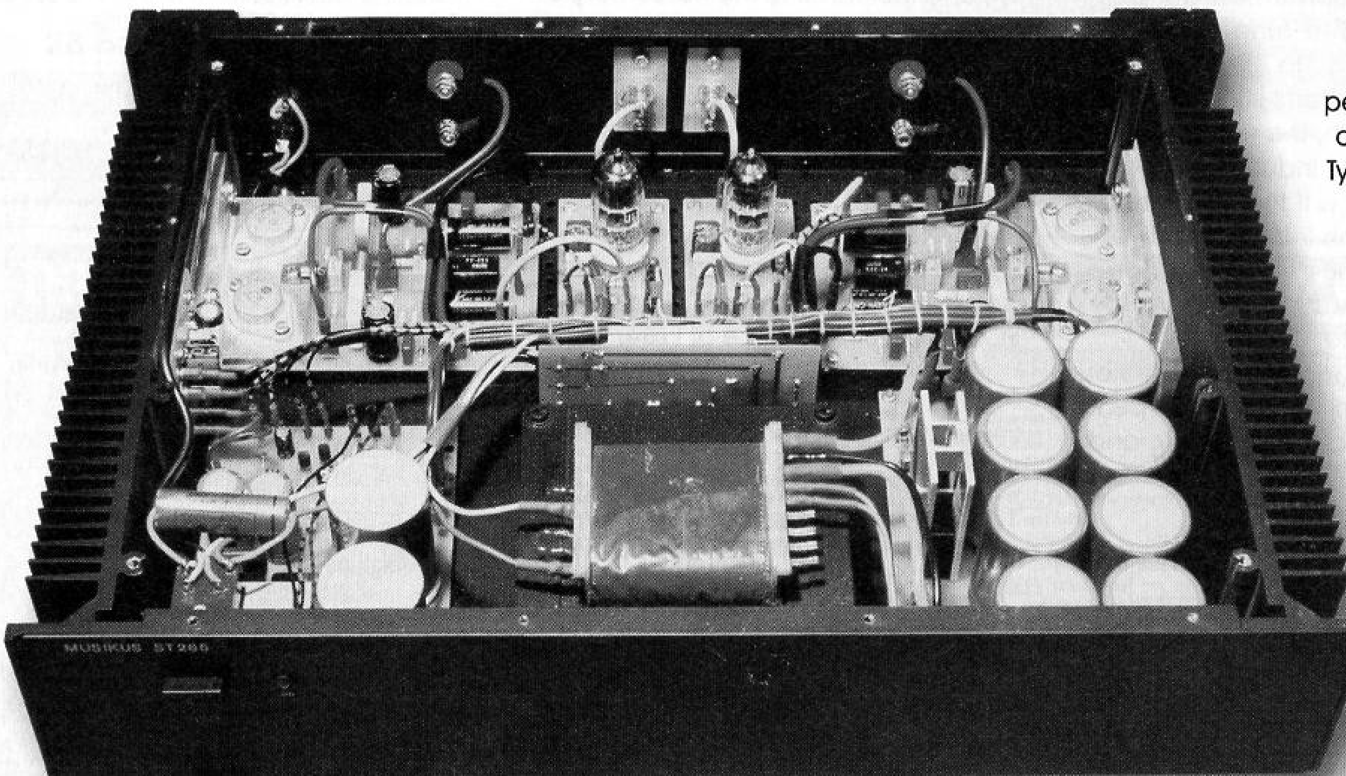
There is no single answer to the question of whether audio amplifiers using transistors are better than those using valves or vice versa. It all depends on the application. Valve amplifiers are undoubtedly better as regards dynamic range, which has to do with the more gradual change in the operating characteristics, which in the case of transistors tends to be abrupt. An attractive compromise is a hybrid amplifier: valve input stages and transistor output stages. This results in an amplifier that offers the best of both worlds.

Design by E. Wincek

hybrid audio amplifier

the best of both worlds?



Whatever the merits or drawbacks of valve and transistor audio amplifiers, because of their design and nature valves lend themselves much better to voltage amplification and transistors to current amplification. In output stages, which are current, or rather power, amplifiers, valves have a further drawback in that they require an output transformer whose price is directly proportional to its quality. In view of this, the present circuit is a hybrid: it uses valves in the voltage amplifier and MOSFET transistors in the current amplifier.

The voltage amplifier is configured as a series-regulated push-pull (SRPP) circuit, which provides high amplification and high-quality performance. It is based on a double triode Type PCC88, which has excellent transconductance and requires relatively low anode voltages.

The current (power) amplifier is based on MOSFET transistors which in operation are reminiscent of valves and have a very high input impedance. These transistors are configured as source followers. Their gate voltage is held stable by constant-current sources and zener diodes.

The result is

Technical data

Input sensitivity for full drive		900 mV
Input impedance		100 kΩ
Power output for full drive	1 kHz sine wave into 4 Ω	2.65 W
Gain at 1 kHz		25 dB
Damping factor at 1 kHz		3.2
Frequency response:	10 Hz	0 dB
	100 kHz	−1.7 dB

an excellent, interesting amplifier that is also fairly easy to build. There are only one valve and two transistors in the signal path. Its tone quality is very good and its power output is sufficient to make the neighbours run for the telephone if the volume were turned up full. Because of the high input impedance, CD players with their high output signal can be coupled directly to the amplifier via a 47–100 kΩ stereo potentiometer.

