Build it Yourself from QST

Part 4: Here's how to take the final steps—mounting your completed project in the enclosure of your choice, testing it and putting it on the air.

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This is the last article in a series on turning a *QST* project into radio gear you can use on the air. In Parts 1 through 3,[8] I described how to figure out what parts you need and how to order them, and how to get started in ground-plane and PC-board construction. A VXO-controlled, 20-meter QRP transmitter (see Part 1) serves as our example project. This month we're going to put that transmitter in a box and get it on the air.

Parts of this article are specific to the Radio Shack metal box (#270-239) we bought in Part 1, but most of the article applies to whatever box you've chosen for your transmitter. Believe me, you can put this transmitter in almost anything—I've built projects in some pretty strange enclosures, like glass jars and cookie tins. You can even use it with no box at all, but it's more convenient if you have a front and back panel to mount jacks and controls.

Tools

I chose the Radio Shack aluminum box because aluminum is easy to work with hand tools. See Fig 20. You'll need 1/8-inch, 3/16-inch and 1/4-inch drill bits; you'll also need larger drills or a hand reamer to make holes for the RF connectors. I got my hand reamer at a local hardware store; Easy Tech and Ocean State Electronics (see Table 1 in Part 1) carry them. If you can't find a hand reamer, you can use a nibbling tool (Radio Shack #64-823) to make large holes, but it's hard to make round holes with a nibbler. A small hand file is useful for removing the sharp edges from drilled holes.

You'll also need some #4-40 machine screws and nuts, and a screwdriver to fit the screws. A package of assorted #4-40 screws from Radio Shack (#64-3011) and a package of #4-40 nuts (#64-3018) will be plenty. Although they're not essential, installing toothed lock washers under every nut can help hold hardware in place. Digi-Key and Ocean State Electronics (see Table 1, Part 1), among other mail-order
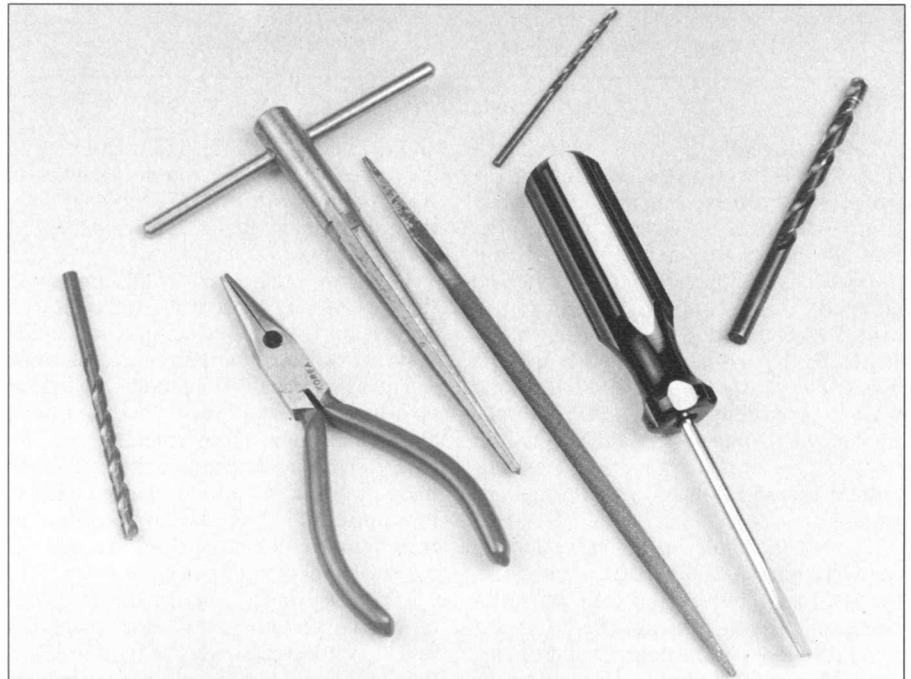
[1]Notes appear on page 34.

