

A PIC SWR Meter

No ham shack is complete without an SWR meter. Why? Because your rig is most content when it can see an SWR of 2:1 or less. To make your rig happy, you should know the SWR level between the rig and the tuner or antenna. How do you do that? With an SWR meter, of course!

I designed this SWR meter to use few parts, to be inexpensive and easy to build. The meter has two subassemblies: the processing unit and the SWR sampling unit. The dc samples of forward and reverse voltage are processed by a programmed PIC¹ microcontroller that computes the SWR and directly drives a large bright display. No calibration against another standard is necessary because the computed number *is* the SWR. The SWR is displayed as two digits—units and tenths of a unit. The processor and the display are mounted on a small PC board that mounts on the panel.

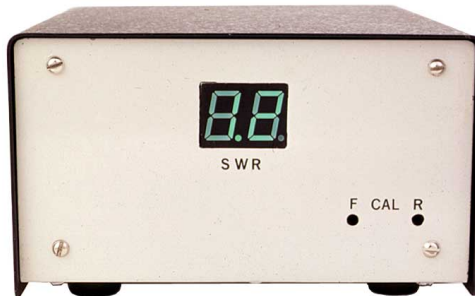
Determining SWR

The PIC has four ADCs (two of which are used in this application), RAM, the EPROM containing the program and an oscillator—everything needed in one small 18-pin package. There's more than enough on-board power in the PIC to directly drive the large LED display. The flow chart of shows how the PIC's program calculates SWR. The PIC's ADCs translate the two dc inputs from the sampling unit into two hexadecimal number equivalents identified as FWD and REV. The program determines if the FWD sample is sufficiently high to make an accurate measurement. If not, the letters LP (for "low power") are displayed. If the input is high enough, the PIC's software uses the following equation to arrive at an SWR value:²

$$(FWD + REV) / (FWD - REV) = SWR \quad (\text{Eq 1})$$

where SWR is a hexadecimal number plus any remainder, REM.

The processor works with hexadecimal numbers that must be converted to decimal for display. If executing Equation 1 results in an SWR of 10 or more, the display indicates HI. If the value is less than 10, the SWR is equal to a decimal value between 1 and 9, because those numbers are the same ¹Notes appear on page 43.



Need an SWR meter for your shack? Build this computing SWR meter!

in the hexadecimal and decimal numbering systems. The quantity (FWD – REV) is equal to one unit of SWR. REM, always less than the divisor, is converted to decimal by multiplying by 0Ah (10 decimal), then dividing again by (FWD – REV). This gives the answer in tenths of an SWR unit. From left to right, the display shows units, a decimal point and the tenths SWR value. A new SWR calculation is made every three milliseconds.

Construction and Circuit Description

In the prototype, the processing unit is mounted behind the enclosure's front panel, with the sampling circuit secured to the rear panel. C1 and C2 of Figure 2 provide a time constant appropriate for SSB. These capacitors should be tantalum units because they also serve to remove stray RF. Tantalum capacitors are physically smaller and are better RF bypasses than aluminum electrolytic capacitors.

The PIC (U1) is a high-impedance CMOS device, so observe proper handling precautions and use a wrist strap. R3 and R4 ensure that the maximum recommended input source impedance is not exceeded at any setting of R1 (FWD) and R2 (REV). Although the digits displayed on DS1 appear to be on continuously, they are alternately illuminated. U2 (a BCD-to-decimal decoder/driver) selects which digit is on at a given time. If you follow my construction technique, use a low-profile crystal in the oscillator circuit because physical clearance above the crystal is limited. Most 9-V plug-in transformers usually have sufficient dc filtering so no more is needed on the PIC board. C7 serves as a regulator-oscillation suppressor; C8 provides glitch suppression when U1 and U2 switch.

For DS1, I selected a bright green, 0.56-inch, two-digit common-cathode Panasonic display that can be seen easily

from a distance. The display segments are connected in parallel; that is, segments a, b, c, etc. of one digit connect to like segments on the other digit. Of course, if you use the ready-made PC board (see Note 1), this wiring is already done for you. (Other common-cathode displays can be used, but they may not fit the ready-made PC board.) I checked the possibility of using RadioShack's 276-075 0.3-inch red displays. Those displays are easy to find, but their visibility, brightness and size pale in comparison to the recommended display. If you elect to use the RadioShack displays, you'll need to make your own PC board for them. The display-segment interconnections can be worked out by referring to the segment designations shown in Figure 2 and on RadioShack's packaging.

