Number 6 on your Feedback card

Fast Charger

Recharge NiCd and NiMH batteries in as little as 30 minutes.

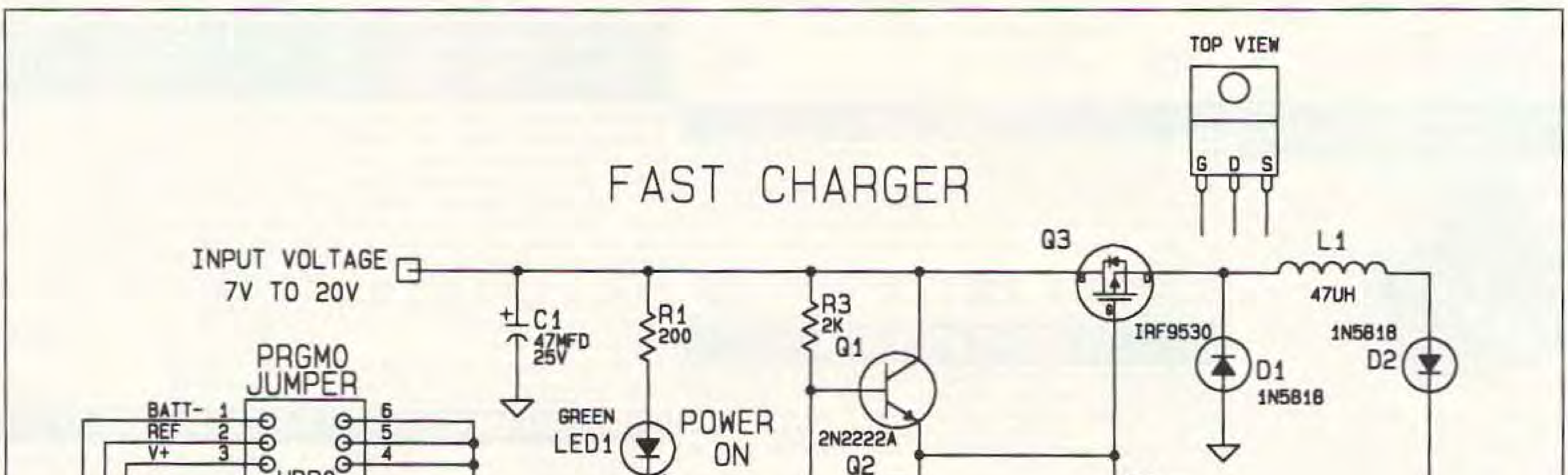
by Richard Togashi KN6PK

Why another NiCd battery recharging article? Well, Fast Charger will not only recharge NiCds, it will fast charge them to the correct capacity in as little as 30 minutes. After fast charging, the circuit will then automatically switch to trickle charge. Any number of cells can be recharged, up to a maximum of 16 cells. Programming jumpers allow different charging rates and different cell counts without any circuit modification. And with a single part replacement, the circuit will charge the new Nickel Metal Hydride (NiMH) batteries.

NiCds are a proven technology in batteries, relatively inexpensive, available in all popular sizes, easy to use and easy to abuse. NiCds, when fully charged, exhibit a decrease in battery output voltage. Fast Charger detects this voltage change during fast charging to ensure the batteries are at full charge capacity. After a full capacity charge, Fast Charger will revert to a trickle charge state, allowing the batteries to be at a full charge state indefinitely.

NiMH batteries are a little different; they are an emerging technology. They are similar to NiCds, but they boast higher current densities than NiCds and there is none of the memory effect NiCds are prone to. There are some drawbacks to the NiMH, since it is a new technology: They are in short supply, are available only in limited sizes, are more expensive, self-discharge faster, and have approximately 80% of the recharging cycles found in NiCds. For high current demand or cyclic applications, NiMHs may be a better choice than NiCds. NiMH batteries require a different recharging scheme. They exhibit a voltage plateau when they are fully recharged. By interchanging an inexpensive IC with a similar device, Fast Charger will be able to detect the NiMH recharging characteristics. This will also allow the NiMH batteries to be charged to the full capacity in a minimum amount of time.

Normal battery chargers charge the batteries at C/10 (where C = capacity) with a constant current for approximately 16 hours.



