TN-39

Handling Piezoresistive Shock Accelerometers
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Abstract:
Due to small size requirements for their intended applications, piezoresistive shock accelerometers generally do not lend themselves to hermetic construction and built-in protection against ESD, unexpected shock events, and over-voltage. For this reason, care must be taken during their use and transport.

In addition to safe handling techniques, this article provides an overview of various adhesive and stud mounting options, along with the advantages and disadvantages of each. Procedures for testing initial impedance, insulation resistance, and zero measurand output allow the user to check for sensor damage prior to use. A brief troubleshooting guide for cabling and best practices for routine calibration are offered in the interest of preserving long-term sensor health and accuracy.

Keywords:
Piezoresistive shock accelerometers, electrostatic discharge, ESD, sensor mounting, adhesive mounting, stud mounting, screw mounting, impedance test, insulation resistance test, zero measurand output test, turn-over test, cable troubleshooting

“Hey! Be careful how you handle that shock accelerometer. You might damage it.”

Sounds crazy, but piezoresistive shock accelerometers designed to measure high-g impacts can be damaged by mishandling. The small size and minimal mass requirements for their intended applications rule out the use of all-welded construction for environmental protection, and bulky electronics for robust ESD, over-voltage and reverse polarity protection.

However, Endevco engineers have designed a range of piezoresistive accelerometers that provide significant protection against electrical, shock and environmental threats. A quad diode is added to the boards of most Endevco piezoresistive accelerometers that provides ESD protection to Class 3B (>8000V) per Section 5.2 of MIL-STD-1686C. Exceptions to this include only the smallest accelerometers like the 7270A, 7280A, 7231C, 71M, 727 and 728. These accelerometers will typically withstand an over-voltage excitation of 10 to 20 percent and reverse polarity for 10 to 30 seconds.

Protection against handling shocks is accomplished through the use of mechanical stops and damping. When selecting accelerometers for your application, be aware that the easiest to damage with handling is an undamped sensor with no stops. One step better is undamped with stops. The most rugged and survivable is a damped sensor with mechanical stops. Epoxy sealing overcomes environmental threats by preventing the ingress of dirt. Some models are rated to IP65 (726CH) or IP67 (701AH, 757AH, 713), or are hermetic (74, 75), which speaks to their performance in humid conditions.
**Electrostatic Discharge (ESD) Considerations**

ESD precautions should be taken when inspecting, mounting and troubleshooting piezoresistive accelerometers.

Where possible and practical, work areas where piezoresistive accelerometers are handled should be equipped with a grounded table, floor mats and wrist straps. Non-condensing relative humidity of the area should be between 20% and 80%. Keep the sensors away from static-accumulating materials, including Formica or finished wood surfaces, vinyl floors, personal clothing, fiberglass chairs, and spray cleaners.

It’s also a good idea to ensure technicians use anti-static tools and equipment. Where grounding is not possible, static eliminators (ionizers) can be used to neutralize charges. Having a supply of anti-static bags for packaging accelerometers when transporting or for storage is a good preventative practice to follow.

If ESD damage does occur, it will typically result in a large shift in the Zero Measurand Output (ZMO). If ESD damage is sufficiently high, complete accelerometer failure is likely, and will present as an extremely large ZMO or an open leg of the Wheatstone bridge.

**Incoming Inspection**

Upon receipt, each accelerometer should be checked to ensure the calibration certificate is present along with the accelerometer, associated cabling/connectors and protective coverings. Figure 1 below presents packaging for the 7264H Piezoresistive Accelerometer.

![Figure 1: 7264H Accelerometer and Shipping Case](image-url)
Three simple tests can be performed to determine proper operation without removing the unit from its shipping container and protective sleeve.

**Impedance test:** Open the accelerometer shipping box and unwind a few inches of cable. Leave the accelerometer in the container. Read the input impedance (Red to Black) and output impedance (Green to White) with an ohmmeter. Refer to the accelerometer Calibration Data Sheet that is included with the unit to determine the proper value of impedance. The measured impedance should be within ±25% of this calibrated value.

