

## A VERSATILE REMOTE CONTROLLER

*Adding remote control to any circuit or device is not as hard as you might think. This article shows you how its done.*

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THE DREAM OF ADDING REMOTE CONTROL to appliances, gadgets, and projects is an old one in electronics. But because of the complexities involved, it is one that has been beyond the skills of many hobbyists. Now, as in so many other areas of electronics, Large Scale Integration (LSI) IC's have come to the experimenter's rescue.

The Motorola MC14457 remote control transmitter and MC14458 remote control receiver IC's, by themselves, form almost 90% of a high-quality infrared or ultrasonic remote-control system that is capable of handling up to 272 commands. Although the IC set was developed for television remote use, and has some special pin functions for that purpose, it is highly flexible and can be used for a myriad of remote-control needs ranging from controlling TV and stereo gear, to remote arming of security systems, to remote programming of computers and robots.

### The remote-control system

The MC14457 IC (see Fig. 1) needs only a keyboard, oscillator, output device, and battery to form a complete remote-control transmitter. Similarly, the MC14458 receiver (also shown in Fig. 1) needs only a power supply, input circuit, and oscillator to function. Both devices are CMOS, and thus require only a minimal amount of supply current.

The transmitter does not have or need an on/off switch. When a button on the keyboard is pressed, the clock oscillator

starts up, the key is decoded, and the correct seven-bit data stream is transmitted via either an array of IR LED's or an ultrasonic transducer. Four of the transmitted bits are actually either data or a command; a fifth "function" bit lets the receiver know the nature of those bits (the function bit is not externally available). Two start bits are added to synchronize the transmission with the receiver. Table 1 shows the 32 possible keys, their codes, and their row/column location.

The data is transmitted in FSK (Frequency Shift Keying) format, using two frequencies divided down from the 500 kHz control clock—38.46 and 41.66 kHz. That FSK transmission, other than using much higher frequencies, is similar in operation to the encoding process used by computer modems.

The 14458 receives the transmitted data through either a photodiode or an ultrasonic transducer. After the signal is amplified and conditioned, the receiver IC decodes it from its FSK form and, according to the state of the function bit, routes it to either the data or the command port.

If the function bit is a 0, the four bits are read as data and are routed to the data port. The data port is two digits wide (each digit is made up of eight bits), and can be configured to accept either one or two digits as a full data word. After a full word is transmitted, a pulse appears on the data available (DA) pin. The data can be either BCD or hexadecimal in format, depend-

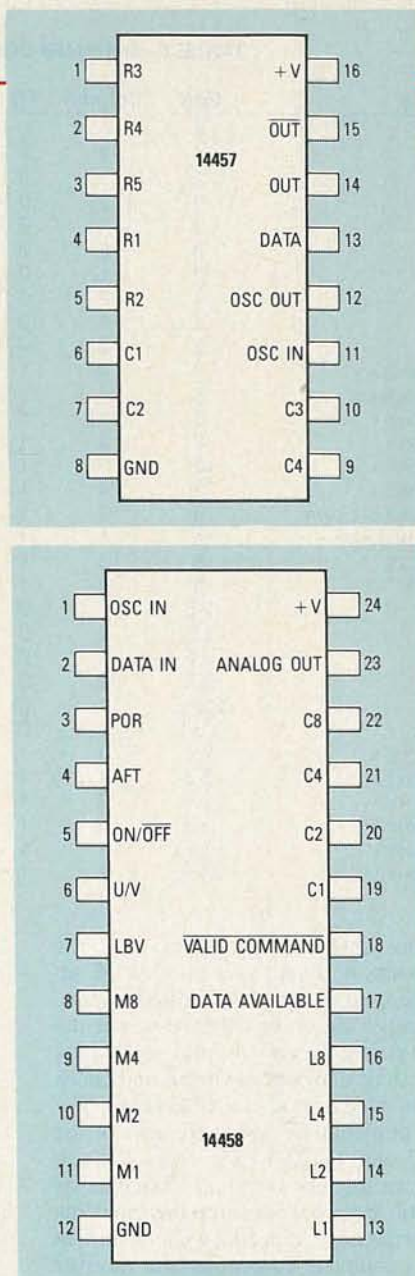


FIG. 1—THE 14457 REMOTE-CONTROL TRANSMITTER IC pinout (top) and the 14458 remote-control receiver IC pinout (bottom). With the addition of a keyboard, oscillators, power supplies, and input and output transducers, the pair of IC's becomes a powerful remote-control system.

ing on the number of keys used in the transmitter, so data words from 00 to 99 (0 to 9 in single digit mode) or 00-FF (0-F) can be transmitted to the data port.

