PCB PIEZOTRONICS INC.

FORCE / TORQUE DIVISION

PRODUCT CATALOG

FTQ-200F

SENSORS FOR LOAD, TORQUE, STRAIN, AND DYNAMIC FORCE

PCB Piezotronics, Inc. – Force / Torque Division

The Force/Torque Division of PCB Piezotronics, Inc. is pleased to provide this catalog as a selection guide of our broad spectrum of standard force, load, torque, and strain measurement products. Within this publication are sensors, accessories, and signal conditioning equipment which have been specifically designed for the detection, measurement, and control of load, torque, strain and dynamic compression, tension, and impact forces.

Strain gage sensing technology is utilized for load cells and torque sensors, whereas piezoelectric quartz sensing technology forms the fundamental sensing principle for strain and dynamic force sensors. Each technique possesses distinct advantages for the particular measurement requirement. By employing a variety of sensing schemes, PCB is able to address a vast array of applications, from monitoring the slightest machinery linkage forces, to capturing the impact of a violent automotive crash, to assessing the torque profile of precision motors used for aerospace vehicles, and controlling press forces and other processes.

PCB Piezotronics, Inc. has been a supplier of precision sensors for acceleration, pressure, and force measurements since 1967. Unmatched customer service, state-of-the-art manufacturing capabilities, and worldwide distribution have contributed to our steady growth and success. Customers from industrial, governmental, educational, aerospace, automotive, medical, and R&D disciplines have relied on PCB to deliver products and solutions for many demanding requirements.

The Force/Torque Division of PCB Piezotronics, Inc. is an integrated team created to address the specific sensor needs of those involved with the measurement of force, load, torque, and strain. Together, the Design, Engineering, Sales, Customer Service, and Marketing personnel within the Force/Torque team draw upon the vast manufacturing resources within PCB to continually provide new, more powerful sensing solutions. Please do not hesitate to call upon us to assist with your measurement requirements and provide our guarantee of **Total Customer Satisfaction.**

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Total Customer Satisfaction Guaranteed

In the interest of continuing product improvement, catalog specifications are subject to change without notice.
Before machining tapped holes for installation, please request a copy of the item's detailed installation drawing.

Force/Torque Sensor Catalog
FTQ-200F-0105

PCB Quality is ISO 9001:2000 Certified
PCB is an EOE/AAP Employer
Printed in USA

PCB Piezotronics, Inc. — Force / Torque Division
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Total Customer Satisfaction

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

☎ Toll-Free Customer Service ☎ 888-684-0004

The Force / Torque Division of PCB Piezotronics offers a direct, toll-free telephone number for customer use. Feel free to call to discuss application requirements, request product literature, request price quotations, place orders, inquire about order status, expedite orders, troubleshoot equipment, or arrange for returns. International customers are invited to call **716-684-0001**. In addition, we can be reached by e-mail at **force@pcb.com**. Our fax number is: **716-684-8877**. We look forward to hearing from you.

24-hour SensorLine℠

PCB offers to all customers, at no charge, 24-hour emergency phone support. This service makes product or application support available to our customers, day or night, seven days per week. To reach a PCB SensorLine℠ customer service representative, call **716-684-0001**.

Web site - www.pcb.com

Detailed product information is featured on PCB's web site — **www.pcb.com**. The web site offers customers educational and technical information, as well as the latest product releases. Additionally, industrial sensors are featured with the ability to place an on-line order at **www.imi-sensors.com**. You may also contact us via our general e-mail address at: **info@pcb.com**.

ISO 9001:2000 Certification

PCB Piezotronics, Inc. is registered by Underwriters Laboratories, Inc. as an ISO 9001:2000 facility and maintains a quality assurance system dedicated to resolving any concern to ensure **Total Customer Satisfaction**. PCB also conforms to the former MIL-STD-45662A and MIL-Q-9858.

ISO 9001 and ISO 10012-1 Compliant Calibration Facility

All Force / Torque Division sensors are calibrated with full traceability to NIST (National Institute of Standards & Technology) and PTB to ensure conformance to published specifications. Certificates of calibration are furnished that include actual measured data. Calibration systems utilized are kept in full compliance with ISO 9001 and ISO 10012-1 standards. Calibration methods are accredited by A2LA to ISO 17025 standards.

Delivery Policy

PCB is committed to making every effort possible to accommodate all delivery requests. Our extensive in-house production capabilities permit us to manufacture most products to order in a timely fashion. In the event that a specific model is unavailable in the time frame that you need, we can usually offer a comparable unit, for sale or loan, to satisfy your urgent requirements. Many products are available, from stock, for immediate shipment. Standard cable assemblies and accessory hardware items are always stocked for immediate shipment and PCB never requires a minimum order amount. If you have urgent requirements, call a factory representative and every effort will be made to fulfill your needs.

Custom Products

PCB prides itself on being able to respond to customers' needs. Heavy investment in machinery, capabilities, and personnel allow us to design, test, and manufacture products for specialized applications. Please contact a PCB application specialist to discuss your special needs.

CE Marking CE

Many PCB products are designed, tested, and qualified to bear CE marking in accordance with European Union EMC Directive. Products that have earned this qualification are so indicated by the CE logo.

Warranty

Instrumentation provided by PCB is covered by a limited warranty against defective material and workmanship for a period of one year. Contact PCB for a complete statement of our warranty.

Accuracy of Information

PCB has made a reasonable effort to ensure that the specifications contained in this catalog were correct at the time of printing. In the interest of continuous product improvement, PCB reserves the right to change product specifications without notice at any time. Dimensions and specifications in this catalog may be approximate and for reference purposes only. Before installing sensors, machining any surfaces, or tapping any holes, contact a PCB application specialist to obtain a current installation drawing and the latest product specifications.

Numerical Model Number Index

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Force / Torque Division Catalog Contents

Precision Manufacturing

Load cell structures are machined using the latest precision CNC turning and milling equipment.

A "gaged" load cell structure is ready for final wiring of the sealed electrical connector.

Under a controlled environment, a skilled technician meticulously bonds strain gages to a load cell structure and connects lead wires to form the Wheatstone bridge sensing element.

DYNAMIC FORCE AND STRAIN SENSORS

Quartz, piezoelectric force sensors are durable measurement devices which possess exceptional characteristics for the measurement of dynamic force events. Typical measurements include dynamic and quasi-static forces as encountered during actuation, compression, impact, impulse, reaction, and tension. Applications for quartz force sensors include balancing, crash testing, crimping, crushing, cutting, drop testing, fatigue testing, forming, fracture testing, machinery testing, materials testing, penetration testing, press monitoring, punching, stamping, tensile testing, and vibration testing.

Since the measurement signal generated by a quartz force sensor will decay over time, long-term, static force measurements are not practical. Short-term, or "quasi-static", measurements are possible within certain time limits depending upon the sensor and signal conditioning used. Due to this limitation, it is not practical to use quartz force sensors in weighing applications where a strain gage type load cell is best suited. For dynamic force applications however, quartz force sensors offer many advantages and several unique characteristics. See page 1.2 for details of these advantages and characteristics. For information on ICP® strain sensors, see page 1.55.

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PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

UNIQUE CHARACTERISTICS AND ADVANTAGES OF QUARTZ FORCE SENSORS

Unique characteristics of quartz force sensors

- **Stiffness —** With a modulus of elasticity between 11 and 15 x 10^6 psi, quartz is nearly as stiff as solid steel. All quartz force sensors are assembled with stacked quartz plates and stainless steel housings. This stiff structure offers an extremely fast rise time enabling response to, and accurate capture of, rapid force transient events.

- **Durability —** Tough, solid-state construction with no moving or flexing components ensures a linear response, with durability and longevity for even the most demanding, repetitive cycling applications.

- **Stability —** The measurement characteristics of quartz are unaffected by temperature, time and mechanical stress, allowing for exceptionally repeatable and uniform measurement results.

- **Small changes under large load —** Quartz force sensors can measure small force fluctuations that are superimposed upon a large, static pre-load. The static load is ultimately discharged by the measurement system.

- **Overload survivability —** Quartz force sensors can typically be used for conducting measurements that may exceed twice their normal range, and can even survive as much as 15 times their rated capacity.

(*For information on* ICP® *strain sensors, see page* 1.55)

Advantages of quartz force sensors

- **Small size —** A typical 1/2 inch diameter quartz force sensor has a linear range through 10k lb (45k N).

- **Quasi-static calibration —** Since accurate, static measurements are possible for a short duration (quasi-static response), many quartz force sensors can be calibrated using known weights as reference standards. This also permits uncomplicated field calibration.

- **Temperature insensitivity —** Quartz has no pyroelectric output, i.e. output due to temperature change. A quartz force sensor, however, can exhibit a temperature response, under quasi-static conditions, due to forces transferred to the crystals by the thermal expansion and contraction of the steel housing. For this reason, the sensor should be insulated from temperature transients when used for quasi-static measurements.

- **High frequency response —** Stiffness and small size provide high frequency response, permitting accurate capture of short-duration, impulse force data associated with an event such as a metal-to-metal impact.

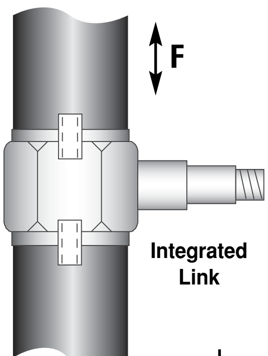
INTRODUCTION TO PIEZOELECTRIC FORCE SENSORS

All quartz force sensors function to measure dynamic force in one or more of the following modes: compression, tension, and impact. Each utilizes quartz-sensing crystals to convert the applied force into a proportional, electrical measurement signal. Some sensors contain built-in, microelectronic circuitry to condition this signal for transmission to readout or recording instruments. These are designated as ICP® sensors. Other sensors output this signal directly, however, a separate charge converter or amplifier then must condition this signal. These are designated as charge output sensors. Ordinarily, ICP® sensors are preferred, as they are more cost effective and easier to implement. Charge output sensors are used mostly when temperatures exceed the limits for ICP® sensors, typically above +250 °F (+121 °C), or under quasi-static measurement circumstances.

There are several basic styles of piezoelectric force sensors, each offering a variety of full-scale measurement ranges and sensitivities. Each style offers both charge output and ICP® sensor versions. More than one style may accommodate a particular measurement requirement, however, selection of the best-suited sensor may be dictated by the application's specification requirements, environmental conditions, and install-ation constraints. The following summarizes the various styles of sensors along with their most common installation techniques.

While several installation techniques may be possible for a particular sensor, it should be noted that the factory calibrated sensitivity is achieved when installed with the recommended pre-load force using the supplied, elastic, beryllium copper mounting hardware. If other hardware, or pre-load forces are used with the sensor, the sensitivity, and possibly the linearity, will be different. For example, using a steel stud could cause a measurement to be low by 30 to 40%. For best results, a sensitivity calibration of the sensor should be performed under installed circumstances. When in doubt, please contact the factory for assistance.

(*For information on* ICP® *strain sensors, see page* 1.55)

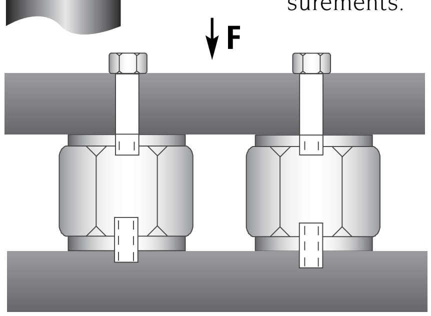


Integrated Link

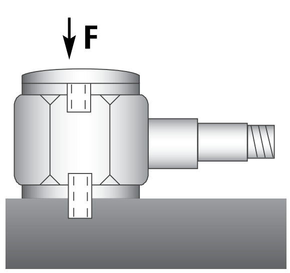
General purpose quartz force sensors

General purpose force sensors are offered in either stud or axial mounted configurations. They are internally pre-loaded and can be used for dynamic compression, tension, and impact force measurements. Tapped mounting holes on both ends of the radial connector style support link, platform, integrated link, and free-standing installations. The axial mounted type offers protection of the electrical connector and sensor cable from potential damage during drop testing and in free-standing installations. Supplied impact caps facilitate impact and drop force measurements.

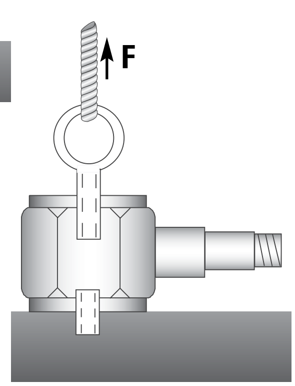
Versions offering full-scale measurement ranges of 10 lb to 5000 lb compression (45 to 22k N) and 500 lb (2200 N) tension are available. For higher ranges, consider the dedicated ring, link, or impact-style sensor configurations. Applications include matrix print-head studies, drop testing, machinery studies, punching and forming operations, tensile testing, fatigue testing, fracture analysis, and materials testing.



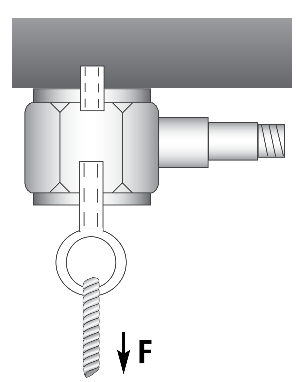
Platform Installation



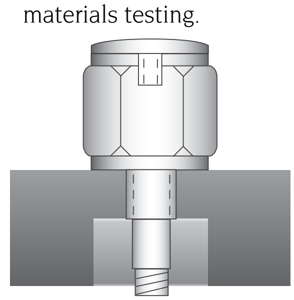
Free-standing Installation



Force Link



Force Link



Free-standing Installation (axial connector)

Force Sensor Configurations

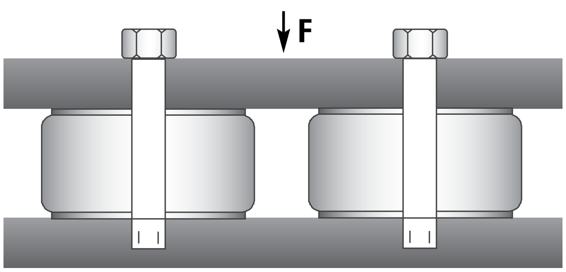
Penetration-style quartz force sensors

Penetration-style sensors are specifically designed for compression and impact force measurements in materials testing applications such as helmet testing. Smooth, cylindrical housings and curved impact caps avoid cutting through specimens permitting yield, deformation, and break point measurements of polymers, composites, and other materials. The axial connector configuration installs into force thruster apparatus and protects the connector from potential damage. Versions offering full-scale measurements of 100 lb to 5000 lb (450 to 22k N) are available. Tension measurements are possible with units having removable caps.

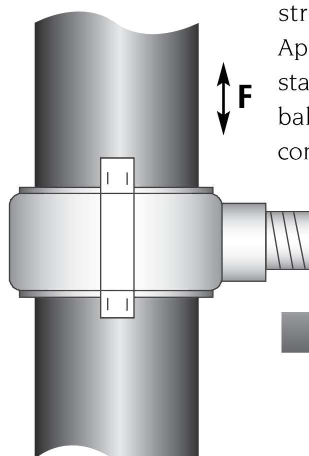
Penetration Sensor

Ring-style quartz force sensors

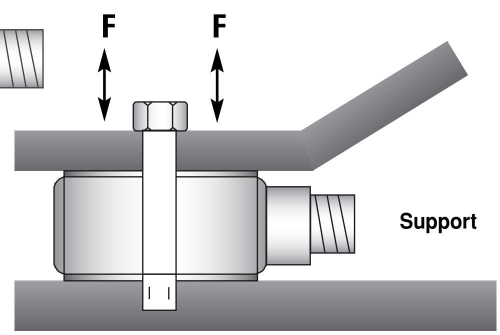
Ring-style sensor configurations measure dynamic compression. Tension measurements are also possible if the unit has been installed with proper pre-load. The through-hole mounting supports platform, integrated link, and support style installations using either a through-bolt or the supplied stud. Versions offering full-scale measurements of 10 lb to 100k lb (45 to 450k N) compression are available. Tension range is dependent upon the amount of applied pre-load and strength of mounting stud used. Applications include tablet presses, stamping, punching and forming operations, balancing, machinery studies, and force-controlled vibration testing.



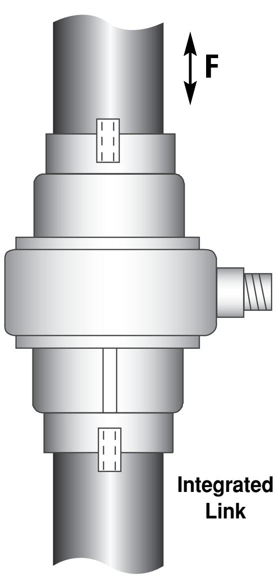
Platform



Integrated Link



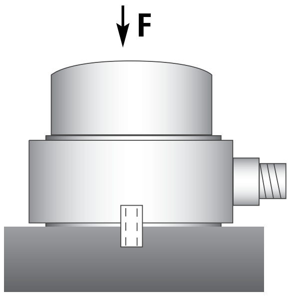
Support



Integrated Link

Link-style quartz force sensors

Link-style sensors measure dynamic compression and tension. They are constructed using a force ring that is under compressive pre-load between threaded mounting hardware. The threaded mounting on both ends of the sensor supports integrated link-style installations. Versions offering full-scale measurements of 10 lb to 50k lb (45 to 220k N) compression and 30k lb (130k N) tension are available. Applications include tablet presses, tensile testing, stamping, punching and forming operations, balancing, machinery studies, and force-controlled vibration testing.



Free-standing
Impact Installation

Impact-style quartz force sensors

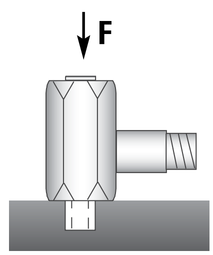
Impact-style sensors are specifically designed for impact force measurements. The sensor is typically mounted in a free-standing manner with the installed impact cap directed toward the oncoming object with which it will collide.

Versions offering full-scale measurements of 10 lb to 50k lb (45 to 220k N) are available. Applications include crash testing, wire crimping and metal forming, machinery studies, impact testing, drop testing, and shock machines.

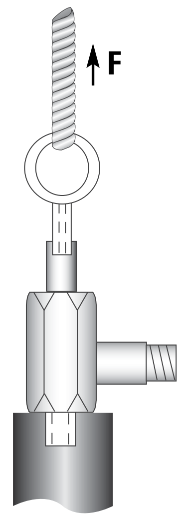
High-sensitivity, miniature quartz force sensors

The miniature sensor configuration permits low-amplitude, dynamic compression, tension, and impact force measurements. Two configurations, one with a tapped mounting hole and impact cap and the other with tapped holes on both ends of the sensor, are available. Link, integrated link, and free-standing installations are possible.

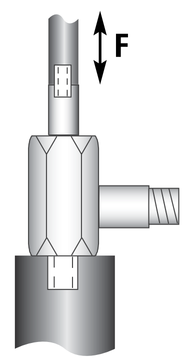
A full-scale measurement range of 2.2 lb (10 N) compression and 1 lb (4.5 N) tension is standard. Additional ranges are available. Applications include matrix print-head studies, wire bonding, and high-frequency, low-level impulse testing.



Free-standing
Impact Installation



Link

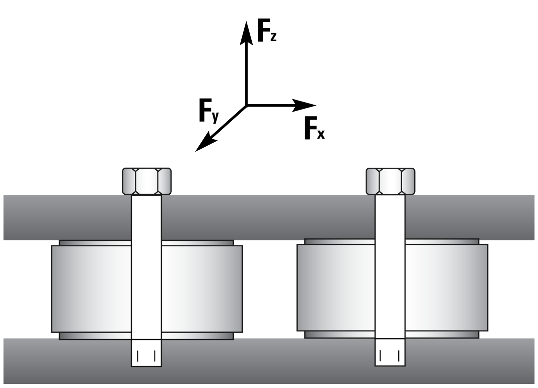


Integrated
Link

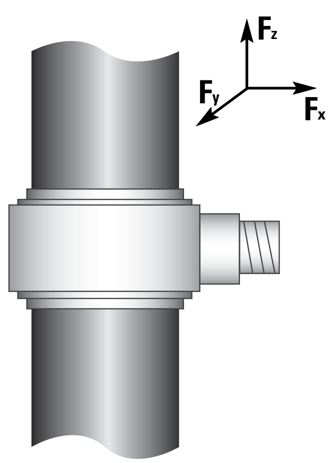
3-Component quartz force sensors

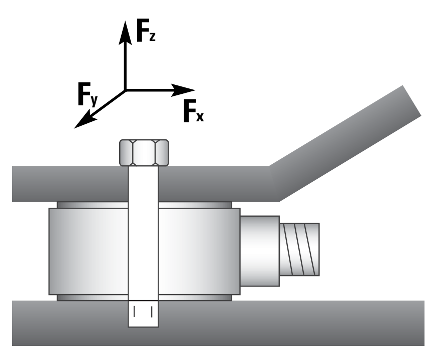
3-Component sensors permit simultaneous measurement of dynamic force vector components in three orthogonal directions. The through-hole mounting supports platform, integrated member, and support-style installations using either a through-bolt or the supplied stud.

Versions offering full-scale measurements of 1000 lb (4500 N) to 10k lb (45k N) compression are available. Applications include machine tool cutting forces, stamping, punching and forming operations, machinery studies, biomechanics, and force-controlled vibration testing.



Platform





Support

Typical Force Sensor Measurement Systems

QUARTZ FORCE SENSING SYSTEMS

As mentioned previously, quartz force sensors are available with or without built-in microelectronic signal conditioning circuitry. Those containing built-in circuitry are designated as ICP® sensors and those without circuitry are designated as charge output sensors. Ordinarily, ICP® sensors are preferred, as they are more cost effective and easier to implement. Charge output sensors are used when temperatures exceed ICP® sensor limits, typically above +250 °F (+121 °C), or under quasi-static measurement circumstances.

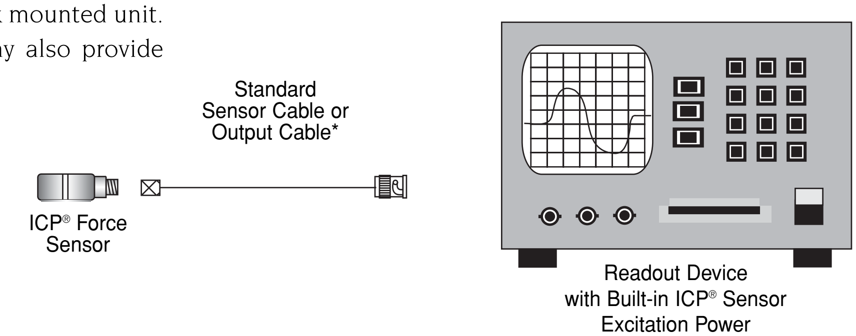
The need for signal conditioning

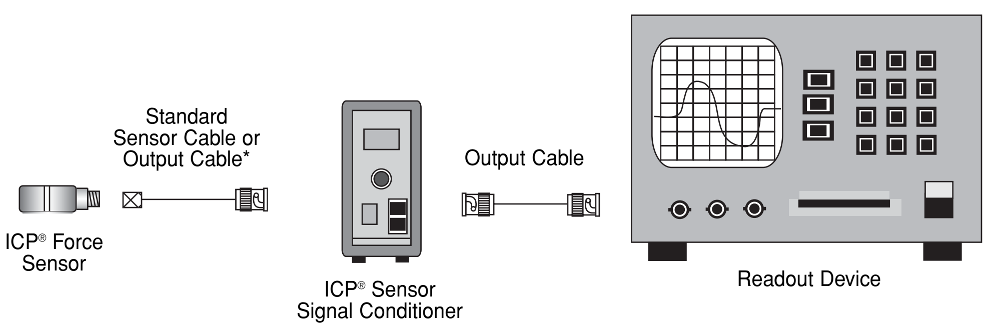
All quartz force measurement systems require some conditioning of the measurement signal that is generated by the force sensing crystals. This signal conditioning primarily serves to convert the high-impedance, electrostatic charge signal, which is generated by the quartz crystal, into a low-impedance voltage that can then be interpreted by readout and recording instruments. This primary conditioning also serves to minimize corruption of the measurement signal by extraneous noise influences. Secondary signal conditioning functions may include amplification, sensitivity normalization, filtering, clamping, summing, or other functions, as required by the specific application.

ICP® sensor signal conditioning

The primary, impedance conversion for an ICP® sensor is carried out by the built-in microelectronic circuitry. This circuitry requires excitation power to energize and function. Excitation power is typically provided by an ICP® sensor signal conditioner, which may be a portable, battery powered device or, a laboratory bench-top or rack mounted unit. Some readout or recording instruments may also provide the proper excitation power to accommodate direct connection to ICP® sensors.

Special purpose ICP® sensor signal conditioners accommodate secondary signal conditioning functions for specific application requirements. An AC/DC coupled unit facilitates quasi-static calibration in the DC coupled mode and drift-free, unattended dynamic operation in the AC coupled mode. For repetitive pulse type applications, such as crimping, pressing, punching, and stamping operations, a clamped-output unit keeps signals ground based and of positive polarity. This assures consistent force peak and profile monitoring for production quality control purposes. Additional models are available which support summing, filtering, switching, and other features as may be required by the specific application.





* Low-noise cables are required to maintain CE conformance.

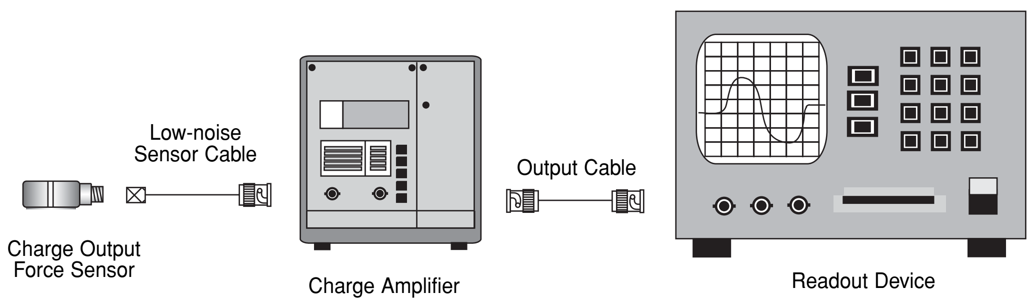
Typical Force Sensor Measurement Systems

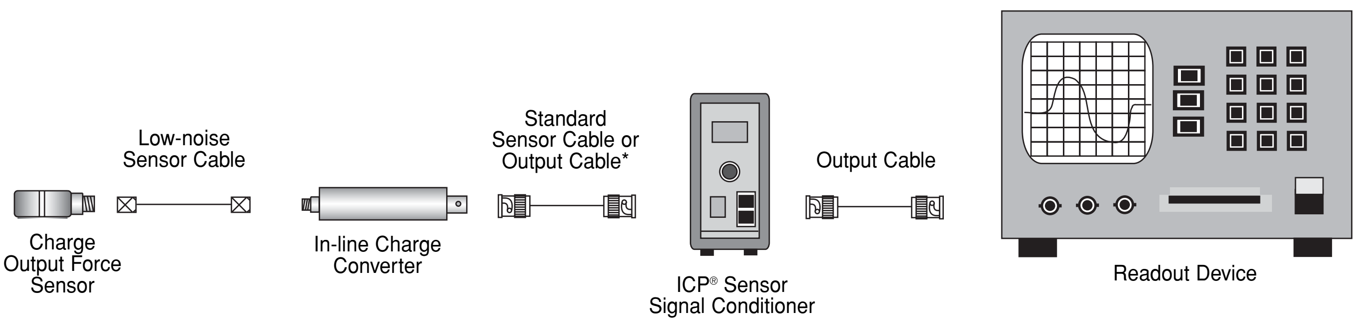
Charge output sensor signal conditioning

There are two techniques for accomplishing impedance conversion in a charge output sensor measurement system. The first utilizes an in-line charge converter with an ICP® sensor signal conditioner. The in-line charge converter may be selected to provide one out of a number of available fixed sensitivity transfer values, including 1, 10 or 100 mV/pC. This technique allows the system to be re-ranged, by selecting an alternative charge converter, to accommodate more than one application, or measurement range, with the same sensor. Benefits associated with ICP® sensors can be achieved with this approach, including long distance signal transmission and lower cost-per-channel.

The other technique for conditioning a charge output sensor signal is with a laboratory-style, electrostatic charge amplifier. This type of charge amplifier offers many signal-conditioning features, including sensitivity normalization, ranging, and filtering. Quasi-static measurements and calibrations are supported with units having the ability of adjusting for long discharge time constants. In addition, one sensor can be ranged for a wide variety of full-scale measurement tasks, thereby taking full advantage of the charge output sensor's wide, linear dynamic range.

Important considerations for charge output sensors include precautions associated with the high-impedance portion of the signal path. To maintain low frequency response and avoid potential signal drift, this portion of the measurement system must be kept clean and dry to preserve a high level of insulation resistance. Also, the use of specially treated, low-noise cable is recommended. Such cable minimizes triboelectric noise, i.e. noise that is caused by frictional effects during cable movement. For these reasons, charge output sensors are not particularly well-suited for dirty, industrial, factory and outdoor environments. ICP® sensors are better suited for such circumstances.





* Low-noise cables are required to maintain CE conformance.

Custom sensors

For specialized applications, the Force/Torque Division of PCB can provide sensors that are custom tailored to suit particular measurement requirements. Available options to standard designs include special ranges, sensitivities, calibration, environmental testing, temperature limits, signal filtering, electrical connectors, materials of construction and discharge time constant values. In addition, we can work with you to completely design sensors for your specific needs.

Typical Dynamic Sensor Applications

- Actuation
- Balancing
- Biomechanics
- Cold Forming
- Coining
- Composites Testing
- Compression
- Crash Testing
- Crimping
- Crushing
- Cutting
- Drop Testing
- Ejecting
- Endurance Testing
- Fatigue Testing
- Fracture Analysis
- Grinding
- Impact
- Machinery Mounts
- Machinery Testing
- Materials Testing
- Matrix Printheads
- Modal Analysis
- Penetration Studies
- Press Monitoring
- Punching Operations
- Quasi-Static Forces
- Reaction Force
- Recoil
- Robotics
- Sports Therapy
- Stamping
- Strain
- Tensile Testing
- Tension
- Vibration Testing
- Wire Bonding

Quartz Sensor Selection Guide – English Measurement Units

General Purpose ICP® Quartz Force Sensors

Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	Coupling Threads	Pages
208A11	10/10 lb	500 mV/lb	100/100 lb	0.0001 lb	≥ 50 sec	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
208A12	100/100 lb	50 mV/lb	1000/500 lb	0.001 lb	≥ 500 sec	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
208A13	500/500 lb	10 mV/lb	5000/750 lb	0.005 lb	≥ 2000 sec	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
208A14	1000/500 lb	5 mV/lb	6k/750 lb	0.01 lb	≥ 2000 sec	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
208A15	5000/500 lb	1 mV/lb	8k/750 lb	0.05 lb	≥ 2000 sec	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
208C01	10/10 lb	500 mV/lb	100/100 lb	0.0001 lb	≥ 50 sec	0.63 in	5/8 hex	10-32	1.20, 1.21
208C02	100/100 lb	50 mV/lb	1000/500 lb	0.001 lb	≥ 500 sec	0.63 in	5/8 hex	10-32	1.20, 1.21
208C03	500/500 lb	10 mV/lb	5000/500 lb	0.005 lb	≥ 2000 sec	0.63 in	5/8 hex	10-32	1.20, 1.21
208C04	1000/500 lb	5 mV/lb	6k/500 lb	0.01 lb	≥ 2000 sec	0.63 in	5/8 hex	10-32	1.20, 1.21
208C05	5000/500 lb	1 mV/lb	8k/500 lb	0.05 lb	≥ 2000 sec	0.63 in	5/8 hex	10-32	1.20, 1.21

* Compression/Tension

General Purpose Charge Output Quartz Force Sensors

Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Capacitance	Height	OD	Coupling Threads	Pages
218A11	5000/500 lb	18 pC/lb	8k/750 lb	14 pF	1.17 in	5/8 hex	M7 x 0.75	1.20, 1.21
218C	5000/500 lb	18 pC/lb	8k/500 lb	14 pF	0.63 in	5/8 hex	10-32	1.20, 1.21

* Compression/Tension

ICP® Quartz Force Rings

Model Number	Compression Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	ID	Coupling Threads	Pages
201A75	5000 lb	1 mV/lb	5000 lb	0.10 lb	≥ 2000 sec	0.2 in	0.75 in	0.25 in	10-32	1.24, 1.26
201A76	5000 lb	1 mV/lb	5000 lb	0.10 lb	≥ 2000 sec	0.2 in	0.75 in	0.25 in	10-32	1.24, 1.26
201B01	10 lb	500 mV/lb	60 lb	0.0002 lb	≥ 50 sec	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.26
201B02	100 lb	50 mV/lb	600 lb	0.002 lb	≥ 500 sec	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.26
201B03	500 lb	10 mV/lb	3000 lb	0.01 lb	≥ 2000 sec	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.26
201B04	1000 lb	5 mV/lb	6000 lb	0.02 lb	≥ 2000 sec	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.26
201B05	5000 lb	1 mV/lb	8000 lb	0.1 lb	≥ 2000 sec	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.26
202B	10k lb	0.5 mV/lb	15k lb	0.2 lb	≥ 2000 sec	0.39 in	0.87 in	0.41 in	5/16-24	1.24, 1.27
203B	20k lb	0.25 mV/lb	25k lb	0.4 lb	≥ 2000 sec	0.43 in	1.10 in	0.52 in	3/8-24	1.25, 1.27
204C	40k lb	0.12 mV/lb	50k lb	0.8 lb	≥ 2000 sec	0.47 in	1.34 in	0.66 in	1/2-20	1.25, 1.27
205C	60k lb	0.08 mV/lb	70k lb	1.0 lb	≥ 2000 sec	0.51 in	1.58 in	0.83 in	5/8-18	1.25, 1.27
206C	80k lb	0.06 mV/lb	90k lb	1.8 lb	≥ 2000 sec	0.59 in	2.05 in	1.03 in	7/8-14	1.25, 1.27
207C	100k lb	0.05 mV/lb	110k lb	2.0 lb	≥ 2000 sec	0.67 in	2.95 in	1.61 in	1 1/8-12	1.25, 1.27

* Compression

Charge Output Quartz Force Rings									
Model Number	**Compression Range**	**Sensitivity**	**Maximum Force***	**Capacitance**	**Height**	**OD**	**ID**	**Coupling Threads**	**Pages**
211B	5000 lb	18 pC/lb	8000 lb	12 pF	0.31 in	0.65 in	0.25 in	10-32	1.24, 1.28
212B	10k lb	18 pC/lb	15k lb	20 pF	0.39 in	0.87 in	0.41 in	5/16-24	1.24, 1.28
213B	20k lb	18 pC/lb	25k lb	28 pF	0.43 in	1.10 in	0.52 in	3/8-24	1.25, 1.28
214B	40k lb	18 pC/lb	50k lb	32 pF	0.47 in	1.34 in	0.66 in	1/2-20	1.25, 1.28
215B	60k lb	18 pC/lb	70k lb	38 pF	0.51 in	1.58 in	0.83 in	5/8-18	1.25, 1.28
216B	80k lb	18 pC/lb	90k lb	80 pF	0.59 in	2.05 in	1.03 in	7/8-14	1.25, 1.28
217B	100k lb	17 pC/lb	110k lb	130 pF	0.67 in	2.95 in	1.61 in	1 1/8-12	1.25, 1.28

* Compression

ICP® Quartz Force Links									
Model Number	**Comp./Tension Range**	**Sensitivity**	**Maximum Force***	**Resolution**	**Time Constant**	**Height**	**OD**	**Coupling Threads**	**Pages**
221B01	10/10 lb	500 mV/lb	100/100 lb	0.0002 lb	≥ 50 sec	1.25 in	0.65 in	1/4-28	1.30, 1.32
221B02	100/100 lb	50 mV/lb	1000/500 lb	0.002 lb	≥ 500 sec	1.25 in	0.65 in	1/4-28	1.30, 1.32
221B03	500/500 lb	10 mV/lb	5000/1000 lb	0.01 lb	≥ 2000 sec	1.25 in	0.65 in	1/4-28	1.30, 1.32
221B04	1000/1000 lb	5 mV/lb	6000/1200 lb	0.02 lb	≥ 2000 sec	1.25 in	0.65 in	1/4-28	1.30, 1.32
221B05	5000/1000 lb	1 mV/lb	6000/1200 lb	0.10 lb	≥ 2000 sec	1.25 in	0.65 in	1/4-28	1.30, 1.32
222B	6000/2500 lb	0.90 mV/lb	7000/2800 lb	0.20 lb	≥ 2000 sec	1.62 in	0.87 in	3/8-24	1.30, 1.33
223B	12k/4000 lb	0.42 mV/lb	15k/4500 lb	0.40 lb	≥ 2000 sec	2.00 in	1.10 in	1/2-20	1.30, 1.33
224C	25k/8000 lb	0.20 mV/lb	31k/10k lb	0.60 lb	≥ 2000 sec	2.50 in	1.34 in	5/8-18	1.30, 1.33
225C	35k/12k lb	0.14 mV/lb	45k/15k lb	0.10 lb	≥ 2000 sec	3.00 in	1.58 in	3/4-16	1.31, 1.33
226C	45k/20k lb	0.11 mV/lb	55k/25k lb	0.44 lb	≥ 2000 sec	3.50 in	2.05 in	1-12	1.31, 1.33
227C	50k/30k lb	0.10 mV/lb	66k/37.5k lb	1 lb	≥ 2000 sec	4.25 in	2.95 in	1 1/4-12	1.31, 1.33

* Compression/Tension

Charge Output Quartz Force Links								
Model Number	**Comp./Tension Range**	**Sensitivity**	**Maximum Force***	**Capacitance**	**Height**	**OD**	**Coupling Threads**	**Pages**
231B	5000/1000 lb	18 pC/lb	6000/1200 lb	12 pF	1.25 in	0.65 in	1/4-28	1.30, 1.34
232B	6000/2500 lb	18 pC/lb	7000/2800 lb	20 pF	1.62 in	0.87 in	3/8-24	1.30, 1.34
233B	12k/4000 lb	18 pC/lb	15k/4500 lb	28 pF	2.00 in	1.10 in	1/2-20	1.30, 1.34
234B	25k/8000 lb	18 pC/lb	31k/10k lb	32 pF	2.50 in	1.34 in	5/8-18	1.30, 1.34
235B	35k/12k lb	18 pC/lb	45k/15k lb	38 pF	3.00 in	1.58 in	3/4-16	1.31, 1.34
236B	45k/20k lb	18 pC/lb	55k/25k lb	80 pF	3.50 in	2.05 in	1-12	1.31, 1.34
237B	50k/30k lb	17 pC/lb	66k/37.5k lb	130 pF	4.25 in	2.95 in	1 1/4-12	1.31, 1.34

* Compression/Tension

Continued on next page

Quartz Sensor Selection Guide
English Measurement Units

3-Component ICP® Quartz Force Sensors										
Model Number	**Axis**	**Compression Range**	**Sensitivity**	**Maximum Force**	**Resolution**	**Time Constant**	**Height**	**L x W**	**Coupling Threads**	**Pages**
260A01	z-axis	1000 lb	2.5 mV/lb	1320 lb*	0.006 lb	≥ 50	0.39 in	1.08 x 0.95 in	5/16-24	1.36, 1.38
	x-, y-axis	500 lb	10 mV/lb	660 lb**	0.002 lb	≥ 500				1.36, 1.38
260A02	z-axis	1000 lb	2.5 mV/lb	1320 lb*	0.006 lb	≥ 50	0.39 in	1.35 x 1.25 in	1/2-20	1.36, 1.38
	x-, y-axis	1000 lb	5 mV/lb	1000 lb**	0.006 lb	≥ 500				1.36, 1.38
260A03	z-axis	10k lb	0.25 mV/lb	11k lb*	0.05 lb	≥ 50	0.79 in	2.25 x 2.25 in	7/8-14	1.36, 1.38
	x-, y-axis	4000 lb	1.25 mV/lb	4400 lb**	0.01 lb	≥ 500				1.36, 1.38

* Compression/Tension ** Shear

3-Component Charge Output Quartz Force Sensors									
Model Number	**Axis**	**Compression Range**	**Sensitivity**	**Maximum Force**	**Capacitance**	**Height**	**L x W**	**Coupling Threads**	**Pages**
260A11/A31*	z-axis	1000 lb	15 pC/lb	1320 lb**	18 pF	0.39 in	0.95 x 0.95 in	5/16-24	1.37, 1.38
	x-, y-axis	500 lb	32 pC/lb	660 lb***	18 pF				1.37, 1.38
260A12/A32*	z-axis	1000 lb	15 pC/lb	1320 lb**	30 pF	0.39 in	1.25 x 1.25 in	1/2-20	1.37, 1.38
	x-, y-axis	1000 lb	32 pC/lb	1000 lb***	30 pF				1.37, 1.38
260A13/A33*	z-axis	10k lb	15 pC/lb	11k lb**	70 pF	0.79 in	2.25 x 2.25 in	7/8-14	1.37, 1.38
	x-, y-axis	4000 lb	32 pC/lb	4400 lb***	70 pF				1.37, 1.38

*Models 260A31, 260A32, and 260A33 have reverse shear polarity for x-, y-axis ** Compression/Tension *** Shear

ICP® Quartz Impact Force Sensors									
Model Number	**Compression Range**	**Sensitivity**	**Maximum Force***	**Resolution**	**Time Constant**	**Height**	**OD**	**Mounting Threads**	**Pages**
200B01	10 lb	500 mV/lb	150 lb	0.0002 lb	≥ 50 sec	0.36 in	0.65 in	10-32	1.44, 1.45
200B02	100 lb	50 mV/lb	600 lb	0.002 lb	≥ 500 sec	0.36 in	0.65 in	10-32	1.44, 1.45
200B03	500 lb	10 mV/lb	3000 lb	0.01 lb	≥ 2000 sec	0.36 in	0.65 in	10-32	1.44, 1.45
200B04	1000 lb	5 mV/lb	5000 lb	0.02 lb	≥ 2000 sec	0.36 in	0.65 in	10-32	1.44, 1.45
200B05	5000 lb	1 mV/lb	8000 lb	0.1 lb	≥ 2000 sec	0.36 in	0.65 in	10-32	1.44, 1.45
200C20	20k lb	0.25 mV/lb	30k lb	0.3 lb	≥ 2000 sec	0.50 in	1.49 in	1/4-28	1.44, 1.45
200C50	50k lb	0.10 mV/lb	75k lb	1 lb	≥ 2000 sec	0.75 in	2.12 in	1/4-28	1.44, 1.45

* Compression

Charge Output Impact Force Sensors								
Model Number	**Compression Range**	**Sensitivity**	**Maximum Force***	**Capacitance**	**Height**	**OD**	**Mounting Threads**	**Pages**
210B	5000 lb	18 pC/lb	10k lb	12 pF	0.36 in	0.65 in	10-32	1.44, 1.46
210B20	20k lb	18 pC/lb	30k lb	150 pF	0.50 in	1.49 in	1/4-28	1.44, 1.46
210B50	50k lb	18 pC/lb	75k lb	250 pF	0.75 in	2.12 in	1/4-28	1.44, 1.46

* Compression

Miniature ICP® Quartz Force Sensors

Model Number	Range	Sensitivity	Maximum Force	Resolution	Time Constant	Height	OD	Mounting Threads	Pages
209C01	2.2 lb*	2200 mV/lb	11 lb*	0.00002 lb	≥ 1 sec	0.61 in	3/8 hex	10-32	1.48, 1.49
209C02	2.2 lb*	2200 mV/lb	11 lb*	0.00002 lb	≥ 10 sec	0.61 in	3/8 hex	10-32	1.48, 1.49
209C11	2.2/1 lb**	2200 mV/lb	11/1 lb**	0.00002 lb	≥ 1 sec	0.83 in	3/8 hex	2-56, 10-32	1.48, 1.49
209C12	2.2/1 lb**	2200 mV/lb	11/1 lb**	0.00002 lb	≥ 10 sec	0.83 in	3/8 hex	2-56, 10-32	1.48, 1.49

* Compression ** Compression/Tension

Penetration-style ICP® Quartz Force Sensors

Model Number	Range	Sensitivity	Maximum Force	Resolution	Time Constant	Height	OD	Mounting Threads	Pages
208A22	100 lb*	50 mV/lb	1000 lb*	0.002 lb	≥ 200 sec	1.41 in	0.50 in	M7 x 0.75	1.52, 1.53
208A23	1000 lb*	5 mV/lb	5000 lb*	0.02 lb	≥ 2000 sec	1.41 in	0.50 in	M7 x 0.75	1.52, 1.53
208A24	2500 lb*	1 mV/lb	5000 lb*	0.10 lb	≥ 2000 sec	1.41 in	0.50 in	M7 x 0.75	1.52, 1.53
208A33	1000/500 lb**	5 mV/lb	5000/750 lb**	0.02 lb	≥ 2000 sec	1.66 in	0.50 in	M7 x 0.75	1.52, 1.53
208A35	5000/500 lb**	1 mV/lb	10k/750 lb**	0.10 lb	≥ 2000 sec	1.97 in	0.50 in	M7 x 0.75	1.52, 1.53
208A45	5000/500 lb**	1 mV/lb	10k/750 lb**	0.10 lb	≥ 2000 sec	1.81 in	1.00 in	M7 x 0.75	1.52, 1.53

* Compression ** Compression/Tension

ICP® Strain Sensor Selection Guide – English Measurement Units

Model Number	Range	Sensitivity	Resolution	Time Constant	Connector	Size (W x L x H)	Weight	Mounting Thread	Pages
M240A01	50 pk με	100 mV/με	0.0001 με	≥ 150 sec	10-32	0.67 x 1.81 x 0.6 in	1.6 oz	M6 x 1.00-6g	1.56, 1.57
M240A02	100 pk με	50 mV/με	0.0002 με	≥ 150 sec	10-32	0.67 x 1.81 x 0.6 in	1.6 oz	M6 x 1.00-6g	1.56, 1.57
M240A03	300 pk με	10 mV/με	0.001 με	≥ 150 sec	10-32	0.67 x 1.81 x 0.6 in	1.6 oz	M6 x 1.00-6g	1.56, 1.57

Continued on next page

Quartz Sensor Selection Guide
Metric Measurement Units

General Purpose ICP® Quartz Force Sensors									
Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	Coupling Threads	Pages
208A11	45/45 N	110 mV/N	450/450 N	0.00045 N	≥ 50 sec	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
208A12	450/450 N	11 mV/N	4500/2200 N	0.0045 N	≥ 500 sec	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
208A13	2200/2200 N	2.2 mV/N	22k/3300 N	0.022 N	≥ 2000 sec	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
208A14	4500/2200 N	1.1 mV/N	36k/3300 N	0.045 N	≥ 2000 sec	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
208A15	22k/2200 N	0.22 mV/N	36k/3300 N	0.22 N	≥ 2000 sec	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
208C01	45/45 N	110 mV/N	450/450 N	0.00045 N	≥ 50 sec	15.9 mm	5/8 hex	10-32	1.20, 1.21
208C02	450/450 N	11 mV/N	4500/2200 N	0.0045 N	≥ 500 sec	15.9 mm	5/8 hex	10-32	1.20, 1.21
208C03	2200/2200 N	2.2 mV/N	22k/2200 N	0.022 N	≥ 2000 sec	15.9 mm	5/8 hex	10-32	1.20, 1.21
208C04	4500/2200 N	1.1 mV/N	27k/2200 N	0.045 N	≥ 2000 sec	15.9 mm	5/8 hex	10-32	1.20, 1.21
208C05	22k/2200 N	0.22 mV/N	36k/2200 N	0.22 N	≥ 2000 sec	15.9 mm	5/8 hex	10-32	1.20, 1.21

* Compression/Tension

General Purpose Charge Output Quartz Force Sensors								
Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Capacitance	Height	OD	Coupling Threads	Pages
218A11	22k/2200 N	4 pC/N	36k/3300 N	14 pF	29.7 mm	5/8 hex	M7 x 0.75	1.20, 1.21
218C	22k/2200 N	4 pC/N	36k/2200 N	14 pF	15.9 mm	5/8 hex	10-32	1.20, 1.21

* Compression/Tension

ICP® Quartz Force Rings										
Model Number	Compression Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	ID	Coupling Threads	Pages
201A75	22k N	0.22 mV/N	22k N	0.45 N	≥ 2000 sec	5.1 mm	19.1 mm	6.4 mm	10-32	1.24, 1.26
201A76	22k N	0.22 mV/N	22k N	0.45 N	≥ 2000 sec	5.1 mm	19.1 mm	6.4 mm	10-32	1.24, 1.26
201B01	45 N	110 mV/N	250 N	0.0009 N	≥ 50 sec	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.26
201B02	450 N	11 mV/N	2700 N	0.009 N	≥ 500 sec	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.26
201B03	2200 N	2.2 mV/N	13k N	0.045 N	≥ 2000 sec	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.26
201B04	4500 N	1.1 mV/N	27k N	0.09 N	≥ 2000 sec	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.26
201B05	22k N	0.22 mV/N	35k N	0.45 N	≥ 2000 sec	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.26
202B	45k N	0.11 mV/N	70k N	0.9 N	≥ 2000 sec	9.9 mm	22.1 mm	10.4 mm	5/16-24	1.24, 1.27
203B	90k N	0.06 mV/N	110k N	1.8 N	≥ 2000 sec	10.9 mm	27.9 mm	13.2 mm	3/8-24	1.25, 1.27
204C	180k N	0.027 mV/N	220k N	3.6 N	≥ 2000 sec	11.9 mm	34.0 mm	16.8 mm	1/2-20	1.25, 1.27
205C	260k N	0.018 mV/N	300k N	4.5 N	≥ 2000 sec	13.0 mm	40.1 mm	21.1 mm	5/8-18	1.25, 1.27
206C	350k N	0.013 mV/N	400k N	8 N	≥ 2000 sec	15.0 mm	52.1 mm	26.0 mm	7/8-14	1.25, 1.27
207C	450k N	0.011 mV/N	500k N	8.9 N	≥ 2000 sec	17.0 mm	74.9 mm	40.9 mm	1 1/8-12	1.25, 1.27

* Compression

Charge Output Quartz Force Rings

Model Number	Compression Range	Sensitivity	Maximum Force*	Capacitance	Height	OD	ID	Coupling Threads	Pages
211B	22k N	4 pC/N	35k N	12 pF	7.9 mm	16.5 mm	6.4 mm	10-32	1.24, 1.28
212B	45k N	4 pC/N	70k N	20 pF	9.9 mm	22.1 mm	10.4 mm	5/16-24	1.24, 1.28
213B	90k N	4 pC/N	110k N	28 pF	10.9 mm	27.9 mm	13.2 mm	3/8-24	1.25, 1.28
214B	180k N	4 pC/N	220k N	32 pF	11.9 mm	34.0 mm	16.8 mm	1/2-20	1.25, 1.28
215B	260k N	4 pC/N	300k N	38 pF	13.0 mm	40.1 mm	21.1 mm	5/8-18	1.25, 1.28
216B	350k N	4 pC/N	400k N	80 pF	15.0 mm	52.1 mm	26.0 mm	7/8-14	1.25, 1.28
217B	450k N	3.8 pC/N	500k N	130 pF	17.0 mm	74.9 mm	40.9 mm	1 1/8-12	1.25, 1.28

* Compression

ICP® Quartz Force Links

Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	Coupling Threads	Pages
221B01	45/45 N	110 mV/N	450/450 N	0.0009 N	≥ 50 sec	31.8 mm	16.5 mm	1/4-28	1.30, 1.32
221B02	450/450 N	11 mV/N	4500/2200 N	0.009 N	≥ 500 sec	31.8 mm	16.5 mm	1/4-28	1.30, 1.32
221B03	2200/2200 N	2.2 mV/N	22k/4500 N	0.045 N	≥ 2000 sec	31.8 mm	16.5 mm	1/4-28	1.30, 1.32
221B04	4500/4500 N	1.1 mV/N	27k/5300 N	0.09 N	≥ 2000 sec	31.8 mm	16.5 mm	1/4-28	1.30, 1.32
221B05	22k/4500 N	0.22 mV/N	27k/5300 N	0.45 N	≥ 2000 sec	31.8 mm	16.5 mm	1/4-28	1.30, 1.32
222B	27k/11k N	0.20 mV/N	30k/12k N	0.90 N	≥ 2000 sec	41.2 mm	22.1 mm	3/8-24	1.30, 1.33
223B	55k/18k N	0.09 mV/N	70k/20k N	1.8 N	≥ 2000 sec	50.8 mm	27.9 mm	1/2-20	1.30, 1.33
224C	110k/35k N	0.05 mV/N	140k/45k N	2.7 N	≥ 2000 sec	63.5 mm	34.0 mm	5/8-18	1.30, 1.33
225C	150k/55k N	0.031 mV/N	200k/70k N	0.45 N	≥ 2000 sec	76.2 mm	40.1 mm	3/4-16	1.31, 1.33
226C	200k/90k N	0.025 mV/N	250k/110k N	2 N	≥ 2000 sec	88.9 mm	52.1 mm	1-12	1.31, 1.33
227C	220k/130k N	0.022 mV/N	300k/170k N	4.5 N	≥ 2000 sec	108.0 mm	74.9 mm	1 1/4-12	1.31, 1.33

* Compression/Tension

Charge Output Quartz Force Links

Model Number	Comp./Tension Range	Sensitivity	Maximum Force*	Capacitance	Height	OD	Coupling Threads	Pages
231B	22k/4500 N	4 pC/N	27k/5300 N	12 pF	31.8 mm	16.5 mm	1/4-28	1.30, 1.34
232B	27k/11k N	4 pC/N	30k/12k N	20 pF	41.2 mm	22.1 mm	3/8-24	1.30, 1.34
233B	55k/18k N	4 pC/N	70k/20k N	28 pF	50.8 mm	27.9 mm	1/2-20	1.30, 1.34
234B	110k/35k N	4 pC/N	140k/45k N	32 pF	63.5 mm	34.0 mm	5/8-18	1.30, 1.34
235B	150k/55k N	4 pC/N	200k/70k N	38 pF	76.2 mm	40.1 mm	3/4-16	1.31, 1.34
236B	200k/90k N	4 pC/N	250k/110k N	80 pF	88.9 mm	52.1 mm	1-12	1.31, 1.34
237B	220k/130k N	3.8 pC/N	300k/170k N	130 pF	108.0 mm	74.9 mm	1 1/4-12	1.31, 1.34

* Compression/Tension

Continued on next page

3-Component ICP® Quartz Force Sensors

Model Number	Axis	Compression Range	Sensitivity	Maximum Force	Resolution	Time Constant	Height	L x W	Coupling Threads	Pages
260A01	z-axis	4500 N	0.56 mV/N	6000 N*	0.027 N	≥ 50	9.9 mm	27.3 x 24.1 mm	5/16-24	1.36, 1.38
	x-, y-axis	2200 N	2.2 mV/N	3000 N**	0.009 N	≥ 500				1.36, 1.38
260A02	z-axis	4500 N	0.56 mV/N	6000 N*	0.027 N	≥ 50	9.9 mm	34.3 x 31.8 mm	1/2-20	1.36, 1.38
	x-, y-axis	4500 N	1.1 mV/N	4500 N**	0.027 N	≥ 500				1.36, 1.38
260A03	z-axis	45k N	0.06 mV/N	50k N*	0.22 N	≥ 50	20.1 mm	57.2 x 57.2 mm	7/8-14	1.36, 1.38
	x-, y-axis	18k N	0.28 mV/N	19k N**	0.045 N	≥ 500				1.36, 1.38

* Compression/Tension ** Shear

3-Component Charge Output Quartz Force Sensors

Model Number	Axis	Compression Range	Sensitivity	Maximum Force	Capacitance	Height	L x W	Coupling Threads	Pages
260A11/A31*	z-axis	4500 N	3.4 pC/N	6000 N**	18 pF	9.9 mm	24.1 x 24.1 mm	1/4-28	1.37, 1.38
	x-, y-axis	2200 N	7.2 pC/N	3000 N***	18 pF				1.37, 1.38
260A12/A32*	z-axis	4500 N	3.4 pC/N	6000 N**	30 pF	9.9 mm	31.8 x 31.8 mm	1/2-20	1.37, 1.38
	x-, y-axis	4500 N	7.2 pC/N	4500 N***	30 pF				1.37, 1.38
260A13/A33*	z-axis	45k N	3.4 pC/N	50k N**	70 pF	20.1 mm	57.2 x 57.2 mm	7/8-14	1.37, 1.38
	x-, y-axis	18k N	7.2 pC/N	19k N***	70 pF				1.37, 1.38

* Models 260A31, 260A32, and 260A33 have reverse shear polarity for x-, y-axis ** Compression/Tension *** Shear

ICP® Quartz Impact Force Sensors

Model Number	Compression Range	Sensitivity	Maximum Force*	Resolution	Time Constant	Height	OD	Mounting Threads	Pages
200B01	45 N	110 mV/N	700 N	0.0009 N	≥ 50 sec	9.1 mm	16.5 mm	10-32	1.44, 1.45
200B02	450 N	11 mV/N	2700 N	0.009 N	≥ 500 sec	9.1 mm	16.5 mm	10-32	1.44, 1.45
200B03	2200 N	2.2 mV/N	13k N	0.045 N	≥ 2000 sec	9.1 mm	16.5 mm	10-32	1.44, 1.45
200B04	4500 N	1.1 mV/N	22k N	0.09 N	≥ 2000 sec	9.1 mm	16.5 mm	10-32	1.44, 1.45
200B05	22k N	0.22 mV/N	35k N	0.45 N	≥ 2000 sec	9.1 mm	16.5 mm	10-32	1.44, 1.45
200C20	90k N	0.06 mV/N	130k N	1.3 N	≥ 2000 sec	12.7 mm	37.8 mm	1/4-28	1.44, 1.45
200C50	220k N	0.022 mV/N	330k N	4.5 N	≥ 2000 sec	19.1 mm	53.7 mm	1/4-28	1.44, 1.45

* Compression

Charge Output Impact Force Sensors

Model Number	Compression Range	Sensitivity	Maximum Force*	Capacitance	Height	OD	Mounting Threads	Pages
210B	22k N	4 pC/N	45k N	12 pF	9.1 mm	16.5 mm	10-32	1.44, 1.46
210B20	90k N	4 pC/N	130k N	150 pF	12.7 mm	37.8 mm	1/4-28	1.44, 1.46
210B50	220k N	4 pC/N	330k N	250 pF	19.1 mm	53.7 mm	1/4-28	1.44, 1.46

* Compression

Miniature ICP® Quartz Force Sensors

Model Number	Range	Sensitivity	Maximum Force	Resolution	Time Constant	Height	OD	Mounting Threads	Pages
209C01	10 N*	500 mV/N	50 N*	0.00009 N	≥ 1 sec	15.5 mm	3/8 hex	10-32	1.48, 1.49
209C02	10 N*	500 mV/N	50 N*	0.00009 N	≥ 10 sec	15.5 mm	3/8 hex	10-32	1.48, 1.49
209C11	10/4.5 N**	500 mV/N	50/4.5 N**	0.00009 N	≥ 1 sec	21.1 mm	3/8 hex	2-56, 10-32	1.48, 1.49
209C12	10/4.5 N**	500 mV/N	50/4.5 N**	0.00009 N	≥ 10 sec	21.1 mm	3/8 hex	2-56, 10-32	1.48, 1.49

* Compression ** Compression/Tension

Penetration-style ICP® Quartz Force Sensors

Model Number	Range	Sensitivity	Maximum Force	Resolution	Time Constant	Height	OD	Mounting Threads	Pages
208A22	450 N*	11 mV/N	4500 N*	0.009 N	≥ 200 sec	35.8 mm	12.7 mm	M7 x 0.75	1.52, 1.53
208A23	4500 N*	1.1 mV/N	22k N*	0.09 N	≥ 2000 sec	35.8 mm	12.7 mm	M7 x 0.75	1.52, 1.53
208A24	11k N*	0.22 mV/N	22k N*	0.45 N	≥ 2000 sec	35.8 mm	12.7 mm	M7 x 0.75	1.52, 1.53
208A33	4500/2200 N**	1.1 mV/N	22k /3300 N**	0.09 N	≥ 2000 sec	42.2 mm	12.7 mm	M7 x 0.75	1.52, 1.53
208A35	22k/2200 N**	0.22 mV/N	45k/3300 N**	0.45 N	≥ 2000 sec	50.0 mm	12.7 mm	M7 x 0.75	1.52, 1.53
208A45	22k/2200 N**	0.22 mV/N	45k/3300 N**	0.45 N	≥ 2000 sec	46 mm	25.4 mm	M7 x 0.75	1.52, 1.53

* Compression ** Compression/Tension

ICP® Strain Sensor Selection Guide – Metric Measurement Units

Model Number	Range	Sensitivity	Resolution	Time Constant	Connector	Size (W x L x H)	Weight	Mounting Thread	Pages
M240A01	50 pk με	100 mV/με	0.0001 με	≥ 150 sec	10-32	17 x 46 x 15.2 mm	45 gm	M6 x 1.00-6g	1.56, 1.57
M240A02	100 pk με	50 mV/με	0.0002 με	≥ 150 sec	10-32	17 x 46 x 15.2 mm	45 gm	M6 x 1.00-6g	1.56, 1.57
M240A03	300 pk με	10 mV/με	0.001 με	≥ 150 sec	10-32	17 x 46 x 15.2 mm	45 gm	M6 x 1.00-6g	1.56, 1.57

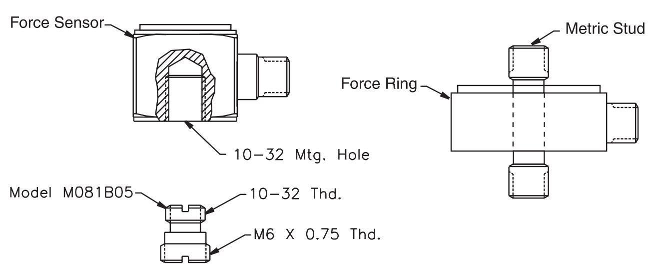
Standard Options for Force Sensors

Option "J" — Ground Isolation (e.g., J223B)

The ground isolation option provides an electrical isolation of $>10^8$ ohm between the force sensor and the test structure. This electrical isolation is achieved by adding a layer of insulating material between the sensor and its mounting hardware. Typically, ground isolation is used when testing machines that are driven by electric motors or around other objects that produce large amounts of electrical noise. Isolating the sensor from the test object also reduces noise induced by electrical ground loops.

Option "M" — Metric Mounting Thread (e.g., M201B03)

This option is used for applications requiring a metric thread for installation. On models for which a separate mounting stud is provided, the option supplies a stud with a metric installation thread. For link-style models that incorporate tapped mounting threads, the optional unit includes metric tapped threads. The table below lists the supplied mounting studs, washers and bushings for all of our standard quartz force sensors. See pages 1.32 to 1.34 for metric threads supplied on link-style sensors.



Typical Metric Mounting

MOUNTING STUDS AND SCREWS

Model	Threads			Length in (cm)	Washer	Bushing	Comment
SHORT STUDS							
081A05	10-32	to	10-32	0.27 (0.69)			Series 209
M081A05	10-32	to	M6 x 0.75	0.27 (0.69)			Series M209
081B05	10-32	to	10-32	0.27 (0.69)			with shoulder for Series 208 and Models 200B01-B05, 210B
M081B05	10-32	to	M6 x 0.75	0.27 (0.69)			adaptor stud w/ shoulder for Models M200B01-B05, M210B
081B20	1/4-28	to	1/4-28	0.37 (0.94)			with shoulder for Models 200C20 & C50, 210B20 & B50
M081B21	1/4-28	to	M6 x 0.75	0.37 (0.94)			adaptor stud for Models M200C20 & C50, M210B20 & B50
M081A62	10/32	to	M6 x 1.0	0.325 (0.83)			Series 208
LONG STUDS							
081A11	10-32	to	10-32	0.73 (1.85)	082B01	083B01	for Models 201B01-B05, 211B
M081A11	M5 x 0.8	to	M5 x 0.8	0.73 (1.85)	082B01	M083B01	for Models M201B01-B05, M211B
081A11	10-32	to	10-32	0.73 (1.85)		083A15	for Models 201A75-A76
M081A11	M5 x 0.8	to	M5 x 0.8	0.73 (1.85)		M083A15	for Models M201A75-A76
081A12	5/16-24	to	5/16-24	0.91 (2.31)	082B02	083B02	for Models 202B, 212B
M081A12	M8 x 1.0	to	M8 x 1.0	0.91 (2.31)	082B02	M083B02	for Models M202B, M212B
081A13	3/8-24	to	3/8-24	1.10 (2.79)	082B03	083B03	for Models 203B, 213B
M081A13	M10 x 1.0	to	M10 x 1.0	1.10 (2.79)	082B03	M083B03	for Models M203B, M213B
081A14	1/2-20	to	1/2-20	1.40 (3.56)	082B04	083B04	for Models 204B, 214B
M081A14	M14 x 1.25	to	M14 x 1.25	1.40 (3.56)	082B04	M083B04	for Models M204B, M214B
081A15	5/8-18	to	5/8-18	1.65 (4.19)	082B05	083B05	for Models 205B, 215B
M081A15	M16 x 1.5	to	M16 x 1.5	1.65 (4.19)	082B05	M083B05	for Models M205B, M215B
081A16	7/8-14	to	7/8-14	1.90 (4.83)	082B06	083B06	for Models 206B, 216B
M081A16	M22 x 2.0	to	M22 x 2.0	1.90 (4.83)	082B06	M083B06	for Models M206B, M216B
081A17	1 1/8-12	to	1 1/8-12	2.28 (5.79)	082B07	083B07	for Models 207B, 217B
M081A17	M30 x 2.0	to	M30 x 2.0	2.28 (5.79)	082B07	M083B07	for Models M207B, M217B
081A70	5/16-24	to	5/16-24	1.42 (3.61)	082B02	083A10	pre-load bolt for Models 260A01, 260A11
M081A70	M8 x 1.25	to	M8 x 1.25	1.42 (3.61)	082B02	083A10	pre-load bolt for Models M260A01, M260A11
081A71	7/8-14	to	7/8-14	2.40 (6.1)	082B06	083A11	pre-load bolt for Models 260A03, 260A13
M081A71	M24 x 3	to	M24 x 3	2.40 (6.1)	082B06	083A11	pre-load bolt for Models M260A03, M260A13
081A74	1/2-20	to	1/2-20	1.11 (2.82)	082M12	083A13	pre-load bolt for Models 260A02, 260A12
M081A74	M12 x 1.25	to	M12 x 1.25	1.11 (2.82)	082M12	083A13	pre-load bolt for Models M260A02, M260A12

Option "N" — Negative Polarity Element (e.g., N202B)

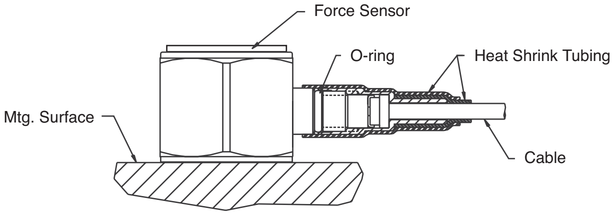
This option reverses the polarity of the output signal to match the requirements of the installation. Most ICP® force sensors normally generate a positive polarity output signal when compressed. During machinery studies, it may be practical for this to be changed to a negative polarity to satisfy signal analysis schemes. This option changes the polarity of the sensor from positive going to negative going when compressed.

Option "P" — Positive Polarity Element (e.g., P218C)

When the phase of the output signal is important, especially for timing and multi-channel applications, it may be necessary to reverse the polarity of the output signal to correspond to the inverting characteristics of the signal conditioner being used. Most charge amplifiers invert the measurement signal and would typically be used with charge output force sensors having a negative signal polarity. In cases where the signal conditioner is a non-inverting device, it may be desirable to use a positive polarity sensor. This option provides a positive polarity charge output sensor without compromise to any other specification.

