.

I recently purchased three relatively complete military boards (Photo 2), using subminiature tubes. One is marked Amplifier type SP3D-2 and the other is Amplifier Type RA-A. As you can see from the photo, these are built with very high quality parts. The tubes are shielded and heatsinked.

Just imagine how things might have been if Bell Labs had never discovered the transistor! (Please don’t write *audioXpress* with who actually developed the transistor—it just strikes me it was Bell). The first versions of the subminiature tubes appear to be scaled-down 7-pin tubes with the

classic round envelope and flying leads exiting the bottom of the glass (Photo 3). These tubes generally have 6.3V filaments and handled up to 175-200V on the plates. These seemed to have appeared in the late 40s-early 50s (I can’t pin down the exact dates—I don’t know whether the information was lost or was never publicized). Around 1954, a second-generation version of these tubes appeared, with some significant differences. They were flattened on two sides, and were slightly smaller.

The major differences in these two types of tubes were the filament and plate voltages. These later flattened tubes had a 1.2V filament and typically a plate voltage of 45-90V, but some were as low as 22V. This led the way for commercial battery-operated “portable” AM radios, as mentioned earlier. I have several of these that used a C or D cell for the filament and a 45V or 22V battery for B+. Quite a number of these type radios that sold combined subminiature tubes and transistors. Brands included Belmont,

Private Ear, Crosley, Hoffman, Emerson, Motorola, Sear Silvertone, and Westinghouse.

These types of radios are extremely collectible, with recent prices for very clean examples selling for \$150-200 on eBay. I also have collected some very nice Zenith hearing aids, and telephone amplifiers that use the subminiature battery tubes (these items are actually gorgeous, with gold-colored aluminum embossed cases). It appears that many of these low-voltage flattened tubes were still manufactured until the late 70s.

AVAILABILITY

Military equipment with subminiature tubes used small sockets, but today these seem to be made of unobtainium. I have purchased several assortments of used submini tubes with the leads shortened to about 1/4”. I recently found a few cinch jones 8-pin miniature tube sockets online, but these are not common. Breadboarding with flying leads is very time consuming, and I plan to use these

sockets to set up an experimenting station.

The commercial equipment I have seen has the leads soldered into the circuit or to the circuit board. Some of the used radiosone tubes I have purchased had 1" long leads and were obviously soldered into military circuits, so you may find them several ways in the used market, depending on the military application.

As I mentioned earlier, these tubes have not generated much interest, and there seems to be a large number reaching the market recently, so I decided to experiment. I bought an assortment of triodes, dual triodes, pentodes, and even a few sharp cutoff pentodes from a gentleman selling bunches of them on eBay. I list his e-mail address and website at the end of the main article, so that you may contact him should you wish to duplicate the amplifiers presented here (AES also lists a number of these tubes). I will warn you, there are a few folks (including some antique dealers) who think these tubes are worth their weight in gold. I have seen people advertising common versions of these tubes for \$30 each, which is about 5-10 times what they are worth.

Most sellers know nothing about any of these tubes and if they don't provide you with a link for the datasheets, I would not recommend doing business with them. Without a datasheet you will be out of luck experimenting with these tubes and finding the right one for your application. I also list a number of sites for tracking down information on subminiature tubes in the reference section of the main article.

I spent some time looking on the web for current commercial and amateur use of these tubes, and the only amplifier I found was made by a com-

pany called ZVEX, whose owner, Zac Vex, offered two amplifiers—one was a one-tube guitar amp and the other a two tube stereo amp. The list price for either of these was over \$500. I e-mailed him several times about my interest and never received a reply. His website is still up and functioning, but of little help for additional contact info. No other contact information or address was listed so I don't know whether these were actually still for sale (I recently saw one of the stereo amps for sale on eBay—it went for over \$350, from a private seller).

I understand that there are one or two esoteric audiophile companies that use some of these tubes, but I didn't run across them in my brief search. I also understand that some condenser mikes use the flattened low voltage tubes.

I found one great article ("A Pocket Preamp," p. 26) on a line amp in *Glass Audio* (4/99) by Eric Barbour. I also found several sites and discussion boards with a number of "sample" circuits or prototypes. After close scrutiny of some of the "proposed" circuits, I doubt they were ever built and tested. Several of the circuits I

found used between 225 and 275V on the output tube plates. I actually tried one of these and promptly toasted the tube (so much for the Internet research).

The datasheets on this power pentode (5902) state a maximum plate voltage of 165V, and the design parameters actually show 120V as adequate. When you think about it, the reason these were designed was to decrease size and weight, which also decreases the size and weight of the power supply, so why would you want to use 275V? There are references to a number of projects on guitar foot pedals, but I was never able to track them down, and several of the hits directed me to chat rooms and the like. There was very little of interest there, except the same old psychobabble from people who have no clue, but certainly have opinions.

