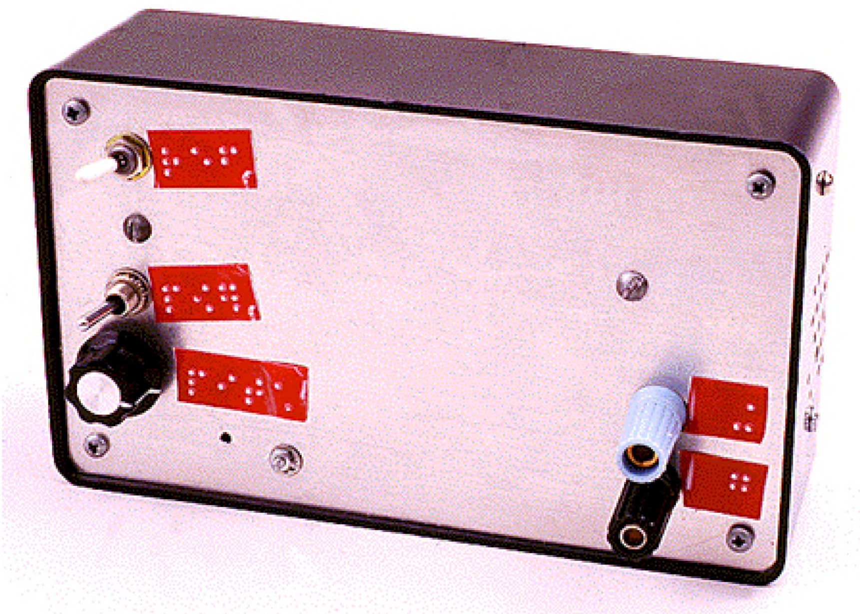
A Relative-Indication Audible Meter Reader

This simple circuit allows blind—and sighted—hams to identify meter readings audibly.

By Anthony McCloskey, WA3CAO



As a blind amateur, I am very interested in methods of adapting off-the-shelf equipment for my use, and I have had a lot of fun building circuits for this purpose. Earlier versions of audible meter-reading circuits were pioneered by Bob Gunderson, W2JIO (now a Silent Key). Bob was a blind ham and a former teacher at what was then the New York Institute for the Blind in New York City. Bob also authored the *Braille Technical Press*. Published in Braille, this magazine featured verbal descriptions of schematics and lots of good information on construction techniques. Having built a number of projects from *BTP*, I decided to continue in electronics as a hobby and as a profession. Following Bob's lead, I'd like to share some ideas for a more modern audible meter reader.

Some Background

The Audible Meter Reader is an offshoot of a circuit designed by Ben Spencer, G4YNM. [1] Ben's circuit monitors the forward and reverse readings of an SWR meter by using both voltage-controlled oscillators (VCOs) of a 74LS629 IC. One oscillator is driven by the SWR meter's forward voltage, the other by its reverse voltage. Through a buffer, each oscillator feeds an earphone of a stereo headset. Each oscillator's frequency is proportional to the voltage at its input pin, so a voltage increase causes an oscillator-frequency increase, and vice versa. Simultaneous monitoring of forward and reverse readings is done by comparing the relative pitches of the two oscillators.

I wanted a circuit that would allow me to obtain relative readings from panel meters commonly used in ham gear and other electronic equipment. Most of these meters have a full-scale voltage drop of approximately 150 mV. I did some experimenting with the 74LS629 and found that the dc input voltage needed to reach the highest output frequency is about 4 V. (Obviously, amplification is needed to increase the 150-mV level available across a meter up to 4 V.) With the 1-µF timing capacitor used in Ben's circuit, the maximum output frequency is about 3 kHz, and decreases linearly with decreasing input voltage. I found that connecting the output of either IC oscillator through a 47-µF capacitor to an 8-Ω speaker provides plenty of volume, so the output amplifier Ben uses in his circuit is unnecessary here.

