VIBRATION FUNDAMENTALS

WHO ARE WE?

PCB PIEZOTRONICS IS A DESIGNER, MANUFACTURER, AND GLOBAL SUPPLIER OF ACCELEROMETERS, MICROPHONES, FORCE, TORQUE, LOAD, STRAIN, AND PRESSURE SENSORS, AS WELL AS THE PIONEER OF ICP®/ IEPE TECHNOLOGY.

THIS INSTRUMENTATION IS USED BY DESIGN ENGINEERS AND PREDICTIVE MAINTENANCE PROFESSIONALS WORLDWIDE FOR TEST, MEASUREMENT, MONITORING, AND CONTROL REQUIREMENTS IN AUTOMOTIVE, AEROSPACE, INDUSTRIAL, R&D, MILITARY, EDUCATIONAL, COMMERCIAL, OEM APPLICATIONS, AND MORE.

Download our tech guide

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T&M SALES ENGINEER | CAT. II VIBRATION ANALYST ISO 18436-2

VIBRATION FUNDAMENTALS

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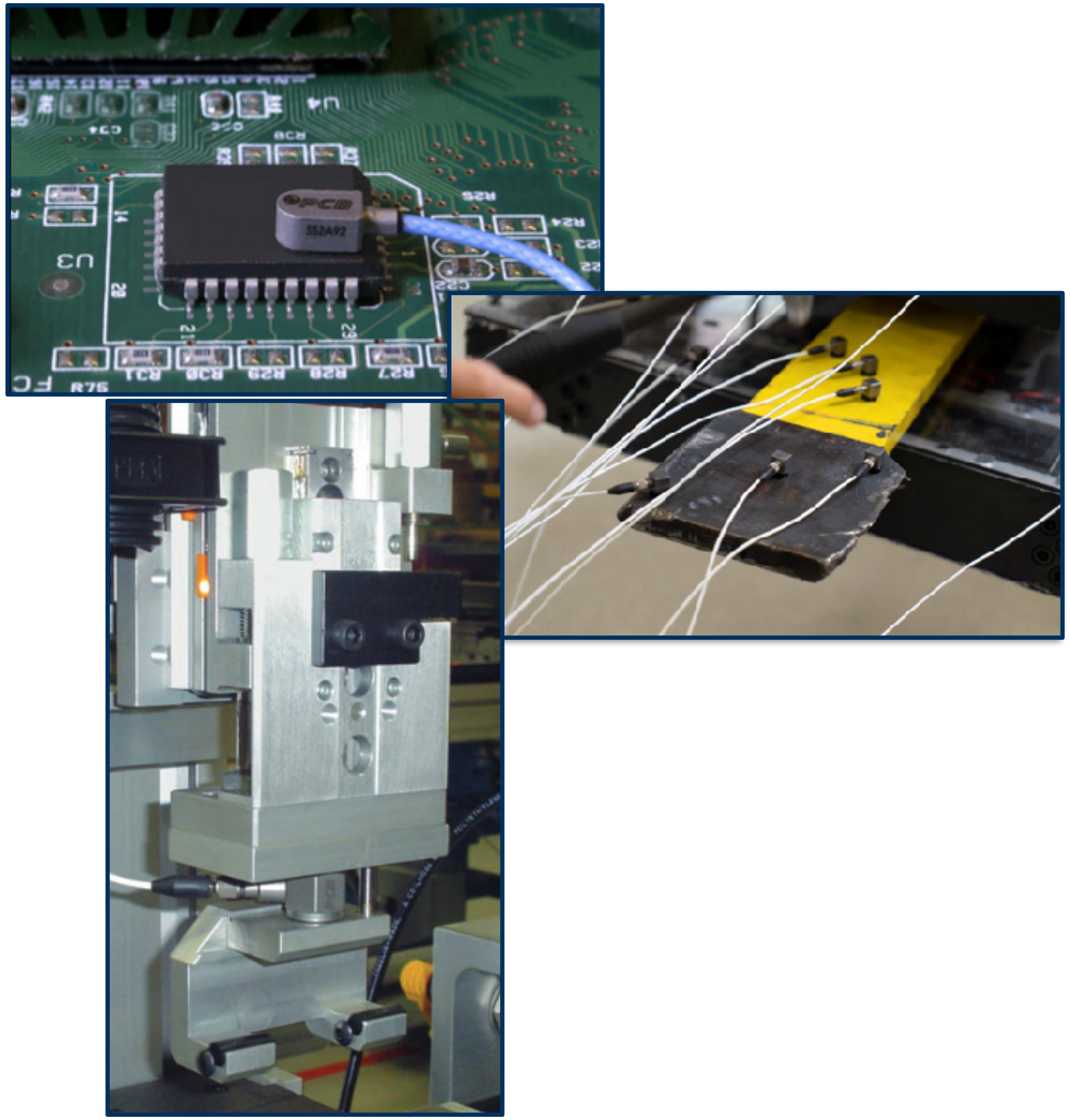


PHYSICS REFRESHER

Newton's Laws of Motion:

1st Law – every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This is normally taken as the definition of inertia.

Equation: $\sum F = 0$

2nd Law – the velocity of an object changes when it is subjected to an external force. The law defines a force to be equal to change in momentum (mass times velocity) per change in time.

Equation: $F = \frac{m \Delta v}{\Delta t}$ $\quad F = ma \quad$ $\frac{m1v1}{t1} = \frac{m2v2}{t2}$

3rd Law – every action (force) in nature there is an equal and opposite reaction. In other words, if object a_1 exerts a force on object a_2, then object B also exerts an equal force on object A, also known as Action / Reaction.

Equation: F $a1 \rightarrow a2 = -Fa2 \rightarrow a1$ $\quad \sum F = m1a1 + m2a2 \ldots$

What is vibration

Definition:

- Vibration occurs when a mechanical structure is disturbed from equilibrium with resulting oscillatory motion about an equilibrium point. The oscillations may be periodic, such as the motion of a pendulum—or random, such as the load on an airplane wing during flight. Characterization of a mechanical system under vibration is composed of acceleration, velocity, and displacement components.

Types:

- **Free** vibration occurs when a mechanical system is set in motion with an initial input and allowed to vibrate freely.
  Examples of this type of vibration are pulling a child back on a swing and letting go, or hitting a tuning fork and letting it ring. The mechanical system vibrates at one or more of its natural frequencies and damps down to motionlessness.

- **Forced** vibration is when a time-varying disturbance (load, displacement or velocity) is applied to a mechanical system.
  Examples of these types of vibration include a washing machine shaking due to an imbalance, transportation vibration caused by an engine or uneven road, or the vibration of a building during an earthquake.

- **Damped** vibration - the energy of a vibrating system is gradually dissipated by friction and other resistances, the vibrations are said to be damped. The vibrations gradually reduce or change in frequency or intensity or cease and the system rests in its equilibrium position. An example of this type of vibration is the vehicular suspension dampened by the shock absorber.

$$Natural/Resonant\ Frequency = \sqrt{\frac{\text{Stiffness}}{\text{Mass}}}$$

The resonant frequency and mass have an inverse relationship, which is instead direct for the resonant frequency and stiffness.

In the world of accelerometers:

- the mass is related to the weight of the accelerometer
- the stiffness of the spring is related to how the accelerometer is mounted on the structure

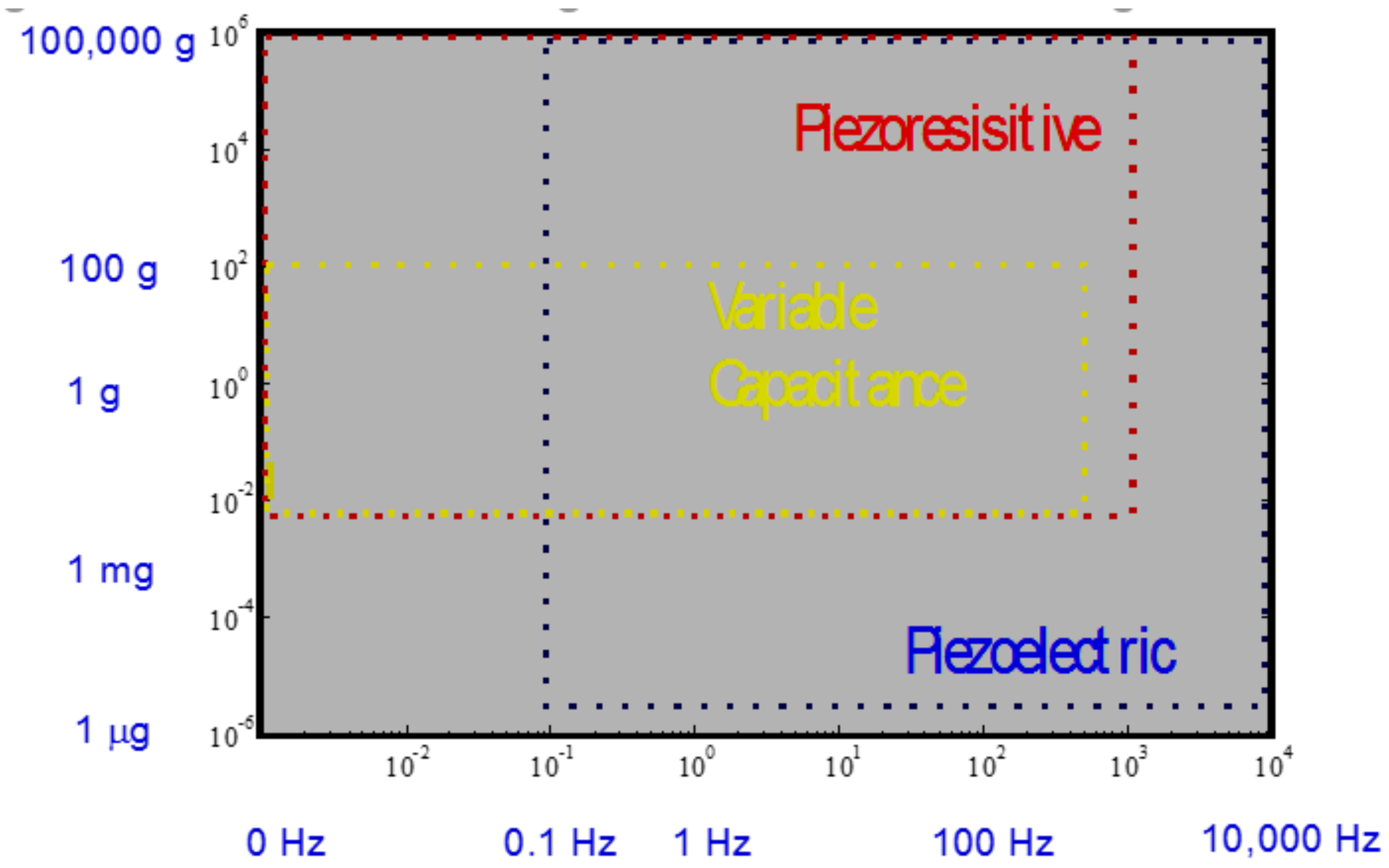
ACCELEROMETERS

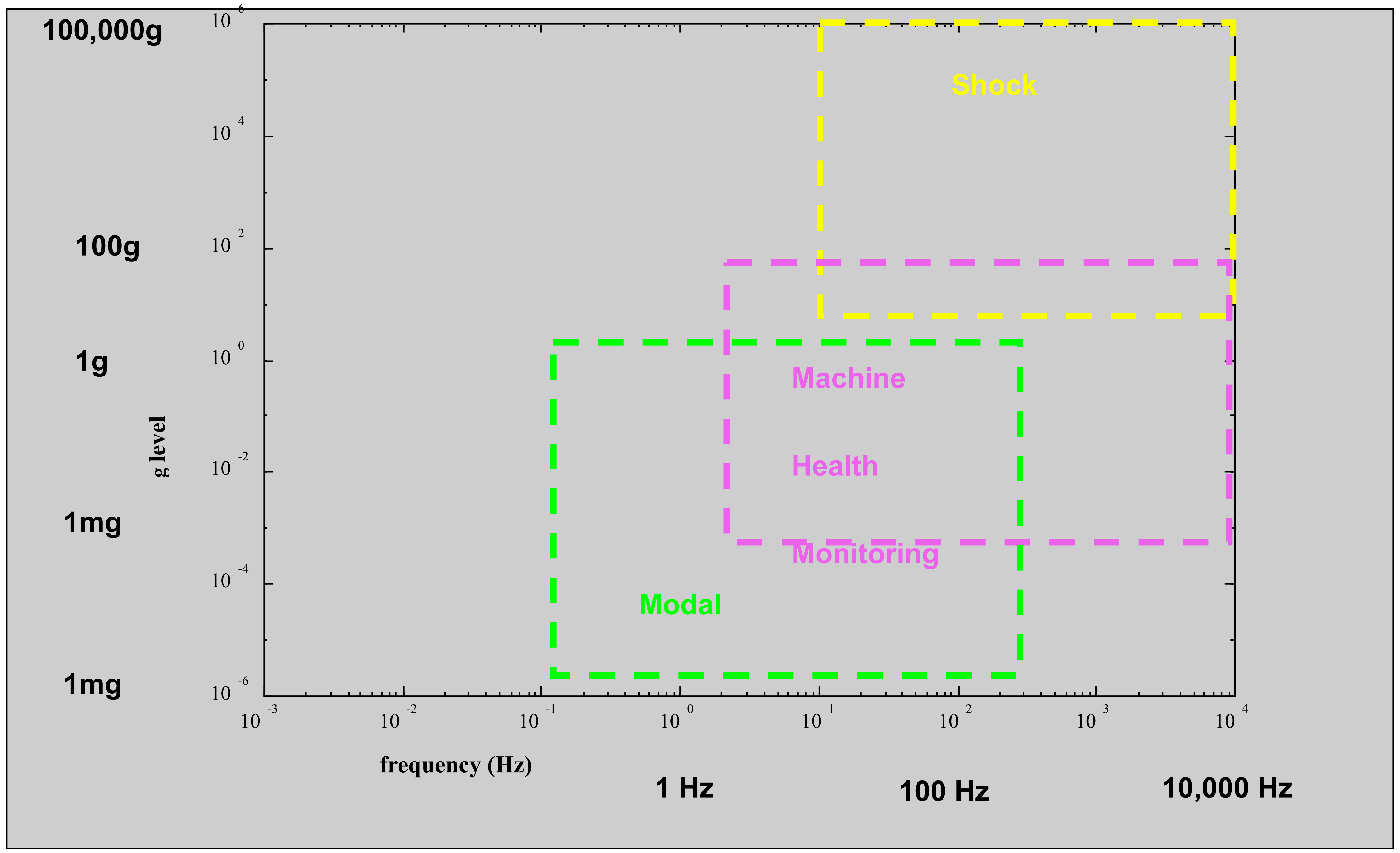
Sensors that generate an electrical output signal that is proportional to applied acceleration and can provide indirect measurement of velocity and displacement.

I. Accelerometer technologies:
   - **Piezoelectric - ICP® & Charge output**
   - **MEMS** – Variable Capacitive (VC) & Piezo Resistive (PR)

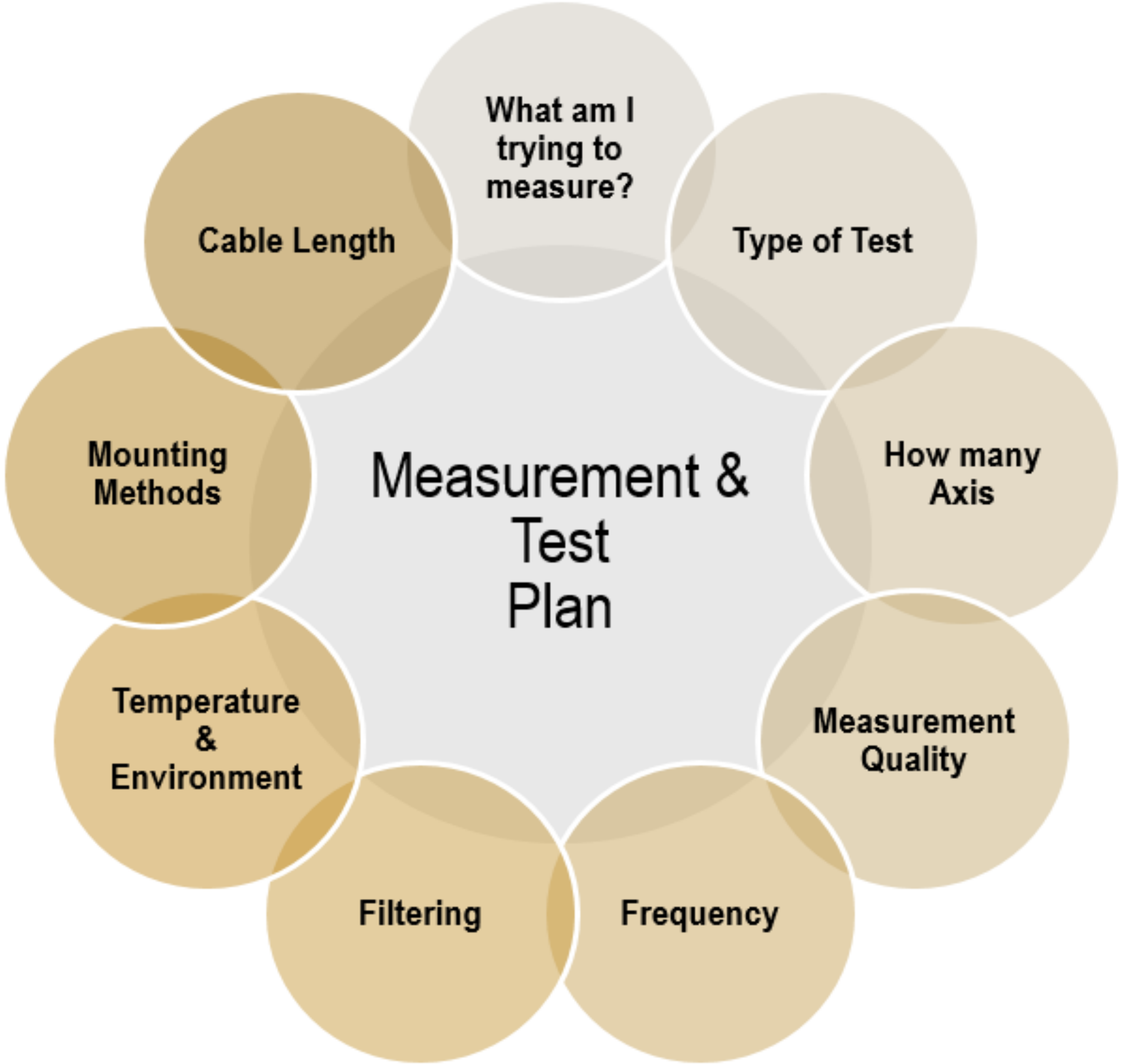
II. Piezoelectric Accelerometer structures:
   - Compression
   - Flexural
   - Planar Shear / Annular Shear

Technologies: Measurement Range vs Frequency



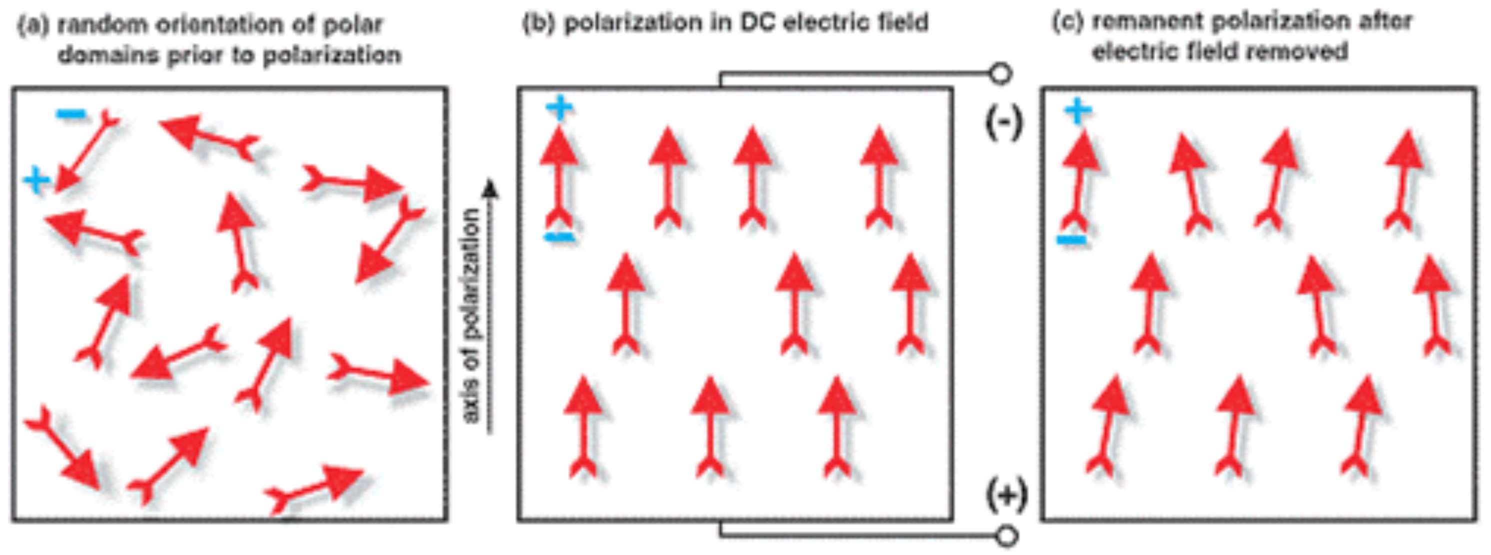


Application	Piezoelectric	Capacitive MEMS	Piezoresistive
Static Acceleration (0 Hz, 1 g) Gravity, Sensor Orientation		✓	✓
G- Force (0 Hz, <25 g) Rocket, Centrifugal, Aircraft		✓	✓
Seismic (<1 Hz, <1 g) Earthquake, Waves, Bridges	✓		
Low Frequency Vibration (<5 Hz, <25 g) Human Motion, Robotics	✓	✓	✓
General Vibration (5 Hz to 500 Hz, <25 g) Electric Motor, Car Suspension	✓	✓	
High Frequency Vibration (>500 Hz, <25 g) Gear Noise Analysis, Turbine Monitoring	✓		
General Shock (<100 Hz, <200 g) General Testing, Shock Absorber Testing	✓	✓	✓
High Impact Shock (<250 Hz, >200 g) Drop Testing	✓		✓
Extreme Shock (>1,000 Hz, >2,000 g) Vehicle Crash Testing, Metal on Metal			✓


What am I trying to measure?
Type of Test
How many Axis
Measurement Quality
Frequency
Filtering
Temperature & Environment
Mounting Methods
Cable Length
Measurement & Test Plan

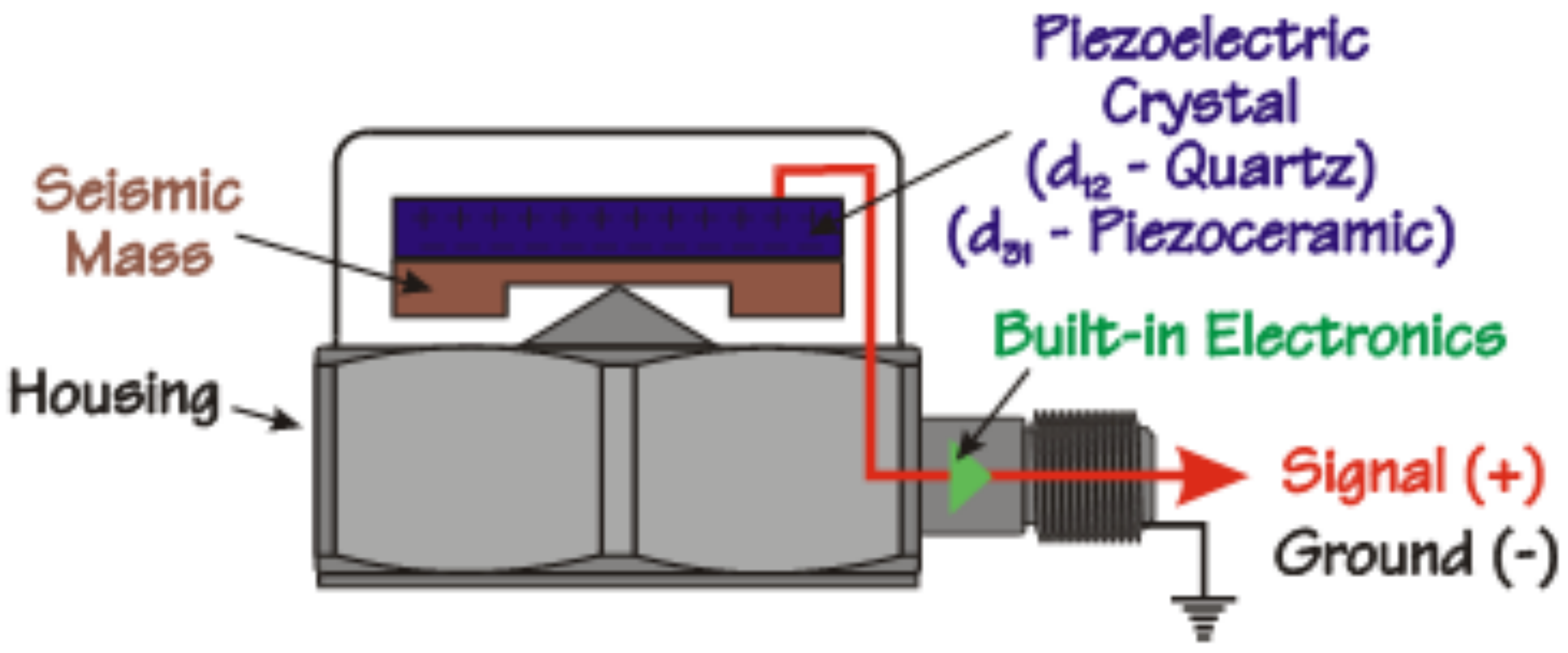
PIEZOELECTRIC MATERIALS

PCB® uses 4 types of piezoelectric materials in sensing elements:

