MRP4 Solar Panel Control Circuit

Build this easy charge controller for your sun-powered station!

by Michael Bryce WB8VGE

Photovoltaics, the direct conversion of sunlight to electricity, is fast becoming the energy technology of the '90s. It's surprising how much energy the newer generation of solar panels can produce. In the not-too-distant past, you would be lucky to see 1 amp under ideal conditions. Today, a single solar panel can easily generate over 4 amps of charge current under clear, sunny skies.

If the solar array was left connected to the batteries all the time, however, severe overcharging would occur. The results would be rather ugly! You can expect physical damage in the form of warped plates, dislocation of the plate's lead paste and excessive electrolyte gassing, resulting in loss of electrolyte. You can easily destroy a brand-new gelled battery in one weekend if you don't have some means of protecting the battery from overcharge.

To prevent battery damage, some means of controlling the current from a solar panel is needed. This device is called a charge controller.

Charge Controllers 101

There are two basic technologies to charge batteries via solar power: shunt mode and series mode. Let's look a little closer at both methods of control.

In a series controller, a relay or transistor switch is in series between the PV (photovoltaic) array and the battery bank. In this case, the controller monitors the terminal voltage of the battery and will turn off the switch when the battery becomes full. Controlling how long the switch remains open or closed determines the state of charge of the battery. By pulse modulating the switch, a trickle charge can be emulated.

As the name implies, shunt controllers divert array power from the batteries by shunting the PV array to ground. A blocking diode isolates the PV array from the batteries. This prevents the controller from discharging the battery bank along with the array when the array is shorted to ground. By monitoring the terminal voltage of the battery, the controller will start to shunt the extra current when the full charge terminal voltage is reached. Many times, the array's energy is dissipated as heat, usually by resistors. Sometimes the array is shorted directly to ground.

You can short the output of a solar panel to ground without causing any damage to the panel. Here's how it works: Power is a function of both current and voltage—power is equal to current times voltage. With nothing connected to the panel, we have zero power because there is no current flowing. Voltage is maximum, current is zero. On the other hand, shorting the output of the panel generates maximum current, but now there is no voltage. The result is again zero power being produced. In real life, using real-life switches, there will be some voltage drop. Therefore, some of the energy from the panel will be released as heat. Since most shunt controllers use a power transistor as the switching device, the collector-emitter junction will drop some voltage. This is exactly how a shunt controller works.

The MRP4 Charge Controller

The MRP4 is a simple shunt charge controller that will handle up to 4 amps of array current. That's enough for a Siemens ProCharger 75 panel. The MRP4 will allow the battery to be charged to 100 percent of its capacity without overcharging. It's simple to set up and, best of all, easy to build. A well-stocked Radio Shack can supply nearly all the parts. A PC board is available, as well as a complete kit of parts. You can build the MRP4 for less than $35—much less with a well-stocked junkbox.

A Look at the Circuit

The MRP4's schematic is shown in Fig-

Photo A. The MRP4 Solar Panel Control Circuit. The chip is an LM324 op amp.