If the function bit is a 1 instead of a 0, the four data bits are read as a command, and are routed to the command port. A received command is latched into the 4-bit port, after which a pulse appears on the valid command (V $\bar{C}$ ) pin. Of the commands, four are internally decoded by the 14458, and twelve require external decoding to be useful.

With 256 data words and 16 commands, plus other specialized single-pin

TABLE 1—4457/4458 COMMAND ENCODING

Key	Row	Column	FB	C8	C4	C2	C1	VC Pulse
0	1	1	0	0	0	0	0	
1	1	2	0	0	0	0	1	
2	2	1	0	0	0	1	0	
3	2	2	0	0	0	1	1	
4	3	1	0	0	1	0	0	
5	3	2	0	0	1	0	1	
6	4	1	0	0	1	1	0	
7	4	2	0	0	1	1	1	
8	5	1	0	1	0	0	0	
9	5	2	0	1	0	0	1	
TOGGLE 1	1	3	1	0	0	0	0	X
TOGGLE 2	1	4	1	0	0	0	1	X
CONT 1	2	3	1	0	0	1	0	X
CONT 2	2	4	1	0	0	1	1	X
CONT 3	3	3	1	0	1	0	0	X
CONT 4	3	4	1	0	1	0	1	X
ANALOG DOWN	4	3	1	0	1	1	0	X
ANALOG UP	4	4	1	0	1	1	1	X
MUTE	5	3	1	1	0	0	0	X
OFF	5	4	1	1	0	0	1	X
A	2/5	1	0	1	0	1	0	
B	2/5	2	0	1	0	1	1	
C	3/5	1	0	1	1	0	0	
D	3/5	2	0	1	1	0	1	
E	2/3/5	1	0	1	1	1	0	
F	2/3/5	2	0	1	1	1	1	
CONT 5	2/5	3	1	1	0	1	0	X
CONT 6	2/5	4	1	1	0	1	1	X
CONT 7	3/5	3	1	1	1	0	0	X
CONT 8	3/5	4	1	1	1	0	1	X
CONT 9	2/3/5	3	1	1	1	1	0	X
CONT 10	2/3/5	4	1	1	1	1	1	X

outputs controlled by the data sent to the two ports, it's easy to see how that IC set can be used in dozens of different ways. By proper use of the data and proper decoding of the commands, almost anything that can be done with switches and knobs can be done over an invisible beam. The only limitation on the usefulness of the 14457 and 14458 is how well you can interface the receiver to the device under control. Before we get into the problems of interfacing and decoding, let's look at how a complete transmitter and receiver are built.

**The transmitter**

Since the 14457 is CMOS, it draws almost no supply current by itself. However, the clock oscillator and the output device are another story—the current drawn by both would normally make battery power impractical. However, the 14457 is designed to shut down the oscillator when it is not needed and the output circuitry draws power only when transmitting, which takes 0.1 seconds per data stream. Those features make both battery power and the lack of an on/off switch completely practical.

Being CMOS, the 14457 can operate from a supply voltage between 5 and 12 volts. The voltage and type of battery used will depend on the type of output. Since the ultrasonic type needs a higher voltage but much less current than the IR type, an

ordinary 9-volt transistor battery can be used for power. The array of IR LED's, on the other hand, need a substantial amount of supply current, so four "AA" or "AAA" cells in series (for a total of 6 volts) should be used. In both Figs. 2 and 3, note that a diode is used to prevent damage to the IC from reversed battery connections and a 50- $\mu$ F capacitor is used to filter transients from the supply line; those components should not be omitted.

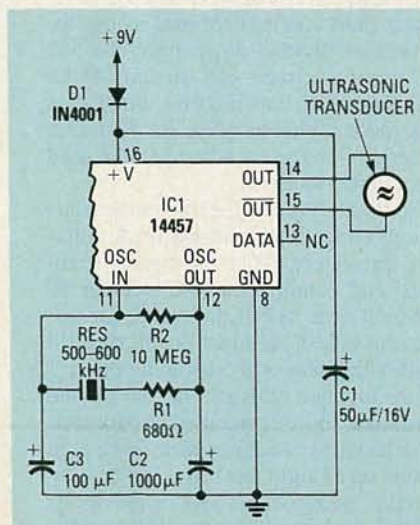


FIG. 2—THE BASIC CONNECTIONS for the transmitter oscillator. Note that this circuit uses an ultrasonic output.

