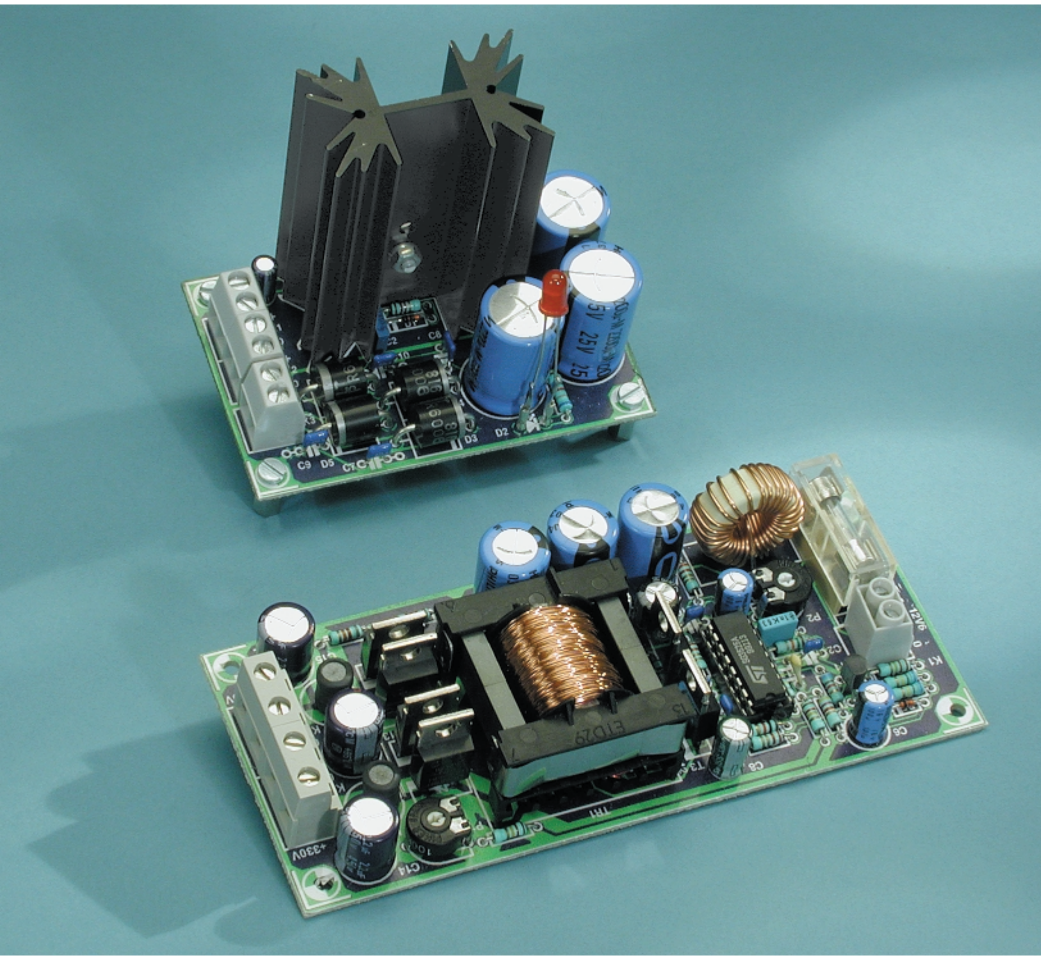
For the Valved RIAA Preamplifier and other applications

High Voltage Supply

330 V from 12 V

Design by T. Giesberts

Although this supply was primarily designed for use with the Valved RIAA Preamplifier, we found that the inverter stage is useful in many other applications. With only a small modification this circuit can be used to power a 20 W PLCE (low energy) lamp from a 12 V car battery.



The Valved RIAA Preamplifier uses two valves, just like the Valve Preamplifier that was published in the June 2000 edition of *Elektor Electronics*. Since the valves' filaments have again been connected in series, the preamplifier requires two DC supply voltages: 12.6 V for the filaments and 330 V for the high voltage supply.

