By Claudio Negro and Valerio Russo

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 requests, 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.

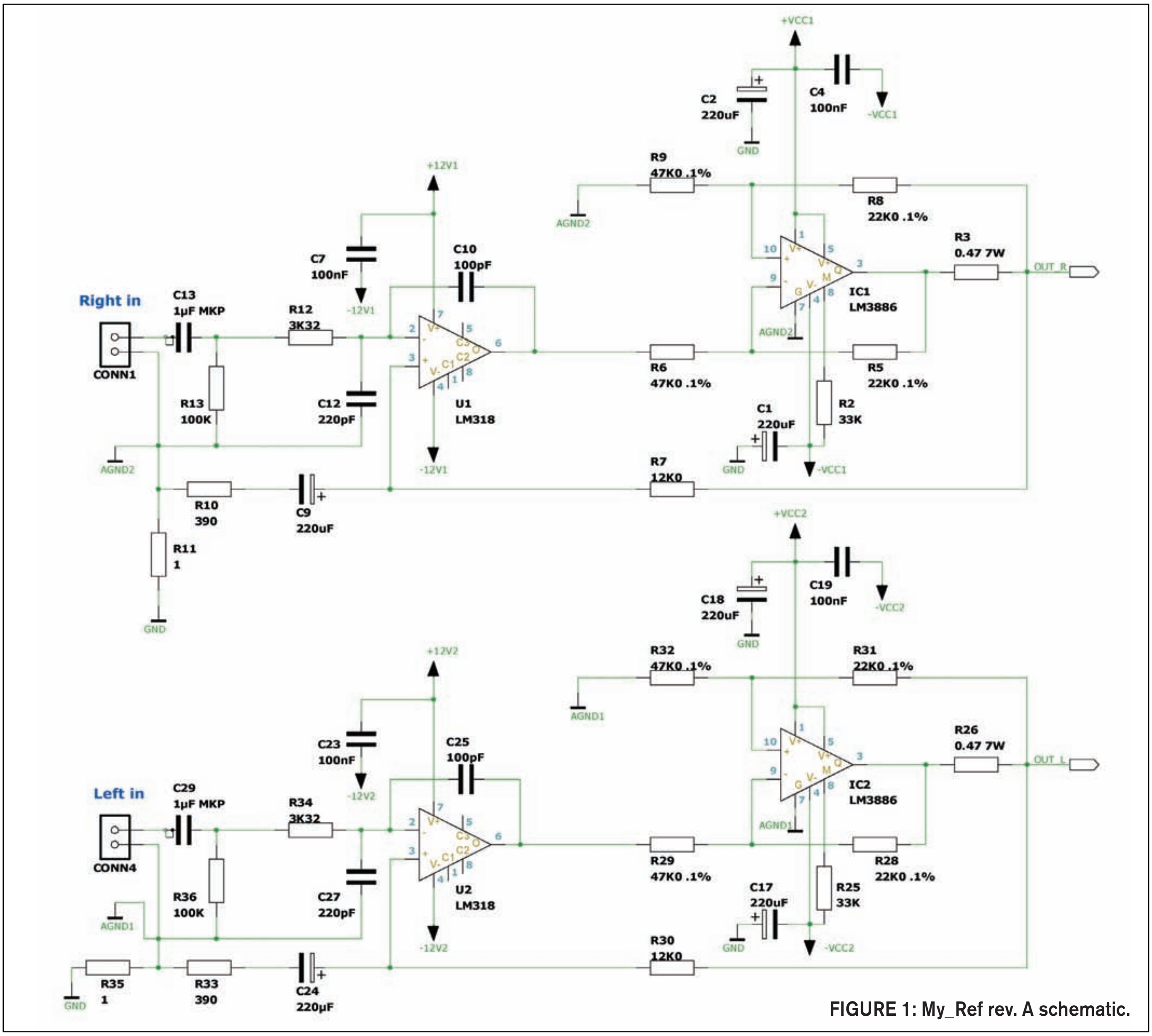


FIGURE 1: My_Ref rev. A schematic.

