The Quad Charger

A constant current NiCd charger.

by Marion D. Kitchens K4GOK

Every ham I know uses NiCd batteries at one time or another. "Nicads" are nice, but they pose the never-ending challenge of keeping a charged set on hand. This often requires keeping a number of various battery packs or individual cells in ready-to-use condition. Most battery chargers are designed for one particular size individual cell, or for particular battery packs. It can be agonizing to have the wrong battery pack on the charger while the one needed is yet to be charged.

Finding the correct charger or setting a variable voltage charger to the proper voltage is an unnecessary hassle. A more useful charger would allow for charging several battery packs or individual cells simultaneously, and would accommodate battery pack voltages ranging from one cell up to eight or more cells; that is, 1.25 volts up to about 12 volts.

The Quad Charger described here was designed and built to take the hassle out of using NiCds. The unit as described provides charge rates for most common NiCds, and provides several trickle charge rates too. Since this unit provides a constant charge current, the output voltage automatically adjusts to that necessary for the battery or pack being charged. NiCds are charged based on the amount of current and the duration (time) that current is injected into the NiCd, so a constant current is a good way to charge them.

The Quad Charger will charge up to four different NiCd cells or battery packs at the same time. It is easy to build via the PCB layout provided, or via point-to-point wiring on perf board. The circuit is straightforward and without gimmicks or tricky adjustments.

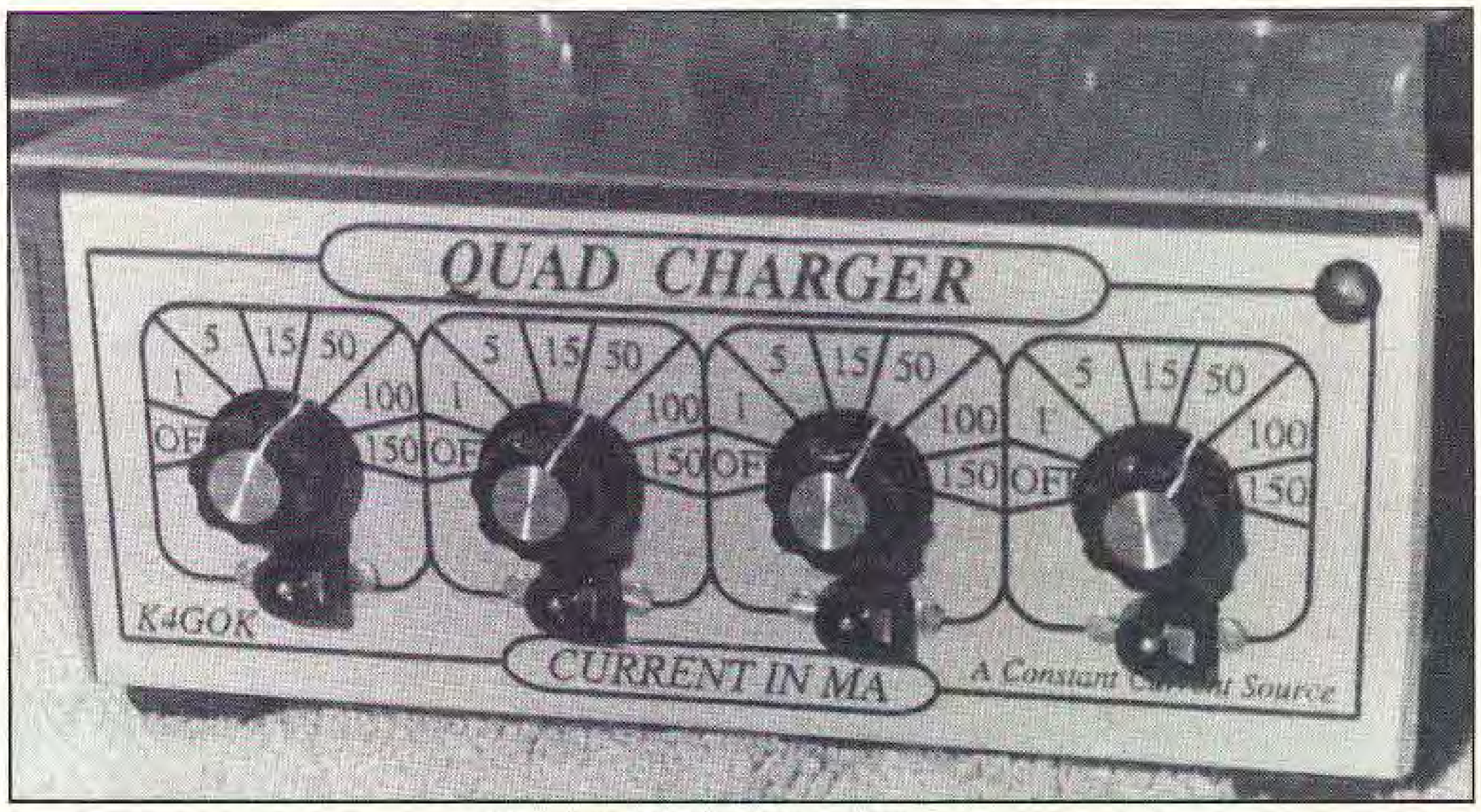

Photo A. Finished Quad Charger.

