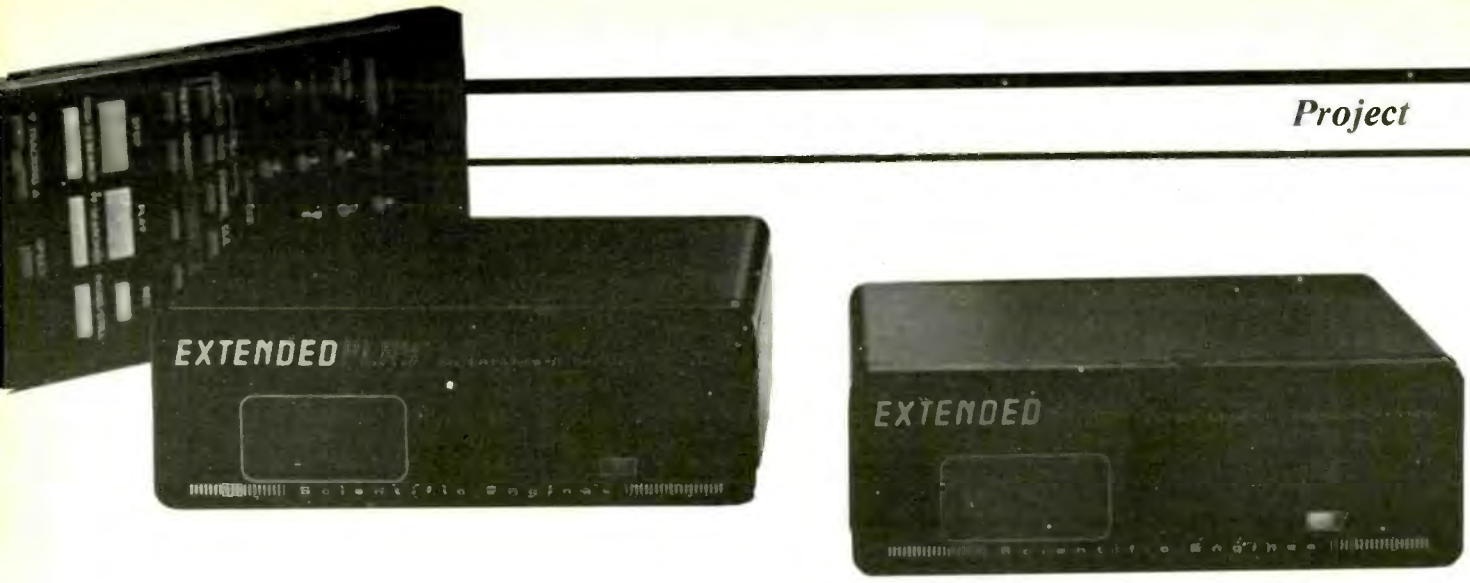


The Extended Play Remote-Control System

(Conclusion)

Operating and construction details for the receiver module, system checkout and installation and use

By Crady M. VonPawlak

Last month in Part 1 of this article, we discussed the theory of operation, construction and initial checkout of the transmitter portion of the Extended Play Remote-Control System. This month we conclude with the receiver module, system checkout and installation and use of the full system. The system enables one to control a VCR or stereo music system with his infrared hand-held remote controls from another location without running connecting wire or cables. Thus, one can watch or listen on a set in another room while maintaining full control of the device in the main room.

About the Circuit

The complete schematic diagram of the receiver circuitry is shown in Fig. 7. Capacitor *C6* and resistor *R9* provide capacitive coupling of the signal impressed on the ac line by the transmitter to coupling transformer *T2*. This RC network plays a secondary role, attenuation of large power-line spikes and transients that can enter *T2* or power transformer *T1*.

