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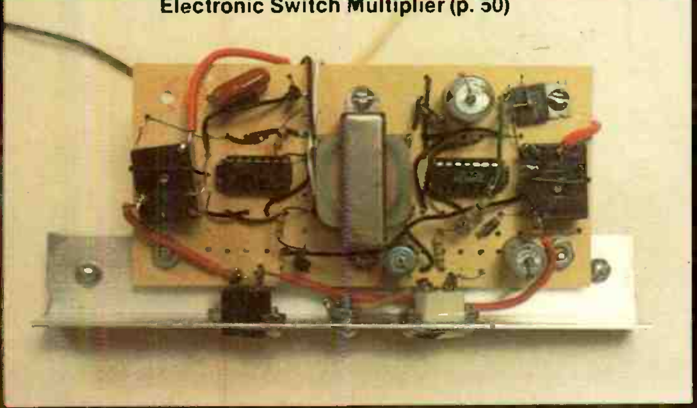

Programmable Appliance Timer (p. 18)

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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

FEBRUARY 1989 VOLUME 6, NUMBER 2

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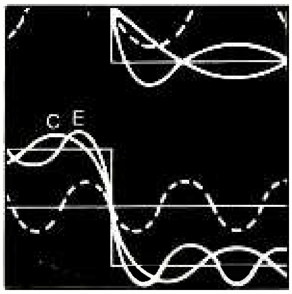

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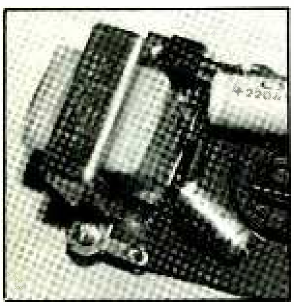

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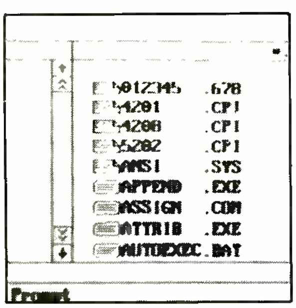

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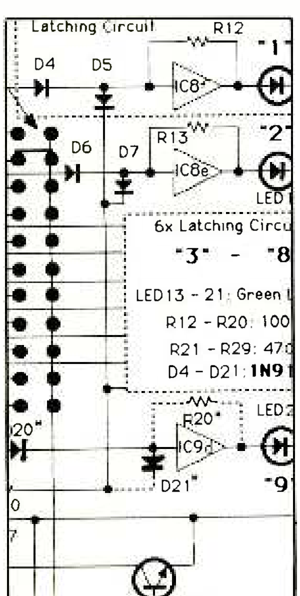

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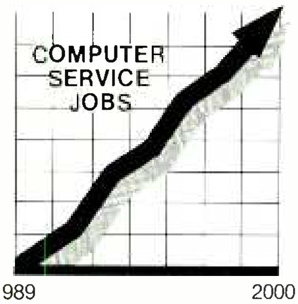

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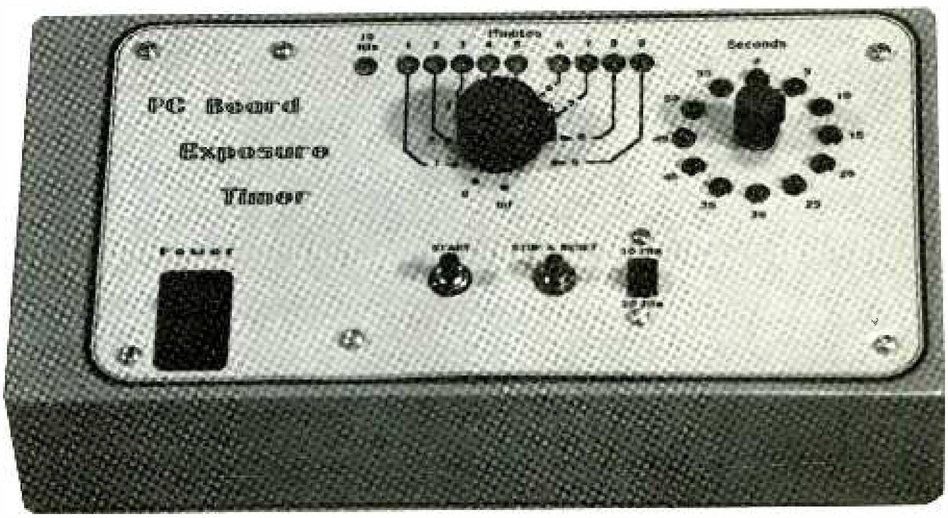
Programmable Appliance Timer

This handy device applies ac line power to any electrical appliance for a preprogrammed period of time up to 20 minutes in 5-second intervals

By Ladislav Hala & Peter Hala



A Programmable Appliance Timer like the one to be described can find application in a wide variety of work environments. Designed to apply ac-line power to an electrical device or appliance for a predetermined period, it offers a range of from 5 seconds to 20 minutes in 5-second intervals. Though the Timer was originally intended for use with exposure lights for photographic printed-circuit processing, we found it to be just as useful in a photography lab, science lab and even in the home kitchen.

Our Appliance Timer is easy to build and operate. It uses printed-circuit construction and only easy-to-get and inexpensive components. Just six switches, each of whose functions is obvious, control all timer operation from turning on power to setting the time interval to starting and stopping a countdown. The Timer can be made to handle loads up to several hundred watts, depending on the power rating of the ac line-switching device used.

About the Circuit

The schematic diagram of the Timer circuit, minus its ac-operated power supply, is shown in Fig. 1. The "heartbeat" of this circuit is 14-stage divide-by-two counter/oscillator *IC1* and frequency-determining components *C1*, *C2*, *R1*, *R2* and crystal *XTAL*. A crystal is used in this circuit for more stable operation than is usually possible with RC elements. Because the crystal is so precise, there is no need for an expensive frequency-counter/ display system.

Two functions are performed by *IC1*. One is generation of a series of pulses whose frequency is that of the crystal; the other is division of the basic oscillator frequency to provide a low-frequency output. Since the crystal specified in the Parts List oscillates at a frequency of 32,768 Hz and the 14-stage binary counter divides by 2^{14} times (or 16,384), the output from *IC1* at pin 3 is 2 Hz. Because crystals are rarely cut to an exact guaranteed frequency, trimmer capacitor *TC1* may be needed in the frequency-determining network to allow you to adjust the oscillator's frequency to exactly 32,768 Hz with the aid of a frequency counter. For less-demanding split-second timing, *C1* and *C2* can be without optional trimmer *TC1*.

Counter *IC2*, clocked at CLK input pin 14 from the output of *IC1*, delivers a pulse every 5 seconds at pin 12. (See Fig. 2 for pinouts of some 4000-series ICs used in this project.) The disadvantage of using a 4017 counter chip is that it divides by only 10 but division by 12 is required in this project. The solution is to use two 4017s, connecting them into the circuit as shown for *IC3* and *IC4* in Fig. 1. Power dissipation is equally shared by the two counters by having each drive only six of the 0 through 55 second light-emitting diodes (*LED1* through *LED12*).

The purpose of the counter is simple. Resetting both *IC3* and *IC4* so that the Q0 outputs at pin 3 are at logic high, the next clock pulse arriving at the counter arrangement changes the states of Q0 and Q1 (the latter at

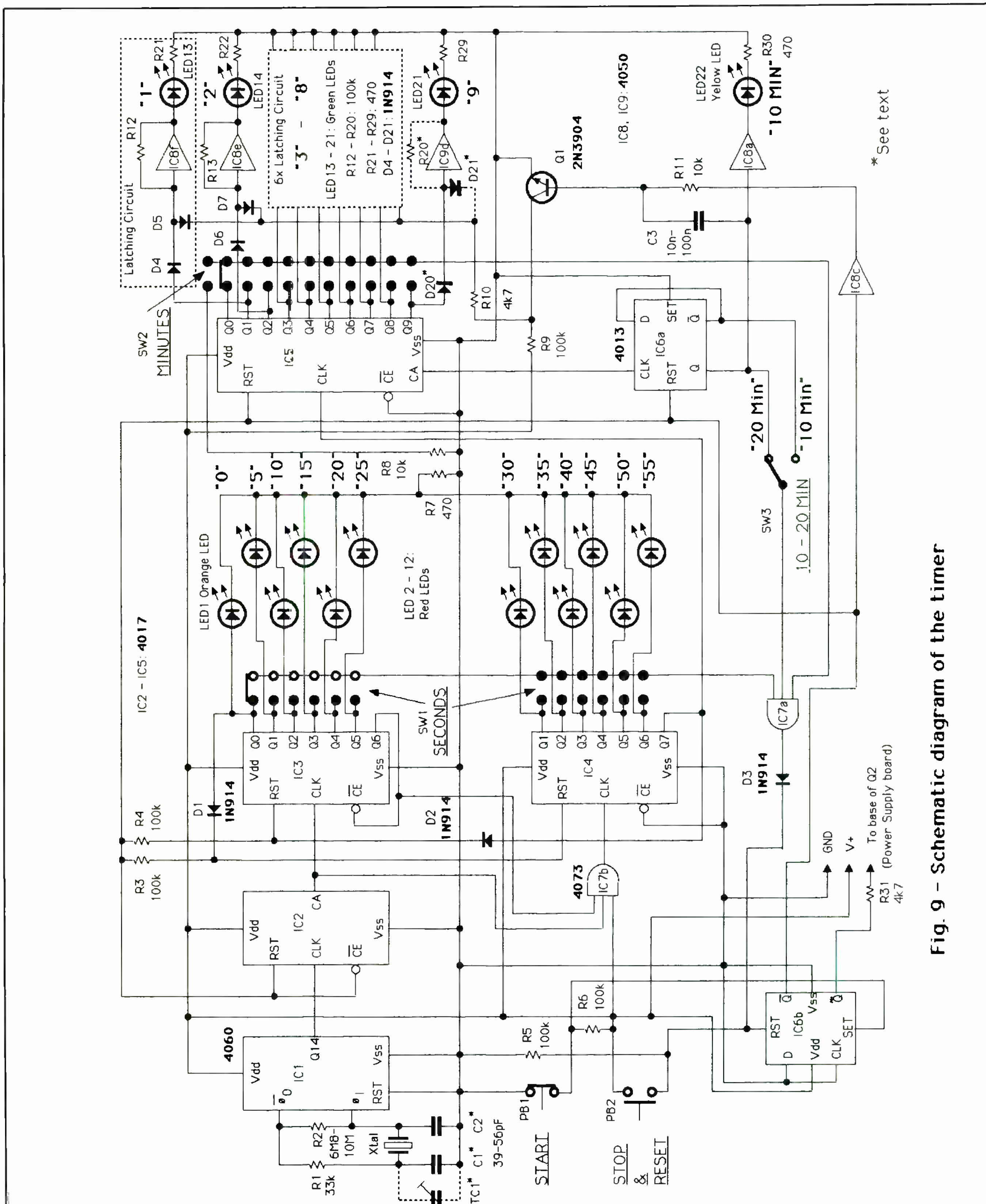


Fig. 1. Schematic diagram of basic counting circuits.

PARTS LIST

Semiconductors
D1 thru D21—1N914 or similar diode
D22 thru D26—1N4002 or similar rectifier diode
IC1—CD4060 14-stage divide-by-12 counter/oscillator
IC2 thru IC5—CD4017 Johnson counter
IC6—CD4013 dual D flip-flop
IC7—CD4073 3-input AND gate
IC8,IC9—CD4050 hex buffer
IC10—78M05 or 7805 fixed +5-volt regulator
IC11—MOC3011, MOC3021 or similar diac optical coupler
LED1—Orange light-emitting diode
LED2 thru LED12—Red light-emitting diode
LED13 thru LED21—Green light-emitting diode
LED22—Yellow light-emitting diode
LED23—Light-emitting diode (optional—see text)
Q1,Q2—2N3904 or similar npn silicon transistor
TR1—IT48 or similar 8- or 10-ampere, 2- or 4-mode triac
Capacitors
C1,C2—39- to 56-pF ceramic disc
C3—0.01- to 0.1-µF ceramic disc
C4—1,000-µF, 15-volt electrolytic
C5—1,000-µF, 16-volt electrolytic
C6—0.01- to 0.1-µF 400-volt ceramic disc, Mylar or polypropylene
C7—0.01-µF, 400-volt ceramic disc
TC1—56-pF or higher trimmer capacitor (optional—see text)
Resistors (¼-watt, 5% tolerance)
R1—33,000 ohms
R2—6.8 to 10 megohms
R3 thru R6,R9,R12 thru R20—100,000 ohms
R7,R21 thru R30—470 ohms
R8,R11—10,000 ohms
R10,R31—4,700 ohms
R32—1,000 ohms (see text)
R33—33 ohms
R34—1,000 ohms
R35—330 ohms (see text)
R36—470 ohms (see text)
R37—39 ohms (see text)
R38—See text
Miscellaneous
PB1—Normally-closed, momentary-action spst pushbutton switch with black button (Radio Shack Cat. No. 275-1548 or similar)
PB2—Normally-open, momentary-action spst pushbutton switch with red button (Radio Shack Cat. No. 275-1547 or similar)
SW1—12-position single-pole non-shorting rotary switch (Radio Shack Cat. No. 275-1385 or equivalent)
SW2—11-position single-pole non-shorting rotary switch (Armaco No. SE 5110 (S5151) or Radio Shack Cat. No. 275-1385 12-position switch)
SW3—3pdt or dpdt slide or toggle switch
SW4—Spst or spdt rocker or toggle switch
T1—12.6-volt, 300-mA power transformer (Radio Shack Cat. No. 273-1385 or similar—see text)
Printed-circuit boards or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for all DIP ICs; suitable enclosure (see text); chassis-mount, 3-conductor ac receptacle; three-conductor ac line cord with plug; 12-volt dc relay with suitably rated contacts (Radio Shack Cat. No. 275-247) to use in place of triac drive circuit (optional—see text); lettering kit (optional—see text); rubber grommet; plastic cable clamp or tie; machine hardware; hookup wire; solder; etc.

pin 2) to low and high, respectively. The state at Q0 of *IC4* remains unchanged because Q6 of *IC3* (pin 7) is still low, which prevents the clock signal from passing through the *IC7B* AND gate and reaching the pin 14 CLK input of *IC4*.

The "ring" counting of *IC3* continues until the Q6 output at pin 5 goes high. At this point, the clock-enable (CE) input at pin 13 of *IC3* disables the input clock signal so that *IC3* ceases counting until this chip is reset. At the same time, *IC7B* is activated so that is passes the clock signal into *IC4*. Hence, *IC4* begins to count the input pulses.

When Q7 of *IC4* at pin 6 goes high, its positive-going pulse edge causes *IC3* to reset so that Q0 of *IC3* becomes high. In turn, this causes *IC4* to reset because the reset input of this IC (pin 15) is connected to *IC3*'s Q0 output. The cycle now repeats.

There is no need to buffer the outputs of the 4017 chips that drive LEDs in this circuit because the 10 milliamperes drawn by each LED decreases the output potential from 10 volts to 8 volts nominal, which is still perceived by the ICs as a high logic state, with a safe margin of at least 3 volts above the normal logical high potential.

Clocking pulses for MINUTES counter *IC5* are taken from the Q7 output at pin 6 of *IC4*. This pulse is about 25 microseconds in duration and is long enough to clock *IC5* via its CLK input at pin 14. With MINUTES counter *IC5*, all 10 count stages are used to drive 10 separate LEDs to indicate elapsed time in minute (60-second) intervals. Since only one of the Q0 to Q9 outputs is active at any given moment, a latching system that converts a "dot" display into a bar-type display was needed.

At least eight latching circuits are required, each implemented as an IC buffer stage, resistor and two diodes. This arrangement is illustrated by *D4*, *D5*, *IC8F* and *R12* at the top-right in Fig. 1.

The IC buffer begins in the reset state and Q0 through Q9 outputs of *IC5* at logic low. (Notice that no latching circuit is used for the Q0 output from *IC5* because it is not necessary to indicate 0 minute.) The inputs to the buffers are held at logic low by positive feedback from the output to the input of the buffers through resistors *R12* through *R20*.

When the first minute has been counted down, the Q1 output at pin 2 of *IC5* becomes high and, in turn, drives its associated IC buffer high through diode *D4*, and minute 1 light-emitting diode *LED13* lights.

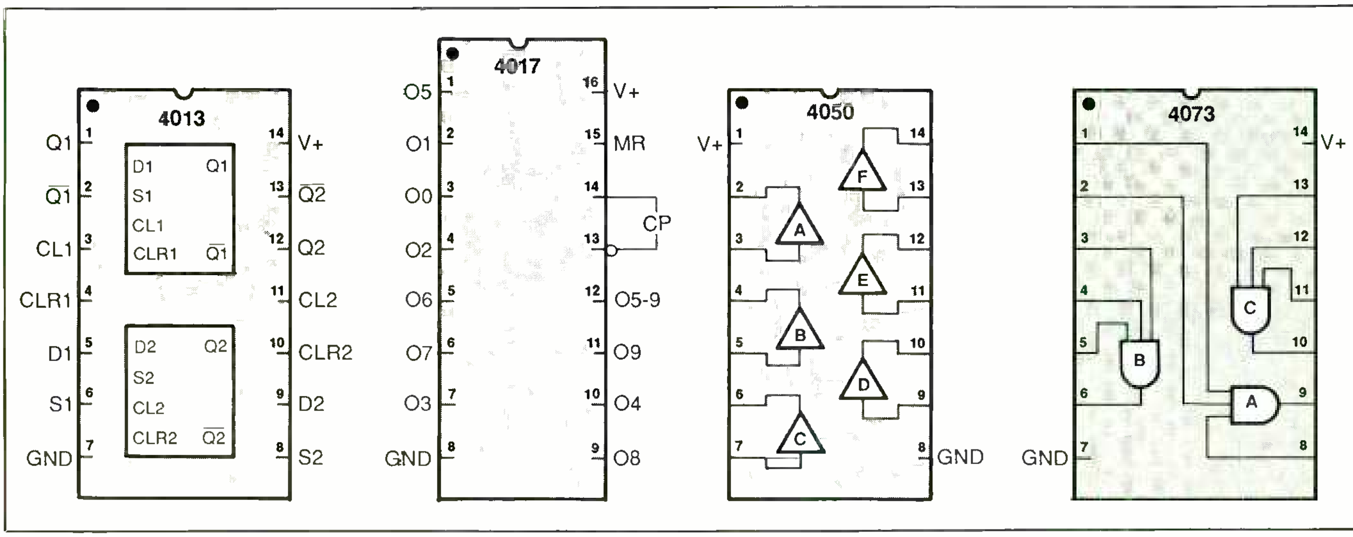


Fig. 2. Pinouts of some 4000-series CMOS ICs used in this project.

When the second minute has been counted down, the Q1 output of *IC5* goes low and the Q2 output at pin 4 goes high, this time lighting minute 2 *LED14*. Latching action keeps the minute 1 LED lit as well. As each minute counts down, the current LED remains on and the next minute LED in numerical order lights.

It is important to avoid loading down the IC buffers by too much because a decrease in the output potential from 10 to 6 volts due to a LED being turned on might not ensure proper latching. The compromise of a 10-milliampere current produces sufficient light without decreasing the output voltage too much.

Reset action of the latching circuitry is accomplished by forward-biasing *D5*, *D7*, *D9*, *D11*, *D13*, *D15*, *D17*, *D19* and *D21*. It is initiated by cutting off transistor *Q1*. Normally, when *Q1* is cut off, these diodes are reverse biased and do not conduct. When *Q1* conducts, it puts the cathodes of these diodes at essentially ground potential, allowing them to conduct and putting the inputs to the buffers at less than 1 volt. This resets all latched buffers. The buffers will remain at logic low due to the latching effect of the feedback resistors.

To provide a 20-minute timing range from the project, divide-by-2 D flip-flop *IC6* is used. This chip's CLK input at pin 11 is driven by the CA (carry) output at pin 12 of *IC5*. The Q output at pin 1 of *IC6* drives buffer stage *IC8A* to light yellow 10-minute *LED22*.

When the Timer is used to control power to an electrically operated device like a printed-circuit-board exposure light (the original purpose in designing the project), three-input AND gate *IC7A* is used. The output of this gate goes high only when all three inputs to it are also high.

Input pins 13 and 11 tie directly to the rotor (common) contact of the SECONDS and MINUTES switches, while input pin 12 goes to 10/20 MIN switch *SW3*. With this arrangement, the switches can be set to a predetermined number of minutes (*SW2* and *SW3* and seconds (*SW1*) and when the all LEDs for the times selected are on, the output of AND gate *IC7A* will go to logic high.

Once the AND gate's pin 10 output goes high, D flip-flop *IC6B* is reset. Acting like an RS flip-flop, this stage's Q output at pin 1 goes low and its Q output at pin 2 goes high. The latter state resets counters *IC2* through *IC6A* and cuts off transistor *Q1* to reset the latching circuitry.

Resetting of *IC2* is important to obtain an exact 5-second initial interval when the Timer is started again by briefly pressing and releasing START pushbutton switch *PB1*. (Any timing sequence can be interrupted and the circuit reset at any time by briefly pressing and releasing STOP/RESET pushbutton switch *PB2*.) The pin 2 Q output of *IC6* remains high until START switch *PB1* is pressed and released. This assures that the clock count is prevented from passing through *IC2*.

Power for the Fig. 1 circuit is provided by the ac-operated circuit shown in Fig. 3. Note also that this circuit contains the elements that are used to switch on and off ac line power to the electrical device being controlled. These elements are shown in the primary side of power transformer *T1* and include all but POWER switch *SW4* and the ac line cord's plug.

Closing *SW4* applies 117-volt ac line power to the primary of *T1*. At *T1*'s secondary appears about 12.6 volts ac, which then converted to pulsating dc by bridge-rectifier *D22* through *D25*and is finally converted to pure dc by filter capacitor *C4*. The +12-volt or so potential across *C4* is now reduced and regulated down to

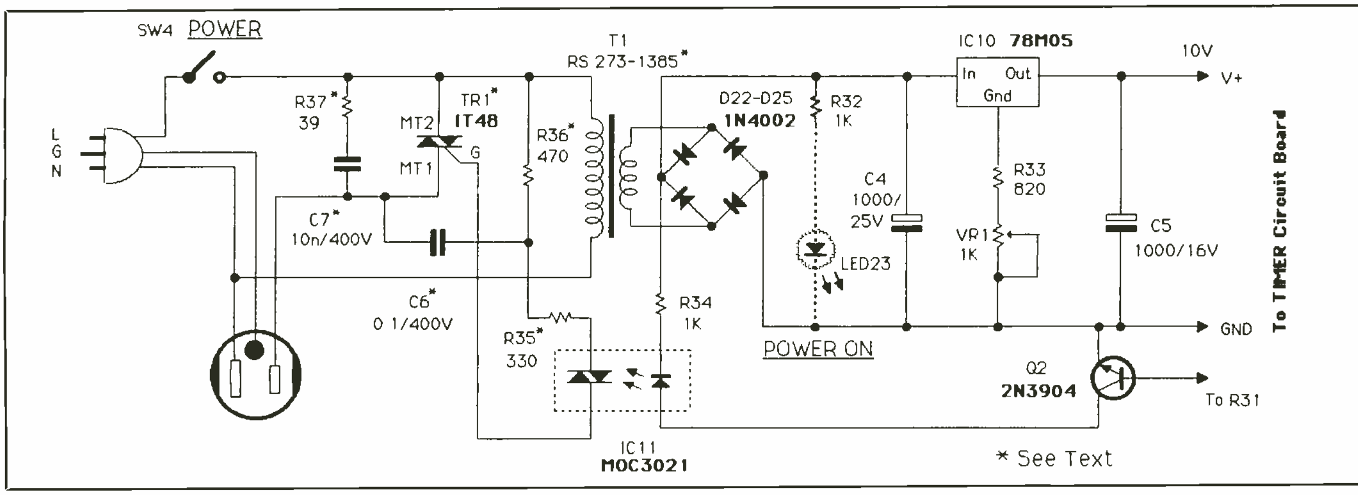


Fig. 3. Schematic diagram of power supply and load controller circuits, the latter built around a triac.

+10 volts by voltage regulator *IC10.*

Note that *IC10*'s ground terminal is not connected directly to ground as is usually the case with three-terminal fixed-voltage regulators. Instead, it goes through fixed resistor *R33* and trimmer potentiometer *VR1* that allow the output of the regulator to be adjusted for a fairly precise +10 volts of regulated dc instead of being a fixed +5 volts had the ground terminal been connected directly to ground. Once the regulated +10 volts is obtained, it is further filtered by *C5* before being delivered to the Fig. 1 circuitry.

Notice that POWER *LED23* and current-limiting resistor *R32* are shown phantomed in Fig. 2. This is because these two components are optional. Though you may wish to install them in your project, there is really no need for a POWER indicator since at least one of the other 22 LEDs in the project will be on whenever power is turned on.

Transistor *Q2* controls triac *TR1* through optical coupler *IC11* in response to the conditions of the Fig. 1 circuit. The triac, in turn, controls power to the electrical device plugged into the ac receptacle shown at the lower-left in the schematic.

The value of resistor *R34* can be greater than that indicated in the schematic and specified in the Parts List. Just keep in mind that it must be low enough to ensure proper triggering of *TR1*. (The minimal current for the LED in the MOC3020 optocoupler of 15 milliamperes or less is typically required for adequate diac control of the triac. For the MOC-3021 or MOC3023, the current is even smaller.)

The *R36/C6* and *R37/C7* component pairs are used for "snubbing" off *IC11* and *TR1*. Generally, inductive loads require these components. If a noninductive load is being switched, these components can be omitted. If you are not sure what kinds of loads will be switched by the project, it is best to build these resistors and capacitors into the Timer. However, if you omit these components, you must raise the value of *R35* to about 1,000 ohms.

If you prefer not to use a triac as the ac-voltage switching element for the load, you can use the simpler power-supply circuit shown in Fig. 4. This circuit replaces the components on the primary side of the power transformer and the optical isolator with a simple electromechanical relay. The remainder of the circuit—that on the secondary side of the transformer—is identical in both circuits.

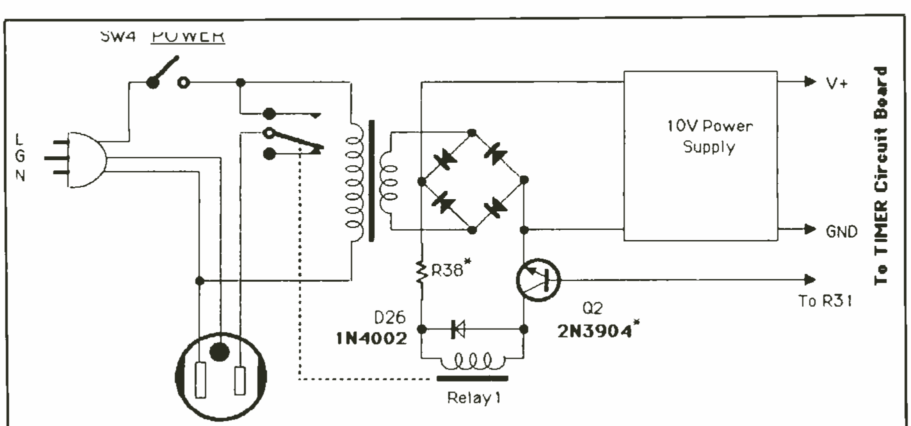


Fig. 4. An alternate controller-circuit arrangement that replaces the triac and its associated components in Fig. 2 with the simpler relay arrangement shown here. The basic power-supply circuitry remains the same.

If you do decide to go with the Fig. 4 circuit, you must upgrade the power-handling capability of the *Q2* transistor so that is has sufficient current and power ratings to handle the additional load presented by the relay's inductive coil. Also, select a 12-volt dc relay that consumes as little power as possible and whose contacts are hefty enough to handle any reasonable load that might be plugged into the control receptacle. A good choice of relays might be the Radio Shack Cat. No. 275-247.

Since the potential across *C4* is 16 to 18 volts, it is imperative that *R38* be included in the Fig. 4 circuit. You calculate the value of resistance to use for *R38* using the formula: $R = (V+ - V_{relay})/I_{relay}$. In this formula, V+ is the supply potential, V_{relay} is the dc voltage rating of the relay's coil and I_{relay} is the dc current rating of the relay's coil. This formula gives only approximate results because it does not take into account the internal resistance of the power supply. For example, if you load the power supply, the voltage across its output decreases as a result of internal resistance. Even so, the figure obtained will be a good starting point from which to work.

You can also use in place of *R38* a zener diode whose zener voltage is equal to the required voltage drop. Using either *R38* or a zener diode, you must calculate the power dissipation of the device and select a device that has no less than three times the rating value of that calculated.

Diode *D26* shown connected across the relay's coil in Fig. 3 is included in the circuit to protect transistor *Q2* from damage due to the collapse of the electromagnetic field and resulting induced high-voltage spike that occurs when power is removed from the relay.

Construction

There is nothing critical about component layout. Therefore, any traditional wiring technique can be used

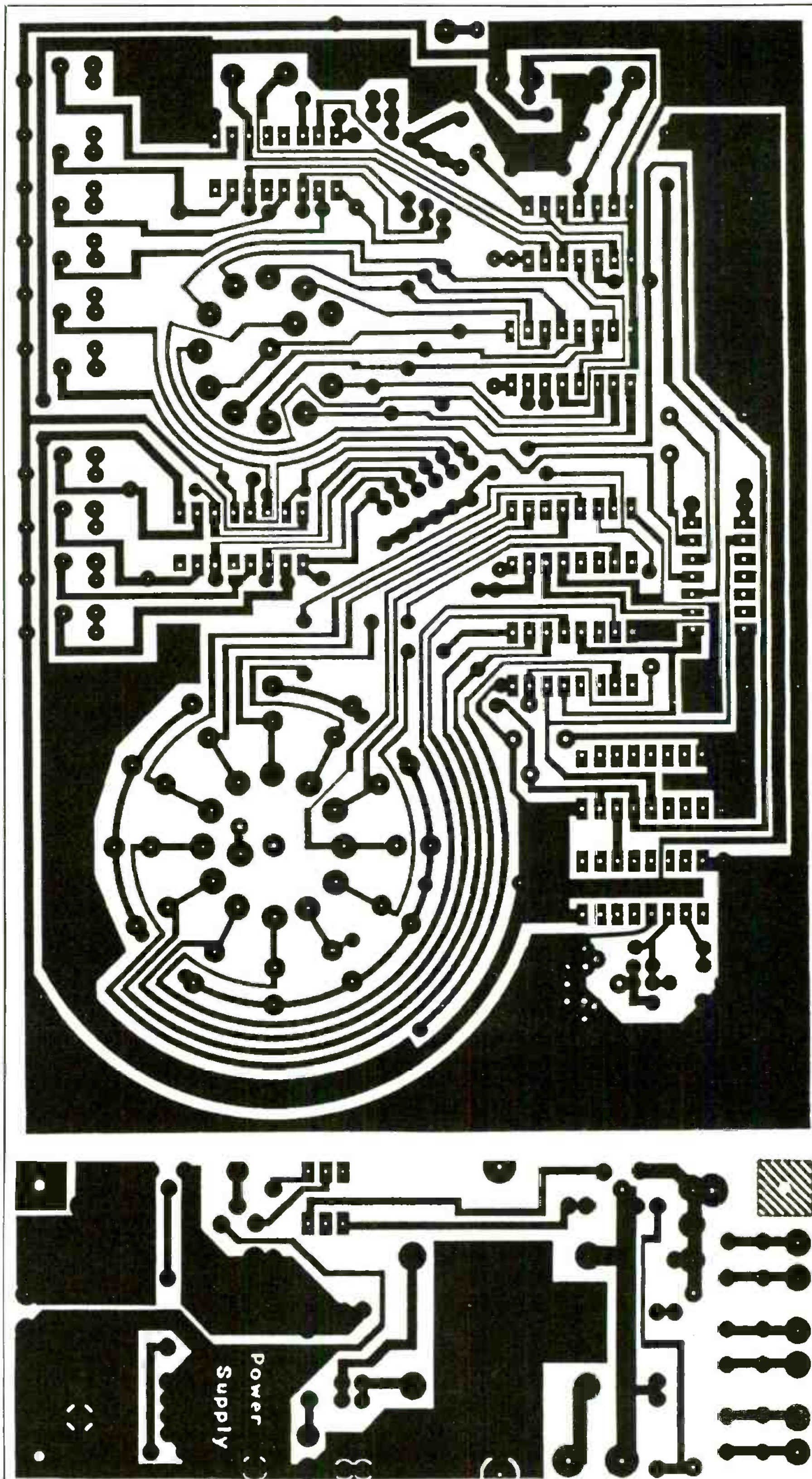


Fig. 5. Actual-size etching and drilling guides for the counter and power-supply/controller printed-circuit boards.

to assemble the Timer. If you wish to have the layout shown for the front panel in the lead photo, it is best to use printed-circuit construction. If you prefer not to make your own pc boards, perforated boards with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware can be used in place of the pc boards. Of course, if you wish simplified construction and no mis-wired connections, use of pc boards is highly recommended. Regardless of the construction technique selected, it is a good idea to use sockets for all DIP ICs. From here on, we will assume printed-circuit construction.

