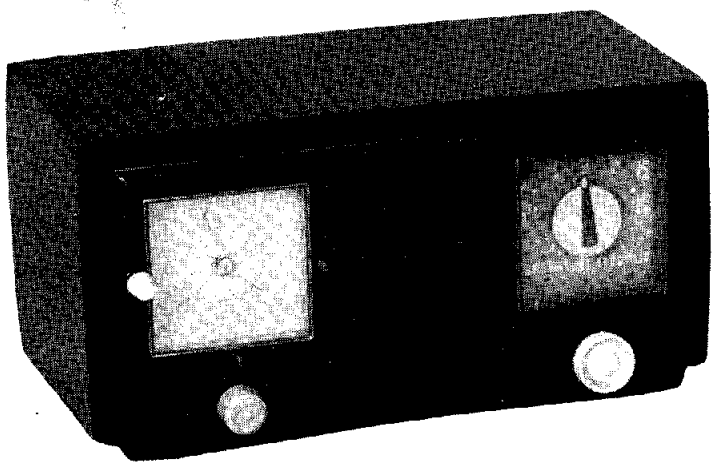
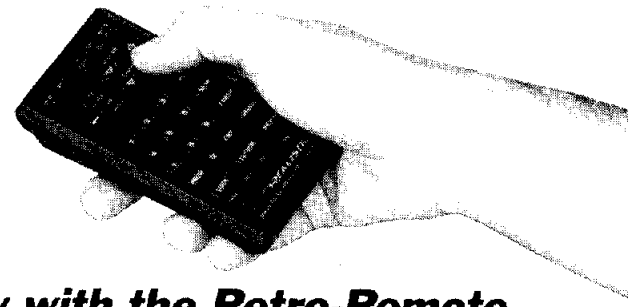
TOD T. TEMPLIN

BUILD THE RETRO-REMOTE





Add remote-control capability to anything that doesn't have it already with the Retro-Remote.

ONE MAJOR FEATURE THAT SEPARATES most consumer electronics from home-built gear is remote-control capability. Even some of the most inexpensive commercially manufactured electronics is equipped with a wireless remote control. Hobbyists have been unable to include remote controls in their projects simply because there is no "off the shelf" circuitry available to do the job. That's not true any longer!

The Retro-Remote Control presented in this article is designed for maximum interfacing flexibility. The versatile circuit can be configured to remotely control the operation of home and automotive entertainment systems, home and auto security alarms, robotics, and almost any other project that might benefit from the addition of wireless remote control. So, whether you want to add remote-control capability to an older device that lacks it, or have shelved an idea for a great stereo project because it wouldn't be as convenient to operate as a store-bought unit, then the Retro-Remote is the perfect solution.

Description

The remote-control system consists of two separate circuit boards. One board contains an infrared receiver/decoder. It is added to the device that you want to operate remotely. The second board is an infrared "training transmitter." Its purpose is to train a commercially available universal "learning" remote control transmitter. The universal remote can then operate your equipment.

The universal remote control that you purchase will undoubtedly be smaller and more attractive than anything you could build easily. Learning remote controls have the added advantage of being able to learn the commands of multiple devices, thereby consolidating the functions of many separate remotes into one. You might already own a learning remote, as they are included with many brands of TVs, VCRs, and stereo receivers. If you don't own a learning remote, one can be purchased from a consumer-electronics store for as little as $20. The author used a Radio Shack Model 150 learning remote that can store codes for controlling up to four devices (TV, VCR, AUX 1, and AUX 2).

The training transmitter ensures that you can select unique codes for controlling "retro" devices that never had remote-control capability. You must be sure that the newly assigned codes will not interfere with those in use by your existing remote-controlled devices.

The training transmitter circuit is battery operated for portability and convenience. It is built on a small PC board that contains a pair of DIP switches to select the address (1 of 256) and command codes (0 through 15). It also contains the encoder IC, a modulator circuit, and the infrared transmitter diode. In practice, the training transmitter is placed next to the learning remote in an "eye to eye" fashion. An address and data command code are selected with the DIP switches, and then the learning remote is "taught" up to 16 commands. If more than 16 commands are required, a second receiver board set to a different address can be built for those commands.

The receiver/decoder board contains a pre-built and aligned infrared receiver module. It also has address and data decoding circuits that match those of the training transmitter, and interfacing circuits to connect it to the device that you want to control. The module can be self-powered or power can be provided by the device it serves.

