



**Model 611M10/03**

**High temperature, charge mode accelerometer with UHT-12<sup>®</sup> shear sensing crystal, 5 pC/g sensitivity, 900 degree F, integral cable to 7/16-27 2-pin connector**

**Installation and Operating Manual**

**For assistance with the operation of this product,  
contact the PCB Piezotronics, Inc.**

**Toll-free: 716-684-0001  
24-hour SensorLine: 716-684-0001  
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## Repair and Maintenance

PCB guarantees Total Customer Satisfaction through its “Lifetime Warranty Plus” on all Platinum Stock Products sold by PCB and through its limited warranties on all other PCB Stock, Standard and Special products. Due to the sophisticated nature of our sensors and associated instrumentation, **field servicing and repair is not recommended and, if attempted, will void the factory warranty.**

Beyond routine calibration and battery replacements where applicable, our products require no user maintenance. Clean electrical connectors, housings, and mounting surfaces with solutions and techniques that will not harm the material of construction. Observe caution when using liquids near devices that are not hermetically sealed. Such devices should only be wiped with a dampened cloth—never saturated or submerged.

In the event that equipment becomes damaged or ceases to operate, our Application Engineers are here to support your troubleshooting efforts 24 hours a day, 7 days a week. Call or email with model and serial number as well as a brief description of the problem.

## Calibration

Routine calibration of sensors and associated instrumentation is necessary to maintain measurement accuracy. We recommend calibrating on an annual basis, after exposure to any extreme environmental influence, or prior to any critical test.

PCB Piezotronics is an ISO-9001 certified company whose calibration services are accredited by A2LA to ISO/IEC 17025, with full traceability to SI through N.I.S.T. In addition to our standard calibration services, we also offer specialized tests, including: sensitivity at elevated or cryogenic temperatures, phase response, extended high or low frequency response, extended range, leak testing, hydrostatic pressure testing, and others. For more information, contact your local PCB Piezotronics distributor, sales representative, or factory customer service representative.

## Returning Equipment

If factory repair is required, our representatives will provide you with a Return Material Authorization (RMA) number, which we use to reference any information you have already provided and expedite the repair process. This number should be clearly marked on the outside of all returned package(s) and on any packing list(s) accompanying the shipment.

## Contact Information

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Repair inquiries: [rma@pcb.com](mailto:rma@pcb.com)

For a complete list of distributors, global offices and sales representatives, visit our website, [www.pcb.com](http://www.pcb.com).

## Safety Considerations

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the precautions required to avoid injury. While our equipment is designed with user safety in mind, the protection provided by the equipment may be impaired if equipment is used in a manner not specified by this manual.

Discontinue use and contact our 24-Hour Sensorline if:

- Assistance is needed to safely operate equipment
- Damage is visible or suspected
- Equipment fails or malfunctions

For complete equipment ratings, refer to the enclosed specification sheet for your product.

## Definition of Terms and Symbols

The following symbols may be used in this manual:



### **DANGER**

Indicates an immediate hazardous situation, which, if not avoided, may result in death or serious injury.

**CAUTION**

Refers to hazards that could damage the instrument.

**NOTE**

Indicates tips, recommendations and important information. The notes simplify processes and contain additional information on particular operating steps.

**The following symbols may be found on the equipment described in this manual:**



This symbol on the unit indicates that high voltage may be present. Use standard safety precautions to avoid personal contact with this voltage.



This symbol on the unit indicates that the user should refer to the operating instructions located in the manual.



This symbol indicates safety, earth ground.



PCB工业监视和测量设备 - 中国RoHS2公布表

PCB Industrial Monitoring and Measuring Equipment - China RoHS 2 Disclosure Table

部件名称	有害物质					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr(VI))	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
住房	O	O	O	O	O	O
PCB板	X	O	O	O	O	O
电气连接器	O	O	O	O	O	O
压电晶体	X	O	O	O	O	O
环氧	O	O	O	O	O	O
铁氟龙	O	O	O	O	O	O
电子	O	O	O	O	O	O
厚膜基板	O	O	X	O	O	O
电线	O	O	O	O	O	O
电缆	X	O	O	O	O	O
塑料	O	O	O	O	O	O
焊接	X	O	O	O	O	O
铜合金/黄铜	X	O	O	O	O	O
本表格依据 SJ/T 11364 的规定编制。						
O：表示该有害物质在该部件所有均质材料中的含量均在 GB/T 26572 规定的限量要求以下。						
X：表示该有害物质至少在该部件的某一均质材料中的含量超出 GB/T 26572 规定的限量要求。						
铅是欧洲RoHS指令2011/65/ EU附件三和附件四目前由于允许的豁免。						

CHINA RoHS COMPLIANCE

Component Name	Hazardous Substances					
	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Chromium VI Compounds (Cr(VI))	Polybrominated Biphenyls (PBB)	Polybrominated Diphenyl Ethers (PBDE)
Housing	O	O	O	O	O	O
PCB Board	X	O	O	O	O	O
Electrical Connectors	O	O	O	O	O	O
Piezoelectric Crystals	X	O	O	O	O	O
Epoxy	O	O	O	O	O	O
Teflon	O	O	O	O	O	O
Electronics	O	O	O	O	O	O
Thick Film Substrate	O	O	X	O	O	O
Wires	O	O	O	O	O	O
Cables	X	O	O	O	O	O
Plastic	O	O	O	O	O	O
Solder	X	O	O	O	O	O
Copper Alloy/Brass	X	O	O	O	O	O

This table is prepared in accordance with the provisions of SJ/T 11364.

O: Indicates that said hazardous substance contained in all of the homogeneous materials for this part is below the limit requirement of GB/T 26572.

X: Indicates that said hazardous substance contained in at least one of the homogeneous materials for this part is above the limit requirement of GB/T 26572.

Lead is present due to allowed exemption in Annex III or Annex IV of the European RoHS Directive 2011/65/EU.

**General**  
**OPERATING GUIDE**

for use with

**PIEZOELECTRIC CHARGE MODE ACCELEROMETERS**

SPECIFICATION SHEET, INSTALLATION DRAWING  
AND CALIBRATION INFORMATION ENCLOSED

PCB ASSUMES NO RESPONSIBILITY FOR DAMAGE CAUSED TO THIS PRODUCT AS A RESULT OF  
PROCEDURES THAT ARE INCONSISTENT WITH THIS OPERATING GUIDE.

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## INTRODUCTION

Congratulations on the purchase of a quality PCB charge mode accelerometer. In order to ensure the highest level of performance for this product, it is imperative that you properly familiarize yourself with the correct mounting and installation techniques before attempting to operate this device. If, after reading this manual, you have any additional questions concerning this sensor or its application, feel free to call an Application Engineer at 716-684-0001 or the closest PCB representative.

