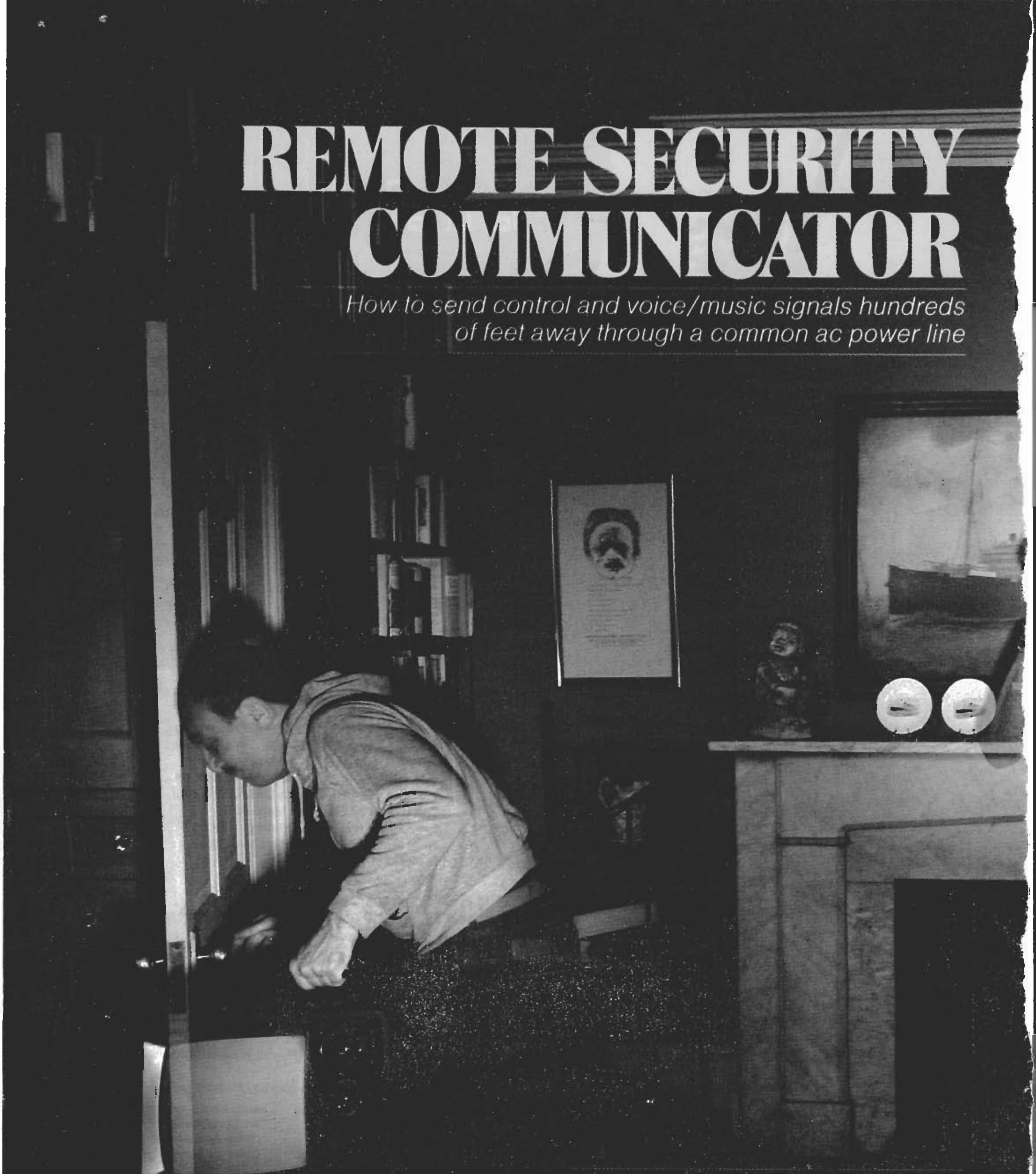
REMOTE SECURITY COMMUNICATOR

How to send control and voice/music signals hundreds of feet away through a common ac power line



By Marty Bergan*

THERE are many wireless intercoms that use the ac power lines as bidirectional communication links between two stations. In this way, two-way voice communication can take place almost

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Photo: Jay Brenner

anywhere within a building without the installation of separate wiring. The Security Communicator described in this article uses this principle to provide a transmission link for a security system as well as a distribution system for music or one-way voice communication. A security sensor as simple as a contact switch on a door or window can be used to protect a room's contents by sending a signal to a remote receiver to sound an alarm.

