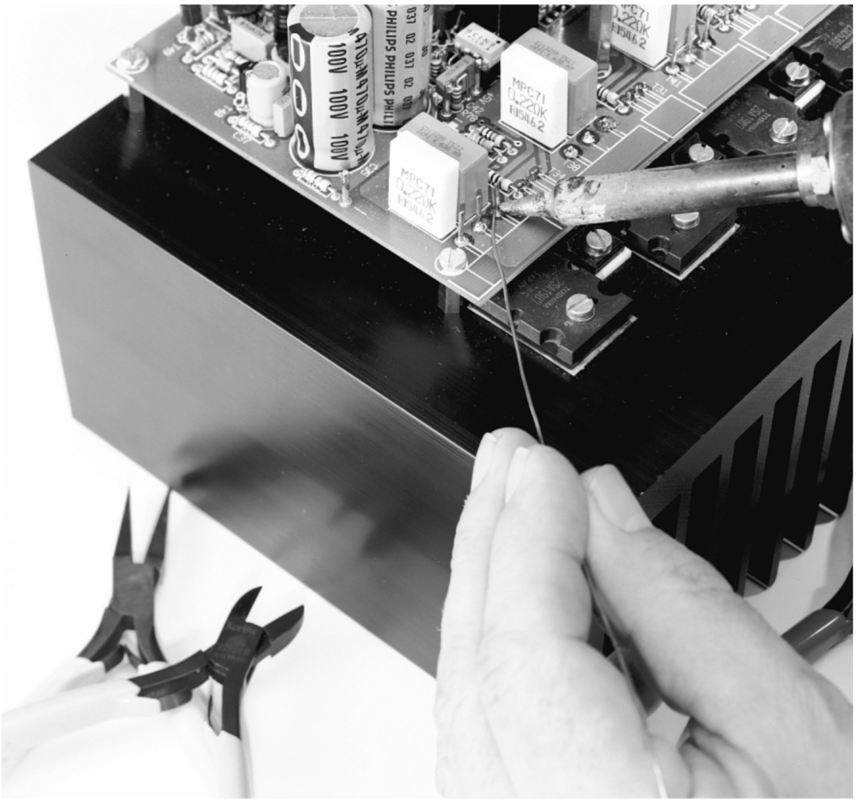
Titan 2000

Part 3: construction and setting up

This third of four parts deals primarily with the construction of the amplifier and ends with a brief resume of its performance and specifications. Let the constructor beware, however: the Titan 2000 is not an easy project and certainly not recommended for beginners in electronic construction.



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INTRODUCTION

It is clear from the first two parts of this article that the Titan 2000 is a complex unit that needs to be constructed and wired up with with great care to ensure the specified performance. For that reason, the construction notes will be more detailed than is usual with projects in this magazine. It is assumed that the protection network and auxiliary power supply have already been built and tested.

MOTHER BOARD

It must be borne in mind that in the case of a fast power amplifier like the Titan 2000, with a gain/bandwidth product of about 0.5 GHz, the board must be an integral part of the circuit. The mother board is therefore designed together with the remainder of the circuit. The length of the tracks, the area of the copper pads, the positions of the decoupling capacitors, and other factors, are vital for the proper and stable operation of the unit. Constructors who make their own boards are therefore advised to adhere strictly to the published layout.

Owing to the power requirements, the various stages are parallel configurations. When these are mounted on the heat sinks, a fairly large parasitic capacitances to earth ensue. This is because for reasons of stability all seven heat sinks must be strapped to earth. It

