

Assembly Manual

Fast Universal Power Charger

by John Clarke

Cat No. **K 3217**

PROJECT INFORMATION SUPPLIED BY
SILICON CHIP - June/July 2001 Issue

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Please read: 'A Safety Guide to Mair Wiring & Handling' before assembling this kit.

DICK SMITH
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A.B.N. 34 000 908 716

K I T

Improved MkII version now charges Lithium-Ion and a huge range of Nicad, NiMH, SLA and lead-acid batteries.

Waiting for your power tool batteries to charge can be a drag, particularly when you wish to use the tool immediately. This Fast Battery Charger can have your tools operational in a short time.

It will charge your power tool batteries in less than 15 minutes for a 1.2Ah Nicad pack. It includes full battery protection and employs end-of-charge detection to ensure that the cells are not damaged. Along with Nickel Cadmium (Nicad) and Nickel Metal Hydride (NiMH) batteries, you can also charge Lithium-Ion batteries, 6V and 12V Sealed Lead Acid (SLA) packs and Lead-Acid car and motorcycle batteries.

This is an improved version of our very popular Multi-Purpose Fast Battery Charger which was first published in the February and March 1998 issues of SILICON CHIP.

While the original charger provided for a host of battery types and voltages, inevitably there were calls from readers who wanted to use it for other voltages and for Lithium-Ion batteries. The original design also had a tendency to prematurely terminate charging on older batteries.

Note that if you built the previous version, you can upgrade to the new design by transferring all the components to the new PC board and changing some of the wiring to the switches.

Charger features

For those not familiar with the previous design, we will now outline the features of this very flexible charger. It uses a Philips TEA11012 IC to perform all the control functions of the circuit. It monitors charging current, battery or cell voltage and battery temperature (optional) and incorporates a timer to shut down charging if other methods of charge detection fail.

It is important when fast charging batteries that they are not over-charged. Both Nicad and NiMH types, if given too much charge, will overheat and be permanently damaged. LiION, SLA and Lead-Acid types should not be charged

beyond a certain voltage or they too will be damaged and their life reduced. Nor should SLA and Lead-Acid batteries be undercharged since this will also lead to a shortened life.

Nicad batteries should also be discharged before recharging in order to consistently provide their maximum capacity.

Our new Fast Battery Charger provides accurate detection of full charge for Nicad and NiMH batteries and precise end-point voltage regulation for LiION, SLA and Lead-Acid types. It also has various protection features to prevent fast charge when the battery temperature is too high or low for Nicad and NiMH types and if the battery voltage is initial-



ly low for all battery types.

An added feature of the charger is the Refresh cycle which is used for Nicad batteries. This discharges the battery so that each cell reaches a nominal 1V before the charger begins to fast charge. Nicad & NiMH batteries are then fully charged and this is detected when the voltage begins to drop off from a maximum value.

If a thermistor is connected to monitor temperature of the battery pack, then the charger detects full charge when the temperature begins to rise at a rapid rate.

Once charged with high current (fast charge), Nicad & NiMH batteries are topped up with a 200mA current for about 90 minutes and then trickle-charged at 62mA to maintain their capacity before use. This trickle charge comprises short bursts of current which average to 62mA. These bursts of current prevent dendritic growth within NiMH and Nicad cells.

LiION, SLA and Lead-Acid batteries are initially fast charged and this current tapers off as the battery voltage approaches 4.1V for LiION and 2.4V per cell for SLA and Lead-Acid types. Charging stops at these voltages.

For 12V SLA and Lead-Acid batteries, this end point corresponds to 14.4V. Charging automatically starts again when the cell voltage falls to 2.2V for SLA and Lead-Acid types and to 3V for LiION.

Timer & LED indicators

The charger incorporates a timer which stops fast charge after a set period (called time-out). This prevents overcharging should the end of charge detection methods fail. Normally, time-out is about 1.6 times the expected charge time of the battery, as determined by the capacity and charge current.

When charging Lead-Acid batteries, the timer is reset at regular intervals to prevent time-out. This is because Lead-Acid batteries have a large capacity and

require a much longer time to charge than the timer can accommodate.

Various indicating LEDs show the status of the Fast Charger: Refresh, Fast, Protect, 100% and No Battery.

The REFRESH LED indicates when a Nicad battery is being discharged. The discharge function is initiated by pushing the adjacent Refresh pushbutton. Refresh is only available when the charger is set to charge Nicad or NiMH batteries although it is not necessary to refresh NiMH batteries since they do not exhibit memory effect.

The FAST LED shows that the charger is delivering a maximum of 6A to the battery under charge. After the battery is charged, the 100% LED is turned on.

While this LED is on, the Charger is in "Topoff" mode which delivers a slow charge at 0.15 of the full fast current. After Topoff, the LEDs are all off and the charger is in trickle mode for Nicad & NiMH batteries but there is no further charge current for LiION, SLA and Lead-Acid types.

The PROTECT LED shows when a battery is shorted or has low voltage after a certain period of charging. It also lights with over or under-temperature if the thermistor in a battery pack is connected.

The NO BATTERY LED only lights when Nicad & NiMH battery types are selected and if the thermistor is not connected to the charger. It simply indicates that the battery is either not connected or has a high impedance.

When using the battery charger it is important to select the correct setting on the front panel for the particular battery under charge. You will need to select the battery type (Nicad, NiMH, LiION, SLA or Lead-Acid) and the battery voltage. Also the timer must be set to give a suitable safety time-out for the capacity of battery connected.

Battery management IC

As noted above, all of the charging features are provided by a single battery

management IC, the TEA1102 from Philips Components. Its block diagram is shown in Fig.1.

It comprises analog and digital circuits which are divided into six separate subsections, as shown on the block diagram. The charge control and output driver section comprises a current source, battery selection, oscillator, comparators, amplifiers and a pulse width modulation (PWM) and analog control output.

Battery voltage is monitored at the Vbat input (pin 19) and this is compared against the Vreg voltage which sets the end-point voltage for charging the selected battery type. Options are for Nicad & NiMH, LiION and SLA.

Note that there is a different Vreg selection for each type of battery but these do not refer to the voltage to which each cell is charged. The V/Vstb (Vstb means Voltage at standby) for Nicad & NiMH batteries refers to an option of either voltage regulation at end of charge or trickle charge. The no-battery selection automatically switches in when the Vbat voltage is above 1.9V.

The comparator monitoring Vbat and Vreg controls the constant current source transistor which is supplied with one of four currents: fast charge, top-off, standby and load. When power is first applied, the TEA1102 is reset and fast charge is selected. Fast charge is set by a resistor at Rref (pin 20) to select the current flow to the IB output at pin 2.

The current from the IB output pin flows through an external resistor to develop a voltage monitored by the two internal op amps, A1 and A4. A1's output is amplified by A3 to give an analog control output at pin 18. A1's output is also compared in A2 against a triangle waveform generated by the oscillator at pin 14. A2's output is applied via a flipflop to provide a pulse width modulated (PWM) output to drive external circuitry to control the charge current.

Refresh (Nicad discharge) is initiated by momentarily connecting the RFSH

Main Features

- Fast charges Nicad, NiMH, LiION, SLA and Lead-Acid batteries
- Suitable for 1.2V, 2.4V, 3.6V, 4.8V, 6V, 7.2V, 8.4V, 9.6V, 12V & 14.4V batteries from 1.2Ah to 4.2Ah plus LiION, 3.6V, 7.2V & 14.4V
- Charges either 6V or 12V SLA batteries from 1.2Ah to 4Ah
- Charges 6V or 12V Lead-Acid batteries of any capacity above 1.2Ah
- Includes a discharger for Nicad batteries
- Top-off charging at end of fast charge plus pulsed trickle charge for Nicad & NiMH
- Voltage limited charge for SLA & Lead-Acid batteries
- Voltage drop & temperature rise (dT/dt) full charge detection for Nicad & NiMH
- Under and over-temperature cutout for battery
- Over temperature cutout for charger
- Short circuit battery protection
- Time-out protection
- Fuse protection
- Multi-LED charge indicators

Specifications

- Fast Charge Currentnominally 6A
- Top-off current (Nicad & NiMH)200mA
- Trickle current (Nicad & NiMH)62mA
- Refresh current (Nicad)2A
- Refresh discharge end-point1V per cell
- Battery-low detect (Nicad & NiMH)0.3V per cell
- Battery-low detect (LiION)0.9V per cell
- Battery-low detect (SLA & Lead-Acid)0.45V per cell
- Battery-high detect (Nicad & NiMH)2V per cell
- Battery-high detect (LiION).....6V per cell
- Battery-high detect (SLA & Lead-Acid)2.97V per cell
- Charge voltage end-point (SLA & Lead-Acid)2.4V per cell
- Charge voltage end-point (LiION)4.1V per cell
- Recharge voltage after end-point (SLA & Lead-Acid)2.2V per cell
- Recharge voltage after end-point (LiION)3V per cell
- Voltage peak detection (Nicad & NiMH)0.25% drop in top value
- Temperature rate detection level (Nicad & NiMH)0.25%
- Under-temperature cutout (Nicad & NiMH)12° C
- Over-temperature cutout (Nicad & NiMH)50° C
- Charge over-temperature cutout80° C
- Fast-charge time-out15, 30 or 60 minutes (nominal)
- Top-off charge time (Nicad & NiMH)about 90 minutes

voltage begins to fall, the lower voltage is not stored but compared with the analog voltage resulting from the digital stored value. A fall of 0.25% indicates that the battery is charged and the charger will then switch to trickle mode.

The DA/AD converter also monitors the thermistor voltage via the NTC input at pin 8. If the thermistor is connected, the DA/AD converter switches off fast charge when there is a sudden rise in temperature of the battery which also indicates full charge. Note that the fast charge will be switched off if a low or high temperature is detected by the Tmin and Tmax comparators.

By the way, NTC stands for the Negative Temperature Coefficient of the thermistors fitted into Nicad and NiMH battery packs. As the temperature rises, the resistance of the thermistor drops (ie, negative coefficient) and this is monitored by the circuit.

The "NTC present" comparator detects the connection of the thermistor, while the T-cut-off comparator switches on for a 0.25% rate of rise in temperature. The MTV input (pin 9) can be used to calibrate the thermistor temperature at Tmax.

The Control Logic section monitors and sets the operation of the various blocks within the IC. Voltage on the FCT

output (pin 10) to ground. This turns off the current source and op amp A4 drives an external transistor connecting across the battery. The current is set by a series current detecting resistor and the 100mV source at the non-inverting input to A4.

The DA/AD converter monitors bat-

tery voltage when charging Nicad & NiMH batteries. As the battery is charging, the voltage gradually increases and at a regular period, the AD converter samples the voltage and stores it as a digital value if the voltage has increased from the previous reading. When the

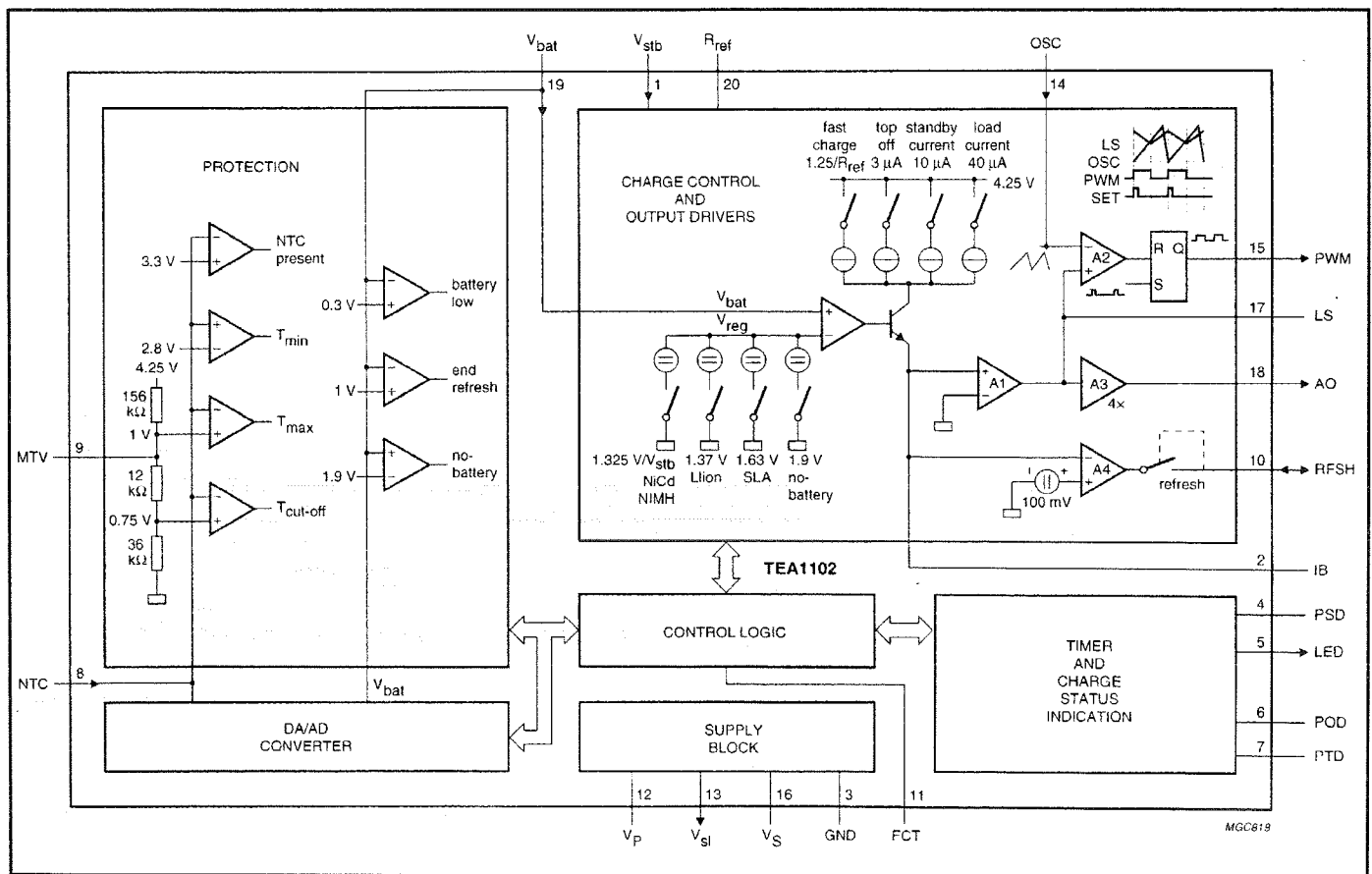


Fig.1: inside the Philips TEA1102 battery management IC. This versatile chip forms the heart of our fast charger.

