Information Guide

Silicon MEMS Accelerometers

Embedded & Packaged Designs

Unamplified mV Output

Summary

This guide provides readers with an understanding of our warranty and returns policy. It describes our calibration capability and provides contact information for offices in North America, Europe and Asia. The sensing technology used in the construction of the accelerometers is described along with suggestions regarding use and installation. Advice is also given regarding practices to avoid when handling these devices. A Glossary of Terms is provided to aid readers in understanding the terms used by T&M professionals involved in dynamic testing applications.

June 2010

Company Overview, Policies and Contact Information

Overview

Measurement Specialties is a global designer and manufacturer of sensors and sensor-based systems which measure pressure/force, position, vibration, temperature, humidity, and fluid properties. Our products are used as embedded devices by original equipment manufacturers (OEMs) or as stand alone sensors for test and measurement to provide critical monitoring, feedback and control input. We are at the heart of many everyday products and provide a vital link to the physical world.

The silicon MEMS technology used in our vibration products was acquired from ICSensors when it was purchased from PerkinElmer on February 16, 2000.
The ICSensors brand brought knowledge and expertise in the areas of design and manufacturing of micromachine silicon pressure sensors, accelerometers and microstructures. A world recognized pioneer in microsensor technology, ICSensors served industrial, medical and aerospace customers.

Warranty

Measurement Specialties, Inc. accelerometers are warranted during a period of one year from date of shipment to original purchaser to be free from defects in material and workmanship. The liability of Seller under this warranty is limited to replacing or repairing any instrument or component thereof which is returned by Buyer, at his expense, during such period and which has not been subjected to misuse, neglect, improper installation, repair, alteration, or accident. Seller shall have the right to final determination as to the existence and cause of a defect. In no event shall Seller be liable for collateral or consequential damages. This warrant is in lieu of any other warranty, expressed, implied, or statutory; and no agreement extending or modifying it will be binding upon Seller unless in writing and signed by a duly authorized officer.

Receiving Inspection

Every Measurement Specialties, Inc. accelerometer is carefully inspected and is in perfect working condition at the time of shipment. Each accelerometer should be checked as soon as it is received. If the unit is damaged in any way, or fails to operate, a claim should immediately be filed with the transportation company.

Service Concerns

If a Measurement Specialties, Inc. instrument requires service, first contact the nearest Measurement Specialties, Inc. representative. They may be able to solve the problem without returning the unit to the factory. If it is determined that factory service is required, call Customer Service at the regional headquarters for an RMA number before return.

Returns

All units being returned to the factory require an RMA (Return Material Authorization) number before they will be accepted. This number may be obtained by calling Customer Service at the regional headquarters with the following information; model number(s), quantity, serial number(s), and symptoms of the problem, if being returned for service. You must include the original purchase order number if under warranty.

Calibration Services
The Vibration Sensors Group in California and its two manufacturing facilities in China and France now offer factory calibration and test services for Piezoresistive, Variable Capacitance, Piezoelectric and Integrated Electronics Piezoelectric (IEPE, ISOTRON, etc.) accelerometers. We offer NIST (US), DKD (Germany), COFRAC (France) traceable calibration services on sensitivity at 100 Hz (102 or 120 Hz in Europe). Sensitivity reference frequencies other than 100/102/120 Hz are available upon request. Users of Measurement Specialties accelerometers can expect quick turnaround for full frequency response calibrations from 10 Hz through resonance and for transverse cross-axis sensitivity testing. Calibration of accelerometers not manufactured by Measurement Specialties may take longer depending on availability of test fixtures and the manufacturer's specifications. Environmental testing over
temperature, centrifuge testing and shock calibration are also offered on a case-by-case basis.
i

Inquiries
Address all inquiries on operation or applications to your nearest Sales Representative, or to the Vibration Applications Support as follows:

Global Headquarters
1000 Lucas Way
Hampton, VA 23666, USA
Tel: +1 757 766 1500

Vibration Sensors Design Center
32 Journey, Suite 150
Aliso Viejo, CA 92656, USA
Tel: +1 949 716 7324

European Headquarters
105 av. du Général Eisenhower
BP 1036, 31023 Toulouse Cedex, France
Tel: +33 (0) 561 194 543

Asian Headquarters
Measurement Specialties (China), Ltd.
F1.6-4D, Tian An Development Compund
Shenzhen, China 518048
Tel: +86 755 8330 1004
Email: vibration@meas-spec.com
Web: www.meas-spec.com/vibration

