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

David Lally

VP Engineering

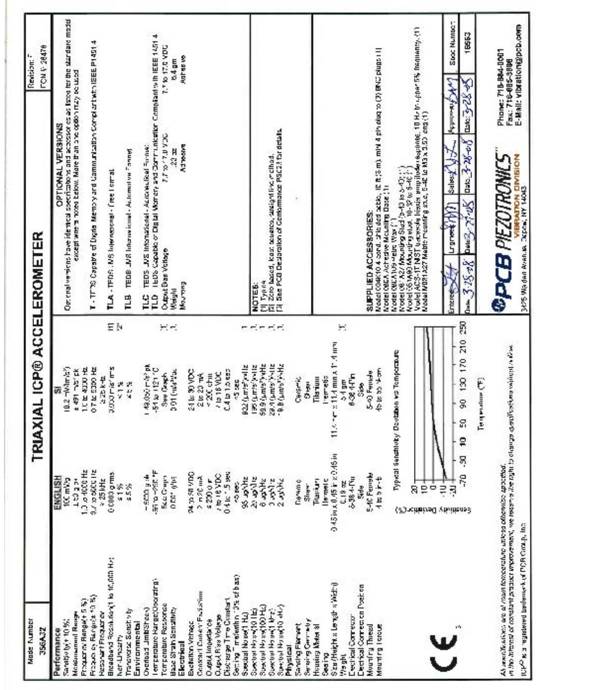
PCB Piezotronics, Inc.

IMAC-XXVII

February 2008

Overview

- **Specification Sheet**
  - **Provides a set of performance characteristics for a particular model of accelerometer**


TRIAXIAL ICP® ACCELEROMETER

Overview

- **How do manufacturers know what to specify?**
  - **ISA-RP37.2-1982 (1995) provides a "Guide for Specifications and Tests for Piezoelectric Acceleration Transducers for Aerospace Testing"**
    - **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**

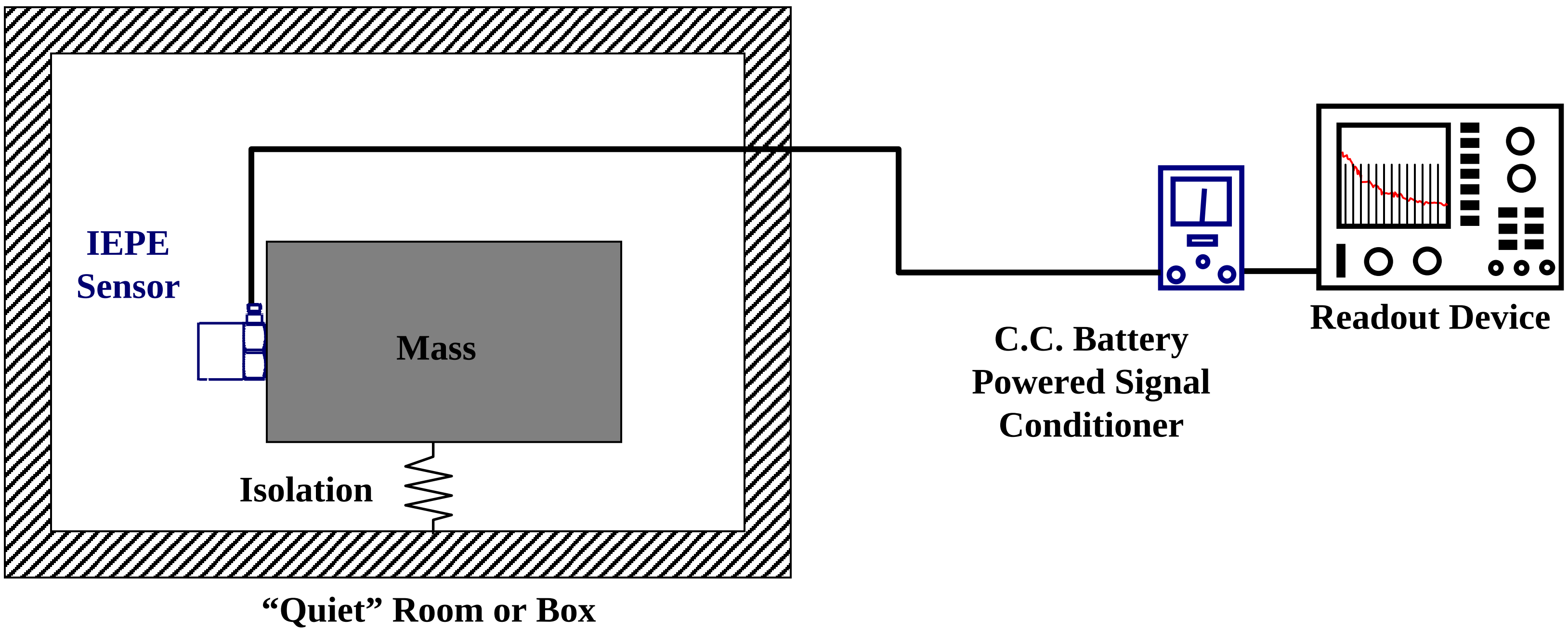
Specification	Typical Variation
Sensor Weight	Tenths of a percent
Temperature Response	A few percent
Noise Floor	100 percent