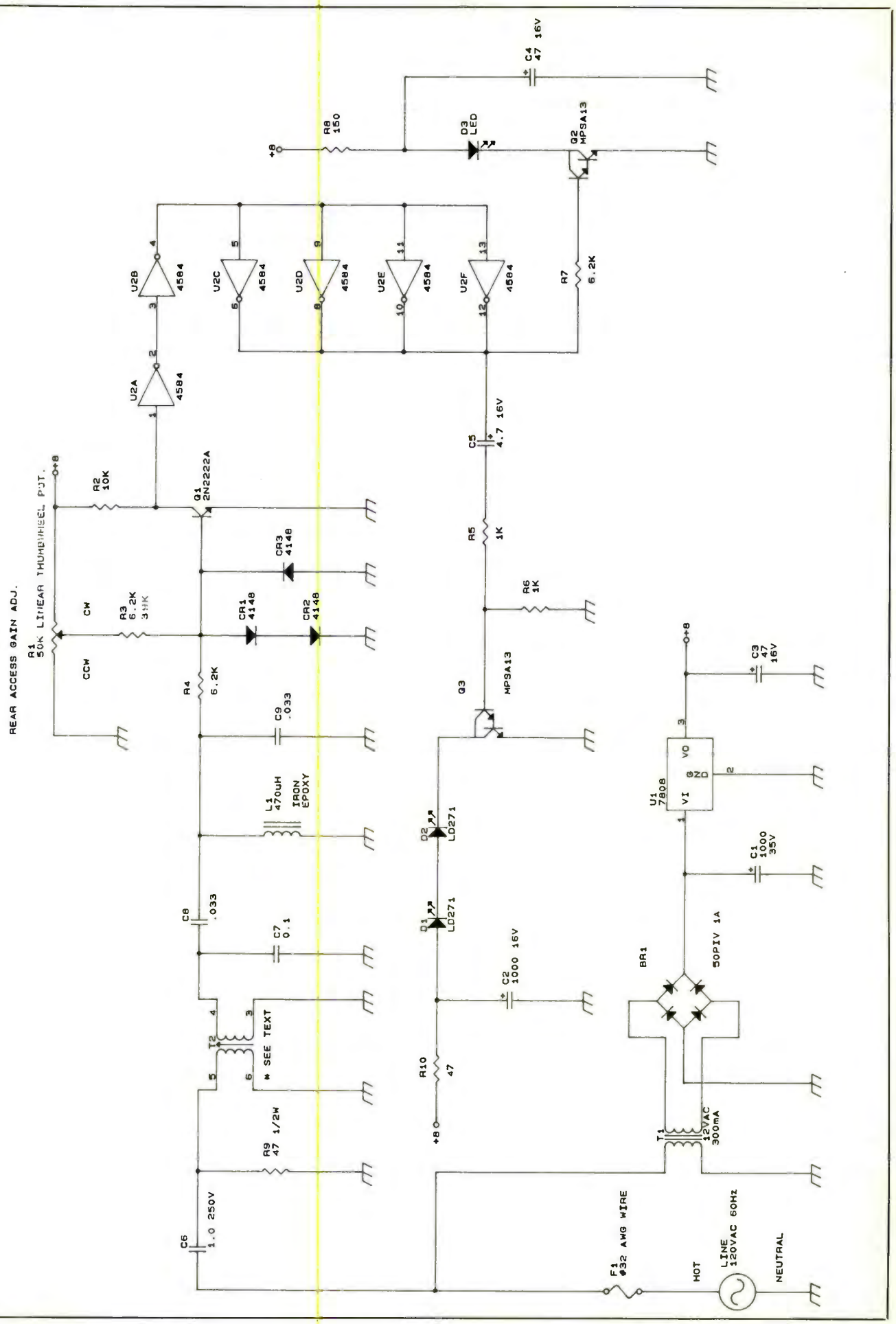
The receive side of *T2* (pins 5 and 6) is impedance-matched to the ac power line. This impedance can vary from 3 to 14 ohms. To accommodate these variations, the receiver circuit has been optimized for a 3-ohm worst-case operation.

As the incoming signal is passed to the secondary of *T2* (pins 3 and 4), it is stepped up by a turns-ratio of approximately 10:1. Capacitor *C7* across this winding forms a high-Q LC resonant tank circuit that is designed for optimum operation in the frequency range of 30 kHz to 60 kHz, which is the anticipated frequency range of the received signal.

This signal is then passed to the series-parallel bandpass filter made up of *C8*, *C9* and *L1*. The circuits thus far described extract and passively amplify only those signals impressed onto the ac power lines by the Extended Play carrier-current transmitter while rejecting the majority of transients, noise and signals produced by non-related, carrier-current devices.

After filtering and amplification, the received signal is passed to current-limiting resistor *R4* and clipping diodes *CR1* and *CR2*. The two diodes limit signal amplitude to a normalized level of approximately 1.4 volts, as seen by transistor *Q1*. Reverse-biased switching diode *CR3* across *CR1* and *CR2* clamps against nega-

Fig. 8. Complete schematic diagram of receiver module circuitry.


REAR ACCESS GAIN ADJ.
R1 50K LINEAR THUMBWHEEL POT.
CW
CCW
R2 10K
R3 6.2K 3%K
R4 6.2K
R5 1K
R6 1K
R7 6.2K
R8 150
R9 47 1/2W
R10 47
Q1 2N2222A
Q2 MPSA13
Q3 MPSA13
D1 LD271
D2 LD271
D3 LED
CR1 4148
CR2 4148
CR3 4148
U2A 4584
U2B 4584
U2C 4584
U2D 4584
U2E 4584
U2F 4584
C1 1000 35V
C2 1000 16V
C3 47 16V
C4 47 16V
C5 4.7 16V
C6 1.0 250V
C7 0.1
C8 .033
C9 .033
L1 470uH IRON EPOXY
T1 12VAC 300mA
T2 * SEE TEXT
BR1 50PIV 1A
U1 7808
VI
GND
VO
+8
F1 #32 AWG WIRE
HOT
NEUTRAL
LINE 120VAC 60Hz

tive-going transients that may enter through the bandpass filter stages.