Two printed-circuit boards are called for in this project. One accommodates all components shown in Fig. 1, the other most of the components shown in Fig. 3. Fabricate these boards using the actual-size etching-and-drilling guides shown in Fig. 5. When both boards are ready, temporarily set aside the smaller one and place the larger one on your work surface oriented as shown in the Fig. 6 wiring guide.

Begin populating the board by installing and soldering into place the IC sockets. Do *not* install the ICs in the sockets until after preliminary voltage checks have been made and you are sure the project has been properly wired. Once the sockets are in place, install and solder into place the jumper wires (identified with the letter "J"). You can use short lengths of bare solid hookup wire for jumpers that are shorter than 1 inch but you must use *insulated* hookup wire for any longer jumpers. When you are finished installing the jumpers, count them; there should be 21 in all.

Next, install the resistors, noting that *R13* through *R16*, *R19* and *R20*) mount upright and that *R8*, shown phantomed just below the IC9 socket, mounts on the *solder* side of the board *after* switch *SW2* has been installed. Follow up with the capacitors and then the diodes. Note that, like *R8*, *C3* mounts on the bottom of the board, its leads tack-soldered to the indicated traces as shown. Also, make absolutely certain that each diode is properly oriented before soldering its leads to the pads on the bottom of the board. Install the transistor, making sure it is properly based before soldering its leads into place. Using heat judiciously, install and solder into place the crystal in the location indicated. Trim any excess lead length after soldering.

Plug the lugs of rotary switches *SW1* and *SW2* into the specified holes in the board and solder into place. Then bend the leads of *R8* as shown and trim each as needed. Tack-solder both leads to the indicated pads on the bottom of the board.

Drill a ⅜-inch or slightly larger hole through a piece of plastic, sheet metal or stiff cardboard. Place this on the shaft of either *SW1* or *SW2* and loosely secure it in place with the switch's hardware. Measure the distance between the bottom of this and the top of the circuit-board assembly. This measurement is how far the bottoms of the light-emitting diodes must be from the top surface of the circuit-board assembly. Remove and discard the plastic, sheet metal or cardboard. If you use LEDs that have flanges around their bases, the measurement applies to the distance between the board and the *tops* of the flanges.

Measure and mark the leads of all LEDs with the measured dimension. It is best to use a permanent black or other dark-color marker for this. Then plug each LED in turn into a pair of holes up to the marks, making sure it is properly polarized, and solder its leads to the copper pads on the bottom of the board. Trim away any excess lead lengths. When all LEDs have been installed, orient them so that they are perpendicular with the board's surface.

If you build your circuitry on a perforated board, it is best to install the LEDs in the front panel of the selected enclosure and interconnect their shortened leads with the appropriate points in the circuit with lengths of hookup wire. If you do this, be sure to insulate all connections with small-diameter heat-shrinkable or insulating plastic tubing.

Strip ¼ inch of insulation from both ends of seven 8-inch lengths of insulated hookup wire. Do the same for three 4-inch lengths. If you are using stranded hookup wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. Plug one end of the 8-inch wires into the holes for the switches and solder into place. Then plug one end of the shorter wires into the TO BASE OF Q2, GND and V+ holes and solder these into place as well. The other ends of these wires will be connected later. Meanwhile, set this circuit-board assembly aside.

Place the smaller printed-circuit board in front of you in the orientation shown and refer to Fig. 7 for wiring instructions. Begin wiring this board by installing and soldering into place first the resistors and then the capacitors and diodes. Make sure the electrolytic capacitors and diodes are properly oriented before soldering their leads to the copper pads on the bottom of the board.

Install and solder into place a six-pin DIP socket in the IC11 location. (If you cannot find a six-pin socket, you can substitute Molex Soldercons®.) Plug the optoisolator into the socket, making sure that no pins overhang the socket or fold under between the optoisolator and socket.

Install and solder into place trimmer control *VR1* as shown. Then plug the leads of *Q2* into the appropriate holes and adjust the height of this transistor so that the bottom of its case is about ¼ to ⅜ inch above the surface of the board and solder into place. Note that both the voltage regulator (*IC10*) and triac (*TR1*) have metal tabs protruding from the tops of their cases. These tabs must be facing *away* from the center of the

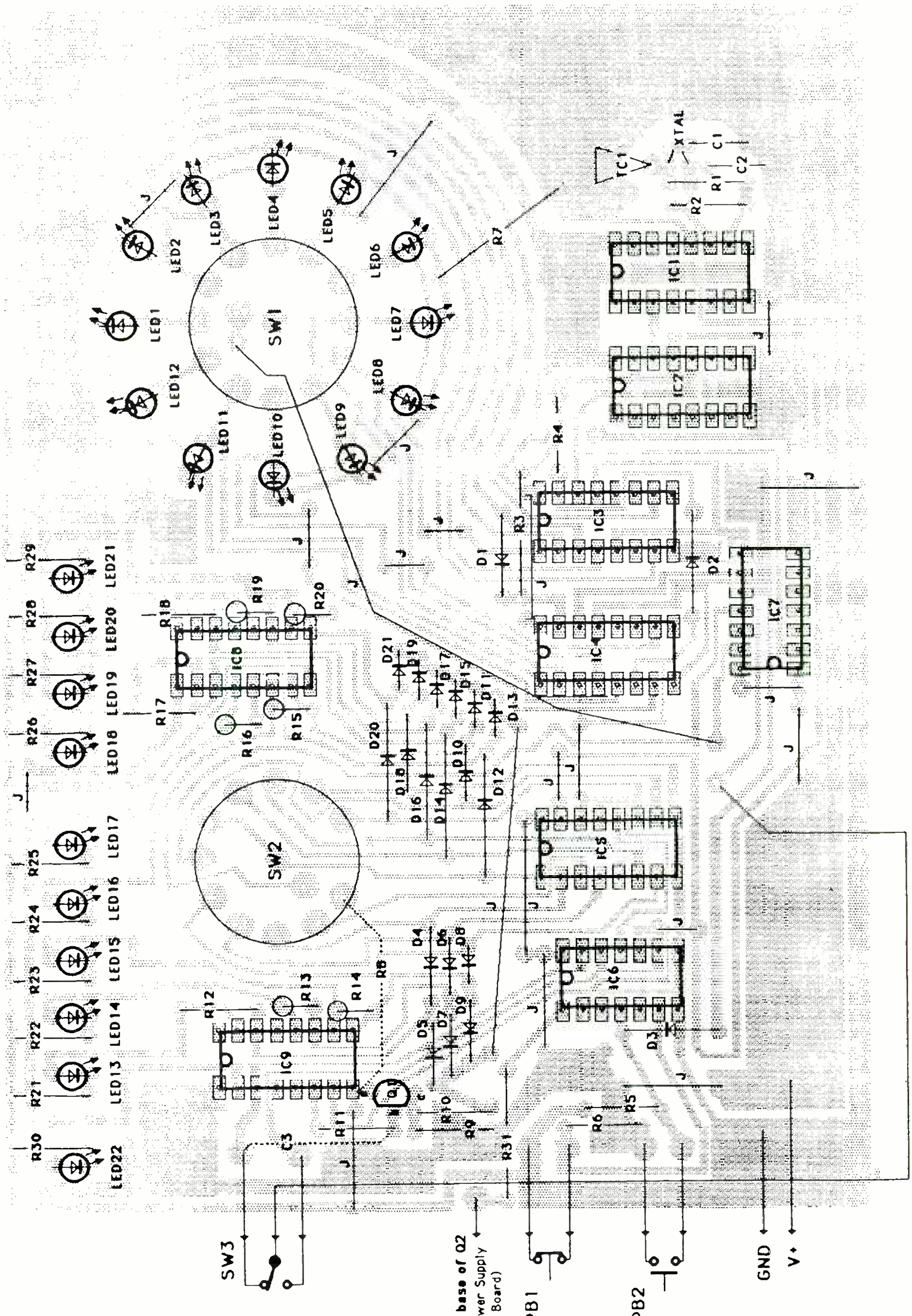


Fig. 6. Wiring guide for counter board.

board when these devices are installed on the board in their respective locations. After plugging the pins of the devices into the holes in the board, push down until the points where the pins widen are flush against the board and solder all pins into place. Trim away excessive pin lengths.

If you have decided to incorporate POWER *LED23* into your project, mount it in place so that the bottom of its case (or the top of the flange around the bottom of its case if you are using flanged LEDs) is ½ inch away from the top surface of the board. Make certain that the LED is properly oriented before soldering it into place. Also, install and solder into place resistor *R32*.

Power transformer *T1* specified in the Parts List should be the old Radio Shack type rated at 12.6 volts and 300 milliamperes with solder lugs on it. The new transformer under the same catalog number from Radio Shack has pc-mount lugs. It is not suitable for this project because it operates hot when loaded by as little as 50 milliamperes. If you cannot locate the older type of transformer, consider using one with better ratings from a different manufacturer. If the transformer is too large to fit on the circuit board, mount it off the board and run wire leads from it to the appropriate holes in the board.

Strip ¼ inch of insulation from both ends of two 6-inch stranded hookup wires. Use 16-gauge or heavier wires here. Tightly twist together the conductors at both ends and sparingly tin with solder. Plug one end of one of these wires and the other outer conductor of the line cord into the *lower* 120V IN hole and solder into place. (If necessary, enlarge the hole at this location to accommodate both wires.) Then plug one end of the other wire into the hole labeled 120V OUT and solder into place.

An enclosure with interior dimensions of 10 × 5 × 2½ to 3 inches will accommodate both boards and has sufficient panel space for the switches and LEDs. Such an enclosure is not commonly available. Unless you can find a chassis box of the required dimensions, you will have to fabricate an enclosure from ¼-inch-thick plywood or Masonite or 16-gauge or so sheet aluminum or steel.

When the enclosure is ready, use the actual-size artwork in Fig. 8 to mark the centers of the holes to be drilled in the top panel for the LEDs, switches and mounting holes for the circuit-board assemblies. After transferring the hole-center locations to the top panel of the enclosure, set aside the artwork and drill appropriate size holes in each marked location. If you are using a rocker-type POWER switch and slide-type 10/20 MIN selector switch, square up the holes as needed.

Continue machining the enclosure by cutting the opening for and

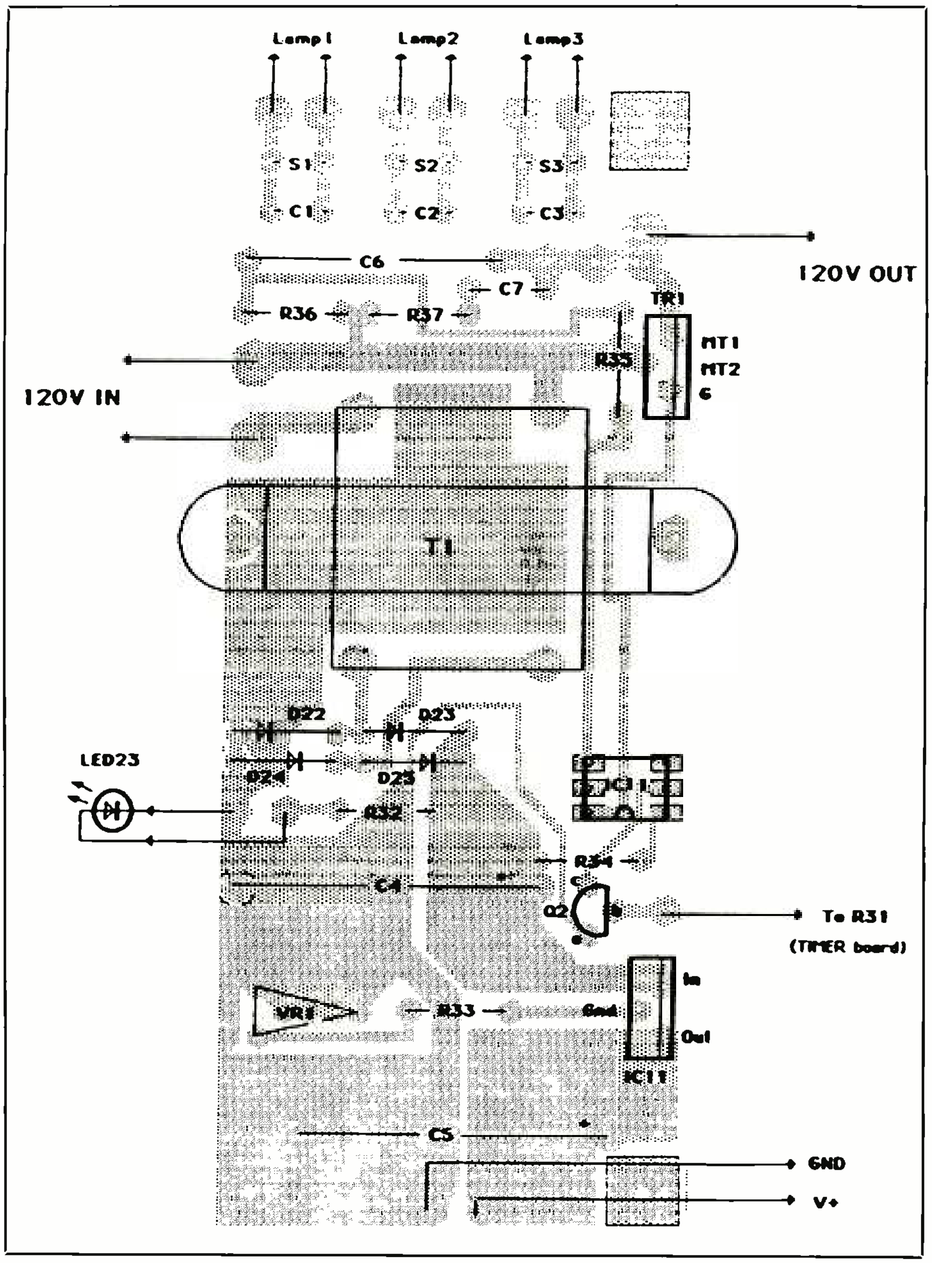


Fig. 7. Wiring guide for power-supply/controller board.

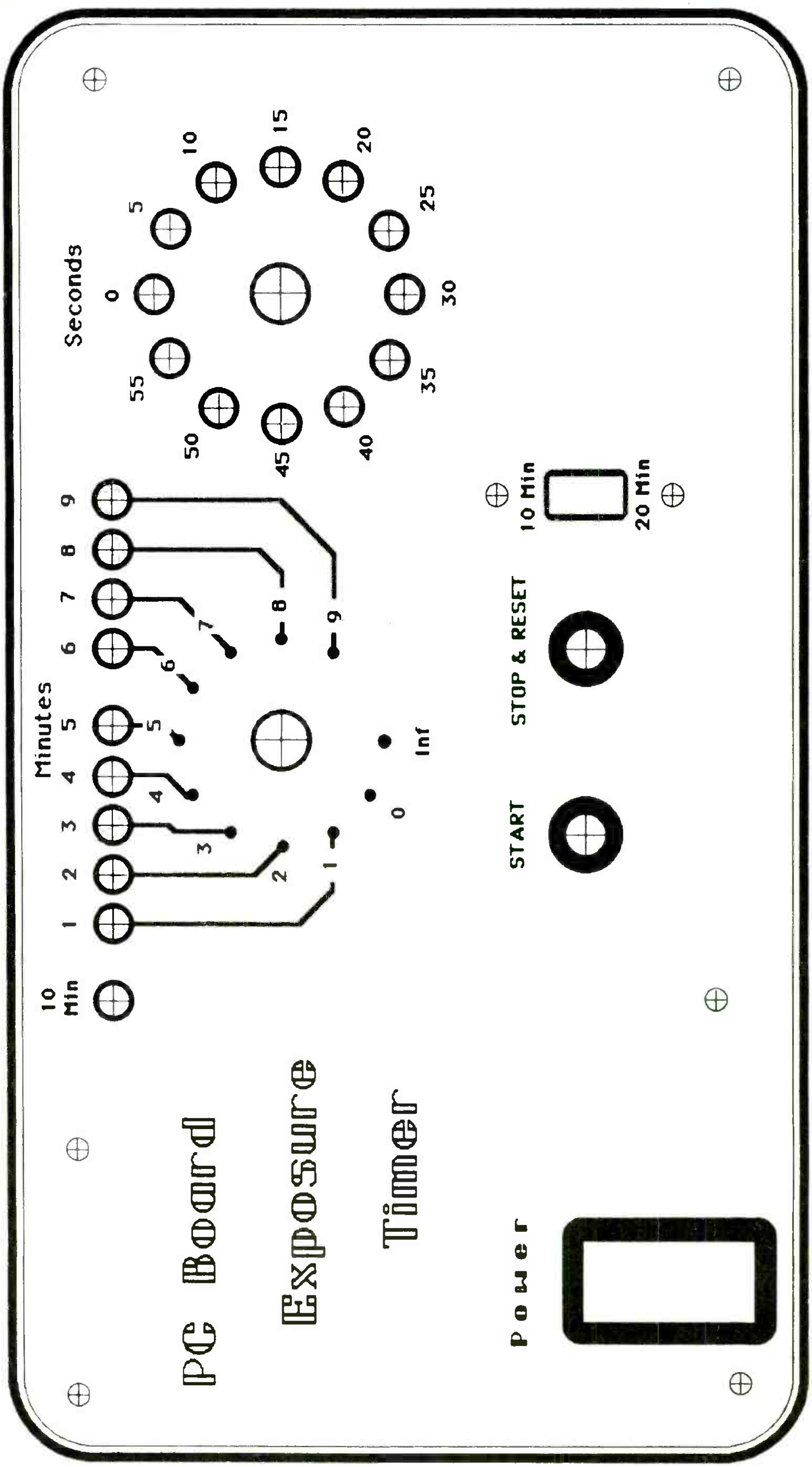


Fig. 8. Actual-size front-panel template for project. Use this as a drilling template and a same-size photocopy as the actual front panel itself.

mounting the chassis-mount ac receptacle on the end panel nearest the POWER switch. Then drill an entry hole for the ac line cord through the rear panel near the receptacle. If the panel is metal, deburr the edges of all holes and place a rubber grommet in the line-cord entry hole.

If you wish, finish and paint the enclosure. When the paint dries, use the Fig. 8 artwork to make an overpanel for the front panel of the enclosure. One way to do this is have Fig. 8 reproduced actual-size as a positive or negative film transparency. Punch all LED, switch and machine-hardware holes as needed. Then use contact cement or spray-on art adhesive to cement the transparency to the front panel of the enclosure.

If you prefer to label the front panel yourself, use Fig. 8 as a guide and apply dry-transfer letters in the appropriate locations. Then spray two or three light coats of clear acrylic over the entire panel to protect the labels.

When the enclosure is ready, route the line cord through its entry hole into the enclosure. Separate the three conductors a distance of 6 inches. Tightly twist together the fine wires in each conductor and sparingly tin with solder.

Mount the switches in their respective locations. Make sure the normally-open and normally-closed pushbutton switches mount in STOP/RESET and START holes, respectively. Then mount the ac receptacle on the end panel. This done, solder one outer conductor of the ac line cord to one lug of the POWER switch and secure the center conductor to the ac receptacle via the screw for the center contact.

(Continued on page 88)

Pulse Circuits

What they are, how they work and where they are used in electronic equipment

By Joseph J. Carr

Though you may not recognize them as such in some cases, pulse circuits are very common in modern electronic equipment. Television, for example, would produce only scrambled images without pulses to synchronize the receiver to the studio camera. Too, radar wouldn't be possible without pulses, Morse code CW transmissions are in reality crude pulses, and digital circuits are inherently pulse circuits.

Pulses can be regular or irregular in shape. They can be periodic, aperiodic or single-event. They might look like a distorted sine wave or have a completely non-sinusoidal shape. Consequently, understanding the basic nature of pulses will help you to better understand pulse circuitry and even aid in furthering your understanding of other circuits.

Though pulse circuits once were of interest to a select few people, the widespread use of digital electronics and the need for analog and digital devices needed to generate pulses have radically changed this view. Even if your interest is purely in digital electronics, knowledge of pulse technology will provide a deeper understanding of all electronics.

Some Pulse Shapes

Pulse shapes vary so much that the only true statement that applies to all of them is that they are not sinusoidal. Indeed, as you will shortly see, the pure harmonic-free sine wave is the one wave shape that does not exhibit at least some pulse-like behavior.

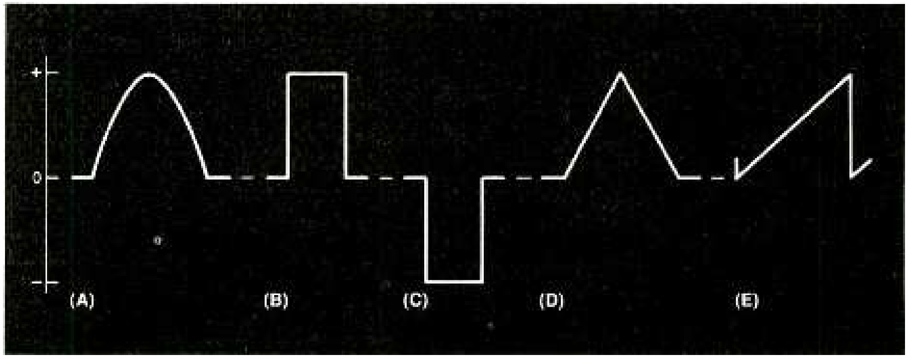


Fig. 1. Typical examples of pulse waveforms: (A) positive half of a sine wave, (B) positive square wave, (C) negative square wave, (D) triangle and (E) ramp.

Refer now to Fig. 1. In (A) is shown a pulse that is derived from a sine wave but is not a perfect sine shape. In this case, you see a half-wave rectified sine wave that, because of its missing half, now exhibits the behavior of a pulse. Positive- and negative-going square pulses are shown in (B) and (C), respectively. (D) illustrates the wave shape of a triangle or "delta" pulse, while (E) is a drawing of a sawtooth pulse.

Some pulses occur as single events. That is, they occur only once (or in response to a stimulus). Other pulses are repetitive and form "pulse trains," as illustrated in Fig. 2. The pulse train shown in Fig. 2(A) is *periodic* because the pulses occur at regular intervals. *Aperiodic* pulse trains are illustrated in Fig. 2(B) and (C). In these cases, the pulses are repetitive but not periodic because they occur irregularly.

In Fig. 2(B), the duration—interval t_1—of each pulse is the same, but the intervals between pulses are different. In Fig. 2(C), even the durations of the pulses are irregular. Although they are seen on occasion, these waveforms are rather unusual. In most cases, we observe either single pulses or periodic pulse trains in actual electronic gear.

A periodic pulse waveform like that shown in Fig. 3(A) contains a series of equal-duration (t_1), equal-interval (t_2) pulses. The total *period* of the pulse (T) is the sum of duration and interval, or $T = t_1 + t_2$.

With pulse circuits, we often use terminology that is a little different from that used in sine-wave circuits. For example, the "frequency" of the pulse train is often given as the "pulse repetition rate" (PRR), which is also called the "pulse repetition frequency" (PRF). As with frequency, if the waveform is left on continuously, the PRF is the reciprocal of the period.

As an example of the above, let's

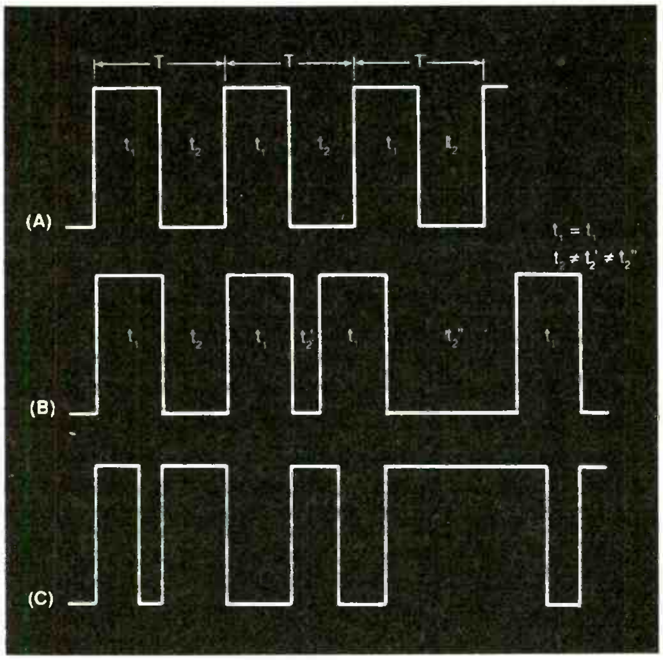
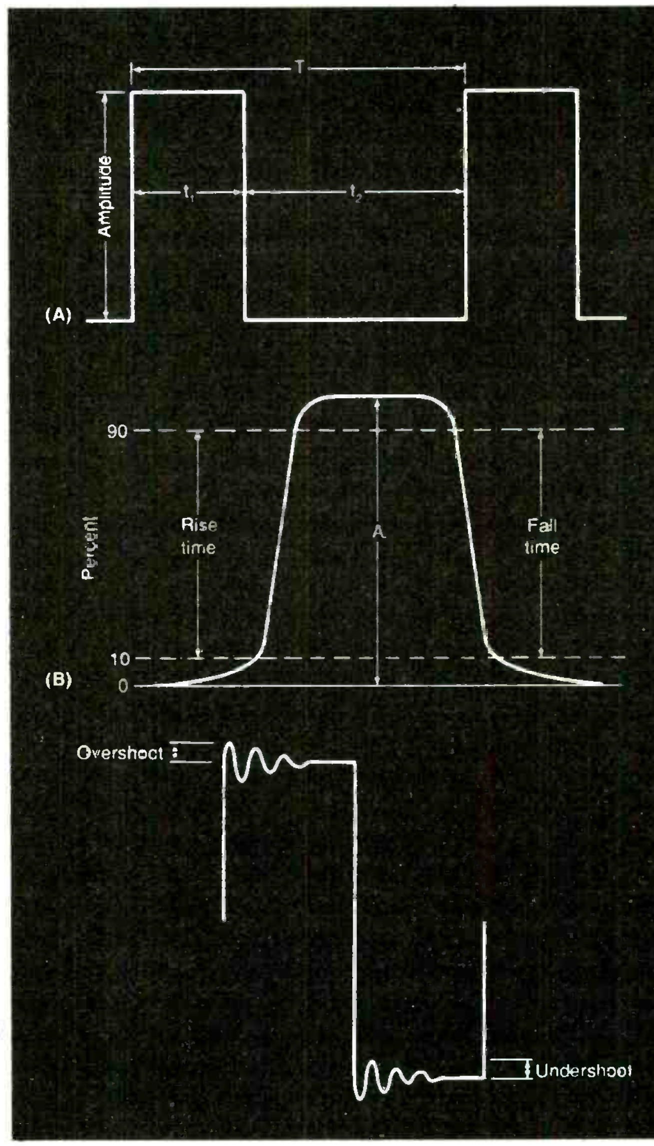


Fig. 2. Periodic (A) pulse train; aperiodic pulse train (B) where time between pulses is irregular; and aperiodic pulse train (C) where both time and pulse widths are irregular.

Fig. 3. Total time T between the beginning of any two successive pulses in a periodic pulse train (A) is the same as for any two other pulses in the train; graphic explanation of rise and fall times of a pulse (B); and overshoot "ringing" on a square-wave pulse (C).



say we have a pulse train in which the pulses are on (t_1) for 1 millisecond (ms) and off (t_2) for 5 ms. The period is T = (t_1 + t_2) = (0.001 second + 0.005 second) = 0.006 second. From this, you obtain a PRF of 1/0.005 second = 166.7 pulses per second (pps). In some circuits, the designer may call PRR/PRF "frequency" and express the figure for the repetition rate in Hertz (Hz). Both types of notation are technically correct, but pps is the one traditionally used.

In pulse circuits, "duty factor" relates to the time the pulse is on—t_1 in Fig. 3(A)—and is expressed as a percentage: DF = $[t_1/(t_1 + t_2)] \times 100\%$. Plugging the t_1 = 1 ms and t_2 = 5 ms figures from the above example into the equation, we have DF = [1 ms/91 ms + 5 ms)] × 100% = 16.7%.

"Rise time" of a pulse is a measure of how fast the pulse makes the low-to-high transition, and "Fall time" is the time required for the pulse to make the high-to-low transition. Unfortunately, pulses often have odd shapes or may have other problems that make the measurements of rise and fall times difficult or even impossible to make.

To overcome this problem (and to standardize the measurement), it has become standard practice to measure pulse rise time as the time required to snap from 10 percent to 90 percent of peak amplitude of the pulse, as illustrated in Fig. 3(B). Conversely, fall time is the period required for the transition from 90 percent to 10 percent of the pulse's peak amplitude.

Perfect square waves are like that shown in Fig. 3(A), and many practical pulse generators produce nearly

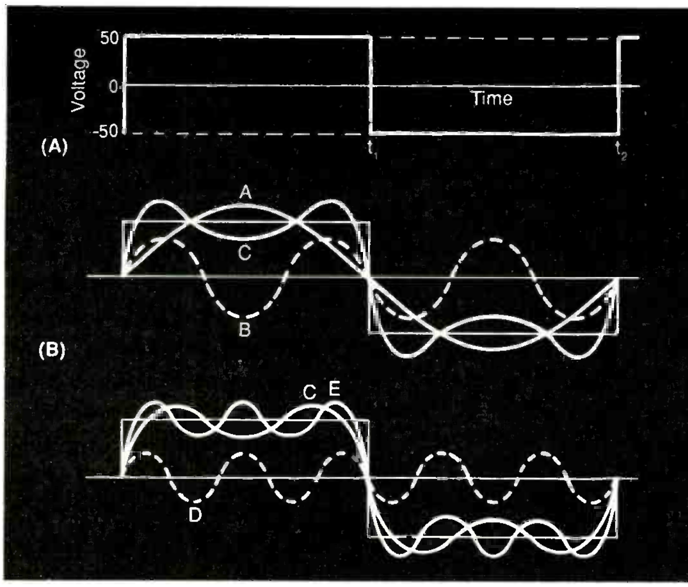


Fig. 4. Sine and cosine waves combine to make up a square wave.

perfect output waveforms. However, sometimes "ringing" occurs on a pulse, as illustrated in Fig. 3(C). A ringing pulse has damped oscillations at the transition points that show up on the waveform as "overshoot" and "undershoot."

There are times when a perfect pulse source exhibits ringing when connected to a circuit but not when connected directly to an oscilloscope's input. In a case like this, the problem might be an unintended LC resonance in the circuit, or it might be more subtle. For example, in one circuit I found ringing that was traced to an oscilloscope probe that had a broken ground wire. The "ground" was being completed through the ac power plug grounds on the scope and signal generator. Restoring the probe's ground eliminated the ringing.

Ringing sometimes occurs in digital circuits as the result of a bad printed-circuit design. One of the earliest microcomputers used a motherboard that had 100 parallel traces that were all too long, especially in larger machines. These traces acted like unterminated transmission lines, and the resulting reflections created ringing (and, incidentally, erratic computer behavior!). Terminating the lines in an absorptive resistance usually solved the problem.

The Making of a Pulse

The only "pure" waveform is a harmonic-free, perfectly undistorted sine wave. All other waveforms, in-

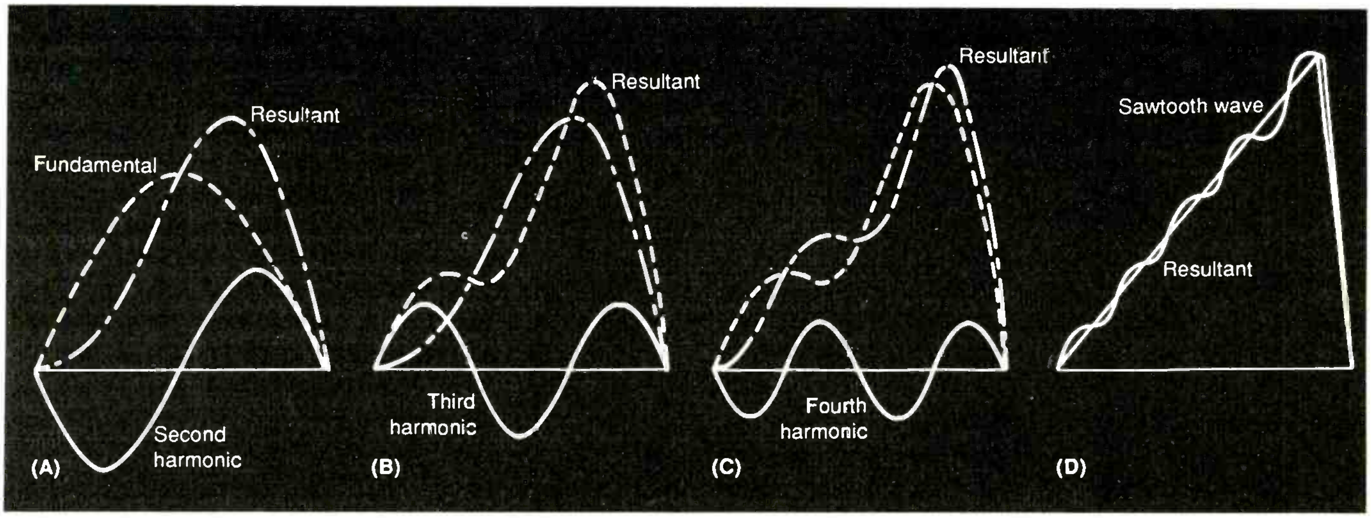


Fig. 5. Graphical depiction of how second, third, fourth and successive harmonics add together to produce a ramp waveform.

