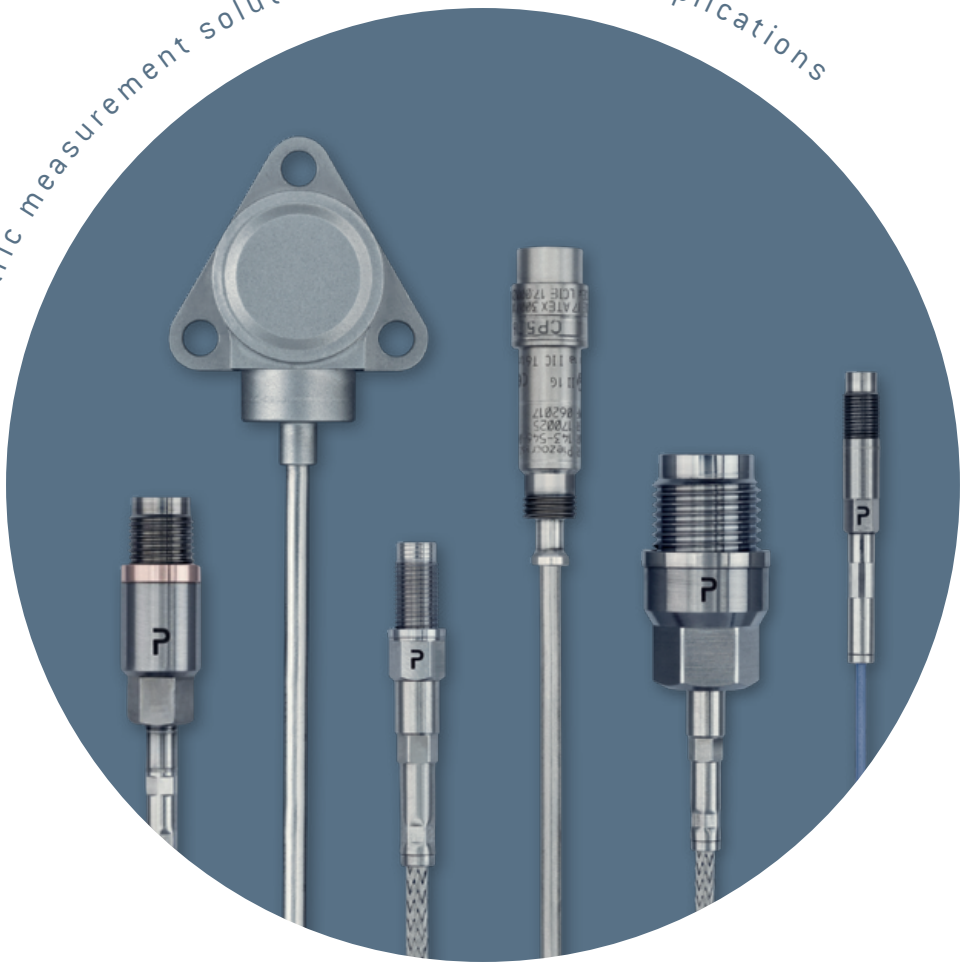
PIEZOCRYST

ADVANCED SENSORICS GMBH

Piezoelectric measurement solutions for demanding applications

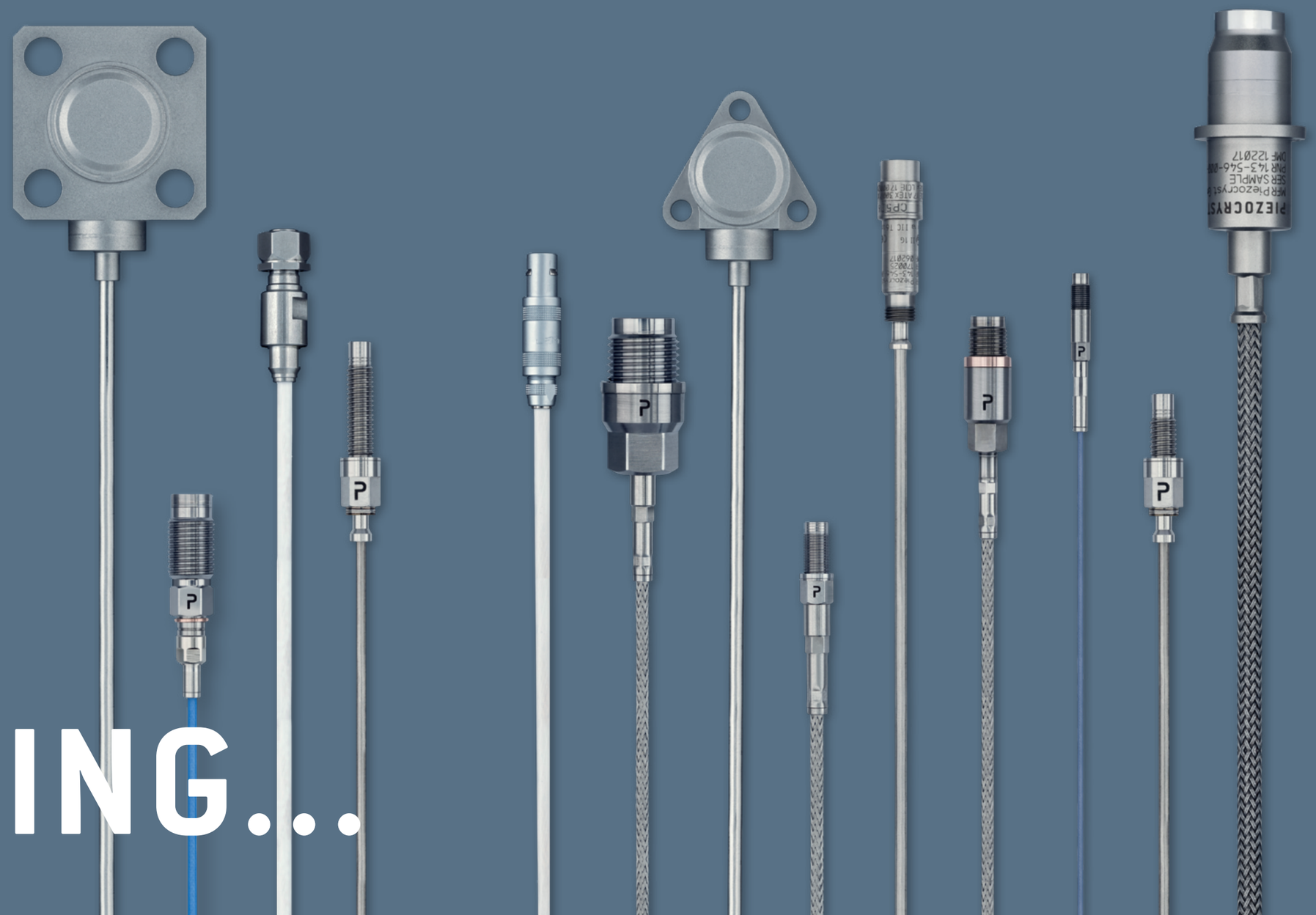


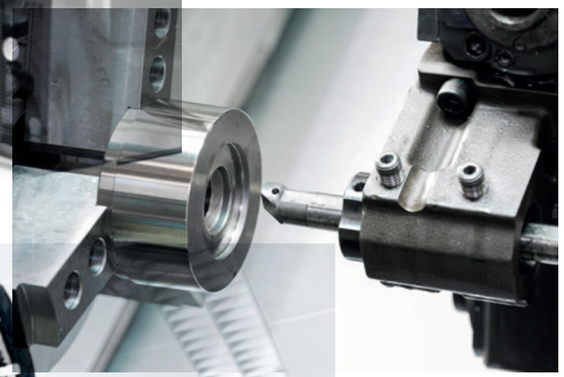
WE ARE PIEZOELECTRIC SENSORS

WE DON'T JUST WANT ANYTHING...

...WE WANT THE BEST PIEZOELECTRIC SENSORS

For clients who demand the highest quality, durability and precision. This is why we count on long-term partnerships and intensive cooperation – within our teams and with our clients. These allow us to develop the innovative and technologically outstanding sensors we are known for. Sensors that help optimize engines, machines and processes and thereby preserve our global resources.





CONTENTS

WHAT WE DO

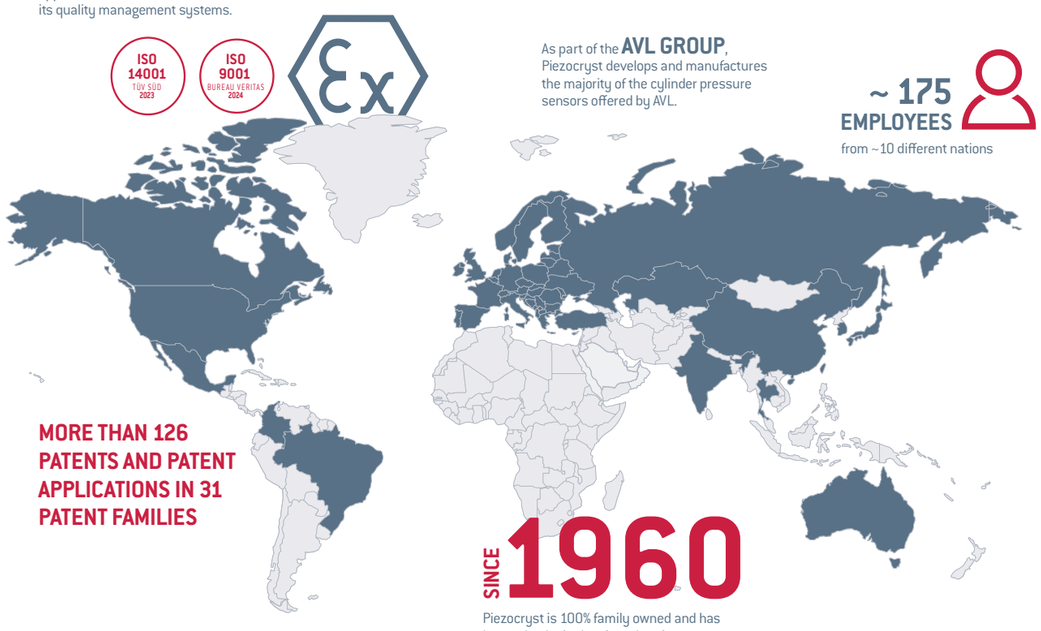
Piezocryst manufactures products that are ATEX and marine certified. To meet the highest quality and environmental standards, Piezocryst actively applies the ISO 9001 and ISO 14001 standards to its quality management systems.

ISO 14001 TÜV SÜD 2023

ISO 9001 BUREAU VERITAS 2024

As part of the **AVL GROUP**, Piezocryst develops and manufactures the majority of the cylinder pressure sensors offered by AVL.

~ 175 EMPLOYEES
from ~10 different nations

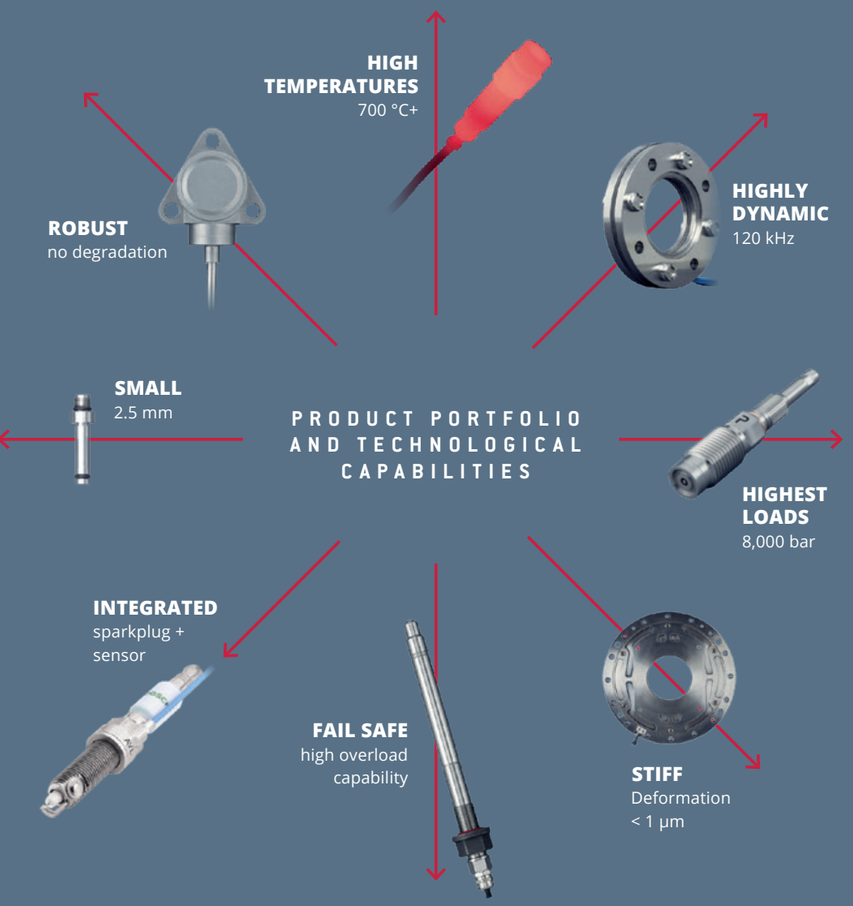


MORE THAN 126 PATENTS AND PATENT APPLICATIONS IN 31 PATENT FAMILIES

SINCE 1960
Piezocryst is 100% family owned and has been a leader in the piezoelectric sensor business since the 1960s.

Today, with more than 60 years of experience in developing and producing piezoelectric measurement solutions, Piezocryst sets the benchmark in many challenging applications throughout the industry. Most of the current portfolio was developed by solving previously impossible measurement tasks together with customers. By taking this approach, Piezocryst was able to acquire very specific application knowledge and to design sensors that can survive in the most extreme environments.

The highest temperatures and temperature gradients, radiation, acceleration: Piezocryst's sensors have seen it all! Therefore, they are capable of meeting any extreme.



Piezoelectric sensors are used when other technologies fail – due to high temperatures, extreme loads, or the required resolution. Compared to the prevalent piezoresistive technology, this is a niche technology, mainly because it is not possible to measure static or DC signals for a longer period (hours). Simply speaking, the static signal slowly vanishes due to physical limitations.
In some typical applications for piezoelectric sensors, the DC component is not of interest (e.g. combustion monitoring in gas turbines) and, in others, the signal consists of recurring or short time features, allowing a short measurement time or periodic levelling of the starting point (e.g. in cylinder measurement, production processes). This might make it less straightforward to apply piezoelectric sensors, requiring the user to invest more thought in the setup and in correctly interpreting the measured signal. But once this has been done, the piezoelectric technology is an extremely robust and reliable solution that enables you to gain incredible insights into your machinery, helping you to perform R&D tasks, condition monitoring or process control.

More detailed information about the technology and specific aspects of piezoelectric measurement are given at the end of this catalogue.

CORE COMPETENCES AND MARKETS

INDUSTRIAL PROCESS CONTROL

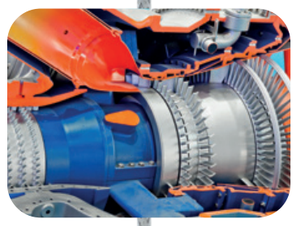
Sensor data are used to optimise the production and reduce the number of defective products, as well as to reduce the wear and tear on expensive tools.

INJECTION MOLDING

Precise measurement of cavity pressure provides production information for each part, ensuring component-specific documentation.

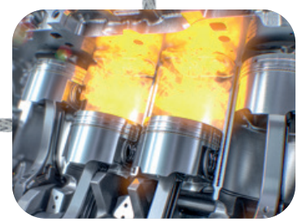
TURBINE

Mounted right where the action happens, high-temperature pressure sensors and accelerometers protect the combustor as the heart of the machine from harmful vibration or combustion instabilities.



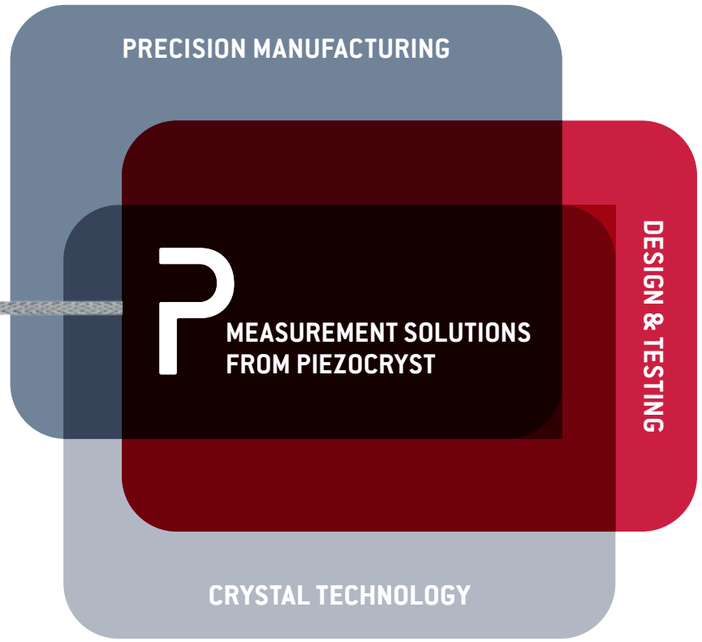
HIGH PRESSURE

Precise measurement of extremely rapid pressure increases of more than 1000 bar/µs and in some cases, and extreme maximum pressures of up to 8000 bar.



