

UNIVERSAL REMOTE CONTROL

ALMOST EVERY PIECE OF MODERN audio/video equipment comes equipped with an infrared remote control. But how many of your home-built electronic projects have a remote control? Probably none, because you can't readily convert a television or VCR remote to your own application, and remote controls that you can easily interface to your own projects are not commercially available.

To us, "Not commercially available" means "Let's build our own!" This article describes a multifunction infrared (IR) remote control system—a transmitter and receiver—that you can build in one evening. The system is designed to control four different types of devices: switches, servo motors, a stepper-motor robot (see **Radio-Electronics**, April 1991), and a dual digital potentiometer IC. Only one kind of device can be controlled at a time, but enough technical information is included in this article for you to adapt the remote-control system to almost any application.

IR transmitter theory

The IR transmitter is based

Add the luxury of a remote control to nearly any project you can think of.

FRED EADY

on IC1, an INS8048L microprocessor that attains high-speed operation with very low power consumption. That microprocessor is responsible for driving and reading the 16-key keypad and generating the 40-kHz modulated infrared drive signal. Let's take an in-depth look at how those two tasks are accomplished.

A schematic depiction of the 16-key keypad is shown in Fig. 1.

If you're interested in the "down and dirty" program details, a fully documented machine language listing (IRXMIT.

ASM) is available as part of a self-unarchiving ZIP file called

IRSYSTEM.EXE on the RE-BBS (516-293-2283, 1200/2400, 8N1). The keypad used in this project was from All Electronics Corp., PO Box 567, Van Nuys, CA 91408 (800)

826-5432, (part No. KP-16). Any functionally equivalent keypad can also be used. Each key contact surface inside the keypad is an intersection of a particular row and column. As you can see from Fig. 1, the 0 key is an intersection of row 1 and column 1, and the 9 key is an intersection of row 4 and column 3. Although the layout of the keys in Fig. 1 doesn't match the actual



layout of the keys on the keypad, Fig. 1 is electrically correct. Also, while the 5x5 grid allows up to 25 keys, the actual keypad has only 16 keys.

Rows 1 through 5 are normally held at a TTL high level. To determine which key has been pressed, IC1 successively applies TTL logic lows to each row from 1 to 5, and then reads the output of the columns. When a key is pressed, its row and column are shorted together, and the low applied to the row is transferred to the column (which is normally held high). As an example, if row 1 is being scanned and the 0 key is depressed, a low will be read by IC1 at column 1. That low will be decoded as a "0." A succession of "0" characters will be sent as long as you hold the 0 key depressed. Table 1 shows how the pins on the back of the keypad connect to the pins on the microprocessor and the corresponding microprocessor ports.

Infrared transmitter

The enemies of the infrared signals that emanate from the transmitter are incandescent light, fluorescent light, and sunlight. Large amounts of



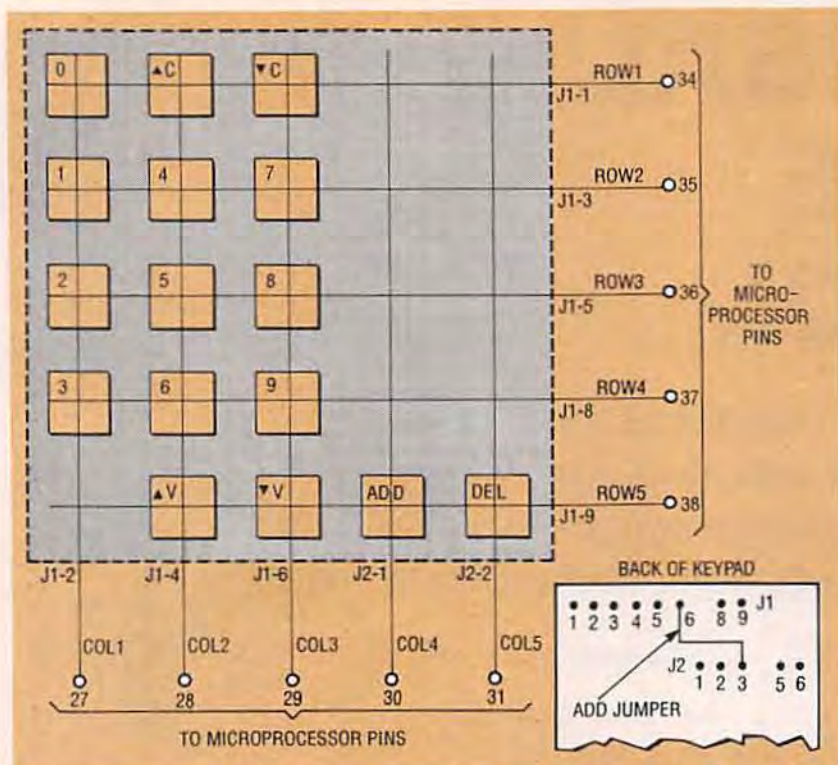


FIG. 1—KEYPAD SCHEMATIC. Each key contact surface is an intersection of a particular row and column. The physical layout of the keypad does not match the electrical layout.