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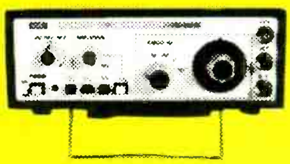

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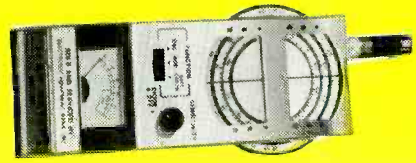

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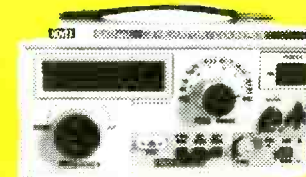

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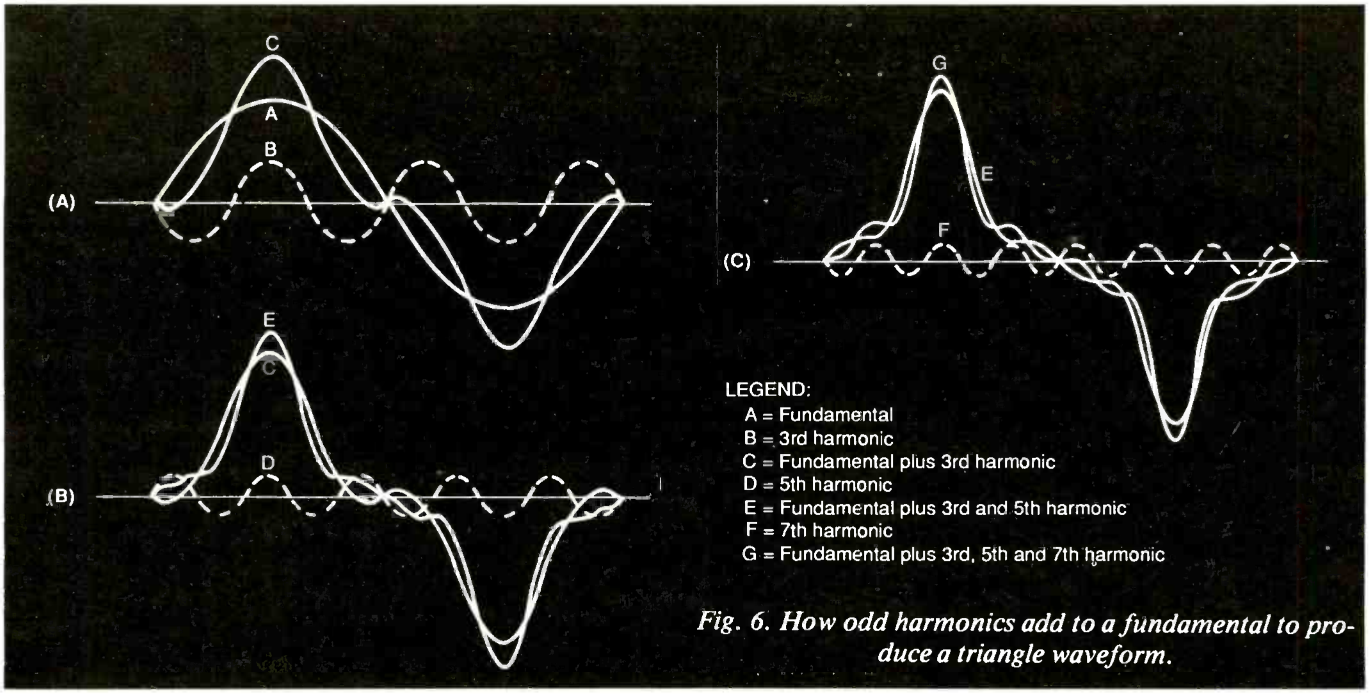

Fig. 6. How odd harmonics add to a fundamental to produce a triangle waveform.

cluding pulses, are made up of a series of harmonically-related sine and cosine waves. Any mathematician can tell you that the list of those sines and cosines form the "Fourier spectrum" of the pulse.

You don't need to dive into heavy mathematics to understand the situation. Figure 4 illustrates how the sines and cosines combine to make up a square wave. The fundamental frequency of the square wave is the lowest-frequency sine wave in the mix, while the others are harmonics of this fundamental. Figures 5 and 6

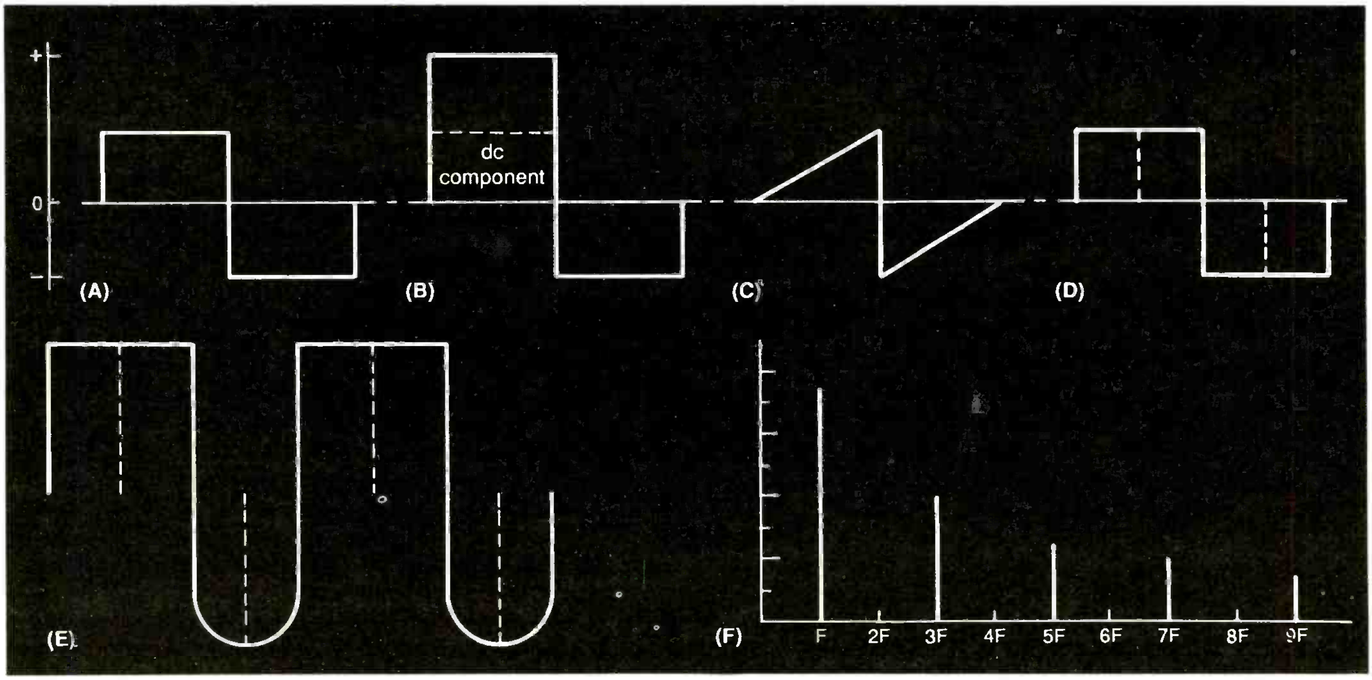

Fig. 7. Symmetry gives a clue to any pulse waveform's frequency content. A variety of pulse waveforms are illustrated in (A) through (E), while (F) depicts the Fourier frequency spectrum for a typical square wave.

show how other waveforms are similarly made up of sine and cosine waves that are harmonically related to each other.

The "symmetry" of any given waveform is a clue to the frequency content of the pulse. "Baseline symmetry" is shown in Fig. 7(A). In this example, the wave is the same shape and amplitude above and below the zero baseline. In contrast, the square wave in Fig. 7(B) is non-symmetrical about the baseline. In this pulse, there is a dc component that makes the positive amplitude greater than the negative amplitude. Another example of baseline symmetry is the sawtooth waveform in Fig. 7(C).

"Half-wave symmetry" is also illustrated in Fig. 7(A) and Fig. 7(C). This is evidenced by the fact that the negative portion is a mirror image of the positive-going portion of the waveform. "Quarter-wave symmetry" is shown in Fig. 7(D) and Fig. 7(E). In Fig. 7(D), the waveform also exhibits half-wave symmetry, while in Fig. 7(E) it does not.

Several things can be deduced from observing the symmetry of pulses:

(1) Baseline symmetry indicates that no dc component is present;

(2) Quarter-wave symmetry indicates that odd harmonics (1st, 3rd, 5th, etc.) are in-phase with the fundamental sine wave;

(3) Half-wave symmetry indicates that there are probably no even harmonics (2nd, 4th, 6th, etc.) present.

A Fourier series chart, such as shown in Fig. 7(F), for any given pulse shape. Figure 7(F) illustrates the Fourier spectrum for a square wave. Note that the square wave has baseline, half-wave and quarter-wave symmetry; so you can conclude that there are no even-order harmonics and that the odd-order harmonics (3F, 5F, 7F, and so on) are in-phase with the fundamental (F). An actual square wave has many more than just the few harmonics, but only a few are shown in Fig. 7(F) for the sake of simplicity.

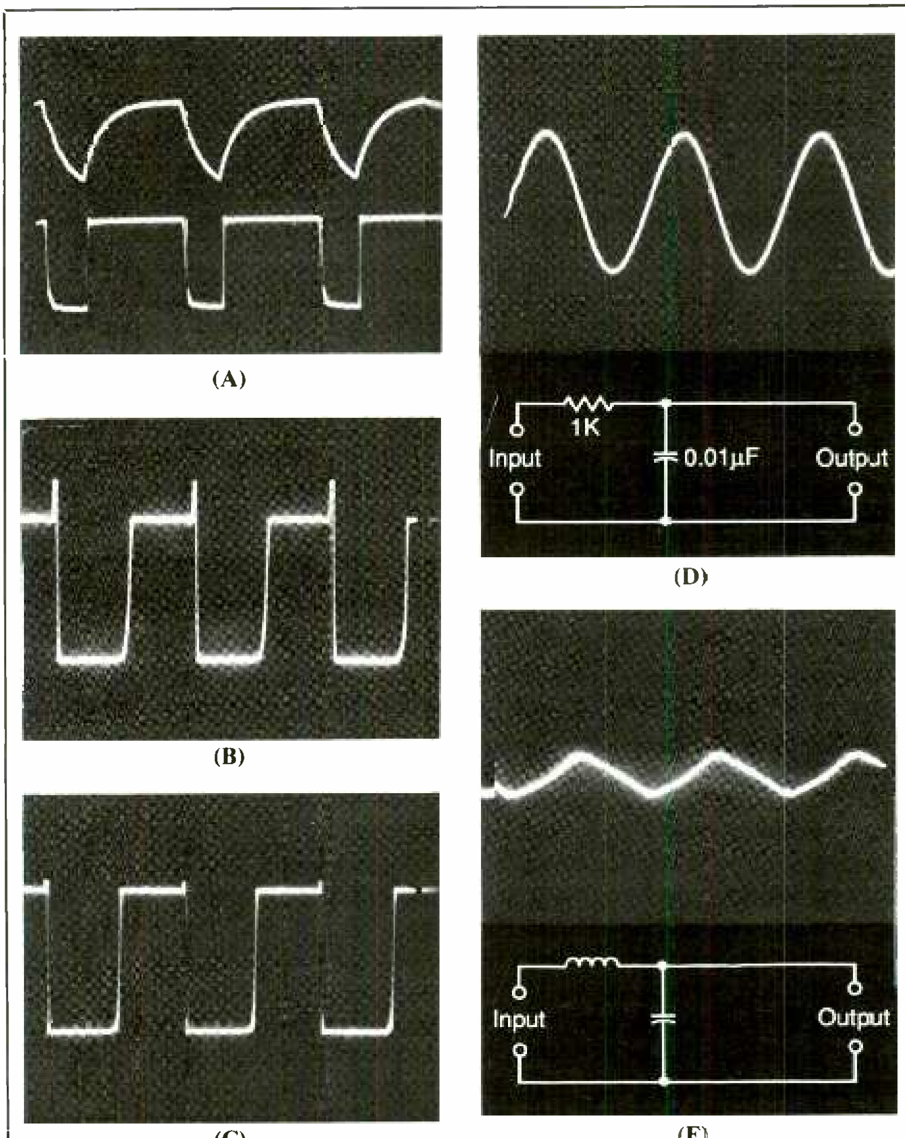

Fig. 8. The 1.5-MHz TTL-level pulse in (A) was applied to a number of circuits and the result monitored with an oscilloscope: with 100-pF and 0.01-µF capacitors connected across the generator's output (B) and (C); through a low-pass RC filter (E).

Why would one care if a pulse is made up of a fundamental and harmonics? The answer is that this determines how a circuit will react to the pulse. You need to know something of the pulse shape in order to set the bandwidth of a circuit. For example, an electrocardiograph (ECG) signal has a fundamental of less than 1 Hz, but the amplifier it drives must be capable of passing 100 Hz because the Fourier components (harmonics) are present in significant amplitude out to this frequency.

Figure 8 shows several situations in which a 1.5-MHz pulse from a TTL generator it applied to various circuits. For the sake of comparison, the output of the pulse generator is shown in Fig. 8(A).

When a 100-picofarad capacitor is connected across the output of the

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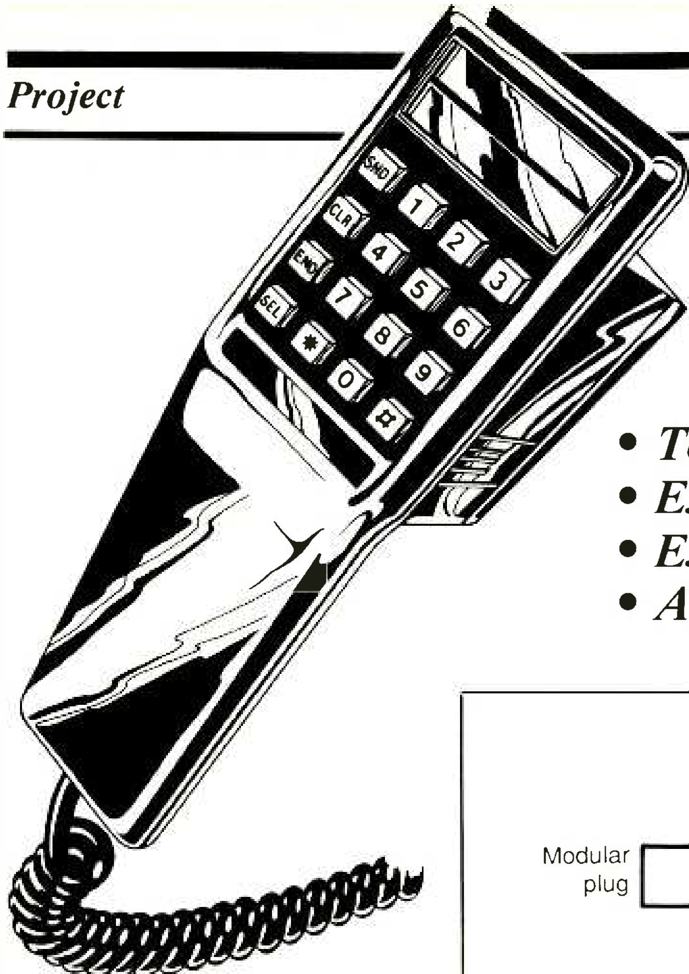
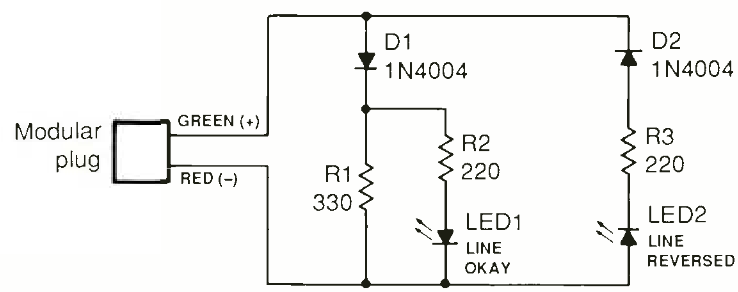


4 Add-On Phone Devices

- *Telephone-Line Checker*
- *Extension Phone Lockout*
- *Extension Phone Busy Indicator*
- *Automatic Hold Device*



PARTS LIST (Fig. 1)

Semiconductors
D1,D2—1N4004 or similar silicon rectifier diode
LED1—Green 2-volt, 20 mA light-emitting diode
LED2—Red 2-volt, 20-mA light-emitting diode
Resistors (½-watt, 10% tolerance)
R1—330 ohms
R2,R3—220 ohms
Miscellaneous
Printed-circuit board or perforated board and suitable Wire Wrap or soldering hardware; suitable enclosure (see text); modular plug-and-cable assembly (Radio Shack Cat. No. 279-310 or similar—see text); hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Set of four ready-to-wire pc boards, $16.95; CD4001BE IC, $2.25; BS107 enhancement-mode FET, $3.00; LM3909 LED flasher, $3.00; any zener diode for any of the last three projects (specify voltage), $1.25 each; MCR 100-4 SCR, $2.50; 1N4004, 50¢ each. Add $1.50 P&H per order. New Jersey residents, please add state sales tax. Items mentioned in this Note apply to all four projects.

Fig. 1. Schematic diagram of Telephone-Line Checker circuit.

By Anthony J. Caristi

You've probably noticed in mail-order catalogs a variety of devices that can be added to a basic home or business telephone instrument to improve performance, add new features or both. These telephone add-ons are hot items, but don't expect to find most of them in any of Ma Bell's Phone Stores or AT&T's direct-sales catalogs. Four such items are presented here. All are low in cost and easy to build. And they are powered by the telephone line (each presenting an extremely small load on the line), so no batteries are needed.

Projects included in this roundup include a handy test device that lets you diagnose and check any telephone jack, outlet or line for proper operation. Another is an automatic hold device, while the remaining two projects are designed to help you avoid accidental or purposeful eavesdropping on an extension instrument.

Each of the projects presented here can be built and used independently of the others, and each connects to the telephone line via a common modular plug/jack arrangement (an FCC requirement for telephone accessory devices). Add one, two, three or even all four projects to your existing telephone line to enhance the utility of your telecommunications system.

Preliminary Information

Each of the projects described here can be assembled in a single evening. To simplify matters, all four projects are accompanied by actual-size artwork for fabricating printed-circuit boards for them and complete Parts Lists, along with details about how the circuits operate. Each project can be used alone. The only outside connections in each case is to the telephone line via a modular jack/cable arrangement. The modular jack is an FCC requirement for all accessories connected to the telephone line, including those described here. It's best to obtain a modular plug-and-cable assembly for the telephone-line connection. Otherwise, you'll have to manually connect the cord to the modular plug, which can be a tedious, frustrating experience without the proper tool.

Although the modular plug assembly may have as many as four conductors connected to it, only the two wires closest to the center are to be used. These conductors have green and red insulation on them. Telephone convention normally assigns the positive (+) polarity to the green-insulated conductor and the negative (−) polarity to the red-insulated conductor. For all four of these projects this green-for-plus and red-for-minus convention must be followed.

If the modular plug/cable assembly comes with spade lugs on the end opposite the plug, do *not* snip them off. Instead, make whatever connections are to be made by splicing wires to the lugs or soldering the lugs themselves directly to the copper pads on the printed-circuit boards on which the projects are assembled.

The reason for not removing the spade lugs is that the conductors in many telephone cords are made up of a delicate "tinsel"-like wire wrapped around a fabric cord that assures a long useful life and maximum flexibility. Because this wire isn't easily solderable, matters are expedited more easily by leaving on the spade lugs. Obviously, if your cord comes with no spade lugs on one end, the conductors there are can be plugged into the appropriate holes in the board and be soldered into place.

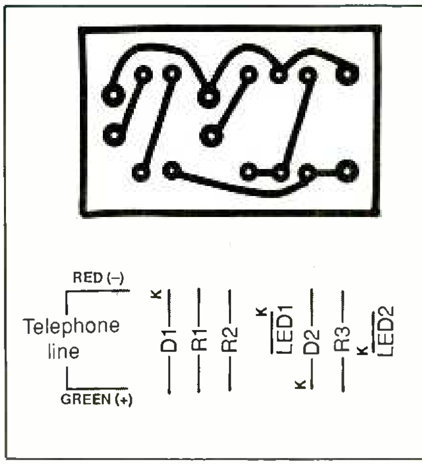


Fig. 2. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for Telephone-Line Checker pc board.

When wiring any of the projects, be very careful to observe proper orientation of all polarized components (electrolytic capacitors, diodes, light-emitting diodes, transistors and integrated circuits). All important orientations are clearly indicated in the wiring guides that accompany each project. Just one component improperly installed will result in an inoperative project and may even result in damage to that component or/and other components in the project.

When you're finished wiring a project, very carefully examine it for cold or poorly soldered connections, solder bridges between closely spaced pads and conductors, etc. If you suspect any connection, reflow the solder on it and, if necessary, add any that may be needed. Solder bridges can be cleared with a soldering iron and wicking type desoldering braid or a vacuum-type desoldering tool. Then resolder the connection. Keep in mind that it's much easier to detect and correct a problem with a newly wired circuit-board assembly than it is after installing the assembly into your telephone system and putting it into service.

Though in this article we assume printed-circuit board construction, any and all of these circuits can also be assembled by traditional point-to-point wiring techniques on perforated board. Use board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Regardless of the type of board used, however, it's a good idea to use sockets for all DIP ICs.

The Projects

As stated earlier, a total of four projects is presented here. In this section, we'll discuss how each works and give special construction information appropriate to each. Let's start with the simplest of the projects:

• *Telephone-Line Checker.* This self-powered instrument can help you to quickly determine if a fault is in your telephone instrument or in the line. Armed with the result obtained with the Telephone-Line Checker, you can troubleshoot your telephone instrument if you've determined that's where the problem is, or place a call to your local telephone company office for a service call should the result indicate that the problem is with the line.

A single telephone line that enters your home or business consists of just two conductors. Across these conductors is a potential of about 50 volts dc under the off-hook condition. When a telephone instrument is in use, this potential drops to between 6 and 8 volts or so as current is drawn from the line. Therefore, it's a simple matter to check for proper line operation by determining the polarity of the two conductors and the approximate amount of current drawn by a simulated telephone load.

A suitable simulated load is shown schematically in Fig. 1. This Telephone-Line Checker circuit is extremely simple in design. With a properly operating telephone line, diodes *D1* and *D2* will be conducting and cut off, respectively. As a result, resistor *R1* loads the line and draws current to simulate a telephone instrument. Light-emitting diode *LED1* turns on to indicate that the line is operational and of the correct polarity.

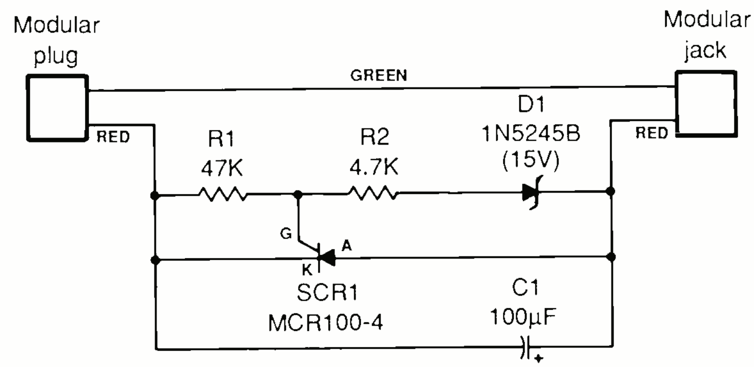
Should there be a polarity reversal in the telephone line, LINE OKAY *LED1* will be off and LINE REVERSED *LED2* will be on. Should the telephone line be dead, of course, neither LED will be on.

The light-emitting diodes need not be labeled in this circuit. In fact, it's probably simpler to use a green emitter for LINE OKAY *LED1* and a red emitter for LINE REVERSED *LED2*, for at-a-glance indication of line condition. The colors green and red are almost universally the accepted to indicate go and no-go, safe and danger, etc.

An actual-size etching-and-drilling guide for the printed-circuit board for this circuit is shown in (A) in Fig. 2. The wiring guide for this board is shown in (B). Wire the board exactly as shown. Making sure to observe proper polarity, mount the LEDs and silicon diodes in their respective locations on the board. Leave about ¼ inch of space between the bottoms of the LED cases and the surface of the board but mount the diodes flat against the board.

House the project inside its own enclosure. Preferable is a miniature clear plastic enclosure, though a small utility box will do if that's all you can obtain. If you use a clear plastic box, use rectangular LEDs. If you use a standard project or utility box, use round LEDs, mounting them in suitably sized holes drilled in the top panel. Interconnect the LEDs with the appropriate holes in the board with short lengths of hookup wire and insulate both connections to the LED leads with small-diameter heat-shrinkable tubing or plastic tubing. Secure the board in place inside its enclosure with a 1-inch-square piece of nonconductive foam tape.

• *Extension Lockout Device.* If you have more than one telephone instrument connected to the same line, you may wish to ensure privacy by automatically disabling one or more extension instruments when the line is in use. The circuit shown in Fig. 3 can be used to automatically lock out any or all telephone instruments connected to the line.



PARTS LIST (Fig. 3)

Semiconductors
D1—1N5425B or similar 15-volt zener diode
SCR1—MCR 100-4 (Motorola) or similar silicon-controlled rectifier

Capacitors
C1—10-μF, 250-volt electrolytic

Resistors (¼-watt, 10% tolerance)
R1—47,000 ohms
R2—4,700 ohms

Miscellaneous
Printed-circuit board or perforated board and suitable Wire Wrap or soldering hardware; modular plug-and-cable assembly (Radio Shack Cat. No. 279-310 or similar); modular jack (Radio Shack Cat. No. 279-353 or similar); solder; etc.

Note: See Note at end of Fig. 1 Parts List.

Fig. 3. Schematic diagram of Extension Phone Lockout circuit.

To accomplish the lockout, you must place the project between the telephone line and the controlled instrument, as shown in Fig. 3. This can be done by using a separate modular telephone plug and jack as shown. For a professional installation, the circuit-board assembly can be installed inside a standard box that has a modular jack on its cover plate and hard wiring the project in series with the telephone line via the red-insulated (–) conductor.

This circuit operates on the principle that the controlled telephone instrument must be powered by activation of silicon-controlled rectifier *RECT1*. When the line isn't in use and the telephone instrument's handset is lifted off-hook, the 50-volt dc potential across the telephone line is sufficient to overcome the zener rating of zener diode *D1*. When this occurs, current flows into the gate (G) of *SCR1* and triggers the silicon-controlled rectifier into conduction, at which point the telephone instrument is placed across the telephone line.

If another telephone instrument connected to the same line is in use when the controlled instrument's handset is picked up, the low voltage across the line isn't sufficient in magnitude to cause *D1* to go into zener action. Hence, *SCR1* won't be triggered into conduction. Consequently, the instrument will not be operational.

Shown in (A) in Fig. 4 is the actual-size etching-and-drilling guide for the Extension Lockout device's printed-circuit board. When this board is ready to be populated, install and solder into place first the resistors, then the capacitors and zener diode and, finally, the silicon-controlled rectifier. Make sure *C1*, *D1* and *SCR1* are properly oriented before soldering their leads to the cop-

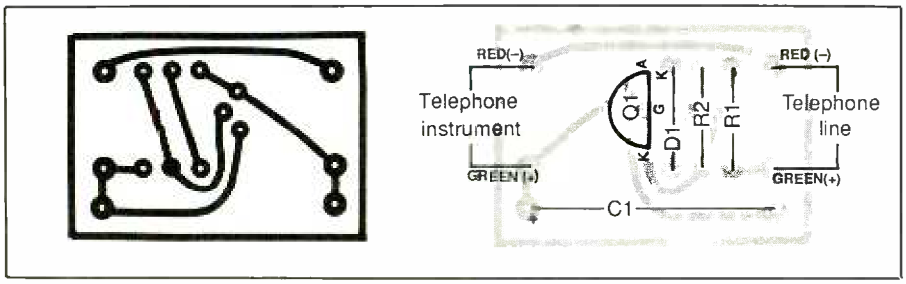


Fig. 4. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for Extension Phone Lockout pc board.

per pads on the bottom of the board.

• *Extension Busy Indicator.* You may wish to avoid the problem of you or someone else lifting the receiver of an extension telephone instrument off the hook when the line is in use but would rather not have such a drastic solution of disabling the instrument as was done above. An Extension Busy Warning Indicator on any or all instruments connected to the same telephone line will light a LED to warn others when the line is in use. It won't stop someone from picking up a receiver and listening in, though, as will the Lockout device shown in Fig. 3; it's simply an alerting device.

A circuit that serves the function of an alerting device is shown schematically in Fig. 5. It automatically lights a LED when the line is in use, providing a visible alert to anyone who wishes to use the instrument not to pick up the receiver. This circuit is recommended for use with Touch Tone telephone instruments since some telephone-line current is required to light the warning LED at the extension instrument. Rotary or pulse-dial instruments require the line current to be interrupted during pulse dialing sequences.

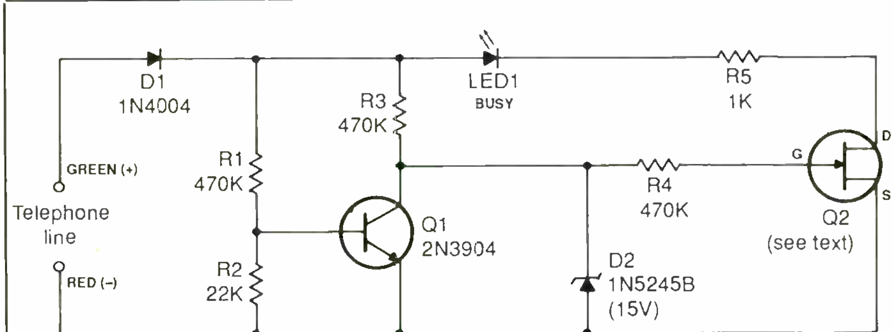
A Busy Indicator can be placed at each instrument on a given line. This way every instrument will signal when the line is in use.

The project operates by monitoring the voltage across the telephone line at all times. When no telephone instrument is being used, the 50-volt dc potential across the line is sufficient to saturate bipolar transistor *Q1*. This results in essentially zero gate-to-source voltage at n-channel field-effect transistor *Q2*. Since *Q2* is an enhancement-mode FET, its drain-to-source impedance is almost infinite, resulting in zero drain current and a LED that is off.

When the telephone line is in use, the potential across it is not sufficient in magnitude to cause *Q1* to conduct. Under this condition, *Q2* becomes forward biased by *Q3* through *R3* and draws a small current from the line to illuminate *LED1*. When *LED1* lights, the caller is warned that an extension instrument on the line is busy and the handset should not be lifted off-hook.

An actual-size etching-and-drilling guide for the printed-circuit board for this project is shown in (A) in Fig. 6. The wiring guide for the board is shown in (B). As mentioned above for the previous two projects, make sure polarity- and orientation-sensitive components are properly installed on the board before soldering their leads into place.

• *Automatic Hold Device.* How many times have you wished that you could continue a conversation on an instrument other than the one you used to answer or originate a call? It's cases like this that call for a "hold" function similar to the one



PARTS LIST (Fig. 5)

Semiconductors
D1—1N4004 or similar silicon rectifier diode
D2—1N5254B or similar 15-volt zener diode
LED1—Red 2-volt, 20-mA light-emitting diode
Q1—2N3904 or similar npn silicon transistor
Q2—BS107 or equivalent n-channel enhancement-mode field-effect transistor

Resistors (¼-watt, 10% tolerance)
R1,R3,R4—470,000 ohms
R2—22,000 ohms
R5—1,000 ohms

Miscellaneous
Printed-circuit board or perforated board and suitable Wire Wrap or soldering hardware; modular plug-and-cable assembly (Radio Shack Cat. No. 279-310 or similar); solder; etc.

Note: See Note at end of Fig. 1 Parts List.

Fig. 5. Schematic diagram of Extension Phone Busy Indicator circuit.

