VIBRATION DIVISION

Series 3800

Capacitive Accelerometer

Installation and Operating Manual

18543

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

Vibration Division toll-free 888-684-0013
24-hour SensorLine™ 716-684-0001
Fax 716-685-3886
E-mail vibration@pcb.com

PCB PIEZOTRONICS INC
VIBRATION DIVISION

1.0 Introduction

This operating guide contains information that will familiarize the user with the basic operation and installation of Series 3800 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 3800 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 3800 Variable Capacitance Accelerometers have been designed and manufactured with following common characteristics:

- 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 uncalibrated DC voltage source, such as a bench-top power supply or portable battery source.

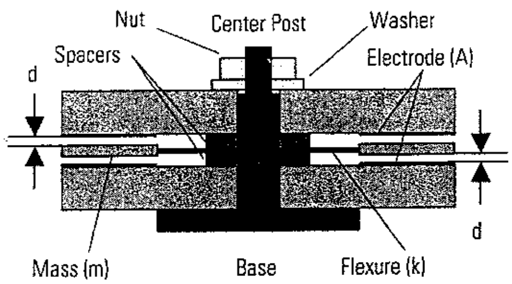

Figure 1a: Sensing Element in "0 g" Condition

- Natural air damping extends the upper frequency range, attenuates unwanted high-frequency vibration, and provides stable performance over the entire operating temperature range.
- Injection-molded plastic housing electrically isolates sensor ground from test structure ground thereby minimizing the chances of ground loop noise.
- Integral cable for easy connection to power source

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 3800 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.

$$F = ma \qquad \text{(Eq. 1)}$$

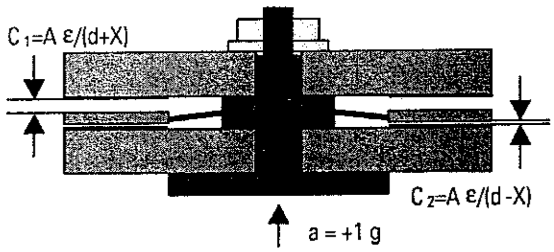

Figure1b: Sensing Element in "+1g" Condition

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).

$X = F/k$ (Eq. 2)

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

$C_1 = (A\varepsilon)/(d+X)$ (Eq. 3)

$C_2 = (A\varepsilon)/(d-X)$ (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.

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

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

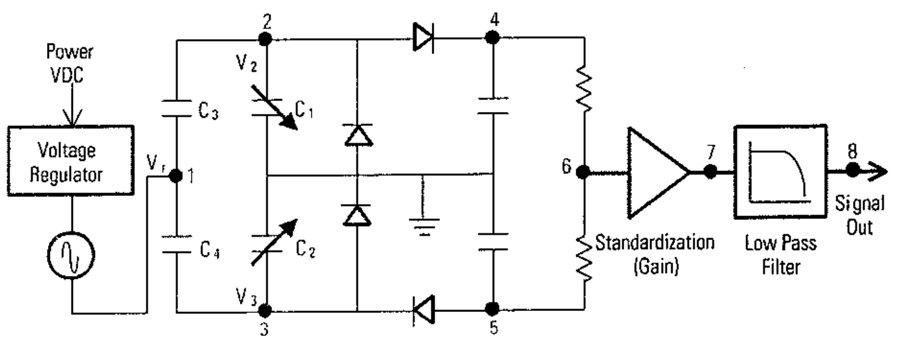

Figure 2a Circuit Schematic

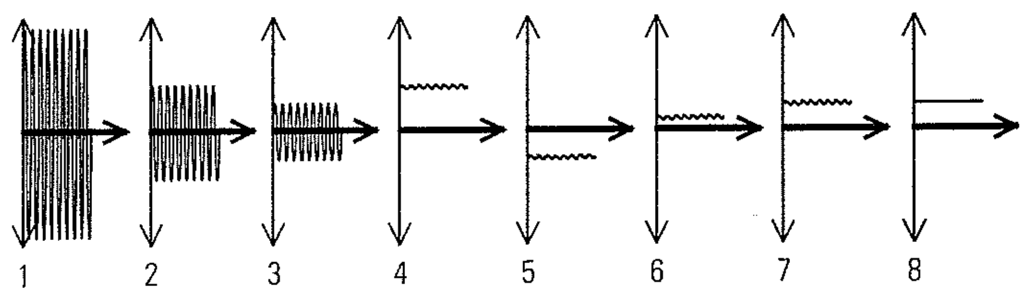

Figure 2b: Response from Circuit from +1g Static Acceleration (x-axis = time and y-axis = voltage)

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

A typical measurement system, like the one shown in Figure 3, consists 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.)

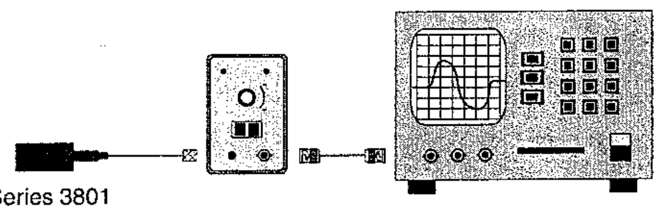

Figure 3: Series 3801 Single Axis Typical System

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.

