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Piezoelectric force sensor SlimLine

Types 9130C, 9132C, 9133C, 9134C, 9135C, 9136C, 9137C

Piezoelectric ring force transducers for tensile and compression forces from 3 kN to 80 kN

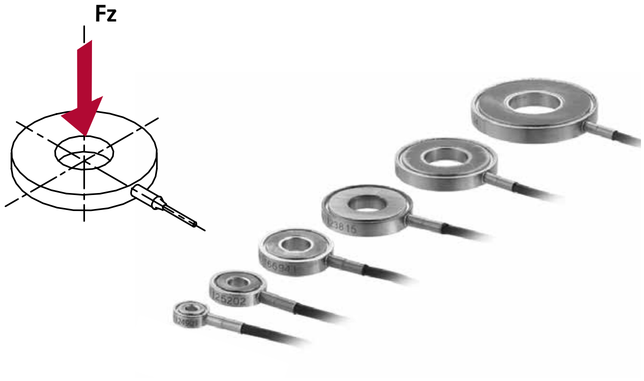
Piezoelectric force sensors, also known as piezoelectric ring force transducer, with extremely flat design for precisely measuring compression forces. Maximum resolution capacity, high stiffness and extremely compact dimensions enable ideal installation in mechanical structures. The case is hermetically sealed and has an integrated, splash-proof connecting cable with connector.

The piezoelectric force sensors SlimLine are supplied **uncalibrated** and must be calibrated in situ after mounting for absolute measurements.

- Extremely small size with large measuring range
- Flexible mounting in force shunt mode
- Also suitable for tensile forces when preloaded
- Measures practically free of displacement, wear and fatigue
- Measures even small forces with high resolution
- Sealed housing (IP65)
- Integrated, non-detachable cable with fluoroelastomer sheath

Description

The force F_z to be measured acts on the sensor via the preloaded or mounting structure and produces a charge that is directly proportional to the force. This is measured by an electrode and fed to the charge amplifier via the integrated cable.



Application

Because of their exceptional stiffness, SlimLine sensors are especially well suited for measuring dynamic forces. Cyclic measurements or measurements over several minutes are also possible, however. The sensor is especially well suited for measuring forces in shunt mode (Fig. 5). This means that the sensor is embedded and preloaded in a structure. As a result, it is loaded with only part of the process force.
Its especially small size is ideally suited for installation in structures such as force plates, fitting strips and tools. The sensor is used in industrial production processes in which forces are monitored or measured. Used in combination with a ControlMonitor, the sensor is ideal for quality control and monitoring.

Technical data

Type		9130C	9132C	9133C	9134C	9135C	9136C	9137C
Measuring range Fz	kN	0 … 3	0 … 7	0 … 14	0 … 26	0 … 36	0 … 62	0 … 80
Overload	kN	3.5	8	17	30	42	72	96
Preloading force (recommended) [1]	kN	0.6	1.4	2.8	5.2	7.2	12.4	16
Nom. sensitivity	pC/N	–3.7 ± 0.3	–4.0 ± 0.3		–4.3 ± 0.3			–4.0 ± 0.3
Nom. sensitivity with preloading set (approx. –8%)	pC/N	–3.4 ± 0.3	–3.7 ± 0.3		–4.0 ± 0.3			–3.7 ± 0.3
Linearity including hysteresis	%FSO	≤±1						
Max. bending moment M_{xy} max. (single load), calc.	N·m	1.4	4.9	15.4	35.0	62.2	134.5	195.7
Axial stiffness (calc.)	kN/µm	1.0	2.3	3.2	5.9	8.2	13.2	19.0
Lateral stiffness (calc.)	kN/µm	0.2	0.6	1.0	1.8	2.7	4.4	6.2
Shear stiffness (calc.)	kN/µm	0.3	0.8	1.2	2.1	3.0	4.9	6.9
Torsional stiffness (calc.)	N·m/°	52	263	853	2,348	4,812	12,174	23,997
Bending stiffness (calc.)	N·m/°	46	253	754	2,303	4,815	12,753	26,443
Insulation resistance	Ω	$\geq 1 \cdot 10^{13}$						
Operating temperature range ΔT	°C	–40 … 120						
Temperature coeff. of the sensitivity	%/°C	–0.02						
Plug connection		KIAG 10-32 neg.						
Degree of protection [2]	EN60529	IP65						
Case material	DIN	1,4542						
Mass	g	1	2	3	5	7	14	27

