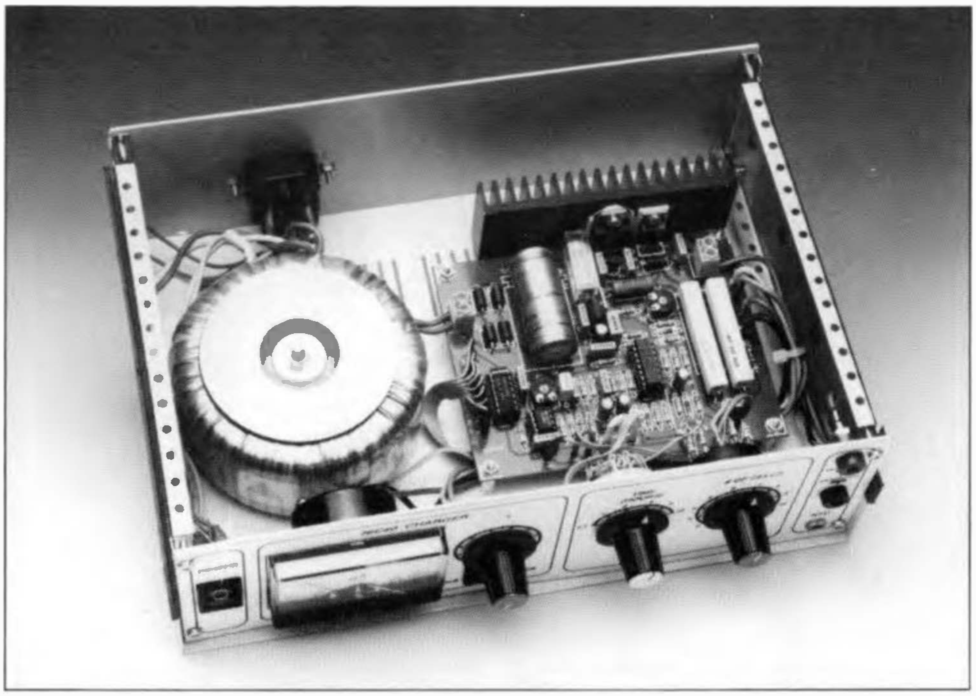
U2400B NiCd BATTERY CHARGER

Design by U. Bangert and W. Ernst



The battery charger takes its name from the IC it is based on: the well-known Type U2400B processor. This IC was designed primarily for use in battery chargers and is, therefore, equipped with a number of specific features.

The processor controls the charging for a preset time at constant current, provided, of course, that the battery was fully discharged before charging began. To make certain that this is always so, the operation always starts with discharging the battery entirely. To that end, pin 10 of the device—see Fig. 1—is made logic high. An internal stage connected to this pin causes the battery to be discharged until the voltage at pin 6 has dropped to 0.525 V. At that instant, pin 10, and immediately thereafter pin 12, goes low and charging can begin. The low level at pin 12 serves to actuate charging circuit T_2-T_3. After charging at full current has taken place for a predetermined time, trickle charging begins. Trickle charging, which may continue for a long period of time, ensures that the battery capacity does not degrade during the life of the battery. It is effected by the processor driving pin 12 low for 100 ms every 16.8 s, which means that effectively the average charging current is reduced to $^6/_{1000}$ of its peak value.

The initial discharge facility may be disabled by connecting pin 6 to earth. This will be reverted to later.

The charging time is predetermined by an external clock at pin 16 or by an internal clock. The internal timer allows three periods to be preset: 30 m; 1 h; and 12 h. Charging during the 30 m and 1 h periods takes place at full current. During the 12 h period, the charging current is pulsed in a similar manner as in trickle charging but the 100 ms pulses now occur every 1.2 s. Effectively, therefore, the battery is charged at $^1/_{12}$ of the full current.

The charging current may be altered with P_2. This preset varies the voltage across it, which changes the duty factor of an internal pulse-width modulator (PWM). This modulator, which drives the charging output, is clocked at a rate of 200 Hz. In this manner, the effective value of the charging current is made continuously variable.

