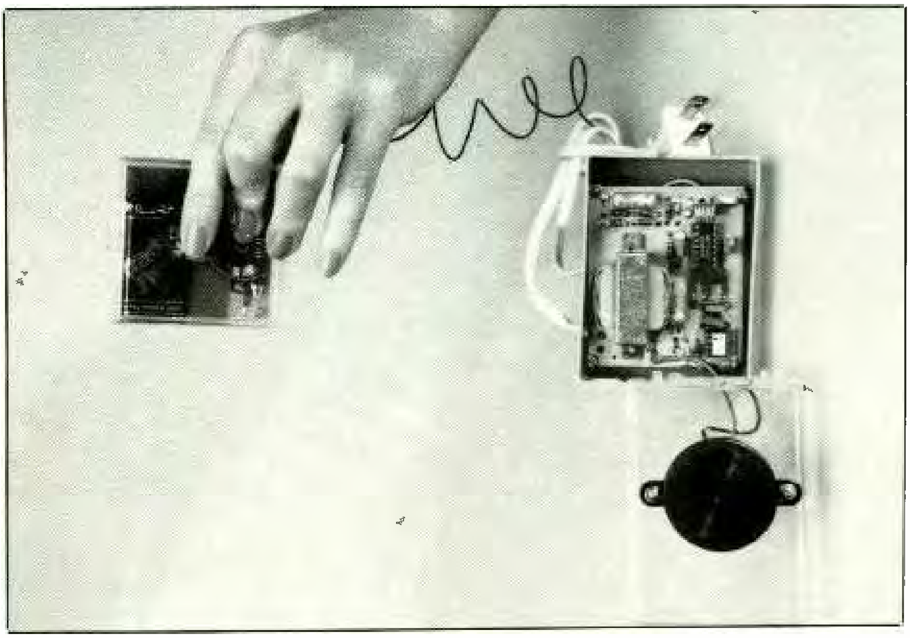
A Radio-Controlled Doorbell

This wireless system makes it easy to add remotely located doorbells so that you can hear someone ringing you at an outside entrance while you are in the basement, attic or other distant area

By Anthony J. Caristi



Is the doorbell wiring in your home or apartment defective? Or would you like to know when a visitor or delivery person rings your entrance doorbell when you are in your basement, workshop or attic, on your patio, or even when you are at poolside? The Radio-Controlled Doorbell presented here offers an easy solution to all these situations. It uses radio waves to bypass the problems posed by running wires throughout your home. Its only condition is that the remotely located receiving element that contains an attention-getting piezoelectric buzzer (instead of a bell or chime) must be positioned close to an ac outlet to provide power. The small transmitter, on the other hand, is battery powered.

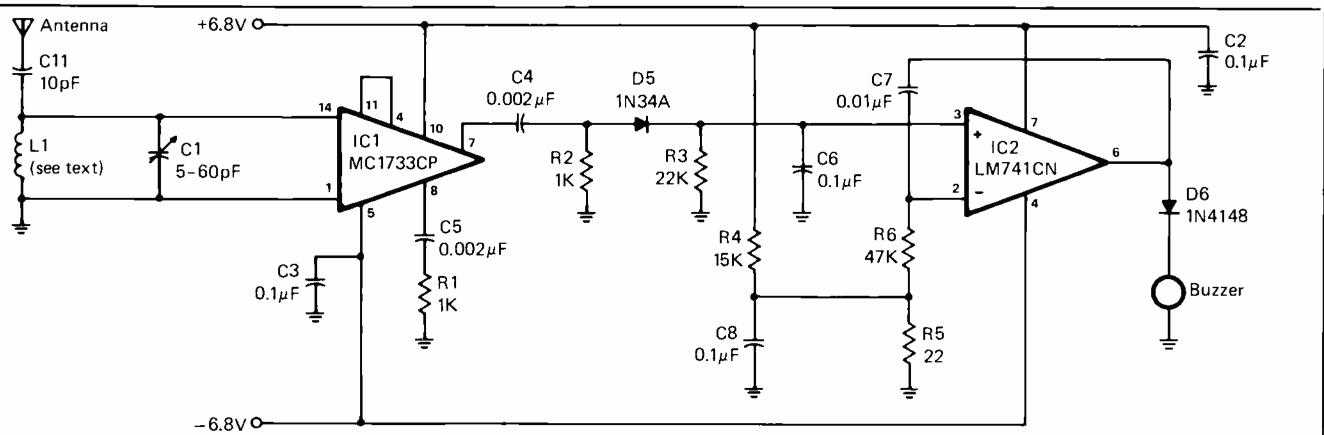
This project takes advantage of Part 15.205 of the FCC Rules and Regulations that permits unlicensed transmitters to be operated as remote-control devices, providing that the r-f energy of the fundamental carrier frequency does not exceed 1,250 microvolts per meter at a distance of 3 meters. Operating at very low power, the Doorbell's transmitter is legally limited in length, but there is no length restriction on the receiver's antenna. It is even possible to take advantage of the enormous signal-gathering power of your home's ac power wiring.

