Switchmode charger delivers "fast charge" to NiCads

This project will charge your NiCad batteries to near rated capacity when you need them in a hurry. It can't overcharge either!

Jonathan Scott

HOW OFTEN have you suddenly needed a set of NiCads only to find that they have little or no charge left in them ? Fuses always blow when torch batteries are at a minimum; events happen when flashgun batteries have been completely exhausted and the 6m band opens just as your rig's portable power pack is getting unusably weak.

These are basic corollaries of Murphy's Law.

NiCads are strange things. They have many wierd and wonderful habits, like the 1% per day (very approximately) self discharge rate. All these factors take some foresight to circumvent, since the recommended charging procedure is the 10 hour rate for 14 hours. But even this apparently elementary approach has drawbacks. The batteries must not be left on indefinitely at this rate. About 24 hours is the recommended maximum duration. It is safe to leave them on the 50 hour rate indefinitely, but here they suffer from even greater apparent capacity reduction than on the 10 hour rate. What's more, this is worsened if they are recharged before being substantially discharged! All in all, a steady discharge cycle followed by just the right amount of charge delivered at a moderate rate gives the healthiest cells. However, this leads us back to the problem of them not being always on hand at full capacity or being damaged by continuous overcharging.

This is where the *fast charger* comes in. It seems that flat NiCads will not only tolerate a controlled fast charge but actually benefit from it in terms of recovery of apparent capacity.

The ETI-563 not only charges "but quick", as the Americans say, but turns itself off preventing "cooking" that will surely follow your forgetting the job. In addition, it achieves this with the inherent efficiency of a switchmode supply. Imagine your flashgun rejuvenated to near full power in just 15 minutes. The effective downtime of penlite cells is thus made bearable to all but the most impatient of persons. Finally the whole device runs so cool that the only heatsink is mounted internally, allowing the unit to fit in a space of only 80 x 150 x 150 mm — small enough for a camera bag or travelling case, at a pinch.

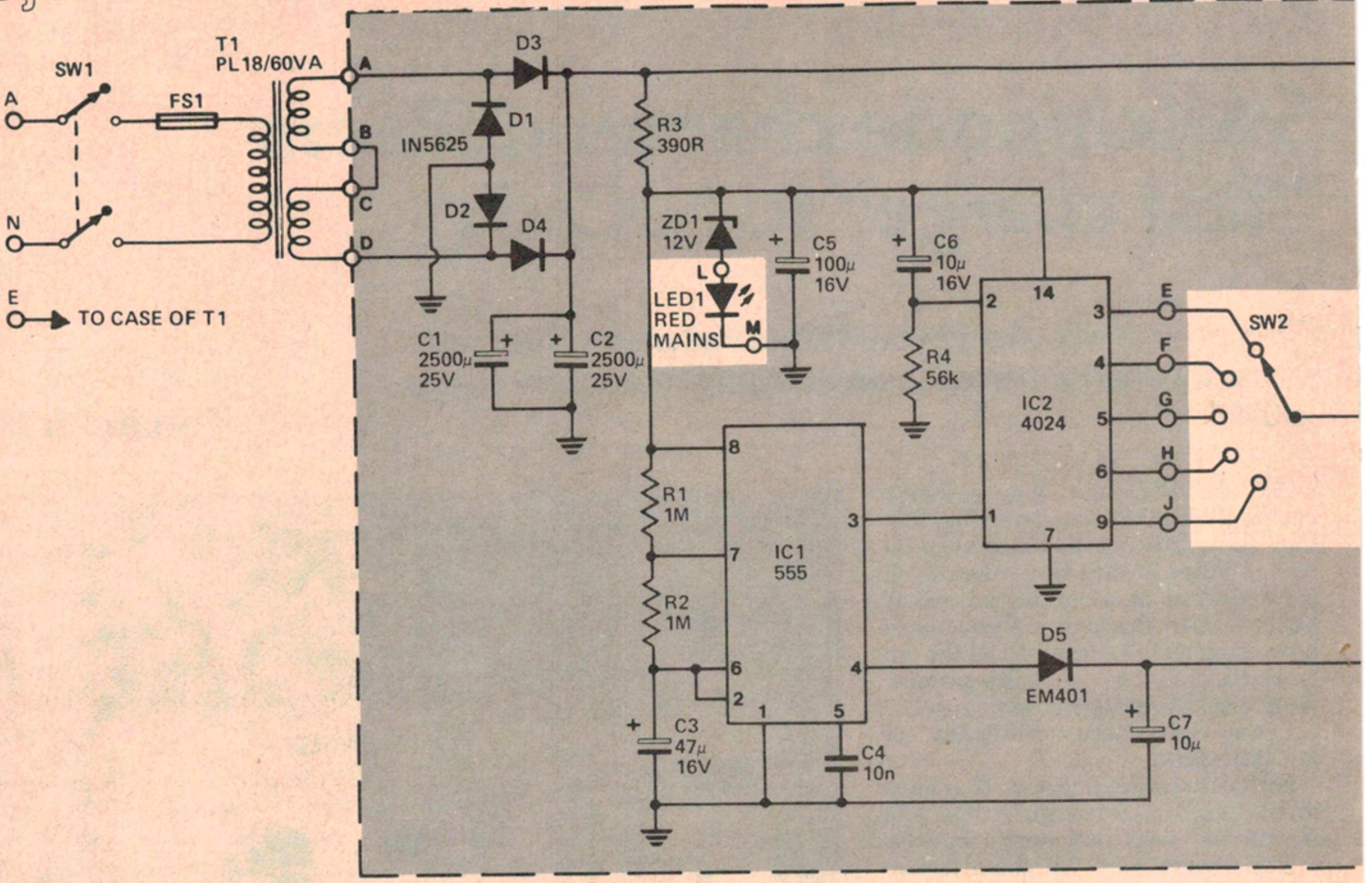
The completed project was housed in a smart PacTec case. Front panel is Scotchcal and will be available from the usual sources (see Shoparound on page 61).