Before mounting parts on the PC board, use it as a template to mark on the enclosure the location of the four corner mounting holes and those for R1, R2 and the display. Make the FWD and REV test points using leads from C3 and C4. When you install the two capacitors, allow their ungrounded leads to project from the back of the board by about 1/4 inch. (These test points are used when calibrating the circuit.) Space the displays from the board so they project through the panel cutout when the board is 3/8-inch or so away from the panel. If you can't find 3/8-inch spacers to mount the display board, 3/4-inch-long #4-40 machine screws—each equipped with three nuts and secured to a corner of the board—will do the job.

Sampling Unit

The sampling unit (Figure 3) I selected is similar to the one shown in *The ARRL Handbook*.³ It has a fairly constant dc output at 100 W on all bands from 160 through 10 meters and delivers the proper sampling voltages. I modified the circuit to suit the

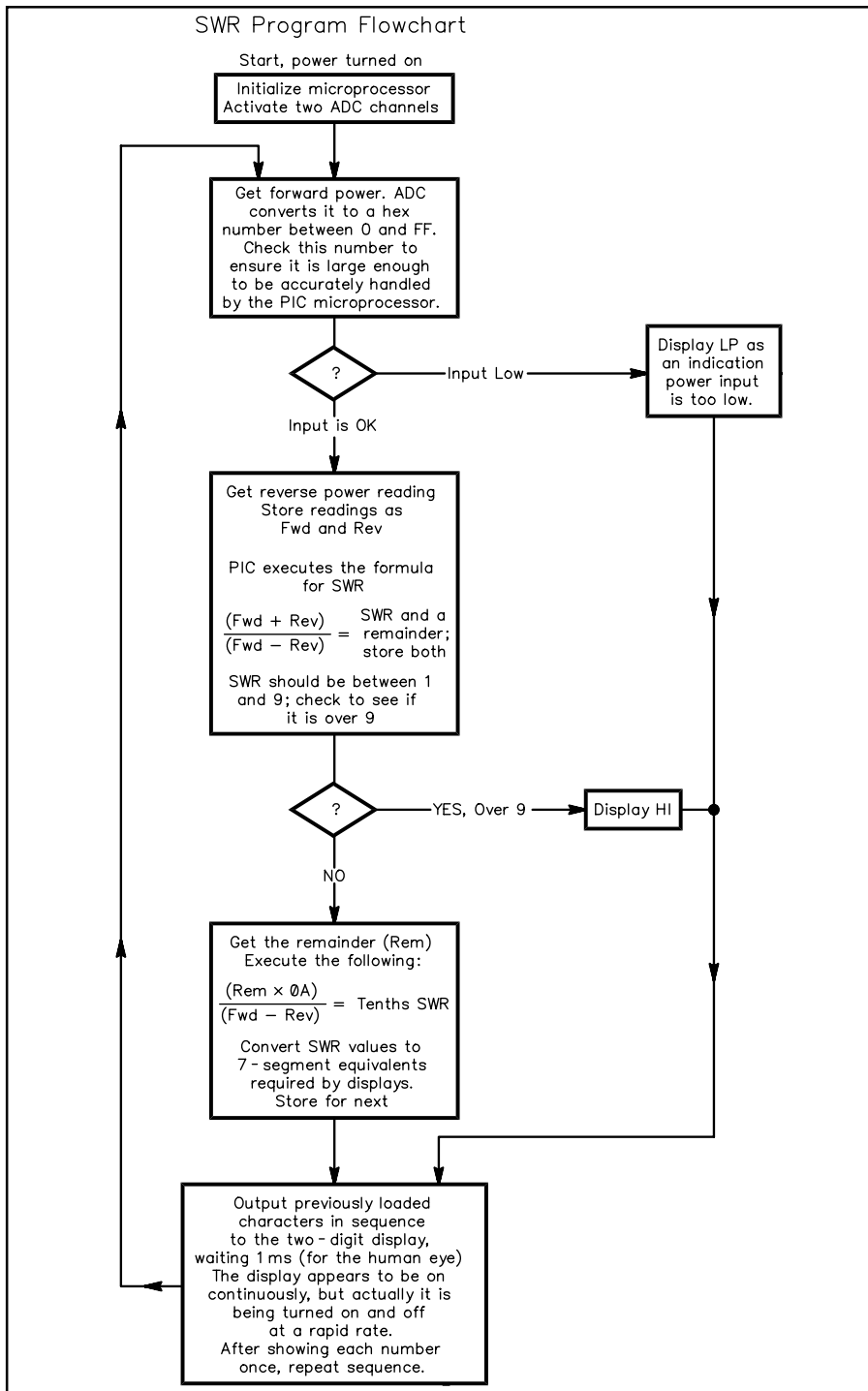


Figure 1—Flowchart showing operation of the PIC's program.

parts available and made it easier to adjust. The pickup voltage decreases as T1 turns are increased. For handling a power level of 1 kW, the *Handbook* suggests using 40 turns on the core. In my prototype, I used small pieces of unetched PC board material secured to the PC-board groundplane with epoxy cement to serve as insulated soldering points for all the components, including the nulling capacitor. The photo shows the **FWD** and **REV** outputs filtered by feedthrough capacitors (optional) mounted on a shield. The shield may not be needed,

