The FET Charge Controller

Whether you're operating a solar-powered ham station or just charging batteries, this controller monitors their state of charge and keeps them safely topped off.

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Photovoltaics, the science of converting sunlight directly to electricity, is fast becoming the energy technology of the '90s. With no moving parts, and generating no noise or pollution once installed, a solar electric system is reliable and elegantly simple—an ideal alternative energy source. Photovoltaic (PV) panels capture energy from sunlight and convert it into electricity. The electricity can be used immediately or stored in batteries.

Remembering the early days of photovoltaics, many people still think PV panels are capable of generating only a few milliamperes. Not anymore! Today, a single panel (1½ feet wide by 4 feet long) can produce up to 3.5 A at 17 V in direct sunlight. Combine two or more panels, and you've got a *real* source of energy on your hands!

If a solar array is continually connected to storage batteries without any precautions, severe battery overcharging occurs. The results are rather ugly. There's physical damage in the form of warped plates, dislocation of the plate's lead paste, and excessive electrolyte gassing resulting in loss of electrolyte. What's needed is a device that takes the worry out of battery charging: I call it the FET Charge Controller (see the sidebar "Charge Controllers 101").

The Charge Controller is ideal for monitoring and controlling a PV array's output current to the battery bank. Even if you don't yet have a PV array, you can still use the controller as a means of monitoring and controlling the output of a battery charger (see the sidebar "Using the FET Controller With a 120-V AC-Operated Charger"). The result: no more fried batteries!

Better Than the Rest

Because this is an easy-to-build project, that doesn't mean it lacks features. What's unique about this controller? Plenty.

- Current capacity up to 30 A. With the specified power MOSFETs (see the sidebar "A Better Controller With MOSFETs"), the controller handles current levels of up to 15 A. By using a beftier diode at D11 and attaching the FETs to a larger heat sink, a current-handling capacity of up to 30 A—the current-handling capability of the PC-board's traces—is possible. (It takes a *lot* of solar panels to generate that amount of current!)
- You can monitor the battery's terminal voltage at the controller's terminal strip, or use remote sense wires connected to the remotely located battery. The FET controller can power itself, or be operated from a separate power supply if desired.
- The controller has extremely low losses. At rated current, the FETs alone drop only about 0.18 V. Voltage drop across the entire controller is less than 0.6 V at rated current.
- Low energy demands. It requires 46 mA to operate in the charging mode, and sleeps using only 30 mA. The sleep-mode current demand can be reduced to 16 mA by not using the built-in ammeter circuit.
- The high- and low-voltage set points are fully adjustable. This allows maximum flexibility when you set about sizing both the array and the battery bank to meet your requirements.
- A low-battery-voltage indicator, delay timer and external-device control relay are included.

How It Works

The controller is rather simple, especially when you break the project into bite-size bits. Several different circuits make up the FET controller.

Refer to Figs 1 and 2. Operating voltage is routed through D1 to protect the circuit from an incorrectly polarized power supply. Four LEDs (DS1-DS4) keep track of the controller's status. You know in an instant what's going on.

U1 contains four identical voltage comparators. U8, a voltage regulator, provides a stable +8-V source. From this source, resistive voltage dividers—including multiturn pots for fine adjustment—are used to set U1's comparators.

The battery's terminal voltage is routed to a voltage divider. This divider is set to half of the battery's voltage by R37