### 1.1 Cables in Explosive Atmospheres

The cable lengths (Integral and Cable and Cable Assemblies) INSTALLED IN AN EXPLOSIVE ATMOSPHERE IS DEFINED IN THE ATEX, IECEx, CSA, ETC. APPROVAL CERTIFICATES.

### 1.2 High Temperature Differential Charge Output Sensor

Ceramic or Single crystal shear-structured accelerometers offer high performance for precision vibration measurements in high-temperature environments. The use of ceramic or single crystal sensing crystals, operating in the shear mode, reduces erroneous output due to base strain, thermal transients, and transverse motion.

Charge mode accelerometers output a strong, high-impedance charge signal directly from their piezoelectric sensing element. They do not contain built-in signal conditioning electronics; the signal is conditioned externally by either a laboratory-style charge amplifier or in-line charge converter prior to being analyzed by a readout or recording device. The absence of built-in electronics permits operation to elevated temperatures of 500 °F (260 °C) for most models or up to 1300 °F (700 °C) for special applications.

These accelerometers are ideal for structural testing, machine monitoring, and vehicular shock, high temperature machinery and power generation turbine and other vibration measurement tasks where high temperatures preclude the use of accelerometers with built-in microelectronics.

Enclosed is a **Specification Sheet**, which lists the complete performance characteristics of the particular accelerometer.

## 2 CABLING

### 2.1 General Precautions and Considerations

#### 2.1.1 Proper Cable Type and Care

Ascertain that you have ordered the correct cable type. Due to the high-impedance nature of the output signal generated by charge mode accelerometers, several important precautionary measures must be followed. When using soft-line cable always use special low-noise PCB Series 045 Low-Noise Cable (or equivalent) for connecting to the input of the differential charge-output accelerometers. For extremely high temperature charge mode applications use mineral insulated (MI) hard-line.

Care and attention to installation is essential, as the reliability and accuracy of your system is no better than that of the output cable. Cables and connectors must be kept clean and dry to maintain high insulation resistance and low frequency response. In the event that the insulation resistance is compromised, inspect, clean, and bake cables and connectors to restore insulation resistance.

### 2.2 Softline Cable

Special high temperature low-noise, shielded cable 2-wire cable assembly is required with charge mode sensors for applications up to 500°F to connect the transducer to the charge amp. When additional mechanical protection is required a stainless steel armor can be used.

The shield acts as a Faraday cage to reduce electrical noise from corrupting the signals, and minimizes capacitively coupled noise from other electrical sources.

Standard, two-wire, or coaxial cable, when flexed, generates a charge between the conductors. This is referred to as triboelectric noise and cannot be distinguished from the sensor's charge output. Low-noise cables have a special graphite lubricant between the dielectric and the braided shield, which minimizes the triboelectric effect and improves the quality of the sensor's charge output signal.



When using separate cables connect the cable to the accelerometer. A small amount of thread-locking compound placed on the connector prior to attachment helps secure the cable during testing. In harsh environments, the connection can be sealed with silicone rubber, O-rings, and flexible heat-shrink tubing.

### 2.3 Integral Hardline Cable

For extremely high temperature (>500°F) charge mode applications use mineral insulated (MI) hardline. Keep cable clean to maintain insulation resistance and good low-frequency response

### 2.4 Hardline Connection Type

#### 2.4.1 PCB / Lemo type connector

The Lemo connector is PCA.0S.302.CLAC42 that is specially adapted for use with hardline cable. The connector is a self-latching system that allows the connector to be mated by simply pushing the plug axially into the socket. When required the connector is disengage by a single axial pull on the outer release sleeve.

#### 2.4.2 High Temperature 2 –pin 7/16-27 UNS connector

This connector is a Model GP, 2 Pin Jack, 7/16-27 thread. The connector is welded to the hardline to provide a high temperature, hermetic connection. The GP connector uses a threaded connection to mate with a GN or QY 2-Socket plug and torqued to 5 ft\*lbs +/- 1 ft\*lb

### 2.5 Differential Charge Amplifier

The differential charge amplifier is purchased separately

A conventional method for conditioning the high-impedance signal generated by a charge output sensor is to use a differential charge amplifiers operate from an ICP® signal conditioner. The unit employs a high gain amplifier to perform the impedance transformation. The charge output of the transducers may be scaled in terms of acceleration, pressure or force. The output is then mV/g, mV/psi or mV/lb, respectively.

## 3 INSTALLATION OVERVIEW

### 3.1 Equipment Inspection

Before installing the accelerometer, verify the insulation resistance (I/R) of the sensor is per specification. I/R can be out of specification due to mishandling and/or damage.

### 3.2 Polarity Test

Use this test to verify the proper polarity response. Improper polarity will adversely affect the use of the sensor for machinery diagnostics such as balancing.

Step 1 – Connect the sensor to a charge amp and any ICP® signal conditioner. Using standard cable, connect the powered sensor to an oscilloscope.

Step 2 – Set the time scale to 20 milliseconds/division

Step 3 – Hold the transducer in hand and tap the bottom. The waveform on the oscilloscope first goes positive as shown in Figure 1. If the waveform goes negative the wiring is reversed, contact PCB for technical support.

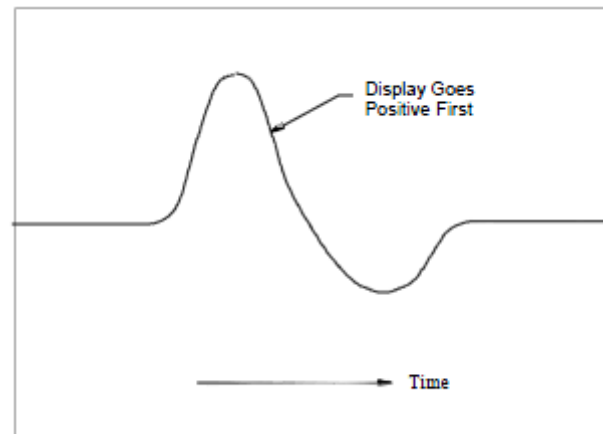


FIGURE 1

### 3.3 Sensor Location

*Characteristics like location, ruggedness, amplitude range, accessibility, temperature, and portability are extremely critical.*

For optimum performance and measurement find a rigid location on the machine casing that most accurately represents the vibration of the rotor, bearing, fan, etc. to be measured.).

