Circuit Circus

By Charles D. Rakes

UNUSUAL USES FOR TRANSDUCERS

This month's Circus starts the new year off with a number of solid-state piezo-transducer circuits. Those critters can be heard chirping their little hearts out in just about every kind of equipment that uses an electronic sounder.

We wake up to the beep-beep sound of our digital clock. Then as we get into our automobile, a beep reminds us to buckle up. And on through the day we hear a beep here, a chirp there, directing our attention from one place to another. With all of the racket created by the piezo sounders, you'd think there's nothing else they can do. Well, it's just not so!

Fixed-Frequency Generator. The circuit shown in Fig. 1 is self-oscillating; in it, a piezo element is used as the frequency-determining component. The circuit produces a tone output that can be used as an encoding signal for remote control or any other application where a fixed-frequency tone signal is required.

An unusual function of that tone-encoding generator is that both an audible tone and a signal are generated at the same time. The circuit's operation is simple. A single op-amp (one fourth of an LM324 quad op-amp) is configured as a standard inverting amplifier.

At power-up, a positive voltage is applied to the non-inverting input of U1 (via R3), forcing its output high. That high travels along three paths. The first path is the tone output. Along the second path, by way of R5, that high is used as the drive signal for BZ1.

In the third path, the high output of U1 is fed back, via R4, to the inverting input of U1. That forces the output of U1 to go low. And that low, when fed back to the inverting input of U1, causes the op-amp output to again go high, and the cycle repeats itself. As configured, U1 provides a voltage gain of 4.7 (gain = R4/R1).

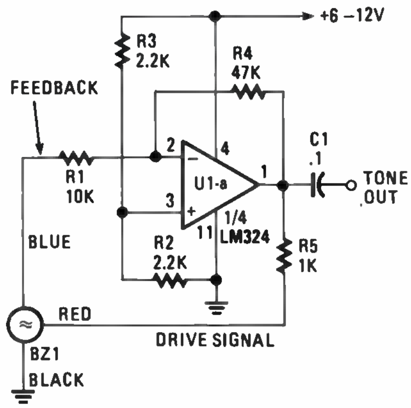

Fig. 1. This self-oscillating circuit uses a three-terminal piezo transducer as the frequency-determining component.

There are a number of "orphan" piezo transducers available on the surplus market. Several three-terminal piezo transducer elements were tried in the circuit and all performed well. The transducer specified in the Parts List comes with three short colored-coded (red, blue, and black) lead wires as indicated in Fig. 1. With the aid of the piezo-transducer pinout shown in Fig. 2, you should have little trouble in connecting any transducer to the circuit.

The outer ring of the piezo element is usually connected to circuit ground. The large, inner circle serves as the driven area, and the small, elongated

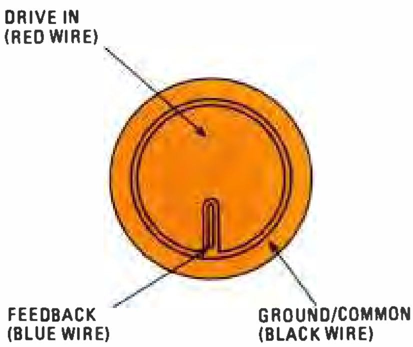

Fig. 2. Here is the pinout diagram for the three-terminal piezo transducer. The outer ring is usually connected to ground; the large inner circle is the driven area, and the elongated section is the feedback.

PARTS LIST FOR THE FIXED-FREQUENCY GENERATOR

U1—LM324 quad op-amp, integrated circuit
R1—10,000-ohm, ¼-watt, 5% resistor
R2, R3—2200-ohm, ¼-watt, 5% resistor
R4—47 000-ohm, ¼-watt, 5% resistor
R5—1000-ohm, ¼-watt, 5% resistor
C1—0.1-µF, ceramic disc capacitor
BZ1—Piezo fixed-frequency transducer, Radio Shack 273-064 or similar
Printed circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

section supplies the feedback signal. Resistor R5 sets BZ1's output-volume level. That level can be increased by decreasing R5 (say, to 470 ohms). To decrease the volume, increase R5 to about 2.2K, or so.