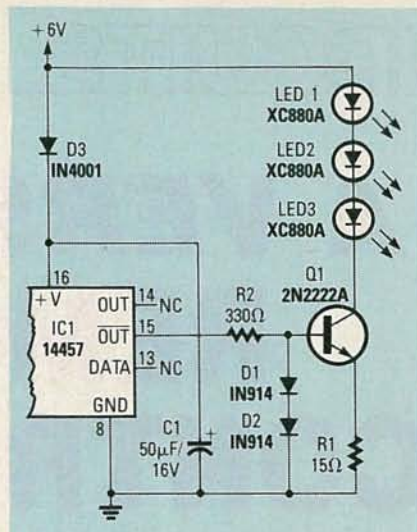


FIG. 3—THE OUTPUT CIRCUIT for an infrared transmitter.

The 14457 has an on-board oscillator circuit; the only external parts required are the frequency-determining components. Both the 14457 and 14458 require an identical control frequency of about 500 kHz. Instead of using a crystal to maintain the frequency, both units use a much cheaper, smaller, and more durable ceramic resonator. While ceramic resonators are less precise than crystals, they are more than accurate enough for many uses, this one included. The exact frequency of the resonators used is not important, as long as they are identical and of about the frequency specified. Suitable resonators are available from the source provided on page 67 (Ordering Information).

The ceramic resonator is used in exactly the same manner as a crystal (Fig. 2), requiring a tank circuit around it to force it to oscillate at the correct frequency. High-Q disc capacitors and metal-film resistors should be used in the tank circuit to promote stability. Note that the 14457 disables the oscillator by clamping pin 11 (OSC IN) to ground.

The output circuit of the ultrasonic transmitter is simpler than that of the IR type and requires no circuitry in addition to the ultrasonic transducer itself. The 14457 uses complementary push-pull outputs to generate a strong, balanced drive signal across the transducer.

The IR output uses only one of the two outputs, since a driver transistor is needed to provide sufficient current to the LED array. Three infrared LED's are used to increase the range of the transmitter. High-output LED's such as XC880A's or TIL906-1's should be used.

There is no real difference in performance or range between the two types of output. The IR output is decidedly cheaper, since a pair of ultrasonic transducers can cost \$25.00 or more, and the parts are more widely available. On the other hand, the IR beam is limited to line-of-sight

### Ordering Information

The following are available from Circuit Specialists, PO Box 3047, Scottsdale, AZ 85257: 14457/14458 transmitter/receiver pair, \$17.00 postpaid; 455-kHz ceramic resonator (Mallory CU455), \$8.50 each, postpaid.

operation, while the ultrasonic signal can bend around corners and other obstacles. In general, the IR type is recommended for hobbyist use.

Besides the push-pull transmitting outputs, the 14457 has another output, the DATA output, that can be used to give a visual indication of transmission. It follows the unencoded binary data used to modulate the FSK transmission. If a driver circuit and LED like that in Fig. 4 are added, the LED will flicker briefly each time data is transmitted. That load will contribute slightly to battery drain, but since it is impossible to see infrared or hear ultrasonics, the feedback of a visual transmission signal could be valuable.

The most difficult part of building the transmitter is the construction of the keyboard. The 14457 has four column and five row inputs, each with its own internal pull-up resistor. To transmit a data digit or command, one column and one (or more) rows must be simultaneously shorted to ground. The problem is that only one type of row-to-column-to-ground keyboard is commonly available, and it is for telephone use, and it has the familiar 12-button pattern. Since that type of keyboard is expensive and difficult to modify to the circuit needed here, it is not practical.

Fortunately, there is an alternative. The ordinary row-to-column type of matrix keyboard may be used with an array of NPN transistors to provide a path to ground. That allows use of the common, inexpensive membrane-type keyboard like that found in many calculators. The NPN transistors may be discrete 2N2222/2N3904 types, or a DIP array such as the CA3046/3086.