These chargers are simply unregulated constant current supplies. On the other hand, Fast Charger is controlled by the Maxium Products MAX712 or MAX713 integrated circuits, allowing a fast high current charge without damage to the batteries. The MAX712 part is used to recharge NiMH batteries. The MAX713 is used to recharge NiCd batteries. The only difference between the parts is the way the part detects the end of a fast charge cycle. The MAX712 detects the end of a fast charge cycle when the battery voltage plateaus; the MAX713 detects the end of a fast charge cycle when the battery voltage starts to decline. When the MAX712/3 senses these output voltage behaviors, it automatically switches to trickle charge. Trickle charge is also reached when the MAX712/3 determines that a maximum expected recharge time interval has elapsed.

Circuitry and Pin Programming

My prototype layout uses a hand-drawn PC board. The only critical signals are the capacitors connected to pin 11 of the MAX712/3 device. These connections should be as short as possible. The other critical path is the inductor, diodes and transistor, which constitutes a switching power supply. The traces to these devices should be as short as possible to reduce the stray inductance/resistance, which will degrade the efficiency of the switching power supply.

The MAX chip contains circuitry that does most of the work. A voltage regulator regulates the output voltage to recharge the batteries, a current-sensing amplifier senses the current through the battery and adjusts the output drive of the pass transistor to control the current into the battery. A temperature sensor option is not utilized in this design. An analog-to-digital circuit samples the battery voltage and determines the output voltage of the battery over time. A timer circuit monitors the charge times and issues a time-out if the expected recharge time has been reached. Finally, control logic monitors the four program pins of the device and controls timing internal to the device.

