

A Talking Wattmeter

Listen! Your wattmeter's *talking* to you—if you've got the Orator hooked up to it, that is!

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The seed for this project was planted a few years ago when, as part of a college course, I designed a talking voltmeter. Stan Briggs, K8SB, convinced me to design a circuit to attach to an analog wattmeter that would allow the wattmeter to talk to his blind friend, Lowell, W8QIY. With Stan's technical and financial support, my first version of the talking wattmeter was born. Now, two years later, aided by the use of a single-chip microcomputer and a compact analog-to-digital (A/D) converter, the talking wattmeter add-on is an economical project I'm sure many hams—not just the visually handicapped—can put to good use.

General Description

One version of the unit is shown in the title photograph. Although this project was initially designed for visually impaired people (most of whom would have no need of labels for a device with so few controls), this project is certain to appeal to sighted radio amateurs as well; hence, labels. To aid the visually impaired, all the controls have been grouped at one end of the enclosure. From left to right, the three front-panel controls are: VOICE/TONE, ON/OFF/VOLUME and TALK. The ON/OFF switch is part of the VOLUME control. An inside view of the Orator is shown in Fig 1.

Fig 2 is a block diagram of the Orator, which is designed to be used in conjunction with an analog wattmeter. A voltage sample, derived from the wattmeter, drives the Orator. One of two modes of operation, VOICE or TONE, is selected by the toggle switch at the left of the control group.

In the VOICE mode, synthesized speech announces the power output in watts

measured by the wattmeter. The Orator range steps from 0 to 190 watts. As you can see from Table 1, there are 32 different output steps available. When the TALK button

Table 1
Talking Wattmeter Power Level Steps

Dc voltage at U5 pin 6	Step	Word Output
0.00	0	Zero
0.08	1	Zero
0.16	2	One
0.24	3	Two
0.32	4	Three
0.40	5	Five
0.48	6	Eight
0.56	7	Ten
0.64	8	Fifteen
0.72	9	Seventeen
0.80	10	Twenty
0.88	11	Twenty-five
0.96	12	Thirty
1.04	13	Thirty-five
1.12	14	Forty
1.20	15	Fifty
1.28	16	Fifty-five
1.36	17	Sixty
1.44	18	Seventy
1.52	19	Eighty
1.60	20	Eighty-five
1.68	21	Ninety-five
1.76	22	One hundred five
1.84	23	One hundred ten
1.92	24	One hundred twenty
2.00	25	One hundred thirty-five
2.08	26	One hundred forty-five
2.16	27	One hundred fifty-five
2.24	28	One hundred seventy
2.32	29	One hundred eighty
2.40	30	One hundred ninety
2.48	31	Out of range

is pushed, the Orator will voice the power level in digits followed by the word *watts*. If the power level is above 190 W, the Orator says *out of range*. This process is shown in the flow chart of Fig 3.

The word table for this project is designed for use with a 0-200 W meter scale. You can use the Orator with a meter having a 0-2000 W scale by mentally multiplying the voiced output by 10. If your wattmeter has a forward and reflected power-selection switch, you will know the SWR is low when the forward power is high and the reflected power is low.

In the TONE mode, the output of a function-generator IC is selected. The output of this IC is a clean audio-frequency sine wave, the pitch varying according to the amplitude of the voltage supplied by the wattmeter. As the voltage increases, the tone frequency increases. This feature is quite handy when tuning your transmitter or antenna tuner for best performance.

Circuit Description

Refer to Fig 4 during the following discussion.

Input Amplifier

The voltage produced by the wattmeter is fed to input amplifier U5, which is configured as a noninverting amplifier. U5 has a very high input impedance; this prevents loading the wattmeter circuit. The input amplifier allows the Orator to be used with almost any wattmeter. R15 controls the gain of U5, and is adjusted to present a voltage that the microcomputer associates with preset power levels. (Increasing the value of R15 increases the amplifier gain.) The output of U5 is fed to the A/D converter (U1) and also to the tone-generator

