measure. analyze. innovate.

Force sensors

Transparent manufacturing processes ensure quality and reduce costs

www.kistler.com

Absolute Attention for tomorrow's world

Kistler develops solutions for challenges in measurement technology with a portfolio that comprises sensors, electronics, systems and services. We push the frontiers of physics in fields such as emission reduction, quality control, mobility and vehicle safety: our products deliver top performance to meet the standards of tomorrow's world, providing the ideal basis for Industry 4.0. This is how we pave the way for innovation and growth – for our customers, and with our customers.

Kistler: the byword for advances in engine monitoring, vehicle safety and vehicle dynamics. Our products deliver data that plays a key part in developing efficient vehicles for tomorrow's world.

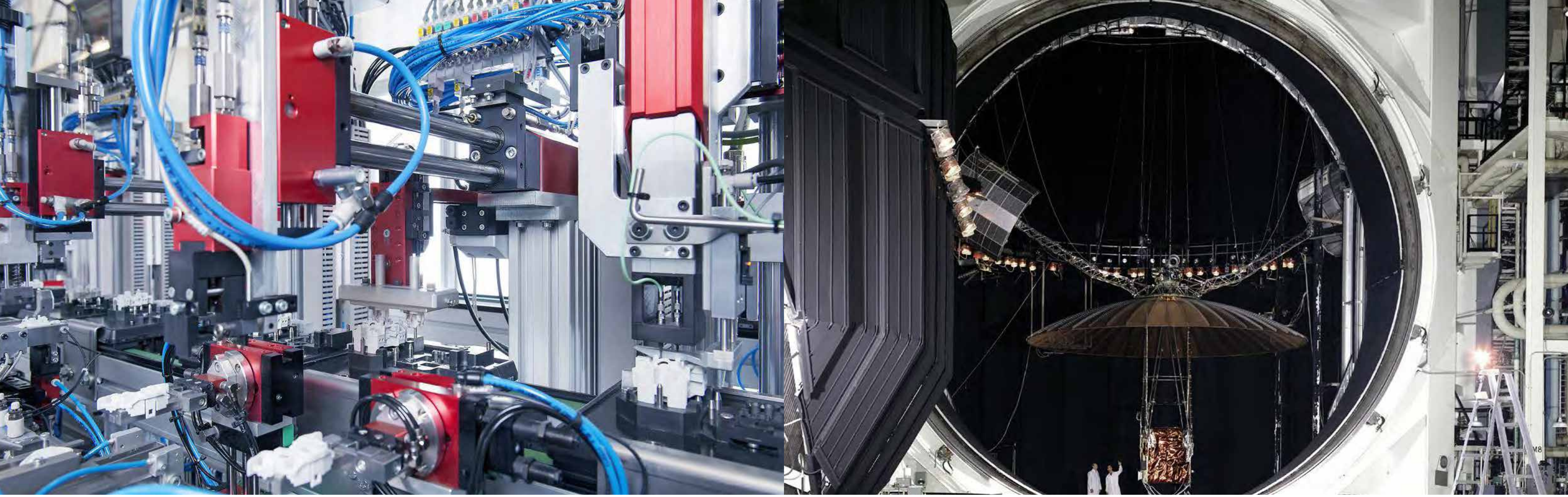
Measurement technology from Kistler ensures top performance in sport diagnostics, traffic data acquisition, cutting force analysis and many other applications where absolutely reliable measurements are required despite extreme conditions.

By supporting all the stages in networked, digitalized production, Kistler's systems maximize process efficiency and cost-effectiveness in the smart factories of the next generation.

Content

Part one: Components

Part two: Know-how



Assembly processes and product testing are just two of the many industrial activities where sensors from Kistler are used

Force sensors for industrial process control

Quality and precision standards in industrial manufacturing are continually increasing while competition is becoming even more fierce, thereby making it essential to optimize and monitor the entire production chain. Kistler's measurement and system technology can help meet these requirements, laying the foundations for zero-defect industrial production.

Ensuring the quality of the end product is always the top priority in the automotive industry and the medical technology or electrical engineering sectors (to mention only a few examples); and this is why strict standards are specified for this purpose. Especially if many individual components are assembled to form one single product, each component must already have been tested by the suppliers: this is the only way to guarantee the quality of the end product. In many such cases, the only solution is to integrate monitoring systems into the production process.

- Force measurement is integrated in the production process
- Process monitoring ensures zero-defect production
- Quality costs are cut because deviations are detected at an early stage
- Process efficiency is optimized due to the flexibility of the measuring equipment

Optimized process efficiency thanks to technology from Kistler
The objective: to implement zero-defect industrial production at the lowest possible cost. Kistler's response: integrated process monitoring, which means direct verification during each process step. This concept is underpinned by sensor technology based on the piezoelectric principle – an approach that is outstandingly suitable for monitoring and optimizing production processes.

Lower quality assurance costs for plant operators
Process-integrated monitoring cuts the costs of quality assurance. This cost-effective solution protects plant operators against the possibility of faulty parts reaching the customer; it also ensures that there is no disruption to any downstream assembly operations.

Increased process efficiency with Kistler – now online!
View our animation to experience convincing, first-class Kistler solutions – the sure way to optimize process efficiency:
www.kistler.com/maxymos

Force sensors for Research & Development

Higher, faster, further. Pushing the limits of the technically achievable in Research and Development requires a maximum degree of reliability and precision in measurement technology. For over 60 years now, Kistler is continuously breaking new ground, and our striving for perfection makes us the preferred partner for industry and research labs alike.

Demanding industries such as aerospace and aviation are operating in extremely challenging and expensive environments. We work in close partnership with various renowned aerospace centers and airplane manufacturer, so our testing expertise not only allows us to offer our partners perfectly suiting measurement devices, but also to provide all our customers the highest achievable performance and reliability of their test equipment.

With our broad and long experience in Research and Development, we are able to assist our customer in the design and construction of their measurement setup, providing profound know-how and the necessary technology to meet their needs and outperform their expectations.

