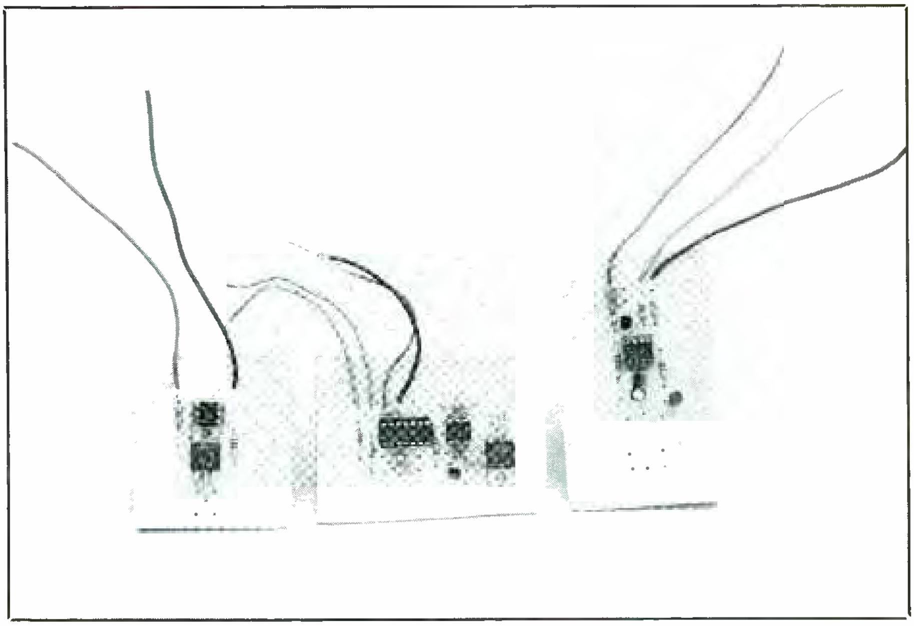
A 6-Channel IR Remote-Control System

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

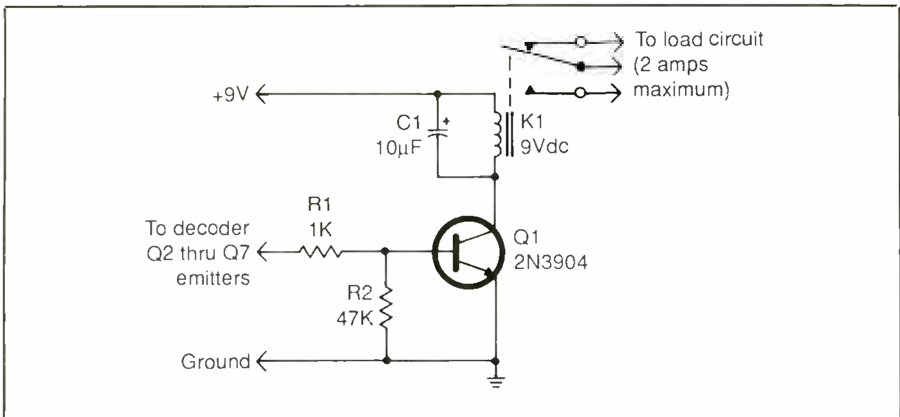


Fig. 1. Simplest type of control circuit contains an electromechanical relay that is driven by a transistor.

transmitter pushbutton is pressed, the potential at the emitter of the driver transistor rises to about +5 volts. This is sufficient to forward-bias relay transistor *Q1* in the Fig. 1 circuit so that collector current flows and energizes relay *K1*.

Shown in Fig. 2 are the actual-size etching-and-drilling guide (A) and wiring diagram (B) for the printed-circuit board for the Fig. 1 relay driver circuit. You can fabricate this and any of the other pc boards presented in this article or you can purchase ready-to-wire boards from the source given in the Note at the end of the Parts List. Guide (A) is laid out for the relay specified for *K1* in the composite Parts List. Hence, if you use a different relay, you will have to modify the layout accordingly.

When wiring the pc board, note in Fig. 2(B) that you must make three connections to the receiver/decoder circuit—to +9 volts, circuit ground and any one of the emitters of driver transistors *Q2* through *Q7*. Be careful not to confuse +9 volts with V_{dd}, which is the regulated 6.8-volt bus. Also, make certain that the transistor is properly based and electrolytic capacitor *C1* is properly oriented before soldering any of its leads to the pads on the bottom of the board.