In order to avoid the need to use a custom transformer the circuit has been designed to use a standard 15 V/3 A mains transformer. As we'll see later, the supply circuit consists of two distinct sections: a conventional 12.6 V filament supply and a step-up converter which boosts the 12.6 V to 330 V. In other words, the filament supply is also used to power the inverter.

Since each section is built on a separate PCB it becomes possible to use them individually in other applications. This is especially useful in case of the inverter, since it makes a great camping light when used in conjunction with a 12 V car battery and a PLCE lamp. These lamps tend to work very well off a 300 V DC supply!

The 12.6 V supply

As we can see in **Figure 1**, this section is a very basic circuit. The 3 A fixed-voltage regulator (TO-220 case) is made to deliver a slightly higher output (12.6 V) by adding an extra diode (D1). The bridge rectifier uses 6 A diodes and is followed by some substantial smoothing capacitors (C4, C5, C6). The bridge rectifier is RF decoupled by C7-C10 and LED D2 functions as the power indicator.

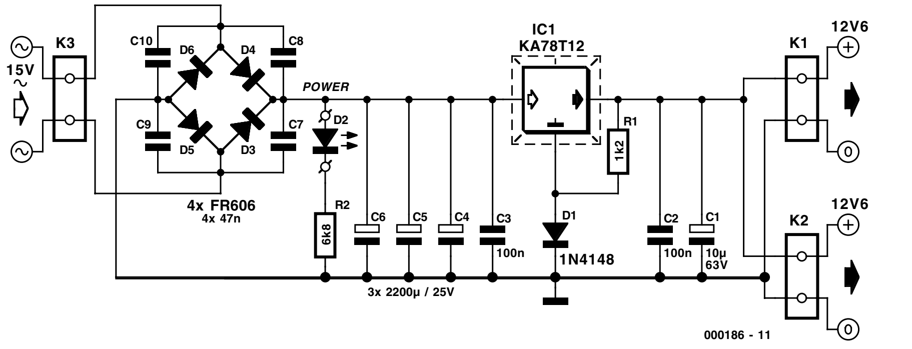


Figure 1. The 12.6 V supply incorporates the well-known diode 'trick', which causes the output to increase by 0.6 V.

COMPONENTS LIST

12.6 V Supply

Resistors:
R1 = 1kΩ2
R2 = 6kΩ8

Capacitors:
C1 = 10µF 63V radial
C2,C3 = 100nF
C4,C5,C6 = 2200µF 25V radial
C7-C10 = 47nF ceramic

Semiconductors:
D1 = 1N4148
D2 = red high-efficiency LED
D3-D6 = FR606 (or similar 6A diode)
IC1 = KA78T12 (3A)

Miscellaneous:
K1,K2,K3 = 2-way PCB terminal block, lead pitch 5mm
For IC1: heatsink type SK129 63,5 STS, 3.5 K/W (Fischer) (Dau Components)
Isolation material for IC1
PCB , order code **000186-2** (see Readers Services page)

Construction of the 12.6 V supply shouldn't cause any problems when the PCB shown in **Figure 2** is used. The heatsink for IC1 (Fischer type SK129 from Dau Components) is placed directly onto the PCB, which results in a compact module. It is very important that an insulating washer is used between IC1 and the heatsink.

There are two PCB terminal blocks (K1, K2) that provide the 12.6 V output voltage. One of these supplies the inverter and the other powers the two in series connected filaments. The third terminal block (K3) is for the 15 V transformer, which should be rated at least 50 VA.