Construction of the Doorbell system has been designed to be simple. The only requirement is that you must use printed-circuit wiring as detailed here. Since the system operates at high frequencies, point-to-point wiring on perforated board is not an acceptable alternative.

About the Circuit

Two basic elements make up the Doorbell system. These are the receiving module and its power supply, and the miniature transmitting module. The schematic diagram of the basic receiver, minus its power supply, is shown is Fig. 1. This tuned radio-frequency (TRF) receiver is built around just two integrated circuits and their support components, plus a piezoelectric buzzer.

Differential r-f amplifier *IC1* has a voltage gain of approximately 400 (52 dB). One input of this IC is grounded; the other is driven by an r-f signal intercepted by the antenna. The r-f signal appears across the



PARTS LIST

Semiconductors
D1 thru D4—1N4001 silicon rectifier diode
D5—1N34A germanium detector diode (Radio Shack Cat. No. 276-1123 or similar)
D6—1N4148 silicon switching diode (Radio Shack Cat. No. 276-1122 or similar)
D7,D8—6.8-volt zener diode (1N5235 or similar)
IC1—MC1733CP differential amplifier (Motorola)
IC2—LM741CN operational amplifier (Radio Shack Cat. No. 276-007 or equivalent)
Q1—2N5179 npn high-frequency transistor
RECT1—50-volt, 1-ampere bridge rectifier
Capacitors (15 or more working volts)
C1,C13—5-to-60-pF trimmer (Radio Shack Cat. No. 272-1340 or similar)
C2,C3,C6,C8,C15—0.1-µF ceramic disc
C4,C5—0.002-µF ceramic disc
C7—0.01-µF ceramic disc
C9,C10—470-µF electrolytic
C11—10-pF, 100-volt ceramic disc
C12—0.001-µF ceramic disc
C14—10-pF ceramic disc
Resistors (¼-watt, 5% tolerance)
R1,R2—1,000 ohms
R3—22,000 ohms
R4—15,000 ohms
R5—22 ohms
R6—47,000 ohms
R7,R8—56 ohms
R9—33,000 ohms
R10—150 ohms
Miscellaneous
B1—9-volt transistor battery
L1,L2—R-f coil (see text)
S1—Spst momentary-action, normally-open pushbutton switch
T1—12.6-volt, 300-mA power transformer (Radio Shack Cat. No. 273-1385A or similar)
Piezoelectric buzzer (Radio Shack Cat. No. 273-069 or similar); printed-circuit boards (see text); wire for L1 and L2; suitable enclosures for receiver and transmitter; ac line cord with plug; zip cord (see text); battery holder and snap for B1; stranded hookup wire for antennas; machine hardware; hookup wire; solder; etc.

