Contents

Titan 2000

Part 2: protection network

This second of four parts deals primarily with the protection network incorporated in the amplifier. This indispensable network safeguards the amplifier and the loudspeakers connected to it against all kinds of error that may arise. The network is an independent entity with its own power supply.

Correction. In last month's first part of this article, it was stated erroneously that the article consists of two parts, whereas in fact it will be described in four parts.

Design by T. Giesberts

INTRODUCTION

As mentioned briefly in Part 1, extensive and thorough protection is a must in an amplifier of this nature. It may well be asked why this is so: is there such a likelihood of mishaps arising? Or is the amplifier so vulnerable? On the contrary: extended tests on the prototype have shown that the Titan 2000 is a very stable and reliable piece of equipment. In fact, unusual means had to be used to actuate the protection circuits during these tests, since not any standard test prompted the amplifier into an error situation.

The extensive protection is necessary because by far the largest number of mishaps occur owing to actions by the user, not because of any shortcomings in the amplifier. For example, the most robust and reliable amplifier can not always cope with extremely high overdrive or overload conditions.

SIX FUNCTIONS

The integrated protection network consists of six sub-circuits:

- power-on delay
- transformer voltage sensor
- temperature sensor
- current sensor
- direct-current sensor
- overdrive sensor

The power-on delay ensures that the relays in the amplifier are energized 50–100 milliseconds after the supply has been switched on to prevent switch-on clicks.

The transformer voltage sensor reacts to the cessation of the secondary voltage of the mains transformers to prevent switch-off clicks and crackles.

The temperature sensor responds to excessive heat sink temperatures, but it should be noted that this works only in

4

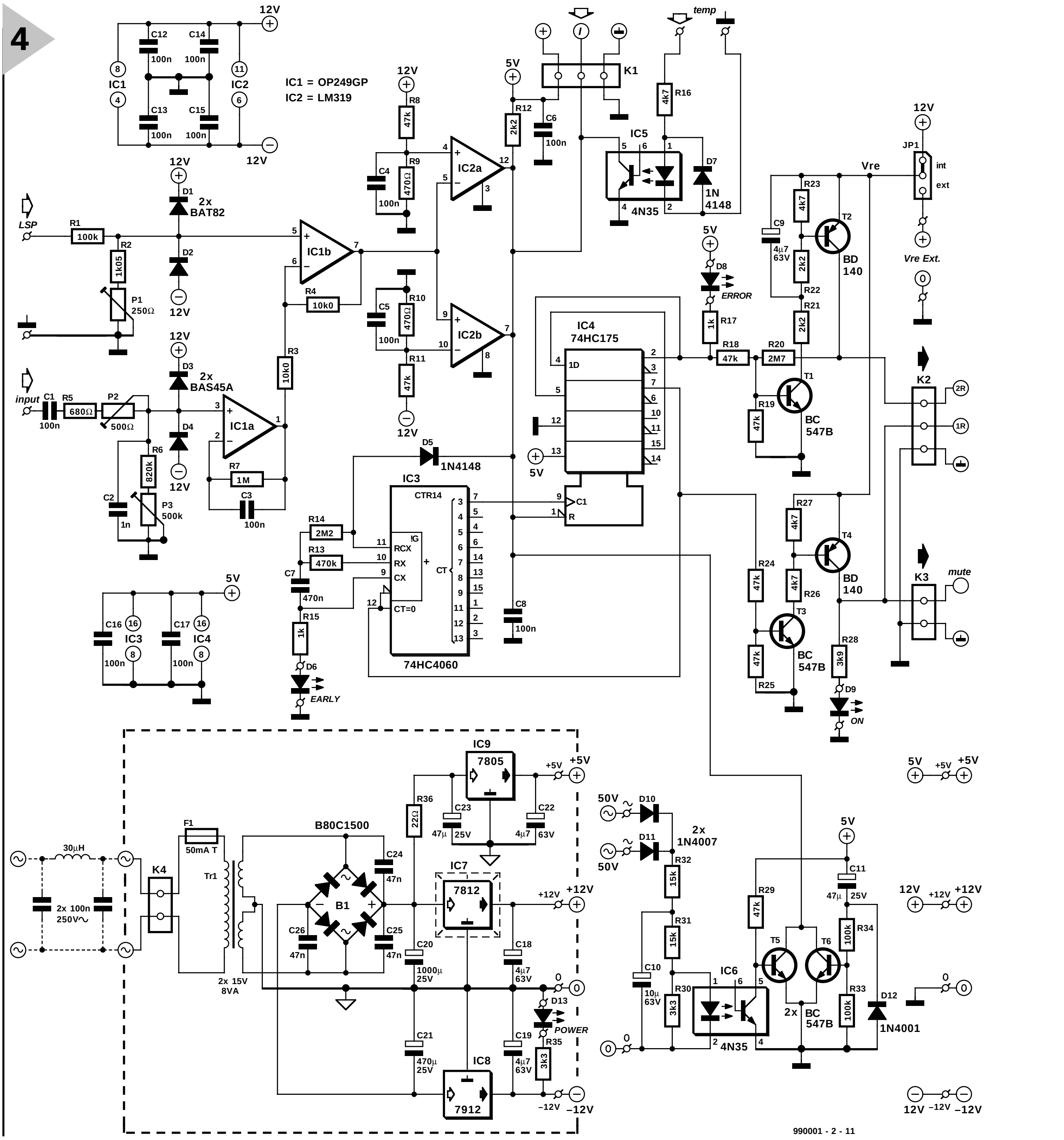


Figure 4. The protection network consists of six sensor circuits each of which causes the input and output relays of the amplifier to be deenergized when a fault occurs.

conjunction with the fan drive, which is reverted to later in this article.

