Endevco

2008 | **Product catalog and measurement resource**

MEGGiTT
smart engineering for
extreme environments

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Delivering extraordinary performance

For over 60 years, we have had the privilege of helping shape the industry we know today by guiding best practices and standards, pursuing the most accurate measurement and calibration methods, and developing products that continue to set benchmarks for precision, reliability and value. The worldwide Endevco team is committed to providing the products, expertise and services that are critical to the advancement of sensing technologies and applications. From our roots as a small research and development firm to our current position as an worldwide industry leader, each Endevco associate brings pride and dedication to achieving those goals.

President's statement

We are pleased to present the 2008 Endevco Product Catalog and Measurement Resource™.

Our goal is to provide the information needed to understand this technology fully, to evaluate the options available to you, and select the right sensing solutions to make your projects and programs successful.

Since 1947, Endevco has delivered superior sensing solutions for demanding shock, vibration and pressure environments in the aerospace, automotive, energy, test and measurement, and medical device sectors.

We are very proud of the industry recognition we received in 2007 for innovation and customer support such as the STARS 200 Award from Cessna for superior supplier performance, the Total Quality Supplier Award from the United Launch Alliance joint venture of Boeing and Lockheed Martin, and a 2007 Best of Sensors Expo Award.

In 2007, we delivered our four-millionth accelerometer to leading medical device manufacturers with no field failures. We supplied the sensors and expertise for the winning university team in an international vehicle safety design competition sponsored by the National Highway Traffic Safety Administration. And we maintained an extraordinary pace in new technology developments and product introductions from high-temperature performance to onboard microprocessor capabilities.

We continue to strive for unmatched customer support with our Guaranteed In-Stock, Replacement Sensors, and Rapid Calibration programs as well as expansion of our sales and support partner network around the world.

On behalf of the entire Endevco team, thank you for your continued support.

Scott Silcock
President

Sensing solutions for advanced technology

Founded in 1947, Endevco Corporation has grown from a small research and development firm to an international corporation, supporting customers with a global network of manufacturing and research facilities, sales offices and field engineers. For over 60 years Endevco has been providing the most trusted solutions for the world's most challenging measurement applications.

Headquartered in San Juan Capistrano, California, Endevco is the world's leading designer and manufacturer of dynamic instrumentation for vibration, shock and pressure measurements. Endevco's accelerometer and shock sensor product offering includes piezoelectric, IEPE, piezoresistive and variable capacitance type devices. Our pressure products include both piezoelectric and piezoresistive type transducers for use in dynamic, static and acoustic applications. All of these transducers are supported by a complete line of related signal conditioners, amplifiers, cables, measurement systems and accessories. Over the years Endevco has earned a reputation for providing mission critical performance for the most challenging aerospace, automotive, defense, industrial, and medical applications where accurate and reliable data is absolutely vital. Examples of this include impact monitoring of NASA's space shuttle, automotive crash and crush safety testing, in-flight gas turbine vibration monitoring, and activity monitoring in pacemakers.

In November 1994, Endevco became ISO 9001 certified. Since then we have achieved ISO 14000 environmental standards certification, which demonstrates our commitment to raising quality standards in measurement technology.

Time after time customers have discovered that Endevco products mean reliable data. Endevco provides measurement solutions based on advanced technology, superior performance and total customer support, worldwide, with quality and delivery to fit your schedule. Join forces with a company you can count on.

Endevco MEMS

Endevco is one of the early pioneers in the art and science of Micro Electro Mechanical Systems (MEMS) design and manufacturing. Since the early 1960's, we have been researching and fabricating these miniature high performance devices in the Silicon Valley. Our facility in Sunnyvale, California utilizes bulk micromachining of silicon to produce many different types of MEMS.

Endevco was the first to manufacture a bossed silicon diaphragm for a pressure transducer. Our MEMS piezoresistive pressure sensors support ranges as low as 1 PSI and as high as 20 000 PSI. Our flip chip pressure sensor offers extremely small size and exceptional output in a surface mountable configuration.

Endevco manufactures many MEMS based piezoresistive accelerometers for a variety of applications. We innovated the first fully micromachined monolithic piezoresistive acceleration sensor, with operating ranges from 2000 to 200 000 g. Our accelerometers have been the standard for automotive crash testing for many years.

Our MEMS variable capacitance accelerometers have been used for over 10 years in the medical and aerospace industries with exceptional reliability. The newest addition to this family incorporates leading edge wafer level packaging to create a hermetic, surface mountable die with low height and a small footprint.

In 2006, Endevco expanded both the size and technical capabilities of the Sunnyvale MEMS wafer fabrication facility. The focus of this expansion was to add controls and equipment to support state-of-the-art equipment to enable fabrication of advanced designs and as well as future high temperature and harsh environment products. Some of the new tools are a deep reactive ion etcher, an optical profiler, which enables complex structures and a scanning electron microscope for metrology. With our enhanced infrastructure and our focus on new product development, we are ready to support our customers' most demanding applications.

Endevco MEMS
Sunnyvale, California

Since 1947 Endevco has been at the forefront of the sensor industry by providing the highest quality products and materials used for challenging measurement applications. As the world's preferred sensor supplier for mission critical applications we continue to leverage our expertise and premier solutions to solve the most demanding applications. Our reputation for being the first in the industry to introduce new products and materials is renowned and often imitated with limited success.

Some of Endevco's notable "firsts":

- First "shear design" accelerometer
- First piezoelectric accelerometers capable of continuous operation at temperatures up to +1400°F (+760°C)
- First and only 200 000 g accelerometer
- First commercially available accelerometers using a micromachined silicon variable capacitance microsensor™ and internal electronics
- First monolithic silicon piezoresistive accelerometer

These industry leading efforts continue today through Research and Development at our San Juan Capistrano, California headquarters as well as over 30 years of ongoing silicon micromachining research and fabrication at our state-of-the-art facility in Sunnyvale, California. Endevco is also working closely with our Meggitt colleagues and industry experts to develop new materials and products to solve next generation applications such as extreme impact (›100 000 x g), high electromagnetic field (›18 T in some railguns) and high temperature (between 300°C and 600°C) environments. These types of applications demand more robust sensors and instrumentation and ultimately rely upon next generation materials and sensor designs. Examples of these include pressure monitoring during deep well drilling and combustion in aeronautical and automotive engines both requiring transducers that can operate in extreme temperature environments.

Commercially available accelerometers based on silicon technology have been shown to survive nearly 100 000 g, but their material properties may inhibit reliable operation in high temperature (›350°C) applications. Additionally, these accelerometers must survive the electromagnetic fields associated with all-electric vehicle technology for military and space applications. In cases where they are utilized at higher temperatures, extensive and expensive packaging methods such as plumbing for water cooling are adopted. Silicon on Insulator (SOI) technology has long been adopted to further extend the operational capability of pressure sensors to temperatures beyond 300° C.

Endevco, Meggitt, and their industry partners are working to develop innovative material solutions that will address both the static and dynamic world of acceleration and pressure measurements in these difficult environments. For both static and dynamic operations up to 600°C, researchers are investigating new materials and processes using MEMS devices and high temperature packaging materials and configurations that will deliver a reliable transducer solution.

For dynamic measurements above 600°C, our scientists and industry partners are investigating novel high temperature Piezoelectric (PE) single crystals including unique Perovskites ceramics that exhibit a morphotropic phase boundary (MPB) and high Curie temperatures.

The enhanced piezoelectric properties of PZT ceramics near the morphotropic phase boundary (MPB), which separates the rhombohedral from the tetragonal phases, were demonstrated in the middle of the 1950s and have since sparked numerous discoveries of related relaxor-based materials.

Recently the growth of relaxor-based compositions in single crystal form has attracted great interest due to their far superior properties in comparison with conventional PZT ceramics. With lower transition temperatures they exhibit larger permitivity and charge/strain coefficients at room temperature. In their single crystal form, relaxor-lead titanate ferroelectrics offer piezoelectric coefficients (d33 › 2000 pC/N) at strain levels of 0.5%. In addition to high piezoelectric coefficients, ultra-high electromechanical coupling (k33 and k15 over 90%) allows for increased transducer bandwidth, greater sensitivity and enhanced acoustic power.

These crystals can be utilized in bending and compression modes as well as composites making them suitable for all electro-mechanical applications in devices such as actuators, transducers, and sensors. Engineers and scientists throughout the world look to Endevco to provide the highest performance, reliability and quality in sensing solutions. Our broad standard product offering and our capabilities to provide custom solutions are unmatched and our focus on developing next generation materials and sensors will continue to provide our valued customers with the most advanced solutions available.

Guaranteed In-Stock

TE Test Essential™

Endevco Guaranteed In-Stock program is the industry's first offering of guaranteed availability of the most popular sensing products

Mission critical performance meets mission critical availability

For 60 years, the world's leading experts have relied on Endevco to deliver unsurpassed performance, reliability and quality and now adding to this list of credits is unsurpassed accessibility.

We have selected over 100 of the most trusted and popular Endevco sensors, cables, electronics and accessories to be part of Endevco's Test Essential™ group of products that are guaranteed to be in-stock at the time of order. The guarantee is also backed with a 5% discount if the Test Essential™ item(s) is not in-stock at the time of order. The first and only guarantee of its kind in the industry! See the Guaranteed In-Stock program conditions below for more details.

The Test Essential™ group of products includes:

PE accelerometers
› 22
› 23
› 2220E
› 2221D
› 2221F
› 2222C
› 2222D
› 2225
› 2226C
› 2228C
› 2248
› 2248M1
› 2271A
› 2276
› 6222S-20A
› 6222S-100A
› 6233C-50
› 6237M70-120
› 6237M71-120
› 7240C
› 7703A-100
› 7704A-50

PR accelerometers
› 2262A-1000
› 2262A-2000
› 7264B-500T
› 7264B-2000T
› 7264C-2KTZ-2-300
› 7264C-2KTZ-2-360
› 7270A-2K
› 7270A-6K
› 7270A-20K
› 7270A-60K
› 7270A-200K

VC accelerometers
› 7290A-10
› 7290A-30
› 7290A-50
› 7290A-100

Isotron accelerometers
› 25A
› 25B
› 27A12
› 35A
› 61C12
› 65-10
› 65-100
› 65HT-10
› 66A12
› 256-10
› 752A12
› 2250A-10
› 2250AM1-10
› 2258A-10
› 5220A-100
› 7250A-10
› 7250AM1-10
› 7253C-10
› 7255A-01
› 7259B-25

Pressure transducers and microphones
› 8507C-2
› 8510B-1
› 8510B-2
› 8510B-5
› 8510B-2000
› 8510C-15
› 8511A-5K
› 8511A-10K
› 8515C-15
› 8530B-500
› 8530B-1000
› 8530C-15
› 8530C-50
› 8530C-100
› 8540-15

High quality, low noise cables
› 3003C
› 3053V-120
› 3060A series
› 3075M6-120
› 3090C series
› 3091F
› 6960
› 6962
› 6963
› 3024-120

Electronics
› 133
› 136
› 2771B-1
› 2771B-10
› 2775B
› 2777A-02-15
› 4430A
› 4830A
› 6634C-ESA

Accessories
› EJ21
› EJ34
› EJ66
› 2980M4
› 2983B
› 2985
› 2986B
› 2988
› 7970
› 10207

For the most up to date listing visit: www.endevco.com/testessential

Guaranteed In-Stock program subject to the following conditions:

Endevco's Guaranteed In-Stock program applies only to select standard Endevco products which are designated as "Test Essential" items and excludes all special, custom or configured products and other standard products which are not designated as "Test Essential".

The "Guaranteed In-Stock" program discount may be applied to a maximum of 10 units per "Test Essential" item shipped in a 30 day period. If higher quantities of "Test Essential" items are needed Endevco representatives will provide the best possible availability to meet customer needs. Our goal is complete satisfaction including quality, performance and delivery.

All "Test Essential" items will be shipped promptly after receipt of order providing all applicable credit approval, export authorization and/or documentation, compliance with applicable Government regulations, quality and/or contractual requirements, and customer account information is satisfied.

Endevco standard terms and conditions apply to all sales and discounts of all "Test Essential" items under the "Guaranteed In-Stock" program.

Endevco reserves the right to modify or terminate the "Guaranteed In-Stock" program and "Test Essential" items at will and without prior notice. If a "Test Essential" item does become obsolete or unavailable for any reason Endevco reserves the right to substitute an equal or superior product to fulfill customer requirements.

The Guaranteed In-Stock program cannot be combined with any other offers, promotions, discounts or pricing agreements. Any discount provided by this program must be taken from Endevco's standard commercial price list.

–R REPLACEMENT sensors

Endevco introduces new offering of economical replacement sensors for updating or upgrading of existing vibration test fixtures.

Endevco's new offering of replacement sensors provide a cost effective way to update or upgrade existing vibration test cells with the most trusted accelerometers available. The offering includes 25 of the most widely used accelerometers at a price savings of 10% or more below the standard model price.

The new –R replacement sensor offering delivers the high performance sensors that Endevco is known for but without the extra accessories and cables which are generally not necessary for updating or upgrading existing test cells. The -R products include the most popular piezoelectric, IEPE and piezoresistive accelerometers that feature detachable cables for easy integration and replacement. The –R offering also provides a lower cost method to support spare sensor inventories which can eliminate costly test cell down time and support regular calibration of critical sensors.

For the most up to date listing visit: www.endevco.com/-R

Guaranteed In-Stock program subject to the following conditions:

Endevco reserves the right to modify or alter –R replacement sensor offering at will and without prior notice. If a –R item does become obsolete or unavailable for any reason Endevco reserves the right to substitute an equal or superior product to fulfill customer requirements. The –R offering is limited to the products identified above and cannot be applied to other products unless specifically released and formally offered by Endevco.

Piezoelectric accelerometers

Part number	Cables	Accessory name	Accessory part number
22-R	3003C-6		
23-R	3003C-6		
2220E-R		Screw, cap Washer Screw assembly	EH96 EHW95 12746
2221F-R		Mounting screw assembly	10207
2222C-R	3093-12		
2222D-R			
2226C-R			
2228C-R		Screw, mach Washer	EH156 EHW53
2230E-R			
2271A-R		Mounting stud	92981-12
2273AM1-R		Mounting stud	92981-12
2273AM20-R		Mounting stud	92981-12
2276-R		Mounting stud	92981-12
7703A-50-R		Mounting stud	92981-12
7703A-100-R		Mounting stud	92981-12

Piezoresistive accelerometers

Part number	Cables	Accessory name	Accessory part number
2262A-2000-R		Mounting stud	92981-12

Piezoresistive accelerometers

Part number	Cables	Accessory name	Accessory part number
65-10-R		Screw, set Screw, cap	EH761 EH755
65-100-R		Screw, set Screw, cap	EH761 EH755
65HT-10-R		Screw, cap Screw, set	EH755 EH761
66A12-R		Screw, set Screw, cap	EH761 EH755
751-10-R		Mounting stud	92981-12
2250A-10-R			
2250AM1-10-R			
2258A-10-R		Screw Washer	EH156 EHW53
7251A-10-R		Mounting screw assembly	10207
7251A-100-R		Mounting screw assembly	10207
7253C-10-R		Harness tie Screw, cap Washer	EW403 EH102 34549

Market solutions

Aerospace

For 60 years, Endevco has been the leader in providing products for flight test, inertial measurement, and pressure profiling. This includes flutter testing of low g's and low frequencies, engine testing with wide frequency requirements and aerodynamic pressures and temperatures and static and dynamic vibration testing. Endevco offers a complete range of extreme environment accelerometers, microphones, airborne amplifiers and pressure transducers for mission critical measurements. Our products are used extensively to measure vibration during ground, in-flight and on-board monitoring of aircraft, surface ship, and submarine engines. We continue to play a key role as new engines are developed, certified, and placed into production, as on the Joint Strike Fighter program.

Endevco also offers high-intensity microphones for measuring the acoustic signatures of missiles and rockets at take-off along with engine pressure studies. These, along with the fuzing devices that Endevco offers, is why more Defense companies rely on Endevco for their missile applications.

If there is a critical measurement involved, such as the space shuttle wing impact detection, Endevco is your source for both products for measurement and the engineering talent to design a system to meet your needs.

Model 71

NEW PRODUCT! The Endevco® model 71 is a family of miniature, rugged, undamped, piezoresistive accelerometers designed for shock measurements. The leadless chip carrier package is designed for surface mount attachment to circuit boards. The highly efficient sensing system of the model 71 is sculpted from single crystal silicon, which includes the inertial mass and strain gages arranged in a four-active-arm Wheatstone bridge circuit. The extremely small size and unique construction of the element provides exceptionally high resonant frequency. On-chip balance resistors provide low zero measurand output and low thermal zero drift. The light weight flat case is designed for adhesive mounting.

New triaxial piezoresistive accelerometer

NEW PRODUCT! This new Endevco® product is an assembly of three model 71 miniature, rugged, undamped, piezoresistive accelerometers designed for shock measurements in three directions. The device can be customized to provide various levels of shock measurement for each axis. For example one can have a 6K-20K-60K or a 20K-20K-60K version etc. Final model number to be released in February 2007.

Model 7290A

The Endevco® model 7290A Microtron® accelerometer family utilizes unique variable capacitance microsensors. The accelerometers are designed for measurement of relatively low-level accelerations in aerospace and automobile environments. Gas damping and internal overrange stops enable the anisotropically etched silicon microsensors to withstand high shock and acceleration loads. Included in the accelerometer is a signal conditioner so that the device can operate from 9.5 V to 18.0 V and provide a high level, low impedance output.

Model 25A

The Endevco® model 25A Isomin™ is an extremely small, adhesively mounted piezoelectric accelerometer designed specifically for measuring vibration in mini-structures and small objects. This accelerometer incorporates an internal hybrid signal conditioner in a two-wire system, which transmits its low impedance voltage output through the same cable that supplies the required 4 mA constant current power. Its light weight (0.2 gm) effectively eliminates mass loading effects. The unit features a single terminal for output connections.

Model 8510B

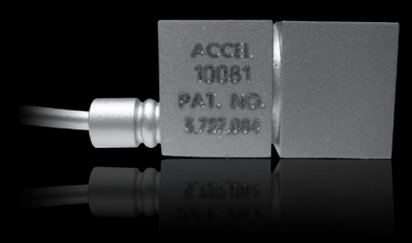
The Endevco® model 8510B is a rugged, miniature, high sensitivity piezoresistive pressure transducer. It has a 10-32 mounting thread, 0.15-inch (3.8 mm) face diameter and is available in ranges from 1 psi to 2000 psi. Its high sensitivity combined with high resonance makes it ideal for measuring dynamic pressure. Endevco pressure transducers feature a four-active arm strain gage bridge diffused into a unique sculptured silicon diaphragm for maximum sensitivity and wideband frequency response. Self-contained hybrid temperature compensation provides stable performance over the temperature range of 0°F to 200°F (-18°C to +93°C).

Model 2221F

The Endevco® model 2221F piezoelectric accelerometer is designed specifically for high temperature vibration measurement on small structures and objects. The unit is hermetically sealed for use in extreme environment and to ensure long term stability. Its light weight (11 gm) effectively minimizes mass loading effects. The model 2221F features Endevco's Piezite® type P-8 crystal element, operating in annular shear mode, which exhibits excellent output sensitivity stability over time. This piezoelectric accelerometer self generates its high impedance output and requires no external power for operation.

Model 2221F
Piezoelectric accelerometer
Space shuttle Discovery

Each of Discovery's leading wing edges are outfitted with 66 Endevco accelerometers to detect impacts and gauge their strength and location. The sensors are highly sensitive and take 20 000 readings per second. This new network of sensors running along the wings provides an electronic nervous system that gives engineers a valuable way to monitor their condition. If impacts occur during the mission, the shuttle engineers can pinpoint the location and check for damage with a camera. The model 2221F is a safety critical device for space shuttle Discovery's return to flight.

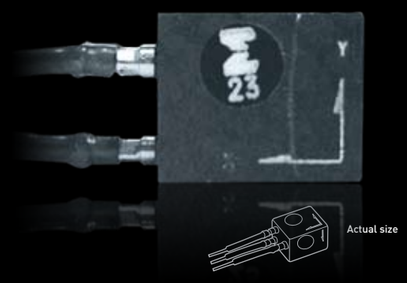


Model 6237M70

The Endevco® model 6237M70 piezoelectric accelerometer is designed specifically for use in extremely high temperature environments such as those experienced on aircraft gas turbines. This accelerometer is designed for continuous operation at +1200°F with long Mean Time Between Failure (MTBF). The small size and light weight of this accelerometer permits installation in cramped locations with minimal structural support. The accelerometer is a self-generating device that requires no external power source for operation.

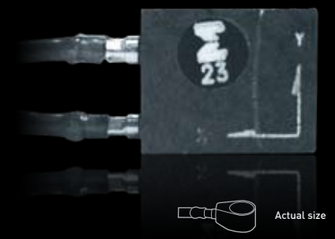
Model 6222S

The Endevco® model 6222S series piezoelectric accelerometers are designed for vibration measurement of gas turbine engines in aircraft and industrial applications. The unit features high sensitivity in a low profile package with a ruggedized connector and standard ARINC 3 point mounting. The 6222S is designed for continuous operation at +500°F with long Mean Time Between Failure (MTBF). The accelerometer is a self-generating device that requires no external power source for operation.



Model 23

The Endevco® model 23 is the world's smallest triaxial piezoelectric accelerometer, designed specifically for vibration measurement or drop testing in three orthogonal axes on small objects such as electronic devices, prototype models, and memory devices. Its light weight, (0.8 gm without the replaceable coaxial cables), effectively eliminates mass loading. All three low-noise cables exit from a single surface to allow mounting flexibility. The accelerometer is a self-generating device that requires no external power source for operation. Like the model 22, the model 23 features Endevco's Piezite® type P-8 crystal element, operating in radial shear mode. The model 23 is the preferred triaxial accelerometer for vibration analysis of small objects and provides superior reliability, even under shock loads.



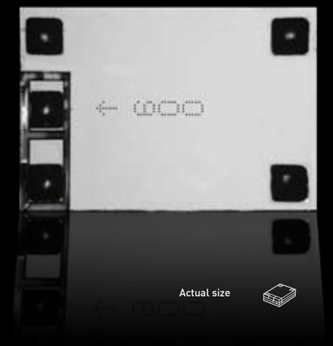
Model 22

The Endevco® model 22 Picomin™ is the world's smallest piezoelectric accelerometer, designed specifically for vibration measurement and drop testing on small objects such as scaled models, circuit boards, and disk drives. Its light weight, (0.14 gm) effectively eliminates mass loading effects. The accelerometer is a self-generating device that requires no external power source for operation and features Endevco's Piezite® type P-8 crystal element, operating in radial shear mode. The design and construction of Endevco's model 22 provides superior output sensitivity stability and reliability over time compared to competitive models.

Medical

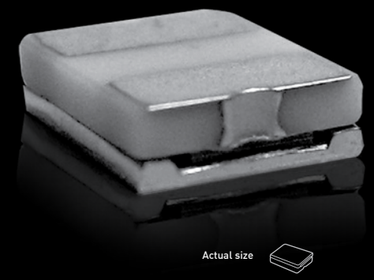
Medical applications present unique design and performance challenges. Examples include the rate responsive heart pacemaker and defibrillator, which are implantable devices that create an appropriate pacing rate and charge response proportional to the patient's level of physical activity and the heartbeat pattern. High reliability, repeatability and very small package size are key criteria for acceleration sensors in these applications. Since 1996, over 5 million Endevco accelerometers have been used in the majority of pacing devices manufactured globally, to provide the data needed to improve the quality of life for these patients.

Internal R&D advances in sensor manufacturing techniques and material properties have opened up several new markets for Endevco acceleration and pressure sensing devices, including external and implanted drug therapy systems, implanted pain management devices, and methods to accurately measure Traumatic Brain Injury (TBI). The ability to offer piezoelectric, self generating sensor technologies, and silicon-based MEMS sensor technologies, places Endevco in a market leading position as new medical procedures evolve which require sensor enabled solutions.



Model 40366

NEW PRODUCT! The Endevco® model 40366 SMT sensor is a hermetically sealed, surface mountable, variable capacitance MEMS device, configured as a three-terminal half-bridge. The sensor has a +/- 2 g full scale range for measurement of fractional-g accelerations in the presence of earth's gravity, and is designed to have low transverse sensitivity. Typical applications include implantable medical devices and high end printed circuit board environment monitoring where DC response is desired.



Model 12M1A

The Endevco® model 12M1A is a piezoelectric accelerometer engineered for easy integration into standard hybrid or SMT electronic packages. The unit exhibits low base strain sensitivity, low pyroelectric output, and extremely high charge output in a very small envelope. The device is widely used in a variety of applications where its self generating power capabilities are required, including implantable medical devices and remote structural monitoring in heavy construction projects.

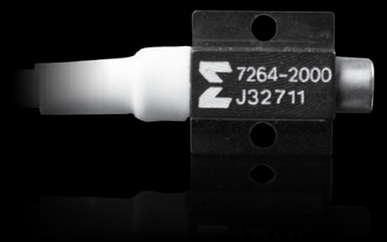
Model 32394

The Endevco® model 32394 is a unique MEMS pressure sensor designed for applications where high sensitivity, overpressure capability and linearity are required in an extremely small package. The unit is available in a 0-15 psia configuration and delivers a nominal 200 mV output when powered with 5 VDC. The unit can be flip chip mounted using either conductive epoxy or solder. Applications for the sensor include implantable medical devices for measuring hemodynamic conditions, and implantable catheters.

Automotive

For 30 years, Endevco's piezoresistive accelerometers have been the industry standard for safety testing with use on vehicle barrier and sled testing and in anthropomorphic test dummies. Endevco piezoelectric, Isotron® and variable capacitance accelerometers are used in vehicle dynamic testing of engines, exhaust systems, components and suspension systems due to their micro-miniature size, high temperature performance and rugged construction. Endevco pressure transducers are used in the automotive testing systems such as Anti-lock Brake Systems (ABS), transmissions, fuel and oil systems and air bag inflators. Using advanced silicon micromachined sensors, these pressure transducers feature a wide frequency response and a high level of output in a miniature size, making it ideal for use in places traditionally inaccessible due to size.

Endevco accelerometers are the premier transducers that were used to create the original specifications from NHTSA and other governing agencies. Continuing in technical leadership, Endevco crash sensors meet or exceed the requirements of SAE specifications J211 and J2570.



Model 7264

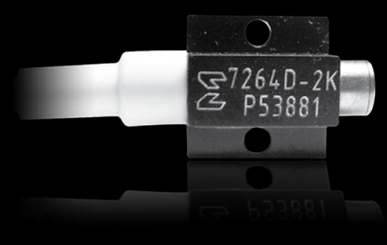
The Endevco® model 7264 series is a family of very low mass piezoresistive accelerometers weighing only 1 gram. They are designed for flutter testing, modal testing, bio-dynamic measurements and similar applications that require minimum mass loading and broad frequency response. They may also be used for shock testing of lightweight systems or structures and meet SAEJ211 specifications for anthropomorphic dummy instrumentation. High accuracy versions and a wide variety of cabling and connector options are available.

Model 7264B

The Endevco® model 7264B is an improvement over the 7264. This model utilizes an advanced micromachined sensor which includes integral mechanical stops. This monolithic sensor offers improved ruggedness, stability, and reliability over previous designs. The Model 7264B has minimum damping, thereby producing no phase shift over the useful frequency range. Model 7264B also meets SAEJ211 specifications for instrumentation for impact testing and SAEJ2570 specifications for anthropomorphic test device transducers. High accuracy versions and a wide variety of cabling and connector options are available.

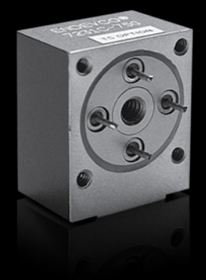
Model 7264C

The Endevco® model 7264C is an improvement over the 7264. It is a direct replacement for the Endevco model 7264 in that the location of the center of seismic mass is the same. This model utilizes an advanced micromachined sensor which includes integral mechanical stops. Model 7264C also meets SAEJ211 specifications for instrumentation for impact testing and SAEJ2570 specifications for anthropomorphic test device transducers. High accuracy versions and a wide variety of cabling and connector options are available.



Model 7264D

NEW PRODUCT! The Endevco® model 7264D is a significant improvement over other sensors of this type. It has a high resonant frequency of over 40,000Hz to allow it to respond to a wider range of frequencies without being influenced by spurious noise. It is a direct replacement for the Endevco model 7264 and 7264C in that the location of the center of seismic mass is the same. Model 7264D also meets SAEJ211 specifications for instrumentation for impact testing and the SAEJ2570 specification for anthropomorphic test device transducers. The model 7264D offers excellent linearity, standard low transverse sensitivity and low ZMO error. A wide variety of cabling and connector options are available.



Model 7231C

The Endevco® model 7231C-750 is a rugged, undamped, medium g level piezoresistive accelerometer designed specifically for automotive crash test studies. This transducer has become the FMVSS 208 standard for anthropomorphic dummy response studies, providing measurements of head, chest, pelvis and other body accelerations in studies for safer vehicle and restraint design. High accuracy versions and a wide variety of cabling and connector options are available.

Model 7265A

The Endevco® model 7265A series, is a family of very low mass, piezoresistive accelerometers designed for flutter testing, biomedical motion studies, and similar applications requiring high sensitivity, good low frequency response and minimum mass loading. This configuration provides a low impedance output. For applications requiring a removable cable, the 7265AM3 is offered.

Model 7285

The Endevco® model 7285 is a low cost solution for crash testing when sensors are required to be placed in known “crush zones”. This sensor is very low mass and has excellent output and performance that is well suited to this application. It is designed for adhesive mounting on any of its four sides. It is packaged ten units per box for most efficient usage. This sensor utilizes decades of experience in design and manufacturing to provide a reliable unit with very high value.

Model 7264 series

Piezoresistive accelerometer

Automakers worldwide

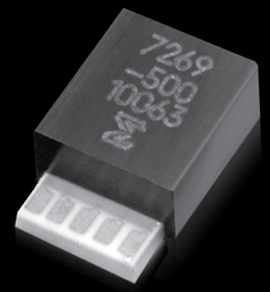
Starting in the mid-1970’s, Endevco accelerometers have been used for automotive safety testing for development and certification to government standards. As the success of the US car companies grew in safety ratings, the rest of the world learned to adopt the same methods, standards, and highly reliable test equipment. Today, automakers throughout the world recognize Endevco 7264 series accelerometers as the gold standard for crash testing, whether used for ATD (crash dummy) measurements or on-vehicle sensing. They have come to rely on the high standards set by the leader in the industry.

Model 7267A

The Endevco® model 7267A is a replaceable-element triaxial accelerometer designed to measure acceleration in three mutually-perpendicular axes. Although designed for installation in anthropomorphic test dummies used in automotive crash studies, it has application wherever triaxial accelerometers are used for steady state or long duration pulse measurements. The model 7267A uses Endevco’s Piezite® piezoresistive elements in half-bridge configuration.

Model 7268C

The Endevco® model 7268C is a miniature triaxial accelerometer designed for crash testing, flutter testing and other applications that require minimal mass loading and a broad frequency response. This accelerometer meets SAEJ211 specifications for anthropomorphic dummy instrumentation. The 7268C uses three advanced micromachined sensors with integral mechanical stops for ruggedness and years of reliable service. A single integral cable carries the 12 wires to the sensor modules.



Model 7269

The Endevco® model 7269 is a sub-miniature, triaxial accelerometer for measuring three orthogonal axes simultaneously. Because of the small size and light weight, the 7269 is ideal for biomechanics research such as the study of head injuries. Applications include testing of ejection seats, heads-up displays and sports helmets. Weighing only 0.4 grams, the 7269 can be used for making measurements on light structures with a minimum of mass loading. The sensors include integral mechanical stops and internal diodes are provided for electrostatic discharge protection.

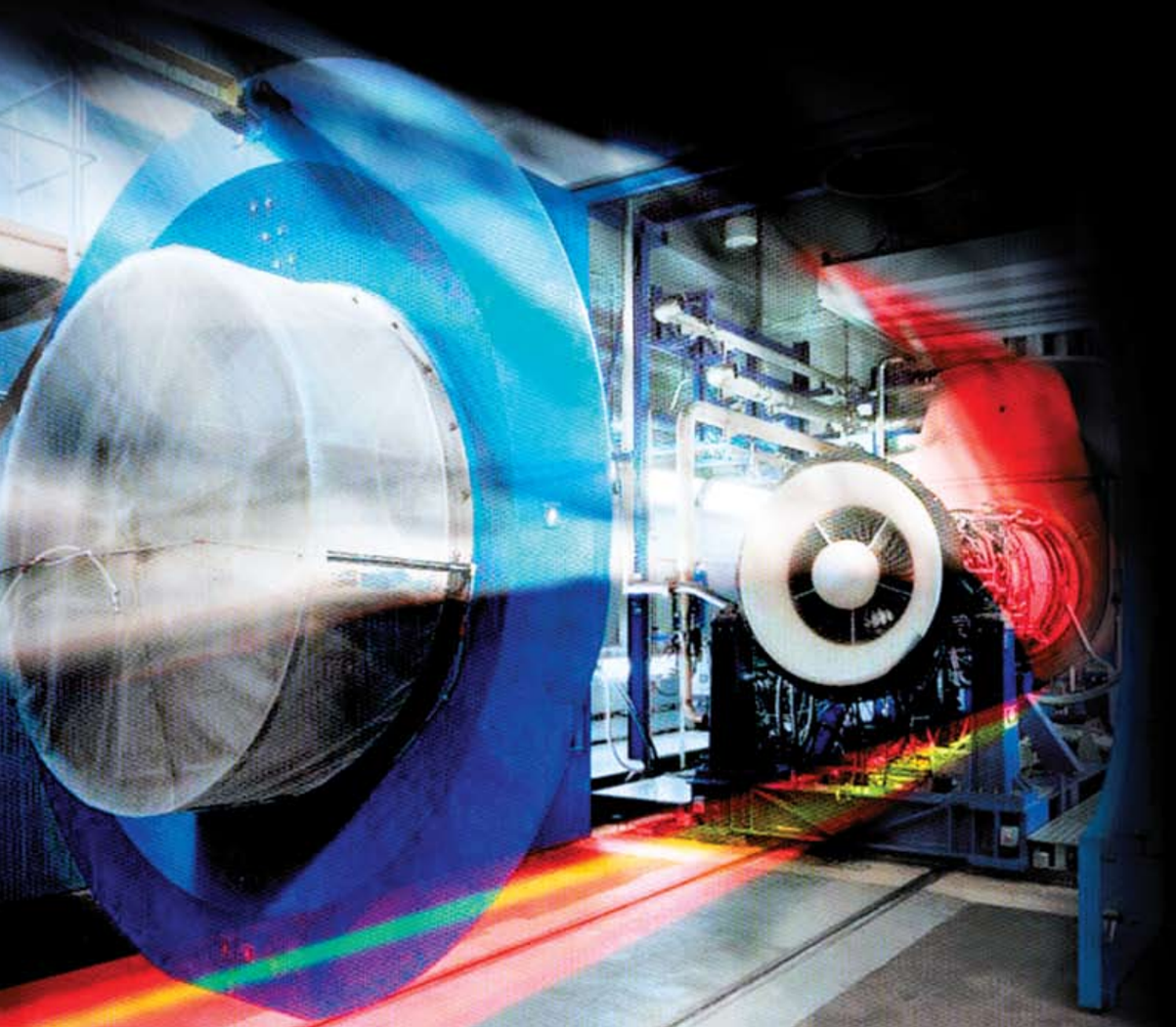
Model 7302BM4

The Endevco® model 7302BM4 angular accelerometer is designed to provide accurate measurements of rotational acceleration. The sensing device consists of a temperature compensated piezoresistive accelerometer, uniquely designed to reject cross axis angular and linear accelerations. The 7302BM4 accelerometer is designed for a variety of automotive, industrial, and aerospace applications. The accelerometer is ideal for dynamic automotive applications including crash testing, suspension and chassis vibration monitoring, and rollover detection. The accelerometer is uniquely qualified for use in WorldSID side impact dummies to measure rotational body accelerations experienced under impact.

Test and measurement

Since 1947, Endevco has been the most trusted provider of dynamic measurement solutions in the field of research, development, test and evaluation. Whether you are measuring mode shapes of disk drive components, skin surface pressures of an experimental aircraft, shock testing to improve product durability or the vibration level of a new hybrid energy system, we offer the most comprehensive and reliable line of transducers, cables, electronics and accessories.

Engineers and scientists throughout the world look to Endevco to provide the highest performance, reliability and quality sensing solutions available. Our broad standard product offering and our capabilities to provide custom solutions is unmatched and we are dedicated to providing our valued customers with the most advanced solutions and services available.



Model 2222C

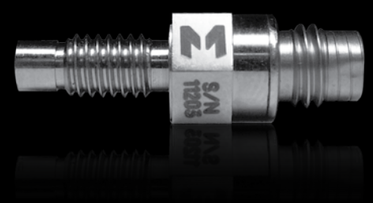
The Endevco® model 2222C is the world's most popular miniature piezoelectric accelerometer for vibration measurement on mini-structures and small objects. Its light weight (0.5 gm without the low-noise replaceable cable) effectively minimizes mass loading. The accelerometer is a self-generating device that requires no external power source for operation. Endevco signal conditioner models 133, 2775A or remote charge converter 2771C are recommended for use with this high impedance accelerometer.

Model 35A

The Endevco® model 35A is an extremely small, adhesive mounted piezoelectric accelerometer with integral electronics, designed specifically for measuring vibration in three orthogonal axes on very small objects. The unit weighs only 1.1 gm, reducing unwanted mass-loading effects. The model 35A is ideal for measuring vibration in scaled models, small electronic components, and biomedical research.

Model 67

New product! The Endevco model 67 is the industry's first miniature, 100 mV/g, high-temp IEPE triaxial accelerometer for environments up to 175°C (347˚F). The unit features welded titanium construction for low weight and a complete seal against the environment. The model 67 uses an Endevco Piezite Type P-8 crystal element operating in the annular shear mode to achieve low base strain sensitivity and excellent output stability over time. It incorporates internal hybrid signal conditioners to achieve a low noise floor.



Model 8530B

The Endevco® model 8530B is a miniature, high sensitivity piezoresistive pressure transducer for measuring absolute pressure. The volume behind the diaphragm is evacuated and glass sealed to provide an absolute pressure reference. Full scale output is 300 mV with high overload capability and high frequency response. It is available in ranges from 200 psia to 1000 psia. Endevco also offers the model 8530C for lower pressure ranges.

Model 2775B

The Endevco® model 2775B is a bench-top, single-channel PE/Isotron® amplifier that accepts inputs from PE, Isotron® or remote charge converters (see model 2771C below), with a wide full scale input range covering from 0.01 to 100 000 EU. The unit provides three standard outputs: an AC output voltage proportional to input; a DC output voltage proportional to input and a Servo output that provides a constant output, typically used in servo or shaker control loops/ systems. The 2775B also accepts two optional input filter modules including a plug-in 4-pole, Butterworth filter that is jumper-configurable for high pass, low pass or band pass filtering and a filter integrator module that provides capability for single or double integration of the input vibration signal. The unit is designed to operate from input power sources of 90-240 VAC/50 Hz to 400 Hz.