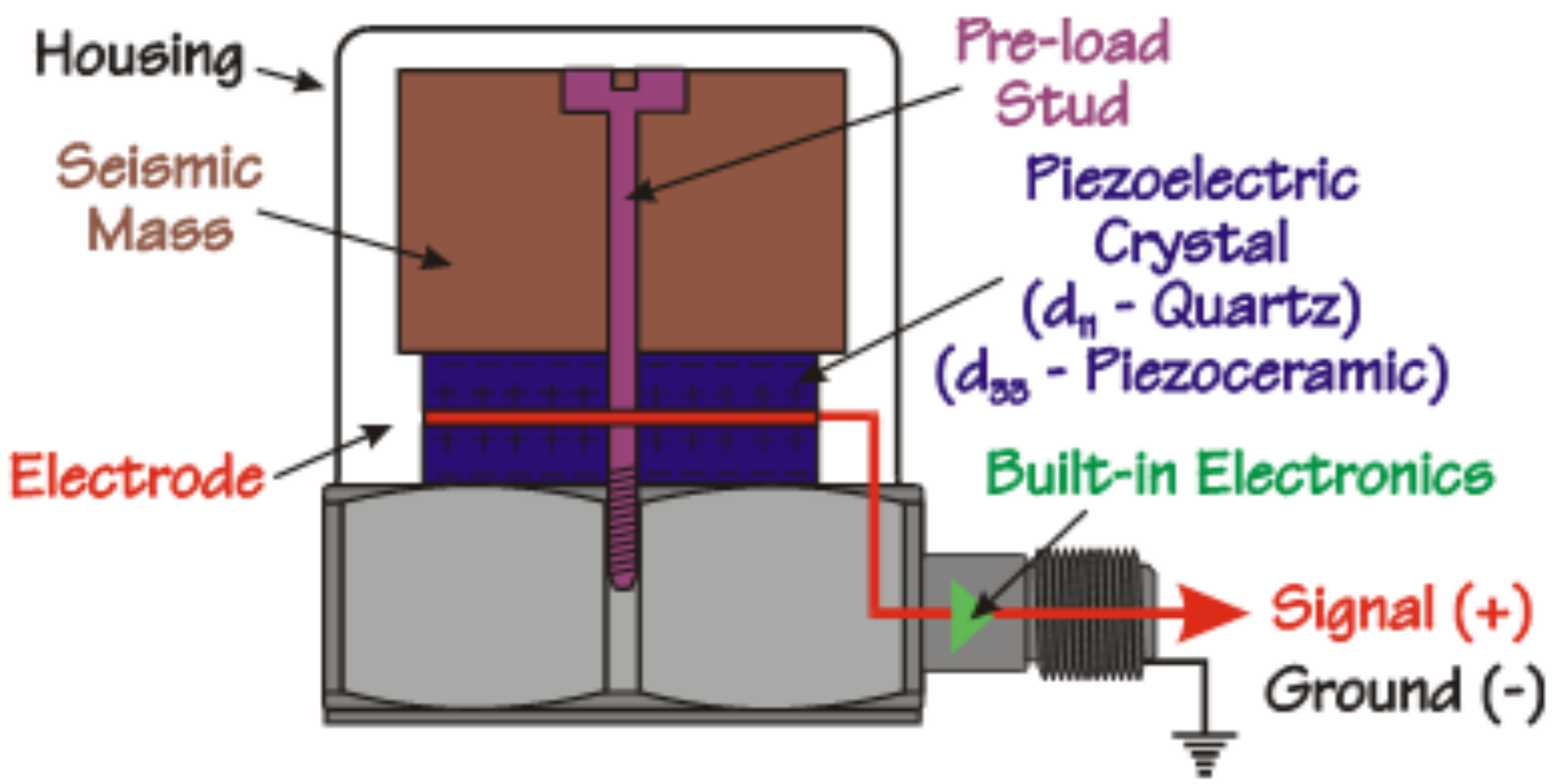
Quartz Crystals • Single Crystal made of SiO_2 molecules • Found naturally in the Earth from millions of years under pressure • Artificially grown under high pressure & temperature in large autoclaves. • High purity, high quality - takes approximately 1 month to grow	**Tourmaline (High frequency blast sensors)** • Naturally occurring family of crystalline minerals with piezoelectric properties that are volumetric in nature.
Polycrystalline Ceramics • Easier to manufacture with increased piezoelectric output over quartz. • Require "poling" to align crystalline structure - application of high DC voltage at high temperature to align the domains along the polling axis. 	**UHT-12 (High temperature use)** • Proprietary crystalline material with stable output over wide temperature range.

PIEZOELECTRIC ACCELEROMETER TYPES

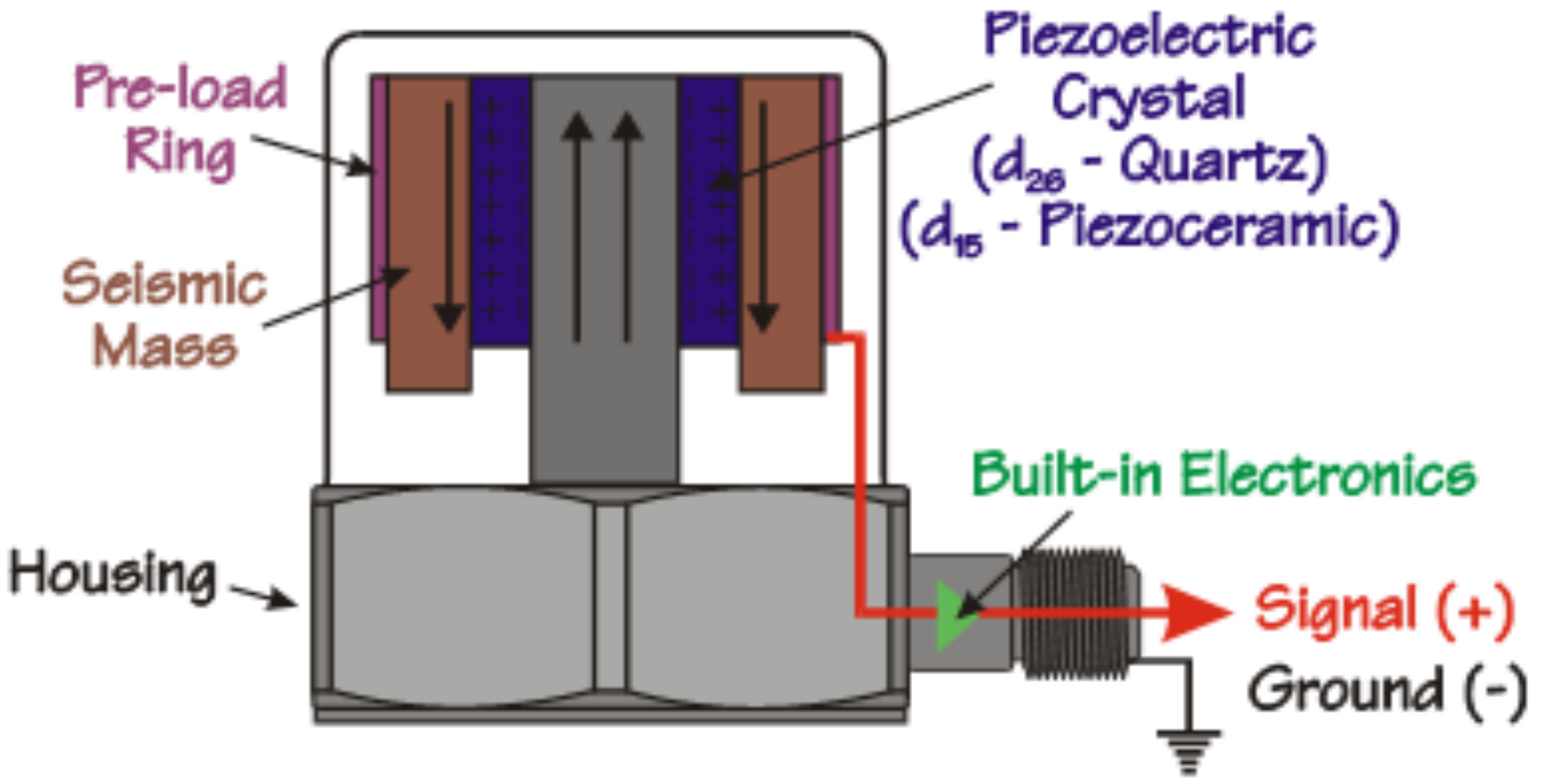
Flexural



Compression



Shear



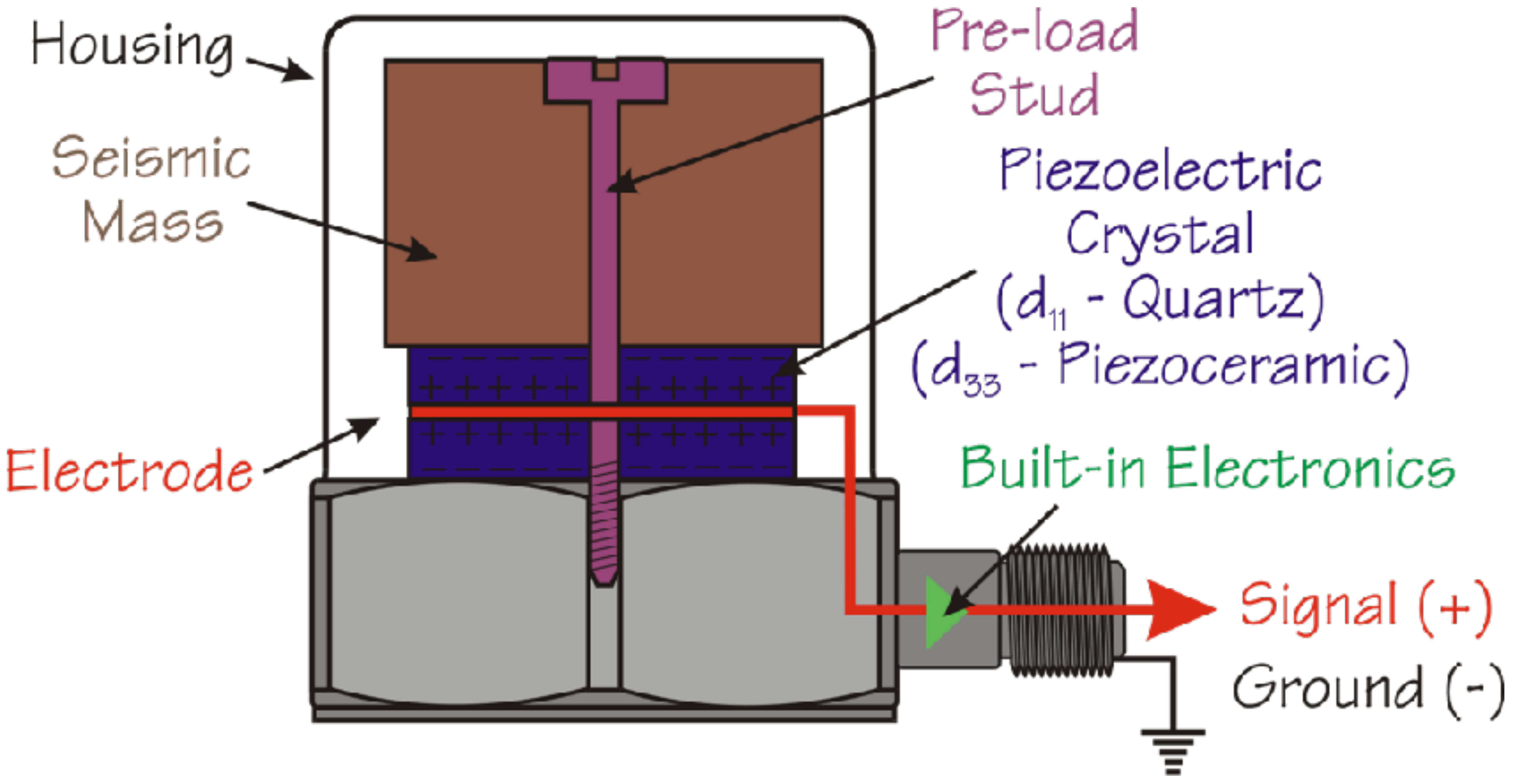
Compression Style

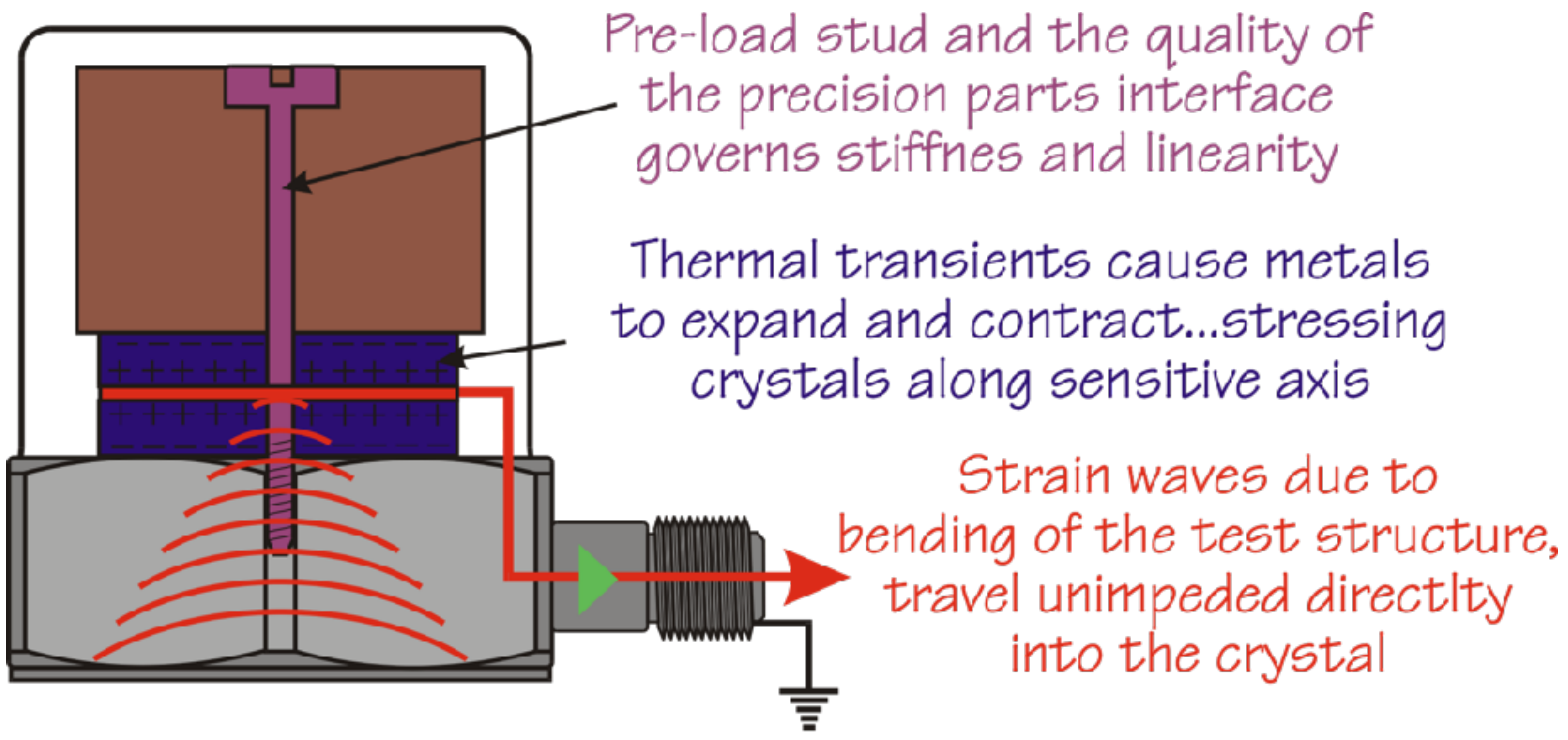
Advantages

Few Parts / Easy to Fabricate
High Resonant Frequency

Disadvantages

Very high thermal transient sensitivity
High base strain sensitivity





Flexural Style

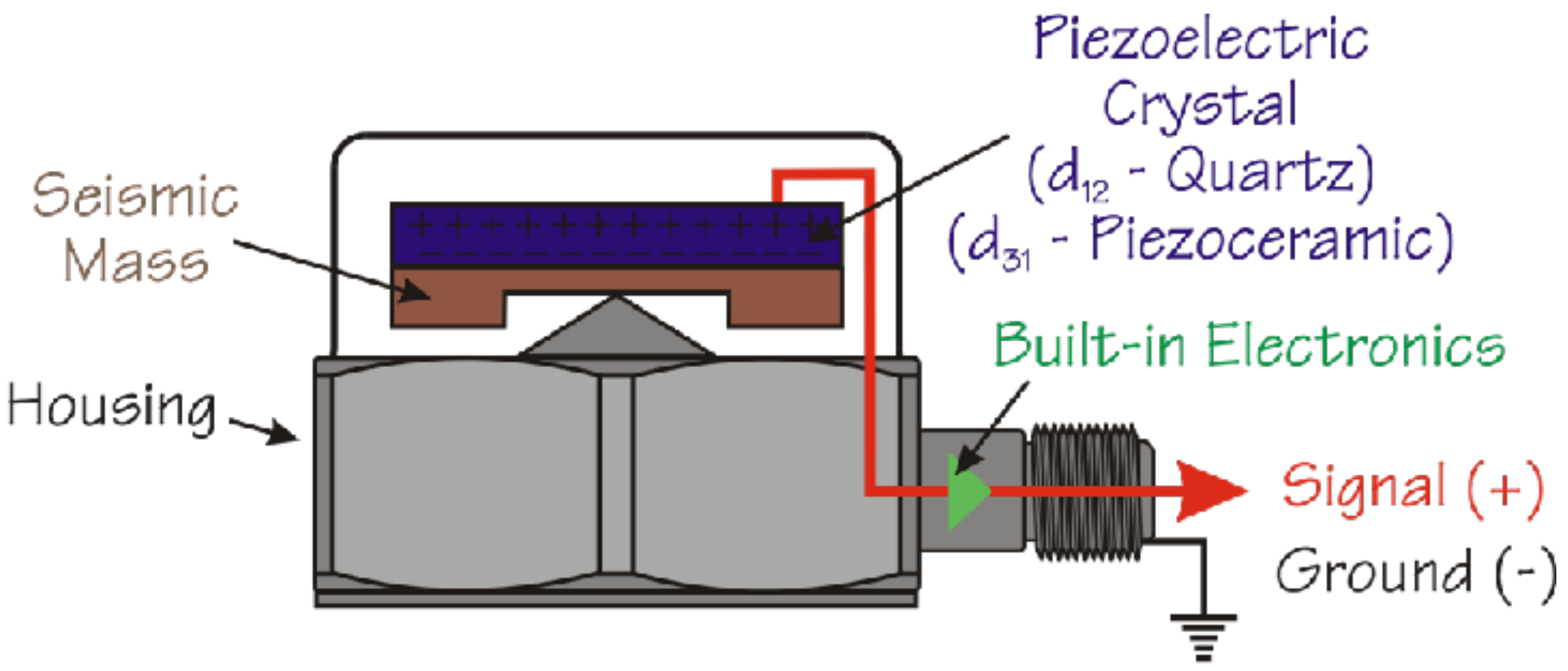
Advantages

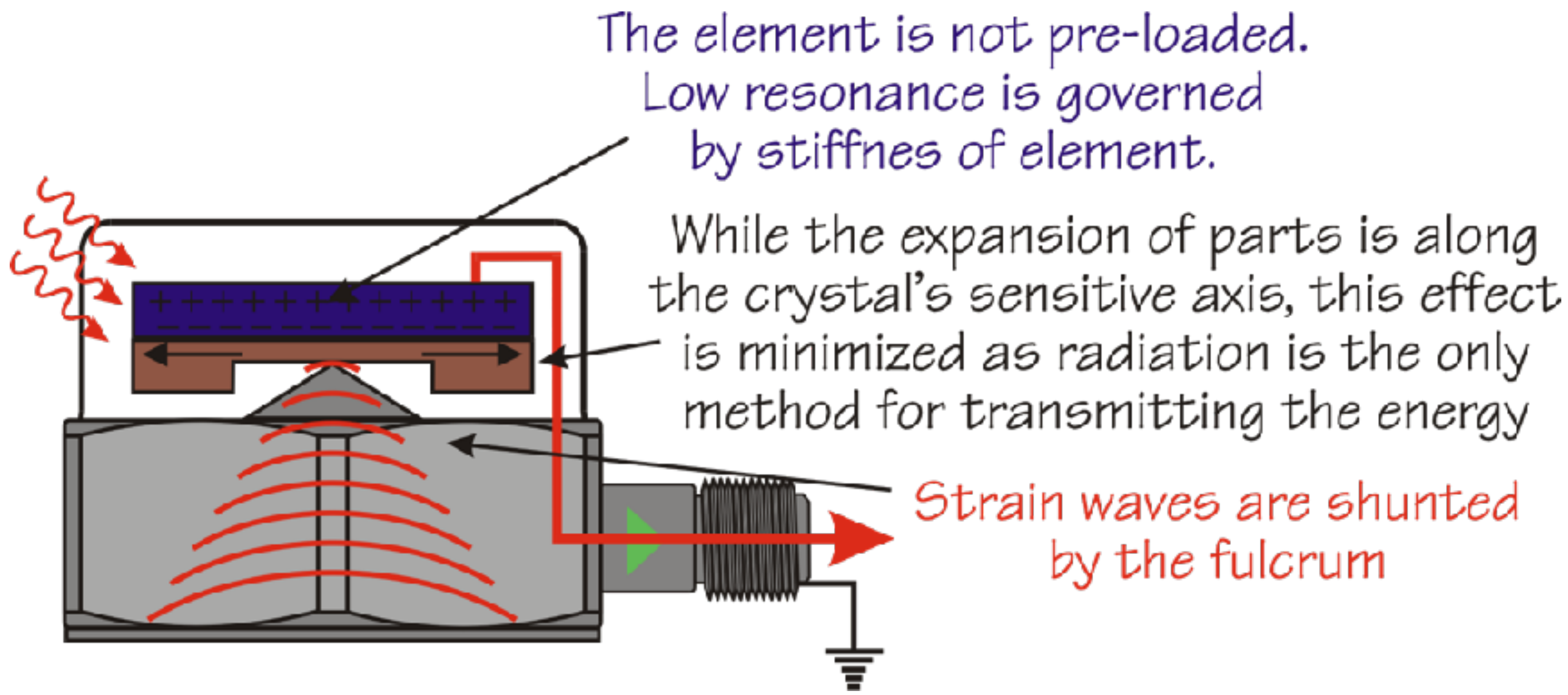
Few Parts - Low Cost
Small Size and Low Profile
Low Base Strain Sensitivity
Low Thermal Transient Sensitivity

High output signals since the crystal is subjected to high stress levels

Disadvantages

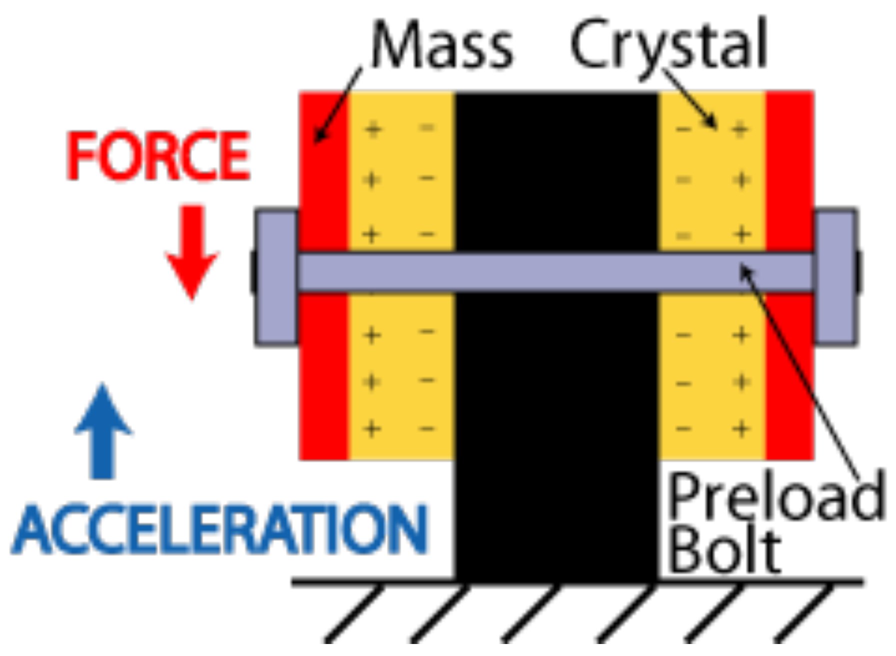
Low Resonant Frequency
- Limited High Frequency Range