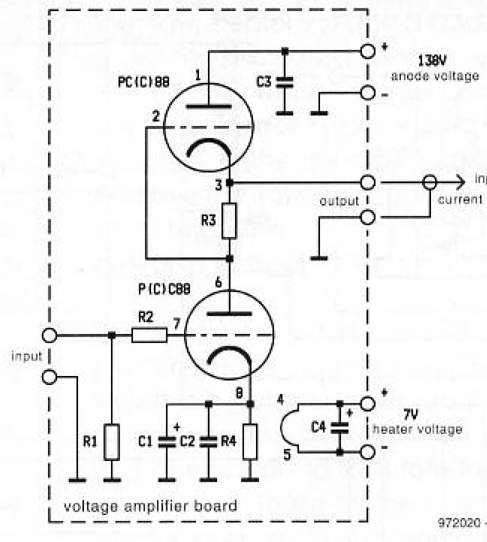
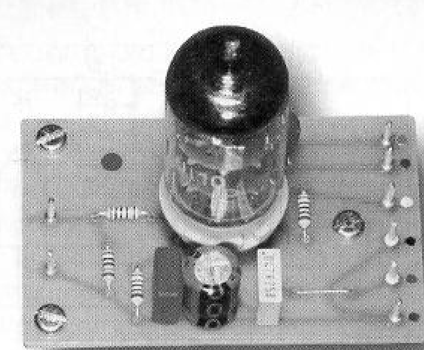
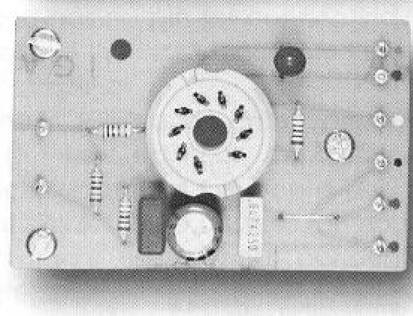


Figure 1. The voltage amplifier board contains, apart from the PCC88, only a few components.





