Surplus Solar: Is It for You?

An affordable alternate backup power system.

by Donald Koehler N7MGT

Looking for a back-up power source for your station? Want some way to power your equipment that is portable, quiet and earth-friendly? Solar power systems will give you all of this and a bit more. The major objection against solar power from most hams seems to be the cost associated with the system components, especially the panels. This article shows how you can use surplus or repaired panels to reduce your system costs.

New panels, tied into a modern "turnkey" system, can't be beat for overall price, efficiency and hassle-free power. Hams, however, have a demonstrated do-it-yourself attitude, both to save money and to learn more about their equipment and their system's maintenance. With the use of surplus panels, described here, and surplus batteries, described in companion article on page 22, you can save a considerable amount over an all-new system.

What About Surplus Panels?

Current prices are much better than in the past, under $10/watt for new commercial panels. New solar panels are often more efficient, producing more watts per square foot of surface area.

Older panels are, for the most part, repairable. These older panels, made from large round silicon cells or smaller square cells, are hitting the surplus market at very attractive prices. Commercial surplus panels are available for about $4/watt, less shipping. Damaged panels can often be obtained for free locally when purchasing other working panels.

Typical surplus sources for panels are local land mobile (commercial two-way) radio providers, railroad surplus, and small solar dealers. I have listed some sources for new and surplus panels at the end of this article. Don't forget to look here, in the pages of *73*; several companies routinely advertise surplus panels.

Besides the obvious sources listed above, try some of these:

- Billboard maintenance and sales companies
- State highway sign maintenance shops
- Oil and gas pipeline operator/service providers
- Local water/waste water and electrical utilities, especially those with extensive SCADA systems
- Canal and irrigation systems service organizations
- Salvage dealers, commercial and military

Last, but not least, get some magazines, such as *Mother Earth News*, *Backwoods Home Magazine* or *American Survival Guide*, or others found in your local bookstore or library, then check out the ads. Write for catalogs and ask about surplus, damaged or over-age/canceled orders. Also check on the local repeater—you never know what will turn up.

Testing the Panels

As with anything you may purchase which is labeled surplus, always test the panels before you hand over your hard-earned cash. This way you'll know how many watts you are really getting, not just the panel rating. It takes little effort and just a few basic tools to check the panels. The minimum tool requirements are: a digital voltmeter, an ammeter or shunt for your VOM, and a variable load.

First, give the panel a close visual inspection (see Photo A). Look for cracked cells, lifted or broken interconnect foils, or delaminated surface or backing covers. Once satisfied, attach your voltmeter and ensure that it is on a high DC setting. Point the panel at the sun and read the voltage produced (see Photo B). Write down this indication, then attach a load. I use an old, wire-wound, military surplus rheostat to provide a variable load. Never use a radio or other equipment to check the output of an unregulated panel—you may damage the gear. Unloaded panels can generate anywhere from 18 to 30 VDC at several amperes current, enough to fry your radio or other equipment.

The load should have an ammeter or shunt connected, in series, to read the current produced by the panel. Hook the ammeter PLUS (+) lead to the PLUS (+) lead of the panel. Then hook the ammeter minus (-) lead to the load. The return is from the load to the panel. WARNING: Always hook up an ammeter through a load; used like a voltmeter, the ammeter will be damaged. All set? Now