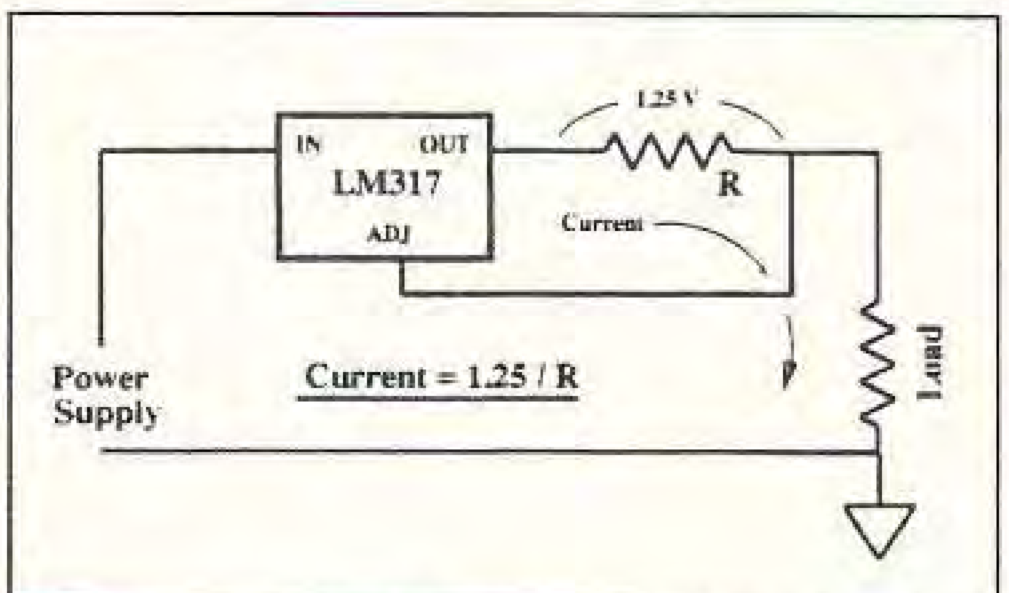

Figure 1. LM317 as a constant current source.

All parts are readily available from suppliers such as Digi-Key.

Theory of Operation

The versatile LM317 voltage regulator is readily usable as a constant current regulator by simply connecting the IC to a resistor. The LM317 is designed to maintain 1.25 volts between its output pin and its "adjust" pin. The electronics within the IC will react to assure that this condition exists at all times (as long as it is physically possible). That means you can put a resistor between those two pins and the LM317 will deliver a constant current through the resistor. The current will then be regulated by the IC in accord with Ohm's Law. All we have to do is connect the desired load, in this case the battery or pack to be charged, in series with this constant current.

Examine Figure 1. The voltage from the supply is applied through the LM317, through the resistor, and to the load. The internal circuitry of the LM317 maintains a constant 1.25 volts across the resistor. If the resistor is 125 ohms, the current will be 10 mA. If it is 12.5 ohms, the current will be 100 mA. Since the current in a series circuit is the same in all parts of the circuit, the load will also have a regulated, constant current. The value of that current will be determined by the value of the resistor.

Note that the current is independent of the load. The current through a single 1.25 volt AA cell will be the same as that through a 9 volt battery pack. And to the obvious question, yes, it is the same for a zero ohm load, i.e. a short circuit. (A constant current supply