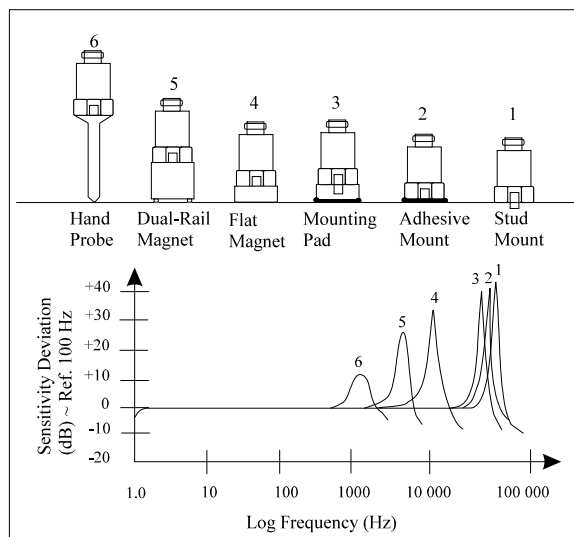
### 3.4 Mounting Sensor

When choosing a mounting method, consider closely both the advantages and disadvantages of each technique. Characteristics like location, ruggedness, amplitude range, accessibility, temperature, and portability are extremely critical. However, the most important and often overlooked consideration is the effect the mounting technique has on the high-frequency performance of the accelerometer.

Shown hereafter are six possible mounting techniques and their effects on the performance of a typical piezoelectric accelerometer. (Note that not all of the mounting methods may apply to your particular sensor.) The mounting configurations and corresponding graph demonstrate how the high-frequency response of the accelerometer may be compromised as mass is added to the system and/or the mounting stiffness is reduced.

**Note:** *The low-frequency response is unaffected by the mounting technique. Its roll-off behavior is dependent*

*upon the coupling type or time constant of the external charge amplifying device. This characteristic may be fixed or adjustable, depending on the charge amplifier. Please refer to the appropriate charge amplifier specification sheet for information on low-frequency characteristics.*

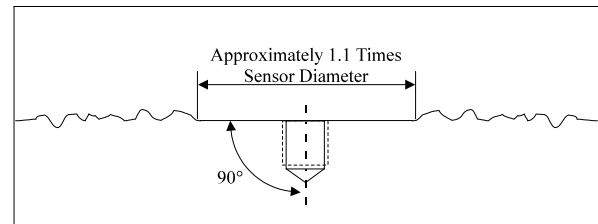


**Figure 1.** Assorted Mounting Configurations and Their Effects on High Frequency

#### 3.4.1 STUD MOUNT

This mounting technique requires smooth, flat contact surfaces for proper operation and is recommended for permanent and/or secure installations. Stud mounting is also recommended when testing at high frequencies.

**Note:** *Do NOT attempt mounting on curved, rough, or uneven surfaces, as the potential for misalignment and limited contact surface may significantly reduce the sensor's upper operating frequency range.*

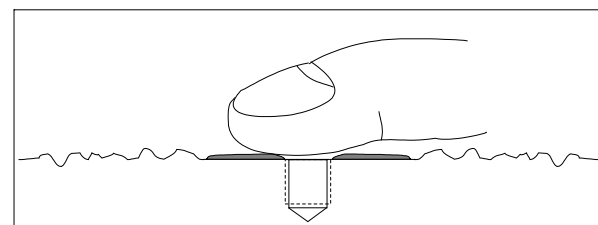


**Figure 2.** Mounting Surface Preparation

**STEP 1:** First, prepare a smooth, flat mounting surface, then drill and tap a mounting hole in the center of this area as shown in Figure 2 and in accordance with the **Installation Drawing** for the specific sensor that is being mounted.

A precision-machined mounting surface with a minimum finish of 63  $\mu\text{in}$  (0.00016 mm) is recommended. (If it is not possible to properly prepare the test structure mounting surface, consider adhesive mounting as a possible alternative.) Inspect the area, checking that there are no burrs or other foreign particles interfering with the contact surface.

**STEP 2:** Wipe clean the mounting surface and spread on a light film of grease, oil, or similar coupling fluid prior to installation.



**Figure 3.** Mounting Surface Lubrication

Adding a coupling fluid improves vibration transmissibility by filling small voids in the mounting surface and increasing the mounting stiffness. For semi-

permanent mounting, substitute epoxy or another type of adhesive.

**STEP 3:** Screw the mounting stud into the base of the accelerometer and hand-tighten. Then, screw the sensor/stud assembly into the prepared tapped hole and tighten to the recommended mounting torque as indicated on the **Installation Drawing**.

**Note:** *It is important to use a torque wrench during this step. Under-torquing the sensor may not adequately couple the device; over-torquing may result in stud failure.*

### 3.4.2 ADHESIVE MOUNT

Adhesive mounting is often used for temporary installation or when the test object surface cannot be adequately prepared for stud mounting. Adhesives like hot glue and wax work well for temporary mounts; two-part epoxies and quick-bonding gels provide a more permanent mount.

**Note:** *Adhesively mounted sensors often exhibit a reduction in high-frequency range. Generally, smooth surfaces and stiff adhesives provide the best frequency response.*

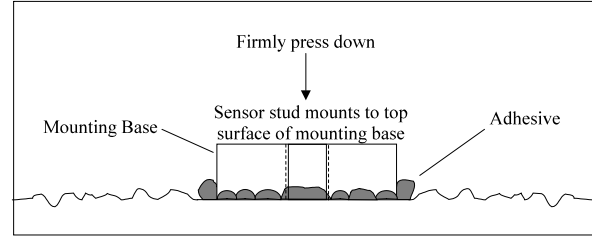
#### METHOD 1 - Adhesive Mounting Base

This method involves attaching a base to the test structure, then securing the sensor to the base. This allows for easy removal of the accelerometer. Also, since the bases are of a “hard-coated” aluminum design, they provide electrical isolation to eliminate ground loops and reduce electrical interference that may be present on the surface of the test object.

**STEP 1:** Prepare a smooth, flat mounting surface. A minimum surface finish of 63  $\mu\text{in}$  (0.00016 mm) generally works best.

**STEP 2:** Stud-mount the sensor to the appropriate adhesive mounting base according to the guidelines set forth in **STEPS 2 and 3** of the Stud Mount Procedure.

**STEP 3:** Place a small portion of adhesive on the underside of the mounting base. Firmly press down on the assembly to displace any extra adhesive remaining under the base.



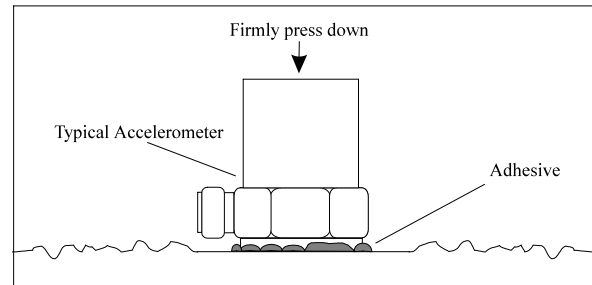
**Figure 4.** Mounting Base: Adhesive Installation

#### METHOD 2 - Direct Adhesive Mount

For restrictions of space or for convenience, most sensors (with the exception of integral stud models) can be adhesive-mounted directly to the test structure.

