



Model 3701D3FA20G
Capacitive Accelerometer
Installation and Operating Manual

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

Toll-free: 800-828-8840
24-hour SensorLine: 716-684-0001
Fax: 716-684-0987
E-mail: info@pcb.com
Web: www.pcb.com



The information contained in this document supersedes all similar information that may be found elsewhere in this manual.

Total Customer Satisfaction – PCB Piezotronics guarantees Total Customer Satisfaction. If, at any time, for any reason, you are not completely satisfied with any PCB product, PCB will repair, replace, or exchange it at no charge. You may also choose to have your purchase price refunded in lieu of the repair, replacement, or exchange of the product.

Service – Due to the sophisticated nature of the sensors and associated instrumentation provided by PCB Piezotronics, user servicing or repair is not recommended and, if attempted, may void the factory warranty. Routine maintenance, such as the cleaning of electrical connectors, housings, and mounting surfaces with solutions and techniques that will not harm the physical material of construction, is acceptable. Caution should be observed to insure that liquids are not permitted to migrate into devices that are not hermetically sealed. Such devices should only be wiped with a dampened cloth and never submerged or have liquids poured upon them.

Repair – In the event that equipment becomes damaged or ceases to operate, arrangements should be made to return the equipment to PCB Piezotronics for repair. User servicing or repair is not recommended and, if attempted, may void the factory warranty.

Calibration – Routine calibration of sensors and associated instrumentation is

recommended as this helps build confidence in measurement accuracy and acquired data. Equipment calibration cycles are typically established by the users own quality regimen. When in doubt about a calibration cycle, a good “rule of thumb” is to recalibrate on an annual basis. It is also good practice to recalibrate after exposure to any severe temperature extreme, shock, load, or other environmental influence, or prior to any critical test.

PCB Piezotronics maintains an ISO-9001 certified metrology laboratory and offers calibration services, which are accredited by A2LA to ISO/IEC 17025, with full traceability to N.I.S.T. In addition to the normally supplied calibration, special testing is also available, such as: sensitivity at elevated or cryogenic temperatures, phase response, extended high or low frequency response, extended range, leak testing, hydrostatic pressure testing, and others. For information on standard recalibration services or special testing, contact your local PCB Piezotronics distributor, sales representative, or factory customer service representative.

Returning Equipment – *Following these procedures will insure that your returned materials are handled in the most expedient manner.* Before returning any equipment to PCB Piezotronics, contact your local distributor, sales representative, or factory customer service representative to obtain a Return

Materials Authorization (RMA) Number. This RMA number should be clearly marked on the outside of all package(s) and on the packing list(s) accompanying the shipment. A detailed account of the nature of the problem(s) being experienced with the equipment should also be included inside the package(s) containing any returned materials.

A Purchase Order, included with the returned materials, will expedite the turn-around of serviced equipment. It is recommended to include authorization on the Purchase Order for PCB to proceed with any repairs, as long as they do not exceed 50% of the replacement cost of the returned item(s). PCB will provide a price quotation or replacement recommendation for any item whose repair costs would exceed 50% of replacement cost, or any item that is not economically feasible to repair. For routine calibration services, the Purchase Order should include authorization to proceed and return at current pricing, which can be obtained from a factory customer service representative.

Warranty – All equipment and repair services provided by PCB Piezotronics, Inc. are covered by a limited warranty against defective material and workmanship for a period of one year from date of original purchase. Contact

PCB for a complete statement of our warranty. Expendable items, such as batteries and mounting hardware, are not covered by warranty. Mechanical damage to equipment due to improper use is not covered by warranty. Electronic circuitry failure caused by the introduction of unregulated or improper excitation power or electrostatic discharge is not covered by warranty.

Contact Information – International customers should direct all inquiries to their local distributor or sales office. A complete list of distributors and offices can be found at www.pcb.com. Customers within the United States may contact their local sales representative or a factory customer service representative. A complete list of sales representatives can be found at www.pcb.com. Toll-free telephone numbers for a factory customer service representative, in the division responsible for this product, can be found on the title page at the front of this manual. Our ship to address and general contact numbers are:

PCB Piezotronics, Inc.
3425 Walden Ave.
Depew, NY 14043 USA
Toll-free: (800) 828-8840
24-hour SensorLineSM: (716) 684-0001
Website: www.pcb.com
E-mail: info@pcb.com

1.0 Introduction

This operating guide contains information that will familiarize the user with the basic operation and installation of Series 3700 Variable Capacitance Accelerometers. However, it is not intended to cover all of the specific measurement challenges that one may encounter while using the device. Therefore, if you have detailed questions or are unsure of how to properly operate the sensor after reading this “Operating Guide”, please contact a PCB Application Engineer using our 24-Hour SensorLine™ at 716-684-0001.

