Considerations For Accelerometer Selection When Monitoring Complex Machinery Vibration

Jeff Rybak
PCB/IMI Sensors

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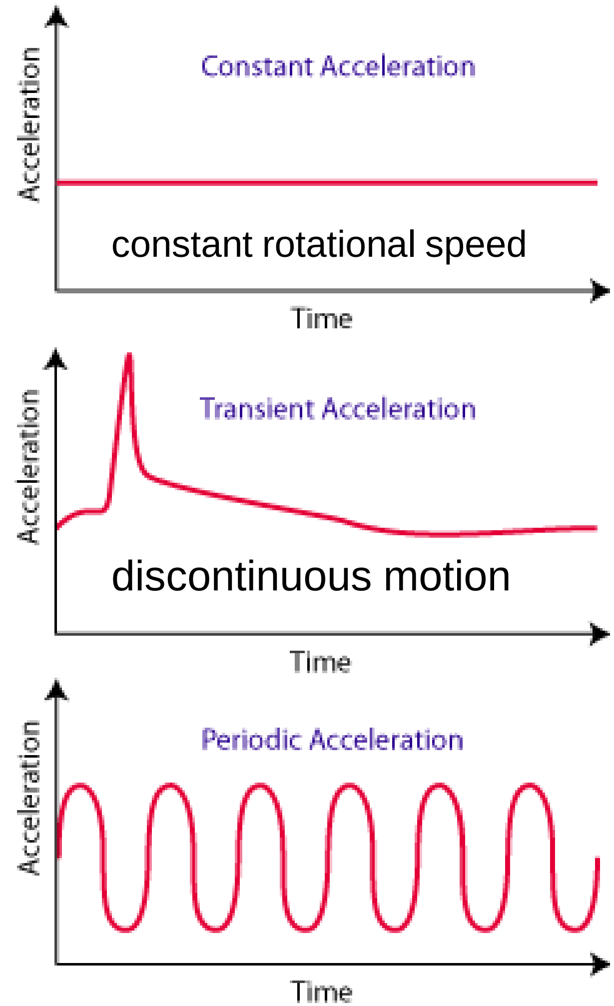
What Is An Accelerometer?

A sensor that measures acceleration



Periodic Acceleration

- Varies over the duration of the event
- Repetitive.
    - **Vibration of rotating machinery such as motors and bearings**
- Periodic acceleration is the result of **continuous motion**.

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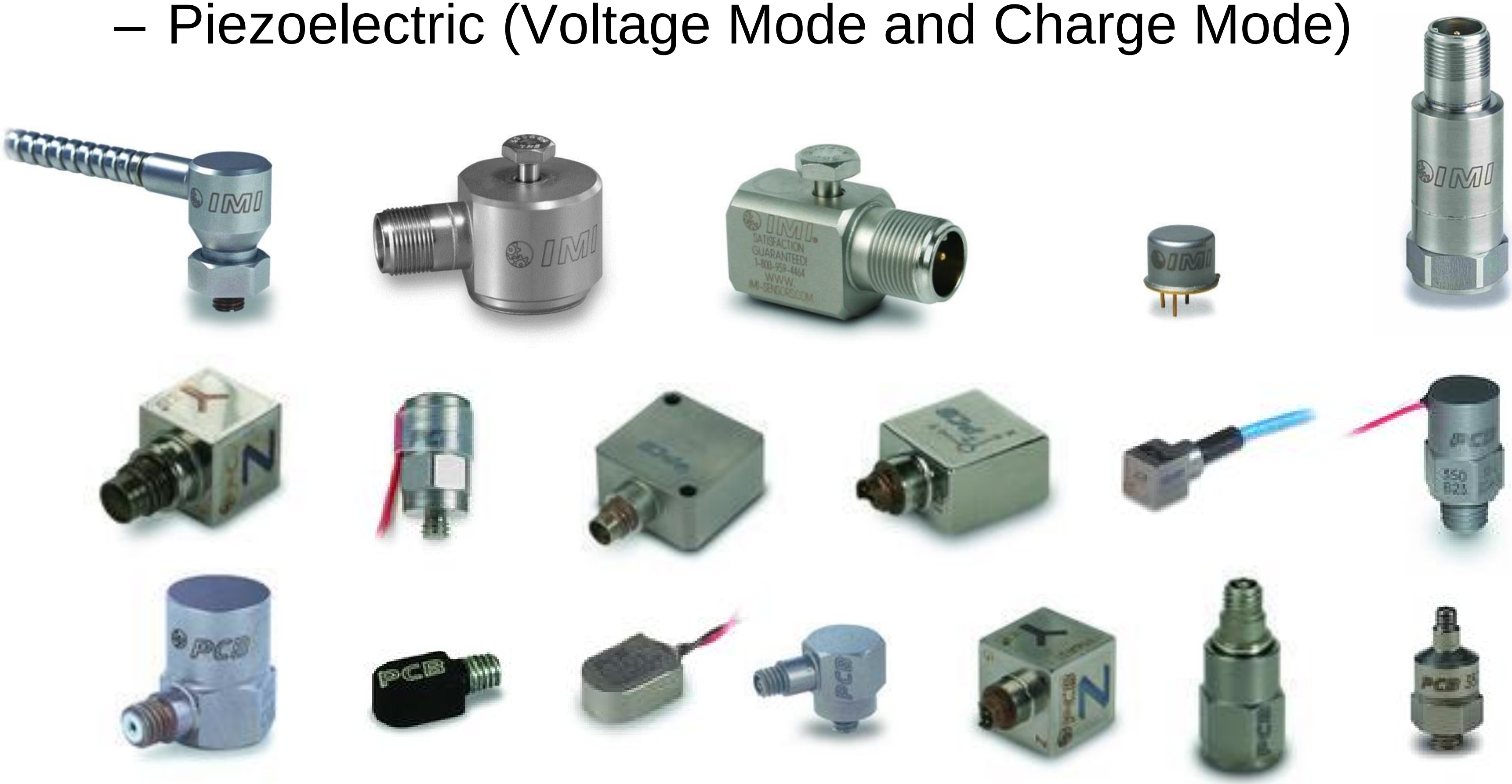
Types of Accelerometers

– MEMS (Variable Capacitive and Piezo-resistive)
– Piezoelectric (Voltage Mode and Charge Mode)



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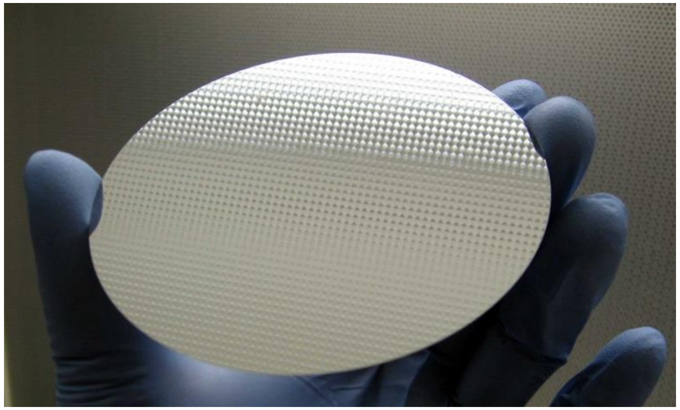
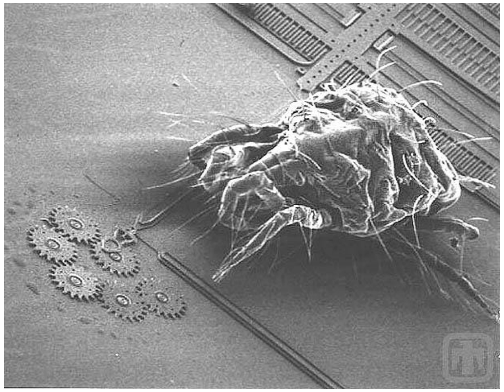
MEMS - What is it?

- Micro Electro Mechanical Systems
  - Made of components between 1 and 100 micrometers in size
  - Overall MEMS devices are 20 micrometers to 1 mm in size
- MEMS are very small mechanical devices
- Made from silicon wafers





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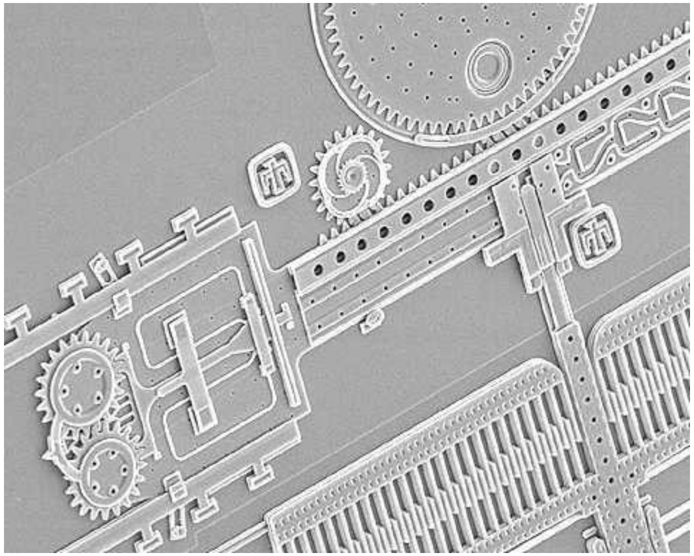
MEMS - What's it used for?

- Accelerometers
  - Air Bag Sensors
- Pressure Sensors
- Gyroscopes
- Display devices - using hundreds of thousands of mirrors on a chip
- Biomedical devices
- Consumer electronics devices (cell phones…)



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MEMS Sensing Technology

There are two primary sensing techniques employed in MEMS accelerometers: **piezo-resistive and variable capacitive**.

Piezo-resistive devices exhibit a change in resistance with respect to applied acceleration.
These units tend to be more rugged and are used for applications requiring higher amplitudes and higher frequency response.

On the other hand, variable capacitive units offer higher sensitivities and are utilized for low amplitude, low frequency applications.

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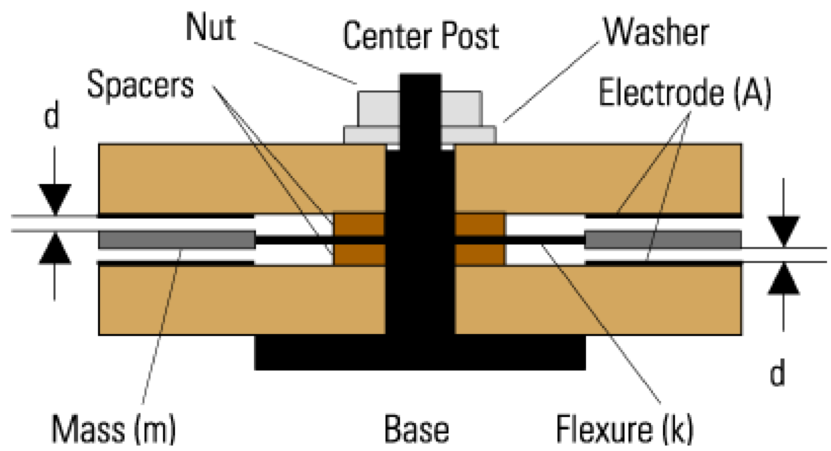
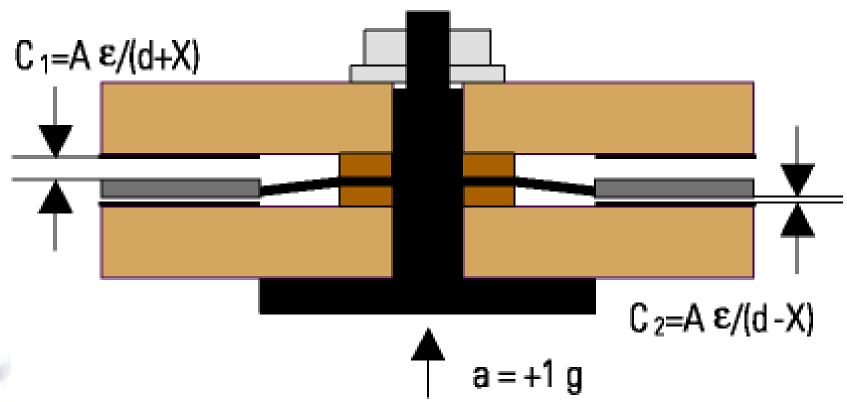
MEMS Sensing Technology

- MEMS DC Response Accelerometers with a **variable capacitive** MEMS chip as the sensing element






Series 3711B11


Series 3713B11


Series 3711B12
(with integral cable)


Series 3713B12
(with integral cable)


Series 3741B12

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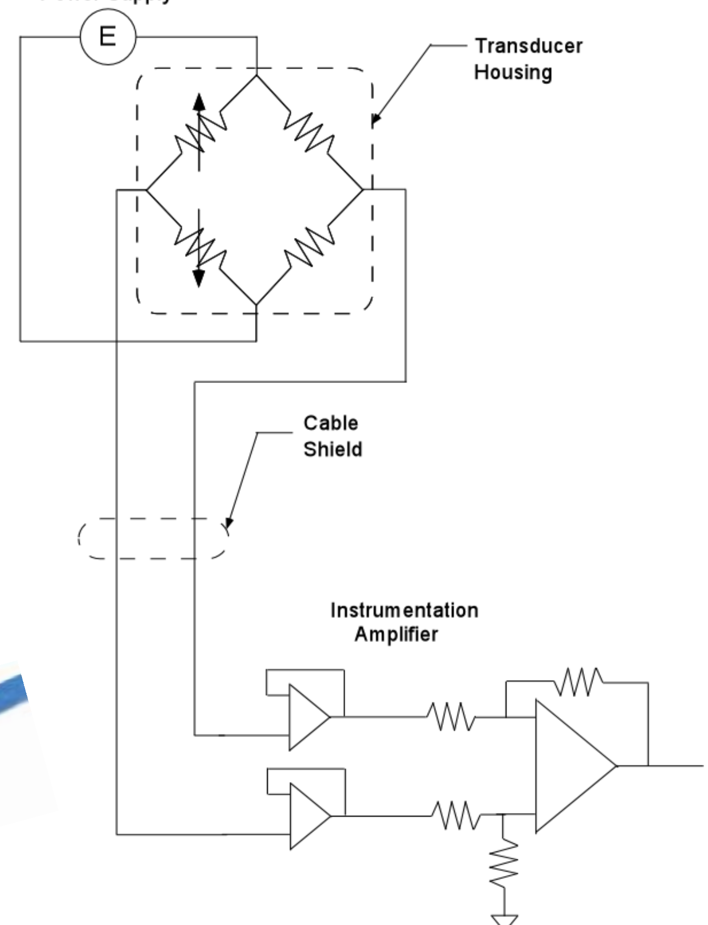
MEMS Sensing Technology

- MEMS DC Response Accelerometers with a Piezo-resistive MEMS chip as the sensing element.

3501



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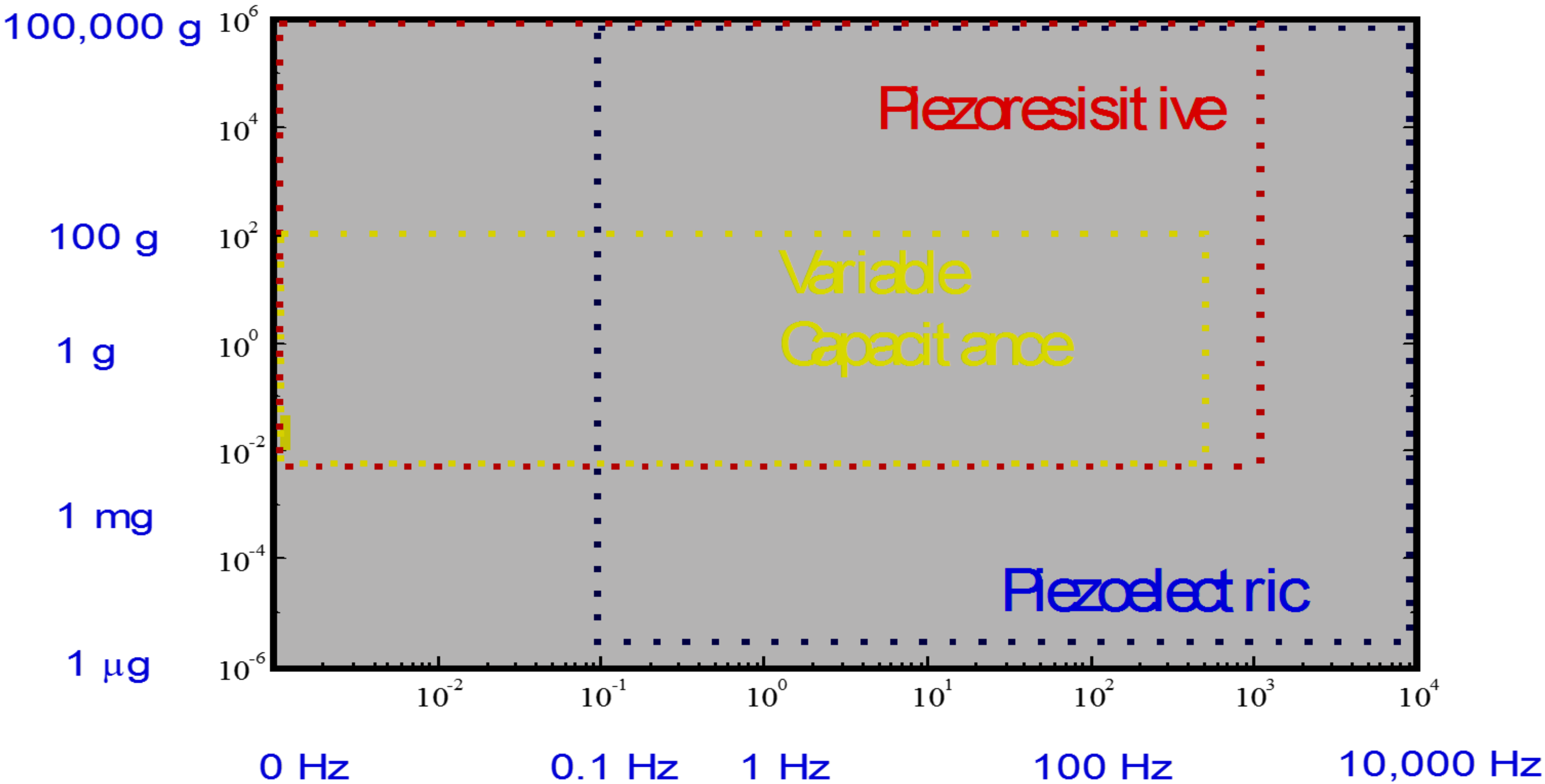
Typical Accelerometer Ranges

Piezoelectric, Piezo-resistive and Variable Capacitance



*** MEMS Accelerometers Measure <1kHz**

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Complex Machinery Vibration Frequencies of Interest

Measure	Typical Frequency Span	Typical Frequency Span
Displacement	<1200 CPM	<20 Hz
Displacement	Non-contact with fluid film bearings	
Velocity	600 to 60,000 CPM	10 Hz to 1000 Hz
Acceleration	>60,000 CPM	>1000 Hz

Table 1

From Basic Machinery Vibrations by Ronald L. Eshleman

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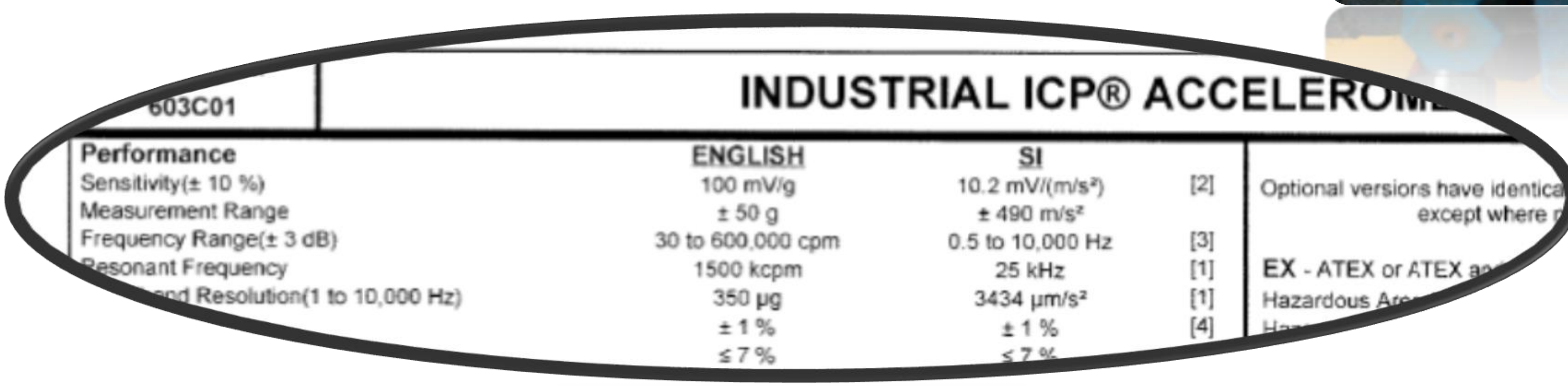
Required Accelerometer Bandwidth

- Dependent upon speed of machine and defects we wish to capture
- Obvious Fault Frequencies are typically between 1.5Hz to 1kHz
  - First few multiples of running speed
    - Balance, misalignment, looseness, etc.
  - First few multiples of bearing fault frequencies
    - For rolling element bearings
  - First few multiples of blade pass frequencies
    - For pumps
  - First few multiples of gear mesh frequencies
    - For gearing systems
- Faults that initiate stress waves like fatigue cracks, impacting, improper gear meshing, cavitation, etc. can excite frequencies exceeding 7kHz.
- **For this reason, a typical industrial piezoelectric accelerometer will have a frequency bandwidth of 0.5Hz to 10kHz (30 to 600,000cpm).**

Piezoelectric Accelerometers

- Most commonly used sensor for monitoring machinery vibration.



603C01 | INDUSTRIAL ICP® ACCELEROM

Performance	ENGLISH	SI		
Sensitivity(± 10 %)	100 mV/g	10.2 mV/(m/s²)	[2]	Optional versions have identica
Measurement Range	± 50 g	± 490 m/s²		except where
Frequency Range(± 3 dB)	30 to 600,000 cpm	0.5 to 10,000 Hz	[3]	
esonant Frequency	1500 kcpm	25 kHz	[1]	EX - ATEX or ATEX a
nd Resolution(1 to 10,000 Hz)	350 µg	3434 µm/s²	[1]	Hazardous Ar
	± 1 %	± 1 %	[4]	
	≤ 7 %	≤ 7 %		

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Sir Isaac Newton
(1642 - 1727)

Newton's Three Laws of Motion

I. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

II. The relationship between an object's mass *m*, its acceleration a, and the applied force *F* is *F* = *ma*.

III. For every action there is an equal and opposite reaction.

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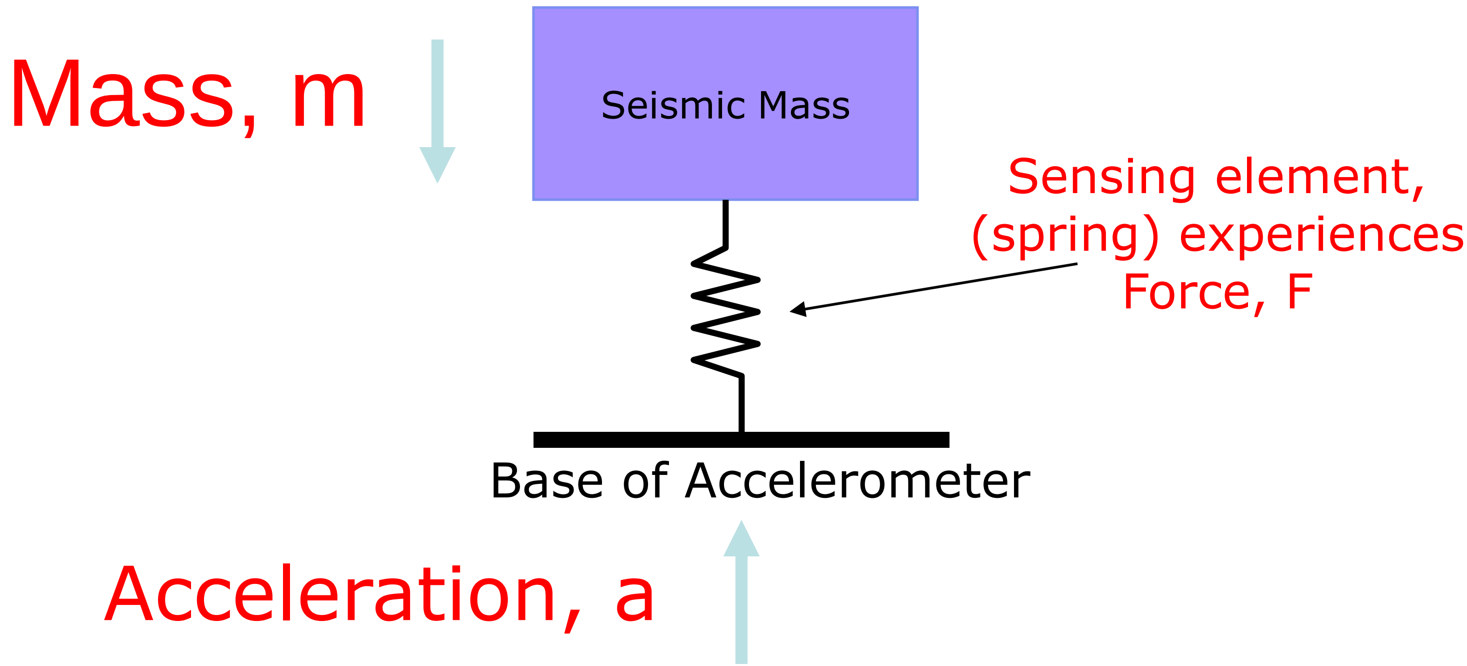
Piezoelectric Accelerometers

- An accelerometer structure can be characterized as a single degree of freedom system that is governed by Newton's 2nd Law of Motion, **F=ma.**



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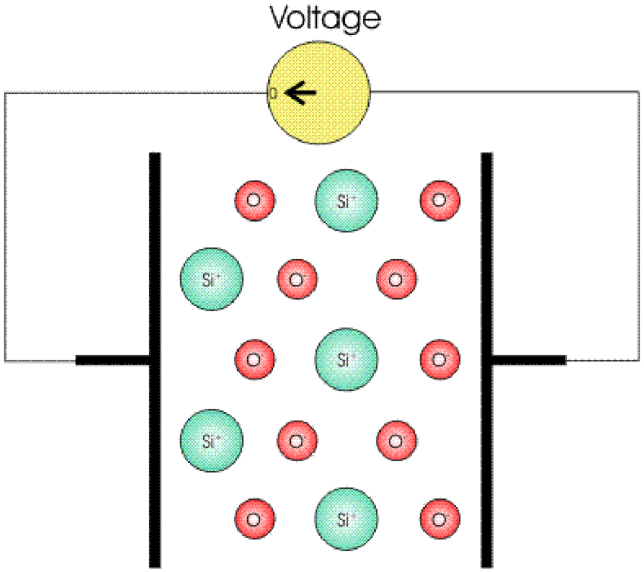
Piezoelectric Effect



- Sensing element is constructed with natural Quartz or man-made Ceramic crystals that are coupled to a seismic mass.
- When accelerated, the mass causes stress on the crystal, which results in a charge accumulating on opposing surfaces and a proportional electrical output signal.