**Insulation Resistance:** If the input and output impedances are within acceptable limits, use a multi-meter, ohmmeter or megohmmeter set at 50 volts maximum. Measure the insulation resistance between:

a. all leads connected together and the cable shield
b. all leads connected together and the transducer case
c. cable shield and the transducer case

All three readings should be 100 megohms as a minimum.

**Zero Measurand Output (ZMO):** After the impedance and insulation resistance tests, measure the output of the accelerometer with zero g acceleration. Turn the unit on its side so that the accelerometer mounting surface is perpendicular to the table top. Apply the specified excitation voltage to the accelerometer and measure its output with a DC millivolt meter. Allow the unit to warm-up for two minutes. The accelerometer should have a Zero Measurand Output (ZMO) within the data sheet specified limits.

If any of these initial checks do not give proper readings, and the reason for the erroneous reading cannot be found, contact PCB.

**Turn-over Test for Incoming or Field Use**

Piezoresistive accelerometers are DC response, thus they can measure the acceleration due to gravity. This characteristic can be employed for a quick check of the accelerometer’s sensitivity for troubleshooting purposes. Orient the sensor flat to level ground (sensitive axis is parallel to level ground). Assuming the sensor has a nominal sensitivity of 0.20 mV/g (for a 2000 g full scale unit) in this orientation, the sensor’s output should read 0.20 mV plus or minus the ZMO (which could be in the 10’s of mV).

Now rotate the sensor 180° (turn the sensor over), making sure the sensitive axis is parallel to level ground. The sensor’s output should now be reading -0.20 mV plus the ZMO. The value is negative because of the polarity feature of the sensor. Polarity simply means the output of the sensor is positive when exposed to a positive-going acceleration and negative when exposed to a negative going acceleration. Subtracting the two values read yields 0.40 mV (ZMO subtracts out).

This is the value expected for the 2 g change to which the accelerometer was exposed (positive 1 g to negative 1 g). The math can be shown this way: 2 g x 0.20 mV/g = 0.40 mV. If your sensor deviates significantly from this value, it is likely the sensor has been damaged.
The turn-over test is very effective when testing high sensitivity accelerometers. Low sensitivity accelerometers, as described in the above paragraph, may give ambiguous readings due to noise pick-up.

**Mounting**

There are various mounting techniques commonly employed for piezoresistive shock accelerometers. Whatever type is employed, it is essential to utilize proper techniques and tools.

**Adhesive Mounting**

When adhesively mounting accelerometers, the amount (thickness) of adhesive may play a critical role in achieving good frequency response. A thin film or minimal amount of adhesive promotes higher transmissibility, and hence a broader frequency response. Prior to mounting accelerometers, clean the mating surfaces with a hydrocarbon solvent such as Loctite™ X-NMS. For the most part, cyanoacrylate, double-sided tape or petro-wax may be used, resulting in a uniform thickness that will provide good results. Hot glue, on the other hand, requires more attention in its application. This is due to the limited time for application before glue hardens.

**Cyanoacrylate:** Tests performed at Endevco indicate that for an accelerometer weighing ≤ 10 grams, cyanoacrylate has the highest merit. Cyanoacrylates are liquid monomers that polymerize forming a hard plastic. This plastic adheres to metal, rubber, glass and various plastics. The thinner the layer of cyanoacrylate, the quicker the cure time.

Generally, for accelerometers with aluminum or stainless steel outer cases, a methyl-based cyanoacrylate is recommended, which bonds metal and glass well. When it is uncertain whether cyanoacrylates are compatible with a particular surface material, separately test a sample piece to be sure.

Advantages: Room temperature cure, fast cure time, broad frequency response and good temperature range.
Disadvantage: Need for a solvent (such as Loctite™ X-NMS or equiv.) to break glue bond down before removing accelerometer, and removal is time consuming. Cyanoacrylate can also be difficult to set on rough surfaces.

**Double-sided tape:** This approach has a fairly broad temperature range.

Advantages: Ease of application and removal, wide temperature range.

Disadvantages: Limited amplitude range.

**Hot glue:** Requires more attention than other adhesive mounting methods, particularly when trying to optimize for higher frequency applications.
Advantages: Ready supply of adhesive (glue sticks), rapid cure time, easy removal

Disadvantages: Very rapid cure time which must be taken into consideration to ensure good adhesion and proper frequency response. This implies that the user should be prepared to mount accelerometer as soon as the glue is applied to mounting surface.