To obviate any possible damage to the battery during fast charging, the processor has an internal failure circuit and two protection circuits: one against overheating of the battery and the other against overcharging the battery.

The battery temperature is monitored via an NTC (negative temperature coefficient) resistor, R_8, and pin 5. If the level at that pin drops below 0.525 V (equivalent to 40 °C), an error is registered. The NTC sensor must, of course, be in close contact wit the battery. Should R_8 itself, or its connections, become defect, the voltage at pin 5 will rise: when this exceeds 2.95 V, an error is signalled.

If the charging voltage per cell rises above 1.6 V, the potential at pin 4 will exceed 0.525 V, whereupon an error is signalled. The voltage of 0.525 V is obtained via a precise potential divider, R_{14}-R_{15}-R_{16}. The voltage across the

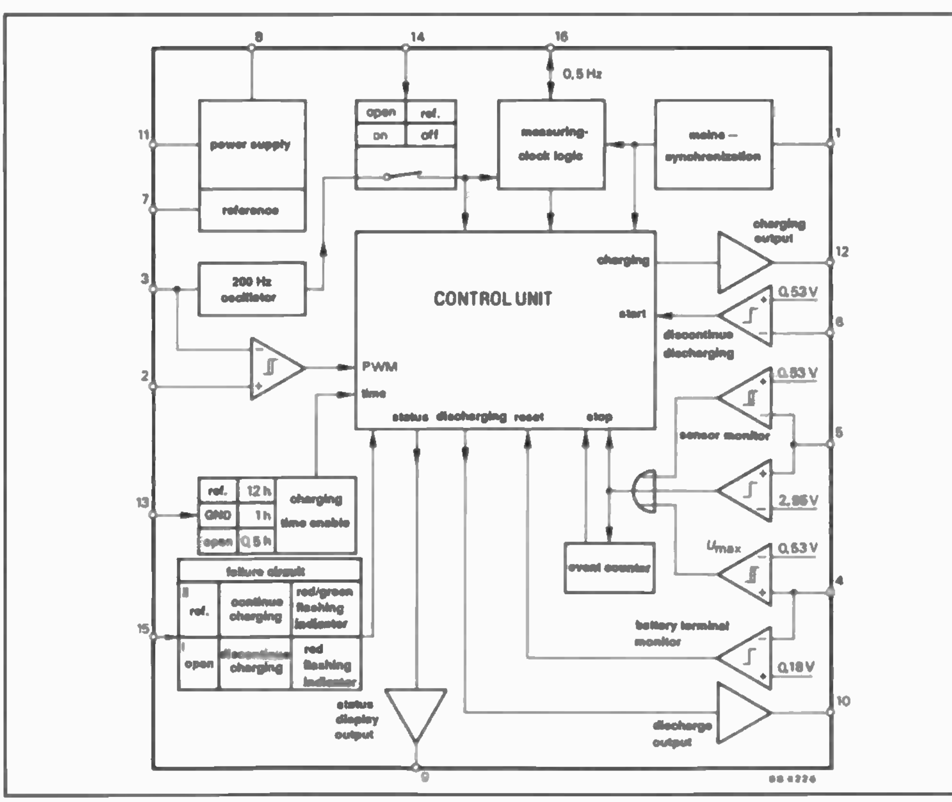


Fig. 1. Block diagram of Telefunken's Type U2400B battery charging processor.