Model 2771C

NEW PRODUCT! The Endevco® model 2771C series remote charge converter (RCC) is the lowest noise RCC available. With up to one-fifth the noise of competitive models it's design features a two-wire, single-ended design to transform a piezoelectric transducer's high impedance charge output to a low impedance voltage proportional to the transducer's output charge. The signal output from the RCC is less susceptible to noise pick-up because of its low impedance voltage. The 2771C is available in fixed gains of 0.1 mV/pC, 1.0 mV/ pC, and 10 mV/pC. The 2771C is also radiation hardened to 1 mega rad and supports IEEE P1451.4 TEDS (transducer electronic data sheet); a memory chip that allows storage and recall of the following sensor data: sensitivity, model number, serial number, manufacturer, date of last calibration and sensor location.

Model 6634C

The Endevco® model 6634C vibration amplifier is a widely used microprocessor-based instrument designed to condition and display vibration data from rotating machinery. The instrument accepts inputs from single-ended, differential PE or Isotron® accelerometers, velocity coils, or remote charge converters. Full scale AC and DC output ranges are programmable in user selected engineering units to represent acceleration, velocity, or displacement. Programming of the unit is accomplished from the front panel keyboard or optional RS-232 computer interface. Up to ten different setups can be stored and recalled from the non-volatile memory. There are two TTL compatible latched alarm outputs provided for warning and alert.

Model 4999

NEW PRODUCT! The Endevco® model 4999 low-pass filter signal conditioner is a low-noise, 16-channel signal conditioner for use with integral electronic piezoelectric, voltage transducers and Remote Charge Convertors (RCC). Each channel provides a constant current supply and a selectable X1 or X10 gain setting. The unique feature of this unit is individual channel ground isolation (eliminates ground loops of various types of sensors) and very low-noise.

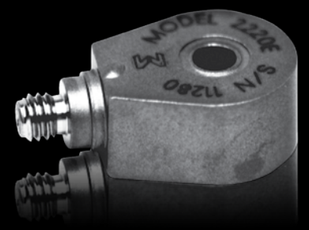
Rear panel BNC Isotron®/IEPE, voltage inputs and outputs.

Model 133

The Endevco® model 133 is a three-channel, piezoelectric and Isotron® signal conditioner that can be programmed manually or through RS-232 and features three LEDs that provide fault status for open/short at the Isotron® inputs. In the normal mode, the LED display indicates the RMS valve (±10%) of the signal present at the output of the selected channel. In the programming mode, the unit is ready for manual programming of existing channel setups. The rear panel contains an RJ-11 connector for the RS-232 serial communications port, an input power connector, and on a per-channel basis, a BNC output connector, a 10-32 input connector for the PE input, and a BNC connector for the Isotron® input. The standard unit is powered by 90-264 VAC, 50/60 Hz.

Model 136

The Endevco® model 136 is a three-channel, DC amplifier that can be programmed manually or through RS-232 and features three LEDs used as fault status indicators for the auto zero function. The model 136 also has two modes of operation like the model 133, normal and programming/setup. The rear panel contains (on a per-channel basis) a BNC output connector and a 9-pin "D" input connector. The unit also features an RS-232 and input power connector.



Model 2220E

The Endevco® model 2220E is the most trusted miniature piezoelectric accelerometer for high temperature (+260˚C) vibration measurement on mini-structures and small objects. The unit is also hermetically sealed and can be through-hole or adhesively mounted which makes it ideal for use in extreme environments up to 5000 g shock. The model 2220E features Endevco's Piezite® type P-8 crystal elements operating in annular shear mode. Its light weight (3.1 gm) effectively eliminates mass loading and the superior workmanship of each unit provides the most reliable measurements available.

Model 2226C

The Endevco® model 2226C is a miniature, adhesive mounted PE accelerometer designed specifically for vibration measurement on small structures and objects. Because of its light weight and excellent reliability it is preferred for applications such as small package drop testing, modal analysis of medium structures and general vibration analysis. The transducer features a top-mounted 10-32 receptacle for installation convenience in limited space. The model 2226C features Endevco's Piezite® type P-8 crystal elements, operating in annular shear mode which provides the most reliable output sensitivity and durability available. The model 2226C has become a Test Essential sensor within the test and measurement community.

Model 35A

Miniature triaxial Isotron accelerometer

Vibration analysis

Researchers throughout the world have called upon Endevco to solve their most basic and most challenging measurement needs. At Claremont McKenna College in Claremont, California researcher Tyler Benner selected Endevco's model 35A to study the induced vibrations in an olympic recurve bow to optimize the tiller setting. In the study Tyler noted "The 35A's 5 mv/g output and scant 1.1 gram weight was the perfect accelerometer for this study". The miniature size of the 35A also allowed them to study the natural frequencies of the bow materials and how this could impact both material selection and design.

Model 8515

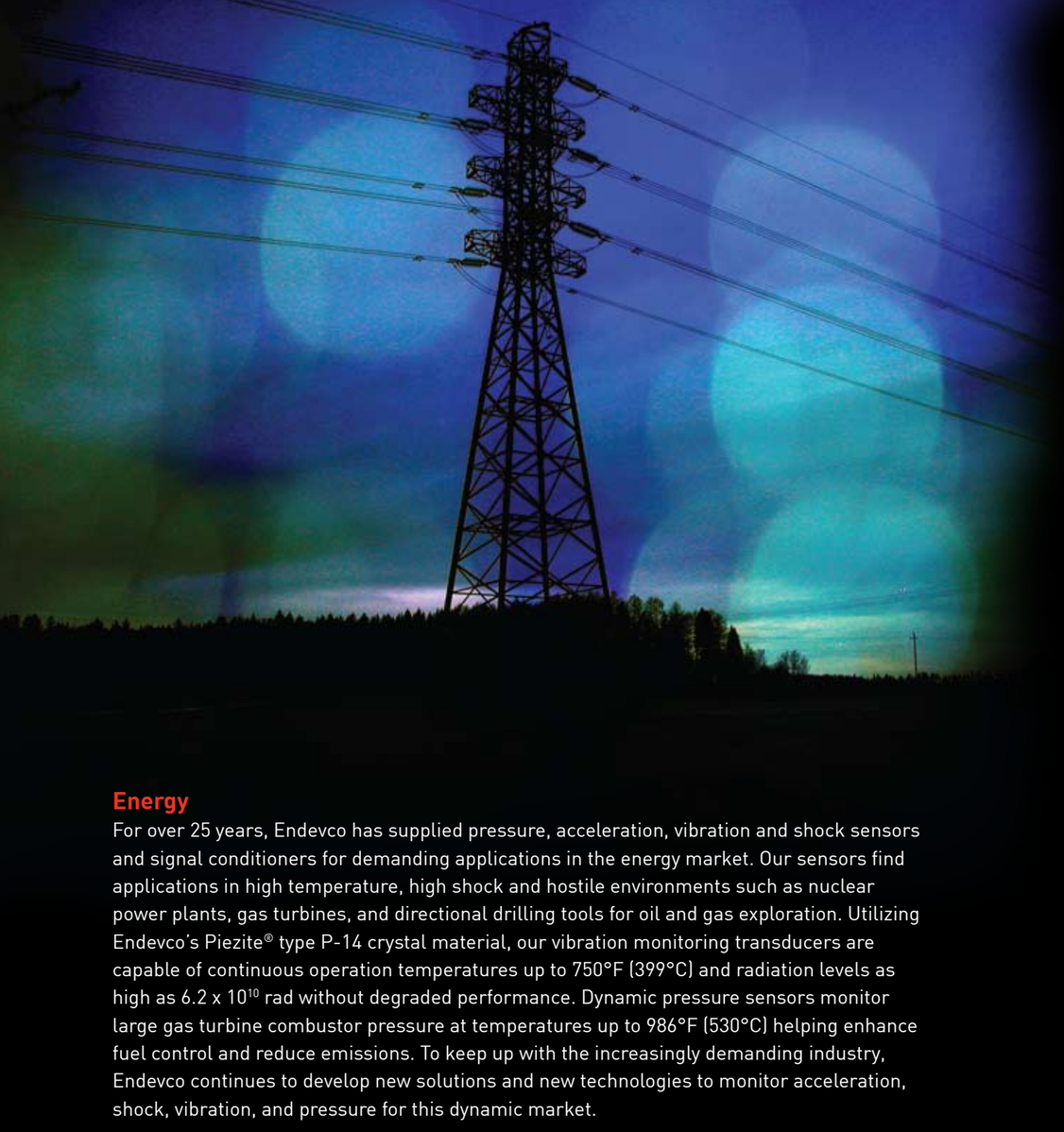
The Endevco(r) Model 8515C is a rugged, miniature, high sensitivity piezoresistive pressure transducer available in 15 and 50 psia full scale ranges. It is surface-mounted and measures 0.030 inch thin by 0.250 inch diameter (0.76mm x 6.3mm). Full scale output is 200 mV with high overload capability, high frequency response, very low base strain sensitivity and excellent temperature performance.

Model 3090C

The Endevco® model 3090C series cable has been the standard for high reliability, low noise soft line coaxial cable for decades. It is a premium general purpose cable designed specifically for use with piezoelectric accelerometers in challenging environments. This fused Teflon® jacketed cable has applications where maximum reliability is essential and where repeated usage is important. The 3090C features stainless steel connectors (center-pin fused into glass insulator, 10-32 threaded nut), a stranded-wire center connector for maximum flexibility and a high cable pullout tensile strength for increased ruggedness and long-term life. The 3090C is the best value cable to assure the highest reliability and maximum durability.

Model 7703A

The Endevco® model 7703A Isoshear series of piezoelectric accelerometers is designed for general vibration measurement or modal analysis of structures and medium to large objects. This hermetically sealed device is extremely stable and insensitive to such environmental inputs as base bending and thermal transients, has been radiation tested up to 10^8 rads and is capable of measurement up to +550°F (+288°C). The model 7703A family features Endevco's Piezite® type P-8 crystal element operating in shear mode and requires no external power source for operation. Signal ground is isolated from the outer case of the unit which features a 10-32 side connector. The 7703 has become a reference standard within the vibration analysis community.



Energy

For over 25 years, Endevco has supplied pressure, acceleration, vibration and shock sensors and signal conditioners for demanding applications in the energy market. Our sensors find applications in high temperature, high shock and hostile environments such as nuclear power plants, gas turbines, and directional drilling tools for oil and gas exploration. Utilizing Endevco's Piezite® type P-14 crystal material, our vibration monitoring transducers are capable of continuous operation temperatures up to 750°F (399°C) and radiation levels as high as 6.2 x 10^{10} rad without degraded performance. Dynamic pressure sensors monitor large gas turbine combustor pressure at temperatures up to 986°F (530°C) helping enhance fuel control and reduce emissions. To keep up with the increasingly demanding industry, Endevco continues to develop new solutions and new technologies to monitor acceleration, shock, vibration, and pressure for this dynamic market.

Land based gas turbines

Model 522

The Endevco® 522 family of dynamic pressure sensors offers high temperature (1000°F/540°C) and frequency response to 45 kHz. They are ideal for high temperature dynamic pressure environments such as combustion chambers, steam pipes or turbines, and chemical reactors. Sensors are all inconel construction with differential and single ended output models available. Hard line cable or flexible high temperature cables are provided depending on model selected.

Model 6917

The Endevco® 6917 family of cables offers outstanding versatility for hot environments that are typically found in gas turbine enclosures and nuclear power plants. They are available with a variety of interface connectors, both military and commercial. Stainless steel or fiberglass shielding can be added for additional heat protection at the hottest end of the cable. Cables are rated to 500°F/260°C. Consult the factory for specific configurations.

Model 6240M10

The Endevco® model 6240M10 piezoelectric high temperature accelerometer is the highest temperature sensor available. This accelerometer is rated at 1200°F/650°C for continuous operation, and to 1400°F/760°C for intermittent service. The small size is ideal for tight locations. A hard line, high temperature cable is installed with the unit to provide a complete hermetically sealed sensor. The sensor offers high sensitivity for low level vibration analysis.

Nuclear

Model 2273A

The Endevco® model 2273A accelerometer is a high temperature (750°F/399°C) radiation hardened piezoelectric vibration sensor. The unit is rated to 6.2x10^{10} rad for gamma exposure and 3.7x10^{18} N/cm2 for neutron flux exposure. Also available are the 2273AM1 and 2273AM20 used specifically in loose parts monitoring systems. Top or side mount connector versions are available.

Model 7703A

The Endevco® model 7703A Isoshear series of piezoelectric accelerometers are designed for general vibration measurement or modal analysis of structures and medium to large objects. This hermetically sealed device is extremely stable and insensitive to such environmental inputs as base bending and thermal transients, has been radiation tested up to 10^8 rads and is capable of measurement up to +550°F (+288°C). The model 7703A family features Endevco's Piezite® type P-8 crystal element operating in shear mode and requires no external power source for operation. Signal ground is isolated from the outer case of the unit which features a 10-32 side connector. The 7703 has become a reference standard within the vibration analysis community.

Model 2771B

The Endevco® model 2771B family of remote charge converters are a low noise, two wire, single ended, compact in line charge amplifier to convert piezoelectric charge output to a proportional voltage output at fixed gains of 0.1, 1.0 or 10 mV/pC. The device supports IEEE 1451.4 TEDs and is designed to allow high impedance piezoelectric transducers to be used with many popular signal analyzers and signal conditioners that feature a built in constant current source (IEPE). The standard 2771B unit offers a 10-32 interface with a female BNC connector and the BM1 version terminates to a male BNC.

Model 8511

Piezoresitive MEMS pressure sensor

Oil and gas exploration

Endevco is the leading supplier of sensing solutions for high pressure, temperature and vibration measurement for oil and gas exploration applications up to 30 000 psi. Products like our model 8511, with pressure ranges from 5K to 30K psi, deliver excellent linearity, high shock resistance and stability up to 200˚F. Endevco's high temperature and shock and vibration measurement solutions provide the highest performance and reliability available in the smallest footprint which make them ideal for acoustical monitoring, impact force and directional change detection and tool vibration during drilling operations. In harsh environments, nobody delivers measurement performance like Endevco.

Model 2771C

NEW PRODUCT! The Endevco® model 2771C series remote charge converter (RCC) is the lowest noise RCC available. With up to one-fifth the noise of competitive models it's design features a two-wire, single-ended design to transform a piezoelectric transducer's high impedance charge output to a low impedance voltage proportional to the transducer's output charge. The signal output from the RCC is less susceptible to noise pick-up because of its low impedance voltage. The 2771C is available in fixed gains of 0.1 mV/pC, 1.0 mV/pC, and 10 mV/pC. The 2771C is also radiation hardened to 1 mega rad and supports IEEE P1451.4 TEDS (transducer electronic data sheet); a memory chip that allows storage and recall of the following sensor data: sensitivity, model number, serial number, manufacturer, date of last calibration and sensor location.

Model 3075M6

The Endevco® model 3075M6 cable assembly offers high temperature capability rated to 900°F/480°C. The assembly offers a 304 stainless steel outer jacket hermetically sealed with glass fired 10-32 connectors. The cable is ideal for high humidity environments. The 3075M6 has an additional fiberglass sleeving to prevent inadvertent grounding.

Oil and gas

Model 7704A

The Endevco® model 7704A high temperature accelerometer (550°F/288°C) is an excellent general vibration sensor for measurement on structures and objects. The unit offers a hermetically sealed design for harsh environments. The unit is designed for low base strain and thermal transients.

Model 65HT-05

New product! The Endevco model 65HT-05 triaxial accelerometer is a miniature, high-temperature device packaged in a 10-mm cube of welded titanium construction and weighs only 5 grams. Using the latest technology in high-temperature components and processes, its micro-electronic circuits are designed and built specifically to operate up to +175°C with a sensitivity of 0.5 mV/g.

Selecting accelerometers for test applications

A wide variety of accelerometers have been developed for measuring vibration, shock, and inertial motion. We will highlight considerations that may affect your sensor selection.

An accelerometer senses motion and produces an electrical output proportional to the magnitude, frequency and amplitude of the input. There are several types of accelerometers—piezoelectric, Isotron® or piezoelectric with internal electronics, piezoresistive and variable-capacitance or VC—each differing in performance, power requirements, uses and signal-conditioning characteristics.

Piezoelectric (PE) accelerometer

The piezoelectric (PE) accelerometer uses a simple spring-mass principle in which a force is generated that relates to amplitude and frequency. This force is applied to the PE element, which develops an electrical charge proportional to the mechanical motion. Different configurations of PE elements are used in accelerometers for specific applications.

Advantages of PE sensors

› The single-ended compression type is optimum for low-level measurements because of the high sensitivity that can be achieved by stacking multiple crystals and connecting them in parallel.

› The shear design allows construction of small, lightweight sensors suitable for monitoring acceleration of small components. A key advantage of the shear design is the isolation of the sensing element from the base, which provides excellent protection from base strain and temperature transients.

› PE accelerometers frequently are used where an extremely rugged high temperature device is required. These devices can measure a wide range of temperatures, from cryogenics to the extreme heat environments of gas-turbine engines or nuclear reactors.

› Gain also can be optimized so you can substitute a smaller accelerometer for a given application. The upper end of the frequency response can be tailored with electronic filtering to match the expected measurement range and suppress natural mechanical resonances. The low-frequency response typically is set at 1 Hz for PE accelerometers and can be pushed close to 50 KHz.

› PE accelerometers are packaged from micro-miniature for small circuit board or hard disk drive testing to larger sizes used in seismic or turbofan applications.

Isotron® accelerometer

The trade name Isotron refers to a piezoelectric (PE) accelerometer with internal electronics (IEPE) to convert charge to a low impedance voltage output. Its temperature response is somewhat limited due to the on-board electronics. The accelerometer's internal electronics result in increased susceptibility to electrostatic discharge (ESD). The selection of this type of accelerometer is primarily when environmental conditions permit its use. Uses include environmental testing, industrial applications, many general purpose applications and shock testing.

Piezoresistive (PR) accelerometer

More recent designs of the PR strain gauge accelerometer consist of a rugged monolithic assembly with solid-state silicon resistors that change resistance in proportion to the applied mechanical stress.

Advantages of PR sensors

› The microfabricated monolithic sensor exhibits a high sensitivity with an excellent signal-to-noise ratio and a typical temperature range of -20°C to 120°C.

› The PR accelerometer features a DC response that makes it useful for measuring long duration pulses such as those experienced in automotive crash test studies and munitions blast testing.

Variable capacitance (VC) accelerometer

The variable capacitance (VC) accelerometer has a sensor element that is sandwiched between a lid and a base and electrostatically bonded to form a parallel-plate capacitor. This accelerometer features DC response, stable damping to give good frequency coverage, and rugged construction. Integral electronics with DC excitation provide a high-level, low-impedance output signal stable from -20°C to 120°C. This sensor is designed for low-g measurement, but can also withstand high g shocks, and is suitable for trajectory monitoring, structural evaluation, flutter testing, automotive suspension, and brake testing.

Sensors with on-board memory

Commonly referred to as smart sensors, accelerometers with on-board memory provide an inherently improved signal-to-noise ratio. The key feature of these new sensors is conformance to the IEEE 1451.4 Transducer Electronic Data Sheet (TEDS) specification, which includes sensor-specific data.

Accelerometer performance characteristics

To obtain acceleration data that is meaningful for your application, you need to understand the performance characteristics of the accelerometers under consideration. There are several types of accelerometers and many designs within each category. The most critical trade-offs relate to sensitivity, weight, and frequency response.

› **Sensitivity**—High sensitivity results in a high signal-to-noise ratio. Interfering electrostatic and electromagnetic noise will be less bothersome than with a low-sensitivity device. This may bring two disadvantages: greater weight and a lower resonant frequency.

› **Mass loading**—Motion of the equipment being tested will be attenuated if the accelerometer's dynamic mass approaches the dynamic mass of the structure on which it is mounted. Consequently, a lightweight sensor must be used for accurate evaluation of low-mass elements.

› **Low-frequency response**—With a PE accelerometer, the low-frequency cutoff often is set at 1 Hz to 5 Hz to reject any pyroelectric output. Some models, however, extend the cutoff to near DC. The PR and VC accelerometers have DC response.

› **High-frequency response**—This is a function of the mechanical characteristics and the method used to attach the device. Most accelerometers exhibit an undamped single-degree-of-freedom response when securely mounted. Response is relatively flat to about 20% of the mounted resonant frequency. Correction factors can be derived for data obtained at higher frequencies. Electronic filtering can increase the flat response to 50% of the mounted resonant frequency.

› **Transverse sensitivity**—The sensor must not produce any significant response when motion is applied in the lateral axes. Sensitivity to lateral motion can be held to ‹5% of the normal sensitivity on an Endevco device.

› **Amplitude linearity**—PE accelerometers have a predictable nonlinearity that can be expressed as a percentage increase in sensitivity as the acceleration increases, such as 1% / 500 g. The upper limit can be determined and expressed for each model. PR and VC sensors are extremely linear and specified for the combination of nonlinearity, hysteresis, and non-repeatability.

› **Temperature sensitivity**—Accelerometer sensitivity varies with temperature. Many accelerometers are optimized for stable sensitivity over a wide temperature range. Typically, the higher the temperature, the higher the degree of error unless compensated.

› **Transient temperature effects**—Compression mode PE and Isotron accelerometers can produce an output with temperature changes. This problem has been virtually eliminated with the advent of shear mode accelerometers (most Endevco accelerometers are shear mode types). Thermal transient errors are at very low frequencies and often go undetected. PR and VC devices have no significant response to temperature changes.

› **Strain effects**—The test item may flex, stretch, or bend at the point where the accelerometer is mounted, causing it to produce an erroneous output. Isolation can be improved by use of insulated mounting studs or adhesive mounting adapters. Shear accelerometers are much less sensitive to such errors than conventional compression types.

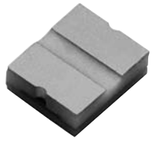
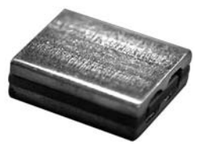
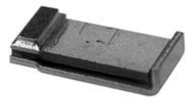
› **Dirty environments**—Every component in the measurement chain must be kept clean and dry to achieve optimum performance. PE accelerometers require more care because they are very sensitive to external contamination due to their high output impedance.

Piezoelectric **accelerometers**

Piezoelectric accelerometers are high impedance charge mode sensors that are known for having a high MTBF. They are used with either a charge amplifier or in-line charge converter, like our 133 or 2771 products. These designs are ideal for use in extreme temperatures or in applications where the actual acceleration range is unknown. Endevco offers the largest selection of accelerometers in a variety of sizes and configurations to meet your testing needs. Special purpose units are available for flight, extreme temperatures and radiation environments.




Model number	23 TE -R	2220E TE -R	2221D TE	2221F TE -R
Description	World's smallest Triaxial. Ideal for testing screening circuit boards and components	Industry standard. Lightweight. Ground isolated.	Low profile Light weight 360° cable orientation	High temperature 360° cable orientation
Sensitivity Typical	0.4 pC/g	3.0 pC/g	17 pC/g	10 pC/g
Weight gram	0.8	3.1	12	11
Sinusoidal limit g	1000	1000	1000	1000
Shock limit g	10 000	5000	5000	3000
Frequency response ±1 dB Hz	3-12 000 (Z)	1-12 000	0.1-10 000	0.1-12 000
Minimum temperature °C(°F)	-73(-100)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	150(300)	260(500)	177(350)	260(500)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	Yes	No	Yes
Mounting method	Adhesive	Screw	Screw	Screw


Model number	12M1A	12M9	12M23	22 TE -R
Description	Miniature high impedance PE accelerometer developed specifically for OEM applications Surface mount	SMT installation OEM applications Rugged Use in hybrid assemblies	SMT installation. OEM applications	World's smallest accelerometer. Ideal for testing or screening circuit boards and components
Sensitivity Typical	1.9 pC/g	1.5 pC/g	1.8 pC/g	0.4 pC/g
Weight gram	0.12	0.15	0.07	0.14
Sinusoidal limit g	500	500	500	2500
Shock limit g	1000	4000	1000	10 000
Frequency response ±1 dB Hz	1-3000	1- ›100	1-3000	3-12 000
Minimum temperature °C(°F)	-65(85)	-65(85)	-65(-302)	-73(-100)
Maximum temperature °C(°F)	150(302)	125(257)	150(302)	149(300)
Signal/ground isolation	No	No	No	Yes
Hermetic seal	No	No	No	No
Mounting method	Conductive adhesive/Solder	Conductive adhesive/Solder	Conductive adhesive/Solder	Adhesive

Model number	2222C TE -R	2222D TE -R	2223D	2224C
Description	Industry standard Light weight (0.5 gm) Adhesive mounting Ground isolated	Use on small structures and PC boards. Use for temperature cycling.	Light weight triaxial. Ground isolated.	General purpose vibration measurements Small size
Sensitivity Typical	1.4 pC/g	1.1 pC/g	12 pC/g	12 pC/g
Weight gram	0.5	1.0	41	16
Sinusoidal limit g	1000	1000	1000	1000
Shock limit g	10 000	10 000	2000	2000
Frequency response ±1 dB Hz	1-10 000	0.1-12 000	1-5000	0.1-10 000
Minimum temperature °C(°F)	-73(-100)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	177(350)	175(347)	177(350)	177(350)
Signal/ground isolation	Yes	No	Yes	No
Hermetic seal	No	Yes	No	No
Mounting method	Adhesive	Adhesive	Screw	Stud

TE = Test Essential product. See page 8 for details
-R = -R replacement sensor available. See page 10 for details

Model number	2225 TE	2225M5A	2226C TE -R	2228C TE -R
Description	High g shock Industry standard for shock accelerometers	High g shock to 100 k	Miniature Lightweight Use on small structures	Triaxial Ground isolated
Sensitivity Typical	0.75 pC/g	.025 pC/g	2.8 pC/g	2.8 pC/g
Weight gram	13	13	2.8	15
Sinusoidal limit g	10 000	10 000	1000	1000
Shock limit g	20 000	100 000	2000	2000
Frequency response ±1 dB Hz	1-10 000	1-10 000	0.1-7000	10-6000
Minimum temperature °C(°F)	-55(-67)	-18(-0)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	177(350)	66(150)	177(350)	177(350)
Signal/ground isolation	No	No	No	Yes
Hermetic seal	No	No	No	No
Mounting method	Stud	Stud	Adhesive	Screw

Model number	2229C	2230E -R	2230EM1	2248 TE
Description	Small, lightweight Stud mounted Ground isolated	Triaxial High temperature Lightweight	Triaxial High temperature Lightweight	Radiation hardened. Small size Lightweight
Sensitivity Typical	2.8 pC/g	3 pC/g	3 pC/g	3.0 pC/g
Weight gram	4.9	17	22.5	13
Sinusoidal limit g	1000	1000	1000	500
Shock limit g	2000	2000	2000	3000
Frequency response ±1 dB Hz	0.1-7000	1-10 000	1-10 000	1-8000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-54(-65)
Maximum temperature °C(°F)	177(350)	260(500)	260(500)	482(900)
Signal/ground isolation	Yes	No	No	No
Hermetic seal	No	Yes	Yes	Yes
Mounting method	Stud	Adhesive	Screw	Screw

Model number	2248M1 TE	2270	2270M8	2271A TE -R
Description	Miniature, high temperature Ideal for engine and gas turbine testing Radiation hardened	Back to back calibration standard Industry standard.	Transfer standard. Stable reciprocity calibration.	Cryogenic accelerometer
Sensitivity Typical	3.0 pC/g	2.2 pC/g	2.2 pC/g	11.5 pC/g
Weight gram	13	40	16.5	27
Sinusoidal limit g	500	1000	1000	1000
Shock limit g	3000	15 000	15 000	10 000
Frequency response ±1 dB Hz	1-8000	2-20 000	2-20 000	1-8000
Minimum temperature °C(°F)	-54(-65)	-54(-65)	-54(-65)	-269(-452)
Maximum temperature °C(°F)	482(900)	177(350)	177(350)	260(500)
Signal/ground isolation	No	Yes	Yes	Yes
Hermetic seal	Yes	No	Yes	Yes
Mounting method	Stud	Stud	Stud	Stud

Model number	2271AM20	2272	2273A	2273AM1 TE -R
Description	Cryogenic accelerometer	Vibration measurements at extreme temperatures. High stability.	Radiation hardened High temperature	Radiation hardened High temperature Case isolated
Sensitivity Typical	11.5 pC/g	13 pC/g	3 pC/g	10 pC/g
Weight gram	27	27	25	32
Sinusoidal limit g	1000	1000	1000	500
Shock limit g	10 000	2000	10 000	3000
Frequency response ±1 dB Hz	1-8000	1-9000	1-10 000	1-7000
Minimum temperature °C(°F)	-269(-452)	-269(-452)	-184(-300)	-55(-67)
Maximum temperature °C(°F)	260(500)	260(500)	400(750)	400(750)
Signal/ground isolation	Yes	No	No	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud	Stud




Model number	2273AM20 -R	2276 TE -R	6222S-20A TE	6222S-50A
Description	Radiation hardened High temperature Case isolated	Radiation hardened. High temperature Case grounded	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated
Sensitivity Typical	10 pC/g	10 pC/g	20 pC/g	50 pC/g
Weight gram	34	30	91	91
Sinusoidal limit g	500	500	2000	1000
Shock limit g	3000	3000	4000	2000
Frequency response ±1 dB Hz	1-7000	1-7000	1-12 000	1-9 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-54(-65)	-54(-65)
Maximum temperature °C(°F)	399(750)	482(900)	260(500)	260(500)
Signal/ground isolation	Yes	No	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Bolt	Bolt




Model number	6222S-100A TE	6233C-10	6233C-50 TE	6233C-100
Description	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated	High temperature Differential output Gas turbine/ ARINC-3 mounting Case ground isolated
Sensitivity Typical	100 pC/g	10 pC/g	50 pC/g	100 pC/g
Weight gram	91	75	110	110
Sinusoidal limit g	500	1000	1000	500
Shock limit g	1000	2000	2000	1000
Frequency response ±1 dB Hz	1-9000	1-8000	0.1-5000	0.1-3000
Minimum temperature °C(°F)	-54(-65)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	260(500)	482(900)	482(900)	482(900)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Bolt	Bolt	Bolt	Bolt




Model number	6237M70 TE	6237M71 TE	6240C-10	6240M10-120
Description	1200°F (650°C) operation Ground isolated Ideal for gas turbine testing	1200°F (650°C) operation Ground isolated Ideal for gas turbine testing	1200°F (650°C) operation Ground isolated. Differential output	Very high temperature 1400°F (760°C) intermitant Single ended output
Sensitivity Typical	10 pC/g	10 pC/g	10 pC/g	5 pC/g
Weight gram	30	30	200	95
Sinusoidal limit g	500	500	1000	250
Shock limit g	2000	2000	2000	1000
Frequency response ±1 dB Hz	1-5000	1-5000	1-4000	1-3000
Minimum temperature °C(°F)	-55(-67)	-54(-65)	-50(-58)	-54(-65)
Maximum temperature °C(°F)	650(1200)	650(1200)	650(1200)	650(1200)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	Yes	Yes
Mounting method	Bolt	Bolt	Bolt	Bolt




Model number	7201-10	7201-50	7201-100	7221A
Description	500°F (260°C) operation High frequency Hermetic	Hermetic General purpose	Hermetic Hight sensitivity	400°F (204°C) operation 360° cable orientation
Sensitivity Typical	10 pC/g	50 pC/g	100 pC/g	10 pC/g
Weight gram	18	20	25	10.5
Sinusoidal limit g	2000	2000	2000	1000
Shock limit g	20 000	10 000	5000	5000
Frequency response ±1 dB Hz	1-15 000	1-10 000	1-8000	.1-12 000
Minimum temperature °C(°F)	-73(-100)	-73(-100)	-73(-100)	-55(-67)
Maximum temperature °C(°F)	260(500)	260(500)	260(500)	204(400)
Signal/ground isolation	No	No	No	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud	Screw

TE = Test Essential product. See page 8 for details

-R = -R replacement sensor available. See page 10 for details




Model number	7221M2	7240C TE	7703A-50 -R	7703A-100 TE -R
Description	500°F (260°C) 360° cable orientation	High frequency to 30 Khz 500°F (260°C) operation Lightweight	550°F (288°C) operation Radiation tested General vibration measurements	550°F (288°C) operation Radiation tested General vibration measurements
Sensitivity Typical	10 pC/g	3.0 pC/g	50 pC/g	100 pC/g
Weight gram	11	4.8	25	29
Sinusoidal limit g	1000	1000	2000	1000
Shock limit g	5000	5000	10 000	5000
Frequency response ±1 dB Hz	2-10 000	1-20 000	1-9000	1-8000
Minimum temperature °C(°F)	-54(-65)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	260(500)	260(500)	288(550)	288(550)
Signal/ground isolation	Yes	No	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Stud	Stud	Stud




Model number	7703A-200	7703A-1000	7703AM5	7704A-50 TE
Description	550°F (288°C) operation High output Modal measurements	550°F (288°C) operation Very high output. Modal measurements	550°F (288°C) operation Radiation tested General Measurements Soaked at 550 F for 48hrs before calibration.	Ground isolated Radiation tested MIL-STD-750 applications
Sensitivity Typical	200 pC/g	1000 pC/g	100 pC/g	50 pC/g
Weight gram	62	120	29	25
Sinusoidal limit g	850	500	1000	2000
Shock limit g	2000	1000	5000	10 000
Frequency response ±1 dB Hz	1-6000	1-3000	1-8000	1-9000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	288(550)	288(550)	288(550)	288(550)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud	Stud



Model number	7704A-100	7722	7724
Description	Radiation tested High stability High sensitivity Wide temperature range	Ultimate cryogenic accelerometer	Ultimate cryogenic accelerometer
Sensitivity Typical	100 pC/g	3.7 pC/g	3.7 pC/g
Weight gram	29	29	29
Sinusoidal limit g	1000	500	500
Shock limit g	5000	2500	2500
Frequency response ±1 dB Hz	1-8000	1-6000	1-6000
Minimum temperature °C(°F)	-55(-67)	-184(-300)	-184(-300)
Maximum temperature °C(°F)	288(550)	177(350)	177(350)
Signal/ground isolation	Yes	No	Yes
Hermetic seal	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud

Model 12M1A
Piezoelectric accelerometer
Structural monitoring

Smart Structures, a leader in wireless advanced systems that test and monitor the health of highways, bridges, peers, high-rise buildings, and power-plants chose to use Endevco's 12M1A accelerometer due to its combination of small form factor, broad frequency response, high shock limit, and high charge output. "We worked very closely with Endevco for two years as we refined our system design and manufacturing process," stated Tom Chiarella, President of Smart Structures, Inc. "Their technical expertise and dedication to helping us succeed were critical elements in advancing key functionality in our product."

Isotron **accelerometers**

Isotron accelerometers feature an integral electronic impedance converter, eliminating the need for an external charge amplifier. They can drive long cables with minimal distortion and noise pick-up. The Isotron electronics are compatible with the industry standard IEPE current sources that are built into many FFT analyzers and data acquisition systems. (Current sources and amplifiers are also available from Endevco). These accelerometers offer the ultimate in testing convenience and are available with a wide selection of ranges, sizes and shapes. Special accelerometers, pioneered by Endevco, include lightweight versions with a 30 kHz bandwidth, high sensitivity units for seismic measurements, and automotive seat pad accelerometers for measuring whole body motion.