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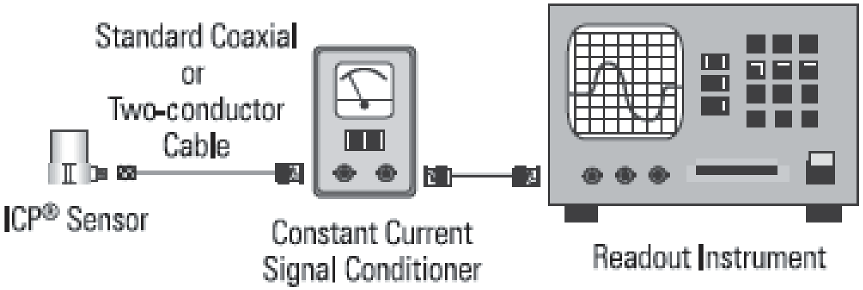
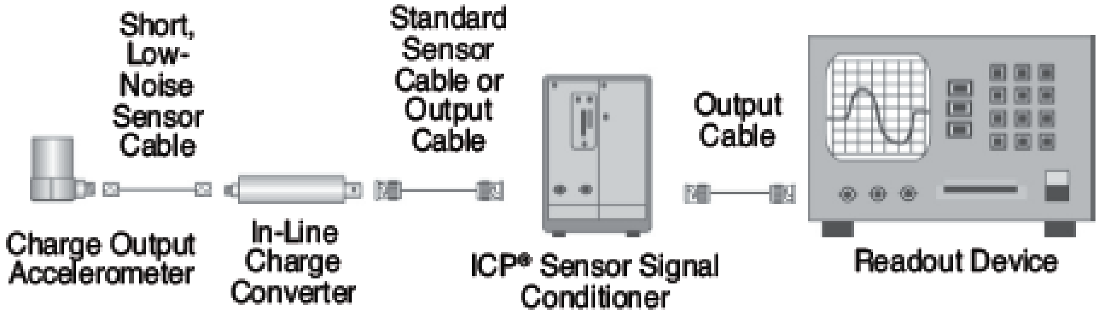
The Piezoelectric Effect

- The charge then can be converted internally (Voltage Mode) or externally (Charge Mode) to a low impedance voltage signal and utilized by appropriate readout and data acquisition equipment.





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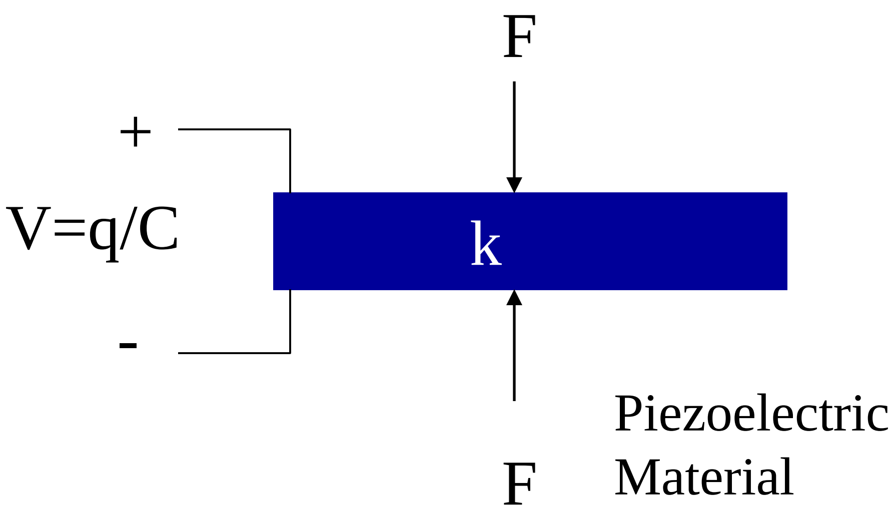
Three Properties of A Piezoelectric Crystal

- It's a Capacitor
- It's Piezoelectric – develops a charge (q) relative to force (F) applied
- It has a modulus of elasticity (spring constant or stiffness)



Qualities of Crystals that are Important for Sensors

- High stiffness -- imparts high frequency response and long life
- High output -- clean signal, good resolution
- Stability -- negligible aging effect
- Wide temperature range
- Temperature insensitivity (Negligible pyro-electric output)
- Economical

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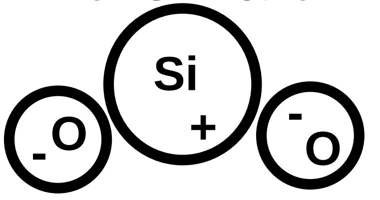
Materials

- Two main types of piezoelectric materials are used today:
  - *Quartz* Crystals
  - Polycrystalline *Ceramic* Crystals

Quartz Crystals

- Single Crystal made of SiO_2 molecules
- Found naturally in the Earth



  - Evolves over millions of years
  - Most is of poor quality useful as jewelry only
- Sensor Quartz is Artificially grown under high pressure and temperature in large autoclaves
  - Very high quality
  - Takes approximately 1 month

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Quartz Crystals

- Advantages
  - Naturally Piezoelectric
    - Excellent long term repeatability
  - Non-pyroelectric
    - Works well in thermally active environments
  - Low Capacitance
    - High Voltage Sensitivity (V=Q/C)
  - Low Temperature Coefficient
    - Little deviation over wide temperature range
  - High Stiffness
    - Extremely linear

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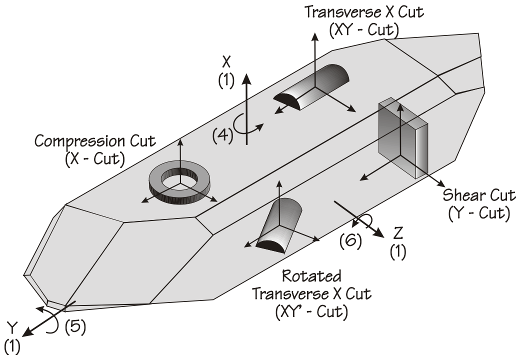
Quartz Crystals

- Disadvantages
  - Limited Temperature Range
    - Non-piezoelectric above 650 F (343 C)
  - **Low Charge Output (2.2pC/N)**
    - Not effective in low-noise, charge-amplified systems
  - Limited Geometry
    - Can only cut crystal in certain number of ways and still remain piezoelectric



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Quartz Accelerometers- Advantages

- Longer term stability - No change in senstivity over time
- Lower thermal transient senstivity - Better for thermally active Environments
- Lower temperature coefficient - Less change in sensitivity over temperature
- Uses voltage Amplifier- Better for Extreme IEPE temperatures -320 ºF to 325 ºF (-196 ºC to 163 ºC)

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Ceramic Crystals

- Man-made material
- **Lead-Zirconate Titanate**, Barium Titanate, Lead Metaniobate
- Polycrystalline structure
  - Naturally isotropic (physical and electrical properties the same in all directions)
  - Naturally non-piezoelectric
  - Becomes piezoelectric through high voltage process known as“Poling”

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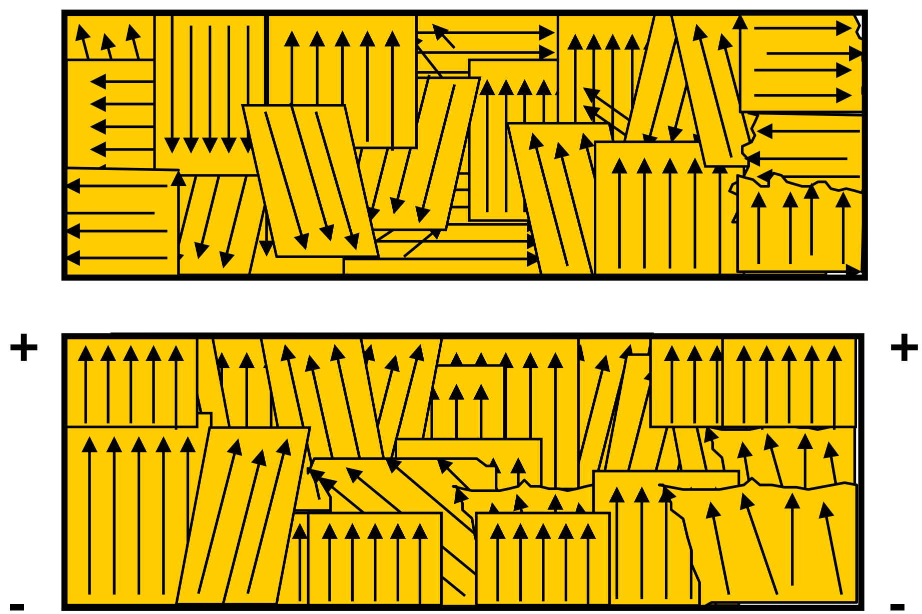
Ceramic Crystals

- **Polarization Process (Poling)**
  - **An extremely high voltage placed on the polycrystalline ceramic causes the dipoles to align themselves.**

BEFORE POLING

AFTER POLING



Ceramic Crystals

- Advantages
  - **High Charge Output (350pC/N)**
    - Excellent for use with tests requiring high sensitivity and/or low-noise, charge-amplified systems
  - Unlimited Geometry
    - “Poling” occurs after shaping
    - Versatility for different sensor designs: plates, annular tubes, cones, etc...
  - **High Temperature Range**
    - Operating temperatures: >1000 F (>540 C)

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Piezo-Ceramic Accelerometers

- Advantages
  - **Better resolution and frequency response** than comparable size quartz accelerometers
  - Easier to make smaller higher resolution accelerometers
  - Can use different crystal geometries for different shear designs
  - Higher charge output for use in Charge Mode Systems

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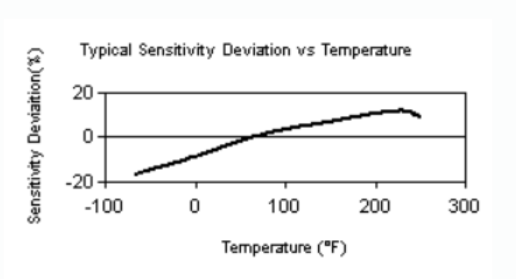
Piezo-Ceramic Accelerometers

- Disadvantages
  - Pyroelectric
    - Unwanted output generated by a thermal input
      - **Only an issue below 0.5Hz**
      - **Shear design eliminates this problem**
  - High temperature coefficient
    - Change in sensitivity over temperature
      - **Correction charts provided**



  - Artificially Polarized
    - Exhibit temporary/permanent changes under large mechanical, thermal or electrical shock
    - Electrical characteristics change over time
      - **Crystal Pre-Aging eliminates this problem**

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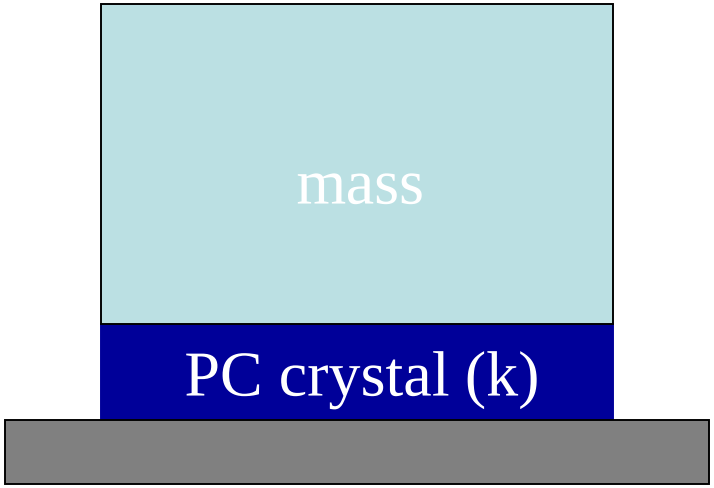
Add a Mass to Make an Accelerometer

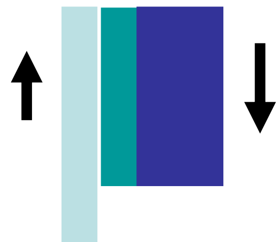
- Newton's 2nd Law, $F = ma$
  - When the mass is accelerated, it produces a force on the crystal
  - A larger mass = more force, higher output (higher sensitivity), and a lower natural frequency (lower frequency range)
  - A smaller mass = less force, less output (lower sensitivity), and a higher natural frequency (higher frequency range)



Accelerometer

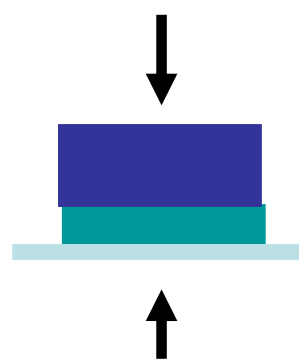
Crystal Structures

- These piezoelectric crystals can be cut and stressed in different ways:
  - Shear



  - Flexural

  - Compression



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Accelerometer Designs

Compression design

Tri-shear design

Flexural beam design

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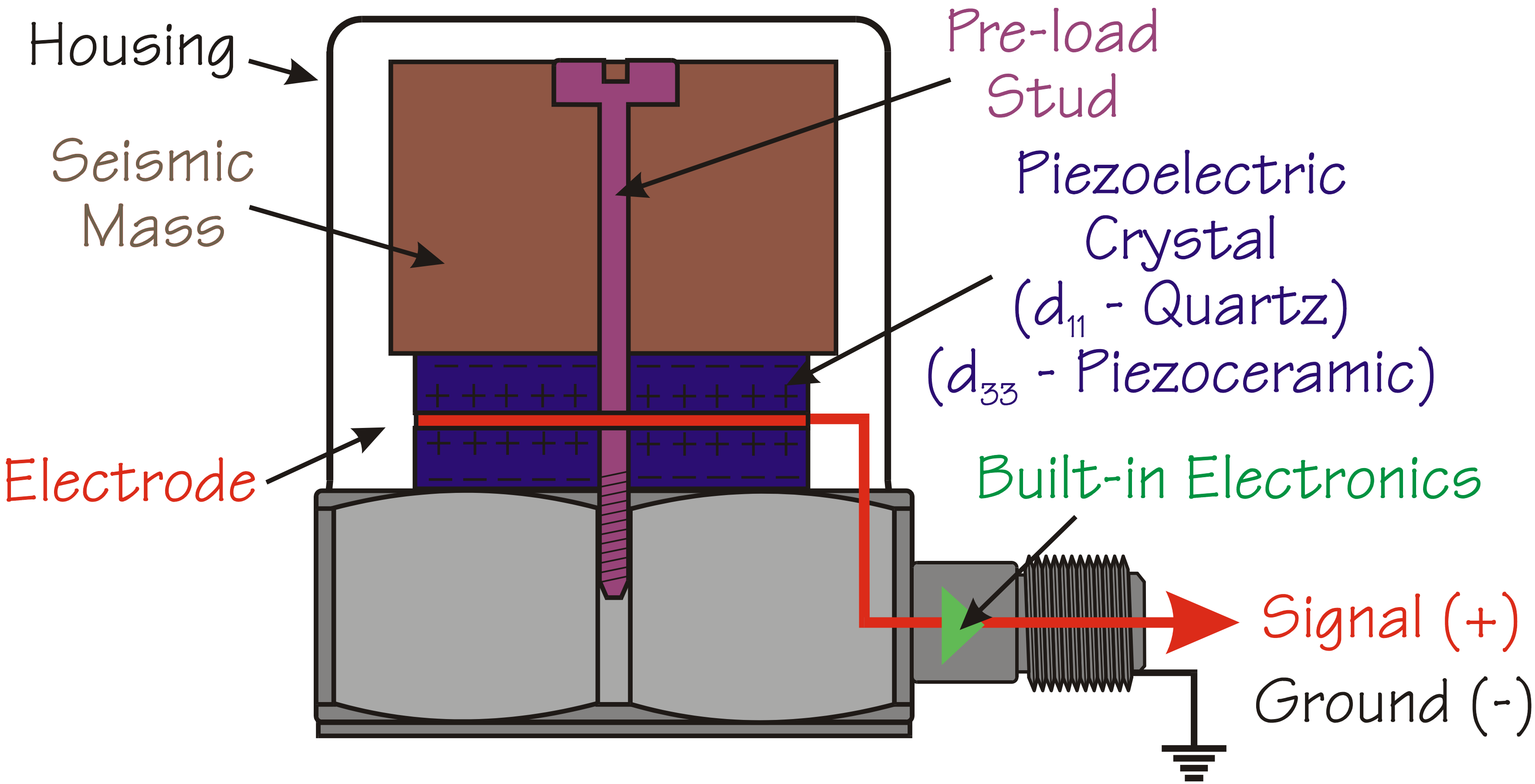
Compression Mode



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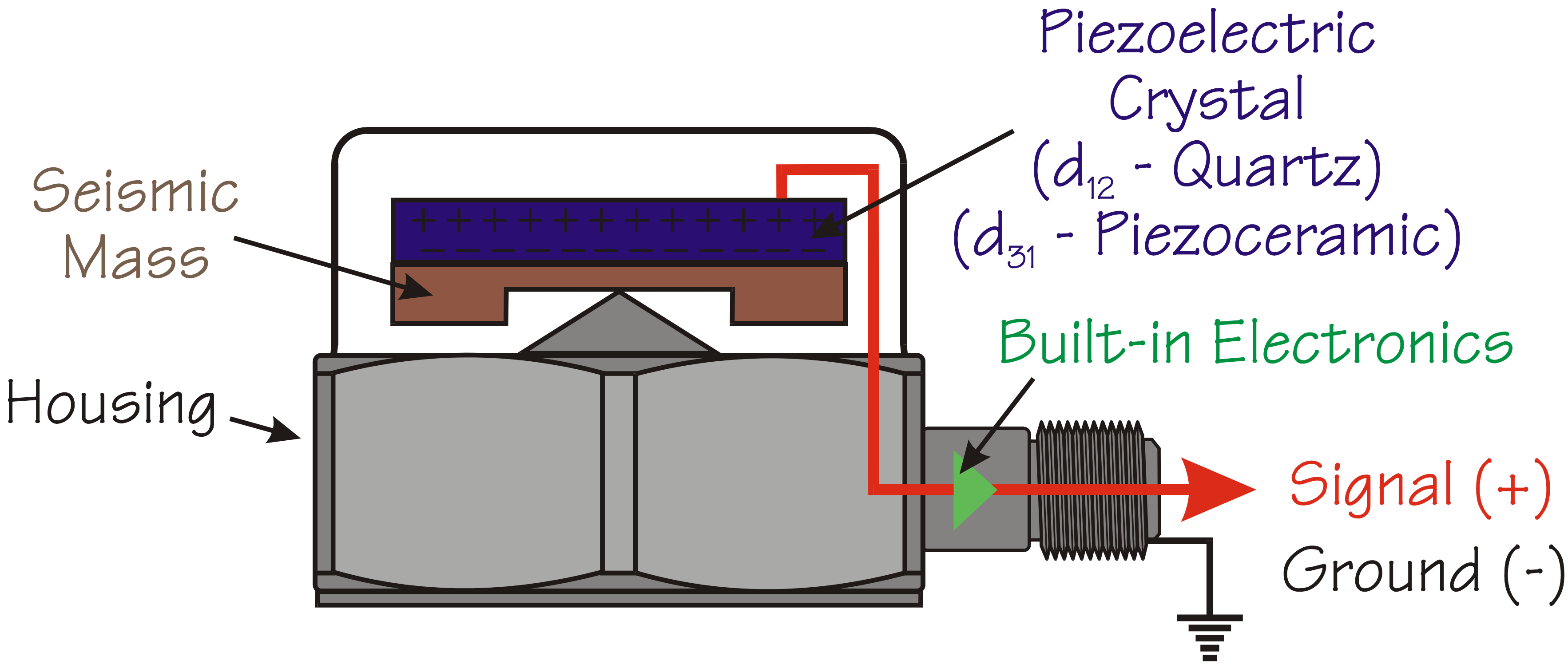
Flexural Mode



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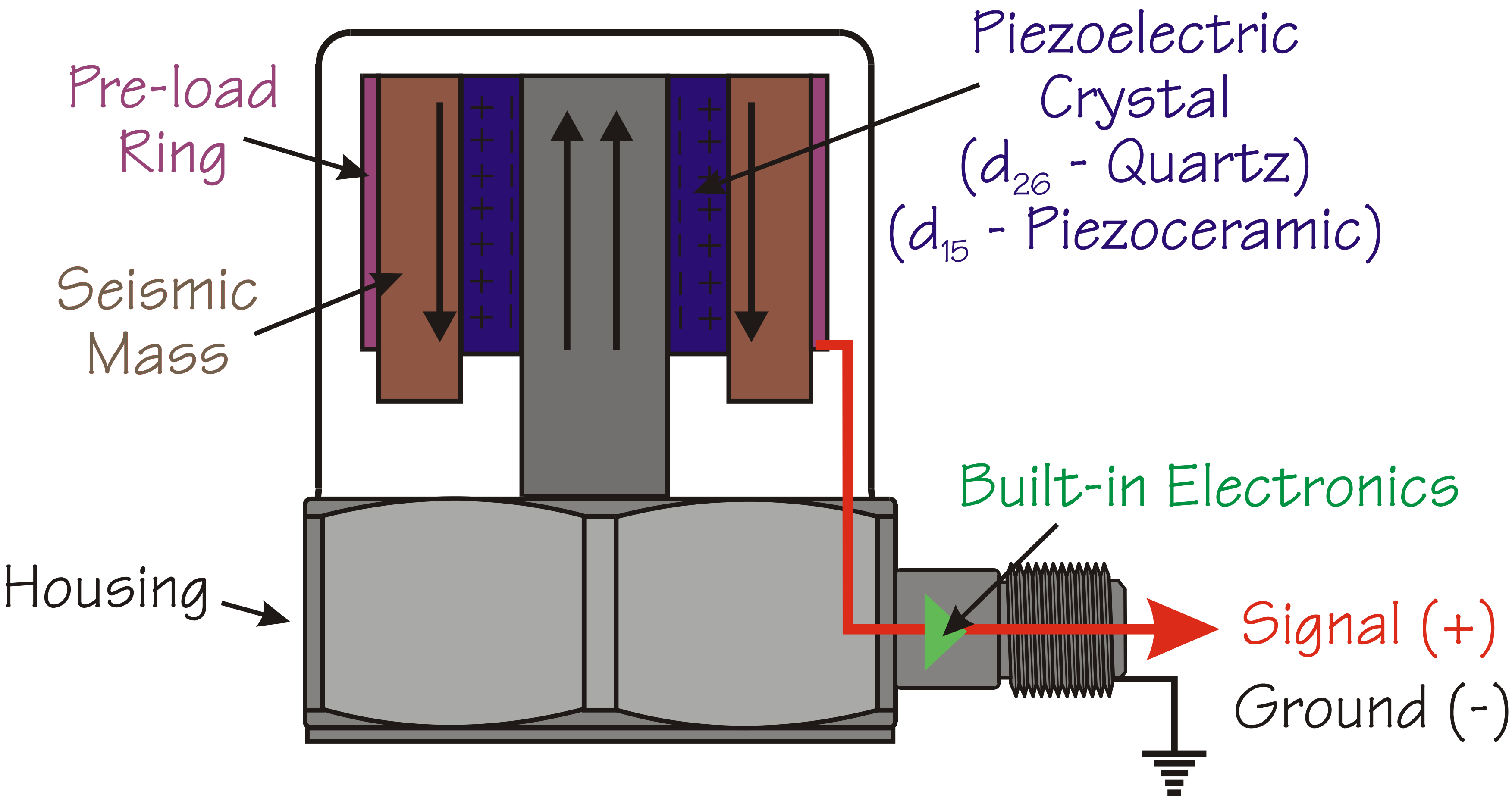
Accelerometer, Shear Mode



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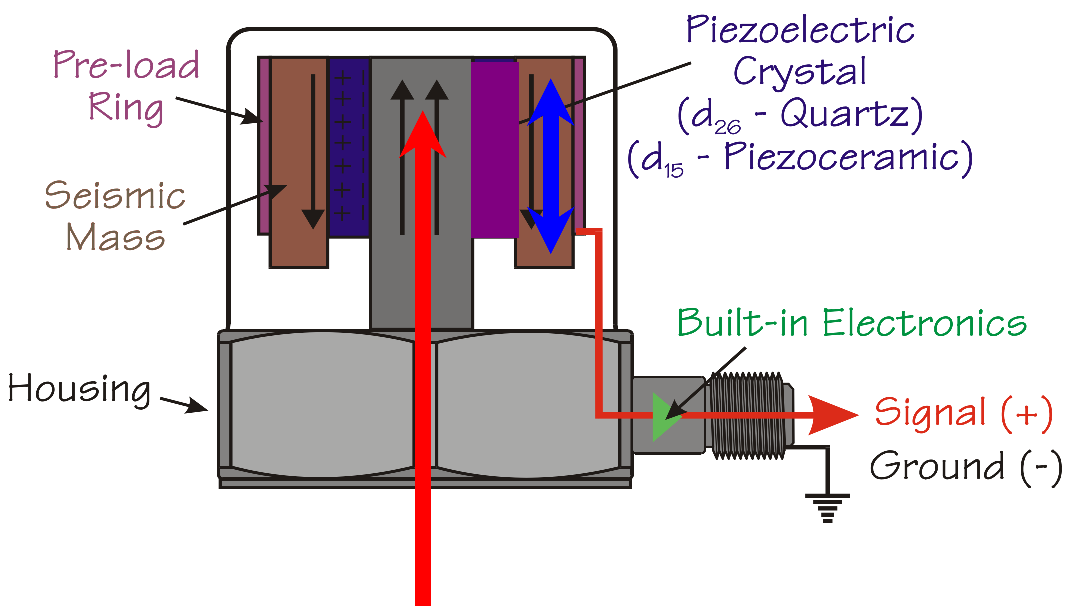
How the Vibration is Sensed

- Piezoelectric Accelerometer
  - Simple single degree-of-freedom device which converts the acceleration aspect of motion into a proportional electrical signal
    - Linear Acceleration



- Amplitude Signal Output is: mV per g (mV per m/s^2)

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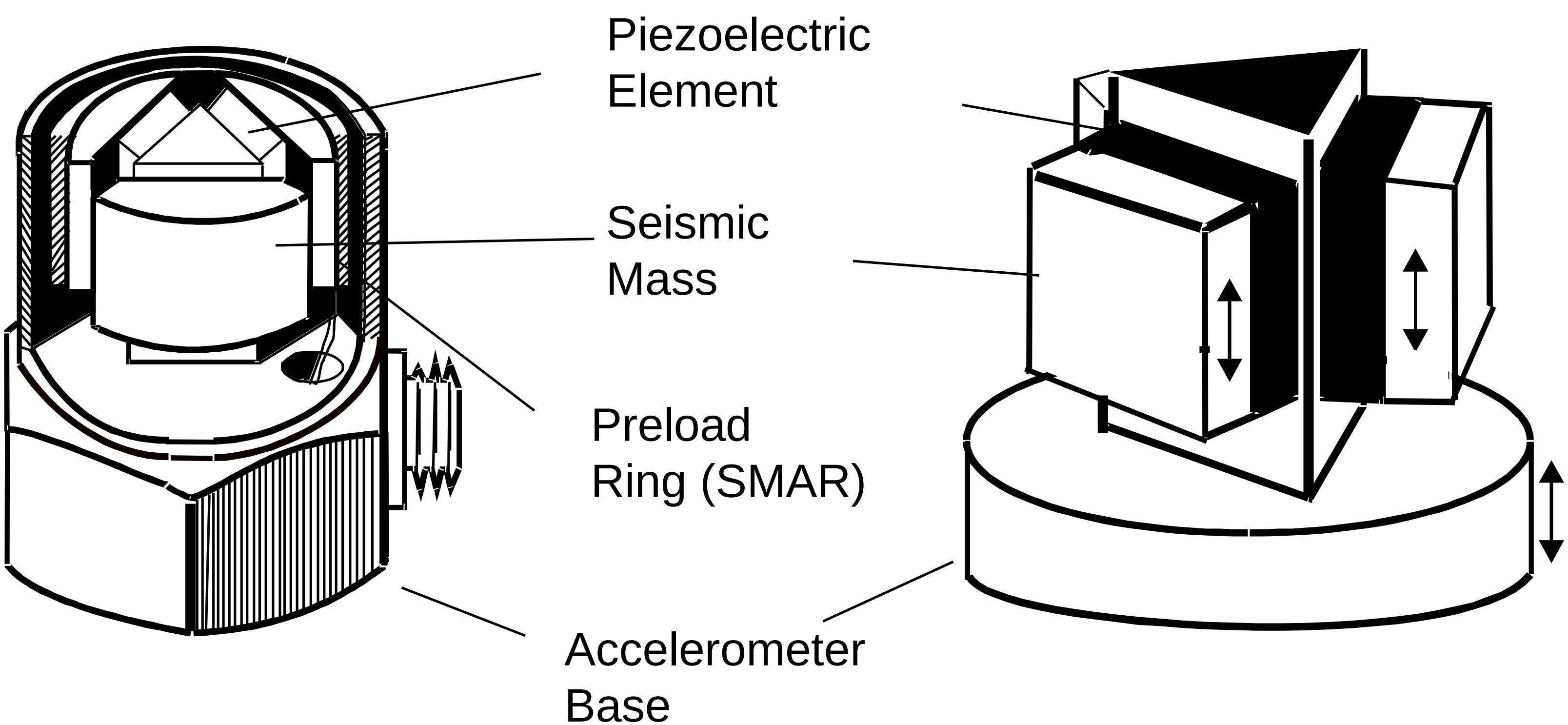
Accelerometer Construction
PCB's "Tri-Shear" Design



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Voltage Mode vs Charge Mode

- Piezoelectric accelerometers: Two Types
- In each type the high impedance charge signal is converted to a low impedance time varying voltage signal
- Type 1 -Accelerometers with built in electronics or IEPE (Internal Electronic Piezoelectric) generic or ICP® (PCB Trademark) - Impedance conversion is done internally in the accelerometer (Voltage Mode).
- Type 2 - Charge output - Impedance conversion is done externally to accelerometer (Charge Mode).