2.0 Common Applications and Features

Series 3700 Variable Capacitance Accelerometers achieve true DC response for measuring uniform (or constant) acceleration and low-frequency vibration. For this reason, they are often used to:

- Perform ride quality assessments of elevators, automobiles, trains, and amusement park rides.
- Analyze the low frequency characteristics of buildings, bridges, and large aerospace objects.
- Acquire tilt and orientation data for feedback control and stabilization purposes.

Because of the critical nature of these and similar test applications, all Series 3700 Variable Capacitance Accelerometers have been designed and manufactured with following common characteristics:

- Rugged, all-welded titanium housing insures reliability and durability in demanding applications and environments.
- Built-in microelectronics provide conveniently standardized sensitivities and low-noise output signals unmatched by similar sensing technologies.
- Internal voltage regulator allows sensor to be powered from virtually any unregulated DC voltage source, such as a bench-top power supply or portable battery source.

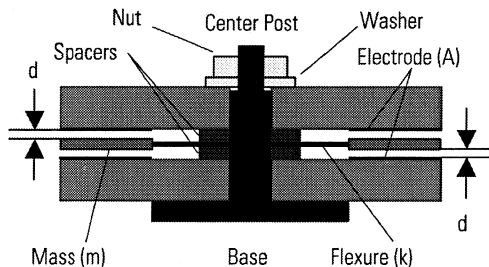


Figure 1a: Sensing Element in “0 g” Condition

- Natural air damping extends the upper frequency range, attenuates unwanted high-frequency vibration, and provides stable performance over the entire operating temperature range.
- Integral ground isolation plate electrically isolates sensor ground from test structure ground thereby minimizing the chances of ground loop noise.
- Hermetic, multi-pin connector or optional sealed, integral cable provides a reliable connection even under the harshest environmental conditions.

3.0 Principle of Operation

In the simplest sense, variable capacitance accelerometers operate on a technique where the capacitance of the internal sensing element changes in proportion to the applied acceleration.

In Series 3700 Variable Capacitance Accelerometers, the sensing mechanism consists of a “washer-shaped,” seismic mass (m) suspended by a proprietary flexure with stiffness (k). This assembly is sandwiched between two circular plates with an electrode area (A), whose distance (d) is closely controlled with precision chemically etched spacers. The resulting air-gap between each electrode and the sensing flexure forms a “mechanical capacitor”. A cross-sectional drawing of this sensing element under a “0 g” condition is depicted in Figure 1a. Figure 1b depicts a “+1 g” condition as may be experienced by the sensor as it rests in the Earth’s Gravitational Field.

As shown in Figure 1b, when the element is accelerated (a), an inertial force (F) is created on the mass (m) according to Newton’s Second Law of Motion.

$$F = ma \tag{Eq. 1}$$

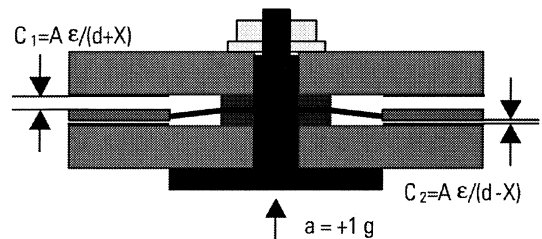


Figure 1b: Sensing Element in “+1g” Condition

This force causes the mass to move a certain distance (X) closer to the lower electrode and the same distance (X) further from the upper electrode. This distance depends on the flexure stiffness (k) and is based on the simple Spring Equation (Hooke's Law).

$$X = F/k \tag{Eq. 2}$$

The change in distance correspondingly changes the capacitance (C).

$$C_1 = (A\epsilon)/(d+X) \tag{Eq. 3}$$

$$C_2 = (A\epsilon)/(d-X) \tag{Eq. 4}$$

where, A= Electrode Area
 ϵ = Permittivity of Air
 d = Distance between Mass and Electrode
 X = Displacement of Mass

The built-in microelectronics contains a capacitive bridge circuit that converts this change in capacitance to a useful voltage signal. A simplified schematic of the circuit is shown in Figure 2a. The theoretical response from the +1g acceleration shown in Figure 1b is depicted by the time traces shown in Figure 2b. The numbers 1 through 8 on Figure 2b correspond to the signals at locations 1 through 8 on Figure 2a. For example, if the signal from location 2 were viewed on an oscilloscope, it would look like the signal shown in graph 2 of Figure 2b.

