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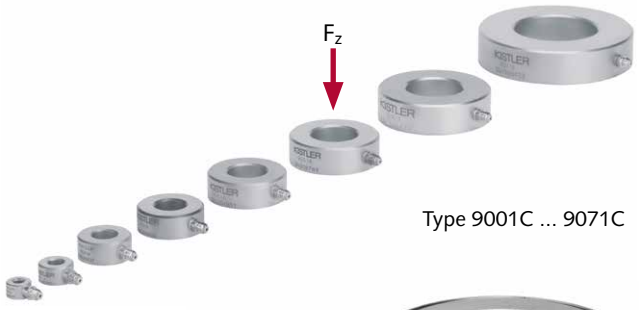
Piezoelectric force sensors

Types 9001C, 9011C, 9021C, 9031C, 9041C, 9051C, 9061C, 9071C, 9081B, 9091B

Piezoelectric ring force transducers for tensile and compression forces from 7.5 kN to 1 200 kN

Piezoelectric force sensors, also known as piezoelectric ring force transducers, for precise measurement of tensile and compressive forces in highest resolution.

- Two calibrated measuring ranges
- Linearity including hysteresis ≤±0.5%
- Extremely high stiffness
- Very compact design
- Extremely low threshold
- Degree of protection: IP68, dependent on cable
- Operating temperature range –70 ... 200°C
- No aging, unlimited service life



Type 9001C ... 9071C

Type 9081B, 9091B

Description

The 90x1 family is a piezoelectric (PE) sensor series for force measurement in the z-direction. The force to be measured is transferred directly to the quartz sensor element located within through the cover and base of the tightly welded steel case. When subjected to a mechanical load, quartz produces an electric charge that is proportional to that load. An outstanding property of quartz is the very low threshold and, thus, a high sensor sensitivity that remains extremely linear over the entire measuring range. Thus the behaviour in a certain measuring range is practically identical for all PE sensors, independent of their size.

This has three unique advantages:

- **Overload protection:** Even very small forces can be measured with a sensor with a large measuring range.
- **High stiffness:** To achieve a construction that is as stiff as possible, a larger sensor can also be used without negatively impacting the quality of the measurement signal.
- **Grouping:** Multiple sensors can simply be added together by electrically connecting them in parallel to a single charge amplifier. The output voltage is then proportional to the sum of all acting forces.

Application

A rugged design, reliability as well as good repeatability of the measurement values are the primary characteristics of these force sensors. Depending on the size of the force, quasistatic measurements can be performed over multiple minutes or hours, whereby the stability of the zero point is heavily dependent on the downstream charge amplifier.
Dynamic measurements (AC mode, peak-to-peak), on the other hand, can last any length of time. The measuring load washers have a practically unlimited service life

Application examples

- Forces in mounting technology
- Forces during spot welding
- Forces in presses
- Force changes in bolted joints under high static preload
- Impact resistance and fatigue strength
- Cutting and forming forces
- Braking and crash forces

