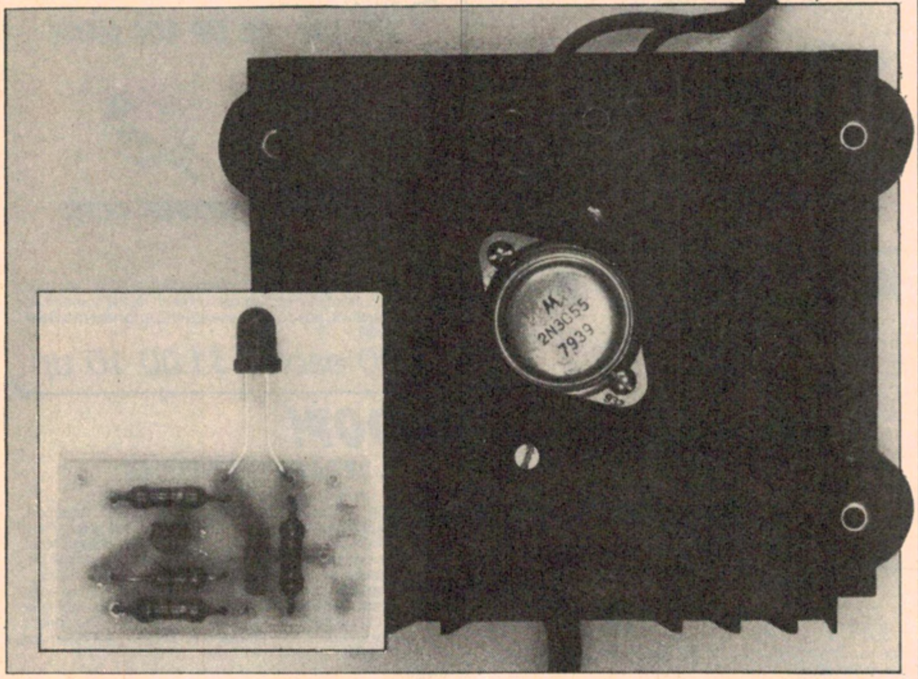
A *damn fast* NiCad battery charger



This project is specifically designed for modellers, photographers and hobbyists who make heavy demands on NiCad batteries quite routinely. There's nothing more frustrating than having your RC model run out of juice as it runs out of sight, or your flash run out of flash at an inopportune moment. If you use NiCads and need a charge — but quick — this project is for you!

Jonathan Scott

SMALL Nickel-Cadmium cells are often employed to replace frequently-used dry cells because they work out cheaper after a lot of recharges, and also because they save you a lot of walking to the corner store to purchase replacements.

There are, however, some properties of these types of cells which enable them to perform tasks other batteries cannot. Most notably, they have a lower internal resistance for a given cell size: A typical penlight NiCad has twenty times less internal resistance than its equivalent dry cell. This means that a lot of power can be drawn from them in a short space of time. They can thus perform a task which demands lots of power over a short period out of a small set of cells. There is a price to pay for this; namely, short cell life. They also exhibit a low total ampere-hour (Ah) capacity under fast discharge conditions.

The most notable use for these properties is the powering of models, particularly aeroplanes and racing cars. Such devices are expected to weigh little and develop a lot of engine power over a short space of time. A set of dry cells simply cannot achieve this. An electric aircraft will typically carry one or two cells and flatten them inside three minutes; a land craft may carry five or so large cells and flatten these inside fifteen minutes. Of course, the cells suffer a great deal for this kind of treatment and tend to expire after ten to twenty uses in the three minute case, or twenty to fifty uses in the ¼-hour case. There are two upshots of this; firstly, the user typcially wants to be able to recover and re-use the cells often in one day, and secondly, he does not really care if the recharge process thrashes the cells a lot, because their discharge is going to kill them fairly quickly anyway.

Toward the goal of charging cells quickly, ETI published a Fast NiCad Charger (Project 563) some time ago (July 1989). This was a mains powered device which incorporated a timer and some sophisticated electronics to make the unit fairly foolproof. While there is no doubt that this project found a home in many a modeller's kit, it was designed at the general level, rather than a specific market. There is a need for a somewhat simpler and yet more powerful charger, designed to run off a car battery or similar portable power reserve, capable of substantially more rapid a current delivery again. This project is it.

