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Load Washers

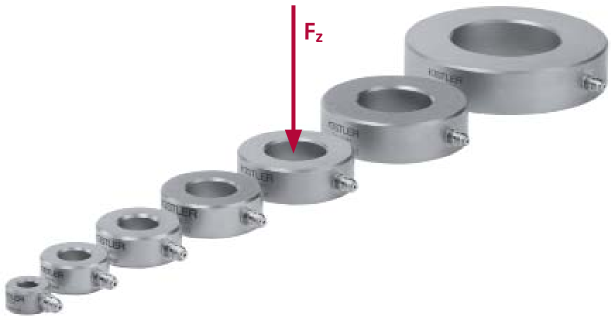
Type 9101A ... 9107A

0 ... 20 kN until 0 ... 700 kN

Force sensor for measuring quasistatic and dynamic forces in industrial monitoring tasks.

The force sensors are delivered **uncalibrated** and must be calibrated in situ **after** mounting.

- Not calibrated
- Linearity incl. Hysteresis ≤±1,5 %
- Extremely high rigidity
- Very compact
- Threshold <0,01 N, independent of measuring range
- Degree of protection IP67
- Operating temperature range –40 ... 120 °C
- No aging, unlimited lifetime



Description

Load washer for force measurement in the z direction. The force to be measured is transferred via the cover and base of the seal-welded steel case to the quartz sensor elements. When subjected to a mechanical load, quartz produces an electrical charge proportional to that load. The sensor sensitivity (a material constant of quartz) and thus the response threshold is practically the same in all load washers. This offers three unique advantages:

- Even very small forces can be measured with a sensor with a wide measuring range giving substantial overload safety
- A sensor with a wide measuring range can be selected in cases where highest possible rigidity is required
- Several sensors can be connected electrically in parallel to a single charge amplifier. The output voltage is then proportional to the sum of all active forces

Application

For monitoring of industrial processes, force sensors are required, which can be easily installed in machinery. Robust design and reliability during continuous operation together with good repeatability of the measured values are additional characteristics of these sensors. Selection of specific dimensions depends on the installation conditions as well as on the mounting conditions for the force shunt.

Application Examples

- Monitoring of compression forces during assembly, testing etc.
- Monitoring of forces during stamping and forming
- Measuring of large forces in force shunt mode

Sensor Mounting

Load washers are generally installed under pretension in a mounting structure, either directly in the force flux of a separate component or in force shunt mode embedded in a machine structure. Whereas with direct force measurement, the largest part of the process force flows through the sensor, in the case of force shunt measurements it is loaded with only a very small part of the process force. Load washers are supplied uncalibrated, because in any case they must be calibrated in situ in the mounting structure for absolute measurements.

Direct Force Measurement in the Force Flux

With direct force measurement, almost the entire process force flows through the sensor. The measuring range must therefore be selected so that the sum of pretensioning force F_v and maximum occurring process force F_z is within the measuring range of the sensor. The mounting surfaces must be flat, rigid and ground (Fig. 6). The pretensioning bolt produces a force shunt of ≈7 … 9 % and a correspondingly reduced sensitivity. In general, a pretensioning force of at least 20 % of the measuring range is recommended; with tensile forces this should be increased accordingly. If possible (considering the process force), pretensioning of 50 % of the measuring range should be used, because the tolerance with regard to bending moments is then at its greatest, see Page 4.

9101A_000-108e-02.16

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Technical Data

	Type	9101A	9102A	9103A	9104A	9105A	9106A	9107A
Measuring range F_z [1]	kN	0 … 20	0 … 50	0 … 100	0 … 140	0 … 190	0 ... 330	0 ... 700
Overload F_z [1]	kN	25	60	120	160	210	360	770
Max. bending moment M_x, M_y [2]	N·m	21	86	217	380	617	1 326	4 229
Rigidity c_z	kN/µm	≈1,6	≈3,4	≈5,4	≈6,9	≈9,8	≈15	≈29
Capacitance C	pF	23	37	54	65	64	148	203
Weight	g	7	20	36	70	80	157	370
Dimensions								
d	mm	6,5	10,5	13	17	21	26,5	40,5
D	mm	14,5	22,5	28,5	34,5	40,5	52,5	75,5
H	mm	8	10	11	12	13	15	17

General Data

Sensitivity [1]	pC/N	≈–4,3
Linearity incl. Hysteresis [3]	% FSO	≤±1,5
Threshold	N	<0,01
Insulation resistance	Ω	$\geq 10^{13}$
Temperature coefficient of sensitivity	%/°C	–0,02
Operating temperature range	°C	–40 … 120
Degree of protection according to EN6052 with cable connected		IP65
with cable Type 1983AD… and welded sensor		IP67

[1] without pretension
[2] F_v = pretension = 0,5 · measuring range; F_z = 0
[3] With a preload of 20 % of the measuring range

