Decoding an Accelerometer Specification Sheet…
What Sensor Manufacturer’s Don’t Tell You!

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Overview

• Specification Sheet
  – Provides a set of performance characteristics for a particular model of accelerometer
Overview

• How do manufacturers know what to specify?
    • This document provides a list of “basic” performance specifications which are “normally included” as well as lists “supplemental” performance specifications, “which may be specified if desired.
  – Use best judgment based to include “important” specifications based on sensor application
  – Comparison to competitor’s specifications
Overview

• Specification Sheet Reality
  – Unfortunately for the test engineer, specification sheets are often generated to be a sales & marketing tool rather than a technical document
    • Goal – Make the sensor look as attractive as possible
  – The ability to make any sensor look good on paper is commonly known in the industry as “specmanship”!
Overview

• Why can specification sheets be confusing
  – Certain specifications may be omitted
    • Spec was left off because engineer or product manager felt it was not important for intended application
    • Controlling cost by not completely testing the sensor
    • Somebody is trying to hide something
  – Sensor performance may be described at “typical” (without an indicated tolerance)
  – Approved standards or industry-wide accepted methods do NOT exist for measuring all sensor characteristics
Decoding a Specification Sheet

• Omission of Specifications
  – A comparison of specification sheets of a similar accelerometer from 5 different sensor manufacturers indicated...

5 of 5 Mfg’s Listed:
Reference Sensitivity
Acceleration Range
Frequency Resp. / Res. Freq.
Broadband Resolution
Transverse Sensitivity
Shock Limit
Operating Temp Range
Temperature Response
Supply Voltage/Current
Output Impedance
Output Bias Voltage
Housing Material & Connector
Sealing
Dimensions / Weight / Mounting

4 of 5 Mfg’s Listed:
Amplitude Linearity

3 of 5 Mfg’s Listed:
Discharge Time Constant
Warm-Up Time
Sensing Element Material
Sensing Element Style
Vibration Limit
Base Strain Sensitivity

2 of 5 Mfg’s Listed:
FS Output Voltage
Grounding
Output Polarity
Thermal Transient Sensitivity

1 of 5 Mfg’s Listed:
Spectral Noise
Magnetic Sensitivity

0 of 5 Mfg’s Listed:
Amplification Factor
Acoustic Sensitivity
Storage Temperature Range
Mounting Error
Sensitivity Stability
Damping
Mounting Surface Preparation
Supply Current Sensitivity
Decoding a Specification Sheet

• “Typical” Specifications
  – When no tolerance is specified, there is “no guarantee” for exact sensor performance related to that particular specification
  – At PCB…
    • “Typical” can be considered synonymous with “average”
    • Specification value defined during qualification testing of prototype and pilot run production builds
      – 30 piece minimum for stock and standard sensors
    • Currently used only for temperature response (also known as thermal sensitivity), noise and weight specifications
  – Review of various manufacturer’s (including “old” PCB) spec sheets may use “typical” to describe sensitivity, frequency response, capacitance, resonance, bias voltage, strain sensitivity, magnetic sensitivity, time constant & output impedance
Decoding a Specification Sheet

• “Typical” Specifications
  – Practical Implication
    • Every sensor passes a “typical” specification
    • Assuming an average value is used, there is still no statistical characterization (e.g. standard deviation) of the specification
    • Depending on sensor design and manufacturing process control, actual performance could vary “greatly” from sensor to sensor

<table>
<thead>
<tr>
<th>Specification</th>
<th>Typical Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Weight</td>
<td>Tenths of a percent</td>
</tr>
<tr>
<td>Temperature Response</td>
<td>A few percent</td>
</tr>
<tr>
<td>Noise Floor</td>
<td>100 percent</td>
</tr>
</tbody>
</table>
Decoding a Specification Sheet

• Specifications Defined in Multiple Ways
  – Threshold
    • The smallest change in acceleration that will result in a measureable change in sensor output. (ISA RP37.1)
    • Often used interchangeably with Residual Noise, Broadband Resolution and Noise Floor
    • Measured in many different ways and may lead to confusion when using or comparing accelerometers
      – broadband - g rms, g pk, g pk-pk
      – frequency limited broadband (1 Hz to 10 kHz) - g rms
      – spectral noise floor - g/√Hz
Decoding a Specification Sheet

- Specifications Defined in Multiple Ways
  - Threshold – Test Set-up
Decoding a Specification Sheet

- Specifications Defined in Multiple Ways
  - Broadband Resolution
    - Early methods simply measured the signal directly on a scope without the use of frequency limiting filters
Decoding a Specification Sheet

- Specifications Defined in Multiple Ways
  - Spectral Noise
  - Today’s procedure uses an FFT Analyzer

![Graph showing noise levels in dB and μV/√Hz across different frequencies.]