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 unweighted

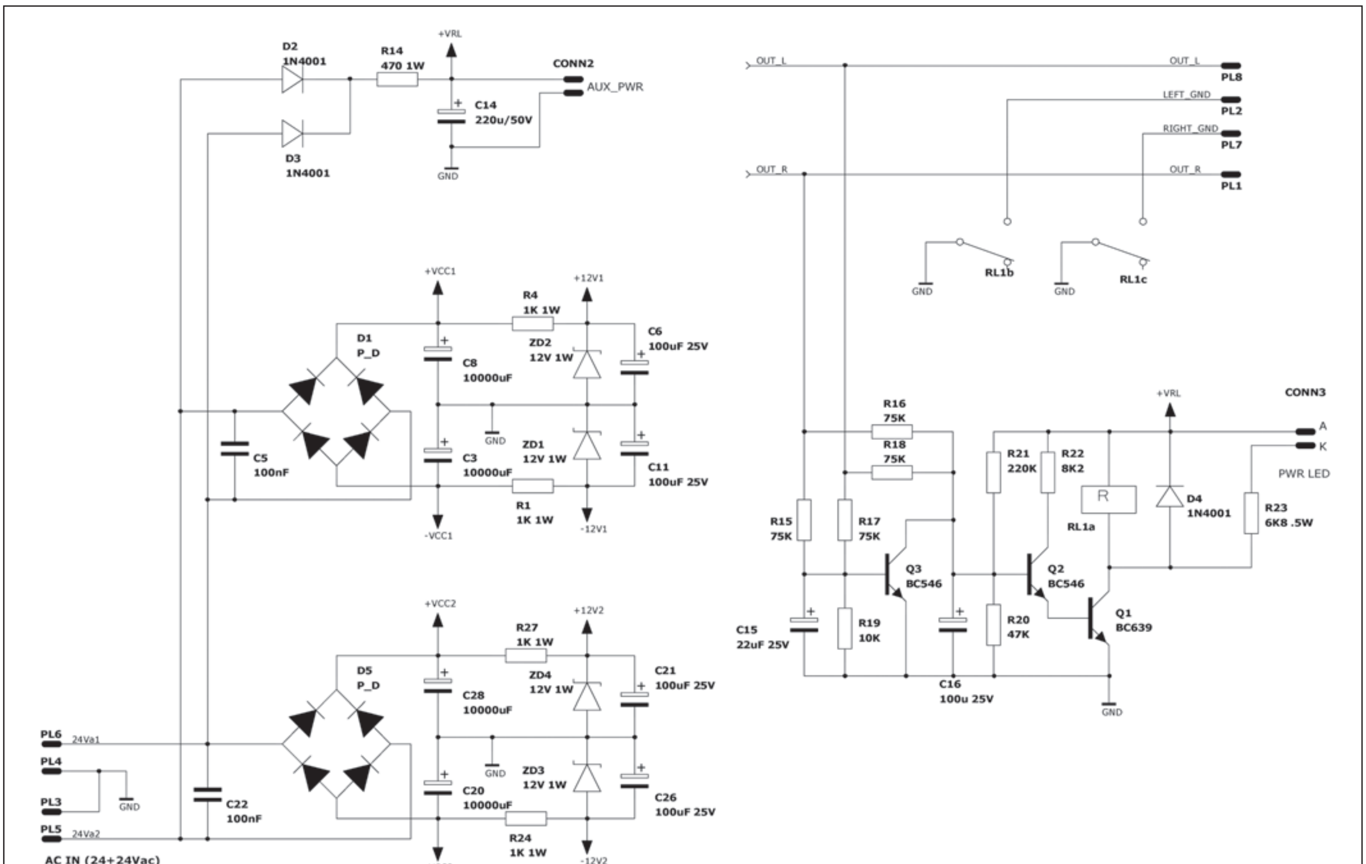


FIGURE 2: My_Ref power supply schematic.