**STEP 1:** Prepare a smooth, flat mounting surface. A minimum surface finish of 63  $\mu\text{in}$  (0.00016 mm) generally works best.

**STEP 2:** Place a small portion of adhesive on the underside of the sensor. Firmly press down on the top of the assembly to displace any adhesive. Be aware that excessive amounts of adhesive can make sensor removal difficult.



**Figure 5.** Direct Adhesive Mounting

### 3.4.3 HANDHELD OR PROBE TIP MOUNT

This method is NOT recommended for most applications. It is generally used only for machinery monitoring and other portable trending applications. Both the accuracy and repeatability at low (<5 Hz) and high frequency (>1 kHz) ranges are questionable.

## 3.5 Route Mineral Insulated Hardline Cable

### 3.5.1 Care

Certain precautions should be used to avoid physical damage and minimize electrical noise. For instance, route the cables away from points that may exceed its

### 3.5.2 Bend Radius

The minimum bend radius ( $r$ ) for both soft-line and hardline cable is determined by the cable diameter as shown below:

Bends Allowed	Cable Diameter	Minimum Bending Radius
Total	$d$	$r$
1	0.125" (3.2 mm)	0.60" (16 mm)
20	0.125" (3.2 mm)	2.0" (50 mm)

### 3.5.3 Clamp Cable

To minimize triboelectric (motion-induced) noise from the cable interfering with the sensors high impedance charge output cable clamps must be used. Clamp the cable as close to the transducer as possible and should be attached to the same surface that the head is mounted (See Figure 3) taking care not to induce stress into the cable and possibly leading to intermittent or broken connections. Continue to clamp the cable at regular intervals of approximately 1.5 ft (0.5 m)

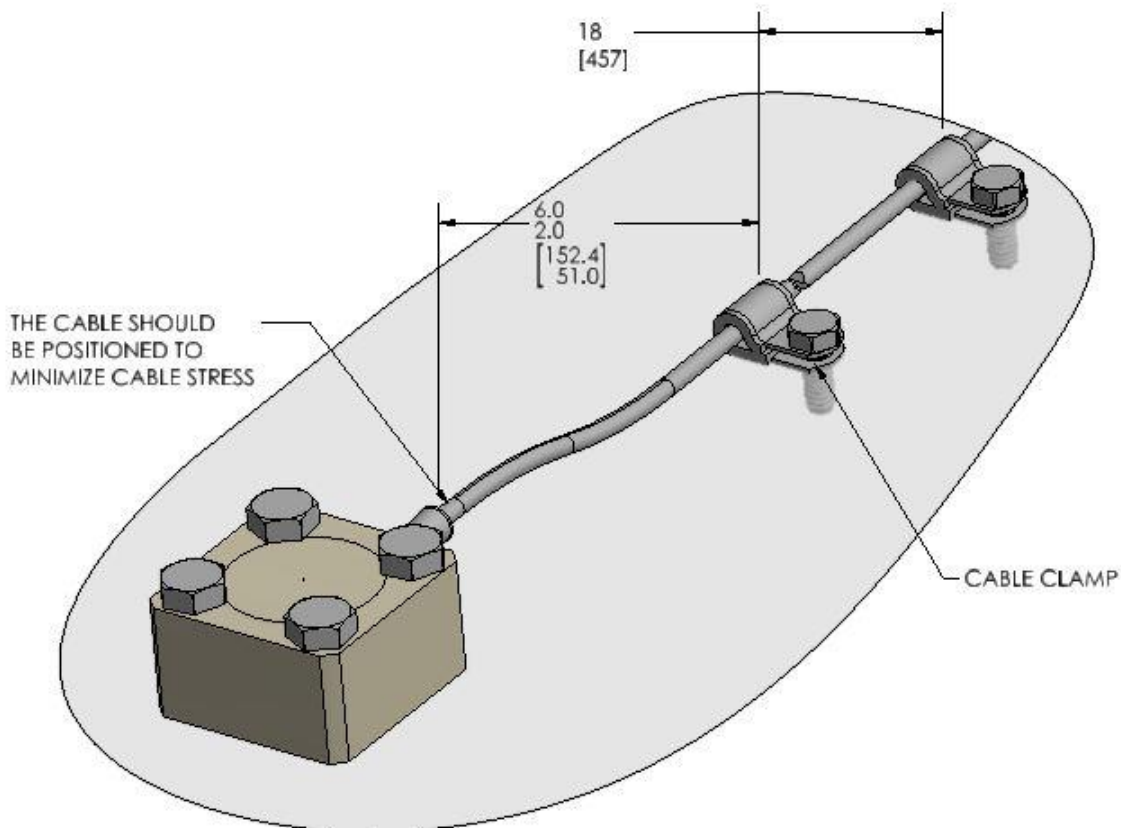
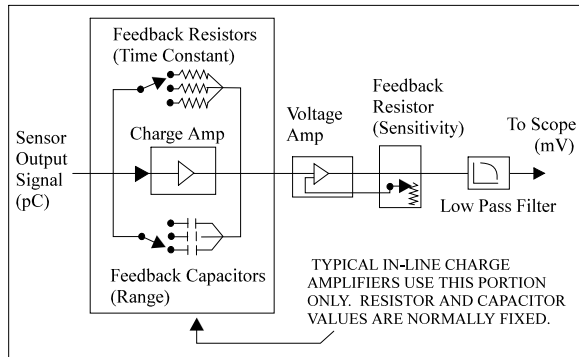


Figure 3

## 4 POWERING

### 4.1 Installation

Before connecting the low-noise cable from the accelerometer to the charge amplifier, be sure to ground both the charge amplifier and the cable. This ensures that an excessive static charge that may have accumulated across the accelerometer or cable is harmlessly discharged. Failure to observe this precaution can result in the destruction of the input FET of certain amplifiers.



Connect the transducer to the input of a PCB differential or equivalent charge amp using low noise cable. **Note:** For optimum noise performance, the cable length between the sensor and the charge AMP should be minimized.

Connect the output of the charge AMP to any ICP® signal conditioner using standard cable. Finally, the output of the signal conditioner may then be connected to an oscilloscope or other monitoring device. This output will be an AC signal (see **specification** for actual frequency response) with a DC bias. Many PCB signal conditioners remove the bias via an AC coupling circuit.