[1] The preloading force is to be adjusted according to the desired tensile/compression force range. The measuring range is thereby reduced proportionately

[2] The IP degree of protection acc. to EN60529 is determined with water. Oils, emulsions, cooling lubricants, etc., usually have a better wetting and penetration capacity. The degree of protection in contact with such liquids is to be classified lower accordingly.

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Application examples

- Monitoring of pressing forces, punching forces, etc.
- Tool monitoring
- Measurement of large forces in force shunt mode
- Installation in dynamometers with small dimensions

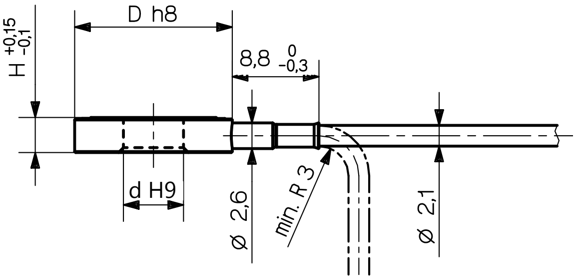

Fig. 1: SlimLine sensor dimensions

Sensor mounting

SlimLine sensors should generally be used only preloaded in a mounting structure:
- direct measurement in the force flux
- indirect measurement in force shunt mode

While most of the process force flows through the sensor with direct force measurement, with force shunt measurements it is loaded with only a very small part of the process force.

Direct measurement in the force flux

With direct force measurement, nearly the entire process force flows through the sensor. The measuring range must therefore be selected so that the sum of preloading force F_V and maximum occurring process force F_z is within the measuring range of the sensor. The mounting surfaces must be flat, stiff and ground (Fig. 3). The preloading bolt produces a force shunt of ≈7 ... 10% and a sensitivity that is reduced accordingly. In general, a preloading force of at least 20% of the measuring range is recommended; with tensile forces, proportionately more. If the process force permits, preloading of 50% of the measuring range should be used as the tolerance with respect to the bending moments is then at its greatest, see page 4.

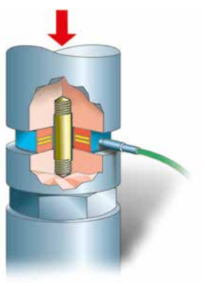

Fig. 2: Direct force measurement

Dimensions

Type	D [mm]	d [mm]	H [mm]
9130C…	8.0	2.7	3.0
9132C…	12.0	4.1	3.0
9133C…	16.0	6.1	3.5
9134C…	20.0	8.1	3.5
9135C…	24.0	10.1	3.5
9136C…	30.0	12.1	4.0
9137C…	36.0	14.1	5.0

Mounting dimensions

Mounting dimensions	Thread		Mounting bore	Plate thickness[1)]
Type	M	Pitch	d1 [mm]	A [mm]
9130C…	M2.5	0.45	2.9	8.0
9132C…	M4	0.7	4.3	8.0
9133C…	M6	1.0	6.4	12.0
9134C…	M8	1.25	8.4	16.0
9135C…	M10	1.5	10.5	20.0
9136C…	M12	1.75	13.0	24.0
9137C...	M14	2.0	15.0	27.0