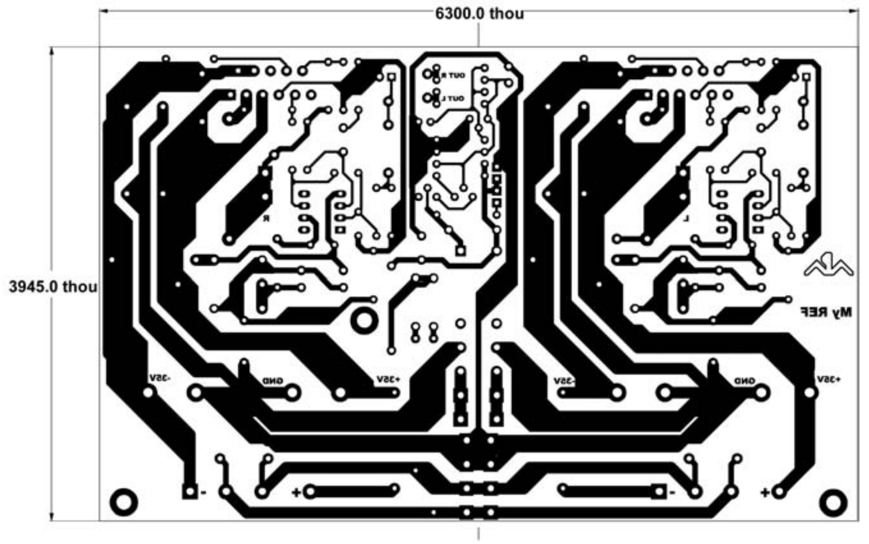


Figure 3: PCB solder side. Actual dimensions: 100 × 160mm.

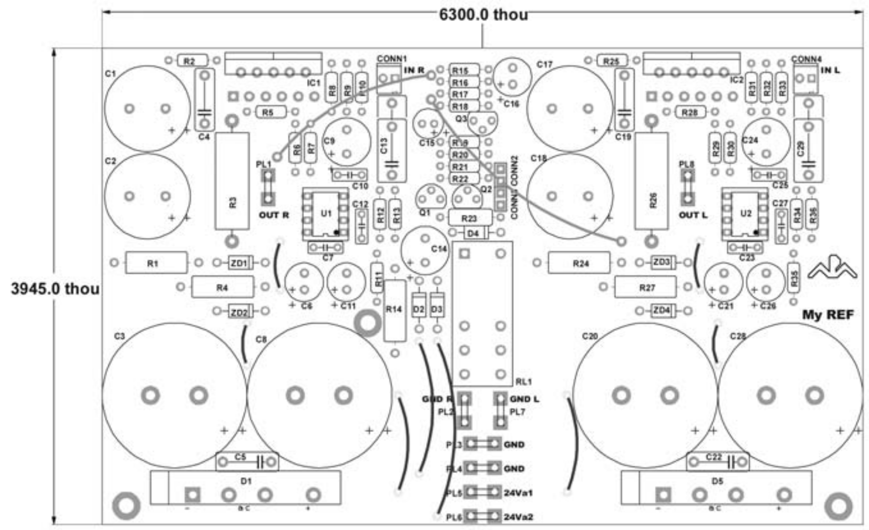


Figure 4: PCB component side.