The contacts of the relay on the slave module can be used to control ac or dc power to the load. When the appropriate transmitter button is pressed, the corresponding LED in the driver emitter-follower stage in the receiver/decoder will turn on simultaneously with energization of the relay. If the LED turns on but the relay does not energize, use a high-impedance digital voltmeter or a multimeter set to the dc-volts function to ascertain that you have 9 volts dc applied between the proper terminals on the slave module and that the drive voltage appears at the input of *R1* when the appropriate button on the transmitter is pressed. Also, check to make sure that *Q1* and *C1* are properly oriented.

• *Solid-State Drivers.* The circuits shown schematically in Fig. 3 and Fig. 4 are in many cases a better way to go to provide momentary control of the power to an ac load. For one thing, they are completely solid-state, which means that they have no moving parts to fatigue and wear out, as will happen with an electromechanical relay. Additionally, the optical isolators in these circuits provide electrical isolation between the low-voltage receiver/decoder control circuit and the load. Hence, you can safely control 117-volt ac lamps, appliances and other ac-line-powered loads with the low voltage circuit of the receiver/decoder.

The optoisolators used in these circuits contain a light-emitting diode

PARTS LIST*

Semiconductors

D1,D2—1N4148 or similar general-purpose silicon diode

IC1,IC2,IC5,IC8—MOC3011 or equivalent optical isolator

IC3—H11D4 or equivalent optical isolator

IC4—CD4001BE quad 2-input NOR gate

IC6,IC7—LM555 timer

LED1—Visible 2-volt, 20 mA light-emitting diode

Q1,Q6,Q7,Q8—2N3904 or similar npn silicon transistor

Q2,Q5,Q9—2N6342 or similar triac

Q3—TIP31 or similar npn silicon transistor

Q4—BS170 or equivalent N-channel enhancement-mode field-effect transistor

Capacitors

C1,C4—10-µF, 25-volt electolytic

C2,C3,C5—0.1-µF, 50-volt ceramic disc

C_t—Value selected for desired timing duration (see text)

Resistors (¼-watt, 10% tolerance)

R1—1,000 ohms

R2,R7,R8,R13,R17—47,000 ohms

R3,R4,R6,R20—100 ohms

R5,R10,R11,R21—150 ohms

R9—220,000 ohms

R12,R14,R16,R18—10,000 ohms

R15—1,000 ohms

R19—470 ohms

R_t—Value selected for desired timing (see text)

Miscellaneous

K1,K2—Spdt 9-volt dc relay (Radio Shack Cat. No. 275-005 or similar; printed-circuit boards; sockets for ICs and optical isolators; suitable enclosures (optional); machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire pc boards, $8.95 each (specify which circuits), MOC3011 optical isolator, $5 each (specify ac or dc); CD4001BE, $2; LM555 timer, $2; transistors, $3 each (specify which needed). Add $2 P&H per order. New Jersey residents, please add state sales tax.

*This is a composite Parts List. Use only those components specified in the specific schematic diagrams of the slave modules you wish to build.

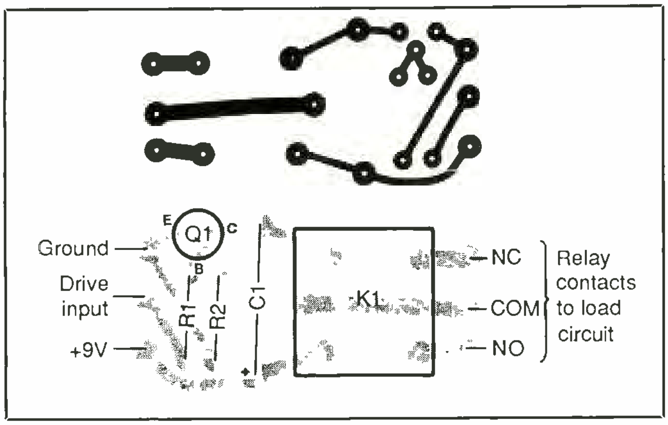


Fig. 2. Actual-size etching-and-drilling guide (upper) and wiring diagram (lower) for Fig. 1 circuit.