Model number	27AM1-10	27AM1-100	35A TE	61C12 TE
Description	Adhesive mount Rugged Lightweight	Adhesive mount Rugged Lightweight	World's smallest triaxial Isotron®	Ideal for modal Quick release mounts iTEDS
Sensitivity Typical	10 mV/g	100 mV/g	5 mV/g	100 mV/g
Weight gram	0.8	1.0	1.1	13
Linear range g	±500	±50	±1000	±50
Shock limit g	5000	5000	2000	5000
Frequency response ±1dB Hz	2-10 000	3-10 000	1-12 000	1-8000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-25(-40)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	No	No	No	Yes
Hermetic seal	Yes	Yes	No	Yes
Mounting method	Adhesive	Adhesive	Adhesive	Adhesive

Model number	25A TE	25B TE	27A11	27A12 TE
Description	World's smallest Isotron® Lightweight Integral cable	World's smallest Isotron® Lightweight Removable cable	Adhesive mount Rugged Lightweight iTEDS	Adhesive mount Rugged Lightweight iTEDS
Sensitivity Typical	5 mV/g	5 mV/g	10 mV/g	100 mV/g
Weight gram	0.2	0.2	0.8	1.0
Linear range g	±740	±740	±500	±50
Shock limit g	2000	2000	5000	5000
Frequency response ±1dB Hz	1-12 000	1-12 000	2-10 000	3-10 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	No	No
Hermetic seal	No	No	Yes	Yes
Mounting method	Adhesive	Adhesive	Adhesive	Adhesive


Model number	61C13	65-10 TE -R	65-100 TE -R	65HT-05 / -1
Description	Ideal for modal Quick release mounts iTEDS	Triaxial Miniature High output	Triaxial Miniature High output	Triaxial High temperature Lightweight
Sensitivity Typical	1000 mV/g	10 mV/g	100 mV/g	0.5 / 1mV/g
Weight gram	13	5	5	5
Linear range g	±5	±500	±50	±10 000 / ±5 000
Shock limit g	5000	10 000	10 000	15 000 / 10 000
Frequency response ±5% Hz	1-8000	0.4-10 000 ±1dB	1.5-6000 ±1dB	3-8000
Minimum temperature °C(°F)	-25(-40)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	175(347)
Signal/ground isolation	Yes	No	No	No
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Adhesive	Stud or Adhesive	Stud or Adhesive	Stud or Adhesive

TE = Test Essential product. See page 8 for details
-R = -R replacement sensor available. See page 10 for details

Model number	65HT-10 TE -R	66A11	66A12 TE -R	67-10 / -100
Description	Triaxial High temperature Lightweight	Triaxial High frequency Lightweight iTEDS	Triaxial High frequency Lightweight iTEDS	Triaxial Small, high temperature accelerometer
Sensitivity Typical	10 mV/g	10 mV/g	100 mV/g	10 / 100 mV/g
Weight gram	5	5	5	14
Linear range g	±500	±500	±50	±500 / ±50
Shock limit g	10 000	10 000	10 000	5000
Frequency response ±1dB Hz	3-8000	0.5-6000	1.5-6000	0.5 to 8000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	175(347)	125(257)	125(257)	175(347)
Signal/ground isolation	No	No	No	No
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud or Adhesive	Stud or Adhesive	Stud or Adhesive	Stud

Model number	86	87-1 / -10	256-10 TE	256-100
Description	Seismic accelerometer Very high sensitivity High resolution	Seismic accelerometer Very high sensitivity High resolution Rugged	Adhesive mount Hermetic Lightweight	Adhesive mount Hermetic Lightweight
Sensitivity Typical	10 V/g	1 / 10 V/g	10 mV/g	100 mV/g
Weight gram	771	170 (6.0 oz)	3.5	3.5
Linear range g	±0.5	±5 / ±0.5	±500	±50
Shock limit g	250	400	2000	2000
Frequency response ±1dB Hz	0.005-100	0.015-380 / 0.05-380	1-9 000	1-9 000
Minimum temperature °C(°F)	-10(-23)	-20(-4)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	100(212)	100(212)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Adhesive	Adhesive

Model number	256HX-10	256HX-100	258A-10	258A-100
Description	Stud mount Hermetic Lightweight	Stud mount Hermetic Lightweight	Stud mount Hermetic Integral stud 10-32 cable	Stud mount Hermetic Integral stud 10-32 cable
Sensitivity Typical	10 mV/g	100 mV/g	10 mV/g	100 mV/g
Weight gram	4.0	4.0	1.3	2.0
Linear range g	±500	±50	±500	±50
Shock limit g	2000	2000	10 000	10 000
Frequency response ±1dB Hz	1-10 000	1-10 000	0.3-15 000	0.3-15 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-54(-67)	-54(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	No	No
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud	Stud

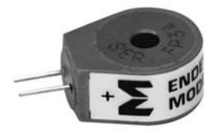
Model number	751-10 -R	751-100	752A12 TE	752A13
Description	High frequency Low noise Low profile	High frequency Low noise Low profile	High frequency Lightweight Low noise iTEDS	High sensitivity Low frequency applications Low noise iTEDS
Sensitivity Typical	10 mV/g	100 mV/g	100 mV/g	1000 mV/g
Weight gram	7.8	7.8	13	13
Linear range g	±500	±50	±50	±5
Shock limit g	5000	5000	5000	5000
Frequency response ±1dB Hz	1-15 000	1-15 000	0.5-30 000 (±2 db)	0.3-10 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-20(-4)	-20(-4)
Maximum temperature °C(°F)	125(257)	125(257)	85(185)	85(185)
Signal/ground isolation	No	No	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Stud	Stud	Stud

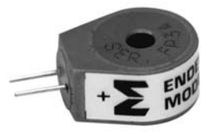
TE = Test Essential product. See page 8 for details

-R = -R replacement sensor available. See page 10 for details

Model number	2250A-10 TE -R	2250AM1-10 TE -R	2255B-01	2255B-1
Description	Isotron® accelerometer Wide bandwidth High signal to noise ratio Lightweight Removable cable	Isotron® accelerometer Wide bandwidth High signal to noise ratio Lightweight Solder pins	Miniature high shock. Internal LP electrical filter to prevent saturations. Integral 1/4-28 mounting stud.	Miniature high shock. Internal filter to prevent resonance saturation. Integral 1/4-28 mounting stud.
Sensitivity Typical	10 mV/g	10 mV/g	0.1 mV/g	1 mV/g
Weight gram	0.4	0.4	2	2
Linear range g	±500	±500	±50 000	±5000
Shock limit g	2000	2000	50 000	50 000
Frequency response ±1dB Hz	2-15 000	2-15 000	2-20 000	0.5-20 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	No	No
Mounting method	Adhesive	Adhesive	Stud	Stud

Model number	2258A-10 TE -R	2258A-100	5220A-100 TE	5221
Description	Lightweight, triaxial Isotron® accelerometer	Lightweight, triaxial Isotron® accelerometer	Rugged industrial Industry standard Wide frequency response	Rugged industrial Industry standard 360° cable orientation
Sensitivity Typical	10 mV/g	100 mV/g	100 mV/g	100 mV/g
Weight gram	15	15	100	145
Linear range g	±500	±50	±80	±80
Shock limit g	2000	2000	5000	5000
Frequency response ±1dB Hz	1-7000	1-7000	1-10 000	1-5000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-50(-58)	-50(-58)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Stud	1/4-28UNRF





Model number	7250A-2	7250A-10 TE	7250AM1-2	7250AM1-10 TE
Description	360° cable orientation Lightweight Flight test applications General purpose	360° cable orientation Lightweight Flight test applications General purpose	360° cable orientation High frequency. Solder pins for reduced weight.	360° cable orientation High frequency Solder pins for reduced weight.
Sensitivity typical	2 mV/g	10 mV/g	2 mV/g	10 mV/g
Weight gram	1.8	1.8	1.8	1.8
Linear range g	±5000	±500	±5000	±500
Shock limit g	10 000	10 000	10 000	10 000
Frequency response ±1dB Hz	3-20 000	4-20 000	3-20 000	4-20 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw

Model number	7250AM7-2	7250AM7-10	7251A-10 -R	7251A-100 -R
Description	360° cable orientation Integral cable Lightweight	360° cable orientation Integral cable Lightweight	360° cable orientation Low profile Flight test applications General purpose	360° cable orientation Low profile Flight test applications General purpose
Sensitivity Typical	2 mV/g	10 mV/g	10 mV/g	100 mV/g
Weight gram	1.8	1.8	10.5	10.5
Linear range g	±5000	±500	±500	±50
Shock limit g	10 000	10 000	5000	5000
Frequency response ±1dB Hz	4-15 000	5-15 000	2-10 000	2-10 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw




Model number	7251A-500	7251AHTM1-500M1	7251B11 / B12	7251HT-10 / -100
Description	High sensitivity 360° cable orientation Low profile	High temperature 360° cable orientation Low profile 10-32 connector General purpose	Wide bandwidth 360° cable orientation General purpose iTEDS	Wide bandwidth 360° cable orientation High temperature
Sensitivity Typical	500 mV/g	500 mV/g	10 / 100 mV/g	10 / 100 mV/g
Weight gram	10.5	14	10.5	14
Linear range g	±10	±10	±500 / 50	±500 / ±50
Shock limit g	5000	5000	5000	5000
Frequency response ±1dB Hz	2-10 000	2-10 000 (+2 / 8%)	2-10 000 (+2 / 8%)	0.2-12 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	125(257)	150(302)	125(257)	150(302)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw




Model number	7251HT-500	7253C-10 TE -R	7255A-01 TE	7255A-1
Description	Wide bandwidth 360° cable orientation High temperature	Triaxial Wide bandwidth Low profile	High g / near-field shock Built in mechanical filter Lightweight	High g / near-field shock Built in mechanical filter Lightweight
Sensitivity Typical	500 mV/g	10 mV/g	0.1 mV/g	1 mV/g
Weight gram	14	3.6	5	5
Linear range g	±10	±500	±50 000	±5000
Shock limit g	5000	2000	300 000	25 000
Frequency response ±1dB Hz	0.2-12 000	2-15 000	3-10 000 (±3 dB)	3-10 000 (±3 dB)
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-18(0)	-18(0)
Maximum temperature °C(°F)	150(302)	125(257)	66(150)	66(150)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	No	Yes	Yes
Mounting method	Screw	Adhesive / Screw	Stud	Stud




Model number	7255AM1	7257ATM6	7257ATM7	7257AT-10-YYYY
Description	Nearfield shock Built in mechanical filter Lightweight Rugged	Flight test Operates from 15-32 Vdc supply. Ground isolated	Flight test Operates from 15-32 Vdc supply. Ground isolated	Flight test Telemetry interface Filtering Built in charge amplifier
Sensitivity Typical	0.10 mV/g	100 mV/g	10 mV/g	10 mV/g
Weight gram	5.0	400 w/cable	400 w/cable	28
Linear range g	±50 000	±25	±250	±250
Shock limit g	300 000	1000	1000	1000
Frequency response ±1dB Hz	3-10 000 (±3 dB)	2-500 (±5%)	2-2000 (±5%)	2-500, 2000, 5000 (±5%)
Minimum temperature °C(°F)	-18(0)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	66(150)	100(212)	100(212)	100(212)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Screw	Screw	Screw




Model number	7257AT-100-YYY	7259B-10	7259B-25 TE	7259B-100
Description	Flight test Telemetry interface Filtering Built in charge amplifier	Very high frequency Lightweight Filtering Built in charge amplifier	Very high frequency Lightweight Filtering Built in charge amplifier	Very high frequency Lightweight Filtering Built in charge amplifier
Sensitivity Typical	100 mV/g	10 mV/g	25 mV/g	100 mV/g
Weight gram	28	4.4	4.4	4.4
Linear range g	±25	±500	±200	±50
Shock limit g	1000	10 000	5000	2000
Frequency response ±1dB Hz	2-500, 2000, 5000 (±5%)	5-10 000	5-10 000	5-10 000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	100(212)	125(257)	125(257)	125(257)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Stud	Stud	Stud

TE = Test Essential product. See page 8 for details

-R = -R replacement sensor available. See page 10 for details

Piezoresistive **accelerometers**

Endevco piezoresistive accelerometers are DC responding, and are ideal for measuring long duration transient events. Applications include automotive crash testing, where Endevco continues to be the world leader. Other applications include high g shock and biomedical applications. Most Endevco piezoresistive accelerometers use silicon micromachined (MEMS) sensors which are produced at Endevco's state-of-the-art facility in Silicon Valley. They are available in surface mount packages, general use configurations and application specific packaging. Most accelerometers are undamped to minimize phase shift and their mechanical design and high resonant frequency ensures reliable service.

Model number	2262A -1000 TE	2262A -2000 TE -R	7231C	7264-200
Description	DC response Critically damped Rugged	DC response Critically damped Rugged	Automotive crash standard DC response Undamped Rugged	DC response Undamped
Sensitivity Typical	0.5 mV/g	0.25 mV/g	0.2 mV/g	2.5 mV/g
Weight gram	28	28	24	1
Linear range g	±1000	±2000	±750	±200
Shock limit g	2500	5000	2500	2000
Frequency response ±5% Hz	0-1500	0-3000	0-2000	0-1000
Minimum temperature °C(°F)	-18(0)	-18(0)	-23(-10)	-18(0)
Maximum temperature °C(°F)	93(200)	93(200)	66(150)	66(150)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	No	No
Mounting method	Stud	Stud	Stud	Screw

Model number	71-6K	71-20K	71-60K	TBD-XX-YY-ZZ
Description	6 Kg shock DC response Surface mount Subminiature	20 Kg shock DC response Surface mount Subminiature	60 Kg shock DC response Surface mount Subminiature	Triaxial accelerometer using model 71 subassemblies
Sensitivity Typical	30 µV/g	10 µV/g	3 µV/g	
Weight gram	0.06	0.06	0.06	
Linear range g	±6000	±20 000	±60 000	
Shock limit g	18 000	60 000	120 000	
Frequency response ± 5% Hz	0-20 000	0-50 000	0-100 000	
Minimum temperature °C(°F)	-54(-65)	-54(-65)	-54(-65)	
Maximum temperature °C(°F)	66(150)	66(150)	66(150)	
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	No	No
Mounting method	Adhesive	Adhesive	Adhesive	

Model number	7264-2000	7264B-500 TE	7264B-2000 TE	7264C-500
Description	Shock testing. DC response Undamped	DC response Undamped Automotive and flutter testing	DC response Undamped Meets J211 specifications	DC response Undamped Meets J211 specifications
Sensitivity Typical	0.25 mV/g	0.80 mV/g	0.20 mV/g	0.80 mV/g
Weight gram	1	1	1	1
Linear range g	±2000	±500	±2000	±500
Shock limit g	5000	5000	10 000	5000
Frequency response ±5% Hz	0-4000	0-3000	0-5000	0-3000
Minimum temperature °C(°F)	-18(0)	-40(-40)	-40(-40)	-18(0)
Maximum temperature °C(°F)	66(150)	93(200)	93(200)	66(150)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	No	No
Mounting method	Screw	Screw	Screw	Screw

TE = Test Essential product. See page 8 for details
-R = -R replacement sensor available. See page 10 for details

Model number	7264C-2000 TE	7264D	7265A	7265A-HS
Description	DC response Undamped Meets J211 specifications	DC response Undamped Meets J211 specifications High resonance frequency	Low frequency Motion studies Flutter testing DC response	Low frequency Motion studies Flutter testing DC response
Sensitivity Typical	0.20 mV/g	0.20 mV/g	5 mV/g	25 mV/g
Weight gram	1	1	4.7	4.7
Linear range g	±2000	±2000	±100	±20
Shock limit g	10 000	10 000	2000	2000
Frequency response ±5% Hz	0-5000	0-6000	0-800	0-500
Minimum temperature °C(°F)	-18(0)	-18(0)	-18(0)	-18(0)
Maximum temperature °C(°F)	66(150)	66(150)	66(150)	66(150)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw



Model number	7265AM3	7267A	7268C-500M1	7268C-2000M1
Description	Low frequency Motion studies Flutter testing DC response	Triaxial. Crash test. Meets SAE-J211	Triaxial. Miniature. DC response	Triaxial. Miniature. DC response
Sensitivity Typical	0.25 mV/g	0.15 mV/g	0.80 mV/g	0.20 mV/g
Weight gram	3.0	50	8	8
Linear range g	±2000	±1500	±500	±2000
Shock limit g	5000	4000	5000	10 000
Frequency response ±5% Hz	0-4000	0-2000 (Z), 0-1200 (X&Y)	0-3000 (Z), 0-1500 (X&Y)	0-3000 (Z), 0-1500 (X&Y)
Minimum temperature °C(°F)	-18(0)	-23(-10)	-18(0)	-18(0)
Maximum temperature °C(°F)	66(150)	66(150)	66(150)	66(150)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	No	No
Mounting method	Screw	Screw	Screw	Screw



Model number	7269-500	7269-2000	7285	7302BM4
Description	Subminiature triaxial Surface mount Ideal for biomedical applications. DC response	Subminiature triaxial Surface mount Ideal for biomedical applications. DC response	Crash testing Rough road testing 400 mV full scale Low cost DC response	Angular accelerometer. Rotational Undamped
Sensitivity Typical	0.80 mV/g	0.20 mV/g	0.20 mV/g	5 mV/krad/sec²
Weight gram	0.4	0.4	1	35
Linear range g	±500	±2000	±2000	50 000 rad/sec²
Shock limit g	5000	10 000	10 000	2500
Frequency response ±5% Hz	0-3000	0-5000	0-4000	0-1600
Minimum temperature °C(°F)	-18(0)	-18(0)	-18(0)	-18(0)
Maximum temperature °C(°F)	66(150)	66(150)	66(150)	121(250)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	No	No	No	Yes
Mounting method	Adhesive	Adhesive	Adhesive	Screw

Model 7264 series
Piezoresitive accelerometer
Automotive crash testing

Endevco's 7264 series of piezoresistive accelerometers have been relied on for over 30 years in crash test applications. These devices are especially suited for use in anthropomorphic test devices (crash dummies) to obtain the critical data needed in assigning the United States government's star rating when NHTSA certifies a new vehicle. The transducers, fully compliant with SAE J211, are designed specifically to mount in all accepted crash test dummies and meet the demanding standards for accuracy and durability of this critical measurement application.

TE = Test Essential product. See page 8 for details
-R = -R replacement sensor available. See page 10 for details

Variable capacitance **accelerometers**

Variable capacitance accelerometers are DC responding sensors that are perfect for measuring motion, long duration events and low frequency vibration. They provide high sensitivities at very low frequencies and outstanding temperature stability. Endevco accelerometers are known for their high shock survivability and fast recovery time, while providing years of accurate measurements. The internal MEMS sensor is manufactured at Endevco's world-class micromachining facility. Endevco variable capacitance accelerometers operate from DC power supplies and require no special signal conditioning.




Model number	7292A-2M1/-30M1/-100M1	7293A-50	7293A-100	7596A-2
Description	Gas damped with overrange stop. Whole body motion studies. Single 10-32 stud mount. DC response	DC response EMI/RFI shield Flight test	DC response EMI/RFI shield Flight test	DC response Ideal for laboratory use High sensitivity
Sensitivity Typical	1000 / 66 / 20 mV/g	40 mV/g	20 mV/g	1000 mV/g
Weight gram	40	14	14	11
Linear range g	±2 / ±30 / ±100	±50	±100	±2
Shock limit g	10 000	10 000	10 000	10 000
Frequency response ±5% Hz	0-15 / 0-800 / 0-1000	0-1000	0-1000	0-15
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	121(250)	121(250)	121(250)	121(250)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Stud	Screw	Screw	Screw




Model number	7290A-2 / -10 TE	7290A-30 TE	7290A-50 / -100 TE	7290D
Description	High sensitivity. Measure low levels and inclination. DC response	High sensitivity Measure low levels Flight and automotive test DC response	Measurement of relatively low level vibration. DC response	High sensitivity. Measure low levels and inclination. DC response
Sensitivity Typical	1000 / 200 mV/g	66 mV/g	40 / 20 mV/g	1000-20 mV/g
Weight gram	11	11	11	11
Linear range g	±2 / ±10	±30	±50 / ±100	±2-100
Shock limit g	10 000	10 000	10 000	10 000
Frequency response ±5% Hz	0-15 / 0-500	0-800	0-1000	0-1000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	121(250)	121(250)	121(250)	121(250)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw




Model number	7596A-10	7596A-30	7596A-50	7596A-100
Description	DC response Ideal for laboratory use High sensitivity	DC response Ideal for laboratory use	DC response Ideal for laboratory use Low level vibration	DC response Ideal for laboratory use Low level vibration Whole body motion
Sensitivity Typical	200 mV/g	66 mV/g	40 mV/g	20 mV/g
Weight gram	11	11	11	11
Linear range g	±10	±30	±50	±100
Shock limit g	10 000	10 000	10 000	10 000
Frequency response ±5% Hz	0-500	0-800	0-1000	0-1000
Minimum temperature °C(°F)	-55(-67)	-55(-67)	-55(-67)	-55(-67)
Maximum temperature °C(°F)	121(250)	121(250)	121(250)	121(250)
Signal/ground isolation	Yes	Yes	Yes	Yes
Hermetic seal	Yes	Yes	Yes	Yes
Mounting method	Screw	Screw	Screw	Screw

Pressure sensors **absolute piezoresistive**

Endevco's miniature absolute pressure sensors measure both dynamic and static pressure. The state-of-the art diaphragm design provides an extremely high output signal and high resonant frequency with extraordinary linearity and repeatability. These units are virtually free of mechanical hysteresis. All sensors are temperature compensated, and special compensated ranges may be selected by the user. Absolute sensors are available in ranges from 15 psia to 2000 psia, full scale range. Some models have operating temperatures up to 260°C (500°F).




Model number	TE 8530C-15 / -50	8530C-100 TE	8540-15 TE	8540-50
Description	15 psia/50 psia Integral cable Detachable cable available 225 mV full scale Ideal for ABS studies	100 psia Integral cable Detachable cable available 225 mV full scale	15 psia High temperature 300 mV full scale Integral cable	50 psia High temperature 300 mV full scale Integral cable
Full scale pressure psi	15 / 50	100	15	50
Sensitivity mV/psi	15 / 4.5	2.25	20	6
Resonant frequency Hz	180 000 / 320 000	500 000	140 000	240 000
Non linearity (Typical) %FSO	0.15 / 0.10	0.1	0.25	0.25
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	121(250)	121(250)	260(500)	260(500)
Burst pressure diaphragm (psi)	75 / 250	400	30	100
Face diameter mm(inch)	3.86(0.152)	3.86(0.152)	3.86(0.152)	3.86(0.152)
Weight gram	2.3	2.3	8.5	8.5
Mounting method	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B




Model number	8515C-15 / -50 TE	8530B-200 / -500 TE	8530B-1000 TE	8530B-2KM37
Description	0.03 inches thin Easy surface mount capabilities High sensitivity	200/500 psia 300 mV full scale Miniature/rugged	1000 psia 300 mV full scale High frequency	2000 psia Detachable cable 600 mV full scale Ideal for ABS studies
Full scale pressure psi	15 / 50	200 / 500	1000	2000
Sensitivity mV/psi	13.3 / 4.0	1.5 / 0.6	0.3	0.3
Resonant frequency Hz	180 000 / 320 000	750 000 / 1 000 000	>1 000 000	>1 000 000
Non linearity (Typical) %FSO	0.2	0.2	0.2	0.2
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	121(250)	121(250)	121(250)	121(250)
Burst pressure diaphragm (psi)	75 / 250	800 / 2000	4000	4000
Face diameter mm(inch)	6.35(0.25)	3.86(.152)	3.86(.152)	3.86(0.152)
Weight gram	0.08	2.3	2.3	2.3
Mounting method	Adhesive	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B




Model number	8540-100	8540-200	8540-500	32394-15
Description	100 psia High temperature 300 mV full scale	200 psia High temperature 300 mV full scale	500 psia High temperature 300 mV full scale	Surface mount flip chip 180 mV full scale
Full scale pressure psi	100	200	500	15
Sensitivity mV/psi	3	1.5	0.6	12
Resonant frequency Hz	350 000	450 000	900 000	180 000
Non linearity (Typical) %FSO	0.25	0.4	0.4	0.50
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-55(-67)
Maximum temperature °C (°F)	260(500)	260(500)	260(500)	100(212)
Burst pressure diaphragm (psi)	200	400	1000	45
Face diameter mm(inch)	3.86(0.152)	3.86(0.152)	3.86(0.152)	N/A
Weight gram	8.5	8.5	8.5	‹ 0.5 g
Mounting method	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B	Epoxy / solder

Pressure sensors, gage/differential **piezoresistive**

Endevco's miniature gage/differential pressure sensors measure both dynamic and static pressure. These sensors are virtually free of hysteresis. All sensors are temperature compensated and special ranges of compensation may be selected by the user. Pressure ranges from 1 psig to 20 000 psig full scale are available, and all units are designed to withstand high overange pressures.

Model number	8510B-1 TE	8510B-2 TE	8510B-5 TE	8510B-200
Description	1 psig 200 mV full scale Rugged DC response	2 psig 300 mV full scale Rugged DC response	5 psig 300 mV full scale Rugged DC response	200 psig 300 mV full scale Rugged DC response
Full scale pressure psi	1 psig	2 psig	5 psig	200 psig
Sensitivity mV/psi	200	150	60	1.5
Resonant frequency Hz	55 000	70 000	85 000	320 000
Linearity %FSO	1.0	1.0	0.5	0.25
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	121(250)	121(250)	121(250)	121(250)
Burst pressure diaphragm/ref (psi)	25 / 25	40 / 40	100 / 100	1000 / 300
Face diameter mm(inch)	3.86(0.152)	3.86(0.152)	3.86(0.152)	3.86(0.152)
Weight gram	2.3	2.3	2.3	2.3
Mounting method	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B

Model number	8507C-1	8507C-2 TE	8507C-5	8507C-15
Description	1 psig, 200 mV full scale DC response, Miniature Wind tunnel applications, Scale models	2 psig, 200 mV full scale DC response , Miniature Wind tunnel applications, Scale models	5 psig, 300 mv full scale, DC response, Miniature, Wind tunnel applications, Scale models	15 psig, 300 mv full scale DC response, Miniature, Wind tunnel applications, Scale models
Full scale pressure psi	1 psig	2 psig	5 psig	15 psig
Sensitivity mV/psi	200	100	60	20
Resonant frequency Hz	55 000	70 000	85 000	130 000
Linearity %FSO	1.5	1.5	0.75	0.5
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	107(225)	107(225)	107(225)	107(225)
Burst pressure diaphragm/ref (psi)	20 / 20	40 / 40	100 / 50	150/50
Face diameter mm(inch)	2.34(0.092)	2.34(0.092)	2.34(0.092)	2.34(0.092)
Weight gram	0.3	0.3	0.3	0.3
Mounting method	RTV flush mount	RTV flush mount	RTV flush mount	RTV flush mount

Model number	8510B-500	8510B-2000 TE	8510C-15 TE	8510C-50
Description	500 psig 300 mV full scale Rugged DC response	2000 psig 300 mV full scale Rugged DC response	15 psig 225 mV full scale High frequency DC response	50 psig 225 mV full scale High frequency DC response
Full scale pressure psi	500 psig	2000 psig	15 psig	50 psig
Sensitivity mV/psi	0.6	0.15	15	4.5
Resonant frequency Hz	500 000	900 000	180 000	320 000
Linearity %FSO	0.25	0.25	0.15	0.1
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	121(250)	121(250)	121(250)	121(250)
Burst pressure diaphragm/ref (psi)	2500 / 300	10 000 / 300	75 / 300	250 / 300
Face diameter mm(inch)	3.86(0.152)	3.86(0.152)	3.86(0.152)	3.86(0.152)
Weight gram	2.3	2.3	2.3	2.3
Mounting method	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B	10-32 UNF-2B




Model number	8510C-100	8511A-5K TE	8511A-10K TE	8511A-20K
Description	100 psig 225 mV full scale High frequency	5000 psi full scale 500 mV full scale Rugged high pressure case	10 000 psi full scale 500 mV full scale Rugged high pressure case	20 000 psi full scale 500 mV full scale Rugged high pressure case
Full scale pressure psi	100 psig	5000 psig	10 000 psig	20 000 psig
Sensitivity mV/psi	2.25	0.100	0.050	0.025
Resonant frequency Hz	500 000	› 1 000 000	› 1 000 000	› 1 000 000
Linearity %FSO	0.1	1.2	2.5	2.5
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	121(250)	121(250)	121(250)	121(250)
Burst pressure diaphragm/ref (psi)	400 / 300	20 000	30 000	40 000
Face diameter mm(inch)	3.86(0.152)	9.7(0.38)	9.7(0.38)	9.7(0.38)
Weight gram	2.3	11	11	11
Mounting method	10-32 UNF-2B	3/8-24 UNF-2B	3/8-24 UNF-2B	3/8-24 UNF-2B

Model 8510B

Piezoresistive pressure sensor for harsh environments

Industrial and powerplant applications

Endevco has been the leader in pressure sensing solutions for harsh environments for decades. Our pressure products are renowned for providing the highest reliability and performance for applications such as shock wave or laminar flow measurement, high pressure and high temperature downhole exploration and drilling tool development. Products like our 8510B pressure sensor family provides precise pressure measurements up to 120˚C in environments up to 2000 psig which makes them ideal for pressure monitoring of pump equipment or pipelines.

Dynamic pressure **piezoelectric**

Endevco offers high temperature piezoelectric dynamic pressure sensors for harsh environments. Applications include combustion monitoring, engine test cells, propulsion systems, or any other measurement that requires dynamic monitoring in high temperature (1000°F/538°C) environments. Endevco offers both single ended and differential sensors to meet a wide variety of applications. Housings are all welded inconel for maximum temperature durability. Units are available with hard line cables.


Model number	522M17	522M25
Description	High temperature Integral hardline cable Use with single-ended charge amplifiers.	High temperature Integral hardline cable Use with differential charge amplifiers. Explosive environments
Charge sensitivity pC/psi	12	17
Resonant frequency kHz	45	20
Vibration sensitivity pC/g	0.05	0.05
Operating static pressure psi	2500	400
Dynamic range psi	500	20
Operating temperature °C (°F)	538(1000)	530(986)
Connector	10-32	EN2997 3 pin
Cable	Hardline	Hardline
Output	Single ended	Differential
Weight grams (without hardline cable)	25	45
Materials of construction	All welded inconel	All welded inconel
Standard cable length Inches	120	21

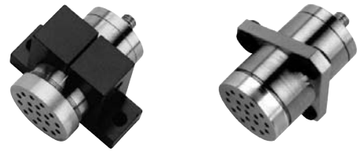
Microphones **piezoresitive**

Piezoresistive microphones are used for measuring high intensity sound over a wide frequency range with a full scale output of 200 mV. Their measurement range is from 95 to 190 dB SPL depending on the model selected. They are available with convenient 10-32 mounting threads, or a smaller version can be mounted using adhesives for flush mounting on flat or contoured surfaces. A full bridge sensor provides for a convenient interface to standard bridge signal conditioning equipment. Applications include flight testing, wind tunnels and engine inlet acoustic studies.

Model number	8507C-1	8507C-2 TE	8510B-1 TE	8510B-2 TE
Description	1 psig Flush mount High intensity sound 200 mV full scale	2 psig Flush mount High intensity sound 200 mV full scale	1 psig Low pressure and high intensity sound. 200 mV full scale	2 psig Low pressure and high intensity sound. 200 mV full scale
Range (dB SPL)	1 psig (95 to 190)	2 psig (95 to 190)	1 psig (95 to 190)	2 psig (100 to 190)
Sensitivity mV/psi	200	100	200	100
Resonant frequency Hz	55 000	70 000	55 000	70 000
Non linearity (Typical) %FSO	1.0	1.0	1.0	1.0
Minimum temperature °C (°F)	-54(-65)	-54(-65)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	107(225)	107(225)	121(250)	121(250)
Burst pressure	20 psi	40 psi	25 psi	40 psi
Face diameter mm(inch)	2.34(0.092)	2.34(0.092)	3.86(0.152)	3.86(0.152)
Weight gram	0.3	0.3	2.3	2.3
Mounting method	Adhesive	Adhesive	10-32 UNF-2B	10-32 UNF-2B

Microphones **piezoelectric**

Endevco's piezoelectric microphones measure high intensity acoustic noise and very low pressure fluctuations over a frequency range of 1 Hz to 10 kHz with a measurement range of 100 to ›180 dB SPL. These hermetically sealed microphones are designed for operation in harsh environments and operate over a temperature range of -55°C to 260°C (-67°F to 500°F). Other outstanding features include insensitivity to altitude changes and ambient vibration.



Model number	2510	2510M4A
Description	High intensity sound High temperature Vibration compensated	High intensity sound High temperature Vibration compensated
Range dB SPL	100 to ›180	100 to ›180
Sensitivity pc rms/psi	1069	1069
Resonant frequency Hz	30 000	30 000
Amplitude linearity dB	±1.0	±1.0
Minimum temperature °C (°F)	-54(-65)	-54(-65)
Maximum temperature °C (°F)	260(500)	260(500)
Face diameter mm(inch)	20.70(0.815)	20.70(0.815)
Weight gram	57	57
Mounting method	Screw	Flush mount, screw

Electronics **signal conditioners and amplifiers**

Endevco offers a comprehensive family of high performance electronic instruments from simple battery operated signal conditioners to computer controlled laboratory quality instruments that measure vibration, shock and pressure. Endevco electronic instruments support piezoelectric (charge-mode), variable capacitance, Isotron (voltage-mode) and piezoresistive sensors. The models 133, 136 and 2775B feature an RS-232 interface and can be controlled by Endevco's optional software (35933A).


Model number	133 TE	136 TE	428	433
Description	Signal conditioner of PE and Isotron® inputs. Multiple filter options	3-channel DC amplifier to condition resistive bridge or voltage type sensors. 200 kHz bandwidth, auto zero, auto balance.	2 channel PE/Isotron amplifier, auto gain, isolation, sensor check	3 channel PE/Isotron signal conditioner for iTEDS™
Input	PE / ISO	PR	PE / ISO	SMART / PE / ISO
Channels	3	3	2	3
Gain	1-1000	1-1000	1-10 000	1-1000
Display	DPM	DPM	Computer	Computer
Broadband noise mV rms	1	5	.5	.5
Lower -3dB Hz	0.03	0	<0.159	0.1
Upper -3dB Hz	100 000	200 000	<100 000	100 000
Power	AC / DC / BATT	AC / DC / BATT	AC / DC	AC / DC
Type of control	Manual / RS-232	Manual / RS-232	RS-232 / Ethernet	RS-232 / Ethernet




Model number	436	482B	2680MX	2685MX
Description	3-channel PR/VC module for Oasis	8-channel Isotron®/IEPE with iTEDS™. Plug into Oasis	Airborne amplifier Miniature EMC protection Charge mode	Airborne amplifier Miniature EMC protection Voltage mode
Input	PR	SMART / ISO	PE / ISO	Isotron
Channels	3	8	1	1
Gain	10-1000	1-100	0.1-100	0.1-100
Display	N / A	Computer	N / A	N / A
Broadband noise mV rms	5	0.15	1.5	1.5
Lower -3dB Hz	0	0.015	3	0.7
Upper -3dB Hz	200 000	100 000	Selection	Selection
Power	AC / DC	AC / DC	20-32 VDC	20-32 VDC
Type of control	RS-232 / Ethernet	RS-232 / Ethernet	Manual	Manual




Model number	2721B	2771B-01	2771B-1 TE	2771B -10 TE
Description	Laboratory charge amplifier. Ideal for very high temperature PE sensors.	In line charge converter IEPE powered Available with male or female BNC.	In line charge converter IEPE powered Available with male or female BNC.	In line charge converter IEPE powered Available with male or female BNC.
Input	PE	PE	PE	PE
Channels	1 or 9 / Rack	1	1	1
Gain mV/pC	1-100	0.1	1	10
Display	N / A	N / A	N / A	N / A
Broadband noise mV rms	100 µVrms	1	1	1
Lower -3dB Hz	1	0.4	0.4	2
Upper -3dB Hz	10 000	40 000	40 000	40 000
Power	±15 VDC	Constant current	Constant current	Constant current
Type of control	Manual	Manual	Manual	Manual




Model number	2771B -20	2771C-01 / -1 / -10	2775B TE	2777A-02 / -10 -10
Description	In line charge converter IEPE powered	In line charge converter IEPE powered Ultra low noise	Laboratory signal conditioner. PE and Isotron® filtering Computer control.	Differential charge converter Low noise Acceleration and velocity outputs
Input	PE	PE	PE / ISO	DIFF PE
Channels	1	1	1 to 6 / Rack	1
Gain mV/pC	20	0.1 / 1 / 10	0.0025 or 10 000	2 / 10 mV/Pc
Display	N/A	N/A	Meter	N/A
Broadband noise mV rms	1	5 / 30 / 50 µV	1	1
Lower -3dB Hz	2	0.4 / 0.4 / Hz	0.2	10
Upper -3dB Hz	40 000	8 / 30 / 50 kHz	20 000	17 500
Power	Constant current	Constant current	100-240 VAC	22-31 VDC
Type of control	Manual	Manual	Manual / RS-232	Manual




Model number	2777A-02 / -10 -15	2777A-02 / -10 -20	2777A-02 / -10 -25	2793
Description	Differential remote Charge converter Optional filters Acceleration and velocity outputs	Differential remote Charge converter Optional filters Acceleration and velocity outputs	Differential remote Charge converter Optional filters Acceleration and velocity outputs	Powers virtually all Isotron®/IEPE type sensors. Status indicators
Input	DIFF PE	DIFF PE	DIFF PE	Isotron
Channels	1	1	1	16
Gain	2 / 10 mV/pC	2 / 10 mV/pC	2 / 10 mV/pC	1-10
Display	N/A	N/A	N/A	N/A
Broadband noise mV rms	1	1	1	0.4
Lower -3dB Hz	15	20	25	1
Upper -3dB Hz	17 500	17 500	17 500	30 000
Power	22-31 VDC	22-31 VDC	22-31 VDC	115-250 VAC
Type of control	Manual	Manual	Manual	Manual




Model number	4416B	4430A TE	4830A TE	4961
Description	Powers virtually all Isotron®/IEPE type sensors. Status indicators Battery powered x1 and x10 gain	High performance signal conditioner. PE Low noise	Accelerometer simulator. Test system integrity. Single-ended and differential.	Power and I/O module for the 4430A
Input	Isotron	PE / PR / ISO	Output only	N/A
Channels	1	1 or 10 / Rack	1	1
Gain	1-10	1-1000	1-10	N/A
Display	N/A	DPM	LCD	N/A
Broadband noise mV rms	0.045	1	2	N/A
Lower -3dB Hz	2	0	N/A	N/A
Upper -3dB Hz	20 000	10 000	N/A	N/A
Power	Battery	From 4961	Battery	90-132 / 200-264 VAC
Type of control	Manual	Manual / GPIB	Manual	N/A




Model number	4999	6634C TE	35771	36020
Description	Low-pass filter conditioner	Vibration amp acceleration Velocity displacement outputs Programmable filters Alarm relays	Plug-in programmable filter for 2775A series signal conditioners.	Break-out panel for the Oasis system
Input	IEPE / Voltage	DIFF PE	Single ended	
Channels	16	1 or 6 / Rack	1	32
Gain	1 or 10	Selectable	1.0 ± .5%	N/A
Display	LED indicator	DPM	N/A	N/A
Broadband noise mV rms	‹ 15-30 µV	2	4 µV rms	N/A
Lower -3dB Hz	DC	2	Selectable	N/A
Upper -3dB Hz	60 000	20 000	Selectable	N/A
Power	115 / 250 VAC	90-240 VAC	From conditioner	N/A
Type of control	Manual	Manual / RS-232	Manual	N/A

Endevco offers a full range of components and systems to help you calibrate your sensors. These include primary standard accelerometers, amplifiers, and full systems, which range from portable, battery-powered units for easy field use to an Automatic Accelerometer Calibration System (AACS). This system can control multiple exciters such as long stroke shakers, high frequency shakers and shock calibrators for traceable calibration on most accelerometers.

We also offer complete calibration services so that you can regularly recalibrate sensors and maintain a high level of precision and accuracy. Many types of calibration are available including absolute vibration calibration-for the lowest uncertainty and comparison techniques for shock and vibration. Endevco can also perform more customized calibrations including environmental calibrations to verify amplitude linearity or frequency, HALT testing or high shock impact testing. Our calibration team is committed to providing the most accurate calibrations available with conformance to NIST or other international standards.

Endevco vibration calibration services

Annual calibration is recommended for accelerometers and their associated instrumentation to ensure the continued accuracy of your dynamic measurements. Accelerometer calibration is available from the same people at Endevco who design, build and calibrate hundreds of accelerometers daily. Calibration is conducted by qualified technicians who are under the supervision of our experienced engineering staff.

Endevco offers a wide selection of calibration services (see examples below) to meet your needs. These include simple back-to-back calibrations and highly accurate absolute calibrations. When you have your calibration conducted by Endevco you will receive:

› A full calibration certificate, with additional important data based on the calibration level selected.

› Calibration conducted in an A2LA accredited laboratory using NIST traceable standards.

› Fast turn-around, typically 3 days.

› Widest selection of calibration services including special requests.

Endevco uses precision, low noise air bearing shakers with a beryllium armature to ensure the highest accuracy with high frequency capabilities. We can also perform a resonance search to further determine the condition of the sensor. Endevco designed equipment is used to test cross-axis sensitivity, another important test of the accelerometer's performance.

What we do:
When we receive your accelerometer, it will be fully inspected and tested. Once your sensor is determined to be operating properly, we will proceed with the requested calibration. If during inspection and testing we determine that the unit is defective, we will advise you regarding the repair or replacement alternatives. In the event we are unable to make the necessary repairs, Endevco can offer an attractive trade-in on a new Endevco product. Contact your local Endevco representative to discuss other options or alternatives.