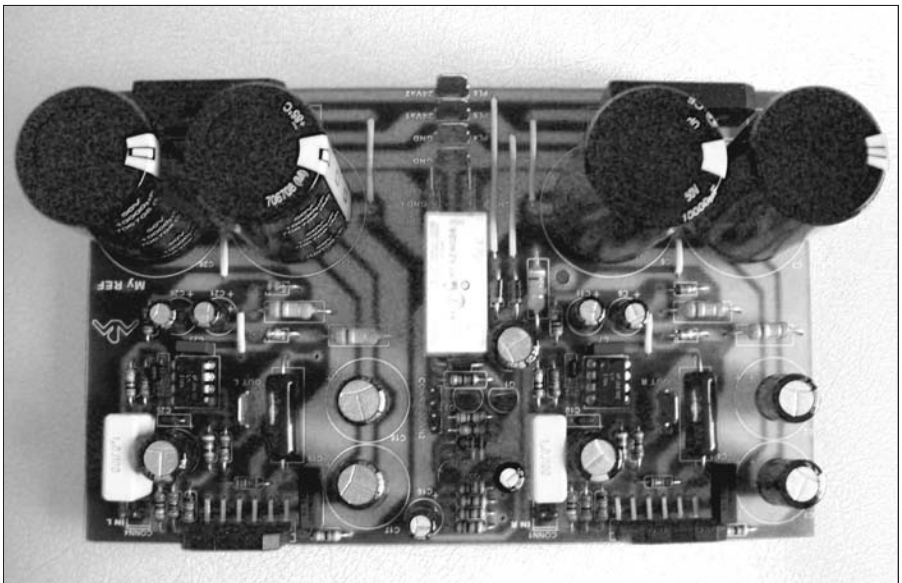


PHOTO 1: The My Ref. completed PCB.

- 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 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 6.8kΩ ½W resistor in series with the LED. The lighting "status" can be