Operation

The device is basically a constant current source delivering about 2.4A, controlled by a timer. The timer is reset at turn-on and permits the current to flow for a period after that. The period is chosen by the capacity selector switch. Thus, the supply is always delivering the maximum current, and merely finishes when the current delivered should have charged the batteries in question.

It is relatively simple to use. Firstly, turn the unit off — this allows the timer to reset. Connect the batteries — up to 12 volts of cells in series — across the terminals. If they are connected backwards they will see a very low impedance and may damage themselves discharging, or if flat they will be charged in the reverse direction, which is very unhealthy! The polarity LED will indicate if cells are connected correctly, but it will not detect voltage of less than two cells-worth. All of which adds up to saying that a double check is a good idea at this point. Next, select the capacity, setting the duration of the charge. Then, turn on. When the due time has elapsed the 'charge' LED will go out, indicating that the unit has shut off.

The charger delivers slightly more than the capacity of the battery. This is designed to allow for the inefficiency of the recharging process; i.e: it takes 14 hours at the 10 hour rate to fully charge up a cell under normal circumstances so ▶



it will take more than an hour at the one hour rate — in fact, more like 1½ hours. The faster you go, the worse the efficiency. If you are not in too much of a hurry, it is a good idea to give a second burst at half capacity later on, to ensure complete charging; though *be careful*, as most NiCads will not like more of a burst at one time than the unit delivers.

For example, let us assume your 2 Ah NiCad torch is quite flat — you left it on last night (absent-minded twit!). So you hook it up and set for a 2 Ah charge. One hour later it turns off. About 2.4 Ah of charge has gone in in one hour, which is all that is likely not to upset the cells. You could pack it up in your camping bag now, as it will have something like 60% charge. However, if you aren't in a big hurry, when you come back two hours later, you put it on again for a 1 Ah (½ hr) charge. At worst, it will then be 90% or so charged, so that's OK.