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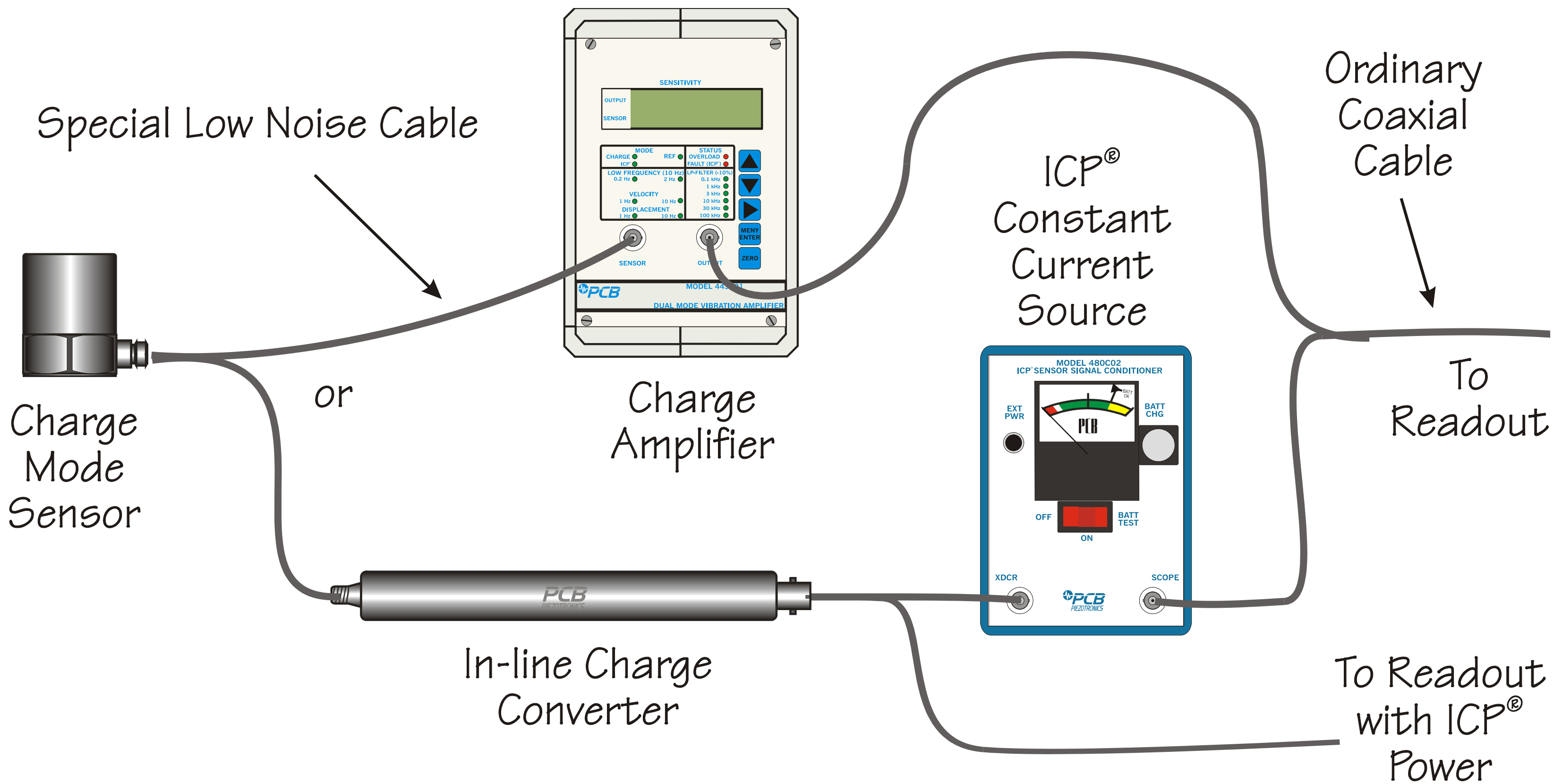
CHARGE MODE SYSTEM

- System Schematic



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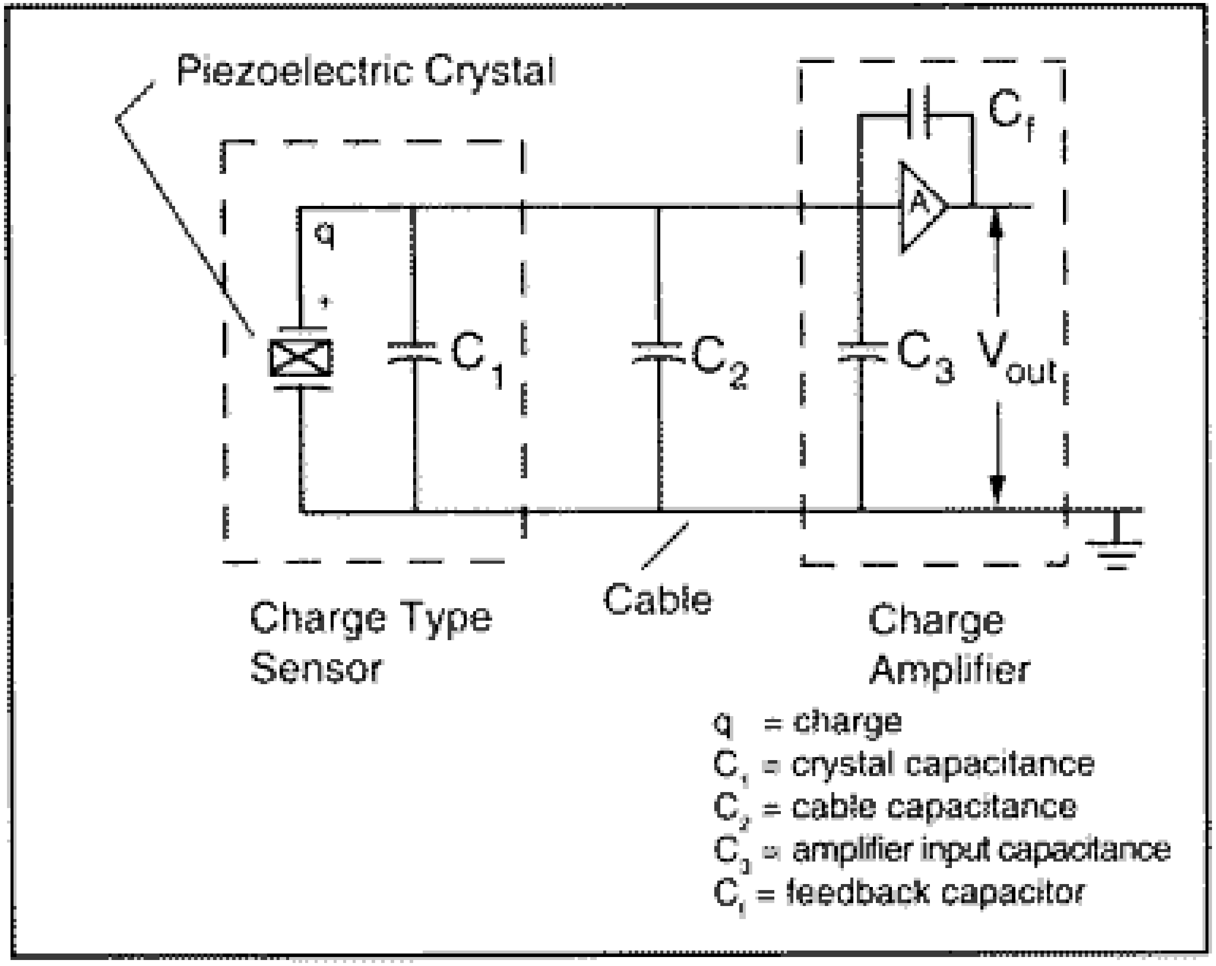
CHARGE MODE SYSTEM



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CHARGE MODE SYSTEM

- **Advantages**
  - <u>High temperature range</u> (1000 F / 540 C)
  - Amplitude range, low frequency limit, and signal normalization can be adjusted at the charge amplifier- Very flexible
- **Disadvantages**
  - High output impedance signal
    - Requires low noise cable easily corrupted by EMI and RFI
    - Often requires expensive charge amplifiers and low-noise cables
    - All high impedance components must be kept dry and clean
    - Signal/noise limited by cable length
    - Difficult to use in contaminated environments
  - Higher per Channel Cost than IEPE Type Systems.

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Charge Mode Accelerometers

- Removing the charge amplifier from the high temperature environment and utilizing hard-line cable allows the accelerometer to withstand as much as 1300°F.

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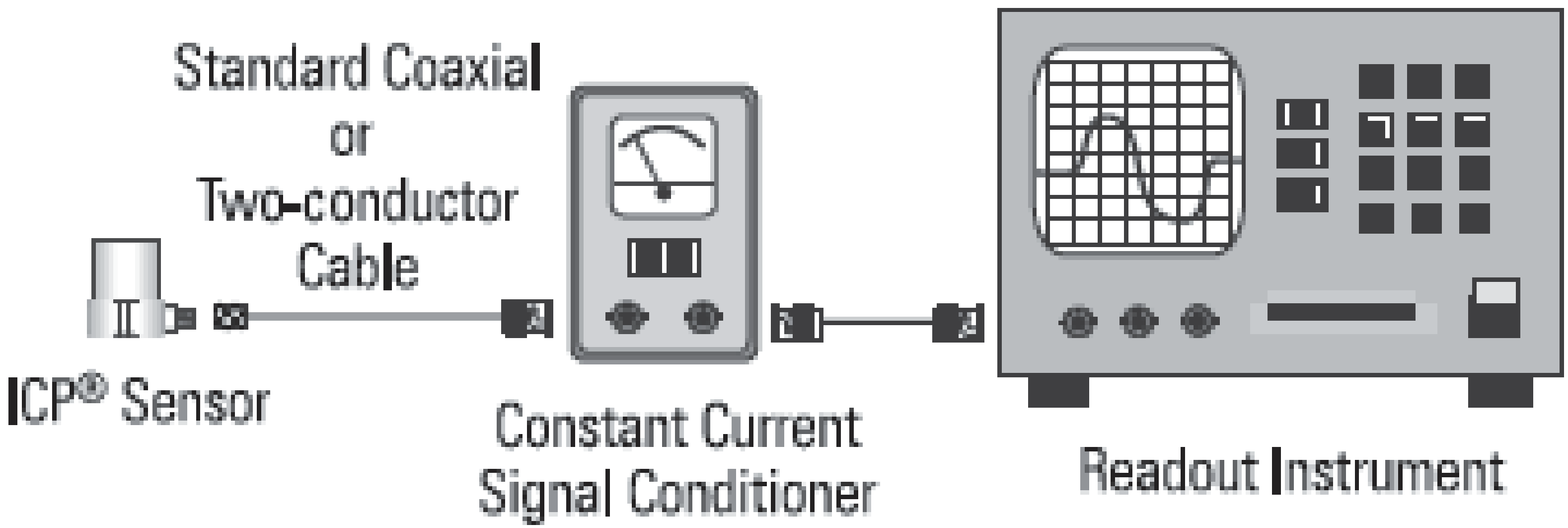
IEPE (ICP®) VOLTAGE MODE SYSTEM



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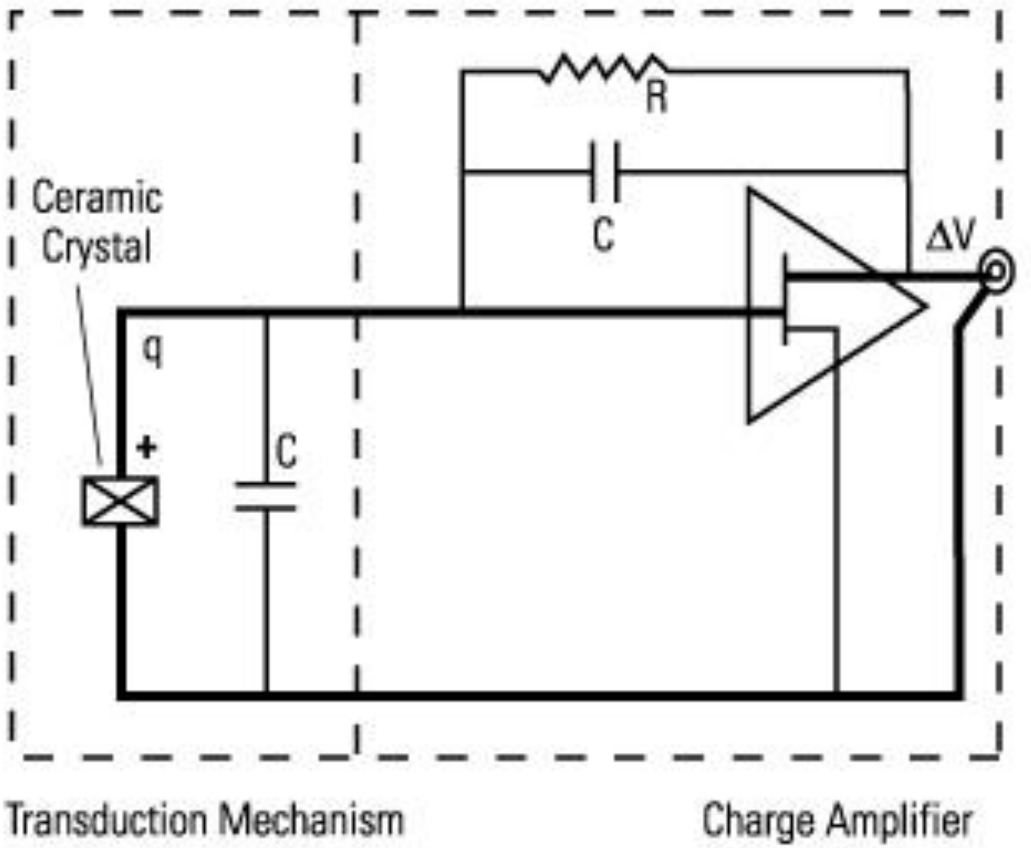
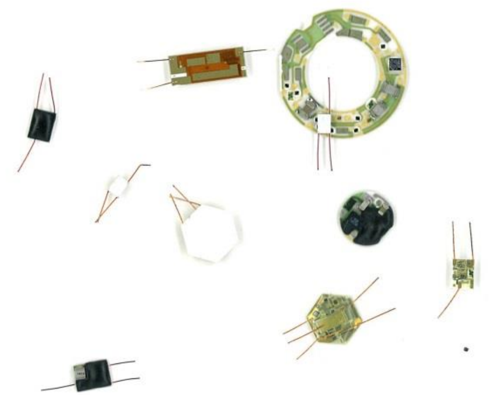
IEPE (ICP®)
VOLTAGE MODE SYSTEM





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APPLICATIONS OF CHARGE and VOLTAGE MODE SYSTEMS

- **Charge Mode**
  - High Temperature Testing
  - Engine Studies, Steam Pipe Vibration, Gas Turbine Monitoring
- **Voltage Mode (IEPE)**
  - Almost Everything Else
  - Modal Analysis, Cryogenic, Shock, **<u>Machinery Monitoring</u>**, Seismic, High Frequency, Structural Testing, Flight Testing, Underwater, Human Vibration, Package Testing

IEPE Temperature Limitations

- Typical IEPE industrial accelerometers are limited to 250°F (temperature limit of silicon).
- Higher temperature electronics now allow us to withstand up to 325°F.

Environmental

Overload Limit (Shock)	5000 g pk	49050 m/s² pk
Temperature Range	-65 to +325 °F	-54 to +163 °C
Temperature Response	See Graph %/°F	See Graph %/°F
Enclosure Rating	IP68	IP68

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Piezoelectric (Dynamic) Accelerometers

- Operates using the piezoelectric effect
- Use natural quartz crystals or artificially **polarized polycrystalline ceramics (PZT)**
- Crystals produce an electrical charge that is proportional to the force applied
- Generally used with a built in amplifier **IEPE** (ICP®) for low impedance voltage output
- **Most commonly used sensor for monitoring machinery vibration.**

- ICP® is a registered trademark of PCB Group, Inc.

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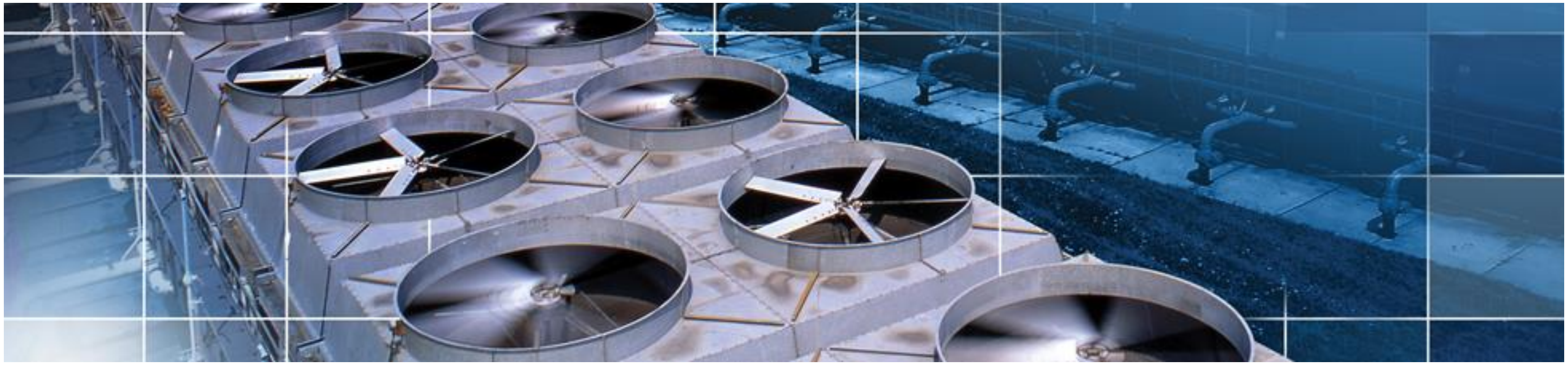
Why Measure Vibration

- It’s the best overall indicator of machine health
- Works on the widest range of machines & faults



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Maintenance Strategies

- Breakdown (Run To Failure)
- Preventive (Time Based)
- Predictive (Condition Based)
- Proactive (Correction & Root Cause)

Predictive (Condition-Based) Maintenance

- Vibration Analysis
- Infrared Thermography
- Ultrasonic Analysis
- Oil particle Analysis
- Motor Current Analysis

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Why Do It?

- Reduce unscheduled downtime
- Improve uptime
- Reduce catastrophic failures
- Improve production scheduling reliability
- Reduce maintenance costs
- Reduce spare parts inventory
- Reduce insurance costs (in some cases)

Common Faults Found with Vibration Analysis

- Unbalance
- Misalignment
- Looseness
- Bearing faults
- Gear faults
- Oil whirl
- Oil whip
- Aerodynamic
- Resonance
- Loose Footing
- Critical speed
- Cavitation
- Recirculation
- Rubs
- Broken rotor bars
- Eccentric rotor
- Stator faults
- Shaft bow

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The PdM Process

- Identify machines and points to be monitored (develop a route or continuously monitor)
- Determine the measurements to be made
- Setup alarm levels for the points
- Measure vibration at a periodic interval
- Trend the data
- Analyze the points that exceed the alarms to determine the fault using:
  - Time waveform analysis
  - FFT (spectrum) analysis
  - HFE analysis (Spike Energy®, PeakVue®, demodulation, etc)
  - Severity charts and specifications

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Data Collection Systems

- Walk Around
  - Uses a portable data collector
    - With magnetically mounted sensor or
    - With permanently mounted sensors and a junction box
- On-line (continuous) monitoring
  - Surveillance
  - Protection (with fast shut down capability)
  - Plant systems
    - PLC, DCS, SCADA, PI with 4-20 mA output sensors and vibration transmitters

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Accelerometer Selection

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What do you want to measure?

- **Acceleration, velocity, or displacement measurements**
  - An accelerometer provides a signal proportional to acceleration
  - If velocity or displacement measurement is desired, there are sensors available with additional circuitry that integrates the acceleration signal into velocity or displacement.
- **Single axis, bi-axial, or tri-axial measurements**
  - Some applications, such as vertical pumps, are ideally monitored in more than one axis of vibration. Does your application require uni-axial, bi-axial or tri-axial measurement?
- **ICP® raw vibration or 4-20 mA transmitter measurements**
  - Vibration can be monitored with accelerometers that provide raw vibration data or transmitters which provide the calculated overall RMS vibration.
    - Vibration Analysis or Control System Interface?
- **Temperature measurements**
  - Both ICP® (IEPE) accelerometers and 4-20 mA transmitters are available with the temperature output option.

Accelerometer Selection

- What is the amplitude of vibration?
- What is the frequency of vibration?
- What is the temperature of the environment?
- Will it be submersed in liquid?
- Will it be exposed to any potentially harmful chemicals or debris?
- Do you prefer a top exit, side exit, or a low profile Swiveler®
- Should you use a precision or low cost sensor?
- Do you need any special approvals?

What is the amplitude of vibration?

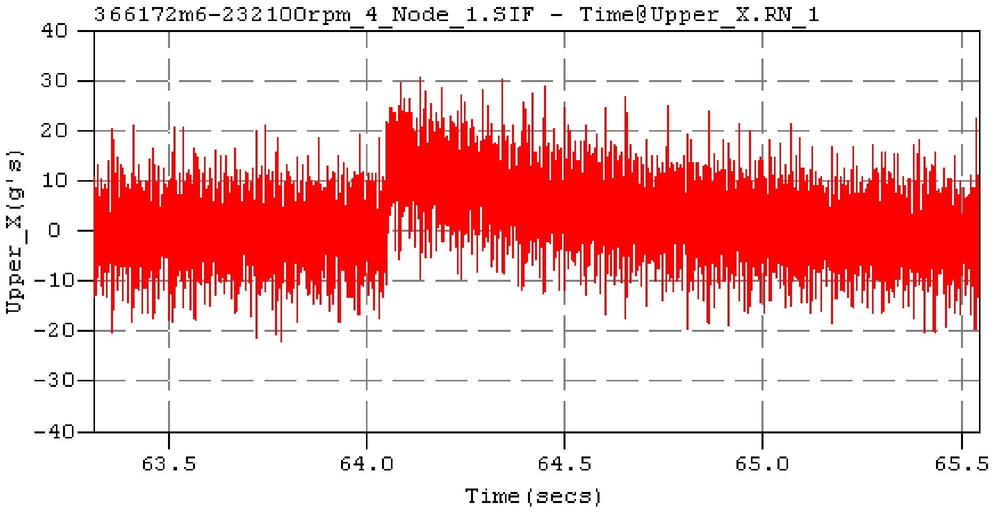
- The maximum amplitude of the vibration being measured will determine the range of the sensor that can be used.
- Typical sensitivities for ICP® accelerometers are 100 mV/g for a standard application (50 g range) and 500 mV/g for a low frequency or low amplitude application (10 g range).
- General industrial applications with 4-20 mA transmitters commonly use a range of 0-1 in/s or 0-2 in/s.

What is the frequency of vibration?

- Piezoelectric materials, by nature, act as high pass filters and as a result, even the best piezoelectric sensor will have a low frequency limit near 0.2 Hz.
- Sensors have natural frequencies where the signal is greatly amplified and possible saturation can occur.
- To combat saturation caused by exciting sensor resonance, most industrial accelerometers have single or double pole RC filters.
- It is critical to select a sensor with a usable frequency range that includes all frequencies of vibration you are interested in measuring.

Amplifier Saturation

- Occurs when the accelerometer is excited at its resonant frequency.
- High Q-factor at resonance causes amplifier to overload (saturate).
- Accelerometer will essentially shut down and then enter into an overload recovery state, during which time no meaningful data can be acquired.
  – NOTE: Filtering the signal in your Data Acquisition or ICP® Signal Conditioner will not help



A PCB PIEZOTRONICS DIV.

Filtered ICP® Accelerometers

There are two reasons to use filtered accelerometers:

1. Extend the usable high frequency range.
2. Minimize the possibility of amplifier saturation.

What does the filter do?

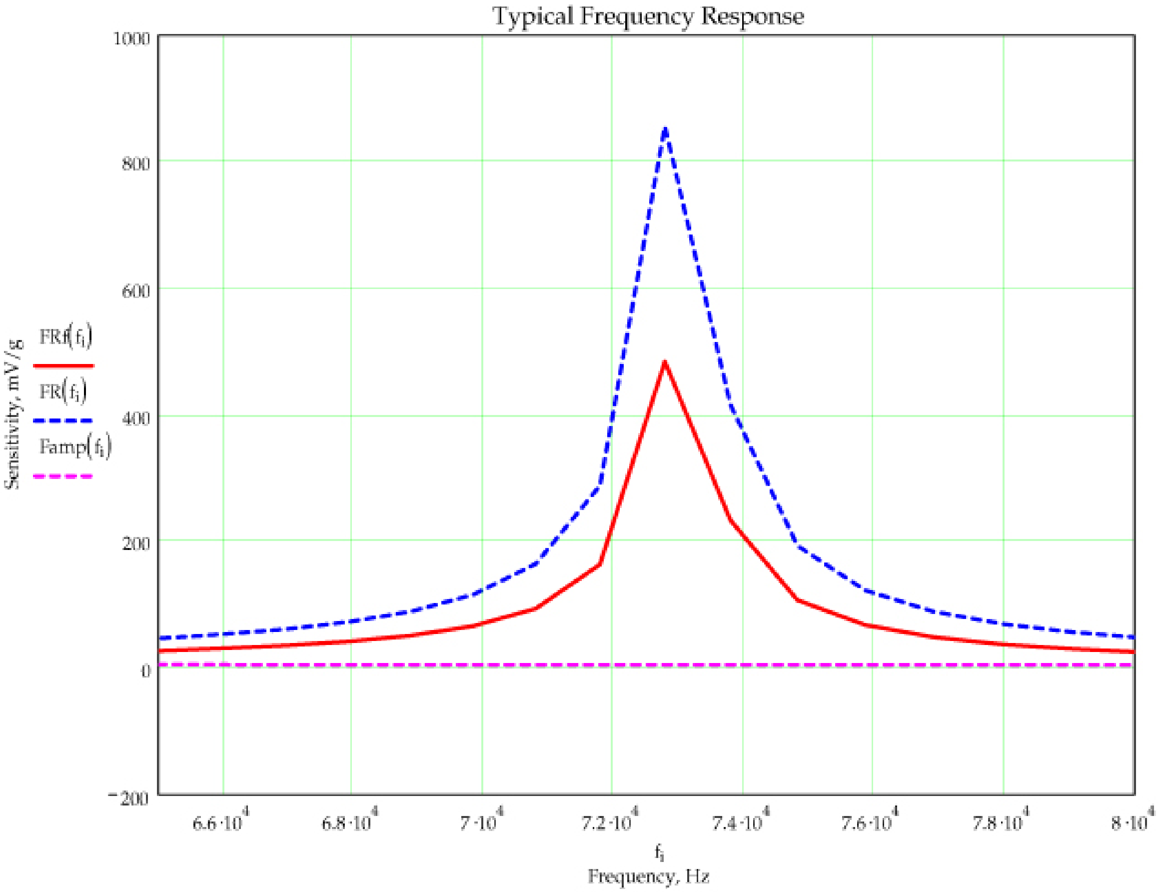
- The filter is typically a “low-pass” type, which attenuates (suppresses) signal generation near the resonant frequency of the sensor.
- This counter-acts the gain, or Q-factor, that is caused by the accelerometer’s mechanical resonance.
- PCB uses either a single pole, or two-pole filter.