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

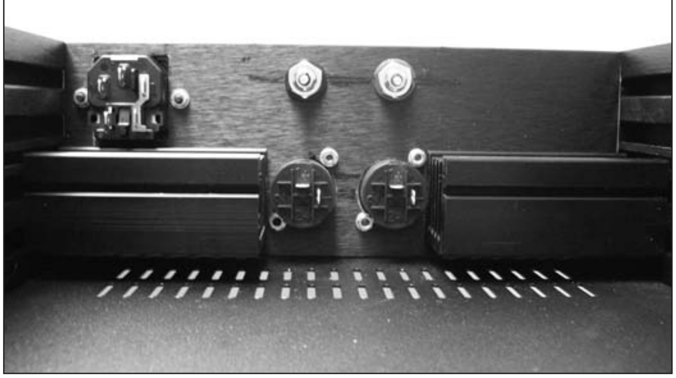


Photo 3: Sheet of bakelite glued to the case to support the transformer

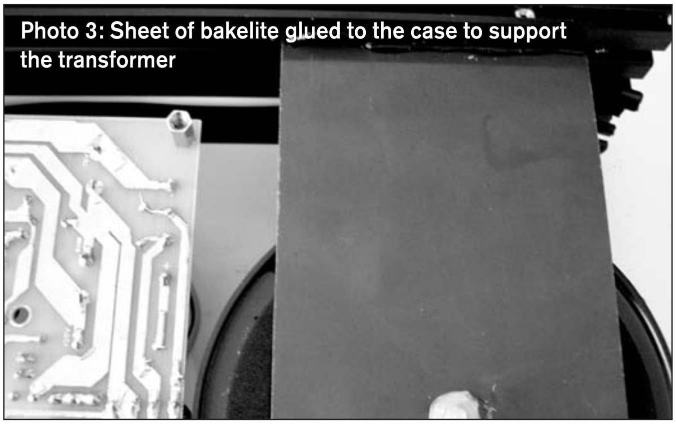


Photo 4: Power line and signal cabling

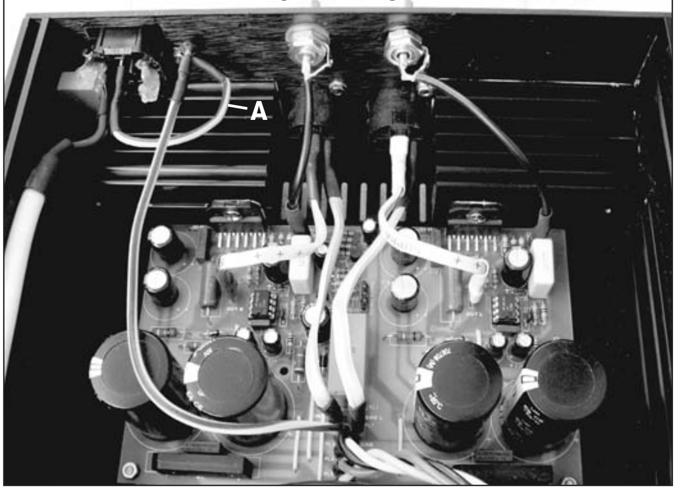


Photo 5: Switch cabling view.

Photo 6: Completed amplifier internal view.

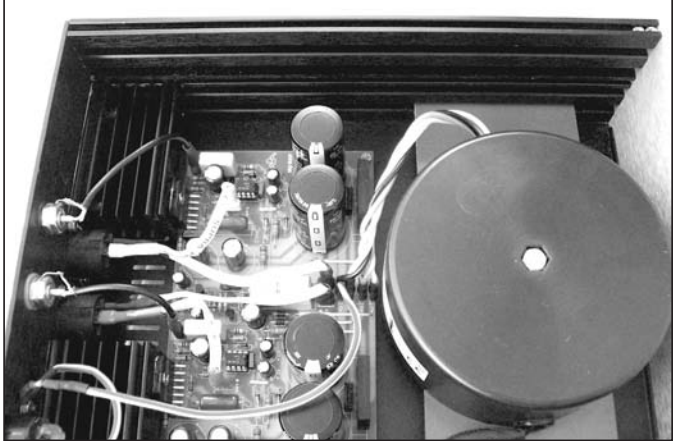
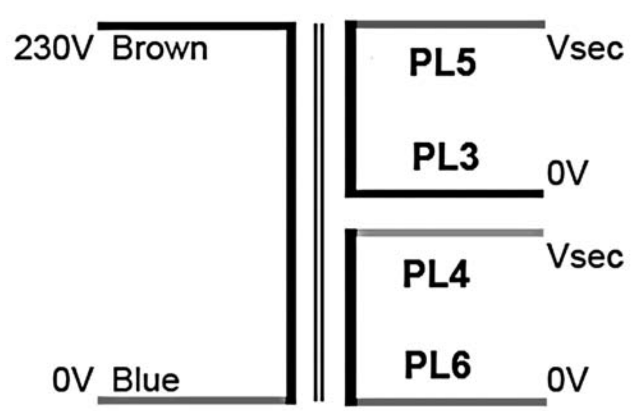


Figure 5: Transformer secondary cabling.