Power to the circuit is in the form of a simple DC voltage. This voltage can be derived from laboratory power supplies, automotive or marine batteries, or other portable power sources. Initially, the power is passed through a voltage regulator. This regulator ensures clean power to microelectronics and fixes the amplitude of the subsequent oscillator chip. (The output voltage from the regulator (V_r) is dependent on which power supply voltage range has been ordered.) By fixing the amplitude of the oscillator output as seen at Location 1 the sensitivity of the accelerometer becomes independent of the supply voltage. This is often advantageous as precise calibration of the power supply is generally not required.

Next, the oscillator output is directed into the capacitance-bridge, where the signal "splits" and travels into each arm of the bridge. Each arm acts as a capacitor divider. The resulting amplitude of the amplitude-modulated signal at Locations 2 and 3 is directly proportional to the changes in capacitance experienced by the sensing element.

$$V_2 = V_r * (1/C_3) / [(1/C_3) + (1/C_1)] \tag{Eq. 5}$$

$$V_3 = V_r * (1/C_4) / [(1/C_4) + (1/C_2)] \tag{Eq. 6}$$

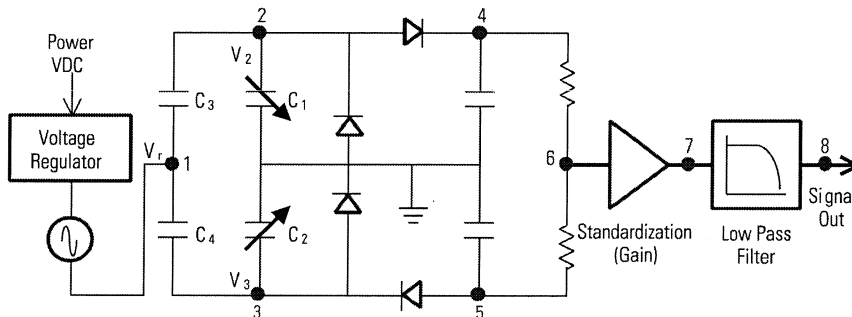


Figure 2a Circuit Schematic

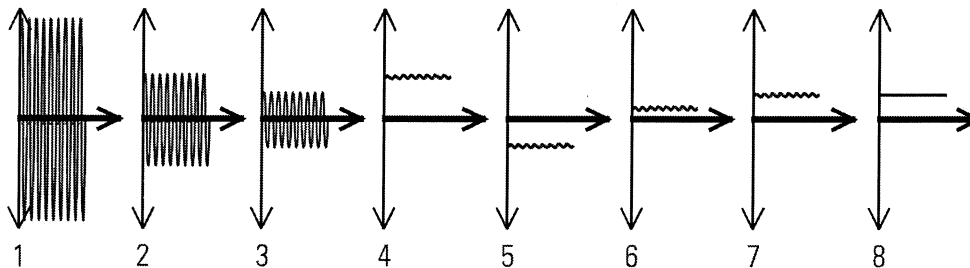


Figure 2b: Response from Circuit from +1g Static Acceleration (x-axis = time and y-axis = voltage)

To demodulate these signals, the signals are passed through a series of diodes and capacitors at Locations 4 and 5. The signals are then summed together at Location 6. At this point, the electrical signal is proportional to the input acceleration.

It would be sufficient to complete the circuit at this point, however, a couple additional features are included to enhance the performance of the sensor. First is the addition of a “standardization” amplifier. This is used to “trim” the range of the sensor to a convenient number such 3g, 20g, 50g or 200g. For example, the amplifier in Figure 2a is used to gain the signal by a factor of 2. In other words, the voltage at Location 7 is twice as large as it is at Location 6. Second, a low-pass electrical filter is used to reduce unwanted signals from high frequency vibration and eliminate any residual affects of the oscillator frequency.

4.0 Typical Measurement System

Typical measurement systems, like the ones shown in Figure 3a and 3b, consist of a sensor, cable, power supply, and readout device. (The readout device, which may be an oscilloscope, analyzer or tape recorder, is not supplied or offered by PCB.)