TABLE 1
KEYPAD CONNECTIONS

Keypad (see Fig. 1)	Microprocessor Pin	Port
J1-1	34	P17
J1-2	27	P10
J1-3	35	P24
J1-4	28	P11
J1-5	36	P25
J1-6	29	P12
J1-8	37	P26
J2-1	30	P13
J2-2	31	P14

Also jumper J1-6 to J2-3
on back of keypad

modulated, noisy infrared energy are produced by those light sources. Most of the interference is modulated in the 50- or 60-Hz range. A simple red plastic filter will screen out some of the noise, but to overcome the extraneous infrared interference, the transmitted infrared signal must be modulated at a high carrier frequency. In our system, the carrier frequency is 40 kHz—which is required by the GPIU52X receiver module used.

The IR transmitter schematic is shown in Fig. 2. The 40-kHz

carrier originates at pin 11 of IC1 (ADDRESS LATCH ENABLE, OR ALE) which provides a square wave that is exactly one fifteenth of IC1's oscillator frequency. In our system, that is 6 MHz divided by 15, or 400 kHz. The 400-kHz signal is applied to the CLK input of IC3, a 4017 CMOS decade counter which is configured to divide by 10 to obtain the desired 40-kHz carrier.

The resultant 40-kHz signal at pin 12 of IC3 is gated by the output port P15 (pin 32) of the microprocessor and fed to pin 3 of inverter/driver IC4, a 4049 CMOS inverting buffer. That buffer serves two purposes: First, it inverts the idle state of IC3 so that MOSFET Q1 is turned off when no characters are being transmitted. Second, it provides sufficient drive to the gate of Q1 so that maximum infrared energy is emitted by the infrared LEDs.

As stated before, the 40 kHz carrier signal at pin 2 of IC4 drives Q1's gate which turns Q1 on and illuminates two IR LED's (LED1 and LED2) producing a 40-kHz modulated IR signal. A logical "1" is a 1-millisecond

pulse of IR light and a logical "0" is a 0.5-millisecond pulse. Each bit is separated by at least 0.5 millisecond to allow the IR detector to synchronize. Figure 3 depicts how a transmitted character "9" would look on an oscilloscope. The transmitted "1's" and "0's" are convined in groups of eight to form 16 distinct characters as shown in Table 2. To avoid sequence errors and to allow the receiver to synchronize between transmissions, a 50-millisecond idle period is placed between transmission of each character.

Infrared receiver

The receiver, whose schematic is shown in Fig. 4, is based on the Sharp GPIU52X IR module, and the INS8048L microprocessor. The IR receiver detects and decodes the IR signal from the transmitter. Once again, if you want the raw details, consult the machine code listings IRSWITCH.ASM, IRSERVO.ASM, IRRECROB.ASM and IRPOT.ASM, which are part of the ZIP file called IRSYSTEM.EXE on the RE-BBS.

The GPIU52X IR Receiver/ Demodulator is a hybrid IC/infrared detector. A PIN (positive-intrinsic-negative) photodiode feeds an amplifier and limiter that provides a strong, clean signal which is filtered to remove all frequencies outside the 40-kHz passband. The resultant signal is demodulated to provide a waveform minus the

TABLE 2
KEYPAD CHARACTERS

Key	Row	Col	Binary
0	ROW1	COL1	00001111
UP C	ROW1	COL2	10100101
DW C	ROW1	COL3	10110100
1	ROW2	COL1	00011110
4	ROW2	COL2	01001011
7	ROW2	COL3	01111000
2	ROW3	COL1	00101101
5	ROW3	COL2	01011010
8	ROW3	COL3	10000111
3	ROW4	COL1	00111100
6	ROW4	COL2	01101001
9	ROW4	COL3	10010110
UP V	ROW5	COL2	11000011
DW V	ROW5	COL3	11010010
ADD	ROW5	COL4	11100001
DEL	ROW5	COL5	11110000