6.0 Powering

Series 3800 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 3800 Variable Capacitance Accelerometers.

Series 3800 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 3800 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

8.1 Using the Earth's Gravitational Field

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 3800 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.

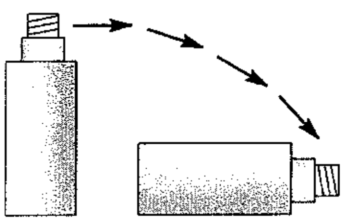

Figure 4: Sensor Verification using Flip Test

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 dynamic instrumentation needs with a Factory Representative. Dial (716) 684-0001.

Model Number
3801D3FB20G

CAPACITIVE ACCELEROMETER

Revision: B
ECN #: 13936

DYNAMIC PERFORMANCE				
Voltage Sensitivity	mV/g [mV/(ms^{-2})]	100 [10,19]	(10%)	
Measurement Range	±g pk [±ms^{-2} pk]	20 [196]		
Frequency Range: (±5%)	Hz	0 to 200		
(±10%)	Hz	0 to 400		
Mounted Resonant Frequency	Hz	≥800		
Phase Response: at 100 Hz, 70°F [21°C]	°	<15		
Damping Ratio	% critical	70		[3]
Resolution (1 Hz to 100 Hz)	μg rms [μms^{-2} rms]	120 [1 200]		[3]
Amplitude Linearity	%	≤2		[1]
Transverse Sensitivity	%	≤5		[2]
ENVIRONMENTAL				
Shock Limit - All Axes (maximum)	±g pk [±ms^{-2} pk]	3,000 [29 400]		
Operating Temperature Range	°F [°C]	-40 to +185 [-40 to +85]		
Storage Temperature Range	°F [°C]	-85 to +250 [-65 to +121]		
Temperature Coefficient	%FS/°F [%FS/°C]	0.005 [0,009]		[3]
Zero g Offset Temperature Coefficient	%FS/°F [%FS/°C]	<±0.14 [<±0,25]		
Strain Sensitivity	g/με [(ms^{-2})/με]	0.0001 [0,001]		[3]
Magnetic Sensitivity	equiv. μg/gauss [ms^{-2}/Tesla]	65 [6,37]		[3]
ELECTRICAL				
Excitation Voltage	VDC	16 to 30		
Current Draw	mA	≤10		
Output Impedance	ohms	50		
Zero g Offset Voltage	mVDC	<±50		
Spectral Noise: (1 Hz)	μg/√Hz [(μms^{-2})/√Hz]	50 [490]		[3]
(10 Hz)	μg/√Hz [(μms^{-2})/√Hz]	20 [196]		[3]
(100 Hz)	μg/√Hz [(μms^{-2})/√Hz]	10 [98]		[3]
Ground Isolation	ohms	>10^8		
MECHANICAL				
Housing	material/sealing	Ryton/Epoxy		
Size (length x width x height)	in [mm]	0.85 x 0.85 x 0.5 [21,6 x 21,6 x 12,7]		
Weight	oz [gm]	1.1 [30]		[4]
Electrical Connector	type/location	Integral Cable/Side		[5]
Mounting	in [mm]	2 x 0.116 [2,9] Thru Holes		

OPTIONAL VERSIONS

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

☒ **M** - Metric Mount
Modify Accessories
(2) Model M081A98 Screw replaces (2) Model 081A98

☐ **HT** – High Temperature Operation
Operating Temperature Range °F [°C] -40 to +250 [-40 to +121]

NOTES:
[1] Zero-based, least-squares, straight line method.
[2] Transverse sensitivity is typically ≤1.5%.
[3] Typical value.
[4] With 10 ft of 010 cable.
[5] Integral cable, 10 ft in length, terminates in labeled pigtails.

SUPPLIED ACCESSORIES:
Model 081A98 Mounting Screw (2)
NIST Traceable Calibration Certificate

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.

