Piezoelectric Accelerometer Specifications and Specmanship

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The selection of accelerometers is based on published specifications. Some items in the specifications may, however, be irrelevant to the application or may be subject to misinterpretation, since test procedures and presentation of test results are not sufficiently standardized. Some items in the specifications are not inclusive. A specification may not be met for the entire range of another item in the specification such as temperature, for example. Certain important specifications are never listed and some manufacturers do not meet their own published specifications. The buyer, commercial or military, is not usually equipped or capable of performing tests to verify the specifications and may base his choice, aside from price and delivery, on the published data of the manufacturer of the accelerometers.

These shortcomings result in unsuitable selections and often lead to unfair competition through "specmanship" by the vendor. *Caveat Emptor*!

Following is a discussion of the specifications that should be considered, including those which are incomplete or missing.

Sensitivity. The sensitivity is stated with a window of ±5, 10 or 20%. For industrial applications, such as machinery health monitoring using trending techniques, a sensitivity window of 5 or even 10% is not deemed necessary and is more costly to achieve.

Acceleration Range. The stated acceleration range is given for frequencies in the operating frequency range using relatively short cables at room temperature. At higher temperatures the range may be lower. Modulated high frequency vibrations at frequencies above the operating range, however, often lead to severe intermodulation or washover distortion producing low frequency false signals. Such signals may set off false alarms, particularly if the signal is integrated to velocity.[1]

Accelerometers with very similar specifications may vary by more than a factor of ten in these distortion products. Therefore, an additional specification item is missing: the acceleration range should be listed when driving a certain capacitive load, 5 nF for example, representing about 100 ft of cable, at 15 kHz. Rather than using a modulated signal, a pure sinusoidal excitation can be used, since it is equivalent to modulation at zero frequency and requires less instrumentation to perform the test. The output bias voltage of the sensor, which is powered through a current limiting diode and carrying the AC and DC on the same wire, will suddenly shift when the sensor is overdriven. It is recommended that a shift of about 10 mV in the bias voltage should set the maximum acceleration for these conditions.

Frequency Response. For industrial accelerometers used for machinery health monitoring there is no need to have a flat response within 5 or 10%. Vibration levels of machinery change much more than 10% due to a malfunction. Moreover, measurements made with accelerometers of different weights will give different acceleration levels above about 5 kHz.[2] When using swept sine or pseudorandom excitation in the calibration, glitches in the response caused by secondary resonances in the housing or connector are often present. These glitches, unless large, should be of no concern for industrial applications. Some manufacturers of accelerometers spend a considerable amount of time and effort to eliminate these glitches. The magnitude of the glitches often varies with the type and attachment of the connector.

With respect to specmanship, the manufacturer of accelerometers may either ignore the glitches in their specification of frequency response, calibrate using swept band limited random noise or discrete frequency signals for the excitation to suppress these glitches, or base the specifications on a test of a design model and not a frequency response test of each unit.

Resonance Frequency. This item is relatively unimportant if the frequency range is stated. The internal amplifiers of the sensor are often compensated for the increase in sensitivity with frequency and, therefore, the response cannot be derived theoretically by the user from the resonance frequency unless the internal circuit is known. A sensor with a lower resonance frequency may have a wider frequency response than a sensor with higher resonance frequency. As a result, this specification may be misleading.

Transverse Sensitivity and Strain Sensitivity. The transverse sensitivity and strain sensitivity varies in a figure resembling an elliptic lemniscate pattern, or an open Figure 8, as a function of the rotation about the sensitive axis. For usual industrial applications, a high transverse sensitivity should be of no concern, a 100% rather than the usual 5% transverse sensitivity might be very desirable.

The strain sensitivity is important for low frequency applications, where the ratio of strain to acceleration is the greatest.[3] The strain sensitivity is also proportional to the acoustic sensitivity. Usually a value of 0.01 g per microstrain is sufficient except for very low frequencies and unusual applications; however, the allowable value may have to be increased for sensors having a low profile. The strain sensitivity is very dependent on mounting torque.

With respect to specmanship, the manufacturer of accelerometers may list the maximum value, the average value, a random value or a value obtained on the design prototype. Different results by a factor greater than fifty have been obtained between manufacturer specifications for strain sensitivity and the results obtained by an independent activity.

Noise (Sometimes Called Resolution). Broadband noise specifications are only necessary when using broadband data acquisition instruments such as a voltmeter or when considering saturation of the first stages of the data acquisitions system. Whenever the signal is filtered as with all FFT analyzers or data collectors, the noise at different frequencies must be specified as is listed, for example, for acoustic sensors, amplifiers, transistors and many other components and sensors. It is reported as the spectrum level or power spectral density, both given in a 1 Hz bandwidth. One cannot derive the spectrum level of the noise from the broadband noise, yet one can derive the broadband noise from the spectrum level of the noise measured over the frequency range. With respect to specsmanship, a sensor with a much higher broadband noise may have a much lower noise at low frequencies, where acceleration levels are low and the noise level is, therefore, important and specifications listing noise or resolution over a large frequency band are of little use and are misleading. Low noise at high frequencies is important for accelerometers used for leak detection and some military and security applications.

Magnetic Sensitivity. This sensitivity, although usually of little concern unless the magnetic field is extremely great, depends on the orientation of the sensor in the magnetic field. The orientation is never listed.

Output Impedance. The output impedance may vary with frequency. The value should be lower than about one third of the impedance of the cable at the maximum frequency of interest in order to have negligible effect on the frequency response.

Hermeticity. Hermeticity, not to be confused with sealing against liquid intrusion or watertightness, is related to long term reliability in hostile industrial environments. Some manufacturers claim sealing by design, others immerse the sensor in water and observe rising bub-bles which is adequate for observing leaks of more than 10^{-4} cc/sec – a value deemed insufficient for claims of her-meticity. Other manufacturers test each unit to 10^{-8} cc/sec – a much more rigorous requirement than the bubble test.

Settling Time. This is the time for the output bias voltage to reach a certain percentage of its final value. The percentage is often not specified.

Missing Specifications. Missing specifications other than those discussed previously:

1. Susceptibility to **Radio Frequency Interference**,[4] now required by the European Community, is not listed in the specifications
2. The calibration of a triaxial accelerometer has no specified test or reporting method. The manufacturer may calibrate the unit mounted to a mounting block and reference the acceleration of the sensor in the triax to a small accelerometer mounted on the block, or reference the response to a sensor mounted on the triax which will provide a flat frequency response to higher frequencies. Totally different frequency responses will be obtained by the two methods. Manufacturers do not all play by the same rules.

1. Schloss, Fred, "Accelerometer Overload," *Sound and Vibration*, Jan. 1989.
2. Schloss, Fred, "Inherent Limitations of Accelerometers for High-Frequency Vibration Measurements," *The Journal of the Acoustical Society of America*, Volume 33, Number 4, Apr. 1961.
3. Owen, Greg and Schloss, Fred, "Limitations in the Use of Piezoelectric Accelerometers for Very Low Frequency Measurements," *Sound and Vibration*, Sept. 1994.
4. Schloss, Fred, "Radio Frequency Interference on Internally-Amplified Accelerometer Signals," *Sound and Vibration*, Feb. 1997.