Which filter style should be used?

- A **single-pole (-6dB/octave)**, low-pass filter is used primarily for extending the usable frequency range, or when the size of the sensor prevents a two-pole from being used.
- A **two-pole (-12dB/octave)**, low-pass filter is better for preventing amplifier saturation.
- PCB uses two styles of electronic amplifiers in its ICP® accelerometers:
  - Charge amplifiers (used more with ceramic crystal accelerometers)
  - Voltage amplifiers (used exclusively with quartz crystal accelerometers)
- Filters can be added to both types of amplifiers and the results are the same.

Single Pole Filter Effect

- Blue line shows behavior without filter.
- Red line shows behavior with filter.
- Purple line shows filter only behavior.



GRAPH: FILTERED CHARGE AMPLIFIER 65 kHz TO 80 kHz

IMI SENSORS
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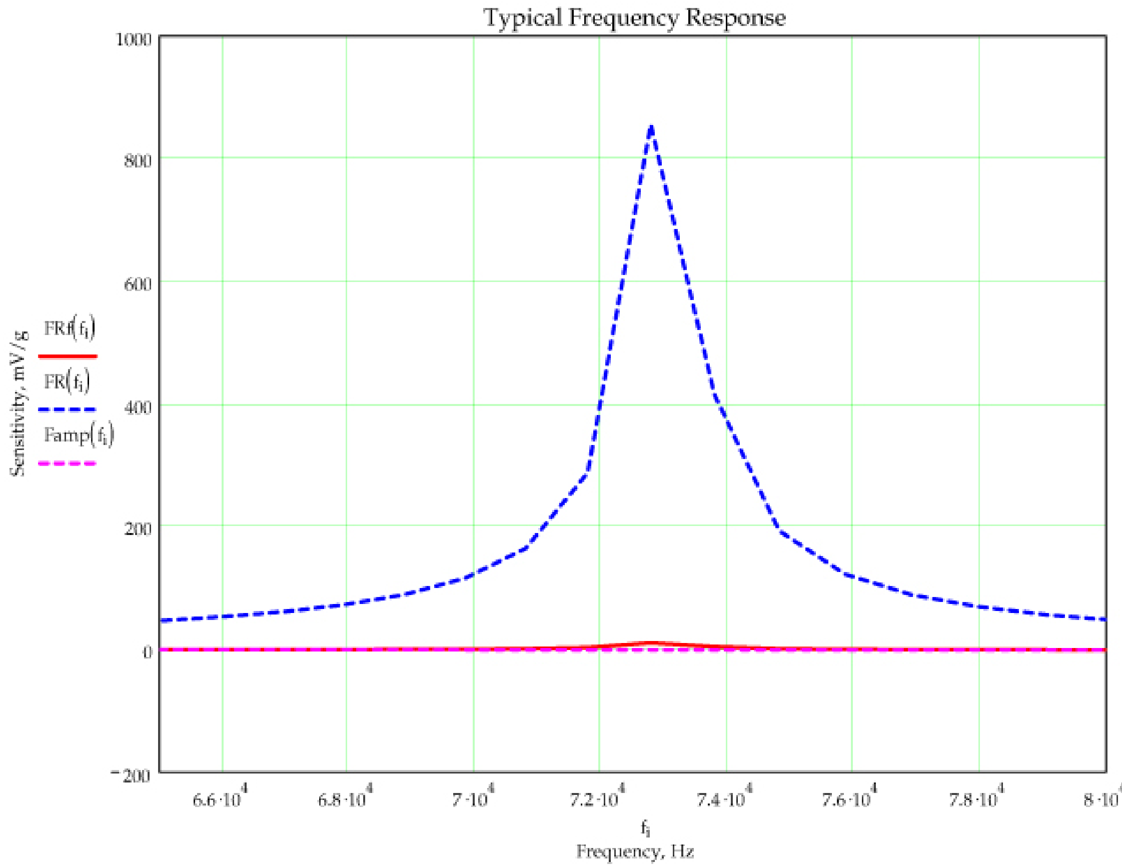
Two Pole Filter Effect

- Blue line shows behavior without filter.
- Red line shows behavior with filter.
- Purple line shows filter only behavior.



GRAPH: 2-POLE FILTERED CHARGE AMPLIFIER 65 kHz TO 80 kHz

IMI SENSORS
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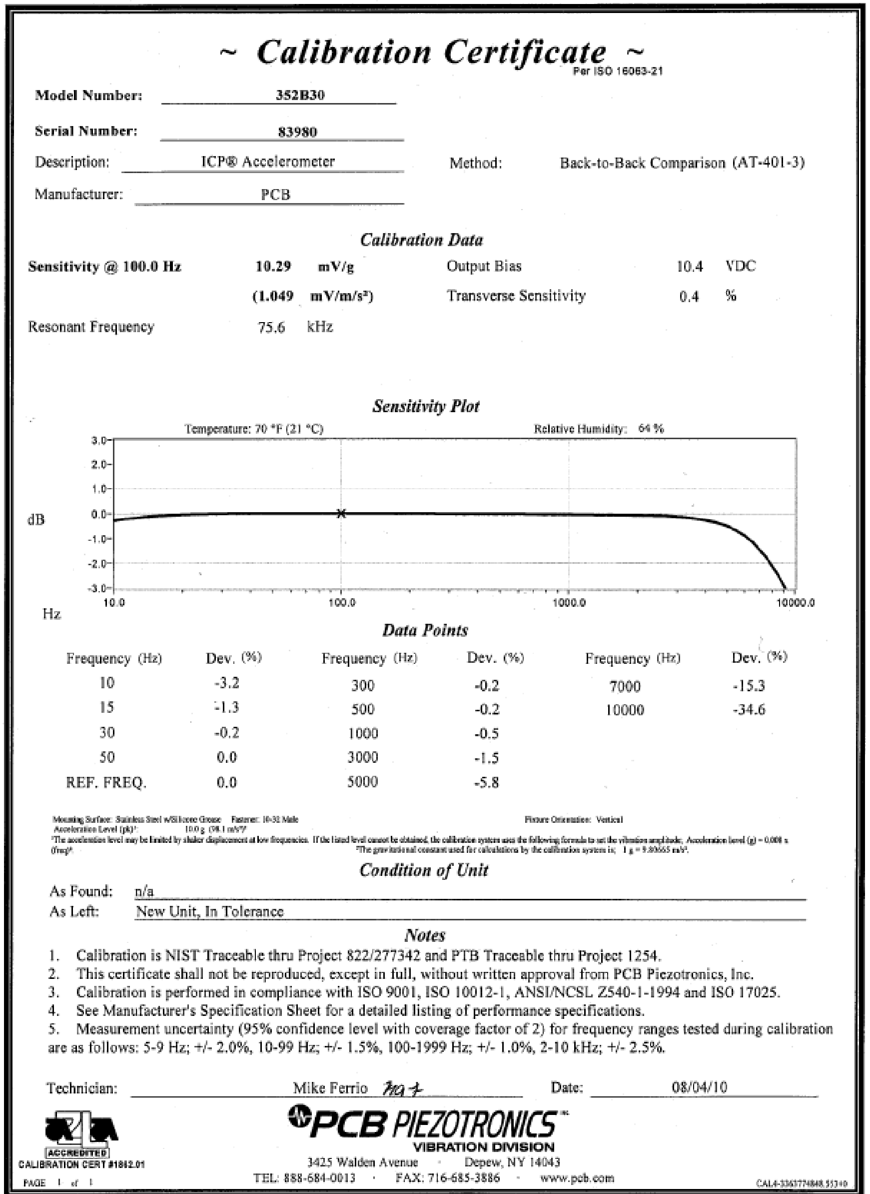
Two Pole Filter Effect



~ Calibration Certificate ~
Per ISO 16063-21

Model Number: 352B30

Serial Number: 83980

Description: ICP® Accelerometer

Method: Back-to-Back Comparison (AT-401-3)

Manufacturer: PCB

Calibration Data

Sensitivity @ 100.0 Hz	10.29 mV/g	Output Bias	10.4	VDC
	(1.049 mV/m/s²)	Transverse Sensitivity	0.4	%
Resonant Frequency	75.6 kHz			

Sensitivity Plot

Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10	-3.2	300	-0.2	7000	-15.3
15	-1.3	500	-0.2	10000	-34.6
30	-0.2	1000	-0.5		
50	0.0	3000	-1.5		
REF. FREQ.	0.0	5000	-5.8		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 10-32 Male Fixture Orientation: Vertical

Acceleration Level (pk)[1]: 10.0 g (98.1 m/s²)[2]

[1]The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration level (g) = 0.008 x (freq)². [2]The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s².

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 822/277342 and PTB Traceable thru Project 1254.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Mike Ferrio Date: 08/04/10

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue · Depew, NY 14043
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

PAGE 1 of 1

Calibration Certificate for model 352B30, which includes a two pole electrical filter

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What is the temperature of the environment?

- Extremely high temperature applications can pose a threat to the electronics built into ICP® accelerometers and 4-20 mA transmitters.
- IMI Sensors offers “HT” or high temperature versions of both ICP® and 4-20 mA sensors.
  - For very high temperature applications such as steam pipe monitoring, charge mode accelerometers are available.
- Charge mode accelerometers do not have built in electronics like ICP® sensors, but instead have remotely located charge amplifiers.
- For ultra-high temperature applications above 500 F, such as gas turbine vibration monitoring, charge mode accelerometers with **integral hard-line cable** are available.

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Will it be submersed in liquid?

- IMI's industrial accelerometers with integral polyurethane cable are completely submersible in liquid for permanent installation to depths corresponding up to 1,000 PSI.
- If the application is not completely submersed but sprayed, such as cutting fluid on machine tools, integral cable is normally recommended as well.

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Will it be exposed to any potentially harmful chemicals or debris?

- IMI’s industrial accelerometers are constructed with stainless steel bodies to be corrosion and chemical resistant.
- If your application is located in an environment with harmful chemicals, consider using PTFE cable with corrosion resistant boot connectors.
- For cables that may come into contact with debris such as cutting chips or workers’ tools, integral armor jacketed cables offer excellent protection.

IMI SENSORS
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Do you prefer a top exit, side exit, or a low profile Swiveler®

- Ultimately, the sensor you select will need to be installed on your equipment in the space available.
- Sensors are available with top and side exit connectors or integral cables.
- IMI's patented Swiveler® design is one of the lowest profile industrial accelerometers available; the locknut design allows the sensor to be oriented in any direction prior to installation which is especially favorable when working with integral cable.

IMI SENSORS
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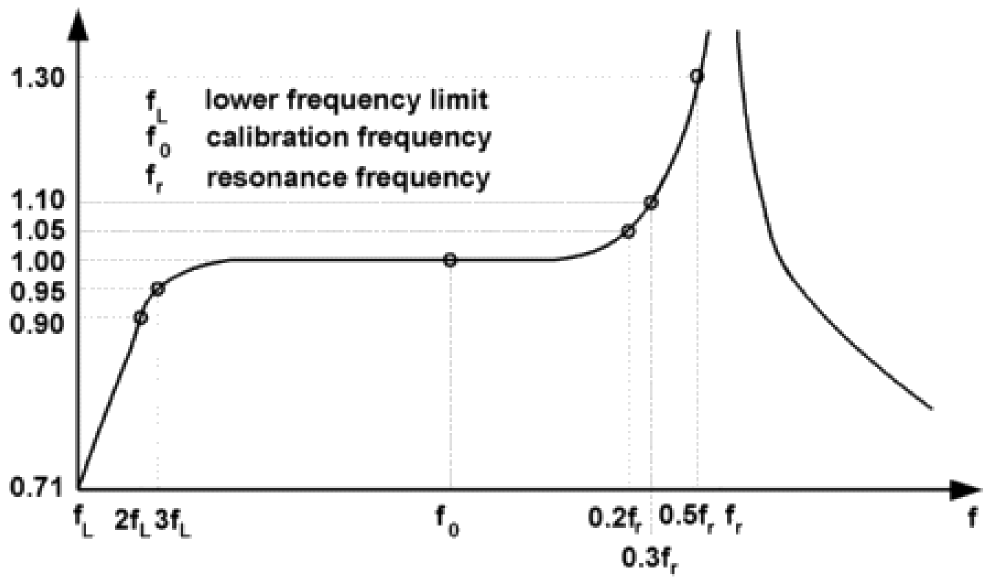
Should you use a precision or low cost sensor?

- Precision accelerometers typically receive a full calibration sweep.
- Low cost accelerometers receive a single point calibration.
- Precision accelerometers have tighter tolerances on some specifications such as sensitivity and frequency ranges.
  - A precision accelerometer may have a nominal sensitivity of 100 mV/g ± 5% (95-105mV/g), while a low cost accelerometer may have a sensitivity of 100 mV/g ± 10% (90-110 mV/g).



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Do you need any special approvals?

- Both ICP® accelerometers and 4-20 mA transmitters are available with CSA and ATEX approvals for use in hazardous areas.
- Many applications in the Energy market require various levels of hazardous area approval.

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Performance Specifications

	ENGLISH	SI	
Performance			
Sensitivity (±10 %)	100 mV/g	10.2 mV/(m/s²)	[1]
Measurement Range	±50 g	±490 m/s²	
Frequency Range (±3 dB)	30 to 600000 cpm	0.5 to 10000 Hz	[4]
Resonant Frequency	1500 kcpm	25 kHz	[2]
Broadband Resolution (1 to 10000 Hz)	350 µg	3434 µm/sec²	[2]
Non-Linearity	±1 %	±1 %	[3]
Transverse Sensitivity	≤7 %	≤7 %	

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Sensitivity

- By design, piezoelectric accelerometers are intended to generate an electrical signal when they are subjected to acceleration. This response is termed the ***sensitivity*** and is primarily expressed in the following units:
  - mV/g
  - mV/(m/s^2)
  - pC/g
  - pC/(m/s^2)

Model Number 352C03	ACCELEROMETER,		
Performance	**ENGLISH**	**SI**	
Sensitivity (±10 %)	10 mV/g	1.02 mV/(m/s²)	
Measurement Range	±500 g pk	±4900 m/s² pk	
Frequency Range (±5 %)	0.5 to 10000 Hz	0.5 to 10000 Hz	
Frequency Range (±10 %)	0.3 to 15000 Hz	0.3 to 15000 Hz	
Resonant Frequency	≥50 kHz	≥50 kHz	
Broadband Resolution (1 to 10000 Hz)	0.0005 g rms	0.005 m/s² rms	[1]
Non-Linearity	≤1 %	≤1 %	[3]
Transverse Sensitivity	≤5 %	≤5 %	

Model Number 357B04	ACCELEROMETER, CHARGE			
Performance	**ENGLISH**	**SI**		Opt
Sensitivity (±15 %)	10 pC/g	1.02 pC/(m/s²)		for
Measurement Range	±2000 g pk	±19600 m/s² pk		J
Frequency Range (+5 %)	9 kHz	9 kHz	[2]	
Frequency Range (+10 %)	12 kHz	12 kHz	[2]	
Frequency Range (+3 dB)	18 kHz	18 kHz	[2]	
Resonant Frequency	≥38 kHz	≥38 kHz		
Non-Linearity	≤1 %	≤1 %	[3]	
Transverse Sensitivity	≤5 %	≤5 %		

IMI SENSORS
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Sensitivity

- – Typically 10, 100, 500 mV/g
  - Tolerance ±5, ± 10, or ± 15%
- – 100 mV/g is the most typical sensitivity for industrial monitoring
- – Maximum output is 5 v so the range for a 100 mV/g sensor is 50 g
- – Calibration shows actual measured sensitivity
  - Low cost - single point calibration @ 100 Hz
  - Precision - have full calibration

Measurement Range

- How much output may be obtained during a reading.

Positive Swing:

Supply Voltage – 1 Volt (for cc Diode) – Non-Linear Region - Sensor Bias Voltage

Bias Voltage is the baseline ---

Negative Swing:

Bias Voltage – 2 Volts (readings below 2 volts may be poor)

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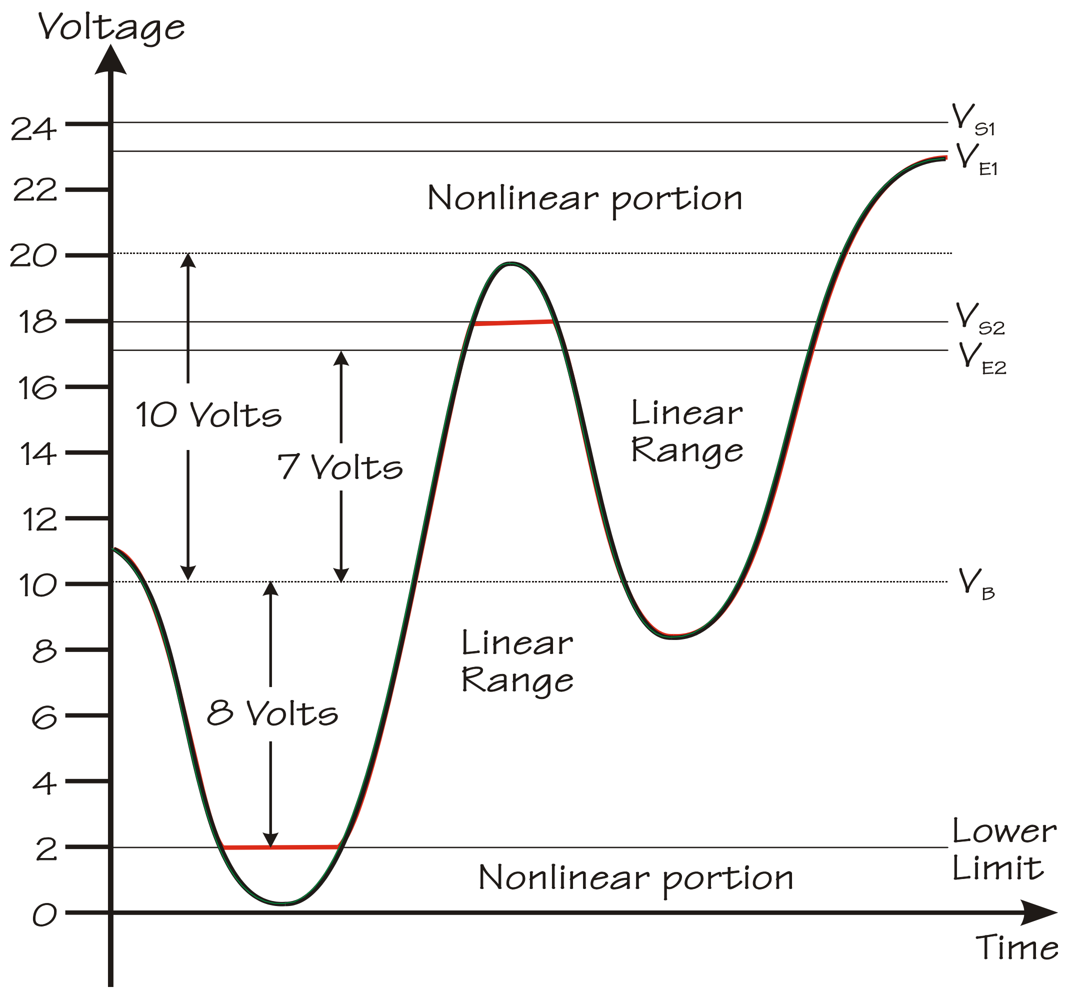
Measurement Range



V_B = Sensor Bias Voltage = 10 VDC

V_{S1} = Supply Voltage 1 = 24 VDC
V_{E1} = Excitation Voltage 1 = V_{S1} -1 = 23 VDC
- **- non-linear portion**
- **Output Signal (+10V / -8V)**

V_{S2} = Supply Voltage 2 = 18 VDC
V_{E2} = Excitation Voltage 2 = V_{S2} -1 = 17 VDC
- **Output Signal (+7V / -8V)**

Bias Voltage Varies from 8VDC to 14VDC
(Voltage swing can be compromised)

Specified amplifier range = +/- 5 Volts
Actual max. amp. range = +/- 10 Volts

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Frequency Range

- Sensors respond to all frequencies
  - High frequency response
    - Mechanical structure of sensor
    - Mounting plays a significant role
    - Cable driving may also affect signal
  - Low frequency response
    - Sensor Discharge Time Constant
    - System Coupling Time Constant

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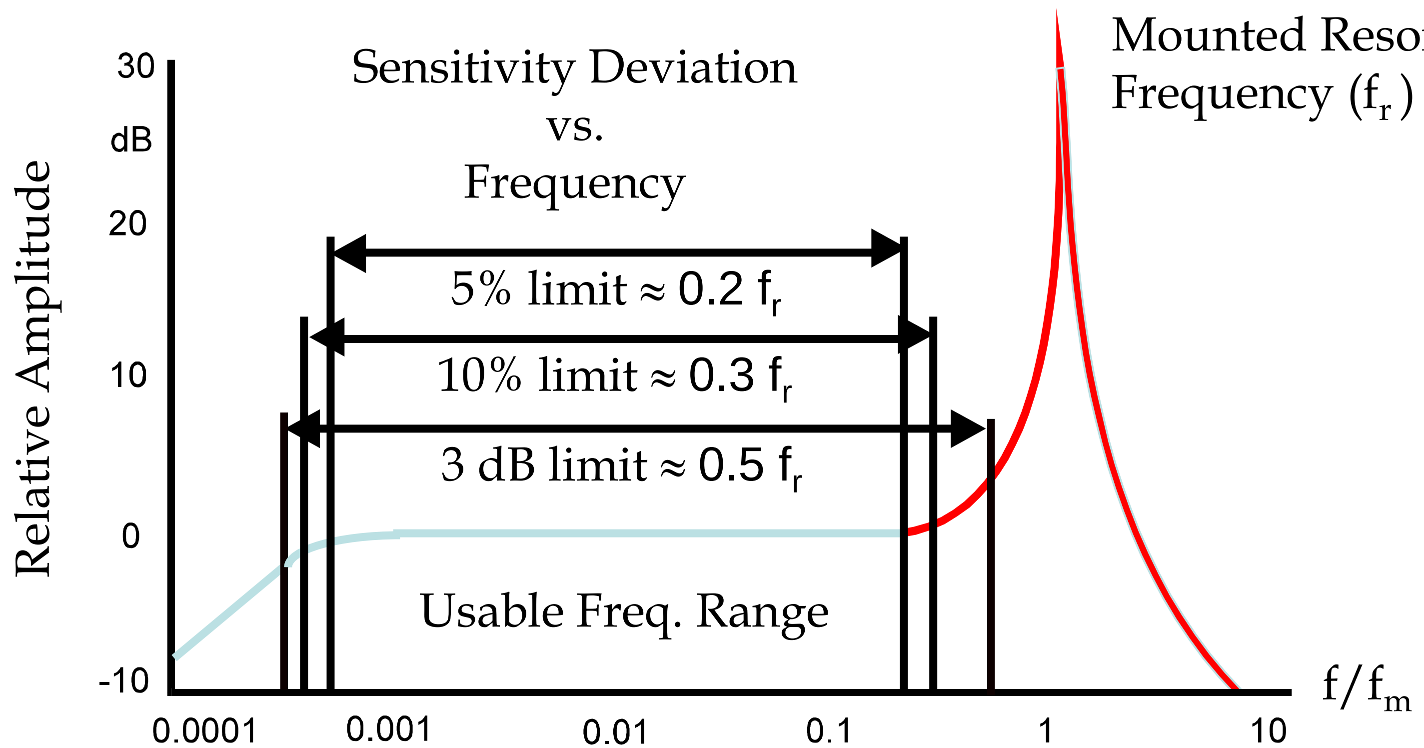
Frequency Range

- Ideal accelerometer treats frequencies of interest the same.



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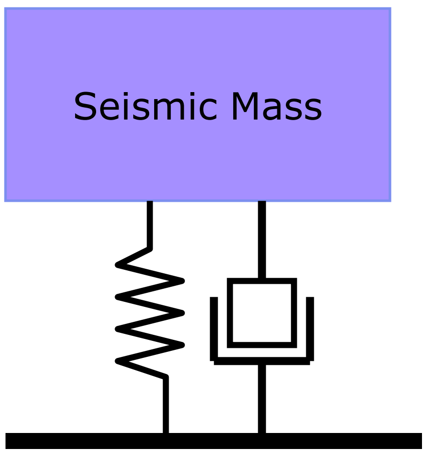
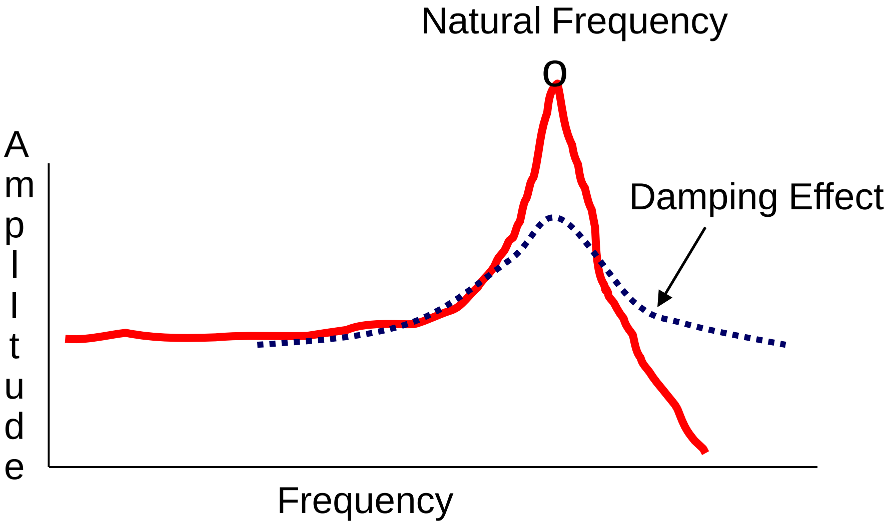
High Frequency Response

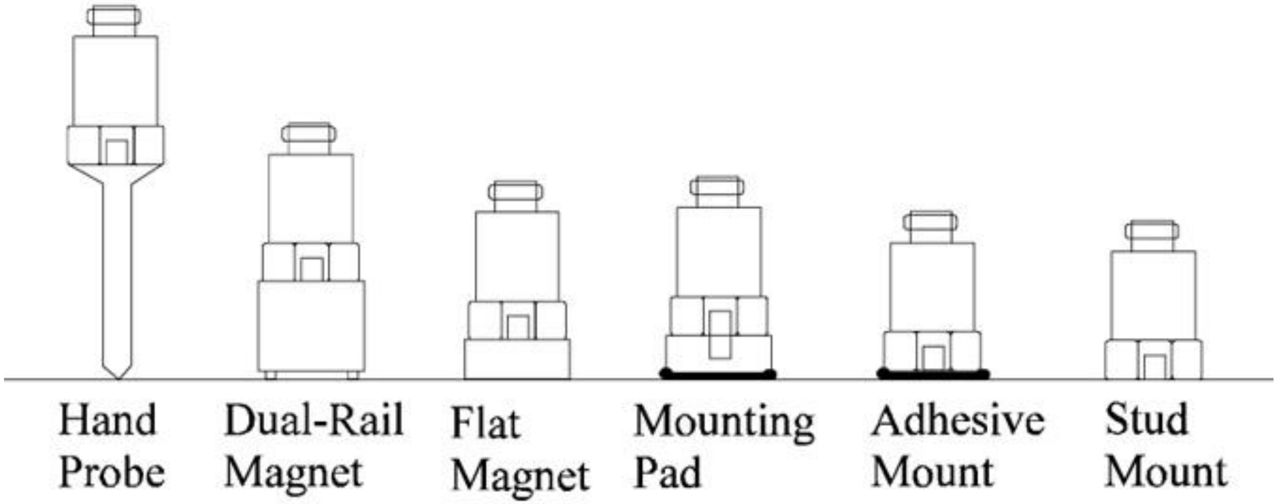
- The upper frequency range of an accelerometer is dependent upon its overall mass, the stiffness of the sensing element, and the amount of damping, if any. The structure will resonate, or ring, at its natural frequency.