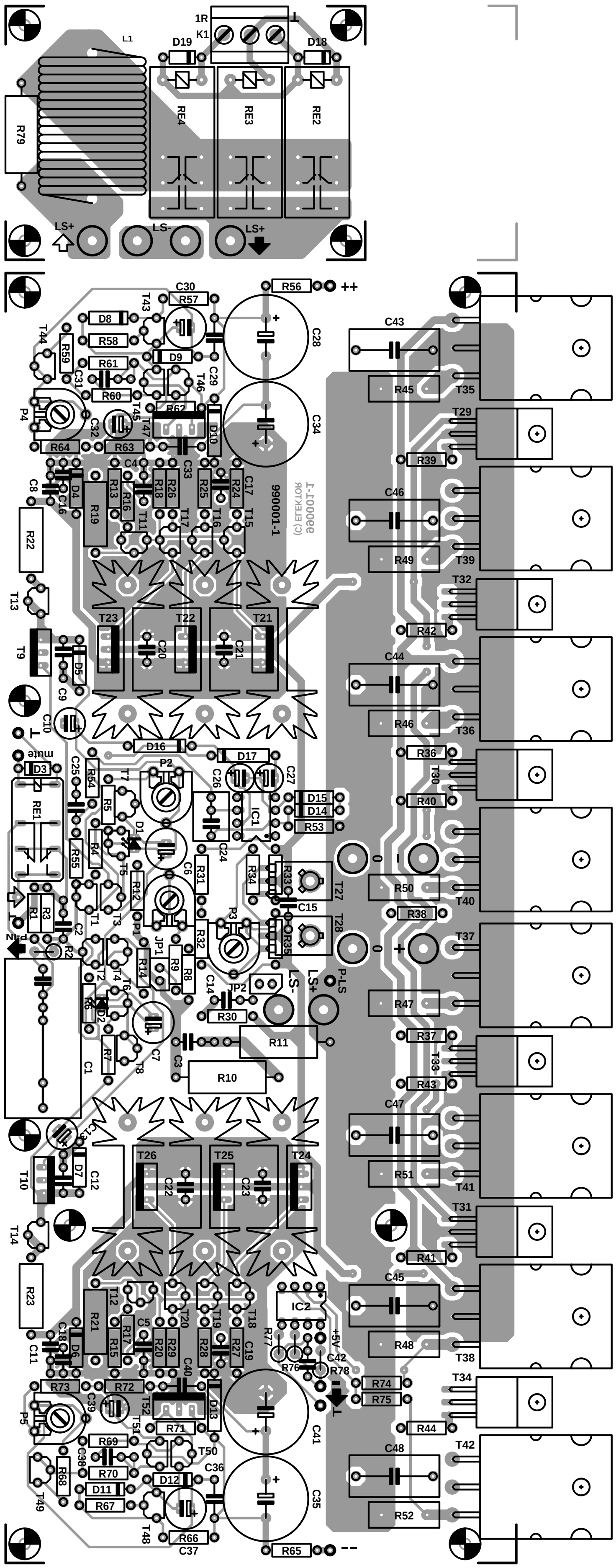


Figure 12. The double-sided printed-circuit board is intended to be combined with the heat sink into a single entity. Before that can be done, however, the section for the output relay and the inductor must be cut off the main section.

Parts lists

It is regretted that, owing to circumstances beyond our control, component codings in the various sections have been duplicated. Consequently, the mother board, protection network board, and auxiliary power supply board contain many components with the same identification (R_1-R_{36}, C_1-C_{26}, D_1-D_{12}, T_1-T_6, IC_1-IC_2, JP_1, K_1).

Amplifier

Resistors:

R_1, R_{53} = 1 MΩ

R_2 = 562 Ω

R_3 = 47 kΩ

R_4, R_6, R_{12}, R_{14}, R_{60}, R_{61}, R_{69}, R_{70} = 22 Ω

R_5, R_{62}, R_{71} = 330 Ω

R_7, R_{34} = 470 Ω

R_8 = 22.1 Ω

R_9 = 390 Ω

R_{10}, R_{11} = 470 Ω, 5 W

R_{13}, R_{15} = 1.00 kΩ

R_{16}, R_{17}, R_{38} = 150 Ω

R_{18}, R_{20}, R_{58}, R_{67} = 270 Ω

R_{19}, R_{21} = 10 kΩ, 1 W

R_{22}, R_{23} = 3.3 kΩ, 1 W

R_{24}–R_{29} = 68 Ω

R_{30} = see text

R_{31}, R_{32} = 22 kΩ

R_{33}, R_{35} = 220 Ω

R_{36}, R_{37} = 560 Ω

R_{39}–R_{44} = 10 Ω

R_{45}–R_{52} = 0.22 Ω, inductance-free

R_{54}, R_{55} = 4.7 MΩ

R_{56}, R_{65} = 15 Ω

R_{57}, R_{63}, R_{66}, R_{72} = 15 kΩ

R_{59}, R_{68} = 5.6 kΩ

R_{64}, R_{73} = 12 kΩ

R_{74}, R_{76}, R_{77} = 100 Ω

R_{75} = 33 Ω

R_{78} = 2.2 kΩ

R_{79} = 2.2 Ω, 5 W

P_1, P_4, P_5 = 4.7 kΩ (5 kΩ) preset

P_2 = 250 Ω, preset

P_3 = 500 Ω, preset

Capacitors:

C_1 = 2.2 µF, metallized polyester (MKP)

C_2, C_3, C_{42} = 0.001 µF

C_4, C_5 = 0.0022 µF

C_6, C_7 = 220 µF, 25 V, radial

C_8, C_9, C_{11}, C_{12}, C_{15} = 0.1 µF

C_{10}, C_{13} = 100 µF, 25 V, radial

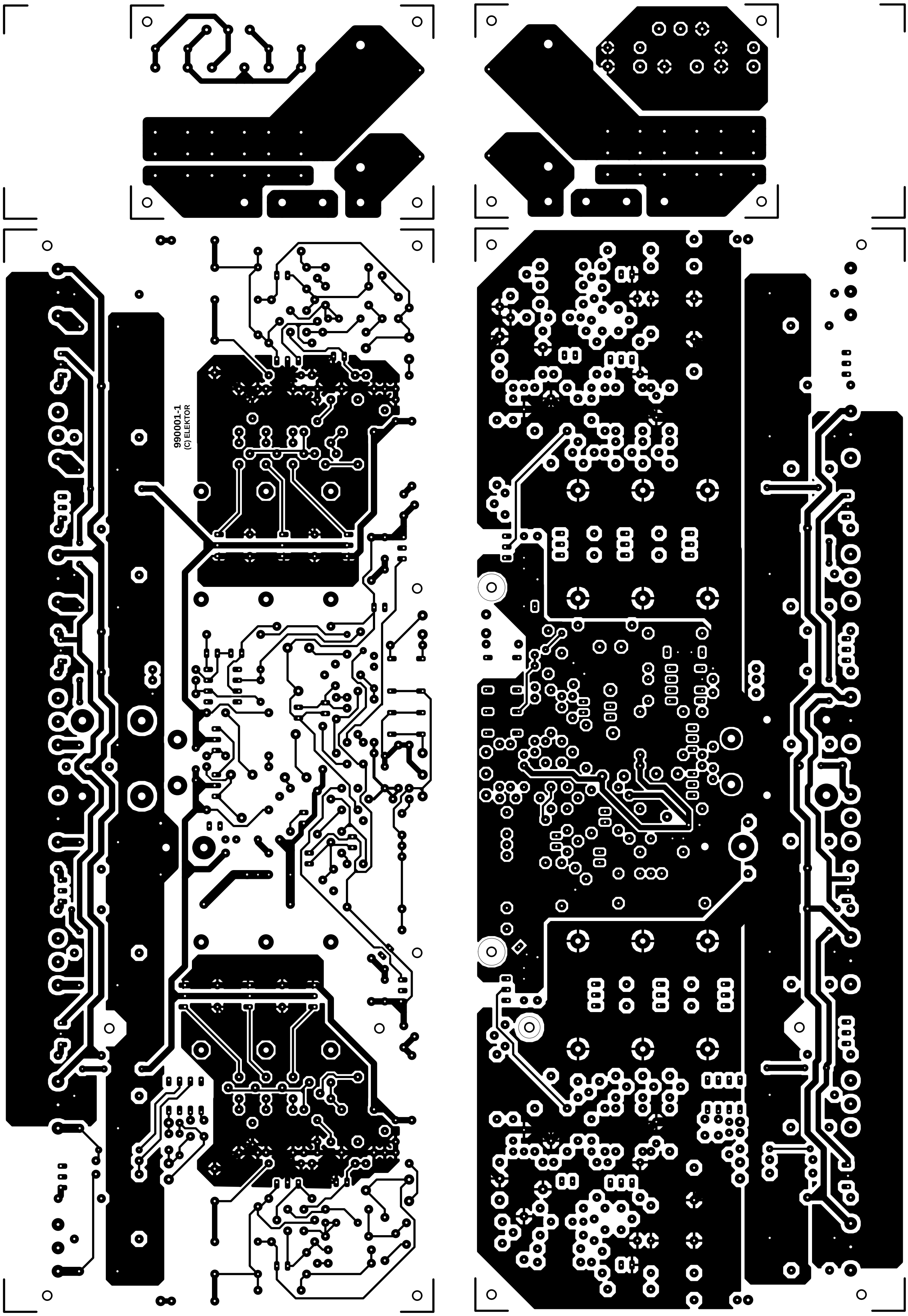
C_{14} = see text

C_{16}–C_{23} = 100 pF, 100 V

C_{24} = 1 µF, metallized polypropylene (MKT)