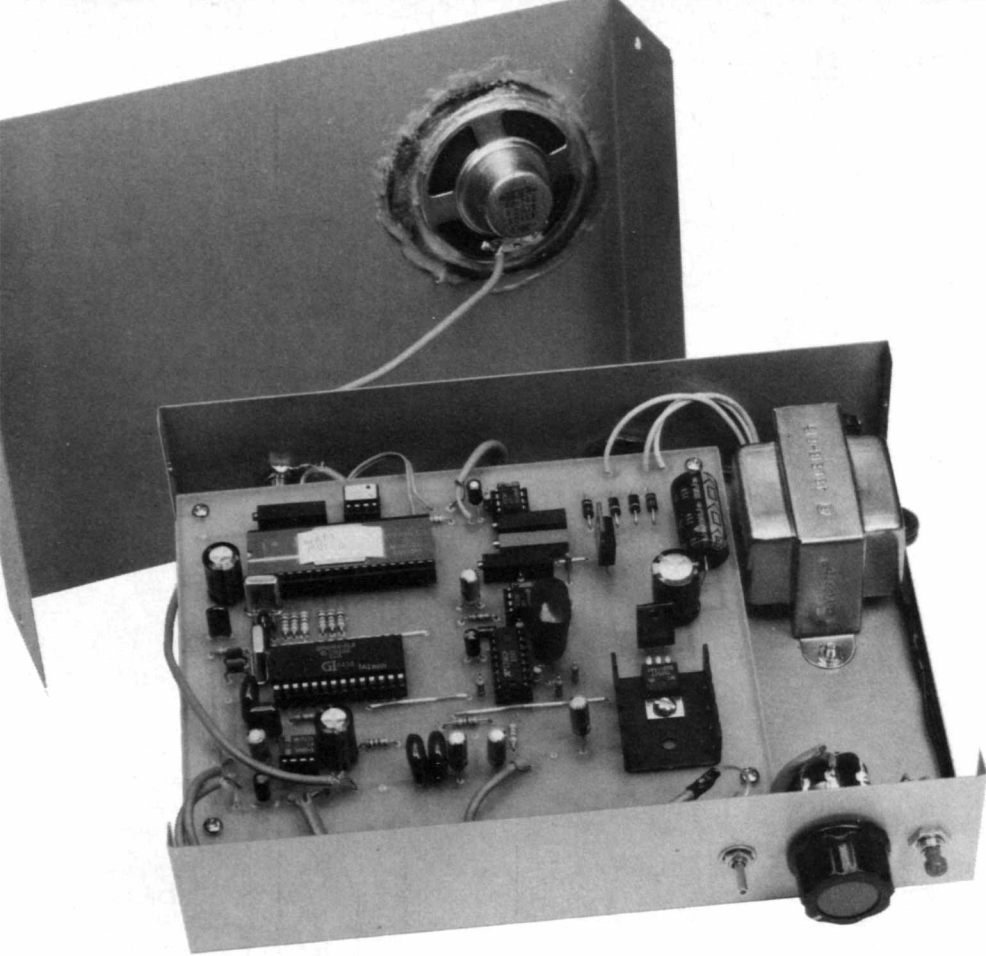


Fig 1—An inside view of the Orator. A Radio Shack enclosure (RS 270-272) houses the components. To avoid having machine-screw heads on the cabinet top, the speaker is held in place by a bead of silicone sealant. (If you follow this procedure, make sure the sealant you use does not contain acetic acid.) At the left foreground, you can see the speech processor chip. Immediately behind it is the 68701 microcomputer. The U8 and its heat sink are visible in the right foreground. Note that T1 fits snugly within the enclosure. If you use a power transformer other than the one specified in the parts list of Fig 5, make sure everything will fit within your chosen enclosure. This unit has no panel labels because it was built for use by a blind ham.

circuit (U6, U7). R16 allows setting the output of U5 to 0 V when the input to it is 0 V.

Analog-to-Digital Converter

U1, the analog-to-digital (A/D) converter, is manufactured by Texas Instruments and is available from Radio Shack®. This inexpensive, 8-pin IC requires few external components to perform its task. The amplified analog wattmeter voltage is converted by U1 to an 8-bit digital value which is transferred *serially* to the microcomputer.

Microcomputer

U2 is a Motorola MC68701 microcomputer. It contains 128 bytes of RAM, 2 kbytes of EPROM and 29 input/output (I/O) ports. The talking wattmeter program resides within the IC's internal EPROM. U2 is connected to the A/D chip and speech processor via its I/O ports.

Speech Processor

The speech processor, U3, is manufactured by General Instruments and is avail-

able from Radio Shack and other sources. This IC was chosen because of its availability and low cost. The speech processor has a table of sounds called *allophones*, which are selected by the microcomputer program. By joining the proper allophones, sounds resembling human speech can be created.

Tone Generator

An XR2206 function generator (U7) is used as a tone generator. This IC is capable of producing a sine-wave output signal. U6, a 741 op amp configured as an inverter, causes the audio-frequency output of U7 to increase in frequency with an increase of meter voltage (output power). Pin 8 of U7 is internally biased at +3 V, and the IC's frequency output varies linearly with the current drawn from this pin. Therefore, when the meter voltage increases, the output of U6 decreases, causing more current to be drawn from pin 8; this increases the output frequency of the tone.