Mounted Resonant Frequency

- The mounted resonant frequency for an accelerometer takes into account the additional mass and stiffness associated with the mounting technique used to connect it to the structure under test.



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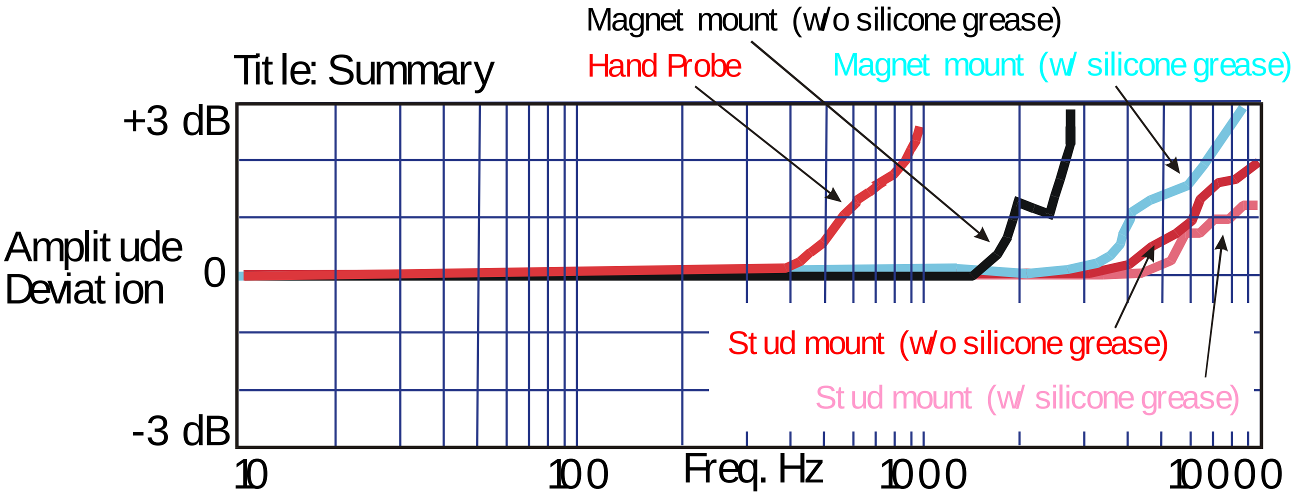
Mounting Frequency Response

- Stud mount (w/ Silicone grease)
- Stud mount (w/o Silicone grease)
- Magnet mount (w/ Silicone grease)
- Magnet mount (w/o Silicone grease)
- Hand Probe



Note: Numbers are for reference only. Actual FR of similar mounts can vary widely.

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Mounting Frequency Response

- The following plots show the frequency and phase response of various mounts as measured with a lab calibration system
  - Stud mounted
  - 0.75”, 15# pull flat magnet
  - 0.75”, 15# pull 2-rail (curved surface) magnet
  - 4” Stainless steel probe (stinger)
    - Photo of probe

IMI SENSORS
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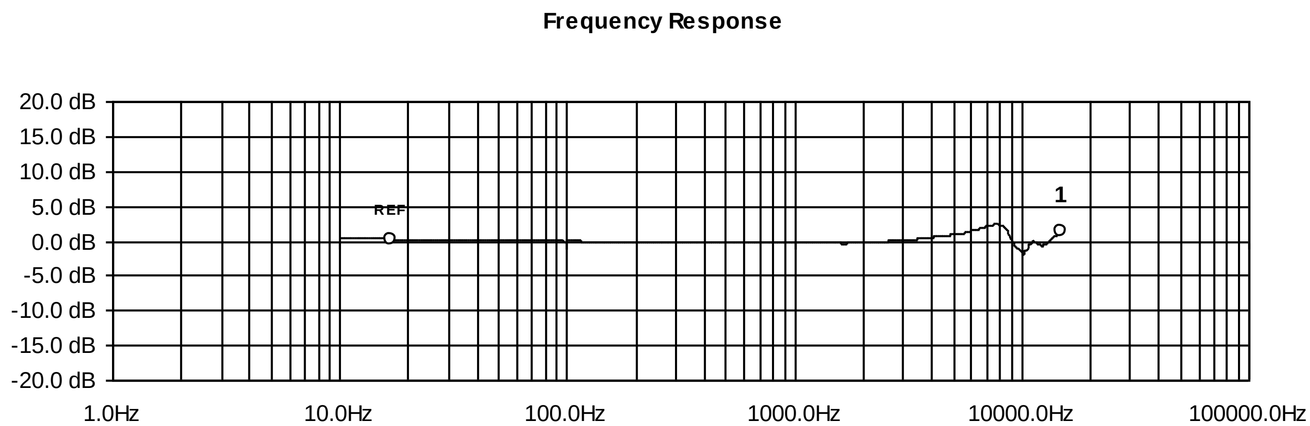
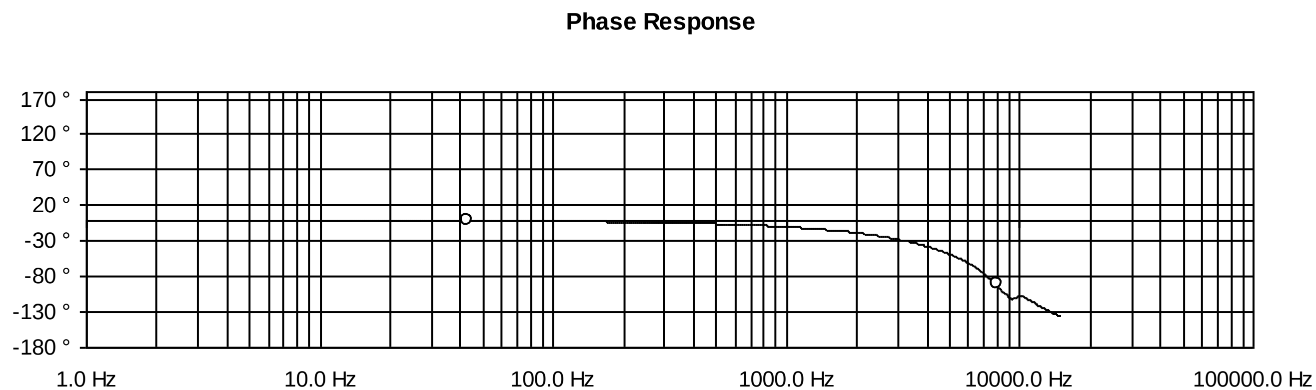
603C01 – 1” Mounting Pad – Stud Mounted





Frequency Response (5%) = 3772 Hz
Frequency Response (3 dB) = >15 kHz
90° Phase Shift = 7983 Hz

IMI SENSORS
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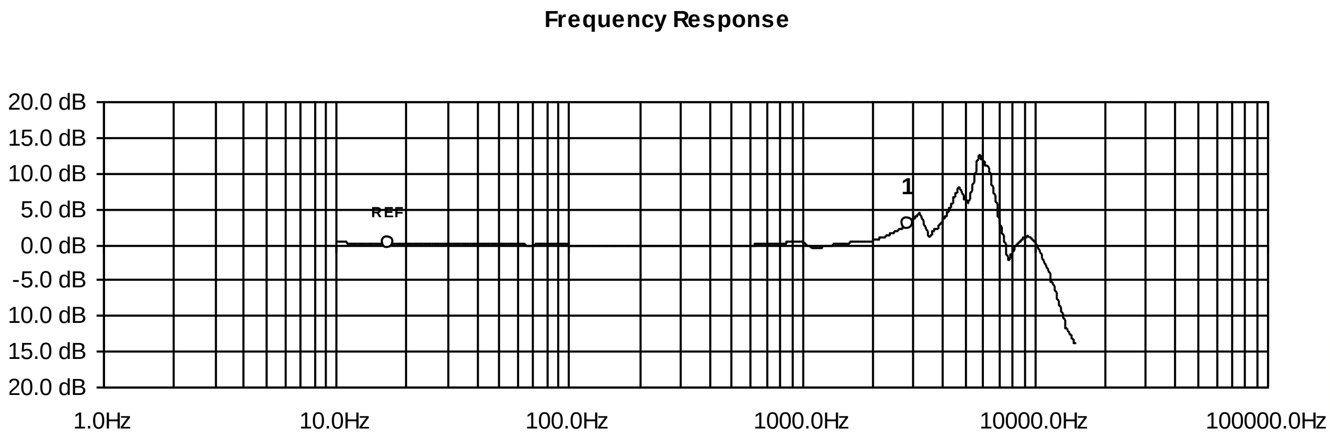
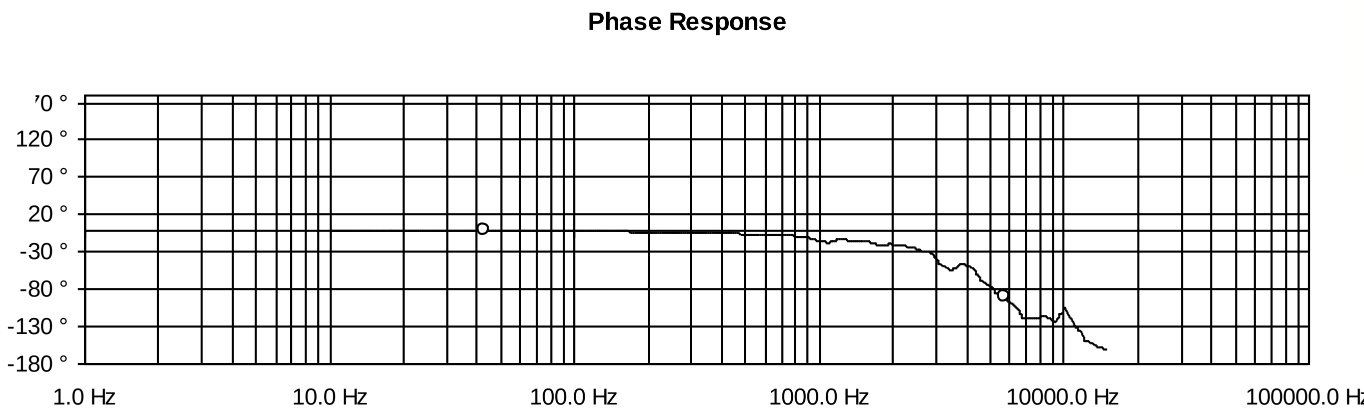
603C01 – 1” Mounting Pad – 0.75” Flat Magnet





Frequency Response (5%) = 1918 Hz
Frequency Response (3 dB) = 3949 Hz
90° Phase Shift = 5692 Hz

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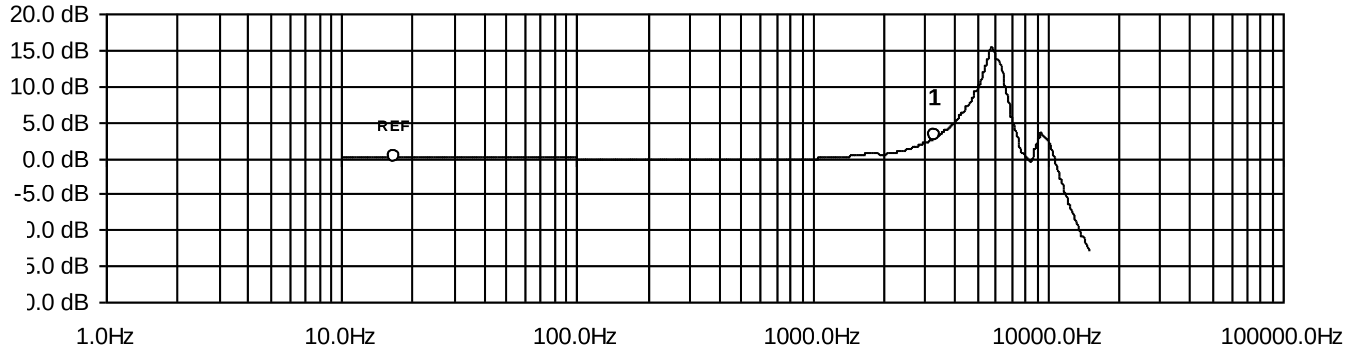
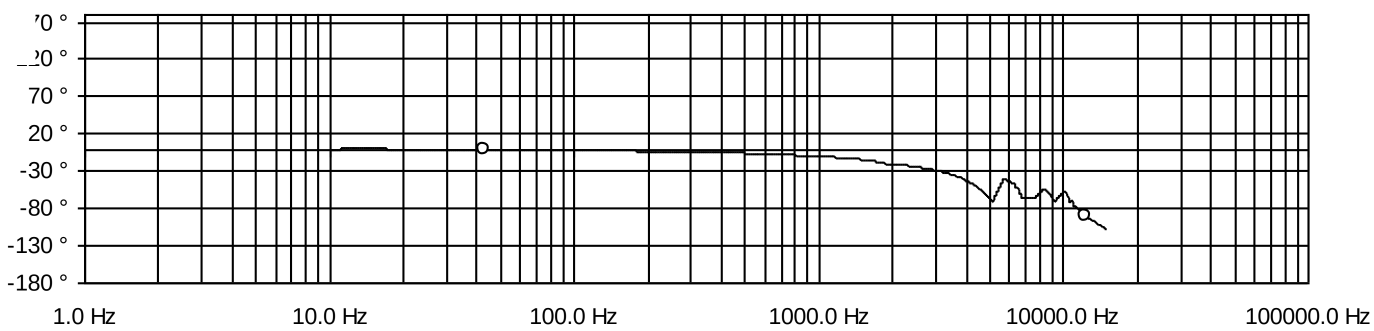
603C01 – 1” Mounting Pad – 0.75” Curved Surface Magnet

Frequency Response



Phase Response



Frequency Response (5%) = 1554 Hz
Frequency Response (3 dB) = 3350 Hz
90° Phase Shift = 12380 Hz

IMI SENSORS
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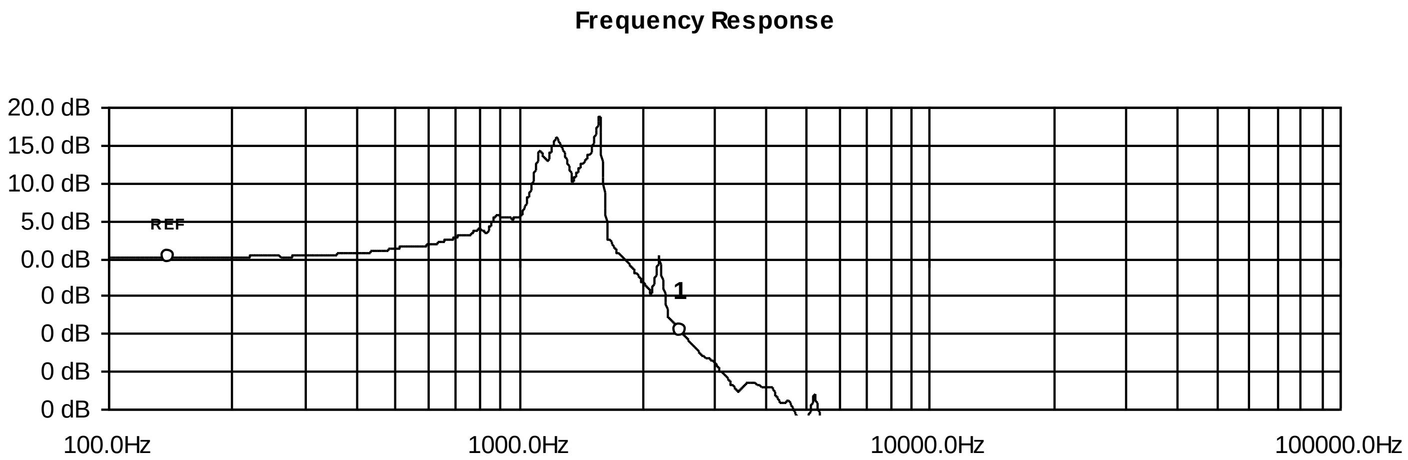
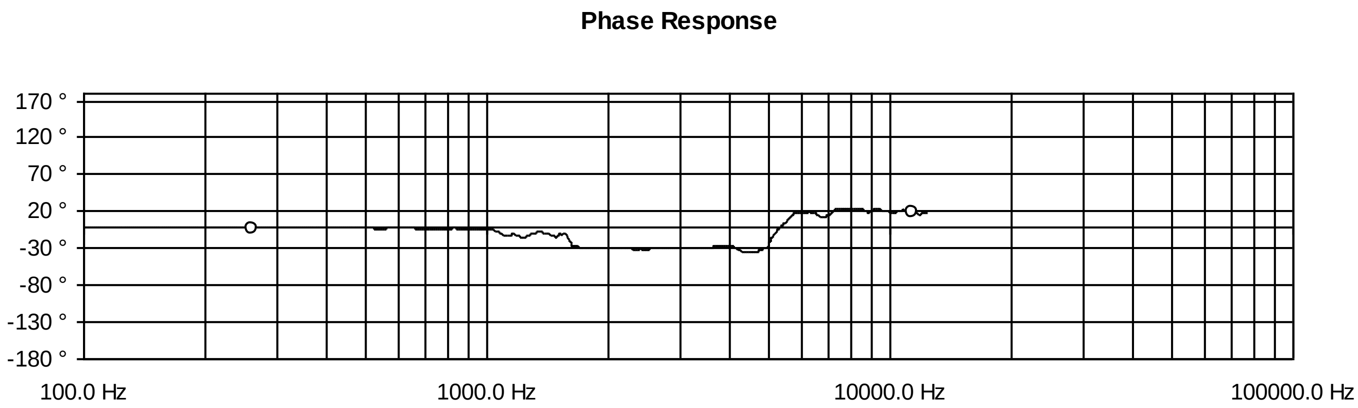
603A01 with 4” Steel Probe





Frequency Response = 715 Hz

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Low Frequency Response

- Low frequency response of an accelerometer is determined by the electrical characteristics of the measurement system.
- Piezoelectric accelerometers are inherently AC coupled and will not respond to DC. (MEMS accelerometers can)
- The following terms are inherent to piezoelectric (PE) accelerometers:
  - AC Coupling
  - Discharge Time Constant
  - High Pass Filter
  - Low Frequency Roll-off

IMI SENSORS
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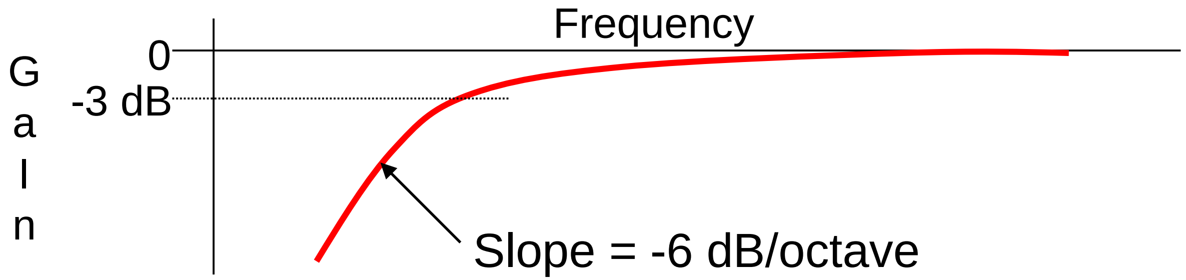
Low Frequency Response

- Since the DTC is essentially a first-order high pass filter, the frequency response profile of the filter will look something like this:



- The relationship between DTC and the attenuation at various frequencies can be represented by the following:

$f_{-5\%} = 0.5/DTC$
$f_{-10\%} = 0.34/DTC$
$f_{-3dB} = 0.16/DTC$

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Sensor Low Frequency Response

DTC (sec)	Frequency (Hz)		
	-5%	-10%	-3dB
.1	5	3.4	1.6
.5	1	.68	.32
1	.5	.34	.16
5	.1	.07	.03
10	.05	.03	.016

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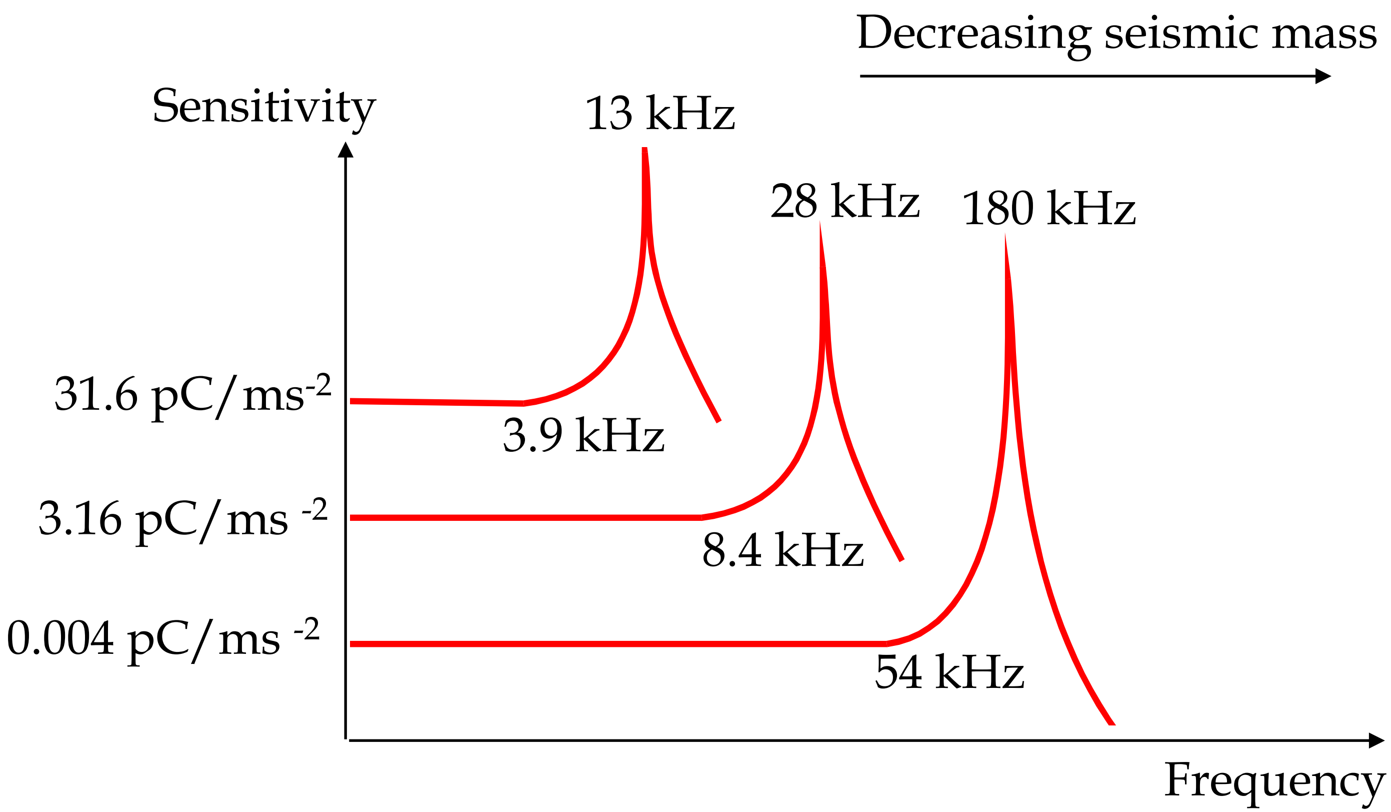
Resonant Frequency of Accelerometer

- Determined by mass and rigidity of design



IMI SENSORS
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Resolution (Noise Floor)

- How low can we measure?
- Electrical characteristic
  - ICP® - Noise floor of internal electronics
  - Charge – Noise of the external charge amplifier
- For Accelerometers
  - **Broadband – the average lowest level over a frequency range.**
  - Spectral – The resolution at a specified frequency.
- Generally, measure x10 above resolution to stay out of electrical noise.

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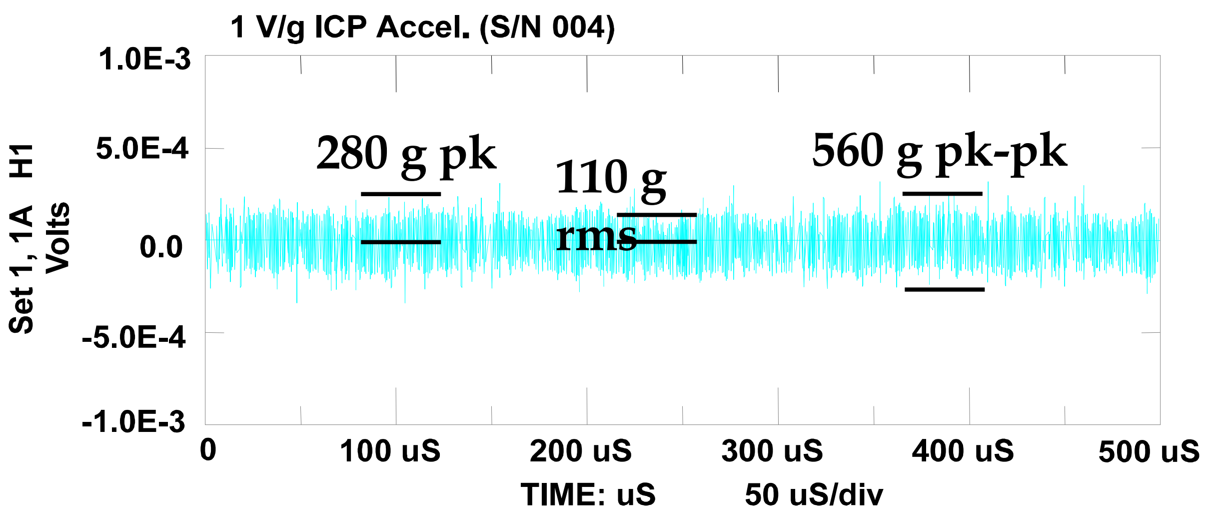
Resolution- Broad Band Noise

- Broadband Noise- Time Domain



IMI SENSORS
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Resolution- Broad Band Noise

- Rotating Machinery
  - Vibration Alert Levels and Running Speed?
  - 600RPM to 10,000RPM
    - 0.1 ips-peak
  - 100RPM
    - 0.02 ips-peak (380µg rms)
    - S/N Ratio of 5 (minimum)
    - 80µg resolution (broadband)

Model: 625B02
Low Frequency Industrial
ICP® Accelerometer

Performance

Sensitivity (±5 %)	500 mV/g	51 mV/(m/s²)
Measurement Range	±10 g	±98 m/s²
Frequency Range (±5 %)	30 to 120000 cpm	0.5 to 2000 Hz
Frequency Range (±10 %)	22 to 240000 cpm	0.37 to 4000 Hz
Frequency Range (±3 dB)	12 to 360000 cpm	0.2 to 6000 Hz
Resonant Frequency	720 kcpm	12 kHz
Broadband Resolution (1 to 10000 Hz)	15 µg	147 µm/sec²
Non-Linearity	±1 %	±1 %
Transverse Sensitivity	≤7 %	≤7 %

IMI SENSORS
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Resolution- Broadband Noise

- PCB measures broadband noise between 1 Hz and 10 kHz.
  - More noise is present in lower frequencies.
- Some competitors will start their measurements at 5 Hz or 10 Hz.
  - By starting the measurement at a higher frequency the sensor could appear to have a "better" noise floor.