9001C_003-421e-08.20

Technical data

Type		9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C	9081B	9091B
Nominal force	kN	7.5	15	35	60	90	120	200	400	650	1 200
Calibration preload	kN	1.5	3	7	12	18	24	40	80	130	240
Calibrated range 1	kN	0 … 6.0	0 … 12	0 … 28	0 … 48	0 … 72	0 … 96	0 … 160	0 … 320		
Calibrated range 2	kN	0 … 0.6	0 … 1.2	0 … 2.8	0 … 4.8	0 … 7.2	0 … 9.6	0 … 16	0 … 32	0 … 52	0 … 96
Calibrated range 3	kN									0 … 650	0 … 1 200
Maximum force	kN	10.5	21	49	84	126	168	280	560	715	1 320
Sensitivity	pC/N	–4.1±0,2	–4.2±0.2	–4.4±0.2						–2.15±0.2	–2.1±0.2
Linearity incl. hysteresis [1]	%FSO	±0.5								±1	
Natural frequency (free-free) [2], calc.	kHz	≥170	≥120	≥75	≥53	≥51	≥42	≥32	≥20	≥14	≥9
Axial stiffness (calc.)	kN/µm	1.1	1.6	3.3	5.2	7.5	9.8	15.4	27.7	35.7	52.3
Lateral stiffness (calc.)	kN/µm	0.20	0.31	0.74	1.3	1.8	2.4	3.9	7.6	9.2	12.9
Shear stiffness (calc.)	kN/µm	0.26	0.4	0.9	1.5	2.2	2.8	4.6	9.0	11.2	15.7
Torsional stiffness (calc.)	kNm/°	0.13	0.39	2.0	4.9	10	18	47	190	318	1 070
Bending stiffness (calc.)	kNm/°	0.13	0.9	2.02	5.2	11	21	55	217	381	1 311
Bending moment sensitivity Maximum bending moment [3] (Mz = 0), calc.	N·m	±5.3	±15	±61	±130	±244	±390	±800	± 2 443	±4 430	±13 260
Temperature sensitivity Sensitivity change (–70°C .. 200°C, Tref = 25°C)	%	±2.5									
Operating temperature range Sensor	°C	–70 … 200								–40 … 120	
Insulation resistance at room temperature (@23°C)	Ω	$\geq 1*10^{14}$							$\geq 1*10^{13}$	$\geq 1*10^{12}$	
Capacitance Sensor	pF	14	17	33	52	70	93	149	303	750	890
Connector type		KIAG 10-32 neg.									
Degree of protection (IEC 60529)	IP	See table, page 9									
Sensor material Cover plate		1.4821								1.4460	
Coat		1.4542								1.4057	
Weight Sensor	g	3	7	20	36	70	80	157	370	910	2 180

[1] Bandwidth relative to the calibrated ranges
[2] In the non-mounted state (not preloaded), the natural frequency is reduced by the installation conditions
[3] With a pretension of 50% of the **nominal force**

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Dimensions Type 9001C … 9071C

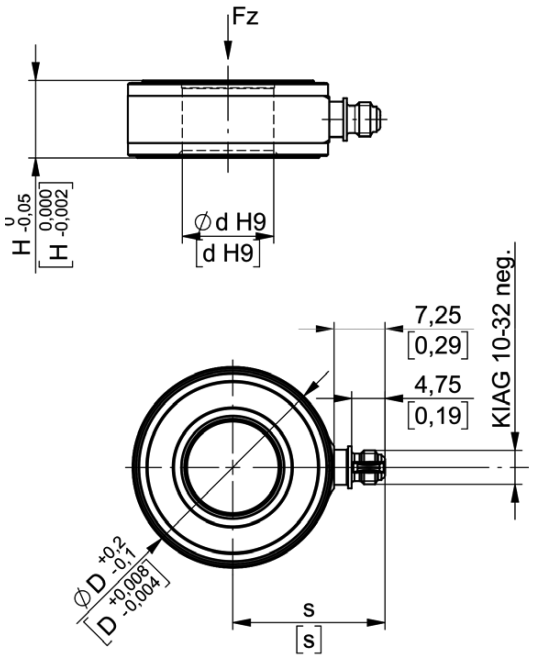

Fig. 1: Dimensions Type 9001C … 9071C

Dimensions

Type	d	D	H	s
9001C	4.1	10.3	6.5	12.75
9011C	6.5	14.5	8	14.85
9021C	10.5	22.5	10	18.6
9031C	13	28.5	11	21.65
9041C	17	34.5	12	24.65
9051C	21	40.5	13	27.65
9061C	26.5	52.5	15	33.65
9071C	40.5	77.2	17	45