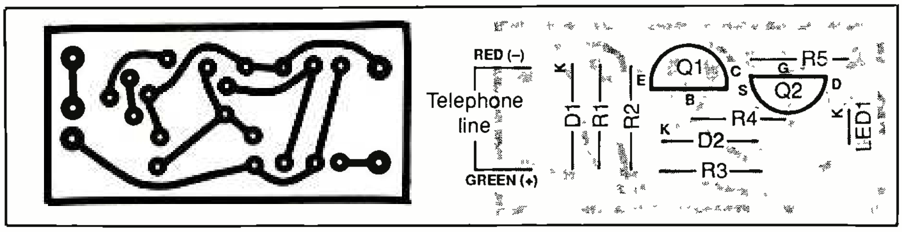
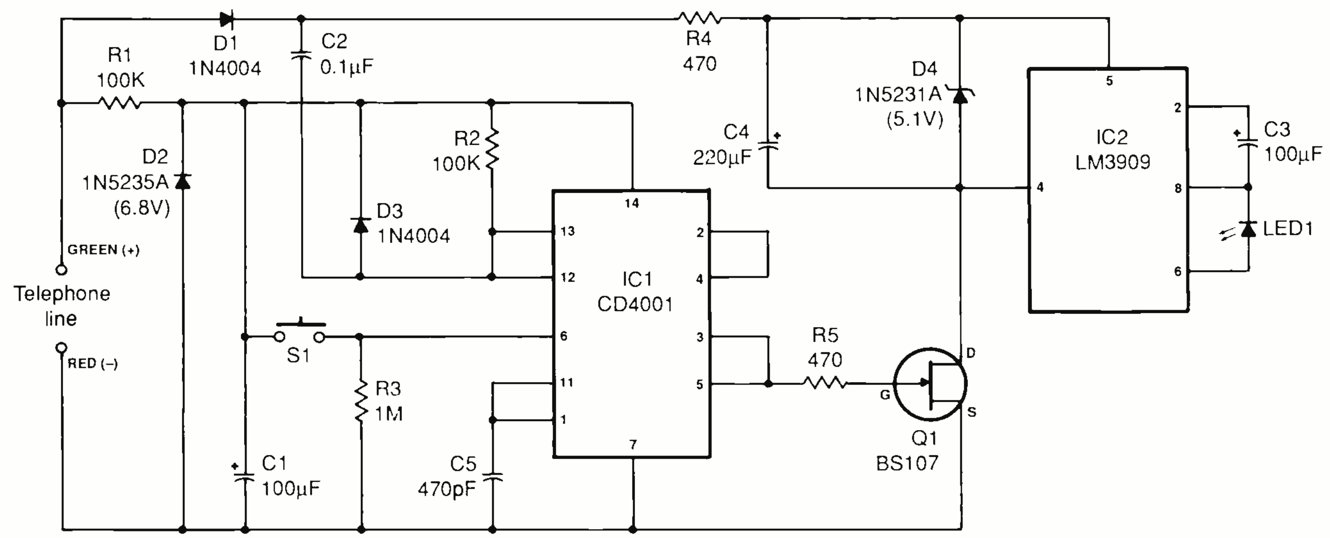


Fig. 6. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for Extension Phone Busy Indicator pc board.

that is standard equipment with virtually every multiple-line business phone. If this is what you want, the circuit shown schematically in Fig. 7 should fill your desires.

The Fig. 7 circuit provides the same feature business phones have and is completely automatic in operation. When you press normally open pushbutton switch *S1*, the circuit seizes the telephone line and holds it while flashing light-emitting diode *LED1*. Once the circuit is in this condition, the instrument's handset can be replaced on the cradle without loss of the connection to the telephone line. When the same instrument's handset or the handset of any other instrument on the same line is lifted from its cradle, the hold feature is automatically disabled and the conversation is allowed to continue in the normal manner.

In the Fig. 7 circuit, a bistable multivibrator or latching circuit made up of two of the four two-input NOR gates inside *IC1* is used as a memory that monitors the status of the telephone line at all times. A bistable



PARTS LIST (Fig. 7)

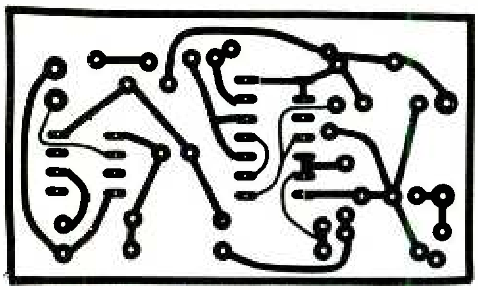
Semiconductors
D1,D3—1N4004 or similar silicon rectifier diode
D2—1N5235A or similar 6.8-volt zener diode
D4—1N5231A or similar 5.1-volt zener diode
IC1—CD4001BE quad 2-input NOR gate
IC2—LM3909N LED flasher (National Semiconductor)
LED1—Red 2-volt, 20-mA light-emitting diode
Q1—BS107 or equivalent n-channel enhancement-mode field-effect transistor

Capacitors
C1—100-µF, 25-volt electrolytic
C2—0.1-µF, 200-volt ceramic or metal-film
C3—100-µF, 10-volt electrolytic
C4—220-µF, 10-volt electrolytic
C5—470-pF ceramic

Resistors (¼-watt, 10% tolerance)
R1,R2—100,000 ohms
R3—270,000 ohms
R4—470 ohms
R5—470,000 ohms

Miscellaneous
S1—Normally-open, momentary-action pushbutton switch
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; sockets for IC1 and IC2; modular plug-and-cable assembly (Radio Shack Cat. No. 279-310 or similar); solder; etc.
Note: See Note at end of Fig. 1 Parts List.

Fig. 7. Schematic diagram of Automatic Telephone Hold Device circuit.



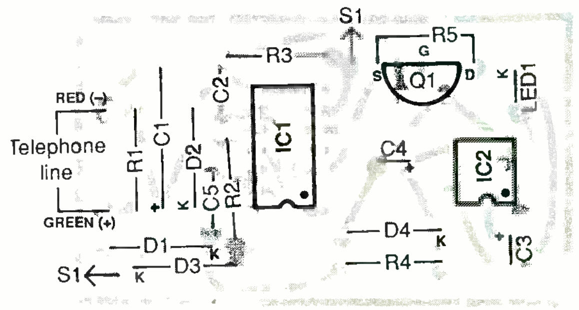


Fig. 8. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for Automatic Telephone Hold Device pc board.

multivibrator has two stable states. At any given moment, the state it assumes depends on the logic levels fed to the multivibrator's two inputs at pins 1 and 6 of *IC1*.

During normal telephone operation, pin 3 of *IC1* is held at logic low since pin 1 of the NOR gate has been fed a logic-high pulse when the telephone instrument's handset was taken off-hook and the connection to the telephone line was made. As a result, *Q1* is cut off and no collector current flows.

When the hold function is activated by briefly pressing and releasing *S1*, the resulting positive pulse fed to pin 6 of *IC1* causes the bistable multivibrator to toggle into its alternate state. This causes pin 3 of *IC1* to go to logic high, and the resulting positive output voltage switches field-effect transistor *Q1* into conduction. Current is then permitted to flow from the telephone line into LED flasher chip *IC2*. Additional current is also drawn by *D4* to ensure that the total current through *Q1* is sufficient to seize the telephone line.

Once the line is seized, the handset can be replaced in the instrument's cradle to hold the call. The flashing LED, driven by *IC2*, provides visual indication that the call is on hold.

When the hold function is activated and the instrument's handset is hung up, the current drawn by the circuit is less than that required by a standard telephone instrument. Hence, the potential across the line rises to about 15 volts from the normal 6 to 8 volts.

When the handset of any instrument connected to the telephone line is removed from the cradle to continue the conversation, the resulting drop in telephone-line potential feeds a negative-going pulse into a third NOR gate inside *IC1*. This gate is configured as an inverter. Its positive output pulse at pin 11 restores the multivibrator to its original standby state, disabling the hold function.

This project is best built into a telephone instrument, with the pushbutton switch and LED installed in a location that makes them accessible from outside the instrument. If your instrument is too small to accommodate the project, build the Hold device into a separate enclosure and equip it with its own modular plug and cable.

Refer to (A) in Fig. 8 for the actual-size etching-and-drilling guide for this project. When the board is ready, wire it exactly according to the wiring diagram in (B). Once again, make sure that electrolytic capacitors, rectifier and zener diodes and the light-emitting diode are properly polarized and that the integrated circuits are properly oriented before soldering their leads or pins to the copper pads on the bottom of the board.

With all these projects, it is important that you keep all parts of the circuit-board assemblies from touching any parts of the telephone instruments with which they are used. The *only* connections used are to be made to the two identified Telephone Line points clearly identified for each project—observe polarity! If you install a project inside a telephone instrument, make certain that it's insulated from the instrument. Similarly, if a project in housed inside a metal enclosure or a plastic enclosure that has a metal panel, make sure no parts of the circuitry touch any metal. Other than these admonitions, assembly, installation and use of each project are simple and straight-forward.

If you exercise care in assembly, none of the projects should fail to operate properly. If you do encounter a problem, however, the best way to determine what's causing it is with a dc voltmeter or a multimeter set to the dc volts function. The meter should have an input resistance of at least 1 megohm.

When troubleshooting any of these projects, always clip the meter's negative or common probe to the negative (red-insulated) side of the telephone line and touch the meter's "hot" test probe to the various points in the circuit. Check voltage levels and polarities as you work from the input (green-insulated telephone-line conductor) through the remainder of the circuit. Refer to the appropriate schematic and circuit description. **ME**

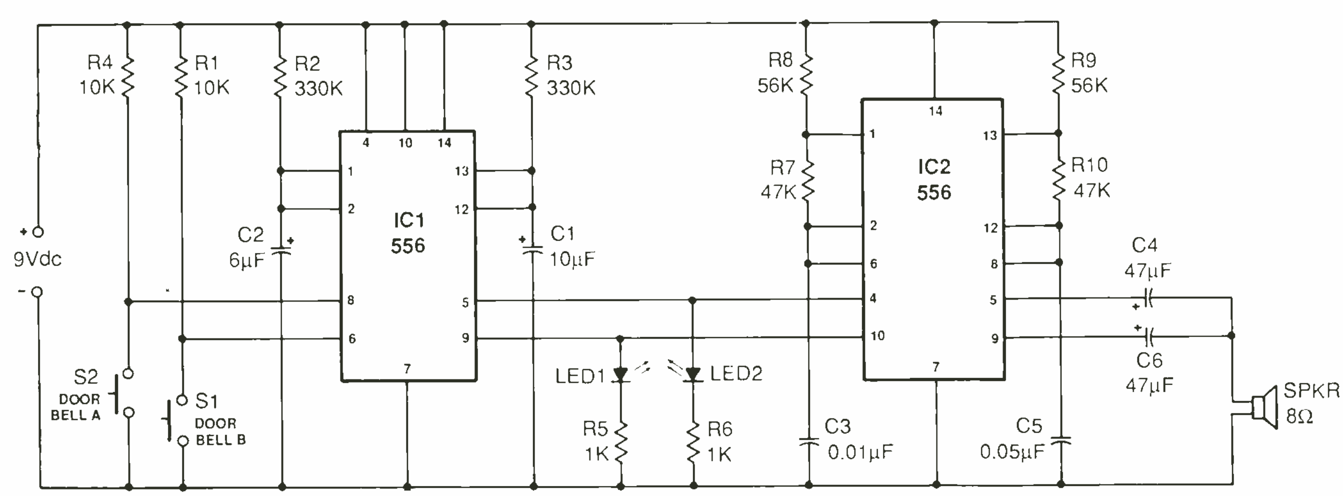
Two-Tone Electronic Doorbell

Sounds distinctively different audio tones when front and back doorbell buttons are pressed

By Charles Shoemaker D.Ed.

If you have front and rear doorbells—or wish to have both—the usual procedure is to wire the pushbuttons for each so that either sounds the same bell or chime. This can be confusing when a visitor presses the rear-door button and you answer the front door. To have distinctively different sounds that will announce to you which button has been pressed, the usual procedure has been to wire the two buttons to different annunciators, like bells and chimes. A much better solution is provided by our Two-Tone Electronic Doorbell, which sounds a distinctively different audio tone that instantly lets you know which doorbell button has been pressed. If both buttons are pressed simultaneously, the project will sound a chord that is a mixture of both tones.

This project not only sounds different tones for the front and rear doorbells, it also sounds them for different durations. This makes it even easier to distinguish which bell button has been pressed. Also, most people have little confidence in doorbell mechanisms and, thus, ring more than once. With our Electronic Doorbell, repeated pressings of a button have no effect while the circuit is in its triggered state, which is



PARTS LIST

Semiconductors
IC1,IC2—LM556 dual timer
LED1—Red light-emitting diode
LED2—Green light-emitting diode
Capacitors (15 WV minimum)
C1—10-µF electrolytic
C2—6-µF electrolytic
C3—0.01-µF ceramic disc
C4,C6—47-µF electrolytic
C5—0.05-µF ceramic disc

Resistors (¼-watt, 10% tolerance)
R1,R4—10,000 ohms
R2,R3—330,000 ohms
R5,R6—1,000 ohms
R7,R10—47,000 ohms
R8,R9—56,000 ohms
Miscellaneous
S1,S2—Existing doorbell pushbutton switches (see text)
SPKR—4- or 8-ohm miniature speaker

Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware; sockets for IC1 and IC2; suitable 9-volt dc power supply (see text); enclosure; 4- or 6-position screw-type terminal strip or barrier block; twisted-pair bell or telephone wire; machine hardware; hookup wire; solder; etc.

Fig. 1. Complete schematic diagram of Two-Tone Electronic Doorbell. Pushbutton switches S1 and S2 are existing doorbell switches. Power this circuit from any plug-in wall-type 9-volt dc power supply.

the duration time of the generated tone. Of course, another pressing after the timed cycle has elapsed will once again sound the tone.

About the Circuit

The complete schematic diagram of the Electronic Doorbell is shown in Fig. 1. In this circuit 556 dual timer *IC1* is configured as two separate astable (one-shot) multivibrators. Triggering of the timers inside the *IC1* chip is accomplished with push-button doorbell switches *S1* and *S2*. Pins 1 through 6 of the IC are assigned to the first on-chip timer, while pins 8 through 13 are assigned to the other timer. Positive and negative supply lines for the 556 dual timer are at pins 14 and 7, respectively.

Note that *IC2* is another dual 556 timer. The timers in this chip are configured to generate two distinctly different audio tones that are fed through coupling capacitors to speaker *SPKR*. Using different tones makes it easy to distinguish between front and rear doorbell activation.

Operation of the circuit is simple and straightforward. Pressing doorbell switch *S1* causes a negative spike to be generated, which is coupled into the first on-chip multivibrator timer at pin 6. When this occurs, output pin 6 goes positive and causes current to flow through *R6* and *LED2*, turning on this green light-emitting diode. The LED is included in this circuit to provide visual indication of the "on" time of the multivibrator.

Output pin 5 of *IC1* is also directly connected to pin 4 of the first timer inside *IC2*. Consequently, the positive voltage that makes *LED2* light enables the timer oscillator. This timer now produces a tone at output pin 5, which is coupled through capacitor *C4* to the speaker.

When *IC1* is triggered, *C2* begins to charge up through *R2* toward the potential on the positive supply rail. When the charge on this capacitor reaches approximately 66 percent of the positive-rail potential, which is about 6 volts when the circuit is powered from a 9-volt source, the output at pin 5 of *IC1* goes low and extinguishes *LED2*. Simultaneously, the first timer inside *IC2* is disabled so that its multivibrator ceases oscillating. As a result, the tone being delivered to the speaker is cut off.

Increasing the value of either *C2* or *R2* increases the "on" time of the first timer inside *IC1*. This "on" time is calculated using the formula: $t_{1ON} = 0.7(2 \times R3) \times C2$. Plugging the values specified for *C2* and *R1* into the formula, we get: $t_{1ON} = 0.7 \times 2 \times 0.33 \times 6$, which yields an "on" time of 2.8 seconds. (Note that capacitor and resistor values are given in microfarads and megohms in this formula.)

The "on" time for the other timer inside *IC1* is calculated in the same manner. Using the values specified for *C1* and *R3*, we obtain: $t_{2ON} = 0.7 \times 2 \times 0.33 \times 10$, which works out to 4.6 seconds.

From the foregoing, it is obvious that this circuit is rigged to sound one tone for a longer period of time than the other. Subtracting the 2.8-second duration of the first timer from the 4.6-second duration of the second timer yields a difference of 1.8 seconds, which is how much longer the second timer's tone is sounded. If a 12-microfarad capacitor were to be used for *C1* instead of the 10-microfarad value specified, time t_{2ON} would be twice that of time t_{1ON}.

Astable multivibrator *IC2* provides the two tones that make front and rear doorbell rings distinctive. Pin assignments for timer 1, timer 2, V+ and ground in *IC2* are the same as for *IC1*, with the exceptions for connections of timing capacitors *C3* and *C5*.

The *C3* side is the higher-frequency oscillator, which generates a 935-Hz tone, while the lower-frequency *C5* side generates a 190-Hz tone. You can calculate these frequencies yourself using the formulas: $f_1 = 1.43/(R8 + 2R7 \times C3)$ and $f_2 = 1.43/(R9 + 2R10 \times C5)$. Plugging values into each formula yields: $f_1 = 1.43/[0.65 + (2 \times 0.047)] \times 0.1 = 953$ Hz, $f_2 = 1.43/[0.056 + (2 \times 0.047) \times 0.05] = 190$ Hz.

As you can see, both *IC2* oscillator outputs are coupled to the same speaker through capacitors *C4* and *C6*. Pressing *S1* causes the higher-frequency tone to be heard from the speaker, while pressing *S2* causes the lower-frequency tone to be heard. Should both switches be pressed at the same time, both tones will be generated and will be reproduced by the speaker as a mix of the two.

Power for the project can be supplied by just about any 9-volt dc source, such as a plug-in type used with many small appliances.

Construction

Owing to the very few discrete components required and the fact that component placement and routing of wiring are not critical, this is a very simple circuit to build. Consequently, you can use any traditional wiring technique when assembling the project, including a printed-circuit board, perforated board and suitable Wire Wrap or soldering hardware or even a medium-size solderless breadboarding block.

If you desire pc construction, fabricate your board using the actual-size etching-and-drilling guide shown in Fig. 2. On the other hand, if you prefer perforated-board construction, rather than going to the effort of making a pc board, use board that has holes on 0.1-inch centers if you do not use a solderless socket. If you use pc- or perf-board construction, it is a good idea to use sockets for *IC1* and *IC2*.

Assuming you opted for pc construction, refer to Fig. 3 for wiring details. (Note: Use the layout shown in Fig. 3 as a rough guide to component placement when assembling the

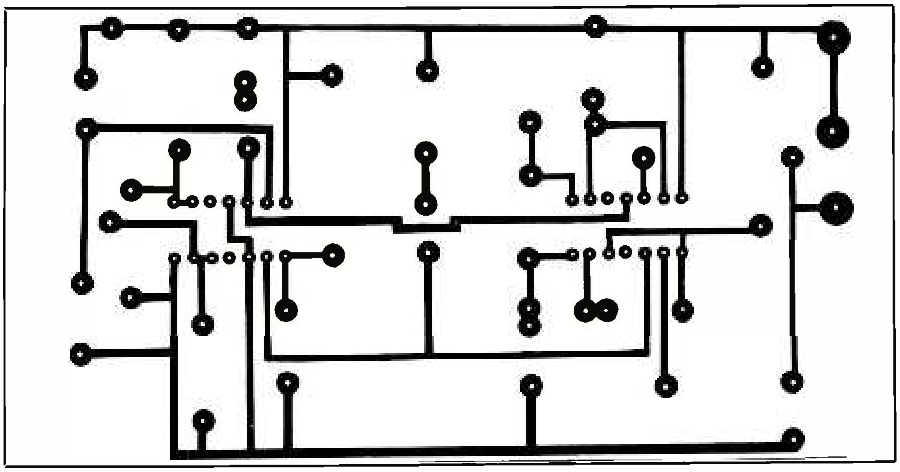


Fig. 2. Actual-size etching-and-drilling guide for making pc board.

circuit using perf board or a solderless socket.) Orient the board in front of you as shown. Then install and solder into place the two DIP IC sockets, but do *not* install the ICs in the sockets until after preliminary voltage checks have been performed and you are certain of your wiring.

Proceed with construction by installing and soldering into place the resistors, followed by the capacitors. Make sure all electrolytic capacitors are properly polarized before soldering their leads to the copper pads on the bottom of the board. Also mount *C5* (or *C4*) on the *bottom* of the board. Use a cut-off capacitor lead or short length of bare solid hookup wire for the single required jumper.

Strip ¼ inch of insulation from both ends of 12 6-inch lengths of hookup wire. If you are using stranded hookup wire, twist together the fine conductors at both ends of each and sparingly tin with solder. Plug one end of each of these wires in turn into the holes labeled S1, S2, LED1, LED2, SPKR, +9V and GND. Solder each wire into place as you install it.

When the circuit-board assembly has been fully wired, it can be housed inside any enclosure that will accommodate it, the speaker and a 4- or 6-contact screw-type terminal strip or barrier block at one end. The last provides a convenient means for connecting the doorbell-switch wires and, optionally, the two power-supply conductors. An ordinary plastic project box that has a removable aluminum panel is an excellent choice for an enclosure, especially since it is much easier to machine than a metal utility box without specialized tools.

Machine the enclosure as needed. Drill mounting holes for the circuit-board assembly, LEDs, terminal strip or barrier block, and a number of small holes in the area over which the speaker will be mounted to permit the sound to escape. Also drill a hole to accommodate the mating jack for the plug at the end of the plug-in dc power supply you will be using with the project, or use a 6-contact terminal strip or barrier block and use two of its contacts for the supply connections instead of drilling the jack hole. Do not drill mounting holes for the speaker if it offers machine hardware mounting. Also drill a couple of holes that will permit suitable hardware to be used to mount the project in the selected location. If you are using a metal enclosure, deburr all but the small sound-escape holes. Run a bead of silicone adhesive around the perimeter of the speaker and set it in place in the enclosure to set at least overnight and preferably longer.

Meanwhile, if they do not already exist, install the two doorbell switches near the front and rear doors of your home and run twisted-pair bell or telephone wire from them to the location where the electronics package will be located. Dress all wiring neatly and hide as much of it as you can behind moldings and other parts of the structure.

When the silicone adhesive has fully set, mount the circuit-board assembly in place with ½-inch-long spacers and 4-40 × ¾-inch machine

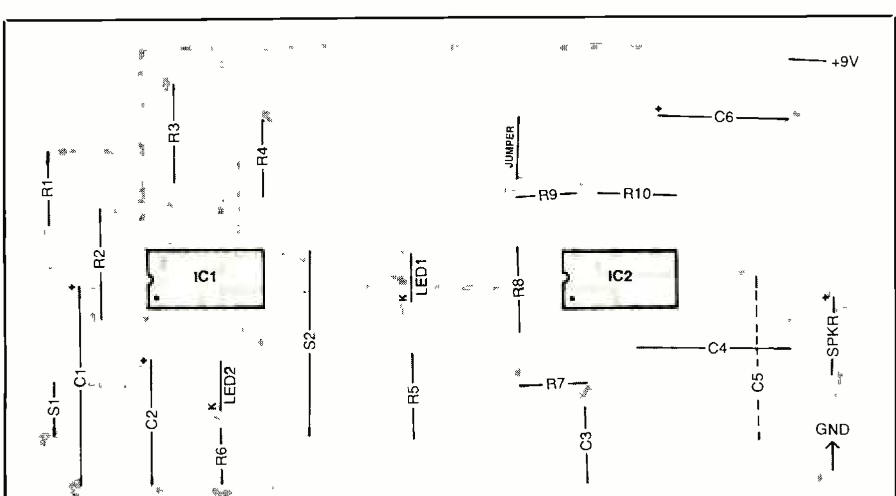


Fig. 3. Wiring guide for pc board.

Experimental Triggering Methods

This "Electronic Doorbell" will trigger with any negative-going pulse. Thus, it allows for other possible triggering schemes and applications. For example, you can replace the standard pushbutton bell switch with a copper touch plate, as illustrated in drawing (A). A length of wire routed from the touch plate to pin 6 of *IC1* completes the circuit. If you wish touch plates at both entries, connect the other to pin 8 of *IC1*. With a little imagination, you can have the pins 5 and 9 outputs of *IC1* drive transistors that control relays to give you control over two different electrically powered devices from two separate locations, while at the same time signaling which device is active.

Another triggering possibility is the photoelectric method illustrated in drawing (B). Here, a photoresistor replaces one or both bell switches. This circuit is activated by shining light on the photoresistor(s). To sound either tone, the photoresistor(s) should be positioned so that they are normally in darkness and respond only when light strikes them. Alternatively, they can have light on them at all times except when an object interrupts the light beam(s). With the photoresistor method of triggering the circuit, you can adapt a shutter mechanism to trigger a one-shot multivibrator state.

Drawing (C) illustrates yet another method of triggering the project. This time, moisture is used as the trigger. The sensors connected to one or both trigger inputs to *IC1* are simple interleaved copper "finger" moisture sensors. When either or both sensors becomes damp enough, the resulting drop in resistance between the electrodes generates the negative-going spike that triggers *IC1*.

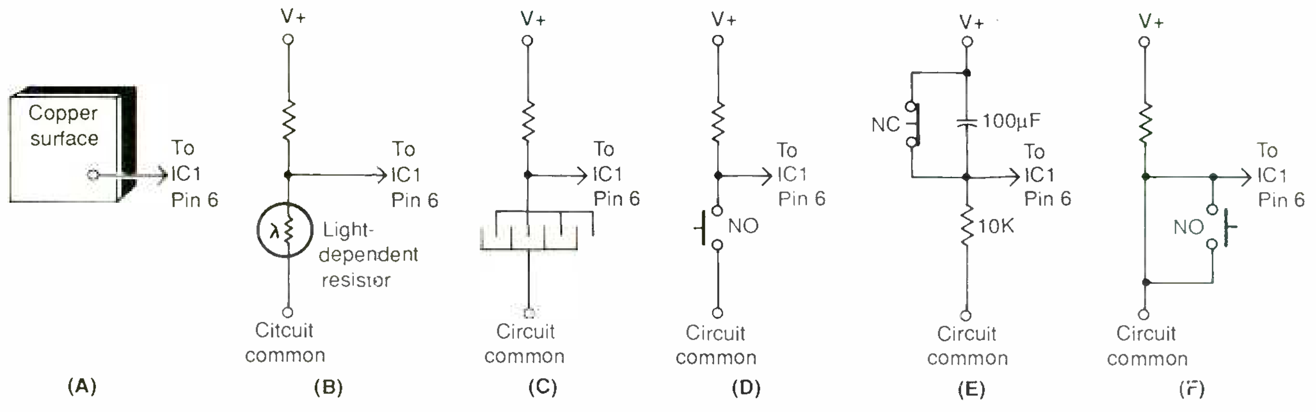
Drawing (D) is also for use in "wet" situations. This time a "float" switch is used to sense when the water level in your basement or anywhere else rises above a certain point. When it does, the switch closes and triggers the project's circuitry to let you know that a problem exists. With a little ingenuity, you can feed the output from *IC1* to a driver transistor that controls a relay. The relay, in turn, then starts up a pump that runs until the water level drops enough to once again open the switch.

By extension, arrangement (D)'s switch can be a temperature sensor that closes when the temperature being monitored in, say, your freezer rises above a certain point to alert you to loss of refrigeration.

The arrangement shown in (E) provides a delayed off-to-on state. It keeps the project triggered as long as the switch is open. Finally, the arrangement shown in (F) provides a very strong negative-going trigger pulse for the project.

As you can see from the foregoing, this project can be adapted to other uses besides serving as a dual doorbell. With the proper switching arrangements, it can serve as the active element of an intruder alarm. For example, wiring to both inputs will let you monitor two locations. Alternatively, separate perimeter sensing-system switch loops can be wired to the two inputs to give you progressive position warning.

Try experimenting with different triggering schemes for this project's circuit to suit different applications. You will find that the circuitry is very adaptive, as we have shown.



Examples of possible alternate triggering techniques to suit applications other than doorbells.

hardware. Locate the wires coming from the SPKR holes in the board and crimp and solder the free end of the one coming from the + hole to the "hot" lug on the speaker. Then crimp an solder the free end of the other wire to the unidentified lug on the speaker. Be careful not to puncture or drop hot solder on the cone of the speaker.

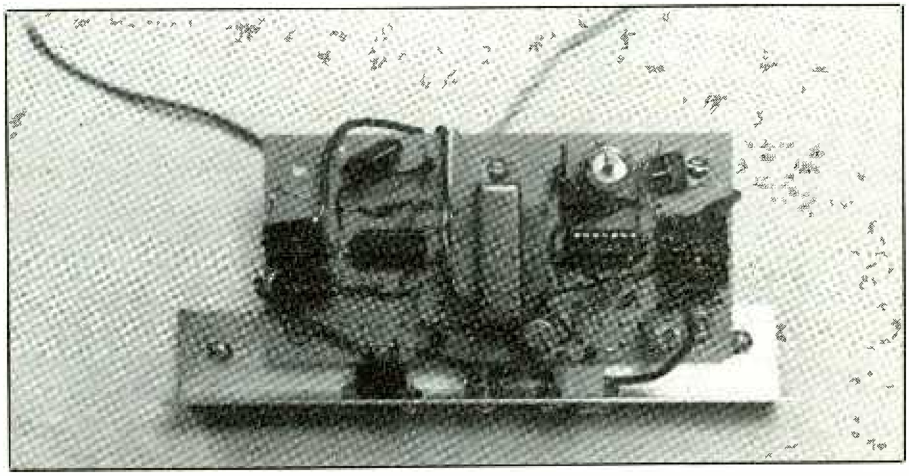
Identify the leads of the red light-emitting diode and clip the cathode one to ½ inch. Form a small hook in the remaining cathode-lead stub. Slip a 1-inch length of small-diameter heat-shrinkable tubing or insulating plastic tubing over the free ends of the *LED1* and *LED2* wires. Crimp

(Continued on page 86)

Switch Multiplier

Digital switching arrangement multiplies the number of ac-operated devices that can be controlled by a single wall switch without requiring house wiring modification

By Robert E. Samuelson



Installation of a new ceiling fan with light assembly in the center of our master bedroom presented some knotty problems. We wanted to control *both* fan and light from the existing wall switch located just inside the entry to the room—not by having to enter the room at night and groping for a pull chain. The single wiring circuit between the existing light fixture in the ceiling and wall switch could not be augmented without breaching the flat roof of our home, and dangling swags and surface wiring were ruled out for aesthetic reasons. Though I could have used commercial wireless control modules, I did not want a device that sits there continuously sucking up power just waiting for the occasional command.

The Switch Multiplier described here provided me with a solution to my dilemma. Though designed specifically to solve my fan/light problem, the Multiplier can be useful in other remote-switching applications in a household. The compact Switch Multiplier was small enough to fit into the metal ceiling box formerly occupied by a flush lighting fixture and now supporting my fan/light assembly—with a bit of bracing, of course.

Operation of the Switch Multiplier is very simple. Flipping the wall switch to ON turns on the light below the fan. A quick flip of the switch to OFF and then back ON turns off the light and on the fan. Another OFF/ON operation turns on both fan and light. Finally, setting the wall switch to OFF and leaving it there disables both fan and light.

About the Circuit

Figure 1 is a simplified representation of the circuitry contained in the Switch Multiplier. It shows how 117-volt ac line power is routed by relays *K1* and *K2* to the light or/and fan when wall switch *S1* is ON. The relays are controlled by a simple sequence-and-hold circuit that is activated by an impulse each time *S1* is switched to ON. The advantages of this system are that it draws no power when it is not in use (*S1* OFF) and no change in your house wiring is required to implement it.

Shown in Fig. 2 is the complete schematic diagram of the Switch Multiplier. The circuit consists of three major sections:

(1) A dc power supply that delivers 12 volts to the relay circuitry, together with a time-delay branch to trigger *IC1*, and a timed holding branch to power *IC1* and *IC2* to keep them alive when *S1* is OFF during an OFF/ON sequence;

(2) Integrated circuits *IC1* and *IC2*, which respond to the commands from wall switch *S1* and provide the proper sequencing and control to the relays;

(3) Relays *K1* and *K2*, which route ac line power to either or both loads, as directed by *IC2*.

Circuit operation is as follows. Power transformer *T1* steps down the 117 volts ac delivered to it from the ac line to 12.6 volts ac. This reduced ac voltage is then converted to pulsating dc by rectifier diode *D1* and is filtered to pure dc by capacitor *C1*. The dc voltage is then regulated to + 12 volts by regulator *IC3* and is then distributed throughout the low-voltage circuitry as needed.

Triggering impulses are generated

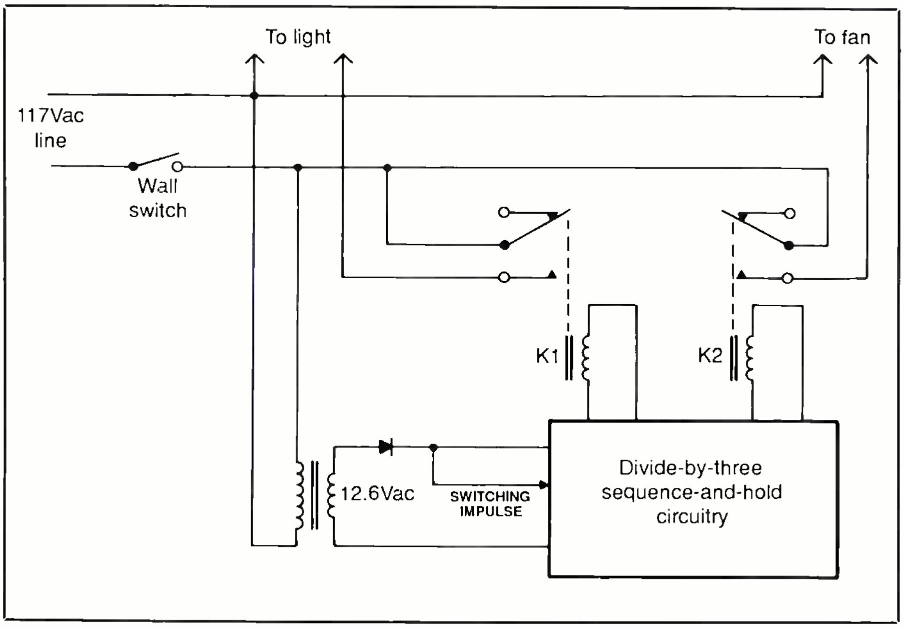


Fig. 1. Simplified diagram of the elements that make up a device that controls two ac-operated electrical devices with a single ac line.

every time *S1* is switched to ON. These impulses are picked off at the junction of *D1*, positive lead of *C1* and INPUT terminal of *IC3* and are sent to the input of *IC1*. To arrive at *IC1*'s input, the trigger pulses must negotiate the time-delay network made up of resistors *R2*, *R3* and *R4* and capacitor *C4*, which imposes a delay of about 0.06 second (60 milliseconds) that holds off triggering *IC1* and *IC2* until these devices are powered up. Discharge time of the network is short enough so that the input to *IC1* goes low while *S1* is being operated; so *IC1* will remain ready for the next trigger pulse.