As shown in Fig. 1, the system utilizes conventional "carrier-current" transmission techniques over ordinary ac building wiring. Frequency modulation is used to minimize the effects of noise that is often found on power lines.

The FM transmitter can be modulated from two sources: either a conventional audio amplifier that can accept a microphone, radio, or other input signal or a 5-kHz tone generator that is turned on when an associated normally-closed contact switch is opened. The remote FM receiver uses a simple audio amplifier and built-in speaker for voice or music output. It also has a digital circuit that operates when the 5-kHz tone is detected to allow control of external loads.

Although the transmitter has only a 30-mW output, it will operate over several hundred feet of power line, even between two buildings if they share the same power line and there is no transformer between.

The sensor switch (controlling the 5-kHz tone generator) at the transmitter can be activated by any electronic or mechanical device that can simulate a simple on/off switch. This approach can also be used to turn on (or off) any appliance at the receiving end of the system via a suitable relay connected to the receiver digital output circuit.

Circuit Operation. The transmitter, shown in Fig. 2, is designed around *IC2*, a chip intended for use in cordless telephones. This IC can operate as an FM modulator between 1.4 and 14 MHz and, although not suitable for true high fidelity, it can handle wide deviations with low distortion. The carrier frequency in this Communicator, 3.125 MHz, is determined by *L1, C3*, and *C4* and was selected so that the companion receiver could use an inexpensive 3.58-MHz color-TV crystal to produce the required 455-kHz intermediate frequency. The FM output from pin 7 (about 600 mV peak-to-peak with less than 1% harmonic distortion) is passed via *R12* and *C7* to the base (pin 2) of a buffer transistor within *IC2*. The emitter of this transistor is grounded via pin 4, while the collector at pin 3 uses *R14* as the load. Resistor *R13* is a bias resistor.

For additional gain and impedance matching to the power line, the output of *IC2* drives transistor *Q1*. The collector load of *Q1* is formed by the primary of *L2* tuned by both a slug and *C10*, with *L5* and *C9* keeping the r-f from entering the operating voltage supply. The secondary winding of *L2* passes the FM signal to the ac power lines through a pair of 1-kV disc ceramic capacitors, *C11* and *C12*. It is imperative that the latter be a very-high-voltage type for safety. Note that the r-f is kept out of power transformer *T1* by the high impedance of inductors *L3* and *L4*.

The transmitter is voice- or music-modulated by a signal applied to *J1* and amplified by *IC1A* and its associated components, with *R1* acting as the gain control. Enough gain is provided in this circuit to allow it to work with most crystal or ceramic microphones. A paper cone speaker can be used as a microphone if the resistance of *R2* is reduced. However, if you use this approach, make sure that the value of *R2* does not drop below 2000 ohms.

A 5-kHz audio oscillator, is formed by *IC1B* with its associated components. The circuit is kept from oscillating by normally closed *S2*. When *S2* is opened, *IC1B* immediately oscillates at 5 kHz and this signal is applied to *IC2* (in parallel with the voice/music input from *IC1A*) to modulate the transmitter. Switch *S2* can be any normally closed switch from a simple pushbutton to a closed-loop intruder alarm system (normally closed switches on windows or doors, or a loop of conductive tape on glass areas). No matter what is used, when the switch circuit is closed, the 5-kHz oscillator does not work; and when the switch is opened, the 5-kHz tone is modulated onto the FM carrier.

The heart of the receiver circuit (Fig. 3) is *IC1*, a low-power, narrow-band FM device that includes the local oscillator, mixer, six i-f limiter stages, afc output, quadrature discriminator, isolated op amp, squelch, scan control, and mute switch. The IC was designed to detect narrow-band FM signals in FM dual-conversion communication equipment. The device has a 20-dB quieting sensitivity of about 8 μV. Signal pickup from the ac power lines is through high-voltage isolating capacitors *C8* and *C9*; coil *L1* tuned by a slug; and *C7*, with *L3* and *L4* acting as a high impedance

