By Sam Ulbing, N4UAU

Surface Mount Technology —You *Can* Work with It!

Part 4—This month, we wrap up the series. Before we do, though, here's that project I mentioned last month...

The first three parts of this article[22] have described rather easy-to-build projects. This one is a bit more complex. If you like to experiment, you have the opportunity to tailor this project to your specific needs and optimize its operation. Build it for a loved one and impress them with your skills! If you spend as much time working on electronic projects as I do, that loved one might appreciate a little project like this made just for them!

Project 4—The Hourglass 10-Minute Timer

This month's project is a modernized version of "A Simple 10-Minute ID Timer," that appears in *The ARRL Handbook*.[23] You can use the Hourglass as an egg timer, or to remind you to move the sprinkler, or put the laundry in the dryer, or as a two-hour timer to remind your teenager it's time to get off the telephone! You start the timer by *turning it upside down*, just like a sand hourglass! As you'll see, the operations of the old and new circuits are similar, but not exactly the same.

[22]Notes appear on page 41.

The Old-Technology Circuit

The *Handbook* circuit (Figure 15) is specified for use with a 12 V supply, which could limit its portability and application. LM555 timer U1 is set up for a short duty cycle: 1 second *on* and 59 seconds *off*. Pin 3 of the 4017 counter, U2, triggers after 10 cycles, increasing the time delay to 600 seconds. The alarm sounds, the circuit resets and starts counting again. Ten minutes is about the maximum practical time delay of this circuit.

The New-Technology Circuit

Surface-mount technology allows us to build this month's project (including its power supply) on a board that fits inside a 35-mm film canister (see Figure 16), so it's completely portable.[24] The low voltage and current demands of the ICs allow powering the circuit with a 3-V lithium battery.

Refer to Figure 17. An RC controlled timer, U1, is routed to a counter, U2, to extend the time base to 10 minutes. When

