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**QST Issue:** Sep 1993
**Title:** Long-Haul H-T Battery System, A
**Author:** Thurman Smithey, N6QX

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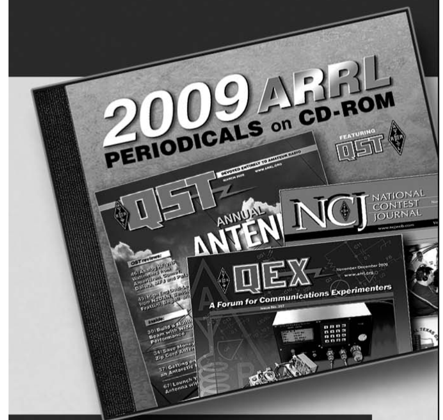
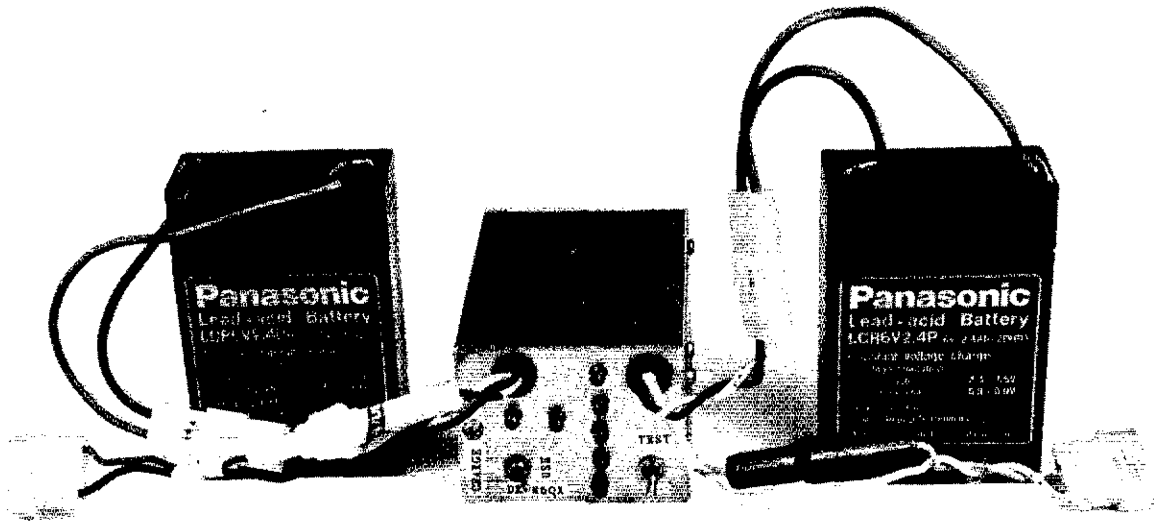


# A Long-Haul H-T Battery System




## It's inexpensive, portable and you can build it yourself!

By Thurman Smithey, N6QX
56 Center St
Chula Vista, CA 91910

It seems that almost every ham owns a VHF and/or UHF hand-held transceiver (H-T), undoubtedly because they serve so many purposes. Sometimes, however, an H-T's utility is limited by its standard-issue, (usually) short-duration batteries. If you're providing public-service communications for an all-day event, for example, you may find that your battery has died long before your stint is over. There are many other situations, including emergencies of all kinds, where a portable, heavy-duty H-T power source would prove advantageous.

Having been caught with a dead battery a time or two, I decided to develop a long-endurance battery system for H-Ts—one that could be carried comfortably in a "fanny pack," or a similar-sized bag slung from a shoulder strap. Here I'll describe the system I developed, and tell you how to build one yourself. Parts cost, including the cost of new batteries, is probably less than the list price of one H-T replacement battery. Purchasing surplus batteries can reduce the cost by approximately half.

And how well does the system work? It runs my H-T (mostly in receive mode,

### Reconditioning Small Lead-Acid Batteries

Small lead-acid batteries are available for very little money at surplus outlets, swap meets and hamfests. I have learned a few things about these batteries that I feel are worth passing along.

