ELECTRONICS NOTEBOOK

Keychain Electronic Projects

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The transistorized "pocket" radios of a few years ago were usually much too bulky for a shirt pocket. The most remarkable physical feature of today's shirt pocket electronic devices is that they really *do* fit in a shirt pocket. In fact, several ultra-thin credit card-sized radios and calculators can be easily slipped into the same pocket.

The frontal dimensions of today's pocket electronic devices are not surprising. But their amazing thinness is an impressive technological achievement. In fact, it is so impressive that until six months ago I was convinced that it was impossible for individual electronics experimenters and engineers to duplicate this feat by hand.

Fortunately, this gloomy outlook has been completely reversed now that miniature surface-mountable components (SMCs) are becoming more widely available. Working with SMCs requires new assembly techniques and careful attention to detail. Nevertheless, I have found that finished circuits made with SMCs can often be assembled more rapidly than conventional circuits using traditional components with leads. Moreover, the tiny size of SMCs and the fact they can be attached to both sides of a circuit board (with either solder or conductive adhesive) provides unprecedented design flexibility. Thanks to surface-mount technology, it is now possible for experimenters and small companies to again take the lead in designing and building creative personal electronic devices.

Though circuits made with SMCs are surprisingly easy to design and assemble, finding surface-mountable components can be difficult. But this situation is beginning to change. For example, the Mouser Electronics catalog lists a variety of surface-mountable resistors, capacitors, ICs and LEDs. If you live in or near a major city, you can purchase SMCs from electronics distributors that represent SMC manufacturers. At last fall's giant WESCON electronics trade show, I found a dozen or so companies that sell assortments of surface-mountable parts. Vector Electronic Company, a firm well known to electronics prototypers, was a pioneer in bringing such kits to market.

The previous two issues of *Modern Electronics* featured a two-part article describing surface-mount technology. This article, which replaced this column, included details about surface-mountable components and soldering methods. Also included were construction details for three miniature circuits made with SMCs. (Back issues are available for $2.50 each.)

The remainder of this column is devoted to three additional circuits whose miniature size is made possible by SMCs. Even if you don't now care to assemble one of these circuits, you will gain a better appreciation of surface-mount technology by reviewing the details of their construction.

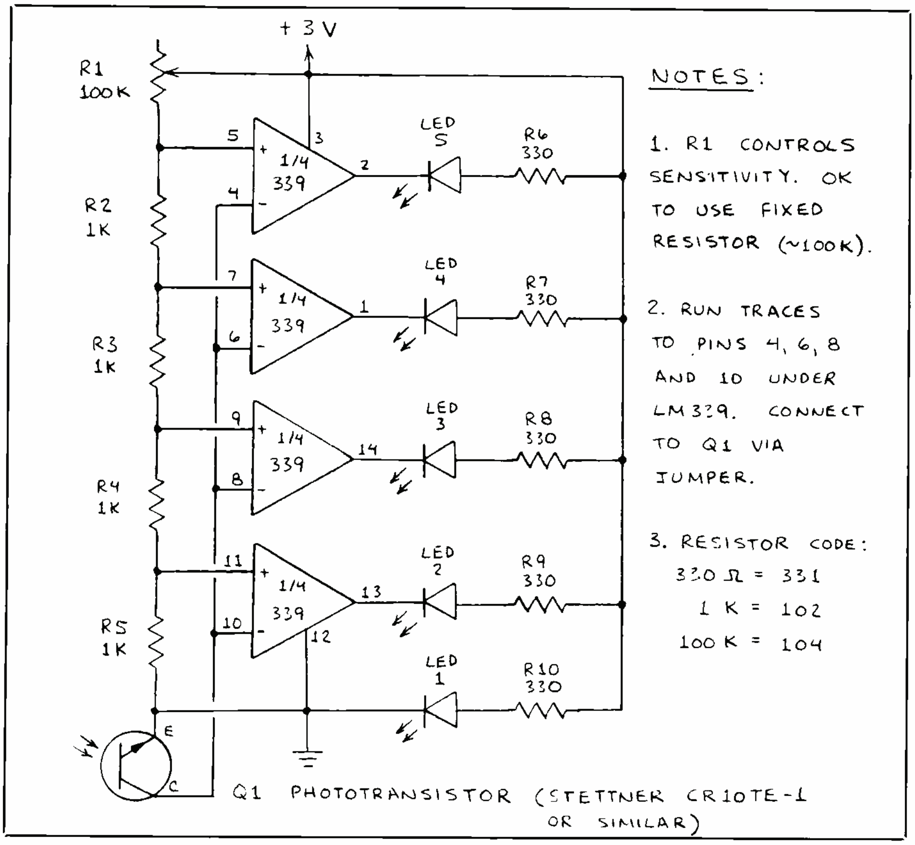

Fig. 1. Light meter with LED bargraph display.

