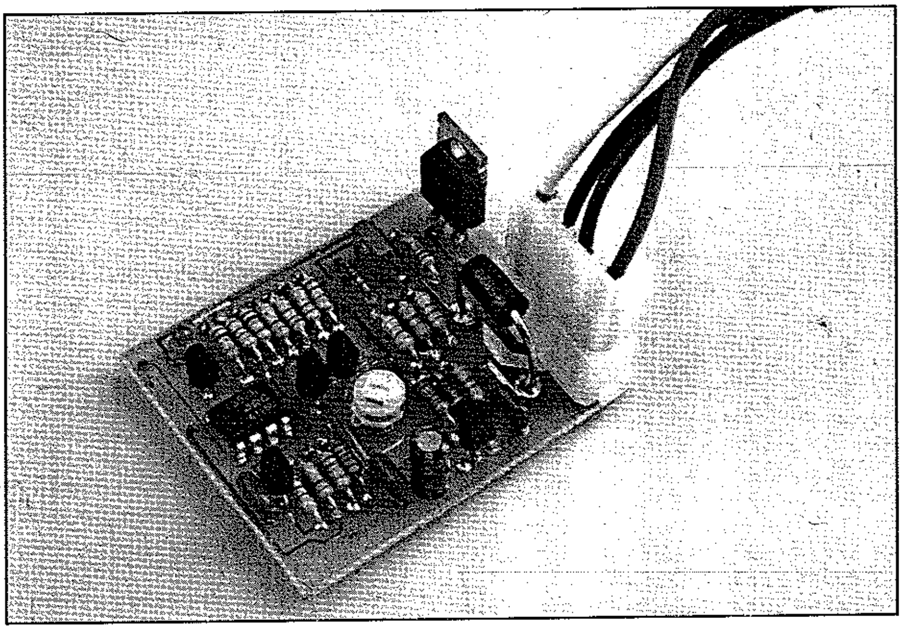
By Michael Bryce, WB8VGE

The Micro M—a Miniature Charge Controller

With this shirt-pocket-size charge controller, you can easily protect your batteries from overcharging when using solar panels—even while portable!



Many hams take their low-power (QRP) rigs to the hilltops and countryside. Packing a small solar panel to power the rig, they're in for a grand time! One of the benefits of running QRP is its diet-like demand for energy. Most QRP/portable setups need only a 5 to 10-W solar panel to supply more than enough juice to operate the rig for days—even weeks at a time—if the sun is shining.

Most of the hams I know who operate QRP/portable don't enjoy carrying a car battery around with them. Instead, the sealed (gelled) lead-acid battery has become quite popular. Depending on the current required by your rig and accessories, suitable battery capacities can be had ranging from 1.2 Ah to 6 Ah. Batteries with capacities of over 6 Ah begin to add noticeable weight to your backpack. Common sense dictates you carry more water and food than battery packs.

A 5-W solar panel can produce more than enough power to fully charge a small gelled lead-acid battery. If you leave your battery and solar panel connected all day while you're out exploring the countryside, it's quite possible you'll have a cooked battery by the time you get back in the evening. To prevent such damage to your battery, you need a charge controller.

Many of us not taking ham radio to the woods are installing solar-powered packet weather stations. By using a micro-powered TNC, an H-T and a weather interface, all you then need to provide up-to-the-minute weather on a packet network is a source of power.[1]

Micro M Features

Here are some of the features most hams want in a portable solar-power control system:

- Low current consumption
- Light weight
- Ease of use
- Simple setup without extensive test gear
- Ruggedness—strong enough to stand up to portable use and abuse
- Able to handle 1 A of panel current

With those guidelines in mind, the Micro M came to be.

The Micro M

The Micro M is a small charge controller using a single power MOSFET as a series switch. It can handle up to 2 A of array current and is protected against overvoltage and reverse polarity. A four-terminal connector marries the controller to your battery and solar panel.