I have borrowed some ideas from some of these sites. The design guidelines for amplifiers is pretty much the same whether you use 7- or 9-pin miniature tubes, 8-pin octal tubes, or even these subminiature tubes—you are just dealing with different plate, grid, and cathode voltages. *ax*

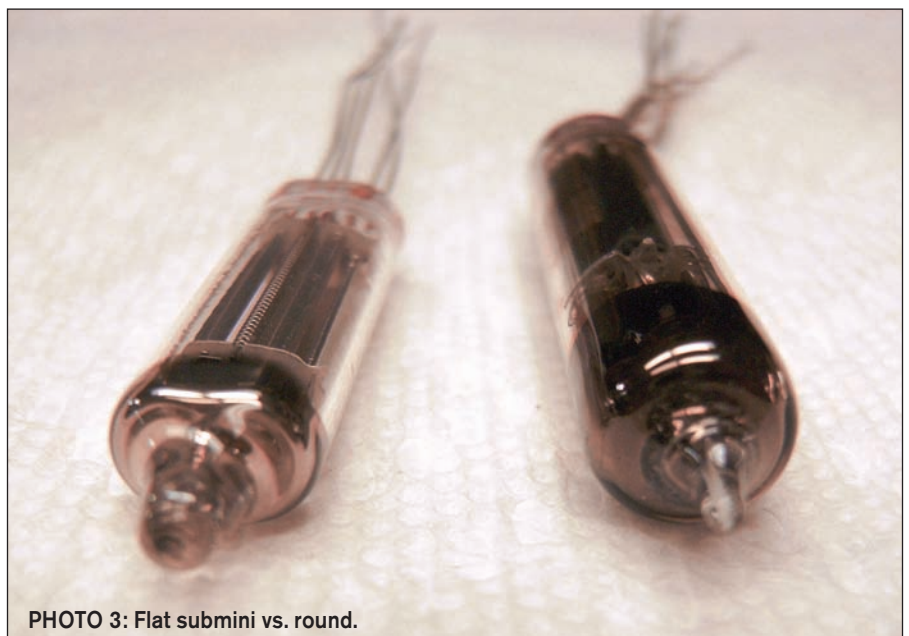


PHOTO 3: Flat submini vs. round.

NEW TECHNOLOGY FROM POLK AUDIO

Polk Audio (www.polkaudio.com) has introduced a top-of-the-line LSiM speaker series with many innovations in the drivers and cabinet. The speaker line includes two four-way tower speakers and a relatively rare three-way bookshelf. For home theater applications, the LSiM line has center and surround channel models. A ten-page technical document on Polk supplied at CES reviews the proprietary technologies. I hope they put it on the Polk website. But until they do, here are a few highlights.



Photo 1: Polk's new speakers

FEATURES

The visual appeal of thin speakers has made them increasingly popular. For Polk, the thin width of their tower speakers (**Photo 1**) is made possible by the elliptical woofers. The narrow front baffle has the added advantage of reducing diffraction of drivers off the front. To have an equivalent box area of a speaker with a wider baffle, the speaker must be deeper. Polk reports that a speaker box with this shape moves less and thus the cabinet puts less energy into the room. Most thin tower speakers use multiple small round drivers, which limit low frequency response. Polk has addressed this with a proprietary elliptical driver called Cassini Ovium. The top-of-the-line speaker uses two 6" x 9" drivers, which, according to Polk, have an effective area of an 11" round driver. The Cassinis are proprietary to the LSiM series.

The side view of the woofers (**Photo 2**) shows the ovals are driven by the voice coil not only at the center but also by beams at the edge. I have indicated the beams from the voice coil edge of

cone in the photo. As with all cone speakers in this LSiM series, the baskets are cast aluminum. The surrounds— injection-molded butyl rubber, and said to be tuned to absorb unwanted cone resonance—are claimed to be impervious to ultraviolet rays, temperature extremes, and humidity. Those who have had to recone a speaker with foam surrounds know the material decomposes relatively easily, at least for older designs.

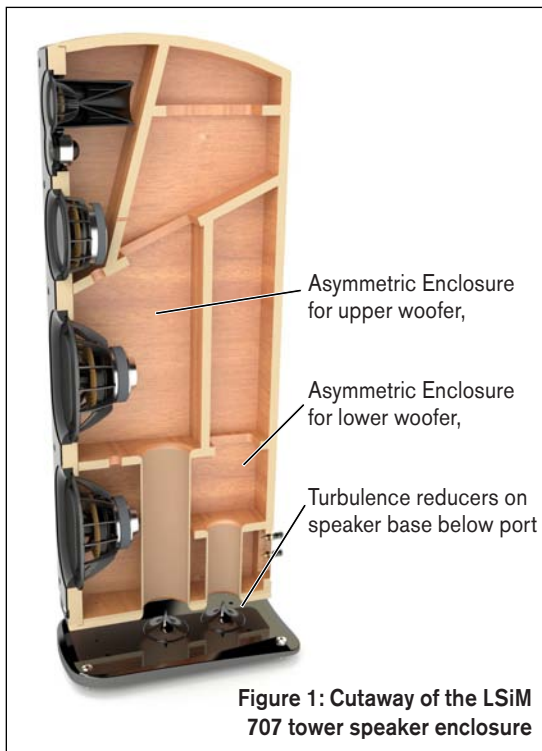


Figure 1: Cutaway of the LSiM 707 tower speaker enclosure

The Cassini Ovium is a true subwoofer crossed over at 80Hz. The novel enclosure that houses the drivers is shown in the cross-section in **Fig. 1**. Both woofers have separate sub-enclosures, and the complex shape of each reduces resonance and standing waves. Each woofer in its enclosure has the same acoustic bass tuning. The different port diameters and lengths

