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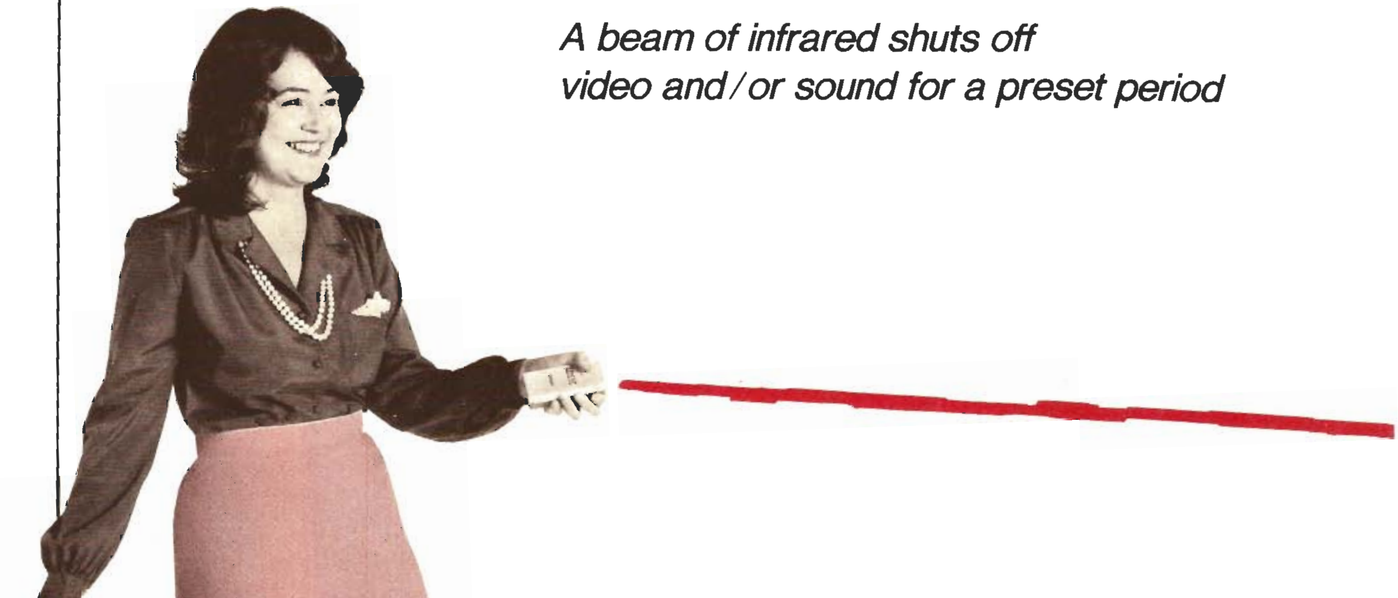
WIRELESS AD*ZAP TURNS OFF TV COMMERCIALS

A beam of infrared shuts off video and/or sound for a preset period



HAS a television commercial ever made you feel like shooting your receiver? Now you can "blow away" commercials without destroying the TV set. The AD*ZAP TV Commercial Killer presented here employs "bullets" of infrared light to kill the sound and/or picture during an annoying advertisement. The project is relatively simple and can be connected to virtually any television receiver with only minor work.

When assaulted by an undesirable commercial, the viewer points a remote transmitter (which can be assembled into a plastic toy pistol or a standard case) at a small photoelectric receiver attached to the TV set and momentarily closes a switch. The transmitter thereupon emits an infrared signal that silences the sound and causes the receiver to start its selectable timing interval (30 or 60 seconds). If a second infrared signal is received during the timing interval, the TV picture tube is darkened. At the end of the interval, normal television-receiver operation is automatically restored. Receipt of a third infrared pulse before the timing interval ends will restore normal TV operation. Since the TV receiver remains powered and in sync during the timing interval, the picture returns without rolling or tearing.

The transmitter is a small, self-contained, battery-powered wireless unit. Its companion receiver is housed in a small metallic enclosure that is generally positioned atop the TV set. The AD*ZAP receiver is powered by a small wall-mount transformer and is connected to the rear panel of the television receiver by means of a multi-conductor cable of convenient length. Disconnecting the AD*ZAP receiver from the TV set leaves the TV fully ready for normal operation.

About the Circuit. The schematic diagrams of two versions of the AD*ZAP transmitter are shown in Fig. 1. At A is the transmitter circuit designed for installation in a plastic enclosure approximately the size of a pack of cigarettes.

BY DIETRICH SEAMAN

The circuit shown at B is almost identical and is designed to be mounted in a plastic-body six-shooter similar to the type used in some electronic target-practice games.

When switch *S1* is closed, battery power is applied to the astable multivibrator comprising 555 timer *IC1* and associated components. The multivibrator begins to oscillate and, when the output pulse causes pin 3 of *IC1* to be low (about 25% of the time), high-level current pulses flow through infrared emitter *LED1*. The LED radiates bursts of infrared at a rate of approximately 3.2 kHz. The exact pulse rate is determined by the setting of trimmer potentiometer *R2*. Capacitor *C3* ensures that enough current is available to the circuit during the time that *LED1* is conducting.

The schematic diagram of the AD•ZAP receiver is shown in Fig. 2. Pulsed infrared from the transmitter causes phototransistor *Q1* to turn on and off at around 3.2 kHz. Before infrared signals reach the phototransistor, they pass through an optical bandpass filter that attenuates much of the incident visible light that would otherwise affect the operation of *Q1*.

Voltage pulses developed across the phototransistor are amplified 60 dB by ac-coupled amplifiers *IC1F* and *IC1E*. These stages, as well as the high-Q, active state-variable filter that follows (*IC1A, IC1B, IC1C*), are part of a CD-4069 hex inverter. Although this CMOS chip is usually employed in a nonlinear operating mode, it is used here as linear amplifier inverter gates, much as low-gain op amps.

Also employed in this fashion is unity-gain buffer amplifier *IC1D*. This buffer supplies filtered pulses to the detector comprising *C6, C7, D1, D2,* and *IC3A*. Diode *D1* is a biased clamper that limits negative excursions of *IC1D*'s output to a level determined by the setting of THRESHOLD potentiometer *R16*. Half-wave rectifier *D2* passes pulsed positive dc to filter *R17C7*. After approximately 10 milliseconds, the voltage across *C7* increases to a level sufficient to trigger the Schmitt trigger—*IC3A, R19*, and *R20*. The output of *IC3A* thus goes to logic 1 when an infrared pulse reaches phototransistor *Q1*. Gate *IC3A*, together with *C8, R21* and *R23*, also acts as a debouncer that generates a clean logic pulse when manual control switch *S1* is closed.

The output of *IC3A* is applied to dual D flip-flop *IC2*. This chip is wired to function as a ÷3 counter. The first pulse applied to it causes pin 1 of *IC2A* (the Q output of the first flip-flop) to go to logic 1. As a result, relay driver *Q2* receives base drive from gate *IC3D* via *R29* and begins to conduct. Relay *K1* interrupts the circuit between the audio output stage of the TV set and the TV loudspeaker, and SOUND OFF indicator *LED1* begins to glow. Also, the logic-1 output of gate *IC3D* is inverted by *IC4A*, and the output of this NAND gate brings the RESET input of multistage counter *IC5* to logic 0. The counter then begins to tally the 60-Hz pulses that are derived from the ac power line, filtered by passive network *C2R34*, and squared up by Schmitt trigger *IC3B*.

If a second pulse appears at the output of *IC3A* due to either the receipt of another burst of infrared or a closure of switch *S1*, the Q output of *IC2A* (pin 1) returns to logic 0 and the Q output of *IC2B* (pin 13) goes to logic 1. The output of *IC3D* remains at logic 1, keeping *Q2* in saturation, but *Q3* begins to receive base drive from the Q output of *IC2B* via *R26*. As a result, relay *K2* becomes energized and PICTURE OFF indicator *LED2* begins to glow. The relay contacts are connected to the nodes of the television receiver's brightness-determining circuit. Closure of contacts D and F causes the screen to darken.

Both relays remain energized until either a third burst of infrared is received, switch *S1* is closed, or counter *IC5* has tallied 1800 pulses for a 30-second delay or 3600 pulses for a 60-second delay, depending on the setting of *S2*. If the counter runs through its cycle undisturbed, it will reset itself via *IC4B* and *IC4A* and will reset *IC2A* and *IC2B* via *IC4B*, *IC4A*, and *IC3C*. Both relays will then be deenergized and normal television reception will be reestablished. The counting cycle can be interrupted and the relay(s) deenergized at any time by a closure of *S1*. Passive components *C9* and *R24* generate a 100-millisecond pulse when power is first applied to the circuit. This pulse is routed to the RESET inputs of *IC2A* and *IC2B* via *IC3C* and ensures that both flip-flops are properly initialized and the relays deenergized in spite of any turn-on transients.

Power required by the AD•ZAP receiver is furnished by the simple supply shown in the lower right corner of Fig. 2. Unregulated dc provided by bridge rectifier *D3* through *D6* and filter capacitor *C11* powers the relay and LED indicator circuits. The CMOS logic ICs are powered by +5 volts regulated, which is furnished by integrated regulator *IC6*. This particular supply voltage was chosen for the CMOS ICs because such circuits when operated in the linear mode exhibit higher gains at lower supply voltages.

Construction. The use of printed-circuit construction techniques is recommended. Suitable full-size etching and drilling guides for the two versions of the AD•ZAP transmitter are shown in Figs. 3A and 3B. The receiver pattern is shown in Fig. 4. The full-size etching and drilling guide of the circuit board that accommodates relays *K1* and *K2* and protective diodes *D7* and *D8* appears in Fig. 5. This latter board should be mounted inside the TV receiver's cabinet. Corresponding component-placement guides for these boards appear in Figs. 6A, 6B, 7, and 8.

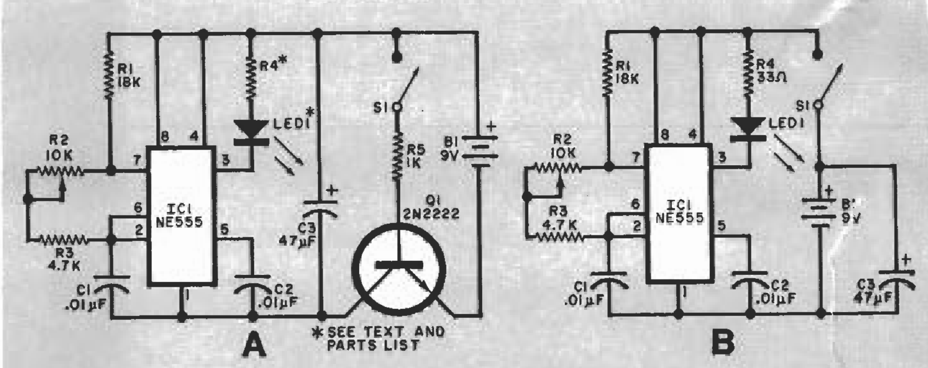


Fig. 1. Schematic diagrams of the box-style (A) and gun-style (B) infrared transmitters.

BOX-STYLE TRANSMITTER PARTS LIST

B1—9-volt transistor battery
C1—0.01μF, 10% tolerance Mylar capacitor
C2—0.01-μF disc ceramic capacitor
C3—47-μF, 10-volt radial-lead aluminum electrolytic or tantalum capacitor
IC1—NE555 timer
LED1—TIL32 unlensed infrared-emitting diode or TIL31 or LED55C lensed infrared-emitting diode
Q1—2N2222 npn silicon switching transistor
The following, unless otherwise specified, are ¼-watt, 10% tolerance, carbon-composition fixed resistors.
R1—18 kΩ
R2—10 kΩ, linear-taper horizontal pc-mount trimmer potentiometer
R3—4.7 kΩ
R4—33 Ω if *LED1* is a TIL32 unlensed diode, 15 Ω if *LED1* is a TIL31 or LED55C lensed diode
R5—1 kΩ
S1—Spst, normally open, momentary-contact pushbutton switch
Misc.—Mounting collar for *LED1*, lens for *LED1* if a TIL32 device is used, printed-circuit board, battery clip, suitable enclosure, solder, pc-board standoffs, suitable hardware, etc.

Note—Pushbutton switch S1 is a Panasonic No. EVQ-P1R component that is available from Digi-Key, Box 677, Highway 32 South, Thief River Falls, MN 56701.

GUN-STYLE TRANSMITTER PARTS LIST

B1—9-volt transistor battery
C1—0.01-μF, 10%-tolerance Mylar capacitor
C2—0.01-μF disc ceramic capacitor
C3—47-μF, 10-volt radial-lead aluminum electrolytic or tantalum capicitor
IC1—NE555 timer
LED1—TIL32 infrared-emitting diode
The following, unless otherwise specified, are ¼-watt, 5%-tolerance, carbon-composition fixed resistors.
R1—18 kΩ
R2—10 -kΩ, linear-taper vertical pc-mount trimmer potentiometer
R3—4.7 kΩ
R4—33 Ω
Misc.—Printed-circuit board, battery clip, plastic-body Coleco electronic-game gun with trigger-actuated switch (*S1*) and lens system, solder, etc.

Note—The Coleco gun is available from Meshna Electronics, Box 62, 19 Allerton Street, East Lynn, MA 01904.

Most components mount directly on the boards or via sockets. Exceptions include phototransistor *Q1*, resistor *R1*, and plug-in wall transformer *T1*. To suppress feedback-induced oscillations, one end of *R1* is connected directly to the base lead of *Q1*. The other end of *R1* and the collector and emitter leads of *Q1* are connected to the appropriate pc foil pads via short lengths of insulated hookup wire. Similarly, *LED1* and *LED2* are connected to the board with insulated hookup wire.

It is good practice to install lengths of spaghetti or heat-shrinkable tubing on the exposed leads of all components that are mounted off the board to prevent accidental short circuits. The AD•ZAP receiver circuit board *must* be housed in a metallic enclosure.

Substitutions should not lightly be made for phototransistor *Q1*. For the device specified and the parameters of the circuit shown in Fig. 2, the phototransistor should function in the linear portion of its response curve for ambient light levels of up to 50 foot-candles of incandescent light or 150 foot-candles of daylight. Sensitivity of the device specified can vary over a 7:1 range. Therefore, the circuit incorporates means to compensate for such sensitivity variations. For example, it may be necessary to change the value of resistor *R3* or to even substitute another phototransistor of the same type. (Note that photodarlingtons have too much gain and will, therefore, not

(Text continued on page 48)

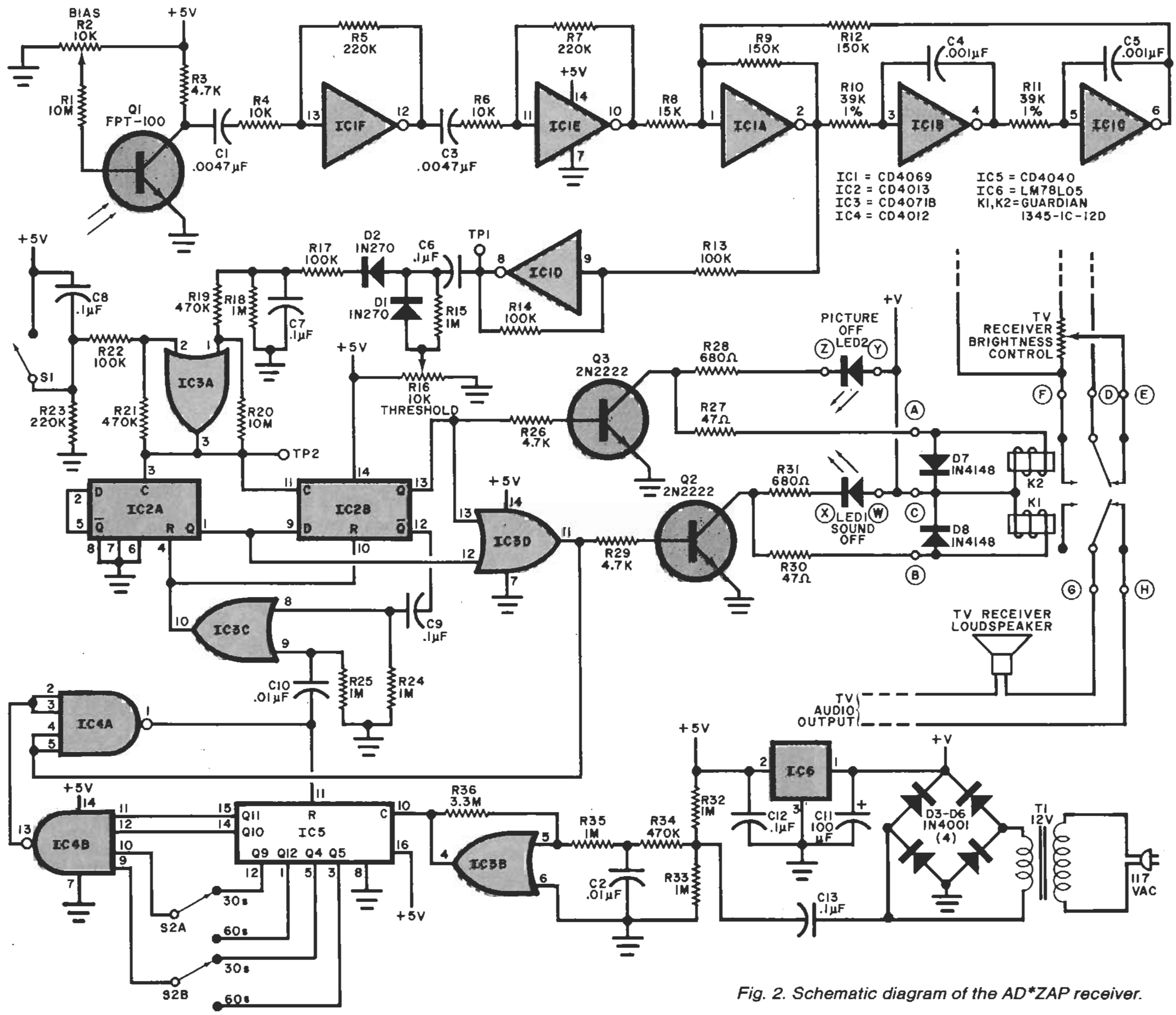


*Fig. 2. Schematic diagram of the AD*ZAP receiver.*

RECEIVER PARTS LIST

C1,C3—0.0047-µF disc ceramic capacitor
C2,C10—0.01-µF disc ceramic capacitor
C4,C5—0.001-µF, 5% tolerance Mylar or polystyrene capacitor
C6,C7,C8,C9,C12, C13—0.1-µF disc ceramic capacitor
C11—100-µF, 25-volt axial-lead aluminum electrolytic
D1,D2—1N270 or equivalent germanium diode
D3 through D6—1N4001 rectifier
D7,D8—1N914 or 1N4148 silicon switching diode
IC1—CD4069 hex inverter
IC2—CD4013 dual D flip-flop
IC3—CD4071B quad 2-input OR gate (device must have B suffix)
IC4—CD4012 dual four-input NAND gate
IC5—CD4040 12-stage binary counter
IC6—LM78L05 5-volt, 100-mA regulator
K1,K2—Spdt relay with 12-volt dc, 1400-ohm coil (Guardian No. 1345-1C-12D or equivalent)
LED1—Yellow light-emitting diode
LED2—Red light-emitting diode
Q1—FPT-100 phototransistor (Fairchild)
Q2, Q3—2N2222 npn silicon switching transistor
The following, unless otherwise specified, are ¼-watt, 5% tolerance, carbon-composition fixed resistors.
R1, R20—10 MΩ
R2, R16—10-kΩ linear-taper, horizontal pc-mount trimmer potentiometer
R3,R26,R29—4.7 kΩ
R4, R6—10 kΩ
R5, R7, R23—220 kΩ
R8—15 kΩ
R9, R12—150 kΩ
R10, R11—39 kΩ, 1%-tolerance, ¼-watt, metal-film
R13, R14, R17, R22—100 kΩ
R15, R18, R24, R25, R32, R33, R35—1 MΩ
R19, R21, R34—470 kΩ
R27, R30—47 Ω
R28, R31—680 Ω
R36—3.3 MΩ
S1—Spst, normally open, momentary-contact pushbutton switch
S2—Dpdt miniature slide switch
T1—12-volt ac, 100-mA wall-mount plug-in transformer
Misc.—Printed circuit board, suitable metallic enclosure, LED mounting collars, grommets, infrared bandpass filter (see note below), heat-shrinkable tubing, hookup wire, solder, pc standoffs, suitable hardware, etc.

Note 1—Pushbutton switch S1 is a Panasonic No. EVQ-P1R component that is available from Digi-Key, Box 677, Highway 32 South, Thief River Falls, MN 56701.

Note 2—There are several possible items that can be used as an infrared bandpass filter. The author used a ¼-inch circular piece of Eastman Kodak Wratten No. 89B gelatin filter. Kodak advises that a piece of unexposed but processed Kodachrome slide film can also be used, as it blocks visible light almost completely but is transparent to infrared. Gelatin Wratten filters measuring 2 inches square are available from Eastman Kodak dealers for approximately $5.00 each.

work.) The phototransistor should be mounted on the front panel of the AD•ZAP receiver's enclosure. The device specified just fits a standard 0.200-inch (Jumbo) LED mounting collar.

An infrared optical filter is mounted in front of the phototransistor's aperture. Use black silicone cement or some similar opaque material to ensure that no light can leak in behind the filter. The two indicator LEDs can also be mounted on the receiver enclosure's front panel. To facilitate interconnection of the receiver circuit and relay board, a multiconductor connector should be mounted on the enclosure.

For convenience, the author mounted

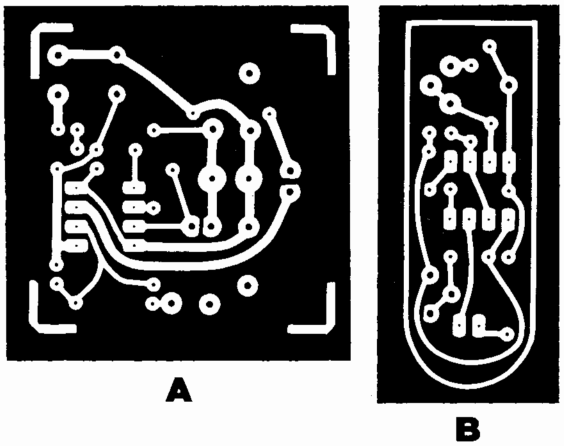


Fig. 3. Full-size etching and drilling guides for the box-style (A) and gun-style (B) transmitter pc boards.

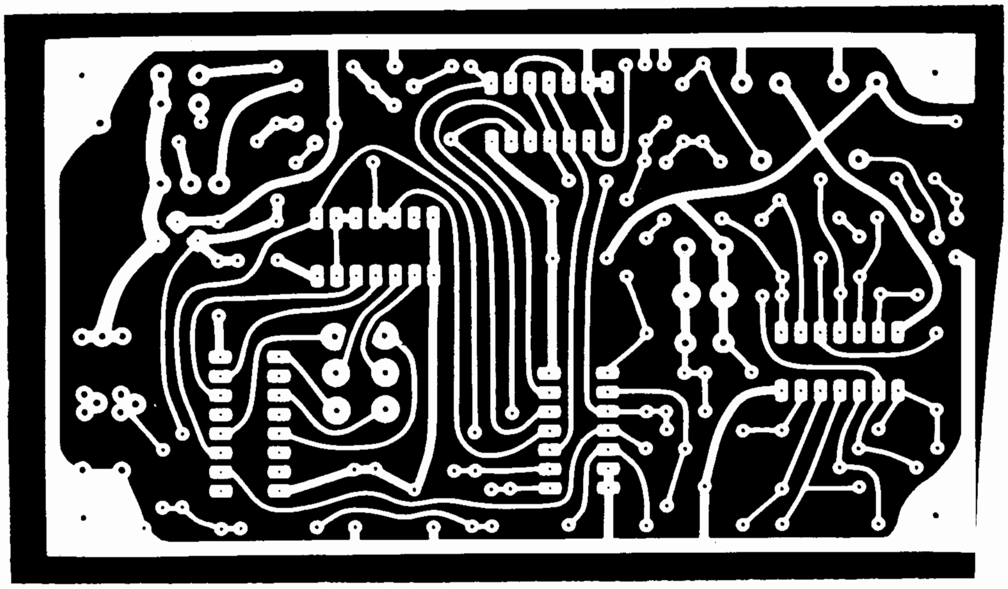


Fig. 4. Full-size etching and drilling guide for the receiver pc board.

his relay board inside the television receiver with which the AD•ZAP system was to be used. If you plan to use your system with more than one TV set, a separate relay board can be used in each. You can substitute the relays specified so long as their coils are rated at 12 volts dc and have resistances of 400 ohms or more. If a dpdt relay is employed for *K1*, the second set of contacts can be used to stop the transport of a video tape recorder during commercial messages.

The transmitter can be housed in a standard plastic enclosure or, for dramatic fun, a plastic six-shooter such as that used by the author. The "gun," manufactured by Coleco for use in a game, contains a trigger-actuated switch and a lens system. The pc board pattern of Fig. 3B was designed for use with this gun. Careful attention to dimensions will ensure proper alignment of the LED with the lenses, giving a narrow, correctly aimed beam.

To fit a nine-volt battery into the handle of the pistol, the internal plastic posts between the holes for the two handle screws must be cut away. This can be done with a heated knife or with a hobby power tool and its saw blade. Also, the terminals on the rear of the trigger-actuated switch must be cut off. The necessary electrical connections between the switch and the rest of the transmitter circuit should be made by soldering suitable lengths of hookup wire directly to the switch's leaf springs. Use a vise to hold the switch and then tin the leaf springs and the ends of the lengths of hookup wire. Place the tinned end of each wire next to the appropriate leaf spring and remelt the solder to form the connection. Work quickly to avoid losing the temper of the springs. Finally, make a 1/8-inch hole in the plastic body over the position occupied by trimmer potentiometer *R2* so that the circuit's frequency of oscillation can be conveniently adjusted.

If you prefer a more conventional transmitter enclosure, you will need a lens to focus the infrared beam. Focusing the invisible beam is difficult. Alter-

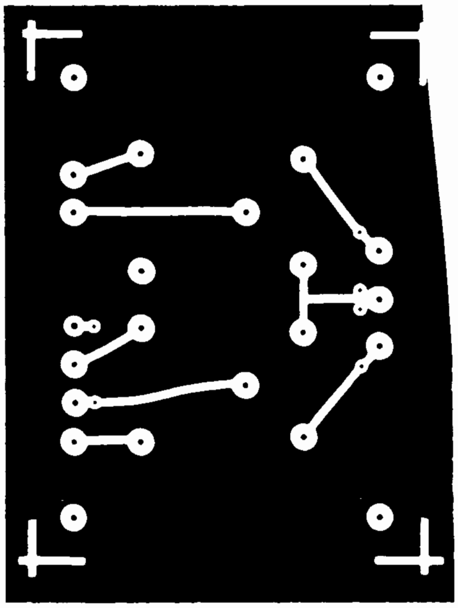
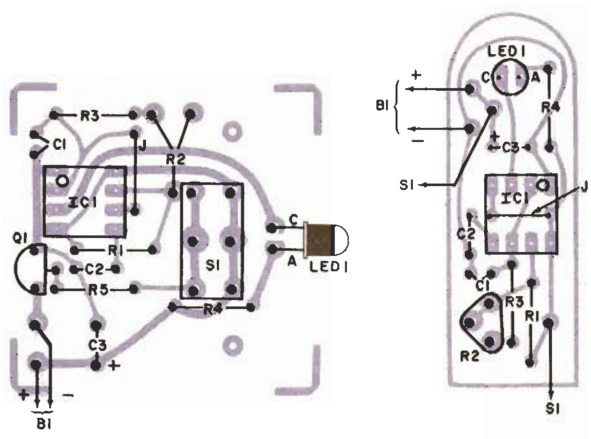


Fig. 5. Etching and drilling guide for relay pc board.



A

B

Fig. 6. Parts placement guides for the box-style (A) and gun-style (B) infrared transmitters.

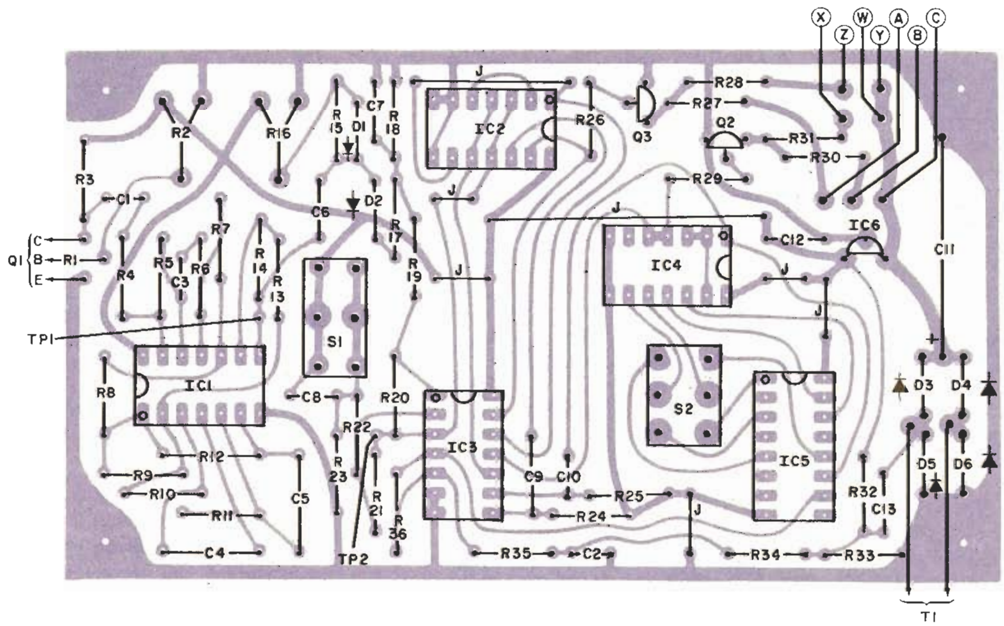


Fig. 7. Parts placement guide for the AD*ZAP infrared receiver printed circuit board.

