ELECTRONICS NOTEBOOK

Touch Tone Remote Control

By Forrest M. Mims III

Though the Bell system developed the Touch Tone system specifically for telecommunications applications, it is also well suited for use in remote control. Touch Tone signals can be easily transmitted by means of wire, radio and light. They can also be transmitted directly through the air as sound waves.

The Touch Tone system provides up to 16 audio-frequency signals that can be used individually or, as when making telephone calls, in sequentially transmitted combinations. Several integrated circuits designed specifically for generating Touch Tone signals are readily available. These chips are designed to be used in conjunction with a crystal that provides a highly stable timebase.

Most tone-based remote-control systems use a single frequency for each signal. While these systems are easy to design and build, they are very susceptible to false triggering. For example, several years ago, I developed a remotely controlled camera system for taking photographs from kites and helium-filled balloons. The camera was triggered by transmitting an audio tone from a handheld transmitter. The signal was detected by a small radio receiver with an integral tone decoder. When the tone decoder detected the transmitted tone, it actuated an optoisolator that tripped the camera's shutter and advanced the film to the next frame.

Though I obtained hundreds of aerial photos with this system, sometimes the camera was tripped when no signal was transmitted. The likely cause of this false triggering was other radio signals that just happened to be modulated at the same frequency, if only for a fraction of a second, as the tone from the system's transmitter.

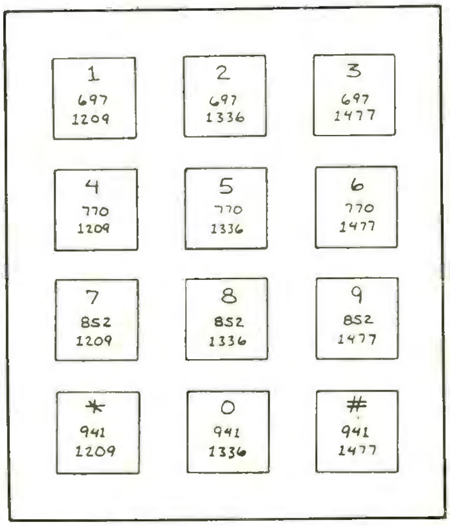

Fig. 1. Simultaneous tone frequencies for a Touch Tone keypad.

The Touch Tone system was designed to be largely immune to such interference. Instead of a single tone, each signal in the Touch Tone system is a pair of superimposed tones. While this arrangement does not provide 100 percent noise immunity, it does substantially reduce the possibility of inadvertent false triggering by interfering tones.

In the telecommunications industry, the Touch Tone system is often referred to to as the Dual Tone Multi-Frequency (DTMF) system. Figure 1 is a diagram of a pushbutton telephone keypad labeled with the frequency pair represented by each key position.

Though not present on standard telephone keypads, four additional frequency pairs are available. The frequencies are divided into a low group (679 to 941 Hz) and a high group (1,209 to 1,633 Hz). The 1,633-Hz frequency is omitted from standard telephone keypads.

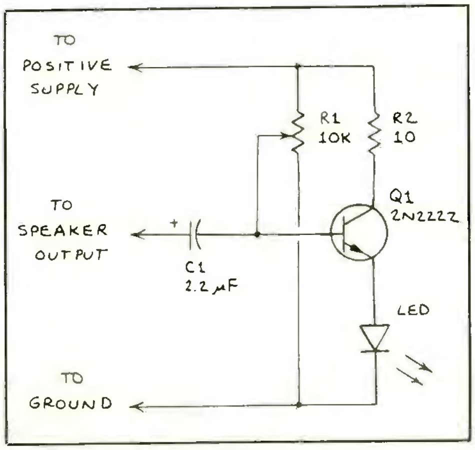

Fig. 2. A LED modulator for a pocket Touch Tone dialer.

When a telephone key is pressed, one frequency from both the low and high groups are selected, and the two tones are superimposed on each other. Since speech, transmission noise and DTMF tones can be simultaneously present on a telephone line, the Bell system carefully designed the DTMF system to avoid interference from non-DTMF signals. The Bell standard for DTMF signals allows a maximum frequency deviation of ±(1.5 percent + 2 Hz). The minimum time required for a tone pair to be recognized is 40 milliseconds, and the required pause between tones must be at least 40 milliseconds.

