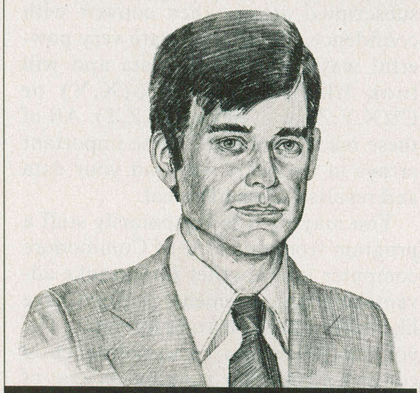


Rediscovering the Transistor
Low-Budget Radio Control
Output Interface for a Digital Timer

By Forrest M. Mims, III

CHANCES are the last circuit you assembled used one or more integrated circuits and few, if any, transistors. That's because falling prices and a wealth of functions have made integrated circuits so pervasive that circuits employing discrete transistors alone are fast becoming rare.

Nearly all the circuits I design and build use integrated circuits. However, while writing a new book last summer ("*Getting Started in Electronics,*" Radio Shack, 1983), I was reminded that there remain many simple applications for which individual transistors are ideally suited.

In this column we'll examine several simple but very useful transistor circuits you may have overlooked in favor of more complicated integrated circuit versions. We'll also compare a few transistor circuits with versions made with IC's to determine if the transistor versions are indeed simpler.

Next, we'll experiment with an inexpensive radio control module kit with many possible applications. Finally, we'll greatly expand the capabilities of a midget digital timer by adding a do-it-yourself output interface.

Rediscovering the Transistor

With the availability of literally hundreds of different kinds of integrated circuits, it's common to design even the simplest circuit around one or more IC's when a transistor or two would suffice. For example, the usual way to drive a meter or trigger a relay in response to a changing voltage or current is to use an operational amplifier or comparator. Often the same function can be performed with one or two transistors.

Another common example is the pulse generator. Most designers use a timer, such as the popular 555 or a pair of cross-coupled gates, when a simple pulse generator is required. Often, however, a simple two-transistor circuit will perform the same function with fewer components.

Let's look at several practical examples of how a simple transistor circuit can provide some or all the functions of an integrated circuit version. I think you'll agree with me that simple transistor circuits still have an important role to play in electronics today.

Moisture Detection Circuits. If asked to design a moisture detection circuit, the typical design engineer will use an op amp or comparator as the principal active circuit element. Figure 1 shows a much simpler approach.

The ultra-simple circuits in Fig. 1 each use a single bipolar transistor as the active element. Most common silicon npn small-signal transistors (2N2222, 2N3904, etc.) can be used.

The moisture meter can be used to measure the level of moisture in a flower pot or in garden soil. Probes can be made from nails or, even better, stainless steel wire. The circuit is calibrated by adjusting *R2* for a meter reading of 1 milliampere when the soil moisture is at the desired level.

The moisture-activated relay in Fig. 1 is a modified version of the moisture meter. The relay is actuated when the moisture level exceeds the level determined by *R2.* If you replace the sensor probes with a circuit board upon which has been etched an interlacing, comb-like grid, the circuit will be actuated when a rain-drop bridges the gap between the two foil patterns.

It's interesting to compare these circuits with integrated versions. The most obvious difference is cost. A suitable transistor can be purchased for under 15 cents if you're willing to pay a dollar or two for a bag of a dozen or more.

Another advantage of the transistor version is simplicity. A transistor has only three connection leads, while connections must be made to at least five of the eight pins of a typical op amp. Furthermore, since most transistors are equipped with leads rather than pins, the transistor moisture detection circuits can be easily assembled on a perforated board the size of a postage stamp.

Finally, at least one of the transistor circuits can be powered by a pair of penlight cells. (The relay circuit requires more voltage to drive the relay.) Though CMOS op amps that can be powered by as little as a volt or two are available, they are far more costly than a single transistor.