Keychain Light Meter

While visiting an office-supply store recently, I discovered some plastic identification tag holders with attached key chains. Those tag holders are made of sturdy plastic and have a 2-millimeter opening for insertion of a small identification card. They appeared to be just the right size for housing miniature surface-mount projects, so I bought several. The keychains are distributed on a wholesale-only basis by the W.T. Rogers Company (Item No. 1132) and retail for around 70¢ each. I purchased mine from the Paul Anderson Company, a large office supplier in San Antonio, Texas.

Figure 1 is the schematic of the first circuit I installed in one of those tag holders. This circuit can be used to indicate voltage and resistance by omitting phototransistor *Q1*. With *Q1* in place, the circuit becomes a rudimentary light meter. When *Q1* is dark, all the output LEDs glow. Conversely, when *Q1* is saturated with light, none of the output LEDs glow. Intermediate levels of light cause varying numbers of LEDs to glow in bargraph fashion.

Known as a parallel or flash analog-to-digital converter, the Fig. 1 circuit consists of a parallel array of comparators, each of which is connected to a reference voltage provided by a tapped voltage divider. Resistors *R1* through *R5* form the voltage divider. The LM339 contains four comparators on a single chip and is an ideal choice for this circuit. The output of each comparator directly drives one of *LED2* through *LED5* through current-limiting resistors *R6* through *R9*. Power-on is indicated by *LED1*.

Figure 2 will help you better appreciate the significance of surface-mount technology. This is a photo of the Fig. 1 circuit (less *Q1*) assembled with conventional through-hole components. (Its construction was described in *Integrated Circuit Projects,* Volume 4, a book I wrote for Radio Shack in 1975.) At 0.45 cubic inch, the keychain version of the circuit occupies less than half the volume of the 9-volt battery (1.1 cubic inches) that powers the conventional version of the Fig. 2 circuit.

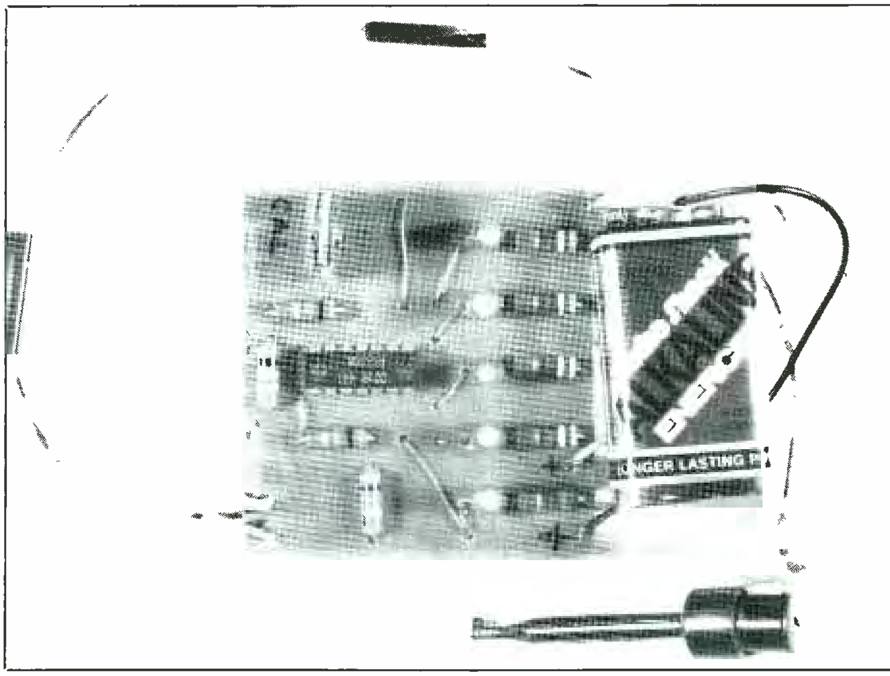

Fig. 2. LED bargraph assembled using conventional components.

