Number 18 on your Feedback card

QRP

Low Power Operation

Michael Bryce WB8VGE
2225 Mayflower NW
Massillon OH 44646

Space restrictions for the March 1993 "QRP" column did not allow me to include the schematic for the controller. We'll take a look at the entire project this month.

Three of the four chips used in the controller are LM324 op amps. They're easy to come by and very inexpensive. Each LM324 consists of four op amps. The LM324 operates on a single power supply, a great advantage over the 741 op amp. If you build the circuit on perf board, notice the unusual location of the VCC pin (pin #4) and ground (pin #11) of this chip. Also, don't short the output of any of the amplifiers or you may damage the chip.

In the March column I described the array detect and power supply systems, as well as the state-of-charge reference source. This time around, we'll look at the FET driver and the driver switching. A quick look at the over-temperature comparator will wind up the tour.

From the voltage divider the battery sense is buffered by U1C. The output is then run to U1B where it is compared to the SOC reference voltage. Two 22 µF capacitors connected back-to-back slowly charge and discharge, depending on the input from the battery sense line. The output, on pin #8, will slowly rise and fall along with the battery's terminal voltage. The output of this amplifier, pin #8, is then routed to two more locations. First, it goes to U3B. This amplifier and U3D compare U3B's output and also act as LED drivers. Op amp U3 controls the function of the charging and charged LEDs.

The output of U1C also goes to U2D. Op amp U2D takes the output from U1C and the SOC reference voltage and will generate a string of pulses when the two voltages are alike. If either one of them changes, the output of U2D will also change. This is how the FETs are switched on and off—by the action of U2D.

The last op amp before the gate driver is U3C. This op amp acts like a switch to provide a nice square wave to the voltage pump. When its output is low, the voltage pump is turned on. This then turns on the FETs and they conduct, passing current from the array to the battery bank.

The voltage pump is nearly identical to the one that I mentioned in the first part of this series. A 4001 CMOS chip will be used as an oscillator running about 300 kHz. The oscillator runs all the time and is never turned off. Gates C and D act as switches to couple the oscillator's energy into the voltage multiplier diodes. The output runs about +22 volts to the gates of the FETs. This is a bit over the maximum limit of the gates and therefore a 20-volt zener diode clamps the gate drive at +20 volts. This +20 volts turns on the FETs.

Photo A. Prototype for the controller.

Although the FETs have a very low RDS (on), they can still generate heat when passing large amounts of current. The blocking diode will generate more heat at higher currents because of the 0.3-volt drop across it. A 10k thermistor monitors the temperature of the heat sink. U2C is a simple comparator checking the thermistor's voltage drop across the other 10k resistor. When the comparator switches states, the output on pin #8 goes high. This high is fed back to the input of the chip, providing a set hysteresis. This will keep the over-temperature shutdown from oscillating at the over-temperature point. The output also goes to the LED driver. When an over-temperature condition occurs, the "charging" LED will be forced off. Also, the SOC reference on pin #13 of U2D will be forced high, turning off U2D. Pin #8 of U3C then becomes high and turns off the voltage pump. The FETs are then turned off during an over-temperature condition. Everything will stay this way until the