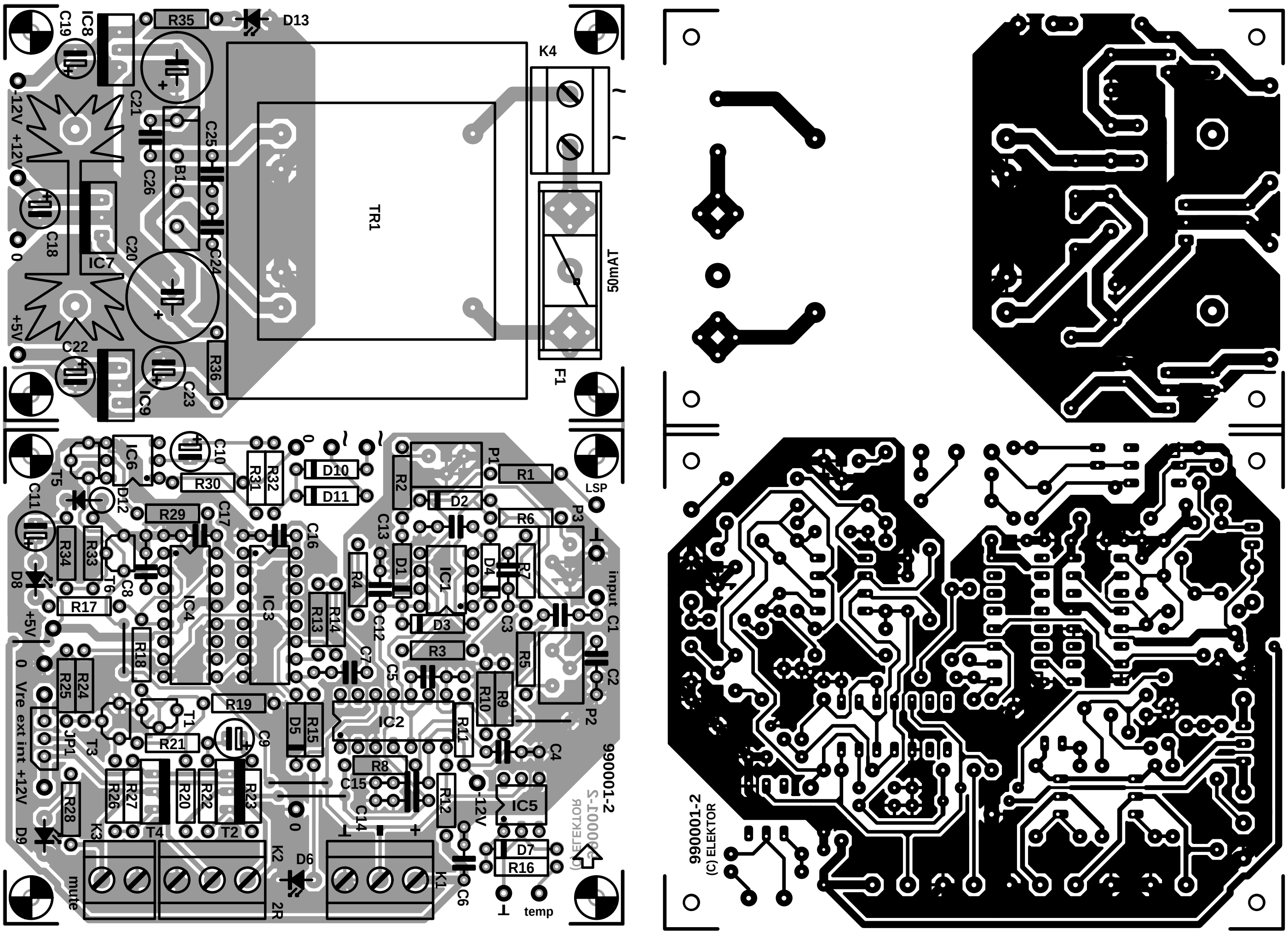
The current sensor monitors the output current, while the direct-current and overdrive sensors form a combined circuit that monitors differences between the input and output signals, and reacts to excessive direct-current levels or distortion. This circuit is the most important and ‘intelligent’, but also the most complex of the six.

All sensors, when actuated, react in the same way: they cause the output relays and the mute relay at the input of the amplifier to be deenergized immediately. This action causes the input signal and the output load to be disconnected from the amplifier. After the fault causing the sensor action has been removed or remedied, the relevant protection circuit is disabled, whereupon the amplifier relays are reenergized after a short delay.