Circuit Description

Refer to **Figure 1** and the verbal schematic provided in the Appendix. U1A is a voltage follower; U1B is a variable-gain dc amplifier with a maximum gain of approximately 50. U1B's gain is controlled by R2, AMPLIFIER GAIN, and its output drives U2A, a 74LS629 connected as a VCO, to generate a *reading* frequency. U2B is a VCO set to a *reference* frequency by means of R3.

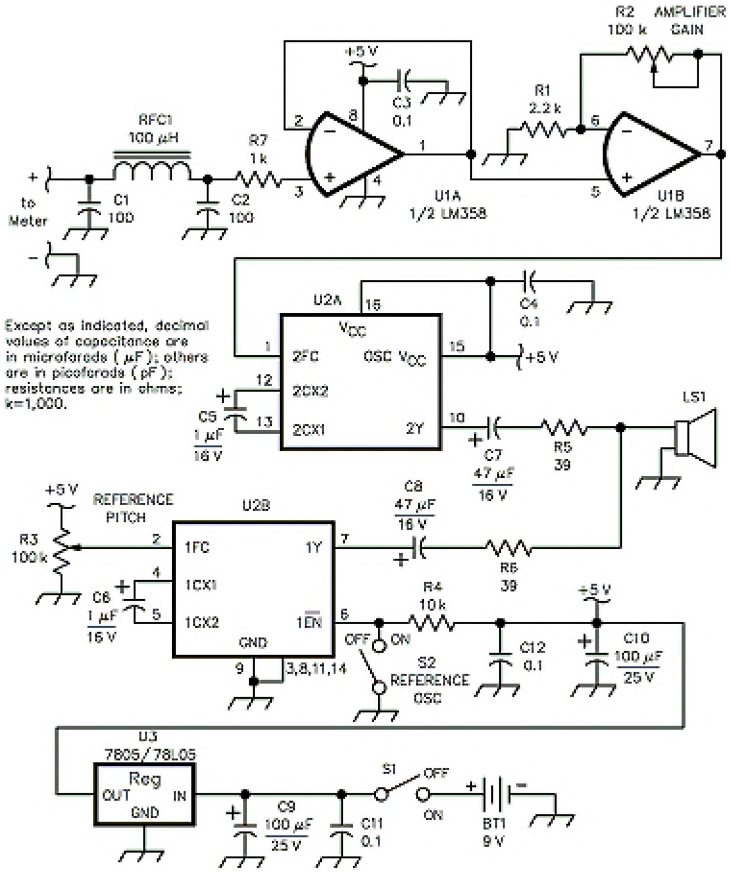


Figure 1—Schematic of the Audible Meter Reader circuit. Parts are available from a number of sources; see the Parts Suppliers list in any recent edition of The ARRL Handbook. Equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units.

C5, C6—1-µF, 16-V electrolytic capacitor

C7, C8—47-µF, 16-V electrolytic capacitor

C9, C10—100-µF, 25-V electrolytic capacitor

R2—100-kW linear-taper trimmer or panel-mount potentiometer (see text)

R3—100-kW linear-taper panel-mount potentiometer

RFC1—100-µH RFC

S1—SPST toggle switch

S2—SPST toggle or push-button switch

U1—LM358 dual op amp

U2—74LS629 dual voltage-controlled oscillator; available from JDR Microdevices, 1850 S 10th St, San Jose, CA 95112-4108; tel 800-538-5000, 408-494-1400; fax 800-538-5005, 408-494-1420; http://www.jdr.com

U3—7805 or 78L05 5-V regulator

Misc: Enclosure, IC sockets, hardware, PC board (see Note 2).

Attached to the terminals of a meter, the tones generated by U2A and U2B provide an audible means of identifying the particular meter reading. Both oscillators feed a single 8-Ω speaker (LS1). When the reading-tone and reference-tone frequencies are equal (producing a zero beat), the meter is at the correct point.

U3 provides a regulated 5-V source when given an input voltage of 7 to 18 V.