IN CYLINDER MEASUREMENT

The sensors are exposed to extreme pressure gradients especially during knocking, high mechanical loads and thermal impacts from the explosion in the cylinder at high cyclic rates, especially in engine control onboard F1 engines.



MACHINING
We manufacture almost all parts in-house in the smallest sizes with extremely tight tolerances (sub-micrometer range), especially from difficult-to-machine nickel-based alloys.

JOINING
Electron beam, laser and pulsed-arc welding provides welds that are long-lasting and gas-tight. This makes the welds absolutely reproducible in all areas where joined materials experience shrinkage or a change in grain size, even for most difficult material pairings.

COATING
We have our own coating technology, which allows the application of a wide variety of coatings with specific properties.

APPLICATION KNOW-HOW
A deep understanding of the application and measurement setup is necessary to optimise the sensor for maximum performance at minimum cost.

DESIGN, SIMULATION AND MATERIAL EXPERTISE
From cutting the crystal in the right way to selecting the treatment of the alloys, with decades of experience our engineering department knows about the importance of the smallest details for the overall performance.

CALIBRATION AND TESTING EQUIPMENT
Some sensor parameters simply cannot be assessed by commercially available equipment, so we are operating many highly specialised setups developed in house, ensuring our sensors will deliver what is expected.

X-RAY
For deeper analysis and quality control in production to meet the highest requirements, we operate our own X-ray machine with 3D-imaging functionality.

HALT TESTS
Many of our sensors need to operate 24/7 for years. To ensure that they will still be working , they have to undergo special test campaigns.

IN-HOUSE-GROWN CRYSTAL
Our $GaPO_4$ is probably the most suitable material for high-performance piezoelectric sensors, particularly when high temperatures come into play. A stable growth process and large stock make us independent of any suppliers or sourcing issues.

SCANNING AND X-RAY
Our sensing elements are checked for any defects and prepared by high-precision machining processes.

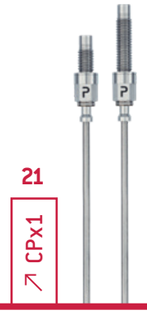
These sensors are designed for extreme conditions and long-term monitoring applications

>500 °C

12-39 HIGH TEMPERATURE

16 ↗ CP-SERIES

High Temperature Pressure Sensor for up to 700 °C



21 ↗ CPx1

High Temperature Miniature Pressure Sensor for up to 650 °C

26 ↗ G-SERIES

High Temperature Accelerometer for up to 700 °C

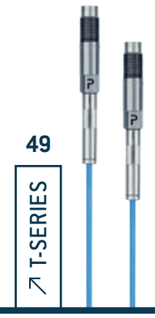
These sensors are designed to capture fast and highly dynamic events

<1000 bar

40-53 DYNAMIC PRESSURE

45 ↗ S-SERIES

Pressure Sensor up to 1000 bar



49 ↗ T-SERIES

Miniature Pressure Sensor Smallest Size Ø 3.5 mm

51 ↗ P-SERIES

Pressure Sensor up to 350 bar

These sensors allow precise measurements of extreme pressure gradients

>1000 bar

54-67 HIGH PRESSURE

58 ↗ H-SERIES

High Pressure Sensor up to 8000 bar

PRODUCTS

WE LIKE IT HOT

↗ PRESSURE SENSORS AND ACCELEROMETER FOR GAS TURBINES AND EXTREME TEMPERATURE APPLICATIONS

Modern gas turbines are designed to operate at the highest efficiency, produce low emissions and offer an operational flexibility that allows quick ramping and low turndown rates. This requires the highest firing temperatures, most advanced combustor designs and combustion monitoring to keep an eye on combustion instabilities. Almost all gas turbine OEMs rely on Piezocryst solutions to perform these critical measurement tasks. While dynamic pressure sensors are used as extreme temperature microphones to analyse and monitor the combustion noise, accelerometers are applied to the bearings or combustor liner to protect the turbine from harmful vibrations. One of the latest challenges that thermo-acoustic engineers have to meet is related to hydrogen combustion with its higher flame propagation speed, requiring the detection of high-fidelity pressure signals from sensors as close as possible to the flame instead of remote sensing solutions. Piezocryst's sensors have been used in direct measurement setups as serial instrumentation for more than a decade, meaning that our company has vast expertise in how to tackle this challenging problem.

The multi-staged combustion taking place in compact combustors with high energy density makes it increasingly difficult to integrate the dynamic pressure sensor at the right spot, i.e. between the fuel injectors, mixing and flame stabilizing appliances and other instrumentation like igniters, temperature probes and flame detectors. Piezocryst's compact sensor solutions allow them to be flexibly integrated to perform R&D tasks and can be packaged to simplify their installation and increase their robustness in the field for the serial application.

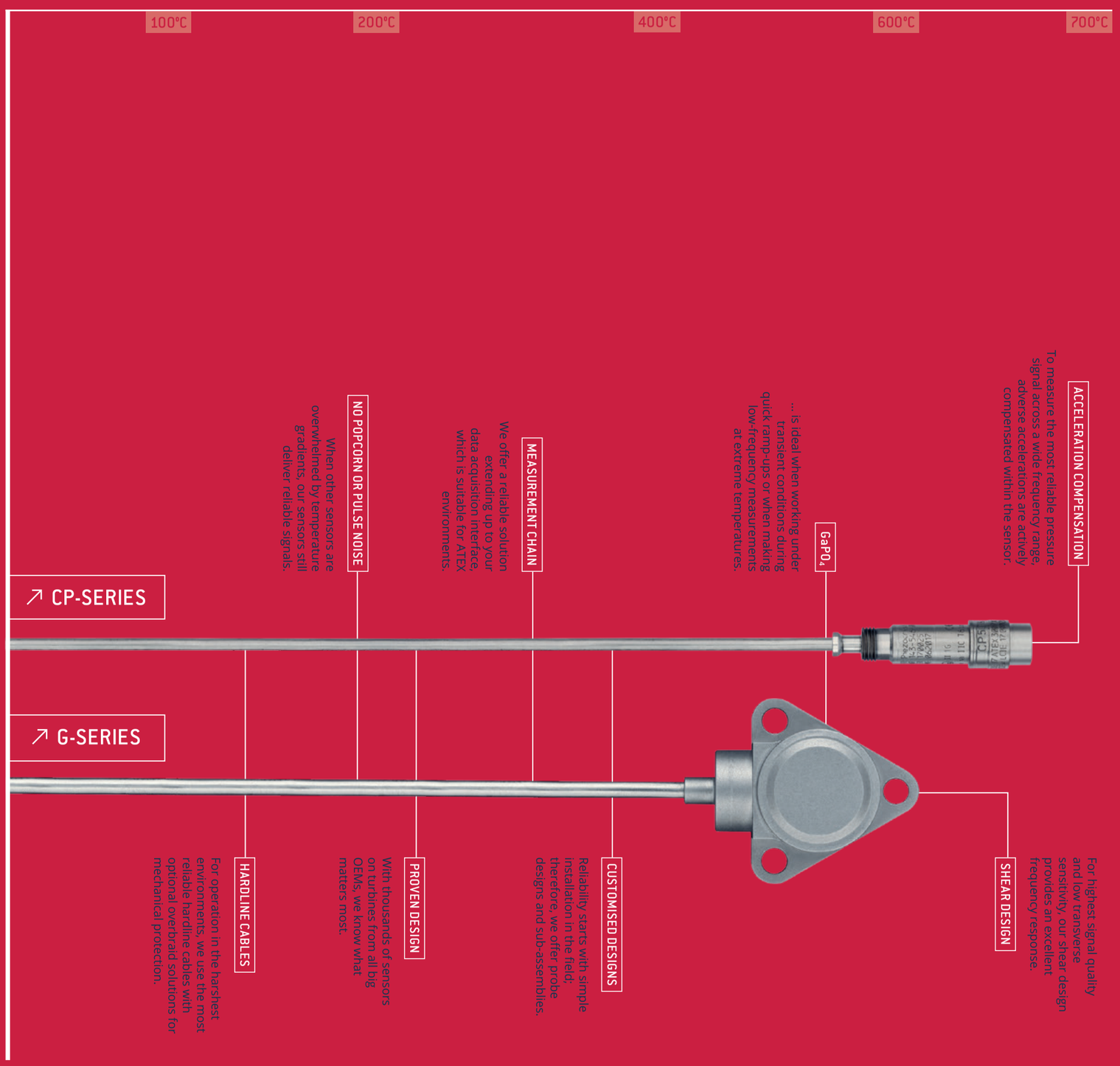
Other typical applications for these sensors include rocket engines, aerodynamics in the exhaust gas path or turbo chargers.

For temperatures up to 750 °C 1380 °F

↗ HIGH TEMPERATURE

Pressure sensors for gas turbines and high temperature applications

100°C 200°C 400°C 600°C 700°C



CP-SERIES:

DESIGNED FOR EXTREME CONDITIONS AND LONG-TERM MONITORING APPLICATIONS

High Temperature Pressure Sensor

- ✓ High temperature stability up to 700 °C (1250 °F)
- ✓ Outstanding signal quality during thermal gradients
- ✓ Highest durability and reliability
- ✓ Internal case insulation
- ✓ Active acceleration compensation available
- ✓ Proven to operate under harsh conditions including hydrogen

For temperatures up to 700 °C 1250 °F

For the most demanding applications that require reliability, operation at extreme temperatures and signal stability, Piezocryst offers a line of case-insulated sensors with outstanding behavior. The sensors, which have a proven design and have been tested for millions of operating hours in numerous heavy duty and industrial gas turbines, are available in various configurations to fit all kind of measurement tasks. Suitable for R&D under the most extreme conditions or for long-term monitoring applications.

The CP5x2, CP5x5 and CP5x6 were designed to directly measure pressure pulsations in a gas turbine combustor. Because these sensors are subjected to extremely high temperatures, heat fluxes and gradients during fast ramp-up and down cycles, the sensor must be highly robust, insensitive to thermal impacts, withstand high acceleration levels, and not show any degradation over its lifetime. The $GaPO_4$ crystal elements and highly specific design enable these CP sensors to deliver clear and reliable pressure signals in the most challenging environments.

Ex

H2 READY

CP-SERIES:	CP5x2	CP5x5	CP5x6

↗ SPECIFICATIONS

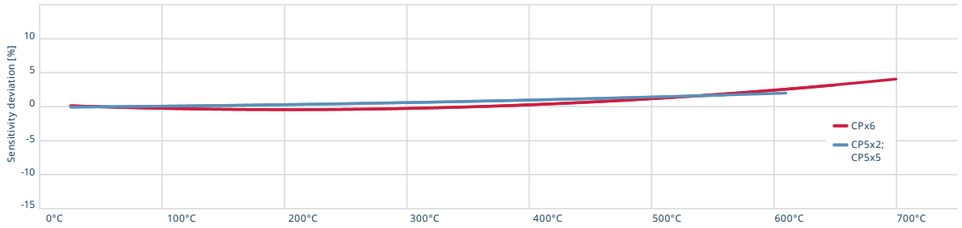
	CP5x2	CP5x5	CP5x6
Operating principle	Piezoelectric charge output		
Sensing element	Industrially grown single-crystal $GaPO_4$ (gallium phosphate)		
Dynamic measuring range	0 ... 50 bar (0 ... 725 psi)		
Overload pressure	> 100 bar (1450 psi)		
Sensitivity (nominal ± 5%)			
95 pC/bar (6.55 pC/psi)	•	•	
100 pC/bar (6,9 pC/psi)			•
Linearity	≤ 0.5 % FSO (0 ... 50 bar, 0 ... 725 psi)		
Operating temperature *			
-70 °C ... +560 °C (-94 °F ... +1040 °F)*	continuous	continuous	
-55 °C ... +650 °C (-67 °F ... +1200 °F)*			continuous
-55 °C ... +700 °C (-67 °F ... +1250 °F)*			short-term
Internal insulation resistance	> 10^{10} Ω (25°C, 77°F), >10^{6} Ω (560 °C, 1040 °F) or >10^{6} Ω (650 °C, 1200 °F)		
Acceleration sensitivity			
Axial	≤ 2 mbar/g (0.03 psi/g)	≤ 0.3 mbar/g (0.004 psi/g)	
Radial	≤ 0.25 mbar/g (0.004 psi/g)		
Frequency range	1 Hz to 10 kHz (resonant frequency > 50 kHz)		
Capacitance (nominal, incl. 1m of cable)	122 pF pole/pole, 157 pF pole/ground		
Mounting torque	see accessories		
Housing material	Nimonic 90, hermetically welded		

* Temperature of sensor head and cable

Available Casings and Cable Configurations	CP5x2	CP5x5	CP5x6
Type 1	X = 38.8 mm	X = 44.8 mm	X = 44.8 mm
Type 2		•	•
Type 3		•	•
Type 4		•	•
Cable	2- pole MI Hardline Cable (double overbraided optional)		
Minimum bending radius cable	16 mm (1 bend), 75 mm (up to 20 bends)		
Connector	2-pin LEMO or High Temperature (7/16“-27UNS-2A)		
Max. temperature connector			
2-pin LEMO	165 °C (330 °F)		
2-pin High Temperature (7/16“-27UNS-2A)	600 °C (1110 °F)		

Piezocryst reserves the right to change specifications without notice.

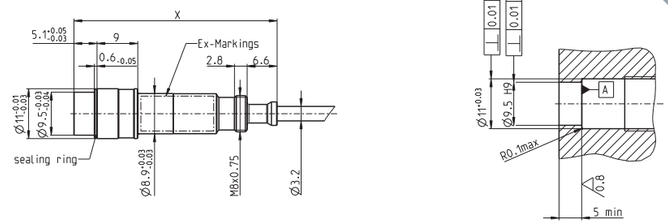
↗ CALIBRATION AND THERMAL SENSITIVITY



CP-SERIES:	TYPE 1	TYPE 2	TYPE 3	TYPE 4

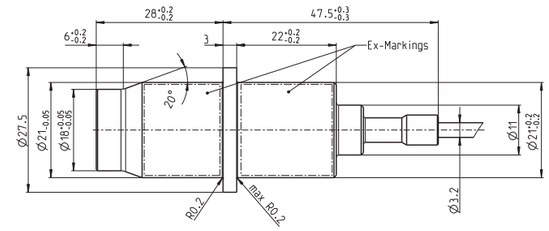
↗ SENSOR AND MOUNT DIMENSIONS

TYPE 1

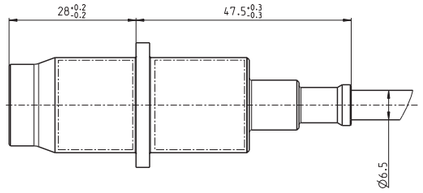


TYPE 2

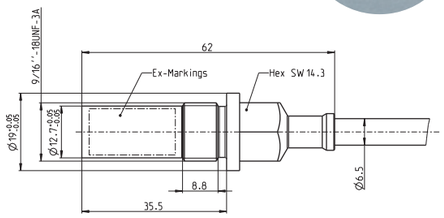
MI Hardline Cable



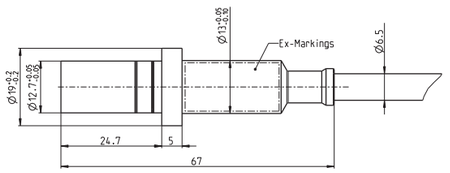
Double Overbraided
MI Hardline Cable



TYPE 3



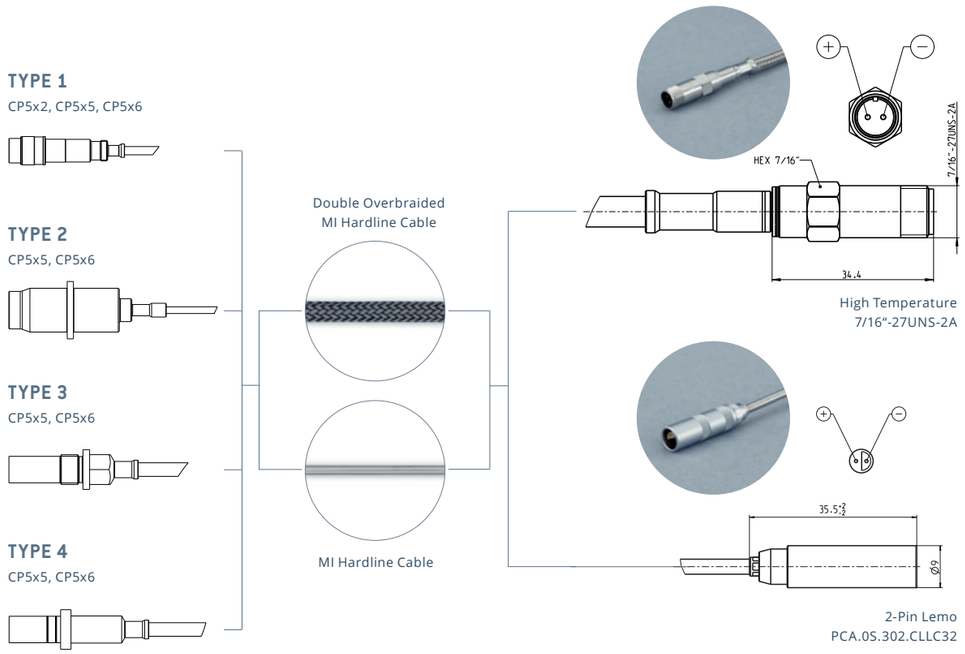
TYPE 4



All dimensions are in mm.