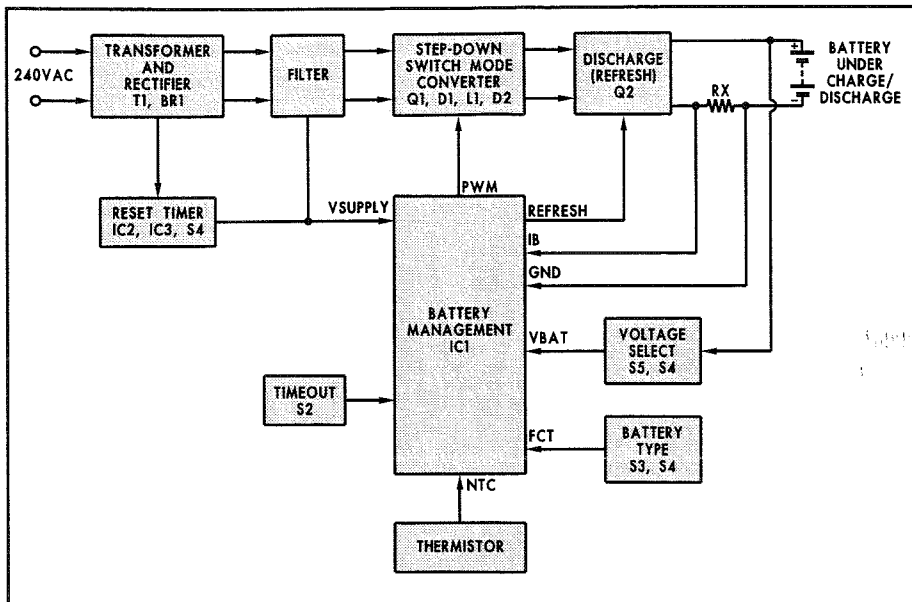


Fig.2: the various functional elements of the charger are shown in this block diagram. Full operation is explained in the text.

input (pin 11) selects the type of battery to be charged. The Supply Block takes its supply at the Vp pin and produces a reference voltage at the Vs output (pin 16). This reference provides an accurate and stable source for the battery end-point voltages. The Vsl output is used to switch on power to external indicating LEDs. These LEDs are driven by pins which serve a dual purpose and are seen in the Timer and Charge Status Indication block.

Pins 4, 6 and 7 are used both as programming pins for the timers and as LED drivers. These pins are initially monitored at power on to check what options are set before the LEDs are lit.

Block diagram

Fig.2 shows how we have used the TEA1102 battery management IC in our charger circuit. Transformer T1 and bridge rectifier BR1 provide an 18V DC supply for the charger circuit. This is lightly filtered to provide DC for the control circuitry but is fed through directly (ie, essentially unfiltered) to the switch-mode step-down converter comprising transistor Q1, inductor L1 and diodes D1 and D2.

In effect, the battery under charge is fed with chopped and unfiltered DC. This allows a considerable saving on electrolytic filter capacitors and reduces power losses in the main series pass transistor, Q1.

Circuit description

Fig.3 shows the full circuit for the Multipurpose Fast Battery Charger.

Power for the circuit comes from T1,

an 18V 6A transformer which feeds the bridge rectifier BR1 and two 10 μ F 100VW polyester capacitors. These supply the peak current to the switchmode supply comprising transistor Q1, diode D1 and inductor L1.

The Pulse Width Modulation output at pin 15 of IC1 drives transistor Q3 which operates as a pulsed "current sink" to provide 34mA base current to Q1. Q1 switches current through inductor L1 and diode D2 into the battery load. When Q1 switches off, diode D1 enables the energy stored in the inductor to flow into the battery. Diode D2 prevents battery current from flowing back into the switch-mode circuit.

The 100 μ F capacitor across the battery is there to filter the supply when no battery is connected so that the "no battery" detection will operate within IC1.

The charge current is monitored by the .05 Ω resistance (two 0.1 Ω 5W resistors in parallel) connected in the ground return path to the emitter of Q2. IC1 monitors this via the IB input at pin 2 which is tied to the same "ground" via a 3.3k Ω resistor.

Its operation is as follows: the Rref output at pin 20 is 1.25V and this is applied to the external 27k Ω resistor to set the current flow from the IB output (pin 2). The PWM output from pin 15 of IC1 controls the charge current into the battery so that the drop across the .05 Ω resistance equals the voltage across the IB resistor to ground. The 0.18 μ F capacitor at the LS output (pin 17) filters the current feedback waveform.

The Rref resistance at pin 20 also sets the oscillator frequency in conjunction

with the 820pF capacitor at pin 14. The frequency of oscillation is about 50kHz. The time-out period is determined by the oscillator frequency and the switch setting at pin 7.

When pin 7 is pulled low via the 33k Ω resistor at switch S2, the timeout is about 15 minutes. An open setting of S2 increases the timeout by a factor of two and when S2 pulls pin 7 high, the timeout is increased by a further factor two. These last two settings give the 30-minute and 60-minute settings.

Battery selection

Detection of battery type is done with using the (Fast Charge Termination) input at pin 11. When pin 11 is grounded via switches S4a and S3a, the SLA battery charge procedure is selected. When S4a is in positions 2 & 3, it ensures that pin 11 is grounded, regardless of the position of S3a.

This prevents Lead-Acid batteries being charged as Nicad or NiMH types which would result in over-charging.

LiION charging occurs when the FCT pin is at about 1.2V, as set by the 30k Ω and 12k Ω resistors. Similarly, Nicad and NiMH battery types are selected when pin 11 is connected via S3 to the 4.25V reference at pin 16.

The Vstb (pin 1) input selects trickle charging after Nicad or NiMH batteries are charged rather than the voltage regulation option when pin 1 is open circuit.

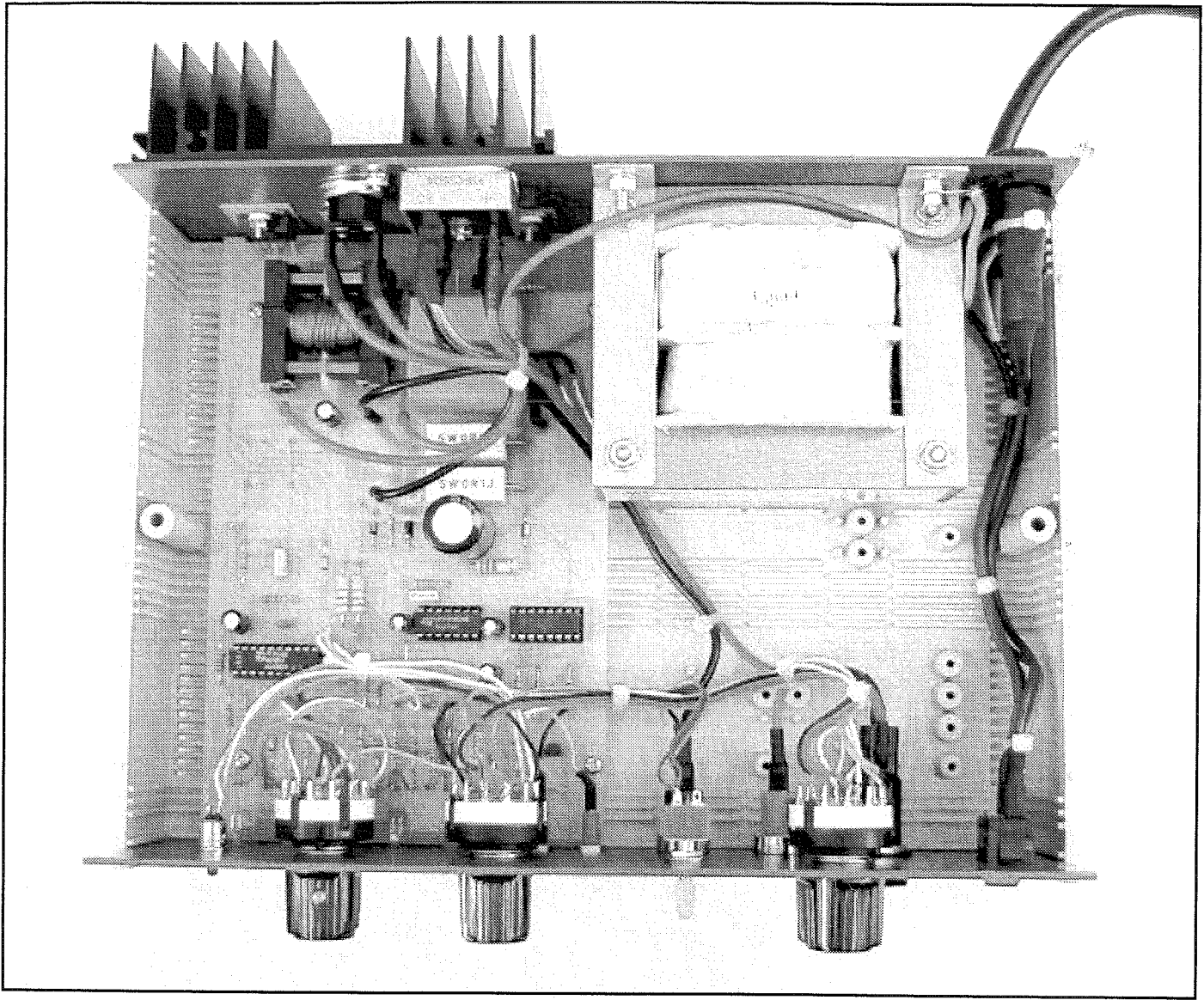
Voltage selection

The Vbat input, pin 19, monitors the battery voltage via a filter network consisting of a 10k Ω resistor and 100 μ F capacitor, and via a resistive divider network switched by S5 and S3b.

For Nicad, NiMH and LiION batteries, the division ratio is such that pin 19 sees only the single cell voltage. For example, with the 6V (5-cell) setting we divide the battery voltage by five to produce the equivalent single-cell voltage. The single cell setting at position 1 of S5 thus provides no resistive division of the voltage.

The voltage divider for SLA and Lead-Acid batteries is selected when S3b is in position 3 or 4. The division ratio for 6V and 12V takes into account that the regulation voltage for SLA types is 1.63V at the Vbat input. For example, with a 12V battery, we want to charge it up to 14.4V or 2.4V per cell, so the division must be 14.4/1.63 or 8.83.

Pin 8, the NTC input, detects if there is a thermistor in the battery pack. The 1M Ω resistor and VR1 at pin 8 pull the



With the exception of the power transformer, bridge rectifier, thermistor and the front panel controls, just about everything else mounts on a single PC board.

voltage up to 4.25V if no thermistor is present and to about 2V if one is connected, at normal room temperature.

The thermistor is heated by the cells under charge and any sudden rise in temperature will produce a voltage drop at the NTC input. The charger will sense this as full charge and cease charging. If a sudden change is not detected before the thermistor voltage reaches 1V, the fast charge will cease because of over temperature.

LED indication is provided on the LED, POD, PTD and PSD pins and controlled via the Vsl output. At power up, all LEDs are off and the IC looks at the POD, PTD and PSD pins to check the division ratio programming set on these pins. After this, the LEDs can be lit when Vsl goes high to turn on transistor Q4 via the 680Ω resistor.

Refresh cycle

Transistor Q2 turns on to discharge

Nicad batteries when the pin 10 output of IC1 is momentarily shorted to ground via S6. Note that the switch-mode circuit is disconnected while Q2 is turned on.

In other words, the discharge current is continuous, not pulsed. Current flow through Q2 and the battery is also via the .05Ω resistance and is detected at the IB input at pin 2. This discharge current is regulated to $100\text{mV}/.05\Omega$ or 2A.