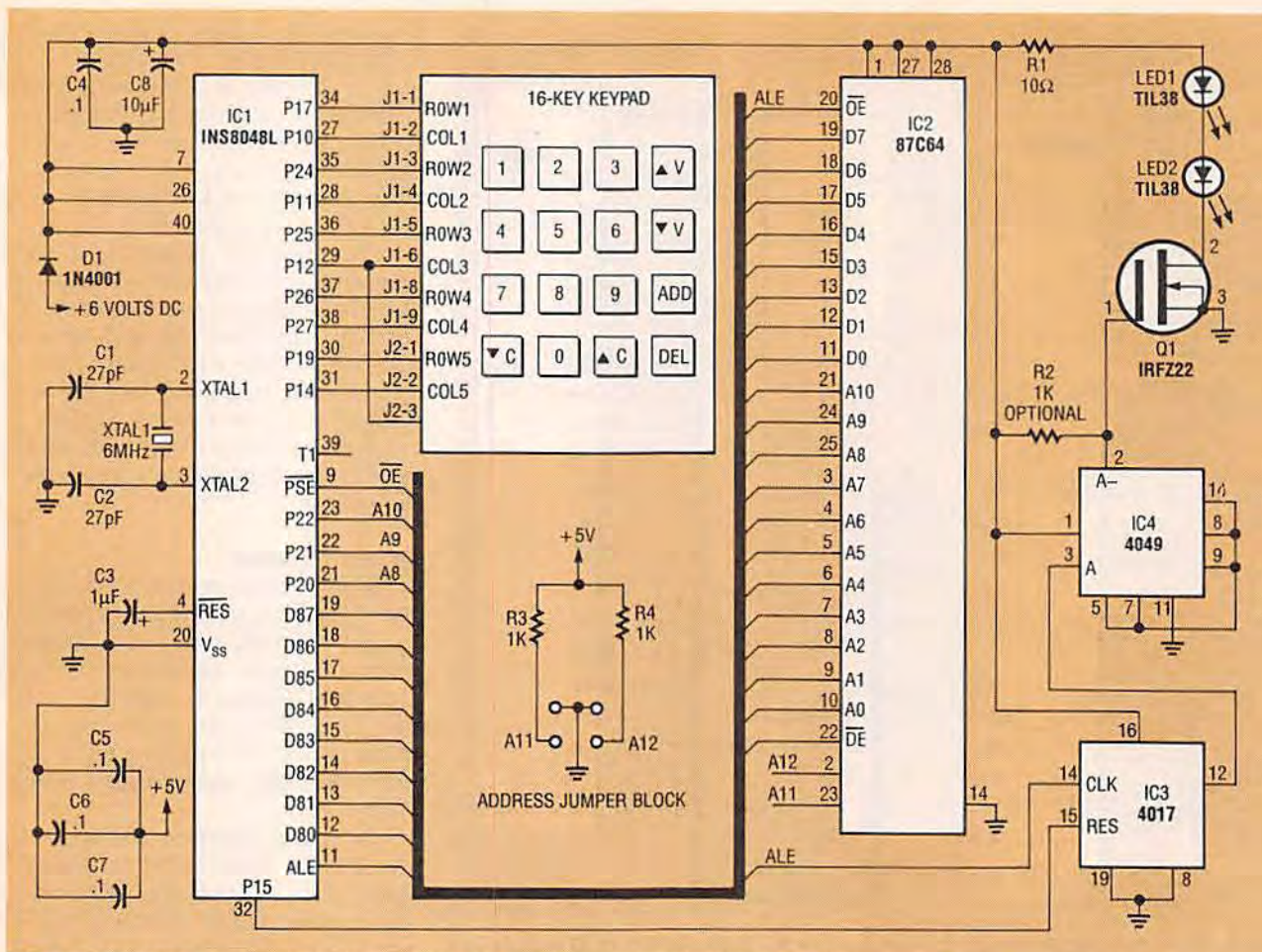


FIG. 2—IR TRANSMITTER SCHEMATIC. The 40-kHz carrier is derived by dividing IC1's oscillator frequency (6 MHz) by 15, to get 400 kHz, which is divided by 10 by IC3.

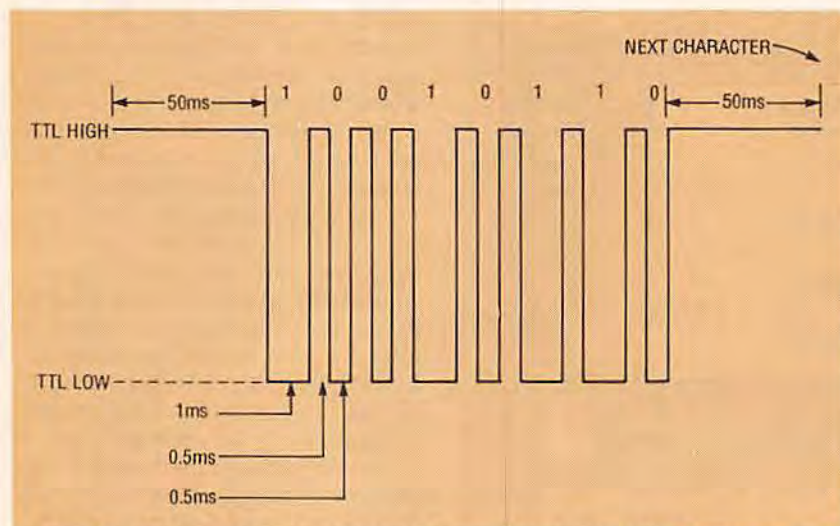


FIG. 3—A TRANSMITTED CHARACTER "9" would look like this if seen on an oscilloscope. The transmitted "1's" and "0's" are put together in groups of eight to form 16 distinct characters as shown in Table 2.

carrier.

The demodulated signal is presented to IC1 via the event counter input (T1, pin 39). At this time the program residing

in IC2 (an 87C64 EPROM) takes over. The idle state of the GPIU52X is normally high. As soon as the output pin of the IR detector transitions low, IC1

starts an internal timer to measure the incoming pulse width. Depending upon whether the pulse width is 0.5 or 1 millisecond, a binary 0 or 1, respectively, is stored in a holding register. Once 8 bits are received, IC1 attempts to match the 8-bit word with a term in its internal table to determine which character has been received. How the received character is used depends upon which one of the four functions is selected.

