WORKBENCH POWER SUPPLY UNIT

Design by K. Schönhoff

A stabilized power supply unit with current limiting is described that not only provides but also accepts power. This property is indispensable, for example, for the testing of batteries.

In principle, the power supply unit, PSU, is fairly straightforward. The part that provides power consists of a main circuit whose output voltage is converted into a variable, stabilized potential with the aid of a preset voltage regulator. A resistor in series with the outputfacilitates current measurements and is also needed for the current limiting circuit.

Apart from the main circuit, there is an ancillary circuit that provides power for the measurement and control circuits for the voltage setting and the variable current limiting respectively.

Moreover, the PSU contains a circuit that makes it possible for power applied to the output from an external source to be accepted. This facility enables the charging and discharge currents of batteries, battery chargers and other power supplies to be tested. It could also enable the PSU to serve as a power zener in certain measurements. Owing to its 'bivalent' nature, the unit strongly resembles a battery. This is achieved not with an esoteric design, but with a mirror image of the main circuit.

Circuit description

The upper part of the main circuit in Fig. 2 *provides* power, whereas the lower part *accepts* power from an external source.

The mains transformer—not shown in Fig. 2—is connected to K_3. Its secondary voltage (24 V) is converted by rectifier D_1–D_4 into a direct voltage of about 35 V. Capacitor C_1 is a smoothing element. Additional smoothing and stabilization is provided by double darlington output stage T_4-T_6, which is driven by IC_{3a} and T_2. The collector-emitter circuit of the output stage is in series with the +ve terminal of the output of the unit, K_4. The –ve terminal of K_4 is linked direct to the negative terminal of C_1.

Series regulator T_4-T_6 obtains its base current normally from T_2, which is connected as a constant-current source. This source contains a potential divider, R_8-R_9, whose terminals are connected to the +ve and ⊥ terminals of regulator IC_1, which provides the 5 V ancillary supply. The input of the regulator is obtained from the secondary winding of Tr_1, bridge rectifier B_1 and smoothing capacitor C_2. The value of R_7 determines the level of the current provided by T_2: here 8 mA.

The output stage does not need the same base current all the time, of course. It must be able to adapt its output voltage and peak current to the requirements of the user as well as to the possible variations in the load. Therefor, the constant current provided by T_2 can be varied by IC_{3a}. This IC decreases the base current (by lowering its output voltage) to T_4-T_6 if the output voltage of the PSU tends to become larger than the set value. Part of the current provided by T_2 then no longer flows to T_4-T_6, but to the output of IC_{3a} via D_5.

Since a darlington has a double base-emitter junction, it will commence conducting only when the base voltage is 1.2 V. If the cathode of D_5 is held at earth potential by the output of IC_{3a}, the voltage at the anode of the diode is at most 0.6 V, which is well below the 1.2 V necessary for the output stage to commence conducting. In other words, the output stage is cut off. This has the advantage that there is then not even a quiescent current through the darlington.

In this way IC_{3a} controls the output voltage of the PSU. Before it can do so, however, it must have information as to the level of the output voltage. In other words, and as usual in a regulated supply, before anything can be controlled, measurements will have to be carried out.

Measurements for IC_{3a} are effected as follows. The non-inverting input of IC_{3a} (pin 3) is connected to preset P_1 via R_1 and K_5-K_6 (see also Fig. 2). However, pin 3 is also connected to the –ve terminal of K_4 via R_2.(after a jump lead has been placed between REF and –).

The inverting input of IC_{3a} (pin 2) is linked to the +ve terminal of K_4 via R_3 (this link is connected to the ⊥ of the ancillary supply circuit.

In this way, the inputs of IC_{3a} are supplied with the potential difference across the +ve and –ve terminals of K_4. The IC compares this potential with the set (P_1) reference voltage. Depending on the measured result, the output of IC_{3a} becomes higher or lower, and in this way the IC

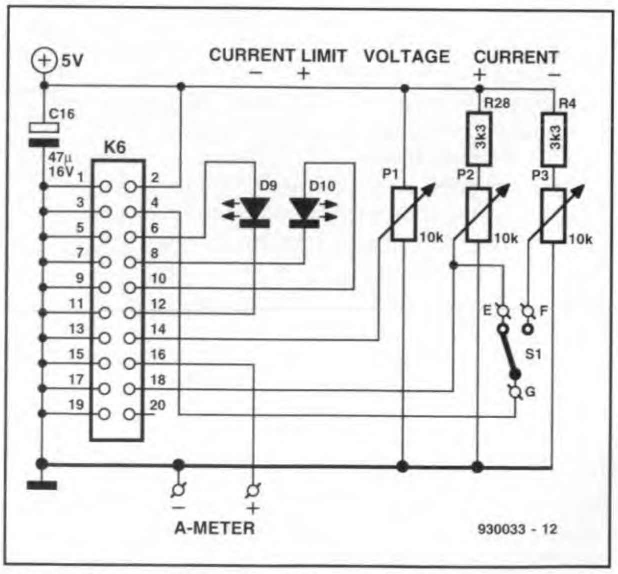


Fig. 1. The control and indicator circuits.