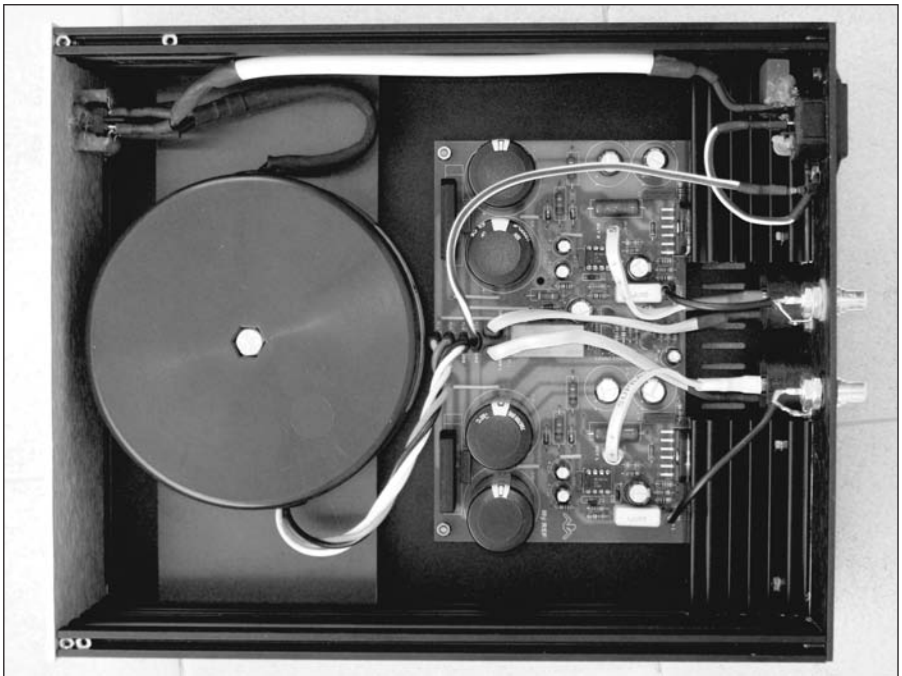


PHOTO 7: Inside the My ref. amp.

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.

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 measurments 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/				

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The Solid-State Duo,
Part 1
Measurements

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

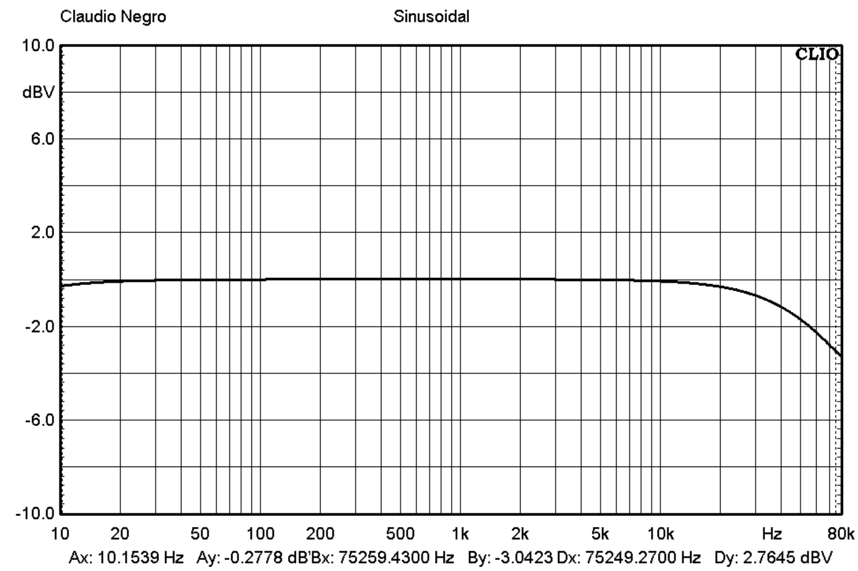

FIGURE 1: Frequency response, at 2.83V RMS, 8Ω load

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.

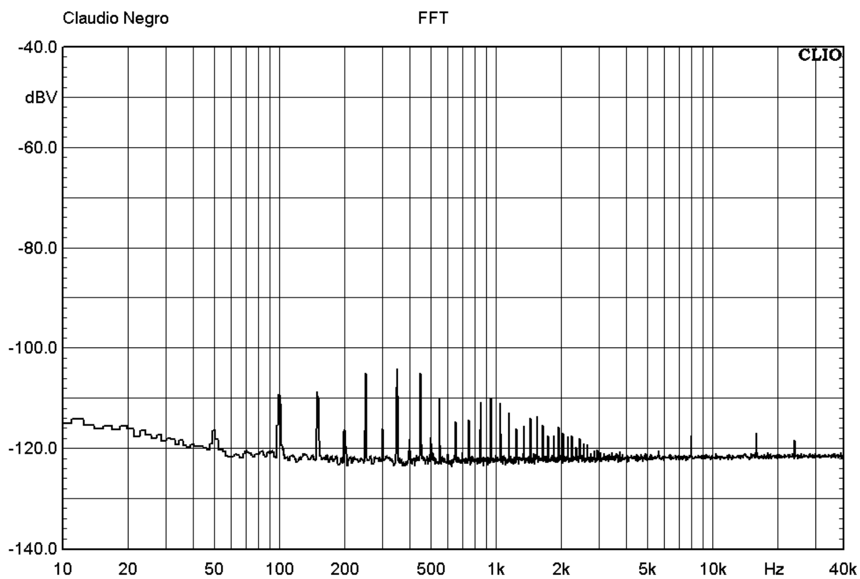

FIGURE 2 : Noise level, input terminated with a 620Ω resistor.