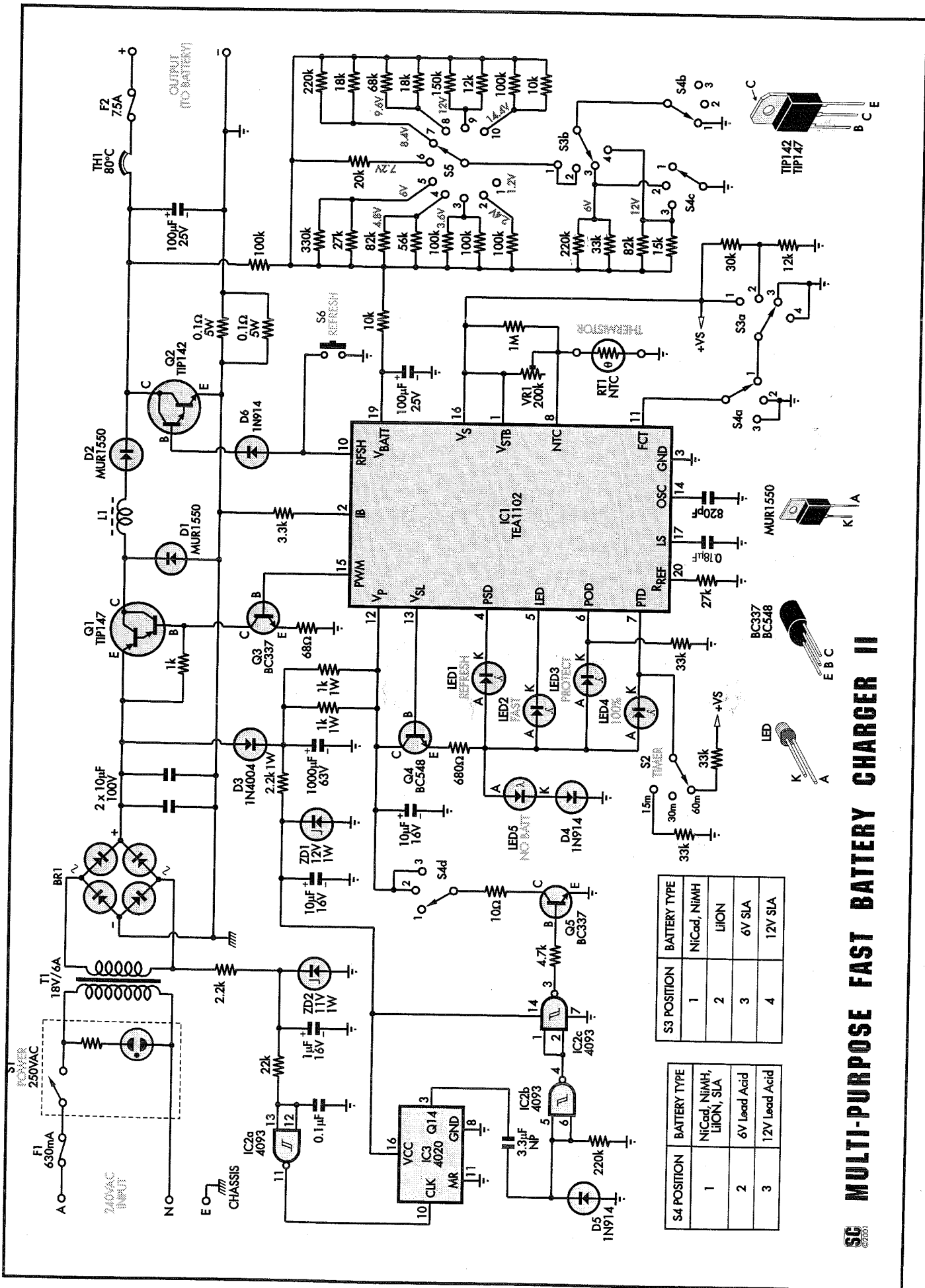
Power

Power for IC1 comes from the positive side of bridge rectifier BR1 which charges a 1000μF capacitor via diode D3. D3 reduces the ripple on the capacitor and also prevents charging current for the battery being drawn from this capacitor.

A 500Ω resistance comprising two 1kΩ resistors in parallel supplies current to pin 12 which has an internal 12V zener diode regulator. A 10μF capacitor decouples this supply rail.

A 2.2kΩ resistor feeds the D3 supply to 12V zener diode ZD1, to power IC2 and IC3. These two ICs form the reset timer. The AC side of bridge rectifier BR1 feeds the 11V zener diode ZD2 via a 2.2kΩ resistor. ZD2 limits the voltage to 11V when the AC goes positive and to -0.7V when the voltage goes negative. The 1μF capacitor across the zener diode smoothes the resulting 50Hz waveform and this is again filtered with a 22kΩ resistor and 0.1μF capacitor and fed to IC2a. This squares up the 50Hz waveform which then clocks IC3.

IC3 is a binary counter with the Q14 output producing a high output every 5.5 minutes. The high output is fed to inverter IC2b via a 3.3μF capacitor and the signal is inverted again by IC2c. IC2c drives transistor Q5 which momentarily pulls pin 12 (the 12V supply of IC1) to ground via a 10Ω resistor. This resets the internal timer of IC1.



S3 POSITION	BATTERY TYPE
1	NiCad, NiMH
2	LiION
3	6V SLA
4	12V SLA

S4 POSITION	BATTERY TYPE
1	NiCad, NiMH, LiION, SLA
2	6V Lead Acid
3	12V Lead Acid

SC MULTI-PURPOSE FAST BATTERY CHARGER II



Fig.3: The complete circuit diagram of the fast charger.

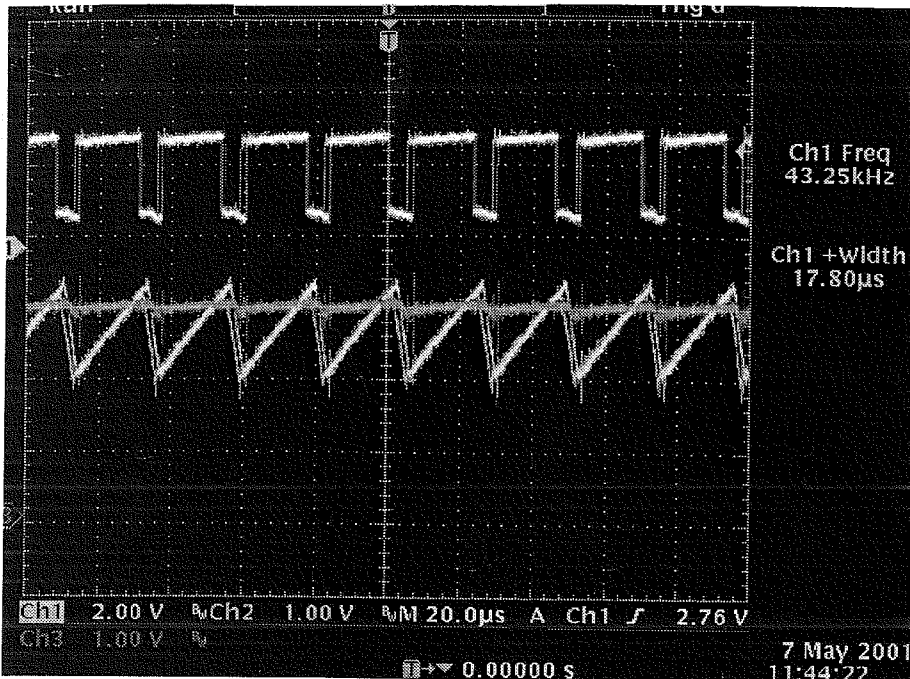


Fig.4: these 'scope waveforms show the switchmode operation of the charger. The triangle waveform is the output of the oscillator at pin 14 of IC1 while the trace intersecting the triangle waveform is the DC output of IC1 at pin 17. These two voltages are compared internally by IC1 to produce the PWM output at pin 15 which is the upper trace. Note that there is some jitter in these traces; this is caused by the fact that the circuit constantly hunts back and forth as it maintains a set current into the battery.

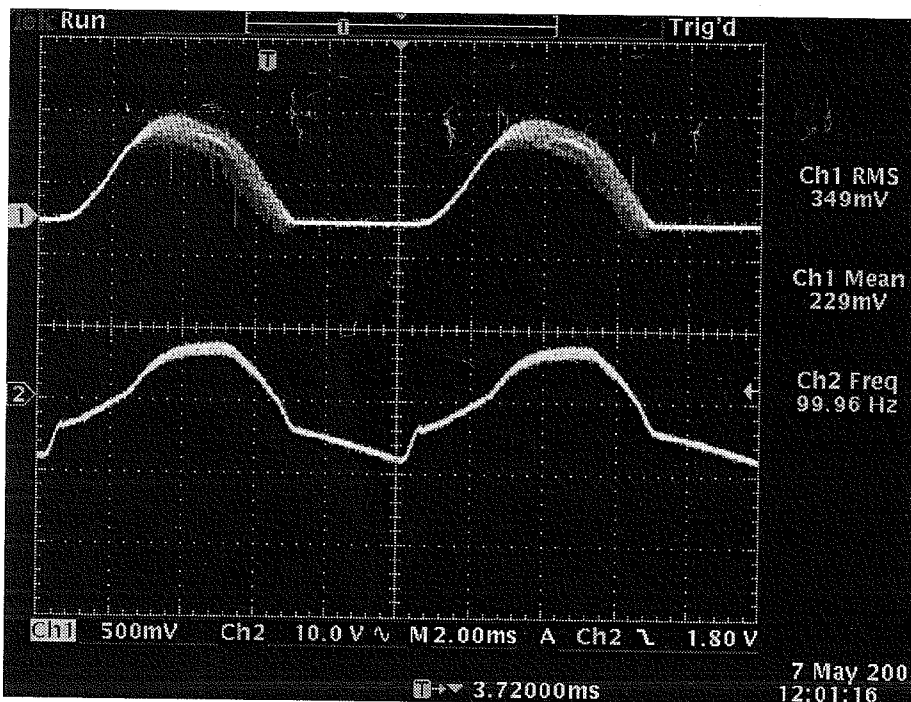


Fig.5: these 'scope waveforms show how the battery is charged with what is essentially switched unfiltered DC. The lower trace is the unfiltered DC input to the anode of diode D3 while the upper trace is the voltage waveform across the two paralleled 0.1Ω sensing resistors. The RMS value of the voltage is 349mV so the resultant current is 6.98A. The mean value (that would be obtained on a standard multimeter) is only 229mV which would indicate an average of 4.58A.

Construction

The SILICON CHIP Universal Fast Battery Charger is housed in a plastic instrument case measuring 257 x 190 x 85mm while the components are mounted on a PC board coded 14106011 (ZA1073B) and measuring 115 x 173mm.

Transformer T1 is mounted sideways onto the rear metal panel as shown in the photographs. Underneath its mounting position on the case are several integral ribs and bushes (mounting pillars). These must be removed to allow the transformer to sit flat.

The easiest way to remove the ribs is with a sharp chisel (careful!!) while the bushes are easily cut out with a large, sharp drill bit. For more detail see "case preparation" on page 17.

The main PC board fits over four integral bushes in the base of the case, secured with self-tapping screws. Other bushes (under the board) may get in the way of the PC board or components - again, these can be easily removed with a large drill.

Begin construction by checking the PC board against the published pattern. There should not be any shorts between, or breaks in, the tracks. If there are, repair these as necessary.

PC stakes are used wherever connections need to be made to the PC board. These are soldered in first, in the positions indicated. Doing these first also acts as a guide to the positions of the links and resistors, which can be soldered in next. Use the accompanying table as a guide to working out which resistor goes where - or measure them with a digital multi-meter.

Note that some resistors are mounted as a parallel combination: one is inserted as normal from the component side of the PC board while the second (shown in Fig.7, page 9) is soldered between the pigtailed of the first resistor on the underside of the PC board.

When inserting the smaller diodes and zeners, take care with their orientation and be sure to place each type in its correct place. Solder in the IC sockets and insert IC's followed by the transistors, also taking care to orient them as shown.

The power transistors and power diodes solder to the PC board but are also secured to the rear panel and heatsink. They are oriented with the metal flange towards the edge of the PC board and are positioned above the board with sufficient lead length to allow them to reach their mounting holes on the rear of the

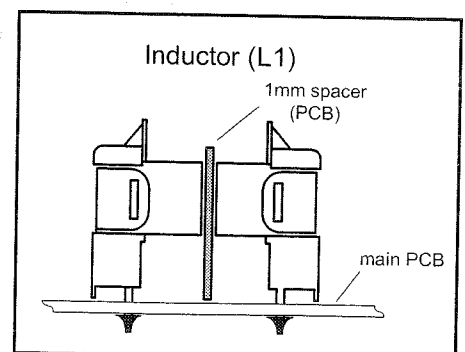


Fig.9: Shows the core spacing required for inductor (L1). A piece of PCB material (1mm thick) measuring 20mm x 10mm is inserted between the two cores to form the correct spacing.