Construction

I built my circuit on a piece of perfboard (see **Figure 2**), using wire-wrap sockets for U1 and U2, but a PC board is available. [2] Parts layout is not critical. I mounted the dc-amplifier gain control on the board, but it can be mounted externally, if desired. My reader is housed in a Radio Shack box (RS 270-627). The ON/OFF switch, REFERENCE OSC ON/OFF switch, and REFERENCE PITCH control are mounted at the left end of the box top, arranged vertically from top to bottom. At the right end of the top surface are two binding posts that accommodate banana plugs and wires.

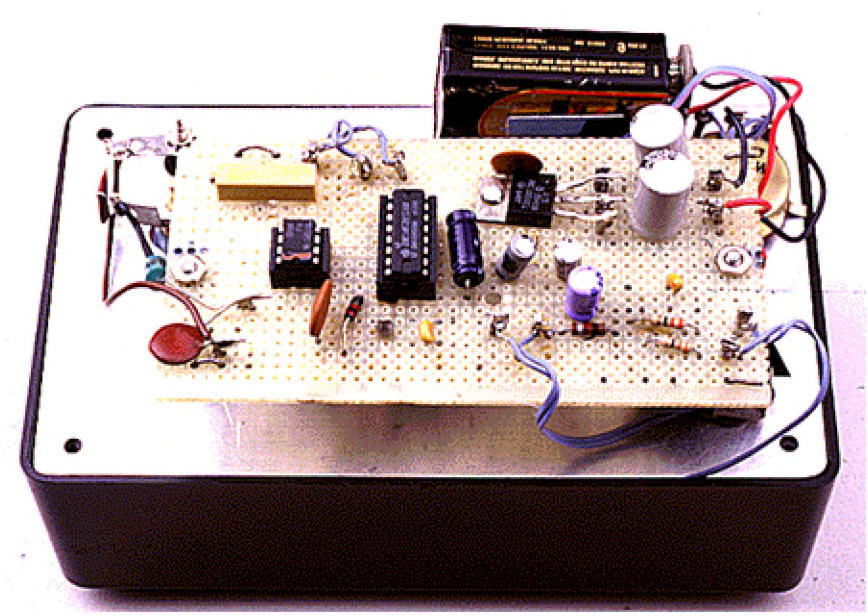


Figure 2—The author's prototype is wire-wrapped on a piece of perfboard, but a PC board is available for more-compact construction (see Note 2).

A $1^1/_4$-inch speaker is attached to the box's right apron. I used a $^5/_{64}$-inch bit and a piece of perf board as a template to make the speaker-grille holes. Speaker-mounting clamps can be made by bending two solder lugs into an L shape.

The circuit has no dc connection to the case. This is intentional. When the reader is connected to a meter, it must "float" across the meter with no other connection to ground or other operating circuitry. Good isolation is absolutely necessary, particularly when reading a meter located in a high-voltage area such as a tube transmitter's plate circuit. Remember: *Safety First!* If the reader's circuit must have an ac connection to the enclosure you have, use good-quality 0.01-µF disc ceramic capacitors with a voltage rating several times the highest dc voltage present in the monitored equipment.

Use a 9-V alkaline battery to power the reader, keep it self-contained and maintain isolation. Be sure that the battery mounting bracket is properly insulated from the chassis. The battery's internal insulation is inadequate for any high-voltage application.

Testing the Reader

Before inserting U1 and U2 into their sockets, connect a dc supply (7 to 18 V) to the board, and check the voltage between the U1 pin 8 and ground, and between U2 pin 16 and ground. You should see +5 V at both pins. If you don't, check for +5 V at the output of regulator U3.

Turn off the power supply and install U1 and U2. Turn on the power supply. With the reader's input terminals connected together, you should hear a 300-Hz tone (approximately) in the speaker. Next, turn on the reference oscillator. You should now hear two tones emanating from the speaker. Rotating the REFERENCE PITCH control through its full range should vary the tone pitch from about 300 to 3000 Hz. If this occurs, the reference oscillator is working correctly.

