Endevco

INSTRUCTION MANUAL

For Piezoresistive Accelerometers

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Endevco

The Endevco® high shock accelerometer family includes both undamped and damped models, offered in a variety of configurations. Table 1 shows a summary of Endevco's current offering of high shock accelerometers. All the listed models are piezoresistive accelerometers.

Table 1. Endevco's offering of high shock accelerometers.

	screw mount, single axis	screw mount, triaxial	stud mount, single axis	surface mount, single axis	surface mount, triaxial
undamped	7270A, 7270AM7	7274A	7270AM4	71	73, 75
damped	7280A, 7280AM7	7284A	2262B, 7280AM4	72	74

Due to the severe environment in which these accelerometers are typically installed, the user should carefully read this instruction manual in its entirety.

A Calibration Certificate is included in the shipment of your Endevco® high shock accelerometer. Additionally, a product specification datasheet can be found at Endevco.com.

HANDLING PRECAUTIONS

Although undamped accelerometers are more susceptible to damage by handling, the following precautions should be taken when handling any accelerometer, whether it is damped or undamped. The amplification factor (or Q) of the undamped accelerometer at its resonant frequency of the seismic element can approach 100 (10 for the damped accelerometers). This means that if an unmounted unit were dropped on a metal surface (such as a table or bench top) and experienced a shock input of 2,000 g, the high frequency content of the metal-to-metal impact could excite the resonance, resulting in an accelerometer response of 200,000 g (20,000 g for the damped accelerometers). Such an event could severely damage the unit, so precautions must be taken to prevent this from occurring. It has been shown that the accelerometers are more vulnerable to damage in the unmounted state, as opposed to being mounted to a large mass test subject. For this reason the unmounted unit must be handled very carefully to avoid such fast rise time impacts.

Endevco® high shock accelerometers are shipped in electrostatic discharge (ESD) safe packaging. When handling any accelerometer it is always best practice to handle with ESD in mind. The accelerometer should only be handled by properly grounded technicians (via wrist straps or heel straps) at ESD safe work stations. 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, showing up as an extremely large ZMO or an open gage of the Wheatstone bridge.

INITIAL CHECKOUT

Upon receipt, the accelerometer should be checked to ensure that it was not damaged in transit. A simple resistance test is a quick way of verifying that all legs in the Wheatstone bridge sensing element are intact.

<u>Resistance Test</u> – Open the accelerometer container, and install a mating cable if required.

Unwind a few inches of cable for easier access to the individual cable wires. Measure the input resistance (red to black) and output resistance (green to white) with an ohmmeter and a pair of clips leads. The measured resistance should be within the specified tolerance as listed on the product specification data sheet.

If the resistance measurements are not within the noted specification, there may be a problem with the accelerometer and the factory should be consulted for further troubleshooting.

MOUNTING SURFACE PREPARATION AND INSTALLATION

Special care should be taken to provide a smooth, clean mounting surface to ensure maximum transmissibility of the shock input. Any small particles or debris trapped between the mounting surface and the accelerometer will degrade the transmission of the high frequency components of the shock input. An uneven mounting surface could also preload the accelerometer and cause unwanted static strain, resulting in possible zero shift during a shock measurement. The surface on which the accelerometer is mounted should have a surface roughness of 32 micro inches rms or better and a surface flatness tolerance of 0.0003”. Drill and tap mounting holes should be perpendicular to the mounting surface within ±1°. When mounting the accelerometer, make sure that 100% of the accelerometer’s bottom surface is in contact with the mounting surface. To further enhance the transmissibility of the shock input, a thin layer of acoustic couplant (or vacuum grease) is recommended between the accelerometer and the mounting surface. Two recommended high temperature acoustic couplants are Echotrace 9000 and Dow Corning DC-111.