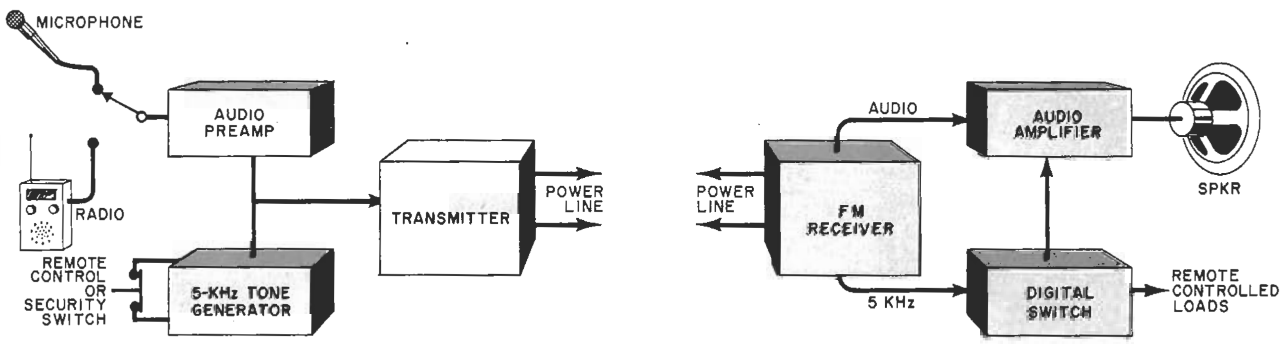


Fig. 1. Basic block diagram of the system with transmitter and receiver plugged into ac line.

PARTS LIST (Fig. 2)

C1,C9,C14,C15,C17,C18—0.1-μF ceramic disc capacitor
C2—0.005-μF ceramic disc capacitor
C3,C6,C8—0.001-μF ceramic disc capacitor
C4—680-pF mica capacitor
C5—1-μF, 16-V electrolytic (radial)
C7—50-pF ceramic disc capacitor
C10—62-pF mica capacitor
C11,C12—0.001-μF, 1-kV disc capacitor
C13—330-μF, 25-V electrolytic (radial)
C16—22-μF, 16-V electrolytic (radial)
D1 through D4—1N4001 diode
D5—1N4148 or 1N914 diode
F1—¼-A fuse
IC1—MC1376 FM modulator
IC2—LM358 dual op amp
IC3—7812 12-V regulator
J1—RCA phono jack
L1,L2—See Fig. 6
L3,L4—12-μH r-f choke
L5—10-μH r-f choke
Q1—MPSA20 transistor
The following are ¼-W, 5% carbon film resistors unless otherwise noted:
R1—1-megohm potentiometer
R2—10 kilohms
R3,R5,R7,R8,R10,R11,R15—100 kilohms
R4—1 megohm
R6,R12,R16—1 kilohm
R9—22 kilohms
R13—56 kilohms
R14—1.8 kilohms
S1—Spst switch
S2—Normally closed pushbutton switch
T1—Transformer (16-V, 100-mA secondary)(Triad F132P, Stancor PPC-2 or similar)
Misc.—Suitable enclosure, fuse holder, mounting hardware, etc.

Note: See Fig. 3 for kit information.