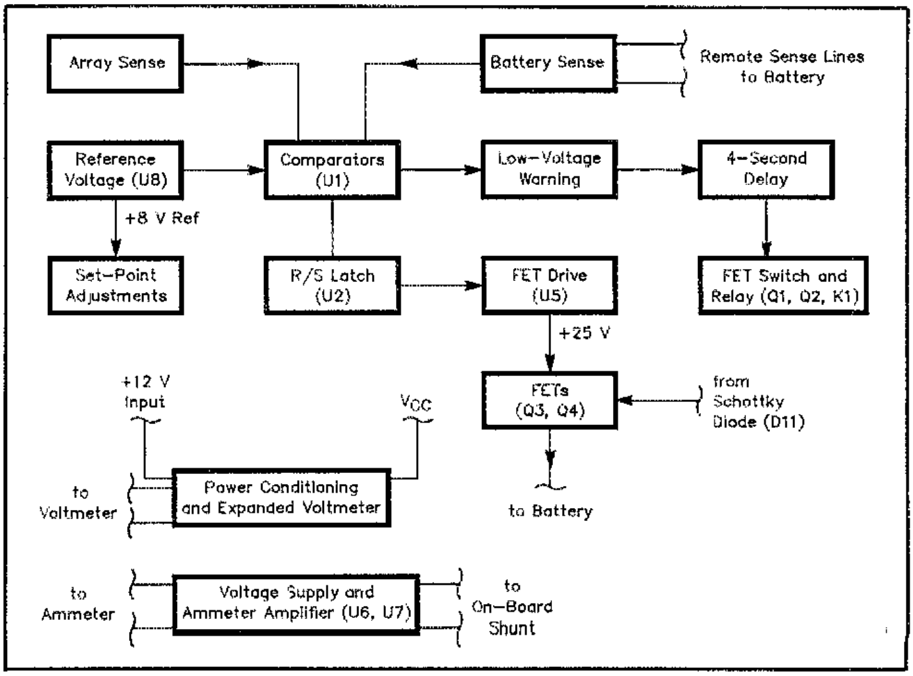


Fig 1—Block diagram of the FET controller's logic.