The 330 V inverter

This part of the supply (see **Figure 3**) is a push-pull-converter that uses an old favourite of ours: the SG3525A. This regulator is an industry standard part that is used in many switch mode supplies. We have used it before in the 'In-Car Audio Amplifier', which we published in 1994. The proper description of this IC is a 'regulating pulse width modulator', which sums up its function perfectly. A special transformer is driven with an alternating voltage by one or more switched transistors, with the driving voltage obviously limited to a safe value. By varying the pulse width of the signal, the amount of power is controlled. The output at the secondary of the transformer is rectified and fed back to the PWM regulator in order to keep the output stable. That completes the feedback loop of the regulator.Since the SG3525A has been described in depth before in Elektor, we will limit ourselves to a brief overview of the device. The regulator uses a reference voltage of 5.1 V. Various internal circuits use this reference: error amplifier, oscillator, PWM comparator and the current source for the soft start. An extra delay circuit has been added to give valve amplifiers enough time to warm up before the HV supply is applied. Because valve amplifiers generally have substantial smoothing capacitors, the soft start period has been increased and the value of 100 µF for C5 is a fair bit higher than usual.

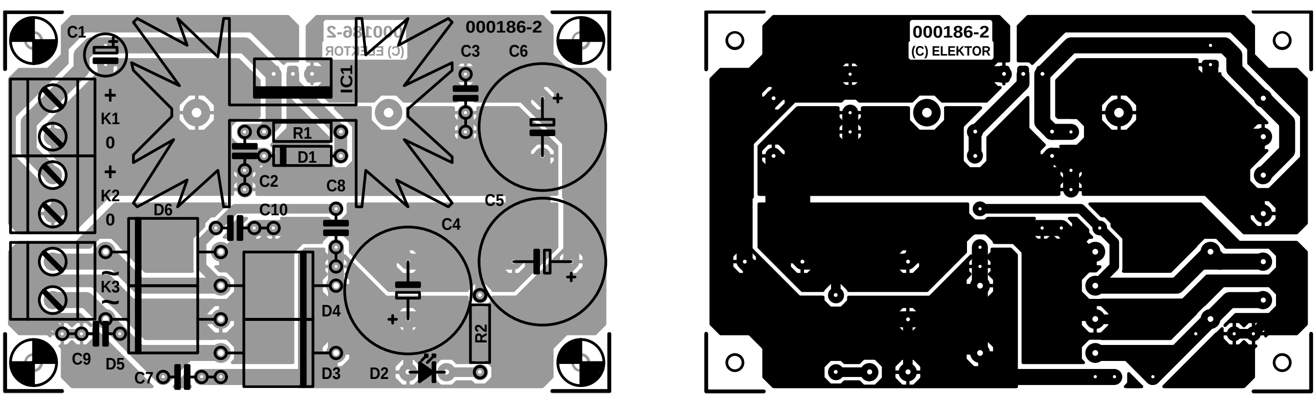


Figure 2. The heatsink just fits on the PCB, which results in a nice compact 12.6 V module.