Note: The following are available from: A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Etched and drilled transmitter pc board for $3.00; etched and drilled receiver pc board for $6.00; MC1733CP integrated circuit for $3.75; 2N5179 transistor for $3.50. Add $1.00 S&H; New Jersey residents, please add state sales tax.

Fig. 1. Schematic diagram of receiver minus its power supply.

tuned circuit composed of *L1* and *C1*. The incoming signal is coupled through *C11* into the tuned circuit, which must be tuned to the carrier frequency of the system's transmitter. This signal is then passed into *IC1* through input pin 14.

Variable capacitor *C1* in the tuned circuit provides a means for tuning the receiver to the system's transmitter carrier. This is necessary to assure that only the system's transmitter—not a standard broadcast FM transmitter operating near the same frequency—triggers the "bell."

Only one of *IC1*'s differential outputs, at pin 7, is used in this application. The amplified r-f carrier voltage that appears at pin 7 is detected by *D5* to produce a dc voltage that is then fed to the noninverting (+) input of operational amplifier *IC2* at pin 3. Capacitor *C6* attenuates any unwanted noise pulses that might be detected by the receiver, which could otherwise result in spurious operation of the buzzer. Op amp *IC2* is configured as a voltage comparator in this setup. This arrangement takes advantage of the operational amplifier's very high gain without requiring negative feedback.

The inverting (−) input at pin 2 of *IC1* is biased with a positive potential of about 10 millivolts to ensure that the output at pin 6 is driven to about −5 volts when no signal is detected by the receiver. This cuts off *D6* to ensure that the buzzer remains silent.

When an r-f signal from the system's transmitter appears at output pin 7 of *IC1*, the positive voltage that results due to detection by *D5* is sufficient to drive the pin 3 input of *IC2* to a level that is greater than 10 millivolts at output pin 6. Since this is greater than the bias level delivered to inverting input pin 2, the output of the op amp is driven to about +5 volts, which is sufficient for *D6* to conduct and turn on the buzzer.

Power for the receiver is supplied from the 117-volt ac line with the power supply shown schematically in Fig. 2. Note that this is a bipolar power supply that delivers both the +6.8 and −6.8 volts with respect to ground required by the receiver circuit. The +12 and −12 volts out of the *D1* through *D5* bridge rectifier circuit are regulated down to the desired +6.8 and −6.8 volts by zener diodes *D7* and *D8* to ensure that the voltages fed to *IC1* do not exceed the IC's maximum ratings under any power-line variation conditions.

Power consumption of the receiver is less than 5 watts. So it is economical to leave it on continuously (average power consumption cost should not exceed 25¢ to 30¢ per month). For this reason, no power cord or switch is included in the circuit. If practical, the receiver's power supply can be wired directly into your house wiring so that it is always ready to signal when a caller "rings." Alternatively, you can use a standard ac line cord and plug this into a convenient ac outlet.

Shown in Fig. 3 is the system's simple transmitter. It consists of a single-transistor oscillator powered by a common 9-volt transistor battery and operates at a carrier frequency of approximately 88 MHz. Operating frequency is basically determined by the tuned circuit made up of *L2* and *C13*. Capacitor *C13* is variable to allow the oscillator's frequency to be set to a point at the low end of the FM radio dial where there are no broadcast transmitters operating to ensure against interference.

Transistor *Q1* is specifically designed for use in very-high-frequency (vhf) oscillator and amplifier applications. Its base is held at r-f ground potential by *C12*. The *L2/C13* tuned circuit is in the collector circuit. The feedback path that initiates and maintains oscillation is through *C14*.