mitigate additive organ pipe resonances that would occur were the ports of the same diameter and length. The ports vent to the base of the enclosure. The cone-shaped structure in the base, which Polk affectionately calls a Hershey Kisses shape, reduces turbulence of the air exiting the bass port. The 3 1/4" midrange driver crosses over at a very low 200Hz and runs to 2kHz before crossing over to the ring radiator tweeter. Typically used to extend down to these frequencies, a 5" to 6.5" driver has a reduced off-axis radiation pattern above 1kHz. The complete speaker's off-axis radiation pattern widens again as the driver crosses over to the tweeter, producing a discontinuity in the horizontal radiation pattern of the speaker.

Polk extended the linear motion voice coil of the 3 1/4" driver so it could operate to 300Hz. **Figure 2** illustrates how the modified gap geometry maintains

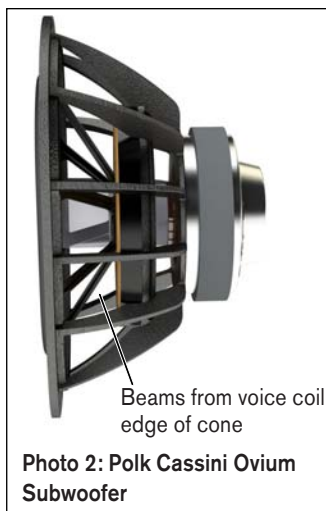


Photo 2: Polk Cassini Ovium Subwoofer

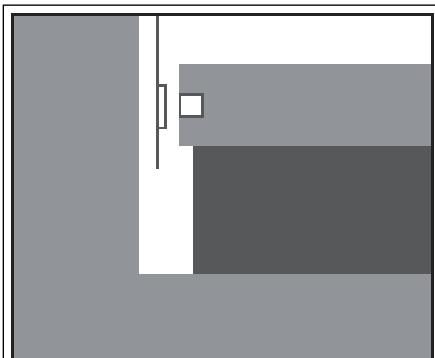


Figure 2: Extended Linear Motion (ELM) voice coil

a large range in which BL is constant. The tall gap has a cut midway, effectively splitting the gap in two. According to Polk, when the cone moves from the center toward the upper gap, the BL from the lower gap is reduced, but increases at the upper gap. The two effects offset to keep BL stable, at least until the coil leaves the upper gap.

Speaker engineers cannot agree whether a cone should have a metallic base or should be a soft plastic or paper. Except for its tweeters, Polk cones are made of a new generation of the company's proprietary polypropylene cones. Called Aerated Polypropylene material, it gets its name because the surfaces of the polypropylene are densely packed to be hard and stiff but the middle layer is filled with air pockets. Polk says this soft middle layer provides good internal damping while the stiff outer layer resists torsion and flexing. New methods of processing technology for the drivers used in these products are said to create a material twice the size of their first generation process for higher stiffness, better damping, and lower density.

The presence of the 3¼" driver in the bookshelf speaker generates a horizontal radiation pattern that is more uniform over frequencies than the radiation pattern associated with the ubiquitous two-way bookshelf with a 6.5" woofer and a tweeter. The added midrange driver improves the dynamic midrange performance of the speaker.

The floor-standing speakers are, in essence, the bookshelf unit combined with the dual-chambered oval subwoofer system. The largest floor-standing speaker, called the LSiM 707, is priced at \$1999. The smaller floor-standing speaker has two 5" × 7" Cassini Oval drivers at \$1499 each. The bookshelf model retails for \$749 each. ■

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POWERSOFT AMPS

Powersoft's M Series of power amplifiers consists of five new models that include two four-channel and three two-channel versions. The amplifiers come in a one-rack-unit chassis, 358mm/14.1" deep and weighing just over 7kg/16lbs.

The M50Q and M28Q are four-channel models, delivering up to 1,250W/channel into 4Ω. The M30D, M20D, and M14D offer two channels each with a maximum output of 1,500W/channel at 4Ω. The entire range reaches down to 360W/channel into 8Ω, resulting in greater flexibility for a wide range of applications. The M Series features Powersoft's advanced plug-in DSP module. When installed and preset to meet the needs of a particular installation, including settings for crossover frequency and curves, basic system EQ, and protection functions, the parameters cannot be tampered with—making the M Series a "plug and safe" power amp.