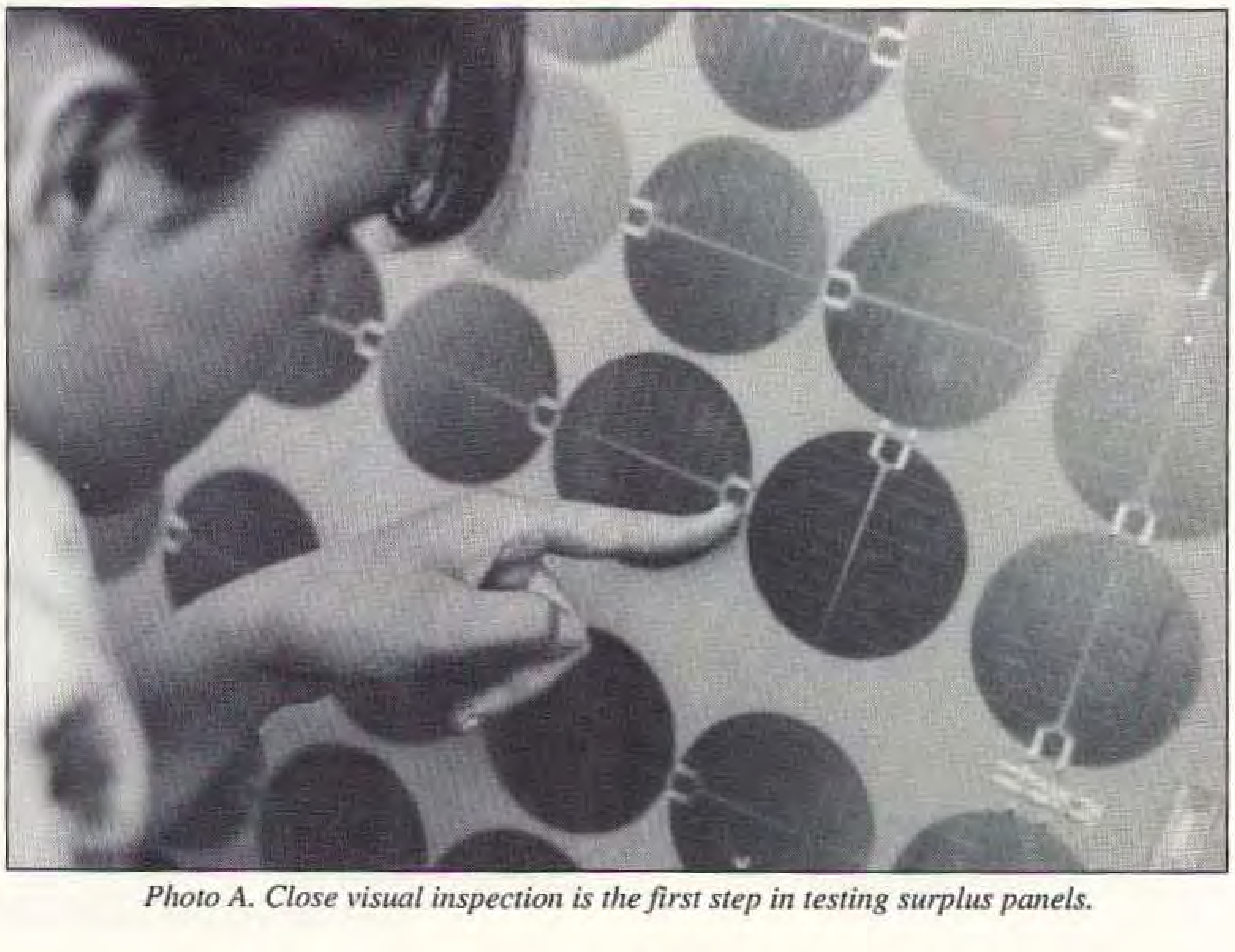

Photo A. Close visual inspection is the first step in testing surplus panels.

point the panel to the sun and read the voltage and current.

Slowly reduce the resistance of the load to increase the current flow produced from the panel. At some point the voltage and current will drop off. Back the load off a bit and note the maximum voltage and current readings. At the same time, take a moment to note the resistance of the load and write it down with all the other data. The rest is easy as pie.

Power equals voltage times current. Power (P) = Current (I) times (X) voltage (E). As an example, a panel you have under test may produce 2.5 amps at 12.5 volts. The panel rating, as measured, is 31.25 watts. Keep in mind that this output will depend on total solar insolution or the rate of delivery of direct solar radiation per unit of horizontal surface area. Simply put, more sun striking the panel produces more power, thus a lower sun angle or shadow results in less power.

What Else to Look For

Anything else to look for while bargain hunting? Added features to look for in a panel are bridging diodes. In newer panels, these diodes allow the panel to continue to produce power even if it is damaged. These panels are worth more than the older type panel pictured in Photo A. Panel frames, interconnect wiring and any tracking devices available should be picked up as part of any deal, if possible. These can improve efficiency of the system and save many of the problems of mounting the panels once home. Use care and the proper gauge of wire and fuses to hook panels to your battery bank. Read the companion articles on finding and testing surplus batteries (page 22) and building a controller circuit (page 10) to complete your system.

Other sources for commercial surplus panels:

SUNELCO Inc., 1-800-338-6844 for orders, P.O. Box 1499, Hamilton MT 59840.

Solar Electric Inc., 4901 Morina Blvd #305, San Diego CA 92117.

Kansas Wind Power, Route 1BW22, Holton KS 66436.

Integral Energy Systems, 109M Argall Way, Nevada City CA 95959.

Photocomm, Inc., 7681 East Gray Road, Scottsdale AZ 85260.

UNI-SOLAR, 1-800-397-2083 for product information, 5278 Eastgate Mall, San Diego CA 92121-2814. 73

Photo B. Test the panel, using care to observe the polarity of the panel output.

