

HAVE YOU EVER WANTED TO MAKE good use of all those infrared (IR) remote control units from TVs, VCRs, and other stereo equipment that have been piling up over the years? Have you ever wanted to add remote-control operation to your electronic projects? This simple-to-build, low-cost construction project will receive and convert the output of virtually any infrared remote-control transmitter with a 40-kHz carrier to logic levels that can control all your favorite toys, from robots to model railroads.

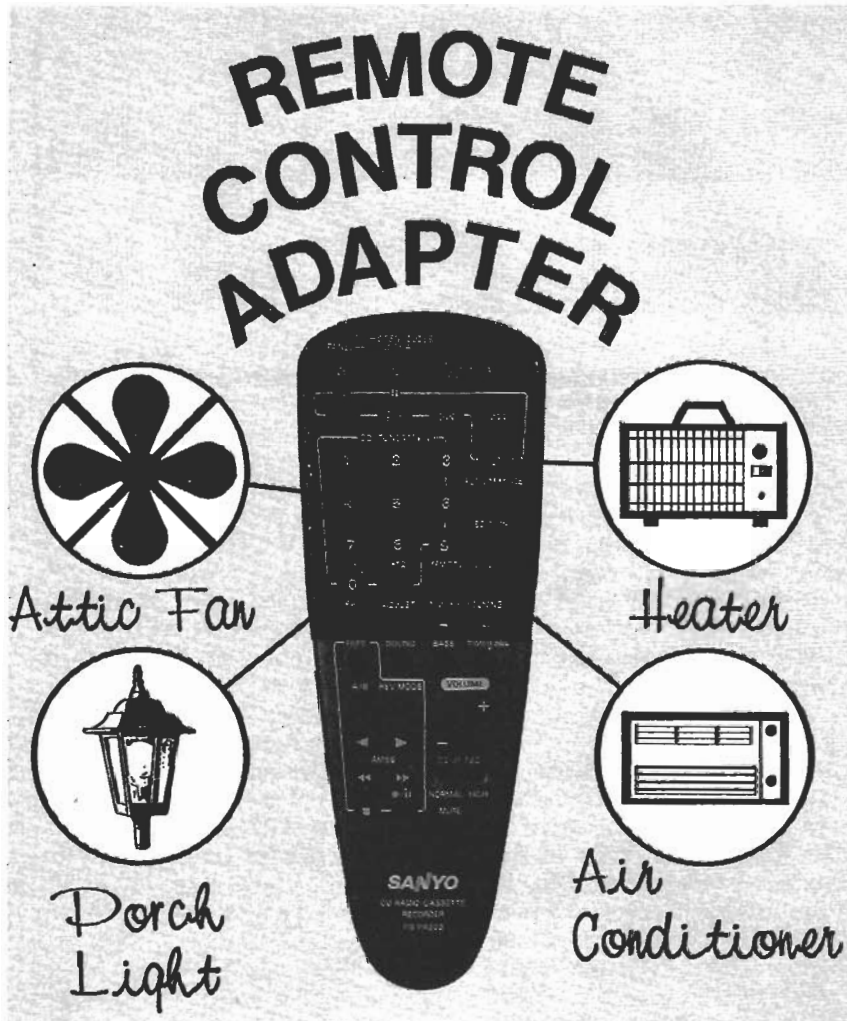
This basic circuit can also turn just about any appliance in your home on and off. These include lamps, fans, radios, alarms, electric locks, space heaters, and air conditioners. You won't have to leave the comfort of your lounge chair. Anything which operates on electricity can be controlled with \$3.00 remote controls found in abundance at surplus dealers and ham fests.

The remote control receiver has seven individual TTL-level outputs that can be programmed to respond to any button on a remote control. Each output can be set up as a latching output that toggles between high only as long as the button is pressed, or as a momentary output that switches and remains high for as long as the remote's button is pressed. To program the receiver, place the unit in its programming mode, aim your remote-control transmitter at it, and press buttons to let the remote-control receiver "learn" and record the data transmitted by the remote.

**Remote control transmitters**

A standard infrared remote-control transmitter has a photodiode that transmits in the near-infrared range and is pulsed on and off at 40 kHz. Although some transmitters have a different carrier frequency, 40 kHz is the most common and is therefore the carrier frequency used in this circuit.