CP-SERIES:	TYPE 1	TYPE 2	TYPE 3	TYPE 4

↗ CONFIGURATIONS AND CONNECTOR DIMENSIONS



↗ SCOPE OF SUPPLY

Sensor	CP5x2 or CP5x5 or CP5x6
Calibration sheet	✓
ATEX certificate	✓
Sealing ring	Type 1 only

↗ ATEX CERTIFICATION

The CP5xx series is Ex approved and, therefore, suitable for use in hazardous environments.

Europe	LCIE 17 ATEX 3007 X
International	IECEx LCIE 17.0002X
cCSAus	70130706
KGS	17-KA4BO-0433X
NEPSI	GYJ22.3546X

Piezocryst reserves the right to change specifications without notice.

CP-SERIES:	CP5x1

High Temperature Miniature Pressure Sensor

- ✓ Robust layout derived from a well-proven design
- ✓ Single crystalline $GaPO_4$ sensing elements
- ✓ High signal-to-noise ratio
- ✓ No pyroelectric effect or popcorn noise
- ✓ Up to 650 °C / 560 °C continuous operation
- ✓ Proven operation under harsh conditions including hydrogen

For temperatures up to
650 °C
1200 °F

R&D measurement tasks differ profoundly from those required for serial applications. The environmental boundary conditions like temperature, mechanical stress or heat flux are often poorly known. Furthermore, the testing time is usually limited, and the measurement position is new, so no or little data are available for comparison. This complex situation demands sensors which deliver a reliable signal which is not influenced by other physical quantities.

The CP5x1 is a versatile miniature pressure sensor that is perfectly suited for measurements in extreme conditions in R&D where space is limited. A particular advantage of the design is that it enables simple integration of the sensor into the setup. The CP5x1 has the robustness of a piezoelectric sensor, while the GaPO4 crystal elements ensure high natural frequency and exceptional signal quality, boosting the limits for R&D applications in hostile environments. It can tolerate excursions into extreme temperatures with high gradients and mechanical stress and still produce a reliable and stable output.

CP-SERIES: CP5x1

↗ SPECIFICATIONS

	CP5x1	
Operating principle	Piezoelectric charge output	
Sensing element	Industrially grown single-crystal $GaPO_4$ (gallium phosphate)	
Dynamic measuring range	0 ... 50 bar (0 ... 725 psi)	
Overload pressure	> 100 bar (1450 psi)	
Sensitivity (nominal)	18 pC/bar (1.2 pC/psi)	
Linearity	≤ 0.5 % FSO (0 ... 50 bar, 0 ... 725 psi)	
Operating temperature *		
Continuous	-55 °C ... +560 °C (-40 °F ... +1040 °F)	
Short-term (< 100 hours)	-55 °C ... +600 °C (-40 °F ... +1110 °F)	
Intermediate (temperature excursion)	-55 °C ... +650 °C (-40 °F ... +1200 °F)	
Internal insulation resistance	> 10^{10} Ω (25°C, 77°F), >10^6 Ω (600°C, 1110°F)	
Acceleration sensitivity	axial ≤ 1 mbar/g (0.01 psi/g)	radial ≤ 0.3 mbar/g (0.004 psi/g)
Frequency range	1 Hz to 50 kHz (resonant frequency > 120 kHz)	
Capacitance (nominal, incl. 1m of cable)	150 pF pole/ground	
Mounting torque	2 Nm	
Housing material	Nickel-based super alloy, hermetically welded	

* Temperature of sensor head and cable

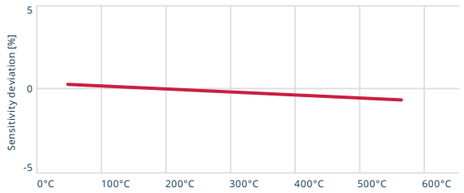
Available dimensions	
X	11 mm or 19.3 mm
Y	M5x0.8 or 10-32 UNF-2A
Cable	2 mm hardline cable
Bending radius	hard line cable: 16 mm (1 bend), 75 mm (up to 20 bends)
Connector	10-32 UNF-2A
Max. connector temperature	500°C (930°F)

Piezocryst reserves the right to change specifications and accessories without notice.

↗ SCOPE OF SUPPLY

Sensor	CP5x1
Extension cable	1m Teflon™ UNF to UNF cable
Coupling	UNF to BNC coupling
Calibration sheet	✓

↗ CALIBRATION AND THERMAL SENSITIVITY



ISO 9001 certified calibration at +20°C with dead weight tester (3, 6, 8, 10, 12, 20, 30, 50 bar). Sensitivity and linearity are determined according to DIN 16086

↗ ATEX CERTIFICATION

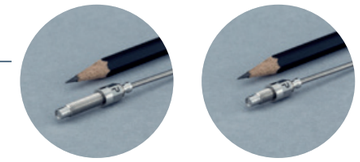
The CP5x1 series is Ex approved and therefore suitable for hazardous environments.

Europe	LCIE 17 ATEX 3027 X
International	IECEx LCIE 17.0024X

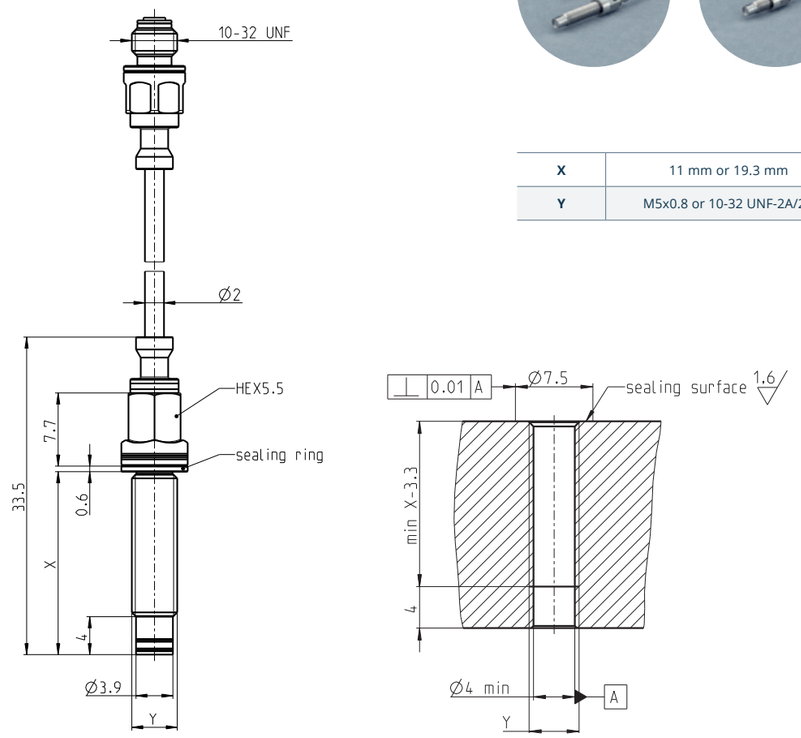
↗ ACCESSORIES

Hardline cable	2-mm hardline 10-32 UNF cable 450 °C max (length: 0.3 m, 1 m, 3 m)
Extension cable	Teflon-coated cable 10-32 UNF to 10-32 UNF or BNC;
Mounting tool	✓
Machining tool for mount	✓
IEPE inline charge amplifier	E1-A1 10 mV/pC
ATEX signal conditioner	E2-Ax charge amplifier and E2-G1 EX barrier

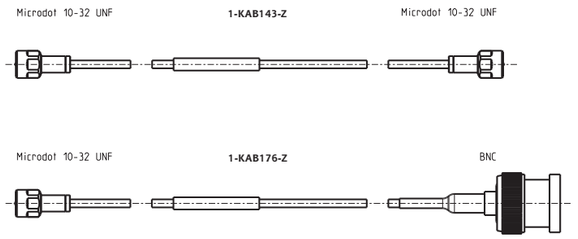
↗ SENSOR AND MOUNT DIMENSIONS



X	11 mm or 19.3 mm
Y	M5x0.8 or 10-32 UNF-2A/2B



↗ EXTENSION CABLE OPTIONS



Available cable length and ordering code:

Length	KAB143*	KAB176*
0.5 m	1-KAB143-0,5	–
1 m	1-KAB143-1	1-KAB176-1
2 m	1-KAB143-2	1-KAB176-2
3 m	1-KAB143-3	1-KAB176-3
5 m	1-KAB143-5	–
7 m	1-KAB143-7	1-KAB176-7
10 m	1-KAB143-10	1-KAB176-10

*Teflon Softline Cable
**Hardline Cable

All dimensions are in mm.

WE ARE PIEZOCRYST

OUR HISTORY IN

HIGH TEMPERATURE SENSORICS

1960s

First pressure transducers made from quartz by AVL for ICE research

1980s

Development of $GaPO_4$ starts with simulations of an ideal piezoelectric crystal

1995

Uncooled $GaPO_4$ sensors introduced for up to 400 °C, serving as the industry benchmark today

2003

Piezocryst establishes itself independently from AVL to focus on applications outside of the automotive industry

2009

5-mm CP5x1, rated at @650 °C as the industry's smallest high temperature dynamic pressure sensor

2009

Industry's first differential high temperature sensor based on artificial single-crystal material for turbine applications sets new standards in signal quality

2019

High temperature accelerometer and differential electronics

2022

More than 6000 turbine sensors in the field and 100,000 sensors for ICE research

2011

CP501 is retrofitted inside several combustors, allowing direct measurement evaluation and additional measurement positions.

CP505's size enables better installation on the combustor liner, increasing frequency range of setup

2012

CP502 is introduced in 5 heavy duty turbines

4 more major OEMs switch to using Piezocryst sensors in their combustion monitoring system

2015

Direct-mounted CP502s replace infinite tube setups in several turbines

Redundant CP505 package replaces a single sensor in the same mount

2016

Flexible production, more than 30 different variants of the CP5xx

2017

F1 engagement starts, resulting in fast-track development capabilities

2019

Customised sensor probe and assembly receives standard on a new heavy duty gas turbine

Piezocryst accelerometer and electronics released for full product line of OEM

2022

New sensor platform introduced, from the 1st sketch to certified instrumentation on a production machine within 1 year

From 2008 and on, Piezocryst sensors were introduced at many big OEMs to replace existing instrumentation in the same installation. Several other new applications and customers were acquired by solving specific problems with tailor-made solutions and involved direct measurements in the combustor.

GAS TURBINE APPLICATION HIGHLIGHTS

HIGH TEMPERATURE > 500°C

DYNAMIC PRESSURE < HIGH PRESSURE > 1000 BAR

G-SERIES:

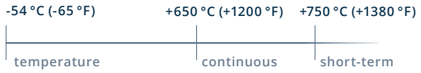
ACCURATE AND RELIABLE VIBRATION MEASUREMENTS UNDER HARSH AMBIENT CONDITIONS

High Temperature Accelerometer

- Robust design for continuous use at 650 °C
- Single-crystal $GaPO_4$ measurement elements in shear mode for low transverse sensitivity and mechanical sensitivity
- Optimally matched materials ensure cleaner signals even when subjected to extreme thermal gradients
- No popcorn effects or spikes due to thermal influences
- Several housing variants, also customisable
- Best durability due to high-performance materials

For temperatures up to
750 °C
1380 °F

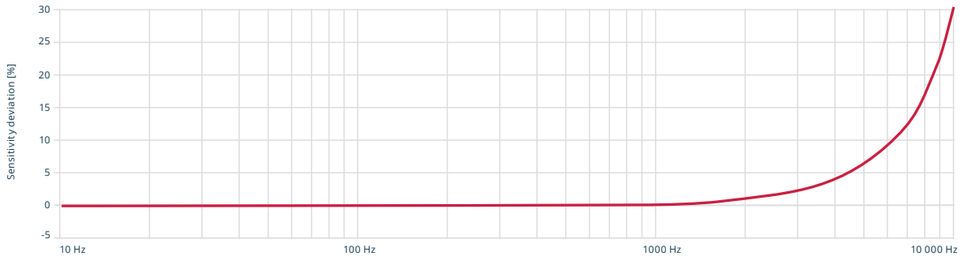
G-Series high temperature accelerometers are ideal for reliable vibration measurements under harsh ambient conditions. Thanks to the ideally matched combination of Piezocryst's $GaPO_4$ crystals, special high-performance alloys and minimised manufacturing tolerances, measurements under high loads and thermal gradients of up to 650 °C are easily possible. This makes the G-Series ideally suited for long-term monitoring as well as for performing R&D tasks. The differential output enables reliable signal transmission even when subjected to the influence of strong electromagnetic fields. The ATEX-certified E2-Ax differential charge amplifiers and the E2-G1 galvanic isolation are suitable for use along the entire measuring chain.

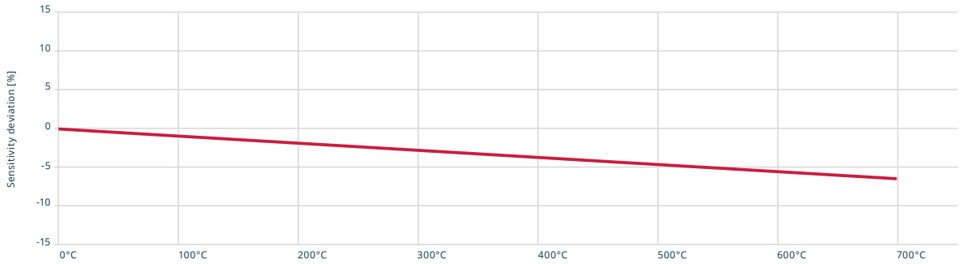


↗ SPECIFICATIONS

	G2-AX
Operating principle	Piezoelectric charge output, shear mode
Sensing element	$GaPO_4$ (gallium phosphate)
Dynamic measuring range	0 ... ±500 g
Shock resistance	±1000 g
Sensitivity (nominal)	~ 3.4 pC/g
Linearity	≤ ±1 % FSO
Operating temperature	continuous: -54 °C ... +650 °C (-65 °F ... + 1200 °F) | short-term (100 h): 750 °C (1380 °F)
Internal insulation resistance	> 10^9 Ω (25 °C, 77 °F), > 10^6 Ω (600 °C, 1112 °F)
Transverse sensitivity	< 5 %
Thermal sensitivity	≤ - 7%
Natural frequency	> 22 kHz
Cable	3.2 mm hardline cable with optional overbraid
Connector	2-pin (7/16"-27UNS-2A) or Lemo
Weight (w/o hardline cable)	75g (G2-A1)

↗ FREQUENCY AND THERMAL BEHAVIOUR





↗ SCOPE OF SUPPLY

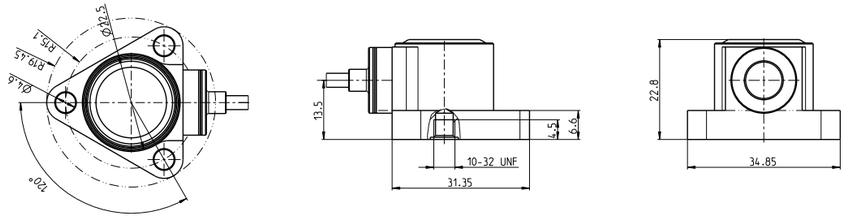
Sensor	✓
Calibration sheet	✓
ATEX certificate	✓

↗ ATEX CERTIFICATION

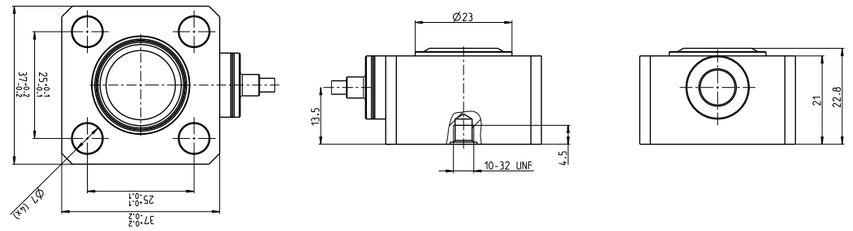
Europe	LCIE 21 ATEX 3011 X
International	IECEx LCIE 21.0014X
cCSAus	pending

↗ SENSOR AND MOUNT DIMENSIONS

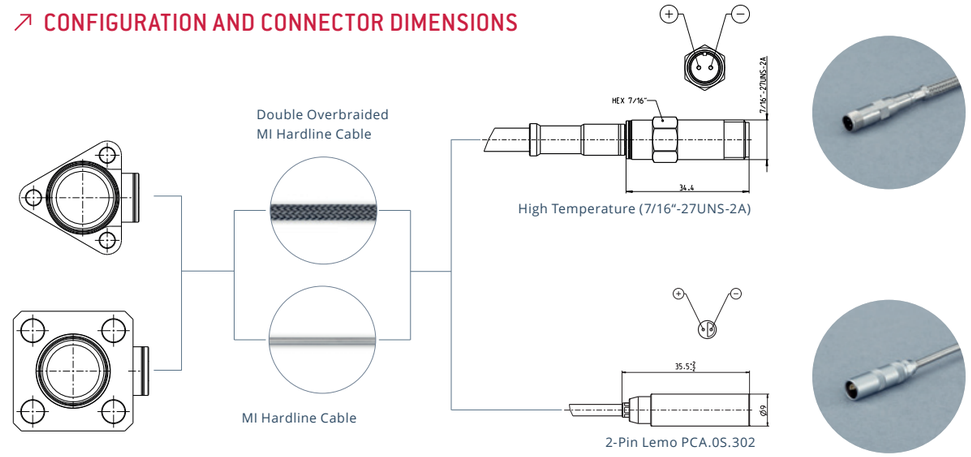
ARINC



SQUARE



↗ CONFIGURATION AND CONNECTOR DIMENSIONS



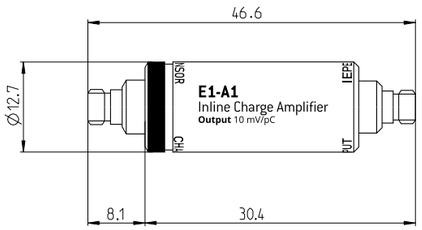
All dimensions in mm, different versions shown

ALL THE LINKS FOR THE STRONGEST (MEASUREMENT) CHAIN

Inline IEPE Charge Amplifier

- ✓ Compact inline charge amplifier
- ✓ 500 pC range
- ✓ IEPE power supply

The E1-A1 is a simple-to-use, high-quality inline amplifier in a miniature package. It is ideal for R&D applications with Piezocryst's single-ended CP5x1 and S-series sensors. When combined with the compatible DAQ input, the IEPE technology enables voltage output and power supply through one coaxial cable.



