IMI SENSORS
A PCB DIVISION

Calibration of Industrial Accelerometers

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IMI Sensors not only calibrates every new sensor before it leaves the building, but also offers after-market recalibration services for both its own sensors as well as competitors' sensors. All calibration activity is performed in a laboratory accredited by the American Association for Laboratory Accreditation (A2LA) in the field of calibration per ISO 17025:2017, General Requirements for the Competence of Testing and Calibration Laboratories.

This article provides more information on the importance of calibration for accurate measurements and the calibration process itself.

Calibration Guidelines Dependent upon Sensing Element

The guidelines for calibrating an industrial piezoelectric sensor are dependent upon the sensing element utilized in the sensor.

- Quartz: Quartz is naturally-piezoelectric mineral that is considered the most stable of all piezoelectric materials. For quartz sensors, the calibration value is guaranteed to remain stable for a minimum of 5 years when used within the published operating guidelines for these sensors.
- Ceramic: Polycrystalline ceramics are manmade materials that have been polarized to exhibit piezoelectric properties. The polarization process consists of subjecting the ceramics to very high DC voltages at high temperatures in order to align the domains along the polarizing axis. Despite this process and efforts to artificially age the units, piezoelectric ceramics still demonstrate a natural decay in output over time and will require recalibration in order to ensure accurate measurements. It is recommended that sensors with ceramic sensing elements be calibrated at least once a year as well as after any suspected physical damage due to excessive mechanical shock, extreme thermal transients, excessive temperatures, or other extreme environmental influences.

Calibration Process

In the broadest sense, the calibration process verifies the amplitude response and system linearity over the intended range of use. A typical calibration process is divided into pre-calibration and final calibration.

Pre-calibration consists of, but is not limited to, two tests- a transverse sensitivity test and a resonant frequency test.

- The first test performed during the pre-calibration process is transverse sensitivity. Transverse sensitivity is the output of a uni-axial vibration sensor when mounted perpendicular to the sensing axis. To perform the test, the sensor is mounted to a transverse calibrator. See Figure 1. There are two reference sensors mounted on the calibrator in addition to the sensor to be tested. The two reference sensors are mounted 90 degrees apart from each other around the test sensor with one measuring vibration on the x axis and one measuring vibration on the y axis. Upon activating the test sequence, the setup is adjusted to ensure that the two reference sensors provide uniform outputs with a 90 degree phase shift and that the test apparatus is demonstrating uniform orbital motion. The system will then calculate a transverse sensitivity. In order to pass the test, the test sensor vibration

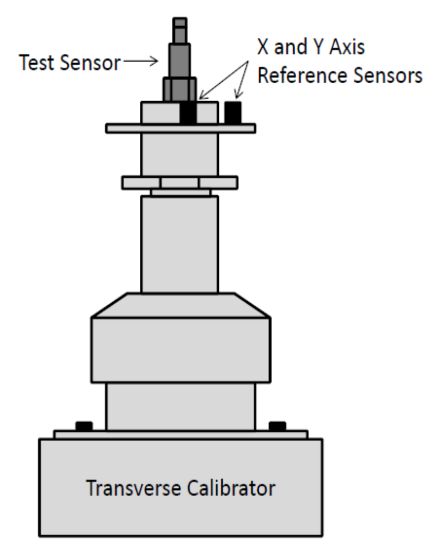


Figure 1: Uni-axial vibration sensor mounted on transverse calibrator.

measurements must match the test sensor's specifications within a particular tolerance.

- The second test performed during the pre-calibration process is resonant frequency. Resonant frequency is the frequency at which the sensor naturally vibrates when excited by a stimulus. To perform the test, the test sensor is stud-mounted with silicone grease to a tungsten alloy mass that is approximately ten times the mass of the sensor. The mass/sensor assembly is then laid on its side on a test bench. The mass is pinged with a ball bearing adhered to a mylar strip and the resulting resonant frequency of the sensor is collected.

Figure 2: Resonant frequency test

For final calibration, the test sensor is tested in a back-to-back calibration test to determine reference sensitivity, frequency response and output bias voltage. During a back-to-back test, the test sensor is mounted in a back-to-back arrangement with a reference sensor with the reference sensor having traceability to primary calibration. Since the motion input is the same for both sensors, the ratio of their outputs is also the ratio of their sensitivities. The sensitivity of the test sensor can be calculated with the formula in Figure 3.

$$\text{TS Sensitivity} = \text{RS Sensitivity} \times \frac{\text{TS Voltage}}{\text{RS Voltage}} \times \frac{\text{RS Gain}}{\text{TS Gain}}$$

TS = Test Sensor   RS = Reference Sensor

Figure 3: Test Sensor Sensitivity Formula

Once the test sensor sensitivity is determined, that sensitivity is then tested at one or multiple frequencies (depending on the calibration service required) to develop a sensitivity plot. In the case of a test sensor being tested at multiple frequencies, the calibration service confirms the linear sensitivity response of the test sensor over the useable frequency range during pre-calibration.

Both sensors can be mounted to an electrodynamic shaker driven with a sinusoidal vibration and the sensitivity of the sensor under test is measured at that particular frequency. Sweeping through the desired range of frequencies then generates a frequency response curve of the test sensor. Air bearing shakers are the preferable type of electrodynamic shaker to be used, as they can provide the highest quality of pure single degree of freedom vibration over the widest frequency range, while minimizing the transverse motion and distortion found on other electrodynamic shakers.

