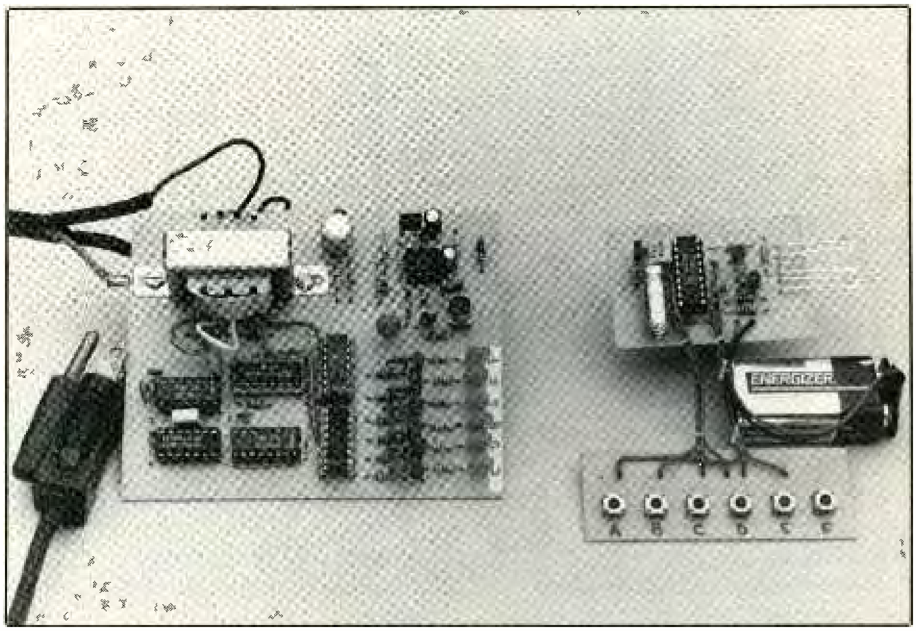
An IR Remote-Control System

(Part 1)

Lets you remotely control up to six lights and appliances from a single hand-held transmitter

By Anthony J. Caristi



Readers who own a remote-controlled TV receiver, VCR or audio system are familiar with the convenience of using wireless infrared remote-control systems. If you've ever wished you could put this type of convenience to work controlling other devices as well, the project to be described is for you. It's a basic IR system that provides on/off control of up to six electrically operated lights and appliances in a single room from a reasonable distance away using a hand-held battery-powered portable transmitter, an ac-powered stationary receiver/decoder and suitable "interface" modules between the latter and devices you wish to control.

The basic system is limited to six channels of control in any given room. However, it can easily be expanded to control up to six devices in as many rooms as you wish from a single transmitter unit. To accomplish this, all you need do is build another receiver/decoder for each room in which you want control, plus whatever interfaces are needed.

In this installment, we focus on operation and construction details for the transmitter and receiver/decoder units. Next month, we will detail how to build a variety of interface devices to control just about any electrically-operated item you wish.

About the Circuit

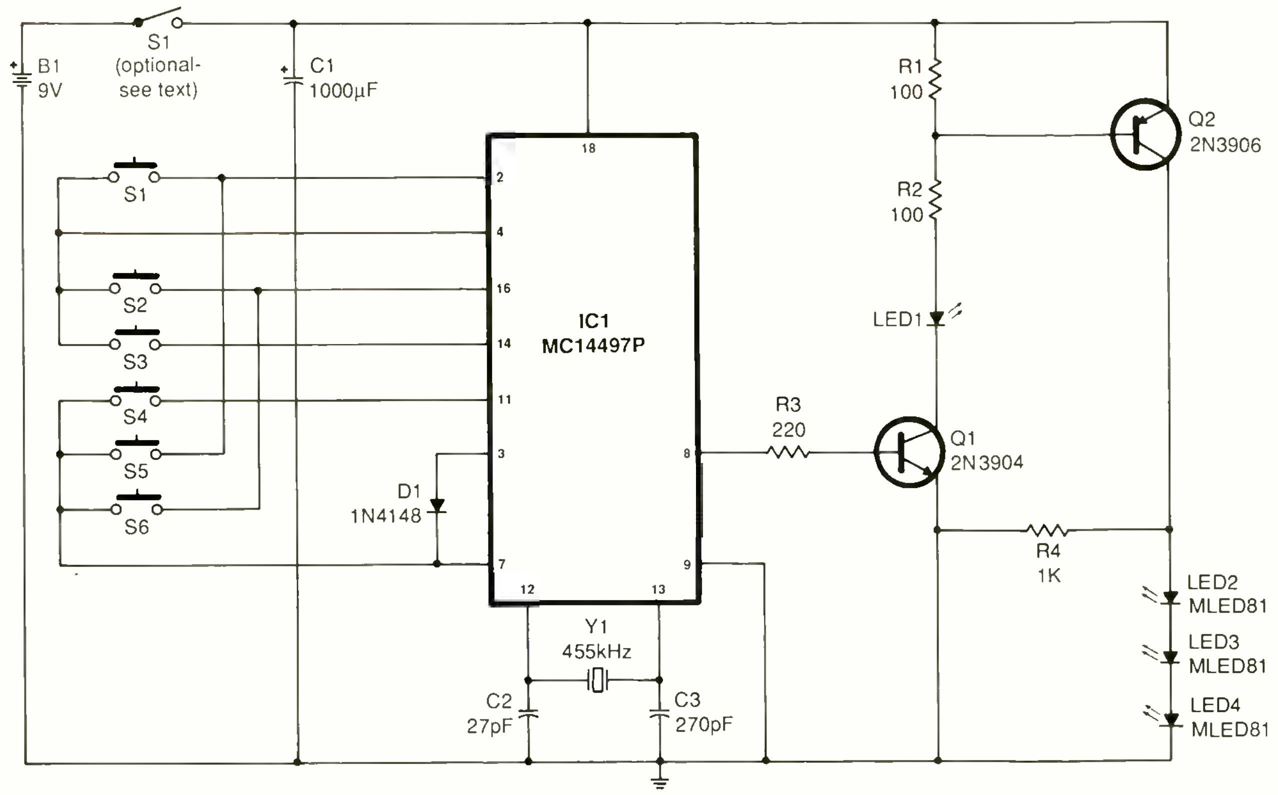
To avoid confusion, we'll discuss operation of the transmitter and receiver/decoder circuits separately.