Figure 3 shows the etched circuit board I made for the keychain light meter. The 0.5-mil thick board is double-sided and can be easily cut to size with scissors. A 12″ × 18″ sheet of this board is available for $2.50 from Edmund Scientific (Cat. No. #R35,652).

Only one side of the board is used for the light-meter circuit. However, surface-mountable components can be soldered to both sides of a double-sided board if provisions are made for making interconnections between the two sides.

As for the board's layout pattern, there isn't one. Instead, I sketched an approximate layout on a notepad. Then I cut the board to size and polished it with steel wool. Next, I placed the various components, including a 2016 lithium coin cell, on the board and marked their terminal or pin locations with a pencil. After removing the components, I penciled in the desired traces. Pins of the LM339 that were to be interconnected were interlinked under the chip. After tracing the penciled traces with a fine point resist pen (Radio Shack Cat. No. 276-1530A or similar), I covered the back of the board with a protective layer of tape and etched away all unwanted copper. Total preparation time was around 45 minutes.

Caution: Always follow the manufacturer's recommendations regarding safety and disposal when using circuit board etchant products. Remember that etchants will permanently stain clothing and painted surfaces and corrode metal.

Incidentally, notice that the board in the upper photo in Fig. 3 shows three solder bumps strategically located around the perimeter of the coin cell. These are simply three small copper lands designed to receive solder bumpers that secure the coil cell in place when the board is slipped into the ID tag holder.

After the board is etched, all component footprints must be plated with either solder or tin to permit soldering. TINNIT™ tin plating chemical is available from The Datak Corp. Or standard rosin core solder can be flowed onto the board's copper traces. It is important to avoid applying excess solder. After plating the board, use desoldering braid to remove any excess solder. For best results, the solder layer should be very thin and as flat as possible.

Wire the board by first positioning the LM339 in place and securing it flat against the board with a piece of masking tape across one end of the chip. This done, touch the pointed tip of a 15-watt soldering iron to a corner pin and apply just a tiny bit of solder. Because of the pretinning of the board's copper traces and the plating on the IC pin, the connection will be instantly made. When a secure connection has been made, carefully remove the tape and make sure the remaining pins are still aligned. If they are, solder the opposite corner pin. Then solder all remaining pins. Use very little solder in all cases.

Chip resistors and LEDs can also be soldered into place with the help of masking tape. Simply attach a chip component to the board with a small piece of tape across one end of the chip. Solder the exposed end as described above. If necessary, gently press the end of the chip into the solder with a pencil eraser or other implement to make sure it is flat against the board. Remove the tape and solder the remaining end to the board. Do *not* try to press the second end of any chip component downward since the other end is already soldered rigidly in place.

This is one reason why it's important that the solder plating over the component footprints be very thin and flat.

Use as little solder as possible when attaching the SMCs. In fact, you may be able to use no solder at all if the solder coating you applied to the footprints is very flat and uniform. In this case you might be able to reflow the solder over the pins or around their terminals by simply pressing them against their footprints with the tip of the iron. Should you accidentally bridge two or more traces with solder, immediately remove the bridge with desoldering braid.

Figure 4 shows the completed keychain light meter (lower photo). Note that only one jumper lead was required (from pin 6 of the LM339 to *Q1*). Though I planned to use a surface-mountable trimmer resistor for *R1*, I later substituted a fixed 100,000-ohm resistor.

Before building this circuit, I spent a good deal of time wondering how to make a switch that would fit into the 2-millimeter space inside the keychain tag holder. Though I tried several approaches, the simplest proved to be the best. The switch is simply the L-shaped piece of 5-mil unetched pc board shown in Fig. 3 covering part of the coin cell. Both sides of the L are covered with transparent tape, which is trimmed to match the outline of the L. A narrow strip of tape is removed from the coin cell side of the end of the L that covers the cell. One end of a short length of wrapping wire is soldered to the opposite end of the L. The other end of this wire is soldered to the negative supply trace on the circuit board. The switch is completed by securing it to the end of the board with a short piece of transparent tape that functions as a hinge.