As you can see, it is alright to give the batteries a second run provided it is spaced some time away from the first. It is alright also to charge batteries that are not fully exhausted. It is unwise to just regularly fast charge without any use in between, or to deliver more than the correct capacity charge in one hit. Similarly it is alright to deliver a half capacity charge to a cell you know to be

HOW IT WORKS

Looking at the circuit, it may be divided into several sections with simple discrete functions: An unregulated dc supply consisting of SW1, T1, D1-D4, C1 and C2; a timing circuit made up of IC1, IC2, Q1 and associated components; the actual switchmode circuit comprising Q4, D6, L1 and surrounding components; the supply controlling circuitry involving Q2, Q3, Q5 and R15. There are also three LED function indicators to give the user some idea of what is going on inside. Each of these sections will be treated in turn.

The unregulated supply is fairly conventional, delivering between 17 V and 25 V at a maximum of about 3 amps. It must be capable of briefly delivering the 2.5 amps starting current required by the regulator controller. Diodes D1 to D4 could in fact have been 1A types, but they would be slightly overtaxed at turnon and thus, in the interests of reliability, 3A types have been specified.

A regulated supply of about 13.7 V is provided for the ICs by R3, C5, ZD1 and LED 1. In this position, LED 1 serves to indicate that the mains voltage is applied and is sufficient to run the unit — if the line voltage falls, LED 1 will dim or go out, indicating an 'unhealthy' condition.

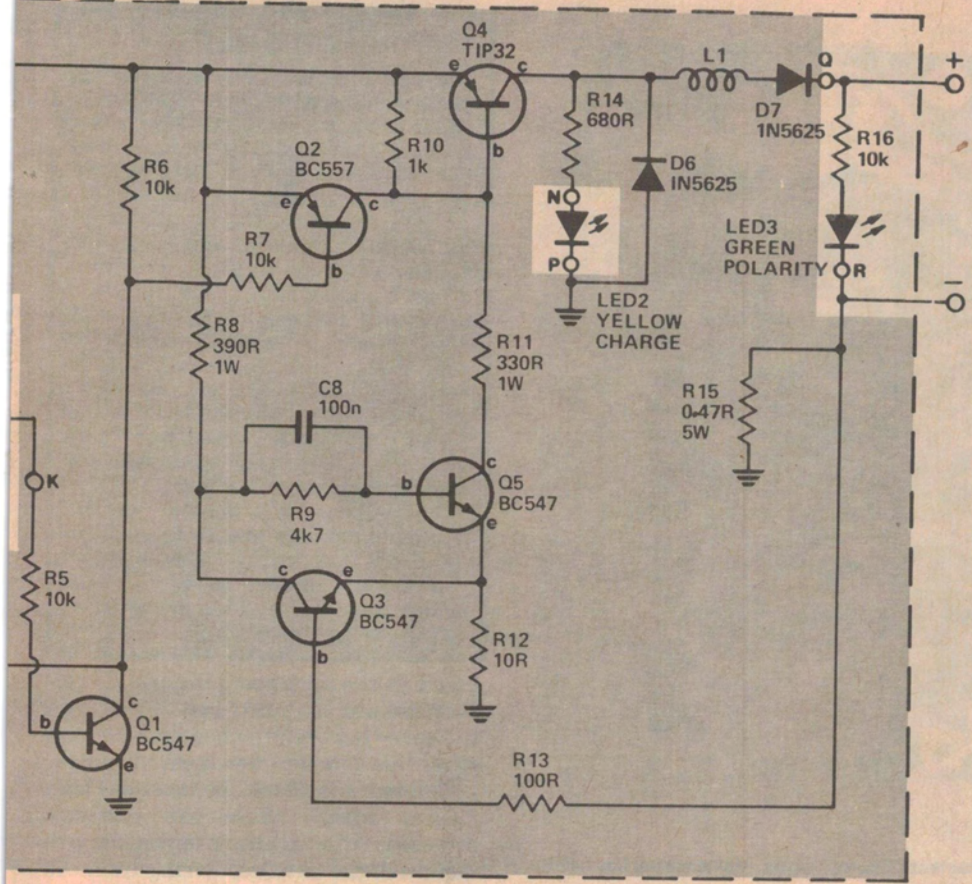
The electronics will withstand the situation indefinitely. However, if the line voltage is very low the current delivered may not reach the correct level for charging (2.4A) and the unit will consequently not be able to deliver the correct charge to the cells being charged at the time.