but it helps brace the cabinet's somewhat flimsy rear panel. I used parallel resistor combinations at R10 through R13 because those values were stocked locally.

The *Handbook* refers to small changes in indicated SWR as power is increased;⁴ this meter exhibits the same effect. The change is caused by differences in diode conduction with current. Because the change is in the order of one or two tenths of an SWR unit, it is of no importance. Placing two 1N34 diodes in parallel reduces this effect, so I kept them in the circuit. I suggest you

use 1N34 diodes with *transparent* bodies; the 1N34 RadioShack diodes with cyan-colored bodies of the *same part number* exhibit a greater variation in characteristics.

Checkout

Before plugging in the ICs, check the power-supply output to be sure it's between 4.95 and 5.05 V.⁵ That done, turn off the supply, insert the ICs (verifying proper orientation) and apply power. The display should greet you by showing **LP**. If it does not, some easy troubleshooting is called for. Ensure the oscillator is running by listening for the presence of its 4-MHz signal with your station receiver. If that's okay, the PIC is probably working. At U1, pin 1, is a handy test signal. Temporarily attach a piezo element (RadioShack 273-071 or similar)—not a buzzer—between U1 pin 1 and ground. You should hear a loud tone of about 368 Hz. If this tone is present, the PIC is driving the displays. If the display problem persists, check the display connections and ensure U2 is properly seated in its socket.

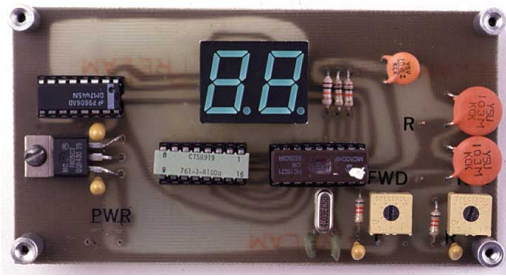
When the display shows **LP**, you may want to verify the PIC's calculation performance. It is an interesting test. See Figure 4 for a simple hookup to simulate all possible SWR values.