When the protection network is actuated, a red LED lights to indicate an error. When the fault has been removed or remedied, the red LED remains on, but a yellow LED flashes to indicate that the amplifier will be reenabled shortly. The red LED then goes out, shortly followed by the yellow, whereupon a green LED lights to indicate that all is well.

COMMON SECTION AND POWER-ON DELAY

The circuit of the integrated protection network, including the +5 V and ±12 V power supplies, is shown in **Figure 4**.



Parts lists

Protection network

Resistors:
R_1, R_{33}, R_{34} = 100 kΩ
R_2 = 1.05 kΩ
R_3, R_4 = 10.0 kΩ
R_5 = 680 Ω
R_6 = 820 kΩ
R_7 = 1 MΩ
R_8, R_{11}, R_{18}, R_{19}, R_{24}, R_{25}, R_{29} = 47 kΩ
R_9, R_{10} = 470 Ω
R_{12}, R_{21}, R_{22} = 2.2 kΩ
R_{13} = 470 kΩ
R_{14} = 2.2 MΩ
R_{15}, R_{17} = 1 kΩ
R_{16}, R_{23}, R_{26}, R_{27} = 4.7 kΩ
R_{20} = 2.7 MΩ
R_{28} = 3.9 kΩ
R_{30}, R_{35} = 3.3 kΩ
R_{31}, R_{32} = 15 kΩ
R_{36} = 22 Ω
P_1 = 250 Ω, multiturn preset (upright)
P_2 = 500 Ω, multitun preset (upright)
P_3 = 500 kΩ, multiturn preset (upright)

Capacitors:
C_1, C_3 = 0.1 µF
C_2 = 0.001 µF
C_4, C_5, C_6, C_8, C_{12}–C_{17} =0.1 µF, ceramic
C_7 = 0.47 µF
C_9, C_{18}, C_{19}, C_{22} = 4.7 µF, 63 V, radial
C_{10} = 10 µF, 63 V, radial
C_{11}, C_{23} = 47 µF, 25 V, radial
C_{20} = 1000 µF, 25 V, radial
C_{21} = 470 µF, 25 V, radial
C_{24}–C_{26} = 0.047 µF, ceramic

Semiconductors:
D_1, D_2 = BAT82
D_3, D_4 = BAS45A
D_5, D_7 = 1N4148
D_6, D_8, D_9, D_{13} = 3 mm high-efficiency LED (yellow, red, green, green respectively)
D_{10}, D_{11} = 1N4007
D_{12} = 1N4001
T_1, T_3, T_5, T_6 = BC547B
T_2, T_4 = BD140

Integrated circuits:
IC_1 = OP249GP (Analog Devices)
IC_2 = LM319N
IC_3 = 74HC4060
IC_4 = 74HC175
IC_5, IC_6 = 4N35
IC_7 = 7812
IC_8 = 7912
IC_9 = 7805

Miscellaneous:
JP_1 = 2.54 mm pin strip and pin jumper
K_1, K_2 = 3-way terminal block, pitch 5 mm
K_3 = 2-way terminal block, pitch 5 mm
K_4 = 2-way terminal block, pitch 7.5 mm
B_1 = bridge rectifier, rectangular, Type B80C1500
F_1 = fuse, 50 mAT and fuse holder
Tr_1 = mains transformer, 15 VA, with 2×15 V secondary
Heat sink (for IC_7) = e.g. Fischer SK104, 50 mm
Mains interference filter

Figure 5. The printed-circuit board of the overall protection network.

The network is linked to the input and output of the amplifier via terminals ‘input’ and ‘LSP’ respectively (to terminals ‘P-IN’ and ‘P-LS’ on the amplifier board).

Terminals ‘50 V≈’ are connected to the secondary windings of the mains transformers.

The three output relays and the mute relay in the amplifier are linked to the protection network via K_2, and K_3 respectively.

The current sensor is connected to the output of optoisolator IC_2 in the amplifier (‘I->’ on the amplifier board) via K_1.

The terminals marked ‘temp’ are intended to be linked to the output of the fan control circuit.

As mentioned earlier, the action of each sensor results in the deenergizing of the output and mute relays in the amplifiers. This implies that the outputs of the the various sensor circuits are interlinked. This is effected by combining the open-collector outputs of these circuits into a wired OR gate with R_{12} functioning as the common pull-up resistance. The combined output signal serves to reset a number of