Let me stress once again that this unit is *not for genral use;* there is a detrimental effect on healthy cells when asked to deliver large currents over short periods. This project also does not have the foolproof nature (or the complexity) of the ETI-563 Fast Charger and can completely cook a battery if left on too long. It is designed for use out in the field where the cells it is charging are needed *damn* fast, and at any price. For a more detailed discussion of the merits and limitations of fast NiCad Charging, you are referred to the article accompanying the ETI-563 Fast NiCad Chrger.

Design details

The circuit is basically a constant current source, delivering a preset current (up to 8 amps) into a load, using a dc voltage source of about three volts more than the voltage which will be required by the load. It uses only common components and half watt resistors so can be constructed with a minimum of effort. Notably, no high power "current sense" resistor is necessary as these often tend to be tricky things to purchase or build — where do you get a 0.075 Ohm, 5 watt resistor? All that is necessary for its construction can be purchased from just about any electronics supplier in the country.

Construction

Before proceeding with the construction of this project there are two things which must be decided. The first is the current you wish to set the regulator to deliver, and the second is the scheme you wish to use to protect the circuit against reverse connection of the supply (typically a car battery). The former is a function of the ampere-hour capacity of the cells you will be charging.

I envisage that the regulator will be used in a fairly rugged environment for charging a single type of cell; therefore the current is set to a predetermined value, eliminating the cost and unreliability of a switch and set of resistors, not to mention the possibility that the switch will be miss-set in operation.

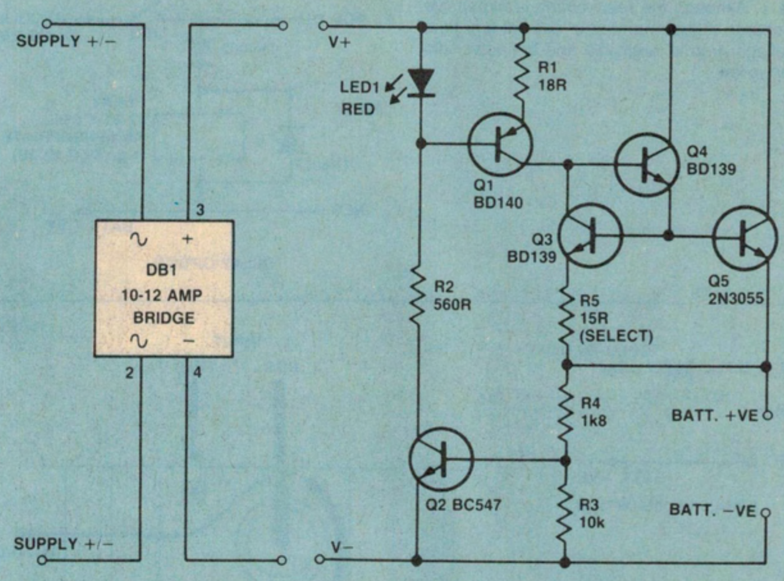
Should you wish to include one, there is nothing to prevent you adding a double or multiple throw switch and a selection of resistors to give a selection of current ranges, but I will proceed here assuming that there will be one current only required. (To effect range selection all that is needed is to switch the emitter resistor of Q3 using a toggle or rotary switch; a pot is not recommended, though a 100R wirewound type would be sufficient).

It seems from experience that the highest safe charge rate for a NiCad is around 4C (C is the cell's Ah capacity) or that current which equals the Ampere-hour rating multiplied by 4/hour. Thus, a 450 mAh battery should be charged for up to about 20-25 minutes at a time at just under two amps. An 1800 mAh battery would accept charging at just over seven amps.

The project described here is capable of up to eight amps guaranteed, and may be 10 A typical. The exact value depends upon many variables concerned with the particular parameters of the specific transistor used for Q5. For a 2N3055, as specified, I have given approximate values required for R5, but the exact value will probably need to be selected, as indicated in the circuit diagram. Fifteens Ohms gave 6 A, on my prototype. Eighteen Ohms gave 5 A and 12 Ohms gave 7 A. To get down to 2 A required 33 Ohms. Using three values as a guide, choose an initial value of R5, but remember that this value may have to be changed later.