1) Recommended minimum plate thickness

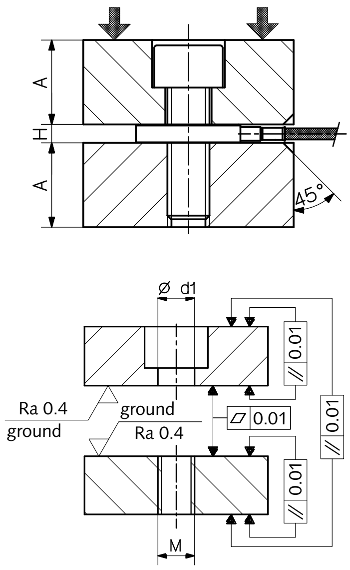

Fig. 3: Mounting dimensions for direct force measurement

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Force shunt measurement

When mounted in force shunt mode, the SlimLine sensor can be used to solve a wide range of measurement problems. The mounting surface must be flat and ground as finely as possible. The SlimLine ring force transducer is mounted preferably with a preloading disk from Kistler (optional accessory) and preloaded to approx. 20% of the measuring range. The structure and preloading disk are to be ground jointly, with the sensor mounted and preloaded. The slight projection P recommended for the preloading disk is achieved by removing the sensor and then again grinding over the structure one path with the same depth of cut. Such a procedure ensures a reproducible force shunt and good linearity.

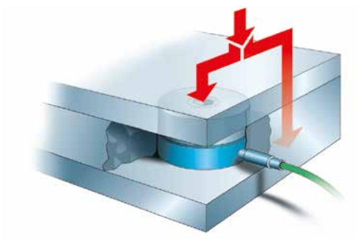

Fig. 5: Force shunt measurement

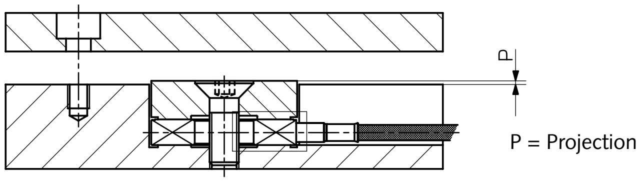

Fig. 6: Installation with preloading disk Type 9410A ...

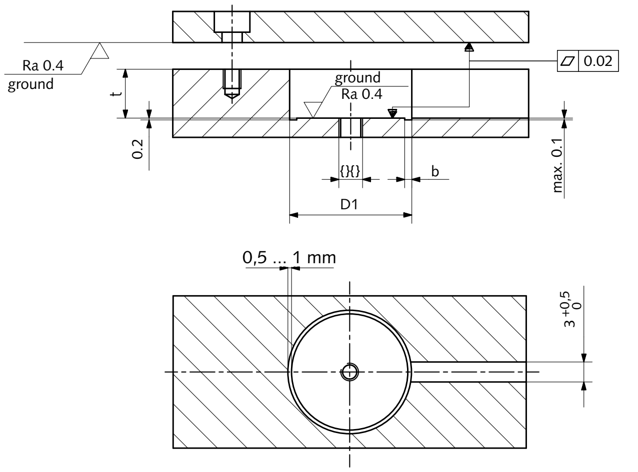

Fig. 7: Mounting in force shunt mode

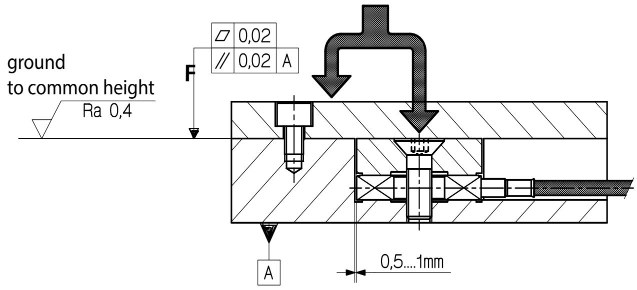

Fig. 8: Assembly with preloading disk Type 9410A…

Mounting dimensions

SlimLine sensor Type	Thread Ma	Bore diameter D1 [mm]	Bore depth t [mm]	Undercut b [mm]	Projection P [µm]
9130C...	M2	8.5	6.5	1.2	0 … 2
9132C...	M2.5	12.5	6.5	1.2	0 … 2
9133C...	M3	16.5	7.7	1.2	0 … 3
9134C...	M4	20.5	7.7	1.2	0 … 3
9135C...	M5	24.5	7.7	1.5	0 … 3
9136C...	M6	30.5	9.5	1.5	0 … 3
9137C...	M8	36.5	12.0	1.5	0 … 3