A Two-Transistor Metronome/Tone Source. Figure 2 shows a simple metronome circuit that, together with its two transistors and a speaker, includes only

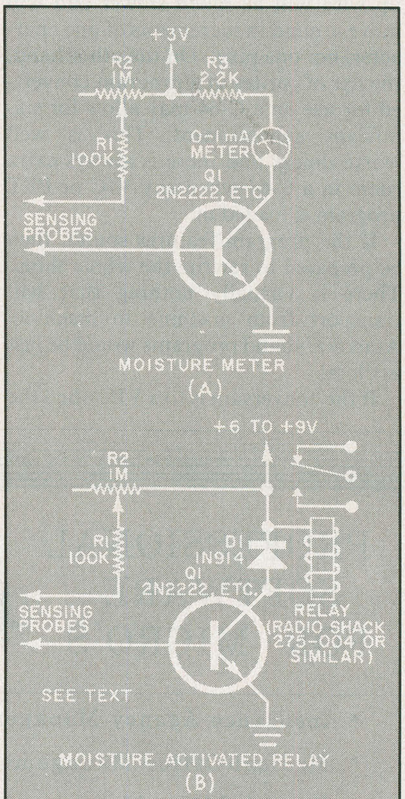


Fig. 1. Transistorized moisture sensing circuits.

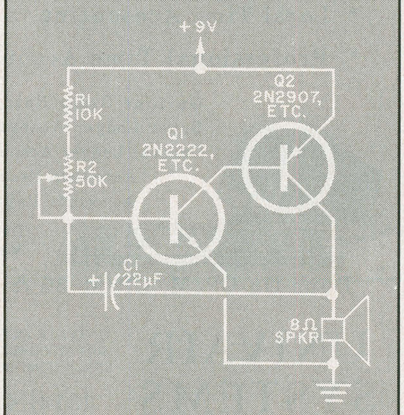


Fig. 2. Simple but effective two-transistor metronome.

six components. Ordinarily the ubiquitous 555 timer is used to make a simple circuit like this. However, the 555 version also requires six components (assuming it, too, employs a resistor in series with its frequency-control potentiometer).

Many common silicon switching and small-signal transistors can be used for *Q1* and *Q2* in Fig. 2. The click rate can be adjusted by adjusting *R1* or changing *C1's* value. Since the transistors have leads rather than pins, it's easy to build this circuit on a small perforated board.

FET Electrometer. The electrometer in Fig. 3 is a good circuit to try on a dry winter day. Though it uses only four components, its meter will indicate the presence of static charges up to several feet away. The circuit I tried, for instance, can detect from several feet away the presence of a plastic comb which I charged by stroking through my hair. Even *very* small movements of the charged comb will cause the meter needle to respond in kind. Potentiometer *R2* allows the circuit to be calibrated.

You can make a permanent version of the electrometer to check for the presence of static electricity near computers and other devices that can be affected by electrostatic discharges. For best results, install the circuit in a plastic box. A circuit board will not be necessary, since the leads of the FET and *R1* can be soldered directly to the meter and the potentiometer. *Q1* should be placed near the top portion of the box. A short, stubby "antenna" wire should extend from the top of the box.

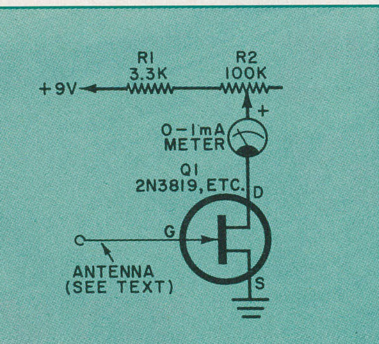


Fig. 3. Schematic of an ultra-simple FET electrometer.

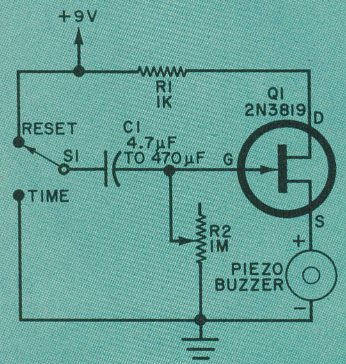


Fig. 4. Schematic of a single-FET timer circuit.