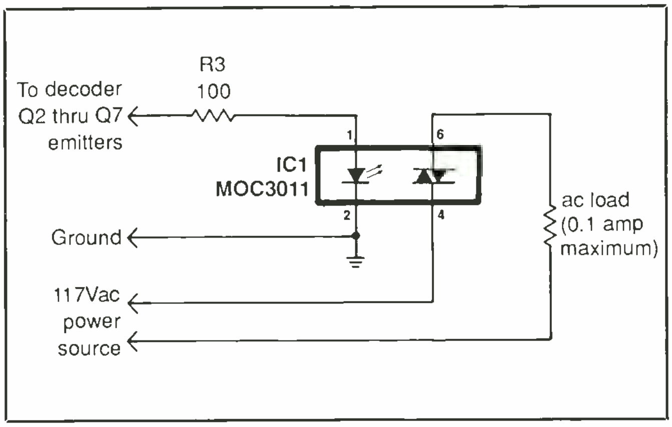


Fig. 3. A simple circuit that can control ac power to a load that draws up to 0.1 ampere.

that is driven by an emitter-follower transistor driver in the receiver/decoder. The LEDs in the optoisolators require at least 10 milliamperes of drive current to reliably switch on the triacs built into these devices. For this reason, it is necessary when using the circuits to slightly modify the driver transistor circuit of any channel in which an optoisolator is used.

To effect the modification, disconnect the LED associated with the selected receiver/decoder driver transistor. Then change the value of the base resistor of the driver transistor from its originally specified 220,000 ohms to 47,000 ohms. This value change ensures that the LED in the optoisolator is supplied with sufficient drive current to activate the internal triac.

The triac contained in the optoisolator is a low-current unit that is rated to handle up to 0.1 ampere. This triac responds to the light generated by the internal LED and switches "on" when the LED is activated. Once triggered on, the triac permits current to flow into the load. Bear in mind that the circuits depicted in Fig. 3 and Fig. 4 should be used only for ac loads that require 117 volts or less.

The basic Fig. 3 circuit is rated to handle loads that require up to 0.1 ampere, which limits its application to a very light load of 12 watts or less. Though 117-volt lamps of this power level are available, they are not common nor desirable in many situations. However, you can use this circuit to drive the coil of an ac relay that, in turn, can safely carry whatever heavier load you wish to control. Such a configuration would also permit multiple-pole switching, which is not directly attainable with the optoisolator.

When load current for the intended application exceeds 0.1 ampere, the Fig. 4 circuit proves to be more useful than does the Fig. 3 circuit. In this circuit, the optoisolator's internal triac is used to provide a gate signal to a second triac that has greater power-handling capability. The second triac then controls the load current. You can use any triac externally that can handle the required load current, but be sure to use some heat sinking in applications where the load current exceeds 2 amperes. The triac specified in the Parts List for this circuit is rated to carry 8 amperes, but it will overheat at that current unless a suitable heat sink is used to siphon off and dissipate the heat.

If your intended application is to control a dc load, you can use the circuit shown schematically in Fig. 5. This circuit uses an optoisolator that is different than those specified for the Fig. 3 and Fig. 4 circuits. It has a light-activated npn transistor instead of a triac and, thus, is capable of controlling a dc current.

To provide a reasonable current to drive loads up to 3 amperes dc, *Q2* has been added to the Fig. 5 circuit in a Darlington configuration. The low-current transistor inside the optoiso-