As shown in Figure 4, connect the **FWD V** test-circuit pot to the +5-V regulated supply (verify the voltage) and connect the arms of the **FWD** and **REV** pots of Figure 4 to the appropriate test points of Figure 2. Almost as soon as the **FWD V** pot is advanced, the **LP** indication should disappear and an SWR value appear. The SWR indication will change as the **REV V** control is adjusted. You will find the SWR changes little, if at all, as the **FWD V** potentiometer is adjusted in either direction. All you need now is a calculator and a digital voltmeter. Using a DVM, read the **FWD V** and **REV V** dc voltages at their respective test points, punch the values into a calculator and following the simple formula, compare the answer with the SWR value displayed. For example:

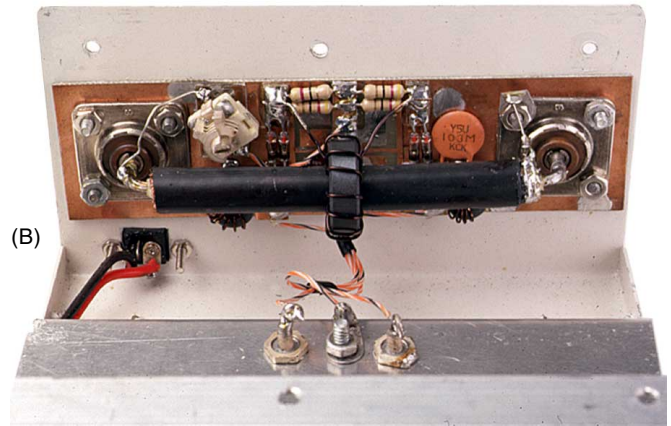
$$\text{FWD} = 4.5; \text{REV} = 1.27; \text{FWD} + \text{REV} = 5.77 \text{ V}; \text{FWD} - \text{REV} = 3.23 \quad (\text{Eq } 2)$$

$$5.77 / 3.23 = 1.786 \text{ SWR}; 1.7 \text{ appears on the display} \quad (\text{Eq } 3)$$

After the test, set the calibration at the test points and balance the bridge. Attach a transmitter and a dummy load to the bridge's coax connectors, J1 and J2 of Figure 3. Check the load's resistance with the DVM to verify it is 50 Ω (especially if you haven't done that lately). Clip a digital voltmeter between the **FWD** test point and ground. Preset R1 and R2 at midposition. Start with low power on CW on your most-used operating frequency. The **LP** display should disappear and an SWR reading appear. If that doesn't happen, check the **REV** test point. If the **REV** is high and the **FWD** is low, the winding on T1 is probably reversed. Exchange the wire ends of T1.



(A)



(B)

The SWR meter's display (A) and pick-up (B) PC boards. In the prototype shown, an air-dielectric trimmer is used at C10.