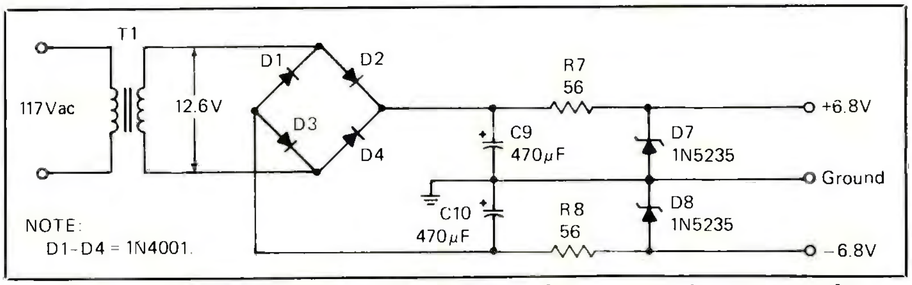


Fig. 2. Schematic diagram of receiver's ac-line-operated power supply.

An unmodulated carrier that can be detected by the system's receiver is generated by the transmitter whose schematic diagram is shown in Fig. 3. The transmitter is unpowered except when "doorbell" pushbutton switch *S1* is pressed. It remains powered only as long as this switch is held closed. Since in this doorbell application the battery is used infrequently and only very briefly when *S1* is pressed to signal a caller, *B1*'s useful life should approach what its normal shelf life would be. Generally, this would be a year or more.

Construction

Due to the very-high r-f frequencies involved in this system, printed-circuit wiring is mandatory, both to ensure proper operation and to conform with FCC regulations. Each of the two circuit boards in this project, one for the receiver and the other for the transmitter, must be double-sided. This is necessary because one side of each board must serve as a ground plane for the circuit.

If you plan to fabricate your own pc boards, use the actual-size etching-and-drilling guides shown in Fig. 4. Start with pc blanks that are copper clad on both sides. Mask off the side that will be the tops of the boards to make sure that when etching the copper on this side remains intact. If you prefer not to make your own pc boards, you can purchase them ready to wire from the source given in the Note at the end of the Parts List.

Although the top (component-mounting) sides of the pc boards are solid copper, certain holes on each must be cleared of the conductive copper cladding so that component leads and pins do not short out. It is not necessary (or even advisable) to etch the copper from these areas, as you do for the conductor traces and pads on the bottom (solder) side of the board.

After etching and bottoms per the

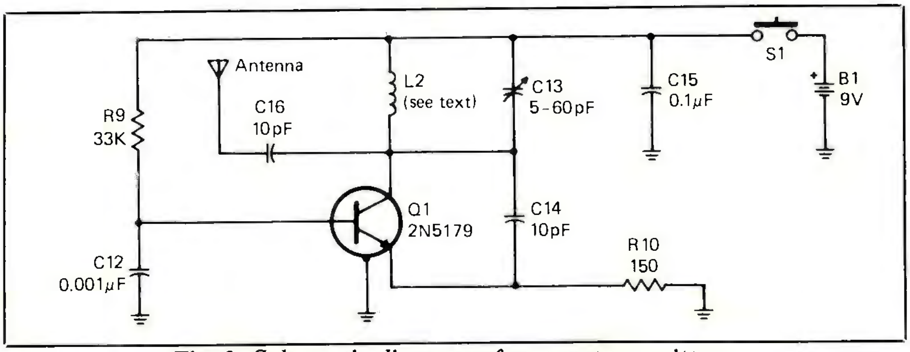


Fig. 3. Schematic diagram of system transmitter.

etching-and-drilling guides, you drill all lead and pin holes. Then refer to Fig. 5 and carefully mark on the copper cladding only those holes indicated. Then use a sharp 3/16" drill bit to remove only enough copper around each marked hole to assure that the component leads or pins that are to go into them will not short out to the ground plane. Work carefully to avoid drilling clear through the board. As you complete removal of the copper for each component's leads or pins, test install the component and check to make sure enough copper has been removed.