In extremely high levels of shock exposure, or if high levels of transverse shock are anticipated, it is recommended that a small amount of adhesive be applied between the bottom of the accelerometer and the mounting surface (adhesive, in this case, will replace the acoustic couplant mentioned above). To enhance adhesion abrade the metal mounting surface (sandblast or fine sandpaper) and then solvent clean (swab with acetone followed by isopropyl alcohol). It should be noted that the adhesive is used to enhance the mounting strength of the high shock accelerometer to its mounting surface, and should never replace the included mounting hardware or any integral mounting threads. To install the accelerometer using screws and adhesive, first apply a thin layer of adhesive to the bottom surface of the accelerometer using an oiler (or toothpick), taking care to keep the adhesive out of the mounting holes. Next, while the adhesive is still in an uncured state, mount the accelerometer using its mounting hardware and apply the appropriate torque (see data sheet or instruction manual for your particular sensor). Cure the adhesive using the manufacturer’s recommendations. Extra care should be exercised to keep the adhesive off the threads of any mounting hardware. As mentioned before, the adhesive is used to enhance the mounting strength of the hardware (i.e. adhesive should never be used alone). For permanent installations, Bacon Industries LCA-9 epoxy is recommended. For temporary installations Aremco Crystalbond™ 509 is recommended. Crystalbond™ 509 is a wax that is applied using a moderate amount of heat and can be cleaned up with acetone. Cyanoacrylate (super glue) is not recommended as a temporary adhesive unless an appropriate solvent (such as acetone) is used to weaken the glue joint before attempting to remove the accelerometer.

Because it is possible for mounting hardware screws or integral studs to loosen under high shock levels, it is highly recommended that the screws or studs be re-torqued, if possible, after each high-level shock test. An alternative approach is to use liquid thread-locking compound (such as Loctite® 262). A loose thread will cause a change in the preload condition, which may cause a shift in ZMO. If a thread becomes significantly loose, allowing relative movement (or "slap") between the accelerometer and the mounting surface, the resonance can be excited and damage to the accelerometer is very likely. If the installation does not permit the periodic re-torquing of threads, or the use of a thread-locking compound, the adhesive technique described above is strongly recommended.

Mounting to low strength material (such as aluminum) is not recommended. However, if such is the case, the use of threaded inserts (such as Heli-Coil®) to increase thread strength is required. Additionally, adhesive must always be used between the transducer and any low-strength mounting surface.

DEMOUNTING THE ACCELEROMETER

Some applications involve permanent sensor installations, with no expectation that the unit will need removal or replacement. However, other applications may call for demounting the accelerometer at some point. Here are some of the common recommendations for demounting.

If the accelerometer was mounted using only the included hardware, or an integral thread built in to the housing, then the sensor can be removed with the appropriate wrench. Simply unscrew the hardware or the sensor and you're good to go. Be aware that some sensors, particularly undamped ones, are especially sensitive to high-frequency content from metal-to-metal impacts. Large and heavy wrenches should be brought to gentle contact with the sensor housing. Forceful metal-to-metal collisions can permanently damage the sensor.

Some sensors are installed with adhesive, either due to the adhesive-mount nature of the unit, or simply for extra strength on top of the mounting threads. For temporary installations using a wax like Aremco Crystalbond™ 509, the wax can be reheated and melted with a hot plate. The wax can then be cleaned up using acetone. Cyanoacrylate (super glue) is a convenient adhesive for mounting the device, but it makes for difficult and messy disassembly. The preferred method for demounting a superglued unit is with an appropriate solvent for the glue. The solvent should be swabbed around the base of the accelerometer; under no circumstances should the accelerometer be soaked or immersed in any liquid. Any residual glue on the device can then be further dissolved or scraped off. Trying to remove the accelerometer by twisting and pulling will excite the resonance and could cause permanent damage to the accelerometer. If the glue bond is too strong for normal removal and no solvent is available, we recommend using a vise to grab on to the sensor housing itself before attempting to shear it off the mating surface with the minimum possible force. The clamp action from a vise is stable, and the large, massive vise helps in attenuating high-frequency content before it reaches the sensor. Note that this vise method is the riskiest and the least recommended. The shearing action at the moment the sensor becomes detached can still cause damage. This method should only be considered if no other options are available.