1 V/g ICP® Accelerometer

-100 dB/√Hz
-180 dB/√Hz
-111 dB/√Hz, 2.8μV/√Hz=2.8μg/√Hz
-131 dB/√Hz, .28μV/√Hz=.28μg/√Hz
-143 dB/√Hz, .07μV/√Hz=.07μg/√Hz
-149 dB/√Hz, .04μV/√Hz=.04μg/√Hz
-152 dB/√Hz, .02μV/√Hz=.02μg/√Hz
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- **Specifications Defined in Multiple Ways**
  - Broadband Noise
    - Integrate spectral noise floor to obtain broadband (but frequency limited) noise floor

7.1 \( \mu V \) = 7.1 \( \mu g \) for a 1 V/g sensor (1 Hz to 10 kHz)
5.7 \( \mu V \) = 5.7 \( \mu g \) for a 1 V/g sensor (5 Hz to 10 kHz)
Decoding a Specification Sheet

• Specifications Defined in Multiple Ways
  – Amplitude Linearity
    • Provides an indication that the sensitivity of the sensor does not vary with acceleration amplitude
Decoding a Specification Sheet

- Specifications Defined in Multiple Ways
  - Amplitude Linearity
    - Most often defined as zero-based, least squares straight line
    - Slope of line = Sensitivity
    - Usually specified as $\leq \pm 1\%$

\[ \text{Input (g)} \]
\[ \text{Output (mV)} \]

Linearity Spec Limits = 5000 * .01 = +/- 50 mV
Printed Linearity = 42 / 5000 * 100 = 0.84\%
Decoding a Specification Sheet

• Specifications Defined in Multiple Ways
  – Amplitude Linearity
    • However, sometimes specified as % FS / g where linearity depicts the maximum sensitivity change
    • For example, 1% per 10,000g, 0 g to 50,000 g means sensitivity can change by 5% over its measurement range

<table>
<thead>
<tr>
<th>Input (g)</th>
<th>Output (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000</td>
<td>5000</td>
</tr>
<tr>
<td>20000</td>
<td>4000</td>
</tr>
<tr>
<td>30000</td>
<td>3000</td>
</tr>
<tr>
<td>40000</td>
<td>2000</td>
</tr>
<tr>
<td>50000</td>
<td>1000</td>
</tr>
</tbody>
</table>

10,000 g sensitivity: 1000 mV/10,000 g = .1 mV/g
50,000 g sensitivity: 5210 mV/50,000 g = .1042 mV/g
Sensitivity Change (.104-.1)/.1*100 = 4.2%
Decoding a Specification Sheet

• Specifications Defined in Multiple Ways
  – ESD / RFI Protection
    • Often listed for industrial health monitoring applications
  – CE Mark
    • Manufacturer determines acceptable level of immunity
  – TEDS
    • Transducer electronic datasheet (V0.9, V1.0, LMS)
  – Low Pass Filtering
    • Does the sensor have a single pole (or higher order) low pass filter to reduce amplification at resonance?
    • Where is and what is the tolerance of the cut-off frequency?
  – Overload Recovery
    • Size & shape of overload pulse. When is sensor “recovered”? 
Decoding a Specification Sheet

- **Other Important Performance Notes**
  - **Transverse Sensitivity**
    - Sensitivity of the accelerometer to acceleration perpendicular to the sensitive access.
    - Simply expressed as % of Axial Sensitivity
      \[
      \% = \frac{\text{Transverse Sensitivity (mV/g)}}{\text{Axial Sensitivity (mV/g)}} \times 100
      \]
    - Test typically conducted at single freq <1000Hz
Decoding a Specification Sheet

- **Other Important Performance Notes**
  - **Transverse Sensitivity**
    - There are directions of maximum and minimum sensitivity
  - Resonance exists at ~40% of axial resonance

![Polar Plot of Transverse Sensitivity](image)

(Outer Ring = 3.0%. Each Ring = 0.5%)

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<table>
<thead>
<tr>
<th>Relative Amplitude</th>
<th>10 dB per Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50</td>
<td></td>
</tr>
<tr>
<td>+30</td>
<td></td>
</tr>
</tbody>
</table>

Axial Response

Transverse Response
Decoding a Specification Sheet

• Other Important Performance Notes
  – Sealing
    • All-Welded, Epoxy Sealed, Hermetic, Sealed by Silicone, and Vented
    • How is Hermetic defined?
      – $10^{-3}$ cc atm/sec – Normal Gross Leak / Bubble Test
      – $10^{-5}$ cc He/sec – Helium Gross Leak / Bubble Test
      – <$10^{-8}$ cc He/sec – Helium Leak Test
Decoding a Specification Sheet

• Other Important Performance Notes
  – Sealing
    • Why is it important?
      – Insulation resistance inside of sensor needs to be on the order of a Teraohm (1E12 ohms) for proper operation
      – Contamination and / or moisture (humidity) inside the sensor due to a poor seal can reduce resistance and cause performance issues such as short time constant, no turn on or a low bias sensor
        • Sensor may appear as fine with single point sensitivity check.
        • Best remedy includes opening sensor, cleaning, “bake out” and reseal (weld or epoxy)
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**Other Important Notes**

- Specifications are defined at room temperature and may be different at min. / max. operating temperature
  - Bias level, Discharge Time Constant, IR, Capacitance
- Only a small portion of specs are used as acceptance test on every accelerometer that is produced
  - Typically: Reference Sensitivity, Frequency Response, Bias, Transverse Sensitivity and Resonant Frequency
- At PCB, stock products are sent through an annual verification process to help insure all performance characteristics still pass the specification limits. This helps to validate process control in manufacturing.
Decoding a Specification Sheet

• Conclusion
  – Similar sensors from different manufacturers are often difficult to compare against one another
  – May need to contact manufacturer to request additional test data if an “important” specification has been omitted
  – Know and trust your vendor.

Caveat Emptor!