Dimensions Type 9081B and 9091B

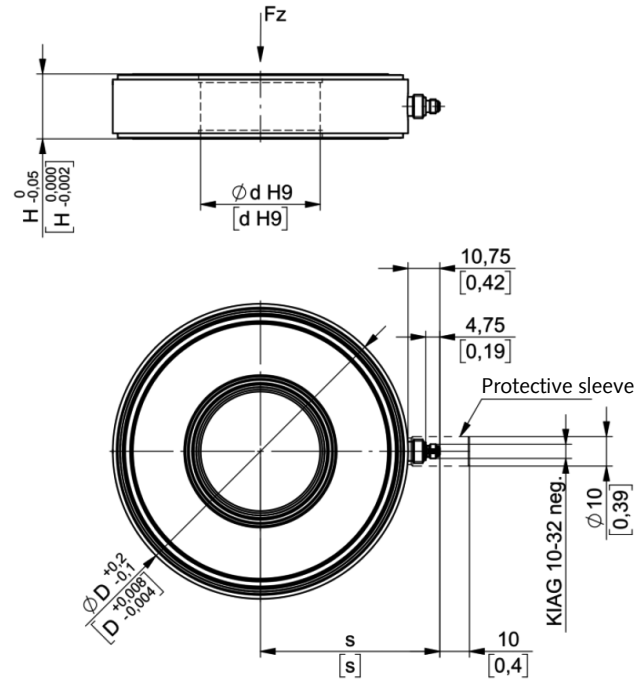

Fig. 2: Dimensions Type 9081B and 9091B

Dimensions

Type	d	D	H	s
9081B	40.5	100	22	60.75
9091B	72	145	28	83.25

Pretension

Piezoelectric force sensors are always used preloaded in a mounting structure. In general, a preloading force of at least 20% of the nominal force is recommended. The recommended, effective measuring range is thereby achieved and the design-related non-linearities in the lowest load range are eliminated.

Reasons for the pretension:

- Highest level of linearity and stability of the measurement signal.
- Measurement of tensile and compression forces, depending on the size of the pretension (see figure)
- Utilization of the high sensor stiffness for a large frequency range
- Ideal force distribution

The pretension must be selected so that the sum of preloading force (Fv) and the process force (±Fz) that arises lies within the measuring range of the sensor at all times (see graphic).
Provided it is technologically possible, the average loading of the sensor should be 50% of the nominal force. At this set point, the tolerance with respect to the bending moment is at its greatest (see below, "bending moment").
When pretensioning, the force must be measured with the sensor itself. The sensitivity specified in the technical data is to be used here. The mounting surfaces must be flat, stiff and, if possible, ground. A mounting kit Type 9422A is included in the delivery scope.

Sensor mounting

Force sensors Type 90x1C must always be mounted on flat, stiff and parallel surfaces under pretension, whereby the force should be uniformly distributed. In order to ensure this for a wide range of applications, Kistler offers an extensive range of mounting accessories.

Force transducers/load cells

The measuring load washer Types 9001C ... 9071C are also available ready for installation as pre-calibrated force transducers (Types 9301C … 9371C). They are ideal for measuring compression and tensile forces; recalibration after mounting is no longer necessary.

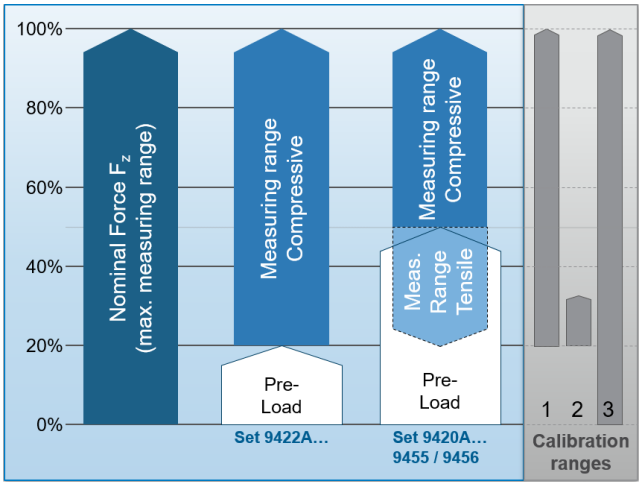

Fig. 3: Measuring and calibrated ranges

Calibration and measuring ranges

The expected error deviations of a sensor are directly dependent on the size of the measuring range and the choice of operating point. The smaller the measuring range the better the linearity and hysteresis. A sensor is typically pretensioned with 20% of the nominal force, which significantly improves the quality of the sensor. Depending on the size, the sensors of the 90x1 series are calibrated in two to three different ranges (see graphic).