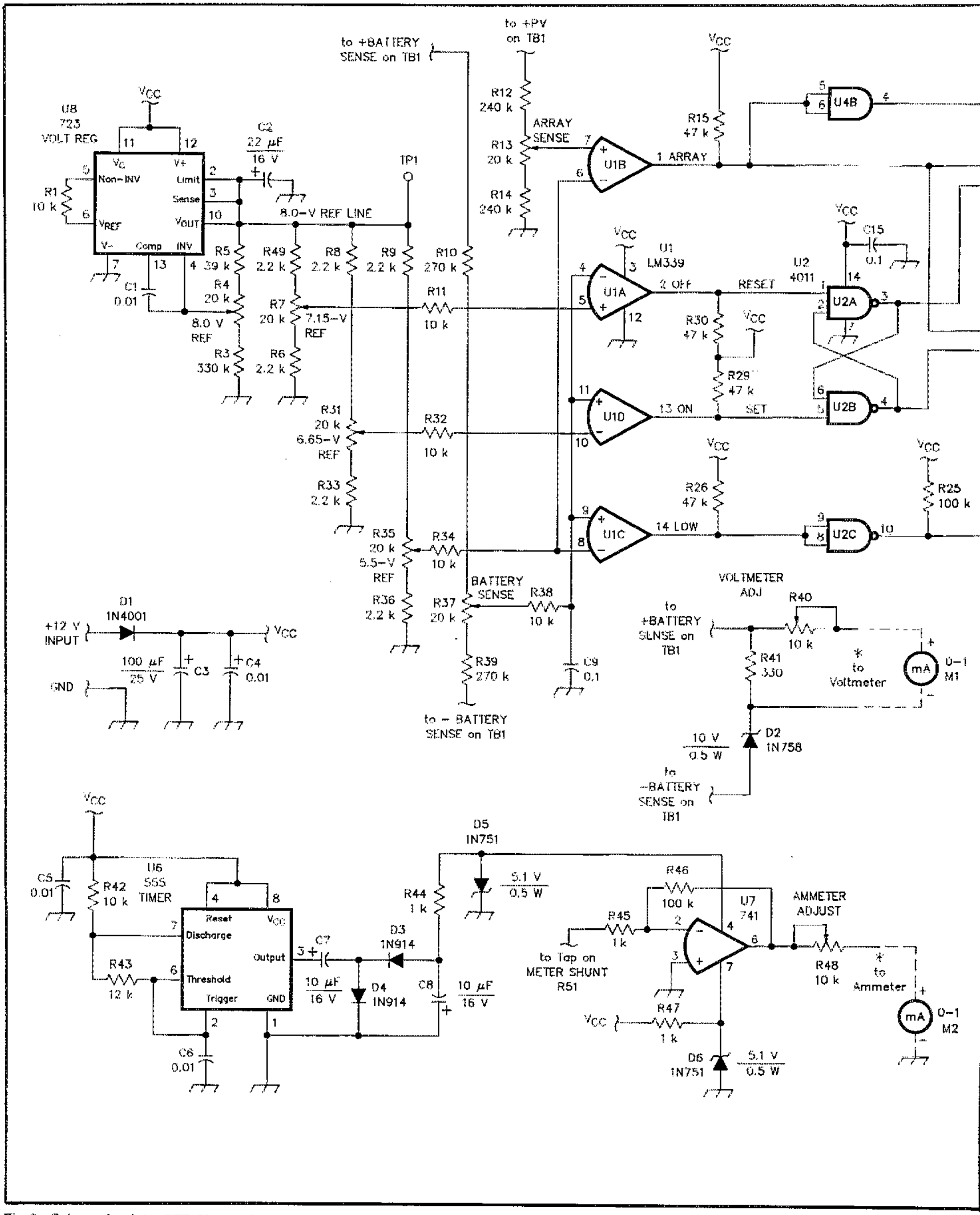
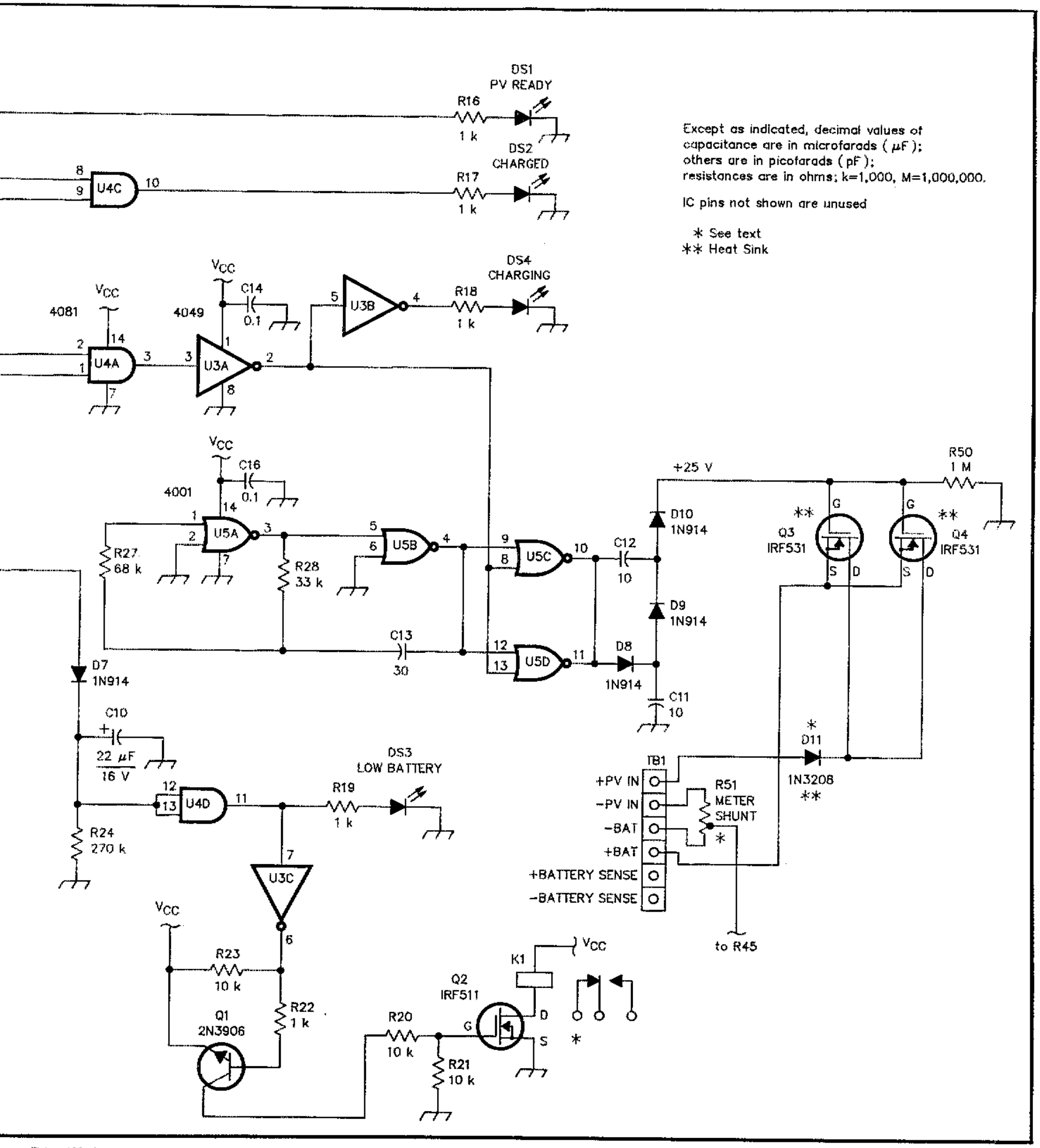


Fig 2—Schematic of the FET Charge Controller. Mouser numbers are Mouser Electronics; RS numbers are Radio Shack; equivalent parts can be substituted. Resistors are ¼-W, 5-% tolerance carbon-composition or film units. Parts are available from Mouser Electronics, tel 800-346-6873 for order placement, customer service and assistance. Mouser has several sales and distribution centers throughout the US. Parts identified with Radio Shack numbers are those listed in the 1992 catalog and are available from Radio Shack outlets. Other parts sources include Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539, and Allied Electronics (several locations throughout the US), tel 800-433-5700. Allied, however, does not stock the MOSFETs. (The ARRL and *QST* in no way warrant these offers.)