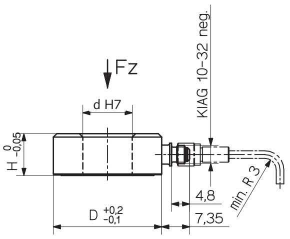

Fig. 1: Dimensions Load washers Type 9101A ... 9103A

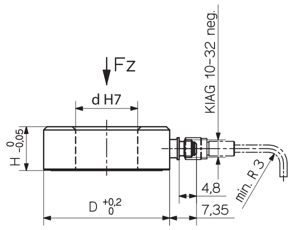

Fig. 2: Dimensions Load washers Types 9104A ... 9107A

Important

When pretensioning, the force must be measured with the sensor itself, using the sensitivity stated in the Technical Data. Since the pretensioning screw produces a force shunt, the sensor must be calibrated again after mounting in order to determine the sensitivity of the particular measuring direction.

Sensor Mounting with Pretensioning Set Type 9422A…

This pretensioning set is not contained in the included accessories and must be ordered separately. It can be used to pretension the sensor up to 30 % of its range. The centering clamp is used to center the sensor with the screw (Fig. 3 and table).

Important

The pretensioning screw produces a force shunt. The sensitivity is then reduced by approximately 8 ... 9 %.

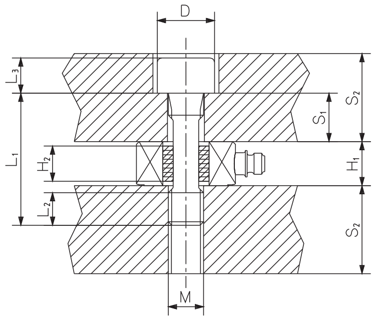

Fig. 3: Mounting with pretensioning screw Type 9422A…

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Sensor Type	Pretensioning Screw Type	Dimensions									Pretension F_v [kN]	Force Shunt %
		M	D	L_1	L_2	L_3	H_1	H_2	S_1	S_2		
9101A	9422A11	M5x0,8	8,5	20	6,5	6	8	6	4	10	5	≈8
9102A	9422A21	M8x1,25	13	30	10	9	10	8	7	16	10	≈9
9103A	9422A31	M10x1,5	16	35	12	11	11	8	9	20	20	≈9
9104A	9422A41	M12x1,75	18	40	14,3	13	12	8	12	25	30	≈9
9105A	9422A51	M14x2	21	45	16,6	15	13	9	15	30	40	≈9

Sensor Mounting with Pretensioning Set Type 9420A...

This pretensioning set is not contained in the included accessories and must be ordered separately. Sets of special pretensioning elements are available for sensor Types 9101A ... 9107A (Fig. 4 and Table). These pretensioning bolts of high tensile steel can be used to pretension the sensor up to 50 % of its range. At the same time, optimum introduction of force is ensured. A mounting set consists of a high-tensile stainless-steel pretensioning bolt, a centering sleeve and two insulating washers.

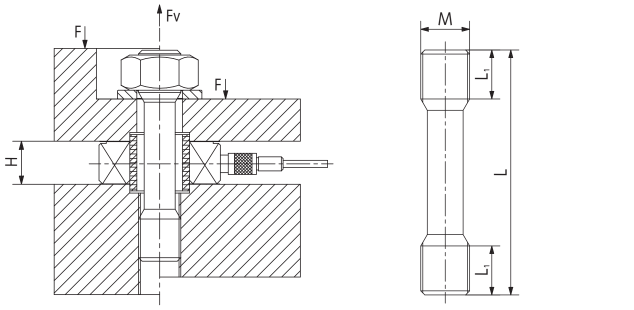

Fig. 4: Mounting with pretensioning screw Type 9420A... (see data sheet 9420A_000-192)

Force Distribution Rings

Contact surfaces must be flat and rigid. If they cannot be precision machined, punctiform overloads and damage to the sensor surface must be prevented by using a force distribution ring (Fig. 5).

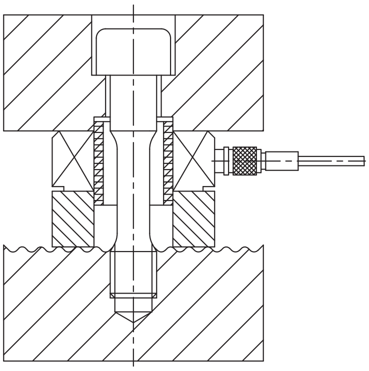

Fig. 5: Mounting with force distribution ring Type 9515 ... 9545

Sensor Type	Set of Pretensioning Elem. Type	Dimensions				Pretension F_v [kN]	Force Shunt %
		M	L	L_1	H		
9101A	9420A11	M5x0,5	28	5	8	3 ... 7	≈7
9102A	9420A21	M8x1	40	8	10	7 ... 18	≈8
9103A	9420A31	M10x1	46	10	11	12 ... 30	≈9
9104A	9420A41	M12x1	60	12	12	18 ... 45	≈8
9105A	9420A51	M14x1,5	62	13	13	24 ... 60	≈7
9106A	9420A61	M20x1,5	80	19	15	40 ... 100	≈7
9107A	9420A71	M27x2	102	26	7	80 ... 200	≈7

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Bending Moment

Bending moments may not only have a negative influence on the measurement, but may even lead to destruction of the sensor. However, when the sensor is mounted in a thrust rod or a press punch, it is often impossible to avoid bending moments entirely.