Accelerometer Characteristics and Use

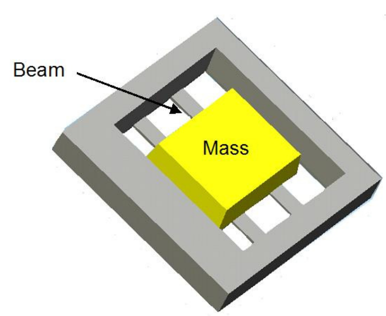
Silicon MEMS Accelerometer

Manufactured from bulk silicon, our piezoresistive sensing technology employs a double cantilever design that provides:

- low off-axis sensitivity, *
- ease of controlling damping and good transduction efficiency.
- greater resonance control and no ringing that is often associated with single cantilever designs.

*Note: Its intrinsically low transverse sensitivity is due to a highly controlled MEMS process that simplifies packaging as no final adjustments are necessary.

Figure 1: Sensing Element With Mass Suspended by Double Cantilever Design



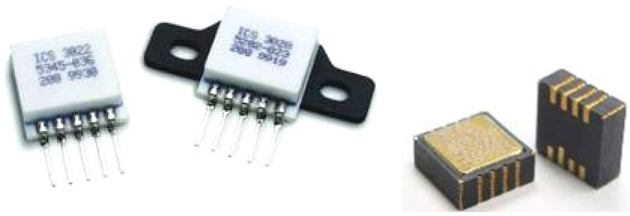
The top and bottom caps that are fused to the sensing strata are used for overforce and shock protection. Gold bonding is used at 300 °C to perform this fusing. This sets the destructive temperature benchmark.

Figure 2: Side View of Sensor with Top and Bottom Caps

Embedded Designs

Our board level Silicon MEMS Accelerometers are designed to be embedded into our customer's vibration monitoring system. Key features of these silicon MEMS accelerometers include DC response, bridge output, wide measurement range, and internal gas damping. They come either in solder pads or solder pins configuration. Performance advantages of our silicon MEMS accelerometers are wide bandwidth, high resolution, and outstanding shock survivability.

Figure 3: Examples of Embedded Designs with mV Output



Packaged Designs

Our packaged DC Response accelerometers support customers in the T&M, Aerospace, Motorsports, Auto-Safety and Transportation marks. They are typically constructed with anodized aluminium housings and are offered with integral 4 conductor outputs. Connector and cable options are available. Key features of these devices include DC response, wide measurement range, lightweight and high-g shock protection. They are most often selected for critical applications due to their wide bandwidth and good shock survivability.

Figure 4: Examples of Packaged Designs with mV Output

Method of Construction

Industrial and "Space-Age" epoxies are used to mount sensor assemblies on substrates. The substrates contain connecting pads for the wire bonds coming from the die and the leads connecting the sensor assembly to external power sources and instrumentation. When an accelerometer experiences mechanical, thermal or electrical shock that exceeds its specifications, the cause of failure is most often traced the components attached to the sensor die rather than the die itself.

To ensure the die and associated components are in good working order prior to leaving our factory, each accelerometer is calibrated and shipped with a calibration certificate specifying performance

Electrical Characteristics

Our silicon MEMS accelerometers use piezoresistive technology in a 4-Arm Wheatstone Bridge configuration. This requires a clean and stable, low noise dc power source or battery supply.

The output sensitivity is ratiometric to excitation voltage so any ripple in the excitation will affect the sensitivity accordingly. The accelerometers are calibrated at 5 or10Vdc excitation but can also be used with an excitation voltage from 2-12Vdc. Excitation voltage greater than 12 volts will cause the unit to heat and eventually fail. However, it is recommended that if you have a non-standard excitation requirement that you make this known to our customer service personnel prior to order placement. A non-standard voltage excitation will affect the calibrated sensitivity, ZMO, and TC errors.

Similarly, if you do require the accelerometer to operate under reverse polarity conditions, you will need to advise customer service so that die configuration can be adjusted. The standard configuration for MEAS accelerometers does not support reversing polarity. The design calls out a parasitic PN junction in series with the bridge. For this reason the positive and negative excitation voltages should not be reversed. Internal heating and possible damage to the unit will result.

Signal Conditioning

MEAS pieozresistive wheatstone-bridge sensing elements have true differential signal outputs. The positive and negative outputs of the unit should be connected to differential input amplifiers with an input impedance of at least 1 Meg Ohm referred to ground. The amplifier should also have good common model rejection and a suitable bandwidth for the application.

