
# BUILD A LADY'S LED TIME/DATE WRISTWATCH ...ONLY $75*

*Less band and batteries.

DIGITAL wristwatches are usually so large and cumbersome that they are unappealing to women. Now, the latest CMOS technology makes it possible to build a state-of-the-art electronic digital wristwatch that is truly sized for a lady's wrist.

The lady's digital wristwatch described here is not only about half the size of most men's watches, but it also gives more information than before in the smaller package. It uses four LED readouts to display the time in hours and minutes and also day of the month and seconds. Because of the relatively high current demands of the LED display, the readout is on an on-demand basis to conserve battery power.

*Single-IC watch provides hours/minutes/seconds/date on demand*

**BY BILL GREEN**

A lady's LED-type digital wristwatch is generally a high-cost item, selling for anywhere from $250 on up for a factory-assembled version. The complete kit of parts and case (minus band and batteries) for this watch is $75, plus handling and postage.

Although the emphasis in this article is on the lady's version of the wristwatch, the electronics package that makes up the timekeeping system can easily be set into the larger cases used for men's watches. Instructions for installation in both types of cases are provided in this article.

**About the Circuit.** The complete schematic diagram of the timekeeping system is based on the circuitry contained in a single large-scale CMOS integrated circuit (see *IC1* in Fig. 1). The IC contains all the counting, decoding, and multiplexing systems, plus an oscillator that works in conjunction with a crystal and several other outboard components.

Outputs from integrated circuit *IC1* are provided for driving hours, minutes, seconds, and date displays *DIS1* through *DIS4*. On-chip provisions are also provided for setting the time and date.