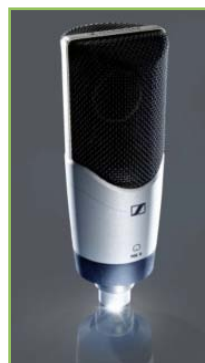
For more information, visit www.powersoft-audio.com.

SENNHEISER MK4

The MK 4, a large-diaphragm true condenser cardioid microphone, manufactured in Germany, is Sennheiser's first large-diaphragm side-address microphone. According to the company, it provides a powerful yet warm sound that is both direct and tight with fine treble resolution.

The MK 4, with its nickel-colored finish, was developed for professional users in project studios, but is equally well suited for other recording environments and is tough enough for use on stage. The MK 4 has a large 1" diaphragm precisely spattered with 24-carat gold. The sturdy metal housing and the elastically mounted capsule make the microphone tough enough for even the most energetic recording situations.

The open front of the suspension mount enables you to position the MK 4 close to the sound source. The microphone has a maximum sound pressure level of 140dB, and its self-noise is 10dB(A). The MK 4 comes complete with a microphone clip and a protective pouch. Optional accessories include an elastic suspension, a foam windshield, and a popshield. You can find all the latest information on Sennheiser by visiting www.sennheiserusa.com.



VISHAY RESISTORS

Vishay Precision Group, Inc., released the enhanced ultra-high-precision Z-Foil VAR, in addition to a new generation of foil power current-sensing resistors. Based on Bulk Metal Foil® technology, the new devices have been specifically designed to minimize the self-inductance and capacitance inherent in all resistors, offering improvements in sound quality by reducing audible distortion. With power ratings as high as 60W, the devices are optimized for use in loudspeaker crossover assemblies, audio power amplifiers, and instrumentation amplifiers.

Vishay Foil Resistors division has enhanced the ultra-high-precision Z-Foil VAR resistor to offer low TCR down to 0.05 ppm/°C typical from 0° C to +60° C, +25° C ref, tolerances down to ±0.005%, and load-life stability to ±0.005% (50 ppm) at +70° C for 2,000 hours at rated power. The device has been bolstered with a thermal stabilization time of <1 s (nominal value achieved within 10 ppm of steady-state value) and can operate at higher frequencies.

The VAR provides a combination of low noise, low inductance/capacitance, and improved thermal response, making it unrivalled for applications requiring distortion-free properties. Its special "naked Z-foil resistor" design, without molding or encapsulation, adds an additional dimension for reducing signal distortion and increasing clarity in signal processing.

The VAR has a low thermal EMF, which is directly attributable to the special design of the device. Thermal EMF results from the thermocouple effect which exists between dissimilar metals.

Further information is available at www.vishayfoilresistors.com.



Current Noise: <-40 dB
Rise Time: 1 ns, Effectively No Ringing

CUSTOM-MOLDED EARPHONES

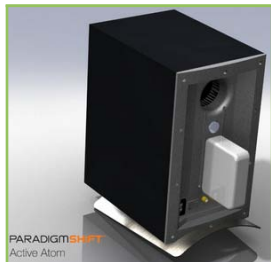
New from Sonomax Technologies, Inc., sculpted eers™ are molded to the unique shape of an individual's ear canal in just four minutes, through a self-fitting system. According to Sonomax, they provide maximum comfort, exceptional sound, and a secure fit, even during vigorous activity. In addition, these custom-molded earphones produce an acoustic seal that delivers a total audio immersion experience, so consumers can safely enjoy music at a fraction of the volume required by generic earphones. Additional information about Sonomax Technologies can be found at <http://sonomax.com>.

MCINTOSH MC601

McIntosh Laboratory's MC601 Monoblock Amplifier boasts a new larger chassis of mirror polished stainless steel, a backlit glass faceplate, and the newly designed 8" wide True Wattmeter, featuring "McIntosh Blue" LED lighting. Other capabilities include Power Guard, a McIntosh circuit innovation that maximizes sound quality at high power levels, and "Sentry Monitor," which provides continuous short circuit protection of the amplifier and connected loudspeakers.

In addition to its higher power rating of 600W, the MC601 features Thermal Track output transistors that allow for cooler, more efficient operation. Other new features are specially designed McIntosh speaker binding posts, Quad Balanced circuit design for highest audio performance, and input and output jacks that allow bi- or tri-amping with multiple MC601s.

The MC601's distortion-canceling, quad-differential design consists of two complete amplifier circuits, whose outputs are combined in the unique McIntosh-crafted autoformers. Total Harmonic Distortion is 0.005% maximum from 250mW to rated 600W mono power output. MC601 delivers absolute transparency and musical accuracy into speaker loads of 2, 4, or 8Ω. For more information visit www.mcintoshlabs.com.



PARADIGM SHIFT

The first in Paradigm's new mass-market line is the Active Atom bookshelf speaker, bi-amped with 100W of power per speaker. It is designed for any device with a 3.5mm mini-jack or RCA outputs and features a built-in Airport Express interface on the rear panel for wireless streaming.