In situations where the signal-conditioning amplifier has a single-ended input, one of the outputs should be left unconnected (with the sensitivity reduced to ½ the specified value). The unused output should not be tied to ground or any low impedance.

Grounding the unused output will result in a short circuit across half of the bridge. This will have an adverse affect on the operation of the sensor. The increased current flowing through one half of the bridge will cause the bridge to be unbalanced with unequal heating and unpredictable results from the other half of the bridge.

Shunt Calibration

Shunt calibration is commonly used to verify proper operation of a Wheatstone Bridge acceleration sensor. Applying a shunt resistor in parallel with one bridge leg lowers the resistance of that leg and causes a change in the bridge output proportional to the resistance change. This output is similar to the bridge response to acceleration so it simulates an acceleration signal and verifies that the bridge circuit is intact and that the signal conditioner is working. It isn't really a calibration because the shunt cal output varies from sensor to sensor. This is because the resistance of silicon sensors varies a lot from unit to unit.

Doing a shunt cal on is very simple. To get a positive shunt cal signal use a 200 KΩ resistor. Check the ZMO (bridge output) with no shunt. Then connect the shunt resistor to Red (+exc) and Green (+sig.) and remeasure the bridge output. Subtract the two outputs and that's the shunt cal signal.

If a negative shunt cal signal is required then connect the shunt resistor between Red (+exc.) and White (-sig.). For another health check of the unit, do both + and – shunt cals and compare the results. They should be within 1-2 mV's.

Example:

ZMO = -4.9 mV

+Rcal> Red/Green Shunted output (200 KΩ) = 52.9 mV > + Cal signal = 52.9-(-4.9) = +57.8 mV

-Rcal> Red/White Shunted output (200 KΩ) = -63.0 mV > + Cal signal = -63.0-(-4.9) = -58.1 mV

Accelerometer Installation

Accelerometers manufactured by Measurement Specialties are typically stud mounted, screw mounted, adhesively mounted or tape mounted.

<u>Stud/Screw Mounting Guidelines</u>

- The mounting surface should be clean and free of any residue or foreign material.
- The mounting surface should be smooth, flat, and with a maximum surface roughness of 32 microinches rms.
- Apply a light coating of coupling fluid (machine oil or silicone grease) on the mating surface to maximize the usable frequency range.
- Torque mounting stud to18 in-lbs.

<u>Adhesive Mounting Guidelines</u>

- The mounting surface should be clean and free of any residue or foreign material.
- The mounting surface should be smooth, flat, and with a maximum surface roughness of 64 microinches rms.
- For best high frequency performance a cyanoacrylate adhesive is recommend. A thin layer offers best frequency response.
- Soften adhesive cured adhesive with a chemical debonder (eg. acetone) prior to removal. Gently shear accelerometer loose from the mounting surface after waiting a few minutes for the debonding agent to penetrate the epoxy. Make sure not to use excessive force as this may damage the accelerometer.

<u>Tape Guidelines</u>

- The mounting surface should be clean and free of any residue or foreign material.
- The mounting surface should be smooth, flat, and with a maximum surface roughness of 64 microinches rms.

- There is increased interest in using tape with accelerometers weighing less than 3 grams. For those applications where the sensing device needs to be removed safely and quickly, the use of 3M™ Double Coated Tapes might be considered. The high tack adhesive provides relatively high initial adhesion and good shear holding power to a variety of surfaces.

Cable Routing

It is critical than when cable lengths longer than 2 inches are required that the cable assembly be properly secured at regular intervals during testing. It is recommended to use clamps, wax, or tape to secure the cable to minimize cable motion that can add noise to the output signal. The initial attachment should be within two to three inches of the accelerometer. Avoid routing cables near high-voltage wires and also ground the shield at the signal conditioner to minimize ground loops.

Frequently Asked Questions

Question: What is maximum length of cable you recommend?
Answer: 360 inches.

Question: Will your accelerometers work when submersed in water?
Answer: Generally no. The exception is our 1201 and 1201F.

Question: At what temperature will your die break down?
Answer: 300 °C. This is the temperature for gold fusing the top and bottom caps.

Question: My signal seems very noisy. What might be the problem?
Answer: Most likely the problem is coming from cable improperly tied down.

Question: What is the highest standard range you can reach?
Answer: We commonly specify 6000g. These units have survived to 10,000g but linearity is closer to 3% than 1%.