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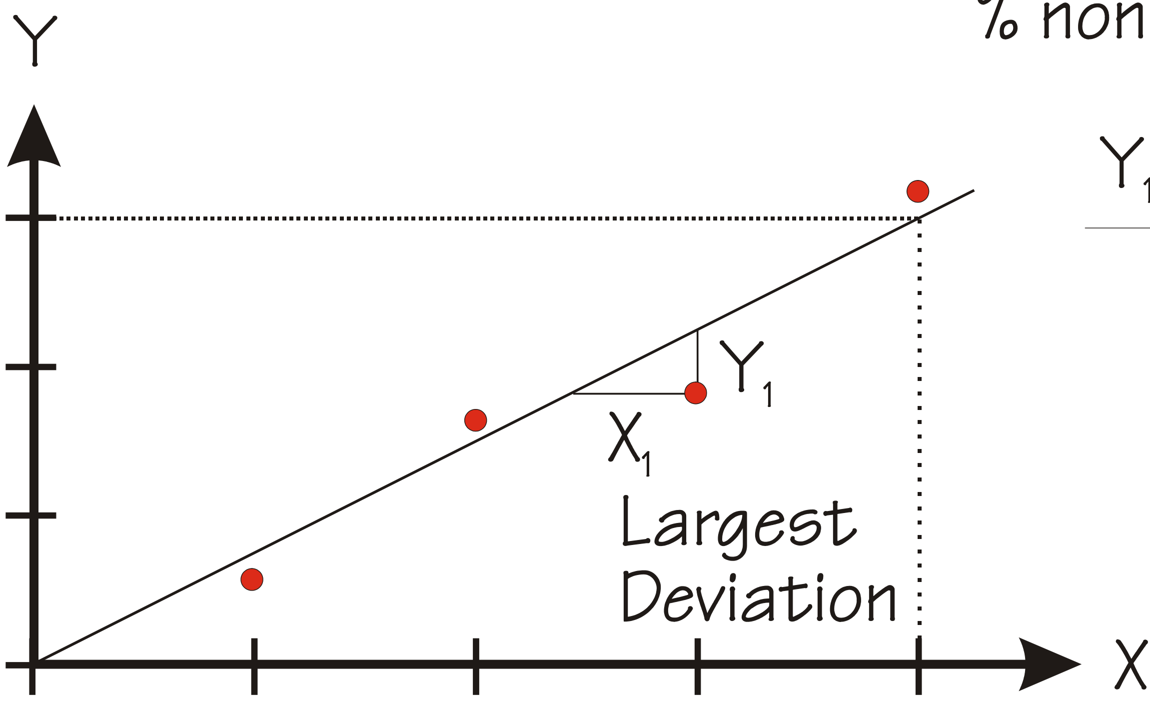
Non-linearity

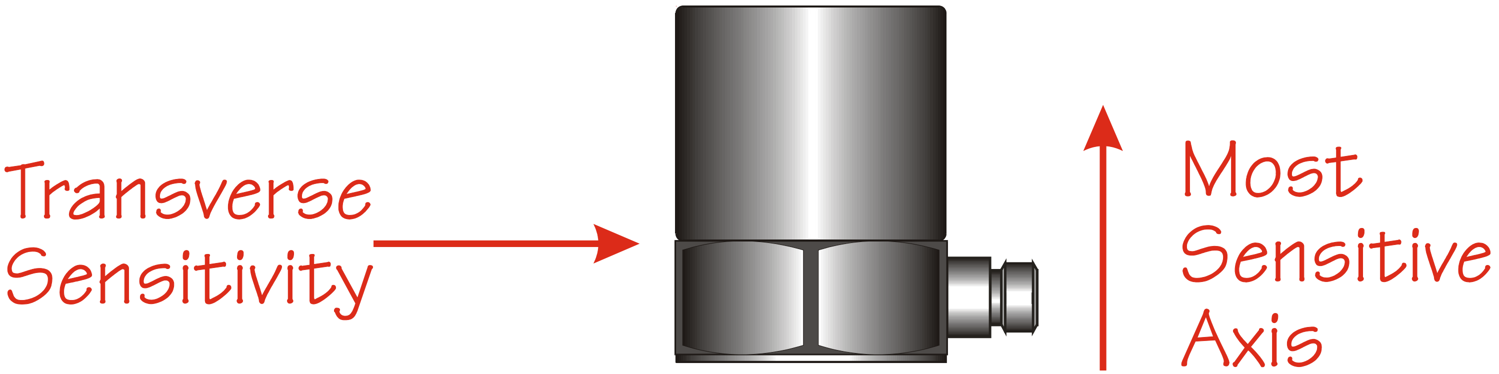
- Defined as % of F.S.O and determined as the best fit straight line through the zero:



$$\% \text{ non-linearity} = \frac{Y_1 * 100}{Y}$$

Transverse Sensitivity

- Represents the output of the accelerometer if an acceleration is applied at 90 degrees of the most sensitive axis.



Transverse Sensitivity

- At PCB, all accelerometers are tested for transverse sensitivity.
- Transverse sensitivity is caused by:
  - Misalignment of parts
  - Improper mounting of the sensor (flatness, perpendicularity)

IMI SENSORS
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Environmental Specifications

Environmental			
Overload Limit (Shock)	5000 g pk	49050 m/s² pk	
Temperature Range	-65 to +250 °F	-54 to +121 °C	
Temperature Response	See Graph %/°F	See Graph %/°F	[2]
Enclosure Rating	IP68	IP68	

IMI SENSORS
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Overload Limit (Shock)

- Sensors can also go into an “over-load” condition without damage
  - However, it may take sensor anywhere from 10 microseconds to 24 hours for the sensor to re-stabilize.
  - This depends on:
    - Type of overload
      - Electronic or Mechanical overload
      - Ceramic destabilization - “jitter” or “noise”
    - Amount of overload

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Overload Limit (Shock)

- Caused by:
  - – Magnetic mounting
  - – Dropping the sensor
  - – Impacting nearby
  - – Careless installation or removal
- Factors involved:
  - – Pulse duration (Frequency content)
    - Metal to Metal vs. Softer material
  - – ‘g’ level

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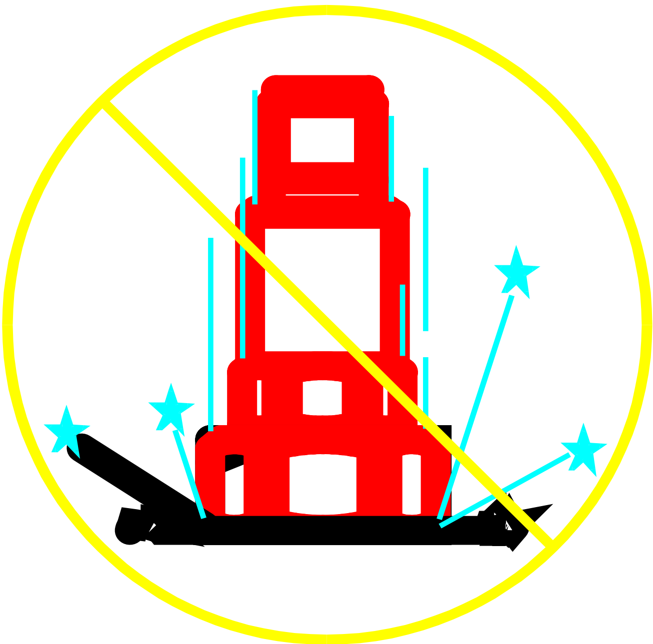
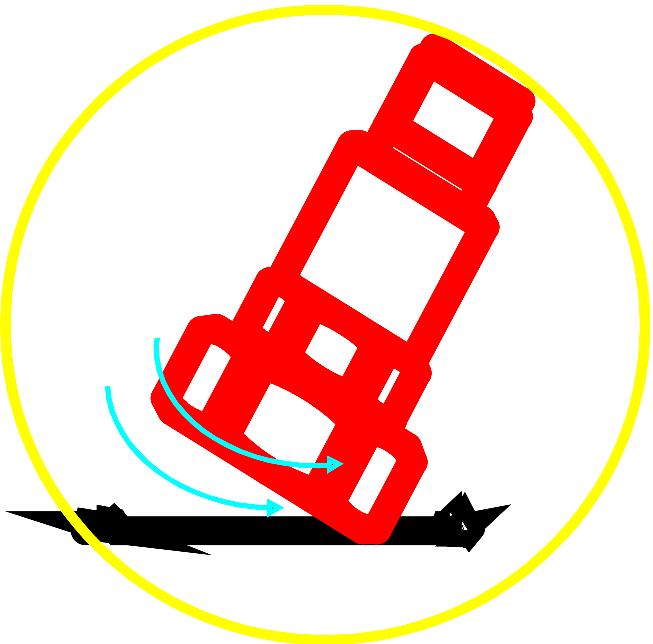
Shock Protection

- Test Set-up



"SNAP" METHOD



"ROCKING" METHOD

MAGNETIC MOUNTING

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Temperature Range

- the ideal working range of the sensor.

- Most ICP® sensors are:
  - 73 to 135°C (-100 to + 275°F)

- Most charge sensors are:
  - 240 to +204°C (-400 to +400°F)

- High Temperature Ranges Available
  - 357C9X…ie 357C90… 650°C (1,200 °F)

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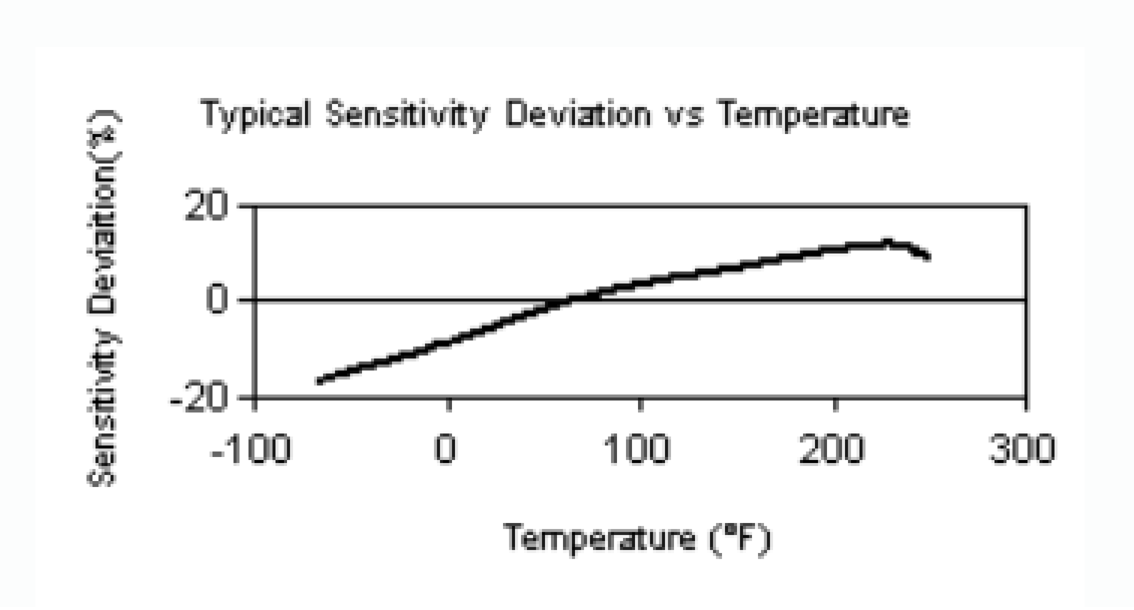
Temperature Response (Coefficient)

– the % change in sensitivity per degree change in temperature

- Usually 0.054%/°C (0.03%/°F)
- For every 100°C temperature change, sensitivity will change 5.4%



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Temperature Precautions

- Thermal Transients can cause signal drift
  - Expansion of the parts surrounding the sensing element cause changes in preload
  - Changes in Preload result in change in sensitivity, thus possible drift.
- Sensors with longer DTC are susceptible to Signal drift.
- Shear design eliminates thermal transient response.

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Enclosure Rating

IP Ratings (Ingress Protection)

A two-digit number established by the International Electro Technical Commission representing different forms of environmental influence:

- **The first digit represents protection against ingress of solid objects.**
- **The second digit represents protection against ingress of liquids.**
- **The larger the value of each digit, the greater the protection.**

IP..	First digit: Ingress of solid objects	Second digit: Ingress of liquids
0	No protection	No protection
1	Protected against solid objects over 50mm e.g. hands, large tools.	Protected against vertically falling drops of water or condensation.
2	Protected against solid objects over 12.5mm e.g. hands, large tools.	Protected against falling drops of water, if the case is disposed up to 15 from vertical.
3	Protected against solid objects over 2.5mm e.g. wire, small tools.	Protected against sprays of water from any direction, even if the case is disposed up to 60from vertical.
4	Protected against solid objects over 1.0mm e.g. wires.	Protected against splash water from any direction.
5	Limited protection against dust ingress. (no harmful deposit)	Protected against low pressure water jets from any direction. Limited ingress permitted.
6	Totally protected against dust ingress.	Protected against high pressure water jets from any direction. Limited ingress permitted.
7	N/A	Protected against short periods of immersion in water.
8	N/A	Protected against long, durable periods of immersion in water.
9k	N/A	Protected against close-range high pressure, high temperature spray downs.

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Electrical Specifications

Electrical			
Settling Time (within 1% of bias)	≤2.0 sec	≤2.0 sec	
Discharge Time Constant	≥0.3 sec	≥0.3 sec	
Excitation Voltage	18 to 28 VDC	18 to 28 VDC	
Constant Current Excitation	2 to 20 mA	2 to 20 mA	
Output Impedance	<150 Ohm	<150 Ohm	
Output Bias Voltage	8 to 12 VDC	8 to 12 VDC	
Spectral Noise (10 Hz)	8 µg/√Hz	78.5 (µm/sec^2)/√Hz	[2]
Spectral Noise (100 Hz)	5 µg/√Hz	49.1 (µm/sec^2)/√Hz	[2]
Spectral Noise (1 kHz)	4 µg/√Hz	39.2 (µm/sec^2)/√Hz	[2]
Electrical Isolation	>100000000 Ohm	>100000000 Ohm	

Settling Time

– The amount of time that a sensor must be powered before a measurement can be made
– The higher the DTC, the longer the settling time.
    - A conservative rule of thumb to follow is that a settling time of 10 times the discharge time constant will allow the signal to decay to within 1% of the output bias.
– Typically 2 to 10 seconds
– This is of concern when running routes with permanently mounted sensors

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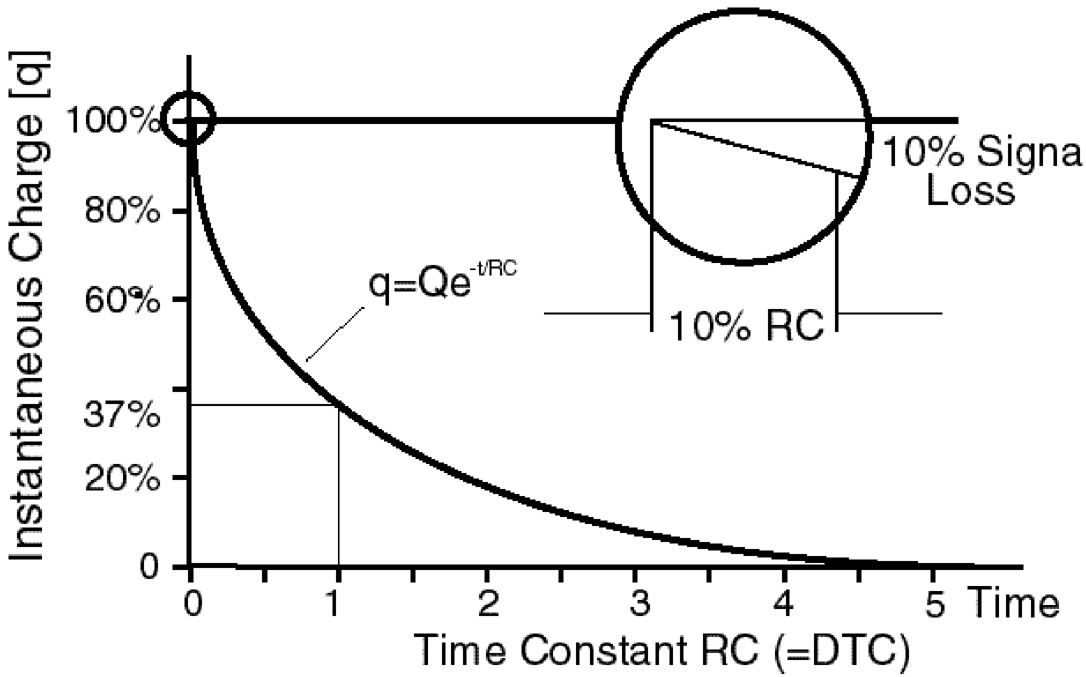
Discharge Time Constant

After a step change in measurand, the DTC is the time required for a sensor or measurement system to discharge its signal to 37% of the original step input value.

There is a direct relationship between DTC and low frequency response.

-The longer the DTC, the lower the frequency of measure



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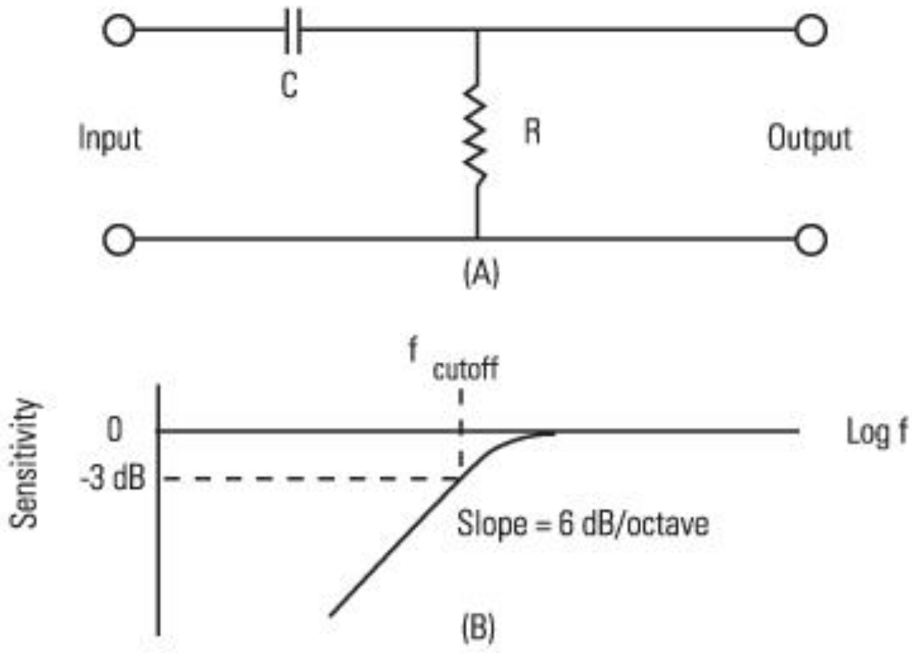
Discharge Time Constant

- The Discharge Time Constant is a function of the electronics.
- The DTC of an ICP® (IEPE) sensor establishes the low-frequency response analogous to the action of a first order, high-pass, RC filter.



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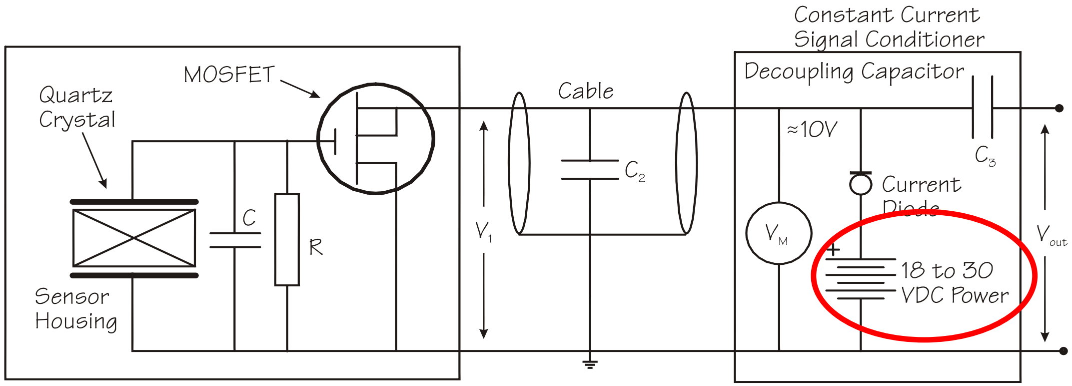
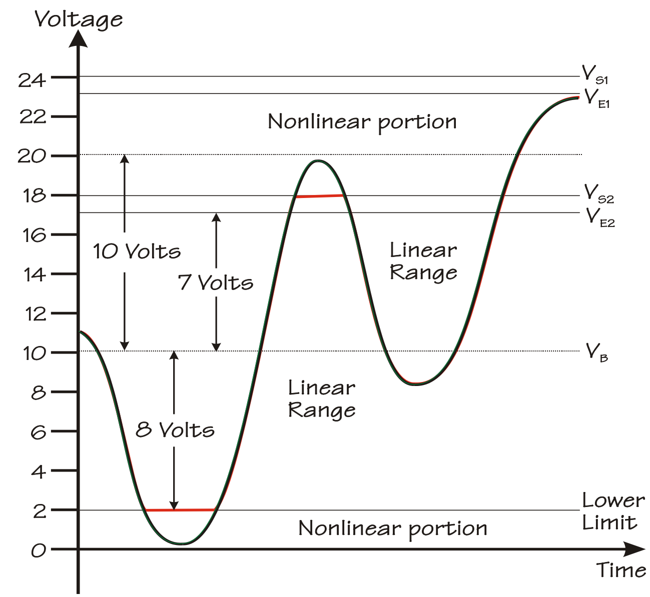
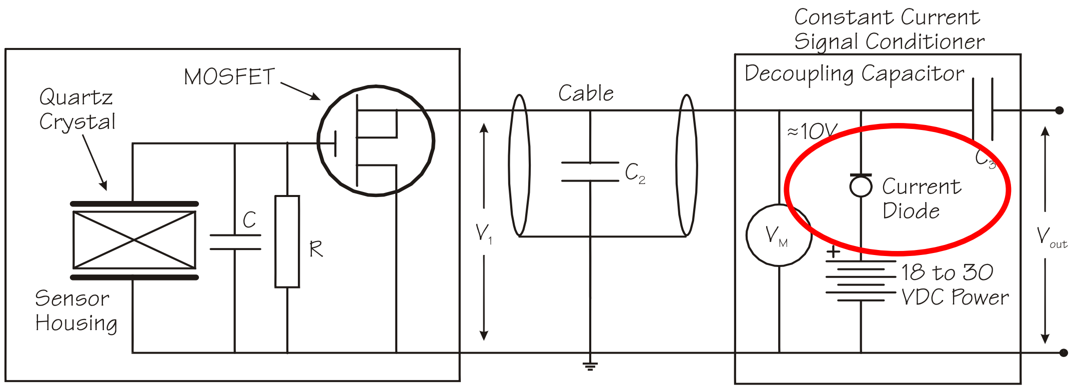
Excitation Voltage

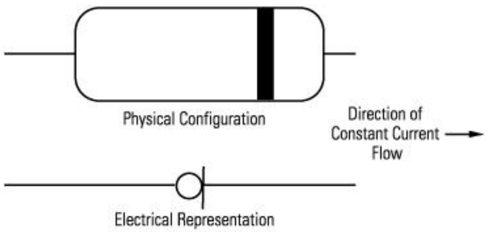




Constant Current Excitation

- The electronics within ICP accelerometers require excitation power from a constant-current regulated, DC voltage source.
  - This power source is sometimes built into vibration meters, FFT analyzers, and vibration data collectors. A separate signal conditioner is required when none is built into the readout.
- The constant current may vary between 2 and 20 mA.
  - A constant current value of 4 mA is typical for most devices.
  - Higher adjustments can be made to drive longer cable runs.