Test the circuit by placing a coin cell, positive terminal down, between the switch and the board. When the exposed copper along the underside of the end of the L is pressed against the negative side of the cell, *LED1* should light. As *Q1* is darkened, *LED2* through *LED5* should turn on in sequence.

If the board passes its operating test, insert it into the tag holder. If all goes well, *LED1* will light when the power cell end of the tag holder is squeezed. If

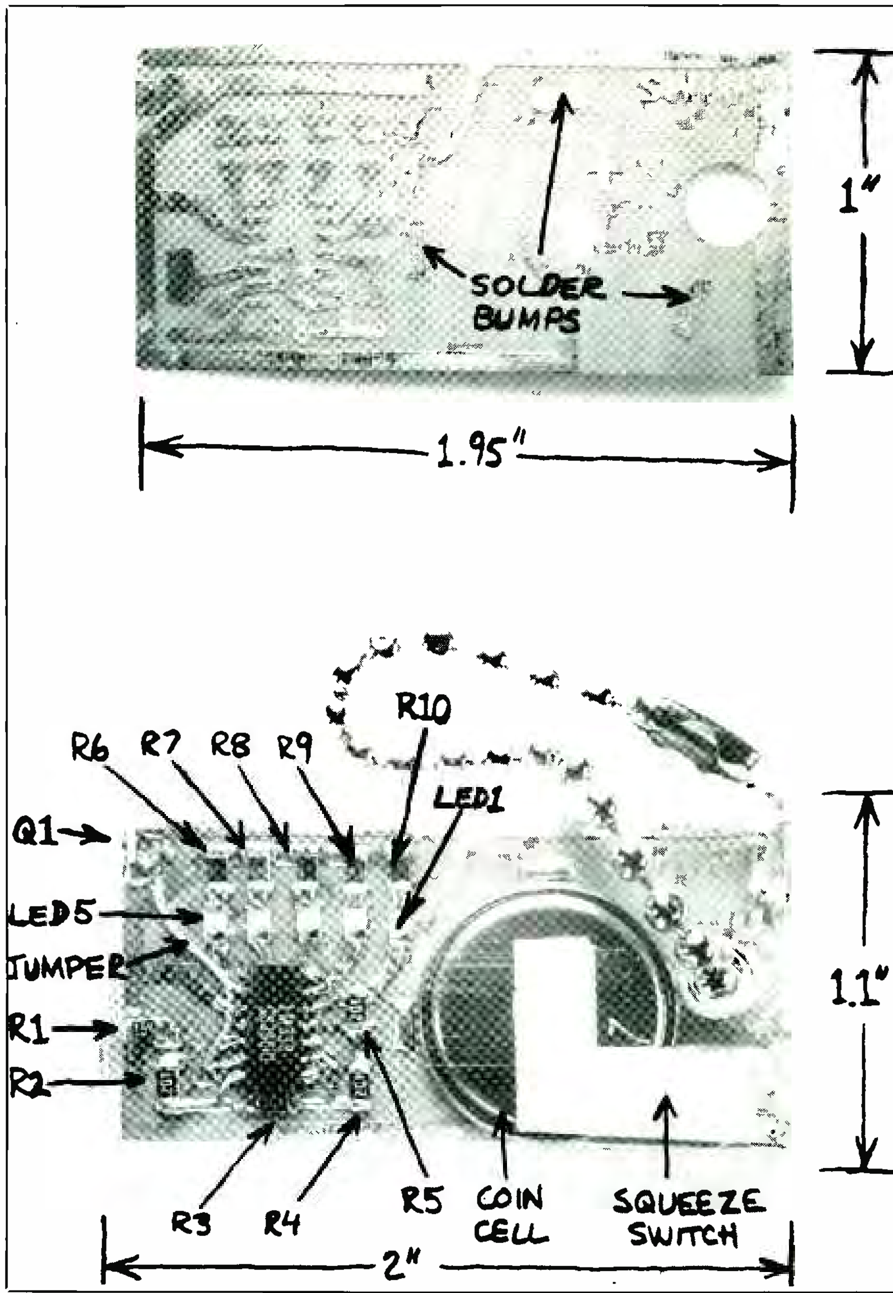

Fig. 3. Etched pc board for lightmeter circuit (upper) and hand-wired board using surface-mountable components (lower).