What do we calibrate?
Piezoelectric, piezoresistive and variable capacitance accelerometers and associated electronics. Endevco can calibrate most non-Endevco accelerometers. Calibration of Endevco pressure transducers is also available.

Traceability and accreditation

Accelerometer calibrations are conducted in our A2LA accredited laboratory. The methods used are in accordance with ANSI/NCSL Z540-1-1994, superseding MIL-STD 45662A and ISO/IEC 17025-2000. Traceability to the National Institute of Standards and Technology is shown as required by military quality control standards.

Absolute calibration model CS120
Absolute calibration by reciprocity provides a measurement uncertainty of 0.5 % at 2 g and a reference frequency of 80, 100, or 160 Hz, as specified by the customer. This absolute calibration method is especially designed for laboratory grade transfer standards or "back-to-back" comparison accelerometers and systems, such as the Endevco model 2270.

All accelerometers submitted for reciprocity calibration CS120 are also comparison calibrated to generate plots showing frequency response from 20 Hz to 10 000 Hz and a resonance search from 100 Hz to 50 000 Hz. CS120L extends the frequency response down to 1 Hz, while CS120H extends the frequency response up to 20 000 Hz and CS120LH does both. CS120UL provides ultra low frequency response with an additional test by turnover in gravity at up to five customer specified frequencies between 0.1 and 10 Hz.

Comparison calibration CS130
This precision sensitivity calibration is offered for all accelerometers and accelerometer/amplifier systems, either Endevco or non-Endevco models. Calibration is performed by comparison of the test accelerometer or system to an Endevco model 2270M7A standard accelerometer which is mounted internally in the Endevco model 2901 shaker. An Endevco model 2270M8 Standard accelerometer, mounted directly on top of the test accelerometer, is used for the comparison of "back-to-back" types. Reference frequency may be selected by the customer between 20 Hz and 1000 Hz. Plots are provided to show frequency response from 20 Hz to 10 000 Hz. CS130L extends the frequency response down to 1 Hz while CS130H extends the frequency response up to 20 000 Hz and CS130LH does both. CS130UL provides ultra low frequency response with an additional test by turnover in gravity at five customer specified frequencies between 0.1 and 10 Hz. Low frequency calibrations down to 1 Hz are performed by comparison to a servo accelerometer mounted on a long stroke air bearing shaker.

CS120 and CS130 calibration results are furnished in a comprehensive report in compliance with ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-2000 with a description of methods used, the reference standards used and their current calibration dates, report numbers and traceability to the National Institute of Standards and Technology (NIST), the estimated uncertainty of the calibrations, the temperature and humidity during the calibrations. The report includes a table of "as received" and "as adjusted" data, a table of listed sensitivity values at specific frequencies, a graph of sensitivity values over the frequency range, another graph of the percent deviation from the reference frequency and a graph of dB deviation in sensitivity.

All calibrations are performed using Endevco model 28951 or 68357 precision automated calibration systems with the ranges and specifications as stated in the table below.

Supplemental calibrations are half-price when ordered in conjunction with any comprehensive sensitivity calibration. They are offered for both Endevco and non-Endevco accelerometers either alone or as systems with companion instrumentation.

Sinusoidal linearity to 100 g CS210
This calibration is provided at 5 g-levels specified by the customer from 1 g to 100 g peak at a single frequency near 200 Hz. An electrodynamic shaker is used to apply the sinusoidal vibration. The results are furnished in a one page report with a calibration uncertainty of ±1%.

Low frequency calibration CS240
Low frequency calibrations from 1 Hz to 30 Hz are performed by comparison to a servo accelerometer mounted on a long stroke air bearing shaker using Endevco model 28951 or 68357 automated calibration systems with the ranges and specifications as stated in the table below for low frequency. The results are furnished on a multi-page calibration report with the reference frequency sensitivity, a graph of sensitivity percent deviation from the reference frequency over the frequency range, and the temperature and humidity during the calibrations. The reference frequency may be selected by the customer.

System sensitivity adjustment CS250
Calibration of systems is performed at room temperature and at a single frequency and amplitude by applying vibration, shock or acoustics as applicable to the transducer and setting the amplifier gain to obtain a specific system sensitivity which is reported. CS210, CS240 and CS250 calibrations are half-price when ordered in conjunction with CS110, CS120 or CS130.

Factory recalibrations CS410/CS420/CS415/CS425
The CS410 is a one page calibration certificate similar to those originally supplied with any new Endevco accelerometer. The data supplied is shown in the calibration section of the appropriate Endevco product data sheet. The CS420 is similar to the CS410 but for non-Endevco accelerometer calibrations. The CS415 and CS425 are the same as the CS410 and CS420 respectively but without transverse sensitivity calibration; therefore they are offered at a slightly lower cost.

Factory recalibrations CS440
This calibration certificate is provided for Engine Vibration Monitoring (EVM) accelerometers. It is similar to the CS410 and CS420.

Custom calibrations
Custom calibration services and blanket order agreements can be arranged to meet special customer needs.

	Reciprocity	Comparison high frequency	Comparison low frequency	Turnover in gravity
Equipment	Double coil shaker	2901 shaker	Long stroke air bearing shaker	Turnover
Frequency	100 Hz	20 Hz to 50 000 Hz	1 Hz to 30 Hz, 1 g	0.1 Hz to 10 Hz
Acceleration	2 g	2 g at 20 Hz, 10 g above	50 Hz 0.3 g at 1 Hz, 1 g above 2 Hz	1 g
Uncertainty (95%, k=2)	± 0.5 %	± 1.2 % at 100 Hz ± 1.5 % 20 Hz to 2000 Hz ± 2.5 % 2000 Hz to 10 000 Hz ± 5 % 10 000 Hz to 20 000 Hz	± 1.5 %	± 1 %

Shock calibration services

Endevco provides a variety of shock calibration services for most accelerometers and accelerometer/amplifier systems. Periodic calibrations are recommended to verify proper function, quality and calibration. It is important that the maximum acceleration level requested does not exceed the limit of the specific model accelerometer to be calibrated. In addition, the accelerometer to be calibrated must have a natural period, equal to the inverse of the resonance frequency, less than 0.2 times the half sine-pulse duration of the pulse shock. The calibration methods Endevco uses are in accordance with ANSI/NCSL Z540-1-1994 (superceding MIL-STD 45662A), ISO-IEC 17025-2000. Traceability to the National Institute of Standards and Technology is shown as required by military quality control standards.

Comparison shock calibration CS110
The Endevco model 2925 Pneumatically Operated Projectile (POP) is used in conjunction with Endevco model 2270 standard accelerometer for shock calibrations up to 10 000 g. This comparison shock calibration method compares the peak output of the test accelerometer or system to the peak output of the model 2270 reference accelerometer. Correction of non-linearity of the model 2270 accelerometer of +1% per 10 000 g is included in the calculation of the test sensitivity. The model 2270 reference accelerometer and the test accelerometer are mounted on an "anvil" in a "back-to-back" configuration. The anvil impact surface is conditioned with a medium to control the pulse duration when it is impacted with a projectile driven with a compressed air source.

SMAC calibration CS111
Above 10 000 g a primary shock calibration method is used with the Endevco model 2973A Shock Motion Accelerometer Calibrator (SMAC) based on the Hopkinson bar principle. Driven with pressurized air, a projectile with a shaped tip impacts a deformable aluminum mitigator on one end of the bar, generating a compression wave. Strain gages are mounted on the bar to measure the compression wave as it travels to the opposite end where the test accelerometer is mounted.

For both C110 and CS111 calibration results are furnished in a comprehensive report with a description of methods used, the reference standards used and their current calibration dates, report numbers and traceability to the National institute of Standards and Technology (NIST), the estimated uncertainty of the calibrations, the temperature and humidity during the calibrations. Figures showing output wave forms of the Reference and test accelerometers at each of three or more g levels, as selected by the customer, are included. For those accelerometers with adequate sensitivity, a plot of normalized sensitivity expressed in dB units versus frequency is provided to indicate the resonance frequency and/or any local resonances up to 50 000 Hz.

Equipment, ranges and uncertainties CS110 CS111
Equipment 2925 POP system 2973A SMAC system shock g range 20 g to 10 000 g ± 10% 10 000 to 100 000 ± 20% pulse shape Approximate half-sine pulse duration see figure on facing page Uncertainty ± 1.9%, 20 to 2000 g ± 5.4% (95% confidence, K=2) 2.6%, 2000 g to 10 000 g

Shock linearity to 10 000 g CS220
The POP calibrator is used to provide five shock levels specified by the customer from 20 g to 10 000 g.

System sensitivity adjustment CS250
Calibration is provided and system sensitivity is reported for measurement systems including a transducer and its associated cable and signal conditioning. The calibration is performed by shock application at one g level as applicable to the transducer and setting the amplifier gain to obtain a specific system sensitivity. The calibration is performed at room temperature and at a single pulse duration and g level.

CS 220 and 250 calibrations are half-price when ordered in conjunction with CS 110, CS120 or CS130 calibrations.

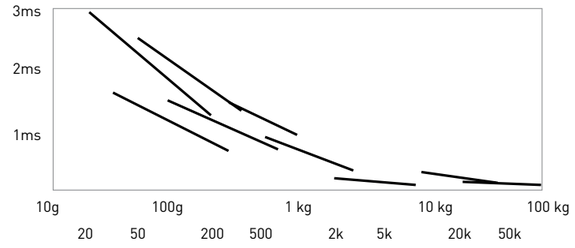
Custom calibrations
Custom calibration services and blanket order agreements can be arranged to meet special customer needs.

Calibration services

Endevco services are provided by rapid response for NIST-traceable calibration certificates for shock, vibration and pressure sensors and microphones from 0.01 Hz to 500 Hz as well as POP calibrations up to 10 000 g. Endevco also provides high-frequency calibration up to 20 000 Hz with resonance search up to 50 000 Hz, leading the industry in accuracy and reliability.

All Endevco calibration services are A2LA accredited

Typical pulse duration vs. shock level



NOTE: Segments represent different anvil/transducer assemblies

Equipment, ranges and uncertainties

	CS110	CS111
Equipment	2925 POP System	2973A SMAC System
Shock g Range	20 g to 10 000 g ± 10%	10000 to 100 000 ± 20%
Pulse Shape	Approximate half-sine	Approximate half-sine
Pulse Duration	See figure above	See figure above
Uncertainty	± 1.9%, 20 to 2 000 g	± 5.4%
(95% confidence, K=2)	2.6%, 2 000 to 10 000 g	

NOTE: Test accelerometers with larger than 0.63 diameter seating surfaces and/or are heavier than about 40 grams may result in increased measurement uncertainty.

Reciprocity or absolute NIST traceable (includes transverse sensitivity, resonance search to 50 kHz or highest specification frequency with 5 page report)

CS120	20 Hz to 10 kHz
CS120H	20 Hz to 20 kHz
CS120L	1 Hz to 40 Hz
CS120LH	1 Hz to 20 kHz
CS120S	20 Hz to 10 Hz system (accelerometer with amplifier)
CS120LH-S	1 Hz to 20 kHz system
CS120LS	1 Hz to 40 Hz system

Comparison calibration (includes transverse sensitivity, resonance search to 50 kHz or highest specification frequency with 5 page report)

CS130	20 Hz to 10 kHz
CS130H	20 Hz to 20 kHz
CS130L	1 Hz to 40 Hz
CS130LH	1 Hz to 20 kHz
CS130S	20 Hz to 10 kHz system (accelerometer with amplifier)
CS130LH-S	1 Hz to 20 kHz system
CS130LS	1 Hz to 40 Hz system
CS130T	20 Hz to 10 kHz triax
CS130UL	0.1 Hz to 2 Hz specified ultra low frequency

Comparison calibration (includes resonance search to 50 kHz or highest specification frequency, 5 page report without transverse sensitivity)

CS135	20 Hz to 10 kHz
CS135L	1 Hz to 40 Hz
CS135LH	1 Hz to 20 kHz

Standard back-to-back comparison calibration (includes 1 page plot certificate)

CS410	20 Hz to 10 kHz (with transverse sensitivity)
CS415	20 Hz to 10 kHz (without transverse sensitivity)
CS410TEDS	20 Hz to 10 kHz (with transverse sensitivity for TEDS units)
CS420	20 Hz to 10 kHz (with transverse sensitivity for non-Endevco accelerometers)
CS425	20 Hz to 10 kHz (without transverse sensitivity)
CS420L	1 Hz to 10 kHz (combined low and high frequency for non-Endevco accelerometers)
CS410SP	Special (for units requiring special testing or outsourced calibration, e.g., force accelerometers)
CS210	Amplitude linearity (5 g-levels from 1 g to 100 g specified by customer)
CS240	1 Hz to 100 Hz (with 5 page report)
CS250	Vibration from 20 Hz to 10 kHz or shock (same as CS110) for systems, e.g., accelerometer and amplifier

Shock calibration (includes transverse sensitivity for units with TS specification)

CS110	20 g to 10 kg (with frequency response 20 Hz to 10 kHz)
CS220	Supplemental shock 5 g-levels (specified by customer, without frequency response)

Environmental calibration

CS310	Sensitivity measurement at reference frequency at customer specified temperatures (with transverse sensitivity)
CS315	Same as CS310 (without transverse sensitivity)
CS500	Electronics products calibration only
CS501	Electronics products repair and calibration

Third party calibration services

Standard back-to-back vibration and shock comparison calibration

CS415	20 Hz to 10 kHz (without transverse sensitivity)
CS135	20 Hz to 10 kHz (with 5 page report)
CS250	20 Hz to 10 kHz (with 5 page report for systems, e.g., accelerometer and amplifier)
Option MULTI	Bi-axial or Tri-axial units
Option H	20 Hz to 20 kHz (without transverse sensitivity)
Option L	5 Hz to 100 Hz (without transverse sensitivity)
Option TEDS	20 Hz to 10 kHz (without transverse sensitivity for TEDS capable units)
CS220	Shock at 5 g-levels (specified by customer from 20 g to 10 kg)
CS110	Shock at 5 g-levels (specified by customer from 20 g to 10 kg with frequency response 20 Hz to 10 kHz)

Calibration service center contact information

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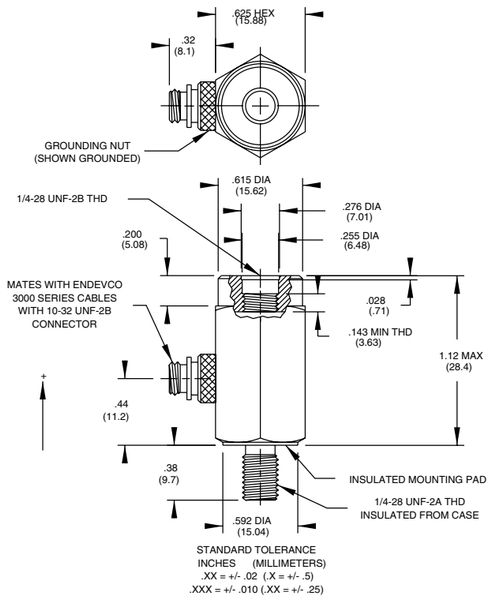
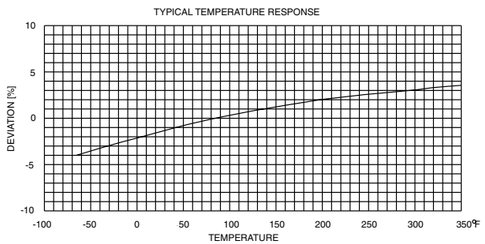
Model 2270
Comparison standard accelerometer

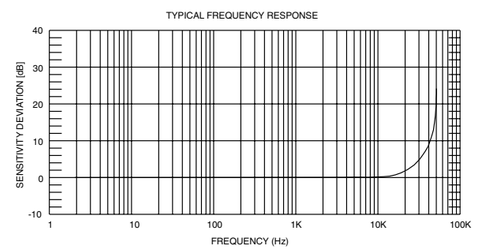
- Laboratory grade primary standard Accelerometer for back-to-back comparison calibration
- Stable P-10 crystal material
- Supplied with absolute calibration at 100 Hz traceable to NIST
- Selectable connection/isolation of signal ground and case

The Endevco® model 2270 primary comparison calibration standard accelerometer is a combination standard accelerometer and calibration fixture used for performing comparison calibrations of other accelerometers. The extremely high stability and very flat frequency response of the accelerometer is achieved through the use of sensing elements made of Endevco P-10 crystal material. The model 2270 has a 1/4-28 tapped hole 0.5 inches deep for attaching units under test. Accessory bushings are provided to mount accelerometers that use 2-56, 6-32, or 10-32 sizes. Additional adapters with 4-40, 4-48, 8-32, and metric M3x0.5 threads are available.

Signal ground can be switched from grounded to isolated at the user's option by means of a knurled nut on the output signal receptacle.







Specifications

All specifications are typical at 75°F (24°C), referenced at 100 Hz and conform to ISA-RP37.2 (1-64) unless otherwise indicated.

Dynamic characteristics

Charge sensitivity	2.2 pC/g ±20% (0.22 pC/ms²)	
Frequency range [1]	Accelerometers up to 35 grams	2 Hz to 20 000 Hz
	Accelerometers between 35 grams and 100 grams	2 Hz to 5000 Hz
Mass loading effect	Sensitivity change due to relative motion resulting from the mass of the test accelerometer plus adapters or fixtures ±0.2% maximum for up to 100 gm at 100 Hz -2% for 50 gm at 10 kHz or 100 gm at 5 kHz	
Shock motion pulse duration [3]	100 µs to 20 ms half sine for accelerometers up to 35 gm 200 µs to 20 ms half sine for accelerometers between 35 gm and 100 gm	
Transverse sensitivity	3% maximum in any direction, 1% available on special order	
Amplitude linearity	Sensitivity increases approximately 0.1% per 100 g, 0 to 15 000 g	
Temperature response	±3% typical -65°F to 350°F (-54°C to 177°C) referenced to room temperature	
Charge sensitivity time stability	±0.2% maximum per year	

Electrical characteristics

Capacitance	1600 pF ±20%
Resistance	20 GΩ minimum; 5000 M Ω minimum at 350°F (177°C)
Isolation	10 MΩ minimum case to mounting stud and signal ground
Polarity	Positive output for acceleration into the base

Environmental Characteristics

Temperature range	-65°F to 350°F (-54°C to177°C)
Humidity	Epoxy sealed
Acceleration limit	15 000 g peak shock, 1000 g peak sinusoidal
Base strain sensitivity	0.25 equivalent g peak per 250µ strain peak
Electromagnetic sensitivity	0.03 equivalent g rms at 100 gauss rms, 60 Hz
Stray voltage sensitivity	0.003 equivalent g per Volt at the mounting stud

Physical characteristics

Weight	1.4 oz. (40gm)
Case material	17-4 PH stainless steel
Sensor	Endevco Piezite type P-10 in the single-ended compression mode
Output receptacle [4]	10-32 UNF threaded coax socket type side connector with grounding nut. Mates with Endevco model 3090C cable assembly
Mounting [5]	Integral mounting stud 1/4-28 UNF thd x 3/8" long. 1/4-28 UNF thd x 1/2" deep for mounting test transducers

Calibration data

Standard	
CS120	Reciprocity calibration includes an absolute reciprocity sensitivity at 100 Hz and 2 g peak, and a comparison frequency response from 20 to 10 000 Hz. Test results are furnished in a formal report that includes transverse sensitivity, resistance, capacitance, and frequency response plots.
Optional	
CS120L	Extends the frequency response calibration down to 2 Hz.
CS120H	Extends the frequency response calibration up to 20 000 kHz
CS310	Temperature Response Calibration, -65°F to 350°F (-54°C to 177°C).

Included accessories

3090C-120	Cable assembly
15071	Adapter stud, 1/4-28 UNF to 10-32 UNF
14159-1	Adapter bushing, 10-32 UNF
14159-2	Adapter bushing, 6-32 UNC
14159-4	Adapter bushing, 2-56 UNC

Optional accessories

14159-3	Adapter bushing, 4-40 UN
14159-5	Adapter bushing, 4-48 UNF
14159-6	Adapter bushing, 8-32 UNC
14159-7	Adapter bushing, M3x0.5

Notes:

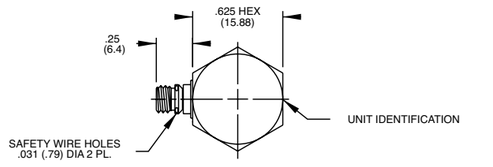
1. Low frequency response will be determined by the characteristics of the charge amplifier used with the 2270 standard accelerometer.
2. Estimated accuracy of correction factor curves showing typical response is ±1%. Sensitivity is the standard output divided by the acceleration motion at the surface provided for attaching test accelerometers.
3. For calibrations with 100 µs duration pulses, the resonance frequency of the test accelerometer should be above 50 kHz.
4. Tighten the grounding nut to the case finger tight - approximately 4 lbf - in (0.7 Nm). Excessive torque could damage the isolated receptacle assembly. The grounding nut should be in contact with the accelerometer housing when case isolated test transducers are being calibrated, and should be disengaged from the accelerometer housing when case grounded test transducers are being calibrated.
5. Recommended torque for attachment is 18 lbf - in (2 Nm). Torque values above 24 lbf - in could cause permanent damage to the isolated bushing assembly.
6. Maintain high levels of precision and accuracy using Endevco's factory calibration services. Call Endevco's inside sales force at 800-982-6732 for recommended intervals, pricing and turn-around time for these services as well as for quotations on our standard products.

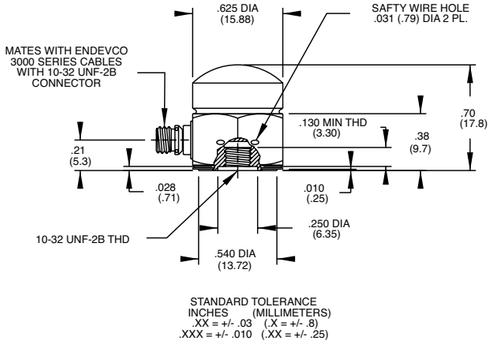
Model 2270M8
Transfer standard accelerometer

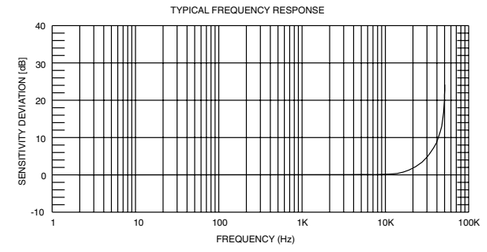
- Transfer standard accelerometer for calibration of back-to-back working standards and reference standards built into shakers
- Stable P-10 crystal material
- High (55 kHz) resonance frequency
- Electrical isolation
- Supplied with reciprocity calibration at 100 Hz

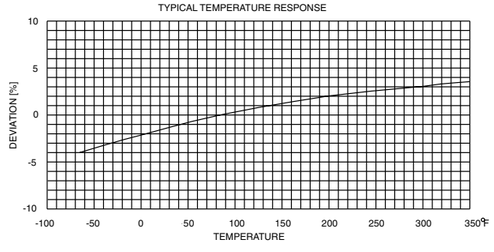
The Endevco® model 2270M8 transfer standard accelerometer is designed for the calibration of back-to-back working standards used in comparison calibrations. It is used extensively in calibrating standard accelerometers built into the armatures of vibration exciters, such as the Endevco model 2901, or comparison standard accelerometers, such as the Endevco model 2270. The Model 2270M8 is particularly valuable as a calibration source when the working standard is to be used at frequencies up to 20 000 Hz.

The model 2270M8 is supplied with an absolute reciprocity calibration at 100 Hz. In addition, a comparison calibration from 20 Hz to 10 000 Hz, including a graph of sensitivity versus frequency, is supplied with all results given in a comprehensive report showing traceability to the NIST. Optional calibrations to extend the frequency response down to 2 Hz or up to 20 000 Hz are also available.









Specifications

All specifications are typical at 75°F (24°C), referenced at 100 Hz and conform to ISA-RP37.2 (1-64) unless otherwise indicated.

Dynamic characteristics

Charge sensitivity	2.2 pC/g ±25% (0.22 pC/ms²)

Charge frequency response [1]

Frequency	2 Hz	100 Hz	1 kHz	2 kHz	5 kHz	10 kHz	20 kHz
Deviation	0%	REF	0%	0%	+2%	+5%	+20%

Mounted resonance frequency	55 kHz typical, with a case resonance of ~3 dB at ~35 kHz
Transverse sensitivity	3% maximum in any direction, 1% available on special order
Amplitude linearity	Sensitivity increases approximately 0.1% per 1000 g, 0 to 15 000 g
Temperature response	±4% typical -65°F to 350°F (-54°C to 177°C) referenced to room temperature

Electrical characteristics

Capacitance	1600 pF ±20%
Resistance	20 GΩ minimum at 75°F (24°C), 100 M Ω minimum at 350°F (177°C)
Isolation	10 MΩ minimum between signal ground and housing
Polarity	Positive output for acceleration into the base

Environmental Characteristics

Temperature range	-65°F to 350°F (-54°C to177°C)
Humidity	Hermetically sealed by welding and by glass/metal seal in receptacle
Acceleration limit	15 000 g peak shock, 1000 g peak sinusoidal in any direction
Base strain sensitivity	1.1 equivalent g peak per 250µ strain peak
Electromagnetic sensitivity	0.06 equivalent g rms at 100 gauss rms, 60 Hz

Physical characteristics

Weight	0.6 oz (16.5 gm) typical
Case material	Stainless steel
Sensor	Endevco Piezite type P-10 in the single-ended compression mode
Output receptacle	10-32 UNF threaded coax socket type side connector. Mates with Endevco model 3090C cable assembly
Mounting	Detachable 10-32 stud 18 lbf-in (2 Nm) mounting torque

Calibration data

Standard	
CS120	Reciprocity calibration includes an absolute reciprocity sensitivity at 100 Hz and 2 g peak, and a comparison frequency response from 20 to 10 000 Hz. Test results are furnished in a formal report that includes transverse sensitivity, resistance, capacitance, and frequency response plots.
Optional	
CS120L	Extends the frequency response calibration down to 2 Hz.
CS120H	Extends the frequency response calibration up to 20 000 kHz
CS310	Temperature response calibration, -65°F to 350°F (-54°C to 177°C).
CS110	Shock calibration
CS210	Sinusoidal linearity calibration

Included accessories

3090C-120	Cable assembly
2981-3	Mounting stud, 10-32 UNF
15071	Adapter stud, 1/4-28 UNF to 10-32 UNF

Optional accessories

2981-4	Mounting stud, m5x0.8

Notes:

1. Low frequency response will be determined by the roll-off characteristics of the charge amplifier used with the 2270M8 standard accelerometer.

2. Maintain high levels of precision and accuracy using Endevco's factory calibration services. Call Endevco's inside sales force at 800-982-6732 for recommended intervals, pricing and turn-around time for these services as well as for quotations on our standard products.

Model 2911
Vibration standard shaker

- Built-in model 2270M18 standard accelerometer
- High performance beryllium armature
- Wide frequency range 2 Hz to 40 kHz
- 10 mm stroke with unique air bearing

The Endevco® model 2911 shaker is designed specifically for the demanding requirements of comparison accelerometer calibration, and features a high performance beryllium armature with a 10 mm stroke displacement, and a unique air-bearing suspension system. Endevco is able to provide a shaker with characteristics superior to any other equipment used for calibrating accelerometers and velocity pickups. The performance advantages of the model 2911 standard-shaker are in its unique design, which includes the model 2270M18, containing a built-in Endevco primary vibration standard accelerometer. With the resonance frequency of the built-in standard far above the armature resonance, the 2911 performs accurate sensitivity and frequency response calibrations at frequencies up to 20 000 Hz and for resonance frequency searches up to 40 000 Hz, virtually free of waveform distortion and transverse motion.

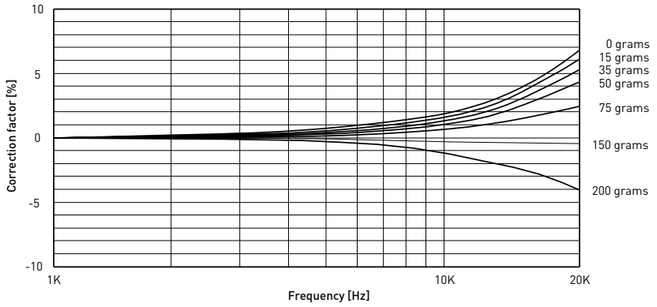
The model 2911 is designed to be an integral part of the Endevco Automated Accelerometer Calibration System (AACS), which is made up of the 68357 calibration controller and the 28978 vibration controller module. AACS is a complete automated system, and its advanced software and signal conditioning makes maximum use of the 2911.

In addition, Endevco recommends use of the model 2270M8 transfer standard accelerometer as a means of maintaining the calibration of the 2911 shaker at the user's facility. The 2270M8 has been specifically developed for calibrating back-to-back primary standard accelerometers.

Uncertainty estimate (95% confidence, k=2)

Equipment used: 2911

±1.2%	100.0 Hz sensitivity
±1.5%	20.0 ‹ f ‹ = 100.0 Hz
±1.2%	100.0 ‹ f ‹ = 2500.0 Hz
±2.5%	2500.0 ‹ f ‹ = 10 000.0 Hz
±5.0%	10 000.0 ‹ f ‹ = 20 000.0 Hz



Specifications

All specifications are typical at 75°F (24°C), referenced at 100 Hz and conform to ISA-RP37.2 (1-64) unless otherwise indicated.

Dynamic characteristics	Model 2270M18 built-in standard
Charge sensitivity	18-22 mV/g 20 mV/g typical
Frequency range	
Calibration	20 to 20 000 Hz
Resonant frequency search	to 40 000 Hz
Mass loading effect [1]	Sensitivity change due to relative motion resulting from the mass of the test accelerometer plus adapters or fixtures (see curves on left page) ±0.2% maximum for up to 100 gm at 100 Hz -2% for 50 gm at 10 kHz or 100 gm at 5 kHz
Amplitude linearity	Sensitivity increases approximately 0.3% per 100 g up to 250 g
Temperature response	0.019%/°F (0.034%/°C) typical

Electrical characteristics	
Output bias voltage	10 V ±2V
Output impedance	100 Ω maximum
Isolation	10 MΩ minimum; signal ground to armature housing
Crystal material	Piezite® element type P-23
Polarity	Positive output for acceleration into the base of the test transducer

Armature characteristics	Armature assembly
Weight	7 oz. (200 gm) typical
Material	Beryllium alloy
Coil resistance	3Ω typical
Continuous coil current	5 A rms without cooling
Test transducer mounting (2)	1/4-28 UNF thread, .38 deep
Armature resonance	60 KHz typical

Shaker characteristics	Model 2911 shaker assembly
Magnetic field	Permanent magnet
Current sensitivity	2 lb/ampere (0.9 kgf/ampere)
Acceleration distortion (3)	2%
Transverse motion (4)	5% maximum
Size	Approximately 6.25" high x 7.2" x 7.2" (159 cm X 183 cm x 183 cm)
Weight	Shaker 40 lbs (18 kg)
	Shipping weight 60 lbs (27 kg) approximately
Air supply	Inlet 1/8-27 pipe thread
	Nipple supplied 1/8-27 pipe thread to 1/4" OD tube
	Pressure 20 to 40 psig

Environmental characteristics	
Temperature	Operating 50°F to 125°F (10°C to 52°C)
	Storage -65°F to 200°F (-54°C to 93°C)
Altitude	Not affected
Humidity	Accelerometer is epoxy-sealed

Calibration data

Standard

CS130L & CS130H

Comparison sensitivity at 100 Hz and 10 g peak, and a comparison frequency response from 2 Hz to 20 000 Hz. Test results are furnished in a formal report that includes sensitivity and frequency response plots

Included accessories

15071	Adapter stud, 1/4-28 UNF to 10-32 UNF
14159-1	Adapter bushing, 10-32 UNF
14159-2	Adapter bushing, 6-32 UNC
14159-4	Adapter bushing, 2-56 UNC
34699	Shaker isolator kit

Optional accessories

14159-3	Adapter bushing, 4-40 UNC
14159-5	Adapter bushing, 4-48 UNF
14159-6	Adapter bushing, 8-32 UNC
14159-7	Adapter bushing, M3x0.5
EHX 268	Acoustic couplant

Notes:

1. Estimated accuracy of correction factor from curves showing typical response is ±1%. Sensitivity is the standard output divided by the acceleration motion at the surface provided for attaching test accelerometers.
2. Recommended torque for attachment is 18 lbf - in (2 Nm). Torque values above 24 lbf - in could cause permanent damage to the mounting threads.
3. Somewhat larger harmonic distortion is present below 5 Hz and above 10 KHz at frequencies which are the 1/3 and 1/5 subharmonics of armature or accelerometer resonance frequencies.
4. Up to 10 000 Hz with a balanced load.
5. Maintain high levels of precision and accuracy using Endevco's factory calibration services. Call Endevco's inside sales force at 800-982-6732 for recommended intervals, pricing and turn-around time for these services as well as for quotations on our standard products.

Model 2924
AACS comparison vibration calibrators

Endevco's low frequency comparison vibration calibrator model 2924A supports the need for high signal-to-noise ratio at low frequencies, by generating larger accelerations at low frequencies. The shaker's six inch peak-to-peak displacement extends calibration frequencies to ‹ 1 Hz (when using a dc-coupled reference accelerometer). Model 2924A features low waveform distortion, very low transverse motion (typically ‹ 1%),low magnetic fields, and very low temperature changes even when running continuously at maximum displacement. Optical over-travel detectors protect the shaker from damage.

Specifications

Frequency range	1 to 200 Hz	
Force rating (continuous)	20 lb (94 N) vector	1 to 100 Hz
Maximum stroke	6.0 in (15.2 cm) pk-pk*	
Rated velocity	60 in/s (150 cm/s) vector	
Maximum acceleration	6g vector	
Air supply	30 psig (28 N/cm^2) minimum 10 micron filter	
Accelerometer included	2 each	7751-500 (7290A-10 suggested if below 1 Hz)
Weight shaker	140 lbs (64 kg)	
Base/mount	450 lbs (205kg)	

* Normal operating transducer displacement is typically 100 mm to allow safety margins

Included accessories

30912	Shaker base/mount assembly
32594	Bearing plate (Qty 2)
31650	Bearing disk (Qty 2)
EH695	.75 - 10 x 2.5 Socket screw (Qty 2)
EH701	.75 - 10 x 1.25 Socket screw (Qty 2)
EHM1027	5/8 Wrench, allen

Optional accessories

7290A-10	Microtron accelerometer
7251A-500	Isotron accelerometer

Model 68357
AACS Controller module

Endevco's Controller module 68357-Y, the core of the automated accelerometer calibration system, is designed to automate transducer calibration, improve overall calibration accuracy, and enhance compliance with ANSI/NCSL Z540-1-1994 and ISO-9000.

Test configuration and test data are stored in a password-protected relational database with extensive cross-references to enhance traceability and record keeping. User-customizable reports are generated automatically. The controller module automatically recalls relevant parameters and sets up model specific calibration conditions, minimizing operator-induced error and measurement uncertainty. Relative humidity and temperature are also reported.

The system has an extensive automated electronic self calibration; internal capacitors and a precision resistive divider allow self calibration of the signal conditioning channels over the entire frequency range, and they can be used to generate charge or voltage signals for the calibration of external amplifiers.

Controller module highlights

User friendly interface
› Graphical menu
› Sophisticated graphics
› On screen instructions
› Basic diagnostics display
› Custom reports
› Set up and store unique configurations

Relational database
› Complete history file
› Historical tracking
› Password protected

Computer control
› Precision signal conditioning
› Automatic internal calibration
› Up to four excitation sources
› Temperature and humidity recording
› Automated capacitance/impedance measurements

Controller module components

Calibration interface panel
Accelerometer input connections
› Computer-controlled switching
› Precision voltage divider and capacitors
› Charge converters
› Programmable oscillator

Signal conditioner
› Model 4430A computer controlled amplifiers (2)
› Model 4960A rack
› Power supply

Controller assembly
› Computer, X86 processor
› 145 GB hard disk minimum
› 1 GB RAM
› Backup storage medium
› 19" color flat panel monitor
› GPIB interface card
› Multifunction A/D, D/A and I/O
› Dual channel data acquisition, 10 Msamples/sec, 16 bit card
› Printer, inkjet, color printer
› (Option - maintenance agreement)

System enclosurement/installation
› Hardware enclosures and desk
› Air supply line, cables and interconnects
› Mounting supports

Model SW68357 controller software
› LabVIEW™ for Windows
› Microsoft® access database

Model 2925
AACS comparison shock calibrator (POP)

Endevco's comparison shock calibrator model 2925 provides an accurate and controlled means of shock sensitivity calibration of accelerometers. The POP is designed to be used with the model 2270 family of back-to-back comparison calibration standard accelerometers. Calibrations are performed at accelerations from 20 g to well above 10 000 g at half-sine pulse durations from 3 ms to 100 µs. The system can be used manually in a stand-alone mode, or in a fully computer-controlled mode.

A Pneumatically Operated Projectile (POP) contained in a barrel is released at a selected air pressure level. The projectile impacts an anvil to which the unit under test and the back-to-back reference accelerometer are mounted. Pressure is regulated with a voltage-controlled regulator, and released with an electrically operated poppet. When the impact occurs, the anvil lifts off a rubber mount, flies a short distance, and is captured by a cushioned fixture. Desired accelerations and pulse durations are produced using combinations of four anvils, two masses, cushion thicknesses and continuously adjustable pressure settings. The POP system provides considerably higher shock levels than those that are available with dropped ball techniques. The wide pulse durations available give flexibility in analysis and reduce the need for filtering.

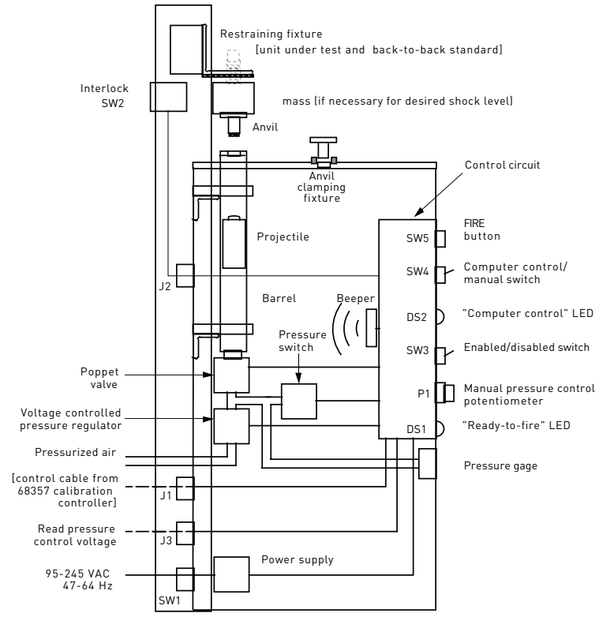
Specifications

Amplitude repeatability	‹ 5% for successive pulses under same conditions
Measurement uncertainty	± 1.9% from 20 g to 2000 g ± 2.6% from 2000 g to 10 000 g
AC power input	95-245 Vac 47-64 Hz, 1 A max
Air supply	60 psi (4 bar), or 5 psi (.3 bar) above highest desired drive pressure, 150 psi (10 bar) maximum. Gas must be dry and filtered to 25 micron maximum particle size.

