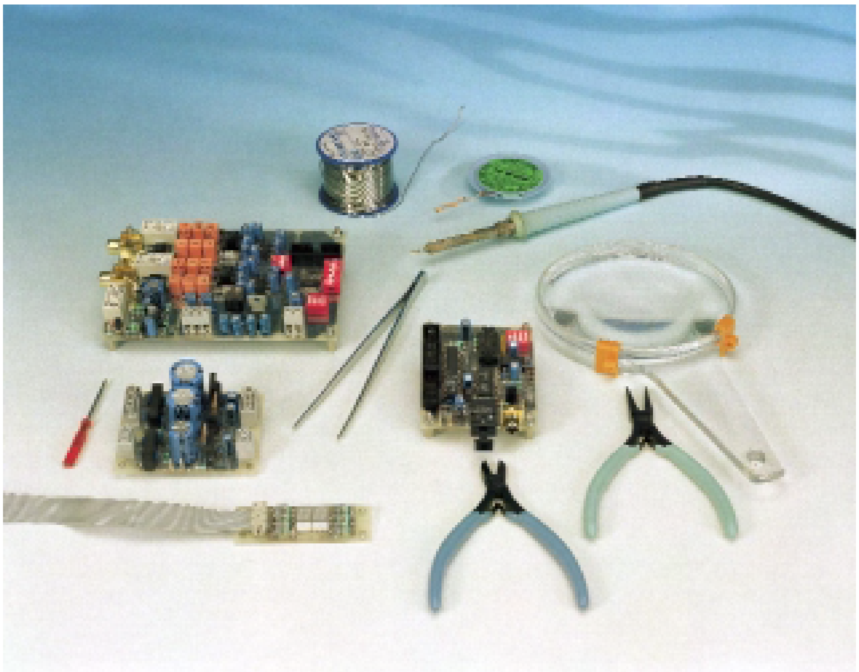
audio DAC 2000

Part 3: practical matters

Readers who have studied and absorbed Parts 1 and 2 of this article will be fully aware of how the Audio DAC 2000 works. What remains to be discussed is the actual building of the converter, and this is done in this third and final part.



Design by T. Giesberts

POWER SUPPLY

Although the summary implies that all parts of the digital-to-analogue converter (DAC) have been discussed, this is not entirely true, because the power supply has not yet been described.

It was seen in Part 2 of this article that the converter ICs need a symetrical ±5 V supply and that this was derived via regulators IC13 and IC14 from the ±12 V supply line for the analogue circuits. Since it is important to keep the supply lines to the converter ICs as short as possible, the regulators are housed on the DAC board.

The receiver section and some other circuits on the DAC board need a single +5 V supply and a symmetrical ±12 V supply. These voltages are produced with the aid of regulators IC15–IC17, which, together with the other components of the power supply, are housed on a separate board, the PSU board.

The circuit of the power supply is shown in **Figure 5**. Note that the +5 V line for the digital circuits is isolated from the ±12 V lines for the analogue circuits.

The earth lines of the two supplies are interlinked on the DAC board between the digital filter and the converter ICs (that is, JP3).

Obviously, the supply consists of not only regulators, but also bridge rectifiers and smoothing capacitors. Resistors R55, R56, and R58 between the rectifiers and smoothing capacitors limit the charging current to the capacitors at power-on, and any resulting interference.

The secondaries of the relevant mains transformers are linked to K11 and K13 respectively. The choice of transformer is up to the constructor, although some suitable models are specified in the parts list.

The power supply is conveniently built on the 'transformer board' described elsewhere in this issue. This board is designed to house all the components required for the present power supply.

Printed-circuit boards

As already mentioned in Part 1, the Audio DAC 2000 is contained on four individual printed-circuit boards: one for the ±12 V and +5 V power supplies; one for the digital audio receiver with display driver; one for a 2-digit LED display; and one for the digital/analogue circuits, the digital filter, the DACs and the analogue output stage. These boards are sections of the double-sided PCB shown in **Figure 6**. This high-quality board is available through our Readers Services. Before any work is carried out, these four sections should be separated from one another along the milled cutting lines, either by snapping or cutting along the lines

It is important to construct the various circuits according to the board layouts and the parts list. It is important that the orientation of the ICs and the polarity of the electrolytic capacitors are strictly observed, since any deviation results unfailingly in a non-working unit.