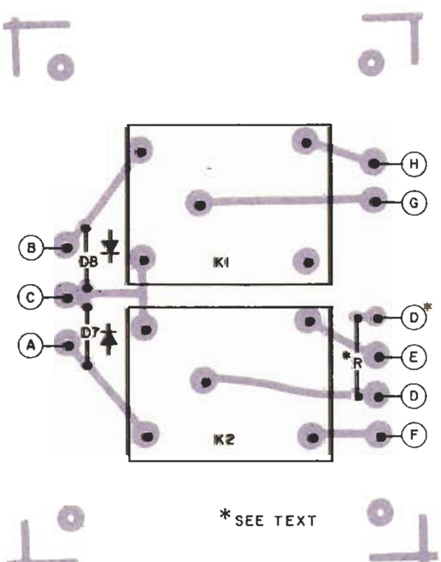


Fig. 8. Component placement guide for the relay pc board.

natively, you can use a Texas Instruments TIL31 or General Electric LED55C infrared-emitting diode. These include internal reflectors and glass lenses and mount in standard 0.200-inch LED mounting collars. They also tolerate larger forward currents, allowing reduction of the value of *R4* in the transmitter to 15 ohms. Pass transistor *Q1* and base resistor *R5* in the circuit of Fig. 1A allow switch *S1* to be a light-action, low-current keyboard switch.

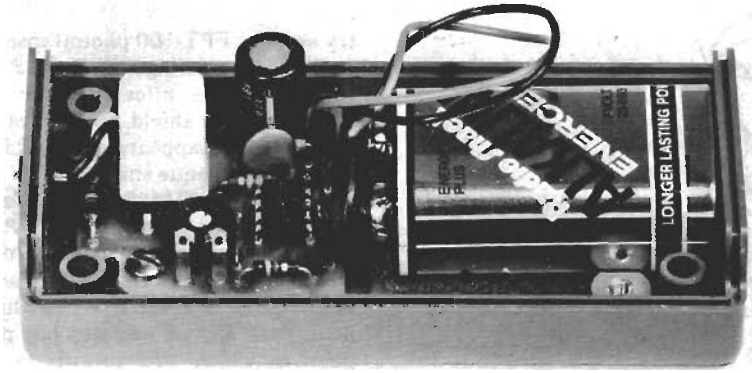
Adjustment. After the receiver and transmitter have been assembled, plug *T1* into a wall socket. With the top of the receiver enclosure removed, monitor the voltage across resistor *R3* with a high-impedance multimeter. Place an unshaded, lighted 60-watt light bulb two feet away from the filter that shields phototransistor *Q1*, and set the wiper of trimmer potentiometer *R2* fully counterclockwise. The voltage across *R3* should be 2.5 $\pm$0.5 V. If necessary, change the value of *R3* to obtain this reading. Should this prove impossible, try another FPT-100 phototransistor.

When the voltage across *R3* is correct, cover the filter aperture with a totally opaque shield and adjust *R2* so that 0.25 volt appears across *R3*. Then remove the opaque shield.

Next, turn *R16* fully counterclockwise and check the voltage at *TP2*. This should be 0 volt. Slowly turn *R16* clockwise. At some point, *TP2* should suddenly go to +5 volts. When this happens, back *R16* off and stop just past the point at which *TP2* returns to 0 volt. Depress switch *S1* momentarily and verify that *TP1* goes to +5 volts with *S1* closed and returns to 0 volt when it is opened; if *TP2* fails to return to 0 volt when *S1* is released, turn *R16* a bit further counterclockwise.

Finally, to set the frequency of the transmitter's astable multivibrator to match the receiver's filter passband, connect an ac voltmeter or oscilloscope between *TP1* and ground. Have a friend monitor the voltage reading while you stand several feet away and "fire" the transmitter at the receiver's infrared filter. Hold the transmitter switch *S1* so that a continuous infrared output is generated. (With a pistol transmitter, pull the hammer back all the way and hold it.) Adjust transmitter trimmer potentiometer *R2* for a maximum voltage reading on the test instrument.

Place the top on the receiver enclosure and secure it in place. Connect the relay board to the rest of the receiver circuit and, if necessary, button up the transmitter enclosure. Making certain that the receiver is getting operating power, aim the transmitter at the receiver's infrared filter. When transmitter switch *S1* is closed momentarily, relay



Photograph of the author's prototype box-style transmitter.

PARTS AND KIT AVAILABILITY

The following are available from Videomega, 2715 N. E. 14th Avenue, Portland, OR 97212. Prices do not include shipping and handling charges ($2 per order). Kits of all components for one transmitter, receiver, and relay board, enclosures, and a nine-volt battery for the transmitters: complete kit for AD*ZAP system employing gun-style transmitter (limited quantities available), No. KZ-S, for $69.00; complete kit for AD*ZAP system employing box-style transmitter, No. KZ-T, for $69.00; complete kit for AD*ZAP system capable of controlling VTR pause circuit, employing gun-style transmitter, and including VTR control cable (limited quantities available), No. KZ-SV, for $79.00; complete kit for AD*ZAP system capable of controlling VTR pause circuit, employing box-style transmitter, and including VTR control cable, No. KZ-TV, for $79.00. Individual kits for additional receivers, transmitters, and relay boards are also available. Write for prices.

Drilled, solder-plated, and silk-screened (component-placement legend) printed-circuit boards are also available separately: Set of boards for receiver, relay circuit, and gun-style transmitter, No. AZ-S, for $16.00; set of boards for receiver, relay circuit, and box-style transmitter, No. AZ-T, for $16.00; set of boards for receiver, relay and VTR pause-control circuits, and gun-style transmitter, No. AZ-SV, for $16.00; set of boards for receiver, relay and VTR pause-control circuits, and box-style transmitter, No. AZ-TV, for $16.00; receiver board only, No. AZ-A, for $7.50.

INSTALLATION WHEN SCREEN CAN'T BE DARKENED.

Here are possible ways of darkening the screen even if it doesn't go fully to black when the BRIGHTNESS control is at minimum. First, you will need a schematic of the television receiver. (If one was not supplied with the receiver or is not available from the manufacturer, try the Sams Fotofact series of publications.) Next, you will have to determine how the brightness of the CRT is controlled, and how the range of the BRIGHTNESS potentiometer is affected by the "one-button" color preset, if any.

Several methods of brightness control are common; the simplest is found in many vintage color receivers and in many contemporary monochrome models. (Figure 9 is typical.) The video signal is capacitively coupled to the cathode of the picture tube, and the BRIGHTNESS potentiometer controls the dc bias voltage that sets the average beam current. The lower the bias voltage, the higher the beam current and the brighter the picture. Resistor *R34* limits the beam current to a maximum value.

Brightness-control circuits of this type almost always are able to send the CRT well past cutoff (screen completely dark). If you have a color receiver that employs a similar circuit (the partial schematic illustrated is of a General Electric HB color chassis), note that the red, green and blue SCREEN controls interact with the BRIGHTNESS control. While a video signal is being received, try adjusting the SCREEN controls for cutoff with the BRIGHTNESS control at its minimum setting. Then, if the CRT image is too dim when the BRIGHTNESS control is advanced to its maximum setting (this will rarely be the case), make the value of *R34* half as large. Check to see that the high voltage is at its specified value before making a substitution for *R34*.

The more usual approach to brightness control in today's solid-state receivers is to vary the dc bias at the input of one of the video amplifiers. Video is either dc- or ac-coupled (or a combination of the two) into the stage, and is sometimes clamped to the bias voltage during the blanking interval. The BRIGHTNESS potentiometer can be wired into the circuit either as a voltage divider (as a three-terminal device) or as a variable resistor (a two-terminal device). In the latter case, the potentiometer is only part of a voltage-dividing network. The Sharp Model XR-2194 typifies the first method, the Sony 9000U the second.

In the Sony, the bias voltage of the Y DRIVE amplifier is mixed with the video signal. The video signal is positive, that is, white is more positive than black. Blanking the screen can therefore be accomplished by bringing the base of the Y DRIVE stage to ground, either directly or by opening the path between the voltage divider that sets the bias and the low-voltage supply from which the bias is derived. In the Sharp receiver, the "one-button" color-preset switch selects between the BRIGHTNESS control and a screwdriver-adjustable trimmer potentiometer that is preset at the factory. Both the front-panel BRIGHTNESS control and the trimmer have range-limiting series resistors that prevent them from cutting off the CRT totally. Blanking can be achieved by having the relay disconnect the ends of the front-panel and trimmer potentiometers that are tied together from the source of low voltage which supplies them.

In some sets, the "one-button" color preset leaves the front-panel BRIGHTNESS control in the circuit, but restricts its effective range. One receiver that uses such a circuit is Toshiba's Model C345, chassis TAC-9310. The base of the fourth video amplifier is biased through a fixed resistor by a voltage divider composed of a fixed resistor and the BRIGHTNESS control, one end of which receives positive voltage via a SUB-BRIGHTNESS control. This latter control limits CRT brightness.

When the receiver's "one-button" color preset is engaged, a fixed resistor is placed in parallel with the front-panel BRIGHTNESS control. This restricts the effective range of the control to its upper half. To have AD*ZAP totally darken the screen, relay *K2* can be wired either to ground the wiper of the SUB-BRIGHTNESS control or connect a fixed resistance of approximately 5000 ohms between the base of the fourth video amplifier and ground. The use of such a resistor rather than a direct short to ground prevents the total loss of the demodulated video signal, which would also disable the sync circuits. This way, when *K2* is deenergized, the picture returns instantly—in sync and with no rolling or tearing. The relay pc board includes provisions for such a resistor (*R*) at point D*.

K1 should pull in and *LED1* glow. When transmitter switch *S1* is closed a second time, *K2* and *LED2* should do likewise. At the end of the interval determined by the setting of receiver switch *S2*, both relays should drop out and both LEDs darken. If *S1* is closed a third time before the receiver times out, this too should de-energize the relays and LEDs. Closure of receiver switch *S1* should initiate the timing sequence or, if it has already begun, interrupt it.

Modifying the TV Receiver. If control of only the audio output of the television is desired the AD*ZAP system can be used with any TV set and installation procedure is simple. However, achieving control of both sound and picture may be somewhat more difficult, depending on the TV set used. Two simple tests will tell you how much of a problem it will be to obtain picture control. If the CRT screen goes completely black when the BRIGHTNESS control is at minimum, installation will be easy. Alternatively, if the receiver has a "one-button" color preset, and the screen goes completely dark when the preset is engaged and the BRIGHTNESS control is at minimum, installation is again not complicated. However, if the screen cannot be wholly "blackened," installation will be more

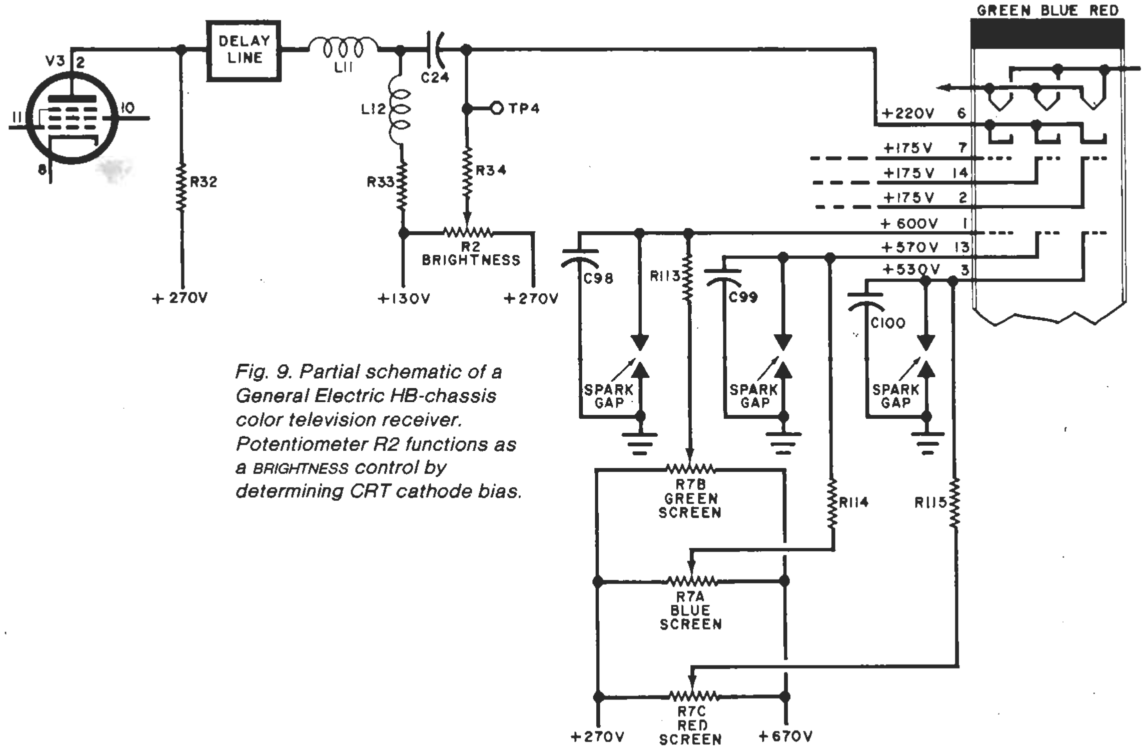
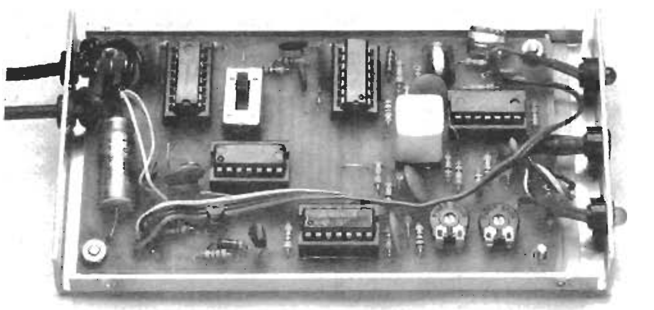


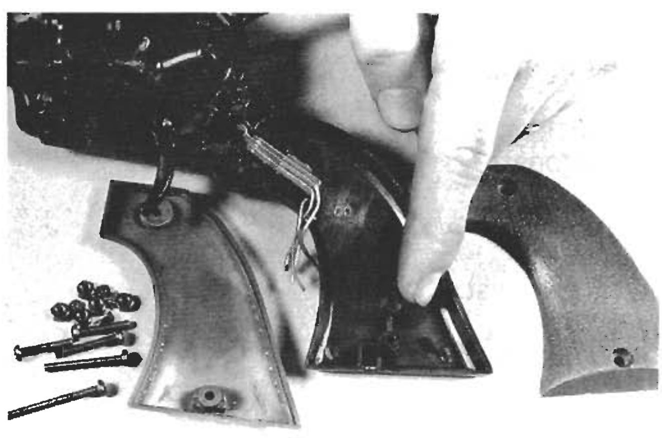
Fig. 9. Partial schematic of a General Electric HB-chassis color television receiver. Potentiometer R2 functions as a BRIGHTNESS *control by determining CRT cathode bias.*

troublesome, as detailed in a boxed section on the opposite page.

Here's the procedure that should be followed if test results are positive. Begin by removing the rear panel of the TV receiver (which should also remove ac power through the interlock) to gain access to the BRIGHTNESS control. Detach the wire connected to the center lug of the BRIGHTNESS control and connect it to point D on the relay printed circuit board. The free ends of the wires from points E and F on the relay board should be soldered to the center and left lugs, respectively, as seen from the *rear* of the BRIGHTNESS control. To control the audio, disconnect one of the two output leads from the loudspeaker and connect it to point H on the relay circuit board. If necessary, extend the length of this lead by splicing on a piece of hookup wire. Solder the splice and insulate it using PVC electrical tape or heat-shrinkable tubing. Then attach one end of suitable length of hookup wire to the free speaker lug, and the other end to point G on the relay circuit board. The relay board can be mounted inside the television cabinet using either screws and standoffs or two or three layers of double-sided adhesive foam tape.



*Photograph shows construction details of the prototype AD*ZAP infrared receiver.*



Photograph of the Coleco surplus plastic pistol modified by the author for use as a transmitter.

Using AD*ZAP. Although the receiver module includes an infrared filter, high levels of ambient light can affect phototransistor *Q1*. Therefore, avoid illuminating the sensor with bright sunlight, and keep incandescent lamps several feet away. The on-axis range of the six-shooter transmitter is more than 35 feet. That of the box-style transmitter is more than 20 feet. Because of its more diffuse radiation, the box-style transmitter need not be critically aimed.

Receiver switch *S1* should be set to provide the desired delay interval. The growing use of 30-second commercial messages on television prompted the inclusion of the switch. A few hour's attentive viewing of TV programs *and* commercials will enable you to judge which delay interval is more useful. To be certain not to miss any desired program material, you may want to avoid darkening the picture, at least at first. ◇

Low-Cost Remote Control of Appliances & Lights

BY GEORGE A. ELLSON

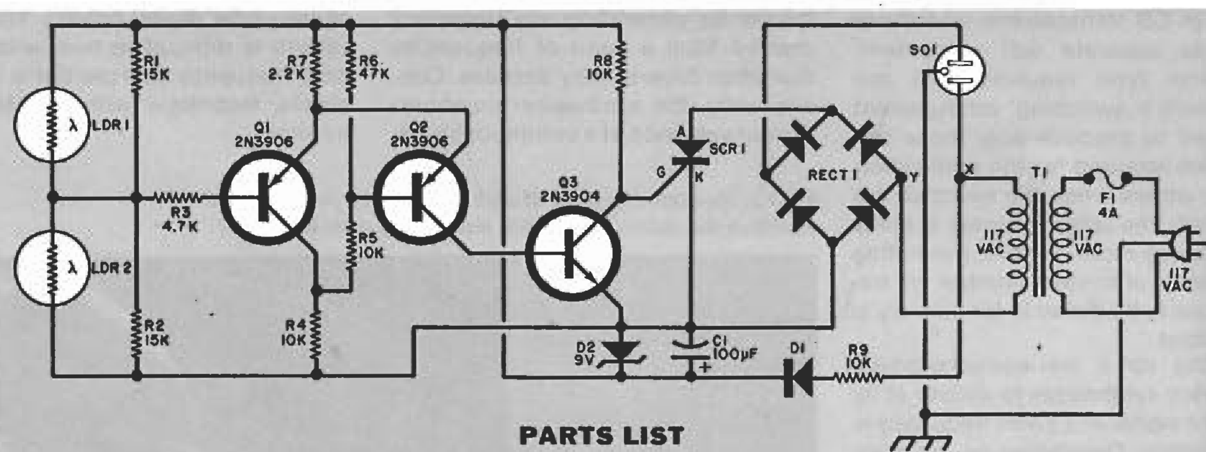
Circuit is triggered on and off by a flashlight's beam

REMOTE control systems have always been popular as step, energy, and time savers. Invalids find them eminently practical for controlling electrical appliances, lights, and radio and TV receivers.

Depending on the specific application and the degree of control desired, a remote-control system can be expensively elaborate or very simple in design. Perhaps the most practical in economy and design is the simple light-activated system of the type described in this article. This system should cost roughly $19 for all parts. It is virtually foolproof to operate, requiring only an ordinary flashlight to trigger it on and off. The system will control virtually any load rated at up to 4 amperes or 450 watts.

About the Circuit. Transistors *Q1* and *Q2* in Fig. 1 form a regenerative bistable switch, using *Q3* as the collector load for *Q2*. The voltage across *R8* is high when *Q3* is cut off and low when *Q3* is saturated. The condition of *Q3* depends on the voltage at the base of *Q1*, which is in turn dependent on the resistance of the *LDR1*/*LDR2* voltage divider. Light-dependent resistors *LDR1* and *LDR2* are photosensitive devices. When their active surfaces are dark, their resistance is at maximum. However, when the surfaces are illuminated, the resistance decreases, the amount of decrease governed by the intensity of the light.

If both LDR's receive the same amount of light, the base bias of *Q1* remains the same. Now, if only *LDR1* is illuminated, its resistance drops and causes *Q1* to go into cutoff. But if only *LDR2* were to be illuminated, its change in resistance would cause *Q1* to go into saturation. The fast regenerative action of the circuit will then cause *Q3* to go into saturation or



PARTS LIST

C1—100-µF, 15-volt electrolytic capacitor
D1—200-PIV, 500-mA silicon rectifier (1N647 or similar)
D2—9-volt, ½-watt zener diode (1N960 or similar)
F1—4-ampere fuse
LDR1,LDR2—Cadmium-sulfide light-dependent resistor (Radio Shack No. 276-677 or similar)
Q1,Q2—2N3906 transistor
Q3—2N3904 transistor
R1,R2—15,000-ohm, ½-watt resistor
R3—4700-ohm, ½-watt resistor
R4,R5,R8—10,000-ohm, ½-watt resistor
R6—47,000-ohm, ½-watt resistor
R7—2200-ohm, ½-watt resistor
R9—10,000-ohm, 1-watt resistor
RECT1—200-PIV, 4-ampere (minimum) rectifier bridge assembly
SCR1—200-PIV, 4-ampere silicon controlled rectifier (General Electric No. 106B or similar)
SO1—Three-wire chassis-mounting ac receptacle
T1—117-volt isolation transformer
Misc.—Three-wire line cord with plug (16 or 14 gauge); aluminum utility box; printed circuit board or perforated board and solder clips; spacers; hookup wire; fuse socket; machine hardware; solder; etc.

Fig. 1. Relative resistances of LDR1 and LDR2 determine operation of bistable switch made up of Q1 and Q2.

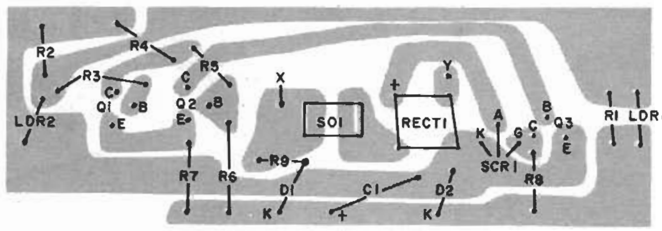


Fig. 2. Actual-size foil pattern for the printed circuit board is shown above. The component placement diagram is at right.

become cut off according to which of the LDR's receives the light.

Once the bistable switch goes into a given state, it will remain in that state (as long as power is applied to the circuit) until the opposite LDR is illuminated.

Resistor *R8* determines the level of the gate voltage applied to *SCR1*. When *Q3* is saturated, this gate voltage is minimum. Conversely, when *Q3* is cut off, the gate voltage is at maximum.

The SCR is connected in series with rectifier assembly *RECT1* and control socket *SO1* across the power line. With no filter capacitor in the circuit, the negative-going ac line alternations are "folded up" to produce 120 positive-going half cycles/second on the anode of *SCR1*. The SCR will not conduct until its gate is made positive with respect to the voltage on the cathode. When this occurs (*Q3* will be cut off), the SCR conducts and powers the electrical device plugged into *SO1*. The SCR will remain conducting for as long as the gate voltage is applied to it. When *Q3* is triggered into saturation, the SCR automatically turns off when the voltage applied to its anode reaches the zero point. Then the device plugged into *SO1* has its power cut off.

Resistor *R9*, diode *D1*, capacitor *C1*, and zener diode *D2* form the low-voltage supply for the transistor circuit.

Construction. Building the light-activated remote control system is best accomplished with the aid of a printed circuit board, the actual-size etching and drilling guide and components placement diagram for which are shown in Fig. 2. Note that all components, with the exception of *LDR1* and *LDR2* and *SO1*, mount on the component side of the board. The isolation transformer, *T1*, and the fuse, *F1*, can be mounted at any convenient point within the enclosure.

Start construction by mounting the components on the top side of the board, putting in *SO1* last. Pay particular attention to the polarities of the diodes, rectifier assembly and electrolytic capacitor *C1* and the lead orientations of the transistors and SCR. Resistor *R9* and diode *D1* mount to the board by only one lead each. (The lead that goes to the board connection for *D1* is the *cathode*.) The anode of *D1* and the free lead from *R9* get soldered together to complete the circuit. Trim off excess lead lengths on the foil side of the board.

Trim the leads of the photocells to ⅜ in. (9.53 mm). Solder the leads of *LDR1* and *LDR2* to the board's conductors in the appropriate locations. Let the photocells extend as far from the surface of the board as their trimmed leads will allow.

Fashion a pair of flat black tubes, each about an inch long and just large enough in diameter to fit over the cases of the photocells. These tubes (they can be made from heavy construction paper but *not* metal) serve as light shields to prevent erratic operation of the system where ambient lighting is variable.

Select an enclosure that will comfortably accommodate the circuit board assembly. The pc board layout shown in Fig. 2 is designed for a two-wire power system. Hence, the case should be all-plastic or all-Bakelite. If you elect to go to a safer three-wire system, you can use a metal case; but make absolutely certain that all three wires from the power cord, socket, and *T1* (the latter mounted on the case instead of the board assembly) are properly connected to avoid shock hazard.

Before mounting the circuit board assembly in place, drill holes through the case directly in line with the photocells. Slide the light shields over the photocells, and mount the board in place.

Operation. The only device needed to trigger the remote control system is an ordinary flashlight. Use a table lamp to check out the system. While it is still plugged into the wall outlet, turn on the lamp. Then, without switching it off, unplug the lamp's cord from the outlet and plug it into *SO1*. Plug the line cord from the remote control system into the wall outlet.

Shine the beam of the flashlight into first one, then the other photocell hole. The lamp should come on and extinguish in step with the movement of the beam from one hole to the other.

The range of the remote control system is directly related to the distance between the photocells. The flashlight beam must be able to illuminate only one photocell at a time. If you desire greater range than the pc assembly setup allows, you can separate the photocells even more. In this case, use shielded cable between them and the circuit board. ◈

CIRCUIT IDEAS

Camera Remote Control

The infra-red remote controller gives the freedom to shoot photos from a distance, even from the other side of a window.

MANY of the more recent cameras to come onto the market have provision for an electric remote release, with the camera either being triggered directly or via an autowinder/motordrive. This type of release simply consists of a twin cable with a push button switch at one end and a plug at the other to match the camera or winder. The switch activates either the electronic shutter or an actuator in the winder. This method gives excellent reliability, but it still requires a long cable to carry the signal to the camera. This can be undesirable for some types of photography, and the cable also makes an excellent trip-wire!

For many purposes it is better to use a wire-less method of control, such as an infra-red or ultrasonic system. The latter offers slightly greater range, but infra-red systems have the advantage of operating quite well through a window, so that the camera equipment outside the house can be operated from within. The camera control system described here is of the infra-red type, operates reliably over a range of at least 6 metres, and is at least equal in this respect to the air release which it was designed to replace. It has mainly been used with a Pentax LX camera plus autowinder, but it also worked well when tried with a Minolta XD7 (which is triggered directly), and it should work with any camera which has an electric release facility. The prototype has been built as a single channel system, but the equipment could easily be modified for multichannel use with multi-camera set-ups, as will be explained in greater detail later.

The System

The block diagram of Figure 1 shows the arrangement used in this remote control system, as it is not practical to use a high output power from the receiver. A simple DC system is consequently impractical, as the signal received from the transmitter would often be swamped by the ambient infra-red level. Instead, an AC system is used, with the transmitter providing an amplitude modulated beam. The infra-red signal is generated using a special type of light emitting diode, and this is driven from an audio oscillator via a buffer stage which provides the fairly high drive current required. This gives a crude form of modulation with the LED simply being switched from fully on to fully off, but for this application nothing more complex is needed.

The audio frequency output from the diode is not likely to be very large in practice, and would typically only be a few tens of microvolts. A high gain amplifier is therefore used to boost this signal to a high enough level to operate the following stage, which is a Phase Locked Loop tone decoder. This circuit has an electronic switch at its output, and this is turned on if an input signal at a frequency within its narrow locking range is received. The transmitter is adjusted so that its operating frequency is at the centre of the locking range, where the PLL decoder is most sensitive.

There are two reasons for the use of a PLL decoder in the circuit; one is simply that it gives almost total immunity to spurious triggering by electrical interference or noise. A second advantage is that it enables two remote control systems

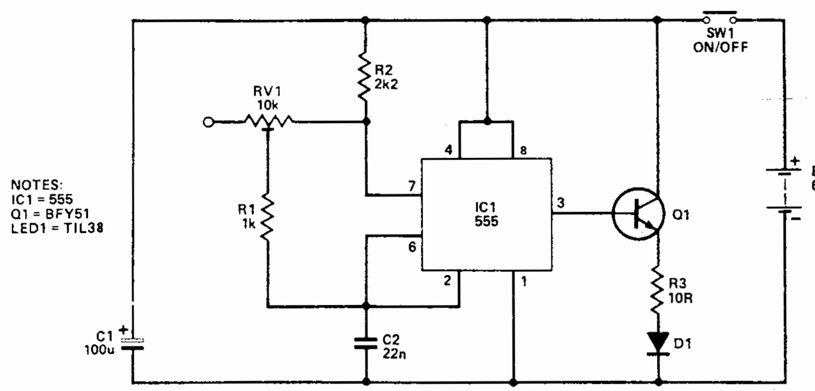


Fig. 2. The circuit diagram of the transmitter stage.

Another special type of diode is used at the receiver to produce an electrical signal from the received infra-red pulses. This is a large photodiode that gives good sensitivity, and although the diode itself is sensitive to a large part of the light spectrum, an integral infra-red filter removes light outside the infra-red range. This prevents strong light in the visible part of the spectrum from saturating the diode and preventing the system from operating properly.

to be used side-by-side without one also activating the other — provided the two operate on slightly different frequencies that is.