Transistors, buffers, & relays

See Fig. 5 for program-selection information. IRSWITCH.ASM, the first of four programs contained in the EPROM, is selected by jumpering both address jumpers (A11 and A12).

Basically, keys 1–8 on the keypad select ports P10–P17 (pins 27–34) of IC1 respectively. The TTL logic levels at P10–P17 can turn on a switching transistor,

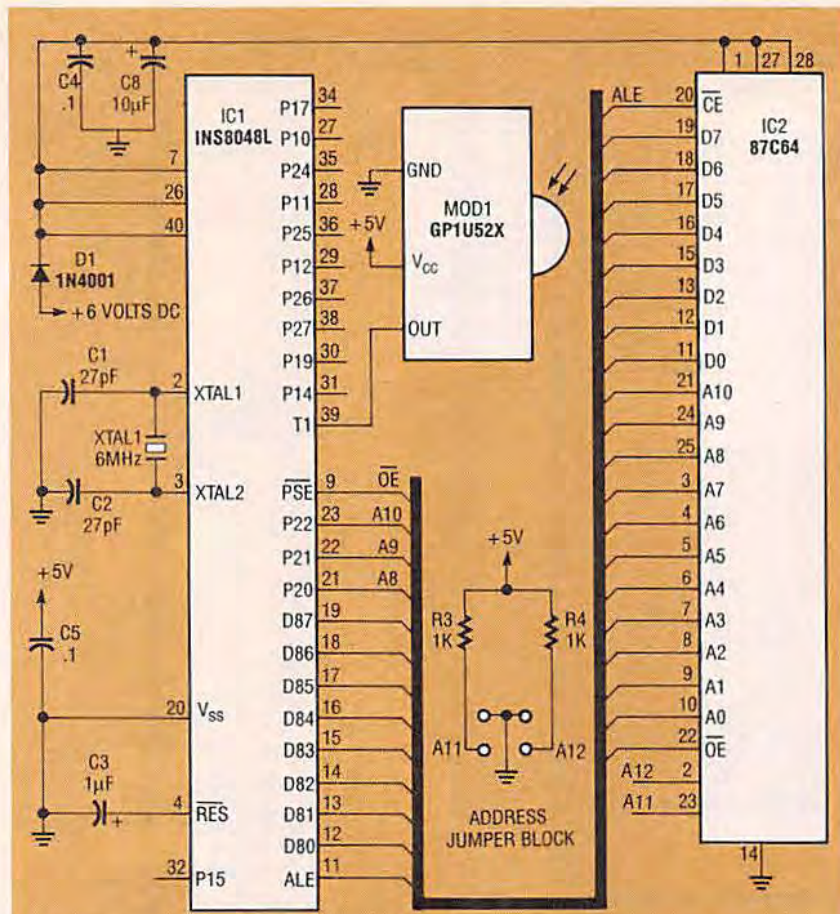


FIG. 4—IR RECEIVER SCHEMATIC. It is based on the Sharp GP1U52X IR module and INS8048L microprocessor. The GP1U52X is a hybrid IC/infrared detector that provides a strong clean signal for later filtering and demodulation.

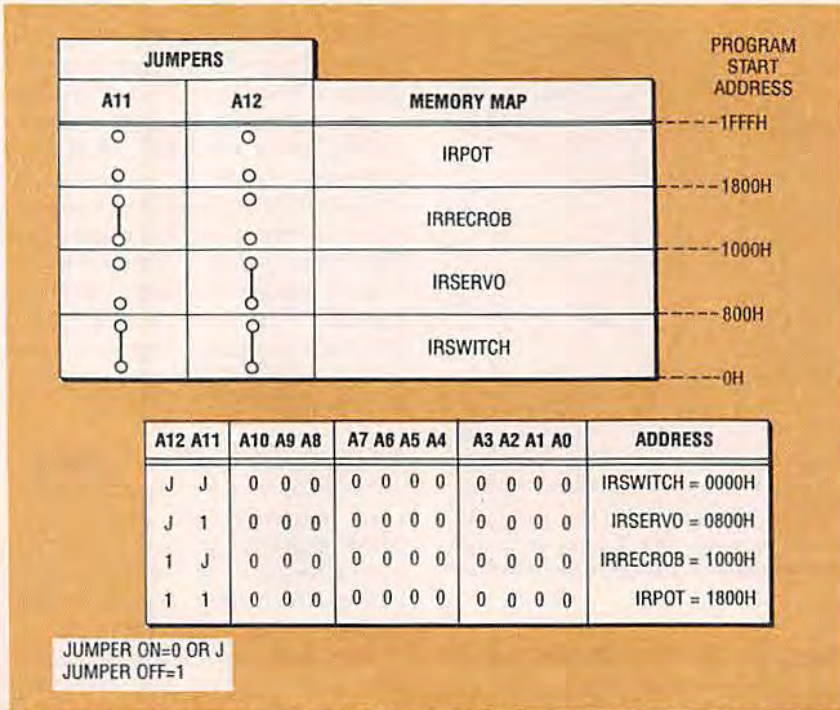


FIG. 5—PROGRAM-SELECTION INFORMATION. Four different programs (IRSWITCH.ASM, IRSERVO.ASM, IRRECROB.ASM, and IRPOT.ASM) are stored in the receiver's EPROM. The programs are selected via jumpers A11 and A12.

drive a TTL buffer, or activate a solid-state relay. Pressing the ADD key allows any following key depression of keys 1 through 8 to output a high on the corresponding port. Conversely, pressing the DEL key followed by any of keys 1 through 8 signals IC1 to take the following port selection low. That allows any of the eight outputs to be turned "on" or "off" individually without interfering with each other. To see this, use a logic probe to check P10 as you press ADD or DEL followed by a 1. ADD 1 should take P10 high while DEL 1 returns P10 to low.