### 4.2 Operation

Once each element is connected, allow a few minutes for the system to thermally stabilize. Place the switch on the charge amplifier in the OPERATE position and proceed with the measurement.

It is often convenient to normalize the accelerometer and charge amplifier system to a precise sensitivity, such as 10.0 or 100.0 mV/g for ease of data analysis. This is accomplished with most PCB laboratory charge amplifiers and some miniature in-line units as well.

For fixed sensitivity charge converters, the system sensitivity (mV/g) is determined as the product of the charge amplifier sensitivity (mV/pC) and the charge sensitivity of the accelerometer (pC/g).

**Note:** When using charge-amplified systems, the noise floor of the system is dependent on the input capacitance to the charge amplifier. Since the cable adds to the capacitance and to minimize the noise threshold, keep the cable length between the accelerometer and the charge amplifier to a minimum. Cable length does not affect the system sensitivity of charge-amplified systems.

Since charge amplifier operation varies, please contact the respective signal conditioner manufacturer or check the product manual for additional information.

## 5 HIGH-TEMPERATURE OPERATION

### 5.1 Introduction

When subjected to elevated temperature, all piezoelectric sensors/hardline cable systems exhibit decreased insulation resistance, due in part to the piezoelectric element, but due mostly to the hardline cable necessary to withstand the high temperatures. This situation can cause serious voltage offset problems in direct-coupled charge amplifiers. To solve this problem, the user must AC couple (capacitor) the charge amplifier to the sensor/cable system. See 5.3 Solution to Reduced Resistance, for complete details, or use different amplifiers.

## 5.2 Reduced Resistance at Charge Amplifier Input

Figure 5.1 illustrates a simplified schematic of a typical direct-coupled charge amplifier where:

- $R_f$  = Feedback resistor (ohms)
- $R_i$  = Input leakage resistance (ohms)
- $E_o$  = Steady-state output voltage (volts)
- $e_i$  = Offset voltage: FET leakage (volts)
- $C_f$  = Feedback capacitor (farads)

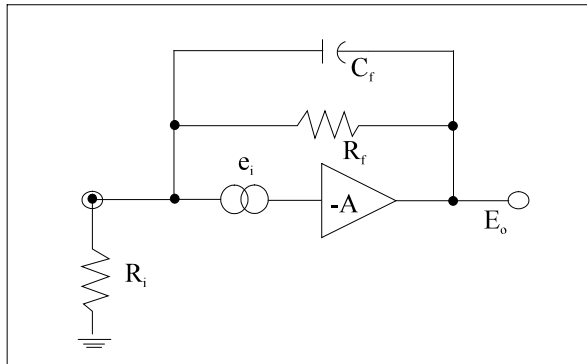


Figure 5.1 Typical Charge Amplifier Schematic

The feedback capacitor  $C_f$  comes into play only in the dynamic situation and its influence does not affect the steady-state situation. The voltage  $e_i$  is a DC offset voltage, usually very tiny (microvolts), that exists at the input gate of the MOSFET circuit. This minute leakage current exists in all real devices.

As demonstrated in Equation 1, the steady-state (DC) output voltage  $E_o$  is:

Equation 1

$$E_o = e_i \left( 1 + \frac{R_f}{R_i} \right)$$

This equation shows that if the input (leakage) resistance at the charge amplifier is extremely high (approaching infinity), the output DC voltage approaches  $e_i$ , usually a very tiny voltage. However, as  $R_i$  decreases, the term

$$1 + \frac{R_f}{R_i}$$

increases, such that the output voltage can, with large ratios of  $R_f/R_i$ , become large enough to result in a large  $E_o$ , perhaps large enough to be outside the normal output voltage range of the charge amplifier.

Because of the feedback capacitor  $C_f$ , this output voltage change usually does not occur rapidly but rather, it manifests itself as a slow drift in the output voltage level. If  $R_i$  is low enough with respect to  $R_f$ , the voltage drift may continue until saturation of the charge amplifier occurs.

## 5.3 Solution to Reduced Resistance

Since the drift or offset problem is caused by a static or steady-state imbalance at the input of the charge amplifier, the solution involves blocking this steady-state effect while allowing the desired dynamic phenomena to pass. This may be accomplished by installing a series capacitor at the input of the charge amplifier, between the offending sensor (or low-impedance hardline) and the input.

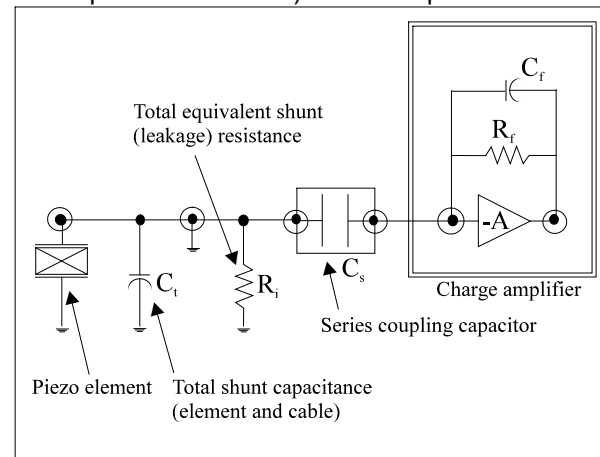


Figure 5.2 Piezoelectric System Block Diagram

Figure 5.2 illustrates a block diagram of the piezoelectric system where:

- $C_t$  = Shunt capacitor
- $C_s$  = Series blocking capacitor

With the series blocking capacitor  $C_s$  in place as shown, the dynamic charge (Q) generated by the sensor element is distributed across the two capacitors,  $C_t$  and  $C_s$ , in proportion to the size (capacitance) of each. If  $C_s$ , for example, is equal to 100 times  $C_t$ , 99% of the charge appears at the input of the charge amplifier, while 1% is across the shunt capacitor  $C_t$ . This results in a 1% decrease in apparent sensitivity of the system.

This therefore demonstrates the importance of selecting the series blocking capacitor at least two orders of magnitude higher than the total shunt capacitance  $C_t$  across the input of the charge amplifier.

It is also important that this capacitor be of high quality, with a leakage resistance of greater than  $10^{12}$  ohms, to avoid the DC offset discussed previously in 5.1, Introduction.

