



**Model 3501A2020KG**

**High Amplitude MEMS Shock 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](mailto:info@pcb.com)  
Web: [www.pcb.com](http://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](http://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](http://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 SensorLine<sup>SM</sup>: (716) 684-0001  
Website: [www.pcb.com](http://www.pcb.com)  
E-mail: [info@pcb.com](mailto:info@pcb.com)

## 1.0 Introduction

This Operating Guide contains information that will familiarize the user with the basic operation and installation of the 3500/3600 Series Piezoresistive (PR) Shock 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 Principle of Operation

PR accelerometers are passive devices which require stable external power, typically a regulated dc voltage such as 10V, or more recently 5V or 3.3V to operate with new electronics. They include silicon strain-sensing elements which change resistance proportionally to the applied acceleration, half of which increase in value with positive acceleration, and half which decrease, as shown in the Wheatstone-bridge circuit of Figure 1. All four resistors in the sensors are active, providing twice the sensitivity of half-bridge device for the same strain levels. The sensitivity of the bridge is proportional to the Excitation voltage.

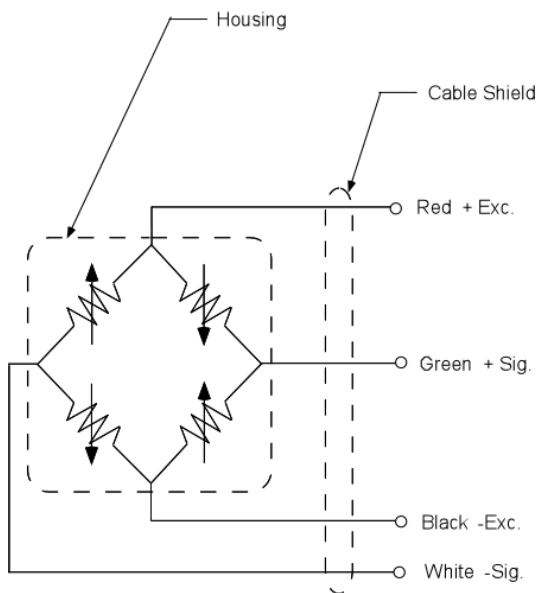


Figure 1 – Wheatstone Bridge Circuit

Terminology related to PR devices includes:

ZMO – Zero Measurand Output, also called bias or offset, is the output when no input acceleration is applied.

TSS – Thermal Sensitivity Shift, the change of sensitivity due to temperature. The sensors are uncompensated, so they

display a slight linear decrease in sensitivity as temperature increases.

TZS – Thermal Zero Shift, the change in ZMO due to temperature. This is less predictable, and from unit to unit may have positive or negative slope, although it will be stable for any one unit.

## 3.0 Features

The 3500/3600 Series use micro-electromechanical systems (MEMS) technology, in which all structural and electronic components are manufactured in silicon using electronic microfabrication technologies. MEMS devices are preferred in many high shock impact measurements over piezoelectric elements, since these PR devices are inherently DC coupled, exploit the strength of single crystal silicon (SCS) and display minimal zero shift. However, an additional characteristic of SCS is extremely low internal damping, which results in susceptibility to overshoot and resonant excitation. Although the stiffness of silicon can allow extremely high resonant frequency in some MEMS shock sensor designs, PCB MEMS uses a different approach in which the resonance frequency is intentionally lowered to reduce the response to higher frequency energy present in shock events. The relatively low resonance also creates displacements of the seismic element sufficient to introduce squeeze film damping. Air is used rather than a fluid so thermal effects on damping are negligible.

Manufactured using recent advances in semiconductor processing, the PCB MEMS design aims at a mildly underdamped sensor with sufficient bandwidth to accurately track rigid-body vehicle deceleration. Resonant amplification is reduced by orders of magnitude, and survivability is increased.

Ruggedness is enhanced through the use of mechanical stops. The sensors are manufactured as the sandwich of three wafers, with the active core surrounded by the two outer wafers which provide hermetic protection and restrict the travel of the proof mass.

Because many such applications are coupled with battery powered conditioning and data acquisition, the PCB MEMS was designed with relatively high value resistors (approximately 10 times that of other devices) to maximize battery life.