In addition to the speakers, Paradigm (www.paradigm.com) is launching its first line of personal sound products, including earbuds, headphones, and gaming headsets.

MARANTZ A/V SYSTEMS

Two new home entertainment products from Marantz include the M-CR603 Network CD Receiver and the NA7004 Network Audio Player. The CD receiver offers a 50W per channel digital amplifier, high-performance AM/FM radio, CD player, plus access to thousands of Internet radio stations, and allows for streaming of popular music services Rhapsody, Napster, and Pandora. You can use it as a connected zone player if you already have a receiver-based home theater system in the family room, allowing for easy control of different zones of audio throughout the home. A variety of inputs and outputs, with the option for bi-amplification, allows for easy system expansion, including the addition of a subwoofer. Features such as a front panel USB input for iPod® add to the M-CR603's convenience and flexibility, and it can also be used as a D/A converter for those who have downloaded music on their PCs for streaming through a home audio system.

The Marantz audio player serves as a digital-to-analog converter for users with large collections of downloaded high-resolution music on their computers or other external storage devices who want to listen through their home audio systems. The NA7004 incorporates a built-in Internet radio, and streams popular music sources such as Napster, Rhapsody, and Pandora. It includes a USB front-panel input for digital connection to iPod® and iPhone devices and a back panel M-XPort for wireless Bluetooth streaming with optional RX101 Bluetooth receiver. The NA7004 also includes access to over 14,000 Internet radio stations.

Additional information is available at www.us.marantz.com.

BOSTON ACOUSTICS A SERIES

Boston Acoustics' new line of high-performance loudspeakers includes two floorstanding speakers—the flagship three-way A 360, with dual 6½" woofers, and a 3½" midrange, the two-way Model A 250 with dual 5¼" woofers; two two-way bookshelf models, A 26, 6½" and A 25 5¼"; and the A 225C two-way center-channel speaker with dual 5¼" woofers. Also included is a compact two-way satellite A 23, 3½", which you can use as a surround or a bookshelf speaker. All A Series three- and two-way models feature Boston's 1" Kortec® soft dome tweeter for superior high-frequency response. Two new powered subwoofers, the 300W (650W peak) ASW 650 front-firing 10" ported and 150W (300W peak) down-firing 10" ported ASW 250, complete the lineup.

In addition, Boston Acoustics is offering a new 5.1-channel surround sound speaker package, the A 2310 HTS. The system delivers immersive cinema-like audio right out of the box. It includes five A Series speakers, four A 23 satellite speakers, one A 223C center channel (sold only as part of the speaker package, with dual 3½" woofers), and the ASW 250 subwoofer.

For more information on the company's full range of advanced products, visit BostonAcoustics.com.



NEW ONKYO PRODUCTS

Onkyo has announced a new range of hi-fi separate components. The three models, the P-3000R preamplifier, M-5000R power amplifier, and C-7000R CD player, incorporate Onkyo's new Dynamic Intermodulation Distortion Reduction Circuitry (DIDRC) to counteract unwanted high-frequency interference. Other features common to all models include audiophile-grade parts—such as massive toroidal transformers and gold-plated terminals—along with a new circuit board construction and separate chassis panels, to eliminate unwanted vibrations.

The P-3000R preamp accepts both analog and digital sources, with connectivity options including

new products

AES/EBU digital connectors and a USB input for PC audio. A high-quality 32-bit Burr-Brown DAC is provided for each stereo channel, to optimize audio performance. Meanwhile, PLL (phase locked loop) technology minimizes the effect of clock jitter, and bi-amping capability provides greater flexibility for audiophile applications.

Onkyo's M-5000R features large front-panel analog power meters, distortion reduction technologies, and high current capabilities.

To ensure minimal signal interference, the C-7000R CD player employs a thermally regulated, high-precision clock with a state-of-the-art crystal oscillator, and you can operate the player in analog-only or digital-only mode. For more information, visit www.onkyousa.com.

KLIPSCH GALLERY

The Klipsch Gallery home audio solution offers users an array of wireless-new media sound systems and sleek, minimalist home theater speakers. The Gallery series consists of four slim, passive speakers (G-12, G-16, G-28, and G-42) and three wireless-new media sound systems (Gallery STUDIO, Gallery FORUM and Gallery ARENA). Each passive speaker can be configured as a left, center, right, or surround speaker. Klipsch Gallery's wireless solutions connect wirelessly over an existing Wi-Fi network and can be controlled with an Apple smart device.

These speakers, which come in a high-gloss black finish, are available at klipsch.com.

NUVO TECHNOLOGIES D460

NuVo Technologies' four-channel D460 digital power amplifier consumes less power than a 60W light bulb, with each channel delivering 60W each. The D460 amplifier is an energy-efficient choice for a wide array of installations and complements NuVo's whole home audio systems, while it is also compatible with third-party equipment. For more information, go to www.nuvotechnologies.com.