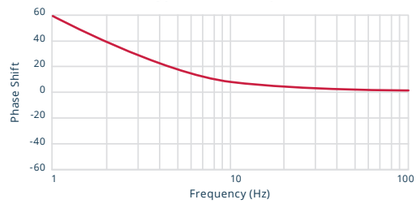
All dimensions in mm
Do not apply power to this system without current limiting, 20 mA MAX!

↗ SPECIFICATIONS

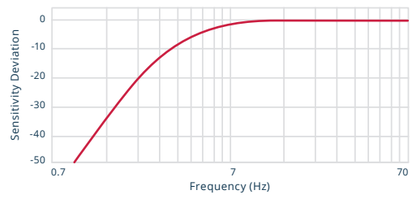
Weight	Max 17 grams
Input / Output connector	Type 10-32
Housing	Hermetically sealed
Sensitivity, ±3%	10 mV/pC
Input range	500 pC
Frequency range, ±5% 2mA	5 to 40,000
Output voltage range	+/-5 Vp
Non-linearity	+/-1% F.S.
Noise floor (5Hz to 10kHz)	10 µV RMS
Maximum input voltage	30 Vp
Minimum source resistance	10 kΩ
Maximum source capacitance	20,000 pF
Turn on time (within 10% of bias)	<1 minute
Thermal coefficient of sensitivity	Max 0.02 %/°C
Supply current range	2 to 20 mA
Compliance voltage range	+18 to +30 VDC
Output impedance, Typ.	<100 Ω
Output bias voltage	10.0 to 13.0 VDC
Discharge time constant	0.1 to 0.3 sec
Polarity	Inverting
Maximum shock	2000 g pk
Operating temperature	-40 to +85 °C

↗ PHASE AND FREQUENCY RESPONSE

Typical Phase Response



Typical Low Frequency Response



Differential Charge Amplifier

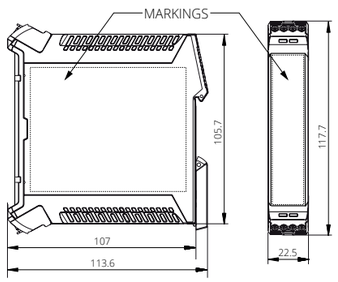
- ✓ Industrial housing or DIN rail mounting option
- ✓ Certified for use in potentially explosive atmospheres
- ✓ Excellent signal quality
- ✓ Configurable input range and filter settings
- ✓ 2-wire current transmission

The Piezocryst E2-Ax charge amplifier series is designed to work in EX zone 1 together with the power supply and EX barrier unit E2-G1. The differential input makes it the perfect match for a measurement chain in combination with Piezocryst's CP pressure sensors or G-series accelerometers. With its robust design, a wide input range and a configurable frequency range between 0.5 Hz and 40 kHz, the E2-Ax can be used to perform almost any monitoring or measuring tasks in the industry.

The amplifier is available with two housing options. The version in a compact industrial housing is perfectly suited for distributed installation close to the sensors. The second option is the ideal solution, if the amplifiers for several channels are mounted in a common housing (Ex-compliant housings are available as an accessory). Gas turbines with multiple cans are a typical application for this installation.

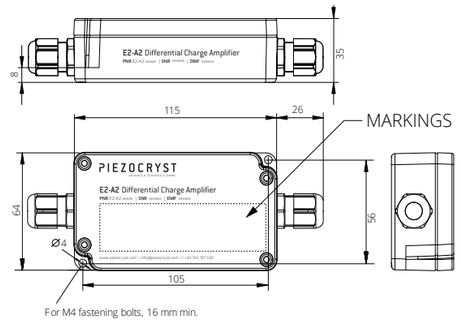
↗ CHARGE AMPLIFIER DIMENSIONS AND MOUNTING

E2-A1 in housing for DIN rail mounting (ordering option 1)



All dimensions in mm, clean housings only with a damp cloth

E2-A2 in industrial housing (ordering option 2)



For M4 fastening bolts, 16 mm min.

↗ SPECIFICATIONS

Amplifier	E2-A1	E2-A2
Operating principle	Differential charge amplifier	
Input range	50 - 20,000 pC	
Linearity	< 0.2 %FSO	
Filters		
High-pass filter	4th order, 24 dB/octave	
High-pass filter settings	0.5 / 1 / 2 / 5 / 10 Hz	
Low-pass filter	3rd order, 18 dB/octave	
Low-pass filter settings	0.2 / 0.5 / 1 / 2 / 5 / 10 / 20 / 40 kHz	
Output		
Output signal range	4 - 20 mA	
Zero Level	12 mA	
Power supply	18 ... 30 VDC	
Supply current @ 24 VDC	25 mA max	
Environmental		
Operational temperature	-20 °C ... 80 °C	
Storage temperature	-30 °C ... 80 °C	
Shock resistance	30 g peak (half sine)	
Vibration resistance	4 g from 10 to 500 Hz	
Housing		
Type	DIN rail mounting, 22.5 mm wide	Industrial aluminium box with cable glands, no grounding required
Protection	IP 20 (in E2-Hx IP 66)	IP 66
Connector	Pluggable 4 pole screw terminals	3 pole screw terminals
Cable glands	in E2-Hx housings, ATEX-compliant	ATEX-compliant
Weight	170 g	280 g

↗ SCOPE OF SUPPLY

Charge amplifier	E2-A1 or E2-A2; zero, amplification and filter settings configured
Documentation	✓

↗ ACCESSORIES

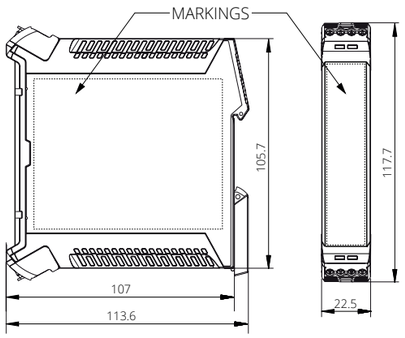
Low noise input cables	SLC-xxxx low-noise cable
	SLB-xxxx low-noise cable with overbraid

EX Barrier with Galvanic Separation

- Includes power supply for E2-Ax line charge amplifier
- mA to V conversion for current input
- 4 kV_{RMS} galvanic separation input to output
- Selectable zero level and conversion
- Status LEDs for loop current and power supply
- 2-mm plugs for direct evaluation of input and output

The Piezocryst E2-G1 EX barrier and galvanic separation unit is designed to complete the measurement chain of CP- or G-series transducers with the E2-Ax differential charge amplifiers. This unit enables the CP-series and G-series sensors, including E2Ax charge amplifier, to be installed in hazardous areas up to Ex zone 0. Two LEDs show whether the correct power supply and current loop to the charge amplifier are present, indicating the health of the electronic installation.

↗ EX BARRIER DIMENSIONS



↗ SPECIFICATIONS

Input range	0 - 20 mA
Overload protection	26 mA
Output signal range	2 - 20 VDC
Zero level	configurable 0-20V
Linearity	< 0.2 %
Bandwith	DC to 40 kHz
Connector	4 pole screw terminals on connector
Temperature range	-20 °C ... 70 °C
Weight	130 g
Power supply	18 ... 30 VDC
Current consumption	< 80 mA no load < 120 mA @ 20 mA load
Installation environment	Pollution degree 2

↗ SCOPE OF SUPPLY & ACCESSORIES

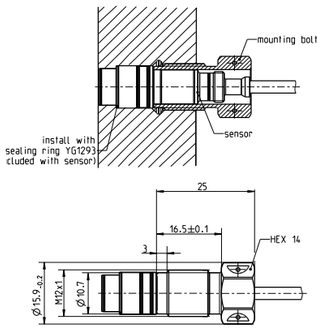
Scope of Supply	
EX barrier	E2-G1 in DIN rail housing, zero level adjusted
Documentation	✓
Accessories	
Power supply	E2-P1 power supply for 24-VDC or 230-VAC input

Mounting Adapters

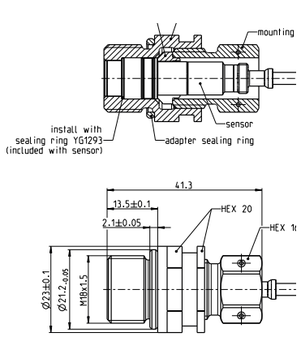
The sensor must be properly mounted to ensure signal quality. If the intended bore can be machined with high accuracy, it is possible to prepare the sensor seat directly in the part. In all other cases, it is possible to use an M18x1.5 adapter with an included sensor seat.
In many applications, it is not possible to use standard adapters. In these cases, Piezocryst offers customised mounting accessories on demand.

	U1-X1	U1-X2	U1-X3
Compatibility	Type 1 CP5x2, CP5x5 and CP5x6 with Lemo	Type 1 CP5x2, CP5x5, and CP5x6	Type 1 CP5x2, CP5x5 and CP5x6 with Lemo
Mounting torque			
Sensor bolt	28 Nm	28 Nm	28 Nm
Mounting bolt	–	75 Nm	75 Nm
Temperature limit	750 °C / 1380 °F	750 °C / 1380 °F	750 °C / 1380 °F
Mount preparation	Drawings for the mount machining are available upon request.		

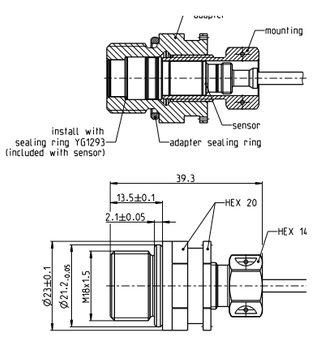
U1-X1



U1-X2



U1-X3



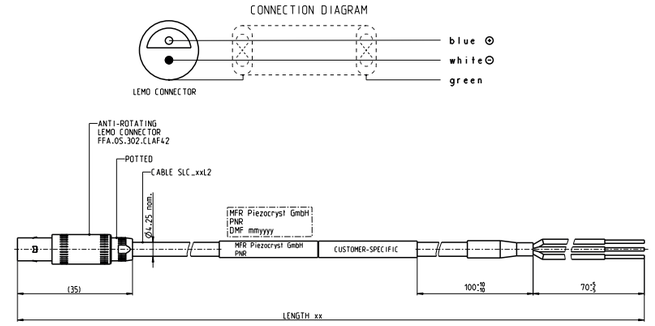
Piezocryst reserves the right to change specifications and accessories without notice.

Low-noise cables

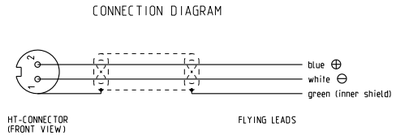
- ✓ Up to 200 °C
- ✓ Reduced triboelectric noise
- ✓ Potted connectors for highest durability and signal quality
- ✓ Additional metal overbraid available
- ✓ Lemo or HT-Connector

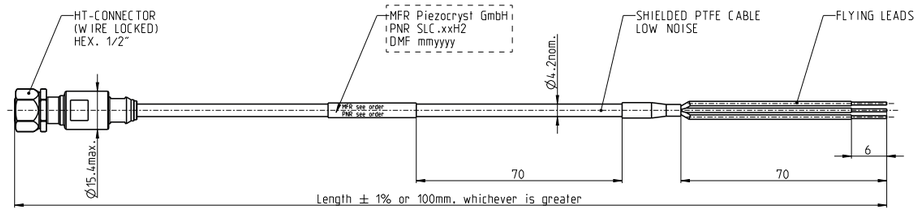
Layout	2-wire low-noise cable
Connector	Lemo: FFA.0S.302.CLAF, HT: 7/16"-27UNS-2B 2-pin
Length	xx in meters e.g. SLC-05L2 for 5 m
Test voltage	2 kV AC (core/core), 1.5 kV AC (core/braid)
Operating voltage Urms	600 V AC
Capacity (±10%)	200 pF/m
Bending radius	7.5 x D (fixed instalation), 15 x D (free movement)
Operating temperature	-190°C ... +200°C (-310°F ... +392°F)
Internal insulation resistance	> 10^{12} Ω (25°C / 77°F)
Braid (for SLB)	stainless steel

SLC-XXL2 (LEMO CONNECTOR)

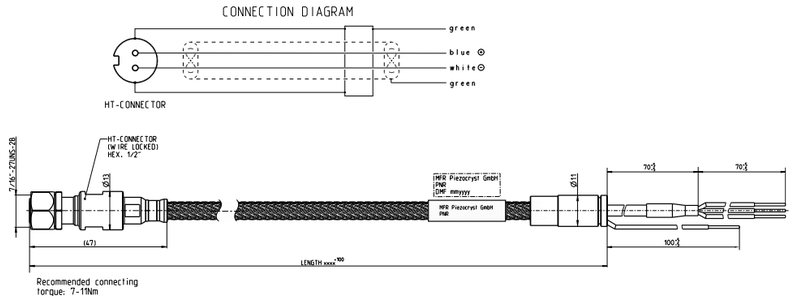


SLC-XXH2 (HT CONNECTOR)





SLB-XXH2 (HT CONNECTOR)



DIFFERENTIAL MEASUREMENT CHAIN

Configuration Sheet Sensor and Cable

Download datasheet

Sensor

- ☐ CP502
- ☐ CP505
- ☐ CP506

Housing

- ☐ **TYPE 1** CP5x2, CP5x5, CP5x6
- ☐ **TYPE 2** CP5x5, CP5x6
- ☐ **TYPE 3** CP5x5
- ☐ **TYPE 4** CP5x5

Type 2,3,4 on request

Sensor

- ☐ G2-A1
- ☐ G2-A2

Hardline cable* length:

- ☐ 1 m
- ☐ 3 m
- ☐ 5 m
- ☐ 10 m
- ☐ braid (on request)

*Hard line cable directly welded to sensor

Connector

- ☐ HT
- ☐ Lemo

Softline cable length:

- ☐ 1 m
- ☐ 3 m
- ☐ 5 m*
- ☐ 10 m*
- ☐ ___ m
- ☐ braid (on request)

*available for single-ended amplifier with BNC connector

Charge amplifier:

- ☐ Differential* (see configuration sheet)
- ☐ Single-ended

*suitable for ATEX

SIGNAL CONDITIONER

DIFFERENTIAL MEASUREMENT CHAIN

Configuration Sheet Signal Conditioning

Download datasheet

SLC Low-noise Cables

High-pass filter

- ☐ 0.5 kHz
- ☐ 1 kHz
- ☐ 2 kHz
- ☐ 5 kHz
- ☐ 10 kHz

Low-pass filter

- ☐ 5 kHz
- ☐ 10 kHz
- ☐ 20 kHz

Sensitivity

- ☐ 2.5 V/bar
- ☐ 5 V/bar
- ☐ ____ V/bar
- ☐ 10 mV/g
- ☐ ____ mV/g

E2-Ax

Housing

- ☐ DIN-Rail (E2-A1)
- ☐ Industrial (E2-A2)