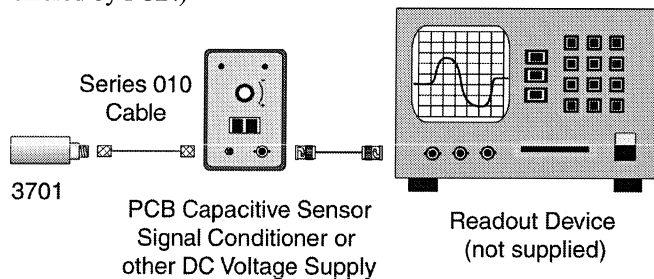


Figure 3a: Series 3701 Single Axis Typical System

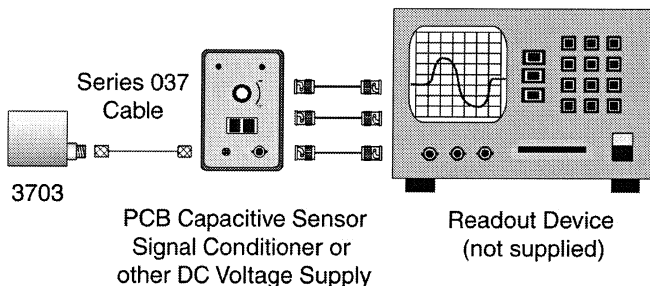


Figure 3b: Series 3703 Triaxial Typical System

5.0 Sensor Installation

When choosing an installation technique, be certain to carefully examine the different application characteristics that may affect sensor performance. Characteristics such as mounting location may limit the use of large mounting blocks or the amplitude range may necessitate the use of a stud mount

rather than using adhesive. A summary of the recommended mounting methods is provided below.

Stud Mount: Recommended for permanent mount applications or in test situations that require a rugged or secure installation. The necessary information, including surface finish, mounting hole dimensions, and recommended mounting torque for installing the sensor is listed on the enclosed Sensor Installation Drawing. It is recommended that an experienced technician or machinist with good machining capabilities adequately prepare the surface.

Adhesive Mount: Recommended for temporary mounting of the sensor or when the test object surface cannot be properly prepared for stud mounting. Wax works well for temporary mount applications under conditions where the operating temperature will not melt the wax or the acceleration levels will not dislodge the sensor from the test object. Cyanoacrylate-based, “quick-bonding” adhesives provide a quick mounting method, while two-part epoxies can be used for a more secure mount. To remove an adhesively mounted sensor, it is best to place an open-ended wrench over the sensor and twist it to shear the adhesive bond. Striking the sensor with a hammer or other object may permanently damage the sensor.

Easy Mount Clip: Recommended when frequent installation and removal of Series 3701 Variable Capacitance Accelerometers is desired. The Easy-Mount Clip can either be stud mounted or adhesively mounted to the test structure. (If adhesively mounting the clip, detach the sensor from the clip while adhering it to the test structure as excessive adhesive may creep through the mounting holes and adhere to the sensor. This will make separation and removal from the clip difficult.) Once the Easy-Mount Clip has been attached to the test structure, the sensor can be easily snapped into and out of the clip. Over time, the Easy-Mount Clip must be replaced as it will “wear-out” and eventually lose its ability to securely hold the sensor.

6.0 Powering

Series 3700 Variable Capacitance Accelerometers contain built-in microelectronics that will operate from any PCB Series 445 or Series 478 Capacitive Sensor Signal Conditioner. These signal conditioners provide the necessary voltage and current required for all of the powering options available on the Series 3700 Variable Capacitance Accelerometers.

Series 3700 Variable Capacitance Accelerometers may also be powered by other voltage sources such as DC voltage laboratory supplies, automotive or marine batteries, or low-voltage supplies designed for powering PC Board components. If you decide to not use a Series 445 or Series 478 Signal Conditioner, insure that the source provides power within the excitation voltage range listed on the specification sheet for

that model. It is important to note that since the accelerometers contain a built-in voltage regulator, precise calibration of the power source is generally not required.