The second thing to be decided, once you have chosen the current required, is the protection scheme. There are three ways you can tackle this. I think it would be foolhardy, to say the least, not to include some protection from reversed supply, particularly as the unit is to be used in a hurried situation in the field. The first method is a single diode, the second is to use a diode bridge, and the third is to use a relay.

Clearly, this decision will be influenced by the cell or battery voltage. A NiCad being fast charged drops up to 1.5 volts. The actual regulator section requires typically three (worst case four) volts 'overhead'. If you are using a car battery it can be expected to deliver almost 12 ▶



HOW IT WORKS — ETI 274

Referring to the circuit diagram, it can be seen that Q4 and Q5 form a Darlington series-pass regulator element. Q3 acts as a comparator, while Q1 acts as an active current source load for Q3. Q2 provides short circuit foldback limiting, while LED1 indicates correct operation and provides a reference.

Initially, consider that there are a few volts across the battery connected to the ouput. Q2 is biased on via R4 and has a collector current of typically 15 mA or so. This current is set by R2. Assume that the supply is around 10 to 12 volts. Thus, Q1 will be biased on. If Q1 is in the active state it acts as a current source delivering approximately 55 mA to the collector of Q3 and base of Q4. Q4 and Q5 will be biased on and hence their combined collector currents will be delivered to the battery.

For a collector current of five amps, the internal resistances of a 2N3055 gives a base-emitter voltage not of the 0.8 V value which might be expected from an ideal exponential device, but more typically 1.2 volts. This circuit will use this internal b-e resistance, already allowed for in the transistor's dissipation specification, as the current sensing element.

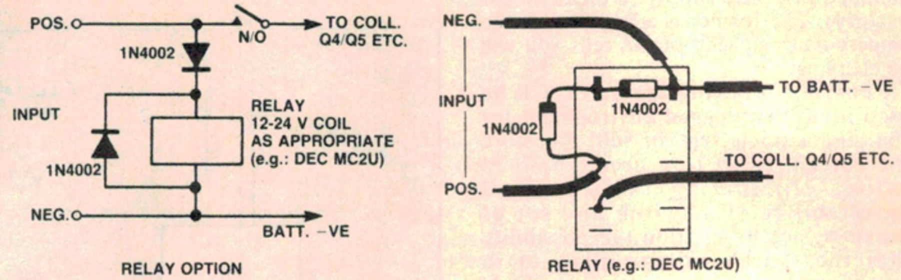
Now, recall that Q1 is delivering a fixed current to be divided between the base of Q4 and the collector of Q3. Q3, which is in close thermal contact with Q5, has a Vbe which is nearly the same as, and tracks that, of Q5. The voltage component of Q5's Vbe, which is due to its emitter current times the internal b-e resistance mentioned above, is substantially placed across R5. Hence, the collector current of Q3 is nearly a constant multiplied by the emitter current of Q5, the current delivered to the load (battery).

There is an equilibrium point where the current drawn by the load produces a collector current in Q3 which exactly leaves sufficient current left over from that suplied by Q1 to feed the base of Q4. Should the load current rise above this point the collector current of Q3 would rise also, removing some drive current from Q4, reducing the load current. Conversely, if load current falls, Q3 leaves more current for Q4, restoring the load current. Hence, current regulation is achieved. R5 affects the ratio of load current to Q3 collector current and so may be selected to define the load current at equilibrium.

Two further effects are utilised. Should the load voltage fall below about 1.1 volts, the level for one cell, Q2 will be biased off, extinguishing LED1 and shutting down the current regulator Q1. This reduces output current, effectively shutting the circuit down. This will occur should either a short circuit or a reverse battery connection occur on the output. It is thus not possible to reverse charge the cell(s) or to overheat the regulator by operating into a short. This shutdown condition is betrayed by the LED extinguishing. In addition, if the load voltage rises too high for the regulator to run properly, as is the case if there is a bad or open connection, Q1 will saturate, reducing the voltage across LED1, again extinguishing it. Thus, the LED indicates successful delivery of current to the load.