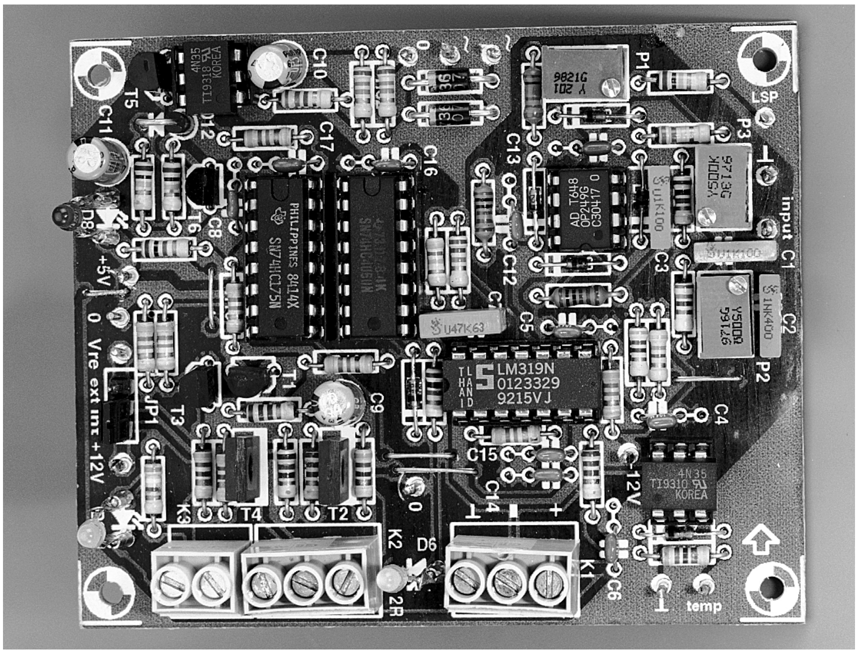


Figure 6. Completed prototype of the protection network.

D-type bistables (flip-flops), contained in IC_4, which are interconnected to form a shift register. Note that D-type bistables are essential since these can be set and reset in a defined manner.

The outputs of IC_4 are used to drive two level converters, T_1-T_2 and T_3-T_4 respectively, which bridge the difference between the 5 V level of the logic ICs and the 12 V supply for the relays. Jumper JP_1 enables a different, external supply voltage (V_{RE}) to be used if 12 V relays are not employed.

Transistors T_1 and T_2 drive Re_1 and Re_2, which are the first to be energized (synchronously). On switch-off, capacitor C_9 ensures that T_2 remains on for some milliseconds longer during which period Re_3 and Re_4 are deenergized (see Part 1).

The power-on delay, which also operates after a fault situation, is more complex than usual. To start with, after the supply voltage us switched on, input CLR of IC_4 is held low (active) for a few seconds by the circuit around T_6. When, after this period, CLR is made high by R_{12} –which happens only when there is no error situation (any longer)–the internal oscillator of IC_3 is enabled via D_5. This results after a few seconds in a clock pulse appearing at the CLK input of IC_4, whereupon Q_4 goes high. The period between the oscillator being enabled and the appearance of the first clock pulse is not defined since, owing to the presence of T_6, a power-on reset is purposely not provided. To ensure a minimum delay in the energizing of Re_1 and Re_2 in spite of this, a high level is clocked into Q_4 after IC_3 has been enabled. The precise moment at which this happens varies, therefore, only when the supply voltage is switched on for the first time.

A period of IC_3/Q_3 later, Q_1 of IC_4 goes high, whereupon Re_1 and Re_2 are energized. After another period, Q_2 of IC_4 becomes high, whereupon Re_3 and Re_4 are energized. At the same time, IC_3 is disabled since its reset is interlinked with Q_2 of IC_4.

The red LED, D_8, in parallel with Q_1 of IC_4 lights when the relays in the amplifier are not energized, either because the amplifier is (not yet) switched on, or owing to an error.

The yellow LED, D_6, is linked to the output of the oscillator in IC_3, causing it to flash until IC_4 is clocked.

The green LED, D_9, is connected in parallel with Re_3 and Re_4, so that it lights only when the amplifier is fully switched on.

TRANSFORMER VOLTAGE SENSOR

The 50 V≈ secondary voltages of the mains transformers in the amplifier are rectified by diodes D_{10} and D_{11}, and smoothed by R_{30}-R_{31}-R_{32}-C_{10}. The values of these components ensure that the LED in optoisolator IC_6 lights sufficiently to hold the associated photo transistor on. This transistor pulls the base of T_5 to ground, causing T_5 to cut off. When the secondary voltages fail, T_5 is switched on immediately via R_{29}, whereupon the D-type bistables in IC_4 are reset.

Use is made of an optoisolator purposely to avoid any risk of earth loops between the supply return and the ground of the protection network, which is linked to the input ground of the amplifier.

TEMPERATURE SENSOR

The temperature sensor works in a manner similar to that of the transformer voltage sensor. The optoisolator in this circuit is IC_5, which, in contrast to IC_6, is normally cut off and comes on only when the heat sink becomes excessively hot.

The sensor reacts to the fan control circuit switching the fan speed to maximum (because the heat sink is getting too hot). A comparator in the fan control circuit then toggles, whereupon IC_5 is actuated via the 'temp' input and resets the D-type bistables in IC_4. This situation changes only after the heat sink has cooled down to an acceptable temperature (although the fans may still be rotating).

CURRENT SENSOR

To nullify high common-mode voltages and to prevent any risk of earth loops, the current sensor also uses an optoisolator, IC_2 (**Figure 5**). However, this is not located on the protection board, but directly at the output of the amplifier.