7.0 Operation

After the sensor has been installed and the cable connected for proper operation, there are a few measurement points to take note of:

- a) After providing power to the sensor, it may be used immediately for taking measurements above 0.1 Hz. However, the sensor requires approximately 15 minutes to fully stabilize for tilt measurements requiring absolute DC response.
- b) To take advantage of the DC response of the accelerometer, the readout device must be in a DC coupled state. Consult the appropriate manufacturer or product manual for your readout device for details.
- c) Because Series 3700 Variable Capacitance Accelerometer can measure static (constant) accelerations, the DC offset voltage will be affected by the positional alignment relative to the Earth's gravity. In other words, when the sensor is mounted perpendicular with the Earth's surface, the offset will equal that as specified on the calibration certificate for "zero-g offset voltage." If the sensor is mounted parallel with the Earth's surface, the sensor will be experiencing 1 g of acceleration and the offset voltage will increase by the sensitivity of the accelerometer.

8.0 Sensor Verification

If the sensor has been handled in a rough manner or before a critical measurement application, it is a good idea to verify that the sensor's sensitivity is still within specification. An accurate static calibration of Series 3700 Variable Capacitance Accelerometers can be performed using the Earth's Gravitational Field as a reference. The sensor can simply be "flipped" (rotated 90°) in the Earth's Gravity to obtain the scaling factor (sensitivity). First, place the accelerometer on its side with its sensing axis perpendicular to the Earth's Gravity (i.e., on a level table). The output from the sensor in this position is known the "zero-g offset" voltage. Then, rotate sensor 90° so that the base rests on the table parallel with the Earth's gravity. The sensor is now experiencing +1g acceleration. Subtract the "zero-g offset" voltage from this output voltage. This value is the sensitivity of the sensor.

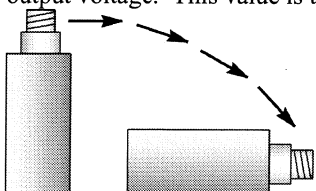


Figure 4: Sensor Verification using flip test

9.0 Sensor Calibration

Due to ISO 9001, ISO Guide 25, or other contractual requirements, it may become necessary to send the accelerometer back to PCB for recalibration. In this case, a complete back-to-back frequency response test will be performed and the "zero-g" offset voltage will be checked with NIST traceable equipment.

10.0 Maintenance and Repair

Because of the sophisticated nature of PCB instrumentation, field repair of the equipment is not recommended. Most PCB sensors are of modular construction and are factory repairable. A repair or replacement quotation is available at no charge. Before returning equipment for repair, it is recommended that the user confer with a factory application engineer (or international representative) to first troubleshoot the problem.

11.0 Return Procedure

To expedite the repair process, contact a factory application engineer to obtain a Return Material Authorization (RMA) number prior to sending equipment to the factory. Please have information, such as model number, serial number and description of the problem, available.

Customers outside the U.S. should consult their local PCB distributor for information on returning equipment. For exceptions to this guideline, please contact the International Sales department to request shipping instructions and an RMA.

For further assistance, please call (716) 684-0001 or fax us at (716) 684-0987. You may also receive assistance via e-mail at sales@pcb.com or visit our web site at www.pcb.com.

12.0 Customer Service / Warranty

The employees of PCB strive to provide superior, unmatched customer service. Should you at any time find yourself dissatisfied with any PCB product for any reason, consult a factory Application Engineer or local representative/distributor to discuss repair, refund, or exchange procedures.

When unexpected measurement problems arise, call our 24-hour Sensor Line to discuss your immediate instrumentation needs with a Factory Representative. Dial (716) 684-0001.

Manual Number: 18542
Manual Revision: A

Model Number
3701D3FA20G

CAPACITIVE ACCELEROMETER

Revision: S
ECN #: 28981

ENGLISH

SI

Performance		
Sensitivity(± 5 %)	10.2 mV/(m/s ²)	[4]
Measurement Range	± 20 g pk	
Frequency Range(± 5 %)	0 to 300 Hz	
Frequency Range(± 10 %)	0 to 500 Hz	
Resonant Frequency	>900 Hz	
Phase Response(100 Hz)	<10 °	
Damping Ratio	0.70	[2]
Broadband Resolution(0.5 to 100 Hz)	80 µg rms	[2]
Non-Linearity	≤ 1 %	[5]
Transverse Sensitivity	≤ 3 %	[6]
Environmental		
Overload Limit(Shock)	± 3000 g pk	
Temperature Range(Operating)	-40 to +185 °F	
Temperature Range(Storage)	-85 to +250 °F	
Temperature Coefficient of Sensitivity	± 0.07 %/°F	[3]
Zero g Offset Temperature Coefficient	≤ 0.010 g/°F	[3]
Base Strain Sensitivity	0.0001 g/µε	[2]
Magnetic Sensitivity	65 equiv. µg/gauss	[2]
Electrical		
Excitation Voltage	16 to 30 VDC	
Current Consumption	≤ 10 mA	
Output Impedance	≤ 75 ohm	
Offset Voltage(0 g)	± 40 mVDC	
Spectral Noise(1 Hz)	35 µg/√Hz	[1]
Spectral Noise(10 Hz)	10 µg/√Hz	[2]
Spectral Noise(100 Hz)	5 µg/√Hz	[2]
Electrical Isolation(Base)	>10 ⁸ ohm	
Physical		
Housing Material	Titanium	
Sealing	Hermetic	
Size (Height x Length x Width)	0.45 in x 0.85 in x 0.85 in	
Weight	.62 oz	
Electrical Connector	4-Pin	
Electrical Connection Position	Side	
Mounting	Through Hole	