## 5.4 Low-Frequency Response Limitations

In a normal charge amplifier, the low-frequency response is set by the RC time constant, as established by the product of  $C_t$  and  $R_i$ . The system acts like a high-pass first order RC filter with a -3 dB frequency established by the relationship:

Equation 2

$$f_o = \frac{.16}{R_f C_f}$$

where:

- $f_o$  = -3 dB Frequency (Hz)
- $R_f$  = Feedback resistor (ohms)
- $C_f$  = Feedback capacitor (farads)

However, after the addition of the series blocking capacitor  $C_s$ , the system becomes the equivalent of two high-pass filters in series, one as previously mentioned and one comprised of series capacitor  $C_s$  and total equivalent shunt resistance  $R_i$ . This new cutoff frequency is:

Equation 3

$$f_o = \frac{.16}{R_i C_s}$$

To avoid compromise of the low-frequency response established by the charge amplifier parameters and illustrated by Equation 2, the product of  $R_i C_s$  should be several orders of magnitude higher than  $R_i C_t$ .

The approximate final system discharge time constant becomes:

Equation 4a

$$TC = \frac{1}{\frac{1}{R_i C_s} + \frac{1}{R_f C_f}} \quad \text{seconds}$$

If the input coupling time constant ( $R_i C_s$ ) is very much greater than the discharge time constant of the charge amplifier ( $R_f C_f$ ), Equation 4a then becomes:

Equation 4b

$$\frac{1}{R_i C_s} \Rightarrow 0 \text{ Seconds}$$

Equation 5

$$TC = R_f C_f$$

With the product  $R_i C_s$  chosen to be much greater than  $R_f C_f$ , the system discharge time constant is simply  $R_f C_f$  (seconds). The feedback parameters of the charge amplifier establish the low frequency characteristics of the system, unaffected by the degraded input resistance parameters of the test sensor and/or cable.

## 5.5 Other Precautions

Always remember to keep the OPR-GND switch on the charge amplifier in the GND position while connecting or disconnecting sensors, cable, or capacitor to the input connector. Stray or accumulated electrostatic charges may build to the point that they may saturate or even damage the input circuitry of the charge amplifier.

Operate the charge amplifier in the SHORT time constant while the sensor is subject to elevated or changing temperatures.

If it is not necessary to procure data during the transition from room temperature to operating temperature, place the OPR-GND switch in the

GND position to keep spurious, thermally generated charges grounded.

It is prudent to momentarily switch to the GND position even during the measurement period to ensure that excess charges do not accumulate at the input of the charge amplifier.

## 6 ACCELEROMETER CALIBRATION

Accelerometer calibration provides, with a definable degree of accuracy, the necessary link between the physical quantity being measured and the electrical signal generated by the sensor. In addition, other useful information concerning operational limits, physical parameters, electrical characteristics, or environmental influences may also be determined. Without this link, analyzing data becomes a nearly impossible task. PCB provides a calibration record that documents the exact characteristics of each sensor. (The type and amount of data varies depending on the sensor type, contractual regulations, and other special requirements.)

Under normal operating conditions, piezoelectric sensors are extremely stable, and their calibrated performance characteristics do not change over time. However, harsh environments or other unusual conditions that cause the sensor to experience dynamic phenomena outside of its specified operating range may temporarily or permanently affect the sensor. This change manifests itself in a variety of ways, including a shift of the sensor resonance due to a cracked crystal, or a temporary loss of low-frequency measuring capability due to a drop in insulation resistance.

For these reasons, it is recommended that a recalibration cycle be established for each accelerometer. This schedule is unique and is based on a variety of factors, such as extent of use, environmental conditions, accuracy requirements, trend information obtained from previous calibration records, contractual regulations, frequency of “cross-checking” against other equipment, manufacturer recommendation, and any risk associated with incorrect readings. International standards, such as ISO 10012-1, provide insight and suggested methods for determining recalibration intervals for most measuring equipment. With the above information in mind and under “normal” circumstances, PCB conservatively

suggests a 12- to 24-month recalibration cycle for most piezoelectric accelerometers.

**Note:** *It is good measurement practice to verify the performance of each accelerometer with a Handheld Shaker or other calibration device before and after each measurement. The PCB Model 394C06 Handheld Shaker operates at a fixed frequency and known amplitude (1.0 g) to provide a quick check of sensor sensitivity.*

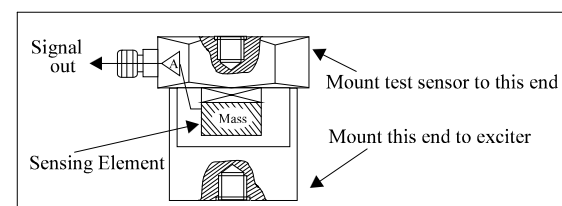
### 6.1.1 SENSOR RECALIBRATION

Accelerometer recalibration services are typically performed by PCB's internal metrology laboratory. (Other international and private laboratories are also available.) The PCB laboratory is certified to ISO 9001, accredited by A2LA to ISO 17025, complies with ISO 10012-1 (and former MIL-STD-45662A), and uses equipment directly traceable to N.I.S.T. This assures an accurate calibration of relevant specifications.

In addition, many companies choose to purchase the equipment necessary to perform the recalibration procedure themselves. While this may result in both a savings of time and money, it has also been attributed to incorrect readings and costly errors. Therefore, in an effort to prevent the common mistakes associated with customer-performed calibration, this document includes a broad overview of the Back-to-Back Calibration technique. This technique provides a quick and easy method for determining the sensitivity of a test accelerometer over a wide frequency range.

### 6.1.2 BACK-TO-BACK CALIBRATION THEORY

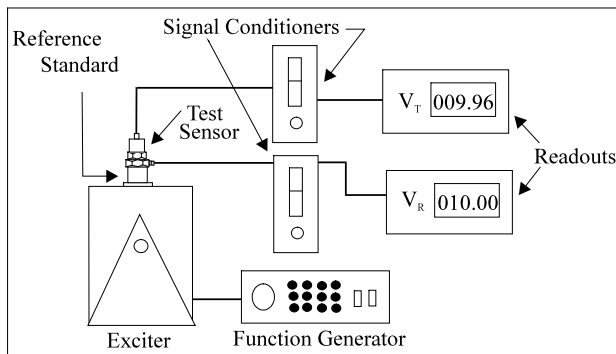
Back-to-Back Calibration is perhaps the most common method for determining the sensitivity of piezoelectric accelerometers. This method relies on a simple comparison to a previously calibrated accelerometer, typically referred to as a reference standard.





**Figure 1. Reference Standard Accelerometer**

These high-accuracy devices, which are directly traceable to a recognized standards laboratory, are designed for stability, as well as configured to accept a test accelerometer. By mounting a test accelerometer to the reference standard and then connecting this combination to a suitable vibration source, it is possible to vibrate both devices and compare the data as shown in Figure 2. (Test setups may be automated and vary, depending on the type and number of accelerometers being calibrated.)