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-

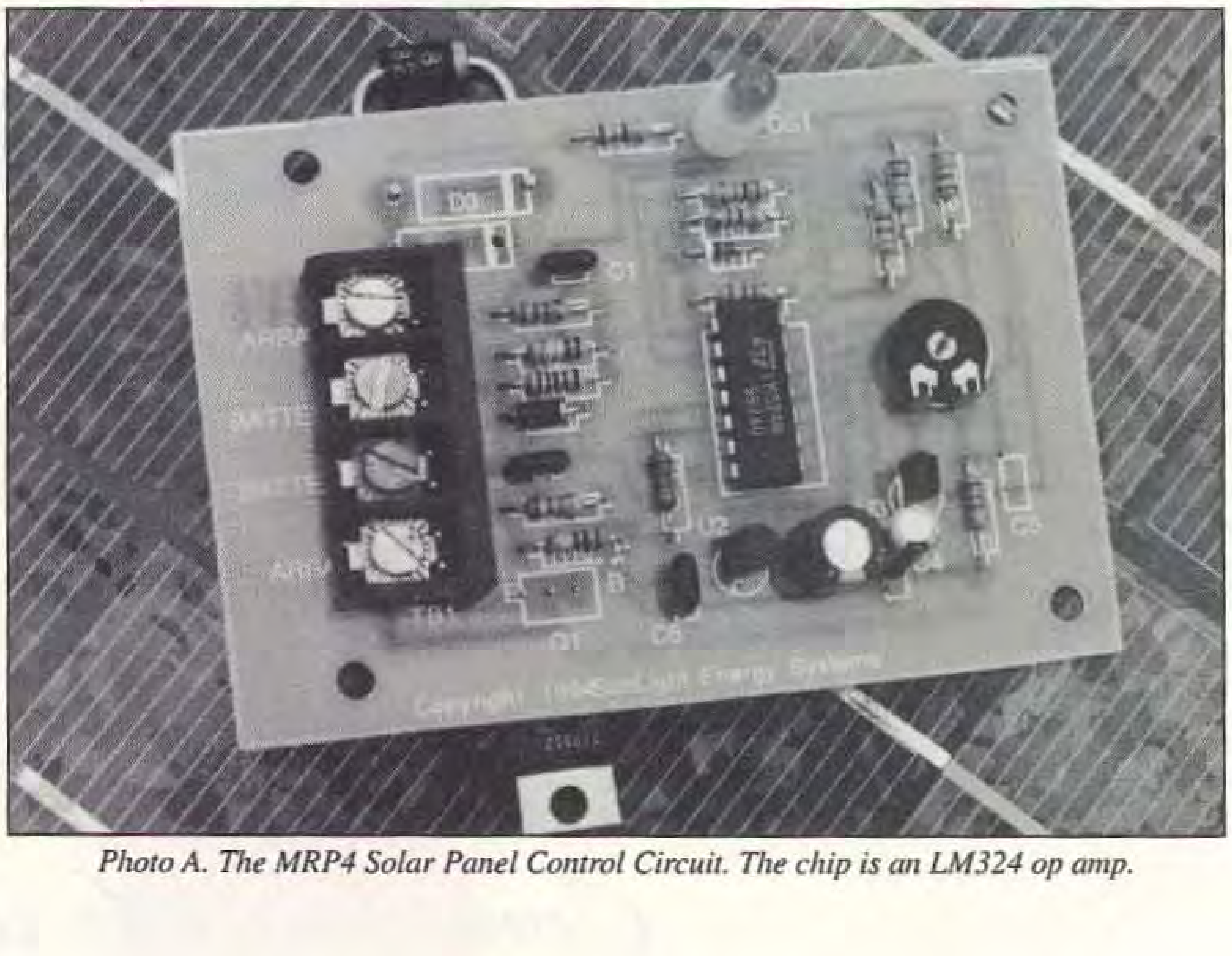

Photo A. The MRP4 Solar Panel Control Circuit. The chip is an LM324 op amp.