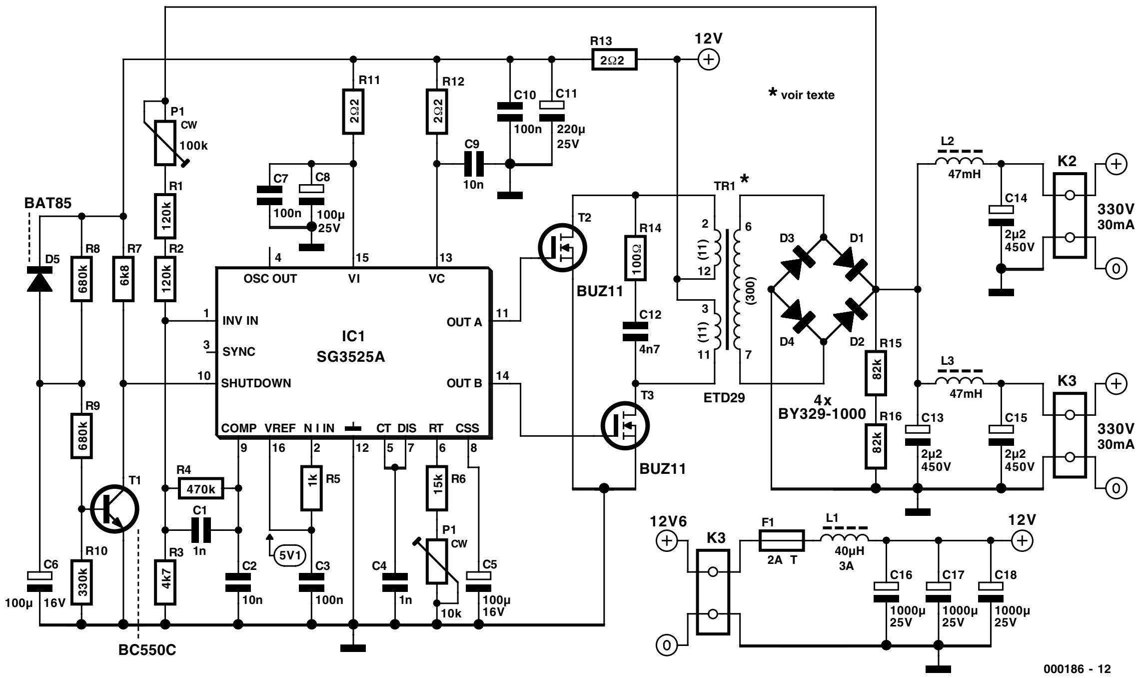


Figure 3. The main parts of the inverter are the integrated regulator (IC1), transformer and bridge rectifier.

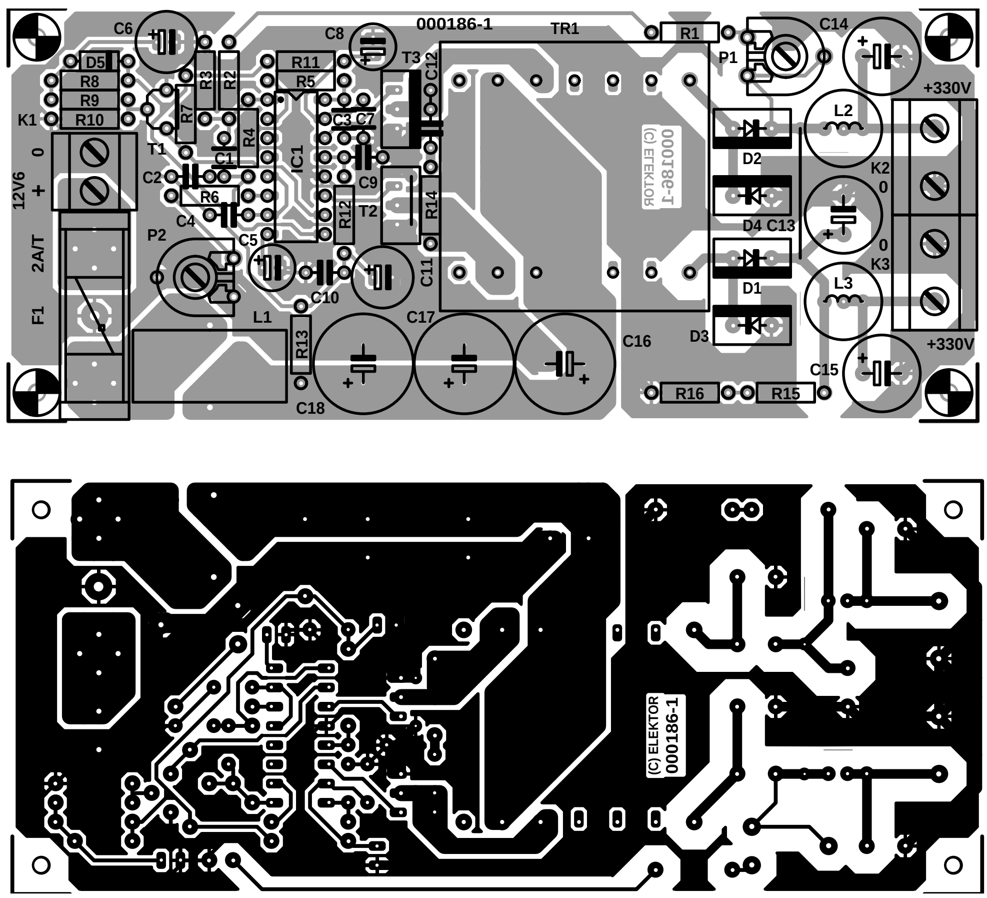


Figure 4. The PCB for the inverter is also tidy and compact.