voltage amplifier

The circuit diagram of the SRPP

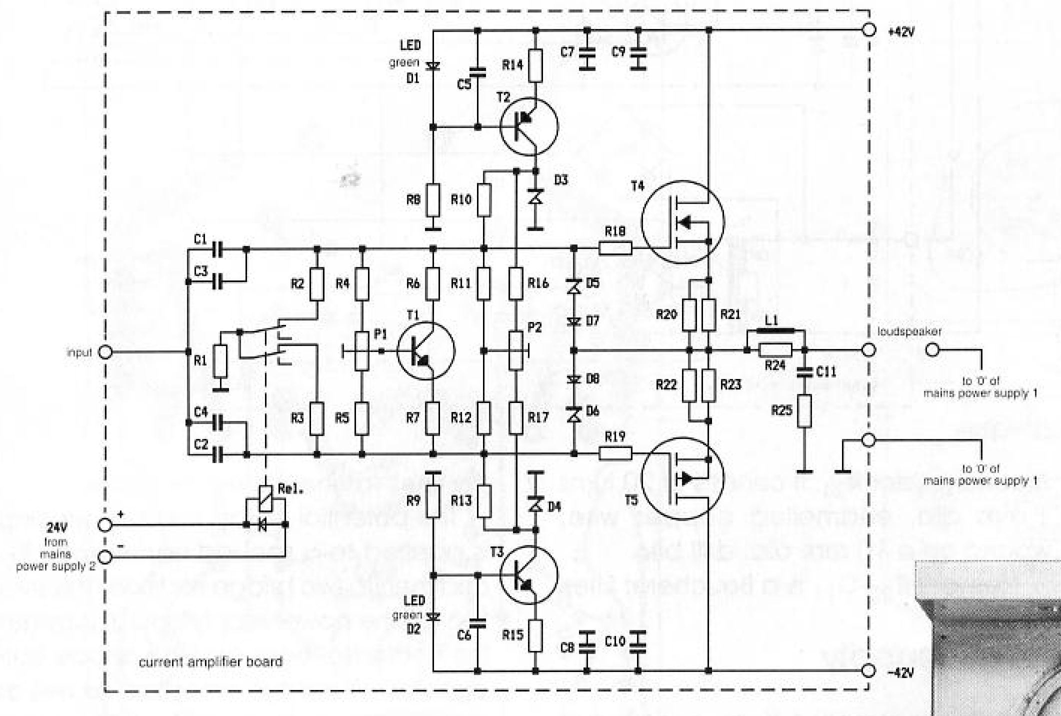


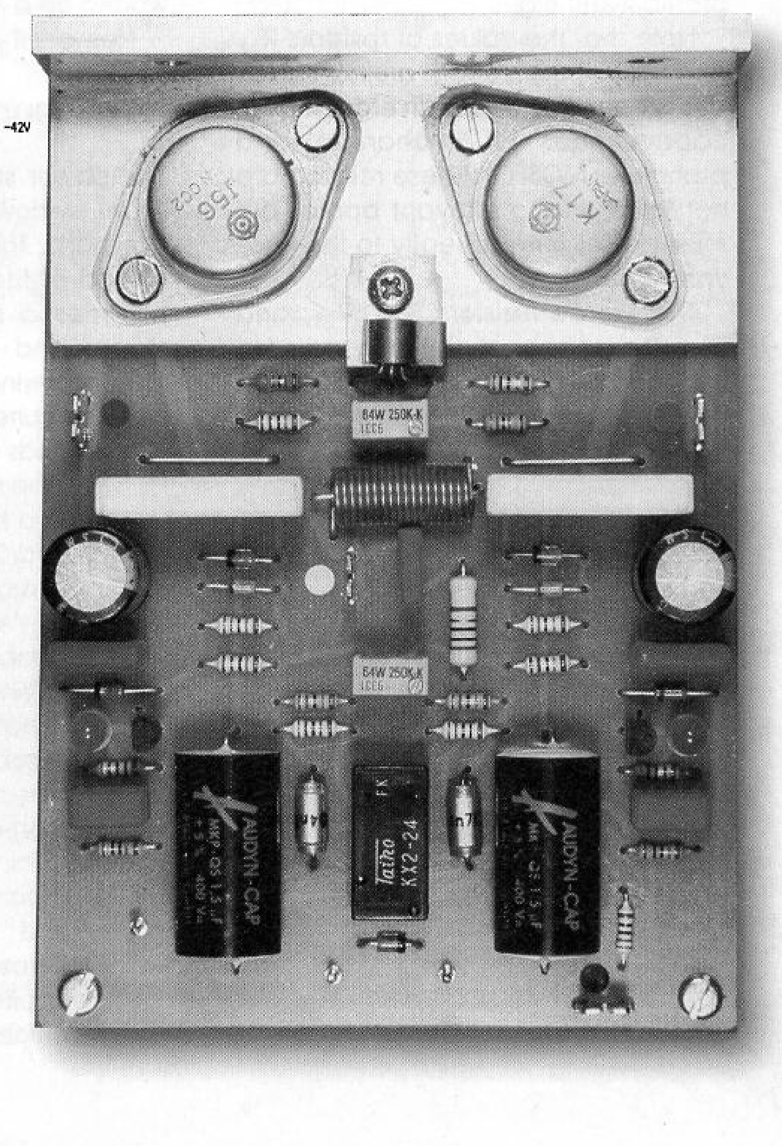
Figure 2. The output amplifier is based on MOSFETs.

voltage amplifier is shown in **Figure 1**. As stated earlier, it uses a double triode Type PCC88. The input is direct coupled (DC) and has an impedance of about 100 kΩ (R_1). An anode voltage of 130–140 V is fine: ideally, it should be 138 V, but not exceed 150 V. Each heater requires a voltage of 7 V: since the two heater are connected in series, the overall heater supply should be 14 V. The connections to the heaters are decoupled by 10 μF tantalum capacitors. The anode of the second triode is also decoupled, in this case by a 0.047 μF polyester type (C_3).

current amplifier

The circuit diagram of the current amplifier is shown in **Figure 2**. It is based on transistors T_4 and T_5, Type 2SK176 (or2SK175) and Type 2SJ56 (or 2SJ55) respectively. If the supply voltage is lowered to ±30 V, and an output power of 50 W is acceptable, Types IRF530/IRF9530 and IRF540/IRF9540 respectively from International Rectifier may also be used to good effect.

Input capacitors C_1 and C_2 are polypropylene (MKP) types, which are shunted by polyester capacitors C_3 and C_4 respectively. In the quiescent state, these capacitors are linked to earth via resistors R_1–R_3



and the relay contacts. The relay trips after about 20 s, when the capacitors are fully charged so that they cannot cause voltage jumps at the output.

The audio signal is applied to the gates of the MOSFETs via the input capacitors and R_{18} and R_{19} respectively. Transistors T_2 and T_3 operate as constant-current sources and ensure stable direct-voltages at the gates. The gate biases are made symmetrical with P_2. The quiescent current is