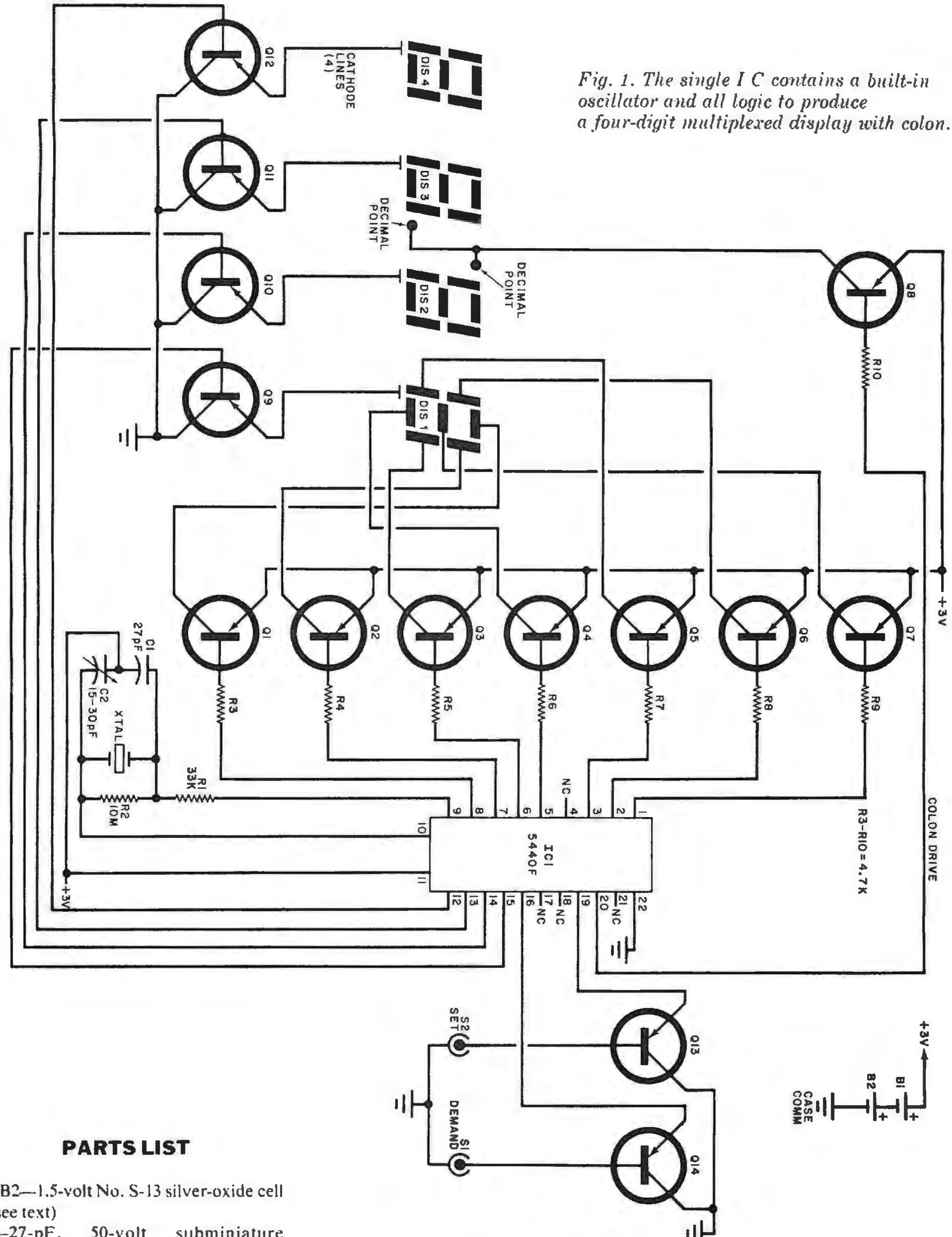



*Fig. 1. The single I C contains a built-in oscillator and all logic to produce a four-digit multiplexed display with colon.*

## PARTS LIST

B1, B2—1.5-volt No. S-13 silver-oxide cell (see text)

C1—27-pF, 50-volt subminiature CK12-BX27OK Kemet capacitor

C2—15-30-pF subminiature trimmer capacitor

DIS1 thru DIS4—Miniature 7-segment LED display with decimal point

IC1—SLC5440F (Solid State Scientific) electronic watch integrated circuit

Q1 thru Q12—MMT71 subminiature transistor (Motorola)

Q13, Q14—2N5139 transistor

R1—33,000-ohm, ⅛-W, 10% resistor

R2—10-megohm, ⅛-W, 10% resistor

R3 thru R10—4700-ohm, ⅛-W, 10% resistor

S1, S2—Touch switch (see text)

XTAL—32,728-Hz miniature crystal (CTS Knight)

Misc.—Display filter; printed circuit board; watch case; watchband; 0.005-in. (0.127-mm) brass stock for battery contacts; tape; thin-walled plastic tubing; epoxy compound; straight pins (2); hookup wire; solder; etc.

Note: The following items are available from Alpha Electronics, P.O. Box 1005, Merritt Island, FL 32592: complete No. LED-1 kit of parts including all components, pc board, and case, but less band and batteries for $75 plus $2.95 postage and handling (specify men's or lady's version); No. LW-1 printed-circuit board for $8.50; SCL5440F MOS integrated circuit (IC1) for $40; 32,768-Hz crystal for $15.

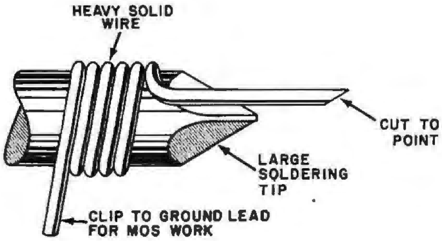



*Fig. 2. To prevent damage to MOS devices during soldering, prepare this special tip for soldering iron.*

Internal logic elements keep the display on for 1⅜ seconds after demand is made via *S1*. (Only the display is on-demand; the logic elements are always powered and driven.)