<u>IMI Sensors' Calibration Services</u>

In calibrating industrial piezoelectric accelerometers, IMI Sensors offers two standards of calibration.

- ICS-1: Calibration supplies a detailed calibration certificate that is in compliance with ISO 10012:2003 "Measurement Management Systems- Requirements for Measurement Processes and Measuring Equipment" and is traceable to the National Institute of Standards & Technology (NIST). A sample ICS-1 calibration certificate is provided in Appendix 1.
- ICS-2: Calibration provides a low-cost option for calibrating industrial sensors which do not require a full range calibration due to their application. This standard provides a single point calibration value that is traceable to the NIST. That value is laser etched on the sensor's case for easy reference. A sample ICS-2 calibration certificate is provided in Appendix 2.

These services are available on all of IMI Sensors' industrial accelerometers as well as any of its competitors' models.

Appendix 1: ICS-1 Sample Calibration Certificate

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 622B01

Serial Number: LW50304

Description: ICP® Accelerometer

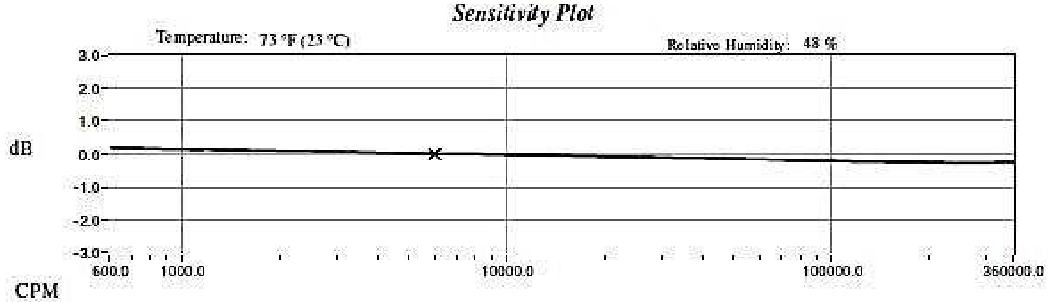
Manufacturer: IMI

Method: Back-to-Back Comparison AT401-3

Calibration Data

Sensitivity @ 6000 CPM	**99 mV/g**	Output Bias	11.1 VDC
	(10.1 mV/m/s²)	Transverse Sensitivity	0.2 %
Resonant Frequency	1885 kCPM		

Sensitivity Plot



Data Points

Frequency (CPM)	Dev. (%)	Frequency (CPM)	Dev. (%)	Frequency (CPM)	Dev. (%)
600	2.3	18000	-0.7	360000	-2.7
900	1.8	30000	-1.2		
1800	1.4	60000	-1.8		
3000	0.9	180000	-2.7		
REF. FREQ.	0.0	300000	-3.1		

Mounting Surface: Stainless Steel w/Silicone Grease Fastener: 1/4-28 Female Fixture Orientation: Vertical
Acceleration Level (pk)[1]: 1.00 g (9.81 m/s²)
[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 683/283498 and PTB Traceable thru Project 10065.
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 Z540.3 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: Lamont Langford Date: 7/22/2015

ACCREDITED
CALIBRATION CERT #1862.02

IMI SENSORS
A PCB PIEZOTRONICS DIV.

Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 - FAX: 716-685-3886 - www.pcb.com

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Appendix 2: ICS-2 Sample Calibration Certificate

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 607A01

Serial Number: 190927

Description: ICP® Accelerometer

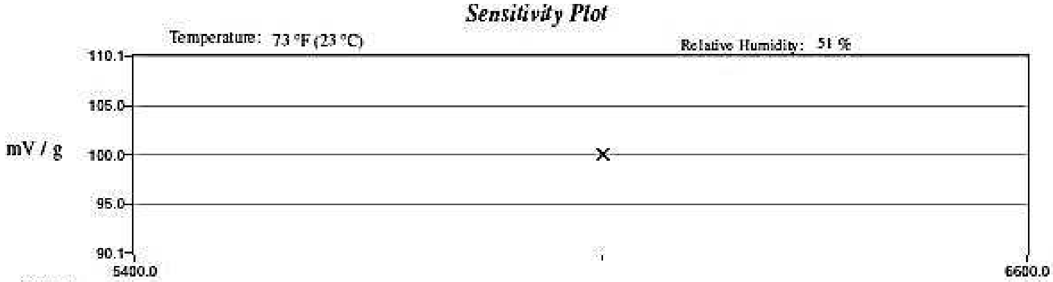
Manufacturer: IMI

Method: Back-to-Back Comparison AT401-3

Calibration Data

Sensitivity @ 6000 CPM	**100 mV/g** (10.2 mV/m/s²)	Output Bias	10.9 VDC

Sensitivity Plot



Data Points

Mounting Surface: Stainless Steel Fastener: Stud Fixture Orientation: Vertical
Acceleration Level (pk)*: 1.00 g (9.81 m/s²)
*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. *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

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Technician: Jonathan Harmon Date: 7/28/2015

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PAGE 1 of 1

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