Option "W" — Water-resistant Connection (e.g., W208C03/002C10)

The water-resistant option provides a cable directly attached and sealed to the sensor's electrical connector with O-rings and heat-shrink tubing. This helps secure and seal the cable to the sensor, provides strain relief, and protects the integrity of the connection. This sealing guards against contamination from dirt and fluids and permits short-term underwater use. Use the option letter "W" as a prefix to the model number. Then add a slash (/) after the model number, followed by the type of cable, length, and appropriate connectors (see cables/accessories section beginning on page 1.69 for a description of cables and connectors). Example shown is a Model 208C03 connected to a 10 ft Model 002C10 cable via a standard 10-32 coaxial plug. The cable itself terminates in a BNC plug. Designate a metric length by adding an "M" in front of the cable type, e.g., W208C03/M002C03 designates a 3-meter cable length.



Water-resistant Cable Attachment

Dynamic Quartz Force Sensors

Quartz force sensors are available in a wide variety of configurations to meet the needs of most dynamic compression, tension and impact measurement requirements. Quartz sensors can also be integrated into machinery parts and linkages for monitoring continuous, repetitive cycles or processes.

General Purpose Quartz Force Sensors

- **Dynamic compression and tension**
- **Impact testing**
- **Stamping and forming**
- **Drop testing**
- **Materials testing**
- **Machinery studies**

General purpose quartz force sensors measure rapidly changing dynamic compression, tensile, and impact forces and adapt to a wide range of applications. They are offered in both ICP® and charge output types and are available to measure full-scale compression forces from 10 to 5000 lb (45 to 22k N) and full-scale tensile forces from 10 to 500 lb (45 to 2200 N). The variety of available sensitivities allow the user to select a model that best fits the dynamic range of the test, thus optimizing the signal to noise ratio. When used in a DC coupled system, these sensors have the ability to measure short-term, quasi-static events as required for calibration and measurements lasting a few seconds in duration. They are easily installed in a variety of applications where stud or axial mounting is required.

Two physical sensor configurations are available. The side-exit connector design has 10-32 tapped mounting holes on both the top and bottom surfaces of the sensor. This type easily adapts to link, integrated link, platform, and free-standing installations. Since the electrical connector extends radially from the sensor, it can be positioned for optimum clearance and cable routing. The sensor is supplied with a curved impact cap that is recommended for use in drop test applications. The curved surface of the impact cap helps to evenly distribute the load over the sensing surface to avoid “edge loading.”

The second configuration has an axial output connector. This sensor is preferred when mounting space is at a minimum and in drop test applications. In drop test applications, the connector and cable are protected from the impacting objects. This improves connector longevity during impact and prevents potential pinching and crushing of the cable during test. A curved impact cap is also supplied with axial connector sensors.

General Purpose Quartz Force Sensors

GENERAL PURPOSE (*complete specifications are featured on page* 1.21)

General purpose piezoelectric force sensors measure both dynamic and quasi-static forces over a wide, full-scale measurement range of 10 lb (45 N) up to 5000 lb (22k N). A removable curved impact cap is supplied with each sensor.

- modal analysis force input
- biomechanics
- mechanical impedance
- tensile testing
- material fracture
- matrix print head
- drop and impact testing
- material testing
- fatigue testing

Accessory key located on page 1.22

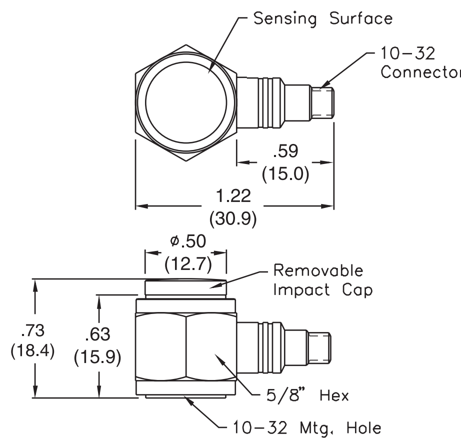
ICP® SENSORS

Models 208C01 to 208C05 — side connector (accessory key ❷②)

Models 208A11 to 208A15 — axial connector (accessory key ❷②)

- Sensitivities from 1 to 500 mV/lb (0.22 to 110 mV/N)
- Full-scale compression ranges from 10 to 5000 lb (45 to 22k N)
- Full-scale tension ranges from 10 to 500 lb (45 to 2200 N)
- 10-32 coaxial connector

CE *



Models 208C01 to 208C05, and 218C

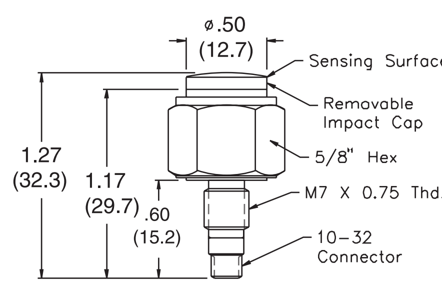
CHARGE OUTPUT SENSORS

Model 218C — side connector (accessory key ②)
Charge sensitivity of 18 pC/lb (4 pC/N)

Model 218A11 — axial connector (accessory key ②)
Charge sensitivity of 18 pC/lb (4 pC/N)

- Compression range to 5000 lb (22k N)
- Tension range to 500 lb (2200 N)
- Temperature range to 400 °F (204 °C)
- 10-32 coaxial connector
- Use with in-line or laboratory-style charge amplifiers

CE *



Models 208A11 to 208A15, and 218A11

Available Sensor Options	
Prefix	Descriptions
N	Negative Polarity
P	Positive Polarity
W	Attached Water-resistant Cable
Designate option as prefix to model number, e.g., Model N208C03 specifies a unit with negative polarity	

* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

General Purpose Quartz Force Sensors

General Purpose Quartz Force Sensors								
		ICP® Sensor Models					Charge Output	
Side Connector Models	**Unit**	**208C01**	**208C02**	**208C03**	**208C04**	**208C05**	**218C**	
Axial Connector Models		**208A11**	**208A12**	**208A13**	**208A14**	**208A15**		**218A11**
Performance Specifications								
Compression Range[1]	lb (N)	10 (45)	100 (450)	500 (2200)	1000 (4500)	5000 (22k)	5000 (22k)	5000 (22k)
Tension Range	lb (N)	10 (45)	100 (450)	500 (2200)	500 (2200)	500 (2200)	500 (2200)	500 (2200)
Maximum Compression	lb (N)	100 (450)	1000 (4500)	5000 (22k)	6k (27k)	8k (36k)	8k (36k)	8k (36k)
Maximum Tension	lb (N)	100 (450)	500 (2200)	500 (2200)[2]	500 (2200)[2]	500 (2200)[2]	500 (2200)	750 (3300)
Sensitivity (± 15%)	value	500 mV/lb	50 mV/lb	10 mV/lb	5 mV/lb	1 mV/lb	18 pC/lb	18 pC/lb
	value	110 mV/N	11 mV/N	2.2 mV/N	1.1 mV/N	0.22 mV/N	4 pC/N	4 pC/N
Resolution (broadband)	lb rms	0.0001	0.001	0.005	0.01	0.05	see note[3]	see note[3]
	N rms	0.00045	0.0045	0.022	0.045	0.22	see note[3]	see note[3]
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	36k	36k	36k	36k	36k	36k	36k
Low Freq. Response (-5%)	Hz	0.01	0.001	0.0003	0.0003	0.0003	see note[3]	see note[3]
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-300 to +400	-300 to +400
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-184 to +204	-184 to +204
Temperature Coefficient	%/°F	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.03	≤ 0.03
	%/°C	≤ 0.09	≤ 0.09	≤ 0.09	≤ 0.09	≤ 0.09	≤ 0.054	≤ 0.054
Electrical Specifications								
Discharge Time Constant[4]	second	≥ 50	≥ 500	≥ 2000	≥ 2000	≥ 2000	see note[4]	see note[4]
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	N/A	N/A
Output Bias Voltage	+VDC	8 to 12	8 to 14	8 to 14	8 to 14	8 to 14	N/A	N/A
Voltage Excitation	+VDC	18 to 30	20 to 30	20 to 30	20 to 30	20 to 30	N/A	N/A
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	N/A	N/A
Capacitance	pF	N/A	N/A	N/A	N/A	N/A	14	14
Insulation Resistance	ohm	N/A	N/A	N/A	N/A	N/A	≥ $1x10^{12}$	≥ $1x10^{12}$
Polarity: Compression		positive	positive	positive	positive	positive	negative	negative
Physical Specifications								
Mounting Thread	size	see note[5]	see note[5]	see note[5]	see note[5]	see note[5]	see note[5]	see note[5]
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	6 (1.05)	6 (1.05)	6 (1.05)	6 (1.05)	6 (1.05)	6 (1.05)	6 (1.05)
Sealing	type	see note[6]	see note[6]	see note[6]	see note[6]	see note[6]	hermetic weld	epoxy
Material (stainless steel)	type	316L / 17-4	316L / 17-4	316L / 17-4	316L / 17-4	316L / 17-4	316L / 17-4	316L / 17-4
Impact Cap Material (stainless steel)	type	17-4 PH	17-4 PH	17-4 PH	17-4 PH	17-4 PH	17-4 PH	17-4 PH
Weight	oz (gm)	0.80 (22.7)	0.80 (22.7)	0.80 (22.7)	0.80 (22.7)	0.80 (22.7)	0.79 (22.4)	0.71 (20.0)
Supplied Accessories[7]								
Mounting Stud (2 each supplied)	model	081B05/M081A62	081B05/M081A62	081B05/M081A62	081B05/M081A62	081B05/M081A62	081B05/M081A62	081B05/M081A62
Impact Cap	model	084A03	084A03	084A03	084A03	084A03	084A03	084A03
Thread Locker Adhesive	model	080A81	080A81	080A81	080A81	080A81	080A81	080A81
Options[8]	**prefix**	**N,W**	**N,W**	**N,W**	**N,W**	**N,W**	**P,W**	**P,W**

NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] Maximum tension for axial connector models 208A13, 208A14, and 208A15 is 750 lb (3300 N).

[3] Resolution, System Discharge Time Constant and Low Frequency range are dependent upon sensor cable and signal conditioning used.

[4] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[5] Side connector models have 10-32 female mounting thread. Axial connector models have M7 x 0.75 male mounting thread.

[6] Side connector models are hermetically sealed. Axial connector models are epoxy sealed.

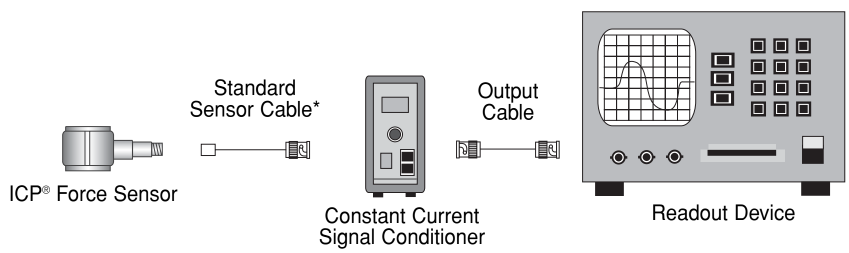
[7] See page 1.69 for complete accessory listings.

[8] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric mounting studs and screws, see page 1.16.

Suggested Sensor Accessories			
Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m)			
The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

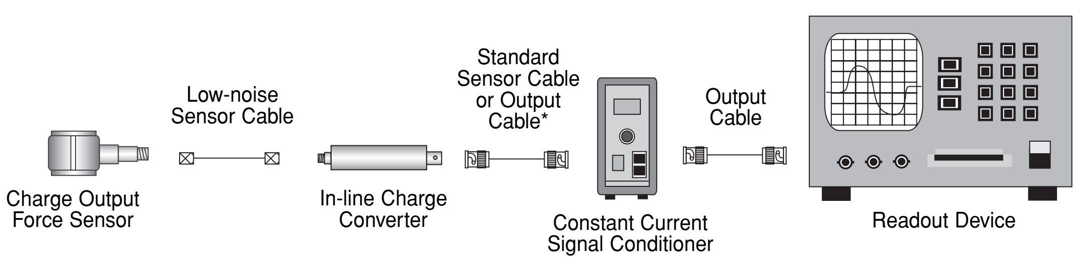
Suggested Sensor Signal Conditioners						
Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62
*LTC = long discharge time constant						

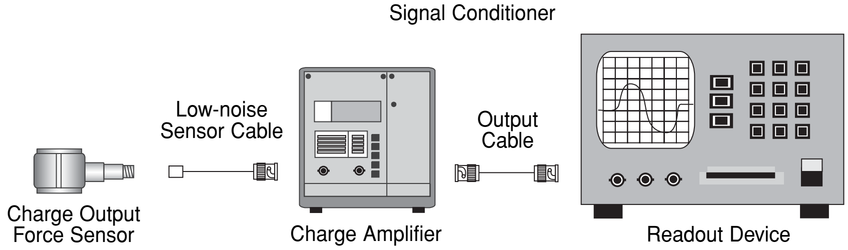
Typical General Purpose ICP® Quartz Force Sensor Measurement System



* Low-noise cables are required to maintain CE conformance.

Typical General Purpose Charge Output Quartz Force Sensor Measurement Systems





* Low-noise cables are required to maintain CE conformance.

Quartz Force Rings

- **Crimping, stamping and press monitoring**
- **Machinery mount forces**
- **Force-controlled vibration testing**
- **Mechanical impedance testing**
- **Recoil of a gun barrel**

Quartz force rings are "donut" shaped sensors that predominantly install as an integrated component to a machine or base plate. They are typically sandwiched between a fixed foundation and a platform, wall, or machine, and may be integrated within a push rod or a link. A unique characteristic of force rings is their ability to allow a portion of a test article to pass through their center hole.

Force rings are constructed with smooth, parallel quartz plates and a hermetically sealed, stainless steel housing. Their durability and longevity stands up to repetitive cycling applications and harsh factory environments. Force rings are also capable of measuring very small forces that are superimposed upon a relatively large, static load. Both ICP® and charge output versions of force rings are available.

A variety of force ring sizes accommodates full-scale compression measurements from 10 to 100k lb (45 to 450k N). For tension measurements, the user must torque the mounting bolt appropriately to achieve the proper pre-load for the tension range desired. The amount of pre-load, or mounting bolt torque, along with the strength of the mounting bolt, determines the tension measurement range capability.

Force rings are excellent sensors for machinery process monitoring applications that can utilize the measurement signal of a force-controlled event. Such feedback measurements improve the consistency and quality of products derived from repetitive operations such as crimping, punching, stamping, pressing, and forming. Force rings may be installed beneath the leg of a machine to alarm of imbalance or loosening of a mount. Additionally, multiple sensors, when installed in a press base or platform, can offer the profile of a force distribution over an area. There are also many applications in the areas of materials testing and fatigue testing for quartz force rings.

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Quartz Force Rings

FORCE RINGS (*complete specifications are featured on pages* 1.26 *to* 1.28)

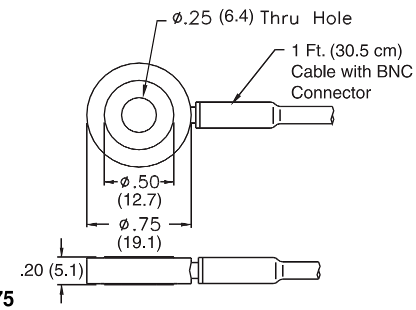
Quartz force rings are available in both ICP® and charge output styles. A variety of sizes ranging from 0.65 to 2.95 in (16.5 to 74.9 mm) in diameter support full-scale compression measurements of 10 to 100k lb (45 to 450k N). Two low profile designs are only 0.20 in (5.08 mm) high, have a compression range of 5000 lb (22k N) are recommended for use in applications where space is limited.

- clamping and pinching
- roll nip profiles
- balancing
- tablet and punch presses
- material testing
- machinery studies

Accessory key located on page 1.27

Model 201A75

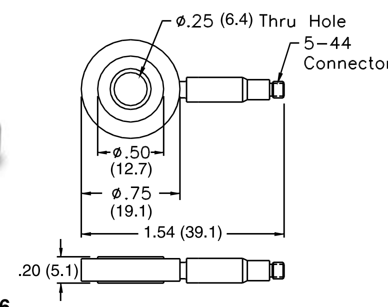
- Sensitivity of 1 mV/lb (0.22 mV/N)
- Compression range to 5000 lb (22k N)
- 0.25 oz (7 gm) in weight
- Low profile of 0.20 inch (5.1 mm)
- Integral cable terminated with a BNC jack



Model 201A75

Model 201A76 (accessory key ❶①)

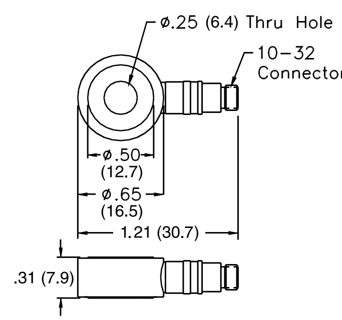
- Sensitivity of 1 mV/lb (0.22 mV/N)
- Compression range to 5000 lb (22k N)
- 0.25 oz (7 gm) in weight
- Low profile of 0.20 inch (5.1 mm)
- 5-44 electrical connector



Model 201A76

Model 201B01 to 201B05 (accessory key ❷②)

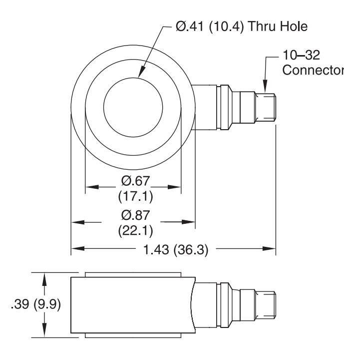
- Sensitivities from 1 to 500 mV/lb (0.22 to 110 mV/N)
- Full-scale compression ranges from 10 to 5000 lb (45 to 22k N)
- 0.5 oz (14 gm) in weight
- Charge output **Model 211B** generates 18 pC/lb (4 pC/N) (accessory key ②)



Models 201B01 to 201B05 and 211B

Model 202B (accessory key ❷②)

- Sensitivity of 0.50 mV/lb (0.11 mV/N)
- Compression range to 10k lb (45k N)
- 0.7 oz (20 gm) in weight
- Charge output **Model 212B** generates 18 pC/lb (4 pC/N) (accessory key ②)

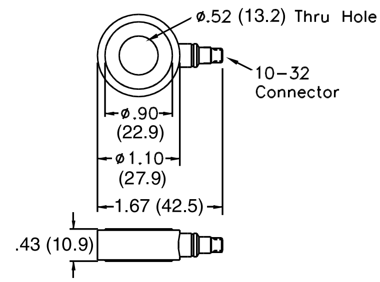


Models 202B and 212B

* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

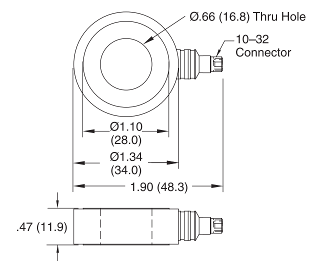
Accessory key located on page 1.27

Model 203B (accessory key ❷②)
- Sensitivity of 0.25 mV/lb (0.06 mV/N)
- Compression range to 20k lb (90k N)
- 1.3 oz (38 gm) in weight
- Charge output **Model 213B** generates 18 pC/lb (4 pC/N) (accessory key ②)



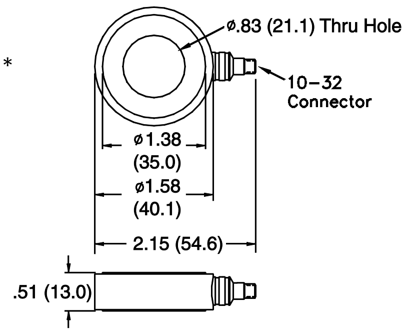
Models 203B and 213B

Model 204C (accessory key ❷②)
- Sensitivity of 0.12 mV/lb (0.027 mV/N)
- Compression range to 40k lb (180k N)
- 2.0 oz (57 gm) in weight
- Charge output **Model 214B** generates 18 pC/lb (4 pC/N) (accessory key ②)



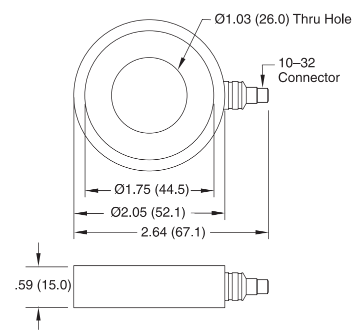
Models 204C and 214B

Model 205C (accessory key ❷②)
- Sensitivity of 0.10 mV/lb (0.022 mV/N)
- Compression range to 60k lb (260k N)
- 2.7 oz (77 gm) in weight
- Charge output **Model 215B** generates 18 pC/lb (4 pC/N) (accessory key ②)



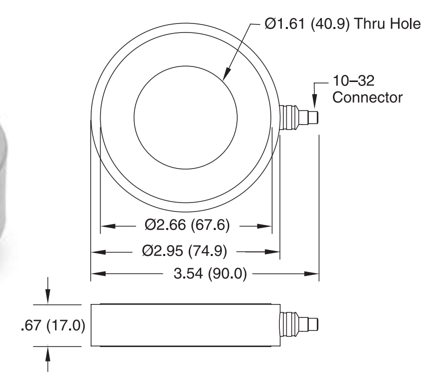
Models 205C and 215B

Model 206C (accessory key ❷②)
- Sensitivity of 0.06 mV/lb (0.013 mV/N)
- Compression range to 80k lb (350k N)
- 5.5 oz (155 gm) in weight
- Charge output **Model 216B** generates 18 pC/lb (4 pC/N) (accessory key ②)



Models 206C and 216B

Model 207C (accessory key ❷②)
- Sensitivity of 0.05 mV/lb (0.011 mV/N)
- Compression range to 100k lb (450k N)
- 11.6 oz (328 gm) in weight
- Charge output **Model 217B** generates 17 pC/lb (3.8 pC/N) (accessory key ②)



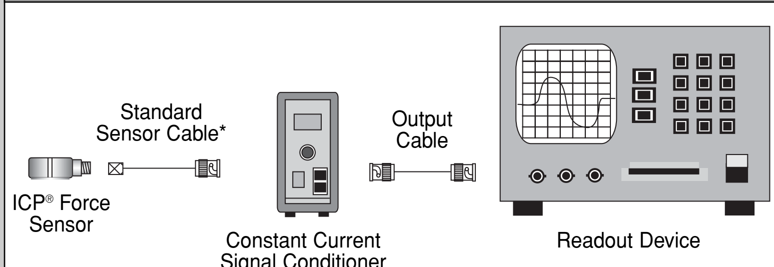
Models 207C and 217B

* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

ICP® Quartz Force Rings

ICP® Quartz Force Rings								
		Low Profile		General Purpose				
Model Number	**Unit**	**201A75**	**201A76**	**201B01**	**201B02**	**201B03**	**201B04**	**201B05**
Performance Specifications								
Compression Range[1]	lb (N)	5000 (22k)	5000 (22k)	10 (45)	100 (450)	500 (2200)	1000 (4500)	5000 (22k)
Maximum Compression	lb (N)	5000 (22k)	5000 (22k)	50 (250)	600 (2700)	3000 (13k)	6000 (27k)	8000 (35k)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	1 (0.22)	1 (0.22)	500 (110)	50 (11)	10 (2.2)	5 (1.1)	1 (0.22)
Resolution (broadband)	lb rms	0.10	0.10	0.0002	0.002	0.01	0.02	0.10
	N rms	0.45	0.45	0.0009	0.009	0.045	0.09	0.45
Amplitude Linearity[6]	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	90k	90k	90k	90k	90k	90k	90k
Low Freq. Response (-5%)	Hz	0.0003	0.0003	0.01	0.001	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications								
Discharge Time Constant[2]	second	≥ 2000	≥ 2000	≥ 50	≥ 500	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive	positive	positive
Physical Specifications								
Recommended Pre-load	lb (N)	1000 (4500)	1000 (4500)	60 (267)	100 (445)	200 (890)	400 (1779)	1000 (4500)
Connector	type	BNC jack	5-44 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	16 (2.8)	16 (2.8)	12 (2.1)	12 (2.1)	12 (2.1)	12 (2.1)	12 (2.1)
Sealing	type	epoxy	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	0.25 (7)	0.25 (7)	0.35 (10)	0.35 (10)	0.35 (10)	0.35 (10)	0.35 (10)
Supplied Accessories[3,4]								
Mounting Stud	model	081A11	081A11	081A11	081A11	081A11	081A11	081A11
Mounting Stud Thread	size	10-32	10-32	10-32	10-32	10-32	10-32	10-32
Anti-friction Washer	model	N/A	N/A	082B01	082B01	082B01	082B01	082B01
Pilot Bushing	model	083A15	083A15	083B01	083B01	083B01	083B01	083B01
Options[5]	**prefix**	**M,N**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**

Typical ICP® Quartz Force Ring Measurement System



* Low-noise cables are required to maintain CE conformance.

NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[3] NIST traceable calibration certificate is supplied with each sensor.

[4] See page 1.69 for complete accessory listings.

[5] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric mounting studs and screws, see page 1.16.

[6] Recommended pre-load is required to meet published specification and calibration.

QUARTZ

ICP® Quartz Force Rings

		High Range					
Model Number	**Unit**	**202B**	**203B**	**204C**	**205C**	**206C**	**207C**
Performance Specifications							
Compression Range[1]	lb (N)	10k (45k)	20k (90k)	40k (180k)	60k (260k)	80k (350k)	100k (450k)
Maximum Compression	lb (N)	15k (70k)	25k (110k)	50k (220k)	70k (300k)	90k (400k)	110k (500k)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	0.50 (0.11)	0.25 (0.06)	0.12 (0.027)	0.08 (0.018)	0.06 (0.013)	0.05 (0.011)
Resolution (broadband)	lb rms	0.20	0.40	0.80	1	1.8	2
	N rms	0.9	1.8	3.6	4.5	8	9
Amplitude Linearity[6]	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	60k	60k	55k	50k	40k	35k
Low Freq. Response (-5%)	Hz	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.08	≤ 0.10	≤ 0.11	≤ 0.12
	%/°C	≤ 0.054	≤ 0.054	≤ 0.14	≤ 0.18	≤ 0.2	≤ 0.22
Electrical Specifications							
Discharge Time Constant[2]	second	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive	positive
Physical Specifications							
Recommended Pre-Load	lb (N)	2000 (8900)	4000 (17 k)	8000 (35k)	12k (53k)	16k (71k)	20k (89k)
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	16 (2.8)	23 (4)	29 (5)	40 (7)	74 (13)	131 (23)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	0.7 (20)	1.3 (38)	2.0 (57)	2.7 (77)	5.5 (155)	11.6 (328)
Supplied Accessories[3,4]							
Mounting Stud	model	081A12	081A13	081A14	081A15	081A16	081A17
Mounting Stud Thread	size	5/16-24	3/8-24	1/2-20	5/8-18	7/8-14	1 1/8-12
Anti-friction Washer	model	082B02	082B03	082B04	082B05	082B06	082B07
Pilot Bushing	model	083B02	083B03	083B04	083B05	083B06	083B07
Options[5]	**prefix**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**

NOTE: See notes on page 1.26.

Accessory key located on this page

Suggested Sensor Accessories

Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❶	Model 018C10	5-44 plug to BNC plug	1.72
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m) The following cables are required to maintain CE conformance:			
①	Model 003P10	5-44 plug to BNC plug	1.71
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

Suggested Sensor Signal Conditioners

Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.26 for a diagram of a typical ICP® force ring measurement system. See page 1.28 for diagrams of typical charge output force ring measurement systems.

*LTC = long discharge time constant

Available Sensor Options

Prefix	Descriptions
M	Metric Mounting
N	Negative Polarity
P	Positive Polarity
W	Attached Water-resistant Cable

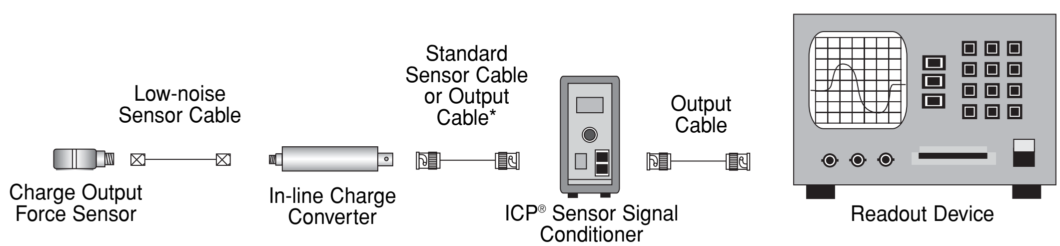
Designate option as prefix to model number, e.g., Model M201B05 specifies a unit for metric mounting.

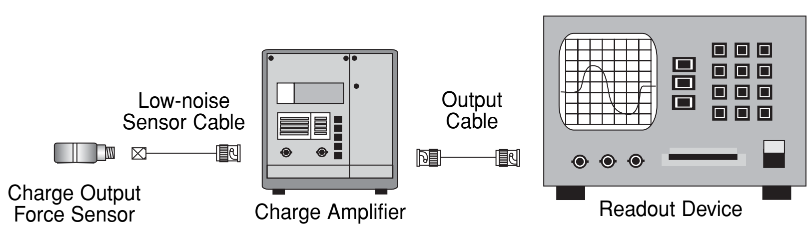
Charge Output Quartz Force Rings

Charge Output Quartz Force Rings								
Model Number [1]	**Unit**	**211B**	**212B**	**213B**	**214B**	**215B**	**216B**	**217B**
Performance Specifications								
Compression Range [2]	lb (N)	5000 (22k)	10k (45k)	20k (90k)	40k (180k)	60k (260k)	80k (350k)	100k (450k)
Maximum Compression	lb (N)	8000 (35k)	15k (70k)	25k (110k)	50k (220k)	70k (300k)	90k (400k)	110k (500k)
Charge Sensitivity (± 15%)	pC/lb (pC/N)	18 (4)	18 (4)	18 (4)	18 (4)	18 (4)	18 (4)	17 (3.8)
Amplitude Linearity [6]	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	90k	60k	60k	55k	50k	40k	35k
Temperature Range	°F	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400
	°C	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204
Temperature Coefficient	%/°F	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.018	≤ 0.018	≤ 0.018	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications								
Capacitance	pF	12	20	28	32	38	80	130
Insulation Resistance	ohm	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Polarity: Compression		negative	negative	negative	negative	negative	negative	negative
Physical Specifications								
Recommended Pre-Load	lb (N)	1000 (4500)	2000 (8900)	4000 (17k)	8000 (35k)	12k (53k)	16k (71k)	20k (89k)
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/μin (kN/μm)	12 (2.1)	16 (2.8)	23 (4)	29 (5)	40 (7)	74 (13)	131 (23)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	0.35 (10)	0.7 (20)	1.3 (38)	2.0 (57)	2.8 (80)	5.5 (155)	12.5 (354)
Supplied Accessories [3,4]								
Mounting Stud	model	081A11	081A12	081A13	081A14	081A15	081A16	081A17
Mounting Stud Thread	size	10-32	5/16-24	3/8-24	1/2-20	5/8-18	7/8-14	1 1/8-12
Anti-friction Washer	model	082B01	082B02	082B03	082B04	082B05	082B06	082B07
Pilot Bushing	model	083B01	083B02	083B03	083B04	083B05	083B06	083B07
Options [5]	**prefix**	**M,P,W**	**M,P,W**	**M,P,W**	**M,P,W**	**M,P,W**	**M,P,W**	**M,P,W**

NOTES:
[1] Special lower ranged calibration for charge output models is available upon request.
[2] 1 lb = 4.448 N (values shown are approximate)
[3] NIST traceable calibration certificate is supplied with each sensor.
[4] See page 1.69 for complete accessory listings.
[5] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric mounting studs and screws, see page 1.16.
[6] Recommended pre-load is required to meet published specification and calibration.

Typical Charge Output Force Ring Measurement Systems





* Low-noise cables are required to maintain CE conformance.

Quartz Force Links

- **Press force monitoring**
- **Stamping, punching, and forming**
- **Machinery studies**
- **Tensile testing**

Quartz force links are constructed by sandwiching a force ring, under pre-load, between two threaded link mounting nuts. This stainless steel assembly is held together by an elastic, beryllium-copper stud. Since force links are factory pre-loaded, they may be used directly for measurements of compression and tension. The use of an elastic stud permits the applied force to be sensed by the crystals with a minimal amount of shunted force. Force links are also capable of measuring very small forces that are superimposed upon a relatively large static load.

A variety of force link sizes accommodates full-scale measurements from 10 to 50k lb (45 to 220k N) compression and from 10 to 30k lb (45 to 130k N) tension. Both ICP® and charge output versions are available. The units may be installed as an integrated member of a machine rod or linkage using studs, bolts, or threaded rods. Eyebolts may also be used for suspending cables from the unit. The solid-state, hermetically-sealed construction provides durability and longevity for repetitive cycling applications and harsh factory environments.

Force links are excellent sensors for machinery process monitoring applications that can utilize the measurement signal of a force-controlled event. Such feedback measurements improve the consistency and quality of products derived from repetitive operations such as crimping, punching, stamping, pressing, and forming.

Quartz Force Links

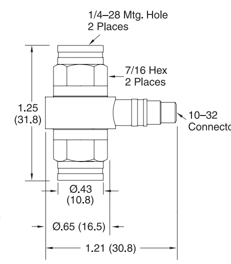
FORCE LINKS (*complete specifications are featured on pages* 1.32 *to* 1.34)

Force link sensors measure compression, tension, reaction, and actuation forces involved in punching, forming, ejecting, pushing, balancing, and machining operations. A variety of sensors supports full-scale measurements ranging from 10 to 50k lb (45 to 220k N) compression and from 10 to 30k lb (45 to 130k N) tension. All models have threaded mounting holes on each end and a 10-32 coaxial electrical connector.

- materials testing machines
- push-rod testing
- machine process monitoring
- mechanical impedance testing
- force controlled vibration
- tablet press monitoring

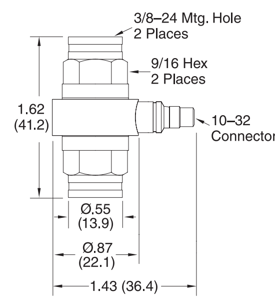
Accessory key located on page 1.33

Model 221B01 to **221B05** (accessory key ❷②)
- Sensitivity ranges from 1 to 500 mV/lb (0.22 to 110 mV/N)
- Full-scale compression ranges from 10 to 5000 lb (45 to 22k N)
- Full-scale tension ranges from 10 to 1000 lb (45 to 4500 N)
- 1.1 oz (31 gm) in weight
- Charge output **Model 231B** generates 18 pC/lb (4 pC/N) (accessory key ②)



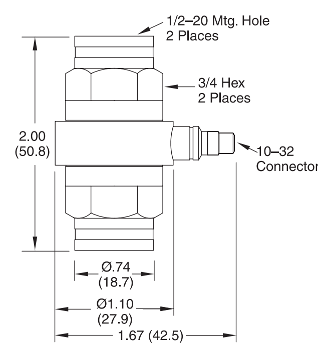
Models 221B01 to 221B05 and 231B

Model 222B (accessory key ❷②)
- Sensitivity of 0.9 mV/lb (0.20 mV/N)
- Compression range to 6000 lb (27k N)
- Tension range to 2500 lb (11k N)
- 2.0 oz (58 gm) in weight
- Charge output **Model 232B** generates 18 pC/lb (4 pC/N) (accessory key ②)



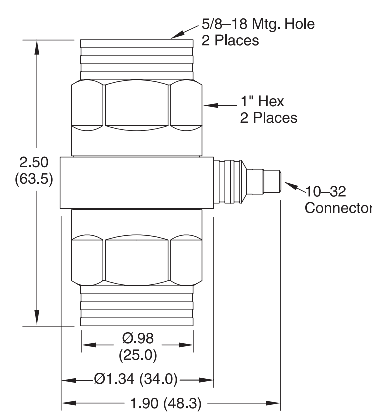
Models 222B and 232B

Model 223B (accessory key ❷②)
- Sensitivity of 0.40 mV/lb (0.09 mV/N)
- Compression range to 12k lb (55k N)
- Tension range to 4000 lb (18k N)
- 4.2 oz (120 gm) in weight
- Charge output **Model 233B** generates 18 pC/lb (4 pC/N) (accessory key ②)



Models 223B and 233B

Model 224C (accessory key ❷②)
- Sensitivity of 0.20 mV/lb (0.05 mV/N)
- Compression range to 25k lb (110k N)
- Tension range to 8000 lb (35k N)
- 8.7 oz (246 gm) in weight
- Charge output **Model 234B** generates 18 pC/lb (4 pC/N) (accessory key ②)



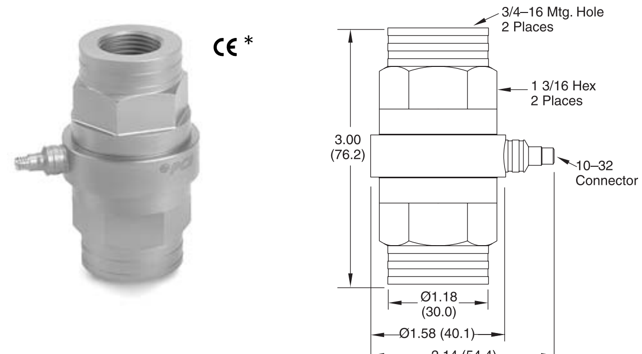
Models 224C and 234B

* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

Accessory key located on page 1.33

Model 225C (accessory key ❷②)

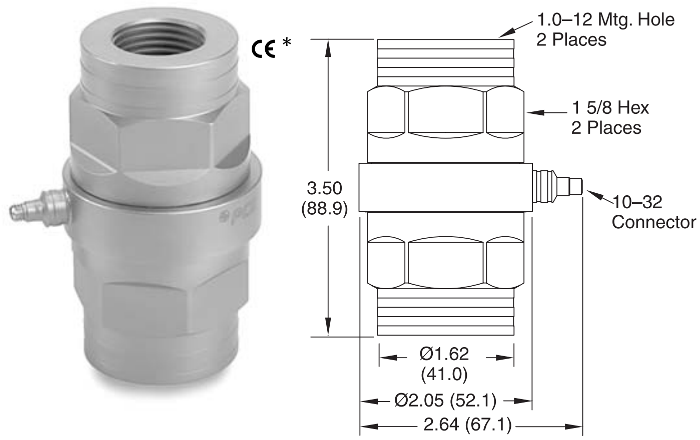
- Sensitivity of 0.14 mV/lb (0.031 mV/N)
- Compression range to 35k lb (150k N)
- Tension range to 12k lb (55k N)
- 14.5 oz (412 gm) in weight
- Charge output **Model 235B** generates 18 pC/lb (4 pC/N) (accessory key ②)



Models 225C and 235B

Model 226C (accessory key ❷②)

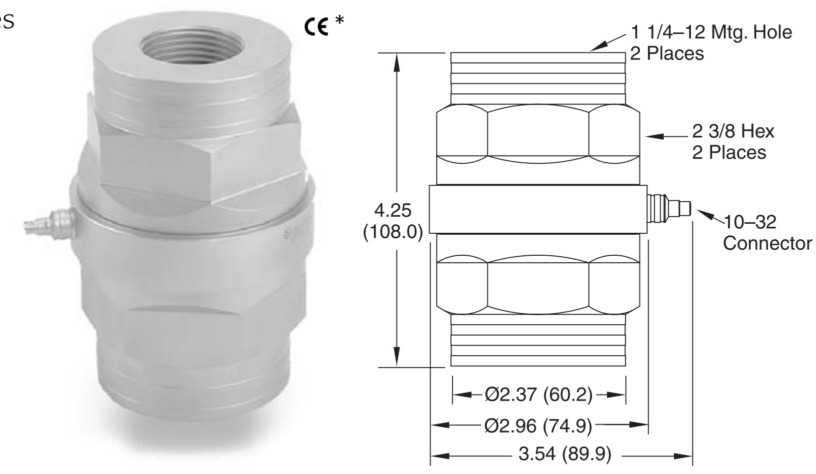
- Sensitivity of 0.11 mV/lb (0.025 mV/N)
- Compression range to 45k lb (200k N)
- Tension range to 20k lb (90k N)
- 32 oz (907 gm) in weight
- Charge output **Model 236B** generates 18 pC/lb (4 pC/N) (accessory key ②)



Models 226C and 236B

Model 227C (accessory key ❷②)

- Sensitivity of 0.10 mV/lb (0.022 mV/N)
- Compression range to 50k lb (220k N)
- Tension range to 30k lb (130k N)
- 83 oz (2353 gm) in weight
- Charge output **Model 237B** generates 17 pC/lb (3.8 pC/N) (accessory key ②)



Models 227C and 237B

* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

Available Sensor Options	
Prefix	Descriptions
J	Ground Isolated
M	Metric Mounting
N	Negative Polarity
P	Positive Polarity
W	Attached Water-resistant Cable

Designate option as prefix to model number, e.g., Model M222B specifies a unit for metric mounting.

QUARTZ

ICP® Quartz Force Links

General Purpose ICP® Quartz Force Links						
Model Number	**Unit**	**221B01**	**221B02**	**221B03**	**221B04**	**221B05**
Performance Specifications						
Compression Range [1]	lb (N)	10 (45)	100 (450)	500 (2200)	1000 (4500)	5000 (22k)
Tension Range	lb (N)	10 (45)	100 (450)	500 (2200)	1000 (4500)	1000 (4500)
Maximum Compression	lb (N)	100 (450)	1000 (4500)	5000 (22k)	6000 (27k)	6000 (27k)
Maximum Tension	lb (N)	100 (450)	500 (2200)	1000 (4500)	1200 (5300)	1200 (5300)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	500 (110)	50 (11)	10 (2.2)	5 (1.1)	1 (0.22)
Resolution (broadband)	lb rms	0.0002	0.002	0.01	0.02	0.10
	N rms	0.0009	0.009	0.045	0.09	0.45
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	15k	15k	15k	15k	15k
Low Freq. Response (-5%)	Hz	0.01	0.001	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications						
Discharge Time Constant [2]	second	≥ 50	≥ 500	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive
Physical Specifications						
Mounting Thread	size	1/4-28 female	1/4-28 female	1/4-28 female	1/4-28 female	1/4-28 female
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	2 (0.35)	2 (0.35)	2 (0.35)	2 (0.35)	2 (0.35)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	1.1 (31)	1.1 (31)	1.1 (31)	1.1 (31)	1.1 (31)
Options [3]	**prefix**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**
Metric Mounting Thread		M6 x 0.75	M6 x 0.75	M6 x 0.75	M6 x 0.75	M6 x 0.75

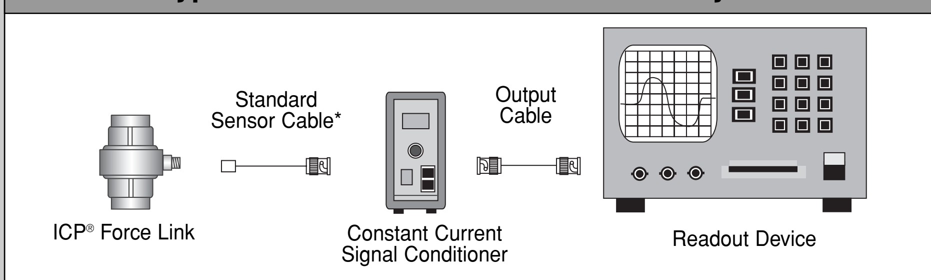
NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[3] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering).

Typical ICP® Force Link Measurement System



* Low-noise cables are required to maintain CE conformance.

High Range ICP® Quartz Force Links

Model Number	Unit	222B	223B	224C	225C	226C	227C
Performance Specifications							
Compression Range[1]	lb (N)	6000 (27k)	12k (55k)	25k (110k)	35k (150k)	45k (200k)	50k (220k)
Tension Range	lb (N)	2500 (11k)	4000 (18k)	8000 (35k)	12k (55k)	20k (90k)	30k (130k)
Maximum Compression	lb (N)	7000 (30k)	15k (70k)	31k (140k)	45k (200k)	55k (250k)	66k (300k)
Maximum Tension	lb (N)	2800 (12k)	4500 (20k)	10k (45k)	15k (70k)	25k (110k)	37.5k (170k)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	0.90 (0.20)	0.42 (0.09)	0.20 (0.05)	0.14 (0.031)	0.11 (0.025)	0.10 (0.022)
Resolution (broadband)	lb rms (N rms)	0.20 (0.9)	0.40 (1.8)	0.60 (2.7)	0.1 (0.45)	0.44 (2)	1 (4.5)
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	12k	10k	8000	6000	5000	4000
Low Freq. Response (-5%)	Hz	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications							
Discharge Time Constant[2]	second	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive	positive
Physical Specifications							
Mounting Thread	size	3/8-24 female	1/2-20 female	5/8-18 female	3/4-16 female	1-12 female	1 1/4-12 female
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	3 (0.53)	4 (0.70)	6 (1.05)	6 (1.05)	11 (1.9)	29 (5)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	2.0 (58)	4.2 (120)	8.7 (246)	14.5 (412)	32 (907)	83 (2353)
Options[3]	**prefix**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**	**J,M,N,W**
Metric Mounting Thread		M10 x 1.0	M12 x 1.25	M16 x 1.50	M20 x 1.50	M24 x 1.50	M30 x 2.0

NOTE: See notes on page 1.32.

Suggested Sensor Accessories

Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m) The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

Suggested Sensor Accessories

Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.32 for a diagram of a typical ICP® force link measurement system.
See page 1.34 for diagrams of typical charge output force link measurement systems.
*LTC = long discharge time constant

QUARTZ

Charge Output Quartz Force Links

Charge Output Quartz Force Links								
Model Number [1]	**Unit**	**231B**	**232B**	**233B**	**234B**	**235B**	**236B**	**237B**
Performance Specifications								
Compression Range [2]	lb (N)	5000 (22k)	6000 (27k)	12k (55k)	25k (110k)	35k (150k)	45k (200k)	50k (220k)
Tension Range	lb (N)	1000 (4500)	2500 (11k)	4000 (18k)	8000 (35k)	12k (55k)	20k (90k)	30k (130k)
Maximum Compression	lb (N)	6000 (27k)	7000 (30k)	15k (70k)	31k (140k)	45k (200k)	55k (250k)	66k (300k)
Maximum Tension	lb (N)	1200 (5300)	2800 (12k)	4500 (20k)	10k (45k)	15k (70k)	25k (110k)	37.5k (170k)
Charge Sensitivity (± 15%)	pC/lb (pC/N)	18 (4)	18 (4)	18 (4)	18 (4)	18 (4)	18 (4)	17 (3.8)
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	15k	12k	10k	8000	6000	5000	4000
Temperature Range	°F	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400	-100 to +400
	°C	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204	-73 to +204
Temperature Coefficient	%/°F	≤ 0.01	≤ 0.01	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.018	≤ 0.018	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications								
Capacitance	pF	12	20	28	32	38	80	130
Insulation Resistance	ohm	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Polarity: Compression		negative	negative	negative	negative	negative	negative	negative
Physical Specifications								
Mounting Thread	size	1/4-28 female	3/8-24 female	1/2-20 female	5/8-18 female	3/4-16 female	1-12 female	1 1/4-12 female
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	2 (0.35)	3 (0.53)	4 (0.70)	6 (1.05)	6 (1.05)	11 (1.9)	29 (5)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Weight	oz (gm)	1.1 (31)	2.0 (58)	4.2 (120)	8.7 (246)	14.5 (412)	32 (907)	83 (2353)
Options [3]	**prefix**	**J,M,P,W**	**J,M,P,W**	**J,M,P,W**	**J,M,P,W**	**J,M,P,W**	**J,M,P,W**	**J,M,P,W**
Metric Mounting Thread		M6 x 0.75	M10 x 1.0	M12 x 1.25	M16 x 1.50	M20 x 1.50	M24 x 1.50	M30 x 2.00

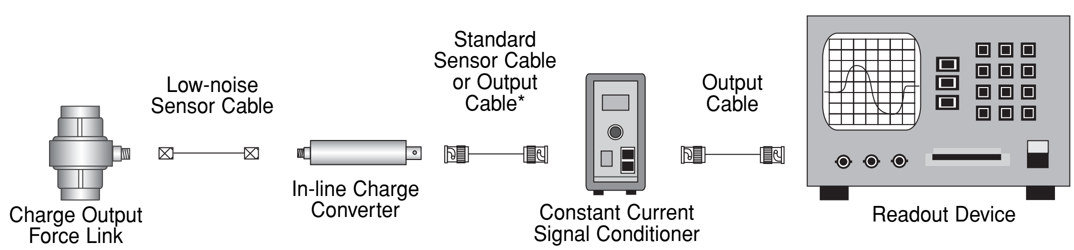
NOTES:

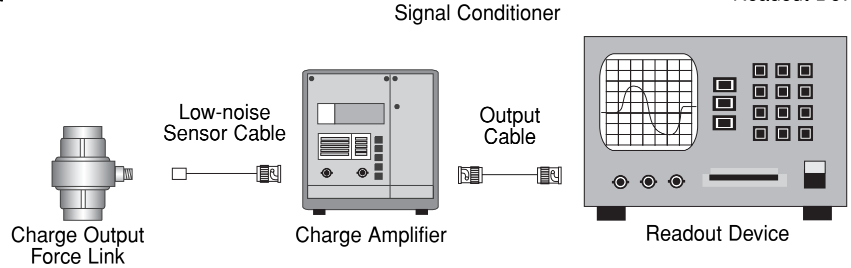
[1] Special lower range calibration for charge output models is available upon request.

[2] 1 lb = 4.448 N (values shown are approximate).

[3] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering).

Typical Charge Output Force Link Measurement System





* Low-noise cables are required to maintain CE conformance.

3-Component Quartz Force Sensors

QUARTZ

- Force-limited vibration testing
- Cutting tool forces
- Force dynamometers
- Engine mount analysis
- Biomechanics research
- Modal analysis

3-Component quartz force sensors are capable of simultaneously measuring dynamic force in three orthogonal directions (X, Y, and Z). They contain three sets of quartz plates that are stacked in a pre-loaded arrangement. Each set responds to the vector component of an applied force acting along its sensitive axis. 3-Component force sensors must be pre-loaded for optimum performance. Pre-loading provides the sensing elements with the compressive loading required to allow the proper transmission of shear forces. Versions are available with ranges up to 10k lb (45k N) in the z-axis (perpendicular to the top surface), and up to 4000 lb (18k N) in the x-and y-(shear) axes. Both ICP® and charge output styles are available.

ICP® designs utilize built-in microelectronic circuitry that provides a low-impedance voltage output via a multi-pin connector. This arrangement offers system simplicity by requiring only a single multi-conductor sensor cable. The low-impedance voltage signal makes this sensor ideal for use in harsh industrial environments.

Charge output 3-component force sensors operate with in-line charge converters or conventional laboratory-style charge amplifiers. The use of laboratory-style charge amplifiers permits each channel to be independently ranged by the user to maximize signal-to-noise ratio. Charge output styles are recommended for higher temperature applications and can also be used for quasi-static measurements with long discharge time constant charge amplifiers.

ICP® 3-Component Quartz Force Sensors

ICP® 3-COMPONENT FORCE SENSORS

(*complete specifications are featured on page* 1.38)

ICP® 3-component force sensors contain integral electronics, eliminating the need for expensive charge amplifiers and low-noise cables. The sensors feature a single, four-pin hermetic connector, and require only a single, multi-conductor cable between the sensor and the multi-channel signal conditioner. This results in lower overall system cost and noise.

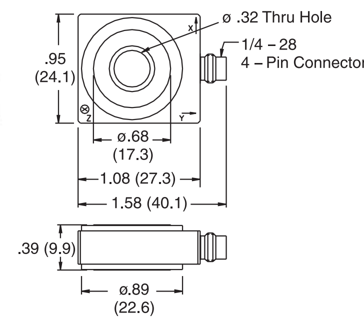
- cutting tool force monitoring
- modal analysis
- biomechanics
- engine mount analysis
- impact testing
- force-limited vibration testing

See pages 1.40 and 1.41 for typical systems and accessories.

Model 260A01

- Sensitivity of 2.5 mV/lb (0.56 mV/N) (z-axis)
- Sensitivity of 10 mV/lb (2.2 mV/N) (x-, y-axis)
- Compression range to 1000 lb (4500 N) (z-axis)
- Compression range to 500 lb (2200 N) (x-, y-axis)
- Side-oriented 4-pin connector

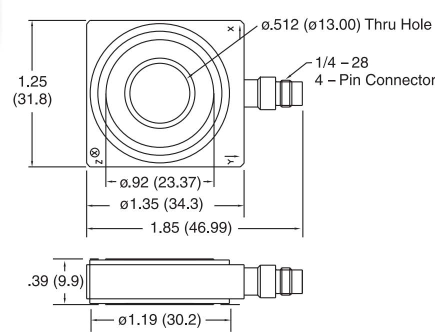
Model 260A01



Model 260A02

- Sensitivity of 2.5 mV/lb (0.56 mV/N) (z-axis)
- Sensitivity of 5 mV/lb (1.12 mV/N) (x-, y-axis)
- Compression range to 1000 lb (4500 N) (z-axis)
- Compression range to 1000 lb (4500 N) (x-, y- axis)
- Side-oriented 4-pin connector

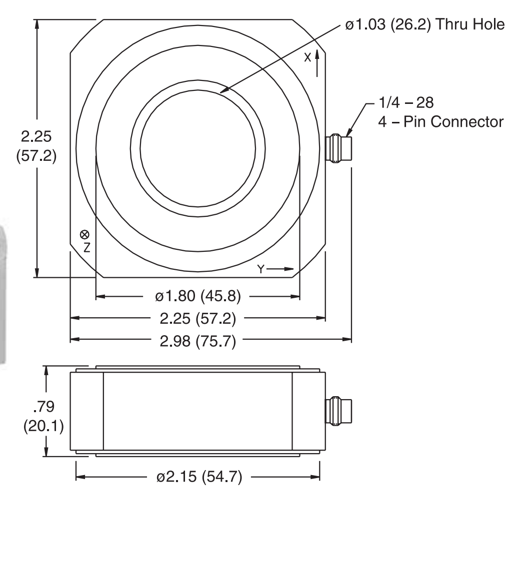
Model 260A02



Model 260A03

- Sensitivity of 0.25 mV/lb (0.06 mV/N) (z-axis)
- Sensitivity of 1.25 mV/lb (0.28 mV/N) (x-, y-axis)
- Compression range to 10k lb (45k N) (z-axis)
- Compression range to 4000 lb (18k N) (x-, y-axis)
- Side-oriented 4-pin connector

Model 260A03



Dimensions shown are in inches (millimeters).

Charge Output 3-Component Quartz Force Sensors

CHARGE OUTPUT 3-COMPONENT FORCE SENSORS

(*complete specifications are featured on page* 1.38)

Charge output 3-component force sensors allow the user to set the range of each channel independently, providing maximum system flexibility. Recommended for high temperature and quasi-static applications.

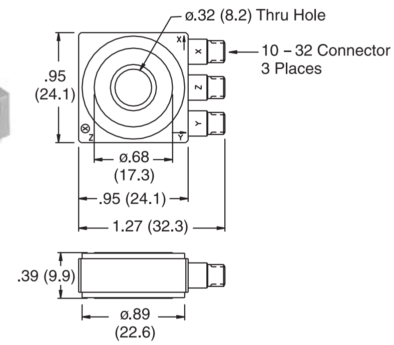
See pages 1.40 and 1.41 for typical systems and accessories.

Model 260A11

- Sensitivity of 15 pC/lb (3.4 pC/N) (z-axis)
- Sensitivity of 32 pC/lb (7.2 pC/N) (x-, y-axis)
- Compression range to 1000 lb (4500 N) (z-axis)
- Compression range to 500 lb (2200 N) (x-, y-axis)
- Three, side-oriented 10-32 coaxial connectors
- Reverse shear polarity **Model 260A31**

CE *

Models 260A11 and 260A31

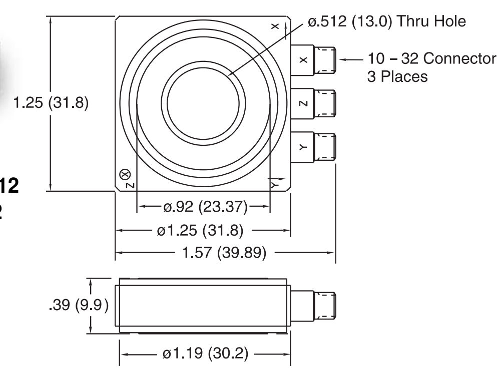


Model 260A12

- Sensitivity of 15 pC/lb (3.4 pC/N) (z-axis)
- Sensitivity of 32 pC/lb (7.2 pC/N) (x-, y-axis)
- Compression range to 1000 lb (4500 N) (z-axis)
- Compression range to 1000 lb (4500 N) (x-, y-axis)
- Three, side-oriented 10-32 coaxial connectors
- Reverse shear polarity **Model 260A32**

CE *

Models 260A12 and 260A32

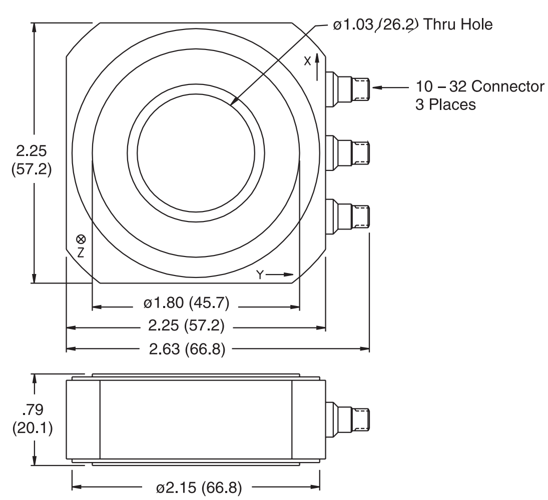


Model 260A13

- Sensitivity of 15 pC/lb (3.4 pC/N) (z-axis)
- Sensitivity of 32 pC/lb (7.2 pC/N) (x-, y-axis)
- Compression range to 10k lb (45k N) (z-axis)
- Compression range to 4000 lb (18k N) (x-, y-axis)
- Three, side-oriented 10-32 coaxial connectors
- Reverse shear polarity **Model 260A33**

CE *

Models 260A13 and 260A33



* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

3-Component Quartz Force Sensors

3-Component Quartz Force Sensors			ICP® Models			Charge Output		
Model Number		**Unit**	**260A01**	**260A02**	**260A03**	**260A11**	**260A12**	**260A13**
Performance Specifications								
Compression or Tension Range	(z-axis)	lb (N)	1000 (4500)	1000 (4500)	10k (45k)	1000 (4500)	1000 (4500)	10k (45k)
Shear Range	(x-, y-axis)	lb (N)	500 (2200)	1000 (4500)	4000 (18k)	500 (2200)	1000 (4500)	4000 (18k)
Maximum Compression or Tension	(z-axis)	lb (N)	1320 (6000)	1320 (6000)	11k (50k)	1320 (6000)	1320 (6000)	11k (50k)
Maximum Shear	(x-, y-axis)	lb (N)	660 (3000)	1000 (4500)	4400 (19k)	660 (3000)	1000 (4500)	4400 (19k)
Sensitivity (± 15%)	(z-axis)	value	2.5 mV/lb	2.5 mV/lb	0.25 mV/lb	15 pC/lb	15 pC/lb	15 pC/lb
		value	0.56 mV/N	0.56 mV/lb	0.06 mV/N	3.4 pC/N	3.4 pC/N	3.4 pC/N
	(x-, y-axis)	value	10 mV/lb	5 mV/lb	1.25 mV/lb	32 pC/lb	32 pC/lb	32 pC/lb
		value	2.2 mV/N	1.1 mV/N	0.28 mV/N	7.2 pC/N	7.2 pC/N	7.2 pC/N
Resolution (broadband)	(z-axis)	lb (N) rms	0.006 (0.027)	0.006 (0.027)	0.05 (0.22)	see note [4]	see note [4]	see note [4]
	(x-, y-axis)	lb (N) rms	0.002 (0.009)	0.006 (0.027)	0.01 (0.045)	see note [4]	see note [4]	see note [4]
Amplitude Linearity [5]		% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Cross-Talk	$F_x \leftrightarrow F_y$	%	± 3	± 3	± 3	± 3	± 3	± 3
	$F_x, F_y \leftrightarrow F_z$	%	± 5	± 5	± 5	± 5	± 5	± 5
Upper Frequency Limit		Hz	90k	90k	39k	90k	90k	39k
Low Frequency Response (-5%)	(z-axis)	Hz	0.01	0.01	0.01	see note [4]	see note [4]	see note [4]
	(x-, y-axis)	Hz	0.001	0.001	0.001	see note [4]	see note [4]	see note [4]
Temperature Range		°F	-65 to +250	-65 to +250	-65 to +250	-100 to +350	-100 to +350	-100 to +350
		°C	-54 to +121	-54 to +121	-54 to +121	-73 to +177	-73 to +177	-73 to +177
Electrical Specifications								
Discharge Time Constant [1]	(z-axis)	second	≥ 50	≥ 50	≥ 50	see note [4]	see note [4]	see notee [4]
	(x-, y-axis)	second	≥ 500	≥ 500	≥ 500	see note [4]	see note [4]	see note [4]
Output Impedance		ohm	≤ 100	≤ 100	≤ 100	N/A	N/A	N/A
Output Bias Voltage		+VDC	8 to 14	8 to 14	8 to 14	N/A	N/A	N/A
Voltage Excitation		+VDC	20 to 30	20 to 30	20 to 30	N/A	N/A	N/A
Constant Current Excitation		mA	2 to 20	2 to 20	2 to 20	N/A	N/A	N/A
Capacitance (all axes)		pF	N/A	N/A	N/A	18	30	70
Insulation Resistance		ohm	N/A	N/A	N/A	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Polarity (in direction of markings)			positive	positive	positive	negative	negative	negative
Physical Specifications								
Recommended Pre-Load		lb (N)	5000 (22k)	10k (44.5k)	40k (177k)	5000 (22k)	10k (44.5k)	40k (177k)
Connector		type	4-pin male	4-pin male	4-pin male	10-32 (three)	10-32 (three)	10-32 (three)
Stiffness	(z-axis)	lb/µin (kN/µm)	10 (1.75)	19 (3.3)	40 (7)	10 (1.75)	19 (3.3)	40 (7)
	(x-, y-axis)	lb/µin (kN/µm)	4 (0.70)	6 (1.05)	15 (2.6)	4 (0.70)	6 (1.05)	15 (2.6)
Sealing		type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)		type	17-4	17-4	17-4	17-4	17-4	17-4
Maximum Allowable Torque	(z-axis)	ft-lb (N-m)	14 (19)	40 (54)	240 (325)	14 (19)	40 (54)	240 (325)
Maximum Allowable Bending Moment	(x-, y-axis)	ft-lb (N-m)	13 (17.6)	70 (94)	325 (441)	13 (17.6)	70 (94)	325 (441)
Weight		oz (gm)	0.93 (26)	1.59 (45)	9.6 (271)	0.87 (24.6)	1.5 (42.5)	9.9 (280)
Supplied Accessories [2]								
Mounting Stud (beryllium-copper)		model	081A70	081A74	081A71	081A70	081A74	081A71
Mounting Stud Thread		size	5/16-24	1/2-20	7/8-14	5/16-24	1/2-20	7/8-14
Anti-Friction Washer		model	082B02	082M12	082B06	082B02	082M12	082B06
Pilot Bushing		model	083A10	083A13	083A11	083A10	083A13	083A11
Optional Models								
Reverse Shear Polarity		model	–	–	–	260A31	260A32	260A33
Options [3]		**prefix**	**M,W**	**M,W**	**M,W**	**M,W**	**M,W**	**M,W**

NOTES:

[1] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[2] See page 1.69 for complete accessory listings.

[3] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric accessory model number and threads, see page 1.16.

[4] Resolution, System Discharge Time Constant and Low Frequency range are dependent upon sensor cable and signal conditioning used.

[5] Recommended pre-load is required to meet published specification and calibration.

3-Component Quartz Force Sensors
Force-limited Vibration Testing

The PCB Force-limited Vibration Testing System is utilized for limiting the reaction force between the shaker and unit under test (UUT) in random vibration testing. Piezoelectric triaxial force sensors facilitate accurate measurement of the input forces. The system also contains the signal conditioning required to process the force sensor signals used for shaker feedback control.

Due to the high cost and uniqueness of sophisticated aerospace and other high-tech equipment, it has become imperative to implement techniques that ensure the safety of the items during vibration qualification testing. Conventional control using acceleration has been shown to cause significant over-testing that may result in damage to the UUT. In force-limited vibration testing, the total input force to the UUT is measured and controlled thereby limiting the "quasi-static" acceleration of the center-of-gravity and ensuring the integrity of the equipment.

Benefits:

- minimizes over-testing
- reduces risk of damage to critical structures
- measures summed forces
- measures force differences (moments)
- simplifies and expedites the test process
- convenient and easy to implement

Signal Conditioning System Component Specifications	
MODEL 443B102 — Dual Mode Amplifier Module	
Channels	1
Display (menu driven)	Backlit 2 x 16 character LCD
Voltage Gain (ICP®)	x0.1 to x1000 (4-digit resolution)
Charge Gain (Charge Output)	0.1 to 10k mV/pC (4-digit resolution)
Discharge Time Constant (Seconds)	0.18, 1.8, 10, 100, 10k, >100k
Drift [1]	<0.03 pC/sec
Broadband Noise (ICP®) [2] (2 Hz to 22.4k Hz)	<3 uV (<110.5 dB)
Broadband Noise (Charge Output) [3] (2 Hz to 22.4k Hz)	<5 fC (<0.005 pC)
Low Frequency Response (-10%)	2, 0.2, 0.03, 0.003, 0.0003, ~0 Hz
High Frequency Response (-10%)	0.1,1, 3, 10, 30, >100k Hz
MODEL 441A101 — AC Power Supply Module	
Power Required	100 to 240 V, 50 to 60 Hz
Power Output	45 W
MODEL 070M70 — Charge Summation Node Module	
Input	8-Channels of charge output sensor signals
Summed Output (Charge Output)	1-Channel (A + B + C + D + E + F + G + H)
Insulation Resistance	>10^{14} Ohm
MODEL 070M69 — Computational Signal Conditioner	
Input	8-Channels of ICP® sensor or voltage signals
Computational Function	[(A-B) + (C-D) + (E-F) + (G-H)] x Gain
Excitation Voltage (ICP®)	24 VDC
Excitation Current (Selectable)	0, 2, 4, 8, 12, 20 mA
Differenced Output	4 Channels: (A-B), (C-D), (E-F), (G-H)
Function Output	1 Channel
Gain	x1, x10, x100
Force-limited Vibration Testing System	
Dimensions (L x W x H)	15.6 x 19.0 x 9.38 in
	(396 x 483 x 238 mm)

See typical system on p. 1.42.

A PCB Force-limited Vibration Testing System contains the sensors and signal conditioning required to process force signals from piezoelectric charge output force sensors for shaker control testing.

Force-limited Vibration Testing System

The sample system described here sums the forces in x- and y-axes and sums the difference of 4 pairs of z-axis signals. Custom systems are available to suit your individual requirements. Please contact the factory for more information.

Notes:

[1] Long discharge time constant mode.

[2] Measured at gain of 1000 (60 dB), input referred, 0.2 Hz low frequency setting.

[3] Measured at gain of 10 V/pC (80 dB) with a 1 nF source capacitance, input referred, short and medium discharge time constant modes.