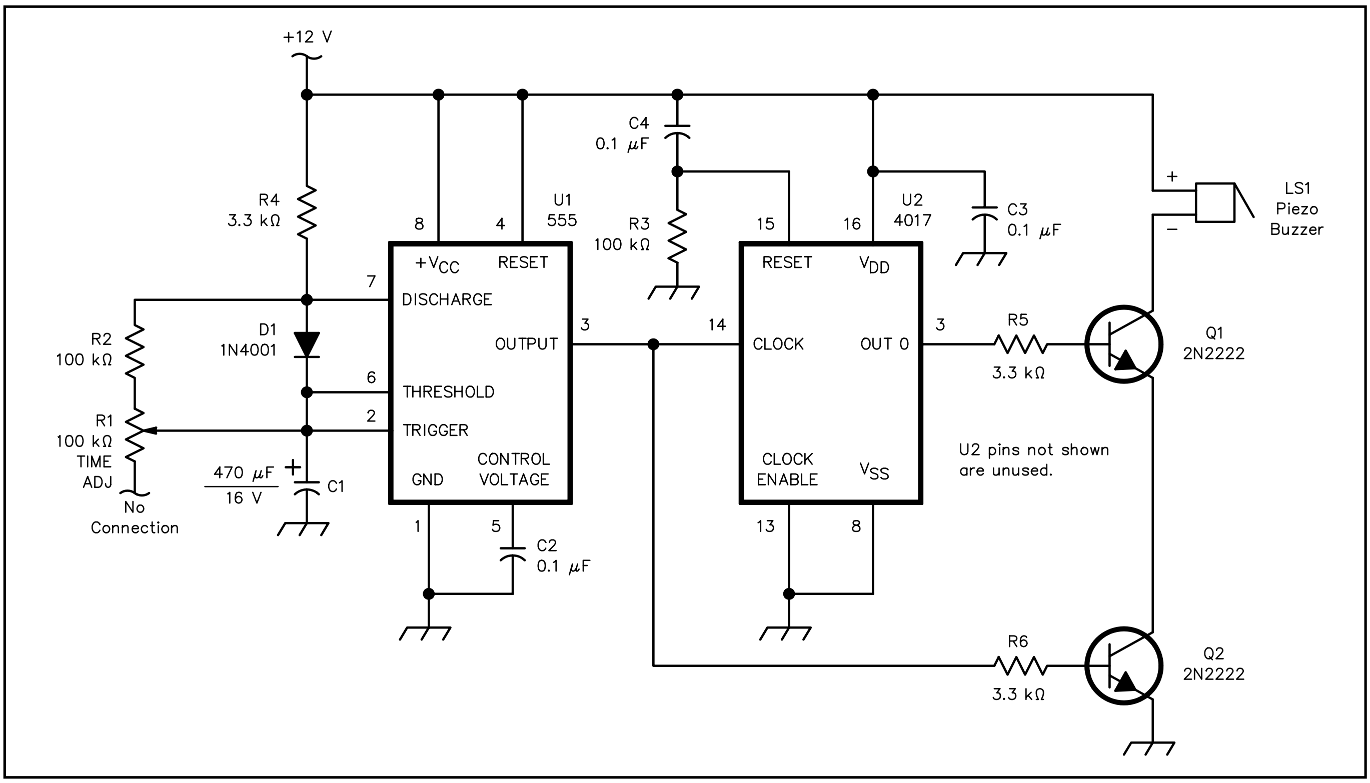

Figure 15—Schematic of the older 10-minute timer. Unless otherwise specified, resistors are ¼ W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

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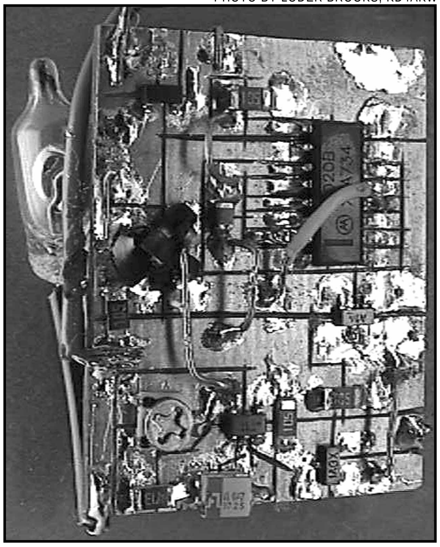


Figure 16—A top view of the SM version of the timer described in the text. The 3-V battery that powers the circuit is mounted on the bottom side of the board.