To calibrate the reader for use with a particular meter movement, connect the reader's input terminals across the chosen meter's terminals. Set the meter for a full-scale reading. Adjust the AMPLIFIER GAIN control (R2) until the U2A tone just reaches its maximum frequency. The reader is now ready for use.

To identify a particular meter reading—say, 150 mA on a 300-mA meter—connect the reader to the meter's terminals. Adjust the metered-circuit's controls to bring the meter to the desired reading; a tone generated by U2A will be heard in the speaker. Next, adjust the reader's REFERENCE PITCH control (R3) until zero beat is heard—that is, until the reference frequency (U2B's output) and the reading frequency (U2A's output) are equal. This is very easy to hear. To return to that meter reading, turn on the reference oscillator by closing S2, and adjust the equipment until the two reader output frequencies are equal. To take multiple readings, you can mark the REFERENCE PITCH dial at various settings for your particular needs, or you can install a rotary switch with a number of different REFERENCE PITCH pots. Then, set each pot to a desired reading. For more information on audible meter reading circuits, see the sidebar, "Audible Meter Reader Techniques."

The reader can be used for dipping or peaking a meter reading by turning off the reference tone and using just the reading tone. I've used the reader with many pieces of equipment in my shack, from my Heathkit dip meter to the panel meter of my Kenwood TS-520 transceiver.

Other Applications

The reader can also be used as an audible field-strength meter by connecting its input terminals to a diode and antenna. You can use the reader to eliminate a conventional meter on the crowded front panel of a small rig. To do this, replace the meter with a resistor exhibiting the same resistance as the meter movement. For example, let's suppose our panel meter has a 100-µA movement. The voltage drop at full scale for most of the common panel meters is 0.15 V. Using Ohm's Law, determine the resistance of the movement by R = E/I = 0.150/0.0001, or 1.5 kΩ. [3]

The Audible Meter Reader is easy to build and inexpensive. I'm sure most hams—sight impaired or not—will find many uses for it around the shack.

Acknowledgments

I would like to thank my friend and colleague Joe Everhart, N2CX, for his encouragement and advice during the writing of this article. Also, my thanks to Ben Spencer, G4YNM, for some really good ideas.

APPENDIX

Verbal Schematic

The negative input terminal of the meter reader is connected to circuit ground. Note that this is the isolated ground of the reader, not necessarily the ground of the meter circuit being read. The positive input terminal goes to C1, a 100-pF capacitor to ground, and to the series connection of RFC1, a 100-µH choke, and R7, a 1-kΩ resistor, to U1A pin 3, the noninverting input. The junction of RFC1 and R7 goes to C2, a 100-pF capacitor to ground. Pin 2, the inverting input of U1A, and the output, pin 1, are tied together. The output of this voltage follower is taken from pin 1. U1A pin 8 connects to +5 V and to C3, a 0.1-µF disc-ceramic capacitor to ground. U1A pin 4 is grounded.

DC Amplifier

U1B is a dc amplifier having a maximum gain of 50 and is wired as follows: Pin 1 of U1A, the output of the voltage follower, is connected directly to U1B pin 5, the noninverting input of this section. Pin 6, the U1B inverting input, connects to R1, a 2.2-kΩ resistor to ground, and to R2, a 100-kΩ pot connected as a rheostat, to pin 7, the U1B output. U1B pin 7 is the output of this dc amplifier.

Reading Oscillator

The output of the dc amplifier, U1B pin 7, is connected directly to pin 1 of U2, the frequency control input for U2A. U2A pin 12 connects to the positive side of C5, a 1-µF electrolytic capacitor, with the negative side of this capacitor connected to U2A pin 13.

