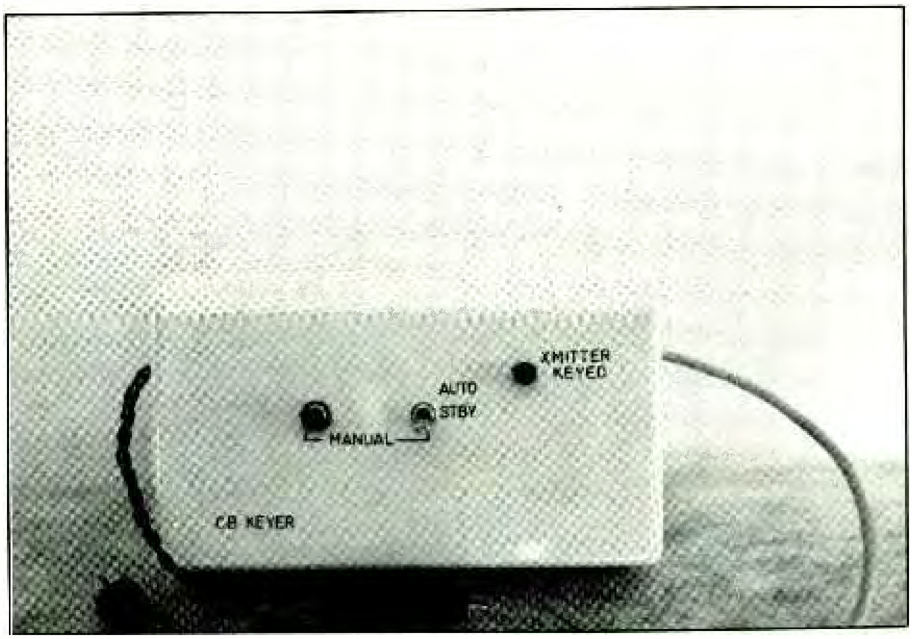
Transmitter Test Keyer

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*

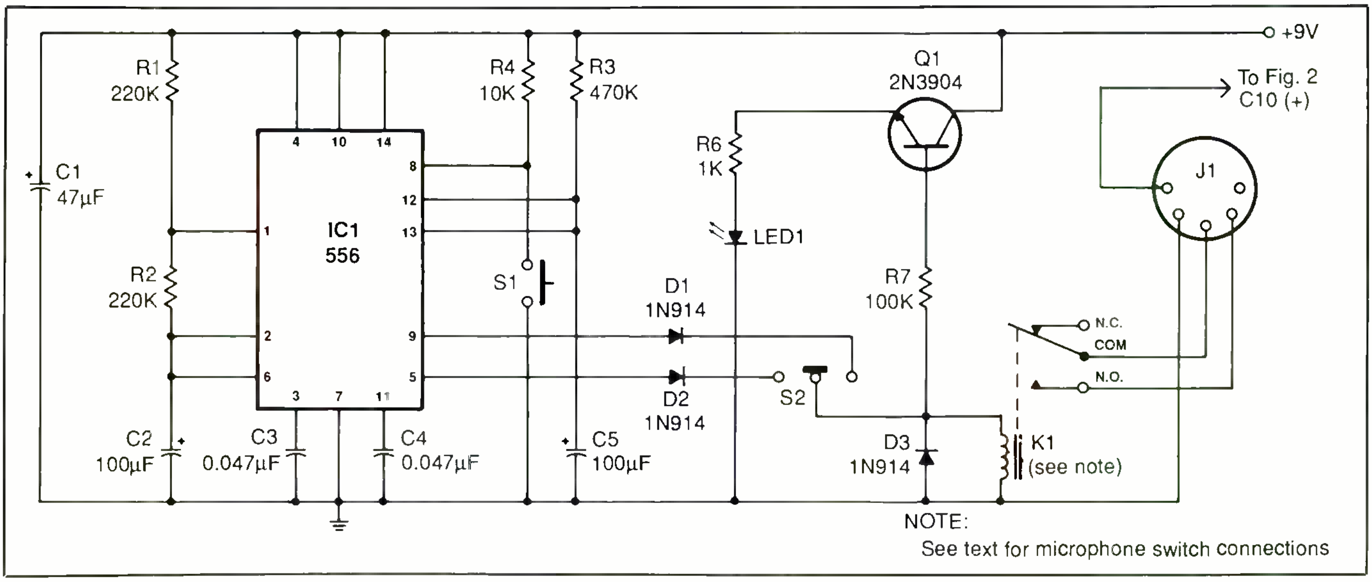


Fig. 1. Schematic diagram of the CB Keyer's switching circuits.

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; hookup wire; solder; etc.

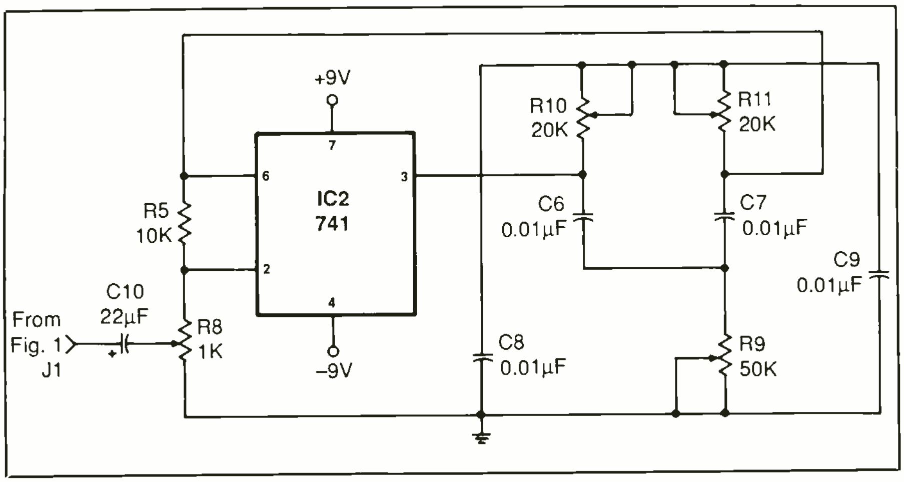


Fig. 2. Schematic diagram of the CB Keyer's audio oscillator.