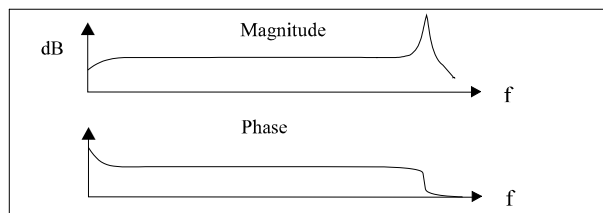


**Figure 2. Typical Back-to-Back Calibration System**

Because the acceleration is the same on both sensors, the ratio of their outputs ( $V_T/V_R$ ) must also be the ratio of their sensitivities. With the sensitivity of the reference standard ( $S_R$ ) known, the exact sensitivity of the test sensor ( $S_T$ ) is easily calculated by using the following equation:

$$S_T = S_R (V_T/V_R)$$

By varying the frequency of the vibration, the sensor may be calibrated over its entire operating frequency range. The typical response of an unfiltered accelerometer is shown in Figure 3.



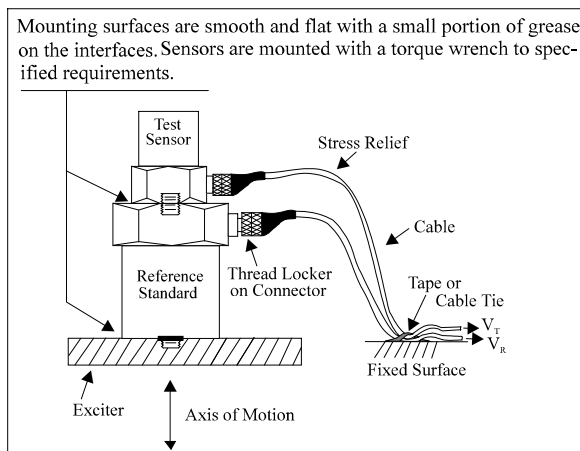
**Figure 3. Typical Test Accelerometer Response**

### 6.1.3 PCB CALIBRATION PROCEDURE

Numerous precautions are taken at PCB to insure accurate and repeatable results. This section provides a brief overview of the primary areas of concern.

Since the Back-to-Back Calibration technique relies on each sensor experiencing an identical acceleration level, proper mounting of the test sensor to the reference standard is imperative. Sensors with mounting holes are attached directly to the reference standard with a stud tightened to the recommended mounting torque. A shouldered mounting stud is typically used to prevent the stud from “bottoming out” in the hole.

Both mounting surfaces are precision-machined and lapped to provide a smooth, flat interface according to the manufacturer's specification. A thin layer of silicone grease is placed between the mating surfaces to fill any imperfections and increase the mounting stiffness. The cables are stress-relieved by first routing them to the shaker head, securing them with tape or cable ties, then routing them to a nearby stationary location. This reduces cable motion, which is especially important when testing charge output sensors and helps to prevent extraneous noise or stresses from being imparted into the system. A typical set-up is shown in Figure 4.



**Figure 4.** Typical Calibration Set-Up

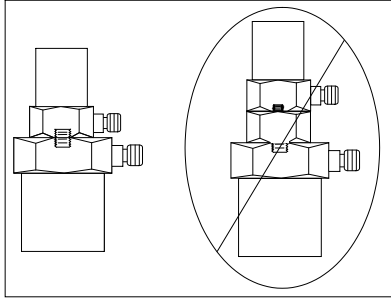
Adhesively mounted sensors use similar practices. However, in this case, a small portion of quick-bonding gel or similar temporary adhesive is used to attach the test sensor to a reference surface designed with a smooth, flat mounting surface.

In addition to mounting, the selection of the proper equipment is critical. Some of the more important considerations include: 1) the reference standard must be specified and previously calibrated over the frequency and/or amplitude range of interest; 2) the shaker should be selected to provide minimal transverse (lateral) motion and minimal distortion; and 3) the quality of the meters, signal generator, and other devices should be selected so as to operate within the limits of permissible error.

### 7.4 COMMON MISTAKES

Most calibration errors are caused by simply overlooking some of the fundamental principals of dynamics. This section attempts to address some of the more common concerns.

For stud-mount sensors, always mount the accelerometer directly to the reference standard. Ensure that the mounting surfaces are smooth, flat, and free of any burrs. Always use a coupling fluid, such as silicone grease, in the mounting interface to maintain a high mounting stiffness. Mount the sensor according to the manufacturer's recommended mounting torque. **DO NOT** use any intermediate mounting adaptors, as the mounted resonant frequency may be reduced and thereby compromise the high-frequency performance. If necessary, use adaptor studs.



**Figure 5.** Stud Mounting

Understand Back-to-Back Calibration limitations. Do not expect the uncertainty of calibration to be any better than  $\pm 2\%$ . (In fact, the uncertainty may

be as high as  $\pm 3\%$  or  $\pm 4\%$  for frequencies  $< 10$  Hz or  $> 2$  kHz.) Since large sensors may affect high-frequency accuracy, verify that the test sensor does not mass load the reference standard. Validate your calibration system with another accelerometer prior to each calibration session. Check with the manufacturer for exact system specifications.

## 7.5 CONCLUSIONS

Without an adequate understanding of dynamics, determining what, when, and how to test a sensor is a difficult task. Therefore, each user must weigh the cost, time, and risk associated with self-calibration versus the services of an accredited laboratory.