Resistors R2 and R3 set the bias for op-amp U1's positive input (pin 3) to half of the supply-voltage level. That allows for a maximum voltage swing at U1's output. Although a quad op-amp is specified in the Parts List, almost any similar low-cost single or dual op-amp will work for U1-a.

Sound-Activated Decoder. Turning our attention to Fig. 3, we see a piezo transducer performing double duty in that it operates as a sound-pickup device as well as a frequency-selective filter. Transducer BZ1, is connected to op-amp U1-a just as in the previous circuit, but with one notable exception—a gain control, potentiometer R3, has been added.

By controlling the gain of the op-amps, the oscillator circuit can be transformed into a sensitive and frequency-selective tone-decoder circuit. With the gain of U1-a set just below the point of self oscillation, the transducer becomes sensitive to acoustically coupled audio tones that occur at (or near) its resonant frequency.

The circuit's operation is comparable to an early and popular type of radio receiver in which regeneration was used to achieve super-high gains using relatively low-gain amplifying vacuum tubes. Regeneration is obtained by adding a controllable positive-feedback path between the receiver's input and output circuitry. And it was the gain obtained via regeneration in receivers of the 1920s that turned a simple one-tube set into a world-wide receiving station.

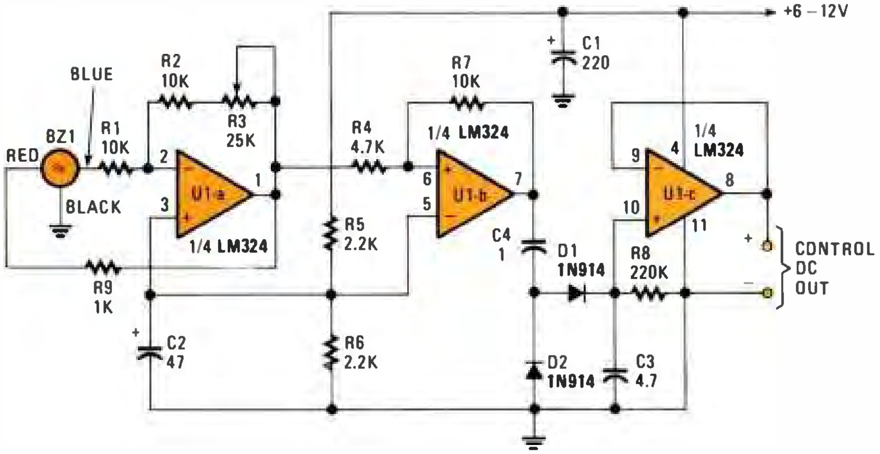

Fig. 3. In the Sound-Activated Decoder, the piezo transducer performs double duty, in that it operates as a sound-pickup device and a frequency-selective filter.

PARTS LIST FOR THE LOW-FREQUENCY CRYSTAL FILTER

U1—LM324 quad op-amp, integrated circuit
R1—47,000-ohm, ¼-watt, 5% resistor
R2–R5—10,000-ohm, ¼-watt, 5% resistor
R6, R7—2200-ohm, ¼-watt, 5% resistor
R8—100,000-ohm, ¼-watt, 5% resistor
C1, C2—0.1-µF ceramic-disc capacitor
C3—47-µF 16-WVDC electrolytic capacitor
C_X—See text
BZ1—Piezo transducer, Radio Shack #273-073 or similar
Printed circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