Here is a complete listing of available DTMF frequency pairs in Hertz:

Signal	Low Tone	High Tone
1	697	1,209
2	697	1,336
3	697	1,477
4	770	1,209
5	770	1,336
6	770	1,477
7	852	1,209
8	852	1,336
9	852	1,477
0	941	1,209
*	941	1,336
#	941	1,477
A	697	1,633
B	770	1,633
C	852	1,633
D	941	1,633

Touch Tone Generators

A Touch Tone remote-control system requires a DTMF tone generator. DTMF tones can be generated by a pair of transistor or integrated-circuit oscillators that have switchable precision resistor networks for generating each of the required tones. A much more reliable and simpler approach is to use a crystal-controlled DTMF IC. Several such chips are available from major electronics parts distributors.

Fig. 3. Two Radio Shack pocket-size Touch Tone (DTMF) dialers.

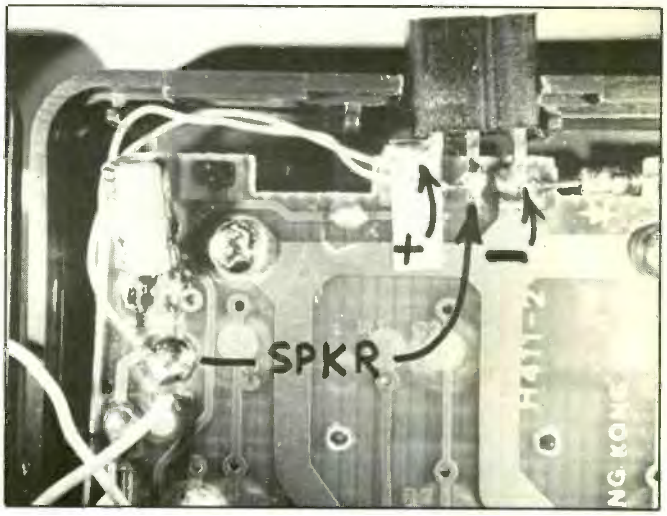

Fig. 4. Internal view of a Touch Tone dialer showing the addition of an interface socket.

Another solution is to salvage the DTMF tone encoder from a discarded telephone. Besides a working DTMF circuit, the telephone will be equipped with a keypad.

Still another approach is to use a pocket-size Touch Tone dialer. These devices are designed to permit a rotary telephone to access Touch Tone services. Some Touch Tone dialers are equipped with a readout and enough memory to store up to 60 or more telephone numbers. Memory-equipped dialers can be used for sophisticated remote-control applications.

An Infrared Touch Tone Transmitter

Touch Tone circuits can be easily adapted to drive an infrared or high-brightness red light-emitting diode. Figure 2 is the schematic for a simple intensity-modulated LED driver that is suitable for use with Touch Tone generators.

In operation, the driver biases the LED with a continuous flow of current. DTMF signals arriving at the base of *Q1* modulate the current through the LED, changing the intensity of the light the LED emits. Potentiometer *R1* controls the bias level of *Q1* and is used to allow the circuit to be tweaked for optimum operation. When adjusting *R1*, be sure to avoid turning its rotor to either extreme. If this should present a problem, add a 1,000-ohm fixed resistor in series with each leg of *R1*.

I have used the Fig. 2 circuit with two different Touch Tone dialers purchased from Radio Shack, both of which are shown in Fig. 3. The unit on the left has a liquid-crystal display and includes a memory that can store 60 numbers that have up to 16 digits in each. It can also store pauses, and it has an automatic shut-off feature.

Referring back to Fig. 3, note that a small rectangular object protrudes from the top of both dialers. These are sockets that are connected to the dialer's electronics. I installed these sockets to permit various LED transmitters to be conveniently connected and removed.