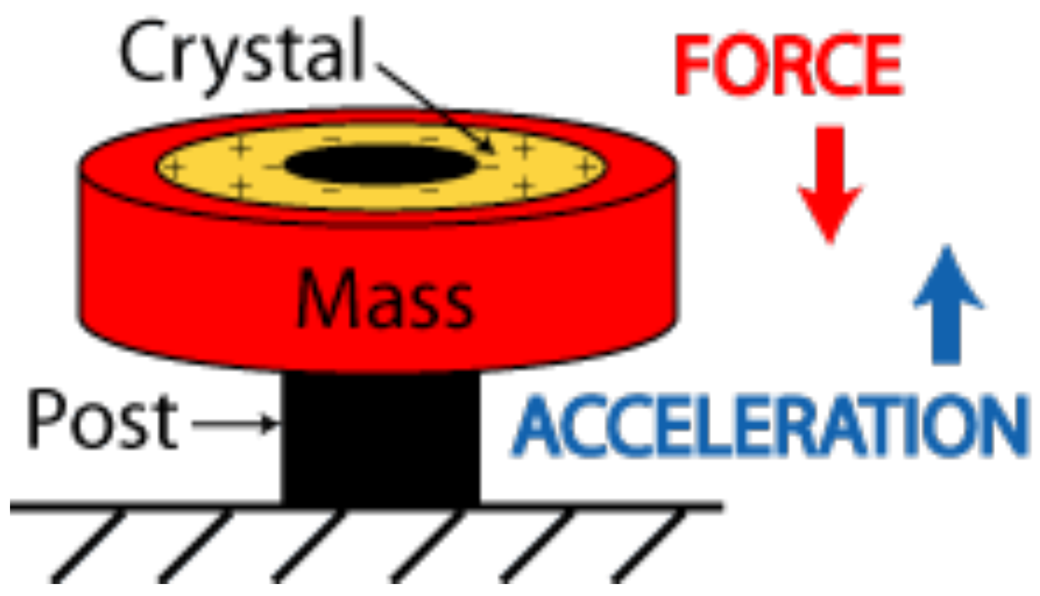




Shear Style

Planar Shear or Annular Shear designs





Advantages

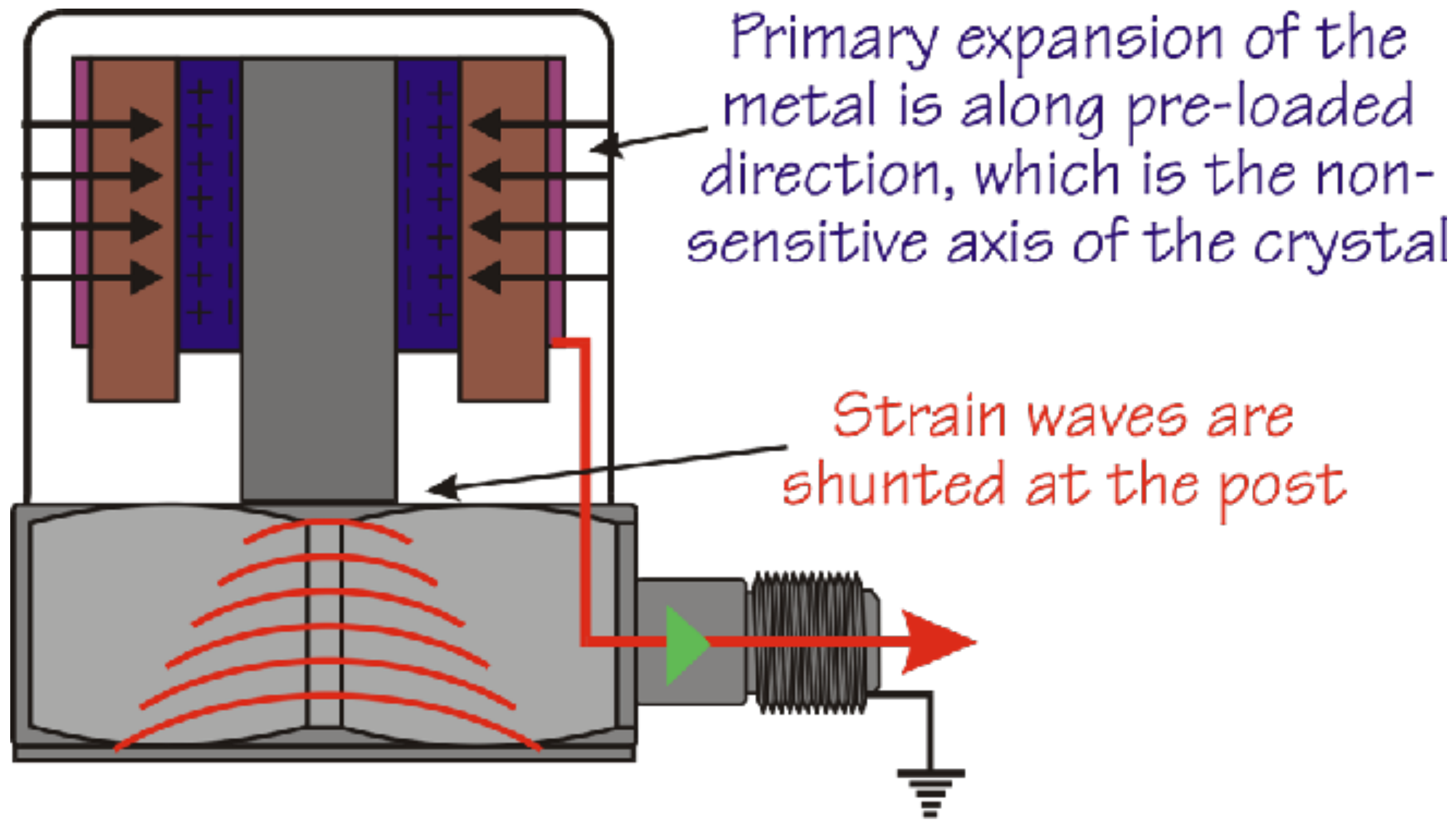
Low Thermal Transient Sensitivity
- Allows for low frequency operation in thermally unstable environments

Very Low Base Strain Sensitivity
- Excellent for use on flexible structures

Small Size

Disadvantages

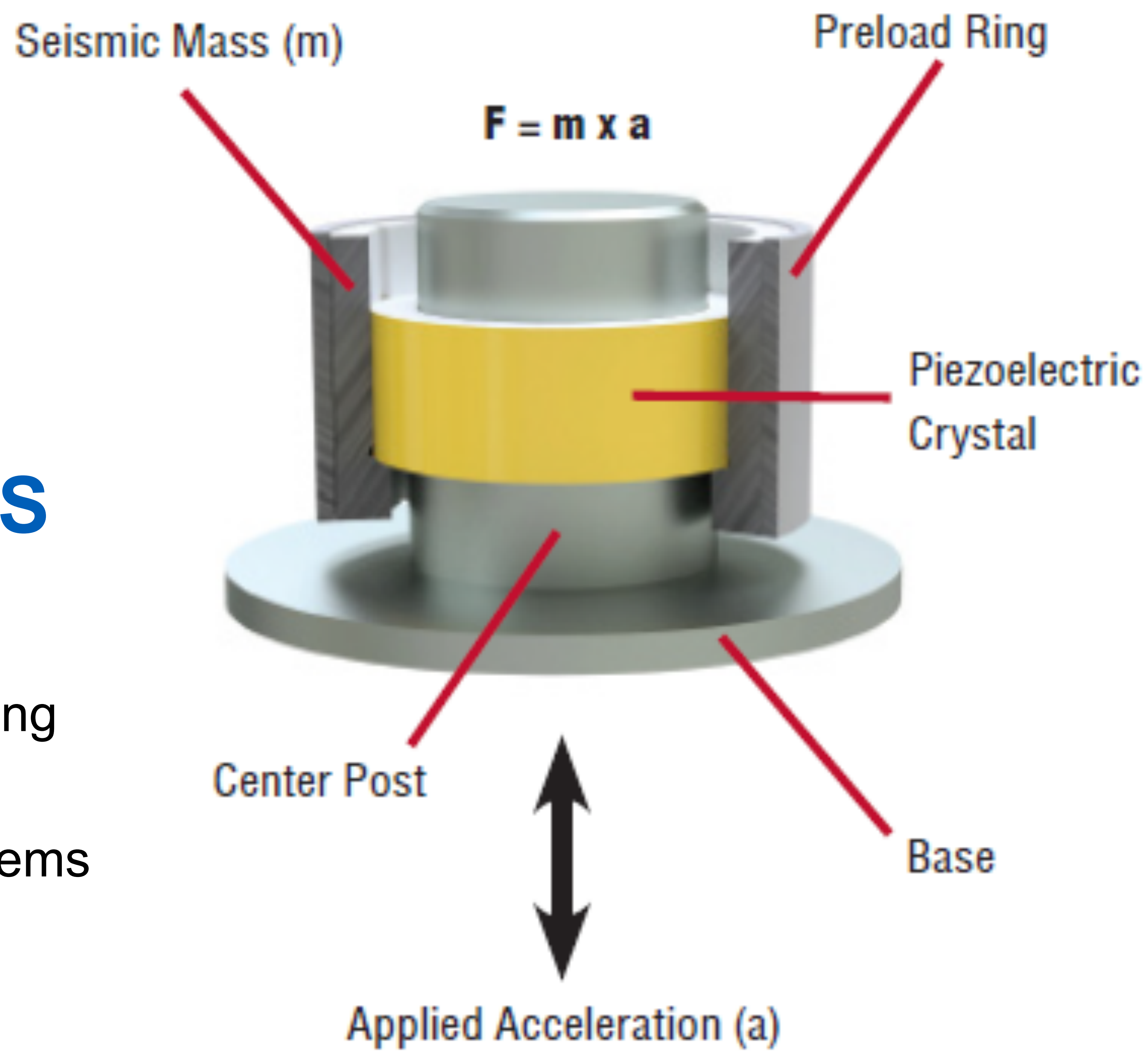
Annular preload ring not suitable for high temp use, driving use of the planar shear design.



PCB PIEZOTRONICS
AN AMPHENOL COMPANY

ICP® & CHARGE ACCELEROMETERS

Piezoelectric accelerometers measure vibration and shock for a wide variety of applications. They incorporate a piezoelectric sensing element with a crystalline atomic structure which outputs an electrical charge when subjected to a load with near zero deflection.
The charge output occurs instantaneously, (making them ideal for dynamic applications) but is subject to decay and therefore not capable of static measurements.

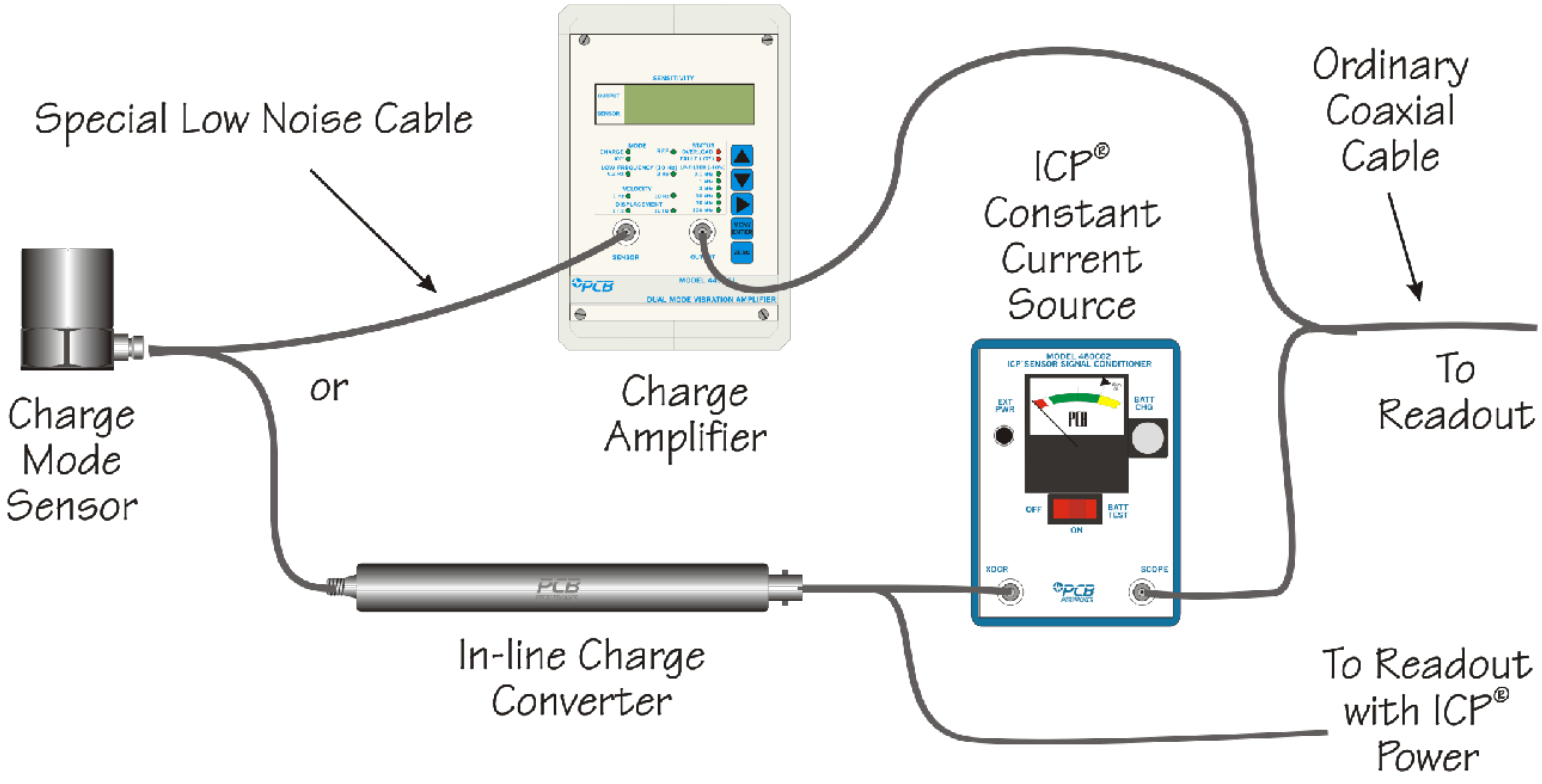


TWO MAIN TYPES OF PIEZOELECTRIC ACCELEROMETERS

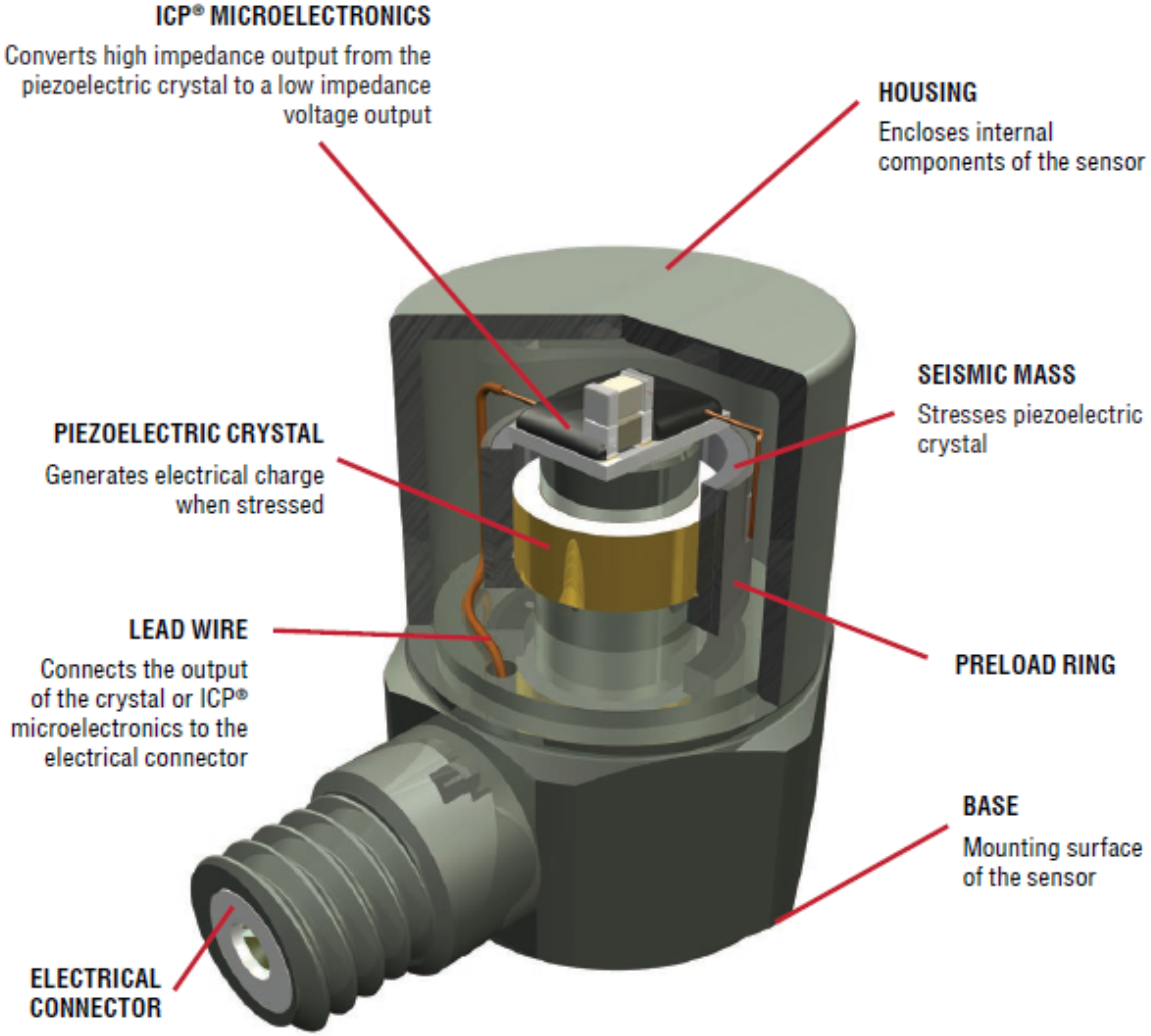
ICP® - Identifies PCB® sensors that incorporate built-in microelectronics.
The ICP® electronics convert a high-impedance charge signal generated by a piezoelectric sensing element into a usable *low-impedance voltage signal* when powered with constant current. The modified signal can be readily transmitted over two-wire or coaxial cables to data acquisition systems or readout devices.

Charge mode - The output of a charge mode accelerometer is a *high impedance signal* which is dependent on electrical insulation for low loss / low noise transmission. It should be converted to a low impedance signal prior to the data acquisition system or readout device. It is important to use low noise cables and avoid using cables with insulation damage or contamination.

Charge Accelerometer Construction



ICP® Accelerometer Construction



ICP® ADVANTAGES

- Simple to operate
- Able to operate in dirty environments over long cable runs
- Uses integral power from all manufacturers' data acquisition systems (may require specific module)

CHARGE MODE ADVANTAGES

- Operating temperature up to +650 °C for UHT-12 element with hardline cable
- Flexibility in adjusting accelerometer output characteristics
- Extended low frequency response with long time constant charge amps

ICP® DISADVANTAGES

- Maximum operating temperature of 180 °C
- Sensitivity and low frequency response are not adjustable
- Requires ICP® fixed-current power

CHARGE MODE DISADVANTAGES

- Additional cost of required charge amplifier or charge converter
- Sensor and cable connections must be kept clean and dry for best performance
- Requires more costly, low noise cable

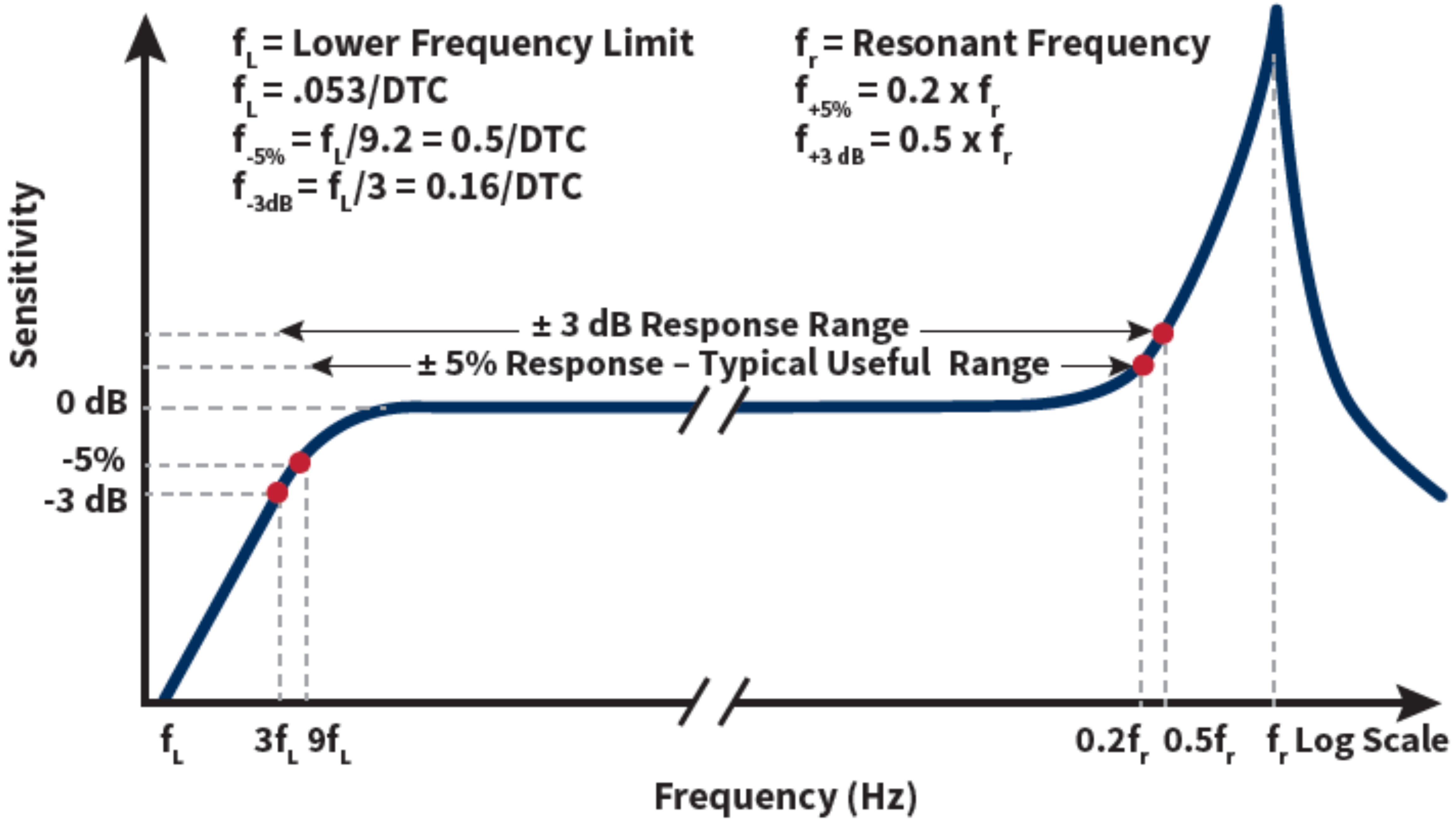
SIGNAL DECAY & DTC

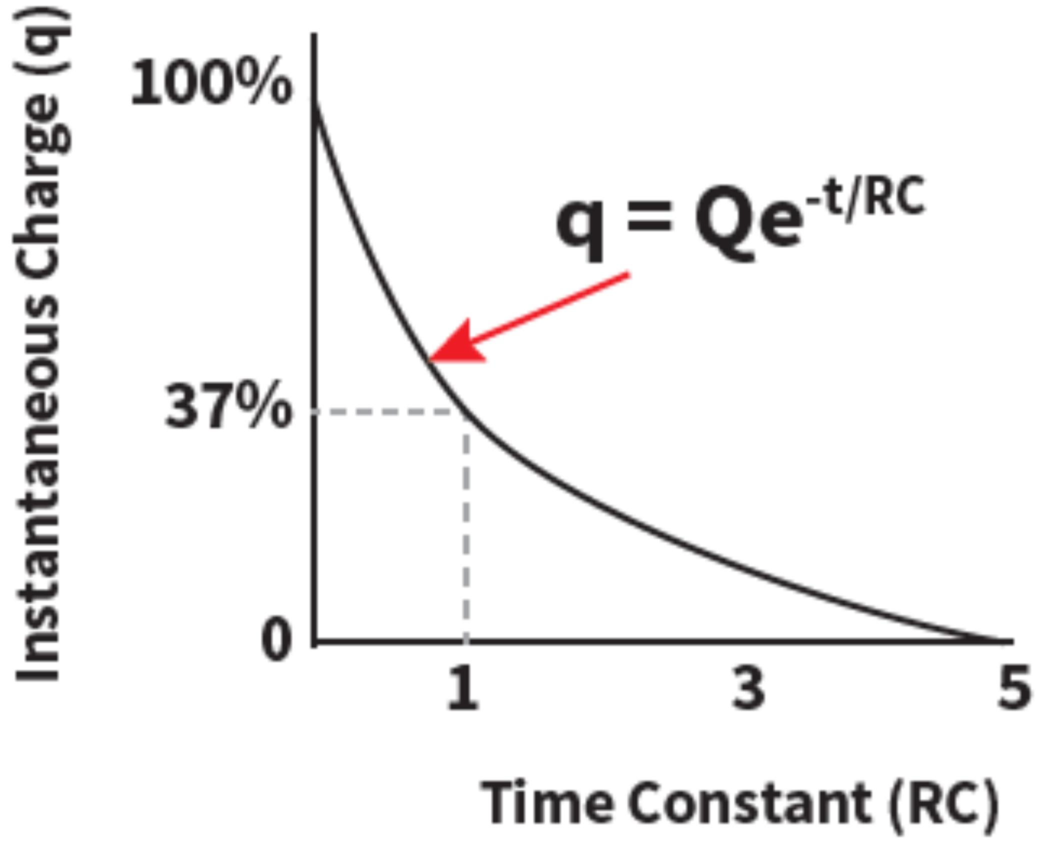
- Discharge Time Constant (DTC) is the time (usually in seconds) required for an AC coupled device or measuring system to discharge its signal to 37% of the original value from a step change of measurand.

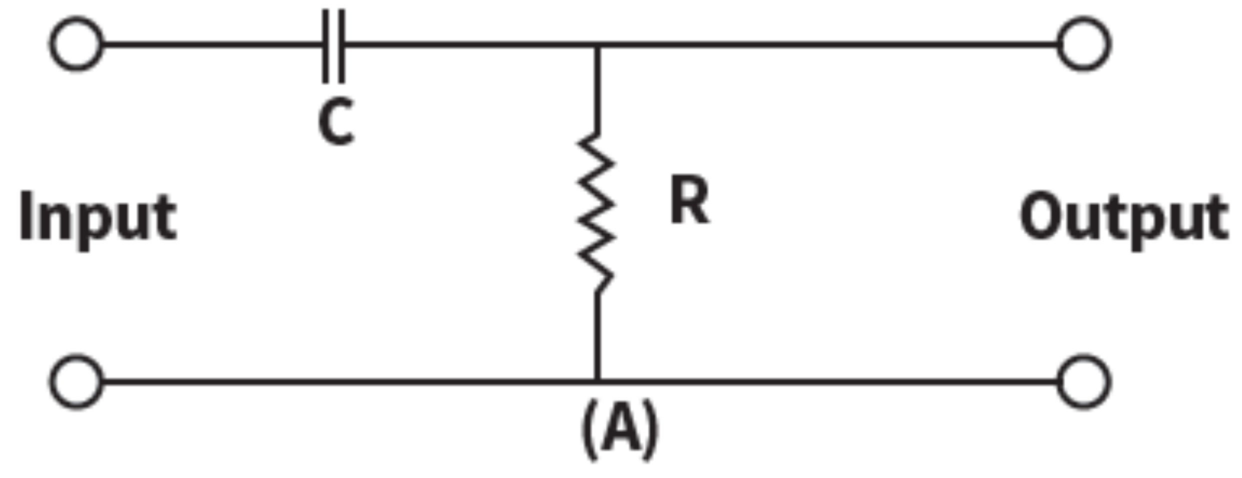
- Follows RC circuit principles where an instantaneous charge immediately begins dissipating at an exponential rate.

- ICP® sensors have fixed DTC based on the values of the internal RC network. When used in AC coupled systems, (sensor, cable, and ICP® signal conditioner) the sensor will take on the DTC characteristics of the ICP® sensor or signal conditioner (whichever is shortest).