## 4.0 Common Applications

The 3500/3600 Series PR Shock Accelerometers achieve true DC response for measuring long duration shock. For this reason, they are preferred for applications in which integration from acceleration to velocity or displacement may be

performed. These are violent events. Because of the critical nature of these and similar test applications, PCB MEMS accelerometers have been designed and manufactured with the following common characteristics:

- Rugged, all-welded titanium housing or ceramic housing insures reliability and durability in demanding applications and environments.
- The MEMS sensor includes overrange stops set at approximately twice the full range.
- Gas damping attenuates unwanted high-frequency output.

## 5.0 Sensor Installation

The 3500/3600 series DC Accelerometers are available in several forms. The titanium packages of the 3501A1220KG, 3501A1260KG and 3501A1320KG, 3501A1360KG have a 1/4 - 28 threaded base for mounting that is also available in M6 x 0.75. The 3501A12 models have low noise cable using conventional copper conductors that exits the sensor parallel to the mounting surface, whereas the 3501A13 models utilize the same cable exiting the sensor perpendicular to the mounting surface. The titanium package of 3503A1020KG uses two 4-40 screws using 0.375"-spaced mounting holes common to industry fixturing. The anodized aluminum packages of 3601A11 and 3641A10 use two 0-80 screws with the 3601A11 using .354"-spaced mounting holes and the 3641A10 using .300"-spaced mounting holes.

When choosing a mounting method for 3500/3600 series models it's important to take characteristics like location, temperature, environment, and surface into consideration. When selecting a surface, a clean, flat contact area is imperative to avoid the potential for misaligned and limited contact that may reduce the sensor's operation. Surface minimums are provided on the enclosed Sensor Installation Drawing. Mounting the sensor will require a clean contact surface to avoid small particles or debris trapped between the mounting surface and sensor that can preload the accelerometer case with unwanted static strain, possibly resulting in zeroshift during a shock measurement.

- Prepare a smooth, flat mounting surface and then drill and tap mounting holes according to the Sensor Installation Drawing.
- Wipe clean the mounting surface and apply a thin film of couplant, such as machinist oil, to enhance transmissibility by filling small voids in the mounting surface and increasing mounting stiffness.

- Hand-tighten the sensor, then torque down to the value listed on the Sensor Installation Drawing. It's also recommended that a thread locking adhesive be applied to the threads.

The ceramic LCC (leadless chip carrier) packages of the 3501A2020KG and 3501A2060KG are designed to be installed on circuit boards with conventional surface mounting techniques. An underfill epoxy is recommended to be used for additional mechanical strength.

## 6.0 Power

Normally PR devices are powered with regulated Excitation, since the sensitivity is proportional to input voltage. Although for the 3500/3600 Series the proportionality is very good (due to minimal self heating of the comparatively high-resistance elements) generally it is recommended to obtain the calibrated sensitivity using the intended Excitation voltage. In integrated applications, in which the data acquisition is powered by the same voltage that supplies the bridge, it is possible to reduce the effect of variations in Excitation on overall system sensitivity by using the excitation voltage as the reference for the data acquisition.

## 7.0 Typical Measurement System

The output from the sensor is typically routed to bridge conditioner then oscilloscopes or various data acquisition instruments. Consult PCB Application Engineering for additional signal conditioning options. 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.

## 8.0 Sensor Verification

Generally the ZMO of a PR transducer is a good measure of the health of the transducer. Input Resistance (from Red to Black) or Output Resistance (from Green or Yellow to White), is less commonly used to check the condition, since resistance changes with temperature. A thorough check of the health (suggested both before and after an expensive test) must include calibration of the sensitivity.

In some laboratories which use piezoresistive transducers, it is customary to check the continuity and gain of the conditioning and data acquisition system using a technique called "Shunt Calibration". By temporarily unbalancing the bridge with a shunt resistor placed in parallel with a leg of the bridge (usually between the "+ Sig" wire and either the "+ Exc" or "- Exc"), dc shifts of the offset are created. Whereas the process

does not calibrate the transducer, it is a check of system gain, with accuracy of the resultant dc shift in output dependent on the degree that the resistances of both the leg of the bridge and the shunt resistor are accurately known. Among other sources of variability, temperature can change the value of the resistors, and therefore the Shunt Calibration output. The user should be aware that because the 3500 Series are full bridge transducers, all legs are active and will have temperature coefficients typical of piezoresistive sensors (approximately +0.1%/degree C).