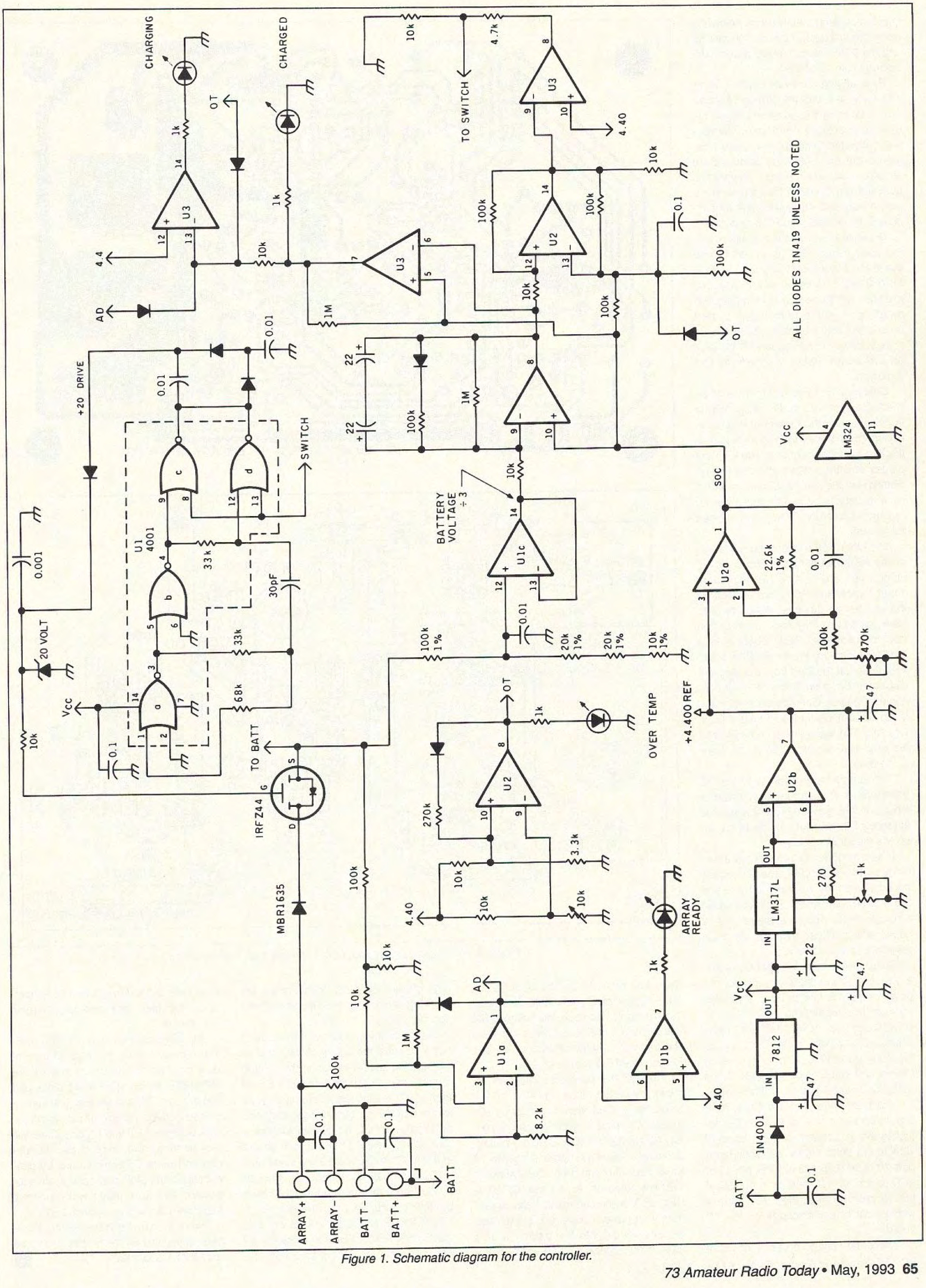

Figure 1. Schematic diagram for the controller.

heat sink's temperature drops below the reference voltage set by the 10k resistor and the 3.3k resistor voltage divider connected to pin 10 of U2C.

By changing the value of the 3.3k resistor, you can alter the turn-on temperature. Lowering the value will raise the over-temperature shutdown. Using a well-calibrated fingertip and a pot, I adjusted the pot until over-temperature shutdown occurred when I thought the heat sink got too hot. I then removed the pot, measured its resistance and installed the nearest value-fixed resistor.

Because this is a rather complex project using almost 16 IC gates, it's best to use a PC board. FAR Circuits (18N640 Field Court, Dundee IL 60118) has one available for $9 plus $1.50 shipping and handling. If you're really up to it, perf board may also be used. There are no special precautions required if it's built on perf board. Photo A shows my first prototype.