- In charge mode sensors, the DTC is dictated by choice of charge amplifier or in-line charge converter and system resistance/ capacitance.







Sensor Information

Model Number:	M353B15
Serial Number:	LW199370
Manufacturer:	PCB
ID Number:	
Description:	ICP® Accelerometer

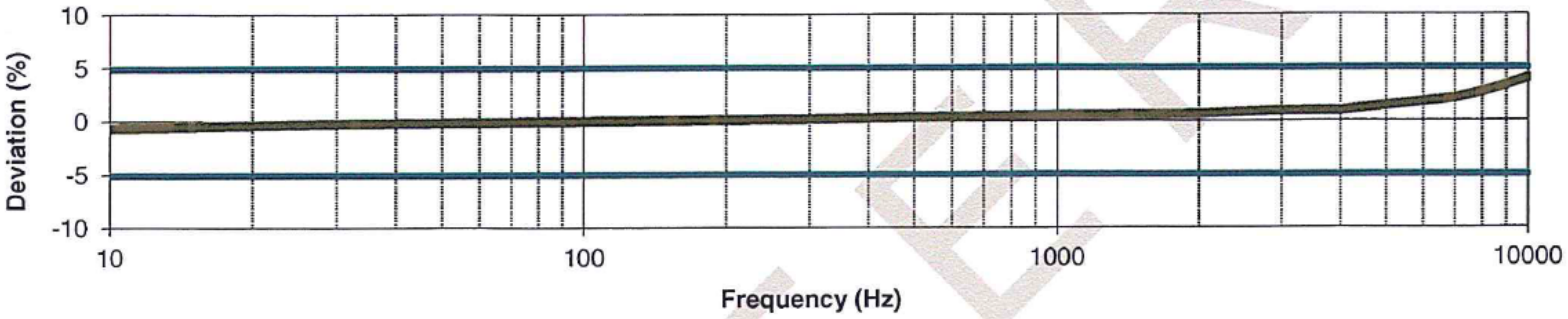
Calibration Data

Sensitivity @ 100 Hz:	0,997	mV/(m/s²)
	9,78	mV/g
Phase @ 100 Hz:	0,2560	deg.
Test Level:	98,07	m/s²
Output Bias Level:	8,7	VDC

Transducer Specifications

Amp. Range:	± 4903	m/s²
Resolution:	0,049033	m/s²
Resonant Freq:	≥ 70000	Hz
Temp. Range:	-54 to 121	°C
	-65 to 250	°F
Axis:	Uni-Axial	

Amplitude Response



TYPICAL PERFORMANCE SPECIFICATIONS

ICP® Accelerometer	Model 352C22	
Sensitivity (±20 %)	10 mV/g	1.0 mV/(m/s²)
Measurement Range	±500 g pk	±4900 m/s² pk
Frequency at -5 %	1.0 Hz	
Frequency at +5 %	10,000 Hz	
Frequency at -3 dB	0.3 Hz	
Frequency at +3 dB	20,000 Hz	
Resonant Frequency	≥50 kHz	
Environmental		
Temperature Range (Operating)	-65 to +250 °F	-54 to +121 °C
Electrical		
Excitation Voltage	18 to 30 VDC	
Output Bias Voltage	7 to 12 VDC	
Discharge Time Constant	1.0 to 3.5 sec	

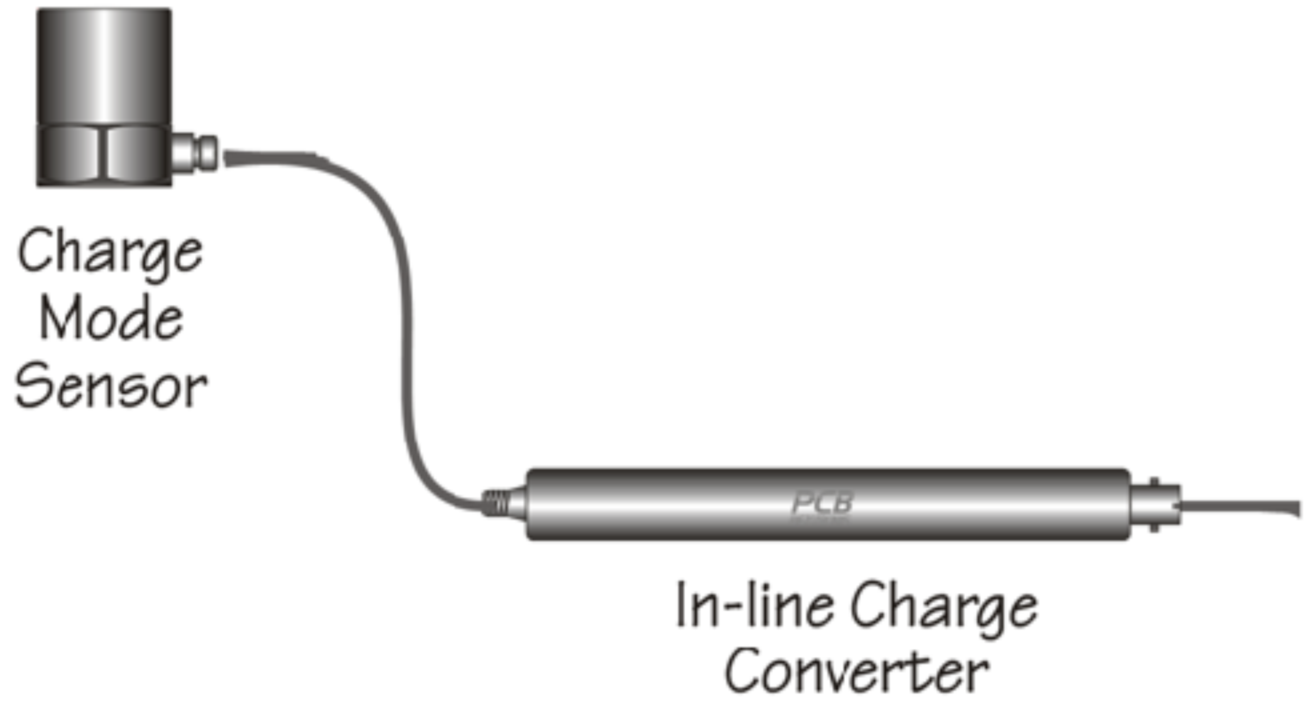
Charge Accelerometer	Model 357C10	
Sensitivity (±20 %)	1.7 pC/g	0.17 pC/(m/s²)
Measurement Range	±500 g pk	±4900 m/s² pk
Frequency at -5 %	Low frequency response is determined by external signal conditioning electronics.	
Frequency at +5 %	10,000 Hz	
Frequency at -3 dB	Low frequency response is determined by external signal conditioning electronics.	
Frequency at +3 dB	20,000 Hz	
Resonant Frequency	≥50 kHz	
Environmental		
Temperature Range (Operating)	-100 to +350 °F	-73 to +177 °C

Charge Mode Sensor

Sensitivity (±15 %)	10 pC/g	1.02 pC/(m/s²)
Measurement Range	±2000 g pk	±19600 m/s² pk

In-line Charge Converter

Sensitivity (±2.5 %) (Charge Conversion)	10 mV/pC
Input Range	±500 pC



Dati relativi alla catena di misura

- Sensitivity = sensitivity sensore * sensitivity in-line charge converter
  che nel nostro caso 100 mV/g
- Measurement range = Input range in-line charge converter / sensitivity del sensore
  che nel nostro caso 50g

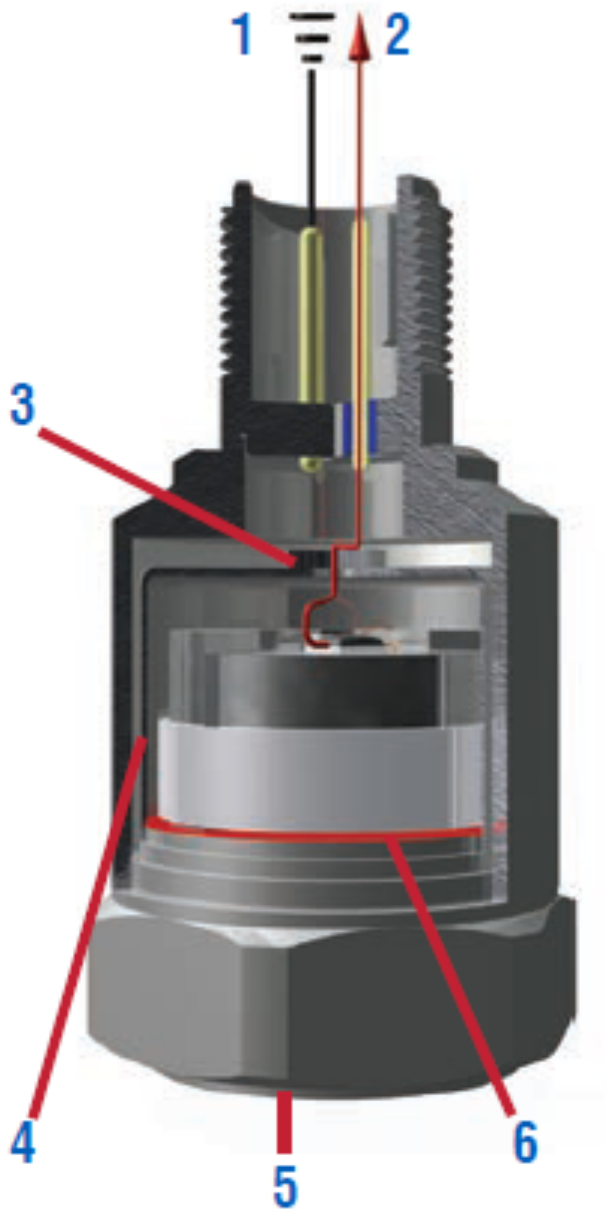
ELECTRICAL ISOLATION DESIGNS

CASE ISOLATION

The sensing element is isolated from the sensor housing.

- Since the signal and signal ground are internally isolated, the cable shield is floated at the sensor end to prevent ground loops
- The shield is grounded only at the readout device
- Sensor can be placed directly on the device under test, no additional base isolation needed
- A two-conductor cable must be used for power and signal transmission

1. Signal Ground
2. Output Signal & Power (+)
3. Capacitor provides ESD protection and RFI filtering
4. Faraday cage shields against environmental noise
5. Case Ground, thru mounting base
6. Coated pad electrically isolates sensing element from outer case



GROUND ISOLATION

Sensor is isolated from mounting surface with an electrically non-conductive material with high insulation resistance.

- Integral Isolation – Incorporate a non-conductive layer isolating the inner sensor from the outer housing

Titanium Isolation Housing

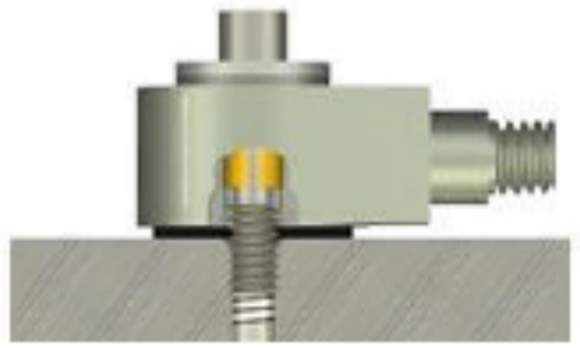
- Anodized Aluminum Isolation - Sensor models that are black in color use anodized aluminum housings for isolation, but potentially degrade with coating wear

Anodized Aluminum Isolation

- Base Isolation – Some accelerometers incorporate an integral isolation mount or models with female threads can add an isolation base – both shown below

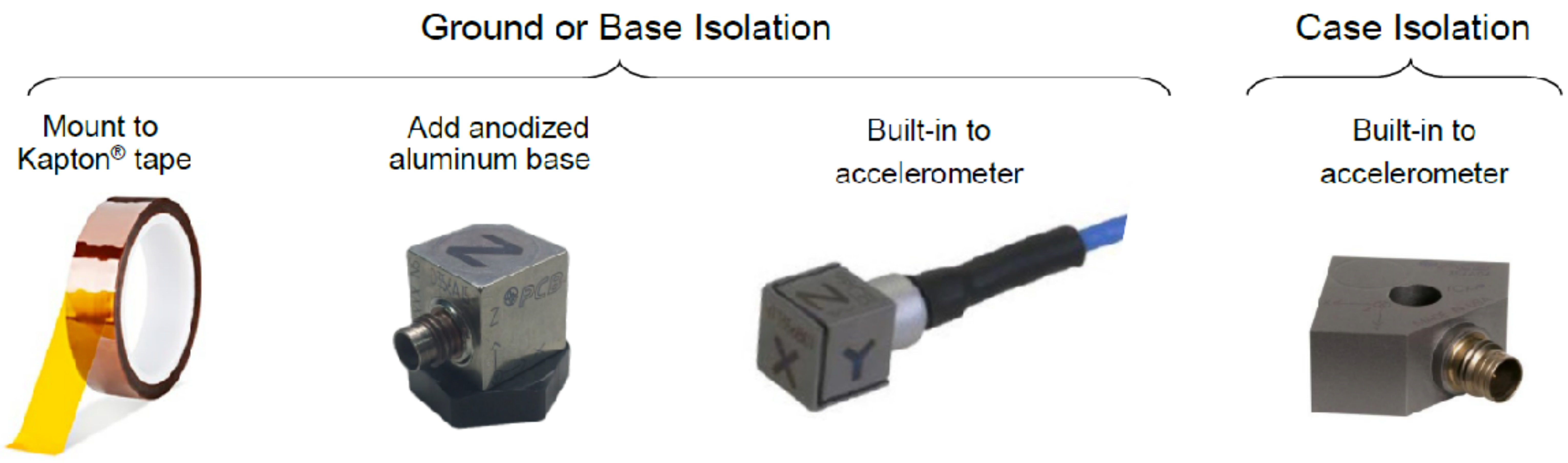
Isolation Base

- The above isolation methods require a cable with at least 1 conductor per channel plus the shield. Use of 2-conductor cables with 1 conductor for signal ground is best practice (shielding optional)

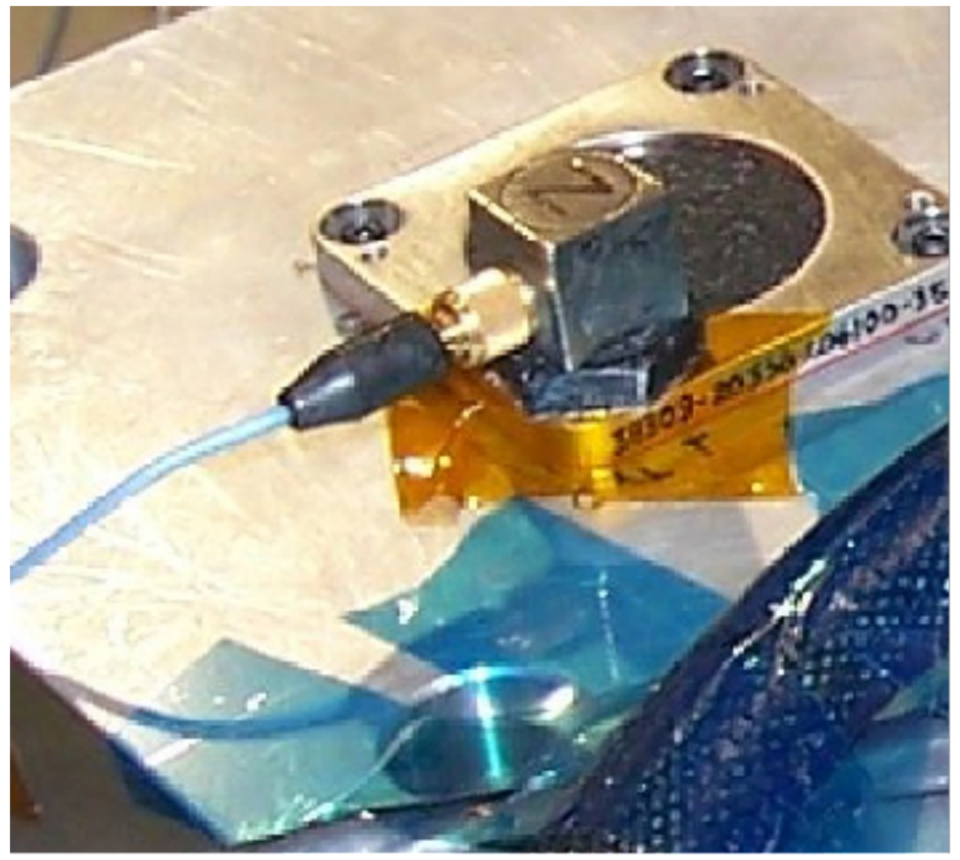


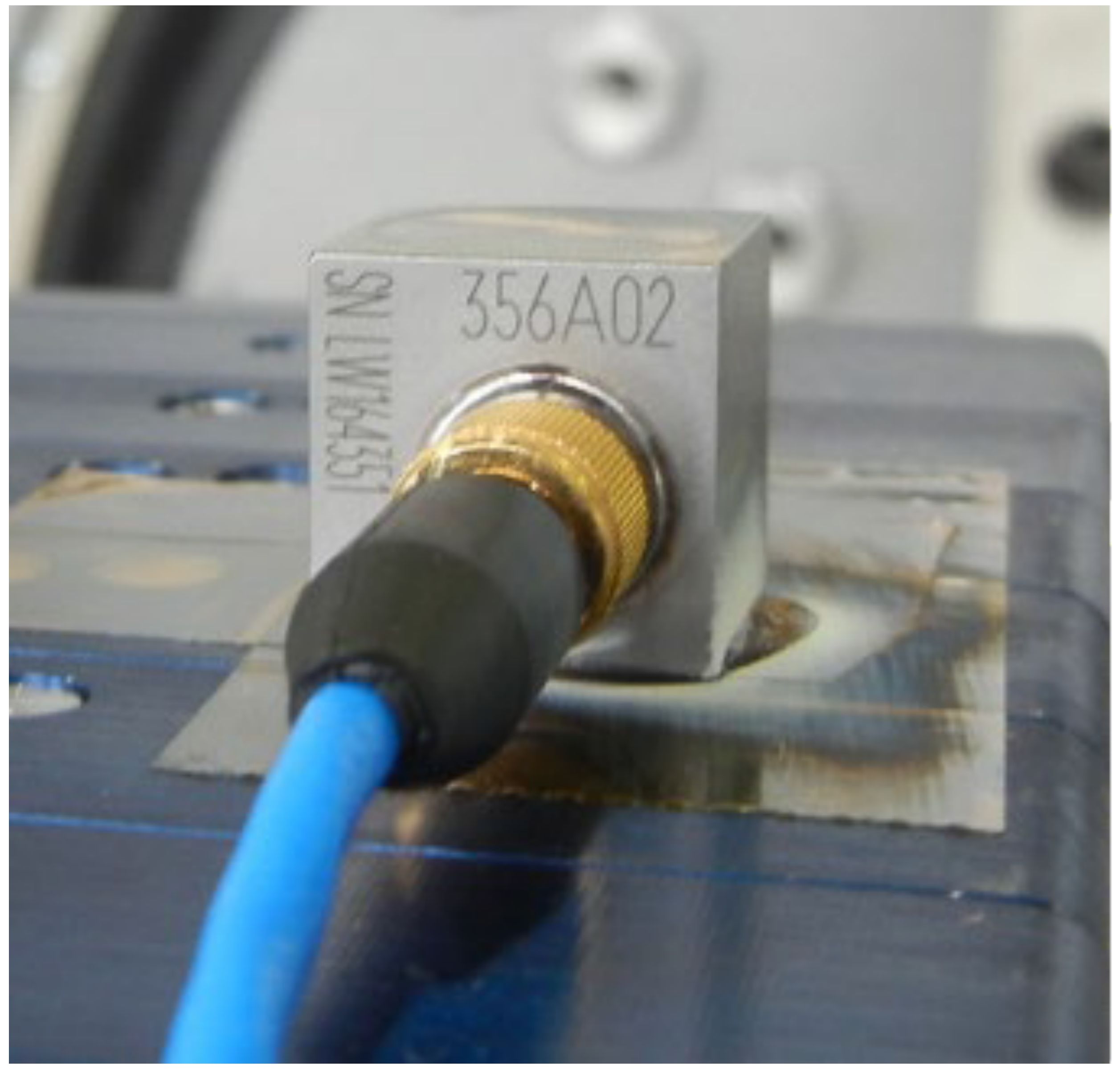
Integral Base Isolation

Electrical Isolation



If using an anodize aluminum base, anodized surfaces can scratch and become on-ground

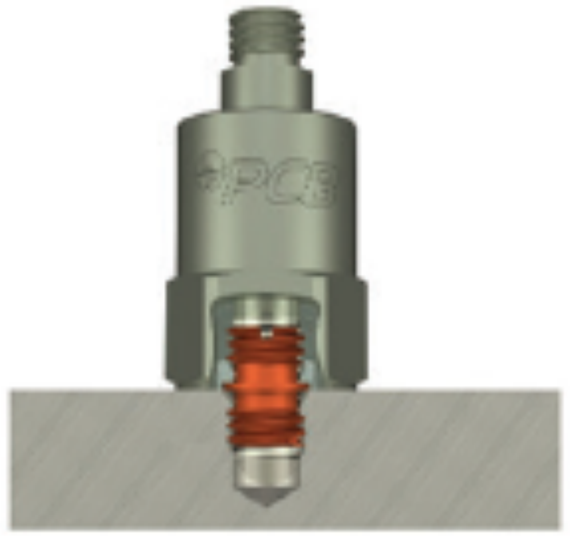




MOUNTING CONSIDERATIONS & AMPLITUDE RANGE

MOUNTING TECHNIQUES

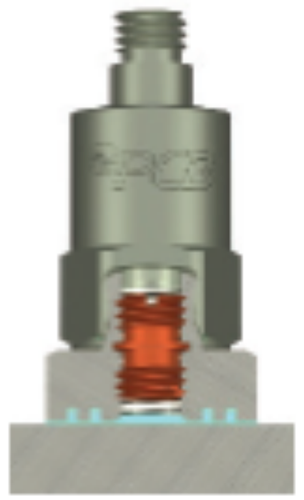
There are a variety of mounting techniques for accelerometers. Each method influences the achievable high frequency measurement range.



STUD MOUNT

Stud mounting (integral or tapped hole) preferred for greatest rigidity.

- **This method provides excellent high frequency response**



ADHESIVE MOUNT

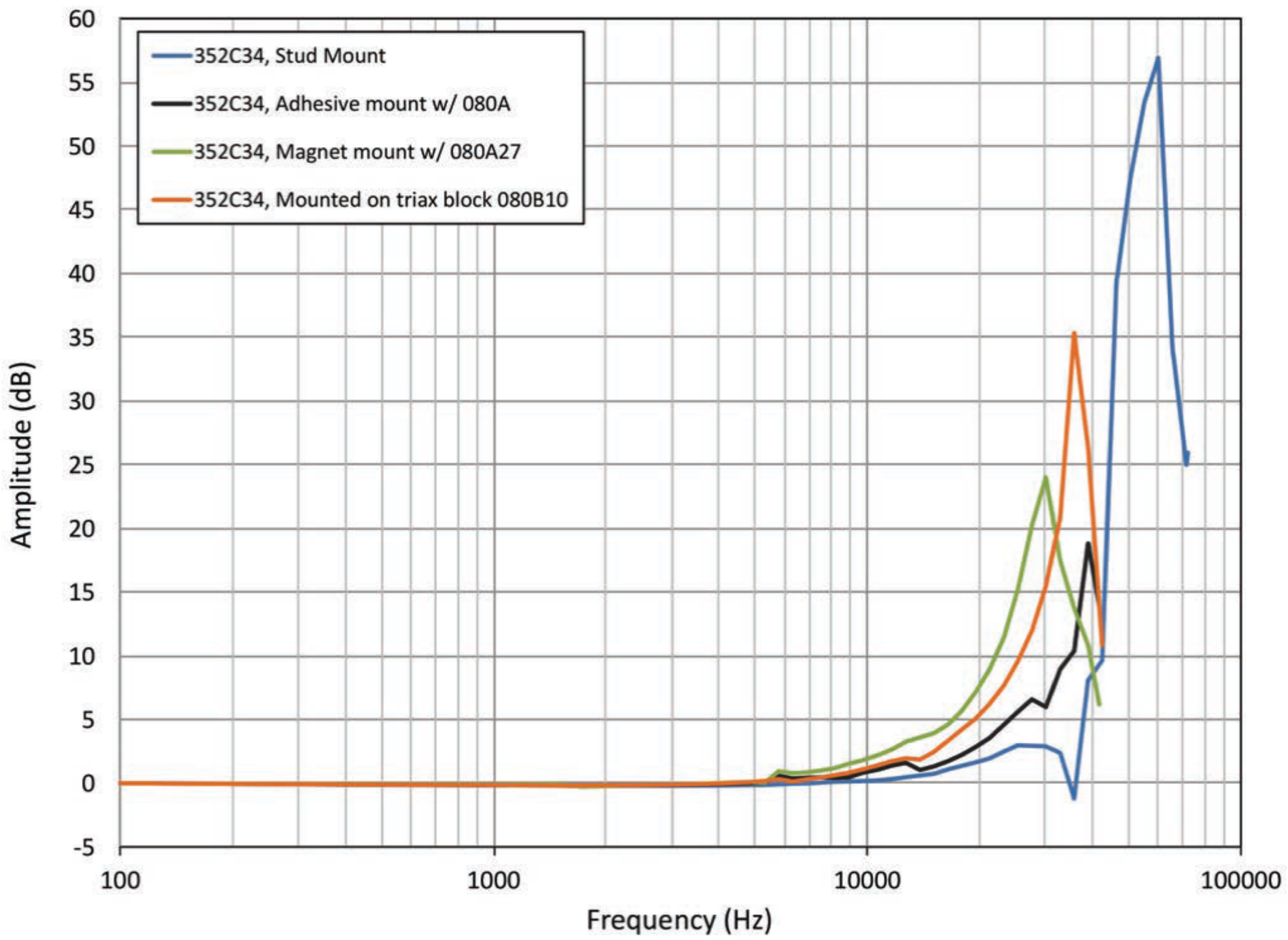
Adhesive mounting bases can be used when other techniques are not practical.

- **Some adhesives have limited use in higher temperature applications**

MAGNET MOUNT

Used for temporary mounting or on curved surfaces.