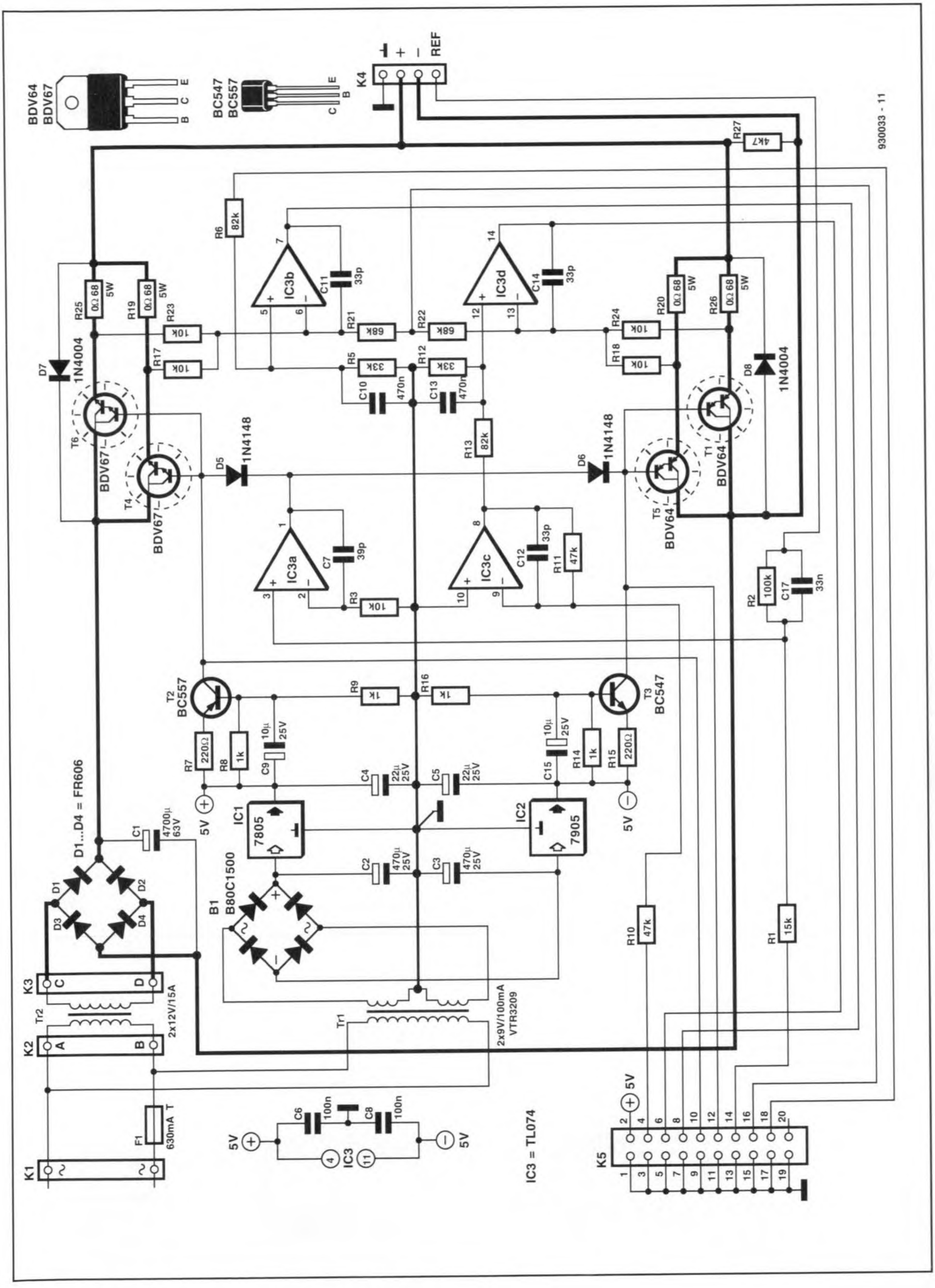


Fig. 2. Circuit diagram of the workbench power supply unit.

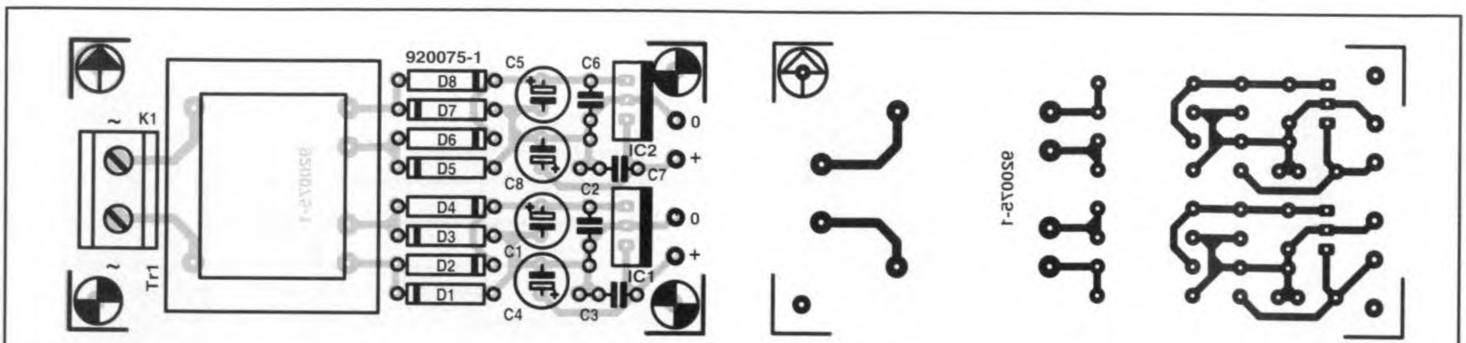


Fig. 3. Printed-circuit board for the auxiliary supply for the digital meter modules.

