An 'intelligent' battery charger

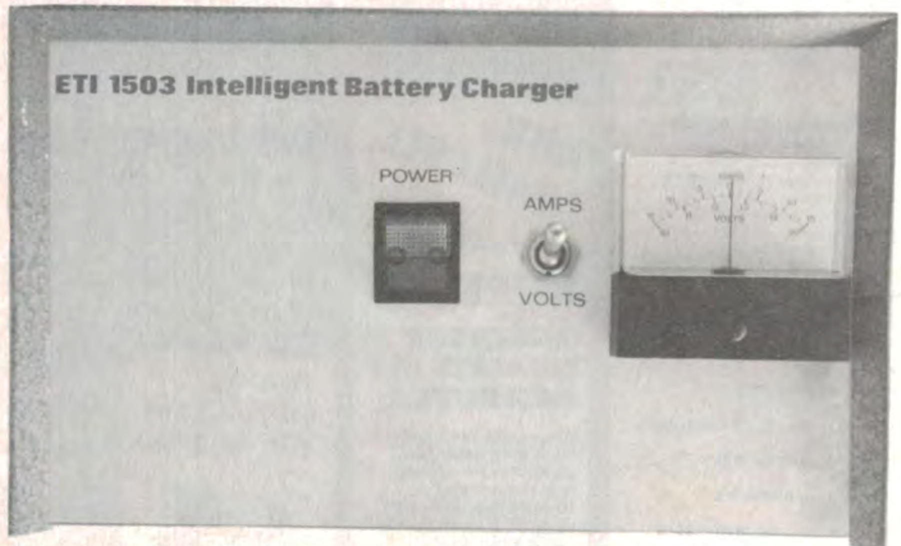
This is no ordinary battery charger. If you run a house alarm system, an amateur repeater or any electronic system with a 12 V battery 'back up' supply, this charger will keep that battery in a healthy state. It has other uses, too.

Jonathan Scott

IT IS PERHAPS too little known a fact that lead-acid batteries are not happy if left fully charged or discharged. They need to be used to stay in good condition. This is not, as a rule, a difficult situation when the battery is in a car, say, because it is called upon to run clocks or parking lights and to start the engine, and is charged when the engine is running. Some cars even arrange for the battery to be discharged to some extent when the engine is running and the lights are on (a mechanism into which we will not go just now). However, sad is the battery used as a burglar alarm power back-up system where it is continuously topped up, awaiting the moment when the mains fails. The battery fails too often before the mains supply!

As well as avoiding that situation, this charger maintains the 'spare' battery you keep in the garage for when that blighter of a P-plate driver son of yours borrows the Kingswood and leaves the lights on in the garage. Perhaps you charge it periodically at present, but the poor battery does not do any of the work that is necessary for its health and well-being.

Many amateur radio repeaters, popular on the VHF and UHF amateur bands for mobile operation with low power transceivers, employ (or should!) a battery back-up system. When a mains failure occurs the battery may be called upon to supply a pretty arduous load, cycling from a relatively low current in the listening mode to much higher currents when transmitting. To provide an operating time anywhere near the battery's rated capacity, the battery must be in 'good' condition. 'Float' or trickle charging will not ensure that.



The completed project was housed in an inexpensive yet attractive metal case, dressed up with a Scotchcal front panel label. A Scotchcal label could be used for the meter scale; however, University Graham Instruments will be supplying ready-made scales for these meters.

It is to overcome this sort of problem that we have designed this 'intelligent' battery charger.

This device monitors the state of charge and waits dormant until the battery is beginning to get flat. When it is low, but not in the deep discharge region, it turns itself on and charges the battery until it is full, whereupon it goes to sleep again until the battery is near exhausted, and so on. This has the disadvantage that there is an element of luck as to how charged the battery will be at any moment, but it is quite likely to be enough to start a car, for example, or to ring an alarm bell for quite a period. And it will be *just the same* in three months time.

In the burglar alarm back-up application this unit is ideal. It can also be used in conjunction with a load, such as the ETI-147 (Oct. 1980), to 'recycle' a battery to restore lost capacity, or perform tests on a battery in a simulated load situation (how long will it run parking lights?). These last two are the original applications for which it was designed.

Although we have not specifically included it in the circuit, it is a good idea to have a small load on the battery when it is connected to the charger. We have provided terminals on the unit from which to draw power, as we expect the unit will be powering an alarm system or similar. If it is used to keep a spare battery healthy we recommend that a load such as a 180 R, 1 W resistor or a one-watt light globe be connected across the terminals to give a constant but small current drain.