A detailed instruction manual with further explanations on installation, dimensioning and wiring can be found in the download area of our website www.kistler.com.

Measurement directly in the force flux or as force shunt

Piezoelectric force sensors are used either directly in the force flux of a separate component or in the force shunt, embedded in a machine structure. With direct force measurement, most of the process force flows through the sensor. With force shunt measurements, on the other hand, it is loaded with only a small part of the process force.

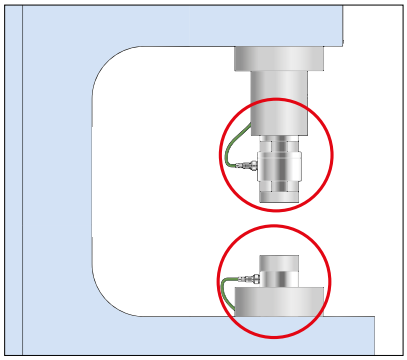

Fig. 4: Directly in the force flux

When mounted in force shunt mode, the ring force transducers can be used to solve a wide range of measurement problems. Through this arrangement, it is possible to measure process forces that exceed the specified nominal load many times over as only part of the force is applied to the sensor itself. The measuring range can thereby be expanded significantly, though with reduced sensitivity and, thus, with lower measurement accuracy. The mounting instructions are generally the same as in direct force flux, though the height tolerances must be very strictly adhered to. Furthermore, the sensor must absolutely be calibrated in the installed state!

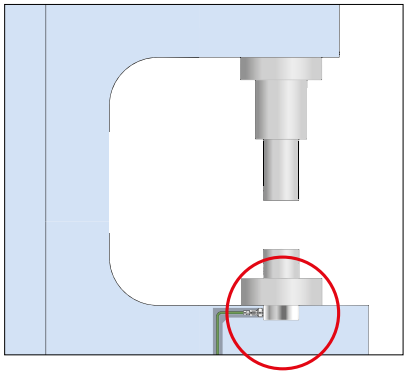

Fig. 5: Force shunt

Bending moment, torque, shear force

Shear forces Fx,y, bending moments Mx,y and torques Mz significantly reduce the measuring range of the sensor through the additional loading and, in the worst case, result in the destruction of the sensor.

Often, these forces cannot be completely avoided, which is why they must absolutely be taken into consideration when designing the measurement setup.

Torsion and shear forces are somewhat less critical: The higher the compression force Fz, the more shear force and torsion can be compensated. If designed improperly, the sensor will just deliver slightly incorrect measurement values.

The bending moment, however, results in an asymmetrical additional loading of the sensor. This can result in damage, even in the normal measuring range of Fz.

The highest permissible bending moment is reached at exactly one half of the nominal load.

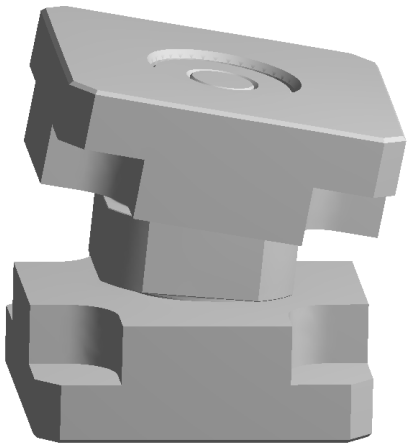

Fig. 6: Bending moment

Attention:
For more exact details and calculation examples, please consult the instruction manual of the corresponding sensor on our website www.kistler.com.

Preloading set Type 9420Ax1

Preloading set 9420Ax1 can be used to measure compression and tensile forces in an application. The set with centering sleeve (1) and high-strength preloading bolts (2) can handle a pretension of up to 50% and is designed for a minimal force shunt and ideal centering. At the same time, it ensures an optimum force application. With the included insulating washers (5), the entire sensor can be installed electrically neutral.