The board can decode 16 command codes at any one of 256 possible addresses, for a total of 4096 available codes. Commands 0 through 11 are user-definable. That is, they decode to simple TTL-level signals which are selected by the user to

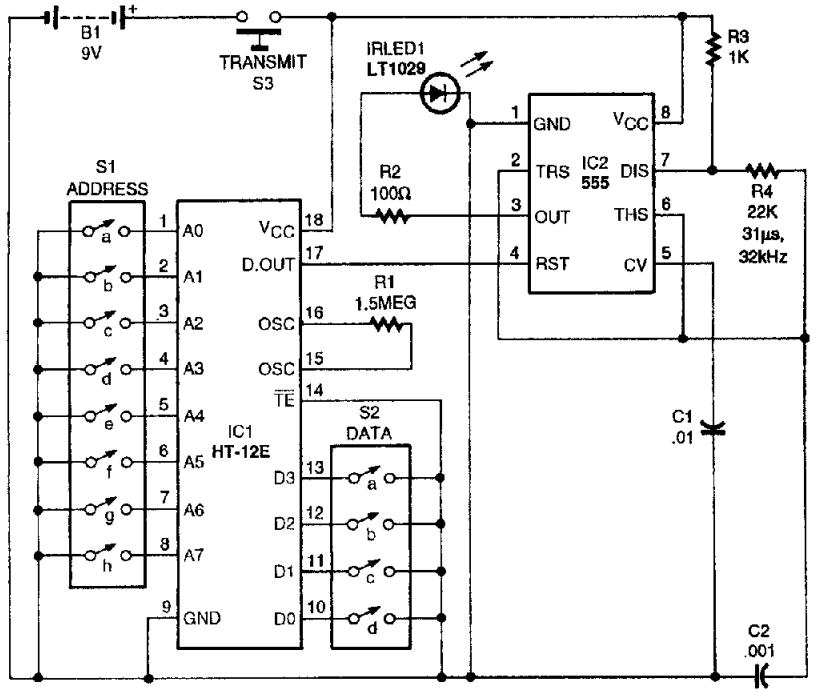


FIG. 1—TRAINING TRANSMITTER SCHEMATIC. The heart of the circuit is an HT-12E remote control encoder manufactured by Holtek Microelectronics.

be either latched or momentary, and high or low, as needed. The 12 decoded commands are brought out to a header for connection to external circuits. The four remaining commands (12, 13, 14, and 15) are hard wired on the decoder board to relays that operate a motorized potentiometer for volume-up and volume-down controls and for power on/off and mute on/off controls.

Transmitter circuitry

Figure 1 is the schematic for the training transmitter. The heart of the circuit is an HT-12E remote control encoder (IC1) manufactured by Holtek Microelectronics. The HT-12E encodes 12 bits of information into a serial stream of data. Eight bits select the system address while the remaining four bits select the data code. Both the address and data are binary-coded decimal (BCD). The encoded serialized data stream appears at pin 17 of IC1 whenever pin 14 (TE, or TRANSMIT ENABLE) is held low. Note that TE is grounded at all times, and transmit switch S13 enables the entire circuit. Resistor R1 sets IC1's internal oscillator frequency to about 3 kilohertz.

A 555 timer (IC2) modulates the encoded data onto a carrier wave and also drives the infrared LED transmitter diode (IRLED1). An infrared modulation frequency of 32 kilohertz was chosen to be compatible with the receiver module. Data from pin 17 of IC1 is routed directly to pin 4 (RESET) of IC2, which is configured as an astable multivibrator with a free-running frequency of about 32 kilohertz. This is determined by R3, R4, and C2. Data going into pin 4 of IC2 effectively turns it on and off in-step with its high or low value, thereby presenting a series of 32-kilohertz pulses that match the data stream to the infrared LED. Resistor R2 limits the current provided by IC2 to a safe value for the LED.

Receiver circuitry

Figure 2 is the schematic of the receiver circuit. The circuit consists of the IR receiver module (MOD1), the HT-12D decoder (IC1), a BCD-to-decimal decoder (IC2), and various driver ICs and relay circuits that interface the Retro-Remote to the outside world. With its clean and stable output, the IR receiver module, whose block diagram is shown in Fig. 3, greatly simplifies the construction and reliability of this part of the circuit. The IR module contains an infrared-sensitive photodiode, followed by a high-gain preamplifier, a limiter circuit, a 32-kilohertz bandpass filter, a demodulator, an integrator, and a Schmitt trigger.