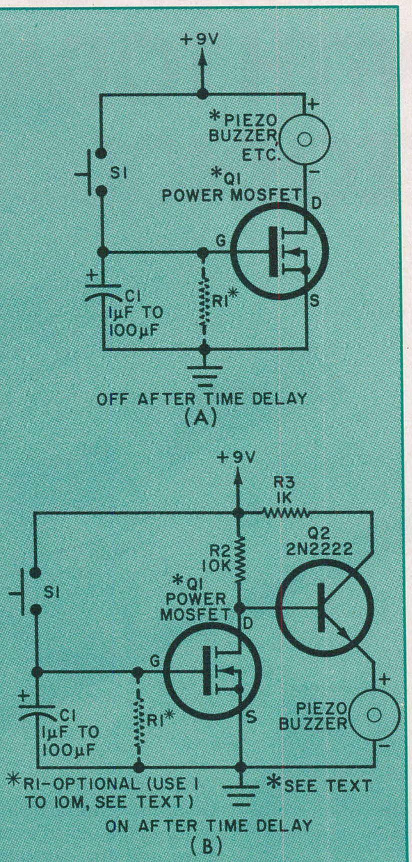


Fig. 5. Two power MOSFET timer circuits.

More sophisticated electrometers can be made with CMOS op amps. But they are more costly, trickier to design, and harder to construct. For a simple indication of the presence of static electricity, the ultra-simple single FET circuit in Fig. 3 may be a better choice.

A FET Timer. When faced with the need to design a timer, I inevitably use a 555 or its CMOS counterpart, the 7555. For brief timing durations of a few minutes, the simple FET circuit in Fig. 4 may be a better choice. Certainly, it's simpler, easier to build, and less expensive.

In operation, when *S1* is switched to RESET, *C1* is charged to near the power supply voltage through *R2.* When *S1* is switched to TIME, *C1* is slowly discharged through *R2.* Eventually, the voltage on *C1* falls low enough to allow *Q1* to switch on, thus allowing the piezoelectric buzzer to sound.

Power MOS Timers. VMOS, TMOS, DMOS, and other MOSFET power transistors can be used to make more effective, longer duration timing circuits than the simple FET version in Fig. 4. Thanks to the ultra-high-impedance input of the MOSFET, time delays of up to half an hour or even longer are possible. And, again, the necessary circuitry is simpler than an IC version using the 555, 7555 or similar timer chips.

Figure 5 shows two simple timers in which a power MOSFET (*Q1*) plays the key role. *Q1* can be a VN10, VN67, IRFD-1Z3 or other common power MOSFET.

The circuit in Fig. 5A is an "Off After Delay" timer. In operation, the piezoelectric buzzer is normally off. When *S1* is momentarily closed, however, *C1* is charged, thus switching on *Q1* and the buzzer. When *C1* eventually discharges through natural leakage paths, transistor *Q1* switches off and silences the buzzer.

Very long time delays are possible when *C1* has a high capacity. For best results, use a capacitor having a very low-loss dielectric. To control the timing cycle, you can add a resistor across *C1*. This resistor, *R1*, will provide a discharge path for the charge on *C1*.

Figure 5B is a modified version of the circuit in Fig. 5A. Here a bipolar transistor (*Q2*) inverts the switching status of *Q1*, thus providing an "On After Delay" operating mode. In this case, the piezoelectric buzzer sounds *after* the time delay is complete.

Though I used a piezoelectric buzzer in both circuits in Fig. 5, you can use a relay, small lamp, motor, portable radio or other device. In any case, do *not* exceed the power rating of *Q1* in Fig. 5A or *Q2* in Fig. 5B. The latter circuit includes a series resistor (*R3*) to limit current through *Q2* and the piezoelectric buzzer. If it's necessary to reduce the drive current in the circuit in Fig. 5A, insert an appropriate series resistor between the positive supply and the controlled device.

Low-Cost Radio Control

Ever since I began experimenting with aerial photography from kites and balloons, I've maintained an active interest in low-cost radio-control equipment. In a previous installment of "Experimenter's Corner" in this magazine (January 1983), I described in some detail two moderately priced radio-control systems with which I've experimented. I also related how I used a simple radio-control system salvaged from a toy car as well as standard radio-control systems to control an airborne Kodak disc camera.