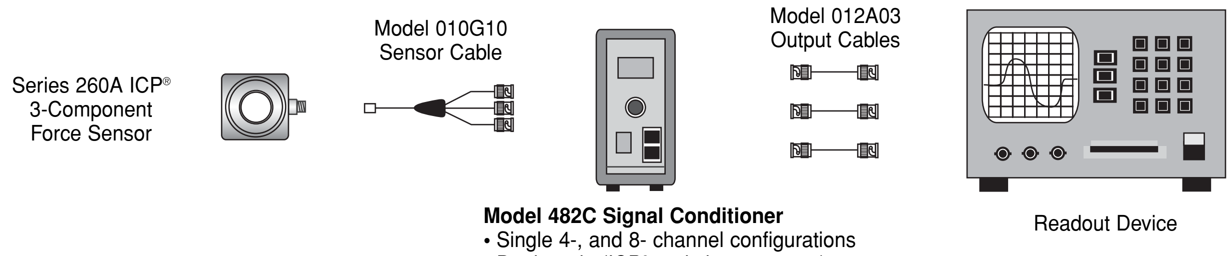
Force-limited Vibration Testing System consists of:

- 441A49 Chassis
- 441A101 AC Power Supply Modules
- 443B102 Dual Mode Amplifier Modules
- 070M69 Computational Signal Conditioner
- 070M70 Charge Summing Node Modules
- 3-Component Force Sensors

QUARTZ

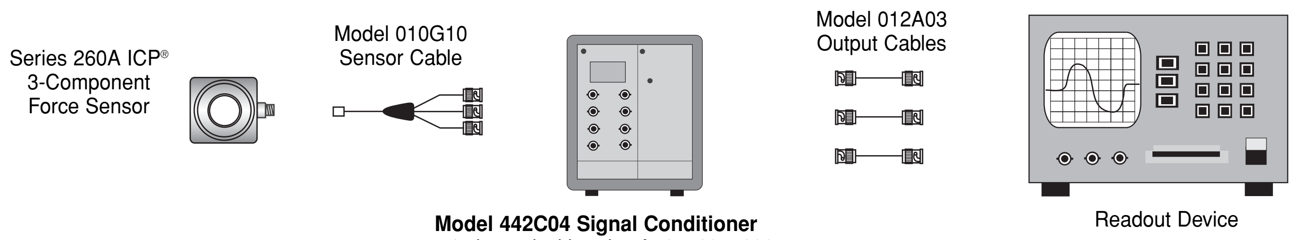
Typical ICP® 3-Component Force Measurement Systems

Low-cost System Utilizing a Unity Gain ICP® Sensor Signal Conditioner



Model 482C Signal Conditioner
- Single 4-, and 8- channel configurations
- Dual mode (ICP® and charge output)
  (See page 1.62 for more information)

System Utilizing a Modular ICP® Sensor Signal Conditioner with Gain



Model 442C04 Signal Conditioner
- 4-channel with gain of x1, x10, x100
  (See page 1.64 for more information)

System can be expanded to accommodate multiple sensors by inserting additional four-channel signal conditioning modules. Request Modular Signal Conditioning Brochure for more information on Modular Signal Conditioning Systems.

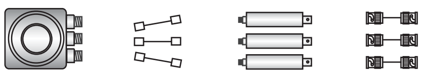
Suggested Sensor Accessories		
Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)		
Model 010G10	4-pin to (3) BNC plugs	1.73
Model 002T10	BNC plug to BNC plug	1.70
Low-noise Sensor Cables		
The following cables are required to maintain CE conformance:		
Model 003C10	10-32 plug to BNC plug	1.71
Model 003A05	10-32 plug to 10-32 plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)		
Model 012A03	BNC plug to BNC plug	1.72
Model 003D03	BNC plug to BNC plug	1.71

Typical Charge Output Force Measurement Systems

Low-cost System Utilizing In-line Charge Converters

Model 003A05 Cable

Model 002T10 Cable*



Series 260A10 Charge Output 3-Component Force Sensor

Series 422 In-line Charge Converters

(See page 1.66 for more information)

To ICP® Sensor Signal Conditioners as shown on pages 1.60 to 1.65

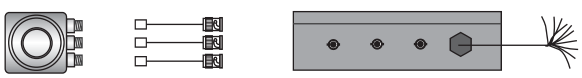
Suggested In-line Charge Converters

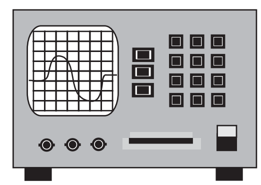
Sensor	Quantity	Model	Axis	Gain
260A11	2	422M120	X,Y	.30303 mV/pC
	1	422M121	Z	.35714 mV/pC
260A12	2	422M131	X,Y	.15625 mV/pC
	1	422M121	Z	.35714 mV/pC
260A13	2	422M122	X,Y	.03623 mV/pC
	1	422M123	Z	.03448 mV/pC

Low-cost System Utilizing 3-Channel Industrial Charge Amplifier

Series 260A10 Charge Output 3-Component Force Sensor

Model 003C10 Cable





Readout Device

Model 421A13 Industrial Charge Amplifier

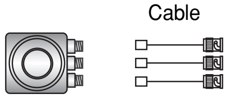
- 3-Channel, surface-mount enclosure
- Three selectable input ranges of 100-1000, 1000-10k, 10k-100k pC
- Long discharge time constant for long duration measurements with an electronic reset option
- Supplied with attached Model 037AD010AD 10 ft (3 m) 10-conductor cable, terminating in pigtails
- Ideal for continuously monitoring industrial crimping and stamping operations

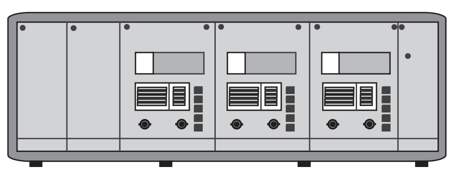
(See page 1.67 for more information)

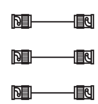
System Utilizing Configurable, 3-Channel Modular Charge Amplifiers

Series 260A10 Charge Output 3-Component Force Sensor

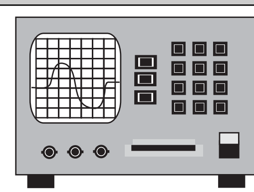
Model 003C10 Cable







Model 012A03 Cable



Readout Device

Configurable Module Charge Amplifier System

(3) Model 443B102 single channel charge amplifier module
- Various low frequency cut-offs including long discharge time constant
- Independent range settings for each channel
- 0.1 to 1000 mV/pC gain

(1) Model 441A101 power supply module

(2) Model 400A17 blank panel

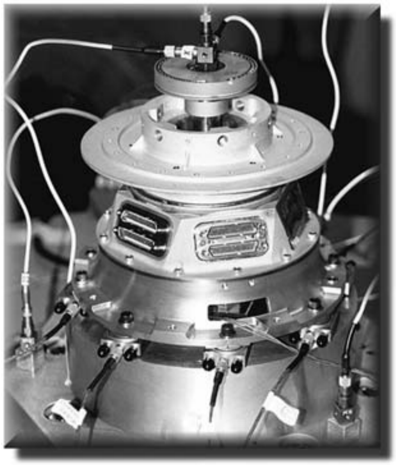
(1) Model 441A49 9-slot chassis

Configurable systems can be constructed with a variety of modules into 2, 3, 5, or 9 slot chassis to accommodate multiple sensors or signal conditioning requirements. Request Modular Signal Conditioning Brochure for more information on Modular Signal Conditioning Systems.

(See page 1.64 for more information)

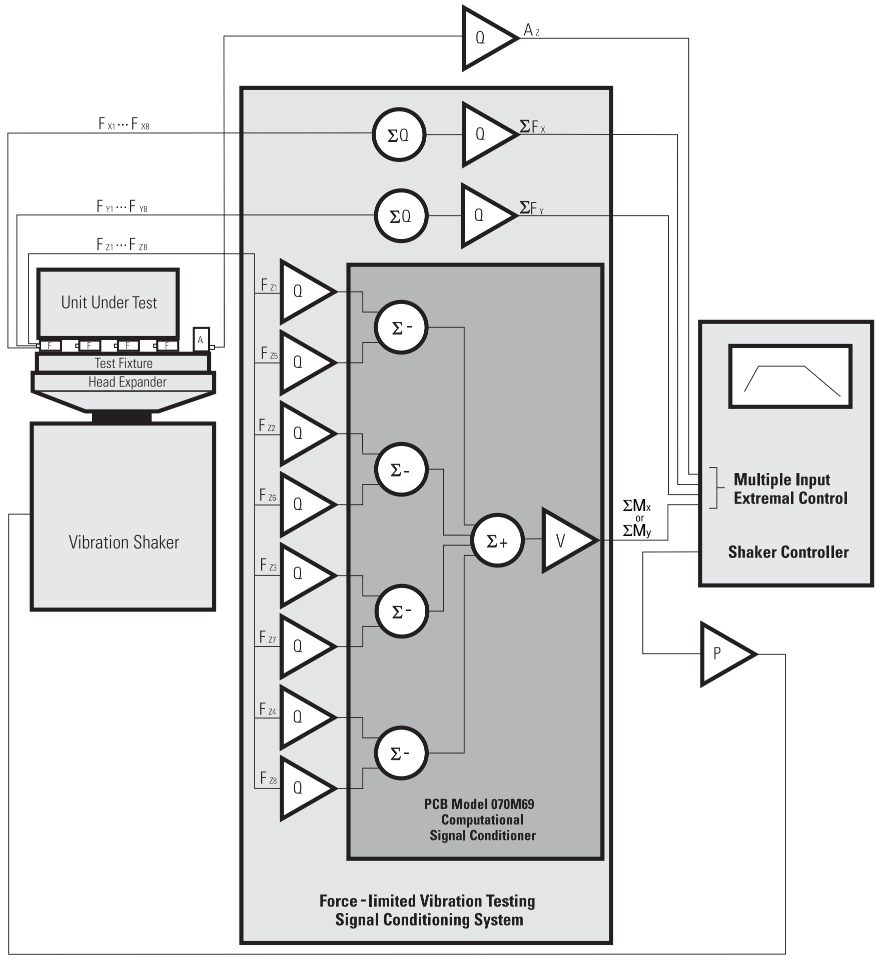
* Low-noise cable is required to maintain CE conformance.

QUARTZ



Force-limited Vibration Testing on an Atmospheric Infrared Sounder (used on Earth Observing System) utilizing 3-component force sensors and accelerometers.

Force-limited Vibration Testing Shaker Control System



LEGEND

- 3-Component Charge Output Force Sensor
- ICP® Accelerometer
- Dual Mode Amplifier
- Power Amplifier
- Voltage Amplifier
- Charge Summation Node
- Difference Amplifier
- Summing Amplifier

F = Force
A = Acceleration
M = Moment

FORCE-LIMITED VIBRATION TESTING

Model 443B102 Dual Mode Amplifier

- Long discharge time constant facilitates calibration and quasi-static measurements
- Digitally set and easy to operate
- Conditions charge output and ICP® sensor signals

Model 070M70 Charge Summation Node

- Sums up to eight, charge output sensor signals
- Eliminates excessive charge amplifiers and keeps system cost to a minimum

Model 070M69 Computational Signal Conditioner

- Conditions and accepts up to 8 sensor signals
- Computes: [(A - B) + (C - D) + (E - F) + (G - H)] x Gain

Series 260A10 Charge Output, 3-Component Force Sensors

Quartz Impact Force Sensors

- **Impact measurements**
- **Crash testing**
- **Punch and tablet presses**
- **Package drop testing**

Quartz impact force sensors are specifically designed for compressive impact loading. Most are supplied with removable impact caps with a curved impacting surface. This helps avoid "edge loading" and directs the applied force to the center of the sensor. The cap provides an added benefit of protecting the surface of the sensor. Should the surface of the cap become damaged through repeated impacting, it can easily and economically be replaced.

Impact force sensors are available in many standard ranges and 3 standard sizes for measuring dynamic and short term static compression and impact forces. Versions are available to accommodate full-scale compression measurements from 10 to 50k lb (45 to 220k N). The low profile and small inertial mass make them an excellent choice for fast transient and repetitive pulse applications.

These sensors measure compression forces on punch presses, tablet presses, metal forming machines, and impact testers. They are commonly used for controlling, monitoring, sorting, counting, adjusting, calibrating, and shock testing.

QUARTZ

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Quartz Impact Force Sensors

IMPACT
(*complete specifications are featured on page* 1.45 *to* 1.46)

Impact force sensors are rugged, stable, hermetically-sealed instruments with a stainless steel design, making them ideal for high frequency dynamic compression and impact testing. Available in both ICP® and charge output styles, these sensors are designed to last millions of cycles under demanding environmental conditions.

- punching and stamping presses
- crash testing
- drop testing

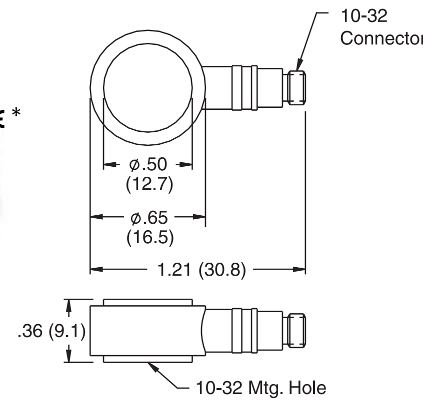
Accessory key located on page 1.46

Models 200B01 to 200B05 (accessory key ❷②)

- Sensitivity ranges from 1 to 500 mV/lb (0.22 to 110 mV/N)
- Full-scale compression ranges from 10 to 5000 lb (45 to 22k N)
- Low profile of 0.36 inch (9.1 mm)
- 0.5 oz (14 gm) in weight
- Charge output **Model 210B** generates 18 pC/lb (4 pC/N) (accessory key ②)

CE *

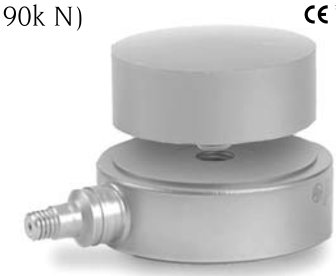
Models 200B01 to 200B05 and 210B



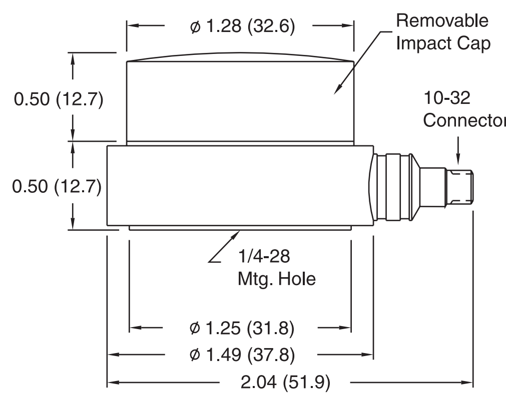
Model 200C20 (accessory key ❷②)

- Sensitivity of 0.25 mV/lb (0.06 mV/N)
- Compression range to 20k lb (90k N)
- Removable impact cap
- 3.1 oz (88 gm) in weight
- Charge output **Model 210B20** generates 18 pC/lb (4 pC/N) (accessory key ②)

CE *



Models 200C20 and 210B20

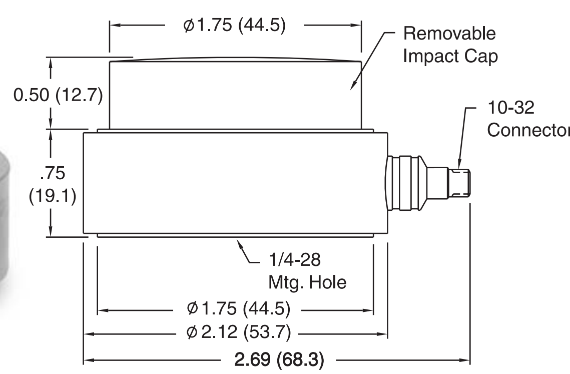


Model 200C50 (accessory key ❷②)

- Sensitivity of 0.10 mV/lb (0.022 mV/N)
- Compression range to 50k lb (220k N)
- Removable impact cap
- 9.9 oz (280 gm) in weight
- Charge output **Model 210B50** generates 18 pC/lb (4 pC/N) (accessory key ②)

CE *

Models 200C50 and 210B50



* Charge output sensors are CE exempt.
Dimensions shown are in inches (millimeters).

ICP® Quartz Impact Force Sensors

QUARTZ

ICP® Quartz Impact Force Sensors								
Model Number	**Unit**	**200B01**	**200B02**	**200B03**	**200B04**	**200B05**	**200C20**	**200C50**
Performance Specifications								
Compression Range [1]	lb (N)	10 (45)	100 (450)	500 (2200)	1000 (4500)	5000 (22k)	20k (90k)	50k (220k)
Maximum Compression	lb (N)	150 (700)	600 (2700)	3000 (13k)	5000 (22k)	8000 (35k)	30k (130k)	75k (330k)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	500 (110)	50 (11)	10 (2.2)	5 (1.1)	1 (0.22)	0.25 (0.06)	0.10 (0.022)
Resolution (broadband)	lb rms	0.0002	0.002	0.01	0.02	0.10	0.30	1
	N rms	0.0009	0.009	0.045	0.09	0.45	1.3	4.5
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	75k	75k	75k	75k	75k	40k	30k
Low Freq. Response (-5%)	Hz	0.01	0.001	0.0003	0.0003	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.08	≤ 0.15
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.14	≤ 0.27
Electrical Specifications								
Discharge Time Constant [2]	second	≥ 50	≥ 500	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 12	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	18 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive	positive	positive
Physical Specifications								
Mounting Thread	size	10-32 female	10-32 female	10-32 female	10-32 female	10-32 female	1/4-28 female	1/4-28 female
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	11 (1.9)	11 (1.9)	11 (1.9)	11 (1.9)	11 (1.9)	63 (11)	97 (17)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4	304L / 17-4
Impact Cap Material (st. stl.)	type	17-4	17-4	17-4	17-4	17-4	440C	440C
Weight	oz (gm)	0.5 (14)	0.5 (14)	0.5 (14)	0.5 (14)	0.5 (14)	3.1 (88)	9.9 (280)
Supplied Accessories [3]								
Mounting Stud	model	081B05	081B05	081B05	081B05	081B05	081A06 / 081B20	081A06 / 081B20
Impact Cap	model	integral [4]	integral [4]	integral [4]	integral [4]	integral [4]	084B23	084A36
Thread Locker	model	080A81	080A81	080A81	080A81	080A81	080A81	080A81
Options [5]	**prefix**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**

NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[3] See page 1.69 for complete accessory listings.

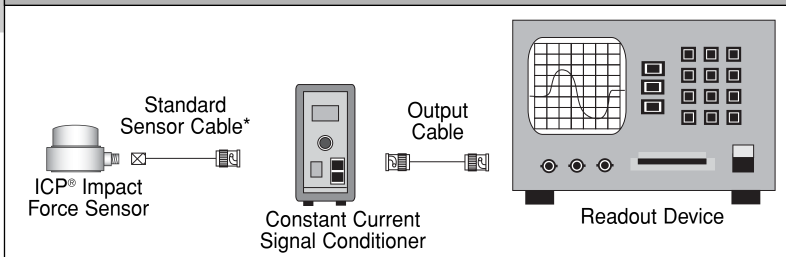
[4] Rubber impact pad supplied.

[5] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric accessory mounting studs and screws, see page 1.16.

Available Sensor Options	
Prefix	**Descriptions**
M	Metric Mounting
N	Negative Polarity
P	Positive Polarity
W	Attached Water-resistant Cable

Designate option as prefix to model number, e.g., Model M200C20 specifies a unit for metric mounting.

Typical ICP® Quartz Impact Force Sensor Measurement System



* Low-noise cable is required to maintain CE conformance.

Charge Output Quartz Impact Force Sensors

Charge Output Impact Force Sensors

Model Number [1]	Unit	210B	210B20	210B50
Performance Specifications				
Compression Range [2]	lb (N)	5000 (22k)	20k (90k)	50k (220k)
Maximum Compression	lb (N)	10k (45k)	30k (130k)	75k (330k)
Charge Sensitivity (± 15%)	pC/lb (pC/N)	18 (4)	18 (4)	18 (4)
Amplitude Linearity	% FS	≤ 1	≤ 2	≤ 2
Upper Frequency Limit	Hz	75k	40k	30k
Temperature Range	°F	-300 to +400	-300 to +400	-300 to +400
	°C	-184 to +204	-184 to +204	-184 to +204
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications				
Capacitance	pF	12	150	250
Insulation Resistance	ohm	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Polarity: Compression		negative	negative	negative
Physical Specifications				
Mounting Thread	size	10-32 female	1/4-28 female	1/4-28 female
Connector	type	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	11 (1.9)	63 (11)	97 (17)
Sealing	type	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	304L / 17-4	304L / 17-4	304L / 17-4
Impact Cap Material (st. stl.)	type	17-4	440C	440C
Weight	oz (gm)	0.5 (14)	3.1 (88)	9.9 (280)
Supplied Accessories [3]				
Mounting Stud	model	081B05	081A06 / 081B20	081A06 / 081B20
Thread Locker Adhesive	model	080A81	080A81	080A81
Impact Cap	model	integral [4]	084B23	084A36
Options [5]	**prefix**	**M,P,W**	**M,P,W**	**M,P,W**

NOTES:

[1] Special lower ranged calibration for charge output models is available upon request.

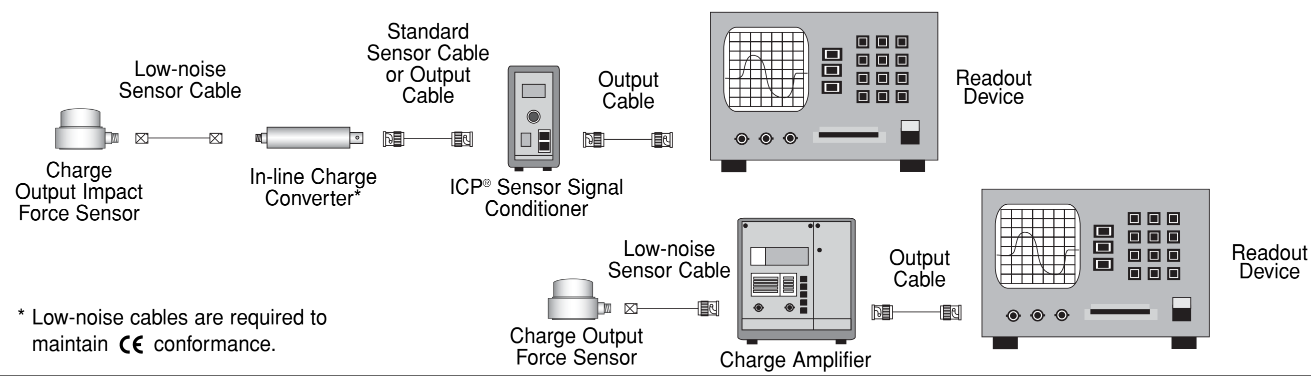
[2] 1 lb = 4.448 N (values shown are approximate)

[3] See page 1.69 for complete accessory listings.

[4] Rubber impact pad supplied.

[5] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric mounting studs and screws, see page 1.16.

Typical Charge Output Quartz Impact Force Measurement Systems



* Low-noise cables are required to maintain CE conformance.

Suggested Sensor Accessories			
Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m) The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72

Suggested Sensor Signal Conditioners

Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.45 for a diagram of a typical ICP® impact force sensor measurement system.

*LTC = long discharge time constant

Miniature ICP® Quartz Force Sensors

- **Very small compression and tension forces**
- **Break point materials testing**
- **Penetration forces**
- **Print head monitoring**

Miniature quartz force sensors are designed for applications demanding small size and very high sensitivity. They can measure forces up to 2.2 lb (10 N) full-scale. They measure impact, reaction, light tension, and actuation forces involved in vibrating, balancing, striking, switching, punching, and pushing operations. They are adaptable for counting, sorting, indicating and similar operations.

Miniature force sensors are available in two standard configurations. One accommodates impact measurements, while the other incorporates a threaded "hat" for compression and tension measurements.

These sensors feature a very high output sensitivity of 2200 mV/lb (500 mV/N) and can follow transient events up to 50 milliseconds in duration. They respond with a rise time of less than 10 microseconds.

Miniature ICP® Quartz Force Sensors

MINIATURE (*complete specifications are featured on page* 1.49)

Miniature force sensors offer a unique combination of characteristics, including high sensitivity, high rigidity, and microsecond response, all in a small package. They are housed in rugged stainless steel and are available with either a 1 or 10 second discharge time constant. The 10 second time constant models allow for extended low frequency measurements associated with longer duration applications in thermally-stable environments.

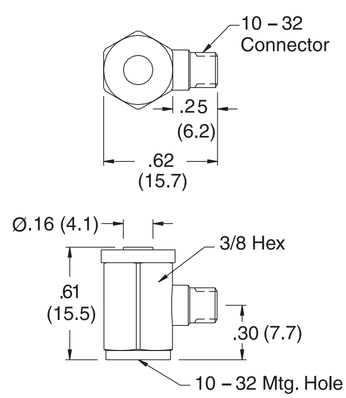
- counting
- indicating
- striking
- sorting
- punching

Accessory key located on page 1.49

Model 209C01 (accessory key ❷②)
- Sensitivity of 2200 mV/lb (500 mV/N)
- Compression range to 2.2 lb (10 N)
- Discharge time constant of ≥ 1 sec
- Integral impact cap

Model 209C02 (accessory key ❷②)
- Sensitivity of 2200 mV/lb (500 mV/N)
- Compression range to 2.2 lb (10 N)
- Discharge time constant of ≥ 10 sec
- Integral impact cap

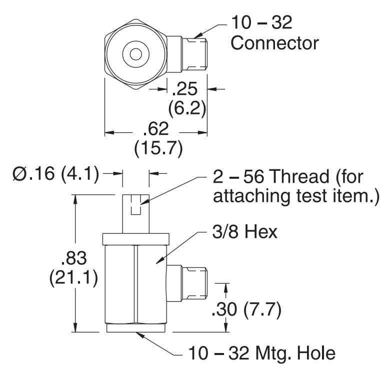
Models 209C01 and 209C02



Model 209C11 (accessory key ❷②)
- Sensitivity of 2200 mV/lb (500 mV/N)
- Compression range to 2.2 lb (10 N)
- Tension range to 1 lb (4.5 N)
- Discharge time constant of ≥ 1 sec
- Integral 2-56 threaded hat for attaching test items

Model 209C12 (accessory key ❷②)
- Sensitivity of 2200 mV/lb (500 mV/N)
- Compression range to 2.2 lb (10 N)
- Tension range to 1 lb (4.5 N)
- Discharge time constant of ≥ 10 sec
- Integral 2-56 threaded hat for attaching test items

Models 209C11 and 209C12



Available Sensor Options	
Prefix	Descriptions
M	Metric Mounting
N	Negative Polarity
W	Attached Water-resistant Cable

Designate option as prefix to model number, e.g., Model M209C01 specifies a unit for metric mounting.

Dimensions shown are in inches (millimeters).

Miniature Force Sensors

Model Number	Unit	209C01	209C02*	209C11	209C12*
Performance Specifications					
Compression Range [1]	lb (N)	2.2 (10)	2.2 (10)	2.2 (10)	2.2 (10)
Tension Range	lb (N)	N/A	N/A	1 (4.5)	1 (4.5)
Maximum Compression	lb (N)	11 (50)	11 (50)	11 (50)	11 (50)
Maximum Tension	lb (N)	N/A	N/A	1 (4.5)	1 (4.5)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	2200 (500)	2200 (500)	2200 (500)	2200 (500)
Resolution (broadband)	lb rms	0.00002	0.00002	0.00002	0.00002
	N rms	0.00009	0.00009	0.00009	0.00009
Upper Frequency Limit	Hz	100k	100k	30k	30k
Low Freq. Response (-5%)	Hz	0.5	0.05	0.5	0.05
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
	%/°C	≤ 0.09	≤ 0.09	≤ 0.09	≤ 0.09
Electrical Specifications					
Discharge Time Constant [2]	second	≥ 1	≥ 10	≥ 1	≥ 10
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 12	8 to 12	8 to 12	8 to 12
Voltage Excitation	+VDC	18 to 30	18 to 30	18 to 30	18 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive
Physical Specifications					
Mounting Thread	size	10-32 female	10-32 female	10-32 female	10-32 female
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/µin (kN/µm)	2 (0.35)	2 (0.35)	2 (0.35)	2 (0.35)
Sealing	type	hermetic weld	hermetic weld	hermetic weld	hermetic weld
Material (stainless steel)	type	17-4	17-4	17-4	17-4
Weight	oz (gm)	0.28 (8)	0.28 (8)	0.29 (8.2)	0.29 (8.2)
Supplied Accessories [3]					
Mounting Stud	model	081A05	081A05	081A05	081A05
Thermal Cover	model	084A38	084A38	084A38	084A38
Options [4]	**prefix**	**M,N,W**	**M,N,W**	**M,N,W**	**M,N,W**

* Use only in thermally-stable environments

NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[3] See page 1.69 for complete accessory listings.

[4] See pages 1.16 to 1.17 for a description of options (specifications for optional versions may differ slightly. Consult factory before ordering). For complete listing of metric accessory model number and threads, see page 1.16.

Suggested Sensor Accessories

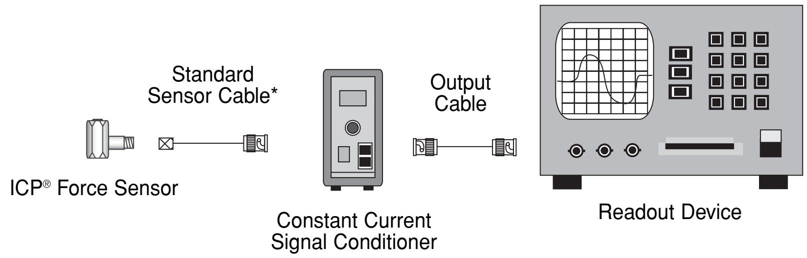
Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m)			
The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

Suggested Sensor Signal Conditioners

Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.50 for a diagram of a typical miniature ICP® quartz force sensor measurement system.
*LTC = long discharge time constant

Typical Miniature-style ICP® Quartz Force Sensor Measurement System



* Low-noise cables are required to maintain CE conformance.

PCB's machining capabilities allow full control of the production of precision parts to insure quality and timely delivery. Capabilities including dual spindle CNC lathes, wire EDM machines, and injection molding machines fabricate in excess of 200,000 parts per month to exacting standards.

Penetration-style ICP® Quartz Force Sensors

- **Material strength testing**
- **Drop testing**
- **Testing of plastics**
- **Penetration testing**

Penetration-style quartz force sensors measure impact and compression forces associated with materials penetration testing. The blunt sensor end makes it possible to measure yield and break point forces on materials such as polymers without cutting through the test specimen.

The blunt impact caps are hemispherical to uniformly distribute force and conform to most penetration testing specifications. Sensors are available with both integral and removable impact caps. Tension measurements can be made with models having removable caps.

These sensors monitor impact forces from 100 to 5000 lb (450 to 22k N) full-scale. They can be used to determine physical properties of plastics and material strength or deformation characteristics of injection molded test specimens and thermal forms. They may be installed at the end of a shaft mounted to a driven fixture that impacts the test specimen.

Penetration-style ICP® Quartz Force Sensors

PENETRATION

(*complete specifications are featured on page* 1.53)

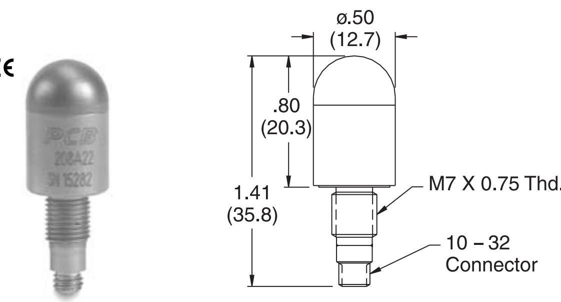
Penetration-style sensors are used to determine material strength or deformation characteristics of polymers and plastics. Built-in microelectronics generate a low-impedance voltage output and a high signal-to-noise ratio. Rugged, stainless steel construction prolongs life under normal use. Temperature range of –65 to +250 °F (–54 to +121 °C) enables laboratory testing in thermal chamber environments. Metric mounting threads are standard for this sensor series.

- polymer and plastics testing
- injection molded specimen testing

Accessory key located on page 1.53

Models 208A22, 208A23 and 208A24
(accessory key ❷②)

- Sensitivity ranges from 1 to 50 mV/lb (0.22 to 11 mV/N)
- Full-scale compression ranges from 100 to 2500 lb (450 to 11k N)
- Integral impact cap



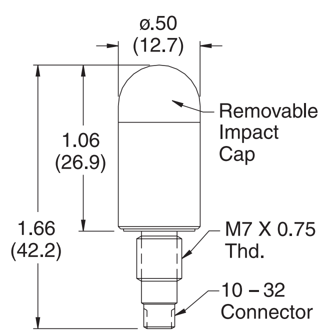
Models 208A22, 208A23 and 208A24

Model 208A33 (accessory key ❷②)

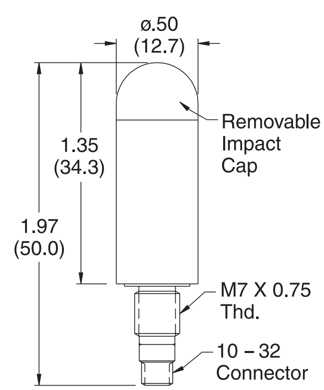
- Sensitivity of 5.0 mV/lb (1.1 mV/N)
- Compression range to 1000 lb (4500 N)
- Tension range to 500 lb (2200 N)
- Removable impact cap

Model 208A35 (accessory key ❷②)

- Sensitivity of 1.0 mV/lb (0.22 mV/N)
- Compression range to 5000 lb (22k N)
- Tension range to 500 lb (2200 N)
- Removable impact cap



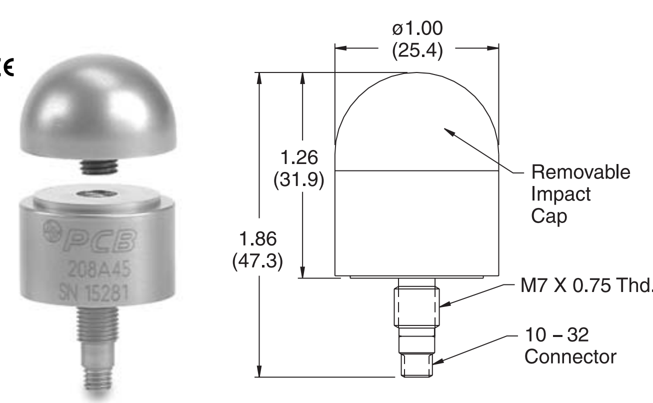
Model 208A33



Model 208A35

Model 208A45 (accessory key ❷②)

- Sensitivity of 1.0 mV/lb (0.22 mV/N)
- Compression range to 5000 lb (22k N)
- Tension range to 500 lb (2200 N)
- Removable impact cap



Model 208A45

Dimensions shown are in inches (millimeters).

Penetration-style ICP® Quartz Force Sensors

Penetration-style Force Sensors							
Model Number	**Unit**	**208A22**	**208A23**	**208A24**	**208A33**	**208A35**	**208A45**
Performance Specifications							
Compression Range [1]	lb (N)	100 (450)	1000 (4500)	2500 (11k)	1000 (4500)	5000 (22k)	5000 (22k)
Tension Range	lb (N)	N/A	N/A	N/A	500 (2200)	500 (2200)	500 (2200)
Maximum Compression	lb (N)	600 (2700)	2500 (11k)	2500 (11k)	5000 (22k)	10k (45k)	10k (45k)
Maximum Tension	lb (N)	N/A	N/A	N/A	750 (3300)	750 (3300)	750 (3300)
Voltage Sensitivity (± 15%)	mV/lb (mV/N)	50 (11)	5 (1.1)	1 (0.22)	5 (1.1)	1 (0.22)	1 (0.22)
Resolution (broadband)	lb rms (N) rms	0.002 (0.009)	0.02 (0.09)	0.10 (0.45)	0.02 (0.09)	0.10 (0.45)	0.10 (0.45)
Amplitude Linearity	% FS	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Upper Frequency Limit	Hz	18k	18k	18k	20k	20k	25k
Low Freq. Response (-5%)	Hz	0.003	0.0003	0.0003	0.0003	0.0003	0.0003
Temperature Range	°F	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250	-65 to +250
	°C	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121	-54 to +121
Temperature Coefficient	%/°F	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.03
	%/°C	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054	≤ 0.054
Electrical Specifications							
Discharge Time Constant [2]	second	≥ 200	≥ 2000	≥ 2000	≥ 2000	≥ 2000	≥ 2000
Output Impedance	ohm	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14	8 to 14
Voltage Excitation	+VDC	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20	2 to 20
Polarity: Compression		positive	positive	positive	positive	positive	positive
Physical Specifications							
Mounting Thread	size	M7 x 0.75 male	M7 x 0.75 male	M7 x 0.75 male	M7 x 0.75 male	M7 x 0.75 male	M7 x 0.75 male
Connector	type	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax	10-32 coax
Stiffness	lb/μin (kN/μm)	5 (0.88)	5 (0.88)	5 (0.88)	5 (0.88)	5 (0.88)	10 (1.75)
Sealing	type	o-ring	o-ring	o-ring	epoxy	hermetic weld	epoxy
Material (stainless steel)	type	316L / 17-4	316L / 17-4	316L / 17-4	316L / 17-4	17-4	316L / 17-4
Impact Cap Material	type	titanium	titanium	titanium	17-4 st. stl.	17-4 st. stl.	17-4 st. stl.
Weight	oz (gm)	0.53 (15)	0.53 (15)	0.53 (15)	0.67 (19)	1.06 (30)	1.80 (51)
Supplied Accessories [3]							
Impact Cap	model	integral	integral	integral	084A19	084A35	084A45

NOTES:

[1] 1 lb = 4.448 N (values shown are approximate)

[2] The Discharge Time Constant (DTC) determines low frequency response according to the relationship $f_{-5\%}=3/(2\pi(DTC))$. Sensors accurately follow transient events lasting a few percent of the DTC. For square wave events, the DTC should be 100 times the event duration. For ramp shape events, the DTC should be 50 times the event duration and for a half sine pulse the DTC should be 25 times the pulse duration. To ensure measurement system compatibility, use DC coupled or Long Time Constant signal conditioners for long duration transient measurements.

[3] See page 1.69 for complete accessory listings.

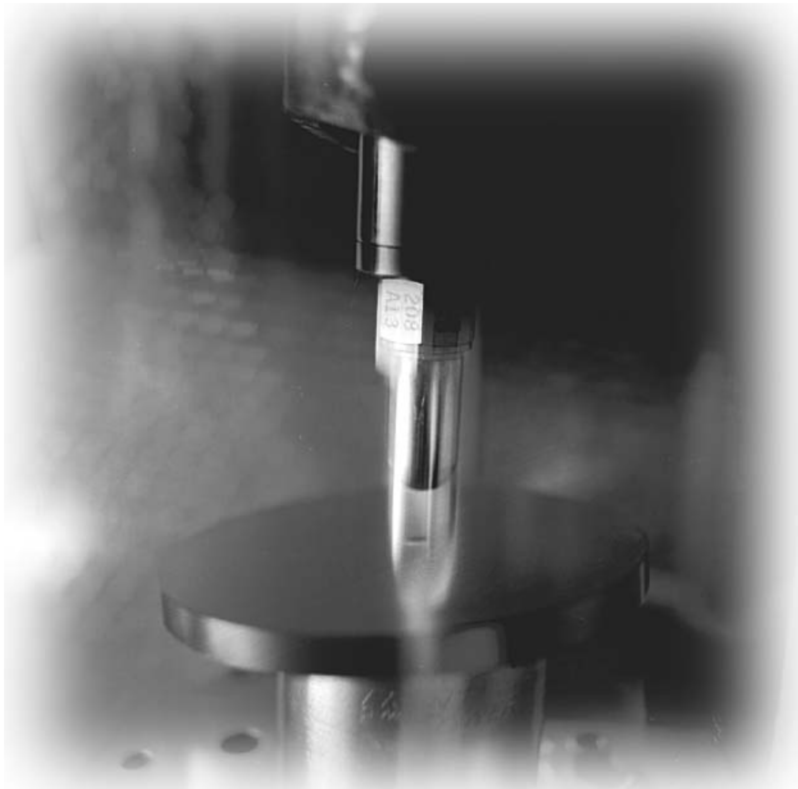
Suggested Sensor Accessories			
Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m)			
The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

Suggested Sensor Signal Conditioners						
Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.54 for a diagram of a typical penetration-style ICP® force sensor measurement system.
*LTC = long discharge time constant

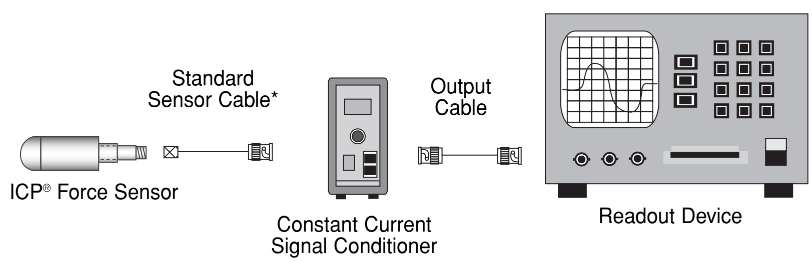
QUARTZ

Penetration-style ICP® Quartz Force Sensors



Penetration-style quartz force sensors measure impact forces to 5000 lb (22k N) for determining yield strength and deformation characteristics of plastics, polymers, and composite materials.

Typical Penetration-style ICP® Quartz Force Sensor Measurement System



* Low-noise cable is required to maintain CE conformance.

ICP® Strain Sensors

- **Measure longitudinal strain on machinery structures**
- **Control press forces and other processes**
- **Monitor quality, safety, and reliability**
- **Robust construction endures harsh, industrial environments**
- **Simple installation is non-invasive to process**

The Series M240 Industrial ICP® Strain Sensors incorporate piezoelectric quartz sensing crystals that respond to a longitudinal change in distance. The resultant strain measurand is an indirect measurement of stress forces acting along the structure to which the sensor is mounted. As such, these devices can provide insight into the behavior of mechanical systems or processes that generate an associated machinery reaction.

Monitoring such measurement signals can provide the necessary indication for process interrupt and pass/fail decisions or for determining wear and degradation of equipment and tooling. The sensors are used for controlling processes in plastic injection molding, stamping, and pressing, as well as monitoring processes and final product quality. These devices are easy to install and can be powered by any ICP® sensor signal conditioner.

Series M240
Industrial ICP® Strain Sensors
(Actual Size)

ICP® Strain Sensors

ICP® STRAIN SENSORS

(*complete specifications are featured on page* 1.57)

Series M240 ICP® Strain Sensors are ideal for process control and other product quality assurance applications that require the measurement of repetitive strain curves. In typical applications, upper and lower control limits are set following a desired strain curve for the process, and if the actual strain curve deviates from the pre-set control limits, the process or equipment is shut down. This prevents the acceptance of non-conforming parts as finished goods. ICP® strain sensors are used for controlling processes in plastic injection molding, stamping, pressing, punching, crimping, forming, and automatic assembly operations. Sensors are constructed of rugged stainless steel housings, are extremely easy to install (using only one supplied fastening screw), and are non-invasive to the test structure except for one drilled and tapped hole. Series M240 Strain Sensors can be powered by any ICP® sensor signal conditioner.

- mechanical stamping, crimping, pressing, and punching presses
- plastic injection molding machines
- forming and other machine tools
- automatic assembly machines

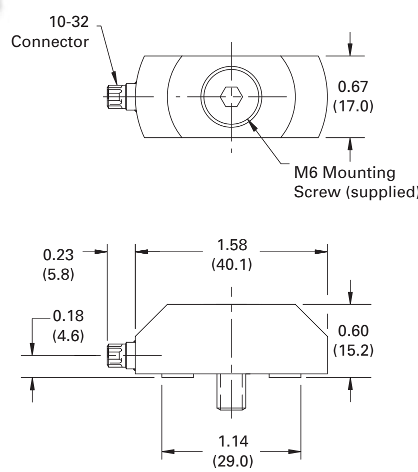
Accessory key located on page 1.57

Model M240A01 (accessory key ❷②)
- Sensitivity (± 20%) of 100 mV/με
- Amplitude range to 50 pk με
- Resolution (1 Hz to 10 kHz) to 0.0001 με
- Discharge time constant of ≥ 150 seconds

Model M240A02 (accessory key ❷②)
- Sensitivity (± 20%) of 50 mV/με
- Amplitude range to 100 pk με
- Resolution (1 Hz to 10 kHz) to 0.0002 με
- Discharge time constant of ≥ 150 seconds

Model M240A03 (accessory key ❷②)
- Sensitivity (± 20%) of 10 mV/με
- Amplitude range to 300 pk με
- Resolution (1 Hz to 10 kHz) to 0.001 με
- Discharge time constant of ≥ 150 seconds

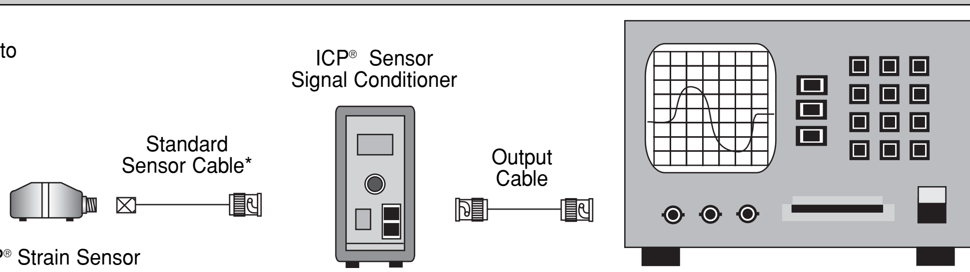
Series M240



Series M240
Industrial ICP® Strain Sensors

Dimensions shown are in inches (millimeters).

Typical ICP® Strain Sensor Measurement System



ICP® Strain Sensors				
Model Number	**Unit**	**M240A01**	**M240A02**	**M240A03**
Performance Specifications				
Range	pk με	50	100	300
Sensitivity (± 20%)	mV/με	100	50	10
Resolution (1 Hz to 10 kHz)	με	0.0001	0.0002	0.001
Low Frequency Response (-5%)	Hz	0.004	0.004	0.004
Linearity	%	± 2	± 2	± 2
Operating Temperature	°F (°C)	-65 to +250 (-54 to +121)	-65 to +250 (-54 to +121)	-65 to +250 (-54 to +121)
Electrical Specifications				
Excitation Voltage	+VDC	20 to 30	20 to 30	20 to 30
Constant Current Excitation	mA	2 to 20	2 to 20	2 to 20
Output Bias Voltage	+VDC	8 to 14	8 to 14	8 to 14
Discharge Time Constant	sec	≥ 150	≥ 150	≥ 150
Physical Specifications				
Sensing Element		quartz	quartz	quartz
Housing	material	stainless steel	stainless steel	stainless steel
Size (W x L x H)	in (mm)	0.67 x 1.81 x 0.6 (17 x 46 x 15.2)	0.67 x 1.81 x 0.6 (17 x 46 x 15.2)	0.67 x 1.81 x 0.6 (17 x 46 x 15.2)
Weight	oz (gm)	1.6 (45)	1.6 (45)	1.6 (45)
Electrical Connector	type	10-32	10-32	10-32
Sealing	type	epoxy	epoxy	epoxy
Mounting Screw		M6 x 1.00-6g	M6 x 1.00-6g	M6 x 1.00-6g
Mounting Screw Torque	ft-lb (N-m)	7.38 (10)	7.38 (10)	7.38 (10)

Suggested Sensor Accessories			
Usage Key	Model	Description	See Page
Standard Sensor Cables 10 ft length (3.0 m)			
❷	Model 002C10	10-32 plug to BNC plug	1.70
Low-noise Sensor Cables 10 ft length (3.0 m)			
The following cables are required to maintain CE conformance:			
②	Model 003C10	10-32 plug to BNC plug	1.71
Output Cables for ALL Sensor Systems 3 ft length (0.9 m)			
	Model 012A03	BNC plug to BNC plug	1.72
	Model 003D03	BNC plug to BNC plug	1.71

Suggested Sensor Signal Conditioners						
Model	Power	Channels	Gain	Coupling	Comment	Page
480C02	battery	1	unity	AC	portable	1.60
480E09	battery	1	x1, x10, x100	AC	portable	1.60
443B02	line	1	0.1 to 1000	AC/LTC*	dual mode	1.64
482C	line	1, 4, 8	x1, x10, x100	AC/DC	dual mode	1.62

See page 1.56 for a diagram of a typical ICP® strain sensor measurement system.
*LTC = long discharge time constant

ICP® Strain Sensors

ICP® strain sensors indirectly monitor forces via strain measurements on machine tools and production machinery. Strain sensors are used for controlling processes in plastic injection molding, stamping, pressing, punching, crimping, forming, and automatic assembly operations. Series M240 Strain Sensors may be powered by any ICP® sensor signal conditioner.

Signal Conditioners

- **Battery powered signal conditioners**
- **Line powered signal conditioners**
- **Multi-purpose signal conditioners**
- **Modular-style signal conditioners**
- **Multi-channel signal conditioners**
- **Charge and impedance converters**
- **Industrial charge amplifiers and sensor simulators**

QUARTZ

Series 482C CE
Multi-purpose signal conditioners for powering pressure, force, and vibration sensors

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Battery Powered Signal Conditioners
for ICP® Sensors

BATTERY POWERED ICP® SENSOR SIGNAL CONDITIONERS

Battery powered signal conditioners offer portable, convenient methods for powering ICP® sensors and conditioning their output signals for transmittal to readout and recording instruments. Most units operate, and are supplied, with standard 9 volt alkaline batteries. Each features a color-coded input circuit check-out meter to alert of proper sensor turn-on or input fault due to open or short-circuit connections. Optional rechargeable versions are equipped with Ni-cad batteries and supplied with an AC powered recharger unit.

Model 480C02
Unity gain, low-noise,
high frequency

Model 480E09
Gain x1, x10, x100

Model 480B21
3-Channel,
gain x1, x10, x100

Battery Powered Signal Conditioners			
Model Number	**480C02**	**480E09**	**480B21**
Style	Basic	Gain	3 channel with gain
Channels	1 channel	1 channel	3 channels
Sensor excitation	28 VDC, 2.5 mA	28 VDC, 2.5 mA	25 to 30 VDC, 3 mA
Gain	unity	x1, x10, x100	x1, x10, x100
Low frequency response (-5%) [1]	0.05 Hz	0.15 Hz	0.15 Hz
High frequency response (-5%)	500k Hz	100k Hz	90k Hz
Broadband noise (at unity gain)	3.25 μV rms	3.25 μV rms	3.54 μV rms
Battery (qty) type	(3) 9 V	(3) 9 V	(3) 9 V
Average battery life	100 hour	40 hour	25 to 40 hour
Input/output connectors	BNC/BNC	BNC/BNC	BNC/BNC
External DC powerable	yes	yes	yes
DC power input jack	3.5 mm	3.5 mm	mini DIN 6-pin jack
Size (height x width x depth)	4.0 x 2.9 x 1.5 in (10 x 7.4 x 3.8 cm)	4.0 x 2.9 x 1.5 in (10 x 7.4 x 3.8 cm)	7.5 x 5 x 2 in (19.1 x 12.7 x 5.1 cm)
Weight	0.62 lb (284 g)	0.75 lb (341 g)	1.1 lb (499 g)
Optional Models			
Rechargeable (supplied with Ni-cad batteries and Model 488A02 AC powered recharger unit)	R480C02	R480E09	N/A
Options			
AC powered recharger unit with (3) 9 V Ni-cad batteries	488A02	488A02	N/A
AC power supply operates from 115 or 230 VAC	488A03	488A03	488A10

NOTE: [1] With 1 megohm load.

LINE POWERED ICP® SENSOR SIGNAL CONDITIONERS

Line powered signal conditioners offer bench-top methods for powering ICP® sensors in the laboratory and conditioning their output signals for transmittal to readout and recording instruments. Each features a color-coded input circuit check-out meter to alert of proper sensor turn-on or input fault due to open or short-circuit connections. AC and DC powerable units can operate either with the supplied AC powered transformer or optional external battery pack. AC/DC coupled outputs offer the ability to achieve true DC frequency response in order to accurately condition very low frequency vibrations or long duration shock pulses.

Model 482A21
Unity gain, low-noise, AC and DC powerable

Model 482A22
4-channel, unity gain, low-noise, AC and DC powerable

Model 482B06
Basic, unity gain

Model 482B11
Gain x1, x10, x100

Model 484B02
Clamped output, unity gain, AC/DC coupled output

Model 484B06
Low frequency, unity gain, AC/DC coupled output

Model 484B11
Low frequency, gain x1, x10, x100, AC/DC coupled output

Line Powered Signal Conditioners

Model Number	482A21	482A22	482B06	482B11	484B02	484B06	484B11
Style	Low-noise AC and DC power	Low-noise AC and DC power	Basic	Gain	Clamped output AC/DC coupled	Low frequency AC/DC coupled	Low frequency with gain
Channels	1 channel	4 channels	1 channel	1 channel	1 channel	1 channel	1 channel
Sensor excitation [1]	26 volt, 2 to 20 mA	26 volt, 2 to 20 mA	24 volt, 2 to 20 mA	24 volt, 2 to 20 mA	24 volt, 2 to 20 mA	24 volt, 2 to 20 mA	24 volt, 2 to 20 mA
Gain	unity	unity	unity	x1, x10, x100	unity	unity	x1, x10, x100
Low frequency response (-5%)	<0.1 Hz [2]	<0.1 Hz [2]	<0.05 Hz	0.17 Hz	DC	DC	DC
High frequency response (-5%)	>1M Hz	>1M Hz	1M Hz	200k Hz	200k Hz	200k Hz	200k Hz
Broadband noise (at unity gain)	<3.25 μV rms	<3.25 μV rms	<3.64 μV rms	N/A	28.8 μV rms	28.8 μV rms	10 μV rms
Power required	36 VDC 120 mA [3]	36 VDC 120 mA [3]	115 VAC 50 to 400 Hz	115 VAC 50 to 400 Hz	115 VAC 50 to 400 Hz	115 VAC 50 to 400 Hz	115 VAC 50 to 400 Hz
Input/output connectors	BNC/BNC	BNC/BNC	BNC/BNC	BNC/BNC	BNC/BNC	BNC/BNC	BNC/BNC
External DC powerable	yes	yes	no	no	no	no	no
DC power input jack	DIN	DIN	—	—	—	—	—
Size (height x width x depth)	6.3 x 2.4 x 11 in (16 x 6 x 28 cm)	6.3 x 2.4 x 11 in (16 x 6 x 28 cm)	4.3 x 1.8 x 6 in (11 x 4.6 x 15 cm)	4.3 x 1.8 x 6 in (11 x 4.6 x 15 cm)	5 x 2 x 10.5 in (12.7 x 5.1 x 26.7 cm)	4.3 x 1.8 x 6 in (11 x 4.6 x 15 cm)	4.3 x 1.8 x 6 in (11 x 4.6 x 15 cm)
Weight	1.51 lb (685 gm)	1.67 lb (756 gm)	1.2 lb (544 gm)	2 lb (907 gm)	2 lb (907 gm)	2 lb (907 gm)	2 lb (907 gm)
Optional Models							
210 to 250 VAC powerable	standard	standard	F482B06	F482B11	F484B02	F484B06	F484B11
Options							
External 36 VDC battery pack	488B07	488B07	N/A	N/A	N/A	N/A	N/A

NOTES: 1. Current is factory set at 4 mA but is user adjustable between 2 and 20 mA
2. With 1 megohm load
3. Supplied with Model 488A04 AC power adaptor (100 to 240 VAC, 50 to 60 Hz input; 36 VDC 120 mA output)

MULTI-PURPOSE SENSOR SIGNAL CONDITIONERS

For powering Pressure, Force, Strain, and Vibration Sensors

Multi-purpose signal conditioners offer versatility for measurement systems utilizing ICP®, TEDS, and charge output piezoelectric sensors. These units provide sensor excitation, signal gain, and filtering options to prepare measurement signals for readout, recording, and analysis. Flexible powering options facilitate fixed or portable operation in laboratory or field applications. Other options, such as AC or DC coupling, switched auxiliary output, clamped output signal, dual mode operation, floating grounds, and signal integration permit system tailoring to meet unique requirements.

Specific versions are easily configured using the model matrix shown on page 1.63. Choose from single-, four-, or eight-channel configurations with keypad or RS-232 computer control. A bright, menu-driven display verifies system setup. A universal AC power adaptor is included. DC power adaptors, including a 12 VDC auto lighter socket adaptor, are available separately.

Series 482C

Series 482C Specifications		
Performance	**English**	**SI**
Channels	1,4,8	1,4,8
Frequency Response (gain x1- buffered) (-5%)	0.05-100k Hz	0.05-100k Hz
Frequency Response (gain x1- unbuffered) (-5%)	0.05 to 1M Hz	0.05 to 1M Hz
Voltage Gain:	x1 (unity)	x1 (unity)
Optional	x1, x10, x100 selectable	x1, x10, x100 selectable
Optional	x0.0025 to 200 selectable	x0.0025 to 200 selectable
Accuracy (at 500 Hz)	± 1%	± 1%
Linearity (10 to 50k Hz)	± 1%	± 1%
Phase Accuracy (at 1k Hz)	± 1 °	± 1 °
Electrical		
Excitation Voltage (to sensor)	10-15 VDC	10-15 VDC
Constant Current Excitation (to sensor)	2 to 20 mA	2 to 20 mA
Spectral Noise (1 Hz) (Gain 10)	20.0 μV/√Hz	-93.9 dB
Spectral Noise (10 Hz) (Gain 10)	1.5 μV/√Hz	-116 dB
Spectral Noise (100 Hz) (Gain 10)	1.0 μV/√Hz	-120 dB
Spectral Noise (1k Hz) (Gain 10)	1.0 μV/√Hz	-120 dB
Spectral Noise (10k Hz) (Gain 10)	1.0 μV/√Hz	-120 dB
Broadband Electrical Noise (1 Hz to 10k Hz) (Gain 10)	125 mV RMS	-78 dB RMS
Overload Threshold	+10 Vpk (± 0.2)	+10 Vpk (± 0.2)
Output DC Offset (max)	50 mV	50 mV
Output Impedance (max)	50 Ω	50 Ω
Channel Isolation (min)	72 dB	72 dB
Power Required	100 to 240 VAC	100 to 240 VAC
Environmental		
Operating Temperature	+32 to +120 °F	0 to +50 °C
Physical		
Electrical Connectors (ICP® Input)	BNC Jack	BNC Jack
Electrical Connectors (Charge Input)	10-32	10-32
Electrical Connectors (Output)	BNC Jack	BNC Jack
Electrical Connectors (Switched Output) (Auxiliary)	BNC Jack	BNC Jack
Size (Height x Width x Depth)	2.97 x 8.07 x 5.52 in	75.44 x 205 x 14 mm

Configuration Guide - How to Order

Base Model

482C- Multi-purpose signal conditioner for ICP®, charge output, and TEDS* capable piezoelectric sensors

Channels

1	Single-channel
4	Four-channel
8	Eight-channel

Power

1	115V/230 VAC
2	DC (battery pack)
3	28 VDC
4	12 VDC auto adaptor

Display and Control

L	LED indicators
C	LED indicators and RS-232 control. Includes TEDS read/write capability.
D	Menu driven display with LED indicators
B	Menu driven display with LED indicators and RS-232 control. Includes TEDS read/write capability.

Gain

0	Unity gain
1	x1, x10, x100 (must select D or B display options above)
2	Incremental gain (x0.0025 to x200) (must select D or B display options above)

Output Signal Coupling

AC	AC-coupled
SW	Switchable AC or DC coupled

Filters

00	No filter
01	100 Hz (-3dB) low-pass filter (Model 477A01)
02	200 Hz (-3dB) low-pass filter (Model 477A02)
03	500 Hz (-3dB) low-pass filter (Model 477A03)
04	1 kHz (-3dB) low-pass filter (Model 477A04)
05	2 kHz (-3dB) low-pass filter (Model 477A05)
06	5 kHz (-3dB) low-pass filter (Model 477A06)
07	10 kHz (-3dB) low-pass filter (Model 477A07)
08	20 kHz (-3dB) low-pass filter (Model 477A08)
09	50 kHz (-3dB) low-pass filter (Model 477A09)
10	100 kHz (-3dB) low-pass filter (Model 477A10)
XX	Customer selectable

Options

00000	None
XXXX1	Clamped output
XXX1X	Single integration
XX1XX	Switchable output (4 to 1)
X1XXX	Dual mode: ICP® or charge sensor input with 0.1 mV/pC converter
X2XXX	Dual mode: ICP® or charge sensor input with 1.0 mV/pC converter
X3XXX	Dual mode: ICP® or charge sensor input with 10.0 mV/pC converter
0XXXX	Floating grounds
1XXXX	Signals grounded

Example

482C - 4 2 L 0 SW 03 13X11 4-channel signal conditioner with battery pack, LED indicators, unity gain, DC coupled output signal, and 500 Hz low-pass filter

Notes

* TEDS capability requires RS-232 control

QUARTZ

Modular-style Signal Conditioners

MODULAR-STYLE SIGNAL CONDITIONERS

Modular signal conditioners are comprised of selected signal conditioning modules, and an AC power supply module, assembled into a 2-, 3-, 5-, or 9-slot chassis. Available modules condition ICP®, charge output, or capacitive sensor signals. The common chassis backplane architecture permits mixing and matching of modules to achieve the desired number of channels and signal conditioning features. Request the "Series 440 Modular Signal Conditioners" brochure for full details of available items.

Modular Signal Conditioning Systems

CE

Modular-style Signal Conditioners

Model 442B216
16-channel, unity gain, with selectable ICP® or voltage mode

Model 442B316
16-channel, unity gain, with selectable AC coupled ICP® or DC coupled voltage mode

Model 442C04
4-channel, gain x1, x10, x100 for ICP® sensors

Model 443B02
Dual mode amplifier for charge output and ICP® sensors with short, medium and long discharge time constants

Modular-style Signal Conditioners

Model Number	442B216	442B316	442C04	443B02 [6]
Channels	16 channels	16 channels	4 channels	1 channel
Sensor excitation [1]	22 volt, 2 to 10 mA	22 volt, 2 to 10 mA	25.5 volt, 0.5 to 20 mA	24 volt, 0 to 20 mA [2]
Gain (each channel)	x1	x1	x1, x10, x100	x0.1 to 1000
Charge sensitivity	N/A	N/A	N/A	0.0001 to 10 volts/pC
Low frequency response (-5%)	0.125 Hz	0.125 Hz	0.05 Hz [3]	2, 0.2, 0.03, 0.003, ~0 Hz [4]
High frequency response (-5%)	30k Hz	30k Hz	100k Hz	0.1, 1, 3, 10, 100, >200k Hz [5]
Broadband noise (at unity gain)	100 μV rms	100 μV rms	10 μV rms	9 μV rms
Power required	100 to 240 VAC	100 to 240 VAC	100 to 240 VAC	100 to 240 VAC
	50 to 60 Hz	50 to 60 Hz	50 to 60 Hz	50 to 60 Hz
Input/output connectors	DB-50 Female/Quad Agilent E1432	DB-50 Female/Quad Agilent E1432	BNC/BNC	BNC/BNC
Size (height x width x depth)	5.05 x 3.6 in [7]	5.05 x 3.6 in [7]	6.2 x 4.25 x 10.2 in	6.2 x 6.05 x 10.2 in
	(128.3 x 91.4 mm)	(128.3 x 91.4 mm)	(15.7 x 10.8 x 26 cm)	(15.7 x 15.4 x 26 cm)
Weight	0.95 lb (0.43 kg)	0.95 lb (0.43 kg)	5.1 lb (2.3 kg)	6.4 lb (2.9 kg)

NOTES:

[1] Current is factory set at 4 mA but is user adjustable up to 20 mA.
[2] Excitation is disabled for charge output sensor input.
[3] With 1 megohm load.
[4] Adjusted by discharge time constant and high-pass filter selection.
[5] Adjusted by low-pass filter selection.
[6] Charge input range for Model 443B02 is limited to 100k pC. For high sensitivity charge output force sensors, use appropriate Series 472B charge attenuator to achieve desired full-scale force range where necessary. See page 1.68.
[7] Conforms to PCB Series 440 Modular System.

Multi-channel Signal Conditioners

MULTI-CHANNEL SIGNAL CONDITIONERS

Multi-channel rack mount signal conditioners contain 8-or 16-channels of simultaneous signal conditioning and can be configured for multiple unit, daisy-linking with computerized set up and control. The building block-style architecture permits factory configuration to include characteristics which best tailor a unit for the specific application and data acquisition requirements. Standard features include ICP® sensor excitation and LED indicators for input fault monitoring and overload detection. Optional features include programmable gain, autoranging, filtering, output switching, integration, IEEE-488, RS-232, and RS-485 interface, and keypad control with LCD display. Units are available to condition signals from ICP® and charge output sensors, or can be set up to accept voltage input signals from other types of sensors. Pre-configured models offer ease of ordering units possessing the most commonly requested features. Request the "Series 481 Multi-channel Signal Conditioners" brochure for full details of available items.

Pre-configured Multi-channel Signal Conditioners

Model 481A01
16-channel, unity gain
for ICP® sensors

Model 481A20
16-channel, unity gain
for ICP® sensors

Model 481A02
16-channel,
gain x1, x10, x100
for ICP® sensors

Model 481A03
16-channel,
continuous gain x0.1 to x200
for ICP® sensors

All Models available in 8- or 16-channel custom configurations

Multi-channel Signal Conditioners

Model Number	481A01	481A02	481A03	481A20
Style	unity gain	selectable gain with keypad & display	continuous gain adjust with keypad & display	unity gain
Channels	8 or 16	8 or 16	8 or 16	8 or 16
Sensor excitation [1]	24 volt, 3 to 20 mA	24 volt, 3 to 20 mA	24 volt, 3 to 20 mA	24 volt, 3 to 20 mA
Gain (each channel)	unity	autoranging x1, x10, x100	continuous x0.1 to x200	unity
Frequency response (± 5%)	0.5 to 100k Hz	0.5 to 100k Hz	0.5 to 90k Hz [2]	0.05 to 1M Hz
Broadband noise (at unity gain)	11 µV rms	11 µV rms	4 mV	11 µV rms
Power required	100 to 240 VAC 47 to 63 Hz	100 to 240 VAC 47 to 63 Hz	100 to 240 VAC 47 to 63 Hz	100 to 240 VAC 47 to 63 Hz
Keypad control	no	yes	yes	no
Computer control	no	RS-232 and RS-485 [3]	RS-232 and RS-485 [3]	no
Input connectors	DB50 and BNC	DB50 and BNC	DB50 and BNC	BNC
Output connectors	DB37 and BNC	DB37 and BNC	DB37 and BNC	BNC
Size (height x width x depth)	3.5 x 19.0 x 16.25 in (9 x 48 x 41 cm)	3.5 x 19.0 x 16.25 in (9 x 48 x 41 cm)	3.5 x 19.0 x 16.25 in (9 x 48 x 41 cm)	3.5 x 19.0 x 16.25 in (9 x 48 x 41 cm)
Weight	15 lb (6.8 kg)	15 lb (6.8 kg)	15 lb (6.8 kg)	15 lb (6.8 kg)

NOTE: [1] Current is factory set at 4 mA but is user adjustable between 3 and 20 mA.
[2] Attains 90k Hz with filter disabled.
[3] Supplied with Windows® based control software program.

Charge and Impedance Converters

CHARGE CONVERTERS

Series 422E charge converters serve to convert charge output sensor signals to low-impedance voltage signals, for transmission over long cables, and interface to data acquisition equipment. They are low in noise, powered by standard ICP® sensor signal conditioners, and install in-line between the sensor and signal conditioner. Charge converters with signal conditioners offer a less expensive technique, compared to the use of laboratory-style charge amplifiers, and are an especially attractive approach for multi-channel requirements. Like charge amplifiers, charge converters also invert the polarity of the measurement signal.

CE

Series 422E

Contact factory for custom ranges and information regarding Series 422M.