It's relatively easy to add an interface socket to a commercial Touch Tone dialer like the ones shown in Fig. 3. In doing so, it is important to observe CMOS handling precautions to avoid permanent and disabling damage to the dialer's internal circuitry. Incidentally, you should be aware that, in most cases, modifying a commercial device voids its warranty.

Since the free space inside a dialer is limited, it is necessary to use a very small connector. I have used Dean's three-terminal connector available from Ace R/C, a major supplier of radio-control equipment. These connectors are supplied in matched plug/socket pairs. The socket is required for the modified dialer and the plug for the transmitter circuit.

Before adding a socket to a tone dialer, plan ahead. Make sure there is ample room for the socket, and be sure the tone dialer is compatible with the LED driver. If you are uncertain about compatibility, temporarily connect mini-clips or solder short lengths of hookup wire to the appropriate terminals inside the dialer. You can then connect these wires to the LED driver and determine whether or not the combination works.

The Fig. 2 driver circuit works well with both of the Touch Tone dialers shown in Fig. 3. The circuits used in these products, however, are subject to change. Nevertheless, should this happen, it is unlikely that the Fig. 2 driver circuit will require modification.

Figure 4 shows a close-up of how a Dean's three-terminal socket can be installed inside the basic Fig. 3 tone dialer (Radio Shack Cat. No. 43-139). Adding the socket shown in Fig. 4 requires only about 15 minutes of your time. First, it's necessary to cut a slot for the socket in the dialer's plastic housing. Open the unit by inserting a thin tool in one of the thin slots below the battery compartment

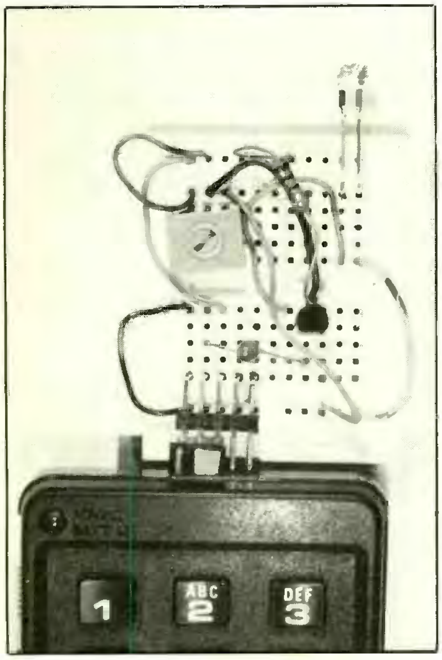

Fig. 5. Breadboarded infrared LED driver connected to a modified DTMF dialer.

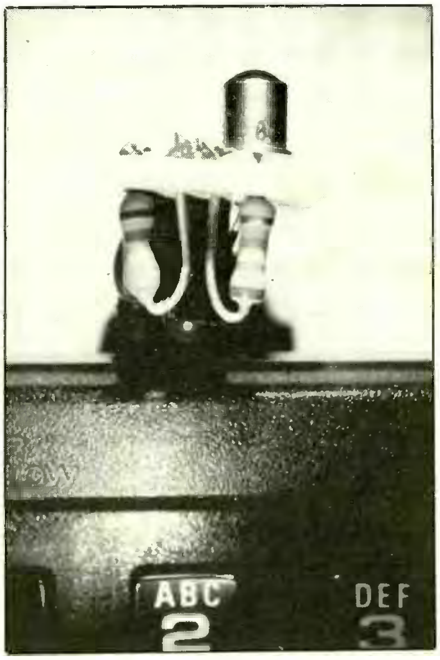

Fig. 6. A miniaturized infrared LED driver plugged into a modified DTMF dialer.

and carefully pry upward. Repeat with the other slot.

Before cutting the slot for the socket, be sure it will fit. Ideally, the socket should be positioned so that one of its terminals can be soldered directly to a power-carrying land or terminal on the circuit board. This is possible with both dialers pictured in Fig. 3. As can be seen in Fig. 4, it's possible to solder one of the socket terminals directly to a circuit-board terminal connected to the negative side of this dialer's three-cell battery power supply.