Before we get into the construction,

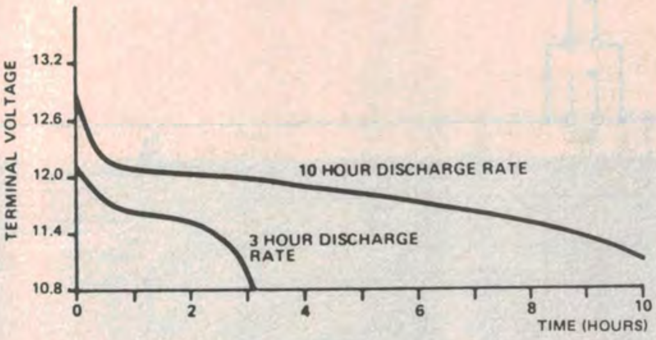


Figure 1. **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

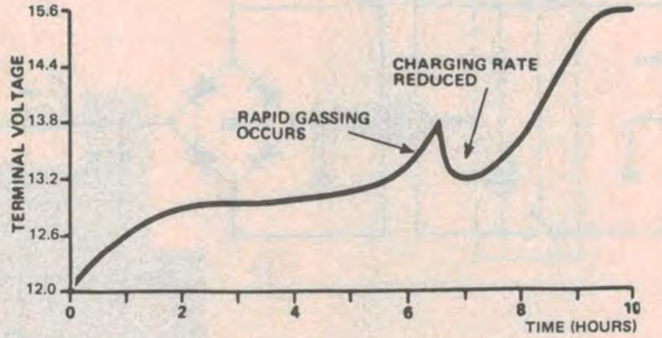


Figure 2. **Charging characteristics of a 12 V (nominal) lead-acid battery. The 'kink' in the curve near six hours is explained in the text.**

let's take a look at the characteristics of lead-acid batteries to gain an understanding of what happens when you discharge and charge them.

Lead-acid batteries

The fully-charged, no-load terminal voltage of a lead-acid cell is between 2.3-2.4 volts. This drops under load to about 2.0-2.2 volts. When discharged, the cell voltage is typically 1.85 volts. The amp-hour capacity is determined from a 10-hour discharge rate. The current required to discharge the battery to its end-point voltage of 1.85 V/cell is multiplied by this time; e.g: a 40 AH battery will provide four amps for 10 hours before requiring recharge. Note however that the amp-hour capacity varies with the discharge current. The same battery discharged at a rate of 10 amps will not last four hours; on the other hand if it is discharged at 1 amp it will last somewhat longer than 40 hours. The typical discharge characteristics of a (nominal) 12 V battery are shown in Figure 1.

The ideal initial charging current for the fully discharged battery (cell voltage under 2.0 V) should be about 20 amps per 100 amp-hours of capacity (i.e: 8 amps for a 40 AH battery). Once the electrolyte begins to gas rapidly, the terminal voltage will be around 13.8 volts and rising rapidly. At this point, the charging current should be reduced to somewhere between 4-8 amps per 100 AH until charging is complete.

At the end of charging, terminal voltage may rise to about 15.6 volts or more, but this decreases slowly after the charger is removed, the terminal voltage then usually reading around 14.0 to 14.4 volts (see Figure 2).

This project may be used with batteries having rated capacities from 4 AH to 100 AH, providing it is set up for the battery in use, according to the set-up procedure given at the end of the article.

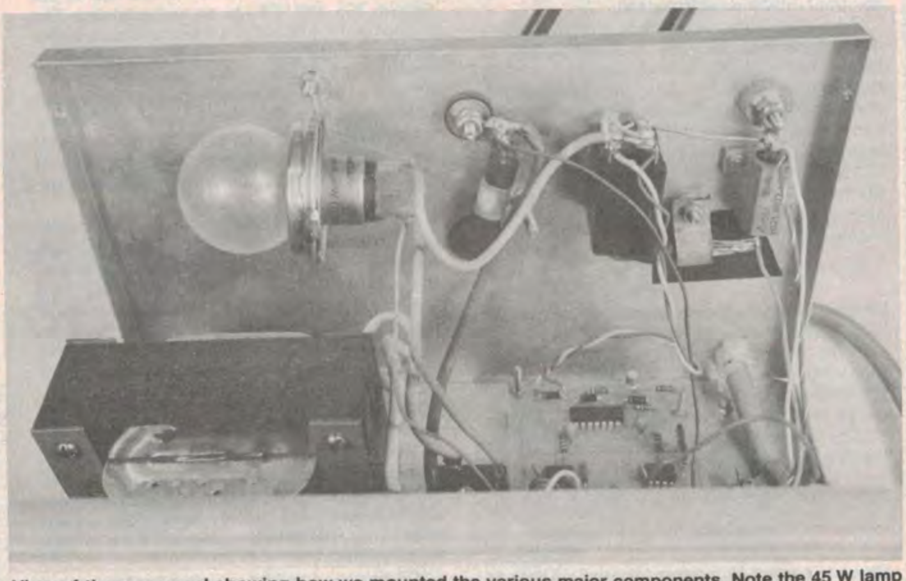
Construction

The component layout is not critical with this project, so there is no need to adhere strictly to the details which follow, provided you know roughly what you are about. The only constraint is that quite a lot of power (60-odd watts) is dissipated by the circuit as a whole and so the design needs to be fairly open and well ventilated.