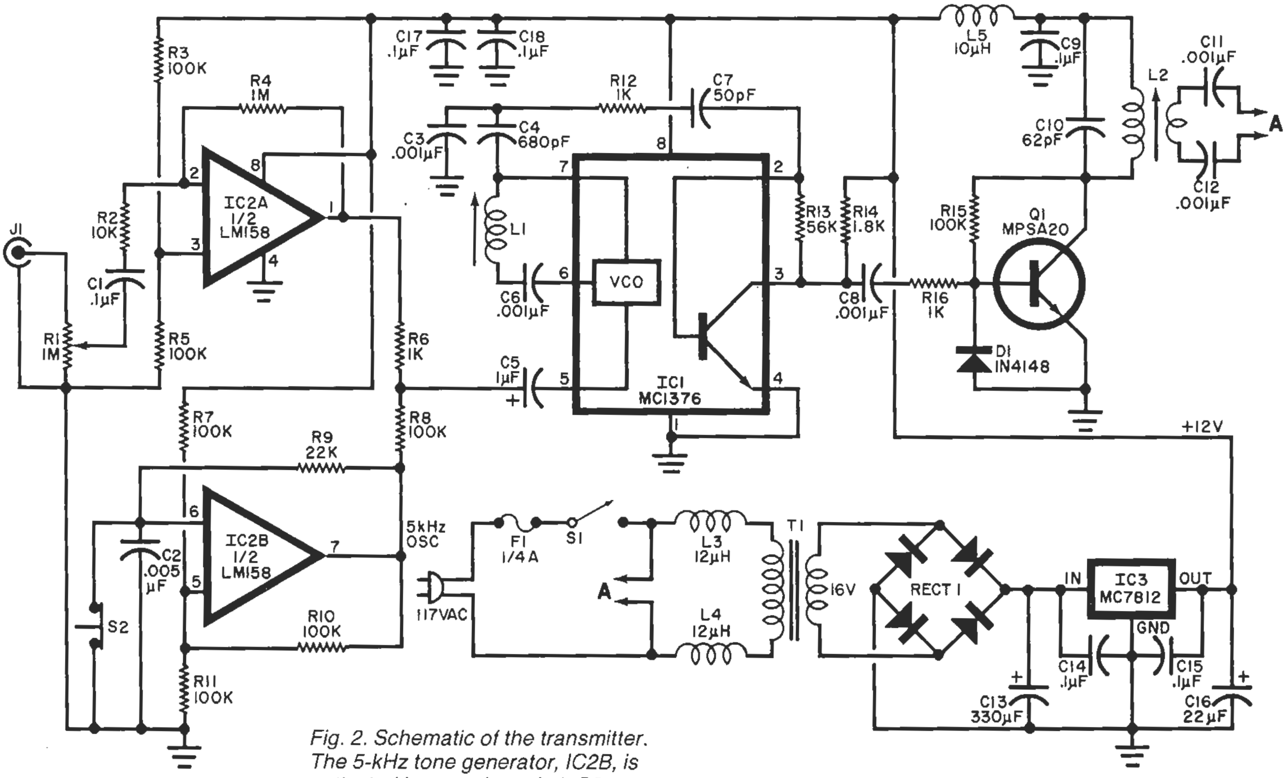


Fig. 2. Schematic of the transmitter. The 5-kHz tone generator, IC2B, is activated by security switch S2.

to keep *T1* from loading the signal.

The local oscillator uses *XTAL1,* a conventional 3.58-MHz color-TV crystal, in conjunction with 5% mica capacitors *C2* and *C3* for stable operation. The mixer output at pin 3 is passed through a 455-kHz ceramic filter *(XTAL2)* to the limiter stages. This ceramic filter narrows the bandpass to ±7.5 kHz to eliminate undesirable audio noise, and simplify i-f tuning.

The signal is then internally connected from the last limiter stage to the quadrature detector that uses *L2* and *C12* as its tank circuit.

The recovered audio is present at pin 10, where any remaining i-f components are removed by filter *R6-C17.* Capacitor *C18* couples the audio to volume control *R20,* whose rotor is connected to audio amplifier *IC3.*

The rotor of *R20* is also connected to pin 16 of *IC1,* the internal mute switch. This signal mutes the audio amplifier when a 5-kHz tone appears in the bandpass. When the tone appears, all that is heard is a short "beep" when the remote switch is opened. Without the mute signal from pin 16, the tone would be heard as long as the remote switch was open.

The op amp within *IC1* has one input internally referenced, with the other input available at pin 12 and the op amp output present at pin 13. In the configuration shown in Fig. 3, the op amp in conjunction with components *R2, R3, R7, C15, C14,* and *C13,* is used for a narrow bandpass filter for the 5-kHz signal. The filter connects to a detector formed by *D1, D2,* and *C20* which drives the squelch input at pin 14. This generates a dc level change at pin 15 that is fed to, and amplified by, *Q2.* A small amount of feedback is inserted by *R12* and *C24* to help square up the rising edge of the level change. SQUELCH potentiometer *R19,* connected between the power and ground, biases the squelch input to any selected level.

The collector of *Q2* drives flip-flop *IC2,* connected as a divide-by-two, resulting in a "push-on, push-off" function. The output of *IC2* at pin 13 drives electronic switch *Q1,* which, when turned on, supplies current via current-limiting resistor *R17* to a load in its emitter circuit. Almost any type of device—a single LED, relay coil, or solid-state relay—can be used as the load. Just make sure that *Q1* can deliver enough current to drive whatever is used. An opto-coupler can be used to drive a high-power device connected to the ac power lines without an isolation transformer.