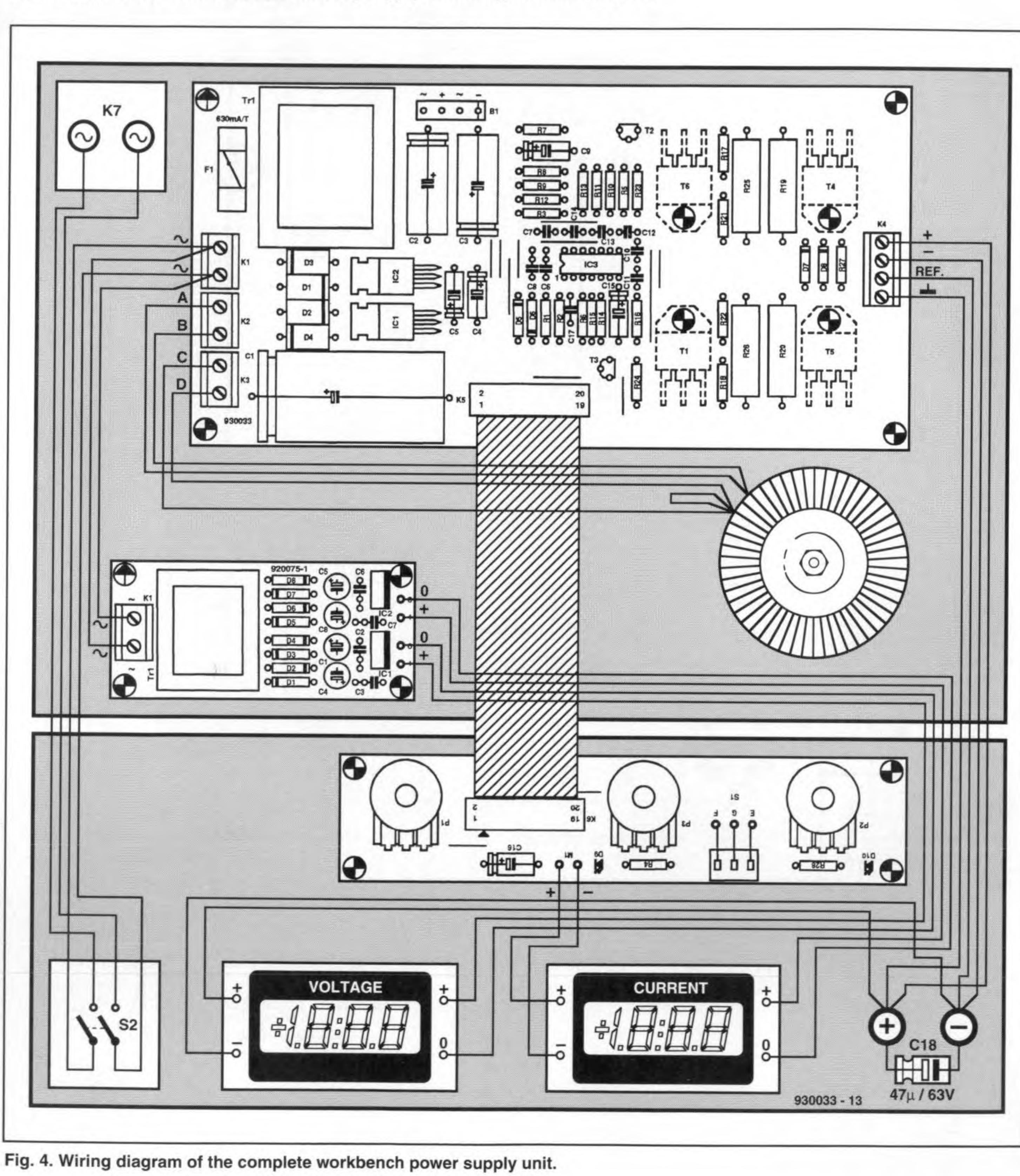


Fig. 4. Wiring diagram of the complete workbench power supply unit.