Inverting Charge Converters for Use with Charge Output Sensors

Charge Converter Models	422E11	422E12	422E13
Gain	100 mV/pC ± 5%	10 mV/pC ± 2%	1 mV/pC ± 2%
Input range ± 2%	± 25 pC	± 250 pC	± 2500 pC
Output voltage range	± 3 volts	± 3 volts	± 3 volts
Frequency response (± 5%)[1]	5 to 110k Hz	5 to 100k Hz	5 to 100k Hz
Broadband noise	60 μV rms	20 μV rms	11 μV rms
Power required	18 to 28 VDC	18 to 28 VDC	18 to 28 VDC
Constant current required	2.2 to 20 mA	2.2 to 20 mA	2.2 to 20 mA
Input connector	10-32 jack	10-32 jack	10-32 jack
Output connector	BNC jack	BNC jack	BNC jack
Size (length x diameter)	3.4 x 0.5 in (8.6 x 1.3 cm)	3.4 x 0.5 in (8.6 x 1.3 cm)	3.4 x 0.5 in (8.6 x 1.3 cm)
Weight	1.1 oz (31g)	1.1 oz (31g)	1.1 oz (31g)
Optional Models			
0.5 Hz (-5%) low frequency	422E01	422E02	422E03

NOTE: [1] High frequency achieved at 20 mA excitation

IMPEDANCE CONVERTERS AND IN-LINE VOLTAGE FOLLOWER AMPLIFIERS

Series 402A In-line voltage follower amplifiers, similar to the Series 422E charge converters, serve to convert charge output sensor signals to low-impedance voltage signals. They are recommended for applications requiring high frequency response up to 1 MHz, and for applications where sensor output (pC/unit) exceeds the maximum input range (pC) allowed in the Series 422E.

CE

Series 401 and 402

The voltage sensitivity, V, of a system including a charge output sensor, low-noise cable and voltage follower amplifier can be determined mathematically by the equation $V=Q/C$ where Q is the charge sensitivity of the sensor in Coulombs and C is the total system capacitance in Farads. The total system capacitance is the result of the sum of the capacitance of the sensor, the capacitance of the interconnect cable, and the input capacitance of the voltage amplifier. Choose a voltage follower amplifier with an input capacitance that provides the sensitivity desired, while keeping the total output voltage (range x sensitivity) within the ±10 volt limit. Voltage follower amplifiers do not invert the polarity of the measurement signal.

Non-Inverting Voltage Follower Amplifiers and Impedance Converters for Use with Charge Output Sensors

Voltage Follower Models	402A	402A02	402A03
Voltage gain (± 2%)	0.98	0.98	0.98
Output Range	± 10 V	± 10 V	± 10 V
Input Capacitance	< 8.0 pF	100 ± 10% pF	1000 ± 10% pF
Discharge time constant	1.0 second	10 second	100 second
Frequency response (± 5%)[1]	0.5 to 1M Hz	0.05 to 1M Hz	0.005 to 1M Hz
Broadband noise	43 μV rms	43 μV rms	43 μV rms
Output bias	9 to 13 V	9 to 13 V	9 to 13 V
Temperature range	-65 to +250 °F (-54 to +121 °C)	-65 to +250 °F (-54 to +121 °C)	-65 to +250 °F (-54 to +121 °C)
Power required	18 to 28 VDC	18 to 28 VDC	18 to 28 VDC
Constant current required	2 to 20 mA	2 to 20 mA	2 to 20 mA
Input connector	10-32 jack	10-32 jack	10-32 jack
Output connector	10-32 jack	10-32 jack	10-32 jack
Size (length x diameter)	1.17 x 0.25 in (28 x 6 mm)	1.17 x 0.25 in (28 x 6 mm)	1.17 x 0.25 in (28 x 6 mm)
Optional Models			
10-32 plug input connector	401A	401A02	401A03

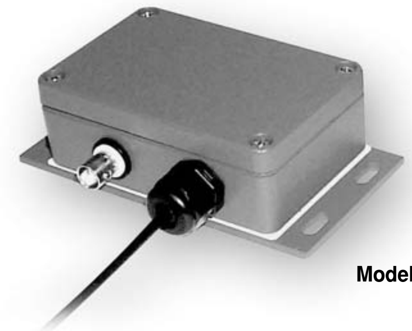
NOTE: [1] High frequency achieved at 20 mA excitation

INDUSTRIAL CHARGE AMPLIFIERS

Model 421A13 is a three-channel charge amplifier that is packaged in a rugged, surface mount, sealed aluminum enclosure and is ideal for fixed installations in a factory environment. The unit is set up via internal adjustments, which prohibits tampering once it is sealed and deployed. A long discharge time constant provides quasi-static and low frequency measurement capability, making this unit suitable for monitoring crimping forces, stamping forces and other press forming operations. The three-channel, cost effective configuration supports use with charge output, 3-component force sensors. Single channel (Model 421A11) version is also available. Additional features include electrical ground isolation, high vibration resistance, and a cord grip for securing the supplied, 10 ft (3 m) interfacing cable.

CE

Model 421A13



Model 421A11

MODEL 421A11 Single Channel Industrial Charge Amplifier	
Channels	1 Channel
Input ranges (selectable for each channel)	± 100 to 1000 pC (Range I) ± 1000 to 10k pC (Range II) ± 10k to 100k pC (Range III)
Sensitivity	5 mV/pC (Range I) 0.50 mV/pC (Range II) 0.05 mV/pC (Range III)
Maximum Output	5 VAC
Frequency range (-5%)	~ 0 to 4000 Hz (Range I) ~ 0 to 10k Hz (Range II) ~ 0 to 12k Hz (Range III)
Broadband noise [1]	11 µV
Power required	15 to 30 VDC, ≤ 19 mA
Input connector [2]	BNC jack
Output connector [3]	screw terminal
Size	4.89 x 1.18 x 2.52 in (124.2 x 30 x 64 mm)
Weight [4]	0.915 lb (415.04 gm)

NOTE: [1] Noise measurements performed at 10k-100k pC range
[2] Optional TNC jack on input, order as 421A11/A. Optional 10-32 (micro) connector on input, order as 421A11/B.
[3] Supplied with 10 ft (3 m) multi-conductor cable & PG-9 cord grip
[4] Including multi-conductor cable

MODEL 421A13 Three-channel Industrial Charge Amplifier	
Channels	3 Channels
Input ranges (selectable for each channel)	± 100 to 1000 pC (Range I) ± 1000 to 10k pC (Range II) ± 10k to 100k pC (Range III)
Sensitivity	5 mV/pC (Range I) 0.50 mV/pC (Range II) 0.05 mV/pC (Range III)
Output	5 VAC
Frequency range (-5%)	~ 0 to 4000 Hz (Range I) ~ 0 to 10k Hz (Range II) ~ 0 to 12k Hz (Range III)
Broadband noise [1]	11 µV
Power required	15 to 30 VDC, ≤ 37 mA
Input connector [2]	BNC jack
Output connector [3]	screw terminal
Size	6.95 x 1.18 x 2.52 in (176.5 x 30 x 64 mm)
Weight [4]	1.320 lb (598.7 gm)

NOTE: [1] Noise measurements performed at 10k-100k pC range
[2] Optional TNC jack on input, order as 421A11/A. Optional 10-32 (micro) connector on input, order as 421A11/B.
[3] Supplied with 10 ft (3 m) multi-conductor cable & PG-9 cord grip
[4] Including multi-conductor cable

DIN RAIL SIGNAL CONDITIONER FOR ICP® SENSORS

Model 682A02 DIN rail mountable, ICP® sensor signal conditioner requires 24 VDC power and provides constant current ICP® sensor excitation. Only 0.97 inch (24.6 mm) wide, the unit is well-suited for high-density installations. Features include selectable gain of x1, x10, and x100.

Model 682A02

SERIES 472B CHARGE ATTENUATORS

Series 472B charge attenuators are used in conjunction with high-sensitivity charge output force sensors when their full-scale output range exceeds the charge input limit of the charge amplifier or converter with which it is used. Series 472B charge attenuators serve to divide the output signal delivered by the force sensor by the factor indicated in the table at right.

Series 472B

MODEL	Divided by
472B01	10
472B02	15
472B03	50
472B04	100

ICP® SENSOR SIMULATOR

Model 492B

Model 492B ICP® sensor simulator installs in place of an ICP® sensor and serves to verify signal conditioning settings, cable integrity, and tune long lines for optimum system performance. By use of an internal oscillator, the unit delivers a 100 Hz sine or square wave at a selectable peak to peak voltage. External test signals from a function generator may also be inserted. This portable unit is battery powered.

ICP® SENSOR SIMULATOR

Model 401A04

Model 401A04 ICP® sensor simulator installs in place of an ICP® sensor and accepts test signals from a voltage function generator. The unit serves to verify signal conditioning settings, cable integrity, and tune long lines for optimum system performance. This unit requires power from an ICP® sensor signal conditioner.

STEP FUNCTION GENERATOR

Model 492B03

Model 492B03 generates a rapid charge or voltage step function from zero to a selected peak value between either 0 and 100k pC or 0 and 10 volts DC. The unit is useful for setting trigger points in recording equipment and verifying charge amplifier and data acquisition equipment setup. This unit is battery powered and portable.

DC POWER CONDITIONER

Model 485B serves to regulate available current from any conventional DC power supply or battery source to a constant value between 2 and 20 mA as required by ICP® sensors. In addition, the unit decouples the sensor's output bias voltage from the measurement signal to enable zero-based measurements with any readout device.

Model 485B

Dynamic Force and Strain Sensor Accessories and Services

- Stock cable assemblies
- Cable specifications
- Connector adaptors
- Custom cable ordering guide
- Cable connector descriptions
- Mounting accessories
- Calibration services

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

STOCK CABLE ASSEMBLIES

The following cable assemblies are generally available for overnight delivery. Should your application require a cable assembly not shown, consult the Custom Cable Ordering Guide on page 1.76 for ordering information.

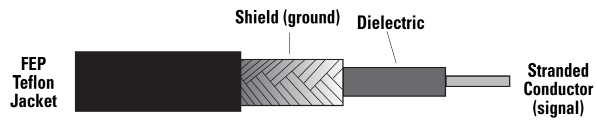
Series 002 Standard Coaxial Cable

Usage

General purpose use with ICP® sensors and low-impedance voltage signals.

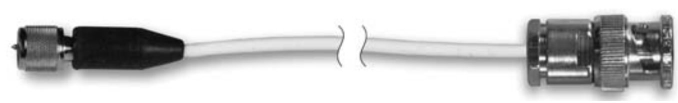
Outer Jacket	Extruded FEP Teflon (waterproof), white	
Diameter	0.075 in	1.9 mm
Capacitance	29 pF/ft	95 pF/m
Temperature Range	-130 to +400 °F	-90 to +204 °C
Impedance	50 ohm	

Construction

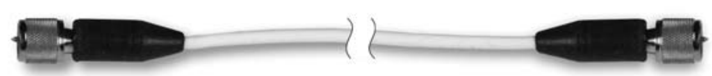


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
002C03	3 ft	0.9 m
002C05	5 ft	1.5 m
002C10	10 ft	3.0 m
002C20	20 ft	6.1 m
002C30	30 ft	9.1 m
002C50	50 ft	15.2 m

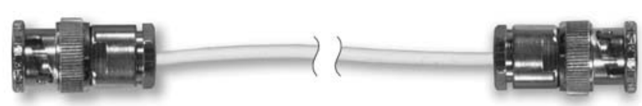


Model Number	Length (feet)	Length (meters)
002A03	3 ft	0.9 m
002A05	5 ft	1.5 m
002A10	10 ft	3.0 m
002A20	20 ft	6.1 m
002A30	30 ft	9.1 m
002A50	50 ft	15.2 m

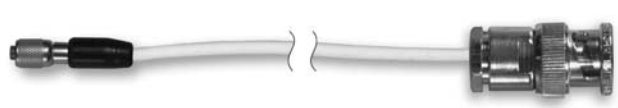


Model Number	Length (feet)	Length (meters)
002B01	1 ft	0.3 m
002B03	3 ft	0.9 m

Model Number	Length (feet)	Length (meters)
002T03	3 ft	0.9 m
002T10	10 ft	3.0 m
002T20	20 ft	6.1 m



Model Number	Length (feet)	Length (meters)
002P03	3 ft	0.9 m
002P05	5 ft	1.5 m
002P10	10 ft	3.0 m
002P20	20 ft	6.1 m
002P30	30 ft	9.1 m



Stock Cable Assemblies

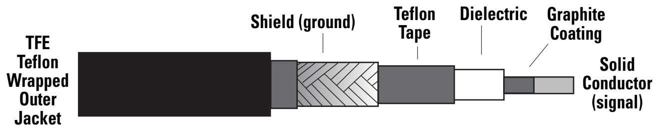
Series 003 Low-noise Coaxial Cable

Usage

General purpose and high temperature use with charge output sensors, high-impedance signals, ICP® sensors, and low-impedance voltage signals. Maintains CE conformance.

Outer Jacket	Wrapped TFE Teflon, blue	
Diameter	0.079 in	2.0 mm
Capacitance	29 to 32 pF/ft	95 to 105 pF/m
Temperature Range	-130 to +500 °F	-90 to +260 °C
Impedance	50 ohm	

Construction



Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
003C03	3 ft	0.9 m
003C05	5 ft	1.5 m
003C10	10 ft	3.0 m
003C20	20 ft	6.1 m
003C30	30 ft	9.1 m

10-32 Coaxial Plug (EB) — BNC Plug (AC)

Model Number	Length (feet)	Length (meters)
003A01	1 ft	0.3 m
003A03	3 ft	0.9 m
003A05	5 ft	1.5 m
003A10	10 ft	3.0 m
003A20	20 ft	6.1 m
003A30	30 ft	9.1 m

10-32 Coaxial Plug (EB) — 10-32 Coaxial Plug (EB)

Model Number	Length (feet)	Length (meters)
003B01	1 ft	0.3 m
003B03	3 ft	0.9 m

10-32 Coaxial Plug (EB) — BNC Jack (AB)

Model Number	Length (feet)	Length (meters)
003D03	3 ft	0.9 m
003D10	10 ft	3.0 m
003D20	20 ft	6.1 m

BNC Plug (AC) — BNC Plug (AC)

Model Number	Length (feet)	Length (meters)
003P03	3 ft	0.9 m
003P05	5 ft	1.5 m
003P10	10 ft	3.0 m
003P20	20 ft	6.1 m
003P30	30 ft	9.1 m

5-44 Coaxial Plug (AG) — BNC Plug (AC)

Stock Cable Assemblies

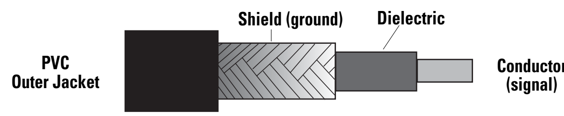
Series 012 Low-cost Coaxial Cable (RG58/U)

Usage

General purpose use with ICP® sensors and low-impedance voltage signals. Recommended for use as a sensor extension cable for long distance signal transmission and as output cable from signal conditioner. Maintains CE conformance.

Outer Jacket	PVC, black	
Diameter	0.193 in	4.90 mm
Capacitance	29 pF/ft	95 pF/m
Temperature Range	-40 to +176 °F	-40 to +80 °C
Impedance	52 ohm	

Construction



Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
012A03	3 ft	0.9 m
012A10	10 ft	3.0 m
012A20	20 ft	6.1 m
012A50	50 ft	15.2 m

BNC Plug (AC) BNC Plug (AC)

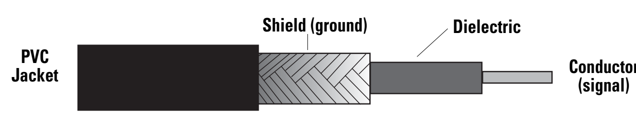
Series 018 Lightweight Coaxial Cable

Usage

General purpose use with ICP® sensors and low-impedance voltage signals. Recommended for use with miniature sensors to reduce cable strain.

Outer Jacket	PVC, black	
Diameter	0.051 in	1.3 mm
Capacitance	55 pF/ft	180 pF/m
Temperature Range	-22 °F to +221 °F	-30 to +105 °C
Impedance	32 ohm	

Construction



Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
018C03	3 ft	0.9 m
018C05	5 ft	1.5 m
018C10	10 ft	3.0 m
018C20	20 ft	6.1 m
018C30	30 ft	9.1 m

5-44 Coaxial Plug (AG) BNC Plug (AC)

Model Number	Length (feet)	Length (meters)
018G03	3 ft	0.9 m
018G05	5 ft	1.5 m
018G10	10 ft	3.0 m
018G20	20 ft	6.1 m
018G30	30 ft	9.1 m

5-44 Coaxial Plug (AG) 10-32 Coaxial Plug (EB)

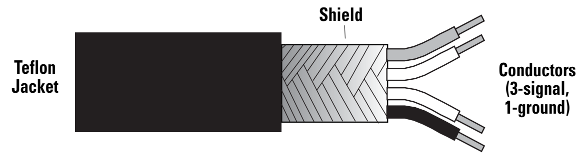
Series 010 Twisted, Shielded Four-conductor

Usage

General purpose use with triaxial ICP® sensors.
Maintains CE conformance.

Outer Jacket	Teflon	
Diameter	0.1 in	2.54 mm
Capacitance	31 pF/ft	102 pF/m
Temperature Range	-130 to +392 °F	-90 to +200 °C

Construction



Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
010G05	5 ft	1.5 m
010G10	10 ft	3.0 m
010G15	15 ft	4.5 m
010G20	20 ft	6.1 m
010G25	25 ft	7.6 m
010G30	30 ft	9.1 m
010G50	50 ft	15.2 m

4-socket Plug (AY) — (3) BNC Plugs (AC)

Model Number	Length (feet)	Length (meters)
010F05	5 ft	1.5 m
010F10	10 ft	3.0 m
010F15	15 ft	4.5 m
010F20	20 ft	6.1 m
010F25	25 ft	7.6 m
010F30	30 ft	9.1 m

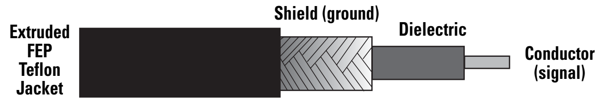
4-socket Plug (AY) — (3) 10-32 Coaxial Plugs (EB)

Model Number	Length (feet)	Length (meters)
010D05	5 ft	1.5 m
010D10	10 ft	3.0 m
010D20	20 ft	6.1 m
010D25	25 ft	7.6 m
010D30	30 ft	9.1 m

4-socket Plug (AY) — 4-socket Plug (AY)

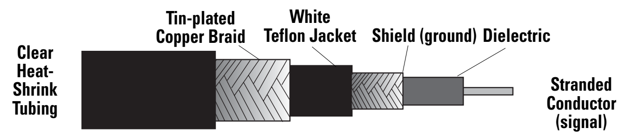
004 - INDUSTRIAL HIGH-TEMPERATURE COAXIAL

004 CABLE: Industrial brown coaxial cable with waterproof, extruded Teflon jacket: 15 pF/ft (49 pF/m), 392 °F (200 °C) maximum temperature, 0.140 inch (3.6 mm) diameter. For use with ICP® sensors in high temperature or corrosive industrial environments.



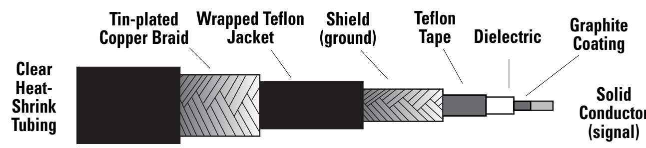
005 - RUGGEDIZED 002-TYPE COAXIAL CABLE

005 CABLE: Ruggedized, 002 cable with tin-plated copper braid and polyolefin heat-shrink tubing: 29 pF/ft (95 pF/m), maximum temperature 275 °F (135 °C), 0.2 inch (5.08 mm) diameter. For use with ICP® sensors, where cable may be prone to being pinched or crushed.



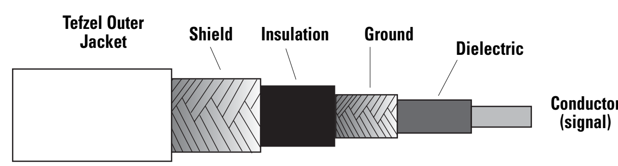
006 - RUGGEDIZED 003-TYPE COAXIAL CABLE

006 CABLE: Ruggedized 003 low-noise cable with tin-plated copper braid and polyolefin heat-shrink tubing: 29 to 32 pF/ft (95 to 105 pF/m), maximum temperature 275 °F (135 °C), 0.2 inch (5.08 mm) diameter. Recommended for charge output or ICP® sensors requiring a durable cable. Maintains CE conformance.



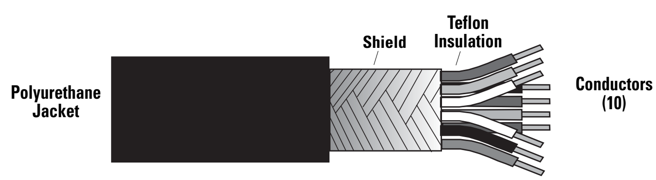
025 - SHIELDED TEFZEL-JACKETED COAXIAL

025 CABLE: White RG178 coaxial with rugged Tefzel® outer insulating jacket: 37 pF/ft (121 pF/m), 390 °F (199 °C), maximum temperature, 0.116 inch (2.95 mm) diameter. For use with ICP® sensors in industrial or Teflon-prohibitive environments.



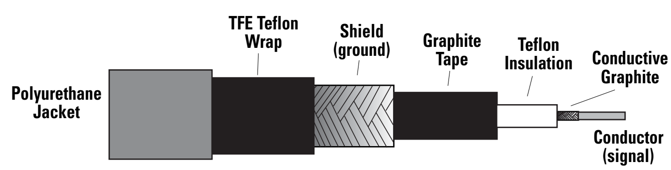
037 - SHIELDED 10-CONDUCTOR

037 CABLE: 10-conductor shielded cable with a polyurethane outer jacket: 250 °F (121 °C), maximum temperature, 0.154 inch (3.91 mm) diameter. Used on the Model 421A11 and Model 421A13 industrial charge amplifiers (see page 1.67).



038 - LOW-NOISE UNDERWATER

038 CABLE: Low-noise coaxial cable with a polyurethane coated, TFE Teflon jacket: 29 to 32 pF/ft (95 to 105 pF/m), 250 °F (121 °C) maximum temperature, 0.119 inch (3.02 mm) diameter. Recommended for underwater use with either ICP® or charge output piezoelectric sensors. Maintains CE conformance.



070A01

SCOPE INPUT T CONNECTOR
BNC plug to two 10-32 coaxial jacks. Used for splitting low-impedance signals.

10-32 COAXIAL COUPLER

070A05

10-32 coaxial jack to 10-32 coaxial jack. Joins two cables terminating in 10-32 coaxial plugs.

BNC T CONNECTOR

070A11

BNC plug to two BNC jacks. Used as a cable splitter.

10-32 HERMETIC FEED-THRU

1/4" max wall thickness 5/16"-32 mtg. thread

070A14

10-32 coaxial jack to 10-32 coaxial jack. Tapped 5/16-32.

MODEL "EB" 10-32 COAXIAL CONNECTOR
10-32 crimp-on style coaxial connector. Requires tool contained in 076C31 kit.

MODEL 076C31 CRIMP-ON CONNECTOR KIT
Includes 1-pin insertion tool, 1 sleeve-crimping tool, and 20 Model "EB" connectors with cable strain reliefs. Wire stripper and soldering iron not included.

Pin tool

Crimping tool

070A02

SCOPE INPUT ADAPTOR
10-32 coaxial jack to BNC plug. For adapting BNC connectors for use with 10-32 coaxial plugs.

CABLE ADAPTOR

070A08

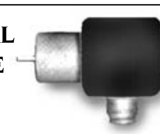
10-32 coaxial jack to BNC jack. Joins cables terminating in a BNC plug and a 10-32 coaxial plug.

BNC COUPLER

070A12

BNC jack to BNC jack. Joins two cables terminating in BNC plugs.

10-32 COAXIAL RIGHT ANGLE CONNECTOR ADAPTOR



070A20

10-32 Coaxial jack to 10-32 coaxial plug. For use in confined locations.

076A25

076A05

076A05 10-32 COAXIAL PLUG
Microdot connector, screw-on type.

076A25 CONNECTOR TOOL
Used to install 076A05 screw-on type microdot connector.

MODEL 076A30 MICRODOT SCREW-ON CONNECTOR KIT
One Model 076A25 Tool and 20 Model 076A05 10-32 coaxial connectors.

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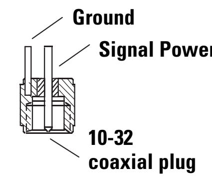
070A03

CONNECTOR ADAPTOR
10-32 coaxial plug to BNC jack. Converts 10-32 connectors for use with BNC plugs. Do not use on sensor connectors.



070B09

SOLDER CONNECTOR ADAPTOR
10-32 coaxial plug to solder terminals. Excellent for high-shock applications. User-repairable.

1/8" max wall thickness 1/2" mtg. thread

070A13

FEED-THRU ADAPTOR
10-32 coaxial jack to BNC jack. Bulkhead connects BNC plug to 10-32 coaxial jack.

085A18

PLASTIC PROTECTIVE CAP
Provides strain relief for solder connector adaptors, as well as protects 10-32 cable ends.

085A40

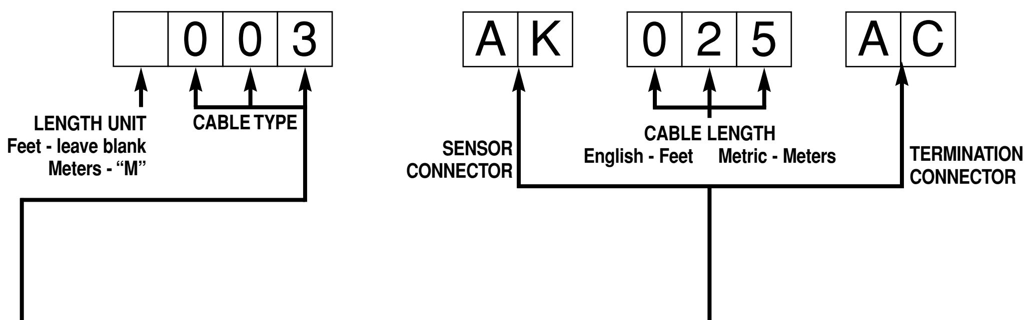
10-32 COAXIAL SHORTING CAP
Used to short charge output sensor connectors during storage and transportation.

Custom Cable Ordering Guide

TO ORDER CUSTOM CABLES:

1. Choose the cable length format desired, either English (ft) or Metric (mm) unit lengths.
2. Choose the desired cable (see pages 1.70 to 1.74 for cable specifications).
3. Find the connector that mates to the sensor (see page 1.77 for connector information).
4. Determine the length of cable required, in English (ft) or Metric (mm) unit lengths.
5. Choose the cable termination connector (see page 1.77).

Example:
Model 003AK025AC defines a 25 ft, low-noise cable with right angle 10-32 plug sensor connector, BNC plug termination connector.



STANDARD CABLE TYPES				
COAXIAL		**DIAMETER in (mm)**		**MAX. TEMP.**
	002 White Teflon jacket, general purpose	0.075	(1.9)	400 °F 204 °C
CE	003 Blue Teflon jacket, low-noise	0.079	(2.0)	500 °F 260 °C
	004 Brown Teflon jacket, industrial	0.140	(3.6)	392 °F 200 °C
	005 Ruggedized 002 type, gen. purp.	0.2	(5.08)	275 °F 135 °C
CE	006 Ruggedized 003 type, low-noise	0.2	(5.08)	275 °F 135 °C
	012 Black vinyl jacket, RG-58/U	0.193	(4.90)	176 °F 80 °C
	018 Black PVC jacket, lightweight	0.051	(1.3)	221 °F 105 °C
	025 Tefzel jacket, industrial	0.116	(2.95)	390 °F 199 °C
CE	038 Low-noise, polyurethane jacket, underwater	0.119	(3.02)	250 °F 121 °C
	TWISTED/SHIELDED 4-CONDUCTOR			
CE	010 Teflon jacket, general purpose	0.1	(2.54)	392 °F 200 °C
	10-CONDUCTOR			
	037 Polyurethane jacket, general purpose	0.154	(3.91)	250 °F 121 °C

The combination of cables and connectors listed are only recommended configurations; other configurations are available. Consult PCB before ordering.

For multi-conductor cables breaking out to more than one connector, consult factory for more information.

STANDARD CONNECTOR TYPES		
LETTER	**CONNECTOR**	**COMPATIBLE CABLES** (Group Key is below)
10-32 THREADED COAXIAL		
EB	10-32 coaxial plug (shock)	010, Group 1
EJ	10-32 coaxial plug (standard)	010, Group 1
AH	10-32 coaxial plug (wire lock hex)	010, Group 1
AK	10-32 coaxial plug (right angle)	010, Group 1
AW	10-32 coaxial plug (solder adapter)	010, Group 1
AL	10-32 coaxial jack	010, Group 1
CY	10-32 coaxial plug (underwater)	038
5-44 THREADED COAXIAL		
AG	5-44 coaxial plug (standard)	010, Group 1
AF	5-44 coaxial plug (right angle)	010, Group 1
LARGE COAXIAL		
AB	BNC jack (locking)	010, Groups 1, 2
AC	BNC plug (locking)	010, Groups 1, 2
FOUR-PIN		
AY	4-pin plug (sockets)	010
CA	4-pin jack (pins)	010
MISCELLANEOUS		
AD	Pigtail (no connector)	All
AZ	Conhex plug	004

Group 1: 002, 003, 005, 006, 018, 025
Group 2: 004, 012

Cable Connector Descriptions

AB BNC Jack
Max Temp 212 °F (100 °C)

AC BNC Plug
Max Temp 212 °F (100 °C)

AD Pigtail (leads stripped and tinned)
Max Temp 490 °F (254 °C)

AF 5-44 Coaxial Plug (right angle)
Max Temp 325 °F (163 °C)

AG 5-44 Coaxial Plug (straight)
Max Temp 490 °F (254 °C)

AH 10-32 Coaxial Plug (straight, with wire locking hex)
Max Temp 490 °F (254 °C)

AK 10-32 Coaxial Plug (right angle)
Max Temp 490 °F (254 °C)

AL 10-32 Coaxial Jack (straight)
Max Temp 325 °F (163 °C)

AW 10-32 Coaxial Plug / Solder Adaptor (user repairable)
Max Temp 490 °F (254 °C)

AY 4-Socket Plug, 1/4-28 Thread (for triaxial sensors)
Max Temp 325 °F (163 °C)

AZ Conhex Plug

CA 4-Pin Jack, 1/4-28 Thread (for triaxial sensors)
Max Temp 350 °F (177 °C)

CY 10-32 Coaxial Plug (underwater)

EB 10-32 Coaxial Plug (straight)
Max Temp 490 °F (254 °C)

EJ 10-32 Coaxial Plug (straight, o-ring seal, spring loaded)
Max Temp 490 °F (254 °C)

Mounting Accessories

081B05
Mounting Stud

084A03
Impact Cap

081A05
Mounting Stud

081A08
Mounting Stud

MOUNTING STUDS AND SCREWS

Model	Threads	Length in (cm)	Comment
SHORT STUDS			
081A05	10-32 to 10-32	0.27 (0.69)	Series 209
M081A05	10-32 to M6 x 0.75	0.27 (0.69)	Series M209
081B05	10-32 to 10-32	0.27 (0.69)	with shoulder for Series 208 and Models 200B01-B05, 210B
M081B05	10-32 to M6 x 0.75	0.27 (0.69)	adaptor stud with shoulder for Models M200B01-B05, M210B
081A08	10-32 to 1/4-28	0.30 (0.76)	adaptor stud
081A06	1/4-28 to 1/4-28	0.37 (0.94)	no shoulder
081B20	1/4-28 to 1/4-28	0.37 (0.94)	with shoulder for Models 200C20 & C50, 210B20 & B50
M081B21	1/4-28 to M6 x 0.75	0.37 (0.94)	adaptor stud for Models M200C20 & C50, M210B20 & B50
M081A62	10-32 to M6 x 1.0	0.325 (0.83)	Series 208
LONG STUDS			
081A11	10-32 to 10-32	0.73 (1.85)	for Models 201B01-B05, 201A75-A76
M081A11	M5 x 0.8 to M5 x 0.8	0.73 (1.85)	for Models M201B01-B05, M201A75-A76
081A12	5/16-24 to 5/16-24	0.91 (2.31)	for Models 202B, 212B
M081A12	M8 x 1.0 to M8 x 1.0	0.91 (2.31)	for Models M202B, M212B
081A13	3/8-24 to 3/8-24	1.10 (2.79)	for Models 203B, 213B
M081A13	M10 x 1.0 to M10 x 1.0	1.10 (2.79)	for Models M203B, M213B
081A14	1/2-20 to 1/2-20	1.40 (3.56)	for Models 204B, 214B
M081A14	M14 x 1.25 to M14 x 1.25	1.40 (3.56)	for Models M204B, M214B
081A15	5/8-18 to 5/8-18	1.65 (4.19)	for Models 205B, 215B
M081A15	M16 x 1.5 to M16 x 1.5	1.65 (4.19)	for Models M205B, M215B
081A16	7/8-14 to 7/8-14	1.90 (4.83)	for Models 206B, 216B
M081A16	M22 x 2.0 to M22 x 2.0	1.90 (4.83)	for Models M206B, M216B
081A17	1 1/8-12 to 1 1/8-12	2.28 (5.79)	for Models 207B, 217B
M081A17	M30 x 2.0 to M30 x 2.0	2.28 (5.79)	for Models M207B, M217B
081A70	5/16-24 to 5/16-24	1.42 (3.61)	pre-load bolt for Models 260A01, 260A11
M081A70	M8 x 1.25 to M8 x 1.25	1.42 (3.61)	pre-load bolt for Models M260A01, M260A11
081A71	7/8-14 to 7/8-14	2.40 (6.1)	pre-load bolt for Models 260A03, 260A13
M081A71	M24 x 3 to M24 x 3	2.40 (6.1)	pre-load bolt for Models M260A03, M260A13
081A74	1/2-20 to 1/2-20	1.11 (2.82)	pre-load bolt for Models 260A02, 260A12
M081A74	M12 x 1.25 to M12 x 1.25	1.11 (2.82)	pre-load bolt for Models M260A02, M260A12
SCREWS			
081A25	10-32	0.50 (1.27)	capscrew
M081A25	M5 x 0.8	0.50 (1.27)	capscrew
081A26	10-32	0.75 (1.91)	capscrew
M081A26	M5 x 0.8	0.75 (1.91)	capscrew

Custom studs are available. Contact factory for details.

ANTI-FRICTION WASHERS AND PILOT BUSHINGS

Washer	Bushing	Usage
082B01	083B01	Models 201B01-B05, 211B
082B01	M083B01	Models M201B01-B05, M211B
N/A	083A15	Models 201A75, 201A76
N/A	M083A15	Models M201A75, M201A76
082B02	083B02	Models 202B, 212B
082B02	M083B02	Models M202B, M212B
082B03	083B03	Models 203B, 213B
082B03	M083B03	Models M203B, M213B
082B04	083B04	Models 204B, 214B
082B04	M083B04	Models M204B, M214B
082B05	083B05	Models 205B, 215B
082B05	M083B05	Models M205B, M215B
082B06	083B06	Models 206B, 216B
082B06	M083B06	Models M206B, M216B
082B07	083B07	Models 207B, 217B
082B07	M083B07	Models M207B, M217B
082B02	083A10	Models 260A01, 260A11, M260A01, M260A11
082B06	083A11	Models 260A03, 260A13, M260A03, M260A13
082M12	083A13	Models 260A02, 260A12, M260A02, M260A12

IMPACT PLATES

Model	Usage	Comment
084A01	Series 208	Flat
084A03	Series 208	Convex
084A19	Model 208A33	Penetration
084A35	Model 208A35	Penetration
084A36	Models 200C50, 210B50	Convex
084A45	Model 208A45	Penetration
084B23	Models 200C20, 210C20	Convex
084M02	Series 208	Flat, hardened for matrix print head applications

Calibration of Dynamic Force Sensors

PCB's calibration laboratory is accredited by The American Association for Laboratory Accreditation (A2LA) to ISO 17025 standards. PCB provides NIST (National Institute of Standards and Technology) traceable calibration and testing services for all force and strain sensor products. Calibrations and re-certifications performed by PCB conform to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 standards.

Each individually-calibrated force sensor is supplied with a certificate indicating calibrated sensitivity as shown in **Figure 13**, page 1.80. Determining the sensitivity of sensors with operating ranges from 5000 to 100k lb (22k to 450k N) is performed by placing the force sensor in a hydraulic press stand. In series with the sensor is a load cell reference force standard selected for the operating range of the sensor. **Figure 14**, on page 1.80 depicts a force sensor calibration press. Reference load cells are calibrated and certified every six months to verify calibrated value. A scaled down test stand is used for lower ranged sensors. Miniature, high-sensitivity models are calibrated by applying a known light weight mass, letting the signal zero, and then quickly removing the mass. Output recorded is the sensitivity of the sensor. Charge output and longer time constant sensors are calibrated by statically applying a known force and recording output data.

In each calibration procedure, data points are plotted at 20% intervals of the sensor's operating range. These points are graphically plotted and the best straight line through zero is drawn.

Should calibrated points fall outside the specified linearity as provided in published specifications, the unit fails calibration and is rejected.

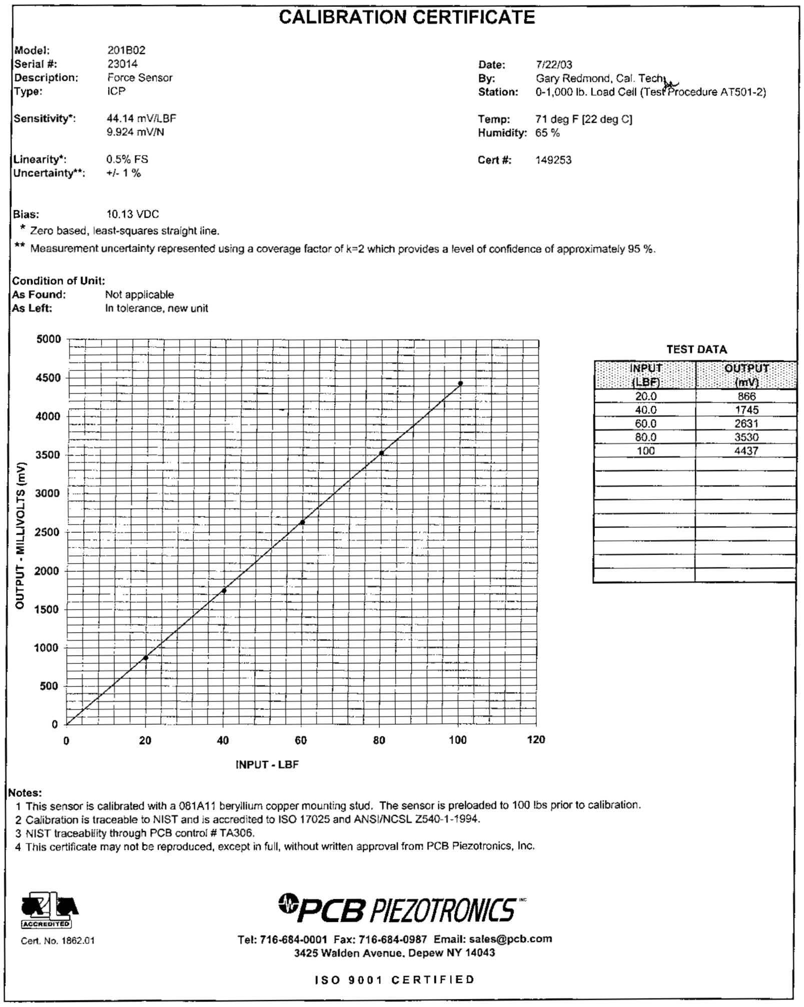
The scope of our accreditation for dynamic force sensors is:

Range	Best Uncertainty [1] (±)
0 to 100k lb (0 to 445k N)	1.0% FS

[1] Best Uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k = 2.

QUARTZ

Dynamic Force and Strain Sensor Calibration Services		
PCB Sensor Calibration Code	Competitor Sensor Calibration Code	
FCS-1	FCS-0	Calibration of dynamic force and strain sensors (complies with ISO 10012-1 and NIST traceable)
FCS-2	FCS-0	Calibration of dynamic triaxial force sensors (complies with ISO 10012-1 and NIST traceable)
FCS-QC	N/A	Special QC documentation for dynamic force sensors
Other calibration services available; contact factory for more information.		



CALIBRATION CERTIFICATE

Model: 201B02
Serial #: 23014
Description: Force Sensor
Type: ICP

Date: 7/22/03
By: Gary Redmond, Cal. Tech
Station: 0-1,000 lb. Load Cell (Test Procedure AT501-2)

Sensitivity*: 44.14 mV/LBF
9.924 mV/N

Temp: 71 deg F [22 deg C]
Humidity: 65 %

Linearity*: 0.5% FS
Uncertainty**: +/- 1 %

Cert #: 149253

Bias: 10.13 VDC

* Zero based, least-squares straight line.

** Measurement uncertainty represented using a coverage factor of k=2 which provides a level of confidence of approximately 95 %.

Condition of Unit:
As Found: Not applicable
As Left: In tolerance, new unit

TEST DATA

INPUT (LBF)	OUTPUT (mV)
20.0	866
40.0	1745
60.0	2631
80.0	3530
100	4437

Notes:
1 This sensor is calibrated with a 081A11 beryllium copper mounting stud. The sensor is preloaded to 100 lbs prior to calibration.
2 Calibration is traceable to NIST and is accredited to ISO 17025 and ANSI/NCSL Z540-1-1994.
3 NIST traceability through PCB control # TA306.
4 This certificate may not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.

ACCREDITED
Cert. No. 1862.01

PCB PIEZOTRONICS
Tel: 716-684-0001 Fax: 716-684-0987 Email: sales@pcb.com
3425 Walden Avenue, Depew NY 14043

ISO 9001 CERTIFIED

Figure 13. Typical Force Sensor Calibration Certificate

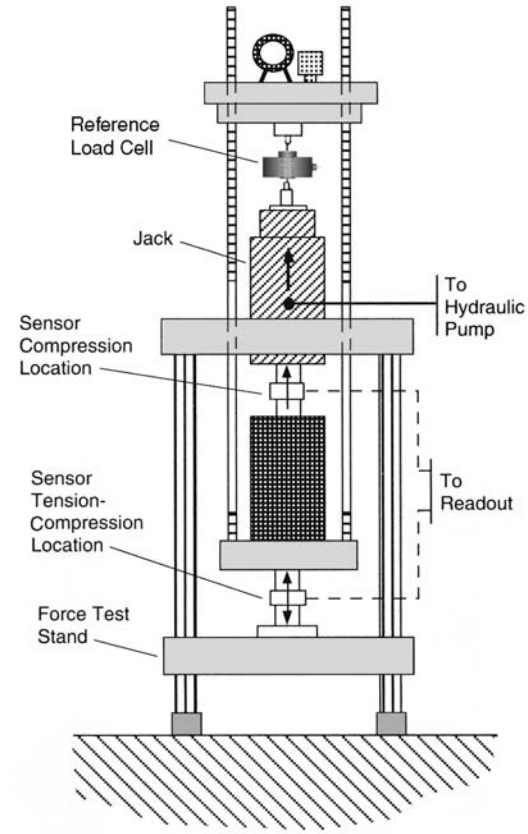


Figure 14.
Force Calibration Fixture, 5000 to 100k lb

Technical Information

- **Introduction to force sensors**
- **Driving long cable lengths**
- **Conversions, article reprints, glossary**
- **Force sensor application inquiry form**

INTRODUCTION TO QUARTZ FORCE SENSORS

Quartz Force Sensors are well-suited for dynamic force measurement applications. They are not interchangeable with strain gage load cells used for static force measurements.

Measurements of dynamic oscillating forces, impact or high speed compression/tension under varying conditions may require sensors with special capabilities. Fast response, ruggedness, high stiffness, extended range and the ability to also measure quasi-static forces are standard features associated with PCB quartz force sensors.

The following information presents some of the design and operating characteristics of PCB quartz force sensors to help you better understand how they function, which in turn, will help you make better dynamic measurements. For information on ICP® strain sensors, see pg. 1.55.

Types of Quartz Force Sensors

This catalog describes two modes of operation for quartz force sensors manufactured by PCB. ICP® (IEPE, or voltage output type sensors) feature built-in microelectronic amplifiers, which convert the high-impedance electrostatic charge signal from the crystals into a low-impedance voltage output signal (ICP® is a registered trademark of PCB Piezotronics). The other type are charge output force sensors, which directly output a high-impedance electrostatic charge signal.

Sensor Construction

Both modes of operation for PCB force sensors feature similar mechanical construction. Most are designed with thin quartz crystal discs that are "sandwiched" between upper and lower base plates. An elastic, beryllium-copper stud holds the plates together and pre-loads the crystals (preloading assures parts are in intimate contact to ensure linearity and provide the capability for tensile force measurements). This "sensing element" configuration is then packaged into a rigid, stainless-steel housing and welded to assure the internal components are sealed against contamination.

Figure 1 illustrates the cross-section of a typical quartz force sensor. This particular sensor is a General Purpose 208 Series compression/tension model with built-in electronics.

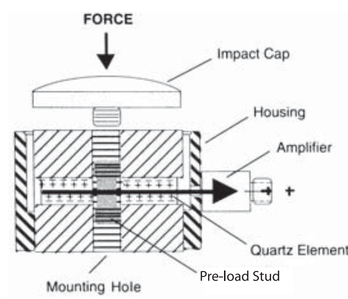


Figure 1. Compression-Tension-Impact Series 208

When force is applied to this sensor, the quartz crystals generate an electrostatic charge that is proportional to the input force. This charge output is collected on electrodes that are sandwiched between the crystals. It is then either routed directly to an external charge amplifier or converted to a low-impedance voltage signal within the sensor. Both these modes of operation will be examined in the following sections.

Conventional Charge Output Sensors

A charge output piezoelectric force sensor, when stressed, generates an electrostatic charge from the crystals. For accurate analysis or recording purposes, this high-impedance charge must be routed through a special low-noise cable to an impedance converting amplifier such as a laboratory charge amplifier or source follower. Connection of the sensor directly to a readout device such as an oscilloscope is possible for high-frequency impact indication, but is not suitable for most quantitative force measurements.

The primary function of the charge or voltage amplifier is to convert the high-impedance charge output to a usable low-impedance voltage signal for analysis or recording purposes. Laboratory charge amplifiers provide added versatility for signal normalization, ranging and filtering. PCB's electrostatic charge amplifiers have additional input adjustments for quasi-static measurements, static calibration, and drift-free dynamic operation. Miniature in-line amplifiers are generally of fixed range and frequency.

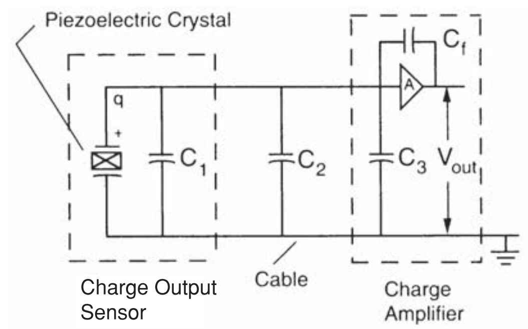
Quartz charge output force sensors can be used at operating temperatures up to 400 °F (204 °C).

When considering the use of charge output systems, remember that the output from the crystals is a pure electrostatic charge. The internal components of the force sensor and the external electrical connector maintain a very high (typically $>10^{12}$ ohm) insulation resistance so that the electrostatic charge generated by the crystals does not "leak away". Consequently, any connectors, cables or amplifiers used must also have a very high insulation resistance to maintain signal integrity.

Environmental contaminants such as moisture, dirt, oil, or grease can all contribute to reduced insulation, resulting in signal drift and inconsistent results.

The use of special, low-noise cable is required with charge output force sensors. Standard, two-wire or coaxial cable, when flexed, generates an electrostatic charge between the conductors. This is referred to as "triboelectric noise" and cannot be distinguished from the sensor's crystal electrostatic output. Low-noise cables have a special graphite lubricant between the dielectric shield which minimizes the triboelectric effect.

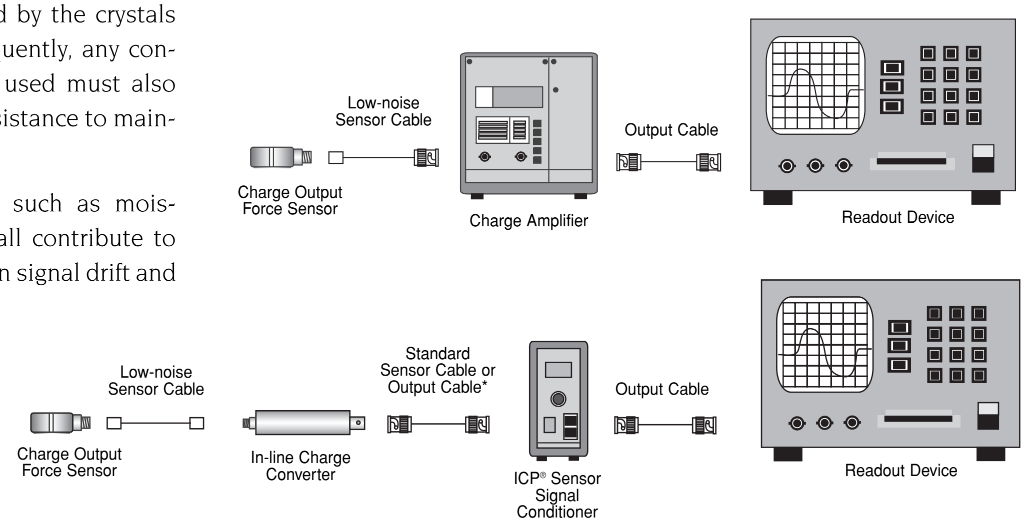
Figure 2 shows a typical charge output sensor system schematic including: sensor, low-noise cable, and charge amplifier.



q = charge signal
C_1 = sensor capacitance
C_2 = cable capacitance
C_3 = amplifier input capacitance
C_f = amplifier feedback capacitor

Figure 2. Charge Output Sensor System Schematic

If the measurement signal must be transmitted over long distances, PCB recommends the use of an in-line charge converter, placed near the force sensor. This minimizes the chance of noise. In-line charge converters can be operated from the same constant-current excitation power source as ICP® force sensors to minimize system cost. **Figure 3** shows two typical charge output systems and their components.



* Low-noise cable is required to maintain CE conformance.

Figure 3. Charge Output Systems

ICP® Low-Impedance Quartz Force Sensors

ICP® force sensors incorporate a built-in MOSFET microelectronic amplifier. This serves to convert the high-impedance charge output into a low-impedance voltage signal for analysis or recording. ICP® sensors, powered from a separate constant current source, operate over long ordinary coaxial or ribbon cable without signal degradation. The low-impedance voltage signal is not affected by triboelectric cable noise or environmental contaminants.

Power to operate ICP® sensors is generally in the form of a low cost, 24 to 27 VDC, 2 to 20 mA constant current supply. **Figure 4** schematically illustrates a typical ICP® sensor system. PCB offers a number of AC or battery powered, single or multi-channel power/signal conditioners, with or without gain capabilities, for use with force sensors (see Signal Conditioners Section of this catalog for available models). In addition, many data acquisition systems now incorporate constant current power for directly powering ICP® sensors. Because static calibration or quasi-static short-term response lasting up to a few seconds is often required, PCB also manufactures signal conditioners that provide DC coupling.

Figure 5. summarizes a complete 2-wire ICP® system configuration.

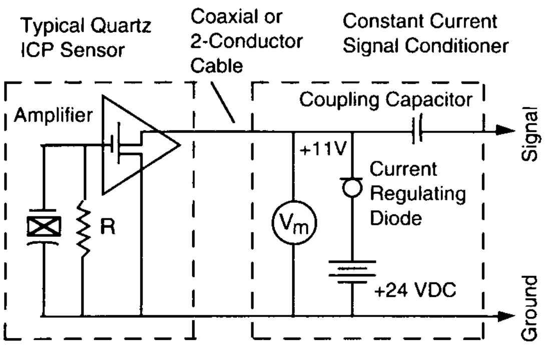
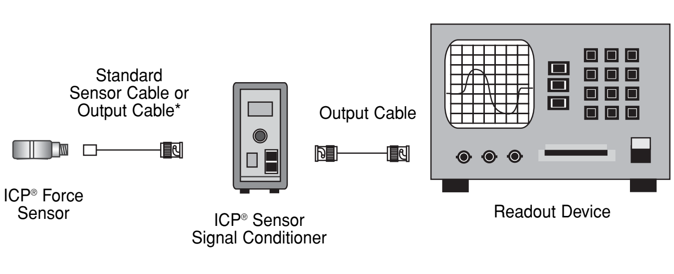


Figure 4. ICP® Sensor System Schematic



* Low-noise cable is required to maintain CE conformance.

Figure 5. Typical ICP® Sensor System

In addition to ease of operation, ICP® force sensors offer significant advantages over charge output types. Because of the low-impedance output and solid-state, hermetic construction, ICP® force sensors are well-suited for continuous, unattended force monitoring in harsh factory environments. Also, ICP® sensor cost-per-channel is substantially lower, since they operate through standard, low-cost coaxial cable, and do not require expensive charge amplifiers.

Polarity

The output voltage polarity of ICP® force sensors is positive for compression and negative for tension force measurements. The polarity of PCB charge output force sensors is the opposite: negative for compression and positive for tension. This is because charge output sensors are usually used with external charge amplifiers that exhibit an inverting characteristic. Therefore, the resulting system output polarity of the charge amplifier system is positive for compression and negative for tension; same as for an ICP® sensor system (reverse polarity sensors are also available).

Why Only Dynamic Force Can be Measured with Piezoelectric Force Sensors

The quartz crystals of a piezoelectric force sensor generate an electrostatic charge only when force is applied to or removed from them. However, even though the electrical insulation resistance is quite large, the electrostatic charge will eventually leak to zero through the lowest resistance path. In effect, if you apply a static force to a piezoelectric force sensor, the electrostatic charge output initially generated will eventually leak back to zero.

The rate at which the charge leaks back to zero is dependent on the lowest insulation resistance path in the sensor, cable and the electrical resistance/capacitance of the amplifier used.

In a charge output force sensor, the leakage rate is usually fixed by values of capacitance and resistance in the low-noise cable and external charge or source follower amplifier used.

Continued on next page

QUARTZ

In an ICP® force sensor with built-in electronics, the resistance and capacitance of the built-in circuitry normally determines the leakage rate.

When a rapid dynamic force is applied to a piezoelectric force sensor, the electrostatic charge is generated quickly and, with an adequate discharge time constant, does not leak back to zero. However, there is a point at which a slow speed dynamic force becomes quasi-static and the leakage is faster than the rate of the changing force. Where is the point at which the force is too slow for the piezoelectric force sensor to make the measurement? See the next section on Discharge Time Constant for the answer.

Discharge Time Constant (DTC)

When leakage of a charge (or voltage) occurs in a resistive capacitive circuit, the leakage follows an exponential decay. A piezoelectric force sensor system behaves similarly in that the leakage of the electrostatic charge through the lowest resistance also occurs at an exponential rate. The value of the electrical capacitance of the system (in farads), multiplied by the value of the lowest electrical resistance (in ohm) is called the Discharge Time Constant (in seconds).

DTC is defined as the time required for a sensor or measuring system to discharge its signal to 37% of the original value from a step change of measurand. This is true of any piezoelectric sensor, whether the operation be force, pressure or vibration monitoring. The DTC of a system directly relates to the low frequency monitoring capabilities of a system and, in the case of force monitoring, becomes very important as it is often desired to perform quasi-static measurements.

DTC Charge Output System

In a charge output system, the sensors do not contain built-in amplifiers, therefore, the DTC is usually determined by the settings on an external charge amplifier. A feedback resistor working together with a capacitor on the operational amplifier determines the time constant. PCB's laboratory-style charge amplifiers feature short, medium and long time constant selections. It is assumed that the electrical insulation resistance of the force sensor and cable connecting to the charge amplifier are larger than that of the feedback resistor in the charge amplifier; otherwise, drift will occur. Therefore, to assure this, the force sensor connection point and cable must be kept clean and dry.

Low Frequency Response of ICP® Systems

With ICP® force sensors, there are two factors which must be considered when making low frequency measurements. These are:

1. The discharge time constant characteristic of the ICP® force sensor.
2. The discharge time constant of the AC coupling circuit used in the signal conditioner (if DC coupling is used, only (1) above needs to be considered).

It is important that both factors be readily understood by the user to assure accurate low frequency measurements.

DTC in ICP® Force Sensors

The DTC is fixed by the components in an ICP® sensor's internal amplifier. Specifications for the ICP® force sensors shown in this catalog list the DTC for each force sensor.

When testing with ICP® sensors, there are two time constants that must be considered for low frequency determination, one being that of the sensor which is a fixed value, and the other being that of the coupling electrical circuit used in the signal conditioner.

When an ICP® sensor is subjected to a step function input, a quantity of charge, q, is produced proportional to the mechanical input. According to the law of electrostatics, output voltage is $\Delta V = \Delta q/\Delta C$ where C is the total capacitance of the sensing element, amplifier, and ranging capacitor.

This voltage is then amplified by the MOSFET amplifier to determine final sensor sensitivity. After the initial step input, the charge signal decays according to the equation:

$$q = Qe^{-t/RC}$$

where:

q = instantaneous charge (C)
Q = initial quantity of charge (C)
R = bias resistor value (ohm)
C = total capacitance (F)
e = base of natural log (2.718)
t = time elapsed since t_0 (sec)

This equation is also graphically represented in **Figure 6** below:

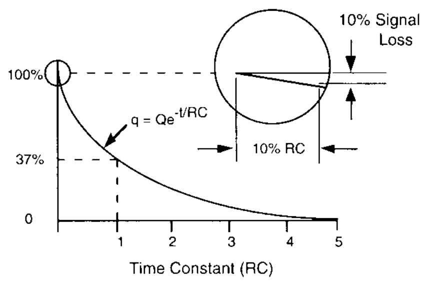


Figure 6. Standard DTC Curve

The product of R and C represents the DTC (in seconds) of the sensor. Sensor time constants vary from just a few seconds to >2000 seconds for standard sensors. Special time constants can be supplied by altering the resistor value, R, in the sensor's built-in circuitry.

Most readout instruments have a high input impedance of >1 megohm. For these systems, the sensor DTC as previously discussed becomes the dominant value and can be used in determining signal discharge rate. However, for signals coupled to low-impedance readout devices, generally <1 megohm, it is necessary to determine the system time constant. This will be explained further in the following section.

Signal Conditioner and Readout Time Constants

The external power supply used with an ICP® force sensor may also have a DTC associated with it. In some ICP® signal conditioners, which feature internal buffer amplifiers or gain amplifiers, the time constant is fixed by various internal components and may be shorter, or longer, than the sensor DTC. In signal conditioners with capacitive-coupled outputs, the DTC is not fixed. In this case, a capacitor used to decouple an ICP® force sensor bias voltage acts with the input impedance of the readout device to create another time constant.

Check the specifications of the signal conditioner to determine if it has a fixed internal DTC, which sets the low frequency response, or if it has a capacitive-coupled output. If the output is capacitive-coupled, the time constant, when fed into the input of the readout, can be calculated as follows:

$$DTC = RC$$

where:

R = input impedance of readout device (ohm)

C = value of coupling capacitor at output of signal conditioner (F)

Note that the output of some capacitive-coupled ICP® sensor power conditioners feature a shunt resistor that overrides the effects of the input resistance of the readout device if it is 1 megohm or greater.

AC coupling in the readout device is also an additional type of DTC. Check specifications for the power conditioners and readout instrument to be sure they are suitable for your particular dynamic measurement. If you have more than one DTC in the system, a time constant that is significantly shorter than the others will usually dominate. Determination of the system DTC for oscillating and transient inputs can be calculated from these equations:

Oscillating inputs: $$DTC = \frac{(R_1C_1)(R_2C_2)}{\sqrt{(R_1C_1)^2 + (R_2C_2)^2}}$$

Transient inputs (lasting up to 10% of smaller DTC): $$DTC = \frac{(R_1C_1)(R_2C_2)}{(R_1C_1) + (R_2C_2)}$$

To avoid potential problems, it is recommended to keep the coupling time constant at least 10 times longer than the sensor time constant. The system discharge time constant determines the low frequency response of the system. It is analogous to a first-order high-pass RC filter. The system's theoretical low frequency roll-off is illustrated in **Figure 7** below, and can be calculated from the following relationships:

3 dB down: $0.16/DTC = f_c$

10% down: $0.34/DTC = f_{-10\%}$

5% down: $0.5/DTC = f_{-5\%}$

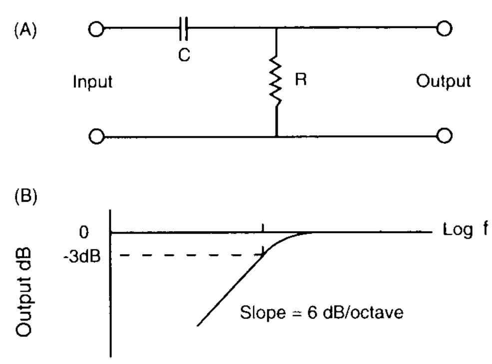


Figure 7. Low Frequency Characteristic of a First-order, High-pass Filter

Long Duration Events and DTC

It is often desired to measure an input pulse lasting a few seconds in duration. This is especially true with force sensor applications where static calibration or quasi-static measurements take place. Before performing tests of this nature, it is important to DC couple the entire monitoring system to prevent rapid signal loss. PCB's AC/DC mode signal conditioners are designed for such applications.

The general rule of thumb for such measurements is that the output signal loss and time elapsed over the first 10% of a DTC have an approximate one to one relationship. If a sensor has a 500 second DTC, over the first 50 seconds, 10% of the original input signal will have decayed. For 1% accuracy, data should be taken in the first 1% of the DTC. If 8% accuracy is acceptable, the measurement should be taken within 8% of the DTC, and so forth. **Figure 8** graphically demonstrates this event.

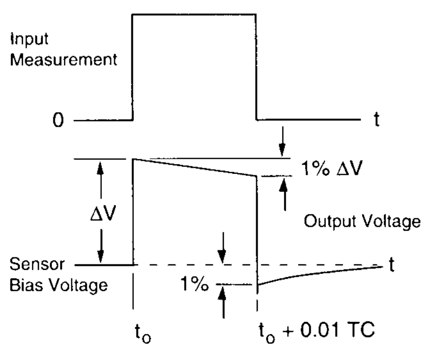


Figure 8. Step Function Response

Left unchanged, the signal will naturally decay toward zero. This will take approximately 5 DTC. You will notice that after the original step impulse signal is removed, the output signal dips below the base line reference point (t_0 +0.01 TC). This negative value is the same value as has decayed from the original impulse (shown as 1% in **Figure 8**). Further observation will reveal that the signal, left untouched, will decay upwards toward zero until equilibrium in the system is observed.

Force Sensor Natural Frequency

Unlike the low frequency response of the sensor, which is determined electrically through the DTC = RC equation, the high frequency response is determined by the sensor's mechanical configuration (unless electrical low-pass filtering has been added). Each force sensor has an upper frequency limit specification which should be observed when determining upper linear limits of operation.

Installation

Proper installation of quartz force sensors is essential for accurate dynamic measurement results. Although rugged PCB quartz force sensors are forgiving to some degree, certain basic procedures should be followed.

Since most PCB force sensors are designed with quartz compression plates to measure forces applied in an axial direction, aligning the sensor and contact surfaces to prevent edge loading or bending moments in the sensor will produce better dynamic measurement results.

Having parallelism between the sensor and test structure contact surfaces minimizes bending moments and edge loading. Flatness of mounting surfaces will also affect the quality of the measurement. Using a thin layer of lubricant on mounting surfaces during installation creates better contact between sensor and mounting surface.

The mounting surfaces on PCB force sensors are lapped during their manufacture to ensure that they are flat, parallel and smooth. Ring-style force sensors are supplied with anti-friction washers to minimize shear loading of the sensor surface when torquing between two surfaces.

Loading to the entire force sensor sensing surface is also important for good measurements. However, this can be difficult if the surface being brought into contact with the force sensor is flat but not parallel to the sensor mounting surface. In this case, an intermediate curved surface can lessen edge loading affects **(See Figure 9)**.

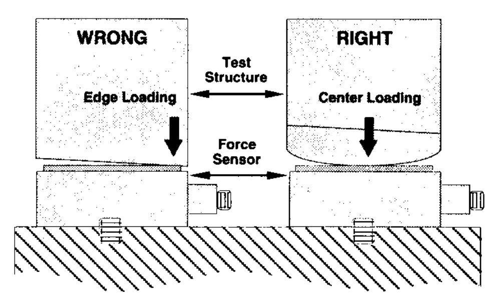


Figure 9. Edge Loading vs. Central Loading

PCB Series 208 force sensors are supplied with a convex curved impact cap to help spread the forces over the entire surface of the force sensor.

One other consideration when mounting force sensors is to minimize unnecessary mechanical high frequency shock loading of the sensors. The high frequency content of direct metal-to-metal impacts can often create short duration, high "g" overloads in structures and sensors. This problem can be minimized by using a thin damping layer of a softer material on the interface surface between the structure and sensor being impacted (it should be considered beforehand whether the slight damping of the high frequency shock is critical to the force measurement requirements). The impact surface on Series 200 and the impact caps on Series 208 Force Sensors are supplied with thin layers of damping material.

Pre-loading Force Rings and 3-Component Force Sensors

PCB ring-style 1-component and 3-component force sensors are generally installed between two parts of a test structure with the supplied elastic beryllium-copper stud or customer-supplied bolt. The stud or bolt holds the structure together, and applies pre-load to the force ring as shown in **Figure 10**. In the typical installation, shown on the left side in **Figure 10**, part of the force between the two structures is shunted through the mounting stud. The amount of force shunted may be up to 7% of the total force for the beryllium-copper stud supplied with the sensor, and up to 50% for steel studs. This typical installation setup is used by PCB during standard calibrations.

A non-typical installation is shown on the right side in **Figure 10**. In this non-typical installation, the stud or bolt used to apply the pre-load does not shunt part of the applied force. The plate on top of the sensor has a clearance hole that the stud or bolt passes through. In this installation, the stud or bolt is not directly connected to the top plate by its threads, as it is in the typical installation, so it does not shunt any force.

NOTE: If any of the following conditions apply to the pre-loading of the force ring in the application, the sensitivity and linearity performance of the sensor will not match the standard PCB calibration values.

1. **Use of a stud or bolt other than the supplied beryllium-copper stud**
2. **Use of no stud or bolt**
3. **Use of an amount of pre-load other than the recommended amount**
4. **Use of the non-typical installation setup shown below**

In these cases, please contact a Force/Torque Division application engineer to discuss your special calibration requirements.

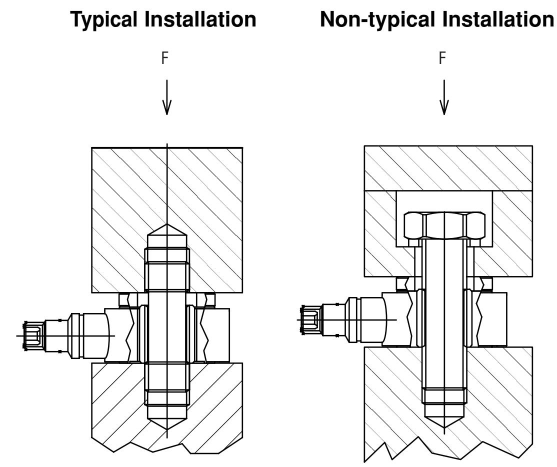


Figure 10. Force Ring Sensor Installations

PCB in-house calibration procedure requires the installation of a force ring with BeCu stud, in the typical installation setup above, in series with a NIST traceable reference sensor. Generally, a pre-load of 20% (full-scale operating range of the force ring) is applied before recording of measurement data. Contact a PCB application specialist for proper pre-load requirements. Allow the static component of the signal to discharge before calibration.