The 12-bit serial signal that is sent from MOD1 when it receives transmitted pulses is buffered and inverted by Q1 and applied to the input of the HT-12D decoder IC, which interprets the first eight bits of the word as address and the last four bits as data. The HT-12D checks three consecutive samples of the received 16-bit word against the address selected by DIP-switch S1. If all three samples match, the VALID TRANSMISSION (VT) output goes high and the four-bit data word is latched onto its output pins. Resistor R8 sets the internal clock frequency of the HT-12D to about 150 kilohertz. Note that the oscillator in the decoder IC must run approximately 50 times faster than the oscillator in the encoder IC.

Although the data on the output pins of IC1 remains valid until a new word is decoded, the VT signal stays high only as long as the actual decoding is being performed. Thus, VT acts like a momentary-contact signal because it is active only as long as a button is pressed on the remote transmitter. The VT output is applied to Q2 which drives relay RY1. The relay provides a connection to ground to light the VT RECEIVED indicator (LED1), and also provides the ground return for the motorized volume-control circuit through RY2 and RY3 (volume up and volume down, respectively). The momentary ground closure is also brought out to the output header pins (HEADER1) for custom user applications that might require it. Note that VT is also routed to IC6, a 7473 dual JK flip-flop, and used as a clock signal.

The latched four-bit BCD data from decoder IC1 is presented to the four-bit input of IC2, a 74154 BCD-to-decimal decoder