The DIP switches, S1–S4, are best soldered directly to the board. An exception is S2 if it is foreseen that processor (that is, software) control may be used at a later stage. In that case, the switch may be housed in a good-quality 8-way IC socket, but even then the board connector should be soldered in place at a later stage.

All supply lines are connected to the boards via terminal blocks that facilitate the wiring or servicing of the relevant circuits. The +5 V line for the digital section is linked to the DAC board. The receiver board is powered via the link between K3 and K5. Some protection against (a too) high supply voltage is provided by diode D4 on the DAC board.

The LED display board is linked to the receiver board via a 10-way flatcable. One end of this cable is connected permanently to the board via a 10-way board connector. The other end is terminated into a 10-way socket. Take good care to use the correct length of cable. The displays are soldered directly to the board.

The digital audio receiver, IC1, is soldered directly to the receiver board. Take care not to damage this IC by electrostatic discharges. Sockets may be used for IC4 and IC5. Crystal oscillator IC3 is also best soldered directly to the board, since it is then as close as possible to the ground plane.

Start populating the DAC board by soldering IC6 to the board — see **Figure 7**. This tiny SMA (surface-mount assembly) IC is housed in a 28-pin SSOP case, whose pins are spaced at only 0.65 mm. This requires extreme care, a tiny soldering iron tip, and possibly a magnifying glass to check the soldering work. Take good care not to overheat the IC: take a pause between soldering, say, 2 or 3 pins at a time.

Next, solder the converter ICs, IC_7 and IC8, in place. These are housed in a standard 20-pin SMD case (SOIC), and are easily soldered. It is best to fit op amps IC9–IC12 in good-quality IC sockets.

Capacitors C27–C38 in the analogue section are 1% close-tolerance types in a square radial format, with the terminals placed at two opposing corners. These types are manufactured by EMZ. Their pitch is standard (7.1 mm), so they could be replaced by metallized film polystyrene or polypropylene types. It should be borne in mind, however, that the larger tolerances of these types may result in significant changes in the frequency and phase responses. The EMZ capacitors specified carry a thin dash that indicates which terminal is linked to the outer layer. Make sure that this pin is linked to ground or to the output of an opamp: this makes the analogue section less sensitive to interference. The same applies to axial capacitors C25 and C26: place the band on these at the output side of opamps IC9 and IC11.

The relays are soldered directly to the board. Do not forget wire bridges JP2 and JP3: these are permanent links which may be made in rather thicker wire than usual.

A final practical hint. To improve the channel separation at high frequencies, it is advisable to shield the left- and right-hand sections of the analogue output filter from one another. This is best done by placing a small (86×13 mm) tin-plate screen between Re2 and IC12. The screen stretches from the edge of the board to DIP switch S4: its position is indicated in **Figure 6** by a dashed line. At the ends, scratch away some of the lacquer on the board with a sharp pen knife to ensure that the screen makes good contact with the copper area at the top of the board which functions as ground plane — soldering the ends of the screen to the copper is even better. In the prototype, the addition of the screen improved the channel separation by 12 dB at 20 kHz.

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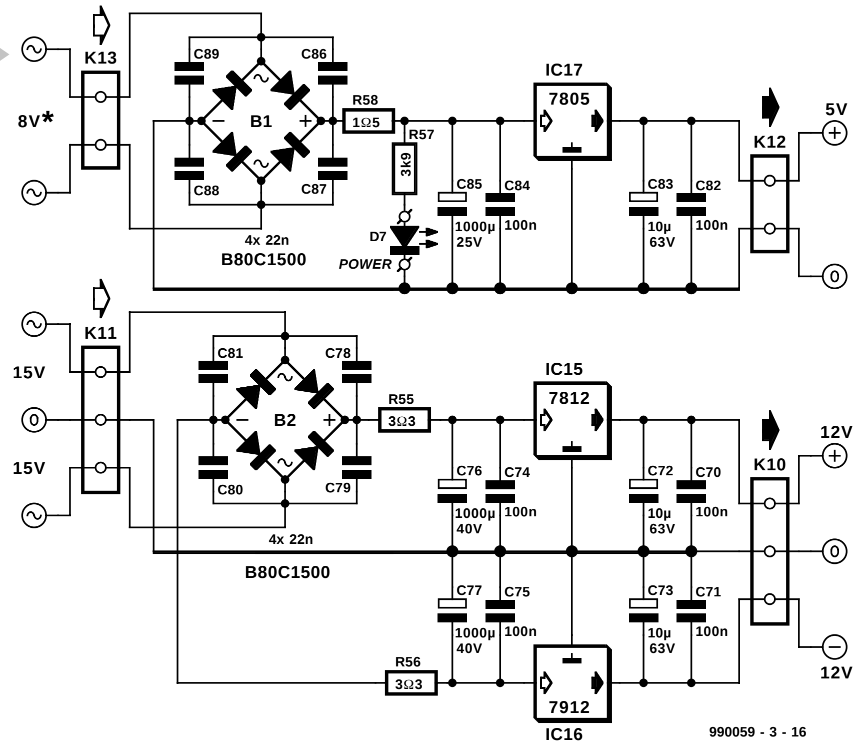