Question: How conservative are you published specifications?
Answer: Very conservative. We can select to much more stringent requirements.

Question: How much warmup time is required?
Answer: About 1 millisecond.

Question: What is the most common problem for sensor failure?
Answer: User experience. Majority of problems are cleared up with some application support over the phone.

Question: Do you ever experience problems with shipping batches of bad units?
Answer: No. All units are tested and calibrated before shipping.

Question: What is static acceleration?
Answer: Force of gravity ..1g. Turning a DC accelerometer on its side and then on its back will generate a different output. This output is due to gravity.

Question: Can you build accelerometers using cable supplied by customers.
Answer: Yes – if the outside diameter of the cable will fit our housing.

Question: Do you offer customer specified connectors and ID chips?
Answer: Yes

Question: Are your sensors CE and RoHS compliant?
Answer: Yes.

Question: Are your calibrations NIST traceable?
Answer: Yes

Question: Why do you have so many different designs?
Answer: Physical packaging and mounting is a critical key to obtaining reliable data.

Glossary of Common Vibration Terms

ACCELEROMETER +g DIRECTION & AXIS ORIENTATION The sensitive axis direction is indicated for each accelerometer series by an arrow on the drawings in the Product Specifications & Drawings. When an accelerometer is mounted to a surface that accelerates with a positive acceleration in the direction of the arrow (+g), the accelerometer produces a positive (+) change in output signal.

COMPENSATED TEMPERATURE RANGE The temperature range in which the sensor meets the specifications for Thermal Zero Shift and Thermal Sensitivity Shift is the Compensated Temperature Range. The sensor continues to function within the Operating Temperature Range; however, the specifications gradually deviate from the data sheet or calibration values.

DAMPING RATIO Having internal damping can be very beneficial to the accelerometer in terms of environmental shock survivability, but at the expense of higher frequency bandwidth. Damping is achieved by filling the sensor cavity with damping fluid (in the case of a bonded strain gage) or applying squeeze-film gas damping (in the case of piezoresistive MEMS) in the design. A reasonably accurate calculation of damping ratio is to take the ratio of the measured sensitivity at near DC versus 2 times the measured sensitivity at resonance. This assumes that the resonance occurs at the 90 degree phase shift point. For example, if the accelerometer sensitivity at 100Hz is at unity (reference) and the resonance peak of the device is measured at +20dB (10X), the damping ratio of the accelerometer is therefore at 0.05.

EXCITATION The recommended voltage with which a standard sensor should be excited is indicated for each sensor type. A high quality, low noise constant voltage source, or battery, is desirable. For a bridge type sensor (without internal amplifier), power supply current requirements may be calculated from I = V/R where I equals the current needed, V equals the excitation voltage and R is the input impedance of the actual sensor to be powered. For amplified products, the power requirements should be stated clearly on the data sheet.

FULL SCALE OUTPUT (FSO) AND SENSITIVITY Full Scale Output (FSO) is defined as the span between the negative range limit and the positive range limit of the sensor (i.e. ±10g rated range = 20g FSO). Values given on datasheets are approximate values and may vary with each sensor. The Sensitivity of a sensor, expressed per unit of input such as g, may be calculated by: Sensitivity = (acceleration output – zero offset)/acceleration input or by determining its dynamic sensitivity in sinusoidal vibration. The actual calibrated Sensitivity value for each sensor is provided on the calibration certificate, or supplied with the sensor, and referenced to its individual serial number.

HYSTERESIS Hysteresis is the difference in sensor output signal at a specific input when applied in the increasing and then decreasing sectors of a single cycle of short time duration at constant temperature. It is expressed as a percentage of FSO.

INPUT AND OUTPUT IMPEDANCE For sensors without amplifiers, the resistance measured between the (+) output line and the (-) output line is the Output Impedance. For best results, instrumentation used to monitor the sensor output should have an input impedance of at least 1 Megohm. Instrumentation with a low input impedance may reduce the sensitivity of the sensor by loading the output (typically a 1% reduction with an input impedance of 100 times the output impedance of the sensor, 2% for 50 times and as much as 5% for 20 times). The input impedance on an unamplified sensor is equal to the bridge resistance plus any series resistors which are in the thermal compensation network.

The actual values of input and output impedance for a particular sensor are recorded on their calibration sheet at room temperature. Both input and output impedances on sensors with piezoresistive sensing elements will change with temperature, in some cases as much as 25% per 50℃ (100℉) or more.