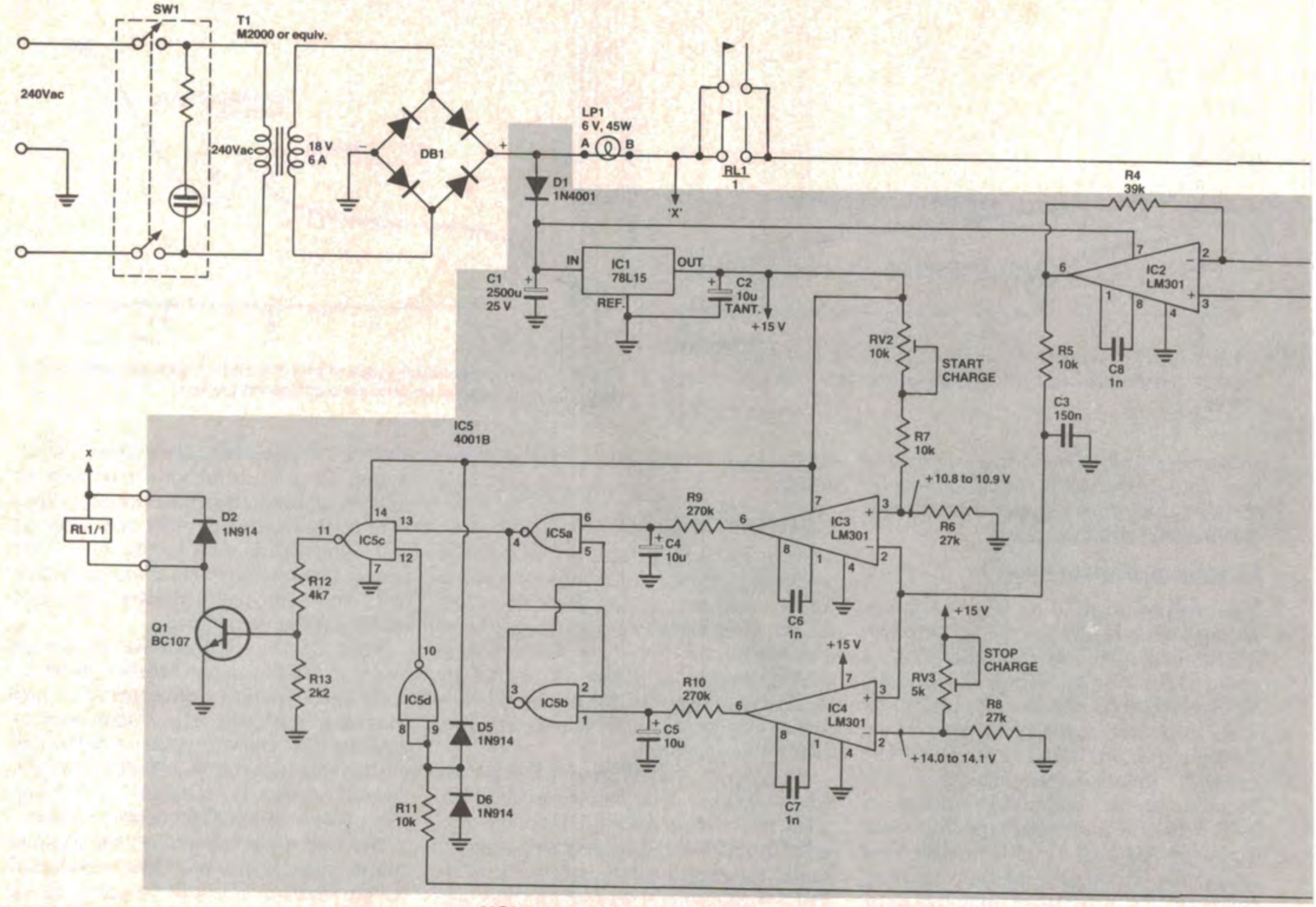
We used a 'K&W' model C1066 box which allows plenty of room and has good ventilation slots in the sides and top. The first step in the construction is to set the major components out inside the box where you will want them and check that there is enough 'room to move' and that wiring will be easy. Mark the positions for mounting holes with a soft lead pencil, then remove the bits and pieces and drill the holes. We used a 6 V headlight globe from Volkswagen for LP1, which we mounted by soldering some 18-gauge tinned copper wire to the metallic collar and forming bolt holes in the ends of the wire. This held it most satisfactorily about 10 mm from the rear panel of the case, just below a set of vent slots.

Next fit the components to the pc board as shown in the overlay, starting with the resistors and capacitors and finishing with the ICs. Take care to observe the correct polarity with the electrolytic capacitors, diodes and ICs. Attach adequate lengths of hookup wire, where applicable, to the pc board.