D1 ensures that the voltage at the junction of R22 and R23 does not go more

negative than -0.6 . Such a situation would cause a current drain from pin 8 of U7 that would exceed its 3 mA limit. R19 is used to adjust the tone frequency to a low growl when the wattmeter reads 0 W; this occurs when the voltage at pin 6 of U6 is approximately +2.7.

Audio Amplifier

U4, an LM386, acts as the audio amplifier. This amplifier is used for both the VOICE and TONE modes. Audio is routed to U4 through S1, the VOICE/TONE selection switch. R28, the VOLUME control, is used to adjust the audio-output level.

Power Supply

See Fig 5. Three voltage levels are needed for the Orator circuit: +12, -12 and +5. U8, the 5-V regulator, requires a heat sink because of its heavy load. U9 and U10, the positive and negative 12-V regulators, respectively, supply little current and do not require heat sinks.

Construction

For those who want to make their own PC board, a PC-board template and parts overlay are shown in Figs 6 and 7. PC boards, parts kits and preprogrammed 68701s are available.¹

Four jumpers are required on this single-sided board. I recommend using sockets for all ICs. There is sufficient room on the board to accommodate the heat sink for the +5 V regulator in a horizontal position (see Fig 1).

In the prototype shown, S3, the ON/OFF switch, mounts at the rear of R28. (You can, however, use a separate toggle switch if you desire.) Use shielded wire between the PC board and R28, S1 and the speaker, LS1. Also use shielded wire between the analog wattmeter and the Orator's input jack, J1.

The Orator should be enclosed in a metal cabinet to help shield the circuit from RFI. If a low-profile cabinet is used to house the Orator, you can place your wattmeter on top of it.

Checkout and Adjustments

Once you've completed stuffing the board, but *before installing the ICs*, it's a good idea to check the power supply voltages. Check for -12 V at U5 pin 4, +12 V at U5 pin 7 and +5 V at U2 pin 7. If these voltages are present, turn off the power supply and install the ICs; *be careful to orient them correctly!*

¹Contact Hal-Tronix Inc, 12671 Dix Toledo Hwy, Southgate, MI 48195, tel 313-281-7773. Orator kit, voice version (less case), \$79.95; CW version (less case), \$69.95. (Both kits include the PC board and programmed 68701 microprocessor.) Programmed 68701 only, \$14.95; PC board only, \$12.95. Please include \$5 for postage and handling on all orders. The ARRL and QST in no way warrant this offer.

