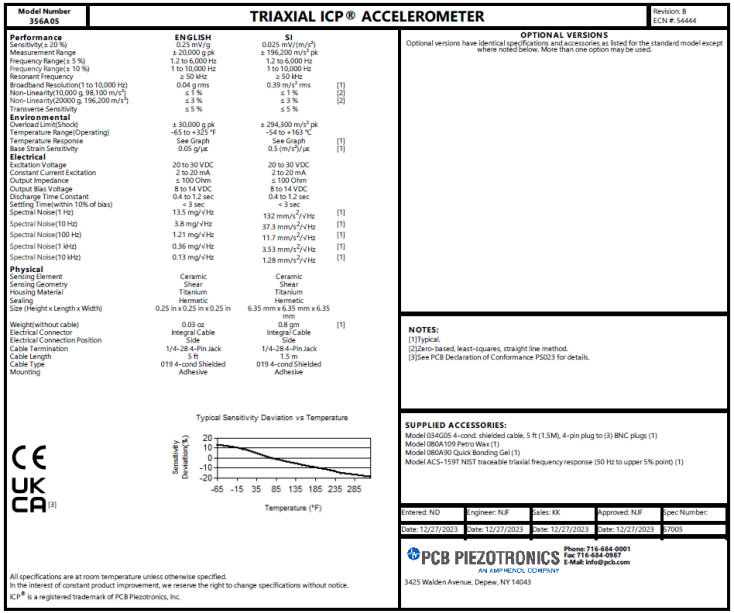
Decoding an Accelerometer Specification Sheet

What Sensor Manufacturer’s Don’t Tell You!

Adapted from IMAC XXVII Presentation by David Lally

Specification Sheet

- Performance characteristics for a particular model of accelerometer



Model Number 356A05

TRIAXIAL ICP® ACCELEROMETER

Revision: B
ECN #: 54444

Performance	ENGLISH	SI	
Sensitivity (± 20 %)	0.25 mV/g	0.025 mV/(m/s²)	
Measurement Range	± 20,000 g pk	± 196,200 m/s² pk	
Frequency Range (± 5 %)	1.2 to 6,000 Hz	1.2 to 6,000 Hz	
Frequency Range (± 10 %)	1 to 10,000 Hz	1 to 10,000 Hz	
Resonant Frequency	≥ 50 kHz	≥ 50 kHz	
Broadband Resolution (1 to 10,000 Hz)	0.04 g rms	0.39 m/s² rms	[1]
Non-Linearity (10,000 g, 98,100 m/s²)	≤ 1 %	≤ 1 %	[2]
Non-Linearity (20000 g, 196,200 m/s²)	≤ 3 %	≤ 3 %	[2]
Transverse Sensitivity	≤ 5 %	≤ 5 %	
Environmental			
Overload Limit (Shock)	± 30,000 g pk	± 294,300 m/s² pk	
Temperature Range (Operating)	-65 to +325 °F	-54 to +163 °C	
Temperature Response	See Graph	See Graph	[1]
Base Strain Sensitivity	0.05 g/με	0.5 (m/s²)/με	[1]
Electrical			
Excitation Voltage	20 to 30 VDC	20 to 30 VDC	
Constant Current Excitation	2 to 20 mA	2 to 20 mA	
Output Impedance	≤ 100 Ohm	≤ 100 Ohm	
Output Bias Voltage	8 to 14 VDC	8 to 14 VDC	
Discharge Time Constant	0.4 to 1.2 sec	0.4 to 1.2 sec	
Settling Time (within 10% of bias)	< 3 sec	< 3 sec	
Spectral Noise (1 Hz)	13.5 mg/√Hz	132 mm/s²/√Hz	[1]
Spectral Noise (10 Hz)	3.8 mg/√Hz	37.3 mm/s²/√Hz	[1]
Spectral Noise (100 Hz)	1.21 mg/√Hz	11.7 mm/s²/√Hz	[1]
Spectral Noise (1 kHz)	0.36 mg/√Hz	3.53 mm/s²/√Hz	[1]
Spectral Noise (10 kHz)	0.13 mg/√Hz	1.28 mm/s²/√Hz	[1]
Physical			
Sensing Element	Ceramic	Ceramic	
Sensing Geometry	Shear	Shear	
Housing Material	Titanium	Titanium	
Sealing	Hermetic	Hermetic	
Size (Height x Length x Width)	0.25 in x 0.25 in x 0.25 in	6.35 mm x 6.35 mm x 6.35 mm	
Weight (without cable)	0.03 oz	0.8 gm	[1]
Electrical Connector	Integral Cable	Integral Cable	
Electrical Connection Position	Side	Side	
Cable Termination	1/4-28 4-Pin Jack	1/4-28 4-Pin Jack	
Cable Length	5 ft	1.5 m	
Cable Type	019 4-cond Shielded	019 4-cond Shielded	
Mounting	Adhesive	Adhesive	