A variable-level voltage divider bias is provided for *Q1* by *R3* and trimmer potentiometer *R1*. This circuit provides a simple method of adjusting overall receiver gain (sensitivity) for setting optimum performance for a given location within your home. Resistor *R2* sets the collector current for transistor *Q1*.

When the received control signal is passed to the base of *Q1*, a current flows through the emitter-collector junction of *Q1*, which causes the collector voltage to appear as a ground (low) potential to the input of *U2*. Resistor *R2* holds the input to one gate of *U2* in a normally high state until a control signal is received.

CMOS hex Schmitt-trigger inverter *U2* cleans up the amplified signal that appears at the collector of *Q1*. It also provides additional drive current to accommodate both the LED visual indicator and the IR driver final output stage.

Visual indication of a received signal is provided by light-emitting diode *D3*. The output signal from *U2* is passed to current-limiting resistor *R7* to drive the base of switching transistor *Q2*. This causes a current to flow through the emitter-collector junction of *Q2* and forward-biases the LED. Current for *D3* is provided by *R8/C4*. Capacitor *C4* maintains a high current at the anode of *D3* while preventing excessive dropouts and spikes from appearing on the 8-volt dc power supply during the LED turn-on and turn-off cycles.

These on/off cycles appear at the same rate and frequency as that of the received signal. This indication can be used in conjunction with the manual gain control to provide for a quick visual reference of receiver gain setting during initial installation of the receiver module.

To communicate with the device(s) to be controlled, the received control signal must be reconstructed and output in its original IR energy. To accomplish this, the shared output of *U2* is passed to the IR output driver. This output is capacitively coupled by *C5*. This ac coupling provides overdrive protection for *Q3* and the power supply should the manual gain be set high enough to force the output of *U2* into a continually on (steady dc) state and/or should any front-end component fail and cause the same effect as excessive current drawn by the IR diodes.

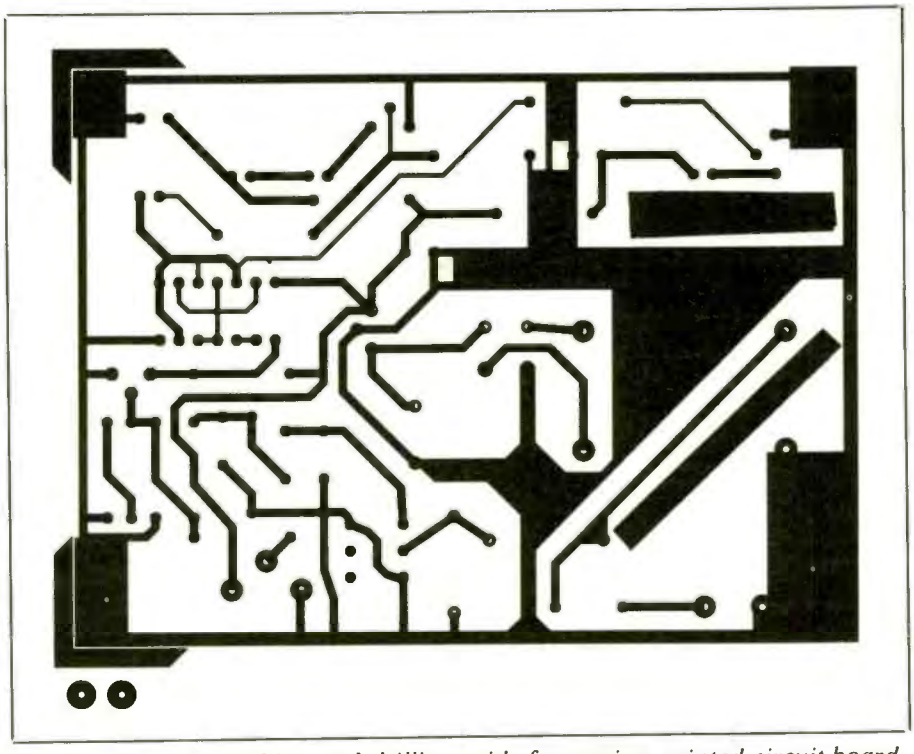


Fig. 9. Actual-size etching-and-drilling guide for receiver printed-circuit board.

Voltage-divider bias of the signal is provided for *Q3* by *R5* and *R6*. The required IR energy is generated by high-output IR-emitting diodes *D1* and *D2*. Buffer capacitor *C2* maintains the high current levels required for proper operation by *D1* and *D2* during reception and re-transmission.