The author was unable to find



***Couch potatoes, sit right where you are—this circuit lets you control virtually anything with any infrared remote control.***

a remote that used a different frequency. If, however, you have one that transmits on a different carrier frequency, simply replace the 40-kHz IR module specified in this circuit with one that's tuned to your transmitter's frequency.

The IR signal is pulse-code modulated when it is transmitted in bursts of 40-kHz pulses, as shown in Fig. 1. Data is encoded on the IR signal by varying the length of the bursts or the time between bursts. The different data patterns indicate which button is pressed on the remote. Figure 1-a shows an IR

signal that encodes data on the carrier by alternating the length of the burst, while Fig. 1-b shows one that alternates the time between bursts. A typical infrared remote-control receiver in a host product will decode the logic levels in the data stream by comparing the pattern of bursts with an internal clock operating at the same frequency as the transmitter.

In most cases, each IR command consists of a pattern of anywhere from 12 to 32 bursts at 40 kHz. This pattern is repeated continuously while the transmitter's button is held

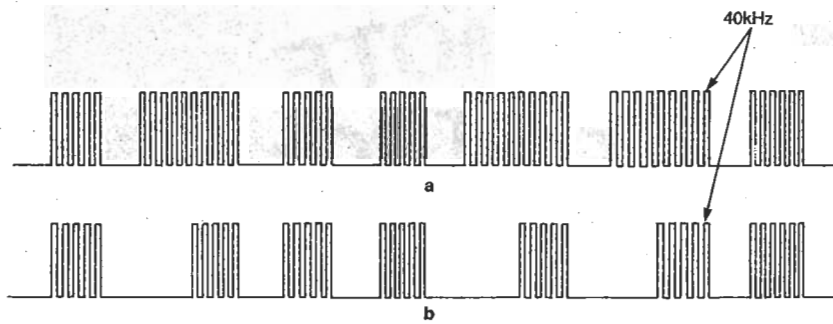


FIG. 1—AN INFRARED SIGNAL is modulated by transmission in bursts. The signal in *a* is modulated by alternating the length of the burst, while the one in *b* is modulated by alternating the time between bursts.

down. The author found one model whose burst pattern was transmitted only upon initial contact with the button, and this pattern was followed by a short burst of the pattern every 100 milliseconds or so until the button was released.

### Circuit theory

The circuit is simplified by the use of the self-contained infrared receiver/demodulator MOD1. A block diagram of the IR module is shown in Fig. 2. The modulated IR signal is detected by the photodiode whose peak sensitivity is in the near-infrared range.

After the signal passes through a preamplifier/limiter, the built-in bandpass filter then rejects all signals outside of 40 kHz. This largely eliminates false triggering from other light sources. The resulting signal (Fig. 3-a) is fed through a demodulator, an integrator, and a comparator which outputs a clean TTL-level pulse stream without the carrier (Fig. 3-b). Notice how a positive-going IR burst produces a corresponding low pulse at the output of the IR module.

A schematic diagram of the remote control receiver is shown in Fig. 4. The heart of the circuit is IC1, a PIC16C54 8-bit CMOS microcontroller manufactured by Microchip. The microcontroller has one eight-bit I/O port and one four-bit I/O port. Each I/O pin can be used and configured individually. That makes it possible to simplify the PC board layout so that only a single-sided board is needed.

The microcontroller stores its data in IC2, a 93LC46 1 kilobit serial EEPROM (electrically erasable programmable read only memory) also manufactured by Microchip. In this application the 93LC46 has a three-line interface with the microcontroller. The three lines are CHIP SELECT, CLOCK, and DATA IN/OUT. Because DATA IN and DATA OUT share the same line, a 1 kilobit resistor (R2) limits the current flow during transitions be-

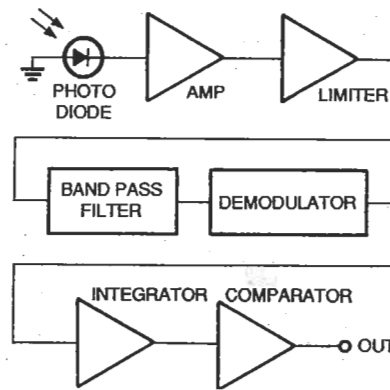


FIG. 2—BLOCK DIAGRAM of the infrared receiver/demodulator module (MOD1).