Preloading disk

Type	for SlimLine sensor	Thread	D2 [mm]	d2 [mm]	H1 [mm]	L [mm]
9410A0	9130C...	M2	8.0	2.7	3.50	8.0
9410A2	9132C...	M2.5	12.0	2.7	3.50	8.0
9410A3	9133C...	M3	16.0	3.2	4.25	10.0
9410A4	9134C...	M4	20.0	4.3	4.25	10.0
9410A5	9135C...	M5	24.0	5.3	4.25	10.0
9410A6	9136C...	M6	30.0	6.4	5.50	14.0
9410A7	9137C...	M8	36.0	8.4	7.00	16.0

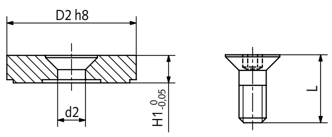

Fig. 9: Preloading disk with flat-head screw

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Bending moment

Bending moments can not only negatively affect the measurement but, in the worst case, can result in the destruction of the sensor. If the sensor is installed in a push rod or a press punch, however, bending moments can often not be completely avoided.

The permissible value for the bending moment M_b is dependent on the sum of preloading force F_p and currently applied process force F_z, whereby the maximum possible bending moment $M_{b,max}$ is reached at half of the range end value B (Fig. 4).

Maximum possible bending moment

Type	Range end value B [kN]	Max. possible bending moment $M_{b,max.}$ [N·m]
9130C...	3.0	1.50
9132C...	7.0	5.15
9133C...	14.0	15.00
9134C...	26.0	35.00
9135C...	36.0	62.00
9136C...	62.0	134.00
9137C...	80.0	244.00

With the table values for B and $M_{b,max}$, the permissible pure bending moment as a function of the preloading force F_p and process force F_z can be estimated as follows:

$$\text{(1a)}\quad M_{b,perm.} \le \frac{2 \cdot M_{b,max}}{B} \cdot (F_p + F_z) \qquad F_p + F_z \le B/2$$

$$\text{(1b)}\quad M_{b,perm.} \le \frac{2 \cdot M_{b,max}}{B} \cdot (B - F_p - F_z) \qquad F_p + F_z \ge B/2$$

In the bending moment graph, the equations (1) limit the range of the permissible bending moment as a function of F_p and F_z.

Bending moment graph

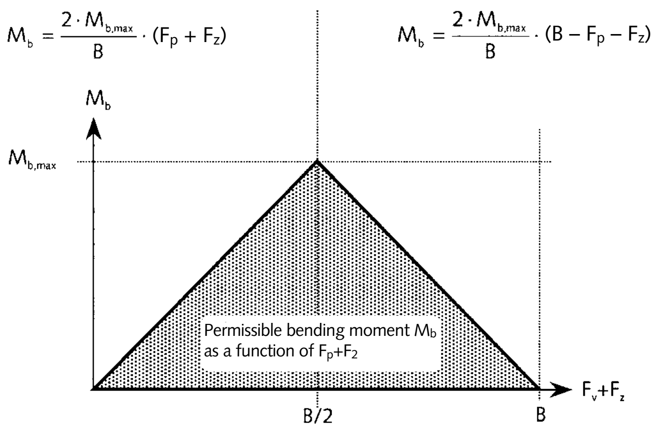

Fig. 4: Bending moment graph (pure bending moment)

Attention

If a bending moment $M_b = F_{x,y} \cdot h$ is produced by a lateral force $F_{x,y}$ at a distance h from the reference plane, this results in a shear force $F_{x,y}$ in the sensor plane. In this case, the maximum permissible bending moment is smaller than the permissible value for a pure bending moment determined according to the equations (1).