Most of the used batteries I have found are completely dead—showing no open circuit voltage at the terminals. A battery in this condition can still be returned to a portion of its original capacity, but it takes a bit of doing and I'm not sure it's worth the effort.

When you first place the battery on charge, it appears for all intents and purposes to be an insulator. Check it with a milliammeter, though, and you find a small current is flowing, which increases with time. If you have the facilities, put a higher voltage on it (I have used 50 volts on a 6-volt battery to get the current started). Be warned: I have also nearly melted a battery or two by not connecting a suitable resistor in the charging circuit to prevent excessive current if the battery came "alive" when I wasn't around.

The application of a higher voltage may, in some cases, not be enough to get the current flow started. I've been successful in moving the process along by applying the charging voltage in *reverse* for about 30 seconds, allowing no more than 0.5 ampere of current to flow. Strange as it may seem, this procedure is often recommended by the manufacturers of these types of batteries. The rationale is that when the battery is inactive for a long time, one of the electrodes becomes surrounded by a film of distilled water, which prevents current flow. Charging in reverse for a brief time has the effect of stirring up the juices and mixing some ions with the distilled water.

Once current flow is started, it can be increased by repeated charging and discharging until the battery begins to act very much like a normal battery. So far, however, I have not been successful in restoring more than about 60% of the original capacity of a battery that has been resurrected in this manner.

When shopping for a lead-acid battery, bring along a small load, such as a small 12- or 6-volt lamp, and use it to test the battery. If the battery lights the lamp, chances are reasonably good that you have a winner. If the battery is completely flat, you have your work cut out for you and may wind up with a mediocre at best. For example, I have one set of used 2.5 Ah batteries that did not require reconditioning. That set puts out as much or more power than the best of three different sets of 4.0 Ah batteries that *did* require reconditioning.

You'll find D-sized cells to be quite popular in the surplus market. They can usually be purchased as individual cells, or as packaged assemblies. I bought one 12-volt assembly (six cells) which I then split to make two 6-volt batteries. The assembly had a decent charge when I purchased it, and made two good 6-volt batteries.

On other occasions, I haven't been so lucky. I recently purchased 20 individual D cells (the price was right), all of which were showing 2.0 volts or greater at the terminals. When I started checking them for use in this project, I kept discarding substandard cells until only eight good ones were left. Except for the time involved, I still wound up with one good battery set for very little money.—*N6QX*