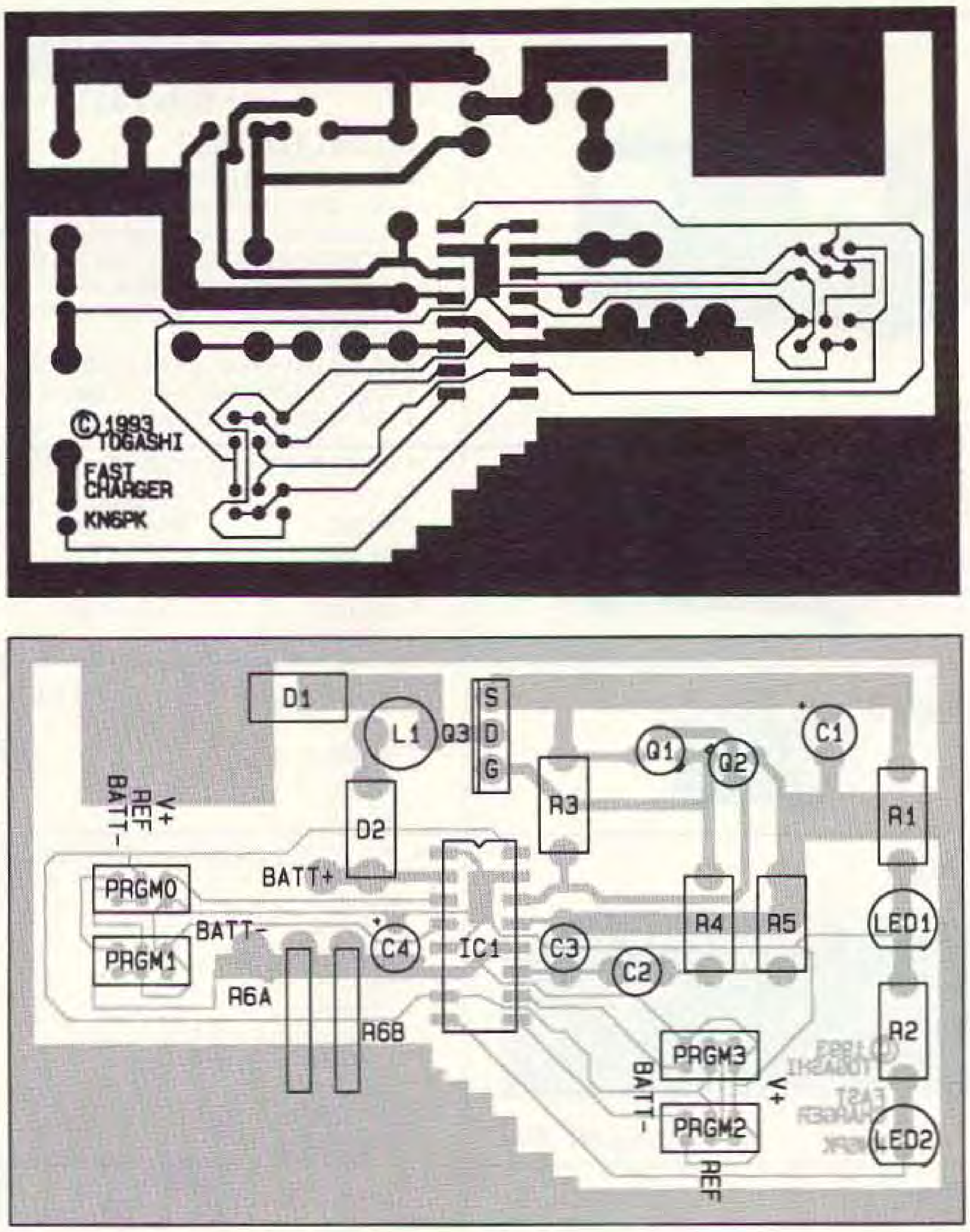


Figure 2. A drilled and etched PC board for the Fast Charger is available for $5 plus $1.50 S & H per order from Far Circuits, 18N640 Field Court, Dundee, IL 60118.

The four program pins of the device set the battery cell count and the expected recharge time. Program pins PRGM0 and PRGM1 set the cell count, the number of cells which the recharger is set to recharge. The cell count is made by either counting the cells or dividing the expected output voltage by 1.2 volts. In my application with four cells, PRGM1 and PRGM0 are shorted to BATT- and V+ respectively. PRGM2 and PRGM3 program pins set the time-out period for the expected recharge time. To determine the expected recharge time, first pick the recharge rate for the circuit. In my de-