When a positive-going signal is present at the base of *Q3*, a current flows though the emitter-collector pn junction of the transistor. This forward-biases *D1* and *D2*. The rate and frequency at which *Q3*, *D1* and *D2* operate exactly matches that of the signal originally emitted by the hand-held IR remote-control transmitter used with the project, though it is at a greatly increased energy level.

A simple regulated dc power supply for the receiver circuit is provided by *T1*, *BR1*, *C1*, *C3* and *U1*.

Construction

For the receiver, you can use either a printed-circuit board or perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware on which to mount and wire the components. If you opt for pc construction and wish to fabricate your own board, use the actual-size etching-and drilling guide shown in Fig. 9. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts list.

From here on, we will assume that you are using pc construction. This being the case, refer to the wiring guide shown in Fig. 10. (If you go the

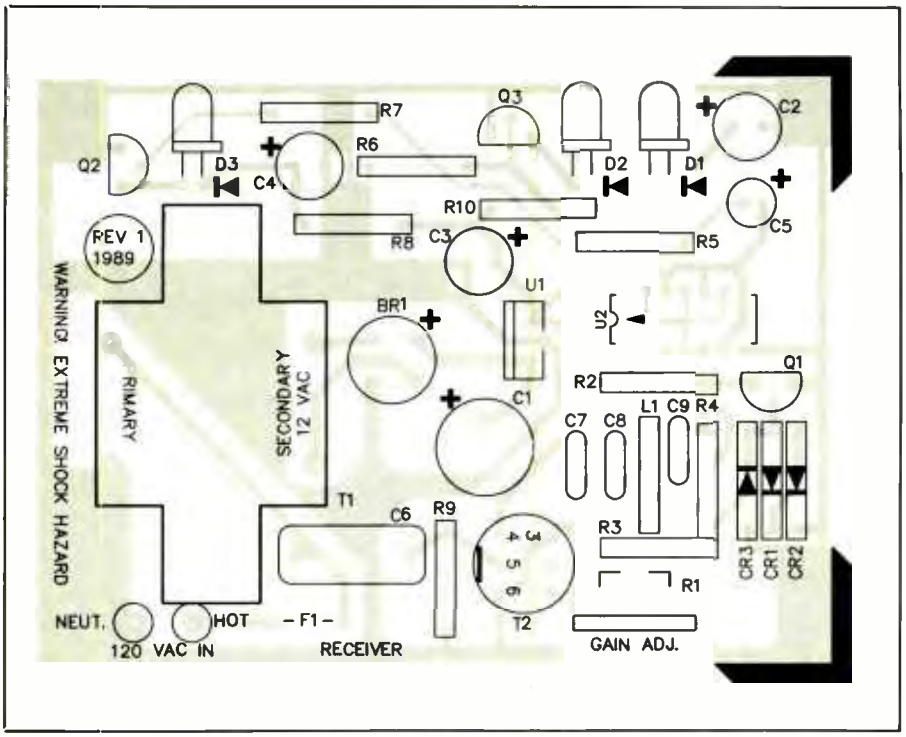


Fig. 10. Wiring guide for receiver pc board.

point-to-point wiring route, use Fig. 10 as a rough guide to component placement.)

Use the same assembly procedure to wire the receiver board as detailed last month for the transmitter board. That is, start by installing and soldering into place the sockets for DIP *IC2*. Do *not* plug the IC into the socket until after you have conducted a voltage check and are certain that the board has been properly wired.

Proceed with installation of the resistors, capacitors and diodes. Make sure the electrolytic capacitors and diodes are properly oriented before soldering their leads into place. Next, install the transistors and then GAIN ADJUST trimmer *R1* in their respective locations. Again, make sure that the transistors are properly based before soldering their leads into place.

Now install power transformer *T1* and coupling transformer *T2* in their respective locations. Make absolutely certain that you do not transpose the primary and secondary leads of *T1* and that the notch on the case of *T2* is oriented along the heavy straight line in the case outline for this component in Fig. 10 before soldering any leads or pins into place.

Install the three LEDs in their respective locations on the edge of the circuit-board assembly as shown. Note that if any LED overhangs the edge of the board, it should do so by no more than 1/16 inch, as illustrated in Fig. 11. Use a short length of No. 32 bare wire for fuse *F1*.

Machine the enclosure that will house the receiver module. This is done in basically the same manner that was described last month for the transmitter module, except that an extra hole, to provide access to trimmer GAIN ADJUST potentiometer *R1* is required in the rear panel. If you are using the type of enclosure supplied with the kit (see Parts List), use the actual-size machining templates provided in Fig. 12 as guides for the rear (A) and front (B) panels. If you are using any other type of enclosure, make suitable adjustments in the templates before using them for machining the panels.