Construction is basically straightforward. Sockets for the ICs really help in troubleshooting the project. If you're really brave, solder everything in, including the ICs. Watch for correct polarity of the diodes and the electrolytic capacitors. Remember, the two 22 µF caps near U1 connect back-to-back. The circuit will not operate correctly if they are placed backwards.

The MBR1635 blocking diode as well as the FETs mount to a heat sink. In my units, I use a 6" x 4" x 1/8" aluminum sheet to hold the PC board as well as the two active devices. Because both have hot cases, they must be insulated from the heat sink. Radio Shack sells a TO-220 mounting kit for about a buck. Also note that the lead from the blocking diode and the drain of the FET are connected together. Carefully bend over the leads of both devices and solder them together. The leads are quite fragile and are easily broken off at the plastic body of the device.

The source lead connects to the PC board via a #12 gauge wire. Another length of #12 gauge wire connects the cathode of the blocking diode to the array via the terminal block.

If you're going to run over 6 amps through the controller, the PC board trace between the + battery terminal and the source lead of the FET should be strengthened. Again, a piece of #12 gauge wire soldered over the trace will take care of the problem.

Setup will require a digital VOM and a variable power supply. Connect the power supply to the battery terminals. Turn on the supply and adjust it to 14 volts. Using your VOM, check for proper voltage of +12 volts at the 7812 regulator. Check for VCC at pins 4 of each LM324 and at pin 14 on the 4001. None of the LEDs should be on at this time.

Check the voltage on pin 7 of U2A. It should be close to 4 or 5 volts. By adjusting the 1k trimmer, set the output of U2A to 4.5 volts. Verify this voltage on pins 10 of U1B, pin 13 of U2D, pin 12 of U3D, pin 10 of U3C and pin 5 of U3B. If you're missing one, then you have a wiring error or solder bridge on the PC board.

Check the voltage on pin 1 of U2. It should be around 4.5 volts. By adjusting the 470k trimmer, you should be able to increase and decrease the voltage. Set this point at 4.766 volts. That's one-third the battery voltage of 14.3 volts, our fully-charged terminal voltage.

Turn off the power supply and remove it from the battery terminal on the block. Reconnect them to the array terminals. Connect a small amp/hour battery (6.5 amp/hour is ideal) to the battery terminals. Adjust the power supply to 16 to 18 volts and turn it on. The "ARRAY" LED will come on, as will the "CHARGING" LED. If you can monitor the current from your power supply, you should see current flowing into the battery at this time. If not, check for +20 volts on the gate of the FET. Also, double-check the blocking diode and FET drain connections for errors.

As the terminal voltage of the battery hits 14.3 volts, the output of U3C will begin sending square waves to the voltage pump. This will rapidly turn the FET on and off, controlling the flow of current into the battery. An oscilloscope connected to pin 8 of U3C will show this clearly. The "CHARGING" LED will now go out and the "CHARGED" LED will come on.

During the charging process, you can try out the over-temperature shutdown by flicking your BIC on the thermistor. The "CHARGING" LED will go out and the "OVER TEMP" LED will come on. All charging will stop at this time until the thermistor cools down. When its temperature is cooled back enough, charging will resume.

By using one FET and the MBR1635, you can get up to 16 amps of current flowing, the maximum rating of the MBR1635. By using an SD51 diode and two or more FETs in parallel, you can increase current capacity up to 45 amps. One BUZ348 FET and a SD51 diode will provide about 20+ amps of current. You can add more FETs in parallel by connecting all the drain and source leads together. The gate leads will require a separate 10k resistor for each FET.

Next month I'll have some troubleshooting tips for the project and some modifications as well.