The colon between units-hours display *DIS3* and tens-of-minutes display *DIS2* is driven by transistor *Q8*. When the time is displayed, the colon glows steadily for a.m. hours and blinks at a 2-Hz rate for p.m. hours. The colon itself is made up of the decimal points built into *DIS2* and *DIS3*.

Miniature transistors interface the outputs of *IC1* with the LED displays. Transistors *Q1* through *Q7* provide current switching for the display segments, while transistors *Q9* through *Q12* are the digit-enable drivers when demand is made for displaying time or date. Resistors *R3* through *R10* in the base circuits of transistors *Q1* through *Q7* decouple the segment and colon driver transistors from *IC1*.

The oscillator circuit built into *IC1* uses a 32,768-Hz crystal (*XTAL* in Fig. 1), capacitors *C1* and *C2*, and resistors *R1* and *R2*, all outboard of the LSI chip, to provide the clock pulses required for driving the system's logic. Capacitor *C2* is made variable to permit the frequency of the clock oscillator to be accurately trimmed for precise timekeeping.

Transistors *Q13* and *Q14* act as switches between the time-demand and time/date setting pins of *IC1* and case ground, which is also the common negative buss for the timekeeping system. These transistors are activated by touching *S2* and *S1*, respectively. When either switch is touched, sufficient leakage current will flow between the center of the switch and the metal case of the watch to saturate that particular transistor. This sends the associated pin of *IC1* to ground and activates the demanded function.

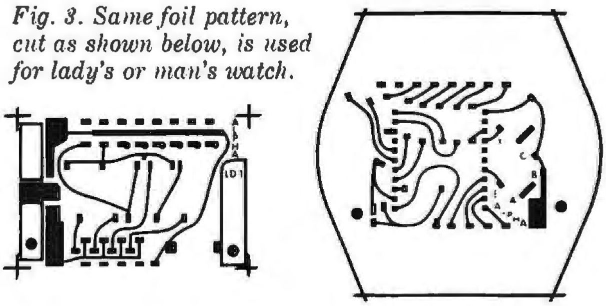
Power for the watch is provided by a pair of silver-oxide cells (*B1* and *B2*) that generate the 3 volts dc required to run the timekeeping system. In the ladies' version, a pair of low-cost S-13 cells are used for power. The larger case volume of the men's version permits larger and more powerful cells to be used, a good choice being the S-76 cell.

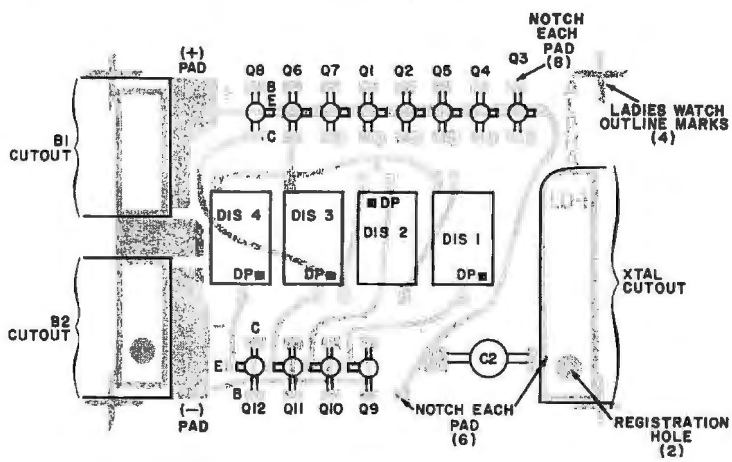
Since *IC1* draws only 10 μW of power, the timekeeping system will yield from eight months to a year of operation from the smaller batteries, provided display demand does not exceed an average of ten times daily. The larger batteries permit more demands per day from the watch.