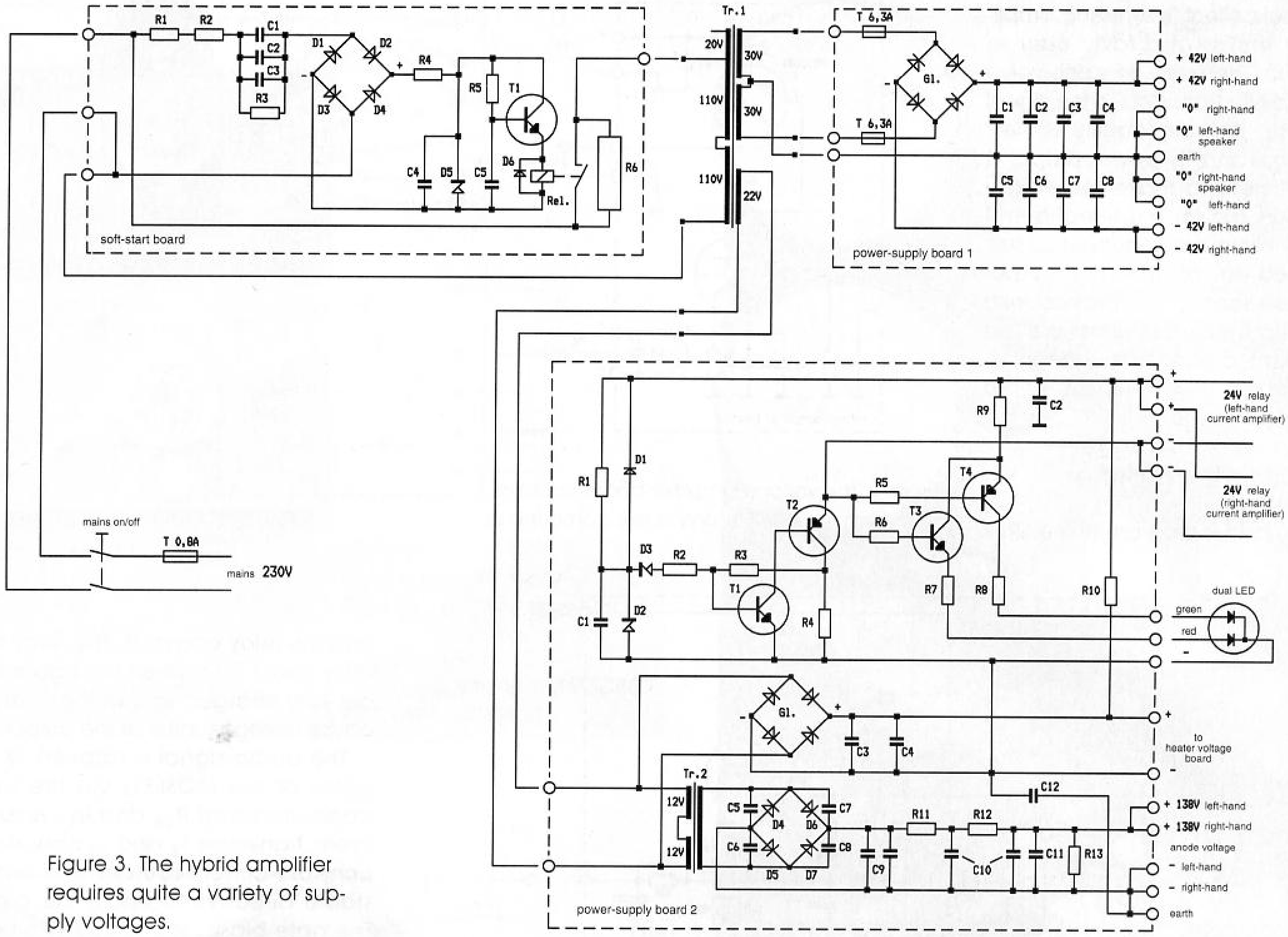


Figure 3. The hybrid amplifier requires quite a variety of supply voltages.

set with P_1. Protection diodes D_5–D_8 prevent the gate voltages becoming prohibitively high.

Note that the values of resistors R_{18} and R_{19} in the gate lines are not equal. This is because of the divergent input capacitances of n-channel and p-channel MOSFETs. These resistors are not fitted on the relevant board, but must be soldered directly to the relevant gate.

The source resistors, R_{20}, R_{21}, and R_{22}, R_{23}, each of 0.47 Ω, may be replaced by single resistors of 0.25 Ω in the R_{20} and R_{22} positions on the board.

Inductor L_1 in the output line is fitted around resistor R_{24}. It consists of 20 turns 1 mm dia. enamelled copper wire, wound on a 10 mm dia. drill bit.

Network R_{25}-C_{11} is a Boucherot filter.

power supply

The power supply whose circuit diagram is shown in **Figure 3** consists of five parts. The first of these is situated ahead of the mains transformer and provides a soft start for the output stages and prevents the fuses from blowing owing to a high switch-on current. This current is limited during the first few seconds after switch-on by R_6.

The mains voltage is applied to a bridge rectifier via R_1, R_2 and C_1–C_3 (which can be discharged via R_3) and then to a 15 V voltage regulator.

Capacitor C_5 is charged via R_5 and after about 2 s reaches a potential that causes T_1 to switch on, whereupon the relay trips. The relay contacts then short-circuit R_6.

Mains transformer Tr_1 has three secondary windings: 2 × 30 V and 1 × 22 V. The voltages across the 30 V windings are applied to a bridge rectifier which provides the ±42 V supply lines for the current amplifier.

The potential across the 22 V winding is applied to a second transformer, Tr_2, and then to two bridge rectifiers. This section (on the power supply board) provides the heater voltages and the anode voltages for the voltage amplifiers, as well as the operating voltage for the relay on the current amplifier board (Figure 2) via a delay circuit.

The delay circuit is based on a Schmitt trigger formed by T_1 and T_2. Capacitor C_1 is charged via R_1 until the potential across it is 10 V. When that level is reached, D_3 comes on, the Schmitt trigger changes state, and the relay on the current amplifier board trips. The relay contacts then link the output of the voltage amplifier to the input of the current amplifier.

The dual LED on the front panel indicates the state of the relay. At switch-on, T_2 is off, so that its collector, and consequently the bases of T_3 and T4, carries the full supply voltage. This results in T_3 conducting, whereupon the red part of the LED lights, whereas T_4 remains off. After about 20 s, the Schmitt trigger changes state, whereupon T_3 goes off and T_4 conducts. This causes the red section of the LED to go out while the green one lights to show that the circuit is operational. When the

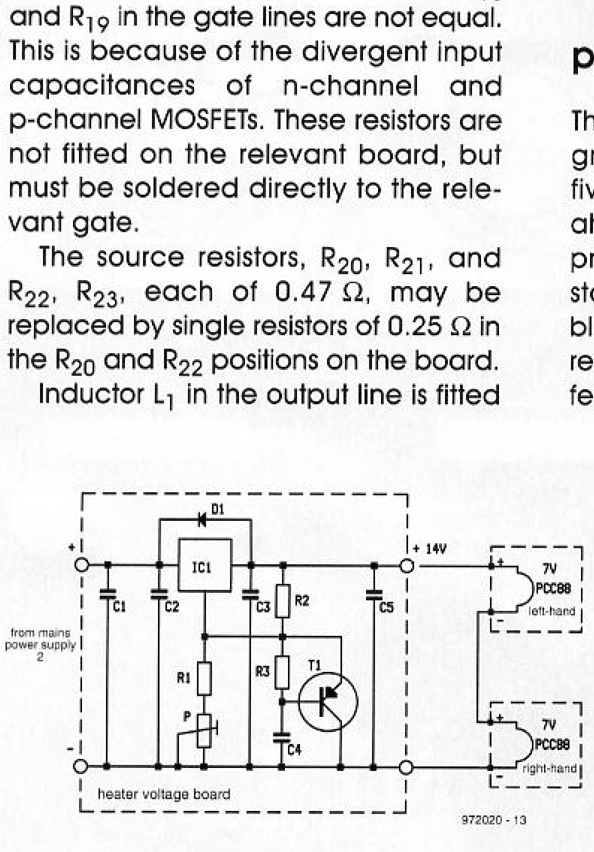


Figure 4. The heater voltage for the PCC88 is regulated. However, it is more important that the heater current is 300 mA.

supply is switched off, C_1 is discharged via D_1. Resistors R_9 and R_{10} and capacitor C_2 decouple the supply lines to the relay.