Figure 5. Circuit diagram of the power supply for the Audio DAC 2000. The +5 V line for the digital circuits is isolated on the board from the ±12 V line for the analogue section.

Enclosure

When the four boards have been completed and checked for possible building or soldering errors, they must be combined into a complete Audio DAC 2000 and housed in a suitable enclosure. The most suitable enclosure is a sturdy metal case, which, as far as appearance is concerned, should preferably match the audio installation with which it is to be used.

The prototype is housed in a Monacor Type UC251/SW enclosure. This is 435 mm wide, 230 mm deep, and 44 mm high — see **Figure 8**. In some countries in which *Elektor Electronics* appears, Monacor products are sold under the brand name 'Monarch'.

The manner in which the boards are arranged in the enclosure is optimal and constructors are well advised

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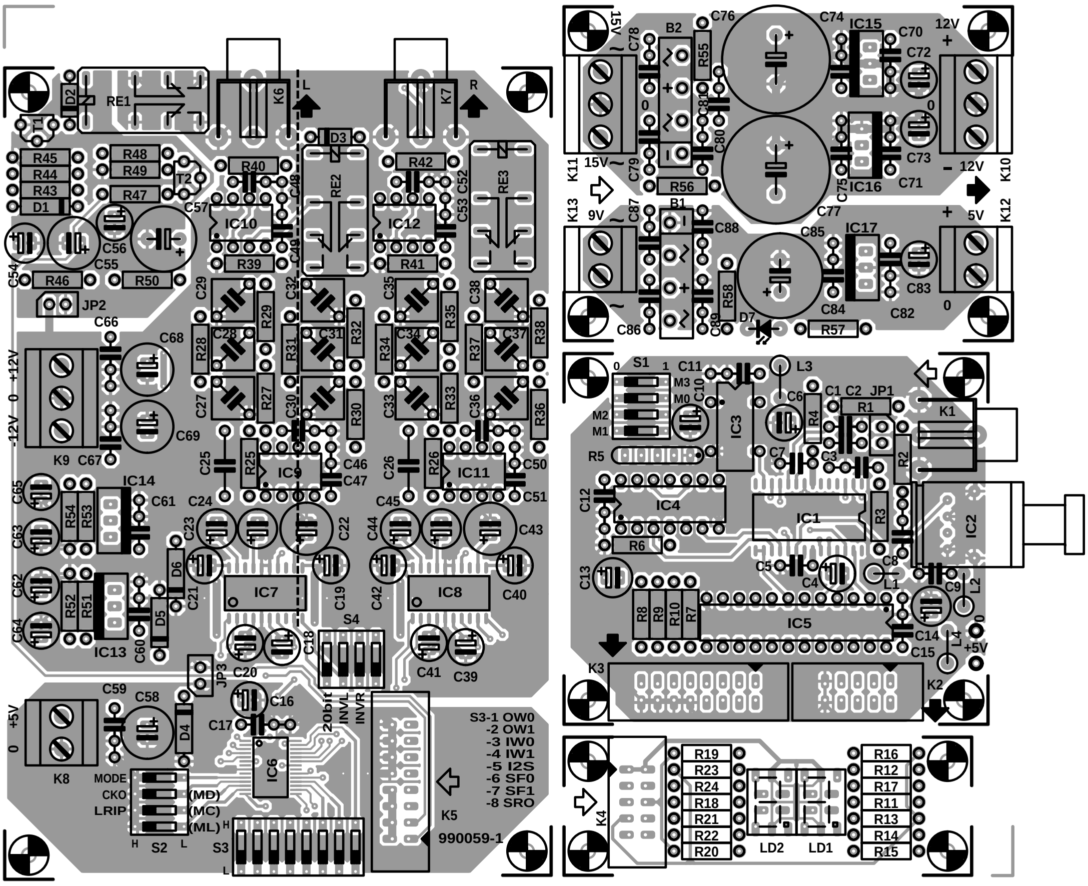


reproduced at 85% of actual size

Figure 6. The double-sided board must be divided into four sub-boards along the fraised lines.