When machining of the panels is complete, do *not* set the self-stick front-panel overlay in place. You must first mount the front panel in place on the enclosure, using the small screws provided, before attempting to mount the overlay, which then covers the entire panel, including the screw heads. Therefore, save installation of the front-panel overlays on both the transmitter and receiver modules until *after* the entire system has been checked out for proper operation.

Meanwhile, pass the unfinished end of the ac line cord through its hole in the rear panel and fasten it in place with a plastic strain relief, or tie a strain-relieving knot in it about 3 inches from the unfinished end on the inside of the panel.

Tightly twist together the fine wires in each line-cord conductor and sparingly tin with solder. Plug the conductors into the 120 VAC IN holes in the receiver circuit-board assembly and solder into place. (Note: Check which conductor you plugged into the hole labeled NEUT in the transmitter board. Regardless of whether its insulation is smooth or ribbed, plug the conductor with the *same* insulation in the NEUT hole in the receiver board.

Now perform voltage checks to ascertain that the receiver module has been properly assembled. For this, you need a dc voltmeter or a multimeter set to the dc-volts function. Clip the common lead of the meter to a convenient circuit-ground point on the receiver circuit-board assembly, such as the metal tab on the bridge-rectifier assembly. When you perform the following voltage tests, make absolutely certain that you do not touch the primary circuit of *T1*. Potentially lethal 117-volt ac line potential is present in this portion of the circuitry.

When you are ready to perform the

MASTER PARTS LIST

RECEIVER

Semiconductors

BR1—50-PIV bridge rectifier assembly
CR1,CR2,CR3—1N4148 switching diode
D1,D2—LD271 1R-emitting diode in T1¾ package
D3—Yellow light-emitting diode in T1¾ package
Q1—2N2222A general-purpose npn silicon transistor
Q2,Q3—MPSA13 Darlington transistor
U1—7808 +8-volt regulator in TO-220 package
U2—CD4584BC CMOS Schmitt-Trigger Inverter

Capacitors

C1—1,000-μF, 35-volt electrolytic
C2—1,000μF, 16-volt electrolytic
C3,C4,C5—47μF, 16-volt electrolytic
C6—1.0μF, 250-volt metalized polyester
C7—0.1μF, 50-volt metalized polyester
C8,C9—0.033μF, 50-volt metalized polyester

Resistors (¼-watt, 5% tolerance)

R2—10,000 ohms
R3—39,000 ohms
R4,R7—6200 ohms
R5,R6—1,000 ohms
R8—150 ohms
R9,R10—47 ohms, ½-watt
R1—50,000-ohm upright pc-mount, noninductive trimmer potentiometer

Miscellaneous

F1—¼-ampere fuse or No. 32 solid bare wire (see text)
L1—470-μH low-power inductor with iron or ferrite core and axial leads
T1—12.6-volt ac, 300-mA pc-mount power transformer
T2—100-μH coupling transformer (TOKO No. 707VX-A03YUK)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); socket for U2; polarized ac power cord; plastic strain relief (optional—see text); suitable enclosure; hookup wire; solder; etc.

TRANSMITTER

Semiconductors

BR1—50-PIV bridge rectifier assembly
CR1—1N5819 Schottky diode
D1—SFH205 photodiode
D2—T1¾ green light-emitting diode
Q1—TIP120 power Darlington transistor (TO-220 package)
Q2—MPSA13 Darlington transistor
U1—78L05 +5-volt regulator
U2—CD4584BC CMOS hex Schmitt-trigger inverter
U3—TDA4060 infrared amplifier with agc

Capacitors

C1—1,000-μF, 35-volt electrolytic
C2—47-μF, 50-volt electrolytic
C3—47-μF, 16-volt electrolytic
C4—47-μF, 35-volt electrolytic
C5—4.7-μF, 16-volt electrolytic
C6—1-μF, 250-volt metalized polyester
C7—0.22-μF, 16-volt metalized polyester
C8—0.33-μF, 16-volt dipped tantalum
C9—0.1-μF, 16-volt metalized polyester
C10—0.1-μF, 100-volt metalized polyester
C11—0.01-μF, 100-volt metalized polyester
C12,C13—220-pF, 16-volt monolithic ceramic

Resistors (¼-watt, 5% tolerance)

R1—100,000 ohms
R2—39,000 ohms
R3—6,200 ohms
R4,R5—1,000 ohms
R6—330 ohms
R7—47 ohms, ½ watt
R8,R9—4.7 ohms, ½ watt

Miscellaneous

F1—¼-ampere fuse (see text)
T1—12.6-volt ac, 300-mA pc-mount power transformer
T2—Coupling transformer (TOKO No. 707VX-A043YUK)
Printed-circuit board; suitable enclosure (see text); ac line cord with plug; sockets for U2 and U3; fine copper mesh for Faraday shield (see text); hookup wire; solder; etc.