Galvanic Isolator

- ☐ Yes
- ☐ No

3rd-party Cables

E2-G1

Power Supply Input

- ☐ DC input
- ☐ AC input
- ☐ Not required

E2-Px POWER SUPPLY

3rd PARTY DAQ

SENSING IN PRODUCTION AND T&M

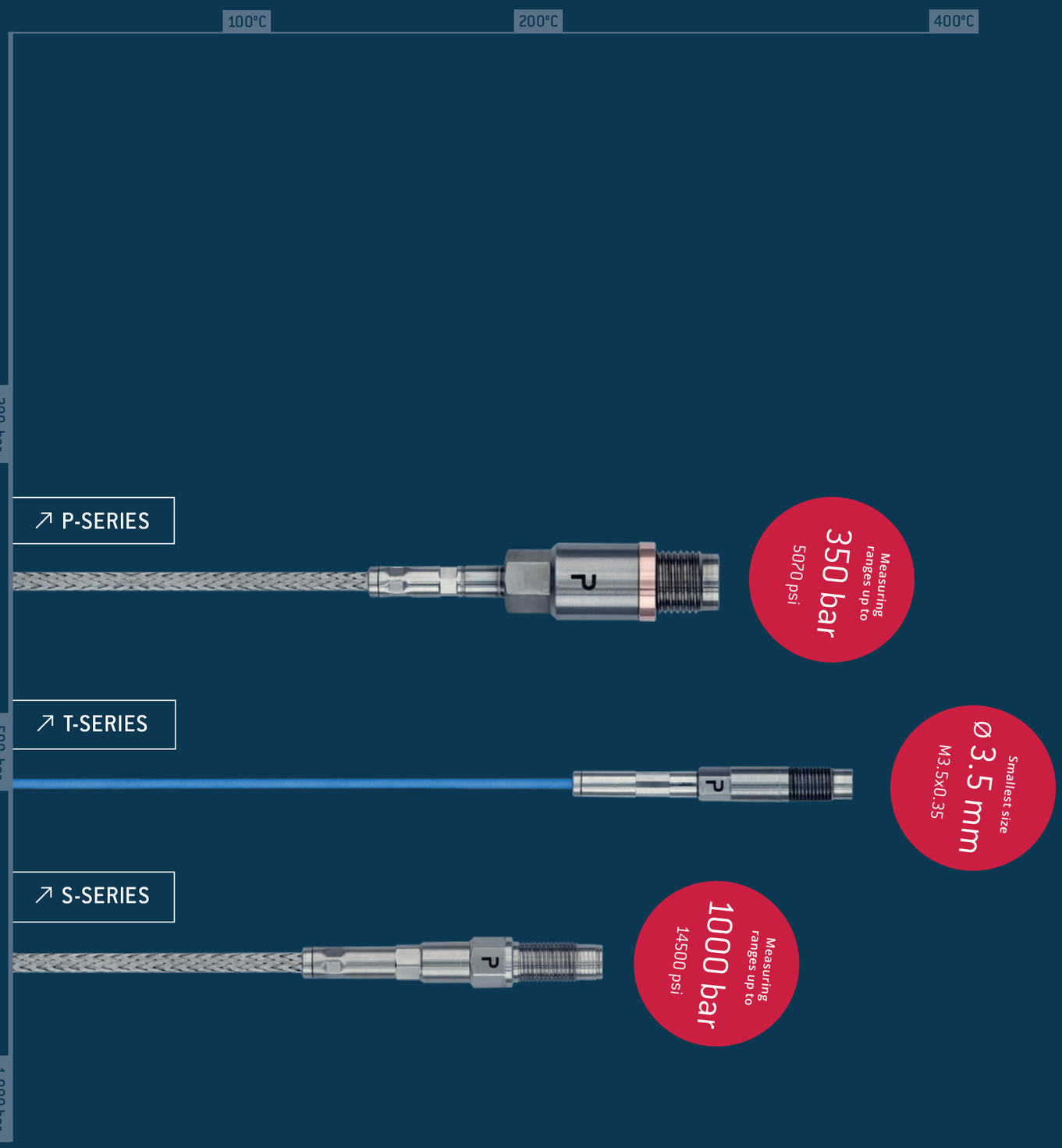
↗ PRESSURE SENSORS IN PRODUCTION LINES OR TEST AND MEASUREMENT APPLICATIONS FOR MONITORING PULSATION LEVELS AND HIGHLY DYNAMIC PRESSURE CYCLES.

Piezoelectric pressure sensors are used in production lines for testing and measurement purposes or for monitoring pulsation levels and highly dynamic pressure cycles. Typically, the sensors are applied when requirements for size, robustness or temperature do not allow the use of any technology. Physical effect like cavitation or water hammer pulses require the use of a sensor with a high overload capacity but also a low threshold for collecting precise data on the actually investigated phenomenon. Piezocryst's S-, T- and P-series come in various shapes and offer various sealing, allowing a flexible integration while minimising the number of changes in the mechanical and physical properties of the setup.

From the smallest M3.5 sensor in the T-series to the 1000-bar high pressure minature sensors models in the S-series, Piezocryst offers absolutely unique sensors for the most demanding applications.

↗ DYNAMIC PRESSURE

S - T - P Series for Test and Measurement



S-T-P-SERIES

OUR SENSORS FOR DETECTING RAPID AND HIGHLY DYNAMIC EVENTS

Piezoelectric Pressure Sensor

- Compact design with M5x0.5 thread
- Various pressure ranges up to 1000 bar (14,500 psi)
- High temperature stability up to 400 °C (750 °F)
- Wide range of applications including hydrogen
- Virtually constant sensitivity over the entire lifetime

Measuring ranges
1000 bar
14 500 psi

The S-series sensors are widely used for performing complex measurement tasks with rapid and high-frequency events and where robustness, precision and repeatability are key requirements. By offering a wide pressure and temperature range, Piezocryst's S-series combines unique features in a compact size with an M5x0.5 mounting thread. Various cable options, accessories and adapters for installation and different sealing options qualify these versatile sensors as solutions for many applications.

Piezocryst's $GaPO_4$ crystal elements, tailored material selection and minimal tolerances in production make these sensors highly precise instruments that deliver a reliable, undistorted signals even when subjected to high temperature gradients. The Double ShellTM decouples the sensing elements from mechanical impact, and its well-proven design elements guarantee the highest durability and constant performance over the entire lifetime.

H2 READY

S-SERIES	S1-B1	S1-B2	S1-B3	S1-D1	S1-K1	S1-K2	S2-A1	S2-K3

↗ SPECIFICATIONS

Name **	S1-Bx	S1-D1	S1-Kx	S2-Ax
Operating principle	Piezoelectric, charge output			
Sensing element	$GaPO_4$ (gallium phosphate)			
Dynamic measuring range				
0 ... 300 bar (0 ... 4350 psi)	•			
0 ... 500 bar (0 ... 7250 psi)			•	
0 ... 600 bar (0 ... 8700 psi)		•		
0 ... 1000 bar (0 ... 14500 psi)				•
Overload pressure				
350 bar (5075 psi)	•			
600 bar (8700 psi)			•	
700 bar (10,150 psi)		•		
1000 bar / 14,500 psi				•
Sensitivity (nominal)				
1.5 pC/bar (0.10 pC/psi)				•
6.5 pC/bar (0.45 pC/psi)		•		
19 pC/bar (1.31 pC/psi)	•		•	
Linearity				
≤ ± 0.3% FSO	•			
≤ ± 0.5% FSO		•	•	•
Operating temperature				
-55 °C ... +120 °C (-67 °F ... +250 °F)			•	
-55 °C ... +350 °C (-67 °F ... +660 °F)				•
-55 °C ... +400 °C (-67 °F ... +750 °F)	•	•		
Thermal sensitivity change *	2%			6%
Internal insulation resistance				
Acceleration sensitivity (typ.)				
axial ≤ 0.5 mbar/g (0.007 psi/g)	•	•	•	•
Shock resistance	>2000 g			
Natural frequency	170 kHz	200 kHz	170 kHz	400 kHz
Capacitance (nominal)	7.5 pF pole/ground			
Mounting torque	Type 1 and Type 2: 1.5 Nm | Type 3: 2 Nm			
Sensor and mount**				
Type 1	•	•	•	•
Type 2	•		•	
Type 3	•			•

* 20°C ... max temperature, full pressure range

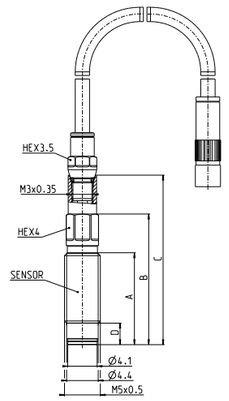
** e.g. S1-A1 is S1-Ax Sensor Type 1
If desired configuration is not available, please contact us!

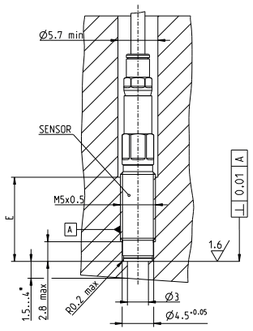
S-SERIES	TYPE 1	TYPE 2	TYPE 3

↗ SENSOR AND MOUNT DIMENSIONS

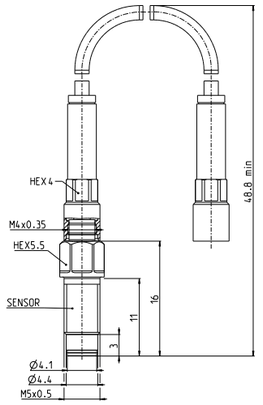
Name	S1-B1	S1-K1	S1-D1	S2-A1
Dimensions Type 1				
A	13 mm		9.5 mm	
B	18.2 mm		14.9 mm	
C	23.6 mm		20.3 mm	
D	3 mm		3.5 mm	
E	7...12 mm		7...10 mm	

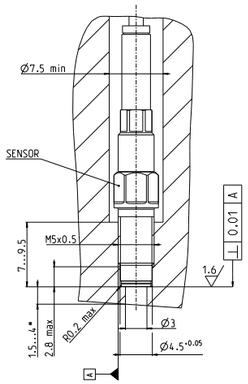
TYPE 1



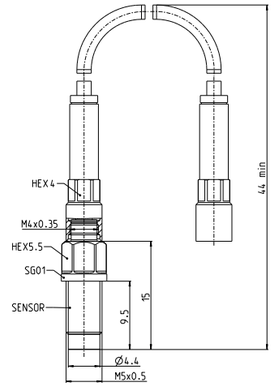


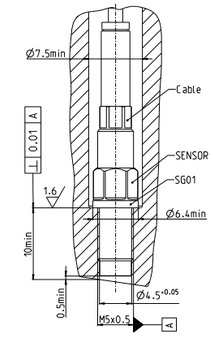
TYPE 2





TYPE 3





All dimensions are in mm.
*1.5 mm for steel, 4 mm for cast iron and aluminium alloys

S-SERIES	S1-B1	S1-B2	S1-B3	S1-D1	S1-K1	S1-K2	S2-A1	S2-K3

↗ SCOPE OF SUPPLY

Sensor	✓
Cable	1-m Teflon™ cable (M4x0.35 to M4x0.35 or M3x0.35 to M3x0.35)
Coupling	M4x0.35 to BNC coupling or M3x0.35 to BNC coupling
Accessory kit	Protection cap and 2 spare O-rings
Calibration sheet	✓
Documentation	✓

↗ ACCESSORIES

Cable / Extension cables	1-10-m Teflon™-coated cable	M3x0.35 to M3x0.35 M3x0.35 to UNF M4x0.35 to M4x0.35 M4x0.35 to UNF
	1-3-m metal-shielded - VitonTM-coated cable	
	1-3-m Viton™ oil-proof cable	
Couplings	M3x0.35 neg. to BNC pos. M4x0.35 neg. to BNC pos. M4x0.35 neg. to M4x0.35 neg. M4x0.35 neg. to M4x0.35 pos.	
Machining tool for mount	Step drill, tap drill, reaming tools	
Mounting tool	Mounting tool set	Mounting socket Torque wrench Dismounting tool
	Cable mounting tool	HEX3.5 or HEX4
Flame arrestors	✓	
Dummy plugs	✓	
Dummy removal tool	✓	
Mounting paste	✓	

T-SERIES	T1-A1	T1-K1

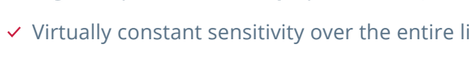
Piezoelectric Miniature Pressure Sensor

- ✓ Miniature design
- ✓ Pressure range up to 500 bar (7250 psi)
- ✓ High temperature stability up to 400 °C (750 °F)
- ✓ Virtually constant sensitivity over the entire lifetime

Smallest size
Ø 3.5 mm
M3.5x0.35

R&D measurements in modern, highly integrated and compact apparatuses are among the most challenging applications for sensors. The mechanical integration represents the bottleneck for many available sensors due to the size. Adverse physical influences such as temperature, heat flux or mechanical stresses can vary greatly due to the experimental character of R&D. The T-series has been developed for these complex conditions which is reflected in its miniature housing and design features.

The T-series is a new generation of sensors which incorporates the Piezocryst technology portfolio in the smallest package so far. With the robustness of the S-series, only 3.5-mm mounting diameter and the exceptional signal quality of $GaPO_4$ crystal elements, the sensors of the T-series allow users to study previously not accessible components. The sensors can withstand high temperature and pressure gradients and still produce a reliable, stable output.



H2 READY

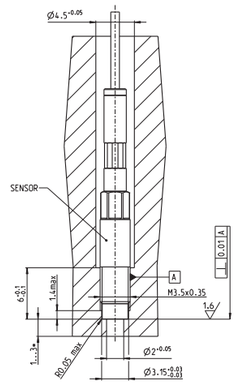
T-SERIES T1-A1 T1-K1

↗ SPECIFICATIONS

	T1-A1	T1-K1
Operating principle	Piezoelectric based on $GaPO_4$ (gallium phosphate) sensing elements, charge output	
Dynamic measuring range	0-300 bar (0-4350 psi)	0-500 bar (0-7250 psi)
Overload pressure	350 bar (5075 psi)	550 bar (8000 psi)
Sensitivity (nominal)	5.3 pC/bar (0.37 pC/psi)	
Linearity	≤ ± 0.5% FSO	
Operating temperature (continuous)	-55 °C ... +400 °C (-67 °F ... +750 °F)	-55 °C ... +120 °C (-67 °F ... +250 °F)
Internal insulation resistance	> 10^{13}Ω (25°C / 77°F), > 10^{9}Ω (400°C / 750°F)	
Shock resistance	> 2000 g	
Natural frequency	170 kHz	
Capacitance (nominal)	3.5 pF pole/ground	
Mounting torque	0.5 Nm	
Scope of Supply		
Sensor	✓	
Cable	1-m Teflon™ cable M2x0.25 to M2x0.25 incl. BNC coupling	
Accessory kit	Protection cap and 2 spare O-rings	
Test record, documentation	✓	
Accessories		
Cables	1-5m Teflon™ coated cable with M2x0.25 connector	
Machining tool	Step drill, tap drill	
Mounting tools	Socket to mount sensor with attached cable in bore, torque wrench, cable mounting tool	

Piezocryst reserves the right to change specifications and accessories without notice.

↗ SENSOR & MOUNT DIMENSIONS



All dimensions in mm, different versions shown

P-SERIES P1-A1 P2-A1 P2-B1 P3-A1 P3-A2

Piezoelectric Pressure Sensor

- ✓ High output signal
- ✓ Internal heat conducting element
- ✓ High temperature stability (400 °C / 750 °F)
- ✓ Virtually constant sensitivity over the entire lifetime

Measuring ranges
350 bar
5070 psi

Measurements made for R&D purposes differ profoundly from those made for serial applications. Boundary conditions like the temperature, mounting environment, mechanical stress or heat flux are not fully evaluated. Furthermore, the testing time is usually limited, and the measurement position is new, so no or little data are available for comparison. This complex situation demands the use of sensors that deliver a reliable signal which is not influenced by other physical quantities. In addition, there should be different sensor configurations that allow easy integration into the setup.

The P-series has been designed for monitoring dynamic and quasistatic pressure of up to 350 bar and features a high accuracy, which makes the sensors also suitable for precise thermodynamic analyses. The sensors' patented sensing element, with Crystal Match™ technology, enables exceptional signal qualities over the entire temperature range. The Double Shell™ design provides high levels of mechanical isolation, shielding it from the influences of the mounting bore and decoupling the piezoelectric elements from the negative influences of mechanical stress.

-50 °C — up to 400 °C

continious operation

H2 READY

P-SERIES: P1-A1 P2-A1 P2-B1 P3-A1 P3-A2

↗ SPECIFICATIONS

	P1-A1	P2-A1	P2-B1	P3-A1	P3-A2
Operating principle	Piezoelectric, charge output				
Sensing element	$GaPO_4$ (gallium phosphate)				
Dynamic measuring range					
0-250 bar (0-3625 psi)	•	•		•	•
0-300 bar (0-4351 psi)			•		
Overload pressure					
300 bar (4350 psi)	•	•		•	•
350 bar (5076 psi)			•		
Sensitivity (nominal)					
20 pC/bar (1.38 pC/psi)				•	•
35 pC/bar, (2.4 pC/psi)	•		•		
45 pC/bar (3.1 pC/psi)		•			
Linearity					
≤ ± 0.3% FSO (0-250 bar, 0-3625 psi)	•	•	•		
≤ ± 0.5% FSO (0-300 bar, 0-4351 psi)				•	•
Operating temperature (continuous)					
-40 °C ... +350 °C (-40 °F ... +662 °F)				•	•
-40 °C ... +400 °C (-40 °F ... +752 °F)	•	•	•		
Sensitivity coefficient	$+1.5*10^{-5}$ °C^{-1}				
Internal insulation resistance	> 10^{13} Ω (25°C / 77°F)				
Acceleration sensitivity (typ.)					
axial ≤ 0.2 mbar/g (0.003 psi/g),		•			•
axial ≤ 1 mbar/g (0.015 psi/g)				•	
axial ≤ 1.3 mbar/g (0.019 psi/g)			•		
axial ≤ 2 mbar/g (0.03 psi/g), radial ≤ 0.2 mbar/g (0.003 psi/g)	•				
Shock resistance	>2000 g				
Natural frequency					
85 kHz	•				
90 kHz				•	•
92 kHz		•			
100 kHz			•		
Capacitance (nominal)					
7 pF pole/ground				•	•
8 pF pole/ground	•	•			
12 pF pole/ground			•		
Mounting torque	3 Nm	6 Nm			20-25 Nm
Housing material	Stainless steel, hermetically welded				

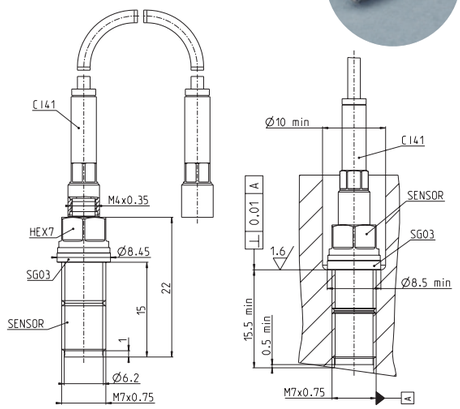
Dimensions	**P1-A1**	**P2-A1**	**P2-B1**	**P3-A1**	**P3-A2**
Type 1	•				
Type 2		T = M4x0.35	T = M3x0.35		
Type 3				•	
Type 4					•
Connector	M4x0.35	M4x0.35	M3x0.35	M4x0.35	M4x0.35

Piezocryst reserves the right to change specifications and accessories without notice.