The values of the relevant components cause the sensor to be actuated when the output current is about 40 A. This may appear a very large current, but this is due entirely to the specified requirement that the amplifier must be capable of delivering 60 V into a load of 1.5 Ω without the protection circuit being actuated. The current level may be lowered to some extent by increasing the value of R_{74} in the amplifier.

Output resistor R_{78} is in parallel with R_{12} by linking terminals 'I', '+5 V' and ground on the amplifier board to K_1 on the protection board via three lengths of insulated, stranded circuit wire twisted together. This arrange-

7

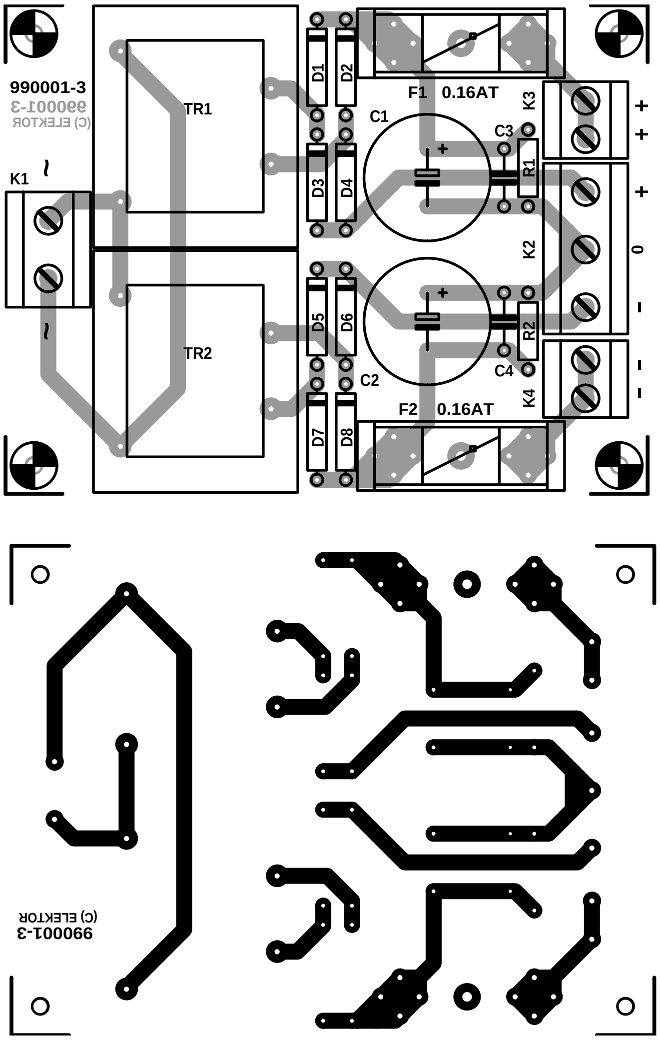


Figure 7. Printed-circuit board for the auxiliary power supply described in Part 1.

Parts lists
Auxiliary power supply

Resistors:
R_1, R_2 = 1 MΩ

Capacitors:
C_1, C_2 = 470 µF, 100 V, radial
C_3, C_4 = 0.1 µF, 100 V, pitch 7.5 mm

Semiconductors:
D_1–D_8 = 1N4007

Miscelleneous:
K_1 = 2-way terminal block, pitch 7.5 mm
K_2 = 3-way terminal block, pitch 7.5 mm
K_3, K_4 = 2-way terminal block, pitch 5 mm
Tr_1, Tr_2 = mains transformer, 1.5 VA, with 12 V secondart
F_1, F_2 = fuse, 160 mAT, and fuse holder

ment ensures a low impedance to any interference and a high reaction speed.

DIRECT-CURRENT AND OVERDRIVE SENSOR

The d.c. and overdrive sensor constantly compares the input and output signals of the amplifier and reacts when the difference between the two is too great. The comparison is effected with the aid of operational amplifier IC_1 which has a very low bias current and a very low offset. It is, of course, essential that during the comparison of the two signals by differential amplifier IC_{1b} the differences in phase and transit times do not lead to error detection. At the same time, the voltage amplification (×43) of the amplifier must be taken into account.

The amplification is compensated by potential divider R_1-R_2-P_1 at input LSP. The potentiometer is a multiturn type to ensure accurate adjustment.

The phase difference is compensated by the circuit based on IC_{1a}. The transit at high and low cut-off points is simulated by first-order networks that can also be adjusted very accurately with multiturn potentiometers P_2 and P_3.

The inputs of IC_{1a} and IC_{1b} are protected by diodes. Since any leakage current of these diodes, combined with the high input impedance (≈ 1 MΩ) of IC_{1a}, might lead to an appreciable offset, and therefore to an unwanted error detection, the diodes, D_3 and D_4, are special types with a leakage current of only 1 nA.

The output of differential amplifier IC_{1b} is monitored by a window comparator formed by IC_{2a} and IC_{2b}. The value of the components used in potential dividers R_8-R_9 and R_{10}-R_{11} ensures that the protection circuit is actuated when the direct voltage reaches a level of ±5 V or the distortion becomes 2.5 per cent. Such distortion will normally be the result of overdrive, but the circuit reacts equally well to oscillations or other spurious signals that cause too large a difference to be detected.