Example 1

A SlimLine sensor Type 9135C... is preloaded with F_p = 10 kN. What bending moment can be tolerated for process forces in the range F_z = 0 ... 12 kN?

$$F_p + F_{z,min} \le B/2$$
$$10\text{ kN} \le 18\text{ kN} \rightarrow \text{(1a)} \rightarrow M_{b,perm.} = \frac{2 \cdot 62\text{ N·m}}{36\text{ kN}} \cdot 10\text{ kN} = 34.4\text{ N·m}$$
$$F_p + F_{z,max} \ge B/2$$
$$22\text{ kN} \ge 18\text{ kN} \rightarrow \text{(1b)} \rightarrow M_{b,perm.} = \frac{2 \cdot 62\text{ N·m}}{36\text{ kN}} \cdot 14\text{ kN} = 48.2\text{ N·m}$$

To prevent an overload within the entire measuring range, the bending moment must not be greater than 34.4 N·m.

Example 2

A SlimLine sensor Type 9132C… is preloaded with 3 kN. How large is the measuring range B with a bending moment M_b of 2 N·m? By solving (1) for F_z, one obtains equations (2) with which the permissible measuring range B for the process force F_z can be calculated as a function of a bending moment M_b.

$$\text{(2a)}\quad F_{z,min} \ge \frac{B \cdot M_b}{2 \cdot M_{b,max}} - F_p$$

$$\text{(2b)}\quad F_{z,max} \le B \cdot \left(1 - \frac{M_b}{2 \cdot M_{b,max}}\right) - F_p$$

Inserting the values for B, $M_{b,max}$ and F_p yields the permissible measuring range for F_z:

from (2a) the max. tensile force F_z = –1.64 kN and
from (2b) the max. compression force F_z = 2.64 kN

Attention

Lateral loads $F_{x,y}$ and/or a torque M_z further reduce the measuring range.

Solving equations (2a) and (2b) for F_p, the minimum necessary or the maximum permissible preloading force can be calculated as a function of the other parameters.

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Compatible cables and charge amplifiers

Sensor/ Kabel/ Adapter	Cable Properties	Length [m] min	Length [m] max	Temp. Range		IEC/EN 60529	Connector Sensor	Connector Amplifier	IEC/EN 60529		Industrial Amplifier 5030A	Industrial Amplifier 5039A	Industrial Amplifier 5073A…	Industrial Amplifier 5074A…	Industrial Amplifier 5877B…	Laboratory Amplifier 5015A…	Laboratory Amplifier 5018A…	Laboratory Amplifier 5080A…	Laboratory Amplifier 5165A…	Laboratory Amplifier 5167A…	KiDAQ
										Channels	1	1	1-4	1-4	1	1	1	1-8	1,4	4,8	4, … ,52
											IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
913xC…	FPM, integrated	0.1	2	-55…200°C		IP65	-	KIAG 10-32 pos.	IP65	Plug screwed	✓	-	-	✓	-	-	-	-	-	-	-
1637C	*Extension cable, PFA, Ø2mm*	*0.3*	*5*	*-55…200°C*	*screwed*	*IP65*	*KIAG 10-32 neg.*	*KIAG 10-32 pos.*	*IP65*		✓	-	-	✓	-	-	-	-	-	-	-
1721	*Adapter for cables with KIAG 10-32 pos. int.*			*-55…200°C*			*KIAG 10-32 neg.*	*BNC pos.*	*IP40*		-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
1729A	*Cable gland with KIAG 10-32 pos. int.*						*KIAG 10-32 neg.*	*KIAG 10-32 neg.*	*IP65*		-	-	-	-	-	-	-	-	-	-	-