Next, fit and interconnect the various components in the box. The metal-clad power resistor, R1, will be carrying up to 15 A or so at maximum and thus should be connected to the battery and the output terminals by short lengths of the heaviest cable possible. We used 6 mm-thick automotive starter-type ▶



View of the rear panel showing how we mounted the various major components. Note the 45 W lamp 'ballast'. The relay was glued in place between the two output terminals. The Arcol metal-clad resistor is mounted as close as possible to the positive output terminal.



HOW IT WORKS — ETI-1503

The overall function of the device is as follows: when the open-circuit potential of the battery falls to below about 10.8 volts the charger turns on, charging the battery until the potential rises to about 14 volts, whereupon it turns off the charging current and waits dormant until the cycle repeats.

Let us start by considering the conditions when a normal, partially charged battery is connected and the unit is dormant. IC2 in conjunction with R1 and the surrounding components are connected to determine the open-circuit voltage potential of the battery even though it may have a load drawing power. IC1's output is equal to the terminal voltage of the battery minus about 4 times the voltage across R1, times the reduction fraction of RV1; mathematically it is:

$$V_{out} = V_{battery\ terminal} - \frac{39k}{10k} \times V_{across\ R1} \times K$$

where K is the fraction between 0 and 1 determined by RV1

When a load current is drawn from the battery a voltage = $I_{load} \times R1$ is dropped across R1. With respect to the voltage at the junction of R1 and the battery (the reference for IC2) this potential is negative. By choosing K to be the correct value, which is:

$$K = \text{Internal Resistance of battery} \times \frac{1}{3.9} \times \frac{1}{R1}$$

$$V_{out} = V_{battery\ terminal} + I_{load} \times IR_{battery} = V_{open\ circuit}$$

Since K cannot, of course, exceed a value of one, the circuit will handle batteries with internal resistances up to 3.9 times R1, or about 85 milliohms. This should be adequate for all car batteries, but doubling R4 to, say, 82k, will enable batteries with up to 180 milliohms internal resistance to be used, and so on.

Having ascertained the function of IC2, let us now consider the action of the rest of the circuit. IC3 and IC4 act as comparators. The output of IC3 goes high when the battery open-circuit voltage falls to below 10.8 volts. This level is set by RV2, which compensates for offsets and component tolerances. The output of IC4 goes high when the open-circuit battery voltage rises to above 14 volts. This is set by RV3. These levels correspond to a battery at the ends of its healthy charge/discharge curve.

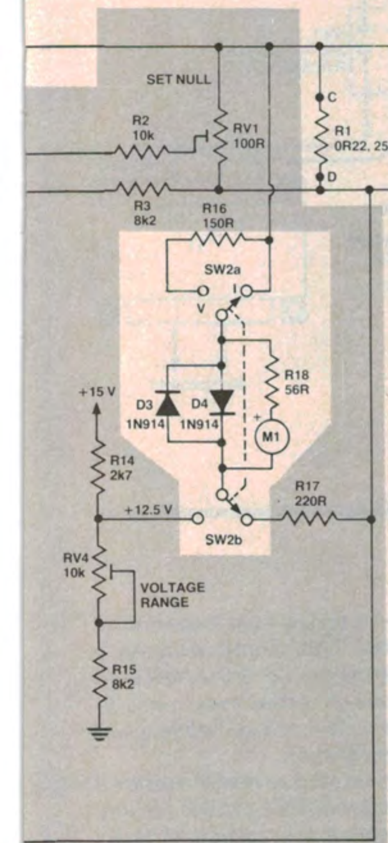
IC5 performs the logic necessary to control the relay. The first two gates (IC5a, IC5b) are coupled as a flip-flop. When the device is idle, the output of IC5a is high and the flip-flop is in the 'discharge' condition. The relay is held off by IC5c. If the battery is very flat, or if the wires are short-circuited, or the battery connected in reverse, IC5d holds the relay off irrespective of the flip-flop condition. When the battery is connected and is only normally discharged, and when the flip-flop is in the charge condition, IC5c turns Q1 on and the relay pulls in connecting the battery to the unregulated supply, again via R1 (permitting actual V_{out} to be measured) and via the light globe, which effectively regulates the current. (More on this in a moment).

IC1 simply provides a voltage reference of about 15 volts, as well as a regulated supply for IC3, IC4 and IC5. The meter and surrounding components provide a convenient 15-0-15 amp current meter and a 10-15 volt suppressed zero voltmeter, which reads the voltage delivered to the load.