- **Magnets can limit the useable frequency range of the accelerometer**



352C34, Stud Mount
352C34, Adhesive mount w/ 080A
352C34, Magnet mount w/ 080A27
352C34, Mounted on triax block 080B10
Amplitude (dB)
Frequency (Hz)
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
100
1000
10000
100000

Petro wax

- Ultra convenient and simple for general purpose vibe testing
- Good for short term testing only
- Frequency response characteristics highly dependent upon surface prep and amount of wax used
- Low melting point, not suitable for warm/high temp applications
- Not suitable for shock applications, sensor can ‘pop’ off

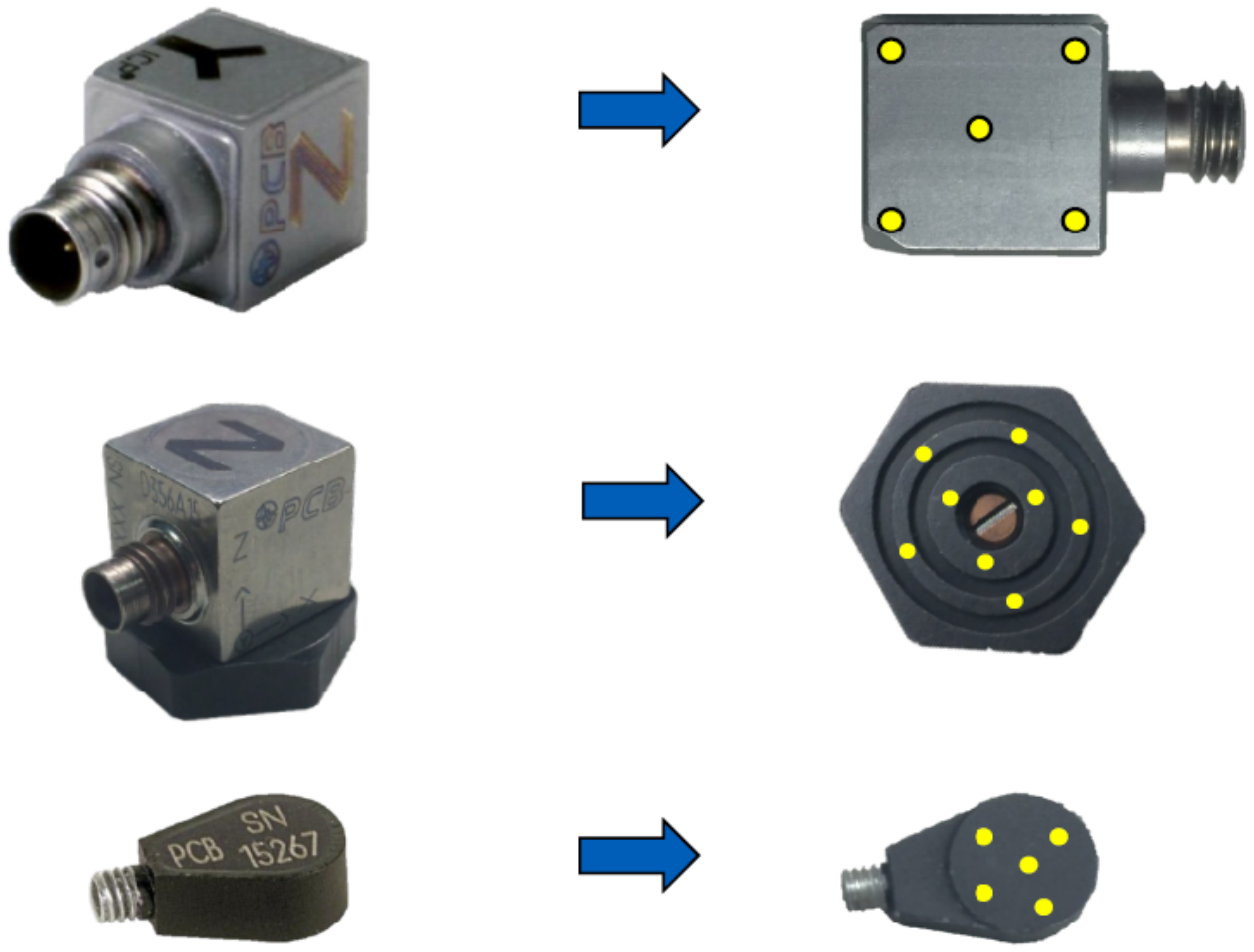
Hot glue

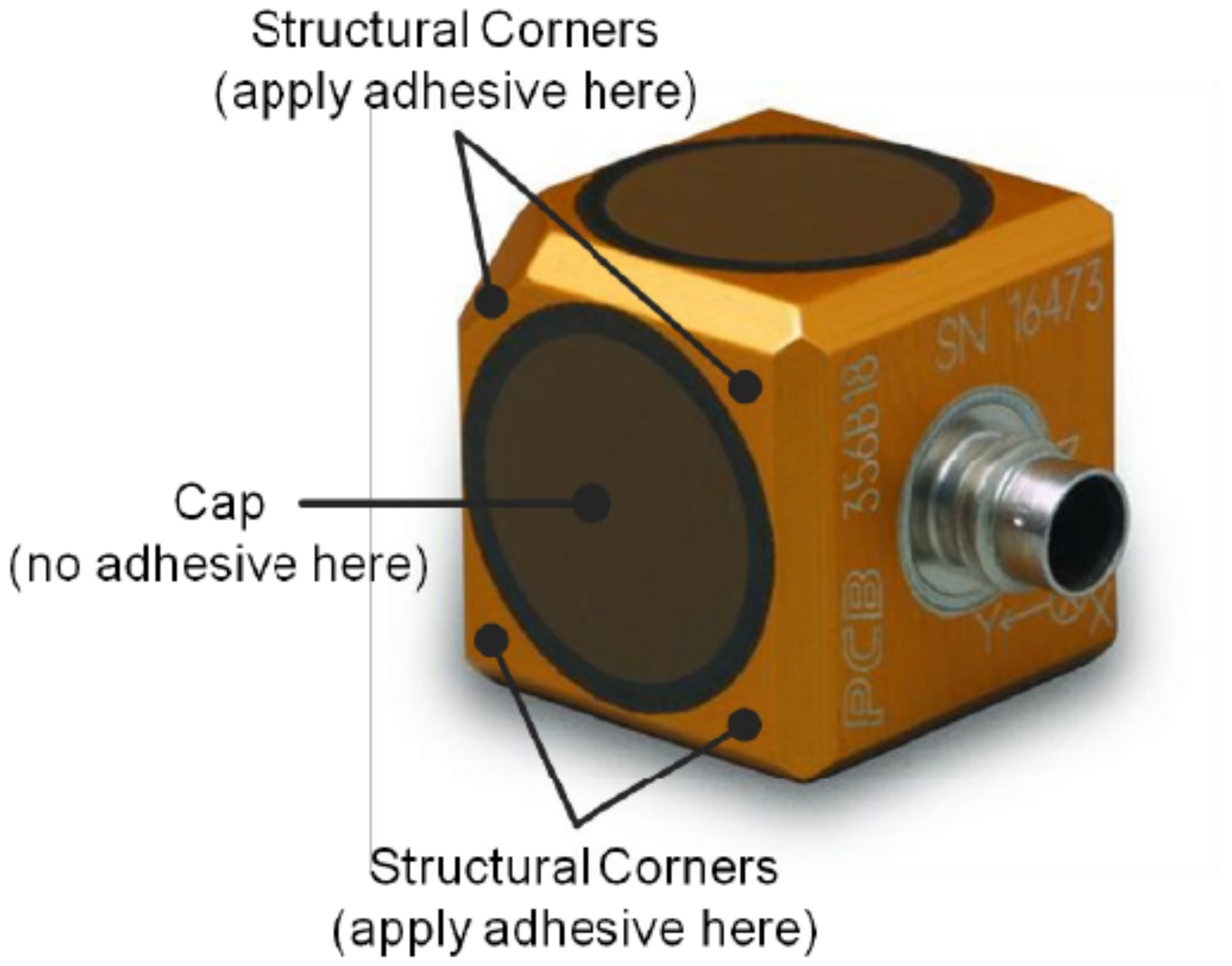
- Allows attachment to poorly-mated surfaces
- Good for short term to mid term testing
- Provides a certain amount of unpredictable damping, and can also depend on how much glue is used
- Frequency response characteristics poor, but generally good enough for modal applications

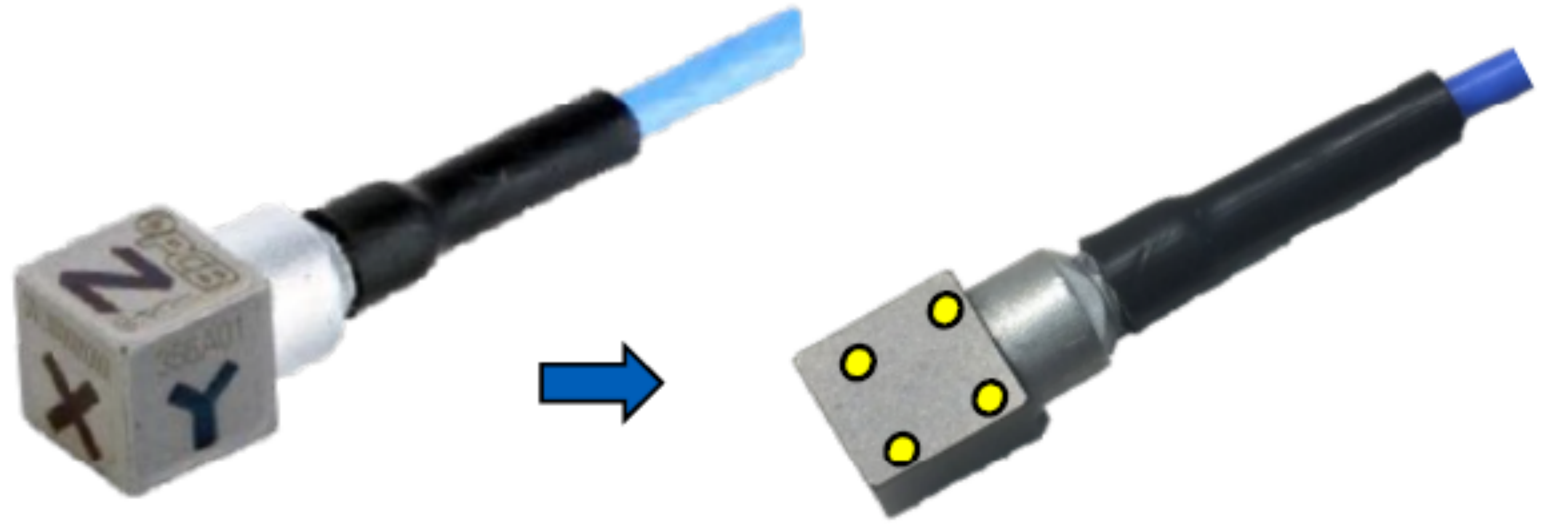
Cyanoacrylate

- “Instant” adhesive; strong, but still removable
- Gel vs liquid – depends upon surface flatness
- Excellent frequency response characteristics
- Provided as a supplied accessory for many PCB accelerometers
- Requires debonding agent (Acetone) to remove accelerometer from test article

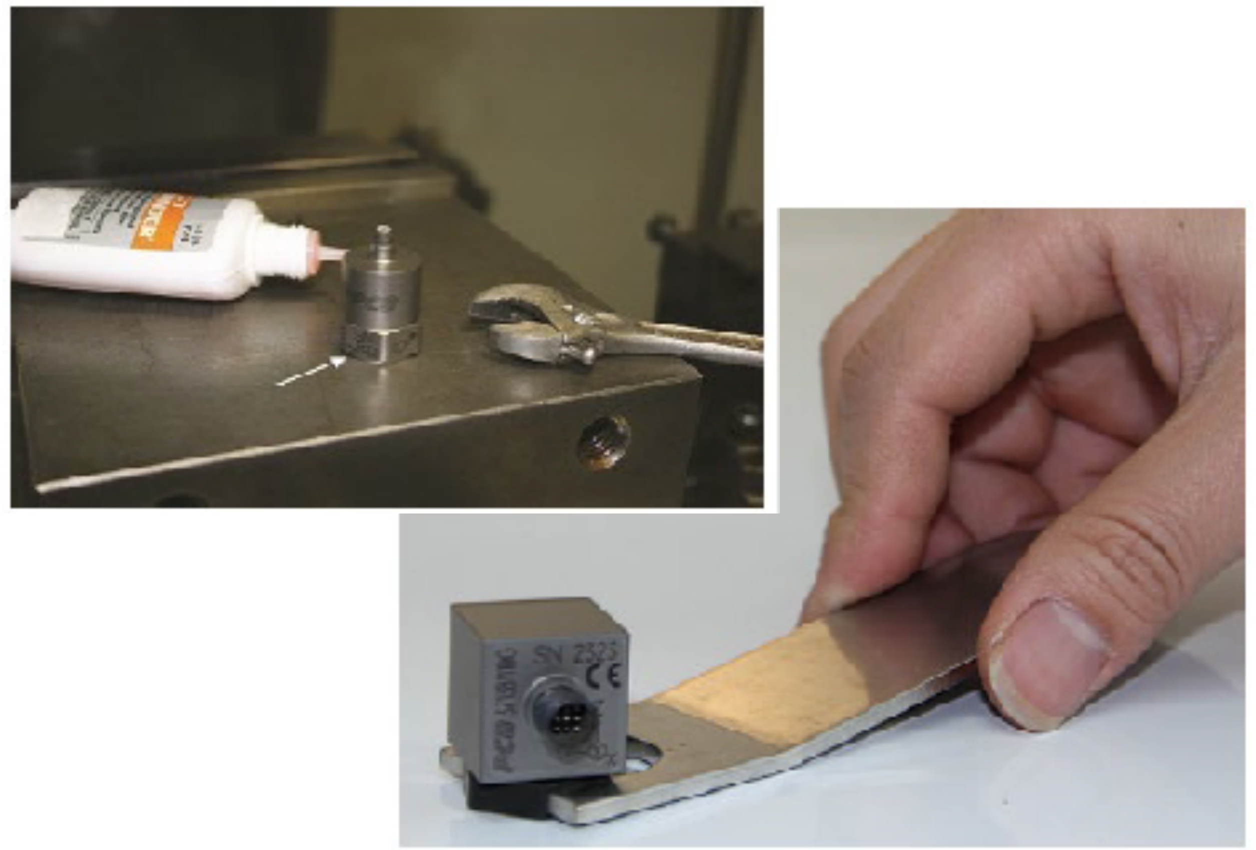
Mounting with glue examples

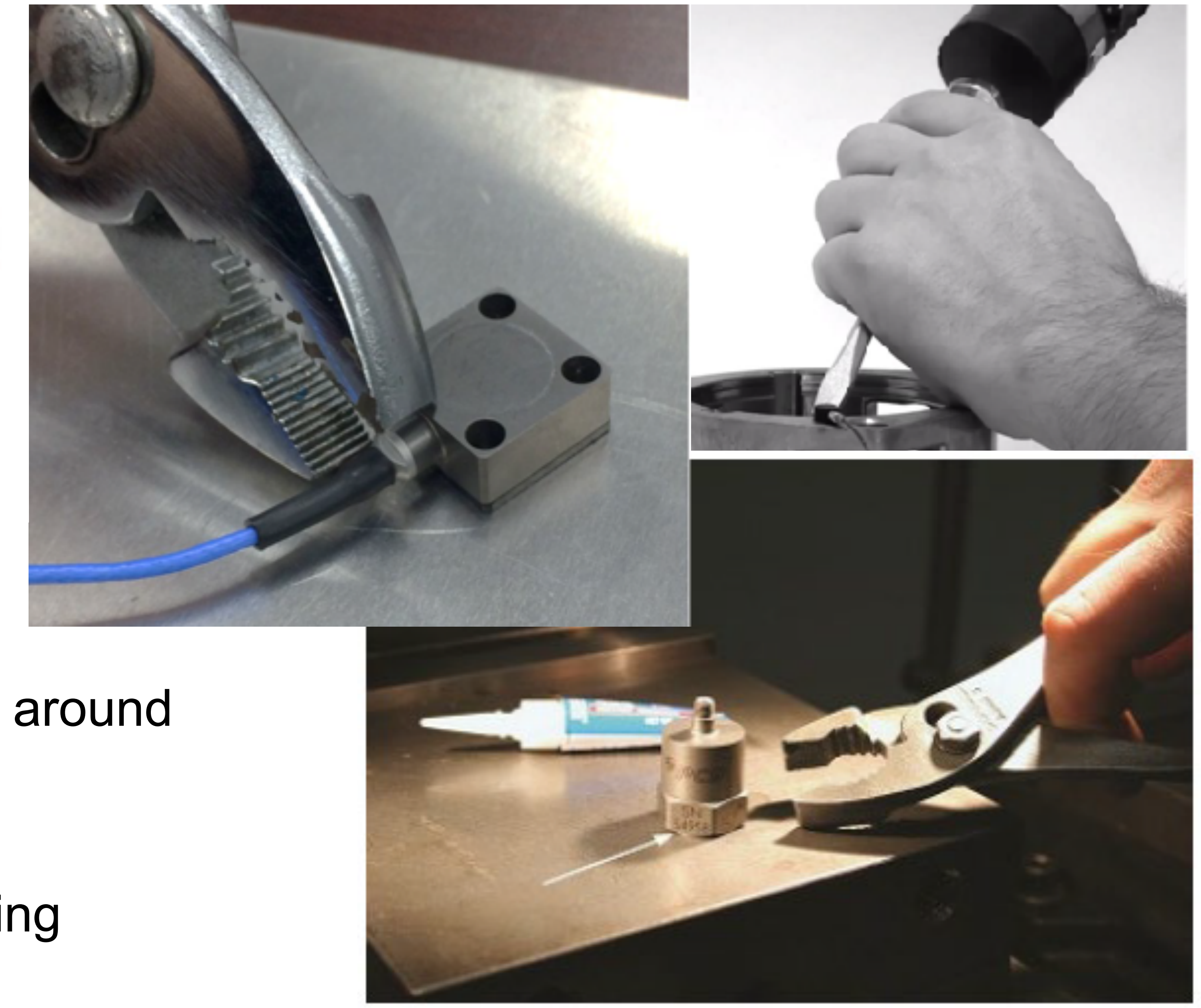






Removing glue mounted accelerometers





- Use appropriate debonding agent to soften your adhesive before attempting removal, a few drops around the edges should suffice. (Locktite 454 can be removed with acetone)
- Once debonding agent has soaked for 2-3 minutes, attempt to remove the accelerometer by twisting (super glue easily fails in shear) with approved tool.
- Use factory supplied removal tool (if provided/available)
- Use a crescent wrench on the hex portion of sensor (cannot crush/damage the sensor)
- After removal, use the same solvent with a swab and clean cloth to remove any remaining adhesive residue on UUT and accelerometer housing.

Wiring

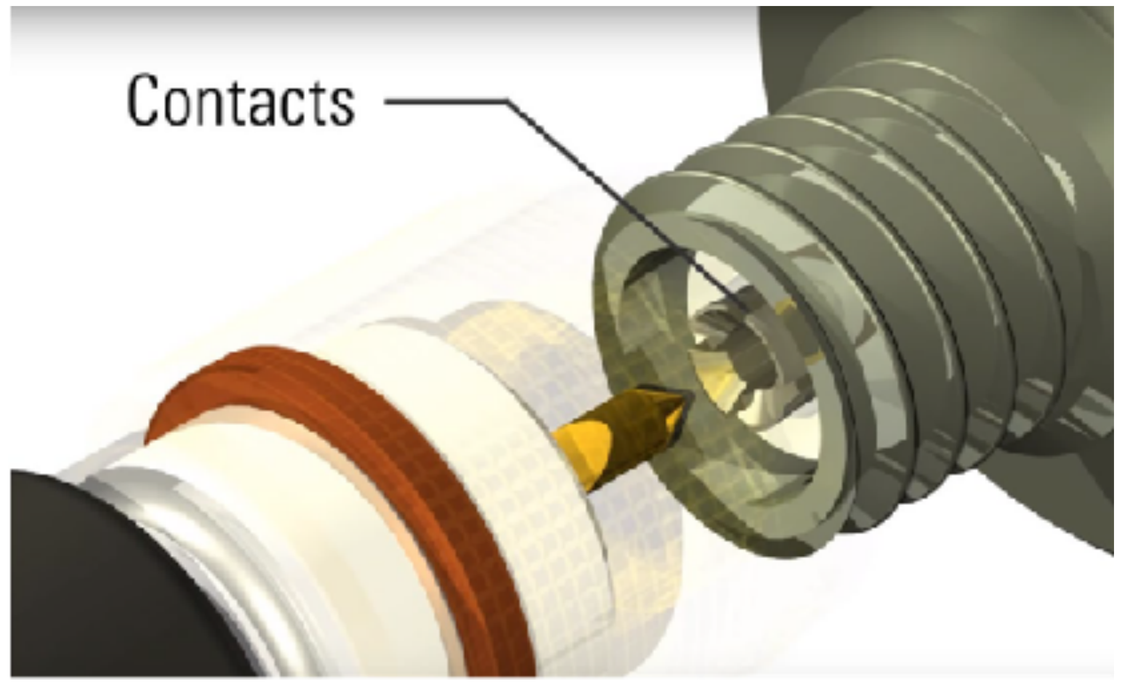
Ground Loops
Unwanted differences in the electrical potential between the sensor and the instrumentation will result in erroneous DC offsets and voltage drops. The entire measurement chain should be grounded at only one point (which is the very purpose of grounding!)

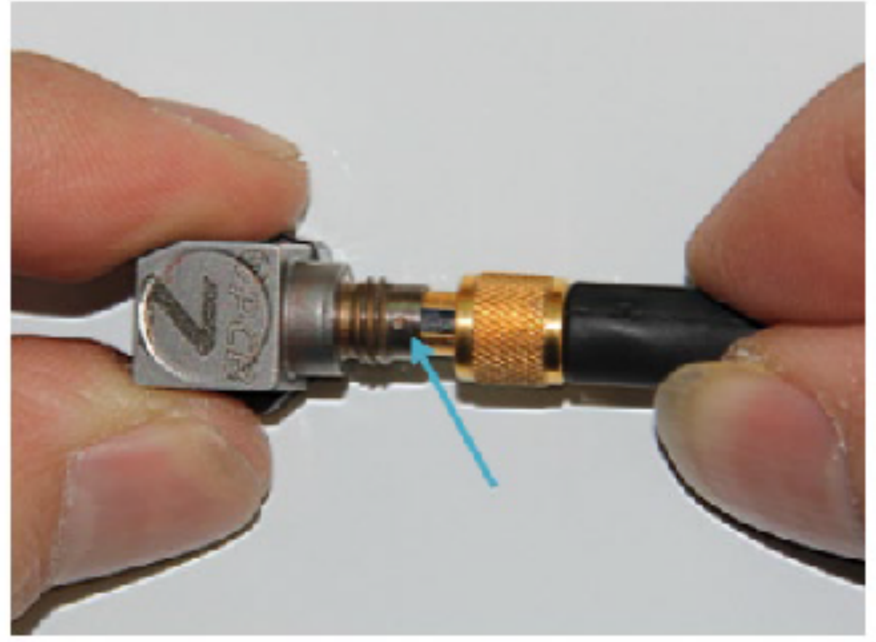
Electromagnetic Noise
Again, the best practice is to avoid long cable lengths where possible; but sometimes special cabling may be needed that is has reinforced shielding to offer EMI protection.

Mechanical Noise
Cable motion will literally induce mechanical strain on the accelerometer which the accelerometer will measure and erroneously report as vibration in your structure.

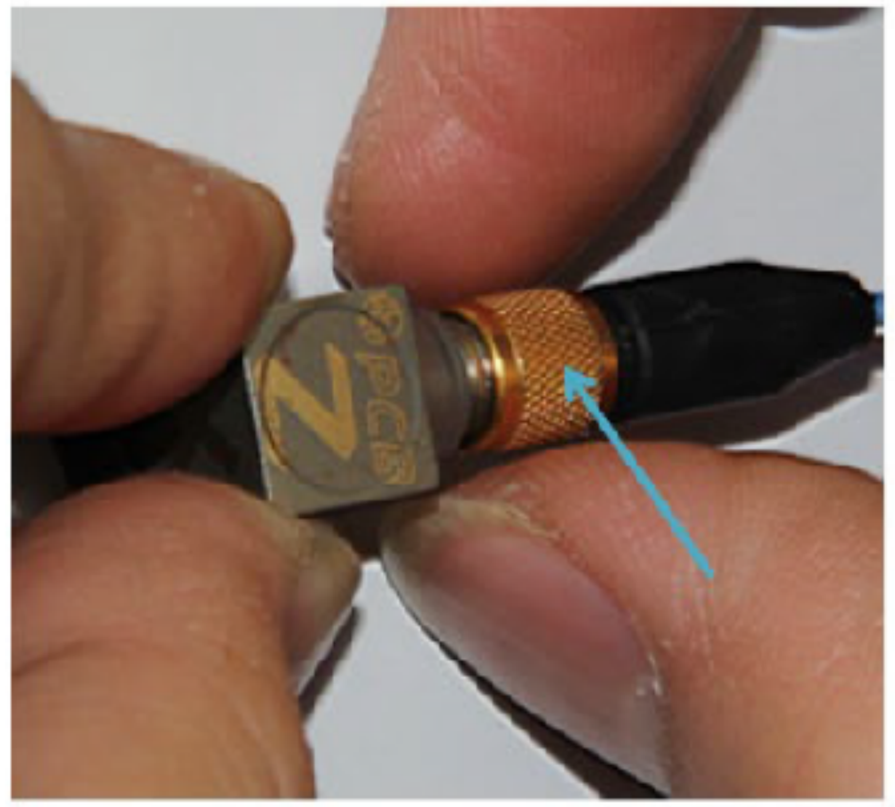
Risk of Losing Connection
The last challenge wiring presents is the possibility that you may lose connection during a test. So strain relieving your cabling is very important to prevent mechanical noise but also to help ensure connection is not lost.