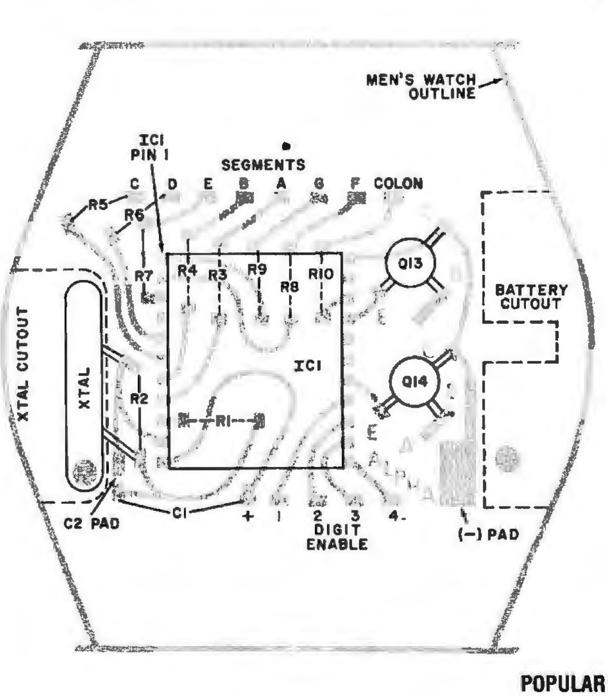
**Construction.** The components used in the wristwatch are physically much smaller and more delicate than those normally found in experimenter projects. One is a MOS LSI device (*IC1*) that requires particularly special handling to avoid damaging it by static electricity. (See the box for details on how to safely handle MOS devices.)

The printed circuit board on which the entire watch is built is extremely small for the number of components it accommodates. It has conductors on both sides, but it has none of the usual

*Fig. 3. Same foil pattern, cut as shown below, is used for lady's or man's watch.*





through-the-board holes for component leads. Lacking mounting holes, and owing to the high density of components and the close spacing between conductors and component leads, a special soldering technique and a very fine pointed soldering iron tip (see Fig. 2) must be employed when assembling the watch.

The soldering technique is familiar to many experimenters, though perhaps not by name. It's called reflow soldering. Before a component is mounted in place on the board, the copper pads and the component's leads are first pretinned with solder. This requires that the leads be cut to exact length and preformed prior to mounting. Then, when the component is set into place, heat from the soldering iron is applied to the joints between leads and pads until the pretinning solder films "reflow" and form sound electrical and mechanical bonds. No extra solder is used once the pads and leads are tinned.

If you examine the actual-size etching guides for the printed circuit board shown in Fig. 3, you will note the case outline for the men's version on the *IC1* side and the crosses that define the limits of the ladies' version on the display side. Also note the areas that must be cut away for the batteries and crystal.

Use a jeweler's or other fine-bladed saw to cut the board to the shape required by the case in which it is to be mounted. Then cut out the notches for the batteries, leaving a narrow "tongue" of board material between the two cutouts. Make the cutout for the crystal. When this is done, use a fine file to smooth all cut edges and to fine-trim the board so that it just fits inside the case without binding.

If you are assembling the men's version of the watch, use a very fine drill to bore a hole through the board near each of the pads marked A through E and COLON, 1 through 4 and −, and the *C2* pad adjacent to the crystal cutout. For the ladies' version, shallowly notch the edges of the board with a file in the center of each of the above pads.

Now, pass a strand of fine wire, pulled from a bundle of No. 22 stranded hookup wire, through each of the holes drilled through the pads on the men's board. Solder the wire to the paired pads on both sides of the board at each hole location. Use solder sparingly, taking care to avoid solder bridges, and clip the excess wires as close as possible to the board's surfaces. For the ladies' version, first pretin the pads scored by the notches on both sides of the board. Reflow-solder the wire to the adjacent pads on both sides of the board, wrapping the wire over the edges of the board in the grooves. Interconnect all but the *C2* pads—which will be connected later—in this manner.

Whichever version of the watch you are building, continue to pretin all the remaining pads on both sides of the pc board with a thin film of solder. Use solder and heat sparingly.