TUBE AMPLIFIER REFERENCE

Elektor's latest publication on "tubed audio" is about as thick as your 12AX7/ECC83 tube is tall! *Fundamental Amplifier Techniques with Electron Tubes* is a must-have for all tube fans and the growing circle of RAFs (retro-audio-aficionados). In 800+ pages author Rudolf Moers covers just about everything you need to know about the fundamentals of electron tubes and the way these devices were designed to function at their best in their best known application: the (now vintage) tube audio amplifier.

The aim of the book is to give the reader useful knowledge about electron tube technology in the application of audio amplifiers, including their power supplies, for the design and DIY construction of these electron tube amplifiers.

Fundamental Amplifier Techniques with Electron Tubes is available from the Webshop at Elektor.com.

VIDEO CABLES

StarTech.com offers a new line of video cables with unique lengths. They are custom-designed for devices that support high-resolution high-definition performance and work with video splitters and switches. Cable lengths for DVI and DisplayPort range from 1 to 50 feet, up to 80 feet for HDMI, and up to 100 feet for VGA. Many cables also feature specialized, angled ends for connections in tight spaces while preventing cable strain. For more information, visit www.startech.com.



ENTRY-LEVEL RECEIVERS

Onkyo has introduced three entry-level home theater receivers with advanced networking capabilities and a front-panel USB interface. Previously costing \$899 and higher, unit prices have been slashed for the 7.2-channel TX-NR609 (\$599), 5.1-channel TX-NR509 (\$399), and 5.1-channel TX-SR309 (\$299). Prices are effective beginning in early April. For more, contact Onkyo at www.onkyousa.com.

CONTRIBUTOR

David A. Rich ("Polk Has Some New Technology") received his MSEE from Columbia University and his Ph.D. from Polytechnic University of NYU. He specializes in the design of analog and mixed-signal integrated circuits and has taught graduate and undergraduate courses in integrated electronics and electroacoustics. Student work under his guidance, including a novel high-efficiency mixed-signal integrated power amplifier, has won numerous awards. His industrial positions include Technical Manager at Bell Laboratories. His portfolio has spanned the design of audio ICs for Air Force One to RF ICs for wireless cell phones, and his innovations have earned 14 patents. He is a Senior Member of the IEEE and has frequently served as chairperson for technical and panel sessions at IEEE conferences. He has been a member of the AES signal processing technical committee and has been Technical Editor for *Audio Critic*. He is the head of the music committee of the Bethlehem Chamber Music Society.

CORRECTION

Author Darcy Staggs was quick to point out that we published the incorrect dimensions for the lumber to make his Disappearing Loudspeakers (March, p. 18). It should read $\frac{3}{4}$ inch $\times$ 5½ inches $\times$ 14 FEET, not inches. We regret the mistake, which was ours, not the author's. —Eds.

tonearm replacement

"Restoration of a Vintage Turntable" by Ron Tipton was informative and enjoyable (2/11 aX, p. 20). However, he replaced the typical tonearm (Shure M2327) that has overhang and cartridge offset with one that does not. While this "works," he's not getting the best sound and performance from his cartridge. Thank you for your creative magazine!

Vincent Mogavero
VMogavero@aol.com

Ron Tipton responds:

Yes, you are technically correct that my tonearm replacement as described in my article was not the "best" choice. But this restoration is a work-in-progress. Since writing the article (Jan. 2010), I have moved

the tonearm closer to the platter. With the Sumiko azimuth-adjustable headshell and Denon DL-103R cartridge, I have about 2mm overhang and reasonable tracking without offset (**Photo 1**). Yes, it does "work" and the performance is much improved over the original Shure tonearm and cartridge.

I am now working on replacing the tonearm with a longer tube by taking design information from Mr. Yeago's article "AR Tonearm Renovation" in the January 2011 aX digital edition (p. 47). I have found a carbon fiber tube that appears to be nearly ideal for this use from www.dragonplate.com.

HELP WANTED

Thank you for running the article by Mr. Touzelet concerning electronic circuit simulation and Excel (9/07 aX, p. 18). As a subscriber, I am mainly interested in loudspeaker design. I searched the Internet but could not find an Excel loudspeaker analogous circuit tool. I recall—but could not find—an article many years past in *Speaker Builder* on the topic of analogous circuit (before Excel was common). However, I ran across "Rhinos" (SB 5/99, p.

26), which was great to read again!

Is there an Excel tool available to model loudspeaker analogous circuits?

Rick Schultz
schultzrick@sbcglobal.net

Note: We do not know of an Excel app for analogous speaker design circuits. Readers who do, please respond.—Eds.

POWER OUTLETS

Gary Galo's article "Keep It Clean" (1/11 aX, p. 8) appears to suggest using 20A receptacles on any home receptacle circuit. In most cases, that is a violation of the National Electrical Code, Article 210.21, b., 3., and may cause you problems with your fire insurance. The overwhelming majority of homes in North America are wired with #14 wire rated at 15A.