C5 is the timing capacitor for this oscillator. Pin 10, the output of this stage, is connected to the positive side of C7, a 47-µF electrolytic capacitor, with the negative side of this capacitor connected to one end of R5, a 39-Ω resistor. The other end of this 39-Ω resistor is connected to the hot speaker terminal. The negative speaker terminal is grounded. U2A pins 15 and 16 are tied together and connected to +5 V. The junction of pins 15 and 16 also goes through C4, a 0.1-µF disc-ceramic capacitor to ground. U2A pins 3, 8, 9, 11 and 14 are tied together and connected to ground.

Reference Oscillator

The top of the REFERENCE PITCH control, R3, a 100-kΩ potentiometer, is connected to +5 V, and its bottom is grounded. The arm of this potentiometer goes to pin 2 of U2B, the frequency control input of U2B. Pin 4 of U2B goes to the positive side of C6, a 1-µF electrolytic capacitor, with the negative side of this capacitor connected to U2 pin 5. Pin 7, the oscillator output of U2B, goes to the positive side of C8, a 47-µF capacitor, with the negative side of this capacitor connected to one end of R6, a 39-Ω resistor. The other end of R6 goes to the hot speaker terminal. U2B pin 6, the active-low enable for U2B, connects to R4, a 10-kΩ resistor to +5 V. U2B pin 6 also connects to one side of S2, an SPST toggle switch. The other side of this switch is grounded. S2 turns the reference oscillator (U2B) on and off.

Voltage Regulator

U3 is a 7805 or 78L05 5-V regulator. The circuit will work well with power-supply input voltages from 7 to 18 V. A 9-V alkaline transistor radio battery is ideal.

The positive side of the unregulated dc-input voltage connects to S1, the ON/OFF SPST toggle switch, and the input pin of regulator U3. The regulator input pin is also bypassed to ground through the parallel combination of C9, a 100-µF electrolytic capacitor, and C11, a 0.1-µF disc-ceramic capacitor. The ground pin of this regulator is grounded directly. Its output pin provides regulated 5 V to the remainder of the circuit. Ac bypassing to ground is provided on the +5-V line by the parallel combination of C10, a 100-µF electrolytic, and C12, a 0.1-µF disc-ceramic capacitor.

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He received an Associate's degree in physics from Montgomery County Community College, and a BS in electrical engineering from Drexel University.

Early on, Tony worked as a radio engineer for WPEN in Philadelphia. In 1978, while working full-time during the day for RCA, Tony began attending Drexel University at night and got his BSEE in 1988. Tony is now employed by Lockheed Martin, where he works on software.

Although electronics is his profession, it's also Tony's hobby. He enjoys building and designing his own ham gear, and adapting off-the-shelf test equipment for his personal use. Tony operates phone and CW on the HF bands, and is also active on 2-meter FM. You can contact Tony at 916 E Hector St, Conshohocken, PA 19428; e-mail **amccloskey@cayman.litc.lockheed.com**.

Notes

[1]Ben Spencer, G4YNM, "An SWR Detector Audio Adapter," *QST*, Jul 1994, pp 24-25; also Feedback, *QST*, Aug, 1994, p 69, and Nov 1994, p 88.

[2]A PC board for this project is available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269, tel 708-836-9148 (voice and fax). Price: $4 each plus $1.50 shipping for up to four boards. Visa and MasterCard accepted with a $3 service charge. A PC-board template package is available for $2 for members, $4 for nonmembers. Send your request for the MCCLOSKEY AUDIBLE METER READER TEMPLATE to the Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111-1494.

[3]For methods of measuring a meter's internal resistance, see Dean Poeth II, K8TM, "How to Measure Large Direct Currents with Common Meters," *QST*, Jan 1996, pp 40-43; W. J. Stanley, KT4HF, "Measuring a Meter's Internal Resistance," Technical Correspondence, Apr 1996, p 79 (also, see Feedback, *QST*, May 1996, p 75); Alan Bloom, N1AL, "Copper-Wire Shunt Precaution," Technical Correspondence, *QST*, Jun 1996, p 72; James G. Lee, W6VAT, "Measure Meter Resistance Accurately," Technical Correspondence, *QST*, Aug 1996, p 71; Mike Bauer, W7GW, "More On Copper Wire Shunts," *QST*, Sep 1996, p 79.—Ed.