A monostable multivibrator is used as the next stage of the receiver, triggered by the output switch of the PLL tone decoder; the monostable drives a VMOS switching transistor which in turn controls the camera. The monostable is used to ensure that the VMOS switch is activated for a long enough time to operate the shutter,

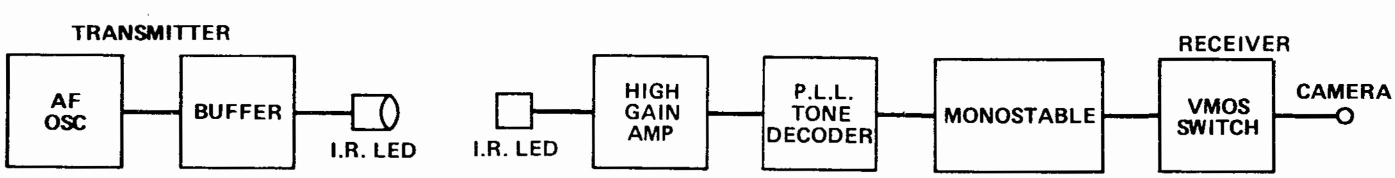


Fig. 1. A block diagram of the whole remote control system.

even if only a brief input signal is received. This helps to give more reliable operation if the system is used at virtually its maximum range.

Transmitter Circuit

Figure 2 shows the circuit diagram of the transmitter, based on a 555 astable oscillator. This gives a roughly squarewave signal, with RV1 used to trim the output to the appropriate frequency (around 5 kHz). The output stage of the 555 is barely able to provide sufficient output current to drive infra-red emitter D1 at the required current of around 150 milliamps, so Q1 is used as an emitter follower buffer stage to give more reliable and consistent results. Operating push-button on/off switch SW1 supplies power to the transmitter and activates the camera.

Receiver Circuit

The receiver unit is a little more complex, as can be seen from the circuit diagram of Figure 3. D2 is the infra-red photo diode· this can be used as a photovoltaic cell, producing an output voltage which is roughly proportional to the received infra-red intensity; however, slightly higher sensitivity is obtained by using it in a potential divider circuit. Here its reverse resistance varies with the received infra-red intensity, giving a varying voltage at the output of the divider circuit. This signal is coupled by C4 to the input of a high gain amplifier which uses Q2 and Q3 as straighforward common emitter amplifiers. C5 rolls-off the response of the first amplifier in the radio frequency range to prevent instability. The coupling capacitors can have quite low values due to the fairly high operating frequency of the transmitter; this helps to filter out 60 Hz hum received from AC lighting which could otherwise drive the amplifier into clipping and desensitize the circuit to the signal from the transmitter.

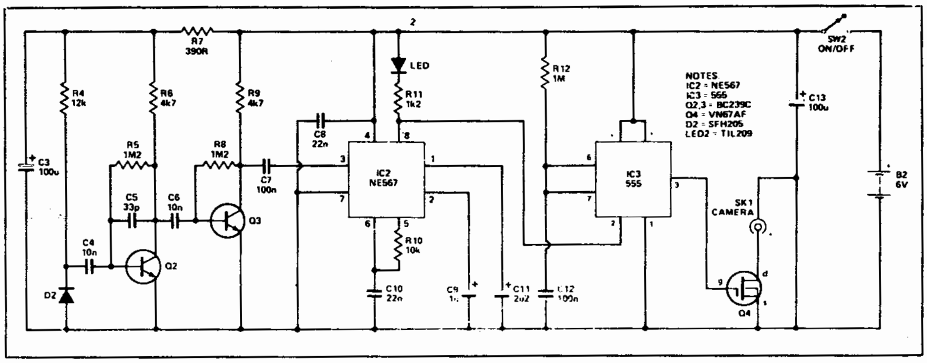


Fig. 3. The circuit diagram of the receiver stage.

An NE567 (IC2) is used in the tone decoder, R11 and D3 form the collector load for its output transistor, and LED1 lights up when the tone decoder is activated. This is useful when adjusting the frequency control of the transmitter, and it also helps when setting-up the equipment ready for use.

The negative output signal from the tone decoder is used to trigger IC3, which is a 555 used in the standard monostable multivibrator configuration. Q4 is the VMOS output transistor, driven direct from the output of IC3; note that the camera or autowinder must be connected to SK1 so that Q4 is fed with signal of the right polarity (centre pin positive).

Construction

The connection from the camera or autowinder to the receiver is made using an electric release for the particular camera or winder you are using, and this remote control unit *can only be used if a suitable release is available.* The push-button switch on the release is removed and a plug to match SK1 is fitted in its place. With the camera or winder connected to SK1 (and switched on where appropriate), a multimeter set to a fairly high DC volts range can be used to determine the polarity of the voltage on SK1 so that this can be correctly wired to the printed circuit board.

Like the transmitter unit, the receiver is powered from four 1.5 V cells. As it is likely that the unit will be left running for long periods, NiCad rechargeable cells are probably the most practical power source, but primary cells can be used if preferred.

Adjustment

RV1 is given the correct setting by trial and error. With the output of the transmitter aimed at D2 in the receiver from a short distance away, it should be possible to get LED1 to light up by adjusting RV1. If not, switch off both units at once and thoroughly recheck them for errors. Once LED1 can be made to light up, it is a matter of gradually moving the two units further apart and readjusting RV1, as necessary, to keep LED1 lit. This is continued until the maximum range of about seven metres is achieved.

Remember that the unit can only function properly if the infra-red radiation from the transmitter has a transparent path to D2 at the receiver. The unit is quite directional, mainly due to the built-in lens of D1, and the output of the transmitter needs to be aimed reasonably accurately at the receiver, especially when the system is used at something approaching its maximum range.

If it is necessary to control two or three cameras, a separate receiver unit for each one must be used. However, C10 in each unit must be given a slightly different value (15nF, 22nF, and 33nF are suitable). A separate transmitter circuit can be used for each receiver, housed in a single case and powered from the same battery. C2 in each transmitter would have the same value as C10 in the receiver unit it is to activate. It would be possible to have a single transmitter circuit with a switched operating frequency, but this would not give the option of firing two or three cameras simultaneously. **ETI**

"Special this week only – our Jacketed Wire comes with two pairs of pants."

EXPERIMENTER'S CORNER

By Forrest M. Mims

A Single-Channel Infrared Remote-Control System

NEAR-INFRARED radiation is well suited for use as a carrier of trigger signals in miniature remote-control applications. No governmental rules or regulations apply to remote-control systems triggered by radiation from near-infrared emitting diodes. Such systems are less susceptible to false signals than similar systems using ultrasonic sound. Furthermore, infrared transmitters can be very compact in size.

However, a 100-mW radio remote-control system does have some advantages. For instance, it can broadcast through obstacles such as foliage, haze, and walls; and its omnidirectional range may easily exceed a city block. Though near-infrared cannot penetrate such obstacles, the use of small lenses at the transmitter and receiver can extend the range of the system to many hundreds of feet. In some applications the pointing problems associated with the narrow beam of such a system are a distinct disadvantage. In applications requiring a high degree of security, however, a narrow beam can be a major asset.

In most cases, radio edges out near-infrared long-range remote-control systems. Infrared, however, can be the clear winner in applications where the distance is under a few tens of feet. Typical applications include remote-controlled garage door openers, TV sets, toys, lamps, and various other devices and appliances.

Single-Channel Remote Control Systems. There are several approaches to single-channel remote control. The most common is the analog of the momentary-contact, push-button switch. The controlled device is actuated only when the transmitted signal is being received. When the transmitted signal is absent, the controlled device is no longer actuated.

Another, less common approach resembles the mechanical push on/push off switch. In this method the controlled device is actuated when a signal, however brief, is received. It remains actuated until another signal pulse is received.

For the purpose of this column, let's designate the first remote-control method Actuated when Pushed or AP for short. We'll call the second method Push On/Push Off or simply PO/PO.

Figure 1 illustrates in block diagram form how both these methods can be implemented. Note that both systems can use the same tone-modulated transmitter. Also note the receivers for both methods share a common detection-preamplification-tone decoding front end.

A simple power amplifier that drives a relay, lamp, or other device completes the receiver that uses the AP approach. The PO/PO receiver requirements are more complex since false signals from inadvertent mutiple input signals must be ignored. This problem is analogous to the well-known contact bounce phenomenon that accompanies the opening and closing of most mechanical switches.

Referring again to Fig. 1, the output from the tone decoder is fed into a one-shot multivibrator that effectively stretches the incoming tone burst from the transmitter into a logic pulse having a duration of several seconds. This pulse sets the flip-flop.

During its timing cycle, the one-shot ignores subsequent input signals from the transmitter. When the timing cycle is complete, the one shot will trigger on the next arriving pulse and, in turn, reset the flip-flop. The set-reset cycle of the flip-flop provides the desired PO/PO action.

Tone-Modulated Transmitters. Figure 2 shows a simple tone-modulated, near-infrared transmitter suitable for short-range, remote-control applications. When *S1* is pressed, *LED1* emits a train of pulses at a frequency determined by *R1*'s setting.

Resistor *R3* limits the current through LED1. Its resistance can be reduced for more current per pulse, hence higher infrared output, as long as the LED's peak current rating is not exceeded. If the LED's forward voltage is 1.5 V, a value typical of some gallium-arsenide devices, then the peak current is given by

$$I = (V_{in} - 1.5) / (R3 + R_{DS})$$

where V_{in} is the power supply voltage and R_{DS} is the drain-source *on* resistance of *Q1*.

The R_{DS} of the VN10KM specified in Fig. 2 is about 5 ohms. Therefore, the peak current through LED1 in Fig 2 is (9-1.5)/(100+5) or 71 mA. This is *well* within the safe operating range for pulsed operation of most near-infrared LEDs. Many LEDs can be driven to a couple of amperes by microsecond pulses as long as a high duty cycle is avoided to prevent excessive heating.

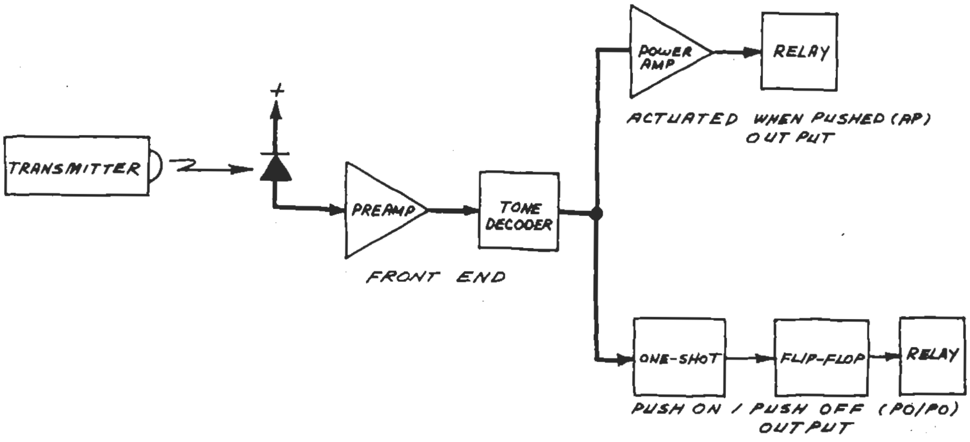


Fig. 1. Block diagram of a single-channel remote-control system.

Incidentally, a CMOS 7555 timer can be substituted for the 555. Similarly, a 2N2222 or similar npn driver transistor can be substituted directly for the VN10KM power FET. Connect the base to pin 3 of the 555, the collector to *R3* and the emitter to the anode of *LED1*.

Figure 3 shows an alternative transmitter you may wish to

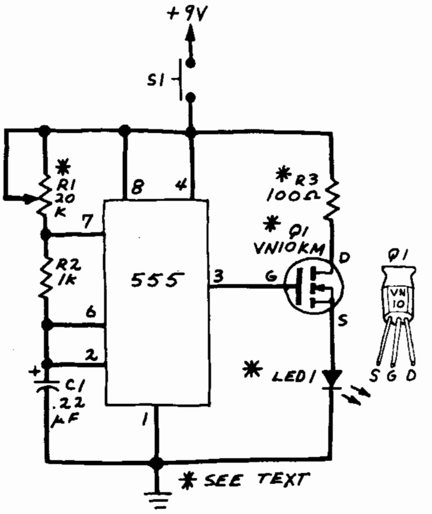


Fig. 2. Infrared remote-control transmitter.

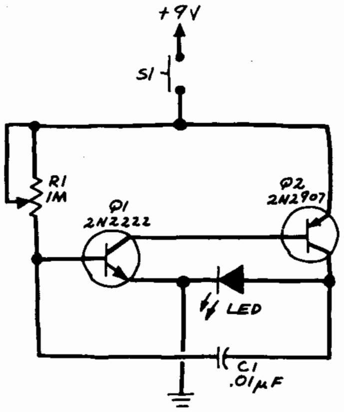


Fig. 3. Alternative infrared transmitter.

construct. (Regular readers of this column may recall this circuit from previous columns.) It's exceptionally efficient and will easily deliver 1.1-A pulses to the LED. It may not be as reliable, however, and it may consume excessive current. For additional details, refer to the "Project of the Month" in the July 1979 issue of POPULAR ELECTRONICS.

A Single-Channel Receiver. The receiver whose circuit is shown in Fig. 4 will provide both AP and PO/PO operation when triggered by either of the near-infrared transmitters described above. The circuit is reasonably sensitive and will not trigger in the presence of line-powered, hence 60-Hz modulated, incandescent and fluorescent lamps.

For example, a tungsten desk lamp placed within a few millimeters of the circuit's photodiode failed to trigger the circuit. Also, the full flash from a Vivitar 283 photographic strobe unit placed 15 cm from the photodiode also failed to initiate a false trigger. However, flashing the strobe closer to the photodiode did cause a false trigger.

In operation, near-infrared from the transmitter is detected by reverse-biased photodiode *D1*. The resultant photocurrent is then amplified by an LM308 op-amp connected as a high-gain, current-to-voltage converter. The amplified signal is coupled via *C3* into a 567 tone decoder tuned to a center frequency of about 3 kHz.

When the 567 receives an in-band signal, pin 8 goes low.

This turns on *LED1* and provides an AP output signal that can be used to drive a small relay or turn on a transistor. In Fig. 4, however, the signal from pin 8 is used to trigger a CMOS 4528 one-shot multivibrator. The 4528 then issues an output pulse that turns on *LED2* and sets the 4027 flip-flop. The flip-flop's Q output then turns on *LED3* and *Q1*, which, in turn, pulls in relay *K1*.

The time delay provided by the 4528 is determined by *R6* and *C7*, either or both of which may be increased to further stretch the incoming tone burst into a longer logic pulse. The values in Fig. 4 give a timing interval of a few seconds.

To preclude triggering on switching transitions and other noise generated within the circuit, it is essential to include capacitors *C8* and *C9*. Both should be placed as close as possible to the 567 power supply pins. If false triggering occurs or if the circuit appears to operate erratically, it may be necessary to install additional 0.1-μF decoupling capacitors directly across the power supply pins of the LM308 and the two CMOS logic chips. Incidentally, be sure to ground all unused inputs of both CMOS chips. Both chips are dual versions, and floating inputs to the unused side may cause excessive current consumption, overheating, and erratic circuit operation.

The LM308 is ideally suited for this circuit. In a pinch you can substitute a 741 or other op amp, but for best results use an LM308. If you have to get it from a mail order company, you might want to buy a few extras. Use them to make low-noise, high-gain amplifiers having a high input impedance.

For best results, avoid substituting a phototransistor for *D1*. While phototransistors will work very well in subdued light, they quickly saturate in the presence of even moderate light levels.

I used a Texas Instruments TIL413 photodiode for *D1*. This low-cost photodiode, which is available from Radio Shack is equivalent in quality to photodiodes that cost considerably more. It incorporates a built-in epoxy lens designed to filter out visible radiation while transmitting near-infrared.

Testing the System. Proper operation of the receiver requires that the tone frequency of the transmitter match closely the center frequency of the receiver's 567 tone decoder. The values shown in Fig. 4 give a center frequency of about 3 kHz. If this frequency is acceptable in your application, *slowly* tune the transmitter while pointing its LED toward the receiver's photodiode.

Indicator *LED1* will flicker as you tune the transmitter through the 567's center frequency. When this occurs, carefully "tweak" the transmitter's tone frequency to give a bright, steady glow from *LED1*. Then move the transmitter LED away until *LED1 just* stops glowing. Again "tweak" the transmitter's tone frequency until *LED1* glows. This optimizes the tuning for the receiver.

The circuit should now operate as follows:

1. Initially, *LED2* glows to indicate the receiver is ready to receive a signal. *LED1* and *LED3* are off.

2. *LED1* glows when a signal is present *and* being received.

3. *LED2* turns off immediately after *LED1* turns on. Note that even the slightest flicker from *LED1* is sufficient to insure that *LED2* will be extinguished.

4. *LED3* switches on or off to indicate the status of the relay. When *LED3* is glowing, the relay is pulled in.

5. *LED2* glows again after the time delay is complete. The receiver is now ready to receive another signal.

Note that if the transmitter is pointed at *D1* for an interval longer than the time delay of the one-shot, *LED2* will turn back on to indicate the receiver is ready to receive another command. If the transmitter is still sending infrared signals to *D1* and is then moved away or turned off, the receiver will be triggered a second time. The flip-flop will then be reset, and the device just actuated will be deactuated. In other words, for true push-on/push-off operation, the transmitter should be operated for only a moment *or* used to sweep a flash of infrared pulses across *D1*.

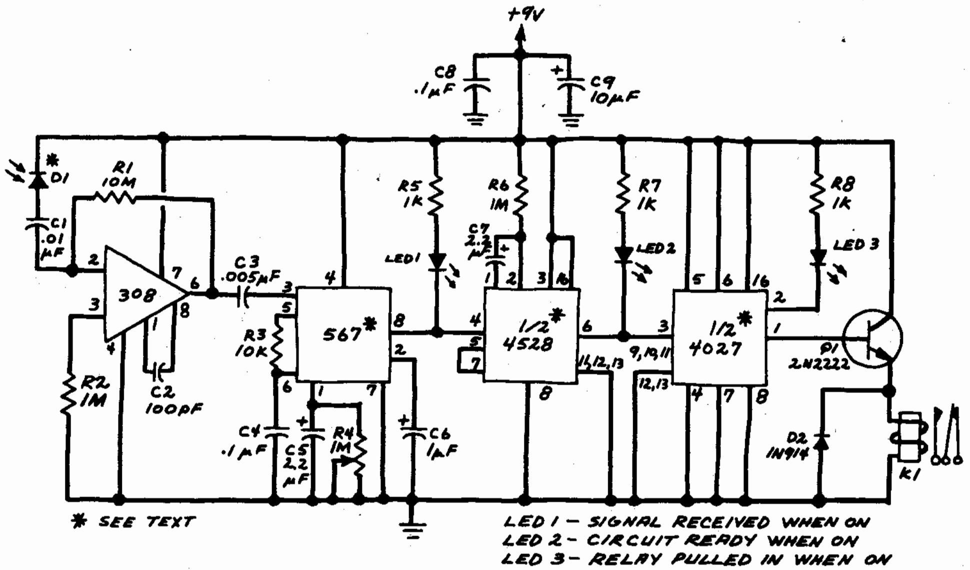


Fig. 4. Complete schematic for an infrared remote-control receiver.

If the circuit appears unreliable, the problem may be associated with properly pointing the transmitter at the receiver. For example, since the 567 requires a minimum number of pulses to acquire lock, a very brief sweep of the transmitter beam across the receiver's photodiode may *not* trigger the circuit, particularly at longer ranges. For this reason it's a good idea to stay with the 3-kHz operating frequency of the system by using the parts values given in Fig. 4.

Low battery voltage and temperature changes can also cause problems. Weak batteries, for instance, may alter the frequency of the transmitter and the center frequency of the receiver. This problem can be alleviated by making sure fresh batteries are used (alkaline batteries will provide good service). Alternately, you can design a line-powered supply or use a voltage regulator chip.

Construction Tips. *Before* building a permanent version, be sure to assemble a test version of the circuit on a solderless breadboard. This way you can test and evaluate its operation and correct any bugs. This step is important since properly tuning and operating the system can be a little tricky.

Be sure to consult the 567 data sheet/application note before attempting to make major changes in the receiver's detection frequency. For instance, the 567 may require a second or more to respond to very-low frequency signals. The data sheet/application note clearly explains this and other operating idiosyncrasies of the 567.

My system gave a range of more than eight feet without external lenses. Doubling the diameter of the photodiode's collection surface will double the range. Narrowing the beam of the transmitter with a suitable lens will give an even greater improvement in performance.

A range of hundreds of feet should be possible with patience and careful attention to detail. But make sure the system works well in the breadboard stage *before* trying such an ambitious range test. A light shield such as a hollow tube lined with black paper or coated with flat black paint might be helpful when the receiver is used in the presence of bright sunlight. Place the tube over *D1* and avoid pointing it at brightly illuminated objects and clouds. An infrared filter can also be used.

Applications. I have used this system to turn the sound of a television off when loud commercials interrupt news programs. The receiver and an external speaker box are connected to the TV's earphone jack by a short cable. This automatically disconnects the TV's internal speaker. The relay in the receiver then switches the external speaker on or off.

I plan to use this or a similar system to remotely control a toy car and a camera. You can probably think of many other applications. In any case, be sure to follow appropriate safety procedures should you use the receiver to actuate line-powered devices. You should avoid using this system in any application which might endanger people or property. For example, using it to control a garage door would require the inclusion of appropriate limit switches and other safety precautions to prevent accidents resultant from erratic operation.

Also, bear in mind the limitations of any remote control system. For example, if this system is used to control a toy boat and the boat exceeds the reception range of the system, you will have a problem. If AP operation is used, the boat will simply ignore the transmitter; if PO/PO operation is used, the boat will continue to follow the last command it received. ◊

Drawing Board

ROBERT GROSSBLATT,
CIRCUITS EDITOR

A remote-control system

IF YOU'RE A REGULAR READER OF THIS column, there's one thing you should realize by now—I'm a firm believer in a systematic approach to design. A sure road to brain damage is trying to design something without analyzing the problem first. The subject we're going to start discussing this month—remote control—is one that requires a systematic approach. There's just no way of doing a sucessful design without planning the whole system out on paper beforehand.

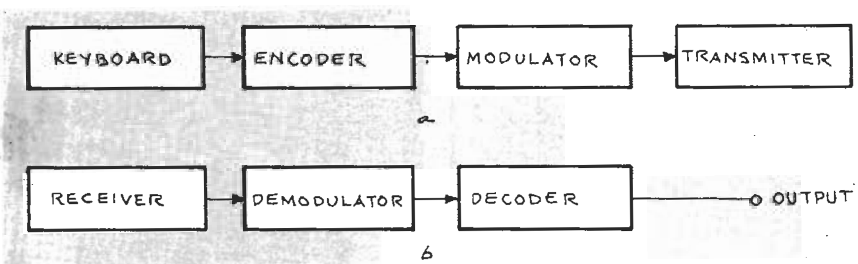


FIG. 1

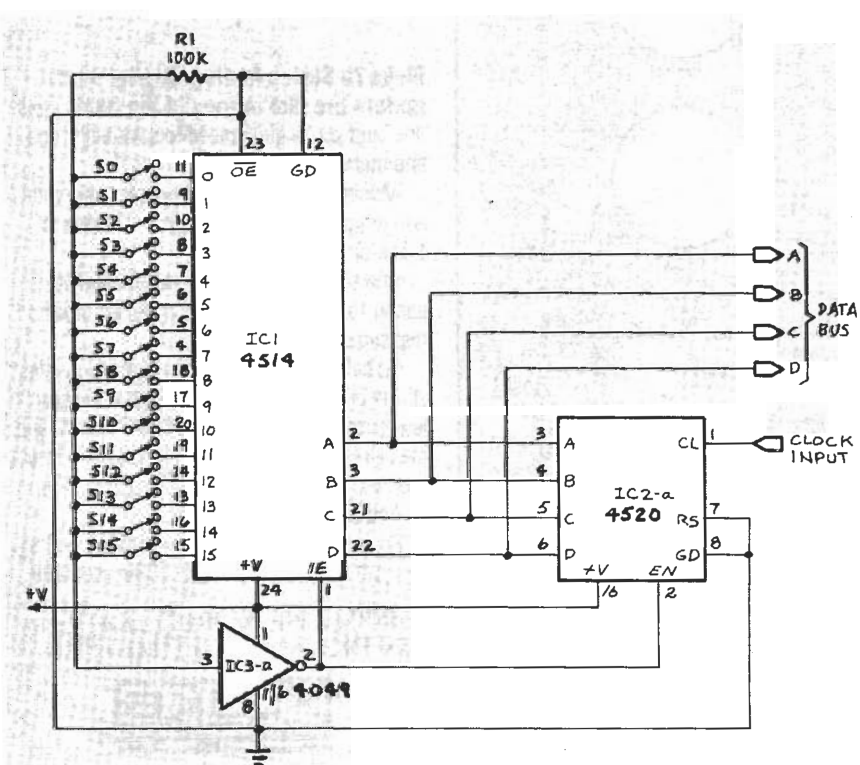


FIG. 2

A remote-control system is more complex than many of the other circuits we've looked at in this column. The degree of complexity is, of course, directly related to how much you want the circuit to do for you. But even if you only want your remote controller to switch your TV on and off from your armchair, the first step is to list the overall specifications of your control system. Our system's specifications are as follows:

1. The transmitter will be battery powered.

2. The transmission medium will be infrared light.

3. The circuit will be able to control at least 10 devices.

4. Standard parts will be used wherever possible.

5. The receiver will be as noise-immune as possible.

If you think about those specifications for a moment, you'll see that the remote-control system is really a combination of two different circuits, each of which has several subsections. The two main sections are the transmitter, shown in Fig. 1-*a*, and the receiver, shown in Fig. 1-*b*. Each of the main sections is a complete circuit in itself, and each must be designed separately before the whole thing can be assembled. But before we can even start thinking about putting the electronics together, we must get an overview of the system's operation.

Keyboard and encoder circuits are nothing new. We've designed them several times in past columns. Basically, we're looking for something that will translate a keypress into a unique binary code and place that code on a data bus.

After the code has been generated, we must modulate it before we send it on to the transmitter. The modulator (and the corresponding demodulator in the receiver) are both new circuits in this column.

The modulator must take the data from the keyboard and convert it to whatever is needed by our transmission circuitry. There are many schemes for accomplishing that. For example, the data can be encoded as FSK (*F*requency-*S*hift *K*eying), AM (*A*mplitude *M*odulation), or DTMF (*D*ual *T*one *M*ulti-*F*requency). We all know the latter from its use in *Touch-Tone* dialing.

After the data has been converted by the modulator, it is passed on to the transmitter. For a transmission medium we could use anything from a pair of twisted wires to ultrasonic sound, but we'll use infrared light. When we begin that part of the design, you'll see that it's very easy to change from one transmission medium to another. I'm using infrared because ultrasonic waves make my teeth hurt.

At the receiving end, the signal is detected, conditioned, and then passed on to the demodulator where it is converted back to its original binary form. Then the decoder turns on the selected output.

Now that we have an overall idea of how the circuit works, let's get started by looking at the transmitter's keyboard encoder.

From keypress to code

Figure 2 shows the schematic of the keyboard encoder we'll use for our remote-control system. The 4514 is a 4- to 16-line decoder with normally low outputs. When a 4-bit binary word is presented at its A–D inputs, the corresponding decoded 0–15 output goes high. Pin 1 is an active-high input enable (IE), and pin 23 is an active-low output enable ($\overline{\text{OE}}$) control. In normal operation, pin 1 must be high and pin 23 must be low. The 4520 is a dual synchronous 4-bit binary counter. We've used it so often that you should be able to recite its pinout in your sleep.