LED1 fails to glow, you will have to remove a slightly wider strip of tape from the end of the switch L. If *LED1* glows when the case is not squeezed, you must bend the end of the L upward slightly before reinserting the board in the case.

The end of the tag holder opposite the keychain holes has a small opening or slot that simplifies removing the board. Insert the end of a small screwdriver or similar implement into this slot and gently push the board out the opposite end until you can grasp it. Then pull the board from the case.

Chip resistors and the SO (small outline) version of the LM339 used in this

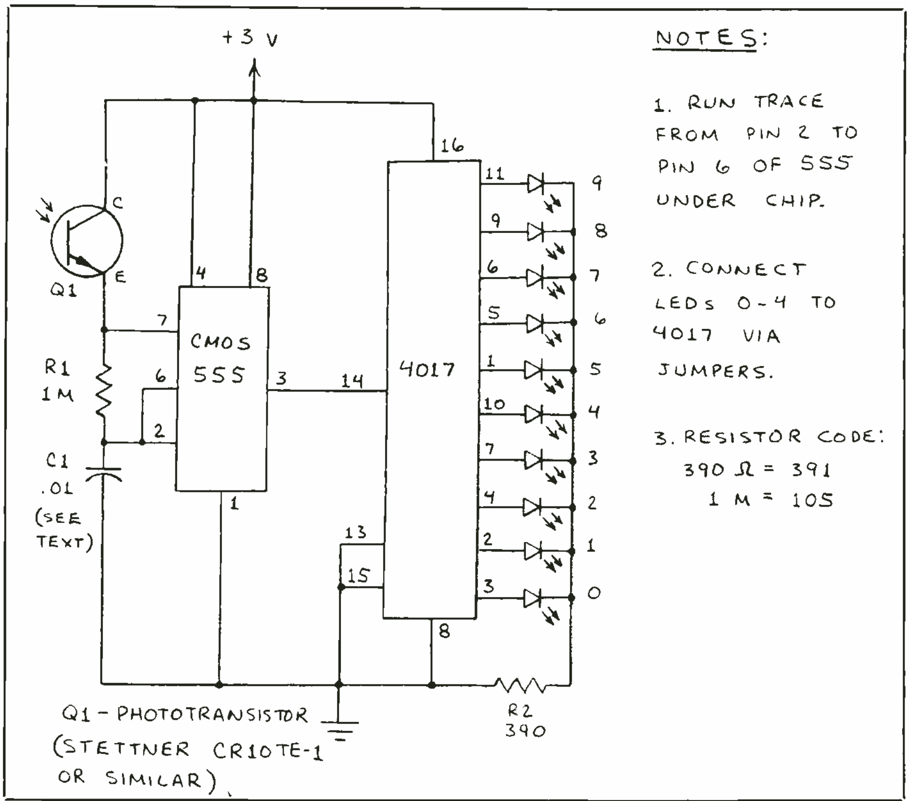

Fig. 4. A light sensor with a rotating LED ring display.

circuit can be obtained from Mouser Electronics and many other sources. The LEDs are Mouser Electronics No. ME351-2711 chip devices or equivalents. Phototransistor *Q1* is a Stettner Electronics No. CR10 TE-1.

Keychain Light Level Indicator

The keychain light meter described above indicates the light level with a bargraph readout. The circuit shown in Fig. 4 is less precise but more fun to build and use. It indicates the intensity of light by means of a ring of 10 LEDs that appears to rotate. The light intensity controls the apparent rotation speed.

A 555 oscillator and a 4017 counter/decoder are the main elements of this circuit. In operation, the 555 generates an oscillating signal whose rate is determined by the light level at *Q1*. For each pulse from the 555, the 4017 advances one step. When *Q1* is dark, the LEDs switch on in a slow sequence and the wheel "rotates" very slowly. When even a very low level of light reaches *Q1*, the ring begins to rotate more rapidly. Rotation rate continues to increase until the light level becomes so high that *Q1* is saturated and the 555 oscillator is disabled.