Note: The following items are available from Scientific Engines, P.O. Box 2295, Everett, WA 98203: Complete Extended Play transmitter and receiver kit (includes pc boards, enclosures, all electronic components, copper screen and self-adhering front-panel overlays), $119.95 plus $3.50 P&H; additional receiver and transmitter kits, $62.95 each plus $2.50 P&H; ready-to-wire transmitter and receiver pc boards, $32.50 per set of two plus $2.50 P&H. Mail orders, make payment via certified check or postal money order; Visa/MasterCard orders, call: (206) 348-7754. Washington residents, please add state sales tax to all orders.

voltage test (*U2* should *not* be in its socket at this time) turn the thumbwheel of trimmer potentiometer *R1* fully counterclockwise, and place the circuit-board assembly on an insulated surface.

Plug the receiver's line cord into an ac outlet and touch the "hot" probe of the meter to pin 14 of the *U2* socket. The meter should register a reading of +8 volts. If you do not obtain the proper reading, touch the "hot" probe of the meter to INPUT pin 1 of regulator *U1*, where you should obtain a meter reading of approximately +20 volts. If you fail to obtain the proper reading at either or both points on the circuit-board assembly, unplug the receiver module from the ac line and carefully check over all component installations and wiring and soldering. Make sure each component is in its appropriate location and those that require polarizing and special basing are properly installed.

Turn over the circuit-board assembly and check all soldering. If you missed any connections, solder them now. If any connection appears grainy or otherwise suspicious, reflow the solder on it. Also, clear away any solder bridges, especially between the closely-spaced pads for the *U2* socket and *T2* with desoldering braid or a vacuum-type desoldering tool. Do not proceed until you

have rectified the problem.

When you are satisfied that the circuit-board assembly has been properly wired, unplug it from the ac line. Allow the charges to bleed off the electrolytic capacitors in the power supply. Then install *U2* in its socket. Make sure the IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Operational Checkout

Place the transmitter and receiver modules back-to-back (all LEDs on both boards facing away from each other) on an insulated surface and plug both units into ac outlets. Using a VCR, TV or other IR remote-control transmitter to activate the transmitter should cause the receiver board to respond. This activity will be evident by the visible LED on that module flashing when any transmitter key is held down.

Now place the Extended Play transmitter and receiver units so that they are face-to-face (all LEDs on both units facing each other). This should cause the system to self-oscillate from IR feedback. You may have to start the ball rolling with a little stimulus from your remote-control transmitter. Although not recommended for more than a few seconds at a time, this test will easily show that everything is working as it should.

When you are confident that both units are performing satisfactorily, it is time for a test using the actual components the system will control. Although the following procedure can be accomplished with a CD player, stereo system or any other IR-controlled appliance, a VCR and some means of sending its output to a remotely located TV receiver will be assumed. Of course, if you have any of these other devices, you can use one of them instead.

Mount the front panels on the transmitter and receiver unit enclosures with the provided screws and carefully install the overlays so that

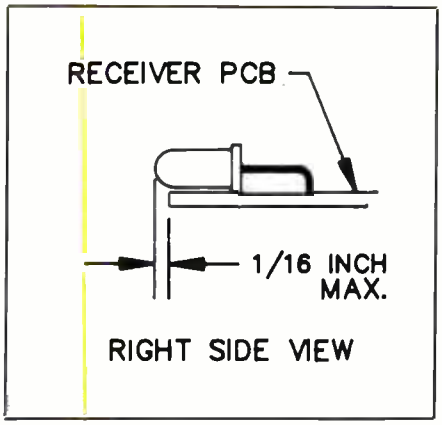


Fig. 11. Mounting details for the LEDs on the receiver pc-board.

the translucent red filter sections are positioned over the rectangular cutouts in the panels. Slide the circuit-board assemblies into their enclosures and mount the rear panels in place, again with the supplied screws.

Position the Extended Play receiver module across the room from your VCR so that its front-panel IR window faces the front of the VCR at a distance of not more than 18 feet. Plug the receiver's line cord into a convenient ac outlet. Use a small screwdriver to slowly adjust the GAIN control through its access hole in the rear panel clockwise until the LED just begins to glow very brightly. Then back off (counterclockwise rotation) until the LED either suddenly goes dark or suddenly glows dimly.

If the LED glows dimly even when the GAIN control is adjusted fully (or nearly) counterclockwise, excessive noise is present on the ac line. You may leave the unit plugged into this outlet or test others in the room for quieter operation. Alternatively, you can make either or both of the following modifications.