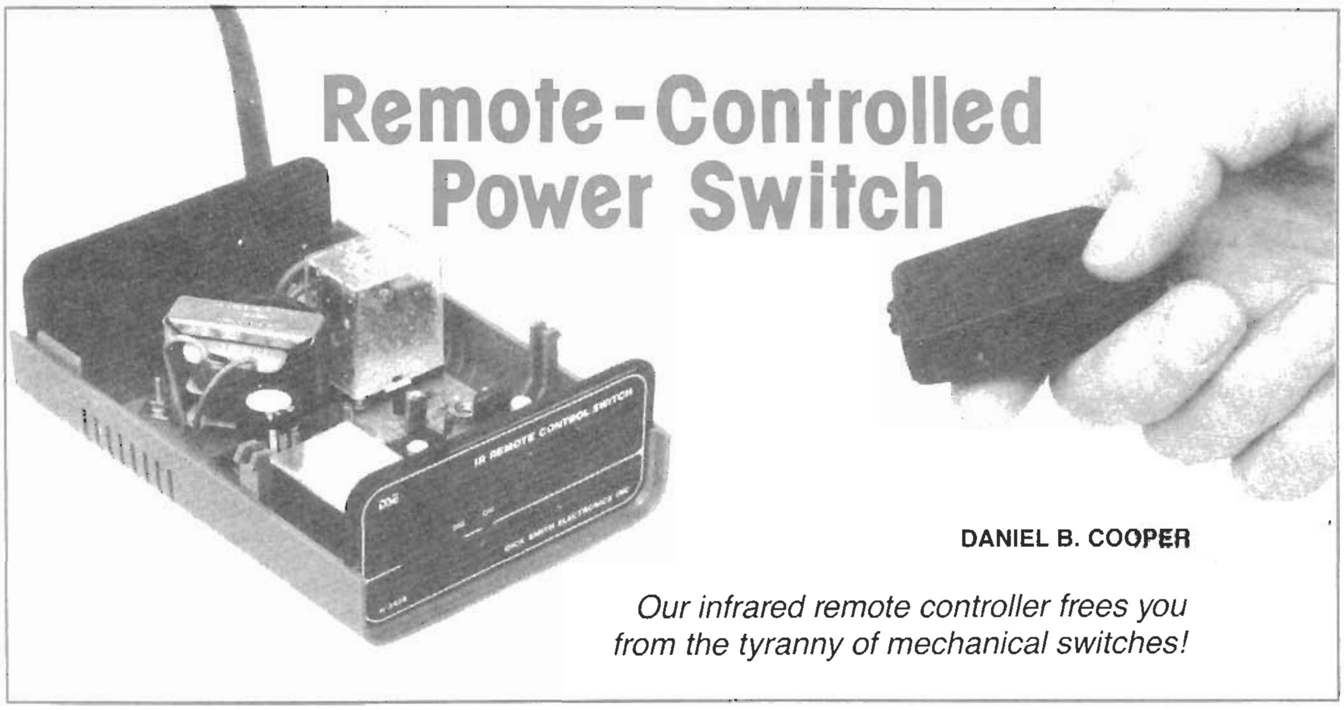
The operation of the keyboard circuit is straightforward. One of the 4520's counters is fed with a clock that causes the counter to cycle through its full 4-bit count (0 to 15) repetitively. The binary inputs of the 4514 are tied to the 4520's outputs, thereby causing its 16 outputs to go high one at a time in turn. Because $\overline{\text{OE}}$ (pin 23) is tied to ground, the 4514's outputs are always enabled. The INPUT ENABLE (pin 1), however, is connected to the common terminal of switches S1–S16 through an inverter. As long as no key is pressed, resistor R1 holds that point low, so the output of the inverter is high, so the 4514 continues to cycle through its various states.

When a key is pressed, however, the outputs continue to cycle until the output corresponding to that key goes high. When that happens, the inverter's input goes high, so its output goes low. That disables the 4514 and the 4520. Therefore, the binary output of the 4520 is frozen on the data bus.

There is one special feature of the circuit that's not immediately apparent. You'll notice that nothing is done to debounce the switches. If you trace through the operation of the circuit carefully, you'll see that it's not necessary—the circuit is inherently bounce-free. If we happen to produce a bounce when the switch is closed, all that happens is that the inputs stay enabled and the 4514 continues to cycle through another full count. But by using the output of the inverter to strobe data into the following stage (which is what we'll do next time), we can ignore the additional pulses.

To see how the circuit works, breadboard it and feed it a clock of some sort—a 555 circuit will do just fine for test purposes. If you slow the clock down to a few Hertz, you'll be able to watch the circuit operate. Slowing the clock and watching the outputs will do more to help you understand how the circuit works than ten pages of written explanations.

The next thing we must do is take the 4-bit binary code from the keyboard and encode it for transmission. But that is a subject for next time. In case you're interested we'll be using the S2579 DTMF Generator from American Microsystems Inc. **R-E**



Remote-Controlled Power Switch

DANIEL B. COOPER

Our infrared remote controller frees you from the tyranny of mechanical switches!

IT SEEMS A CRIME THAT SLEEK, SEXY stereos, VCR's and other electronic appliances must be operated by something so crude as a mechanical switch. There's really nothing wrong with a switch, but you must be within arm's reach to operate it. And when you're sitting comfortably in an easy chair and want to turn a TV, a stereo, or a lamp across the room on or off, it's mighty inconvenient to have to stand up, walk over to the device, and flip its switch.

Of course, if you're fortunate enough to own a remote-controlled TV or stereo, then you're *partly* free of the tyranny of mechanical switches. But what about radios, lamps, and the myriad of other devices that must be operated manually?

We've got the solution. The easy-to-build IR (*I*nfra-*R*ed) control system described here can be built for under $40. You can then control any device that draws as much as 1500 watts of power. The device can be 30 or more feet away.

Our controller consists of a *very* small (2 × 1½ by ½ inches) battery-powered transmitter and an AC-powered receiver that measures only 5½ × 3½ × 1½ inches. To use the controller, just plug the receiver into a wall outlet near the device you want to control, and then plug that device into the receiver. Then use the hand-held transmitter to turn the device on and off at your convenience. That's all there is to it!

How it works

The schematic diagram of the transmitter is shown in Fig. 1. As you can see, the transmitter is built around two CMOS 555 timer IC's (TLC555's). The TLC555 is quite similar to its bipolar cousin, but it requires less than 100 μA of supply current, and that's important when a circuit must be powered from a very small battery, as our transmitter is.

The transmitter generates a modulated 35-kHz IR signal. The 35-kHz carrier frequency is generated by IC2, and the 1500-Hz modulating signal is generated by IC1. The 1500-Hz output of IC1 appears as in Fig. 2-*a*; the modulated output of IC2 appears as in Fig. 2-*b*. An expanded view of each spike in that waveform is shown in Fig. 2-*c*.

The output of IC2 drives LED1 through resistor R5; that LED provides visual indication that the transmitter is working. In addition, IC2 drives transistor Q1, which in turn drives the two infrared LED's (LED2 and LED3).

The transmitter is powered by a miniature 12-volt battery, which is sometimes called a "lighter" battery from its use in electronically-ignited cigarette lighters. Although the battery supplies sufficient voltage for the circuit and is small enough to fit in a tiny case, it cannot directly source the high current needed to drive the two IR LED's. To provide that current, we pre-charge capacitor C6 and then dump all the charge it contains when S1 is pressed. When S1 is not pressed, power to the IC's is cut off. However, C6 is kept charged via R8. Then, when S1 is pressed, the current stored in C6 can be used to drive the LED's for as much as ½ second. That's plenty of time for the receiver to pick up a signal.

When C6's charge is exhausted, the

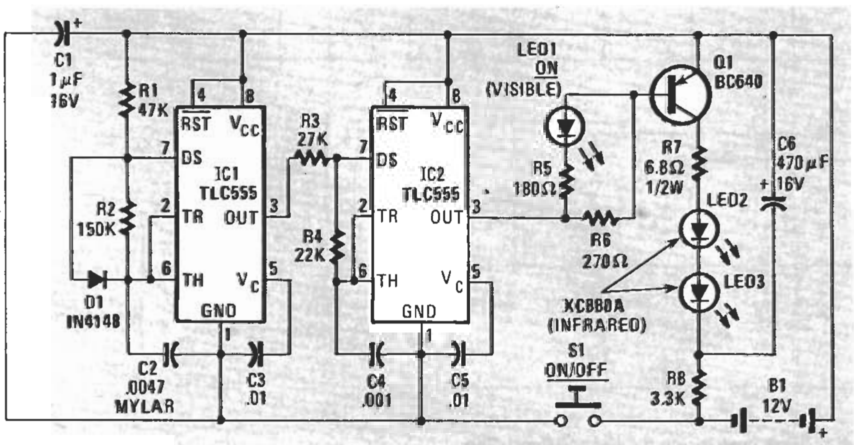


FIG. 1—THE TRANSMITTER IS BUILT AROUND TWO CMOS 555's that generate a modulated 35-kHz signal; that signal is transmitted by the two infrared LED's, LED2 and LED3.

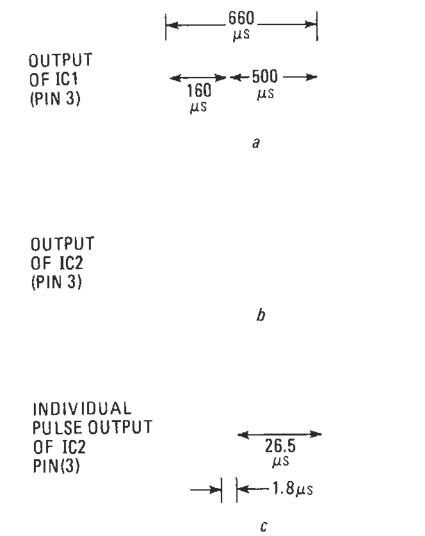


FIG. 2—THE 1500-Hz MODULATING SIGNAL is shown in *a*; the modulated 35-kHz carrier signal is shown in *b*; and one cycle of the 35-kHz bursts is shown in *c*.

output of the LED's drops to about one-third of their peak power. When S1 is released, C6 begins to recharge; it reaches 90% of capacity in about one second, and full capacity in five to six seconds.

At distances under ten feet, that charge time will be of no consequence because, at that distance, the receiver can pick up the reduced signal. At greater distances, though, it may be impossible for the receiver to respond twice in a very short period of time—less than about a second. But you should have no trouble if you wait for several seconds between each use of the transmitter.

The receiver

It is relatively easy to design an IR remote-control system, but most simple designs are hampered by either low sensitivity or high susceptibility to noise. The outstanding feature of our receiver is its high-sensitivity, low-noise input preamplifier, which is built around an μPC1373 IR remote-control preamplifier (IC1 in Fig. 3).

The IC is contained in an eight-pin SIP (*S*ingle *I*nline *P*ackage), and it incorporates circuitry that not only conditions a signal from a photodiode, but also varies the bias on the diode to accommodate changing lighting conditions. The μPC1373 also has a sensitive 30–40 kHz tuned detector, automatic gain control, a peak detector, and an output waveshaping buffer.

All that circuitry allows the the weak signal picked up from photodiode D2 to be output as a clean, logic-level demodulated signal; that signal is, in fact, an exact replica of the signal produced by IC1 in the transmitter!

The preamp stage is very sensitive to various forms of noise and RF interference, so, for maximum accuracy, the entire preamp circuit should be shielded and bypassed. Our PC-board layout, discussed below, has been optimized for low-noise performance.

The demodulated signal from the preamp stage is sent to IC4-a, a 74C14 Schmitt trigger. The squared-up 1500-Hz signal is then sent to the clock input of IC5-a, half of a 4013 dual "D" flip-flop. The flip-flop is configured as a binary divider, so the frequency of its output signal is exactly half the frequency of its input signal, but it has a duty cycle of exactly 50%.

That 750-Hz signal is clipped to approximately 0.7 volts p-p by diodes D3 and D4. The clipped signal is then fed to IC6, a 567 tone decoder. The output of that IC goes low whenever the frequency of the signal fed to it is within its lock range—the range of frequencies within which the IC will respond—of its internal VCO (*V*oltage-*C*ontrolled *O*scillator).

The center of the VCO's lock range is set by components R16, R17, and C17. The trimmer potentiometer (R16) allows

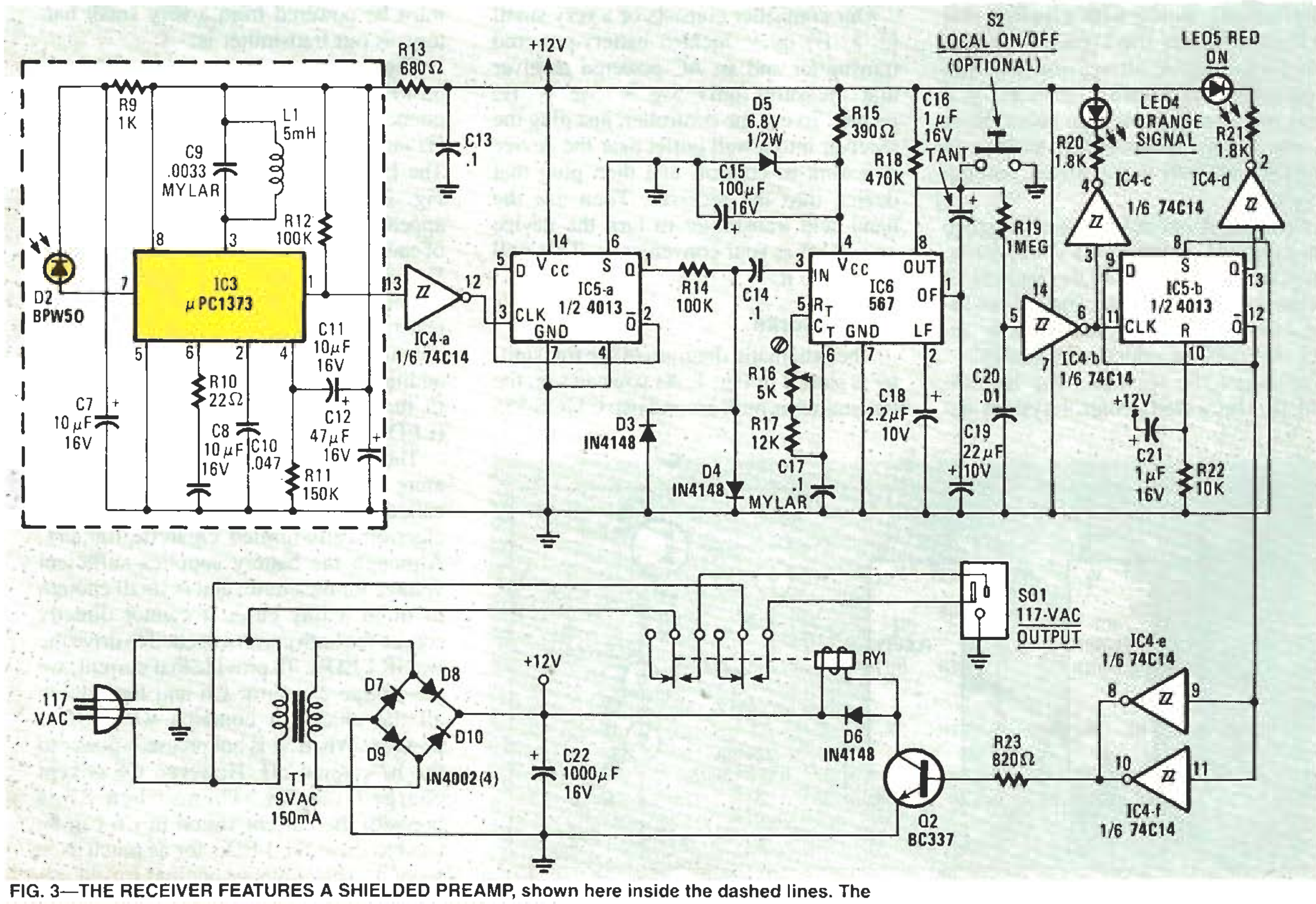


FIG. 3—THE RECEIVER FEATURES A SHIELDED PREAMP, shown here inside the dashed lines. The output of the preamp is squared up and fed to a PLL tone-decoder (IC6); the output of the PLL is fed through a bi-stable latch (IC5-b), which provides the ON/OFF function.

you to vary the center frequency to match the output of your transmitter. The lock range of the VCO is set by C18. We use a 2.2 μF capacitor here for a moderately narrow lock range—about 110 Hz. That provides an overall range of 750 Hz ±55 Hz. The length of time a signal of that frequency must be present to obtain output is set by capacitor C19; the 22-μF value sets that time at about 10 ms.

When IC6 detects a signal of the proper frequency, pin 8 goes low. Since that output is an open-collector transistor, a pull-up resistor (R18) is required for proper operation. The output signal is fed through another Schmitt trigger (IC4-b), which drives another "D" flip-flop, IC5-b. That flip-flop is configured as a bistable latch; each successive input causes the output to change state.

Schmitt trigger IC4-b also drives IC4-c, which in turn drives LED4, SIGNAL, which lights up whenever a signal is received. The Q output of IC5-b drives IC4-d, which in turn drives LED5, ON, which lights up whenever the output is in the *on* state. The $\overline{Q}$ output of IC5-b drives two parallel-connected inverters, IC4-e and IC4-f; they turn transistor Q2 on when $\overline{Q}$ goes low. That transistor energizes the relay; its contacts switch the device you're controlling on and off. Diode D6 is wired across the coil of the relay to suppress the reverse spikes generated by the coil whenever it is de-energized. Without D6, Q2 might be destroyed.

Components C21 and R22 are connected to the latch's R input; they provide a power-on-reset function. In other words, they ensure that the relay will be off when power is first applied to the receiver. At power-up, C21 is effectively a short circuit, so R is high. In that reset state, the Q output of the flip-flop is low, the $\overline{Q}$ output is high, so Q2 and the relay are off. But, as C21 charges through R22, the voltage across C21 increases, and eventually the R input drops to ground and allows the IC to respond to input signals.

We have made provision for an optional LOCAL ON/OFF switch, S2. Since the 567 has an open-collector output, S2 can be used to force the inverter's input low and thus alternate the state of the latch without damaging the 567.

The receiver is powered by a nine-volt, 150-mA transformer that delivers about 12-volts DC after rectification by diodes D7–D10 and filtering by C22. Since most of the receiver circuit is voltage-independent, no regulator is used. However, the 567 requires a supply voltage less than nine volts. Therefore, resistor R15, capacitor C15, and Zener diode D5 are used to provide a regulated, filtered 6.8-volt DC source.

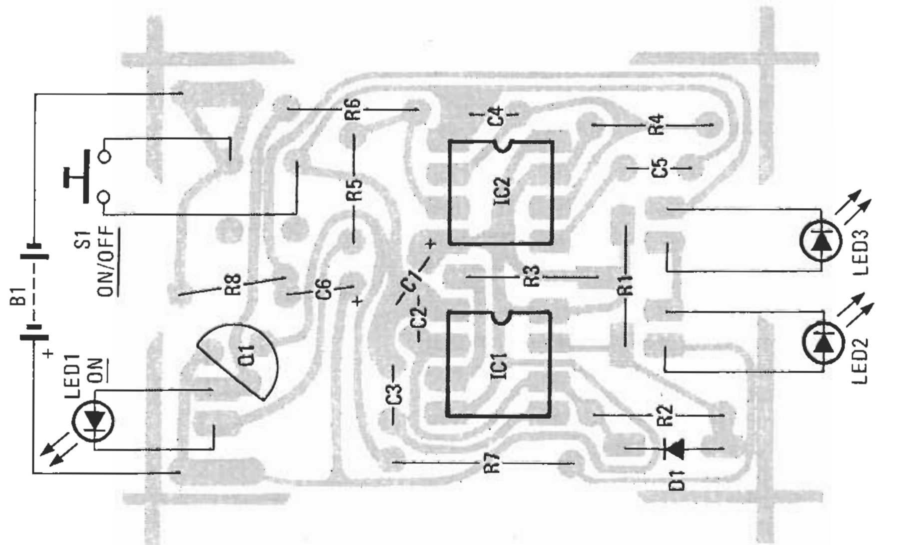


FIG. 4—COMPONENTS MOUNT ON THE TRANSMITTER BOARD as shown here.

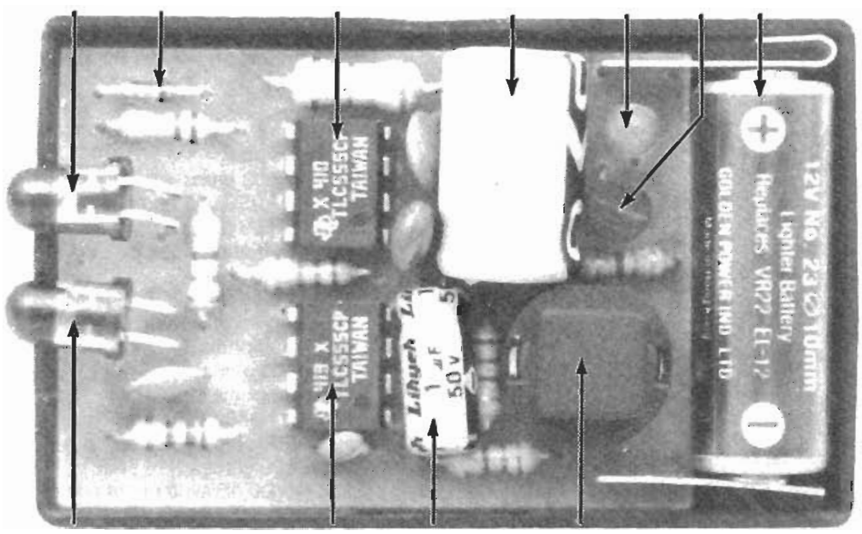


FIG. 5—THE COMPLETED TRANSMITTER appears as shown here. The legs of the electrolytic capacitors (C1 and C6) must be bent horizontally for those capacitors to fit in the case.

Construction

We recommend that you use PC boards, especially for the receiver, as the performance of its preamp can be degraded by improper layout. You can etch your own boards using the foil patterns shown in PC Service; pre-etched boards are included with the kits sold by the source mentioned in the Parts List.

When your boards are etched, inspect them for shorts and opens. Correct any problems and clean the boards with steel wool. Now build the transmitter. Install all components except the battery clips and the three LED's according to the diagram in Fig. 4. Take care to orient the capacitors, the IC's, D1, and Q1 correctly. As you can see in Fig. 5, the leads of C1 and C6 must be bent at a right angle: the capacitors are then mounted horizontally. The flat edge of S1 should face Q1.

Next solder the battery clips to the board. The bump on the negative clip should face inward, and the hook on the positive clip should face outward. Now insert LED1 into its holes with the flat side toward the positive battery clip, but do not solder it in place yet. Lay the PC board in the top half of the case, adjust the position of the LED to line up with its mounting hole, and then solder the LED in place.

Now insert the two IR LED's (LED2 and LED3) into their holes with their flat sides toward the side of the board the negative battery clip is mounted on. Solder them in place about ⅜ inch above the surface of the PC board. Carefully bend their leads so that they are parallel with the board and with each other, and so that the center of each LED is about 5/16 inch above the surface of the board.

Lay the board in the lower half of the case and carefully mark where the center of each LED touches the front edge of the case. Remove the board and use a small rattail file or a similar tool to cut out a precise half-circle for each LED. Check your progress often to avoid overcutting.

Snap both halves of the case together without the board in place and mark where the edges of the holes meet the upper half of the case. Take the case apart and carefully file out the holes in the upper half to match those in the lower half of the case.

Now lay the board in the case. Then insert B1 and press S1; LED1 should remain lit for as long as S1 is pressed. If the LED doesn't light, make sure the battery is inserted correctly. If it is, use a frequency counter or an oscilloscope to verify that both TLC555's are oscillating. If they are, make sure that LED1 is mounted correctly. If you still haven't isolated the problem, you may have installed Q1 incorrectly, or you may have installed Q2 by mistake.

When the board is debugged, complete assembly of the transmitter. Insert the board into the lower half of the case and then snap both halves together. If desired, the IR LED's can be pushed back into the case so that they do not protrude.

Building the receiver

Since the components are not so closely spaced, building the receiver is somewhat easier. Referring to Fig. 6, solder all electronic—not mechanical—components to the board, except for LED4, LED5, D2, and T1. Be careful to orient all polarized devices correctly; IC3 should be mounted with the bevel oriented toward the transformer. Don't forget to solder the jumpers in place.

Bolt T1 to the board with its secondary wires toward C22. Keeping the leads as short as possible, solder the primary and the secondary wires to the appropriate pads. To prevent shorts, ensure that all strands of each wire pass through its hole. Clip off and insulate the transformer's center tap.

Solder three 3-inch pieces of 18-gauge wire to the output pads near the relay. Connect the opposite ends of those wires to the appropriate terminals on SO1.

Now solder D2 in place with its base about ⅛ inch above the surface of the board and with the beveled corner toward the center of the board. Mount LED4 and LED5 with their flat sides facing each other; the center of each LED should be about ¼ inch above the board. The LED's will be parallel to the board and to each other if they are mounted correctly.

Now solder four thick pieces of bus wire to the four holes where the shield will mount. The shield can be bent as shown in Fig. 7 from a thin piece of tin. Also, cut a ⅞- × 1⅜-inch piece of tin plate for the bottom of the PC board. However, don't solder either shield in place until you have verified that the preamp circuit works exactly as intended.

Strip the sheath of the AC cord so that one inch of each conductor protrudes; strip, twist, and tin ¼ inch of each conductor. Pass the cord through the rear panel, insulate it with a grommet, and solder the leads to the board. Then press SO1 into the rear panel and solder the three wires to the correct terminals. Your receiver should resemble the one shown in Fig. 8.

Now insert the red plastic IR filter into the front panel so that its legs are horizon-

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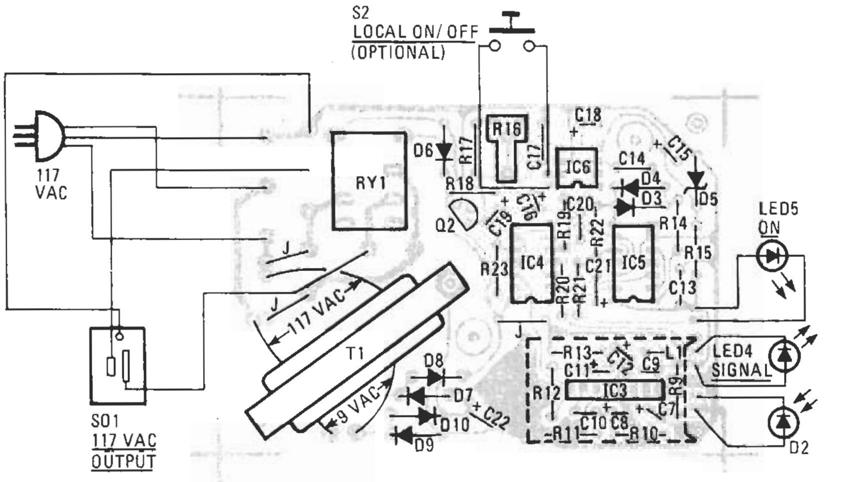

FIG. 6—COMPONENTS MOUNT ON THE RECEIVER BOARD as shown here. One shield must be soldered to each side of the board after testing confirms that the preamplifier works.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
- R1—47,000 ohms
- R2, R11—150,000 ohms
- R3—27,000 ohms
- R4—2200 ohms
- R5—180 ohms
- R6—270 ohms
- R7—6.8 ohms, ½-watt
- R8—3300 ohms
- R9—1000 ohms
- R10—22 ohms
- R12, R14—100,000 ohms
- R13—680 ohms
- R15—390 ohms
- R16—5000 ohms, trimmer potentiometer
- R17—12,000 ohms
- R18—470,000 ohms
- R19—1 megohm
- R20, R21—1800 ohms
- R22—10,000 ohms
- R23—820 ohms

Capacitors
- C1—1 µF, 16 volts, electrolytic
- C2—0.0047 µF, mylar
- C3, C5, C20—0.01 µF, ceramic disc
- C4—0.001 µF, ceramic disc
- C6—470 µF, 16 volts, electrolytic
- C7, C8, C11—10 µF, 16 volts, electrolytic
- C9—0.0033 µF, mylar
- C10—0.047 µF, ceramic disc
- C12—47 µF, 16 volts, electrolytic
- C13, C14—0.1 µF, ceramic disc
- C15—100 µF, 16 volts, electrolytic
- C16—1 µF, 16 volts, tantalum
- C17—0.1 µF, mylar
- C18—2.2 µF, 10 volts, electrolytic
- C19—22 µF, 10 volts, electrolytic
- C21—1 µF, 16 volts, electrolytic
- C22—1000 µF, 16 volts, electrolytic

Semiconductors
- IC1, IC2—TLC555, CMOS 555 timer
- IC3—µPC1373, IR photodiode preamplifier
- IC4—74C14, hex Schmitt trigger
- IC5—4013, dual "D" flip-flop
- IC6—567, tone decoder
- D1, D3, D4, D6—1N4148, signal diode
- D2—BPW50, infrared photodiode
- D5—1N5526A, 6.8-volt, 400-mW, Zener diode
- D7–D10—1N4002, rectifier diode
- LED1—visible miniature red LED
- LED2, LED3—XC880A, infrared LED
- LED4—visible miniature orange LED
- LED5—visible miniature red LED
- Q1—BC640 (ECG383)
- Q2—BC337 (ECG159)

Other components
- B1—12-volt miniature "lighter" battery
- RY1—relay, DPDT, 10-amps, 12-volts
- L1—5 mH inductor
- S1—miniature SPST momentary pushbutton
- S2—miniature SPST momentary pushbutton (optional)
- T1—9-volt, 150-mA, PC-mount transformer

Note: The following kits and components are available from Dick Smith Electronics, P. O. Box 8021, Redwood City, CA 94063: Complete receiver including all parts, case, and mounting hardware, no. K-3428, $32.00; transmitter including all parts, case, but less battery, no. K-3429, $7.95; transmitter battery, no. S-3335, $1.19; receiver case, no. H-2503, $5.95; transmitter case, no. H-2497, $1.95; $2.50; BPW-50 IR photodiode, no. Z-1956, $2.50; µPC1373 IR photodiode preamplifier, no. KZ-6174, $2.50; twelve-volt relay, no. S-7200, $4.95; nine-volt transformer, no. M-2840, $2.50. All orders must add $1.50 plus 5% of total price for shipping and handling. California residents must add 6.5% sales tax. Orders outside the U. S. must be in U. S. funds and add 15% of total price.

POWER SWITCH

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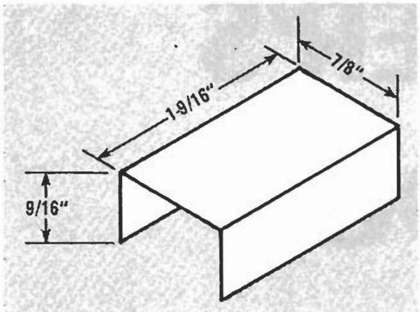


FIG. 7—CUT AND BEND THE UPPER SHIELD from a thin piece of tin as shown here.

until you get some response from the circuit. Don't worry about making an exact adjustment. The adjustment we're doing now is preliminary; the receiver must be fine-tuned to obtain maximum range of about 30 feet.

After you get a response, solder the shields in place. The easiest way to do that is to melt a small amount of solder in each corner of the shield. Then set the shield in place and heat each corner in turn to let the solder flow onto the pin.