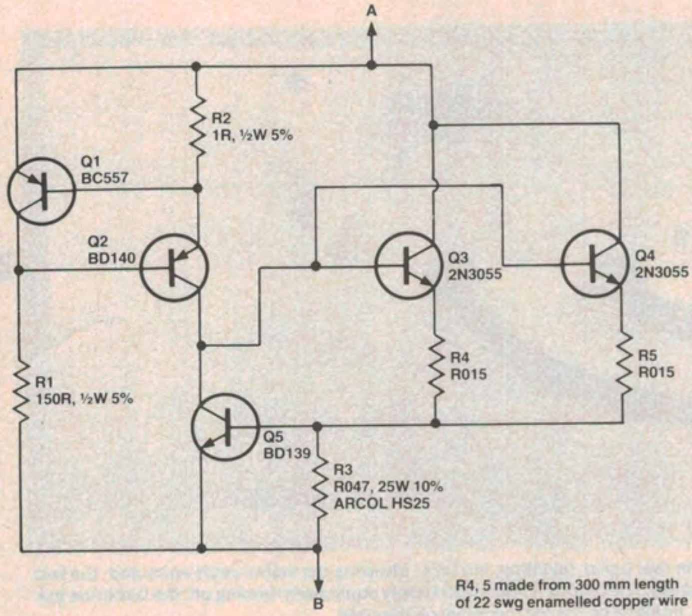
When the battery open-circuit potential falls to below the preset limit (10.8 V), IC3 toggles the flip-flop and RL1 pulls in. The charge current flows until the output of IC4 goes high, toggling the flip-flop back to the original state and turning the relay off. While charging, the current is effectively regulated by LP1 (a 6 V, 45 W light globe). The globe exhibits a characteristic of $I \alpha V^2$, which tends to hold the current at around 5-6 A after it warms up. Initial charging current will be higher. This method of current regulation is by far the cheapest, and causes no RFI, etc. In case anyone should experience trouble getting such a globe, such as might be the case if you do not have a Volkswagen parts place nearby (many old VWs have 6 V headlights), we have included a circuit which can be substituted. It is at once clear how much nicer is the globe approach!

LIGHT GLOBE SUBSTITUTE

Transistors Q1 and Q2 form a current source, feeding about 600 mA out of the collector of Q2. This turns on Q3 and Q4 until 0.6 volts is dropped across the R047 resistor, R3. At this point, Q5 turns on and removes the excess drive current from Q3/4, regulating the current in this fashion. The two R015 resistors, formed by about 300 mm of 22 swg each, ensure that Q3 and Q4 share the load roughly equally. Q3 and Q4 must be mounted on a suitable heatsink.



The circuit is fairly straightforward. The M-2000 transformer (T1) is rated to deliver 6 A at 18 V. However, it will deliver more than twice the output current for short periods, without distress, and we've taken advantage of that. The secondary voltage loads down somewhat, but that's been taken into account. Note that the relay has its contacts paralleled.



Circuit of the light globe substitute.

cables, which ran to the bolt-on battery terminals, rather than the alligator clips usually found on battery chargers and jumper leads. This minimised resistance and hence voltage drop with heavy load currents. The voltage sensing circuitry expects a low resistance path to the battery, so this arrangement is by far the best.

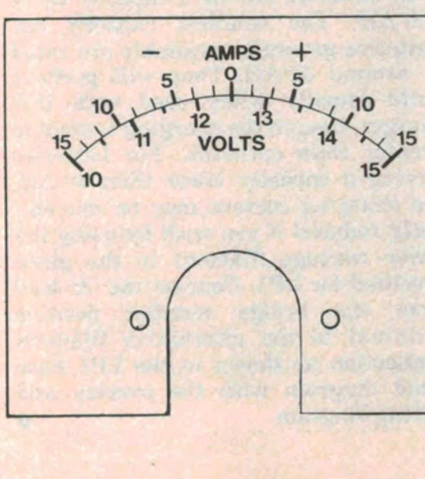
The leads connecting transformer, diode bridge, lamp and output terminals need to be fairly heavy, but not so heavy as the battery leads — ordinary automotive hookup wire (32 x 0.2 mm) or 1.5 mm tinned copper wire in spaghetti is quite adequate.