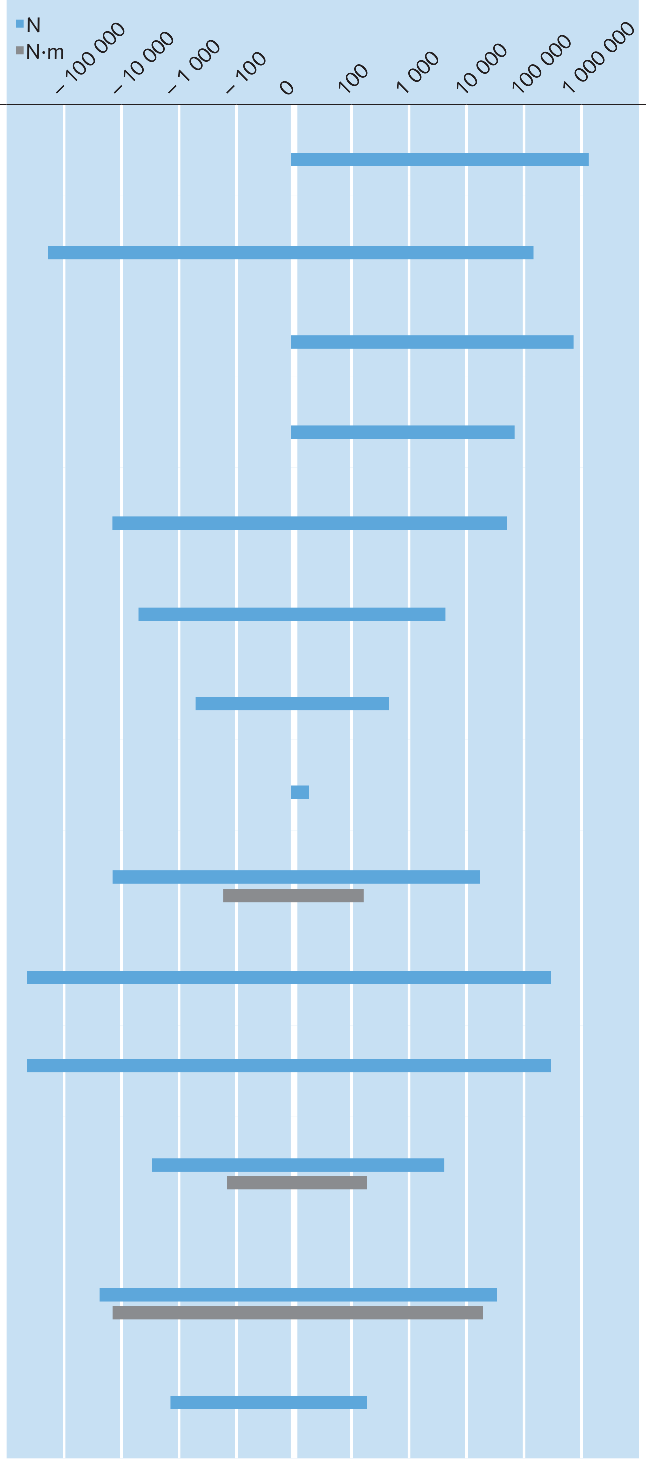
Overview of sectors

- Aerospace technology
- Transport and traffic
- Automobile engineering
- Shipbuilding and maritime industries
- Energy and environmental technology
- Oil and gas
- Chemical industry
- Pharmaceutical industry
- Semiconductor and electronics industry
- Paper and cellulose industry
- Food and beverage industry
- Construction and mining
- Medical technology
- Mechanical engineering
- University research

