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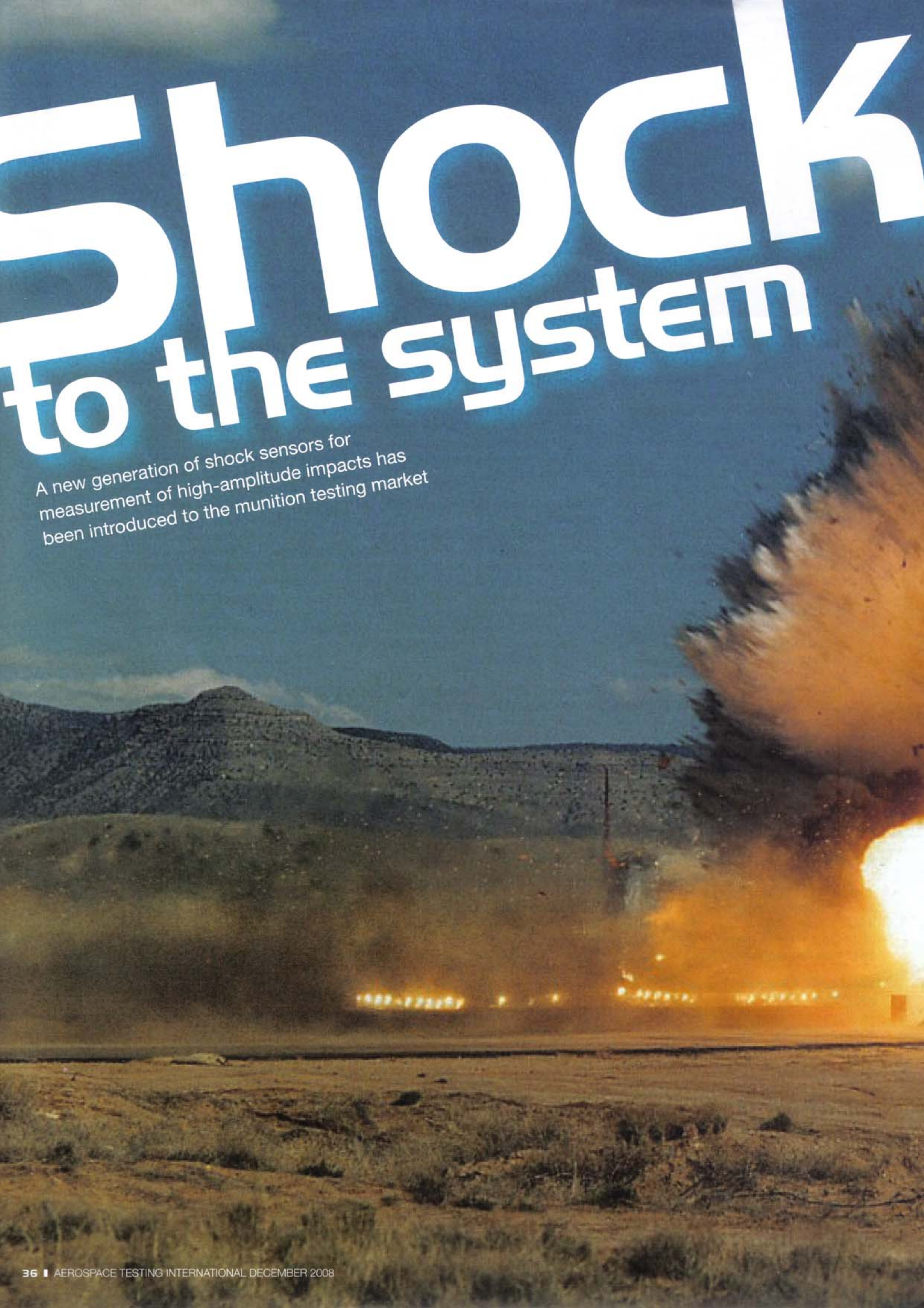
Shock to the system

A new generation of shock sensors for measurement of high-amplitude impacts has been introduced to the munition testing market



Bjorn Ryden

Measurement of high-amplitude shock impacts is a notoriously challenging and difficult task. Metal-to-metal impacts that are typically encountered during shock testing can impart high-frequency inputs that are totally detrimental to sensor measurements. Common practice has been to use undamped piezoresistive MEMS (micro electromechanical systems) sensors in order to resolve accurate measurements and mitigate zero shifts associated with other measurement technologies. These piezoresistive MEMS sensors have been the standard choice for shock measurements in a wide range of applications, including, but not limited to: fuzing in munitions; safe and arming in munitions, impact and shock testing; sled and crash testing; drop testing; and pyroshock testing.