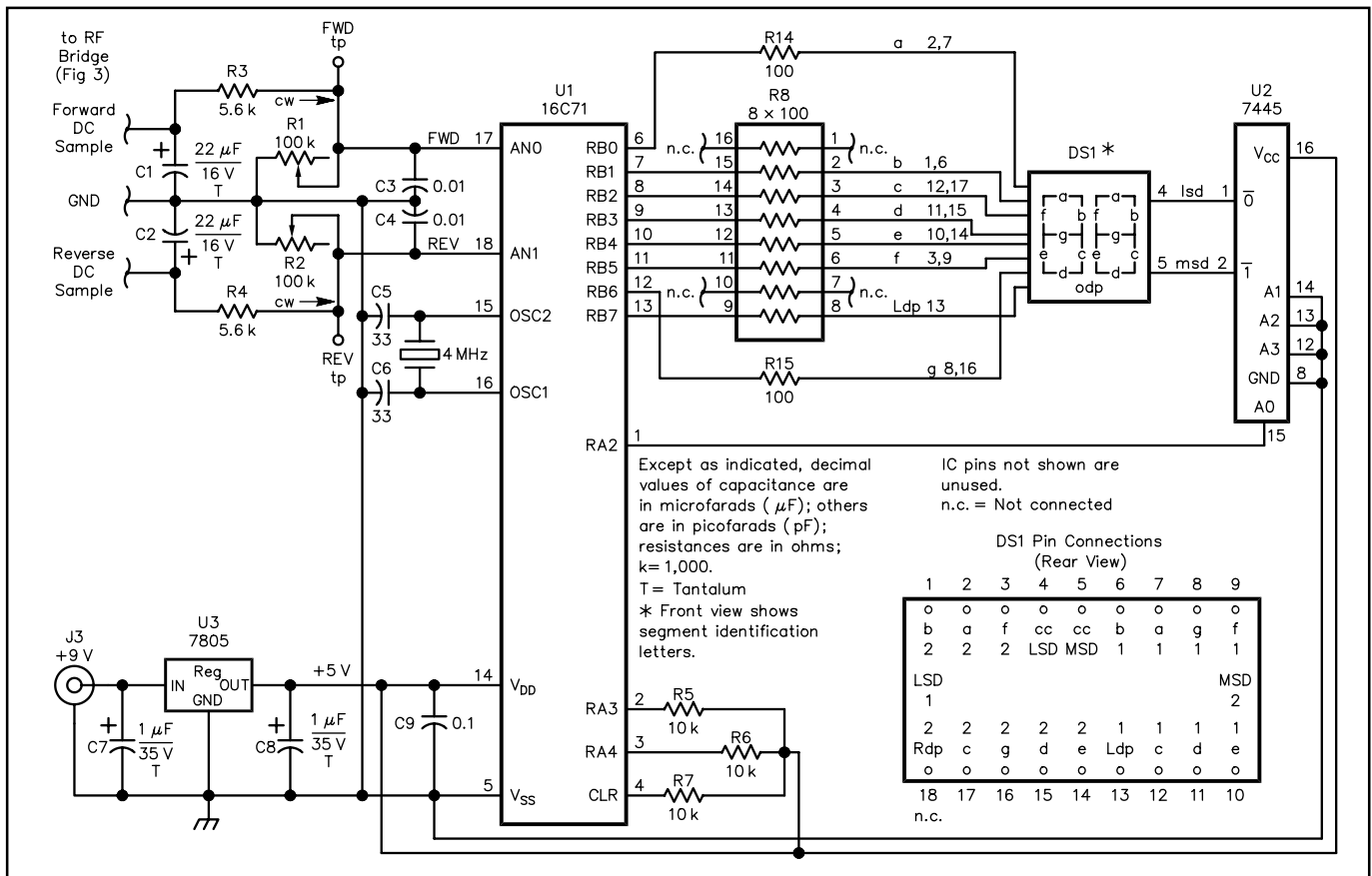


Figure 2—Schematic of the PIC SWR meter circuit. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted; n.c. indicates no connection. DK part numbers are Digi-Key; RS = RadioShack; JCO = Jameco. Parts are available from Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674, fax 218-681-3380; <http://www.digikey.com> (Panasonic displays, inside back cover of their catalog); Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002; tel 650-592-8097, domestic fax, 800-237-6948, international fax, 650-592-2503; info@jameco.com; <http://www.jameco.com> and RadioShack—see your local distributor. RadioShack Faxback number: 800-323-6586 (24 hrs, 7 days).

- C1, C2—22 μ F, 16 V tantalum (JCO 94094)
- C3, C4—0.01 μ F (RS 272-131, JCO 15229)
- C5, C6—33 pF disc ceramic (from RS 272-0806 assortment, or JCO 97244)
- C7, C8—1 μ F, 35 V tantalum (RS 272-1434, JCO 33662)
- C9—0.1 μ F, 50 V disc ceramic (RS 272-0135, JCO 15270)
- DS1—Panasonic LN526GK two-digit green display (DK P-359; a JCO 24707 red/orange display is a suitable substitute and is pin-compatible with the Panasonic display.)
- J3—Coaxial dc jack (RS 274-1565)
- R1, R2—100 k Ω trimmer (JCO 43027)
- R3, R4—5.6 k Ω (JCO 31270)
- R5-R7—10 k Ω (JCO 29911)
- R8—100 Ω DIP resistor network (JCO 108556)
- U1—7445N, BCD-to-decimal decoder/driver (JCO 50403)
- U2—7805T 5-V, 1-A positive regulator (RS 276-1770, JCO 51262)
- Y1—4-MHz crystal, low profile HC-49/U holder (JCO 137832); see text.
- Misc: Cabinet 3 \times 5 \times 5^{5/8}-inch HWD (RS 270-253); two 16-pin low-profile sockets (RS 276-1998, JCO 112221); one 18-pin low-profile socket (RS 276-1992, JCO 112230); 9-V dc wall transformer, center pin positive (JCO 100845); short length of RG-8 coaxial cable; epoxy cement (RS 64-2313); four 3/8-inch threaded spacers (JCO 77500); approximately 12 feet of #22 enameled wire (RS 278-1345); PC board (RS 276-1499). A 24-pin socket (JCO 112264) will accept the 18-pin display and allow it to project farther through the panel. Remove the unused socket pins before mounting the socket on the PC board.