The Micro M is easily built on a double-sided PC board. It's so small, you can fit *four* assembled Micro Ms into your shirt pocket! The Micro M is light on your budget, too. You can build your own Micro M for under $25—much less if you've got a well-stocked junk box. Parts are readily available by mail order. A PC board and a complete kit of parts can be purchased, too.[2]

How It Works

Refer to Figure 1. R1, R2, and R18 form a voltage divider to feed a fraction of the battery's terminal voltage to one section of an LM358 op amp (U1A) configured as a voltage comparator.

We need a reference voltage to compare to the sampled battery voltage. The Micro M uses a 2.5-V reference diode. I chose the National LM336Z 2.5 (D1) as it is easy to come by and inexpensive. Since we're not launching missiles, the 5% toler-

[1]Notes appear on page 43.

Assembly

You can build your own version of the Micro M using any method you choose. However, if you're planning to use the Micro M in the outback, I highly recommend using a PC board.[3] The PC board for the Micro M is double sided with plated-through holes, and has provisions for a board-mounted AMP connector. This makes connections to and from the Micro M painless. You can also hard wire the Micro M into your own application if you desire.

Because this is such a simple project, assembly requires only a mindful eye on the single electrolytic capacitor and other polarity sensitive components. Be sure all solid-state devices are installed correctly. Use a grounded wrist strap when handling the power MOSFET. It's static sensitive, but very hardy once installed on the PC board.

Normally, using a socket for U1 is a good idea. However, I recommend you pass on using one if you plan on using the Micro M out in the field. Solder U1 to the board if you plan to do backpacking in the south 40.

The PC board is quite small and compact, so it's easy to create a solder bridge. A small-tipped soldering iron and a steady hand are required.

Setup and Adjustments

After ensuring your PC board has no solder bridges or incorrectly placed components, connect the Micro M battery input terminals to your power supply. Set your power supply for 14.2 V.[4] This is the turn-off voltage for a fully charged 12-V gelled lead-acid battery.

Set trimmer R18 (**TURN-OFF ADJ**) fully CCW. With your VOM, probe the gate lead of Q4. You should measure about +12 V on the gate. Slowly turn R18 clockwise until Q4's gate voltage drops to zero. You may want to repeat the preceding steps to ensure you have the trimmer set as closely as possible to your turn-off voltage. That's all the adjusting you need to do. Because the trimmer is easy to bump, apply a glob of paint or other sealer to hold it in place.

Deflux the board with denatured alcohol and then apply a conformal coating to the PC board. This prevents oxidation from forming between the various traces and pads on the PC board. If you desire, the PC board can be potted to seal out the environment. Although not very attractive, I have sealed an entire Micro M using hot-melt glue. The heat from the glue doesn't seem to hurt the components in any way.

Putting the Micro M to Use

All you need to do is connect a solar panel and a battery to their proper locations (PV and BATTERY), respectively. If you use the AMP connector, you'll need to add the necessary wires. Of course, it's a good idea to use different color wires to avoid confusion in the woods.

The Micro M can fit inside just about any QRP rig made. Two strips of double-sided foam tape or epoxy will hold the PC board in place. There are two holes in the PC board that accept #4-40 screws.

With a solar panel and battery connected, and the panel sitting in the sun, all current is directed toward the battery. DS1 will be on. When the battery terminal voltage reaches 14.2 V, DS1 will go dark. After a few seconds, the LED will turn back on. DS1 will then blink on and off signaling a fully charged battery. Don't disconnect the array from the battery at this time. Allow the Micro M to fully charge the battery. You can leave the Micro M connected indefinitely without harm to the battery.

Odds and Ends

You may be wondering why there is no heat sink on Q4. The MOSFET specified has an extremely low R_{DSon}. Even with a drain current of 1 A, there's hardly any voltage drop across the MOSFET. With an R_{DSon} of 0.035 Ω, the power dissipated by Q4 is only 0.14 W with an array current of 2 A.