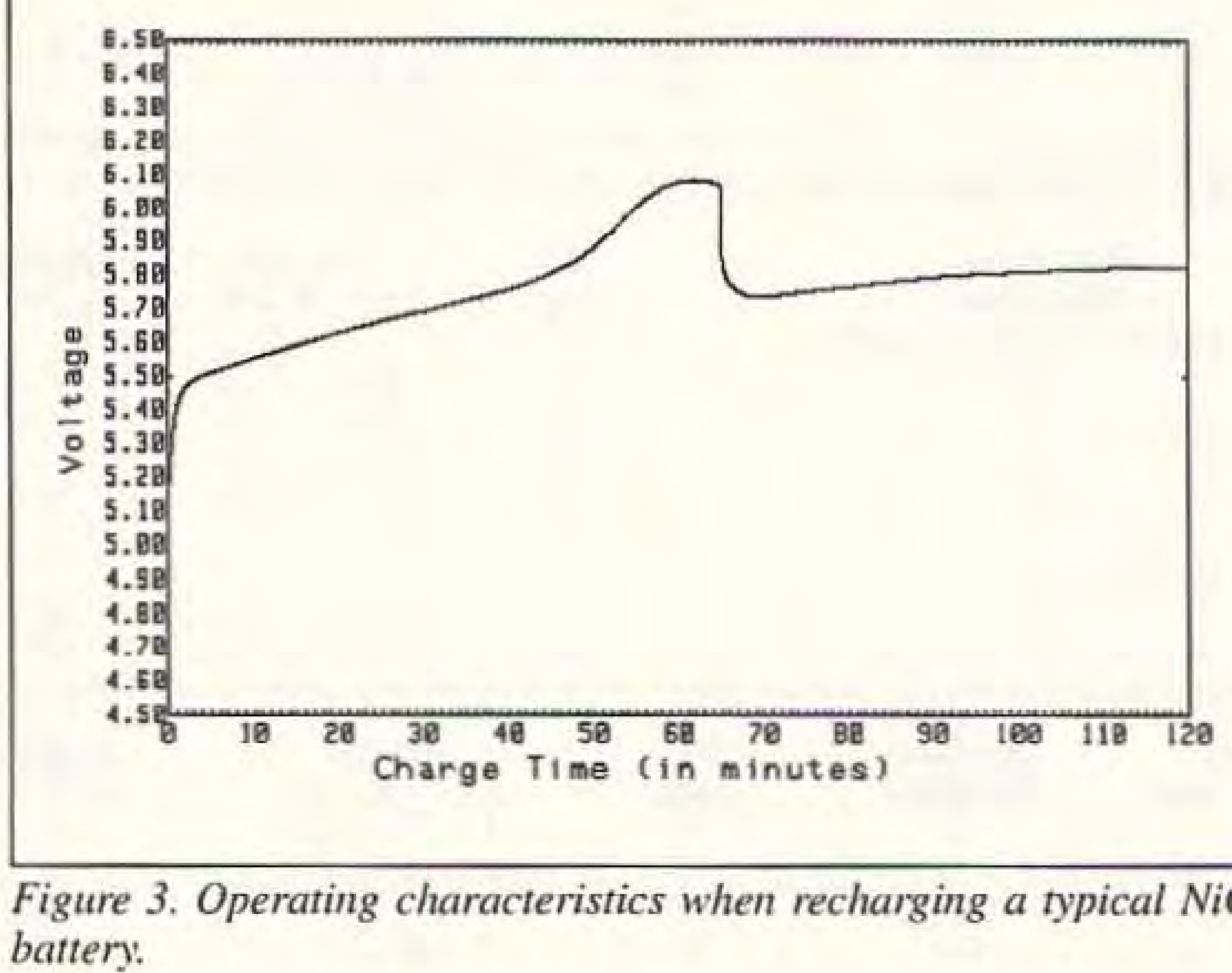


Figure 3. Operating characteristics when recharging a typical NiCd battery.