Coils *L1* in the receiver and *L2* in the transmitter must be hand-wound. This is a simple operation that requires only a 1/4" coilform (a standard wooden lead pencil will do) and a length of No. 20 enameled magnet wire. Simply wind five turns of the wire for each coil, leaving about 1/2" of lead length at each end of each coil. After winding each coil, slip it off the coilform and use a sharp knife to scrape away 3/8" of the insulating enamel from the lead ends. Then carefully spread the coils so that their leads plug into the proper holes of the receiver and transmitter boards (left and right, respectively, in Fig. 6). Space the turns of the coils evenly. Remove the coils, identify which is which, and set them aside until called for during circuit board wiring.

Referring to the left guide in Fig. 6, wire the receiver board exactly as shown. When you install trimmer capacitor *C1*, mount it so that the adjustment slot is connected to the "cold" side of the circuit. Failure to do this can result in a difficult-to-tune circuit. You can use sockets for the integrated circuits to facilitate easy replacement should either or both become defective during the circuit's lifetime. Even though pin 1 of *IC1* is to go to ground, this will be adequately accomplished by soldering its socket pin on the bottom of the board.

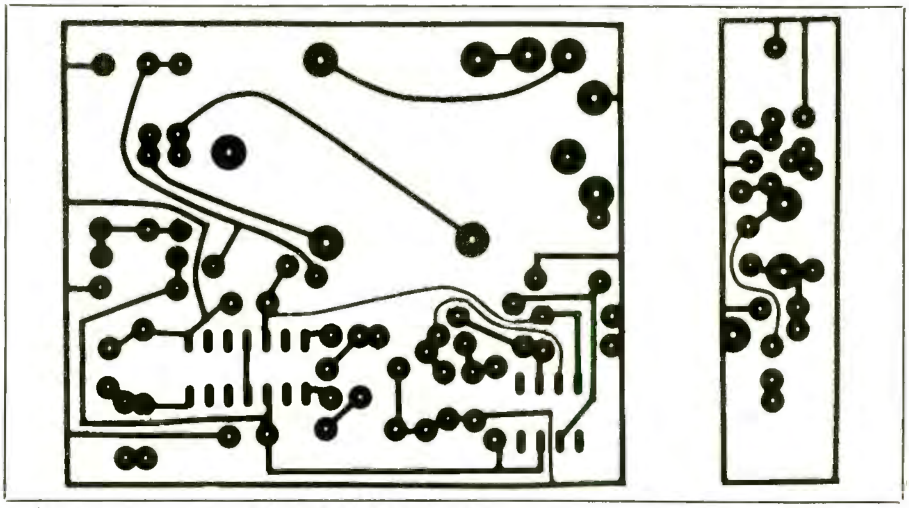


Fig. 4. Actual-size etching-and-drilling guides for receiver and transmitter.

As you install the components on the receiver board, ground-plane side up, make sure you properly orient the diodes, electrolytic capacitors and power transformer, and make sure that you do not forget *L1*. Solder all leads and pins to the pads surrounding the holes through which they pass on the bottom of the board. Then flip over the board and note which component leads are to be soldered to the ground plane, as evidenced by those that pass through holes that are *not* cleared of copper. In each case where a component lead is to connect to the ground plane make a good soldered electrical connection. This is very important because if you fail to make these extremely short ground connections, the circuit will not operate as desired at the very-high 88-MHz frequency for which it is designed.

Install the ICs (or sockets) in their respective locations, making certain that they are properly oriented. Solder the pins only to the pads on the bottom of the board. All pins of both ICs should pass through holes that have been cleared of ground-plane copper. Hence, no IC pin should be soldered to the ground plane. When you are finished wiring the board carefully inspect it for solder bridges