Anvil dash #	Anvil dash #	Pressure psi	Acceleration (typical)	Pulse duration (typical)	Test accelerometer minimum resonance
1	1	20-30	20-200 g	3-1.2 ms	1.7-4.2 kHz
2	1	20-30	35-300 g	1.6-.6 ms	3.1-8.3 kHz
1	2	20-30	50-400 g	2.5-1.3 ms	2-3.8 kHz
2	2	20-30	90-700 g	1.5-.7 ms	3.3-7 kHz
1	none	20-40	300-1 kg	1.5-.9 ms	3.3-5.6 kHz
2	none	20-40	500-2 kg	.9-.5 ms	5.6-10 Khz
3	none	20-40	800-3 kg	.7-.35 ms	7-14 kHz
4	none	20-40	2k-10 kg	.2-.1 ms	25-50 kHz
		-60	-15 kg	- ‹ .1 ms	- › 50 kHz

Shock characteristics of selected anvil/mass/pressure combinations

Note
The values in this table are approximate and intended as general guidelines. They are based on undamaged pad configuration. Results with worn or damaged pads could differ significantly.



Model 28959F/FV
Portable accelerometer calibrator

- Portable, rechargeable battery
- Ideal for In-situ end-to-end calibration
- Test Range: Up to 10 g's, 10 Hz to 10 kHz
- Calibration traceable to NIST
- Integral printer provides handy record
- Internal memory for over 1600 tests
- RS-232 interface transfers field data
- 14-Point calibration report traceable to NIST included

The Endevco model 28959F/FV portable calibrator is designed to provide precision calibration for various types of accelerometers in the field. It is also perfect for test engineers and technicians needing on-site end-to-end calibration of their complete measurement chain.

Model 28959F/FV is a self-contained system which includes built-in vibration exciter, signal generator, computer-controlled amplifier/servo mechanism, reference accelerometer, thermal printer, RS232, serial interface, LCD display screen, signal conditioners and all necessary connectors and mounting accessories. The unit can be powered by AC line voltage or its internal rechargeable batteries. The calibrator is very powerful yet user-friendly. Operation may be learned quickly by inexperienced operators.

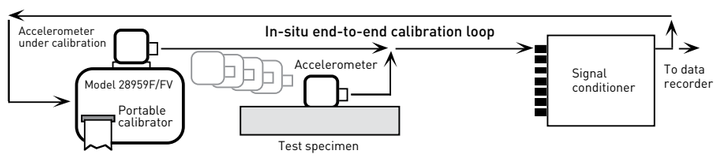
Model 28959F/FV is designed to accept charge and voltage mode piezoelectric accelerometers directly. Test amplitude is adjustable up to 10 g's over the frequency range of 10 Hz to 10 kHz. An internal reference accelerometer traceable to NIST serves as the comparison standard.Internal static RAM stores over 1600 test results. Sensitivity is supplied in English or metric engineering units. An automatic self test feature provides measurement integrity at every power-up.

Special features

- Displays and saves serial number and type, test parameters, date/time, and test results
- Calculates sensitivity automatically
- Hard copy record from built-in printer
- Verify accelerometer polarity
- Built in charge convertor for charge mode devices
- Built in constant current source for voltage mode devices (Isotron® type)
- Battery powered with built in charger
- Help screens assist operator

End to end system calibration

The following example depicts an end-to-end calibration of one vibration measurement channel:



Specifications

Dynamic characteristics

Calibration	Traceable to NIST (USA) standard at 2g from 20 Hz to 10 kHz			
Measurement uncertainty				
Acceleration	10 Hz to 2 kHz, ±0.3 dB 2 kHz to 10 kHz, ±1 dB			
Frequency range	10 Hz to 10 kHz			
Frequency readout accuracy	0.001% ±1 count			
Amplitude range	subject to displacement limit of 0.1 inch (2.54mm) pk-pk			
Frequency vs. Maximum Load	≤ 100gm	≤ 250gm	≤ 500gm	≤ 750gm
10 Hz to 100 Hz	10g	4g	2g	1g
100 Hz to 1 kHz	7g	5g	2g	1g
1 kHz to 10 kHz	3g	2g	n/a	n/a
Reference accelerometer output	50 mV/g, ±2% @ 100 Hz			

Report format

Visual display	4 lines of 20 characters, 5x7 dots LCD display with backlit
Print-out	5x7 dot matrix integral thermal printer. Paper width: 2.3"

Data storage/interface

Internal memory	128K byte, store up to 1600 individual test results
Serial interface	RS-232 with a DB-9 female connector

Power equipment

Power	Battery powered with Auto Power Management. Operational during charging. Built-in charger accepts 115VAC, 50/60Hz -28959F (220VAC option available - 28959FV)

Physical characteristics

Dimensions	11" h x 10" w x 7" d (279 mm x 178 mm x 254 mm)
Weight	21 lbs. (9.6 kg)
Environmental	Operational from +10°F to +120°F (-12°C to +50°C) @ 95% RH

Included accessories

P/N 6006-0008	Power cord
P/N 0228-0072-01	Spanner wrench
P/N 0228-0071-01	Accelerometer mounting fixtures. Various 1/4-28 mounting stud adaptors
EHM 1476	To 1/4-28 UNF stud
EHM 1477	To 10-32 UNF stud
EHM 1478	To 2-56 UNC threaded hole
EHM 1479	To 6-32 UNC threaded hole
EHM 1480	To 10-32 UNF threaded hole
P/N 3090CM50	Input cable, voltage mode
P/N 3090CM51	Inpute cable, charge mode
P/N 2112-0007	Spare input connector
P/N 201-211-25C (SEIKO)	Printer paper (available in many office supply sources)

Optional accessories

P/N 30279	Mounting fixture for PR/VC accelerometer
P/N 31283	Mounting fixture for adhesive-mounted accelerometers
P/N 31207	Serial interface software for PC compatible
P/N 2270M8	Transfers standard accelerometer for calibration of standards built into shakers

Factory recalibration

CS 830	14-Point calibration traceable to NIST, recommended yearly

Note

Maintain high levels of precision and accuracy using Endevco's factory calibration services. Call Endevco's inside sales force at 800-982-6732 for recommended intervals, pricing and turn-around time for these services as well as for quotations on our standard products

Cables

For over 60 years, accelerometer cabling has been a priority at Endevco. Early in our history, we started manufacturing our own high quality, low noise cable using specially designed machinery. Today we continue to produce state-of-the-art cable for routine testing and mission critical applications. For harsh, high temperature applications, Endevco's highly engineered hardline cable is up to the challenge.

Low noise transducer cables and accessories

Endevco designs and manufactures its own cables and connectors specifically for dynamic testing. In these tough and challenging environments, accuracy depends as much on cables and connectors as it does on transducers. Our engineers are well schooled in all the critical parameters in cable and connector designs that can affect signal transmission. As a result, these parameters are carefully optimized in our products to ensure data quality and reliability. When it comes to this kind of in-house custom capability, ordinary commercial cable and transducer companies just don't compare.

No application is too tough.
You'll find Endevco premium cable in today's most demanding applications:

- Defense
- Aerospace
- Aviation
- Space program
- Laboratory
- Automotive
- Nuclear
- Custom accelerometer cabling

Differential, low noise cables
Endevco offers a variety of low noise, shielded twisted pair cable assemblies designed for use with differential piezoelectric accelerometers having two pin receptacles with 7/16-27UNS-2A threads. This cable is specifically designed with high force contacts and alumina inserts for high temperature exposure with Teflon jacket. Specific models are available to handle high temperature (500°F/260°C) environments which are ideal for industrial and marine turbine applications. Cable assemblies are available with a variety of interface connectors and selectable lengths. Raw cable is also available for your custom applications.

High impedance cable assemblies
Endevco offers a series of low noise, high impedance stranded center conductor. All models come with a standard 10-32 interface on one end and customer selectable connector on the other end. These soft line cables offer Teflon or silicon jacket (model dependent) with a low bend radius for tight applications. All models offer low noise treatment and excellent reliability. These cables are designed for difficult environments where moisture and temperature may be an issue. Temperature range for these cable assemblies is from -300°F/-184°C to 500°F/260°C (consult factory for specific models).

Low impedance cable assemblies
Endevco offers a wide variety of designs for low impedance accelerometers. Models are available with one, two or four conductors. Models are available with shielded or unshielded designs. For four conductor cables, the customer interface connectors terminate in single or multiple connectors. Endevco offers a wide variety of interface connector options. Contact the factory for specific model information.

Miniature cable assemblies
Endevco offers miniature and subminiature low noise cable assemblies. These cable assemblies offer either 1 UNM, 1-64 UNC, or 6-64 UNF termination depending on the model. Some models offer high temperature (500°F/260°C) operation. Consult the factory for information on specific models.

High temperature cable assemblies
Endevco offers both hard line and soft line cables for high temperature (to 900°F/482°C) environments. Hard line cables are supplied with a fiberglass jacket over a stainless steel sheath to prevent inadvertent grounding. Designs are available for either single ended or differential Piezo accelerometers or dynamic pressure sensors.

Raw cable
Endevco also offers raw cable for those users who have specialty applications. Consult factory for product information and availability.

We test and guarantee every inch
All cable is not created equal. In fact, cable quality from other manufacturers can vary greatly—from spool to spool, even inch to inch—mainly because of inferior or non-existent test methods and standards.

At Endevco, we take extra measures to ensure the quality and consistency of every cable length. Utilizing the latest cable testing technology, we perform 100% continuous testing. Under carefully controlled conditions, every length of low-noise cable is repeatedly flex-tested to verify its low noise characteristics.

Built for dynamic environments
For ensuring top performance in any dynamic environment, Endevco cable is also tested for noise, resistivity, thermal and shock cycle and spark testing, as well as:

- Vibration—random and sine
- Dielectric breakdown
- Shield effectiveness (multimeter)
- All Endevco cable meets or exceeds the most stringent international standards. Endevco earned its ISO 9001 certification in 1994.

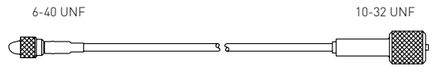
Standard miniature cable assemblies for piezoelectric accelerometers

3003C

The Endevco model 3003A is a sub-miniature, low noise coaxial cable assembly designed for use with Endevco models 22 and 23 high impedance accelerometers. It mates with the Endevco 3093 and 3095A series of standard size coaxial cables. The 3003A is a miniature semi-rigid cable with a 1.00 UNM outside thread connector at one end and a 1-64 UNC-2A inside thread at the other. Instructions on installing this cable, which are supplied with model 22 and 23 accelerometers, should be rigidly followed. Model 22 and 23 accelerometers have 3003C-6 (six inch length) cables installed as a standard accessory in addition to a 3095A-120 (10 ft. length).

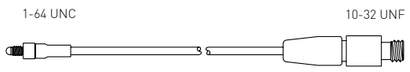
3091F

The Endevco model 3091F cable assembly is a low noise, Teflon® jacketed, coaxial cable for use on high impedance or low impedance piezoelectric accelerometers which utilize a 6-40 UNF-2B threaded connector. The opposite end is terminated with an inside thread 10-32 connector. The 3091F features an improved shield crimp and laser welded center conductor to contact socket termination and 500°F operating temperature. This cable assembly is typically used with Endevco model 2220D and 7250A accelerometers. The standard length for this cable is 10 ft.(3091F-120).



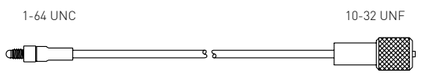
3093

The Endevco model 3093 is a replacement cable assembly for use with the Endevco model 2222C accelerometer. It mates with the Endevco 3000 series of standard size coaxial cables. This cable is a TFE jacketed sub-miniature cable treated for low noise generation, has an outside thread 10-32 connector at one end and an outside 1-64 RH thread at the other. The standard length for this cable is 1 ft.(3093-12).



3095A

The Endevco model 3095A is the same as the model 3093 with the exception that one end is terminated with an inside thread 10-32 connector and the other end of the cable assembly is terminated with an outside 1-64 RH thread. The standard length for this cable is 10ft. (3095A-120).



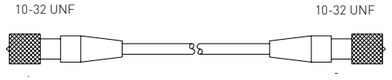
Specifications

Electrical characteristics		**3003C**	**3091F**	**3093**	**3095A**
Capacitance, nominal	pF/ft	65	40	30	30
Center conductor resistance, nominal	Ω/ft	20	0.6	0.6	0.6
Physical characteristics					
Conductor					
Size	AWG	40	33	33	33
Material		Copperweld	Copperweld	Copperweld	Copperweld
Primary insulation		Teflon®	Teflon®	Teflon®	Teflon®
Shield		Silver plated copper	Silver plated copper	Silver plated copper	Silver plated copper
Jacket material		Teflon®	Teflon®	Teflon®	Teflon®
Overall diameter	in	0.020	0.060	0.060	0.060
Weight (nominal)	gm/in	0.013	0.013	0.013	0.013
Bend radius, min	in	0.20	0.12	0.12	.012
Standard cable length(s)	in	6	21, 120, 180, 240	12	120
Connector characteristics					
Type		1.00 UNM to 1-64 UNC-2A	6-40 UNF-2B to male 10-32	1-64RH to fem 10-32	1-64 RH to male 10-32
Bend relief		N/A	Silicone rubber	Silicone rubber	N/A
Environmental characteristics					
Temperature range	F°	-100 to +350	-300 to +500	-100 to +350	-100 to +350
Noise		1.0 pk-pk pC	1.5 pk-pk pC	1.5 pk-pk pC	1.5 pk-pk pC

Standard cable assemblies for piezoelectric accelerometers

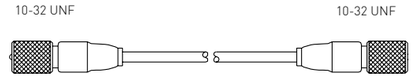
3060A

The Endevco model 3060A is a high temperature(+500°F), silicone jacketed, low-noise softline cable. The 3060A is designed for applications involving tight bends and complicated cable routing. With its seamless silicone outer jacket, this cable provides enhanced flexibility and minimum exposure to moisture contamination. There is a 10-32 connector provided at each end of the cable assembly. Standard cable length is 10 feet (3060A-120).



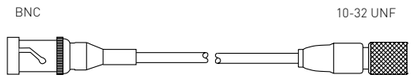
3090C

The Endevco model 3090C is a high reliability low-noise softline coaxial cable. It is a premium general purpose cable designed specifically for use with piezoelectric accelerometers in severe environments. This fused Teflon® jacketed cable has applications where maximum reliability is essential and where repeated usage is important. The cable features (1) stainless steel connectors (center pin fused into glass insulator, 10-32 threaded nut), (2) a stranded-wire center connector for maximum flexibility; and (3) a high cable pullout tensile strength for increased ruggedness and long-term life. Connector design features make the cable an excellent choice for high humidity, high temperature conditions. Temperature rated from -423°F to +500°F, the cable also has guaranteed low noise characteristics. The fused Teflon® jacket of the 3090C is recommended in applications where cable abrasion will be encountered. Standard cable length is 10 feet (3090C-120).



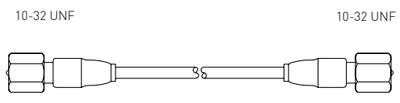
3090CM12

The Endevco model 3090CM12 low-noise cable has the same ruggedness and reliability as the model 3090C. The 3090CM12 is designed with a male BNC at one end and a 10-32 connector at the other. The temperature rating for the cable and 10-32 connector is -423°F to +500°F. The temperature rating for the BNC connector end is -85°F to +329°F. Standard cable length is 10 feet (3090CM12-120).



3096

The Endevco model 3096 cable assembly is a low-noise, Teflon® jacketed, coaxial cable with a Kevlar® reinforcement braid and stainless steel, hermetic connectors. It features a new improved backshell, strain relief design, silver plated stranded center conductor, and shield. This cable is specifically designed for piezoelectric use in severe environments. The model 3096 is temperature rated from -67°F to +500°F. Standard cable length is 10 feet (3096-120).



Specifications

Dynamic characteristics		**3060A**	**3090C**	**3090CM12**	**3096**
Capacitance, nominal	pF/ft	36	36	32	35
Center conductor resistance, nominal	Ω/ft	0.154	0.5	0.5	0.5
Physical characteristics					
Conductor					
Size	AWG	28	30	30	30
Material		S.P. Copperweld	S.P. Copperweld	S.P. Copperweld	S.P. Copperweld
Primary insulation		Teflon®, noise treated	Teflon®, noise treated	Teflon®, noise treated	Teflon®, noise treated
Shield		Silver plated copper braid	Silver plated copper braid	Silver plated copper braid	Silver plated copper braid
Jacket	Material	Silicone	Teflon®	Teflon®	Teflon®
Overall diameter	in	.092	.080	.080	.105
Weight (nominal)	gm/in	0.029	0.029	0.029	0.029
Bend radius, min	in	0.950	0.850	0.850	0.850
Standard cable length(s)	in	36, 120, 240, 360	12,36,120,240 360, 600, 900	120, 240, 600	120, 240
Connector characteristics					
Type		10-32 to 10-32	10-32 to 10-32	10-32 to BNC	10-32 to 10-32
Bend relief		Flourosilicone rubber	Flourosilicone rubber	Flourosilicone rubber	Flourosilicone rubber
Environmental characteristics					
Temperature range	F°	-100 to +500	-432 to +500	-432 to +500	-67 to +350
Noise		1.5pk-pk pC	1.5pk-pk pC	1.5pk-pk pC	1.5pk-pk pC

Standard cable assemblies for Isotron® accelerometers

3006

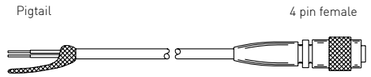
Endevco's model 3006 cable is a miniature Teflon® jacketed coaxial cable that mates with a special 1.20 UNM Endevco receptacle on one end and a 10-32 type plug on the other end. It is intended for use with low impedance transducers, such as Endevco model 25B and 2250A Isotron accelerometers that do not require noise treated cables. The model 3006 is temperature rated from -58°F to +257°F. Standard cable length is 10 feet (3006-120).

3024

The Endevco model 3024 cable is a low-cost twisted pair cable with Teflon® insulated conductors. No shielding or overall jacket is provided. It is designed to be used with low impedance transducers, such as Endevco model 25A, 2250AM1, 2255B and 7255A Isotron accelerometers. The accelerometer end of the cable is soldered to the leads extending from the accelerometer, and the other end is terminated with a 10-32 center pin connector. The cable is not shielded or noise treated and should not be used with high impedance piezoelectric accelerometers. Model 3024M1 is a shielded, S.P. copper braid, version of the Model 3024.This version is designed for high noise and EMI environments. This cable is temperature rated from -300°F to +350°F. Standard cable length is 10 feet (3024-120).

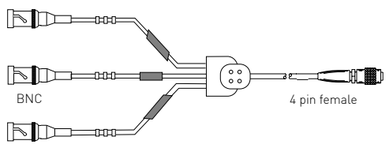
3027A

The Endevco model 3027A cable assembly is a four conductor shielded cable designed to operate with low impedance accelerometers. This cable utilizes the solderless crimp style conductor to pin method. The shield is crimped and soldered to the connector case. The outer jacket is gray silicone with an internal Teflon® insulation. There is a four pin receptacle at the accelerometer end and tinned leads at the other end. The 3027A is designed to be used with model 63A and 2258AM2 accelerometers. The temperature rating for this cable assembly is -148°F to +257°F. Standard cable length is 10 feet (3027A-120).



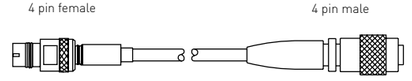
3027AM3

The Endevco model 3027AM3 is a cable assembly designed to mate with triaxial Isotron accelerometers such as models 65A & 2258AM2. One end of the cable assembly features a 4-pin receptacle while the other end branches into 3 male BNC plugs. The 3027AM3 is temperature rated from -67°F to +185°F. Standard cable length is 10 feet (3027AM3-120).



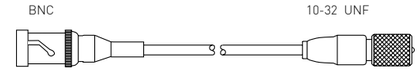
3027AM4

The Endevco model 3027AM4 is an extension cable for use with the 3027AM3 cable assembly. This cable has a male 4-pin connector at one end and a female version at the other. The temperature rating for this cable assembly is -148°F to +257°F. Standard cable length is 10 feet (3027AM4-120).



3061

The Endevco model 3061 has a male 10-32 miniature coax connector at one end and a male BNC at the other. The model 3061 is temperature rated from -148°F to +500°F. Standard cable length is 10 feet (3061-120).



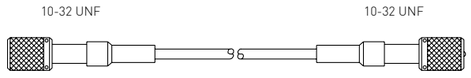
Specifications

Electrical characteristics		**3006**	**3024/M1**	**3027A**	**3027AM3**	**3027AM4**	**3061**
Capacitance, nominal	pF/ft	42	N/A	16	30	16	28
Centor conductor resistance, nominal	Ω/ft	16	0.066	0.3	0.2	30	0.25
Physical characteristics							
Conductor							
Size	AWG	36	28	32	28	32	30
Material		Copper	S.P. copper	S.P. copper	Copper	Copper	S.P. copper
Primary insulation		Teflon®	Teflon®	Teflon®	PVC	Silicone	Teflon®
Shield		Gold plated copper	N/A (M1, s.p. copper)	T.P. copper	Alumylar	Copper	S.P. copper braid
Jacket	Material	Flourocarbon	Teflon®	Silicone	PVC	Teflon®	Teflon®
Overall diameter	in		0.035 (M1 0.94)	0.094	0.105	0.105	0.080
Weight (nominal)	gm/in	0.042	0.29	0.38	0.38	0.38	0.29
Bend radius, min	in	0.120	0.750	0.50	0.850	0.50	0.950
Standard cable lengths	in	120	120, 240	120, 240	36, 120	120	36, 120 240, 480
Connector characteristics							
Type		.120 UNM to to 10-32	Tinned leads to 10-32	4-pin rec. to tinned leads	4-pin rec. to 3x BNC	4-pin plug 4-pin rec.	10-32 to BNC
Bend relief			N/A	Flourisilicone rubber	Silicone rubber	N/A	
Environmental characteristics							
Temperature range	F°	-58 to +257	-300 to +350	-148 to +257	-67 to +185	-148 to +257	-148 to +500

High temperature cable assemblies

3075M6

The model 3075M6 hardline cable assembly is designed for use at high temperatures (+900°F) and high humidity. It is hermetically sealed and will operate in severe environments. The 3075M6-XXX has a fiberglass jacket over a stainless outer sheath to prevent inadvertent grounding. Both ends of the cable are terminated with a glass fired 10-32 connector. This cable is used with high temperature single ended piezoelectric accelerometers such as Endevco's model 2276.



33268

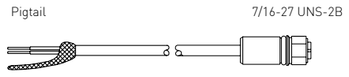
The 33268 is a high temperature (+900°F) 10-32 to 10-32 in-line adaptor. This adaptor enables the user to connect two 3075M6 hardline cables together.

6918M30

The Endevco model 6918M30 cable assembly is designed for use with high temperature (+900°F) differential, piezoelectric accelerometers, which utilize a two pin receptacle with 7/16-27 UNS-2A threads.
This cable is used as an extension from extremely high temperatures to temperatures more suitable to the softline differential cable model including our model 6917D,which is rated to +550°F or model 6917B, which is rated to +500°F. The 6918M30 cable is used with differential piezoelectric accelerometers such as Endevco's model 6233C.

6917B and 6917D

The Endevco® models 6917B and 6917D cable assemblies are designed to mate with differential type piezoelectric accelerometers which utilize a two pin receptacle with 7/16-27 UNS-2A threads. They are typically used in turbofan environments and both provide 80 pC/ft maximum capacitance and 1G Ohm resistance between the signal leads. The 6917B can operate in environments up to 500°F and the 6917D up to 550°F with 600°F possible for intermittent periods. They also feature a specially designed plug assembly with high force contacts and alumina inserts for high temperature operation. The 6917B includes a removable backshell which allows for field replacement while the 6917D back shell is protected against mechanical damage by a Viton boot which is also splash proof.



NOTE: Dash number indicates cable length in inches. Endevco manufactures a variety of custom high temperature cable assemblies for gas turbine applications etc., contact Endevco Applications Engineers for assistance.

Specifications

Dynamic characteristics		**3075M6**	**6918M30**
Capacitance, nominal	pF/ft.	63	80 (between signal leads)
			110 (either signal lead to shields)
Center conductor resistance, nominal		0.4Ω/ft.	
	(between signal leads)		50 MΩ min. @R.T.
			1MΩ min. @ +900˚F
	(either signal lead to shield)		50 MΩ min. @ R.T.
			1MΩ min. @ 900˚F

Physical characteristics			
Conductor			
Size		0.01 in. O.D.	Solid wire
Material		nickel	600 Inconel
Primary insulation		MgO	MgO
Jacket	material	304L SS	304L SS
Outside diameter	In	0.070 (with sleeving .135 to .140)	0.25 max
Weight (nominal)	gm/in	0.33	1.50
Bend radius, min.	in	0.75	0.850
Standard cable lengths	in	120, 180, 300, 480, 600	60, 240, 360

Connector characteristics			
Type		10-32 to 10-32, male (pin) (glass fired/welded)	inside thread 7/16 plug (mates to accelerometer) to 2 pin disconnect, 7/16-27 UNS-2A (mates to 6917B/C plug assembly)

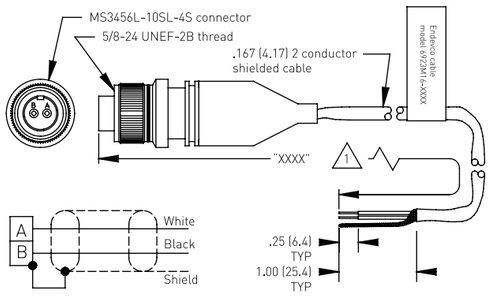
Environmental characteristics			
Temperature range	F˚	-300 to +900	Hardline section -65˚F to +1200˚ Accelerometer mating connector plug and 2 pin disconnect -65˚F to +900˚F

Shielded twisted-pair industrial cable assemblies

6923

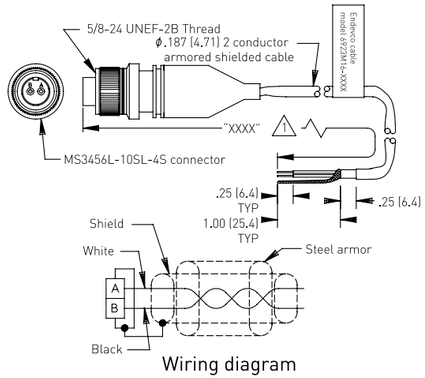
The Endevco® model 6923 series cable assemblies are designed to interface with accelerometers having MIL-C-5015C two pin threaded connectors. Applications are typically high reliability measurements that are found in marine and aircraft engine environments.

The model 6923M9 cable assembly incorporates 20 AWG twisted pair conductors shielded by a single silver braided copper shield and covered by abrasion resistant extruded white TFE tape for a rugged, durable assembly. Alternatively, the model 6923M16 utilizes 22 AWG twisted-pair conductors with both an inner electrical shield and an outer armor braided tin shield to provide added strength and abrasion resistance. The 6923M16 assembly is protected using extruded black TFE jacket material. These cable assemblies are designed for reliable operation in the most stringent of industrial environments and are rated for IP67 moisture conditions. Both assemblies incorporate an MS3456L-10SL-4S connector with a molded Viton® backshell to provide for sealing against moisture or other fluids. Cable lengths of 10 ft (120 inches) are standard, however, custom cable lengths are available by specifying the length in inches after the model number (e.g. 6923M9-180, for 180 inch end-to-end length).



Wiring diagram

Model 6923M9



Wiring diagram

Model 6923M16

Specifications

Electrical characteristics	Units	6923M9	6923M16
Capacitance			
Between signal leads	pF/ft.	20	
Etheir signal to shield	pF/ft.	75	
Resistance			
Between signal leads	G Ω minimum	1	
	G Ω minimum	1	
Physical characteristics			
Cable material			
Conductor		20 AWG Silver plated copper (19 strands of 32 AWG)	22 AWG Tin plated copper (19 strands of 34 AWG)
Conductor insulation		Black and white TFE	
Shield		Braided silver plated annealed copper	Braided tin plated annealed copper
Armor			Braided SSTL, 90% coverage, min.
Jacket		Extruded TFE white	Extruded TFE black
Weight	g/in	0.73	1.13

Connector characteristics		
Accelerometer interface	P/N	MS 3456L-10SL-4S (or equivalent)
Free end		Leads and shield stripped and tinned
Environmental characteristics		
Temperature range	F° (C°)	-65°F to +392°F (-54°C to +200°C)

Tests performed	
Capacitance resistance	pF @ 1000 Hz
Between leads	G Ω @ 100 VDC
Either signal lead to shield	G Ω @ 100 VDC

Technical papers

For 60 years Endevco has been the leader in sensing solutions to measure vibration, shock and pressure phenomena. In addition to providing world class products, services and support Endevco is also known for publishing some of the most comprehensive technical papers on the subject of transducer measurements. The technical papers included in this section are the most downloaded papers from the Endevco website at www.endevco.com and represent just a portion of the total available papers for review. We continue to add papers as they are developed and encourage our customers to visit the site each month to review the new additions.

Endevco also offers technical training courses at our San Juan Capistrano California headquarters or in some cases in-house training at customer facilities. The updated schedule for these short courses can be found on the Endevco website at www.endevco.com.

Because of the wide frequency response and measuring range, piezoelectric accelerometers (including IEPE-Isotron types) are the most widely used sensors for vibration measurements.

The output of the "self-generating" sensors in PE accelerometers is charge. That is, the "spring" sensing elements provide a given number of electrons proportional to the amount of applied stress (piezein is a Greek word meaning to press). There are many natural and man-made materials which display this characteristic, usually in the form of crystals or ceramic, although some are polymers. All such materials have a regular crystalline molecular structure, with a net charge distribution which changes when strained.

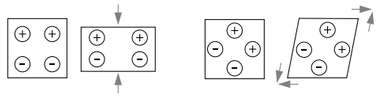


Figure 1. Piezoelectric materials are usually made of ions oriented in a crystal cell, which has a structure in which a net change in the separation of the positive and negative charges occurs when the cell is strained. The direction of the separation (which, depending on the crystal is not necessarily in the direction of the applied force) defines the surfaces on which the electrical signal appears. Compression sensitivity is shown on the image above, (an example of a linear DOF). This example would not develop net charge on the sides for the given strain. On the right depicts the result of shearing stresses (a torsional DOE).

One property all piezoelectric materials share is that they have no center of symmetry in the unit cell of the structure. Deforming a symmetric cell produces no electric fields.

Piezoelectric materials may also have a dipole (which is the net separation of positive and negative charge along a particular crystal direction) when unstressed. In such materials, fields can be generated by deformation from stress or temperature, causing piezoelectric or pyroelectric output, respectively. The effects are reciprocal. The PE sensor can be made to distort with the application of a field or temperature. PE sensors without a dipole (such as quartz) are not pyroelectric.

The pyroelectric outputs can be very large unwanted signals, generally occurring over the long time periods associated with most temperature changes. They might not be noticed if the signal conditioner does not respond to those low frequencies, but they can be very large as thermal rates and gradients increase. (The polymer PE materials have such high pyroelectric output that they are often used as thermal detectors.) Some types of PE materials also produce very high frequency "glitches" in response to thermal transients that can be easily mistaken for acceleration events.

Charges are actually not "generated", just displaced. (Like energy and momentum, charge is always conserved.) What is generated is an electric field along the direction of the dipole. Metallic electrodes on faces at the opposite extremes of the gradient provide mobile electrons, which move from one face, through the signal conditioning, to the other side of the sensor to cancel the generated field. The quantity of electrons depends on the voltage created and the capacitance between the electrodes. A common unit of charge from an accelerometer is the picocoulomb, or 10^{-12} Coulomb, which is slightly over 6 million electrons.

The position of the electrodes depends on the crystal orientation and the type of stress to be sensed. A given material may be sensitive to several directions and types of strain. (Note that the two simplified examples of Figure 1, showing compression and shear strains, corresponding to linear and rotational DOF's, are the same crystal material, simply rotated 45°.) It is important to note that the alignment of the sensitive axis of the accelerometer (affecting cross—axis sensitivity) is only as good as the net alignment of the dipoles with respect to the faces.

Many types of PE materials are used, with the choice being a trade-off of charge sensitivity, dielectric coefficient (which, with geometry, determines the capacitance), thermal coefficients, maximum temperature, frequency characteristics and stability. The best signal-to-noise ratios generally will come from the highest piezoelectric coefficients.

Naturally occurring piezoelectric crystals, such as tourmaline or quartz, generally have low charge sensitivity, nearly one hundred times smaller than that of the more commonly used ferroelectric materials. Allowing smaller size for a given sensitivity, ferroelectric materials are usually man-made ceramics in which the crystalline domains (regions in which dipoles

are naturally aligned) are themselves aligned by a process of artificial polarization.

Polarization usually occurs at temperatures very much higher than operating temperatures, to speed up the process of alignment of the domains. Depolarization, or relaxation, can occur at lower temperatures, (but at very much lower rates) and can also occur with applied voltages and preload pressures. Depolarization always results in loss of sensitivity. Tourmaline is a natural crystal which does not suffer such depolarization, used particularly at very high temperatures.

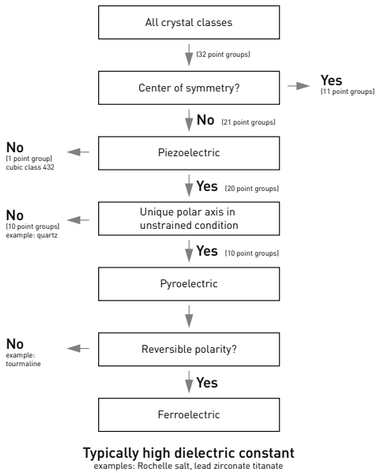


Figure 2. Classifications of crystal types. A center of symmetry exists at a point in a crystal cell if all atoms have an exact twin an equal distance on the other side of the point. Crystals with centers of symmetry are not piezoelectric. A dipole is formed by a net separation of the center of the negative charges with respect to the center of the positive charges within the unit cell of the crystal. If the dipole exists in the unstrained state, the unit will have pyroelectric sensitivity. Ferroelectric materials are defined as those in which the direction of the dipole can be reversed.

PE accelerometers are called self-generating transducers. They produce an electrical output signal without the use of an external electrical power source. Nothing comes free in nature, of course; they transduce mechanical strain energy in the ceramic into electrical energy in the circuit, (hence the generic name "transducer"), actually drawing a small amount of energy from the mounting surface. An important consequence of this is that PE transducers cannot be used to measure steady-state (dc) accelerations.

Such acceleration would put a fixed amount of energy into the crystal and a fixed number of electrons at the electrodes. Conventional voltage measurement would bleed electrons away, as does the internal resistance of the sensor. (High temperature or humidity in the transducer will make things worse by reducing the resistance value). Energy would be drained and the output would decay despite the constant input acceleration.

The piezoelectric transducer is effectively a voltage source driving a series capacitor C, producing a charge Q across its plates according to V = Q / C. Making a measurement requires connecting the sensor to a meter through cables. Cable and meter input capacitance is in parallel with the transducer. The voltage Vi decreases as total input capacitance increases, proportional to the ratio of the sensor capacitance to the total capacitance.

Voltage measurements of PE transducers are impractical because the measurement amplitude is then directly dependent on the cable and system capacitances. Input impedance of the amplifier would also directly affect the response at low frequencies, possibly raising the high-pass corner into the frequency band of interest. (The list goes on and on. Use of voltage amplifiers to measure PE output is not recommended.)

Instead of measuring voltage, a charge should be measured with a charge convertor, as shown in Figure 3. It is a high impedance operational amplifier with a capacitor as its feedback. Its output is proportional to the charge at the input and the feedback capacitor only, and is nearly unaffected by the input capacitance of the transducer or attached cables. The high-pass corner frequency is set by the feedback capacitor and resistor in a charge convertor, not the transducer characteristics. (The transducer resistance changes noise characteristics, not the frequency.)

As with the PE transducers, charge convertor outputs are ac or capacitively coupled, (where "ac" is alternating current; that is, they do not pass steady—state dc direct current values). At low frequencies there is significant attenuation and phase shifts. Depending on application, this is not necessarily a limitation. Practically speaking, no acceleration lasts indefinitely. If time constants are long enough, the ac-coupled transducer will suffice.

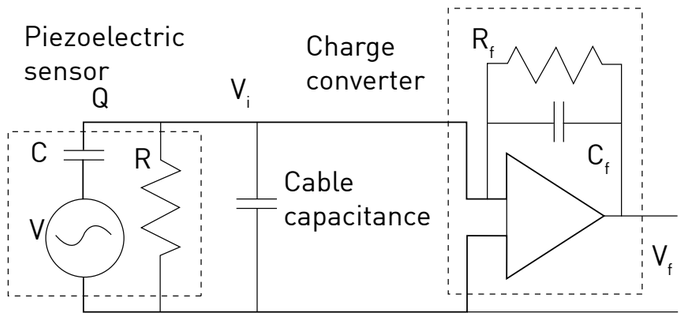


Figure 3. Equivalent circuit of a PE sensor and a charge convertor. The charge output of a sensor is equivalent to a voltage source driving a series capacitor. The parallel internal resistance of the sensor drains off the electrons, preventing dc response. Because the net output of the sensor is charge, the voltage output is shunted by the parallel capacitance of a cable. A charge convertor is not affected by such input capacitance. It is a high impedance operational amplifier which drives a feedback capacitor with a charge equal to -Q (balancing the input Q, since effectively no current flows into the input node), resulting in output voltage Vo = Q/C

PE transducers are generally extremely rugged. Designs have been refined over many decades to optimize sensitivity and bandwidth and to reduce thermal and strain sensitivities. However, there are several aspects that require care in use or interpretation of results.

- Apparent low frequency response can be affected by zero shifting in extreme shock.
- Some PE materials display a "droop" in frequency response of charge output.

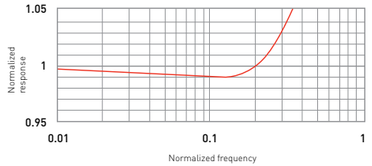


Figure 4. "P8 Droop". Some ferroelectric sensors have a frequency-dependent dielectric coefficient, resulting in a sag in the frequency response of a percent or two per decade of frequency.

- Thermal transients can saturate the high-pass input filters of charge convertors. Some pyroelectric outputs are large enough to depolarize an unconnected ferroelectric PE transducer after a large temperature excursion. (Moral: Keep such transducers connected to signal conditioning during temperature changes.)
- Perhaps the most important limitation of PE transducers is the requirement that they be used with "noise treated" cables. Otherwise, motion in the cable can displace triboelectric charge which adds to the charge measured by the charge convertor (described later).