• *Transmitter.* Shown in Fig. 1 is the complete schematic diagram of the transmitter circuit. This one-chip circuit is powered by an ordinary 9-volt transistor battery. It provides a series of 28.4-kHz infrared energy pulses that are encoded according to which of the six pushbutton switches is pressed at any given moment.

When no transmitting switch is activated, the circuit remains in standby, drawing virtually no current from battery *B1*. When any one of switches *S1* through *S6* is pressed, its closed contacts activate circuitry inside *IC1* that causes the transmitter to generate a group of pulses that are sent through the air by infrared-emitting diodes *LED1*, *LED2* and *LED3*. These pulses are repeated at 90-millisecond intervals, as long as the particular switch is held closed.

Designed specifically as a PCM (pulse code modulation) transmitter, *IC1* is capable of encoding up to 62 channels in accordance with the selection of one row input terminal and one scanner input terminal, which are shorted together by means of a single-pole switch. As mentioned above, in this project only six channels are used, specifically channels 2, 4, 6, 8, 10 and 12. These are identified in this project as channels A through F, respectively.

Integrated circuit *IC1* is capable of operating in either FSK (frequency shift keying) or AM (amplitude mod-



PARTS LIST (Transmitter)

Semiconductors
D1—1N4148 or similar silicon diode
IC1—MC14497P remote-control transmitter
LED1—2-volt, 20-mA red visible light-emitting diode
LED2,LED3,LED4—MLED81 or equivalent infrared light-emitting diode
Q1—2N3904 or similar npn silicon transistor
Q2—2N3906 or similar npn silicon transistor

Capacitors (16-WV or greater)
C1—1,000-µF, 16-volt radial-lead electrolytic
C2—27-pF ceramic disc or film
C3—270-pF ceramic disc or film
Resistors (¼-watt, 10% tolerance)
R1,R2—100 ohms
R3—220 ohms
R4—1,000 ohms
Miscellaneous
B1—9-volt battery
S1 thru S6—Normally open spst push-button switch
S7—Spst toggle or slide switch (optional—see text)
Y1—455-kHz ceramic resonator
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; socket for IC1; 9-volt battery snap connector and holder; suitable enclosure; hookup wire; solder; etc.

Note: See Receiver Parts List for availability of pc board and semiconductors.

Fig. 1. Complete schematic diagram of transmitter circuit.

ulation) mode. Diode *D1*, connected between pins 3 and 7 of the chip, programs the circuit to operate in AM mode. Figure 2 illustrates the output pulse train generated by the circuit when channel 2 (channel A hereafter) is transmitted.

The output pulse train, called a "word," consists of a series of 28.4-kHz bursts that represent a binary code of ones and zeros of the selected channel. The least-significant bit (LSB) follows the second start bit, and the most significant bit (MSB) is last. This format is commonly referred to as "serial" data.

In Fig. 2, the binary word for channel A (channel 2 for the IC) is 000010, which indicates that all bits are zero except one, which has a binary weight of 2. The pulse train contains two additional bursts, called start bits, which precede the binary-coded word. In this pulse train, the position of the amplitude modulation for each bit of the word determines if the bit is a "1" or a "0," as in Fig. 3. A bit with a value of 1 is transmitted with the infrared burst occupying the first half of the allotted space. If the bit is zero, the second half of the space contains the burst.

Although this project uses only six channels, the chip is capable of encoding channel numbers 0 through 62 by transmitting six bits of information, any of which may be a one or zero. Thus, channel 0 would consist of a code word of 000000, channel 1 would consist of code word 000001, and so on up consecutively to channel 61, which would have the code word 111101. Channel 62 is automatically sent when the transmitting key is released, signifying end of transmission (EOT). Channel 63 is not used at all.

Frequency control of the transmitter output is provided by 455-kHz ceramic resonator *Y1*. Frequency dividing circuits inside *IC1* generate the 28.4-kHz IR modulating frequency as well as the timing for the output pulse train.

Transistors *Q1* and *Q2* serve as a driver circuit for the three IR LEDs. Using three LEDs as shown provides almost triple the amount of infrared energy with no increase in battery current drain. As long as visible light-emitting diode *LED1* in the collector circuit of *Q1* lights when a transmitter button is pressed, the battery has sufficient energy to power the circuit.

• *Receiver/Decoder*. Shown in Fig. 4 in three sections is the complete schematic diagram of the receiver/decoder circuitry. Integrated circuit *IC7* detects and amplifies the infrared pulses generated by the transmitter and detected by IR detector diode *D1*. The six remaining chips in this circuit decode the transmitted pulse train, and emitter-follower transistor *Q2* through *Q7* output stages provide six channels. Since this project contains just six active channels, only three bits of the transmitted word are needed for full control.

The specified chip used for *IC7* has been specifically designed to serve as an infrared detector/amplifier. Infrared energy striking photodetector *D1* is coupled to the pin 7 input of *IC7*. The 28.4-kHz IR bursts are converted to electrical pulses by *D1*. The resulting electrical pulses are amplified, and the amplitude-modulated waveform is detected to produce the waveform envelope that contains the binary-coded information of the transmitted pulse train. Wave-shaping circuitry inside *IC7* provides a clean, solid waveform at the pin 1 output. This is inverted by *Q1* and fed to the decoder circuit for further processing.