COMPONENTS LIST

Resistors:
R1 = 75Ω
R2 = 220Ω
R3 = 470Ω
R4,R50 = 4Ω7
R5 = 4-way 10kΩ SIL-array
R6 = 10kΩ
R7-R10 = 22Ω
R11-R24 = 820Ω
R25,R26 = 2kΩ49 1%
R27,R30,R33,R36 = 3kΩ57 1%
R28,R34 = 4kΩ12 1%
R29,R35 = 3kΩ92 1%
R31,R37 = 3kΩ65 1%
R32,R38 = 3kΩ32 1%
R39,R41,R45,R49 = 1MΩ
R40,R42 = 100Ω
R43,R44,R47,R48 = 150kΩ
R46 = 10Ω
R51,R53 = 249Ω 1%
R52,R54 = 750Ω 1%
R55,R56 = 3Ω3
R57 = 3kΩ9
R58 = 1Ω5

Capacitors:
C1,C2 = 10nF ceramic
C3 = 68nF
C4,C6,C10,C16,C62-C65,C72,
C73,C83 = 10µF 63V radial
C5,C7 = 47nF ceramic
C8,C9,C11,C12,C15,C17,C46-C53,
C59,C60,C61,C66,C67,C70,C71,
C74,C75,C82,C84 = 100nF ceramic
C13,C14,C23,C24,C44,C45,
C54 = 47µF 25V radial
C18-C21,C39-C42 = 4µF7 63V radial
C22,C43,C58,C68,C69 = 100µF 25V radial
C25,C26 = 47pF [1] axial (EMZ)
C27,C33 = 2nF2 1% [1] (EMZ)
C28,C34 = 4nF7 1% [1] (EMZ)
C29,C35 = 330pF 1% [1] (EMZ)
C30,C36 = 1nF 1% [1] (EMZ)
C31,C37 = 1nF5 1% [1] (EMZ)
C32,C38 = 270pF 1% [1] (EMZ)
C55 = 220µF 25V radial
C56 = 1µF 63V radial
C57 = 470µF 25V radial
C76,C77 = 1000µF 40V radial
C78-C81,C86-C89 = 22nF ceramic
C85 = 1000µF 25V radial