Integral electronics Isotron PE accelerometers

Many piezoelectric accelerometers include integral miniature hybrid amplifiers, which, among other advantages, eliminate the requirement of noise treated cable. Most require an external constant current power source. Both the input supply current and output signal are carried over the same two-wire cable.

IEPE design offers several benefits. Its low impedance output provides relative immunity to the effects of poor cable insulation resistance, triboelectric noise, and stray signal pickup. Output-to-weight ratio of IEPE transducers is higher than with PE transducers.

Additional functions can be incorporated into the electronics, including filters, overload protection, self identification, etc.

Lower cost cable and conditioning can be used, since the conditioning requirements are comparatively lax, compared to PE. Dynamic range, instead, (the total possible swing of the output voltage) is affected by bias and compliance voltages. Only with large variations in current supply would there be problems with frequency response when driving high capacitance loads.

A disadvantage is that the electronics generally limit the transducer to narrower temperature extremes. Also, although generally not a problem for calibration, the necessarily small size of the amplifier may preclude the more sophisticated features of a full-blown laboratory amplifier. Slew limiting, or sometimes high output impedance, is also a concern with these transducers when driving long cables or other capacitive loads. It can often be remedied by increasing the amount of drive current.

The circuits do not necessarily need to be charge convertors, since the capacitance due to leads between the sensor and the amplifier is small and well controlled. Quartz is used in the voltage mode, that is, with source followers, because its small dielectric coefficient provides comparatively high voltage per unit charge. Voltage conversion also aids ferroelectric ceramics which have the sag in frequency response in charge mode described above. The amplitude frequency response in the voltage mode is quite flat.

Isotron and charge mode piezoelectric accelerometers, selection criteria

Should one use a high impedance PE charge mode type accelerometer, or one with internal electronics (Isotron or IEPE?) This is one of the most commonly asked questions fielded by our application engineers. Aside from the key determining factor, namely their operating temperature ranges, there are four important factors that deserve careful consideration.

Dirty environments

With any type of measurement system, every component in the measurement chain (the sensor, cable, and amplifier) should be kept clean and dry in order to achieve the desired performance characteristics. If water gets into the cable connector, for example, a fault condition will develop in either a PE or IEPE system. However, PE accelerometers are especially sensitive to external contamination due to their high impedance, requiring more care in daily maintenance. In test environments where heavy moisture and contaminants exist, the low output impedance of IEPE sensors has an obvious advantage.

Long cable run

Signal-to-noise ratio in the PE based system is a function of the amount of capacitance (length of cable) between the sensor and the charge amplifier. In applications where long cables (over 200 ft) are needed between the charge amplifier and the accelerometer, two points require consideration:

› With a typical charge amplifier, the addition of 6000 pF of cable capacitance (200 ft) will increase the noise floor of the amplifier by about 4 times. Although the relationship between cable length and amplifier noise is not linear, the noise increase from less than 50 ft of cable is typically considered negligible.

› With a very long cable run, the difference in cost between noise treated cables and ordinary coaxial cables may be significant.

Range flexibility

One of the long-standing advantages of a PE based system is its ability to change its usable dynamic range. In a typical shock and vibration measurement application, the range of measurement is unknown. During the equipment selection/setup process, the test engineer usually estimates the required maximum range based on past experiences and supplements that with a safety factor when choosing the range of the accelerometer. With an IEPE accelerometer, if the peak acceleration level exceeds the engineer's estimates, part of the accelerometer output signal would appear clipped, because the full scale range (rated maximum output swing) of the transducer is fixed at the factory. The engineer has no other option but to employ a different model with a higher range. On the other hand, with a high impedance PE transducer and an external charge amplifier, the engineer can manipulate the full scale range adjustment on the amplifier, and the test may continue without requiring a substitution. This is due to the fact that most PE accelerometers are capable of greater than 120 dB of dynamic range. Using an external charge amplifier gives the user the flexibility to customize the operating range in any given test.

Durability

Consider the following scenario — two piezoelectric accelerometers with identical physical design. One is equipped with internal electronics (IEPE), the other without (PE). It is undeniable that the PE type scores much higher than the IEPE type in mean-time-between-failure (MTBF) due to its simplicity. This distinction is most relevant when applied to extreme environmental conditions.

In many environmental stress screening (ESS) applications where the accelerometers are usually inside the test chamber, the transducers will experience the same thermal cycling and dynamic profile that the test article is exposed to. If an IEPE accelerometer is used in this case, the internal amplifier and the crystal element see the chamber condition at all times. With a PE accelerometer, on the other hand, the charge amplifier would be sitting outside of the chamber at ambient condition, minimizing the unnecessary stress on the amplifier. It can therefore be argued that PE accelerometers are more durable than IEPE types under certain conditions.

In addition, all electronic components, including the internal amplifier inside all IEPE type designs, are sensitive to ESD damage. It is not difficult to "fry" the circuit of an IEPE transducer on a very low humidity day when ESD precaution was not exercised. PE accelerometers, however, are inherently insensitive to ESD.

There are many situations where one type of accelerometer design is preferred over the other. It is necessary to consider all the advantages and limitations (Figure 1) before selecting between PE and IEPE. When in doubt, our experienced application engineers will help you choose the right type for your specific applications.

Sensor type	Advantages	Limitations
PE (piezoelectric)	› Adjustable full scale output through range changes in charge amplifier › High temperature operation to 700°C available for special purpose devices › Interchangeable with existing charge systems with no system compatibility issues › Simpler design, fewer parts, more durable › Charge converter electronics are usually at ambient condition, away from test environment, minimizing necessary stress	› More care/attention is required to install and maintain high impedance systems at peak operating condition › Special low noise cable required to minimize triboelectric noise (generated by cable motion) › Capacitive loading from long cable run results in noise floor increase › External charge amplifier is required for operation
IEPE (Isotron, etc.)	› Less operator attention, training and installation expertise required › Uses standard coaxial cable or ribbon wire › Drives long cables without noise increase or loss of resolution › Operates directly into many data collectors with built-in constant current input › Operates across slip rings › Lower total system cost per channel	› Full scale output characteristics fixed within sensor—lack of range adjustability › Relatively limited temperature range (‹125°C for general purpose, ‹150°C for special purpose) › Discharge time constant (affects low frequency response characteristics) is fixed within the sensor › Sensitive to ESD (Electrostatic Discharge) › The built-in amplifier is always exposed to the same test environment as the sensor

High sensitivity miniature pressure sensors

Endevco's innovative design approach provides miniature pressure transducers that are not only small and have high frequency response, but also have excellent linearity, high sensitivities, and stability characteristics superior to many other pressure transducers. Nonlinearities of 0.1% FS (Best Straight Line) are not unusual, along with 300 mV output at full scale with 10 V input. Ranges to as low as 1 psi (~7 kPa) are feasible in a case diameter of 0.1 inch (2.34 mm).

Are these transducers subminiature flat-diaphragm diffused silicon designs? In one word, no! They use four piezoresistive silicon elements in a Wheatstone bridge, but their similarities to earlier designs end there. The patented design implementation is novel and provides basic advantages to earlier designs.

Traditionally, miniature silicon pressure transducers have been made similar to most large flat diaphragm strain gage transducers. When pressure is applied to a flat diaphragm, bending stress is distributed over its surface, changing from compression in one area to tension in another. Strain gages can be positioned on a diaphragm to provide increasing and decreasing resistance. For more than two generations four-arm Wheatstone bridge transducers have been made this way, by simply cementing gages to one side of a metallic flat diaphragm.

Figure 1 — Photograph of diaphragm taken with scanning electron microscope 0.05 in. (1.25 mm) O.D.

Now for almost a generation transducers have been made with piezoresistive gages diffused into flat circular diaphragms of silicon, thus providing atomically bonded elements. By using silicon semiconductor technology, miniaturization was achieved. The process has not, however, provided other technical advantages. It simply reduces the diameter of the circular diaphragms and permits extremely thin diaphragms.

A pressure transducer design can be made dramatically more efficient if the stresses can be concentrated at the locations where the strain gages are placed. Stress should not be spread over a large area such as on a flat circular diaphragm. In general, if a structure is under bending stress, stress concentration can be achieved by varying the thickness of the bending element. This is one of the basic conceptual differences which provide the superior performance of all Endevco transducers.

The sculptured diaphragm

Endevco diaphragms are shaped to concentrate stress using a combination of plate and beam theory. This can be visualized by referring to Figure 1 which shows a circular diaphragm having two thicknesses. It is considerably thicker at the outer edge and has two islands in the middle section. Notice how close the islands come to each other and to the edge. Figure 2 shows a photomicrograph of a diagram sectioned to show this. One can easily see that a distributed load, or pressure, on one side results in stress concentrations at points A, B and C where all the bending occurs. If a stress sensitive material is placed at A, B and C, a sensor with improved efficiency results in comparison to the flat diaphragm. The gage elements for our design are diffused into the diaphragm over the entire grooves at points A, B and C.

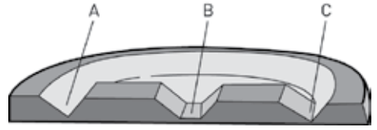


Figure 2 — Photomicrograph of diaphragm section through notches and islands.

Formed by anistropic etching

Our diaphragms are fabricated from single-crystal silicon. This material is anistropic, meaning that its physical properties vary according to the direction in which they are measured. Another characteristic of anisotropic materials is that their chemical reaction rates may vary according to crystalline directions. When placing a crystal of silicon in a caustic bath, such as hot hydrazine, the material is etched faster in certain directions than others. Simply put, the material seems to have a mind of its own, and it forms well defined patterns and contours. By controlling etch bath parameters, the ratio of etching rates with direction can exceed 30 to 1. This results in precise control of shape. As can be seen by Figures 1 and 2, the technique provides deep notches and flat bottoms to the thinned sections. To obtain optimum transducer performance, the crystal must be correctly oriented. Then, using a multiple step lithographic, etching, and diffusing process, the part is fabricated. This technology is basic to the semiconductor industry. It should be mentioned that varieties of etch patterns and contours can be achieved which permit the concept to be used over a wide range of pressures and sizes.

Transverse gage approach

The sculpturing of the diaphragm explains a significant part of the benefits of the Endevco design, but not all. Optimizing the piezoresistive characteristics is also important. The piezoresistive coefficients of silicon semiconductor materials vary with the direction of stress in the crystal and with the dopant material and its amount. Most prior art devices have been designed to stress the gage material so that the gage increases its length. If such a gage were placed in the stress concentration groove of the sculptured diaphragm, it would be stitched back and forth from one end to another — a miniaturization of the larger wire and foil gage approaches. As the groove bends, the effective gage length would change. Another approach is to use a transverse gage; that is, one that is laid lengthwise in the groove. As the groove bends, this gage is strained so that it effectively changes width.

P-Type (110) silicon gage material has an important peculiarity. Its response to transverse strain is equal and opposite to its response to strain parallel to its length. With the appropriately doped material in the groove and with pressure applied, the strain is transverse to the length of the groove and the groove is protected from strain parallel to its length by the full thickness material. In other words, it does not bend in that direction. The piezoresistive sensitivity of this P-Type (110) gage is quite high and its variation with temperature is fairly low. The companion advantage to this approach is that the silicon diaphragm lends itself to anisotropic etch patterns which facilitate this configuration.

Linearity advantages

A fundamental benefit from using the stress concentrated transverse gage is that pressure transducer amplitude linearity can be excellent. The change of resistance with stress for a single parallel P (110) gage is a more linear function than that for a transverse gage. When used in a bridge configuration, however, with one element in tension and the other in compression, the transverse gage approach can be better. A parallel gage has decreasing sensitivity with increasing stress in both tension and compression. The bridge nonlinearity is the average nonlinearity of both. The transverse gage has decreasing sensitivity in tension and increasing sensitivity in compression, so that the average nonlinearity is close to zero.

The requirement for equal and opposite strain fields is a restraint on transducer design. This is the reason for the relatively wide central groove shown in Figure 1. On the other hand, the designer can counteract other nonlinearities in a design by shifting the strain balance between the increasing and decreasing gages. In production practice, the balance of strain levels can be maintained closely enough to provide nonlinearities to full scale of about 0.1% to 0.4% BSL, depending on product and range. The combination of using stress concentration and transverse gages provides about three times better linearity to full scale than the alternative flat-diaphragm approaches. This advantage can be even greater for pressures above full scale. Many of the Endevco pressure transducers provide 1 volt of output with less than 1% nonlinearity.

Sensitivity and stability advantages

The output from these transducers is about 300 mV at full-scale when 10 Vdc is applied. This higher than normal value is a result of two factors:

- The transverse gage approach, which is more linear than the parallel gage approach, permits higher outputs for equivalent nonlinearities.
- Concentration of the stresses over the entire area of the 4 strain gages, and only over that area, increases efficiency.

From a practical standpoint each of these transducers can be used over a very wide span of pressures. They can even be used for measurements above the specified full range. The Endevco specifications show a value for typical nonlinearity for pressures to 3 times full scale, and all transducers are tested to 3 times full scale. In many ways, this suggests that full scale has been chosen conservatively. It is a pressure level where the transducer still has an unusually high overrange capability.

Because silicon is an excellent spring material the transducers have low hysteresis, usually below 0.05%. At temperatures below 600°C, the silicon stress-strain curve has no plastic zone and the material has essentially no creep. Even at pressures above full scale, and sometimes to diaphragm fracture, the transducers perform with little error.
Single crystal silicon is a strong material whose strength depends significantly on the quality of the material. The technique for growing the crystal, the technique for forming the part, the resultant dislocation density, surface scratches and micro-pits are all important factors. Because less of the effective area of the diaphragm is under high stress with this design than with others, the probability is better that the diaphragm will withstand higher pressures. These aspects are particularly advantageous for the low range transducers. For example, a 2 psi full scale transducer withstands typically 40 psi, or 20 times full scale.
So that the performance inherent in this sculptured diaphragm is not degraded when it is used to produce a finished transducer, the diaphragms are first attached to a heavy ring. This ring is also made of silicon and the parts are joined with glass at high temperature. The end result is essentially an all silicon assembly having a thickness ratio from the edge of the diaphragm to the working areas of about 20:1. By taking this design approach the diaphragm is rigidly supported and the strain takes place in the strain gages where it should.

Results and conclusions

The performance of pressure transducers using the anisotropic etch diffused silicon diaphragm is best described by the product specifications. Transducers with normal ranges of 1 psi (~7 kPa) to 20 000 psi (138 MPa) are available. As one can see, when reviewing the specifications this approach provides a low range capability, high sensitivity, improved linearity, and good stability—all resulting from an innovative design approach.

Guide to accelerometer installation

In many applications, the mounting method is as important as the selection of the accelerometer. If the motion of the test structure is not accurately transmitted to the transducer, it cannot be accurately measured. Any mounting method different from that used for calibration should be characterized for its dynamic behavior over the intended frequency and amplitude range. Generally the recommended mounting method for shock and vibration measurements is that used for calibration.

Surface preparation

Transducer mounting technique and surface preparation can affect the amplitude-frequency response of the measurement, particularly at high frequencies.

Care should be taken to ensure a flush mating with a smooth, flat surface. Nicks, scratches, or other deformations of the mounting surface or the transducer will affect frequency response. Good machine shop practices are usually adequate:

Surface flatness	0.0003" TIR
Surface roughness	32 micro inch
Perpendicularity of hole:	1 degree ±.5°
Tap class	2

A thin application of a light lubricant will improve transmissibility, filling voids with nearly incompressible fluid and thereby increasing compressive stiffness of the joint. This is particularly important for measurements above 2 kHz, at which any changes in resonance have a significant effect on measurements.

Mounting using threaded studs

The best way to mount a transducer is using the recommended mounting stud. Stud mounting provides highest transmissibility since the test surface and accelerometer are virtually fused together. The transducer should be mounted with the specified stud or screw, so that the entire base of the transducer is in intimate contact with the surface of the test article. For a mounting stud, it must be of the correct length and incorporate a flange to prevent "bottoming" of the stud in the accelerometer, which may cause strain induced errors. A torque wrench should be used to mount all accelerometers to ensure repeatability in the installation of the transducers and to prevent thread damage. The mounting torque recommended by the manufacturer should be followed. Endevco offers standard anodized aluminum cementing studs for adhesively mounting a stud mount accelerometer at a minimal cost. For higher temperature requirements, the model 2985 stainless steel stud may be required. Contact Endevco application engineers to review the multitude of mounting studs available.

Mounting using adhesives

Most miniature accelerometers can only be mounted using an adhesive, which becomes part of the structure being measured. The stiffness of the cured adhesive is critical to the measurement performance of the total system. No adhesive is as stiff as a normal mounting stud. The more adhesive joints there are between the test structure and the accelerometer, the greater will be the degradation of transmissibility.

Since the manufacturer calibrates its transducer using a specific mounting adhesive, following the manufacturer's recommendation is critical in obtaining the intended performance. Different adhesives should be evaluated over the intended frequency and amplitude range. Figure 1. shows the effects different adhesives have on the frequency response of a 10-gram accelerometer performed at 10 g's. At room temperature, cyanoacrylate has the best coupling characteristics over a wide frequency range. Hot glue (glue gun) seems to be least effective, but it can be easily applied and removed. Dismounting an adhesively mounted transducer must be carried out with great care. It should not be removed with impacts, but instead with solvents, allowing softening of the bond, supplemented by light shearing torque. All traces of adhesives should be removed using recommended solvents only. Most damages to miniature accelerometers are caused by improper removal techniques. Endevco provides mounting and removal instructions with each accelerometer designed for adhesive mounting. These recommendations for mounting and removal will ensure continued error free operation of the accelerometer.

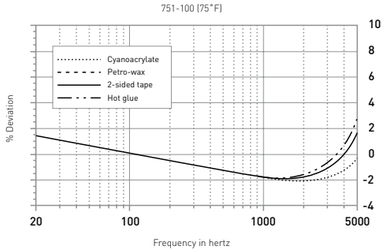


Fig. 1. Frequency response curves with various adhesives

For applications at temperature extremes, there are commercially available adhesives that are specifically formulated to handle the hot or cold environments. For cryogenic applications, a room temperature cure, two component polymer epoxy resin system has been proven to be effective down to –200°C. It is important for a low temperature adhesive to be able to withstand cryogenic thermal shock without showing signs of cracking. For applications at very high temperature (up to 700°C), ceramic based adhesives are typically used due to their heat resistant properties. But ceramic adhesives also require a high curing temperature, which prevents its use in most transducer mounting applications. At lower temperatures (from a maximum of 200°C to 300°C), a few commercial suppliers offer proprietary modified epoxy resins that are room temperature cured, and can operate up to 260°C.

Mounting using magnetic adapters

Magnetic mounting adapters are popular in industrial vibration monitoring applications where quick point to point measurements are to be made periodically. Most magnetic adapters are massive, and they are only useful for low frequency measurements below a few hundred Hertz. Figure 2. shows a typical response of an accelerometer mounted on a magnetic mounting adapter running at 10 g's. Note that the accelerometer in this example is relatively lightweight (<10 gram). With heavier units, such as those designed for industrial applications, the frequency response degradation would be more pronounced.

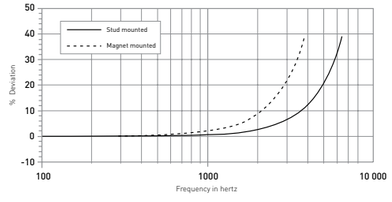


Fig. 2. Sample frequency response curve, stud vs magnetic mount

Special attention is required when using a magnetic mounting adapter. During installation, the magnetic force that pulls the adapter/accelerometer assembly towards the mounting structure often induces an unexpectedly high level of shock input to the accelerometer at the time of contact, causing damage in the sensing elements or the internal electronics. Effective use of magnets for mid-level frequencies requires detailed surface preparation, which may extend the overall test timeframe.

Triaxial mounting blocks and isolation adapters

Many installations require the transducer to be mounted on an adapter block for triaxial (three orthogonal axes) measurement, or for electrical ground isolation purposes. The block itself becomes part of the structure being measured, and acts as an additional spring mass system, whose transfer function needs to be defined before use. To maximize transmissibility, a good mounting block or adapter should be as small, light weight, and stiff as possible.

Most damage to miniature accelerometers is caused by improper removal techniques

The ideal material is beryllium, but it is not commonly used due to safety regulations and cost. Other materials, such as magnesium or aluminum are widely used with some compromise in transmissibility above 10 kHz. It is therefore recommended that the accelerometers be calibrated together with the mounting block or adapter. There are triaxial accelerometers manufactured by Endevco that come in a single housing, designed to minimize mounting block related effects. There are also transducers that feature built-in electrical ground isolation, which eliminates the use of an isolation adapter.

Endevco triaxial blocks are precision machined with tight tolerances for optimum mounting. Endevco model 2950, with an anodized aluminum surface, enables the user to electrically isolate three accelerometers from the measurement surface. This triaxial block also has counterbored holes for installing cap screws, for accelerometer taps, from the opposite side, thereby enabling orientation of side connector accelerometers for common cable exit direction of all three accelerometers. Contact Endevco application engineers for the mounting block most appropriate for your specific requirement.

Fig. 3. Various Endevco triaxial mounting blocks and mounting studs.

A. Conversion factors

1. Multiple and submultiple prefixes

Symbol	Prefix	Multiple
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto*	10^{2}
da	deca*	10
d	deci*	10^{-1}
c	centi*	10^{-2}
m	milli	10^{-3}
µ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

*avoid where possible

2. International (SI) system of units

Basic Units

Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electrical current	ampere	A
temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

Supplemental Units

plane angle	radian	rad
solid angle	steradian	sr

Derived units (with special names)

Quantity	Name	Symbol	Formula
electric charge	coulomb	C	A x s
electric capacitance	farad	F	A x s/V
electrical inductance	henry	H	V x s/A
electrical potential	volt	V	W/A
electrical resistance	ohm	Ω	V/A
energy (work and heat)	joule	J	N x m

Derived Units

Quantity	Name	Symbol	Formula
force	newton	N	kg x m/s^2
frequency	hertz	Hz	l/s
illuminance	lux	lx	lm/m^2
luminous flux	lumen	lm	cd x sr
magnetic flux	weber	Wb	V x s
magnetic flux density	tesla	T	Wb/m^2
power	watt	W	J/s
pressure	pascal	Pa	N/m^2

3. Length

Multiply	by	to obtain
angstrom (Å)	10^{-10}*	meters
feet	0.30480*	meters
	12.0*	inches
inches	1000	mil
	25.40*	millimeters
	0.02540*	meters
	0.08333	feet
kilometers	3280.8	feet
	0.6214	miles
	1094	yards
meters	39.370*	inches
	3.2808	feet
	1.094	yards
miles (statute)	5280*	feet
	1.6093	kilometers
	0.8694	miles (nautical)
millimeters	0.03937*	inches
miles (nautical)	6076	feet
	1.852*	kilometers
yards	0.9144*	meters
	3.0*	feet
	36.0*	inches

*Exact

4. Area

Multiply	by	to obtain
acres	43560*	sq. feet
	4047	sq. meters
	4840*	sq. yards
square cm	0.1550	sq. inches
square feet	144.0*	sq. inches
	0.09290	sq. meters
	0.1111	sq. yards
square inches	645.16*	sq. millimeters
square kilometers	0.3861	sq. miles
square meters	10.764	sq. feet
	1.196	sq. yards
square miles	640*	acres
	2.590	sq. kilometers

5. Volume

Multiply	by	to obtain
acre-foot	1233.5	cubic meters
cubic cm	0.06102	cubic inches
cubic feet	1728*	cubic inches
	7.480	gallons (U.S.)
	0.02832	cubic meters
	0.03704	cubic yards
cubic inches	16.387	cubic cm
	0.01732	quarts (liquid)
cubic meters	35.315	cubic feet
	264.2	gallons (U.S.)
	1.308	cubic yards
	1000	liters
cubic yards	27.0*	cubic feet
	0.7646	cubic meters
gallons (Imperial) (U.K.)	277.4	cubic inches
	1.201	gallons (U.S.)
	4.546	liters
gallons (U.S.) (liquid)	231.*	cubic inches
	3.7854	liters
	4.0*	quarts
quart (U.S.) (liquid)	0.9463	liters

*Exact

6. Mass

Multiply	by	to obtain
carat	0.200*	grams
grams	0.03527	ounces (avdp.)
kilograms	2.2046	pounds (avdp.)
ounces (avdp.)	28.350	grams
pound (avdp.)	16.0*	ounces (avdp.)
	453.6	grams
stone (U.K.)	6.350	kilograms
	14	pounds (avdp.)
ton (long) (2240 lb)	1016.0	kilograms
ton (short) (2000 lb)	907.2	kilograms
ton (metric) (tonne)	1000.0*	kilograms

7. Angles

Multiply	by	to obtain
cycle (360°)	6.283	radians
degree	0.017453	radians
Hertz (c/s)	6.283	radians/second
rev./minute	0.1047	radians/second
radians	57.2958	degrees
grade	0.900*	degrees

8. Force

Multiply	by	to obtain
dynes	10^{-5}*	newton
grams (force)	980.7	dynes
kilogram (force)	9.80665*	newtons
	1.00*	kilopond
newton	105*	dynes
	0.1020	kilogram (force)
	3.597	ounce (force)
	0.2248	pound (force)
	7.2330	poundal
ounce (force)	0.2780	newton
	0.0625*	pound (force)
pound (force)	16.00*	ounce (force)
	0.45359	kilogram (force)
	4.448	newtons
ton (force) (short)	2000*	pounds (force)
	8896	newtons

*Exact

9. Moment or torque

Multiply	by	to obtain
ounce (f) inch	0.007061	newton meters
pound (f) inch	1.152	kgf cm
	0.1130	newton meters
pound (f) foot	1.356	newton meters
newton meters	0.7376	pound (f) foot

10. Pressure

Multiply	by	to obtain
atmospheres	1.01325*	bars
	33.90	feet of H_2O
	29.92	inches of Hg
	760.0*	mm of Hg (torr)
	101.325*	kN/m^2 (k Pa)
	14.696	pounds/sq. inch
bar	75.01	cm of Hg
	105*	N/m^2 (Pa)
	14.50	pounds/sq. inch
dyne/cm^2	0.1000*	N/m^2 (Pa)
inches of H_2O	248.84	N/m^2 (Pa)
	0.07355	inches of Hg
kg (f)/cm2	14.22	pounds/sq. inch
kg (f)/m2	9.80665*	N/m^2
mm of Hg (torr)	133.32	N/m^2
	0.01933	pounds/sq. inch
	13.595	mm of H_2O
newtons/cm2	1.450	pounds/sq. inch
N/mv (pascal)	1.450 x 10^{-4}	pounds/sq. inch
pounds/sq. foot	0.19242	inches of H_2O
	47.880	N/m^2 (Pa)
pounds/sq. inch	0.06805	atmospheres
	2.036	inches of Hg
	27.708	inches of H_2O
	68.948	millibars
	703.77	mm of H_2O
	51.72	mm of Hg
	0.68948	N/cm^2
	6894.8	N/m^2 (Pa)
	7.031 x 10^{-4}	kg (f)/mm^2

*Exact

	PSI	Pascal	Bar	Millibar	In. Hg	In. H_2O	mm Hg	mm H_2O	ATM	kg/cm^2
PSI	1	0.00014504	14.504	0.014504	0.49118	0.036127	0.019337	0.0014223	14.696	14.223
Pascal	6894.6	1	100 000	100	3386.5	249.08	133.32	9.8068	101 320	98 067
Bar	0.068946	0.00001	1	0.001	0.033865	0.0024908	0.0013332	9.8068E-05	1.0132	0.98068
Millibar	68.946	0.01	1000	1	33.865	2.4908	1.3332	0.98068	1031.2	980.68
In. Hg	2.0359	0.00029529	29.529	0.029529	1	0.073552	0.039368	0.0028959	29.92	28.959
In. H_2O	27.68	0.0040147	401.47	0.40147	13.596	1	0.53525	0.039372	406.78	393.72
mm Hg	51.714	0.0075006	750.06	0.75006	25.401	1.8683	1	0.073558	760	735.59
mm H_2O	703.05	0.10197	10 197	10.197	345.32	25.399	13.595	1	10332	10 000
ATM	0.068045	9.8692E-06	0.98692	0.00098692	0.033422	0.0024583	0.00131558	9.6788E-05	1	0.9678
kg/cm^2	0.070305	1.0197E-05	1.0197	0.0010197	0.034531	0.0025399	0.0013595	0.0001	1.0332	1

11. Velocity

Multiply	by	to obtain
feet/minute	5.080*	mm/second
feet/second	0.3048*	meters/second
inches/second	0.0254*	meters/second
km/hour	0.6214	miles/hour
knot	0.5144	meters/second
	1.151	miles/hour (U.S.)
meters/second	3.2808	feet/second
	2.237	miles/hour (U.S.)
miles/hour	88.0*	feet/minute
	0.44704*	meters/second
	1.6093	km/hour
	0.8684	knots

12. Acceleration

Multiply	by	to obtain
acceleration of gravity (g)	9.80665*	meters/second^2
	32.174	feet/second^2
	386.088	inches/second^2
cm/second^2 (gal)	0.010*	meters/second^2
feet/second^2	0.3048*	meters/second^2
inches/second^2	0.02540*	meters/second^2

13. Power

Multiply	by	to obtain
ergs/second	10^{-7}*	watts
foot pounds (f)/second	1.356	watts
horsepower (electric)	746.0*	watts
horsepower (U.K.)	745.7	watts
	550	foot pounds/s
BTU/second	1055.9	watts

*Exact

14. Energy, heat

Multiply	by	to obtain
BTU (mean)	1055.9	joules
	0.2520	kg-calories (mean)
	107.7	kg (f) m
calorie, gram (mean)	4.190	joules
erg	10-7*	joules
eV	1.60×10^{-12}	ergs
	1.6×10^{-19} joules	
foot pound (force)	1.3558	joules
	0.13825	kg (f) meter
	9.80665*	joules
watt hour	3600*	joules
	3.409	BTU
watt second	1.00*	joule
newton meter	1.00*	joule

15. Temperature

Celsius to Kelvin	$K = °C + 273.15$
Celsius to Fahrenheit	$°F = 9/5\ °C + 32$
	$= 1.8\ (°C + 40) - 40$
Fahrenheit to Celsius	$°C = 5/9\ (°F - 32)$
	$= \frac{(°F + 40)}{1.8} - 40$
Fahrenheit to Kelvin K	$K = 5/9\ (°F + 459.67)$
Fahrenheit to Rankine	$°R = °F + 459.67$
Rankine to kelvin	$K = 5/9\ °R$

16. Electrical

Multiply	by	to obtain
oersted	79.58	ampere/meter
faraday	96490	coulombs
gauss	10^{-4}*	tesla
gilbert	0.7958	ampere turn
maxwell	10^{-8}*	weber

*Exact

A. Mathematics

1. Useful constants

π	=	3.14159	π^2	=	9.8696
2π	=	6.283	$(2\pi)^2$	=	39.478
4π	=	12.566	$\frac{1}{2\pi^2}$	=	0.1013
$\frac{\pi}{2}$	=	1.570	$\sqrt{\pi}$	=	1.772
$\frac{1}{\pi}$	=	0.3183	Log π	=	0.49715
$\frac{1}{2\pi}$	=	0.1592	$\sqrt{3}$	=	1.7320
$\sqrt{2}$	=	1.41421	$\frac{1}{\sqrt{3}}$	=	0.5773
$\frac{1}{\sqrt{2}}$	=	0.7071	$\sqrt{10}$	=	3.162
e	=	2.718281828			

2. Trigonometric relationships

	0°	30°	45°	60°	90°	180°	270°
sine	0	0.500	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1.00	0	– 1.00
cosine	1.00	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	0.500	0	– 1.00	0
tangent	0	$\frac{1}{\sqrt{2}}$	1	$\sqrt{3}$	+ ∞	0	– ∞

3. Quadratic equation solution

$$x = \frac{-b \pm \sqrt{b^2 - 4\,a\,c}}{2a}$$

where: $ax^2 + bx + c = 0$

4. Decibel formula

Power: $dB = 10 \log \frac{W}{W_0}$

Pressure, Voltage, Charge, etc.: $dB = 20 \log \frac{p}{p_0}$

$dB = 20 \log \frac{E_1}{E_2}$

Ratio (except power)	dB – +	Ratio (except power)	Ratio (except power)	dB – +	Ratio (except power)
1.000	0.0	1.000	.316	10.0	3.16
.988	0.1	1.012	.251	12.0	3.98
.977	0.2	1.023	.199	14.0	5.01
.966	0.3	1.035	.158	16.0	6.31
.955	0.4	1.047	.126	18.0	7.94
.944	0.5	1.059	.100	20.0	10.00
.891	1.0	1.12	.0316	30.0	31.62
.841	1.5	1.19	.0100	40.0	100
.794	2.0	1.26	.0032	50.0	316
.708	3.0	1.41	10^{-3}	60.0	10^3
.631	4.0	1.58	10^{-4}	80.0	10^4
.562	5.0	1.78	10^{-5}	100	10^5
.501	6.0	2.00	10^{-6}	120	10^6
.447	7.0	2.24	10^{-7}	140	10^7
.398	8.0	2.51	10^{-8}	160	10^8
.355	9.0	2.82	10^{-9}	180	10^9

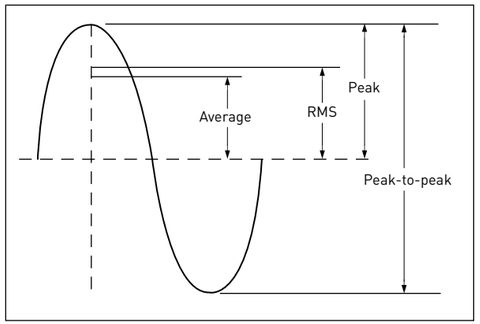
5. Mathematical symbols

× or ·	Multiplied by	>	Is greater than
÷ or :	Divided by	>>	Is much greater than
+	Positive. Plus. Add	<	Is less than
-	Negative. Minus. Subtract	<<	Is much less than
±	Positive or negative Plus or minus	∓	Negative or positive Minus or plus
≥	Greater than or equal to	≤	Less than or equal to
∴	Therefore	∠	Angle
= or ::	Equals	Δ	Increment or decrement
□	Identity	≅	Is approximately equal to
⊥	Perpendicular to	||	Parallel to
≠	Does not equal	|n|	Absolute value of n

C. Dynamic measurements

1. Sinusoids (applies only to sinusoids)

rms value	=	0.707 x peak value
rms value	=	1.11 x average value
peak value	=	1.414 x rms value
peak value	=	1.57 x average value
average value	=	0.637 x peak value
average value	=	0.90 x rms value
peak-to-peak	=	2 x peak value
crest factor	=	(applies to any varying quantity)



2. Mechanical impedance

$Z = \frac{F}{v} = \frac{F}{\omega d} = \frac{\omega F}{a}$

having units of $\frac{\text{lb-sec}}{\text{inch}}$ or $\frac{\text{newton-sec}}{\text{meter}} = \frac{Ns}{m}$

dynamic mass: $Z_a = \frac{F}{a}$ dynamic stiffness: $Z_a = \frac{F}{d}$

where all terms are phasors, having a magnitude and direction.

mass (M) = $\frac{\text{weight (W)}}{\text{acceleration (g)}}$

3. Displacement, velocity, acceleration relationships

(for sinusoidal motion only)

$d = d_0 \sin 2\pi ft$

$v = d_0 2\pi f \cos 2\pi ft$

$a = -d_0 (2\pi f)^2 \sin 2\pi ft$

$G = \frac{\text{acceleration}}{g}$

$v_0 = 6.28\, f\, d_0 = 3.14\, f\, D$

$v_0 = 61.42 \frac{G}{f}$ in./s pk

$v_0 = 1.560 \frac{G}{f}$ m/s pk

$d_0 = 9.780 \frac{G}{f^2}$ inches pk

$d_0 = 0.2484 \frac{G}{f^2}$ meters pk

where: d_0 = peak displacement

D = pk-pk displacement

G = acceleration in g units

f = frequency in Hz

T = period in seconds

$g = 9.806\ 65\ m/s^2 = 386.09\ in./s^2 = 32.174\ ft/s^2$

$G = 0.0511\, f^2 D$ (where: D = inches peak-to-peak)

$G = 2.013\, f^2 D$ (where: D = meters peak-to-peak)

$T = \frac{1}{f}$ seconds

4. Motion of a single-degree-of-freedom system

natural frequency: $f_n = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{g}{\delta_{st}}}$

where: δ_{st} = static deflection

ω = angular frequency in radians

$k = \frac{\text{force}}{\text{deflection}} = \frac{m\,a}{d}$

transmissibility (undamped): $T = \frac{1}{1 - \omega^2/\omega_n^2} = \frac{1}{1 - f^2/f_n^2}$

critical damping: $c_c = 2\sqrt{km}$

damping ratio: $\zeta = \frac{C}{C_c} = \frac{c}{2\sqrt{km}}$

amplification factor (at resonance): for $\zeta < 0.1$, $Q = \frac{1}{2\zeta}$

5. Transient measurements

Pulse Shape	Minimum RC/T (1)	(2)	Minimum Resonance Frequency Hz (3)	Minimum Low Frequency Response, f_5 Hz (4)
Half sine	16	7	$\frac{5}{T}$	$\frac{0.03}{T}$
Sawtooth	16	7	$\frac{2.5}{t}$	$\frac{0.03}{T}$
Square	50	20	$\frac{2.5}{t}$	$\frac{0.01}{T}$

where: RC = low frequency time constant in seconds

$$= \frac{1}{2\pi f_c} \approx \frac{1}{2 f_5}$$

f_c = frequency for –3 dB response
f_5 = frequency for –5% response
T = pulse duration in seconds
t = rise or fall time in seconds

(1) for 2% accuracy in peak amplitude.
(2) for 5% accuracy in peak amplitude.
(3) for transducer, (based on ratio indicated peak to actual peak approximately 1.1 maximum).
(4) for signal conditioner or associated electronics, for 2% accuracy in amplitude.