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.

Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used.

HT - High temperature, extends normal operation temperatures
Temperature Range(Operating) -40 to +250 °F -40 to +121 °C

NOTES:

- [1] Offset tolerance is based on 10 Ft of 010 test cable.
- [2] Typical.
- [3] Valid from 70°F to 185°F [21°C to 85°C]
- [4] Measured at 100 Hz, 1 grms.
- [5] Zero-based, least-squares, straight line method.
- [6] Transverse sensitivity is typically ≤ 1 %
- [7] See PCB Declaration of Conformance PS027 for details.

SUPPLIED ACCESSORIES:

- Model 080A152 Easy Mount Clip (1)
- Model 081B64 off ground screw assembly (2)
- Model ACS-11 NIST traceable amplitude and phase response from 0.5 Hz to upper 5% frequency (1)
- Model M081B64 off ground screw assembly (2)

Entered: <i>BLS</i>	Engineer: <i>AF</i>	Sales: <i>MDC</i>	Approved: <i>LAB</i>	Spec Number:
Date: <i>6/23/08</i>	Date: <i>6/26/08</i>	Date: <i>6/20/08</i>	Date: <i>6/20/08</i>	6637



3425 Walden Avenue, Depew, NY 14043

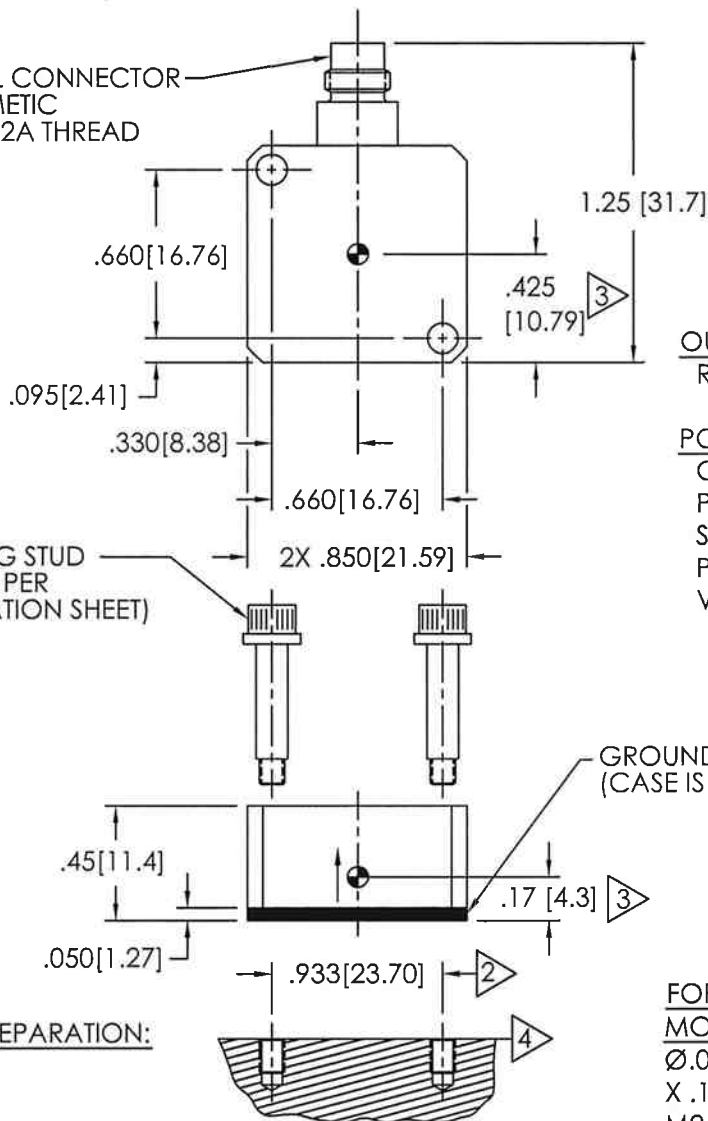
Phone: 716-684-0001
Fax: 716-685-3886
E-Mail: vibration@pcb.com