The 22 V secondary of Tr_1 is linked to the secondary winding of Tr_2. Since the current drawn by the two valves does not exceed 5 mA, the rating of this transformer (150 mA) is more than adequate. The voltage across the primary is some 130 V, which is rectified by D_4–D_8 and smoothed by C_9 and C_{10}. Capacitors C_5–C_8 and C_{11} are anti-interference devices. When the supply is switched off, electrolytic capacitors C_9 and C_{10} are discharged via R_{13}.

The –ve line of the unregulated heater voltage (about 24 V) is connected to earth not directly but via C_{12}.

The 'raw' heater voltage is applied to a variable, integrated voltage regulator, IC_1, on the heater voltage board (**Figure 4**). Transistor T_1 provides a gradual increase in the voltage supply to the heaters. The voltage regulator needs a small heat sink.

construction

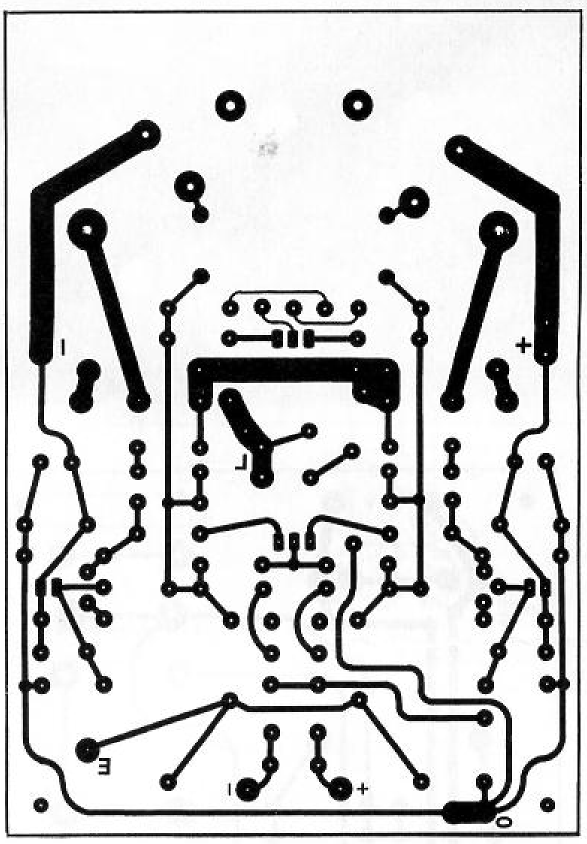
The stereo amplifier consists of eight printed-circuit boards (see **Figure 5),** which are not available ready made. All boards are provided with suitable PCB connectors to facilitate their interconnection. Those for the mains power supply and on the current amplifier board have 6.3 mm dia. pins, all others have 1.3 mm pins.

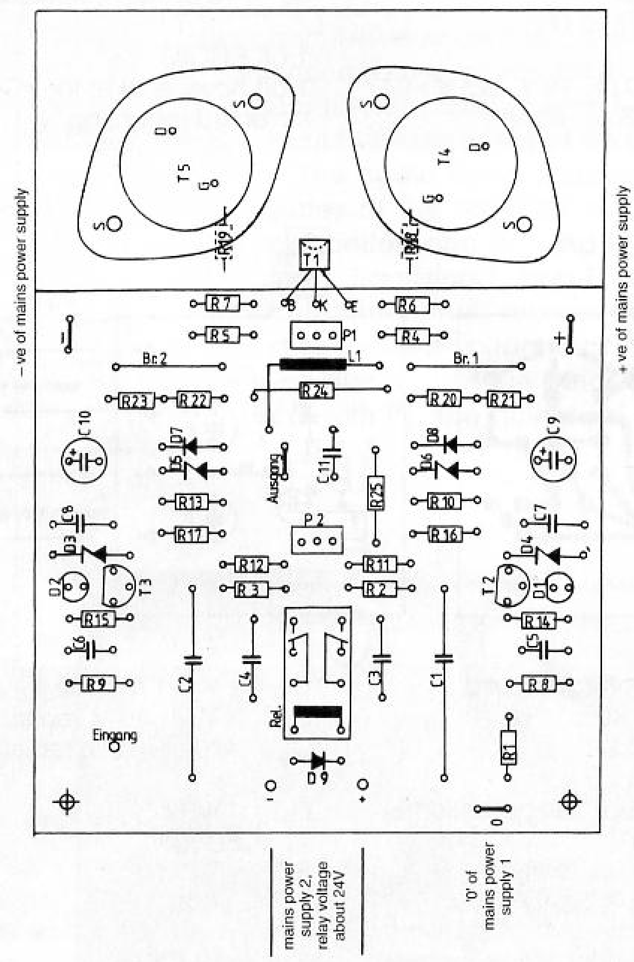
It is imperative that the –ve lines on all boards are kept separate and are strapped to earth at only one spot on the enclosure so as to prevent earth loops.