CONSTRUCTION AND SETTING UP

The integrated protection network is best built on the printed-circuit board shown in **Figure 5**. Populating this board should not present any undue difficulties, but it should be noted that diodes D_6, D_8, D_9 and D_{13}, are not located on the board, but are linked to it via flexible, stranded circuit wire. They are fitted to the front of the enclosure.

Jumper JP_1 will normally be in position 'intern' unless relays with a coil voltage other than 12 V are used.

A prototype of the completed protection board is shown in **Figure 6**.

All input and output terminals of the board are clearly marked with the same symbols as shown in Figure 4. Most interconnections can be made in thin, stranded hook-up wire to DEF61-12, but the input and output links ('input' and 'LSP') must be screened audio cable.

Although the power supply for the protection network can be fitted on the same board, the relevant section may be cut off and fitted elsewhere. Of course, the supply lines must then be linked to the relevant terminals on the protection board via insulated, stranded hook-up wire.

The power supply is straightforward. From the secondary output of the specified mains transformer, Tr_1, a symmetrical ±12 V supply is obtained with the aid of regulators IC_7 and IC_8. From the same secondary, a +5 V supply for the digital circuits is obtained with the aid of regulator IC_9. Since the relays are fed by the +12 V line, regulator IC_7 must be fitted on a heat sink.

To ensure that the protection network is not actuated by interference on the mains supply, it is advisable to precede the power supply by a suitable noise filter. This may be made from a 30 µH choke and two 0.1 µF, 300 V≈ capacitors as shown in dashed lines in Figure 4.

The network is set up by maximizing the common-mode suppression with the aid of an oscilloscope or a multimeter with sufficient bandwidth. Measurements need to be made at 1 kHz, 20 kHz, and 20 Hz. The open-circuit amplifier is driven as far as possible by a suitable sine-wave generator or CD player with a test CD.

With a signal of 1 kHz, set P_1 for minimum sign al at the output of IC_{1b}, follow this with a signal of 20 kHz and adjusting P_2, and finally, with a signal of 20 Hz, by adjusting P_3. Since the settings influence one another to some extent, the potentiometers should be set a couple of times, perhaps also at some different audio frequencies.

POWER SUPPLY

The auxiliary power supply described in Part 1 is best constructed on the printed-circuit board shown in **Figure 7**. The mains voltage is linked to K_1, the ±70 V to K_2 and the +85 V and –85 V lines to K_3 and K_4 respectively. Since all currents are low level, the wiring may be made in thin, insulated, stranded hook-up wire. A completed prototype board is shown in **Figure 8**.

The main supply for the amplifier is a straightforward, unregulated type, providing an output of ±70 V. Its circuit diagram is shown in **Figure 9**.

Since the specified requirements call for a 2 Ω load, the supply must be rated at 1000 VA, which necessitates two toroidal transformers. To prevent unforeseen equalizing currents, the dual secondaries are not linked in parallel, but are individually connected to a bridge rectifier. The outputs of the rectifiers can be connected in parallel without any problem. The rectifiers need to be mounted on a suitable heat sink such as a Type SK01.

It should be clear that the wiring of the power supply must allow for the large output currents of the amplifier. In the prototype, the electrolytic capacitors are linked by 3 mm thick strips of aluminium. The remainder of the wiring should be in insulated, high-current wire to BS6231 with a conductor size of 50/0.25 mm (2.5 mm^2) or better. The use of car-type connectors is recommended.

Note that the power supply as described is intended for use with a mono(phonic) amplifier that can deliver 800 W into 2 Ω and should remain stable with loads of 1.5 Ω. If you are certain that you will always use 4 Ω or 8 Ω loads, the power supply requirements may be relaxed to some extent. A reasonable relaxation is the use of 2×50 V/300 VA transformers and 10,000 µF/100 V smoothing capacitors. The rating of the primary fuses may then be reduced to 1.5 AT.

MAINS-ON DELAY

The use of a mains-on delay is recommended when heavy loads are to be switched on, as in the case of the present amplifier. Such a delay circuit switches on the mains to the load gradually to ensure that the switch-on current remains within certain limits and to prevent the mains fuses from blowing.

The most recently published (in this magazine) mains-on delay is found in the July/August 1997 issue (p. 74), whose circuit diagram is reproduced in **Figure 10**. Its printed-circuit board is readily connected with the primary windings of the two mains transformers. The board is not available ready-made, however, and its diagram is, therefore, reproduced in **Figure 11**.