After experimenting with various kinds of radio-control systems, I found that those having both a crystal-controlled transmitter *and* receiver are far more reliable than those in which only the transmitter is crystal controlled. Generally, the cheap systems used in radio-controlled toy cars do *not* have a crystal-controlled receiver.

My preference for crystal-controlled receivers is due to the serious noise and interference problems that often occur. Since a non-crystal-controlled receiver is broadly tuned, it may detect signals from CB radios and other sources being broadcast on nearby frequencies.

Though the commercial radio-control systems having crystal-controlled receivers are generally far superior to their non-crystal-controlled counterparts, there are some applications in which interference may not pose a serious problem. In these cases, if you have a need for a very low-cost radio control system, you may wish to consider a pair of pre-assembled remote control modules recently offered for sale by Radio Shack (catalog number 277-1012). These circuits appear very similar to those used in inexpensive radio-controlled cars.

The modules, which are sold together, include a crystal-controlled transmitter and a non-crystal-controlled receiver. The transmitter board is 1" wide and 3.6" long. The receiver board is 1.4" wide and 3" long. Both modules are powered by a 9-volt battery. In addition, the receiver requires a pair of 1.5-volt cells if the circuit is to drive the two small dc motors for which purpose it was originally designed.

Figure 6 is a block diagram showing both the transmitter and receiver. The transmitter consists of a 27.145-megahertz crystal-controlled oscillator which drives a single-stage radio-frequency amplifier. A two-transistor multivibrator modulates the amplifier with several switch-selectable combinations of audio-frequency control signals.

Figure 7 shows the circuitry of the

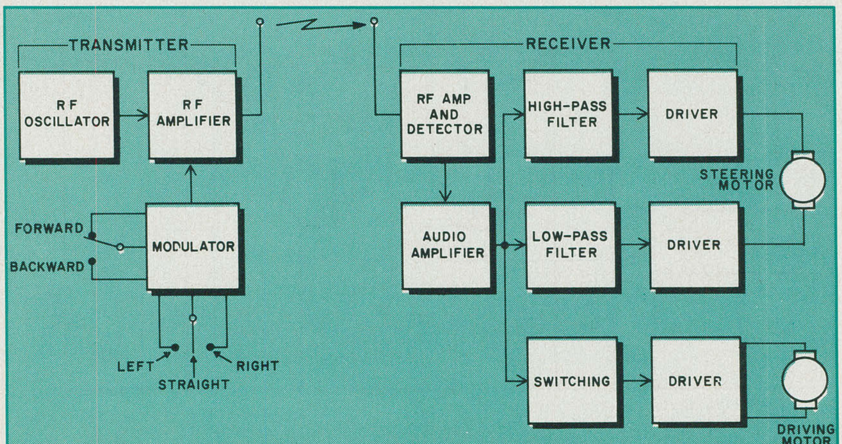


Fig. 6. Block diagram of remote-control module pair.

transmitter's oscillator *(Q2)* and r-f amplifier *(Q1)*. Transformers *T1* and *T2* can both be adjusted for peak operating performance. For simplicity, Fig. 7 shows the audio-frequency modulator as a function block. I'll have more to say about the modulator later.

The receiver consists of an inductively-tuned (non-crystal) radio-frequency amplifier and detector followed by a stage of audio-frequency amplification. Two filters and a network of output driver transistors complete the circuit.

In its intended operating mode, the receiver's output stages are connected to two small dc motors. One motor, the one which propels the toy car, is always on when the receiver is on. It propels the car in a forward direction when the transmitter signal is tone-modulated. When the carrier from the signal is not modulated, the motor's direction of rotation is reversed, and the car is propelled backwards.

The second motor controls the direction of travel. It steers the car either left or right, depending upon which of two modulation frequencies is selected.

Figure 8 is a simplified view of one of the two receiver's motor drive circuits. Depending upon the control signals at the inputs to each output stage, the polarity of the voltage at output terminals A and B is reversed. See the truth table in Fig. 8 for details.

Incidentally, the circuit in Fig. 8 can be implemented with power MOSFETs. I once described one way this can be done in a "Project of the Month" column for this magazine (October 1982).