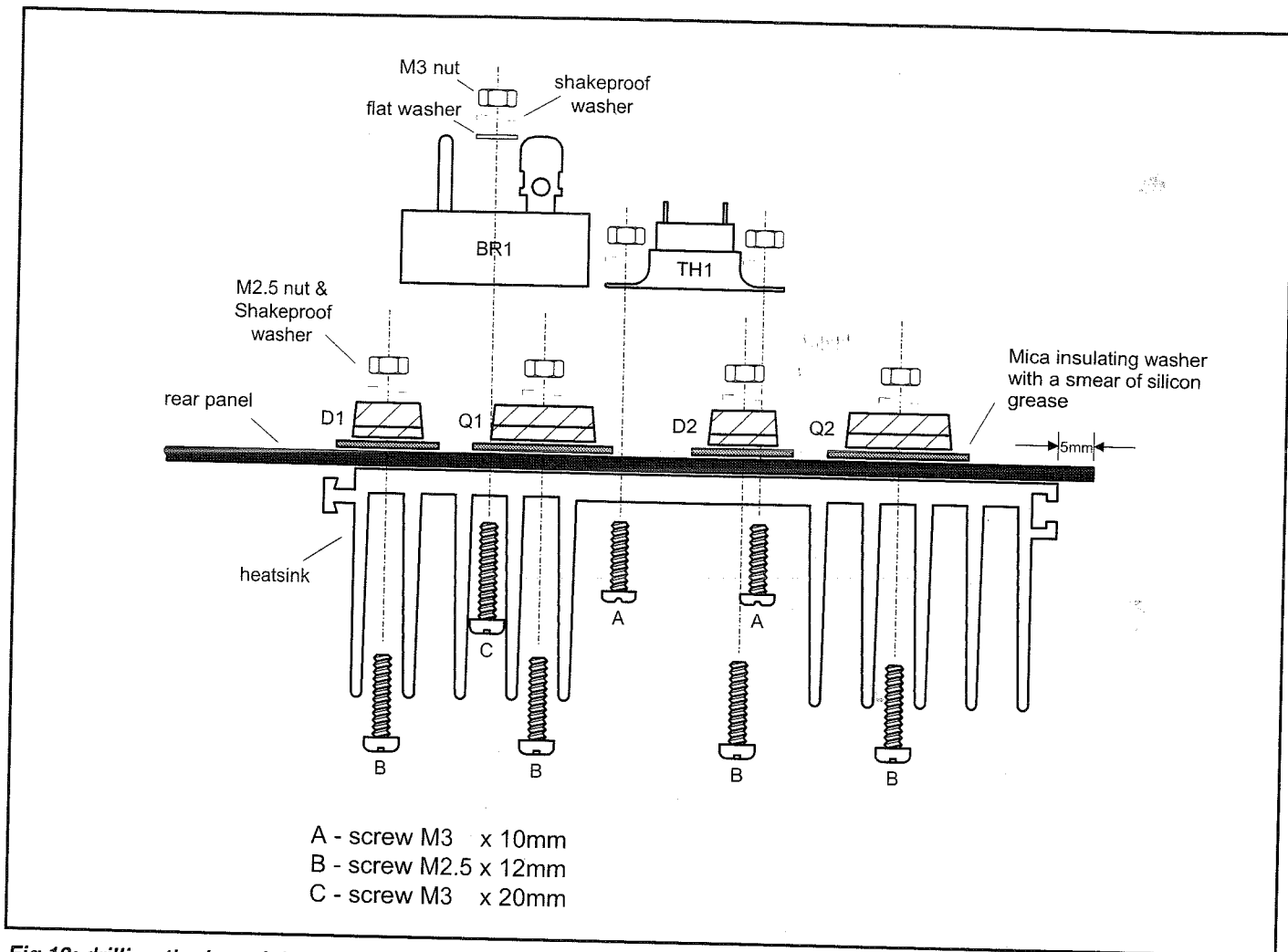
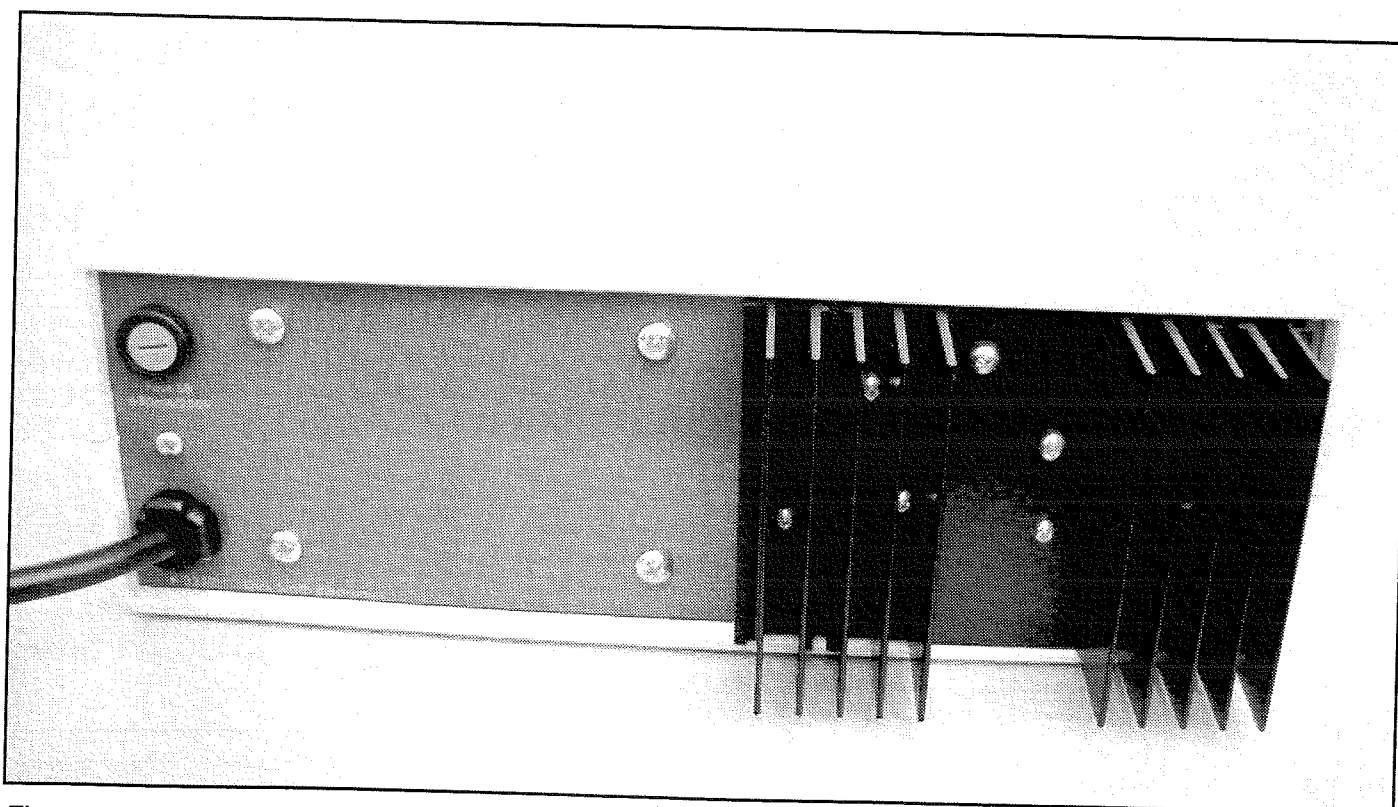


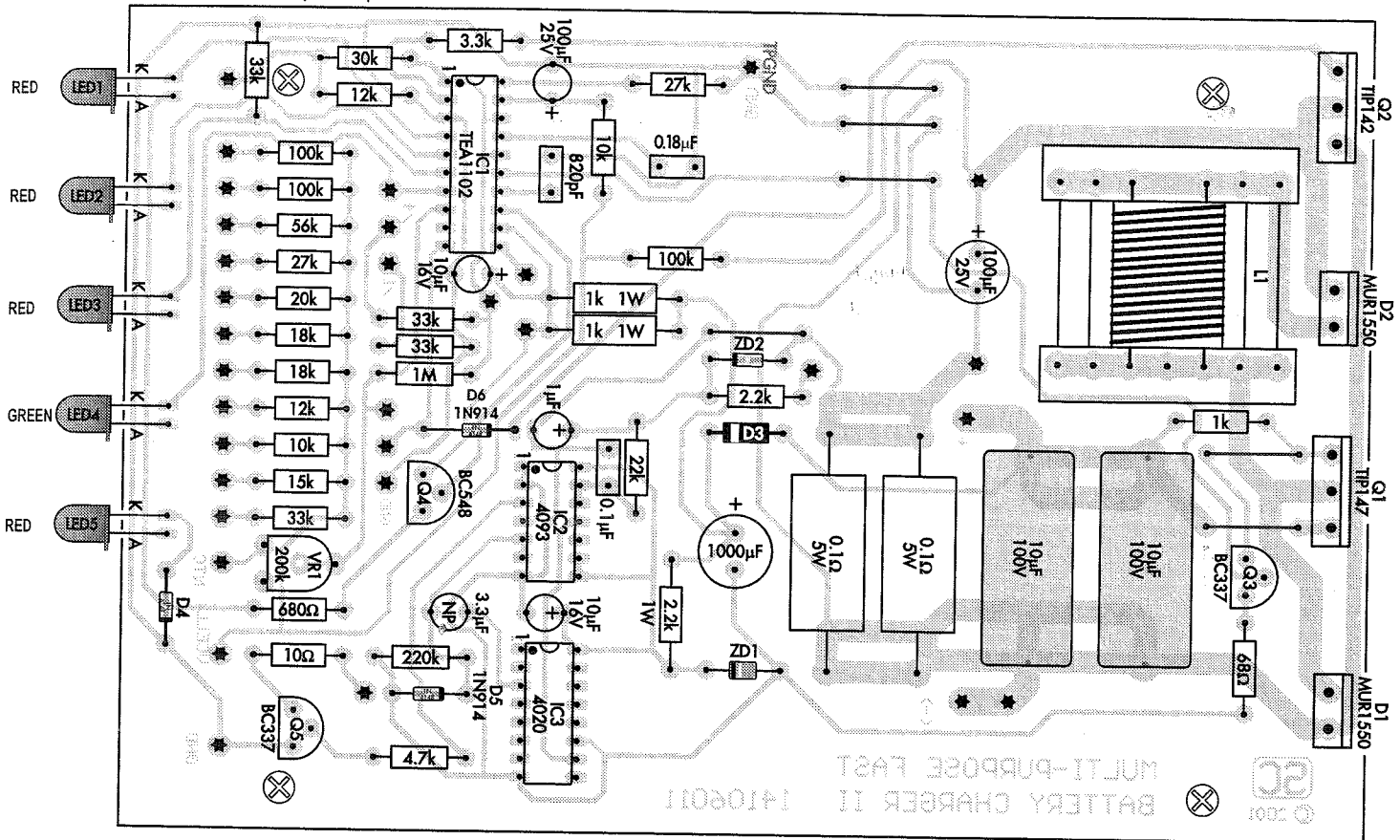
Fig.12: drilling the heatsink and using the rear panel as a template. Position the heatsink flat onto the rear panel at about 5mm from the edge. Mark hole positions for darlington transistors (Q1 & Q2), fast recovery diodes (D1 & D2), thermostat (TH1) and bridge rectifier (BR1). Before you commence drilling check that all holes are positioned correctly and line-up between the heatsink fins as shown.



The rear panel of the charger isn't particularly inspiring. Power in, fuse and a heatsink are the only obvious bits. The four screws hold the power transformer in place against the rear panel.

LEGEND:
 * = PC BOARD PIN
 NP = NON-POLARISED (BIPOLAR) CAPACITOR

Note - PCB tracks around the output devices (Q1, Q2, D1 & D2) have been altered a little in order for the devices to line-up with the heatsink channels.



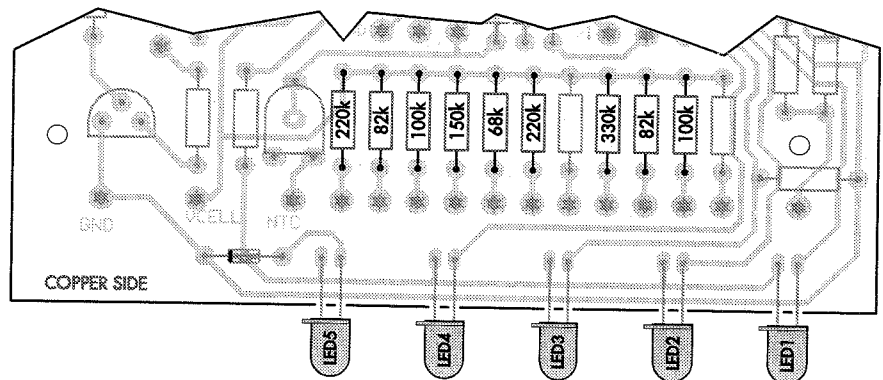
Figs. 6 & 7: show both sides of the PC board, with the relevant section of the underside shown at right.

case. Before soldering devices into place double check rear panel mounting holes are aligned to the transistor & diode holes.

Capacitors can be soldered in next. The accompanying capacitor table shows the various codes, one of which should be written on each component. The electrolytic capacitors must be oriented with the correct polarity (with the exception of the 3.3µF bipolar type which can be mounted either way). Now install the trimpot.

In similar fashion to the power transistors, the LEDs solder to the PC board and also emerge through the front panel. To allow this, the LEDs are inserted through the board with just enough length poking through to allow soldering. The LEDs are then bent over over so that they can protrude through the holes in the panel. We don't have to remind you to make sure they're the right way around, do we? No, we didn't think so. . .

The inductor (L1) is wound with two lengths of 1mm enamelled copper wire, wound in "bifilar" mode - the two lengths are wound as one with each turn of the winding actually being two turns side-by-side, one from each length of



wire.

Fig.8 explains this method of winding. First, if the wire is supplied as a two-metre length cut it exactly in half. Now let's see . . . each length will be, uhh, um, too hard . . .

Next remove the insulation (enamel) from one end of each of the two lengths of wire and terminate (solder) the two ends onto two pins on the underside of the transformer bobbin. The actual pins used doesn't matter since they are connected together on the PC board anyway.

Now wind on the two windings of 20 turns by holding both lengths of wire between your thumb and forefinger and winding them on as one (ie, side-by-side).