Actually, any type of SPST normally open switches could be used to build a keyboard, with one connection of each

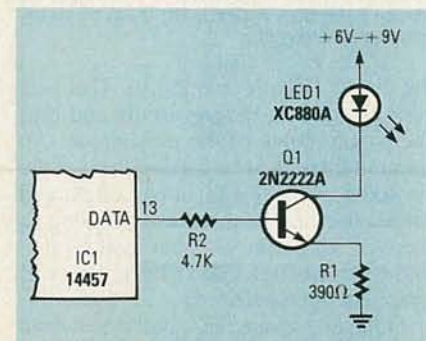


FIG. 4—THIS CIRCUIT can be added to give a visual indication of the transmitted signal.

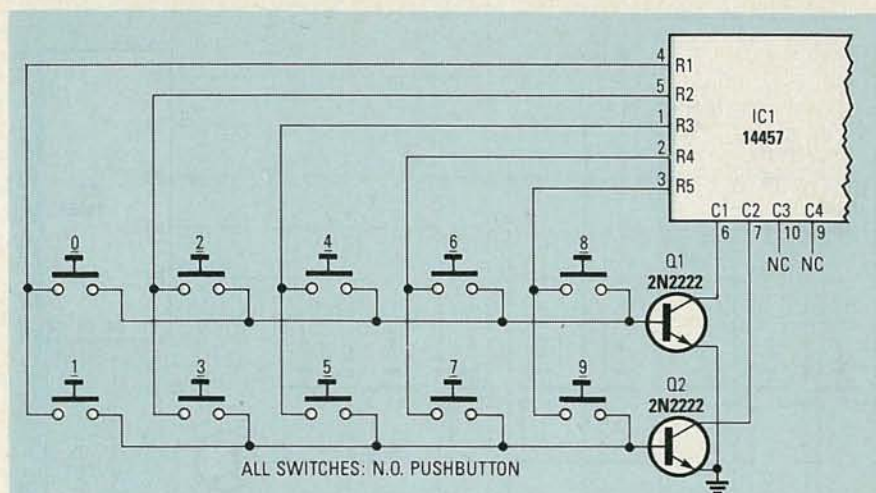


FIG. 5—THE 10-KEY keyboard. Each SPST normally-open switch shorts one row to one column. Note that the column 3 and 4 pins are left unconnected.

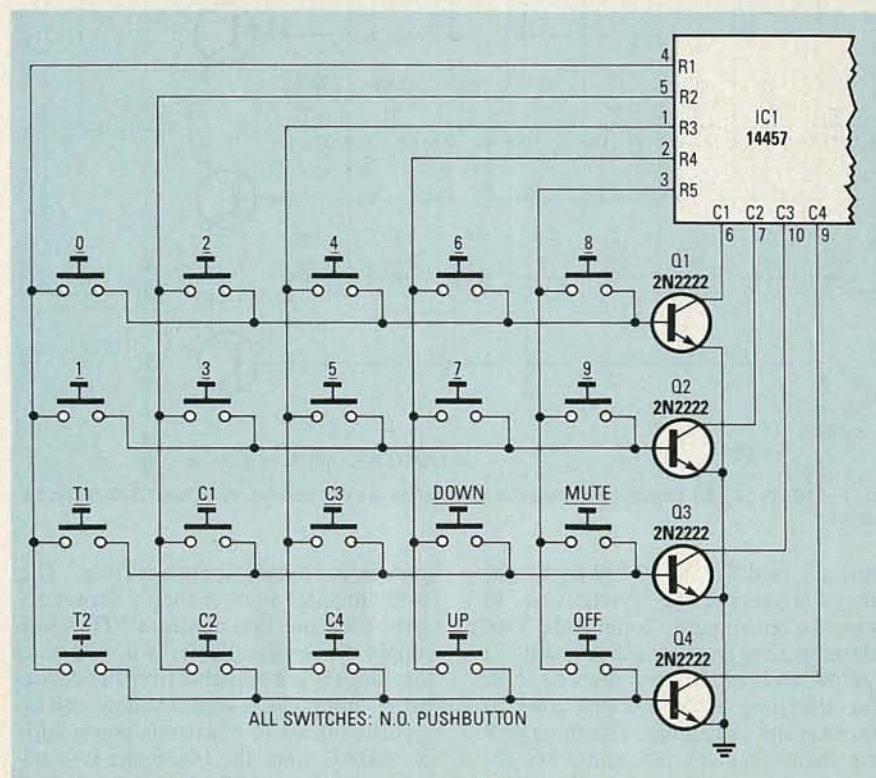


FIG. 6—THE 20-KEY keyboard. Either discrete transistors or an NPN IC array can be used.

switch going to the correct row and the other going to the correct column. Although that type of keyboard will be more expensive and much larger than the membrane type, the keys can be laid out in any desired pattern.