C_{25} = 0.68 µF

C_{26}, C_{27}, C_{32}, C_{39} = 2.2 µF, 63 V, radial


990001-1
(C) ELEKTOR

C_{28}, C_{34}, C_{35}, C_{41} = 470 µF, 100 V, radial
C_{29}, C_{33}, C_{36}, C_{40} = 0.22 µF, 100 V
C_{30}, C_{37} = 47 µF, 63 V, radial
C_{31}, C_{38} = 0.015 µF
C_{43}–C_{48} = 0.1 µF, 630 V

Inductors:
L_1 = see text

Semiconductors:
D_1, D_2 = LED, red, flat
D_3, D_{18}, D_{19} = 1N4148
D_4, D_6 = zener, 5.6 V, 500 mW
D_5, D_7 = zener, 15 V, 1.3 W
D_8, D_{11} = zener, 30 V, 1.3 W
D_9, D_{12} = zener, 39 V, 1.3 W
D_{10}, D_{13}, D_{16}, D_{17} = 1N4004
D_{14}, D_{15} = zener, 12 V, 500 mW
T_1, T_4, T_5, T_{15}–T_{17} = BC560C
T_2, T_3, T_6, T_{18}–T_{20} = BC550C
T_7, T_8, T_{43}, T_{48} = BF245A
T_9 = BF871
T_{10} = BF872
T_{11}, T_{50}, T_{51} = BC640
T_{12}, T_{45}, T_{46} = BC639
T_{13}, T_{14} = BF256C
T_{21}–T_{23} = MJE350
T_{24}–T_{26} = MJE340
T_{27} = BD139
T_{28} = BD140
T_{29}–T_{31} = 2SC5171 (Toshiba)
T_{32}–T_{34} = 2SA1930 (Toshiba)
T_{35}–T_{38} = 2SC5359 (Toshiba)
T_{39}–T_{42} = 2SA1987 (Toshiba)
T_{44}, T_{49} = BF256A
T_{47} = BD712
T_{52} = BD711

Integrated circuits:
IC_1 = OP90G
IC_2 = 6N136

Miscellaneous:
JP_1, JP_2 = 2.54 mm, 2-way pinstrip and pin jumper
K_1 = 3-way terminal block, pitch 5 mm
Re_1 = relay, 12 V, 600 Ω
Re_2–Re_4 = relay, 12 V, 16 A, 270 Ω
Heat sink for T_{21}–T_{26} = 38.1 mm, 11 K W^{-1} (Fischer Type SK104-STC; TO220)
Heat sink for drivers/output transistors, 150 mm, 0.25 K W^{-1}, Fischer Type SK157
Ceramic isolation washers for T_{21}–T_{34}: Fischer Type AOS220
Mica isolating washers for T_{35}–T_{42}
PCB Order no 990001-1 (see Readers Services towards end of this magazine)

is, of course, of paramount importance that these capacitances are as small as feasible. For this reason, it is vital that in the thermal coupling of T_{21}–T_{34} 1.5 mm thick ceramic—not mica—isolating washers are used. Mica washers may, however, be used with the output transistors since parasitic capacitances there are of no significance.

The component and track layouts of the mother board are shown in **Figure 12**. It will be seen that the board consists of two sections: the mother board proper and the output-relay board. The latter must be cut off before any other work is done. Later, when it is built up, it is mounted on the mother board with the aid of four 50 mm long metal spacers in such a way that the LS– and LS+ terminals on the two boards are above each other. The spacers also provide the electrical link between the boards.

The completed relay board is shown in **Figure 13**. Inductor L_1 is made from a doubled-up length of 1.5 mm enamelled copper wire wound in two layers of eight turns each around a 16 mm former (such as a piece of PVC pipe). After the coil has been wound, the PVC pipe is removed and the four windings connected in parallel. See **Figure 14**.