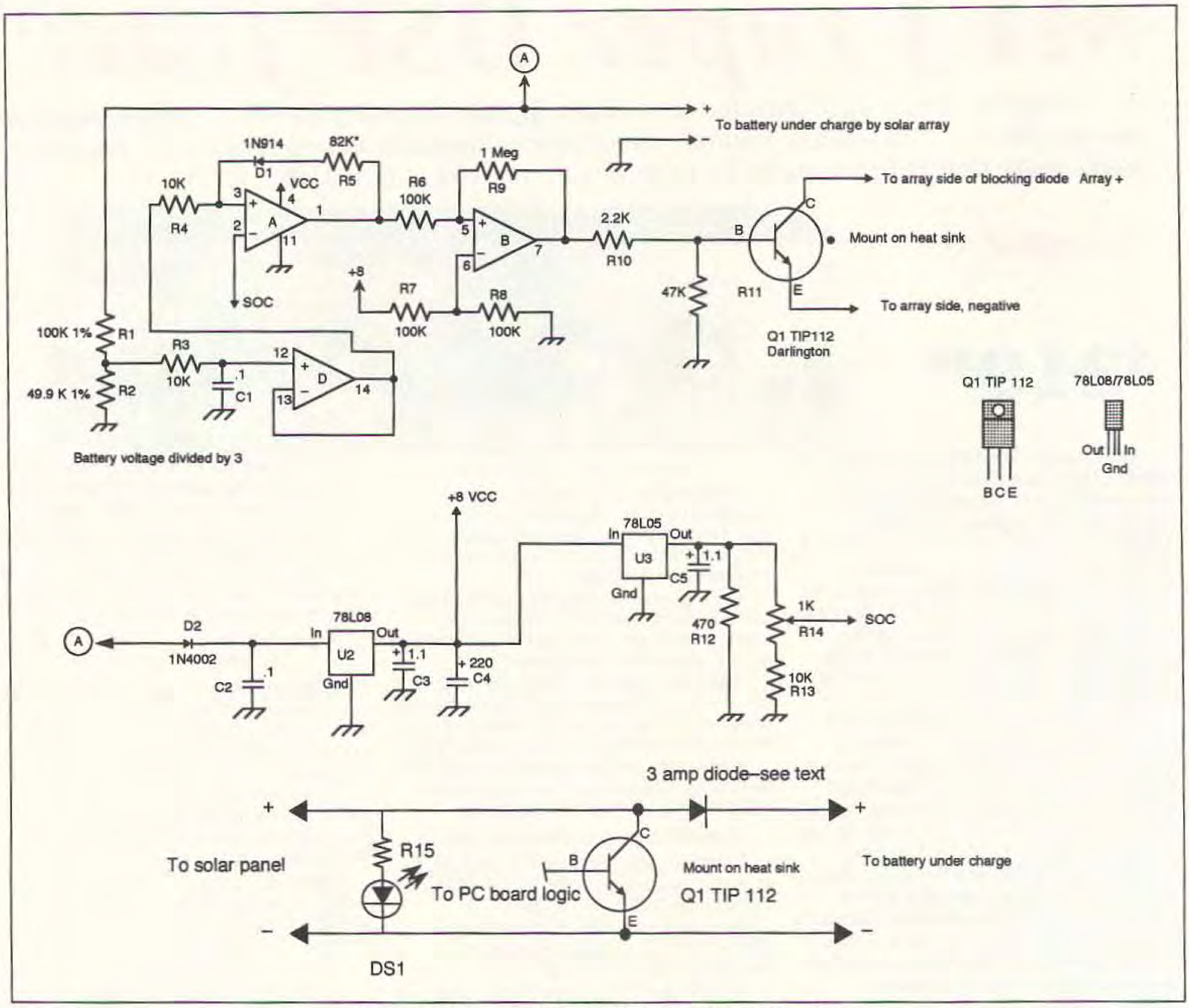

Figure 1. Schematic for the MRP4 Solar Control Circuit.

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

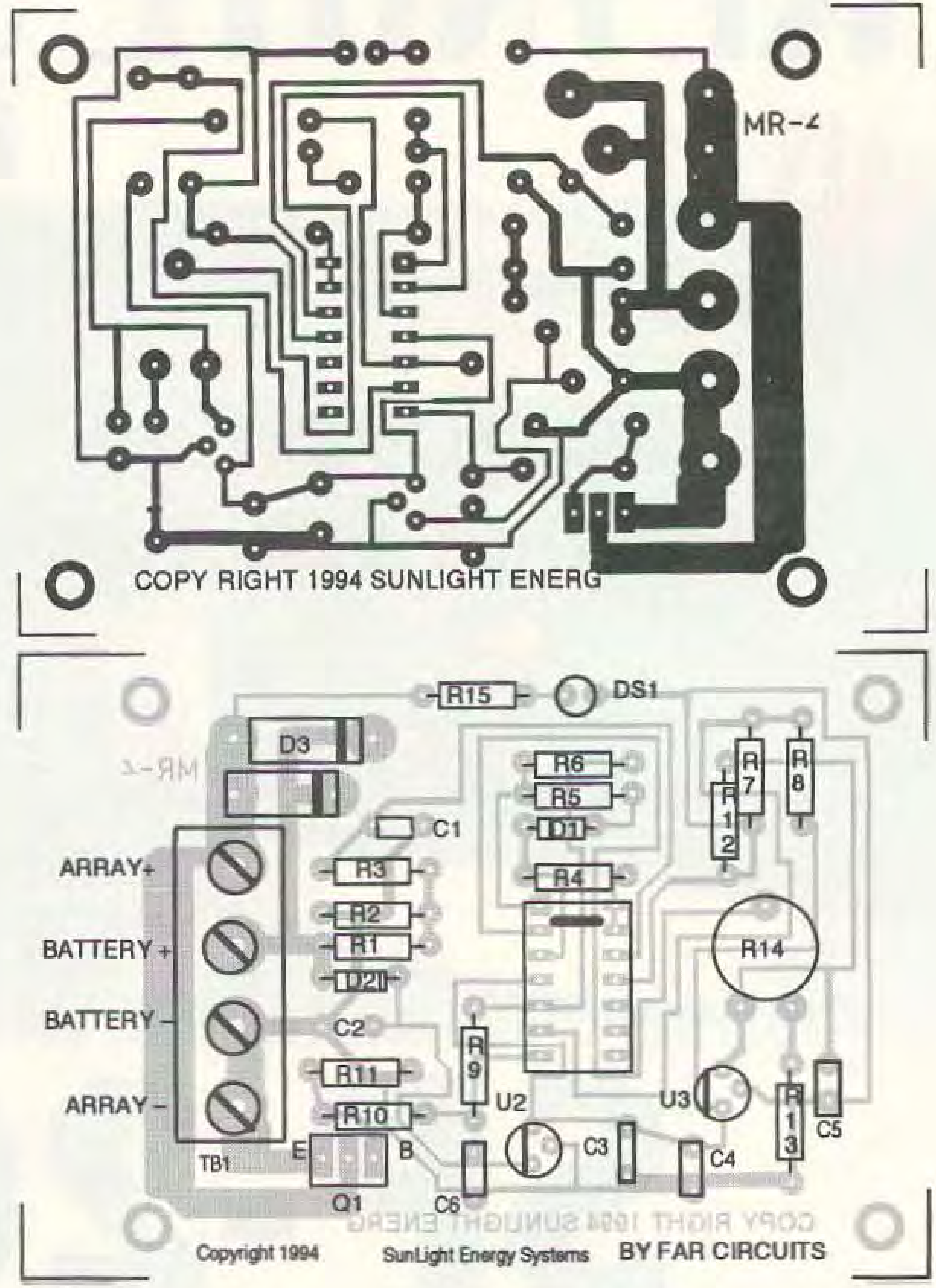

Figure 2. A drilled and etched PC board is available for $4.75 plus $1.50 S&H per order from FAR Circuits, 18N640 Field Ct., Dundee, IL 60118.