Fig 20—You'll need 1/8-inch, 3/16-inch and 1/4-inch drill bits, needle-nose pliers, a screwdriver, a small round file and a hand reamer.

suppliers, carry them. Many home-improvement centers carry all of this hardware, tools, and then some.

Panel Layout

The dc power leads, **ANTENNA** connector and **RX OUT** jack are mounted on the back panel. (So is the **SIDETONE OUT** jack if you added the sidetone oscillator described last month.) The **SPOT** switch, **KEY** jack and **FREQUENCY** capacitor are mounted on the front panel. It's best to orient the circuit board so the connections to the panel are as short as possible—this is one reason I put the **KEY** jack on the front panel, but I also think it's more convenient there. You can mount the **KEY** jack on the back panel if you like—it's your project!

Marking, Center-Punching and Drilling

Once you know where everything goes, you can mark the panels for the holes. Be sure to locate connectors far enough from

the box edges to allow for their outer dimensions. Fig 21 shows how I laid out the panels. I used the part of the box with the bent-over flanges as the top of the box.

If you want to make sure you don't scratch the box as you drill the holes, temporarily cover the entire box with masking tape. I usually don't bother.

Measure carefully and mark the center of each hole with a permanent marker (something that won't rub off as you work with the box). It's a good idea to center-punch the holes so the drill won't wander away from the marked hole as you drill. You can do this with a special center-punch tool, but I just use a large (8- or 10-penny) nail. Use a block of wood to support the panel from behind and center the nail or punch on the mark where you'll be drilling, as shown in Fig 22. Strike the punch with a hammer—one or two light taps should be enough to make a small indentation in the metal. Punch all the holes the same way.
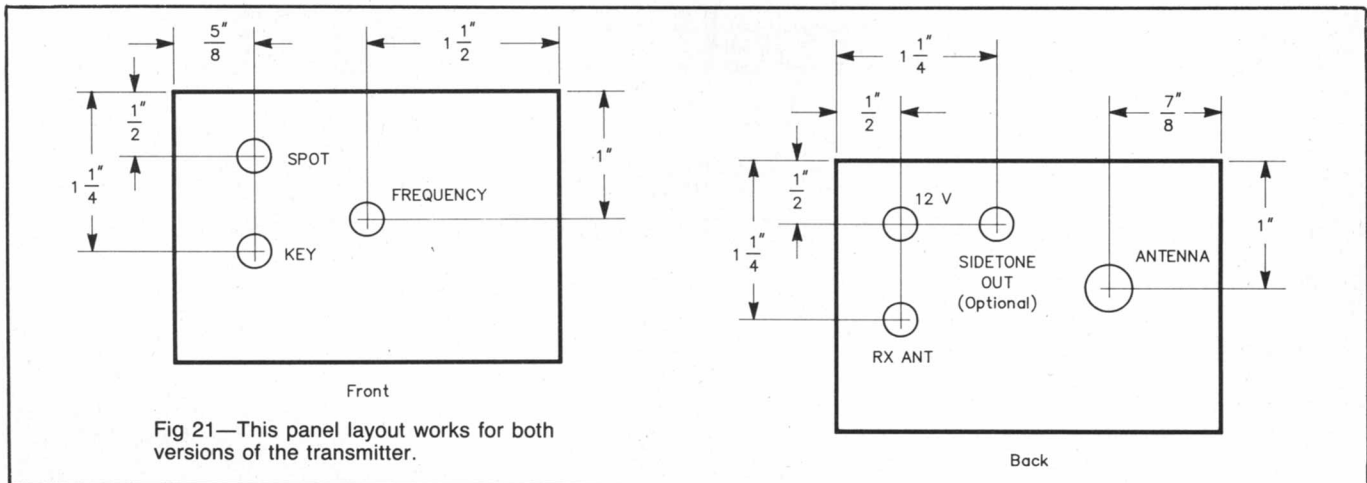
Fig 21—This panel layout works for both versions of the transmitter.