It is important to make sure that none of the socket's terminals touch the wrong conductors on the circuit board. Referring back to Fig. 3, note that a small rectangle of tape has been placed below the socket's left terminal to isolate it from the adjacent copper land.

After the right terminal of the socket is soldered to the negative supply land on the circuit board, the center terminal of the socket connects to the positive speaker terminal (indicated by a red dot) with a short length of wrapping wire. A second piece of wrapping wire is used to connect the left socket terminal to the positive power-supply terminal near the lower-left portion of the circuit board. (*Important:* Observe CMOS handling precautions when making these connections!)

A breadboarded version of the Fig. 2 LED driver connected to the socket of the modified Touch Tone dialer is shown in Fig. 5. Connection to the socket is made by means of a right-angle Molex$^{\text{TM}}$ connector. Using the Touch Tone dialer with a breadboarded version of the LED driver permits the driver to be tested before a permanent version of the circuit is assembled.

The breadboarded version of the transmitter pictured in Fig. 5 can be installed on a tiny perforated board that measures only 0.5 by 0.75 inch. Figure 6 shows a miniaturized version of the circuit plugged into the socket of the modified Tone Dialer shown in Fig. 4. With exception of the LED, all components and a three-terminal Dean's plug are installed on one side of the board. The two resistors shown in the photo replace *R1* in Fig. 2. Their values were selected after *R1* was adjusted for optimum results when the LED driver was used with the receivers to be described.

Touch Tone Receivers

Touch Tone receiver/decoder integrated circuits are made by several manufacturers. Precision switched capacitor filters played a key role in the development of such chips.

Silicon Systems Inc. and Teltone Corp. both manufacture single-chip DTMF receivers. I have experimented with receiver chips made by both companies, both of which require only a 3.58-MHz crystal and a single resistor. Both chips have a single signal input pin and four three-state binary-encoded output pins. Let's look at how a receiver made by each company can be used with a simple infrared detector/receiver to receive and decode DTMF signals transmitted by the Fig. 2 circuit.

- *Teltone M-957 DTMF Receiver.* This 22-pin DIP chip requires a positive supply of from 5 to 16 volts. Incoming signals can be directly or capacitively coupled to pin 12.

Several control and output pins add to the M-957's versatility. A complete description of this chip is given in its specifications sheet. Here are some of its key features:

The A and B inputs at pins 8 and 9, respectively, can be used to adjust the receiver's sensitivity to incoming signals that have an amplitude of as little as 31 dBm. Output Enable (OE) at pin 3 controls whether the output pins are active or placed in a high-impedance state. The hex input at pin 2 determines whether the four output pins provide a standard 4-bit binary hexadecimal output or a 2-of-8 binary code.

The Strobe output at pin 18 indicates when a valid frequency pair is present at the input. This output can be used to provide a shift-left pulse for a digital readout controlled by shift registers. Normally, pin 18 is at logic 0. When a valid DTMF signal appears at the input and is verified (decoded), pin 18 goes to logic 1.