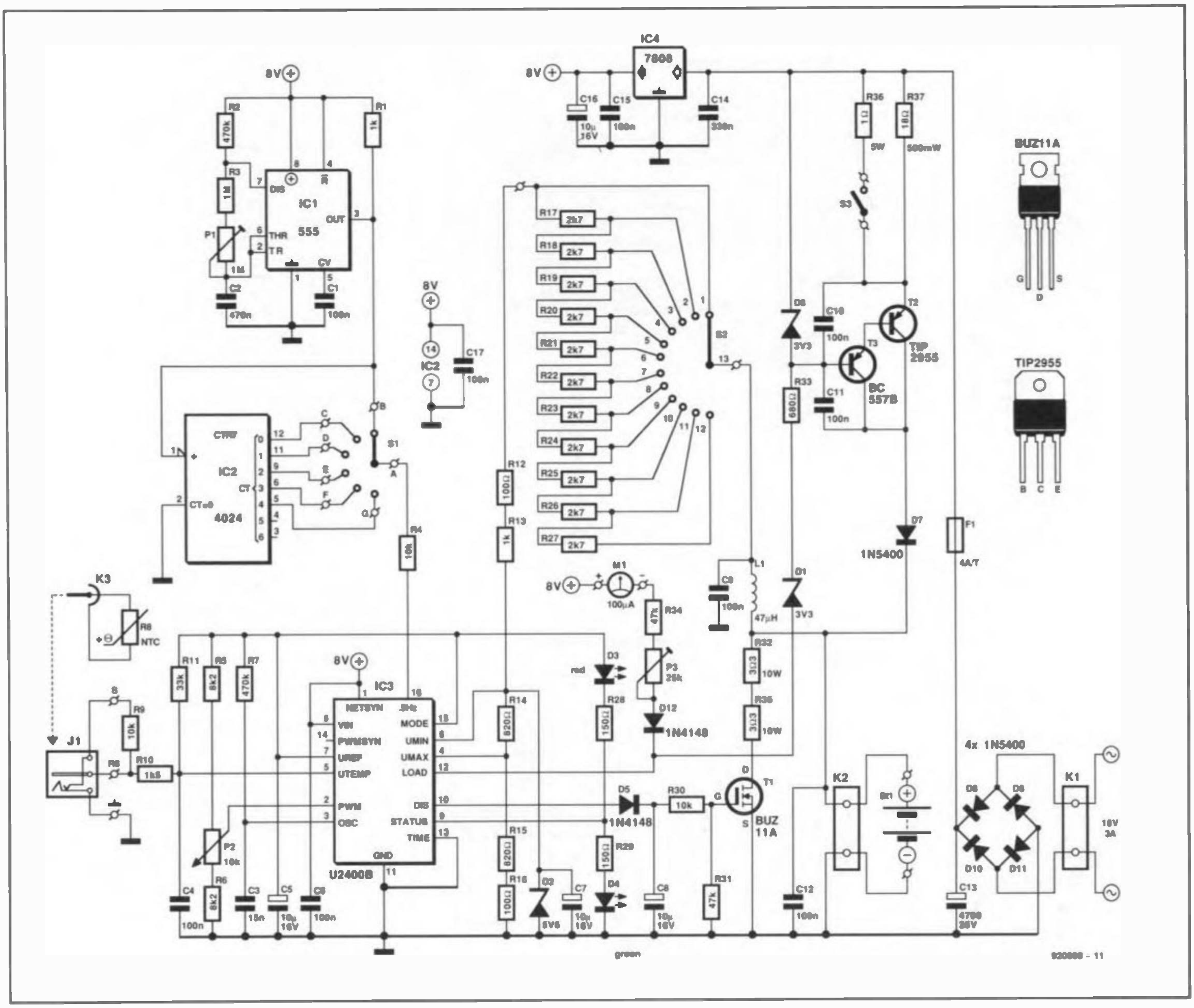


Fig. 2. Circuit diagram of the U2400B NiCd battery charger.

divider is held steady by zener diode D_2.

After an error has been signalled to the failure circuit, the processor stops the charging as long as the error persists. Once the error has been removed, charging is recommenced. If, however, a second error is registered, further action depends on the level at pin 15. If that pin is open, trickle-charging is substituted. In that case, D_3 (red) lights. If, however, the reference voltage (3 V, pin 7) is connected to pin 15, as in the present circuit, D_3 and D_4 flash alternately. When the error is removed, continued flashing indicates that the remainder of the charging can be undertaken.

