

Circle 521

Special Amplifier Conditions Piezo-Film Signal

GARY SELLANI

Maxim Integrated Products, 120 San Gabriel Dr.,
Sunnyvale, CA 94086; (408) 737-7600.

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 5k. 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

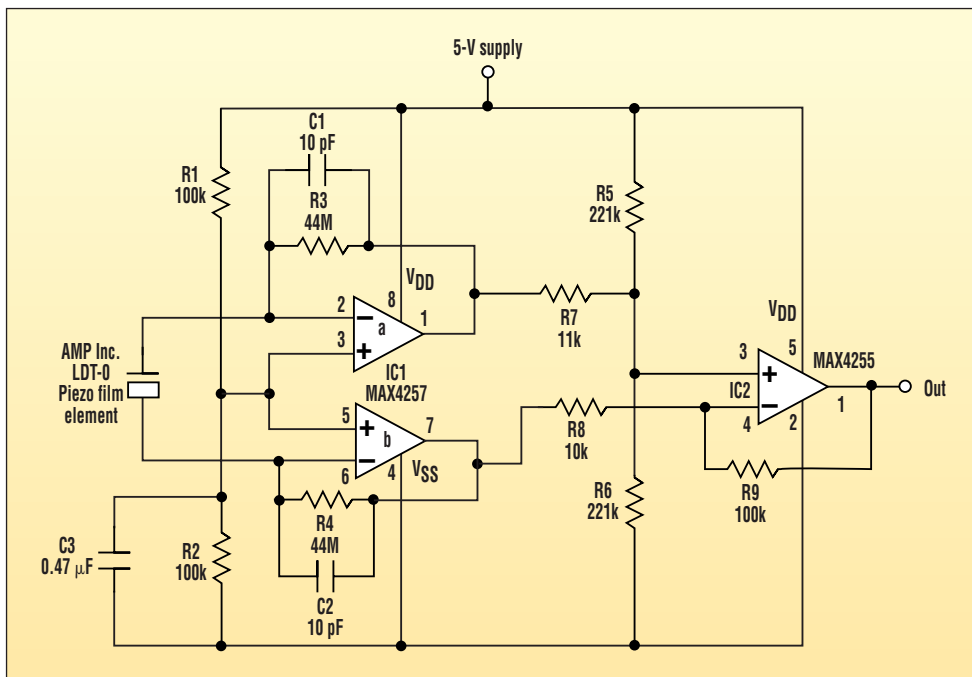
of C1 and C2. As a result, each half of the circuit has a gain of $C1/C_{EQ} = 96$.

The differential amplifier also acts as a first-order high-pass filter. To simplify analysis, let $C1 = C2 = C$ and $R3 = R4 = R$. 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 $C = 10$ pF and $R = 44M$, 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.

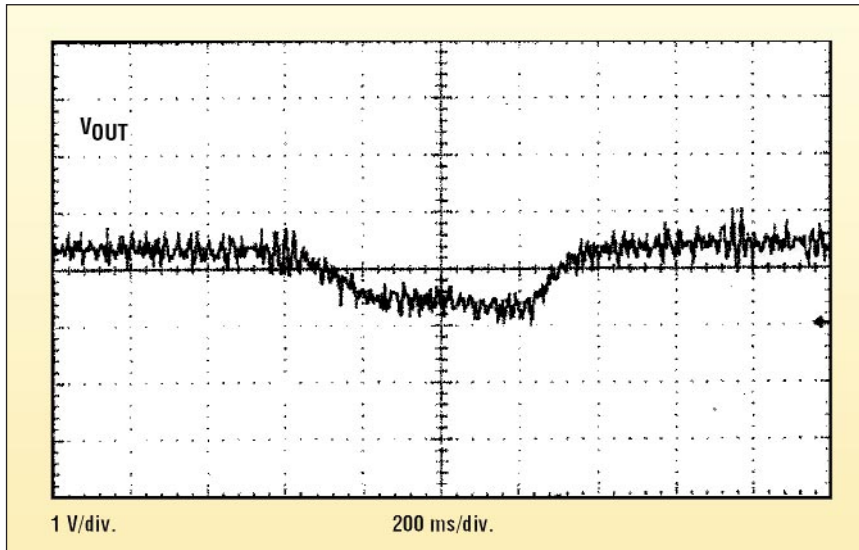
Differential-to-single-ended conversion is performed by IC2 and the resistors R5, R6, R8, and R9. The values shown give a differential gain of 20.

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.

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.