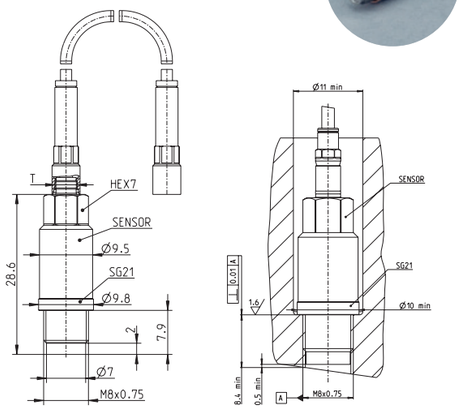
P-SERIES: P1-A1 P2-A1 P2-B1 P3-A1 P3-A2

↗ SENSOR AND MOUNT DIMENSIONS

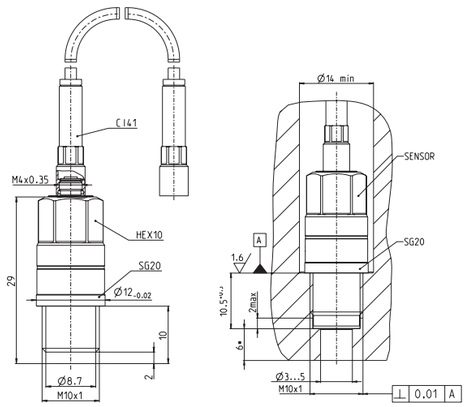
TYPE 1



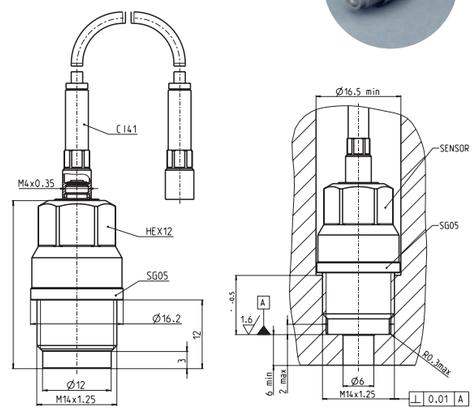
TYPE 2



TYPE 3



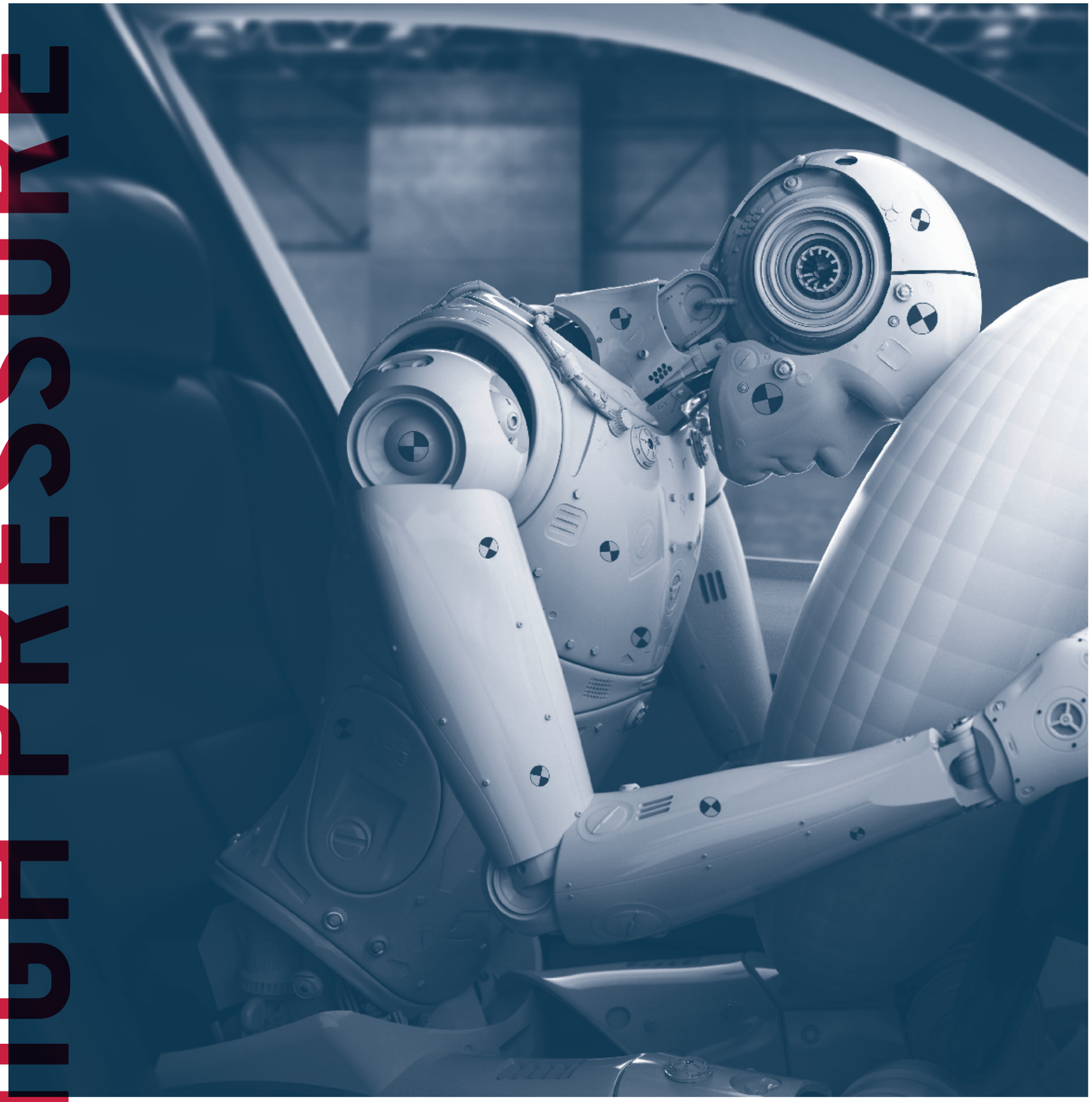
TYPE 4



↗ SCOPE OF SUPPLY

Sensor	✓
Cable	1-m Teflon™ cable
Coupling	M4x0.35 to BNC coupling
Gaskets	✓
Accessory kit	Protection cap and 2 spare O-rings
Calibration sheet	✓
Documentation	✓

OUR SENSOR FOR HIGH PRESSURE



↗ HIGH PRESSURE TRANSDUCERS FOR ACCURATE AND RELIABLE MEASUREMENT UNDER EXTREME PRESSURE CHANGES

Under extreme pressure change conditions, an extremely rigid sensor construction is required to prevent any disturbance due to hysteresis and the associated restoring forces. Piezocryst high pressure sensors are based on a load-stable crystal cut in the longitudinal mode. These sensors have a special Double Shell™ construction, which decouples the sensor from disturbances within the installation environment. In addition, due to the extreme need for compressive strength and thermal shock protection, the membrane must be made of high-performance alloys with very narrow tolerances to ensure the durability and signal quality. Another important factor in performance is the seal. Piezocryst has developed a special sealing system that will stay safely sealed under high-pressure gradients and mechanical shock conditions, while distributing the resulting forces so that the Double Shell™ housing is not subject to interference. This enables the user to obtain measurement results with a new kind of data quality.

The product range includes pressure sensors for measuring ranges up to 2000, 6000 and 8000 bar. All of these sensors have an M10 thread, so that measurements for different pressure ranges within one bore are possible.

↗ HIGH PRESSURE

Highest pressure – highest requirements

100°C

200°C

2.000 bar

HIGHLY RESISTANT MEMBRANE

To withstand the tremendous impact of shockwaves, the H-Series uses a reinforced membrane.

OPTIMSIED HOUSING

The reliable M8 mounting thread with mechanically decoupled DoubleShell housing minimises errors caused by mounting-induced stress.

$GaPO_4$

Is a material unlike any other piezoelectric material. Its lack of pyroelectricity (response to temerpature) makes it ideal for performing measurements under transient conditions.

FAST

The piezoelectric sensing principle allows for the use of the stiffest materials to resolve highly dynamic events, e.g. shockwaves.

↗ H-SERIES

Measuring ranges up to

8000 bar

116 000 psi

8.000 bar

H-SERIES

PRECISE MEASUREMENT OF EXTREME PRESSURE GRADIENTS

Piezoelectric High Pressure Sensor

- Highest pressure range up to 8000 bar (116,000 psi)
- Ideal for fast pressure gradients, i.e. shockwaves
- Outstanding temperature stability
- Highest durability and reliability

Measuring ranges up to 8000 bar 116,000 psi

The H-series sensors are piezoelectric sensors that have been designed to measure the most demanding dynamic pressure changes of up to 8000 bar. These changes are observed in the form of shockwaves caused by explosions or fast pressure drops in various media. The unique gallium phosphate ($GaPO_4$) single-crystal sensing elements are characterised by their superior sensitivity and linearity and are unaffected by temperature changes (no pyroelectricity). In combination with the high mechanical stiffness, the H-series is well-suited for performing reliable dynamic high pressure measurements and allows for the detection of small pressure variations throughout the whole pressure range.

The front sealing housing with a M10x1 mounting thread along with the clamp screw makes the sensors insensitive to different tightening torques and mounting conditions. Thus, the H-series provides a versatile and easy to mount high pressure sensing solution with long term stability.

↗ SPECIFICATIONS

	H-2	H-6	H-8
Operating principle	Piezoelectric based on $GaPO_4$ (gallium phosphate) sensing elements, charge output		
Dynamic measuring range	0-2000 bar (0-29000 psi)	0-6000 bar (0-87000 psi)	0-8000 bar (0-116000 psi)
Overload pressure	2200 bar (31900 psi)	6600 bar (95700 psi)	8800 bar (127600 psi)
Sensitivity (nominal)	5.2 pC/bar (0.36 pC/psi)	3 pC/bar (0.21 pC/psi)	2.3 pC/bar (0.16 pC/psi)
Linearity	< ±1 % FSO		
Operating temperature (continuous)	-55 °C ... 200 °C (-67 °F ... 392 °F)		
Thermal sensitivity shift	± 0.02 %/°C		
Internal insulation resistance	> 10^{13} Ω (20°C / 68 °F)		
Acceleration sensitivity (typ.)	axial ≤ 2 mbar/g (0.03 psi/g), radial ≤ 5 mbar/g (0.07 psi/g)		
Rise time	< 1 µs		
Shock resistance (axial / radial)	25,000 g / 10,000 g		
Natural frequency	> 240 kHz		
Capacitance (nominal)	8 pF pole/ground		
Mounting torque	20 Nm		
Housing material	Stainless steel, hermetically welded		
Weight	~ 12 g		

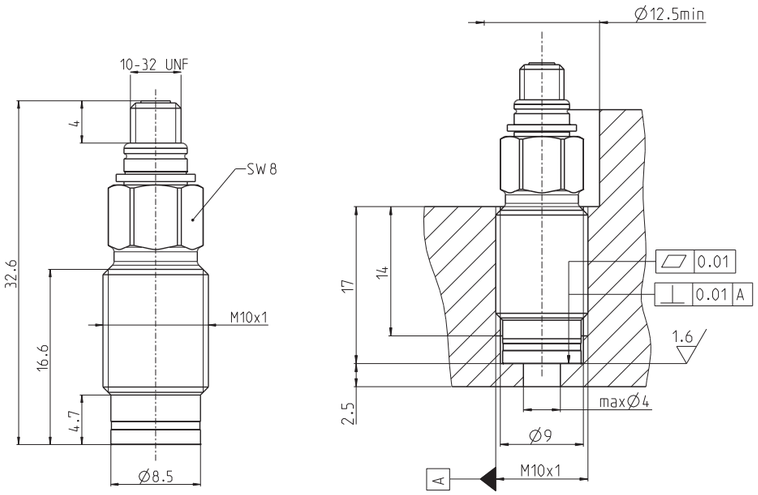
↗ SCOPE OF SUPPLY

Sensor and 5 pcs sealing rings	✓
Cable	1 m Teflon™ coated with 10-32 UNF connector incl. BNC coupling
Test record, documentation	✓

↗ ACCESSORIES

Cable	0.5-10-m Teflon™ coated with M4x0.35 or 10-32 UNF connector
Sealing rings	Sets á 5 pcs
Mounting tool	Socket to mount sensor with attached cable in bore, torque wrench
Other	Membrane protection, silicon grease

↗ SENSOR AND MOUNT DIMENSIONS



MATCHING CABLES FOR EACH SENSOR

Piezo Input Cables

Piezo input cables are high-performance low-noise co-axial cables for connecting piezoelectric sensors to a charge amplifier. The additional carbon layer between the dielectric and shield reduces the triboelectric noise due to vibrations and cable movements.

Type	CI41	CI42	CI4V
Connector	M4x0.35 pos. - M4x0.35 pos.	M4x0.35 pos. - M4x0.35 pos.	M4x0.35 pos. - M4x0.35 pos.
Cable material	Teflon-coated	Metal shielded – Teflon-coated	Viton oil-proof
Max. temperature	200 °C	200 °C	200 °C
Cable diameter	2 mm	2.4 mm	2 mm
Mounting torque	0.5 Nm	0.5 Nm	0.5 Nm
Length	1 m, 2 m, 3 m	1 m, 2 m, 3 m	1 m, 2 m, 3 m
Sensor	S-series (Type 2, 3) P1-A1, P2-A1, P3-A1, P3-A2	S-series (Type 2, 3) P1-A1, P2-A1, P3-A1, P3-A2	S-series (Type 2, 3) P1-A1, P2-A1, P3-A1, P3-A2

Type	UCT		CI31	CI32
Connector	M4x0.35 pos. - 10-32 UNF		M3x0.35 pos. - M3x0.35 pos.	M3x0.35 pos. - M3x0.35 pos.
Cable material	Teflon-coated		Teflon-coated	Metal-shielded – Teflon-coated
Max. temperature	200°C		200°C	200°C
Cable diameter	2 mm		2 mm	2.4 mm
Mounting torque	0.5 Nm		0.5 Nm	0.5 Nm
Length	1 m, 2 m, 3 m	5 m, 10 m	1 m, 2 m, 3 m	1 m, 2 m, 3 m
Sensor	S-Series (Type 2, 3), H-Series P1-A1, P2-A1, P3-A1, P3-A2		S-Series (Type 1), P2-B1	S-Series (Type 1), P2-B1

Type	CI3V	CI33	CI37
Connector	M3x0.35 pos. - M3x0.35 pos.	M3x0.35 pos. - M4x0.35 pos.	M3x0.35 pos. - M4x0.35 pos.
Cable material	Viton oil-proof	Teflon-coated	Metal-shielded - Viton-coated
Max. temperature	200 °C	200 °C	200 °C
Cable diameter	2 mm	2 mm	2.4 mm
Mounting torque	0.5 Nm	0.5 Nm	0.5 Nm
Length	1 m, 2 m, 3 m	1 m, 2 m	1 m, 2 m, 3 m
Sensor	S-series (Type 1), P2-B1	S-series (Type 1), P2-B1	S-series (Type 1), P2-B1

Couplings

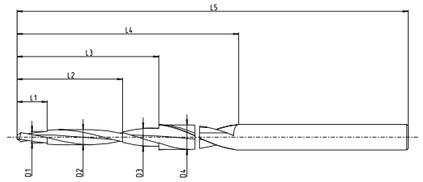
Various couplings for the connection of the piezo input cables to charge amplifiers with BNC connectors or for extending the range of the cables.

Type	E127M	CC21	CC31	CC41	CC42
Connector	10-32 UNF neg. - BNC pos.	M2 pos. - BNC pos.	M3 neg. - BNC pos.	M4 neg. - BNC pos.	M4x0.35 neg. - M4x0.35 neg.

Machining and Mounting Tools

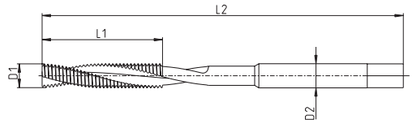
Specially designed step and tap drills to machine the mounting bore for the individual sensors are available. Especially if front-sealing sensors (S-series and T-series) are being used, precise machining of the sensor seat is required to guarantee proper sealing and highest performance up to the maximal pressure. To make it easier to install the sensors into the mounting bore and to ensure proper mounting torque, a collection of mounting sockets is available which are suited to mount the sensor with the attached cable.