CABLE HANDLING

There are two important considerations regarding the mating cable when installing the accelerometer. First, since the cable will be exposed to the same high level shocks as the accelerometer, care needs to be taken to prevent damage to the cable. Relative motion between the cable and the accelerometer can cause cable failure and/or a significantly shortened life. Second, the signal voltage on the leads of the cable will be at a very low level, and any excessive movement of the cable could cause noise on the signal lines. Because of the above factors, it is important that the following cable recommendations be observed.

If possible, the mounting preparation should allow for the cable to be routed perpendicular to the primary shock direction to reduce the amount of tensile stress on the cable. To strain relieve the cable close to the accelerometer, form a small bend (~¼" radius) in the cable within two to three inches of the connector interface, and then tack the cable to the mounting surface with tape. Next, completely secure the cable between the accelerometer case and the tape to the mounting surface by encapsulating with a silicone RTV. A recommended silicone RTV is Loctite® item number 37463, which is an air curing RTV which will be tack-free in 15-20 minutes, test ready in roughly an hour and fully cured in 24 hours (assuming 70ºF and 50% relative humidity). In routing the remaining portion of the cable to the signal conditioner, it is important that there be sufficient slack in the cable, i.e. the cable should not be pulled tight between the test specimen and the signal conditioner.

ELECTRICAL CONSIDERATIONS

1. Excitation Voltage – The high shock accelerometers are typically calibrated using an excitation voltage of 10.000 ± 0.005 Vdc, or at 5.000 ± 0.005 Vdc depending on model, unless otherwise specified at the time of order (the maximum excitation voltage without damage is 12 Vdc). If a voltage other than the voltage used at the time of calibration is applied to the unit, the ZMO and sensitivity will differ from the specified value on the Calibration Certificate, thus excitation voltages other than the calibrated voltage should be specified at the time of order. The accelerometer requires a clean, well-regulated, constant voltage power supply.

2. Cable Length Considerations – Many Endevco® piezoresistive accelerometers are calibrated with 48 inches of cable, unless otherwise specified at the time of order. When using cables longer than 10 – 20 feet, two effects must be taken into consideration:

   a. *Input Voltage Attenuation*: Resistance in the excitation voltage wires may reduce the voltage to the sensor. The reduced voltage can be calculated as follows:

$$V_{att} = V_{exc}\left(\frac{R_S}{R_{cable}+R_S}\right)$$

V_{att}	=	Attenuated excitation voltage applied to sensor.
V_{exc}	=	Excitation voltage from power supply.
R_s	=	Input resistance of sensor, from Cal Cert.
R_c	=	Resistance of additional cable beyond the calibrated length. $R_c = 2 * R_{wire}$, the resistance of one of the cable wires.

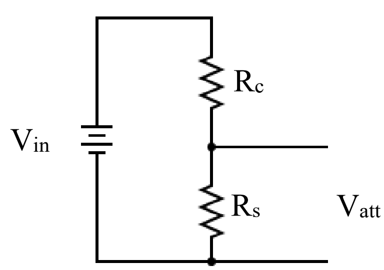

Figure 1: Simplified "voltage divider" circuit between sensor and cable.

Long cable lengths reduce the actual excitation voltage applied to the sensor. When this occurs, the sensitivity of the device also decreases.

$$S_{att} = V_{att} * S_{cal}$$

S_{att}	=	Attenuated sensitivity
V_{att}	=	Attenuated excitation voltage applied to sensor
S_{cal}	=	Sensitivity of sensor, from Cal Cert.