[1] *polystyrene/polypropylene*

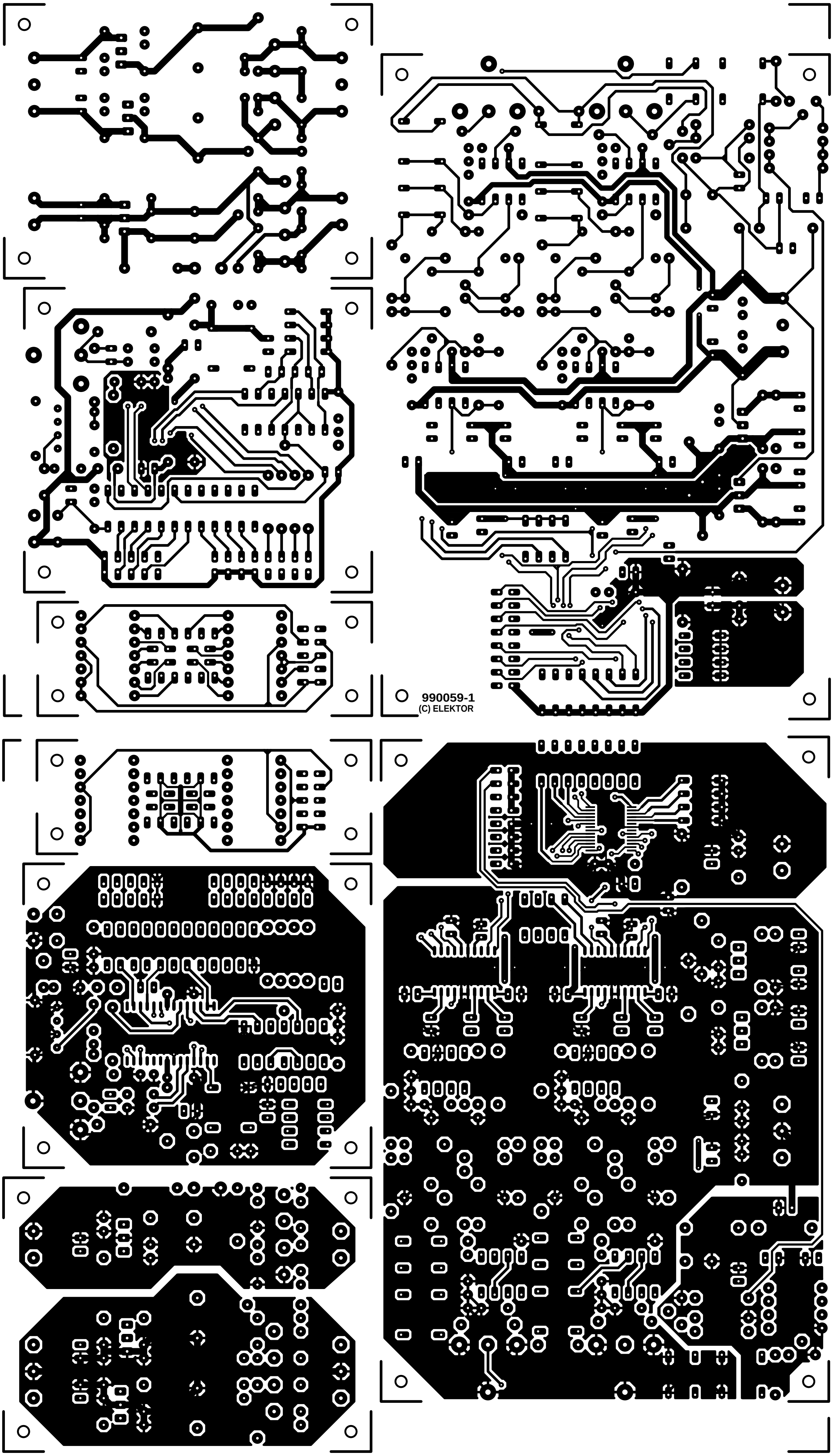
EMZ, Elektromanufaktur Zangenstein
Hanauer GmbH & Co.
Siemensstrasse 1
D-92507 Nabburg
Germany
Tel. +49 9433 898-0
Fax +49 9433 898-188

Inductors:
L1-L4 = 47 µH

Semiconductors:
D1 = 1N4001
D2,D3 = 1N4148
D4,D5,D6 = 5V6 1W3 zener diode
D7 = LED, red, high-efficiency
LD1,LD2 = HDN1075O (Siemens)
T1,T2 = BC517
IC1 = CS8414-CS (Crystal)
IC2 = TORX173 (Toshiba)
IC3 = 6.144MHz SG531P (Seiko Epson)
IC4 = 74HCT32
IC5 = GAL22V10B-25LP (ready-programmed, order code **996530-1**, see Readers Services pages)
IC6 = DF1704E (Burr-Brown)
IC7,IC8 = PCM1704U (Burr-Brown)
IC9...IC12 = OPA627AP (Burr-Brown)
IC13 = LM317 (TO220)
IC14 = LM337 (TO220)
IC15 = 7812
IC16 = 7912
IC17 = 7805

Miscellaneous:
JP1 = 2-way pinheader + jumper
JP2,JP3 = wire link *
K1,K6,K7 = cinch socket, PCB mount (Monacor/Monarch type T-709G)
K2 = 10-way boxheader
K4 = 10-way PCB-connector (for flat-cable)
K3,K5 = 16-way boxheader
K8,K12,K13 = 2-way PCB terminal block, raster 5 mm
K9,K10,K11 = 3-way PCB terminal block, raster 5 mm
S1,S2,S4 = 4-way DIP-switch
S3 = 8-way DIP-switch
B1,B2 = B80C1500, rectangular case
Re1,Re2,Re3 = V23042-A2003-B101, 12V/600 Ω (Siemens)
Supply transformers: 2x15 V/4 VA (e.g. Block FLD4/15; Hahn BVUI 3020165; Monacor FTR-415), and 2x8(or 9) V/4 VA (e.g.. Block FLD4/8; Hahn BVUI 3020161; Monacor FTR-49 – see transformer board elsewhere in this issue)
PCB, order code **990059-1**, see Readers Services pages.