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

## 9.0 Sensor Calibration

For shock accelerometers, the most appropriate, accurate and reliable calibration is with a comparison shock using a back-to-back reference and pneumatic exciter, as described in ISO 16063-22, “Methods for the calibration of vibration and shock transducers — Part 22: Shock calibration by comparison to a reference transducer.” PCB offers this calibration as a service.

## 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](mailto:sales@pcb.com) or visit our web site at [www.pcb.com](http://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.

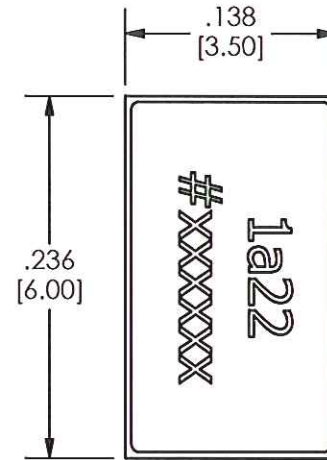
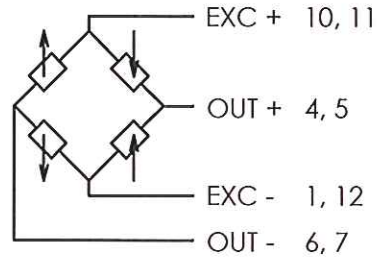
| Model Number<br>3501A2020KG   | <b>HIGH AMPLITUDE MEMS SHOCK ACCELEROMETER</b>   |  | Revision: NR<br>ECN #:   |                     |                      |                   |                     |              |                       |                       |                       |                       |              |
|---|--|--|--|---------------------|----------------------|-------------------|---------------------|--------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------|
| <b>Performance</b><br>Sensitivity(± 50 %)(at 10 VDC excitation)<br>Sensitivity<br>Measurement Range<br>Frequency Range(± 1 dB)<br>Resonant Frequency<br>Damping Ratio<br>Non-Linearity<br>Transverse Sensitivity                                  | <b>ENGLISH</b><br>0.010 mV/g<br>0.001 mV/V/g<br>± 20 kg<br>0 to 10,000 Hz<br>>60 kHz<br>5 % Critical<br>± 1 %<br>≤ 3 %               | <b>SI</b><br>0.001 mV/(m/s <sup>2</sup> )<br>0.0001 mV/V/(m/s <sup>2</sup> )<br>± 196,100 m/s <sup>2</sup> pk<br>0 to 10,000 Hz<br>>60 kHz<br>5 % Critical<br>± 1 %<br>≤ 3 % | <b>OPTIONAL VERSIONS</b><br>[1] Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used.<br><br>[4]  |                     |                      |                   |                     |              |                       |                       |                       |                       |              |
| <b>Environmental</b><br>Overload Limit(Shock)<br>Overload Limit(Mechanical Stops)<br>Temperature Range(Operating)<br>Temperature Coefficient of Sensitivity<br>Zero g Offset Temperature Shift<br>Base Strain Sensitivity<br>Magnetic Sensitivity | ± 60,000 g pk<br>≥ 30 kg<br>-65 to 250 °F<br>-0.11 %/°F<br>± 10 mV<br>0.10 g/µε<br>10 µg/gauss                                       | ± 588,000 m/s <sup>2</sup> pk<br>≥ 294,200 m/s <sup>2</sup> pk<br>-54 to 121 °C<br>-0.20 %/°C<br>± 10 mV<br>0.98 (m/s <sup>2</sup> )/µε<br>0.98 (m/s <sup>2</sup> )/Tesla    | <b>NOTES:</b><br>[3] [1] Verified with test data provided on supplied calibration certificate.<br>[2] [2] Settling Time is the maximum time after power-up for the Offset Voltage to be within +/-2% of Measurement Range output of the final offset value. Mounting surface must be at thermal equilibrium.<br>[5] [3] Half-sine pulse duration, ≥ 20 µsec.<br>[4] [4] Typical.<br>[4] [5] -65 to +250 °F, ref. 75 °F (-54 to +121 °C, ref. 24 °C)  |                     |                      |                   |                     |              |                       |                       |                       |                       |              |
| <b>Electrical</b><br>Excitation Voltage(Maximum)<br>Current Consumption<br>Input Resistance(± 2000 ohm)<br>Output Resistance(± 2000 ohm)<br>Offset Voltage(at 10 VDC excitation)<br>Settling Time   | 15.0 VDC<br><3 mA<br>6000 ohm<br>6000 ohm<br>-40 to +40 mVDC<br>0.01 sec   | 15.0 VDC<br><3 mA<br>6000 ohm<br>6000 ohm<br>-40 to +40 mVDC<br>0.01 sec   | [1] [1] [1] [2]<br><b>SUPPLIED ACCESSORIES:</b><br>Model ACS-62 Shock Calibration of Piezoresistive High Amplitude Accelerometers  |                     |                      |                   |                     |              |                       |                       |                       |                       |              |
| <b>Physical</b><br>Sensing Element<br>Sensing Geometry<br>Housing Material<br>Sealing<br>Size (Height x Length x Width)<br>Weight<br>Electrical Connector<br>Mounting   | Piezoresistive MEMS<br>Full Active<br>Ceramic<br>Epoxy<br>0.085 in x 0.236 in x 0.138 in<br>0.005 oz<br>Solder Tabs<br>Surface Mount | Piezoresistive MEMS<br>Full Active<br>Ceramic<br>Epoxy<br>2.16 mm x 6.00 mm x 3.50 mm<br>0.15 gm<br>Solder Tabs<br>Surface Mount   | [4]<br><table border="1" data-bbox="1129 824 1925 909"> <tr> <td>Entered: <i>Jot</i></td> <td>Engineer: <i>JCF</i></td> <td>Sales: <i>MFG</i></td> <td>Approved: <i>EB</i></td> <td>Spec Number:</td> </tr> <tr> <td>Date: <i>11-13-09</i></td> <td>Date: <i>11-12-09</i></td> <td>Date: <i>11-12-09</i></td> <td>Date: <i>11-13-09</i></td> <td><b>43076</b></td> </tr> </table> <div data-bbox="1134 950 1585 1047" style="text-align: center;"> <br/> <b>PCB PIEZOTRONICS</b><br/> VIBRATION DIVISION<br/> 3425 Walden Avenue, Depew, NY 14043 </div> <div data-bbox="1627 966 1921 1039" style="text-align: right;"> <b>Phone: 716-684-0001</b><br/> <b>Fax: 716-685-3886</b><br/> <b>E-Mail: vibration@pcb.com</b> </div> | Entered: <i>Jot</i> | Engineer: <i>JCF</i> | Sales: <i>MFG</i> | Approved: <i>EB</i> | Spec Number: | Date: <i>11-13-09</i> | Date: <i>11-12-09</i> | Date: <i>11-12-09</i> | Date: <i>11-13-09</i> | <b>43076</b> |
| Entered: <i>Jot</i>   | Engineer: <i>JCF</i>   | Sales: <i>MFG</i>  | Approved: <i>EB</i>  | Spec Number:        |                      |                   |                     |              |                       |                       |                       |                       |              |
| Date: <i>11-13-09</i>   | Date: <i>11-12-09</i>  | Date: <i>11-12-09</i>  | Date: <i>11-13-09</i>  | <b>43076</b>        |                      |                   |                     |              |                       |                       |                       |                       |              |
| <i>All specifications are at room temperature unless otherwise specified.<br/> In the interest of constant product improvement, we reserve the right to change specifications without notice.</i>   |  |  |  |                     |                      |                   |                     |              |                       |                       |                       |                       |              |