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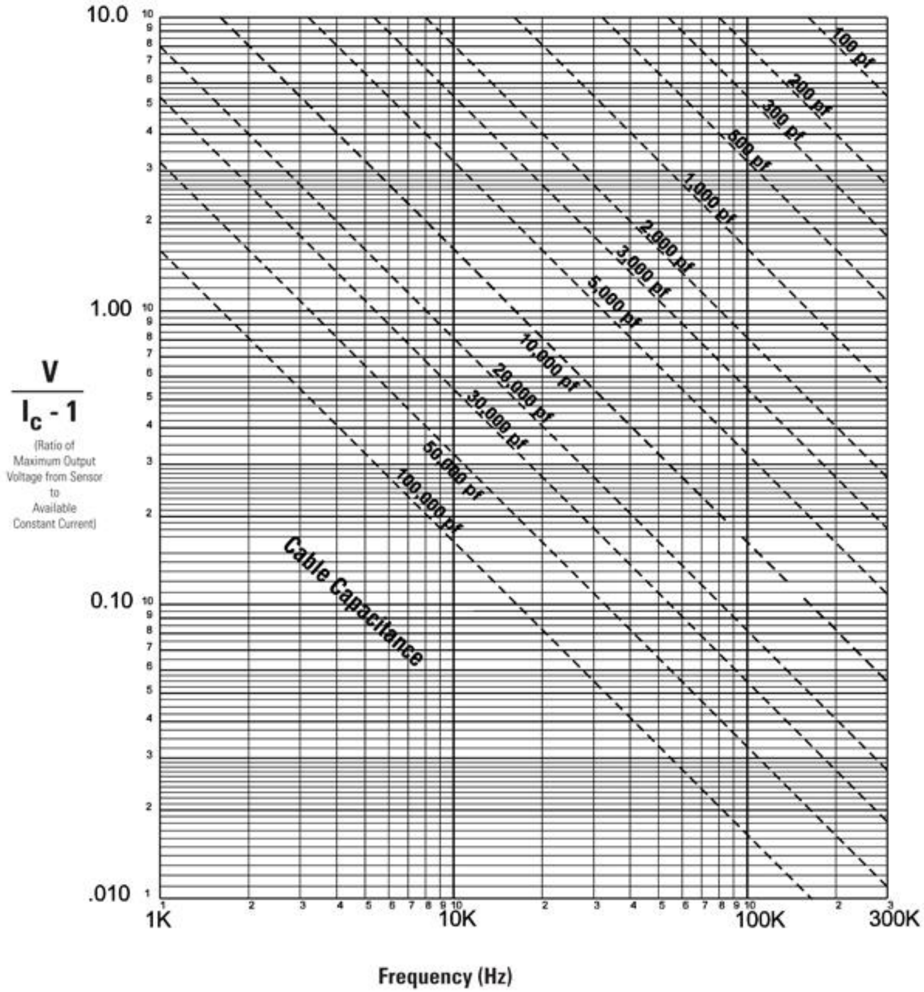
Output Impedance



$$f_{max} = \frac{10^9}{2\pi CV / (I_c - 1)}$$

f_{max} = Maximum frequency (Hz)
C = Cable capacitance (pF)
V = Maximum output voltage from sensor (volts)
I_c = Constant current level from power unit (mA)
10^9 = Scale factor to equate units

- ICP® (IEPE) accelerometers have very low output impedance (<150Ω)
  - This improves S/N and ability to drive signal over hundreds of feet of cable through harsh environments.
- The maximum frequency that can be transmitted over a given cable length can be calculated or obtained from this nomograph.

$$f_{max} = \frac{10^9}{2\pi CV / (I_c - 1)}$$

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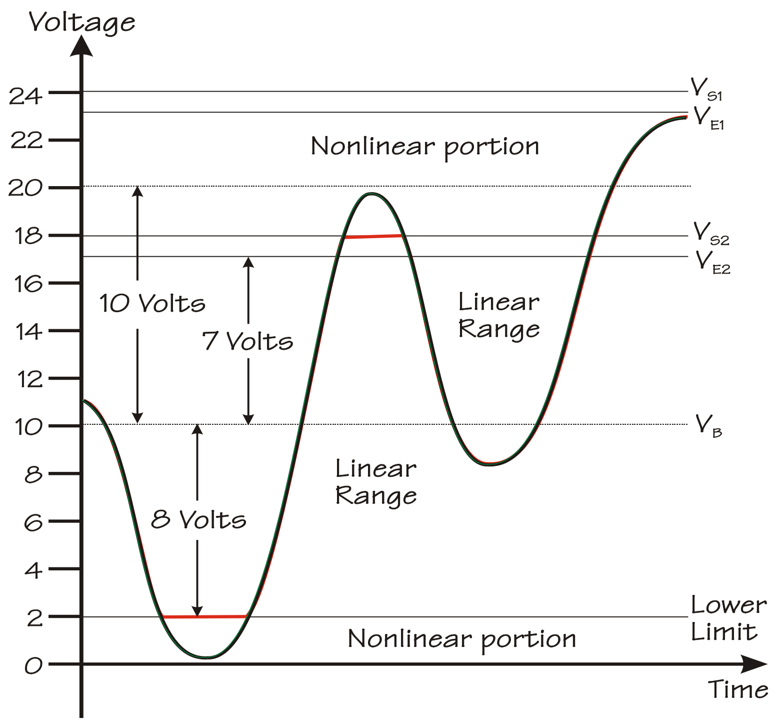
Output Bias Voltage

- The voltage level required to turn on the internal impedance conversion circuit.
  - Typical bias levels are 8 to 14VDC
- The output bias level also determines output voltage swing.



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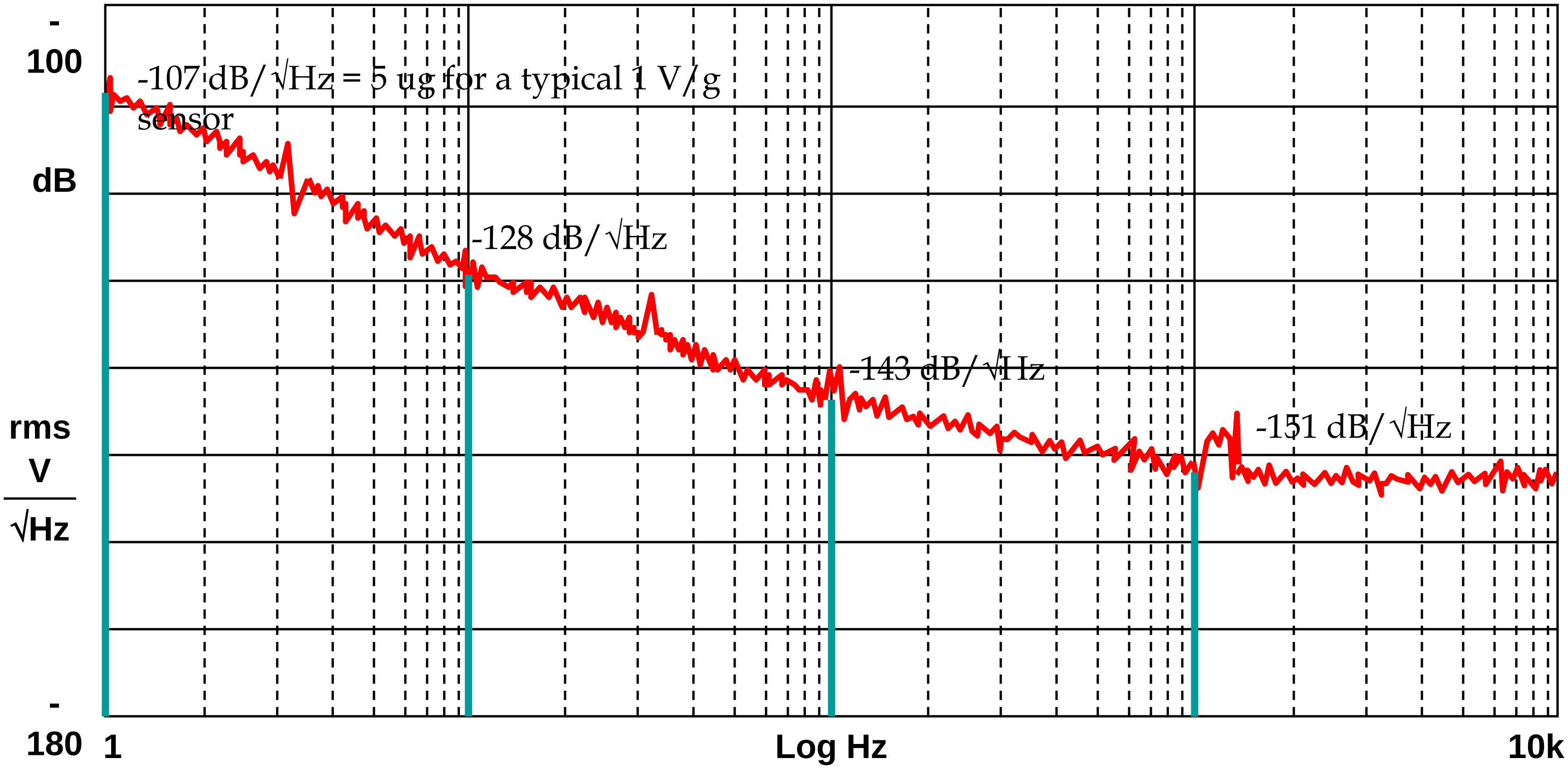
Spectral Noise

- How low can one measure?
- Electrical characteristic
  - ICP® - Noise floor of internal electronics
  - Charge – Noise of the external charge amplifier
- For Accelerometers
  - Broadband – the average lowest level over a frequency range.
  - **Spectral – The resolution at a specified frequency.**
- Generally, measure x10 above resolution to stay out of electrical noise.

Spectral Noise



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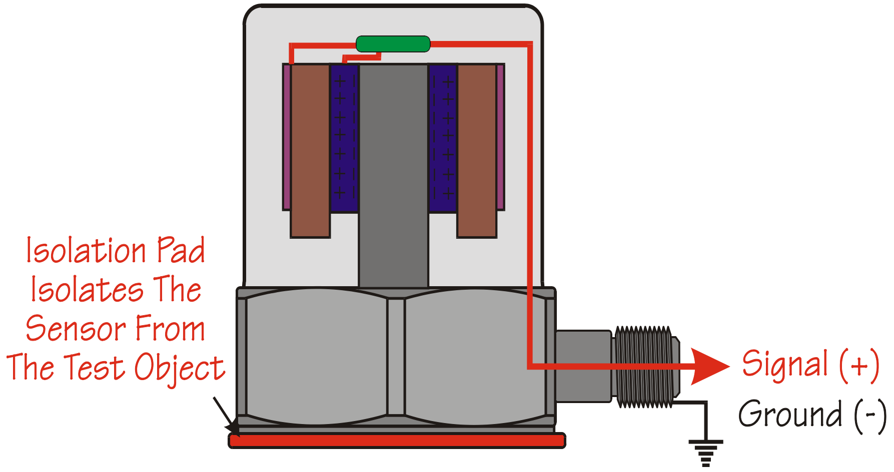
Electrical Isolation

- Ground isolated accelerometers have the electrical components isolated from the case and are much less susceptible to ground induced noise.
- A typical electrical isolation value is >100MOhms

Electrical Base Isolation

- Base Isolation
  - Isolates ground from test object
    - Engine monitoring, testing electric motors
    - Reduces potential for ground loops
    - Reduces electrical interference generated by "noisy" test objects



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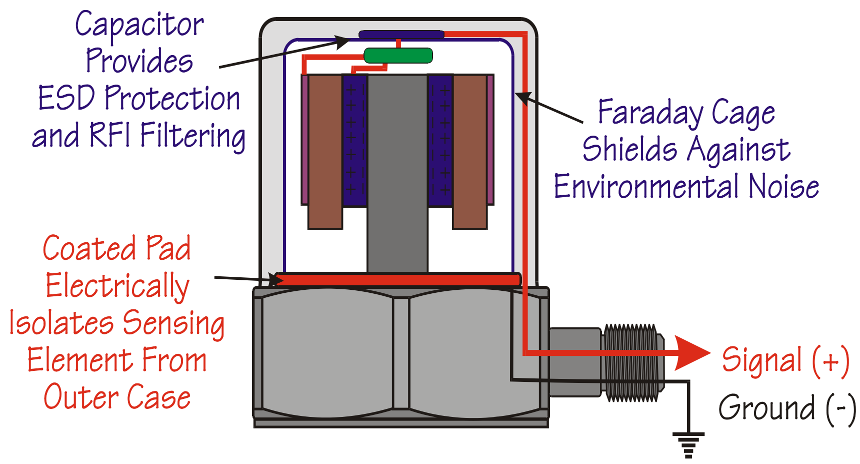
Electrical Case Isolation

- Case Isolation
  - Fully isolates and surrounds element
    - Predictive maintenance, seismic studies, generators
    - Reduces potential for ground loops
    - Reduces electrical interference generated by “noisy” test objects
    - Provides filtering of environmental noise (RFI)



IMI SENSORS
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Physical Specifications

Physical			
Size - Hex	11/16 in	18 mm	
Size - Height	1.65 in	42.2 mm	
Weight	1.8 oz	51 gm	
Mounting Thread	1/4-28 Female	No Metric Equivalent	[5]
Mounting Torque	2 to 5 ft-lb	2.7 to 6.8 Nm	
Sensing Element	Ceramic	Ceramic	
Sensing Geometry	Shear	Shear	
Housing Material	Stainless Steel	Stainless Steel	
Sealing	Welded Hermetic	Welded Hermetic	
Electrical Connector	2-Pin MIL-C-5015	2-Pin MIL-C-5015	
Electrical Connection Position	Top	Top	

IMI SENSORS
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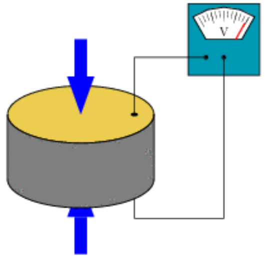
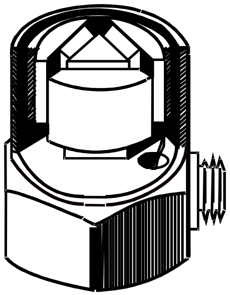
Physical Specifications

- Ceramic Sensing Element
  - Higher charge per unit force than quartz
    - More sensitivity and better resolution
- Shear Sensing Geometry
  - Lower base strain sensitivity
  - Lower transverse sensitivity
  - Lower thermal transient response
- Welded Hermetic Sealing
  - Preserves insulation resistance and sensitivity tolerance





IMI SENSORS
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Who is IMI Sensors?

- IMI stands for **I**ndustrial **M**onitoring **I**nstrumentation
  - Established in 1990 to focus on durable sensors for machinery monitoring applications
- Global leader in design and manufacture of low cost industrial accelerometers, vibration and pressure sensors, switches and instrumentation
- Service the predictive maintenance (PdM), process monitoring/protection, and power generation/energy markets
- Division of PCB Piezotronics, Inc.

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Who is PCB Piezotronics?

For over 45 years PCB® has been dedicated to the development of sensor technology and serving the needs of test and measurement professionals worldwide.

IMI SENSORS
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Who is PCB Piezotronics?

- Pioneer of ICP® Technology
- Established IEPE technology (integrated electronics) as the measurement standard
- Specialize in development and manufacture of sensors designed to measure vibration, shock, force, pressure, torque, strain, acoustics, load and blast.
- Total Customer Satisfaction is at the core of our company culture
- In-house staff of experienced Application Engineers and courteous Customer Service Representatives who provide 24/7 technical support to customers
- Largest Piezoelectric sensor manufacturer in the World

IMI SENSORS
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PCB Group Structure

PCB GROUP INC.

Operating Subsidiaries & Divisions:

PCB PIEZOTRONICS INC.

IMI SENSORS
A PCB PIEZOTRONICS DIV.

LARSON DAVIS
A PCB PIEZOTRONICS DIV.

PCB LOAD & TORQUE

TMS THE MODAL SHOP

ACCUMETRICS INC.

PCB Group is an independent, privately-owned company that acts as the management vehicle for its subsidiaries in an effort to insure their combined success.

Subsidiaries directly interact with one another on a regular basis.

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PCB Overview

- Founded in 1967 by Bob and Jim Lally
- Developed and Patented ICP® (Integrated-Circuit-Piezoelectric)
- Headquartered on a 6-acre, 150,000 sq ft campus in Depew, NY
- Additional manufacturing footprint in 5 states across the U.S.
- Over $180 million in annual sales (all Group companies)
- Global distribution network in over 50 countries
- Approximately 1,100 employees worldwide
- Customer base of over 10,000
- 1,500 catalog models

IMI SENSORS
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Where It All Began

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Our Vision

Continuously improve and deliver

Total Customer Satisfaction

to consistently provide reasonably priced, quality products on time to the schedules of our customers

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The Culture

- We live, work, and play by our brand promise of Total Customer Satisfaction (TCS)
- We recognize that we exist because of the customer and not the other way around
- We have a 24/7 Sensor Hotline staffed by experienced Application Engineers who pay personal attention to satisfying customer needs
- Platinum products – immediate shipment + lifetime warranty
- **All of our products are backed by our unwavering satisfaction guarantee**
  - **If our customers are not satisfied, we will repair, replace, exchange or refund their money**

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Manufacturing Capabilities

PCB continually invests in people, advanced manufacturing capabilities, and state of the art facilities.

Machine Shop

Electrical Discharge Machining (EDM)

Laser Interferometry and Vision Analysis Inspection

Microelectronics Assembly

Swiss Style Screw Machining

Anechoic Acoustic Testing and Calibration

Other Capabilities Include:

- ❑ Laser welding and etching
- ❑ Silicon wafer fabrication
- ❑ Ceramics fabrication
- ❑ Hydrogen furnace glass-to-metal hermetic sealing
- ❑ Spectral density and vibration testing and analysis

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Global Network

PCB Operations are supported by a network of international offices and distributors in all the major technology centers around the world

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Industrial Applications

- Market Groups
  - Predictive Maintenance (PdM)
  - Process Monitoring and Protection
  - Energy (Power Generation / Oil & Gas)
- Typical Industries Served
  - Pulp and Paper
  - Oil and Gas
  - Petrochemical & Chemical Plants
  - Steel and Metals
  - Mining
  - Pharmaceutical
  - Water and Wastewater Treatment
  - Machine Tools
  - Food Processing

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Machinery Monitored

- Motors
- Machine Tools (Spindles)
- Pumps
- Compressors
- Fans
- Cooling Towers
- Gear Boxes
- Gas Turbine
- Wind Turbines
- Gas Pipelines
- Natural Gas Wells
- Mining Equipment
- Paper Machines
- Rolling Mills

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Industrial Product Range

Echo® Wireless
Vibration Sensor

EchoPlus®
Wireless Junction Box

Instantly Converts Existing Sensors to Wireless!

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Typical Sensor Options

- 2-pin MIL
- Integral polyurethane cable
- Integral Teflon® cable
- Integral armor jacketed cable
- 10, 100, 500 mV/g sensitivities
- Hazardous area approvals
- Velocity, temperature, and/or raw voltage output options
- Most products are CE marked

IMI SENSORS
A PCB PIEZOTRONICS DIV.

Low Cost ICP® Accelerometers

- Hermetically Sealed
- Top or side exit
- Patented Swiveler® mounting technique
- Single frequency calibration
- Intrinsically safe models

IMI SENSORS
A PCB PIEZOTRONICS DIV.

Precision ICP® Accelerometers

- Single axis, Biaxial, &Triaxial versions
- Ideal for FFT analysis
- Velocity output versions available
- Low bias voltage versions available
- Intrinsically safe & Mine safety certified versions available

IMI SENSORS
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4-20 mA output sensors

- 640 Series of vibration transmitters
  - Continuous Protection of Overall Vibration
  - Predictive maintenance groups and some OEM business
  - Typically connected to existing PLC or DCS

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DIN Rail ICP® to 4-20 mA Transmitter

- Series 682AX3 Din Rail Transmitters
  - Compatible with ICP® Accelerometers
  - Typically used for out of balance & misalignment detection
  - Programmable integration
  - Pluggable filters
  - BNC for raw vibration

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Echo® Wireless

Vibration Monitoring System

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Why Go Wireless?

Earlier Warning, Frees up Personnel

- ✓ Reduces downtime and lost productivity
  - ✓ Increases sample rate on machinery and identifies problems sooner than route-based monitoring
  - ✓ Frees up technical experts for fault analysis
- ✓ Simplifies installation & reduces monitoring costs
  - ✓ Eliminates the need for running expensive cable
  - ✓ Monitors more assets with less human resources
- ✓ Allows for safe data collection in dangerous areas

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Echo® Wireless
Vibration Monitoring System

Point to Point	ERRF	Alarm Based Monitoring
• Sensor transmits directly to receiver	• "**Extended Range Radio Frequency**"	• Provides periodic data to determine machine's health
• **No mesh networks, gateways, or repeaters** are required	• Extreme Low RF Noise	• Allows for **Overall Trending**
	•Transmissions over **1000s of ft**	•Supplements or replaces route based monitoring
	• Extremely **low power** (.75 mW)	• **Focuses resources** on machines that need attention, not healthy machines.

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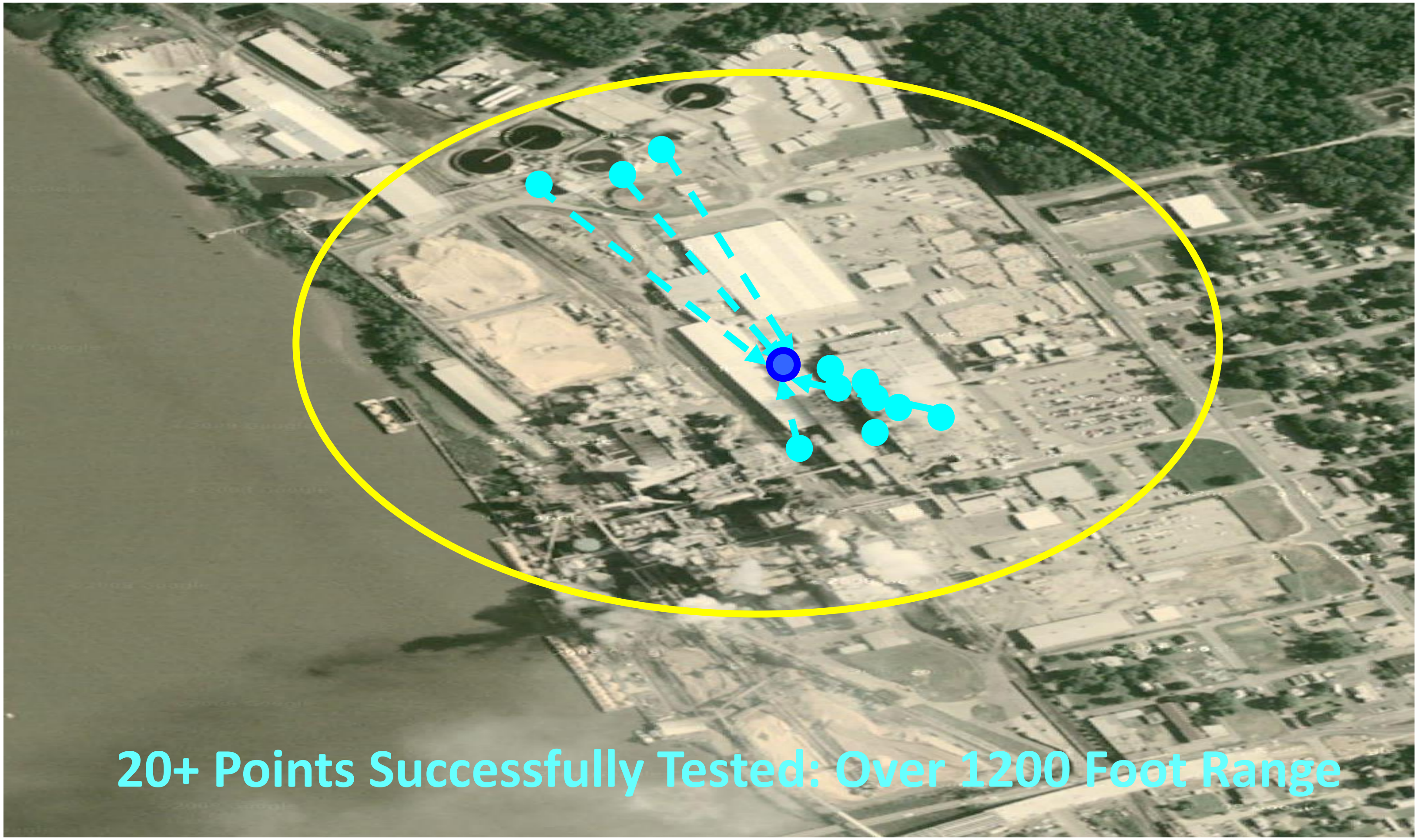
Paper Mill

Even with antenna inside a building, points were picked up in other buildings & outside.



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Chemical Plant

Good in-plant test results even with a bad receiver location

30+ Points Successfully Tested: Over 1200 Foot Range

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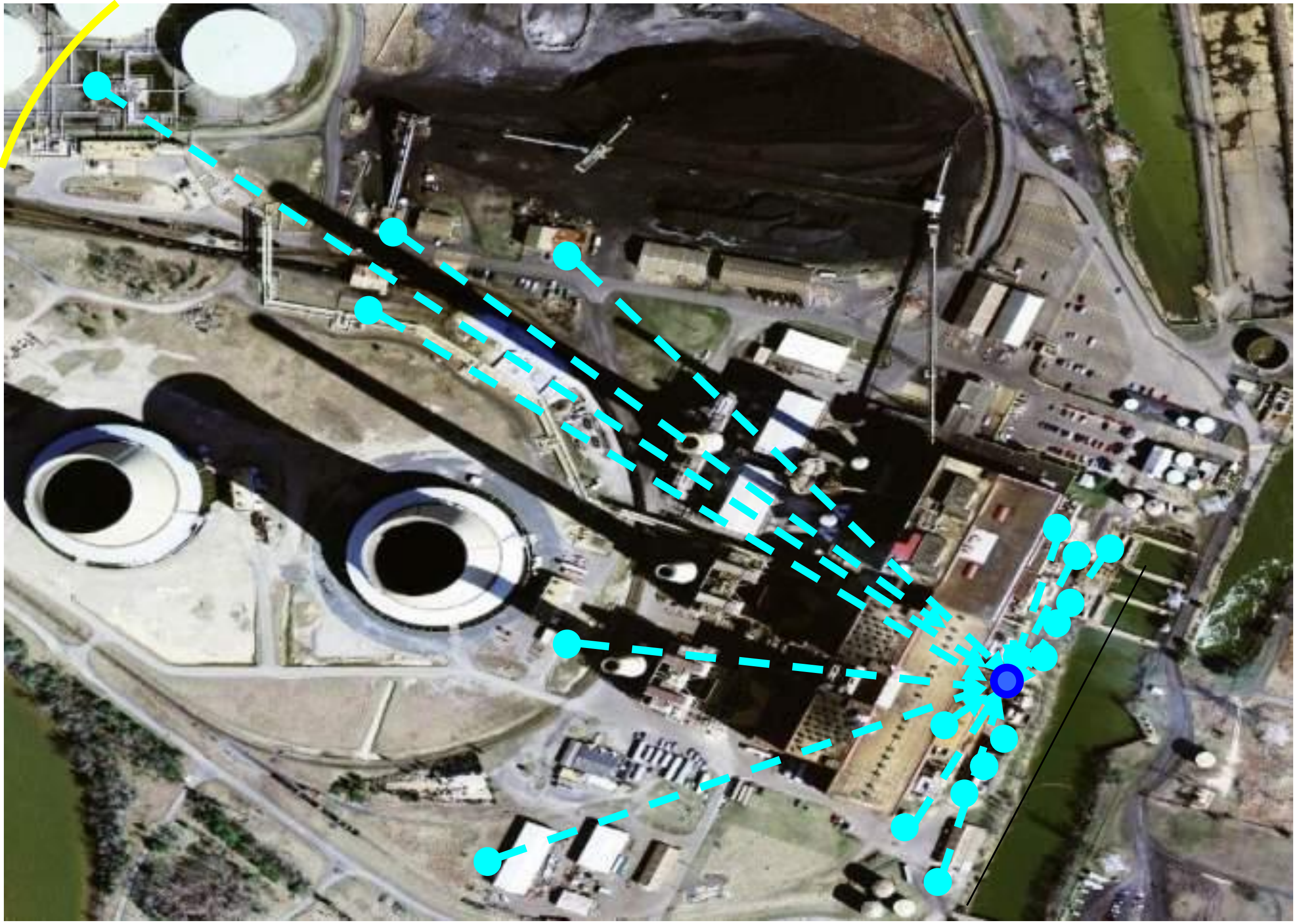
Power Generating Station

Good test results even inside a small metal building inside another



20+ Points Successfully Tested: Over 1/3 Mile Range

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Suburban Environment

Extremely far transmission distance in open environments

2 Points Successfully Tested: Nearly 1.5 Mile Range

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System Components

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Echo® Wireless Receiver

- Low noise 916 MHz frequency band
- Up to 1.5 mile radius range
- Secure encrypted data
- 400 Sensors per Receiver
  At default transmission interval of 8 hours
- Connects via Ethernet to Network or Local Computer
- Variable Gain Antenna Options

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Echo® Wireless Vibration Sensor

- Eliminates expensive cable runs.
- Can measure enclosed points where cables may not be an option.
- Ideal for machinery with external moving components.
- Battery life greater than 5 years
- Raw Vibration output version also available.