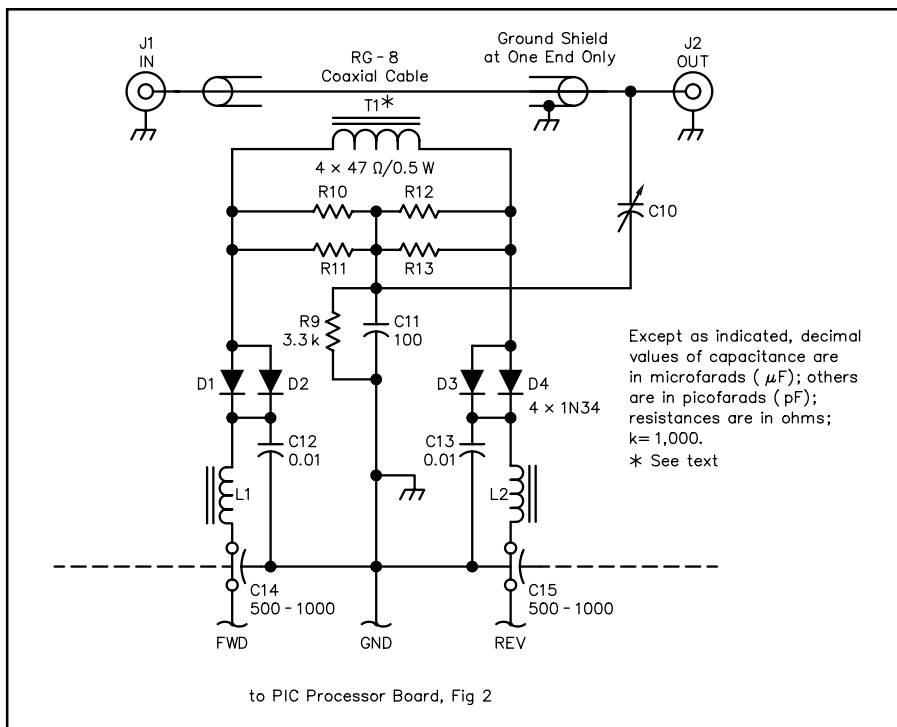


Figure 3—Schematic of the pick-up unit. J1 and J2 are approximately 3³/₄-inches apart (on center) to accommodate a 4³/₈-inch length of RG-8 coax used as the primary winding of T1.

- C10—3.5-13-pF air-variable trimmer capacitor, 250 V (JCO 134818)
- C11—100 pF silver mica (JCO 16002)
- C12, C13—0.01 μF, 50 V disc ceramic (JCO 15229)
- C14, C15—Optional 500-pF feedthrough capacitors, 50 V or more
- D1-D4—1N34 germanium diodes (RS 276-1123); see text.
- J1, J2—SO-239 coaxial connector (RS 278-201)

- L1, L2—10 turns #22 enameled wire on an FT-43-2401 ferrite bead; (one source of ferrite beads and toroid cores is Amidon, Inc, 240 Briggs Ave, Costa Mesa, CA 92626; tel 800-898-1883, 714-850-4660, fax 714-850-1163).
- R9—3.3 kΩ, 1/2 W resistor (RS 271-1122)
- R10-R13—47 Ω, 1/2 W (RS 271-1105)
- T1—FT-82-61 toroid core wound with 11 evenly spaced turns of #22 enameled wire

Then, while monitoring the **FWD** test point, increase power to normal. Adjust R1 so the test point voltage is 4.5 V. This allows for handling slightly more power without exceeding the maximum of 5 V.