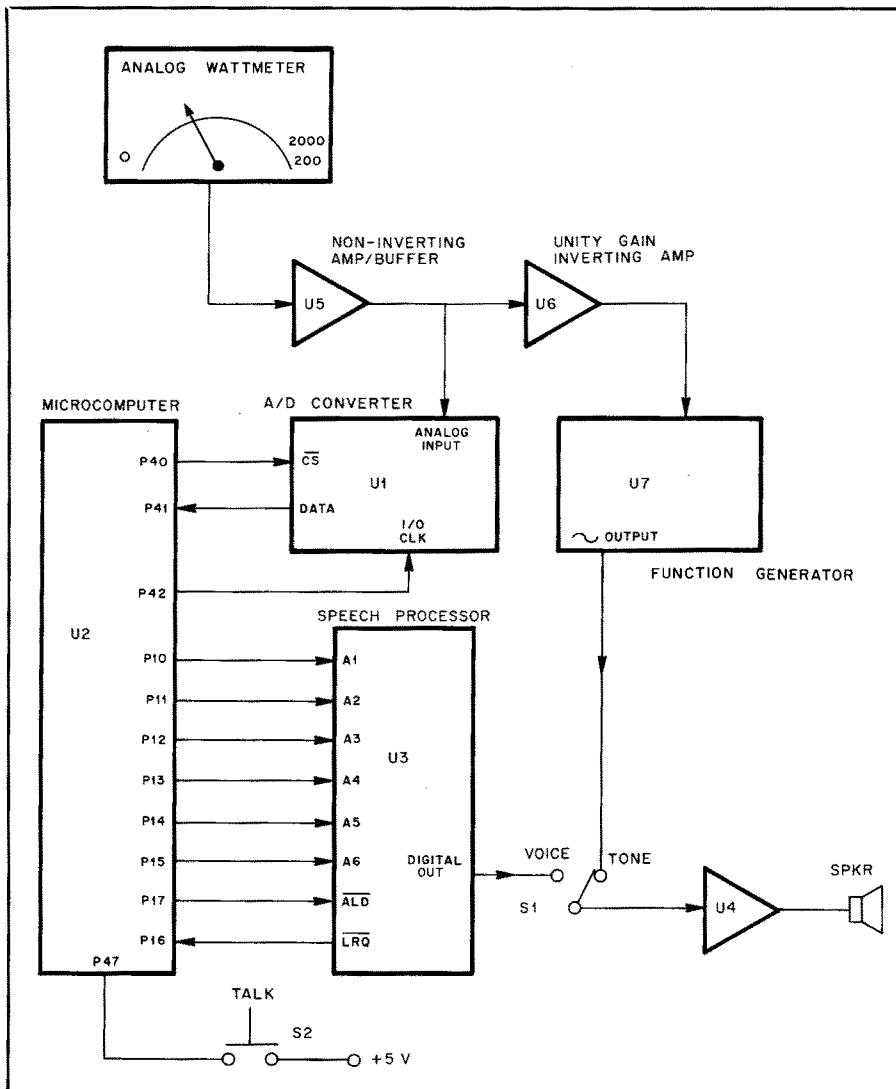


Fig 2—Block diagram of the talking wattmeter. Refer to text.

Use an accurate voltmeter when making the following adjustments; almost any accurate digital voltmeter should provide the required resolution.

- Turn on the Orator and set R28 to mid scale
- Adjust R13 to obtain +2.56 V at U1, pin 1.
- Ground pin 3 of U5, and adjust R16 until the voltage at U5, pin 6, reads 0.00.
- With pin 3 of U5 still grounded, move S1 to the TONE position and adjust R19 until the audio frequency output from the speaker is a low growl. The voltage at U6, pin 6, should be about +2.7 V when this adjustment is correctly made.
- Now, move S1 to the VOICE position and with pin 3 of U5 still grounded, push S2 (TALK); the Orator should say *zero watts*.

Connecting the Orator to Your Wattmeter

Find a point in your wattmeter that provides a level of less than +2.5 V when reading full scale. This point should deliver

a voltage level proportional to the meter scale in both forward and reverse directions. In most cases, if it's absolutely necessary, you can connect the Orator directly across the meter terminals, but the voltage at that point will likely require a lot of amplification.

Connect the center conductor of the interconnecting cable to the voltage source, and connect the cable shield to the wattmeter common point (usually ground). The other end of the cable connects to the Orator at J1. Turn on your transmitter. With a dummy load connected to the transmitter, set the transmitter output power at 55 W, as read on your wattmeter. Then, adjust R15 until the Orator says *55 watts*. (At this time, the voltage at U5 pin 6 should be +1.28.) When making this adjustment, you can use other output power levels in lieu of 55 W so long as you pick the corresponding voltage level and speech processor words from those given in Table 1. To ensure the Orator is not affecting the wattmeter circuit, disconnect the interconnecting cable and check to see that the

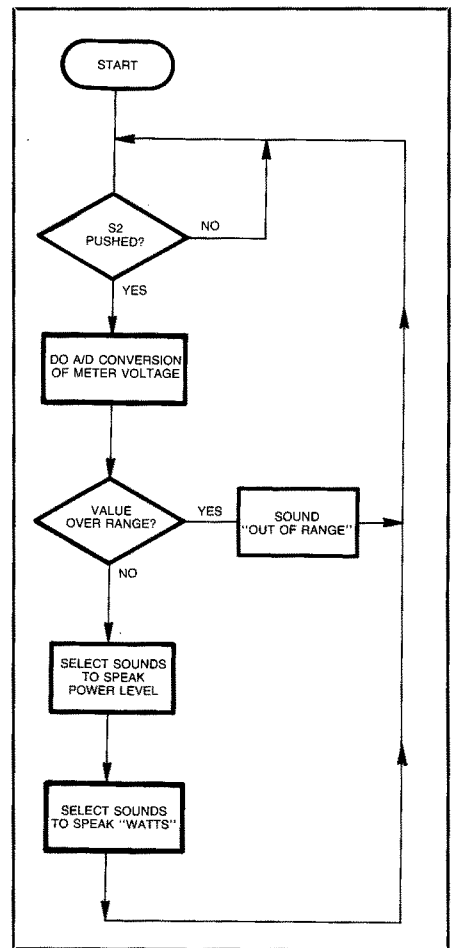


Fig 3—Flow chart of the microcomputer program used to drive the speech processor.

wattmeter reading remains the same.

From here on, the Orator should track the wattmeter. Also, the tone-generator output should generate a higher-frequency tone as the output power increases.

CW Option

I've written a program that will sound the power-output level in Morse code. The CW version has 98 steps, from 0 to 212 watts. With this option, you don't need U3, Y2, C4-C8 (inclusive), R7 and R8. C8 is replaced with a 220-Ω resistor, and a jumper is installed between R9 and U2, pin 13. The same calibration procedure given earlier is followed, but now, the voice output is replaced by Morse code at a tone frequency of 775 Hz. The CW speed is fixed at the time the microcomputer is programmed, so you must specify the code speed you prefer when you order the programmed IC.