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**

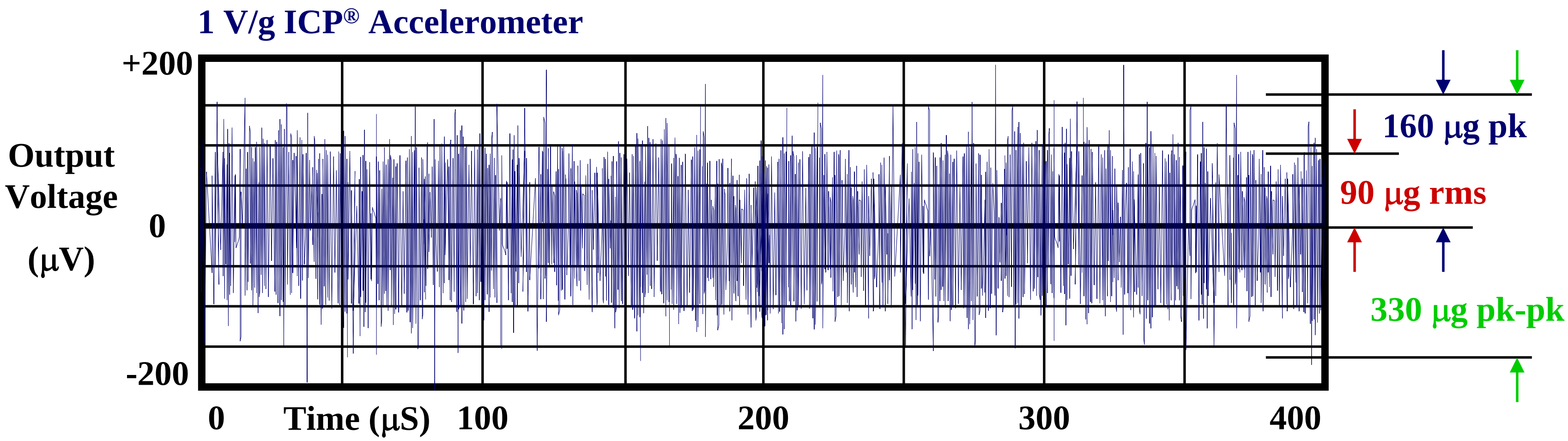
Decoding a Specification Sheet

- **Specifications Defined in Multiple Ways**
  - **Threshold – Test Set-up**



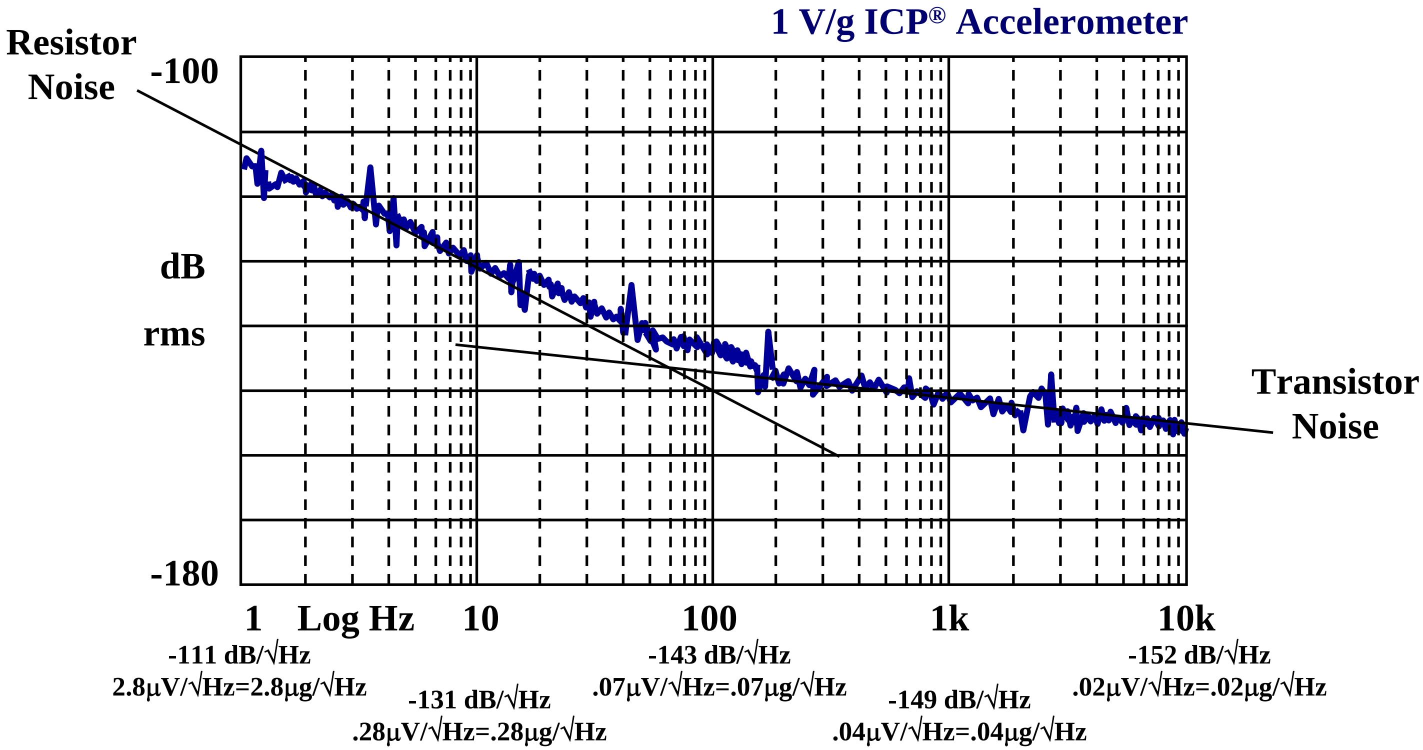