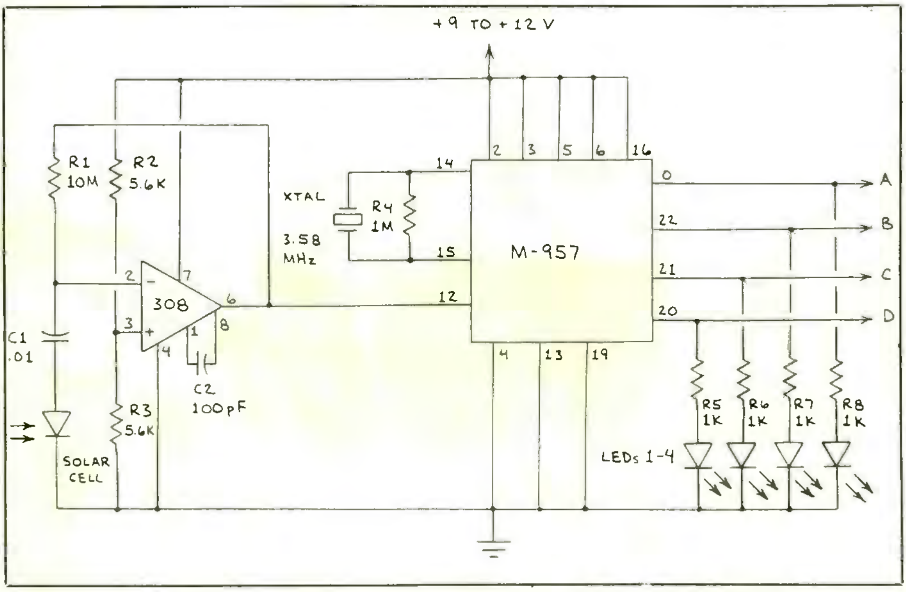

Fig. 7. A Touch Tone remote-control infrared receiver built around the Teltone chip.

Finally, output BD at pin 7 provides an early indication of the presence of a possibly valid DTMF signal. Normally, BD is at logic 0. Within 18 milliseconds of receiving a possibly valid DTMF signal, BD goes to logic 1. The Strobe output requires more than twice this time (40 milliseconds).

A kit consisting of the M-957 receiver, 3.58-MHz crystal, 10-megohm resistor and data sheet can be ordered from High Technology Semiconductors, 2512 Chambers Rd., Suite 204, Tustin, CA 92680 (714-259-7733). Cost is $14.95 plus $2.30 for UPS shipping in the continental U.S. California residents must add state sales tax. The company accepts telephone credit-card orders.

Shown in Fig. 7 is a straightforward DTMF infrared receiver designed around Teltone's M-957 chip. The circuit's detector is a standard silicon solar cell. It is coupled through *C1* to the input of an LM308 operational amplifier, which is operated with a 10-megohm feedback resistor to provide very high gain. The LM308's output is directly coupled to the M-957's signal input. Each of the four outputs of the M-957 directly drives an LED through a 1,000-ohm series resistor.

How the 4-bit output from the M-957 can be decoded to provide 16 individual outputs, one for each DTMF tone, is illustrated in Fig. 8. The outputs from the decoder can directly drive low-current LEDs. A relay driver that permits each output to control a much larger load than otherwise possible is shown in Fig. 9. The

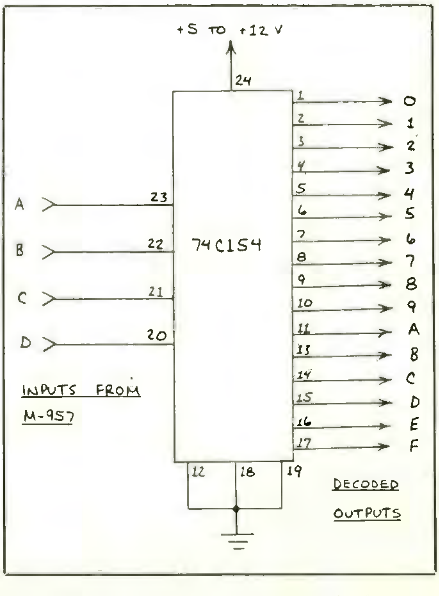

Fig. 8. A 1-of-16 decoder for Teltone's M-957 tone decoder.

four LEDs in Fig. 7 can be omitted if the outputs are connected to an alternative output device, such as the Fig. 8 decoder.

This receiver will respond to the Fig. 2 transmitter over a range of several hundred feet. If a small fresnel magnifying lens is placed in front of the solar cell, the receiver can be triggered from across a room. Since this narrows the beam from the transmitter, careful pointing will be required.

Suitable fresnel lenses are available from office supply and department stores. A wide variety of lenses of all kinds is available from Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 08007.

A high-power near-infrared AlGaAs emitter that radiates at 880 nanomoeters will give the greatest range. A super-bright AlGaAs red LED will give a shorter range, but its beam can be seen in a darkened room.