IC1 is connected as an astable multivibrator with a period of around 110 seconds. IC2 is a seven-stage binary counter. C6 and R4 ensure that, at turnon, the counter is reset to zero. The five, more significant, outputs are made available on the five contacts of SW2. Due to the resetting, no matter which position SW2 is set to, the base of Q1 is initially held low and so it is turned off. However, C7 holds its collector low for a fraction of a second. This has the effect of momentarily holding Q2 on. The purpose of this will be pointed out later on.

Once C7 charges up to rail potential via R6, pin 4 of IC1 is no longer held low and so IC1 is free to commence oscillation. It oscillates until sufficient pulses are counted by IC2 to send high the output selected by SW2. Just how many pulses this represents is a function of which output was selected, and hence SW2 defines the duration of the timer interval.

When the selected output does go high, Q1 is turned on, Q2 is turned on and IC1's reset line is held low, inhibiting further clocking of the counter, IC2.

When Q2 is turned on, it diverts any possible drive current from the base of Q4, ensuring that it is held off and that no current is passed from the unregulated supply to the load. Q2 also holds Q4 off momentarily after initial power-up in order to give the transformer a chance to charge C1 and C2 without having to



— ETI 563

cope, at the same time, with the starting current of the main switching regulator circuitry.

Once the timer has run its course Q2 holds the regulator off, preventing any further charging of the connected cells. During charging (i.e: when Q4 is conducting) Q2 does not conduct and can be ignored.

When, a split second after turn on, Q2 isolates, Q3/Q4/Q5 are able to start regulating. Initially, Q3 will be held off via R13 and R15, and Q5 will be turned on by current flowing into its base via R8 and R9. Thus, it will draw current through R11 and turn Q4 on. Q4 will immediately saturate, raising its collector voltage to near rail potential. A current will build up through Q4, L1, D7 the load (consisting of the cells to be charged) and R15. The rate of current build-up will be limited by the inductance of L1. When this current builds up to about 2.5 A, 1.2 V will be dropped across R15. The current Q5 is drawing via the base of Q4 will develop about 0.5 V across R12, and thus the 1.2 V across R15 will be enough to turn Q3 on. When Q3 turns on it removes drive from Q4's base, turning it off. Since the collector load of Q3 is higher than that of Q5 it draws less current and the voltage appearing on their common emitter resistor, R12, drops a small amount, turning Q3 on harder.

Transistors Q3 and Q5 actually form a Schmitt trigger. Q5 now having been turned off, Q4 also turns off. The collapsing field in L1 tries to maintain the output current and, having no other path, conducts via D6, referred to as the "freewheel" diode. When the current in L1 decays sufficiently for the voltage across the current sense resistor, R15, to fall to the lower 'Schmitt' level of Q3/Q4, both these transistors again change state, and the circuit returns to the initial conditions.

The whole cycle repeats and the average load current is held constant. LED 2 turns on whenever Q4 turns on, and will glow more brightly when the switchmode circuit is running at a higher duty cycle. For those interested, this gives an idea of how much power is being delivered by the supply.

The power dissipation of the electronics will be substantially independent of the load current/voltage product. i.e: unlike a conventional regulator, the switchmode device does not dissipate a significantly larger amount of power when the load drops less voltage.

R16 and LED3 simply detect correct voltage applied across the terminals. Owing to the voltage drop of the LED, it will not detect a voltage less than about 2 V.

Reverse-connected batteries will see a low impedance in the regulator circuitry via D7, L1, D6 and R15 — so quite a large current may flow from the batteries if they have some charge left and the voltage is above several volts. The POLARITY indicator (LED3) should light, if more than 2 V is left in the batteries, before power is applied.

only half or slightly less used up — just don't overcharge badly or charge too long at the fast rate. The cells will get warm, but not burning hot, if all is well.