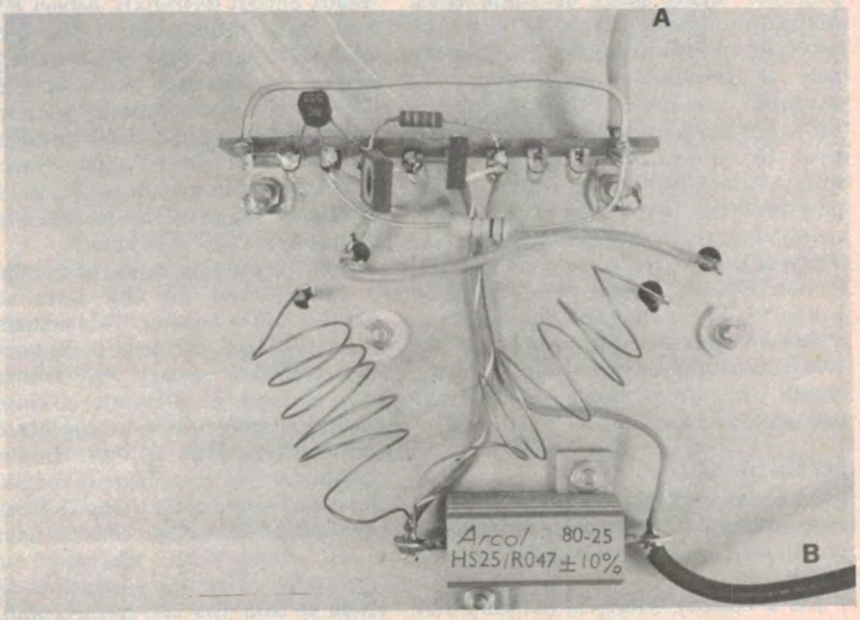
Follow the interconnection diagram to complete the circuit. If you like, a large and chunky bezel can be fitted to an appropriate part of the front panel so that it is illuminated by the globe when the unit is charging.

We felt this to be a little superfluous as light streams out of the ventilation slots!

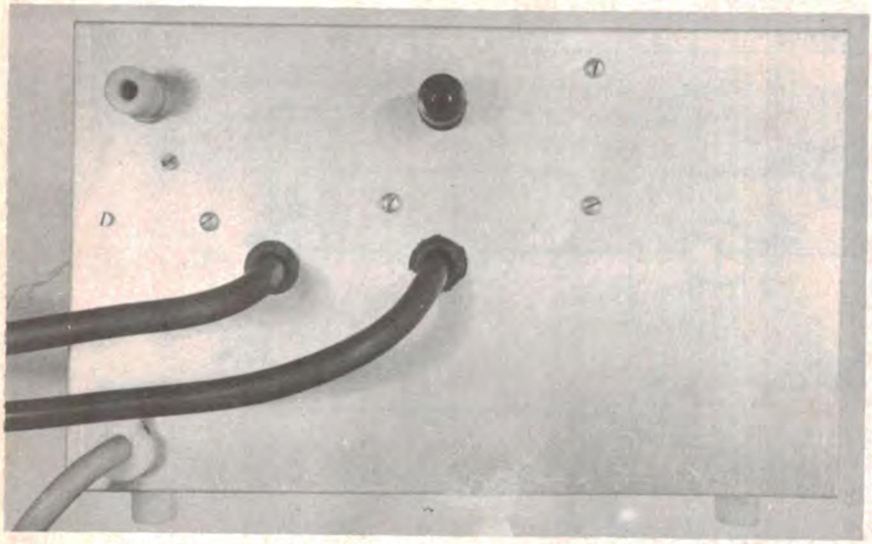
The mains wiring should be installed ▶

Full-scale artwork for the TD-66 1-0-1 mA meter. University Graham Instruments will be supplying meters for this project with this scale fitted.

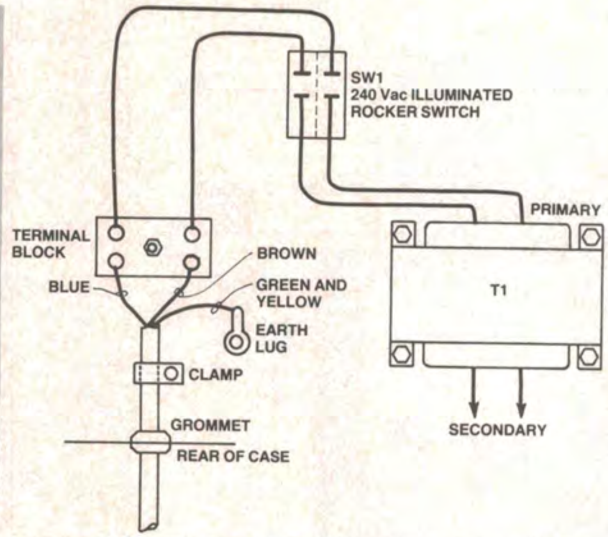




Construction of the light globe substitute circuit. Layout is not critical.



View of the rear panel (exciting, isn't it!), showing the mains cable entry and the two battery cables. The output terminals to supply equipment running off the batteries are at the top, positive on the left, negative on the right.



Mains cable wiring. Be sure to sleeve all exposed connections for your own protection.

with care, the mains input lead being physically 'shielded' from the pc board by a cardboard 'screen'.