6. Spring constant of materials

(in compression)

$$k = \frac{EA}{t}$$

where: E = elastic modulus
A = area of material
t = thickness of material

7. Velocity change during impact

$$\Delta v = \int_{t_1}^{t_2} a\,dt = (2\,g\,h_1)^{1/2} + (2\,g\,h_2)^{1/2}$$

for half-sine pulse: $\int a\,dt = 0.636\,a\,dt$
for sawtooth pulse: $\int a\,dt = 0.5\,a\,dt$
where: h_1 = height of drop
h_2 = height of rebound
a = peak acceleration
$t_2 - t_1$ = duration of pulse

8. Random excitation

$$G = \sqrt{B}\,G_0$$

where: G = rms level in g units
B = frequency bandwidth in Hz
G_0 = acceleration density in g/Hz

crest factor = $\frac{\text{peak magnitude}}{\text{rms magnitude}}$

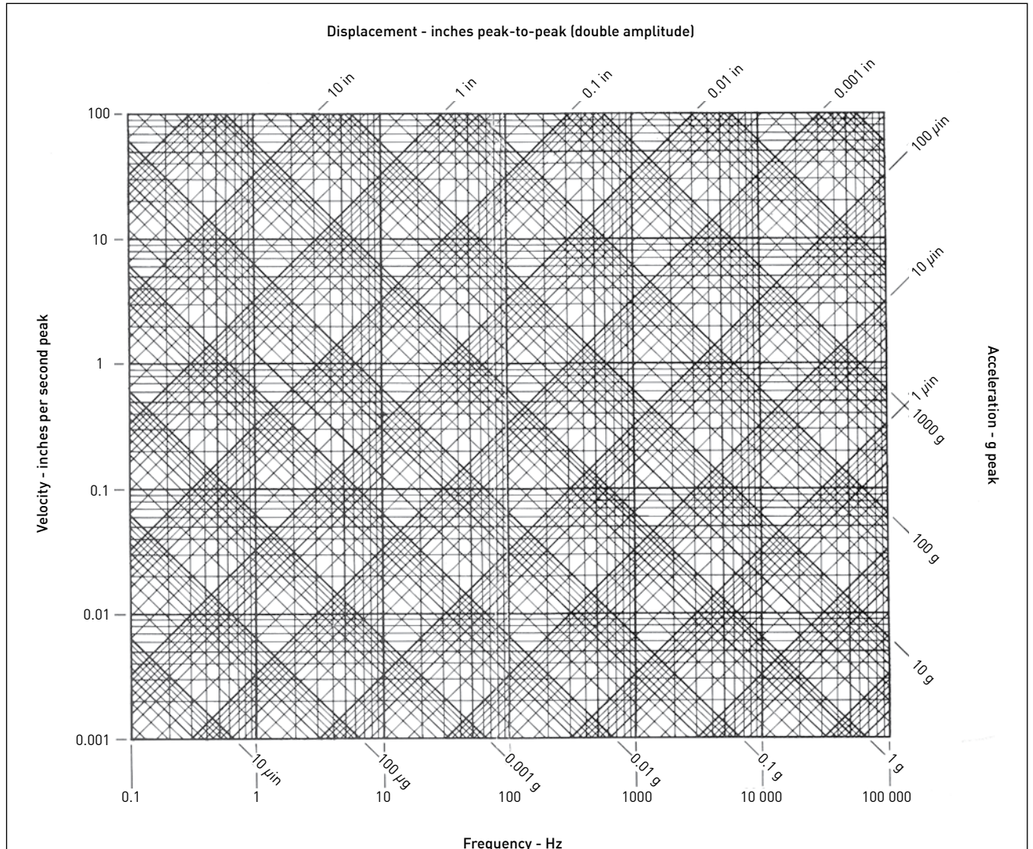
9. Resonance frequency of first bending mode

(Unloaded beams)

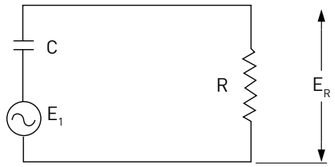
$$f_n = C\sqrt{\frac{EIg}{L^4W}}$$

where: C = constant, function of method of support
E = elastic modulus
I = moment of inertia of cross section
g = acceleration of gravity
L = length
W = weight per unit length

Support Method	C
Cantilever	0.56
Point support each end	1.57
Both ends fixed	3.56
Totally unsupported	3.56



10. Relative response of RC circuit



The above curve shows the relative voltage across the load R in a simple RC network as a function of f x R x C, where:

f = frequency, in hertz
R = load resistance, in ohms
C = capacitance, in farads

11. Angular motion (sinusoidal)

Measurand	Magnitude	where:
Angular displacement	$\theta = \theta_0 \sin 2\pi ft$	θ_0 = peak angular displacement
Angular	$\Omega = 2\pi f\, \theta_0 \cos 2\pi ft$	
Velocity:	$\Omega_0 = 2\pi f\, \theta_0$	Ω_0 = peak angular velocity
Angular	$a_0 = 4\pi^2 f^2 \theta_0 = 2\pi f\, \Omega_0$	a_0 = peak angular acceleration
Arc distance:	$s = r\theta$	θ = radians r = radius of rotation
Tangential	$v_t = r\Omega$	Ω = radians/s
Velocity:		
Tangential	$A_t = r\alpha$	α = radians/s2
Acceleration:	$G_t = \frac{r\alpha}{386.1}$ g units	r = inches
	$Gt = \frac{r\alpha}{9.806}$ g units	r = meters

12. Acceleration due to rotational motion

$G = 0.000028\,42\, r\, n^2$

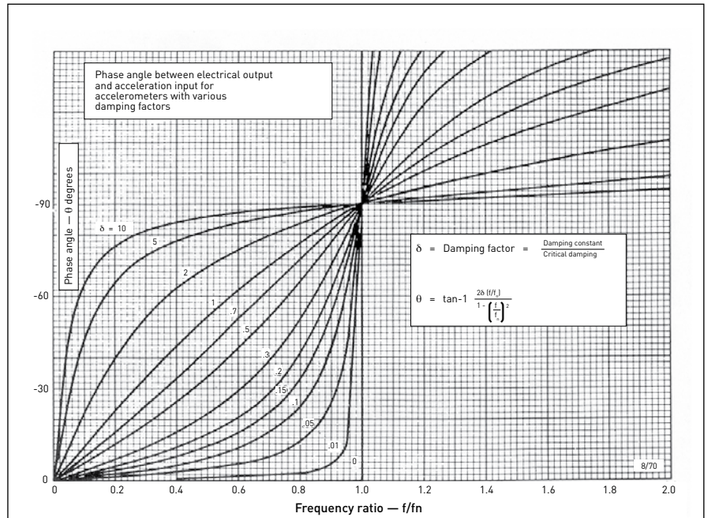
where: G = acceleration, in g
r = radius arm, in inches
n = revolutions per minute

$G = 0.10225\, rf^2$

where: r = radius of arm, in inches
f = revolutions per second

$G = 4.02568\, rf^2$

where: r = radius of arm, in meters
f = revolutions per second



13. Machinery vibration monitoring

Many defects in rotating machinery manifest themselves in specific vibration patterns or signatures. Spectrum analysis of running vibration can give important clues to causes within the machinery. A recorded spectrum (signature) taken on the new (presumably non-defective) machine is extremely helpful for later analysis and diagnosis.

Frequency	Possible Cause
1 x operating speed	Imbalance Misalignment Bent Shaft Looseness Electrical
2 x operating speed	Misalignment Bent shaft
Harmonics of operating speed	Loose mounts or bearing caps
Subharmonics of operating speed	Oil Whirl Bearing cage defects
Non-integer multiples of operating speed	Rolling element bearings Gears Belts Blades or vanes
Powerline frequency harmonics	Electrical

Blades or Vanes

Missing or cracked blades cause an imbalance which produces vibration at operating speed; a large number of harmonics around the blade passing frequency (operating speed x number of blades) indicates a broken or missing blade.

Electrical

Vibration components at 2x powerline frequency, or sidebands around the operating speed at 2x slip frequency often indicate a shorted stator or broken rotor bar. Induction motors normally produce frequency components at the number of poles times the operating speed.

Gears

Gear mesh frequencies (gear rotational speed x number of teeth) are always present to some extent. Gear defects cause these components to greatly increase in amplitude. Also, sidebands around the gear mesh frequency often appear at the rotational speed of the defective gear.

Imbalance

A large component at operating speed is usually considered to indicate an imbalance condition. Severe imbalance can also cause harmonics. Load variation and pump cavitation can also cause similar symptoms.

Misalignment

Large component at 2x operating speed accompanied by high level axial vibration characterizes misalignment.

Oil whirl

Fluid film bearings experiencing oil whirl exhibit components at around 0.45 x operating speed.

Rolling element bearings

Ball or roller bearings can produce many frequency components, depending on the design of the bearings. These are functions of the number of rolling elements, pitch diameters, ball or roller diameters, and operating speed. They are often accompanied by harmonics and operating speed sidebands. Formulas commonly used are given below.

P = Pitch diameter
D = Rolling element diameter
f = Frequency
N = Number of rolling elements
C = Contact angle
S = Operating speed (rpm)

Outer race	$f = \left(\frac{N}{2}\right)\left(\frac{S}{60}\right)$	$\left(1 - \frac{D}{P} \cos C\right)$
Inner race	$f = \left(\frac{N}{2}\right)\left(\frac{S}{60}\right)$	$\left(1 + \frac{D}{P} \cos C\right)$
Ball defect	$f = \left(\frac{P}{2}\right)\left(\frac{S}{60}\right)$	$\left(1 + \left(\frac{D}{P}\right)2 \cos C2\right)$
Fundamental train (Worn cage)	$f = \left(\frac{1}{2}\right)\left(\frac{S}{60}\right)$	$\left(1 - \frac{B}{D} \cos C\right)$

14. Sensitivity, gain and scaling

Accelerometers are available with sensitivities varying over an extremely wide range in order to better tailor sensitivities and resonance frequencies to specific applications. However, this requires careful consideration of gain settings and scaling of amplifiers in order to provide good signal-to-noise ratios without overdriving and clipping or saturation.

In applications where there is little risk of exceeding the estimated peak acceleration or pressure, system gain can be set with only a small margin ("headroom") over the expected peak amplitude. This provides maximum amplification with consequent best possible resolution. In other applications, however, where the expected peak amplitude of the measurand may be known with less certainty, a more conservative approach may be required to prevent accidental clipping and loss of data. If the measurand does exceed the predicted level, accurate measurement of the real peak is usually of vital importance. This requires a lower gain with consequent reduced resolution.

Transducer sensitivity is normally expressed as the ratio of electrical output to mechanical input (i.e., mV/g, mV/psi). To generalize, let us use EU (Engineering Units) for the measurand, S for Sensitivity, G for Gain, O for Output, and Pk for amplifier maximum peak output. (Gain may be mV/mV or mV/pC).

Then: O = EU x S x G

To avoid clipping, O < Pk; to achieve maximum resolution, we want to maximize O. If H = the ratio of Pk/O ("Headroom factor"), then:

Pk = H x O = H x EU x S x G

Example:
An airborne amplifier Model 2680MX has peak-to-peak output of 4.65 volts; this is Pk = 2.325 V, or 2325 mV. Using a 2221D accelerometer with S = 17 pC/g to measure an estimated 10g peak, you must decide how much headroom to allow. Assume 100% or 2:1; H = 2. So:

H = 2, EU = 10g, S = 17 pC/g, determine G,
Pk = 2325 mV; G = Pk/(H x EU x S)
G = 2325/(2 x 10 x 17)
G = 2325/340 = 6.838

So, select the 2680M4, M5, or M6 with gains of 1-10, 2-20, or 5-50; and adjust the gain to 6.838. Expected full scale peak output will then be O=EU x S x G or, O=10 x 17 x 6.838=1162.46 mV, half of the dynamic range of the system.

If the estimated vibration level were expressed in g RMS, you should expect peaks of 3 to 6 times the RMS level. In most applications, a crest factor (ratio of peak to RMS) of 6 is a good choice. Again, however, if the estimate is relatively uncertain, using a higher crest factor is wise, to avoid clipping.

Most laboratory amplifiers provide settings to input sensitivity and desired output in mV/g or full scale range. Thus the user need not know what the gain is. For example, using the Model 102 Isotron signal conditioner, with a model 7251-10: S = 9.85, and output sensitivity set at 50 mV/g, (output sensitivity could be set from 1 to 100 mV/g), Pk is 10V, so the maximum acceleration level without clipping is Pk/50mV or 200g. If the full scale output (e.g. on a model 2775A) is Pk (V or mV) and full scale range is R (g), then the output sensitivity will be Pk/R.

D. Electric circuit formula

1. Ohm's law for DC circuits:

$I = \frac{E}{R} = \frac{P}{E}$ $\quad R = \frac{E}{I} = \frac{P}{I^2} = \frac{E^2}{P}$

$E = IR = \frac{P}{I}$ $\quad P = I^2 R = E I = \frac{E^2}{R}$

where: I = amperes
E = volts
P = watts
R = ohms

2. Ohm's law for AC circuits:

$I = \frac{E}{Z} = \frac{P}{E \cos \theta}$ $\quad E = IZ = \frac{P}{I \cos \theta}$

$Z = \frac{E}{I} = \frac{P}{I^2 \cos \theta} = \frac{E^2 \cos \theta}{P}$

$P = I^2 Z \cos \theta = EI \cos \theta = \frac{E^2 \cos \theta}{Z}$

where: $\cos \theta = \frac{R}{Z} = \frac{P}{EI}$ = power factor
θ = angle of lead or lag between current and voltage.
Z = ohms

3. Resistors or capacitors in series:

$R_t = R_1 + R_2 + R_3 + ...$

$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$

4. Resistors or capacitors in parallel:

$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

$C_t = C_1 + C_2 + C_3 + ...$

5. Two resistors in parallel

$Rt = \frac{R_1 R_2}{R_1 + R_2}$

$R1 = \frac{R_1 R_2}{R_1 - R_2}$

6. Reactance

$X_c = \frac{1}{2\pi fC}$

$X_L = 2\pi fL$

7. Impedance

Series Circuit: $Z = \sqrt{R^2 + (X_L + X_c)^2}$

Parallel Circuit: $Z = \frac{RX}{\sqrt{R^2 + X^2}}$

8. Quantity of charge in a capacitor

$Q = CE$

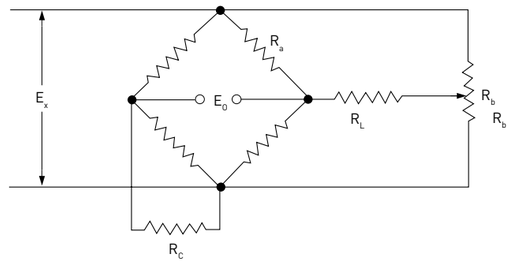
where: Q = charge, in coulombs
E = voltage across capacitor, in volts
C = capacitance, in farads

E. Signal conditioning

1. Calibration resistors for wheatstone bridges

$R_c = \frac{R_a}{4} \left(\frac{E_x}{E_o} - 2 \right)$

where: R_c = single shunt calibration resistor, ohms
R_a = bridge arm resistance, ohms
E_x = bridge excitation voltage, volts
E_o = desired change in output voltage, volts



2. Bridge balance limiting resistor

$R_L = \frac{R_a}{4} \left(\frac{E_x}{E_o} - 2 \right)$

where: R_L = series limiting resistor, ohms
E_b = balance range required, volts

3. Tracking filter equations

Time for output of a filter, in response to a step function, to attain 99% of its final value:

$t = \frac{4}{B}$ seconds

where: B = bandwidth of filter at –3dB response

Maximum sweep rate of a narrow band filter for less than 1% error due to filter blurring.

$R = \frac{B^2}{4}$ Hz/second

4. Conversion charge to voltage sensitivity

$E_s = \frac{1000\, Q_s}{C_p + C_t}$

where: E_s = voltage sensitivity, mV/g
Q_s = charge sensitivity, pC/g
C_p = transducer capacitance, pF
C_t = total external capacitance, pF

5. Filter circuits

a. Terminology

1. **Bandwidth**, for band-pass filters, difference between two frequencies at equal attenuation levels at -3 dB.
2. **Cut-off frequency**, fc, frequency at which response is -3 dB reference the maximum response.
3. **Delay time (phase shift)**, time for a specific point on a signal wave to pass through a filter.
4. **Frequency response**, relationship of signal amplitude vs. frequency through filter.
5. **Insertion loss**, the essentially constant attenuation in the pass band of the filter.
6. **Order (poles) of a filter**, n, the number of reactive components (capacitors or inductors) in the filter.
7. **Overshoot**, initial increase of output amplitude above final steady state level for a step input.
8. **Q-factor**, for band pass filters $Q = f_o / \Delta f$ where Δf is bandwidth at -3 dB and fo is center frequency.
9. **Rise time (or fall time)**, time for output to rise (or fall) from 10% to 90% of final magnitude.
10. **Shape factor, for bandpass filter**s, ratio of bandwidth at -60 dB to bandwidth at -3 dB response.
11. **Skirt (rolloff)**, terminal slope of attenuation of frequency response, usually expressed as 6n dB/octave, where n is the order of the filter.
12. **Transient response**, output of filter for a step input or impulse input.

b. Filter types

1. **Low-pass**, attenuates high frequencies.
2. **High-pass**, attenuates low frequencies.
3. **Band-pass**, attenuates both high and low frequencies.
4. **Active**, includes amplifier.
5. **Passive**, utilizes only capacitors, inductors, and/or resistors.
6. **Digital**, signal processing algorithms executed on digitized data.

c. Specific filter characteristics

1. Butterworth

a. Maximally flat amplitude vs. frequency response in the pass band.

b. Attenuation is -3 dB at fc, the cut-off frequency, the intersection of skirt asymptote with zero attenuation level.

c. Attenuation above fc is asymptotic to 6n dB/ octave.

d. Phase shift characteristics are not linear.

e. Rise time and overshoot increase with order, n.

f. Rise time is good.

g. Satisfactory for steady state signals.

2. Bessel

a. Phase shift is linear with frequency.

b. Rolloff slope is less than Butterworth, just above fc.

c. Overshoot, rise time, and settling time are longer than Butterworth.

d. Best for transient measurements.

3. Tchebycheff

a. Equal ripple amplitude across the pass band.

b. Rolloff beyond fc initially exceeds 6n dB/octave, then approaches that rate at higher frequencies.

c. Rise time and overshoot increase with order, n.

d. Phase shift worse than Butterworth.

e. Used where sharp cutoff is required and phase shift is not critical.

4. Butterworth-Thompson

a. Compromise between maximally flat frequency response and maximally flat time delay (linear phase shift).

b. Cutoff frequency is intersection of asymptote of skirt with zero dB attenuation level.

c. Attenuation increases with frequency in the pass band.

d. Overshoot is smaller than Butterworth filter.

e. Skirt approaches 6n dB/octave at higher frequencies.

5. Elliptic

a. Minimal ripple in the passband.

b. Very sharp cutoff.

c. Very steep terminal slopes are available.

d. Sidebands in the no-pass frequency range.

6. Driving long lines

$$E_o = \frac{I_m}{\sqrt{\frac{1}{R_L^2}} + \sqrt{\frac{(2\pi fpL)^2}{10^{12}}}}$$

E_o = maximum output voltage of signal conditioner, in volts, without exceeding current rating.

I_m = maximum output current, in milliamperes.

R_L = resistive termination at end of cable, in kilo-ohms.

f = maximum frequency, in k Hz.

p = capacitance, in pF per unit length of cable.

L = length of cable in selected units.

7. Data acquisition and transient capture memory requirements

Although the Nyquist Criterion requires (only) that the sampling rate be more than twice the highest frequency in the sample, most authorities agree that reconstruction of the time history requires five to ten samples per cycle of the highest frequency present. Using a ratio of SR samples per cycle, B bits resolution, maximum frequency F, recording time T, and C channels to be recorded, the memory required, M bits, is:

M = SR x B x F x T x C

Example: 30 seconds of 4 channels, 8 bit resolution, 4 kHz max frequency, and 10 samples per cycle:

M = 10 x 8 x 4000 x 30 x 4

M = 38 400 000 bits (38.4 megabits).

Table of standard annealed bare copper wire

Gage (AWG) or (B&S)	Diameter inches nom.	Area circular mils.	Weight pounds per M ft.	Resistance at 68°F Ohms per M ft.	Current capacity (Amps)-insulated
0000	.4600	211600.	640.5	.04901	**225**
000	.4096	167800.	507.9	.06180	**175**
00	.3648	133100.	402.8	.07793	**150**
0	.3249	105500.	319.5	.09827	**125**
1	.2893	83690.	253.3	.1239	**100**
2	.2576	66370.	200.9	.1563	**90**
3	.2294	52640.	159.3	.1970	**80**
4	.2043	41740.	126.4	.2485	**70**
5	.1819	33100.	100.2	.3133	**55**
6	.1620	26250.	79.46	.3951	**50**
7	.1443	20820.	63.02	.4982	
8	.1285	16510.	49.98	.6282	**35**
9	.1144	13090.	39.63	.7921	
10	.1019	10380.	31.43	.9989	**25**
11	.09074	8234.	24.92	1.260	
12	.08081	6530.	19.77	1.588	**20**
13	.07196	5178.	15.68	2.003	
14	.06408	4107.	12.43	2.525	**15**
15	.05707	3257.	9.858	3.184	
16	.05082	2583.	7.818	4.016	**6**
17	.04526	2048.	6.200	5.064	
18	.04030	1624.	4.917	6.385	**3**
19	.03589	1288.	3.899	8.051	
20	.03196	1022.	3.092	10.15	**2**
21	.02846	810.1	2.452	12.80	
22	.02535	642.4	1.945	16.14	
23	.02257	509.5	1.542	20.36	**1**
24	.02010	404.0	1.223	25.67	
25	.01790	320.4	.9699	32.37	
26	.01594	254.1	.7692	40.81	**0.5**
27	.01420	201.5	.6100	51.47	
28	.01264	159.8	.4837	64.90	
29	.01126	126.7	.3836	81.83	
30	.01003	100.5	.3042	103.2	**0.2**
31	.008928	79.7	.2413	130.1	
32	.007950	63.21	.1913	164.1	
33	.007080	50.13	.1517	206.9	**0.1**
34	.006305	39.75	.1203	260.9	
35	.005615	31.52	.09542	329.0	
36	.005000	25.00	.07568	414.8	**0.05**
37	.004453	19.83	.06001	523.1	
38	.003965	15.72	.04759	659.6	
39	.003531	12.47	.03774	831.8	
40	.003145	9.888	.02993	1049.	**0.02**

F. The Environment

1. Constants

speed of light C = 2.997925 x 10^{10} cm/s
= 983.6 x 10^{6} ft/second
= 186 284 miles/second

velocity of sound (dry air at 15° C) Vs = 340.3 meters/second
= 1116 feet/second

Gravity g = 9.80665 meters/second^2
= 32.174 feet/second^2
= 386.089 inches/second^2

1 atmosphere = 14.70 psi
= 101.33 kPa (kN/m^2)
= 2116 lbf/ft^2

2. Acoustic and vibration decibels

All quantities are expressed in root-mean-square (rms) values. For interpolations, see Section B-4, Ratios.

Acceleration		Velocity	Sound pressure level in air	
db	**g**	**m/s**	**Pa (N/m^2)**	**psi**
0	1 x 10^{-6}	1 x 10^{-8}	2 x 10^{-5}	2.90 x 10^{-9}
20	1 x 10^{-5}	1 x 10^{-7}	2 x 10^{-6}	2.90 x 10^{-8}
40	1 x 10^{-4}	1 x 10^{-6}	2 x 10^{-3}	2.90 x 10^{-7}
60	1 x 10^{-3}	1 x 10^{-5}	0.02	2.90 x 10^{-6}
80	.01	1 x 10^{-4}	0.2	2.90 x 10^{-5}
100	0.1	1 x 10^{-3}	2.0	2.90 x 10^{-4}
120	1.0	0.01	20	2.90 x 10^{-3}
140	10	0.1	200	0.0290
160	100	1.0	2 x 10^{3}	0.290
180	1000	10	2 x 10^{4}	2.90

Reference levels:

Sound power P_o = 1 pW = 10^{-12} W
= 10^{-5} erg/s

Airborne Sound Pressure P_{og} = 20 µPa = 0.0002 µbar
= 0.0002 dyne/cm2

Waterborne Sound Pressure p_o = 1 µPa = 10 µbar
= 10^{-5} dyne/cm^2

Acceleration a_o = 1 µg where
g = 9.806 65 m/s^2
= 386.089 in/s^2

Velocity v_o = 10^{-8} m/s = 10^{-6} cm/s

1 psi rms = 170.8 dB re 20 µPa
1 atmosphere = 14.70 psi

3. Octave bands

Octave bands are also centered at preferred frequencies, using the center frequencies of bands 3, 6, 9... or they can be defined as successive sets of three 1/3 octave filters, starting with Bands 2-4.

Band no.	Nominal center frequency Hz	Exact center frequency Hz	Passband Hz
3	2	2.00	1.41-2.82
6	4	3.98	2.82-5.62
9	8	7.94	5.62-11.2
12	16	15.85	11.2-22.4
15	31.5	31.62	22.4-44.7
18	63	63.10	44.7-89.1
21	125	125.89	89.1-178
24	250	251.19	178-355
27	500	501.19	355-708
30	1000	1000.0	708-1410
33	2000	1995.3	1410-2820
36	4000	3981.1	2820-5620
39	8000	7943.3	5620-11 200
42	16 000	15 848.9	11 200-22 400

4. Acoustic analysis

Preferred center frequencies and passbands for acoustic frequency spectrum analysis are defined in ISO R 266 and ANSI S1.6—1984. Nominal frequencies are normally used to identify the bands, but true center frequencies are calculated from 10e n/10, where n is the band number. Because of this formula, 1/3 octave filters are also sometimes referred to as 1/10 decade filters.

Band No.	Nominal center frequency Hz	Exact center frequency Hz	Passband Hz
1	1.25	1.26	1.12-1.41
2	1.6	1.58	1.41-1.78
3	2	2.00	1.78-2.24
4	2.5	2.51	2.24-2.82
5	3.15	3.16	2.82-3.55
6	4	3.98	3.55-4.47
7	5	5.01	4.47-5.62
8	6.3	6.31	5.62-7.08
9	8	7.94	7.08-8.91
10	10	10.0	8.91-11.2
11	12.5	12.59	11.2-14.1
12	16	15.85	14.1-17.8
13	20	19.95	17.8-22.4
14	25	25.12	22.4-28.2
15	31.5	31.62	28.2-35.5
16	40	39.81	35.5-44.7
17	50	50.12	44.7-56.2
18	63	63.10	56.2-70.8
19	80	79.43	70.8-89.1
20	100	100.00	89.1-112
21	125	125.89	112-141
22	160	158.49	141-178
23	200	199.53	178-224
24	250	251.19	224-282
25	315	316.23	282-355
26	400	398.11	355-447
27	500	501.19	447-562
28	630	630.96	562-708
29	800	794.33	708-891
30	1000	1000.0	891-1120
31	1250	1258.9	1120-1410
32	1600	1584.9	1410-1780
33	2000	1995.3	1780-2240
34	2500	2511.9	2240-2820
35	3150	3162.3	2820-3550
36	4000	3981.1	3550-4470
37	5000	5011.9	4470-5620
38	6300	6309.6	5620-7080
39	8000	7943.3	7080-8910
40	10 000	10 000.0	8910-11200
41	12.5K	12 589.3	11.2-14.1K
42	16K	15 848.9	14.1-17.8K
43	20K	19 952.6	17.8-22.4K

5. Temperature

Fahrenheit to Rankin	°R = °F + 459.67°
Celsius to Kelvin	°K = °C + 273.15°
Fahrenheit to Celsius	°C = 5/9 (°F - 32) °C = 5/9 (°F + 40) - 40
Celsius to Fahrenheit	°F = 9/5 (°C + 40) - 40 °F = (°C + 40) 1.8 - 40

Conversion Between °F and °C

°C ◄ °F °C ► °F			°C ◄ °F °C ► °F		
-273.15	-459.67	-	-15.9	+5	41.0
-268	-450	-	-12.2	10	50.0
-262	-440	-	-6-67	20	68.0
-251	-420	-	-1.11	30	86.0
			0.00	**32**	**89.6**
-240	-400	-	+4.44	40	104.0
-212	-350	-	10.0	50	122.0
-184	-300	-	15.6	60	140.0
-169	-273	-459.7	21.1	70	158.0
-157	-250	-418	26.7	80	176.0
-129	-200	-328	32.2	90	194.0
-101	-150	-238	37.8	100	212.0
-73.3	-100	-148	93.3	200	392
			121	**250**	**482**
-62.2	-80	-112	149	300	572
-53.9	-65	-85	204	400	752
-51.1	-60	-76	260	500	932
-40.0	-40	-40.0	316	600	1112
-28.9	-20	-4.0	399	750	1382
			427	**800**	**1472**
-23.3	-10	+14.0	538	1000	1832
-20.6	-5	23.0	649	1200	2192
-17.8	0	32.0	760	1400	2552

6. Temperature reference points

°C	°F	
-273.15	-459.67	Absolute Zero
-268.6	-451.5	Helium, boiling point
-252.87	-423.2	Hydrogen, boiling point
-195.8	-320.4	Nitrogen, boiling point
-183.0	-297.4	Oxygen, boiling point
-78.5	-109.3	Carbon Dioxide, sublimes
0.00	32	Water, solid-liquid equilibrium
0.01	32.02	Water, triple point
100	212.	Water, liquid-vapor equilibrium
232	450.	Tin, melting point
419.5	787.1	Zinc, solid-liquid equilibrium
444.6	832.3	Sulfur, liquid-gas equilibrium
960.8	1761.4	Silver, solid-liquid equilibrium
1063	1945.4	Gold, solid-liquid equilibrium
1084	1983.	Copper, melting point
1773	3221.	Platinum, melting point

7. Undersea pressure

P = A + 0.445 D

where: P = absolute pressure in psi
A = atmosphere pressure in psi
D = depth, in feet

P = A + 10.0 D

where: P = absolute pressure, in kPa
A = atmospheric pressure, in kPa
D = depth, in meters

8. U.S. standard atmosphere (1962) (at 45˚ latitude)

Altitude feet	Temperature °F	°C	Pressure millibars	Density lb/ft3
-1000	62.6	17.0	1050	.0787
-500	60.8	16.0	1032	.0776
0	59.0	15.0	1013	.0765
500	57.2	14.0	995	.0754
1K	55.4	13.0	977	.0743
2K	51.9	11.0	942	.0721
3K	48.3	9.1	908	.0700
4K	44.7	7.1	875	.0679
5K	41.2	5.1	843	.0659
6K	37.6	3.1	812	.0639
7K	34.0	1.1	782	.0620
8K	30.5	-0.8	753	.0601
9K	26.9	-2.8	724	.0583
10K	23.4	-4.8	697	.0565
12K	16.2	8.8	645	.0530
14K	9.1	-12.7	595	.0497
16K	2.0	-16.7	549	.0466
18K	-5.1	-20.6	506	.0436
20K	-12.3	-24.6	466	.0408
22K	-19.4	-28.5	428	.0381
24K	-26.5	-32.5	393	.0355
26K	-33.6	-36.4	360	.0331
28K	-40.7	-40.4	330	.0308
30K	-47.8	-44.4	301	.0287
32K	-54.9	-48.3	275	.0266
34K	-62.1	-52.3	251	.0247
36K	-69.2	-56.2	228	.0229
38K	-69.7	-56.5	207	.0208

(At 45° latitude)

Altitude feet	Temperature °F	°C	Pressure millibars	Density lb/ft3
40K	-69.7	-56.5	188.2	.01890
42K	-69.7	-56.5	171.0	.01717
44K	-69.7	-56.5	155.4	.01560
46K	-69.7	-56.5	141.2	.01418
48K	-69.7	-56.5	128.4	.01288
50K	-69.7	-56.5	116.6	.01171
55K	-69.7	-56.5	91.8	.00922
60K	-69.7	-56.5	72.3	.00726
65K	-69.7	-56.5	56.9	.00572
70K	-67.4	-55.2	44.9	.00448
75K	-64.7	-53.7	35.4	3.51×10^{-3}
80K	-62.0	-52.2	28.0	2.76
85K	-59.3	-50.7	22.2	2.17
90K	-56.5	-49.2	17.61	1.710
95K	-53.8	-47.7	14.00	1.350
100K	-51.1	-46.2	11.14	1.068×10^{-3}
110K	-41.3	-40.7	7.10	.665
120K	-26.1	-32.3	4.60	.415
130K	-10.9	-23.8	3.02	.264
140K	+4.3	-15.4	2.01	.170
150K	+19.4	-7.0	1.361	$.1112 \times 10^{-3}$
160K	27.5	-2.5	0.930	.0747
170K	27.5	-2.5	0.637	.0512
180K	18.9	-7.3	0.435	.0356
190K	8.1	-13.3	0.295	.0247
200K	-2.7	-19.3	0.1980	$.01696 \times 10^{-3}$
220K	-43.5	-41.9	0.0854	.00804
240K	-86.4	-65.8	0.0337	.00354
260K	-129.3	-89.6	0.0119	.00141
280K	-134.5	-92.5	0.00387	.000466
300K	-126.8	-88.2	0.00127	.000149

Conversion factors

1 foot = 0.3048 meters

1 bar = 14.50 pounds/sq. foot
= 2088 pounds/sq. foot
= 105 Pa (N/m^2)
= 29.53 inches Hg
= 401.8 inches H_2O

1 lb/cu ft = 16.018 kg/cu meter

Product selection guide

Absolute pressure products

Automotive crash test products

Electronics products

Extreme temperature products

Gage and differential pressure products

Gas turbines

522	+600˚C, dynamic pressure	See pg 29, 61
6240C-10	+650°C, balanced differential output, 10 pC/g, detachable cable	See pg 39
6233C	+482°C, balanced differential output, three hole mount	See pg 38
6222S-20A,-50A,-100A	Balanced differential output, three hole mount	See pg 15, 38
6237M70	+650°C, coaxial output, ground isolated, 10-32 connector	See pg 15, 39
6237M71	+650°C, coaxial output, sensitive axis perpendicular to mounting bolt	See pg 39
6917	+500 F high temperature braided cable assembly	See pg 29

General purpose products

256-10	Low-cost, modal ready, 10 mV/g, hermetically sealed, Isotron	See pg 44
256-100	Low-cost, modal ready, 100 mV/g, hermetically sealed, Isotron	See pg 44
256HX-10	Low-cost, stud mount, isolated case, 10 mV/g, Isotron	See pg 45
256HX-100	Low-cost, stud mount, isolated case, 100 mV/g, Isotron	See pg 45
2221D	High output, 17pC/g, ring shape	See pg 35
2222C	Industry standard, adhesive mount	See pg 23, 35
2222D	Industry standard, adhesive mount, connectorized	See pg 35
2223D	Triaxial, 12pC/g, ground isolated	See pg 35
2224C	Top connector, general purpose	See pg 35
2225	High g shock, industry standard	See pg 36
2226C	+177°C, lightweight, top connector, adhesive mount	See pg 24, 36
2228C	+177°C, triaxial, ground isolated	See pg 36
2229C	+177°C, lightweight, top connector, stud mount	See pg 36
2255B-01	Isotron shock accelerometer, 0.1 mV/g, built-in 30 kHz LP filter	See pg 46
2255B-1	Isotron shock accelerometer, 1 mV/g, built-in 30 kHz LP filter	See pg 46
2258A-10	Triaxial, 10 mV/g, hermetically sealed, ground isolated	See pg 46
2258A-100	Triaxial, 100 mV/g, hermetically sealed, ground isolated	See pg 46
7201-10	+260°C, general purpose, 10-32 side connector, 10 pC/g	See pg 39
7201-50	+260°C, general purpose, 10-32 side connector, 50 pC/g	See pg 39
7201-100	+260°C, general purpose, 10-32 side connector, 100 pC/g	See pg 39
7221A	+204°C, hermetically sealed, center bolt mount, 360° cable orientation	See pg 39
7251A-10	Wide bandwidth, center bolt mount, low profile, 10 mV/g	See pg 47
7251A-100	Wide bandwidth, center bolt mount, low profile, 100 mV/g	See pg 47
7255A-01	Isotron, shock accelerometer, built-in 10 kHz mechanical LP filter, 0.1 mV/g	See pg 48

Industrial machine monitoring

5220A-100	Industrial standard two-pin 5015C connector, 100 mV/g +/-10%	See pg 46
5221	Industrial standard low profile side exit 5015C connector, 100 mV/g +/-10%	See pg 46

Light weight products

12M1A	Lightweight biomorph accel., SMT installation, 9 kHz resonance frequency, 1000 g shock limit	See pg 17, 34, 41
12M9	Lightweight biomorph accelerometer, SMT w/wirebond, 1.5 pC/g, 4000 g shock limit	See pg 34
12M23	Miniature biomorph accelerometer, SMT installation, 1.8 pC/g, 8 kHz resonance frequency	See pg 34
22	World's smallest, 0.14 gm	See pg 15, 34
23	World's smallest triaxial, lightweight, ground isolated	See pg 15, 35
25A	World's smallest Isotron, adhesive mount, 5 mV/g, ground isolated	See pg 13, 42
25B	World's smallest Isotron, adhesive mount, 5 mV/g, detachable cable	See pg 42
27A11	World's smallest iTEDS, hermetically sealed, 10 mV/g, 5000 g limit	See pg 42
35A	Miniature triaxial Isotron, 5 mV/g, adhesive mount	See pg 23, 43
65	Miniature Isotron, triaxial, 10 and 100 mV/g	See pg 43
71	High shock DC response, surface mount, 6k to 60k g	See pg 13, 50
258A	Stud mount Isotron, hermetically sealed, 10 and 100 mV/g	See pg 45
2222C	Industry standard, adhesive mount	See pg 23, 35
2250A-10	Miniature, lightweight (0.4gram), 10 mV/g, adhesive mount	See pg 46
2250AM1-10	Lightweight (0.4gram), 10 mV/g, adhesive mount, solder pin connection	See pg 46
7250A	360˚ cable orientation, lightweight, flight test applications, general purpose	See pg 47
7253C-10	Low profile triaxial Isotron, 10 mV/g, bolt or adhesive mount	See pg 48
7264C	DC response, automotive crash standard, undamped, overtravel stops	See pg 19, 20, 51, 52, 57
7269	Triaxial, miniature, lightweight, DC response, overtravel stops	See pg 21, 53
8507C	Miniature pressure sensor, 1-15 psig ranges	See pg 58, 62
8515C	Miniature, low profile pressure sensor, 15 and 50 psi	See pg 27, 56
32394-15	Microminiature pressure sensor, flip chip design, 0-15 psia, 200 mV full scale@5 VDC input	See pg 17, 56
40366	Miniature VC accelerometer, hermetic, SMT installation, +/-2g range with 10g overange stops	See pg 17

Low frequency and low level accelerometers

87	Very high sensitivity, high resolution, 1 or 10 V/g	See pg 44
752A13	High sensitivity, low noise, iTEDS, 1 V/g	See pg 45
2262A	DC response damped, hermetic, hex base, 1000 and 2000 g available	See pg 51
7265A-HS	DC response, mechanical stops, damped, 5 and 25 mV/g available	See pg 20, 52
7290A	DC response, low-level acceleration and inclination, very high sensitivity	See pg 13, 54
7293A	DC response, low-level, EMI/RFI shield, 20 and 40 mV/g	See pg 55
7596A	DC response, low-level acceleration, whole body motion, 40 to 1000 mV/g	See pg 55
7703A-100	+288°C, signal return isolated from case, 100 pC/g, 10-32 side connector	See pg 27, 30, 40
7703A-200	+288°C, signal return isolated from case, 200 pC/g, 10-32 side connector	See pg 27, 30, 40
7703A-1000	+288°C, signal return isolated from case, 1000 pC/g, 10-32 side connector	See pg 27, 30, 40