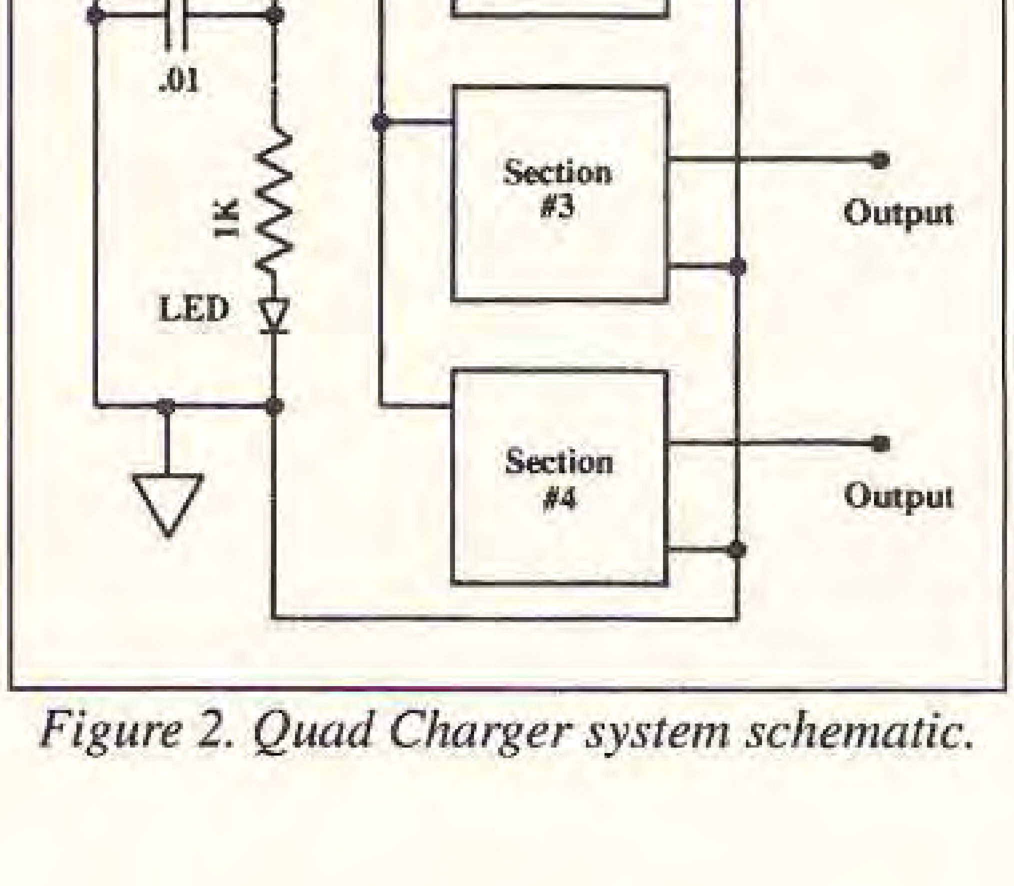

Figure 2. Quad Charger system schematic.

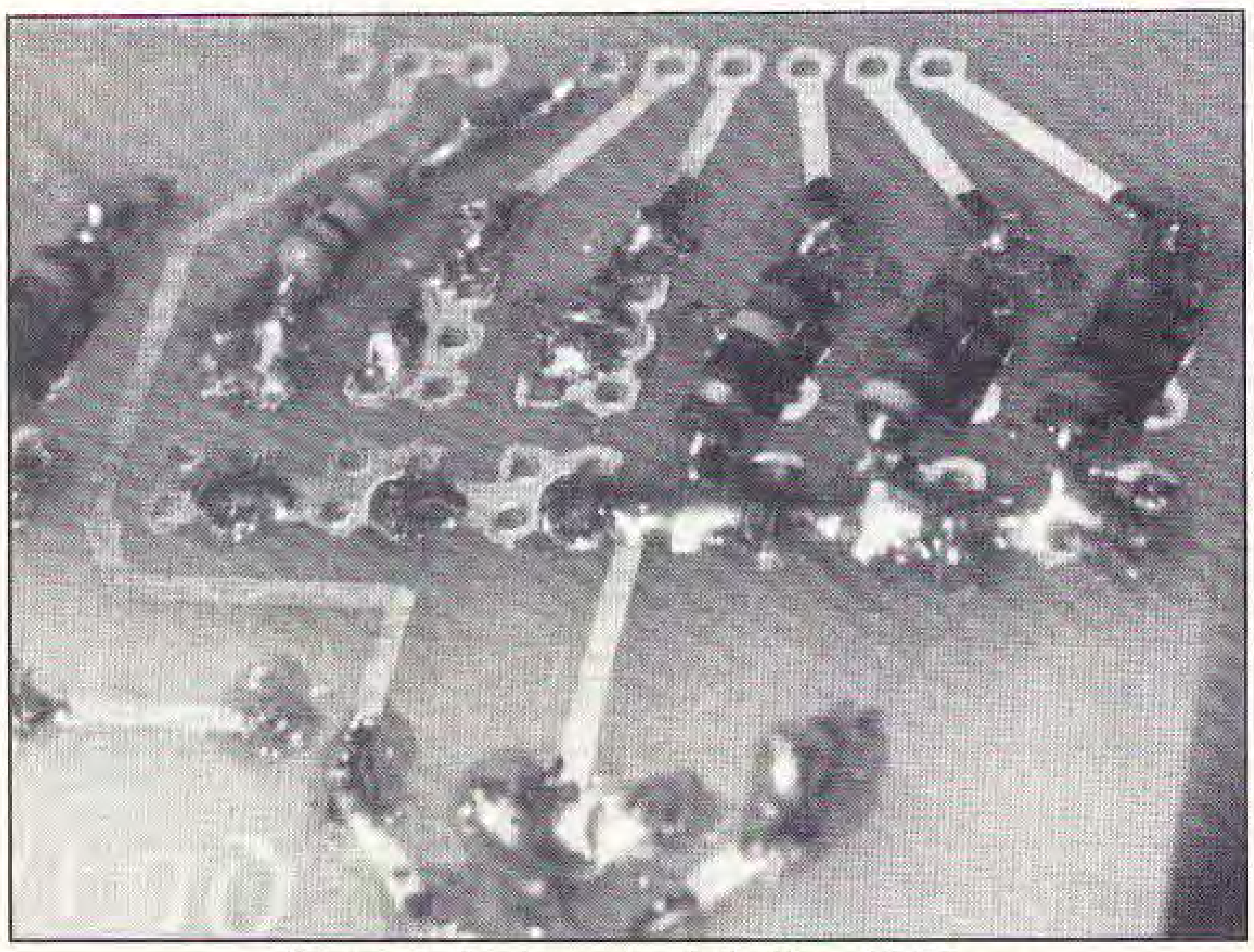

Photo B. Resistors on foil side of PCB.