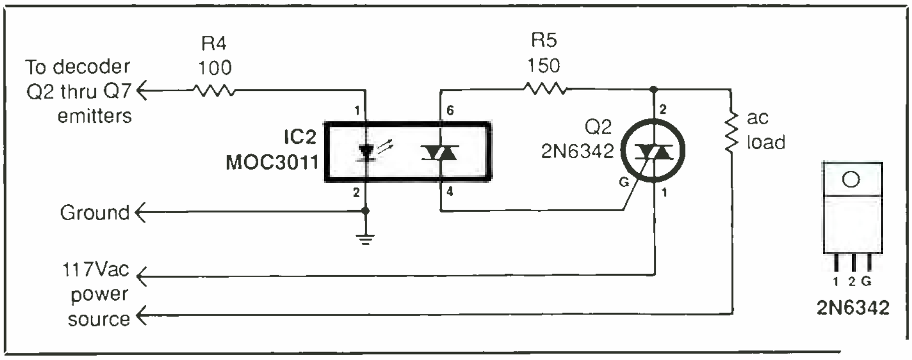


Fig. 4. This control circuit can handle ac loads that exceed 0.1 amp

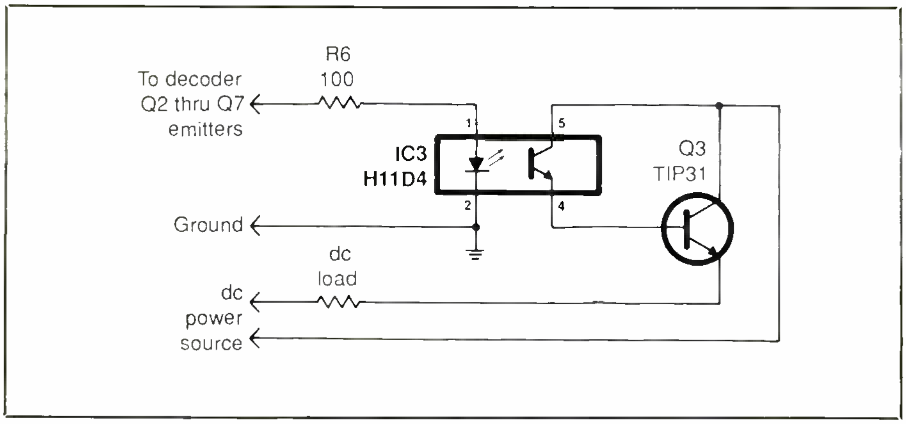


Fig. 5. This circuit controls power to a dc load using a Darlington transistor arrangement to handle up to 3 amperes of dc current.

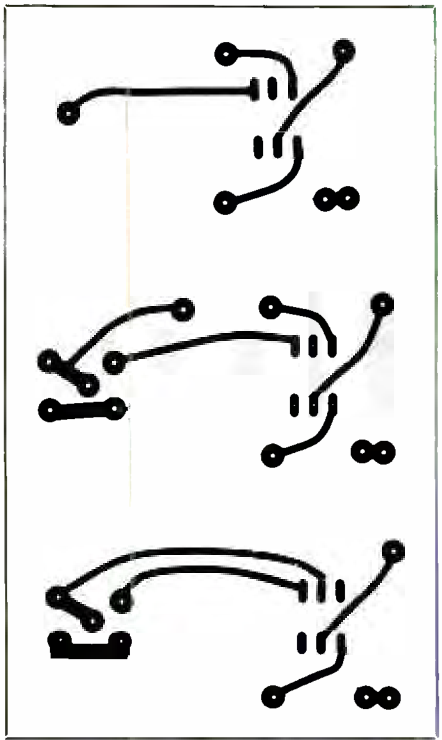


Fig. 6. Actual-size pc guides for Fig. 3 circuit (upper), Fig. 4 circuit (center) and Fig. 5 circuit (lower).

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

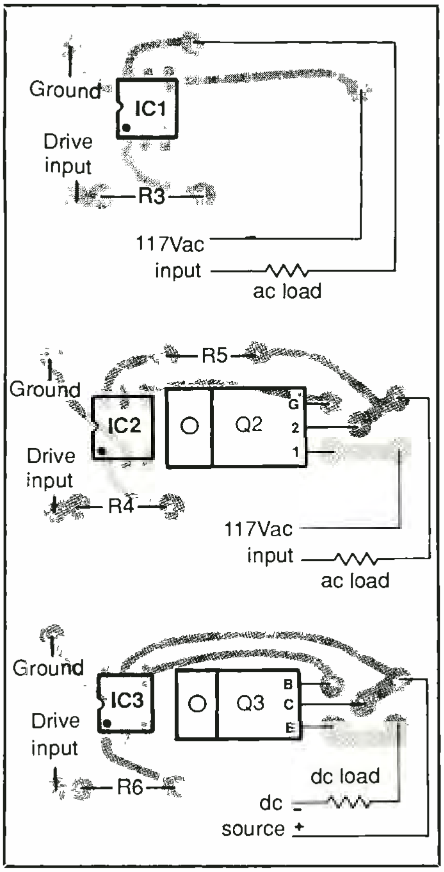


Fig. 7. Printed-circuit wiring guides for Fig. 3 circuit (upper), Fig. 4 circuit (center) and Fig. 5 circuit (lower).