3-Component force sensors must be pre-loaded to achieve proper operation, particularly for the shear x-, and y-axis. The recommended applied pre-load for 3-component force sensors is 10 times their x-axis or y-axis measurement range. This pre-load provides the sensing crystals with the compressive loading required to achieve an output in response to shear direction input forces. As with force rings, the sensitivity achieved from a 3-component force sensor is dependent upon the applied pre-load and the elasticity characteristics of the mounting bolt or stud used. If the unit is to be installed with a stud or bolt other than the supplied elastic, beryllium-copper stud, a calibration using the actual mounting hardware must be preformed. Errors in sensitivity of up to 50% can result by utilizing studs or bolts of different materials.

Typical Piezoelectric System Output

The output characteristic of piezoelectric sensors is that of an AC coupled system, where repetitive signals will decay until there is an equal area above and below the original base line. As magnitude levels of the monitored event fluctuate, the output will remain stabilized around the base line with the positive and negative areas of the curve remaining equal. **Figure 11** represents an AC signal following this curve (output from sensors operating in DC mode following this same pattern, but over an extended time frame associated with sensor time constant values).

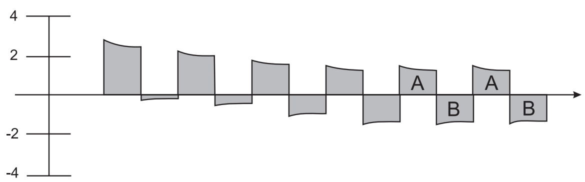


Figure 11. Repetitive Pulse, AC Signal

Example: Assuming a 0 to 3 volt output signal is generated from an AC coupled force application with a one second steady-state pulse rate and one second between pulses. The frequency remains constant, but the signal quickly decays negatively until the signal centers around the original base line (where area A = area B). Peak-to-peak output remains the same.

Repetitive Pulse Applications

In many force monitoring applications, it is desired to monitor a series of zero-to-peak repetitive pulses that may occur within a short time interval of one another. This output signal is often referred to as a "pulse train". As has been previously discussed, the AC coupled output signal from piezoelectric sensors will decay towards an equilibrium state, making it look like the positive force is decreasing. In this scenario, it would be difficult to accurately monitor a continuous zero-to-peak output signal such as those associated with stamping or pill press applications. With the use of special ICP® sensor signal conditioning equipment it becomes possible to position an output signal positive going above a ground-based zero. Operating in drift-free AC mode, PCB's Model 482C42 signal conditioner provides the constant current voltage excitation to ICP® force sensors and has a zero-based clamping circuit that electronically resets each pulse to zero. As outlined in **Figure 12**, this special circuitry prevents the output from drifting negatively, and provides a continuous, positive polarity signal.

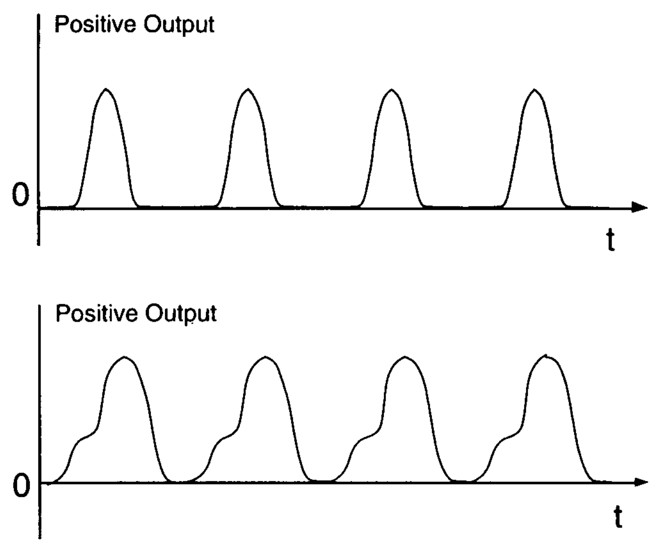
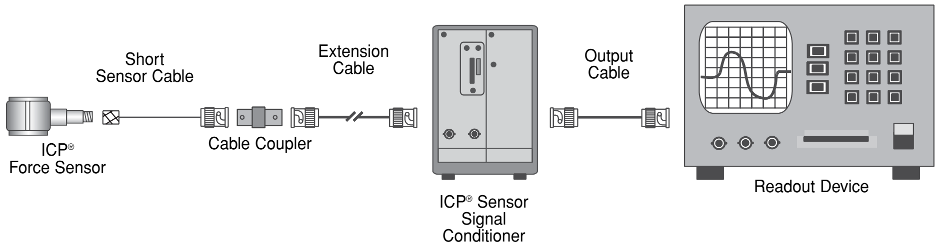


Figure 12. Positive Polarity, Zero-based AC Output

CABLE DRIVING CONSIDERATIONS AND CONSTANT CURRENT LEVEL



Operation over long cables may effect frequency response and introduce noise and distortion when an insufficient current is available to drive cable capacitance.

Unlike charge output systems, where the system noise is a function of cable length, ICP® sensors provide a high-voltage, low-impedance output well-suited for driving long cables through harsh environments. While there is virtually no increase in noise with ICP® sensors, the capacitive loading of the cable may distort or filter higher frequency signals depending on the supply current and the output impedance of the sensor.

Generally, this signal distortion is not a problem with lower frequency testing within a range up to 10k Hz. However, for higher frequency vibration, shock, or transient testing over cables longer than 100 ft (30 m), the possibility of signal distortion exists.

The maximum frequency that can be transmitted over a given cable length is a function of both the cable capacitance and the ratio of the peak signal voltage to the current available from the signal conditioner according to:

$$f_{max} = \frac{10^9}{2\pi CV / (I_C - 1)}$$

where, f_{max} = maximum frequency (hertz)
C = cable capacitance (picofarads)
V = maximum peak output from sensor (volts)
I_C = constant current from signal conditioner (mA)
10^9 = scaling factor to equate units

Note that in the equation, 1 mA is subtracted from the total current supplied to the sensor (Ic). This is done to compensate for powering the internal electronics. Some specialty sensor electronics may consume more or less current. Contact the manufacturer to determine the correct supply current. When driving long cables, the equation above shows that as the length of cable, peak voltage output or maximum frequency of interest increases, a greater constant current will be required to drive the signal.

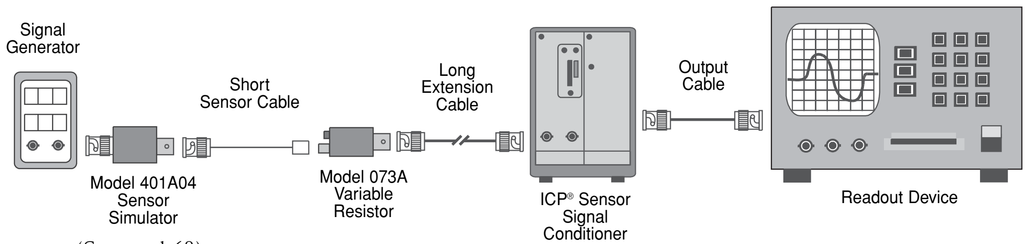
The nomograph on page 1.91 provides a simple, graphical method for obtaining the expected maximum frequency capability of an ICP® measurement system. The maximum peak signal voltage amplitude, cable capacitance, and supplied constant current must be known or presumed.

For example, when running a 100 ft (30 m) cable with a capacitance of 30 pF/ft (98 pF/m), the total capacitance is 3000 pF. This value can be found along the diagonal cable capacitance lines. Assuming the sensor operates at a maximum output range of 5 volts and the constant current signal conditioner is set at 2 mA, the ratio on the vertical axis can be calculated to equal 5. The intersection of the total cable capacitance and this ratio result in a maximum frequency of approximately 10.2k Hz.

The nomograph does not indicate whether the frequency amplitude response at a point is flat, rising, or falling. For precautionary reasons, it is good general practice to increase the constant current (if possible) to the sensor (within its maximum limit) so that the frequency determined from the nomograph is approximately 1.5 to 2 times greater than the maximum frequency of interest.

Note that higher current levels will deplete battery powered signal conditioners at a faster rate. Also, any current not used by the cable goes directly to power the internal electronics and will create heat. This may cause the sensor to exceed its maximum temperature specification. For this reason, do not supply excessive current over short cable runs or when testing at elevated temperatures.

Experimentally Testing Long Cables



(*See page* 1.68)

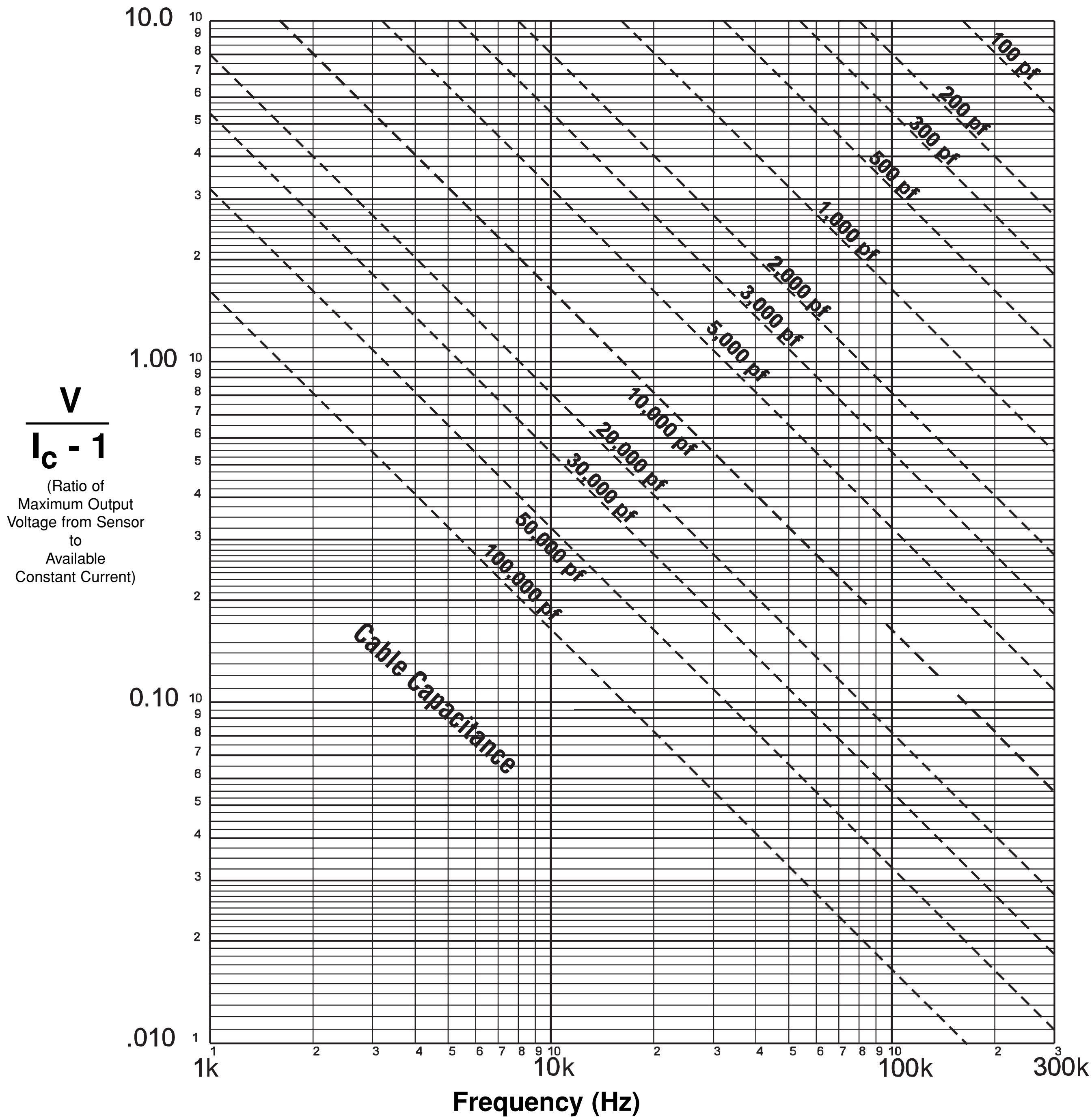
To more accurately determine the effect of long cables, it is recommended to experimentally determine the high frequency electrical characteristics.

The method illustrated below involves connecting the output from a standard signal generator into a unity gain, low-output impedance (<5 ohm) instrumentation amplifier in series with the ICP® sensor. The extremely low output impedance is required to minimize the resistance change when the signal generator/amplifier is removed from the system.

In order to check the frequency/amplitude response of this system, set the signal generator to supply the maximum amplitude of the expected measurement signal. Observe the ratio of the amplitude from the generator to that shown on the scope. If the ratio is 1:1, the system is adequate for your test. If necessary, be certain to factor in any gain in the signal conditioner or scope. If the output signal is increasing (+25% for example), add series resistance to attenuate the signal. Use of a variable 100 ohm resistor will help set the correct resistance more conveniently. Note that this is the only condition that requires the addition of resistance. If the signal is decreasing (-25% for example), the constant current level must be increased or the cable capacitance reduced.

It may be necessary to physically install the cable during cable testing to reflect the actual conditions encountered during data acquisition. This will compensate for potential inductive cable effects that are partially a function of the geometry of the cable route.

Cable Driving Nomograph



$$f_{max} = \frac{10^9}{2\pi CV / (I_c - 1)}$$

f_{max} = Maximum frequency (Hz)
C = Cable capacitance (pF)
V = Maximum output voltage from sensor (volts)
I_c = Constant current level from power unit (mA)
10^9 = Scale factor to equate units

Conversion and Useful Formulas

Voltage sensitivity of a charge output piezoelectric sensor:

$$V = \frac{q}{C}$$

V = voltage sensitivity
q = charge sensitivity
C = capacitance of sensor

Voltage sensitivity of a charge output piezoelectric sensor with source follower:

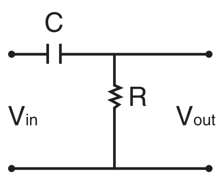
$$V = \frac{q}{C_1 + C_2 + C_3}$$

C_1 = capacitance of sensor
C_2 = capacitance of interconnecting cable
C_3 = input capacitance of unity gain source follower

Time constant for a first-order, high-pass filter:

t = RC

R = resistance in ohm
C = capacitance in farads
t = time constant in seconds



Lower corner frequency (-3 dB) for an RC time constant:

$$f_C = \frac{1}{2\,\pi\,RC}$$

f_C = frequency at which signal is attenuated by -3 dB

Lower -5% frequency point for an RC time constant:

$$f_{-5\%} = \frac{3}{2\,\pi\,RC}$$

$f_{-5\%}$ = frequency at which signal is attenuated by 5%

Approximate upper +5% frequency point for single-degree-of-freedom mechanical system:

$$f_{+5\%} = \frac{f_r}{5}$$

$f_{+5\%}$ = frequency at which signal is amplified by 5%
f_r = natural (resonant) frequency

Approximating two time constants in series for oscillating signals:

$$\frac{(R_1C_1)\,(R_2C_2)}{\sqrt{(R_1C_1)^2 + (R_2C_2)^2}}$$

Approximating two time constants in series for transient inputs lasting up to 10% of the smaller time constant value:

$$\frac{(R_1C_1)\,(R_2C_2)}{(R_1C_1) + (R_2C_2)}$$

Rise time of a piezoelectric sensor:

$$t_r = \frac{1}{2\,f_r}$$

t_r = rise time
f_r = natural (resonant) frequency of the sensor

Acceleration:

$$\frac{m}{sec^2} = \frac{g}{9.81}$$

Temperature:

$$°C = \frac{(°F-32)\,5}{9}$$

Weight:

$$gm = \frac{lb}{453.59}$$

$$gm = \frac{oz}{28.35}$$

1 kg = 2.204 lb

1 lb = 4.448 N

1000 lb = 4.448k N

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Use of charge 3-component force sensors and pre-configured modular signal conditioning system to perform non-destructive vibration testing, Dave Corelli, 1999.

Glossary of Terms

Reprinted with permission from Application Note: AN 243-1, "Effective Machinery Measurements Using Dynamic Signal Analyzers," Hewlett-Packard Company, 1991. Editing and additions performed by PCB Piezotronics, Depew, NY, 1998.

Acceleration — The time rate of change of velocity. Typical units are ft/s2, meters/s2, and G's (1G = 32.17 ft/s2 = 9.81 m/s2). Acceleration measurements are usually made with accelerometers.

Accelerometer — Transducer whose output is directly proportional to acceleration. Most commonly use piezoelectric crystals to produce output.

Aliasing — A phenomenon which can occur whenever a signal is not sampled at greater than twice the maximum bandwidth of the signal. Causes high frequency signals to appear at low frequencies. Aliasing is minimized by filtering the signal to a bandwidth less than fi the sample rate. When the signal starts at 0 Hz (baseband signals), *bandwidth* can be exchanged to *maximum frequency* in the definition above.

Alignment — A condition whereby the axes of machine components are either coincident, parallel, or perpendicular, according to design requirements.

Amplification Factor (Synchronous) — A measure of the susceptibility of a rotor to vibration amplitude when rotational speed is equal to the rotor natural frequency (implies a flexible rotor). For imbalance type excitation, synchronous amplification factor is calculated by dividing the amplitude value at the resonant peak by the amplitude value at a speed well above resonance (as determined from a plot of synchronous response vs. rpm).

Amplitude — The magnitude of dynamic motion or vibration. Amplitude is expressed in terms of peak-to-peak, zero-to-peak, or rms. For pure sine waves only, these are related as follows: rms = 0.707 times zero-to-peak; peak-to-peak = 2 times zero-to-peak. DSAs generally read rms for spectral components, and peak for time domain components.

Anti-aliasing Filter — Most commonly a low-pass filter designed to filter out frequencies higher than 1/2 the sample rate in order to minimize aliasing.

Anti-friction Bearing — See Rolling Element Bearing.

Asymmetrical Support — Rotor support system that does not provide uniform restraint in all radial directions. This is typical for most heavy industrial machinery where stiffness in one plane may be substantially different than stiffness in the perpendicular plane. Occurs in bearings by design, or from preloads such as gravity or misalignment.

Asynchronous — Vibration components that are not related to rotating speed (also referred to as nonsynchronous).

Attitude Angle (Steady-State) — The angle between the direction of steady-state preload through the bearing centerline, and a line drawn between the shaft centerline and the bearing centerline. (Applies to fluid-film bearings.)

Auto Spectrum (Power Spectrum) — DSA spectrum display whose magnitude represents the power at each frequency, and which has no phase.

Averaging — In a DSA, digitally averaging several measurements to improve accuracy or to reduce the level of asynchronous components. Refer to definitions of rms, time, and peak-hold averaging.

Axial — In the same direction as the shaft centerline.

Axial Position — The average position, or change in position, of a rotor in the axial direction with respect to some fixed reference position. Ideally the reference is a known position within the thrust bearing axial clearance or float zone, and the measurement is made with a displacement transducer observing the thrust collar.

Balancing Resonance Speed(s) — A rotative speed that corresponds to a natural resonance frequency.

Balanced Condition — For rotating machinery, a condition where the shaft geometric centerline coincides with the mass centerline.

Balancing — A procedure for adjusting the radial mass distribution of a rotor so that the mass centerline approaches the rotor geometric centerline.

Band-pass Filter — A filter with a single transmission band extending from lower to upper cutoff frequencies. The width of the band is normally determined by the separation of frequencies at which amplitude is attenuated by 3 dB (a factor 0.707).

Bandwidth — The distance between frequency limits at which a band-pass filter attenuates the signal by 3 dB. In a DSA, the measurement bandwidth is equal to [(frequency span)/(number of filters) x (window factor)]. Window factors are: 1 for uniform, 1.5 for Hanning, and 3.4 for flat top (P301) and 3.6 for flat top (P401). See flat top for more information.

Baseline Spectrum — A vibration spectrum taken when a machine is in good operating condition; used as a reference for monitoring and analysis.

Blade Passing Frequency — A potential vibration frequency on any bladed machine (turbine, axial compressor, fan, etc.). It is represented by the number of blades times shaft-rotating frequency.

Block Size — The number of samples used in a DSA to compute the Fast Fourier Transform. Also the number of samples in a DSA time display. Most DSAs use a block size of 1024. Smaller block size reduces frequency resolution.

Bode — Rectangular coordinate plot of 1x component amplitude and phase (relative to a keyphasor) vs. running speed.

BPFO, BPFI — Common abbreviations for ball pass frequency of defects on outer and inner bearing races, respectively.

Bow — A shaft condition such that the geometric centerline of the shaft is not straight.

Brinneling (False) — Impressions made by bearing rolling elements on the bearing race; typically caused by external vibration when the shaft is stationary.

Calibration — A test during which known values of the measured variable are applied to the transducer or readout instrument, and output readings varied or adjusted.

Campbell Diagram — A mathematically constructed diagram used to check for coincidence of vibration sources (i.e. 1 x imbalance, 2 x misalignment) with rotor natural resonances. The form of the diagram is like a spectral map (frequency versus rpm), but the amplitude is represented by a rectangular plot, the larger the amplitude the larger the rectangle. Also known as an interference diagram.

Cascade Plot — See Spectral Map.

Cavitation — A condition which can occur in liquid-handling machinery (e.g. centrifugal pumps) where a system pressure decrease in the suction line and pump inlet lowers fluid pressure and vaporization occurs. The result is mixed flow which may produce vibration.

Center Frequency — For a bandpass filter, the center of the transmission band, measured in a linear scale.

Charge Amplifier — Amplifier used to convert accelerometer output impedance from high to low, making calibration much less dependent on cable capacitance.

Coherence — Measures how much of the output signal is dependent on the input signal in a linear and time-invariant way. It is an effective means of determining the similarity of vibration at two locations, giving insight into the possibility of cause and effect relationships.

Constant Bandwidth Filter — A band-pass filter whose bandwidth is independent of center frequency. The filters simulated digitally by the FFT in a DSA are constant bandwidth.

Constant Percentage Bandwidth — A band-pass filter whose bandwidth is a constant percentage of center frequency. 1/3 octave filters, including those synthesized in DSAs, are constant percentage bandwidth.

Critical Machinery — Machines which are critical to a major part of the plant process. These machines are usually unspared.

Critical Speeds — In general, any rotating speed which is associated with high vibration amplitude. Often, the rotor speeds which correspond to natural frequencies of the system.

Critical Speed Map — A rectangular plot of system natural frequency (y-axis) versus bearing or support stiffness (x-axis).

Cross Axis Sensitivity — A measure of off-axis response of velocity and acceleration transducers.

Cycle — One complete sequence of values of a periodic quantity.

Damping — The quality of a mechanical system that restrains the amplitude of motion with each successive cycle. Damping of shaft motion is provided by oil in bearings, seals, etc. The damping process converts mechanical energy to other forms, usually heat.

Damping, Critical — The smallest amount of damping required to return the system to its equilibrium position without oscillation.

Decibels (dB) — A logarithmic representation of amplitude ratio, defined as 10 times the base ten logarithm of the ratio of the measured power to a reference. dBV readings, for example, are referenced to 1 volt rms. dB amplitude scales are required to display the full dynamic range of a DSA.

Degrees of Freedom — A phrase used in mechanical vibration to describe the complexity of the system. The number of degrees of freedom is the number of independent variables describing the state of a vibrating system.

Digital Filter — A filter which acts on the data after it has been sampled and digitized. Often used in DSAs to provide anti-aliasing protection before internal re-sampling.

Differentiation — Representation in terms of time rate of change. For example, differentiating velocity yields acceleration. In a DSA, differentiation is performed by multiplication by *j*w in the frequency domain, where w is frequency multiplied by 2p. (Differentiation can also be used to convert displacement to velocity.)

Discrete Fourier Transform — A procedure for calculating discrete frequency components (filters or lines) from sampled time data. Since the frequency domain result is complex (i.e., real and imaginary components), the number of frequency points is equal to half the number of time samples (for a real FFT). When using zoom analysis, the FFT uses complex time data and then the number of frequency lines is equal to the number of time samples.

Displacement — The change in distance or position of an object relative to a reference.

Displacement Transducer — A transducer whose output is proportional to the distance between it and the measured object (usually the shaft).

DSA — See Dynamic Signal Analyzer.

Dual Probe — A transducer set consisting of displacement and velocity transducers. Combines measurement of shaft motion relative to the displacement transducer with velocity of the displacement transducer to produce absolute motion of the shaft.

Dual Voting — Concept where two independent inputs are required before action (usually machine shutdown) is taken. Most often used with axial position measurements, where failure of a single transducer might lead to an unnecessary shutdown.

Dynamic Motion — Vibratory motion of a rotor system caused by mechanisms that are active only when the rotor is turning at speeds above slow roll speed.

Dynamic Signal Analyzer (DSA) — Vibration analyzer that uses digital signal processing and the Fast Fourier Transform to display vibration frequency components. DSAs also display the time domain and phase spectrum, and can usually be interfaced to a computer.

Eccentricity, Mechanical — The variation of the outer diameter of a shaft surface when referenced to the true geometric centerline of the shaft. Out-of-roundness.

Eccentricity Ratio — The vector difference between the bearing centerline and the average steady-state journal centerline.

Eddy Current — Electrical current which is generated (and dissipated) in a conductive material in the presence of an electromagnetic field.

Glossary of Terms

Electrical Runout — An error signal that occurs in eddy current displacement measurements when shaft surface conductivity varies.

Engineering Units — In a DSA, refers to units that are calibrated by the user (e.g., in/s, g's).

External Sampling — In a DSA, refers to control of data sampling by a multiplied tachometer signal. Provides a stationary display of rpm-related peaks with changing speed.

Fast Fourier Transform (FFT) — A computer (or microprocessor) procedure for calculating discrete frequency components from sampled time data. A special case of the Discrete Fourier Transform, DFT, where the number of samples is constrained to a power of 2 for speed.

Filter — Electronic circuitry designed to pass or reject a specific frequency band.

Finite Element Modeling — A computer aided design technique for predicting the dynamic behavior of a mechanical system prior to construction. Modeling can be used, for example, to predict the natural frequencies of a flexible rotor.

Flat Top Filter — FFT window function which provides the best amplitude accuracy for measuring discrete frequency components. Note: there are several different flat top windows. The HP proprietary P401 is the "best" flat top window. P301 is the most common.

Fluid-film Bearing — A bearing which supports the shaft on a thin film of oil. The fluid-film layer may be generated by journal rotation (hydrodynamic bearing), or by externally applied pressure (hydrostatic bearing).

Forced Vibration — The oscillation of a system under the action of a forcing function. Typically forced vibration occurs at the frequency of the exciting force.

Free Vibration — Vibration of a mechanical system following an initial force - typically at one or more natural frequencies.

Frequency — The repetition rate of a periodic event, usually expressed in cycles per second (Hz), revolutions per minute (rpm), or multiples of a rotational speed (orders). Compare to orders that are commonly referred to as 1x for rotational speed, 2x for twice rotational speed, etc.

Frequency Response Function — The amplitude and phase response characteristics of a system.

G — The value of acceleration produced by the force of gravity.

Gear Mesh Frequency — A potential vibration frequency on any machine that contains gears; equal to the number of teeth multiplied by the rotational frequency of the gear.

Hanning Window — FFT window function that normally provides better frequency resolution than the flat top window, but with reduced amplitude accuracy.

Harmonic — Frequency component at a frequency that is an integer multiple of the fundamental frequency.

Heavy Spot — The angular location of the imbalance vector at a specific lateral location on a shaft. The heavy spot typically does not change with rotational speed.

Hertz (Hz) — The unit of frequency represented by cycles per second.

High Spot — The angular location on the shaft directly under the vibration transducer at the point of closest proximity. The high spot can move with changes in shaft dynamics (e.g., from changes in speed).

High-pass Filter — A filter with a transmission band starting at a lower cutoff frequency and extending to (theoretically) infinite frequency.

Hysteresis — Non-uniqueness in the relationship between two variables as a parameter increases or decreases. Also called deadband, or that portion of a system's response where a change in input does not produce a change in output.

Imbalance — Unequal radial weight distribution on a rotor system; a shaft condition such that the mass and shaft geometric center lines do not coincide.

Impact Test — Response test where the broad frequency range produced by an impact is used as the stimulus. Sometimes referred to as a bump test. See impulse response for more information.

Impedance, Mechanical — The mechanical properties of a machine system (mass, stiffness, damping) that determine the response to periodic forcing functions.

Impulse Response — The response of a system to an impulse as input signal. The output then produces the impulse response that is the time domain equivalent to the Frequency Response Function, FRF.

Influence Coefficients — Mathematical coefficients that describe the influence of system loading on system deflection.

Integration — A process producing a result that, when differentiated, yields the original quantity. Integration of acceleration, for example, yields velocity. Integration is performed in a DSA by dividing the frequency lines by *j*w, where w is frequency multiplied by 2p. (Integration is also used to convert velocity to displacement.)

Journal — Specific portions of the shaft surface from which rotor applied loads are transmitted to bearing supports.

Keyphasor — A signal used in rotating machinery measurements, generated by a transducer observing a once-per-revolution event. The keyphasor signal is used in phase measurements for analysis and balancing. (Keyphasor is a Bently Nevada trade name.)

Lateral Location — The definition of various points along the shaft axis of rotation.

Lateral Vibration — See Radial Vibration.

Leakage — In DSAs, a result of finite time record length that results in smearing of frequency components. Its effects are greatly reduced by the use of weighted time functions such as Flat top or Hanning windows.

Linearity — The response characteristics of a linear system remain constant with input level and/or excitation signal type. That is, if the response to input *a* is $k \cdot a$, and the response to input *b* is $k \cdot b$, then the response of a linear system to input $(a + b)$ will be $(k \cdot a + k \cdot b)$, independent of the function *k*. An example of a non-linear system is one whose response is limited by mechanical stop, such as occurs when a bearing mount is loose.

Lines — Common term used to describe the filters of a DSA produced by the FFT (e.g., 400 line analyzer).

Linear Averaging — See Time Averaging.

Low-pass Filter — A filter whose transmission band extends from dc to an upper cutoff frequency.

Mechanical Runout — An error in measuring the position of the shaft centerline with a displacement probe that is caused by out-of-roundness and surface imperfections.

Micrometer (MICRON) — One millionth (.000001) of a meter. (1 micron = 1 x E^{-6} meters @ 0.04 mils.)

MIL — One thousandth (0.001) of an inch. (1 mil = 25.4 microns)

Modal Analysis — The process of breaking complex vibration into its component modes of vibration, very much like frequency domain analysis breaks vibration down to component frequencies.

Mode Shape — The resultant deflected shape of a rotor at a specific rotational speed to an applied forcing function. A three-dimensional presentation of rotor lateral deflection along the shaft axis.

Modulation, Amplitude (AM) — The process where the amplitude of a signal is varied as a function of the instantaneous value of a another signal. The first signal is called the carrier, and the second signal is called the modulating signal. Amplitude modulation always produces a component at the carrier frequency, with components (sidebands) at the frequency of the carrier frequency plus minus the modulating signal.

Modulation, Frequency (FM) — The process where the frequency of the carrier is determined by the amplitude of the modulating signal. Frequency modulation produces a component at the carrier frequency, with adjacent components (sidebands) at frequencies around the carrier frequency related to the modulating signal. The carrier and sidebands are described by Bessel functions.

Natural Frequency — The frequency of free vibration of a system. The frequency at which an undamped system with a single degree of freedom will oscillate upon momentary displacement from its rest position.

Nodal Point — A point of minimum shaft deflection in a specific mode shape. May readily change location along the shaft axis due to changes in residual imbalance or other forcing function, or change in restraint such as increased bearing clearance.

Noise — Any component of a transducer output signal that does not represent the variable intended to be measured.

Nyquist Criterion — Requirement that a sampled system needs to be sampled at a frequency greater than twice the bandwidth of the signal to be sampled.

Nyquist Plot — A plot of real versus imaginary spectral components that is often used in servo analysis. Should not be confused with a polar plot of amplitude and phase of 1x vibration.

Octave — The interval between two frequencies with a ratio of 2 to 1.

Oil Whirl/Whip — An unstable free vibration whereby a fluid-film bearing has insufficient unit loading. Under this condition, the shaft centerline dynamic motion is usually circular in the direction of rotation. Oil whirl occurs at the oil flow velocity within the bearing, usually 40 to 49% of shaft speed. Oil whip occurs when the whirl frequency coincides with (and becomes locked to) a shaft resonant frequency. (Oil whirl and whip can occur in any case where fluid is between two cylindrical surfaces.)

Orbit — The path of the shaft centerline motion during rotation. The orbit is observed with an oscilloscope connected to x and y-axis displacement transducers. Some dual-channel DSAs also have the ability to display orbits.

Oscillator-demodulator — A signal conditioning device that sends a radio frequency signal to an eddy-current displacement probe, demodulates the probe output, and provides output signals proportional to both the average and dynamic gap distances. (Also referred to as Proximitor, a Bently Nevada trade name.)

Peak Hold — In a DSA, a type of averaging that holds the peak signal level for each frequency component.

Period — The time required for a complete oscillation or for a single cycle of events. The reciprocal of frequency.

Phase — A measurement of the timing relationship between two signals, or between a specific vibration event and a keyphasor pulse. Phase is often measured as a function of frequency.

Piezoelectric — Any material which provides a conversion between mechanical and electrical energy. For a piezoelectric crystal, if mechanical stresses are applied on two opposite faces, electrical charges appear on some other pair of faces.

Polar Plot — Polar coordinate representation of the locus of the 1x vector at a specific lateral shaft location with the shaft rotational speed as a parameter.

Power Spectrum — See Auto Spectrum.

Pre-load, Bearing — The dimensionless quantity that is typically expressed as a number from zero to one where a preload of zero indicates no bearing load upon the shaft, and one indicates the maximum preload (i.e., line contact between shaft and bearing).

Pre-load, External — Any of several mechanisms that can externally load a bearing. This includes “soft” preloads such as process fluids or gravitational forces as well as “hard” preloads from gear contact forces, misalignment, rubs, etc.

Proximitor — See Oscillator/Demodulator.

Radial — Direction perpendicular to the shaft centerline.

Radial Position — The average location, relative to the radial bearing centerline, of the shaft dynamic motion.

Glossary of Terms

Radial Vibration — Shaft dynamic motion or casing vibration which is in a direction perpendicular to the shaft centerline.

Real-time Analyzer — See Dynamic Signal Analyzer.

Real-time Rate — For a DSA, the broadest frequency span at which data is sampled continuously. Real-time rate is mostly dependent on FFT processing speed. If the definition of real-time rate is “not miss any data”, the real-time rate will be window dependent. The real-time rate will decrease when using any other window than uniform.

Rectangular Window — See Uniform Window.

Relative Motion — Vibration measured relative to a chosen reference. Displacement transducers generally measure shaft motion relative to the transducer mounting.

Repeatability — The ability of a transducer or readout instrument to reproduce readings when the same input is applied repeatedly.

Resolution — The smallest change in stimulus that will produce a detectable change in the instrument output.

Resonance — The condition of vibration amplitude and phase change response caused by a corresponding system sensitivity to a particular forcing frequency. A resonance is typically identified by a substantial amplitude increase, and related phase shift.

Rolling Element Bearing — Bearing whose low friction qualities derive from rolling elements (balls or rollers), with little lubrication.

Root Mean Square (rms) — Square root of the arithmetical average of a set of squared instantaneous values. DSAs perform rms averaging digitally on successive vibration spectra, frequency line by frequency line.

Rotor, Flexible — A rotor which operates close enough to, or beyond its first bending critical speed for dynamic effects to influence rotor deformations. Rotors which cannot be classified as rigid rotors are considered to be flexible rotors.

Rotor, Rigid — A rotor which operates substantially below its first bending critical speed. A rigid rotor can be brought into, and will remain in, a state of satisfactory balance at all operating speeds when balanced on any two arbitrarily selected correction planes.

Runout Compensation — Electronic correction of a transducer output signal for the error resulting from slow roll runout.

Seismic — Refers to an inertially referenced measurement or a measurement relative to free space.

Seismic Transducer — A transducer that is mounted on the case or housing of a machine and measures casing vibration relative to free space. Accelerometers and velocity transducers are seismic.

Signal Conditioner — A device placed between a signal source and a readout instrument to change the signal and/or bandwidth. Examples: attenuators, preamplifiers, charge amplifiers, filters.

Signature — Term usually applied to the vibration frequency spectrum which is distinctive and special to a machine or component, system or subsystem at a specific point in time, under specific machine operating conditions, etc. Used for historical comparison of mechanical condition over the operating life of the machine.

Slow Roll Speed — Low rotative speed at which dynamic motion effects from forces such as imbalance are negligible.

Spectral Map — A three-dimensional plot of the vibration amplitude spectrum versus another variable, usually time or rpm.

Spectrum Analyzer — An instrument which displays the frequency spectrum of an input signal.

Stiffness — The spring-like quality of mechanical and hydraulic elements to elasticity deform under load.

Strain — The physical deformation, deflection, or change in length resulting from stress (force per unit area).

Subharmonic — Sinusoidal quantity of a frequency that is an integral submultiple of a fundamental frequency.

Subsynchronous — Component(s) of a vibration signal which has a frequency less than shaft rotative frequency.

Synchronous Sampling — In a DSA, it refers to the control of the effective sampling rate of data; which includes the processes of external sampling and computed resampling used in order tracking.

Time Averaging — In a DSA, averaging of time records that results in reduction of asynchronous components with reference to the trigger.

Time Record — In a DSA, the sampled time data converted to the frequency domain by the FFT. Most DSAs use a time record of 1024 samples.

Torsional Vibration — Amplitude modulation of torque measured in degrees peak-to-peak referenced to the axis of shaft rotation.

Tracking Filter — A low-pass or band-pass filter which automatically tracks the input signal versus the rpm. A tracking filter is usually required for aliasing protection when data sampling is controlled externally.

Transducer — A device for translating the magnitude of one quantity into another quantity.

Transient Vibration — Temporarily sustained vibration of a mechanical system. It may consist of forced or free vibration or both. Typically this is associated with changes in machine operating condition such as speed, load, etc.

Transverse Sensitivity — See Cross-Axis Sensitivity.

Trigger — Any event which can be used as a timing reference. In a DSA, a trigger can be used to initiate a measurement.

Unbalance — See Imbalance.

Uniform Window — In a DSA, a window function with uniform weighting across the time record. This window does not protect against leakage, and should be used only with transient signals contained completely within the time record.

Vector — A quantity which has both magnitude and direction (phase).

Waterfall Plot — See Spectral Map.

Force Sensor Application Inquiry Form

The force sensors listed in this catalog represent our most popular sensors, which are only a fraction of the sensors we offer. In addition to our standard sensors, PCB can customize sensors to meet your specific needs. Please fill out this inquiry form with any information available to you, so that we may help you with your dynamic measurement application. If you would like to discuss your application, or if it is not listed, please call, fax, E-mail, or write to PCB for suggestions.

Name: ______________________________ Date: ______________________________

Company: ______________________________ Phone: ____________________Ext.: ________

Dept.: ______________________________ Fax: ______________________________

Address: ______________________________ City/State: __________________Zip ________

QUARTZ

1. NATURE OF REQUEST

❑ Inquiry ❑ Order ❑ Quotation ❑ Delivery Information ❑ Complaint ❑ Trouble with Equipment

❑ Service or Repair ❑ Equipment Operation ❑ Visit required from PCB or Sales Representative in your area

2. DESCRIBE THE APPLICATION (check all that apply)

INDUSTRY

❑ Crimping and Stamping
❑ Machine Tool
❑ Automotive
❑ Aerospace
❑ Laboratory Research
❑ Biomedical
❑ Military
❑ Other

MEASUREMENT TYPE

❑ Compression
❑ Tension
❑ Impact
❑ Press Monitoring
❑ Machine Monitoring
❑ Penetration
❑ Package Testing
❑ Force Controlled Vibration
❑ Cutting Tool
❑ Engine Mount
❑ Biomechanic
❑ Material Strength
❑ Drop Testing
❑ Other

3. PHYSICAL

Physical Design: ❑ General Purpose ❑ Rings ❑ Links ❑ 3-Component ❑ Impact ❑ Miniature ❑ Penetration

Desired Characteristics:

Sensitivity ____________ mV/lb or ____________ pC/lb

Maximum Weight ____________ grams

Size Limitation H ____________, L ____________, W ____________; or ____________ Diameter

4. DYNAMIC

What is the approximate dynamic force level to be measured? (compression/tension) ______________ / ______________ lb

What is the maximum force expected to be present? (compression/tension) ______________ / ______________ lb

What is the desired resolution? ____________ lb

What is the maximum frequency of interest? ____________ Hz or ____________ CPM

What is the minimum frequency of interest? ____________ Hz or ____________ CPM

5. MECHANICAL AND ENVIRONMENTAL

Continuous operating temperature range (min. to max.): ____________ to ____________ °C, to ____________ °F

Will the temperature be cycling? ____________ If yes, at what cycling profile? ______________________________

What is the storage temperature? ____________ °C, ____________ °F

Describe in detail, operating environment ______________________________

Continued on next page

Force Sensor Application Inquiry Form

6. CABLING AND MOUNTING

Electrical Connection Location: ❑ Axial (Top) Exit ❑ Radial (Side) Exit

Connector Type: ❑ 10-32 ❑ 5-44 ❑ Integral Cable ❑ Four-Pin ❑ Other_______________

Cable Type: ❑ Coaxial Cable ❑ Four-Conductor ❑ Other _______________

Other Cable Requirements _______________

Mounting Type: ❑ Removable Stud ❑ Integral Stud ❑ Captive Bolt ❑ Adhesive ❑ Magnetic Base ❑ Other_____________

Thread Size: ❑ 5-40 ❑ 10-32 UNF ❑ 1/4 -28 UNF ❑ Other _______________

7. ELECTRICAL

What is the readout device? ❑ A to D ❑ Scope ❑ Other (specify) _______________

What is the input impedance of the readout device (if applicable)? _______________

Can the readout device supply 24 to 27 VDC and 2 to 20 mA excitation to sensor? _______________

What kind of signal conditioner would you like? Single channel __________ Multiple channel __________ How many? _____________

What cable lengths will be driven? Cable length _________ ft, _________ m Cable Capacitance _________ pF/ft, _________ pF/m

Will the cable be near electromagnetic interference sources (i.e., AC power lines, radio equipment, motors, and generators)?

Describe: _______________

Is the sensor or cable located near areas prone to electrostatic discharges? _______________

Should the sensor be: ❑ Ground-Isolated ❑ Case-Isolated

8. OTHER SPECIFIC REQUESTS OR REQUIREMENTS

____

____

____

____

____

Force/Torque Division

PCB Piezotronics, Inc. • 3425 Walden Avenue • Depew, NY 14043 • 716-684-0001 • Fax: 716-684-8877

TORQUE SENSORS

Torque sensors manufactured by the Force/Torque Division of PCB fall into two categories of measurement: reaction torque and rotational torque. Both styles utilize strain gages, which are configured into a wheatstone bridge circuit, as their primary sensing element. Accuracies are typically within 0.1% and optional speed sensors permit additional measurement of rotational speed (RPM) and horsepower calculations.

Reaction torque sensors are rigid structures with no moving parts and are typically mounted in a fixed position. Their output signal varies proportionally to an applied torsional force. Applications for reaction torque sensors include torsional testing machines, brake testing, bearing friction studies, dynamometer testing, and viscosity and lubrication studies.

Rotary torque sensors employ a freely rotating shaft within a fixed housing. When installed, the rotating shaft becomes a coupling between a driving mechanism and an absorber or load. As the shaft is torsionally stressed, a proportional change in the output signal is observed. Changes in rotational speed and load affect the torque that is measured. Applications for rotary torque sensors include electric motor testing, automotive engine testing, dynamometer testing, drive train measurements, and gearbox testing.

Series Number Index

Table of Contents

TORQUE

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Strain Gage Torque Sensor Configurations

Reaction torque sensors

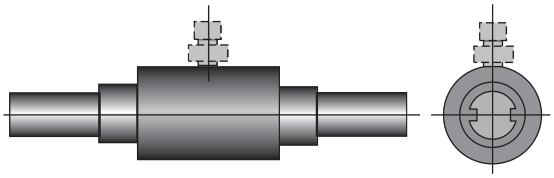
Reaction torque sensors are suitable for a wide array of torque measurement applications. They are typically used in torsional test machines, motor dynamometers, or in any application where rotation is limited to 360° or less. Due to the fact that these sensors do not utilize bearings, slip-rings, or other rotating elements, their installation and use can be very cost effective.

The rigid sensor mechanically resists rotation and will experience a torsional stress in response to an applied torsional force. This stress causes a proportional resistance change to occur in the strain gages, resulting in a voltage shift in the sensor's output signal. You might consider a reaction torque sensor to be similar to a pickle jar with a tight lid. As you try to twist the lid of the jar, the reaction torque experienced by the jar increases until the lid becomes loosened.

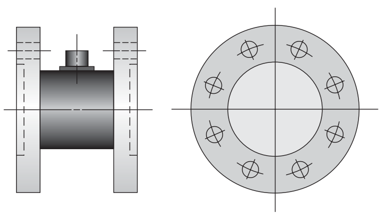
Reaction torque sensors are particularly useful in applications where the introduction of inertia due to a rotating mass between the driver motor and driven load is undesirable.

An example of this can be found in small motor testing, where introduction of a rotating mass between the motor and load device will result in an error during acceleration. For these applications, the reaction torque sensor can be used between the driver motor, or driven load, and ground. An added benefit is that such an installation is not limited in RPM by the torque sensor.

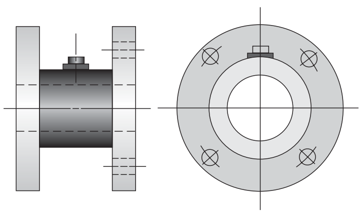
Shown below are some of the standard reaction torque sensor configurations offered by the Force/Torque Division. Capacities range from 5 to 500k in-lb (0.56 to 56.5k N-m).



Keyed Shaft Ends



Flange Ends



Hollow

Rotating shaft torque sensors

Rotating shaft torque sensors are designed to mount in-line between a driving source, and an absorber, or load. They are used in engine dynamometers, electric motor testing, hydraulic pump testing, fan testing, and a multitude of other applications.

The Force/Torque Division offers a choice of rotary transformer or slip-ring type torque sensors. For most applications, a rotary transformer-type sensor will be recommended. The rotary transformer is a non-contacting type of sensor, providing very low maintenance, quiet operation (with an excellent signal-to-noise ratio), higher speed ratings, and better accuracy. This type of sensor should be used with an AC carrier excitation source, ideally operating at 3.28 kHz.

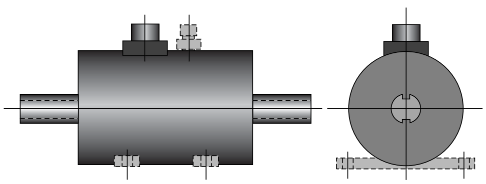
The torque sensor's shaft is coupled between the rotating driving mechanism under test and a load. A variety of mounting styles are offered including keyed shaft, flange, and flange-shaft. As the driving mechanism (such as an electric motor or automotive engine) turns the shaft, a torsional stress occurs, which causes a proportional resistance change in the strain gages, resulting in a voltage shift in the sensor's output signal. As the speed and the load on the rotating coupling changes, so too will the torque.

Rotary transformer torque sensors offer high accuracies and RPM ratings. They are designed with an advanced transformer, shaft and housing to provide enhanced durability in rugged industrial applications.

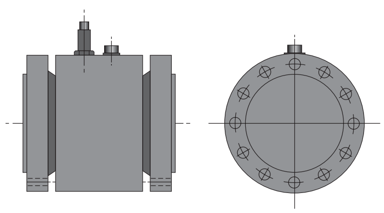
Slip-ring torque sensors utilize a set of coin silver rings mounted concentrically on the rotating shaft. A spring mounted brush carrier, with cam actuated lifter, is an integral part of the sensor design, and carries silver/graphite type brushes which provide contact to the rotating ring.

This type of sensor, while demanding greater maintenance due to brush/ring wear, does offer certain advantages. The slip-ring sensor offers compatibility with existing DC-type strain gage instrumentation, and may provide a shorter coupled length in applications where space is at a premium.

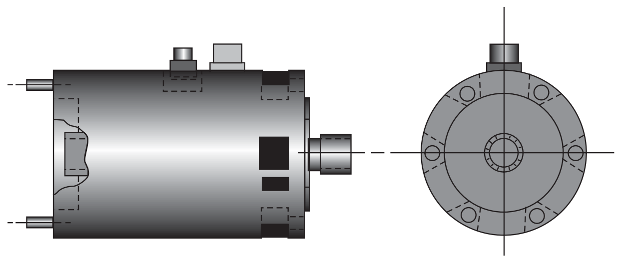
Rotating shaft torque sensors are available in a wide range of configurations, with capacities from 50 in-oz to 100k in-lb (0.35 to 11.3k N-m).



Keyed Shaft Ends



Flange Ends



AND Flange-Shaft

TORKDISC®

The TORKDISC® is a short-coupled, torsionally stiff structure that is ideal for a wide range of applications requiring high-accuracy, in-line rotary torque measurements. The sensor consists of a spring element which is torsionally loaded as torque is applied between an inner and outer mounting surface. Male and female pilots are provided to ensure good concentricity as the TORKDISC® is bolted into a driveline. Torque is transmitted by friction created between the mounting surfaces of the TORKDISC® and customer-provided mounting fixtures. 16-Bit digital telemetry signal trans-mission provides noise-free operation. The TORKDISC® is available in a wide range of capacities from 1k to 225k in-lb (113 to 25.4k N-m).

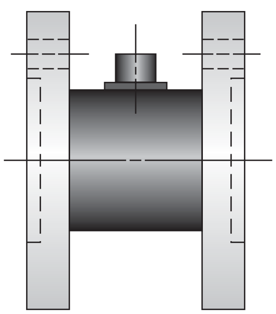
TORQUE

Typical Torque Sensor Measurement Systems

Typical measurement system for Series 2300 reaction torque sensor

All PCB Force / Torque Division reaction torque sensors utilize strain gages that are configured in a wheatstone bridge as their primary sensing element. The resistance value of the strain gages changes when torsional load is applied to the sensing structure and consequently, any voltage through the bridge circuit will be varied. The wheatstone bridge requires a regulated DC voltage excitation that is commonly provided by a strain gage signal conditioner. The resultant output signal from the torque sensor is typically expressed in units of millivolt per volt of excitation. This millivolt signal then varies proportionately to the applied torque. The strain gage signal conditioner provides zero and span adjustments to scale its 0 to 5 VDC analog output to be proportional to any desired input range. Additional features of the signal conditioner may include a digital display and alarm set point limits.

Reaction torque sensors are provided with an electrical connector, and cable assemblies are necessary to interface this connection to the strain gage signal conditioner. Two types of cable are commonly available, and their use is dependent upon signal transmission distance. Cable assemblies may be selected with a terminating connector, which makes it easier to connect to a PCB strain gage signal conditioner, or with a pigtail termination that allows connection to screw terminal connections on other styles of strain gage signal conditioners.



Series 2300

Reaction Torque Sensor Cables
(see page 2.30 to 2.31)

Models 8159, 8160A, 8161A, and 8162
Reaction Torque Sensor Signal Conditioners
(see pages 3.20 to 3.23)

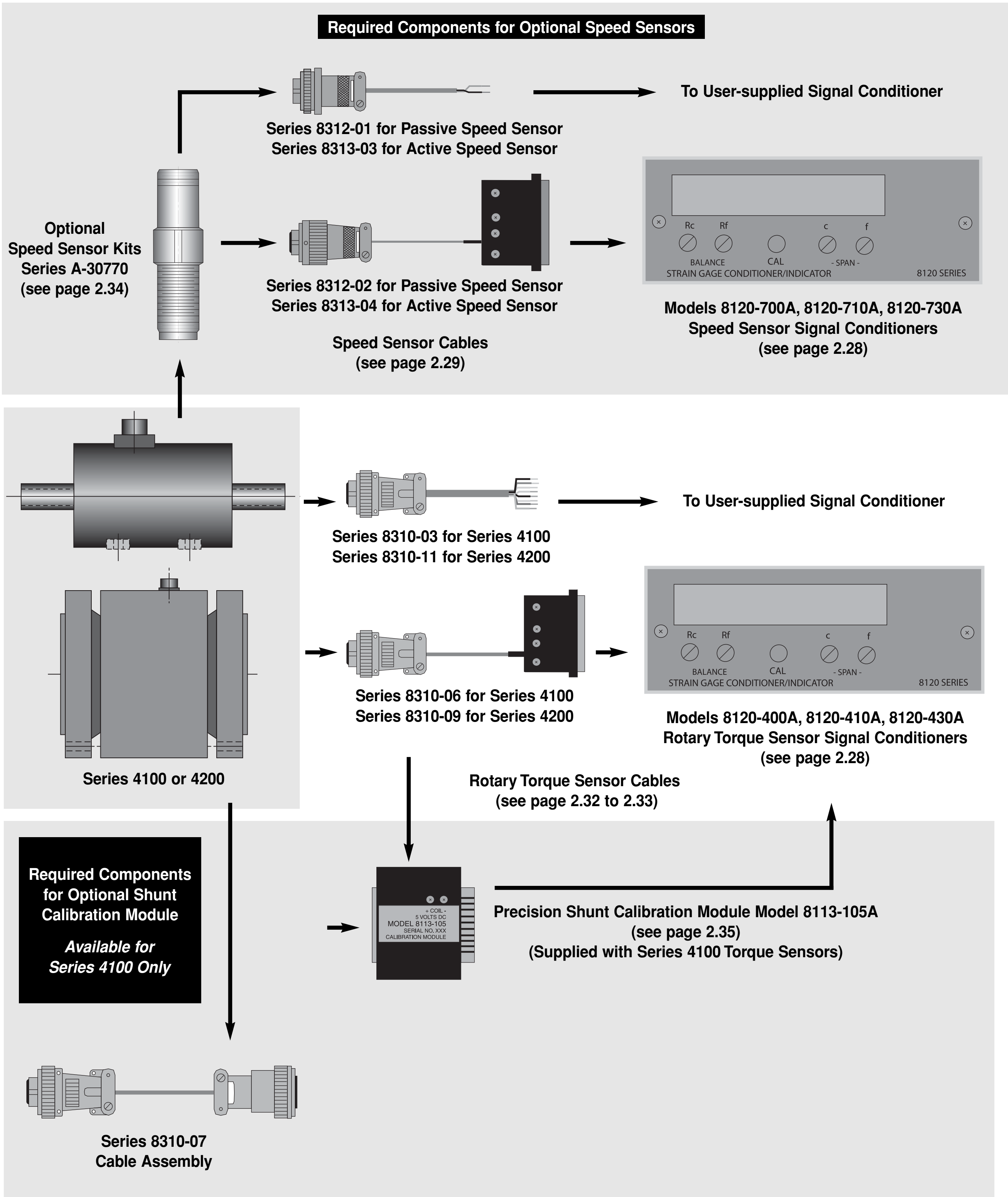
Typical measurement system for Series 4100 and 4200 rotary torque sensor

Rotary torque sensors utilize strain gages that are configured in a wheatstone bridge as their primary sensing element. The resistance value of the strain gages changes when torsional load is applied to the sensing structure and consequently, any voltage through the bridge circuit will be varied. The wheatstone bridge requires a regulated AC voltage excitation that is commonly provided by a strain gage signal conditioner. The resultant output signal from the torque sensor is typically expressed in units of millivolt per volt of excitation. This millivolt signal then varies proportionately to the applied torque. The strain gage signal conditioner provides zero and span adjustments to scale its 0 to 5 VDC analog output to be proportional to any desired input range. Additional features of the signal conditioner may include a digital display and alarm set point limits.

Most rotary torque sensors can accommodate an optional speed sensor to facilitate monitoring of the revolutions-per-minute of the system or for horsepower calculations. Speed sensors are Hall Effect devices whose output varies as a gear tooth passes its sensitive face. A typical speed gear within a rotary torque sensor will possess 60 teeth in order to provide 60 pulses per revolution of output from the speed sensor. Speed sensors require a DC excitation voltage that is commonly provided by a Hall Effect sensor signal conditioner.

Rotary torque sensors are provided with an electrical connector, and cable assemblies are necessary to interface this connection to the strain gage signal conditioner. Optional speed sensors incorporate their own electrical connector and will require a separate cable assembly and signal conditioner. Cable assemblies may be selected with a terminating connector, which makes it easier to connect to PCB's strain gage and Hall Effect signal conditioners, or with a pigtail termination that allows connection to screw terminal connections on other styles of strain gage and Hall Effect signal conditioners.

Typical Torque Sensor Measurement Systems



Typical Torque Applications

- Viscosity and Lubrication Studies
- Dynamometer
- Torsion Testing
- Brake Testing
- Bearing Friction
- Stepping Switch Torque
- Fractional HP Motor Testing
- Pump Testing
- Transmission Testing
- Efficiency Testing
- Electric Motor Testing
- Gear Box Efficiency Testing
- Fuel Pump Testing
- Hydraulic Pump
- Blower Testing
- Chassis Dynamometer
- Differential Testing
- Cantilevered Aerospace Hydraulic Pumps
- Cantilevered Aerospace Hydraulic Motors
- Drive Shaft Torque Measurement
- Torque Wrench Calibration
- Pulley Torque Testing
- Automotive Belt Testing
- Machine Feedback Testing
- Drive Shaft Torque
- Windmill Testing
- Assembly Production Machine Testing
- Torsion Bar Testing
- Reaction Torque

Torque Sensor Selection Guide

Reaction Torque

	Small Capacity Flange Mount			Flange Mount				
Size (dia x length) - in	2 x 2.25	3.5 x 2.75	2 x 3	4 x 3	5 x 3.5	8 x 7.38	9.75 x 8.5	14 x 10.5
Size (dia x length) - cm	5.08 x 5.72	8.89 x 6.99	5.08 x 7.62	10.16 x 7.62	12.7 x 8.89	20.32 x 18.75	24.77 x 21.59	35.56 x 26.67
Flange Dia B.C. - in	1.69	3	1.25	3.25	4.25	6.5	8	11
Flange Dia B.C. - cm	4.29	7.62	3.18	8.26	10.8	16.51	20.32	27.94
Connector	6-pin PT	6-pin PT	6-pin PT	6-pin PT	6-pin PT	6-pin PT	6-pin PT	6-pin PT
Page	2.12	2.12	2.12	2.10	2.10	2.10	2.10	2.10
Capacity	**Model Number**							
5 in-lb (0.56 N-m)	2308-01A*	2309-01A*						
10 in-lb (1.1 N-m)	2308-02A*	2309-02A*						
20 in-lb (2.3 N-m)	2308-03A*	2309-03A*						
50 in-lb (5.6 N-m)			2508-01A					
100 in-lb (11 N-m)			2508-02A					
200 in-lb (23 N-m)			2508-03A					
500 in-lb (55 N-m)			2508-04A					
1000 in-lb (115 N-m)			2508-05A					
2000 in-lb (225 N-m)				2301-01A				
5000 in-lb (565 N-m)				2301-02A				
10k in-lb (1130 N-m)					2302-01A			
20k in-lb (2250 N-m)					2302-02A			
50k in-lb (5650 N-m)						2303-01A		
100k in-lb (11.3k N-m)						2303-02A	2304-01A	
200k in-lb (22.6k N-m)							2304-02A	
300k in-lb (33.9k N-m)								2305-01A
500k in-lb (56.5k N-m)								2305-02A

* Aluminum load cells (low weight).
All other models are steel.

TORKDISC®				
	Flange Mount			
Rotor Size (dia x thk) - in	7.00 x 1.10	8.49 x 1.10	9.49 x 1.64	17.98 x 2.09
Rotor Size (dia x thk) - cm	17.78 x 2.79	21.59 x 2.79	24.13 x 4.17	45.72 x 5.31
Receiver Size (l x w x h) - in	7.17 x 7.46 x 1.92	7.17 x 7.46 x 1.92	7.17 x 7.46 x 1.92	7.17 x 7.46 x 1.92
Receiver Size (l x w x h) - cm	18.21 x 18.95 x 4.88	18.21 x 18.95 x 4.88	18.21 x 18.95 x 4.88	18.21 x 18.95 x 4.88
Speed (RPM)	15k	10k	10k	4.5k
Page Number	2.22	2.22	2.22	2.22
Capacity	**Model Number**			
1000 in-lb (113 N-m)	5302C-03A*			
2000 in-lb (226 N-m)	5302C-01A*			
5000 in-lb (565 N-m)	5302C-02A			
6250 in-lb (706 N-m)	5302C-04A			
10k in-lb (1130 N-m)		5308C-01A		
20k in-lb (2250 N-m)		5308C-02A		
30k in-lb (3400 N-m)		5308C-03A		
50k in-lb (5650 N-m)			5309C-01A	
100k in-lb (11.3k N-m)			5309C-02A	
120k in-lb (13.5k N-m)				5310C-03A
180k in-lb (20.3k N-m)				5310C-01A
200k in-lb (22.5k N-m)				5310C-02A
225k in-lb (25.4k N-m)				5310C-04A

*Denotes aluminum models. All other models are steel.

Rotary Transformer											
	Keyed Shaft Ends										
Size (dia x length) - in	4 x 6.5	4 x 10	4 x 10	4.8 x 12.75	5.5 x 15.75	6.5 x 19	4 x 10	4 x 10	4 x 12.75	5.5 x 15.75	6.5 x 19
Size (dia x length) - cm	10.16 x 16.51	10.16 x 25.4	10.16 x 25.4	12.19 x 32.39	13.97 x 40	16.51 x 48.26	10.16 x 25.4	10.16 x 25.4	10.16 x 32.39	13.97 x 40	16.51 x 48.26
Shaft Dia. - in	0.38	0.75	1	1.5	2.25	3	0.75	1	1.5	2.25	3
Shaft Dia. - cm	0.97	1.91	2.54	3.81	5.72	7.62	1.91	2.54	3.81	5.72	7.62
Connector	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS	5-pin MS
Speed (RPM)	10k	20k	20k	15k	6700	6000	10k	10k	10k	6700	6000
Page	2.16	2.16	2.16	2.16	2.16	2.16	2.14	2.14	2.14	2.14	2.14
Capacity	**Model Number**										
50 in-oz (0.35 N-m)	4102-01A										
100 in-oz (0.71 N-m)	4102-02A										
200 in-oz (1.41 N-m)	4102-03A										
500 in-oz (3.53 N-m)	4102-04A										
1000 in-oz (7.06 N-m)	4102-05A										
100 in-lb (11 N-m)		4103-01A					4203-01A				
200 in-lb (23 N-m)		4103-02A					4203-02A				
500 in-lb (55 N-m)			4104-01A					4204-01A			
1000 in-lb (115 N-m)			4104-02A					4204-02A			
2000 in-lb (225 N-m)			4104-03A	4105-01A				4204-03A	4205-01A		
5000 in-lb (565 N-m)				4105-02A					4205-02A		
10k in-lb (1130 N-m)				4105-03A	4106-01A				4205-03A	4206-01A	
20k in-lb (2250 N-m)					4106-02A					4206-02A	
36k in-lb (4065 N-m)					4106-03A	4107-01A				4206-03A	4207-01A
50k in-lb (5650 N-m)						4107-02A					4207-02A
100k in-lb (11.3k N-m)						4107-03A					4207-03A

Torque Sensor Selection Guide

Rotary Transformer		
	Flange Mount	
Size (dia x length) - in	6 x 9.35	6 x 9.94
Size (dia x length) - cm	15.24 x 23.75	15.24 x 25.25
Shaft Diameter - in	1.58	1.58
Shaft Diameter - mm	4	4
Number of teeth	16	24
Flange Dia B.C. - in	5	5
Flange Dia B.C. - cm	12.7	12.7
Connector	5-pin MS	5-pin MS
Speed (RPM)	15k	15k
Page	2.20	2.20
Capacity	**Model Number**	
50 in-lb (5.6 N-m)	4115A-01A	4115K-01A
100 in-lb (11 N-m)	4115A-02A	4115K-02A
200 in-lb (23 N-m)	4115A-03A	4115K-03A
500 in-lb (55 N-m)	4115A-04A	4115K-04A
600 in-lb (68 N-m)		4115K-05A
1000 in-lb (115 N-m)	4115A-05A	4115K-06A
1200 in-lb (135 N-m)		4115K-07A
2000 in-lb (225 N-m)		4115K-08A
2400 in-lb (270 N-m)		4115K-09A
3600 in-lb (405 N-m)		4115K-10A
5000 in-lb (565 N-m)		4115K-11A
6000 in-lb (675 N-m)		4115K-12A
10k in-lb (1130 N-m)		4115K-13A

All models are steel.

Rotary Transformer	
	Flange Mount
Size (dia x length) - in	5.5 x 6.38
Size (dia x length) - cm	13.97 x 16.21
Flange Dia B.C. - in	3.63
Flange Dia B.C. - cm	9.22
Connector	5-pin MS
Speed (RPM)	8k
Page	2.18
Capacity*	**Model Number**
20k in-lb (2250 N-m)	4149-01A
24k in-lb (2700 N-m)	4149-02A
30k in-lb (3389.5 N-m)	4149-03A

All models are steel.

* Capacity from 5k to 30k in-lb FS (565 to 3389.5 N-m FS) are available. Contact factory for details.

Options for Torque Sensors

Shunt Resistor — A fixed resistor which is placed in parallel or shunted across a strain gage bridge to provide a known test signal to permit the user with a means of easily performing an accurate system calibration of a torque sensor and signal conditioner.

High Output — The normal full-scale output of a strain gaged based torque sensor is between 1 and 3 mV/V. In high-noise environments, a higher output is advantageous from a signal-to-noise ratio standpoint. 5 mV/V full-scale output is available on all models as an option.

Metric Dimensions and Capacities — Our standard product is manufactured with English dimensions and capacities and is calibrated with English standards. Metric dimensions, capacities, and calibration data (converted from English calibration data) are optionally available.

Strain Gage Torque Sensors

- **Reaction torque measurements**
- **Low-maintenance rotary transformer type**
- **Noise-free digital telemetry type**
- **NIST traceable**

Torque sensors manufactured by the Force/Torque Division of PCB fall into two categories of measurement; reaction torque and rotational torque. Reaction torque sensors convert the torque applied to a fixed sensor into a useable measurement signal. Examples of reaction torque applications include automotive brake testing, dynamometer testing, and bearing friction and lubrication studies. Rotational, or rotary, torque sensors typically measure the torque generated by rotating devices such as electric motors, automotive engines, transmissions, pumps, and compressors.

Reaction torque sensors are machined from a single piece of rigid steel that is instrumented with strain gauges in a wheatstone bridge circuit. They have no moving parts and are typically flange mounted into a fixed position.

Rotary torque sensors employ a freely rotating shaft within a fixed housing. The shaft is instrumented with strain gages in a wheatstone bridge circuit. Either slip-rings with brushes or a non-contact rotary transformer facilitates electrical connection to the rotating strain gages. Advantages of the rotary transformer approach include less maintenance and less signal noise.

The TORKDISC® represents a new approach to rotary torque measurements. Rather than slip-rings or rotary transformers, the TORKDISC® contains a miniature, 16-bit digital telemetry transmitter. Digitized measurement signals are picked up by a circumferential antenna and relayed to a receiver unit where they are conditioned to both a current and voltage output signal. Advantages include smaller sensor size and noise-free, digital signal transmission.

Custom torque sensors have been developed for unique or specialized applications. Please call to discuss any special needs.