Modifying the Transmitter. In this month's lead topic I discussed the advantages of using discrete transistors rather than integrated circuits in some simple circuits. Radio Shack's radio-controlled modules, however, go too far. Both circuits use transistors exclusively, the receiver having 18 of them!

Although both the transmitter and receiver work well, I decided to modify the transmitter to permit transmission of a much wider range of carrier signals. I also designed a relatively simple circuit that replaces the mechanical switches used to control the carrier tone with logic signals. The external modulator circuit shown in Fig. 9 illustrates the latter circuit.

Though the transmitter's on-board, two-transistor multivibrator can be modified, I chose to use a 555 timer IC. This is a good example of where an IC

Q1	Q2	Q3	Q4	A	B
ON	OFF	ON	OFF	+	–
OFF	ON	OFF	ON	–	+

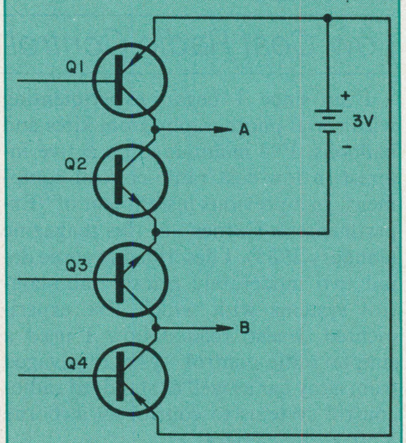


Fig. 8. Receiver polarity reversal output stage.

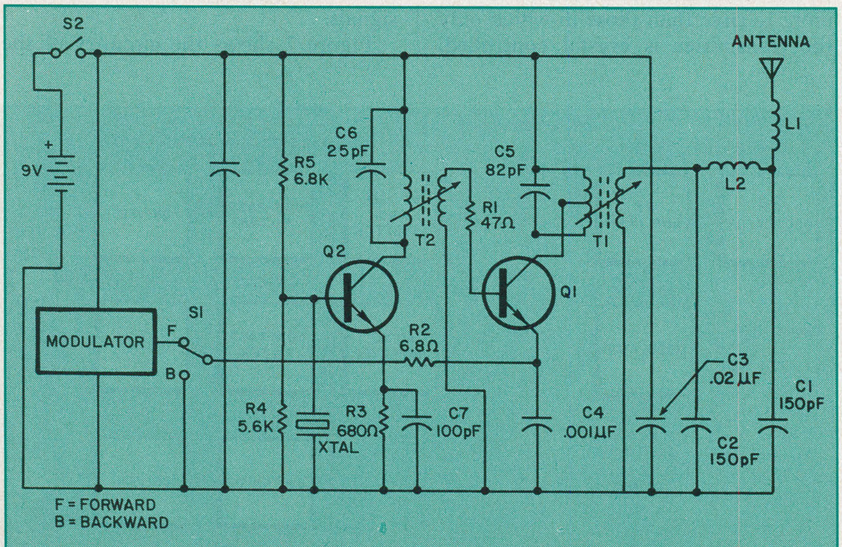


Fig. 7. Radio Shack remote-control transmitter.

provides more versatile operation than a transistor version.

In operation, the 555 oscillates at a frequency determined by *R2* and *C1*. Logic signals at inputs A and B determine which of two values of *R1* is selected, thereby controlling the modulation frequency. The output from the modulator (pin 3 of the 555) should be connected directly to the 68-ohm resistor shown as *R2* in the circuit diagram supplied with the transmitter module. Use the transmitter's 9-volt battery to power the circuit.