Ignoring the drivers and output transistors for the moment, the construction of the mother board is traditional. As always, great care must be taken during the soldering and placing of components. Do not forget the thermal coupling of T_1-T_3, T_2-T_4, D_1-T_5, D_2-T_6, T_{45}-T_{46}, and T_{50}-T_{51}, as already pointed out in Part 1. Also, T_{21}–T_{23} and T_{24}–T_{26} must be mounted on a heat sink, and isolated from it by means of a ceramic washer. When this is done, fit the composite heat sinks on the board, and link them to earth.

The input signal and the ±85 V supply lines are linked to the board via standard solder pins.

For connecting the ±70 V supply lines and the relay board, 3 mm screw holes are provided. Metal spacers are to be fixed to these and cable connectors to the top of the spacers.

MAIN HEAT SINK

When the mother board has been completed, and carefully checked, as far as described, it and the drivers and output transistors, T_{27}–T_{42}, must be mounted on the main heat sink. This is a 150 mm high Type SK157 from Fischer with a thermal resistance of 0.25 K W^{-1}. This is admittedly a very tedious job. It is vital that all requisite fixing holes are drilled accurately in the heat sink and preferably tapped with 3 mm thread. The template delivered with the ready-made board is almost indispensable for this work.

When the holes have been drilled (and, possibly, tapped) transistors T_{27} and T_{28} should be fitted first (this is important because they become inaccessible after the board has been fitted). They must be located as close as possible to the output transistors and not in the position indicated on the board. Again, the template makes all this clear. Their terminals must then be extended with the aid of short lengths of equipment wire, which are later fed through the relevant holes on the board and soldered to the board via, for instance, a three-way pin header.

The terminals of the drivers and output transistors must be bent at right angles: those of the former at the point where they become thinner and those of the latter about 5 mm from the body of the device. When this is done, screw all transistors loosely to the heat sink, not forgetting the isolating washers. If it is intended to use fan cooling, the requisite temperature sensor—that is, a Type BD140 transistor— should also be attached to the heat sink at this stage. The template does not show a location for the sensor, but it seems sensible to fit it at the centre close to T_{37} or T_{40}.

The next step is to fit all ten spacers to the heat sink: these should all be 10 mm long. In the prototype, spacers with a 3 mm screwthread at one end were used. Two of the spacers merely provide additional support for the relay board and another two form the electrical link between the negative supply line and the heat sink.

When all this work is done, the board should look more or less like that in **Figure 15**. Note that because of tests later on, there are, as yet, no ceramic isolating washers fitted on the prototype.

The next, and most tedious, step is to combine the board and heat sink. It is, of course, vital that all spacers are exactly opposite the relevant fixing holes and—even more tedious—that the terminals of all transistors are inserted into the correct mounting holes. Bear in mind that the metal

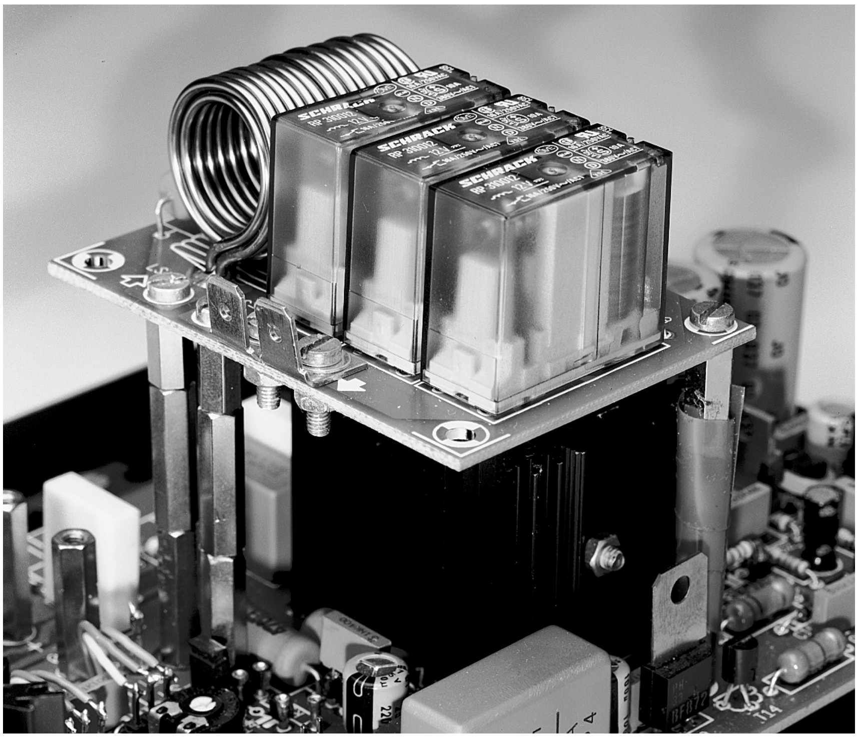


Figure 13. Illustrating how the relay board is mounted on the mother board with the aid of spacers.