In fact, it's a good idea to have two chargers: a "standard" one, like the ETI-578 (June issue) for 'regular' use, and this one for "emergencies".

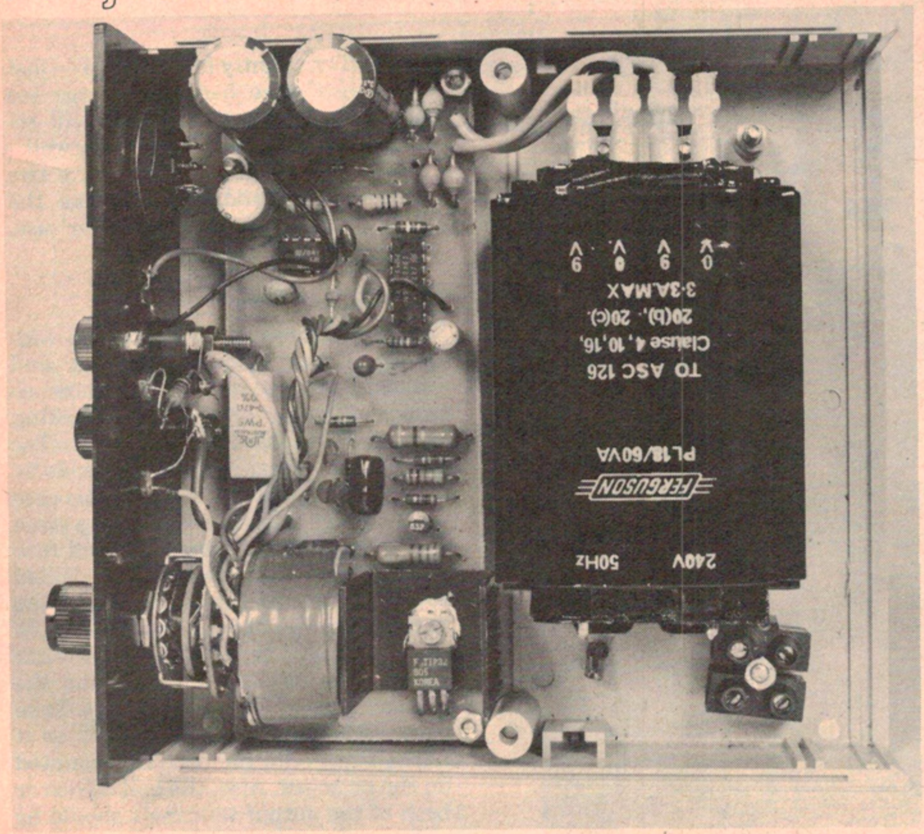
Construction

This project is relatively easy to construct if you follow the layout and wiring diagrams. It is best to commence construction by drilling and working the case. We housed the unit in a PacTec plastic case measuring 155 mm wide by 65 mm high by 160 mm deep. This case comes apart in four pieces — a top piece and a bottom piece plus front and rear panels. The rear panel was drilled to take a mains cable clamp and the mains fuse. The front panel contains the three LEDs, the capacity selector switch, the output terminals and the mains (labelled "START") switch. Take care with the placement of SW2 as it backs right onto the coil, L1, mounted on the pc board. Also, the bolt on one or both of the output terminals should be shortened to clear the components on the pc board. If you use a different mains switch to the one we selected, take care that it will clear the components on the pc board behind it. We chose a Dick Smith type, cat. no. S-1393, as it takes up little space behind the panel and is easy to operate.