Summary

The speech processor does not have a high-quality voice. For this application, however, it is adequate. Slightly better voice quality can be obtained by using a 3.12-MHz crystal (instead of the

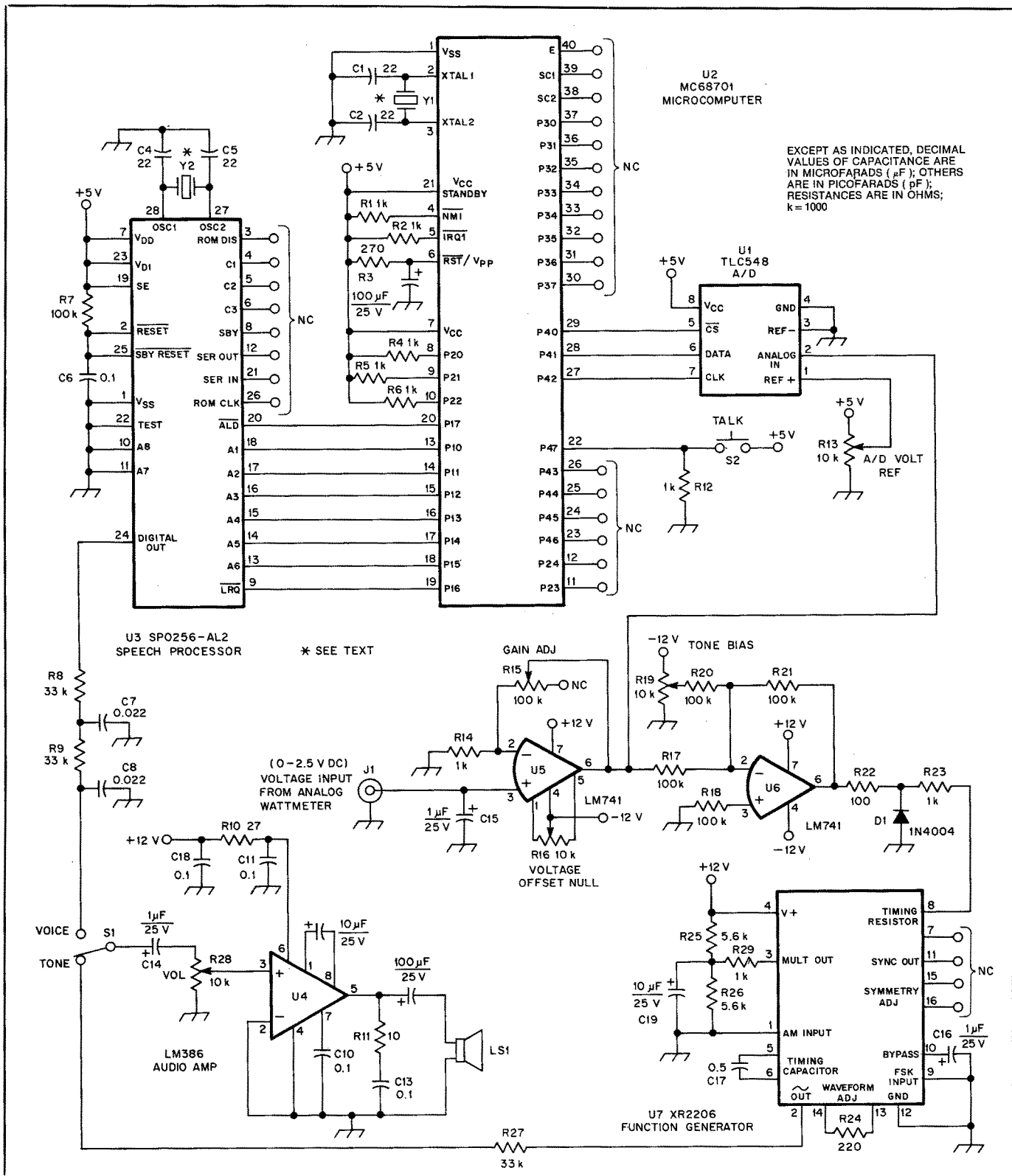


Fig 4—Schematic diagram of the Orator. PC boards, programmed EPROMs and kits are available from Hal-Tronix (see note 1). Many parts for this project can be obtained from your local Radio Shack store or Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-8097. (RS numbers in parentheses are Radio Shack stock numbers.)

J1—Phono connector (RS 274-346).

LS1—8-Ω speaker (RS 40-245).

R13, R16, R19—10-kΩ trimmer

(RS 271-1343).

R15—100-kΩ trimmer (Jameco).

R28—10-kΩ panel-mount (RS 271-1721).

Note: S3 of Fig 5 mounts on the rear of this control.

S1—SPDT toggle (RS 275-625).

S2—SPST push button (RS 275-1547).