The 14457 allows the use of up to 32 keys, 16 for the data digits 0 through F, and 16 for commands. Any of those keys and commands may be used independently, with or without any other keys. Also, any lesser part of the 32-key pattern can be used. Let's look at three such sub-patterns, and the full 32-key version.

The simplest keyboard (Fig. 5) uses only 10 keys, those corresponding to the digits from 0 through 9. That pattern

would be ideal for security system disarming, with the receiver input mounted behind a window or near a door. Note that the two unused column inputs are left unconnected; since they have internal pull-ups, no external disabling is required.

A somewhat more complex keyboard, the 20-key version (Fig. 6), is probably the best compromise between usefulness and too much complexity. That keyboard adds the following to the 10-key keyboard: OFF, ANALOG UP, ANALOG DOWN, MUTE, two uncommitted toggle-type commands, and four uncommitted continuous-type commands. (We'll talk about the command types in a moment.)

Since all of the available rows and col-

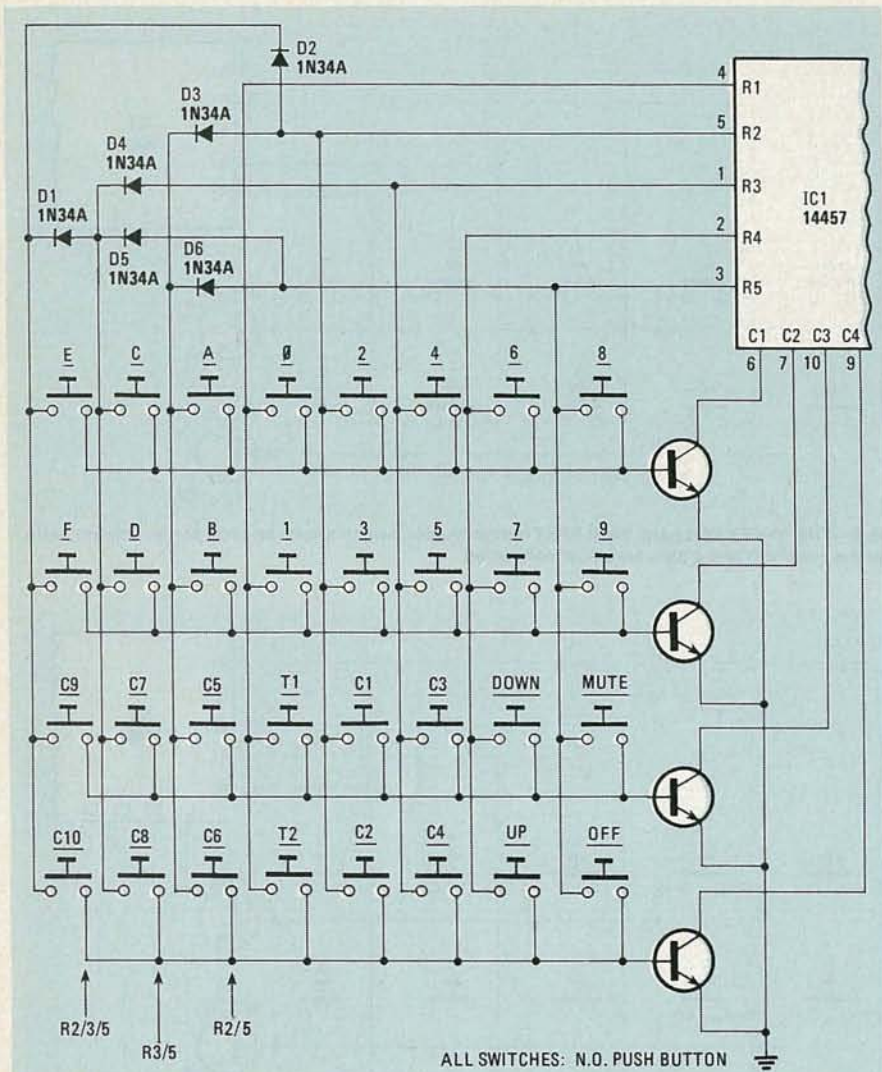


FIG. 7—THE 26/32-KEY keyboard. If the extra commands are not needed, switches C5–C10 can be deleted.

umns are used for the 20-key keyboard, three extra rows must be “synthesized” to access the remaining 12 commands. That is done by using an array of diodes (Fig. 7) to allow each of the new rows to short more than one of the existing rows to ground at the same time. The three new rows are labelled 2/5, 3/5, and 2/3/5, indicating the existing rows used to synthesize each.