While flipping *S1* to OFF and then back to ON, power must be maintained on *IC1* and *IC2* to preserve the existing state of *IC2* until the cycle is stepped ahead. To accomplish this, a timed holding branch circuit is employed. This branch is made up of rectifier diode *D2*, 100-microfarad capacitor *C3* and 100,000-ohm resistor *R2*.

When *S1* is closed (ON), *C3* quickly charges to approximately 12 volts, taking about 10 milliseconds to do so. But when *S1* is opened (OFF), the time constant of the *C3R3* network, which is about 10 seconds, maintains sufficient voltage on *IC1* and *IC2* to preserve their status until the wall switch is again closed.

CMOS 4023 triple 3-input NOR gate *IC1* is wired in this circuit to form a Schmitt trigger that provides a clean, sharp input to *IC2*. CMOS 4027 JK flip-flop *IC2* is configured as a divide-by-three circuit here. Three successive closures of *S1* step *IC2* through three sequential states. Connecting the proper outputs of *IC2* through *R6* and *R7* to the relay circuits as shown will then provide the desired sequence of LIGHT/FAN/BOTH/OFF. See Fig. 3 for the internal connections of the logic circuitry.

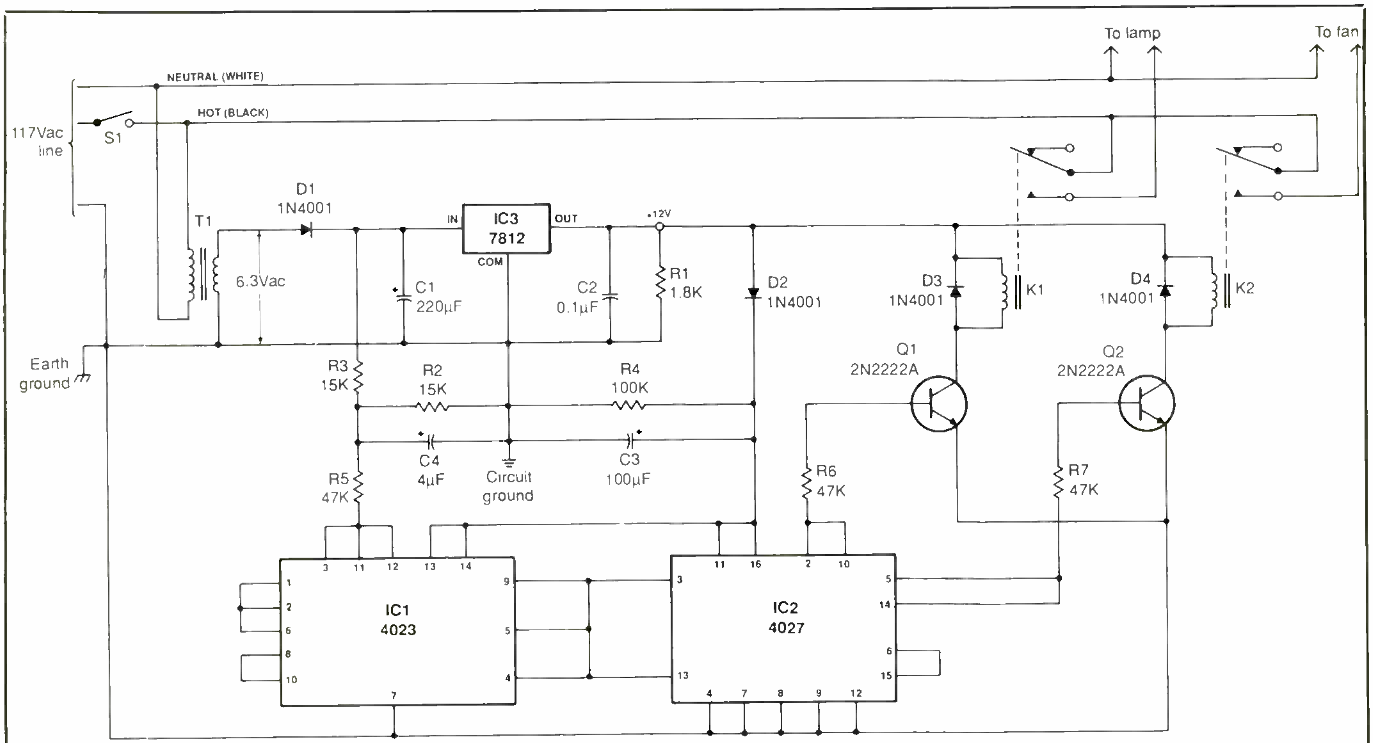
Relays *K1* and *K2* in this project are Radio Shack Cat. No. 275-248 units that have 320-ohm, 12-volt dc coils and contacts rated at 10 amperes. The contact rating is adequate for light-to-moderate loads, such as the fan and light for which the project was designed. The driving circuits for the relays are conventional. They are made up of transistors *Q1* and *Q2* for *K1* and *K2*, respectively. Diodes *D3* and *D4* are surge suppressers, and resistors *R6* and *R7* isolate the transistors from the outputs of *IC2*.

Construction

This is a simple, straightforward project that requires no special component layout or routing of conductors. The only admonition to bear firmly in mind is that you must take care to place conductors and connections that carry 117-volt ac line power as far as possible from the low-voltage portions of the circuit.

You can build the project using any wiring technique that suits you. For this project, perforated-board construction is perhaps the simplest way to go. If you do go this route, use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. If you prefer printed-circuit wiring, feel free to design and fabricate your own pc board. Should you wish to use prototyping board instead, choose the type that accepts DIP integrated circuits and has extra connecting points for each IC pin. In any case, whatever wiring technique you decide to use, it is a good idea to use sockets for *IC1* and *IC2*.

The miniature Radio Shack relays specified for *K1* and *K2* in the Parts List will fit standard perforated boards, but remember to observe full precautions for the terminals that will be at 117 volts ac line potential when the project is operating. Be certain to allow adequate clearance between these high-voltage points and the low-voltage points in the circuit layout. Also, if you are using printed-circuit or prototyping board, check the copper traces to which the 117-volt-level connections will be made. If the traces appear to be skimpy or fragile, augment them by carefully soldering in parallel lengths of 18- or 16-gauge solid wire to carry the moderate current that will be drawn by the loads.



PARTS LIST

Semiconductors

D1 thru D4—1N4001 silicon rectifier diode

IC1—4023 CMOS triple 3-input NAND gate

IC2—4027 CMOS dual JK flip-flop

IC3—7812 + 12-volt regulator

Q1,Q2—2N2222A or similar general-purpose silicon npn transistor

Capacitors

C1—220-µF, 25-volt electrolytic

C2—0.01-µF ceramic disc

C3—100-µF, 35-volt electrolytic

C4—4-µF, 35-volt electrolytic

Resistors (¼-watt, 10% tolerance)

R1—1,800 ohms (½-watt)

R2—100,000 ohms

R3,R4—15,000 ohms

R5,R6,R7—47,000 ohms

Miscellaneous

K1,K2—Miniature 12-volt, 100-mA or less relay with 10-ampere spdt contacts (Shack Cat. No. 275-248 or similar; other applications may require relays with different coil ratings and contact ratings/arrangements—see text)

S1—Existing ac lighting wall switch

T1—Miniature 12.6-volt, 300-mA power transformer (Radio Shack Cat. No. 273-1385 or similar)

Circuit board (perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware or pc board of your own design (see text); suitable enclosure; sockets for DIP ICs; terminal strips and connectors as needed; 18-gauge or heavier stranded wire; wire nuts; machine hardware; hookup wire; solder; etc.

Fig. 2. Complete schematic diagram of the Switch Multiplier designed to handle two moderate-power loads, such as a ceiling fan and its lighting fixture.

You can avoid some possible difficulties later on if you mount the relays on the circuit-board assembly with their connection pins pointing upward *away from* the board. Secure the relays to the top surface of the board with silicone adhesive or even a simple U clamp made from short lengths of insulated hookup wire routed through holes in the board and soldered securely into place.

Using Fig. 2 as a guide, wire together the project's circuit. However, do *not* make the connections between the relay contacts and 117-volt ac line. These will be made later, after suitable voltage and operational checks have been completed.

In the lead photo is shown a photo of the original version of the Switch Multiplier, which was built to control my ceiling fan and its accessory lighting fixture. This version was built on a Radio Shack Cat. No. 276-151 Dual IC Experimenters PC Board and has been faithfully turning on and off my bedroom fan and light for more than four years. Notice here that the relays (shown as the black squares at opposite ends of the board) are mounted with their connection pins pointing upward, away from the board.

Figure 4 shows the same circuit built more recently for a different application. This version was assem-

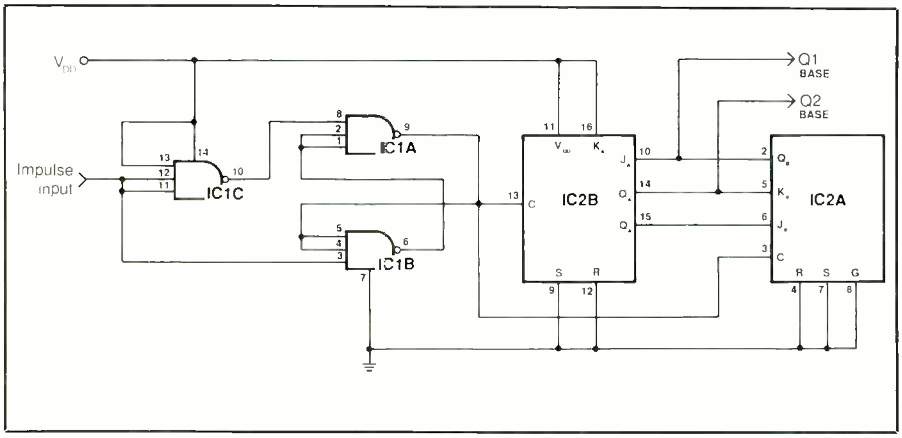


Fig. 3. Details of internal logic-circuit wiring.

bled on a Radio Shack Cat. No. 276-170 Experimenters PC Board. This particular board has copper traces with multiple pads for each IC pin on the bottom of the board. In this version of the project, the pins of the miniature relays (the two squares to the right of the ICs) are plugged into the holes in the board, rather that pointing upward away from the board's surface.

The boards used in both versions of the project have provisions for mounting and connecting DIP IC sockets. This greatly reduced the amount of time and effort needed to drill holes and make connections.

When you assemble your project, mount the IC sockets—*not* the ICs themselves—into place first. Mounting of the circuit-board assembly, power transformer *T1* and voltage regulator *IC3* require machine screws, nuts and lockwashers. Also, make sure to provide a good, solid electrical ground during installation.

Your choice of housing for your Switch Multiplier depends on the application for which the project is built. If you build it for the fan/light application for which I originally designed the project, the circuit-board assembly must be mounted inside a protective enclosure that has provisions for making the necessary 117-volt ac input and output connections. As you can see in Fig. 4, a pair of chassis-mount ac receptacles mounted on the metal L bracket at the bottom of the photo provide the means for connecting the fan and lamp to the project. If you go this route, you must equip the fan and light power conductors with their own separate ac plugs. Alternatively, these conductors can be wired directly into the circuit.

In the case of the original application for the Switch Multiplier to control a fan and a lamp, removal of the glass and reflector of the existing flush-mount lighting fixture left a metal box measuring 9 × 9 × 4 inches. This was set into the ceiling. If you plan on using the project for this same type of application in a location where the fixture is not set into the ceiling but is designed to accommodate a hanging light fixture, you may have to remove the existing box, enlarge the hole and use a box that is large enough to accommodate the circuitry. In either case, you will need a length of 1 × 1-inch angle iron to provide a reinforcing support for the weight of the fan and light. The angle iron also provides a convenient mounting bracket for the circuit-board assembly.

Ac-line input conductors to the Switch multiplier should be stranded wires not less than 16 gauge in size. Make all hookups with ordinary wire nuts. Outputs to the fan and lamp (or other medium-duty loads) should also be made with stranded wires, these not less than 18 gauge in size.

If you are building the project for any purpose other than to control a fan and lighting fixture, house the circuitry in any enclosure that will suit your needs. Then make connections according to the demands of the items being controlled.

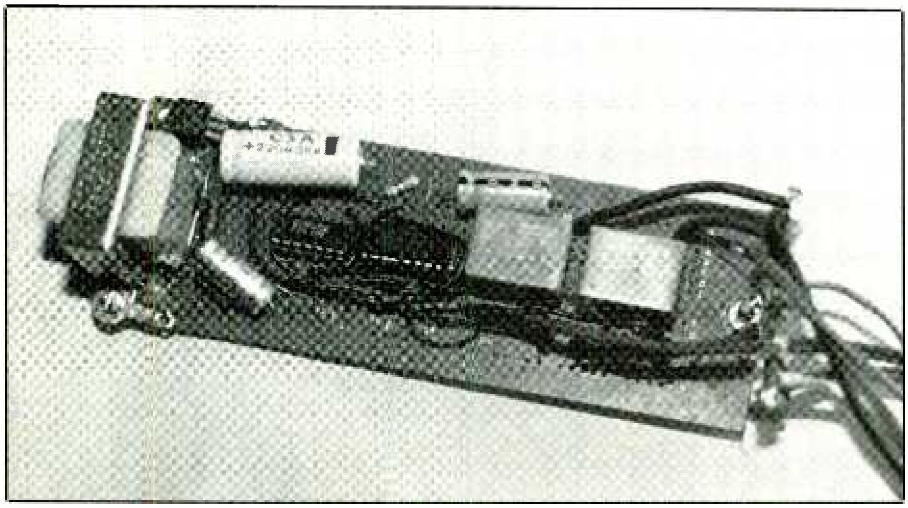


Fig. 4. A later version of the project (the original is shown in the lead photo) wired on a DIP style prototyping board that has copper traces that interconnect several pads for each IC-pin hole and with relay pins plugged into the hole matrix.

With DIP integrated circuits still not installed in their sockets and no ac-line-level connections made to the contact lugs of the relays, carefully check all wiring and soldered connections. It is a good idea to use a magnifying glass for this inspection. Check especially between closely spaced pads and conductors for solder bridges.

If you locate any suspicious connections, reflow the solder around it. Clear any solder bridges with desoldering wick or a vacuum-type desoldering tool. Then use an ohmmeter set to a high range to make a "tour" of the circuit, checking all points that are and are not supposed to be at ground level. Then set the ohmmeter to a low range and check the polarities of all four rectifier diodes. Be careful here because some meters reverse the polarity of the test voltage delivered to their probes. If you consistently get a wrong-polarity indication, suspect the polarity of the test voltage.

Do not proceed to powering up the project until you are absolutely certain that all wiring is correct and that all components are in their correct locations and are installed in proper orientation. Once everything checks out okay, proceed to a live check of the 12-volt dc portion of the project. Before you do this, however, keep firmly in mind that you will be working around potentially lethal ac line potentials. Exercise extreme caution at all times when working on the powered-up circuit!

Connect a temporary ac line cord —switched, if possible, to simplify operational checks—to the primary leads of the power transformer, using wire nuts. Make sure that these connections are solidly made and that no part of the line-potential wiring is exposed. At this point, there should be no other points in the circuit that will be at 117 volts ac when the circuit is powered.

Use a dc voltmeter or multimeter set to dc volts to make the following voltage checks. The meter should have at least a 1-megohm input resistance. Connect the meter's common probe to a convenient circuit-ground point and plug the line cord into a convenient ac outlet. Switch on power if you are using a switched line cord.

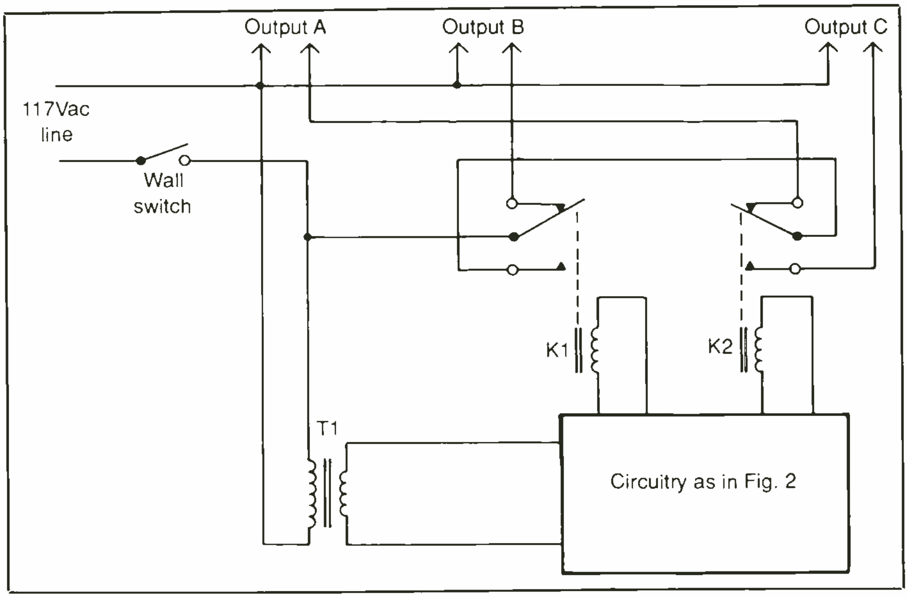


Fig. 5. Wiring for controlling three loads with a single ac line.

Measure the potential at the junction formed by *C1* and *R3*; you should obtain a meter reading of about +14 volts. At the junction formed by *R2* and *R3*, the reading should be about +7 volts. Then the potential measured at the top of *R1*, *C2*, *D2*, *K1* and *K2* should be +12 volts, as should be the reading at the junction formed by *D2*, *C3* and *R2*. If you pull the plug (or switch off the line cord), the reading at the *D2/C3/R2* junction should very slowly decrease as the charge on the capacitor in this timing circuit bleeds off.

If you do not obtain the proper reading at any point, remove ac power from the circuit and rectify the problem. Do *not* proceed until you have corrected the problem.

Allow the charges to leak off all capacitors. Then, exercising the normal precautions for handling MOS devices, install *IC1* and *IC2* in their respective sockets. Make sure that each is properly oriented before inserting it and that no pins overhang the sockets or fold under between ICs and sockets. With a continuity checker or an ohmmeter set to a low range, check operation of the contacts of *K1* and *K2* as follows.

First, connect the checker's or ohmmeter's leads to the normally-open contacts of *K1* and then *K2* and note the indications obtained. In both cases, there should be no sound from the checker or low resistance or short circuit from the meter. Move the tester's or meter's probes to the normally-closed contacts of first one and then the other relay. In both cases, there should be continuity on the order of zero ohm.

Leave the checker's or ohmmeter's probes connected to the normally-open contacts of *K1* and power up the circuit. You should now obtain an indication of continuity. Checking the normally-open contacts of *K2* should yield an infinity reading.

Turn off and then on the ac power to the project. Now the indication across the normally-open contacts of *K2* should be continuity and across the normally-open contacts of *K1* should be open. Once again turn off and then on ac power. Now the indications across the normally-open contacts of both relays should be continuity. Finally, turn off power altogether and check all combinations of relay contacts; normally-open contacts should show infinite resistance and normally-closed contacts should show continuity.

If you do not obtain the appropriate indications in all cases, remove ac power from the project and troubleshoot it. Rectify the problem before proceeding.

Once all indications are correct, finish wiring the 117-volt ac input and output connections to the relays. Always use at least 18-gauge—and preferably 16-gauge—stranded wire for all conductors that carry line-level voltages from the ac line and to the loads. Then perform an actual in-circuit operational check of the project as detailed above.

When working on the connections in the ceiling electrical box, make sure that you kill ac power to this branch circuit by removing the appropriate fuse from the fuse box or flipping the appropriate circuit breaker's toggle to OFF. If you are not sure which fuse to remove or circuit breaker to flip, kill power at the main fuse or breaker. If you are not sure about what you are doing with regard to the ac line, have someone who does help you or have a licensed electrician do the installation.

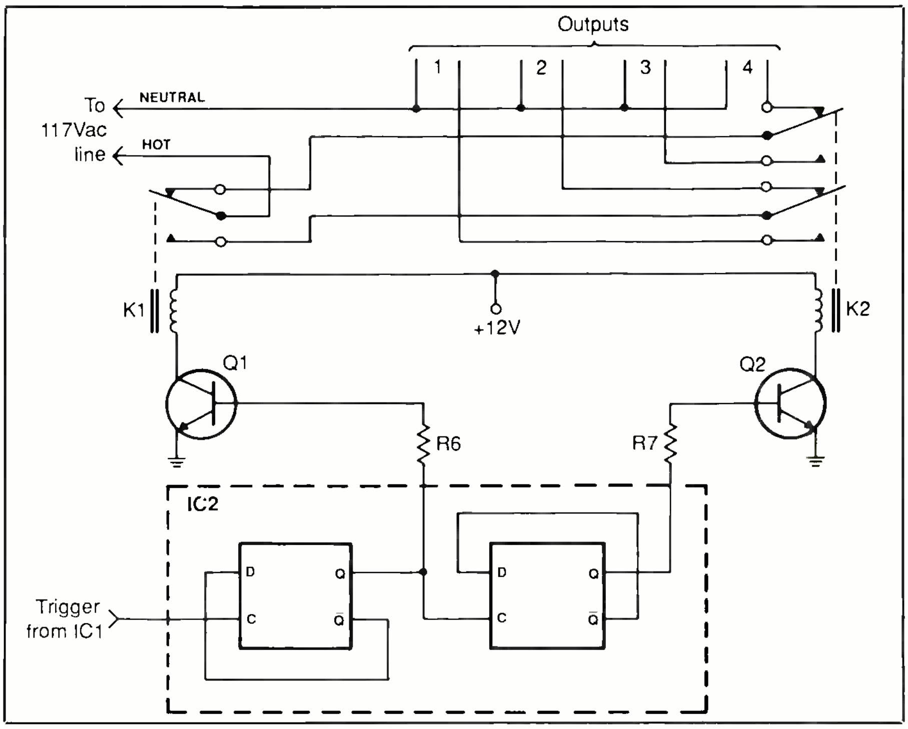


Fig. 6. A one-of-four selector wiring arrangement. This option requires that IC2 and K2 in the original circuit be replaced as detailed in the text.

Other Applications

As mentioned above, the Switch Multiplier is not limited to use as a fan/light controller. In one possible alternative application, the project can be used as a single circuit that controls, say, a patio light and, separately, a floodlight—from inside your home. Of course, control can be exercised over any combination of light options, such as strings of perimeter, path or driveway lights. Since these are all outside installations, be sure to house the circuitry inside a weatherproof box located under the eaves at a location convenient to normal 117-volt ac wiring.

Another possible application for the project is as a remote selector for three different loads. This can be accomplished with a simple change in wiring of the contacts of *K2*, as illustrated in Fig. 5.

Yet another application is to expand the project to serve as a one-of-four selector by replacing *IC2* with a CMOS 4013 dual D flip-flop and wiring it as a divide-by-four counter and replacing *K2* with a relay that has dpdt contacts (for example, Radio Shack's Cat. No. 275-218 relay). Connections for this arrangement are illustrated in Fig. 6.

Though the original circuit was designed to switch loads that require 117-volt ac line power, it can be wired to switch low-voltage loads as well. To accomplish this, you would change the wiring to the contacts of the relays to route the low voltage instead of the 117 volts from the ac power line.

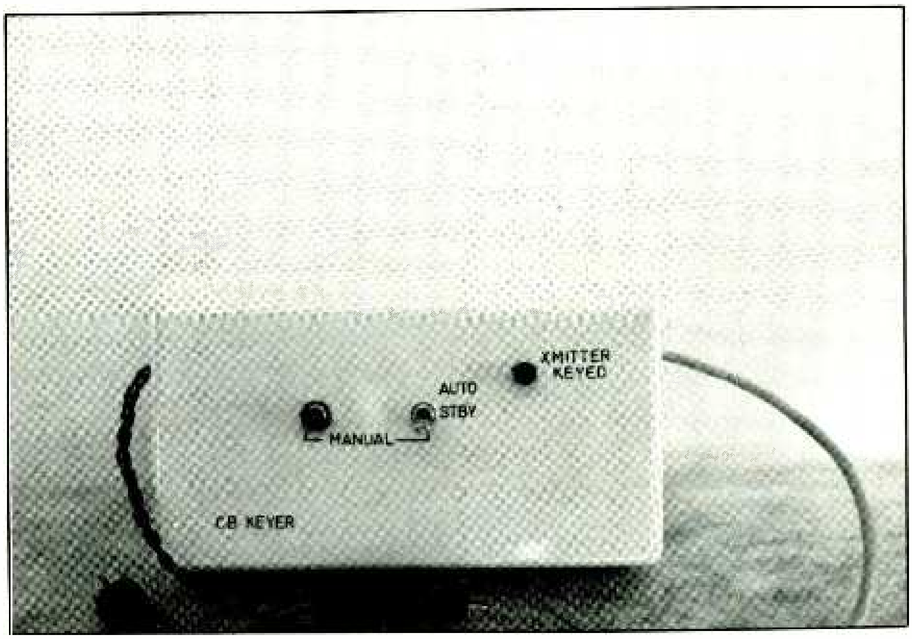
To have the project's power supply deliver the necessary low dc voltage to such things as lighting, solenoid-operated water valves and the like, replace *T1* with a heftier power transformer. A good choice here is Radio Shack's Cat. No. 273-512 power transformer, which outputs 25 volts center-tapped at its secondary. Use the 25-volt tap connected through the relay contacts to power the loads being controlled by the project.

If you use the Switch Multiplier to control anything other than a ceiling fan and lighting fixture, do not exceed the contact rating of the relays. If the loads you expect to control draw more than about 7.5 amperes, upgrade the relays or have the project's relays control power relays. Also, upgrade the gauge of the ac-line input and output wiring to safely handle the amount of power that will be drawn by the loads. **ME**

Transmitter Test Keyer

Automatic/manual keying device simplifies bench testing of modulation and r-f-transmitter sections of radio transceivers

By Michael Swartzendruber



When testing the modulation and r-f-amplifier sections of my Citizens Band radios, it is sometimes necessary to key the microphone and inject a test tone to obtain meaningful test results. Old timers at the servicing game usually whistle into the set's microphone while holding it keyed in one hand and use their other hand to probe the circuitry. This is a very chancy procedure to say the least, firstly because very few people have calibrated pure-tone whistles and, secondly, because with one hand occupied with the microphone, only one hand is left to juggle two test probes. The solution to this dilemma is my CB Keyer, which can also be used with amateur, marine and other radio transceivers.

This project combines a tri-mode automated microphone keyer with a pure-tone generator. It is easy to use, with just two switches that give you the option of either automatic or manual modes of operation. Also, using printed-circuit construction and readily available integrated circuits (plus passive components), it is a breeze to build.

About the Circuit

The complete schematic diagram of the CB Keyer, minus its power supply, is shown in two parts. The portion shown in Fig. 1 is the timer/switching arrangement, while that shown in Fig. 2 is the free-running oscillator circuit.

In addition to the MANUAL and AUTOMATIC modes already mentioned, the Keyer also has a STANDBY mode. Mode selection is via center-off switch *S2* in Fig. 1. In the AUTOMATIC mode, the project keys the CB radio's microphone input once every 2 minutes for an on period of 1 minute, during which time the 1-kHz tone developed by the oscillator in Fig. 2 is sent to the radio through the microphone input connector on the latter. (Note that the project replaces the CB radio's microphone during testing. The Keyer's jack, *J1* plugs into the connector on the radio from which the microphone is removed, and a dummy load is used in place of an antenna.) This on/off keying cycle has been determined to be of sufficient duration for most signal-tracing tests to be performed.

In the MANUAL trigger mode, the CB radio's microphone is keyed for a period of one minute whenever the command is issued by pressing and releasing pushbutton switch *S1* in Fig. 1. The microphone is then switched off until the Keyer is triggered again by pressing and releasing *S1*. Each time the microphone is in the keyed condition, the 1-kHz tone is injected into the radio via the microphone input.

All timing for the project is accomplished with the 556 dual timer chip. Separate resistor/capacitor elements control the individual timing cycles for each of the chip's two timer stages.

One of *IC1*'s timers is configured as a monostable multivibrator. The other timer is wired as a free-running (astable) multivibrator.

Outputs from the two timers, at pins 5 and 9, are routed through *D2*

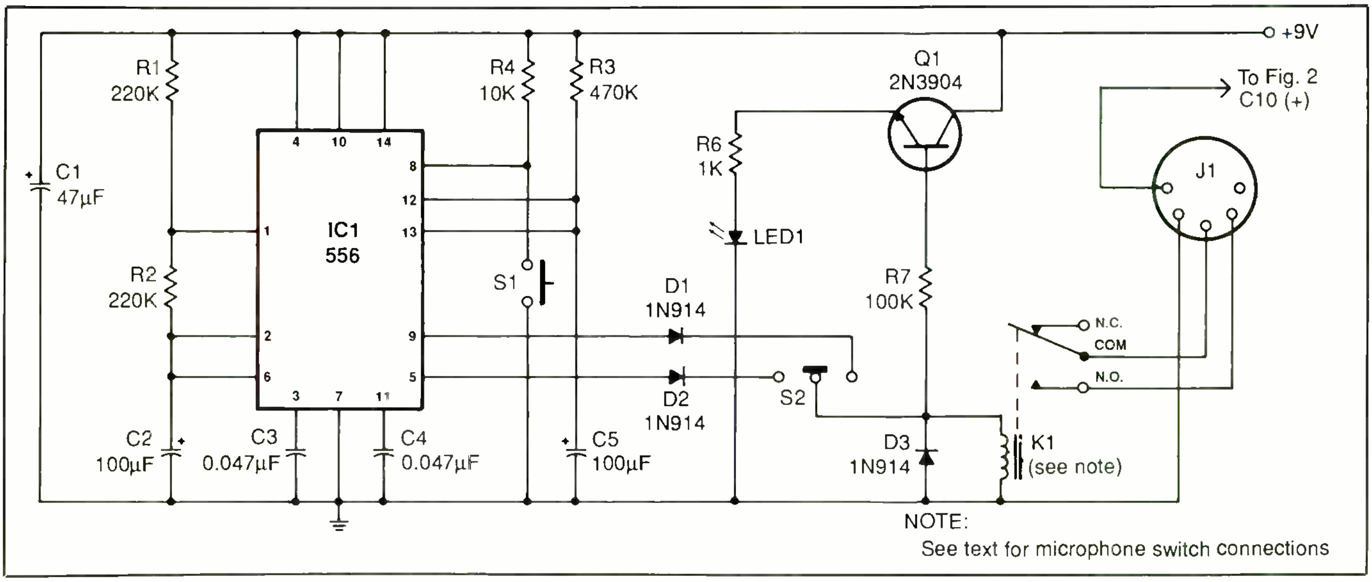


Fig. 1. Schematic diagram of the CB Keyer's switching circuits.

and *D1* to *S2*. In turn, *S2* applies one of these signals, depending on the setting of the switch, to the coil of relay *K1*. When *K1* energizes, in the AUTOMATIC mode, its lower contact closes and completes the microphone keying circuit inside the CB radio. Setting *S2* to its center-off STANDBY position, the CB Keyer is prevented from keying the CB radio.

The circuit shown in Fig. 2 illustrates a special-application arrangement for a conventional operational amplifier. Here, the circuitry around op amp *IC2* serves two functions that allow the chip to form a stable oscillator. Separate resistive/capacitive loops *R10/C6* and *R11/C7* provide two signals that are fed from output pin 6 to input pin 3 of *IC2*. The significant fact here is that the currents in these feedback loops are out-of-phase with each other, with the phase angle set by trimmer control *R9*.

When the currents in the two feedback loops are 180 degrees out-of-phase with each other, the op amp will oscillate. If *R9* is not set properly (loop currents not 180 degrees out-of-phase with each other), the output waveform from the oscillator circuit will be distorted.

Frequency of oscillation for the Fig. 2 circuit is set by adjusting trimmer controls *R10* and *R11*. For oscillation conditions to exist, *R10* and *R11* must be set for equality.

Keying signals generated by the CB Keyer can be triggered by pressing and releasing pushbutton switch *S1*. This action triggers the monostable multivibrator circuit in *IC1* and keys the CB radio's microphone circuit. After about 70 seconds, the multivibrator returns to its stable "off" state. It remains off until you once again press and release *S1*.

Each time a signal is applied to relay *K1*'s coil, transistor *Q1* conducts.