Photo C. LM317 mounting, showing off-set arrangement.

is pretty neat because a short across the output is perfectly acceptable and causes no harm!)

The LM317 requires a certain amount of current in and of itself to operate. This is identified as the "quiescent" current in the literature. The quiescent current flows from the supply through the LM317, out of the "adjust" pin, and into the load. Its value is typically around 0.35 mA, and can be neglected in most cases. If you want exact currents, however, you will have to account for that current in any analysis or adjustment of the circuit. Using pots in the circuit allows for exact setting of the current, including effects of the LM317 quiescent current. Because of the quiescent current, the OFF position of the rotary switches will result in a small current in any connected load.

The LM317s must be able to dissipate the heat generated when they are used in the Quad Charger. The thermal "design point" is reached when operating at the maximum supply voltage and maximum output current, with the output shorted to ground. Assuming a 13.8 volt supply and 150 mA, the maximum power the LM317 must dissipate as heat is just under 2 watts. It requires a heat sink to do that without overheating.

Figure 2 shows the system schematic of the Quad Charger. Figure 3 shows the detailed schematic of one of the four identical charger sections.

Construction

The Quad Charger is basically a simple circuit, but with lots of connections. PCB construction is recommended because of the number of solder connections involved; however, point-to-point wiring on perf board is quite feasible. See Figure 4 for the PCB layout and parts placement. The parts placement drawing shows where the parts are located on the PCB. The pots can be replaced with fixed resistors if exact currents are not required—see "Alternate Construction" below.

It is good practice to build one portion of the Quad Charger at a time. Install the pots first. Trimmer pots R4, R5, and R6 have fixed resistors in parallel. These resistors are mounted on the solder side of the PCB. Install the fixed resistors after installing the pots.

Note the orientation of the four diodes, and install them correctly. Observe polarity when installing the eight tantalum capacitors. Don't forget to install the jumper wire.

Make all the connections to the output jacks and rotary control switches. If using coaxial output jacks, make sure you match the jacks and plugs. Many coaxial jacks and plugs look alike but are not compatible. Note that there is no connection to the first (OFF) position of the control switches. The