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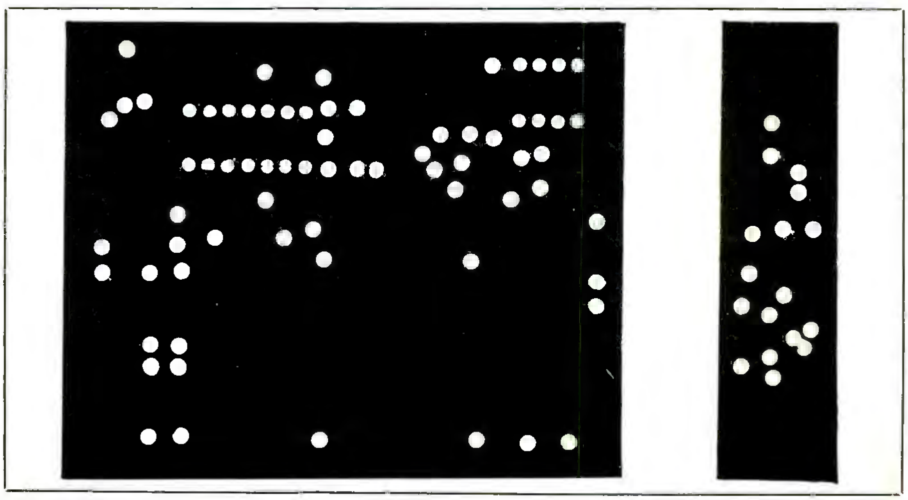

Fig. 5. Top views of top (ground-plane) sides of receiver (left) and transmitter (right) pc boards showing holes that must be cleared of copper cladding.

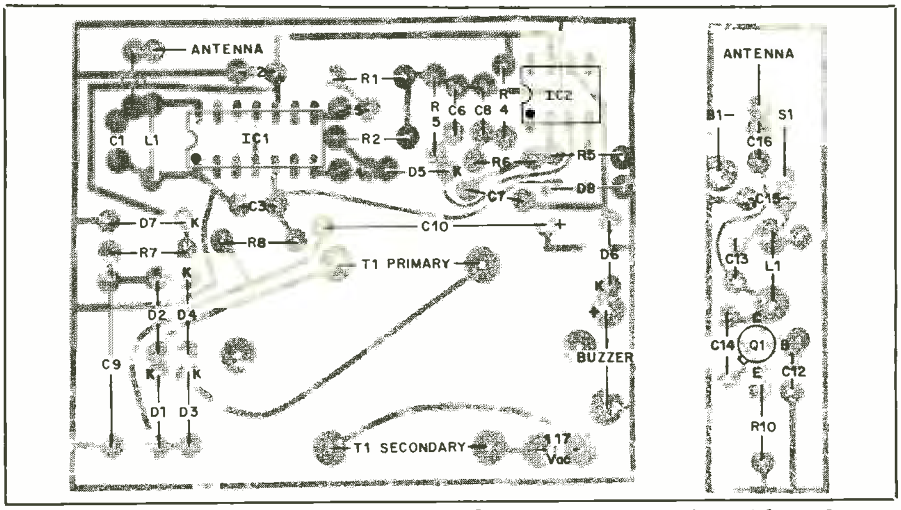

Fig. 6. Wiring guides for receiver (left) and transmitter (right) boards.

between closely spaced conductors on the bottom of the board, especially between the IC pads. Do not install the antenna wire and buzzer yet.

Now wire the transmitter board exactly as shown in the right guide in Fig. 6, again taking care to properly orient the transistor. When installing *C13*, observe the same instructions as for *C1* above. Also note that the transistor has four leads, one of which is internally connected to the case. Be sure the emitter, base, collector and case (shield) leads plug into the appropriate holes in the board and that you solder to the ground plane those component leads that pass through holes from which no copper has been removed.

You can use a short length of stranded hookup wire for the transmitter's antenna to achieve the desired operating range. Start with an 18″ wire connected to the transmitter's board as shown in Fig. 5.

Since there is no restriction on the length of the antenna used for the receiver, you should use as long a stranded hookup wire as necessary to achieve maximum system sensitivity. Start with about a 36″-long wire, connecting it to the receiver board as indicated in Fig. 4.