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

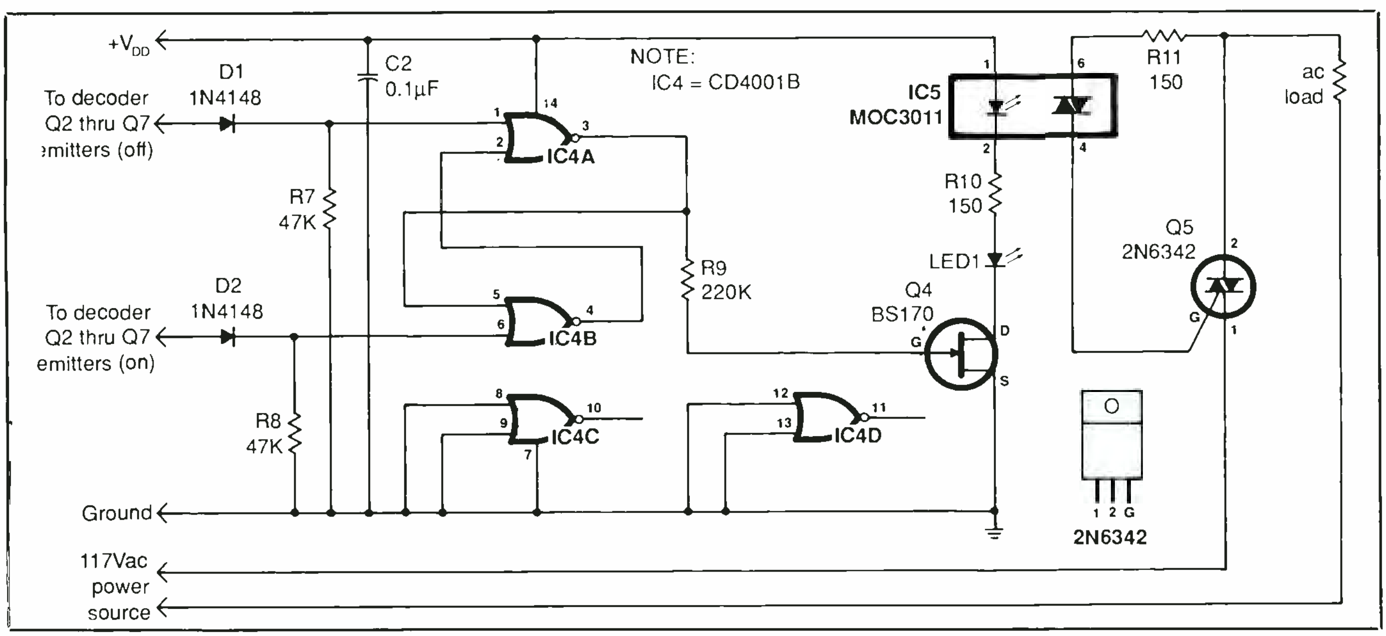


Fig. 8. This latched control circuit uses two transmitter/ receiver channels to lock on and off power to load. Previous circuits give momentary action.