When the supply voltage is switched on, the U2400B is enabled; if no battery is connected, the red LED will light. When a battery is then connected, the potential at pin 4 will be 200–525 mV, provided that the voltage per cell is not lower than 0.6 V. After about 2 s (during which time the LEDs do not light), the processor will become fully operational. What happens if the cell voltage is below 0.6 V will be discussed later.

During the discharge phase, the red LED flashes; when charging is in progress, the green LED flashes. When the battery is being trickle-charged, the green LED lights continuously.

Circuit description

The mains transformer for the power supply is not shown in Fig. 2. It provides a secondary voltage of 18 V at a load current of 3 A. After the secondary voltage has been rectified and filtered, it is lowered to 8 V by regulator IC_4, and used to drive control circuits IC_1–IC_3 and the ammeter. Since the secondary voltage may be as high as 30 V under no-load conditions, IC_4 is mounted on a small heat sink. Also, since the potential at pin 12 of IC_3 must not exceed 27 V, D_1 is inserted in the line to the charging circuit.

The charging circuit, based on T_2 and T_3, is a simple constant-current source. When the level at pin 12 of IC_3 is low, D_6 is on, resulting in a constant voltage at the base of T_3. Since the potential drop across the base-emitter junctions of Darlington pair T_2 and T_3 is a steady 1.5 V, the voltage across R_{36} and R_{37} is a constant 1.8 V. When S_3 is open, the current through the transistors, that is, the charging current, is thus 100 mA. When S_3 is closed, the emitter resistors are in parallel, so that the charging current is 2 A. Diode D_7 prevents the battery discharging when the charger is switched off. Since the dissipation of T_2 may be as high as 35 W (one cell and a charging current of 2 A), it is mounted on a suitable heat sink.

Since the discharge output is also controlled by the PWM, the positive pulses at pin 10 of IC_3 charge capaci-