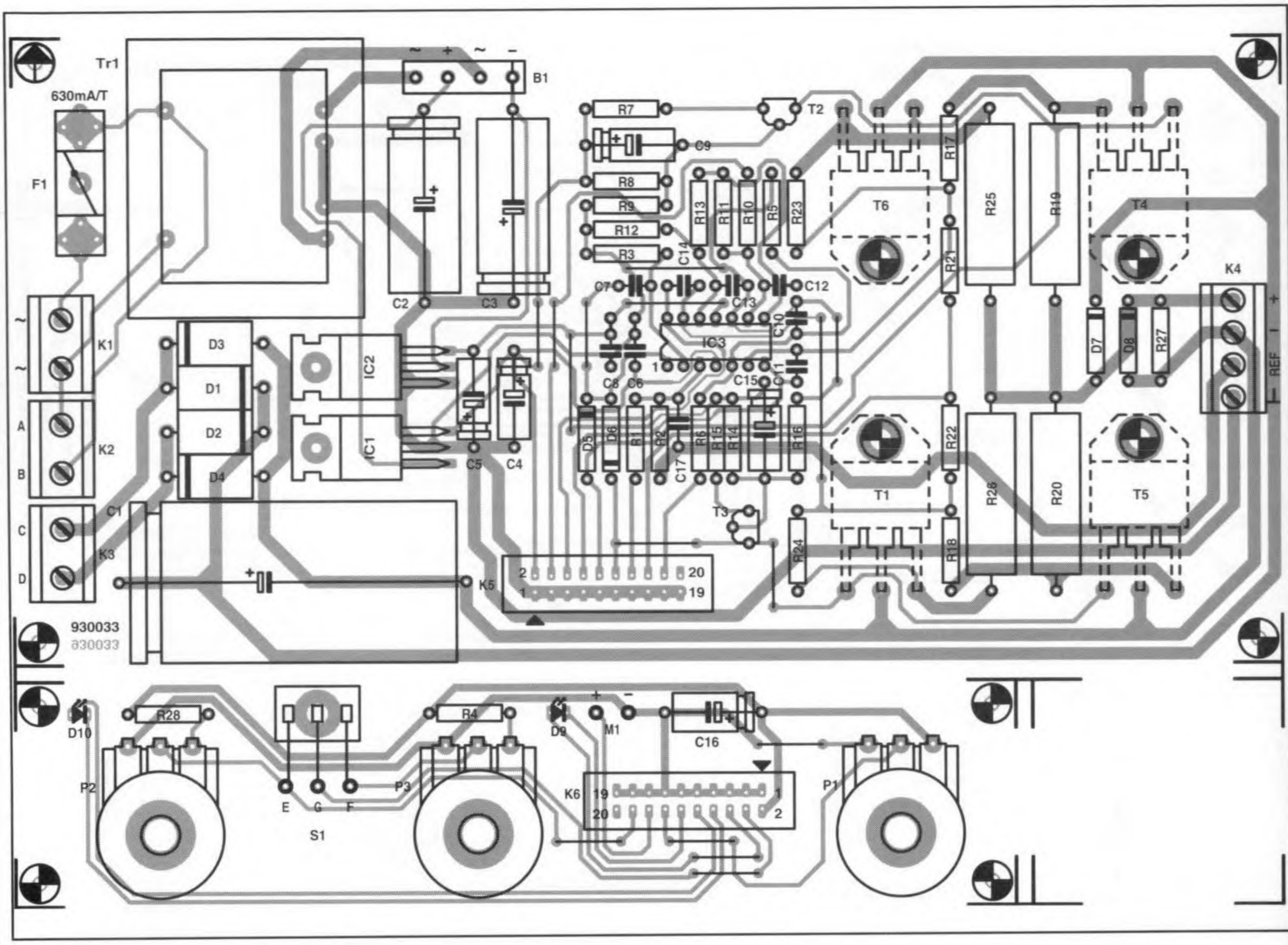


Fig. 5a. Printed-circuit board for the power supply unit – component layout.

PARTS LIST

Resistors:
R1 = 15 kΩ
R2 = 100 kΩ
R3, R17, R18, R23, R24 = 10 kΩ
R4, R28 = 3.3 kΩ
R5, R12 = 33 kΩ
R6, R13 = 82 kΩ
R7, R15 = 220 Ω
R8, R9, R14, R16 = 1 kΩ
R10, R11 = 47 kΩ
R19, R20, R25, R26 = 0.68 Ω, 5 W
R21, R22 = 68 kΩ
R27 = 4.7 kΩ
P1–P3 = 10 kΩ (multiturn)

Capacitors:
C1 = 4700 μF, 63 V
C2, C3 = 470 μF, 25 V
C4, C5 = 22 μF, 25 V
C6, C8 = 100 nF
C7 = 39 pF
C11, C12, C14 = 33 pF
C9, C15 = 10 μF, 25 V
C10, C13 = 470 nF
C16 = 47 μF, 16 V
C17 = 33 nF
C18 = 47 μF, 63 V

Semiconductors:
B1 = B80C1500
D1–D4 = FR606
D5, D6 = 1N4148
D7, D8 = 1N4004
D9, D10 = LED, 3 mm, red
T1, T5 = BDV64 (or TIP147)
T2 = BC557
T3 = BC547
T4, T6 = BDV67 (or TIP142)
IC1 = 7805
IC2 = 7905
IC3 = TL074

Miscellaneous:
K1–K3 = 2-way terminal block, 7.5 mm pitch
K4 = 4-way terminal block, 5 mm pitch
K5, K6 = 20-way box header
K7 = mains entry
S1 = single-pole change-over switch
S2 = double-pole mains switch
F1 = fuse holder with 630 mA slow-blow fuse for PCB mounting
Tr1 = mains transformer, 2×9 V, 100 mA secondary (Monacor VTR3209)
Tr2 = toroidal mains transformer, 2×15 V, 5 A secondary (Amplimo 41012)
Heat sink SK47/100 SA (Dau UK Ltd; 70–75 Barnham Road; Barnham PO22 0ES; Telephone 0243 553 031)
2 off flatcable socket, 20-way
Short length of 20-way flatcable
2 off DVM LCD module (Conrad 136026)
PCB Type 930033
Front panel foil Type 930033-F
Enclosure (Telet LC1050)

MODULE SUPPLY

Capacitors:
C1, C4, C5, C8 = 47 μF, 25 V, radial
C2, C3, C6, C7 = 100 nF, ceramic

Semiconductors:
D1–D8 = 1N4004
IC1, IC2 = 7809

Miscellaneous:
K1 = 2-way terminal block, 7.5 mm pitch
Tr1 = mains transformer, 2×9 V, 1.5 VA secondary (Monacor VTR1209)
PCB Type 920075