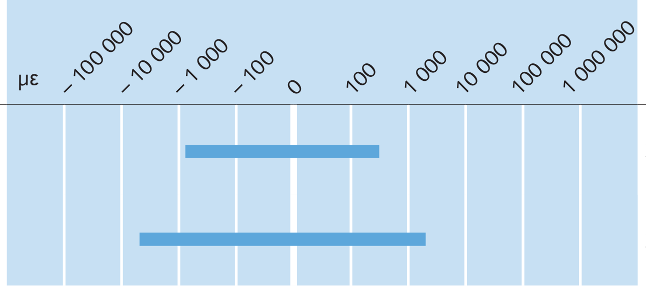
Product overview: force sensors

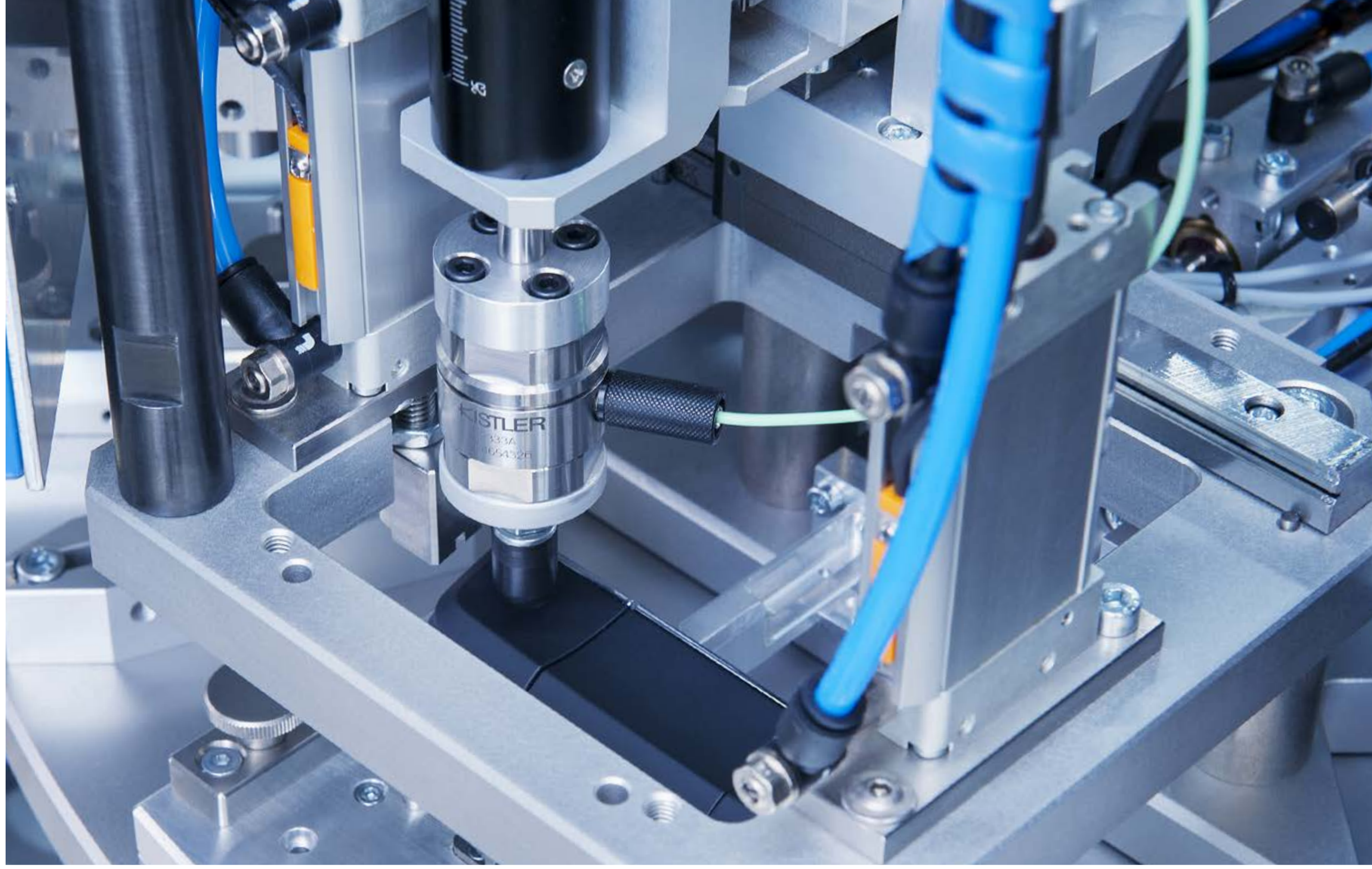
Piezoelectric sensors

	Direct force measurement	Measurement Type	Preloaded	Ready for measurement	Pages
	Force sensor	F_z			8, 14–15
	Force link	F_z	•	•	10–11
	Press force	F_z	•	•	12–13
	Force ring SlimLine	F_z			16–17
	Force link SlimLine	F_z	•	•	18–19
	Shear force ring SlimLine	F_y			20–21
	Low force sensor	F_z	•	•	22–23
	Miniature force sensor	F_z		•	24–25
	2-component force sensor	F_z, M_z	•	•	27
	3-component force sensor	$F_{x,y,z}$		•	28–29
	3-component force link	$F_{x,y,z}$	•	•	30–31
	6-component force sensor	$F_{x,y,z}$ $M_{x,y,z}$	•	•	32
	Dynamometers	$F_{x,y,z}$ $M_{x,y,z}$	•	•	34–35
	Strain gauge force sensors	F_z		•	40–43



	Indirect force measurement	Measurement Type	Preloaded	Ready for Measurement	Pages
	Surface strain sensor	με		•	37
	Strain measuring pin	με		•	38–39





1-component force sensors

The force sensors in our portfolio utilize the outstanding properties of piezo crystals and quartzes, providing the basis for our sensor technology.

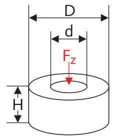
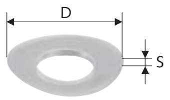
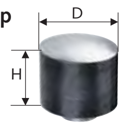
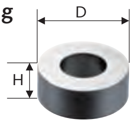
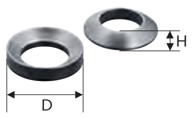
The ring force transducer is the standard piezoelectric measuring element. The sensor elements themselves are only slightly preloaded. They are typically integrated into the existing structure at the measuring point, where they are installed with the required preload. This preload corresponds to a load offset.

Our force links and press force sensors can be used directly by customers for immediate measurements. These preloaded quartz force links are calibrated in the factory, and are suitable for measuring compression and tensile forces.

Our low level force sensors are designed for extremely small forces. Thanks to their internal structure, these sensors are up to 30 times more sensitive so that even the smallest forces can be measured reliably.

Benefits
- Extremely rigid, so that high natural frequencies can be attained
- High loading capacity
- Durable
- Compact design
- Broad measuring range
- Direct measurements in the force flux
- Measurements without deflection are possible
- Extensive range