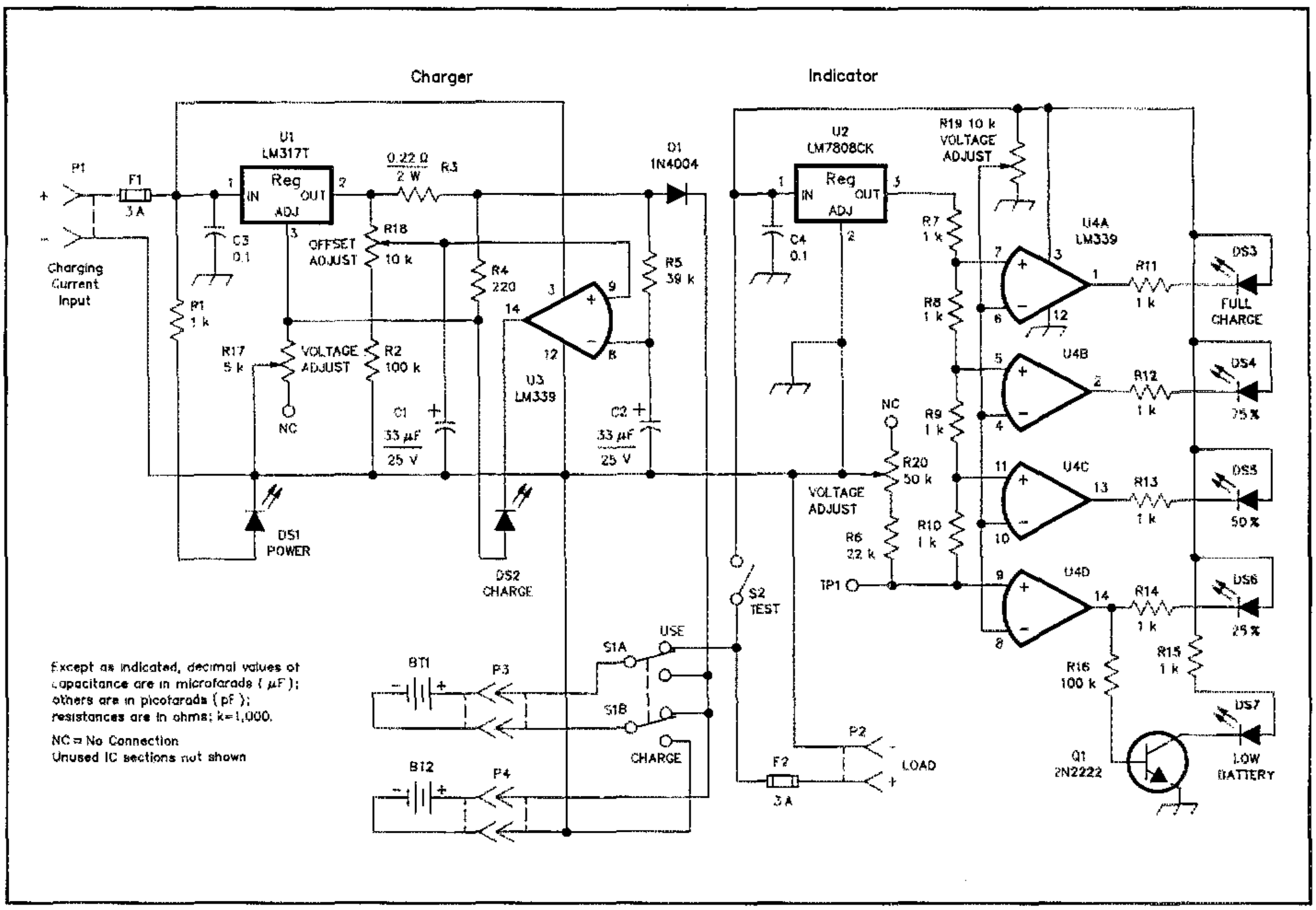



Fig 1—Schematic of the long-haul H-T battery system. Resistors are ¼-watt, 5%-tolerance carbon-composition or film except as noted below.

BT1, BT2—Panasonic LCR6V2.4P (Digi-Key Corp, 701 Brooks Ave South, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539. Digi-Key p/n P262), or Radio Shack 23-181.
C1, C2—33-µF, 25-V electrolytic.
C3, C4—0.1-µF ceramic disc.
D1—1N4004.
DS1—T-1¾ yellow.
DS2, DS3, DS4 DS5, DS6—T-1¾ green.
DS7—T-1¾ red.
Q1—2N2222.
R3—0.22 Ω, 2 W (Ocean State RM2-0.22).
R17—5 kΩ, ½ W, linear taper, 15 turn (Digi-Key 3006P-502-ND).
R18, R19—10 kΩ, ½ W, linear taper, 15 turn (Digi-Key 3006P-103-ND).
R20—50 kΩ, ½ W, linear taper, 15 turn (Digi-Key 3006P-503-ND).
S1—Miniature double-pole, double-throw toggle switch.
S2—Miniature single-pole, single-throw momentary normally open switch.
U1—LM317T adjustable voltage regulator (Radio Shack 276-1778).
U2—LM7808CK voltage regulator (Ocean State 7808).
U3, U4—LM339 quad comparator (Radio Shack 276-1712).

admittedly) *continuously* for 2½ days. Charge time for the 2.5 ampere-hour (Ah) battery is only 6 to 8 hours.

### System Description

My long-endurance H-T battery system requirements included:

- **Battery Charging**: The battery must be chargeable from any 10- to 15-volt dc source.
- **Automatic shut off**: The charger must shut off automatically when the battery is completely charged. An indicator must be provided to signal when charging is complete.
- **Discharge level indication**: There must be an accurate means to indicate the discharge level of the battery *as it is being used.*
- **Output regulation**: The battery output voltage must be regulated to suit the requirements of any H-T that can't be operated directly from its 12-volt output.