D1—1N4001, 50-PIV, 1-A silicon.
D2—1N758A, 10-V/0.5-W Zener (Mouser 333-1N758A).
D3, D4, D7-D10, 1N914 or 1N4148 (Mouser 333-1N914, RS 276-1122).
D5, D6—1N751A, 5.1-V/0.5-W Zener (Mouser 333-1N751A, RS 276-565).
D11—1N3208, 50-PIV, 15-A Schottky diode, DO-5 case (Mouser 584-1N3208).
DS1-DS4—LEDs.
K1—SPDT miniature relay; 12-V dc, 38-mA, 320-Ω coil; 10-A, 125-V ac contacts (Radio Shack 275-248).
M1, M2—0- to 1-mA meter (Radio Shack 270-1754; Mouser 541-MS-DMA-001).
R4, R7, R13, R31, R35, R37—20-kΩ, 25-turn trimmer pot, vertical adjustment (Mouser 594-64W203).
R40, R48—10-kΩ, vertical-mount, single-turn pot (Mouser 320-1510-10K).
R51—See text.
Q1—2N3904 (Mouser 570-2N3904, RS 276-2016).
Q2—IRF511 (Mouser 584-IRF511, RS 276-2072).
Q3, Q4—IRF531 (Mouser 584-IRF531); in a pinch, IRF511s can be used.
U1—LM339 (Mouser 511-LM339AD).
U2—4011 (Mouser 511-4011, RS 276-2411).
U3—4049 (Mouser RS 276-2449).
U4—4081 (Mouser 511-4081).
U5—4001 (Mouser 511-4001, RS 276-2401).
U6—555 (Mouser 511-NE555N).
U7—741 (Mouser 570-LM741N).
U8—723 (Mouser 511-LM723CN).
Misc: 6-position terminal strip (Mouser 506-8PCV-06), heat sinks, (Mouser 567-7-179-BA; RS 276-1363), weatherproof enclosure (Hammond 1414TH type 12, (10 × 8 × 4 inches HWD), hardware.

Charge Controllers 101

Two basic technologies are used to charge batteries via solar power: shunt mode and direct switching mode. The FET controller uses the direct switching method. Let's look a little closer at the different charge-control methods.

As the name implies, shunt controllers divert array power from the batteries by shunting the array to ground. A blocking diode isolates the controller from the batteries. This prevents the controller from discharging the battery bank along with the array. A feedback loop controls the logic between the battery and the shunt. By monitoring the terminal voltage the logic starts 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. Shunt controllers generate lots of heat, and they're unsuitable for large arrays because of this heat.[*] A shunt controller was described by C. Philip Chapman, W6HCS, Paul D. Chapman, and Alvin H. Lewison.[†]

The direct-switching controller is the most popular controller and several have appeared in print.[‡] In a direct-switching controller, a relay or transistor switch between the array and the battery bank controls charging current. In this case, the controller monitors the battery's terminal voltage and turns off the switch when the battery reaches full charge. Relays are prone to fail because they're mechanical. Transistor switches are lossy and require massive heat sinks to keep them cool. A single-stage direct-switching controller has a hard time achieving a fully charged battery; two-stage controllers are used most often. In the FET controller, direct switching is used. The pulse-charging method allows full charging.—*WB8VGE*

*Because of the heat given off by shunt controllers used with large arrays, smaller units are used in a master/slave combination. The master controls the slaves. If one of the slave units overheats, the rest of the array still generates some power to charge the batteries.

†C. P. Chapman, P. D. Chapman, A. Lewison, "Amateur Use of Solar Electric Power,—*Part 1*" *QST*, Oct 1982, pp 11-14; —*Part 2*, *QST*, Nov 1982, pp 30-34. See also Feedback, *QST* Jun 1983, p 42.

‡M. Bryce, "Total Solar," *73 Magazine*, May 1986, pp 60-64; J. Halliday, "Solar Powering a Ham Station," QST, Aug 1980, pp 11-12; D. Blakeslee, "An Electronic Switch for a Solar Panel," *QST*, Aug 1980, pp 12-13.

(**BATTERY SENSE**). If the battery's voltage is 14, the output of the divider is 7 V. The same applies to the array voltage—it's divided in half.

Gates A and B of U2 are used as an R/S latch. At sunrise, the controller wakes up when the array voltage reaches 11. This turns on the R/S latch and the drive to Q3 and Q4, and the **PV READY** LED (DS1) comes on. Then, Q3 and Q4 and the **CHARGING** LED (DS4) are turned on. Any array current being produced goes directly to the battery bank.

As more array current flows into the battery, its terminal voltage rises. When the terminal voltage reaches 14.3 (the full-charge set point), the R/S latch turns off. This removes drive from Q3 and Q4, turns on the **CHARGED** LED (DS2) and extinguishes the **CHARGING** LED.