1-component force sensors

Technical data		Type	9001C	9011C	9021C	9031C	9041C	9051C	9061C	9071C	9081B	9091B
												
Measuring range	F_z[1]	kN	0 ... 7.5	0 ... 15	0 ... 35	0 ... 60	0 ... 90	0 ... 120	0 ... 200	0 ... 400	0 ... 650	0 ... 1 200
Calibrated meas. ranges	F_z F_z	kN kN	0 ... 6[2] 0 ... 0.6[2]	0 ... 12[2] 0 ... 1.2[2]	0 ... 28[2] 0 ... 2.8[2]	0 ... 48[2] 0 ... 4.8[2]	0 ... 72[2] 0 ... 7.2[2]	0 ... 96[2] 0 ... 9.6[2]	0 ... 160[2] 0 ... 16[2]	0 ... 320[2] 0 ... 32[2]	0 ... 650 0 ... 52	0 ... 1 200 0 ... 96
Sensitivity	F_z[1]	pC/N	≈ – 4.1	≈ – 4.2	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 2.15	≈ – 2.1
Dimensions	D d H	mm mm mm	10.3 4.1 6.5	14.5 6.5 8	22.5 10.5 10	28.5 13 11	34.5 17 12	40.5 21 13	52.5 26.5 15	77.2 40.5 17	100 40.5 22	145 72 28
Rigidity	$c_{A,z}$	kN/µm	≈ 1.1	≈ 1.6	≈ 3.3	≈ 5.2	≈ 7.5	≈9.8	≈ 15.4	≈ 27.7	≈ 35.7	≈ 52.3
Weight		g	3	7	20	36	70	80	157	370	910	2 180
Operating temp. range[3]		°C	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 70 ... 200	– 40 ... 120	– 40 ... 120
Connector			KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.
Deg. of protection to IEC/EN 60529 screwed with cable (e.g. 1631C...) welded with cable (e.g. 1983AD...)		IP65 IP68	• •	• •	• •	• •	• •	• •	• •	• •	• •	• •
Preloading screw[4] Thread × pitch/ length Preloading force		Type Fv (kN)	**9422A01** M3x0.5/19 2.5	**9422A11** M5x0.8/25 6	**9422A21** M8x1.25/38 15	**9422A31** M10x1.5/45 30	**9422A41** M12x1.75/52 45	**9422A51** M14x2/59 60				
Accessories												
Preloading element Thread × pitch/ length Preloading force		Type Fv (kN)	**9420A01** M3x0.5/22 4	**9420A11** M5x0.5/28 7	**9420A21** M8×1/40 18	**9420A31** M10×1/46 30	**9420A41** M12×1/60 45	**9420A51** M14×1.5/62 60	**9420A61** M20×1.5/80 100	**9420A71** M27×2/102 200	**9455** M40×2 325	**9456** M64×3 600 (hydraulic)
Insulating washer Dimensions		Type D (mm) S (mm)		**9517** 14 0.125	**9527** 22 0.125	**9537** 28 0.125	**9547** 34 0.125	**9557** 40 0.125	**9567** 52 0.125	**9577** 75 0.125		
Force distributing cap Dimensions		Type D (mm) H (mm)	**9509** 10 10	**9519** 14 15	**9529** 22 20	**9539** 28 25	**9549** 34 30	**9559** 40 40	**9569** 52 50	**9579** 75 60		
Force distributing ring Dimensions		Type D (mm) H (mm)	**9505** 10 6	**9515** 14 8	**9525** 22 10	**9535** 28 11	**9545** 34 12	**9555** 40 13	**9565** 52 15	**9575** 75 17		
Spherical washer Dimensions		Type D (mm) H (mm)		**9513** 12 4	**9523** 21 6	**9533** 24 7	**9543** 30 8	**9553** 36 10	**9563** 52 14	**9573** 75 20		

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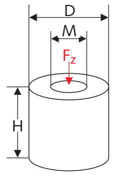
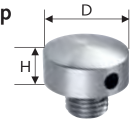
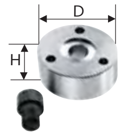
[1] without preloading
[2] with a preload of 20% of the measuring range
[3] operating temperature range depends on the cable used
[4] included in delivery

1-component force transducers

Technical data		Type	9301C	9311C	9321C	9331C	9341C	9351C	9361C	9371C
										
Measuring range	F_z	kN	– 3 … 3	– 6 … 6	– 14 … 14	– 24 … 24	– 36 … 36	– 48 … 48	– 80 … 80	– 160 … 160
Calibrated meas. ranges	F_z	kN	0 … 3	0 … 6	0 … 14	0 … 24	0 … 36	0 … 48	0 … 80	0 … 160
	F_z	kN	0 … – 3	0 … – 6	0 … – 14	0 … – 24	0 … – 36	0 … – 48	0 … – 80	0 … – 160
	F_z	kN	0 … 0.03	0 … 0.06	0 … 0.14	0 … 0.24	0 … 0.36	0 … 0.48	0 … 0.8	0 … 1.6
Sensitivity	F_z	pC/N	≈ – 3.1	≈ – 3.4	≈ – 3.7	≈ – 3.9	≈ – 3.9	≈ – 3.9	≈ – 4.0	≈ – 3.9
Dimensions	D	mm	11	15	23	29	35	41	53	76
	H	mm	25	30	45	52	62	72	88	108
	M		M5	M6	M10	M12	M16	M20	M24	M30
Rigidity	$c_{A,z}$	kN/μm	≈ 0.245	≈ 0.398	≈ 0.724	≈ 0.550	≈ 1.51	≈ 1.756	≈ 2.597	≈ 4.794
Natural frequency	$f_n(z)$	kHz	≈ 58.5	≈ 50.6	≈ 41.2	≈ 20.7	≈ 29.7	≈ 27.9	≈ 23.8	≈ 19.9
Weight		g	14	28	90	170	330	480	1 020	2 500
Operating temp. range [1]		°C	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120
Connector			KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.
Deg. of protection to IEC/EN 60529										
screwed with cable (e.g. 1631C...)		IP65	•	•	•	•	•	•	•	•
welded with cable (e.g. 1983AD...)		IP68	•	•	•	•	•	•	•	•
With basic insulation			•	•	•	•	•	•	•	•
Preloaded			•	•	•	•	•	•	•	•
Ready for measurement			•	•	•	•	•	•	•	•

Accessories										
Force distributing cap		**Type**	**9500A0**	**9500A1**	**9500A2**	**9500A3**	**9500A4**	**9500A5**	**9500A6**	**9500A7**
Dimensions		D (mm)	8.5	12.5	18	23	31	35	45	64
		H (mm)	4	6	9	12	15	18	22	32
Flange		**Type**	**9501A0**	**9501A1**	**9501A2**	**9501A3**	**9501A4**	**9501A5**	**9501A6**	**9501A7**
Dimensions		D (mm)	25	34	44	56	70	84	102	136
		H (mm)	9	11	18	22	29	37	44	53