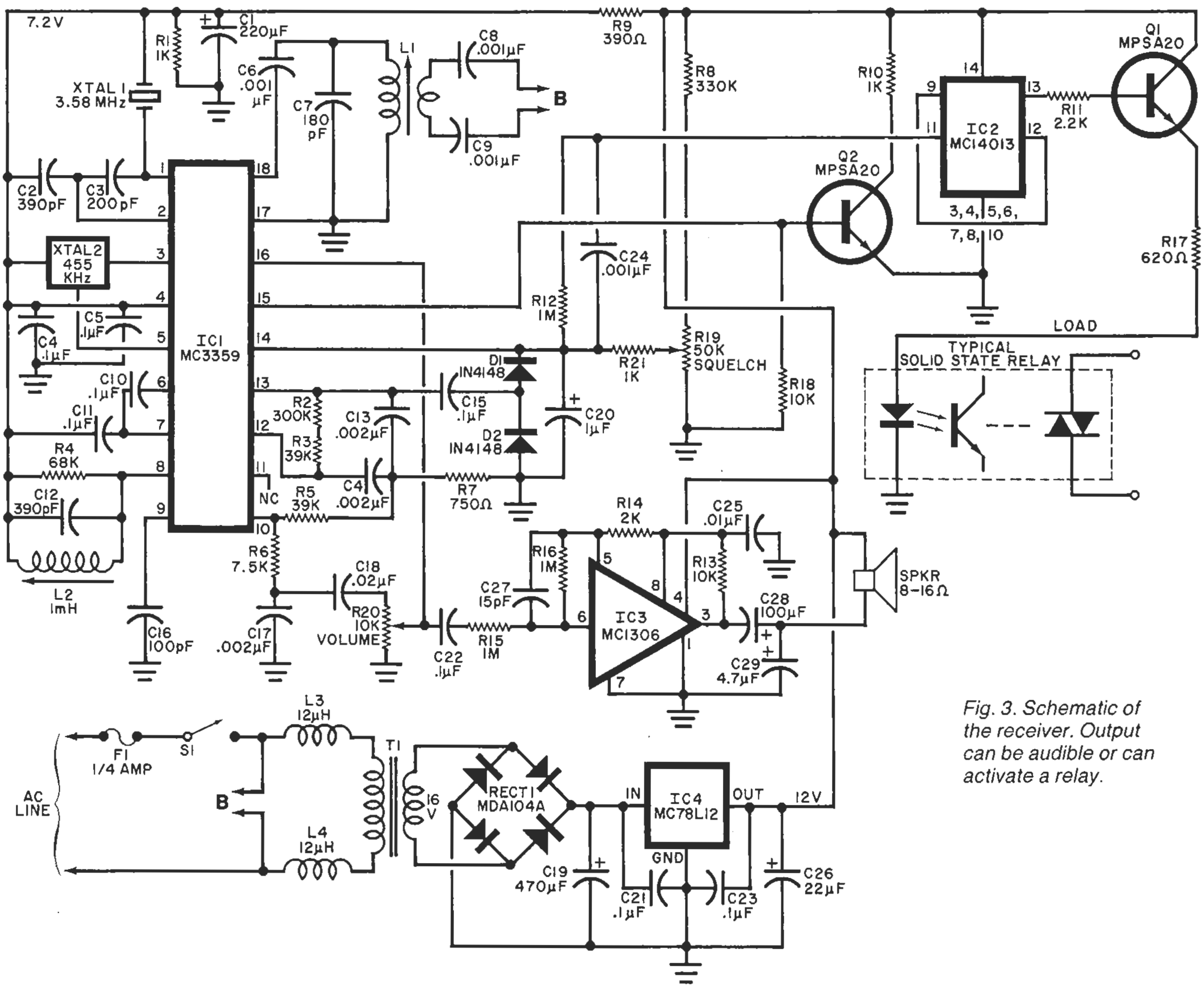


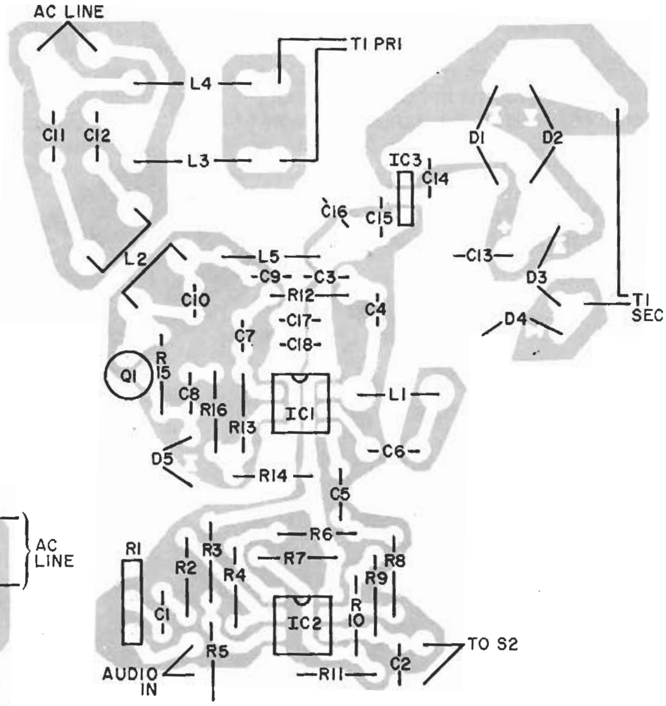
Fig. 3. Schematic of the receiver. Output can be audible or can activate a relay.

PARTS LIST (Fig. 3)

C1—220-µF, 16-V electrolytic (radial)
C2—390-pF mica capacitor
C3—200-pF mica capacitor
C4,C5,C10,C11,C15,C21,C22,C23—0.1-µF ceramic capacitor
C6,C24—0.001-µF disc capacitor
C7—180-pF mica capacitor
C8,C9—0.001-µF, 1-kV disc capacitor
C12—390-pF mica capacitor
C13,C14,C17—0.002-µF disc capacitor
C16—100-pF mica capacitor
C18—0.02-µF disc capacitor
C19—470-µF, 25-V electrolytic
C20—1-µF, 16-V electrolytic (radial)
C25—0.01-µF disc capacitor
C26—22-µF, 16-V electrolytic (radial)
C27—15-pF mica capacitor
C28—100-µF, 16-V electrolytic (radial)
C29—4.7-µF, 16-V electrolytic (radial)
D1,D2—1N4148 diode
F1—¼-A fuse
IC1—MC3359P FM demodulator
IC2—14013 flip-flop
IC3—MC1306 audio amplifier
IC4—78L12 12-V regulator
L1,L2—See Fig. 6
L3,L4—12-µH r-f choke