Decoding a Specification Sheet

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



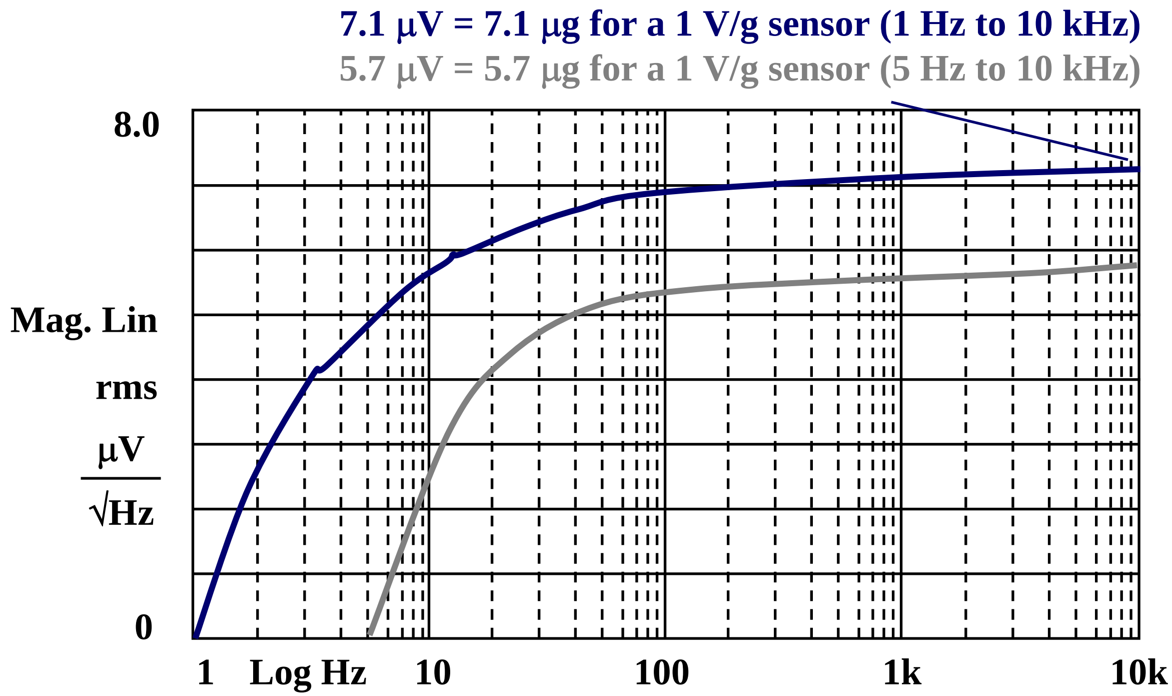
Decoding a Specification Sheet

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