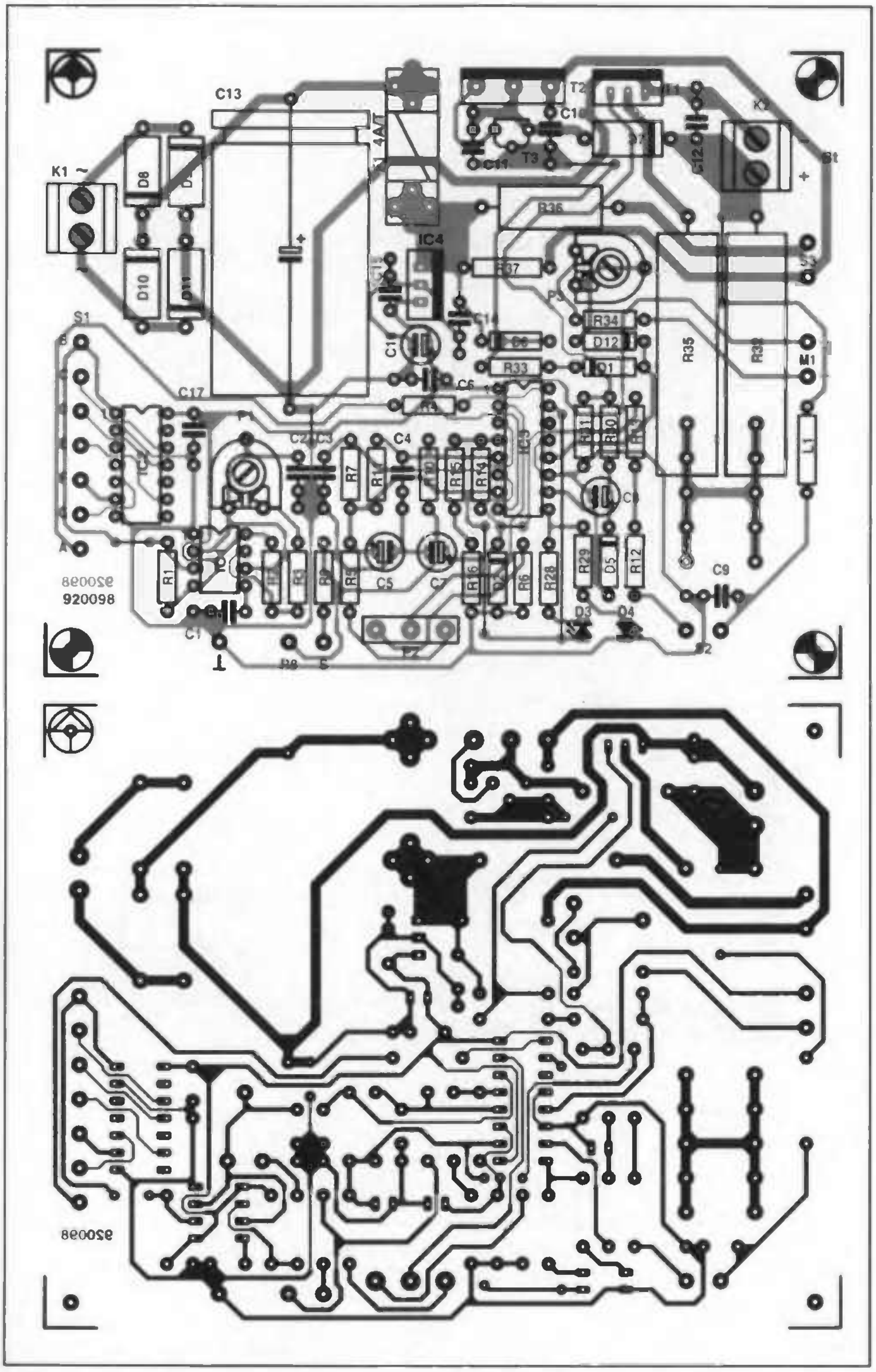


Fig. 3. Printed-circuit board for the U2400B NiCd battery charger.

PARTS LIST

Resistors:
R1, R13 = 1 kΩ
R2, R7 = 470 kΩ
R3 = 1 MΩ
R4, R9, R30 = 10 kΩ
R5, R6 = 8.2 kΩ
R8 = 10 kΩ, NTC
R10 = 1.5 kΩ
R11 = 33 kΩ
R12, R16 = 100 Ω
R14, R15 = 820 Ω
R17–R27 = 12.7 kΩ
R28, R29 = 150 Ω
R31, R34 = 47 kΩ
R32, R35 = 3.3 Ω, 9 W
R33 = 680 Ω
R36 = 1 Ω, 5 W
R37 = 18 Ω, 0.5 W
P1 = 1 MΩ preset
P2 = potentiometer, 10 kΩ, linear
P3 = 25 kΩ preset

Capacitors:
C1, C4, C6, C9–C12, C15, C17 = 100 nF
C2 = 470 nF
C3 15 nF
C5, C7, C8, C16 = 10 μF, 16 V, radial
C13 = 4700 μF, 25 V
C14 = 330 nF

Inductors:
L1 = 47 μH
Tr1 (not shown) = mains transformer, 18 V, 3 A secondary

Semiconductors:
D1, D6 = zener diode 3.3 V, 400 mW
D2 = zener diode 5.6 V, 400 mW
D3 = LED, 3mm, red
D4 = LED, 3 mm, green
D5, D12 = 1N4148
D7–D11 = 1N5400
T1 = BUZ11A
T2 = TIP2955
T3 = BC557B
IC1 = NE555
IC2 = 4024
IC3 = U2400B
IC4 = 7808

Miscellaneous:
F1 = fuse, 4 A, with holder for PCB
K1, K2 = 2-way terminal block, pitch 5 mm
M1 = moving coil meter, 100 μA
S1 = 1-pole, 6-position rotary switch
S2 = 1-pole, 12-position rotart switch
S3 = single-pole on-off switch
Heat sink Type SK81 (1.5 K W^{-1})
PCB Type 920098: see page 70.

tor C_8. The resulting voltage across this capacitor switches on T_1. This is always providing that a current of >0 A has been preset. Since T_1 is a power MOSFET, which has a very low on resistance, the discharge load is formed almost entirely by R_{32} and R_{35}. Although the discharge current depends on the battery voltage, IC_3 ensures that all types of battery are discharged correctly.