To fine-tune the receiver, set it up in a position where you can get a clear line of sight to it for a distance of about 30 feet. Position yourself about five feet from the receiver, point the transmitter at the receiver, and press the TRANSMIT button.

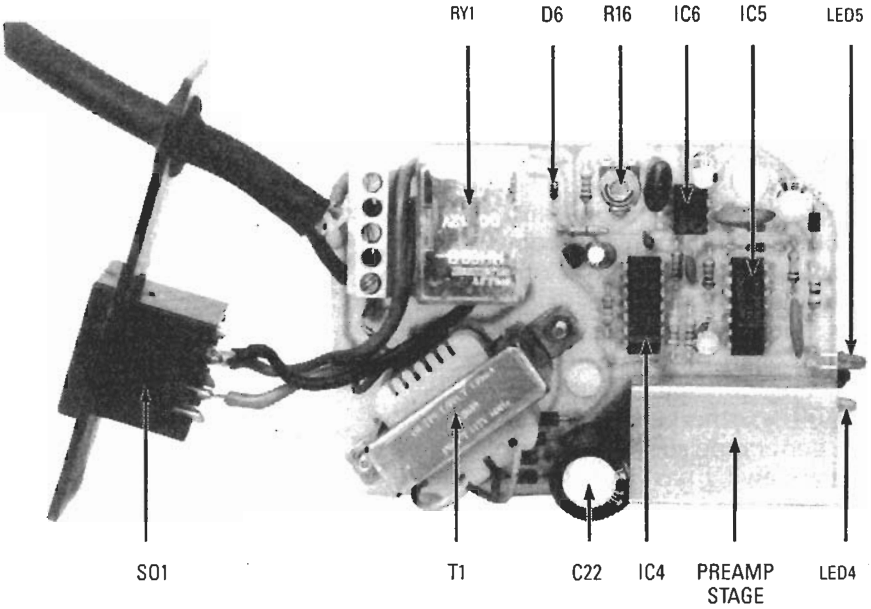


FIG. 8—THE RECEIVER'S PC BOARD should appear as shown here after all components have been mounted.

tal. Then fit the panel over the two LED's so that the legs of the filter fit around the photodiode. Insert the panel-board assembly into the bottom half of the receiver case.

Testing and alignment

Plug the receiver into an AC outlet. The SIGNAL LED should light briefly and then go out, and the ON LED should remain off. Set trimmer potentiometer R16 to the center of its range.

Now aim the transmitter at the photodiode and press S1. With a little luck, the center frequency of the 567 will be close enough to the transmitter's output frequency that the SIGNAL LED will light up temporarily. The ON LED should light up and stay lit, and the relay should latch on. A second press of the button will turn the LED and the relay off—that is, of course, only if you're lucky.

If the receiver doesn't respond, adjust R16 slightly and try again. Repeat that

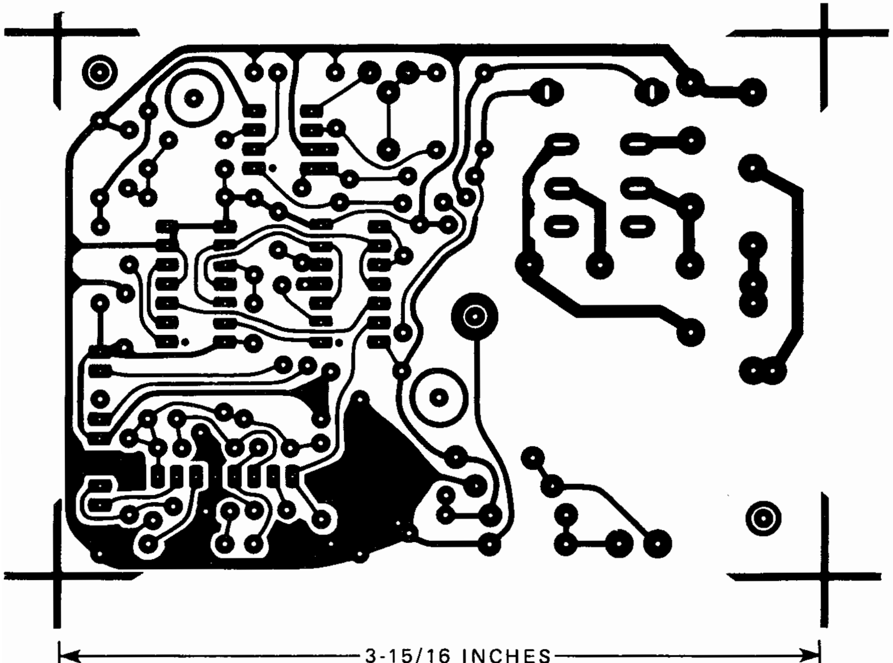
If the receiver responds, back up another five feet and try again. Remember to let the transmitter recharge for a few seconds between transmissions, particularly when you're standing back at distances of ten feet or more.

Continue backing up in five-foot segments until you reach a point where the receiver will not respond. At that point, adjust R8 slightly and try again. An assistant to handle the transmitter would be helpful.

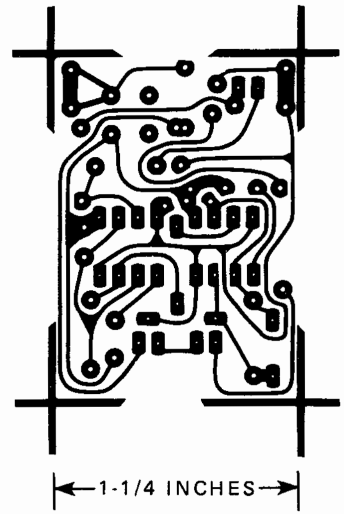
Even under worst-case conditions, the receiver should be able to respond when the transmitter is 20 feet away. If you can adjust it to respond to signals only up to a certain distance but no farther, your problem is likely due to overly bright lighting, electrical or RF noise, or something else. Don't blame the receiver!

Assemble the case and plug the device you want to control in. You're now free to operate that device at your convenience, free from the tyranny of its switch! **R-E**

PC SERVICE



FREE YOURSELF from the tyranny of mechanical switches with our IR remote switch. The PC pattern for the receiver sectio...



PC PATTERN for the IR remote switch's hand-held transmitter

HARDWARE HACKER

Remote controls
Infrared receivers
A new A/D converter
New data book resources
Analog computer interfacing

Remote controls and a great A/D converter!

DON LANCASTER

WE WILL START OUT WITH OUR USUAL reminder that this is your column and that you can get both technical help and off-the-wall networking by calling the Guru hisself per the "Need Help?" box. The best calling times are during weekdays, 8–5, mountain standard time.

Also as is usual, I have gathered pretty near every source mentioned here into a common "Names and Numbers" table. Several of those addresses are where you go to get more info or to follow up on any specific product.

Let us see. I have now found yet another low-cost source for those data-access arrangement telephone transformers that we looked at last month. Do check out the Tamura model *TTC-142*. They're available for under a dollar in very large quantities.

The developments in superconductivity continue at an astonishing pace. By switching to materials made of aluminum, barium, and the thallium used in rat poison, the critical temperatures have now been raised another 30 degrees to 120 Kelvin. Which is now halfway up to dry-ice temperature.

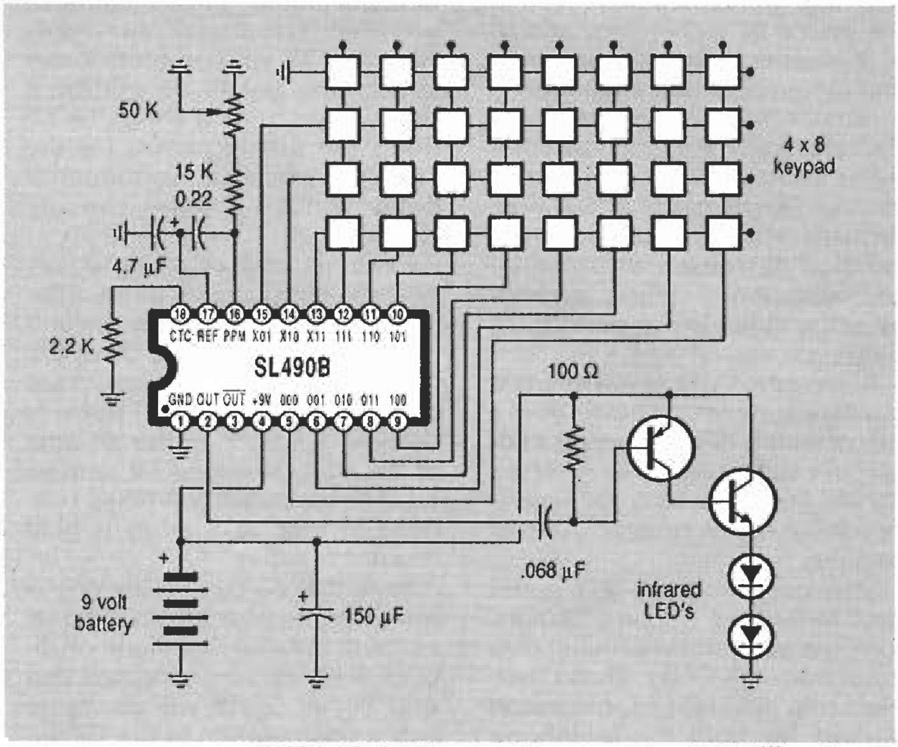


FIG. 1—A HANDHELD REMOTE-CONTROL transmitter can send up to 32 different commands. Each command outputs a repeating code of six brief light pulses.

The new materials are also much cheaper and more stable. It does remain to be seen whether their current densities will end up high enough for real-world uses.

One very good source of most superconductor info is *Science* magazine, which is published by the American Association for the Advancement of Science, and is available at most larger libraries. Those 120-K superconductors are detailed in the February 16 issue.

There's also a very interesting tutorial on free-electron lasers in the March 4, 1988 *Science*; and the first details on what probably is the final elusive proof to Fermat's last theorem (a classic and infuriatingly subtle math problem) are found in their March 18 copy.

Onward and upward...

Remote controls

There sure is a lot of help-line interest lately in remote-control circuits. All you **Radio-Electronics** hackers are now trying to remote-control everything from HO-gauge trains through hi-fi audio, home entertainment, to commanding an amazing assortment of robotics, aides for the handicapped, on up to industrial-process controls and even full-size racing cars.

NEED HELP?

Phone or write your **Hardware Hacker** questions directly to:
Don Lancaster
Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

It turns out that there is no "best" or even a "standard" way of handling any remote-control problem, nor is there one single circuit that will do all things for all people. It depends on what you are remote-controlling over what channel, how reliable the control has to be, how many others are using the same channel, the amount of security required, the available power, what types of outputs you need, etc...

The popular carriers for remote control do include tones over the phone line; fiber optics; radio links including ham and CB; sonic and ultrasonic sound; both regular and infrared light; the AC power-line RF techniques; and all of those usual computer networks and serial ASCII data channels.

Most remote controls these days are digital, and often are computer controlled. Any analog or varying signals (such as audio or the flaps on a R/C model plane) are handled by some sort of digital communication scheme, perhaps by using either pulse position or duty-cycle modulation.

At any rate, I've just run into two outstanding free data books from a pair of widely different integrated-circuit manufacturers. They should keep you busy for several years' worth of remote-control hacking.

Start out with the bright green new *Integrated Circuit Solutions for Communications* product data book from MX-COM. Those people build specialized integrated circuits for both the telephone and radio communications trade. The typical single-quantity chip prices are in the $10–25 range.

Some of their more interesting devices include the *MX204* speech scrambler, their brand new *MX403* selective calling transponder, the *MX315* tone-controlled squelch circuit, and their *MX205* digital tone-generator chip.

Then, check into that magenta *Satellite, Cable and TV Integrated Circuit Handbook* from Plessey.

There are many dozens of very interesting and low-cost circuits in that book. Once again, it will take years to fully explore all of the hacker potential of those unique chips.

As a ferinstance, we can start out with the *SL490-B* remote-control transmitter shown in Fig. 1. The intended use is for a hand-held, battery-powered infrared remote-control transmitter, as are popular with TV sets and VCR's.

The same circuit can be used with ultrasonic transducers or most any other control channel.

A total of 32 commands are available that use a five-bit pulse position modulated code. When used with infrared diodes, pulse widths of 15 microseconds are also used. The five-bit word is sent out most significant bit first.

The timing period of a digital logic "1" varies with the application, but is usually made as long as possible. Otherwise, functions such as a TV volume control may change too fast to be usable. A digital logic "0" will always be 1.5 times the timing period for the logic "1," while the word-interval delay will be 3 times the "1" period.

Each of the command sequences consist of six pulses. The first is a start pulse. The second pulse is delayed by the "1" or the "0" time of the most significant command bit. The third pulse is delayed by the "1" or the "0" time of the next command bit, and so on. The six pulse groupings continue as long as the key is held down.

Note that no current limiting is provided for the infrared-light-emitting transmitting diode or diodes. It is thus very important that your circuit layout will discharge only a small portion of the 150 microfarad capacitor charge into the output LED per pulse, and that the supply voltage to the chip itself not drop in the process.

While most any infrared LED could be used, you'll more than likely get the best results with one or two high-power, high-brightness lamps, driven by a suitable pair of high-gain, and high pulse current transistors.

The infrared output power can be increased with a mirror or else a directional reflector.

Infrared receivers and decoders

There are a number of suitable decoder chips and circuits detailed in the Plessey handbook. They vary with whether you need analog outputs for volume controls or whatever, and on whether you are in a television-receiver or a computer environment.

Figure 2 shows us an infrared preamplifier circuit that should automatically convert the received infrared pulses into some noise-free digital pulses of just the correct amplitude for further processing. A two-chip receiver is normally used, with the preamplifier receiving and cleaning up the pulses, and the separate decoder converting all the receiver code bursts into actual output commands.

The data book does include a suggested circuit layout for their *SL486* preamp. An infrared sensitive photodiode is used for the light receiver, while those capacitors provide bandpass filtering for good noise rejection.

The preamp circuit is normally placed inside a shielded case that has a plastic filter in front of it; the filter passes infrared but rejects room illumination.

This month, let's have us a double contest. Just dream up a new or unusual remote-control ap-

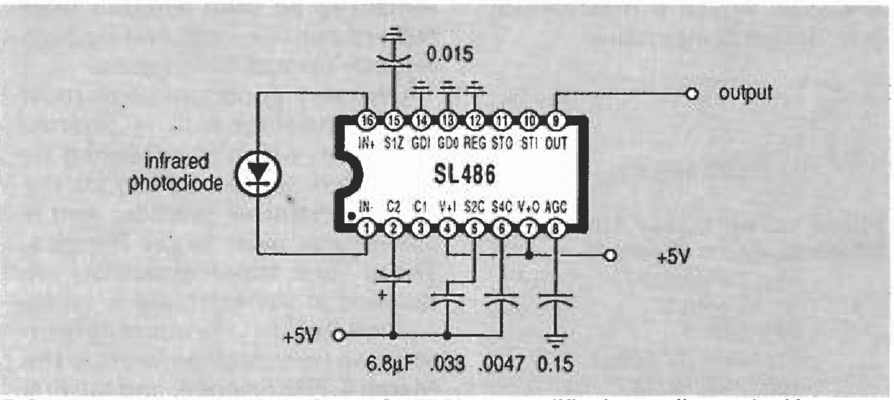


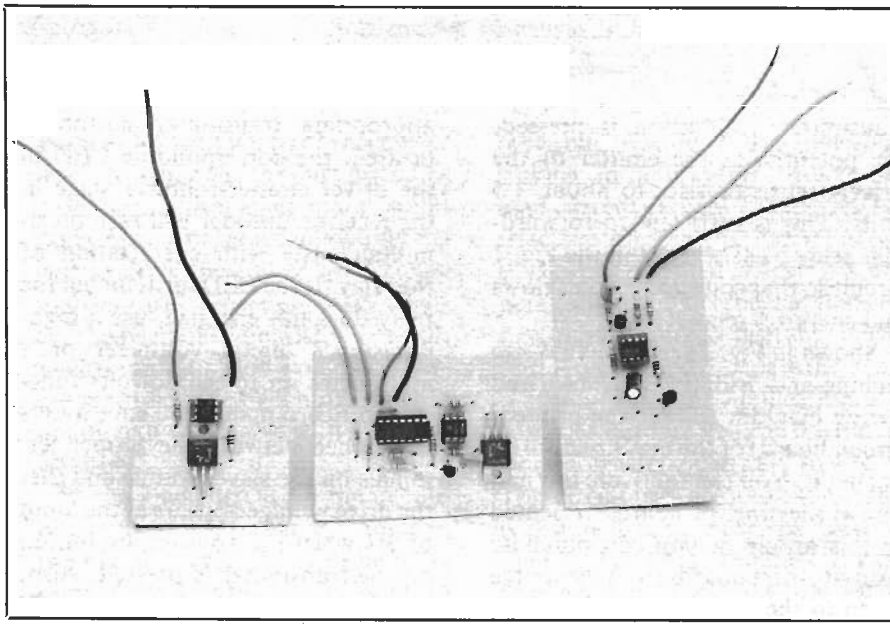
FIG. 2—AN INFRARED REMOTE-CONTROL preamplifier is usually required between your receiving photodiode and the final digital decoder circuitry.

A 6-Channel IR Remote-Control System

Part II (Conclusion)

How to build control slave modules

By Anthony J. Caristi



Last month in Part I of this series, we described a basic TV-receiver/VCR infrared remote-control system that provides on/off control of up to six separate electrically operated devices. In this concluding installment, we focus on how to build several types of slave circuits that will permit you to control virtually any type of device from the system's battery-powered, hand-held transmitter. Each of the slave circuits described here is elementary in nature and is designed to accommodate a limited or single load application. The sum of all circuits presented should satisfy most residential load requirements without any modifications or additions.

The Slave Circuits

We will deal with each slave circuit individually so that each will be a complete project package in itself. That is, we will discuss theory of operation, followed by complete construction details.

• *Simple Relay Circuit.* Figure 1 illustrates the simplest type of control circuit. It contains a common dc relay that is driven by a transistor. The single-pole, double-throw relay contacts can be used to switch power to any type of load circuit that does not exceed the 2-ampere contact rating of the relay. A readily available relay is specified in the Parts List, but you can substitute another relay that has heftier contacts if your application requires greater current. Too, if the application calls for more than one supply voltage, you can choose a relay that has a greater number of contact pairs.

The circuit shown in Fig. 1 offers momentary operation because the relay will be energized only during the time the transmitter pushbutton for the channel to which the relay is assigned is held down. Releasing the transmitter button causes the relay contacts to spring back to the unenergized position.

Power for the relay is supplied by the 9-volt output of the receiver/decoder power supply featured last month. The specified relay has a 9-volt coil. However, you can substitute a relay with a 5- or 6-volt dc coil if you connect an appropriate voltage-dropping resistor in series with its coil so that the potential applied to the coil does not exceed its dc voltage rating. Determining what value resistor to use is a simple Ohm's law calculation, once you measure the resistance of the relay coil you intend to use. You can also use a relay that has a 12-volt dc coil if it will operate reliably at 9 volts (most 12-volt relays will do this, but check to make sure before purchasing one).

Resistor *R1* connects to the emitter of one of the emitter-follower transistors *Q2* through *Q7* in the receiver/decoder. When the corresponding

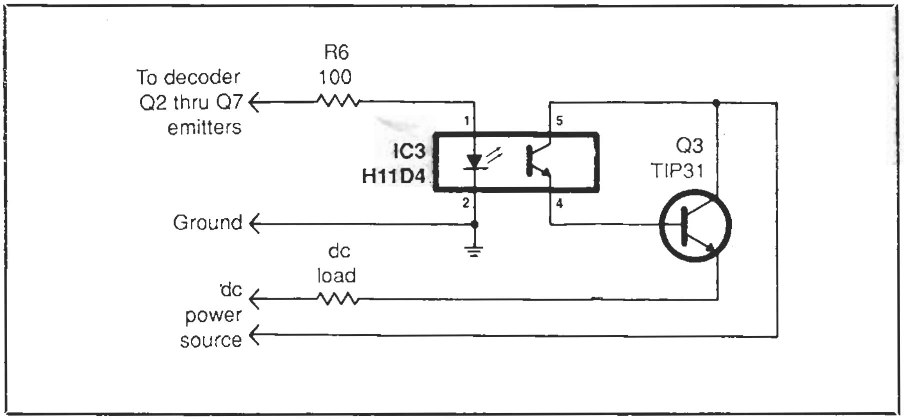


Fig. 5. This circuit controls power to a dc load using a Darlington transistor arrangement to handle up to 3 amperes of dc current.

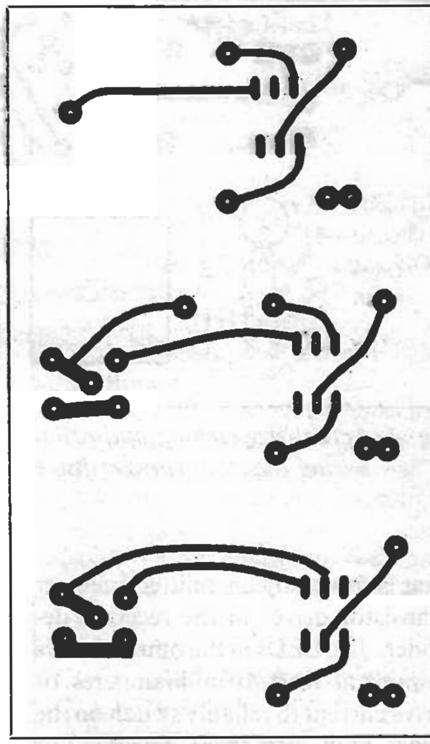


Fig. 6. Actual-size pc guides for Fig. 3 circuit (upper), Fig. 4 circuit (center) and Fig. 5 circuit (lower).

lator drives base current into *Q2*. In turn, *Q2* controls the load current, which must be 3 amperes or less if no heat sinking is used on *Q2*.

You can build the solid-state driver circuits just discussed on printed-circuit boards made using the actual-size etching-and-drilling guides given in Fig. 6. Guides (A), (B) and (C) are for the Fig. 3, Fig. 4 and Fig. 5 circuits, respectively. Wiring guides for the three pc boards are shown in Fig. 7 and are (A), (B) and (C) keyed accordingly.

When wiring these boards, make sure you install polarized components in the correct orientations. A socket is recommended for each six-pin optical isolator. Since six-pin DIP IC sockets are not readily available, you might have to cut down a standard socket that has a greater number of pins or use Molex Soldercon sockets. Also, note that *Q2* in guide (C) must be installed on the dc slave module board up-side down for correct orientation.

The optoisolator in the slave module is driven by the selected channel's emitter-follower transistor in the receive/decoder. This will require a two-conductor cable to effect the connections between the circuit-board assemblies. Be sure to observe proper connections because a reversal of these two wires will prevent the LED in the optoisolator from operating and, thus, that channel from responding to the command from the transmitter.

If you experience a problem in operating the load circuit, measure the voltage between pins 1 and 2 of the optoisolator as you hold down the appropriate transmitter pushbutton. During this test, you should obtain a reading of about 1.5 volts, which indicates that the optoisolator is being activated. If you carefully short together the output pins of the optoisolator (pins 4 and 6 of the ac module, or pins 5 and 6 of the dc module), the load should energize.

If you encounter any problems getting any module to operate properly, always begin checkout with a careful review of component installations (especially orientations in polarity- and basing-sensitive components) and soldering. Also, make sure that the decoder driver transistor circuit was modified as instructed above; if it is correct, try a new opto isolator.

• *Latched Control Circuit*. The slave circuits so far discussed are all momentary-action in nature, activating the load for only as long as the appropriate transmitter pushbutton switches are held down. If you wish to turn on or off a device with a simple push of a switch and have it remain in the condition selected even after the transmitter switch is released, you need a latching circuit. To accomplish this, two discrete controls are required—one for on and the other for off. Thus, *two* transmitting channels are needed to implement this dual function, as illustrated in Fig. 8.

Latching action is provided in Fig. 8 by a pair of NOR gates that are configured as a common bistable multivibrator or flip-flop. Such a circuit has two stable states, each depending upon the logic levels fed to the inputs of the IC at pins 1 and 6. The outputs of the gates at pins 3 and 4 always assume opposite logic levels and remain in the selected conditions until the proper input pin is driven with a logic 1 pulse.

Each input of the latching circuit is driven by its own emitter-follower stage in the receiver/decoder, such as channels A and B. Under quiescent operating conditions, when no transmitter pushbutton is pressed, the logic level at both inputs of the circuit is

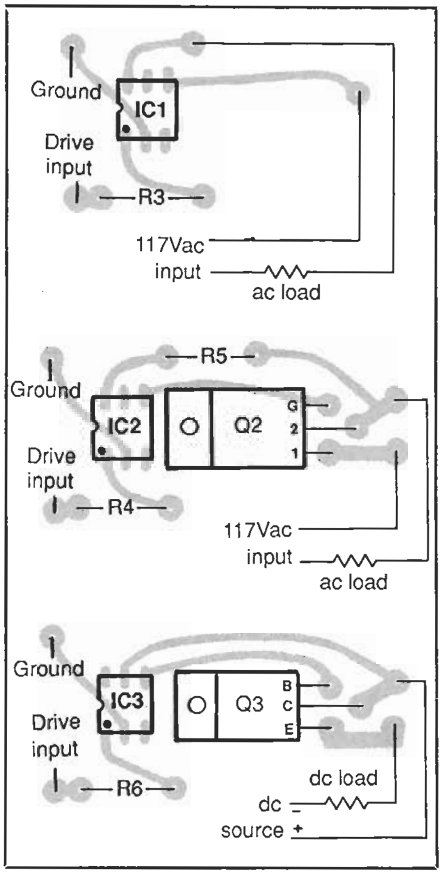


Fig. 7. Printed-circuit wiring guides for Fig. 3 circuit (upper), Fig. 4 circuit (center) and Fig. 5 circuit (lower).

0 and the flip-flop remains as it was when it was last triggered.

Assuming that the present state of the flip-flop circuit represents a logic 0 condition at pin 3 of *IC4A*, field-effect transistor *Q4* has zero bias fed to its gate, which results in no current flow between its drain (D) and source (S). This extinguishes the LED in optoisolator *IC5* and, thus, no power being delivered to the load.

When the transmitting channel that controls pin 6 of *IC4B* is activated, the resulting logic 1 level on pin 6 causes the flip-flop to toggle and output pin 4 of the gate to assume a logic 0 condition. Simultaneously, pin 3 goes to logic 1 and the circuit remains in this state even after the transmitting pushbutton is released.

The change in logic level at pin 3 of *IC4A* forward biases *Q4*, which turns on the LED in the optoisolator. A LED connected in series with the drain of *Q4* provides visual indication that the circuit is energized. The triac is switched on and completes the power feed so that current flows into the load.

In a similar manner, when the alternate transmitter pushbutton controlling pin 1 of *IC4A* is activated, the flip-flop is toggled to its opposite logic state, disconnecting power from the load. As you can see, the load can be switched on and off repeatedly as long as the transmitting pushbuttons are alternately activated.

The actual-size etching-and-drilling guide and wiring diagram for the latching circuit are shown in Fig. 9. When wiring this circuit, be sure to use sockets for the optoisolator and integrated circuit, and pay strict attention to the orientations of the polarized components. Just one component placed backwards in the circuit will prevent that channel from operating.

Power for the Fig. 8 circuit is obtained from the regulated V_{dd} dc source in the receiver/decoder. Two additional wires are needed to provide the drive signals to *IC4*. The load can be powered by any 12- to 117-volt ac source.

To provide solid logic levels to the inputs of the slave module, the two LEDs in the selected transmitter channels should be disconnected. A

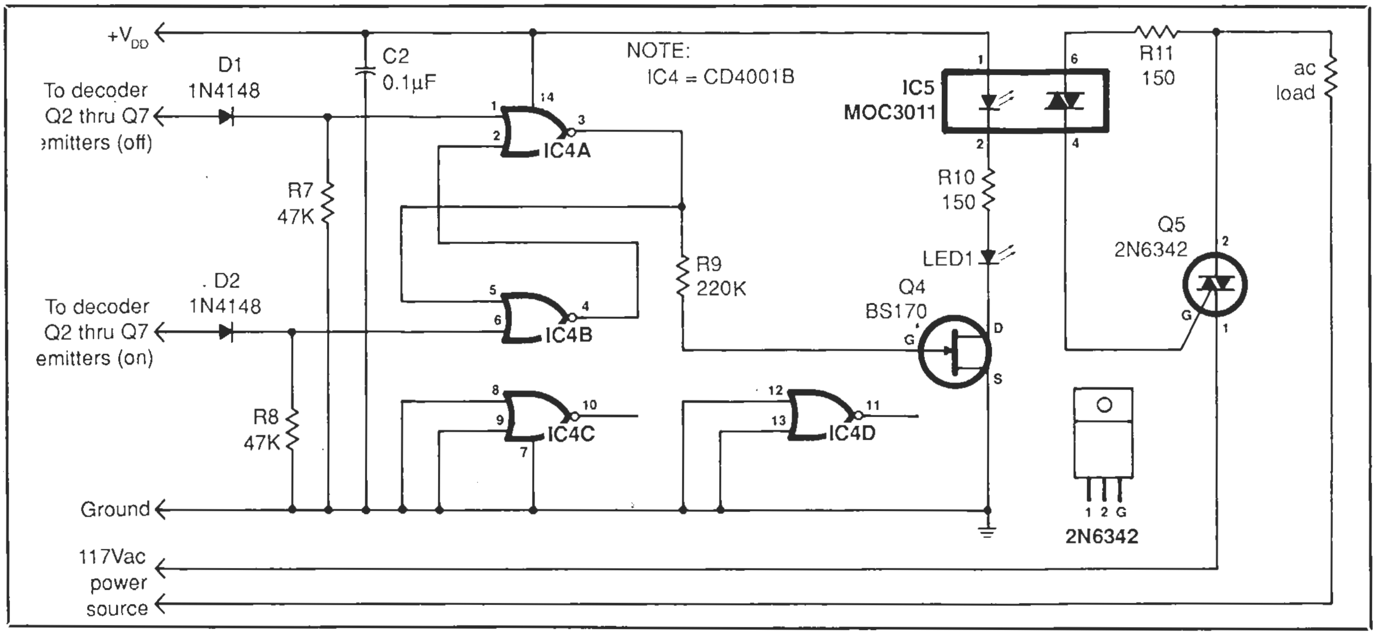


Fig. 8. This latched control circuit uses two transmitter/ receiver channels to lock on and off power to load. Previous circuits give momentary action.