Referring to Fig. 4A, form the leads of the 12 subminiature transistors (*Q1* through *Q12*) exactly as shown. Place the transistor on a flat surface with the side on which the raised marker in the center is facing up. Place your thumbnails on the collector and base leads near the transistor's case and gently but firmly press down until the leads are flat against the case sides. Repeat the procedure for the emitter lead.

Pretin with solder the leads of the transistors near their cases. Trim the transistor leads to just fit on the appropriate solder pads on the pc board. Then, referring back to Fig. 3 for component placement and orientation, reflow-solder the transistors down.

Referring to Fig. 4B, prepare the leads of the four displays (*DIS1* through *DIS4*). Before clipping away any leads, carefully examine the individual displays to locate the decimal points for proper orientation. Once you are sure of the orientation of each of the displays, remove the leads specified. Then carefully bend the leads of each display with longnose pliers as shown in the side-view drawings. Pretin the bent leads of each of the displays and reflow-solder the displays in their respective locations, trimming leads as necessary and making sure to mount *DIS2* upside-down so that its decimal point and the decimal point of *DIS3* form a colon. Work carefully, and keep the displays in line with each other.

Place a narrow strip of insulating tape on the board under the free leads of the displays. Starting at *DIS1*, bend down the pin for segment E of each display until it touches the tape. Solder a length of thin bare wire (one strand from a length of No. 22 stranded hookup wire) across the E-segment pins, terminating it at the collector pad of *Q5*.

Place a second layer of tape over the E-segment wiring and repeat the above procedure for the D-segment leads, terminating their wire at the collector pad of *Q4*. Continue working in this manner for the remaining segment leads, terminating the C, G, A, and B wires at the collector pads of *Q3*, *Q7*, *Q1*, and *Q2*, respectively. There is no need to bridge the G-segment leads of *DIS1* and *DIS2* since they share a common conductor once they are soldered down to the pads on the pc board. Also, no interconnecting wiring is needed for the F-segment leads to the collector of *Q6* for the same reason.

Install trimmer capacitor *C2* with its adjustment slot facing away from the board's surface. Wrap the lead near the crystal slot over the edge of the board and solder it to the pads on both the top and bottom of the board.

Next, install all the resistors, except *R2*, on the IC side of the pc board. Do not forget to tin the leads after they have been trimmed and formed. When properly installed, the resistors should lie flat against the board's surface.

Being very careful to observe the instructions for MOS devices in the box, remove *IC1* from its protective carrier. Bend its leads downward about 1/32 in. (0.8 mm) from the flat side. At a point about 3/32 in. (2.4 mm) from the bottom of the IC package, bend the leads out at a 90° angle. Temporarily place *IC1* in position over its pads and, noting the position of pin 1 (it has an extra extension coming off the lead as shown in Fig. 4C), clip away the excess

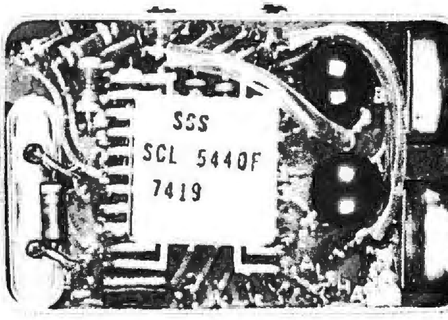



*Photo shows how components are mounted on pc board.*

lead lengths. Tin the lead stubs and carefully reflow-solder the IC's leads to the appropriate pads on the pc board. When in place, the IC should sit close atop the resistors mounted under it.