Before building a surface-mount version of this circuit, assemble a test version using conventional components and a solderless breadboard. This will allow you to select an appropriate value for *C1* that gives an optimum rotation rate for the light levels you want to monitor.

Figure 5 shows the completed keychain light sensor with rotating ring readout. The board for this circuit is laid out in the same fashion as that for the Fig. 1 circuit. The chief difference is that more jumpers are used. Compare the circuit diagram in Fig. 4 with the completed circuit in Fig. 5 and you can see that jumpers are used to connect *LED0* through *LED4* to the respective pins of the 4017.

A do-it-yourself squeeze switch identical to the one used in the Fig. 1 circuit is used for this new circuit. The SO version of the 4017 and all resistors and capacitors can be purchased from Mouser Electronics and many other sources. The SO 555, preferably the CMOS or low-power version, is available from Signetics, Exar and the SMD™ Technology Center. Transistor *Q1* is available from Stettner Electronics.

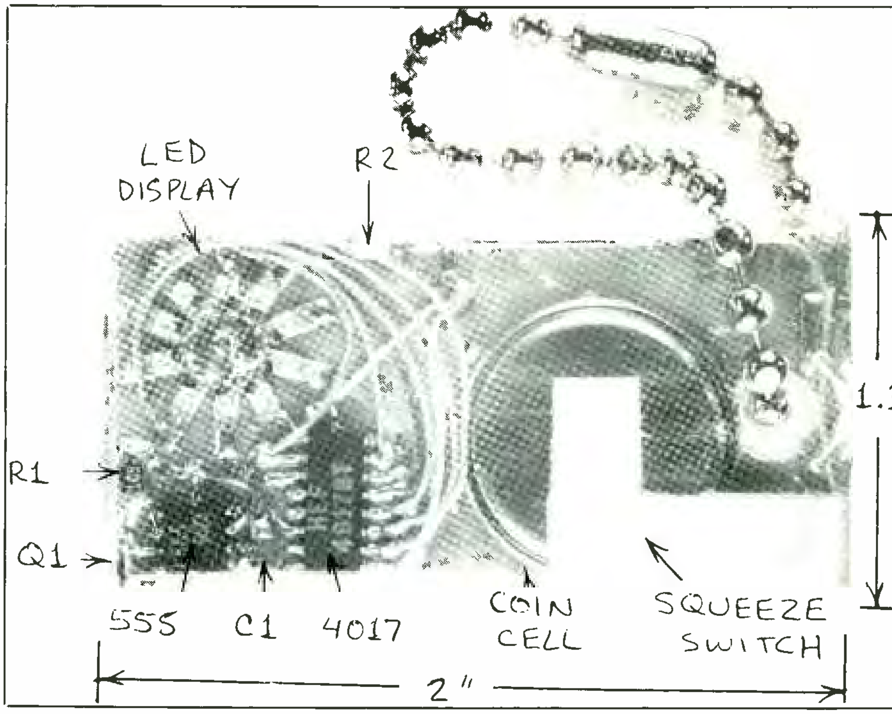

Fig. 5. Wired miniature SMT light sensor with rotating ring display.

Ultraminiature LED Pulse Transmitter

Regular readers of this column and my books may recognize the circuit at the left in Fig. 6 as one of my favorite LED pulse drivers. This simple circuit can drive an LED with a series of hefty pulses having an amplitude of hundreds of milliamperes and a duration of around 20 microseconds.

Though I have built many versions of this circuit, some quite small, availability of surface-mount components has allowed me to assemble the tiniest version yet. At the right in Fig. 6 is shown a photo of the result. The complete infrared pulse transmitter (less battery) measures only 8 mm × 9 mm and is just slightly over a millimeter thin. In other words, the entire circuit is smaller than the nail on your little finger.

I laid out the board for this circuit in the same manner as those described above. But because of its tiny dimensions, I did not trim the board to size until it was completed. In the meantime, it remained as a corner on a postage-stamp-size board.

Notice that the completed circuit includes a jumper wire. The jumper connects the positive supply lead (lower lead extending from board at right in Fig. 6) with the emitter terminal of *Q1*.