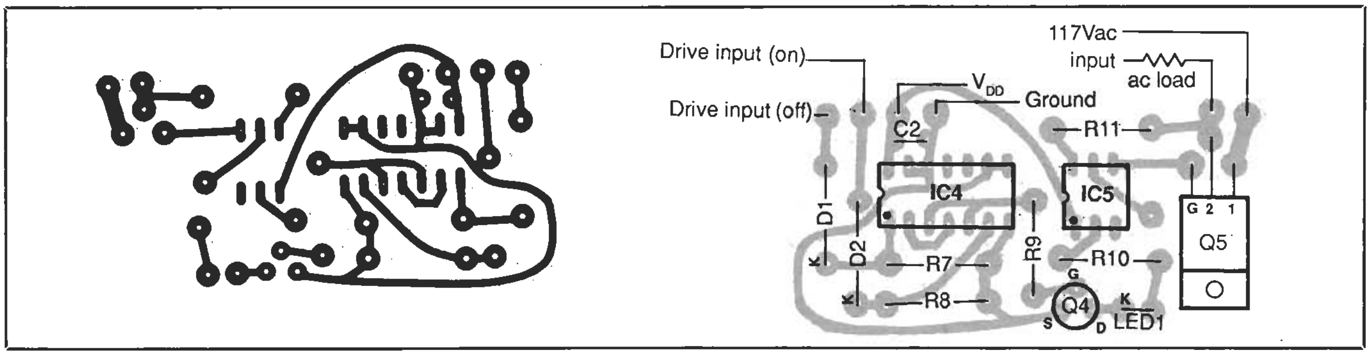


Fig. 9. Actual-size etching-and-drilling guide (left) and wiring diagram (right) for pc board used to assemble Fig. 8 circuit.

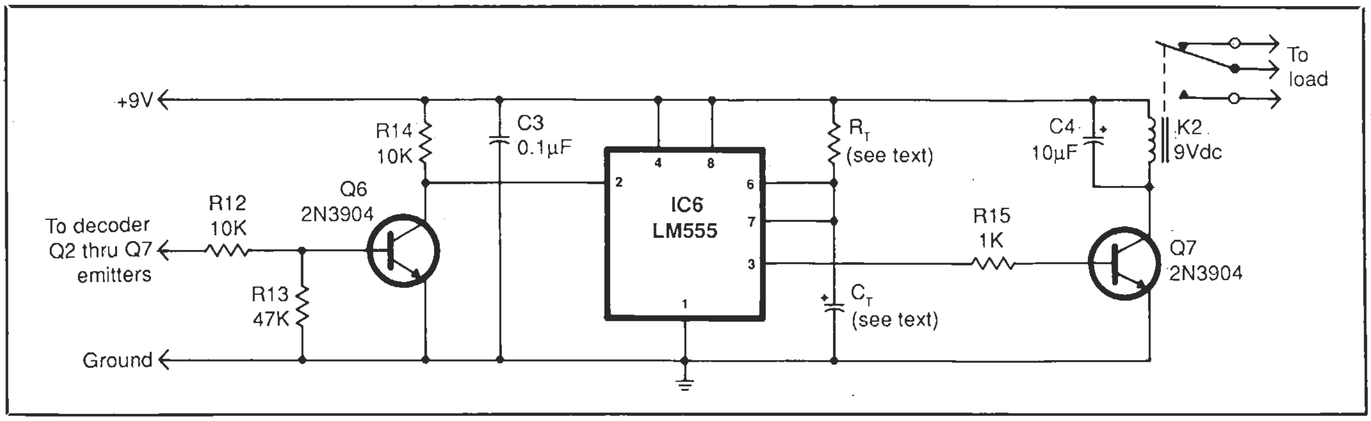


Fig. 10. This timed output pulse circuit latches power on for a predetermined time using only one transmitter/receiver channel. It is designed to use a standard electromechanical relay.

LED is shown in the slave module to provide visual indication of the status of the latching circuit.

If you experience a problem with this slave module, check the logic levels at the inputs as each appropriate transmitter pushbutton is pressed. If the LED in the slave circuit operates normally, turning on and off as the transmitter channels are alternately energized, the problem lies with the optoisolator or output circuit.

To troubleshoot this circuit, carefully short together pins 4 and 6 of the optoisolator to ascertain that the load turns on when the optoisolator is activated. Also, check load wiring to be sure that it agrees with Fig. 8. If the wiring is correct, try replacing *IC5*.

• *Timed Output Pulse*. The final slave circuit, shown schematically in Fig. 10, utilizes just one transmitting channel and permits a load to be powered for a predetermined period of time when its transmitter pushbutton is pressed and then released. This is accomplished through use of the common 555 timer IC.

In Fig. 10, *IC6* is configured as a monostable or "one-shot" multivibrator. When the appropriate receiver/decoder driver transistor (*Q2* through *Q7*) is activated, the resulting signal fed to the base of *Q5* in the slave circuit causes the transistor to saturate. This results in a near-zero voltage at the collector and triggers on *IC6*.

When the circuit is dormant, the voltage at pin 3 of *IC6* remains at zero. Once the chip is triggered by pressing the transmitter pushbutton, the potential at pin 3 rises to about +8 volts. At the same time, capacitor C_t is permitted to charge through R_t at a rate determined by RC time constant R_tC_t. When the capacitor reaches about ⅔ of the supply voltage, it is suddenly discharged by a transistor within the IC and pin 3 of that chip returns to its dormant state of 0 volt. The cycle repeats only when a new signal appears at the base of *Q5* in response to pushing the transmitter button.

During the time pin 3 of *IC6* is in its active state, *Q6* is forward-biased and *K2* is energized. The contacts of the relay control power to the load circuit. This circuit is capable of providing timed cycles of less than 1 second to 15 minutes or more. For very short timing cycles, it is important that the transmitter switch be released before the end of the cycle. If it is not released in time, a second cycle

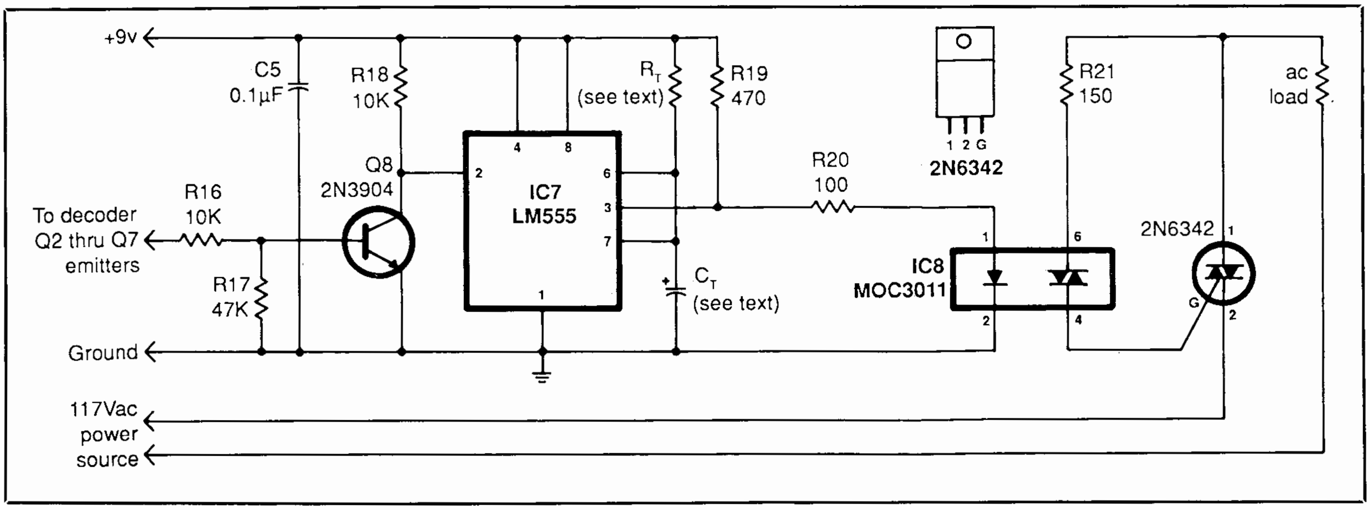


Fig. 11. This timed output pulse circuit replaces the electromechanical relay with an optical isolator.

will automatically begin.

The time required for *IC6* to complete one cycle is easily calculated using the formula $T = (1.1)(R_t)(C_t)$, where T is time in seconds, R_t in ohms and C_t in Farads. For relatively long timing cycles (1 minute or longer), you may use resistor values as high as 4.7 megohms if necessary.

There is almost no limit of the value of the capacitor that can be used. However, if you need a timed cycle duration of greater than 1 or 2 minutes, use low-leakage electrolytic or tantalum capacitors. This will provide the greatest accuracy and repeatability of your cycle. Timed cycles of 15 minutes duration are easily obtained using low-leakage electrolytic capacitors.

The Fig. 10 circuit is designed to drive a standard electromechanical relay. An optical isolator can also be used, as shown in Fig. 11. Here, the positive output voltage of *IC7* drives the LED in the optoisolator. As with the previous circuits that use this component, the load is powered through the action of the light-sensitive triac or transistor within the optoisolator.

Figure 12 gives the actual-size etching-and-drilling guides for the pc boards needed for the relay and optical-isolator circuits, and Fig. 13 shows the wiring details for the same circuits letter-keyed in the same way.

When wiring these circuits, use sockets for the integrated circuits and optical isolator. Again, make sure the ICs and optoisolator are properly oriented as you plug them into their respective sockets and that no pins overhang the sockets or fold under between devices and sockets.

Wire the timed slave modules to the +9-volt output of the receiver/decoder power supply. One additional connection from one of the *Q2* through *Q7* driver emitters is required for each module as well. For this application, it is not necessary to disconnect the LED of the driver emitter-follower transistor in the receiver/decoder.

If you have a problem with a timed slave module, check the input at *R16* to be sure that it is driven by a signal of about +5 volts when the appropriate transmitter pushbutton is pressed. Measure the potential at pin 3 of the timer IC to determine that it rises to about +8 volts when the IC is triggered. If you obtain a normal indication, check the wiring to the load circuit. If the module still does not operate as it should, try replacing the

(Continued on page 81)

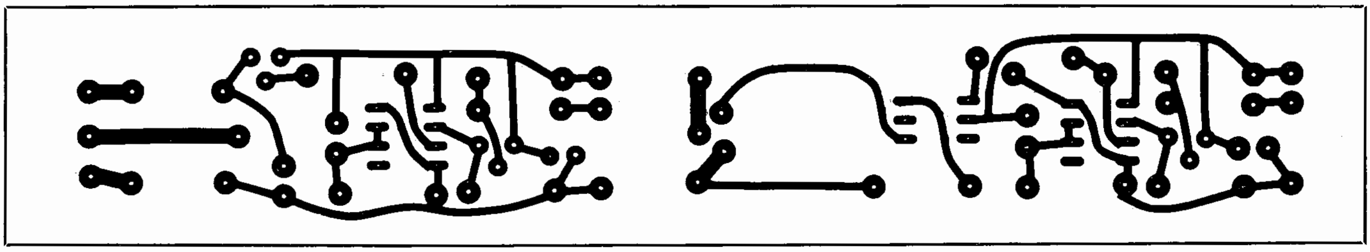


Fig. 12. Actual-size etching-and-drilling guides for fabricating pc boards for Fig. 10 (left) and Fig. 11 (right) circuits.

A 6-Channel IR Remote-Control System *(from page 47)*

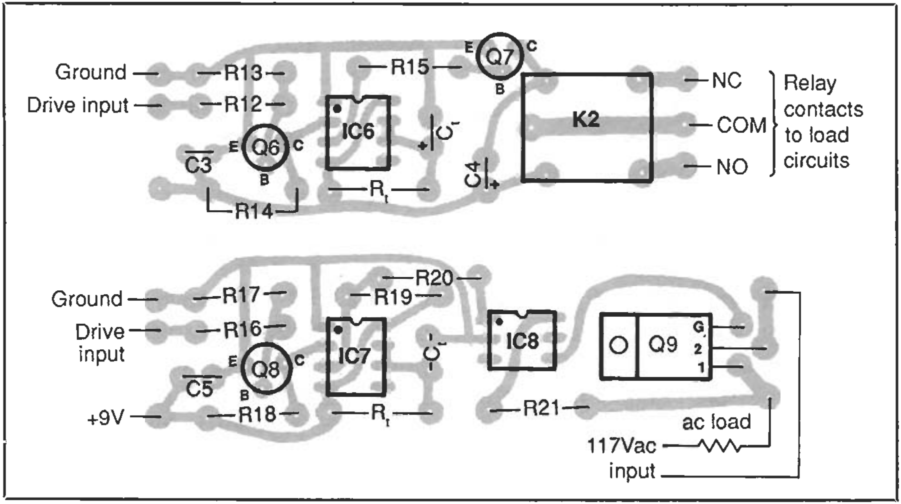
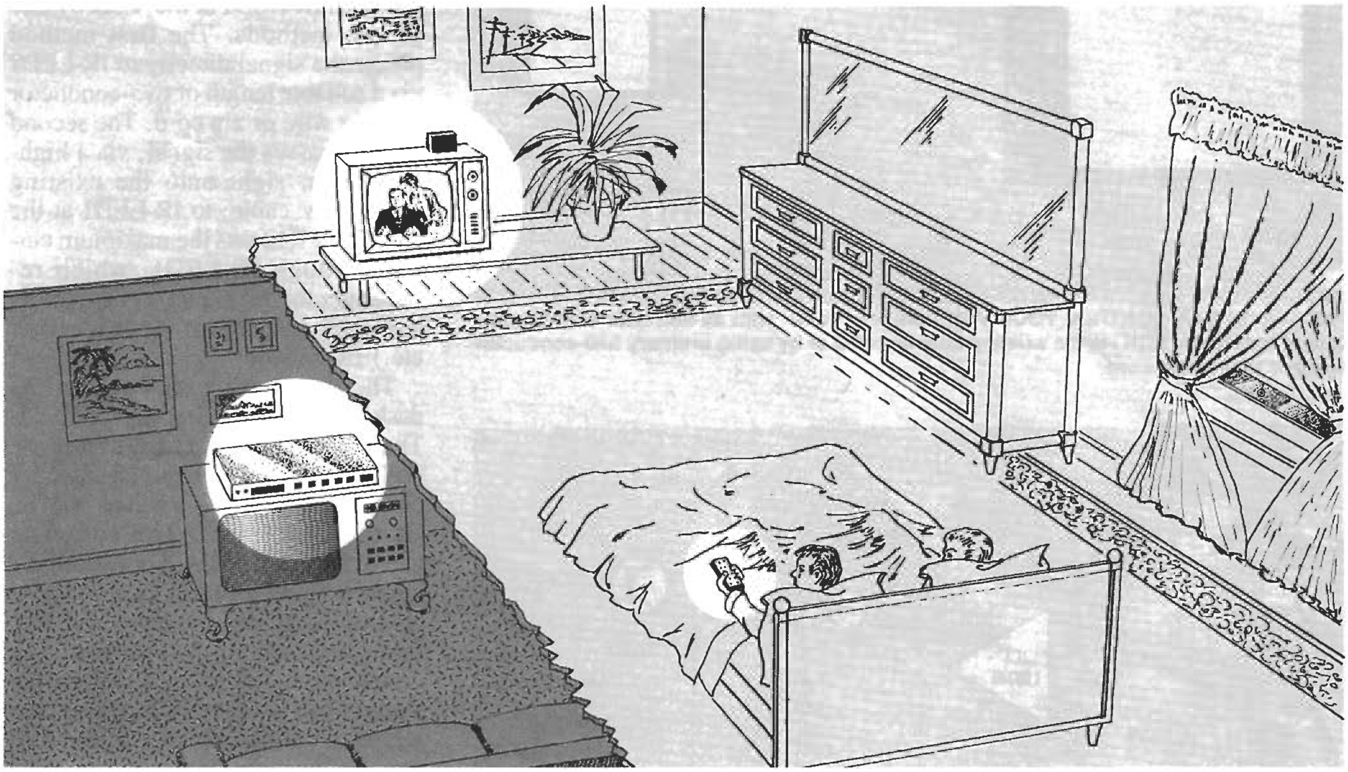


Fig. 13. Pc wiring guides for Fig. 10 (upper) and Fig. 11 (lower) circuits.

optical isolator.

This completes our discussion of interface circuits that can be used between the receiver/decoder and loads to be controlled. Obviously, we have not covered every possible type of interface circuit. In fact, we have covered only a few of the many possible circuits that can be used in this system. You will undoubtedly think up other circuits that can be used for unique control applications. ME

REMOTE CONTROL



EXTENDER

Control your VCR and watch video tapes from any room in your home with our VCR extender!

ROBERT A. HEIL

WHILE THE NUMBER OF FAMILIES THAT have two VCR's in their home is steadily increasing, owning two VCR's is still considered an expensive luxury for most. But now you can get the benefits of having two VCR's for a fraction of the cost with our VCR extender. Our easy-to-build device will let you watch your VCR from *any* room in your home and still maintain full remote-control capabilities. And the extender is not limited only to VCR's—it will relay *any* IR-transmitted signal. So even if you have an old manually controlled TV in your bedroom, you'll be able to use all the remote-control features of the VCR in your living room!

The extender mounts next to your TV set and can be operated via your IR remote control from a distance of 20–30 feet depending on ambient light conditions. The unit uses inexpensive, easy-to-get parts, and does not require RFI or IR shielding. Also, several extenders can be connected in parallel, so that you can extend your VCR to as many locations as you like.

Using the extender unit, remote-control signals can be sent to the VCR via the existing coaxial cable (if you have cable television), as shown in Fig. 1, or by using ordinary two-conductor speaker wire or zip cord. The latter will eliminate the need for the two additional filters that are required for the coaxial-cable system but, of course, will require two lines—one for the out-going IR signals, and a second for the returning video or RF.

Circuitry

Refer to the schematic in Fig. 2 for the description of the basic circuit. A signal from an IR remote control enters phototransistor Q1, where it is converted from IR radiation to a frequency pulse and then passed to decoupling-capacitor C1. Resistor R1 keeps Q1 from saturating too quickly from visible light. Because the IR signals from a remote control are not that strong, Q1 is kept constantly conducting, via IR-LED2, which was added to increase the range during extreme low-light conditions. IR-LED2 is positioned directly behind Q1 and aimed at the base, where it emits a small amount of IR radiation, ensuring that Q1 will continue to conduct without IR or visible light.

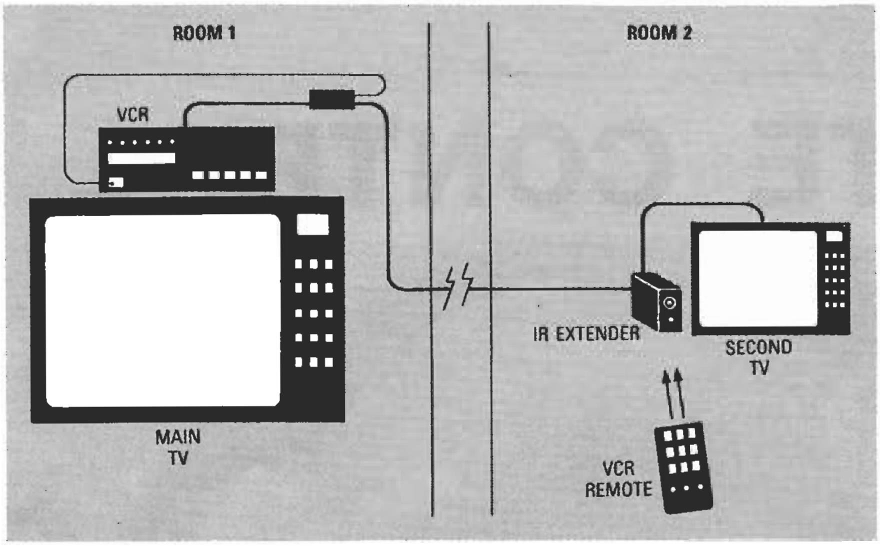


FIG. 1—YOU CAN CONTROL YOUR VCR from any TV set with an extender unit. Signals can be sent to the VCR via the existing coaxial cable or by using ordinary two-conductor speaker wire or zip cord.

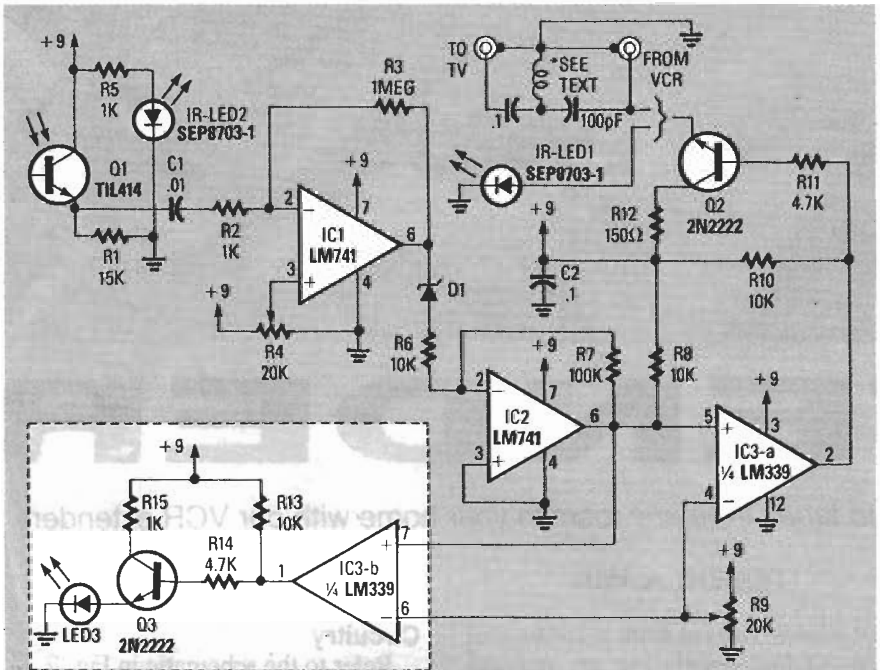


FIG. 2—A SIGNAL FROM AN IR REMOTE CONTROL is converted from IR radiation to a frequency pulse that can be transmitted through coaxial TV cable or any other two-conductor wire to another room, where it's converted back into an IR signal.

The signal from C1 is amplified by a factor of 1000 by IC1, with gain set by R2 and R3. It is then passed to D1, a 5.1-volt Zener diode, which is used as a voltage shifter. The anode stays low until the input voltage at pin 2 of IC1 rises higher than the reference voltage at pin 3, which is set by R4. When that happens, the output of IC1 goes high and avalanches D1, producing a voltage rise at the anode along with the signal. The signal is then passed to IC2 where it is amplified by a factor of 10. Pin 3 of IC2 is tied to ground. That allows any signal higher than ground to be amplified and sent to pin 5 of IC3 via pull-up resistor R8. IC3 is a comparator, in which the output goes high when the reference voltage at pin 4 (set via R9) is exceeded by the smallest amount.

IC1 and IC2 are independent 741 op-amps. Separate op-amps were used because IC1 is referenced at pin 3 while IC2 is tied to the ground rail at pin 3. Dual or quad op-amps share a common bias network and power-supply leads—that produces noise at the reference point, so very small signals could not be detected. But by using two independent op-amps, the noise level is reduced and the circuit sensitivity is increased.

The output of IC3 (pin 2) is pulled up by R10 and sent through R11 to the base of Q2, which then passes the signal to IR-LED1 at the VCR by one of two methods. The first method passes the signal directly to IR-LED1 via a suitable length of two-conductor speaker wire or zip cord. The second method passes the signal, via a high-pass filter, right onto the existing coaxial TV cable, to IR-LED1 at the other end. R12 sets the maximum current through IR-LED1, which retransmits the IR signal to the receiving unit's (the VCR, stereo receiver, etc.) IR window.

The components enclosed in the dashed lines in Fig. 2 are optional. That circuit causes an LED to flash on and off rapidly when the IR-extender circuit is activated by a signal from an IR remote control. The circuit is useful in that LED3 will only flash if a signal is being received from a remote control—that way you know if the IR signal is reaching the extender. The circuit works as follows: When the signal from pin 6 of IC2 exceeds the reference voltage set by R9, the output of IC3 causes Q3 to conduct, driving LED3. That can be either a red or green non-IR LED, and R15 sets its current (brightness level).

Construction

A foil pattern is provided in PC Service, and is available separately. (See Parts List.) If you wish to hard-wire the circuit, place the external components as close together as possible to keep stray capacitance to a minimum.

The Parts-Placement diagram is shown in Fig. 3. Be sure that pin 1 on all three IC's faces Q1, and mount Q1 with enough lead length (approximately ¾-inch) so that it will be able to protrude through a hole in the project box. The flat side of Q1 (the collector) is connected to +9-volts DC. Mount IR-LED2 so that it can be positioned directly behind Q1 (that way it can emit a small amount of IR into the base of Q1 during low-light conditions), as shown in Fig. 4. The flat sides (the cathode) of D1, D2, and D3 are attached to ground.

If you are going to use the existing coaxial cable in your home to transmit

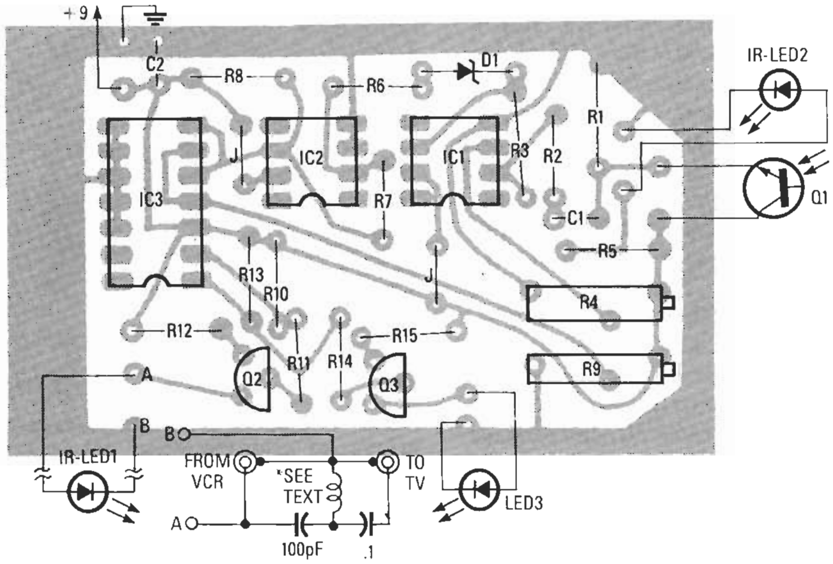


FIG. 3—PARTS-PLACEMENT DIAGRAM. Mount Q1 so that it can protrude through the project box. Either IR-LED1 *or* the filter circuit attaches to pads A and B.

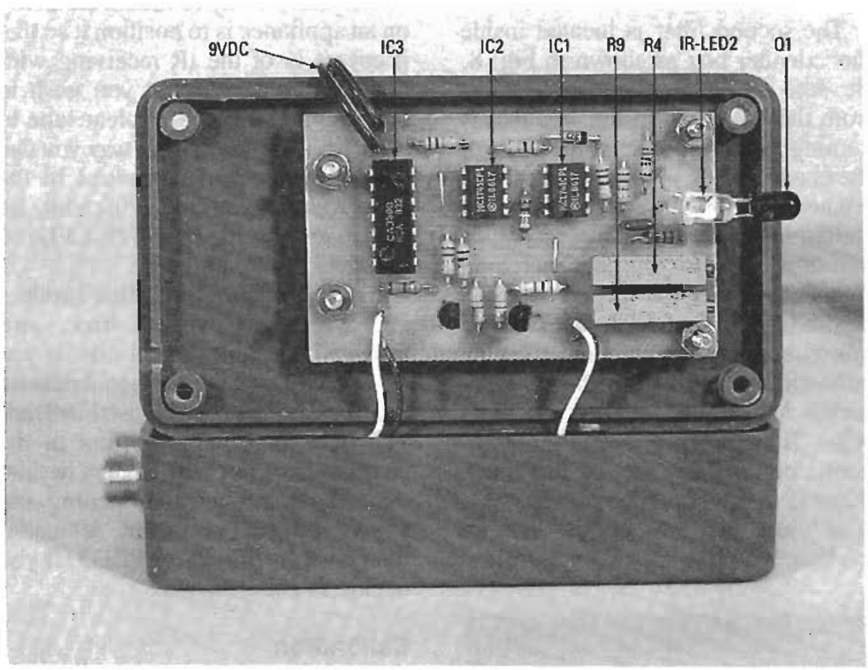


FIG. 4—MOUNT IR-LED2 so that it can be positioned directly behind Q1 as shown. That way it can emit a small amount of IR into the base of Q1 during low-light conditions.

the signals, then two filters are required to decouple the DC voltage and to attenuate the transmitted signal. That keeps the TV tuner or VCR from receiving any harmful DC voltages. The only consequence of doing it that way is that there is an interchanging between the control signal and the video signal that takes place in the coaxial cable when the extender is activated; that results in a small amount of interference that is visible on the TV screen when a command is being sent.