↗ STEP DRILLS



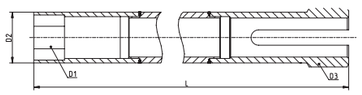
Type	Sensor	D1	D2	D3	D4	L1	L2	L3	L4	L5
MD10	–	6.3	–	8.5	–	20	–	215	270	–
MD11	S-series Type 2	3	4.5	7.5	–	10	19	134	190	–
MD12	S-series (B1,K1)	3	4.5	5.7	–	10	19	134	190	–
MD27	T-series	2	3.13	4.5	–	10	16	134	190	–
MD22	P1-A1	6.2	–	10	–	20	–	215	270	–

↗ TAP DRILLS

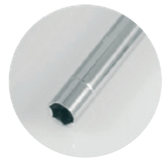


Type	Sensor	D1	D2	L1	L2
MT11	S-series Type 2 and 3	M5x0.5	6	14	200
MD12	S-series Type 1	M5x0.5	7.5	15	200
MT32	T-series	M3x0.35	4.5	15	200
MT21	P1-A1	M7x0.75	8	19	250
MT31	P1-A1	M10x1	10	20	250

↗ MOUNTING SOCKETS



Type	Sensor	D1	D2	D3	L
TT01	S-series Type 2, 3	HEX5.5	7.3	HEX8	220
TT21	S-series Type 1	HEX4	5.6	HEX8	220
TT66	T-series	HEX3	4.5	HEX8	220
TA13	H-series	HEX8	11.5	HEX12	200
TT11	P1-A1, P2-A1, P2-B1	HEX7	9.5	HEX8	250
TT07	P3-A2	HEX12	15.8	HEX16	250
TA16	P3-A1	HEX10	13.8	HEX14	139



↗ GASKETS

Shoulder-sealing sensors use gaskets as sealing between the sensor and mounting bore. The use of optimised gasket materials reduces additional stress due to thermal expansion and guarantees the best sensor performance over the entire lifetime.

Type	Sensor	Quantity
SG25	H-2, H-6	5 pcs
SG26	H-8	5 pcs
SG03	P1-A1	5 pcs
SG21	P2-A1, P2-B1	1 pc
SG05	P3-A2	5 pcs
SG20	P3-A1	5 pcs
SG01	S-serie Type 3	1 pc

↗ DUMMY PLUGS

If the sensor is unmounted, the port can be closed with a dummy plug. For deep bores a dummy removal tool is available.

	For Sensor	Removal Tool
DG01	S-series Type 2	TD01
DG04	P1-A1	TD01
DG09	P2-x1	TD01
DG11	P3-A1	TD01
DG12	P3-A2	TD01
DG24	S-series Type 1	TD13
DG41	T1-x1	TD41

↗ MOUNTING ADAPTER

Mounting adaptors are used to install a smaller sensor into existing or large mounting bores. More adapters are available upon request.

	Sensor	Mounting Bore	Recommended Torque
MA01	S-series Type 1 and 2	P2-x1	6 Nm
MA02	S-series Type 1 and 2	P3-A1	10 Nm
MA03	S-series Type 1 and 2	P3-A2	20 Nm
MA04	P2-x1	P3-A2	20 Nm

↗ CABLE MOUNTING TOOLS

TC01	M4×0.35 with HEX4
TC02	M3×0.35 with HEX3.5
TC21	M2×0.25 without HEX

↗ TORQUE WRENCH

TT02	1/4" socket incl. 1/4" SQR drive TT36 (DIN3120), Torque range: 0.5-4.5 Nm

Accessories Overview

Mounting Adaptor

Dummy Plug

Machining Tools

Standard Tools

Mounting Tools

Gaskets

Sensor	Cables													Dummy Plugs								Dummy Removal Tool			Mounting Adapters			
	CI04	CI21	CI31	CI32	CI33	CI37	CI38	CI3V	CI41	CI42	CI4V	UCT	DG01	DG04	DG09	DG11	DG12	DG24	DG41	TD01	TD13	TD41	MA01	MA02	MA03	MA04
T1-x1		✓																	✓			✓						
Sx-x1			✓	✓	✓	✓	✓	✓										✓			✓		✓	✓	✓		
Sx-x2									✓	✓	✓	✓	✓							✓			✓	✓	✓		
S1-B3			✓	✓	✓	✓	✓	✓																				
S2-K3									✓	✓	✓	✓											✓	✓	✓			
P1-A1									✓	✓	✓	✓		✓						✓								
P2-A1									✓	✓	✓	✓			✓					✓						✓		
P2-B1			✓	✓	✓	✓	✓	✓							✓					✓						✓		
P3-A1									✓	✓	✓	✓				✓				✓								
P3-A2									✓	✓	✓	✓					✓			✓								
H2, H6	✓																											
H8	✓																											

*for aluminium, cast iron or standard steel

CC42

CI21

CC21, CC31, CC41

CI31

CI41

CI32

CI42

CI3V

CI4V

	Step Drills*					Seat Dressing Tool*		Tap Drills*					Gaskets							Cable Mounting Tools			Mounting Sockets								Torque Wrench
	MD11	MD12	MD22	MD26	MD27	MR01-85	MR01-180	MT11	MT12	MT21	MT31	MT32	SG01	SG03	SG05	SG20	SG21	SG25	SG26	TC01	TC02	TC21	TT01	TA16	TA13	TT07	TT11	TT21	TT66	TT02
					✓							✓										✓							✓	✓
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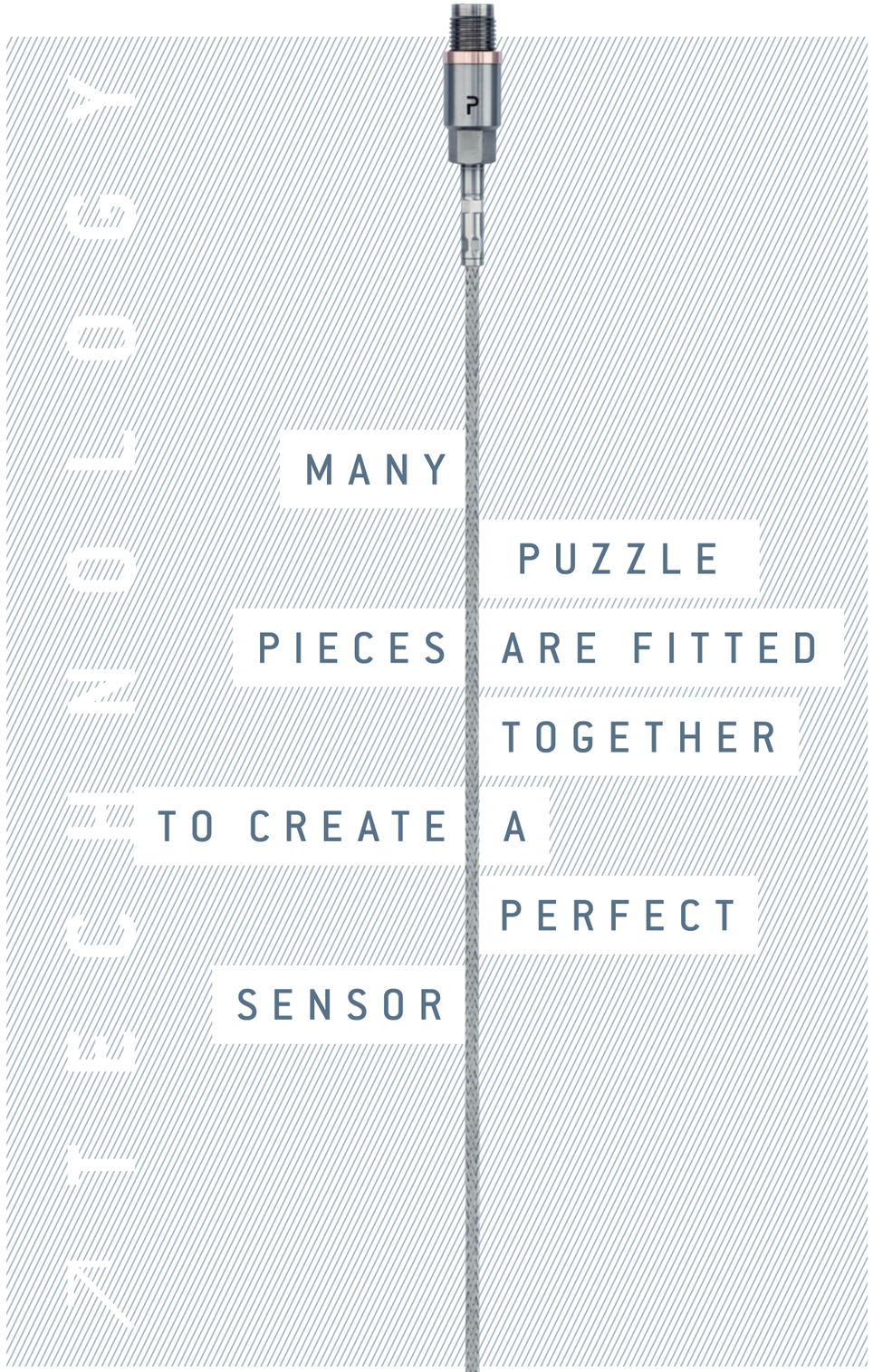
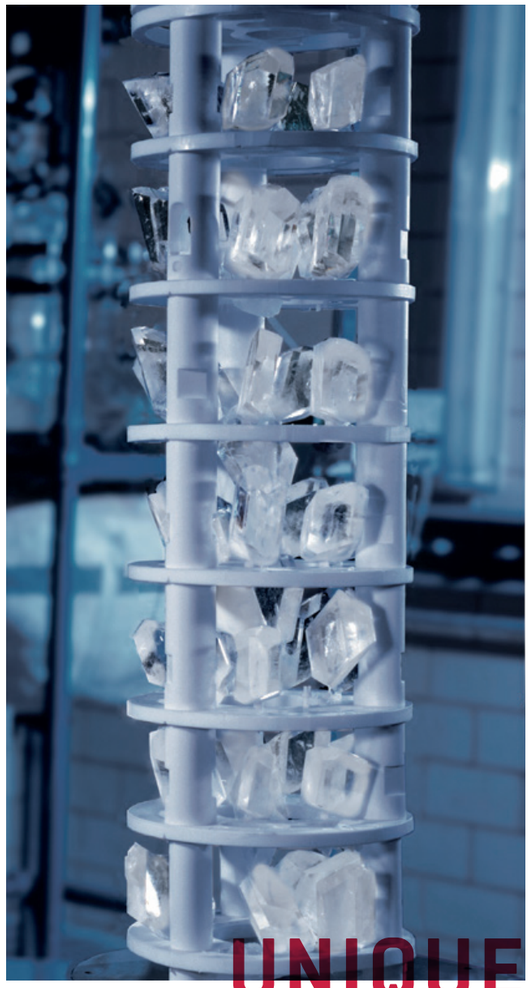




UNIQUE GaPO$_4$ CRYSTALS

↗ CRYSTAL TECHNOLOGY

- ✓ 100 % in-house crystal growth
- ✓ Cutting-edge manufacturing methods

Piezocryst is one of the few European companies to maintain their own crystal growth and processing facility, as well as the only company worldwide that can produce single-crystal gallium phosphate ($GaPO_4$). Unchanged, $GaPO_4$ is probably the most suitable material for high performance piezoelectric sensors, particularly when high temperatures come into play.
$GaPO_4$ is not pyroelectric, it has absolute linear temperature-dependent sensitivity, and its high and uniform rigidity allows for near-perfect sensor behaviour. Another advantage is the extremely high internal resistance of the material. This is significantly better than that of other piezoelectric materials and particularly at higher temperatures, it enables new sensing possibilities.

Piezocryst manufactures crystal elements in a highly complex process. First, the single crystal $GaPO_4$ is examined in order to detect the smallest impurities in the crystal by using an optical scanning process. Then, pure $GaPO_4$ is processed mechanically by using tight angular tolerance to produce sensing elements with defined mechanical and sensing properties. Each of these sensing elements is visually inspected for perfect corner and edge qualities, and only top quality elements are utilised in the sensors. This process is responsible for the high signal quality and the low serial production variation in Piezocryst sensors, but also contributes significantly to a longer product lifetime.

SUB-MICRON TOLERANCES AND ELECTRON BEAM WELDING: A PIECE OF CAKE

↗ JOINING TECHNOLOGY

In Piezoelectric sensors - and especially in high-end sensors - the surface quality and plane parallelism of all elements within the line of force affect the measurement properties. Inevitably, high demands are placed on the joining technology. Welds must be continuous and gas-tight, must connect totally different materials together, and must be absolutely reproducible with all respects, such as in terms the shrinkage or a change in the grain size of the joined materials. To meet these requirements, Piezocryst uses electron beam technology in addition to laser and pulsed-arc welding. This allows us to produce well-defined and low-tolerace welds with high demands on depth-to-width ratio.

To guarantee the quality of these challenging welds, controls are regularly carried out during the production process. Serial parts are sanded and etched, and the welds are measured and checked for conformity under a microscope. This is crucial to ensure the high signal quality and the low variation of Piezocryst sensors and contributes significantly to their long product lifetimes.

↗ PRECISION MANUFACTURING

In order to continually ensure the highest product quality in sensors, Piezocryst manufactures almost all parts in-house. The special challenge lies not only in creating tiny sensors that comply with the extremely tight ranges of tolerance (for example, the height tolerances are often in the sub-micrometer range), but also in the fact that the components are manufactured from difficult-to-machine nickel-based alloys. These alloys are as harden while they are being processed, and this cannot be rectified. In addition, some of these materials harden at the time of processing and cannot be rectified. Many components are 100% controlled to meet our high quality standards. To ensure the highest measurement accuracy, special precision machines operated exclusively by highly qualified staff are used in the manufacturing process.

- Precision processing with accuracies down to 0.2 µm
- Coating technologies for noble metals, ceramic layers and conductive ceramics
- Laser and electron beam welding processing, assembly in a cleanroom by specially trained personnel
- 100% quality check of all critical parts and the use of sophisticated calibration and testing processes
- All critical parts are manufactured in-house to ensure the highest quality
- All production staff have completed 4.5 years of full-time in-house special training before being involved in the production of parts for customers

NOBLE METALS, INSULATING AND CONDUCTIVE CERAMICS

↗ COATING TECHNOLOGY

Within a piezoelectric sensor, small charge amounts are generated during the operating that must be transported to the amplifier without loss. This is a particular challenge in the area of high temperature sensor systems, because the insulation resistance of insulating materials significantly decreases at high temperatures. Since the chemical reactivity of the materials increases substantially as the temperature increases, all coatings must be extremely robust and resistant to corrosion.

Piezocryst has developed its own coating technology, which allows the application of a wide variety of coatings with specific properties. In simple terms, surfaces must be made so that they are either conducting or non-conducting, but in many cases surfaces are also chemically passivated. The required coating technology includes different materials. These are of high quality, but are also expensive, such as gold or platinum. In addition, ceramic insulating layers a few nanometers thick can be used.

↗ ASSEMBLY

In order to achieve the best properties and the lowest possible sensor failure rates, piezoelectric sensors must be assembled in an absolutely dust-free environment. Even the tiniest amounts of impurities could degrade the measurement properties and reduce the product lifetime in extreme cases. To rule this out, every single component is cleaned in a complex series of processes and assembled to create the sensors in the cleanroom. Within this ultra-clean environment, only precision devices are used to accurately position the components. For some special applications, the humidity and dryness of the materials are controlled or specific atmospheres are created inside the sensors. By cleverly combining these features, it is possible to produce sensors with the lowest variation that meet the highest quality standards in terms of their accuracy and durability.

ASSEMBLY IN AN ABSOLUTELY DUST-FREE ENVIRONMENT

GOLD, PALLADIUM, PLATINUM: WHATEVER IT TAKES

↗ CALIBRATION

Every single piezoelectric sensor is calibrated before being shipped and is supplied with an individual calibration record. In special cases, the sensors are calibrated directly at the customer's location. Each calibration setup is performed in accordance with national and international standards, and each calibration result is stored on a secure server. This means that, even after many years of use, the calibration value of the sensor can still be compared to the original values. In order to achieve the most informative calibration results, critical sensors are pre-aged under realistic conditions and then calibrated after a run-in phase. For this purpose, Piezocryst maintains specific loading systems, such as test motors or high-temperature pressure-pulsation systems, with which the sensors are retracted.

↗ DESIGN AND MANUFACTURING SERVICES

HIGH PERFORMANCE COMPONENTS

Piezocryst also offers design and manufacturing services in the area of precision mechanics, optics and other specialised components. Our expertise with materials, joining and coating technology, and design enables us to ensure that these components will meet highest demands in terms of their reliability and performance.