Q1,Q2—MPSA20 transistor
The following are ¼-W, 5% carbon film resistor unless otherwise noted:
R1,R10,R21—1 kilohm
R2—300 kilohms
R3,R5—39 kilohms
R4—68 kilohms
R6—7.5 kilohms
R7—750 ohms
R8—330 kilohms
R9—390 ohms
R11—2.2 kilohms
R12,R15,R16—1 megohm
R13,R18—10 kilohms
R14—2 kilohms
R17—620 ohms
R19—50-kilohm linear-taper pot.
R20—10-kilohm audio-taper pot.
RECT1—MDA104A
S1—Spst switch
SPKR—8- or 16-ohm loudspeaker
T1—Transformer (16-V, 100-mA secondary)
XTAL1—3.58-MHz color-TV crystal
XTAL2—455-kHz ceramic filter (Kyocera KBF455 or Murata CFU455)
Misc.—Suitable enclosure, fuse holder, mounting hardware, etc.

Note: The following are available from Circuit Specialists, 738 S. Perry Lane, Tempe, AZ 85281: complete transmitter kit TR1 at $36.50; complete receiver kit XR1 at $49.95. Also available separately are the transmitter and receiver pc boards at $4.95 each.

Fig. 4. Exact-size foil pattern (left) and component layout for the transmitter.