The connections to the input and output of the voltage amplifier must be in single screened cable with the screen connected to earth only on the voltage amplifier board.

Consequently, the current amplifier board has no pin for connecting the screen of the input lead from the voltage amplifier.

The MOSFETs and T_1 must be screwed to, but isolated from, an aluminium bracket that links the board and the heat sink for these devices (do not forget ample use of heat conducting paste).





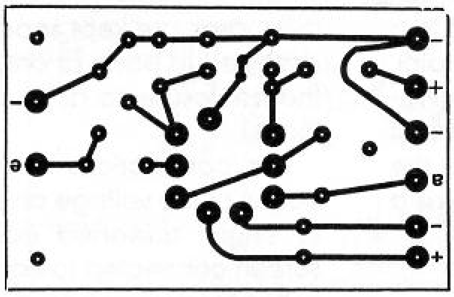
Current amplifier board:
T_1, R_2, R_3 = 160 Ω
R_4 = 680 Ω
R_5, R_{16}, R_{17} = 750 kΩ
R_6 = 10 Ω
R_7 = 22 kΩ
R_8, R_9 = 10 kΩ
R_{10}, R_{13} = 820 kΩ
R_{11}, R_{12} = 180 kΩ
R_{14}, R_{15} = 200 Ω
R_{18} = 680 Ω
R_{19} = 510 Ω
R_{20}, R_{21}–R_{23} = 0.47 Ω, 5 W
R_{24} = 5.1 Ω, 1 W
R_{25} = 10 Ω, 1 W
P_1, P_2 = 250 kΩ, potentiometer for board mounting, upright

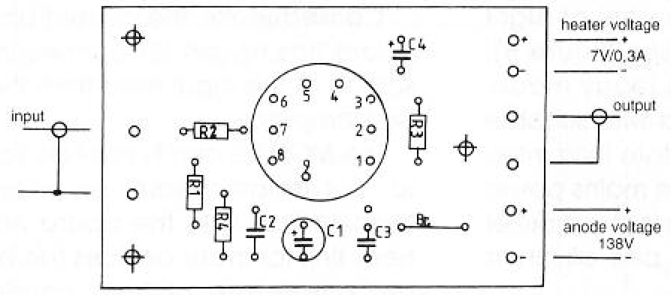
C_1, C_2 = 1.5 μF, 250 V, metallized polypropylene (MKP)
C_3, C_4 = 4.7 μF, 160 V, metallized polyester (MKT)
C_5, C_6 = 0.68 μF, 63 V
C_7, C_8 = 0.22 μF, 100 V
C_9, C_{10} = 330 μF, 63 V, radial
C_{11} = 0.022 μF, 100 V

D_1, D_2 = LED, 5 mm, green
D_3, D_4 = zener, 15 V, 1 W
D_5, D_6 = zener, 12 V, 500 mW
D_7, D_8 = 1N4148
T_1 = 2SC1775
T_2 = BC560
T_3 = BC550
T_4 = 2SK176 or 2SK175 (see text)
T_5 = 2SJ56 or 2SJ55 (see text)

L_1 = see text
Re_1 = 24 V miniature relay, 2 make contacts, coil resistance 1400 Ω

Figure 5. Layouts of the various PCBs used in this design. Two voltage amplifier boards and two current amplifier boards are needed for a stereo amplifier. Note that there is no board for the mains power supply.



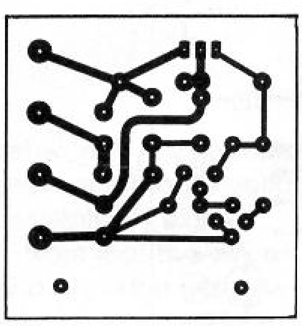


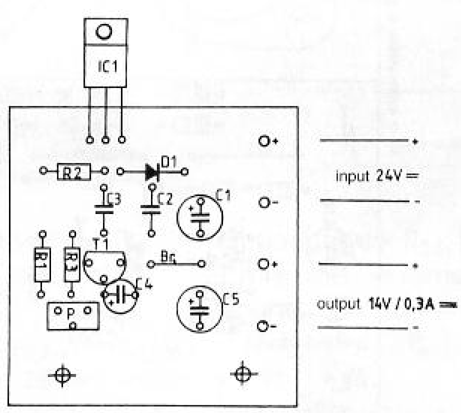
Voltage amplifier board:

R_1 = 100 kΩ
R_2 = 1 kΩ
R_3, R_4 = 510 Ω

C_1 = 470 μF, 16 V, radial
C_2 = 0.68 μF, 63 V
C_3 = 0.047 μF, 250 V
C_4 = 10 μF, 35 V, tantalum

