Specialized Sensors for Railroad Applications

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Governments have responded to global concerns about transportation safety with legislation that strives to ensure passengers arrive at their destinations unharmed. This has been the main driving force in the rail industry for the development of smart vehicles and systems. These designs typically rely on increasing numbers of imbedded sensors for feedback and control.

In the US, the legislation is often very specific and requires the use of accelerometers with high accuracies in rail applications. The following examples are from the Code of Federal Regulations that stem from the Federal Railroad Safety Act of 1970 (49 U.S.C. §§ 20101-20144; 21301-21304)

1. The vertical acceleration, as measured by a vertical accelerometer mounted on the car floor, shall be limited to no greater than 0.55 g single event, peak-to-peak.
2. The lateral acceleration, as measured by a lateral accelerometer mounted on the car floor, shall be limited to no greater than 0.3 g single event, peak-to-peak.
3. The combination of lateral acceleration L and vertical acceleration V within any period of two consecutive seconds as expressed by the square root of $V^2 + L^2$ shall be limited to no greater than 0.604 g, where L may not exceed 0.3 g and V may not exceed 0.55 g.

Meeting such codes is a challenge but achievable by applying the latest and appropriate technologies in sensor designs. The Vibration Sensors Business group of Measurement Specialties Inc. has specifically developed a series of accelerometer and inclinometer products for the transportation marketplace since its inception. Over the past three years, their California design group has introduced a wide range of products for general plug & play and custom applications. The group is now in the process of releasing a family of accelerometers and inclinometers for automatic train monitoring (ATM), track stability, wheel flats, track alignment, rail displacement, ride quality, lateral acceleration and impact detection.

The rapid acceptance of these new products has been derived from years of experience in designing products for the transportation industry. Technologies employed include, but are not restricted to:

- Silicon MEMS – Next generation silicon MEMS (Micro-Electro-Mechanical Systems) technology for superior accuracy and stability performance.
- Bonded Strain Gage – Tried and true sensing technology with the unique advantage of fluid damping.
- Piezoelectric Film or Ceramic – Piezoelectric designs offer unique capabilities for dynamic applications at low cost.
- Variable Resistance – Based on the conductive fluid principle for precise tilt measurement in harsh environments.

The bulk of rail-related sensors developed to date for ATM, track stability, and ride quality use proprietary silicon MEMS sensing elements by Measurement Specialties. This technology provides excellent output stability, wide usable bandwidth, and excellent temperature performance. One of the enabling functions, with this new generation of silicon MEMS design, is its built-in self test feature. This unique internal self-test function enables the seismic mass to be moved by an applied voltage. Unlike typical bridge type devices that support "shunt calibration" (which is only a form of electrical connectivity verification), this self-test capability allows the entire device to be tested dynamically. This includes the mechanical structure of the sensor and the signal conditioning electronics. By applying a voltage to the self-test input pin, the sensor output exhibits a voltage change which is proportional to the full scale output. This makes it possible to verify, not only proper function of the device but also to detect a parametric error, giving a better indication of a partial or a developing failure. The output voltage of the accelerometer is the sum of the output signals caused by the acceleration of the sensor and by the electrostatic self-test force. Therefore, the accelerometer is still fully functional when the self-test function is activated. This capability has proven to be indispensable in applications where the location of the sensor does not allow easy access for periodic calibration.

The extreme temperature condition in most transportation environments poses a serious technical challenge for any accelerometer and inclinometer. For a sensor to perform with high precision in the freezing cold of the Baltic or under the baking sun in Arizona, it is necessary to include some form of active temperature compensation internal to the sensor. Active error correction is commonly found in most static measurement devices, but difficult to implement with dynamic sensors where the frequency response is typically much broader. Measurement Specialties has applied semi-custom ASIC solutions to several amplified product lines for the transportation industry.

The ASIC circuitry conditions the output of the sensor element and corrects the sensitivity and offset changes that occur over temperature. As a result, the output signal is compensated in real time and no trimming is required by the user. The data used to set the performance of the accelerometer over its entire operating range is stored within the ASIC at the factory. These coefficients can be re-programmed in subsequent calibrations over the life of the sensor. Another added benefit of a compensated accelerometer is its interchangeability when sensor replacements are eventually required.

A unique group of rail-specific accelerometers developed for wheel flats, rail displacement, and impact detection employ bonded strain gage sensing elements from Measurement Specialties. This technology provides a distinct measurement advantage – controlled internal damping. Damping (overdamping in particular) is a very desirable characteristic that permits the measurement of low level, low frequency information in the presence of high g shock. If an undamped accelerometer is used to measure wheel motion in a train bogie, for example, high frequency shock bursts caused by wheel flat defects can sometime mask the desired low level, low frequency information. When an undamped accelerometer is excited into resonance by shock bursts and goes into an overloaded state, no amount of subsequent low pass filtering in the signal conditioner can 'recover' the desired data. But, when a critically damped or overdamped accelerometer is used, the natural roll-off characteristic of the sensor can mechanically filter the unwanted bursts and allows the low level, low frequency information to be measured accurately.

Using the right technology in purposefully designed configuration, today's accelerometers and inclinometers play a significant role in keeping our modern trains and transport vehicles on the right track.

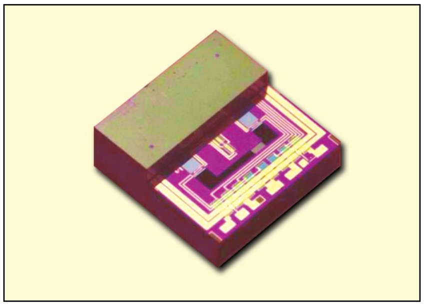

Figure 1. Silicon MEMS die.

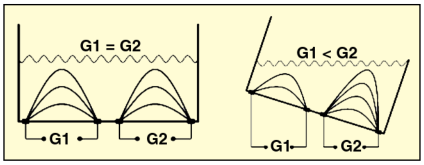

Figure 3. D-Series inclinometer based on water-glass princple

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