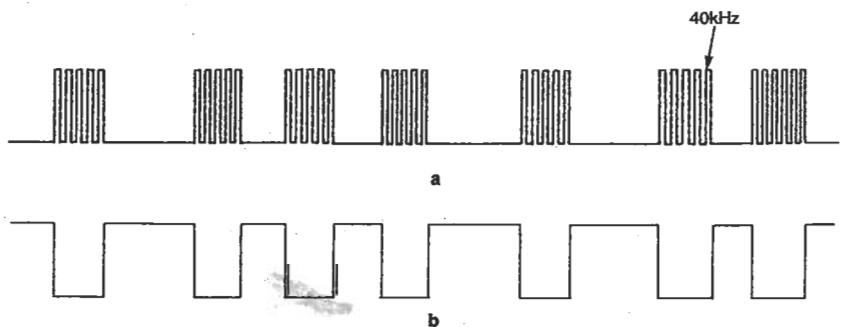


FIG. 3—THE OUTPUT WAVEFORM of the infrared module (*b*) with respect to the 40-kHz IR signal received at its input (*a*).

tween writing and reading when there are conflicting logic levels.

The microcontroller communicates with the 93LC46 by placing a logic high on the CHIP SELECT pin. Data is then transferred serially to and from the 93LC46 on the positive transition of the clock line. Each read or write function is preceded by a start bit, an opcode identifying the function to be performed (read, write, etc.), then a seven-bit address, followed by the eight bits of data which is being written to or read from that address. Immediately preceding and following all write operations, the microcontroller sends instructions to the 93LC46 which enables or disables the write function, thereby protecting the data that has been stored.

In the programming mode, IC1 reads an IR data stream from MOD1 and converts it to data patterns that can be stored in IC2. These data patterns are held for comparison while the unit is in normal operation. More on this later.

Power for the circuit is conditioned by IC3, a 78L05 low-current, 5-volt regulator which will accept any DC input voltage between 7 and 25 volts. Capacitors C1 and C2 stabilize the operation of the regulator. Crystal XTAL1 sets the internal oscillator of IC1 to 4 MHz. Jumper JU1 consists of two closely spaced pads on the PC board that, when momentarily jumpered with a screwdriver or other piece of metal, places IC1 in the programming mode and lights LED1.

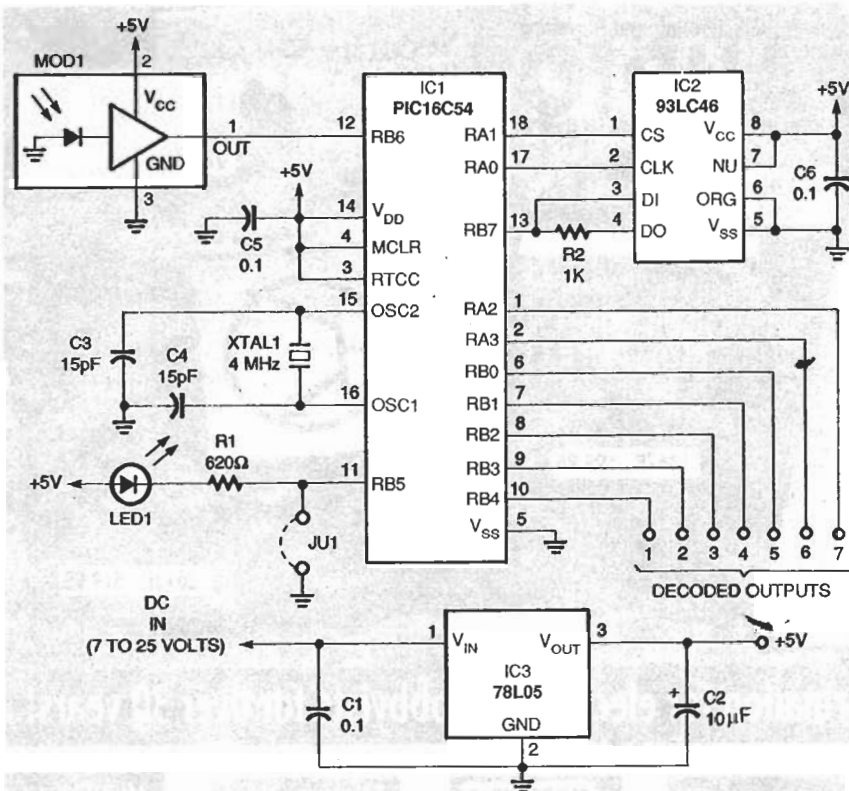


FIG. 4—SCHEMATIC DIAGRAM of the IR remote control receiver. The microcontroller (IC1) decodes and analyzes the output from the IR module, compares it to previously stored patterns in EEPROM IC2, and activates the appropriate I/O pin if a match is found.