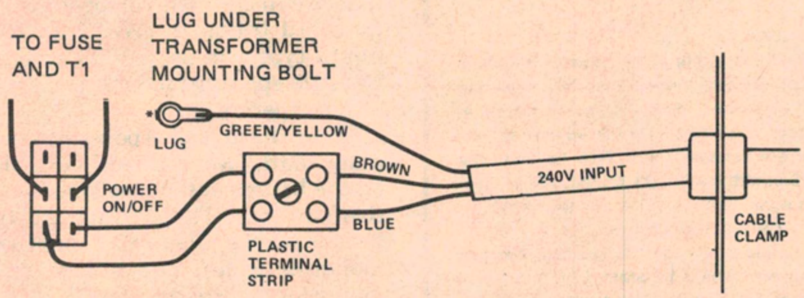
Using the unloaded pc board as a template, mark the mounting hole positions on the bottom of the case and then drill them to size. Then, using the transformer as a template, mark and drill its mounting holes, and a hole for the mains input terminal block.

The printed circuit board may be assembled next. Using the component overlay as a guide, mount all the resistors and capacitors taking care that you have the electrolytics and tantalums correctly oriented. Next, mount the diodes. Make sure you have them correctly oriented, as well. The TIP32 and its heatsink may be mounted next. Smear a little silicone grease on the metal tab of the transistor case and on the heatsink. Put the transistor leads in place but don't solder them yet and place the heatsink in position on the pc board. Bend the transistor over such that the hole in its metal tab and the holes in the heatsink and pc board line up. Bolt them all together. The transistor leads may now be soldered.

The coil, L1, may be wound and mounted next. Coil winding details are ▶



Internal view of the project, showing general placement of components. Mains wiring has been removed for the sake of clarity.



Mains wiring diagram

COIL DATA

The coil, L1, is not critical in value. It needs to have an inductance of at least 300 uH and present a minimum of internal resistance. It should also be physically compatible so that it fits in the space between the rear of SW2 and the heatsink on Q4.

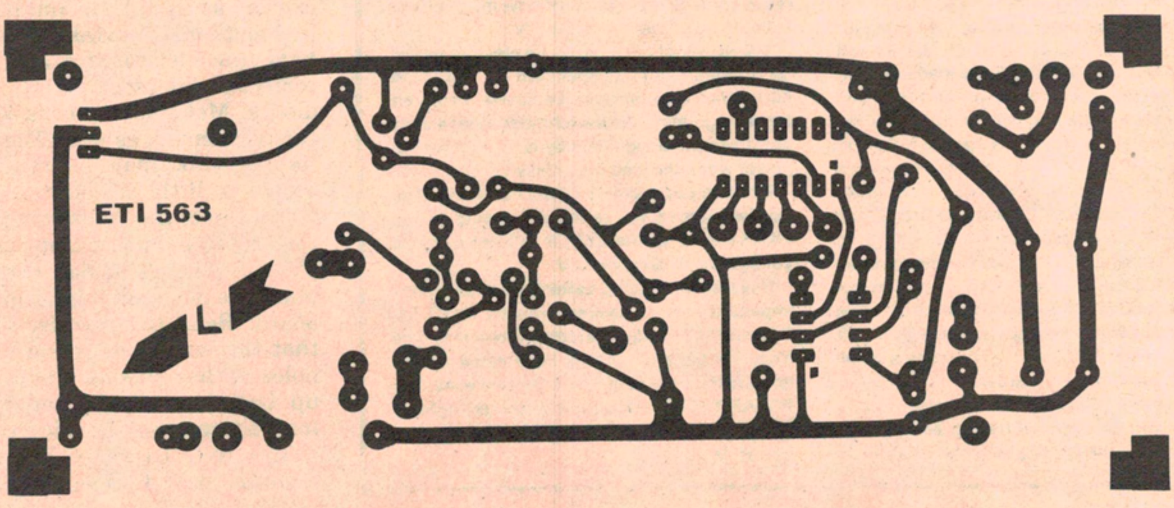
For the sake of simplicity, we wound ours on a standard Philips pot core former. The coil consists of about 120 turns of 1.0 mm diameter enamelled wire. The former has an internal diameter of 21 mm and is 19 mm deep. The internal resistance of the coil turned out to be about one ohm. This is really about the upper limit of internal resistance that the circuit will tolerate and no thinner gauge should be used. It gets quite hot, not surprisingly, as it dissipates more than Q4! Note that no core is used.

