Applications Using the PIC-Power Meter

This HF-VHF meter sports 80 dB of calibrated resolution and an easy to use LCD interface. From QRP to antenna tuning, this meter will become a favorite tool on your bench.

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Figure 1—Exterior view of the PIC power meter.

Introduction

This meter was presented in detail in a recent *QEX* article.[1] The Analog Devices 8307 log amplifier, described in an earlier article by Hayward and Larkin,[2] is built up on a small, shielded, RF module within the chassis. Power levels from –70 to +7 dBm, from 1 to 500 MHz, may be measured with this device. The display is shown in Figure 1. Another board holds the liquid crystal (LCD) display and a programmable integrated circuit (PIC) processor for controlling the system. Figure 2 shows the interior layout.

With the addition of a small microprocessor, and flash memory, calibration points for absolute power levels may be stored within the unit. You can perform power measurements with this meter referenced to any available source. Power levels are displayed on the screen in dBm or watts. For higher-power measurements, an external coupler may be used. When using a coupler, on-screen offset is accounted for within the software. In addition, a high-accuracy differential measurement mode allows the operator to measure insertion loss with resolution better than 0.1 dB. Amplifier gain, return loss and VSWR can be measured and displayed using the differential mode as well.

If you don't have a general purpose RF power meter for your bench, this project may be of interest to you. More ambitious amateurs may find the generic PIC CPU and LCD module useful for other projects as well. The PIC chosen for this project has numerous analog to digital (A/D) input pins, along with additional pins for driving additional peripherals.

For those interested in replicating this project, parts are available via Kanga US.[3] This includes preprogrammed PIC processors with the latest revision of the PIC power firmware. All source code used to develop this project is available via the Internet. A link is provided at the end of this article. More details are included in the *QEX* article as well.

RF Module

At the heart of the RF module is the Analog Devices AD8307 logarithmic amplifier (log amp). RF power is terminated in a 50 Ω resistor on the board. The RF voltage is measured by the log amp; it converts the power level to an absolute voltage, which increases 25 mV for every dB of increase in power. An operational amplifier (op-amp) in the RF module scales the output voltage of the log amp further. This improves the precision of the measurements slightly.

Another application of the meter is the measurement of insertion loss, or stage-to-stage gain. In those cases, the absolute power level isn't as important as the difference between measurement points. For this mode, a second op-amp provides a higher gain measurement, yielding higher precision to the PIC processor. A D/A converter produces a reference voltage for the meter to measure against. The result is that differential power measurements with resolution better than 0.1 dB are feasible.

For antenna return loss measurements, if the power difference extends beyond 10 dB, the PIC software will automatically shift out of this higher precision mode and present a value to the display that represents the difference between the two absolute power levels.

The RF module must be enclosed in its own RF tight enclosure. A limited number of interface wires should be fed to the board via feed-through capacitors, soldered to the wall of the RF enclosure. It is important to shield the RF module from the CPU module to prevent

[1]Notes appear on page 30.

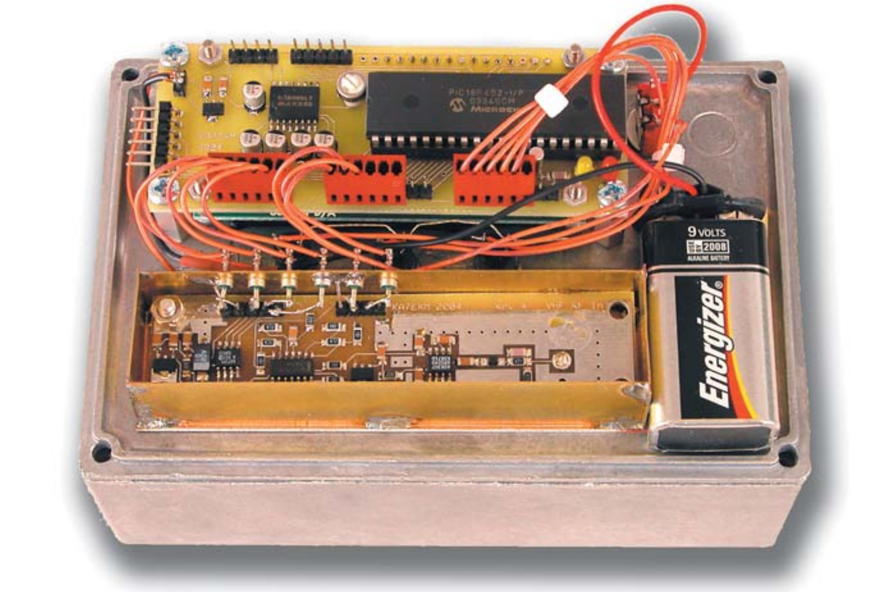

Figure 2—Inside view of the meter. The CPU module is on the top, RF measurement on the bottom. The LCD is mounted under the CPU module.

the detector from seeing RFI from the nearby CPU.

The maximum input power level is +7 dBm. Although this is relatively low for measuring transmitter output levels, the addition of a 40 or 50 dB coupler[4] will extend this value up to the 100 W range.