Due to construction costs and lack of a mandate to do otherwise, 20A receptacle circuits are extremely rare outside of the kitchen or laundry. Installing a 20A receptacle on a 15A circuit is a violation, but multiple 15A receptacles are allowed on a 20A circuit because individual portable devices requiring over 15A are uncommon. Yes, multiple 15s equal 30A or more, but the intent is to avoid misleading the user into expecting 20A. The code does not want you to rely unnecessarily on the over-current protection devices, which can fail. You can verify the rating of the circuit in question by checking the rating of the circuit breaker or the fuse (assuming it has not been improperly replaced) in your distribution panel.

There is no excuse to violate the code. Specification Grade receptacles rated at 15A are available, but they are not stocked in either size by most chain stores. I have not checked this out, but I wonder whether a receptacle designed to accommodate a 20A plug would grip the 15A plug of your amplifier any better or even as well as one specifically designed for 15A. One contact of a 20A receptacle must be split to accept the interlock tab of the "T" shaped blade



PHOTO 1: Netronics turntable with tonearm modifications.

on a 20A plug, which means less contact area for the 15A flat blade. Reliability usually goes with simplicity.

Most Hospital grade receptacles are mechanically the same as Specification Grade (Specification Grade implies Best Quality), but the Hospital Grade version is subject to additional independent testing (for pull-out—not contact resistance) and given a specially marked front identifying the Hospital certification as required by the code for hospitals. Carrying the higher grade “Underwriter’s Laboratory” (UL) certification label requires a higher fee that is passed on to the consumer. Because contact resistance is your concern and not the risk of a wrongful-death lawsuit from someone accidentally disconnecting your equipment, the value of Hospital certification is questionable.

Furthermore, gold plating on a power plug seems inappropriate. The high pressure contacts of a power receptacle are designed to cut through surface corrosion when inserting the plug, and gold is too soft to survive that action leaving the substrate metal bare. Gold is best for delicate small signal connections because of its corrosion resistance, but the harder nickel makes more sense when dealing with the mechanical stresses of power connections. I also question whether pull-out resistance/friction is an accurate indicator of contact pressure/conductance. A rough contact surface would produce more friction but also more electrical resistance.

*Dennis L. Green, P. E.
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Gary Galo responds:

Mr. Green is absolutely correct that connecting a 20A outlet to 14AWG wiring is a clear violation of code, and should *never* be done. However, in the sixth paragraph of my article, in the middle of the very first page, I wrote:

“Normally, you should hire a licensed electrician to perform any electrical work in your house. If you are knowledgeable and experienced enough to do the work yourself, it’s your responsibility to make certain that your installation is electrically safe, and that it complies with local, state, and national electrical codes. Failure to do so may compromise electrical safety and jeopardize your

homeowner’s insurance coverage.”

A tutorial on electrical codes as they pertain to AC house wiring was beyond the scope of my article and any reader who follows my advice in this paragraph will avoid any practices that are either unsafe, illegal, and/or may jeopardize insurance coverage. Mr. Green is right—there’s no excuse to violate the code. Following the advice that I gave will ensure that this doesn’t happen. If you have any doubts, hire a licensed electrician to perform your installation. If you choose to do the work yourself, pay an electrician to perform an inspection of your work, and get a written statement that your work complies with all electrical codes. I hope I have now made myself clear.

Mr. Green states that “the overwhelming majority of homes in North America are wired with #14 wire rated at 15A.” I’d like to see some verifiable data to back this up. If it’s true, it’s a shocking (no pun intended) statistic. Our house was built in 1973 and all of the original wiring is 12AWG, with the exception of a now-unused line that once ran an electric water heater—that one is 10AWG. Code or not, I consider 12AWG wiring a minimum acceptable standard, even for 15A power outlets. Using 12AWG wire also forces your electrician to use the screw terminals on the outlets, rather than simply shoving the stripped wires into the push terminals on the rear (push terminals are only large enough to accept 14AWG wire). If I was having a new house built, I’d insist on 12AWG wiring throughout, and I’m glad our house has it.

It’s instructive to look at the internal construction of the 15A and 20A outlets, so I

broke open a pair of outlets. **Photo 1** shows a standard-grade 15A outlet on the left (59 cents at Lowe’s) and a 20A specification-grade outlet on the right (\$3.64). These outlets are made by Cooper Wiring Devices, a well-respected company, and are typical of the construction used in these types of outlets. The contacts in the 15A standard outlet are angled to form a “V,” so most of the connection is made on one end of the inserted plug blade. If you insert a plug, you’ll see that there is no surface contact on at the open end of the “V,” and you can slide a piece of index card at least halfway in.

On a 20A plug—for those readers who have never seen one—the neutral blade is perpendicular to the hot blade, so this type of plug can only be inserted into a 20A outlet. Inside the outlet, the split contacts accommodate this perpendicular pin. In the 20A specification-grade outlet on the right, the inside contacts are straight so the entire surface makes contact with the plug blade. Add to this the two split contact edges opposite the flat surface, and you have considerably more contact surface area than in the 15A receptacle (subjectively it looks like at least twice as much contact area). Physically, an inserted plug is noticeably harder to remove. Note that both hot and neutral have the same type of connector, with the split on one side, even though it’s only needed on the neutral side to accommodate a 20 plug. This arrangement is also used for the hot side because it makes a superior connection.