Drill all the holes with the 1/8-inch drill first. Leave the wood block behind the panel, wear eye protection and hold the box firmly—the drill bit can grab as it goes through the panel. I've had boxes fly out of my hands and spin around when the drill grabbed; this is not fun. Once you've drilled all the holes with the 1/8-inch bit, switch to the 1/4-inch bit and redrill the holes. *Don't* try to drill 1/4-inch holes without predrilling pilot holes with the smaller bit! Doing so will almost guarantee that the bit will walk away from the center mark and grab as it goes through the panel.

The 1/4-inch holes will be large enough for everything but the **RX OUT** phono jack, the **SPOT** push button and your **ANTENNA** connector. If you're using a BNC connector and you've got the right-sized drill bits, just drill out the 1/4-inch holes using the larger bit. Be extra careful when you use the larger bits—they're even more prone to grabbing the panel as they pass through.

If you don't have the right-sized bits, or you're using an SO-239 antenna connector, you'll need to use the reamer, the file or the nibbling tool for the larger holes. You can use your file to make the holes slightly larger, but it will be a lot of work to make large holes with a file. Using the nibbler will take some practice, and it's appropriately named. You must "nibble" small pieces from the edge of the hole until it's large enough, and then round the hole with a file. It's a pain in the neck—you're better off trying to find the right-sized drill bits!

Once you've got all the holes drilled, use a file or large drill bit to remove the burrs (sharp pieces of metal) from the edges of the holes. Then mark the screw holes for the RF connectors. You can mount the **ANTENNA** connector (BNC or SO-239) with its flange either inside or outside the box. (I like to mount them with the flange outside the box.) Two screws in opposite corners are enough—you don't need to use all four holes in the connector. Place the connector in the hole and use a pen to mark the mounting hole locations, then punch

and drill them with the 1/8-inch bit. You may need to drill the mounting holes in BNC flanges with the 1/8-inch drill bit— the holes in many BNCs' flanges are tapped for #3 screws.

I like to use phono connectors with flanges. Phono connectors that mount with a single nut around the connector bushing may work loose unless you use lock washers that usually don't come with them (1/4-inch internal-tooth lock washers, available at home improvement centers, are just right for Radio Shack's #274-346 phono connectors). Mount flanged connectors outside the box, making certain that their center conductors do not touch the edges of their panel holes.

If you're using a ground-plane transmitter board, it's time to drill mounting holes in it if you haven't already done so. Drill two 1/8-inch holes in opposite corners of the board. (The PC board already has mounting holes drilled in its corners.) Two holes are enough to mount a ground-plane
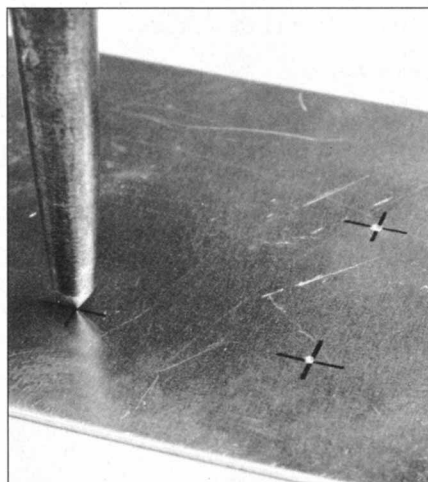

Fig 22—Use a center punch or an 8- or 10-penny nail to make a small indentation at the center of each hole so the drill bit won't walk away from where you want to drill.

board, but use all four for the PC board. Center the board in the bottom of the box and mark and center punch the holes. Then drill the holes with the 1/8-inch bit, and deburr them with the file.

Painting and Labeling

When all the holes are drilled, you can paint the box and label the controls. I usually don't bother with this either—the paint usually flakes off or scratches so it looks worse than bare aluminum. If I can't remember what the controls do, I mark them with a permanent felt-tip marker. It may not look professional, but I don't care.