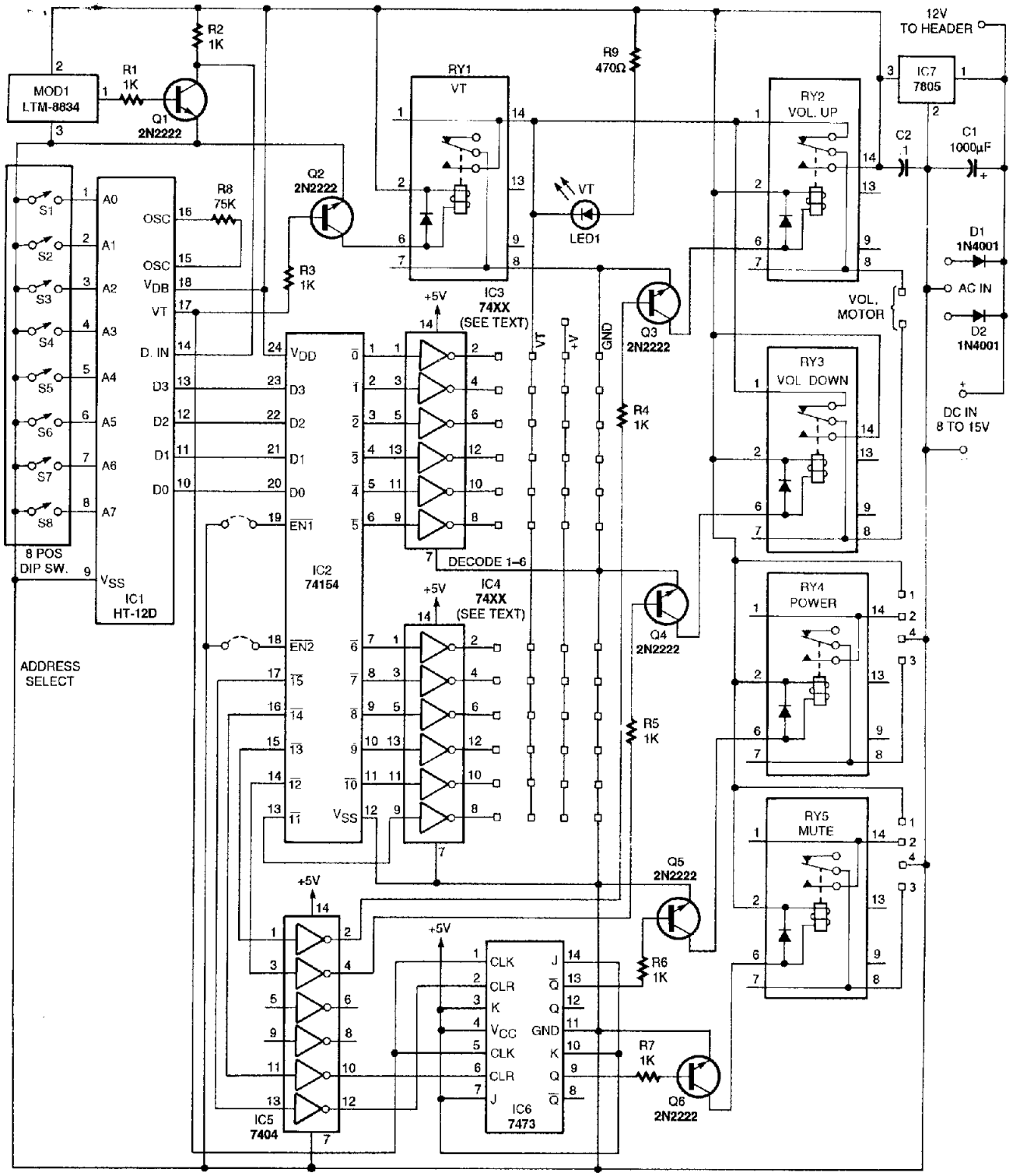


FIG. 2—RECEIVER/DECODER SCHEMATIC. The circuit consists of the IR receiver module (MOD1), an HT-12D decoder, a BCD-to-decimal decoder (IC2), and various driver ICs and relay circuits.

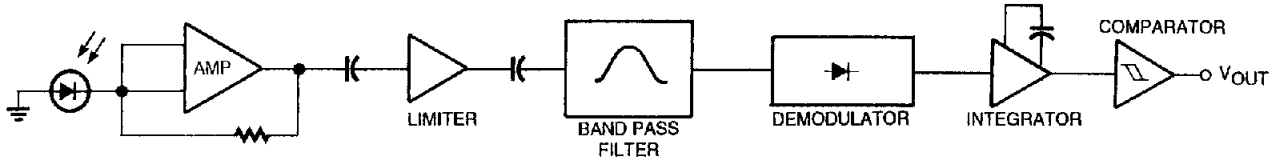


FIG. 3—THE IR MODULE (MOD1) simplifies the construction and improves the reliability of the circuit.

which has active-low outputs. The first 12 outputs of IC2 (0 through 11) are connected to inverters IC3 and IC4. The particular inverters selected for IC3 and IC4 should depend on your requirements, but they must be either hex inverters or hex buffer drivers. It is possible to drive LEDs or small relays directly by selecting either the 7406 hex inverting buffer driver or the 7407 hex non-inverting buffer driver. Both of those ICs have open-collector outputs which are rated for about 40 milliamperes and up to 30 volts. The inverter you select should depend on whether you want active-high (7406) or active-low (7407) outputs. If you want to interface with additional TTL or CMOS circuits, obtain a 7404 hex inverter. That IC will provide active-high TTL output signals. Depending on your needs, you might want IC3 and IC4 to be different ICs—one inverting and one non-inverting. The outputs of IC3 and IC4 are brought out to HEADER1 along with VT, ground, and a power-supply bus which can be jumpered to either 5 or 12 volts, as required.

Outputs 12 through 15 of IC2 are reserved for four circuits on the receiver board. These are power on/off, mute on/off, and volume up/down. The volume up/down feature requires a motor-driven potentiometer. Outputs 12 and 13 of IC2 are inverted by IC5 before they turn on Q3 and Q4, which are the drivers for RY2 and RY3, respectively. Those relays are cross connected in a DPDT arrangement so that the output taken at their wipers changes polarity

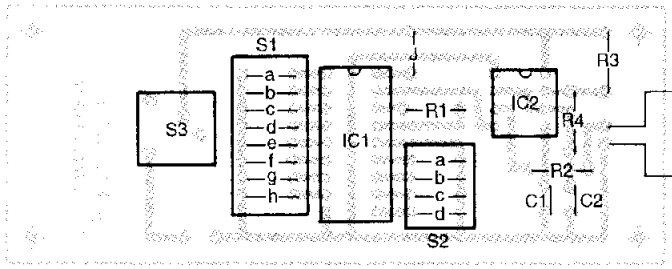


FIG. 4—TRANSMITTER PARTS-PLACEMENT. The small board makes a nice handheld unit.