LEDs have always been tough to see in bright light. You can replace the LED specified with one of the high-brightness LEDs available. (Check with various surplus electronic parts suppliers for great prices on high-brightness LEDs.) On the other hand, you can elect not to use the LED at all to reduce current drain. If you go this route, you can eliminate Q1 and its associated support components (R11, R12 and DS1).

Packing a rig and enough battery power to operate it can be a lesson in engineering. I've used two 7.2-V R/C NiCd packs wired in series (14.4 V) with great success. The only requirement is that the rig being powered by the battery packs must be able to handle the higher operating voltage. The higher voltage also adds a bit more kick to the transmitted signal. Of course, you'll need to reset the state-of-charge to reflect the use of the NiCd batteries.

No matter what battery type you plan on using during your trip to the great outdoors, don't use standard fuses. Such fuses are great if you're sitting at home, but out in the middle of the forest, how many spares are enough? I suggest you use a PolySwitch device in your portable setup. These resettable fuses are like circuit breakers, but faster and entirely solid state. A suitable Raychem PolySwitch is available from Digi-Key (part number RUE110). Rated at 1.10 A at 30 V, it should be suitable for many QRP rigs. Best of all, it's only a buck!

Part Substitutions

A variety of dual op amps can replace the LM358. I've used an LM2904 without any noticeable difference in operation. If you build your version of the Micro M on perfboard, two sections of an LM324 or LM224 op amp will do.

The 1%-tolerance resistors used for R1 and R2 have a 50-PPM temperature coefficient and have better temperature stability than standard resistors. You can get by with standard 5%-tolerance resistors if need be.

Many NPN and PNP transistor substitutes (such as the 2N2222 and the 2N2907) will work fine in place of the transistors I've specified. I've used a variety of power MOSFETs in the Micro M with equal success, including the IRFZ44, IRF511, IRFZ40 and IRFZ30.

Whether you're camping on a mountain ridge or providing emergency communications, you'll find the Micro M an invaluable accessory to your backpack. What do I use my Micro M for? Why, to recharge my solar-powered weed trimmer, of course!

Notes

[1] An Ohio state park uses a Micro M controller to protect a lead-acid battery used in an announcement box along a walking trail.

[2] A complete kit of Micro M parts including the PC board is available from SunLight Energy Systems, 2225 Mayflower NW, Massillon, OH 44647. Price: $25, including shipping to any US location. The double-sided PC board with plated-through holes is $12, including shipping. A template package containing the *double-sided* PC-board pattern and a part overlay is available from the Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111. The price is $2 postpaid for ARRL members ($4 for nonmembers). Please identify your request for the BRYCE MICRO M TEMPLATE.

[3] The PC board artwork in Circad format is available from CompuServe in the QRP section of the HAMNET forum (the file name is MICRO.ZIP). This file includes the schematic, top foil, bottom foil and silk screen along with an ASCII version of the setup instructions. You can also obtain this file from the ARRL BBS (860-594-0578) and from the Internet (ftp to **oak.oakland.edu, dir pub/hamradio/arrl**).

[4] A flooded-cell lead-acid battery requires a bit higher voltage to fully recharge.

Mike Bryce, WB8VGE, began building early on. His first homebrew project—a transmitter out of the Handbook*—began only two days after his Novice license arrived in 1975. Since then, the homebrewing never stopped. Mike currently holds an Extra Class license.*

Mike's written several storage battery and alternative energy articles for QST. *A busy guy, he also writes a monthly* QRP *column for* 73 Magazine, *a column for* Radio Fun, *and is a frequent contributor to* QRP Quarterly *and* Nuts and Volts Magazine. *Mike is a past president of the Massillon Amateur Radio Club.*

An avid QRPer, Mike spends most of his spare time building projects. His main interest, however, lies in alternative energy sources, particularly solar energy. Mike operates Sunlight Energy Systems, a small company he started in 1984 that's geared toward advancing the use of solar power. Since 1978, Mike's entire radio shack has been running on solar power. Now, 50% of his house is solar powered, too! You can reach Mike at 2225 Mayflower NW, Massillon, Ohio 44647.

ance of D1 is more than ample. R4 limits the current to the LM336Z.