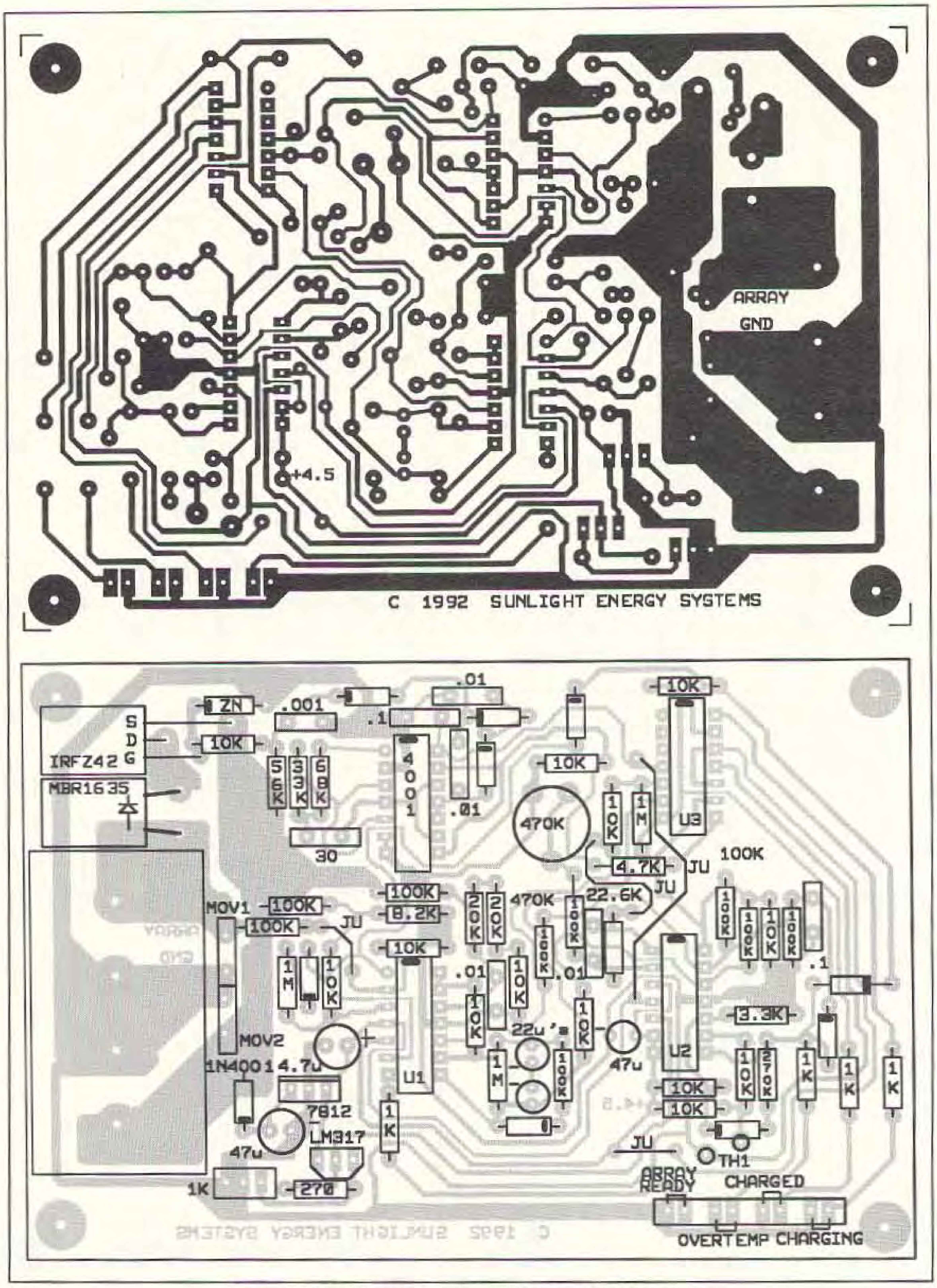

Figure 2. PC board pattern and parts placement for the controller.