U1—TLC548 serial A/D converter

(RS 276-1796).

U2—MC68701 microprocessor (Jameco).

(Programmed 68701s can be obtained from Hal-Tronix; see note 1.)

U3—SP0256AL2 speech processor

(RS 276-1784).

U4—LM386 audio amplifier (RS 276-1731).

U5, U6—LM741 op amp (RS 276-007).

U7—XR2206 function generator (Jameco).

Y1, Y2—3.58-MHz color-burst crystal (see text).

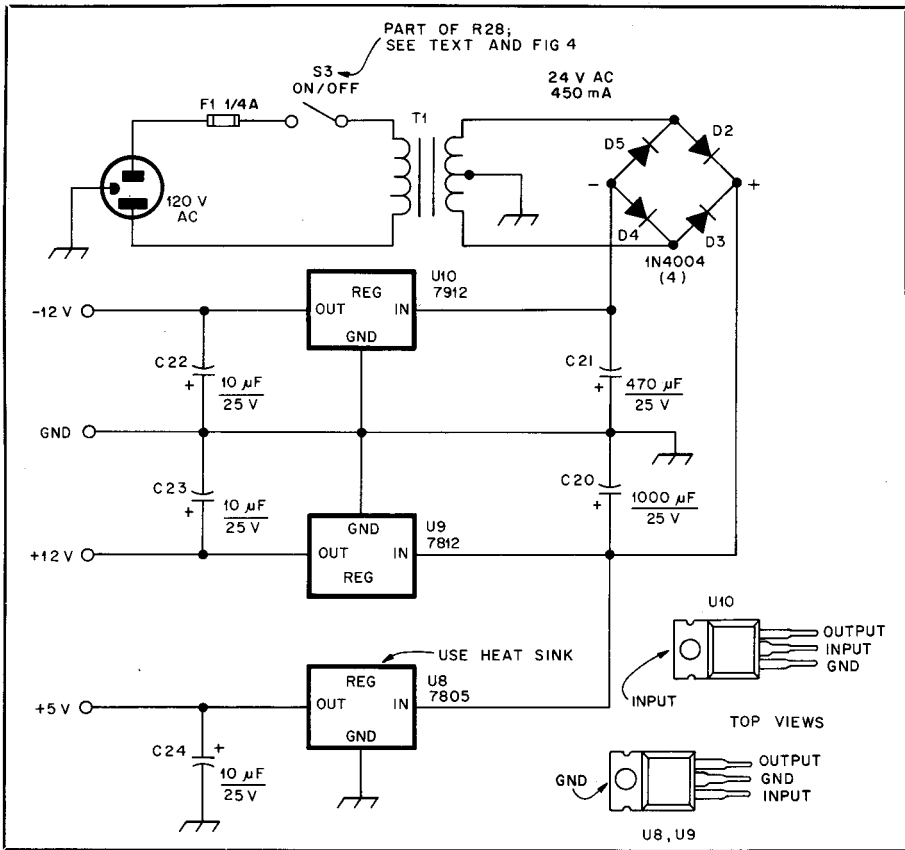
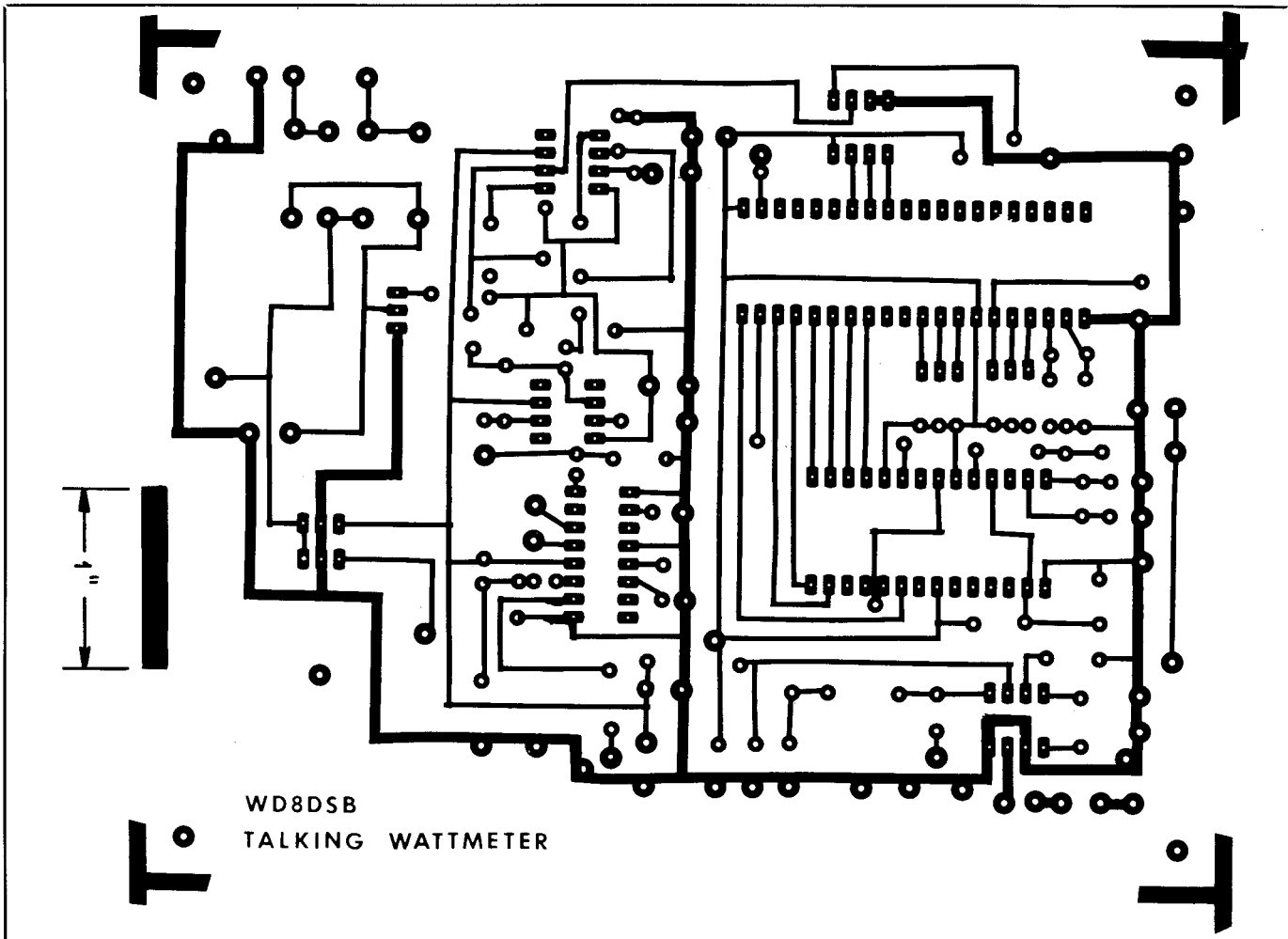


