What You Need to Know About MEMS Accelerometers for Condition Monitoring

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Many highly integrated and easy to deploy condition monitoring products that employ a microelectromechanical system (MEMS) accelerometer as the core sensor are appearing on the market. These economical products help to reduce the overall cost of deployment and ownership and, in the process, expand the universe of facilities and equipment that can benefit from a condition monitoring program.

Solid-state MEMS accelerometers have many attractive attributes when compared to legacy mechanical sensors, but unfortunately their use for condition monitoring has been restricted to applications that can tolerate the use of lower bandwidth sensors for products such as low cost, standard-based smart sensors. In general, noise performance is not low enough to serve diagnostic applications that require lower noise over higher frequency ranges and bandwidths beyond 10 kHz. Low noise MEMS accelerometers are available today with noise density levels anywhere from 10 $\mu g/\sqrt{Hz}$ to 100 $\mu g/\sqrt{Hz}$, but are restricted to a few kHz of bandwidth. This hasn't stopped condition monitoring product designers from using a MEMS with noise performance that is just good enough in their new product concepts and for good reason. As a technology based on solid-state electronics and built-in semiconductor fabrication facilities, a MEMS offers several compelling and valuable advantages to the designer of condition monitoring products. Putting aside the performance factor, here are the main reasons why MEMS accelerometers should be of interest to anyone in the field of condition monitoring.

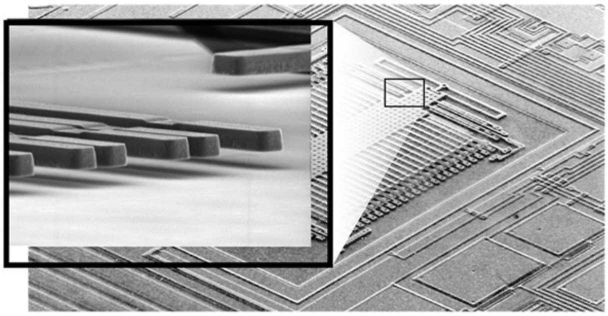

Figure 1. A scanning electron microscope (SEM) image of an inertial MEMS accelerometer. Polysilicon fingers are suspended in a depressurized cavity to enable movement and electrical capacitance proportional to acceleration is measured by adjacent signal conditioning electronics.

Let's start with the size and weight. For airborne applications, such as in health and usage monitoring systems (HUMS), weight is extremely expensive, with fuel costs of thousands of dollars per pound. With multiple sensors typically deployed on a platform, weight savings can be enjoyed if the weight of each sensor can be reduced. Today, a higher performance triaxial MEMS device in a surface-mount package with less than 6 mm × 6 mm in footprint can weigh less than a gram. This small size and the highly integrated nature of many MEMS products also enable the designer to shrink the size of the final package, reducing weight. The interface of a typical MEMS device is single supply making it easier to manage and more easily lending itself to a digital interface that can help save on the cost and weight of cables, too.

Solid-state electronics also can impact the size of the transducer. A smaller form factor triaxial mounted on a printed circuit board (PCB) and inserted into a hermetic housing suitable for mounting and cabling on a machine, can help enable a smaller overall package, offering more mounting and placement flexibility on the platform. In addition, today's MEMS devices can include significant amounts of integrated, single voltage supply signal conditioning electronics, providing analog or digital interfaces with very low power to help enable battery-powered wireless products. For example, the ADXL355, a high resolution, high stability triaxial accelerometer has an integrated Σ-Δ analog-to-digital converter (ADC), with an effective resolution of 18 bits and an output data rate of 4 kSPS, and consumes less than 65 μA per axis.

The topology of a MEMS signal conditioning circuit with both analog and digital output variations is common and opens up options for the transducer designer to adapt the sensor to a wider variety of situations, enabling a transition to digital interfaces commonly available in industrial settings. For example, RS-485 transceiver chips are widely available and open market protocols, such as Modbus RTU, are available to load into an adjacent microcontroller. A complete transmitter solution can be designed and laid out with small footprint surface-mount chips that can fit within relatively small PCB areas, which can then be inserted into packages that can support environmental robustness certifications requiring hermetic or intrinsically safe characteristics.

A MEMS has demonstrated to be very robust to changes in the environment, as well. The shock specifications of today's generation of devices are stated to 10,000 *g*, but in reality can tolerate much higher levels with no impact on sensitivity specifications. Sensitivity can be trimmed on automatic test equipment (ATE) and designed and constructed to be stable over time and temperature to 0.01°C for a high resolution sensor. Overall operation, including offset shift specifications, can be guaranteed for wide temperatures ranges, such as −40°C to +125°C. For a monolithic triaxial sensor with all channels on the same substrate, cross axis sensitivity of 1% is commonly specified. Finally, as a device designed to measure the gravity vector, a MEMS accelerometer has a dc response, maintaining the output noise density to near dc, limited only by the 1/f corner of the electronic signal conditioning and, with careful design, can be minimized to 0.01 Hz.

Perhaps one of the biggest advantages of MEMS-based sensors is the capability to scale up manufacturing. MEMS vendors have been shipping high volumes for mobiles, tablets, and automotive applications since 1990. This manufacturing capability residing in semiconductor fabrication facilities for both the MEMS sensor and the signal conditioning circuit chip is available to industrial and aviation applications as well, helping to lower the overall cost. Moreover, with more than a billion sensors shipped for automotive applications over the last 25 years, the reliability and quality of MEMS inertial sensors have been demonstrated to be very high. MEMS sensors have enabled complex crash safety systems that can detect crashes from any direction and appropriately activate seatbelt tensioners and airbags to protect occupants. Gyroscopes and high stability accelerometers are also key sensors in vehicle safety controls. Today's automotive systems make extensive use of MEMS inertial sensors to enable safer, better handling cars at low cost and excellent reliability.

Currently, there is tremendous interest and investment in MEMS technology for many applications. In addition to the many attractive qualities of a MEMS, MEMS inertial sensors also help alleviate many of the quality problems that plague other materials and architectures. MEMS inertial sensors have been utilized in demanding consumer, aviation, and automotive applications for more than 25 years and have been subjected to high shock and demanding environments. Has the time come for MEMS to further penetrate applications demanding higher performance, such as condition monitoring? It is fully expected that the performance of MEMS will continue to improve dramatically, providing more options for designers of condition monitoring equipment and enabling a new generation of smart sensors, wireless sensors, and low cost, vertically integrated systems. Stay tuned for more information on this subject in the near future.

About the Author

Ed Spence is the marketing manager for Analog Devices' Industrial Sensors Business Unit, responsible for high performance accelerometers. Analog Devices designs and manufactures high performance inertial sensors (accelerometers, gyroscopes), as well as highly integrated solutions, such as inertial measurement units (IMUs).
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