Once wound, cut the excess wires off, strip the insulation from their ends and terminate the wires onto the pins on the

opposite side of the former. Again, the actual pins used are not important.

Insert one core in place and secure with a clip. Now place the 1mm spacers on the two faces of the inserted core and place the second core in position, securing it with the clips supplied. Insert this inductor assembly into the appropriate place on the PC board and solder in place.

That pretty much completes the PC board assembly - all that's left now is to mount the board (and everything else) inside the case.

Assembly

Place the PC board into the case (on its four bushes) the power transistors and diodes should line up with the rear panel holes.

Place the heatsink against the rear

Parts List - Universal Fast Battery Charger II

- 1 PC board coded 14106011, (ZA1073B) 115 x 173mm
- 1 front panel
- 1 rear panel
- 1 plastic instrument case
- 1 heatsink
- 1 18V 6A mains transformer
- 1 ETD29/16/10 transformer assembly with 3C85 cores (L1)
(Philips 2 x 4312 020 37502 cores, 1 x 4322 021 34381 bobbin, 2 x 4322 021 34371 clips)
- 1 NTC thermistor (DSE R-1797) (RT1)
- 2 3AG panel-mount safety fuse holders (F1,F2)
- 1 630mA slow-blow 3AG fuse
- 1 7.5A fast-blow 3AG fuse
- 1 SPST Neon illuminated mains rocker switch (S1)
- 1 SPDT centre-off toggle switch (S2)
- 1 2-pole, 4-position rotary switch (S3)
- 1 4-pole, 3-position rotary switch (S4)
- 1 single pole, 10-position rotary switch (S5)
- 1 80°C thermal cutout (TH1)
- 1 momentary normally off push button switch (S6)
- 1 banana panel socket (Red)
- 1 banana panel socket (Black)
- 1 banana plug (Red)
- 1 banana plug (Black)
- 1 micro banana panel socket (Red)
- 1 micro banana panel socket (Black)
- 1 micro banana plug (Red)
- 1 micro banana plug (Black)
- 4 insulating bushes for TO-220 and TO-218 packages
- 2 TO-218 mica insulating washers
- 2 TO-220 mica insulating washers
- 32 PC stakes
- 1 mains cord with plug
- 1 mains cord grip grommet
- 2 PCB spacers (thickness 1mm) 10 x 20mm to gap L1
- 1 length of 0.5mm tinned copper wire
- 1 length of 1mm enamelled copper wire
- 11 small cable ties
- 2 solder lugs for earth terminals
- 1 trimpot 200k or 250k ohm
- 2 alligator clips (Red & Black)
- 3 knobs

Semiconductors

- 1 TEA1102 fast charge IC (IC1)
- 1 4093 / MC14093 quad Schmitt NAND gate (IC2)
- 1 4020 / MC14020 binary divider (IC3)
- 1 TIP147 PNP power Darlington transistor (Q1)
- 1 TIP142 NPN power Darlington transistor (Q2)
- 2 BC337 / 2N3642 / 2N5818 NPN transistors (Q3,Q5)
- 1 BC548 / BC108 / 2N5818 NPN transistor (Q4)
- 2 MUR1550 / BYW81P/200 fast recovery diodes (D1, D2)
- 1 1N4004 1A diode (D3)
- 3 1N914 / 1N4148 diodes (D4,D5,D6)
- 1 35A 400V bridge rectifier KBPC3504 (BR1)
- 1 12V 1W zener diode 1N4742 / BZX85C12 (ZD1)
- 1 11V 1W zener diode BZX85C11 (ZD2)
- 4 red LEDs (LED1-LED3, LED5)
- 1 green LED (LED 4)

Capacitors

- 1 1000µF 63VW PC electrolytic
- 2 100µF 25VW PC electrolytic
- 2 10µF 16 / 25VW PC electrolytic
- 2 10µF 100VW MKT polyester (Philips 373 series)
- 1 3.3µF bipolar electrolytic
- 1 1µF 16 / 50VW PC electrolytic
- 1 0.18µF MKT polyester
- 1 0.1µF MKT polyester
- 1 820pF ceramic

Resistors (0.25W 1%)

1 1MΩ	1 330kΩ	3 220kΩ
1 150kΩ	5 100kΩ	2 82kΩ
1 68kΩ	1 56kΩ	4 33kΩ
1 30kΩ	2 27kΩ	1 22kΩ
1 20kΩ	2 18kΩ	1 15kΩ
2 12kΩ	2 10kΩ	1 4.7kΩ
1 3.3kΩ	1 2.2kΩ	1 2.2kΩ 1W
2 1kΩ 1W	1 1kΩ	1 680Ω
1 68Ω	1 10Ω	2 0.1Ω 5W

Miscellaneous

Solder, machine screws & nuts (see guide to screw allocation), hook-up wire (refer to guide page 17), heat shrink tubing, IC sockets & instructions..

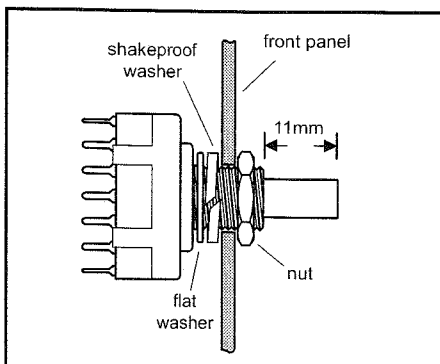


Fig.14: once the rotary switches have been programmed as shown in fig.18 secure each switch to the front panel using a flat washer, shakeproof washer and nut. Using a hacksaw or sharp side cutters, shorten the rotary switch shaft to a length of 11mm. This will allow the knob to sit neatly when secured in place.

panel and mark out the hole positions for drilling into the heatsink.

Note that you must line up the heatsink so that the screws for Q1, Q2 D1, D2, bridge rectifier and thermistor will pass through the heatsink between the heatsink fins. Drill out and deburr these holes. See Fig.12 for further details.

Attach the PC board to the case with self-tapping screws.

Secure the transistors and diodes to the rear panel and heatsink with a screw, nut, mica insulating washer and insulating bush.

Note - smear each side of the mica washer with silicon grease (heatsink compound) before mounting.

Check that the metal tabs of the devices are indeed isolated from the case

(rear panel) by measuring the resistance to the case with a multimeter - it should show open circuit.

Apply a smear of heatsink compound on the face of the rectifier (BR1) before securing it to the rear panel. It is not necessary to insulate the rectifier case from the rear panel.

Pass the mains cord through its cord-grip grommet and secure the grommet into its rear panel hole. Also attach the fuseholder and secure the transformer with 4mm screws, star washers and nuts. Attach the earth wire (green/yellow stripe) to the solder lug and secure to the top right transformer bolt as shown the wiring overlay.

The front panel can now be loaded with the switches, terminals and fuseholder.

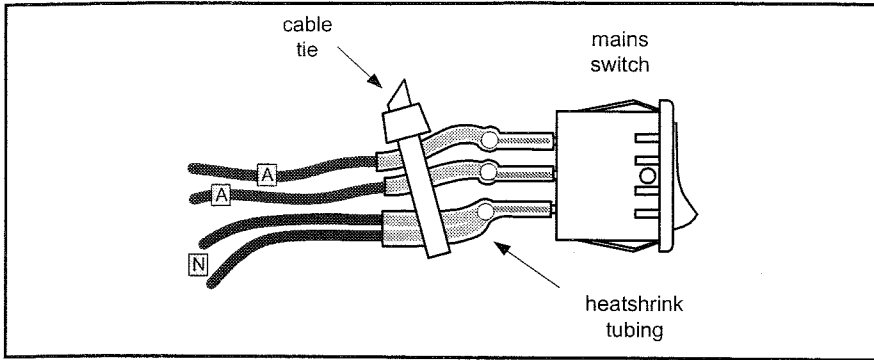


Fig.17: use heatshrink tubing to insulate the switch terminals once all wiring is soldered in place. Finally, a cable tie is used to secure wiring as close as possible to the switch terminals.

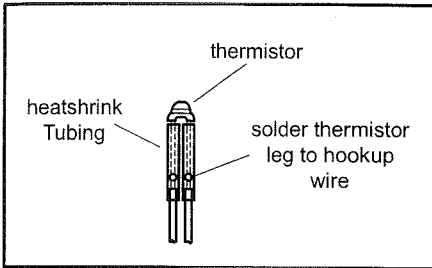


Fig.15: Shows how to sheath the thermistor with heatshrink tubing once figure-8 hookup wire is soldered to each of the leads.

The shafts of the rotary switches need to be cut down with a hacksaw. As shown in Fig. 14. Many rotary switches supplied these days are universal - the

number of positions required need to be set. If this is the case, you will need to set S5 as a 10-position, S3 as a 4-position, and S4 as 3-position type.

This is done by removing the locking collar from beneath the star washer and nut and rotating the switch fully anticlockwise. Then reinsert the locking washer into position 10 for S5, position 3 for S4 and position 4 for S3.

Now assemble all the front panel components. Follow the wiring diagram, using coloured hookup wire.

The mains wiring must be done using mains-rated wire, with the ter-

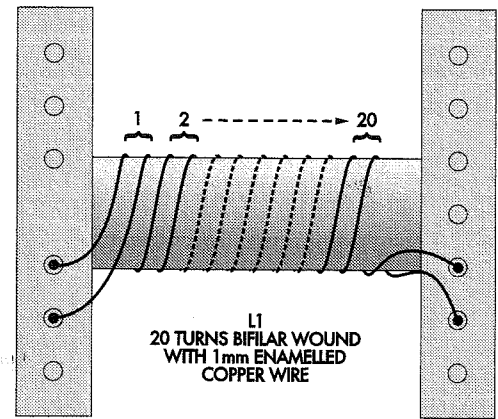


Fig. 8: the detail of the inductor winding. It has two windings but both go on as one.

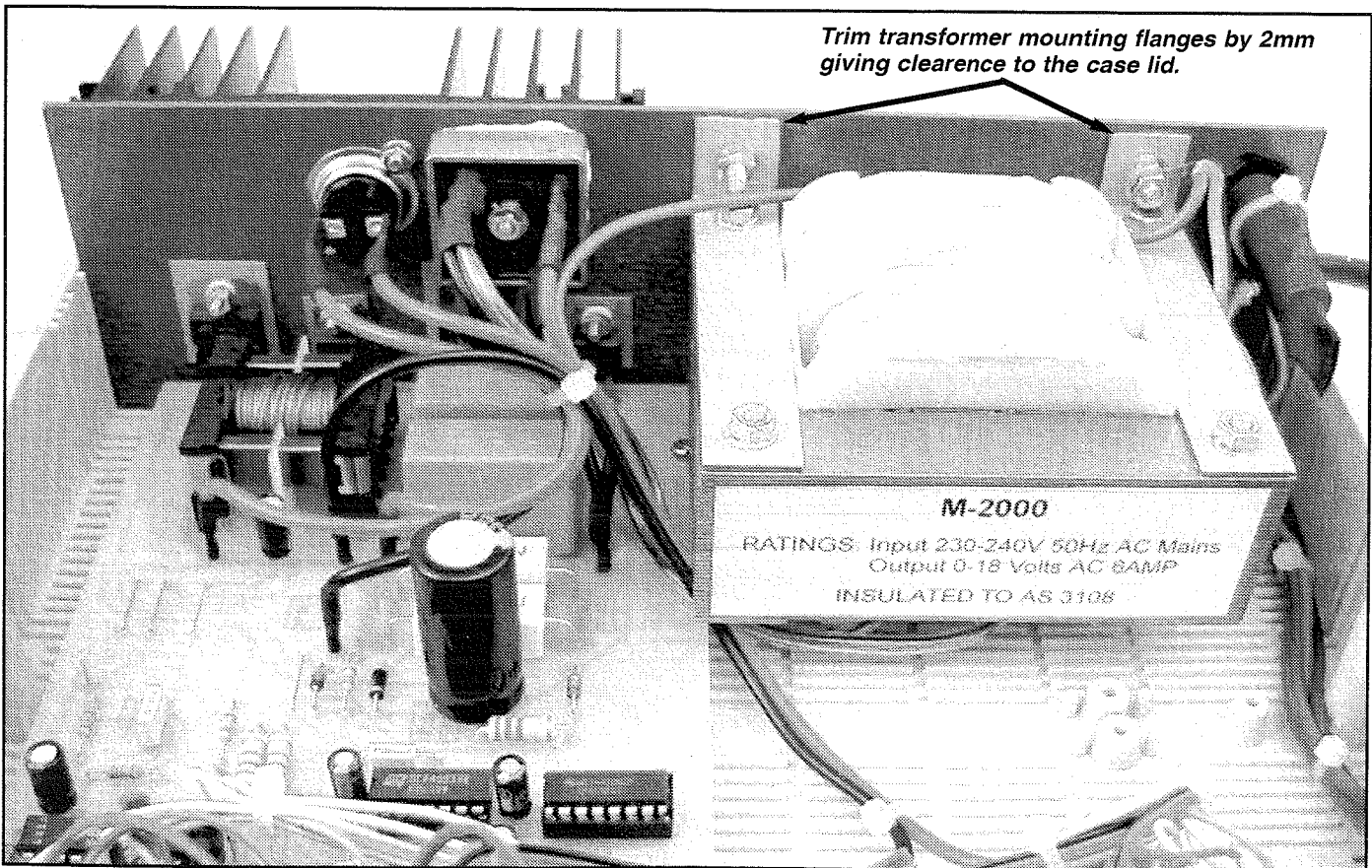
minals for the fuse and power switch sheathed (insulated) with heatshrink tubing.