Fig 5—Schematic diagram of the power supply. (RS numbers in parentheses are Radio Shack stock numbers)
 D2-D5, incl—1N4004.
 F1— $\frac{1}{4}$ -A fuse (RS 270-1270).
 S3—SPST (RS 271-1740) mounted on rear of R28; see text and Fig 4.
 T1—120-V pri; 24-V CT, 450 mA sec (RS 273-1366).
 U8—7805 positive 5-V, 1-A regulator (RS 276-1770; equip this IC with a heat sink such as an RS 276-1363).
 U9—7812 positive 12-V, 1-A regulator (RS 276-1771).
 U10—7912 negative 12-V, 1.5-A regulator (Jameco).

Fig 6—Circuit-board etching pattern for the Orator. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.



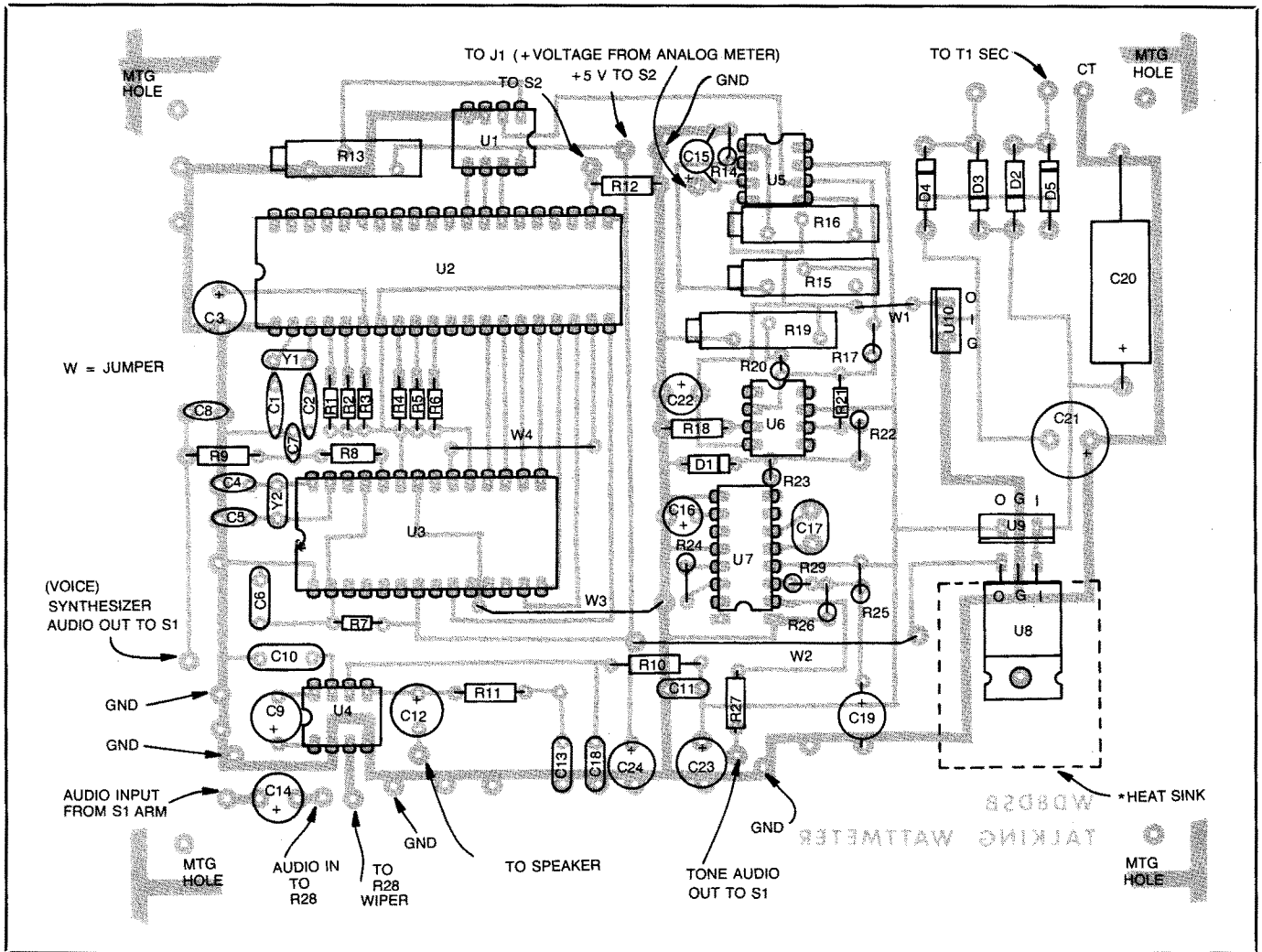


Fig 7—Parts-placement guide for the Orator. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern.

3.579-MHz crystal) at Y2 as recommended by the IC manufacturer. Whether or not the increase in speech quality is worth the additional cost (color-burst crystals are inexpensive—some free for the taking!) is something you'll have to decide.

Stan, K8SB, and I designed the circuit consisting of U4, U5, U6 and U7 as a stand-alone tuning aid that can be powered by two 9-V batteries. You can assemble that circuit by itself and place it across the meter movement of virtually any meter to provide an audio tuning aid.

The talking wattmeter circuit is nothing more than a voltage-measuring device connected to a speech processor through a microcomputer IC, and coupled to an audio-tone generator. Therefore, this circuit can be used in many other applications by changing the program that resides in the microcomputer's EPROM. Some ideas that come to mind include a talking voltmeter, talking rotator-position indicator and talking thermometer—the applications are practically endless. If you have a specific interest in using the Orator for another application, I welcome your ideas and will