Form the leads of *Q13* and *Q14*, trim them to fit the pads on the board, and tin the stubs. Set the transistors, one at a time, in place on the board and reflow-solder their leads to the ap-

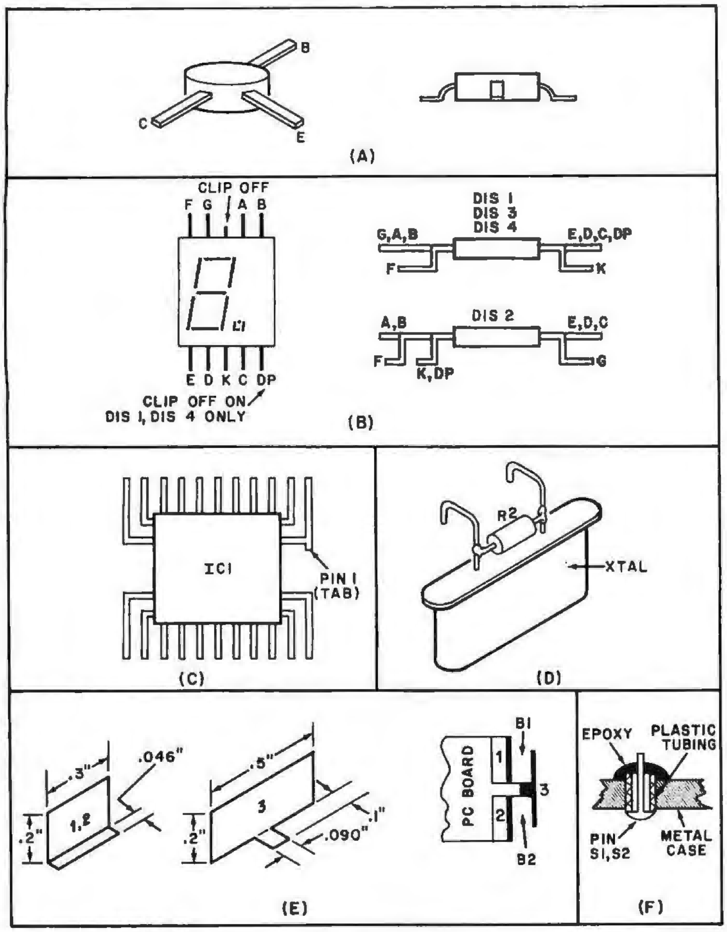



*Fig. 4. Details for pin forming and assembly of parts.*

propriate pads. Then solder one end of a 1-in. (25.4-mm) length of bare hookup wire to the base pad of *Q13*. Repeat for *Q14*. The free ends of the wires will be connected later.

Cover the metal case of the crystal with a layer of insulating tape. Form the crystal's leads as shown in Fig. 4D. Clip the leads of *R2* to 1/16 in. (1.59 mm) and solder this resistor across the leads of the crystal as shown, close to the case of the crystal. Set the crystal into its slot, and tin its leads. Reflow-solder the leads to the appropriate pads on the PC board. Form and clip the leads of *C1* to length. Tin the leads and solder them to the pads on the circuit board.

Temporarily tack solder a length of hookup wire to the battery + pad on the board and another to the battery − pad on both sides of the board. Connect these wires, properly polarized, to a 3-volt dc supply. Two 1.5-volt cells of any type connected in series will do nicely.

The wire attached to the base pad of *Q14* is the active part of time demand switch *S1*, while the wire attached to the base of *Q13* is the active part of time/date SET switch *S2*. A low resistance must be present between the switch to be used and battery − (case when the timekeeping package is installed in its case) to activate the function desired. Use your index finger to make contact between the battery − lead and the *S1* wire. If the watch is operating properly, the display will come on and indicate some random number of hours and minutes. The display will remain on for 1 3/8 seconds after you remove your finger from contact with the wire.

After the display extinguishes, again contact the *S1* wire, this time twice in quick succession. On the first contact, the display will indicate hours and minutes, while on the second contact, it will indicate the date and seconds. Unless continuous contact is made with the *S1* wire, the display will extinguish after 1 3/8 seconds.

**Setting the Watch.** To set the hours and minutes, touch the *S1* wire while maintaining contact with the battery − wire. Release the *S1* wire, and, before the display blanks, touch the *S2* wire. This will blank out the minutes displays and leave on the hours display(s). Touch the *S1* wire until the display indicates the proper number of hours. Don't forget to get the time in the proper cycle (a.m. or p.m.), while observing the colon.