PARTS LIST

Semiconductors
D1,D2,D3—1N914 or similar silicon switching diode
IC1—556 dual timer
IC2—741 operational amplifier
LED1—Light-emitting diode (Radio Shack Cat. No. 276-033 or similar
Q1—2N3904 or similar general-purpose silicon npn transistor

Capacitors
C1—47-µF, 16-volt electrolytic
C2,C5—100-µF, 16-volt electrolytic
C3,C4—0.047-µF polypropylene
C6 thru C9—0.01-µF ceramic disc
C10—22-µF, 16-volt electrolytic

Resistors (½-watt, 5% tolerance)
R1,R2—220,000 ohms
R3—470 ohms
R4,R5,R7—10,000 ohms
R6—1,000 ohms
R8—1,000-ohm pc-mount trimmer potentiometer
R9—50,000-ohm pc-mount trimmer potentiometer
R10,R11—20,000-ohm pc-mount trimmer potentiometer

Miscellaneous
J1—5-pin DIN jack (Radio Shack Cat. No. 274-033 or similar)
K1—6- to 9-volt dc relay with 1-ampere contacts
S1—Spst normally-open, momentary-action pushbutton switch
S2—Spdt center-off miniature toggle switch (Radio Shack Cat. No. 275-325 or similar)
Printed-circuit board, protoboard or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for IC1 and IC2; suitable enclosure; ±9-volt dc power source (see text); machine hardware; hook-up wire; solder; etc.

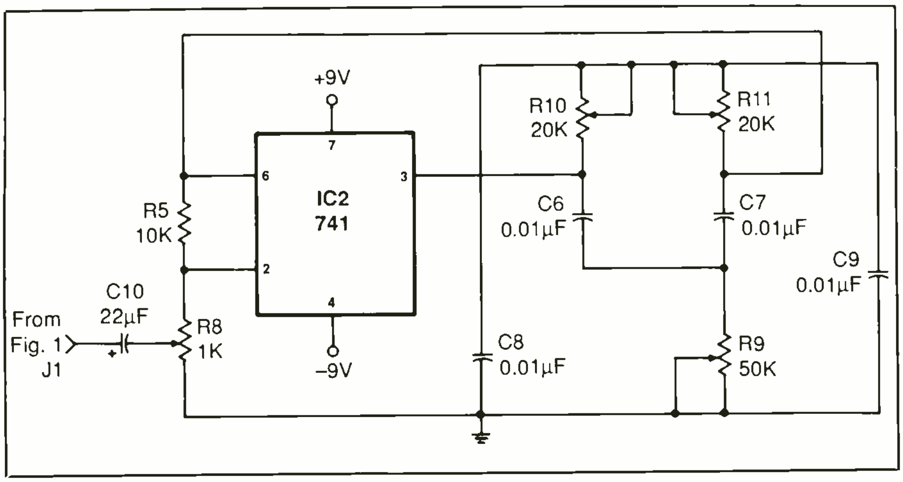


Fig. 2. Schematic diagram of the CB Keyer's audio oscillator.

Collector current then causes light-emitting diode *LED1* to provide a visual indication that the CB radio to which the project is connected has been keyed.

No power-supply circuit schematic is shown here for the simple reason that the project will operate off virtually any of the commonly available 9-volt dc supplies that plug directly into an ac outlet. You can use this type of supply or build one from scratch using any of the many schematic diagrams published in electronics magazines and books.

Looking at Fig. 2, you can see that this project requires a power supply that can deliver both +9 and −9 volts with reference to ground. Keep this in mind when selecting or building a power supply for the project or when using a bench-type supply.

Construction

There is nothing critical about component layout. Therefore, just about any traditional technique can be used to assemble and wire the project. You can assemble the project's circuitry on a printed-circuit board or on perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware and point-to-point wiring. Another alternative is to wire the circuit on prototyping board, or so-called "protoboard." Whichever way you go, however, it is a good idea to use sockets for the ICs.

If you wish to use a printed-circuit board, fabricate it using the actual-size etching-and-drilling guide given in Fig. 3. Once the board is ready, orient it in front of you as shown in Fig. 4 and begin wiring it. Start by installing and soldering into place the DIP IC sockets. Do *not* install the ICs themselves in the sockets until after preliminary voltage checks have been made and you are certain that the power buses are properly wired.

After the sockets are in place, install the resistors and then the trimmer potentiometers. Follow with the diodes, making certain that they are properly oriented before soldering their leads to the copper pads on the bottom of the board. Next come the capacitors. Once again, make sure that the electrolytic capacitors are properly oriented before soldering them into place.

Depending on the physical size and configuration of the relay, mount it directly on the circuit-board assembly with silicone adhesive or epoxy cement or save it for mounting on one of the walls of the enclosure in which the project's circuitry will be housed. Then use short lengths of hookup wire to interconnect the relay's contacts and coil lugs with the appropriate points on the circuit-board assembly.

Figure 1 assumes that the CB Keyer will be used with transceivers that require a switch-closing action to key the radio and, hence, shows connections from *J1* going to *K1*'s normally-open (N.O.) contacts. However, there may be transceivers that require a switch-opening action and, thus, require that *J1* be connected to the normally-closed (N.C.) contacts of relay *K1*.

If you plan on servicing a variety of transceivers, it is a good idea to route the wiring between *J1* and *K1*'s contacts through a switch that will allow you to select between the two requirements as needed. If this is the case, make modifications in the wiring to accommodate the switch.

Strip ¼ inch of insulation from both ends of seven 8-inch-long hookup wires (wires with different color insulation is recommended to help you keep track of what you are doing). If you are using stranded hookup wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. (Do this for *all* stranded wires used in the project.) Plug one end of these wires into the holes labeled K1 COIL S1 and S2 and solder them into place.

As mentioned above, this project can be driven by any of a choice of different power supplies. If you use a bench-type supply, you need a three-conductor cable that measures about 36 inches long or separate *stranded* hookup wires, preferably with color-coded insulation. Terminate the supply ends of the cable or wires in color coded alligator clips or banana plugs.

If you use a stranded-wire cable, loosely twist the wires together their entire length, but leave about 4 inches untwisted at the free end and 6 inches untwisted at the clip or plug end. Slip over the free end two 1-inch lengths of small-diameter heat-shrinkable tubing, positioning it 4 and 6 inches, respectively, from the free

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Decide which alligator clips or banana plugs will go to which polarity of dc voltage and which will go to power supply ground or common. Affix to each clip or plug a label that bears the legend +9V, -9V or GND. Set the cable aside until you are ready to install it.

If you prefer to use separate 9-volt dc wall supplies to drive the project, clip the output connectors from the cables of both. Separate the conductors a distance of 2 inches or so and strip ¼ inch of insulation from the ends of each. Tightly twist together the fine wires in each conductor and tin with solder.

Taking care to prevent the exposed conductors from touching each other or any metal, connect a dc voltmeter or a multimeter set to read dc volts across the output of one supply and plug the supply into an ac outlet. Observe the polarity of the voltage reading in the meter's display. If it is positive (+), place a label with a "+" on it on the conductor connected to the meter's "hot" probe and another label with a "–" on it on the other conductor. Conversely, if the reading is negative, place the "+" label on the conductor to which the meter's *common* probe is connected and the "+" label on the other conductor. Do the same for the second supply.

Should you build a power supply from scratch and plan on housing it inside the project's enclosure, you need three short wires to connect it to the circuit-board assembly. These wires connect into the circuit via the holes in the circuit-board assembly labeled +9V DC, -9V DC and GND. The other ends connect to the appropriate buses in the supply.

Strip ¼ inch of insulation from both ends of two 4-inch-long hookup wires. Plug one end of these wires into the holes labeled LED1 in the circuit board and solder into place. It helps if you use color-coded wires here, red-insulated for anode and black-insulated for cathode (K).

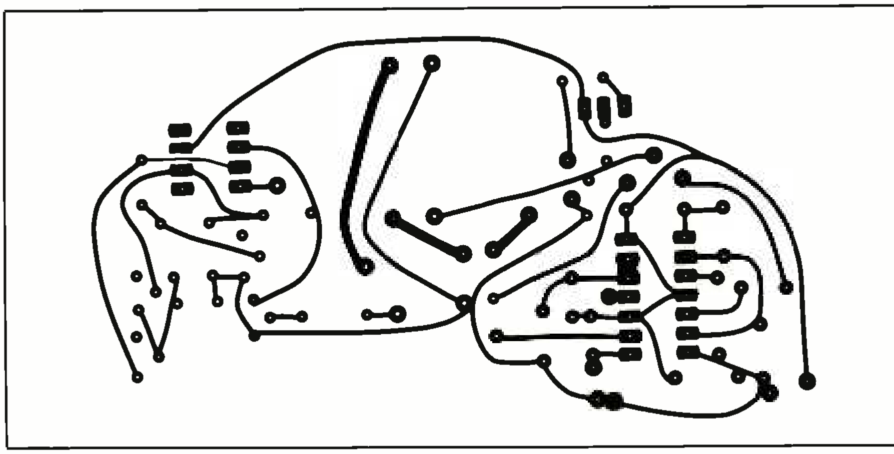


Fig. 3. Actual-size etching-and drilling guide for project's printed-circuit board.

Slip over the free ends of both LED1 wires a 1-inch length of small-diameter heat-shrinkable tubing or insulated plastic tubing. Trim the cathode lead of the LED to ½ inch and form a small hook in the remaining stub. Crimp the free end of the black-insulated wire coming from the LED1 K hole to the hooked lead and solder the connection. Repeat for the remaining lead and anode wire. Then slide the tubing up over the connections until both are flush against the bottom of the LED's case and shrink into place.

Just about any enclosure that will easily accommodate the circuit-board assembly (and internal power supply if you use it) can be used with this project. Easiest to work with is a plastic project box, but an all-aluminum utility box can also be used.

Machine the enclosure as needed. This includes drilling mounting holes for the circuit-board assembly (and power supply if it is to be internal), the two switches (or three switches if you are incorporating the switch that will allow you to select between normally-open and normally-closed relay contacts) and LED and entry/exit holes for the power cable or ac line cord for the internal supply and the cable that will connect the project to the CB radio.

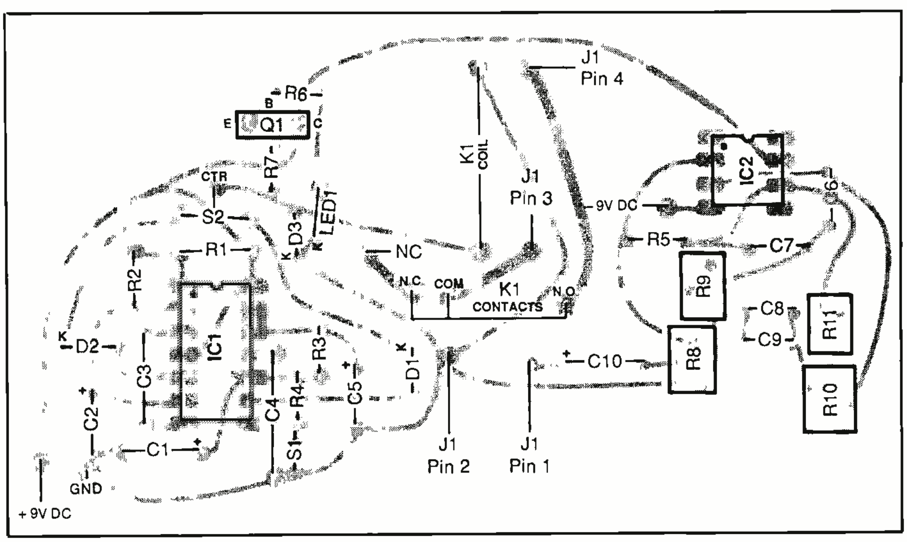


Fig. 4. Wiring guide for pc board.

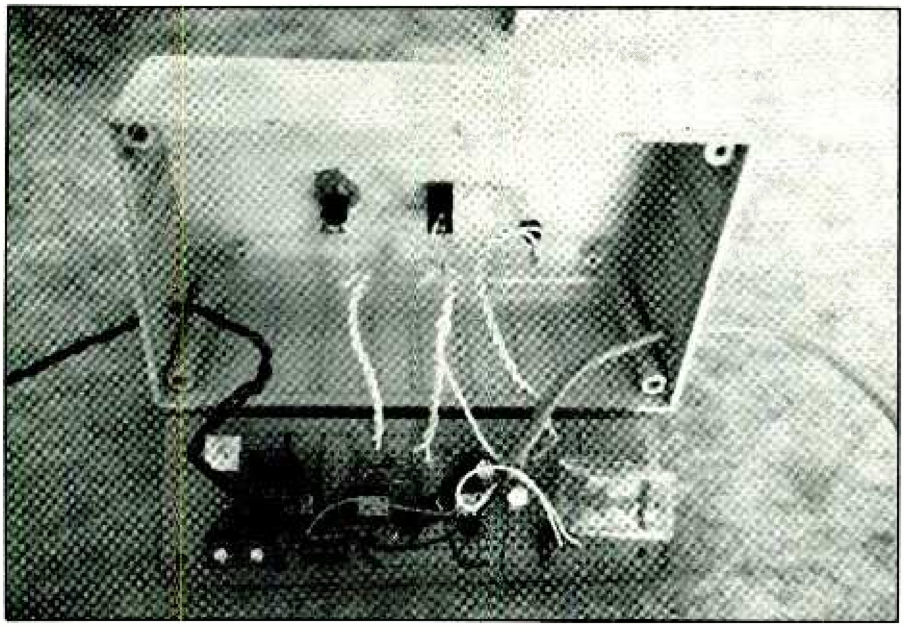


Fig. 5. Interior view of author's prototype built on prototyping board. This version requires a separate dual-polarity bench-type dc power supply.

If you are using a metal enclosure or a plastic enclosure with an aluminum panel and have drilled holes through the panel, deburr the holes. Then line the cable entry/exit holes with small rubber grommets.

When the enclosure is ready, label the front panel as shown in the lead photo. If you elected to incorporate the third switch, label its alternate positions N.C. and N.O.. To apply dry-transfer lettering, it is important to first thoroughly clean and dry the enclosure. This done, label the panel and then protect the lettering with two or more light coats of clear spray acrylic. Allow each coat to dry before spraying on the next.

If you are using an external power supply, whether a bench type or individual 9-volt dc wall transformers, route its cable through the hole drilled for it. Inside the enclosure, tie a knot about 8 inches from the free end to serve as a strain relief.

Plug the free ends of the cable conductors into the holes in the circuit-board assembly labeled +9V DC, −9V DC and GND, observing the labeling you used previously. Solder all conductors into place. Double check polarities with an ohmmeter.

If you are using separate plug-in supplies, it may be necessary to enlarge their cable entry hole and use a larger rubber grommet to get the two to enter the enclosure via the same hole. Tie the strain-relieving knot in the two-cable pair.

Twist together one the "+" labeled conductor of one supply and the "−" labeled conductor of the other. Plug this pair into the board hole labeled GND (if necessary, enlarge the hole to accommodate the double-thickness conductor) and solder into place. Then plug the remaining two conductors into the proper +9V DC and −9V DC holes and solder them into place.

Prepare a 36-inch length of four-conductor cable as follows. First, remove 3 inches and ¾ inch of outer plastic jacket from opposite ends. Strip ¼ inch of insulation from the ends of the conductors at the end of the cable from which 3 inches of jacket was removed. Strip ⅛ inch of insulation from the conductors at the other end of the cable. Tightly twist together the fine wires in each conductor and sparingly tin with solder.

Route the end of the cable from which 3 inches of outer jacket was removed through the hole drilled for it in the enclosure and tie a knot in it about 8 inches from the free end inside the enclosure. Plug the free ends of these conductors into the holes labeled J1 PIN 1 through J1 PIN 4 and solder into place.

To prepare the other end of the four-conductor cable, you must know the requirements of the transceiver that is to be serviced by the project. The numbering arrangement shown for *J1* in Fig. 1 is only for schematic reference purposes. Do *not* use this numbering scheme! It may or may not work for the specific CB transceiver you have in mind. Instead, refer to the transceiver's schematic diagram or to a tabular listing that tells you which connector pins are to go to where and wire the cable accordingly.

If you wish to service a variety of CB transceivers that have different pin assignments, you will want a reconfigurable connector. To achieve this, consider interrupting the cable with a "breakout box" that will allow you to reconfigure the cable with jumper wires as needed. Such a box can be made using the smallest size DIP IC solderless socket housed inside a small plastic project box and secured in place with epoxy cement or silicone adhesive.

Bring the cut ends of the cable into the box in such a way that they can be secured from being pulled loose accidentally. This can be accomplished by tying strain-relieving knots in the two ends of the cable or with plastic cable clamps secured to the walls of the enclosure.

Bring the conductors coming from the project to one side of the socket and plug them into four holes in the matrix. (Remove an additional ⅛ inch of insulation from each conductor and tin with solder if you do this.) Plug the conductors of the portion of the cable that goes to *P1* into four holes on the other side of the socket.

Label the conductors for easy identification. Then strip ¼ inch of insulation from both ends of four 3-inch solid hookup wires. Use these jumper wires to configure the connector as needed for any given CB transceiver's requirements.

Before proceeding to final assembly, visually inspect all soldered connections on the board. Solder any connection you missed and reflow the solder on any connection that appears to be suspicious. If you locate a solder bridge, especially in the vicinity of the IC socket solder pads and closely spaced conductor, use desoldering braid or a vacuum-type desoldering tool to remove them.

When you are satisfied that the board is ready for final installation, mount the switches and LED in their respective holes, securing the latter with plastic cement if it does not remain in place by friction. Mount the circuit-board assembly in place with ½ inch spacers and ¾-inch machine hardware. Do the same for the power-supply assembly if you built one for housing inside the enclosure.

Checkout & Use

Before installing the ICs in their respective sockets, apply power to the CB Keyer and measure the voltages at the socket pins. Make absolutely certain that the polarities of the voltages in the circuit are correct. If you obtain an incorrect reading at any point, power down and correct the problem before proceeding.

Use a dc voltmeter or a multimeter set to read dc voltage to make your tests. Connect the meter's common probe to a convenient circuit ground, such as the anode lead of *D3*. Then touch the meter's "hot" probe to pins 4, 10 and 14 of the IC1 socket and pin 7 of the IC2 socket. In all cases, the reading obtained should be approximately +9 volts. Disconnect the meter's common probe from circuit ground and connect the "hot" probe to this point instead and touch the common probe to pin 4 of the IC2 socket. The reading should be approximately +9 volts, indicating that a −9-volt potential appears at this pin. (Note: If you are using a DVM or DMM, you need not reverse its probes to make the negative measurement. Simply touch the "hot" probe to pin 4 of the IC2 socket and note that a "−" sign appears alongside the voltage reading.)

When you are sure the project is correctly wired, disconnect power from it. Then plug the ICs into their respective sockets. Observe proper orientation and make sure that no pins overhang the sockets or fold under between ICs and sockets.

Before you connect the CB Keyer to a transceiver, some operational checks should be performed. Start by setting all four trimmer controls to mid-position. Power up the circuit and set MODE switch *S2* to AUTOMATIC. The relay's contacts should open and close in a specific repeating sequence. You can hear the contacts opening and closing and verify this operation with an ohmmeter. Simultaneously with the relay energizing, *LED1* should light and remain on for the duration of the timed-on cycle.

If you obtain the proper indications, set *S2* to its center STANDBY position. This should disconnect both timer circuits from the relay and the LED should extinguish and remain dark. Finally, test the manual-keying function by setting *S2* to MANUAL and pressing *S2*. When you do this, the LED should light and the relay energize. Then the relay should deenergize and the LED extinguish.

If the circuit operates as described, all that is left to do is calibrate the the oscillator. To do this, connect a frequency counter to the oscillator's output at pin 6 of *IC2* and read the frequency. If it is not 1 kHz, *slowly* adjust the setting of *R10* and note the trend of the displayed frequency change. If it is approaching the 1-kHz mark in small increments, you are adjusting in the correct direction. If not, reverse direction.

Before going too far with setting *R10*, very slowly adjust the setting of *R11* and note the trend of of the displayed frequency. Each adjustment should bring the oscillator's output frequency closer to the 1-kHz mark. If it does not, reverse direction on both trimmer controls.

The proper way to adjust this oscillator's frequency-determining elements is to alternately adjust the settings of *R11* and *R12* until the displayed frequency is exactly 1 kHz. If you adjust one trimmer too far, oscillation will cease. In this case, simply back off on the adjustment until oscillations return and work with the other trimmer.

After the oscillator is ticking away at 1 kHz, remove the frequency counter connections and replace them with an oscilloscope. If you do not observe a sine waveform on the scope's screen, adjust the setting of *R9* until you obtain the best sine waveform possible from the oscillator. However, keep in mind that too severe an adjustment of *R9* will cause oscillations to cease. If this occurs, back off on the adjustment to bring back the oscillations.

Adjustment of *R9* should have no effect on the frequency of oscillations. However, just to be certain, repeat the entire calibration procedure at least twice.

Use trimmer control *R8* to adjust the level of the signal delivered to *J1*. To make the proper setting for this trimmer control, keep in mind that you should use the largest-excursion sine-wave signal that does not overdrive the CB transceiver's modulator or cause severe clipping in other parts of the radio.

Once the CB Keyer is working properly, button it up to ready it for use on your testbench.

To use the CB Keyer, all you have to do is disconnect the transceiver's microphone and replace it with the

(Continued on page 87)

Experimenting With an Infrared Receiver Module

By Forrest M. Mims III

The Technology of infrared remote control has been available since 1962. In that year, highly efficient near-infrared-emitting diodes were developed. Only in recent years, however, have infrared remote controllers become widely available. Their most popular application is the control of home-entertainment equipment, such as TV receivers, videocassette recorders and audio components and systems.

A spin-off from the widespread acceptance of infrared remote control is the availability of inexpensive infrared receiver modules. One such module is the Sharp Corporation's GP1U52X. This receiver module is now available from Radio Shack (Cat. No. 276-137; $3.49). This time around, we'll take a close look at this impressive receiver module and some of the ways you can put it to use.

Much of what we'll discuss will apply to any of the infrared receiver circuits and modules used in remote-ly controlled television receivers, videocassette recorders, audio gear and other appliances. Therefore, if you have access to a discarded appliance that can be operated by an infrared remote controller, you may be able to salvage the receiver circuit from it and try it in place of the GP1U52X module.

The Receiver Module

Though the GP1U52X is not as sensitive as a receiver that you can assemble from a photodiode and high-gain operational amplifier, it has surprisingly high sensitivity. As Fig. 1 shows, the GP1U25X is smaller than a receiver you can assemble on your own. Moreover, it is a complete system that includes a bandpass filter, demodulator and output comparator.

Designed to be powered by a 5-volt source, the GP1U52X is rated for a maximum power supply potential of 6.3 volts. The upper limit is determined by a miniature 47-microfarad capacitor that is rated at 6.3 volts contained inside the module. The module is specified for a maximum current consumption of 5 milliamperes.

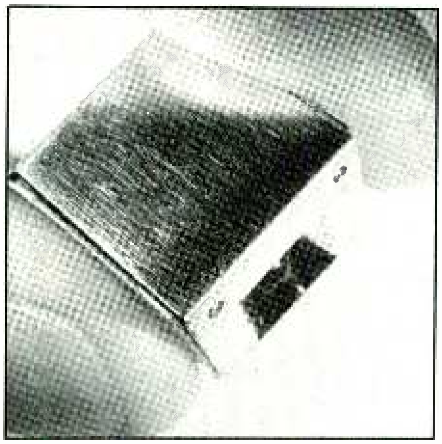


Fig. 1. Photo of the GP1U52X infrared receiver module.

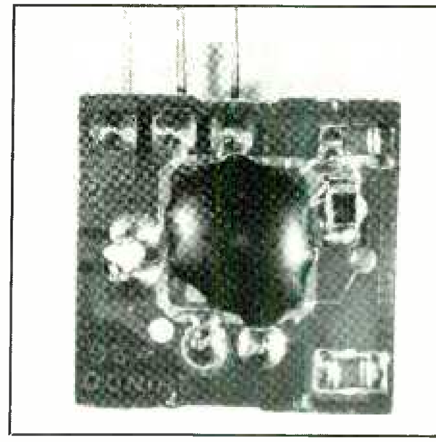


Fig. 2. The hybrid circuit board inside the GP1U52X module.

Shown in Fig. 2 is the bottom side of the tiny hybrid circuit-board assembly inside the GP1U52X module. The black blob of epoxy in the center of the board covers the single integrated-circuit chip that incorporates the receiver's amplifier and signal-processing circuitry. Two ceramic chip capacitors are soldered to the upper-left and lower-left corners of the board. A single chip resistor is located just above the lower chip capacitor.

Shown just above the encapsulated chip on the board are the two soldered pins that provide connections to the on-board photodiode. The two soldered pins on the right side of the epoxy blob are those for the 47-microfarad capacitor.

How the Module Works

Information about the GP1U52X module beyond what is supplied by Radio Shack was not possible to obtain for this column. Based on a close examination of a disassembled module and Radio Shack's block diagram, from which Fig. 3 is adapted, it's possible to figure out how the module works.

Pulsed infrared signals are detected by a silicon PIN photodiode. The photodiode is encapsulated in a near-infrared-transmissive epoxy material that absorbs visible light. The diode's package includes a small molded lens that increases the infrared gathering power of the device and provides some degree of directional sensitivity.

The photodiode transforms the signals it receives into a photocurrent that is amplified by an op amp. A limiter restricts the peak level of the signal. The bandpass filter is tuned for a maximum frequency response of 40,000 pulses per second (pps). Signals within about 4,000 pps of the bandpass frequency are passed on to an integrator and then a comparator that acts as a threshold circuit. If the signal that appears at the input of the comparator exceeds a preadjusted value set to exceed the noise level, the comparator switches on when a 40,000-pps signal is received by the photodiode.

Ideally, the bandpass filter would block all out-of-band signals. In practice, however, out-of-band signals of sufficient amplitude do get through. More about this later.

If a series resistor is used to restrict the flow of current to a few milliamperes, the comparator's output can directly drive a low-current LED or piezoelectric buzzer. Or it can trigger a driver transistor that, in turn, can drive a relay, lamp, motor or other external device.

Using the Receiver

If you've ever designed and built a lightwave receiver using individual components, you'll find that the GP1U52X is

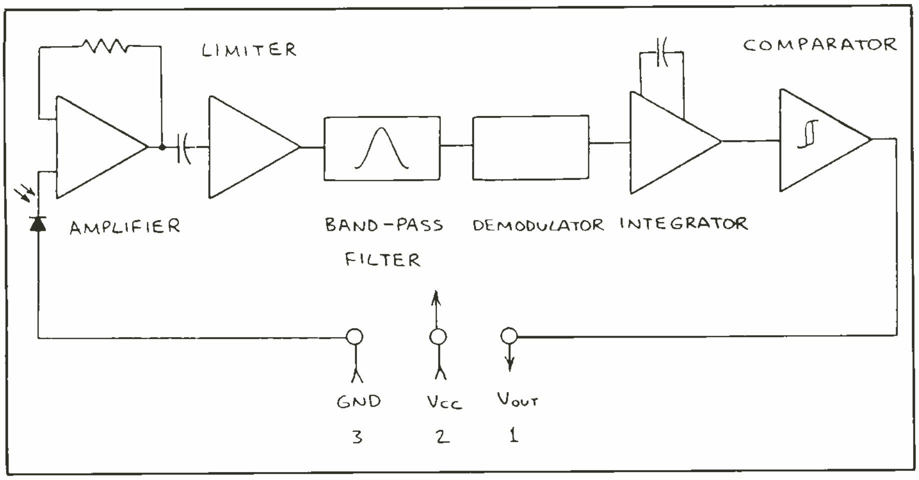


Fig. 3. Block diagram of GP1U52X infrared receiver module.

amazingly easy to use. As you can see by referring to the outline view of the module in Fig. 4, the module has only three pins. Pin 1 is the device's output, pin 2 its positive supply and pin 3 its ground.

Shown in Fig. 5 is a simple method that can be used to verify operation of the module. The LED connects directly to the module's output pin in the polarity shown. Series resistor *R1* limits current through the LED to 2.5 milliamperes.

A piezoelectric buzzer can be substituted for the LED in Fig. 5 to give an audible output. The buzzer should be the kind with a self-contained oscillator and not just the piezoelectric element. Correct polarity must be observed when connecting the buzzer into the circuit. A buzzer I tried consumed only 1.5 milliamperes when it was emitting a tone.

Figure 6 shows how to insert a transistor driver between the receiver and buzzer. Since the series resistor remains unchanged, current consumption of the buzzer is unchanged. In both circuits, you can insert a 10,000-ohm potentiometer or trimmer resistor between the series resistor and positive supply line to provide a means for controlling volume.

Ideally, the LED will glow or the buzzer will sound when a train of 40,000 pps of near-infrared pulses is received by the module's photodiode in Figures 5 and 6. Actually, the receiver will trigger on almost any light signal. Therefore, you will observe occasional flashes from the LED or hear "chattering" or "beeps" from the buzzer when the receiver is illuminated by ordinary room lighting. Before getting into why the receiver falsely triggers, though, let's try some simple experiments with the basic circuits given in Figures 5 and 6.

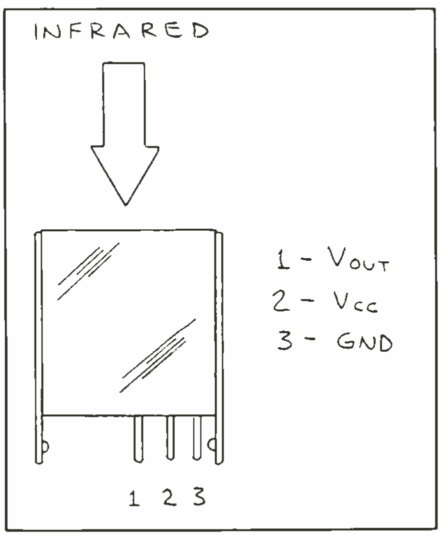


Fig. 4. Pinouts of the GP1U52X.

If you have an infrared remote-control unit for a TV receiver or VCR, point it at the receiver module and press any of its buttons. The LED will probably flash or the buzzer will beep in response.

If you use the Fig. 6 circuit, the sound of the buzzer may be annoying. As already noted, you can reduce the level of the buzzer's sound by placing a 10,000-ohm potentiometer between *R2* and the positive power-supply line. You can also reduce the sound level by placing some tape over the buzzer's sound-venting hole.

I happen to own a VCR made by Sharp, the company that makes the GP1U52X receiver module. When I pointed the VCR's infrared remote-control unit at the module, with the latter connected as shown in Fig. 5, and pushed some of its buttons, the LED rapidly blinked on and off. The receiver was quite sensitive to the signals sent by this "transmitter." Indeed, the receiver would respond even to stray reflections when the transmitter was pointed anywhere in my office and shop.

I opened the remote-control unit and found that a 1.5-ohm resistor was connected between the unit's single LED and ground. An oscilloscope connected across this resistor revealed periodic bursts of a dozen or so pulses were generated. Each pulse had a duration of 15 microseconds.

Since both the IR transmitter and the receiver module were made by Sharp, I wasn't surprised to find that the pulses within each burst had a pulse repetition rate of approximately 40,000, which, of course, is the center frequency of the receiver's bandpass filter.

As measured across the 1.5-ohm resistor, the amplitude of each pulse was 0.4 volt. From Ohm's law (I = E/R), this gives a peak current per pulse of 0.4/1.5, or 267 milliamperes.

Incidentally, the number of pulses within each burst and their relative positions were constant for a specific key on the remote-control unit. Pressing different keys altered the pulse pattern within a burst. A microprocessor connected to the receiver decodes the pulses within the bursts to determine which key has been pressed.

False Triggering

Before looking at a circuit for a transmitter you can build, let's examine the

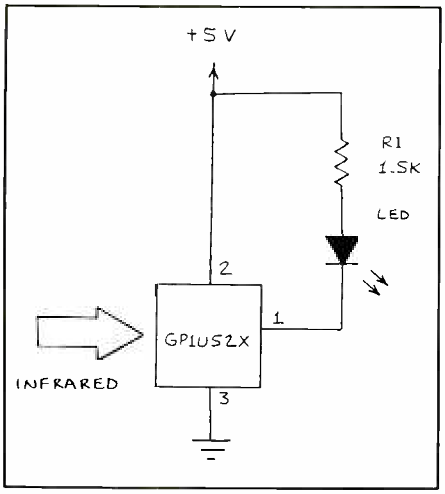


Fig. 5. Adding a LED to the GP1U52X's receiver module's output.

GP1U52X's susceptibility to false triggering. After you make the connections shown in Fig. 5 or Fig. 6, you'll probably observe occasional random flashes from the LED or beeps from the buzzer even when no infrared signal is present. These flashes are caused by stray illumination from room lights or sunlight entering a window.

If your work area is lighted by a fluorescent source, the output LED may flash rapidly or even appear to glow continuously. It will flash only occasionally if you prevent excessive stray light from striking the photodiode.

Since the receiver's circuitry contains a bandpass filter, you're probably wondering why it responds to ambient light. To understand why this occurs, let's begin by looking at sunlight since it isn't even modulated.