To prevent U1 from oscillating at the state-of-charge turn-off voltage we'll select, R5 and R6 provide a small amount of hysteresis. With the values shown, there's a window of about 0.4 V between the off and resume voltages.

When U1A switches states, the signal is applied to U1B. This section is also configured as a voltage comparator. But now we compare the output of U1A to a fixed voltage source supplied by R8 and R9. This squares up the switching before passing the signal along to the output transistors.

There are three transistor switches used in the Micro M. If a photovoltaic (PV) panel is connected to the charge controller—and the sun is shining—DS1 illuminates when Q1 turns on. R12 limits the current flowing through DS1.

At the same time, Q2—now fully saturated—pulls Q3's base low. Q3 conducts and applies the battery voltage to the gate of the power MOSFET, Q4. With Q4 on, array current flows. Q4 is in series between the PV array's negative lead and ground. By using a power MOSFET in the negative lead, we avoid the need for complex high-side switching components.

Zener diode D2, R17 and C1 protect Q4's gate from damage caused by static discharges coming in from the array leads. R16 connects Q4's gate to its source, ensuring that Q4 turns off completely.

By using the battery voltage to turn on Q4's gate, we're assured that Q4 will turn on hard. Q4's gate must see at least 10 V to be fully enhanced. At lower gate voltages, Q4 operates in its linear region. Although this isn't what we desire, it also means the Micro M will charge a battery with its terminal voltage as low as 7 V! The power MOSFET I used can be replaced with an enhanced-gate MOSFET. Enhanced-gate MOSFETs are fully enhanced with only 5 V on the gate (DK IRLZ44).

When the battery's terminal voltage reaches the OFF set point, U1 switches states and everything shuts off. DS1 goes dark and Q4 stops conducting array current. At this time, the battery's terminal voltage begins to fall. When the terminal voltage drops to approximately 0.4 V below the OFF set point, the entire process repeats. So, a fully charged battery causes DS1 to blink on and off. The blink rate is determined by the size of the solar panel and battery capacity. Battery conditions such as age and depth of discharge have an effect as well.

Although the circuit's current requirements are next to none, I added U2, a small, 100-mA voltage regulator. It serves more as a safety device than a voltage regulator. U1 is quite happy until you apply over 16 V to its V_{CC} input pin. (This is easy to do if you connect the solar panel to the battery input terminals.) Without U2, the LM358 would end up a crispy critter. U2 is bypassed by C3, C4, and C5 to ensure stability. Without U2, the off voltage would vary as the supply voltage moves about. U2 prevents this from happening.

I've been known to connect something up backward now and then. To prevent such an occurrence from cooking the Micro M, D4, a 1N4002 diode, provides reverse-polarity protection.

A 3-A Schottky diode, D3, prevents the battery from discharging into the solar panel at night.