- *SSI 202P DTMF Receiver*. SSI's 202P 18-pin DIP DTMF receiver chip can be powered by 5 to 16 volts and is designed to be powered by a single 5-volt supply. Like the M-957, the 202P has several control and output functions that enhance operation. A complete description of these functions is given in the device's data sheet. These include:

The Output Enable (OE) at pin 3 that controls whether the output pins are active or placed in a high-impedance state. The Hex input at pin 2 determines whether the four output pins provide a standard 4-bit binary hexadecimal output or a 2-to-8 binary code.

The Detection Valid (DV) output at pin 14 indicates when a valid frequency pair is present at the input. Normally, pin 14 is at logic 0. When a valid DTMF signal appears at the input and is verified (decoded), pin 14 goes to logic 1.

The SSI 202P tone receiver and data sheet, complete with sample circuits is available from Radio Shack for $12.95 (Cat. No. 276-1303), as is the required 3.58-MHz crystal (Cat. No. 272-1310) for $1.69.

The Fig. 7 Teltone M-957 DTMF infrared receiver can easily be adapted for use with the SSI 202P. Though it is almost identical to the Fig. 7 circuit, the 202P circuit shown in Fig. 10 is shown to avoid possible errors.

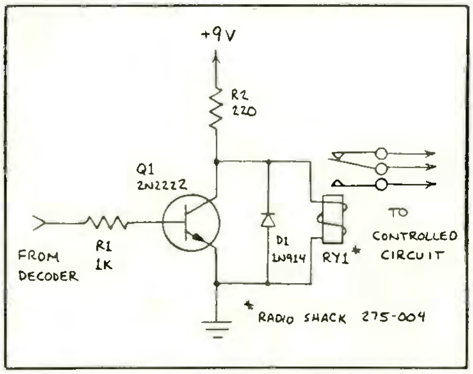

Fig. 9. A relay driver circuit for the Fig. 8 decoder chip.

Operation of the Fig. 10 circuit is essentially identical to that of the Fig. 7 circuit. Moreover, the Fig. 10 circuit can also be connected to the Fig. 8 output decoder and Fig. 9 relay driver. The most important difference between the two circuits is that the 202P chip must *not* be operated with a supply that delivers more than 7 volts.

To test the relative performance of the M-957 and 202P DTMF infrared receivers, I assembled both on a single solderless breadboard. The output from a single solar-cell receiver was connected to each chip's input so that each would receive the same signal. These tests revealed that both chips performed nearly equally well when coupled to the same infrared receiver. Though the M-957 was slightly more sensitive, the difference was so slight as to be negligible.

A more important observation was that the base of *Q1*, the LED driver in Fig. 2, required a slight readjustment for both DTMF receivers to simultaneously receive incoming signals. For other adjustments of *R1*, neither or only one of the two receivers would operate.

Going Further

The simple DTMF infrared remote-control circuits presented here can be modified to increase their sensitivity and versatility. They can also transmit signals through optical fibers.

Though these DTMF remote-control circuits use near-infrared or visible light as a transmission medium, there is no reason why a twisted-pair cable or radio cannot be used instead. In any event, the DTMF system offers a very convenient and relatively noise-immune method for achieving reliable remote control. **ME**

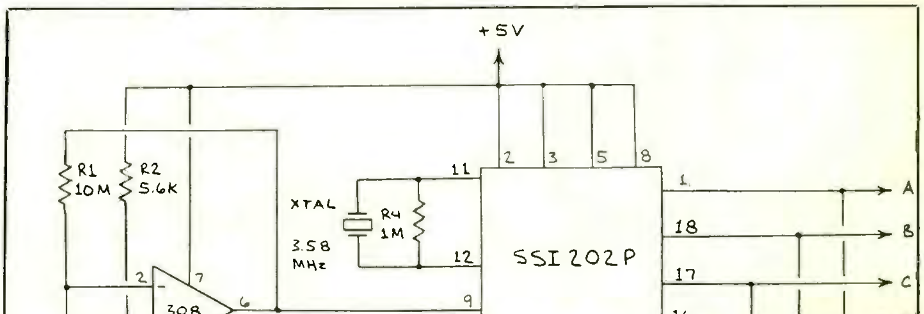

Fig. 10. A Touch Tone remote-control infrared receiver built around SSI's chip.