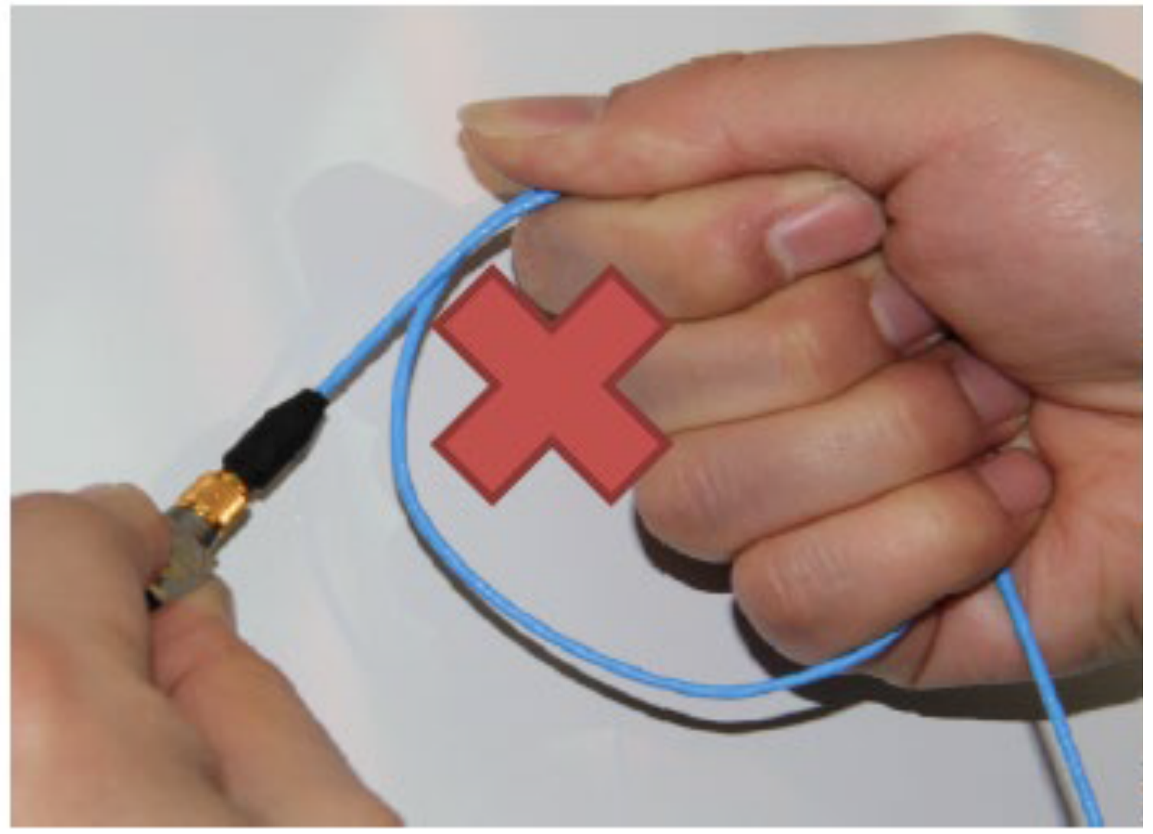
Cable installation

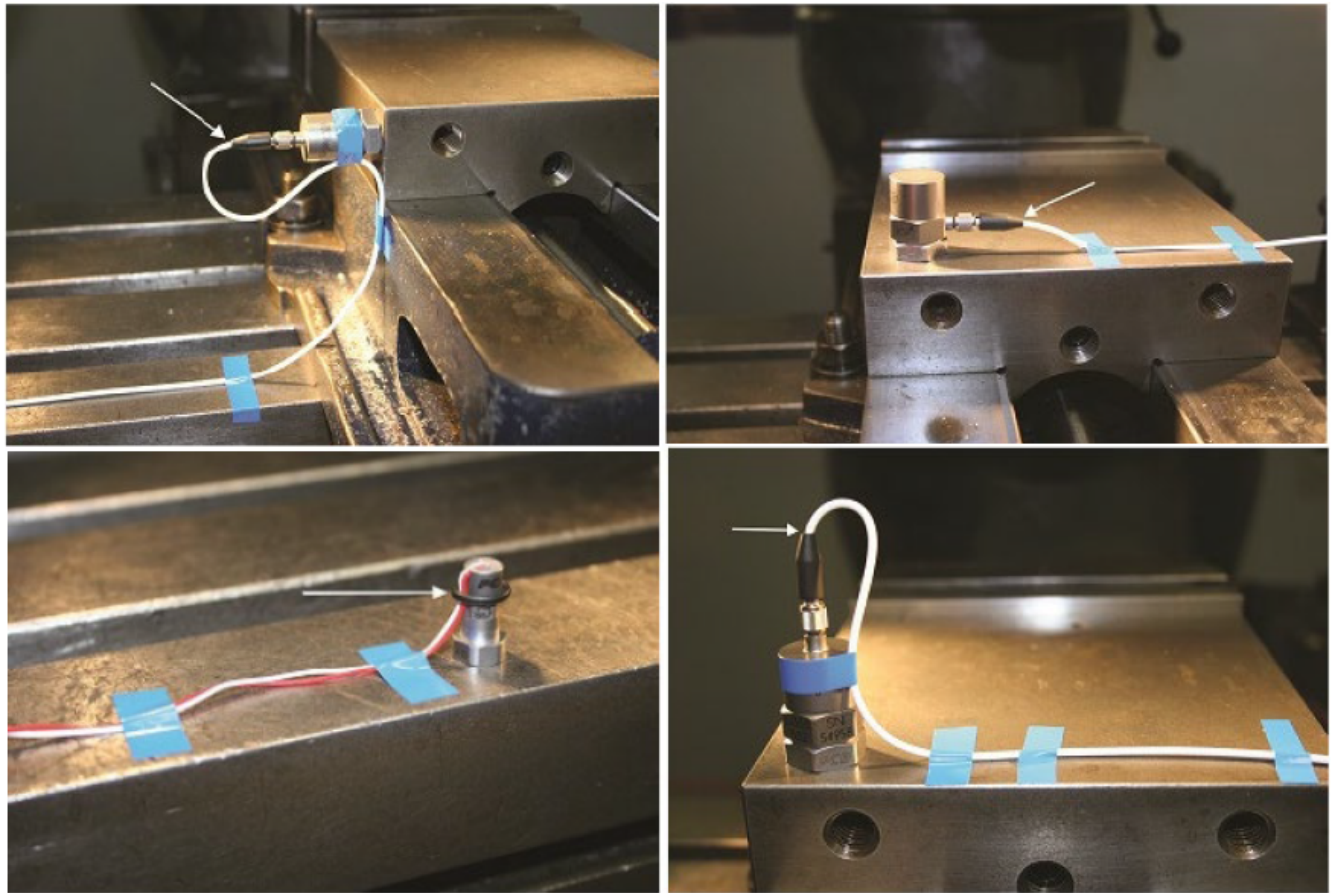




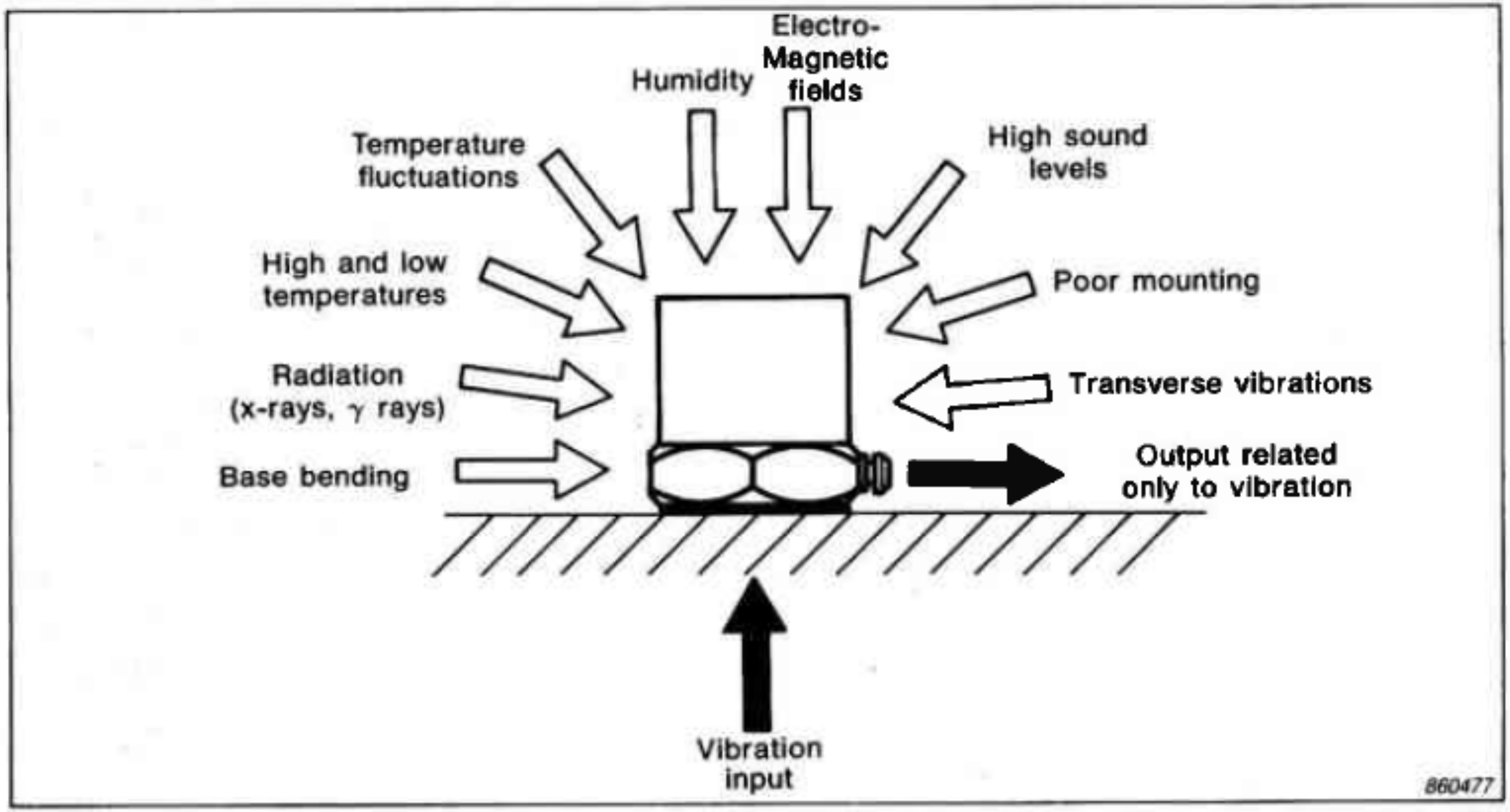
The accelerometer's 10-32 jack has 4 'prongs' to ensure good electrical contact with pin of mating cable. If proper cable installation is not followed, damage to the electrical contacts may occur.







Undesired Response



FILTERED ACCELEROMETERS

- Mechanical shock events can excite the high frequency resonance of the piezoelectric crystal, saturating the signal and leading to clipping in the ICP® signal conditioning amplifier.
- To help alleviate this event, PCB offers low pass filtering in select accelerometers which suppresses the effects of any crystal resonance before it can enter and over range the ICP® signal conditioning amplifier.
- Another purpose for filtering is to extend the usable high frequency range of the sensor by minimizing crystal resonance, resulting in an extended flat frequency response.

Applications where filtering may be needed

- Powertrain Development
- Climatic Chamber Testing
- Powertrain NVH
- Cylinder head
- Vehicle Systems NVH
    - Under-hood
    - Exhaust Testing
    - Brake Testing
- Component and Systems Performance
- Vehicle Road Load & durability
- Racing
- Flight Testing
- Aerospace applications - High-frequency airframe vibration monitoring
- General purpose applications with potential for signal saturation

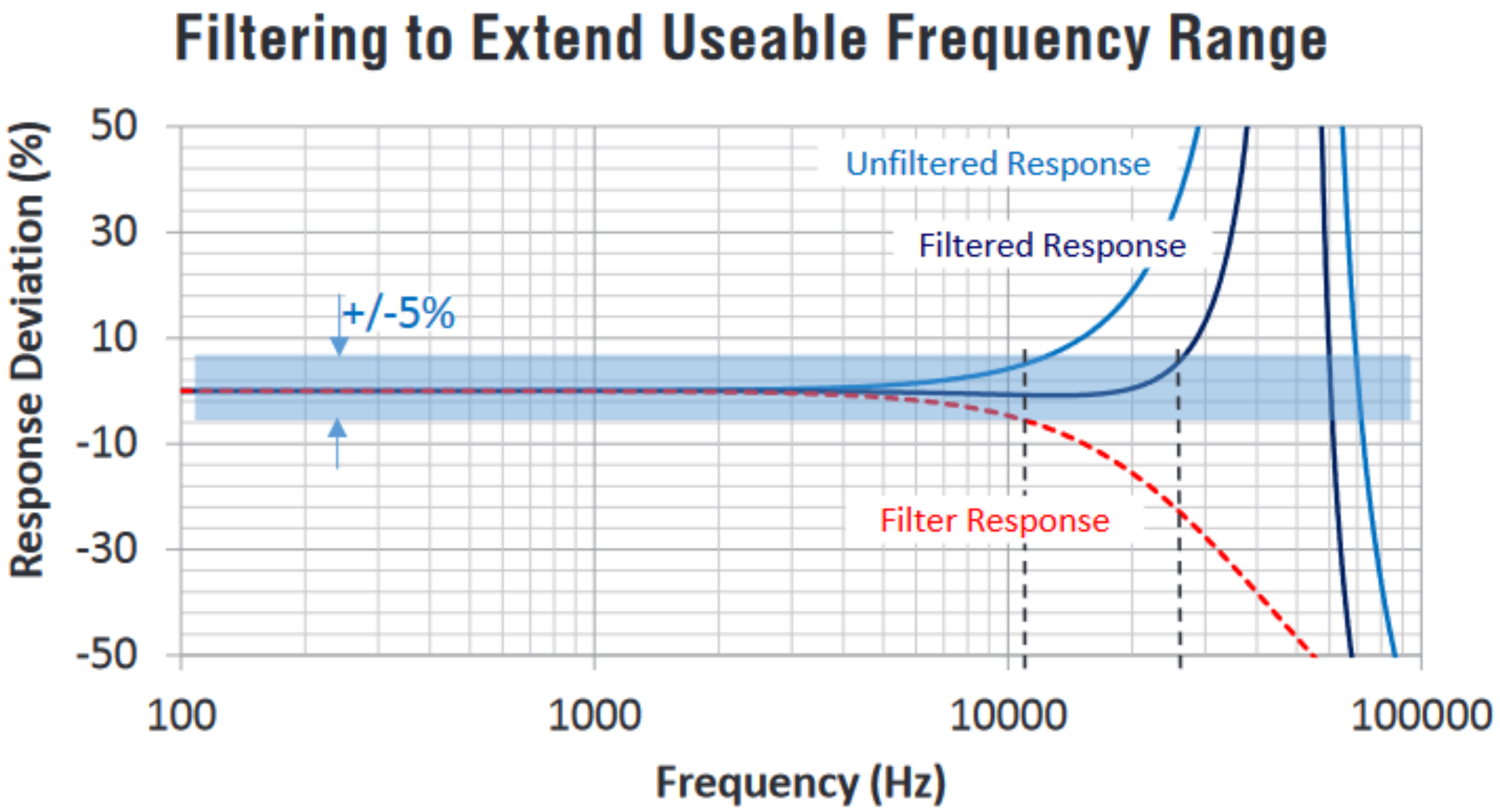
Filter characteristics

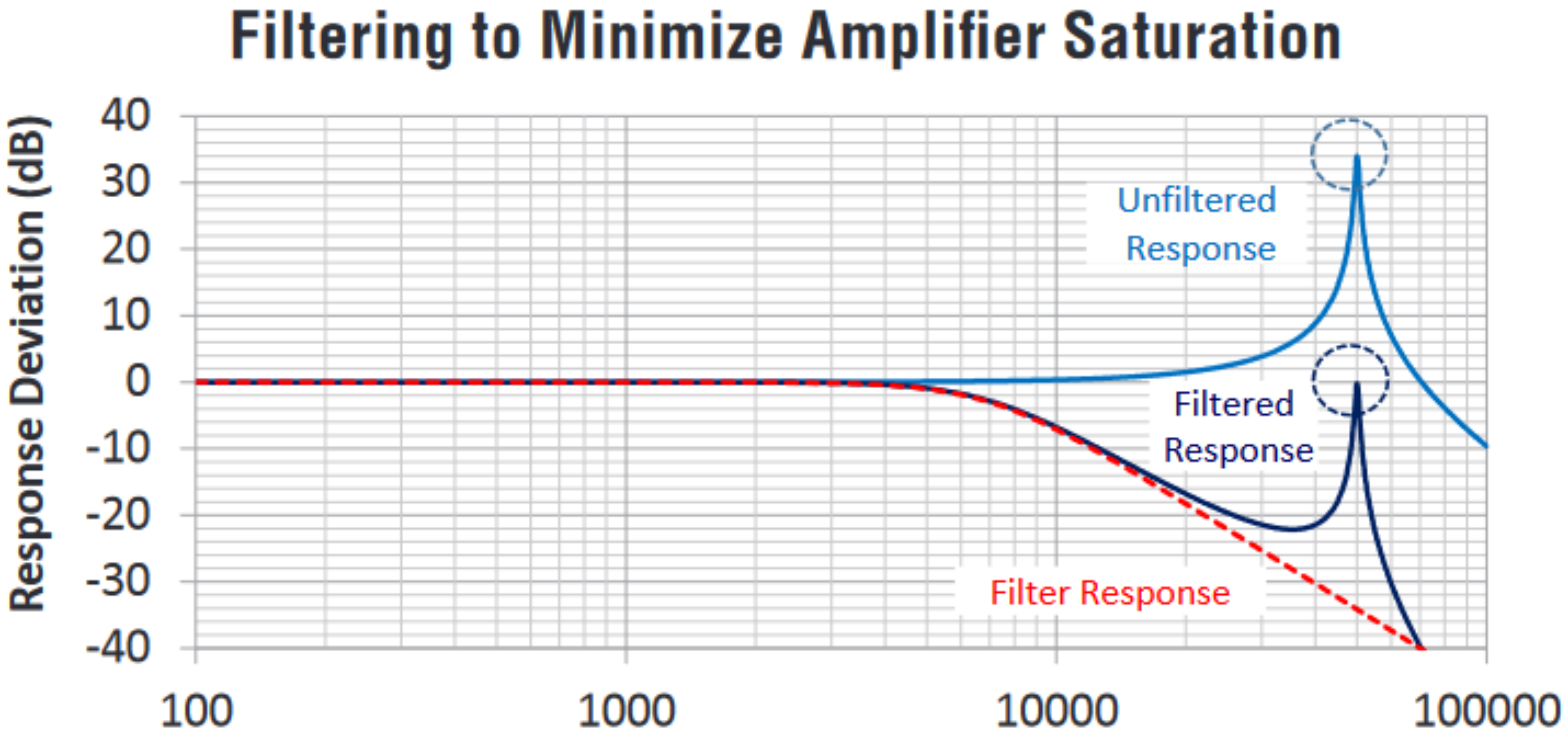
PCB integrates a low pass filter between the sensing crystal and the ICP® amplifier on a select number of accelerometers, avoiding amplifier saturation and extending useful frequency response. These filters are uniquely specified based on the intended application environment and the design of the sensor. Two values are represented on PCB's product specification sheet that define this filter:

Electric Filter Roll Off – the severity of the filter

- 1st Order (Single Pole or 6 dB / Octave) - commonly used to extend useable frequency range
- 2nd Order (Two Pole or 12 dB / Octave) - commonly used to avoid amplifier saturation

Electric Filter Corner Frequency – the frequency at which the signal of interest is attenuated 3 dB





TEMPERATURE CONSIDERATIONS

Most ICP® sensors: - 73 to 135°C

Most charge sensors: - 240 to +204°C

Temperature 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%

Normally this is an inverse relationship *Temperature goes up, sensitivity goes down*

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.

MEMS ACCELEROMETERS

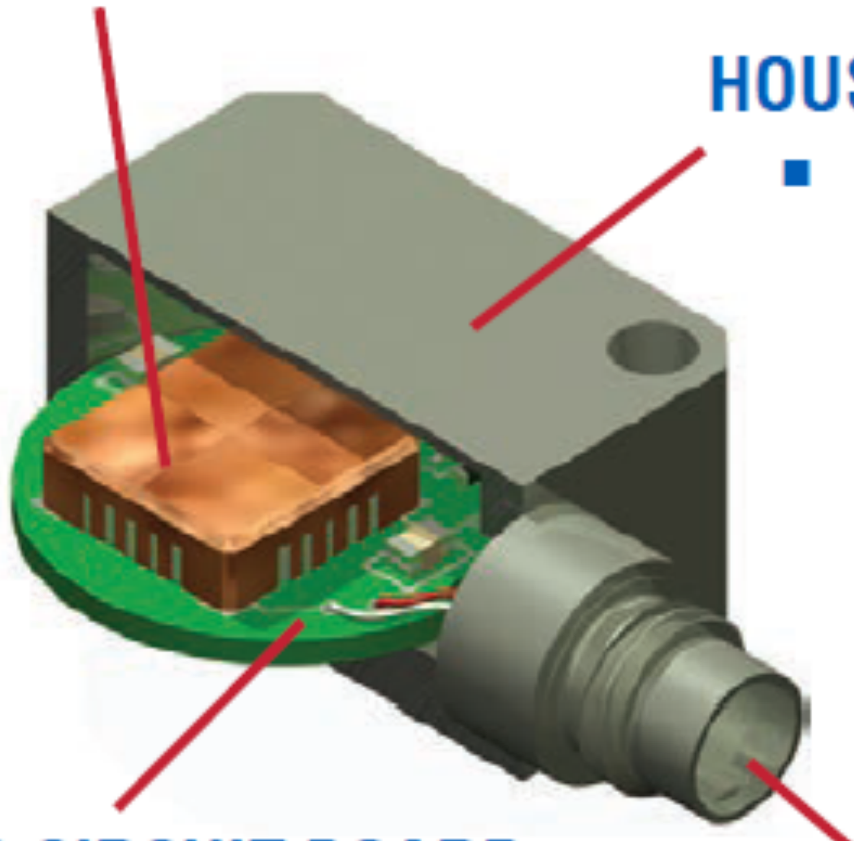
MEMS applies to Micro-Electro-Mechanical System; where micro-fabrication methods are used to construct mechanical sensing elements at the microscopic level from silicon materials. Unlike Charge & ICP® accelerometers, MEMS accelerometers can measure frequencies **down to 0 Hz (static or DC acceleration).**

PCB® offers two types of MEMS accelerometers:

- **Variable Capacitive (VC) MEMS** accelerometers are *lower range, high sensitivity* devices used for structural monitoring and constant acceleration measurements.
- **Piezoresistive (PR) MEMS** accelerometers have measurement ranges for the *higher 'G' levels used in shock and blast applications*, with lower sensitivity and damping.

MEMS VC sensing element

- A micro-machined proof mass is suspended between two parallel plates forming upper and lower air gaps. An electrical charge is applied across the gaps, making them pseudo-capacitors. Motion excites the proof mass, causing a change in gap height and a corresponding change in capacitance. The capacitance change is scaled into a DC output proportional to the acceleration.



HOUSING

- Provides hermetic sealing of sensors

PRINTED CIRCUIT BOARD

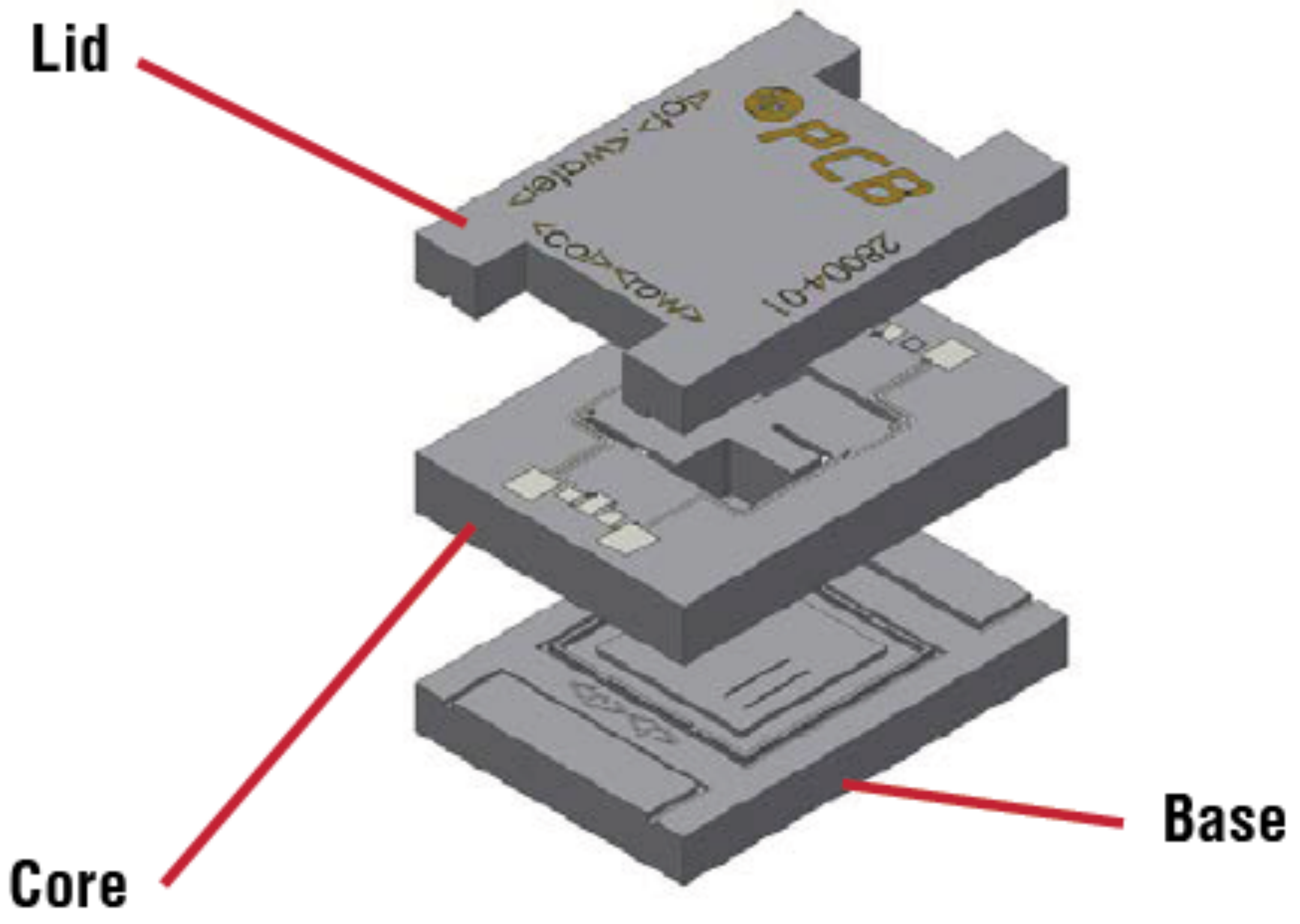
- For voltage regulation, protection, and temperature compensation
- Conditioning circuitry provides a high sensitivity output
- Compensates for zero bias and sensitivity errors over temperature

ELECTRICAL CONNECTOR

- Connects to mating cable for signal transmission and power

An accurate static calibration can be performed using the Earth's gravity as the acceleration reference. Place the accelerometer in a +1g orientation so that the base is resting on the mounting surface and the model number is facing up.
Invert the sensor by flipping it 180°, placing the model number face down on the mounting surface. The sensor should output -1g acceleration.

