SHOCK ACCELEROMETERS

A new micro electromechanical system sensor has been introduced to capture the full pulse in high-impact environments

BY ROBERT SILL

Acceleration measurements in high-velocity impact and penetration environments require damped piezoresistive (PR) shock sensors to capture the complete pulse width and avoid extraneous out-band frequencies. Three high-g accelerometer signals can now be provided by a single surface-mount triaxial package embedded in the circuitry of a shock recorder. This configuration replaces the mounting of three discrete conventional single axis packages, routing and handling their individual cables, and attempting to get shockproof connections.

PR single crystal silicon (SCS) accelerometers with micro-electromechanical systems (MEMS) technology are used in many high-shock impact measurements. An undesirable characteristic of SCS is its extremely low internal damping, which results in susceptibility to overshoot and resonant excitation. Older MEMS devices for extreme shock applications were designed to maximize their resonant frequency. The intent was to avoid accelerometer over-range problems by fixing the resonance of the accelerometer above the frequency content of any mechanical excitation stimuli.

However, surprisingly low energy impacts were still found to cause resonance amplification and resultant failure. More energetic impacts easily exceeded the capabilities of this older design. As a by-product of these megahertz resonances, resultant sensor seismic element displacements were so small that effectively no internal damping was possible. Therefore bulky external mechanical isolators often had to be employed to protect the transducer and isolate it from high frequencies. Isolator design had to pay considerable attention to preserving enough bandwidth to track the residual rigid body motion and/or structural dynamics of interest for the device under test.

In PCB’s new damped approach, the resonant frequency is intentionally lowered to reduce the response of the accelerometer to higher frequency energy that may be present in shock events. The relatively low resonance enables displacements of the seismic element sufficient to introduce squeeze-film damping using air as the medium. Air is used since thermal effects on its performance are negligible. The design is manufactured using recent advances in semiconductor processing, and targets a mildly under-damped sensor with sufficient bandwidth to accurately measure test item rigid-body or structural response over the frequency range of interest. Accelerometer resonant amplification is reduced by orders of magnitude and accelerometer survivability is increased.

The advanced design of the new Series 3503C matches bandwidth to shock applications. Single DOF above resonance acts as a two-pole filter and squeeze-film damping reduces resonant amplification. Test FFTs of impact data were taken to show the benefits of damping. Figure 1 is the new PCB sensor and Figure 2 is the legacy sensor mounted in its mechanical isolator. The two agree for data below 20kHz. These FFT results show that the new sensor’s low resonance and squeeze-film damping effectively filtered higher frequency components, whereas the broadband noise and high-Q, 380kHz resonance of the 20kG legacy sensor comes through. Note the difference in how much the high-frequency energy is filtered.

Squeeze-film damping can eliminate the need for mechanical filtering when measuring penetration and pyrotechnic events. Resolution is improved over undamped sensors as the gain of conditioning and data acquisition systems can be scaled to the measurement range rather than the high Q of undamped sensors. Data acquisition can be simpler. The sample rates and filter requirements needed to avoid aliasing of the new sensor are much less severe than required with older sensor types. Compared to the older mechanical isolation techniques, increased miniaturization is possible by putting the new sensor on a circuit board with surface mount options. Another differentiator in the new sensor is the resistance of the bridge, which is approximately 5,000Ω.
High-g accelerometers

Overtravel stops are also installed to work with the damping to improve survivability in over-range conditions. Measurements have proven the dynamic and thermal performance, and exceptional transverse sensitivity confirmed the symmetry of the SCS inherent in the advanced techniques used in processing this new sensor.

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FIGURE 2: The broadband noise and high-Q, 380kHz resonance of the 20kG legacy sensor comes through despite mechanical isolation

— almost 10 times higher than the traditional design. For applications requiring battery power, this new sensor has high-resistance gauges with power dissipation that is an order of magnitude smaller. Since they are implanted into the heat sink of the flexures, these self-heating effects are further minimized, and the parameters of sensitivity and zero are a more linear function of excitation. Similarly, the warm-up thermal drift is small. Transverse sensitivity – the resistance to side impacts – is also of an advanced design. The inherent transverse sensitivity in older sensors results from structural asymmetries in the mass and flexures, or electrical asymmetries in the piezoresistive gauges. After a transverse input, the new sensor generates strains of such magnitude and polarity that the outputs of the gauges cancel in the bridge. The result is a reduction in transverse output from 5% of the input shock for legacy sensors down to less than 3%.

The new design is installed into a co-fired ceramic leadless chip carrier with hermetically sealed cover and solderable surface mount pads.

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