3) Washer
4) Hexagonal nut

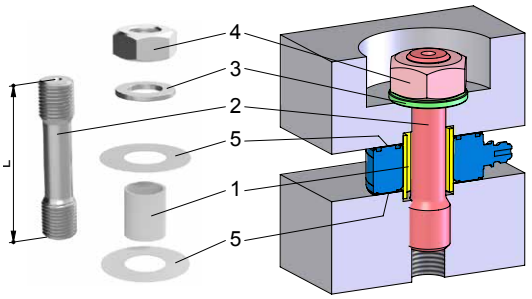

Fig. 7: Installation of preloading set Type 9420Ax1

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Preloading set	**Type**	**9420A01**	**9420A11**	**9420A21**	**9420A31**	**9420A41**	**9420A51**	**9420A61**	**9420A71**
Force shunt	%	≈10	≈7	≈8	≈9	≈8	≈7	≈7	≈7
Thread		M4x0.5	M5x0.5	M8x1	M10x1	M12x1	M14x1.5	M20x1.5	M27x2

Preloading screw Type 9422Ax1

Customers who only measure positive forces in the Fz direction (compression forces) require a lower preload. Ideal for them is set 9422Ax1, consisting of preloading screw (1) and centering clip (2). The screw can be preloaded with up to 30% of the rated range. Further accessories such as insulating washers can be ordered separately if necessary.

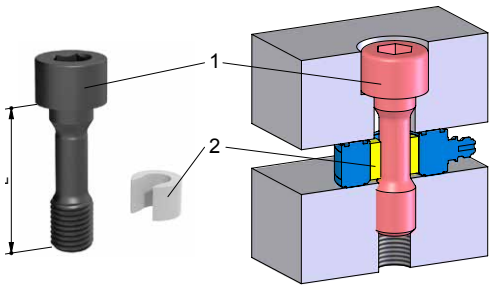

Fig. 8: Installation of preloading screw Type 9422Ax1

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Preloading set	**Type**	**9422A...**	**9422A...**	**9422A...**	**9422A...**	**9422A...**	**9422A...**	**–**	**–**
Force shunt	%	≈7	≈8	≈9	≈9	≈9	≈9		
Thread		M3x0.5	M5x0.8	M8x1.25	M10x1.5	M12x1.75	M14x2		

Preloading sets Type 9455 and Type 9456

With the preloading elements of Type 9455 and 9456, a preloading force of 400 kN (Type 9081B) and 600 kN (Type 9091B), respectively, can be achieved. Such high forces are typically applied hydraulically and can be performed if necessary as a service in the main factory in Winterthur, Switzerland.

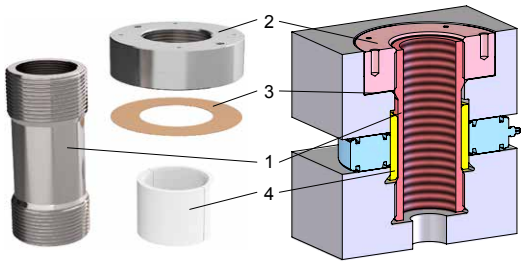

Fig. 9: Installation of preloading set Type 9455/9456

	Type	9081B	9091B
Preloading set	**Type**	**9455**	**9456**
Force shunt	%	≈9	≈9
Thread		M40x2.0	M64x3.0

Accessories

Force distributing ring Type 95x5

The contact surfaces must be just as flat and stiff as the contact surfaces of the sensor itself. If they cannot be finished, local overstressing and damage to the sensor surface must be prevented through the use of a force distributing ring (1).