Use heavy duty wiring for the connections between the rectifier and PC board, the thermal switch and to the output terminals and fuse F2.

Tidy up the wiring with cable ties and insert the front panel into its slots in the case with the LEDs protruding through the holes.

You will need to make up some heavy-duty leads to connect from the output terminals to a battery, using heavy-duty banana plugs and large alligator clips.

The thermistor, too, requires a connecting lead. This can be light-duty figure-8 or twisted hookup wire, terminated in minia-



An angled view of the rear of the case, particularly showing the method of mounting the power transistors and diode, the thermistor, bridge rectifier (block in the middle), transformer and mains wiring. Note that all mains wiring must be insulated with heatshrink tubing, as shown on the fuseholder at right of picture.

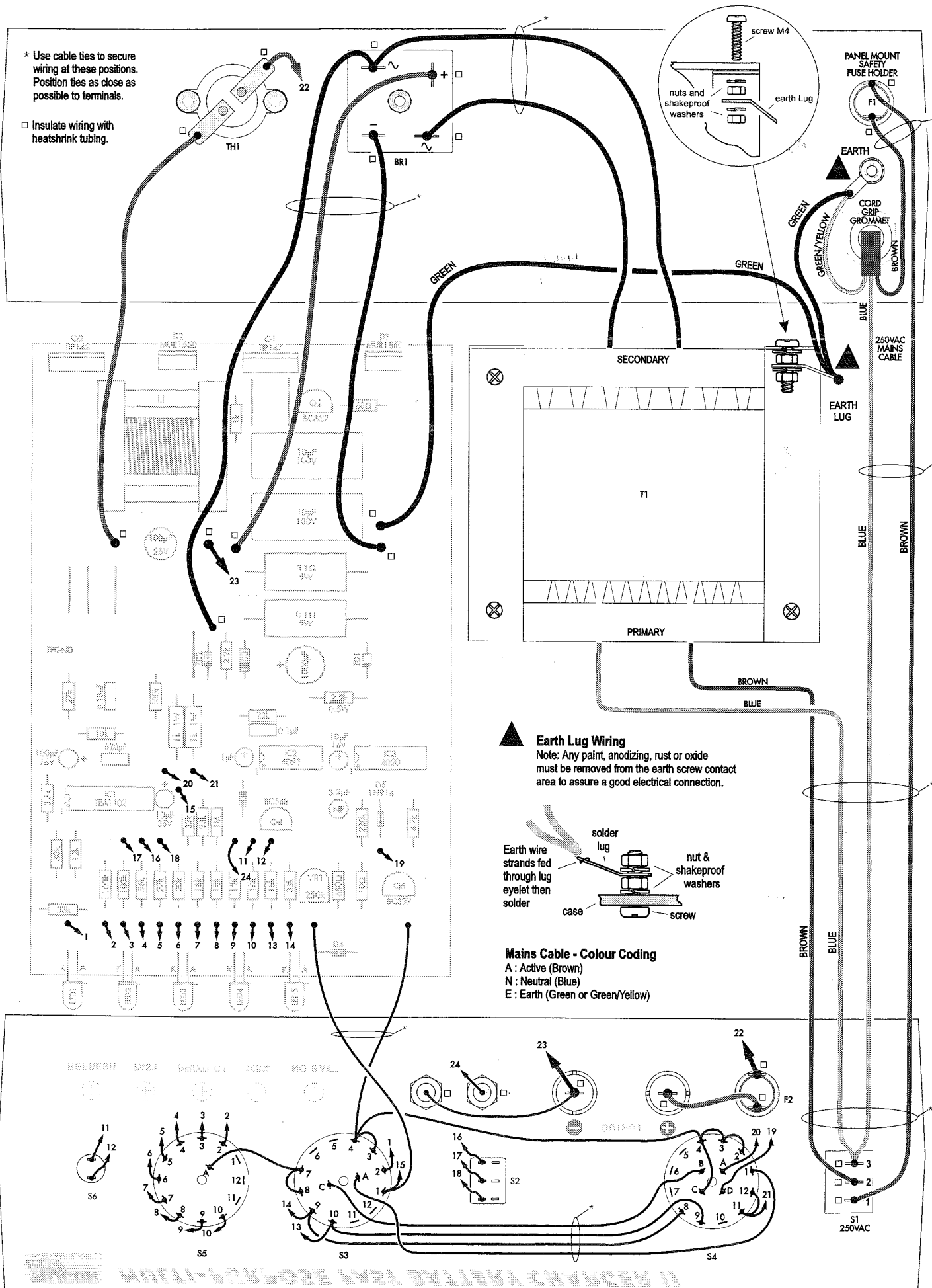


Fig.10: the complete wiring diagram of the charger, shown with the two panels laid out and flat.

Resistor Colour Codes - Universal Fast Charger

Value	4-Band Code (1%)	5-Band Code (1%)
1M Ω	brown black green brown	brown black black yellow brown
330k Ω	orange orange yellow brown	orange orange black orange brown
220k Ω	red red yellow brown	red red black orange brown
150k Ω	brown green yellow brown	brown green black orange brown
100k Ω	brown black yellow brown	brown black black orange brown
82k Ω	grey red orange brown	grey red black red brown
68k Ω	blue grey orange brown	blue grey black red brown
56k Ω	green blue orange brown	green blue black red brown
33k Ω	orange orange orange brown	orange orange black red brown
30k Ω	orange black orange brown	orange black black red brown
27k Ω	red violet orange brown	red violet black red brown
22k Ω	red red orange brown	red red black red brown
20k Ω	red black orange brown	red black black red brown
18k Ω	brown grey orange brown	brown grey black red brown
15k Ω	brown green orange brown	brown green black red brown
12k Ω	brown red orange brown	brown red black red brown
10k Ω	brown black orange brown	brown black black red brown
4.7k Ω	yellow violet red brown	yellow violet black brown brown
3.3k Ω	orange orange red brown	orange orange black brown brown
2.2k Ω	red red red brown	red red black brown brown
1k Ω	brown black red brown	brown black black brown brown
680 Ω	blue grey brown brown	blue grey black black brown
68 Ω	blue grey black brown	blue grey black gold brown
10 Ω	brown black black brown	brown black black gold brown

Capacitor Codes

Value	IEC	EIA
0.0018 μ F	1.8n	182
0.1 μ F	100n	104
820pF	820p	821

ture banana plugs. The thermistor leads themselves should be sheathed in heat-shrink tubing where they solder to the connection lead. (See Fig.15).

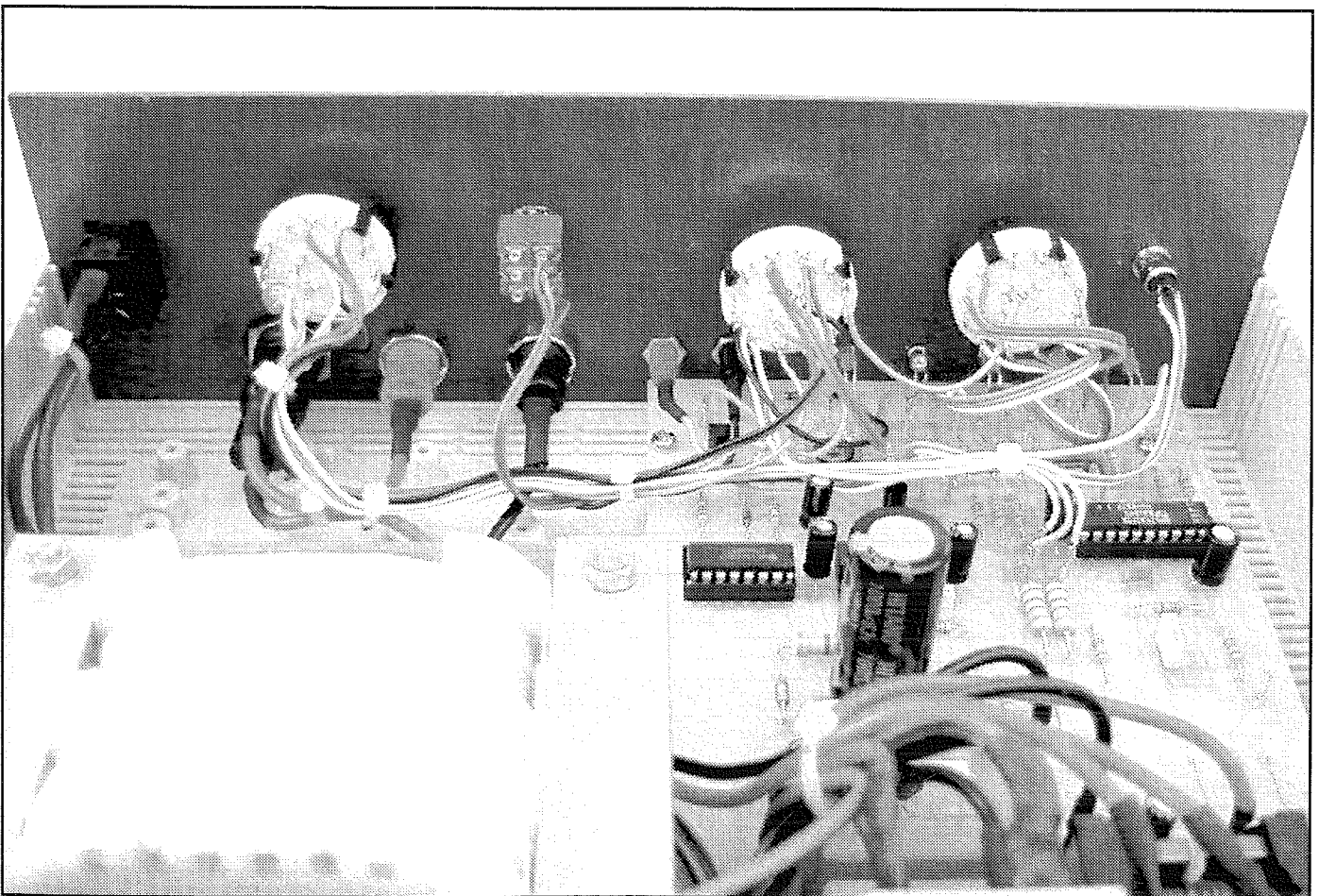
Testing

Check your work carefully to ensure correctly placed components, orientation of the polarised parts and wiring.

Test that the earth termination connects to the rear panel case by measuring the resistance between the earth pin on the mains plug and the case. It should be zero ohms (or very close).

Now apply power and measure the voltage between the TP GND PC stake and pin 12 on IC1. You should measure about 12VDC. Check that pin 14 and pin 16 of IC2 and IC3 are at 12V. Switch S3 & S4 to the NiCd & NiMH position and check that the "no battery" LED lights.

Connect the NTC thermistor and check



Here's similar view to the earlier photo, this time looking from rear to front and showing the switch wiring. Follow the wiring diagram and photos and you should have no difficulties.

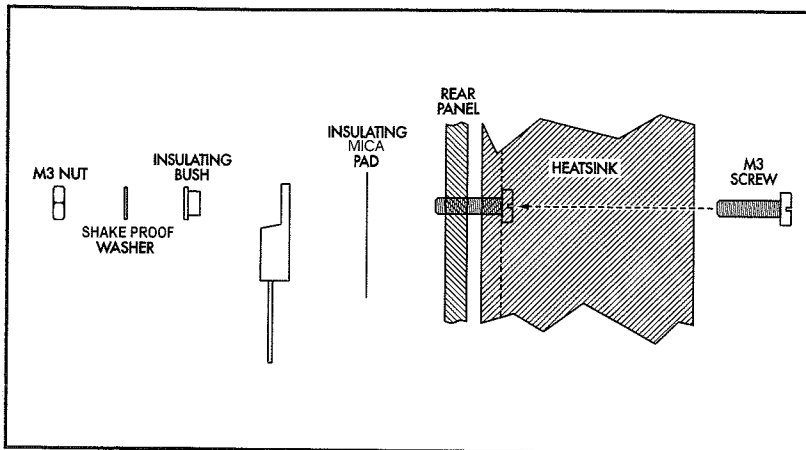
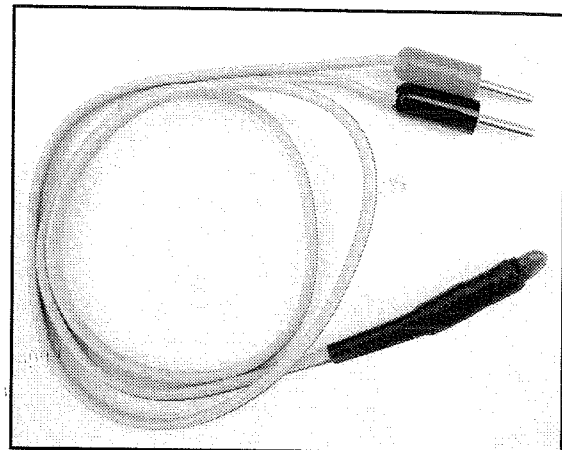


Fig.11: cross-section through the heatsink, panel, semiconductor and its mounting hardware. It's vital that the power transistors and diode are insulated from the rear panel.



The thermistor mounted on its flying leads. Connection to the front panel is via miniature banana plug.