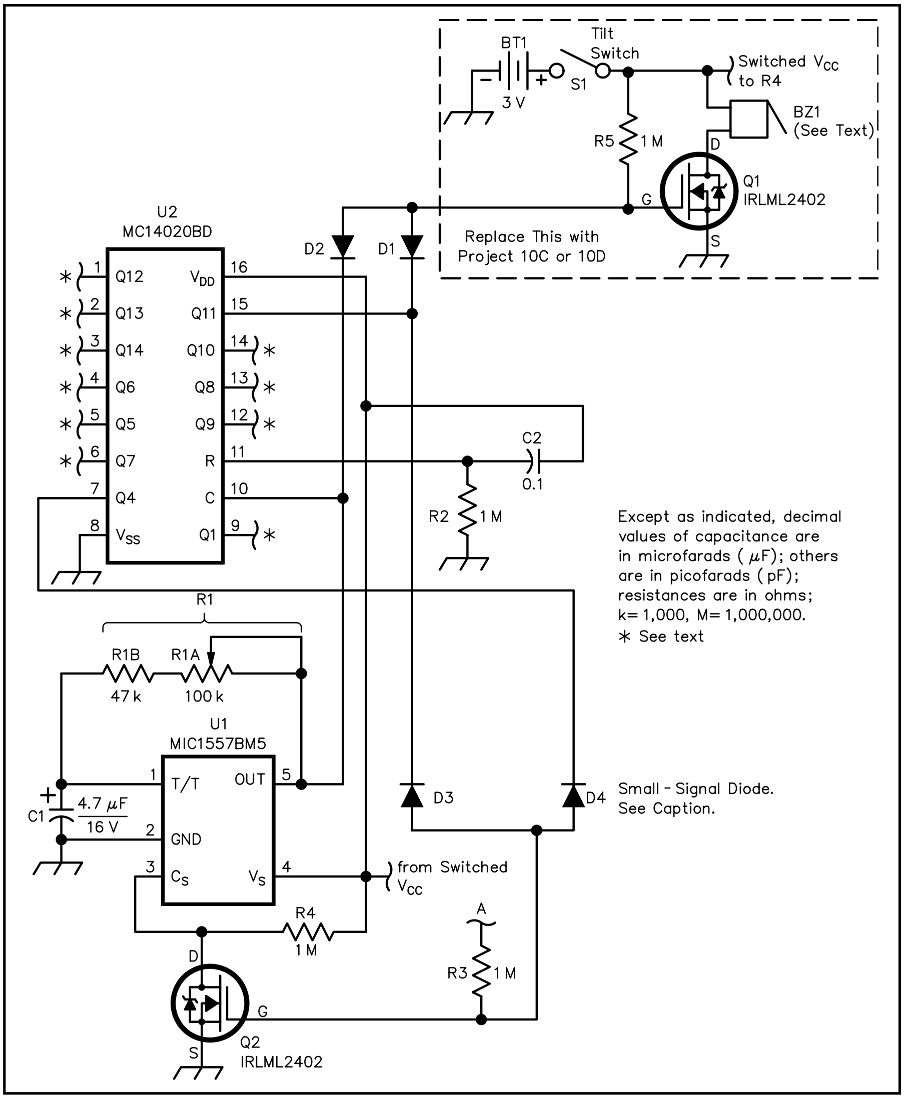


Figure 17—Schematic of the SM "hourglass" 10-minute timer. A 3-V lithium battery powers the circuit. The section of the circuit enclosed in dashed lines can be replaced by either of the circuits shown in Figures 18A and 18B. Unless otherwise specified, resistors are 5% tolerance SM units. The resistors I used are SM devices in 1206 cases. Equivalent parts can be substituted. See the sidebar "Manufacturers and Distributors of SMT Equipment and Parts," in Part 1, *QST*, May 1999, for a list of suppliers.

BT1—3-V, lithium CR2032, etc.
BZ1—Piezo buzzer (see text)
C1—4.7 µF, 16 V tantalum.
C2—0.1 µF ceramic (I used a SM device in a 0805 case).
D1/D2, D3/D4—BAW56LT1 (common-anode diode pairs in an SOT23 case); pairs of 1N914 or 1N4148 diodes can be substituted.
Q1, Q2—IRLM2402 MOSFET
R1A—100-kΩ pot (Bourns 3364W)
SW1—Encapsulated tilt switch (available from author)
U1—MIC1557BM5, Micrel IttyBitty RC timer/oscillator
U2—MC14020BD, 14-bit binary counter
Misc: Battery holder, Keystone #3002.

the 10 minute limit is reached, the appropriate pin on U2 goes high, turning on a switch, Q1, which sets off an alarm.

U1 of Figure 17 is an MIC1557. Dubbed the "IttyBitty RC Timer" by the manufacturer,[25] it's an SOT-23 version of the 555. R1 and C1 set the cycle time. (R1 is composed of a pot, R1A, and a fixed-value resistor, R1B.) I use a 50%-duty-cycle timer because it requires fewer parts than an asymmetrical-duty-cycle timer. I selected a cycle time of about one second because the data sheets for the LM555 and the MIC1557 indicate that capacitor leakage affects the accuracy of periods longer than 10 seconds. With just a one-second cycle time, it's necessary to use a longer delay in U2, so I added an MC14020, a 14-bit binary counter that can count up to 16,384. By using a count of 1024—and adjusting the values of R1 and C1—I achieved an accurate 10-minute delay.

This flexible circuit can be modified for longer or shorter delays, from as little as a few seconds to as long as 24 hours! (See **Experimenting with the Timer** later.) I had a difficult time finding counters in SM packages, and as you can see in the photo, the chip is "huge." (Perhaps this indicates there's a better way to handle delay circuits with SMT.)