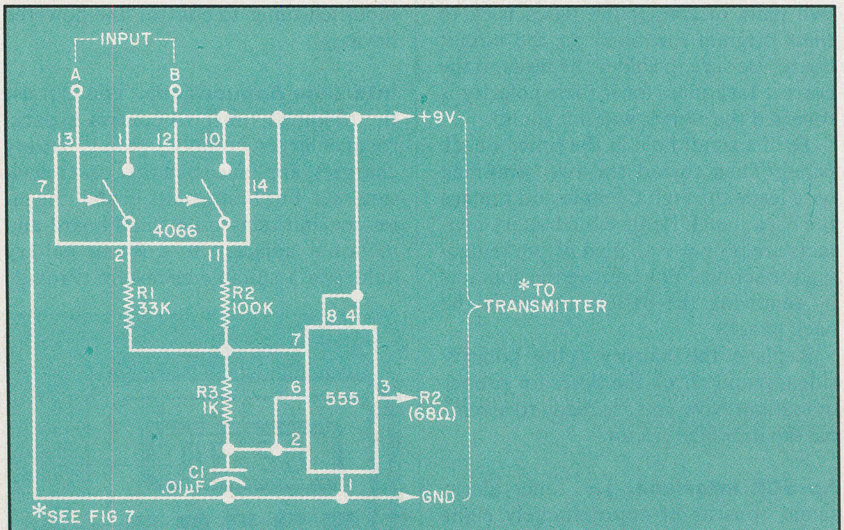
You can easily modify the modulator circuit in Fig. 9 by changing the values of *R1, R2,* and *C1*. For fast carrier-frequency changes, you can substitute potentiometers for *R1* and *R2*. The receiver can also be modified.

Modifying the Receiver. Though the Radio Shack receiver was designed to drive small dc motors, it will also drive other devices. Figure 10, for example, shows how it can be used to drive a pair of *tricolor* LEDs.

It's very simple to connect the LEDs to the receiver module. Be sure to use the two series resistors to limit the current to the LEDs to a safe value.

The truth table in Fig. 9 shows the various color and on-off combinations of the two LEDs for all four logic combinations that can be applied to inputs A and B. Of course, the LEDs will also respond to the various control combinations available from the unmodified transmitter.

Going Further. If you're interested in



INPUT		RCVR OUTPUT	
A	B	M1	M2
L	L	—	RED
L	H	—	GREEN
H	L	RED	GREEN
H	H	RED	GREEN

Fig. 9. External modulator circuit for radio-control transmitter.

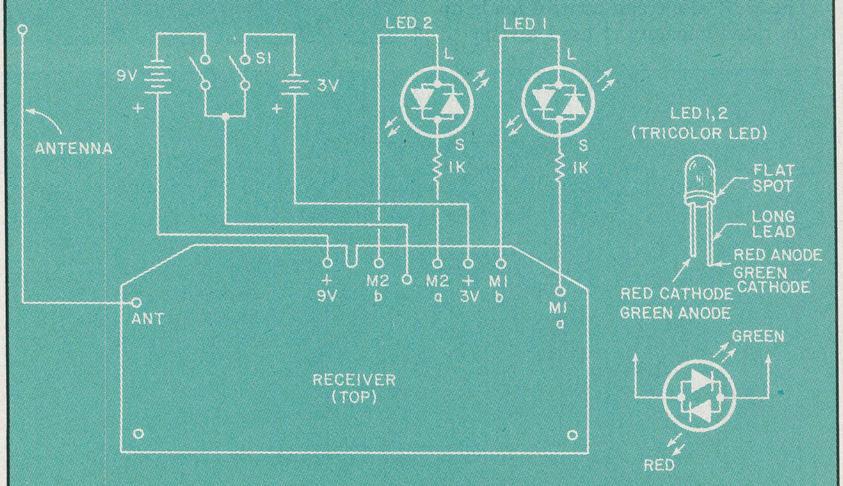


Fig. 10. How to connect LEDs to the receiver.

experimenting with these low-cost radio-control units, by now you may have already thought of other possible modifications. Besides electronic modifications and enhancements, you can physically modify the circuits so they will better fit a pair of small enclosures.

The transmitter is particularly well-suited for physical modification since the carrier modulator and r-f oscillator are at opposite ends of the circuit board. It's a simple matter to cut the board in half and mount the r-f oscillator section on a separate board upon which you can then assemble an IC modulator like the one in Fig. 9. Or you can stack the two halves of the existing board to form a more compact transmitter assembly.

Summing up, this pair of radio-control modules offers many possibilities for experimentation. Be sure to keep in mind the limitations of the receiver and the low power of the transmitter. For applications requiring more range and better noise and interference immunity, spend more money and buy a system that's completely crystal-controlled and includes on-board noise rejection circuitry.