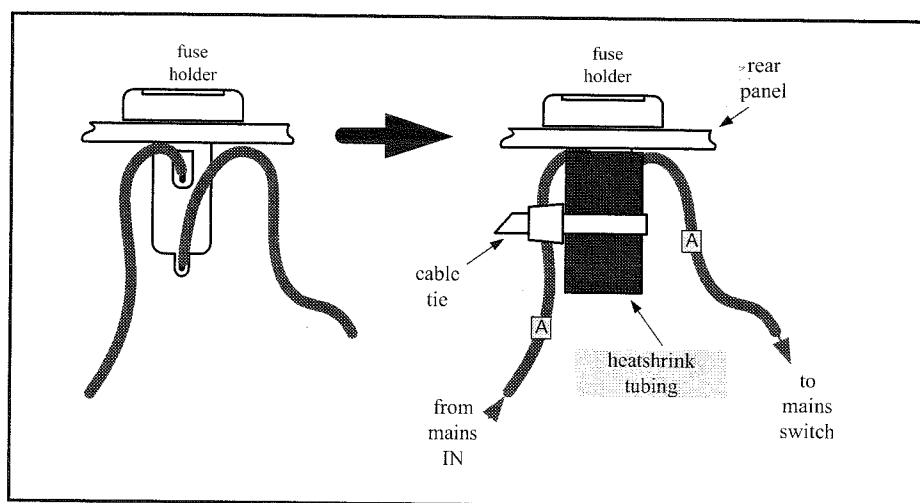
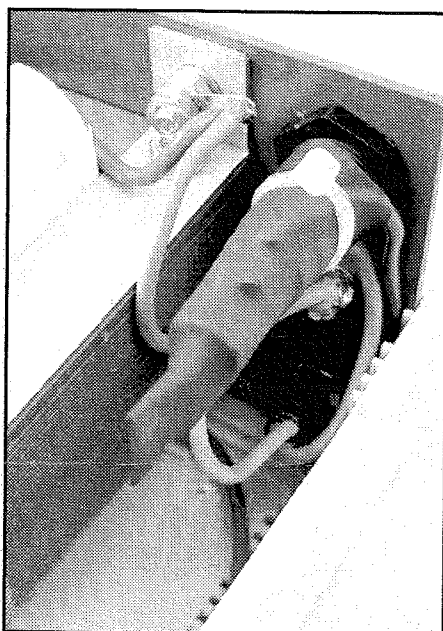
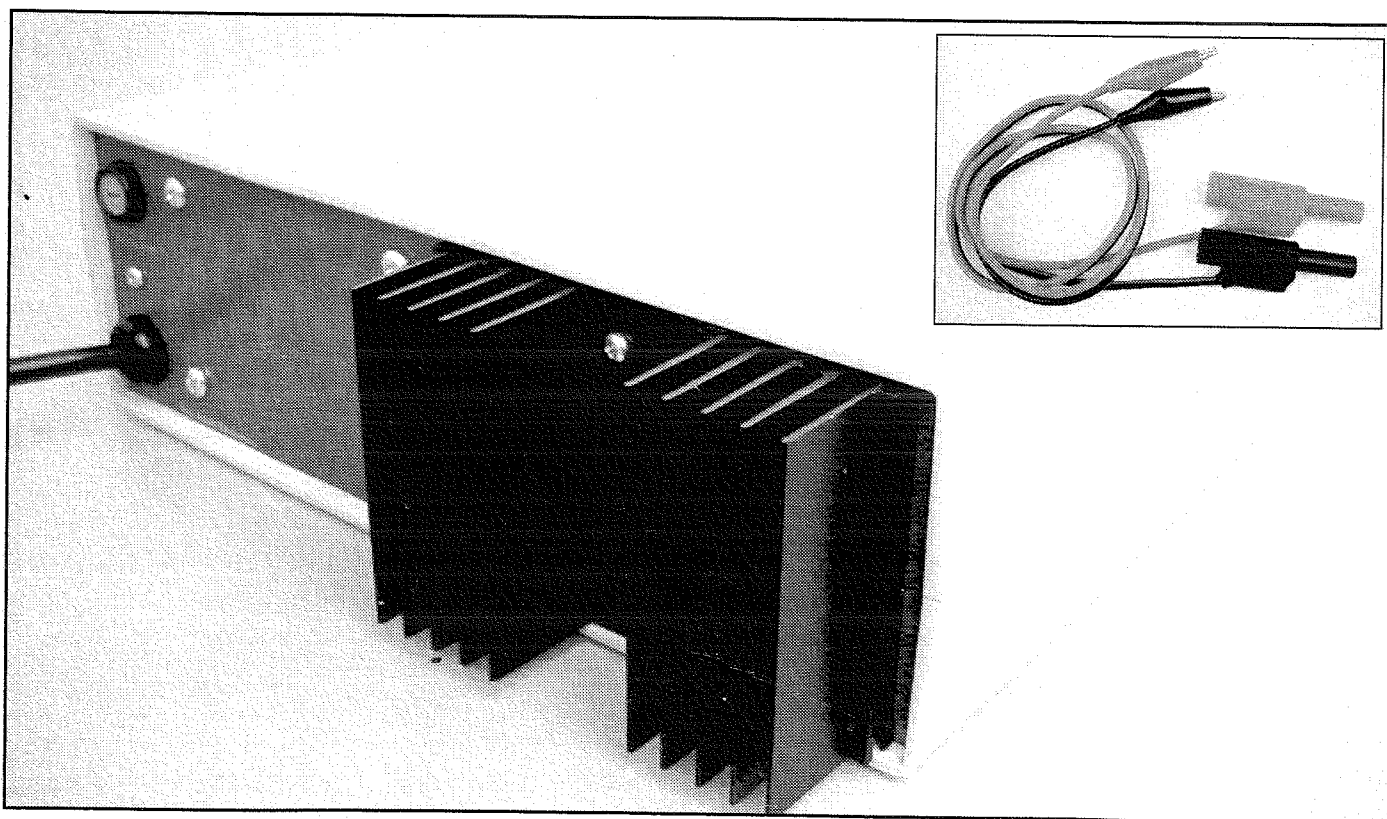


Fig.16: shows how to insulate the fuse holder using a length of heatshrink tubing once the mains cable is terminated. This is done by sliding a piece of tubing over its entire length and applying heat carefully until the tubing shrinks in size forming a tight fit. Finally, use a cable tie around the total assembly for added safety.



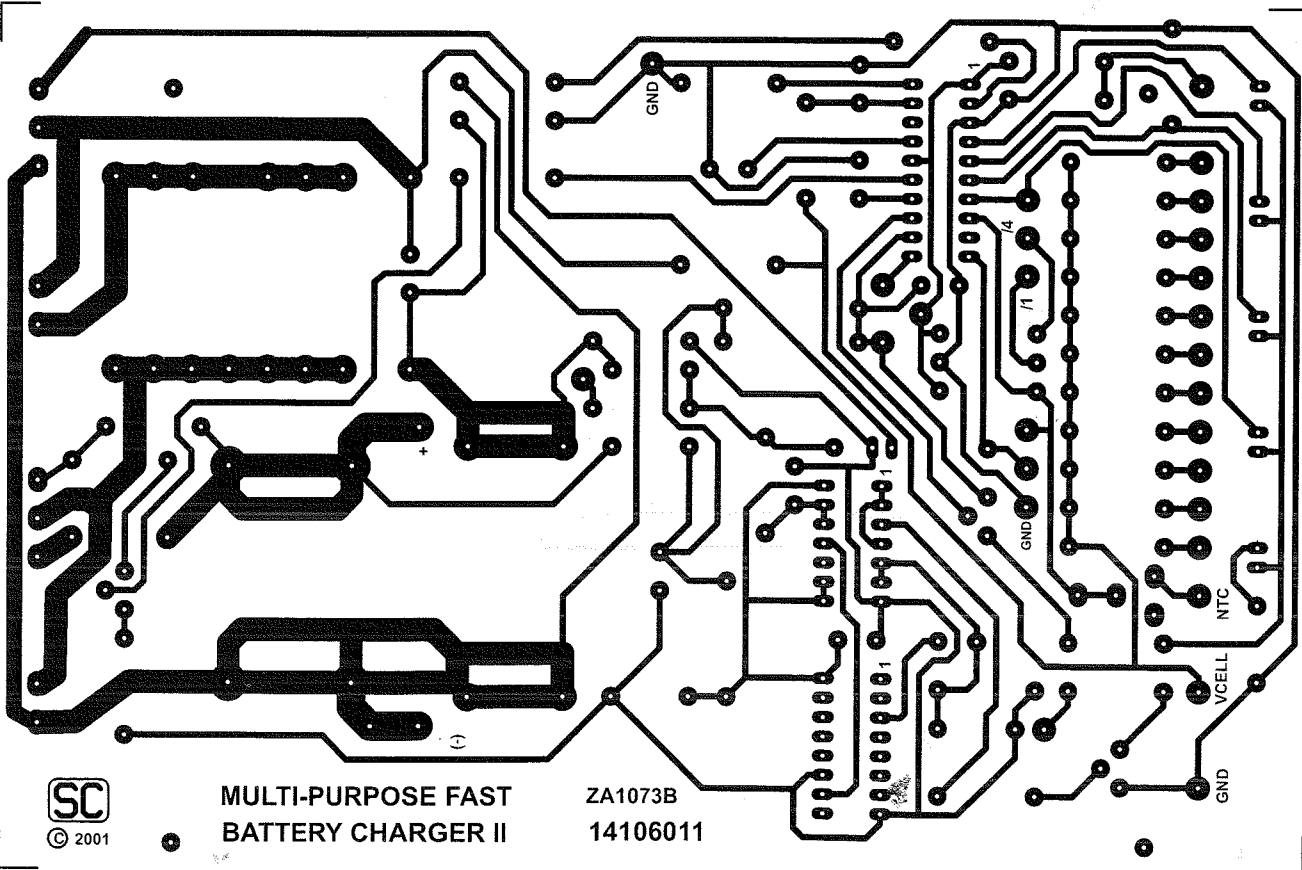
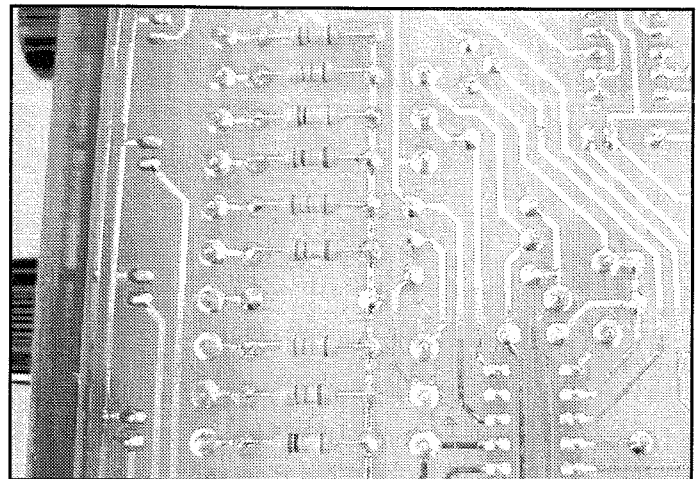
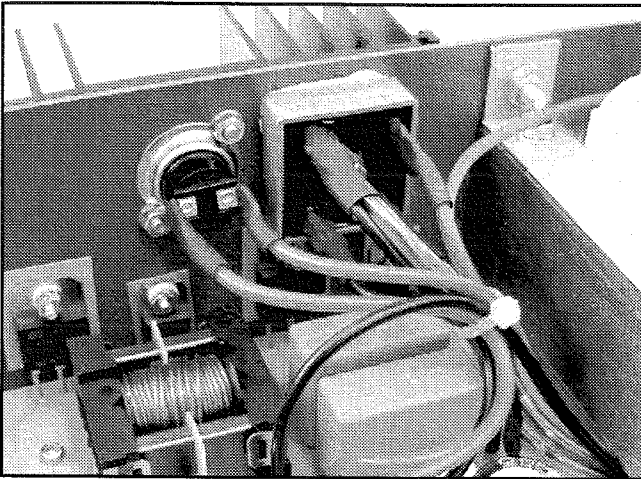
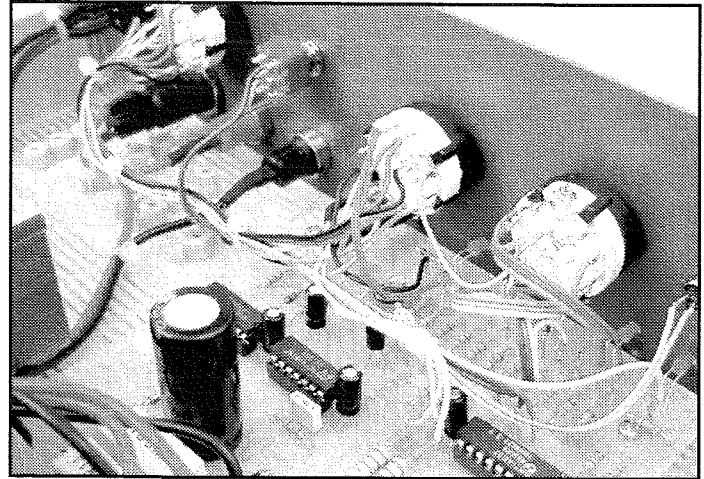
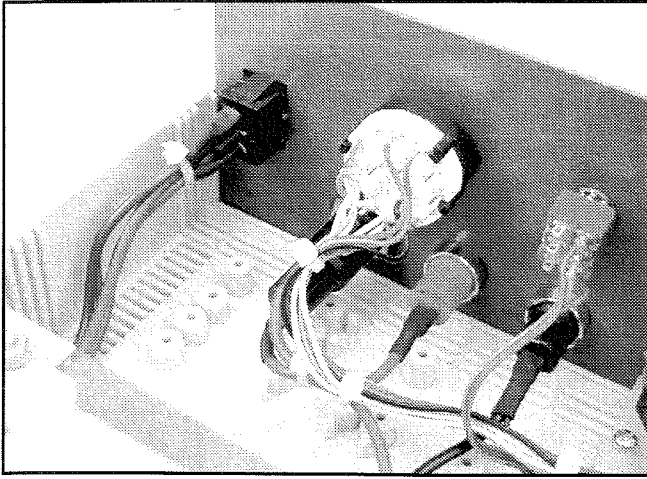


Fig.13: Full-size artwork for the main PC board.

that the voltage at pin 8 of IC1 is at about 2V when the temperature is around 25°C. Adjust VR1 for this voltage.