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 ends and shrink tightly into place.

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).

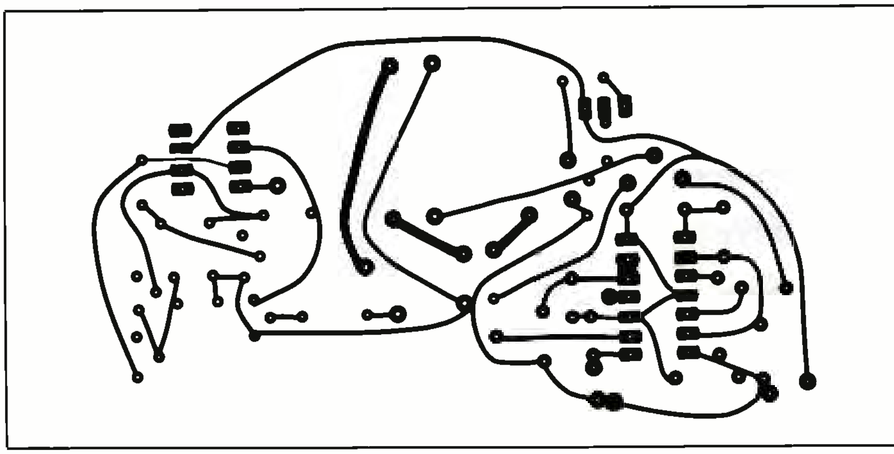


Fig. 3. Actual-size etching-and drilling guide for project's printed-circuit board.

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.

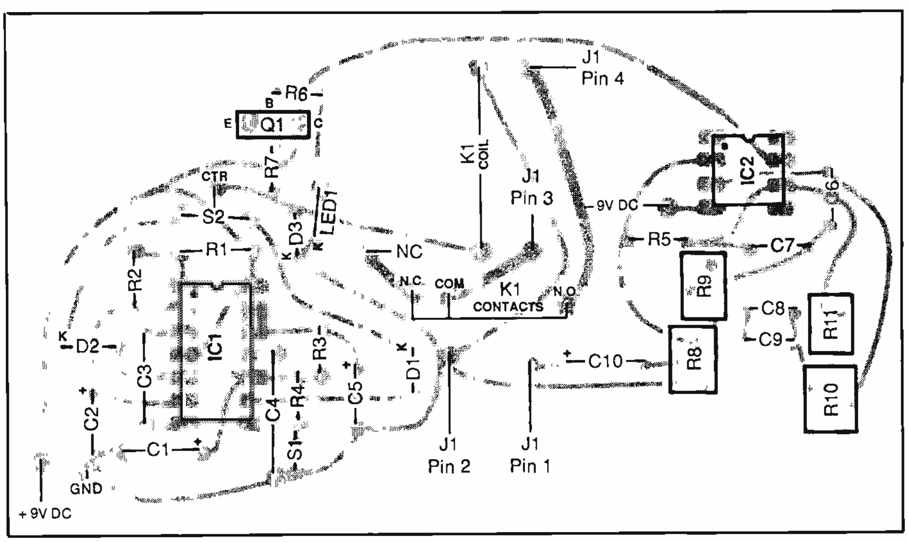


Fig. 4. Wiring guide for pc board.

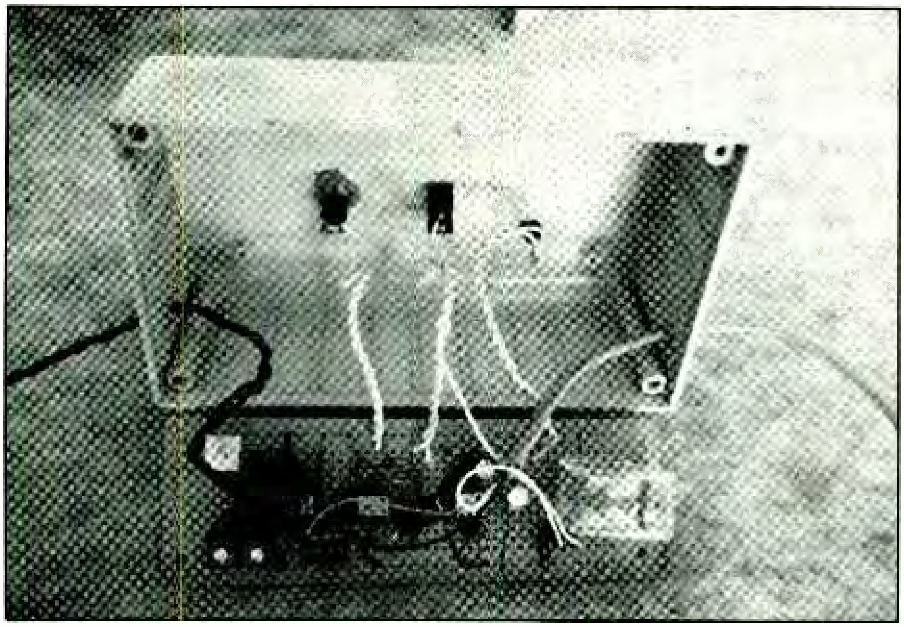


Fig. 5. Interior view of author's prototype built on prototyping board. This version requires a separate dual-polarity bench-type dc power supply.

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

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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