Microphones

2510	Vibration compensated, high temperature, 100 to › 180 dB SPL	See pg 62
2510M4A	Vibration compensated, high temperature, 100 to › 180 dB SPL, flush mount	See pg 62
8507C	Miniature, -97 dB sensitivity, flush mount	See pg 58, 62
8510B	Miniature, -92 dB sensitivity, 10-32 mounting	See pg 14, 60, 62

Medical/SMT

12M1A	Lightweight biomorph accelerometer, SMT installation, 1.9 pC/g, 1000 g shock limit	See pg 17, 34, 41
12M9	Lightweight biomorph accelerometer, SMT w/wirebond, 1.5 pC/g, 4000 g shock limit	See pg 34
12M23	Miniature biomorph accelerometer, SMT installation, 1.8 pC/g, 8 kHz resonance frequency	See pg 34
32394-15	Microminiature pressure sensor, flip chip design, 0-15 psia, 200 mV full scale@5 VDC input	See pg 17, 56
40366	Miniature VC accelerometer, hermetic, SMT installation, +/-2g range with 10g overange stops	See pg 17

Nuclear applications

2248	+482˚C, lightweight, flange mount, radiation hardened	See pg 36
2248M1	+482˚C, lightweight, integral stud, radiation hardened	See pg 37
2771B	In line charge converter	See pg 30, 65, 66
2771C	Ultra low noise in line charge converter	See pg 24, 31, 66
2273A	+399˚C, radiation hardened, case grounded accelerometer	See pg 29, 37
2273AM20	Radiation hardened, ground isolated, top connector PE accelerometer	See pg 38
2276	+482˚C, radiation hardened, case grounded, side connector	See pg 38
3075M6	Hardline cable, +482˚C, hermetically sealed	See pg 31, 94
7703A-100	+288˚C, signal return isolated from case, 100 pC/g, 10-32 side connector	See pg 27, 30, 40

Products for shock

71-6K	High level shock, DC response, high resonance frequency, PR	See pg 13, 50
71-20K	High level shock, DC response, high resonance frequency, PR	See pg 13, 50
71-60K	High level shock, DC response, high resonance frequency, PR	See pg 13, 50
2225	High g shock, industry standard, PE, 20K g shock	See pg 36
2225M5A	Very High g shock, industry standard, PE, 100K g shock limit	See pg 36
2255B-01	Isotron shock accelerometer, 0.1 mV/g, built-in 30 kHz LP filter, 50K g shock limit	See pg 46
7231C	Automotive crash standard, DC response, undamped, 0.2 mV/g	See pg 20, 51
7255A-01	Isotron, shock accelerometer, built-in 10 kHz mechanical LP filter, 0.1 mV/g	See pg 48
7255A-1	Isotron, shock accelerometer, built-in 10 kHz mechanical LP filter, 1mV/g	See pg 48
7264	DC response, automotive crash standard, undamped, 2.5 mV/g	See pg 19, 20, 51, 53
7264B	DC response, automotive crash standard, undamped, overtravel stops	See pg 19, 20, 51, 53
7265AM3	DC response detachable cable, undamped, automotive crash standard	See pg 20, 52
7267A	Triaxial, 1500g, DC response replaceable sensors, undamped, SAE-J211 S705	See pg 21, 52

Products for testing movement

2262A	DC response damped, hermetic, hex base, 0.25 mV/g and 10.5 mV/g	See pg 51
7293A	DC response, low-level, EMI/RFI shield, 20 and 40 mV/g	See pg 55
7596A-2	DC response, 1 V/g, low-level acceleration, lab test	See pg 55
7290A-30	DC response, 66 mV/g, low-level acceleration, field test	See pg 13, 54
7290A-100	DC response, 20 mV/g, low-level acceleration, field test	See pg 13, 54

Space and flight products

2221F	+260°C, 10 pC/g, center mount, PE accelerometer	See pg 14, 35
2510	100 to >180 dB SPL, vibration compensated, high temperature microphone	See pg 62
2510M4A	Special mounting for flush diaphragms, high temperature	See pg 62
7250A-10	Flight test ready, lightweight (1.8 gm), 10 mV/g, hermetically sealed	See pg 47
7250AM1-10	Lightweight (1.8 gm), 10 mV/g, hermetically sealed, solder pin connection	See pg 47
7257AT	Isotron, telemetry ready, operational from +15 to + 32 V dc, 4-pole LP filter	See pg 49
7290A-2	DC response, 1 V/g, low-level acceleration, field test	See pg 13, 54
7290A-10	DC response, 200 mV/g, low-level acceleration, field test	See pg 13, 54
7290A-30	DC response, 66 mV/g, low-level acceleration, field test	See pg 13, 54
7290A-100	DC response, 20 mV/g, low-level acceleration, field test	See pg 13, 54
8507C-2	Pressure transducer (microphone), miniature, -97dB sensitivity, flush mount	See pg 58, 62
8510B-1	Pressure transducer (microphone), -92dB sensitivity,10-32 mounting	See pg 14, 60, 62
8510B-2	Pressure transducer (microphone), -97dB sensitivity, 10-32 mounting	See pg 14, 60, 62

Specialty products

2273A	+399°C, radiation hardened, case grounded, PE accelerometer	See pg 29, 37
2273AM1	+399˚C radiation hardened, ground isolated, side connector	See pg 37
2273AM20	+399˚C radiation hardened, ground isolated, top connector	See pg 38
2276	+482°C, Radiation hardened, case grounded, side connector	See pg 38
2510	100 to >180 dB SPL, vibration compensated, high temperature, microphone	See pg 62
2680M6X	1 ch. PE amplifier, 6-pole filter options	See pg 65
2680MX	1 ch. PE amplifier, biased/unbiased outputs, 2 pole filter options	See pg 65
2685MX	1 ch. Isotron amplifier, dual gain outputs, 2 pole filter options	See pg 65
2771B-01	1 ch. PE remote charge converter gain of 0.1	See pg 30, 65
2771B-1	1 ch. PE remote charge converter gain of 1.0	See pg 30, 65
2771B-10	1 ch. PE remote charge converter gain of 10	See pg 30, 65
6237M70	+650°C, coaxial output, ground isolated, 10-32 connector	See pg 15, 39
6237M71	+650°C, coaxial output, sensitive axis perpendicular to mounting bolt	See pg 39
7259B-10	Isotron, high frequency (30 kHz), lightweight (4.6 gm), 10 mV/g	See pg 49
7259B-25	Isotron, high frequency (30 kHz), lightweight (4.6 gm), 25 mV/g	See pg 49
7259B-100	Isotron, high frequency (30 kHz), lightweight (4.6 gm), 100 mV/g	See pg 49
7290A-30	DC response, 66 mV/g, low-level acceleration, field test	See pg 13, 54
7290A-100	DC response, 20 mV/g, low-level acceleration, field test	See pg 13, 54
7596A-30	DC response, 66 mV/g, low-level acceleration, lab test	See pg 55
7596A-100	DC response, 20 mV/g, low-level acceleration, lab test	See pg 55
8507C-2	Pressure transducer (microphone), miniature, -97 dB sensitivity, flush mount	See pg 58
8510B-1	Pressure transducer (microphone),-92 dB sensitivity,10-32 mounting	See pg 58, 62
8510B-2	Pressure transducer (microphone),-97 dB sensitivity, 10-32 mounting	See pg 58, 62

Piezoelectric

Model	Sensitivity Typical pC/g	Weight gram W/O cable	Sinusiodal limit g	Shock limit g	Frequency response ± 1dB (Hz)	Min. temp. °C (°F)	Max. temp. °C (°F)	Signal/ground isolation	Hermetic seal	Mounting methods
12M1A	1.9	0.12	500	1000	1-3000	-65 (-85)	150 (300)	No	No	Solder/Cond adh
12M9	1.5	0.15	500	4000	1- >100	-65 (-85)	125 (257)	No	No	Solder/Cond adh
12M23	0.07	0.12	500	1000	1-3000	-65 (-85)	150 (300)	No	No	Solder/Cond adh
22/22-R	0.4	0.14	2500	10 000	3-12 000	-73 (-100)	150 (300)	Yes	No	Adhesive
23/23-R	0.4	0.8	2000	10 000	3-12 000	-73 (-100)	150 (300)	Yes	No	Adhesive
2220E/2220E	3	3.1	1000	5000	1-12 000	-55 (-67)	260 (500)	Yes	Yes	Screw
2221D	17	12	1000	5000	0.1-10 000	-55 (-67)	177 (350)	Yes	No	Screw
2221F/2221F-R	10	11	1000	3000	0.1-12 000	-55 (-67)	260 (500)	Yes	Yes	Screw
2222C/2222-R	1.4	0.5	1000	10 000	1-10 000	-73 (-100)	177 (350)	Yes	No	Adhesive
2222D/2222D-R	1.1	1.0	1000	10 000	0.1-12 000	-55 (-67)	175 (347)	No	Yes	Adhesive
2223D	12	41	1000	2000	1-5000	-55 (-67)	177 (350)	Yes	No	Screw
2224C	12	16	1000	2000	0.1-10 000	-55 (-67)	177 (350)	No	No	Stud
2225	0.75	13	10 000	20 000	1-10 000	-55 (-67)	177 (350)	No	No	Stud
2225M5A	0.025	13	10 000	100 000	1-10 000	-18 (0)	66 (150)	No	No	Stud
2226C/2226C-R	2.8	2.8	1000	2000	0.1-7000	-55 (-67)	177 (350)	No	No	Adhesive
2228C/2228C-R	2.8	15	1000	2000	10-6000	-55 (-67)	177 (350)	Yes	No	Screw
2229C	2.8	4.9	1000	2000	0.1-7000	-55 (-67)	177 (350)	Yes	No	Stud
2230E/2230E-R	3	17	1000	2000	1-10 000	-55 (-67)	260 (500)	No	Yes	Adhesive
2230EM1	3.0	22.5	1000	2000	1-10 000	-55 (-67)	260 (500)	No	Yes	Screw
2248	3.0	13	500	3000	8000	-54 (-65)	482 (900)	No	Yes	Screw
2248/M1	3.0	13	500	3000	1-8000	-55 (-67)	482 (900)	No	Yes	Screw/Stud
2270	2.2	40	1000	15 000	2-20 000	-54 (-65)	177 (350)	Yes	No	Stud
2270M8	2.2	16.5	1000	15 000	2-20 000	-54 (-65)	177 (350)	Yes	Yes	Stud
2271A/2271A-R	11.5	27	1000	10 000	1-8000	-269 (-425)	260 (500)	Yes	Yes	Stud
2271AM20	11.5	27	1000	10 000	1-8000	-269 (-425)	260 (500)	Yes	Yes	Stud
2272	13	27	1000	2000	1-9000	-269 (-425)	260 (500)	No	Yes	Stud
2273A	3	25	1000	10 000	1-10 000	-184 (-300)	400 (750)	No	Yes	Stud
2273AM1-R	10	34	500	3000	1-7000	-55 (-67)	400 (750)	Yes	Yes	Stud
2273AMJ/AM20	10	34	500	3000	1-7000	-55 (-67)	400 (750)	Yes	Yes	Stud
2273AM20-R	10	34	500	3000	1-7000	-55 (-67)	400 (750)	Yes	Yes	Stud
2276/2276-R	10	30	500	3000	1-7000	-55 (-67)	482 (900)	No	Yes	Stud
6222S-20A	20	91	2000	4000	1-12 000	-55 (-67)	260 (500)	Yes	Yes	Bolt
6222S-50A	50	91	1000	2000	1-9000	-55 (-67)	260 (500)	Yes	Yes	Bolt
6222S-100A	100	91	500	1000	1-9000	-55 (-67)	260 (500)	Yes	Yes	Bolt
6233C-10	10	75	1000	2000	1-8000	-55 (-67)	482 (900)	Yes	Yes	Bolt
6233C-50	50	110	1000	2000	0.1-5000	-55 (-67)	482 (900)	Yes	Yes	Bolt
6233C-100	100	110	500	1000	0.1-3000	-55 (-67)	482 (900)	Yes	Yes	Bolt
6237M70	10	30	500	2000	1-5000	-55 (-67)	649 (1200)	Yes	No	Bolt
6237M71	10	30	500	2000	1-5000	-55 (-67)	649 (1200)	Yes	No	Bolt
6240C-10	10	200	1000	2000	1-4000	-50 (-58)	649 (1200)	Yes	Yes	Bolt
6240M10-120	5	95	250	1000	1-3000	-54 (-65)	649 (1200)	Yes	Yes	Bolt
7201-10	10	18	2000	20 000	1-15 000	-73 (-100)	260 (500)	No	Yes	Stud
7201-50	50	20	2000	10 000	1-10 000	-73 (-100)	260 (500)	No	Yes	Stud
7201-100	100	25	2000	5000	1-8000	-73 (-100)	260 (500)	No	Yes	Stud
7221A	10	10.5	1000	5000	1-12 000	-55 (-67)	204 (400)	Yes	Yes	Screw
7221M2	10	11	1000	5000	2-10 000	-54 (-65)	260 (500)	Yes	Yes	Screw
7240C	3	4.8	1000	5000	1-20 000	-55 (-67)	260 (500)	No	Yes	Stud
7701A-50	50	25	2000	10 000	1-9000	-55 (-67)	288 (550)	No	Yes	Screw/Stud
7701A-100	100	29	1000	5000	1-8000	-55 (-67)	288 (550)	No	Yes	Screw/Stud
7701A-200	200	62	850	2000	1-6000	-55 (-67)	288 (550)	No	Yes	Screw/Stud
7701A-I000	1000	120	500	1000	1-3000	-55 (-67)	288 (550)	No	Yes	Screw/Stud
7702A-17	17	25	2500	12 000	1-14 000	-55 (-67)	288 (550)	No	Yes	Screw/Stud

Piezoelectric (continued)

Model	Sensitivity Typical pC/g	Weight gram W/O cable	Sinusiodal limit g	Shock limit g	Frequency response ± 1dB (Hz)	Min. temp. °C (°F)	Max. temp. °C (°F)	Signal/ground isolation	Hermetic seal	Mounting methods
7702A-50	50	25	2000	10 000	1-4000	-55 (-67)	288 (550)	No	Yes	Screw/Stud
7703A-50	50	25	2000	10 000	1-9000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703A-50-R	50	25	2000	10 000	1-9000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703A-100	100	29	1000	5000	1-8000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703A-100-R	100	29	1000	5000	1-8000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703A-200	200	62	850	2000	1-6000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703A-1000	1000	120	500	1000	1-3000	-55 (-67)	288 (550)	Yes	Yes	Stud
7703AM5	100	29	1000	5000	1-8000	-55 (-67)	288 (550)	Yes	Yes	Stud
7704A-17	17	25	2500	12 000	1-14 000	-55 (-67)	288 (550)	Yes	Yes	Stud
7704A-50	50	25	2000	10 000	1-9000	-55 (-67)	288 (550)	Yes	Yes	Stud
7704A-100	100	29	2000	5000	1-8000	-55 (-67)	288 (550)	Yes	Yes	Stud
7722/7724	3.7	29	500	2500	1-6000	-269 (-452)	177 (350)	No/Yes	Yes	Stud

Isotron

Model	Sensitivity Typical mV/g	Weight gram W/O cable	Linear range g	Shock limit g	Frequency response ± 1dB (Hz)	Min. temp. °C (°F)	Max. temp. °C (°F)	Signal/ground isolation	Hermetic seal	Mounting methods
25A/B	5	0.2	± 740	2000	1-12 000	-55 (-67)	125 (257)	Yes	No	Adhesive
27A11	10	0.8	± 500	5000	2-10 000	-55 (-67)	125 (257)	No	Yes	Adhesive
27A12	100	1.0	± 50	5000	3-10 000	-55 (-67)	125 (257)	No	Yes	Adhesive
27AM1-10	10	0.8	± 500	5000	2-10 000	-55 (-67)	125 (257)	No	Yes	Adhesive
27AM1-100	100	1.0	± 50	5000	3-10 000	-55 (-67)	125 (257)	No	Yes	Adhesive
35A	5	1.1	± 1000	2000	1-12 000	-55 (-67)	125 (257)	No	No	Adhesive
61C12	100	13	± 50	5000	1-8000	-25 (40)	125 (257)	Yes	Yes	Adhesive
61C13	1000	13	± 5	5000	1-8000	-25 (-40)	125 (257)	No	Yes	Adhesive
65-100	100	5	± 50	10 000	1.5-6000 ±1dB	-55 (-67)	125 (257)	No	Yes	Adhesive/Stud
65HT-05	0.5	5	± 10 000	15 000	3-8000	-55 (-65)	175 (347)	No	Yes	Stud
65HT-1	1	5	± 5000	10 000	3-8000	-55 (-65)	175 (347)	No	Yes	Adhesive/Stud
65HT-10	10	5	± 500	10 000	3-8000	-55 (-67)	175 (347)	No	Yes	Adhesive/Stud
65HT-10-R	10	5	± 500	10 000	3-8000	-55 (-67)	175 (347)	No	Yes	Adhesive/Stud
66A11	10	±5	± 500	10 000	0.5-6000	-55 (-67)	125 (257)	No	Yes	Adhesive/Stud
66A12/66A12-R	100	5	± 50	10 000	1.5-6000	-55 (-67)	125 (257)	No	Yes	Adhesive/Stud
67-10	10	14	± 500	5000	0.5-8000	-55 (-67)	175 (347)	Yes	Yes	Adhesive/Stud
67-100	100	14	± 50	5000	0.5-8000	-55 (-67)	175 (347)	Yes	Yes	Adhesive/Stud
86	10 V/g	771	± 0.5	250	.005-100	-10 (-23)	100 (212)	Yes	Yes	Stud
87-1/-10	1/10 V/g	170	± 51.05	400	.015/.05-380	-20 (-4)	100 (212)	Yes	Yes	Stud
256-10/-100	10/100	3.5	± 500/50	2000	1-9000	-55 (-67)	125 (251)	Yes	Yes	Adhesive
256HX-10/-100	10/100	4.0	± 500/50	2000	1-10 000	-55 (-67)	125 (257)	Yes	Yes	Stud
258A-10	10	1.3	± 500	10 000	0.3-15 000	-54 (-65)	125 (257)	No	Yes	Stud
258A-100	100	2	± 50	10 000	1.5-15 000	-54 (-65)	125 (257)	No	Yes	Stud
751-10/-100	10/100	7.8	± 500/50	5000	1-15 000	-55 (-67)	125 (257)	No	Yes	Stud
751-10-R/-100-R	10/100	7.8	± 500/50	5000	1-15 000	-55 (-67)	125 (257)	No	Yes	Stud
751-500	500	11.3	± 10	1000	1-9000	-55 (-67)	125 (257)	No	Yes	Screw/Stud
752-10/-100	10/100	7.8	± 500/50	5000	1-18 000	-55 (-67)	125 (257)	No	Yes	Screw/Stud
752-500	500	11.3	± 10	1000	1-9000	-55 (-67)	125 (257)	No	Yes	Screw/Stud
752A12	100	13	± 50	5000	.05-30 000 (±2dB)	-20 (-4)	85 (185)	Yes	Yes	Stud
752A13	1000	13	± 5	5000	.03-10 000	-20 (-4)	85 (185)	Yes	Yes	Stud
2250A/AM1-10	10	0.4	± 500	2000	2-15 000	-55 (-67)	125 (257)	Yes	No	Adhesive
2250A-10-R	10	0.4	± 500	2000	2-15 000	-55 (-67)	125 (257)	Yes	No	Adhesive
2250AM1-10-R	10	0.4	± 500	2000	2-15 000	-55 (-67)	125 (257)	Yes	No	Adhesive
2255B-01/-1	0.1/1	2	± 50K/5K	50 000	2/.5-20 000	-55 (-67)	125 (257)	Yes	No	Stud
2256AM2	5	5	± 700	2000	3-3000 ±5%	-185 (-301)	125 (257)	Yes	Yes	Adhesive
2258A-10/-100	10/100	15	± 500/50	2000	1-7000	-55 (-67)	125 (257)	Yes	Yes	Screw

Isotron (continued)

Model	Sensitivity Typical (pC/g)	Weight (gram) W/O cable	Sinusoidal limit (g)	Shock limit (g)	Frequency response ± 1dB (Hz)	Min. temp. °C (°F)	Max. temp. °C (°F)	Signal/ground isolation	Hermetic seal	Mounting methods
5220A-100	100	100	± 80	5000	1-10 000	-50 (-58)	125 (257)	Yes	Yes	Stud
5221	100	145	± 80	5000	1-5000	-50 (-58)	125 (257)	Yes	Yes	Bolt
7250A-2/-10	2/10	1.8	± 5000/500	10 000	3/4-20 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7250AM1-2	2	1.8	± 5000	10 000	3-20 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7250AM1-10	10	1.8	± 500	10 000	4-20 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7250AM7-2	2	1.8	± 5000	10 000	4-15 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7250AM7-10	10	1.8	± 500	10 000	5-15 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251A-10	10	10.5	± 500	5000	2-10 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251A-10-R	10	10.5	± 500	5000	2-10 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251A-100	100	10.5	± 50	5000	2-10 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251A-100-R	100	10.5	± 50	5000	2-10 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251A-500	500	10.5	± 10	5000	2-10 000	-55 (-67)	125 (257)	Yes	Yes	Screw
7251AHT-500M1	500	14	± 10	5000	2-10 000 (+2%/8%)	-55 (-67)	150 (302)	Yes	Yes	Screw
7251B11/B12	10/100	10.5	± 500/± 50	5000	2-10 000 (+2%/8%)	-55 (-67)	125 (257)	Yes	Yes	Screw
7251HT-10/-100	10/100	14	± 500/± 50	500/5000	0.2-12 000	-55 (-67)	150 (302)	Yes	Yes	Screw
7251HT-500	500	14	± 10	5000	.2-12 000	-55 (-67)	150 (302)	Yes	Yes	Screw
7253C-10/	10	3.6	± 500	2000	2-15 000	-55 (-67)	125 (257)	Yes	No	Adhesive/Screw
7253C-10-R	10	3.6	± 500	2000	2-15 000	-55 (-67)	125 (257)	Yes	No	Adhesive/Screw
7255A-01	0.1	5	± 50 000	300 000	3-10 000 ±3 dB	-18 (0)	66 (150)	Yes	Yes	Screw
7255A-1	1	5	± 5000	25 000	3-10 000 ±3 dB	-18 (0)	66 (150)	Yes	Yes	Screw
7255AM1	0.10	5	± 50 000	300 000	3-10 000 ±3 dB	-18 (0)	66 (150)	Yes	Yes	Stud
7257ATM6	100	400 w/ cable	± 25	1000	(± 5%) 2-500	-55 (-67)	100 (212)	Yes	Yes	Screw
7257ATM7	10	400 w/ cable	± 250	1000	(± 5%) 2-2000	-55 (-67)	100 (212)	Yes	Yes	Screw
7259B-10/-25/-100	10/25/100	4.6	± 500/200/50	10 000/5/2	5-10 000	-55 (-67)	125 (257)	Yes w/ stud	Yes	Stud
7754A-1000	1000	115	± 5	1000	0.01-2000	32 (90)	85 (185)	Yes w/ stud	Yes	Screw/Stud
77257AT-10-YYY	100	28	± 250	1000	2-500, 2k, 5k	-55 (-67)	100 (212)	*Yes	Yes	Screw

AC Electronics

Model	Input	Channels	Gain	Display	RTO Noise	Low freq. -3 dB (Hz)	High freq. -3 dB (Hz)	Power	Type of control
133	PE/Isotron	3	0 to 1000	DPM	1 mVrms	0.03	100 000	AC/DC/BATT	Manual/RS-232
428	PE/Isotron	2	0 to 1000	Computer	.5 mVrms	‹0.159	›100 000	DC	RS232 or Ethernet
433	PE/Isotron	3	0 to 1000	Computer	0.4 mVrms	0.1	100 000	DC	RS232 or Ethernet
482B	Isotron	8	1 to 100	Computer	0.15 mVrms	0.015	100 000	DC	RS232 or Ethernet
2685MX	Isotron	1	0.1 to 100		1.5 mVrms	0.7	Selection	20-32 VDC	Manual
2690MX	PE	1	0.1 to 100		1.5 mVrms	3.0	Selection	DC	Manual
2721B	PE	1	1 to 100		100 µVrms	1	10 000	± 15 VDC	Manual
2771C-X	PE	1	0.1 to 20		5-50 µVrms	0.2	40 000	CONST. CURRENT	Manual
2775B	PE/Isotron	1	.03 to 1000	Meter	1 mVrms	0.2	200 000	AC	Manual
2777A-X	DIFF PE	1	2 or 10		1 mVrms	6	17 500	DC	Manual
2793	Isotron	16	1 or 10		0.4 mVrms	0.3	30 000	AC	Manual
4416B	Isotron	1	1 or 10		45 µVrms	2	20 000	AC/DC/BATT	Manual
4430A	PE/PR/Isotron	1 to 10/Rack	1 to 1000	DPM	1 mVrms	0	100 000	AC/BATT	Manual/IEEE488
4999	IEPE/Voltage	16	1 to 10	LED indicator	‹15-30 µV	DC	60 000	115/250 VAC	Manual
6634C	DIFF PE	1 to 6/Rack	Selectable	DPM	2 mVrms	0.12	20 000	AC/Manual/RS-232	
35918-XX	PE	1	0.1 or 1		1 mVrms	0.05	200 000	4430A	4430A

Gage/Differential - Piezoresistive

Model	Full scale pressure psi	Sensitivity mV/psi	Resonant frequency Hz	Linearity % FSO	Min. Temp. °C (°F)	Max. Temp. °C (°F)	Burst pressure diaphragm/ref psi	Face diameter mm (inch)	Weight gram	Mounting methods
8507C-1	1	200	55 000	1.5	-54 (-65)	107 (225)	20/20	2.34 (0.092)	0.3	RTV flush mount
8507C-2	2	150	70 000	1.5	-54 (-65)	107 (225)	40/40	2.34 (0.092)	0.3	RTV flush mount
8507C-5	5	60	85 000	0.75	-54 (-65)	107 (225)	100/50	2.34 (0.092)	0.3	RTV flush mount
8507C-15	15	20	130 000	0.5	-54 (-65)	107 (225)	150/50	2.34 (0.092)	0.3	RTV flush mount
8510B-1	1	200	55 000	1.0	-54 (-65)	121 (250)	25/25	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-2	2	150	70 000	1.0	-54 (-65)	121 (250)	40/40	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-5	5	60	85 000	0.5	-54 (-65)	121 (250)	100/100	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-200	200	1.5	320 000	0.25	-54 (-65)	121 (250)	1000/300	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-500	500	0.6	500 000	0.25	-54 (-65)	121 (250)	2500/300	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-2000	2000	0.15	900 000	0.25	-54 (-65)	121 (250)	10 000/300	3.86 (0.152)	2.3	10-32 UNF-2B
8510C-15	15	15	180 000	0.15	-54 (-65)	121 (250)	75/75	3.86 (0.152)	2.3	10-32 UNF-2B
8510C-50	50	4.5	320 000	0.1	-54 (-65)	121 (250)	250/250	3.86 (0.152)	2.3	10-32 UNF-2B
8510C-100	100	2.25	50 000	0.1	-54 (-65)	121 (250)	400/300	3.86 (0.152)	2.3	10-32 UNF-2B
8511A-5K	5000	0.1	›1 000 000	1.2	-54 (-65)	121 (250)	20 000	9.7 (0.38)	11	3/8-24 UNF-2B
8511A-10K	10 000	0.05	›1 000 000	2.5	-54 (-65)	121 (250)	30 000	9.7 (0.38)	11	3/8-24 UNF-2B
8511A-20K	20 000	0.025	›1 000 000	2.5	-54 (-65)	121 (250)	40 000	9.7 (0.38)	11	3/8-24 UNF-2B

Absolute

Model	Full scale pressure psi	Sensitivity mV/psi	Resonant frequency Hz	Linearity % FSO	Min. Temp. °C (°F)	Max. Temp. °C (°F)	Burst pressure diaphragm/ref psi	Face diameter mm (inch)	Weight gram	Mounting methods
8515C-15	15	13.3	180 000	0.2	-54 (-65)	121 (250)	75	6.35 (0.25)	0.08	Adhesive
8515C-50	50	4	320 000	0.2	-54 (-65)	121 (250)	250	6.35 (0.25)	0.08	Adhesive
8530B-200	200	1.5	750 000	0.2	-54 (-65)	121 (250)	800	3.86 (0.152)	2.3	10-32 UNF-2B
8530B-500	500	0.6	1 000 000	0.2	-54 (-65)	121 (250)	2000	3.86 (0.152)	2.3	10-32 UNF-2B
8530B-1000	1000	0.3	›1 000 000	0.2	-54 (-65)	121 (250)	4000	3.86 (0.152)	2.3	10-32 UNF-2B
8530B-2KM37	2000	0.3	›1 000 000	0.2	-54 (-65)	121 (250)	4000	3.86 (0.152)	2.3	10-32 UNF-2B
8530C-15	15	15	180 000	0.15	-54 (-65)	121 (250)	75	3.86 (0.152)	2.3	10-32 UNF-2B
8530C-50	50	4.5	320 000	0.1	-54 (-65)	121 (250)	250	3.86 (0.152)	2.3	10-32 UNF-2B
8530C-100	100	2.25	500 000	0.1	-54 (-65)	121 (250)	400	3.86 (0.152)	2.3	10-32 UNF-2B
8540-15	15	20	140 000	0.25	-54 (-65)	260 (500)	30	3.86 (0.152)	8.5	10-32 UNF-2B
8540-50	50	6	240 000	0.25	-54 (-65)	260 (500)	100	3.86 (0.152)	8.5	10-32 UNF-2B
8540-100	100	3	350 000	0.25	-54 (-65)	260 (500)	200	3.86 (0.152)	8.5	10-32 UNF-2B
8540-200	200	1.5	450 000	0.4	-54 (-65)	260 (500)	400	3.86 (0.152)	8.5	10-32 UNF-2B
8540-500	500	0.6	900 000	0.4	-54 (-65)	260 (500)	1000	3.86 (0.152)	8.5	10-32 UNF-2B

Gage/Differential -Piezoelectric

Model	Full scale pressure psi Static/Dynamic	Sensitivity pC/psi	Resonant frequency	Max temp. °C (°F)	Face diameter Nominal (in)	Weight grams (exludes cable)	Mounting method	Output connector type
522M17	2500/500	12	45 kHz	535 (1000)	0.485	25	Smooth/Case	10-32,THD
522M25	2500/400	17	45 kHz	538 (1000)	0.312	45	375-24,THD	7/16,THD

Microphones

Model	Range dB	Sensitivity mV/psi	Resonant frequency kHz	Amplitude linearity dB	Minimum temperature °C (°F)	Maximum temperature °C (°F)	Burst pressure dB	Face diameter mm (inch)	Weight gm	Mounting method
Piezoresistive										
8507C-2	100 to 190	150	70	±0.5	-54 (-65)	107 (225)	›197	2.34 (0.092)	0.3	RTV flush mount
8510B-1	95 to 190	200	55	±0.5	-54 (-65)	121 (250)	›195	3.86 (0.152)	2.3	10-32 UNF-2B
8510B-2	100 to 190	150	70	±0.5	-54 (-65)	121 (250)	›197	3.86 (0.152)	2.3	10-32 UNF-2B
Piezoelectric										
2510	100 to ›180	1069	30	1.0	-54 (-65)	260 (500)		20.70 (0.815)	57	Screw
2510M4A	100 to ›180	1069	30	1.0	-54 (-65)	260 (500)		20.70 (0.815)	57	Screw

Piezoresistive

Model	Sensitivity mV/g	Weight gram g	Linear range g	Shock limit Hz	Frequency response	Minimum temp.	Maximum temp. °C (°F)	Signal/ground isolation °C (°F)	Hermetic seal	Mounting methods
71-6K	0.03	0.06	± 6000	18 000	0-20 000	-54 (-65)	66 (150)	Yes	No	Adhesive
71-20K	0.01	0.06	± 20 000	60 000	0-50 000	-54 (-65)	66 (150)	Yes	No	Adhesive
71-60K	0.003	0.06	± 60 000	120 000	0-100 000	-54 (-65)	66 (150)	Yes	No	Adhesive
2262A-100	5	28		2000	0-1300	-18 (0)	93 (200)	Yes	Yes	Stud
2262A-200	2.5	28		2000	0-1300	-18 (0)	93 (200)	Yes	Yes	Stud
2262A-1000	0.5	28	± 1000	2500	0-1500	-18 (0)	93 (200)	Yes	Yes	Stud
2262A-2000	0.25	28	± 2000	5000	0-3000	-18 (0)	93 (200)	Yes	Yes	Stud
7231C	0.2	24	± 750	2500	0-2000	-23 (-10)	66 (150)	Yes	No	Screw
7264-200	2.5	1	± 200	2000	0-1000	-18 (0)	66 (150)	Yes	No	Screw
7264-2000	0.25	1	± 2000	5000	0-4000	-18 (0)	66 (150)	Yes	No	Screw
7264B-500	0.8	1	± 500	5000	0-3000	-40 (-40)	93 (200)	Yes	No	Screw
7264B-2000	0.2	1	± 2000	10 000	0-5000	-40 (-40)	93 (200)	Yes	No	Screw
7264C-500	0.8	1	± 500	5000	0-3000	-18 (0)	66 (150)	Yes	No	Screw
7264C-2000	0.2	1	± 2000	10 000	0-5000	-18 (0)	66 (150)	Yes	No	Screw
7264D	0.2	1	± 2000	10 000	0-6000	-18 (0)	66 (150)	Yes	No	Screw
7265A	5	4.7	± 100	2000	0-800	-18 (0)	66 (150)	Yes	Yes	Screw
7265A-HS	25	4.7	± 20	2000	0-500	-18 (0)	66 (150)	Yes	Yes	Screw
7265AM3	0.25	3	± 2000	5000	0-4000	-18 (0)	66 (150)	Yes	Yes	Screw
7267A	0.15	50	± 1500	4000	0-2000	-23 (-10)	66 (150)	Yes	Yes	Screw
7268C-500M1	0.8	8	± 500	5000	0-3000(z)	-18 (0)	66 (150)	Yes	No	Adhesive
7268C-2000M1	0.2	8	± 2000	1000	0-3000(z)	-18 (0)	66 (150)	Yes	No	Adhesive
7269-500	0.8	0.4	± 500	5000	0-3000	-18 (0)	66 (150)	Yes	No	Adhesive
7269-2000	0.2	0.4	± 2000	10 000	0-4000	-18 (0)	66 (150)	Yes	No	Adhesive
7270A **Parts are itar. specs can be obtained via Endevco										
7285	0.20	1	± 2000	10 000	0-4000	-18 (0)	66 (150)	Yes	No	Adhesive
7302BM4	5 mV/krad/sec^2	35	50 K rad/sec^2	2500	3-1600	-18 (0)	121 (250)	Yes	No	Screw

Variable capacitance

Model	Sensitivity mV/g	Weight gram	Linear range g	Shock limit g	Frequency response Hz	Minimum temp. °C (°F)	Maximum temp. °C (°F)	Signal/ground isolation	Hermetic seal	Mounting methods
7290A-2	1000	11	± 2	10 000	0-15	-55 (-67)	121 (250)	Yes	Yes	Screw
7290A-10	200	11	± 10	10 000	0-500	-55 (-67)	121 (250)	Yes	Yes	Screw
7290A-30	66	11	± 30	10 000	0-800	-55 (-67)	121 (250)	Yes	Yes	Screw
7290A-50	40	11	± 50	10 000	0-1000	-55 (-67)	121 (250)	Yes	Yes	Screw
7290A-100	20	11	± 100	10 000	0-1000	-55 (-67)	121 (250)	Yes	Yes	Screw
7290D-2-Y-ZZZ	1000 ± 50	15	± 2	5000	0-15	-55 (-67)	125 (257)	Yes	Yes	Screw
7290D-10-Y-ZZZ	200 ± 10	15	± 10	5000	0-500	-55 (-67)	125 (257)	Yes	Yes	Screw
7290D-30-Y-ZZZ	66 ± 4	15	± 30	10 000	0-800	-55 (-67)	125 (257)	Yes	Yes	Screw
7290D-50-Y-ZZZ	40 ± 2	15	± 50	10 000	0-1000	-55 (-67)	125 (257)	Yes	Yes	Screw
7290D-100-Y-ZZZ	20 ± 1	15	± 100	10 000	0-1000	-55 (-67)	125 (257)	Yes	Yes	Screw
7292A-30M1	66	40	± 30	10 000	0-800	-55 (-65)	121 (250)	Yes	Yes	Stud
7293A-50	40	14	± 50	10 000	0-1000	-55 (-65)	121 (250)	Yes	Yes	Screw
7293A-100	20	14	± 100	10 000	0-1000	-55 (-65)	121 (250)	Yes	Yes	Screw
7296A-100	20	11	± 100	10 000	0-1000	-54 (-65)	121 (250)	Yes	Yes	Screw
7596A-2	1000	11	± 2	10 000	0-15	-54 (-65)	121 (250)	Yes	Yes	Screw
7596A-10	200	11	± 10	10 000	0-500	-54 (-65)	121 (250)	Yes	Yes	Screw
7596A-30	66	11	± 30	10 000	0-800	-54 (-65)	121 (250)	Yes	Yes	Screw
7596A-50	40	11	± 50	10 000	0-1000	-54 (-65)	121 (250)	Yes	Yes	Screw

DC electronics

Model	Input	Channels	Gain	Display mV rms	RTO Noise Hz	Lower -3 dB (Hz)	Upper -3 dB (Hz)	Power	Type of control
136	PR	3 or 9/Rack	0 to 1000	DPM	5	0	200 000	AC/DC/BATTERY	Manual/RS-232
436	PR	3	0 to 1000	Computer	1 mVrms	DC	200 000	AC	RS232 or Ethernet
4428A	PR	1	10 to 100	DPM	5	0	60 000	AC	Manual
4430A	PE/PR/ISO	1 or 10/Rack	1 to 1000	DPM	1	0	100 000	AC	Manual/GPIB

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Warranty and remedy

a) Each Endevco Product is warranted to conform to its published specifications for the periods shown below from date of its first shipment to Buyer, or the minimum period required by applicable law, whichever is longer (the "Limited Warranty").

- Piezoelectric transducers 3 years
- Piezoresistive transducers 1 year
- Isotron® (integral electronic piezoelectric transducers) 1 year
- Pressure transducers 1 year
- Microtron® (variable capacitance transducers) 1 year
- Electronic instrumentation 1 year
- In-Warranty Product returned for repair or replacement – Warranty is ninety (90) days or end of original warranty period, whichever occurs later. (For Product that is returned under warranty and are tested and no fault found, Seller will be entitled to reimbursement from Buyer of the testing and evaluation charges.
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