We've used a standard ETD29 type former with N27 core material for the (home wound) transformer. The switching frequency has been kept relatively low (30 kHz) in order to save on smoothing capacitors at the primary side. Furthermore, three of them have been connected in parallel, which splits the current between them. This design can deliver a power of about 30 W.

The oscillator frequency can be set with P2 within a wide range (±7 kHz) to compensate for the tolerance of C4 (1 nF MKT), although the exact frequency isn't critical. To facilitate maximum power transfer, the dead time has been kept to a minimum by connecting the discharge output directly to CT and by keeping the value of C4 as small as possible.

The reference voltage is decoupled by C3 and fed to the non-inverting input of the error amplifier by R5. The output of the error amplifier (COMP) is also the input of the PWM comparator, which determines the pulse width. C2 limits the bandwidth and provides stability. The 330 V output voltage is fed to the inverting input of the error amplifier via potential divider P1/R1/R2/R3,

COMPONENTS LIST

330-V converter

Resistors:
R1,R2 = 120kΩ
R3 = 4kΩ7
R4 = 470kΩ
R5 = 1kΩ
R6 = 15kΩ
R7 = 6kΩ8
R8,R9 = 680kΩ
R10 = 330kΩ
R11,R12,R13 = 2Ω2
R14 = 100Ω
R15,R16 = 82kΩ
P1 = 100kΩ preset H
P2 = 10kΩ preset H

Capacitors:
C1 = 1nF ceramic, lead pitch 5mm
C2,C9 = 10nF ceramic, lead pitch 5mm
C3,C7,C10 = 100nF ceramic, lead pitch 5mm
C4 = 1nF MKT, lead pitch 5mm
C5,C6 = 100μF 16V radial
C8 = 100μF 25 V radial
C11 = 220μF 25V radial
C12 = 4nF7
C13,C14,C15 = 2μF2 450V radial, lead pitch 5mm, diameter 10mm
C16,C17,C18 = 1000μF 25V radial

Inductors:
L1 = suppressor coil 40μH 3A, type SFT10-30 (TDK)
L2,L3 = 47mH, e.g., 2200R series type 22R476 (Newport Components)

Semiconductors:
D1-D4 = BY329-1000 (Philips)
D5 = BAT85
T1 = BC550C
T2,T3 = BUZ11
IC1 = SG3525A(N) (ST Microelectronics)

Miscellaneous:
K1 = 2-way PCB terminal block, lead pitch 5mm
K2,K3 = 2-way PCB terminal block, lead pitch 7.5mm
F1 = fuse 2AT (time lag) with PCB mount holder
TR1 = ETD29 (Block) *
primary: 2 windings 11 x (3 x 0.5 mm parallel) ecw
secondary: 1 winding 300 x 0.3 mm ecw
PCB, order code **000186-1** (see Readers Services page)