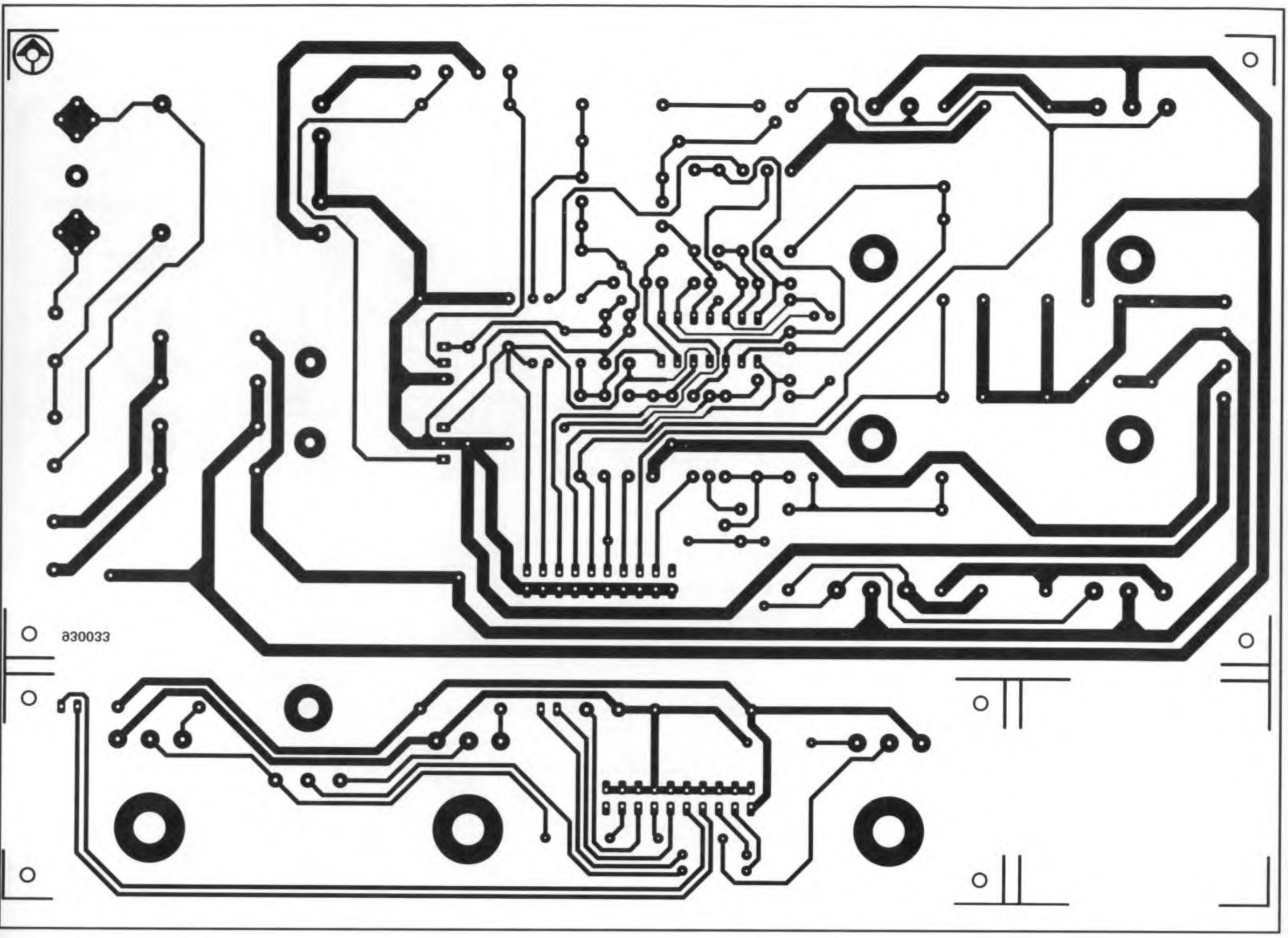


Fig. 5b. Printed-circuit board for the power supply unit – copper track layout.

controls the output voltage at K_4. With values of R_1 and R_2 as shown, the output voltage can be varied to about 33 V.

The current limiting operates roughly in the same manner, but here IC_{3b} carries out the controlling and measuring. Also, the inputs of this IC are not connected across the +ve and –ve terminals of K_4, but across a current-measuring resistance in series with the output. This resistance consists of emitter resistors R_{19} and R_{25}. Since the entire output current flows through these resistors, it is evaluated simply by measuring the voltage across the resistors and applying Ohm's law.

The measuring circuit for the current limiting is based on IC_{3b}. The inverting input of this opamp (pin 6) is linked to one side of R_{19} via R_{17} and to one side of R_{25} via R_{23}. The other input (pin 5) is connected to the current-limiting preset, P_2 (see Fig. 2). As soon as the potential across the emitter resistors rises above the level set with P_2 (corresponding to the peak current), IC_{3b} reduces, or completely cuts off, the base current to the output stage. That current is then diverted to the output of IC_{3b} via D_{10} (Fig. 2). Thus,

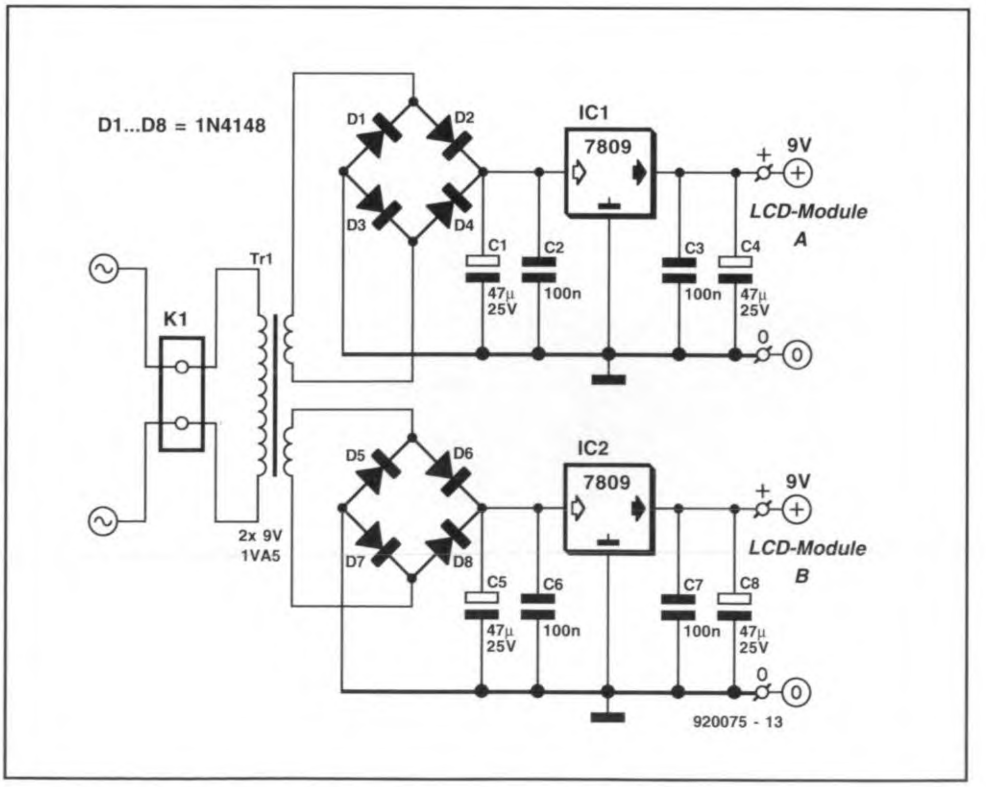


Fig. 6. Circuit diagram of the auxiliary supply for the digital meter modules.