Typical Sensitivity Deviation vs Temperature

CE
UK CA [3]

All specifications are at room temperature unless otherwise specified.
In the interest of constant product improvement, we reserve the right to change specifications without notice.
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OPTIONAL VERSIONS
Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used.

NOTES:
[1] Typical.
[2] Zero-based, least-squares, straight line method.
[3] See PCB Declaration of Conformance PS023 for details.

SUPPLIED ACCESSORIES:
Model 034G05 4-cond. shielded cable, 5 ft (1.5M), 4-pin plug to (3) BNC plugs (1)
Model 080A109 Petro Wax (1)
Model 080A90 Quick Bonding Gel (1)
Model ACS-159T NIST traceable triaxial frequency response (50 Hz to upper 5% point) (1)

Entered: ND	Engineer: NJF	Sales: KK	Approved: NJF	Spec Number:
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PCB PIEZOTRONICS
AN AMPHENOL COMPANY
Phone: 716-684-0001
Fax: 716-684-0987
E-Mail: info@pcb.com
3425 Walden Avenue, Depew, NY 14043

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”
  - List of **basic** performance specifications which are **normally included** + **supplemental performance specifications**, which **may be specified if desired**
- Use best judgment to include “important” specifications based on sensor application
- Compare to competitor’s specifications

Specification Sheet Reality

- Unfortunately for the test engineer, specification sheets are sometimes generated to be a sales & marketing tool rather than a technical document
  - Goal – Make the sensor look as attractive as possible
- Commonly known in the industry as “specmanship”

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 spec sheets of a similar accelerometer from 5 different sensor manufacturers indicated

5 of 5 Manufacturers 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 Manufacturers Listed:
Amplitude Linearity

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

2 of 5 Manufacturers Listed:
FS Output Voltage
Grounding
Output Polarity
Thermal Transient Sensitivity

1 of 5 Manufacturers Listed:
Spectral Noise
Magnetic Sensitivity

0 of 5 Manufacturers 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

- For PCB Sensors, **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 spec sheets may use “typical” to describe sensitivity, frequency response, capacitance, resonance, bias voltage, strain sensitivity, magnetic sensitivity, time constant, & output impedance

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

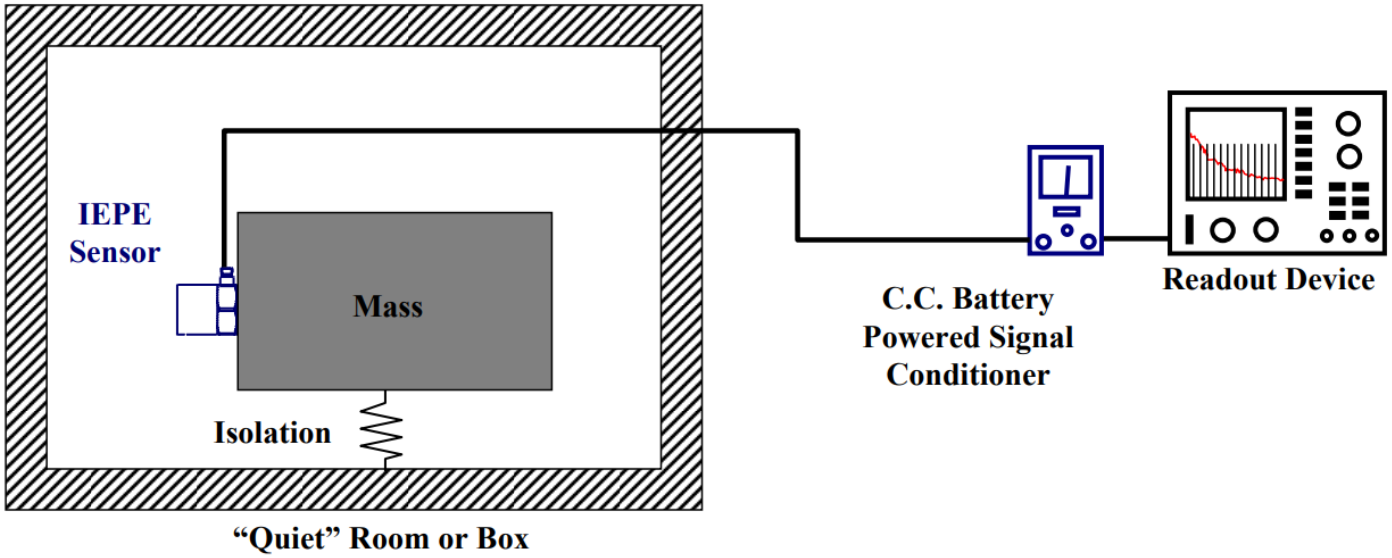
Specification	Typical Variation
Sensor Weight	Tenths of a percent
Temperature Response	A few percent
Noise Floor	100 percent