The permissible value for the bending moment M_b is dependent on the sum of the pretensioning force F_v and the current process force F_z applied, in which the maximum possible bending moment $M_{b,max}$ is reached at $F_v+F_z = B/2$.

Maximum Possible Bending Moment

Type	Range Limit Value B [kN]	Max. Possible Bending Moment $M_{b,max.}$ ($F_v + F_z = B/2$) [N·m]
9101A	20	21
9102A	50	86
9103A	100	217
9104A	140	380
9105A	190	617
9106A	330	1 326
9107A	700	4 229

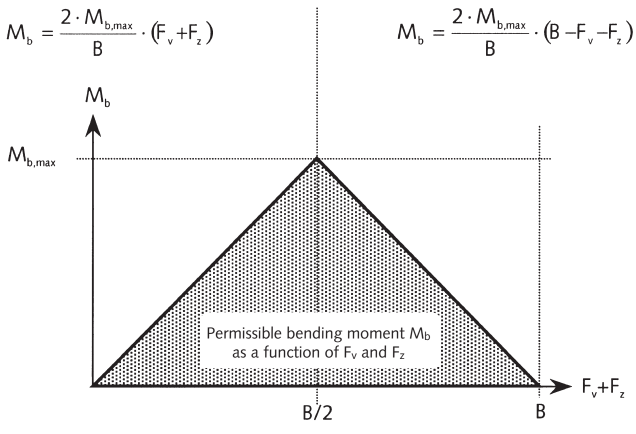
With the table values for B and $M_{b,max}$, the permissible pure bending moment as a function of the pretensioning force F_v and the process force F_z can be estimated as follows:

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

$$(1b)\quad M_{b,perm.} \leq \frac{2 \cdot M_{b,max}}{B} \cdot (B - F_v - F_z) \qquad F_v + F_z \geq B/2$$

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

Bending Moment Graph



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 will lead to a shear force $F_{x,y}$ in the sensor plane. In this case, the maximum permissible bending moment is lower than the permissible value for a pure bending moment determined using the equations (1).

Example 1

A load washer Type 9103A is pretensioned with 30 kN. What bending moment is acceptable for process forces in the range of 0 … 50 kN?

$$F_v + F_{z,min} \leq B/2$$
$$30\text{ kN} \leq 50\text{ kN} \rightarrow (1a) \rightarrow M_{b,perm} = \frac{2 \cdot 217\text{ N·m}}{100\text{ kN}} \cdot 30\text{ kN} = 130{,}2\text{ N·m}$$

$$F_v + F_{z,max} \geq B/2$$
$$80\text{ kN} \geq 50\text{ kN} \rightarrow (1b) \rightarrow M_{b,perm} = \frac{2 \cdot 217\text{ N·m}}{100\text{ kN}} \cdot 20\text{ kN} = 86{,}8\text{ N·m}$$

To prevent an overload within the whole force measuring range, the bending moment must not be greater than 130 N·m.

Example 2

A load washer Type 9101A is pretensioned with 6 kN. How wide is the measuring range with a bending moment of 4 N·m? By resolving (1) according to F_z, we get the equations (2) with which the permissible measuring range for the process force F_z can be calculated as a function of a bending moment.

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

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

Inserting the values for B, $M_{b,max}$ and F_v produces the permissible measuring range for F_z

from (2a) max. tensile force $F_z =$ –4,09 kN and
from (2b) max. compression force $F_z =$ 12,10 kN

Attention

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

When the equations (2a) and (2b) are resolved according to F_v, the minimum pretension force required or the maximum permissible pretension force can be calculated as a function of the other parameters.

9101A_000-108e-02.16

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Mounting in Force Shunt Mode

The widest variety of measuring problems can be solved with the load washer mounted in force shunt mode. The mounting surface must be flat and be ground as finely as possible. The sensor can be center aligned at both the inner and outer sheaths. For mounting as in Fig. 6, the measuring surface of the sensor and the separation surface of the machine structure must be machined together. In all cases, the sensor must be machined only on one side to a maximum of 0,20 mm. Depending on applications, the sensor is pretensioned from 10 % to 20 % of the measuring range. This is done by placing a steel foil (a few µm thick) on the measuring surface of the sensor or by pretensioning with a special nut (Fig. 6).