5635

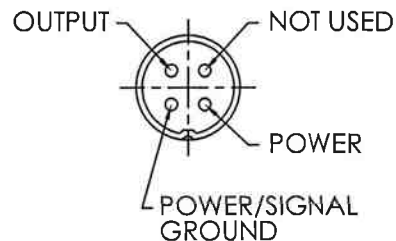
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REVISIONS			
REV	DESCRIPTION	ECN	APP'D
K	UPDATED NOTES	26484	KEN L
L	UPDATE MOUNTING STUD CALLOUT	29364	

ELECTRICAL CONNECTOR
4 PIN, HERMETIC
1/4-28 UNF-2A THREAD



FRONT VIEW OF CONNECTOR



OUTPUT SIGNAL:
REFERENCE TO GROUND.

POWER:
CONNECT TO DC VOLTAGE
POWER SUPPLY. SEE
SPECIFICATION SHEET FOR
PROPER EXCITATION
VOLTAGE.

1 MOUNTING STUD
(SUPPLIED PER
SPECIFICATION SHEET)

GROUND ISOLATION BASE
(CASE IS POWER/SIGNAL GROUND)

FOR "M" OPTION
MOUNTING HOLE PREPARATION:
Ø.081 [2.05]
X .180 [4.57] ∇ MIN
M2.5 X .45-6H
X .130 [3.30] ∇ MIN

MOUNTING HOLE PREPARATION:
Ø.089 [2.26]
X .180 [4.57] ∇ MIN
4-40 UNC-2B
X .130 [3.30] ∇ MIN

5.) SEE SHEET 2 OF 2 FOR CABLE STRAIN RELIEF INFORMATION.

4 RECOMMENDED MOUNTING SURFACE SHOULD BE FLAT TO WITHIN .003 [.08] TIR OVER
Ø.375 [9.52] WITH A 32/ [.08] FINISH FOR BEST RESULTS.

3 CG-CENTER OF SIESMIC MEASUREMENT

2 DIAGONAL MOUNTING DIMENSION BETWEEN HOLES.

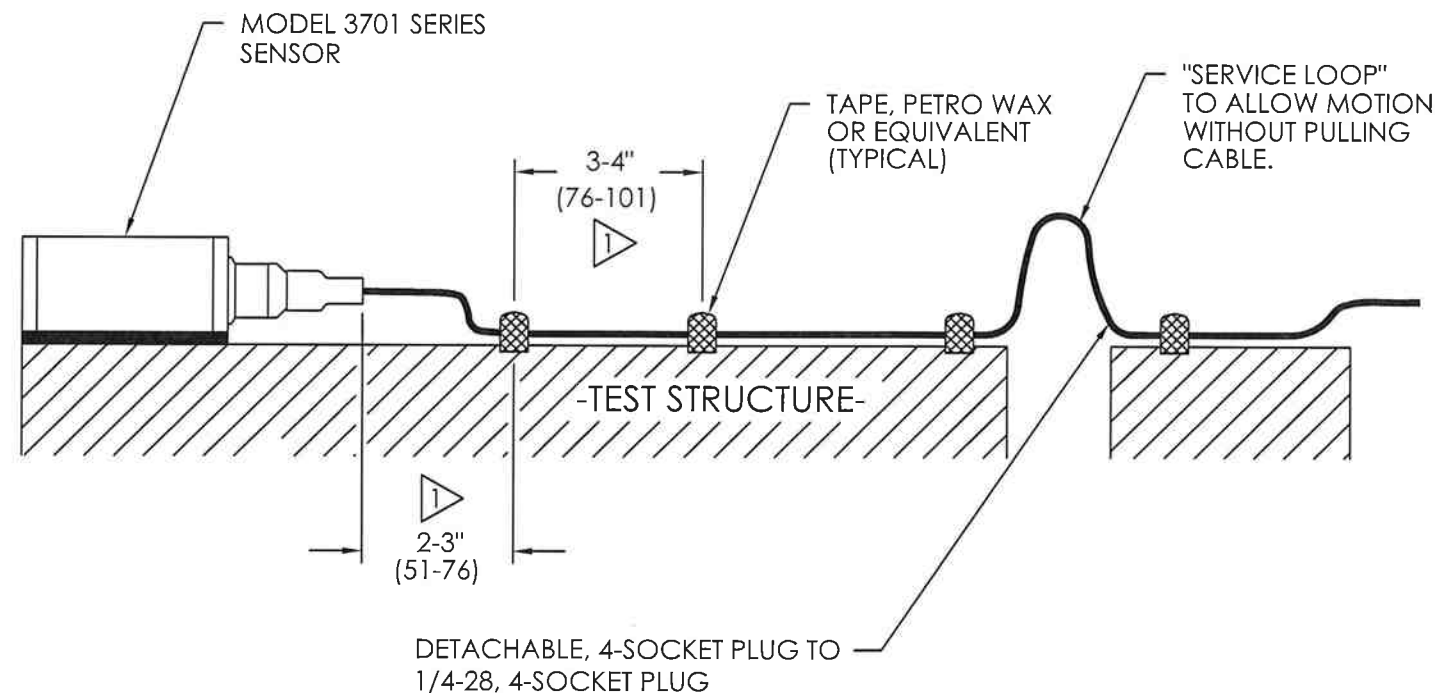
1 RECOMMENDED MOUNTING TORQUE ON CAP SCREW, 4-5 IN-LBS [45-55 N-CM].