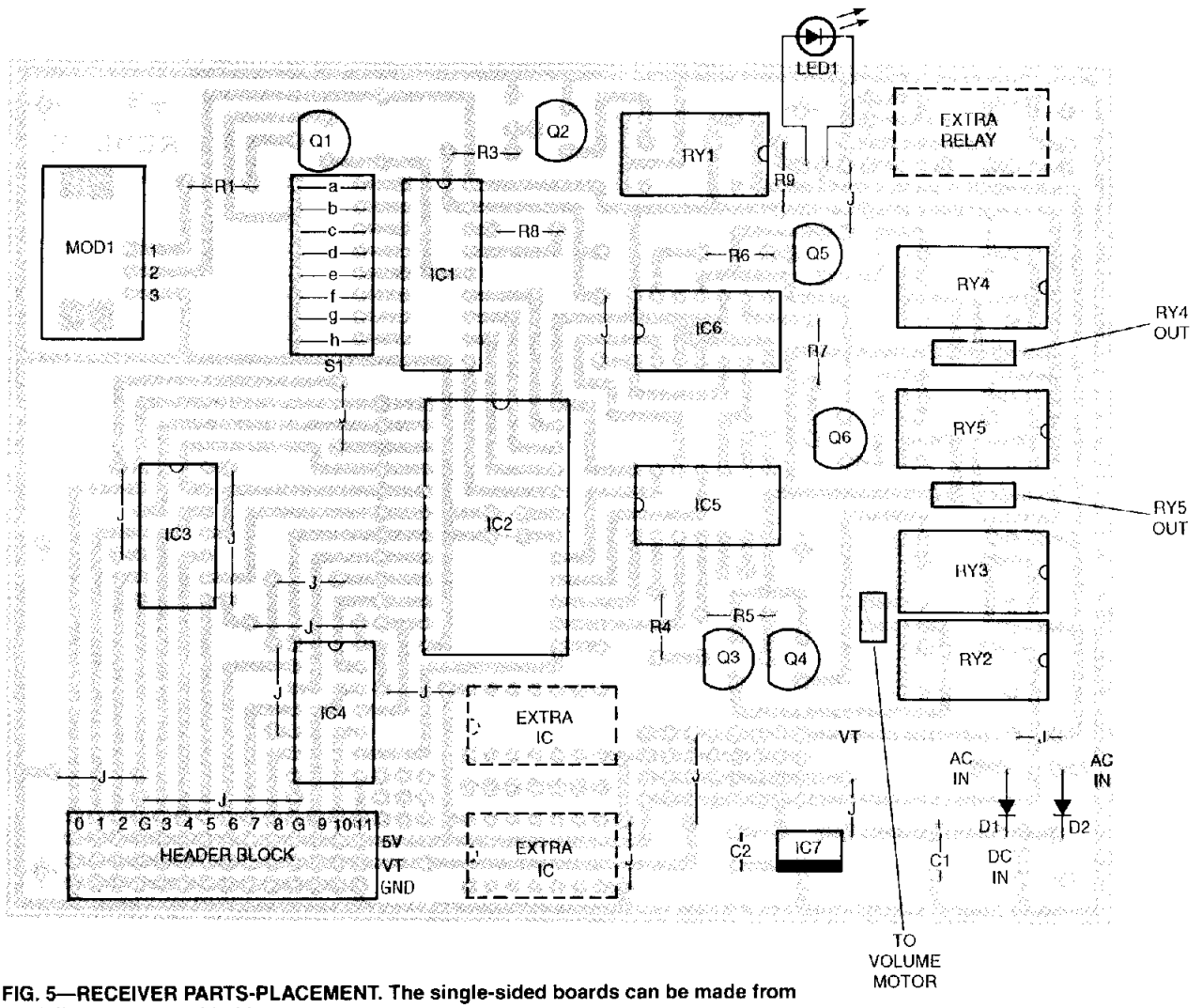


FIG. 5—RECEIVER PARTS-PLACEMENT. The single-sided boards can be made from the foil patterns provided here.

PARTS LIST—TRANSMITTER

All resistors are ¼-watt, 5%

R1—1.5 megohms
R2—100 ohms
R3—1000 ohms
R4—22,000 ohms

Capacitors

C1—0.01 μF, polyester
C2—0.001 μF, polyester

Semiconductors

IRLED1—LT1029 infrared LED or equivalent
IC1—HT-12E remote control encoder (Digi-Key part No. HT-12E-ND)
IC2—555 timer

Other components

S1—8-position DIP switch
S2—4-position DIP switch
S3—normally-open push button

Miscellaneous: 18-pin IC socket, 8 pin IC socket, 9-volt battery and connector, PC board