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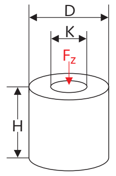
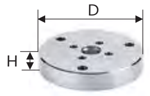
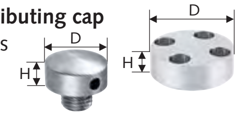
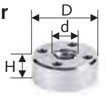
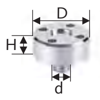
[1] operating temperature range depends on the cable used

1-component force transducers, press force

Technical data		Type	9313AA1	9313AA2	9323AA	9323A	9333A	9343A	9363A	9383A	9393A	9337A40
												
Measuring range	F_z	kN	0 ... 5	0 ... 20	0 ... 10	0 ... 20	0 ... 50	0 ... 70	0 ... 120	0 ... 300	0 ... 700	0 ... 70
Permissible tensile force	F_z	kN	0 ... – 0.5	0 ... – 2	0 ... – 1	0 ... – 2	0 ... – 5	0 ... – 10	0 ... – 20	0 ... – 50	0 ... – 120	
Calibrated meas. ranges	F_z F_z F_z	kN kN kN	0 ... 0.05 0 ... 0.5 0 ... 5	0 ... 0.2 0 ... 2 0 ... 20	0 ... 0.1 0 ... 1 0 ... 10	0 ... 0.2 0 ... 2 0 ... 20	0 ... 0.5 0 ... 5 0 ... 50	0 ... 0.7 0 ... 7 0 ... 70	0 ... 1.2 0 ... 12 0 ... 120	0 ... 3 0 ... 30 0 ... 300	0 ... 7 0 ... 70 0 ... 700	0 ... 5 0 ... 50
Sensitivity	F_z	pC/N	≈ – 10	≈ – 10	≈ – 9.6	≈ – 3.9	≈ – 3.9	≈ – 3.9	≈ – 3.8	≈ – 1.9	≈ – 1.9	
Output signal		V										0 ... 10
Dimensions	D K H	mm mm mm	13 M2.5 10	19 M4 14	20 M5×0.5 26	20 M5×0.5 26	30 M9×0.5 34	36 M13×1 42	54 M20×1.5 60	100 S28×2 130	145 31 190	50 45
Rigidity	$c_{A,z}$	kN/µm	≈ 0.56	≈ 1.50	≈ 1.30	≈ 1.20	≈ 2.30	≈ 2.60	≈ 4.40	≈ 7.90	≈ 10.0	≈ 2.34
Natural frequency	$f_n(z)$	kHz	>38	>35	>74.5	>72	>55	>47	>35	>17	>11.3	>32
Weight		g	10	25	50	47	137	240	800	6490	18 663	520
Operating temp. range 1)		°C	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 10 ... 70
Connector			KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg	KIAG 10-32 neg	KIAG 10-32 neg	KIAG 10-32 neg	KIAG 10-32 neg	KIAG 10-32 neg	KIAG 10-32 neg	M12×1 8-pole, shielded
Deg. of protection to IEC/EN 60529 screwed with cable (e.g. 1631C...) welded with cable (e.g. 1983AD...) screwed with cable (e.g. 1787A...)		 IP65 IP68 IP67	 • •	 • •	 • •	 • •	 • •	 • •	 • •	 • •	 • •	 •
Preloaded			•	•	•	•	•	•	•	•	•	•
Ready for measurement			•	•	•	•	•	•	•	•	•	•

Accessories												
Flange Dimensions		Type D (mm) H (mm)	**9580A7** 27 7	**9580A8** 35 8	**9580A9** 40 8	**9580A9** 40 8	**9580A0** 62 11	**9580A1** 70 13	**9580A2** 100 22	**9580A4** 180 30	**9580A6** 220 48	**9594A1** 80 13
Force distributing cap Dimensions		Type D (mm) H (mm)	**9500A00** 6 3	**9500A01** 10.5 5	**9582A9** 20 8.5	**9582A9** 20 8.5	**9582A0** 30 11	**9582A1** 36.5 13	**9582A2** 56 22	**9582A4** 100 50	**9582A6** 145 80	**9582A1** 36.5 13
Spigot Dimensions		Type D (mm) L (mm)	**9590A7** 5 12.5	**9590A8** 10 20.5								
Female thread adapter Dimensions		Type D (mm) H (mm)			**9584A9** 20 8	**9584A9** 20 8	**9584A0** 30 11	**9584A1** 36.5 14	**9584A2** 56 21	**9584A4** 100 30	**9584A6** 150 48	**9584A1** 36.5 14
Male thread adapter Dimensions		Type D (mm) H (mm)			**9586A9** 20 8	**9586A9** 20 8	**9586A0** 30 11	**9586A1** 36.5 14	**9586A2** 56 21	**9586A4** 100 30	**9586A6** 150 48	**9586A1** 36.5 14

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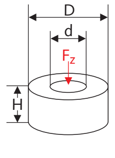
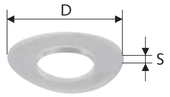
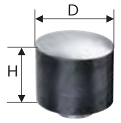
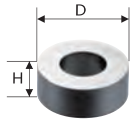
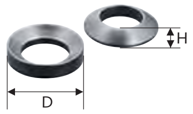
1) operating temperature range depends on the cable used

1-component force sensors

Technical data		Type	9101C	9102C	9103C	9104C	9105C	9106C	9107C
									
Measuring range	F_z [1]	kN	0 ... 20	0 ... 50	0 ... 100	0 ... 140	0 ... 190	0 ... 330	0 ... 700
Calibrated meas. ranges	not calibrated								
Sensitivity	F_z [1]	pC/N	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4	≈ – 4.4
Dimensions	D	mm	14.5	22.5	28.5	34.5	40.5	52.5	77.5
	d	mm	6.5	10.5	13	17	21	26.5	40.5
	H	mm	8	10	11	12	13	15	17
Rigidity	$c_{A,z}$	kN/μm	≈ 1.6	≈ 3.3	≈ 5.2	≈ 7.5	≈ 9.8	≈ 15.4	≈ 27.7
Weight		g	7	20	36	70	80	157	370
Operating temp. range [2]		°C	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120
Connector			KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.
Deg. of protection to IEC/EN 60529									
screwed with cable (e.g. 1631C...)		IP65	•	•	•	•	•	•	•
welded with cable (e.g. 1983AD...)		IP68	•	•	•	•	•	•	•