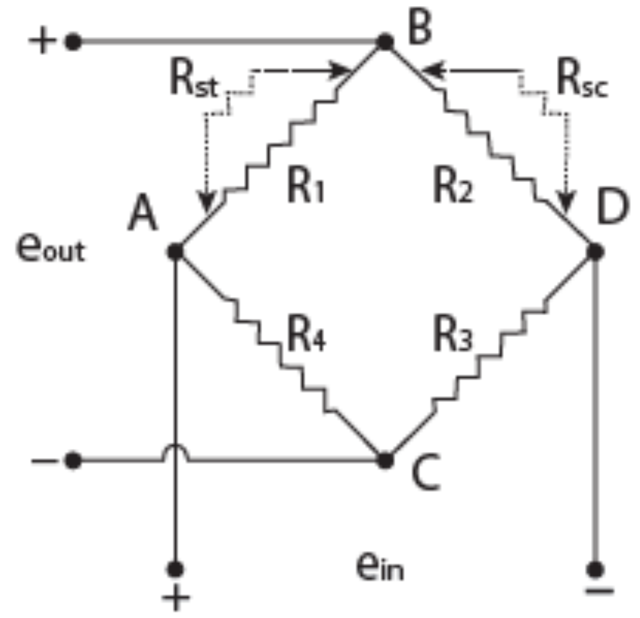
MEMS PR sensing element



- The sensing elements and seismic mass are comprised of flexures on a middle layer sandwiched between upper and lower layers.
- The bending of these flexures causes a measurable change in resistance that is proportional to the applied acceleration.
- Different measurement ranges are achieved by using different flexures, changing the stiffness of the sandwich.
- Gas damping lowers resonant amplification and reduces the response to high frequency energy.

MEMS PR ACCELEROMETER FUNCTION AND OPERATION

- To take advantage of the DC response of MEMS accelerometers, the signal conditioner and readout device must be in a DC coupled state.
- PR accelerometers should be powered with a regulated voltage source because sensitivity is proportional to excitation voltage. The recommendation is to use the excitation voltage listed on the calibration certificate to obtain the calibrated sensitivity value.
- The sensing elements are arranged in a fully active Wheatstone bridge configuration. The bridge uses variable resistors, two that increase with the input acceleration or force, and two that decrease.



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PCB TEST ACCELEROMETERS VS. IMI / INDUSTRIAL ACCELEROMETERS

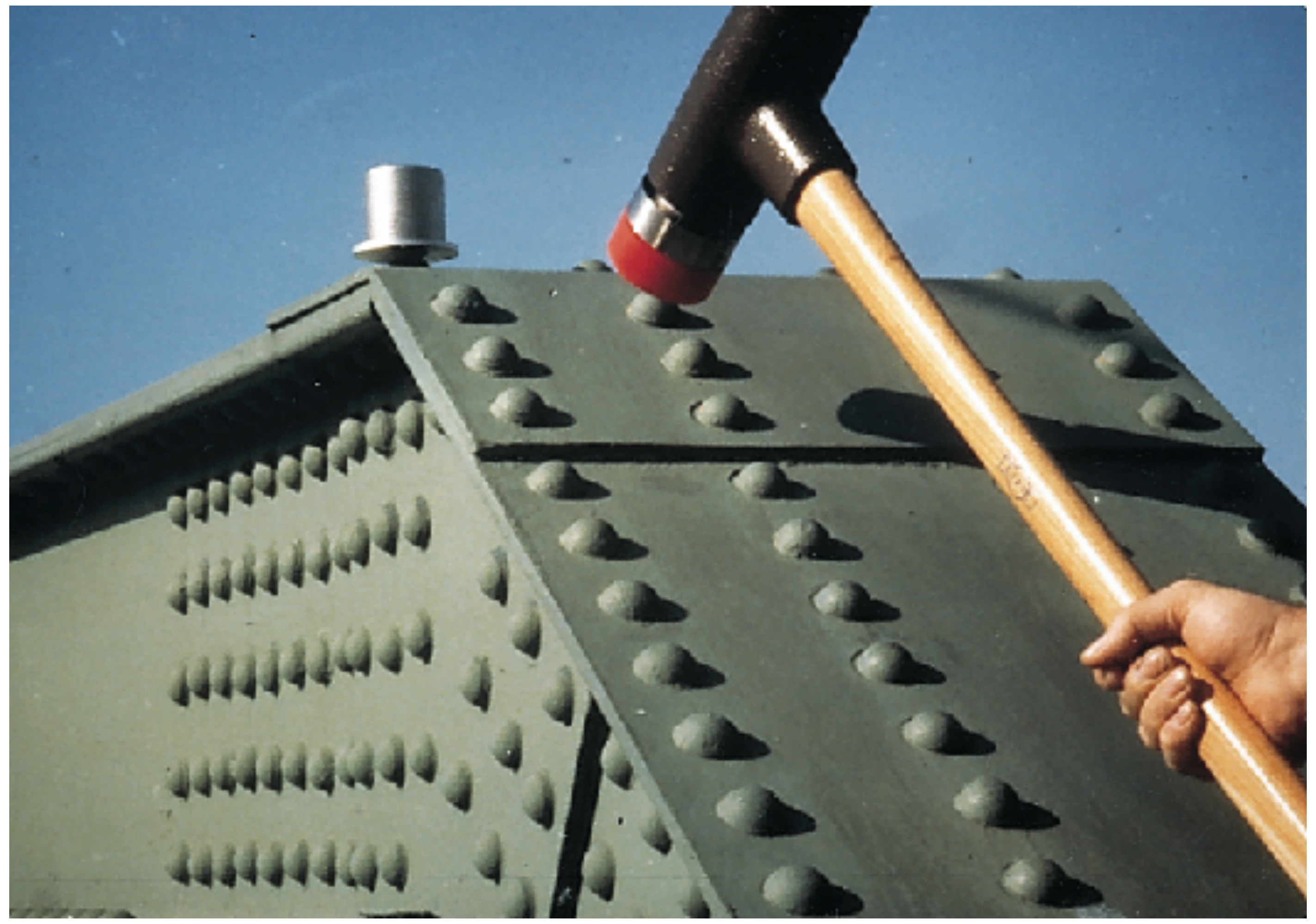
Test Accelerometers

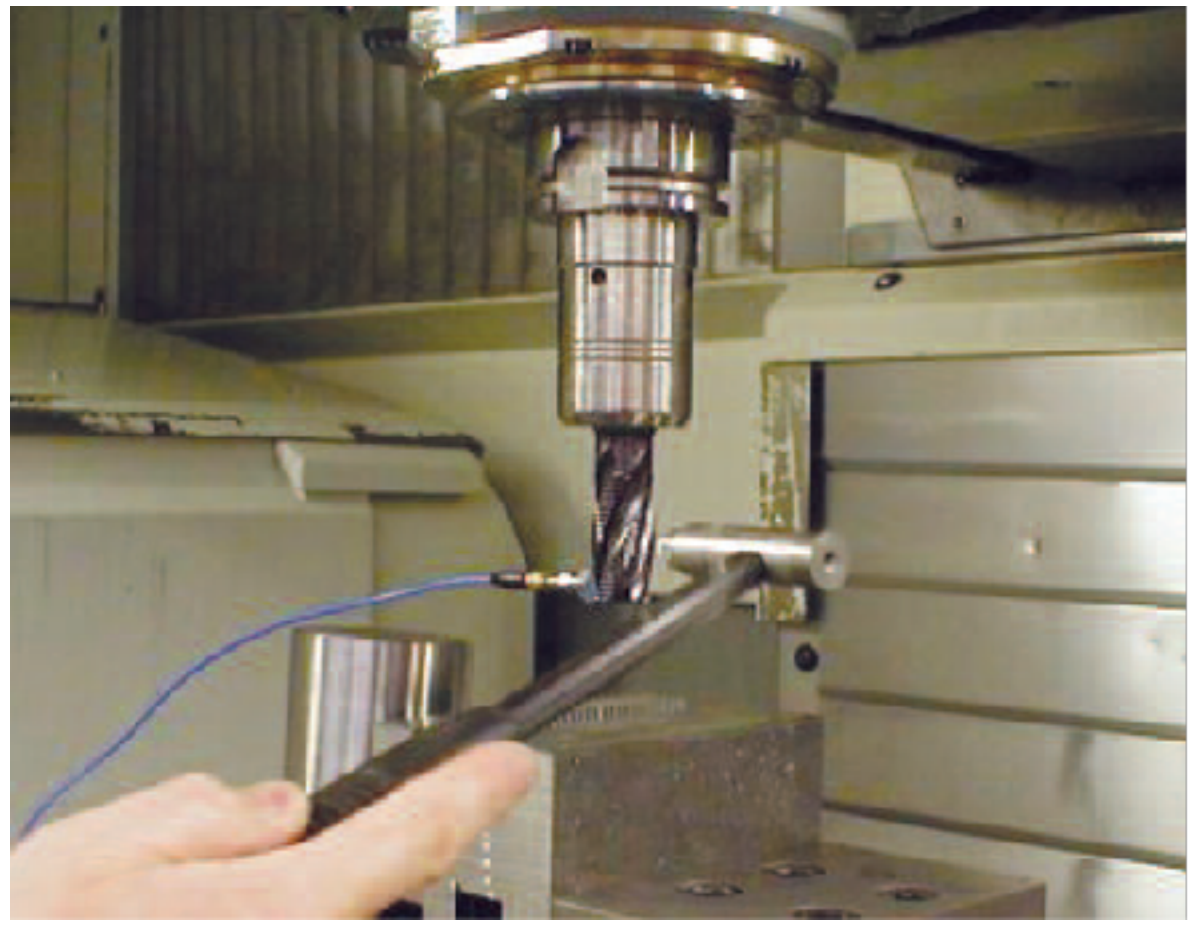
- Smaller in size to avoid mass loading of test structures
- Sensor housing material can be titanium, aluminum, and different stainless steels to keep it lightweight
- Small connectors (5-44 or 10-32) to fit onto small accels
- Sensitivity tolerances are tighter – usually +/- 5%
- Sensing elements fully constructed by technicians, provides tight tolerances

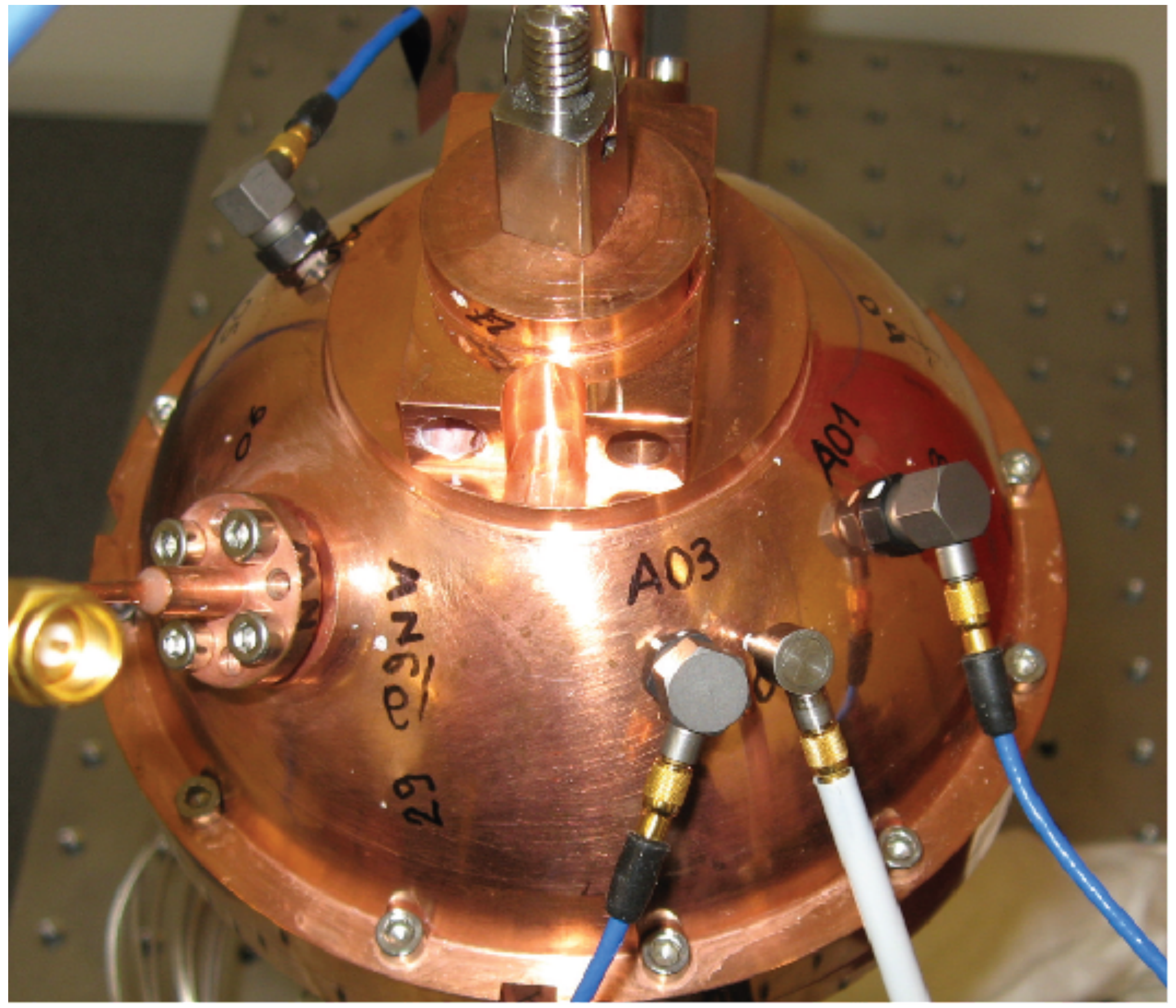
IMI Accelerometers

- Larger in size to withstand more abuse by vibration technicians and environments
- Case isolated and ground isolated design
- Material type stainless steel – 304L or 316L
- Large 2-pin MIL-C 5015 connector most common for single axis units
- Hermetically welded together
- Low cost models use internal pellet accelerometer, looser sensitivity tolerances at +/- 10% or +/- 20%

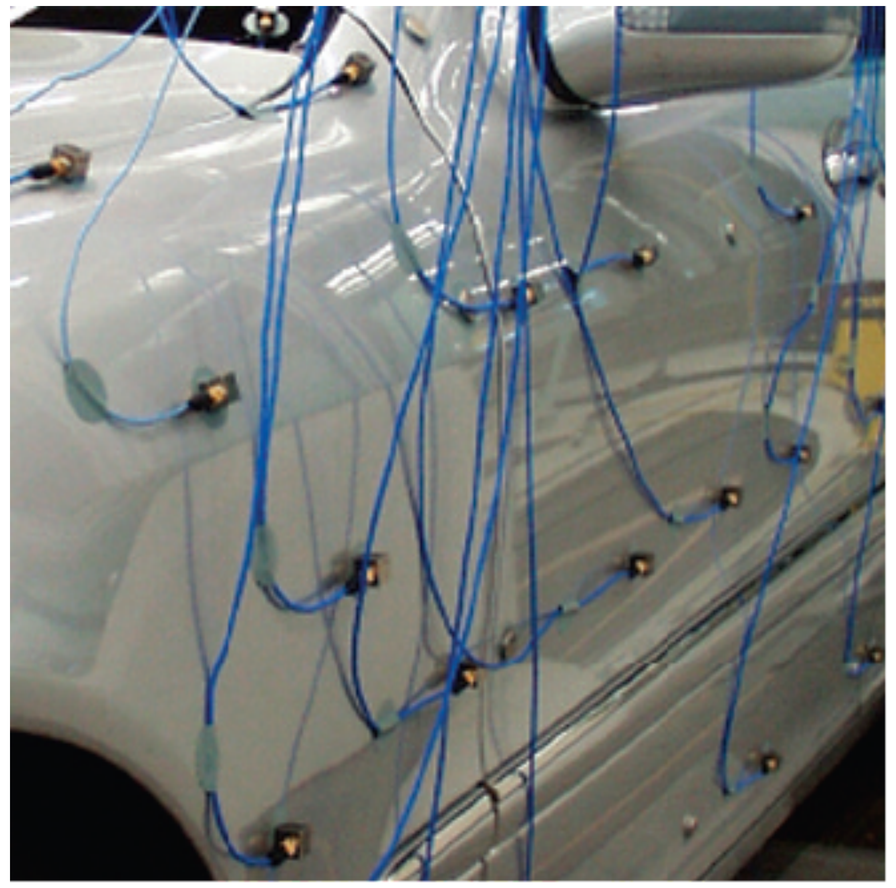
TESTING

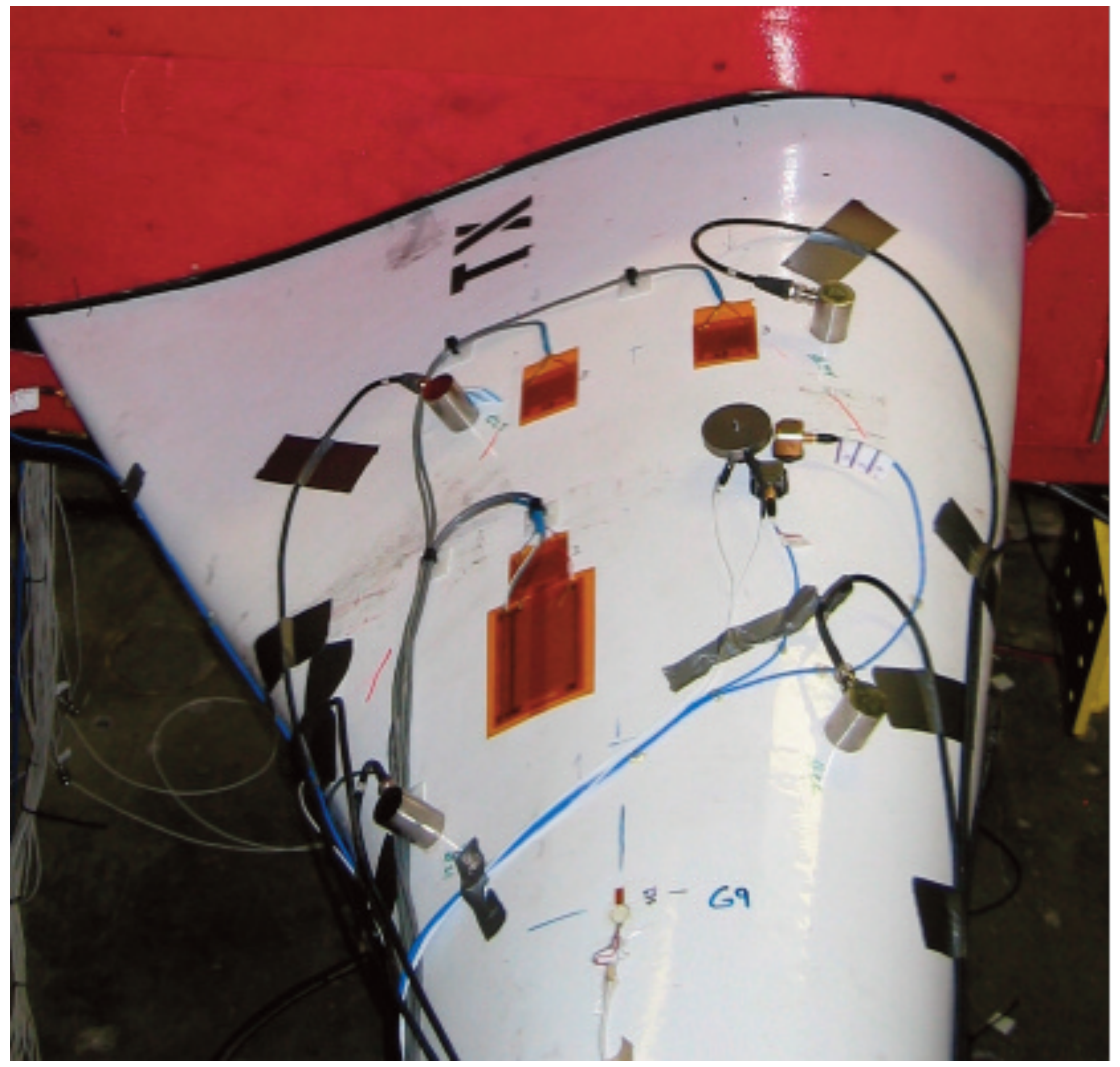


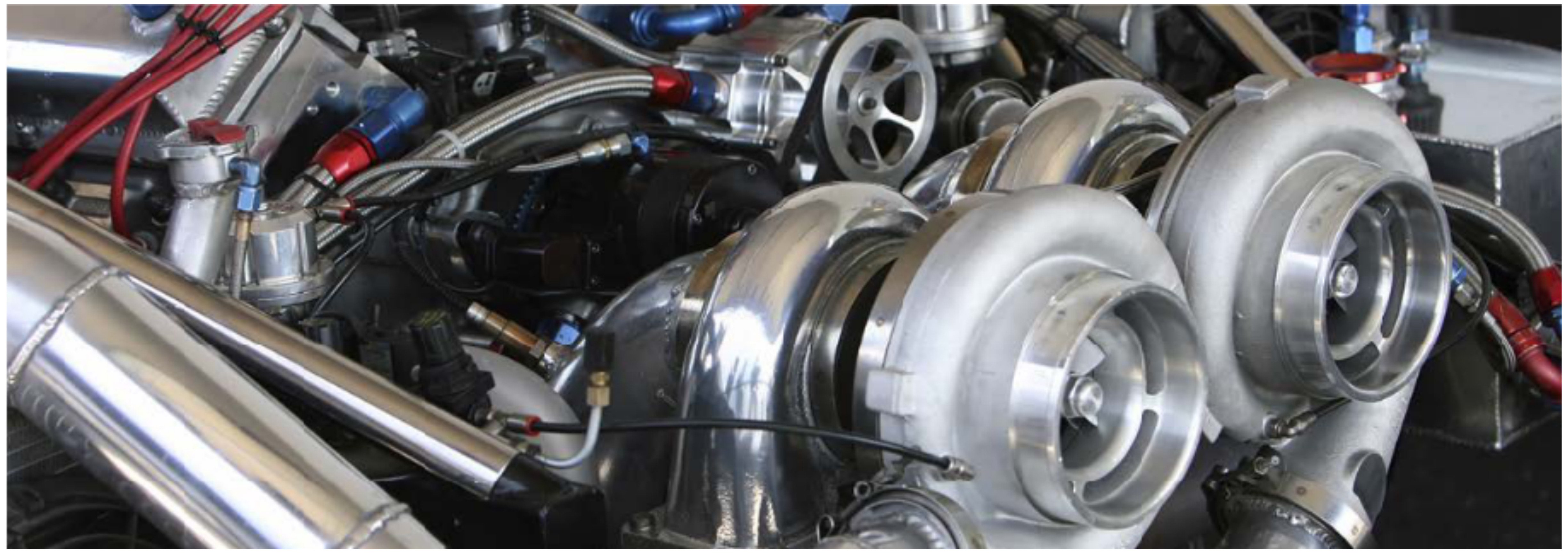




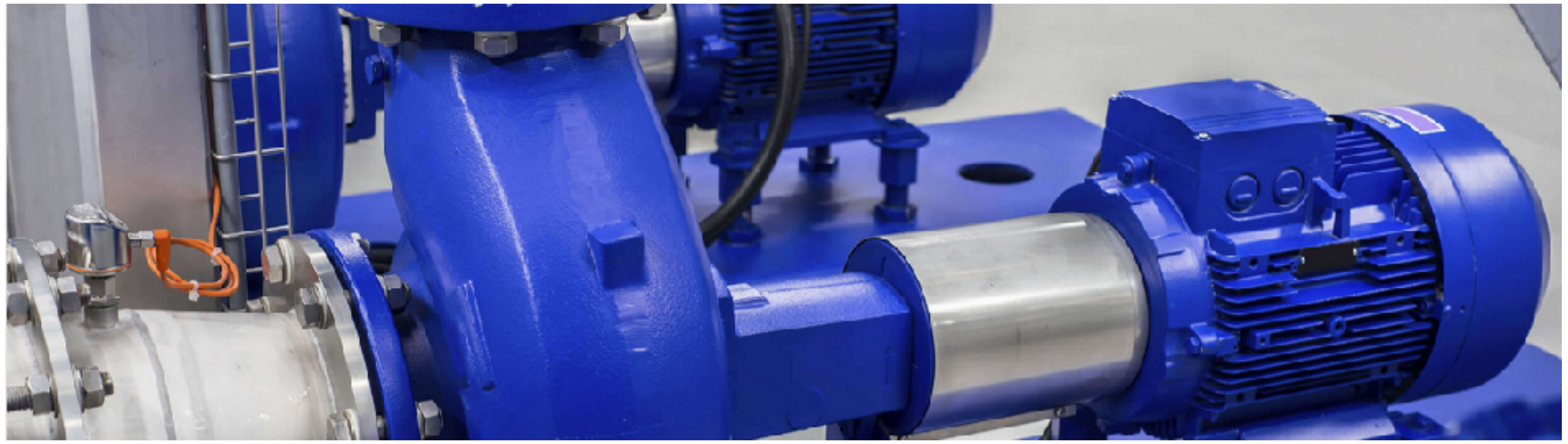
AERO / AUTO

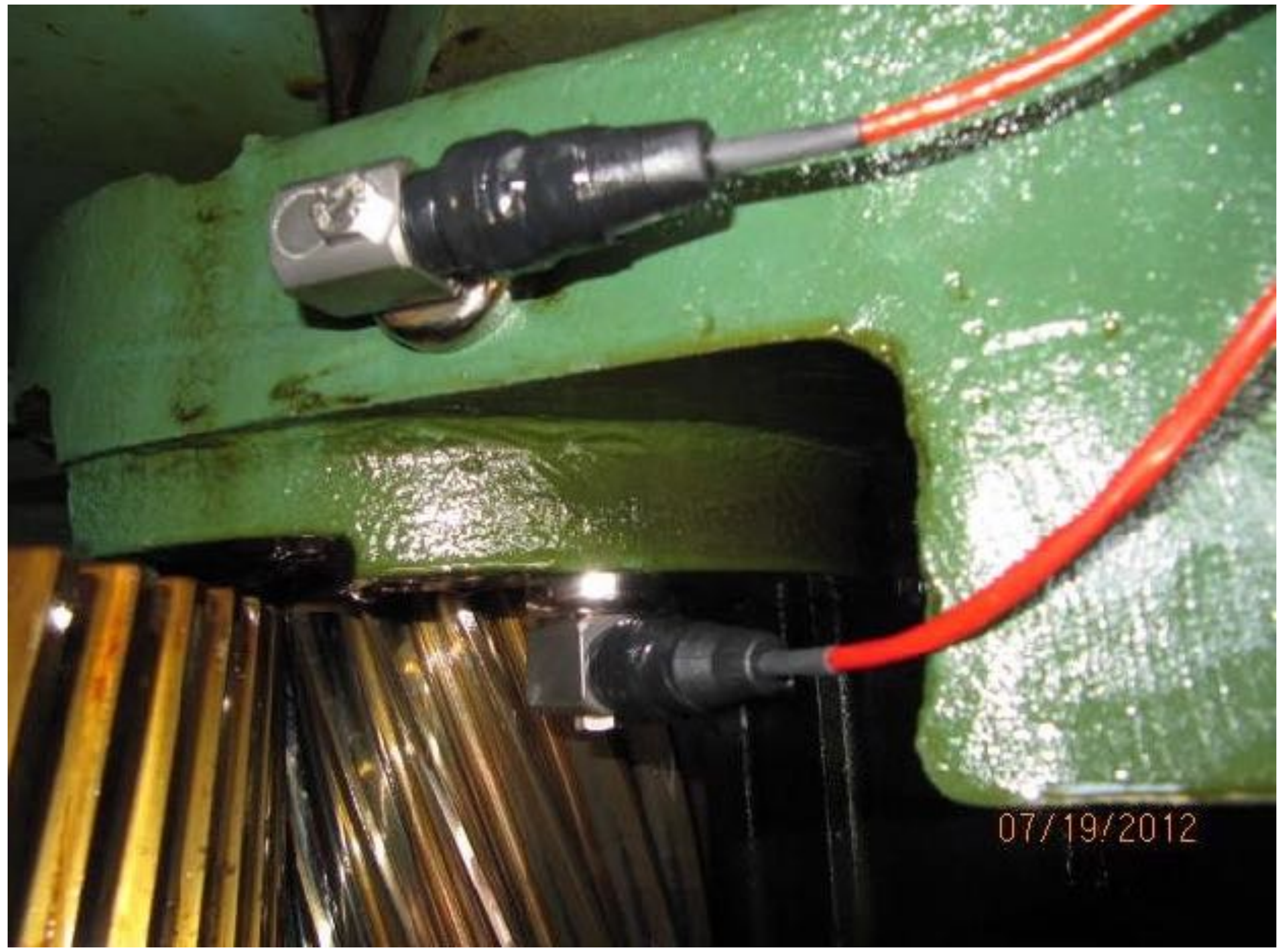






INDUSTRIAL





WHY MEASURE VIBRATION?