PARTS LIST—RECEIVER

All resistors are ½-watt, 5%

R1–R7—1000 ohms
R8—75,000 ohms
R9—470 ohms

Capacitors

C1—1000 μF, 25 volts, radial electrolytic
C2—0.1 μF, Mylar

Semiconductors

D1, D2—1N4001 diode
LED1—red generic light-emitting diode
IC1—HT-12D remote control decoder (Digi-Key part No. HT-12D-ND)
IC2—74154 4- to 16-line decoder
IC3, IC4—7404 or similar hex inverter (see text)
IC5—7404 hex inverter
IC6—7473 dual J-K flip-flop
IC7—7805 5-volt regulator
Q1—Q6—PN2222 NPN transistor

Other components

RY1, RY4, RY5—HE721A0510 SPST DIP relay, N.O. (Hamlin 5-volt 700 series, see text)
RY2, RY3—HE721C0510 SPDT DIP relay, N.O. (Hamlin 5-volt 700 series, see text)
S1—8-position DIP switch
MOD1—32-kHz infrared remote-control receiver module (Digi-Key part No. LT1033-ND or equivalent)

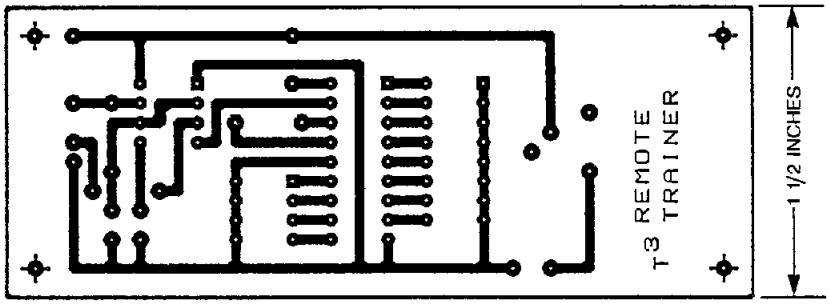
Miscellaneous: 11 × 4 header-pin block; 2-, 3-, 4-, and 6-pin headers; 24-pin IC socket; 18-pin IC socket; 16-pin IC socket; three 14-pin IC sockets; PC board; solder

ORDERING INFORMATION

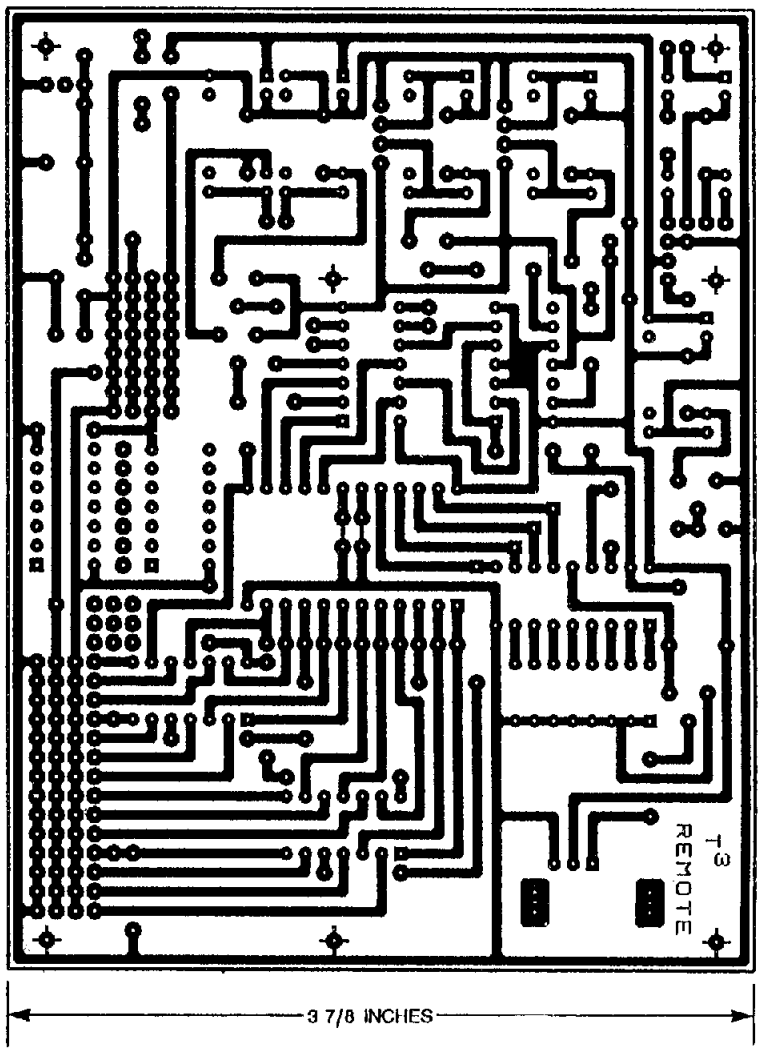
Note: The following items are available from T3 Research, Inc., 5329 N. Navajo Ave., Glendale, WI. 53217-5036:

- **Training Transmitter PC board—$6.00**
- **Receiver/decoder PC board—$12.00**

Add $2.00 S&H to any order. Wisconsin residents must add 5½% sales tax. Other "hard to find" parts including motor-driven potentiometers are available. Send SASE for current list and prices.