The output at pin 15 of U2 triggers Q1 through D1. Q1 is not just any MOSFET—the IRLML2402 is a state-of-the-art device. Its gate turn-on voltage is only 1.5 V, and at 3 V, the MOSFET is fully on. (Not too many years ago, MOSFETs required 10 or 12 V to turn on. Most logic-level MOSFETs today still require 5 V, which makes them useless in a 3-V supply project.) Although the IRLML2402 is packaged in a Micro 3 package (which is smaller than an SOT-23 package), its *on* resistance is only 0.25 Ω and it can switch current levels up to 1 A.

You might ask, "Why not use a bipolar transistor instead of a MOSFET?" There are several reasons. Transistors require bias current, MOSFETs do not. A small transistor with a 30 mA load develops a 300 mV drop. The MOSFET has only a 4 mV drop, an important consideration when the supply voltage is only 3 V.[26] Also, a MOSFET can be used as a comparator. At levels less than 1 V (for this device), the MOSFET is *off*, and for levels above 1.5 V, it is *on*.

I wanted to use an **AND** condition to sound the buzzer, BZ1. D2 connects the gate of Q1 to the output of U1. This arrangement turns on the buzzer only when U2 pin 15 is positive *and* pin 5 of U1 is positive. Because the level at U1 pin 5 changes at about one cycle per second, the result is a pulsating buzzer that is more noticeable and uses less power than a continuously sounding buzzer. Another reason I could not use a transistor at Q1 is because the voltage drops of D1 and D2 result in a low voltage level of 0.6 V at Q1; that is too high to turn off a transistor.

With a battery-powered device, I didn't want the timer to cycle continually; that would deplete the battery if I forgot to shut

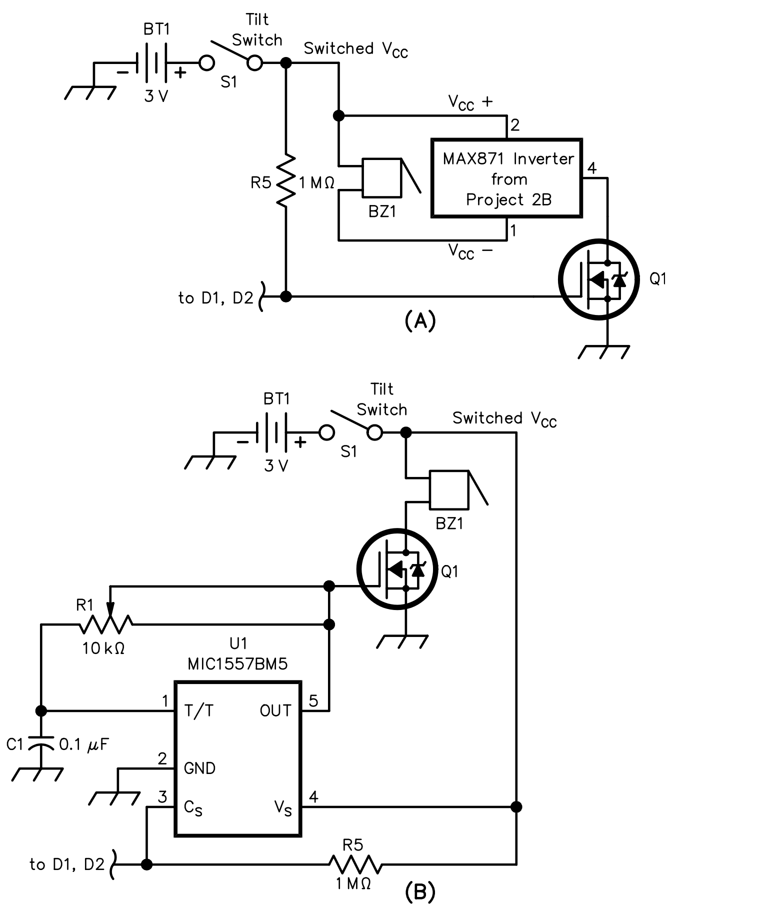
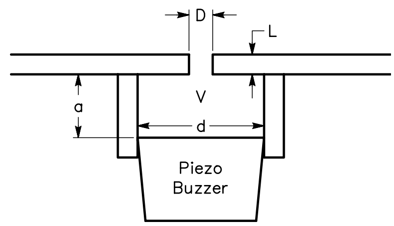