If you heat up the thermistor slightly by gripping tightly between your finger and thumb the voltage should drop. If the temperature rises then it is either a very hot day and your body temperature is lower than that of the air (unlikely during winter!) or you have the wrong type of thermistor (eg, a PTC instead of NTC).

When charging a battery make sure you select the correct battery type and voltage on the front panel switches. Also set the timer for the closest timeout period for the particular battery capacity. If you are charging a lead-acid battery then the timeout setting does not matter.

You may wish to check the charge current using an RMS meter or a digital oscilloscope which reads RMS. If a standard multimeter (ie, not a true RMS

type) is used, you can expect the reading across the two 0.1W resistors in parallel to be about 200mV. An RMS reading should show about 300mV which is equivalent to 6A.

Note that the heatsink and Q1 will run hot on fast charge and so the charger should be provided with sufficient ventilation to prevent the thermal cutout operating.

Case Preparation

A few minor alterations will be required to the case before mounting any hardware such as the transformer, heatsink and PCB.

1. Transformer

As you will note, the transformer required by the circuit is quite large and will be of snug fit in between the top and bottom case halves. This can only be achieved by removing some of the ribbing and moulded stand-offs from both top and bottom sections of the case as shown in the accompanying photograph.

Use a pair of sharp small side cutters to nibble away the ribbing.

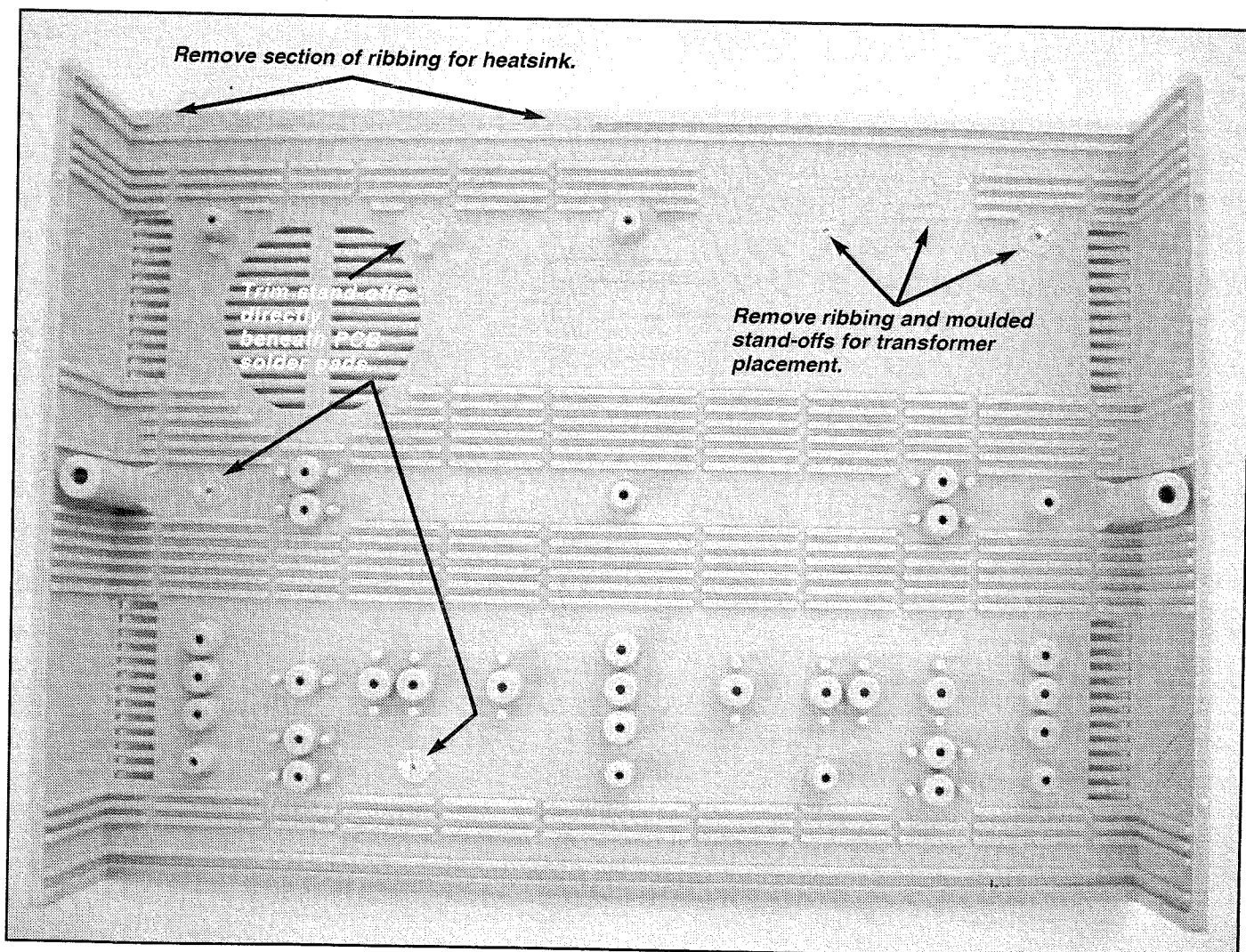
On the other hand, when mounting the transformer to the rear panel it may be necessary to adjust the transformers mounting flanges (using a pair of bull-nose pliers) so the holes correspond to those in the panel. Holes in each of the four flanges can be enlarged from 5mm to 6mm diameters allowing the transformer to be correctly centred in the case. Also it may be necessary to file/cut short the transformer mounting flanges by about 2mm, giving ample clearance

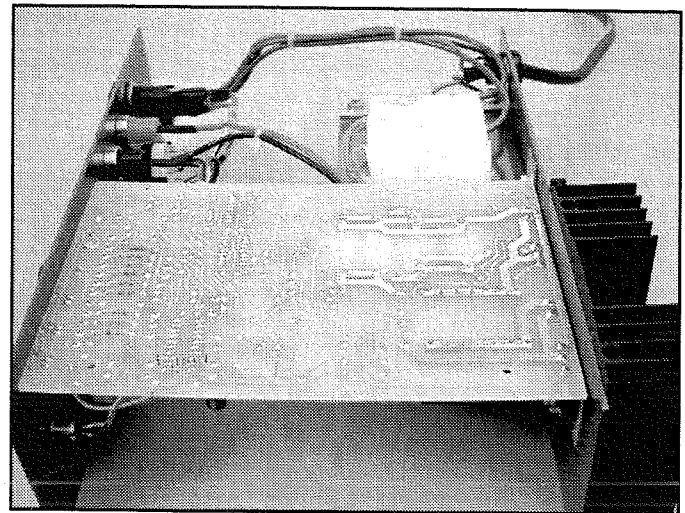
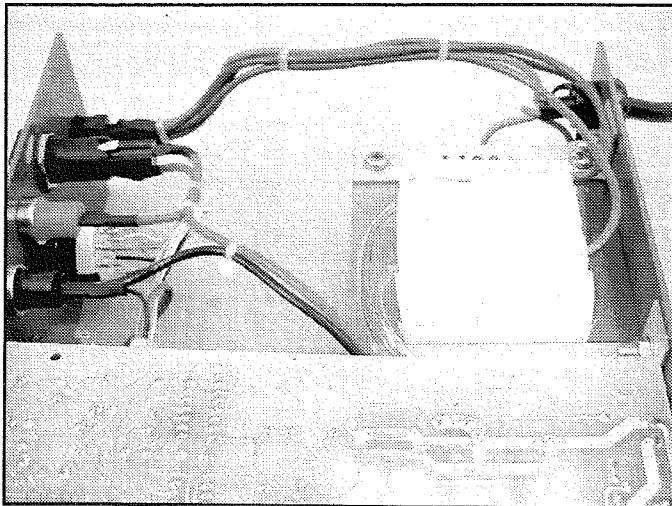
for the case lid. (see photo on page 11).

2. Heatsink

Before mounting the heatsink and rear panel into the case, it will be necessary to remove a section of ribbing (approximately 1mm in depth) from both case halves as shown in the photograph

This will then allow for correct positioning of the heatsink without fouling the case. To do this job, we suggest using a sharp implement such as a Stanley knife.





Wire & Cable Guide

Due to the different types of cables supplied within this kit, we have provided a guide to assist constructors in using the correct size cable for the correct job.

Enamel Copper Wire (1mm dia)

For coil (L1)

Tinned Copper Wire (0.5mm dia)

For PCB wire links

Rainbow Cable

Rotary Switches (S3, S4 & S5)

Toggle Switch (S2)

Push On Switch (S6)

Mini Pin Sockets (Thermistor)

Mains Rated Hook-up Wire (Brown)

Power Switch

Mains Fuse Holder (F1)

Mains Rated Earth Wire (Green)

Earth Lug (rear panel)

Earth Lug (transformer)

Heavy Duty Hook-up Wire (red & black)

Bridge Rectifier

Thermostat

Output terminals

Fuse Holder (F2 - front panel)

Speaker Cable (small)

Thermostat Test Lead

Figure '8' Power Cable

Battery Clip Leads

Screw Size and Allocation Guide

Printed Circuit Board to Case

4 x Screw self tapper
No4 x 6mm

Power Transistors & Diodes

4 x Screw M2.5 x 12mm
4 x Nut M2.5
4 x Washer shakeproof M3

Thermostat

2 x Screw M3 x 10mm
2 x Nut M3
2 x Washer shakeproof M3

Bridge Rectifier

1 x Screw M3 x 20mm
1 x Nut M3
1 x Washer shakeproof M3
1 x Washer flat M3

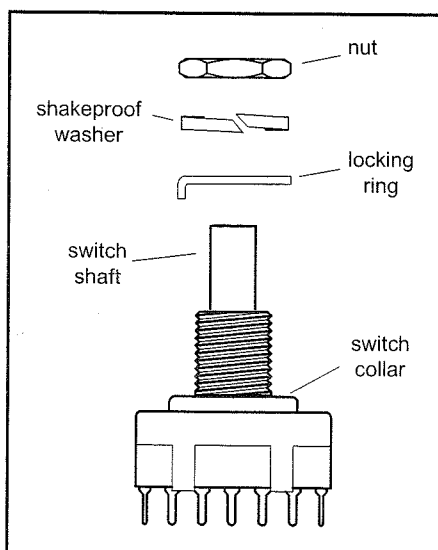
Transformer

4 x Screw M4 x 12mm
5 x Nut M4
5 x Washer shakeproof M4
1 x Solder lug (suit M4 screw)

Earth Lug (Rear Panel)

1 x Screw M3 x 10mm
2 x Nut M3
2 x Washer shakeproof M3
1 x Solder lug (suit M3 screw)

Figure 18: Programmable Rotary Switch



The rotary switch/s supplied within this kit can be programmed to switch between 2 to 12 positions. Please refer to the following for correct switch settings as required by the circuit.

Switch - S5 (1 pole / 10 position)

1. To prepare the rotary switch to lock for a 10 position travel, firstly remove the nut, shakeproof washer and locking ring from the switch collar.

2. Rotate the switch shaft fully anti-clockwise until it reaches the end of its travel.

3. Re-install the locking ring into the rotary switch collar making sure the tong section is aligned and inserted into the hole corresponding with the number "10". This now limits the switch travel to 10 positions.

4. With the locking ring in position carefully mount the rotary switch to the front panel using the nut, flat washer and shakeproof washer provided. Please refer to figure 14 for further details.

Switch - S3 (2 pole / 4 position)

Please follow the above steps (1, 2 and 4) when programming the rotary switch S3 for a 4 position travel.

Note, step 3 will now read, "Re-install the locking ring into the rotary switch collar making sure the tong section is aligned and inserted into the hole corresponding with the number "4". This now limits the switch travel to 4 positions.

Switch - S4 (4 pole / 3 position)

Please follow the above steps (1, 2 and 4) when programming the rotary switch S4 for a 3 position travel.

Note, step 3 will now read, "Re-install the locking ring into the rotary switch collar making sure the tong section is aligned and inserted into the hole corresponding with the number "3". This now limits the switch travel to 3 positions.

Charging Low Capacity Battery Packs

The charger as described is not designed to charge "Low Capacity" batteries less than 1.2Ah with voltages below 6 volts. (eg. battery packs consisting of "AA" & "AAA" cells.)

If you wish to charge such battery packs (of 6 volts or greater), the charge current can be reduced by simply replacing the 0.18uF MKT capacitor at pin 17 of IC2 with a 0.0018uF.

Assembly Notes



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