* see text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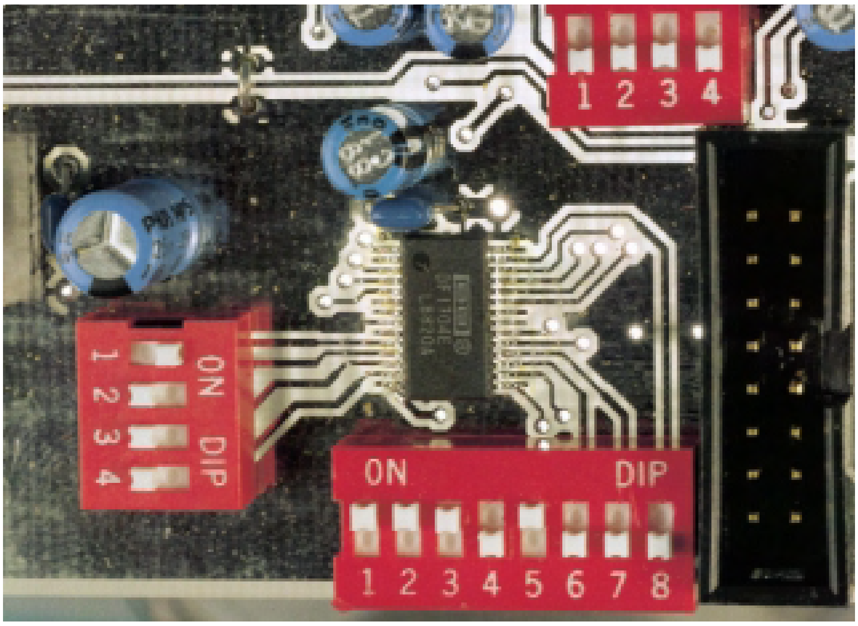


Figure 7. Soldering IC6 into place requires a steady hand, good eyesight and precision tools.

to use the same arrangement: the DAC board in one corner, the receiver board next to it, the supply board in front of this, and the transformer board in the remaining corner.

The only items to be fitted on the front panel are the mains on/off switch and the display that shows the sampling rate. If desired, power diode D7 may be added to this, but this is not really necessary since LD1 and LD2 function very well as on/off indicator.

The interwiring may be gleaned from Figure 8, but is summarized for convenience's sake.

- K2 on the receiver board is linked to K4 on the display board just behind the front panel via a 10-core flatcable.
- K5 on the DAC board is linked to K3 on the receiver board via a 16-core flatcable. This link also connects power to the receiver board. Mind the orientation of pin 1 on the connectors.
- K12 (+5 V) on the supply board is linked to K8 on the DAC board via two cables.
- K10 (±12 V) on the supply board is linked to K9 on the DAC board via three cables.

FINALLY

Testing a digital-to-analogue converter by ear is hardly possible or sensible. Noticeable differences, such as can be detected in the case of loudspeakers, cannot be expected. Nevertheless, a test audience felt that the DAC 2000 sounded better than a number of other available types of DAC. They found the sound cleaner and the stereo image clearer.