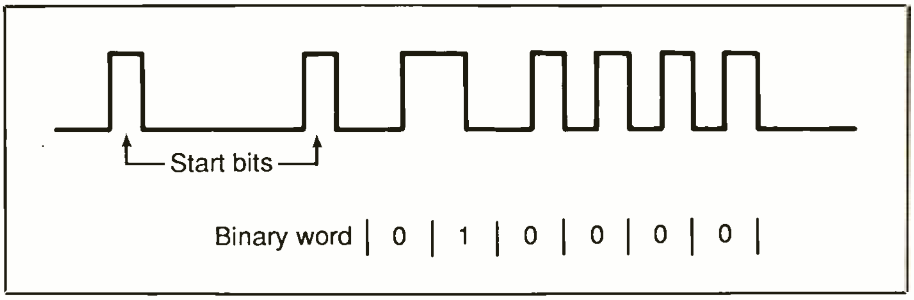


Fig. 2. Binary word for channel A is 000010, which indicates that all bits are 0 except one, which has a binary weight of 2.

As shown in Fig. 2, the recovered transmitted pulse train (channel A is illustrated) contains six bits of information that must be decoded to determine which of the six possible channels, A through F, has been transmitted. A truth table illustrating the six possible code combinations is shown in Fig. 5.

Since each individual bit of the coded word occurs in sequence, the information presented by the pulse train is in serial data form. To recover and store this information, serial-to-parallel converter *IC4* is used. This eight-bit shift register IC is capable of converting data from serial form to parallel form and latching it in its output stages. Operation of the decoder circuit is best understood by referring to timing diagram Fig. 6, which illustrates what the waveforms should look like at various points in the circuit.

To synchronize the decoder timing circuits with the transmitter, ceramic resonator *Y1* operates at the same 455-kHz frequency as the resonator in the transmitter. Gate *IC1C* is wired to operate as a simple inverter and is biased into its unstable linear region by means of *R5*. The ceramic resonator, connected between output pin 10 and input pins 8 and 9 of the gate, causes the circuit to oscillate at the resonant frequency of *Y1*. Gate *IC1D*, also wired as an inverter, is used as a buffer for the oscillator.

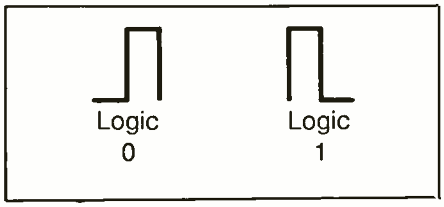


Fig. 3. Position of amplitude modulation for each bit of the word determines if bit is a 1 or a 0.

Gates *IC1A* and *IC1C* are configured to form a bistable multivibrator, or common flip-flop. This circuit has two stable states that depend upon the logic levels fed to the inputs at pins 1 and 6. This circuit is a latch that controls operation of counter divider *IC3* and shift register *IC4*.

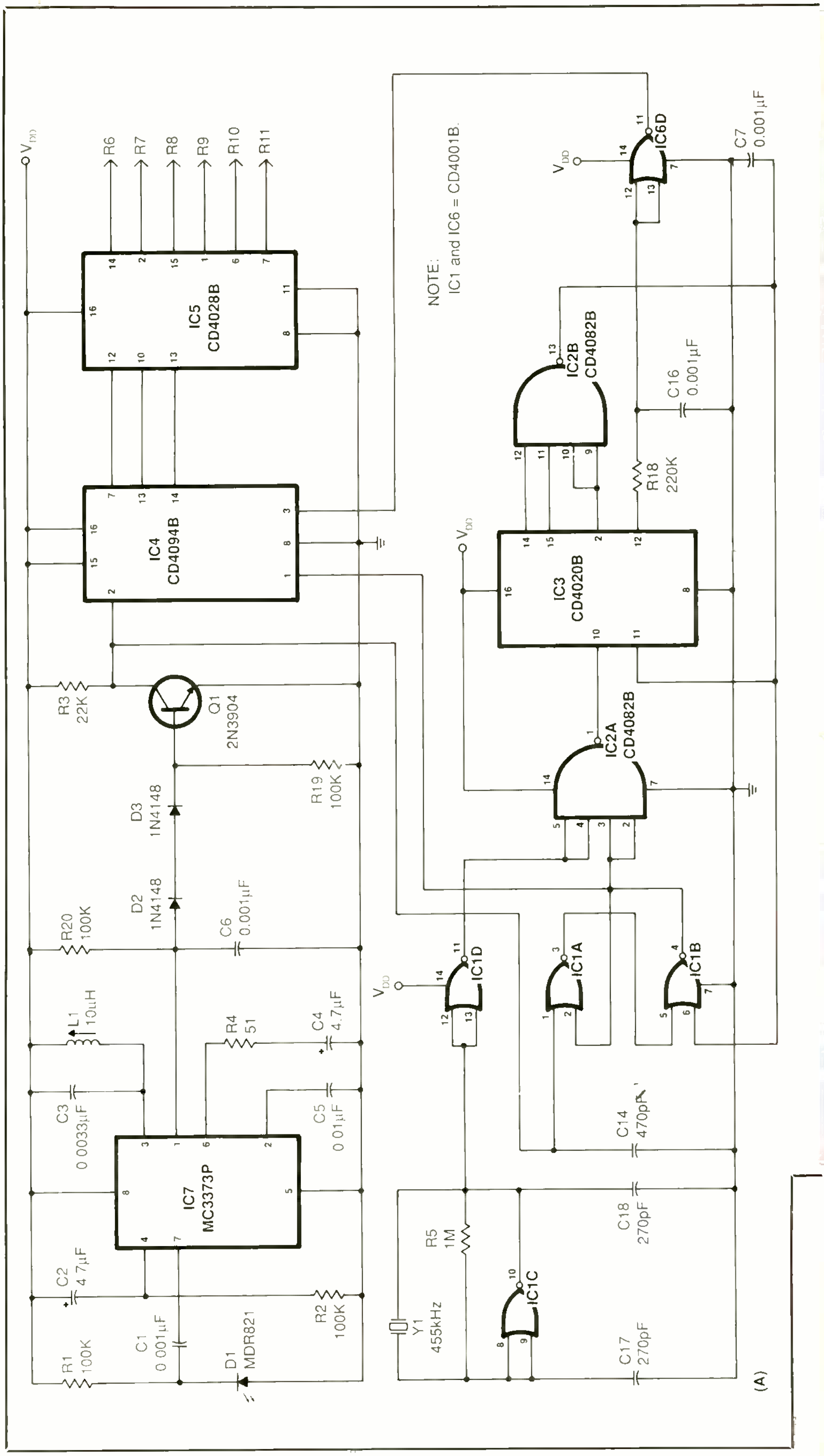
When the first pulse of the received transmission reaches input pin 1 of *IC1A*, output pin 3 of this gate assumes a logic 0 level and pin 4 goes to logic 1. The output at pin 4 of *IC1B* enables AND gate *IC2A* and allows the oscillator waveform to be impressed upon the clock input of *IC3* at pin 10. At the same time, shift register *IC4* is enabled by the logic 1 level that is fed to its strobe input at pin 1.