Our local Lowe’s does carry 15A specification-grade outlets mentioned by Mr. Green, though most hardware stores don’t. I examined one of these, also made by Coo-

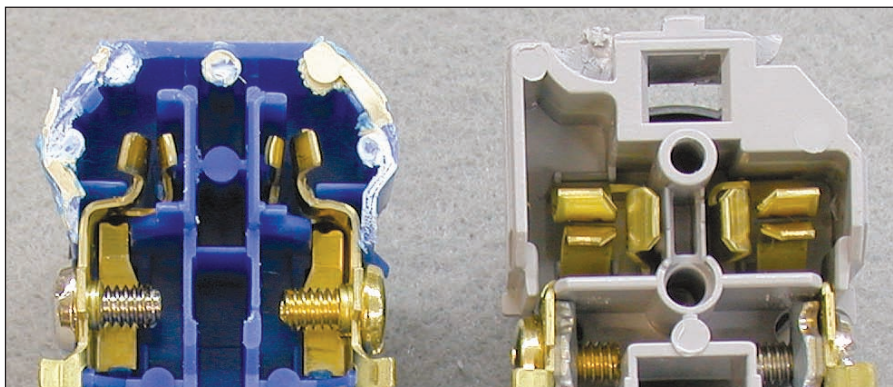


Photo 1: Internal construction of common 120V AC receptacles. In the 15A standard-grade outlet on the left the contacts are angled, forming a “V.” The plug blade does not make contact at the open end of the “V.” In the 20A specification-grade receptacle on the right, the inside contact is straight, making contact with the entire plug blade, and the edges of the split side increase contact area even further.

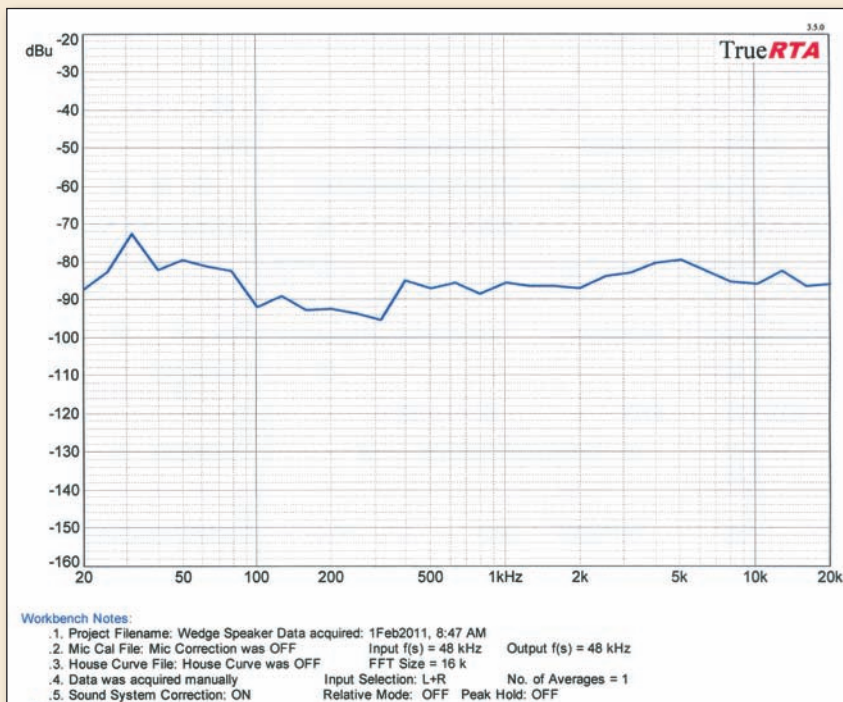
per, and found their internal construction to be identical to the 20A outlet. The only physical difference seems to be the lack of the perpendicular slot in the plastic, which prevents insertion of a 20 plug. As with the 20A specification-grade receptacle, both hot and neutral use the split-contact arrangement on one side.

The tighter connections found in specification-grade and hospital grade outlets are also beneficial when used with heavy power cords, such as the ones I described in the article. The weight of these cords makes them more susceptible to partial unplugging. But, from a purely electrical standpoint, a tighter connection is usually a better connection, assuming that the contact surfaces are smooth.

Mr. Green's points about the value of gold plating on AC plugs and receptacles are well taken. I suspect that most audiophiles plug their equipment into the wall once, and leave things alone for extended periods. But, I agree that repeated insertion and removal will probably wear off the gold plating, negating its value. ■

WEDGE PROJECT

As a follow-up to Ken Bird's Wedge Speakers (3/11 *aX*, p. 8), here's an in-room response measurement of the speaker system:



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