TORQUE

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

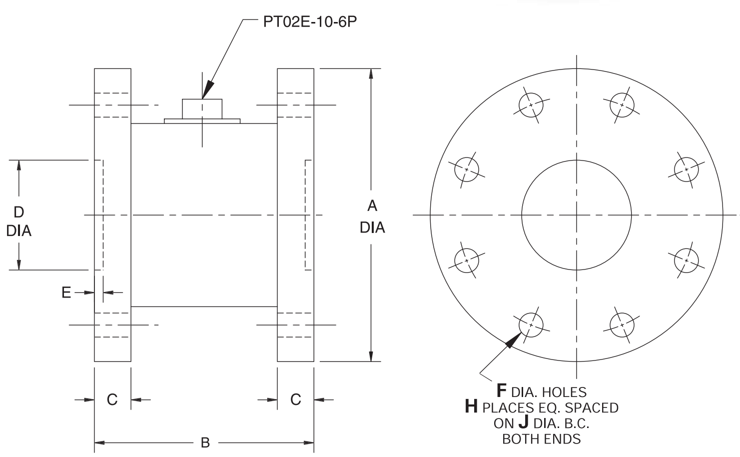
Reaction Torque Sensors
2000 – 500k in-lb

FLANGE MOUNT REACTION TORQUE SENSORS

- viscosity and lubrication studies
- torsion testing
- bearing friction
- dynamometer
- braking testing
- stepping switch torque

Series 2301, 2302, 2303, 2304, 2305 —
flange mount reaction torque sensors

- Capacities from 2000 to 500k in-lb FS (225 to 56.5k N-m FS)
- 2 mV/V output sensitivity
- Flange mount both ends
- High torsional stiffness



Series 2301, 2302, 2303, 2304 and 2305

Dimensions — inches (cm)								
Series	**A**	**B**	**C**	**D**	**E**	**F**	**H**	**Flange Dia. B.C.**
2301-01A	4 (10.16)	3 (7.62)	0.5 (1.27)	1.5 (3.81)	0.12 (0.3)	0.33 (0.84)	8	3.25 (8.26)
2301-02A	4 (10.16)	3 (7.62)	0.5 (1.27)	1.5 (3.81)	0.12 (0.3)	0.33 (0.84)	8	3.25 (8.26)
2302-01A	5 (12.7)	3.5 (8.89)	0.75 (1.91)	2 (5.08)	0.25 (0.64)	0.39 (0.99)	8	4.25 (10.8)
2302-02A	5 (12.7)	3.5 (8.89)	0.75 (1.91)	2 (5.08)	0.25 (0.64)	0.39 (0.99)	8	4.25 (10.8)
2303-01A	8 (20.32)	7.38 (18.75)	1.5 (3.81)	3.5 (8.89)	0.31 (0.79)	0.64 (1.63)	8	6.5 (16.51)
2303-02A	8 (20.32)	7.38 (18.75)	1.5 (3.81)	3.5 (8.89)	0.31 (0.79)	0.64 (1.63)	8	6.5 (16.51)
2304-01A	9.75 (24.77)	8.5 (21.59)	1.5 (3.81)	4 (10.16)	0.31 (0.79)	0.77 (1.96)	8	8 (20.32)
2304-02A	9.75 (24.77)	8.5 (21.59)	1.5 (3.81)	4 (10.16)	0.31 (0.79)	0.77 (1.96)	8	8 (20.32)
2305-01A	14 (35.56)	10.5 (26.67)	2 (5.08)	6 (15.24)	0.31 (0.79)	1.02 (2.59)	8	11 (27.94)
2305-02A	14 (35.56)	10.5 (26.67)	2 (5.08)	6 (15.24)	0.31 (0.79)	1.02 (2.59)	8	11 (27.94)

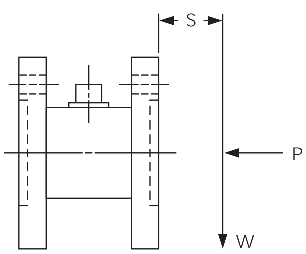
	Specifications						Extraneous Load Limits		
Model Number	Capacity in-lb (N-m)	Safe Overload in-lb (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Ringing Frequency Hz	Weight lb (kg)	Material	Overhung Moment WxS in-lb (N-m)	Shear W lb (N)	Thrust P lb (N)
Flange Mount Reaction Torque Sensors									
2301-01A	2000 (225)	3000 (340)	380k (42.9k)	1000	5 (2.27)	steel	1000 (115)	1000 (4450)	2000 (8900)
2301-02A	5000 (565)	7500 (850)	1.29M (145k)	1800	5 (2.27)	steel	2500 (280)	2500 (11.1k)	5000 (22.2k)
2302-01A	10k (1130)	15k (1700)	2.98M (337k)	1400	10 (4.54)	steel	5000 (565)	5000 (22.2k)	10k (44.5k)
2302-02A	20k (2250)	30k (3400)	7.5M (847k)	2200	10 (4.54)	steel	10k (1130)	10k (44.5k)	20k (89k)
2303-01A	50k (5650)	75k (8500)	10.2M (1.15M)	750	58 (26.3)	steel	25k (2825)	10k (44.5k)	50k (220k)
2303-02A	100k (11.3k)	150k (16.9k)	25.7M (2.9M)	1250	58 (26.3)	steel	50k (5650)	20k (89k)	100k (450k)
2304-01A	100k (11.3k)	150k (16.9k)	21.4M (2.4M)	690	106 (48.1)	steel	50k (5650)	15k (66.7k)	100k (450k)
2304-02A	200k (22.6k)	300k (33.9k)	53.9M (6.1M)	1100	106 (48.1)	steel	100k (11.3k)	30k (130k)	200k (900k)
2305-01A	300k (33.9k)	450k (50.8k)	75.8M (8.6M)	560	220 (99.8)	steel	150k (16.9k)	30k (130k)	300k (1.3M)
2305-02A	500k (56.5k)	750k (84.7k)	150M (16.9M)	780	220 (99.8)	steel	250k (28.2k)	50k (220k)	500k (2.2M)

Common Specifications

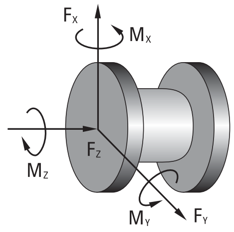
Output (nominal) . . . . 2 mV/Volt
Non-linearity (max) . . . . 0.1% FS
Hysteresis (max) . . . . 0.1% FS
Non-repeatability (max) . . . . 0.02% FS
Bridge Resistance (nom) . . . . 350 ohm
Excitation (recommended) . . . . 10 Volts

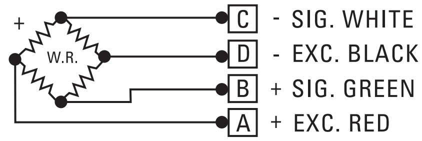
Excitation (max) . . . . 20 Volts
Temp. Range (compensated) . . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . . . -65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) . . . . . . 0.002% FS/°F (0.0036% FS/°C)
Temp. Effect on Output (max) . . . . . . 0.002% reading/°F (0.0036% reading/°C)

Supplied Accessories	
Mating Connector (if cable is not purchased) Model 181-012A	
Shunt Calibration Resistor	
Optional Accessories	
	See Page
Interconnecting Cable	2.30 to 2.31
Signal Conditioner	2.28
Options (see page 2.8)	
High Output	
Built-in Shunt Resistor	
Metric Capacities	



Extraneous load limits are extraneous side force, thrust and bending moment that may be applied without electrical or mechanical damage to the torque sensor. Do not exceed moment (W x S) or shear (W) whichever attained first.





Wiring Diagram

Typical systems located on page 2.4

TORQUE

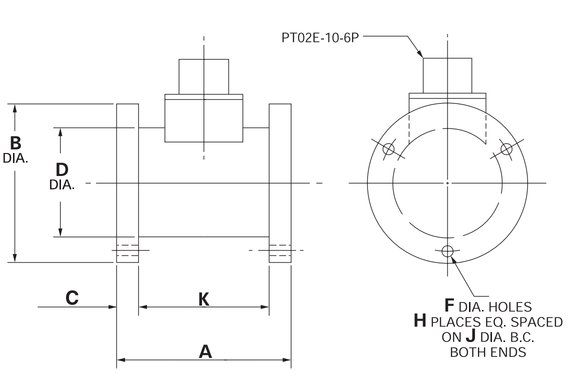
Reaction Torque Sensors
5 – 1000 in-lb

SMALL CAPACITY FLANGE MOUNT REACTION TORQUE SENSORS

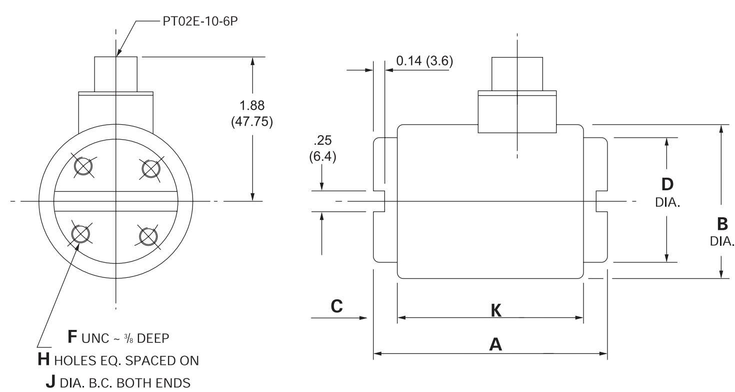
- bearing friction
- fractional HP motor testing
- viscosity measurements
- small motor dynamometer

Series 2308, 2309, 2508 — small capacity flange mount reaction torque sensors

- Capacities from 5 to 1000 in-lb FS (0.56 to 115 N-m FS)
- 2 mV/V output sensitivity
- Flange mount both ends
- High torsional stiffness



Series 2308 and 2309



Series 2508

Dimensions shown are in inches (millimeters).

Dimensions — inches (mm)								
Series	A	B	C	D	F	H	J	K
2308	2.25 (57.2)	2 (50.8)	0.25 (6.4)	1.39 (35.3)	0.13 (3.3)	3	1.69 (42.9)	1.75 (44.5)
2309	2.75 (69.9)	3.5 (88.9)	0.25 (6.4)	2.5 (63.5)	0.28 (7.1)	4	3 (76.2)	2.25 (57.2)
2508	3 (76.2)	2 (50.8)	0.31 (7.9)	1.63 (41.4)	10-24	4	1.25 (31.8)	2.38 (60.5)

Reaction Torque Sensors

5 – 1000 in-lb

	Specifications						Extraneous Load Limits		
Model Number	Capacity in-lb (N-m)	Safe Overload in-lb (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Ringing Frequency Hz	Weight lb (kg)	Material	Overhung Moment WxS in-lb (N-m)	Shear W lb (N)	Thrust P lb (N)
Flange Mount Reaction Torque Sensors									
2308-01A	5 (0.56)	7.5 (0.85)	175 (20)	200	0.2 (0.09)	aluminum	2.5 (0.28)	2.5 (11)	5 (22)
2308-02A	10 (1.1)	15 (1.69)	500 (55)	350	0.2 (0.09)	aluminum	5 (0.56)	5 (22)	10 (45)
2308-03A	20 (2.3)	30 (3.4)	1400 (160)	580	0.2 (0.09)	aluminum	10 (1.1)	10 (45)	20 (90)
2309-01A	5 (0.56)	50 (5.6)	340 (38)	90	1.3 (0.59)	aluminum	2.5 (0.28)	2.5 (11)	5 (22)
2309-02A	10 (1.1)	50 (5.6)	960 (110)	150	1.3 (0.59)	aluminum	5 (0.56)	5 (22)	10 (45)
2309-03A	20 (2.3)	50 (5.6)	2700 (300)	250	1.3 (0.59)	aluminum	10 (1.1)	10 (45)	20 (90)
2508-01A	50 (5.6)	75 (8.5)	2350 (266)	380	1 (0.45)	steel	50 (5.6)	13 (58)	200 (900)
2508-02A	100 (11)	150 (17)	6700 (775)	620	1 (0.45)	steel	100 (11.3)	20 (90)	280 (1250)
2508-03A	200 (23)	300 (34)	18.8k (2100)	1040	1 (0.45)	steel	200 (22.6)	26 (116)	400 (1780)
2508-04A	500 (55)	750 (85)	73.6k (8300)	2050	1 (0.45)	steel	250 (28.2)	500 (2225)	500 (2225)
2508-05A	1000 (115)	1500 (170)	127k (14.3k)	2700	1 (0.45)	steel	500 (56.5)	800 (3560)	660 (2950)

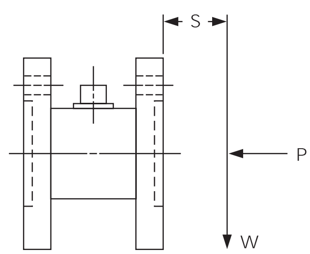
Common Specifications

Output (nominal) .... 2 mV/Volt
Non-linearity (max) .... 0.1% FS
Hysteresis (max) .... 0.1% FS
Non-repeatability (max) .... 0.05% FS
Bridge Resistance (nom) .... 700 ohm[1]
Excitation (recommended) .... 10 Volts

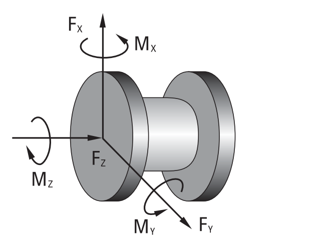
Excitation (max) .... 20 Volts
Temp. Range (compensated) .... +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) .... -65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) .... 0.002% FS/°F (0.0036% FS/°C)
Temp. Effect on Output (max) .... 0.002% reading/°F (0.0036% reading/°C)

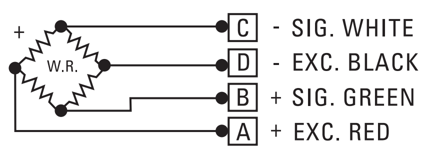
NOTE: [1] 500 and 1000 in-lb capacities — 350 ohm

Supplied Accessories	
Mating Connector (if cable is not purchased) Model 181-012A	
Shunt Calibration Resistor	
Optional Accessories	
	See Page
Interconnecting Cable	2.30 to 2.31
Signal Conditioner	2.28
Options (see page 2.8)	
High Output	
Built-in Shunt Resistor	
Metric Capacities	



Extraneous load limits are extraneous side force, thrust and bending moment that may be applied without electrical or mechanical damage to the torque sensor. Do not exceed moment (W x S) or shear (W) whichever attained first.





Wiring Diagram

Typical systems located on page 2.4

Rotary Transformer Torque Sensors
100 – 100k in-lb

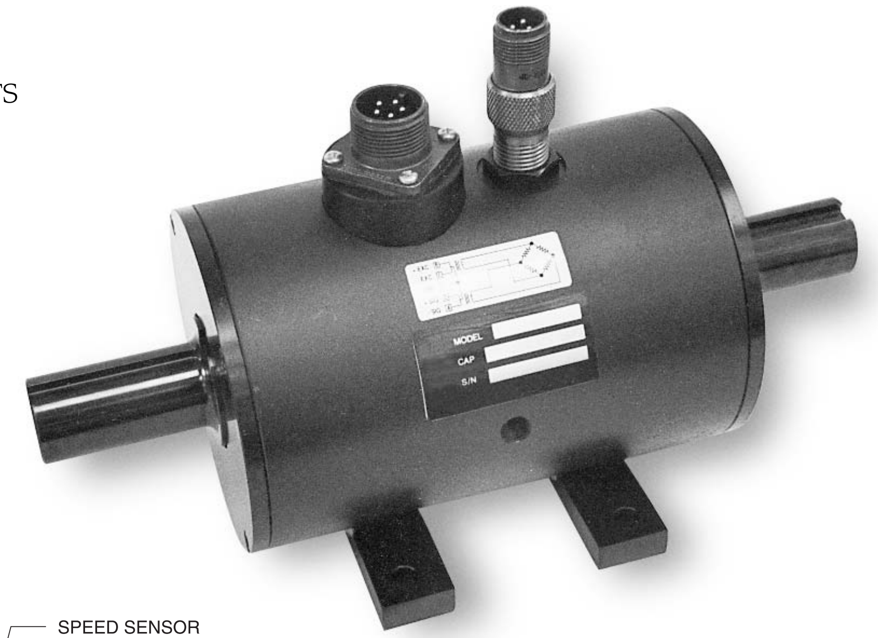
SHAFT END ROTARY TRANSFORMER TORQUE SENSORS

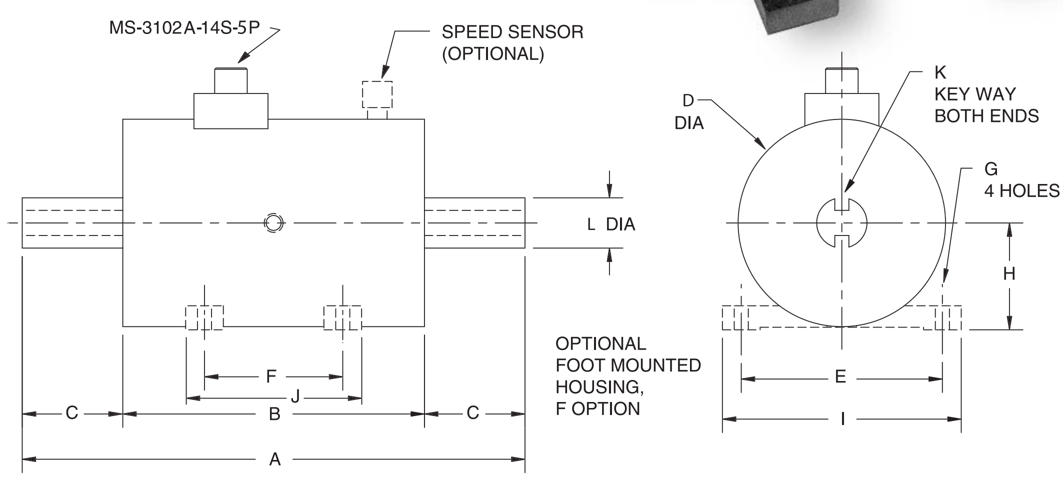
Non-contact rotary transformer

- pump testing
- efficiency testing
- engine dynamometer
- transmission testing
- electric motor testing
- gear box efficiency testing

Series 4203, 4204, 4205, 4206, 4207

- Capacities from 100 to 100k in-lb FS (11 to 11.3k N-m FS)
- 2 mV/V output sensitivity
- Shaft ends
- Optional foot-mounted housing
- Integral shunt calibration network
- Temperature compensated





Series 4203, 4204, 4205, 4206 and 4207

Dimensions — inches (cm)												
Series	A	B	C	D	E	F	G	H	I	J	K	L
4203	10 (25.4)	6 (15.24)	2 (5.08)	4 (10.16)	4 (10.16)	2.75 (6.99)	0.28 (0.71)	2.13 (5.4)	4.75 (12.07)	3.5 (8.89)	0.19 (0.48)	0.75 (1.91)
4204	10 (25.4)	6 (15.24)	2 (5.08)	4 (10.16)	4 (10.16)	2.75 (6.99)	0.28 (0.71)	2.13 (5.4)	4.75 (12.07)	3.5 (8.89)	0.25 (0.64)	1 (2.54)
4205	12.75 (32.39)	6 (15.24)	3.38 (8.59)	4 (10.16)	5.25 (13.34)	3 (7.62)	0.41 (1.03)	2.5 (6.35)	6.25 (15.88)	4 (10.16)	0.38 (0.97)	1.5 (3.81)
4206	15.75 (40.01)	8.25 (20.96)	3.75 (9.53)	5.5 (13.97)	6 (15.24)	4 (10.16)	0.53 (1.35)	3 (7.62)	7 (17.78)	5.25 (13.34)	0.5 (1.27)	2.25 (5.72)
4207	19 (48.26)	8.75 (22.23)	5.13 (13.13)	6.5 (16.51)	7 (17.78)	4 (10.16)	0.53 (1.35)	3.5 (8.89)	8.5 (21.59)	5 (12.7)	0.75 (1.91)	3 (7.62)

Rotary Transformer Torque Sensors
100 – 100k in-lb

Specifications

Model Number	Capacity in-lb (N-m)	Maximum Speed RPM	Overload in-lb (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Rotating Inertia in-lb sec^2 (N-m sec^2)	Weight lb (kg)	Housing Material
Rotating Transformer Torque Sensors with Shaft Ends							
4203-01A	100 (11)	10k	300 (34)	15k (1700)	0.004 (0.0005)	10 (4.5)	aluminum
4203-02A	200 (23)	10k	600 (68)	30k (3400)	0.004 (0.0005)	10 (4.5)	aluminum
4204-01A	500 (55)	10k	1500 (170)	85k (9600)	0.0026 (0.0003)	10 (4.5)	aluminum
4204-02A	1000 (115)	10k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	10 (4.5)	aluminum
4204-03A	2000 (225)	10k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	10 (4.5)	aluminum
4205-01A	2000 (225)	10k	6000 (375)	700k (79.1k)	0.008 (0.0009)	12 (5.4)	aluminum
4205-02A	5000 (565)	10k	15k (1700)	950k (107k)	0.008 (0.0009)	12 (5.4)	aluminum
4205-03A	10k (1130)	10k	15k (1700)	950k (107k)	0.008 (0.0009)	12 (5.4)	aluminum
4206-01A	10k (1130)	6700	30k (3400)	4M (452k)	0.036 (0.0004)	35 (15.9)	steel
4206-02A	20k (2250)	6700	60k (6775)	10M (1.1M)	0.036 (0.0004)	35 (15.9)	steel
4206-03A	36k (4065)	6700	60k (6775)	15M (1.7M)	0.036 (0.0004)	35 (15.9)	steel
4207-01A	36k (4065)	6000	100k (11.3k)	20M (2.3M)	0.15 (0.017)	70 (31.8)	steel
4207-02A	50k (5650)	6000	150k (16.9k)	20M (2.3M)	0.15 (0.017)	70 (31.8)	steel
4207-03A	100k (11.3k)	6000	150k (16.9k)	25M (2.8M)	0.15 (0.017)	70 (31.8)	steel
Rotating Transformer Torque Sensors with Shaft Ends and Foot Mount							
4203F-01A	100 (11)	10k	300 (34)	15k (1700)	0.004 (0.0005)	17 (7.7)	steel
4203F-02A	200 (23)	10k	600 (68)	30k (3400)	0.004 (0.0005)	17 (7.7)	steel
4204F-01A	500 (55)	10k	1500 (170)	85k (9600)	0.0026 (0.0003)	17 (7.7)	steel
4204F-02A	1000 (115)	10k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	17 (7.7)	steel
4204F-03A	2000 (225)	10k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	17 (7.7)	steel
4205F-01A	2000 (225)	10k	6000 (375)	700k (79.1k)	0.008 (0.0009)	22 (10)	steel
4205F-02A	5000 (565)	10k	15k (1700)	950k (107k)	0.008 (0.0009)	22 (10)	steel
4205F-03A	10k (1130)	10k	15k (1700)	950k (107k)	0.008 (0.0009)	22 (10)	steel
4206F-01A	10k (1130)	6700	30k (3400)	4M (452k)	0.0036 (0.0004)	40 (18.1)	steel
4206F-02A	20k (2250)	6700	60k (6775)	10M (1.1M)	0.0036 (0.0004)	40 (18.1)	steel
4206F-03A	36k (4065)	6700	60k (6775)	15M (1.7M)	0.0036 (0.0004)	40 (18.1)	steel
4207F-01A	36k (4065)	6000	100k (11.3k)	20M (2.3M)	0.15 (0.017)	75 (34)	steel
4207F-02A	50k (5650)	6000	150k (16.9k)	20M (2.3M)	0.15 (0.017)	75 (34)	steel
4207F-03A	100k (11.3k)	6000	150k (16.9k)	25M (2.8M)	0.15 (0.017)	75 (34)	steel

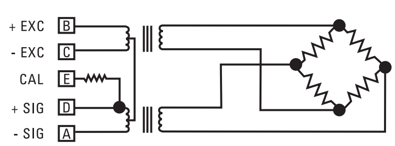
Common Specifications

- Output (nominal) . . . . . 2 mV/Volt
- Non-linearity (max) . . . . . 0.05% FS
- Hysteresis (max) . . . . . 0.05% FS
- Non-repeatability (max) . . . . . 0.02% FS
- Bridge Resistance (nominal) . . . . . 350 ohm
- Excitation Frequency . . . . . 3.28k Hz [1]
- Excitation Voltage (AC/RMS) . . . . . 5 to 10 Volts
- Bridge Current @ 5VAC . . . . . 30 mA
- Temp. Range (compensated) . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
- Temp. Range (usable) . . . . . -25 °F to +170 °F (-32 °C to +77 °C)
- Temp. Effect on Zero (max) . . . . . 0.001% FS/°F (0.0018% FS/°C)[2]
- Temp. Effect on Output (max) . . . . . 0.001% reading/°F[2] (0.0018% reading/°C)[2]

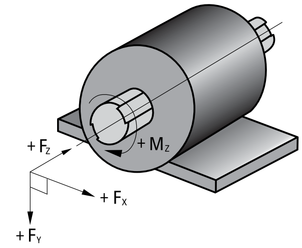
NOTE: [1] Consult factory for use with 3.0k to 5.0k Hz excitation frequencies
[2] Series 4203 - temp. effect on output (max) 0.002% FS/°F (0.0036% FS/°C). Temp. effect on zero (max) 0.002% FS/°F (0.0036% FS/°C).

Supplied Accessories	
Mating Connector (if cable is not purchased) Model 180-019A	
Built-In Shunt Resistor	
Built-In Star Bridge	
Optional Accessories	**See Page**
Interconnecting Cable	2.32 to 2.33
Signal Conditioner	2.28
Active Speed Sensor Kit Model A-30775-1A	2.34
Passive Speed Sensor Kit Model A-30774A	2.34
"Type K" Thermocouple	2.35

Options (see page 2.8)
Foot Mount — Add "F" in Model Number (see above table)
Metric Capacities



Wiring Diagram



Typical systems located on page 2.5

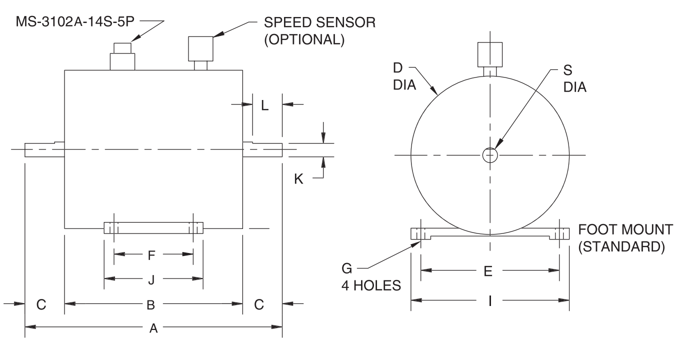
Rotary Transformer Torque Sensors
50 in-oz – 100k in-lb

SHAFT END ROTARY TRANSFORMER TORQUE SENSORS

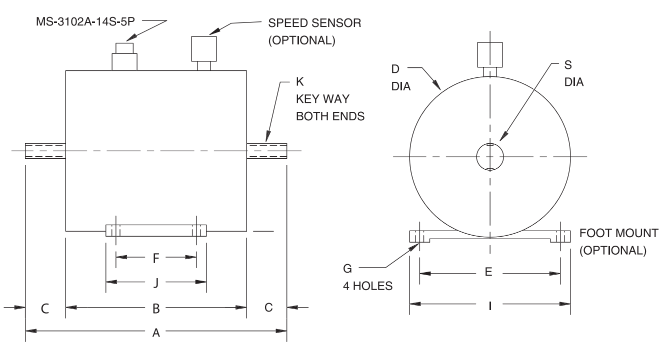
- fuel pump testing
- hydraulic pump
- transmission development
- chassis dynamometer
- hydraulic motor
- blower testing
- dynamometer
- aerospace

Series 4102, 4103, 4104, 4105, 4106, 4107

- Capacities from 50 in-oz to 100k in-lb FS (5.6 to 11.3k N-m FS)
- 2 mV/V or 2.5 mV/V output sensitivity
- Shaft ends
- High signal to noise ratio
- High accuracy
- High torsional stiffness



Series 4102



Series 4103, 4104, 4105, 4106 and 4107

Dimensions — inches (cm)

Series	A	B	C	D	E	F	G	H	I	J	K x L	S
4102	6.5 (16.51)	4.5 (11.43)	1 (2.54)	4 (10.16)	3.5 (8.89)	2 (5.08)	13/64	2.1 (5.33)	4 (10.16)	2.5 (6.35)	0.34 x 0.75 (0.86 x 1.91)	0.38 (0.97)

Dimensions — inches (cm)

Series	A	B	C	D	E	F	G	H	I	J	K	S
4103	10 (25.4)	6 (15.24)	2 (5.08)	4 (10.16)	4 (10.16)	2.75 (6.99)	0.28 (0.71)	2.13 (5.41)	4.75 (12.07)	3.5 (8.89)	0.19 (0.48)	0.75 (1.91)
4104	10 (25.4)	6 (15.24)	2 (5.08)	4 (10.16)	4 (10.16)	2.75 (6.99)	0.28 (0.71)	2.13 (5.41)	4.75 (12.07)	3.5 (8.89)	0.25 (0.64)	1 (2.54)
4105	12.75 (32.39)	7.25 (18.42)	2.75 (6.99)	4.75 (12.07)	5.25 (13.34)	3 (7.62)	0.41 (1.03)	2.5 (6.35)	6.25 (15.88)	4 (10.16)	0.38 (0.97)	1.5 (3.81)
4106	15.75 (40.01)	8.25 (20.96)	3.75 (9.53)	5.5 (13.97)	6 (15.24)	4 (10.16)	0.53 (1.35)	3 (7.62)	7 (17.78)	5.25 (13.34)	0.5 (1.27)	2.25 (5.72)
4107	19 (48.26)	8.75 (22.23)	5 (12.7)	6.5 (16.51)	7 (17.78)	4 (10.16)	0.53 (1.35)	3.5 (8.89)	8.5 (21.59)	5 (12.7)	0.75 (1.91)	3 (7.62)

Specifications

Model Number	Capacity in-oz (N-m)	Maximum Speed RPM	Overload in-oz (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Rotating Inertia in-lb sec² (N-m sec²)	Weight without Foot Mount lb (kg)	Weight with Foot Mount lb (kg)	Housing Material
Shaft Ends with One Flat								
4102-01A	50 (0.35)	10k	150 (1.05)	400 (45)	0.0009 (0.0001)	N/A	15 (6.8)	aluminum
4102-02A	100 (0.71)	10k	300 (2.10)	1000 (115)	0.0009 (0.0001)	N/A	15 (6.8)	aluminum
4102-03A	200 (1.41)	10k	600 (4.25)	2500 (280)	0.0009 (0.0001)	N/A	15 (6.8)	aluminum
4102-04A	500 (3.53)	10k	1500 (10.6)	5500 (625)	0.0009 (0.0001)	N/A	15 (6.8)	aluminum
4102-05A	1000 (7.06)	10k	3000 (21.2)	8000 (900)	0.0009 (0.0001)	N/A	15 (6.8)	aluminum
Model Number	**Capacity in-lb (N-m)**	**Maximum Speed RPM**	**Overload in-lb (N-m)**	**Torsional Stiffness in-lb/rad (N-m/rad)**	**Rotating Inertia in-lb sec² (N-m sec²)**	**Weight without Foot Mount lb (kg)**	**Weight with Foot Mount lb (kg)**	**Housing Material**
Shaft Ends with Two Key Ways								
4103-01A	100 (11)	15k	300 (33)	13.5k (1525)	0.0026 (0.0003)	18 (8.2)	19.5 (8.8)	steel
4103-02A	200 (23)	15k	600 (66)	33k (3725)	0.0026 (0.0003)	18 (8.2)	19.5 (8.8)	steel
4104-01A	500 (55)	15k	1500 (170)	85k (9600)	0.0026 (0.0003)	18 (8.2)	19.5 (8.8)	steel
4104-02A	1000 (115)	15k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	18 (8.2)	19.5 (8.8)	steel
4104-03A	2000 (225)	15k	3000 (340)	150k (16.9k)	0.0026 (0.0003)	18 (8.2)	19.5 (8.8)	steel
4105-01A	2000 (225)	15k	6000 (675)	700k (79.1k)	0.0084 (0.001)	28 (12.7)	30.5 (13.8)	steel
4105-02A	5000 (565)	15k	15k (1700)	950k (107k)	0.0084 (0.001)	28 (12.7)	30.5 (13.8)	steel
4105-03A	10k (1130)	15k	15k (1700)	950k (107k)	0.0084 (0.001)	28 (12.7)	30.5 (13.8)	steel
4106-01A	10k (1130)	6700	30k (3400)	4.1M (460k)	0.036 (0.004)	40 (18.1)	44 (20)	steel
4106-02A	20k (2250)	6700	60k (6775)	11.8M (1.3M)	0.036 (0.004)	40 (18.1)	44 (20)	steel
4106-03A	36k (4065)	6700	60k (6775)	11.8M (1.3M)	0.036 (0.004)	40 (18.1)	44 (20)	steel
4107-01A	36k (4065)	6000	100k (11.3k)	17.7M (2M)	0.152 (0.017)	80 (36.3)	85 (38.6)	steel
4107-02A	50k (5650)	6000	150k (16.9k)	20M (2.3M)	0.152 (0.017)	80 (36.3)	85 (38.6)	steel
4107-03A	100k (11.3k)	6000	150k (16.9k)	20M (2.3M)	0.152 (0.017)	80 (36.3)	85 (38.6)	steel

Common Specifications

- Output (nominal) . . . . . 2 mV/Volt[1]
- Non-linearity (max) . . . . . 0.05% FS
- Hysteresis (max) . . . . . 0.05% FS
- Non-repeatability (max) . . . . . 0.02% FS
- Bridge Resistance (nominal) . . . . . 350 ohm
- Excitation Frequency . . . . . 3.28k Hz
- Excitation Voltage (AC/RMS) . . . . . 5 to 10 Volts
- Bridge Current @ 5VAC . . . . . 50 mA
- Temp. Range (compensated) . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
- Temp. Range (usable) . . . . . -65 °F to +170 °F (-54 °C to +77 °C)[2]
- Temp. Effect on Zero (max) . . . . . 0.001% FS/°F (0.0018% FS/°C)[2][3]
- Temp. Effect on Output (max) . . . . . 0.001% reading/°F[2][3] (0.0018% reading/°C)[3]

NOTE: [1] Series 4104, 4105 — output (nominal) 2.5 mV/V
[2] Series 4102 — temp. range (usable) -20 °F to +170 °F (-29 °C to +77 °C)
temp. effect on zero (max) 0.002% FS/°F (0.0036% FS/°C)
temp. effect on output (max) 0.002% FS/°F (0.0036% FS/°C)
[3] Series 4103 — temp. effect on zero (max) 0.002% FS/°F (0.0036% FS/°C)
temp. effect on output (max) 0.002% FS/°F (0.0036% FS/°C)

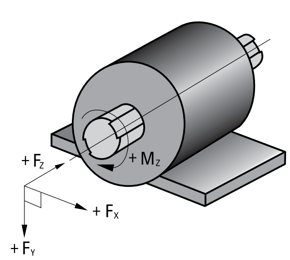
Supplied Accessories	See Page
Mating Connector (if cable is not purchased) Model 180-019A	
Precision Shunt Calibration Module Model 8113-105A	2.35
Optional Accessories	
Interconnecting Cable	2.32 to 2.33
Signal Conditioner	2.28
Active Speed Sensor Kit Model A-30775-1A	2.34
Passive Speed Sensor Kit Model A-30774A	2.34
"Type K" Thermocouple	2.35

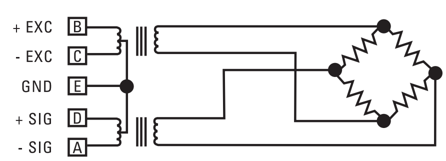
Typical systems located on page 2.5

Options (see page 2.8)

Foot Mount —
- Series 4102 Std.
- Series 4103 A-30773A
- Series 4104 A-30773A
- Series 4105 A-30789A
- Series 4106 A-30790A
- Series 4107 A-30791A

Metric Capacities





Wiring Diagram

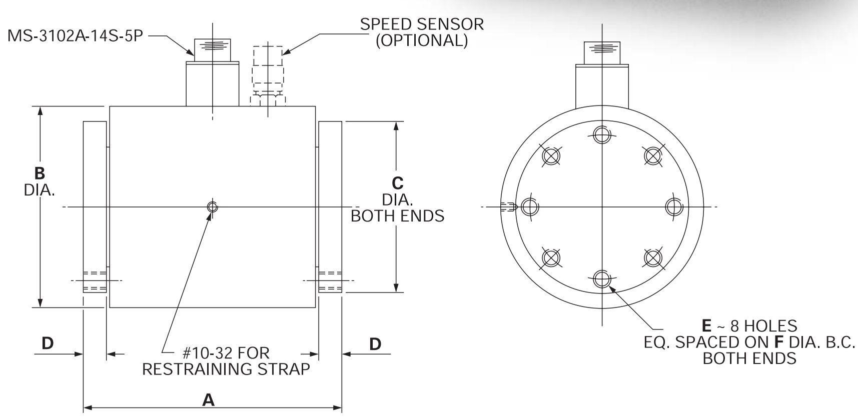
Rotary Transformer Torque Sensors
5K – 30k in-lb

FLANGE END ROTARY TRANSFORMER TORQUE SENSORS

- 4-square dynamometer
- differential testing
- chassis dynamometer
- engine dynamometer

Series 4149

- Standard capacities from 20k to 30k in-lb FS (2250 to 3389.5 N-m FS)
  Other capacities from 5k to 30k in-lb FS (565 to 3389.5 N-m FS)
  are available - contact factory for details
- 2 mV/V output sensitivity
- Short length with flange ends
- High signal-to-noise ratio
- High torsional stiffness



Series 4149

Dimensions — inches (cm)						
Series	**A**	**B**	**C**	**D**	**E**	**F**
4149	6.38 (16.21)	5.5 (13.97)	4.25 (10.8)	0.56 (1.42)	3/8-24	3.63 (9.22)

Rotary Transformer Torque Sensors
5k – 30k in-lb

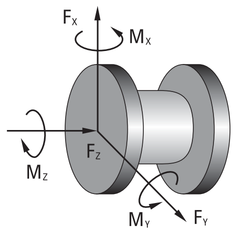
	Specifications						
Model Number	Capacity in-lb (N-m)*	Maximum Speed RPM	Overload in-lb (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Rotating Inertia in-lb sec^2 (N-m sec^2)	Weight lb (kg)	Material
Rotating Transformer Torque Sensors with Shaft Ends							
4149-01A	20k (2250)	8000	30k (3400)	3.7M (418k)	0.061 (0.007)	23 (10.4)	steel
4149-02A	24k (2700)	8000	36k (4065)	4M (452k)	0.061 (0.007)	23 (10.4)	steel
4149-03A	30k (3389.5)	8000	36k (4065)	2M (225k)	0.061 (0.007)	23 (10.4)	steel

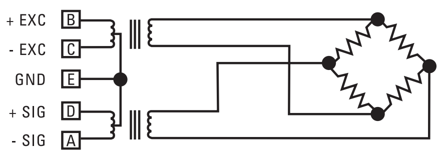
Common Specification

Output (nominal). . . . . 2 mV/Volt
Non-linearity (max) . . . . 0.1% FS
Hysteresis (max) . . . . 0.1% FS
Non-repeatability (max) . . . . 0.05% FS
Bridge Resistance (nominal). . . . . 350 ohm
Excitation Frequency. . . . . 3.28k Hz
Excitation Voltage (AC/RMS). . . . . 5 to 10 Volts
Bridge Current @ 5VAC . . . . 50 mA
Temp. Range (compensated). . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . -65 °F to +170 °F (-54 °C to +77 °C)
Temp. Effect on Zero (max) . . . . 0.001% FS/°F (0.0018% FS/°C)
Temp. Effect on Output (max) . . . . 0.001% reading/°F (0.0018% reading/°C)

***** Capacities from 5k to 30k in-lb FS (565 to 3389.5 N-m FS) are available - contact factory for details.

Supplied Accessories	
	See Page
Mating Connector (if cable is not purchased) Model 180-019A	
Precision Shunt Calibration Module Model 8113-105A	2.35
Optional Accessories	
	See Page
Interconnecting Cable	2.32 to 2.33
Signal Conditioner	2.28
Active Speed Sensor Kit Model A-30775-1A	2.34
Passive Speed Sensor Kit Model A-30774A	2.34
“Type K” Thermocouple	2.35
Options (see page 2.8)	
Metric Capacities	





Wiring Diagram

Typical systems located on page 2.5

For rotary torque application solutions, see also page 2.22 for TORKDISC® rotary torque sensor systems.

Rotary Transformer Torque Sensors
50 – 10k in-lb

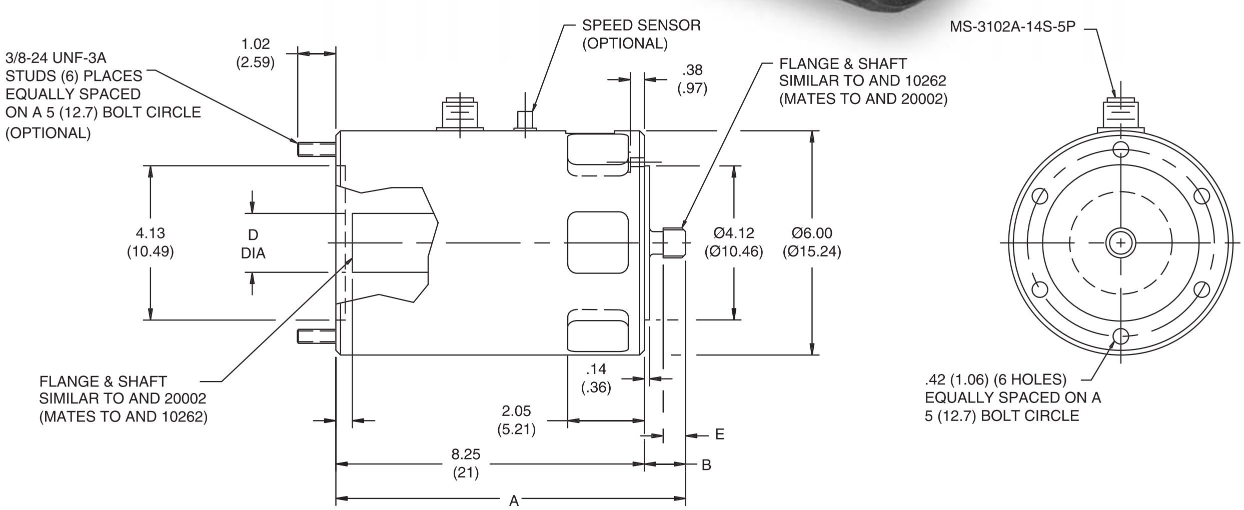
AND FLANGE-SHAFT ROTARY TRANSFORMER TORQUE SENSORS

Specifically designed for testing of

- cantilevered aerospace hydraulic pumps
- cantilevered aerospace hydraulic motors

Series 4115A, 4115K

- Capacities from 50 to 10k in-lb FS (5.6 to 1130 N-m FS)
- 2.5 mV/V output sensitivity
- Splined shaft drive
- High signal-to-noise ratio
- High torsional stiffness



Series 4115A, 4115K

Dimensions shown are in inches (centimeters).

Dimensions — inches (cm)						Internal and External Spline Data			
Series	A	B	C	D	E	Pressure Angle	Pitch Dia — in (cm)	Pitch	Number of Teeth
4115A	9.35 (23.75)	1.10 (2.79)	0.25 (0.64)	1.58 (4)	0.6 (1.52)	30°	0.8 (2.03)	20/30	16
4115K	9.94 (25.25)	1.69 (4.29)	0.38 (0.97)	1.58 (4)	1 (2.54)	30°	1.2 (3.05)	20/30	24

	Specifications						
Model Number	Capacity in-lb (N-m)	Maximum Speed RPM	Overload in-lb (N-m)	Torsional Stiffness in-lb/rad (N-m/rad)	Rotating Inertia in-lb sec² (N-m sec²)	Weight lb (kg)	Material
Flange-Shaft Rotating Transformer Torque Sensors							
4115A-01A	50 (5.6)	15k	150 (17)	4500 (500)	0.0047 (0.0005)	46 (20.9)	steel
4115A-02A	100 (11)	15k	300 (34)	13.5k (1525)	0.0048 (0.0005)	46 (20.9)	steel
4115A-03A	200 (23)	15k	600 (68)	33k (3725)	0.0049 (0.0005)	46 (20.9)	steel
4115A-04A	500 (55)	15k	1500 (170)	94k (10.6k)	0.005 (0.0006)	46 (20.9)	steel
4115A-05A	1000 (115)	15k	1500 (170)	94k (10.6k)	0.005 (0.0006)	46 (20.9)	steel
4115K-01A	50 (5.6)	15k	150 (17)	4500 (500)	0.0048 (0.0005)	47 (21.3)	steel
4115K-02A	100 (11)	15k	300 (34)	13.5k (1525)	0.0049 (0.0005)	47 (21.3)	steel
4115K-03A	200 (23)	15k	600 (68)	33k (3725)	0.005 (0.0006)	47 (21.3)	steel
4115K-04A	500 (55)	15k	1500 (170)	94k (10.6k)	0.0051 (0.0006)	47 (21.3)	steel
4115K-05A	600 (68)	15k	1800 (200)	120k (13.6k)	0.0051 (0.0006)	47 (21.3)	steel
4115K-06A	1000 (115)	15k	3000 (340)	204k (23k)	0.0052 (0.0006)	47 (21.3)	steel
4115K-07A	1200 (135)	15k	3600 (405)	204k (23k)	0.0052 (0.0006)	47 (21.3)	steel
4115K-08A	2000 (225)	15k	6000 (675)	204k (23k)	0.0052 (0.0006)	47 (21.3)	steel
4115K-09A	2400 (270)	15k	7200 (815)	380k (42.9k)	0.0055 (0.0006)	47 (21.3)	steel
4115K-10A	3600 (405)	15k	10.8k (1220)	420k (47.5k)	0.0058 (0.0007)	47 (21.3)	steel
4115K-11A	5000 (565)	15k	15k (1700)	500k (56.5k)	0.0062 (0.0007)	47 (21.3)	steel
4115K-12A	6000 (675)	15k	15k (1700)	500k (56.5k)	0.0062 (0.0007)	47 (21.3)	steel
4115K-13A	10k (1130)	15k	15k (1700)	500k (56.5k)	0.0062 (0.0007)	47 (21.3)	steel

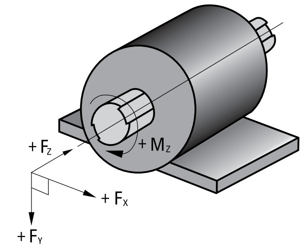
Common Specifications

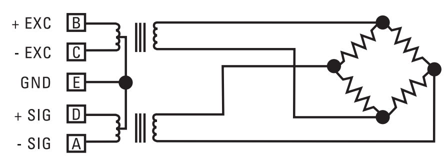
Output (nominal) . . . . . 2.5 mV/Volt
Non-linearity (max) . . . . . 0.05% FS
Hysteresis (max) . . . . . 0.05% FS
Non-repeatability (max) . . . . . 0.03% FS
Bridge Resistance (nominal) . . . . . 350 ohm
Excitation Frequency . . . . . 3.28k Hz
Excitation Voltage (AC/RMS) . . . . . 5 to 10 Volts
Bridge Current @ 5VAC . . . . . 50 mA
Temp. Range (compensated) . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . . -65 °F to +225 °F (-54 °C to +107 °C)

Temp. Effect on Zero (from +70 °F to +225 °F) . . . . . 0.002% FS/°F (0.0036% FS/°C)
Temp. Effect on Span (from +70 °F to +225 °F) . . . . . 0.002% reading/°F (0.0036% reading/°C)
Temp. Effect on Zero (from -65 °F to +70 °F) . . . . . 0.02% FS/°F (0.036% FS/°C)
Temp. Effect on Span (from -65 °F to +70 °F) . . . . . 0.02% FS/°F (0.036% FS/°C)
Maximum Bending Moment . . . . . 1200 in-lb (135 N-m) [1]

NOTE: [1] Bending moment induced by overhung pump weight

Supplied Accessories	
	See Page
Mating Connector (if cable is not purchased) Model 180-019A	
Precision Shunt Calibration Module Model 8113-105A	2.35
Optional Accessories	
	See Page
Interconnecting Cable	2.32 to 2.33
Signal Conditioner	2.28
Active Speed Sensor Kit Model A-30775-1A	2.34
Passive Speed Sensor Kit Model A-30774A	2.34
"Type K" Thermocouple	2.35
Options (see page 2.8)	
Metric Capacities	





Wiring Diagram

Typical systems located on page 2.5

TORKDISC® — ROTARY TORQUE SENSOR SYSTEM

For dynamometer and other applications requiring a robust rotary torque transducer where axial space is at a premium. On-board the transducer is a field-proven electronic module that converts the torque signals into a high-speed digital representation. Once in digital form, this data is transmitted to a non-contacting pick-up loop, with no risk of noise or data corruption. A remote receiver unit converts the digital data to a high-level analog output voltage, frequency output, and a serial digital output.

- chassis dynamometer
- engine dynamometer
- 4-square dynamometer
- efficiency testing
- drive shaft torque measurement

Series 5302C, 5308C, 5309C, 5310C

- Compact
- Low weight
- High torsional stiffness
- 16-Bit digital telemetry
- Immune to RF interference
- Low sensitivity to axial and thrust bending moments
- Robust construction

Series 5302C

See page 2.24 for TORKDISC® sensor dimensions and outline drawing.

TORKDISC® Rotary Torque Sensor System

Model Number	Unit	5302C-01A	5302C-02A	5302C-03A	5302C-04A	5308C-01A	5308C-02A	5308C-03A
Continuous Rated Capacity	in-lb (N-m)	2000 (226)	5000 (565)	1000 (113)	6250 (706)	10k (1130)	20k (2250)	30k (3400)
Bolt Joint Slip Torque[1]	in-lb (N-m)	3300 (373)	10k (1130)	3300 (373)	10k (1130)	35k (4000)	35K (4000)	35k (4000)
Safe Overload	in-lb (N-m)	6000 (678)	15k (1695)	3000 (339)	15k (1695)	30k (3400)	60k (6775)	75k (8500)
Failure Overload	in-lb (N-m)	8000 (904)	20k (2260)	4000 (452)	20k (2260)	40k (4500)	80k (9050)	100k (11.3k)
Torsional Stiffness	in-lb/rad (N-m/rad)	5.8M (655k)	14.5M (1.6M)	2.9M (328k)	14.5M (1.6M)	33.5M (3.8M)	67M (7.6M)	100M (11.3M)
Torsional Angle @ Capacity	degrees	0.02	0.02	0.02	0.02	0.017	0.017	0.017
Rotating Inertia	in-lb sec^2 (N-m sec^2)	0.056 (0.006)	0.117 (0.013)	0.056 (0.006)	0.117 (0.013)	0.24 (0.027)	0.24 (0.027)	0.24 (0.027)
Axial Load Limit[2]	lb (N)	500 (2224)	1000 (4448)	250 (1112)	1000 (4448)	1350 (6000)	2700 (12k)	4000 (17.8k)
Lateral Load Limit[2]	lb (N)	500 (2224)	1000 (4448)	250 (1112)	1000 (4448)	1650 (7300)	3375 (15k)	5000 (22.2k)
Bending Moment Limit[2]	in-lb (N-m)	1500 (169)	3000 (339)	750 (85)	3000 (339)	5000 (565)	7500 (850)	10k (1130)
Maximum Speed	RPM	15k	15k	15k	15k	10k	10k	10k
Rotor Weight	lb (kg)	3.5 (1.59)	9 (4.08)	3.5 (1.59)	9 (4.08)	10 (4.5)	10 (4.5)	10 (4.5)
Rotor Material		steel	steel	steel	steel	steel	steel	steel

TORKDISC® Rotary Torque Sensor System (con't)

Model Number	Unit	5309C-01A	5309C-02A	5310C-01A	5310C-02A	5310C-03A	5310C-04A
Continuous Rated Capacity	in-lb (N-m)	50k (5650)	100k (11.3k)	180k (20.3k)	200k (22.5k)	120k (13.5k)	225k (25.4k)
Bolt Joint Slip Torque[1]	in-lb (N-m)	85k (9600)	110k (12.4k)	268k (30.3k)	268k (30.3k)	268k (30.3k)	268k (30.3k)
Safe Overload	in-lb (N-m)	100k (11.3k)	200k (22.6k)	540k (61.0k)	600k (67.8k)	360k (40.7k)	675k (76.3k)
Failure Overload	in-lb (N-m)	125k (14k)	250k (28.2k)	720k (81.3k)	800k (90.4k)	480k (54.2k)	900k (101.7k)
Torsional Stiffness	in-lb/rad (N-m/rad)	115M (13M)	230M (26M)	1.1B (124M)	1.2B (138M)	730M (82.5M)	1.35B (152.5M)
Torsional Angle @ Capacity	degrees	0.017	0.017	0.01	0.01	0.01	0.01
Rotating Inertia	in-lb sec^2 (N-m sec^2)	0.874 (0.099)	0.874 (0.099)	7.514 (0.848)	7.514 (0.848)	7.514 (0.848)	7.514 (0.848)
Axial Load Limit[2]	lb (N)	5000 (22.2k)	10k (44.5k)	13.5k (60k)	14k (62k)	12k (53k)	15k (66.7k)
Lateral Load Limit[2]	lb (N)	5000 (22.2k)	10k (44.5k)	13.5k (60k)	14k (62k)	12k (53k)	15k (66.7k)
Bending Moment Limit[2]	in-lb (N-m)	25k (2825)	50k (5650)	90k (10.2k)	95k (10.7k)	80k (9050k)	100k (11.3k)
Maximum Speed	RPM	10k	10k	4500	4500	4500	4500
Weight	lb (kg)	30 (13.6)	30 (13.6)	100 (45)	100 (45)	100 (45)	100 (45)
Material		steel	steel	steel	steel	steel	steel

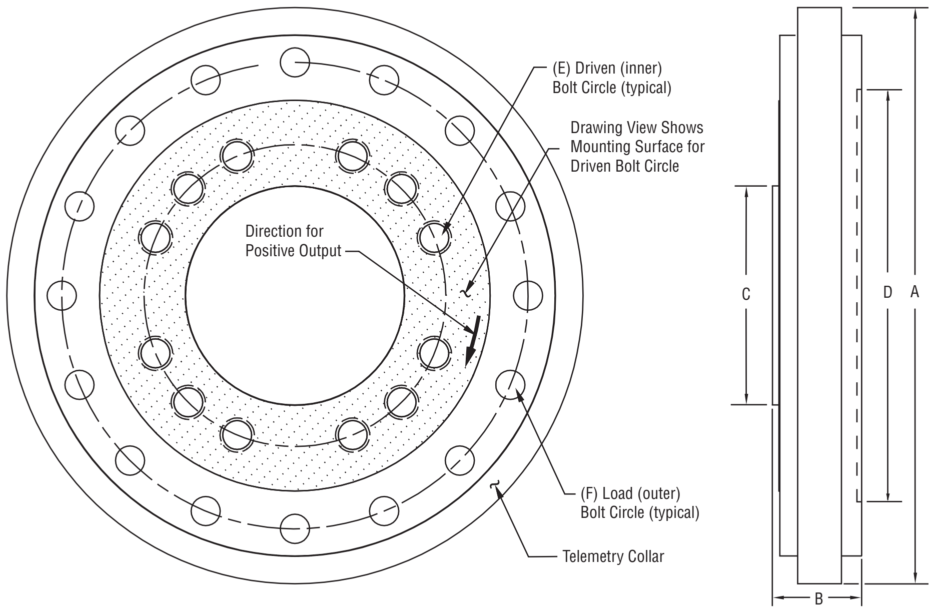
Common Specifications

Output at rated capacity (analog/voltage) . . . . 0 ± 10 Volts
(Frequency) . . . . 10k Hz ± 5k Hz
(Digital)[3] . . . . QSPI
Combined effect of non-linearity, hysteresis, and non-repeatability . . . . ± 0.1% FS
Temperature range, compensated . . . . +70 °F to +170 °F
Temperature effect on output within the compensated range . . . . ± 0.003% FS/°F
Temperature effect on zero within the compensated range . . . . ± 0.003% FS/°F
Temperature range, usable . . . . +60 °F to +185 °F
Electronics measuring bandwidth[4] . . . . 2000 Hz
Digital resolution 16-Bit
Digital sample rate . . . . 26,000 samples/second
Permissible radial float, rotor to stator . . . . ± 0.13 in.
Permissible axial float, rotor to stator . . . . ± 0.25 in.
Power requirements . . . . 90-240 VAC, 50-60 Hz

NOTE: The acceptable cable lengths between the electronics box and the stator portion of the TORKDISC® is 24, 80, or 112 ft (7.3, 24.4, or 34.1 m), as supplied from factory. Do not shorten cable; coil any excess.

[1] Bolt joint slip torque is calculated assuming a coefficient of friction (μ) of 0.1 and that grade 8 socket head cap screws are used and tightened to 75% of yield for steel sensors and 30% of yield for aluminum sensors. Model 5309C-02A requires the use of Supertanium bolts on the inner bolt circle diameter to maintain proper clamping frictional forces, tightened to 70% of yield.
[2] Extraneous load limits reflect the maximum axial load, lateral load, and bending moment that may be applied singularly without electrical or mechanical damage to the sensor. Where combined extraneous loads are applied, decrease loads proportionally. Request Application Note AP-1015 regarding the effects of extraneous loads on the torque sensor output.
[3] Request Technical Note FTQ-STN5 regarding digital output signal.
[4] Output can be filtered via internal DIP switch (33, 55, 125, 250, 450 Hz).

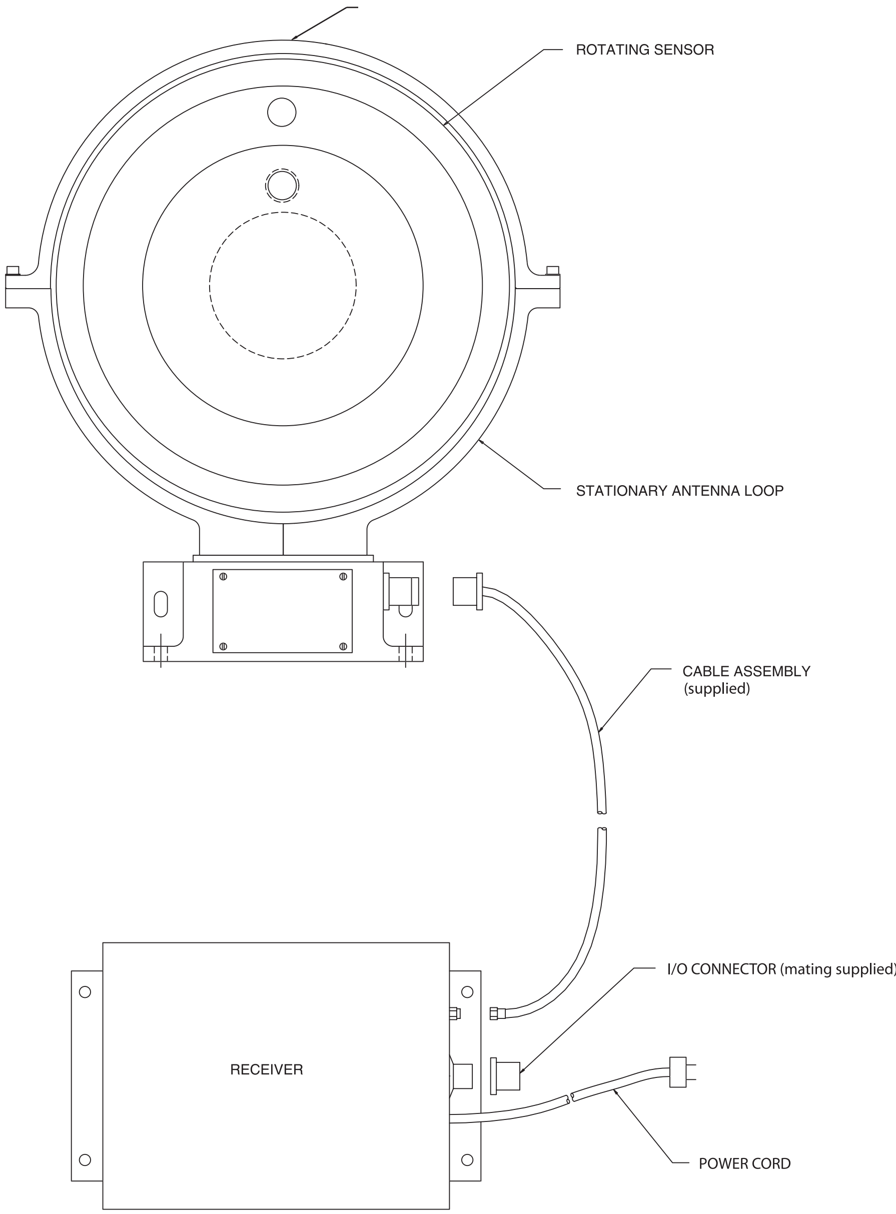
TORKDISC® Rotary Torque Sensor System
1k – 225k in-lb



Request Detailed Drawing for Installation

TORKDISC® Sensor Dimensions

	A	B	C	D	E	F
Series	O.D. - Outside Diameter (including telemetry collar)	Overall Thickness	Male Pilot Diameter	Female Pilot Diameter	Driven (inner) Bolt Circle	Load (outer) Bolt Circle
5302C	7.00 in (177.8 mm)	1.10 in (27.9 mm)	1.999 in (50.8 mm)	4.375 in (111.1 mm)	(8) 3/8-24 threaded holes, equally spaced on a 3.00 in (76.20 mm) B.C.	(8) 0.406 in (10.31 mm) dia through holes equally spaced on a 5.00 in (127.0 mm) B.C.
5308C	8.49 in (215.5 mm)	1.10 in (27.9 mm)	2.748 in (69.9 mm)	5.513 in (140.0 mm)	(8) 5/8-11 threaded holes, spaced on a 3.75 in (95.25 mm) B.C.	(8) 0.531 in (13.49 mm) dia through holes equally spaced on a 6.5 in (165.0 mm) B.C.
5309C	9.49 in (241.0 mm)	1.64 in (41.7 mm)	3.998 in (101.5 mm)	7.500 in (190.5 mm)	(12) 5/8-11 threaded holes, spaced on a 6.0 in (152.4 mm) B.C.	(16) 0.531 in (13.49 mm) dia through holes equally spaced on a 8.5 in (215.9 mm) B.C.
5310C	17.98 in (456.7 mm)	2.09 in (53.0 mm)	5.499 in (139.7 mm)	11.001 in (279.4 mm)	(12) 7/8-14 threaded holes, spaced on a 9.0 in (288.6 mm) B.C.	(16) 0.780 in (19.8 mm) dia through holes equally spaced on a 13.0 in (330.2 mm) B.C.



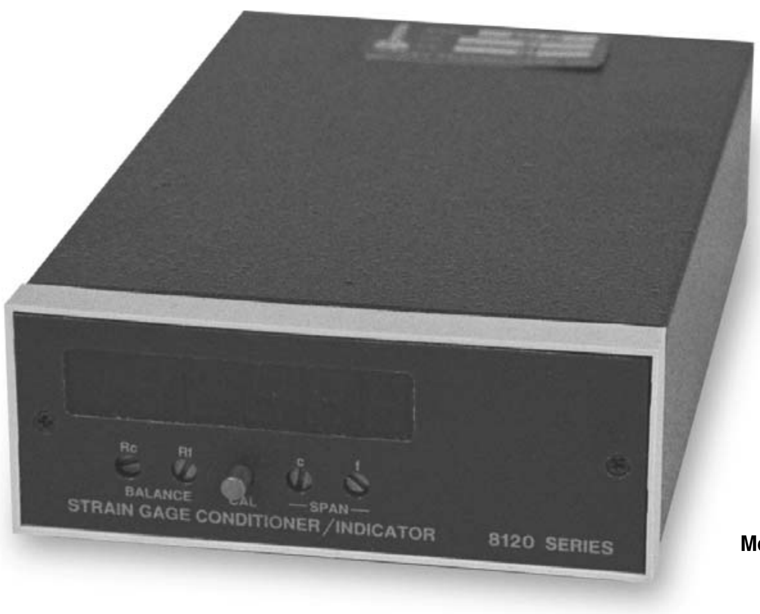
The TORKDISC® and receiver make up a complete system. No additional signal conditioning is required. The receiver box provides voltage, frequency, and digital output via a 25-Pin (F) D-Sub connector.

Photo courtesy of Mustang Dynamometer

The robust construction, high stiffness, and low rotating inertia of the TORKDISC® make it ideal for applications such as chassis and engine dynamometers. The TORKDISC® system consists of a rotating sensor flange, a fixed receiving antenna, and a signal conditioning module. Torque is measured using a unique strain gage structure within the rotating flange. The measurement signal is then digitized, and is transmitted without wires to the receiving antenna. The signal is conditioned to a voltage, frequency, and digital output.

Torque Sensor Accessories and Services

- **Strain gage signal conditioners**
- **Cable assemblies**
- **Speed sensors**
- **Shunt calibration modules and thermocouples**
- **Calibration services**



Model 8120-110A

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

PCB 716-684-0001 **Force/Torque Division toll-free** 888-684-0004 **Fax** 716-684-8877 **E-mail** force@pcb.com **Web site** www.pcb.com

Signal Conditioners
For use with Torque or Speed Sensors

The Series 8120 family of signal conditioners are designed for use with either strain gage reaction torque sensors, strain gage rotary torque sensors, or Hall Effect speed (RPM) sensors. Within each category, the series offers a choice of either a basic signal conditioner, signal conditioner with digital display, or signal conditioner with digital display and Hi-Lo set points. Each unit delivers a 0 to ± 5 Volts analog output signal.

Available Signal Conditioner Options (Consult Factory)		Can be Combined with One of the Options Listed
B	12 Volt DC Power	P, C, G, R
P	Peak Capture	F, B
C	4 to 20 mA Current Output	F, B
F	230 VAC Power	P, C, G, R, S
G	± 10 Volt Output (0.1% FS Non-linearity)	F, B
R*	Dual Limits - Mechanical Relays	F, B
S*	Dual Limits - Solid State Relays	F

** Model 8120-130A Only*

Supplied Accessories
Star Bridge Sensor Simulator* (if precision shunt calibration module is not supplied)
Mating Connector (if cable is not purchased)
Power Cord
* Hall Effect signal conditioners are not supplied with a star bridge, as they contain built-in crystal oscillators

Models
8120-100A,
8120-400A, and
8120-700A

Models
8120-110A,
8120-130A,
8120-410A,
8120-430A,
8120-710A, and
8120-730A

Sensor/Excitation	*Strain Gage DC Excitation (Reaction)	Strain Gage AC Excitation (Rotary)	Hall Effect (Speed)
Basic Signal Conditioner	**8120-100A**	**8120-400A**	**8120-700A**
Signal Conditioner with 4 1/2 digit LED display 3 Hz refresh rate	**8120-110A**	**8120-410A**	**8120-710A**
Signal Conditioner with LED display and Hi-Lo set points (TTL compatible)	**8120-130A**	**8120-430A**	**8120-730A**
Input transducers	90-2000 ohm	90-1000 ohm	0.1-200V
Excitation	5 or 10 VDC	2 VAC (RMS) @ 3.28 kHz	9 VDC
Accuracy	± 0.05% FS	± 0.05% FS	± 0.05% FS
Balance range	10 turn coarse and fine pots, ± 1.5 mV/V imbalance	10 turn coarse and fine pots, ± 1.5 mV/V imbalance	—
Span range	10 turn coarse and fine pots, 1 to 8 mV/V	10 turn coarse and fine pots, 0.5 to 5 mV/V	Selectable ranges of 0, 100, 200, 500, 1000, 2000, 5000, 10k, 20k, 50k
Active filter	Selectable 2, 200, 2000 Hz	Selectable 2, 400 Hz	2 Hz on input ranges of 0-500 Hz, 10 Hz on all other
Output ripple and noise	0.02% FS (RMS) with 2 Hz filter 0.15% all other filter ranges	0.02% FS (RMS) with 2 Hz filter 0.15% all other filter ranges	0.1% FS (RMS) from 20%-100% of input range
Input power	110/120 VAC @ 50-400 Hz, 9 watts max	110/120 VAC @ 50-400 Hz, 9 watts max	110/120 VAC @ 50-400 Hz, 9 watts max
Operating temp. range	0 to +130 °F (0 to +54 °C)	0 to +130 °F (0 to +54 °C)	0 to +130 °F (0 to +54 °C)
Weight (approx.)	2 lb (0.9 Kg)	2 lb (0.9 Kg)	2 lb (0.9 Kg)

*** For additional signal conditioners for use with reaction torque sensors, see pages 3.20 to 3.23**

Speed Sensor Cable Specifications and Standard Models

The following tables provide specifications and configuration diagrams for the variety of cable types available. Where applicable, standard cable assembly model numbers are provided. Standard models can be less costly than custom cables and available for immediate shipment. For alternate cable lengths or custom models, contact the factory.