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. 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.

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.

Used Batteries for Ham Stations

Another way to save money on power systems.

by Donald E. Koehler N7MGT

How can you save money on batteries to use at home for solar or back-up power systems? For small stations or any other purpose with limited equipment requirements, purchasing used or surplus batteries may be your best value. This article will explore the where and how of buying used batteries, and will also describe sources, test procedures, and cautions.

Before You Buy

First, when is a battery no longer a battery? Answer, when it is toxic waste or hazardous waste! Before you even start looking for used batteries, find a recycler or salvage business which will take in "dead" lead-acid batteries. Even in the best of deals, I have had to purchase "lots" of used batteries which contained the occasional dead battery. It is better to know you have a place for the legal disposal of any of these batteries before you start. While on the phone, ask what the center will pay for used batteries.

Now then, take a moment to determine the voltage and current requirements for your equipment. Inverters, devices which turn DC current into AC current suitable for regular home appliances, are rated in both volts and amperes. You will find this information on the manufacturer's data plate. If operating DC-powered equipment like a portable HF station or scanner, add up the current draw from each piece of equipment that will be operating together. Write down this total current requirement. Your total battery bank capacity should be at least twice this number for the longest battery life in your system.

For the sake of this article, I will assume you will use equipment requiring 12 or 24 volts and the current draw won't be much more than 30 amperes. Higher current levels will require you to really look closely at engineering practices beyond the scope of the information presented here.

WARNING: While the *voltage* of these batteries may appear to be low, the *current*-producing potential is lethal! See the sidebar for battery safety tips.

What kind of battery will fit your needs? By and large, "flooded cell" or wet cell lead-acid batteries are the easiest to find and least expensive. Gelled-electrolyte and NiCd batteries may be the next best bet for low-current demand applications, typically communications equipment. Any battery you consider should be a "deep-cycle" type. Automotive or truck batteries can be used, they just won't last very long in a solar/battery/inverter system. A good deep-cycle battery, even one you purchased used, should give more than five years of useful service life. New batteries will go more than 10 years; in properly-engineered "float" systems, double that service life can be expected.

Sources for Used Batteries

Start with the local phone book to develop a list of potential sources where you can purchase used batteries. Try local golf courses, material-handling equipment companies, local exchange carriers (the phone company or local cable company), large computer operations (such as banking centers) or, if you're near a military installation, the Defense Reutilization and Marketing Organization or salvage yard. Now let's take a look at each source.