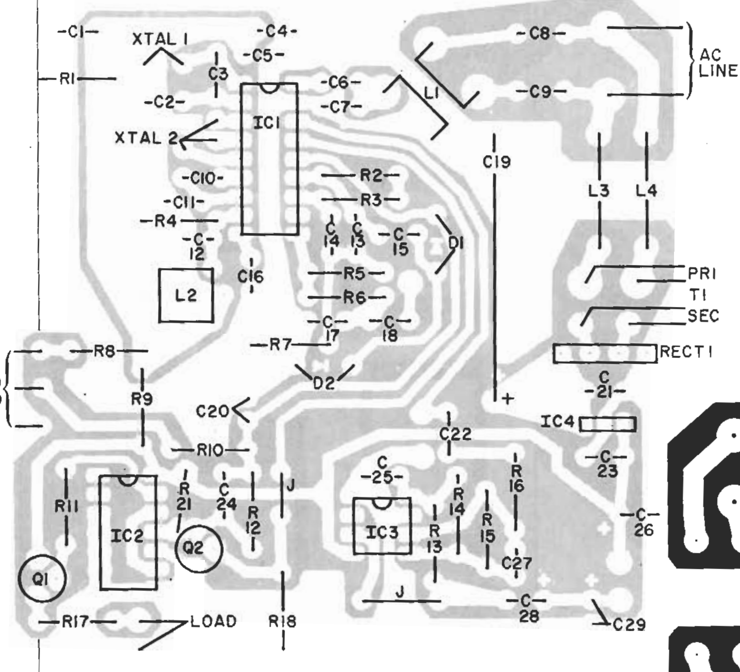
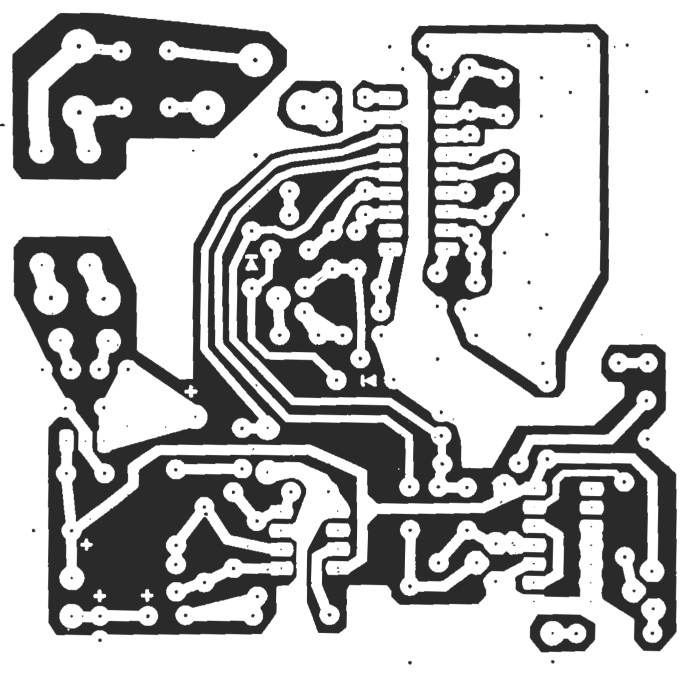


Fig. 5. Exact-size foil pattern (below) and component layout for the receiver.



Audio amplifier *IC3* can provide an output of about ½ W into an 8- or 16-ohm speaker. If more gain is required, reduce the value of series resistor *R15*. However, do not go below 100,000 ohms.

Construction. The system can be constructed using point-to-point wiring or pc boards. A foil pattern and component layout for the transmitter are shown in Fig 4, and for the receiver in Fig 5. Low-profile low-capacitance sockets should be used for both *IC1*s to minimize stray capacitance in the r-f circuits.

As shown in Fig. 6, the transmitter oscillator coil, *L1*, uses a ⅜" diameter plastic form having a #2 ferrite tuning slug. It is closely wound with 36 turns of #28 enameled wire with each end connected to suitable solder pins on the form. The receiver quadrature coil, *L2*, consists of 150 turns of #36 enameled wire tightly wound and layered on a ¼" diameter form about ¾" long. The form should have a #1 powdered-iron tuning slug core (Miller 23AO14-1 or similar). Both line coupling coils (*L2* in the transmitter and *L1* in the receiver) are fabricated in the same way. Wind 80 turns of #28 enameled wire tightly on a ⅜" diameter form having a #2 ferrite tuning slug. Cover the winding with two layers of high-voltage Mylar tape for insulation. Wind 20 turns of #28 enameled wire over the tape to use as the secondary winding. The windings can be held in place with glue or coil dope.

Use shielded cable for the audio lines connected to the remote inputs (microphone or radio). When wiring the shielded cable to the volume control of the receiver, connect the shield to the pc board at only one point. This avoids a ground loop, and a possible source of hum.

The transmitter and receiver can be housed in almost any suitable enclosure. It is only necessary to provide access to pushbutton switch *S2* (or a connector for a remote switch), *J1*, and if desired, volume control *R1*. The receiver requires access to volume control *R20* and the LOAD connectors.