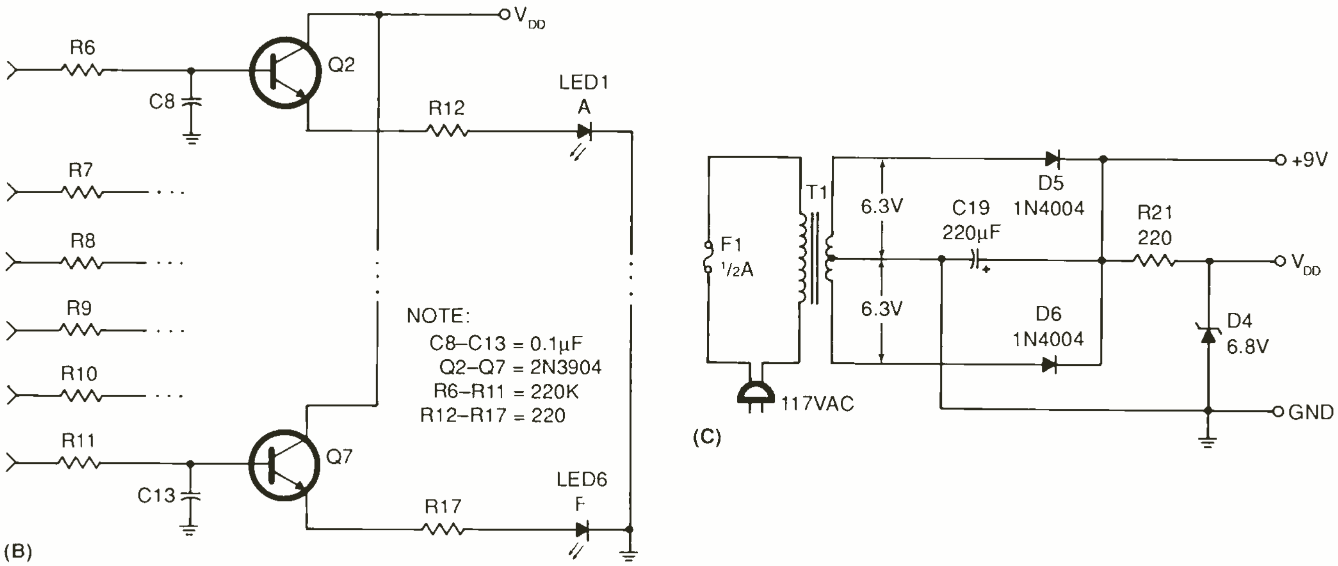
Integrated circuit *IC3* is a 14-stage binary ripple counter. This chip serves two functions in this circuit. The first part of the chip, consisting of nine binary stages, is used as a divide-by-512 circuit that provides the correct clock rate for the shift register. This clocking signal appears at output pin 12. The second part of the chip, along with AND gate *IC2B*, is used as a divide-by-11 counter that permits the shift register to be clocked just 11 times during each discrete transmission. This will cause the three desired bits of the serial transmission to be stored in the outputs of *IC4* at locations represented by pins 7, 13 and 14.

The detected signal from *Q1* goes to the serial input at pin 2 of *IC4*. At the onset of the first start pulse, when the latch circuit is set to the active state, the shift register is clocked synchronously with the transmitter. Hence, each pulse of the transmitted word enters *IC4* and is shifted down the line like a bucket brigade. The clock pulses are delayed by an RC network composed of *R18* and *C16* to ensure that the data is present at the serial input of *IC4* before the shift takes place.

The output circuits of *IC4* assume the logic levels of the input pulses as they enter the chip and shift down the line. When the count of 11 is complete, the reset pulse generated at pin 13 of *IC2B* sets the latch back to the idle state, stops the clock inputs of *IC3* and *IC4*, resets *IC3* to a count of zero, and latches the outputs of *IC4* so that the transmitted word is stored in its output registers. The circuit remains in this condition until the next group of pulses is received by *IC7*.