Specifications Defined in Multiple Ways

- **Threshold**: The smallest change in acceleration that will result in a measurable 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

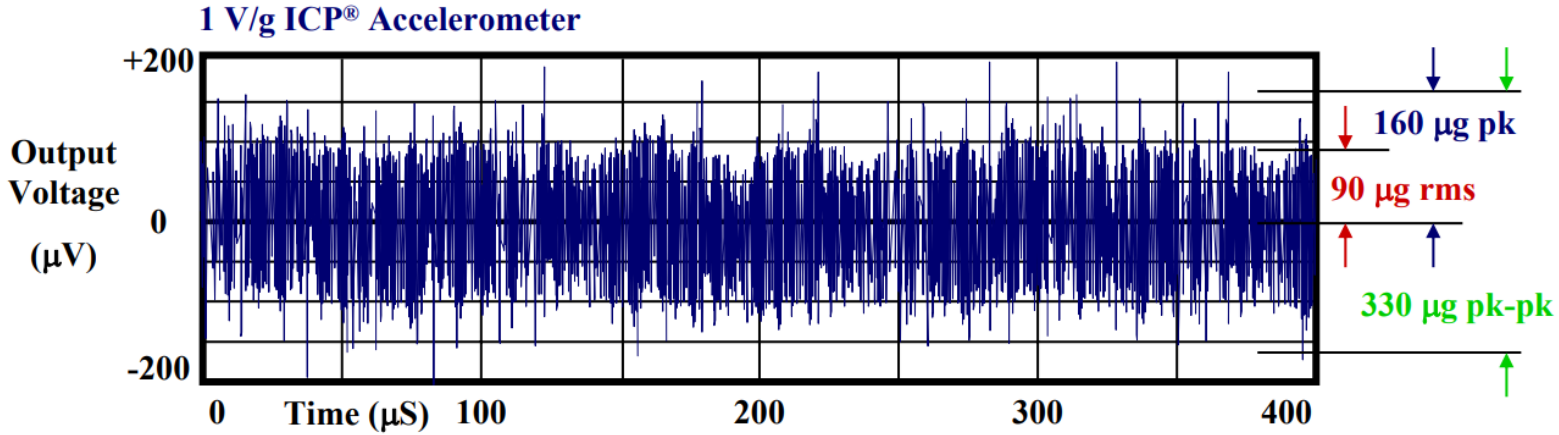
Specifications Defined in Multiple Ways

- **Threshold Test Setup**



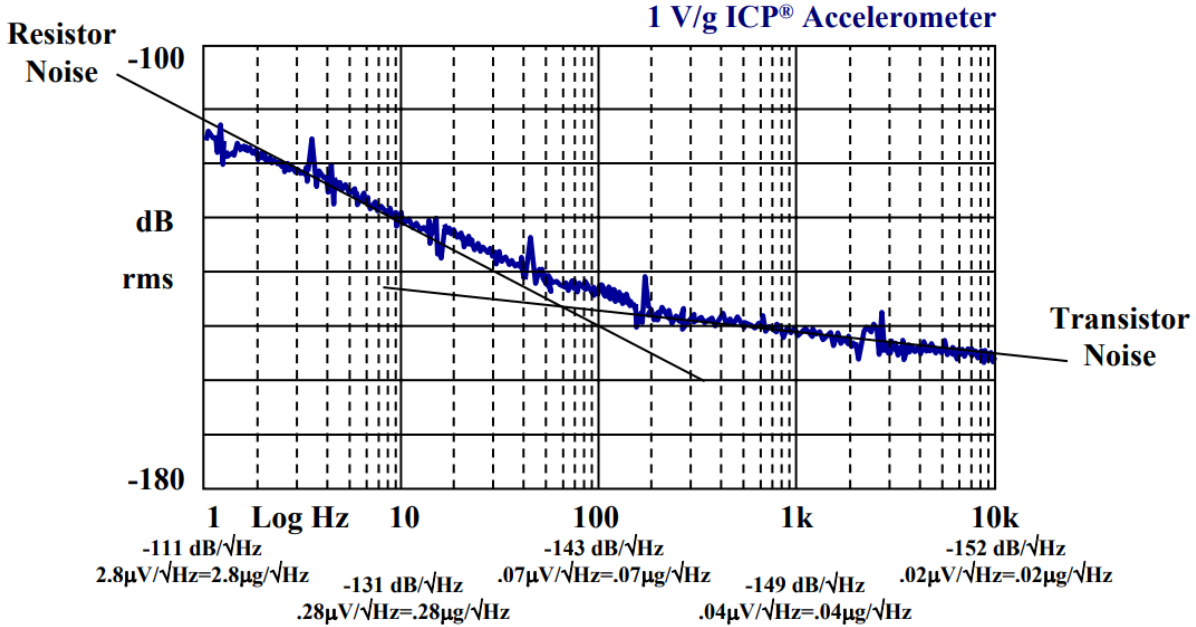
Specifications Defined in Multiple Ways

- **Broadband Resolution:** Early methods simply measured the signal directly on a scope without the use of frequency limiting filters