PARTS LIST FOR THE SOUND-ACTIVATED DECODER

U1—LM324 quad op-amp, integrated circuit
D1, D2—1N914 general-purpose small-signal diode
R1, R2, R7—10,000-ohm, ¼-watt, 5% resistor
R3—25,000-ohm potentiometer
R4—4700-ohm, ¼-watt, 5% resistor
R5, R6—2200-ohm, ¼-watt, 5% resistor
R8—220,000-ohm, ¼-watt, 5% resistor
C1—220-µF, 25-WVDC electrolytic capacitor
C2—47-µF, 25-WVDC electrolytic capacitor
C3—4.7-µF, 25-WVDC electrolytic capacitor
C4—0.1-µF, ceramic-disc capacitor
BZ1—Piezo fixed-frequency transducer, Radio Shack #273-064 or similar
Printed circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

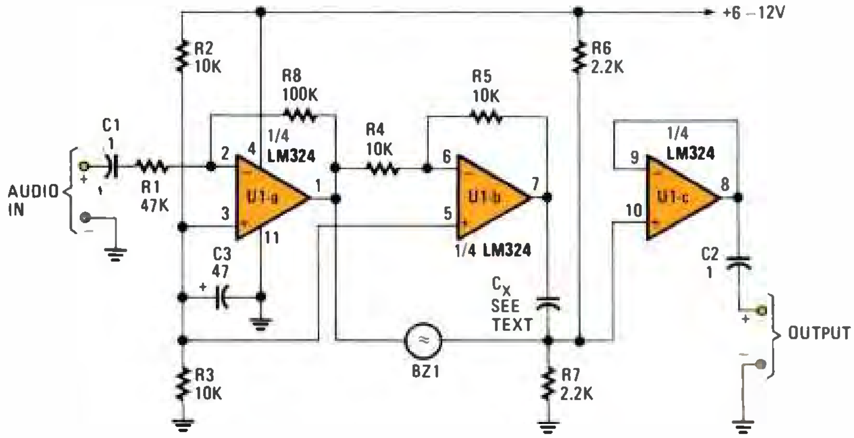

Fig. 4. In this circuit, the piezo transducer functions like a low-frequency, quartz crystal in a narrow band, crystal-filter circuit.

In-band audible tones reaching the transducer's surface cause the transducer to vibrate in step with the incoming sound wave. The regenerative action of the circuit then causes the signal to be amplified to a 1½- to 2-volt level. The output of U1-a is fed to U1-b, where the signal is doubled. The boosted signal is then fed across a dual-diode rectifier circuit to the input of a voltage follower, consisting of U1-c only.

The circuit's output can be used to activate optocouplers, drive relay circuits, or to control almost any DC-operated circuit. The DC signal at the output of U1-c varies from zero to over six volts, depending on the input-signal level. One unusual application for the Sound-Activated Decoder would be in extremely high-noise environments, where normal broadband microphone pickup would be useless. Because piezo transducers respond *only* to frequencies within a very narrow bandwidth, little if any of the noise would get through the transducer

Low-Frequency Crystal Filter. Another interesting job that the piezo transducer can perform is to function like a super low-frequency, quartz crystal in a narrow-band crystal-filter circuit. The circuit shown in Fig. 4 is the piezo equivalent of a super-selective crystal filter.

In a typical crystal-filter circuit, the crystal's internal capacitance is electronically canceled to keep unwanted and out-of-band signals from getting through and showing up at the filter's output. Internal capacitance normally runs in the low picofarad range for crystals and in the 20- to 30,000-pF range for the piezo transducers.

In a quartz circuit, a small trimmer capacitor is used to tweak out the capacitance effect, but to use the same approach for the piezo filter, you'd need to gang at least 100 broadcast-band tuning capacitors together to achieve the same effect.

With our piezo-transducer circuit, op-amp U1-a doubles the level of the input signal. That magnified signal is fed to one leg of BZ1, while at the same time being fed to the inverting input of U1-b. Op-amp U1-b, with a voltage gain of one, inverts the signal's waveform, which is next fed through capacitor C_x and then to the other side of the piezo element.

If the value of C_x equals the internal capacitance of the piezo element, the transducer's capacitance effect is canceled out. Several piezo transducers come with a list of their electrical characteristics, including their internal-capacitance figure. If the information isn't available, it can be determined with the aid of a capacitance decade-box or a capacitance meter.