Twelve-way rotary switch S_2 ensures that the overvoltage monitoring is adapted to the number of cells contained in the battery. Zener diode D_2 protects pins 4 and 6 of IC_3 from too high a voltage if, for example, S_2 is set to the position for a single cell and a 12-cell battery is connected to the charging terminals. The potential at either of these pins must not exceed 6 V. This switch is a make-before-break type to minimize voltage surges during switching.

Rotary switch S_1 links the U2400B to the external clock, an astable multivibrator (AMV) based on the well-known Type NE555 timer IC. The clock rate is set to 1 Hz, that is, a period of 1 s, with P_1 (this is, by the way, the only calibration required). This switch is a break-before-make type to prevent short-circuiting of IC outputs. The outputs of scaler IC_2 provide six frequencies, corresponding to six diferent charging times—see Fig. 5.

The voltage set with P_2 controls the PWM and thus the charging current. The voltage range is extended by R_6 and R_9, so that at the two extreme settings of P_2 a narrow 'dead zone' exists. This ensures that the charging current can be set correctly between zero and maximum.

The NTC sensor is connected to the

charger via a switched jack socket, J_1. In this way, the resistor may be removed when a sealed battery is being charged. Since the sensor cannot come into close thermal contact with such a battery, temperature monitoring is impossible and it is, therefore, better removed. Resistor R_9 then simulates a 'cool' sensor, whereupon charging can commence.

The many 100 nF capacitors and inductor L_1 serve to decouple any incoming RF radiation and spurious voltage peaks on the mains supply.

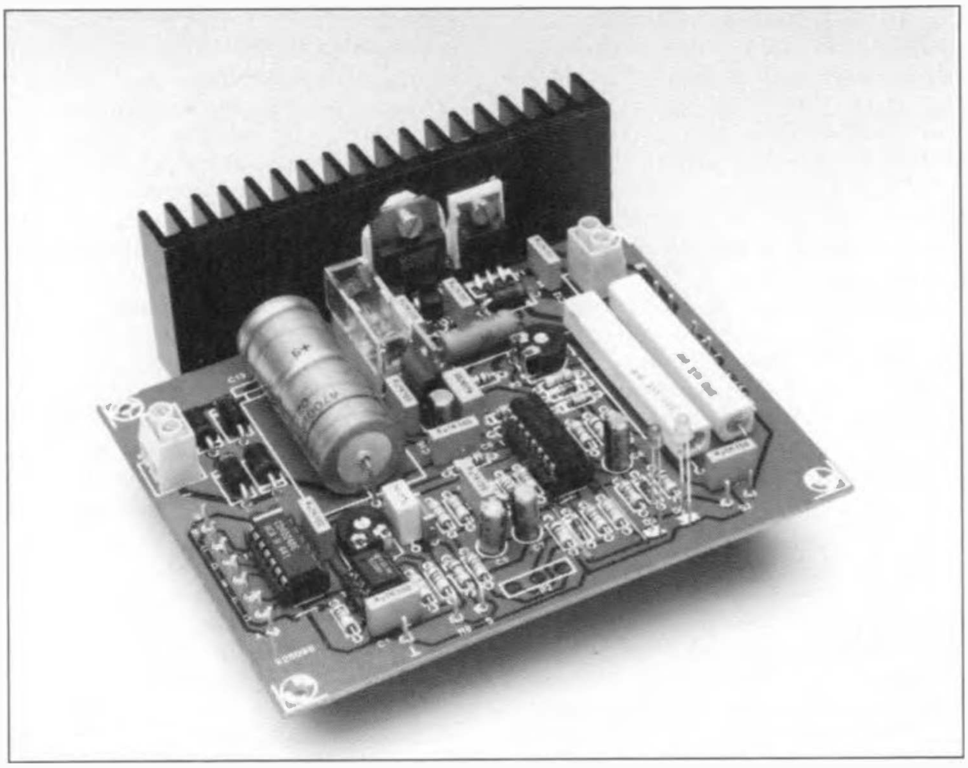


Fig. 4. The completed printed-circuit board showing the position of the heat sink.