The desired six-bit binary information, illustrated in Fig. 6, is stored in the output circuits of *IC4* at pins 5, 6, 7, 14, 13 and 12, with the least-signif-





PARTS LIST (Receiver)

Semiconductors
D1—MRD821 or equivalent infrared photodetector (Motorola)
D2,D3—1N4148 or similar silicon diode
D4—1N5235B or similar 6.8-volt zener diode
D5,D6—1N4004 or similar silicon rectifier diode
IC1,IC6—CD4001B quad 2-input NAND gate
IC2—CD4082B dual 4-input AND gate
IC3—CD4020B 14-stage binary counter
IC4—CD4094B 8 bit shift register
IC5—CD4028B BCD-to-decimal decoder
IC7—MC3373P infrared receiver/amplifier
Q1 thru Q7—2N3904 or similar npn silicon transistor

Capacitors (16-WV minimum)
C1,C6,C7,C16—0.001-μF ceramic disc
C2,C4—4.7-μF, 16-volt radial-lead electrolytic
C3—0.0033-μF Mylar or metal-film
C5—0.01-μF ceramic disc
C8 thru C13—0.1-μF ceramic disc
C14—470-pF ceramic disc
C15—100-μF, 16-volt radial-lead electrolytic
C17,C18—270-pF ceramic disc
C19—220-μF, 16-volt radial-lead electrolytic

Resistors (¼-watt, 10% tolerance)
R1,R2,R19,R20—100,000 ohms
R3—22,000 ohms
R4—51 ohms
R5—1 megohm
R6 thru R11,R18—220,000 ohms
R12 thru R17,R21—220 ohms

Miscellaneous
F1—½-ampere slow-blow fuse
L1—10-μH inductor (Toko No. 126LNS-T1032Z)
T1—12.6-volt C.T. power transformer (Radio Shack Cat. No. 273- 1365 or similar)
Y1—455-kHz ceramic resonator
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; sockets for all DIP ICs; three-conductor ac line cord with plug; fuse holder; suitable enclosure; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Transmitter pc board, $7.50; receiver pc board, $15.50; MC3373P, $3.00; MC14497P, $15.00; CD4001B; $1.25; CD4082B, $1.25; CD4020B, $2.00; CD4094B; $2.25; CD4028B; $1.75; three MLED81s, $6.50; MRD821, $4.00; 1N5235B, $1.00; L1, $4.00; Y1, $3.75 each. Add $2.00 P&H. New Jersey residents, please add state sales tax.

Fig. 4. Complete schematic diagram of receiver/decoder circuit, shown here in three sections.

icant bit stored at pin 12. The information contained at pins 13, 14 and 7 of *IC4* is the only data required for this six-channel decoder. Note that the bits of data (see Fig. 6) stored at these three terminals represent a binary number between 1 and 6.

BCD-to-decimal decoder *IC5* accepts four bits of binary-coded-decimal data and provides a single output that represents the decimal equivalent of the data fed to its input. Since the data to be decoded is contained in just three bits, the most-significant-bit input at pin 11 of *IC5* is grounded, and the data from *IC4* is fed to the three remaining inputs at pins 7, 14 and 13. This permits *IC5* to decode the information stored in *IC4* and to provide a logic 1 output at the output pin (14, 2, 15, 1, 6 or 7) of the transmitted channel.

The decoded output at one of the pins of *IC5* remains at logic 1 level for as long as the transmitting switch is held closed. When the switch is opened, the transmitter generates the EOT (end-of-transmission) code (channel 62), and the logic level at the decoded output pin returns to logic 0. In this manner, the decoded output is automatically returned to a logic 0 level at the end of each transmission.

The emitter-follower stages *Q2* through *Q7* in Fig. 4(B) are driven by the outputs of *IC5*. RC filtering ensures that no transistor will be driven into conduction during the time that the circuit is shifting data. When any transmitter switch is closed, the appropriate transistor stage is driven into conduction and turns on the LED that identifies the selected channel. The output of each emitter-follower stage can be used to drive a variety of circuits to perform the desired remote action.

Power for the receiver/decoder circuit is provided by the 117-volt ac line using the dc power supply whose circuitry is shown schematically in Fig. 4(C). The 117 volts ac from the power line is converted to 12.6 volts ac by power transformer *T1*. This reduced ac voltage is rectified to pulsating dc by full-wave rectifier *D5/D6*. The pulsating dc is then filtered to pure dc by capacitor *C19*.

Two dc output voltages are available from the power supply: an unregulated +9 volts and a regulated (by zener diode *D4*) +6.8 volts V_{DD}. The +9-volt output will be used by the interface circuits, which will be covered next month. Since the receiver/decoder circuit should never be shut off, there is no power switch in the primary circuit of *T1*.

Construction

Both transmitter and receiver are best wired on separate single-sided printed-circuit boards. You can fabricate your own pc boards using the actual-size etching-and-drilling guides shown in Fig. 7 (transmitter) and Fig. 8 (receiver/decoder), or you can purchase ready-to-wire boards from the source given in the Note at the end of the Parts List. Alternatively, you can wire the transmitter circuit on perforated board that has holes on 0.1-inch centers using suitable soldering hardware. Whichever way you go, though, it is a good idea to use sockets for all ICs. However, use only pc-board construction for the receiver/decoder to assure that its very-high-gain amplifier operates with maximum stability.

Begin building this project by wiring the simple transmitter. Place the transmitter's pc board in front of you in the orientation shown in Fig. 9 and install and solder into place the IC socket. Do ***not*** install the IC itself in the socket until after you have checked out the wired circuit.

Install and solder into place the remaining on-board components. Make sure that electrolytic capacitor *C1* and the diode and LEDs are properly oriented before soldering their leads into place. Then, making certain that the 2N3904 npn and 3906 pnp transistors are installed in the Q1 and Q2 locations, respectively, and that both transistors are properly based, solder their leads into place. Install and solder into place resonator *Y1*, using heat judiciously.

Strip ¼ inch of insulation from both ends of 14 4-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. Then plug

CHANNEL	BINARY WORD					
	LSB					MSB
A	0	1	0	0	0	0
B	0	0	1	0	0	0
C	0	1	1	0	0	0
D	0	0	0	1	0	0
E	0	1	0	1	0	0
F	0	0	1	1	0	0

Fig. 5. Truth table illustrates that project has six possible channel code combinations.