NATURAL FREQUENCY The Natural Frequency is the frequency at which the sensor's active sensing element goes into resonance and responds with maximum movement for a specific applied input in its undamped state. At the Natural Frequency, Phase Shift between the applied input and the output signal is 90°. Exposing a sensor to inputs at a frequency greater than 40% of the Natural Frequency can cause damage to the sensor if it is not appropriately protected by damping or overrange stops. With a piezoresistive accelerometer, damping within the sensor can reduce or eliminate a resonance condition and protect itself from high frequency rich mechanical inputs.

NON-LINEARITY Non-Linearity is the deviation of the sensor output signal from a theoretical straight line which has been fitted to the data points of an actual calibration. It expresses the maximum deviation of all data points in that calibration and is sometime expressed as a percentage of FSO, usually as a ±% error band, or % of reading.

NON-REPEATABILITY Non-repeatability is the deviation in sensor output signal levels when a specific input is applied in consecutive cycles of short time duration under the same conditions, such as temperature and direction of increasing or decreasing input. It can be determined by performing two consecutive short time duration calibration cycles and can be expressed as ±%FSO.

OPERATING TEMPERATURE RANGE The temperature range in which the sensor functions without damage from thermal effects is the Operating Temperature Range. Exposure to temperatures above or below the Operating Temperature Range may cause permanent damage to the sensor.

OVERRANGE LIMIT The Overrange Limit is the maximum input to which the sensor can be exposed without damage.

SEALING Sealing is the assembly method by which the sensor is protected from moisture in the surrounding environment. The most desirable sealing method is hermetically seal. This can be achieved by joining the individual piece parts together by soldering, welding, brazing, glassing, or other commonly accepted manufacturing processes.
Another common sealing method is epoxy seal. It is achieved by joining the piece parts by applying adhesive or potting compound to mitigate the incursion of moisture into the sensor assembly.

THERMAL SENSITIVITY SHIFT (TSS) The change in sensitivity of the sensor as a function of temperature is the Thermal Sensitivity Shift. It is usually expressed as a percent reading change in sensitivity for a specified change in temperature such as ±0.01%/℃ and is generally linear with moderate temperature changes. The Thermal Sensitivity Shift can be eliminated or minimized by using sensitivity numbers determined at or near the temperature of use.

THERMAL ZERO SHIFT (TZS) The change in the Zero Offset as a function of temperature is the Thermal Zero Shift. Thermal Zero Shift should not be confused with zero drift as a function of time or warm-up. It may be expressed as either a %FSO for a specific temperature change such as ±0.01%FSO/℃ or in voltage units such as ±0.2mV/℃ and it is not a linear function. Powering a sensor with an excitation voltage other than the one it was compensated with, as indicated on the sensor's calibration certificate, may cause the Thermal Zero Shift to vary from the stated specification.

Zero offset shifts due to thermal shocks may be minimized by employing various overcoatings or heat shields to either reflect or slow down the thermal shock wave. In dynamic measurements, the sensor output may be AC coupled to completely eliminate the zero offset and thermal zero shift.

TRANSVERSE SENSITIVITY Transverse Sensitivity is the sensitivity to input in the non-sensitive, cross-axis direction, and it is a potential source of measurement error in a user's application. Transverse specifications are generally achieved by manufacturing design and are only calibrated or certified by purchase order request at additional charge.

WEIGHT In some measurements, the weight of the sensor is very critical and should be a minimum. Keep in mind that if the sensor undergoes a "g" force, the apparent weight of the unit is its static value times the "g" load. If a sensor weighed 1/2 kilo- gram (1.1 pounds) and was subjected to 500g, the apparent weight would be 250 kilograms (550 pounds) at 500g.

ZERO OFFSET Also know as Zero Measurand Output (ZMO) where the measurand can be acceleration or pressure, etc., the electrical output of the sensor when there is no applied input is the Zero Offset. It is sometimes referred to as the sensor's "null bias" or "baseline". As accelerometers can statically sense the earth's gravitational force of 1g, an accelerometer should be in any of its non-sensitive axis orientations in respect to gravity to determine its true Zero Offset. A slight misalignment can significantly affect the measurement. A more accurate measure of ZMO (ZAO for an accelerometer) is by adding a +1g output measurement to a -1g output measurement and dividing by 2.
This method minimizes error contributions from misalignment with true zero-g and transverse sensitivity. In applications requiring static zero reference over time, periodic zero offset checks are recommended. For dynamic measurements, the zero offset can be completely eliminated through AC coupling.