RETRO TRANSMITTER FOIL PATTERN.



RETRO RECEIVER FOIL PATTERN.

depending on which relay closes. The potentiometer motor will rotate clockwise with one polarity and counterclockwise with the opposite polarity. The ground return of the volume-control circuit must be routed through the VT relay so that the motor will run only during the reception of a valid command. Otherwise, the latched data of IC1 would cause the motor to run continuously until it decoded a new command.

Output 14 (pin 16) of IC2—the speaker mute function—is inverted by IC5 and connected to one half of IC6, a dual J-K flip-flop. The flip-flop is wired as an alternating latch that is clocked by the VT signal. The first time IC2 decodes decimal 14 (when the mute button is pressed on the remote control), pin 16 goes to a logic low, presenting a logic high at the clear input (CLR) of

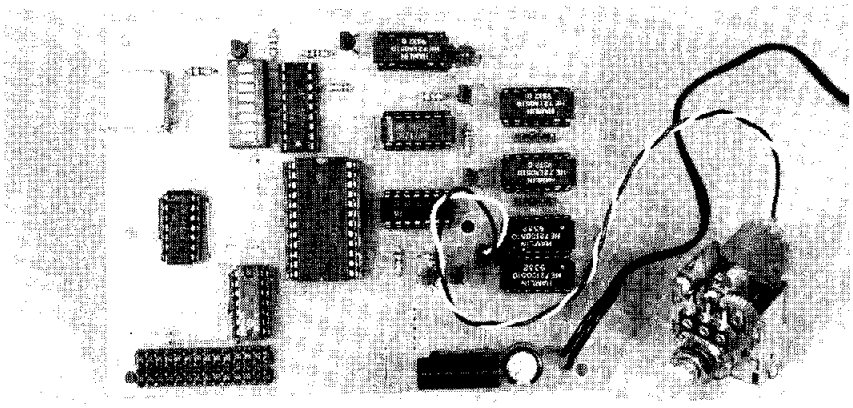


FIG. 6—COMPLETED RECEIVER board can be mounted in its own case or inside the device you want to control remotely.

the flip-flop via IC5. Simultaneously, VT presents a logic high to the clock input. Because the J and K inputs are always set high, the Q output goes high. That, in turn, switches on Q6 and closes relay RY5. If the mute button is pressed a second time, pin 16 of IC2 remains low, but a new VT is received by the flip-flop. That clocks IC6, causing the Q output to go low and open the relay. Note, however, that once latched, pressing any valid key on the remote control will cause a VT signal to clock IC6 into the opposite state. The circuit is wired that way so that an "unmute" occurs whenever a function such as volume up/down or a channel change is requested.

The power on/off function is almost identical to the mute function except that the relay drive signal is taken from the $\overline{Q}$ output (pin 13) of latch IC6-b. In the absence of valid decoded data, pin 13 of IC6 is high, which causes the power on/off relay to close. The power circuit operates the same as the mute circuit except that the first received and decoded power-on command turns the power off. That might seem backwards only until you have cycled the power circuit once. After that it will appear to function normally. The advantage of doing it this way is that pressing any valid key on the remote will switch the power on, but pressing the power key is the only way to switch the circuit off.Builders can wire the flip-flop differently, select a different style flip flop IC latch, or do away with IC6 entirely by using self-latching relays. Select components which suit your particular needs.

A 7805 5-volt regulator, IC7, provides the necessary 5 volts to power the standard TTL devices, the IR receiver module, and the HT-12D decoder IC.

Construction

Building the Retro-Remote is easy. The parts are installed in the training transmitter and receiver boards as shown in the parts-placement diagrams of Figs. 4 and 5. The single-sided boards are easy to make yourself from the foil patterns provided here, or you can purchase finished boards from the source given in the Parts List. Work carefully with a fine-tipped soldering iron and watch out for inadvertent solder bridges.