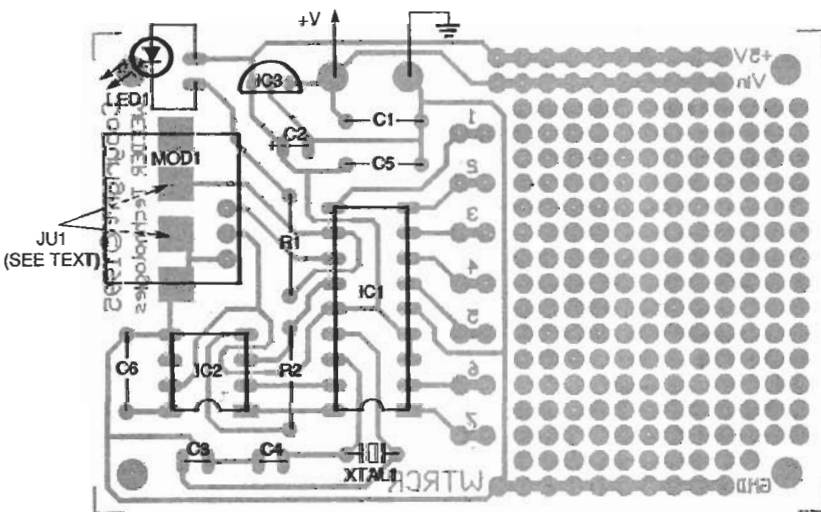


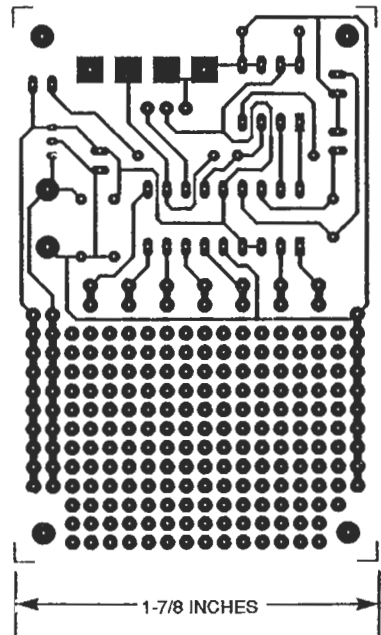
FIG. 5—PARTS PLACEMENT DIAGRAM. The bare section of the board is reserved for experimental components for your own circuitry.

**PIC firmware**

A pre-programmed PIC16C54 is available from the supplier mentioned in the Parts List. The source and object code are available on the Gernsback BBS (516-293-2283, v.32, v.42bis) as a file called IREC.ZIP for those who wish to program their own

PICs and have the proper equipment to do so.

As mentioned earlier, the exact protocol that indicates logic levels from different remote controls can vary from manufacturer to manufacturer. Because of this, the firmware in IC1 is configured so it does not try to



FOIL PATTERN for the IR receiver.

identify logic "1's" or "0's" when recording the data stream related to each button on a remote. Instead it measures the width of each IR burst and the time between bursts. That information can then be used to find a match while the control is in normal operation.

There are only 16 eight-bit registers available in IC1 to process and hold information before storing it in memory. Because both the bursts and the time between bursts must be measured, a 32-burst pattern will require 64 measurements. To compress the data so it can be handled by only 16 registers, IC1 must perform a series of tricks as follows: Because a change in either the length of the bursts or the time between bursts (but not both) will be used by the transmitter to encode the data, measurements of each (per cycle) can be added together and placed in the same register.

In addition, because the circuit recognizes only a change in length rather than the actual length, the most significant four bits of each measured value are not important and can be stripped off. These two processes make it possible to store four time values in each eight-bit register for a total of 64 measurements.