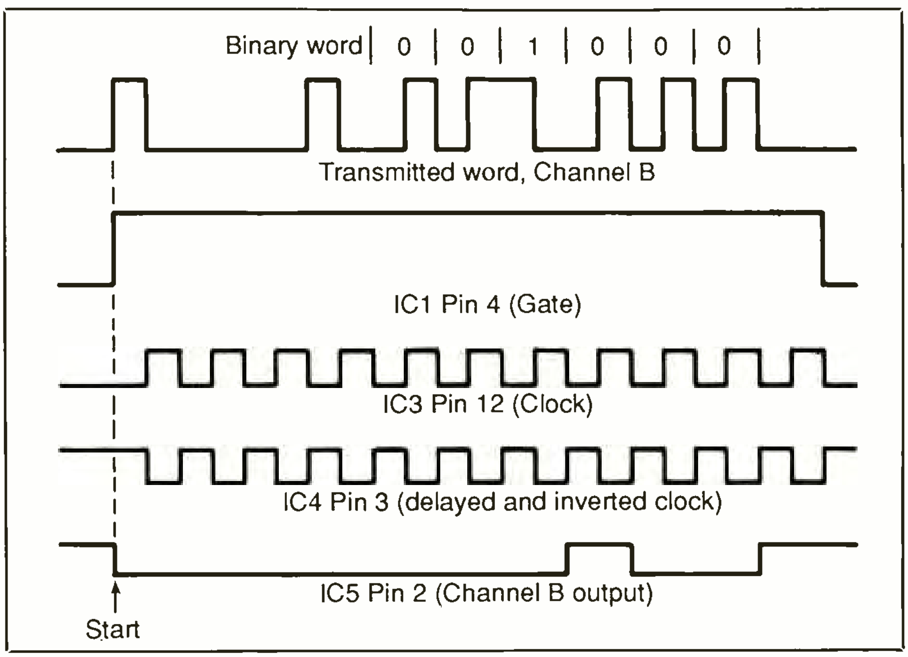


Fig. 6. Decoder circuit timing diagram.

one end of these wires into all remaining unoccupied holes in the board, except those labeled B1, and solder them into place.

You have the option of incorporating into your transmitter circuit power switch *S1* or leaving it out and wiring the positive (+) terminal of the battery directly to the B1+ pad. Current drain of the circuit is very low (about 10 microamperes) in standby, but if you anticipate that there will be extended periods lasting weeks at a time during which the transmitter will not be used, installation of *S1* is recommended.

Plug the black-insulated negative (−) lead of the 9-volt battery snap connector into the B1− hole and solder it into place. If you opted to omit *S1* plug the red-insulated positive (+) lead of the connector into the B1+ hole and solder it into place. Otherwise, prepare another 4-inch wire as above, plug one end of it into the B1+ hole and solder it into place. Then crimp and solder the free end of this wire to one lug of *S1* and the red-insulated lead of the battery connector to the other lug of the switch.

It is important that you wire the three IR LEDs into the circuit in proper polarity. If even one of these components is wired backward, none of the LEDs will operate. You will not be able to visually determine if these LEDs are operating. If necessary, use an ohmmeter to ascertain the polarity of each. (The polarity can be identified in a similar manner as with any semiconductor diode.)

Once you have determined the polarity of each IR LED, clip the cathode (K) leads of all three to a length of ½ inch. Form a small hook in the remaining cathode-lead stub in each case. Slide a 1-inch length of small-diameter heat-shrinkable or insulating plastic tubing over the free ends of all LED wires coming from the circuit-board assembly. Then crimp and solder the free ends of the wires coming from the LED2, LED3 and LED4 K holes individually to the cathode leads. Trim the other leads of the LEDs to ½ inch and crimp and solder them to the end of the remaining LED wires. Slide the tubing up over the soldered connections until it is flush with the bottoms of the device cases and shrink into place.

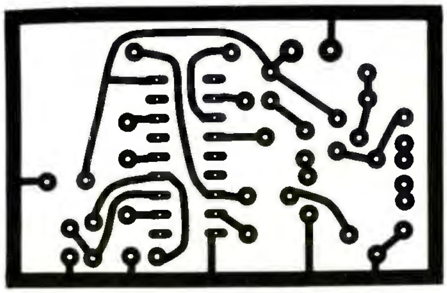


Fig. 7. Actual-size etching-and-drilling guide for transmitter pc board.

Wire visible light-emitting diode *LED1* to the ends of the LED1 wires coming from the circuit-board assembly exactly as you did for the IR LEDs, including using insulating tubing on its leads.

Referring to Fig. 1 and Fig. 9, wire the six pushbutton switches into the circuit, using additional hookup wire as needed to complete the wiring.

House the transmitter circuit board and battery in a plastic box that is small enough to hold comfortably in one hand and allows you easy access to the six pushbutton switches and clear line of sight to *LED1* that will mount on its top surface.

Machine the box as needed. You do not have to drill mounting holes for the circuit-board assembly, which will be held in place with a layer of thick double-sided foam tape. However, you should plan on using a clip-type holder for the battery, which requires a single mounting hole. Remaining machining includes drilling mounting holes for the buttons of the pushbutton switches (and a rectangular slot and small hardware holes for the power switch if you use it) and four holes for the visible and IR LEDs.