### The Batteries

Battery choice is very important. I selected sealed, paste-electrolyte, lead-acid types. They hold their charge better than NiCds and they're readily available at reasonable prices. I chose two 6-volt batteries which are paralleled for charging, then connected in series to provide a 12-volt source for powering H-Ts. An added benefit of this switchable series/parallel approach is that it allows the use of either battery to supply 6-volt loads (video cameras, video lights, portable electric lanterns and so on).

In addition to the battery, the other three parts of the system are the charger, the battery-condition indicator and the output regulator.

### Charger Circuit Description

A sealed, 12-volt lead-acid battery (2 to 4 ampere hours [Ah] capacity) is fully charged when its terminal voltage reaches about 15 volts and the charge current has dropped from its initial value to about 0.25 amperes. This assumes that the charging source maintains a constant voltage at the end of the charge cycle. The charger shutoff circuitry uses this current drop to define the full-charge condition.

The batteries are connected through connectors P3 and P4. S1 is placed in the **CHARGE** position to connect the batteries to the charger circuit. Charge current is supplied through connector P1 and applied to the input (pin 1) of the LM317T regulator, U1. A yellow LED (DS1) lights to indicate the application of charging power. R17 sets the output of U1 to 8.5 volts. R18 is adjusted so that 100 mV appears between its wiper and the junction of R3 and pin 2 of U1. With power applied to the circuit and no current flowing in R3, this offset voltage appears between pins 8 and 9 of U3, an LM339 quad comparator. In this state, the voltage at pin 9, the noninverting terminal, is 100 mV less than the voltage on pin 8, the inverting terminal. Therefore, the comparator output at pin 14 is *low*.

With batteries connected to the charger, however, the initial charging current flowing through R3 and D1 is approximately 0.8 amp, resulting in a voltage drop across R3 of about 176 mV. The inverting terminal of comparator U3 is now negative with respect to the noninverting terminal by 76 mV. As a consequence, the comparator output switches to *high*. C1 and C2 prevent a racing condition that might otherwise cause the comparator to change state before the charging current is established. At the outset, the output of U1 is less than 8.5 volts because R3 is used in the voltage-determining circuit in a negative feedback (current limiting) mode. U1's output voltage rises as the battery voltage increases, until it reaches about 8.4 volts. The charging current, and the voltage across R3, remain nearly constant at less than their initial values for most of the charge cycle. When the batteries approach their full-charge condition, their voltage rises. This decreases the charging current through R3, which results in decreased voltage across R3. The voltages appearing at pins 8 and 9 of U3 become equal when the voltage drop across R3 is reduced to the amount of the offset (100 mV). This equals a charging current of 455 mA, shared between two batteries, or about 227 mA for each battery.

When the voltage across R3 becomes *less* than 100 mV, comparator in U3 changes state and pin 14 goes low. This draws current through R4 and lights DS2. R4 is in the voltage-determining circuit of U1. The additional current drawn through R4 by U3 reduces the voltage at pin 3 of U1, dropping the output voltage lower than the battery voltage. D1 prevents current from the batteries from flowing backward in the circuit, so there is essentially no current through R3.

With no current flowing through R3, pin 9 of U3 is lower than pin 8 by 100 mV. The comparator output remains low and no additional charging takes place. The lighting of DS2 signals that the charge cycle is complete. At that point, the charging power source is disconnected, S1 is switched to the **USE** position and the batteries are available to power whatever device is connected to P2.

### Battery-Condition Indicator Circuit Description

In Fig 1, U2, an LM7808CK 8-volt regulator, provides a stable reference voltage when S2 is closed. The string of equal-value resistors (R7 through R10) functions as a four-way voltage divider. Since the resistor values are equal, the resulting voltage drops across each resistor are equal. Even so, the voltage drops can be increased or decreased (as a group) by adjusting R20. A simple computation and a voltage measurement at TP1 determines the R20 adjustment—as we'll see later.