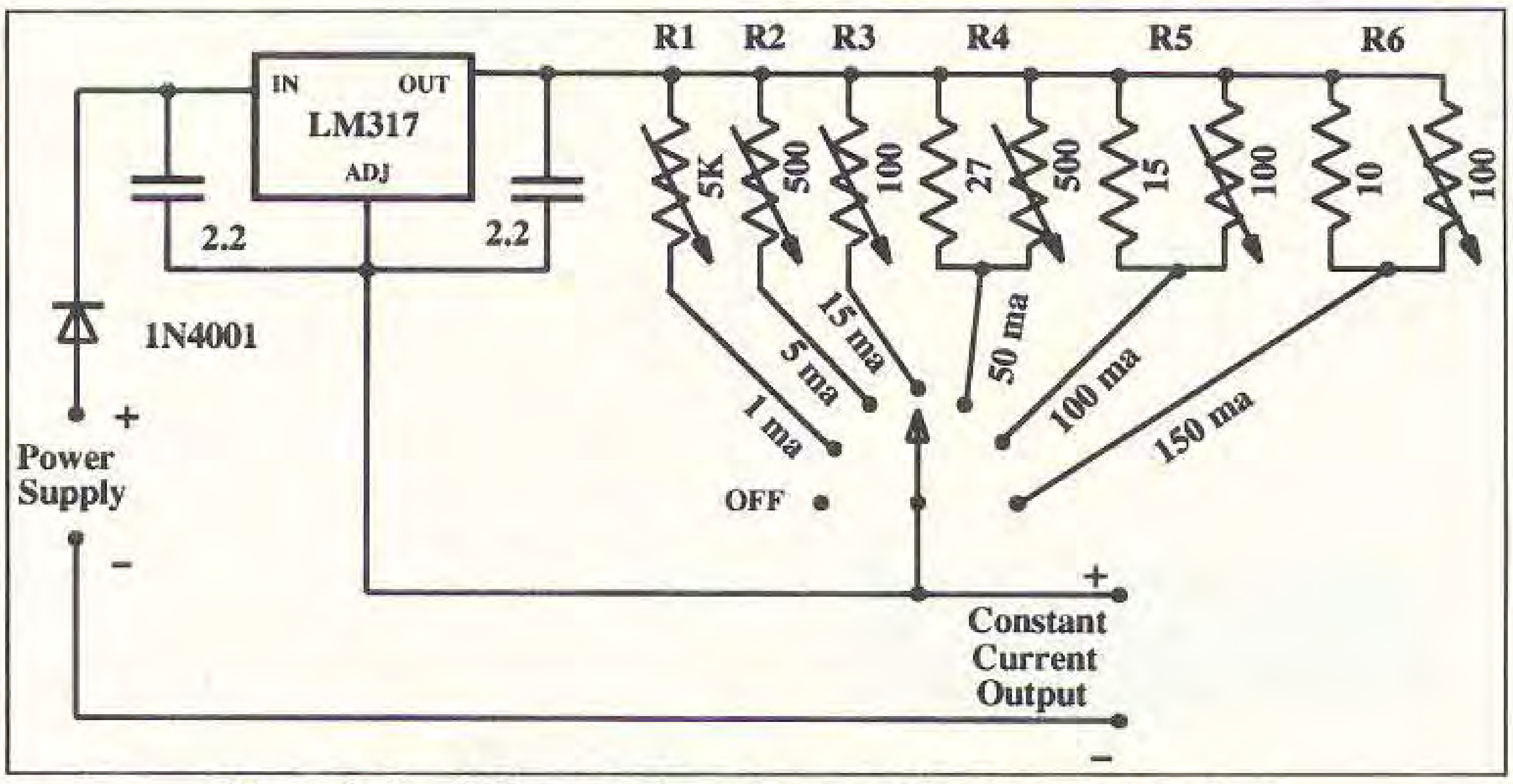

Figure 3. Quad Charger schematic (one of four identical sections).

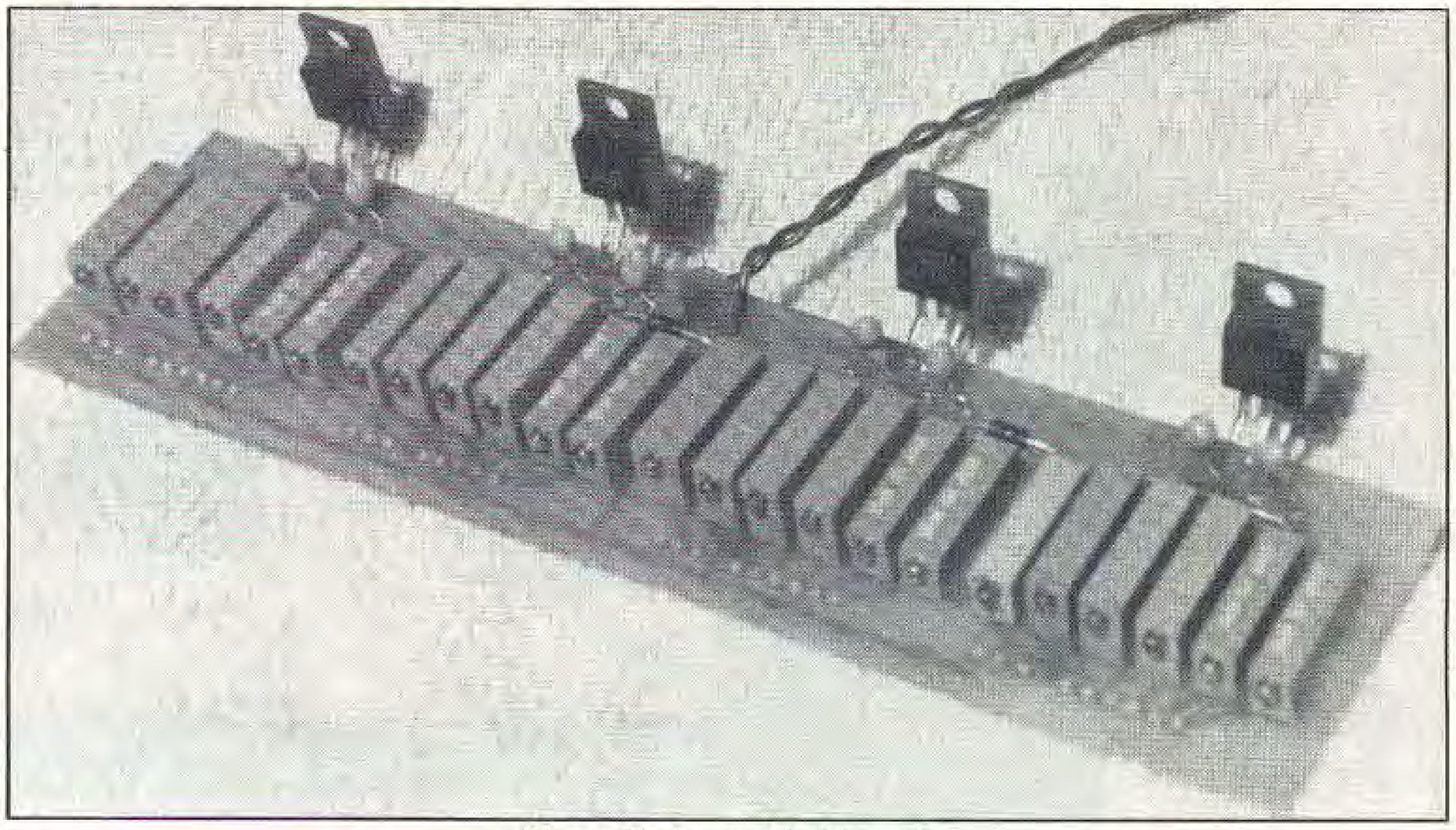

Photo D. Assembled board.