UNLESS SPECIFIED TOLERANCES		DRAWN	MDF	1/16/09	MFG	BAS	1/16/09	 3425 WALDEN AVE. DEPEW, NY 14043 (716) 684-0001 EMAIL: SALES@PCB.COM	
DIMENSIONS IN INCHES	DIMENSIONS IN MILLIMETERS [IN BRACKETS]	CHK'D	ECB	1/21/09	ENGR	TCJ	1/16/09		
DECIMALS XX ±.03 XXX ±.010	DECIMALS X ±0.8 XX ±0.25	APP'D	EB	1/16/09	SALES	RL	1/16/09		
ANGLES ±2 DEGREES	ANGLES ±2 DEGREES	TITLE							CODE IDENT. NO. 52681
FILLETS AND RADII .003 - .005	FILLETS AND RADII [0.07 - 0.13]	INSTALLATION DRAWING MODEL 3701 SERIES DC ACCELEROMETER						DWG. NO. 5635	
DD011 REV. D 01/17/08								SCALE: 1.33X	SHEET 1 OF 2

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REVISIONS			
REV	DESCRIPTION	ECN	APP'D
- SEE SHEET ONE -			

5635



FASTEN CABLE TO TEST STRUCTURE TYPICALLY WITHIN 2-3"(51-76) OF SENSOR. THEN FASTEN AGAIN WITHIN 3-4"(76-101) OF PREVIOUS ATTACHMENT. BETWEEN THE TEST STRUCTURE AND A FIXED STRUCTURE, ALLOW A SERVICE LOOP LARGE ENOUGH TO PREVENT PULLING OF THE CABLE WHEN SHAKING. MORE ATTACHMENT POINTS WILL PROVIDE LESS NOISE IN THE RESULTING DATA. LOOSE CABLES OR PARTS ELSEWHERE ON THE TEST STRUCTURE CAN ALSO GENERATE "NOISE" ON THE SIGNAL RECEIVED FROM THE MODEL 3701 SERIES.

UNLESS SPECIFIED TOLERANCES		DRAWN	MDF	1/16/09	MFG	BAS	1/16/09	 <small>3425 WALDEN AVE., DEPEW, NY 14043</small> <small>(716) 684-0001 EMAIL: SALES@PCB.COM</small>
DIMENSIONS IN INCHES	DIMENSIONS IN MILLIMETERS (IN BRACKETS)	CHK'D	ECB	1/21/09	ENGR	TCJ	1/16/09	
DECIMALS XX ±.03 XXX ±.010	DECIMALS X ±0.8 XX ±0.25	APP'D	EB	1/16/09	SALES	RL	1/16/09	DWG. NO.
ANGLES ±2 DEGREES	ANGLES ±2 DEGREES	TITLE INSTALLATION DRAWING MODEL 3701 SERIES DC ACCELEROMETER						5635
FILLETS AND RADII .003 - .005	FILLETS AND RADII [0.07 - 0.13]							SCALE: 1.25X
DD012 REV. D 01/17/08								SHEET 2 OF 2