Audible Meter-Reading Techniques

A number of circuits have been developed to make it possible for blind hams to read analog meters via audio. These meter-reading circuits have been used for relative and actual readings, using either variable amplitude or variable pitch. Here is a short discussion of some techniques.

The ear is poor at noting absolutes such as weak, moderate or loud volume—or low, medium, or high pitch, except, of course, for those who are gifted with perfect pitch. However, the ear is very good at *comparing differences*, and can accurately determine whether a sound is getting weaker or stronger, or if its pitch is increasing or decreasing. The ear is also superb at determining when tones are at the same pitch. When signals at two different frequencies are processed by a nonlinear detector (for example, the product detector of a CW receiver), they mix, producing sum and difference frequencies. Similarly, the human ear has a nonlinear logarithmic response. When it hears tones of different frequencies, the sum and difference products are heard as additional tones or beat notes. When the difference between the original tones is small, the audible beat note produced is a low frequency and is easily discernible. If one tone is adjustable, you can match frequencies by making the beat note increasingly low in frequency and noting that it disappears entirely when the two tones are equal—the zero-beat phenomenon.

Amplitude-Nulling Circuits

Amplitude-nulling meter-reader circuits use the ear’s ability to detect when a tone is at minimum amplitude. These circuits sample the dc voltage across the terminals of the analog meter (most analog current meters have a voltage drop of 150 to 200 mV across them at full-scale deflection. Voltmeters use series multiplier resistors to convert voltage to current.) This meter-voltage drop is summed with a variable dc voltage of opposite polarity through a high resistance. This variable dc voltage is derived from a potentiometer equipped with a pointer and a calibrated Braille dial. The high end of the Braille dial corresponds to the full-scale reading of the meter being read. The sum of the “bucked” voltages is fed through a chopper transistor driven at an audio rate. The output of the chopper is an audio square wave whose amplitude is proportional to the amplitude of the summed dc voltages. This square wave is fed to an amplifier to drive headphones or a loudspeaker. When the sound level is at minimum, the reading is then taken from the Braille dial. (In the earliest version of this circuit I remember seeing, the chopper circuit was made using a synchronous vibrator of the same type used in car-radio power supplies of the 1940s and 1950s. It was rough on batteries, but worked well.) If only relative readings are needed, the voltage across the analog meter can be fed directly to the chopper circuit, and the meter reading dipped or peaked using minimum or maximum amplitude.

Pitch-Indication Circuits

Another class of circuits relies on the ear’s ability to detect changes in the pitch or frequency of sound. As noted earlier, this technique can be used for relative readings or actual readings. For actual readings, the circuit is very similar to the tone-nulling circuit described earlier. The analog-meter voltage drop is summed with an opposite-polarity voltage from a potentiometer-controlled variable voltage. In this circuit, instead of feeding the summed voltage through a chopper, it is used to drive the input of a voltage-controlled oscillator (VCO) such as the one described in this article. When the two voltages are equal, the pitch of the VCO is at a minimum.

In the accompanying article, an approach to a relative meter-reading circuit is described. This circuit uses two VCOs. One VCO is driven by the voltage drop across the meter, while the second VCO is connected to a variable voltage source from a calibrated potentiometer. As with the amplitude nulling circuit, the high end of the dial corresponds to a full scale meter deflection. Both VCOs are connected to a common loudspeaker or headphones. The tones are monitored while the calibrated control is adjusted. When the tones are at an equal pitch (zero beat), the meter reading can be taken from the calibrated dial. Alternatively, the operator can set the pitch with the calibrated dial, then adjust the equipment he is trying to read until the pitches are equal.

The pitch-indication approach has the advantage of permitting continuous analog reading. By comparing pitches, one can tell whether the meter is reading above or below the intended point.—*WA3CAO*