Mounting the Board

Mount the board in the box *before* you mount all the connectors and switches, and wire the PC board before you mount it in the box. (You can wire the ground-plane board after you've mounted it in the box— another advantage of ground-plane over PC-board construction.) Cut two 12-inch lengths of hookup wire (it's most convenient to use two different colored wires if you have them), strip one end of each and solder them to the + and −**12 V** connections. You don't need shielded wire for the **ANTENNA** and **RX OUT** connections in this project—the connectors are close enough to the board that hookup wire works fine. Cut 6-inch lengths of solid hookup wire, strip one end of each and solder them to the **SPOT** switch, **KEY, RX OUT, ANTENNA** and **FREQUENCY** capacitor locations on the board. There's no PC-board hole for the connection to the ground side of the **SPOT** switch (it's connected to +12 V) so I carefully soldered a wire to the bottom of the board on the trace near the emitter of Q1.

The circuit board's mounting screws will electrically connect it to the aluminum box. Unless an author tells you otherwise, you can depend on this connection for the ground returns of circuits and jacks that carry only dc (in this project, the **KEY** jack and 12-V power). It's *not* a good idea to expect circuit-board mounting hardware to
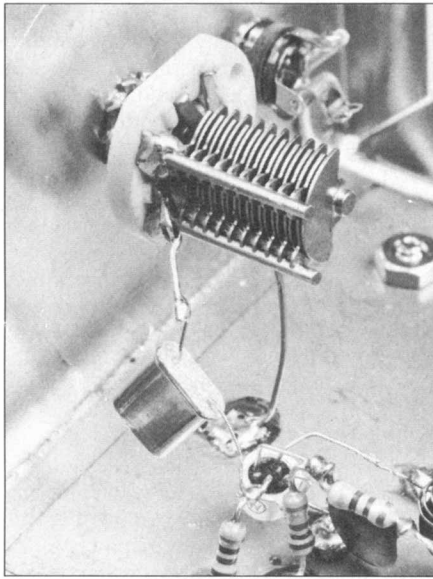
Fig 23—Connect the wire from the crystal to the side of the tuning capacitor that is not grounded to the chassis.

handle ground returns for ac circuits (audio and RF) because this can cause unwanted coupling and feedback. This applies to the transmitter's **RX OUT** and **ANTENNA** jacks, and the ground return for the **FREQUENCY** capacitor. Using coax for the **RX OUT** and **ANTENNA** jacks avoids this problem because you can (and should) ground the coax braid at both ends of each run. If you don't use coax to connect the **RX OUT** and **ANTENNA** jacks to your board, solder a 6-inch piece of wire to circuit-board ground adjacent to where these jacks' ungrounded (*hot*) wires leave the board. (Some PC-board designs include ground-foil holes for this—the FAR Circuits board for our 20-meter transmitter does.) Also do this for **SIDETONE OUT** if you added the sidetone oscillator.

You must use spacers between the back of the PC board and the box so the traces on the board do not touch the aluminum box. You can buy spacers, but I just used two extra #4-40 nuts on each screw. Poke

the screws though the holes from the outside, thread two nuts onto the screws and tighten them down. Then place the PC board over the screws and add another nut on top of the PC board. The ground-plane board does not require spacers, so you only need one nut per screw.

If you built the sidetone oscillator, and you built it in a corner of your ground-plane board, you've already mounted it! If you built the sidetone on a scrap of ground-plane board, you can mount it to the chassis with a single screw and nut. Or you can solder a heavy wire or two between its foil and the copper foil of the main transmitter board. It's low-mass, so it won't shake loose and go anywhere.

Wiring The Panels

Once you've got the board mounted in the box, attach the jacks and switches. Mount all the components in the appropriate holes. Nut drivers work best for tightening the nuts on the **SPOT** switch (and **FREQUENCY** capacitor, if you used one that mounts with a single nut over its shaft bushing), but if you don't have a nut driver you can use needle-nose pliers or a small adjustable wrench.