For those people with no access to a VW dealer or other source of suitable 6 V globes, we have provided a tested current regulator circuit. We constructed ours using a tag strip which bolted neatly on to the power transistor collector connections (see pic, p. 41). This is a last resort, as it is more costly and less easy to install than a simple lamp, and demands some sort of careful heatsinking. We built ours on a separate small sheet of 1 mm thick aluminium, though there is no reason why you should not use a panel of the box if physically convenient. We mounted two pre-drilled heatsinks to the transistors to dissipate most of the heat. Be sure to fit the 2N3055s carefully, removing burrs which might puncture the insulating washers and using adequate thermal compound. The value of the two R015 resistors (R4, R5) is not critical, though care should be taken to ensure that they are equal in value as their function is to make the two transistors share the load. We made them with about 300 mm of 22 swg enamelled wire each.

Setting up

Once construction is completed, the unit may be set up for correct operation after you have carried out a *thorough* wiring check.

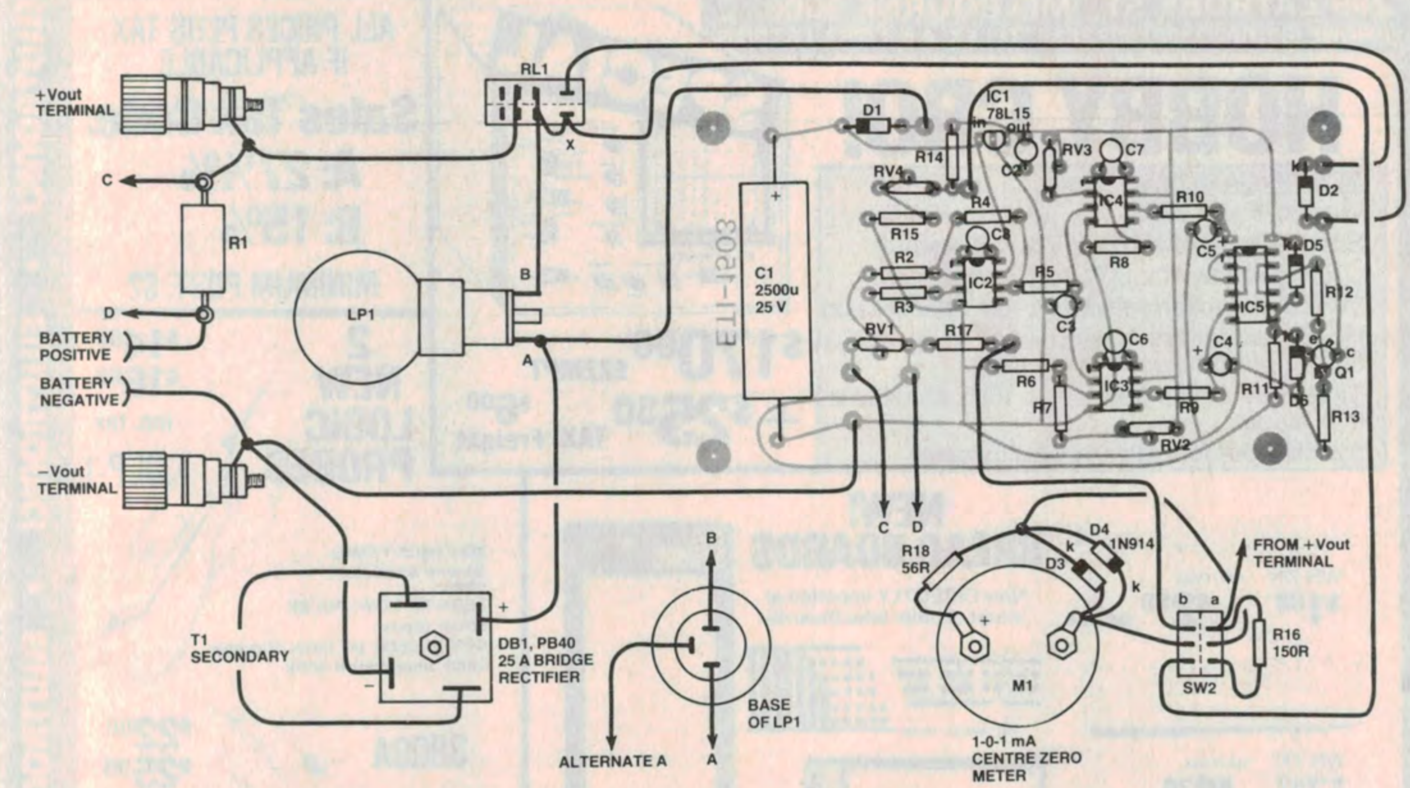
Fit a battery which is not very flat and turn the unit on. It may come on in the charge mode or it may be dormant, depending on the actual battery terminal voltage. To set the charger up you will need a multimeter with a sensitivity of at least 20k/volt.

First, operate the meter switch so that the meter reads volts (V). Connect your multimeter across the output terminals on the rear of the case, set it to read volts, and adjust RV4 so that the front panel meter reads the same voltage as the multimeter. Once RV4 has been adjusted, connect your multimeter (still on the same range) between pin 2 of IC4 (multimeter positive lead) and 0 V (black output terminal). Adjust RV3 so that your multimeter reads 14.0 to 14.1 volts here. This adjusts the point where the charger turns off ('STOP CHARGE'). Next, connect your multimeter between pin 3 of IC3 (multimeter positive lead) and 0 V, and adjust RV2 to obtain about 10.8 to 10.9 volts here. This sets the point where the charger turns on ('START CHARGE').