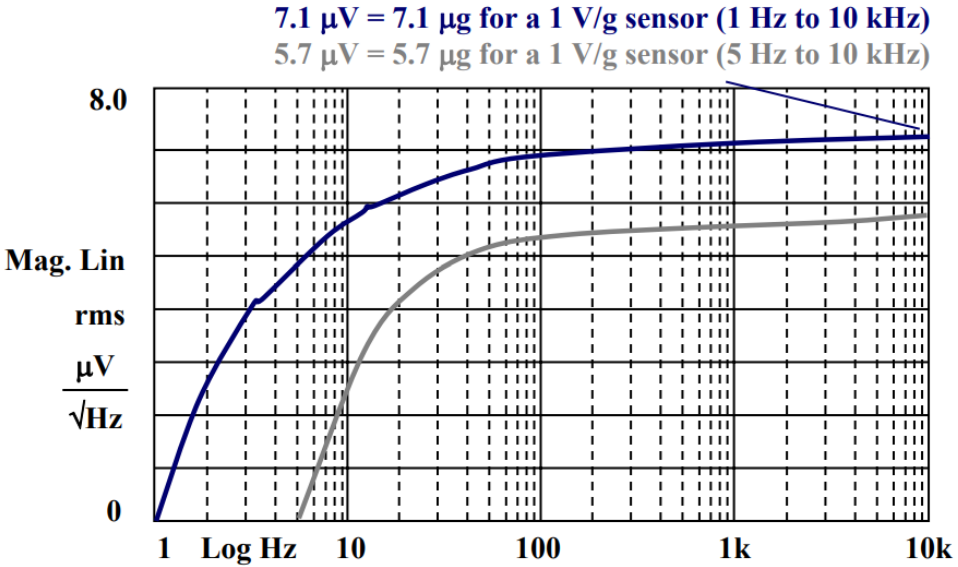
Specifications Defined in Multiple Ways

- **Spectral Noise:** Today's procedure uses an FFT Analyzer



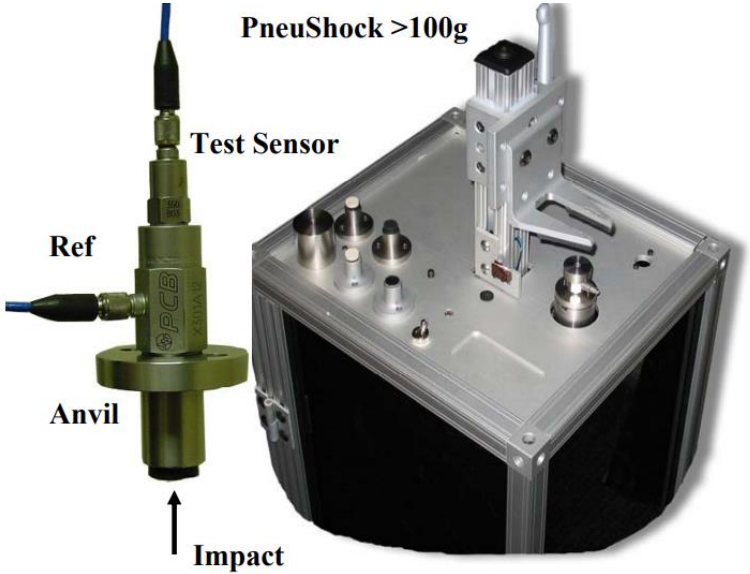
Specifications Defined in Multiple Ways

- **Broadband Noise:** Integrate spectral noise floor to obtain broadband (but frequency limited) noise floor



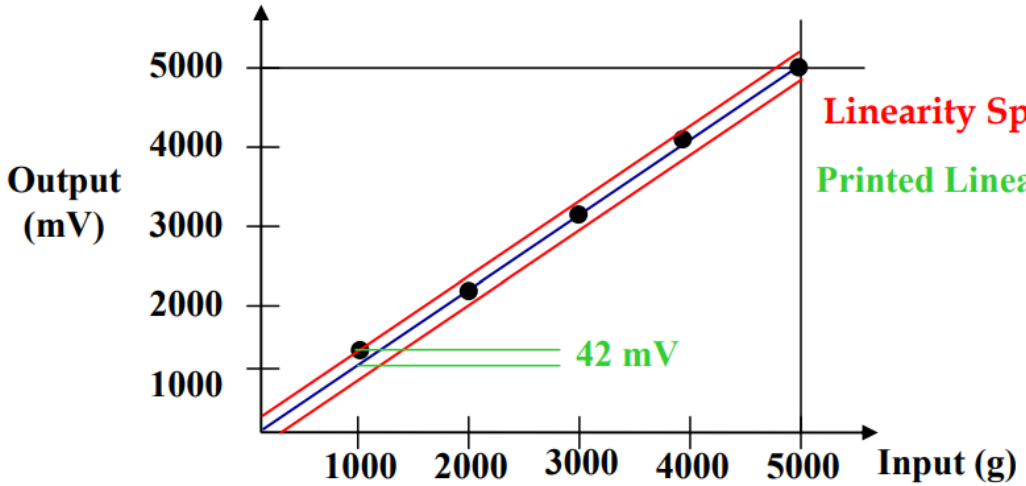
Specifications Defined in Multiple Ways

- **Amplitude Linearity:** Provides an indication that the sensitivity of the sensor does not vary with acceleration amplitude



Specifications Defined in Multiple Ways

- **Amplitude Linearity:** Most often defined as zero-based, least squares straight line
  - Slope of line = Sensitivity
  - Usually specified as <±1%