Construction

The charger is best built on the PCB shown in Fig. 3. This board has been designed so that the operating controls, S_1–S_3 and the LEDs are mounted on one side and the power transistors on the other side. The power transistors must be fixed with the use of insulating washers and plenty of heat conducting paste. A heat sink rated at 1.5 K W^{-1} is then fitted behind the transistors (again with plenty of heat conducting paste)—see Fig. 4. It is also possible to fit the power transistor to the inside rear panel of the enclosure and the heat sink to the outside (again, use plenty of heat conducting paste and insulating washers and bushes). If the heat sink is fitted inside the enclosure, make sure that there is adequate ventilation (drill a number of small holes in the top panel or fit a small extractor fan).

Commence the populating of the board with fitting the wire links. Load resistors must be mounted at least 10 mm ($^7/_{16}$ in) above the board's surface. Resistors R_{17}–R_{27} must be soldered direct to the relevant terminals of S_2—see Fig. 2. Only two wires then link the switch to the board.

Preset P_1 is adjusted by using either an oscilloscope or a frequency counter between terminal B of S_1 and earth. In the first case, set P_1 to obtain a period of 1 s; in the second case, adjust it to obtain a frequency of 1.0 Hz.

If neither of these instruments is available, set P_1 to the centre of its travel and S_1 to position 30 min (B). Select the number of cells (S_2) and the required charging current (S_3 and P_2). Switch on the mains, whereupon the red LED should light (do not insert the NTC sensor). Connect a battery to the charging terminals, when after two seconds the red LED should begin to flash, indicating that discharging has commenced. Shortly thereafter, charging begins and the green LED starts flashing. Note the time during which the LED continues to flash. Any deviation from 30 min should be corrected with P_1. This method may require the calibration to be repeated several times before the length of the period is right.

The ammeter is calibrated simply by measuring the voltage across R_{37}, preferably with a standard analogue voltmeter, setting S_3 to position 100 mA, and adjusting P_2 for maximum current. When the voltage across R_{37} is 1.8 V, adjust P_3 for full-scale deflection (FSD) of the meter. This calibration should, of course, be carried out in the charging mode.

Hints and modifications

Before connecting a battery to the charger, make sure that the switches are set as required and that the red LED lights