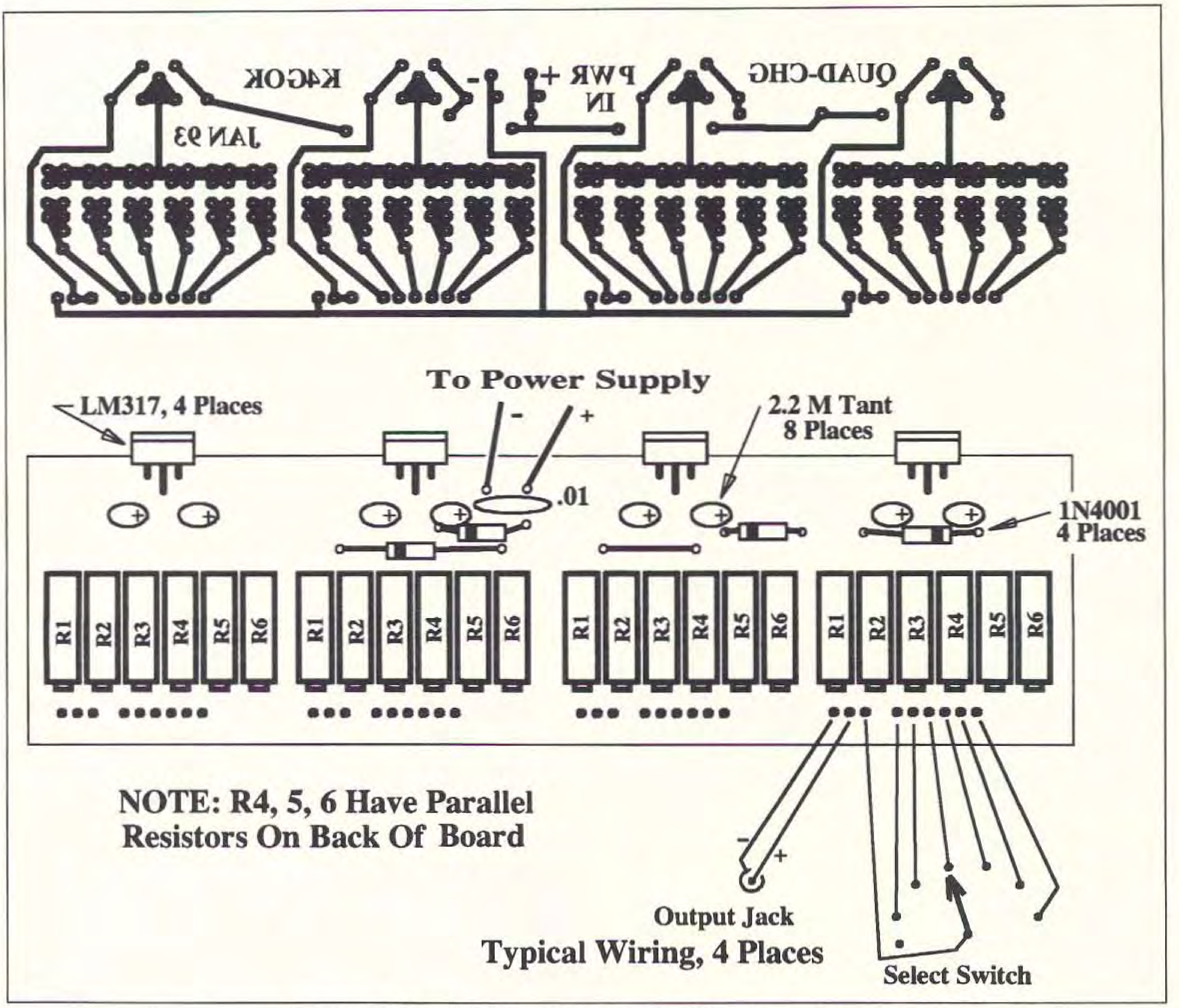

Figure 4. PCB layout (view from the component side), and parts placement.

OFF lug on these switches should therefore have nothing connected.

Mount the LM317s to the board in a vertical position, orienting them as shown in the photos and parts placement drawing. Bend the LM317 leads so that the mounting tabs are offset about 1/8" beyond the edge of the PCB. The LM317s are used to mount the PCB inside the cabinet. Solder the LM317s to the PCB, mount the LM317's to the heat sink, and the PCB requires no further mounting. A completed circuit board is shown in Photo D.

The Parts List describes the components used in the Quad Charger. It is important to put the LM317 ICs on a good heat sink (Photo E). Be sure to use insulators between the LM317s and the heat sink. The LM317 mounting tabs must not make electrical connection to the heat sink or to each other. If a metal enclosure is used, the rear panel might make a suitable heat sink. Photo E shows the heat sink I used. It is considerably more than adequate.