Touch the *S2* wire to blank out the hours display and turn on the minutes display. Then touch *S1* until the correct number of minutes is displayed. Touch *S2* again to blank the display.

The date and seconds are set in a similar manner. First touch the *S1* wire twice to turn on the date and seconds function. Before the display blanks out, touch *S2*. This blanks the seconds and locks on the date displays. Touch *S1* until the display indicates the correct date. Touch *S2* to blank out the date and turn on the seconds. Touch *S1* to reset the displays to 00. Release the *S1* wire. When the real time corresponds to the time set in the watch, touch *S1*.

The above procedure checks out the operation of the timekeeping system prior to final assembly. It should be performed again exactly as outlined after the watch is fully assembled and ready to wear. Once you have checked the operation of the timekeeping system, remove the wires temporarily connected to the battery + and − pads.

**Final Assembly.** Referring to Fig. 4E, prepare three pieces of brass shim stock as shown. Mount and solder them into place as shown in the circuit

## HANDLING MOS DEVICES

Because MOS devices—both discrete and integrated circuit—can be permanently damaged by static electricity charges, observe the following rules when handling and working with them:

- Never wear synthetic clothing; cotton is best.
- Ground anything that is to come into contact with the MOS device before it is installed in its circuit—including work area, tools, and yourself.
- Never let go of a MOS device after removing it from its special conductive carrier until it is installed in its circuit. When a good MOS device is removed from a circuit, immediately install it in a protective (conductive) carrier designed for MOS devices.
- Never install or remove a MOS device from a circuit when the power is on.

## ALTERNATE DESIGN CHOICE

The digital wristwatch described in this article uses a Solid State Scientific IC to perform all time-keeping functions. As we were going to press, we were informed that another version of the kit has also become available from the same supplier mentioned in the Parts List. The new version uses either of two IC's made by Mostek.

While both the SSS and Mostek IC watches are designed to use LED displays, their drive systems are different. The SSS chip requires outboard isolation transistors to drive the LED segments, while the Mostek has built into it high-current outputs that can drive the displays directly. Both approaches have advantages and disadvantages.

The advantages to the SSS approach include the ability to vary the current through the drive transistors and LED's by changing resistor values to lower display brightness and extend battery life. Another advantage is that if one of the LED drive transistors should ever become defective, only that transistor need be replaced. The disadvantage of the SSS approach, of course, is those seven extra driver transistors that make assembly more complex.

Taking the Mostek chip approach offers the advantages of bright display, on-chip segment drivers, and the elimination of seven transistors, which simplifies assembly. The disadvantages are that the display brightness cannot be varied. Also if only one of the output drive circuits becomes defective, the entire chip must be replaced.

Both chips offer hours and minutes time indication with separate date and seconds on demand. The SSS chip offers time only in a 12-hour format, with a.m. hours indicated by a steady glow of the colon and p.m. hours by the colon pulsing on and off. The Mostek chips offer a choice of either 12- or 24-hour time format. The colons glow steadily; so, there is no indication of a.m. or p.m. in the 12-hour watch. (It's not needed in the 24-hour watch.) A.m. and p.m. are indicated only when time is being set.

Further differences include two-button operation for the SSS chip as opposed to three-button for the Mostek chip. With the Mostek watch, if you want the time, you have to touch the demand contact continuously for as long as it takes to read the display. However, when you touch the contact on the SSS watch, you can let go immediately and the display will remain on 1.35 seconds after release. Finally, the Mostek watch kit is $5 more expensive than the SSS kit.

The Mostek chip has one more function worth noting. The chip can be used as a stopwatch with a 1-second resolution. A resume function permits the elapsed-time count to be stopped during times out and resumed again without having to go to a reset-to-zero mode. When used as a stopwatch, the watch does not keep track of time and date, which means that the time and date must be set into the watch after using it as a stopwatch.