**Important Note:** For adhesively mounted accelerometers, the cleanliness requirement extends to the complete accelerometer. If there is adhesive left on the base, there will be a base-to-device coupling problem. If there is glue elsewhere, the characteristics of the transducer's sides and top could change and result in additional crosstalk.

**Screw and Stud Mounting**

Technicians should refer to manuals and datasheets for each accelerometer requiring screw or stud mounting, as various mounting instructions such as torque and mating connection on the test object may vary. Generally, for screw or stud mounted devices, the mounting surface must be very flat, with low roughness, and must be perpendicular to the threaded hole(s) used to mount the accelerometer. If there was adhesive used on any of the surfaces, a thorough cleaning is absolutely necessary to remove all traces of the adhesive. Any aberrations on the mounting surface will produce base strain causing errors in the reading.

Having said this, below are some installation tips.

1. The mounting surface should be clean and free of burrs.

2. Do not cement the unit to the mounting structure. Use the supplied mounting accessories.

3. Remove the unit from the protective sleeve if the sleeve is present. Without the protective sleeve, it is recommended that the unit be handled by the case, and not the cable. This is to prevent the unit from slapping the mounting surface during installation.

4. For screw mounted accelerometers, turn the screws into the mounting holes using the supplied tools and recommended torque. This is roughly equivalent to finger tight with the supplied wrench. Installation of the unit with higher torque values, dry threads, or thread adhesives is not recommended as excessive torque will be required to break the screw loose when the accelerometer is dismounted. Do not use snap type torque wrenches.

5. As practical, tie down the cable within 2 to 3 inches (4 to 6 cm) from the unit. Whipping of the cable during vibration and shock will strain the cable unnecessarily at the unit, and produce noise.

6. Connect the unit to the signal conditioner and check for proper functioning through the use of standard techniques.
Cables

Because of the fine gage wiring used and the multitude of wires, connection errors can be a problem with piezoresistive accelerometers. Connecting wires to the wrong pins or solder bridges between connector pins are the most common wiring errors. Endevco products follow the industry standard for wire colors; however, one should confirm the color codes when using non-Endevco products. (Red for + excitation, black for - excitation, green for + signal output, and white for - signal output).

Troubleshooting Overview: During setup, technicians sometimes report high voltage outputs or no voltage output. For purposes of our discussion, assume that a connector has been attached to one end of sensor cable, and power has been applied between the green and black wires. There are now three conditions that can exist: open resistor, shorted resistor and normal. The more common problem is an open resistor caused by excessive current.

Table 1: Malfunction Options

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal bridge</th>
<th>Open arm</th>
<th>Shorted arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input resistance</td>
<td>500 Ω</td>
<td>1 kΩ</td>
<td>512 Ω</td>
</tr>
<tr>
<td>Output resistance</td>
<td>1 kΩ</td>
<td>1 kΩ</td>
<td>343 Ω</td>
</tr>
<tr>
<td>Supply current</td>
<td>20 mA</td>
<td>5 mA</td>
<td>20 mA</td>
</tr>
<tr>
<td>ZMO</td>
<td>43 mV</td>
<td>5 Volts</td>
<td>0 Volts</td>
</tr>
</tbody>
</table>

The most frequent problems technicians report are intermittent connections causing signal noise. This may be caused by worn contacts, mismatched pins and sockets, damaged or fatigued conductors and shield wires, moisture, corrosion or improper mating of connectors. In addition, a long length of cable makes a very efficient antenna for receiving any kind of electromagnetic energy. The very shock and vibration being measured may cause intermittent contacts or may loosen coupling devices.

Recalibration

Sensitivity and ZMO calibration are suggested to be performed at 6 to 12 month intervals, depending on usage. Ordinarily, recalibration needs to be performed only at 12 month intervals, if it is known that the accelerometer has not been used beyond its rated specifications. If the unit is operated in severe environments, it may be desirable to use shorter calibration intervals. Your company’s quality system is the final determination of the frequency needed for calibration. Contact PCB for local calibration facility information or return the unit to Endevco for calibration.