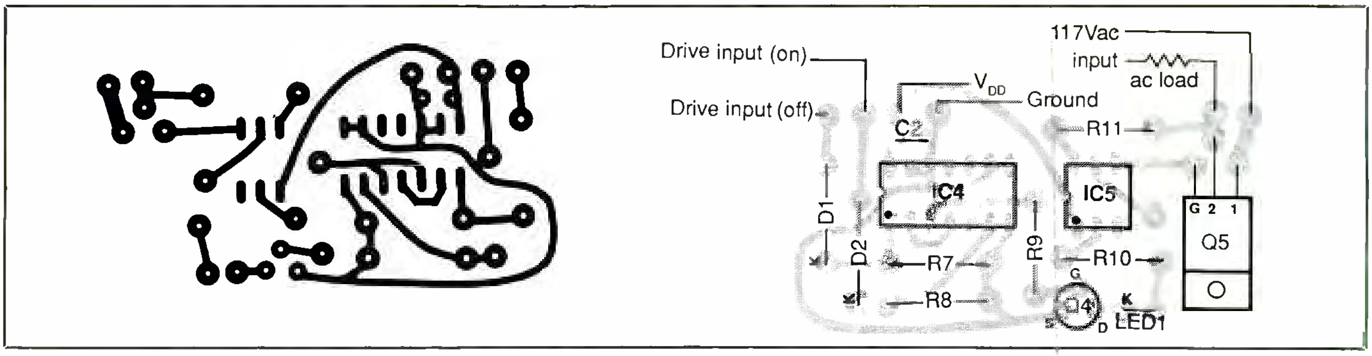


Fig. 9. Actual-size etching-and-drilling guide (left) and wiring diagram (right) for pc board used to assemble Fig. 8 circuit.

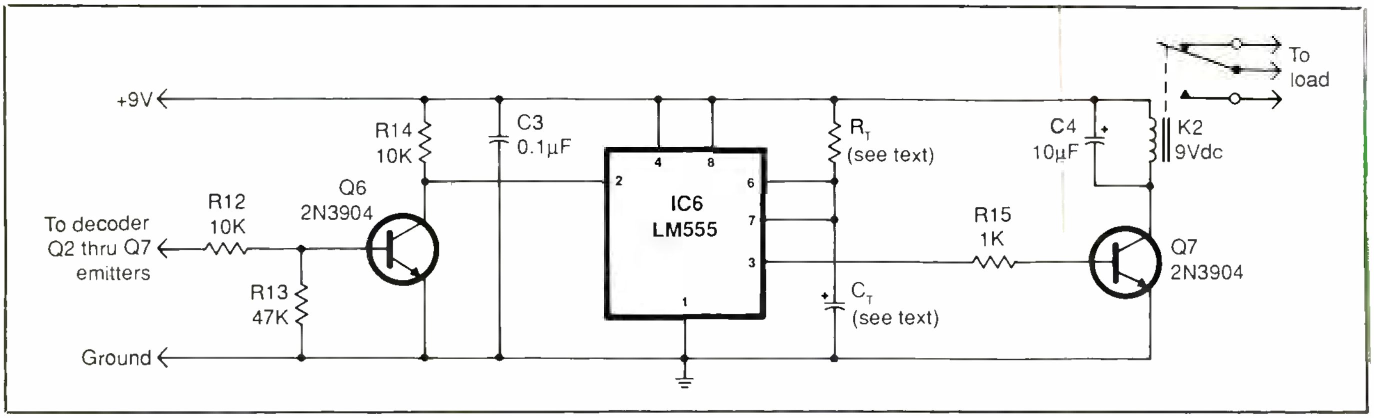


Fig. 10. This timed output pulse circuit latches power on for a predetermined time using only one transmitter/receiver channel. It is designed to use a standard electromechanical relay.