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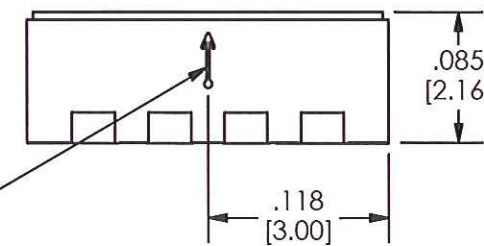
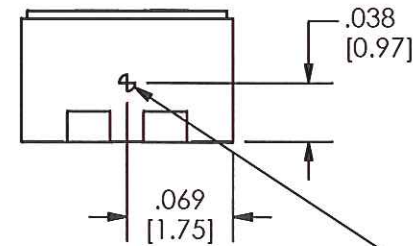
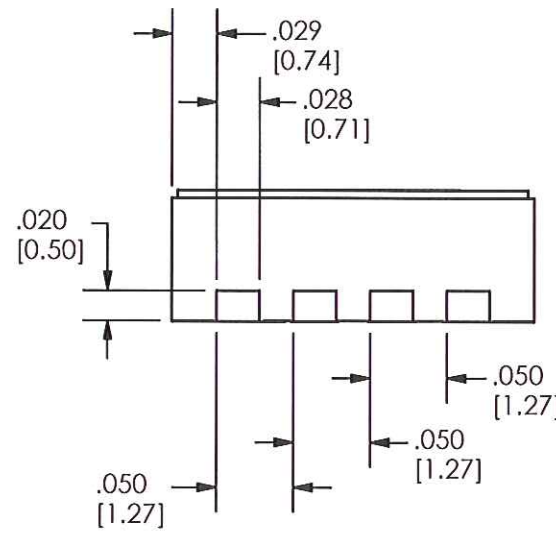