Accessories									
Preloading screw		Type	**9422A11**	**9422A21**	**9422A31**	**9422A41**	**9422A51**		
Thread × pitch/length			M5×0.8/26	M8×1.25/39	M10×1.5/46	M12×1.75/53	M14×2/60		
Preloading force		Fv (kN)	5	10	20	30	40		
Preloading element		Type	**9420A11**	**9420A21**	**9420A31**	**9420A41**	**9420A51**	**9420A61**	**9420A71**
Thread × pitch/length			M5×0.5/28	M8×1/40	M10×1/46	M12×1/60	M14×1.5/62	M20×1.5/80	M27×2/102
Preloading force		Fv (kN)	7	18	30	45	60	100	200
Insulating washer		Type	**9517**	**9527**	**9537**	**9547**	**9557**	**9567**	**9577**
Dimensions		D (mm)	14	22	28	34	40	52	75
		S (mm)	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Force distributing cap		Type	**9519**	**9529**	**9539**	**9549**	**9559**	**9569**	**9579**
Dimensions		D (mm)	14	22	28	34	40	52	75
		H (mm)	15	20	25	30	40	50	60
Force distributing ring		Type	**9515**	**9525**	**9535**	**9545**	**9555**	**9565**	**9575**
Dimensions		D (mm)	14	22	28	34	40	52	75
		H (mm)	8	10	11	12	13	15	17
Spherical washer		Type	**9513**	**9523**	**9533**	**9543**	**9553**	**9563**	**9573**
Dimensions		D (mm)	12	21	24	30	36	52	75
		H (mm) (total)	4	6	7	8	10	14	20

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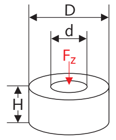
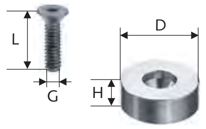
[1] without preloading
[2] operating temperature range depends on the cable used

1-component force sensors, SlimLine

Technical data		Type	9130C…	9132C…	9133C…	9134C…	9135C…	9136C…	9137C…
									
Measuring range	F_z [1]	kN	0 … 3	0 … 7	0 … 14	0 … 26	0 … 36	0 … 62	0 … 80
Calibrated meas. ranges	not calibrated								
Sensitivity	F_z [1]	pC/N	≈ – 3.7	≈ – 3.8	≈ – 3.8	≈ – 3.8	≈ – 3.8	≈ – 3.8	≈ – 3.8
Dimensions	D d H	mm mm mm	8 2.7 3	12 4.1 3	16 6.1 3.5	20 8.1 3.5	24 10.1 3.5	30 12.1 4	36 14.1 5
Rigidity	$c_{A,z}$	kN/µm	≈ 1	≈ 2.3	≈ 3.2	≈ 5.9	≈ 8.2	≈ 13.2	≈ 19
Weight (without cable)		g	1	2	3	5	7	14	27
Operating temperature range		°C	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 20 … 120
Connector (with integrated cable)			KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.
Deg. of protection to IEC/EN 60529		IP65	•	•	•	•	•	•	•

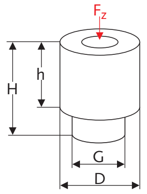
Accessories									
Preloading disk Dimensions		**Type**	**9410A0**	**9410A2**	**9410A3**	**9410A4**	**9410A5**	**9410A6**	**9410A7**
		G	M2	M2.5	M3	M4	M5	M6	M8
		L (mm)	8	8	10	10	10	14	16
		D (mm)	8	12	16	20	24	30	36
		H (mm)	3.5	3.5	4.25	4.25	4.25	5.5	7

[1] without preloading

1-component force sensor assembly kits comprising 2, 3 or 4 sensors

Technical data		Type	9130CA…	9132CA…	9133CA…	9134CA…	9135CA…	9136CA…	9137CA…
									
Assembly kit comprises		Type	9130C	9132C	9133C	9134C	9135C	9136C	9137C
Connector (sensors are connected undetachably to the flange bushing)			Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.
Deg. of protection to IEC/EN 60529 with connected cable (e.g. 1971A…)		IP65	•	•	•	•	•	•	•

1-component force transducers, SlimLine

Technical data		Type	9173C…	9174C	9175C	9176C	9177C
							
Measuring range	F_z	kN	– 3 … 12	– 5 … 20	– 8 … 30	– 16 … 60	– 20 … 75
Calibrated meas. range	F_z	kN	0 … 12	0 … 20	0 … 30	0 … 60	0 … 75
Sensitivity	F_z	pC/N	≈ – 3.5	≈ – 3.5	≈ – 3.5	≈ – 3.5	≈ – 3.5
Dimensions	D	mm	18	22	26	32	38
	H	mm	22	24	28	34	38
	h	mm	14	16	19	23	28
	G		M12×1.25	M16×1.5	M20×1.5	M24×2	M30×2
Rigidity	$c_{A,z}$	kN/µm	≈0.7	≈1.2	≈1.6	≈2.4	≈3.4
Natural frequency	$f_n(z)$	kHz	≈74	≈66	≈57	≈47	≈40
Weight (without cable)		g	28	40	81	147	227
Operating temperature range		°C	– 20 … 80	– 20 … 80	– 20 … 80	– 20 … 80	– 20 … 80
Connector [1] (with integrated cable)			KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.	KIAG 10-32 neg.
Deg. of protection to IEC/EN 60529		IP65	•	•	•	•	•
With basic insulation			•	•	•	•	•
Preloaded			•	•	•	•	•
Ready for measurement			•	•	•	•	•
Coupling Type 1729A included (KIAG 10-32 pos. – 10-32 pos.)			•	•	•	•	•

Accessories						
Force distributing cap	**Type**	**9416A3**	**9416A4**	**9416A5**	**9416A6**	**9416A7**
Dimensions	D (mm)	14	18	22	28	34
	H (mm)	6	8	9	9	9.8

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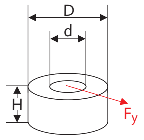
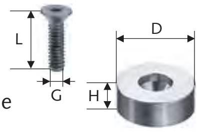
[1] plug coupling Type 1729A2

1-component force sensors, SlimLine for shear force

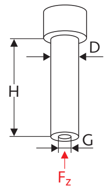
Technical data		Type	9143B...	9144B...	9145B...	9146B...	9147B...
							