Drill the mounting holes for the three IR LEDs in the end panel of the box that will be facing away from you when holding the project in your hand. The hole pattern should have

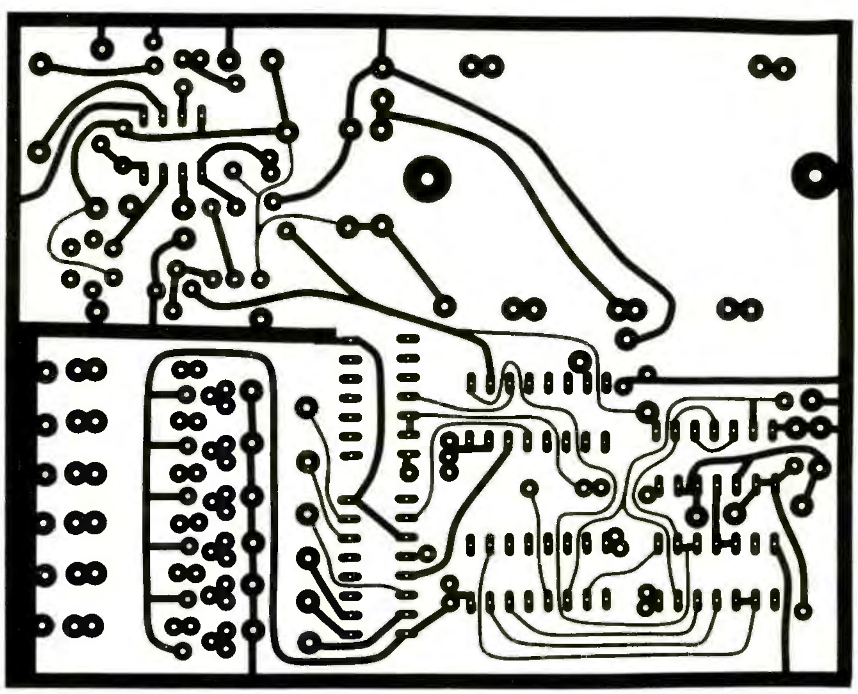


Fig. 8. Actual-size etching-and-drilling guide for receiver/decoder pc board.

the three LEDs mounted so that their emitted energy points in the same direction for all three to assure that your transmitter has the greatest possible range. Orient the LEDs so that they are parallel and as close as possible to each other.

Carefully check all wiring. Make sure each component is installed in its correct location and is properly oriented. Flip over the circuit-board assembly and check your soldering. Solder any missed connections, reflow the solder on any suspicious connection and remove any solder bridges with desoldering braid or a vacuum-type desoldering tool.

Mount the battery clip and circuit-board assembly in place. Then carefully plug the cases of the IR LEDs into their respective holes and, if necessary, secure each in place with a small drop of fast-setting clear epoxy cement or a daub of silicone adhesive from the *inside* of the box so as not to obstruct the emitted IR energy when the transmitter is keyed.

Mount the switch buttons in their respective holes in the top panel of the box, using the hardware provided with them. Then mount the visible LED in its hole in the same manner used to mount the IR LEDs. Save installation of the IC in the socket until after you have performed a preliminary voltage check and are certain of your wiring and soldering.

Since the receiver will be set in a permanent location, from which it will control some appliance or device, it is powered from the 117-volt ac line using a small 12.6 volt transformer. It is important that you use a three-conductor line cord to feed the primary of the transformer. The grounded line cord conductor must be tied to both circuit ground and the frame of the transformer to minimize any stray interference from other devices in the area.

Mount the photodetector directly on the circuit-board assembly facing the outside of the enclosure used to house the receiver. Because it is the most sensitive part of the circuit and is sensitive to unwanted electrical pickup, be sure keep the detector close to the board. You will note that one side of the detector has the "lens" that gathers and focuses the infrared energy. This side should be directed towards the planned location of the transmitter.

Inductor *L1* has five pins, only two of which are active. They are the two end pins on the side that has three pins in line. You can cut off the center pin prior to installing the inductor on the circuit board.

As you can see, the receiver/decoder board requires seven jumper wires, as shown in Fig. 10. Use insulated hookup wire to make these jumper connections to make certain that none of the jumpers short to another. Make each wire only as long as needed to permit routing between the terminating holes in the board.

If you have decided to delete one or more transmitting channels, you can also omit the corresponding driver circuits and LEDs driven by *IC5*.

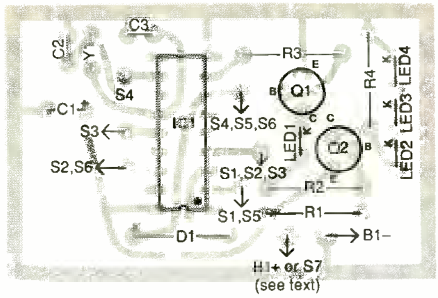


Fig. 9. Wiring guide for transmitter pc board.

Checkout & Use

Check out the transmitter first, since it will be necessary to have it operating to be able to check out the receiver. Be sure to use a known fresh 9-volt battery to power the circuit. You can use an ohmmeter to check the transmitting switches first. If you have a general-purpose triggered-sweep oscilloscope, examine the output pulse waveform and compare it with that of Fig. 1.

With *IC1* not installed in its socket

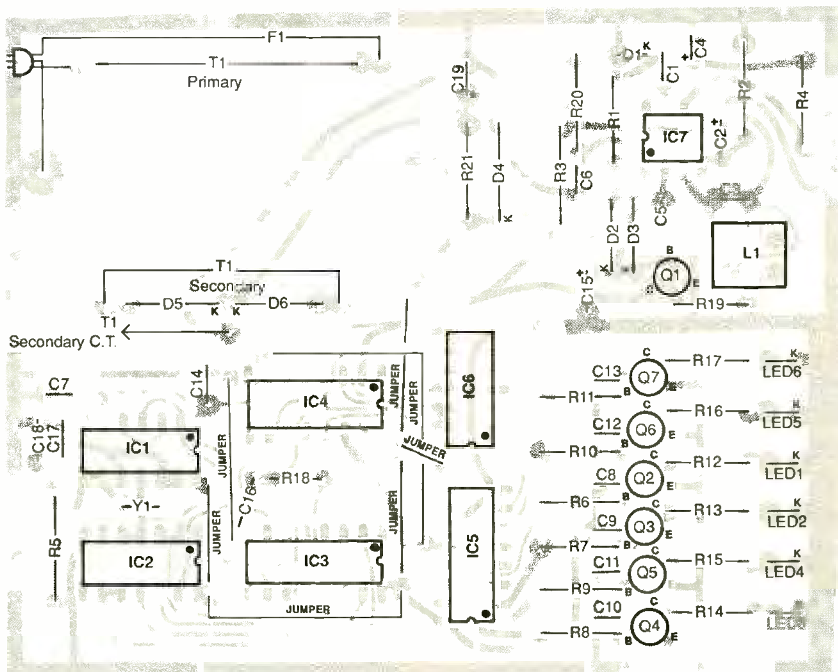


Fig. 10. Wiring guide for receiver/decoder pc board.