When charging current ceases to flow, the battery's terminal voltage begins to drop. When it drops to the resume-charge point (13.3 V), the R/S latch is turned on again and the whole process repeats. There's a 1-V hysteresis between the *on* and *off* set points.

The full-charge and resume-charge points can be adjusted to whatever hysteresis level you want. The closer together the two points are, the faster the controller cycles on and off. This rapid-cycle charging method keeps the battery fully charged without excessive electrolyte gassing. In fact, you can adjust the set points so closely as to cause both the **CHARGED** and **CHARGING** LEDs to simultaneously light dimly.

Toward dusk, the array no longer supplies enough current to charge the battery to 14.3 V. Q3 and Q4 remain on, allowing any current being produced to flow into the battery bank. At dusk, the array voltage drops below the level (11 V) required by the array comparator, U1A. At this point, the FET Charge Controller goes to sleep, waiting for dawn to restart the cycle.

Low-Voltage Warning and Relay Driver

If a low battery-voltage condition occurs (say you too-deeply discharge the battery), comparator U1C senses it. When the terminal voltage falls to 11, the comparator switches states and quickly charges C10 via D7. Then, DS3, the **LOW BATTERY** LED, lights and remains on as long as the terminal voltage remains below the set point. Also, U3C, Q1 and Q2 energize K1. If, however, a heavy load briefly trips the comparator, then switches back to normal, the charge on C10 is sufficient to keep DS3 on and K1 energized for about five seconds. You can vary the delay time by changing the value of R24, the 270-kΩ resistor. The greater the resistance, the longer the delay.

K1's contacts handle up to 10 A. In this project, the relay's contacts are unused, so they're available to you for controlling another device such as an external bell or generator. Repeater operators can use the relay's contacts to take a high-power RF amplifier off line, or signal a low-battery condition at the repeater site.

Expanded-Scale Voltmeter and Current Amplifier

An expanded-scale voltmeter keeps an eye on the battery's terminal voltage. D2, R40, R41 and an inexpensive 0- to 1-mA meter (M1) comprise the circuit. Although not a digital voltmeter, this expanded-scale 10- to 15-V meter provides a resolution of 0.1 V. With this on-board expanded voltmeter, you can readily monitor the batteries' state of charge without digging out your VOM.

To avoid using an expensive ammeter, I employ a simple shunt (R51), a 741 op amp (U7) and another 0- to 1-mA meter (M2). R51 consists of a coil of #12 wire and resides on the PC board next to TB1. The shunt is in the negative lead between the array and the battery. A tap on the shunt is adjusted to provide full-scale indication on M2 with R48, the **AMMETER ADJ** pot, set at maximum resistance. This ammeter gives you an indication of how much current is flowing into the battery bank.

U7 requires a negative supply. Although voltage-converter ICs exist, they're not always readily available. The method I use is cheap, simple and works: rectify the output of a 555 timer (U6) operating as an

Using the FET Controller With a 120-V AC-Operated Charger

If you don't have an array of PV panels in the backyard, you can still use the controller to keep a battery charged and ready to go. Few or no changes are required in the controller circuitry. Be sure to include reverse-current protection for the charger.[*] The diode on the PC board will do the job.

Cheap discount-store battery chargers deliver an unacceptable amount of ac. I recommend using a regulated power supply, nothing fancy. Adjust the output voltage to 16. Connect the charger to the **PV IN** terminals. The battery connections remain the same. (I use a simple LM723 regulator and two 2N3055 pass transistors in my charger; the transformer can continuously deliver 12 A. The charger has no overvoltage protection device.)

When you turn on the supply/charger, the FET controller takes over. When the batteries are charged, the controller begins cycling on and off.—*WB8VGE*

*G. Thurston III, "Practical Battery Back-Up Power for Amateur Radio Stations," *QST*; —*Part 1*, Mar 1990, pp 34-37 ;—*Part 2*, Apr 1990. pp 32-35 (see also Feedback, *QST*, May 1990, p 39;—*Part 3*, May 1990, pp 25-27.

[1]Notes appear on page 50.

astable multivibrator. U6's negative-voltage output is regulated by D5, a 5.1-V Zener diode. D6, another 5.1-V Zener diode, regulates the positive-supply output.

D11, a 15-A Schottky diode, prevents the battery from discharging into the PV array at night. The diode also protects the FETs from reverse polarity (in case you install them incorrectly!). A standard silicon diode can be used instead of a Schottky diode, but the voltage drop across the silicon diode (about 0.7 V) is almost three times greater than that of the Schottky (less than 0.2 V). Schottky diodes are cheap ($1.50 to $3.00), so there's not much to be gained by using a silicon diode. In sum, I recommend you stick with the Schottky diode.