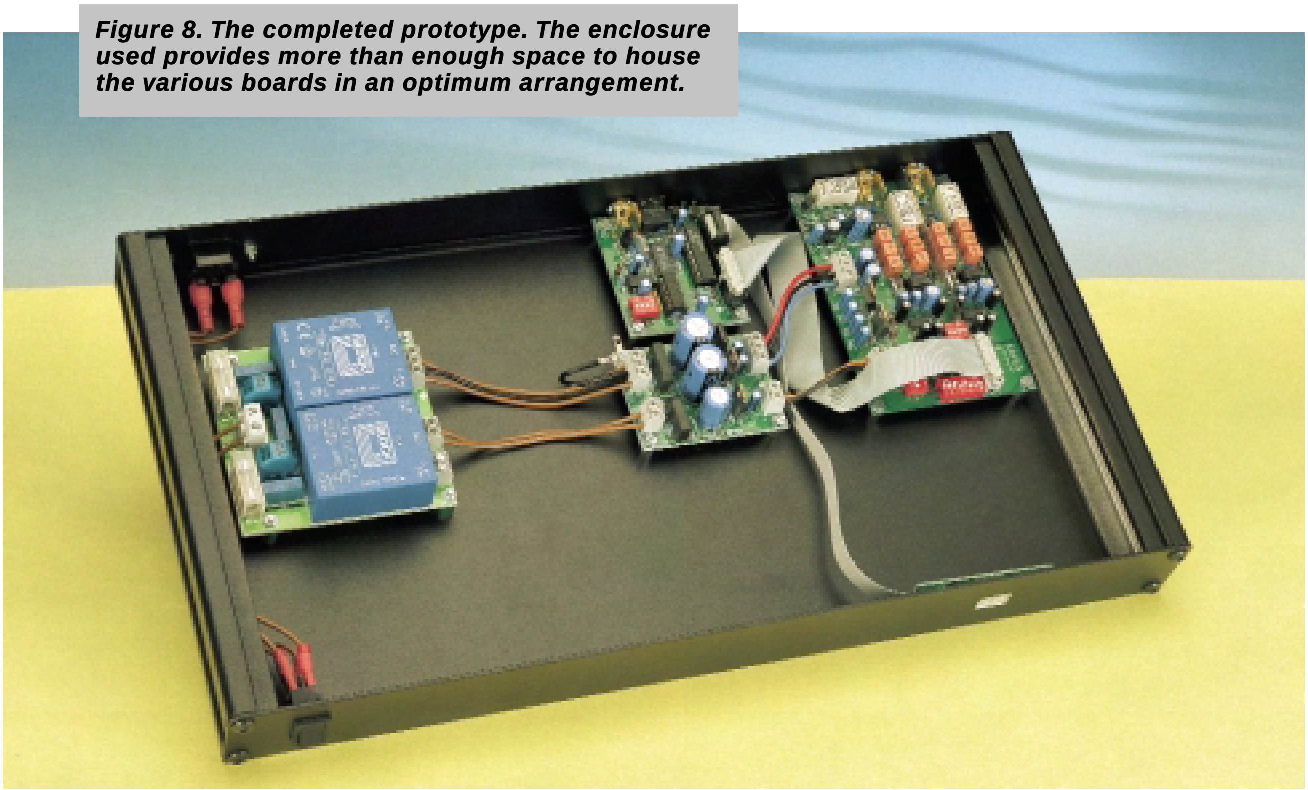
The test results in the box give a further judgment of the quality of the converter. They call for a few comments.

- The bandwidth of sampling frequencies 32 kHz, 44.1 kHz, and 48 kHz, is exactly equal to half the sampling rate, since at these frequencies the bandwidth of the analogue filter is larger than that of the steep-skirted digital filter. At 88.2 kHz and 96 kHz, the bandwidth is determined by the analogue filter.
- The THD + N at a sampling rate of 96 kHz is measured at a bandwidth of 22 kHz, because at lower sampling rates the analogue output filter has a bandwidth of 26 kHz. The reduction gives a more honest comparison of the three measurements.

[990059-3]

Text: S. van Rooij

Figure 8. The completed prototype. The enclosure used provides more than enough space to house the various boards in an optimum arrangement.



Technical specification

Properties

- 1 coaxial input and 1 optical input
- suitable for sampling rates of 32–96 kHz
- 2-digit readout of sampling rate
- 8× oversampling
- 24-bit digital filter
- 24-bit digital-to-analogue converters
- digital de-emphasis
- switchable third-order analogue output filter
- isolated supply lines for digital and analogue sections

Electrical characteristics

Nominal input voltage at coaxial input	0.5 V_{pp} into 75 Ω
Nominal output voltage	2.1 V r.m.s.
Frequency range (–3 dB)	0–f_S/2 (f_S = 32/44.1/48 kHz)
	0–42 kHz (f_S = 88.2/96 kHz)
Amplitude at 20 kHz	–0.94 dB (f_S = 32, 44.1, 48 kHz)
	–0.66 dB (f_S = 88.2, 96 kHz)
Bandwidth analogue filter	26 kHz (Butterworth at f_S = 32/44.1/48 kHz)
	42 kHz (Bessel at f_S = 88.2/96 kHz)
Output impedance	100 Ω
Signal-to-noise ratio	≥ 114 dBA
THD + N (1 kHz, B = 80 kHz)	0.0016% (44.1 kHz, 16-bit)
	0.001% (48 kHz, 24-bit)
	0.0008% (96 kHz, 24-bit, B = 22 kHz)
IMD (60 Hz/7 kHz, 0 dB)	0.0035%
Linearity error	< 0.5 dB/–90 dB (according to datasheet)
	0.2 dB/–110 dB (measured)
Channel separation (1 kHz)	> 115 dB
Dynamic range	> 100 dB