Both filters must be installed between the last output stage and the tuner of your second TV, as shown in Fig. 5. (If you have an amplifier to boost your VCR output, then the amplifier becomes the last output stage.)

The first filter, located after the last output stage, can be constructed in two ways: The first way—and also the easiest—is to purchase a Radio Shack high-pass filter (PN 15-579). Remove the rubber gromet and slide back the case, as shown in Fig. 6. Take a 4- to 5-foot length of small-gauge two-conductor speaker wire or zip cord, and scrape away enough potting material

PARTS LIST

All resistors ¼-watt, 5%.
R1—15,000 ohms
R2, R5, R15—1000 ohms
R3—1 megohm
R4, R9—20,000 ohms, 20-turn potentiometer
R6, R8, R10, R13—10,000 ohms
R7—100,000 ohms
R11, R14—4700 ohms
R12—150 ohms

Capacitors
C1—0.01 µF, disc capacitor
C2—0.1 µF, disc capacitor

Semiconductors
IR-LED1, IR-LED2—SEP 8703-1, infra-red light-emitting diode
LED3—light-emitting diode, red or green
Q1—TIL 414 phototransistor
Q2, Q3—2N2222, NPN transistor
D1—5.1-volt Zener diode
IC1, IC2—LM741 op amp
IC3—LM339 comparator

Other components
T1—120-volts AC/9-volts DC, wall transformer

Miscellaneous: 4-40 hardware, standoffs, tape, speaker wire, etc.

Note: The following two filters are needed only for transmitting through coaxial TV cable (see text).

Parts for the first filter
1 0.1-µF disc capacitor, 1 100-pF disc capacitor, 1 inductor (see text), 1 chassis-mount F connector, 1 cable-mount F connector, a piece of coaxial TV cable, cardboard, 2 washers, copper tape or aluminum foil.

Parts for the second filter
1 0.1 µF disc capacitor, 1 100-pF disc capacitor, 1 inductor (see text), 2 chassis-mount F connectors.

Note: An etched and drilled PC board is available postpaid for $7.50 in U.S. funds from Fen-Tek, P.O. Box 5012, Babylon, NY 11707-0012. NY residents must add sales tax.

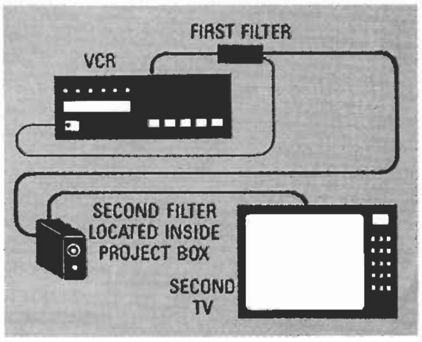


FIG. 5—TWO FILTERS are required if you want to use your current coaxial cable.

at the filter's F connector to attach one wire to the center pin and the other to the ground side (see Fig. 6). Run the

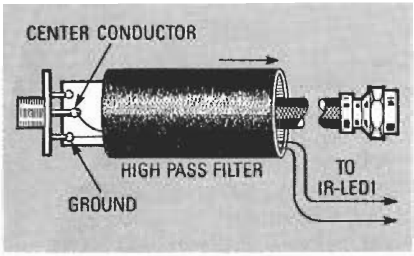


FIG. 6—A RADIO SHACK HIGH-PASS FILTER (PN 15-579) can be used for the first filter if you don't want to make your own.

wire through the case and then slide the case back over the filter. Use RTV silicone to reseal the area where you removed the grommet. Attach IR-LED1 to the other end of the wire. Remember that the wire that you attached to the center pin of the F connector is positive for IR-LED1.

For those true do-it-yourselfers, the other way is shown in Fig. 7. Because solder will not easily adhere to metal plating, file or sand away a small amount of the metal plating on the F connector and washer before soldering. When the filter is finished, wrap a piece of cardboard around it and tape in place. (The cardboard found on a blister pack works well.) The filter should then be wrapped with copper tape or aluminum foil for RF shielding. Make sure that a small piece of copper tape or aluminum foil is in contact with the washers at both ends of the filter to effectively complete the ground shield. You can also build the filter in a small metal case.

The inductors can be obtained in an inductor assortment from Radio Shack (PN 273-1601), or by making your own. If you purchase the inductor assortment, the ½-inch enameled wire-wound inductors have a value of 10 µH. Combined with a 100-pF capacitor, the filter should have a cutoff frequency of about 5 MHz.

If you wind your own inductor, use 22-gauge enameled copper wire, and wind 6½ turns on an 8-32 screw. Remove the screw and coat the outside of the windings with non-conductive RTV silicone. That will keep the windings from deforming during assembly. Scrape and tin both ends of the inductor. The value of the inductor should be approximately 100–200 nH. (It is much more difficult to make a 10-µH coil by hand, and because a 100- to 200-nH coil will do the job, that's what we'll make.) When that is combined with a 100-pF capacitor, the cutoff frequency should be about 35–50 MHz. The formula used for calculating the cutoff frequency is: $F = 1/2\pi\sqrt{LC}$.

The second filter is located inside the extender box as shown in Fig. 8. Be sure to attach the output wires from the PC board to the side that is coming from the other filter and not the one to the TV set. Label the two F connectors as in and out to make installation easier. If you have a TV set that uses a 75- to 300-ohm matching transformer, then the second filter can be omitted. In that case, just solder a bus wire from the center pins of both F connectors, and attach the positive output lead for IR-LED1 to that bus wire. Then bus-wire the grounds together on the F connectors and attach them to the PC board's ground.

If you decide to use the two-wire system, you can install a terminal block inside the project case, or you can solder the wire directly to the PC board. Just make sure that the grounded lead gets soldered to the cathode of IR-LED1.

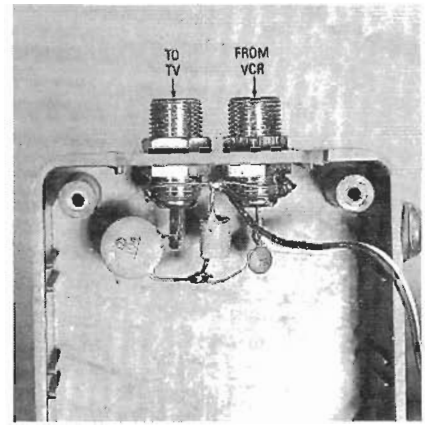


FIG. 8—THE SECOND FILTER, if required, is installed inside the project box across the two F connectors.

The easiest way to mount IR-LED1 on an appliance is to position it so that it covers ¼ of the IR receiving window on the device that you wish to control. Use a piece of clear tape to secure it to the unit. That way you can still use your remote control in the same room as your receiving unit. Be sure to insulate the legs of IR-LED1 so that they don't short out.

The PC board is installed inside a small plastic project box, and mounted on ¼-inch stand-offs. If you do not have stand-offs, then 3 nuts on top of each other can be used instead. The hole for Q1 in the front of the project box is not critical. Just be sure that Q1 fits through the opening and slightly protrudes outward. A smaller hole must be drilled for LED3, if you decide to use it.

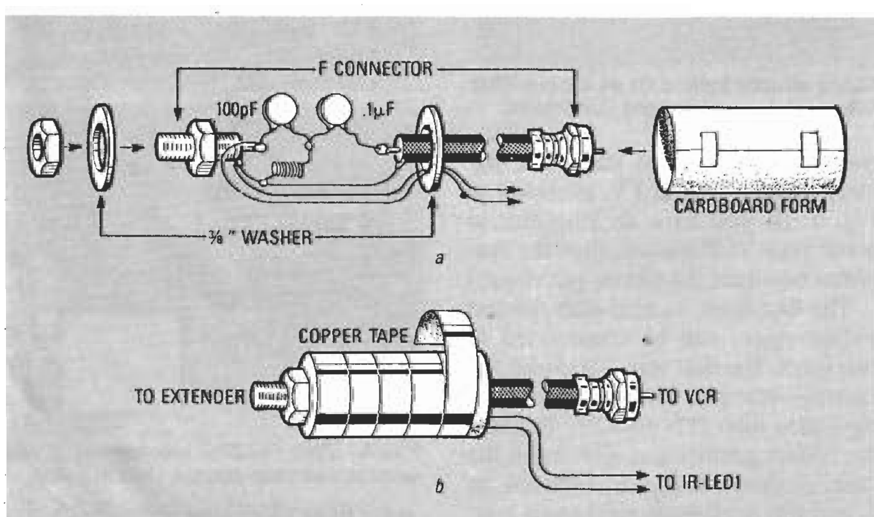
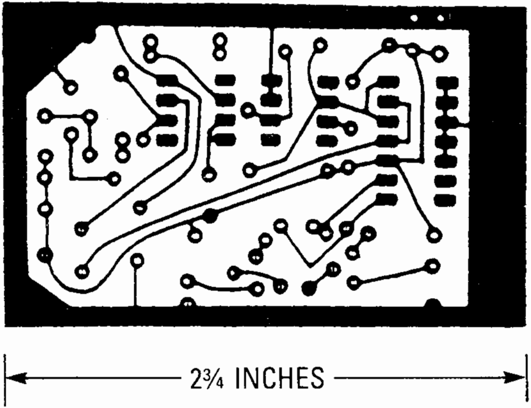


FIG. 7—YOU CAN MAKE YOUR OWN FILTER by first building the assembly shown in (*a*), and then wrapping it with copper tape or aluminum foil (*b*).

Calibration

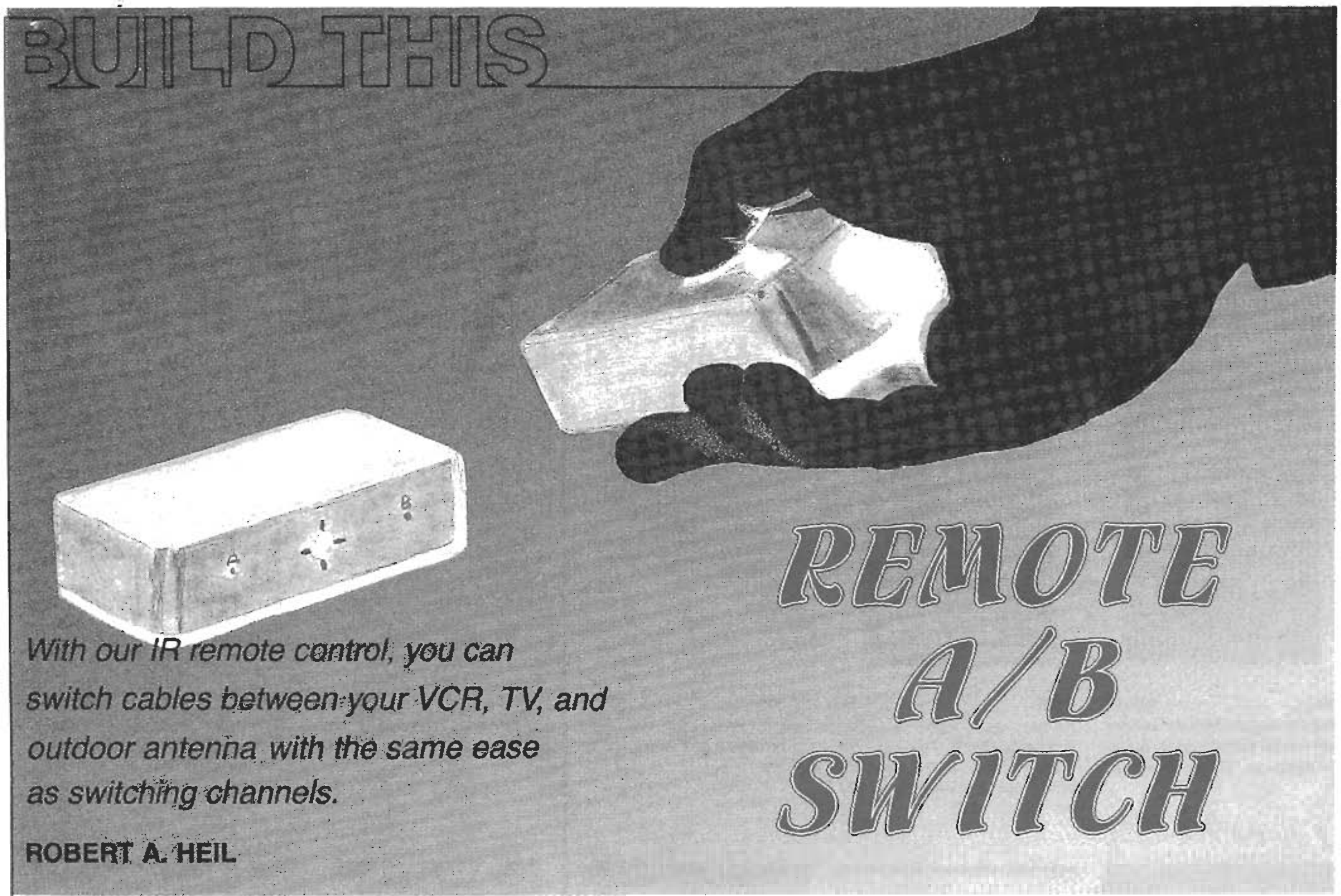
Apply power and make sure that nothing gets too hot. If anything does, then recheck your connections. Then, connect a voltmeter across IR-LED1. Adjust R9 until the output drops to approximately 0.004 volts. Then attach the voltmeter to pin 3 of IC1. Adjust R4 for 4.55 ± 0.05 volts. Remove the test lead and reconnect it across IR-LED1. Again, adjust R9 until the output goes high, and then back off slowly until it drops to approximately 0.004 volts. If you used the optional LED circuit, then there is no need to connect a voltmeter across IR-LED1, because LED3 will light when the output of IR-LED1 is high, and it goes out when it's low. **R-E**



THE IR EXTENDER foil pattern.

If you built the IR remote-control extender (**Radio-Electronics**, May 1989), and noticed noise or snow on your TV screen when using the device, a 0.1-µF ceramic-disc capacitor connected between the intersection of D1 and R6 and ground will cure the problem. Other problems with the unit's operation may be caused by a poorly regulated +9-volt DC supply (which is often true with many of the inexpensive plug-in power adapters). The addition of a 9-volt Zener diode across the +9-volts (cathode to positive, anode to negative) will eliminate the possibility of any power-supply related problems.—*Editor*

BUILD THIS



REMOTE A/B SWITCH

With our IR remote control, you can switch cables between your VCR, TV, and outdoor antenna with the same ease as switching channels.

ROBERT A. HEIL

DON'T YOU WISH THAT YOU COULD SWITCH the cables between the outside antenna, VCR, and TV without the hassles of bending over the TV, reaching behind the VCR, and fumbling in dim light to disconnect one cable while connecting others? It doesn't take long before that type of inconvenience forces you to buy a manually operated A/B switch. And for awhile that seems to clear things up. But after going through all that trouble, you still have to get up from your cozy chair to throw the A/B switch by hand. If only you could do the whole thing remotely.

Well that's just what we've done. Our A/B switch operates by an infrared (IR) light beam just like your TV remote control, and that makes it possible to switch TV cables without ever having to leave the comfort of your own chair.

And that's not all! By using a power relay instead of a high-frequency relay, our unit becomes a remote-control power switch for small appliances and lamps. A third module containing a standard relay can be used to remotely turn on and off just about anything else.

A/B switch setup

Here are four tried-and-true setups using our IR remote A/B switch.

- Figure 1 shows a setup in which the incoming television signal is first put through a splitter that outputs two identical signals attenuated between 2–4 dB. (Even though the attenuation is undesirable, it can't be helped.) One signal is fed into the cable box, where it's re-modulated to a TV carrier frequency (usually channel 3), and then routed to the VCR that must be tuned to the same channel. The output of the VCR is then fed to the B input. The other splitter output is fed directly into the A input.

Selecting the B position allows you to watch cable on channel 3. To record a cable program while watching another channel is no problem if your TV is cable-ready. Begin recording your program, then flip the A/B switch to position A. Use your TV remote control to select the desired channels on your TV tuner. If your TV set is not cable-ready, then that setup won't work; but don't despair, maybe the setup in Fig. 2 can help you.

- Figure 2 shows the A/B switch between the cable box and the VCR. If you have an older TV and a remote-controlled cable-ready VCR, you can use the VCR to tune in the unscrambled cable channels. Position A restores full operation to your VCR tuner including multiple programming features, assuming it's cable-ready. In that setup, the TV must be tuned to Channel 3 at all times.
- Figure 3 shows a setup that allows you to watch unscrambled cable channels (or a tape playback) on the second TV that's cable-ready, while viewing scrambled cable or a VCR tape on the main TV set. If a family member decides to play a tape or record a program, you can retreat to the second TV and watch something else.
- Figure 4 uses two A/B switches. You can watch either the VCR or cable box on channel 3, or unscrambled channels using your cable-ready TV tuner. If you add an IR remote extender as described and featured in the May, 1989 issue of **Radio-Electronics**, the second TV can be anywhere in the house.

As you can see, A/B switches can be used in many ways to contour a system to your liking. If the input

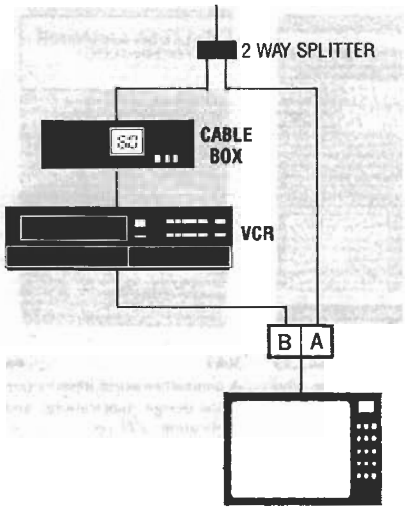


FIG. 1—YOU CAN RECORD a scrambled show while watching an unscrambled one with this setup. Your TV must be cable-ready to do so.

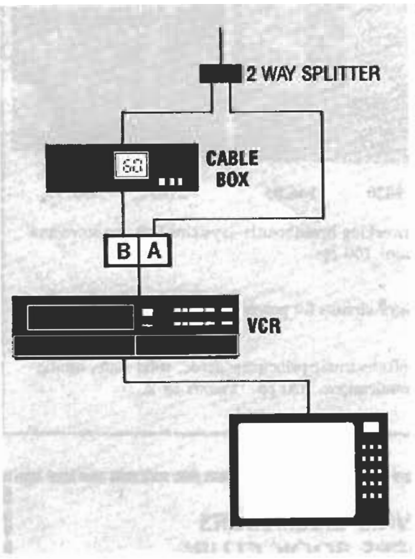


FIG. 2—THOSE WITH OLDER TV SETS and a cable-ready VCR prefer this setup.

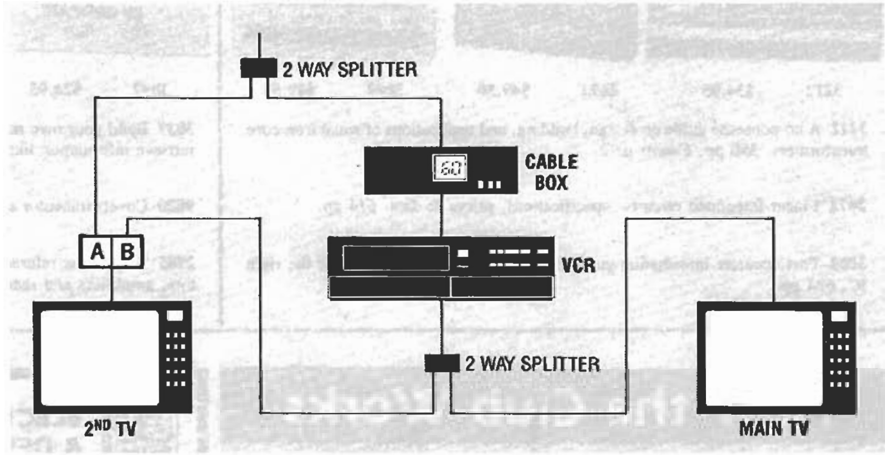


FIG. 3—USE THE A/B SWITCH TO CONNECT A SECOND TV with an option to watch either unscrambled cable via the A input, or scramble cable or a VCR tape via the B input.

signal loses too much strength due to signal splitters, just add a 10-dB signal booster (such as Radio Shack's 15-1118) between the input of the first splitter and the cable trunk line. Besides all the elaborate setups you can create, an A/B switch can also be used to keep an emergency antenna hooked up in case of a cable blackout in your area.

IR transmitter

The IR transmitter is a transistor oscillator that pulses an IR diode at 850 Hz. The IR output is quite strong, even when working off 3 volts. Figure 5-*a* shows the IR transmitter circuit.

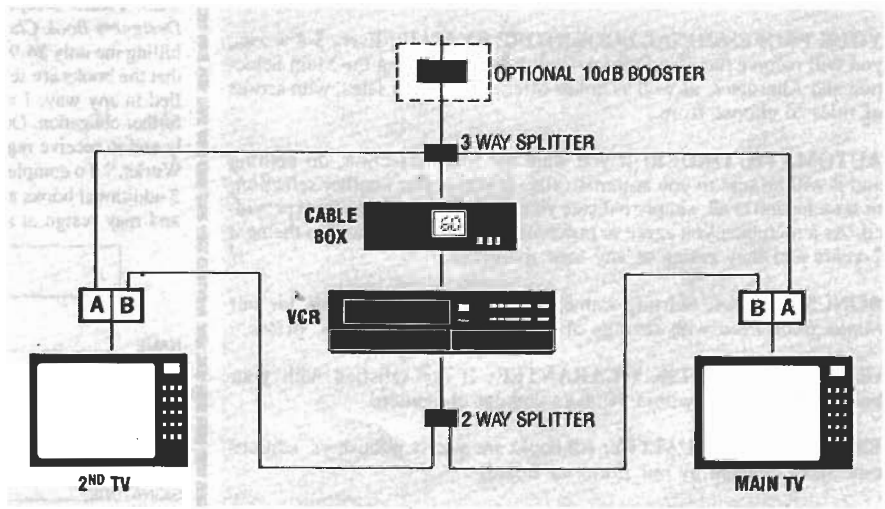


FIG. 4—THIS SETUP USES TWO A/B SWITCHES to provide more viewing options.

When S1 is depressed, Q4 and Q5 begin oscillating at a frequency determined by R16 and C11; changing C11 to a smaller value increases the frequency. Diode LED4 is an infrared light-emitting diode, while LED3 is a red 2-mA mini light-emitting diode that's connected across LED4 so you can visually monitor the output.

IR receiver

Figure 5-*b* shows the receiver circuitry. The infrared signal from the IR transmitter passes through a front-end magnifying lens and falls on Q1, a light-sensing phototransistor, where the IR radiation is converted into electrical pulses. The pulses are coupled through C1 and R1 to IC1's inverting input. The biasing of Q1 is set to keep it from saturating too quickly from ambient room light.

Op-amp IC1's gain is set to × 1000 by the R2-R3 feedback network. The reference voltage at IC1's non-inverting input is set at one half the supply voltage by R5 and R6; that forces the output, pin 6, to one half the supply voltage. Op-amp IC1 is usually powered from a bipolar supply; however, a single-ended supply can be used—as we did—if a midpoint ground is created. The output signal can then vary above and below that (bias) artificial ground.

The output pulses are then passed through R7 and decoupled by C2 before entering pin 3 of IC2, a tone decoder. Here, IC2 compares the pulse's frequency with an internal voltage-controlled oscillator that's set to a specific frequency by potentiometer R17, and C3. The frequency-lock range is set by C5. The delay period, the time between when the pulses are received and when pin 8 of IC2 goes low, is set by C4. Pull-up resistor R9 is needed because pin 8 is an open-collector output. Capacitor C7 shapes up that output, which is then passed to IC4-a where the signal is inverted from low to high.

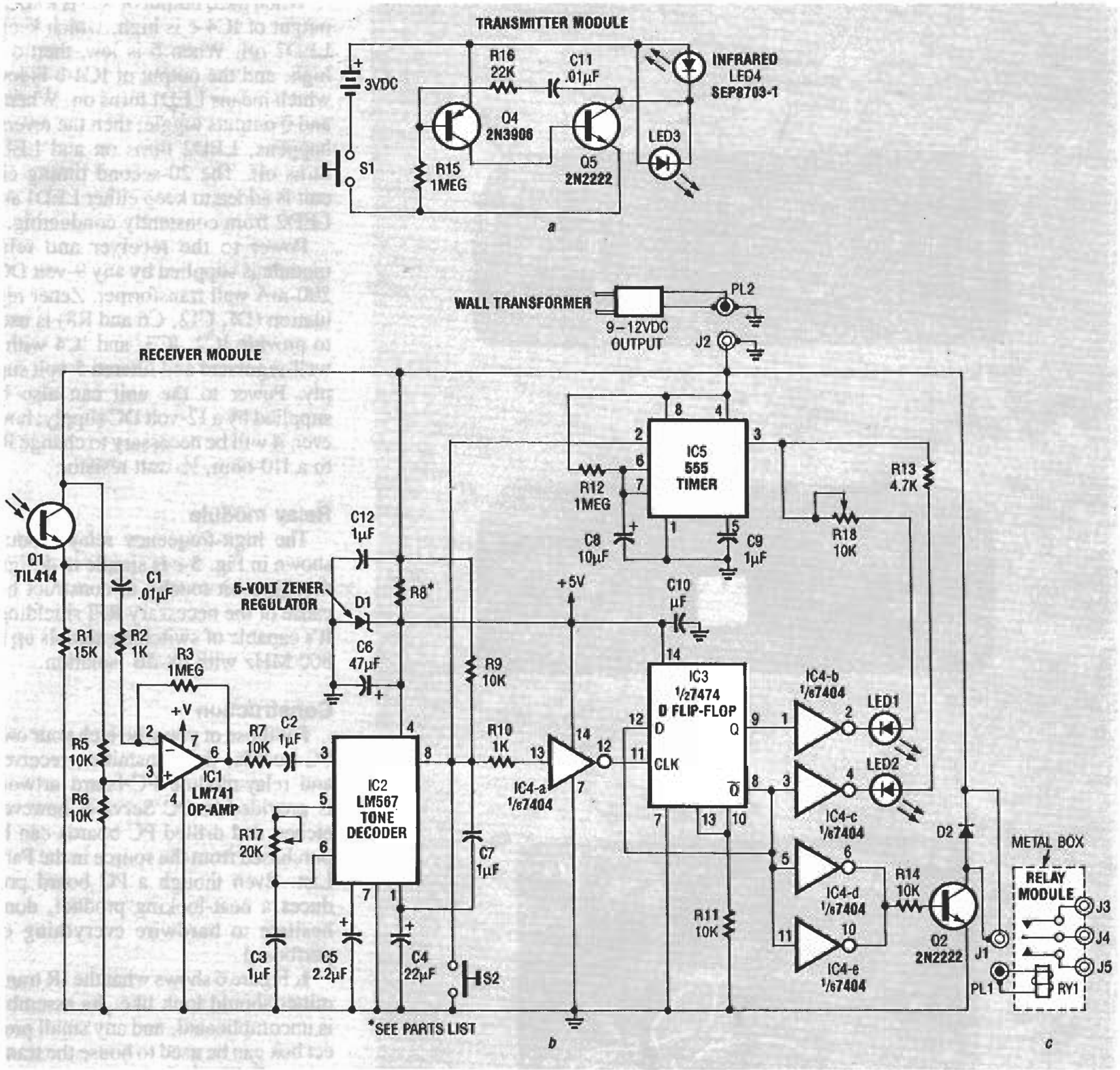


FIG. 5—THE INFRARED TRANSMITTER *(a)* can't get much simpler than this: two transistors with RC feedback. The infrared receiver *(b)* uses a number of optional components. For example, IC5 is used to turn the A/B indicator LEDs off after about 15 seconds. The relay module *(c)* is simple in design, although a bit complicated to construct.

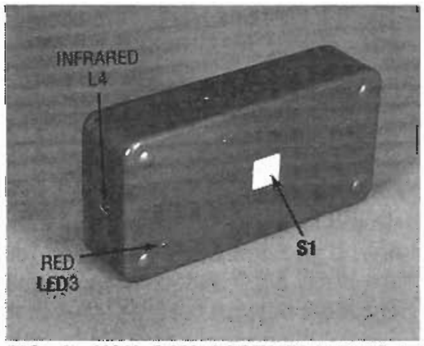


FIG. 6—YOU CAN ASSEMBLE THIS IR transmitter even smaller than the author's model. This project case is about the same size as a regular remote control.

The Q and $\overline{Q}$ outputs of D flip-flop IC3 toggle on the rising edge of the output from IC4-a. The two inverters IC4-d and IC4-e are connected in parallel to double the available driving current to Q2. When IC3's $\overline{Q}$ output goes high, inverters IC4-d and -e go low, and that turns on Q2. The bottom side of relay RY1 is grounded by Q2, which energizes the relay coil, so the contacts throw to the opposite position. Diode D3 protects the collector of Q2 by suppressing negative voltage spikes that occur when the relay coil is de-energized.

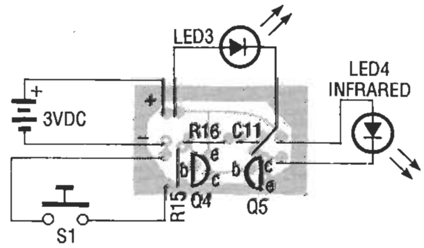


FIG. 7—THE IR-TRANSMITTER PC board should take you about 5 minutes to stuff. Instead of using LED3 as an indicator, try a low-voltage buzzer.