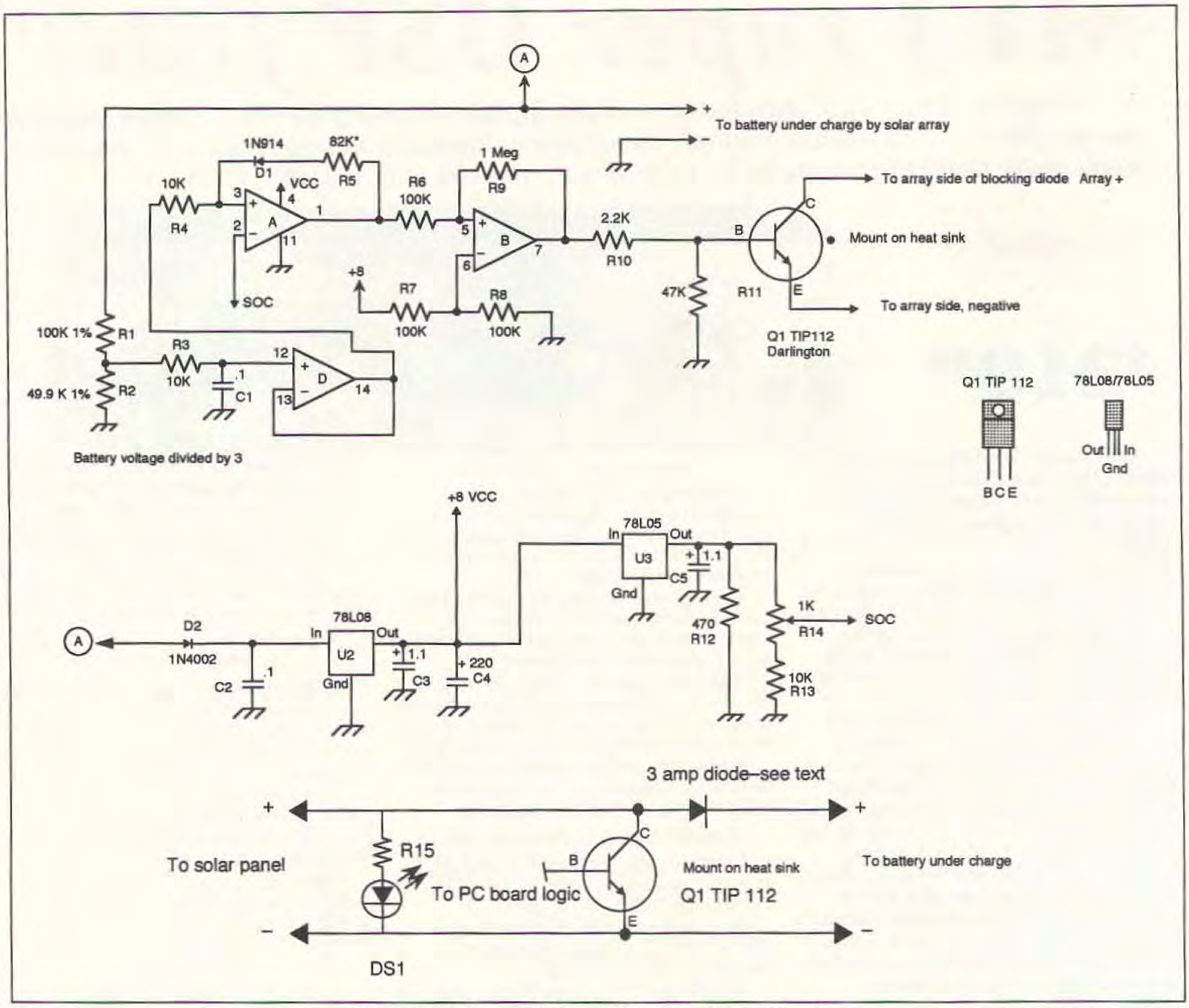

Figure 1. Schematic for the MRP4 Solar Control Circuit.

ure 1. The heart of the project is an LM324 op amp. Only three of the four amplifiers in the chip are used in this project.

To determine the state of charge of the battery, we monitor its terminal voltage. Resistors R1 and R2 divide the battery's voltage by three. Amplifier D buffers this voltage before passing it along to amplifier A. This amplifier is configured as a voltage comparator. The battery's terminal voltage, now divided by three, is compared to the state-of-charge reference voltage.

The state of charge (SOC) is determined by a 78L05 three-terminal voltage regulator. Resistor R12 keeps a constant load on the regulator to improve its stability. Trimmer R14, along with R13, sets the state of charge by dropping the regulated +5 volts slightly. This is our state-of-charge set point. The state-of-charge set point is three times the value. If you want the controller to turn off the charging current at 14.3 volts, then the SOC voltage at pin #2 of U1A would be 4.766 volts. The highest you can set the state of charge is 15 volts. That's the full output of the 78L05 regulator times three.

Even though the battery sense is divided by one-percent resistors, there may be some final adjustment needed to the SOC trimmer for the exact state-of-charge voltage at the battery terminals. The circuit is protected against reverse polarity by a 1N4002 diode.

When the array starts to produce energy, all the array's power goes into the battery via the blocking diode. As the battery becomes full, its terminal voltage will rise. When the terminal voltage reaches the state-of-charge set by R14, the comparator switches states. Some of the output is fed back to the sense line. This raises the voltage of the sense line up slightly. By doing so, we introduce some hysteresis to the comparator.

At the same time, the output also is squared up by the third amplifier. Its output drives the shunt transistor fully on. Since the transistor is fully saturated, it shorts the array to ground. This stops the battery from charging. The blocking diode prevents the battery from being shorted to ground when the transistor turns on.

With the array shorted to ground, the terminal voltage of the battery begins to drop. But, because of the hysteresis, the terminal voltage drops below that of the state of charge. Depending on the value of the resistor in the hysteresis loop, the battery voltage will drop a volt or so. When the terminal voltage drops below the hysteresis threshold, the comparator switches off. This reverses the action of the transistor switch, turning it off. Once again, full array current is allowed to flow into the battery and the process is repeated. The battery is then protected from overcharge by shorting out the array when the state of charge has been reached.