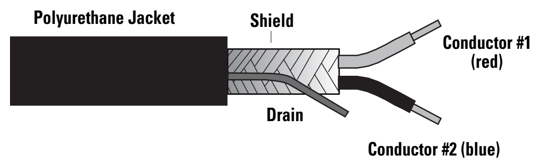
General Purpose Twisted, Shielded Pair Cables

Usage

General purpose, 2-conductor, twisted, shielded, pair cable with a black polyurethane jacket. Use with speed sensors.

Outer Jacket	Polyurethane, black	
Diameter	0.25 in	6.35 mm
Capacitance	36 pF/ft	118 pF/m
Temperature Range	-58 to +250 ºF	-50 to +121 ºC

Construction

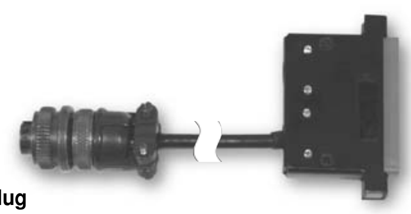


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8312-01-05A	5 ft	1.5 m
8312-01-10A	10 ft	3.0 m
8312-01-20A	20 ft	6.1 m
8312-01-50A	50 ft	15.2 m

2-Socket Plug — Pigtails

Model Number	Length (feet)	Length (meters)
8312-02-05A	5 ft	1.5 m
8312-02-10A	10 ft	3.0 m
8312-02-20A	20 ft	6.1 m
8312-02-50A	50 ft	15.2 m



2-Socket Plug — Card Edge

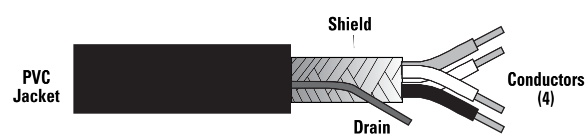
Twisted, Shielded, Four-Conductor Cables

Usage

General purpose, use with speed sensors. 24AWG common stranded tinned copper drain wire, polypropylene insulated, twisted pair in a chrome PVC jacket.

Outer Jacket	PVC, grey	
Diameter	0.168 in	4.27 mm
Capacitance	35 pF/ft	44.3 pF/m
Temperature Range	-4 to +140 ºF	-20 to +60 ºC
Impedance	45 ohm	

Construction

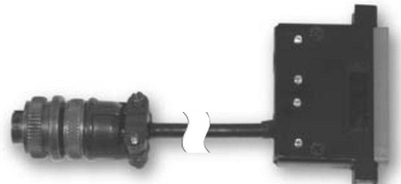


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8313-03-05A	5 ft	1.5 m
8313-03-10A	10 ft	3.0 m
8313-03-20A	20 ft	6.1 m
8313-03-50A	50 ft	15.2 m

3-Socket Plug — Pigtails

Model Number	Length (feet)	Length (meters)
8313-04-05A	5 ft	1.5 m
8313-04-10A	10 ft	3.0 m
8313-04-20A	20 ft	6.1 m
8313-04-50A	50 ft	15.2 m



3-Socket Plug — Card Edge

Reaction Torque Sensor Cable Assemblies

Recommended Reaction Torque Sensor Signal Conditioners and Cables				
	Recommended Signal Conditioners			
	8120 Series	**8159 Series**	**8160A**	**8161A, 8162, & Pigtails**
Reaction Torque Sensor Type	**Recommended Cables**			
Reaction Torque with PT connector <20 ft (6.1 m)	8311-04-xxA	8311-17-xxA	8311-15-xxA	8311-01-xxA
Reaction Torque with PT connector ≥20 ft (6.1 m)	8311-05-xxA	8311-18-xxA	8311-15-xxA	8311-02-xxA

"xx" indicates length in feet.

Standard lengths include 5 ft (1.5 m), 10 ft (3 m), 20 ft (6.1 m), & 50 ft (15.2 m).

Reaction Torque Sensor Cable Specifications and Standard Models

The following tables provide specifications and configuration diagrams for the variety of cable types available. Where applicable, standard cable assembly model numbers are provided. Standard models can be less costly than custom cables and available for immediate shipment. For alternate cable lengths or custom models, contact the factory.

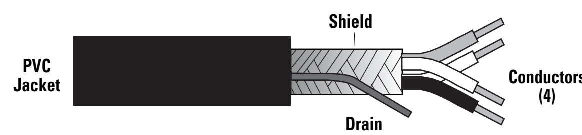
Four-Conductor Cables

Usage

General purpose, use with reaction torque sensors. 24AWG common stranded tinned copper drain wire, polypropylene insulated, twisted pair in a chrome PVC jacket. Use when desired cable is < 20 feet (6.1 m).

Outer Jacket	PVC, grey	
Diameter	0.168 in	4.27 mm
Capacitance	35 pF/ft	44.3 pF/m
Temperature Range	-4 to +140 °F	-20 to +60 °C
Impedance	45 ohm	

Construction

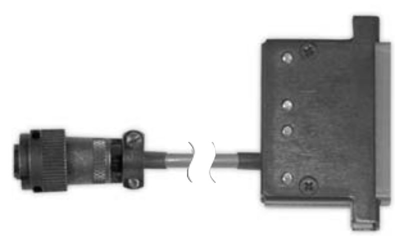


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8311-01-05A	5 ft	1.5 m
8311-01-10A	10 ft	3.0 m

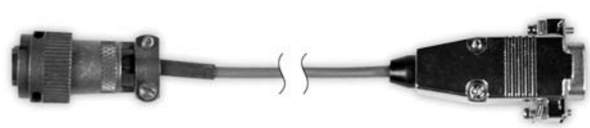
PT **Pigtails**

Model Number	Length (feet)	Length (meters)
8311-04-05A	5 ft	1.5 m
8311-04-10A	10 ft	3.0 m



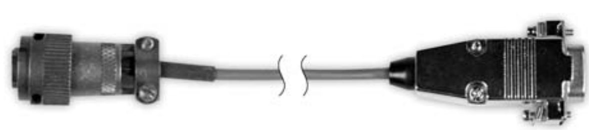
PT **Card Edge**

Model Number	Length (feet)	Length (meters)
8311-15-05A	5 ft	1.5 m
8311-15-10A	10 ft	3.0 m
8311-15-20A	20 ft	6.1 m
8311-15-50A	50 ft	15.2 m



PT **9-Pin (M) D-Sub**

Model Number	Length (feet)	Length (meters)
8311-17-05A	5 ft	1.5 m
8311-17-10A	10 ft	3.0 m



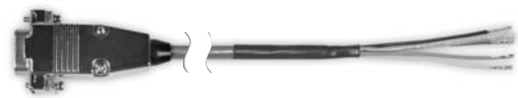
PT **9-Pin (M) D-Sub**

Continued on next page

Reaction Torque Sensor Cable Assemblies

Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8314-20-05A	5 ft	1.5 m
8314-20-10A	10 ft	3.0 m



9-Socket (F) D-Sub — Pigtails

Model Number	Length (feet)	Length (meters)
8314-21-05A	5 ft	1.5 m
8314-21-10A	10 ft	3.0 m

15-Pin (M) D-Sub — Pigtails

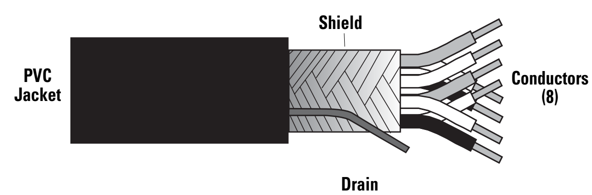
Eight-Conductor Cables

Usage

General purpose, use with reaction torque sensors. 24AWG common stranded tinned copper drain wire, polypropylene insulated, twisted pair in a chrome PVC jacket. Use when desired cable is ≥ 20 feet (6.1 m).

Outer Jacket	PVC, grey	
Diameter	0.363 in	9.22 mm
Capacitance	13.5 pF/ft	44.3 pF/m
Temperature Range	-4 to +140 °F	-20 to +60 °C
Impedance	100 ohm	

Construction

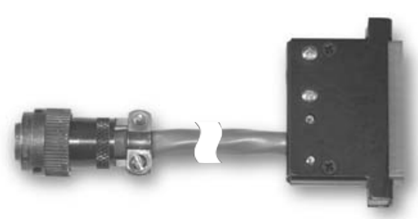


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8311-02-20A	20 ft	6.1 m
8311-02-50A	50 ft	15.2 m

PT — Pigtails

Model Number	Length (feet)	Length (meters)
8311-05-20A	20 ft	6.1 m
8311-05-50A	50 ft	15.2 m



PT — Card Edge

Model Number	Length (feet)	Length (meters)
8311-18-20A	20 ft	6.1 m
8311-18-50A	50 ft	15.2 m

9-Pin (M) D-Sub — PT

Rotary Torque Sensor Cable Assemblies

Recommended Rotary Torque Sensor Signal Conditioners and Cables		
	Signal Conditioners	
	8120 Series	Pigtails (other)
Rotary Torque Sensor Type	Recommended Cables	
4100 Series Rotary Transformer Torque	8310-06-xxA	8310-03-xxA
4200 Series Rotary Transformer Torque	8310-09-xxA	8310-11-xxA
"xx" indicates length in feet. Standard lengths include 5 ft (1.5 m), 10 ft (3 m), 20 ft (6.1 m), & 50 ft (15.2 m).		

Rotary Torque Sensor Cable Specifications and Standard Models

The following tables provide specifications and configuration diagrams for the variety of cable types available. Where applicable, standard cable assembly model numbers are provided. Standard models can be less costly than custom cables and available for immediate shipment. For alternate cable lengths or custom models, contact the factory.

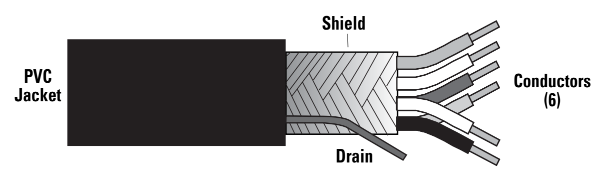
Six-Conductor Cables

Usage

General purpose, use with rotary torque sensors. Aluminum-polyester shielded 24AWG common stranded tinned copper drain wire, twisted pair in a PVC jacket.

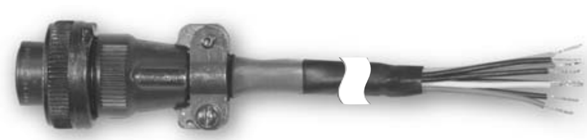
Outer Jacket	PVC, grey	
Diameter	0.359 in	9.12 mm
Capacitance	12.5 pF/ft	41.0 pF/m
Temperature Range	-4 to +140 °F	-20 to +60 °C
Impedance	100 ohm	

Construction



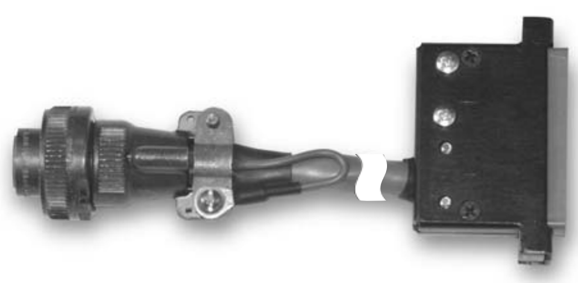
Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8310-03-05A	5 ft	1.5 m
8310-03-10A	10 ft	3.0 m
8310-03-20A	20 ft	6.1 m
8310-03-50A	50 ft	15.2 m



5-Socket Plug Pigtails

Model Number	Length (feet)	Length (meters)
8310-06-05A	5 ft	1.5 m
8310-06-10A	10 ft	3.0 m
8310-06-20A	20 ft	6.1 m
8310-06-50A	50 ft	15.2 m



5-Socket Plug Card Edge

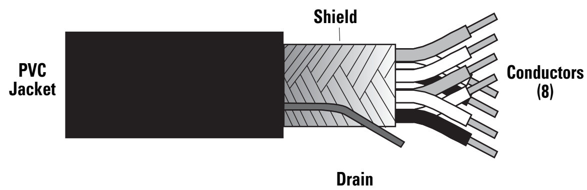
Eight-Conductor Cables

Usage

General purpose, use with rotary torque sensors. Aluminum-polyester sheilded 24AWG common stranded tinned copper drain wire, twisted pair in a PVC jacket.

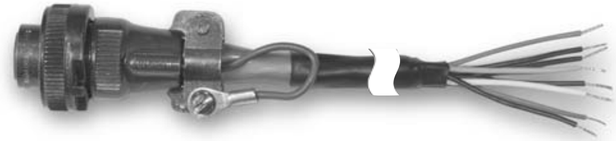
Outer Jacket	PVC, grey	
Diameter	0.359 in	9.12 mm
Capacitance	12.5 pF/ft	41.0 pF/m
Temperature Range	-4 to +140 °F	-20 to +60 °C
Impedance	100 ohm	

Construction



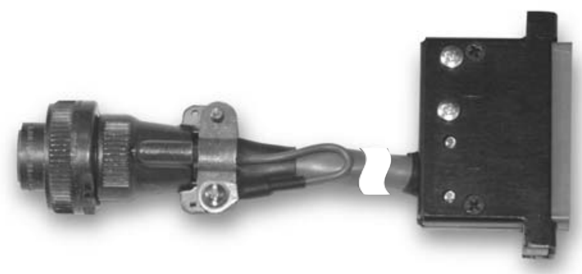
Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8310-11-05A	5 ft	1.5 m
8310-11-10A	10 ft	3.0 m
8310-11-20A	20 ft	6.1 m
8310-11-50A	50 ft	15.2 m



5-Socket Plug Pigtails

Model Number	Length (feet)	Length (meters)
8310-09-05A	5 ft	1.5 m
8310-09-10A	10 ft	3.0 m
8310-09-20A	20 ft	6.1 m
8310-09-50A	50 ft	15.2 m



5-Socket Plug Card Edge

Torque Sensor Accessories

SPEED SENSORS

Speed sensors may be used with rotary torque sensors to provide a measurement of rotational speed. Horsepower can then be calculated using the speed and torque measurements by the following relationship:

$$HP = \frac{\text{Torque (in-lbs)} \times \text{RPM}}{63025}$$

These devices install into ports provided on Series 4100 and 4200 torque sensors. The output of a speed sensor switches in the presence of ferromagnetic material such as steel gear teeth. Output amplitude and wave-form are affected by gear speed and tooth shape.

Speed sensor gears are usually made with 60 teeth. A speed sensor used with a 60 tooth gear will have an output of 100 Hz for a shaft speed of 100 RPM.

Proper orientation of the sensor tip, relative to gear movement, is required. See drawing below for orientation information.

Speed Sensors Kits

MODEL NUMBER	UNIT	A-30775-1A	A-30774A
Specifications			
	Type	Active	Passive
Supply Voltage	VDC	5 to 15	Self-generating
Supply Current - typical	mA	15	—
Frequency Range	Hz	0 to 20k	200 to 20k
Output Voltage - logic 0	VDC	0.6 max	—
- logic 1	VDC	2.4 min	—
Output Voltage	V P-P	—	10 to 170
Supplied Accessories			
Mating Connector		180-021A	180-017A
		(MS3106A-10SL-3S)	(MS3106A-10SL-4S)
Cable Clamp		180-018A	180-018A
		(MS3057-4A)	(MS3057-4A)
Pin Out			
A		5 to 15 VDC	Signal Output
B		Signal	Signal Common
C		Common	—

Optional Accessories

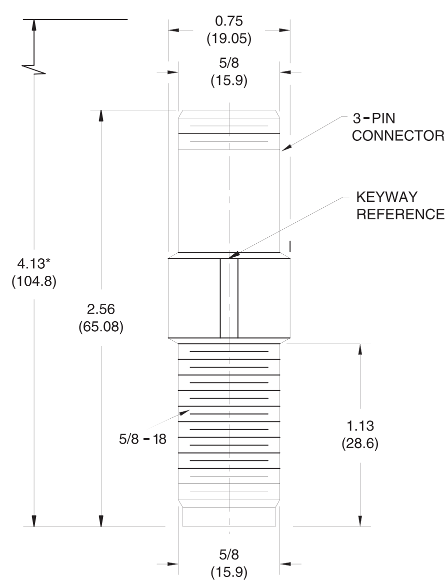
	See Page
Interconnecting Cable	2.29
Signal Conditioner	2.28

Model A-30775-1A —
active speed sensor kit

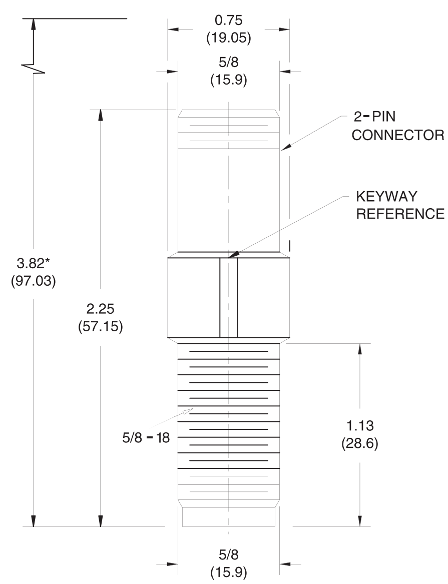
- Requires supply voltage
- 0 to 20,000 RPM max
- 3-pin connector

Model A-30774A —
passive speed sensor kit

- Self-generating
- 200 RPM to rated speed of torque sensor
- 2-pin connector



Active Speed Sensor



Passive Speed Sensor

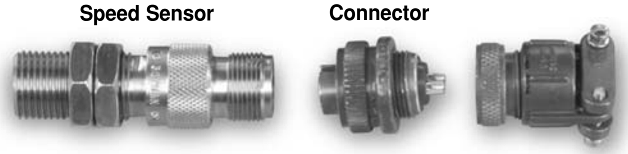
* Length with mating connector

Kit Components

Speed Sensor

Mating Connector

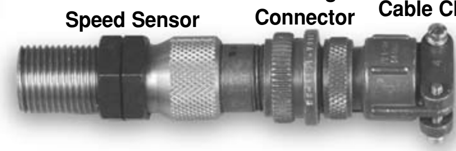
Cable Clamp



Speed Sensor

Mating Connector

Cable Clamp



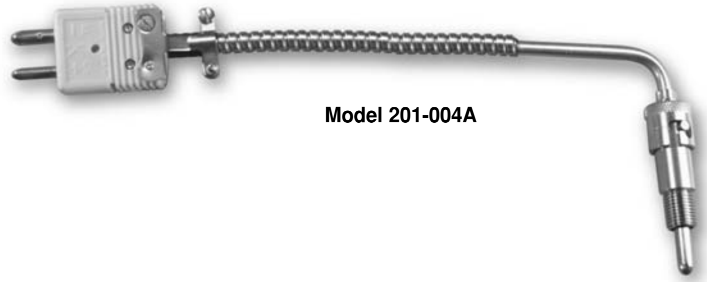
Assembled Kit

Torque Sensor Accessories

THERMOCOUPLES — K-TYPE

Thermocouples are offered as an option on our rotating torque sensors to monitor bearing temperatures.

A pre-drilled hole (3/8-24) is provided on each torque sensor for easy installation. Available Type "K" thermocouples are housed in 304 stainless steel and are supplied with a 5 feet long, 0.275 inch diameter (1.5 m, 7 mm) flexible steel armored cable.



Model 201-004A

Description	Model Number	Cold End Termination
Thermocouple with 90° bend	201-004A	2-pin male connector
Bayonet Adaptor (supplied with thermocouple for all other models)	201-002A	N/A
Bayonet Adaptor (supplied with thermocouple for Models 4115K and 4115A)	201-008A	N/A

PRECISION SHUNT CALIBRATION MODULE (use with Series 4100 Rotary Transformers)

Shunt calibration modules provide a known resistance which produces a known signal that simulates an output from the strain gages in the torque sensor.

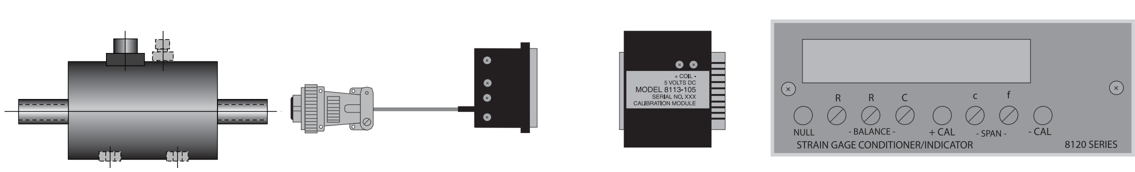
Model 8113-105A — relay activated precision shunt calibration modules with built-in star bridge

- Supplied with all Series 4100 Rotary Transformer Torque Sensors
- Card edge connectors

Card Edge Receptacle

Model 8113-105A

Typical Installation Including Shunt Calibration Module



Series 4100 Rotary Transformer Torque Sensor · **Series 8310-06 Cable Assembly** · **Precision Shunt Calibration Module** · **Series 8120 Rotary Torque Sensor Signal Conditioner**

TORQUE

Torque Sensor Calibration Services

PCB Piezotronics maintains a completely-equipped calibration laboratory for calibration and re-certification of strain gage based torque sensors, single axis load cells, and multi-axis transducers. These services are available for sensors manufactured by PCB as well as other companies.

Calibrations and re-certifications performed by PCB are traceable to the National Institute of Standards and Technology (NIST) and conform to ISO/IEC 17025-1999 and ANSI/NCSL Z540-1-1994. PCB's calibration laboratory is accredited by The American Association for Laboratory Accreditation (A2LA) to ISO 17025 standards.

The scope of our accreditation for torque sensors is:

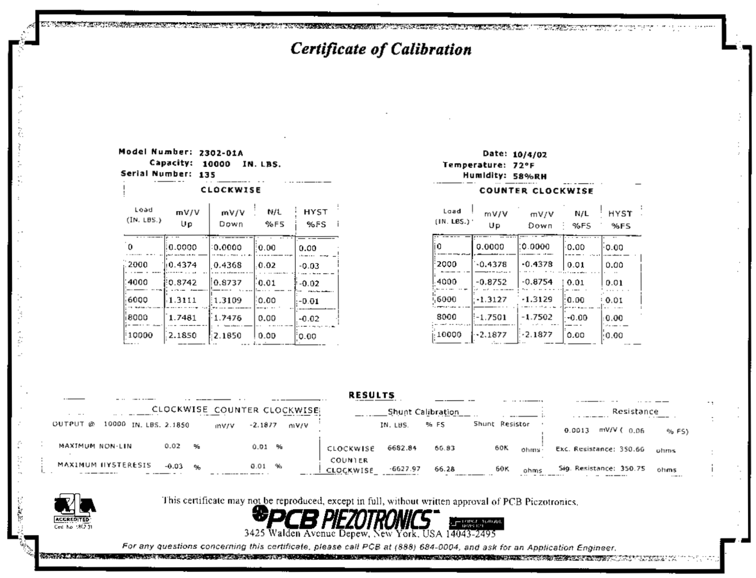
Range	Best Uncertainty [1] (±)
10 to 25k in-lb (1.1 to 2.8k N-m)	0.04% FS
25k to 100k in-lb (2.8k to 11.3k N-m)	0.14% FS
100k to 500k in-lb (11.3k to 56.5k N-m)	0.09% FS

[1] Best Uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k = 2.

Basic Calibration

Standard calibration services include five (5) ascending and descending points in the clockwise and counterclockwise directions for torque sensors. Charted calibration data is provided in a theoretical vs. actual format with mV/V, non-linearity, and hysteresis provided at each increment. Shunt calibration data is also provided along with a precision shunt calibration resistor. The standard calibration service includes a basic certificate of NIST traceability.

Cutaway view of a rotary transformer torque sensor with optional speed sensor installed.



Certificate of Calibration

Model Number: 2302-01A
Capacity: 10000 IN. LBS.
Serial Number: 135

Date: 10/4/02
Temperature: 72°F
Humidity: 58%RH

CLOCKWISE

Load (IN. LBS.)	mV/V Up	mV/V Down	N/L %FS	HYST %FS
0	0.0000	0.0000	0.00	0.00
2000	0.4374	0.4368	0.02	-0.03
4000	0.8742	0.8737	0.01	-0.02
6000	1.3111	1.3109	0.00	-0.01
8000	1.7481	1.7476	0.00	-0.02
10000	2.1850	2.1850	0.00	0.00

COUNTER CLOCKWISE

Load (IN. LBS.)	mV/V Up	mV/V Down	N/L %FS	HYST %FS
0	0.0000	0.0000	0.00	0.00
2000	-0.4378	-0.4378	0.01	0.00
4000	-0.8752	-0.8754	0.01	0.01
6000	-1.3127	-1.3129	0.00	0.01
8000	-1.7501	-1.7502	-0.00	0.00
10000	-2.1877	-2.1877	0.00	0.00

RESULTS

	CLOCKWISE	COUNTER CLOCKWISE
OUTPUT @ 10000 IN. LBS.	2.1850 mV/V	-2.1877 mV/V
MAXIMUM NON-LIN	0.02 %	0.01 %
MAXIMUM HYSTERESIS	-0.03 %	0.01 %

Shunt Calibration

	IN. LBS.	% FS	Shunt Resistor
CLOCKWISE	6682.84	66.83	60K ohms
COUNTER CLOCKWISE	-6627.97	66.28	60K ohms

Resistance

0.0013 mV/V (0.06 % FS)
Exc. Resistance: 350.66 ohms
Sig. Resistance: 350.75 ohms

ACCREDITED

This certificate may not be reproduced, except in full, without written approval of PCB Piezotronics.

PCB PIEZOTRONICS
3425 Walden Avenue Depew, New York, USA 14043-2495

For any questions concerning this certificate, please call PCB at (888) 684-0004, and ask for an Application Engineer.

Torque Sensor Calibration Services		
PCB Sensor Calibration Code	**Competitor Sensor Calibration Code**	
TCS-1A	TCS-0	Calibration of torque sensor, 5-point, single bridge, up to 5000 in-lb (565 N-m)
TCS-1B	TCS-0	Calibration of torque sensor, 5-point, single bridge, above 5000 in-lb (565 N-m) and up to 30k in-lb (3400 N-m)
TCS-1C	TCS-0	Calibration of torque sensor, 5-point, single bridge, above 30k in-lb (3400 N-m) and up to 250k in-lb (28.2k N-m)
TCS-1D	TCS-0	Calibration of torque sensor, 5-point, single bridge, above 250k in-lb (28.2k N-m) and up to 500k in-lb (56.5k N-m)
TCS-2A	TCS-0	System calibration (torque sensor, signal conditioner, cable), 5-point, single bridge, up to 5000 in-lb (565 N-m)
TCS-2B	TCS-0	System calibration (torque sensor, signal conditioner, cable), 5-point, single bridge, above 5000 in-lb (565 N-m) and up to 30k in-lb (3400 N-m)
TCS-2C	TCS-0	System calibration (torque sensor, signal conditioner, cable), 5-point, single bridge, above 30k in-lb (3400 N-m) and up to 250k in-lb (28.2k N-m)
TCS-2D	TCS-0	System calibration (torque sensor, signal conditioner, cable), 5-point, single bridge, above 250k in-lb (28.2k N-m) and up to 500k in-lb (56.5k N-m)
Other calibration services available; contact factory for more information.		

Torque Sensor Technical Information

- **Introduction to torque sensors**
- **Glossary of terms**

Principle of Operation

All torque sensors manufactured by the Force-Torque Division of PCB are strain gage based measuring instruments whose output voltage is proportional to applied torque. The output voltage produced by a resistance change in strain gages that are bonded to the torque sensor structure. The magnitude of the resistance change is proportional to the deformation of the torque sensor and therefore the applied torque.

The four-arm Wheatstone Bridge configuration shown in **Figure 1** depicts the strain gage geometry used in the torque sensor structures. This configuration allows for temperature compensation and cancellation of signals caused by forces not directly applied about the axis of the applied torque.

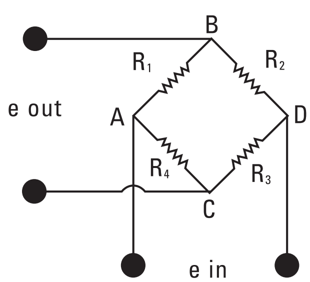


Figure 1.
Wheatstone Bridge

A regulated 5 to 20 volt excitation is required and is applied between points A and D of the wheatstone bridge. When torque is applied to the transducer structure the wheatstone bridge becomes unbalanced, thereby causing an output voltage between points B and C. This voltage is proportional to the applied torque.

Series 2300 reaction torque sensors have the wiring code illustrated in **Figure 2**:

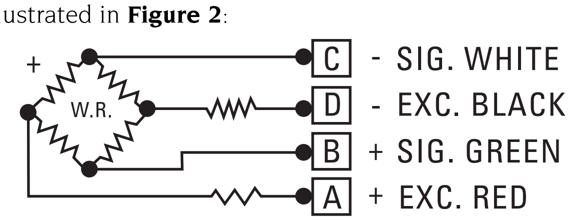


Figure 2.
Series 2300 Reaction Torque Sensor Wiring Code

Series 4100 rotary transformer torque sensors have the wiring code illustrated in **Figure 3**:

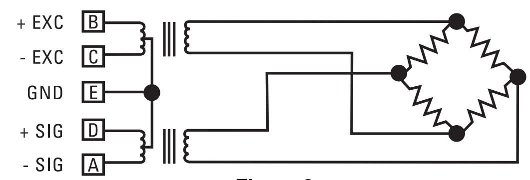


Figure 3.
Series 4100 Rotary Transformer Torque Sensor Wiring Code

Series 4200 rotary transformer torque sensors have the wiring code illustrated in **Figure 4**:

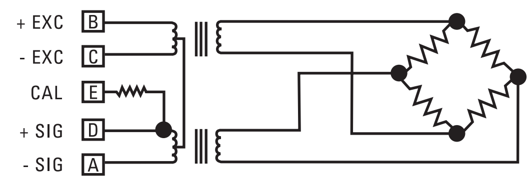


Figure 4.
Series 4200 Rotary Transformer Torque Sensor Wiring Code

Axis Definition

All PCB torque sensors comply with the Axis and Sense Definitions of NAS-938 (National Aerospace Standard-Machine Axis and Motion) nomenclature and recommendations of the Western Regional Strain Gage committee.

The axes are defined in terms of a "right-handed" orthogonal coordinate system as shown in **Figure 5**:

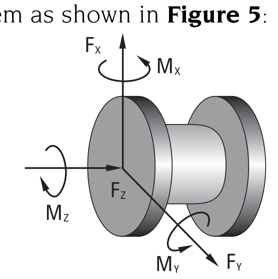


Figure 5.
Right-handed Orthogonal Coordinate System

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Introduction to Torque Sensors

The principal axis of a transducer is normally the z-axis. The z-axis will also be the axis of radial symmetry or axis of rotation. In the event there is no clearly defined axis, the following preference system will be used: z, x, y.

Figure 6 shows the axis and sense nomenclature for our torque sensors. A (+) sign indicates torque in a direction which produces a (+) signal voltage and generally defines a clockwise torque.

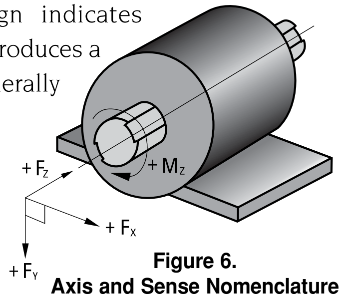


Figure 6.
Axis and Sense Nomenclature for Torque Sensors

Torque Sensor Structure Design

Torque sensor structures are symmetrical and are typically manufactured from steel (SAE 4140 or 4340) that has been heat-treated to Rc 36 to 38. Common configurations are solid circular shaft, hollow circular shaft, cruciform, hollow cruciform, solid square, and hollow tube with flats.

The solid square offers advantages over the solid circular design, especially in capacities greater than or equal to 500 in-lb (55 N-m). The solid square offers high bending strength and ease of application of strain gages. Torque sensors with capacities less than 500 in-lb (55 N-m) are usually of the hollow cruciform type. The hollow cruciform structure produces high stress at low levels of torque, yet has good bending strength. Common configurations are shown in **Figure 7**.

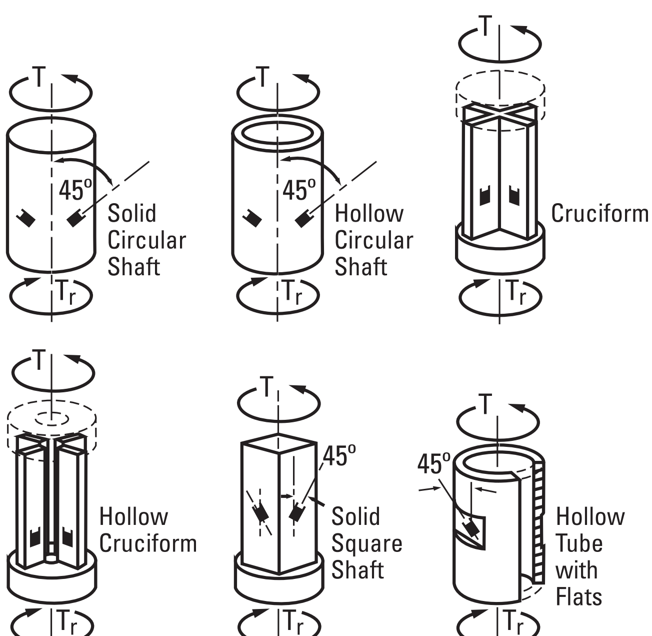


Figure 7.
Common Configurations of Torque Sensors

A variety of end configurations are available, including: keyed shaft, flange, and spline. (See below).

Keyed Shaft

Flange Drive

Spline Drive

Reaction Torque Sensors

Typical reaction torque sensor applications include:

- Viscosity and lubrication studies
- Bearing friction
- Stepping switch torque
- Axle torsion test
- Starter testing
- Automotive brake testing

Reaction torque is the turning force or moment, imposed upon the stationary portion of a device by the rotating portion, as power is delivered or absorbed. The power may be transmitted from rotating member to stationary member by various means, such as the magnetic field of a motor or generator, brake shoes or pads on drums or rotors, or the lubricant between a bearing and a shaft. Thus, reaction torque sensors become useful tools for measuring properties such as motor power, braking effectiveness, lubrication, and viscosity.

Reaction torque sensors are suitable for a wide range of torque measurement applications, including motor and pump testing. Due to the fact that these sensors do not utilize bearings, slip-rings, or any other rotating elements, their installation and use can be very cost effective. Reaction torque sensors are particularly useful in applications where the introduction of a rotating inertia due to a rotating mass between the driver motor and driven load is undesirable. An example of this can be found in small motor testing, where introduction of a rotating mass between the motor and load device will result in an error during acceleration. For these applications, the reaction torque sensor can be used between the driver motor, or driven load, and ground. An added benefit is that such an installation is not limited in RPM by the torque sensor. PCB manufactures reaction torque sensors with capacities ranging from a few inch ounces to 500k in-lb (56.5k N-m), in configurations including keyed shaft and flange.

Rotary Torque Sensors

Typical rotary torque sensor applications include:

- Chassis dynamometer
- Engine dynamometer
- Efficiency testing
- Clutch testing
- Blower or fan testing
- Small motor / pump testing

Rotating torque sensors are similar in design and in application to reaction torque sensors, with the exception that the torque sensor is installed in-line with the device under test. Consequently, the torque sensor shaft rotates with the device under test. In PCB Series 4100 and 4200 models, the rotating torque sensor shaft is supported in a stationary housing by two bearings. Signal transfer between the rotating torque sensor shaft and the stationary housing is accomplished by means of slip-rings, or rotary transformers.

Rotary Transformers

Rotary Transformers provide a non-contact means of transferring signals to and from the rotating torque sensor structure. Rotary transformers are similar to conventional transformers, except that either the primary and secondary winding is rotating. For rotating torque sensors, two rotary transformers are used. One serves to transmit the excitation voltage to the strain gage bridge, while the second transfers the signal output to the non-rotating part of the transducer. Thus no direct contact is required between the stationary and rotating elements of the transducer (see **Figure 8**).

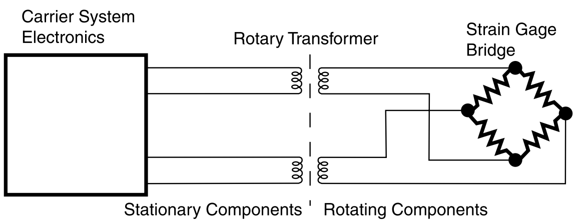


Figure 8.

Rotary transformers are made up of a pair of concentrically wound coils, with one coil rotating within or beside the stationary coil. The magnetic flux lines are produced by applying a time varying voltage (carrier excitation) to one of the coils (see **Figure 9**).

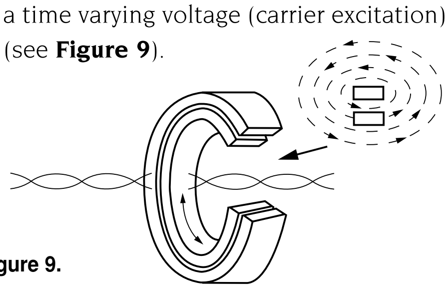


Figure 9.

Figure 10 depicts a typical rotary transformer torque sensor:

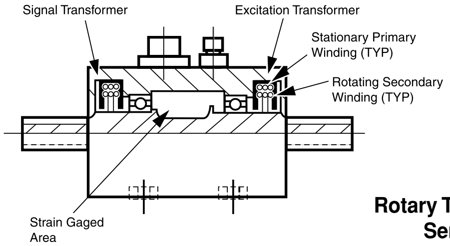


Figure 10. Rotary Transformer Torque Sensor Diagram

Transmission of energy through any transformer requires that the current be alternating. A suitable signal conditioner with carrier excitation in the range of 3 to 5000 Hz is required to achieve this.

Mechanical Installation of Keyed Shaft Torque Sensors

Proper installation must be observed when assembling a torque sensor into a driveline. Careful selection of components must be made so that problems are not created which could lead to part failure or danger to personnel.

Shaft misalignment

Provision must be made to eliminate the effects of bending and end loading on the torque sensors shaft due to parallel offset of shafts, angular misalignment, and shaft end float. The proper use of couplings can reduce these problems to a negligible level.

All shafts must first be aligned mechanically, as accurately as possible, to lessen the work the couplings must do. Alignment within 0.001 inch per inch of shaft diameter is normally satisfactory, however, for some critical applications such as high speed, this level of alignment is not acceptable, and a tighter tolerance must be achieved. Please contact our factory, or your coupling vendor, for information regarding your application.

Torque sensor with foot-mounted housing installation

A foot-mounted torque sensor has a plate on its housing, which can be securely attached to a machine base or bedplate. This installation reduces the mass in suspension on the couplings and can increase the shaft's critical speed, if the torque sensor is within its speed rating. Normally, if both the driving and load sources are fully bearing-supported in foot-mounted housings, and the torque sensor housing is foot-mounted, double-flex couplings should be used on each shaft end. Double-flex couplings provide for two degrees of freedom, meaning they can simultaneously allow for angular and parallel misalignment, and reduce the effects of bending on the torque sensor shaft. Half of each coupling weight is supported on the torque sensor's shaft, and the other half is carried by the driving and load shafts.

Torque sensor with floating shaft installation

A floating shaft torque sensor does not have a foot-mount plate on the housing, nor is the housing affixed to a bed-plate in any other fashion. It depends on being carried by the driver and load shafts for its support. The housing, which is meant to remain stationary and not rotate with the shaft, must be restrained from rotating with a conductive flexible strap. Tapped threaded holes are provided on the side of the housing for this purpose. The other end of the strap is bolted to a bedplate or other stationary-grounded member, which will electrically ground the torque sensor housing to the electrical system ground.

Therefore, with the floating shaft, there is just one degree of freedom between each shaft end of the torque sensor and the adjacent mating shaft, which is bearing-supported (driver and load shafts) on the bedplate. Consequently, a single flex coupling is required at each end of the torque sensor.

Error Analysis

PCB typically supplies accuracy information on its products in the form individual errors. They are non-linearity, hysteresis, non-repeatability, effect of temperature on zero unbalance, and effect of temperature on output.

The customer can combine these individual errors to establish the maximum possible error for the measurement, or just examine the applicable individual error. If the temperature remains stable during the test, the temperature related errors can be ignored. If the sensor is used for increasing load measurement only, ignore the hysteresis error. If the load measurement is near the full capacity, the linearity error can be ignored. If the capability exists to correct the data through linearization-fit or a look-up-table, the error in the measurement can be minimized. A sophisticated user can get rid of all the errors except for the non-repeatability error in the measurement.

Often overlooked by the customer is the error due to the presence of non-measured forces and bending moments. Even though the single axis of measurement sensors are designed and built to withstand these non-measured forces and bending moments (extraneous loads), the errors due to them are present. The user can design the set-up to eliminate or minimize these extraneous loads. However, if these extraneous loads are present, the errors due to them should be considered.

Application Questionnaire

1. Determine the capacity required

A. What is the maximum expected torque, including transients?
B. What is the minimum expected torque?
C. What is the typical expected torque?
D. What are the dynamics of the system, i.e. frequency response?
E. What are the maximum extraneous loads that the torque sensor will be subjected to?

2. How will the torque sensor be integrated into the system?

A. What are the physical constraints, i.e. length, diameter?
B. Will the torque sensor be foot-mounted or floated?
C. Couplings, torsionally stiff, or torsionally soft?

3. What type of environment will the torque sensor be operating in?

A. Maximum temperature?
B. Minimum temperature?
C. Humidity?
D. Contaminants, i.e. water, oil, dirt, dust?

4. What speed will the torque sensor be required to rotate?

A. What length of time will the torque sensor be rotating, and at what speed?

Glossary of Terms

Accuracy — Stated as a limit tolerance, which defines the average deviation between the actual output versus theoretical output.

In practical transducer applications, the potential errors of non-linearity, hysteresis, non-repeatability and temperature effects do not normally occur simultaneously, nor are they necessarily additive.

Therefore, accuracy is calculated based upon RMS value of potential errors, assuming a temperature variation of ± 10 °F, full rated load applied, and proper set-up and calibration. Potential errors of the readout, cross-talk, or creep effects are not included.

Ambient Conditions — The conditions (humidity, pressure, temperature, etc.) of the medium surrounding the transducer.

Ambient Temperature — The temperature of the medium surrounding of transducers.

Calibration — The comparison of transducer output against standard test loads.

Calibration Curve — a record (graph) of the comparison of transducer output against standard test loads.

Combined Error (Non-linearity and Hysteresis) — the maximum deviation from a straight line drawn between the original no-load and *rated load* outputs expressed as a percentage of the *rated output* and measured on both increasing and decreasing loads.

Compensation — The utilization of supplementary devices, materials, or processes to minimize known sources of error.

Creep — The change of transducer output occurring with time, while under load, and with all environmental conditions and other variables remaining constant.

Note: Usually measured with *rated load* applied and expressed as a percent of *rated output* over a specific period of time.

Creep Recovery — The change in no-load output occurring with time, after removal of a load, which has been applied for a specific period of time.

Cross-talk — With one component loaded to capacity, and the other unloaded, the output of the unloaded component will not exceed the percentage specified of its full-scale capacity.

Deflection — The change in length along the *primary axis* of the load cell between no-load and *rated load* conditions.

Drift — A random change in *output* under constant *load* conditions.

Error — The algebraic difference between the indicated and true value of the load being measured.

Excitation, Electrical — The voltage or current applied to the input terminals of the transducer.

Fatigue Capacity — Capacity as percentage of the nominal load limit capacity, and based on 100 X 10^6 cycles (minimum) from zero to full fatigue capacity and 50 X 10^6 cycles (minimum) from full fatigue capacity tension to full fatigue capacity compression load.

Hysteresis — The maximum difference between the transducer output readings for the same applied load, one reading obtained by increasing the load from zero and the other by decreasing the load from *rated load*.

NOTE: Usually measured at half *rated output* and expressed in percent of *rated output*. Measurements should be taken as rapidly as possible to minimize *creep*.

Insulation Resistance — The *DC* resistance measured between the transducer circuit and the transducer structure.

NOTE: Normally measured at fifty volts *DC* and under *standard test conditions*.

Natural Frequency — The frequency of free oscillations under no-load conditions.

Nominal Load Limit Capacity — It is the designed normal maximum capacity of a transducer. Output sensitivity of the transducer is based on this capacity unless specified.

Non-linearity — The maximum deviation of the *calibration curve* from a straight line drawn between the no load and *rated load* output, expressed as a percentage of the *rated output* and measured on increasing load only.

Output — This signal (voltage, current, etc.) produced by the transducer.

NOTE: Where the output is directly proportional to excitation, the signal must be expressed in terms of volts per volt, volts per ampere, etc. of excitation.

Output, Rated — The algebraic difference between the *outputs* at no-load and at *rated load*.

Overload Rating — The maximum load in percent of *rated capacity*, which can be applied without producing a permanent shift in performance characteristics beyond those specified.

Primary Axis — The axis along which the transducer is designed to be loaded; normally its geometric centerline.

Rated Capacity (Rated Load) — The maximum *axial load* that the transducer is designed to measure within its specifications.

Repeatability — The maximum difference between transducer output readings for repeated loading under identical loading and environmental conditions.

Resolution — The smallest change in mechanical input, which produces a detectable change in the output signal.

Sensitivity — The ratio of the change in *output* to the change in mechanical input.

Shunt Calibration — Electrical simulation of transducer output by insertion of known shunt resistors between appropriate points within the circuitry.

Shunt-to-load Correlation — The difference in output readings obtained through electrically simulated and actual applied loads.

Glossary of Terms

Standard Test Conditions — The environmental conditions under which measurements should be made, when measurements under any other conditions may result in disagreement between various observers at difference times and places. These conditions are a follows:

Temperature 72 °F ± 3.6 °F (23 °C ± 2 °C)

Relative Humidity: 90% or less

Barometric Pressure: 28 to 32 inch Hg

Static Extraneous Load Limits — Static Extraneous Load Limits are calculated such that only one extraneous load (Fx or Fy or Mx or My or Mz) can be applied simultaneously with 50% of the nominal load limit applied.

Temperature Effect on Output — The change in *output* due to a change in *transducer temperature.*

NOTE: Usually expressed as a percentage of load reading per degree Fahrenheit change in *temperature*.

Temperature Effect on Zero Balance — The change in *zero balance* due to a change in *transducer temperature.*

NOTE: Usually expressed as the change in *zero balance* in percent of *rated output* per degrees Fahrenheit (change in temperature).

Temperature Range, Compensated — The range of temperature over which the transducer is compensated to maintain *rated output* and *zero balance* within specified limits.

Temperature Range, Usable — The extremes of temperature within which the transducer will operate without permanent adverse change to any of its performance characteristics.

Terminal Resistance — The resistance of the transducer circuit measured at specific adjacent bridge terminals at standard temperature, with no-load applied, and with the excitation and output terminals open-circuited.

Terminal Resistance, Excitation — The resistance of the transducer circuit measured at the excitation terminals, at standard temperature, with no-load applied, and with the output terminals open-circuited.

Terminal Resistance, Signal — The resistance of the transducer circuit measured at the output signal terminals, at standard temperature, with no-load applied, and with the excitation terminals open-circuited.

Traceability — The step-by-step transducer process by which the transducer calibration can be related to primary standards.

Zero Balance — The output signal of the transducer with rated *excitation* and with no-load applied, usually expressed in percent of *rated output.*

Zero Return — The difference in *zero balance* measured immediately before *rated load* application of specified duration and measured after removal of the load, and when the output has stabilized.

Zero Shift, Permanent — A permanent change in the no-load output.

Zero Stability — The degree to which the transducer maintains its *zero balance* with all environmental conditions and other variables remaining constant.

Application Notes and Technical Articles

To order copies of the following application notes, just write or call the Force/Torque Division toll-free at 888-684-0004.

Application Notes

AP-1001 Extraneous Loads

AP-1002 Equivalent Force of a Falling Object

AP-1003 Mechanical Installation of PCB Torque Transducers

AP-1004 Installation of PCB Driveline Torque Transducers

AP-1005 Service Maintenance of PCB Slip-ring Torque Transducers

AP-1006 Routine Maintenance of Slip-ring Torque Transducers

AP-1007 Dynamometer Installation of PCB Model 1401 Load Cell

AP-1008 Spline Lubrication PCB Model 4115A & K, Preliminary Release

AP-1009 Explosive Environment

AP-1010 Air-Oil-Mist Lubrication

AP-1011 Effects of Thrust and Bending Moment on The Torque Output of Torque Disk. Model 5304-101-01

AP-1012 Grease Lubrication

AP-1013 Effects of Thrust, Lateral, Loads and Bending Moment on the Torque Output. Models 5307-01 & 5307-02

AP-1014 AOM Lubrication for Models 4115A-101 & 4115A-107

AP-1015 Effects of Extraneous Loads on TORKDISC® Series 5308 and 5309

AP-1016 Shunt Calibration of a Strain Gage Sensor

Technical Articles

TA-1001 What is a Transducer?

TA-1002 Cross-talk in a Multi-Component Sensor

TA-1003 Accuracy

LOAD CELLS

Load cells manufactured by the Force/Torque Division of PCB address many force measurement, monitoring and control requirements in laboratory testing, industrial, and process control applications. All models utilize strain gages, which are configured into a wheatstone bridge circuit as their primary sensing element, along with temperature and pressure compensation. A variety of configurations and capacities address a wide range of installation scenarios. Fatigue-rated load cells are offered for applications where high cyclic loads are being monitored, such as with fatigue testing machines or repetitive processes.

Model Number Index

Table of Contents

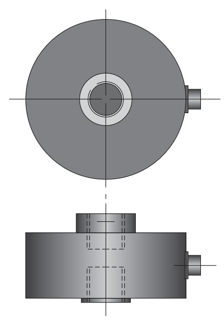
PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

Strain Gage Load Cell Configurations

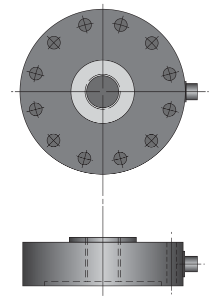
General purpose load cells

General purpose load cells are suitable for a wide range of general force measurement applications, including weighing, dynamometer testing, and material testing machines. Most of these designs operate in both tension and compression, and offer excellent accuracy and value.

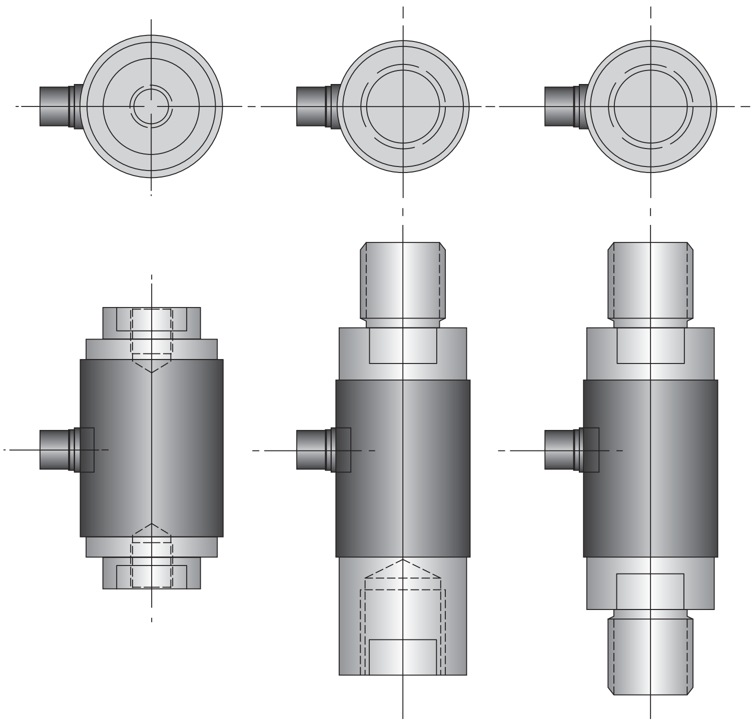
A variety of configurations are available as shown below. Units range in capacity from as small as 25 lb, to as large as 100k lb (110 N to 450k N) full-scale.



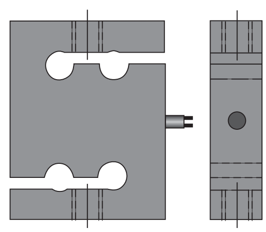
Canister



Low Profile



Rod End



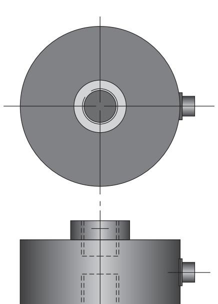
S-beam

Fatigue-rated load cells

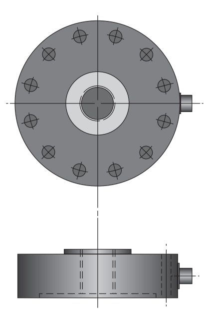
Fatigue-rated load cells are specifically designed for fatigue testing machine manufacturers and users, or in any application where high cyclic loads are present. All fatigue-rated load cells are guaranteed against fatigue failure for over 100 million fully reversed cycles.

These rugged load cells are manufactured using premium, fatigue-resistant, heat-treated steels. Internal flexures are carefully designed to eliminate stress concentration areas. Close attention is paid to the proper selection and installation of internal strain gages and wiring to ensure maximum life.

Fatigue-rated load cells are available in a variety of configurations, and in capacities from 250 lb to 50k lb (1100 N to 220k N) full-scale.



Canister



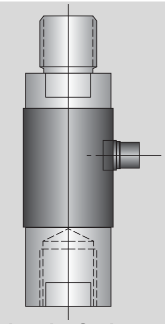
Low Profile

Typical Load Cell Measurement Systems

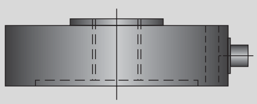
Typical measurement system for Series 1000 load cells

All PCB Force/Torque Division strain gage load cells utilize strain gages that are configured in a wheatstone bridge as their primary sensing element. The resistance value of the strain gages changes when load is applied to the sensing structure and consequently, any voltage through the bridge circuit will be varied. The wheatstone bridge requires a regulated DC voltage excitation that is commonly provided by a strain gage signal conditioner. The resultant output signal from the load cell is typically expressed in units of millivolt per volt of excitation. This millivolt signal then varies proportionately to the force applied to the load cell. The strain gage signal conditioner provides zero and span adjustments to scale its 0 to 5 VDC analog output to be proportional to any desired input range. Additional features of the signal conditioner may include a digital display and alarm set point limits.

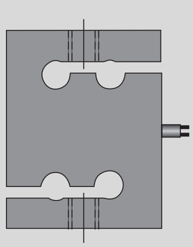
Load cells are provided with either an electrical connector or integral cable. Cable assemblies are necessary to interface load cells having an electrical connector to the strain gage signal conditioner. Two types of cable are commonly available, and their use is dependent upon signal transmission distance. Cable assemblies may be selected with a terminating connector, which makes it easier to connect to a PCB strain gage signal conditioner, or with a pigtail termination that allows connection to screw terminal connections on other styles of strain gage signal conditioners.



Rod-style, Series 1300



General Purpose, Low Profile, Low Profile Fatigue-rated Series 1100, 1200 and 1400



S-beam, Series 1500

Load Cell Cables (see pages 3.24 to 3.26)

Models 8159, 8160A, 8161A and 8162 Load Cell Signal Conditioners (see pages 3.20 to 3.23)

Typical Load Cell Applications

- Component Testing
- Weighing
- Quality Control
- Material Testing
- Seat Testing
- Torque Arm
- Life Cycle Testing
- Bumper Impact
- Structural Testing
- Press Applications
- Calibration Standard
- Wire or Cable Tension
- Hydraulic Actuators
- Production Monitoring
- Safety Testing
- Biomedical Applications
- Crash Barriers
- Push/Pull Testing
- Seat Belt Testing
- Brake Pedal Testing
- Bumper Testing
- Steering Column Impact
- Fatigue Testing
- Bridge Testing
- Concrete Testing
- Seat Structure Testing
- Fabric Wear Testing
- Bushing and Bearing Testing
- Plugs and Seal Testing
- Dynamometer
- Engine Performance Testing

Load Cell Selection Guide

General Purpose Canister Load Cells	
Size (dia x height) - in	2.75 x 1.5
Size (dia x height) - mm	69.9 x 38.1
Thread	1/4-28
Connector	6-pin PT
Page	3.8
Capacity	**Model Number**
25 lb (110 N)	1102-05A
50 lb (225 N)	1102-01A*
100 lb (445 N)	1102-02A*
200 lb (900 N)	1102-03A*
300 lb (1350 N)	

* Aluminum load cells (low weight). All other models are steel.

General Purpose Low Profile Load Cells			
Size (dia x height) - in	4.12 x 1.37	6.06 x 1.75	8 x 2.5
Size (dia x height) - mm	104.6 x 34.8	153.9 x 44.5	203.2 x 63.5
Thread	5/8-18	1 1/4-12	1 3/4-12
Connector	6-pin PC	6-pin PC	6-pin PC
Page	3.10	3.10	3.10
Capacity	**Model Number**		
500 lb (2225 N)	1233-01B*		
1000 lb (4450 N)	1233-02B*		
2000 lb (8900 N)	11233-03B*		
5000 lb (22.2 k N)			
10k lb (44.5k N)		1204-01B	
20k lb (89k N)		1204-02B	
50k lb (220k N)		1204-03B	1208-01B
100k lb (450k N)			1208-02B
200k lb (900k N)			

* Aluminum load cells (low weight). All other models are steel.

Fatigue-rated Low Profile Load Cells			
Size (dia x height) - in	4.12 x 1.37	6.06 x 1.75	8 x 2.5
Size (dia x height) - mm	104.6 x 34.8	153.9 x 44.5	203.2 x 63.5
Thread	5/8-18	1 1/4-12	1 3/4-12
Connector	6-pin PC	6-pin PC	6-pin PC
Page	3.12	3.12	3.12
Capacity	**Model Number**		
250 lb (1100N)	1433-01B*		
500 lb (2225 N)	1433-02B*		
1000 lb (4450 N)	1433-03B*		
2500 lb (11.1k N)			
5000 lb (22.2k N)		1404-01B	
10k lb (44.5k N)		1404-02B	
25k lb (111k N)		1404-03B	1408-01B
50k lb (220k N)			1408-02B
100k lb (450k N)			

* Aluminum load cells (low weight). All other models are steel.

General Purpose Rod-style Load Cells		
Size (dia x height) - in	2.25 x 4.5	1.71 x 4.5
Size (dia x height) - mm	57.2 x 114.3	43.4 x 114.3
Thread	5/8-18	1-14
Connector	6-pin PT	6-pin PT
Page	3.14	3.14
Capacity	**Model Number**	
1000 lb (4450 N)	1302-01A*	
2000 lb (8900 N)	1302-02A*	1303-01A*
5000 lb (22.2k N)	1302-03A	1303-02A*
10k lb (44.5k N)	1302-04A	1303-03A
20k lb (89k N)		1303-04A
50k lb (220k N)		

* Aluminum load cells (low weight). All other models are steel.

Continued on next page

Load Cell Selection Guide

General Purpose S-beam Load Cells			
Size (l x w x h) - in	2.75 x 3.07 x 0.84	3.50 x 3.32 x 1.34	4.00 x 3.32 x 1.59
Size (l x w x h) - mm	69.9 x 77.9 x 21.4	88.9 x 84.3 x 34.1	101.6 x 84.3 x 40.5
Thread	3/8-24	1/2-20	3/4-16
Connector	6-pin PT	6-pin PT	6-pin PT
Page	3.16	3.16	3.16
Capacity	**Model Number**		
100 lb (445 N)	1538-01B		
200 lb (900 N)	1538-02B		
2000 lb (8900 N)		1539-03B	
5000 lb (22.2k N)			1540-01B
All models are stainless steel, with aluminum cover.			

Options for Load Cells

Options for Load Cells

Shunt Resistor — A fixed resistor which is placed in parallel or shunted across a strain gage bridge to provide a known test signal to permit the user with a means of easily performing an accurate system calibration of a load cell and signal conditioner.

Dual-Bridge — Provides two signals for purposes of redundancy or to send a signal to two devices, such as a local area display and a data recorder.

Trimmed Output — The output of a strain gage based load cell is typically nominal (± 15%) of specification. A trimmed output is within a 1/4% of the specified output.

Metric Threads and Capacities — Our standard product is manufactured with English attachment threads and English capacities and is calibrated with English standards. All load cell models are available with metric attachment threads, metric capacities, and metric calibration data (converted from English calibration data).

Strain Gage Load Cells

- **Low profile**
- **Low deflection**
- **Fatigue-rated**
- **NIST-traceable calibration**
- **Temperature and pressure compensated**

The Force/Torque Division of PCB Piezotronics manufactures a wide range of strain gage load cells for aerospace, automotive, industrial, and process control applications.

General purpose load cells are suitable for a wide range of routine static force measurement applications, including weighing, dynamometer testing, and material testing machines. Most general purpose designs operate in both tension and compression, and are available in configurations including: canister, low profile, rod end, and s-beam styles. Capacities from 25 lb to 100k lb (110 N to 450k N) full-scale are available.

Fatigue-rated load cells are specifically designed for fatigue testing machine manufacturers and users, or in any application where high cyclic loads are present. Applications include material testing, component life cycle testing, and structural testing. All fatigue-rated load cells are guaranteed against fatigue failure for 100 million fully reversed cycles. Capacities are available from 250 lb to 50k lb (1100 N to 220k N) full-scale.

For special or unusual applications, please call to discuss your needs with one of our force application specialists.

PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

General Purpose Load Cells
25 – 300 lb

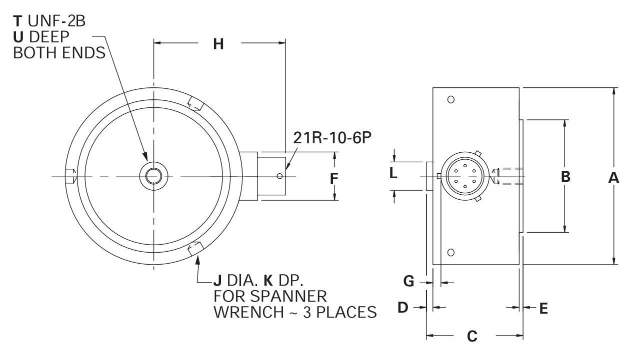
GENERAL PURPOSE LOAD CELLS

Tension and compression measurements

- component testing
- weighing
- quality control
- material testing
- seat testing
- torque arm

Series 1102 — general purpose canister-style with 6-pin connector

- Capacities from 25 to 300 lb (110 to 1350 N) FS
- 2 mV/V output sensitivity
- Low profile design



Series 1102

Dimensions — inches (mm)													
Series	A	B	C	D	E	F	G	H	J	K	L	T	U
1102	2.75 (69.9)	1.75 (44.5)	1.5 (38.1)	0.1 (2.5)	0.06 (1.5)	0.75	0.13 (3.3)	2.05 (52.07)	0.22 (5.5)	0.13 (3.3)	0.44 (11.2)	1/4-28	0.38 (9.7)

	Specifications						Extraneous Load Limits		
Model Number	Capacity lb (N)	Overload lb (N)	Deflection at Capacity in (mm)	Ringing Frequency Hz	Weight lb (gm)	Material	Side Force Fx or Fy lb (N)	Bending Moment Mx or My in-lb (N-m)	Torque Mz in-lb (N-m)
Canister Load Cells with 6-Pin Connector									
1102-05A	25 (110)	37.5 (165)	0.003 (0.08)	2100	0.67 (304)	aluminum	25 (110)	25 (2.8)	35 (4)
1102-01A	50 (225)	75 (330)	0.003 (0.08)	2800	0.67 (304)	aluminum	50 (225)	50 (5.6)	35 (4)
1102-02A	100 (445)	150 (675)	0.003 (0.08)	3800	0.67 (304)	aluminum	100 (445)	100 (11)	65 (7.3)
1102-03A	200 (900)	300 (1350)	0.003 (0.08)	5400	0.67 (304)	aluminum	200 (900)	200 (23)	65 (7.3)
1102-04A	300 (1350)	450 (2000)	0.003 (0.08)	7000	0.67 (304)	aluminum	300 (1350)	300 (34)	65 (7.3)

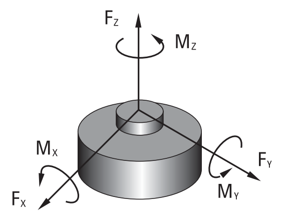
Common Specifications

Output (nominal). . . . . 2 mV/V
Non-linearity (max) . . . . 0.05% FS [1]
Hysteresis (max). . . . . 0.05% FS [1]
Non-repeatability (max). . . . . 0.02% FS [1]
Bridge Resistance (nom). . . . . 700 ohm
Excitation (recommended). . . . . 10 Volts

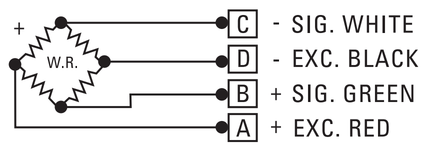
Temp. Range (compensated). . . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . - 65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) . . . . 0.002% FS/°F (0.0036% FS/°C)
Temp. Effect on Output (max) . . . . 0.002% of reading/°F (0.0036% of reading/°C)

NOTE: [1] Model 1102-05A — non-linearity 0.1%, hysteresis 0.1%, non-repeatability 0.05%.

Supplied Accessories	
Shunt Calibration Resistor	
Optional Accessories	
	See Page(s)
Mating Connector Model 181-012A	3.28
Interconnecting Cable	3.24 to 3.26
Signal Conditioner	3.20 to 3.23
Load Button	3.27
Rod Ends	3.27
Options (see page 3.6)	
Built-in Shunt Resistor	
Dual Bridge	
Trimmed Output	
Metric Threads and Capacities	



The above chart tabulates maximum extraneous side force, bending moment and torque that may be applied singularly without electrical or mechanical damage to the load cell. Where combined extraneous loads are applied, decrease above loads proportionally.



Wiring Diagram

Typical systems located on page 3.3

Low Profile Load Cells
500 – 100k lb

LOW PROFILE LOAD CELLS

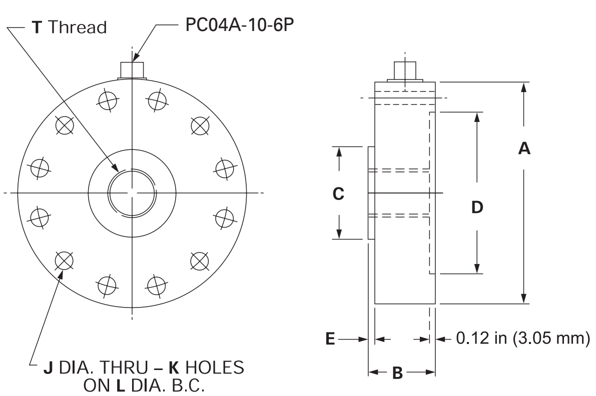
For higher range tension and compression measurements

- component testing
- material testing
- structural testing
- life cycle testing
- bumper impact
- press applications

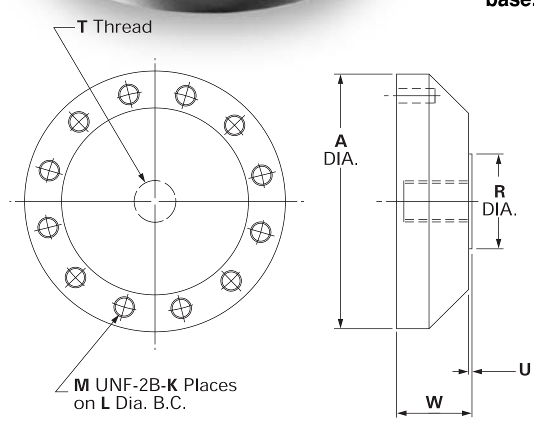
Series 1204, 1208, 1233

- Capacities from 500 to 100k lb (2225 to 450k N) FS
- 2 mV/V or 3 mV/V output sensitivity
- 6-pin connector
- Optional mounting base available

Load cell shown with optional mounting base.



