

Circle 521

# Special Amplifier Conditions Piezo-Film Signal

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Piezoelectric films are capable of electromechanical, mechano-electrical, and pyro-electrical conversions, which correspond to the functions of loudspeakers, microphones, and temperature sensors. In the circuit, the piezo-film element performs pyro-electrical and mechano-electrical conversions, acting primarily as a temperature sensor and only incidentally as a microphone (*Fig. 1*).

Because the electrical analog of a piezo-film sensor is a capacitor in series with a voltage source, the sensor exhibits high output impedance and requires a high-impedance buffer amplifier. The circuit shown includes a differential charge amplifier followed by a differential-to-single-ended amplifier. The differential topology reduces line-noise pickup, which is a problem in high-gain circuits.

A dual op amp (IC1) endows the differential charge amplifier with single-

supply operation and low supply current. R1, R2, and a small bypass capacitor (C3) set the input common-mode voltage at the mid-supply level. Thermal noise generated by these resistors isn't amplified by the differential amplifier. Instead, the noise appears as a common-mode signal at the differential outputs and is attenuated by common-mode rejection in the following stage. Because thermal noise is proportional to resistance, this topology—by not amplifying biasing noise—offers the advantage of lower supply current for a given noise target.

The differential stage's ac gain is set by the C1 and C2 values relative to the sensor capacitance ( $C_{EQ}$ ). In this case,  $C_{EQ}$  measures 484 pF at 1 kHz, with an equivalent series resistance (ESR) of 5 k. The sensor can be modeled as a differential voltage source in series with two capacitors of value  $2C_{EQ}$ . R3 and R4 have little effect at high frequencies because feedback is dominated by the reactance

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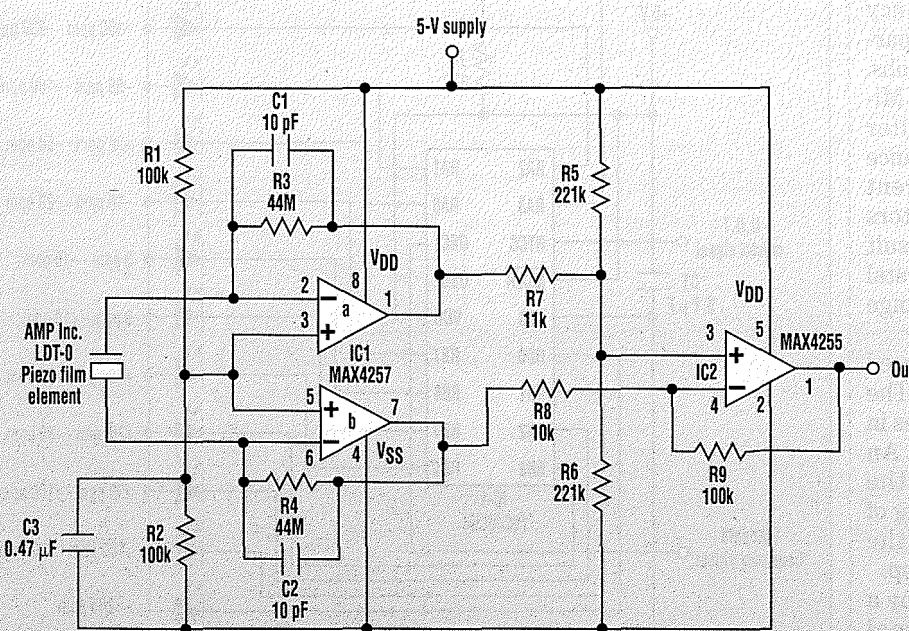
of C1 and C2. As a result, each half of the circuit has a gain of  $C_1/C_{EQ} = 96$ .

The differential amplifier also acts as a first-order high-pass filter. To simplify analysis, let  $C_1 = C_2 = C$  and  $R_3 = R_4 = R$ . Then, an inspection of either half of the amplifier shows a pole at  $1/2\pi RC$  and a gain of  $C_{EQ}/C$  at infinite frequency. Because ac gain is proportional to  $C_{EQ}/C$ , a high ac gain implies a small C. In this case  $C = 10 \text{ pF}$  and  $R = 44 \text{ M}$ , which leads to a corner frequency of 360 Hz. R must be very large for good low-frequency response. Lowering the corner frequency means increasing the value of R, but the op amp's input leakage flowing in a large feedback resistor can produce a large offset voltage. To counter this effect, the dual op amp shown is a CMOS device chosen for its small input leakage, which is only 1 pA.

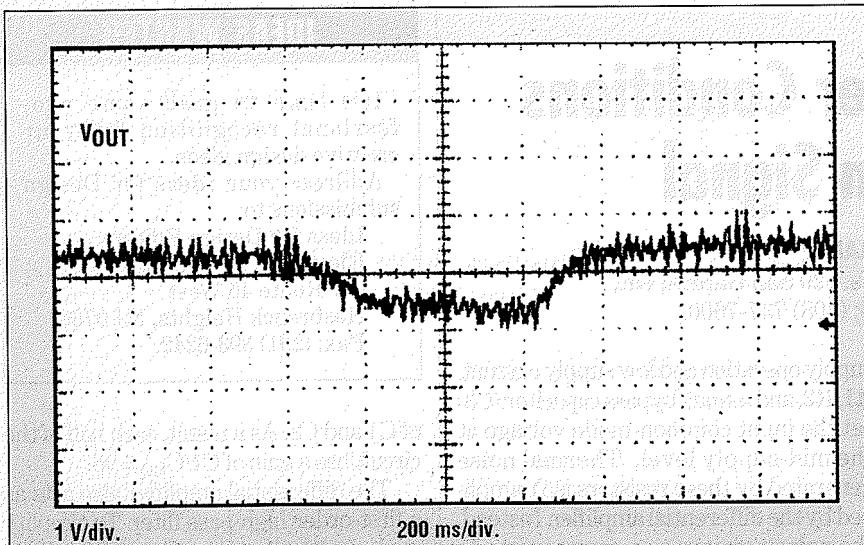
Differential-to-single-ended conversion is performed by IC2 and the resistors R5, R6, R8, and R9. The values shown give a differential gain of 20.