Figure 18—Two modifications you can make to the basic hourglass timer of Figure 17. At A, use of a piezo buzzer requiring a higher supply voltage (6 V) can take advantage of the MAX871 inverter circuit described in Project 2B. R5 is a 1 MΩ resistor in a 1206 SM case. An externally driven buzzer can employ the circuit shown at B using an MIC1557. Component identifications are those given in Figure 17. Note the value change of R1.

R1—10-kΩ pot (Bourns 3364W)



f_0 = Resonant frequency
C = Speed of sound (3.44×10^5 mm/s) = 344 m/s
D = Diameter of the sound emission hole
L = Depth of sound emission hole
d = Diameter of chamber
a = Depth of chamber
V = Volume of resonant chamber = πda

$$f_0 = \frac{CD}{4}\sqrt{\frac{1}{\pi V\left(L + 0.75D\right)}}$$

Figure 19—Here's the fundamental approach to constructing a resonator to improve the loudness and purity of the buzzer's tone. The resonant frequency (f_0) should equal twice the frequency of the buzzer to increase sound pressure. Do not make dimension D too small, or the acoustic resistance will increase. The equation is a starting point; experimentation will optimize your results (see text). Dimensions are in millimeters unless otherwise noted.

off the timer. This circuit shuts itself off. The buzzer sounds for about three seconds, and if it is not restarted, the circuit goes to sleep. It works like this: D3 and D4 form an **AND** gate controlling Q2. After pin 15 of U1 goes high and the buzzer sounds, the timer continues to count until U2 pin 7 also goes high. Then, Q2 turns on and pin 3 of U1 goes low. Pin 3 is U1's **CHIP SELECT** pin; when it goes low, U1 stops running and its current drain is reduced to 1 μA. With U1 sleeping, its output goes low. That shuts off the buzzer via D2. Total current drain while sleeping is about 5 μA. Under these conditions, a lithium 2032 battery should last several years.

To restart the timer (from sleep mode or when it is buzzing), just turn it upside down and then right side up. The tilt switch turns the power off, then on. C2 and R2 form a power-up reset that restarts U2 at 0 with a positive pulse to pin 11 through C2.

Experimenting with the Timer

Using the right audio transducer makes a major difference in audibility. Most transducers require more than 3 V to operate. I tried a RadioShack 273-074 transducer and it worked, but its output level was quite low. One way to raise the sound level is to raise the buzzer voltage. I did that with the circuit of Project 2B, as shown in Figure 18A. Some parts catalogs list piezo transducers that are externally driven and operate at 1.5 or 3 V. (The RadioShack buzzer mentioned earlier is internally driven: It has a square-wave generator built into it). I used a piezo transducer driven by an MIC1557, as shown in Figure 18B. It has a loud signal, but I found that setting the exact frequency needed for maximum sound was tricky. The best signal I could obtain came from a TMB-05[27] buzzer that I placed in a resonator and drove with the MAX871 circuit.

A Resonator

A neat way to improve the loudness and purity of the buzzer's tone (some piezo resonators have a harsh note) is to place the buzzer in a Helmholtz resonator.[28] This is a cylinder or tube designed to resonate at a certain frequency. Every resonator I used made the sound available from the transducer louder and clearer. The information in Figure 19 can help you design a resonator. If the math bothers you, try using a simple resonator made from a half-inch water pipe PVC end cap and drill a 3-mm diameter hole in the end; it worked well for me. I ground down the material surrounding the hole to make it thinner (smaller L) and adjusted the distance (A) for maximum sound. Best results are obtained when the tube's resonant frequency is about twice that of the piezo transducer's frequency.