CPU Module

The CPU module utilizes a PIC, the 18F452. This is the pin-compatible big brother of the popular 16F877. The part contains an A/D converter with numerous input pins available for analog measurements. The PIC is packaged in a 40 pin dual inline package (DIP) that allows the processor to be easily exchanged, should there be a need to upgrade the firmware in the future.

The LCD is a 16 character by 2 row module manufactured by Lumex. It is mounted to the back of the PCB with standoffs. This provides an easy mounting system for the home experimenter. In addition, the PIC can talk to the LCD through jumper wires between the two boards, avoiding the need for ribbon cables.

The CPU module was designed to handle a variety of projects, not just the PIC power meter. There are two LEDs on the CPU module. Several pins talk to the RF module and receive inputs from the menu driven interface. All remaining pins on the PIC are available at header pins distributed around the board. A variable resistor allows for adjustment of the LCD contrast. The board also has provision for adding a MAX232 IC, to provide an RS-232 serial interface, to allow data communication to and from the PIC.

On one end of the CPU board is another header that can mate with a number of in-circuit debugger systems such as the Microchip ICD-2 or the CCS Mach-X. This allows the developer to program and debug the PIC in-place. That is how the program was developed for this project.

Both the RF and CPU modules are constructed on printed circuit boards. Since some components in this project are only available in surface-mount (SMT) packages, I chose to lay out both boards with about 90% SMT. Assembly of this project should be straightforward, with only a few components having tight pitches that might require a steady hand.

Operating the Meter

With the advent of newer miniature "appliances" from the major vendors, most Amateur Radio operators have become accustomed to driving their radios by using a menu-driven interface. Often, the bottom of the LCD display is lined with push buttons. The buttons perform different functions, depending upon what the radio is doing. The operator can shift to another bank of functions by pressing an F button, or perhaps scrolling an optical shaft encoder until their selection is found.

I've grown accustomed to scrolling around within the menu system on my FT-817 to change power levels, alter CW speed, or rapidly pop between memories or bands. The '817 incorporates an F (function) key that wakes up the bottom line of the display into a menu-driven mode. Buttons A, B and C perform various features shown on the display.

I chose to integrate a similar approach in the power meter. Subsequent presses of the F button will advance the operator to the next set of features. Typically, when you choose a setting, the menu line will return to blank until you need to set or change something again.

The meter is very easy to operate. To measure absolute power, simply turn it on! To invoke an advanced function, press the F key, and the bottom line will have selections appear. These selections may be chosen by pushing the button immediately below the function label. The sequence is shown in Figure 3.

To make a relative power measurement, such as the insertion loss of a filter, start by applying your reference signal to the meter. Press F, then 0. Future measurements will show the power level relative to this reference.

If you are using a 40 dB tap coupler, press F, then TAP. This will shift the measurement on the display automatically.

VSWR may be shown during return-loss measurements. If you wish to turn this off, press F (until you get to the third menu), and then press VSWR. The > character indicates whether the mode is enabled or not.

Measuring Power

Remember that the meter's input terminates your signal in 50 Ω, and you should not exceed +7 dBm (about 5 mW) input to the meter. If you do exceed +7 dBm, the display will flash the absolute power value to alert you to lower the input power as soon as possible.

If your power level does exceed the upper limit of the log amplifier, it is easy to use the meter with a coupler. The coupler is a device that will pass a sample of the signal going to a load such as an antenna or a dummy load. The sample will be an accurate fraction of the power available to the meter. The coupler described in the article by Hayward and Larkin was a 40 dB tap. This means that any value measured with the tap in line would be 40 dB lower than its actual value. The connectivity and readout are shown in Figure 4.

When adding the tap to your measurement setup, press F and then TAP. The letter T will show on the display next to the absolute power value to remind you that you are using the tap. The display is shown in Figure 5.

Measuring Insertion Loss or VSWR

To measure the insertion loss of a filter, apply a reference signal to the power meter. Press F, then 0. The meter will store this value in its memory and establish a reference voltage that is representative of this signal. From there, a filter, or gain stage can be inserted. The differ-

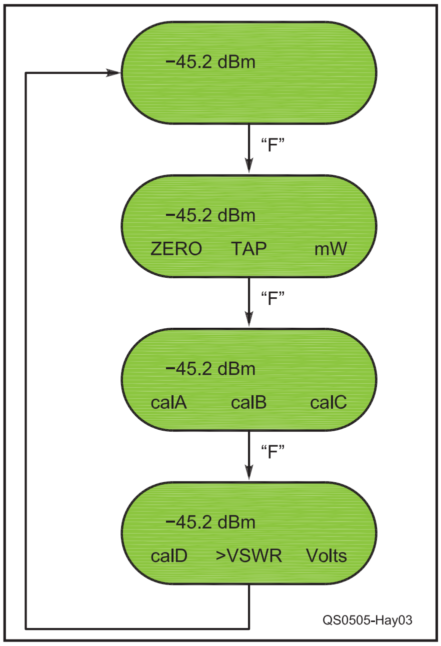

Figure 3—Accessing all menu functions is easy with the function key.