In order to offer a cost-effective solution for these types of applications, Measurement Specialties Inc has introduced a new generation of shock sensors for measurement of high amplitude impacts. These sensors incorporate a new piezoresistive MEMS sensor element that stems from years of research and development at the company's wafer foundries. The MEMS sensors are manufactured using silicon-on-insulator (SOI) wafers that are processed with the latest photoresist lithography, piezoresistor implantation, deep reactive ion etching (DRIE) and chemical wet etching techniques. The development has resulted in an undamped piezoresistive MEMS shock sensor with a stable output for high-amplitude shock measurements.

The MEMS sensor design also focused on providing a stable long-term zero output with minimal power consumption. The piezoresistors, configured in a full-active Wheatstone bridge on the MEMS element, were optimized for more than 4,000 ohms impedance, a high k-factor, and low coefficient of resistance to provide minimal heating of the gauges, low current consumption, and stable temperature response. Nominal recommended excitation voltage for the sensors is 10Vdc for optimum response, but the sensors can also be powered with lower voltages if necessary, realizing that the sensitivity is ratiometric to excitation voltage.

To qualify the performance of the high-amplitude shock sensors, the designs were subjected to an extensive qualification program. The testing included high-amplitude shock linearity testing (best fit straight line), overload shock limit, frequency response and resonant frequency testing, transverse sensitivity testing, thermal zero and thermal sensitivity shift, and long-term zero drift stability.

Amplitude shock testing was conducted using a Hopkinson bar test set-up that incorporates strain gauges as the reference measurement at the end of the bar. The Hopkinson bar generates the shock pulse by firing an air pressurized projectile at the front of the bar, which propagates a shock pulse toward the unit under test at the front end of the bar.

The shock sensors were subjected to amplitude shock testing up to levels greater than 40,000g (392,266m/s^2) to characterize the response. The typical response of testing shows that the shock sensors hold more than 2% BFSL amplitude linearity, and validated that the shock sensors are qualified for use to ranges up to ±40,000g (392,266m/s^2).

At an input load of 31,000g (304,006m/s^2) at ~20kHz, generated by the Hopkinson bar, the shock sensor response is a clean signal with minimal zero acceleration offset typical of piezoresistive shock sensors. The FFT (fast Fourier transform) spectrum of the sensor response was also analyzed and confirmed the anticipated resonant frequency to be greater than 110kHz.

The sensors are offered in a variety of different packages to accommodate different test configurations. A miniature hermetically sealed LCC package is offered for embedded applications. This design is ideal for board mount applications where miniature size and footprint are required. The LCC package is 0.250in^2 (6.35mm^2) with a height of 0.070in (1.78mm). The sensor is sealed in an inert environment to mitigate any moisture ingress. The miniature size also enables packaging of this device in a triaxial configuration for measurement of shock loads in all three axes. The LCC package features an open Wheatstone bridge configuration that can be used to balance the zero output prior to the signal conditioning circuitry.

For bolt mount applications, a rugged stainless steel package in an industry standard footprint is offered with an integral cable. This package is ideal for test applications in which the sensor needs to be bolted to a structure to measure high-velocity impacts. This package also features a welded cover to protect the sensor from ambient environments and particle impacts. The cable features a braided shield with a Teflon jacket with four Number 36 AWG conductors. The zero output is trimmed internally to the sensor and offers a true plug-and-play sensor for the shock testing instrumentation engineer. Custom triaxial packages are also available where measurements in the three orthogonal axes are required. ∎

Bjorn Ryden is the product manager of vibration sensors with Measurement Specialties Inc in USA

TAKE THE PULSE

Pyroshock (also called pyrotechnic shock) testing is designed to simulate the high-frequency, high-magnitude shock pulse that a product may experience as the result of an explosive event, such as the separation of the booster rockets on the space shuttle or an explosive impact on a military tank structure.

Although pyroshock rarely damages structural members, it can easily cause failures in electronic components that are sensitive to the high-frequency pyroshock energy. The types of failures commonly include relay and crystal oscillator chatter, larger components becoming detached from the circuit board, hard failures of small circuit components, and dislodging of contaminants (i.e. solder balls), which cause short circuits, etc. Damage to critical components of equipment used in space or military applications can be severe in terms of overall function of the system, and the potential for loss of life due to the malfunction of the equipment.

Because of the absence of analytical techniques to predict structural response to a pyroshock, current satellite, aerospace and weapon manufacturers and suppliers must rely on testing for qualification of their systems and components that will be exposed to pyroshock environments.

Pyroshock differs from other types of mechanical shock in that there is very little rigid body motion of the product in response to the pyroshock. The pyroshock acceleration time-history measured on the structure is oscillatory and approximates a combination of decayed sinusoidal accelerations with very short duration in comparison to common mechanical shock.

The Hopkinson bar test set-up determines properties at high rates of strain