Measurements were made with switch settings as follows

S1	S2	S3	S4
-1 off	-1 on	-1 on	-1 off
-2 off	-2 off	-2 on	-2 off
-3 off	-3 off	-3 on	-3 off
-4 on	-4 off	-4 off	-4 NC
		-5 on	
		-6 off	
		-7 off	
		-8 off	

Performance characteristics

For completeness' sake, the electrical specifications are complemented by a set of performance characteristics. Some comments on these are:

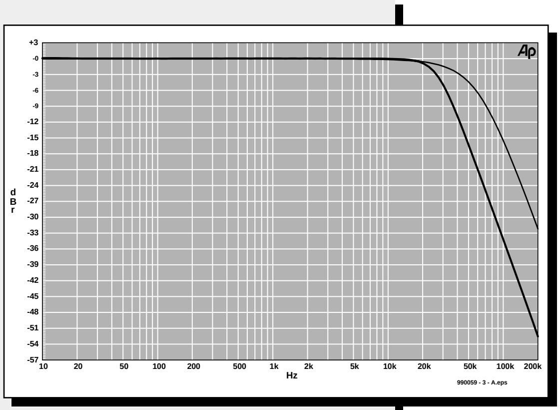
Curve **a** is the frequency response of the analogue output filters, measured by injecting a current into the current-to-voltage converters, so that the first filtering by C25 and C26 is included.

Curve **b** is the THD + N characteristic at full drive. This was measured with the aid of a test compact disk (16-bit, 44.1 kHz). The increase in distortion above 3 kHz is small and remains below 0.005% up to 20 kHz. At higher audio frequencies the speed of the DACs will of course have an effect.

Curve **c** illustrates the linearity of the DACs. The amplitude sweep was carried out with test tones of 400 Hz, provided with dither to make measurements up to –110 dB at 16 bit possible.

Curve **d** represents the channel separation between the two channels from 40 Hz upwards. Below this only the noise threshold would be measured. Even at 20 kHz the channel separation is > 88 dB in both cases. Measurements were made with the tin plate screen fitted as mentioned in the text.

Curve **e** shows the frequency spectrum at 1 kHz at full drive and a sampling rate of 48 kHz at 24 bit. Note that all harmonics are well below –100 dB.

a


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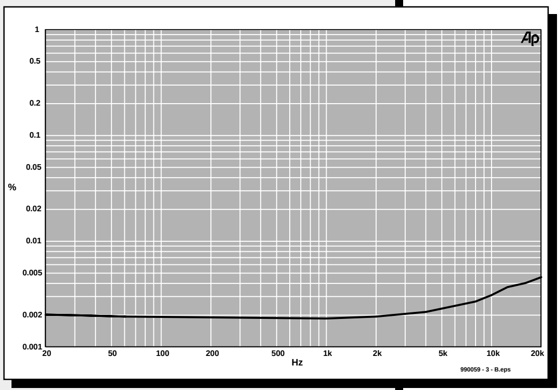
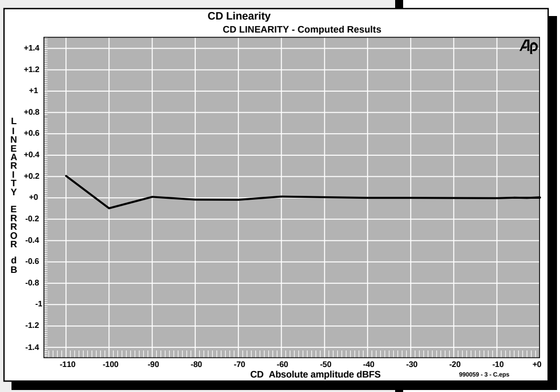
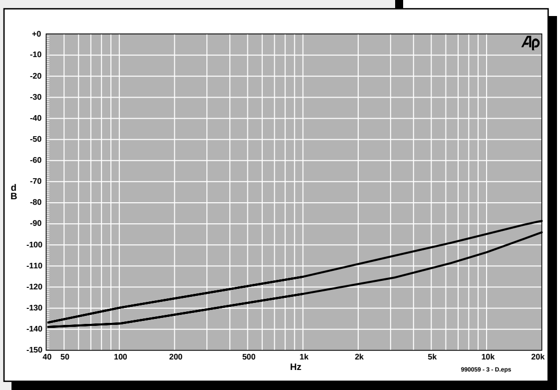


c


d


e