Driving servos

Hobby-grade servos are commonly found in radio-controlled model aircraft and cars. However, because servos convert electrical pulses to mechanical motion, they do have many other uses. Servos are easy to use once you understand how they work.

The most common hobby servos have a three-wire termination: positive voltage, ground, and signal input. Positive voltage is usually +5-volts DC and the signal is a TTL-compatible variable-width pulse. A 1.5-millisecond pulse will center the servo rotor. Increasing the pulse width to 2 milliseconds will move the servo rotor fully clockwise. Decreasing the pulse width to 1 millisecond moves the servo rotor fully counterclockwise. So, a pulse width between 1 and 2 milliseconds will cause the rotor to travel in a specific direction and distance depending on the applied pulse width. Pulses are normally applied about every 16 milliseconds to hold the servo rotor in position. In our application, pulses are applied every 45 milliseconds.

The IR remote control system can control a maximum of two hobby servos as shown in Fig. 6. The program IRSERVO.ASM, which is selected by jumpering only A12, is used to drive them. The servos are operated by pressing the UP v and DOWN v keys for counterclockwise and clockwise rotation, respectively. The o key will center the selected servo rotor. Selection of servos 1

and 2 is performed by pressing 1 for servo 1 and 2 for servo 2. The drive signal for servo 1 originates at pin 27 of IC1 (P10) and the drive signal for servo 2 originates at pin 28 (P11). When servo 1 is active, a high is present at pin 35 of IC1 (P24), and when servo 2 is active, a high is present at pin 38 (P27). You can use those outputs to drive LED indicators with a PN2222 transistor, as shown in Fig. 6.

Robot remote control

Do you remember Ken the robot from the April 1991 issue of **Radio-Electronics**? He had a mind of his own, but the IR remote-control system will let you teach him some manners. The IR system gives you override control of Ken's motions. You will need to change or reprogram the original 8748H microcontroller with the new version of the machine language, IRROBOT.ASM, which is included in the ZIP file IRSYSTEM.EXE on the RE-BBS. (A new, preprogrammed 8748H containing IRROBOT.ASM is available from the source given in the Parts List.)

The IR receiver unit, which must be mounted directly on the robot, decodes the UP V key as forward, DOWN V as reverse, UP C as left, and DOWN C as right. The o key stops Ken in his

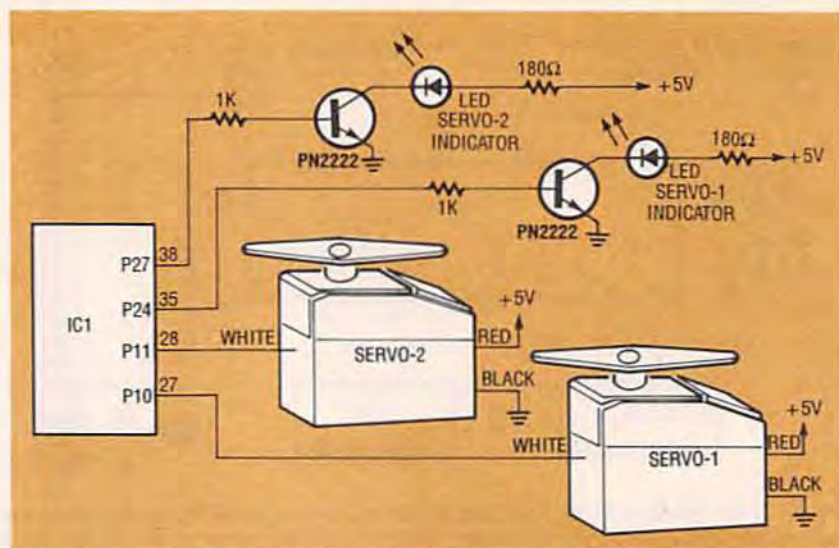


FIG. 6—THE IR REMOTE CONTROL SYSTEM can control a maximum of two hobby-grade servos. The LED's indicate which servo is active.

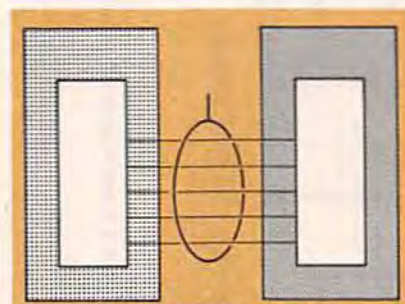


FIG. 7—THE IR RECEIVER can be mounted on Ken the robot (see **Radio-Electronics**, April 1991) to give you full control over him.

tracks. If you want Ken to roam as he originally did, the DEL key puts him in his roving mode. All of the key combinations and codes used to manipulate Ken,

as well as details on how it's done, can be found in the header section and main body of the program IRRECROB.ASM (included in IRSYSTEM.EXE). That program is set by jumpering only A11. Figure 7 details the connections between the IR receiver unit and the robot.