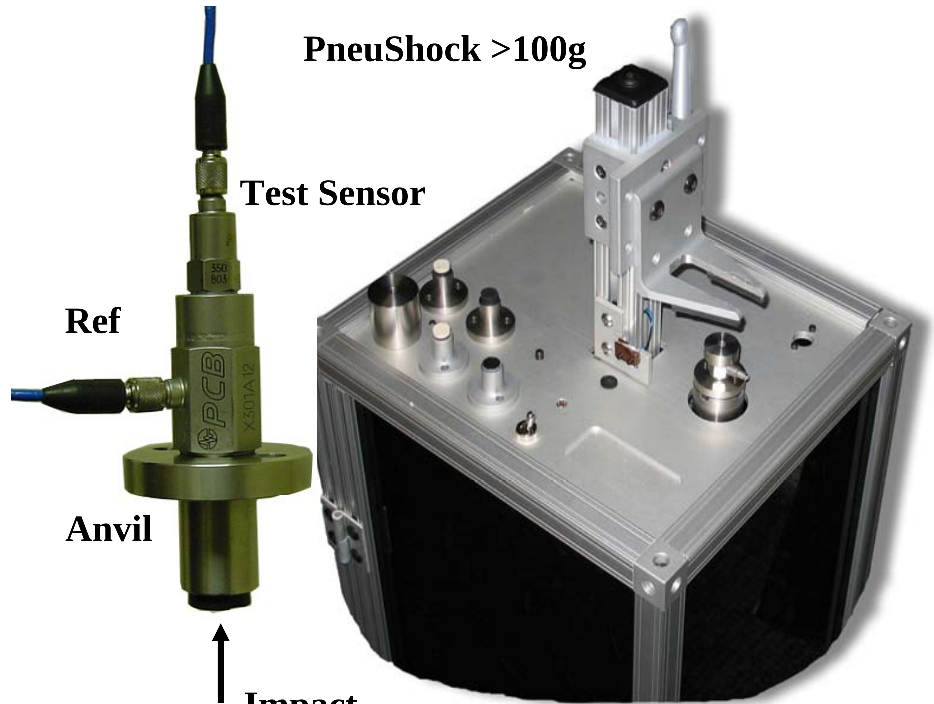
Decoding a Specification Sheet

- **Specifications Defined in Multiple Ways**
  - **Broadband Noise**
    - **Integrate spectral noise floor to obtain broadband (but frequency limited) noise floor**