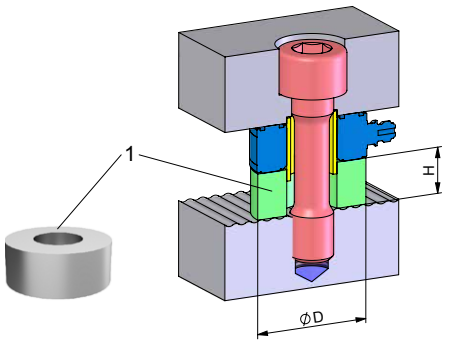

Fig. 10: Installation of force distributing ring Type 95x5

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Force distributing ring	**Type**	**9505**	**9515**	**9525**	**9535**	**9545**	**9555**	**9565**	**9575**
D	mm	10	14	22	28	34	40	52	75
H	mm	6	8	10	11	12	13	15	17
D	*in*	*0.39*	*0.55*	*0.87*	*1.1*	*1.34*	*1.57*	*2.05*	*2.95*
H	*in*	*0.24*	*0.31*	*0.39*	*0.43*	*0.47*	*0.51*	*0.59*	*0.67*

Force distributing cap Type 95x9

The force to be measured must be distributed evenly on the contact surface of the force transducer. If a concentrated application of force cannot be avoided, a force distributing cap (1) compatible with the sensor ensures an ideal distribution of force.

2) Centering pin
3) Allen screw

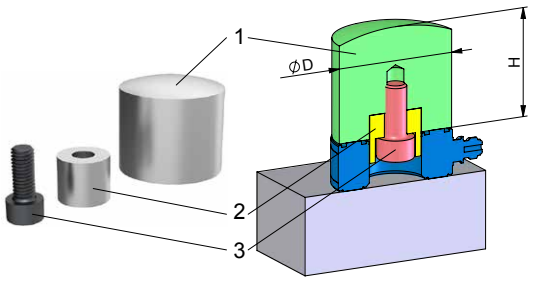

Fig. 11: Installation of force distributing cap Type 95x9

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Force distributing cap	**Type**	**9509**	**9519**	**9529**	**9539**	**9549**	**9559**	**9569**	**9579**
D	mm	10	14	22	28	34	40	52	75
H	mm	10	15	20	25	30	40	50	60
D	*in*	*0.39*	*0.55*	*0.87*	*1.1*	*1.34*	*1.57*	*2.05*	*2.95*
H	*in*	*0.39*	*0.59*	*0.79*	*0.98*	*1.18*	*1.57*	*1.97*	*2.36*

Spherical washer Type 95x3

If the surfaces cannot be made perfectly parallel, a spherical washer (1) must be used to compensate for this. A finished, even contact surface is still required, however.

H* = height at 0° parallelism

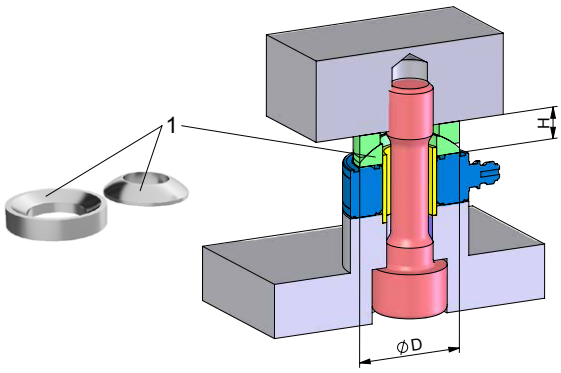

Fig. 12: Installation of spherical washer Type 95x3

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Spherical washer	**Type**	**-**	**9513**	**9523**	**9533**	**9543**	**9553**	**9563**	**9573**
D	mm		12	21	24	30	36	52	75
H	mm		4	6	7	8	10	14	20
D	*in*		*0.47*	*0.83*	*0.94*	*1.18*	*1.42*	*2.05*	*2.95*
S	*in*		*0.16*	*0.24*	*0.28*	*0.31*	*0.39*	*0.55*	*0.79*

Insulating washers Type 95x7

In case of interference due to ground loops or an electrical potential that differs between the measurement object and the amplifier, the sensor must be installed insulated. The insulating washer sets ensure a clean potential separation. In order to function correctly, the insulating washers should only be used once, and only on finished contact surfaces.