A complete kit for the Mostek IC watch, including pc board, case, and all electronics, but excluding band and batteries, sells for $79.95 plus $2.95 for shipping and handling. Specify lady's or man's version and give No. DD-12 for the 12-hour or DD-24 for the 24-hour version. The IC's are available separately for $40 each: specify 5030M (12-hr) or 5031M (24-hr). Also available are the No. LW-2 pc board for $8.50, and the crystal for $15.

board detail. Use solder sparingly, but make sure to obtain good mechanical as well as electrical joints. Solder the minus pad on the IC side of the board to the minus battery clip.

Temporarily set the timekeeping module inside the watch case, display properly positioned in its window, to check the fit. The fit should be fairly loose, without binding anywhere. Remove the pc board assembly from the watch case.

Measure the inside depth of the watch case and subtract 1/16 in. (1.59 mm) from the figure obtained. Cut a strip of electrical tape to this width and 3 5/8 in. (76.2 mm) long. Press the tape strip to the inside walls of the ladies' watch case, leaving a gap in the center of the top wall. This insulation is necessary in the men's watch case only in the area where the batteries might come into contact with the case. Also apply a strip of tape on the inside of the case top in the battery area.

Epoxy the filter over the display window in the watch case. Set the case aside until the epoxy has had time to completely set.

Then, temporarily set the pc board assembly into the watch case, positioning the display so that it is in the center of the window area. If the assembly binds because of the insulating tape, carefully trim it with a fine file for a snug fit. Locate and mark two points above and clear of the components on the board for *S1* and *S2*.

Remove the pc assembly from the watch case and set it aside. Then drill a hole at each of the marked locations. Use a drill that is the same size as—or perhaps the tiniest bit smaller than —the diameter of the thin-walled plastic tubing that will be installed in these holes to insulate *S1* and *S2* from the case.

Referring to Fig. 4F, slip a short length of the plastic tubing into each of the holes, positioning it so that it is almost flush with the outside wall and protrudes about 1/32 in. (0.8mm) beyond the inside wall of the watch case. Slip a straight pin into each piece of tubing from outside the case. Then epoxy pins and tubing to the case as shown. When the epoxy has had time to set, trim the straight pins, leaving just enough of their length behind to permit the wires coming from the bases of *Q13* and *Q14* to be soldered to them.

At this time, wristband support pins must be attached to the exterior of the metal watch case. In the prototype watch shown in the photo, small-diameter brass tubing was silver soldered to the case. If another type or style of wristband than that shown is used, appropriate metal brackets must be fashioned for them and silver soldered to the watch case.

If you have access to a frequency counter, you can initially set the crystal oscillator's frequency for a reading of 32,768 Hz by adjusting *C2*. The counter connects to the watch via pin 10 of *IC1* and the case. Do not set the frequency to exactly 32,768; instead, set it about 0.5 Hz low to offset the loading effect of the counter on the oscillator.

If you do not have access to a frequency counter, you can tune the oscillator by trial and error. Operate the watch for some period of time. Assuming the time is off by some number of seconds, tune *C2* and operate the watch again. Continue to operate and tune until you are satisfied that the timekeeping system is tracking with the smallest of errors.

Replace the watch module inside the case, making sure the displays are centered in the window area. Solder a short length of the thin bare wire from the battery – pad to the wall of the watch. To get to bare metal on the wall, notch out only as much of the tape as needed for the connection.

Slip a length of thin-walled plastic tubing over each of the wires coming from the bases of *Q13* and *Q14*. Connect and solder the loose ends of these wires to the *S1* and *S2* pin stubs. Then, taking care to observe the correct polarity, install *B1* and *B2* in their holders. Push the cells down until they seat against the top of the watch case. Then install the bottom cover.

The ultimate timekeeping accuracy can be within one or two seconds a month if you take care to precisely trim *C2*. ◈