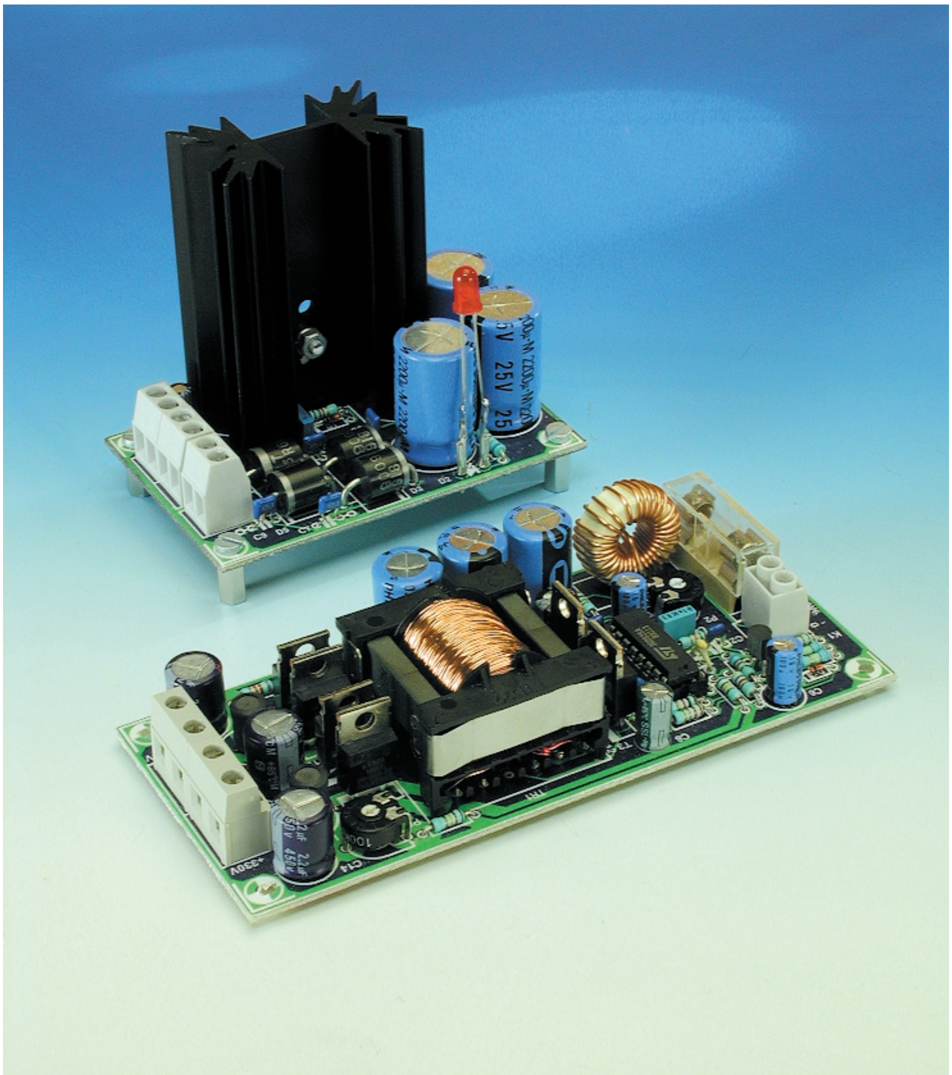
* see text

where R4 determines the open loop gain. P1 is used to adjust the value of the output voltage. The range has purposely been made fairly large (theoretically 270 V to 370 V), which gives the inverter plenty of scope for use in other applications. Slightly lower or higher output voltages can be obtained by varying the number of secondary turns proportionally (e.g. 273 turns would give 300 V). Keep in mind that if you use too many turns you can still get the correct output voltage, but at a reduced efficiency because the output is peak-rectified. The surplus energy will then be lost and dissipated in the transformer.

The modest circuit around T1 provides a delay of about 45 seconds between the application of the 12.6 V supply and taking the shutdown input low; this has to be below 0.6 V to enable the inverter. C6 is charged slowly by the potential divider of R8/R9/R10, which causes the voltage at the base of T1 to rise slowly and causes it to conduct. D5 causes C6 to discharge quickly when the supply is switched off.

R11, R12, R13 and C7-C11 are used to decouple the supply to the PWM regulator. R14/C12 reduce the spikes that are caused by the fast switching of transistors T2 and T3. The alternating voltage at the secondary is rectified by four fast soft-recovery diodes (D1-D4). Smoothing is carried out by 450 V radial electrolytics (C13, C14, C15). These are followed by low pass filters that reduce the ripple of the switching frequency even further. We've assumed that the inverter will be used with a stereo amplifier so we've provided two supply outputs, each with its own filter network (L2/C14, L3/C15). For the inductors we've used the 2200R-series from Newport Components, but the board will also accept the 8RB and 10RB series from Toko (available from Cirkit).