Two sections of U2 operate as an astable multivibrator to drive Q3 and Q4. C10, C11, D8, D9 and D10 comprise a voltage multiplier that produces the required 25 V from the multivibrator.

Construction

You can use perfboard, wire-wrap or "dead-bug" construction methods, but using a PC board adds years to your life (well, it *does* make construction easier!). PC boards and parts kits are available.[1] (Fig 3 shows a photo of an early prototype of the Charge Controller.) Except for the meters, all parts mount on the PC board. If you decide to do your own parts gathering, the total cost of the project can be anywhere between $30 and $100, depending on how well-stocked your junk box is and how and where you acquire your parts. To initially adjust the controller, all you'll need is a variable-voltage power supply (0 to 20 V will do) and a reliable, high-input-impedance voltmeter. (A digital meter is easier to read accurately, but I've successfully used an analog meter, too).

Because the FET controller uses CMOS devices, use standard CMOS static protection measures when you install the controller's transistors and ICs. In other words, use common sense. Don't drag your feet across the carpet and then open the bag containing the FETs or ICs! Use a grounded wrist-strap.[2]

When inserting parts on the PC board, pay particular attention to the polarity of the diodes, electrolytic capacitors and the LEDs, and install them with proper orientation. Use sockets for the ICs. All connections to the array and battery are made via a terminal strip, TB1. The specified strip handles wire sizes up to #10.

The board requires the installation of five jumpers; be sure you install them all. When installing R9 (the 2.2-kΩ resistor connected to pin 10 of U8), make a loop at its free end where it exits the **TP1** pad; this is a test point. Mount Q3 and Q4 from the *foil* side of the PC board (see Fig 3). Allow sufficient lead length to permit the FET tabs to reach the heat sink. D11 needs a heat sink, too. I used a TO-220 heat sink, (1-3/4 inches long, 1 inch high and wide, 1/8-inch thick), enlarging its mounting hole to accommodate the diode's stud. (A piece of **U**-shaped aluminum can be used as a heat sink; the Schottky diode drops less than 0.2 V, so it dissipates little power. A silicon diode would require better heat sinking, as it will dissipate about *three times* the power of the Schottky diode. (Another reason to stick with the Schottky diode.) A short length of stranded #12 wire connects the diode's anode to the PC board pad near TB1. Secure D11 firmly to the PC

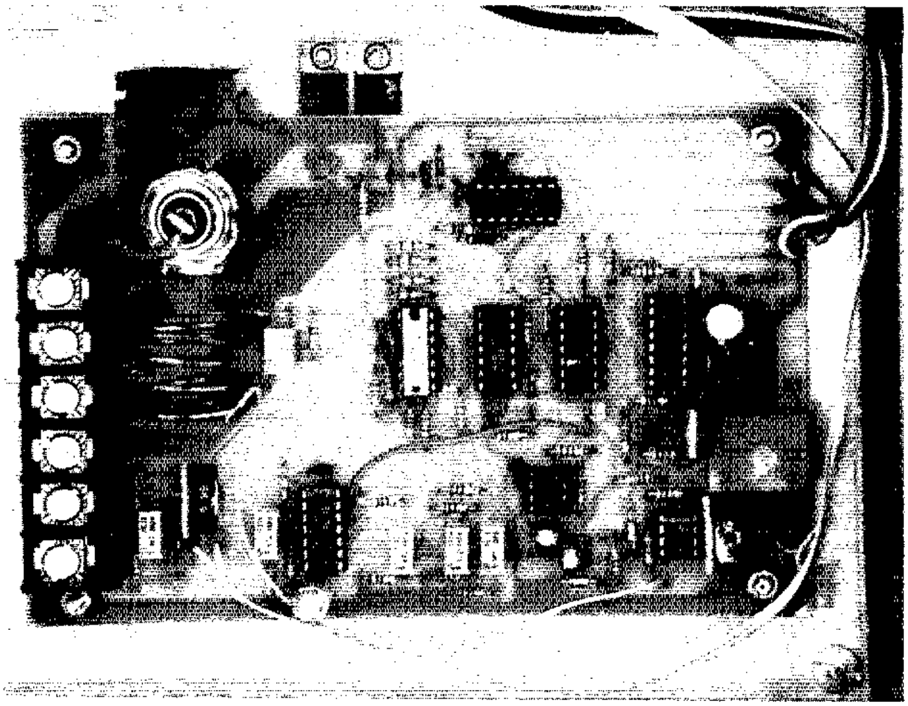


Fig 3—A photo of an earlier version of the FET Charge Controller mounted in its enclosure. (Current versions of the board have the PC-board mounting holes isolated from the ground foil.) TB1 is to the left, with R51 (the ammeter shunt) immediately behind it. Above TB1 is D11, mounted on its heat sink. Q3 and Q4 are immediately to the right of D11 and are attached to an aluminum-plate heat sink bolted to the enclosure. (You can see a color photo of the fully assembled FET Charge Controller in the Up Front section of this issue on page 11.) K1 is in the lower right-hand corner.