The CHARGING LED will then flash on and off as the shunt transistor shorts the array to ground. The CHARGING LED gets its operating power directly from the PV array. The rate of flashing will be determined by several factors, such as the charge current from the array and the condition of the battery.

Construction

There is nothing critical about building the MRP4. It can be built using any method you're comfortable with. This includes the use of perf board and dead-bug construction. However, using the PC board designed for the MRP4 speeds construction. The PC board makes troubleshooting easier, too.

This is a simple project, so begin by stuffing the PC board with the resistors. Next add the IC socket and the terminal board. Finish up by installing the regulator and capacitors. The shunt transistor must be heat-sinked. Failure to do so will destroy the device. You can use an aluminum TOP220 heat sink or, by bending down the tab of the transistor, you can use the metal case holding the PC board. If you go this route, be sure you use a TOP220 mounting kit to keep the tab insulated from the case. Likewise, you can bend down the blocking diode and use the case to help heat-sink it, too. Apply a small dab of thermal compound to help conduct the heat to the metal.

Setup and Adjustments

You'll need an adjustable power supply, a digital VOM and a solar panel to adjust the MRP4.

Start by connecting the power supply to the battery terminals. With the power supply sitting at 14 volts, check for VCC on pin #4 of U1. Check the output of the 78L05 regulator. It will be very close to +5 volts. From the wiper of trimmer R14, set this voltage to your state of charge. Remember, it will be your state of charge