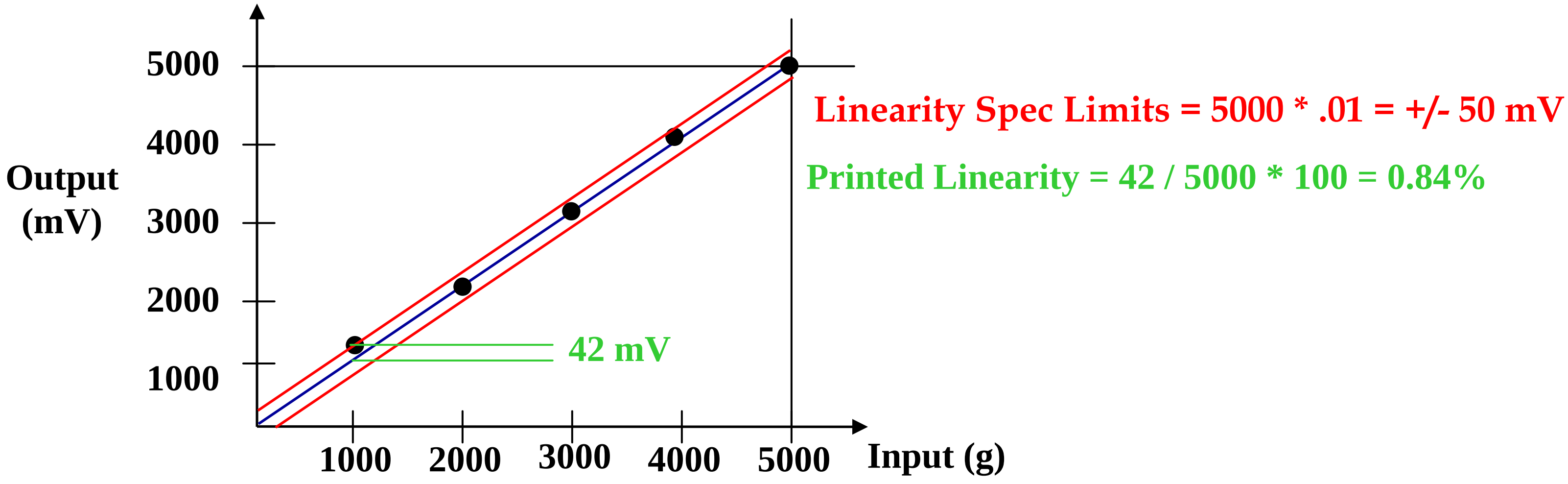
Decoding a Specification Sheet

- **Specifications Defined in Multiple Ways**
  - **Amplitude Linearity**
    - **Provides an indication that the sensitivity of the sensor does not vary with acceleration amplitude**



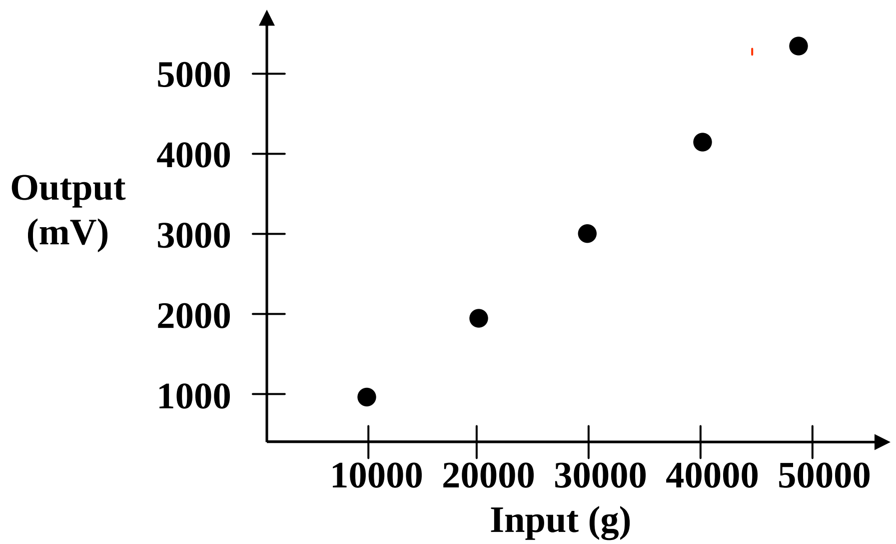
Decoding a Specification Sheet

- **Specifications Defined in Multiple Ways**
  - **Amplitude Linearity**
    - **Most often defined as zero-based, least squares straight line**
      - **Slop of line = Sensitivity**
      - **Usually specified as <±1%**



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**



10,000 g sensitivity:
1000 mV/ 10,000 g = .1 mV/g

50,000 g sensitivity:
5210 mV / 50,000 g = .1042 mV/g

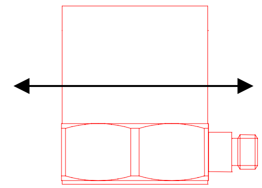
Sensitivitiy Change
(.104-.1)/.1*100 = 4.2%