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

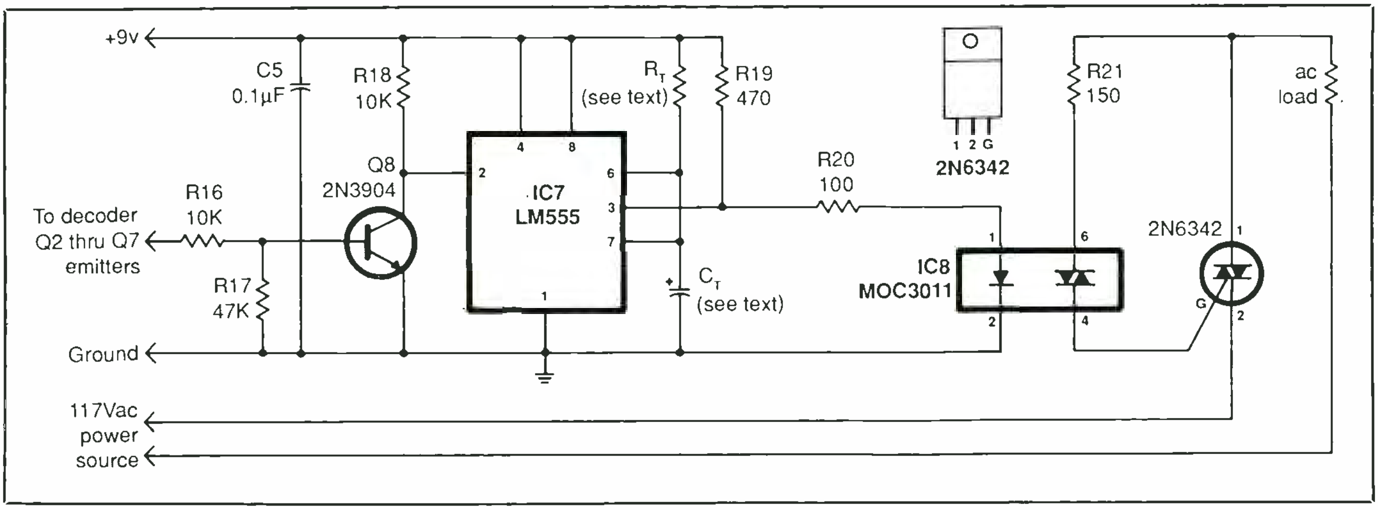


Fig. 11. This timed output pulse circuit replaces the electromechanical relay with an optical isolator.

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

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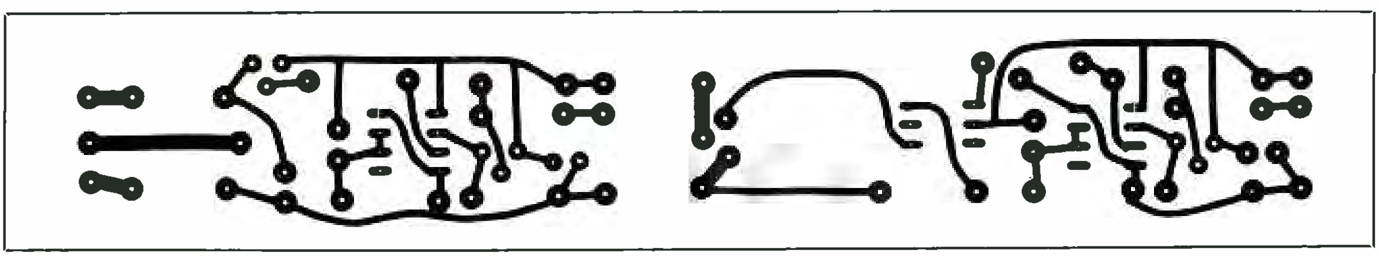

Fig. 12. Actual-size etching-and-drilling guides for fabricating pc boards for Fig. 10 (left) and Fig. 11 (right) circuits.

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

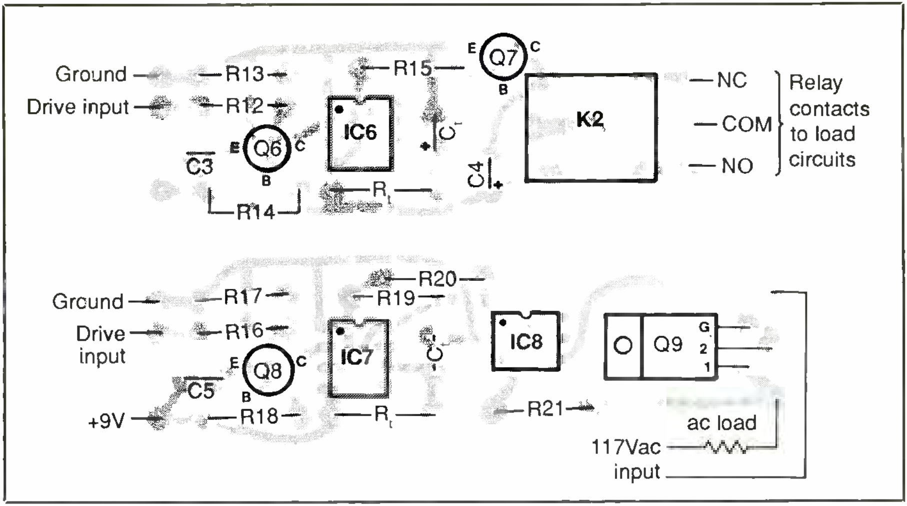

Fig. 13. Pc wiring guides for Fig. 10 (upper) and Fig. 11 (lower) circuits.

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