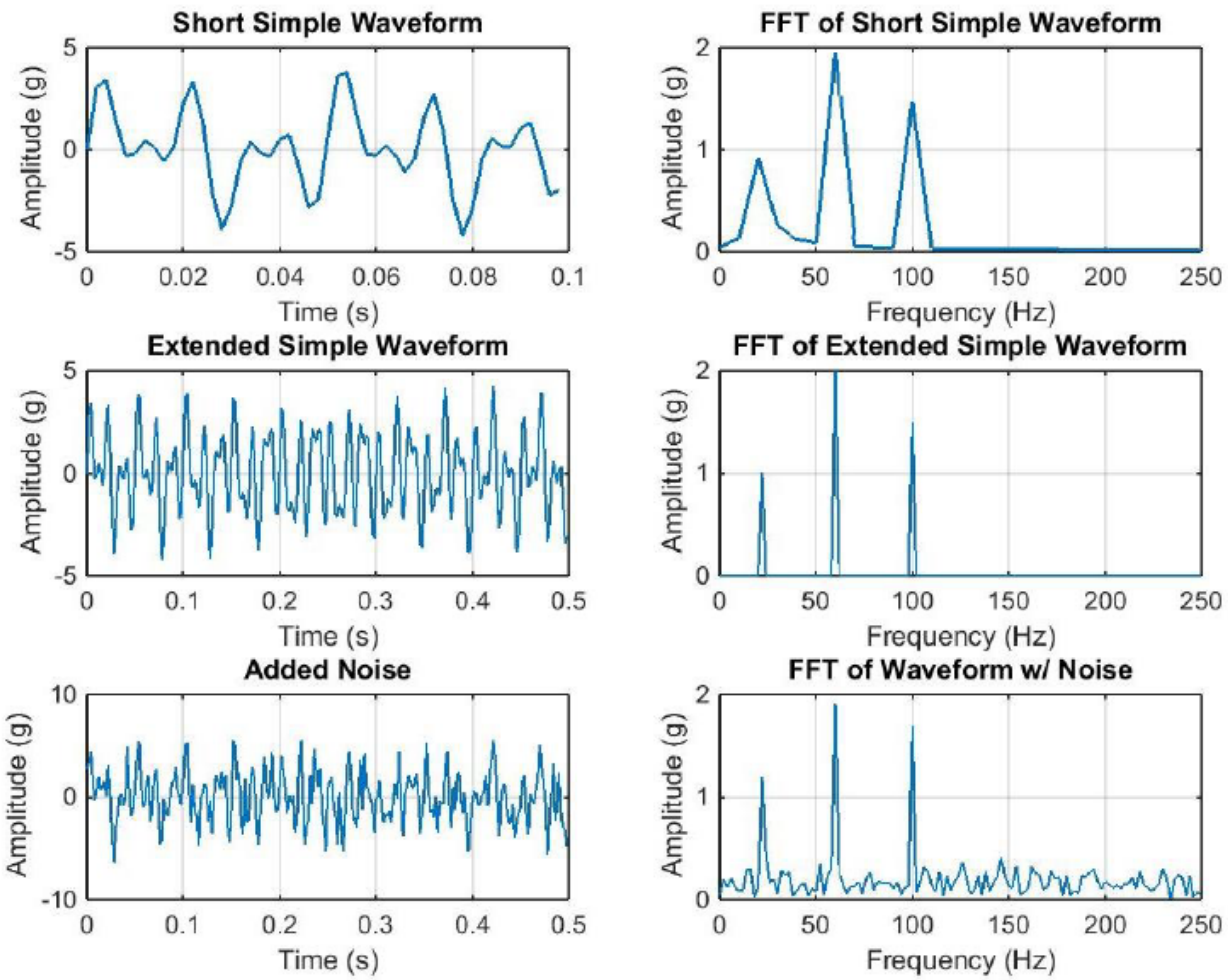
- Best overall indicator of machine health
- Works on the widest range of frequencies and faults

COMMON FAULTS FOUND WITH VIBRATION ANALYSIS

- Imbalance
- Misalignment
- Gear faults
- Resonance
- Critical speed
- Cavitation
- Broken rotor bars
- Eccentric rotor
- Stator faults
- Shaft bow

METHODS TO LOOK AT VIBRATION DATA

- **Time waveform analysis**– a plot of amplitude versus time, can be used with acceleration or velocity measurement
  - Time waveforms display a short time sample of the raw vibration
- **Fast Fourier Transformation Spectrum– FFT Spectrum** - the signal is broken down into specific amplitudes at various component frequencies
  - identify and track vibration occurring at specific frequencies
  - particular machinery problems generate vibration at specific frequencies. this information to diagnose the cause of excessive vibration



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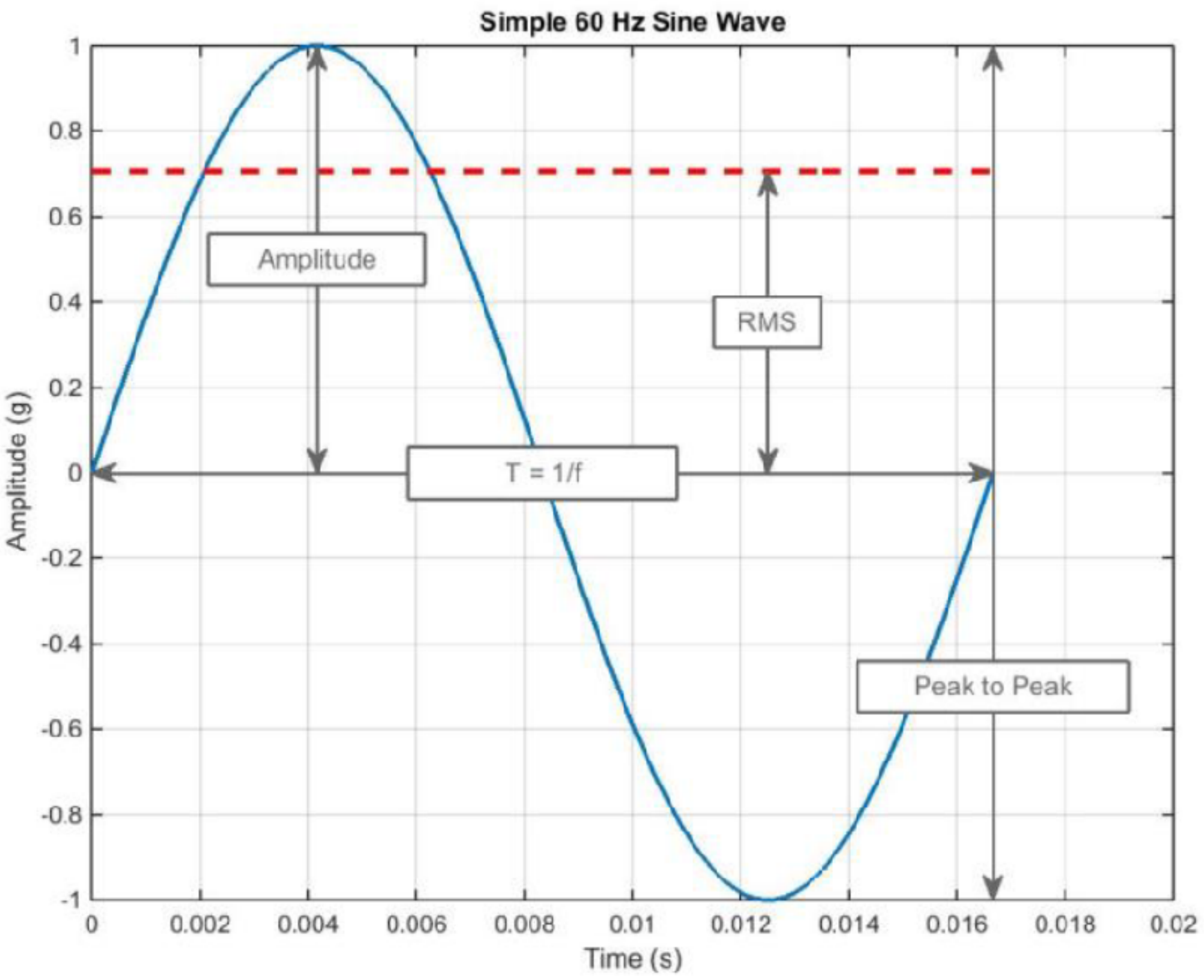
METHODS TO LOOK AT VIBRATION DATA

The **peak or amplitude** is valuable for shock events but it doesn't take into account the time duration and thus the **energy** in the event.

The same is true for **peak-to-peak** with the added benefit of providing the maximum excursion of the wave, useful when looking at **displacement information**, specifically clearances.

The **RMS** (root mean square) value is generally the most useful because it is directly related to the **energy content** of the vibration profile and thus the **destructive capability of the vibration**. RMS also takes into account the time history of the wave form.

RMS = 0,707 x g-pk



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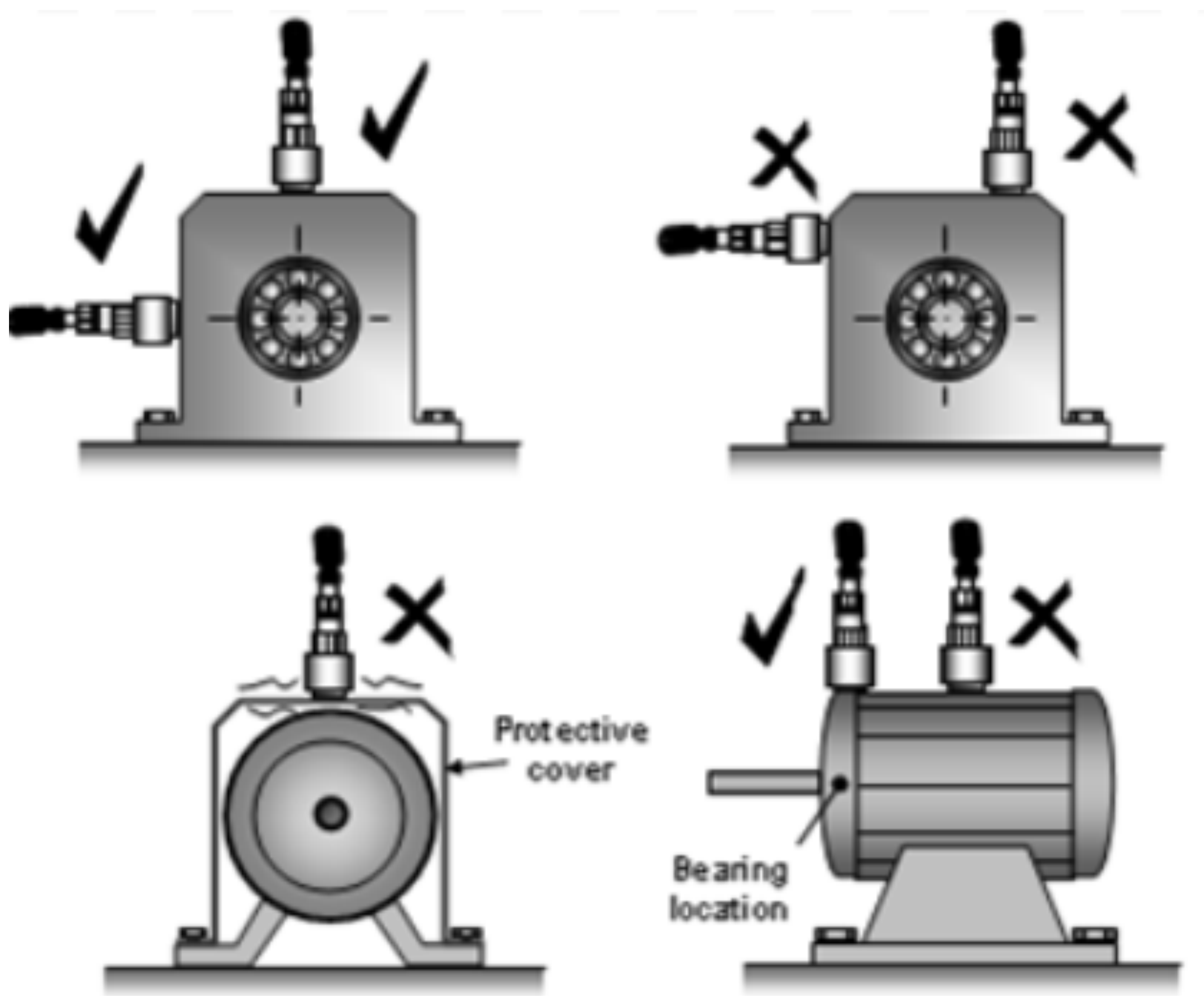
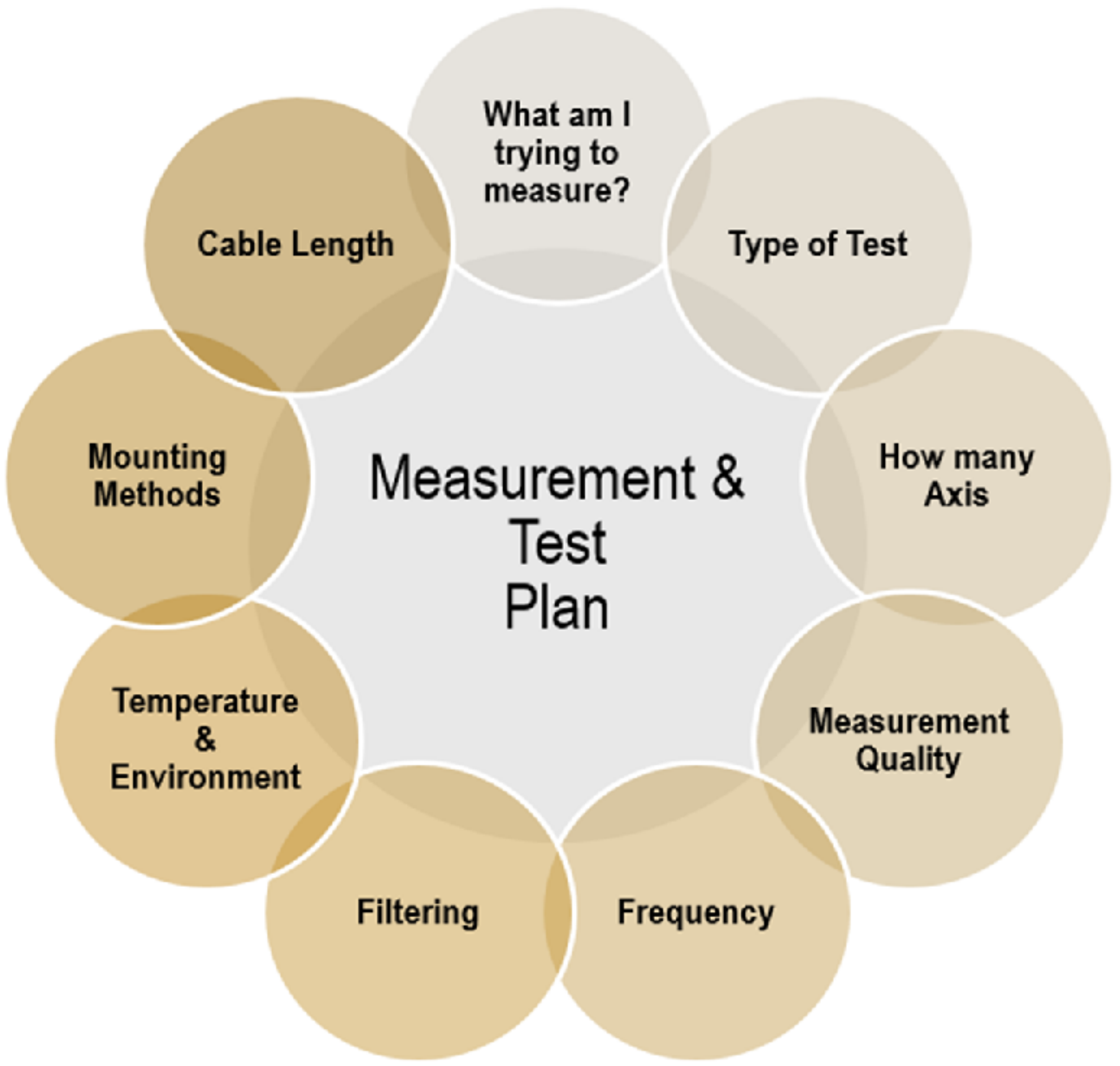
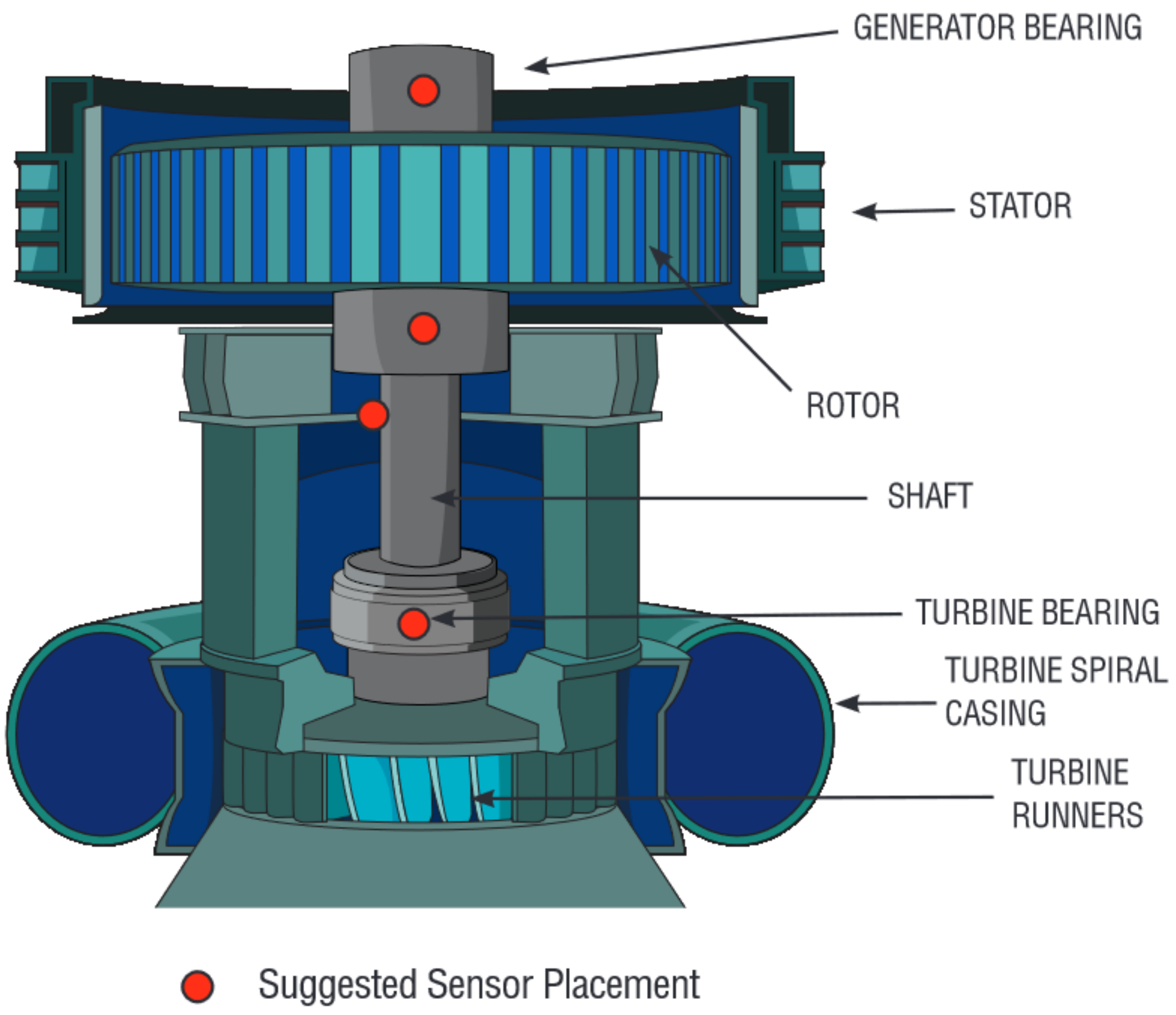
SENSOR PLACEMENT

- Key to accurate vibration measurement is placement of the transducer at a point that is responsive to machine condition
- The vibration sensor should be as close as possible to the bearing as physically possible
- Horizontal and vertical locations at the bearing centerline are used to sense the vibrations from radial forces, such as unbalance
- Vibrations in the axial direction are measured in the load zone of the bearing
- Often equipment now has covers and shrouding for protection, so in these instances a permanently installed accelerometer should be used and run the output to a junction box





What am I trying to measure?
Type of Test
How many Axis
Measurement Quality
Frequency
Filtering
Temperature & Environment
Mounting Methods
Cable Length
Measurement & Test Plan



GENERATOR BEARING
STATOR
ROTOR
SHAFT
TURBINE BEARING
TURBINE SPIRAL CASING
TURBINE RUNNERS
Suggested Sensor Placement

QUIZZETTONE

Un accelerometro piezoelettrico è adeguato per misure

1. Dinamiche
2. Statiche
3. Entrambe le opzioni sopra citate

Un accelerometro piezoresistivo è adeguato per misure

1. Dinamiche
2. Statiche
3. Entrambe le opzioni sopra citate

Con un accelerometro piezoelettrico riesco a misurare l'accelerazione di gravità, in stato di quiete?

1. Sì
2. No

Vantaggi di un sensore piezoelettrico ICP

1. Utilizzo ad alte temperature o temperature criogeniche
2. Buon funzionamento con cavi molto lunghi
3. Impiegato in ambienti “sporchi” / “ostili”
4. Relativamente più economico di una catena di misura charge
5. Possibilità di “variare” la sensibilità del sensore

Il montaggio di un accelerometro tramite base magnetica implica

1. Riduzione del range di frequenza misurabile, con tagli delle alte frequenze
2. Riduzione del range di frequenza misurabile, con tagli delle basse frequenze
3. Nessuna riduzione del range di frequenza
4. Riduzione della sensibilità del sensore

Il metodo di montaggio “migliore” / “raccomandato” rimane sempre il

1. Montaggio ad incollare
2. Montaggio tramite stud
3. Montaggio tramite magnete

Il termine “ground isolated” sta ad indicare che

1. L’elemento sensibile è all’interno di una “gabbia di Faraday”
2. Il sensore ha un case costruito con materiale non conduttivo
3. E’ il maggior “grado” di protezione elettrica che un sensore può avere

Posso impiegare un sensore VC per misure a partire da 0Hz

1. sì
2. no

In generale, la sensibilità di un accelerometro piezoelettrico è sensibile a

1. Variazioni di temperatura
2. Variazione acccelerazione
3. Variazione di frequenza

Un accelerometro charge, ha un output

1. A bassa impedenza
2. Ad alta impedenza
3. Dipende

Il momento delle domande….

Dott.ssa Valentina Tollerini
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Grazie per l’attenzione

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