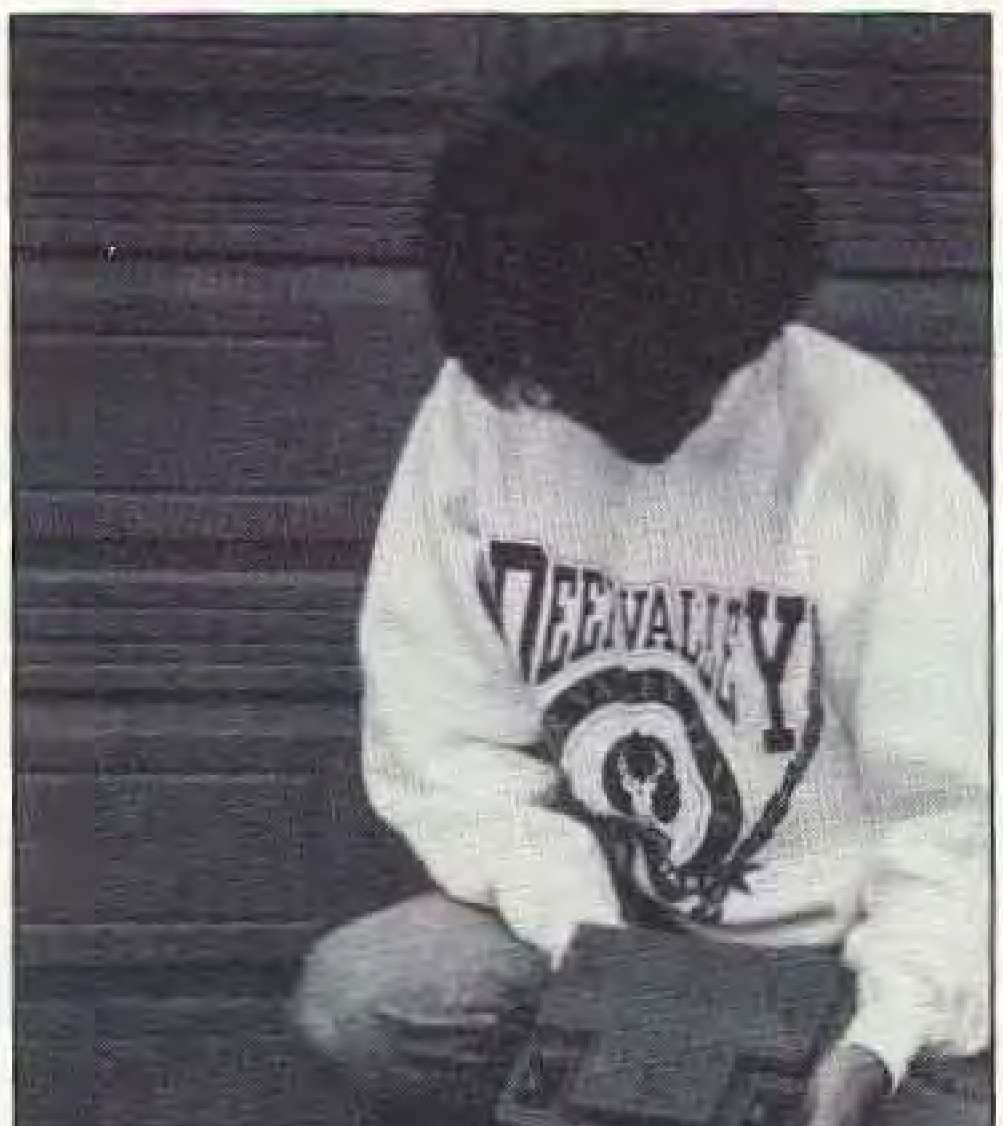

Photo A. These batteries were free for the taking—240 amp/hr. capacity for the effort of hauling them away.

Golf courses in urban areas typically use electric golf carts. These carts typically have six batteries, each one rated at 6 volts direct current (VDC). These batteries are also deep-cycle and capable of large current production. Small enough to move by hand, they are my favorite for small solar systems. Most good-sized golf courses buy batteries by the pallet load and the turnover in used batteries is high. Talk to the greens-keeper or someone in the cart barn. Expect to pay about $3 each. Before you pay, be sure you test the batteries you buy. If you establish a long-term relationship with that golf business, the possibility exists that you can "buddy up" with the course on a battery buy. This will net you a pallet load of identical batteries at a better price than you could get on your own. If a pallet load is too many batteries for your specific needs, split it up with friends.

Material-handling companies that sell or service electric forklifts or pallet movers are another place to try. Batteries used in material-handling equipment tend to be very large and heavy. Local exchange carriers like the phone company use either "glass-wall" cells or large conventional lead-acid batteries. Be careful—a friend of mine picked up a load of glass-wall cells "as a good deal" and some were leaking. The local recycler wouldn't touch them. It cost him major bucks to legally dispose of the now-hazardous waste! I mention these two sources only as a comparison. Very few folks have a need for the current levels these kinds of monsters can produce.

If you are going to power your entire home exclusively with solar recharged batteries, then by all means look for large glass-wall cell arrays. Telco batteries generally have excellent records on service and age. The cells are usually 2 VDC, so it is easy to set up 12 or 24 volt arrays. After all, batteries are where you find them.