8

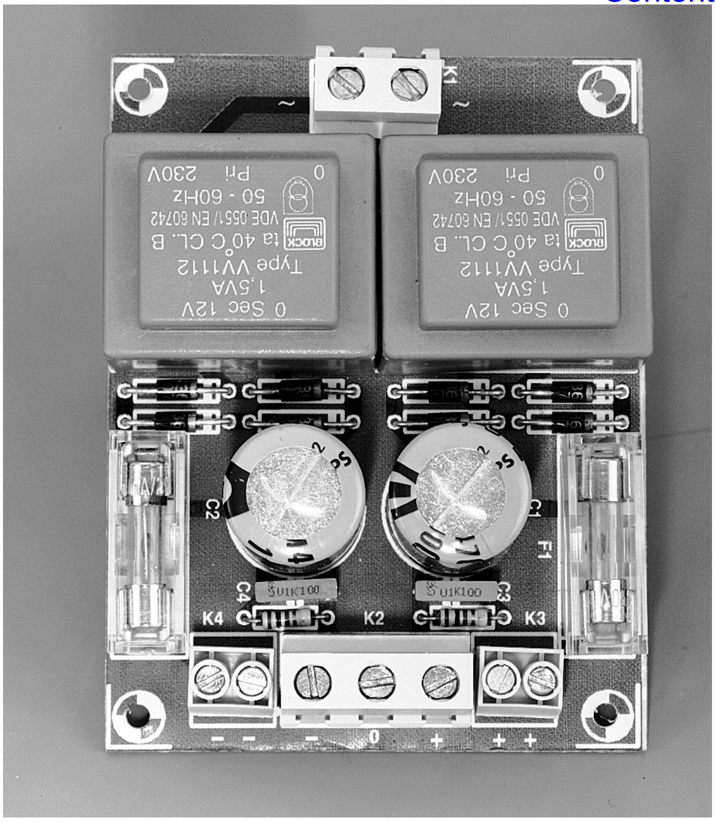


Figure 8. The auxiliary power supply is small enough to fit in most enclosures.

9

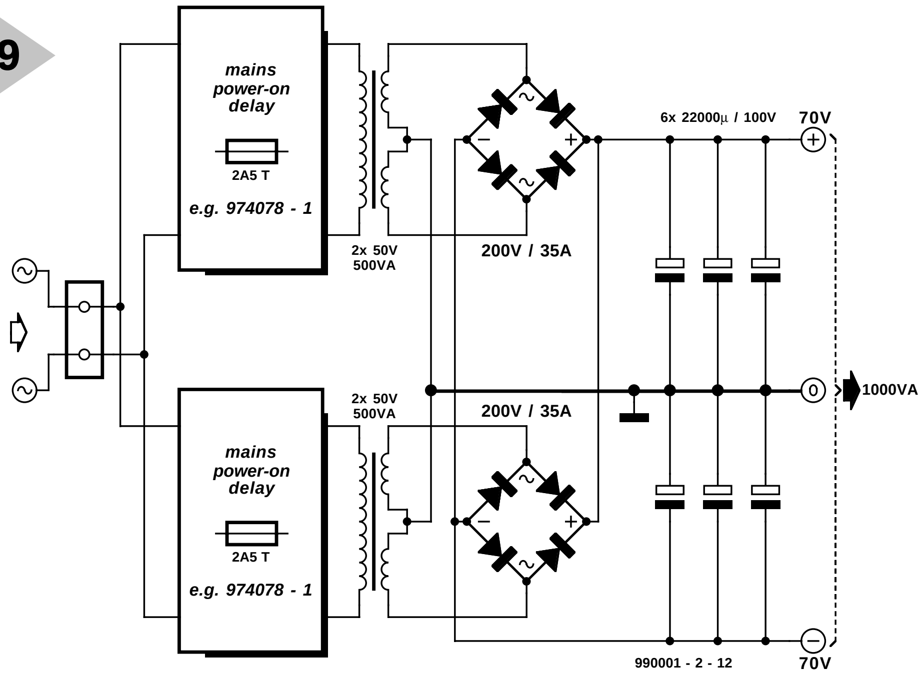


Figure 9. The main power supply for the amplifier is a heavy-duty entity in which the six capacitors are particularly impressive.

10

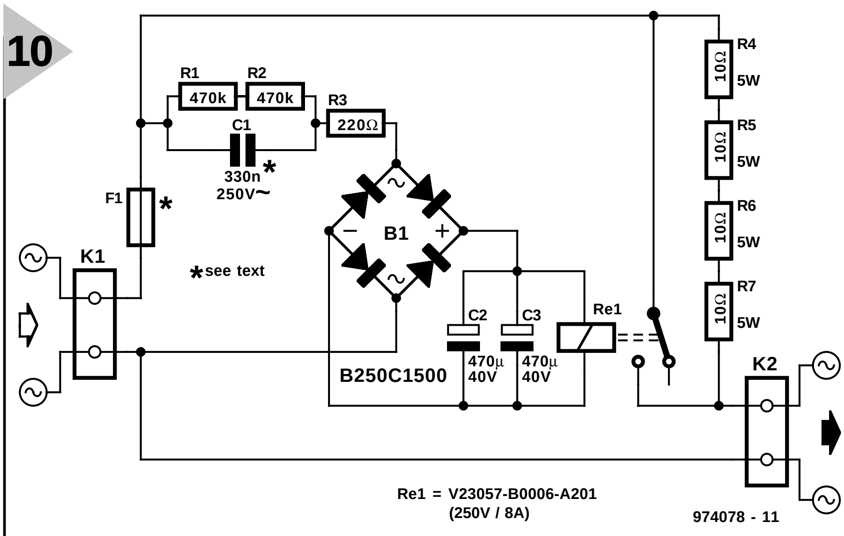


Figure 10. The mains-on delay ensures that the switch-on current remains within certain limit. Two of these delays are required for each Titan 2000.