consider writing the program for that application. Please include an SASE for replies.

Acknowledgments

I'd like to thank Stan Briggs, K8SB, for sharing a wealth of knowledge, reviewing this manuscript with his wife Ruth, WB8AFO, and for being such a great friend. Thanks also to Phillip Irish, who allowed me to use his design of an MC68701 EPROM burner for this project. Finally, thanks to Lowell Miller, W8QIY, for putting the original circuit through many hours of on-the-air testing.

APPENDIX

All the analog wattmeters I've tested have a meter voltage that is related to the power level by the following function:

$$P = V^2/K$$

where

- P = power
- V = meter voltage
- K = a constant

For the microcomputer reference table, I used

an arbitrary constant (K) equal to 0.03, then calculated the power level for steps of 0.08 V. When connected to a meter with a different K value, the voltage level at a particular power level is different. (After using the Orator with several different wattmeters, the chosen constant has proved to be satisfactory.)

The voltage level that the microcomputer associates with a particular power level, divided by the actual meter voltage for that same power level, is equal to the amount the actual meter voltage must be multiplied by to match the microcomputer reference voltages. This is done electronically by using R15 to adjust the amount of input amplifier gain.

Don Kirk was first licensed in 1976 at the age of 16. He currently holds an Amateur Extra Class license and a General Radiotelephone license. Don received an Associate of Applied Science degree from Henry Ford Community College (Dearborn, Michigan) in 1983. He followed this up by earning a Bachelor of Engineering Technology degree from Wayne State University in 1985.

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