Fig. 13: Insulating washers Type 95x7

Attention

These insulating washers with collar can only be used where there are no built-in, continuous centering bushes.

	Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C
Insulating washer	**Type**	**–**	**9517**	**9527**	**9537**	**9547**	**9557**	**9567**	**9577**
D	mm		14	22	28	34	40	52	75
H	mm		1.125						
D	*in*		*0.55*	*0.87*	*1.1*	*1.34*	*1.57*	*2.05*	*2.95*
H	*in*		*0.0049*						

Measuring chain

Measure Connect Amplify

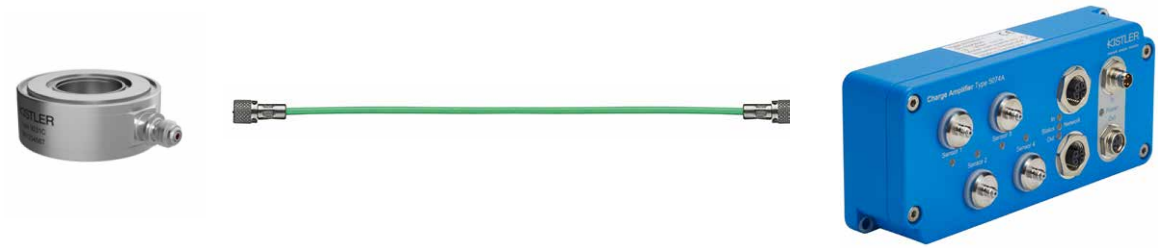

Fig. 14: Measuring chain

Connecting cable

All sensors of 9001...9091 feature a KIAG 10-32 neg. connection and are compatible accordingly with all KIAG 10-32 pos. cable connectors. Only high-insulation coaxial cables with low capacitance that produce only a very small amount of static electricity may be used as connecting cables for piezoelectric sensors. Kistler uses cables made of high-quality PFA or oil-proof FPM here.

On the sensor side, the IP protection class acc. to EN60529 is generally dependent on the used connector. For IP65, the standard 10-32 KIAG cable connector with knurled nut is used; for increased requirements in harsh environments, the industrial-suited 10-32 KIAG pos. int. version is used which, if necessary, can be tightly welded with the sensor case and IP68 achieved.

Compatibilities of cables and charge amplifiers

											Industrial Amplifier					Laboratory Amplifier					DAQ
											5030A	5039A	5073A...	5074A...	5877B...	5015A...	5018A...	5080A...	5165A...	5167A...	KiDAQ
										Channels	1	1	1-4	1-4	1	1	1	1-8	1,4	4,8	4, ... 52
Cable	Cable Properties	Length [m] min	Length [m] max	Temp. Range	IEC/EN 60529		Connector Sensor	Connector Amplifier	IEC/EN 60529		IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
1631C...	PFA	0.1	100	-55...200°C	Plug screwed	IP65	KIAG 10-32 pos.	BNC pos.	IP40	Plug screwed	-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1641B...	PFA	0.1	100				KIAG 10-32 pos. 90°	BNC pos.			-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1633C...	PFA	0.1	50				KIAG 10-32 pos.	TNC pos.	IP65		-	✓	✓	-	-	-	-	-	-	-	-
1635C...	PFA	0.1	15				KIAG 10-32 pos.	KIAG 10-32 pos.			✓	-	-	✓	-	-	-	-	-	-	-
1957A...	PFA, steel braiding	0.1	10				KIAG 10-32 pos.	KIAG 10-32 pos.			✓	-	-	✓	-	-	-	-	-	-	-
1900A23A12..	PFA superflexible, drag chain proven	0.3	20	-40...200°C		IP67	KIAG 10-32 pos. hex	BNC pos.	IP40		-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1900A23A11..							KIAG 10-32 pos. hex	KIAG 10-32 pos. hex	IP67		✓	-	-	✓	-	-	-	-	-	-	-
1900A21A120x	FPM flexible steel hose	0.4	20	-20...200°C			KIAG 10-32 pos. hex	BNC pos.	IP40		-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1900A21A110x							KIAG 10-32 pos. hex	KIAG 10-32 pos. hex	IP67		✓	-	-	✓	-	-	-	-	-	-	-
1983AD...	FPM	0.1	5	-20...200°C		IP68	KIAG 10-32 pos. int.	BNC pos.	IP40		-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1939A...	PFA	0.1	20	-55...200°C	Plug welded[1]	IP67	KIAG 10-32 pos. int.	BNC pos.	IP40		-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1941A...	PFA	0.1	20				KIAG 10-32 pos. int.	TNC pos.	IP65		-	✓	✓	-	-	-	-	-	-	-	-
1921...	PFA	0.1	20				KIAG 10-32 pos. int.	KIAG 10-32 pos.			✓	-	-	✓	-	-	-	-	-	-	-
1969A...	PFA, steel braiding	0.5	10				KIAG 10-32 pos. int.	KIAG 10-32 pos. int.[2]			✓	-	-	✓	-	-	-	-	-	-	-
1967A...	PFA, steel braiding, isolated	0.5	10				KIAG 10-32 pos. int.	KIAG 10-32 pos. int.[2]			✓	-	-	✓	-	-	-	-	-	-	-
1983AC...	FPM	0.1	5	-20...200°C		IP68	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.[2]	IP65		✓	-	-	✓	-	-	-	-	-	-	-