A Better Controller With MOSFETs

I chose to use MOSFETs for several reasons: They're faster switches than bipolar transistors, have a high input impedance, require little turn-on current, are inexpensive (about $3 or less each) and easy to obtain.

The *on* resistance—$r_{DS(on)}$*—of a power MOSFET is an important figure of merit: It determines the amount of current the device can handle without excessive power dissipation. When a MOSFET switches from off to on, its drain-to-source resistance falls from a very high value to $r_{DS(on)}$.

This controller uses two IRF531 N-channel power MOSFETs (and an IRF511 relay driver). Each IRF531, with an $r_{DS(on)}$ of only 0.18 Ω, handles a drain current of up to 15 A.

High-Side Switching

In some situations, connecting the load to the negative bus is either convenient or necessary. Such is the case with this controller. The photovoltaic (PV) array is in series with the battery, with the FET switch between the two. This is known as *high-side* switching.

Instead of using more-expensive P-channel MOSFETs as a high-side switch, another choice is to use a less-expensive N-channel MOSFET with the load placed in the source circuit, with the switch operating as a source follower. Because a source follower operates at a small voltage loss, its gate voltage must equal the output voltage *plus* the gate-to-source voltage at that particular load current. Thus, the gate voltage should be well above the supply voltage. To obtain positive gate turn-on, V_{GS}† should be greater than 10 V. Consequently, the gate voltage for a 12-V system could approach 22 V.—*WB8VGE*

*The dc resistance between the drain and source terminals with a specified gate-to-source voltage applied to bias the device to the *on* state.

†The dc gate-to-source voltage.

board using a toothed lock washer beneath the mounting nut, so that the lock washer bites into the PC-board's copper trace and makes a good connection.

Setup and Testing

Before applying voltage to the PC board, check and recheck your work. Then, get your variable-output power supply and voltmeter. Setup is easy and shouldn't take more than 20 minutes to accomplish.

On the foil side of the PC board, solder lengths of wire to the **+12 V** and **−12 V** input-voltage terminals. Twist together these two wires and connect the opposite ends to the **BATTERY SENSE** terminals on the foil side of the PC board. Connected this way, the Charge Controller's supply voltage is also connected to the **BATTERY SENSE** terminals.

To make R51, the ammeter shunt, wind a 12-inch length of #12 solid copper wire around a ¾-inch-diameter wooden dowel or similar form. Install the shunt on the PC board. Connect a wire from the **TO SHUNT** pad (one end of R45) to a point at the end of the shunt next to the **− BATT** terminal. We'll adjust this tap position later.

Use a jumper wire to connect **+ BATTERY SENSE** to **+ PV IN**. This makes the controller think the array is active. Set your variable-voltage power-supply output at 14 V. Connect the supply to the proper **BATTERY SENSE** terminals. When you do this, some of the LEDs may light.

With your voltmeter connected between common and pin #4 of U1, adjust the **BATTERY SENSE** pot (R37) for 7 V at that pin. Next, attach the voltmeter probe to **TP1** and adjust the **8.0 REF**erence pot (R4) for *exactly* 8.0 V. If you have a 0-1 mA meter connected to the expanded-voltmeter pads, adjust R40 **(VOLTMETER ADJ)** for a reading of 14 V; that's 0.9 mA on the meter face.) Probe pin 7 of U1 and adjust the **ARRAY SENSE** pot (R13) for 7 V. Adjust the **5.5-V REF**erence pot for 5.5 V at pin 6 of U1. These adjustments set the PV-array and low-battery set point at 11 V.

With R37 **(6.65 REF)**, set the voltage on pin 10 of U1 at 6.65; this is half the turn-on voltage (13.3). Set the voltage at U1 pin 5 for 7.15 by adjusting R7 **(7.15 REF)**; this is half the controller's turn-off voltage (14.3). You can alter these voltage levels for your particular application later, but for now, let's see how the controller works.