The reference voltages are applied to the noninverting terminals of the four comparators of U4, another LM339. The inverting terminals are all connected to a common voltage which is referenced to the battery voltage. (The ratio is adjusted by R19.) Four green LEDs (DS3 through DS6) are connected to the comparators.

When S2 is closed (placing power on the indicator), the battery voltage is applied to pin 1 of U2 as well as the LEDs. If the referenced battery voltage is greater than a given comparator's reference voltage, that comparator's output is low and its LED glows. If the referenced battery voltage is less than a given comparator's reference voltage, that comparator's output goes high and its LED does not illuminate.

If the reference voltage is correct and R19 and R20 are properly adjusted, all four LEDs glow when the battery is fully charged. The first LED (DS3) switches off when 75% of the charge remains. The second LED is extinguished when a 50% charge remains. The third LED winks out at 25% and the fourth switches off when the low-voltage condition is reached (when the battery should be taken out of service and recharged). As a safeguard against the problems of negative indications, a fifth LED (DS7) was added (with Q1 and U4D acting as a switch) to provide a constant **LOW BATTERY** indication. This red LED lights when the fourth green LED is extinguished.

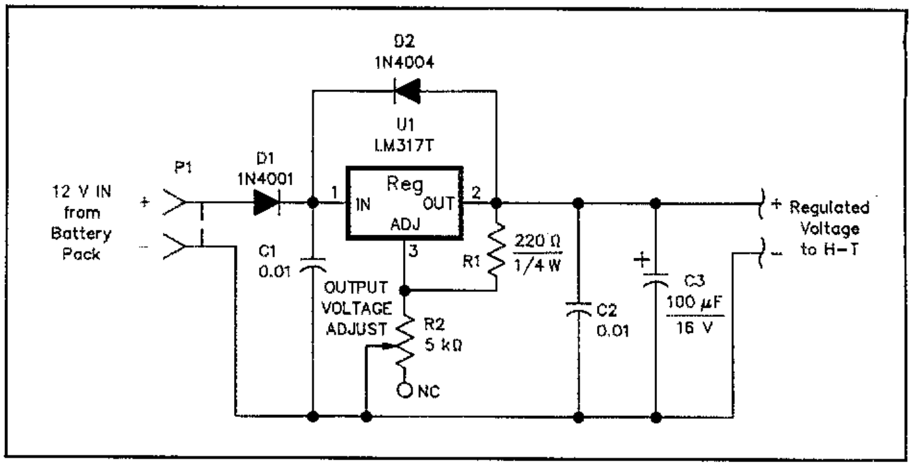



Fig 2—Voltage regulator schematic. Resistors are ¼-watt, 5%-tolerance carbon-composition or film except as noted below.
C1, C2—0.01-µF ceramic disc.
C3—100-µF, 15V electrolytic.
D1—1N4001.
D2—1N4004.
R2—5 kΩ, ½ W, linear taper, 15 turn (Digi-Key 3006P-502-ND).
U1—LM317T adjustable voltage regulator (Radio Shack 276-1778).

### Output Regulator Circuit Description

Many H-Ts are designed to be operated on 12 volts and thus don't require this regulator circuit. For this reason, the regulator is not included on the same board with the charger/indicator. (The regulator schematic is shown in Fig 2.) If your H-T requires less than 12 volts, the regulator can be set to provide the required voltage. U1, an LM317T adjustable regulator, is at the heart of this simple circuit. R2, a 5-kΩ potentiometer, adjusts the output of U1 to suit your H-T.

You'll need to provide a connector to fit your H-T. I made an adapter for my Kenwood TR-2500 using the case of a defunct battery pack. This is a good way of making the power connection, since it is reliable and attractive. In addition, the empty case provides space for the voltage regulator.