spacers for linking –, +, LS+, and LS–, are already on the board. As the terminals of the output transistors are slightly longer than those of the drivers, it may be possible to do this work in two stages: output transistors first and drivers second. It may prove necessary to turn one or more of the transistors slightly, which is the reason that the fixing screws have not yet been tightened. When all terminals are correctly inserted, these screws must, of course, be tightened firmly.

The final step is to fix the relay board on the spacers that form the link for the LS– and LS+ terminals.

SETTING UP

Before the amplifier module can be taken into use, presets P_2–P_5 must be set as required. Preset P_1 is intended only for possibly adjusting the balance in case of a bridge configuration.

Start by turning P_3 (the quiescent-current control) fully anticlockwise and P_2, P_4, and P_5, to their centre position. Check the outputs of the power supply and auxiliary power supply and, if these are correct, link the +70 V line to pins '+' and '0', the –70 V line to '–' and '0', the +85 V line to '+ +' and the -85 V line to '--'. For absolute safety, link the ±70 V lines temporarily via a 10 Ω, 5 W resistor.

Next, set P_4 and P_5 for voltages of +78 V and –78 V respectively at the cases of transistors T_{47} and T_{52} respec-

Figure 14. Air-cored inductor L_1 is formed by laying two windings each of eight turns of doubled-up each on top of one another. The former is a length of 16 mm diameter PVC pipe as used by plumbers. The resulting four windings are simply connected in parallel.

tively (the cases of these transistors are linked to the output of the relevant regulator). It is important that the negative and positive voltages are numerically identical.

Since the parameters of the n-p-n and p-n-p transistors in the input stage are never exactly identical, there may be a slight imbalance. This may be corrected by adjusting the output of current source T_5 with the aid of preset P_2 to give a potential of exactly 0 V at the output (pin 6) of IC_1 (when 'cold').

Finally, insert an ammeter (set to 500 mA or 1 A range) in the +70 V or –70 V line, and adjust P_3 carefully for a quiescent current of 200 mA (cold condition—that is, immediately after switch-on). With a large drive signal, the quiescent current may increase to some 600 mA, but at nominal temperatures, its level will stabilize at 200–400 mA. Note that these fluctuations have no noticeable effect on the performance of the amplifier.

CHECK AND TEST

When the amplifier has been switched on for about half an hour, the voltages shown in Figure 2 (Part 1) may be verified. Note that voltage levels depending on the setting of current sources habitually show a substantial spread: 30 per cent is quite common. All measurements should be carried out with a good digital voltmeter or multimeter with a high-impedance input.

Other than the test voltages in the circuit diagram, there are some others that may be checked. For instance, the proper functioning of the output transistors may be ascertained by measuring the voltage across R_{45}–R_{52}. Hold one test probe against the loudspeaker terminal and with the other measure the potential at the emitters of all output transistors. The average value should be about 20 mV, but deviations of up to 50 per cent occur.

The voltage amplifier operation may be checked by measuring its current drain: if this is within specification, the voltage across R_{56} and R_{65} must be within 0.8–1.1 V (after the amplifier has been on for at least half an hour).

Finally, the potential drops across the emitter resistors of differential amplifiers T_{45}-T_{46} and T_{50}-T_{51} must not differ by more than a factor 2. Too large a factor is detrimental to the stable operation of the amplifiers. A too large difference may be corrected by changing the value of R_{62} or R_{71}, as the case may be. If this is unsuccessful, the relevant transistor pair will have to be replaced.

When all is well, the resistors in series with the ±70 V lines should be removed. Note that a rectified voltage of 70 V, let alone one of 140 V, is lethal. It is therefore absolutely essential to switch off the power supply and verify that the residual voltages have dropped to a safe value before doing any work on the amplifier.

Next month's instalment will deal with the wiring up of the amplifier and its performance, including specifications.

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Figure 15. The PCB is delivered with a template to ensure that the transistors are fitted at the correct location on the heat sink.