Measuring range	F_y	kN	– 0.9 ... 0.9	– 1.7 ... 1.7	– 2.7 ... 2.7	– 4 ... 4	– 8 ... 8
Calibrated meas. ranges	not calibrated						
Sensitivity	F_y	pC/N	≈ – 6.5	≈ – 7.5	≈ – 7.5	≈ – 7.5	≈ – 8.1
Dimensions	D	mm	16	20	24	30	36
	d	mm	6.1	8.1	10.1	12.1	14.1
	H	mm	3.5	3.5	3.5	4	5
Rigidity (Z-axis)	$c_{A,z}$	kN/µm	≈3	≈6.3	≈7.8	≈12.8	≈ 18.8
Rigidity (Y-axis)	$c_{S,y}$	kN/µm	≈1.2	≈2.4	≈3.1	≈5.1	≈ 7.1
Weight (without cable)		g	3	5	7	14	27
Operating temperature range		°C	– 20 ... 120	– 20 ... 120	– 20 ... 120	– 20 ... 120	– 20 ... 120
Connector (with integrated cable)			KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.
Deg. of protection to IEC/EN 60529		IP65	•	•	•	•	•

Accessories							
Preloading disk		**Type**	**9410A3**	**9410A4**	**9410A5**	**9410A6**	**9410A7**
Dimensions		G	M3	M4	M5	M6	M8
		L (mm)	10	10	10	14	16
		D (mm)	16	20	24	30	36
Tightening torque		H (mm)	4.25	4.25	4.25	5.5	7
		M (N·m)	10	23	46	79	135

1-component force sensor assembly kits for shear force comprising 2, 3 or 4 sensors

Technical data	Type	9143BA...	9144BA...	9145BA...	9146BA...	9147BA...
						
Assembly kit comprises	Type	9143B	9144B	9145B	9146B	9147B
Connector (nondetachable sensors are connected to the flange bushing)		Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.	Fischer flange 7-pole, neg.
Deg. of protection to IEC/EN 60529 with connected cable (e.g. 1971A...)	IP65	•	•	•	•	•

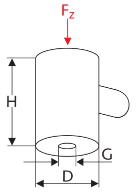
1-component force transducer, low force

Technical data		Type	9205	9207	9215A	9217A
						
Measuring range	F_z	N	– 50... 50	– 50... 50	– 20... 200	– 500... 500
Calibrated meas. ranges	F_z F_z F_z	N N N	0 ... – 0.5 / 0 ... 0.5 0 ... – 5 0 ... 5 0 ... – 50 0 ... 50	0 ... – 0.5 / 0 ... 0.5 0 ... – 5 0 ... 5 0 ... – 50 0 ... 50	0 ... 2 0 ... 20 0 ... 200	0 ... 5 0 ... – 50 0 ... 50 0 ... – 500 0 ... 500
Sensitivity	F_z	pC/N	≈ – 115	≈ – 115	≈ – 95	≈ – 105
Dimensions	D H G	mm	M10×1 28.5 M3 (female thread)	M10×1 28.5 M3 (female thread)	M5×0.5 12.5 M2 (female thread)	M10×1 28.5 M3 (female thread)
Rigidity	$c_{A,z}$	N/µm	≈ 4	≈ 4	≈ 100	≈ 15
Natural frequency	$f_n(z)$	kHz	>10	>10	>50	>20
Weight		g	19	19	2.5	16
Operating temp. range [1]		°C	– 50... 150	– 50... 150	– 50... 180	– 50... 150
Connector			KIAG 10-32 neg., radial	KIAG 10-32 neg., axial	M4×0.35 neg.	KIAG 10-32 neg.
Deg. of protection to IEC/EN 60529						
screwed with cable (e.g. 1631C...)		IP65	•	•	•	•
welded with cable (e.g. 1983AD...)		IP68	•	•	•	•
Preloaded			•	•	•	•
Ready for measurement			•	•	•	•

Accessories					
Coupling element	Type	**9405**	**9405**		**9405**
Dimensions	D (mm)	6.3	6.3		6.3
	H (mm)	18	18		18
Force introducing cap	Type	**3.220.139** [2]	**3.220.139** [2]	**3.220.217** [2]	**3.220.139**
Dimensions	D (mm)	6.3	6.3	4	6.3
	H (mm)	7	7	3.8	7

[1] operating temperature range depends on the cable used
[2] included in delivery

1-component force transducer, miniature

Technical data		Type	9211	9213sp	9212
					
Measuring range	F_z	kN	0 ... 2.5	0 ... 2.5	– 2.2 ... 22.2
Calibrated meas. ranges	F_z	kN	0 ... 0.25	0 ... 0.25	0 ... 2.2
	F_z	kN	0 ... 2.5	0 ... 2.5	0 ... 22.2
Rigidity	$c_{A,z}$	kN/µm	0.4	0.26	0.87
Natural frequency	$f_n(z)$	kHz	≈ 200	≈ 200	≈ 70
Sensitivity	F_z	pC/N	≈ – 4.4	≈ – 4.4	≈ – 1
Dimensions	D	mm	6	6	17.8
	H	mm	6	8.5	12.7
	G			M2.5 (female thread)	10-32 UNF
Weight		g	1.5	2	19
Operating temp. range [1]		°C	– 40... 200	– 40... 200	– 196... 150
Connector			KIAG 10-32	KIAG 10-32 BNC pos.	KIAG 10-32
Cable technology					
Single wire with/without plug			•	•	
Coaxial			•	•	•
Replaceable cable			•	•	•
Deg. of protection to IEC/EN 60529		IP65	•	•	•
Preloaded					•
Ready for measurement			•	•	•