If you've set all the reference pots correctly, you'll have a working controller. To find out if everything is working properly, vary the input voltage a bit. Reduce the power-supply output voltage to 10. See that the **LOW VOLTAGE** LED lights, K1 energizes and the **PV READY** LED goes dark. Slowly increase the supply output voltage. The **LOW VOLTAGE** LED should extinguish, K1 de-energize, and the **PV READY** LED should light (at about 13.3 V). Increase the voltage more and the **CHARGING** LED should illuminate. Increase the power-supply voltage beyond 14.3. Check that the **CHARGED** LED lights and the **CHARGING** LED extinguishes. Remove the jumper from the **+PV IN** terminal. Touch a jumper lead from ground to the **PV IN +** terminal: The **PV READY** and all other LEDs should extinguish.

Adjusting the Set Points

The voltage set points just discussed work fine for most installations. If you have a large battery bank (approximately 450 Ah), you might want to lower the turn-off voltage when using an array that delivers less than 48 W (3 A at 16 V). Likewise, an array producing 20 A or so requires different set points when used with a small battery (say, 100 Ah). When adjusting the set points, you want enough hysteresis to have the **CHARGING** LED come on for at least several seconds (preferably a minute or two), and then turn off.

Putting It All Together

Because the tabs of Q3 and Q4 are electrically hot, they must be insulated from their heat sink if it's connected to chassis or circuit common. Standard TO-220 mounting kits work fine. I mounted the PC board and Q3 and Q4 on a 7 × 9 × 1/8-inch aluminum plate using 1/4-inch plastic standoffs. This provides ample heat sinking for the FETs.

The 7- × 9-inch aluminum panel is secured to the inside of a standard 8 × 10 × 4-inch hinged electrical box; this makes a sturdy and attractive cabinet. The LEDs and meters are mounted on the front panel. I used ribbon cable to connect the LEDs to the PC board.

If you don't want to use the controller's remote-sense feature, jumper these terminals to the **+ BAT** and **− BAT** terminals. Otherwise, run the remote-sense wires directly to the battery.

Connect the battery to the controller first, then connect the array. If you have a disconnect switch between the array and the controller, close it. You should see the **PV READY** and **CHARGING** LEDs illuminate, and the voltmeter indicate the battery's voltage. Depending on the battery's state of charge, the ammeter may indicate some reading. To adjust it, set your digital voltmeter to read current and place it in series with the array line. If you use a 0- to 1-mA meter for M2, its scale covers 0 to 10 A. If your digital meter reads, say, 5 A, adjust R48 for a reading of 5 on the meter face. (Remember: This isn't a high-accuracy ammeter, but gives you a close approximation of the current flow.) If you can't adjust the pot for the proper reading, you need more resistance (more wire) at R1. Rewind your shunt coil appropriately. If you can't lower the meter reading, move the shunt tap so less of the shunt is being used. If you don't want to use the on-board ammeter, remove U6 and U7. You'll save 25 mA or so of power-supply current drain without these chips installed.

That's it! The controller is ready to go. When the battery is charged, the controller cycles on and off, keeping the battery at full charge, without "gassing" it.

Troubleshooting

Before any of the comparators will work, +8.0 V from U8 must be present. Check for +25 V at the gates of Q3 and Q4. If the ammeter meter isn't working correctly, check for +5.1 V and −5.1 V at U7's pins 7 and 4, respectively. Check again to ensure you didn't forget any of the five jumpers. Is it nighttime? Remember, the controller goes to sleep when it's dark....

Summary

The FET controller is versatile, simple and easy to build. If you want to get the most out of your PV array and battery bank, this controller will do the job.

Notes

[1]PC boards are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; price $18.95 plus $1.50 s/h. A kit of parts (excluding the case and meters) is available from SunLight Energy Systems, 2225 Mayflower NW, Massillon, OH 44647; price: $74.95 plus $4.50 s/h.

[2]B. Bergeron, "ESD—Electrostatic Discharge—*Part 1*, *QST*, Apr 1991, pp 19-21; *—Part 2*, *QST*, May 1991, pp 28-29 and 33.

Mike's first home-brewed project—a transmitter out of the Handbook*—began only two days after his Novice license arrived in 1975. The homebrewing has never stopped. Mike currently holds an Extra Class license.*

Mike writes a monthly QRP column for 73 Magazine *and a column for* Digital Digest. *He also writes for* QRP Quarterly. *Mike's done several articles on battery storage and alternate energy in* CTM *magazine. He's served as past president for the Massillon Amateur Radio Club and currently edits the club's newsletter,* The Feedback.

An avid QRPer, Mike spends most of his time building projects. His main interest, however, lies in alternative energy sources, particularly solar energy. Mike operates a small company geared toward the advancement of the use of solar power: SunLight Energy Systems has been going since 1984. Since 1978, Mike's entire shack has been running on solar power. Now, 30 percent of his house runs on solar power!