A photodiode's photocurrent is linear over six or seven decades of light intensity. Therefore, a photodiode can be operated in the presence of considerable background illumination. A pulsed signal will be detected so long as it produces a pulse of photocurrent that exceeds the steady photocurrent produced by a CW (continuous-wave) source such as sunlight or a battery-powered incandescent lamp. In other words, the receiver module can function in the presence of some sunlight.

What we're concerned about here is false triggering. Why does the module emit output pulses when it is illuminated by stray sunlight? The answer is that the amplified photocurrent has a noisy upper fringe. When a noise spike exceeds the system's threshold, the output LED flashes.

Incandescent and fluorescent lights are modulated by the alternating nature of the household ac line current that powers them. You can easily prove this by connecting a solar cell to the input of an audio amplifier. When you point the cell toward these light sources, the speaker driven by the amplifier will emit the familiar 60-Hz hum. Light from a fluorescent lamp switches on and off more frequently than does that from an incandescent lamp. Therefore, the hum or buzz produced by fluorescent lamps is more intense than that from incandescent lamps. The hot filament of an incandescent lamp remains heated and continues to glow during the zero-crossing of the applied current. This "thermal-lag" effect reduces the modulation depth caused by alternating current.

Both incandescent and fluorescent lamps will cause the receiver module to trigger. Since the bandpass filter in the receiver's circuitry is designed to pass signals that have a rate that is within 4,000 pps on either side of the 40,000-pps center frequency, why does the system trig-

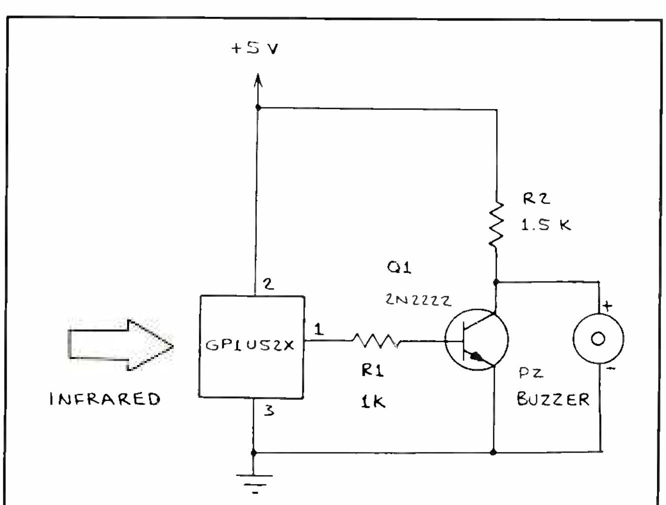
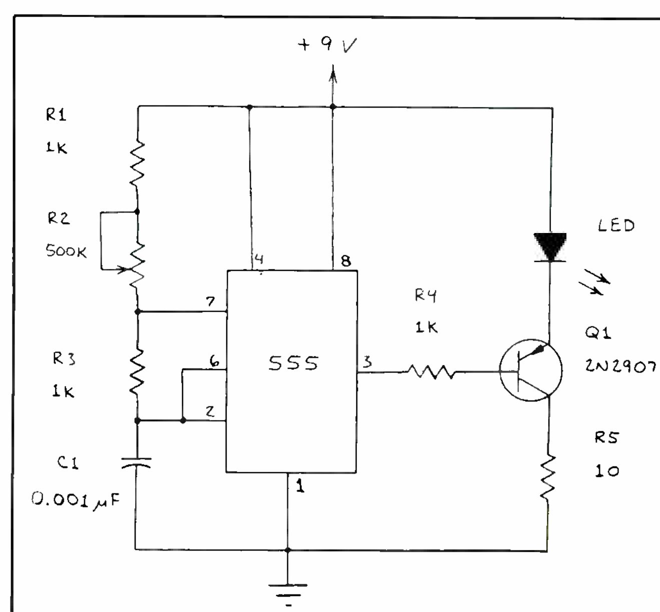


Fig. 6. An infrared receiver with a piezoelectric-buzzer output.

Fig. 7. Schematic diagram of a 40-kHz infrared transmitter.



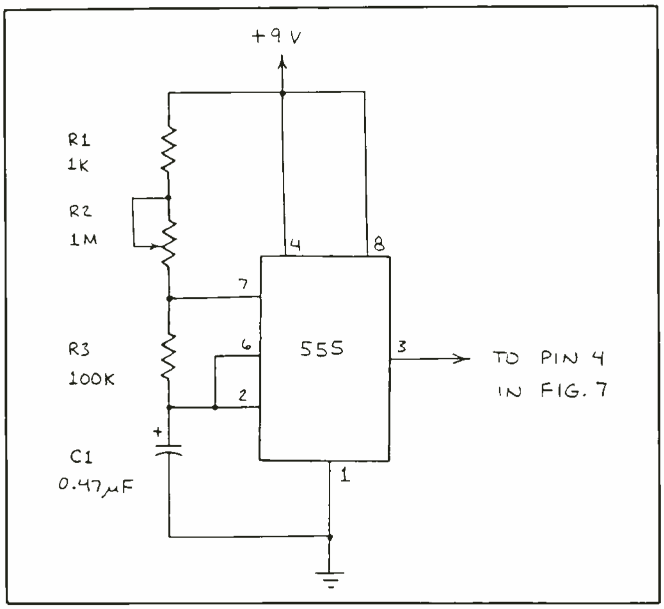
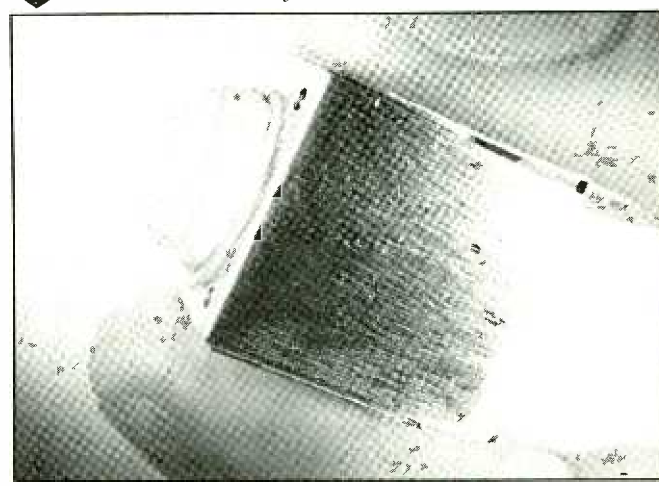


Fig. 8. An automatic switcher circuit for the Fig. 7 transmitter.

Fig. 9. The GP1U52X receiver module with a clear plastic foot "lens."



ger on a 60-Hz signal? Obviously, the receiver's bandpass filter is not perfect. Stray signals that fall well outside its nominal passband will be detected, especially when the photodiode is pointed toward them.

False triggering can be reduced by placing a near-infrared filter between the photodiode and light source. For this application, glass absorption filters work best. Several layers of developed color photographic film will function as a near-infrared filter if you have this handy.

Another way to reduce false triggering is to place a collimator tube over the photodiode. This collimator will then reduce the stray light that strikes the detector and gives the detector a much more directional response. A short length of 0.25-inch-diameter heat-shrinkable tubing works well. Cut a slit part or the way up one end of the tubing to allow it to fit over the photodiode's leads.

Incidentally, materials that block visible light may be nearly transparent to the near-infrared radiation the photodiode is designed to detect. Before using heat-shrinkable tubing as a collimator, I used an infrared viewer to check its ability to block near-infrared radiation. When observed through the viewer, an operating near-infrared LED appeared like a brilliant searchlight. However, the beam was completely blocked by the heat-shrinkable tubing.

This test can also be accomplished with a LED pulse modulated at an audio frequency and a photodiode connected to the input of a small audio amplifier that, in turn, drives a small speaker. Position the photodiode so that it can readily receive the signal from the LED. Then place the collimator material you're testing over the LED. If the material does indeed block infrared radiation, the tone produced by the receiver will be greatly or even totally attenuated.

Near-IR Transmitter

Many different near-infrared transmitters will activate the GP1U52X module. In Fig. 7 is shown the schematic diagram of a simple transmitter designed around a 555 timer configured as an astable oscillator. This oscillator delivers a train of pulses to *Q1* at a frequency determined by the setting of *R2*. When *Q1* is switched into conduction, the LED receives a pulse that has a duration of a few microseconds and peak current of 350 milliamperes. I measured the current by connecting an oscilloscope across *R5*.

Potentiometer *R2* in Fig. 7 can be adjusted to provide a pulse repetition rate of 40,000 (the center frequency of the GP1U52X). This adjustment is best accomplished by connecting a frequency counter across *R5* or *C1* and observing its display as *R2* is adjusted. Alternatively, you can point the LED at the receiver (built using the circuit shown in Fig. 5 or Fig. 6) and adjust *R2* for best results. The optimum 40,000-pps setting can be found by permitting only a small amount of the radiation emitted by the LED to reach the receiver's photodiode.

The duration of the pulse from the LED can be increased by increasing the resistance of *R3*. This is best done by first connecting an oscilloscope across *R5* and observing the change in pulse duration on its CRT screen as you try different values of resistance for *R3*. However, keep in mind that increasing pulse duration also increases the transmitter's current consumption.

You can easily add a switching circuit to the Fig. 7 transmitter circuit that will automatically transmit bursts of 40,000-pps pulses. To do this, first disconnect pin 4 of the 555 in Fig. 7. Then adjust the setting of *R2* in Fig. 8 to control the rate at which the bursts are transmitted. For a very slow transmission rate, increase the value of *C1*.

Getting Greater Range

The reception range of the GP1U52X receiver module can be increased with the aid of an external lens. Assuming the lens is properly focused, doubling the diameter of the lens will approximately double the receiver's reception range.

An ultra-simple lens that increases the receiver module's range to some degree is illustrated in Fig. 9. The "lens" is a plastic foot, a clear dome with a coating of adhesive applied to its flat side. The lens is simply pressed into place. Clear plastic feet are available from Radio Shack (Cat. No. 64-2365) and other electronics parts distributors.

For greater range, you can use a larger lens. Inexpensive plastic Fresnel lenses and magnifiers are available in various sizes from office-supply dealers and variety stores. Many kinds of lenses are also available from surplus parts/equipment dealers and from Edmund Scientific Co. (101 E. Gloucester Pike, Barrington, NJ 08007).

You can also increase the receiver's range by narrowing (concentrating) the transmitter's beam with a lens. However, narrow transmitter beams are difficult to aim with good accuracy over long distances. This is especially true when the beam is infrared radiation that is invisible to the human eye.

Going Further

You can easily adapt an infrared receiver module like Sharp's GP1U52X for simple on/off remote-control applications. To control large loads, use a relay in place of the piezoelectric buzzer in Fig. 6. Depending on the relay chosen for this application, it will probably be necessary to reduce the value of *R2*. Of course, be sure to observe proper safety precautions if you use the relay to switch 117-volt ac line current.

There are many applications for infrared remote-control receiver modules beyond straightforward remote control. They can be used as receivers in break-beam intrusion alarms. Unfortunately, false triggering can prove to be a problem here. One possible solution is to connect the receiver's output to a missing-pulse detector designed around a 555 timer. This will reduce the impact of false triggering; but the circuit may fail to warn of an intrusion if the break occurs at the same time as a noise pulse.

Another possible application for infrared receiver modules is pulse-frequency-modulated voice communications. The GP1U52X module seems to be particularly well-suited for this application because its 40,000-pps center frequency is well above the range of human hearing and, thus, simplifies demodulation of the received signal.

For additional information about missing-pulse detectors, see books and applications notes for the 555 timer chip. I show a sample circuit on page 12 of my *Engineer's Mini-Notebook: 555 Timer IC Circuits* (Radio Shack, 1984).

I've written many articles and several books on lightwave communications. Much of the material in these articles and books can be applied to infrared remote-control applications. *A Practical Introduction to Lightwave Communications* (Howard W. Sams & Co., 1982) is currently not in print, but you might be able to find it in a library that has a good technical reference section.

For additional information about pulse-frequency-modulated lightwave communications, see *The Forrest Mims Scrapbook* (McGraw-Hill, 1983, pp. 40 through 42). Also see *Forrest Mims' Circuit Scrapbook II* (Howard W. Sams & Co., 1987, pp. 118 through 121). ME

Power-Supply & GFCI Chips, Remote Humidity & Moisture Sensors

By Art Salsberg

Raytheon's Semiconductor Division (Mountain View, CA) comes up with some very interesting ICs from time to time. About a year or so ago, for instance, it introduced the RC4292, a power-supply controller that's exceptionally useful.

The device converts the standard −48V off-hook telephone voltage to the +5V and +12V required by digital and analog circuits, including computer peripherals and telecommunications processors. It accepts input voltages from −20V to −120V, producing output between −24V to +24V with 0.1%/V line regulation.

With up to 250-mA output, it can drive a transistor that acts as a power switch to handle a 10W load as it controls a transformer's primary current. Packaged as an 8-lead mini-DIP, it contains seven major circuit functions: temperature stabilized voltage reference, error amplifier, temperature stabilized oscillator, current comparator, PWM control flip-flop and logic, shunt regulator and output driver.

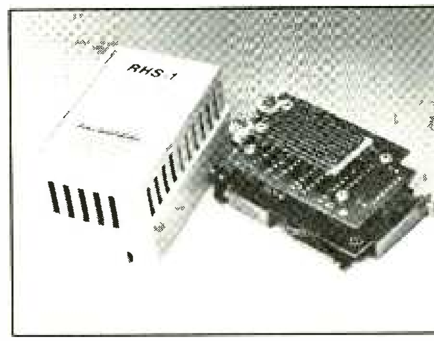
Another Raytheon device, recently announced, is its RV4145 low-power ground fault interrupter controller (GFI) IC for 110V and 220V ac systems. GFI's are growing in popularity, of course, to protect against hazardous grounding conditions. When activated, the IC controls a relay that opens the circuit before a harmful shock occurs.

The RV4145 incorporates a 26V zener shunt regulator, an op amp, and an SCR driver. Adding two sense coils, a bridge rectifier, an SCR and a relay, the device detects and protects against both hot wire to ground and neutral wire to ground faults. Its quiescent current is 450 mA and it meets U.L. 943 timing standards to avoid false triggering due to line noise. It comes packaged as an 8-lead DIP or with a small outline (SO) DIP.

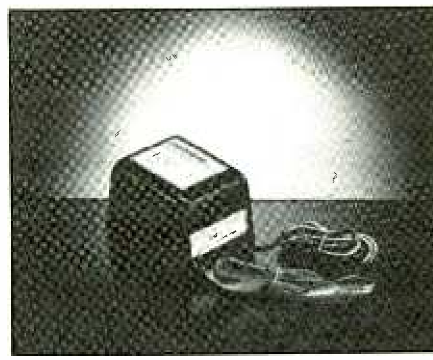
When a short circuit or fault occurs, a magnetic path between the two sense coils is closed. The resulting ac closes a positive feedback path around the op amp, causing it to oscillate. When this voltage's peaks exceed the SCR trigger comparator's threshold, the SCR output goes high. This, in turn, energizes the relay that disconnects the ac line.

Humidity Sensing

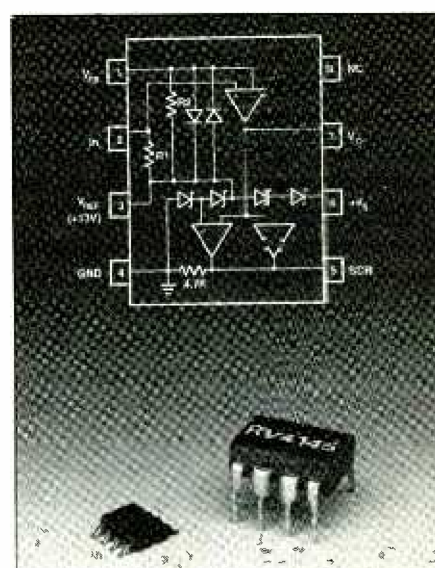
Humidity can be sensed in a number of ways. One type of device responds to temperature changes, using wet-bulb and dry-bulb elements. Another is based on moisture retained on a substance, which



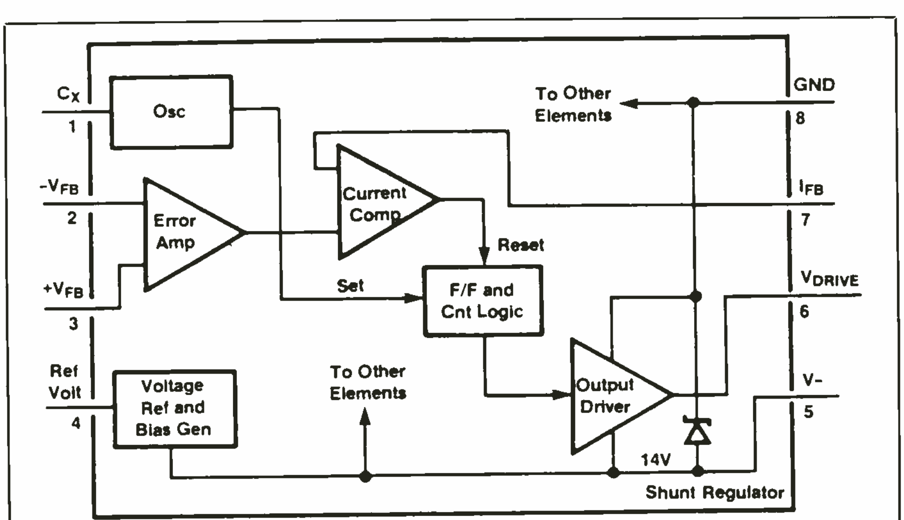
Industrial Computer Designs, Inc.'s Model RHS-1 remote humidity sensor.



The RMS-1 remote moisture sensor from Industrial Computer Designs, Inc.



Internal details and pinouts for the Raytheon RV4145 low-power GFCI chip and available package configurations.



Internal details and pin assignments for Raytheon's 4292 power-supply controller chip.

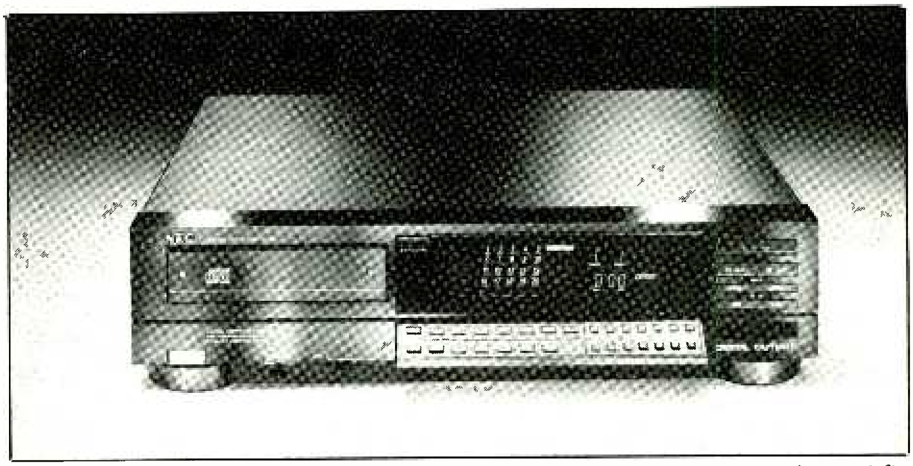
might cause an electrical change that can be measured electronically. Whatever the method, there's a great use for humidity-sensing equipment in many areas.

A remote humidity sensor from Industrial Computer Designs, Inc. (818-889-3179), model-numbered quite appropriately as RHS-1, is designed to convert relative humidity into a linear electrical representation. Its output corresponds to a humidity range of 0% to 100% (0 to +5V dc). The unit connects directly to a microcomputer with a standard A/D converter or to panel meters. Inexpensive telephone wire can be used for connection to a remote computer interface. The device is designed for monitoring computer rooms and laboratories, among other environmental applications.

The Westlake Village, CA-located company also has a remote moisture sensor, model RMS-1, that monitors changes in ground moisture via microcomputer or instrumentation. The unit includes a probe that's to be buried slightly below the soil (at least six inches) to check/monitor farm soil, for leak detection, lawn sprinkler control, and similar applications. Typical power required is 8-9V dc, 15 mA. As with the previously cited humidity sensor, its output is an analog electrical output signal. **ME**

Buying A CD Player

By Curt Phillips



NEC's Model CD-720 compact-disc player uses separate analog power supplies and fiber-optic coupling to minimize noise transmission between its analog and digital circuits. It permits programming of up to 24 tracks for playback in any order desired and remembers programming choices for up to 10 discs simultaneously. Among its other features are 4× oversampling, a multi-function wireless remote controller and a calendar-like track display.

If you've wandered into a record store recently, you've certainly noticed that the LPs have been shuffled to the back of the place and that compact discs (CDs) and recorded cassettes have taken over the most desirable merchandising locations.

Should you not yet own a CD player or if you purchased one of the very early models, there are several reasons why you might want to consider buying one now. As I discuss some these considerations, I'll also be commenting on an NEC Model CD-720 compact disc player I've been examining.

Although NEC is perhaps better know for its "Multi-Sync" computer video monitors, its Audio/Video Division offers a full line of entertainment electronic products, among them four CD players. The one examined here is the company's top-of-line model with a suggested retail of $579. In the general spectrum of CD players, however, it is a mid-priced model.

There are a host of factors to be weighed when evaluating the worthiness of a CD player. The technical ones may be broken down to three categories: audio specifications, design philosophy and operating features.

Specifications

Evaluating audio specs is both easy and very difficult. It's easy because any CD player you look at will have better specifications than other types of audio gear. For example, the CD-720's total harmonic distortion (THD) is rated as 0.0025%! (Presumably, this is referenced to 1 kHz at 0 dB.) Signal-to-noise ratio is listed as 105 dB (A-weighted, I assume)! Dynamic range is 98 dB!

As wonderfully good as these specifications appear, they're rather commonplace in the CD-player field. So when looking at specs, you have to distinguish between numbers that are meaningfully better or worse, such as a THD of 0.03% instead of 0.003%.

In the specifications game, you might add channel separation, where 90 dB at 1 kHz divides excellent from just plain old good. Insofar as frequency response is concerned, all the players feature 20 to 20,000 Hz. Look for the + and − deviation figures when comparing specs. The smaller the deviation, the flatter (and better) the response, of course.

There are some important specs you might have difficulty finding, too, such as phase shift in degrees, cueing time in seconds, and defective tracking data, among others.

Specifications alone can't reveal the whole performance story. With the consistency of excellence displayed among CD players, it's also very difficult to distinguish between different models. This is where looking at a maker's design philosophy may be helpful.

Design Aspects

One distinguishing design aspect for CD players is the number of laser beams used, which can be one or three. A CD player uses a laser beam to read the microscopic pits and flats on a compact disc, which are the digital representations of the music recorded.

Most middle- to upper-priced CD players now split a laser's output into three beams, using the middle one to actually read the music data, while leading and trailing beams assist in tracking. Tracking efficacy is particularly welcome when a CD has been scratched or damaged in other ways. Interestingly, though, there are fine CD player brands that use only a single beam and still maintain fine tracking when faced with disc defects through other design means. (It seems that Japan-made players tend to use split beams, while European makes do not.) Hence, beam splitting is not a sure indicator of better tracking.

Compact discs were designed to have their digital information read (or sampled) 44,100 times per second (44.1 kHz) to achieve 20,000 Hz top-end reproduction. Early CD players used analog filters with a very steep roll-off above 20 kHz to eliminate ultrasonic images that can cause serious sound distortion. But such filters cost a lot of money if they're expected to avoid causing phase distortion.

Nowadays, a CD platter's data is *oversampled* at, typically, two to four times the standard rate. Digital filters are commonly used today to eliminate the ultrasonic images at the harmonics of the sampling frequency. This also produces ultrasonic images, but at 88.2 kHz (for 2×

oversampling) or 176.4 kHz (for 4× oversampling). Since these are further away from the 20-kHz hearing limit, they can be eliminated more easily. The CD-720 uses 4× oversampling digital filters that are typical for players in its price range. NEC's two least-expensive CD players use double oversampling.)

However much oversampling (if any) is really needed is the subject of controversy. While some players do have 8× oversampling, and one (Cambridge) has 16×, several high-end players (like the Nakamichi OMS-7AII) in the $2,000 (retail) range use 4× oversampling; so the oversampling rate is not a sure-fire indicator of quality.

The presence of two digital-to-analog (D/A) converters separates the mid- to high-end CD players from the low-cost ones. Time-sharing one D/A converter can be done, as low-cost players prove, but it can cause some degradation of the audio signal.

On most players, the D/A converter(s) work with 16 bits of data at a time, but some manufacturers are touting 18-bit D/A converters as providing more accurate reproduction. The CD-720 uses 16-bit D/A converters. As with oversampling, there is controversy over just how many bits are optimal for D/A converters.

The CD-720 uses separate power supplies for the digital and analog circuits, which can help prevent transmission of noise and distortion from one section to the other. It also uses fiber-optic coupling to electrically isolate the digital and analog stages to further reduce noise transmission. Both design features are worth noting when comparing CD players.

Operating Features

The operating features available on compact-disc players will confound and amaze anyone who hasn't kept abreast of the technology. The CD-720 has a full complement of such features.

For example, the CD-720 lets you program up to 24 tracks on a disc for playback in any order you desire. It will remember your programming choices for up to 10 discs simultaneously. Another playback option is to allow the player to choose the next track to play at random.

Any track can be accessed directly using the numeric keypad, and you can "fast-forward" through a track to find a desired passage. Some CDs are indexed, and the CD-720 allows for cueing on indexed points.

Its "Intro-Scan" feature allows one to preview a CD by having the CD-720 play only a sample of each track. The length of the preview sample defaults to 10 seconds, but it can be varied from 1 to 60 seconds at the user's option.

The player also offers several features to make it easier to record your CDs onto cassette tape. In the "Auto Edit" mode, you enter the time available on one side of a cassette, and the player will show how many tracks you can record, starting with the first track. If the CD contains a short track that will fit in the remaining space on that side of the tape, the number corresponding to that track will blink on the front panel.

In the "Disc Edit" mode, the player will store the table of contents from up to five discs, so you can program the playback order of tracks on those discs. By first specifying the length of the tape, the player will help you to fit the most selections possible on the tape.

The CD-720 has an "Auto Fade Out" function that will automatically fade the music out when the specified time is up. This provides smooth editing. It will automatically insert a few seconds of silence between tracks, so the tape will be easier to use with programmable cassette tape decks.

One function not included on the CD-720 is a built-in dynamic compression circuit. When making cassette tapes for use in a noisy environment (like in an automobile), it is useful to compress the dynamic range of the music. Very few CD players have this feature, though.

Most of the functions available on the front panel are accessible from a wireless remote controller that is included with the CD player. Having remote control alone is a motivating force to buy a CD player or upgrading the one you have. It may be aerobically debilitating, but having access to all those features from an easy chair is addicting. Impressively, the remote uses two AA cells that are *included*! (Remember all those "batteries not included" Christmas gifts?) The volume of the headphone and a "variable-volume" output is controlled from the front of the player, but no volume control is available from the CD-720's hand-held remote controller. For those of us who have not yet upgraded to a remote-controlled amplifier, this would be a useful feature.

The styling of the CD-720 is simple and uncluttered. The well-designed fluorescent display shows a calendar-style 24-track chart and has indicators for the disc number, track number and index number. The display also shows time elapsed in the current track, total time elapsed, time remaining in the current track and total time remaining. Although the photo shows it with the programming control panel under the display open, it closes to present a plain black surface. The CD-720 is built to handle the new 3-inch CD singles without the use of an adapter.

The Listening Test

After considering the specifications, design philosophy and operating features (and your budget), a listening test is the final phase of the CD-player selection process. Your local dealer can let you listen to many CD players on the market.

Be sure, when doing comparison listening with any audio equipment, that the volume level is equal for both components being evaluated and that you listen to the same program material on both. Preferably, you'll be listening to CDs that you're familiar with. Listen, too, with high-grade headphones to eliminate the false contribution that room acoustics can make. If you're lucky, the least-expensive one will sound the best. ME

Your comments and suggestions are welcome. You can contact me through The Source (BDK887), Delphi (CURTPHIL), CompuServe (73167,2050) or at P.O. Box 678, Garner, NC 27529.

The Fall COMDEX Show

By Ted Needleman

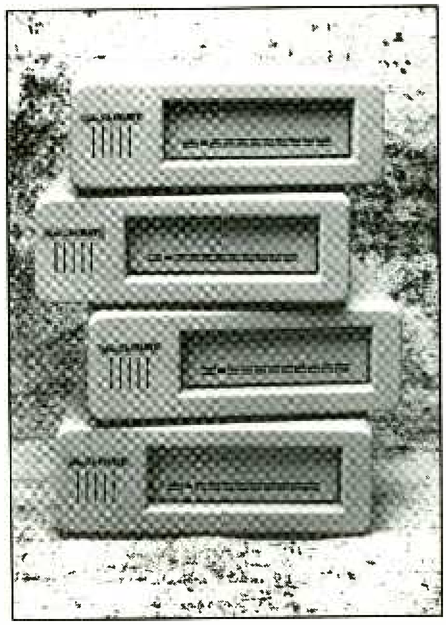
I've just gotten back from the Fall COMDEX in Las Vegas and my overall impression of the show is "What a zoo!" COMDEX, for those of you who missed my comments on the Spring show is the twice-a-year "Big Event" in the computer industry. Ostensibly for dealers and other volume resellers of hardware and software, the show attracts hordes of press and industry analysts.

While the Spring show in Atlanta was large, the Fall show was immense. Almost 100,000 people showed up to see 1,700 exhibitors. The exhibits were located in the huge Convention Center and six other locations (mostly hotels) scattered about Las Vegas.

This year's shows were remarkable not for the particular products that were shown, but for the huge number of companies that were displaying their products. While most of the major hardware and software companies who ordinarily exhibit were there, there were also newcomers. Many of these were not in the main hall (these spots were awarded to those companies that have exhibited before), but in the West Hall of the Convention Center and the outlying hotels.

While the following is by no means a complete list of those companies and products that caught my eye, some of the more interesting exhibitors included some old "friends" mentioned before in this column. Traveling Software, whose Lap-Link and Battery Watch products were reviewed previously, were showing those products, the Mac-Link (which lets you transfer files between Macs and PCs), and the new Wizard-Link. This is a special cable and software that let you up- and download to and from Sharp's new Wizard hand-held organizer.

The Wizard has built-in software, an LCD display, and the ability to use ROM and RAM cards. One of the new available cards (the product has just recently been introduced) is a Time and Expense Management system, also written by Traveling Software for Sharp.



Crate Technology's hard-disk drives are cost-effective add-ons for the Macintosh Plus, Mac SE and Mac II computers. Capacities up to 80 megabytes are available.

I'll probably do a more in-depth review of the Wizard at some future time—I've had mine for about six weeks and am already finding it indispensable. Sharp has sold over a million in Japan in the last year, and Traveling Software's enhancements make it even more attractive.

The Complete PC, whose hand scanner, fax board and answering machine I've reviewed, was showing its new scanner line and fax board. The Complete Communicator includes a 9,600-baud fax, 2,400-baud modem and answering machine add-on, all on one board, which also has a port for one of the scanners. At $899, it looks like a good buy and takes up only a single slot in a computer. I've got one and I'll let you know in the future if it is as good as it seems.

The Complete PC also was showing two new hand scanners and a page scanner. The hand scanners are 2.25-inch (scan width) model, which will replace the earlier "Complete Hand Scanner." Though it appears to be identical, the new model offers selectable 200/300/400-dot-per-inch resolution. Also new from this company are a ½-page (4-inch scan width) 200-dpi scanner and an inexpensive ($899) sheet-fed page scanner with 300-dpi resolution. Those should be available soon, too.

Dresselhouse Computer Products, whose SmartPrint Intelligent Printer Switch impressed me a few months back, has followed up with a Laser Sharing System. While the Printer Switch allowed you to connect up to six printers to a PC, the new switch allows up to six PCs to share a laser printer. It is available in a four-port version for $179 and a six-port version for $199.

Scanners and other desktop publishing/graphics products, along with fax boards and laser printers, were the hits of the show. Logitech, whose mouse was reviewed a couple of issues ago, was showing its 200-dpi ScanMan ½-page hand-held, DFI was showing a 400-dpi ½-page hand-held that uses yellow-green light to obtain a better pick-up of red-based skin tones, and Sharp was displaying a ½-page frame that is placed over the page to be scanned. With the Sharp scanner, a motorized scanner passes a fluorescent light source (like those used in photocopiers) and the scanning head over the object being scanned. At $995, the Sharp unit is a bit pricey, but it scans at high resolution in color.

DFI was also demonstrating its Video Capture-1000. This is an inexpensive ($249) board that can capture an image from a standard video camera, VCR or other video source. A similar board, called ComputerEyes, has been available for a handful of computer brands for several years from Digital Vision. This year, Digital Vision has developed a color version of the board. Neither Digital Vision's nor DFI's board is a frame grabber that is able to freeze a single video frame. Instead, both use a variation of the slow-scan technique, taking between 6 and 10 seconds to build up a full-screen video image.

There are plenty of frame-grabber boards around. One of the least expensive is from Willow Peripherals, Inc. At $699, its Publisher's VGA board offers not only frame-grabbing capability, but also a VGA video adapter that can be used even when the frame grabber is not in use. An additional feature is that Willow's board doesn't require a second video monitor to use the frame-grabbing capability, as most other boards of this type need.