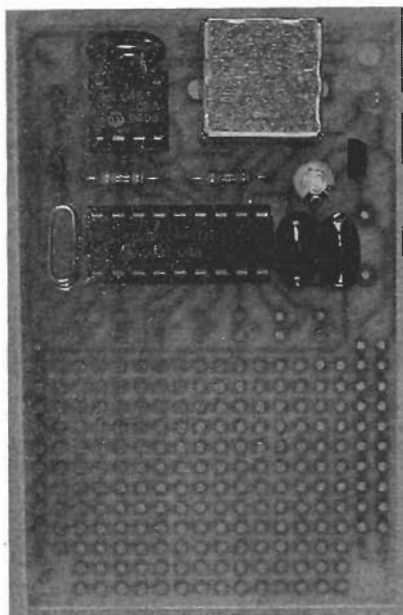


FIG. 6—COMPLETED BOARD. The infrared module greatly reduces the number of parts required.

After IC1 enters its programming mode (when it detects a low on pin 5 of port B), it waits to receive an IR signal from a remote-control transmitter. A set of 32 bursts are sampled from the beginning of the IR signal's data stream, measured, and stored in IC2. The pattern is then assigned to I/O pin 1, and the microcontroller flashes the LED to indicate that the recording process is complete for that button.

If the remote control's button is held down following the flash of the LED, the I/O pin is configured for momentary operation. If the button is released immediately, the I/O pin is configured for toggled operation. The microcontroller then waits for the next button to be pressed on the remote and repeats the same procedure, assigning the next pattern to I/O pin 2, and so on. After seven patterns have been stored, IC1 turns off the LED and returns to normal operation.

During normal operation, IC1 waits for any IR signal to be received, determines its burst pattern in the same way as in the programming mode, and looks for a match in memory. If a match is found, IC1 either toggles the state of the corresponding I/O pin or holds the pin logic

## PARTS LIST

All resistors are 1/4-watt, 10%

R1—620 ohms

R2—1000 ohms

### Capacitors

C1, C5, C6—0.1  $\mu$ F, polyester

C2—10  $\mu$ F, 35 volts, electrolytic

C3, C4—15 pF, ceramic disc

### Semiconductors

IC1—PIC16C54-XT/P pre-programmed 8-bit microcontroller (Microchip)

IC2—93LC46 serial EEPROM (Microchip)

IC3—78L05 low-power 5-volt regulator

LED1—light-emitting diode, any color

### Other components

MOD1—40-kHz infrared remote control receiver module (Digi-Key part No. LT1060-ND or equivalent—Digi-Key also has IR modules tuned to 32 kHz and 36 kHz. Digi-Key can be reached at 800-344-4539.)

XTAL1—4-MHz crystal

**Note: The following items are available from Weeder Technologies, PO Box 421, Batavia, OH 45103, 513-752-0279:**

- Etched and drilled PC board (WTRCR-B)—\$8.50.

- All board-mounted components including pre-programmed PIC16C54 (WTRCR-C)—\$23.50

- Pre-programmed PIC16C54 only (PIC-RCR)—\$16.00

All orders must include an additional \$3.50 for shipping and handling. Ohio residents must add 6% sales tax.

high until the IR signal ceases, depending on the configuration of the individual I/O pin as was previously defined in the programming mode.

### Construction

A foil pattern is provided for those who wish to make their own board, or a prefabricated board can be purchased from the source given in the Parts List. The PC board measures less than 2  $\times$  3-inches, and about half of the board space is a prototyping area reserved for circuitry you might want to add for your particular application, including AC or DC power-control circuits.

Refer to the parts-placement

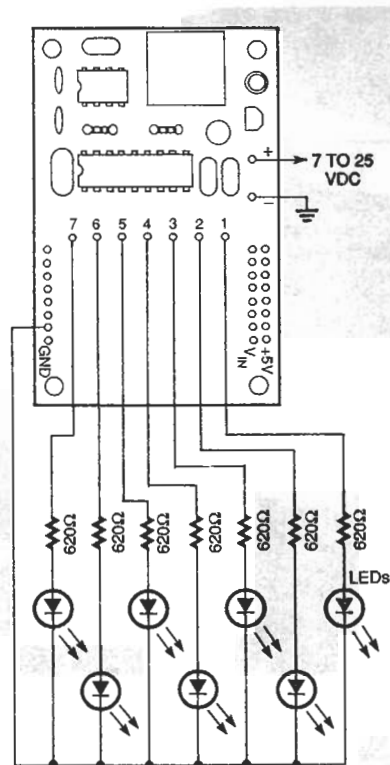


FIG. 7—USE THIS TEST SETUP to check out your finished project. A separate LED indicates when each I/O pin goes high.