Remote potentiometer

Program four, IRPOT.ASM, remotely controls a digital potentiometer. The DS1267 dual solid-state potentiometer (made by Dallas Semiconductor) is composed of 256 resistive sections. Tap points are provided between each resistive section, and each tap point is accessed

PARTS LIST—TRANSMITTER

All resistors are 1/4-watt, 5%.

R1—10 ohms

R2-R4—1000 ohms

Capacitors

C1, C2—27 pF, ceramic disk

C3—1 μF, 35 volts, tantalum

C4-C7—0.1 μF, Mylar

C8—10 μF, 10 volts, electrolytic

Semiconductors

IC1—INS8048L microprocessor (National)

IC2—87C64 EPROM with transmitter program installed

IC3—MC14017 CMOS decade counter

IC4—MC14049 CMOS inverting buffer

D1—1N4001 diode

Q1—IRFZ22 MOSFET

LED1, LED2—TIL38 infrared light-emitting diode

Other components

XTAL1—6-MHz crystal

Miscellaneous: On/off switch, 16-key keypad (All Electronics part number KP-16 or equivalent), PC board, plastic case, 6-volt battery, ribbon cable, wire, solder, etc.

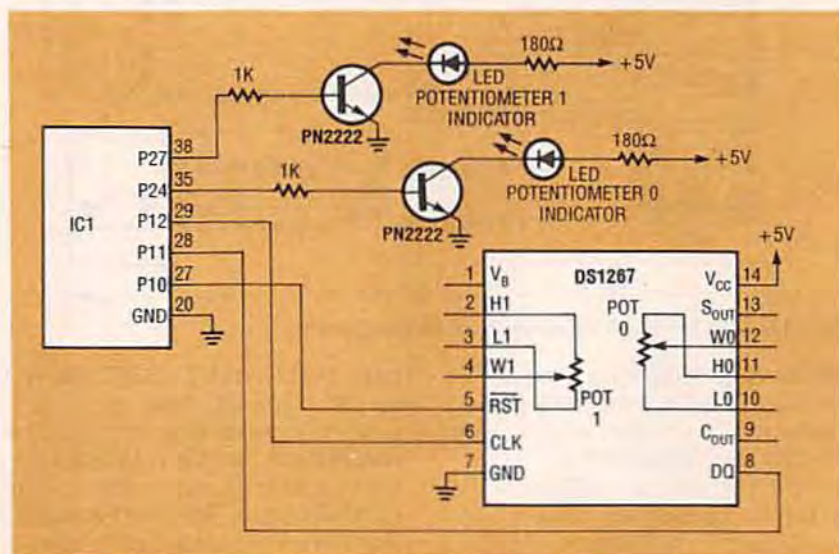


FIG. 8—THE IR SYSTEM can remotely control a DS1267 dual solid-state potentiometer.