Strip and solder the wires to the **SPOT** switch and **KEY** jack; cut the wires if they're too long. Connect the wire from the crystal to the ungrounded terminal of the **FREQUENCY** capacitor (Fig 23). If you panel-mounted your **FREQUENCY** capacitor, give it a ground wire even if its mounting bushing grounds its rotor (moving plates). If your **FREQUENCY** capacitor's mounting hardware grounds neither its rotor nor its stator (stationary plates), you have a choice of which to ground. Ground the rotor. Solder hot and ground wires to the connectors on the back panel and run the dc wires through the hole in the back panel.

You can twist together the dc wires, and wires to the **RX OUT**, **ANTENNA** and **SIDE-TONE OUT** jacks (if you didn't use coax), to make things neater. I wrapped the dc wires with electrical tape to hold them firmly in the hole in the box. If you used
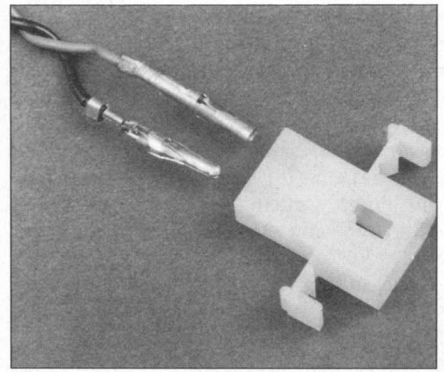

Fig 24—Assembling Radio Shack #274-222 power connectors. Crimp and solder a male connector pin to one power lead, and solder a female pin to the other lead. Push the pins into the plastic shell from the back.

Radio Shack #274-222 power connectors, strip the ends of the wires, solder a male connector pin to one wire and a female connector pin to the other wire and push the pins into the plastic connector shell (see Fig 24). Solder the other half of the polarized power connector to another pair of wires and connect them to your power supply. Make sure the positive side of the power supply connects to the **+** connection on the circuit board.

If your **FREQUENCY** capacitor has a 3/16-inch-diameter shaft, remove the setscrew from one of the knobs you bought. Hold the knob firmly with pliers or a vise, and drill the 1/8-inch shaft hole out with the 3/16-inch drill bit. Don't drill all the way through the knob! It's not easy to drill the knob straight without a drill press, but you can do it if you're careful. (This is why I told you to buy more than one knob—if you make a mistake you can try again.) Once you get the hole drilled, replace the set-screw, slip the knob over the capacitor shaft and tighten the set-screw.

Testing the Transmitter

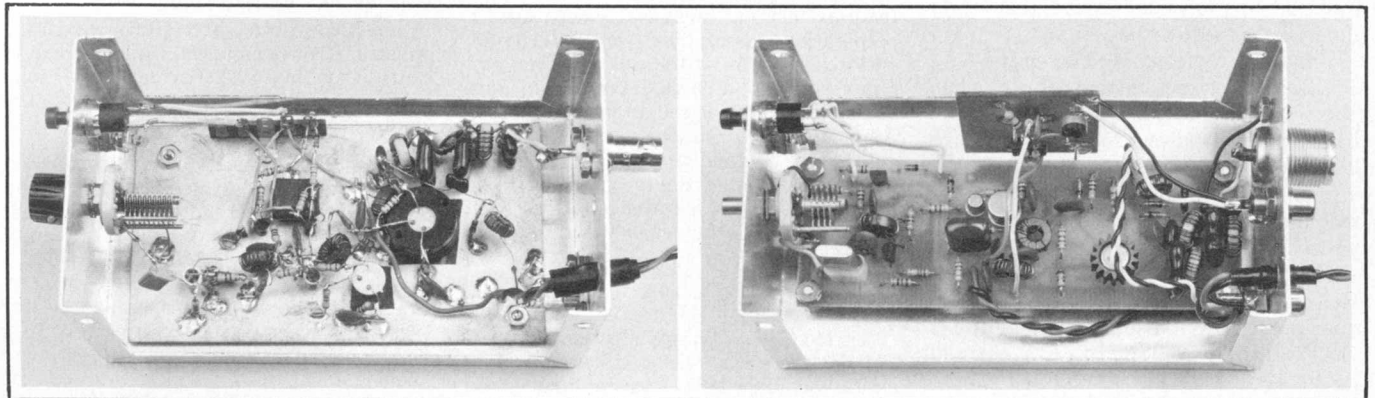Once everything's connected, the inside of your transmitter box should look some-