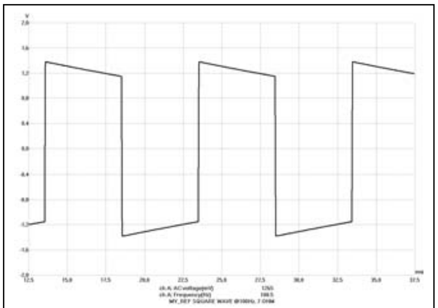

FIGURE 3: Square wave response, 100Hz, 2.5Vpp, 7Ω load.

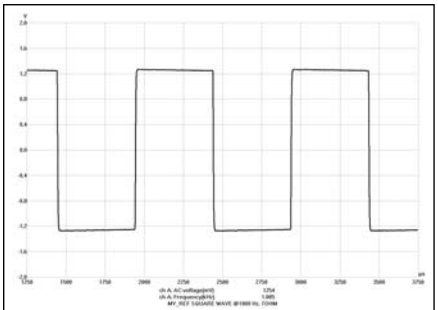

FIGURE 4:Square wave, 1000Hz, 2.5Vpp, 7Ω load

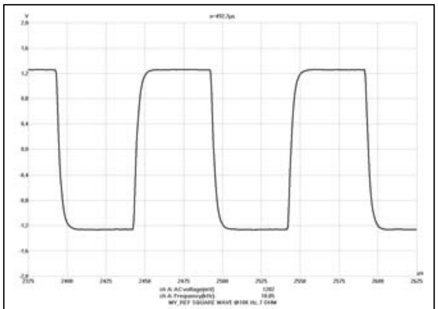

FIGURE 5:Square wave response, 10000Hz, 2.5Vpp, 7Ω load.