To allow for customizing, the receiver board has space for an extra relay, two extra ICs, and many extra pads in the interface area. The DIP relays specified in the Parts List have built-in protection diodes. If the relays you use don't have these diodes, there are pads on the PC board at each relay location where you can add them, but they will have to be mounted on the solder side of the board. Not all DIP relays have the same pinouts. Be sure to use relays with pinouts that match those shown.

Any power source with an output between 8 and 15 volts that can supply a least 250 milliamperes is suitable for the receiver. Diodes D1 and D2 are necessary only if your power source is AC. A clip-on heatsink for IC7 is recommended if your power source is 12 volts or more. Figures 6 and 7 show the completed boards.

It is not necessary to mount the IR module on the receiver/decoder PC board. If you prefer, cut an appropriate length of shielded, balanced microphone cable and attach a pair of three-pin female header sockets to make a jumper cable. Then mount the IR module in a suitable location, and mount the decoder board wherever it's convenient or out of the way. The IR module need not be in the same room as the decoder PC board—the author installed a Retro-Remote receiver board in the trunk of his car to operate stereo equipment. The IR module is discretely hidden behind an air conditioning vent grill on the dashboard. To be sure that the Retro-Remote is receiving properly, mount the valid transmission-received LED away from the circuit board in a visible location.

Interfacing

The small DIP relays specified for this project are not intended to switch either high voltage or high currents. If you want to switch 120-volts AC power for a TV set or any other AC load, use the DIP relay on the Retro-Remote to actuate a relay with a higher power rating capable of handling the load.

If you are working with TTL or CMOS circuits, as might be found in robotic and security systems, then it is only necessary to select appropriate buffer/driver ICs for IC3 and IC4 to get the proper logic. If you need to use relays in your project, as will most often be the case, then use a pair of 7404 hex inverter ICs for IC3 and IC4 followed by a 1K resistor and a general-purpose NPN transistor to drive a relay. Wire the relay as RY2 is wired in Fig. 2.

Programming notes

Begin programming by selecting an address on the training transmitter. If you have only one Retro-Remote system, select address 256 by leaving all eight ad-

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dress DIP switches open, address zero with all eight switches closed, or anything in between. Regardless of the address you select, be sure to set the same address on the receiver/decoder board.

Apply power to the receiver and connect a 9-volt battery to the transmitter. Test the training transmitter and receiver by aiming the transmitter at the receiver and pressing the transmit switch. If the circuit is working correctly, the valid transmission LED on the receiver will light up as long as you hold down the transmit switch. The VT LED should light regardless of the settings of the DATA DIP switches (S2 a–d). If the LED does not light, find and repair the mistake.

Follow the manufacturer's instructions for programming the learning remote. Operate the training transmitter as you would any other remote control. As discussed earlier, the power-on command is decoded by the receiver as decimal 15. But, because the training transmitter understands only BCD, set all four data DIP switches at logic high (1111).

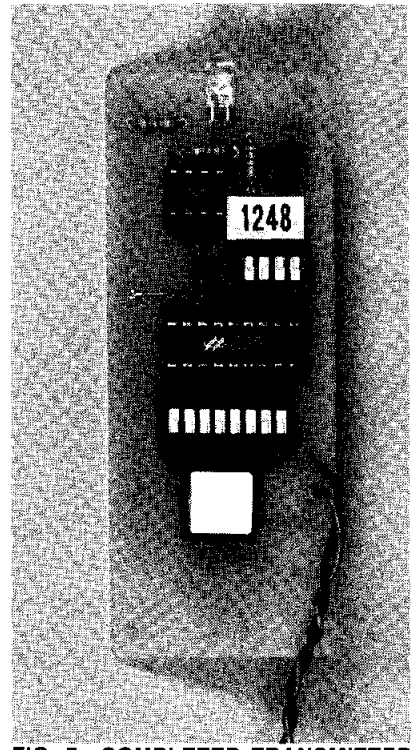

FIG. 7—COMPLETED TRANSMITTER BOARD. This board allows unique coding that won't interfere with nearby remote-controlled equipment.

Now activate the learning remote's learning mode, press the on button, and press the transmit button on the training transmitter until the learning remote indicates that it has received the command. Next set the mute function as decimal 14 (1110), volume-up as decimal 13 (1101), and volume-down as 12 (1100).

How you program the remaining 12 receiver command codes is your choice. You might want to map 0 through 9 to buttons 0 through 9 on the remote. That still allows for two additional commands. Don't forget to program all your other remote controls into the learning remote too. Ω