Alternate Construction

The recommended construction for the Quad Charger is with pots for adjusting the charge currents. However, since there is nothing critical about charging NiCds with an exact current, combinations of fixed resistors can be substituted for the pots. Table 1 shows several combinations of fixed parallel resistors that can be used. Any pair of resistors from column A, B, or C can be used. Select a pair that you have readily available. The chart shows, for example, three possible combinations (12/22, 15/20, 18/15) for R6. [The notation "12/22" means a 12 ohm resistor in parallel with a 22 ohm resistor.] Any of the pairs shown for R6 will produce approximately 150 mA charge current. A current variation of +/-10% from that recommended will not be significant in charging NiCds.

Because the quiescent current mentioned above is a substantial part of 1 mA and varies between individual LM317s, a bit of trial and error may be required to get a suitable set of fixed resistors at R1. But since this is a trickle charge setting, don't worry about obtaining an exact current value.

There is nothing special about having four sections to the Quad Charger. Any number of charging sections can be constructed by adding or deleting sections. Typically, a builder will underestimate the need, so build more than it now appears you will use. This is a highly useful circuit; save yourself some hassle and don't underestimate your needs.

Supply Voltage

Some notes are in order about the power supply to be used with the Quad Charger. Obviously a NiCd pack can't be charged from a supply of lesser voltage. Further, the LM317 requires about 3 volts across its terminals for proper operation. So the minimum supply voltage is that of the fully-charged NiCd, plus 3 or more volts. There is also an upper limit of 37 volts dictated by the LM317. The LM317 is designed to handle 1.5 amps of current, so that is not a prob-

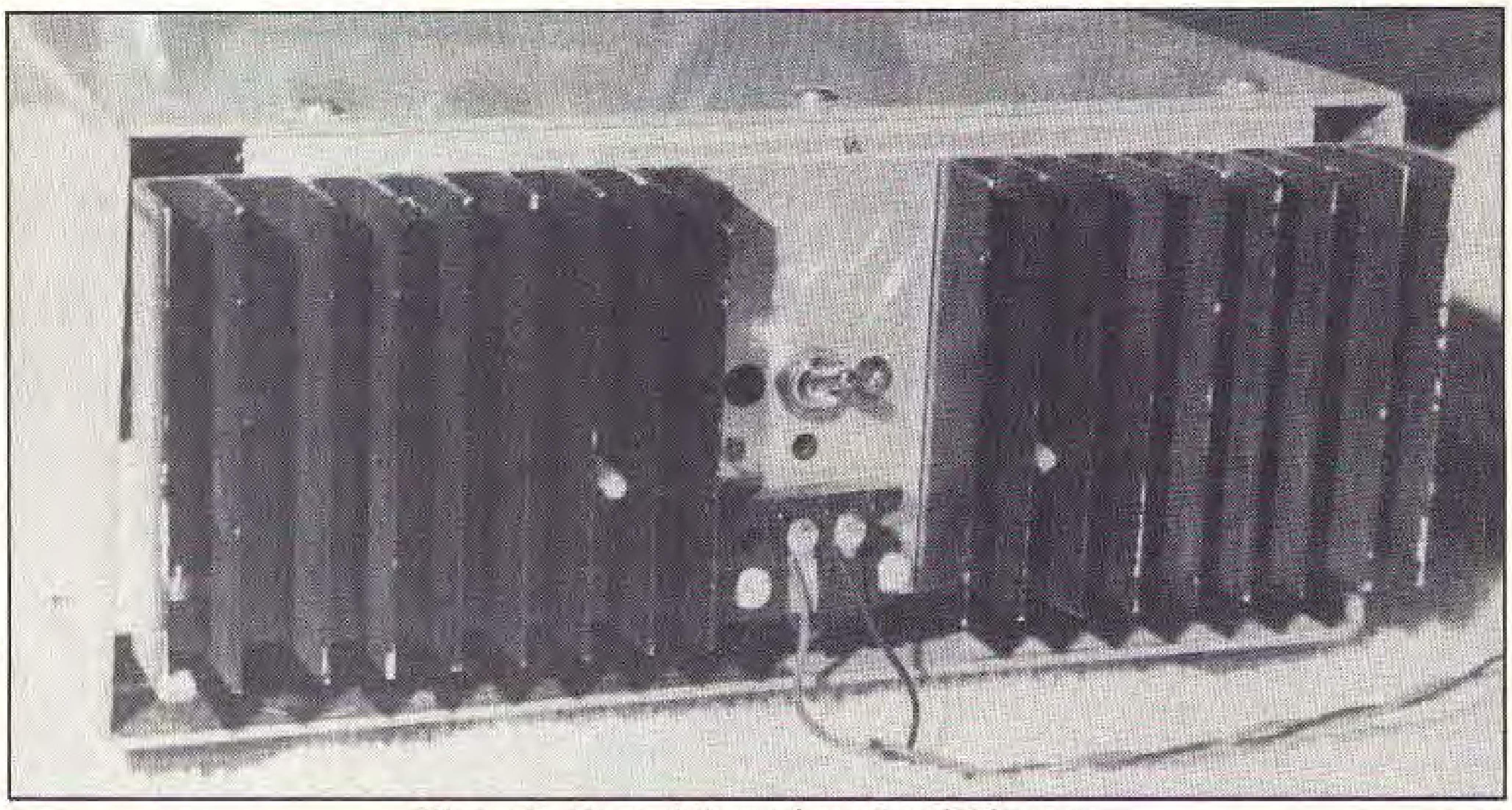

Photo E. Heat sink used on Quad Charger.

lem in the Quad Charger circuit.