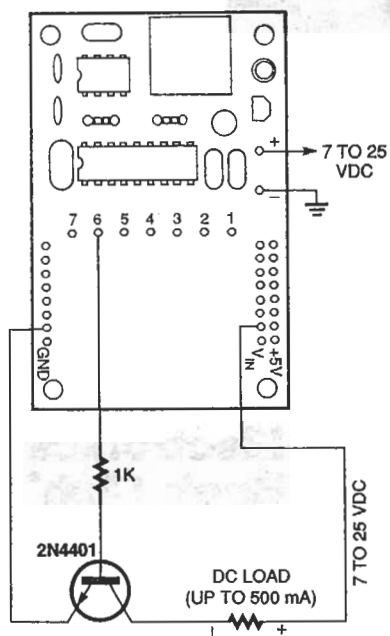


FIG. 8—THIS CIRCUIT can turn on any DC load up to 500 milliamperes.

diagram, Fig. 5, and begin by soldering in the two IC sockets for IC1 and IC2. Next mount all resistors and capacitors, paying particular attention to the orientation of polarized capacitor

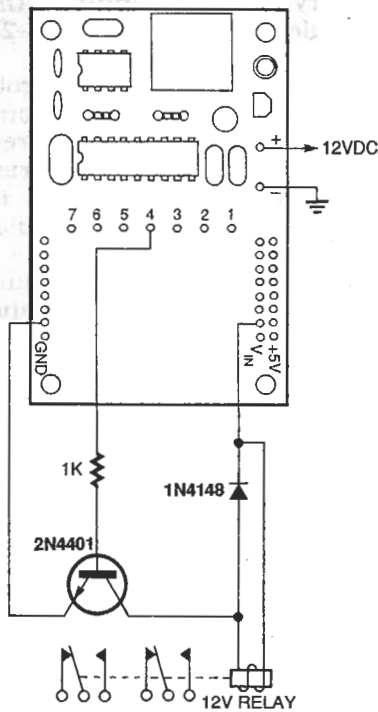


FIG. 9—FOR HEAVIER CURRENT demands, this circuit shows the remote control receiver interfaced to a relay.

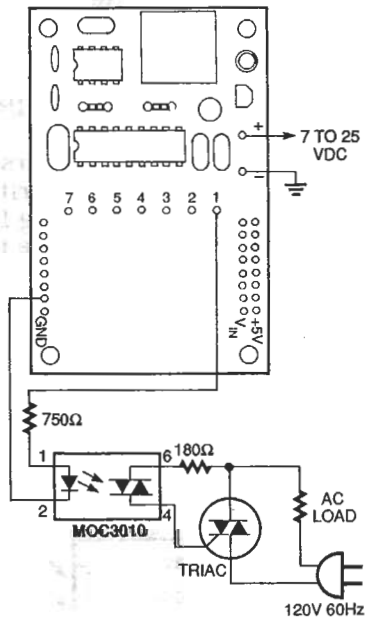


FIG. 10—AC LOADS including lamps, fans, stereos, and more can be controlled with this circuit.

C2. Solder in crystal XTAL1, voltage regulator IC3, and the LED. Finish by mounting the IR module, and be sure to solder the two mounting tabs on its case for making a good ground connection.

After all components have

been mounted, examine the solder side of the board for solder bridges and/or cold solder joints and resolder if necessary. Carefully plug IC1 and IC2 into their sockets following the orientation shown in Fig. 5. Figure 6 shows a photograph of the completed board.

### Operation

To test the receiver, set up the board as shown in Fig. 7. This circuit will turn on a separate LED for each I/O pin that goes logic high, letting you study the unit's operation and understand how it works and how it is programmed. Until you have decided on a specific application for the receiver circuit, tem-

porarily solder seven solid-conductor wires to the I/O terminals on the PC board and connect them to a solderless breadboard to be used for your test circuit. The breadboard will allow you to make experimental changes without having to solder and desolder.

Put fresh batteries in your remote control and set up the receiver so that you can aim the transmitter directly at the receiver's IR module at a distance of 2 to 3 feet. Do not hold the transmitter closer than 2 feet or the IR module will be overdriven, and the data being recorded will be unreliable. Make sure that there are no fluorescent lights shining on the IR module, as that light can also cause various programming errors.