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Either a two- or a three-wire piezo transducer works well with the circuit. If a three-wire transducer is used, connect the driven and common sections to the circuit (see Fig. 2 for pinout), using it as a two-wire device.

The filter's output is coupled to a voltage follower, U1-c, isolating the transducer from the output load. If the capacitance value of the transducer used in the circuit isn't known, substitute a capacitance decade-box in place of C_x and set it to about .015 microfarads to start.

Apply power to the circuit and a signal generator to the input; set the generator's frequency to about 1 kHz above the resonant frequency of the transducer, and its output level at about 500 millivolts. Connect a oscilloscope or an AC voltmeter to the filter's output. Adjust the oscilloscope's gain so that the filter's output signal covers about 70% of the vertical screen.

Adjust the capacitance decade-box for a minimum output signal. Remove the decade box and connect a capacitor of the same value in its place. Slowly sweep the audio generator to the transducer's resonance frequency and observe the output level and the bandwidth of the filter.

The gain of U1-a can be raised or lowered as needed to work with just about any level of input signal; the gain is calculated: gain = R8/R1. Don't change the unity gain of op-amp U1-b because its only function in the circuit is to invert the output of U1-a.

The output of U1-c can be fed to a dual-diode rectifier circuit (as was done in Fig. 3) to provide a DC output to drive a variety of circuits.

Encoder/Decoder. The transducer circuit shown in Fig. 5—consisting of a 567 phase-locked loop (PLL), a piezo transducer, LED, and a few support components—can be operated as either a tone encoder or decoder by changing the position of S1. The operating frequency of that dual-purpose circuit is determined by C3 and R2. Capacitors C1 and C2 are not critical and can be of almost any value between 1 and 5 microfarads. When the circuit is receiving an on-frequency signal, LED1 lights.

Although a two wire-piezo transducer, with a resonance frequency of 2500 Hz, was used in the circuit (see the Parts List) any piezo unit should work as long as the values of C3 and R2 are selected to tune to the transducer's operating frequency.

With power on and S1 in the "B" position, adjust R2 for the loudest tone output. The circuit should be tuned to the resonance frequency of the transducer. In that position, the circuit can be used as an acoustical or tone signal encoder. Next, switch to the "A" position and aim an on-frequency audible tone toward the transducer; the LED should light, indicating a decoded signal.

The LED can be replaced by an optocoupler or relay to control just about anything that's electrically operated. A single op-amp audio amplifier can be added between the transducer and U1 to detect weak audio tones. Use the U1-a amplifier circuit shown in Fig. 4, and select R1 and R8 to set the amp's gain as needed. ■

PARTS LIST FOR THE ENCODER/DECODER

U1—567 phase-locked loop (PLL), integrated circuit
LED1—light-emitting diode (any color)
R1—1000-ohm, ¼-watt, 5% resistor
R2—25,000-ohm potentiometer
C1, C2—4.7-µF, 16-WVDC electrolytic capacitor
C3—0.02-µF ceramic-disc capacitor
BZ1—Piezo transducer, Radio Shack 273-073 or similar
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

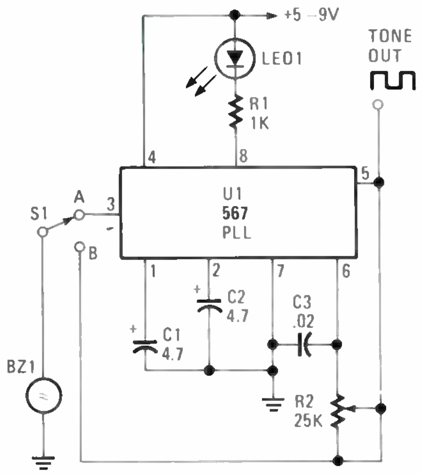

Fig. 5. This transducer circuit—consisting of a 567 phase-locked loop (PLL), a piezo transducer, LED, and assorted components—can be operated as a tone encoder or decoder, depending the position of S1.