It is possible to use a short insulated jumper wire connected from the antenna side of *C11* to one side of the ac line at the primary side of the power transformer in the power supply section to pick up the transmitter's signal. Make absolutely certain if you do this that *C11* is rated at at least 200 volts and preferably 1,000 volts, and make sure to insulate the antenna wire to eliminate any possibility of shock hazard. This arrangement takes advantage of the enormous signal-gathering power of your home's ac wiring. A disadvantage of this arrangement is that electrical noise on the ac power line is likely to periodically cause the receiver's beeper to sound when no one has pressed the transmitter's switch.

You can house the receiver and transmitter circuits in suitably sized plastic boxes. For the transmitter, which will normally be in a location near your front door that is accessible to any passerby, you might want to use a metal box that mounts on a wall, or mount the circuitry behind a more secure panel with only the pushbutton switch accessible. If you are planning on using the receiver as a portable unit that can be taken to different locations in and around your home as needed, a better box might be one of those plastic types with an aluminim front panel.

Mount the transmitter's battery close to the circuit board assembly. The receiver requires 117-volt ac power and must, therefore, be mounted in a location where line power is available if it is to be permanently mounted. In any event, the piezoelectric buzzer should be mounted on the front of the box so that its sound can be clearly heard.

Checkout and Use

The transmitter must be checked out first to set it to the desired frequency. You can do this with the help of a standard FM broadcast radio or receiver. Tune the latter to a "dead" spot on the dial near 88 MHz where there are no stations broadcasting.

Turn on your FM radio and tune it to a spot near 88 MHz where no station is broadcasting. All you should hear at this point is a steady rush of static. Move the transmitter away from the FM receiver as far as practical and press and hold its pushbutton switch as you tune *C13* with a plastic alignment tool until you hear the static coming from the FM radio.

Tune *C13* so that the transmitter's frequency is peaked to the setting of the FM radio. This is a very sensitive adjustment that takes a lot of patience to perform correctly. Be sure you peak the transmitter to the FM radio because there may be one or several false settings that are not at the correct frequency. If you set the transmitter to one of these false frequencies, you may not be able to get your Doorbell to work properly.

Caution: Under no circumstances should you set the transmitter to a frequency beyond 108 MHz. This portion of the radio spectrum is reserved for aircraft communications. The FCC Rules and Regulations strictly forbids transmitting of remote-control devices in the 108-to-130 MHz band!

When the transmitter has been tuned to the correct frequency, use it to tune the system's receiver. For this operation, you will need a plastic alignment tool and a sensitive dc voltmeter (a digital multimeter set to low ac volts will do) or an oscilloscope. If possible, have someone operate the transmitter across the room from where you are working on the receiver.

Connect the voltmeter or oscilloscope, set to its most sensitive range, across *R3* in the receiver. Have your helper press and hold the pushbutton switch on the transmitter as you adjust the setting of *C1* for maximum voltage across *R3*, as indicated by the voltmeter or oscilloscope. You may find that as you approach peak, the instrument will have to be set to a less-sensitive range.

As the voltage indicated exceeds 10 millivolts, the piezoelectric buzzer should sound. Continue adjusting *C1* until the indicated voltage has reached its peak. If you go beyond the peak indication, back off and stop at peak. This completes adjustment of the system.

To check operating range, vertically orient the receiver and transmitters and walk away from the receiver while holding down the pushbutton switch of the transmitter. If the resulting operating range is too great for your application, it is suggested that you reduce transmitter radiation by shortening its antenna in ½" increments at a time until the range is just right or perhaps just a bit better than you really need. You may have to peak the receiver after doing this if the transmitter's frequency is affected by the trimming.

There is an alternative way you can reduce the sensitivity of the system without having to trim transmitter antenna length. You can reduce the receiver's sensitivity by increasing the value of *R5*. This resistor sets the operating bias on *IC2*. By increasing the value of *R5*, you increase the transmitter signal strength required to set off the buzzer.

It is always best to set your remote Doorbell for the shortest satisfactory operating range. By doing this, you avoid interference with other transmitting and receiving equipment in your area. **ME**