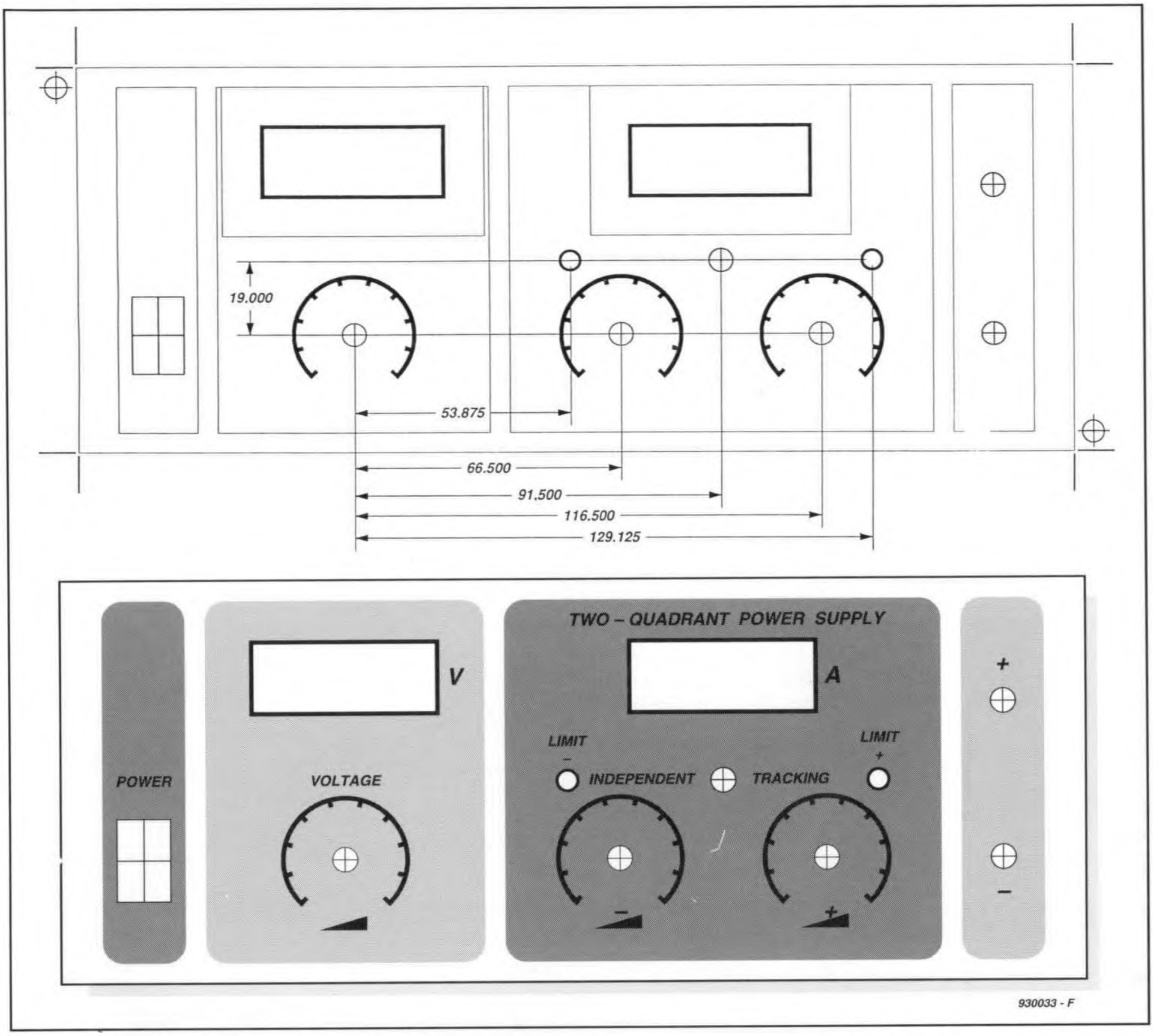


Fig. 7. Front panel design for the workbench power supply unit. Dimensions are shown in millimetres.

the lighting of this LED indicates that current limiting is in operation. With component values as shown, the maximum current that can be set with P_2 is 2.9 A.

The lower half of the diagram functions in virtually the same way as the upper half. Double darlington D_1-D_5 operates as a variable connection between the +ve and –ve terminals of K_4. The base current of this output stage is also controlled by IC_{3a}.

Constant maximum base current for the output stage is provided by T_3; opamp IC_{3d} cuts off the stage if the level of the current provided by the 'load' exceeds the set level. In this case, also, the base current of the output stage is diverted to a diode, D_9. The lighting of this LED thus indicates that the upper current level has been reached or exceeded. Since the current is an incoming, not an outgoing, one, inverter IC_{3c} is needed to provide IC_{3d} with the correct reference level.

From the foregoing description, it is clear that the diagram in Fig. 2 does not show the entire circuit: the remainder is given in Fig. 1. This part of the circuit is constructed on an ancillary printed-circuit board that is connected to the mother board by a short length of flatcable linking K_5 and K_6.

Figure 1 also contains switch S_1, which enables choosing between controlling the limits of both the outgoing and the incoming currents with one preset and controlling each of them separately

The complete wiring diagram is given in Fig. 3. This also shows the main transformer, connected to K_3, and a supply board, which is required if digital meter modules are used. The supplies to these mdules must be kept isolated from each other and from the remainder of the circuit. Diagrams of the circuit and associated PCB of the modules are given in Fig. 3 and Fig.5 respectively.

Figure 3 shows that the supply is a straightforward design, using a mains transformer with two separate secondary windings, rectifiers, smoothing capacitors and regulator ICs, that provides two isolated 9 V supply rails.

Construction

The mother board and ancillary board are shown in one piece in Fig. 6. The two parts must be separated before any work is done on them. The suggested front panel is shown in Fig. 7. The boards and front panel foil are available through our Readers' services—see page 70.

Due care must be taken in the construction of the power supplies and other mains (power line) carrying parts. Pay particuar attention to retaining safe distances between power carrying parts and the enclosure and the low-power circuits. Use heavy-duty, insulated circuit wire for the power carrying lines.