When IR-light pulses of the correct frequency are received, pin 8 of IC2

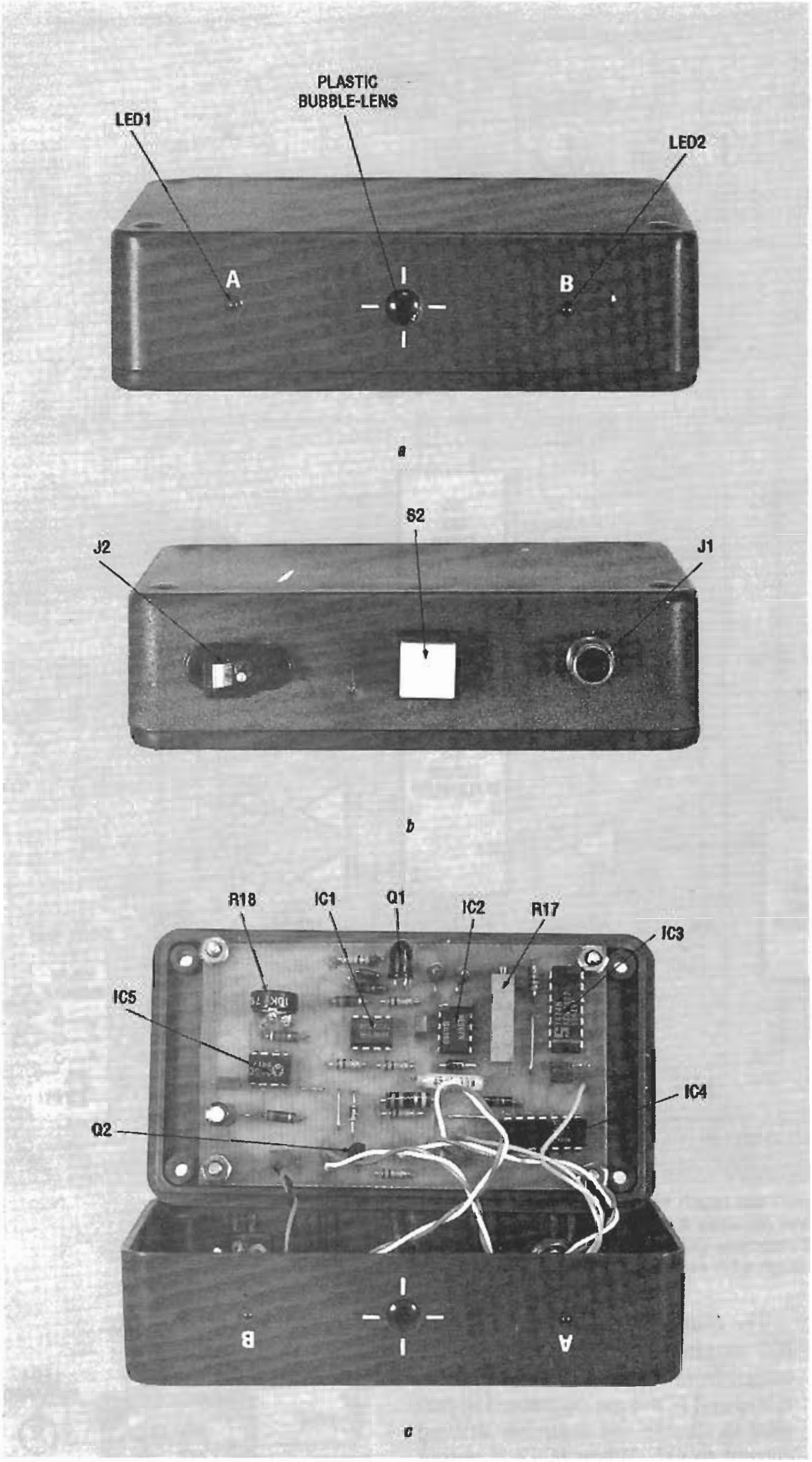


FIG. 8—THE AUTHOR HAS JAZZED UP the front panel *(a)* with rub-on-lettering and decals. The rear panel *(b)* shows J1, the DC current path for energizing the relay's coil, S2, which manually toggles the A/B switch, and J2, the DC-input jack. The opened IR receiver *(c)* reveals the author's handy work.

goes low; that forces pin 2 of IC5 low, which starts the timer. Pin 3 goes high for about 20 seconds, supplying voltage to LED1 and LED2. The timing cycle is set by R12 and C8. Resistor R13 limits the current through LED2. Potentiometer R18 is used to match the current through LED1 to that of LED2, so that both LED's glow with equal brightness.

When the $\overline{Q}$ output of IC3 is low, the output of IC4-c is high, which keeps LED2 off. When $\overline{Q}$ is low, then Q is high, and the output of IC4-b is low, which means LED1 turns on. When Q and $\overline{Q}$ outputs toggle, then the reverse happens, LED2 turns on and LED1 turns off. The 20-second timing circuit is added to keep either LED1 and LED2 from constantly conducting.

Power to the receiver and relay module is supplied by any 9-volt DC, 200-mA wall transformer. Zener regulation (D1, C12, C6 and R8) is used to provide IC2, IC3, and IC4 with a well-regulated and filtered 5-volt supply. Power to the unit can also be supplied by a 12-volt DC supply; however, it will be necessary to change R8 to a 110-ohm, ½-watt resistor.

Relay module

The high-frequency relay module shown in Fig. 5-*c* is simple in design, though a bit touchy to construct because of the necessary RFI shielding. It's capable of switching signals up to 800 MHz with 68-dB isolation.

Construction

For those of you who etch your own PC boards, the transmitter, receiver, and relay-module PC-board artwork is provided in PC Service; however, etched and drilled PC boards can be purchased from the source in the Parts List. Even though a PC board produces a neat-looking product, don't hesitate to hardwire everything on perfboard.

1. Figure 6 shows what the IR transmitter should look like. Its assembly is uncomplicated, and any small project box can be used to house the transmitter. Drill a hole in the box's front just large enough for IR LED4 to peek through; then mount the circuit board, shown in Fig. 7, and position LED4 in the whole you just drilled. The flat side of LED4 is connected to C11. The optional indicator LED5 is located in the corner, and can be fixed securely in place with a small drop of *Krazy Glue*.

2. Figure 8 shows what the IR receiver should look like. The PC board should be mounted on ¼-inch standoffs. If you don't have standoffs, then use three nuts on top of each other. The large hole for the lens of Q1 in the front of the project box is made with a 5/16 drill bit. Bevel the inside of the hole to give the lens more mounting surface.

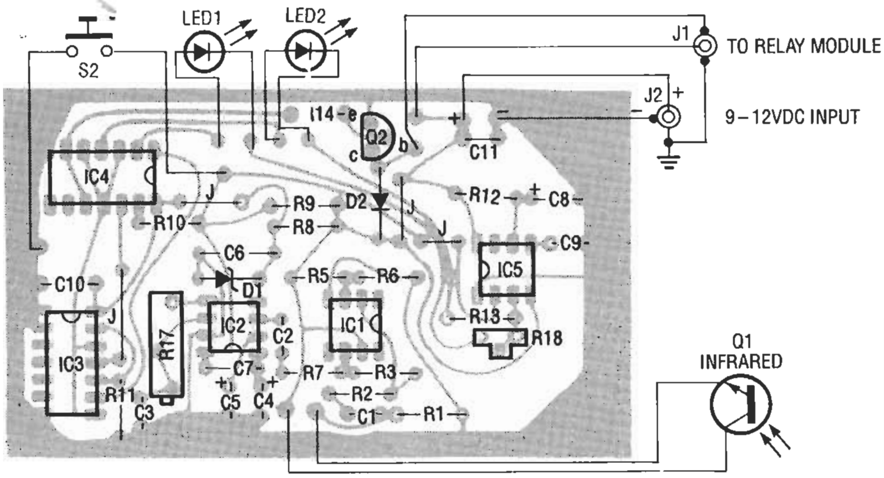


FIG. 9—STUFFING THE IR-RECEIVER PC BOARD should present no special problems.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—15,000 ohms
R2, R10—1000 ohms
R3, R12, R15—1 megohm
R5, R6, R7, R9, R11, R14—10,000 ohms
R8—68 ohms, ½-watt for 9-volts DC
R8—110 ohm ½-watt for 12-volt DC
R13—4700 ohms
R16—22,000 ohms
R17—20,000-ohms, 20-turn trimmer potentiometer
R18—10,000-ohms, 1-turn trimmer potentiometer

Capacitors
C1, C11—.01 µF, (CK05 type) molded ceramic
C2, C3, C7, C9, C10, C12—1 µF, (CK05 type) molded ceramic
C4—22 µF, 16 volts, tantalum
C5—2.2 µF, 35 volts, tantalum
C6—47 µF, 35 volts, electrolytic
C8—10 µF, 35 volts, electrolytic

Semiconductors
LED1, LED2—Mini red LED's
LED3—micro red LED
LED4—SEP8703-1 Infrared LED
D1—5.1-volt DC, 1-watt Zener
D2—IN914 switching diode
Q1—TIL414, NPN Infrared phototransistor
Q2, Q3, Q5—2N2222, NPN transistor
Q4—2N3906, PNP transistor
IC1—LM741 op-amp
IC2—LM567 tone decoder
IC3—7474 D flip-flop
IC4—7404 hex inverter
IC5—LM555 timer

Other components
T1—9–12-volt DC, 200 mA, wall transformer
S1, S2—SPST momentary switch
RY1—SPDT (Digi-Key PN Z701-ND) high-frequency relay, Omron
J1—phono jack
J2—5-mm DC power jack
J3–J5—coax F-connector jacks
PL1—phono plug
PL2—5-mm DC power plug

Miscellaneous
Two 1.5 N(size) cell batteries, shielded wire, hookup wire, hardware, plastic and metal enclosures, RFI shield tape.

Notes: The Omron high-frequency relay Z701-ND is available from Digi-Key Corporation for $6.96 plus shipping (800-344-4539). Etched and drilled PC boards are available from RAH, 16 Heritage, Irvine, CA 92714. The transmitter PC board is $4.00. The receiver PC board is $8.00. The relay PC board is $4.50. The three-board kit is $15.00. All prices are in US funds only. California residents must add sales tax.

The lens is made out of a clear-plastic bubble foot (Radio Shack, 64-2365), which has a natural magnifying ability. The sticky glue on the lens' back surface must be removed. Rubbing a little isopropyl alcohol across the surface with your finger tip should do the job. Apply a small amount of *Krazy Glue* to the bevel side of the mounting hole, then carefully install the lens so that the bubble faces outward, and the flat side faces Q1. Make sure that the lens is not angled.

Indicators LED1 and LED2 are located on both sides of the lens, and can be mounted in two ways. If you have miniature LED holders, then drill the prescribed hole size and mount them in the holders. The other way is to drill holes just large enough—a snug fit—to push the LED through. Find a washer that will fit over the LED but not past the lip, and use a drop of *Krazy* glue to anchor the LED to the washer; then place another drop on the washer and slide the assembly through the LED mounting hole, anchoring it to the project box. The washer acts as a spacer to stop the LED from protruding outward too far.

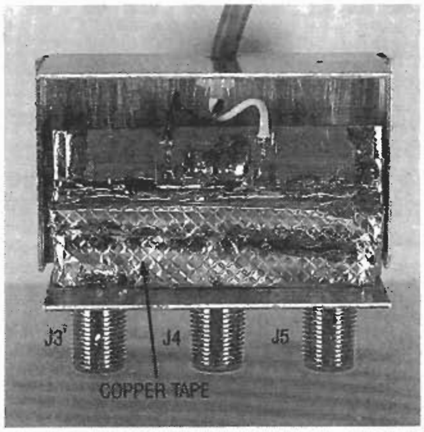


FIG. 10—LOOK AT THE DELICATE WORK needed to construct an RFI shield out of copper tape.

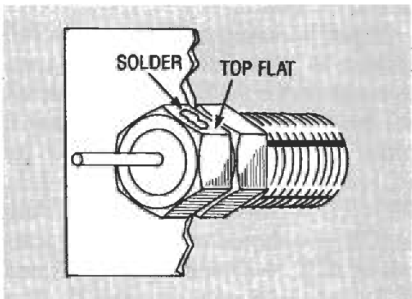


FIG. 11—HERE'S A TIP FOR constructing a RFI shield. Before soldering the copper tape to the nut flats, tin the flats with a little solder first. The relay is on the underside of the PC board as viewed from this angle.

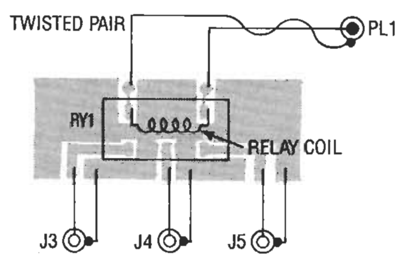


FIG. 12—THE RELAY MODULE'S PC board uses a large ground plane; that helps to shield the relay from stray RF-signals that could cause interference.

If you hardwire the receiver circuit,

(Continued on page 48)

REMOTE A/B SWITCH

continued from page 45

remember to place the components as close together as possible to keep stray capacitance low. If you use the PC board, follow the parts placement in Fig. 9, making sure that the IC's and components that are polarity-sensitive are correctly orientated. Mount Q1 with enough lead length to be positioned directly behind the bubble lens. The collector (flat side) of Q1 is connected to the positive supply. The cathodes of LED1 and LED2 (flat side) are connected to IC4-b and IC4-c, respectively.

3. Figure 10 shows what the relay module should look like. If you choose to hard wire the relay module, use a double-sided copper board, and a shielded enclosure such as a LMB box chassis, Model No. *M00*. Another RFI shield should be constructed out of copper tape, and should enclose jacks J3, J4, and J5. Constructing that RFI shield isn't easy. With a small file, remove the plating from the top flat of the nuts securing the coax jacks in place. Figure 11 shows you how that's done. Apply some solder to the flats, and secure a piece of copper-shield tape at a 90-degree angle across the flats, then heat the tape so that the solder melts and adheres to the tape. Be sure to leave enough tape at the ends to bend down and solder to the copper-tape ground shield created earlier.

Now drill and mount the three coax jacks, J3–J5. One in the center and the other two ¾-inch to the right and left of center. Label the center jack "To TV" and the other jacks "A" and "B." Drill a hole in the opposite panel for the relay's DC supply line.

If you use a single-sided PC board, Fig 12, it may be necessary to shield the non-copper side with ½-inch copper tape to hold down the RFI. Apply two copper-tape strips across the board's length; however, be sure to scrape the copper tape—using an *Ex-acto* knife—so that the relay pins don't get shorted out. Drill feed-through holes for the relay pins and the DC voltage line. The ground pin on the relay remains grounded to the shield. Install RY1 on the tape side of the board. Be sure that the relay is properly orientated before soldering into place.

The DC line to the relay can be made out of any two-conductor wire. Be sure to leave enough wire length to place the relay module behind the TV set. The positive wire to the relay is connected to the center conductor of PL1.

Calibration

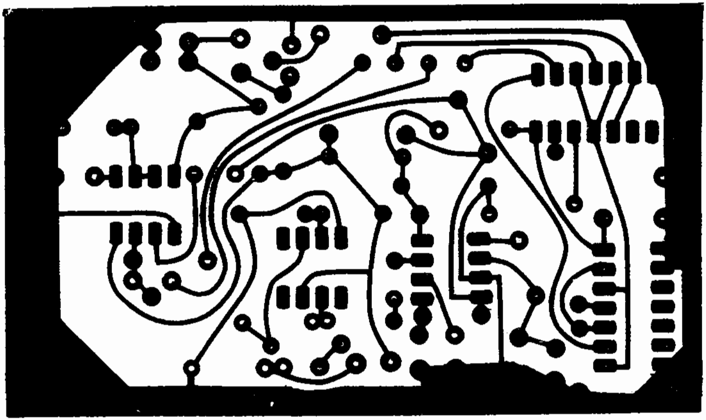
Apply power to the receiver and make sure that nothing gets hot. If something does, that indicates trouble, so immediately turn the power off and check the board for incorrectly placed parts such as diodes, capacitors, and IC's.

Calibration should be made with RY1 connected to the circuit. Attach a DC voltmeter or oscilloscope to IC2 pin 8. Hold the transmitter approximately one foot from the receiver, aiming it directly at the lens. While depressing the transmitter switch, adjust R17 until IC2 pin 8 drops low. Release the switch and IC2 pin 8 should return high. If you don't have a meter handy, then watch the indicators LED1 and LED2. If the circuit is working properly, the indicators will light alternately each time S1 is pressed. After 10 seconds or so, both indicators should turn off. Place your finger on the relay module and you should feel a click each time S1 is pressed. Vary the adjustment of R17 to find the limits at which IC2 will respond, then center the adjustment between the two limits. Adjust R18 to match the brightness of LED1 to LED2. If more brightness is needed, lower the value of R13 and then readjust R18. The timing cycle of IC5 can be made longer or shorter by varying R12 and C8.

Other relays

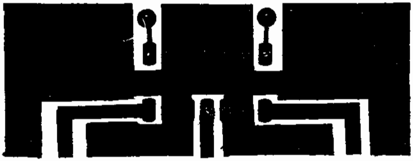
A power relay can be used instead of an RF relay (RY1). Although the power relay won't require shielding, a metal enclosure is recommended to provide a proper chassis ground. Make sure that the power relay has a high enough rating for your appliance; contacts rated at 10 amps are usually sufficient. If the relay coil requires more current than Q2 can deliver, replace Q2 with a 2N3053 or TIP 31, which can handle the extra load current and dissipate the heat generated by the power requirement. A general-purpose relay module can be hardwired in an unshielded plastic enclosure. Q2 should be able to energize the relay coil. **R-E**

PC SERVICE



3 5/8 INCHES

A/B RECEIVER.



2 1/8 INCHES

A/B RELAY MODULE.

MORE PC SERVICE ON PAGE 82.

DRAWING BOARD

Remote-control transmitter

ROBERT GROSSBLATT,
CIRCUITS EDITOR

IT'S AMAZING HOW QUICKLY THINGS change. My first experience with DTMF (*D*ual *T*one *M*ulti-*F*requency) was at the 1964/65 World's Fair in New York City. The telephone company had managed to modify a local exchange to use tone dialing and the fair grounds were dotted with prototypes of pushbutton pay phones. It was the first time they were seen and people lined up to use them.

Tone generation and detection was a nightmare back then. The circuits needed to produce accurate tones were both complex and touchy. And detection was even more difficult. Integrated circuitry made it a bit easier because general-purpose IC's like the 567 could be set up to decode particular frequencies. But it was all analog, and component drift, due to aging and temperature changes, made the circuitry less than ideal.

The digital revolution has simplified the generation of DTMF tones. The IC we're going to use, AMI's 2579, has everything you need to generate DTMF tones built right in the IC, and believe me—that's a far cry from the old days. The only external components needed are a crystal and a resistor.

We showed the 2579's pinout last time, but neglected to explain how it works. We'll do that in a moment, but first let's take a minute to talk about DTMF in general.

Tone generation

The DTMF tones are a series of discreet frequencies broken into two groups of tones—the high group and the low group. Figure 1 shows how each column and each row of a telephone keypad is asso-

		HIGH GROUP 1209 Hz	1336 Hz	1477 Hz	1633 Hz
LOW GROUP	697 Hz	1	2	3	A
	770 Hz	4	5	6	B
	852 Hz	7	8	9	C
	941 Hz	*	0	#	D

FIG. 1

ciated with a tone of a particular frequency. There are eight tones, four per group. By arranging them in a 4 × 4 matrix, sixteen combinations are possible. Standard telephones use only seven of the available tones, but most DTMF IC's generate all eight. Table 1 shows how connecting various 2579 inputs high and low in various combinations produces various output tones.

When you push a button on a telephone keypad (or any keypad that uses the DTMF system), the circuit produces two tones, one each from the corresponding row (high group) and column (low group). When those tones are received, the receiving circuit must split the incoming audio into separate high- and low-group tones before it's able to decide which key you pressed. And, although DTMF decoding has become much easier, due to the use of special digital IC's, detecting the tones is still more complex than generating them.

Generating DTMF tones with AMI's 2579 is incredibly simple. As you can see in Fig. 2, the output of the keyboard circuit we put together last time is connected to the row inputs (pins 11–14) of the 2579; the column inputs (pins 3, 4, 5, and 9) are left floating. We can let the column inputs float, because they're tied high by internal 50K resistors. The colorburst crystal and the 10-megohm resistor are paralleled across pins 10 and 11, the chip's oscillator inputs. And that's all there is to it.

The output of the IC is DC emitter coupled; it is designed to drive a 120-ohm load. As the circuit stands, pressing a key will cause a signal composed of the two DTMF frequencies to show up at the output. In order for everything to work properly, however, we must take account of two additional pins of the 2579.

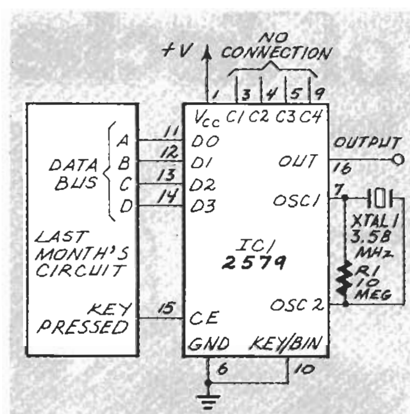


FIG. 2

Pin 15 is an active-high *C*hip *E*nable (CE). We control that pin with a signal from the keyboard that lets the 2579 know when a valid keypress has been made. If you examine the keyboard circuit in the last installment, you'll see there's a built-in "key-pressed" line—the common leg of the switches—that's tailor-made for this application.

In the keyboard circuit, the 4514

TABLE 1-2579 OUTPUTS

C1	C2	D3	D2	D1	D0	OUTPUT FREQUENCIES (Hz) LOW GROUP	HIGH GROUP	KEYPAD EQUIVALENT
1	1	0	0	0	1	697	1209	1
1	1	0	0	1	0	697	1336	2
1	1	0	0	1	1	697	1447	3
1	1	0	1	0	0	770	1209	4
1	1	0	1	0	1	770	1336	5
1	1	0	1	1	0	770	1447	6
1	1	0	1	1	1	852	1209	7
1	1	1	0	0	0	852	1336	8
1	1	1	0	0	1	852	1477	9
1	1	1	0	1	0	941	1336	Ø
1	1	1	0	1	1	941	1209	*
1	1	1	1	0	0	941	1477	#
1	1	1	1	0	1	697	1633	A
1	1	1	1	1	0	770	1633	B
1	1	1	1	1	1	852	1633	C
1	1	0	0	0	0	941	1633	D
0	1	Valid data				High group only		Single tone
1	0	Valid data				Low group only		Single tone

generates a high when a key is pressed. We used an inverter to flip the signal to control some pins of the 4514 and the 4520. The uninverted signal is exactly what we need for controlling the CE input of the 2579.

The overall sequence of operation is this: When a key is pressed, four bits of data are placed on the data bus. Next the "key-pressed" line goes high, the keyboard is frozen (debounced), and the 2579 is enabled.

The 2579 has an active-low MUTE output designed to let additional circuitry know that the 2579 is producing a tone. When valid data is present on the input bus, MUTE goes low. That signal is usually used to turn off the speaker and the microphone when the IC is used as the guts of a telephone. We don't intend to use the MUTE output, but keep it in mind—it may come in handy.

Another feature of the 2579 that you may find useful is available when you're using the IC in the binary (non-keyboard) mode. In that mode, the binary inputs are fed to the row inputs and the column inputs are ignored. However, two of the column inputs, C1 and C2 (at pins three and four), can still come in handy. When valid data is presented to the row inputs and CE is high, bringing C1 low will cause the 2579 to produce only the high-group frequency. If C2 is brought low, the 2579 will produce only the low-group frequency.

Signal conditioning

Now that we have a circuit that produces a DTMF-encoded signal by pressing a key, we have to condition the signal before sending it to the transmitter. In our case, all we really need is something to amplify the output.

There are two considerations we should keep in mind as we start designing that part of the circuit: power consumption and the final output. We're building a handheld encoder/transmitter that's going to run off a nine-volt battery, so we must be careful about the amount of power that the circuit uses. Because our final output is modulated infrared light, we can afford to keep the circuit nice and simple—and inexpensive.

An op-amp is perfect for our amplifier. Op-amps come in every imaginable flavor, don't use much power, are nice and stable, and best of all, are very forgiving. Since all we're looking for is a little bit of gain and buffering, we can use just about any op-amp.

To keep our circuit options open, and make sure that the transmitter is as flexible as possible, we'll use one quarter of an LM324 quad op-amp. You might ask why we use a quad package

DRAWING BOARD

continued from page 83

when all we need is a single op-amp. The answer is that, if we decide to add audio (or other circuitry) to the transmitter, it may be convenient to have an extra op-amp on board. One nice thing about the LM324 is that it's a low-power device and it's perfectly happy working from a single-ended supply.

However, if we really wanted to cut down on silicon, we could make our amp by daisy-chaining some of the unused inverters from the keyboard circuit. If you're into minimalist circuit design, feel free to substitute parts. You can even get rid of the inverter and replace it with a transistor. When it comes to experimenting, just remember Grossblatt's Sixth Law: Breadboards aren't made of stone. (It would be difficult to insert components if they were.—*Editor*)

The complete transmitter is shown in Fig. 3. The output of the op-amp is coupled to a 2N2222, which has enough output capability to drive two LED's. The use of two LED's increases the amount of power used by the transmitter, but it also increases its range. However, since the LED's draw current only when a key is pressed, a nine-volt battery should last fairly long.

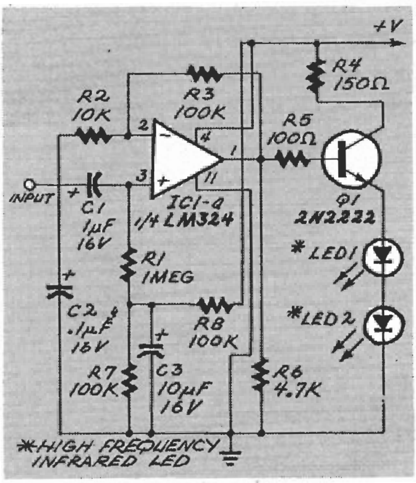


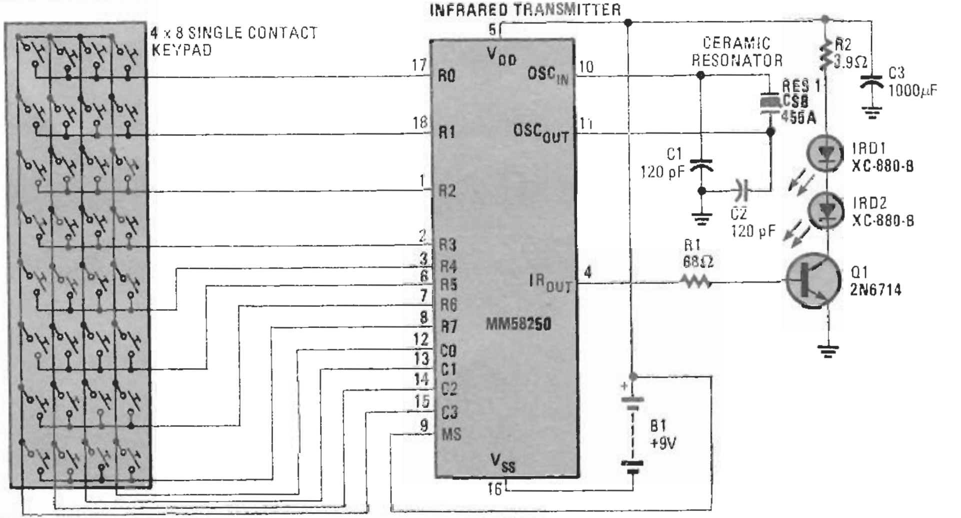
FIG. 3

You should use high efficiency LED's, which—wonder of wonders—you can find at Radio Shack. To increase range, you can use more than two LED's, but make sure that you don't allow more than about 40 ma of current flow through them, or you may burn them up.

Unless you're a mutant and can see infrared light, you won't be able to look at the LED's to see if the circuit is working. When you breadboard the circuit, substitute regular LED's for the infrared ones. If they flicker when you push a button, the circuit works. After you debug the circuit, replace the visible LED's with infrared ones.

Next month we'll start talking about the receiver and see what we have to do to build one. Remember that it's a bit more complex than the transmitter. **R-E**

94 Popular Electronics **FactCard** **MM58250: Infrared Transmitter**



MM58250: Infrared Transmitter

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS	TYP	MAX	UNITS
Supply Voltage Supply Current (Active) Oscillator Frequency*		 455	10 5	V mA kHz
Output Voltage Logic "0" Logic "1"	150 µA Sink 10mA Source		0.6	V V
Output Current	$V_{DD}-1.4V$		−20	mA
Input Levels Logic "0" Logic "1"	MS=0, $4.5 \leq V_{DD} \leq 5.5$ Direct Mode		0.5	V V
Input Current R_0-R_6, MS R_7	MS=0, $4.5V \leq V_{DD} \leq 5.5V$ $0V \leq V_{IN} \leq V_{DD}$ $V_{IN}=0.4V$		 1.0 0.6	 µA mA
Input Current R_0-R_7 MS	MS=1, $3.0V \leq V_{DD} \leq 10V$ $V_{IN}=0.4V$ $0V \leq V_{IN} \leq V_{DD}$		 1.6 1	 mA µA
Output Current Logic "1" Source "1" Source Logic "0" Sink "0" Sink	MS=1 $V_{DD}=3V$, $V_{OUT}=V_{DD}-1V$ $V_{DD}=10V$, $V_{OUT}=V_{DD}-1V$ $V_{DD}=3V$, $V_{OUT}=0.4V$			µA µA µA µA
Output Current Logic "1" Logic "0"	MS=0, $4.5V \leq V_{DD} \leq 5.5V$ $V_{OUT}=0.4V$		 1	 µA