[1] screwed: IP65 [2] welded: IP67

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Charge amplifiers
Various criteria are decisive when selecting the right charge amplifier for a given application. Among the most important are the number of channels, the measuring range, the type of measurement and the frequency range. At this point, only a tabular summary is shown to provide an overview. More detailed information and explanations are available in the force product catalog and in the respective data sheets at www.kistler.com.

Digital laboratory amplifiers: LabAmp
The latest generation of universal laboratory charge amplifiers; with integrated data acquisition for dynamic or quasistatic measurements; network ready with web interface.

Fig. 15: LabAmp Type 5165A and Type 5167A

Analog laboratory amplifiers: Type 5015A, 5018A and 5080A
The proven analog charge amplifiers for laboratories and research. With very wide measuring range and high flexibility (Type 5080A).

Fig. 16: Laboratory charge amplifiers Type 5015A and Type 5080A

Industrial amplifiers
Size- and function-optimized amplifiers for continuous use in daily work. Bus-capable; some with further functions. (evaluation of force curves, etc.)

Fig. 17: Industrial amplifiers Type 5073A and 5074A (from left) At the right is the maXYmos BL Type 5867B…

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Included accessories	Type
• Special grease	1063
• Preloading screw for pretensioning 20% of the nominal force, including centering sleeve (only with sensors Type 9001C ... 9051C)	9422A01 … 9422A51

Optional accessories	
• Preloading element for pretensioning up to 50% of the nominal force, including mounting accessories	9420A01 … 9420A71
• Preloading element for big force sensors Type 9081 and 9091	9455, 9456

Mounting accessories (optional)	
• Force distributing ring for piezoelectric force sensor	95x5
• Spherical washer for piezoelectric force sensor	95x3
• Insulating washer for piezoelectric force sensor	95x7
• Force distributing cap for piezoelectric force sensor	95x9

Cables (optional)

- Connection and extension cables
  Data sheet for cables for force and torque sensors (1631C_000-346)

Ordering key

Type 90 □ C

Piezoelectric force sensor	
Range 0 … 7.5 kN	**01**
Range 0 … 15 kN	**11**
Range 0 … 35 kN	**21**
Range 0 … 60 kN	**31**
Range 0 … 90 kN	**41**
Range 0 … 120 kN	**51**
Range 0 … 200 kN	**61**
Range 0 … 400 kN	**71**

Type 90 □ B

Piezoelectric force sensor	
Range 0 … 650 kN	**81**
Range 0 … 1 200 kN	**91**

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