Other Time Delays

In Figure 17, instead of connecting D1 to pin 15 of U2, you can attach it to another pin to obtain a different time delay. Table 2 shows the delays you can achieve when using a one-second cycle time at U1. By adjusting the values of R1 and C1, you can obtain nearly any time delay you want. For the arrangement to work correctly, the U2 pin you use to trigger Q1 must have a greater number of counts than the pin you use to shut down the circuit, which is why the data in Table 2 starts at 16 counts.

If you make your own PC board, you can customize it as needed. The premade PC board (see Note 24) is designed so you can add the circuits of Figure 18A or B on a separate board to drive the buzzer.

Construction Comments

I used a 0.005-inch wheel for the critical cuts at U1, Q1 and Q2 (see Figure 20). For the other cuts, I switched to a 0.009-inch wheel. The 0.005-inch cut is so narrow that

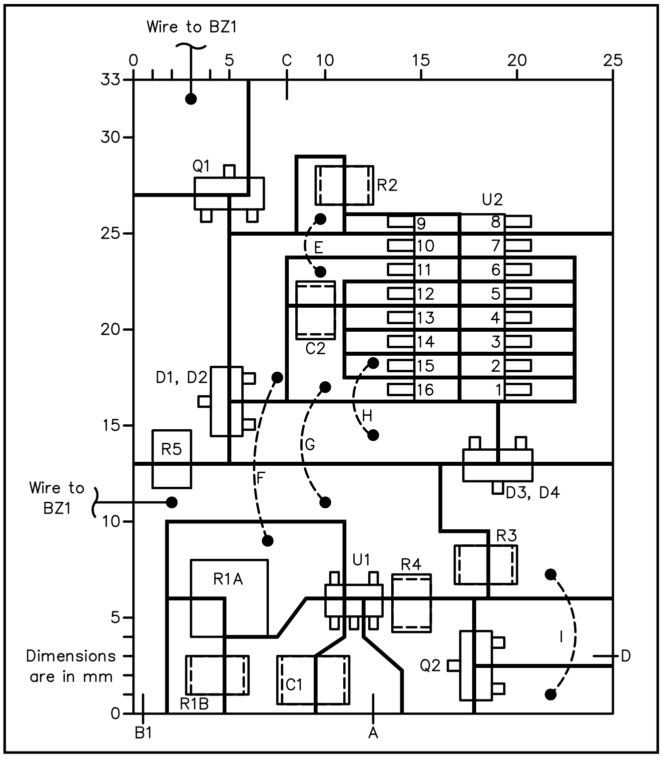


Figure 20—PC board layout of the 10-minute timer. Heavy lines designate cuts made in the foil to create component-mounting islands as described in Part 1 of this series.