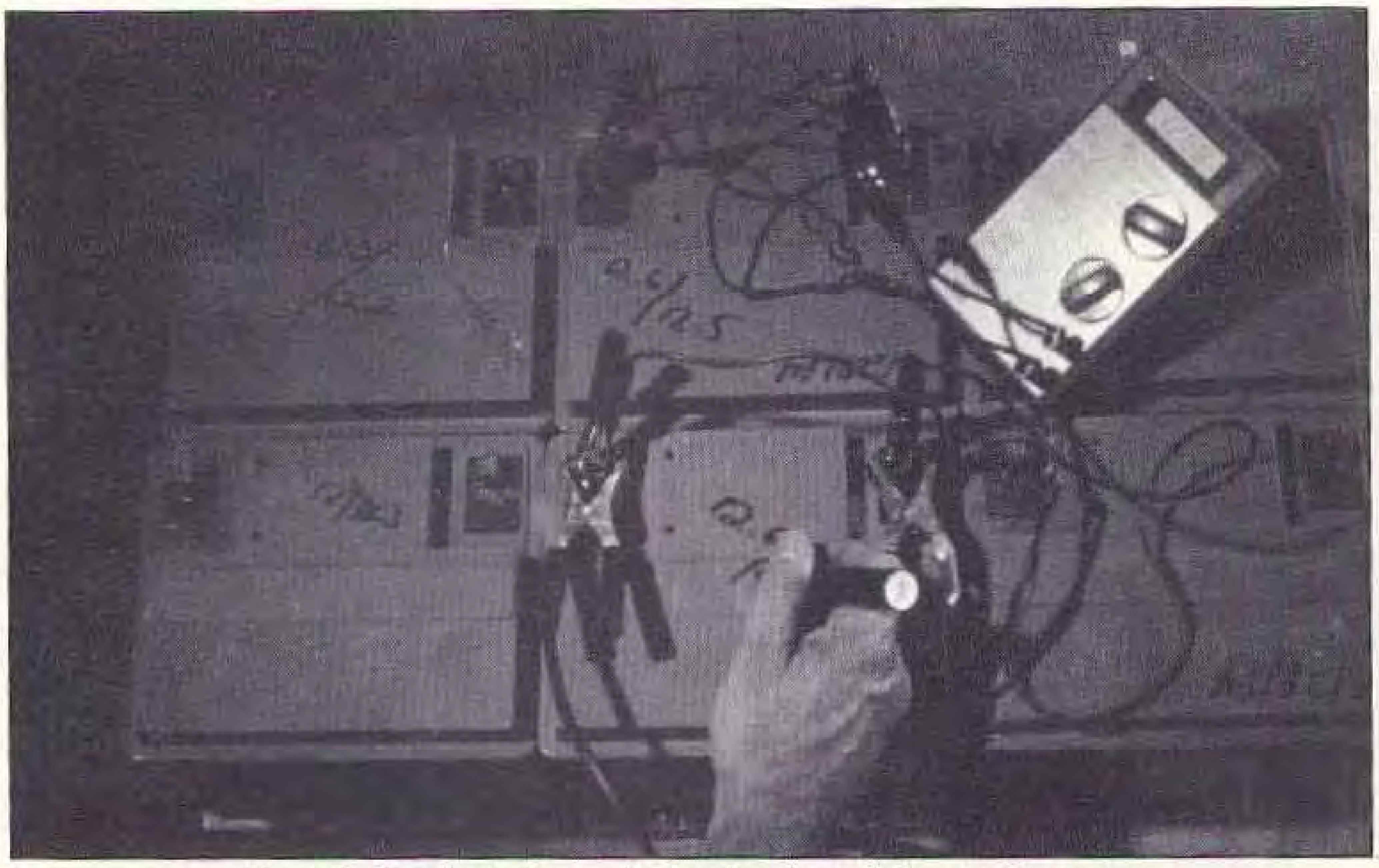

Photo B. Test batteries under load and mark the results on top.

Computer centers with large Uninterruptable Power Systems (UPS) may be a good source of high quality, deep-cycle batteries. About the size of a large auto battery: These cells are small enough to move by hand and most are the gelled-electrolyte type. The cells have "lived" in a well-engineered system, so even cells that are more than five years old should be good for home use. As always, test before you buy. Check with the operations or maintenance supervisor of the local banking or credit card center.

The last source is the Defense Reutilization and Marketing Organization, or DRMO, on a military base near you. This source represents a real crapshoot. My experience is that the folks who work at the DRMO are friendly and helpful, but you have to know what you are looking for in a battery. They can also poll DRMOs in other states or at other bases to see if anything like what you are seeking is available. The big bonus: The batteries they sell are clearly marked as to condition, age and type. Most of the lead-acid and NiCd batteries they sell have been neutralized, to be sold as scrap metal and cannot be re-activated. These can be recognized by the holes drilled into each cell and they will usually be marked with a bright red tag. Sometimes batteries can be found that are still usable. The price is usually pretty good, but the sales are by "lots." Before attending any auctions, go inside and talk to the friendly folks. They really want to sell you something, so ask their advice. I have always received good treatment and a fair deal. Now, how do you test the darn things?

"Before attending any auctions, go inside and talk to the friendly folks. They really want to sell you something, so ask their advice. I have always received good treatment and a fair deal."

Testing Used Batteries

The testing of used batteries is not hard and is a two-part process. You will need a couple of tools. First, a good quality digital voltmeter. Available from retail stores like Radio Shack, they run about the same as an analog (pointer) meter. Second is a "load," something to draw current while you check voltages. I use an old automobile headlamp. The other instrument is a thing called a hydrometer. This is used to check the specific gravity of the battery acid in a wet cell. Be sure you tell the salesperson you will be checking batteries containing acid. You can use the kind that has little floating balls in a tube, available at local auto parts stores or service centers.

Now, another word about safety. *Before* you go out to check and test batteries, let's review some basic safety procedures. One: The darn things are heavy! Use your legs and not your back to lift or move batteries. Second: They contain a powerful acid. When you go to check specific gravity, wear gloves and eye protection! If you are like me, you will follow the advice of professionals and wear a rubber or acid-proof plastic apron, shoe covers and long-sleeved shirts. Old clothes are a must here!

Look at the batteries prior to testing. Are they clean and free from cracks and leaks? Do all of the cells have liquid in them, enough to cover the plates? Are the terminals solidly attached (do they move)? Do the cells each have their own caps or covers, and do they match? They do? OK, let's move on.

Now you are ready for the first test! Take the battery you will test and attach the test leads from your digital voltmeter, being sure to use the correct polarity on the leads. Read the voltage. On a 6 volt battery, fully charged, you should see about 6.3 VDC registered on the meter. Now attach the load. On my auto headlamp, I use a set of old jumper cable clips to allow attachment to the battery under test. The advantage of the headlamp is that I can see it light up, so I know it is pulling current from the battery. The lamp is equal to about a 35 watt load.

With the load attached and drawing current, read the meter. It should not have changed from the first reading. If you are checking several batteries, use a piece of chalk and mark the battery with the two voltages. For instance: 6.3/6.2. Continue on with the rest of the lot. Now you can see, at a glance, which batteries hold up best under a load. Once the batteries are marked, you are ready for step two.