Fig 25—Inside the completed transmitters. The PC-board transmitter (right) also includes the sidetone oscillator described in Part 3.

thing like one of the two examples in Fig 25. Now you're ready to test the transmitter. You'll need a dummy antenna—a 47-ohm, 2-watt resistor works great, or you can wire a pair of Radio Shack 100-ohm, 1-watt metal-oxide resistors (271-152) in parallel. Don't use wire-wound resistors for your dummy antenna—they have too much inductance and may cause your transmitter to do unexpected things.

Plug in the dummy antenna, connect the power supply (through a multimeter, if you have one, set for measuring current) and switch it on. If you've got an oscilloscope, connect it to the dummy antenna with the probe center conductor on the center of the antenna connector. If you don't have an oscilloscope, put the dummy antenna near the **ANTENNA** jack of your receiver and tune the receiver near the transmitter's crystal frequency.

When you press the **SPOT** switch, the transmitter should draw about 12 milliamps, and you should see RF on your oscilloscope or hear the transmitter in your receiver. You may have to tune the receiver slightly to find the transmitter—switch in the receiver's widest IF filter. When you key the transmitter, it should draw about 260 milliamps, and you should see more RF on your oscilloscope (or hear a louder signal in your receiver).

If nothing happens when you press the **SPOT** switch, it's likely that the transmitter oscillator isn't working. Check all the connections in that area of the circuit. If you can't find any bad connections, try replacing the VXO transistor (Q3). If the oscillator works, but the transmitter

doesn't draw more current when you key it, the problem is in a later stage. Again, check all your connections. Look for cold solder joints on the PC board—remelt any connections that look suspicious. Replace transistors only as a last resort—the problem is usually somewhere else.

If you built the sidetone oscillator and your receiver has a sidetone input, connect a cable between the transmitter's **SIDETONE OUT** jack, J4, and the receiver's sidetone input. Set R20, **SIDETONE LEVEL**, to the center of its range. Key the transmitter and adjust **SIDETONE LEVEL** for the volume you want.

On the Air

Once you've got the transmitter working into a dummy antenna, you can connect your outside antenna to the transmitter and connect a short cable from the transmitter's **RX OUT** jack to your receiver. Now you're ready to get on the air.

If you're new to low-power operating, see *The ARRL Operating Manual*[9] for an introduction to QRP. QRP isn't like operating with a high-powered station. If you're extremely lucky, there will be a loud station calling CQ on your crystal frequency when you turn on your receiver. More likely, you won't hear anyone, or you'll hear stations in a QSO. This is fine—just wait until they finish the QSO, and then call the louder of the two stations. (If the louder station closes down [signs with CL], call the other station.)

If I don't hear anyone at all, I use the "wait and pounce" technique. I spot the transmitter on the receiver, and then leave

the receiver on while I do something else in the shack (I usually work on another project!). Sooner or later, someone will find the quiet frequency and start calling CQ, and I'm right there to answer them. If they don't hear my return call, someone else usually does, and then I call one of them after they end their QSO. As an absolute last resort, I call CQ. But I'd much rather let someone else do the work!