Alignment. Using a dc voltmeter, check for +12 volts at the output of *IC4*, the voltage regulator in the receiver, and approximately 7.2 volts at pin 4 of *IC1*. Using an oscilloscope, check pins 1 and 2 of *IC1* for the presence of 3.58 MHz.

Turn off the power to the receiver, then disconnect the power line from the ac wall receptacle. Remove the connections between *C8* and *C9* and the power line. Connect these capacitors to the output of a signal generator tuned to approximately 3.12 MHz and having a deviation of 3 to 4% or a maximum of 7.5 kHz at 1 mV rms output. With the receiver power turned on, use a scope to observe a 455-kHz sine wave at *IC1*, pin 5. Adjust the slug within *L1* to maximize this signal amplitude. It may be necessary to retune the signal generator slightly, since ceramic filter *XTAL2* determines the 455 kHz. In either case, adjust *L1* and the signal generator to maximize the signal. Once this has been done, move the scope to *IC1*, pin 10 (audio output), and tune *L2* for maximum amplitude of the sine wave. Some residual 455 kHz may still appear at pin 10.

Observe the signal at the *C18* end of VOLUME control *R20* and note that a clean sine wave appears at that point in the circuit.

Remove the test equipment, turn off the receiver, and unplug its power cord from the wall socket. Reconnect *C8* and *C9* to the line cord connectors.

With the receiver turned on and the volume control set to midscale or higher, and with no incoming signal, adjust squelch control *R19* until a hiss (similar to that heard from a conventional FM receiver when it is tuned between stations) is heard.

Connect the transmitter to a wall socket and turn on the power. Apply some type of audio signal (microphone, radio, audio signal generator, etc.) to *J1*, at an amplitude of about 10 mV rms. Adjust the slug within transmitter coil *L1* until the audio source is heard in the receiver. If *L1* cannot be tuned to the receiver, the value of *C4* can correct frequency.

Once a signal is received, adjust the transmitter output coil, *L2*, to maximize the signal at the receiver.

Set the receiver volume control to the desired level, then adjust the level control (*R1*) in the transmitter for the highest level without distortion. After this, adjust the receiver volume for the desired listening level.

To test the 5-kHz tone circuit, connect a LED across the LOAD terminals of the receiver with the anode to *Q1*'s emitter and the cathode to ground. Depress (open) *S2* in the transmitter and listen for the tone at the receiver. The LED should not change state when the switch is depressed. The tone can be blocked by adjusting squelch control *R19* at the receiver, until the audio is just muted. As muting occurs, the logic circuit should change state as indicated by the LED.

If a momentary action of the digital switching is desired (with the output load enabled only when the remote 5-kHz switch is opened and held open, then disabled normally), remove *IC2* and connect pins 11 and 13 on its socket together (bypassing the flip-flop so that *Q2* directly drives *Q1*).

Separate the receiver and transmitter by several rooms, and test for operation of both voice and 5-kHz tone operation. ◇

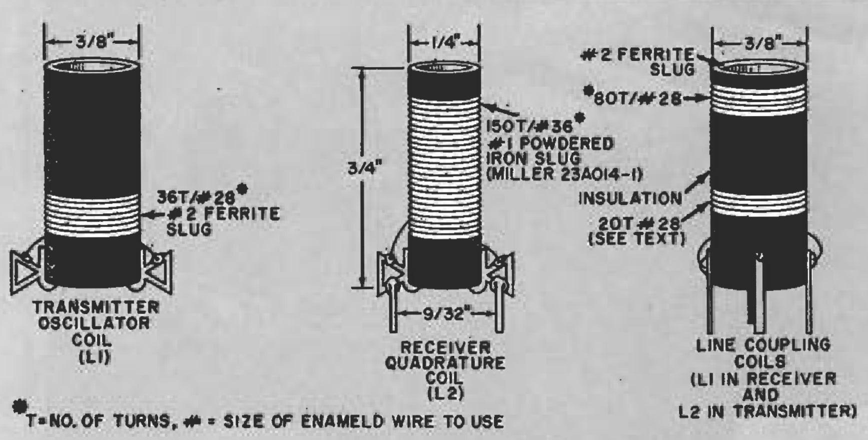


Fig. 6. Follow the instructions in the text and the diagrams above for winding the various coils.