The supply voltage will be a determining factor in the size of the necessary heat sink. The lower the supply voltage the smaller the required heat sink, and vice versa.

Checkout and Adjustment

After soldering all the components in place, carefully check for solder bridges and open connections. Check carefully at the PCB where the connections to the switches are made. Remove any solder bridges before proceeding.

Set all the pots near their mid-range position. The exact setting is not important, but the pots should not be at zero ohms. Select the 1 mA position for all the control switches. Remove anything connected to the output jacks. The LM317s should be mounted to their heat sink to prevent excessive heating during checkout. Connect a 12 volt power supply to the Quad Charger through your mA meter. The Quad Charger (without the LED connected) should draw no current. Note that the LED will draw about 10 mA if used. Check for bad connections if the total current is beyond that for the LED.

Connect a 100 ohm resistor in series with your mA meter and plug it in the output jack of the first charger section, then immediately note the meter reading. It should not be more than a few mA. Adjust R1 until the meter reads 1 mA. Switch to the 5 mA position and adjust R2 for a 5 mA reading on the meter. Adjust R3 and R4 for 15 mA and 50 mA respectively at the appropriate switch positions. With the switch set in the 50 mA position, short across the 100 ohm resistor to verify that the current remains at 50 mA with and without the resistor in the circuit. Remove the 100 ohm resistor, and adjust R5 and R6 for 100 mA and 150 mA with the switch in the respective positions.

Repeat this procedure for each of the remaining three sections.

Check the LM317s for any signs of excessive heating during and after the above adjustments; they should stay cool enough to touch comfortably. As a final check of the heat sink size, put a short across all four output jacks and set all four switches for 150 mA. Check the temperature of the LM317s. If they get too hot to touch comfortably, a more capable heat sink is required. A reasonable way to estimate temperature is to remember that your body (finger) temperature is about 98 degrees F, and that 105-110 degrees feels warm to the touch. A temperature of about 120-130 degrees is too hot for me to touch comfortably for very long.

When your Quad Charger checks out OK as described above, it is ready to use!

Conclusion

The Quad Charger has been in use at this QTH for a couple of years. It has proven highly useful, and is in daily use. It saves a good bit of hassle and concern, and provides a set of charged NiCds any time they are needed. 73

Table 1. Some Useful Parallel Fixed Resistor Values (All 1/4 Watt Resistors)

Charge Current	Resistor	Parallel Combinations A	B	C
1 mA	R1	2.2k	2.7k/6.8k	3.3k/4.7k
5 mA	R2	270	330/1.5k	470/680
15 mA	R3	110/560	150/200	150/200
50 mA	R4	27/330	33/100	47/51
100 mA	R5	12	15/68	22/27
150 mA	R6	8.2	10/47	15/18

"XX/YY" means parallel a resistor of XX ohms with one of YY ohms. A single number in a column means use a single resistor of that value. Select any combination from column A,B, or C.

Parts List (For One of Four Identical Sections)

IC-1	LM317T
C1, C2	2.2 µF tant.
D1	1N4001 or similar
R1	5k pot
R2	500 ohm pot
R3	100 ohm pot
R4	500 ohm pot paralleled with 27 ohm resistor
R5	100 ohm pot paralleled with 15 ohm resistor
R6	100 ohm pot paralleled with 10 ohm resistor

Note: All pots are Bourns series 3006P or similar

Output jack and plug of builder's choice

Rotary switch, 12 positions, one pole (seven positions used)

Single items needed for the entire Quad Charger:

- ON/OFF switch, SPST
- LED and 1k resistor
- PCB or perf board, cabinet, etc.

Drilled and etched PC boards are available from FAR Circuits, 18N640 Field Ct., Dundee IL 60118, for $6.50 plus $1.50 S&H.

See Table 1 for alternate construction parts.

Rules of Thumb for Charging NiCds

The recommended charge current is usually indicated on the pack or cell in question, along with the recommended charge time. If not, there are some reasonable rules of thumb for charging a NiCd. Charge a NiCd (pack or individual cell) at a rate in mA that is equal to 1/10 the value of the NiCd rating in mA/hr. For example, a 500 mA/hr. NiCd should be charged at 50 mA. NiCds require a total charge energy input equal about 1.5 times their mA/hr. rating. That means a NiCd should be charged at the "rule of thumb" rate for 15 hours. To recap, a NiCd should be charged at 1/10 its mA/hr. value for 15 hours.

Most AA size NiCds should be charged at 50 mA for 12 to 15 hours. Most C size NiCds, and many D size NiCds, should be charged for 18-20 hours at 100 mA. Or charge the C and D size NiCds for 12-15 hours at 150 mA. A 9 volt "transistor" size NiCd should typically be charged at 10-15 mA for 12-15 hours.

I trickle charge AA size NiCds at 1 mA and C and D size NiCds at 5 mA.