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

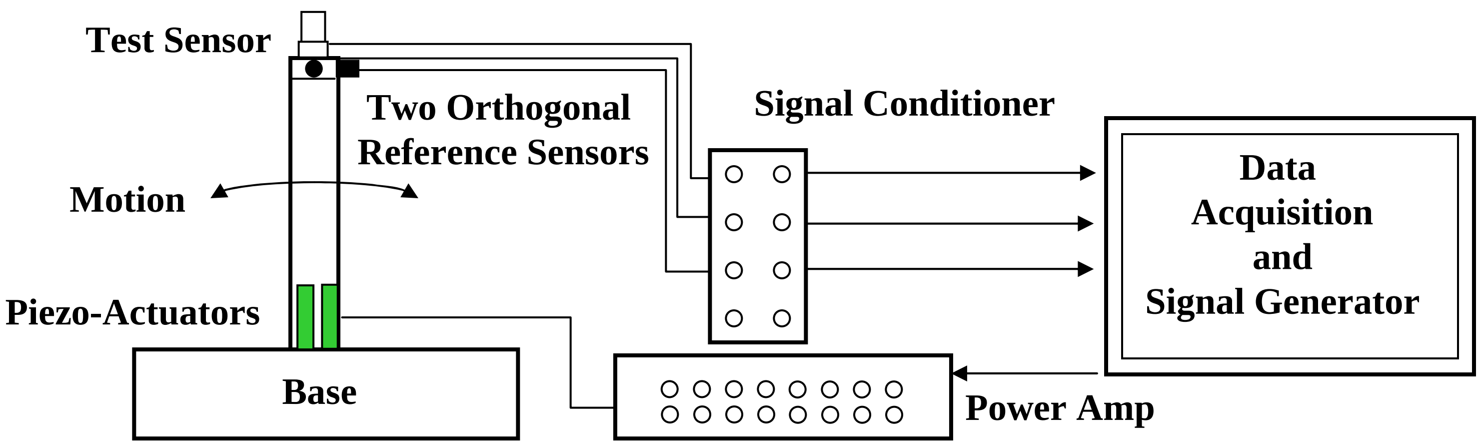
- **Other Important Performance Notes**
  - **Transverse Sensitivity**
    - **Sensitivity of the accelerometer to acceleration perpendicular to the sensitive access.**
    - **Simply expressed as % of Axial Sensitivity**



Off Axis Motion

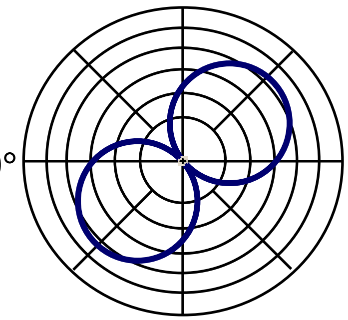
$$\% = \frac{\text{Transverse Sensitivity (mV/g)}}{\text{Axial Sensitivity (mV/g)}} \times 100$$

    - **Test typically conducted at single freq <1000Hz**

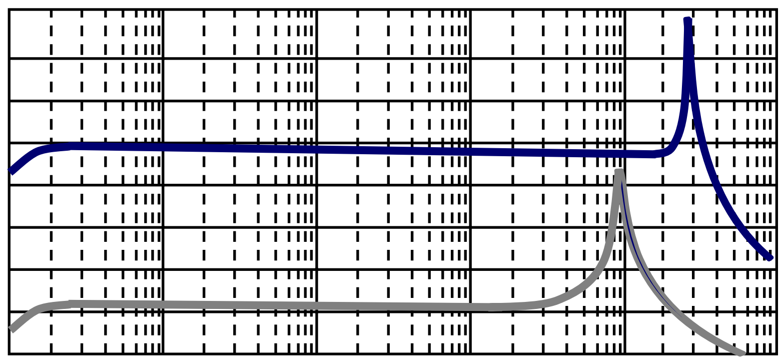


Decoding a Specification Sheet

- **Other Important Performance Notes**
  - **Transverse Sensitivity**
    - **There are directions of maximum and minimum sensitivity**



    - **Resonance exists at ~40% of axial resonance**



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)**

Decoding a Specification Sheet

- **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!