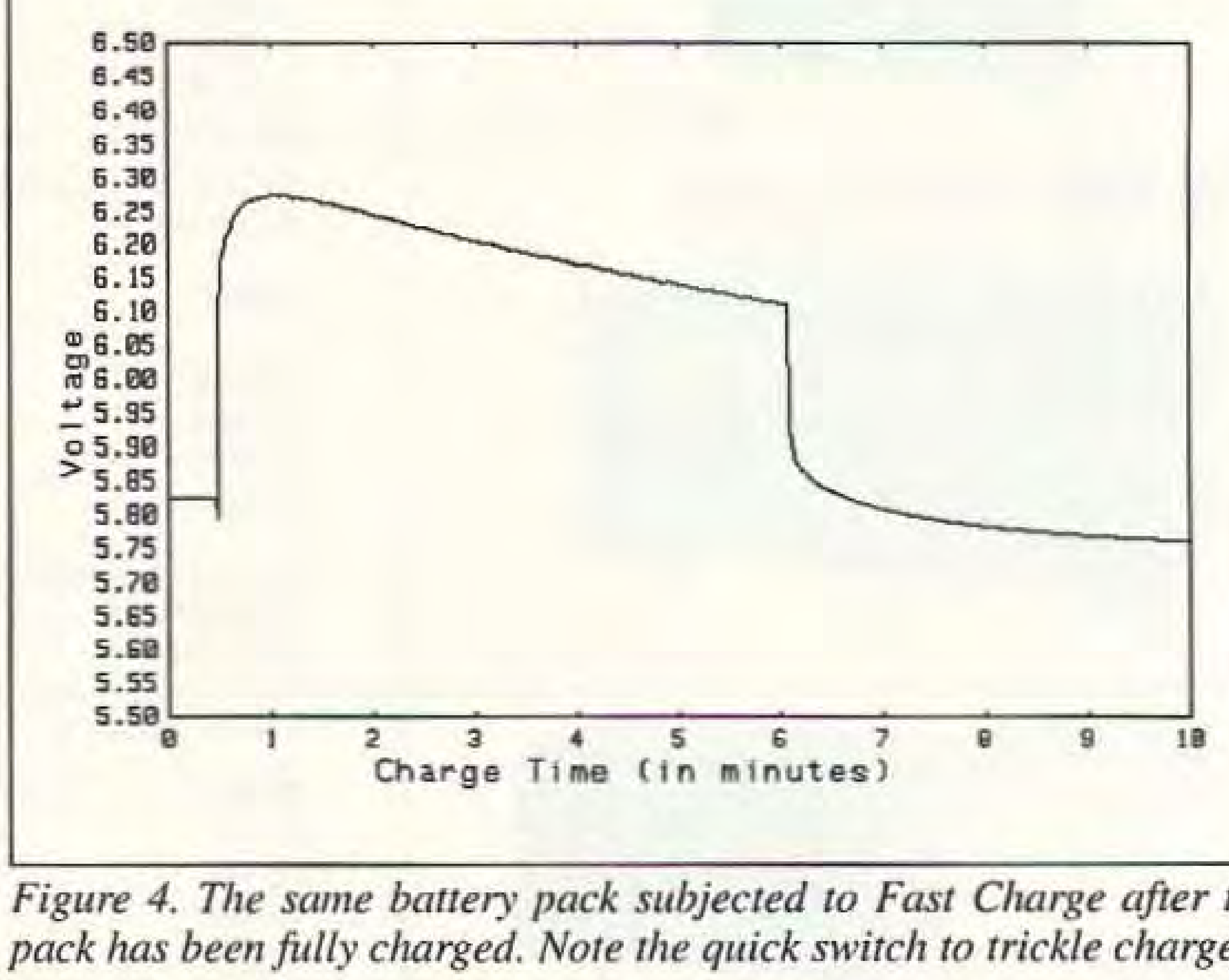


Figure 4. The same battery pack subjected to Fast Charge after the pack has been fully charged. Note the quick switch to trickle charge.

sign, the batteries I want to recharge are AA 500 mA per hour cells. I set Fast Charger to recharge the cells at 1 times the capacity, or 1C. Rechargeable batteries are not 100% efficient when recharged, so the expected recharge time is approximately 20% higher than the expected time, hence for 1C recharge rate, the expected recharge time is about one hour and 15 minutes. The closest time interval available for a one hour and 15 minute time-out is 90 minutes, which is enabled by shorting PRGM2 and PRGM3 to the REF voltage pin.

Table 1 defines the program pin programming to select the desired settings for the number of cells and for the time period. The Charge Rate in C is the charge rate as set by R6. I use jumper blocks with shorting blocks (like the ones used in PCs to set up the expansion cards) to set the programming options. DIP switches or jumpers can also be used. PRGM3 also sets the trickle charge current value. When PRGM3 is open, the trickle charge current is the fast charge rate divided by 32. When PRGM3 is connected to REF, the trickle charge current is the fast charge rate divided by 16. When PRGM3 is connected to BATT-, the trickle charge current is the fast charge rate divided by 8. My application uses the PRGM3 pin tied to REF, so my trickle charge rate is 500 mA divided by 16, or 31 mA.

Q1-Q3, L1, D1 and D2 form a DC-DC switching power supply which supplies a current source to the batteries with overvoltage protection. D1 and D2 are Schottky Barrier Rectifiers which have low-forward voltage drops and are fast devices (low internal capacitance) to keep the DC-DC converter at peak efficiency. Q1 and Q2 boost the drive to Q3, turning Q3 on hard and off hard. Q3 was chosen for the low drain to source resistance of 0.3 ohms. With such a low drain to source resistance, no heat sink is required for Q3, i.e. Power Dissipation = (drain current)^2 x (drain to source resistance) which is below 100 milliwatts. L1 is charged by Q3. When Q3 turns on, current is stored in L1 and discharges through D2 into the battery. When Q3 turns off, current will continue to flow through L1 from the current stored in L1 and through D1. L1 must be both electrically large to accommodate the large current flow and physically large to prevent saturation (saturation is when L1's core cannot hold any more magnetic flux, causing L1 to look like a resistor with a resistance value of the inductor wire). For topology buffs, the topology used here is the Positive Buck Converter.

LED1 and LED2 are used for charging indicators. When power is applied to Fast Charger, LED1 illuminates. When fast charging is active, both LED1 and LED2 illuminate. When fast charging is complete, LED2 extinguishes and LED1 remains on.

Power to the Fast Charger requires a 1 volt input voltage over the highest battery voltage, with a minimum voltage of 7 volts and a maximum voltage of 20 volts. The maximum battery voltage is: (1.65 volts) x (the number of cells). The minimum current required is equal to the fast charge current. I built my Fast Charger to run off a car battery to recharge RC Slope Glider batteries. If home use is expected, then a wall-mount transformer with the appropriate DC output voltage and current is all that is needed.

Operating the Fast Charger is simple. Plug or switch the desired program input pins to match the cell count and the charging time requirement. Apply power to the Fast Charger circuit and install the batteries. Fast charging will begin, and the batteries are charged to the peak capacity when the fast charging cycle is completed. The batteries may be left attached to the Fast Charger for the batteries to receive a trickle charge. At the end of the fast charge, the batteries may feel warm, but they should not feel excessively hot (greater than 120 degrees Fahrenheit). If the batteries become hot, then the fast charge current is too excessive. Increasing the value of R6 will alleviate the problem.