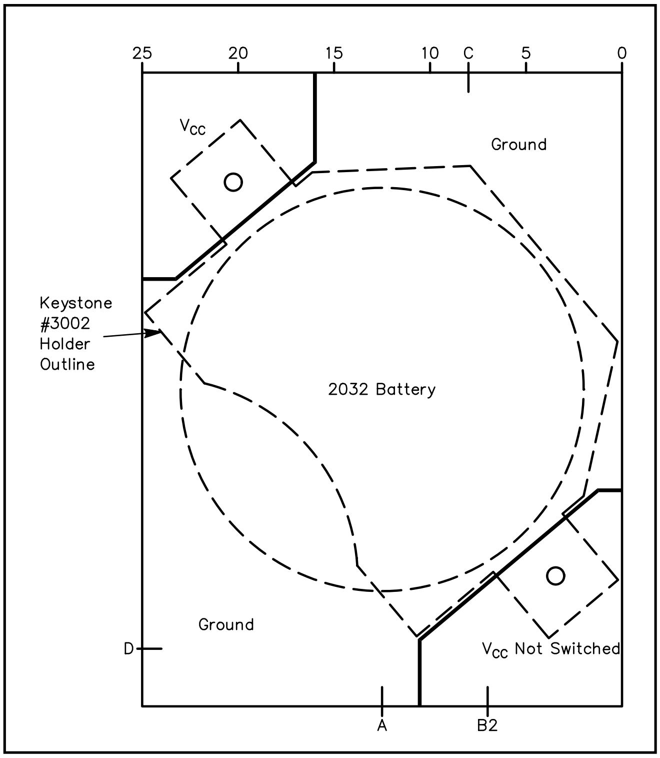


Figure 21—The 3-V battery occupies the bottom side of the 10-minute timer. Again, the heavy lines indicate where cuts are made in the PC-board foil.

solder tends to bridge the gaps. With a 0.009-inch cut, bridging is much less likely to occur. The circuit is on the board's top side; the battery and holder are on the bottom as shown in Figure 20. The tilt switch is connected between B1 of Figure 20 and B2 of Figure 21.

Summary

After completing these projects described over the past months, you should feel comfortable working with SMT devices. And, as I do, you'll probably be turning the pages of *QST* looking for a neat SMT radio project. A couple of the projects I would like to see include: a small, inexpensive VHF transceiver and a pocket-size HF receiver. In addition to the Maxim parts I mentioned earlier, Phillips Semiconductor sells a single-chip SMT AM receiver, MicroChip has an SMT microprocessor and Texas Instruments (TI) has a highly efficient SMT Class-D stereo amplifier. The parts are there. I hope we amateurs start to make use of them. [Let's see some of those projects! *QST* depends on readers and authors such as Sam and you for projects. Send your manuscripts to Steve Ford, WB8IMY, 225 Main St, Newington, CT 06111; **sford@arrl.org**.—*Ed.*]

Table 2

Timer Delay for a U1 Cycle Time of One Second

Pin	*Counts*	*Time*
5	16	16 s
4	32	32 s
6	64	1 m 4 s
13	128	2 m 8 s
12	265	4 m 16 s
14	512	8 m 32 s
15	1024	17 m 4 s
1	2048	34 m 8 s
2	4096	1 h 8 m 16 s
3	8192	2 h 16 m 32 s

Time shown in hours, minutes and seconds.

Notes

[22]Parts 1, 2, and 3 of this series appear in the April, May and June 1999 issues of *QST*, pages 33-39, 48-50 and 34-36, respectively.

[23]R. Dean Straw, N6BV, Ed., *The 1999 ARRL Handbook* (Newington: ARRL, 1998), p 22.58

[24]A limited number of parts kits are available from me for $11, which includes all the parts (including the hard-to-find tilt switch) except for the buzzer and PC board. If you want a premade PC board, add $2 (Florida residents must add sales tax). Piezo buzzers are widely available at places like RadioShack or many of the parts sources listed in the article.

If you are interested in learning to make your own boards as I described in Part 1, I have a limited number of parts kits available. These consist of a 3 × 6-inch double-sided copper-clad board, eight cutoff wheels (two 0.005 inch, four 0.009 inch and two 0.025 inch) and the special mandrel recommended for use with the ultra-fine cutoff wheels; price: $13. (Florida residents must add sales tax.)

[25]The MIC1557 has a brother, the MIC1555, optimized for monostable operation. It is described in the same data sheet.

[26]These are the results of measurements I made.

[27]The TMB-05 internally driven buzzer is made by Star Micronics, 70-D Ethel Rd West, Piscataway, NJ 08854; tel 800-782-7636 (X512), fax 732-572-5095; **sales@starus.com**; **http://www.starmicronics.com/product/audio/index.cfm**. See the Star Micronics Buzzers and Transducers catalog, page 5.

[28]A resonator based on this principle is described by Wally Millard, K4JVT, "A Resonant Speaker for CW," Hints and Kinks, *QST*, Dec 1987, p 43–*Ed.*

You can contact Sam Ulbing, N4UAU, at 5200 NW 43rd St, Suite 102-177, Gainesville, FL 32606; **n4uau@afn.org**.