If cable lengths longer than 20 feet are required then it is recommended to use a signal conditioner with an excitation sense (remote sense) feature. In brief, to use excitation sense a secondary cable (longer) is spliced to the existing accelerometer cable (shorter). The extension cable has two extra wires; one wire is connected to the accelerometer's positive input lead and the other to the accelerometer's negative input lead. The two extra wires are used to measure the actual voltage at the accelerometer and adjust the supplied excitation voltage accordingly until the target value is achieved. The effect of the voltage drop due to the series resistance in the wires is eliminated by measuring the voltage using a high input impedance voltmeter.

b. *Cable Capacitance*: Long cable leads act as an RC filter, which can cause significant attenuation of high frequencies. A rough calculation for the cut-off frequency of such a filter is as follows:

$$f_c = \frac{1}{2\pi RC}$$

f_c	=	Cutoff frequency, in Hz (-3dB point)
R	=	Sensor output resistance
C	=	Cable capacitance (conductor-to-conductor)

In general, the above effects are insignificant when cable length is 20 feet (6 meters) or less. If your sensor comes with an integral cable longer than 20 feet, the above effects are already accounted for in the factory calibration. These effects must only be considered when longer extension cables are installed by the customer. Contact Applications Engineering for more information, if required.

3. Impedance Matching – A third electrical consideration is signal attenuation on the output wires. However, this effect is only relevant when the sensor's output resistance is comparable to the DAQ equipment's input impedance. For most cases, the input impedance of a DAQ channel is on the order of 1 MΩ, far higher than any Endevco sensor resistance. This means that attenuation on the sensor output is effectively nullified. For more information, see PCB technical note TN-32, How Impedance Relationships Influence Measurement Results.

OPERATING PRECAUTIONS

While these high shock accelerometers can be extremely rugged, they can also be extremely fragile under very specific operating conditions, namely under resonance excitation. Due to the extremely high levels of shock encountered and the potential for resonance excitation, the user should **read this section carefully** before operating.

RESONANT FREQUENCY EXCITATION

Undamped sensors utilize an undamped sensing element, which means its resonant frequency is more easily excited as compared to a damped counterpart. Undamped piezoresistive sensors from Endevco also do not incorporate any mechanical overtravel stops, which means the displacement of the proof mass is not restricted. Since the amplification factor for an undamped accelerometer can be up to 100, if there is sufficient high frequency content in the shock event, the excessive amplitude of the seismic mass can be well over the overrange capability and cause permanent damage to the accelerometer. Endevco damped accelerometers use light gas damping to reduce resonant frequency excitation, but with an amplification factor (or Q) of approximately 10, it is still possible to excite the resonant frequency.

Another thing to note is that Endevco undamped accelerometers include two masses, each with a separate resonant frequency. If both resonant frequencies are excited, a beat frequency may be apparent in your data that will be at a frequency that is the difference between the two resonant frequencies. Although the beat frequency will be apparent in the time history, it will not translate to the Fourier transform. Endevco damped accelerometers use only a single seismic system so there are no concerns with beat frequencies.

Although resonance excitation cannot always be avoided, the user can take measures to reduce the amount of high frequency energy transmitted to the accelerometer. If high out-of-band energy is anticipated and cannot be suppressed, damped sensors are generally recommended over undamped sensors.

BANDWIDTH AND AMPLITUDE LINEARITY

Endevco undamped accelerometers do not use mechanical over travel stops, and so accurate measurements are permitted over a wide frequency and amplitude range. Undamped accelerometer data are typically considered accurate (±5%) to one-fifth of the resonant frequency and, because there are no overtravel stops to limit the displacement of the proof mass, reasonable amplitude linearity can be observed well beyond the rated full scale range.

On the other hand, Endevco damped accelerometers do incorporate both damping and mechanical overtravel stops. These features improve the survivability and reliability in increasingly harsh environments by suppressing the resonant frequency excitation and limiting the displacement of the proof mass to safe levels. The trade-off here is that these features also limit the amplitude linearity of the accelerometer. Experimental data has shown that linear data can be obtained up to a minimum of 1 ½ times full scale range (often times up to 2 times range), but the data will become nonlinear as you move beyond that. This nonlinear effect is basically a gradual reduction in sensitivity as the acceleration level increases above 1 ½ times full scale range; this is because the interaction between the gas damping and mechanical overtravel stops begin to limit the displacement of the proof mass. For this reason, to ensure linear data in the presence of resonant excitation, it is important to monitor the amplitude of the resonant frequency excitation and make sure it is below 1 ½ times full scale range.