### Construction

The charger is built on a 2¼- × 3½-inch circuit board. The prototype was constructed on perf board, but I highly recommend that you use a printed-circuit board. You can make your own or order the PC board from FAR Circuits.[1]

The circuitry is housed in a 4 × 2 × 2¾-inch aluminum box. The circuit board is supported inside the box on three angle brackets made of stiff steel wire bent to shape. The circuit board is mounted flush with the end of the box that is farthest from the indicator. This leaves space between the box and the board edge at the indicator for wires to pass to and from the switches, LEDs and grommets. The board edge on which U1 is mounted must also be flush with the side of the box so that U1 can use the box as a heat sink. The LEDs are cemented into their ³⁄₁₆-inch holes using epoxy adhesive. U1 is mounted near the board edge abutting the side of the box and is bolted to the box using an insulating kit.

Four connectors are used—one for each battery, one for the charging source, and one for the device to be powered by the batteries. Select connectors that fit your requirements.

I recommend you make a power cable

[1]A PC board and part overlay are available from FAR Circuits, 18N640 Field Court, Dundee, IL 60118; price $4.50 plus $1.50 shipping and handling per order. Check or money order only; credit cards not accepted. The PC-board template and part overlay are available free of charge from the ARRL Technical Department Secretary. With your request for the SMITHEY LONG-HAUL H-T BATTERY SYSTEM PC BOARD TEMPLATE PACKAGE, send a #10 SASE.

with an in-line connector and fuse. Use connectors that mate with whatever dc-power source you intend to use to charge the batteries. I use a cigar-lighter plug which allows me to charge my batteries from an automobile electrical system.

The cable connecting the batteries to your H-T or other device should also include an in-line fuse. If you intend to build the voltage regulator circuit, be advised that the voltage regulator IC should be mounted on a small heat sink. This regulator can deliver up to half an amp or so on transmit.

All parts used in the project, with the exception of the new batteries, are common parts which can be found in any electronics parts store or catalog. A source for the batteries is listed in the parts list (see Fig 1 caption).

### Calibrating the Charger

After you've completed construction and checked your work, connect a 12-volt power source to the charger input (P3) *before* you install U3 and connect the batteries. DS1 should glow. Measure the voltage at pin 2 of U1 (referenced to ground) and adjust R17 until U1's output is 8.5 volts. Disconnect the power source and install U3. Reconnect the power source and measure the voltage difference between pins 8 and 9 of U3, adjusting R18 until pin 9 is 100 mV less than pin 8.

### Calibrating the Battery-Condition Indicator

I have determined that no single calibration of the indicator unit is truly accurate with several different battery types. Fig 3 shows the discharge characteristics of four different batteries, all with the same 100-ohm load, all having just been charged using the charger. The variations are great enough to significantly affect the accuracy of the indicator.

If you buy new batteries of the type shown in the parts list, you can be confident using the discharge characteristics of battery #1 in Fig 3 to calibrate your indicator. If you have elected to use batteries that have seen previous service, I recommend that you run a simple discharge test on the batteries before performing final calibration of the indicator. (Charge the battery using the calibrated charger, then attach a 100-ohm load and plot the discharge characteristic as was done for Fig 3.)

If you have more than one set of batteries with different discharge characteristics, I recommend that you calibrate for the best set, and take into account the difference when you read the charge remaining in the weaker set(s). That way, the charge remaining at any time will be nearly equal for the different batteries.

Given a small, constant load—such as an H-T in the receive mode—the discharge voltage curve over time is nearly linear until the battery voltage drops to about 12 volts. A battery should be taken out of service and recharged when its voltage under load drops to 12 or less. This rule seems to apply regardless of the battery brand.

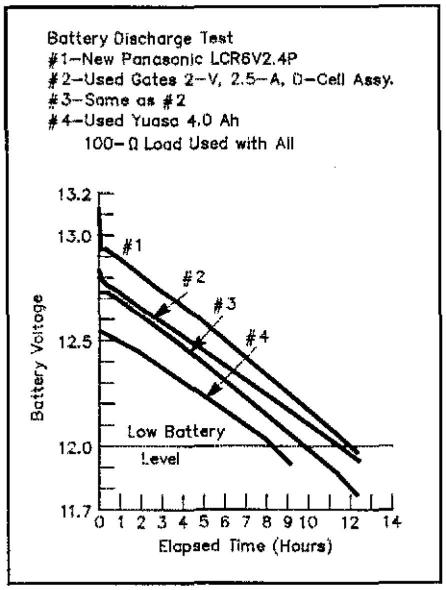



Fig 3—Battery discharge test results.