If all 32 keys made accessible by adding those synthesized rows are used, six more continuous-type commands are available, along with the six hexadecimal digits A through F. If only access to the hex digits is desired, the six command keys can be deleted, leaving the 26-key keyboard. The only thing that determines whether BCD or hex data can be transmitted is whether or not the hex digit keys are available. If the 10- or 20-key keyboard is used, only BCD data may be sent; with the 26- and 32-key versions, either BCD or hex data can be transmitted.

### The receiver

The receiver half of the remote-control

system is slightly more complex. The 14458 requires a power supply between 5 and 6 volts, and thus can use a TTL power supply if one is available. If a voltage in that range is not available from the device being controlled, a higher voltage can be regulated down or a separate power supply added. Since the 14458 and its outboard circuitry are CMOS, not more than 20–30 mA of supply current should be required.

The 14458 has three inputs, one for the incoming signal (DATA IN), one for the oscillator frequency (OSC IN), and one used for automatic power-on reset (POR). The POR input, pin 3, has an internal pull-up resistor and needs only a 0.22–0.47  $\mu\text{F}$  capacitor between it and ground for operation. With such a capacitor in place, when power is applied to the 14458 all of its outputs and internal registers will be reset to 0.

The oscillator used in the 14458 (Fig. 8) is almost identical to that used in the transmitter, except that the receiver requires an external active element, a 4069UB inverter (the active element is

internal on the 14457). The ceramic resonator used in the 14458's oscillator must be identical to that used in the transmitter.

The FSK signal is received, as described earlier, by either a photodiode or an ultrasonic transducer. The transducer can be directly connected to an amp input, but the photodiode requires a pull-up biasing resistor from 22K–220K, with the exact value determined experimentally once

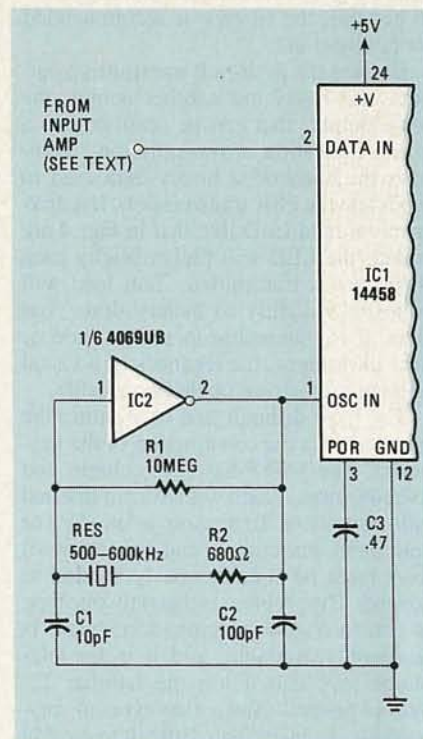


FIG. 8—THE BASIC CONNECTIONS for the receiver oscillator. For single digit operation, pin 9 (M\*) would be tied to +5V, and pin 6 (U/V) would be grounded.

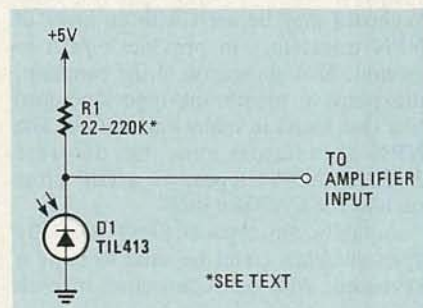


FIG. 9—FOR BEST SENSITIVITY and range, the value of the bias resistor, R1, must be determined experimentally.

the circuit is built (see Fig 9). That bias resistor controls the sensitivity and thus the pickup range of the photodiode. An infrared filter must be used in front of the photodiode to exclude ambient light and further increase its sensitivity. Although a piece of red plastic like that used for display filters can be used, a true IR filter will give better performance.

From the pickup, the signal is sent to an amplifier. We'll show you a suitable amplifier and finish things up. **R-E**