ESD SENSITIVE  
CLASS 2 HANDLING REQUIRED

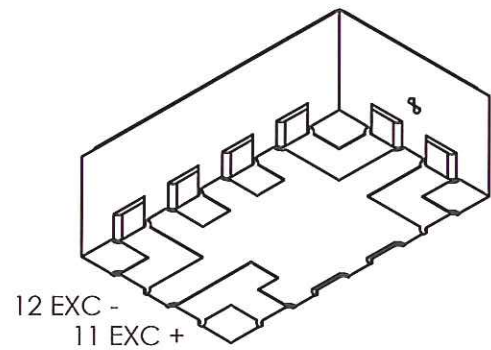
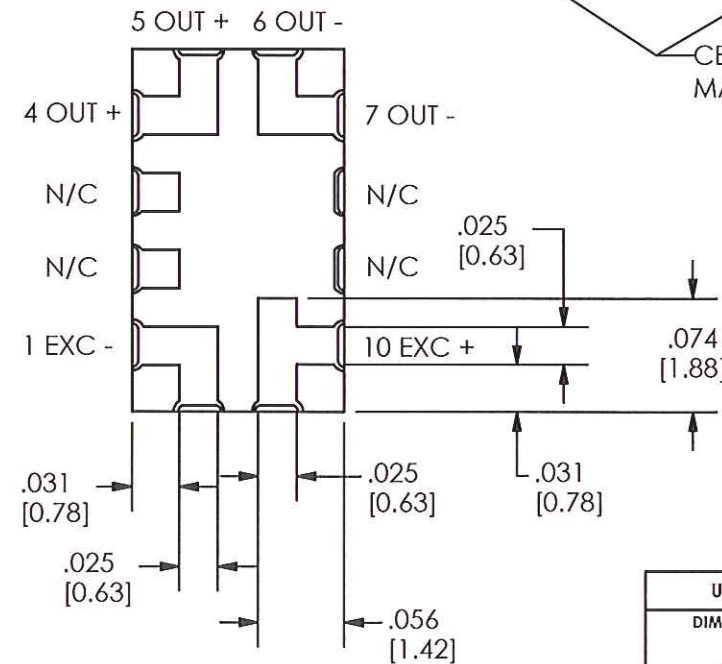


ABBREVIATED  
MODEL NUMBER  
REFERS TO  
3501A2020KG

DIRECTION OF ARROW  
DEPICTS ACCELERATION  
CAUSING POSITIVE OUTPUT



CENTER OF SENSITIVITY IS LOCATED BY THIS  
MARK AND BY THE BASE OF THE ARROW



| REVISIONS |                               |       |
|-----------|-------------------------------|-------|
| REV       | DESCRIPTION                   | DIN   |
| A         | .050 DIMENSION SHOULD BE .056 | 34654 |

| UNLESS OTHERWISE SPECIFIED TOLERANCES ARE: |   | DRAWN  | CHECKED | ENGINEER          |          |
|--|---|--|---------|-------------------|----------|
| DIMENSIONS IN INCHES                       | DIMENSIONS IN MILLIMETERS [IN BRACKETS] | MDJ  | FCB     | BJI               | 12/23/10 |
| DECIMALS XX ±.03<br>XXX ±.010              | DECIMALS X ±.08<br>XX ±.25              | TITLE  |         |                   |          |
| ANGLES ± 2 DEGREES                         | ANGLES ± 2 DEGREES                      | OUTLINE DRAWING<br>3501A2020KG SHOCK SERIES<br>SURFACE MOUNT |         |                   |          |
| FILLETS AND RADII<br>.003 - .005           | FILLETS AND RADII<br>0.07 - 0.13        | CODE IDENT. NO.<br>52681                                     |         | DWG. NO.<br>43207 |          |
|  |   | SCALE: FULL  |         | SHEET 1 OF 1      |          |

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