Fully charged battery voltage can vary considerably (see Fig 3). Depending on the brand, battery potential at the beginning of the discharge cycle can vary from 13 to 12.55 volts. Fortunately, the provisions for adjustment of the indicator are flexible enough to accommodate any batteries you're likely to find.

Calibrate the indicator based on the assumptions we've just discussed. In other words, assume that its voltage-versus-time curve will be linear with a constant, small load, and that it will need recharging when the voltage decreases to 12 volts. Compute the voltage you want to see at TP1 as follows:

$$V_{TP1} = V_{Ref} \times \frac{V_{Low}}{V_{Full}}$$

$V_{Ref}$ is the voltage output of U2 at pin 3, in this case 8.0 volts. $V_{Low}$ is the voltage selected for **LOW BATTERY** indication (12 volts). $V_{Full}$ is the battery voltage at full charge.

To calibrate the indicator, you'll need a variable-voltage power supply with a range of 11.5 to 13 volts. After determining the voltage that you want at TP1, apply 12 volts to pin 1 of U2 and adjust R20 until the voltage at TP1 reaches the desired level.

Now reduce the voltage to the $V_{Low}$ value and adjust R19 until DS6 goes out and DS7 comes on. That's all there is to it! DS3 should now go out at a battery voltage of 12.75, DS4 at 12.50, DS5 at 12.25 and DS6 at 12.00. When DS6 turns off, DS7 lights to tell you your battery needs to be charged.

While you have your variable-voltage supply connected, check that all four green LEDs do in fact go on and off at the correct voltages. If not, you may want to try calibrating using the transition of DS5 and a calibrating potential of 12.25 volts. Then, recheck for accuracy on all four LED set points. You should be able to get them all transitioning within 50 mV of the stated voltages.

For maximum accuracy, $V_{Ref}$ should be measured with the same voltmeter you used to set the voltage at TP1. To calibrate the indicator for another battery with different characteristics, merely substitute the appropriate numbers in the equation above. To further improve accuracy, I measured all the 1-kΩ resistors used in the project and selected the four that were most nearly equal for R7 through R10.

### Additional Thoughts

I use a common fanny pack to house the batteries and the charger/indicator when I want to carry the system around. In the one I bought, there's plenty of room for the equipment and accessory cables. Although I elected to discontinue using large batteries, I was able to get a pair of 4.0-Ah batteries in the pack and the weight wasn't too objectionable. The box housing the charger/indicator gets quite warm while batteries are being charged, so it should not be left in the pack when charging is in progress.

### Summary

I've had a great deal of enjoyment in developing this low-tech project, and even more enjoyment out of using the long-haul battery system with my own H-T. Try one yourself and I'm sure you'll like it as much as I do.

*Thurman Smithey, N6QX, was introduced to Amateur Radio in the late 1930s as a high school student. It wasn't until his retirement from the Navy, 30 years later, that he finally obtained his license. He was first licensed to the General class as WA6FUY in 1968. Thurman acquired a sailboat the same year and has enjoyed operating maritime mobile while doing some blue water sailing. Thurman holds a Master of Science degree in Engineering Electronics.*

# Strays

### HAM AWARENESS GALA IN WESTERN THEME PARK

◊ It's fun for the whole family at Scottsdale, Arizona's, Family Amateur Radio Event (FARE), Sunday, September 19, at North Scottsdale's Rawhide Western Village.

Held in conjunction with the ARRL's Ham Radio Awareness Day, 13 Arizona radio clubs are participating in the get-together, which will feature an HF special-event station signing K7UGA (held by former US Senator Barry Goldwater) from 1700 to 2400Z.

For more information, contact Len Winkler, KB7LPW, at 602-861-0303.