1 off PCC88
1 off noval socket for PCC88 for board mounting





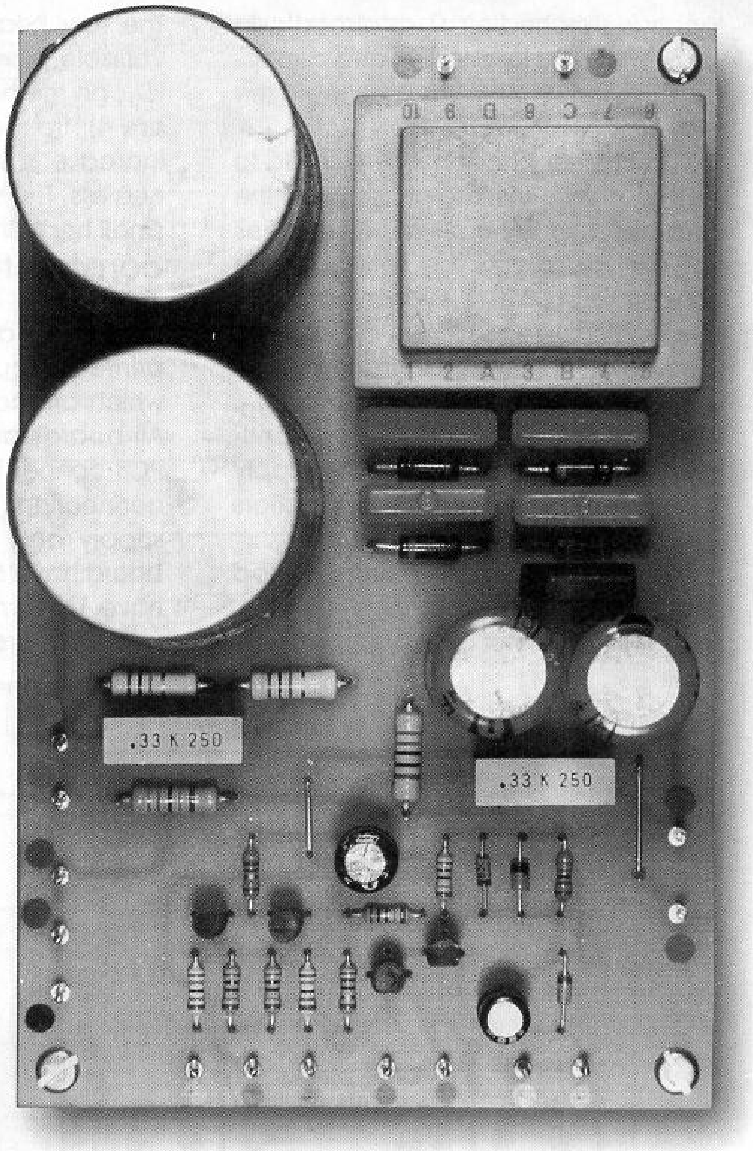
Heater voltage board:

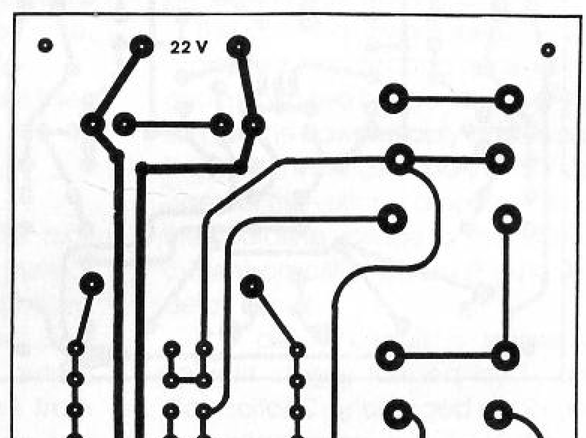
R_1 = 2.2 kΩ
R_2 = 270 Ω
R_3 = 150 kΩ
P = 1 kΩ preset potentiometer, radial

C_1 = 47 μF, 35 V, radial
C_2, C_3 = 0.1 μF, 100 V
C_4 = 4.7 μF, 16 V, radial
C_5 = 470 μF, 16 V, radial

D_1 = 1N4148
T_1 = BC560

IC_1 = LM317





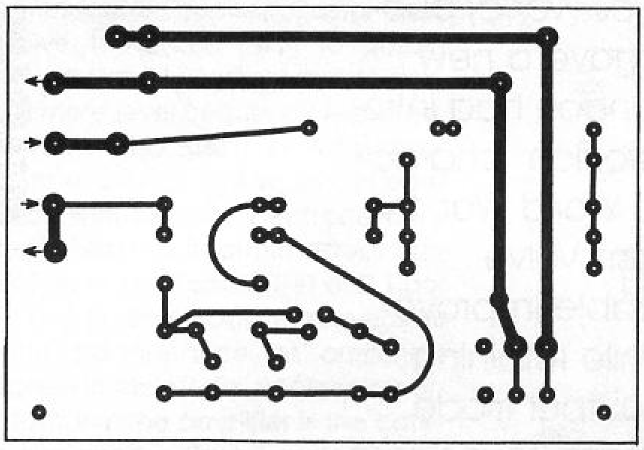
calibration

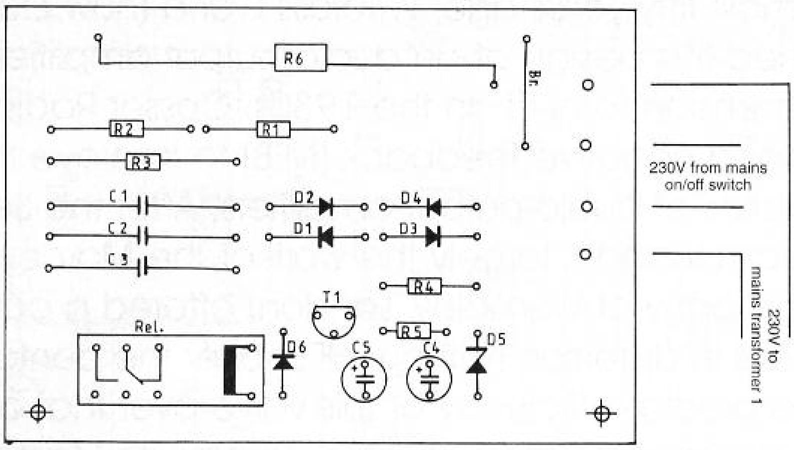
Before the power is switched on, set P_1 and P_2 on the current amplifier board to the centre of their travel and the preset on the heater voltage board to minimum. Temporarily insert 10 Ω, 1 W resistors in the supply lines to the current amplifier board. The amplifier output should remain open.