L1 filters the input supply and F1 protects the input supply from overload, which is important when, for example, a car battery is



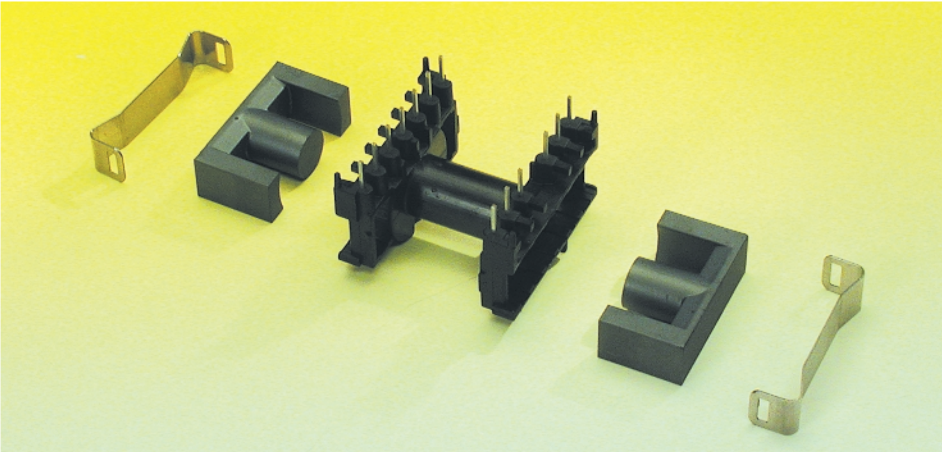


Figure 5. This shows an exploded view of the transformer parts.

used as source. For an even cleaner supply you should thread both 330 V cables through a large ferrite bead, which reduces common mode interference.

Construction of the inverter

The PCB for the 330 V inverter is shown in **Figure 4**. Because of the high voltages present, the layout is such that there is a minimum separation of 3 mm between the HV tracks and the earth plane. It is for this reason that the wire link between the cathodes of D1 and D2 is routed away from the low-voltage section (otherwise it could have been a track between the diodes).

Populating the board is simply a matter of carefully going through the parts list and soldering the components in place. The only part that could cause problems is transformer TR1. But this isn't as complicated as it might appear, since we can use a transformer kit supplied by Block (EB29 — see **Figure 5**). This also contains a pre-cut insulating foil, which is used to isolate the three windings from each other. The laying of subsequent windings is made easier by the tightly placed insulating foil. The ends of the secondary windings can be covered with the supplied insulating sleeve, which reduces the possibility of shorts between the windings.

The two primary windings consist of 11 turns of three strands of 0.5 mm enamelled copper wires, which are wound in parallel (next to each other) as if it was one conductor. The first winding is made between pins 3 and 11. This should cover the former with one layer of 0.5 mm copper wire. A layer of insulating foil is placed tightly across this, after which the next primary is wound between pins 2 and 12. This too is covered with a layer (or two) of insulating foil. Both primary windings have to be wound in the same direction to make sure that they are more or less identical. This ensures that the field has the smallest possible offset, which improves the performance of the transformer.

If you make the secondary winding very carefully, it is possible to use 0.4 mm wire, which reduces its resistance (resulting in better efficiency). But note that a sloppily wound 0.3 mm winding can fill the former almost completely. The transformer doesn't have an air gap!

And finally…

Once both boards have been populated and tested, they can be mounted with a 15 V transformer in an enclosure. It might appear easiest to mount the supply and Valved RIAA Preamplifier in one enclosure, but to obtain the best quality, and to keep interference to a minimum, we would recommend that the supply and the preamplifier are mounted in separate enclosures. If you do decide to mount them in one enclosure, you should at least have a metal screen between the supply and preamplifier sections, and the distance between the boards should be made as large as possible.

When we tested for interference suppression in our lab we weren't disappointed. When the Valved RIAA Preamplifier was used in conjunction with this power supply we measured the 60 kHz component at –90 dB, which is below the noise level of a typical phono signal. The 30 kHz component caused by the field of the inverter was at a level of –110 dB. Both measurements are relative to an output signal of 200 mV.

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