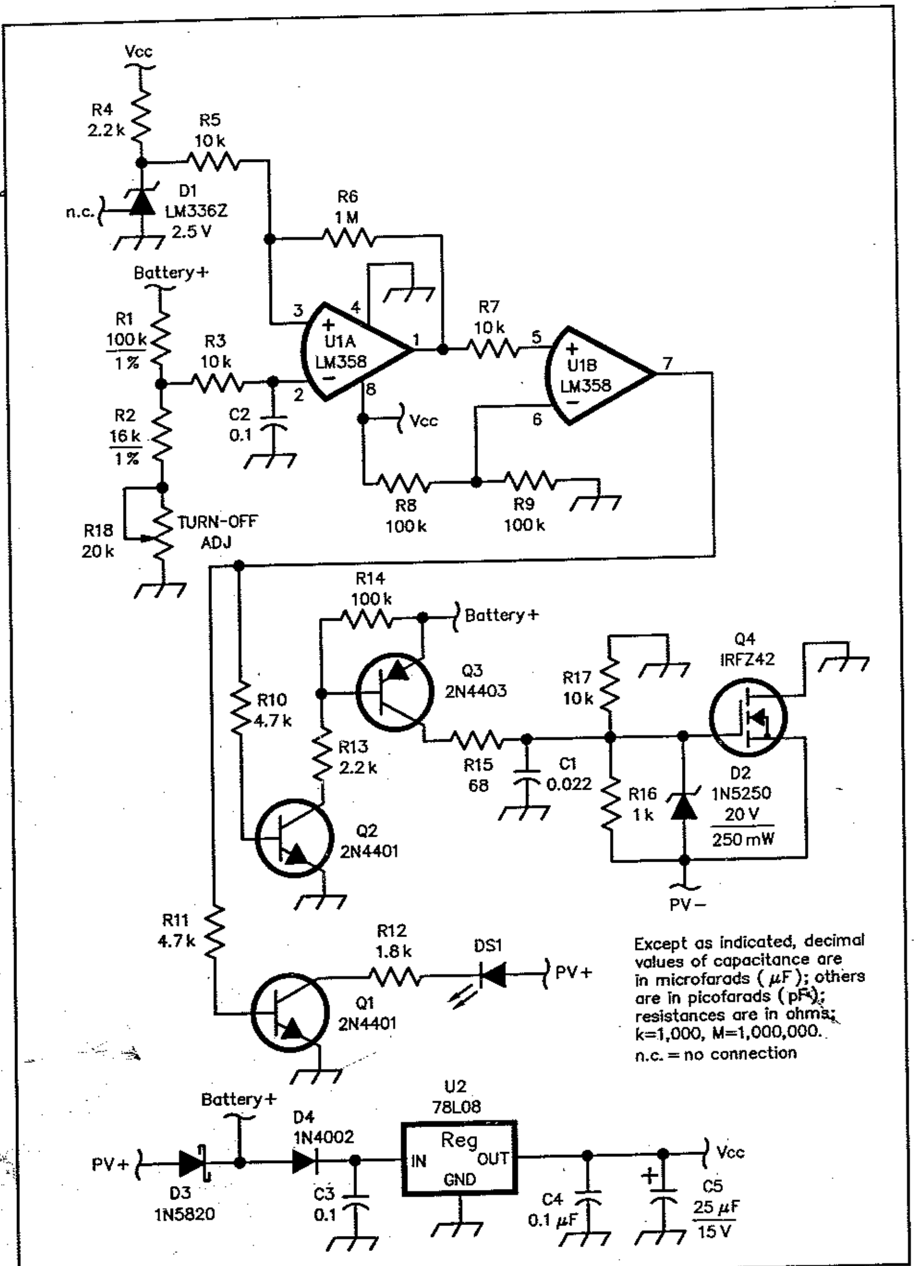


Figure 1— The Micro M circuit. DK part numbers in parentheses are Digi-Key (Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674; fax 218-681-3380; on the Web at **http://www.digikey.com**).

Parts are also available from Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952; tel 800-524-6464; 614-264-6464; fax 614-264-5414. Equivalent parts may be substituted.

D1—LM336Z 2.5-V reference diode (DK LM336Z2.5)
D2—1N5250 Zener diode (DK 1N5250BCT)
D3—1N5820, 3-A Schottky diode (DK 1N5820CT)
D4—1N4002 (DK 1N4002CT)
DS1—Red LED (DK P300)
Q1, Q2—2N4401 NPN transistor (DK 2N4401); 2N2907 (see text)
Q3—2N4403 or 2N3906 PNP transistor (DK 2N3906A); 2N2222 (see text)
Q4—N-channel power HEXFET (DK IRFZ42)
R18—20-kΩ PC-mount trimmer potentiometer (DK 36C24)
U1—LM358 op amp (DK LM358AN)
U2—78L08 regulator (DK AN78L08)
Misc: PC-board pin-header (DK A1470); in-line plug (DK A14282); male pins (DK A1441); female sockets (DK A1440).