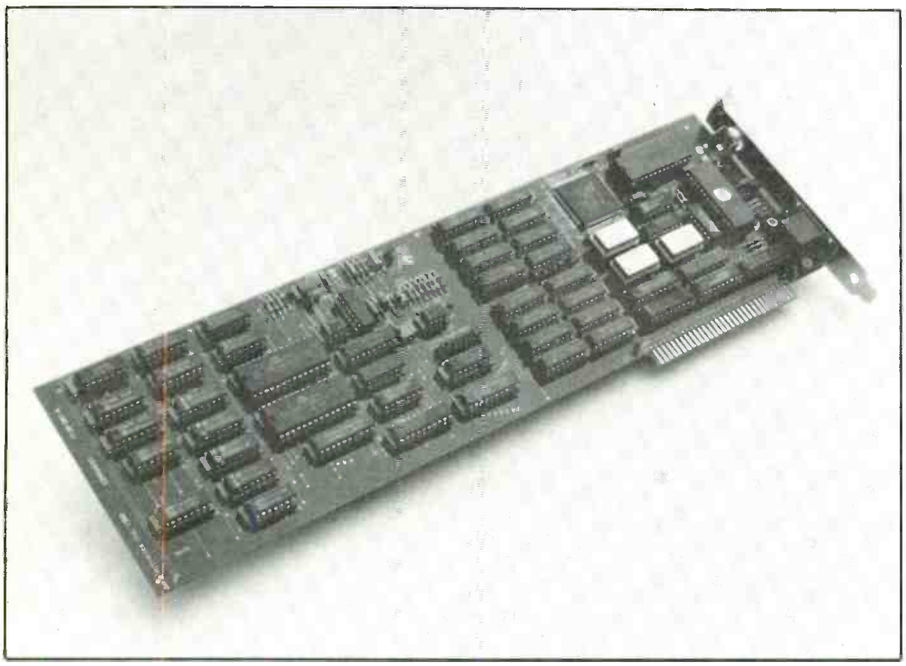
Another piece of hardware that caught my eye was the Trackstar E from Diamond Computer Systems, Inc. This board allows you to read and run Apple II software on a PC or compatible. The Macintosh was also well-represented at the show with numerous hardware and software vendors.

Crate Technology, started last year as Apple Crate, first offered external hard-disk cabinets for the Mac. Dealers bought the box, installed an SCSI Seagate hard disk, and sold the complete system to a user, usually at a rock-bottom price. This year, the company changed its name to Crate Technology, installed the drive in the box, and is still managing to be extremely competitive. It's also introduced the Tape Crate, a tape backup system for the Mac, and internal hard disks for the Mac SE and Mac II.

SYZYGY, which is pronounced somewhat like a sneeze, is a "groupware" software product for managing activities, resources, schedules and budgets. Available from Information Research, whose ActionTracker management software has been well-received, SYZYGY provides Activity Lists, multi-level Gantt charts, calendar, to-do lists and other management tools.

Less expensive but impressive in its own way is Ken Skier's No-Squint Laptop Cursor. For $39.95, this RAM-resident 1K program actually lets you see the cursor on your laptop's CD screen. Ken is someone I've known casually for a number of years and have the greatest respect for. A tremendous programmer and designer, he's also the author of Epson's SkiWriter word processor and Ashton-Tate's ByLine desktop-publishing software. If you have a laptop, send Ken the forty bucks; his program is worth it in eyestrain saved alone.

Another software package worth tak-



Willow Peripherals' frame-grabber board includes a VGA video adapter that can be used even when the frame-grabbing feature is not being used. This board does not require a second video monitor to use frame grabbing as most others do.

PC CAPERS . . .

ing a look at is QAPLUS, from Diagsoft, Inc. This is an advanced diagnostics package that runs on any PC, XT, AT or 386 system and includes disk, video, RAM, keyboard, numeric coprocessor, COMM port and printer tests. I haven't yet had the chance to play with the review copy I was given, but Intel must think it's pretty good since it's the diagnostics included with its MicroSystem/AT computers.

Of course, all of the above represent just a smattering of those products on display at the show. Compaq's new 286 laptop was in evidence not only in that company's booth but in numerous booths around the show. Advances in printers were also very evident. Expect to see numerous 400-dpi laser printers in the next year. Advances in laser controllers and "naked" laser engines (which do not contain embedded controllers but rely on a card in the PC) will assure this. Also expect to finally see a PostScript page-description language successfully cloned. There were several companies showing (and supposedly shipping) these products.

The show was large, as noted earlier, and many of the company representatives I spoke with promised to send review copies and units. It should be a very interesting couple of months ahead. ME

Products Mentioned

Mac-Link, Wizard-Link
Traveling Software, Inc.
18702 North Creek Pkwy.
Bothell, WA 98011
(206) 483-8088

Complete Communicator,
Hand Scanners
The Complete PC
521 Cottonwood Dr.
Milpitas, CA 95035
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8560 Vineyard Ave.
Rancho Cucamonga, CA 91730
(714) 945-5600

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W. Sacramento, CA 95691
(916) 373-1234

ComputerEyes
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66 Eastern Ave.
Dedham, MA 02026
(617) 329-5400

Publisher's VGA
Willow Peripherals, Inc.
190 Willow Ave.
Bronx, NY 10454
(800) 444-1585

Trackstar E
Diamond Computer Systems, Inc.
1225 Tiros Way
Sunnyvale, CA 94086
(408) 736-2000

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PC-DOS 4: A New Shell Game

By John McCormick

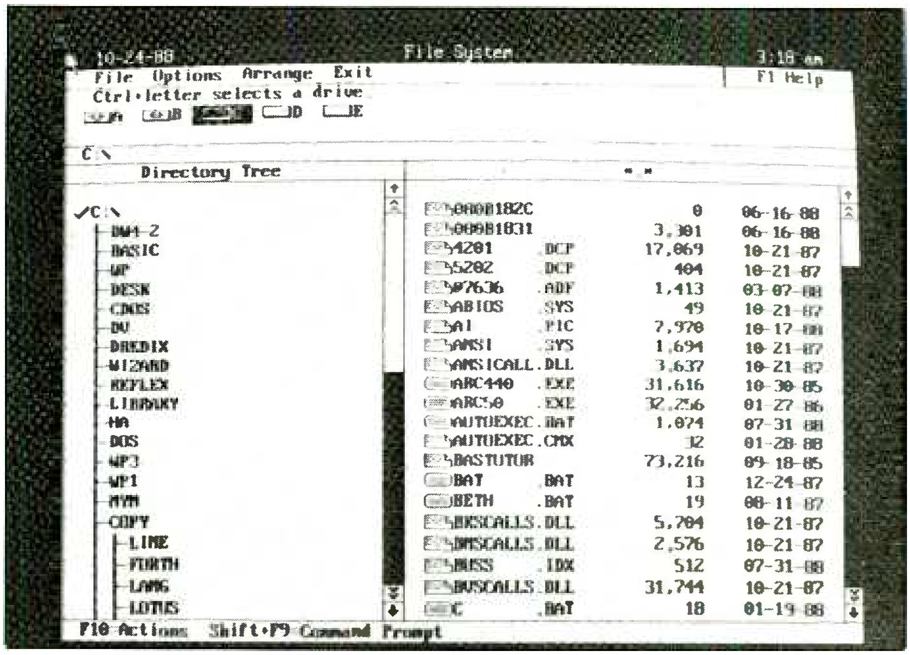

Fig. 1. DOS 4.0 displays a graphics directory tree as well as typical file listings.

With little fanfare, IBM released PC-DOS 4.0. This is Microsoft's and IBM's latest upgrade of the popular DOS operating system. It comes on five 5.25-inch 360K disks or two 720K 3.5-inch disks, at a cost of $95 as an upgrade or for $150 to new users.

The new DOS, which is still a single-tasking system, provides a number of enhancements and a completely new user interface, all of which should pacify many users who often complain (with good reason) about DOS's strange limitations and decidedly unfriendly characteristics. It's expected that an MS-DOS version will be produced by developer Microsoft for use with compatibles.

As typified by past DOS releases, the 4.00 first version has bugs; so one can expect improved versions. There's already said to be a 4.01 version that's still packaged as 4.00, for example.

Why A New DOS?

With this DOS upgrade, it's clearer than ever that DOS isn't expected to disappear quickly just because the new-generation OS/2 has the limelight. The OS/2 multitasking system is just too powerful and costly for home personal use and even for many small businesses. Furthermore, it's not designed to run with 8088 or 8086 microprocessor-based computers. DOS 4.xx, however, continues the durable single-tasking operating system with a host of welcome, long overdue enhancements.

Among the added features is a file-management shell with pull-down menus based on the SAA (Systems Applications Architecture) standards. Also, DOS 4.0 removes the 32M-byte hard-disk partition limitation, something that OS/2 will probably get around to with the Standard Edition and Extended Edition versions 1.1 (the one with Presentation Manager). There's support for a mouse, too, as well as for expanded memory.

DOS Shell

DOS shells aren't new, of course. A number of popular software utilities have been around for some years that make it easy on the operator's memory to work with DOS. Now DOS itself is finally catching up.

With DOS 4.0, you don't have to remember all those arcane DOS commands. Just make your choice from the opening, friendly program start screen, which will take you into a file-manager DOS Shell with easy-to-use pull-down

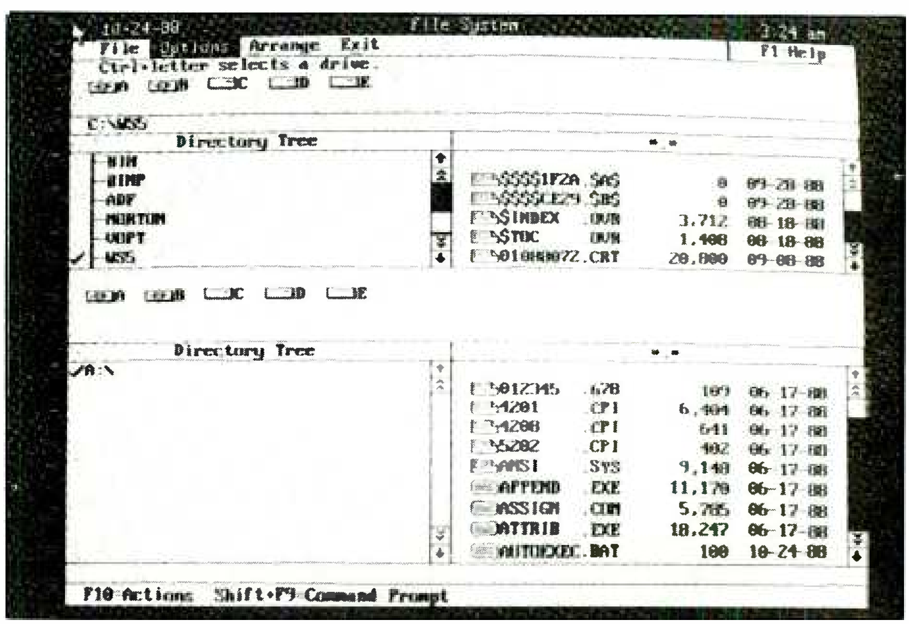

Fig. 2. The user has the option of splitting the screen to see and work with multiple files.

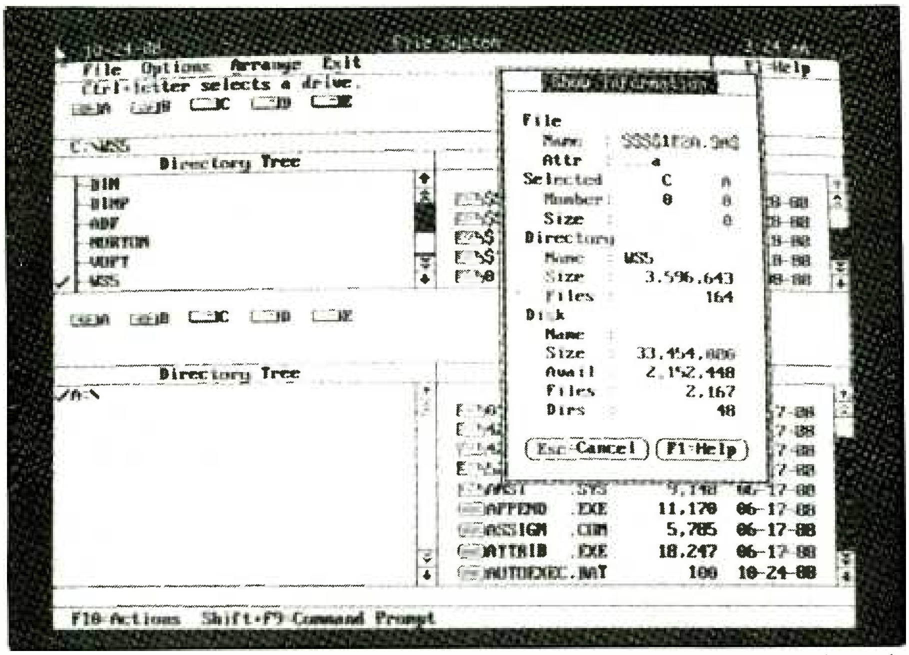

Fig. 3. The new operating system makes extensive use of pull-down menus, as pictured.

menus. The new system's graphical tree directory screen is a nice assist, with a text listing of files in a side window to its right. All this lets the beginner or less-experienced user navigate easily through otherwise challenging DOS commands.

Every major feature, such as COPY, FORMAT, DEL, etc., is available through these menus and dialogue boxes. Succinctly written Help boxes are at one's

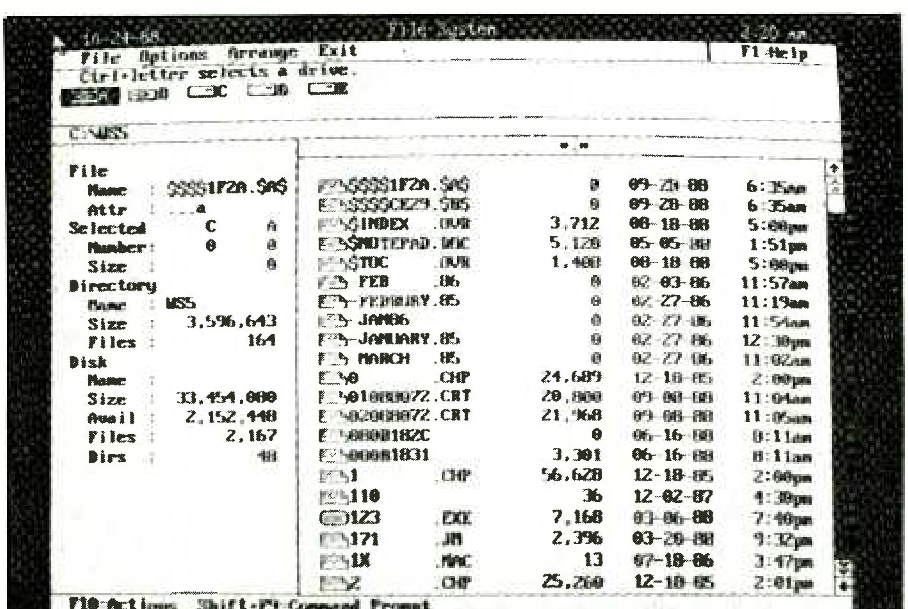

Fig. 4. General file information can be listed in place of the graphics tree.

fingertips, too. Directory/file management is eased by the optional screen displays: single-file list (contents of single directory); multiple-file list (shows files in two directories); and the system-file list, which displays information about highlighted file names, including file attributes and environment information such as number of files and directories, DOS version, and available disk space.

These choices are selected from the ARRANGE label on the top-of-the-screen Action Bar, which is accessed by pressing the F10 function key, repeatedly pressing the TAB key, or by clicking a mouse button. The OPTIONS menu lets you select files from multiple directories for easy copying or deleting of files.

In addition to the help screens and the new graphic interface, DOS 4.0 has added several new commands as well as improved the operation of or added capabilities to familiar DOS commands. Here are some examples:

- MEM produces a memory-usage map for any program.
- SWITCHES modifies the way the keyboard acts, letting an enhanced keyboard emulate the older models.
- XMA2EMS.SYS isn't a new command, but rather the SYS file for Expanded Memory support (EMS), as IBM finally acknowledges that many users employ more than 640K of RAM.

Twenty-one old DOS commands have been modified, too, and the GOTO command is no longer supported in BAT files. Most of the changes involve addition of the /X parameter to commands like FASTOPEN and BUFFERS. This switch forces the use of any available expanded memory to free up space in the lower 640K.

MODE now modifies the key repeat rate which could formerly be changed only with one of many separately purchased utility programs.

FORMAT and TREE have nice enhancements. FORMAT can now be set for different-density disks just by specifying the size in KB, instead of explicitly showing N: and T: numbers—something most of us did long ago with batch files. Furthermore, disk formatting informafrom 655,360 (640K). In contrast, DOS 3.30 leaves 599,232 bytes free, a significant difference. Letting the DOS SHELL operate in resident mode eats up another 6K of RAM.

Conclusions

This is a very interesting upgrade. It provides both minor and major enhancements. It's one that many new DOS users will appreciate. Power users, in turn, may not have much need for the DOS SHELL interface, but they'll find the new /X switch, which lets some utilities use eXpanded memory, to be very helpful, as well as the support for large disk drives.

Beginners and those who have never felt comfortable with the enigmatic "C " prompt will love the new user shell that makes most common DOS commands easy enough for anyone to access. The help screens and pull-down menus should go a long way toward making DOS less intimidating for casual users to learn and operate.

Unfortunately, the shortcomings of the DOS 4.00 version are rampant. Even ignoring bugs and incompatibility with some software, most of which will doubtlessly be caught up with when the traditional DOS 4.1 upgrade is produced, the new operating system isn't appropriate for everyone.

For example, while the Shell will work with IBM MDA non-graphics as well as VGA, EGA and CGA graphics displays, it fails to support the very popular Hercules monochrome graphics adapter! You wouldn't be in the market for the new DOS, either, if you don't have user memory to spare, a hard disk that you want to partition beyond 32 megabytes, or a fast computer. If it's only the DOS Shell that you're hot for, you can get it all (and more) with a stand-alone program like the Norton Commander.

Even if the promises of DOS 4.0 were exceptionally attractive, it would be wise to wait for a later version that takes into account existing inadequacies. Nevertheless, DOS 4.xx is certainly a major advance. Its increased power will be greeted happily by many corporate computer managers.

BOOKS

Understanding & Repairing CB Radios For the Professional Technician by Lou Franklin. (C.B. City Int'l., P.O. Box 31500, Phoenix, AZ 85046. Soft cover. 365 pages. $29.94 + $2.50 S&H.)

As its title states, this 8½" × 11" book was written to guide the professional technician through troubleshooting and repair of CB radios. It covers all kinds of CB radios from early 23-channel AM-only tube and transistor types right on up to modern 40-channel multi-mode AM/FM/SSB/CW models with ICs and PLL synthesizer tuning used by amateur-radio operators. Coverage also includes U.S., UK and other imported models.

Beginning with a discussion of technical specifications and measuring equipment the book goes on to troubleshooting techniques. A third chapter is devoted entirely to methods of generating signal frequencies that are used in making bench tests. Much of the remainder of the book thoroughly analyzes the theory behind the various types of circuits employed in CB transceivers, devoting separate chapters to receiver circuits, transmitter circuits and power supplies. Throughout these chapters, the book emphasizes simple troubleshooting techniques and shortcuts. They also detail how to align receiver, transmitter and PLL synthesizer systems. Tips on solving RFI, TVI and ignition-noise problems are also detailed. A shopping guide tells where to find CB-related items.

There is also an extensive chapter on antennas and transmission lines. This chapter details how to select, install and repair all types of mobile and base-station antennas. Noise and interference problems are handled in an appendix at the back of the book. Another appendix consists of an FCC frequency chart.

NEW LITERATURE

Surge Suppressor Brochure. CPS Electronics' four-color illustrated "Electra Guard® Suppressor Program" brochure describes the consumer-grade product line of Electra Guard surge suppressors. It includes individual product photos and descriptions. Technical specifications are spelled out in a color-coded table in which colors correspond to the level of power protection available in each unit. For a copy of the brochure, write to CPS Electronics, Inc., 4151 112 Terrace N., Clearwater, FL 34622.

the free end of the *LED2* wire coming from the K hole to the hook and solder the connection. Do the same for the other LED lead and *LED2* wire. Repeat for the green LED and the *LED1* wires on the circuit-board assembly. Then slide the tubing up over the connections until it is flush with the bottoms of the LED cases and shrink into place.

Plug the LEDs into the holes drilled for them and, if necessary, secure them in place with clear fast-set epoxy or plastic cement. If you are using a jack for bringing dc power into the enclosure, mount it in its hole. Otherwise, mount the screw-type terminal strip or barrier block in its location. Connect and solder the free ends of the +9V and GND wires to the jack's lugs (watch polarity!) or to two of the lugs on the terminal strip or barrier block (mark the polarity of each contact on the enclosure as you make each connection). Then crimp and solder the free ends of the S1 and S2 wires to four separate lugs on the strip or block and label the contacts accordingly.

Checkout & Use

With the ICs still not installed in their sockets, plug the power supply into its jack (or fasten it to its contacts on the terminal strip or barrier block) and plug it into an ac outlet. Connect the common probe of a dc voltmeter or a multimeter set to the dc volts function to circuit ground. Then touch the "hot" probe to pins 4, 10 and 14 of the *IC1* socket and pin 14 of the *IC2* socket. The meter should indicate about +9 volts.

You should also obtain a +9-volt reading at pins 1, 2, 6, 8, 12 and 13 of the *IC1* socket but nothing at pins 3, 5, 9 and 11. Similarly, you should obtain a +9-volt reading at pins 1, 2, 6, 8, 12 and 13 of the *IC2* socket but nothing at pins 3, 4, 5, 9, 10 and 11. These readings are based on *empty* IC sockets.

If you do not obtain these readings, power down the project and rectify the problem. Then, when you have ascertained that the project has been correctly wired, make sure no power is applied to it and install the ICs in the sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets.

Power up the project once again. Then use a short jumper wire to momentarily bridge the *S1* contacts of the terminal strip or barrier block for *S1*. You should hear an audio tone from the speaker. If you do, momentarily bridge the contacts for *S2*. You should also hear an audio tone, but one of a different (higher or lower) frequency.

When you are sure that the project is working properly, mount it in the selected location and run power to it. Terminate the wires from your front and rear doorbells at the terminal strip or barrier block to finish construction and installation. The Electronic Doorbell is now in service. **ME**

Pulse Circuit *(from page 37)*

generator, the trace shown in Fig. 8(B) was the result. Note here that a little undershoot "ringing" occurred. When the capacitance was increased to 0.01 microfarad, the result was the lower trace shown in Fig. 8(C). Note here the rounding that occurred (compared with the upper trace). This capacitance resulted from rolling off the higher harmonics, leaving only a few harmonics to form the pulse. The "sharpness" of the rise and fall times is dependent upon the higher harmonics.

In Fig. 8(D) is shown the result of a low-pass RC filter consisting of a 1,000-ohm series resistance and a shunt capacitance of 0.01 microfarad. With this arrangement, both the sharpness and amplitude of the pulse decreased substantially over what they were in the previous case.

It is possible to roll off enough harmonics that the square-wave pulse takes on a sine-wave shape. In Fig. 8(E) is shown the result of making an L-section low-pass filter from a 100-microhenry inductor and a 100-picofarad capacitor. Almost all of the harmonics are removed from the pulse; hence, the square wave looks more like a sine wave—which is why the low-pass filter on a ham or CB set prevents TVI (television interference).

This concludes our discussion on pulse shaping. By knowing what pulses are and how they are generated and affect the circuits in which they are used, you will greatly increase your understanding of modern electronics, especially in the digital area. ME

Test Keyer *(from page 64)*

Keyer's cable, disconnect its antenna and attach a dummy load, set the project's switches as desired and apply power.

At this point, it is important to make two observations. Firstly, never use the CB Keyer while the transceiver is connected to an antenna; always use a dummy load in place of an antenna. Secondly, do not omit capacitor *C9* from the circuit; if you do, severe and permanent damage can occur to both the CB Keyer and the transceiver to which it is connected during a test.

As you use the CB Keyer, you will come to appreciate its automated keying action that simplifies testing and troubleshooting at your service bench. The Keyer automates the keying of the microphone input of a transceiver and simultaneously injects a 1-kHz tone freeing your hands to more constructively probe the transceiver's circuits with an oscilloscope, meter or other instrument. ME

Place the circuit-board assemblies side by side near the open rear of the enclosure. Secure the free end of the wire coming from the lower 120V AC hole in the smaller circuit board assembly to one outer conductor contact of the receptacle via the appropriate screw. Crimp and solder the free end of the wire coming from the upper 120V AC hole to the other lug of the POWER switch. Route the wire coming from the 120V OUT hole to the remaining connection on the receptacle and secure it in place with the appropriate screw.

Now plug the free end of the TO BASE OF Q2 wire on the larger circuit board assembly into the TO R31 hole in the smaller board and solder into place.

Preliminary Checkout

Because dangerous ac line power is routed through portions of this circuit, it is important that all components on the primary side of the power transformer be wired correctly before attempting to power up the system to make voltage checks. Review all wiring for this circuit, marking each run off on a photocopy of Fig. 3 (or Fig. 4 if you decided to use the simpler circuit).

When you are sure of your wiring, use an ohmmeter set to its highest range to measure the resistance in *both* directions between the prongs of the power plug in every combination with the POWER switch opened. In all cases, you should obtain an infinite resistance indication ("overrange" if you are using a DMM). You should obtain the same results when the test is repeated on the project's receptacle.

If you obtain any indication other than infinite resistance during this test, do *not* plug the line cord into an ac outlet. Instead, recheck your wiring and correct the problem before proceeding.

If you do obtain the proper resistance readings with the POWER switch open, close the switch and repeat the tests on the line cord's plug, this time using a low ohmmeter range. When making checks between the blade-shaped prongs, you should obtain a fairly low resistance (the dc resistance of the power transformer's primary winding). However, you should still obtain an infinite reading between both blade prongs and the remaining round prong even on the highest resistance range. There is no need to make tests on the ac receptacle on the project. Once again, if you do not obtain the appropriate readings, correct the problem before proceeding.

Now place an insulating surface on your workbench. A thick sheet of corrugated cardboard is good. Arrange the circuit-board assemblies so that they are not touching each other or any part of the enclosure if the enclosure is made of metal. Switch to the dc-volts function of your meter and set it for a full-scale range that will accommodate readings up to 20 volts or so. Clip the meter's common probe to a convenient point in the circuit that is at ground potential.

Plug the project's line cord into a convenient ac outlet and set the POWER switch to "on." Touch the meter's "hot" probe to the OUT pin of regulator *IC10*. The meter should indicate a potential of some positive voltage. If so, adjust the setting of *VR1* on the smaller board for a meter reading of precisely + 10 volts. Then probe pin 16 of the *IC1* through *IC5* and pin 14 of the *IC6* through *IC9* sockets on the larger circuit-board assembly. Once again, all readings should be + 10 volts. If you do not obtain the appropriate readings at any point, pull the project's plug from the ac line and correct the problem. Do *not* proceed until the problem has been rectified.

With no power applied to the project, crimp and solder the free ends of the wires coming from the larger circuit-board assembly to the lugs of the pushbutton and slide switches. Then carefully install the ICs into their respective sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between the ICs and sockets.

Disconnect the wire that bridges the base of *Q2* on the small circuit-board assembly and *R31* on the larger board at one end of the wire. Also disconnect one end of the V+ wire and temporarily install a 1,000-ohm, 1-watt resistor in series with the free end of this wire and the hole from which it was removed. The resistor will protect a short-circuited component, assuming there is one in the project, for a long time while the circuit is under power.

With power applied and the POWER switch set to "on," you should obtain a reading of 4.5 to 5 volts across the 1,000-ohm resistor. If either *LED1* (the 0 SECONDS LED) has not come on or the measured potential across the resistor is greater than 6 volts ac, something is wrong with the circuit. Power down and correct the problem.

Once the problem has been corrected and with the 1,000-ohm still connected into the circuit, press and release the START pushbutton switch. To decrease the 5-second clocking time, you can bridge the crystal with a wire shorting link. This will decrease each timing step to less than a second, allowing you to quickly check if the Timer is behaving as it should. Once you know the Timer is operating properly, power down the project, remove the 1,000-ohm resistor and reconnect the wire to the hole from which it was removed. Reconnect the other wire.

Test the switching circuit by plugging a table lamp into the project's ac receptacle. Make sure the lamp is turned on first. Plug the project into an ac receptacle and set the POWER switch to "on." Select a timing interval with the rotary and slide switches and press and release the STOP/RESET button to initialize the Timer. Then press and release the START button and time how long the lamp

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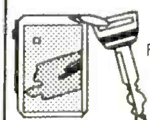

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74LS670	1 10

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74S00	30
74S02	30
74S03	35
74S04	35
74S08	35
74S09	45
74S10	40
74S11	40
74S20	40
74S64	40
74S74	45
74S86	45
74S11	55
74S13	70
74S13	80
74S153	85
74S157	85
74S163	1 25
74S174	85
74S175	85
74S189	2 50
74S251	75
74S257	85
74S280	1 90
74S299	2 50
74S374	1 40

CMOS

74C00	25
4000	20
4001	20
4002	25
4006	60
4007	20
4011	20
4012	25
4013	30
4015	35
4016	30
4019	40
4027	65
4023	30
4024	45
4025	25
4035	60
4040	65
4041	75
4042	50
4046	80
4047	75
4049	30
4050	30
4051	50
4052	60
4060	75
4066	40
4068	60
4069	25
4070	30
4071	25
4072	25
4073	45
4076	55
4077	30
4078	40
4081	25
4082	30
4085	45
4086	55
4093	45
4160	50
4163	55
4416	55
4428	55
4449	55
4497	55
4502	75
4511	65
4516	85
4517	85
4518	95
4519	80
4528	75
4532	85
4538	85
4555	80
4556	45
4573	60
4574	60
4581	95
4585	80
40098	55
40107	55
45155	55

EPROM

2716	3 25
2732	3 95
2764	3 95
27128-25	$5
27256	7 95

LINEAR IC'S

LM308H	50
LM309K	85
LM307H	50
LM308	70
LM308H	70
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LM311N	40
MC3177	75
LM318H	90
CA3[illegible]	45
LM324N	95
LM339N	45
LM380N	80
LM386N	80
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MC7806	45
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MC78M24	45
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MC7915	45

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8035	1 95
8085	1 95
Z 80A DMA	4 95
Z 80A CTC	1 50
UDN6118A	50
UDN6128A	55
UDN6184A	60
UDN7180A	65
UDN7186H	95
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ICM7225IPL	$9
MM5481	75
N8T22	15
74H04	15
7545[illegible]	25

Transistors & DIODES

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C1222(PN)	7/1
2N2222A	10/1
2N2613	65
2N2907A	10/1
2N2904A	5/1
2N3055	60
2N3643	10/1
2N3791(SGS)	1
2N3904	10/1
2N3906	10/1
2N4249	10/1
2N5962	7/1
TIP 29B	50
2SD898	2 50
2SC1172B	2 25
HOUSE #216	
TO 92 NPN	25/1
1N749	10/1
1N914A	40/1
1N4148	40/1
1N4001	30/1
1N4004	25/1
1N4007	15/1
1N5231B	5/1

LOW PRO IC SOCKETS

8 Pin/.09, 14 Pin/.13, 16 Pin/.15, 18 Pin/.17, 20 Pin/.19, 22 Pin/.21, 24 Pin/.23, 28 Pin/.26, 40 Pin/.28
Zero Insertion Test Socket 28 Pin $5.00

WIRE WRAP IC SOCKETS

14 Pin .55, 16 Pin .60, 24 Pin .85, 40 Pin/1.35

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Rectangular Green	10/$1.50, 100/$13.95
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Hewlett Packard 7 Seg .4" Red Annode #7650	75
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FUTABA# 13-ST-12A 13 Digit Gas Display	$2
Taiwanese LCD Clock with Push Buttons	$2

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SPEAKERS

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50K Dual Pot Audio Taper	85
1,000uF 25V Radial Mini Lytic	4/$1
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DPDT RT Angle Mini PC Toggle (On Off On)	65
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Radial Lytics — 1uF 50V 13, 2.2uF 50V 13, 3.3uF 50V 14, 4.7uF 40V 12, 10uF 50V 14, 22uF 35V 15, 33uF 35V 15, 47uF 35V 15, 100uF 25V 20, 220uF 35V 22, 330uF 35V 33, 470uF 35V 39, 1,000uF 16V 45, 1,000uF 75V Axial 75
3,200uF 50V Twist Lock 65
3,300uF 50V Axial Lytic 85
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Multi Turn Precision Trimpots, 100 Ohm, 200 Ohm, 500 Ohm, 1K, 2K, 5K, 10K, 20K, 25K, 50K, 100K, 200K, 250K, 500K, 1Meg — 75 Each	100/$66
Zenith TV Replacement IC Special 221-42, 221-43, 221-45, 221-48, 221-69, 221-79, 221-87, 221-96, 221-104, 221-105, 221-106, 221-140	$1 Each
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Motion Detect. ULN2232 IC Only 3/$2	20/$10
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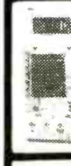

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