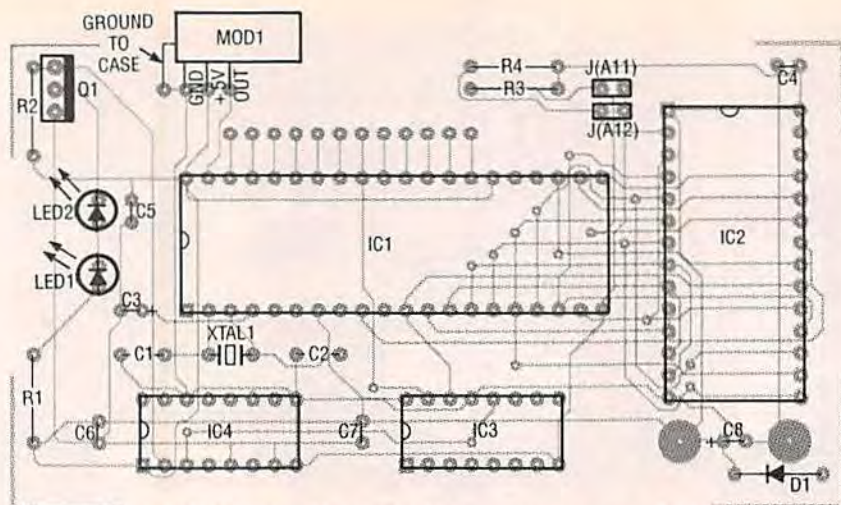
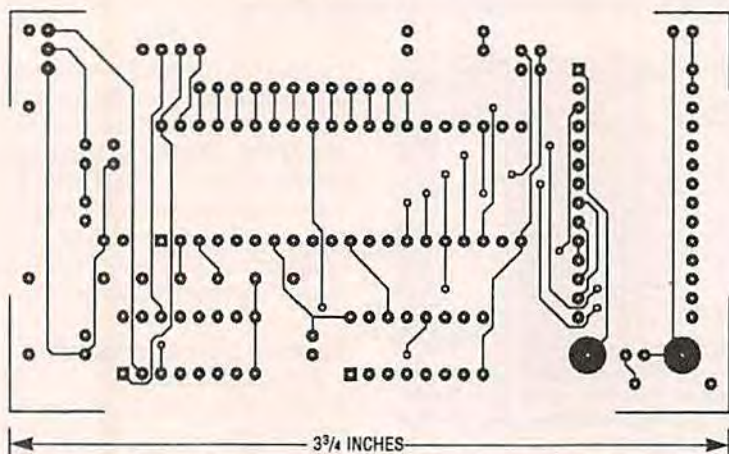
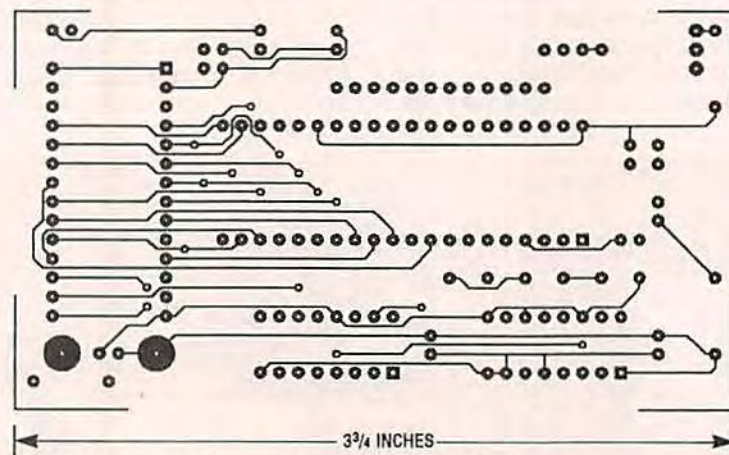


FIG. 9—THE TRANSMITTER AND RECEIVER are on the same PC board. Build the transmitter first, checking off each part in the transmitter parts list as you go. Put it aside when done, and then build the receiver.



COMPONENT SIDE for the IR transmitter and receiver boards.



SOLDER SIDE for the IR transmitter and receiver boards.

by the wiper. By clocking a 17-bit digital code into the DQ pin, each potentiometer within the IC can be adjusted independently. The part is available with different resistance values, depending on your needs.

Figure 8 shows how to con-

nect the DS1267 to IC1 on the receiver board. The UP ∇ and DOWN ∇ keys raise and lower the resistance, while 0 selects potentiometer 0 and 1 selects potentiometer 1. We use the 0 and 1 keys here instead of 1 and 2 because the DS1267 data sheet

PARTS LIST—RECEIVER

All resistors are 1/4-watt, 5%.

R1, R2—not used

R3, R4—1000 ohms

Capacitors

C1, C2—27 pF, ceramic disk

C3—1 μ F, 35 volts, tantalum

C4, C5—0.1 μ F, Mylar

C6, C7—not used

C8—10 μ F, 10 volts, electrolytic

Semiconductors

IC1—INS8048L microprocessor (National)

IC2—87C64 EPROM with receiver programs installed

IC3, IC4—not used

D1—1N4001 diode

Q1—not used

LED1, LED2—not used

Other components

XTAL1—6-MHz crystal

MOD1—GP1U52X IR detector module (Sharp), or Radio Shack part number 276-137

Miscellaneous: On/off switch, PC board, two jumper blocks, wire, solder, etc.

Note: A complete kit of parts for the transmitter and receiver (not including a battery and case) is available for \$49.00 plus \$3.00 S&H from Fred Eady, PO Box 541222, Merritt Island, FL 32954. Check or money order only. For technical assistance call 407-454-9905.

labels the potentiometers as 0 and 1. Again, pin 35 of IC1 is high when potentiometer 0 is active, and pin 38 is high when potentiometer 1 is active. You can also use the LED indicator circuits connected to pins 35 and 38 of IC1. Both jumpers A11 and A12 must be removed to access IRPOT.ASM.

Common factors

The receiver and transmitter circuitry are almost identical, and they are built on the same PC board. Parts common to both circuits have the same part number, and parts added or removed from one of the circuits will have corresponding part numbers added or removed. So, when a particular part number that's contained in both circuits is mentioned, the part performs the same function in both circuits. When a part contained in only one of the circuits is mentioned, the reference is limited to that particular circuit.

The first and most important part common to both circuits is

Continued on page 76

UNIVERSAL REMOTE

continued from page 56

IC2, an 87C64 8K × 8 CMOS EPROM, which contains the machine language instructions for all functions provided by the remote-control system. The 87C64 is identical to the industry-standard 27C64, except that the 87C64 contains an internal address latch and the 27C64 part does not. For those interested in programming the EPROM, there is a modification you can make to the programmer we ran in November 1991. Send a self-addressed stamped envelope to the author for details (see the parts list). In normal use of the INS8048L, address lines A0-A7 need a separate 74LS373 address latch because the lower eight data and address lines are multiplexed between address and data by the INS8048L processor. Because power consumption must be kept to a minimum, and space is at a premium, eliminating a 74LS373 address latch by using the built-in function of the 87C64 works in our favor.