and no battery connected to the circuit, verify the wiring to the transmitting switches by connecting an ohmmeter to the appropriate pins of the *IC1* socket and pressing each transmitting pushbutton switch in turn. Ascertain that the proper pins of the socket are shorted together as indicated in accordance with the Fig. 1 transmitter schematic diagram.

If you have determined that the transmitting switches are properly wired install *IC1* in its socket, orienting it as shown in Fig. 1 and making sure that no pins overhang the socket or fold under between IC and socket.

Connect a fresh 9-volt battery to the circuit via the snap connector and press any transmitting switches. Light-emitting diode *LED1* should flash brightly at a rapid rate of about 10 times per second.

Although you will not be able to see the infrared flashes, an oscilloscope probe connected between the collector of *Q2* and circuit ground will display the encoded pulse train that is being transmitted. Transmit on channels A and B (one at a time) to verify that the transmitted pulse train displayed on the screen of the oscilloscope agrees with the pulse waveforms shown in Fig. 2 and Fig. 3.

Press each transmitting switch in turn and verify that *LED1* flashes at a rapid rate as long as the pushbutton of the switch is pressed. This completes transmitter checkout.

If you do not obtain the correct response as when checking out the transmitter, you must troubleshoot the circuit before proceeding to receiver checkout. To do this, first inspect the circuit-board assembly to ascertain that all components are installed in the correct locations and that they are properly oriented, using Fig. 9 to guide you. Also, inspect the board for open and short circuits, and bad solder joints. And do not forget to verify the polarity of the connections to the battery. If all else fails, replace the battery with a fresh one. Finally, check *IC1* to make sure it is oriented properly and is firmly seated in its socket.

Before installing the integrated circuits in the sockets on the receiver circuit-board assembly, apply power to the primary side of the transformer and check with ac voltmeter or multimeter set to the ac volts function that the power supply is operating properly. Be careful not to touch any part of the primary circuit of the transformer, where potentially lethal 117-volt ac line power appears.

Next, use a dc voltmeter or a multimeter set to the dc volts function that has an input resistance of 1 megohm or more to measure the voltage across *D4*. You should obtain a reading of about 6.8 volts. If you do not obtain the correct voltage reading, check the orientations of *D4*, *D5* and *D6*, and double check to make sure that no short circuit exists between the cathode of *D4* and circuit ground. Also, check the orientations of electrolytic capacitors *C15* and *C19*. Do *not* proceed until you are satisfied that the power supply is performing properly.

When you are satisfied that the power supply is operating properly, disconnect the line cord from the 117-volt ac source and allow time for the electrolytic capacitors to discharge. Then install the integrated circuits in their respective sockets. Make certain that you orient each IC properly and that no pins overhang the sockets or fold under between ICs and sockets. Seat each IC securely in its socket.

Place the transmitter near the receiver (it will not be necessary to have the transmitting LEDs directly in line with the photodetector) and press one of the transmitter's buttons. The appropriate LED in the receiver should turn on and exhibit a slight flicker for as long as the pushbutton is held down.

At this time, you can adjust *L1* for maximum receiver sensitivity. This adjustment is not critical, however. The proper way to adjust this coil is to use an oscilloscope to monitor the 28.4-kHz pulses at pin 3 of *IC7* as you adjust *L1* for maximum waveform amplitude. When making this adjustment, orient the transmitter and receiver so that the received signal is relatively weak. One way to do this is to partially block the infrared beam with an opaque object. Another is to separate the two units physically, though this way entails having an assistant operate the transmitter as you make the coil adjustment

Try each transmitter pushbutton to ascertain that the respective LED in the receiver turns on. If each transmitting pushbutton activates its corresponding receiver LED, try operating the transmitter from across the room, pointing the infrared LEDs towards the photodetector. You should be able to achieve a response at a distance similar to that obtained from your TV or VCR remote-control.

If you are not able to obtain the proper responses, power down the receiver and troubleshoot it—assuming, of course, that the transmitter is operating properly. To do this, use a triggered-sweep oscilloscope to examine the waveforms in the receiver.

Examine the waveform at the collector of *Q1* in the receiver as channel A pushbutton is activated. Normal indication here is a pulse train similar to that shown in Fig. 2. Then check pin 11 of *IC1* to ascertain that the oscillator is operating. The signal at this point should be a 455-kHz square wave. Next, examine the clock signal at pin 12 of *IC3*, which should be a train consisting of 11 square pulses, as in Fig. 3.

Check the outputs of *IC4* at pins 7, 14 and 13 to verify that the logic levels at these terminals agree with the truth table of Fig. 3 as each channel is transmitted in turn. Note that the logic levels are verified only during the time between transmissions, where the data is latched into the output registers of the chip.

Ascertain that the outputs of *IC5* at pins 14, 2, 15, 1, 6 and 7 assume a logic 1 condition when the appropriate transmitter pushbutton is pressed. This will, in turn, forward bias the corresponding emitter-follower transistor and its LED.

When you are able to turn on each LED in response to pressing its corresponding transmitter pushbutton, checkout is done.

Coming Next Month

Next month, we will show how this infrared remote-control system can be used to operate just about any electrical device that you may desire. Our coverage will include a variety of circuits that interface the project with a variety of electrical devices and appliances ranging from low-power on up to high-power devices.