Line-noise rejection depends on the match between C1 and C2, but tight-tolerance capacitors are expensive (in general, this is a disadvantage of differential charge amplifiers). If you can't obtain a perfect match, however, the circuit's first-order rejection is still better than that of a single-ended amplifier.

Incorporating gain in a differential-to-single-ended converter degrades the common-mode rejection. To avoid this problem, the differential-to-single-ended circuit can be replaced with a unity-gain differential-to-single-ended converter and an additional single-ended gain stage.



1. This differential amplifier is designed to extract the piezo-film sensor's pyro-electrical signal.



**2.** A soldering iron passing about six inches from the sensor in Figure 1 caused this dip in the circuit's output signal, demonstrating the pyro-electrical sensitivity of this circuit.

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A scope display demonstrates the pyro-electrical (heat sensing) capability of this circuit (Fig. 2). The dip in the trace was caused by a heated soldering iron that moved quickly past the sensor at a distance of about six inches. The sensor's acoustic pickup produced the smaller signals riding on this trace. These can be cancelled by adding a replica circuit that responds to the same ambient acoustical noise, but not to the heat.

**Circle 522**

## Microcontroller-Based Circuit Measures Crystal Tolerance

YONGPING XIA

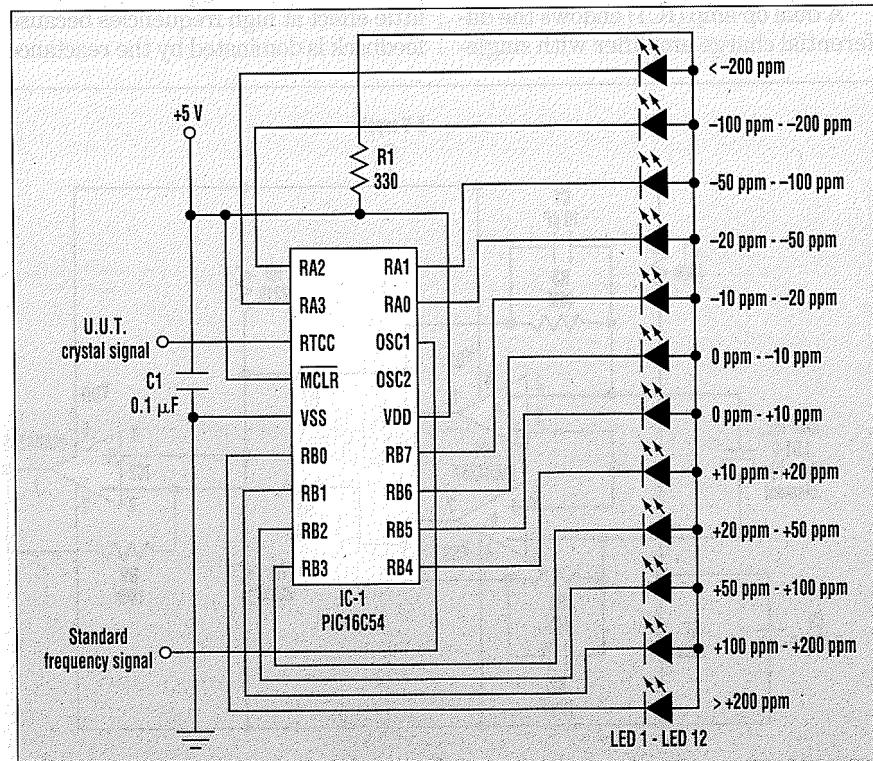
Teldata Inc., 8723A Bellanca Ave., Los Angeles, CA 90045.

Frequency tolerance is one of the most important parameters of a crystal. Determining the tolerance by measuring the crystal frequency directly isn't always convenient, particularly for large-volume sorting jobs. The circuit shown here employs Microchip's low-end microcontroller (PIC16C54) to measure the tolerance and sort the crystals into different ppm ranges using 12 LED indicators (see the figure). The measured result (in ppm) is independent to the crystal frequency. The useful frequency range falls between 1 MHz and 20 MHz.

A standard frequency signal is used to provide the PIC16C54's clock. The delay loop in the program executes in exactly 800,000 instruction cycles. An 8-bit counter (TMR0) in the PIC16C54 is reset at the beginning of this loop and the content of the counter is read at the end of the loop.

Because the counter is driven by a measured (UUT) crystal signal through a divide-by-8 prescaler, the counter's content will reflect the er-

ror between the standard signal and measured signal. For instance, the counter will count 400,000 if the measured signal has the same frequency as the standard signal. The decimal number 400,000 equals to 61A80H in hexadecimal. Since the counter contains only eight bits, the higher three digits (61A) will be omitted. Thus, the measured crystal has no frequency



This microcontroller measures the crystals' tolerance, and then sorts it into one of twelve ranges.