Take your hydrometer and check the

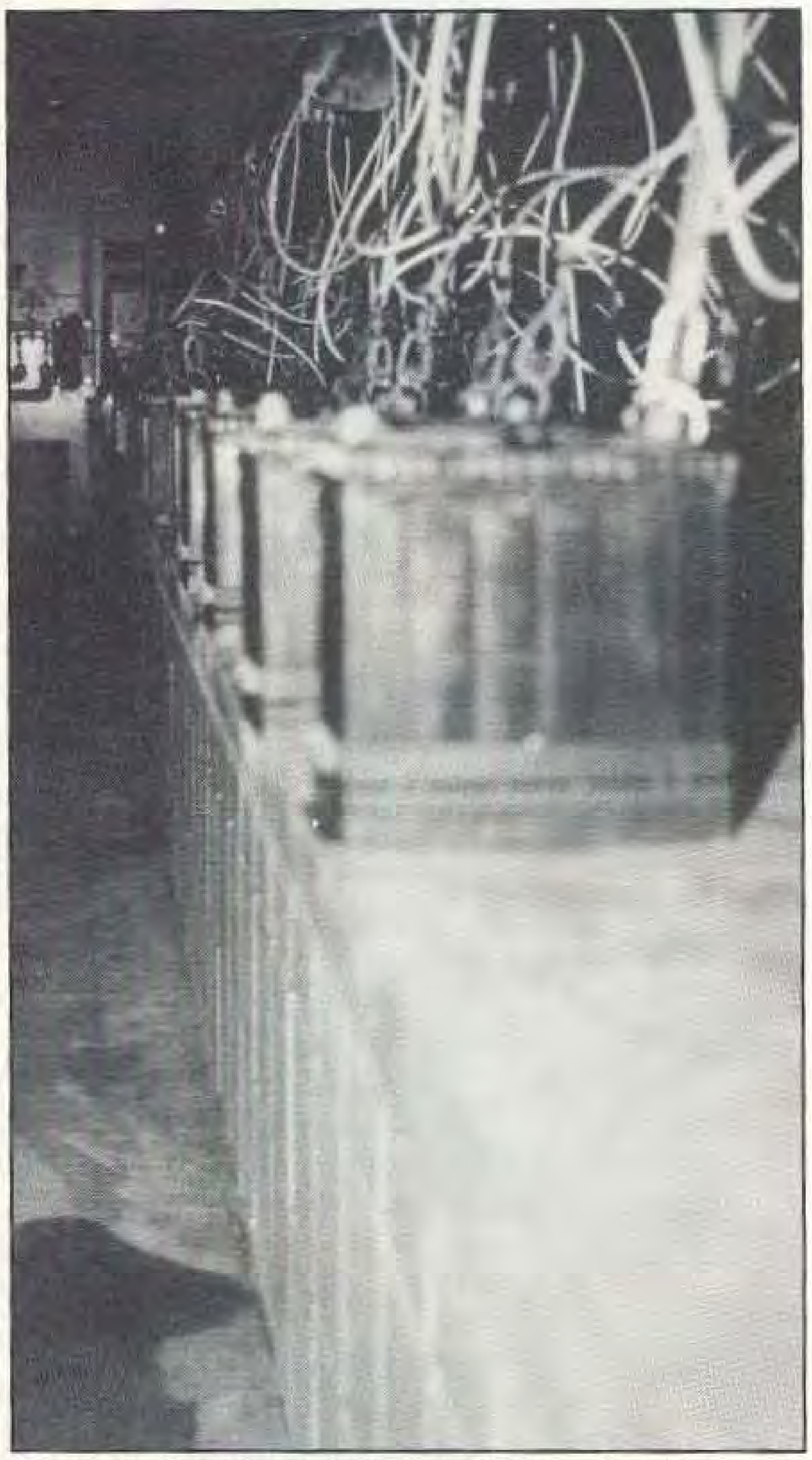

Photo C. Used batteries abound, if you know where to look.

specific gravity (SG). This is a pass/fail kind of test, since it shows the state of battery charge; it does not prove that the battery is good. The specific gravity depends on the type of battery you are testing. Ask what it should be—figures can range from a high of 1.300 to a low of 1.65/1.75. Batteries used in cold climates have an SG of around 1.300. In warmer climates, an SG of 1.65 will allow more current to be pulled from a system battery. Temperature will affect the SG and capacity of the battery. (NOTE: A battery may lose most or even all of its capacity in cold temperatures.) If the battery does not meet the minimum SG, think again about parting with your money.

Remember, clean batteries work better and last longer than batteries which are dirty or corroded. Keep the terminals and outside of the batteries clean—you will save both time and energy.

Now then, how much to pay? Depends. I pay about $3 for used golf-cart batteries, as that is the salvage price. If the battery looks in good shape, passes the tests and is the right size for your needs, go a bit better than the salvage price. Look at it this way: You are saving the owner the cost of hauling his batteries to the recycling center. That is the other reason you checked the price paid by the center first. Drag it home, hook it (or them) to your system and enjoy the fact that you are helping the environment while saving money.

Thanks to the real experts at the 3rd Wing, Elmendorf AFB (AK) battery shop for the DRMO and battery info.

Safety Warnings

Batteries can be dangerous—pay attention to these common-sense safety rules!

- •Keep batteries away from children or pets.
- •Personal Protective Equipment (PPE): Minimum safety equipment includes acid-proof gloves, eye protection and heavy leather shoes; strongly recommended is an acid-proof apron, shoe coverings and a long-sleeved shirt.
- •Batteries are heavy, so use proper lifting techniques.
- •Batteries vent hydrogen gas when charging, so make sure your storage/use area has enough air flow to prevent buildup of explosive gases.
- •DO NOT SMOKE around batteries, charging or not.
- •Use a regulator when charging batteries from a solar system or other unattended method.
- •DO NOT MIX battery types or voltages.
- •In earthquake country, secure the battery so it won't move or spill.
- •It is OK to set batteries on a concrete surface. However, any spilled acid may ruin the concrete.
- •Protect terminals so they cannot be shorted together.
- •If in doubt, check with a professional battery service organization or dealer. Be safe, not sorry.