Resistors *R1* and *R2* and capacitor *C1* are available from Mouser Electronics. The infrared LED is a Stettner Electron-

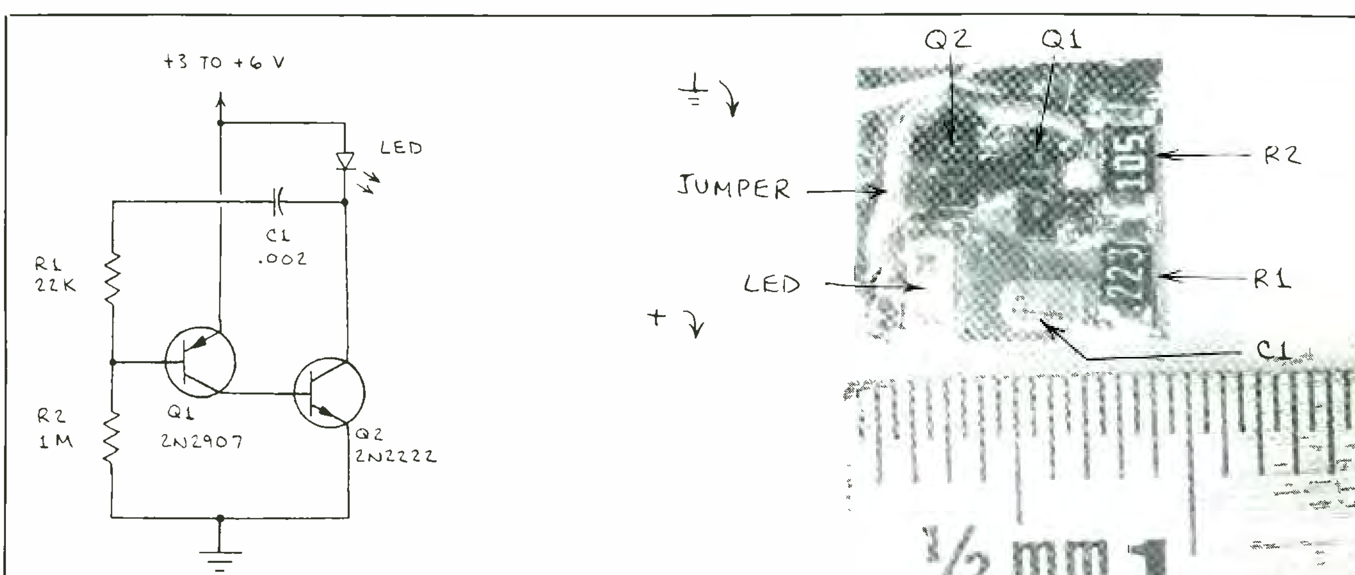

Fig. 6. A LED pulse transmitter (left) and SMT version of the circuit with scale (right).

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Mouser Electronics
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SMD Technology Center
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Stettner Electronics, Inc.
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Franklin Park, IL 60131
800-251-4558 (toll free)

Vector Electronic Co.
12460 Gladstone Ave.
P.O. Box 4336
Sylmar, CA 91342
818-365-9661

ics No. CR10 IR. The SOT-23 transistors are available from many sources; the ones I used were purchased in 50-unit reels from the Surface Mount Technology Center.

Going Further

Each of the miniature circuits described here was built in less than three hours. That's certainly comparable with the time required to assemble much larger versions of the same circuits using conventional components. The only tools I used were an inexpensive handheld soldering iron, desoldering braid, tweezers and a magnifying loupe. In other words, surface-mount technology is well within the grasp and budget of most experimenters.

This came as quite a surprise to some of the surface-mount experts who examined these circuits at last fall's WESCON. Most of these engineers are so involved with highly sophisticated surface-mount soldering methods that they have overlooked the fact that simple tools will also work. Of course, specialized tools and equipment can simplify the assembly of surface-mount circuits. But not having access to such equipment doesn't prohibit access to the surface-mount age.

I hope you are by now as excited as I am by the prospects opened up by surface-mount technology. Since building the circuits described above, I have assembled a new family of miniature surface-mount projects without using a soldering iron. These new circuits illustrate more of the exciting possibilities that await those who join the surface-mount technology age. Since I think you will find them rather interesting, I'll describe them in a future column. **ME**