Move the DVM to the **REV** test point and adjust C10 for a null. The null should be very low, 0 V or little more at full power. Recheck the **FWD** level and tweak R1 for a reading of 4.5 V, if necessary. Turn off the transmitter and swap the cables to J1 and J2. With the transmitter set at the same power level, adjust R2 for 4.5 V at the **REV** test point. Restore the cabling. Check the operation of the meter on the all bands you operate while monitoring the **FWD** test point voltage. If you find a band where the voltage is high, set R1 and R2 on that band. It is normal to have some voltage-level variation on the various bands. We don't want to feed more than 5 V to the PIC's input.

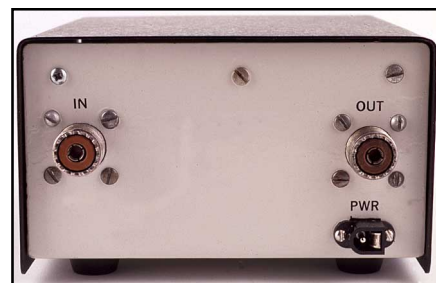
Summary

I am learning to write code for the PIC (thanks to John, W2FS)⁶ and have made the assembly listing available as well as the hex file. A PIC can eliminate a lot of hardware and is tolerant of beginners' mistakes. I was unable to program the 16C71 with any

of several simple programmers. So I purchased a Microchip PICSTART PLUS that programmed the same chip with the same hex file first try. Ah! Success! The package contains the programmer, instruction manuals, a CD-ROM and two large data books. Programmed PICs and a PC board are available (see Note 1). Happy PIC'n!

Notes

- ¹Programmed 16C71 PICs, PC boards and some parts for this project are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269, tel 847-836-9148 (voice and fax). A semi-kit consisting of a programmed PIC, pick-up and display PC boards, a crystal and a two-digit display is priced at \$24 plus \$1.50 shipping for up to two semi-kits; PC boards only, \$9 plus \$1.50 per set. Visa and MasterCard accepted with a \$3 service charge. A copy of the PIC code (.ASM and .HEX) is available in PICSWR.ZIP at <http://www.arrl.org/files/>.
- ²Mark J. Wilson, AA2Z, Ed, *The 1987 ARRL Handbook*, (Newington: ARRL, 64th ed., 1987), page 25.14.
- ³*The 1987 ARRL Handbook*, p 34.12.
- ⁴Robert Schetgen, KU7G, Ed, John Grebenkemper, K16WX, "The Tandem Match—An Accurate Directional Wattmeter," *The 1996 ARRL Handbook*, (Newington: ARRL, 73rd ed., 1995) p 22.37.
- ⁵I've found 7805s that deliver 4.8 V. Although this is acceptable logic voltage, this level re-



Rear-panel view of the SWR meter.

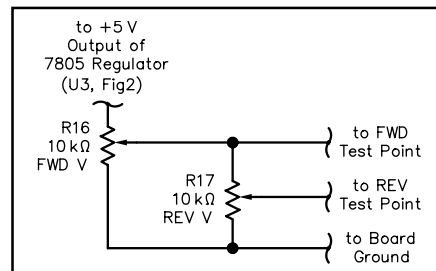


Figure 4—A simple circuit for testing and adjusting the SWR meter without applying RF power. See text.

- R14, R15—10 k Ω pot, RS 271-1715; optional parts, two knobs (RS 274-424) and case (RS 270-1801), or pot (JCO 29081), knobs (JCO 104176) and case (JCO 18921).

stricts the operating range of the ADCs in the PIC.

⁶John Hansen, W2FS, "Using PIC Microcontrollers in Amateur Radio Projects," *QST*, Oct 1998, pp 34-40.

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All photos by Joe Bottiglieri, AA1GW. **QST**

Strays

YEAR 2000 ON THE MERIDIAN

◇ Radio amateurs from the Cray Valley Radio Society are planning to establish a DX-pedition-style station on the prime meridian at Greenwich, London for two months from December 31, 1999 to February 29, 2000. In the first 24-hour period radio contact will be made with amateur stations around the world as their own median lines pass into the year 2000, starting with ZL and finishing with KH6. With the support of the Radio Society of Great Britain and the Radio Communications Licensing Agency, the unique call sign of M2000A has been issued to the station for this event only. For further information see the M2000A Web site at <http://www.qsl.net/m2000a>.

Next Stray