If a diode bridge is installed in the supply line it does not matter which way round the supply is connected. A single diode will simply shut the circuit off if connected wrongly, but drops about 0.8 volts, compared to 1.6 volts with the bridge. If neither of these voltage drops is acceptable, a relay may be used to protect the regulator from reversed supply. The regulator requires about three volts of overhead, so the protection scheme must be selected with the available supply voltage and the required load voltage in mind, as described in the text.

Figure 1. Although the relay option is expensive, it can charge a large number of cells at one time. The voltage drop is negligible and the power dissipation is low.



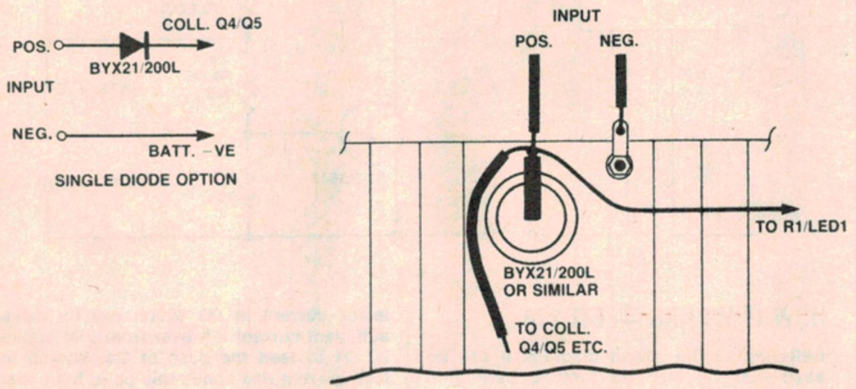


Figure 2. The single diode option is cheap, has a voltage drop of about 0.8 V and average power dissipation.

volts. Hence, it may be shown that a relay which drops negligible volts allows five cells in series (nominally a 6¼ volt stack) to be handled from one car battery, a single diode allows four, as does a bridge — just. (The sum here is V supply-4 divided by 1.5 for the relay, Vs-4.9 divided by 1.5 for the single diode, and Vs-5.8 divided by 1.5 for the bridge).

Although the bridge costs a little more than a single diode it allows you to ignore the polarity of the supply connections as the circuit effectively 'rectifies' the input to give the correct polarity irrespective of supply orientation. If you can afford the voltage drop, it is the best method, particularly as bridges of the appropriate power rating are simpler to mount and connect to than their equivalent diode counterparts. The relay option (see Figure 1) is expensive and is really only recommended for those situations where it is the only resort to obtain the capacity to handle the required number of cells. The supply can be up to 24 volts nominal, so this should not be necessary.

I recommend the bridge option as this seems the best and most convenient choice. It entails a few dollars more in cost than the single diode, but it is easier to mount and easier to use.

Having decided upon the circuit elements, the current to be delivered and the voltage into which it will be delivered, you are fixed. The next step is to figure out how much heatsink is needed. If you are using a 12 volt supply and delivering 6 A or less a '4"' heatsink is adequate. (These are generally rated to dissipate 2° C/W in still air). However, if the product of supply volts and current is in excess of about 70, a larger heatsink is to be recommended. Remember that the circuit may have to dissipate almost that figure in watts worst case, so it is a good idea to have the capability. In any case, if the 2N3055 case gets hot enough to boil water the heatsink is too small! (It is not unusual for it to get rather too hot to touch when working very hard, so don't let that worry you).

You are now ready to obtain the components and commence the actual construction. The first step is to drill the heatsink. If you are duplicating the prototype, follow the diagram here. Otherwise, you can set out the parts as you see fit. It is good practice to put the main heat disspiating element, the 2N3055, near the centre of the dissipating surface.

I used terminals on the output of the unit and had a fixed automotive grade ('heavy duty') cable for the battery connection, but you should use whatever connection will best suit your application. For instance, you may have some standard kind of plug to fit your models, or whatever, or perhaps you many want to use car battery bolt-on connectors on the input. Be sure to make provision to clamp any cables. Also remove any burrs and dags that could penetrate insulation washers on the transistors.