Switch on the mains and set the heater voltage to 14 V. Since the PCC88 is a series-regulated device, it is, however, better, and more accurate, to set the heater current to 300 mA (after a heating up period of, say, 10 minutes).

Next, connect a digital voltmeter (DVM) across one of the 10 Ω resistors and adjust P_1 to obtain a reading of 1 V, which corresponds to a quiescent current of 100 mA. Then, connect the DVM across the output terminals and adjust P_2 for a reading of 0 mV.

Switch off the mains and remove the two 10 Ω resistors. Switch on the mains again. Connect the DVM across R_{20} or



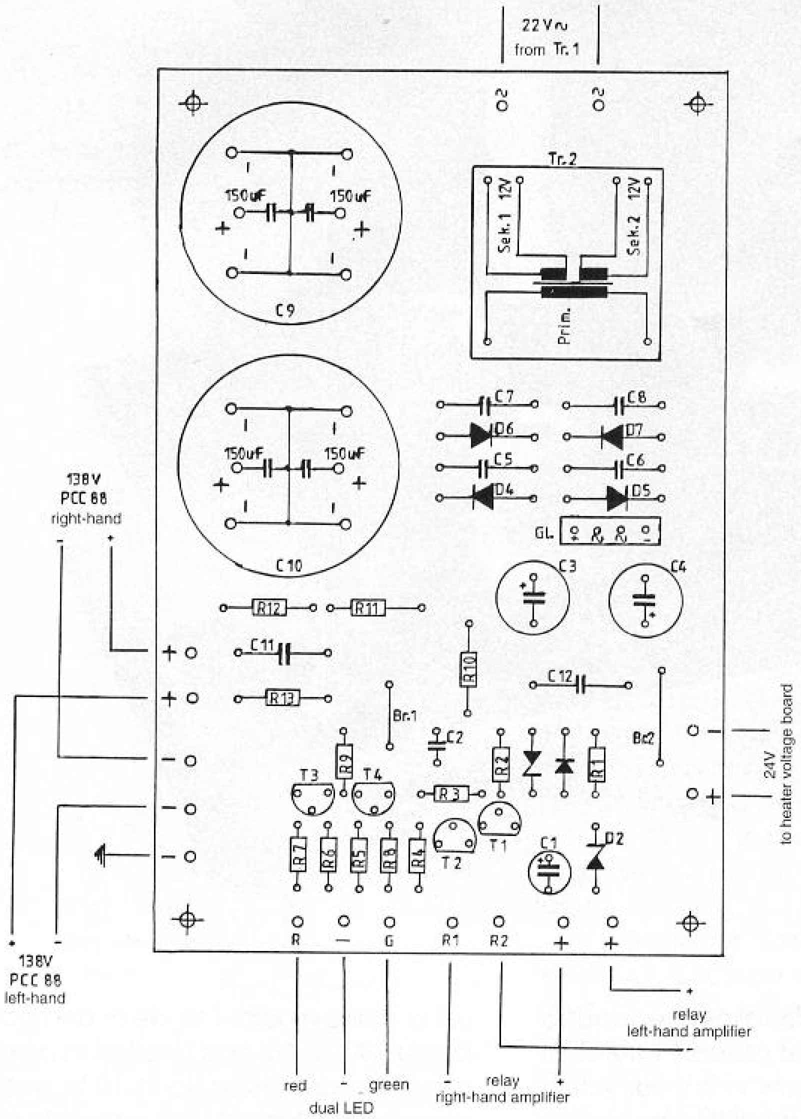


Soft-start board
R_1, R_4 = 120 Ω, 1 W
R_2 = 150 Ω, 1 W
R_3 = 1 MΩ, 1 W
R_5 = 10 kΩ
R_6 = 100 Ω, 11 W

C_1 = 0.1 μF, 250 V a.c.
C_2, C_3 = 0.33 μF, 250 V
C_4 = 470 μF, 16 V, radial
C_5 = 100 μF, 16 V, radial

D_1–D_4 = 1N4007
D_5 = zener, 15 V, 1 W
D_6 = 1N4148
T_1 = BC550
Re_1 = 12 V relay, 1 make contact, rating: 16 A

R_{22} and adjust P_1, if necessary, to obtain a reading of 230–250 mV. Leave the amplifier on for a couple of hours and recheck this voltage. Finally, connect the DVM across the output terminals and recheck that the reading is 0 mV, adjusting P_2 is necessary. [972011]



Power supply board:
R_1 = 330 kΩ
R_2, R_3, R_5, R_6 = 100 kΩ
R_4 = 10 Ω
R_7, R_8 = 1.3 kΩ
R_9 = 100 Ω
R_{10} = 220 Ω, 1 W
R_{11}, R_{12} = 1 kΩ, 1 W
R_{13} = 220 kΩ, 1 W

C_1 = 100 μF, 16 V, radial
C_2 = 100 μF, 35 V, radial
C_3, C_4 = 2200 μF, 40 V, radial
C_5–C_8 = 0.01 μF, 250 V
C_9, C_{10} = 150 μF, 350 V
C_{11}, C_{12} = 0.33 μF, 250 V

D_1 = 1N4148
D_2 = zener, 12 V, 500 mW
D_3 = zener, 10 V, 500 mW
D_4–D_7 = 1N4007
G_1 = B40C1500/1000
T_1, T_3 = BC550
T_2, T_4 = BC560

Tr_2 = 130 V primary, 2 × 12 V secondary transformer, rating: 150 mA