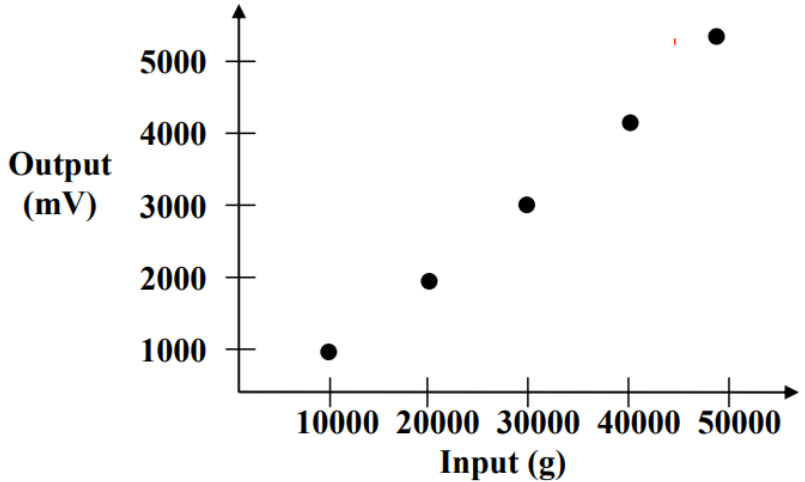


Linearity Spec Limits = 5000 * .01 = +/- 50 mV

Printed Linearity = 42 / 5000 * 100 = 0.84%

Specifications Defined in Multiple Ways

- **Amplitude Linearity:** is 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%

Specifications Defined in Multiple Ways

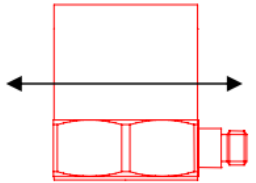
- **ESD / RFI Protection** – Often listed for industrial health monitoring applications
- **CE Mark** – Manufacturer determines acceptable level of immunity
- **TEDS** – Transducer electronic datasheet (V0.9, V1.0, LMS)
- **Low Pass Filtering** – Does the sensor have a single pole (or higher order) low 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”?

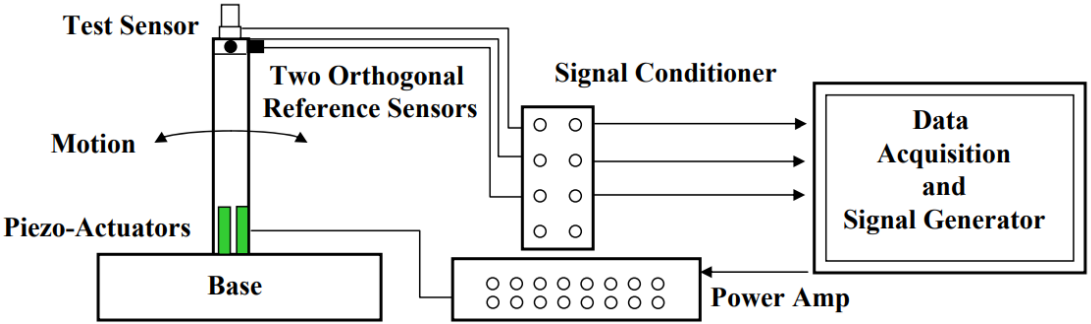
Other Important Performance Notes

- **Transverse Sensitivity**
  - Sensitivity of the accelerometer to acceleration perpendicular to the sensitive axis
  - Simply expressed as % of Axial Sensitivity

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

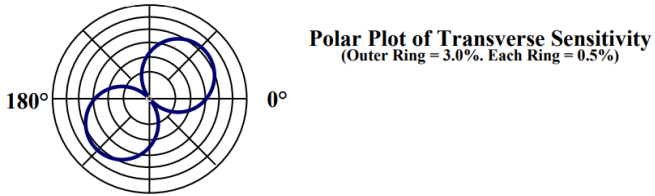
  - Test typically conducted at single frequency <1000Hz



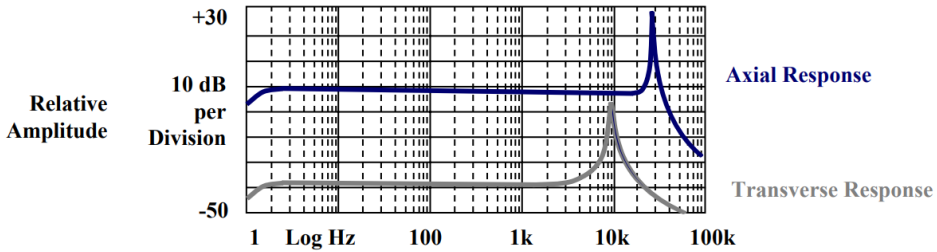


Other Important Performance Notes

- **Transverse Sensitivity**
  - There are directions of maximum and minimum sensitivity



  - Resonance exists at ~40% of axial resonance



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

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)

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.

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!