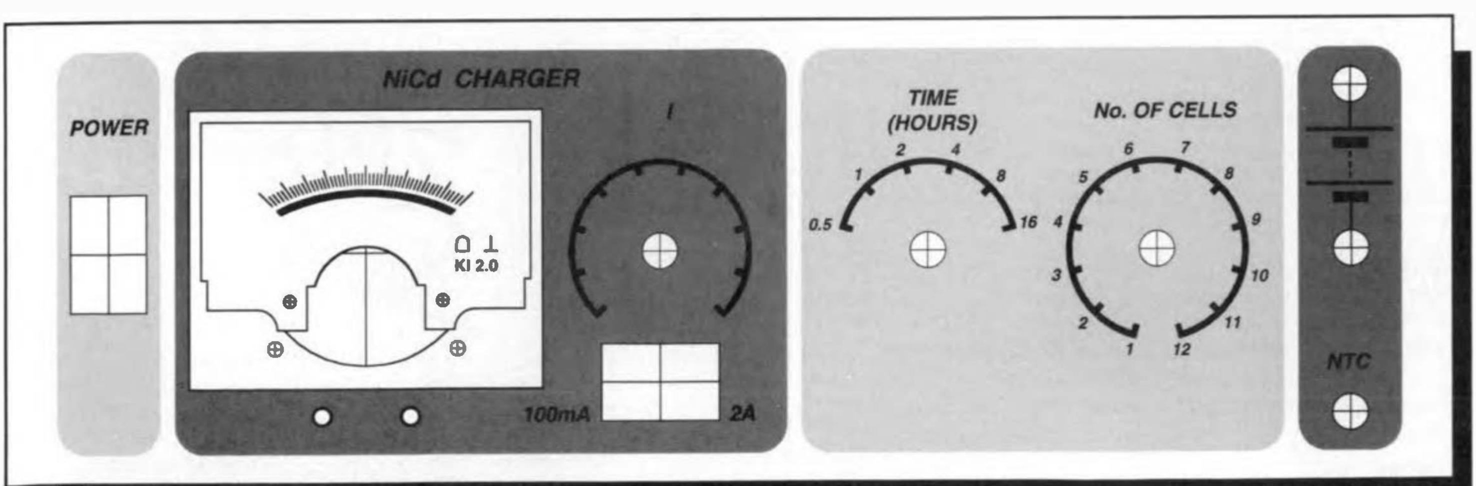


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Fig. 5. A front panel foil for the charger (here shown reduced to 75%) is available ready made – see page 70.

when the charger is switched on. If it does not, it may help to switch the mains off and then on again. These precautions are necessary in view of the fact that it happens once in a blue moon that undefined levels occur at the IC inputs when the switch is turned.

It is advisable to overcharge the battery by about 20% as a matter of course. That is, charge a 500 mAh battery as if it were a 600 mAh type. Divide this capacity by the desired charging time (in h) to arrive at the charging current to be set. Say, for example, that in the case of the 500 mAh battery the charging time should be 30 min. A quick calculation gives a charging current of 1.2 A. If fast charging is contemplated, make sure that the battery is designed to cope with it.

The charger is not able to register that a battery has been connected to the charging terminals when the voltage per cell has dropped below 0.6 V. Although such a battery can be given a quick (<1 m) boost by connecting it to a mains adaptor with current limiting, it is far better to use the additional circuit shown in Fig. 6 to cope with flat batteries. Spring-loaded switch S_4 connects a 10 kΩ resistor, R_{38}, between pins 4 and 7 of IC_3, thereby 'tricking' the circuit into starting charging. These additional components are best connected into the circuit at junction R_{14}-R_{15} and the +ve terminal of C_5. To prevent accidental operation of the switch, it is best to use a flush (set-in) type or to fit it at the rear panel.

It may also prove useful to connect a flush spring-loaded switch, S_5, across capacitor C_7 with which to end the discharge. When this switch is pressed, charging will commence.

If only small cells or batteries (up to no more than 600 mAh) are to be charged, it may be useful to restrict the peak charging current to 1.2 A. In that case, the rating of the heat sink may be reduced to 2.5 K W^{-1}, R_{36} to 1.8 Ω, 4 W, and the transformer secondary rating to 1.8 A. The scale of the meter must, of course, also be adapted.

If charging of 10-cell batteries only is foreseen, S_2 may be a 10-way switch, R_{26} and R_{27} are not required, and the secondary voltage of T_1 needs to be only 15 V. If only 6-cell batteries are to be charged, S_2 may be a six-way type, R_{22} to R_{27} may be omitted, and the secondary transformer voltage needs to be 10–12 V only. In both cases, smaller heat sinks will suffice. ■

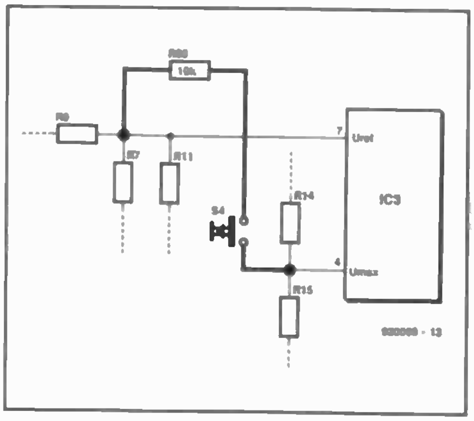

Fig. 6. If charging flat batteries is a frequent requirement, a simple switch and a 10 kΩ resistor are a worthwhile extra.