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EchoPlus®

Wireless Junction Box

- Converts existing standard wired ICP® sensors to wireless operation
- Allows for wireless operation of high temperature, submerged, and other specialized piezoelectric sensors.
- Extremely cost effective
- Also functions as a switchbox with handheld data collectors

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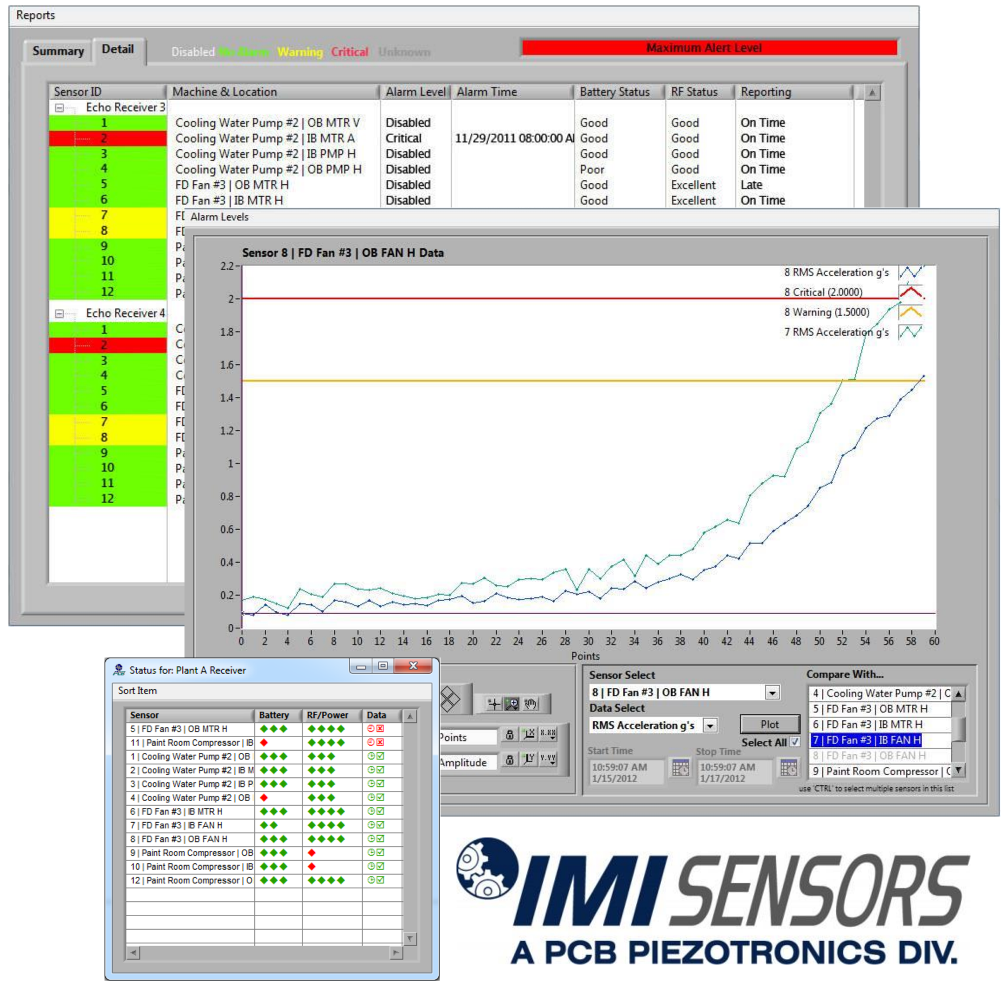
Echo® Wireless Monitoring Software

- Visual Alarms
- Email Alert Notifications when Alarms are tripped
- Access to Historical Data
- Creation of Trend Plots
- Signal Strength and Battery Status Display
- Easily Programs Sensors and Alarms



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Echo® Wireless Customers

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Success at Plastics Manufacturer

- A large domestic polymer plant has been effectively running the Echo® Wireless System for over 3 years.

- **System consists of**:

  10 EchoPlus® Wireless Junction Boxes

  &

  10 Echo® Wireless Sensors

  90 Points Monitored

Our wireless vibration monitoring system caught 6 bearing faults in their motors and pumps within the first year of operation.

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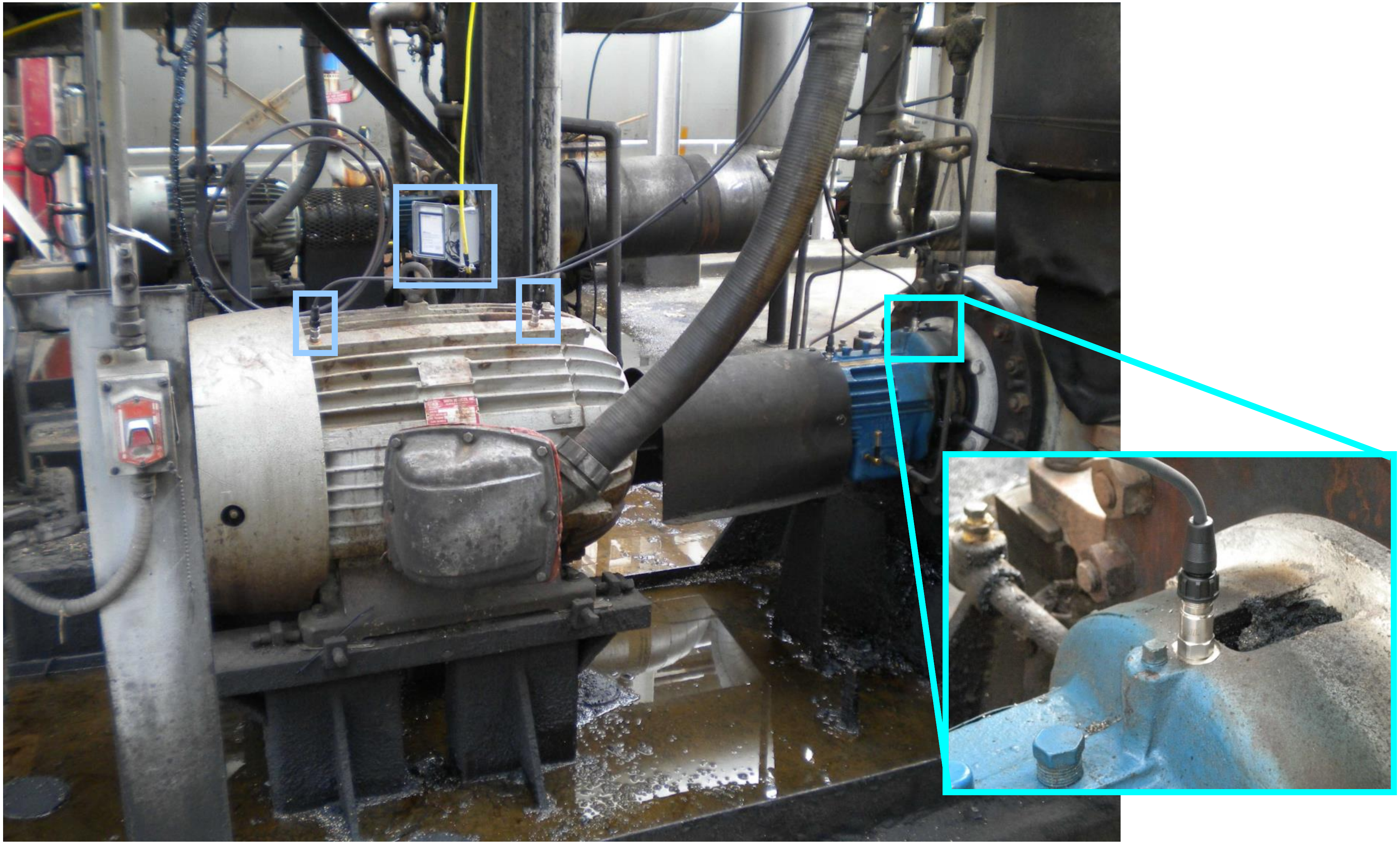

Proactive replacement of these bearings has already saved them tens of thousands of dollars.

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Bearing Fault Detector

- Series 682A05 Bearing Fault Detector
  - Two 4-20 mA output signals
  - Similar output to a peak-vue overall

The Bearing Fault Detector
Sinusoidal Problem Detection

Accelerometer → Real Time Buffered Vibration

Accelerometer → Filter → RMS/DC Conversion → 4-20 mAmp Conversion →

Unbalance, Misalignment, etc

IMI SENSORS
A PCB PIEZOTRONICS DIV.

Universal Transmitter

- Series 682A06 Universal Transmitter
  - Ideal for customers that do not have access to a PLC or DCS System
  - Provides set point relays based on 4-20 mA inputs
  - Removable face plate for programming multiple channels
  - Provides loop power

Programmable Panel Meter

- Series 683A Vibration Indicators (panel meters)
  - Can be used with ICP or 4-20 mA inputs
  - Provide up to 4 set point relays
  - Adjustable time delay
  - Integration to velocity or displacement (ICP version)
  - Retransmit option

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Vibration Switches

- Electronic Vibration Switches

Series 686A: Two-Wire Electronic Switch

Series 685B: Electronic Dual Switch

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686A Series Two-wire Electronic Smart Vibration Switch

IMI SENSORS
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Features

- Microprocessor controlled with no moving parts or mechanical adjustments
- Base models have fixed velocity set point threshold ranging from 0.25-6.0 ips peak (for installations where the vibration limit is known)
- Fully USB programmable
- Solid state relay for reliable operation
- Monitors vibration velocity for consistent results
- 2-wire operation uses existing switch wires
- *Remote Reset Anywhere*™ for safety and convenience
- Exclusive *MAVT*™ sets alarm threshold automatically
- Eliminates false trips with programmable delays
- Hazardous area approvals
- Hermetically sealed design- NO LEAKS!!

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Magnetically Adjustable Vibration Threshold (MAVT™).

- Field setup of threshold value using a magnetically actuated sensor within the housing of the vibration switch.
- The sensor is activated by touching the housing of the switch, at the proper location, with a strong, permanent magnet.
- This contact initiates a course of action within the microprocessor to change the vibration threshold value.

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MAVT™ Functionality

- When installed on operating machinery, the magnetic actuation begins a **30 second period where the vibration experienced is averaged** over that span
- The **average vibration is then doubled** and the result becomes set as the new threshold value
- **This value can also be more precisely achieved using a controlled vibration shaker (699A02 or 699A06).**

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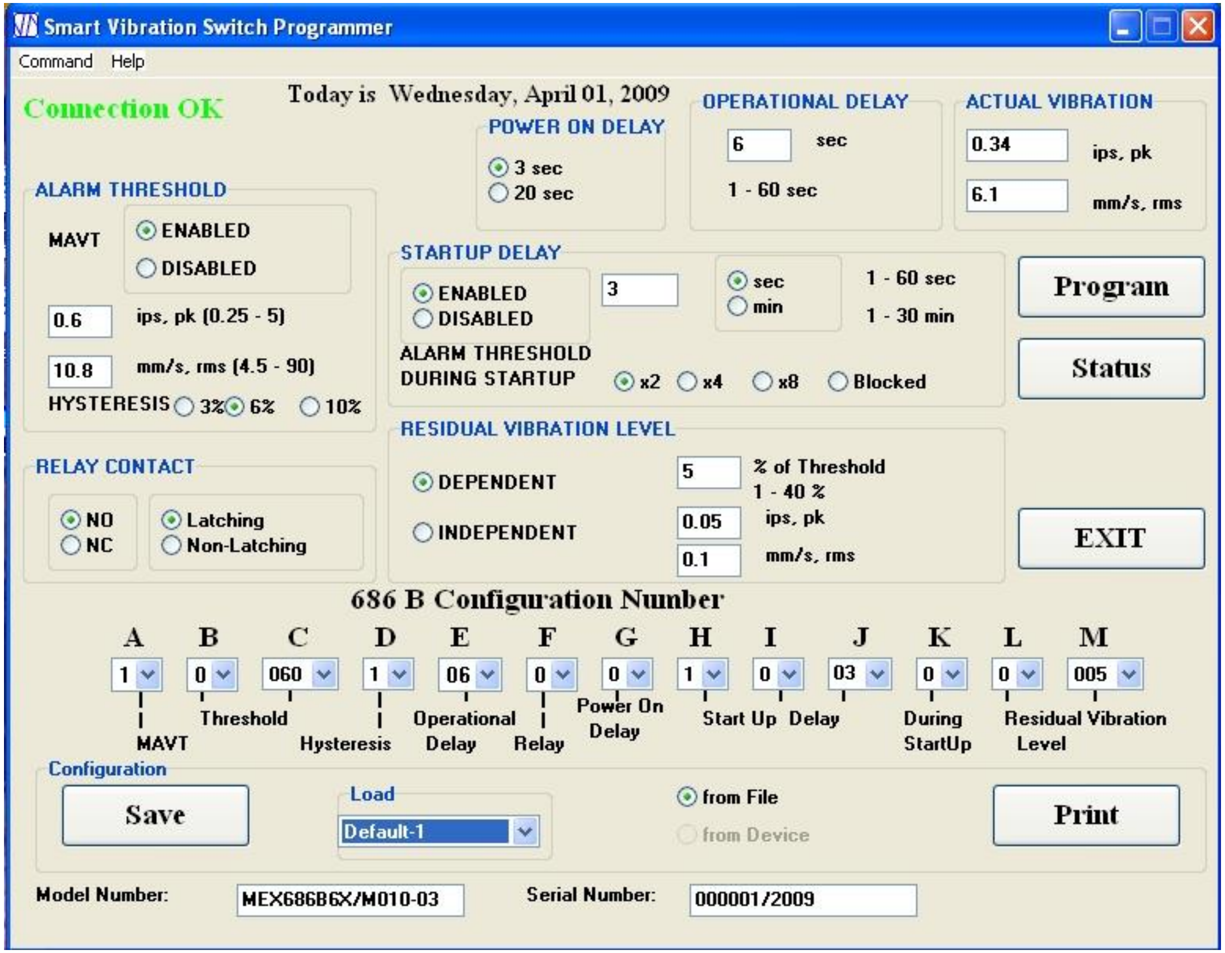
Programming the Smart Vibration Switch



USB Programmer Main screen

- Set switch parameters
- Read the actual vibration
- Program the switch
- Read the switch settings
- Set/read configuration number
- Print/Save configurations

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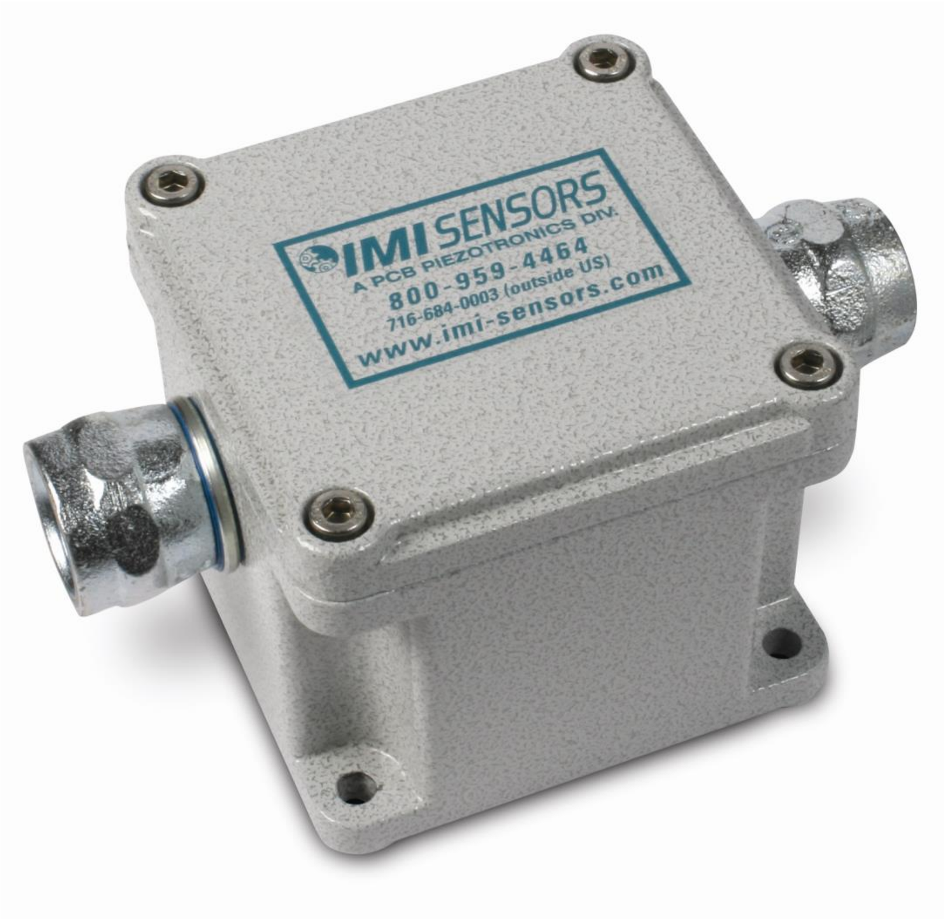
685B Series Electronic Vibration Switch



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Features

- Integrated 100mV/g Accelerometer (external ICP® sensor optional)
- Universal 85-245Vac, 50/60 Hz Power Supply (24 Vdc also available)
- Dual 5 Amp Triac Outputs or Form C Relay Outputs
- Triac NO/NC; Field Selectable
- 4-20mA Output Standard (unlike many competitive models)
- Local and Remote Reset
- Unique 4-20mA Calibration for High Precision
- Two connection Interfaces (unlike most competitive models)
- Dual Cord Grip Interface Standard (1/2” NPT optional)
- 2Hz to 1kHz Frequency Response
- Raw Vibration Output via BNC connection (optional)
- Standard Ranges: 5g, 1.5ips, 15mils
- Intrinsically Safe Versions Available

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RMP – Reciprocating Machinery Protector

- Model 649A01 – Reciprocating Machinery Protector
  - Detects impact severity
  - Provides early detection based on overall vibration level
  - Counts the number of impacts that exceed specified threshold
  - USB Programmable, Loop powered

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RMP – Reciprocating Machinery Protector

- Early warning of faults such as:
  - Loose rod nuts
  - Loose bolts
  - Worn pins
  - Rubbing
  - Liquid in the process
- Optional third pin for raw vibration output

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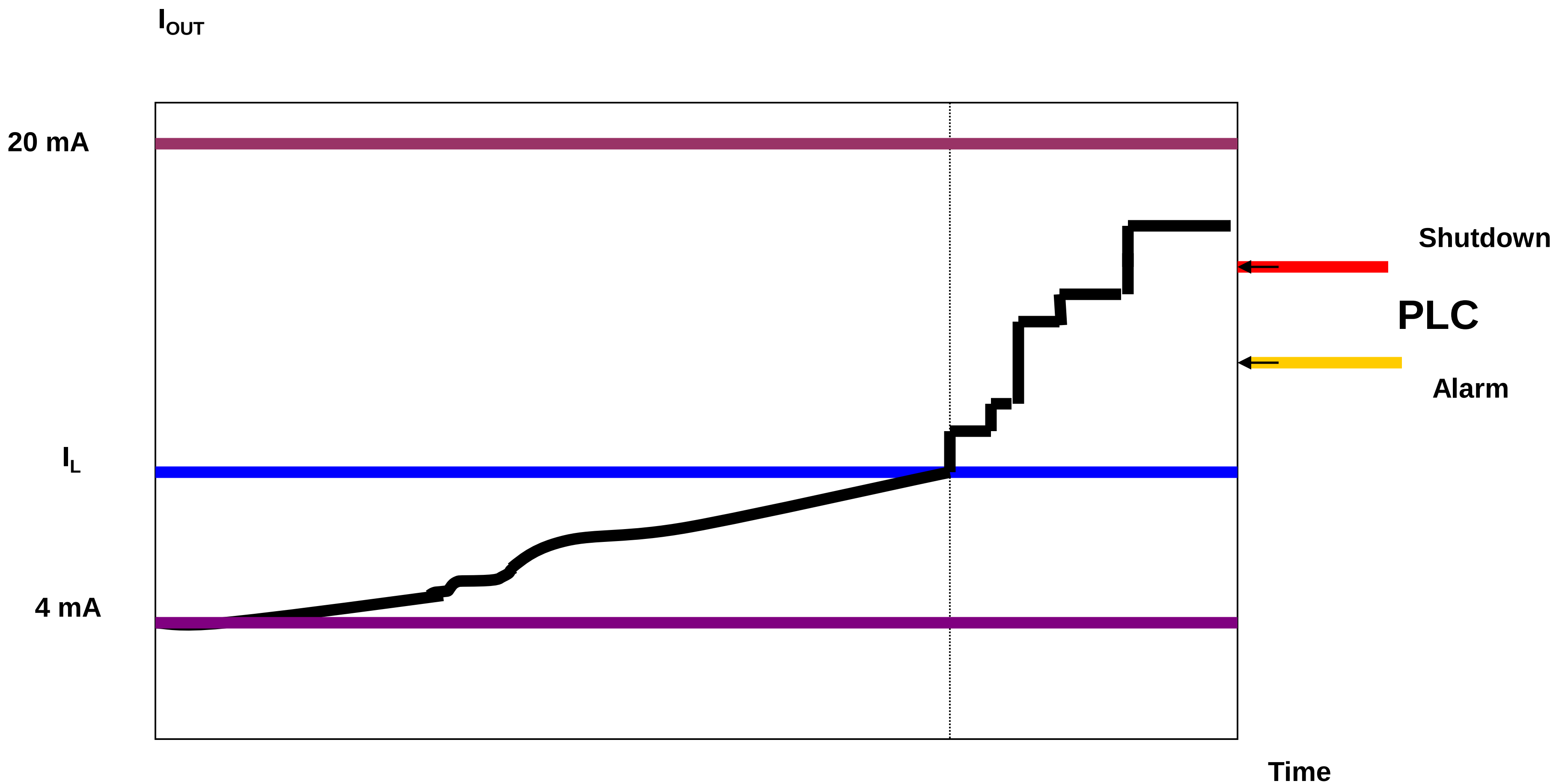
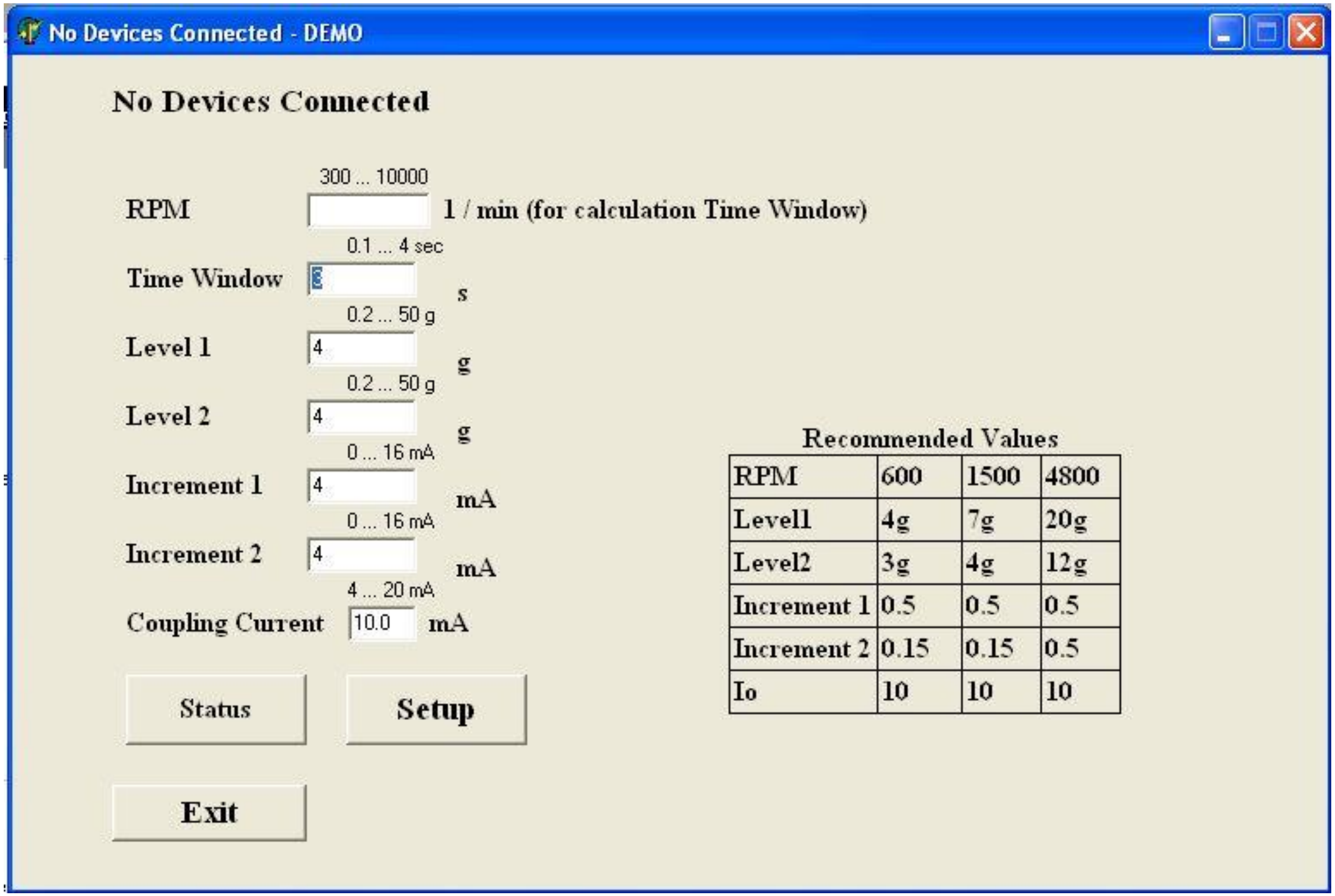
Shock Measurement for Reciprocating Compressors



RMP User Interface



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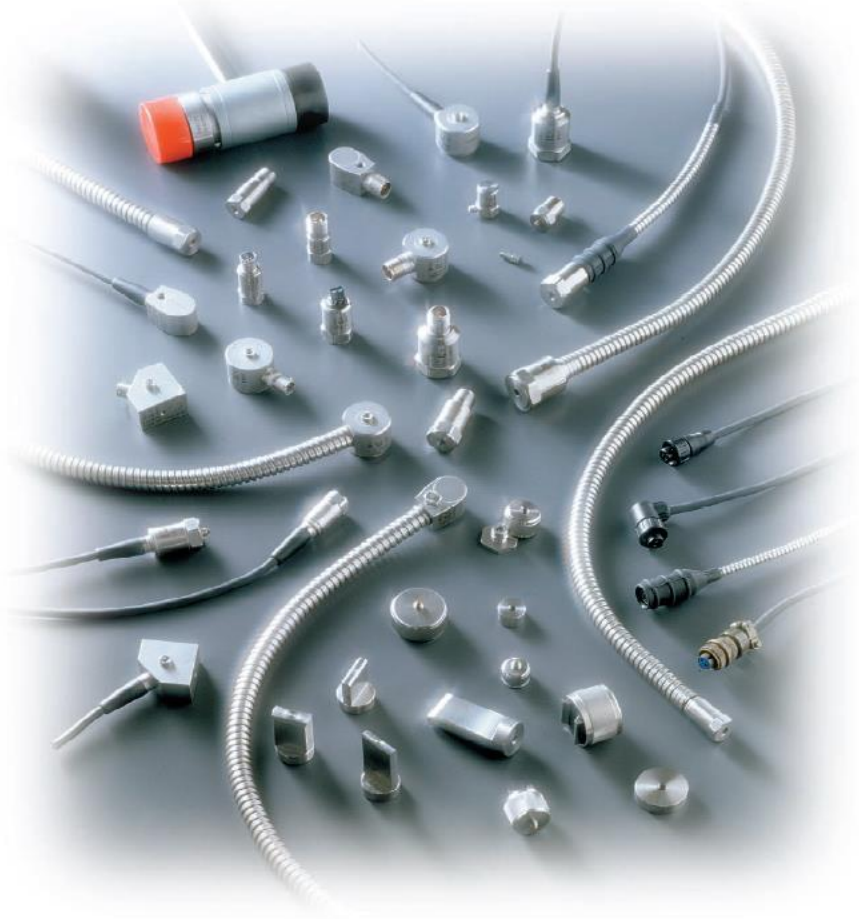
Questions & Answers



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