I ran into the following problems: If Fast Charger draws excessive current, check Q1 and Q2, they may be swapped causing the excessive current draw; if Fast Charger will not go into trickle charge, verify C2 and C3 values.

PRGM 1 and PRGM 2 Pin Connections to Define Cell Count

No. of Cells	PRGM1 Connection	PRGM0 Connection
1	V+	V+
2	open	V+
3	REF	V+
4	BATT-	V+
5	V+	open
6	open	open
7	REF	open
8	BATT-	open
9	V+	REF
10	open	REF
11	REF	REF
12	BATT-	REF
13	V+	BATT-
14	open	BATT-
15	REF	BATT-
16	BATT-	BATT-

PRGM 2 and PRGM 3 Connections to Define Time-out to Trickle Charge and Associated Charge Rate

Time-out (minutes)	Charge Rate in C	PRGM3 Connection	PRGM2 Connection
22	not used	V+	REF
33	not used	V+	BATT-
45	2.0C to 1.5C	open	REF
66	1.4C to 1.1C	open	BATT-
90	1.0C to 0.8C	REF	REF
132	0.7C to 0.5C	REF	BATT-
180	0.4C	BATT-	REF
264	0.25C	BATT-	BATT-

Table 1. To control the charge rate, the current sensing resistor must be chosen. First pick the rate to recharge the batteries (between 0.25C and 2C). The current sensing resistance value is: R6 = (0.25 volts) / [(fast charge rate) x (battery capacity)]. I require a rate of 1C for my 500 mA/hour batteries, so the resistor value is calculated as follows: R6 = (0.25 volts) / [(1C) x (0.5 A/hours)] = 0.5 ohms.

Parts List

Part	Description	Digi-Key #	Price ($)
C1	Capacitor, 47 uF 25V	P5696	0.24
C2	Capacitor, 33 pF	P4018	0.06
C3	Capacitor, 100 pF	P4024	0.06
C4	Capacitor, 1 uF 25V	P6742	0.53
D1,D2	Diode, 1N5818	1N5818	0.56
IC1	IC, MAX713 or MAX712	MAX713CPE	
		MAX712CPE	6.27
L1	Inductor, 47 uH, 1 amp	TK4355	2.68
LED1	Green LED	P303	0.18
LED2	Red LED	P300	0.25
Q1	Transistor, 2N2222A	PN2222A	0.19
Q2	Transistor, 2N2907A	PN2907A	0.19
Q3	Transistor, P enhancement FET, Rds = 0.3 ohms	IRF9530	2.40
R1	Resistor, 200 1/4W	200Q	0.05
R2	Resistor 470 1/4W	470Q	0.05
R3	Resistor, 2k 1/4W	2KQ	0.05
R4	Resistor, 48.7k 1/4W 1%	48.7KX	0.11
R5	Resistor, 1.5k 1/4W	1.5KQ	0.05
R6	Resistor, as required for IC	1.0Q	0.05
HDR0-HDR3	Header, 6-pin	S2012-06-ND	1.11
JMPR0-JMPR3	Jumper for headers	S9000-ND	1.09
Socket	Socket for IC1	ED3316	0.83