Adding an Output Interface to a Digital Timer

One of the handiest gadgets in my office is a West Bend Electronic Timer™. This compact, crystal-controlled device is a digital countdown timer that sounds an alarm at the conclusion of a preset, user-programmable interval. The interval can range from 1 second to 99 minutes and 99 seconds.

Figure 11 is a pictorial view of the timer's front panel. The unit is operated by keying in the desired interval and pressing START. When the count reaches 00M 00S, the timer emits a rapid series of attention-getting chirps. The chirps will sound for one minute or until the STOP/RESET key is pressed.

The countdown can be halted temporarily by pressing STOP/RESET. The countdown will resume when START is pressed. Pressing STOP/RESET twice clears the display to 00M 00S.

Adding Output Leads. On the back of the timer is a handy clip that allows the unit to be attached to a belt or pocket. It also functions as a desk stand. A magnet in the clip permits the timer to be temporarily attached to a metal surface.

Just below the bottom of the clip is a small Phillips screw. When this screw is removed, the back panel of the timer can be gently pried away from the front panel by inserting a flat screwdriver blade in the continuous, thin slot that separates the two panels. Be sure to pry along the bottom slot near the screw hole to avoid breaking the plastic snap retainers on the inside, upper edge of both panels.

After you lift the back panel away, temporarily set aside the power cell. Note the wires leading to a cylindrical component in the back panel. This is the piezoelectric alerter. The volume of sound that can be delivered by an alerter so small is truly remarkable.

Use a grounded or battery powered soldering iron to remove both alerter leads from the circuit board. Wrap appropriately colored lengths of wrapping wire around the exposed wires of each lead, solder in place, and then solder the two pairs of connection wires back to their original locations on the circuit board. Be sure to solder the leads to the correct locations, for if their polarity is reversed the alerter will not sound.

Drill a small hole in the timer's back panel. Then thread the two wrapping wire leads through the hole and replace the back panel. Be sure the battery contacts are properly aligned *before* replacing the screw. (You can see the contacts by removing the battery cover on the back panel.)

Replace the battery (plus polarity side up) and check the timer for proper operation. Now you are ready to assemble the interface circuit.

An SCR Interface. The timer alarm signal consists of approximately eight bursts per second of 125-microsecond pulses having a 2.4-volt peak-to-peak amplitude. The pulses have a frequency of 4 kilohertz. Figure 12 shows a simple SCR interface that switches on upon arrival of the first pulse and remains on until manually reset.

The SCR alone can control loads up to its rated capacity. I used a relay to provide isolation between the timer and the load and to increase the circuit's switching power. *D1* reduces the possibility of 8-Hz chatter while the timer's alarm is sounding. *D2* protects the SCR from reverse voltage developed across the relay's coil when the reset switch is opened.

Not all SCR's will be reliably triggered by the timer's alarm signal. I had good results with Motorola's SCR1128 and Radio Shack's 276-1067.

Incidentally, you're on your own when you modify a manufactured electronic device such as this timer! Any warranty may be voided. And you must exercise caution to avoid damaging the timer's internal circuitry. You *must* also use caution and follow appropriate safety requirements should you use the modified timer to control line-powered devices.

Interface Applications. You can use the modified timer to control a darkroom enlarger, outdoor lighting, battery chargers, appliances, radios, and television sets. For best results, install the interface and relay on a small board and mount it adjacent to a 9-volt battery holder in a suitable enclosure. Provide

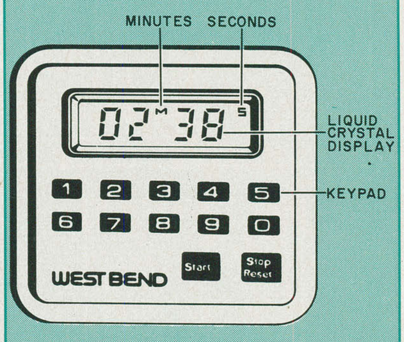


Fig. 11. Front panel of West Bend timer.