Next, fit the transistors and diode or bridge, etc, to the heatsink. Fit the terminals and/or clamp the cables in place. When all the parts that need to be secured to the heatsink have been bolted in, put the assembly aside. Now solder the four resistors and two transistors (Q7, Q2) to the small pc board, as shown in the overlay. This can be mounted either on the heatsink (if it's big enough) or inside a zippy box bolted to the heatsink.

Finally, interconnect all the components as shown in the wiring diagram. It is convenient if Q3/4/5 have been mounted close enough together to allow their leads to join directly. Resistor R5 is wired directly in place.

After carefully checking the wiring (remember that a mistake can easily incinerate the whole lot in one fell swoop) apply the supply. Confirm that the 'Batt + VE' terminal is indeed at nearly the full supply. Connect a load. If you have an old set of NiCads, or a headlight globe, use this instead of a good set at first. Measure the current being delivered. If it is too high, replace R5 with a resistor of larger value, or vice versa. You will be able to pick the correct value on the second or third attempt no matter how far out the original estimate. Check that either shorting the output or leaving it open causes LED1 to go out. If this is the case, all is well and you're set to go. ●

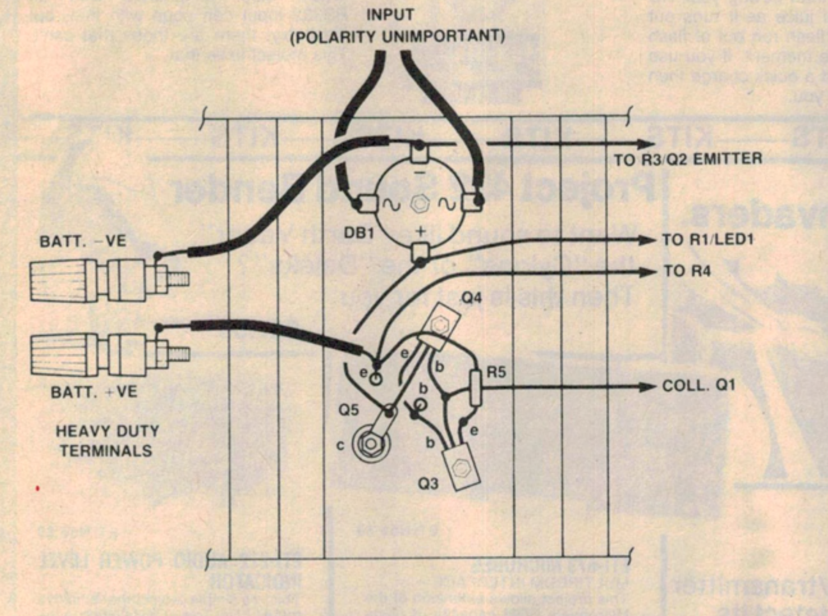


Figure 3. The diode bridge option costs a little more than the single diode but its advantage is that it can be connected in either way ignoring the polarity of the supply connections. It dissipates more power than the other options and has a voltage drop of about 1.7 V.

PARTS LIST — ETI-274

Resistors ....all ½W, 5%
- R1 ....18R
- R2 ....560R
- R3 ....10k
- R4 ....1k8
- R5 ....12-33R, see text

Semiconductors
- DB1 ....10-12 A bridge rectifier (PA40F or similar)
- LED1 ....TIL220R red LED
- Q1 ....BD140
- Q2 ....BC547, BC107
- Q3, Q4 ....BD139
- Q5 ....2N3055

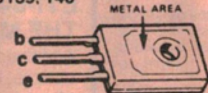
Miscellaneous
ETI-274 pc board; UB2 zippy box (if required) 60 x 113 x 196mm or similar; 100mm heatsink or larger; heavy duty terminals; heavy duty figure-8 cable (coded red/black); TO-220 transistor insulating and mounting hardware (two sets); TO3 mounting hardware; hookup wire — medium and heavy duty; nuts, bolts, etc.

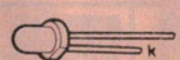
Price estimate $22-25

COMPONENT PINOUTS

BC547 etc

BD139, 140





LED, TIL220R

ETI-274 PCB