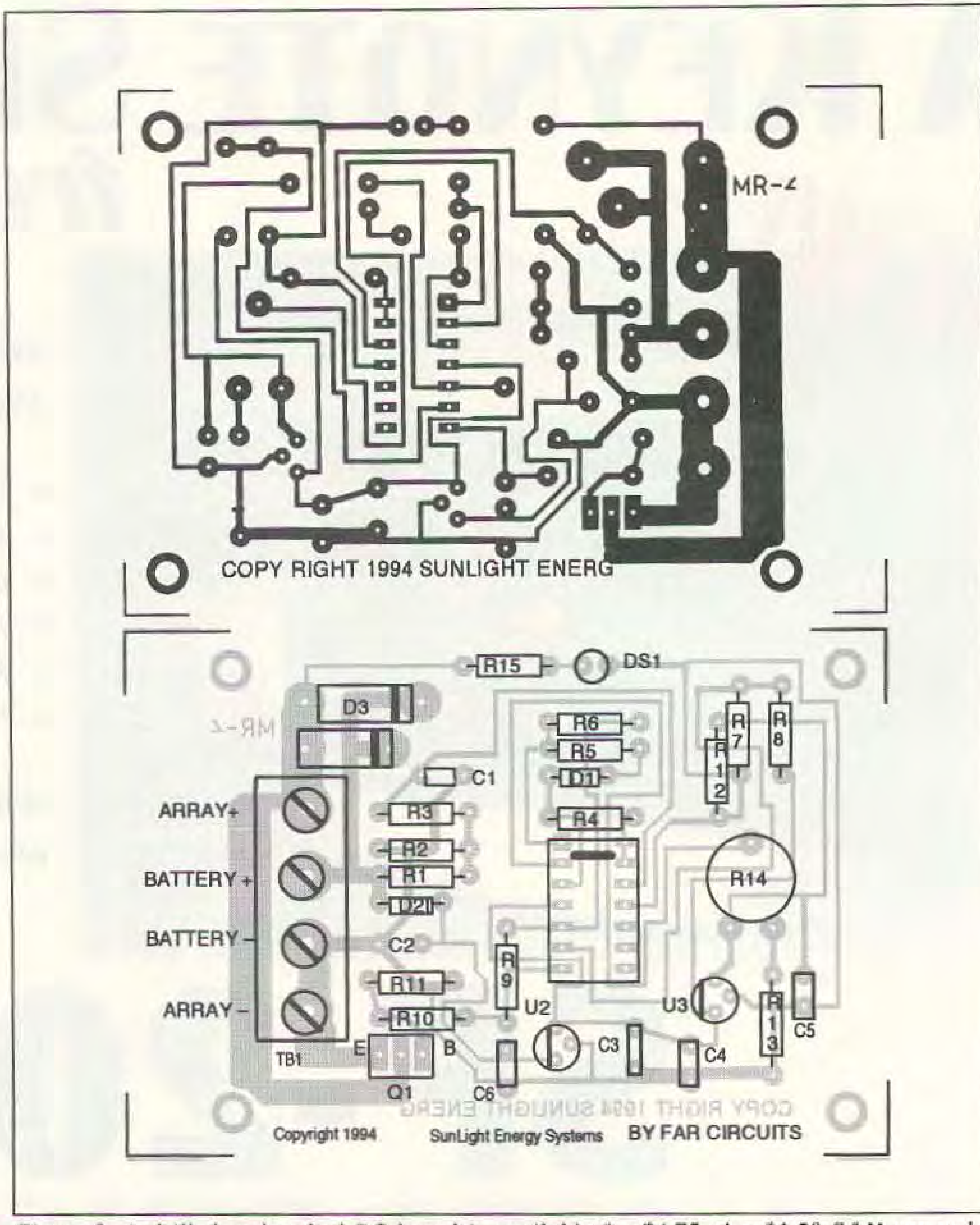

Figure 2. A drilled and etched PC board is available for $4.75 plus $1.50 S&H per order from FAR Circuits, 18N640 Field Ct., Dundee, IL 60118.

divided by three.

Probe the base of Q1 with the VOM. Now slowly increase the power supply voltage. When the power supply reaches the state-of-charge set point, the base will go high. Now slowly reduce the voltage of the power supply. You should be able to drop the voltage down to around 13.5 volts before the base goes low again. This completes the setup and adjustment. You might need to touch up the trimmer if you don't see the exact set point you require. Again, this is because of the slight difference in com-ponents in the battery sense line. During these tests, the charging LED will remain dark.

Final Hook-Up

The only way to really see how the MRP4 works is with a solar panel. So, connect the MRP4 to the battery to be charged first. Then connect the solar panel. Of course, the solar panel needs to be placed in direct sun to charge the battery. The CHARGING LED will come on. When the battery reaches full charge, the charging LED will begin to blink on and off. With an MP75 solar panel, the shunt transistor's heat sink should be politely warm to the touch. Don't use any other source of energy other than a solar panel. Don't use your power supply!

Any time the array produces power, the LED will come on.

Parts List

R1	100k 1%
R2	49.9k 1%
R3	10k
R4	10k
R5	82k
R6	100k
R7	100k
R8	100k
R9	1 meg
R10	2.2k
R11	47k
R12	470
R13	10k
*R14	1k
R15	1.8k
C1	0.1
C2	0.1
C3	1.1 TAN
C4	200 µF
C5	1.1 TAN
D1	1N914
D2	1N4002
D3	1N5821
U1	LM324
U2	L8LO8
U3	L8LO5
Q1	TIP 112
Heat sink, solder, etc.	
*Trimmer	Mouser #531-PT10V-1k
Terminal block	Mouser #506-4PCV-04

You can change the TIP 112 to a power MOSFET if you wish. The pins of the MOSFET will fit the same holes as the TIP 112. Change R10 from 2.2k to 100 ohms and R11 from 47k to 100k. Nothing else needs to be changed for this modification. You can use just about any low RDSon power MOSFET instead of the TIP 112. I've used an IRFZ44 in the past with very good results.

For more current capacity, there are two extra pads on the PC board for a second 1N5821 diode in parallel.

A PC board is available from FAR Circuits, 18N640 Field Ct., Dundee IL 60118, for $4.75 plus $1.50 S&H.

A complete kit of parts, including the PC board and terminal block, is available for $30 (including first-class postage) from Sunlight Energy Systems, 2225 Mayflower NW, Massillon OH 44647.

This may occur without any substantial charging taking place. In fact, bright moonlit nights may make the LED glow slightly!

Uh-Oh! It Don't Work!

If the MRP4 fails to operate, check for VCC on pin #4 of the LM324. Also, you must have the proper reference voltage from the 5 volt regulator.

If the battery won't come up to the state of charge, you may have more load on the battery than the solar panel can replace. Either reduce your loads or increase the charging current to the battery.

An open shunt transistor will allow the battery to become overcharged. Check the base voltage to see if the device is being turned on. If there is base voltage, and the battery is overcharging, then Q1 has failed.

By connecting the solar panel only, with no battery connected to the MRP4, you'll overheat the shunt transistor. This happens because the MRP4 oscillates by turning itself on and then off. Be sure there is a battery connected to the MRP4 when the solar panel is active.

That's It!

The MRP4 will protect your battery from overcharging when you're using a solar panel. It's simple, effective and oh so easy to build. It's a perfect project for a rainy afternoon. ■