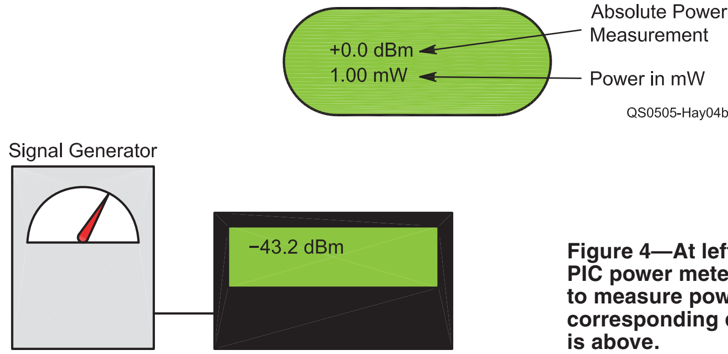

Figure 4—At left, the PIC power meter set up to measure power. The corresponding display is above.

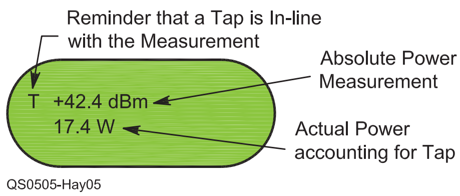

Figure 5—Using a coupler (tap) to measure higher power levels.

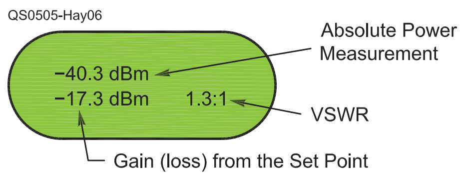

Figure 6—Measuring differences in power level. This includes return-loss and VSWR.

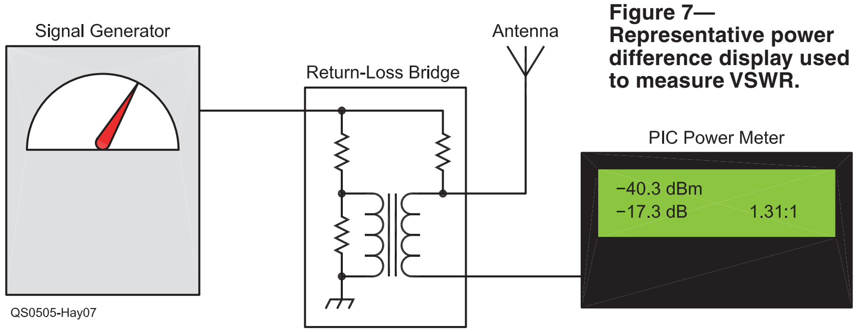

Figure 7—Representative power difference display used to measure VSWR.

ence in signal level will be shown on the second line of the display as shown in Figure 6.

By adding a return loss bridge to the system, as shown in Figure 7, return loss or VSWR of your antenna may be measured. A signal source at the frequency of interest is applied to the load to be tested through the return loss bridge. The DETECT port of the bridge is then terminated at the power meter. Power is applied without the load connected. F is pressed and then 0 to store the reference value at full reflection. Then the load to be measured is connected to return loss bridge. The return loss, and optionally, the VSWR, will be shown on the display.

This is especially useful for tuning smaller VHF antennas. Once a calibrated RF value is established at the meter, the antenna can be adjusted and results are seen immediately on the screen.

Acknowledgments

A big thanks goes to Microchip application engineer Steve Bible, N7HPR, for advice and encouragement on working with the PIC on Amateur Radio projects. Thanks also to CCS for their generous assistance with the PIC-C compiler. The PIC CPU, in combination with the CCS-C compiler and ICD, proved to be a very easy package for home project development. Thanks also to Wes Hayward, W7ZOI, and Bob Larkin, W7PUA, for consultations associated with this project.

Further construction details, along with schematics and theory of operation, are presented in the *QEX* article. Parts are made available via Kanga US. If you are interested in developing your own project with the CPU/LCD module, it is available separately. Source code may be downloaded via the author's Web site listed below.

Notes

[1]R. Hayward, KA7EXM, "A PIC-based HF/VHF Power Meter," *QEX*, May/Jun 2005, pp 3-10.

[2]W. Hayward, W7ZOI, and R. Larkin, W7PUA, "Simple RF-Power Measurement," *QST*, Jun 2001, pp 38-43.

[3]Parts are available from Kanga US in a variety of configurations including pre-programmed CPUs and full parts kits. See **www.kangaus.com** for details.

[4]See Note 2.

First Licensed in 1979, Roger Hayward, KA7EXM, is active in portable VHF hill-topping adventures, as well as experiments in the shack. He is married, with three children and lives in Beaverton, Oregon. Experiment notes, software source code and updates, and a chronicle of past adventures may be found on his Web site at **www.ka7exm.net**. *You can reach the author at 13405 SW Juanita Pl, Beaverton, OR 97008 or at* **ka7exm@arrl.net**. QST