Mount power transistors, T_1, T_2, T_5, and T_6, as follows. Replace the rear panel of the enclosure by a heat sink as specified in the parts list. Drill four fixing holes for the transistors into the heat sink, using the board as template. Fit the transistors on to the heat sink with the aid of insulating washers and heat conducting paste. Bend the transistor terminals such that they fit neatly into the relevant holes in the board when this is laid on to the heat sink assembly. It is assumed here that the board has been completely populated. If all is well, fit the board on to the heat sink assembly using 10 mm (3/8 in) spacers. Then, with a slim soldering iron, solder the transistor terminals to the copper side of the board. Finally, fix the complete assembly to the enclosure.

When populating the ancillary board, note that the LEDs must be fitted to the copper side of the board.

The interwiring is shown clearly in Fig. 3.

If digital meter modules are used (built on the board in Fig. 5), note that a voltmeter is used to measure current, so that an additional resistor is required. If you lay the module in front of you on the table with its copper side up and the inputs at the right, there are some solder pads at the bottom left where a through connection must be made to enable a range to be selected. Make that connection at the second pad from the left (2 V range). Solder a 576 kΩ, ±1%, resistor between that connection and the –ve input. Then, remove the 1 kΩ resistor at the extreme right of the voltage divider. The module will then read input and output currents in A.

Voltage measurements can be taken with an unmodified module set to the 200 V range.

With reference to Fig. 3, note particularly that the through connections at K_4, as well as C_{18}, must be placed at the terminals behind the front panel, that is, C_{18} is fitted in parallel with the terminals.

Next, test the unit with open enclosure by checking whether all direct supply voltages are present.

Check that on K_4 the +ve terminal is connected to ground and the –ve terminal to REF.

Turn the voltage control and check that the voltmeter module shows a voltage.

Then, connect a suitable load to the output and check that the ammeter module reacts correctly.

Check whether the current limiting is actuated when the aappropriate preset is turned down.

If all these checks and tests are satisfactory, carry them out again with higher voltages and currents. Use a suitable rated load resistor.

If everything is still all right, check that the current-sink section operates correctly. For safety's sake, connect a resistor in series with one of the supply terminals: this will function as an emergency current limiter if something is disastrously wrong.

Connect a variable voltage source to K_4 and increase its output gradually.

Check that the current limiter circuit is actuated when the relevant preset is turned.

Then, remove the series resistor and check the correct action of the current limiting preset again.

If all is correct, the enclosure can be closed, whereupon the workbench power supply unit is ready for use. ■