In both circuits, capacitors C1 and C2 are used by the built-in oscillator of IC1. A 6-MHz crystal (XTAL1) ensures high accuracy for timing routines, and it provides the basis for the 40-kHz carrier on the transmitter module. All 0.1 μF capacitors are standard TTL noise-bypass components, while C8, a 10 microfarad electrolytic, minimizes voltage drop at the battery terminals. Capacitor C3 is used to reset the processor.

In the transmitter, R1 limits current and, along with Q1, allows a high-current 40-kHz pulse to be applied to the IR LED's. Resistors R3 and R4 provide pull-up for address lines A11 and A12. On the transmitter, install jumpers A11 and A12.

The system is designed to operate from a +6-volt DC supply. Diode D1 drops the +6-volts DC down to around +5.3 volts. The system works fine without the diode, but it's best to leave it in the circuit because voltages above +5 volts can lower the life expectancy of semiconductors.



FIG. 10—THE PROTOTYPE TRANSMITTER is housed in a plastic case with a single-sided, copper-clad PC-board blank machined as its top panel.

Building the system

As mentioned before, the transmitter and the receiver are both on the same PC board. You can use the supplied foil patterns to make your own (you'll need at least two), or they are available from the source given in the Parts List. The transmitter and receiver boards are identical except for a few components. Figure 9 shows the parts-placement diagram for both boards. Follow the parts list for the board you are building, and install only the parts in that list. Check off each part as you install it to avoid confusing the two boards. Build the transmitter first, and put it aside when it is done.

Install the capacitors, paying special attention to their polarities. Be sure to install jumpers at the A11 A12 locations for the transmitter only. It's advisable to use sockets in this project. Install the IR LED's and R1. Mount them in any position as long as they can be able to radiate IR freely. Gate-pull-up resistor R2 is optional.

Once you are satisfied that all your work is correct, attach the 16-key keypad with a piece of ribbon cable. Cut a piece of copper-clad perforated construction board with holes 0.1-inch on centers to the same size as the keypad. Mount it over the keypad pins and solder the perforated construction board to the keypad pins. This will make it easier to solder and mount the keypad.

A functioning transmitter

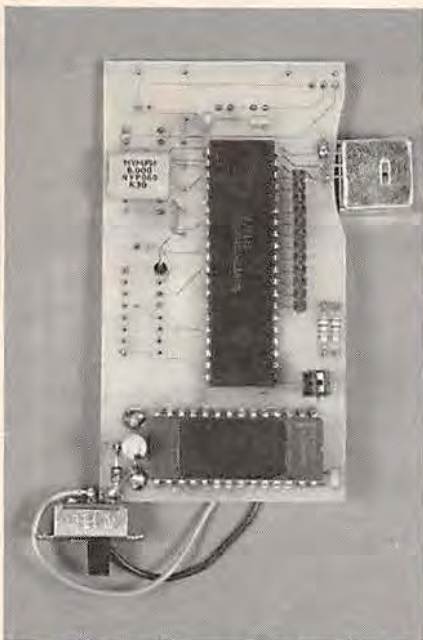


FIG. 11—THE RECEIVER BOARD can be mounted on the project you are adapting it to. You can attach the GPIU52X IR module directly to the PC board as shown here, or run wires to it off-board.

can be tested with the GPIU52X infrared detector module from the receiver. You'll also need a logic probe or scope. Attach a +5-volt DC supply to the GPIU52X (see Fig. 9 for pinout information). Apply power to your probe or scope, which should be connected to the output pin of the IR detector. Apply power to the transmitter and press any key. You should see a change in the scope pattern from the output pin of the IR module if the transmitter is operating properly.

Install the transmitter in a suitable enclosure. A red acrylic lens will improve the appearance of the remote control, but it is not a requirement. The layout of the components on the circuit board is not critical. The prototype is housed in a plastic case with a single-sided copper-clad PC-board blank machined as the top panel (the copper side is installed on the inside of the case). Rectangular openings were cut in the blank for mounting the power switch and keypad. Brass strips, soldered from the copper on the top panel to the copper on the perfboard installed on the keypad, are used to mount the keyboard to the top panel. The prototype has a

6-volt "J"-type battery because of its size and shape. However, any +6-volt DC power source will be satisfactory for this project. The prototype transmitter is shown in Fig. 10.

Now assemble the receiver. Install the parts indicated in the parts list for the receiver and the parts-placement diagram. Attach the GPIU52X to the PC board or, optionally, run wires to it off-board. Be sure to ground the metal case of the module. Install jumper blocks at the A11

and A12 locations as shown in Fig. 11. The figure shows the completed module.

Test the receiver module in the switch mode (jumper A11 and A12 on the receiver). With a logic probe to monitor P10 (pin 27 of IC1 on the receiver), you should be able to toggle P10 by pressing ADD or DEL followed by a 1. ADD 1 should take P10 high while DEL 1 returns P10 to low. If this function works, the rest of the applications will also operate properly.

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