A free-wound coil wound with 1.25 mm diameter enamelled wire would doubtless run cooler. Inductors intended for use in loudspeaker crossover networks will also suffice, providing they have an internal resistance below one ohm.

given in the accompanying box. Whatever coil you use, make sure it will fit in the space between the heatsink and the rear of SW2 mounted on the front panel.

The two ICs should be mounted last. Again, ensure these are correctly oriented. After all the components are mounted, the external wiring from the pc board may be done. The connections to the transformer secondary are fortunately supplied with slide-on connectors. Cut two to length and attach them to their positions on the pc board. Note that, from the wiring diagram, the two *outer* terminals of the transformer secondary connections are bridged to connect the windings in series. Make up a short lead to effect this connection, as shown in the internal picture.

Wiring to SW2 is fairly straightforward. Refer to the overlay drawing for details. These wires may be colour-



coded to assist identification, or attached one at a time. Make sure they're all long enough. Wiring to the front panel components can only be done with the whole unit disassembled. The two wires from the pc board to the output terminals should be of a heavy gauge (10/010 as a minimum) as the output current is 2.4A. Note that R16 is mounted between the positive output terminal and the anode of LED3.

The mains wiring should be connected as shown in the wiring diagram. The rear of the mains switch should be protected by sleeving and/or a 'separator' made from heavy card. Mains wiring should be done in heavy gauge wire, such as 10/010, with suitably rated insulation. Some wires stripped from your mains cable would suffice. Make sure the earth lead to the transformer case is longer than the mains active and neutral input wires going to the terminal block. Sleeve the terminals of the fuse holder.

Check everything before you finally assemble the components into the case. Assemble the rubber feet before mounting the pc board and transformer to the bottom of the case.

Powering up

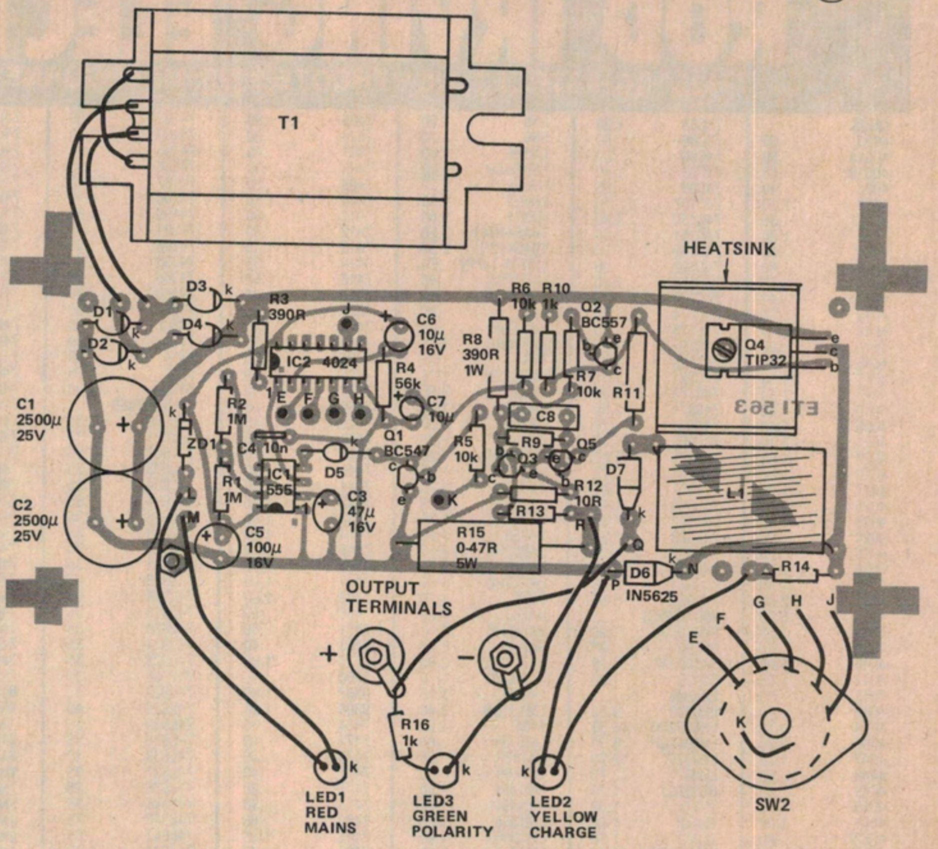
No electrical adjustment or alignment is necessary. Connect an ammeter in series with a discharged battery and connect to the output terminals — watch polarity. Select the minimum capacity (250 mAh). Plug in and turn the START switch on. The three LEDs should light and the ammeter should read close to 2.4 A. If all is not well, switch off and check your wiring again.