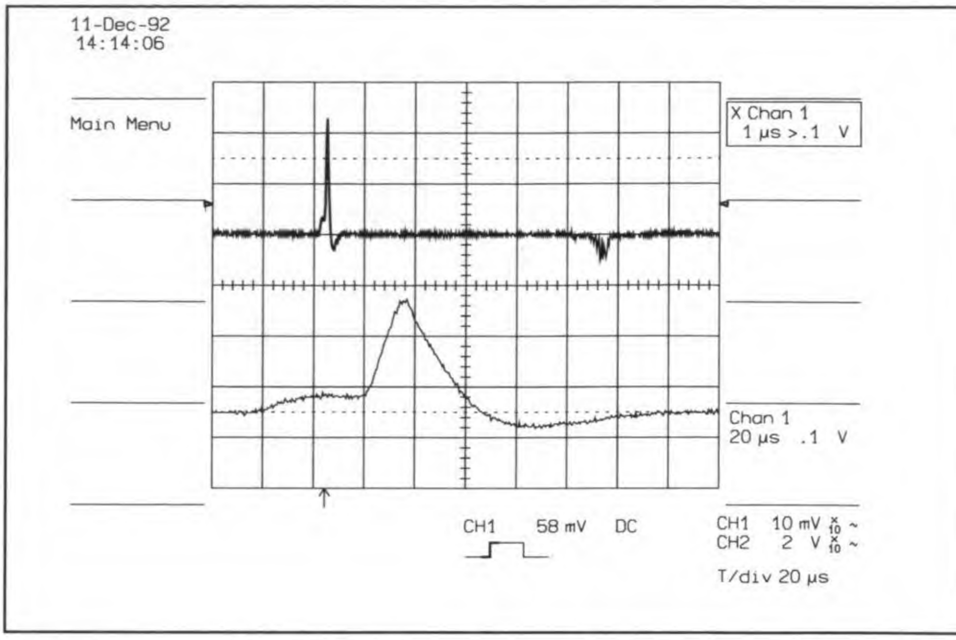
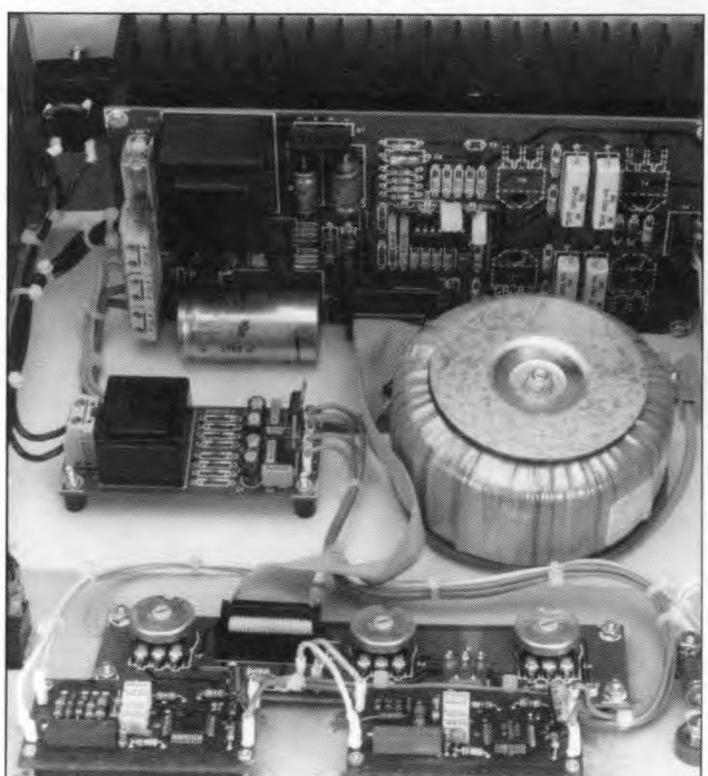
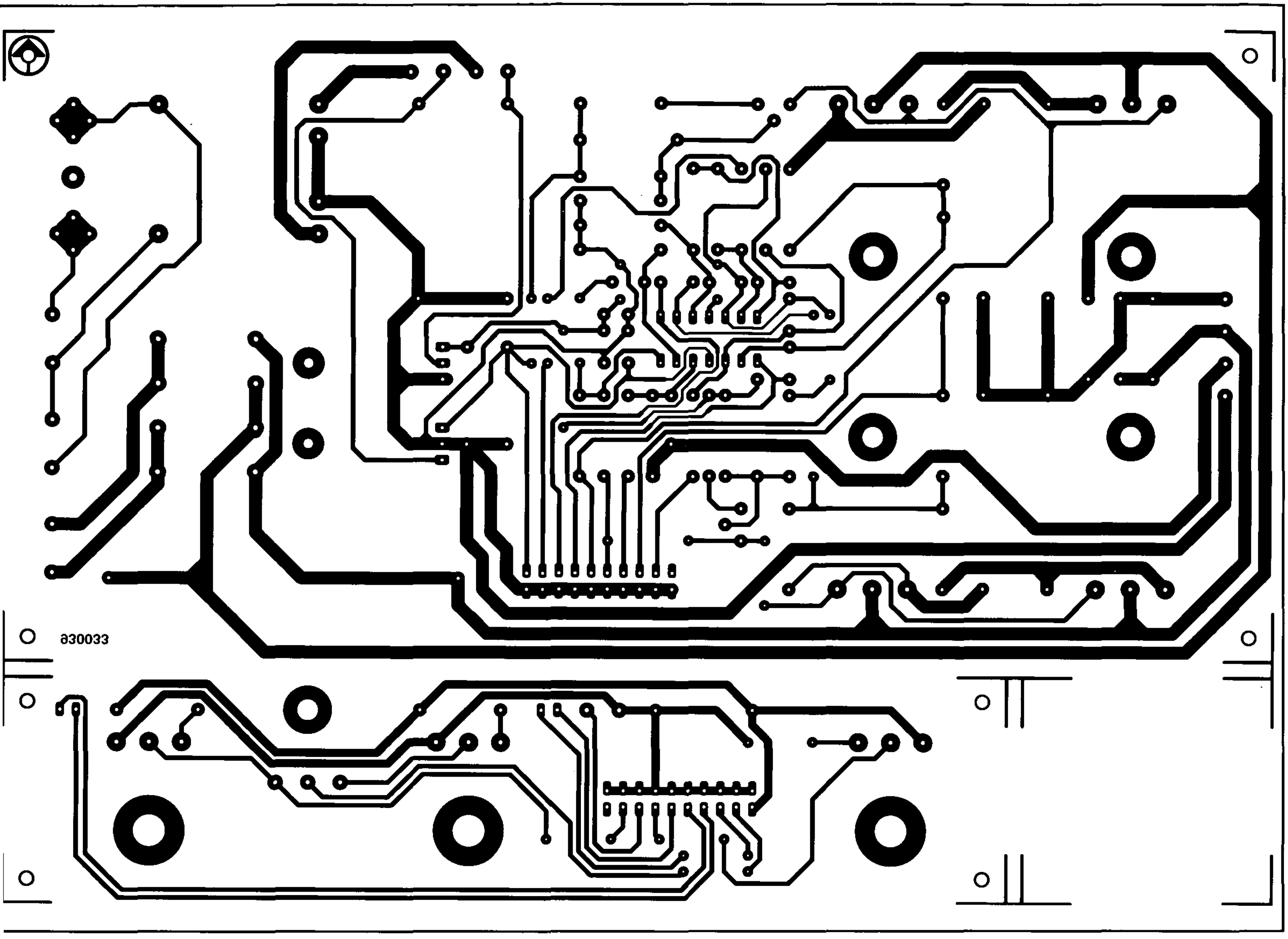


Fig. 8. The measured dynamic performance of the power supply unit. The output current was a square-wave at a level of 2 A. The peak in the upper curve shows the reaction to the switching off of the current, while the dip shows what happens at switch-on. The lower curve shows the peak magnified.

Brief Technical Data

Output voltage continuously variable between 0 V and 30 V
Peak output current 3 A
Peak sink current 3 A
Separately presettable current limiting for output and sink currents
Current limiting indication by LED
Switch for independent/tracking selection.

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CORRECTIONS AND UPDATES

Digital Audio/visual system (Multi-purpose Z80 card)

May and June 1992

An extensive description of a modification to the memory backup circuit on the Multi-purpose Z80 card is available free of charge through our Technical Queries service.

FM stereo signal generator

May 1993

Capacitors C17 and C19 should have a value of 33nF, not 3nF3 as indicated in the circuit diagram and the parts list of the multiplex generator.

Workbench PSU

May 1993

The polarity of capacitor C15 is incorrectly indicated on the PCB component overlay (Fig. 5a), and should be reversed. The circuit diagram (Fig. 2) is correct.

Transformer TR2 is incorrectly specified in the circuit diagram (Fig. 2) and in the parts list. The correct rating of the secondary is 2 × 12V/5A. Also note that the secondary windings are connected in series to give 24 V.

Audio DAC

September 1992

The polarity of capacitors C25 and C58 is incorrectly indicated on the component overlay of the D-A board (order code 920062-2), and should be reversed.

U2400B NiCd battery charger

February 1993

The value of resistors R17 through R27 should be 2.7kΩ, not 12.7kΩ as stated in the parts list.

VHF/UHF receiver

May 1993

In Fig. 4, the connections to ground of the AF amplifier outputs, pins 5 and 8, should be removed. The amplifier outputs are connected to the loudspeaker only. The relevant printed circuit board is all right.