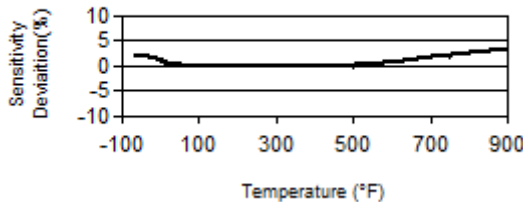



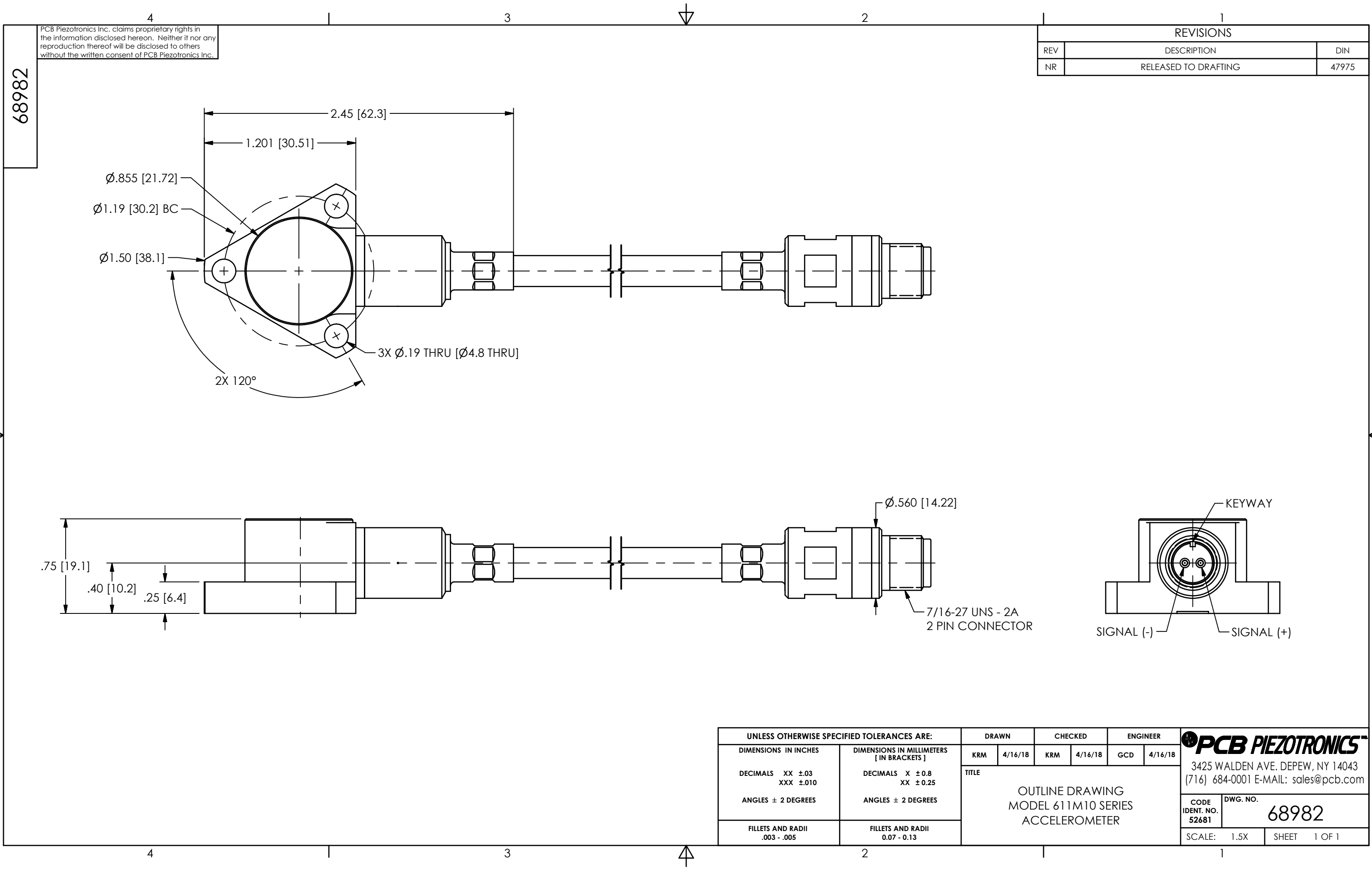
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Depew, NY 14043

Model Number <b>611M10</b>	<b>CHARGE OUTPUT ACCELEROMETER</b>			Revision: A ECN #: 49030		
<b>Performance</b>	<b>ENGLISH</b>	<b>SI</b>	<b>OPTIONAL VERSIONS</b>			
Sensitivity(± 5 %)	5.0 pC/g	.510 pC/(m/s²)	Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used.			
Measurement Range	± 500 g pk	± 4905 m/s² pk				
Frequency Range(+10 %)	5 kHz	5 kHz				
Resonant Frequency	20 kHz	20 kHz				
Non-Linearity	≤ 1 %	≤ 1 %				
Transverse Sensitivity	≤ 5 %	≤ 5 %	<b>NOTES:</b> [1] Typical. [2] Low frequency response is determined by external signal conditioning electronics. [3] Zero-based, least-squares, straight line method. [4] Transverse sensitivity is typically ≤ 3%. [5] See PCB Declaration of Conformance PS158 for details.			
<b>Environmental</b>						
Overload Limit(Shock)	± 1000 g pk	± 9810 m/s² pk				
Temperature Range	-65 to +900 °F	-54 to +482 °C				
Temperature Response	See Graph	See Graph				
<b>Electrical</b>						
Capacitance(Pin to Pin)	240 pF	240 pF				
Capacitance(Pin to Case)	210 pF	210 pF				
Capacitance(Unbalance Between Pins)	≤ 2 pF	≤ 2 pF				
Insulation Resistance(Pin to Case 70°F)	>10 <sup>9</sup> Ohm	>10 <sup>9</sup> Ohm				
Insulation Resistance(Pin to Pin 70°F)	>10 <sup>9</sup> Ohm	>10 <sup>9</sup> Ohm				
Insulation Resistance(Pin to Pin 900°F)	>100 kohm	>100 kohm				
<b>Physical</b>						
Sensing Element	UHT-12	UHT-12				
Sensing Geometry	Shear	Shear				
Housing Material	Inconel	Inconel				
Sealing	Hermetic	Hermetic				
Size (Height x Diameter)	0.75 in x 1.5 in	19 mm x 38.1 mm				
Weight(with cable)	14.22 oz	403.1 gm				
Electrical Connector	7/16-27 2-Pin	7/16-27 2-Pin				
Electrical Connection Position	Side	Side				
Cable Length	10 ft	3.05 m				
Cable Type	Integral Hardline Cable	Integral Hardline Cable				
Mounting	Through Holes (3)	Through Holes (3)	<b>SUPPLIED ACCESSORIES:</b> Model 081A99 Cap Screw (3) Model ICS-8 NIST-traceable single-axis amplitude response calibration from 600 cpm (10Hz) to upper 10% frequency.			
<div><p>[5]</p></div>						
Typical Sensitivity Deviation vs Temperature						
						
All specifications are at room temperature unless otherwise specified. In the interest of constant product improvement, we reserve the right to change specifications without notice. ICP® is a registered trademark of PCB Group, Inc.						
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DIMENSIONS IN INCHES	DIMENSIONS IN MILLIMETERS [ IN BRACKETS ]	KRM	4/16/18	KRM	4/16/18	GCD	4/16/18		
DECIMALS XX ±.03 XXX ±.010	DECIMALS X ± 0.8 XX ± 0.25	TITLE  OUTLINE DRAWING MODEL 611M10 SERIES ACCELEROMETER							
ANGLES ± 2 DEGREES	ANGLES ± 2 DEGREES								
FILLETS AND RADII .003 - .005	FILLETS AND RADII 0.07 - 0.13							<div>CODE IDENT. NO. 52681</div> <div>DWG. NO.  68982</div>	
								SCALE: 1.5X	SHEET 1 OF 1