In the transmitter module, replace *C7* with a 0.1-microfarad polyester

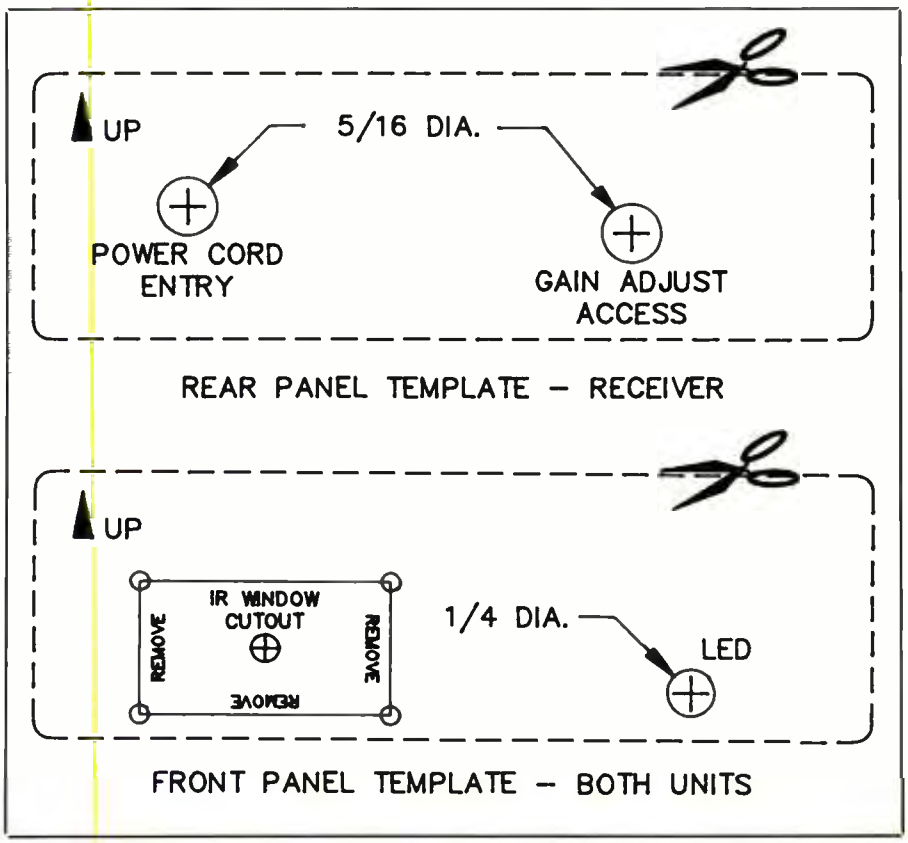


Fig. 12. Machining templates for rear (A) and front (B) panels of receiver enclosure.

or Mylar capacitor. This slightly reduces the threshold of the IR circuit but otherwise leaves unaffected the 18-foot-plus range of the project. In the receiver module, place a 1,000-ohm resistor across (in parallel with) *C7*. This effectively lowers the Q of the LC tank circuit to reduce noise-induced "ringing." Neither of these modifications will noticeably reduce the performance of the circuits.

Once you have set the receiver threshold, play a prerecorded videocassette through the VCR. After pressing PLAY, check the remote TV receiver (it is assumed that you have run video and audio cables from the VCR to the remote TV receiver beforehand) to be sure it is playing whatever is recorded on the tape.

Place the Extended Play transmitter on or near the remote TV receiver. Using the remote-control transmitter supplied with the VCR, press PAUSE (not being able to see the VCR indicator lights may take some getting used to if you have never used a remote-remote control system before). If you correctly assembled the Extended Play transmitter and receiver modules and your house wiring provides good coupling, the TV image displayed on the TV receiver screen should freeze to a still picture.

This simple test verifies that the system is, indeed, operating as it should. If you wish, you can resume picture action, stop it, fast forward or rewind to another section of the tape to check out these functions as well. However, if even one function works via the Extended Play link, all other functions will as well.

If your VCR does not respond properly during the system operational check, something is wrong with the wiring in either the transmitter or the receiver module or both. In this event, power down both units and carefully check over your work.

If you have a problem and use an oscilloscope to perform any tests in the Extended Play circuits, do *not* make any connections to ground. If the scope you use has a three-prong power-cord plug, use a three-to-two-prong adapter between it and the ac outlet before use.