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

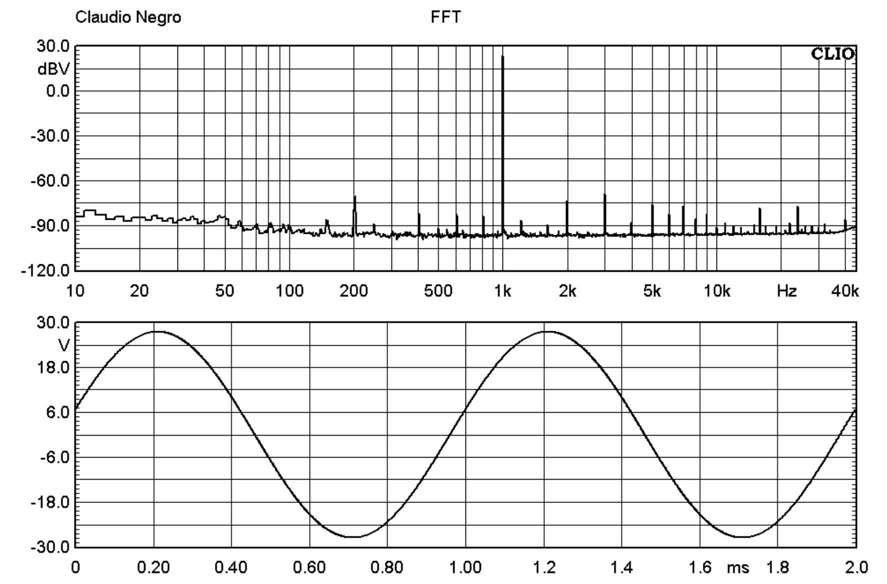

FIGURE 6: FFT and wave response before clipping, 1000Hz, 19.4V RMS, 8Ω load

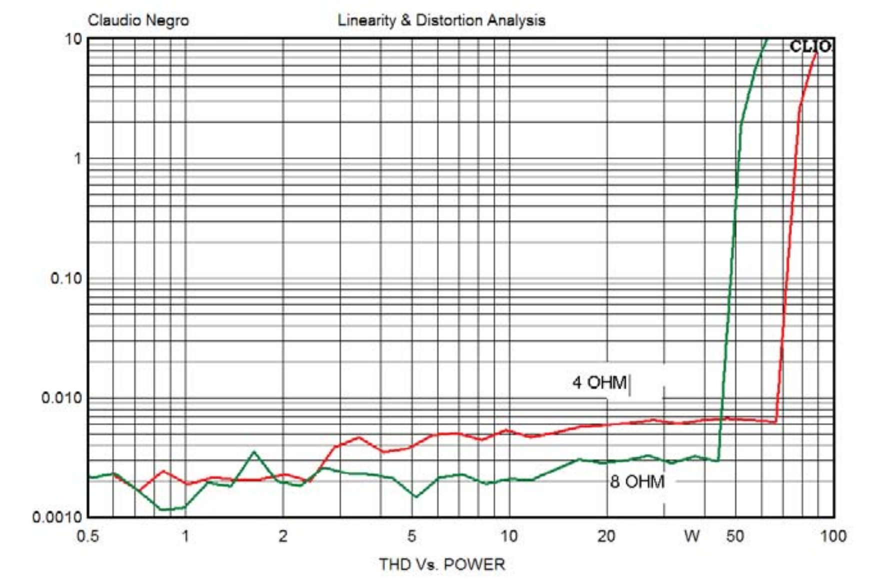

FIGURE 7: THD vs. power, 4 and 8Ω load

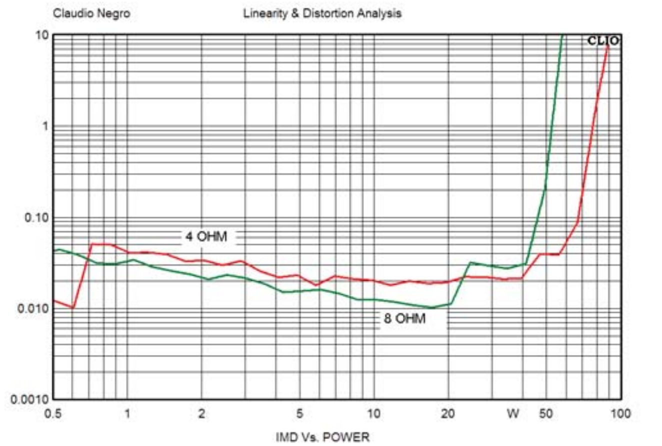

FIGURE 8: IMD vs. Power, SMPTE

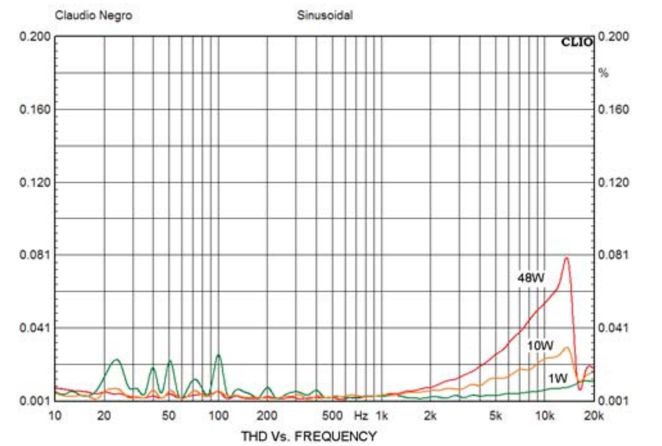

FIGURE 9: THD vs. Frequency, 1-10-48 Watt, 8 Ω load