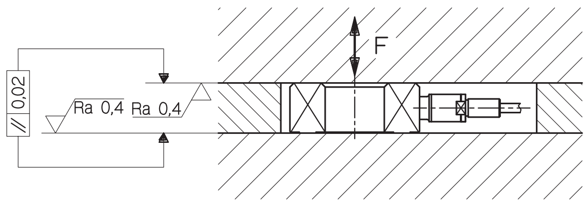
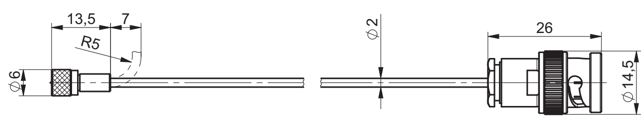


Fig. 6: Mounting for force shunt measuring

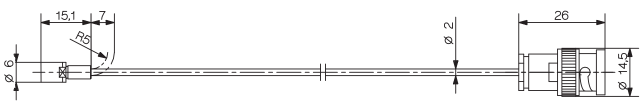
Connection

Only high-insulation coaxial cables with low capacitance producing only very low triboelectricity during movement must be used for connecting piezoelectric sensors. For industrial environments, we recommend using the types listed in the Accessories.
For more stringent requirements in a harsh environment, the industrial, integrated cable connector KIAG 10-32 with O-ring is used. If required, the connector can be seal welded to the sensor case.
At low requirements normal cable connector 10-32 KIAG can be used with knurled nut.

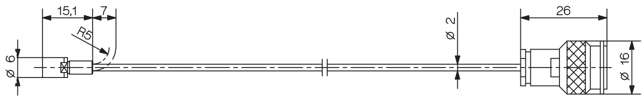
Connecting Cable for Sensors with KIAG 10-32 neg. Connector Typ 1631C…



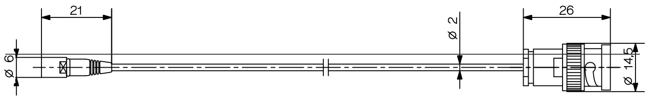
Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1939A… (integrated cable connector for industrial environments)



Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1941A… (integrated cable connector for industrial environments)

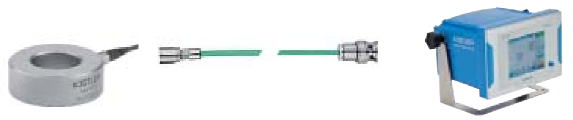


Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1983AD… (integrated cable connector for industrial environments)

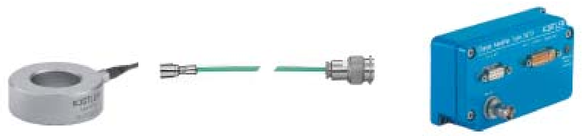


Please refer to data sheet 1631C_000-346 for further information on the cables.

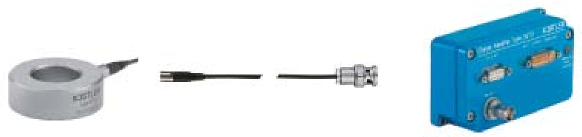
Sensor Type 910xB	Connecting Cable Type 1939A…	maXYmos BL Type 5867B…



Sensor Type 910xB	Connecting Cable Type 1941A…	Charge Amplifier Type 5073A121



Sensor Type 910xB	Connecting Cable Type 1983AD	Charge Amplifier Type 5073A111



Sensor Type 910xB	Connecting Cable Type 1631C...	Charge Amplifier Type 5073A111

9101A_000-108e-02.16

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Accessories Included	Type/Art.No.
• None	

Optional Accessories	Type/Art. No.
• Set of pretensioning elements for load washers (see data sheet 9420A_000-192)	9420A…
• Pretensioning screw for load washers	9422A…

Mounting Accessories	
• Force measurement with load washers (see data sheet 9001A_000-182)	
• Force distribution ring for load washers (see data sheet 9505_000-193)	95x5
• Spherical washer for load washers (see data sheet 9505_000-193)	95x3
• Insulating washer for load washers (see data sheet 9505_000-193)	95x7
• Force distribution cap for load washers (see data sheet 9505_000-193)	95x9

Cables

- Connecting and extension cables
  Data sheet cables for force, torque and strain sensors (1631C_000-346)

Ordering Key

Type 910 ☐ A

Load washer 0 … 20 kN	**1**
Load washer 0 … 50 kN	**2**
Load washer 0 … 100 kN	**3**
Load washer 0 … 140 kN	**4**
Load washer 0 … 190 kN	**5**
Load washer 0 … 330 kN	**6**
Load washer 0 … 700 kN	**7**

9101A_000-108e-02.16