Contests are great for QRP operating, especially after the initial few hours and people are getting desperate for new blood. You'll find their ears have developed quite well, even for weak QRP signals!

Summary

If you're like me, once you've got the building bug, you won't let your soldering iron stay cold for long. Warming it up the very first time is the hardest part! In this four-part series, I've shown how you can build your own radio gear from published *QST* articles. I hope you've enjoyed building the transmitter we used for our example project, and I know you'll enjoy using it on the air. Now, the next time you think about adding another *QST* project to your station, you'll know where to start.

Notes
[8]B. Hale, "Build It Yourself from *QST*," *Part 1, QST,* Apr 1992, pp 31-36; *Part 2, QST,* May 1992, pp 35-39; *Part 3, QST,* Jun 1992, pp 42-45.
[9]J. Bauer, "Less is More...Or Enjoying QRP," S. Ford, ed, *The ARRL Operating Manual,* 4th ed (Newington: ARRL, 1991), pp 3-16 and 3-17. Available from the ARRL Bookshelf as #1086. **QST**

New Products

MORSE MAGAZINE
☐ *Morsum Magnificat* aims to provide international coverage of all aspects of Morse code telegraphy—past, present and future. It's targeted toward all Morse enthusiasts, amateur or professional, active or retired. It brings together material relating to the traditions and practice of Morse that would otherwise be lost to posterity.

The quarterly magazine measures 8½ × 6 inches and features many black-and-white photographs. Issue no. 23 (Easter 1992) had 48 pages. One-year subscriptions in the US cost $17 for surface mail and $21 for airmail, cash only. (The US Postal Service recommends the use of Registered Mail when sending cash overseas.—*Ed.)*

First published in Holland by Rinus Hellemons, PAØBFN (SK), in 1983, it's now published in Britain. The editor is Geoff Arnold, G3GSR, of G. C. Arnold Partners, which also publishes *Radio Bygones.* Write to *Morsum Magnificat,* 9 Wetherby Close, Broadstone, Dorset BH18 8JB, England, tel 44-202-658474.

Strays

NEW SACRAMENTO HAM STORE
☐ What would you want offered at your "dream" Amateur Radio retail store? Mike Carpenter, KC6VWM, and Fred Sober, AB6GQ, asked that of local hams. The result is Sacramento Amateur Radio Outlet, which opened in April. Carpenter's new store features "extras," such as free license exam preparation classes; free use of the large, enclosed parking lot for club activities and swapfests; and a large inventory of rare components for do-it-yourselfers. Sacramento Amateur Radio Outlet is also a factory authorized sales and service center for many brands of Amateur Radio equipment. The address is 4020 #C California St, Carmichael, California, and the telephone number is 916-944-7302.

QST congratulates...
☐ Gerald L. Park, W8QS, Professor of Electrical Engineering at Michigan State University and adviser to the MSU Amateur Radio Club, W8SH, on receiving the first Presidential Award for Outstanding Community Service from MSU President John DiBiaggio.

☐ Vance Vogel, W4OVE, of Gibsonton, Florida, president of V. V. Vogel Farms Inc, on being inducted into the Florida Agricultural Hall of Fame in a ceremony at the Florida State Fair in Tampa February 11.

I would like to get in touch with...

☐ anyone who's successfully operating Amateur Radio equipment with more than 10 watts output in a 1992 Toyota Camry. John Harman, W8JBH, 26612 E Cove Dr, Tavares, FL 32778.

☐ anyone involved in M1 carbine production during WWII, and anyone who has any kind of software for the Tandy TRS-80 Model II computer. Tom Johnson, N4TJ, 109 Kimberly Ln, Florence, SC 29505.

☐ anyone who has a current address for Webster-Chicago (Webcor, formerly of 5610 W Bloomingdale, Chicago) or knows where I could locate parts for an old reel-to-reel tape recorder. Don Miller, W2MQB, 517 Accabonac Hwy, PO Box 3005, The Springs, NY 11937-0395.