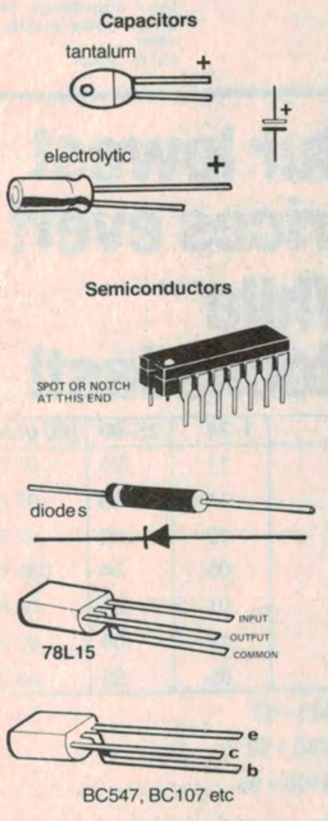
Finally, the unit needs to be adjusted to compensate for the internal resistance of the battery. This adjustment is simple, but will need to be done for each different battery with which the unit is used. If the unit is charging initially it may be best to toggle it off for convenience. This is most easily accomplished by momentarily connecting the positive end of C5 to the 15 V supply ('out' pin of IC1). Next, connect a load of a few amps to the charger's output terminals, either via a switch or flying leads so that you can connect and disconnect it. Then adjust RV1 so that no change in voltage occurs on the output of IC2 (pin 6) when the load is connected or disconnected. This should not be done with a flat battery — i.e: if the unit goes to charge mode at initial switch-on, let it charge for a few hours before completing the calibration.

Strictly speaking, the recalibration of RV1 does not need to be redone for any new battery connected, especially if the battery is just going to be left alone and is not intended for back-up work, such as a burglar alarm battery. The internal positive lead resistance will be roughly similar for similar capacity batteries, so this can be neglected if you are only leaving the battery on for a short while, as might be the case if you transfer the car battery onto the charger for a day or a few days. However, RV1 should be recalibrated if the installation is to be considered permanent or if the batteries are very different in capacity.

The charger was designed to be used with batteries having a capacity up to 100 AH. The smallest capacity car batteries generally available are rated at around 32 AH. They will perform quite happily when used with this charger, though the charging current is greater than optimum. For batteries having a capacity lower than 40 AH, the charging current may be conveniently reduced if you wish by using the lower wattage filament in the globe specified for LP1. Connect the 'A' lead from the bridge rectifier positive terminal to the alternative filament connection as shown in the LP1 Base Lead diagram with the overlay and wiring diagram. ●



COMPONENT PINOUTS



PARTS LIST — ETI-1503

Resistors all ½W, 5% unless noted

R1	R022, 25 W (Arcol, metal clad type)
R2,R5,R7,R11	10k
R3,R15	8k2
R4	39k
R6, R8	27k
R9,R10	270k
R12	4k7
R13	2k2
R14	2k7
R16	150R
R17	220R
R18	56R

Capacitors

C1	2500u/25 V electro.
C2,C4,C5	10u/16 V tantalum or RBLL
C3	150n
C6,C7,C8	1n ceramic

Semiconductors

D1	1N4001 or similar
D2-D6	1N914 or similar
DB1	25A bridge rectifier
IC1	78L15 3-terminal regulator
IC2,IC3,IC4	LM301
IC5	4001
Q1	BC107, BC547 etc

Miscellaneous

RV1	100R trimpot
RV2, RV4	10k trimpot
RV3	5k trimpot
M1	1-0-1 mA centre-zero panel meter
RL1	12 V SPST relay with 10 A contacts or DPST with 5 A contacts.
LP1	6V, 45 W or 50 W Volkswagen headlamp globe
T1	240 V to 17-18 V transformer, 6 A secondary (i.e: DSE M-2000)
SW1	Rocker switch, 240 Vac rated with neon illumination.
SW2	Spring-return action DPDT toggle switch

Case — 255 x 160 x 160 mm or similar (e.g: K&W Series C1066); ETI-1503 pc board; wire; mains cable clamp, mains lead and plug; battery cables and clamps; one red and one black heavy duty terminals.

Supplementary parts — substitute for LP1

Q1	BC557 etc.
Q2	BD140
Q3,Q4	2N3055
Q5	BD139
R1	1R, 1 W
R2	150R, ½W
R3	R047, 25 W (Arcol, metal clad type)
R4,R5	see text.

Transistor insulated mounting components, heatsinks, nuts, bolts, etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$78 - $86

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.