Feed-through cable Type 1729A

Cable	Cable Properties	Length [m] min	Length [m] max	Temp. Range		IEC/EN 60529	Connector Sensor	Connector Amplifier	IEC/EN 60529		Industrial Amplifier 5030A	Industrial Amplifier 5039A	Industrial Amplifier 5073A…	Industrial Amplifier 5074A…	Industrial Amplifier 5877B…	Laboratory Amplifier 5015A…	Laboratory Amplifier 5018A…	Laboratory Amplifier 5080A…	Laboratory Amplifier 5165A…	Laboratory Amplifier 5167A…	KiDAQ
										Channels	1	1	1-4	1-4	1	1	1	1-8	1,4	4,8	4, … ,52
											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]			✓	-	-	✓	-	-	-	-	-	-	-
1979A…	FPM	0.1	20	-20…200°C			KIAG 10-32 pos. int.	Fischer 9-pole neg.			-	-	-	-	-	-	-	-	-	-	-
1983AC…	FPM	0.1	5			IP68	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.[2]	IP65		✓	-	-	✓	-	-	-	-	-	-	-

[1] screwed: IP65

[2] welded: IP67

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Optional accessories	**Type**
• Preloading disk for SlimLine sensor Type 9130C…	9410A0
• Preloading disk for SlimLine sensor Type 9132C…	9410A2
• Preloading disk for SlimLine sensor Type 9133C…	9410A3
• Preloading disk for SlimLine sensor Type 9134C…	9410A4
• Preloading disk for SlimLine sensor Type 9135C…	9410A5
• Preloading disk for SlimLine sensor Type 9136C…	9410A6
• Preloading disk for SlimLine sensor Type 9137C…	9410A7
• Coupling KIAG 10-32 neg. – BNC pos.	1721
• Coupling KIAG 10-32 neg. – KIAG 10-32 neg.	1729A

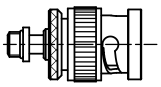


Fig. 10: Coupling Type 1721

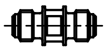


Fig. 11: Coupling Type 1729A

For further compatible products please check our webpage www.kistler.com/force.

Ordering key

Type 913 ☐ C ☐

☐

Measuring range

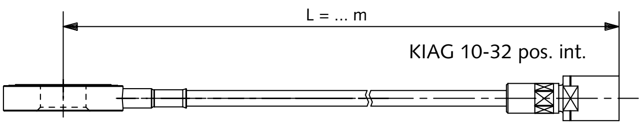
0 … 3 kN	**0**
0 … 7 kN	**2**
0 … 14 kN	**3**
0 … 26 kN	**4**
0 … 36 kN	**5**
0 … 62 kN	**6**
0 … 80 kN	**7**

With KIAG 10-32 pos. integrated	**2**

Cable length L = 2 m (standard)	**1**
Customized cable length 0,1 ... 2 m	**9**

Cable length has to be specified separately when placing the order.

Plug connection:



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Further information

Piezoelectric force sensor SlimLine kit

Two, three or four SlimLine force sensors are grouped into a sealed (IP65) plug connection with an individually selected cable length. Signal recording can be performed as summation signal (parallel connection) or as single signal. Further information can be found on www.kistler.com/force.

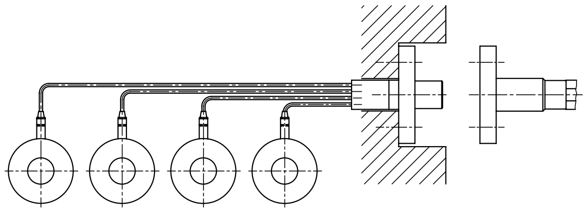

Fig. 12: Piezoelectric force sensor SlimLine kit

Piezoelectric load cells SlimLine

The calibrated SlimLine force transducers Types 9173C… to 9176C… are suitable for the measurement of tensile and compression forces. The SlimLine sensors are mounted ground-isolated in preloading elements. For further information check www.kistler.com/force.

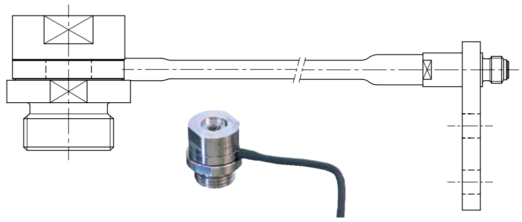

Fig. 13: Piezoelectric load cell/force transducer