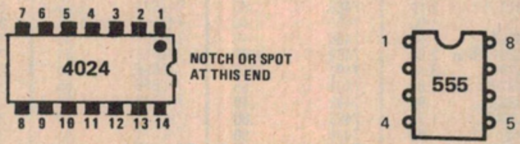
The charge times of the capacity selector switch should be checked. Should they be extremely short or long, this could be due to a large tolerance in C3. To compensate for this, R2 may be adjusted down to 560k or up to 1M5, say, to reduce or increase the time, respectively.

Using it

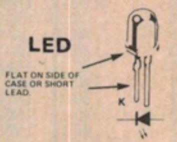
The unit should be switched OFF before connecting a battery. When you connect the battery, the green LED, marked POLARITY, should light if the battery has been correctly connected. If the battery is completely discharged, the LED will not light as it requires somewhat over 2 V to operate. In this case, carefully check the battery connections.

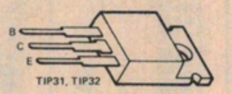
If all is well, turn the capacity selector switch to the appropriate position and operate the START switch. At the appropriate time later, the unit will switch off and your battery will be ready for use. ●

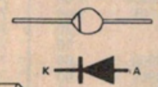


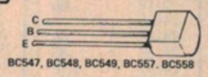


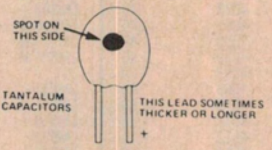
ICs viewed from top











PARTS LIST — ETI 563

Resistors	all ½W, 5% unless noted	IC2	4024
R1,R2	1M	Q1,Q3,Q5	BC547 or similar
R3,R8	390R	Q2	BC557 or similar
R4	56k	Q4	TIP32
R5,6,7,16	10k	D1,2,3,4,6,7	1N5625, 3 A diodes
R9	4k7	D5	EM401 or similar
R10	1k	LED1	TIL220R, or sim. (red)
R11	330R	LED2	TIL220Y, or sim. (yellow)
R12	10R	LED3	TIL220G, or sim. (green)
R13	100R		
R14	680R		
R15	0R47 (0.5 ohm), 5W wirewound		
Capacitors			
C1,C2	2500u, 25 V electro		
C3	47u, 16 V tantalum		
C4	10n greencap		
C5	100u, 16 V electro		
C6,C7	10u, 16 V tantalum		
C8	100n greencap		
Semiconductors			
IC1	555		

Miscellaneous

Case — PacTec 155 mm x 160 mm x 65 mm, plus four rubber feet to suit; Transformer PL18/60VA 2 x 9 V @ 3 A or similar; Fuse: 500 mA 3AG; Fuse holder to suit; DPDT switch (SW1): Dick Smith No. S-1393 or similar (see text) rated at 240 Vac, 1 A or more; Single-pole five position switch (SW2); Knob to suit SW2; Scotchcal front panel; one red and one black terminal; One two-way mains barrier strip connector; Mains cable clamp; Mains cable and three-pin plug; Heatsink: Dick Smith No. H-3402; Wire; Nuts, bolts etc.

Printed circuit board — ETI-563