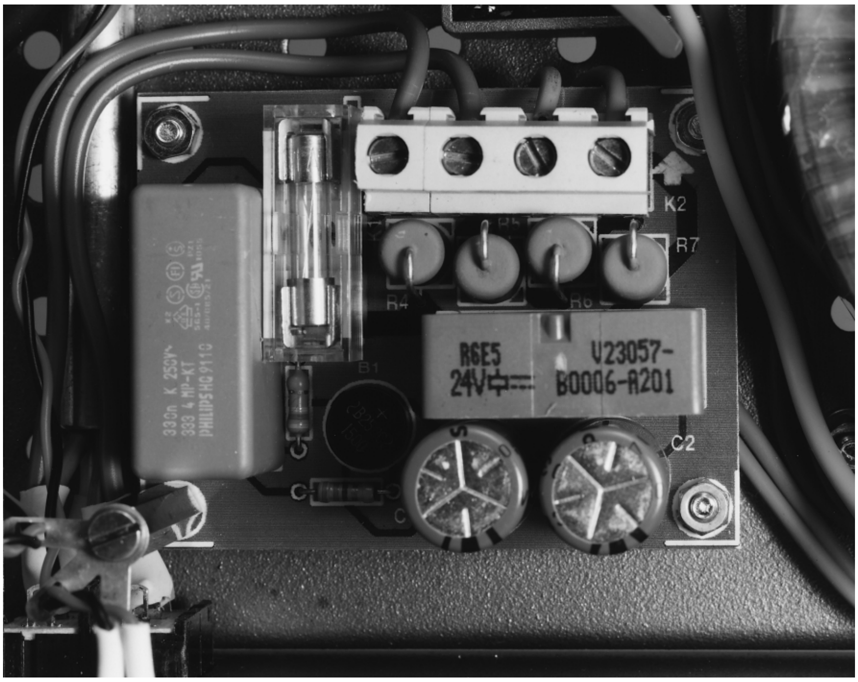
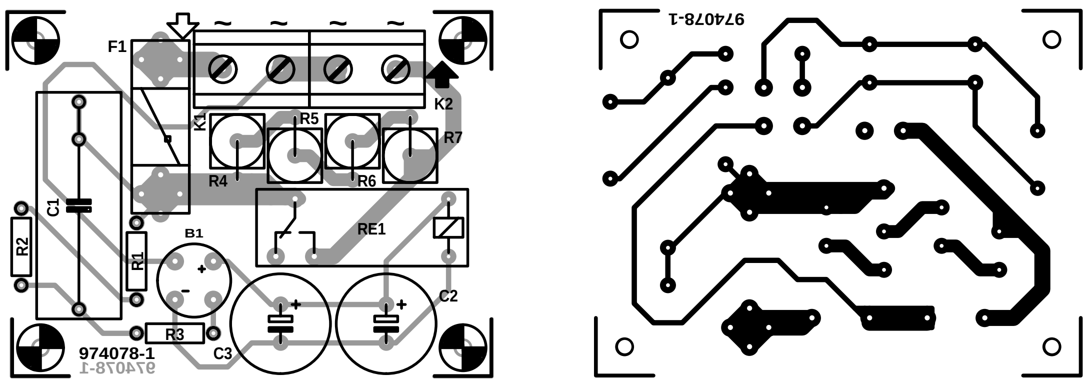


Figure 11. Printed-circuit board for the mains-on delay circuit, which is not available ready made.

11



The delay arranges for the load, that is, the Titan 2000, to be switched on in two stages. In the first of these, the switch-on current is limited by series network R_4–R_7. After the delay determined by capacitors C_2 and C_3, the series network is shorted by a relay contact, whereupon the full current flows between K_1 and K_2.

Relay Re_1 can switch up to 2000 VA. Its supply voltage is obtained from the mains with the aid of rectifier B_1, capacitor C_1 and resistor R_3.

Since the amplifier power supply uses two mains transformers, two mains-on delay circuits are needed.

Fuse F_1 functions as a primary mains fuse for the amplifier.

Capacitor C_1 is a metallized paper type intended especially for use with mains voltage applications.

Bear in mind that the circuit is linked directly to the mains supply and thus carries lethal voltages.

Next month's third instalment of this article deals with the construction of the amplifier, a few other practical matters, and some measurements.

[990001-2]

Parts lists

Mains-on delay circuit

Resistors:
R_1, R_2 = 470 kΩ
R_3 = 220 Ω
R_4–R_7 = 10 Ω, 5 W

Capacitors:
C_1 = 0.33 µF, 300 V a.c.
C_2, C_3 = 470 µF, 40 V

Miscellaneous:
K_1, K_2 = 2-way terminal block, pitch 7.5 mm
B_1 = bridge rectifier, round, Type B250C1500
Re_1 = relay, coil 12 V, 1200Ω; contact rating 250 V, 8 A
F_1 = see text