DD032 Rev.G 2/16/99

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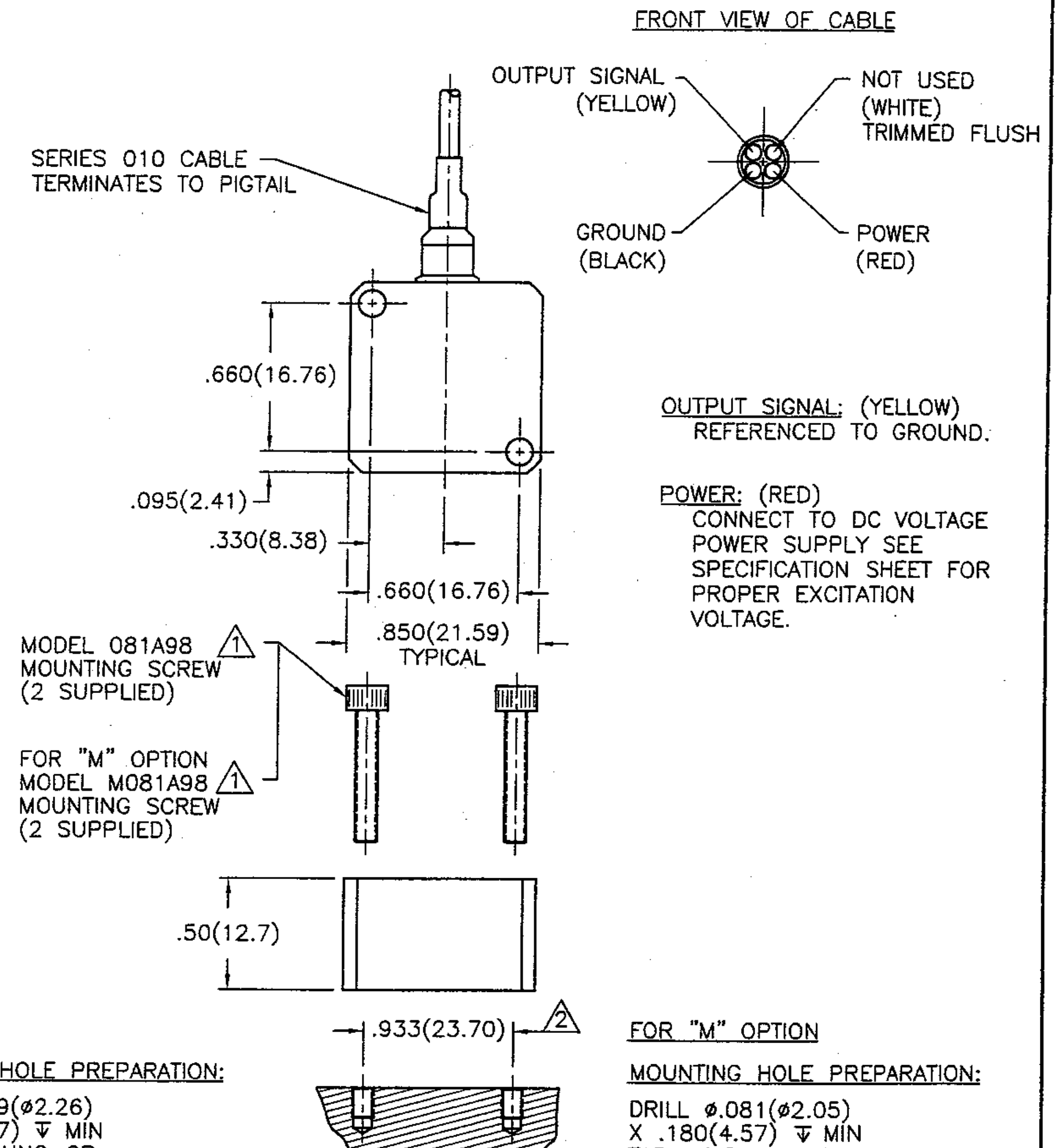
Drawn:	Eng: JCB	Sales: SL	Appd:	Spec Number:
Date: 8/24/01	Date: 8/24/01	Date: 8/24/01	Date: 8/24/01	12771

15839

APPLICATION		
NEXT ASS'Y	USED ON	VAR

REVISIONS				
REV	DESCRIPTION	ECN	DATE	APP'D
A	UPDATED PIN OUT	14024	9/13/01	



OUTPUT SIGNAL: (YELLOW)
REFERENCED TO GROUND.

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

MOUNTING HOLE PREPARATION:

DRILL ⌀.089(⌀2.26)
X .180(4.57) ↧ MIN
TAP 4-40 UNC-2B
X .130(3.30) ↧ MIN

FOR "M" OPTION

MOUNTING HOLE PREPARATION:

DRILL ⌀.081(⌀2.05)
X .180(4.57) ↧ MIN
TAP M2.5 X 0.45-6H
X .130(3.30) ↧ MIN

△2 DIAGONAL MOUNTING DIMENSION BETWEEN HOLES.

△1 RECOMMENDED MOUNTING TORQUE ON CAP SCREW, 4-5 IN-LBS(45-55 N-CM).

UNLESS SPECIFIED TOLERANCES							
DIMENSIONS IN INCHES DECIMALS XX ±.01 XXX ±.005 ANGLES ±2 DEGREES	DIMENSIONS IN MILLIMETERS (IN PARENTHESIS) DECIMALS XX ±0.3 XXX ±0.13 ANGLES ±2 DEGREES	DRAWN	10/26/01	MFG	JBS	11/6/01	PCB PIEZOTRONICS 3425 WALDEN AVE. DEPEW, NY 14043 (716) 684-0001 EMAIL: SALES@PCB.COM
		CHK'D		ENGR			
		APP'D	11/6/01			11/06/01	CODE IDENT. NO. 52681
FILLETS AND RADII .003 - .005	FILLETS AND RADII (0.07 - 0.13)	TITLE	INSTALLATION DRAWING MODEL 3801 SERIES DC ACCELEROMETER				DWG. NO. 15839
DD011 REV. B 03/13/98							SCALE: 1.33 SHEET 1 OF 1