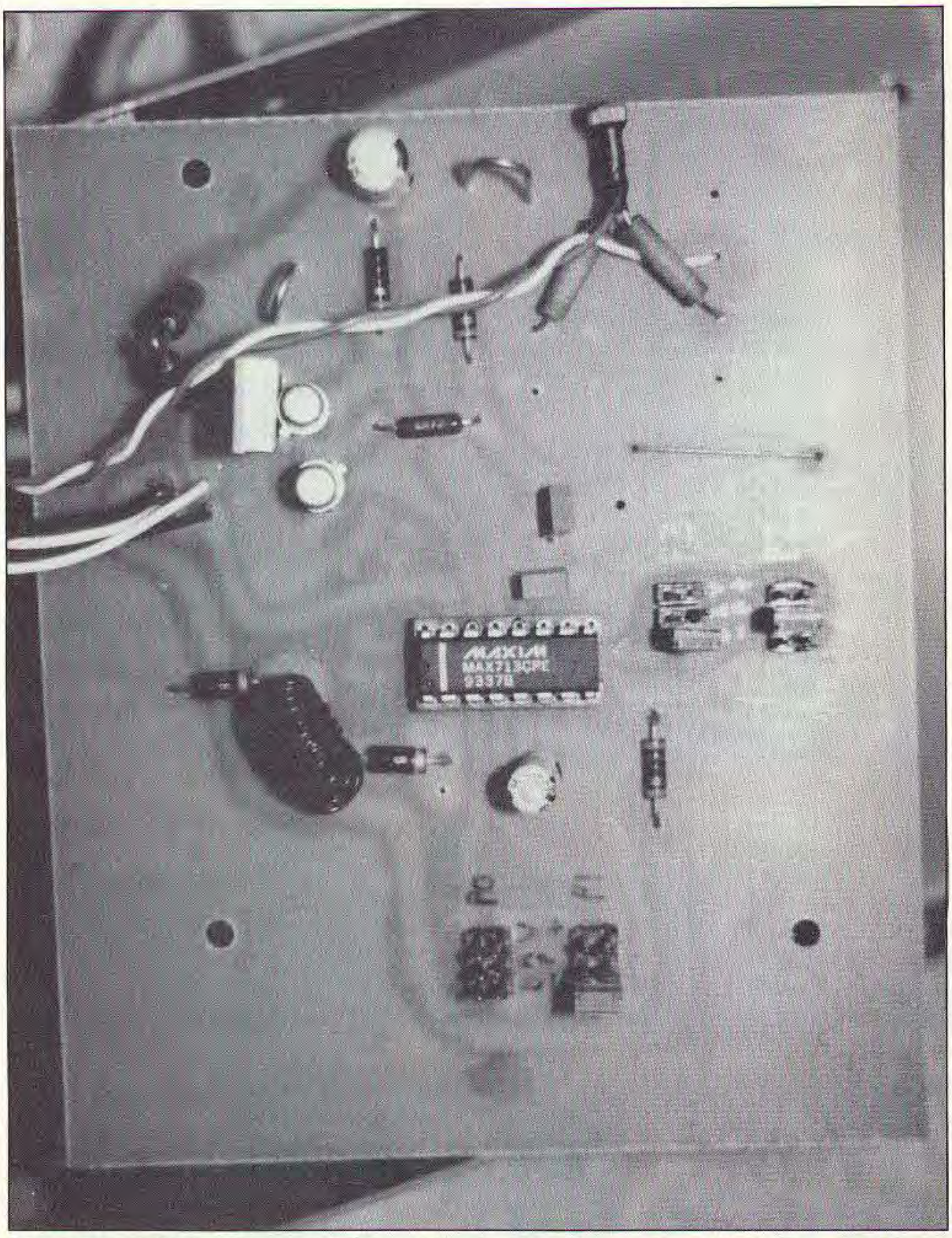


Photo A. A drilled and etched PC board for the Fast Charger is available from for $5 plus $1.50 S & H per order from Far Circuits, 18N640 Field Ct., Dundee, IL 60118..

All the parts used on this project are available from Digi-Key Corporation, (800) 344-4539.

Schematic

The schematic in Figure 1 shows the circuitry. The left side of the schematic shows the programming devices. Shorting jumpers, headers with jumper shorting blocks or switches can substituted for these devices. R6 is shown as two resistors. This allows custom values of non-standard resistance by using readily available standard resistance values and placing them in parallel.

Figure 3 shows the operating characteristics when recharging a battery. A four-cell 500 mA hour NiCd pack was subjected to the Fast Charger. The chart shows the battery output voltage verses time. The start of the plot is power applied to the Fast Charger. Battery voltage increases with charging and then peaks at about 60 minutes into the charge. The battery voltage peaks and then begins to fall. Fast Charger detects the drop in battery voltage and shuts off the fast charge current and enters trickle charge at approximately 65 minutes into the charge.

Figure 4 shows the same battery pack subjected to Fast Charger after the pack has been fully charged. Again the chart shows battery voltage versus time. Since the pack is fully charged, the battery voltage peaks quickly and then the output voltage begins to drop. After approximately five minutes and 30 seconds into the charge, Fast Charge detects the drop in battery output voltage and changes from fast charging to trickle charging.

I hope that Fast Charger recharges your batteries as easily, quickly and automatically as it does mine. Fast Charger allows convenient quick charging of virtually any battery pack on the market.

I would like to thank Jim Keller KD6JWO for setting up and programming the HP Chart Recorder used for Figures 3 and 4, and for building the first "production" unit. 73