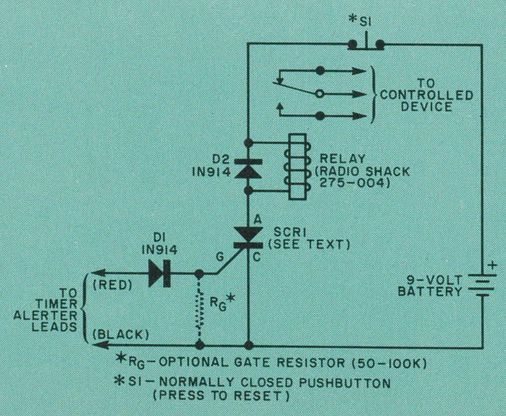


Fig. 12. Output interface circuit to connect to the timer alerter.

suitable plugs and jacks for connecting the timer to the interface and the interface to the device being controlled.

The timer can be clipped to a suitable shoulder or extension on the interface enclosure. Alternatively, you can use adhesive-backed squares of hook and loop fasteners. This will allow you to remove the timer when it's not being used to control the interface.

WARNING: You *must* follow safe wiring procedures if you use this circuit to control devices powered by the household line. Insulate *all* exposed connections. Do *not* exceed the contact ratings of the relay. The timer and interface should *not* be used for any application in which a circuit malfunction might cause injury to people or property.

Going Further. The timer I used is made by The West Bend Company (Box 1976, West Bend, WI 53095). I purchased mine at a department store for about $12.

Recently I've seen advertisements from three other companies showing timers having an almost identical appearance to the West Bend unit, but selling for as much as $29.95! You may be able to modify these and other digital timers with the help of the circuit in Fig. 12. In any case, shop around for the best buy. You may save more than enough to pay for the interface circuit . . . and possibly enough to buy a second timer!

A New Fiber-Optic Breakthrough

For the past decade, several major telecommunications companies and laboratories have engaged in an unofficial contest to establish a world record for the transmission of lightwave communications through the longest length of uninterrupted optical fiber. The signal must not be boosted along its path by the use of lightwave repeaters or regenerators.

The winner of this contest changes every few months and sometimes more often than that. The previous champion, Bell Laboratories, held the record for four months. Recently, however, scientists at Japan's Nippon Telegraph and Telephone announced a new record at a Tokyo conference on lightwave communications. The Japanese scientists successfully transmitted a 445.8-megabits-per-second signal through an optical fiber 134 kilometers (83.27 miles) long!

The optical source for this latest telecommunications achievement was a state-of-the-art distributed-feedback laser emitting at a wavelength of 1.53 micrometers in the near-infrared. At this wavelength, the optical fiber used in the demonstration had an optical attenuation of only 0.23 dB/km.

Incidentally, while the Japanese record may stand for a while, it will inevitably fall before the onslaught of new technological advances. Though the eventual distance record for conventional sources and fibers may not far exceed the recent Japanese figure, new sources and fibers designed to operate farther into the infrared may eventually provide repeaterless links of up to a thousand miles or more!

Device Developments

An Integrated Tone Ringer. Motorola has introduced the MC34012 tone ringer IC, the latest in a rapidly growing family of chips designed for telephone applications. The MC34012 permits the heavy and bulky electromechanical bell assembly in a conventional telephone to be replaced by a piezoelectric alerter.

In operation, the MC34012 is powered by the ac ring signal transmitted through the telephone line. The chip rectifies this signal and generates a square wave that drives the alerter. The chip's internal oscillator and frequency dividers provide a 12.5-Hz warble and tones that alternate between a high and low frequency. The sound volume can be adjusted by means of an external potentiometer between the chip and the alerter.

Telephone circuitry and equipment must be highly reliable and remain unaffected by voltage transients that may arrive through the telephone line. The MC34012 incorporates an internal SCR that fires when the on-chip voltage regulator draws more than 50 milliamperes, thereby protecting the chip's input circuitry.

Though primarily intended for telephone applications, the MC34012 would make an ideal sound generator chip for any kind of electronic, audible warning device. Three different versions of the chip in 8-pin miniDIP packages are available: 400/500 Hz, 800/1000 Hz, 1600/2000 Hz.

When this chip reaches the experimenter market, it should be reasonably priced because it sells for only $1.24 in quantities of 100. As soon as I can obtain a sample, I'll experiment with it and relate the results in a future column. ◇