In order for damping to be effective, more displacement of the proof mass is required, which results in a lower resonant frequency (as compared to undamped sensors). This lower resonant frequency limits the bandwidth, and in general, the damped accelerometers are accurate to 10 kHz (±1dB or better).

DATA ACQUISITION AND ANTI-ALIASING PRECAUTIONS

With any shock testing it is always best practice to use recording equipment with enough bandwidth to resolve the highest frequency component present, which is usually the resonant frequency of the accelerometer. Even with the excitation of resonance, if linear filtering is used and the amplitude during resonance does not cause saturation to the signal conditioning (or go beyond the linear range of the damped accelerometer), the high amplitudes experienced during resonance will not degrade the accuracy of the actual shock data recorded at lower frequencies.

The user should also be aware of aliasing and its effect on the data. A simple, and by no means complete, explanation of aliasing is as follows. Aliasing occurs during digitization when you have energy in the analog time history at a frequency higher than one-half of the sampling rate (the Nyquist frequency). Once digitized, the aliased frequencies will fold back over the Nyquist frequency into the frequency range of interest resulting in errors in the data. To prevent aliasing, the sampling rate should be at least two times (preferably ten times) the highest frequency present. The highest frequency present in almost all situations will be the resonant frequency of the high shock accelerometer. Better yet, an analog anti-alias filter should be placed before digitization with a cutoff frequency of at least one-half (preferably one-tenth) the sampling rate. The anti-alias filter safeguards against any unpredictable out-of-band energy and is the most reliable approach to acquiring good quality, non-aliased data.

CLEANING

If desired, dirty accelerometers may be wiped clean using a damp cloth and a solvent such as acetone. **Do not soak or immerse** the unit in any solvent or water. Do not use any sharp tool such as a screwdriver to remove dirt or contaminants. Any temporary adhesives, such as wax or cyanoacrylate, used to mount the accelerometer should be cleaned with an appropriate solvent (such as acetone).

RECALIBRATION

As with any measuring device, optimum accuracy is maintained by periodic recalibration. Sensitivity and ZMO calibration should be performed at 6 to 12 month intervals depending on usage. Ordinarily, recalibration need only be performed at 12 month intervals if it is known that the accelerometer has not been used beyond its rated specifications. If the unit is used under severe environments, it may be desirable to use shorter calibration intervals. When testing at high levels (levels exceeding the accelerometer's full scale range) it is recommended that calibration be performed every six months or after each high amplitude test.

The general health of the accelerometer can be assessed by measuring the ZMO and comparing the value to the most recent calibration certificate. The ZMO can be checked by applying a well-regulated excitation voltage (10 Vdc in most cases, unless otherwise specified at time of order) to the red-black leads and reading out the differential voltage between the green-white leads. Changes in ZMO of up to ±20mV with time and usage are not uncommon and are not necessarily a sign of a damaged accelerometer. Changes of greater than ±20mV may indicate damage to the sensor and the accuracy of subsequent measurements is question. If possible, an accelerometer that has experienced a large

ZMO shift should be replaced or returned for recalibration. Any ZMO reading approaching one-half of the excitation voltage or up to the excitation voltage is a sure sign of accelerometer failure. The simple resistance check described in the "Initial Checkout" section above can also be used to evaluate accelerometer health.

After performing the above tests, if you are still uncertain about the health of your accelerometer please contact Applications Engineering. An Application Engineer will be able to discuss the health of your accelerometer in more detail and suggest if it is healthy, needs recalibration or needs replacement. Endevco maintains an accelerometer recalibration service with NIST traceability in the United States. Endevco European Regional offices maintain accelerometer recalibration services with traceability to applicable national standards.

QUESTIONS

If you have any questions regarding the use of these accelerometers (or any other Endevco® product) please contact Endevco/PCB at 1-716-684-0002 in North America, or your local sales representative.