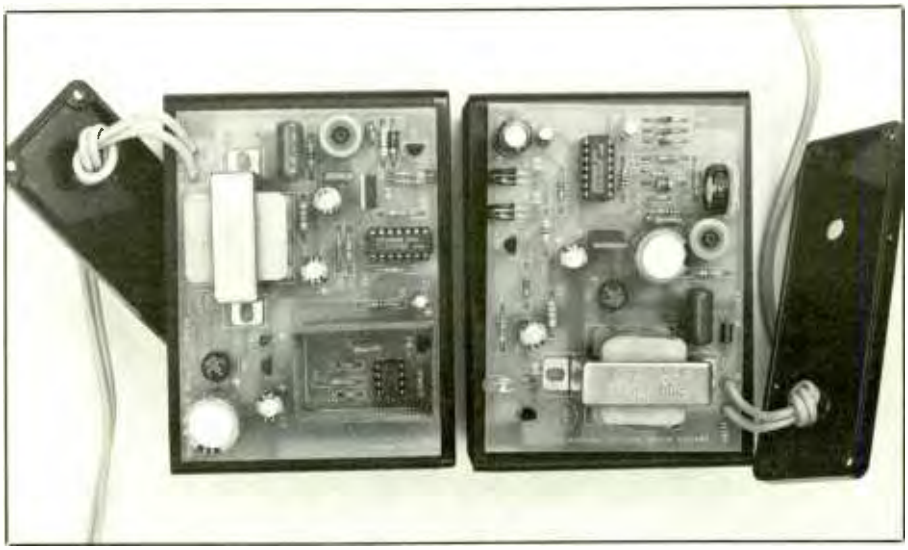


Fig. 13. Photo shows fully wired transmitter (left) and receiver (right) circuit-board assemblies just prior to installation in the enclosures atop which they sit.

System Installation

Placement of the Extended Play transmitter(s) and receiver in your home depends as much on room layout as on personal taste. You can pretest different locations for the receiver using a hand-held remote-control transmitter to emulate the proposed positioning. If a given location works well with the remote-control transmitter, it will almost certainly work as well with the receiver.

As a matter of convenience, you may want to experiment with placing the receiver directly on top of or alongside your VCR. If a window or light-colored wall directly faces the VCR from across the room, the receiver should be able to beam the control signals at the wall with enough energy that they reflect back to the VCR without significant loss.

The transmitter can be placed beside or atop most TV receivers without experiencing erratic behavior. However, computer monitors produce a great deal more emi (electromagnetic radiation, or noise) than do TV receivers. If your remote TV receiver is located close to a computer, try to keep the Extended Play transmitter at least 24 inches from the computer monitor. Any interference from the computer monitor can be identified by continuous erratic flashing of the transmitter LED.

Some Caveats

When you are setting up the Extended Play or any carrier-current system for permanent use there are several things to watch for. One is cable TV converter-box IR remote control systems. Although the majority of these systems are well designed, some are poorly designed with regard to method of IR transmission. A very few converters (the type distributed by some cable TV franchises) use an unmodulated IR signal to transmit the control codes. In affect, these systems simply use slow on/off pulses that make them susceptible to false signals and may or may not be accurately retransmitted by the Extended Play system.

High noise levels may appear on the ac power lines used to carry the Extended Play signals. Although this

is not a significant problem, it appears at the receiver as a constant, dim glowing of the LED indicator. You can tackle the problem by modifying the transmitter or/and receiver as described above to deal with this problem.

A final consideration is the house wiring itself. Because of the manner in which the incoming 240 volts ac is divided into its two respective 117-volt ac legs, it is possible for two outlets in the same room to be on completely different circuits, each 180 degrees out-of-phase with the other (with respect to neutral). This single anomaly in the house wiring is the biggest hurdle to be overcome by any carrier-current system.

In effect, for an ac outlet on one circuit to communicate with another on a different circuit using carrier-current transmission requires that the signal make a round-trip via the step-down transformer located somewhere in your neighborhood.

The solution for this is as simple as placing a 0.01-microfarad high-voltage capacitor (rated at 400 volts or greater) directly across the 240-volt ac line somewhere in your home. This capacitor can be installed at the outlet of any 240-volt ac appliance or at the breaker box (or fuse panel) where the 240-volt line enters your home. A good choice for such a capacitor is the Radio Shack Cat. No. 272-160. Rated at 2,000 volts (2 kV), it will easily handle permanent installation across a 240-volt ac line.

If you decide to install this capacitor, exercise extreme caution! Bear firmly in mind that 240 volts ac is *lethal*. Therefore, before even attempting to make any connections, make sure to open the main breaker (or remove the main fuse) at the junction box to shut down *all* power within your home so that you can work in complete safety. As a further precaution, check the "dead" house wiring with an ac voltmeter prior to touching any house wiring.

This modification is recommended by several manufacturers of carrier-current controllers in their installation manuals and troubleshooting guides. Although this should be looked upon as a last resort (few homes actually need this modification), it will benefit any carrier-current accessories you presently own.

Now that you have established an IR link via the ac wiring in your home, some interesting possibilities are possible. For example, you can use the Extended Play system as a burglar alarm accessory, a remote appliance controller and more, assuming you come up with suitable interfaces. Add to this list lights, heaters, fans and air conditioners, all of which should be able to be controlled with the proper interfaces. Even a personal computer with an IR transmitter adapter is not inconceivable! With a bit of ingenuity on your part, you can probably think up dozens of other control applications for the Extended Play. **ME**