Aspects of this work include:

- Analysis of existing concepts or components to identify possible vulnerabilities, and based on that, the development of improved designs
- The development of concepts suitable for mass production (technically and commercially) and the selection of appropriate production technology
- A comparison of different materials or material pairings with respect to their suitability regarding the specific requirements
- The design and construction of prototypes
- Testing and evaluation of prototypes in laboratory and field installations
- The identification and evaluation of important properties by performing simulation and other studies (stress, temperature and load resistance, media compatibility, acceleration sensitivity, natural frequency, thermodynamic behavior, etc.)
- Calibration and testing in Piezocryst testing facilities, including accelerated life tests with respect to temperature, acceleration, pressure, force, etc.
- The development of new testing systems for accelerated life testing
- Specific end-of-line tests and logistic arrangements

↗ CUSTOMISED SENSORS

TAILOR-MADE SOLUTIONS

In addition to offering general application-specific solutions, Piezocryst also offers customised piezo sensors. Together with our partners and customers, we analyse the specific application and propose solutions that ideally meet cost requirements and maximise benefits. We consider it particularly important to achieve a balance between maximising the signal quality and ensuring a long product lifetime and thus high reliability. For this purpose, Piezocryst can draw on a wide range different technologies, which can be specifically combined to develop the ideal product.
In addition to the sensor itself, all necessary accessories are also considered in the development process. In addition to perfect-cabling (separable / waterproof / oil-tight / high-temperature resistant / metal-reinforced / plug-in), the charge amplifier is included in the design process and tuned to meet the specific needs of the application.
Another key element is optimising the sensor mounting position to maximise product lifetime and potential signal quality. In this case, the application is examined to optimise the sensor placement regarding temperature, acceleration, undesirable forces and distortion, but also in terms of desired pretention. By carefully tuning these parameters, product lifetime can be significantly increased, and thus the best possible data quality can be ensured.

Tailor-made solutions are already possible in low annual numbers, and in many cases this is already economically feasible with starting quantities of 50-100 measurement chains per year.

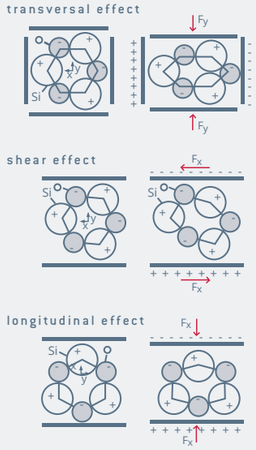
GLOSSARY

GENERAL

PIEZOELECTRICITY

A property of crystals or solids to accumulate charges in response to applied mechanical stress. In crystals, this is a property of the unit cell, depending on the composition of the crystal.

PIEZOELECTRIC EFFECT OF QUARTZ:



PYROELECTRICITY

Depending on the crystal lattice, piezoelectric materials may also generate charges due to thermal gradients. $GaPO_4$ is not pyroeletric, as opposed to piezoelectric ceramics and, e.g. tourmaline.

INSULATION RESISTANCE

A high insulation resistance is crucial when measuring in the quasistatic mode for longer periods. The resistance between the signal leads and between the respective lead and the shield (housing) is measured for differential output designs. The insulation resistance decreases as the temperature increases, but $GaPO_4$ has also excellent qualities in this regard, enabling very low frequent measurements to be made at high temperatures. A common cause for an insulation resistance issue is contamination of the connector, in this case the connector has to be cleaned by a special treatment.

IN CYLINDER MEASUREMENT

Measuring the pressure inside internal combustion engines exposes the sensor to extreme pressure and thermal gradients, mechanical stress and vibration. Still, R&D applications have different requirements than onboard large engines or high performance racing engines, resulting in a wide variety of sensors.

SINGLE ENDED AND DIFFERENTIAL OUTPUT

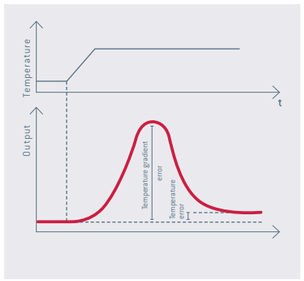
A common design used for piezoelectric sensors is the single-ended output. The signal is read between the sensor's housing and an inner isolated electrode, typically connected by a coaxial cable. A differential output has both outputs isolated from the sensor housing and, hence, this is also referred to as ground or case-isolated output.

TEMPERATURE ERROR

Because the mechanical properties of the sensor materials change as the temperature changes, deviations in the sensitivity also occur. This can be described by using a diagram or coefficient when relatively linear behaviour is observed.

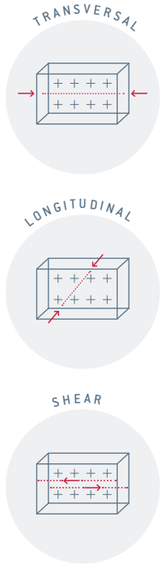
TEMPERATURE GRADIENT ERROR

A temperature change which increases the output signal. This effect is especially high if the piezoelectric material is also pyroelectric.



SENSING MODES

The way the crystal is cut affects how the charges appear on the surface, i.e. due to the way the force is applied, either in longitudinal direction or perpendicularly (transversal). Accelerometers often use shear mode, where charges are generated by a shear force on the crystal.



NATURAL FREQUENCY, RESONANCE FREQUENCY OR EIGENFREQUENCY

This is determined by the shape and material contants and, respectively, by the stiffness of the crystal elements (comparable to a spring) and the mass of the membrane or the seismic mass in accelerometers. It behaves like a mass-spring system with a strictly defined resonance frequency. Measurements can be made below or above the natural frequency.

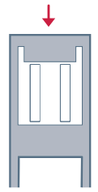
POPCORN OR PULSE NOISE

Spike-like signals that occur during temperature cycling or gradients due to intrinsic properties of some sensing materials (ceramics) or improper material and surface pairings (stick-slip effect).

PRESSURE SENSOR

PIEZOELECTRIC PRESSURE SENSORS

Piezoelectric pressure sensors transform pressure into charge in a direct physical way. The membrane converts the pressure into force, directly related to the charges released by the sensing elements.



As piezoelectricity is an intrinsic property of the crystal unit cell on the microscopic scale, this sensor principle can read smallest pressure deviations. At the same time, the extremely rigid crystal is in the direct line of force below the membrane. The main portion of the force is absorbed by the crystal itself and not by the delicate membrane, mitigating membrane fatigue and enabling static loads that exceed the measuring range by orders of magnitude. This results in extremely high resolutions. The pressure sensitivity depends on the size of the membrane (larger membrane -> higher force on sensing elements), number of stacked elements (in the longitudinal mode) or shape of elements (in the transversal mode), and, of course, the piezoelectric constant of the sensing material (high for ceramics, lower for crystals).

DYNAMIC (UNSTEADY) PRESSURE

Dynamic pressure is defined as a changing pressure where the rate of change over time is not zero. Dynamic pressure represents the pressure fluctuations around a certain pressure level (static pressure). It is the time variable component of the total pressure.

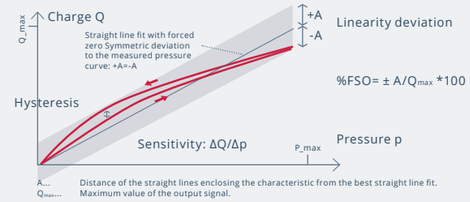
STATIC (STEADY) PRESSURE

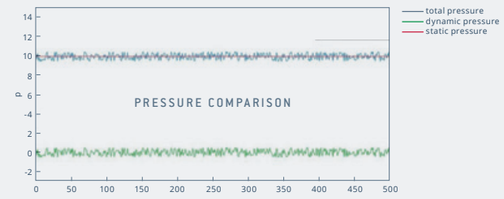
Non-varying pressure. It is therefore constant over time and is the base level of the total pressure. NOTE: For dynamic pressure measurements pressure with a rate of change below 2 Hz is referred to as static pressure.

LINEARITY [%]

Because the sensitivity defines how much signal is generated per pressure unit, we assume that this sensitivity is the same for all applied pressures. A variation in this context is defined by the term called linearity. The maximum deviation (+A, -A) is expressed as a percentage of the maximum pressure within the measuring range which is called full-scale output (FSO). This value should be as close to zero as possible. Piezocryst uses at least square linearity with a forced zero level.

SENSITIVITY, LINEARITY DEVIATION AND HYSTERESIS OF A PIEZOELECTRIC SENSOR





TOTAL PRESSURE

The sum of static pressure and dynamic pressure.

ACCELERATION SENSITIVITY

Vibration and acceleration exert an inertial force on the sensing elements due to the mass of the membrane. This force can be reduced in the axial direction by compensating for the acceleration, using additional sensing elements loaded with a seismic mass and internally connecting these, so that the acceleration signal is cancelled out false. Sensitivity is usually given in axial direction, if it is not stated separately.

FREQUENCY RANGE

In general, this is up to half the resonance frequency, but it can be limited by other factors. The lower value is determined by the electronics used and the measurement setup. Frequencies well above the resonance frequency can also be assessed. Gracing incidence causes damping at very high frequencies and large membrane sizes.

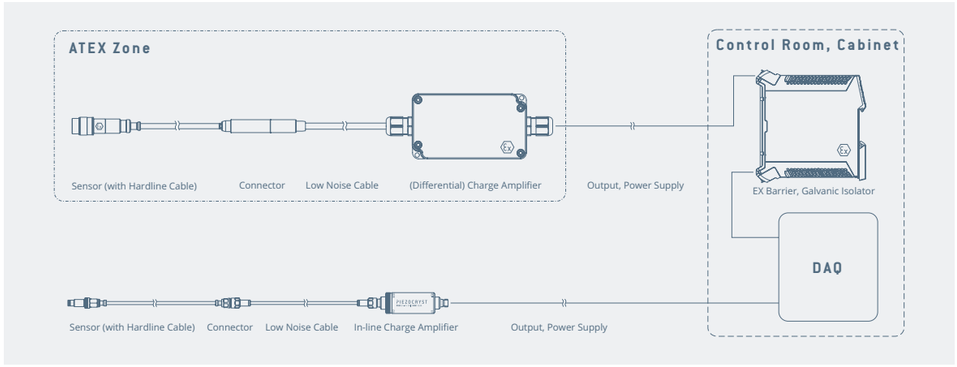
MOUNTING RESONANT FREQUENCY

The aerodynamically driven resonant frequencies that occur due to transducer mounting at the point of measurement, e.g. a recess/standoff pipe with the transducer mounted on the pipe termination results in organ pipe resonance. A formula to determine the frequencies can be found below. In the formula, L is the length of the recess and c is the speed of sound of the measured fluid. c varies mainly varies with temperature and density of the medium. f=c/4L [kHz]

GLOSSARY

PIEZOELECTRIC MEASUREMENT CHAIN AND SIGNAL

EXAMPLES OF TWO PIEZOELECTRIC MEASUREMENT CHAINS



LOW-NOISE CABLE

The construction with a dissipative layer and special materials reduces the generation of charges by triboelectricity (friction) from mechanical stress, resulting in lower noise levels. These cables are used to connect the sensor to the charge amplifier.

HARDLINE AND SOFTLINE CABLES

To withstand operating temperatures, some sensors have a metal integral cable, that is welded directly to the sensor. In a zone of lower temperature a softline low noise extension cable is connected.

NOISE

Any unwanted signal in the measurement system other than the desired output. Noise sources include thermal, acoustic, mechanical and electrical influences like ground loops.

HIGH-PASS FILTER AND TIME CONSTANT

An overload of the charge amplifier's reference capacitor, caused by the drift, is prevented by continuous discharge through the feedback resistor. A static signal decreases to the zero line in a characteristic discharge curve of a capacitor.

CHARGE AMPLIFIER WITH 4 – 20 mA OUTPUT

The charge amplifier is supplied by a current loop and modulates the current on the basis of the signal. The amplifier is not a current source; it only modulates the supplied current by its internal resistance. For dynamic signals, usually 12 mA corresponds to the zero level.

EX BARRIER AND GALVANIC SEPARATOR, GALVANIC ISOLATOR

Ex barriers like Zener barriers limit the amount of energy that can enter the circuitry in the Ex zone. Galvanic isolators sperate two circuitries in a way that no direct conduction path is available, which is also an effective way to break ground loops.

OUTPUT SIGNAL

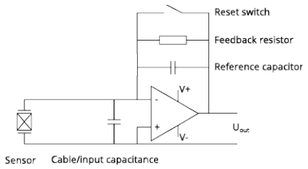
The output of the measurement chain is usually a voltage signal which is subsequently digitalised and processed. The frequency range of the output is defined by the charge amplifier. Due to mounting influences, noise and especially charge amplifier filters, the output signal often differs significantly from the physical signal.

RESOLUTION AND THRESHOLD

Resolution is usually referred to as the ratio between the smallest detectable signal (or threshold) and the full span. The threshold is the smallest change in the measurand or physical signal that results in a change of the electrical output. The sensor itself would detect even the smallest signals, so the noise level of the measurement chain is the reason for a certain threshold.

CHARGE AMPLIFIER

This is more accurately referred to as a charge converter, since charges are not amplified but converted to a current or voltage output. Charge amplifiers are the main reason for the drift of the signal, limiting the ability to measure static signals. This is either compensated by using a high-pass filter, respectively, time constant for continuous measurements or by performing a reset in quasistatic measurements.



Working principle of an amplifier with reset and feedback resistor

QUASISTATIC MEASUREMENT

High quality charge amplifiers with high internal resistance levels can be used to measure in a quasistatic mode for some time with only limited drift. Measurements lower than 0.1 Hz are considered quasistatic.

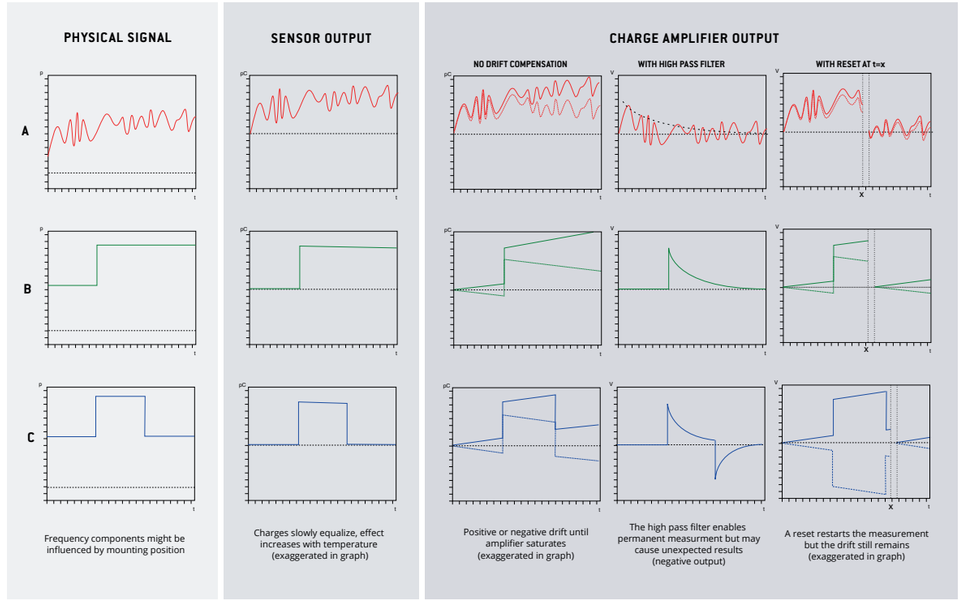
RESET

The reference capacitor is discharged, and the output signal is set to zero, by using a switch. This is used for quasistatic measurements or repetitive features, e.g. in process control.

OVERLOAD AND SATURATION

If the reference (range) capacitor of the charge amplifier is full or saturated, no further signals can be read. The device is in overload until the capacitor is discharged through the feedback capacitor or a reset.

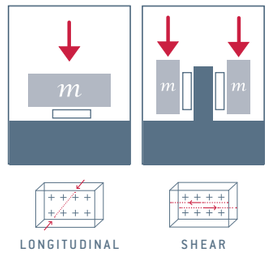
PHYSICAL SIGNAL, SENSOR OUTPUT AND CHARGE AMPLIFIER OUTPUT IN DIFFERENT OPERATING MODES



ACCELEROMETER

PIEZOELECTRIC ACCELEROMETERS

A seismic mass on a piezoelectric sensing element causes a signal that is proportional to the acceleration. The inertia of the mass results in mechanical stress that affects the elements when the housing is moved. Accelerometers are typically designed either in the bulk mode using the longitudinal or shear effect.



FREQUENCY RANGE

Lower value is determined by the electronics. For the higher limit, 5 % and 10 % deviation values are given, referring to the base sensitivity.

MOUNTED RESONANCE FREQUENCY

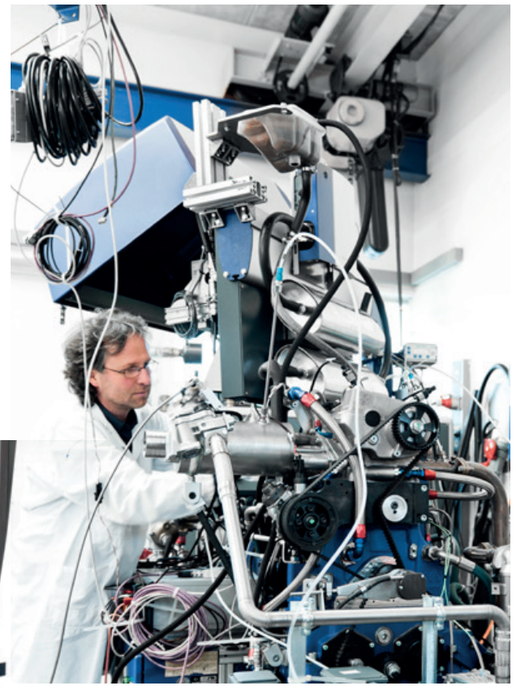
Since the seismic mass can have a significant weight compared to the housing, the resonant frequency of a free hanging accelerometer would differ from that of a mounted one (with the mass of the housing).

TRANSVERSE SENSITIVITY

Sensitivity in transverse direction of the measurement axis, usually given as % value.

TRANSVERSE SENSITIVITY

Sensitivity in the transverse direction of the measurement axis, usually given as a percentage.



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PIEZOCRYST

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