Series 1204, 1208, and 1233



Series 1204, 1208, and 1233

Dimensions — inches (mm)													
Series	**A**	**B**	**C**	**D**	**E**	**J**	**K**	**L**	**M**	**R**	**T**	**U**	**W**	**Base PN**
1204	6.06 (153.9)	1.75 (44.5)	2.42 (61.5)	4.33 (110)	0.12 (3.1)	0.41 (10.4)	12	5.13 (130.3)	3/8-24	2.25 (57.2)	1 1/4-12	0.03 (0.8)	1.75 (44.5)	D-30427-3A
1208	8 (203.2)	2.5 (63.5)	3.5 (88.9)	5.25 (133.4)	0.25 (6.4)	0.53 (13.5)	16	6.5 (165.1)	1/2-20	3.5 (88.9)	1 3/4-12	0.06 (1.5)	2 (50.8)	D-30110-1A
1233	4.12 (104.6)	1.37 (34.8)	1.27 (32.3)	2.875 (72.4)	0.12 (3.1)	0.28 (7.1)	8	3.5 (88.9)	1/4-28	1.25 (31.8)	5/8-18	0.03 (0.8)	1.13 (28.7)	C-30396-6A

	Specifications						Extraneous Load Limits		
Model Number	**Capacity lb (N)**	**Overload lb (N)**	**Deflection at Capacity in (mm)**	**Ringing Frequency Hz**	**Weight lb (kg)**	**Material**	**Side Force Fx or Fy lb (N)**	**Bending Moment Mx or My in-lb (N-m)**	**Torque Mz in-lb (N-m)**
Low Profile Aluminum Load Cells with 5/8-18 Thread									
1233-01B	500 (2225)	750 (3300)	0.001 (0.03)	5000	1.06 (0.48)	aluminum	500 (2225)	500 (2225)	500 (2225)
1233-02B	1000 (4450)	1500 (6675)	0.001 (0.03)	7000	1.06 (0.48)	aluminum	1000 (4450)	1000 (4450)	1000 (4450)
1233-03B	2000 (8900)	3000 (13.3k)	0.001 (0.03)	10k	1.06 (0.48)	aluminum	2000 (8896)	2000 (8896)	2000 (8896)
Low Profile Load Cells with 1 1/4-12 Thread									
1204-01B	10k (44.5k)	15k (66.7k)	0.0015 (0.038)	5500	8.96 (4.06)	steel	5000 (22.2k)	5000 (565)	5000 (565)
1204-02B	20k (89k)	30k (130k)	0.0015 (0.038)	8000	8.96 (4.06)	steel	10k (44.5k)	10k (1130)	10k (1130)
1204-03B	50k (220k)	75k (335k)	0.0015 (0.038)	12k	8.96 (4.06)	steel	25k (111k)	25k (2825)	25k (2825)
Low Profile Load Cells with 1 3/4-12 Thread									
1208-01B	50k (220k)	75k (335k)	0.002 (0.05)	6750	25.5 (11.57)	steel	25k (111k)	25k (2825)	25k (2825)
1208-02B	100k (450k)	150k (665k)	0.002 (0.05)	9550	25.5 (11.57)	steel	50k (220k)	50k (5650)	50k (5650)

Common Specifications

Output (nominal)
- 500 – 2000 lb Capacity . . . . 2 mV/V
- 10k – 100k lb Capacity. . . . . 3 mV/V

Non-linearity (max) . . . . 0.05% FS [1]
Hysteresis (max). . . . . 0.05% FS [1]
Non-repeatability (max). . . . . 0.02% FS [1]
Bridge Resistance (nom). . . . . 700 ohm
Excitation (recommended). . . . . 10 Volts

Temp. Range (compensated) . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . -65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) . . . . 0.001% FS/°F [2] (0.0018% FS/°C)
Temp. Effect on Output (max) . . . . 0.002% reading/°F (0.0036% reading/°C)

NOTE: [1] Series 1208 — non-linearity 0.1% FS, hysteresis 0.1%, non-repeatability 0.05%.

Refer to page 3.13 for options, optional accessories, suggested accessories, wiring diagram, and extraneous load limit diagram.

Fatigue-rated Load Cells
250 – 50k lb

LOW PROFILE, FATIGUE-RATED LOAD CELLS

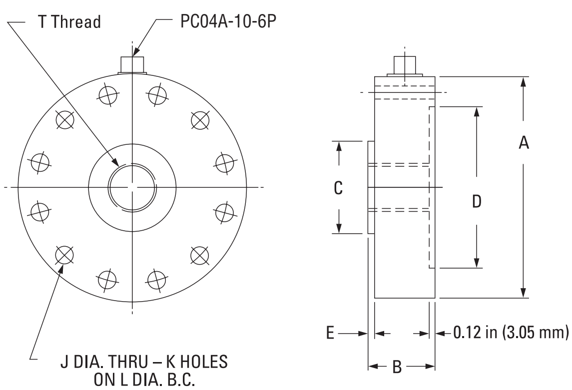
Fatigue-rated load cells are rugged devices manufactured using premium heat-treated, fatigue-resistant steels.

- material testing
- structural testing
- life cycle testing
- torque arm
- component testing
- calibration standard

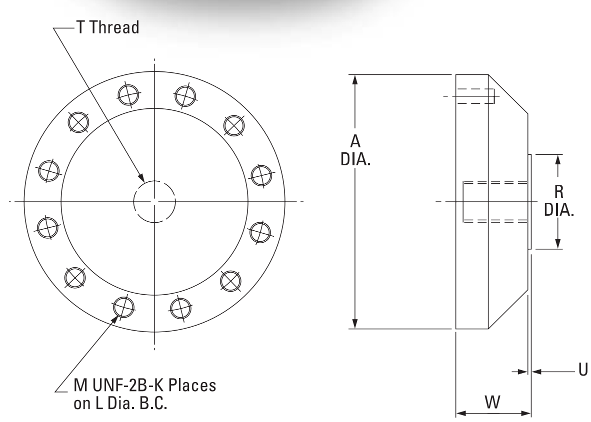
Series 1404, 1408, and 1433 — low profile, fatigue-rated

- Capacities from 250 to 50k lb (1100 to 220k N) FS
- 1 mV/V and 1.5 mV/V output sensitivity
- 6-pin connector
- Fatigue-resistant steel or aluminum
- Optional mounting base available

Load cell shown with optional mounting base.



Series 1404, 1408, and 1433



Series 1404, 1408, and 1433

Dimensions — inches (mm)														
Series	**A**	**B**	**C**	**D**	**E**	**J**	**K**	**L**	**M**	**R**	**T**	**U**	**W**	**Base PN**
1404	6.06 (153.9)	1.75 (44.5)	2.42 (61.5)	4.33 (110)	0.12 (3.1)	0.41 (10.4)	12	5.13 (130.3)	3/8-24	2.25 (57.2)	1 1/4-12	0.03 (0.8)	1.75 (44.5)	D-30427-3A
1408	8 (203.2)	2.5 (63.5)	3.5 (88.9)	5.25 (133.4)	0.25 (6.4)	0.53 (13.5)	16	6.5 (165.1)	1/2-20	3.5 (88.9)	1 3/4-12	0.06 (1.5)	2 (50.8)	D-30110-1A
1433	4.12 (104.6)	1.37 (34.8)	1.27 (32.3)	2.875 (72.4)	0.12 (3.1)	0.28 (7.1)	8	3.5 (88.9)	5/8-18	1.25 (31.8)	5/8-18	0.03 (0.8)	1.13 (28.7)	C-30396-6A

Fatigue-rated Load Cells
250 – 50k lb

	Specifications						Extraneous Load Limits		
Model Number	**Capacity lb (N)**	**Overload lb (N)**	**Deflection at Capacity in (mm)**	**Ringing Frequency Hz**	**Weight lb (kg)**	**Material**	**Side Force Fx or Fy lb (N)**	**Bending Moment Mx or My in-lb (N-m)**	**Torque Mz in-lb (N-m)**
Fatigue-rated Low Profile Aluminum Load Cells with 5/8-18 Thread									
1433-01B	250 (1100)	500 (2225)	0.001 (0.03)	2350	1.06 (0.48)	aluminum	250 (1100)	250 (1100)	250 (1100)
1433-02B	500 (2225)	1000 (4450)	0.001 (0.03)	3500	1.06 (0.48)	aluminum	500 (2225)	500 (2225)	500 (2225)
1433-03B	1000 (4450)	2000 (8900)	0.0005 (0.013)	5500	1.06 (0.48)	aluminum	1000 (4450)	1000 (4450)	1000 (4450)
Fatigue-rated Low Profile Load Cells with 1 1/4-12 Thread									
1404-01B	5000 (22.2k)	10k (44.5k)	0.001 (0.03)	5500	8.96 (4.06)	steel	5000 (22.2k)	5000 (565)	5000 (565)
1404-02B	10k (44.5k)	20k (89k)	0.001 (0.03)	8000	8.96 (4.06)	steel	10k (44.5k)	10k (1130)	10k (1130)
1404-03B	25k (111k)	50k (220k)	0.001 (0.03)	12k	8.96 (4.06)	steel	25k (111k)	25k (2825)	25k (2825)
Fatigue-rated Low Profile Load Cells with 1 3/4-12 Thread									
1408-01B	25k (111k)	50k (220k)	0.001 (0.03)	6750	25.5 (11.57)	steel	25k (111k)	25k (2825)	25k (2825)
1408-02B	50k (220k)	100k (450k)	0.001 (0.03)	9550	25.5 (11.57)	steel	50k (220k)	50k (5650)	50k (5650)

Common Specifications

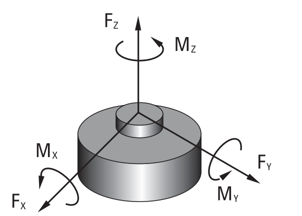
Output (nominal)
- 250 – 1000 lb Capacity . . . . 1 mV/V
- 5000 – 50k lb Capacity . . . . 1.5 mV/V

Non-linearity (max) . . . . 0.05% FS [1]
Hysteresis (max) . . . . 0.05% FS [1]
Non-repeatability (max) . . . . 0.02% FS [1]

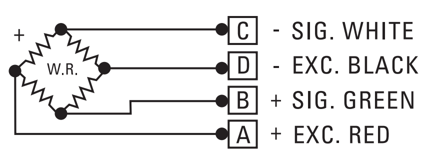
Bridge Resistance (nom) . . . . 700 ohm
Excitation (recommended) . . . . 10 Volts
Temp. Range (compensated) . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . -65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) . . . . 0.001% FS/°F (0.0018% FS/°C)
Temp. Effect on Output (max) . . . . 0.002% reading/°F (0.0036% reading/°C)

NOTE: [1] Series 1408 — non-linearity 0.1% FS, hysteresis 0.1%, non-repeatability 0.05%.

Supplied Accessories	
Shunt Calibration Resistor	
Optional Accessories	
	See Page(s)
Mating Connector Model 182-025A	3.28
Interconnecting Cable	3.24 to 3.26
Signal Conditioner	3.20 to 3.23
Load Button	3.27
Rod Ends	3.27
Mounting Base (see Dimensions Table)	
Options (see page 3.6)	
Built-in Shunt Resistor	
Dual Bridge	
Trimmed Output	
Metric Threads and Capacities	



The above chart tabulates maximum extraneous side force, bending moment and torque that may be applied singularly without electrical or mechanical damage to the load cell. Where combined extraneous loads are applied, decrease above loads proportionally.



Wiring Diagram

Typical systems located on page 3.3

LOAD

Rod-style Load Cells
1000 – 20k lb

SMALL DIAMETER ROD-STYLE LOAD CELLS

Lower weight aluminum for lower ranged units, high-strength steel for higher ranged units

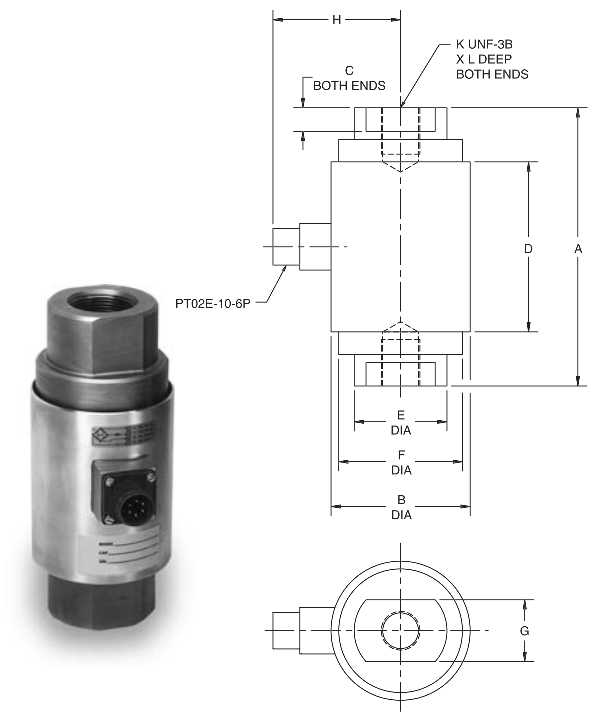
- Ideal for tension applications
- quality assurance
- cable, chain, or wire tension
- process automation
- hydraulic actuators
- production monitoring

Series 1302 — small diameter with female threads

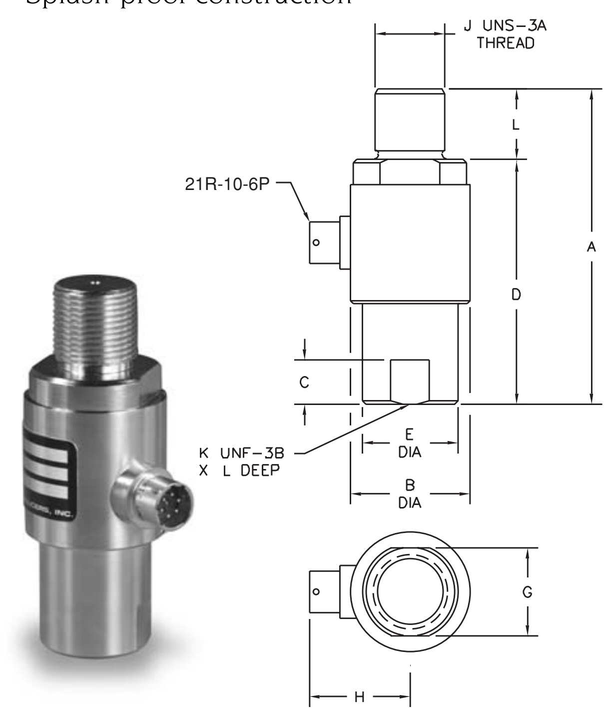
- Capacities from 1000 to 10k lb (4450 to 44.5k N) FS
- 2 mV/V output sensitivity
- 6-pin connector

Series 1303 — small diameter with male/female threads

- Capacities from 2000 to 20k lb (8900 to 89k N) FS
- 2 mV/V output sensitivity
- 6-pin connector
- Splash-proof construction



Series 1302



Series 1303

Dimensions — inches (mm)											
Series	A	B	C	D	E	F	G	H	J	K	L
1302	4.5 (114.3)	2.25 (57.2)	0.38 (9.7)	2.75 (69.9)	1.5 (38.1)	2 (50.8)	1 (25.4)	2 (50.8)	N/A	5/8-18	0.75 (19.1)
1303	4.5 (114.3)	1.71 (43.4)	0.63 (16)	3.5 (88.9)	1.37 (34.8)	N/A	1.25 (31.8)	1.44 (36.6)	1-14	1-14	1 (25.4)

Rod-style Load Cells
1000 – 20k lb

	Specifications						Extraneous Load Limits		
Model Number	**Capacity lb (N)**	**Overload lb (N)**	**Deflection at Capacity in (mm)**	**Ringing Frequency Hz**	**Weight lb (kg)**	**Material**	**Side Force Fx or Fy lb (N)**	**Bending Moment Mx or My in-lb (N-m)**	**Torque Mz in-lb (N-m)**
Rod-style Load Cells with 5/8-18 Female/Female Thread									
1302-01A	1000 (4450)	1500 (6675)	0.002 (0.05)	2600	1.7 (0.77)	aluminum	500 (2225)	1000 (115)	2000 (225)
1302-02A	2000 (8900)	3000 (13.3k)	0.002 (0.05)	3500	1.7 (0.77)	aluminum	700 (3100)	1500 (170)	3000 (340)
1302-03A	5000 (22.2k)	7500 (33.3k)	0.002 (0.05)	3500	4.2 (1.9)	steel	2000 (8900)	4000 (450)	4000 (450)
1302-04A	10k (44.5k)	15k (66.7k)	0.002 (0.05)	5000	4.2 (1.9)	steel	2500 (11.1k)	6000 (675)	6000 (675)
Rod-style Load Cells with 1-1/4-12 Male/Female Thread									
1303-01A	2000 (8900)	3000 (13.3k)	0.003 (0.08)	6000	0.5 (0.23)	aluminum	50 (225)	125 (14)	150 (17)
1303-02A	5000 (22.2k)	7500 (33.3k)	0.003 (0.08)	9000	0.5 (0.23)	aluminum	150 (675)	500 (55)	600 (68)
1303-03A	10k (44.5k)	15k (66.7k)	0.003 (0.08)	8000	1.25 (0.57)	steel	300 (1350)	800 (90)	1100 (125)
1303-04A	20k (89k)	30k (130k)	0.003 (0.08)	10k	1.25 (0.57)	steel	700 (3100)	2000 (225)	3000 (340)

Common Specifications

Model Number	**1302**	**1303**	**1322**
Output: mV/Volt (nominal)	2	2	2
Non-linearity: % FS (max)	0.05	0.1	0.15
Hysteresis: % FS (max)	0.05	0.1	0.15
Non-repeatability: % FS max)	0.02	0.05	0.05
Bridge Resistance (nom)	350 ohm		
Excitation (recommended)	10 Volts		

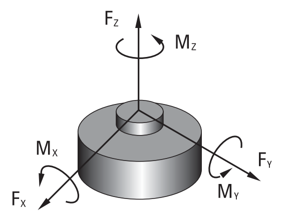
Temp. Range (compensated) . . . . . +70 °F to +170 °F (+21 °C to +77 °C)

Temp. Range (usable) . . . . . - 65 °F to +200 °F (-54 °C to +93 °C)

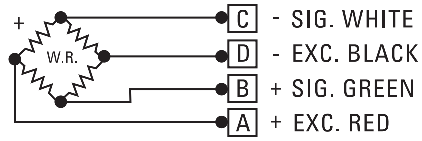
Temp. Effect on Zero (max) . . . . . 0.002% FS/°F (0.0036% FS/°C)

Temp. Effect on Output (max) . . . . . 0.002% reading/°F (0.0036% reading/°C)

Supplied Accessories	
Shunt Calibration Resistor	
Optional Accessories	
	See Page(s)
Mating Connector Model 181-012A	3.28
Interconnecting Cable	3.24 to 3.26
Signal Conditioner	3.20 to 3.23
Rod Ends	3.27
Options (see page 3.6)	
Built-in Shunt Resistor	
Dual Bridge	
Trimmed Output	
Metric Threads and Capacities	



The above chart tabulates maximum extraneous side force, bending moment and torque that may be applied singularly without electrical or mechanical damage to the load cell. Where combined extraneous loads are applied, decrease above loads proportionally.



Wiring Diagram

Typical systems located on page 3.3

LOAD

S-beam Load Cells
100 – 5k lb

S-BEAM LOAD CELLS

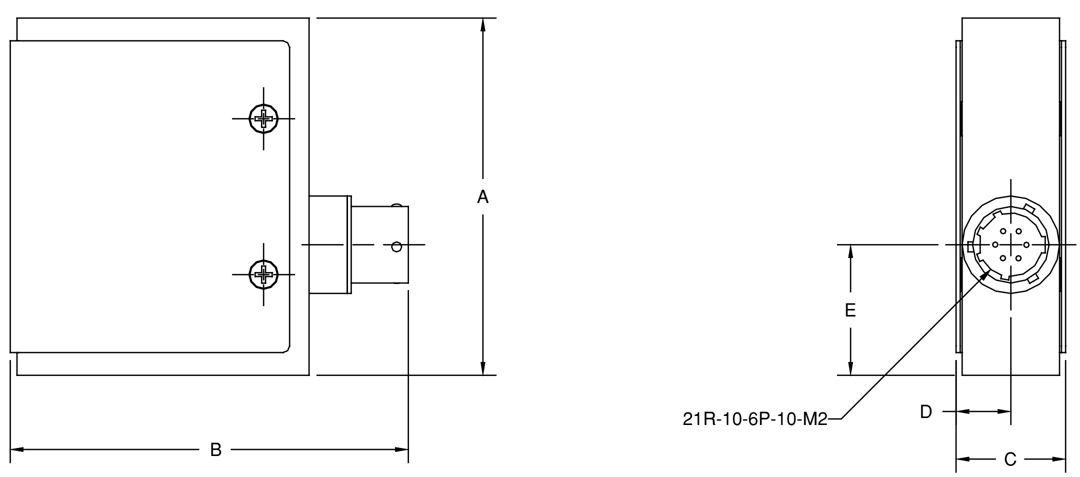
Universal load cell for tension and compression

- weighing applications

Series 1538, 1539, and 1540

Capacities from 100 to 5000 lb (445 to 22.2k N) FS

- 2 mV/V output sensitivity
- 6-pin connector
- Stainless steel construction



Series 1538, 1539, and 1540

Dimensions — inches (mm)						
Series	**A**	**B**	**C**	**D**	**E**	**T**
1538	2.75 (69.9)	3.07 (77.9)	0.84 (21.4)	0.42 (10.7)	1.01 (25.5)	3/8-24
1539	3.50 (88.9)	3.32 (84.3)	1.34 (34.1)	0.67 (17.1)	1.38 (34.9)	1/2-20
1540	4.00 (101.6)	3.32 (84.3)	1.59 (40.5)	0.80 (20.2)	2.00 (50.8)	3/4-16

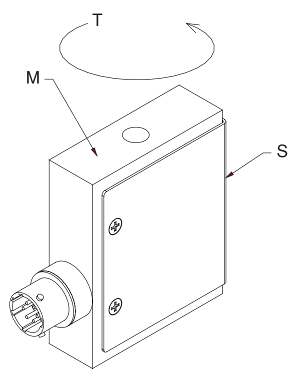
	Specifications						Extraneous Load Limits		
Model Number	**Capacity lb (N)**	**Overload lb (N)**	**Deflection at Capacity in (mm)**	**Ringing Frequency Hz**	**Weight lb (kg)**	**Material**	**Side Force Fx or Fy lb (N) S**	**Bending Moment Mx or My in-lb (N-m) M**	**Torque Mz in-lb (N-m) T**
S-beam Load Cells with 3/8-24 Mounting Thread									
1538-01B	100 (445)	150 (675)	0.006 (0.15)	730	1.0 (0.45)	st. steel	25 (110)	25 (2.8)	25 (2.8)
1538-02B	200 (900)	300 (1350)	0.006 (0.15)	990	1.0 (0.45)	st. steel	50 (225)	50 (5.6)	50 (5.6)
S-beam Load Cells with 1/2-20 Mounting Thread									
1539-03B	2000 (8900)	3000 (13.3k)	0.003 (0.08)	1125	2.30 (1.04)	st. steel	500 (2225)	500 (55)	500 (55)
S-beam Load Cell with 3/4-16 Mounting Thread									
1540-01B	5000 (22.2k)	7500 (33.3k)	0.004 (0.10)	1330	3.80 (1.75)	st. steel	1250 (5550)	1250 (140)	1250 (140)

Common Specifications

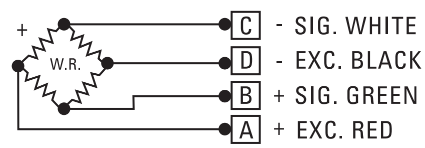
Output (nominal) . . . . 2 mV/Volt
Non-linearity (max) . . . . 0.05% FS
Hysteresis (max) . . . . 0.05% FS
Non-repeatability (max) . . . . 0.02% FS
Creep in 20 min . . . . 0.03% FS
Bridge Resistance (nom) . . . . 350 ohm
Excitation (recommended) . . . . 10 Volts
Excitation (max) . . . . 20 volts

Temp. Range (compensated) . . . . +70 °F to +170 °F (+21 °C to +77 °C)
Temp. Range (usable) . . . . -65 °F to +200 °F (-54 °C to +93 °C)
Temp. Effect on Zero (max) . . . . 0.0015% FS/°F (0.027% FS/°C)
Temp. Effect on Output (max) . . . . 0.0008% reading/°F (0.0014% reading/°C)

Optional Accessories	
	See Page(s)
Mating Connector Model 181-012A	3.28
Interconnecting Cable	3.24 to 3.26
Signal Conditioner	3.20 to 3.23
Load Button	3.27
Rod Ends	3.27



The above chart tabulates maximum extraneous side force, bending moment and torque that may be applied singularly without electrical or mechanical damage to the load cell. Where combined extraneous loads are applied, decrease above loads proportionally.



Wiring Diagram

Typical systems located on page 3.3

LOAD

Load cell structures may be machined into a variety of configurations to adapt to a multitude of measurement, monitoring, and control applications.

Strain gage sensing elements are examined and tested to insure integrity, accuracy, and longevity.

Load Cell Accessories and Services

- Strain gage signal conditioners
- Cable assemblies
- Mounting accessories
- Calibration services

LOAD

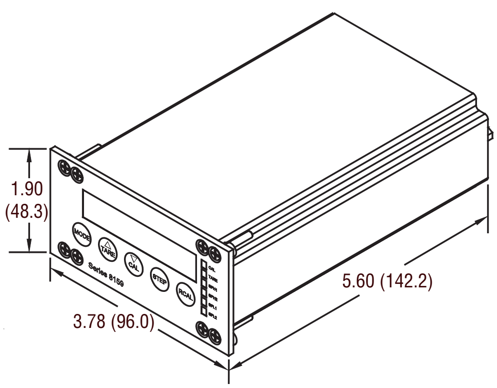
PCB PIEZOTRONICS INC.
FORCE / TORQUE DIVISION

A variety of signal conditioners are offered for use with strain gage load cells and reaction torque sensors. These units provide the necessary, regulated excitation voltage and deliver conditioned output signals for recording, control, or analysis purposes.

Series 8159 — Digital Force Indicator / Controller

- Operates from 115 or 230 VAC power
- Provides 5 or 10 VDC strain gage bridge excitation
- Delivers ± 10 Volts and 4 to 20 mA output signals
- 5-digit, red LED display with 1/8 DIN panel mounting
- 4 programmable set points with LED status indicators
- Easy, menu-driven setup
- Optional RS-232 output

Series 8159



Series 8159
Dimensions shown are in inches (millimeters)

See page 3.28 for mating connectors for transducer and input/output connections.

How to order

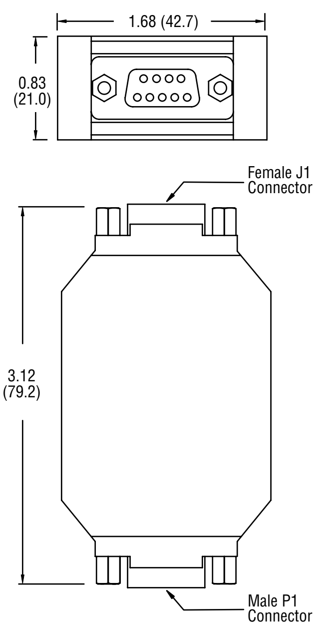
Base Model	
8159–	115 VAC Powered Indicator with Transducer Excitation
F	Prefix for 230 VAC Powered Version (internal jumper selectable)
Communications	
0	None
1	RS-232 (transmit only)
Sense Leads (internal jumper selectable)	
0	Disabled
1	Enabled (recommended for cables >20 ft (6.1 m))
Bridge Excitation (internal jumper selectable)	
1	10 VDC
5	5 VDC
Full-scale Input (internal switch selectable)	
1	1.5 mV/V
2	2.5 mV/V
3	3.5 mV/V
Version Code	
A	Initial Release
Example	
8159– 0 0 1 2 A	115 VAC Powered Indicator with 10 VDC Transducer Excitation and 2.5 mV/V Full Scale Input

Series 8160 — In-line Strain Gage Signal Conditioner

- Operates from 12 to 24 VDC power
- Provides 5 or 10 VDC strain gage bridge excitation
- Delivers ± 5 Volts and 4 to 20 mA output signals
- Adjustable zero and span
- Small size
- Multi-pin input and output connectors
- Built-in, switch-activated, shunt calibration

Series 8160

See page 3.28 for mating connectors for transducer and input/output connections.



Series 8160
Dimensions shown are in inches (millimeters)

How to order

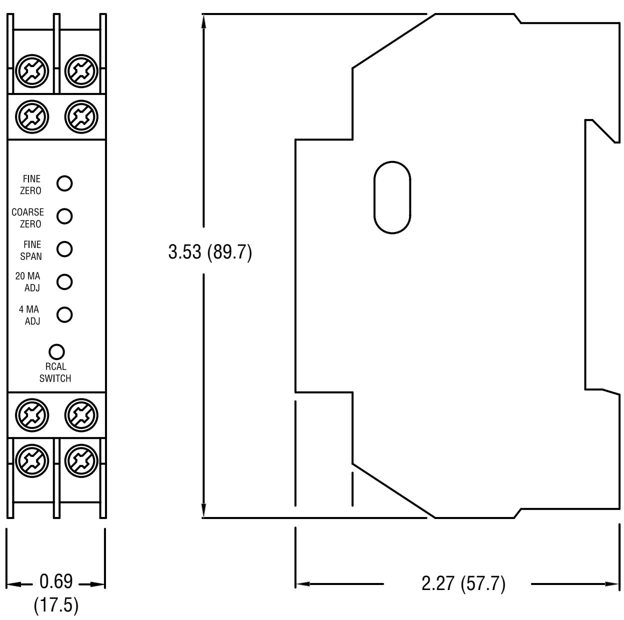
Base Model				
8160–	In-Line Strain Gage Signal Conditioner			
	Calibrated Output Signal			
	0	Voltage		
	1	Current		
		Bridge Excitation (internal jumper selectable)		
		1	10 VDC	
		5	5 VDC	
			Version Code	
			A	Initial Release
Example				
8160–	**0**	**1**	**A**	Strain gage signal conditioner with ± 5 Volts and 4 to 20 mA output signals, 10 VDC bridge excitation, and calibrated in voltage.

Series 8161 — DIN Rail Mount Signal Conditioner

- Operates from 12 to 28 VDC power
- Provides 5 or 10 VDC strain gage bridge excitation
- Delivers ± 5 or ± 10 Volts and 4 to 20 mA output signals
- Built-in, switch-actuated, shunt calibration

Switch Positions for Input Signal Range Adjustment			
Sensitivity (mV/V) Vexc = 5 VDC	Sensitivity (mV/V) Vexc = 10 VDC	SW2 Settings 1 2 3 4	SW2 1 = SW "ON"
7.0 to 11.0	3.5 to 5.5	0 0 0 1	"ON" 1 0 1 2 3 4
4.6 to 7.0	2.3 to 3.5	0 0 1 0	
3.0 to 4.6	1.5 to 2.3	0 1 0 0	
2.0 to 3.0	1.0 to 1.5	1 0 0 0	
1.5 to 2.0	0.75 to 1.0	1 0 1 0	
1.0 to 1.5	0.50 to 0.75	1 1 0 1	
0.9 to 1.0	0.45 to 0.50	1 1 1 1	

Series 8161



Series 8161
Dimensions shown are in inches (millimeters)

How to order

Base Model				
8161–	DIN Rail Mount Strain Gage Signal Conditioner			
	Calibrated Output Signal			
	0 Voltage			
	1 Current			
		Output Signals (internal jumper selectable)		
		1 ± 10 Volts and 4 to 20 mA		
		5 ± 5 Volts and 4 to 20 mA		
			Bridge Excitation (internal jumper selectable)	
			1 10 VDC	
			5 5 VDC	
				Version Code
				A Initial Release
Example				
8161–	**0**	**1**	**1**	**A** Strain gage signal conditioner with ± 10 Volts and 4 to 20 mA output signals, 10 VDC bridge excitation, and calibrated in voltage.

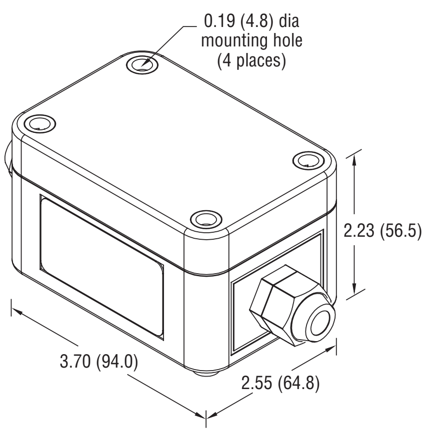
Series 8162 — In-line Strain Gage Signal Conditioner

- Operates from 12 to 28 VDC power
- Provides 5 or 10 VDC strain gage bridge excitation
- Delivers ± 5 or ± 10 Volts and 4 to 20 mA output signals
- Built-in, switch-actuated, shunt calibration
- IP66 (NEMA 4X) enclosure
- Screw terminal connections

Switch Positions for Input Signal Range Adjustment

Sensitivity (mV/V) Vexc = 5 VDC	Sensitivity (mV/V) Vexc = 10 VDC	SW2 Settings 1 2 3 4	SW2 1 = SW "ON"
7.0 to 11.0	3.5 to 5.5	0 0 0 1	"ON" 1 0 1 2 3 4
4.6 to 7.0	2.3 to 3.5	0 0 1 0	
3.0 to 4.6	1.5 to 2.3	0 1 0 0	
2.0 to 3.0	1.0 to 1.5	1 0 0 0	
1.5 to 2.0	0.75 to 1.0	1 0 1 0	
1.0 to 1.5	0.50 to 0.75	1 1 0 1	
0.9 to 1.0	0.45 to 0.50	1 1 1 1	

Series 8162



Series 8162
Dimensions shown are in inches (millimeters)

How to order

Base Model

- **8162-** Strain Gage Signal Conditioner

Calibrated Output Signal

- **0** Voltage
- **1** Current

Output Signals (internal jumper selectable)

- **1** ± 10 Volts and 4 to 20 mA
- **5** ± 5 Volts and 4 to 20 mA

Bridge Excitation (internal jumper selectable)

- **1** 10 VDC
- **5** 5 VDC

Version Code

- **A** Initial Release

Example

8162- 0 1 1 A Strain gage signal conditioner with ± 10 Volts and 4 to 20 mA output signals, 10 VDC bridge excitation, and calibrated in voltage.

LOAD

Stock Cable Assemblies

Recommended Load Cell Signal Conditioners and Cables				
	Recommended Signal Conditioners			
	8120 Series	**8159 Series**	**8160A**	**8161A, 8162, & Pigtails**
Load Cell Type	**Recommended Cables**			
Load cell with PT connector ≤20-ft	8311-04-xxA	8311-17-xxA	8311-15-xxA	8311-01-xxA
Load cell with PT connector ≥20-ft	8311-05-xxA	8311-18-xxA	8311-15-xxA	8311-02-xxA
Load cell with PC connector <20-ft	8315-04-xxA	8315-17-xxA	8315-15-xxA	8315-01-xxA
Load cell with PC connector ≥20-ft	8315-05-xxA	8315-18-xxA	8315-15-xxA	8315-02-xxA

"xx" indicates length in feet.

Standard lengths include 5 ft (1.5 m), 10 ft (3 m) 20 ft (6.1 m), & 50 ft (15.2 m).

Load Cell Cable Specifications and Standard Models

The following tables provide specifications and configuration diagrams for the variety of cable types available. Where applicable, standard cable assembly model numbers are provided. Standard models can be less costly than custom cables and available for immediate shipment. For alternate cable lengths or custom models, contact the factory.

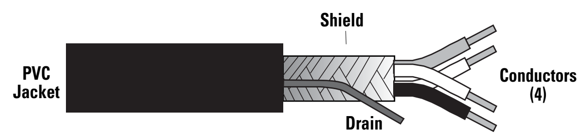
Four-Conductor Cables

Usage

General purpose, use with load cells. 24AWG common stranded tinned copper drain wire, polypropylene insulated, twisted pair in a chrome PVC jacket. Use when desired cable is < 20 feet (6.1 m).

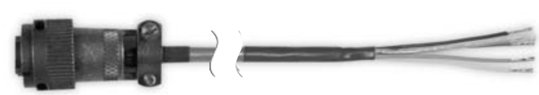
Outer Jacket	PVC, grey	
Diameter	0.168 in	4.27 mm
Capacitance	35 pF/ft	44.3 pF/m
Temperature Range	-4 to +140 °F	-20 to +60 °C
Impedance	45 ohm	

Construction



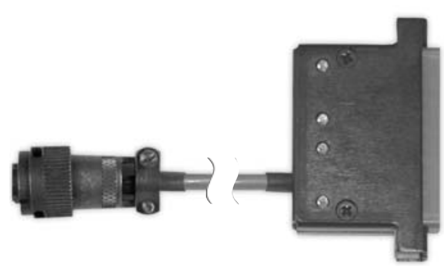
Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)
8311-01-05A	5 ft	1.5 m
8311-01-10A	10 ft	3.0 m



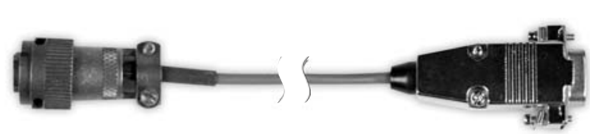
PT **Pigtails**

Model Number	Length (feet)	Length (meters)
8311-04-05A	5 ft	1.5 m
8311-04-10A	10 ft	3.0 m



PT **Card Edge**

Model Number	Length (feet)	Length (meters)
8311-15-05A	5 ft	1.5 m
8311-15-10A	10 ft	3.0 m
8311-15-20A	20 ft	6.1 m
8311-15-50A	50 ft	15.2 m

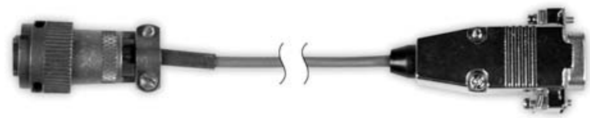
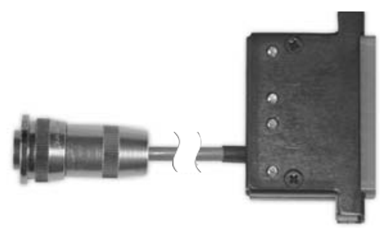
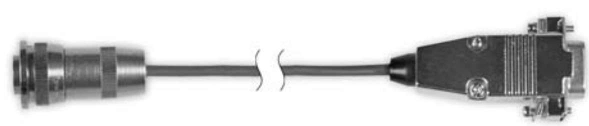
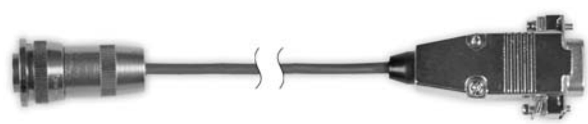
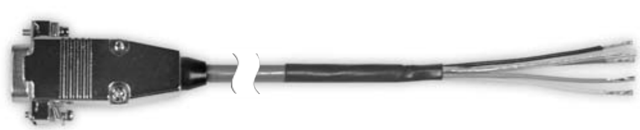
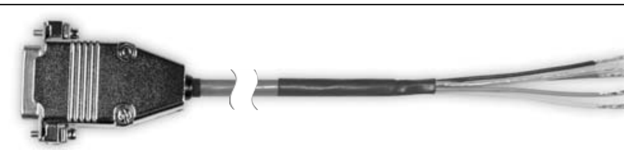


PT **9-Pin (M) D-Sub**

Continued on next page.

Four-Conductor Cables, continued

Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)	
8311-17-05A	5 ft	1.5 m	 PT / 9-Pin (M) D-Sub
8311-17-10A	10 ft	3.0 m	
8315-01-05A	5 ft	1.5 m	 PC / Pigtails
8315-01-10A	10 ft	3.0 m	
8315-04-05A	5 ft	1.5 m	 PC / Card Edge
8315-04-10A	10 ft	3.0 m	
8315-15-05A	5 ft	1.5 m	 PC / 9-Pin (M) D-Sub
8315-15-10A	10 ft	3.0 m	
8315-15-20A	20 ft	6.1 m	
8315-15-50A	50 ft	15.2 m	
8315-17-05A	5 ft	1.5 m	 PC / 9-Pin (M) D-Sub
8315-17-10A	10 ft	3.0 m	
8314-20-05A	5 ft	1.5 m	 9-Socket (F) D-Sub / Pigtails
8314-20-10A	10 ft	3.0 m	
8314-21-05A	5 ft	1.5 m	 15-Socket (F) D-Sub / Pigtails
8314-21-10A	10 ft	3.0 m	

Stock Cable Assemblies

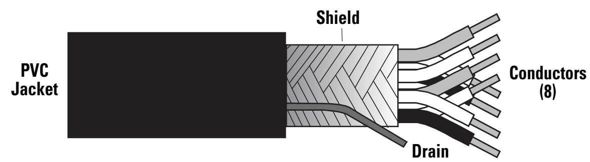
Eight-Conductor Cables

Usage

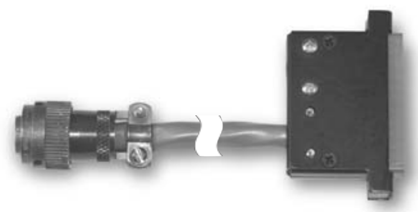
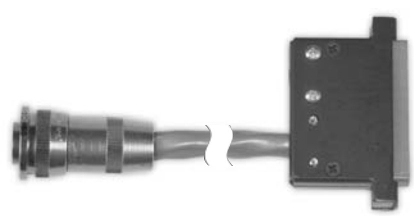
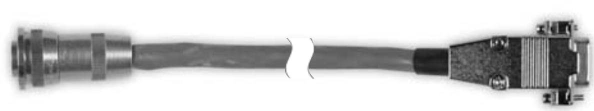
General purpose, use with load cells. 24AWG common stranded tinned copper drain wire, polypropylene insulated, twisted pair in a chrome PVC jacket. Use when desired cable is ≥ 20 feet (6.1 m).

Outer Jacket	PVC, grey	
Diameter	0.363 in	9.22 mm
Capacitance	13.5 pF/ft	44.3 pF/m
Temperature Range	-4 to +140 ºF	-20 to +60 ºC
Impedance	100 ohm	

Construction

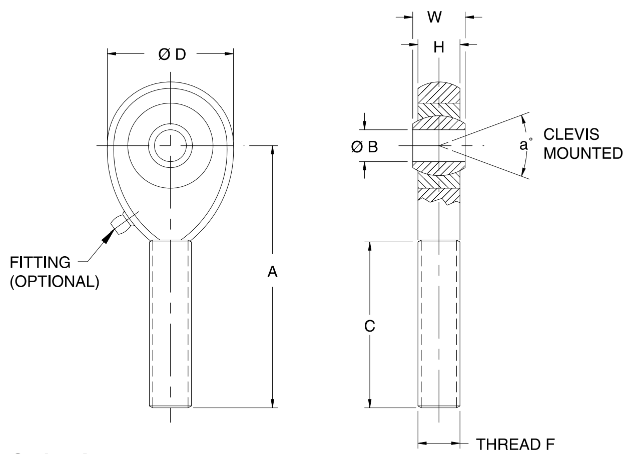


Standard Cable Assemblies

Model Number	Length (feet)	Length (meters)	
8311-02-20A 8311-02-50A	20 ft 50 ft	6.1 m 15.2 m	 PT — Pigtails
8311-05-20A 8311-05-50A	20 ft 50 ft	6.1 m 15.2 m	 PT — Card Edge
8311-18-20A 8311-18-50A	20 ft 50 ft	6.1 m 15.2 m	 PT — 9-Pin (M) D-Sub
8315-02-20A 8315-02-50A	20 ft 50 ft	6.1 m 15.2 m	 PC — Pigtails
8315-05-20A 8315-05-50A	20 ft 50 ft	6.1 m 15.2 m	 PC — Card Edge
8315-18-20A 8315-18-50A	20 ft 50 ft	6.1 m 15.2 m	 PC — 9-Pin (M) D-Sub

ROD ENDS

Rod ends are designed to maintain tension loading alignment between a load cell and mounting surface.

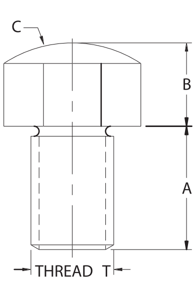


Series A-20357

Rod Ends										
Model Number	Thread UNF-3A	Dimensions — inches (mm) B	W	H	A	D	C	a (deg.)	Static Load lb (N)	Weight lb (g)
A-20357-1A	1/4-28	0.19 (4.8)	0.31 (7.9)	0.25 (6.4)	1.56 (39.6)	0.75 (19.1)	1 (25.4)	10	2150 (9600)	0.04 (18)
A-20357-2A	3/8-24	0.31 (7.9)	0.44 (11.2)	0.34 (8.6)	1.94 (49.3)	1 (25.4)	1.25 (31.8)	12	5300 (23k)	0.25 (113)
A-20357-3A	1/2-20	0.44 (11.2)	0.56 (14.2)	0.44 (11.2)	2.44 (62)	1.31 (33.3)	1.5 (38.1)	12	23k (100k)	0.25 (113)
A-20357-4A	5/8-18	0.5 (12.7)	0.63 (16)	0.5 (12.7)	2.63 (66.8)	1.5 (38.1)	1.63 (41.4)	10	31k (135k)	0.38 (172)
A-20357-5A	3/4-16	0.63 (16)	0.75 (19.1)	0.56 (14.2)	2.88 (73.2)	1.75 (44.5)	1.75 (44.5)	13	40k (180k)	0.6 (272)
A-20357-6A	1-14	1 (25.4)	1.38 (35.1)	1 (25.4)	4.13 (104.9)	2.75 (69.9)	2.13 (54.1)	14	43k (190k)	2.1 (953)
A-20357-7A	1 1/4-12	1.25 (31.8)	1.09 (27.7)	0.94 (23.9)	4.13 (104.9)	2.75 (69.9)	2.13 (54.1)	7	44k (195k)	2.4 (1089)

LOAD BUTTONS

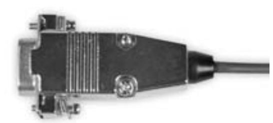
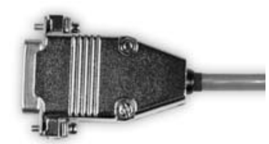
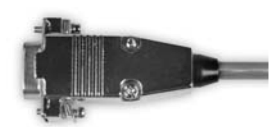
Load buttons are designed to direct applied forces to the measuring axis of a load cell used in compression.



Series C-20099

Load Button				
Model Number	Thread T	Dimensions — inches (mm) A	B	C
C-20099-1A	1/4-28	0.37 (9.4)	0.25 (6.4)	0.75 (19.1)
C-20099-2A	3/8-24	0.5 (12.7)	0.37 (9.4)	2 (50.8)
C-20099-3A	1/2-20	0.62 (15.7)	0.5 (12.7)	2 (50.8)
C-20099-4A	5/8-18	0.62 (15.7)	0.5 (12.7)	2 (50.8)
C-20099-5A	1-14	0.87 (22.1)	0.75 (19.1)	4 (101.6)
C-20099-6A	1 1/4-12	1 (25.4)	0.75 (19.1)	4 (101.6)
C-20099-7A	2 3/4-8	2.5 (63.5)	2.5 (63.5)	6 (152.4)
C-20099-8A	3/4-16	0.6 (15.2)	0.3 (7.6)	6 (152.4)

Mating Connectors

Mating Connectors	
Optional mating connectors are used for load cells and signal conditioners. **Model Number**	
181-012A Features cable strain relief. For use with load cells which have an "A" at end of model number, and Series 1500 S-beam load cells.	 **6-Socket PT Connector and Back Shell**
182-025A Features cable strain relief. For use with load cells which have a "B" at end of model number, except for Series 1500 S-beam load cells.	 **6-Socket PC Connector and Back Shell**
182-026A For transducer connection to Series 8159 Signal Conditioner (see page 3.20).	 **9-Pin (M) D-Sub Connector and Back Shell**
182-027A For input/output connection to Series 8159 Signal Conditioner (see page 3.20).	 **15-Socket (F) D-Sub Connector and Back Shell**
182-022A For input/output connection to Series 8160 Signal Conditioner (see page 3.21).	 **9-Socket (F) D-Sub Connector and Back Shell**
182-023A For transducer connection to Series 8160 Signal Conditioner (see page 3.21).	 **9-Pin (M) D-Sub Connector and Back Shell**

Load Cell Calibration Services

PCB Piezotronics maintains a completely-equipped calibration laboratory for calibration and re-certification of strain gage based torque sensors, single axis load cells, and multi-axis transducers. These services are available for sensors manufactured by PCB as well as other companies.

Calibrations and re-certifications performed by PCB are traceable to the National Institute of Standards and Technology (NIST) and conform to ISO/IEC 17025-1999 and ANSI/NCSL Z540-1-1994. PCB's calibration laboratory is accredited by The American Association for Laboratory Accreditation (A2LA) to ISO17025.

The scope of our accreditation for load cells is:

Range		Best Uncertainty [1] (±)
0 to 100 lb	(0 to 445 N)	0.04% FS
100 to 10k lb	(445 to 45k N)	0.06% FS
10k to 100k lb	(45k to 445k N)	0.08% FS

[1] Best Uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor k = 2.

Basic Calibration

Standard calibration services include five (5) points ascending and descending in tension and compression. Charted calibration data is provided in a theoretical vs. actual format with mV/V, non-linearity, and hysteresis provided at each increment. Shunt calibration data is also provided along with a precision shunt calibration resistor. The standard calibration service includes a basic certificate of NIST traceability.

Load Cell Calibration Services

PCB Sensor Calibration Code	Competitor Sensor Calibration Code	
LCS-1A	LCS-0	Calibration of load cell, 5-point, single bridge, up to 5000 lb (22.2k N)
LCS-1B	LCS-0	Calibration of load cell, 5-point, single bridge, above 5000 lb (22.2k N) and up to 50k lb (220k N)
LCS-1C	LCS-0	Calibration of load cell, 5-point, single bridge, above 50k lb (220k N)
LCS-2A	LCS-0	System calibration (load cell, signal conditioner, cable), 5-point, single bridge, up to 5000 lb (22.2k N)
LCS-2B	LCS-0	System calibration (load cell, signal conditioner, cable), 5-point, single bridge, above 5000 lb (22.2k N) and up to 50k lb (220k N)
LCS-2C	LCS-0	System calibration (load cell, signal conditioner, cable), 5-point, single bridge, above 50k lb (220k N)
Other calibration services available; contact factory for more information.		

Certificate of Calibration

Model Number: 1102-01A
Serial Number: 513
Capacity: 50 LBS.

Date: 04/16/2003
Temperature: 71°F
Humidity: 30%

TENSION				
Load (lbs.)	**Up** (mV/V)	**Down** (mV/V)	**N/L** (%FS)	**HYST** (%FS)
0	0.0000	0.0001	0.00	0.01
10	0.3989	0.3991	-0.02	0.01
20	0.7982	0.7984	-0.02	0.01
30	1.1975	1.1976	-0.02	0.01
40	1.5968	1.5970	-0.02	0.01
50	1.9965	1.9965	0.00	0.00

COMPRESSION				
Load (lbs.)	**Up** (mV/V)	**Down** (mV/V)	**N/L** (%FS)	**HYST** (%FS)
0	0.0000	-0.0001	0.00	0.01
10	-0.3986	-0.3988	0.03	0.01
20	-0.7968	-0.7973	0.04	0.03
30	-1.1949	-1.1952	0.04	0.02
40	-1.5928	-1.5929	0.04	0.01
50	-1.9901	-1.9901	0.00	0.00

RESULTS

	TENS	COMP	Shunt Calibration			Resistance			
			(lbs.)	% FS	Shunt Resistor	0.0005	mV/V (	0.0250	%FS)
OUTPUT @ 50 LBS. (mV/V):	1.9965	-1.9901							
MAX NON-LINEARITY (%FS):	-0.02	0.04	36.28	72.56	120 K Ohms	Exc. Resist.		350.66	ohms
MAX HYSTERESIS (%FS):	0.01	0.03	36.55	73.10	120 K Ohms	Sig. Resist.		350.75	ohms

ACCREDITED
Cert. No. 1862.01

PCB PIEZOTRONICS INC. FORCE/TORQUE DIVISION

3425 Walden Avenue Depew, New York, USA 14043-2495

For any questions concerning this certificate, please call PCB at (888) 684-0004, and ask for an Application Engineer.

Load Cell Technical Information

- **Introduction to load cells**
- **Glossary of terms**

Principle of Operation

The Force-Torque Division of PCB manufactures a wide variety of load cells whose output voltage is proportional to the applied force produced by a change in resistance in strain gages which are bonded to the load cell's structure. The magnitude of the change in resistance corresponds to the deformation of the load cell and therefore the applied load.

The four-arm Wheatstone Bridge configuration shown in **Figure 1** depicts the strain gages used in our load cells. This configuration allows for temperature compensation and cancellation of signals caused by forces not directly applied to the axis of the applied load.

A regulated 5 to 20 volt DC or AC rms excitation is required and is applied between A and D of the bridge. When a force is applied to the transducer structure, the Wheatstone Bridge is unbalanced, causing an output voltage between B and C which is proportional to the applied load.

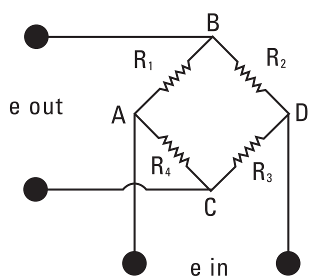


Figure 1.
Wheatstone Bridge

Most all load cells manufactured by the Force/Torque Division of PCB follow a wiring code established by the Western Regional Strain Gage committee as revised in May 1960. The code is illustrated in **Figure 2**.

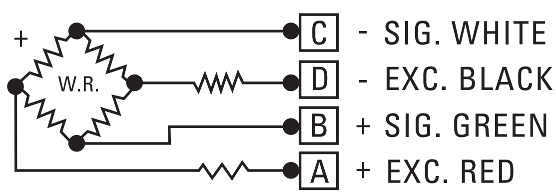


Figure 2.
Load Cell Wiring Code

Axis Definition

Our load cells comply with the Axis and Sense Definitions of NAS-938 (National Aerospace Standard-Machine Axis and Motion) nomenclature and recommendations of the Western Regional Strain Gage committee.

These axes are defined in terms of a "right handed" orthogonal coordinate system as shown in **Figure 3**.

A tensile load exhibits a positive (+) polarity going output, while a compressive load exhibits a negative (-) polarity going output.

The primary axis of rotation or axis of radial symmetry of a load cell is the z-axis.

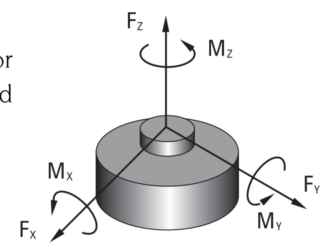


Figure 3.
Right-handed Orthogonal Coordinate System

Load Cell Classification

PCB manufactures load cells under two classifications. They are General Purpose and Fatigue-rated.

General Purpose

General purpose load cells are designed for a multitude of applications across the automotive, aerospace, and industrial markets. The general purpose load cell, as the name implies, is designed to be utilitarian in nature. Within the general purpose load cell market there are several distinct categories. They are: precision, universal, weigh scale, and special application. PCB primarily supplies general purpose load cells into the universal and special application categories. Universal load cells are the most common in industry.

Special application load cells are load cells that have been designed for a specific unique force measurement task.

Continued on next page

Special application load cells can be single axis or multiple axis. They include but not limited to:

- Pedal Effort
- Crash Barrier
- Tow Ball
- Bumper Impact
- Seat Belt
- Hand Brake
- Femur
- Tire Test
- Steering Column
- Road Simulator
- Skid Trailer
- Gear Shift

Fatigue-rated

Fatigue-rated load cells are specially designed and manufactured to withstand millions of cycles. They are manufactured using premium fatigue-resistant steel or aluminum and special processing to ensure mechanical and electrical integrity, as well as accuracy. Fatigue-rated load cells manufactured by the Force/Torque Division are guaranteed to last 100 million fully reversed cycles (full tension through zero to full compression). An added benefit of fatigue-rated load cells is that they are extremely resistant to extraneous bending and side loading forces.

Error Analysis

The Force/Torque Division typically supplies accuracy information on its products in the form of individual errors. They are: non-linearity, hysteresis, non-repeatability, effect of temperature on zero, and effect of temperature on output.

The customer can combine these individual errors to establish the maximum possible error for the measurement or just examine the applicable individual error. If the temperature remains stable during the test, the temperature related errors can be ignored. If the sensor is used for increasing load measurement only, ignore the hysteresis error. If the load measurement is near the full capacity, the linearity error can be ignored. If the capability exists to correct the data through linearization-fit or a look-up table, the error in the measurement can be minimized. A sophisticated user can get rid of all the errors except for the non-repeatability error in the measurement.

Often overlooked by the customer is the error due to the presence of non-measured forces and bending moments. Even though the single axis of measurement sensors are designed and built to withstand these non-measured forces and bending moments (extraneous loads), the errors due to them are present. PCB engineers can design the set-up to eliminate or minimize these extraneous loads. However, if these extraneous loads are present, the errors due to them should be considered.

Due to cost restraints, the Force/Torque Division, as with its competition, does not typically measure or compensate for errors due to extraneous loads. If the presences of these extraneous loads are known, the user should request the transducer manufacturer to run a special test, at extra cost, to define and quantify the extraneous load errors. These errors are defined as cross-talk errors.

Typical Application Examples:

Hydraulic Actuators
Material Fatigue Testing
Life Cycle Testing
Torque Arm
Quality Control
Tank Weighing

Application Questionnaire

1. Determine the capacity required

A. What is the maximum expected load?
B. What is the minimum expected load?
C. What is the typical expected load ?
D. What are the dynamics of the system, i.e. frequency response?
E. What are the maximum extraneous loads that the load cell will be subjected to?

2. How will the load cell be integrated into the system?

A. What are the physical constraints, i.e. height, diameter, thread?
B. Will the load cell be in the primary load path or will the load cell see forces indirectly?

3. What type of environment will the load cell be operating in?

A. Maximum temperature?
B. Minimum temperature?
C. Humidity?
D. Contaminants, i.e. water, oil, dirt, dust,?

4. What accuracy is required?

A. Non-linearity?
B. Hysteresis?
C. Repeatability?
D. Cross-talk?

Accuracy — Stated as a limit tolerance, which defines the average deviation between the actual output versus theoretical output.

In practical transducer applications, the potential errors of non-linearity, hysteresis, non-repeatability and temperature effects do not normally occur simultaneously, nor are they necessarily additive.

Therefore, accuracy is calculated based upon RMS value of potential errors, assuming a temperature variation of ± 10 °F, full rated load applied, and proper set-up and calibration. Potential errors of the readout, cross-talk, or creep effects are not included.

Ambient Conditions — The conditions (humidity, pressure, temperature, etc.) of the medium surrounding the transducer.

Ambient Temperature — The temperature of the medium surrounding of transducers.

Calibration — The comparison of transducer output against standard test loads.

Calibration Curve — a record (graph) of the comparison of transducer output against standard test loads.

Combined Error (Non-linearity and Hysteresis) — the maximum deviation from a straight line drawn between the original no-load and *rated load* outputs expressed as a percentage of the *rated output* and measured on both increasing and decreasing loads.

Compensation — The utilization of supplementary devices, materials, or processes to minimize known sources of error.

Creep — The change of transducer output occurring with time, while under load, and with all environmental conditions and other variables remaining constant.

Note: Usually measured with *rated load* applied and expressed as a percent of *rated output* over a specific period of time.

Creep Recovery — The change in no-load output occurring with time, after removal of a load, which has been applied for a specific period of time.

Cross-talk — With one component loaded to capacity, and the other unloaded, the output of the unloaded component will not exceed the percentage specified of its full-scale capacity.

Deflection — The change in length along the *primary axis* of the load cell between no-load and *rated load* conditions.

Drift — A random change in *output* under constant *load* conditions.

Error — The algebraic difference between the indicated and true value of the load being measured.

Excitation, Electrical — The voltage or current applied to the input terminals of the transducer.

Fatigue Capacity — Capacity as percentage of the nominal load limit capacity, and based on 100 X 10^6 cycles (minimum) from zero to full fatigue capacity and 50 X 10^6 cycles (minimum) from full fatigue capacity tension to full fatigue capacity compression load.

Hysteresis — The maximum difference between the transducer output readings for the same applied load, one reading obtained by increasing the load from zero and the other by decreasing the load from *rated load*.

NOTE: Usually measured at half *rated output* and expressed in percent of *rated output*. Measurements should be taken as rapidly as possible to minimize *creep*.

Insulation Resistance — The *DC* resistance measured between the transducer circuit and the transducer structure.

NOTE: Normally measured at fifty volts *DC* and under *standard test conditions*.

Natural Frequency — The frequency of free oscillations under no-load conditions.

Nominal Load Limit Capacity — It is the designed normal maximum capacity of a transducer. Output sensitivity of the transducer is based on this capacity unless specified.

Non-linearity — The maximum deviation of the *calibration curve* from a straight line drawn between the no load and *rated load* output, expressed as a percentage of the *rated output* and measured on increasing load only.

Output — This signal (voltage, current, etc.) produced by the transducer.

NOTE: Where the output is directly proportional to excitation, the signal must be expressed in terms of volts per volt, volts per ampere, etc. of excitation.

Output, Rated — The algebraic difference between the *outputs* at no-load and at *rated load*.

Overload Rating — The maximum load in percent of *rated capacity*, which can be applied without producing a permanent shift in performance characteristics beyond those specified.

Primary Axis — The axis along which the transducer is designed to be loaded; normally its geometric centerline.

Rated Capacity (Rated Load) — The maximum *axial load* that the transducer is designed to measure within its specifications.

Repeatability — The maximum difference between transducer output readings for repeated loading under identical loading and environmental conditions.

Resolution — The smallest change in mechanical input, which produces a detectable change in the output signal.

Sensitivity — The ratio of the change in *output* to the change in mechanical input.

Shunt Calibration — Electrical simulation of transducer output by insertion of known shunt resistors between appropriate points within the circuitry.

Shunt-to-load Correlation — The difference in output readings obtained through electrically simulated and actual applied loads.

Glossary of Terms

Standard Test Conditions — The environmental conditions under which measurements should be made, when measurements under any other conditions may result in disagreement between various observers at difference times and places. These conditions are a follows:

Temperature 72 °F ± 3.6 °F (23 °C ± 2 °C)

Relative Humidity: 90% or less

Barometric Pressure: 28 to 32 inch Hg

Static Extraneous Load Limits — Static Extraneous Load Limits are calculated such that only one extraneous load (Fx or Fy or Mx or My or Mz) can be applied simultaneously with 50% of the nominal load limit applied.

Temperature Effect on Output — The change in *output* due to a change in *transducer temperature.*

NOTE: Usually expressed as a percentage of load reading per degree Fahrenheit change in *temperature*.

Temperature Effect on Zero Balance — The change in *zero balance* due to a change in *transducer temperature.*

NOTE: Usually expressed as the change in *zero balance* in percent of *rated output* per degrees Fahrenheit (change in temperature).

Temperature Range, Compensated — The range of temperature over which the transducer is compensated to maintain *rated output* and *zero balance* within specified limits.

Temperature Range, Usable — The extremes of temperature within which the transducer will operate without permanent adverse change to any of its performance characteristics.

Terminal Resistance — The resistance of the transducer circuit measured at specific adjacent bridge terminals at standard temperature, with no-load applied, and with the excitation and output terminals open-circuited.

Terminal Resistance, Excitation — The resistance of the transducer circuit measured at the excitation terminals, at standard temperature, with no-load applied, and with the output terminals open-circuited.

Terminal Resistance, Signal — The resistance of the transducer circuit measured at the output signal terminals, at standard temperature, with no-load applied, and with the excitation terminals open-circuited.

Traceability — The step-by-step transducer process by which the transducer calibration can be related to primary standards.

Zero Balance — The output signal of the transducer with rated *excitation* and with no-load applied, usually expressed in percent of *rated output.*

Zero Return — The difference in *zero balance* measured immediately before *rated load* application of specified duration and measured after removal of the load, and when the output has stabilized.

Zero Shift, Permanent — A permanent change in the no-load output.

Zero Stability — The degree to which the transducer maintains its *zero balance* with all environmental conditions and other variables remaining constant.

Application Notes and Technical Articles

To order copies of the following application notes, call the Force/Torque Division toll-free at 888-684-0004.

Application Notes

AP-1001 Extraneous Loads

AP-1002 Equivalent Force of a Falling Object

AP-1003 Mechanical Installation of PCB Torque Transducers

AP-1004 Installation of PCB Driveline Torque Transducers

AP-1005 Service Maintenance of PCB Slip-ring Torque Transducers

AP-1006 Routine Maintenance of Slip-ring Torque Transducers

AP-1007 Dynamometer Installation of PCB Model 1401 Load Cell

AP-1008 Spline Lubrication PCB Model 4115A & K, Preliminary Release

AP-1009 Explosive Environment

AP-1010 Air-Oil-Mist Lubrication

AP-1011 Effects of Thrust and Bending Moment on The Torque Output of Torque Disk. Model 5304-101-01

AP-1012 Grease Lubrication

AP-1013 Effects of Thrust, Lateral, Loads and Bending Moment on the Torque Output. Models 5307-01 & 5307-02

AP-1014 AOM Lubrication for Models 4115A-101 & 4115A-107

AP-1015 Effects of Extraneous Loads on TORKDISC® Series 5308 and 5309

AP-1016 Shunt Calibration of a Strain Gage Sensor

Technical Articles

TA-1001 What is a Transducer?

TA-1002 Cross-talk in a Multi-Component Sensor

TA-1003 Accuracy

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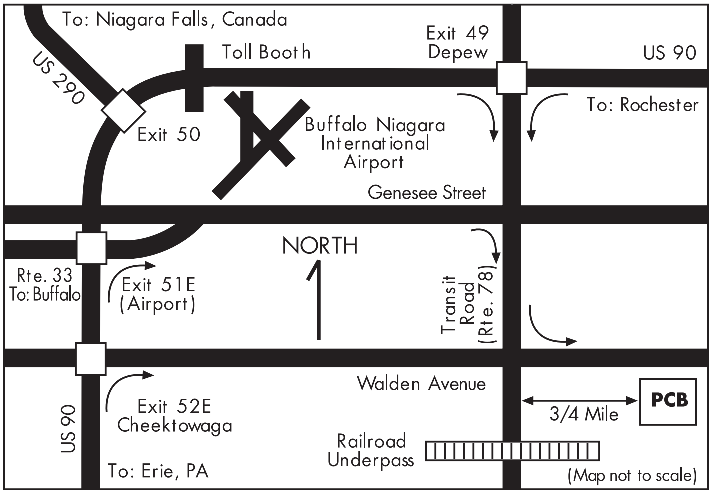

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