Apply power to the receiver. Locate the two square pads directly underneath the IR module and briefly short them together with the tip of a screwdriver; this will cause the LED to light and remain on. Point the transmitter at the receiver and press and hold the button you wish to assign to I/O pin 1. After approximately a half second delay, the LED will flash off then back on. Release the button on the remote immediately if you want I/O pin 1 to be configured for toggled operation. Otherwise, hold the button down until the LED flashes a second time if you want the I/O pin to be configured for momentary operation. Next, select the button you wish to assign to I/O pin 2 and repeat the procedure. Continue until all seven I/O pins have been dedicated to a button on the remote. After the last I/O pin has been programmed, the receiver will automatically halt the programming mode and turn off the LED. Note that you must program all I/O pins before the programming mode will be terminated.

Now point the remote at the receiver and press the buttons that you programmed the receiver to recognize; the appropriate LEDs in the test circuit of Fig. 7 should turn on and off. You can assign more than one

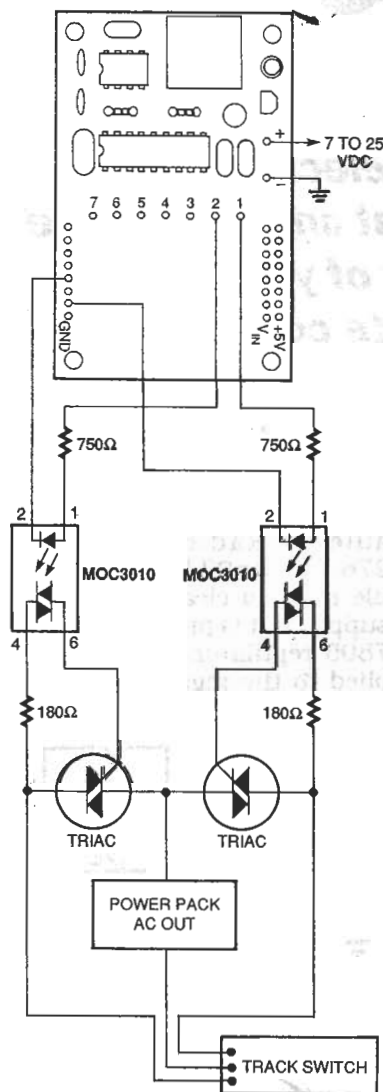
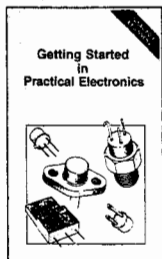


FIG. 11—THIS SETUP can be used on a model railroad to control the track switches.

Continued on page 83

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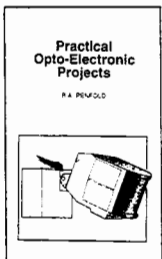


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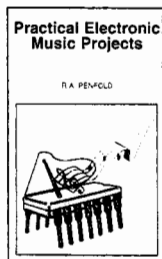
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I/O pin to a single button on the transmitter. For example, one I/O pin could be set up to toggle between high and low each time the button is pressed, while another (set to momentary) could perform a different function, depending on how long that same button is held down. For example, pressing a button could lower a projection screen, while holding down the same button could dim the lights to a certain level.

Figure 8 shows how an I/O pin can be made to drive a DC load up to 500 milliamperes with the aid of a transistor. This same circuit can be repeated on all I/O pins to control seven different loads. Applications include controlling servos and motors in robotics, or turning any 9-volt battery-powered device on and off. If larger loads with greater current demands must be driven, Fig. 9 shows how to interface a relay to the circuit. Although a 12-volt relay is shown, any relay that operates on a voltage from 7 to 25 volts DC can be substituted by powering the receiver circuit with the same voltage.

For AC applications, an optoisolator and triac can switch line current from a standard 120-volt AC outlet, as shown in Fig. 10. Be careful when working with 120-volt AC power. Most triacs have their metal tabs tied directly to one of their main terminals. You will receive a shock if you touch the tab while power is applied. If heavy AC loads are driven and the triac must have a heatsink, mount the triac to the heatsink with insulating hardware and check for short circuits to ground with an ohmmeter before plugging the circuit into an AC outlet.

Model railroad buffs can control track switches with the circuit in Fig. 11. Two I/O pins are required per switch—one for each direction. The I/O pins must be configured as momentary. The receiver can also control other railroad accessories in the system.