Accessories					
Thrust washer [2]		Type	**9411**	**9413**	
Dimensions		D (mm)	5.5	5.5/2.8	
		H (mm)	2	2	

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[1] operating temperature range depends on the cable used
[2] included in delivery

Kistler as your development partner

We view every application as an exciting challenge — broaching, sawing, thread tapping, polishing and honing, as well as classical applications such as milling, drilling, turning and grinding. We shall be glad to act as your development partner, working with you to devise individual solutions for your measurement tasks. We can draw on our lengthy experience as specialists in measuring a variety of parameters including force, acceleration and acoustic emissions. Our services range from advisory support through to engineering of ready-to-install solutions.

Capturing highly dynamic forces in cutting processes

Kistler's piezoelectric sensors record highly dynamic processes with optimum signal quality. They offer valuable insights into the actual process, providing the basis for reliable, productive and reproducible manufacturing processes.

Machining test for cylindrical grinding

The Institute of Machine Tools and Factory Management at the Technical University of Berlin (TU Berlin) used a special dynamometer to analyze grinding processes. This made it possible to determine and improve part quality, wear mechanisms and the critical material removal rate limit.

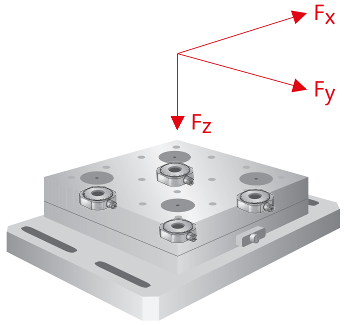
Multi-component force sensors

Kistler's piezoelectric sensors with multiple measuring directions are the elite class of piezoelectric force measuring instruments. These highly sensitive measuring elements are compactly embedded in the case, which is made of selected high-grade steel.

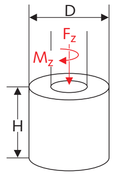
Multi-component load washers are the basic elements of the measurement technology. The sensor elements themselves are only slightly preloaded; they are integrated into the customer's structure and installed with the required preload. This preload corresponds to a load offset. Our force links can be used directly by customers for immediate measurements. These preloaded quartz force links are calibrated in the factory. They can be used in both directions along all measuring axes.

Multi-component force sensors are generally installed in groups of four, in what are known as dynamometers or measurement platforms. Single signals from the piezoelectric sensors can be summed by grouping the individual connectors together. This makes it possible to set up dynamometers that cover the range from 3-component force measurements to 6-component force/moment measurements. For this purpose, Kistler offers prepared sensor kits, as well as ready-to-use dynamometers.

Benefits
- Multi-component measurement
- Extremely rigid, so high natural frequencies can be attained
- Durable
- High loading capacity
- Compact design

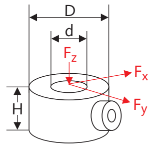


2-component transducer, miniature

Technical data		Type	9345B	9365B
				
Measuring range	F_z M_z	kN N·m	– 10 … 10 – 25 … 25	– 20 … 20 – 200 … 200
Calibrated meas. ranges	F_z	kN	0 … 1 0 … 10	0 … 2 0 … 20
	M_z	N·m	0 … – 2.5/0 … 2.5 0 … – 25/0 … 25	0 … – 20/0 … 20 0 … – 200/0 … 200
Rigidity (calculated)	$c_{A,z}$ $c_{T,z}$	kN/µm N·m/µm	≈ 1.7 ≈ 0.19	≈ 2.8 ≈ 0.92
Natural frequency	$f_n(z)$ $f_n(M_z)$	kHz kHz	>41 >32	>33 >25
Sensitivity	F_z M_z	pC/N pC/N·m	≈ – 3.7 ≈ – 190	≈ – 3.6 ≈ – 140
Dimensions	D H	mm mm	39 42	56.5 60
Weight		g	267	834
Operating temperature range		°C	– 40 … 120	– 40 … 120
Connector			V3 neg.	V3 neg.
Deg. of protection to IEC/EN 60529 screwed with cable (e.g. 1698AB...)		IP68	•	•
Preloaded			•	•
Ready for measurement			•	•

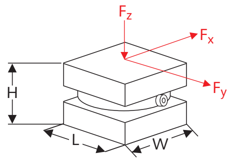
Multi-component force calibration: measuring of cylinder positions

3-component force sensors

Technical data		Type	9017C/9018C	9027C/9028C	9047C/9048C	9067C/9068C	9077C/9078C
							
Measuring ranges	F_x, F_y F_z	kN kN	– 1.5 ... 1.5 – 3... 3 Standard installation with 9.5 kN preloading	– 4... 4 – 8... 8 Standard installation with 20 kN preloading	– 15 ... 15 – 30 ... 30 Standard installation with 70 kN preloading	– 30 ... 30 – 60 ... 60 Standard installation with 140 kN preloading	– 75 ... 75 – 150 ... 150 Standard installation with 350 kN preloading
Calibrated meas. ranges	F_x, F_y F_z F_z (without preloading)	kN kN kN	0 ... 1.5 0 ... 3 0 ... 12.5	0 ... 4 0 ... 8 0 ... 28	0 ... 15 0 ... 30 0 ... 100	0 ... 30 0 ... 60 0 ... 200	0 ... 75 0 ... 150 0 ... 500
Sensitivity	F_x, F_y F_z	pC/N pC/N	≈ – 25 ≈ – 11	≈ – 7.8 ≈ – 3.8	≈ – 8.1 ≈ – 3.7	≈ – 8.1 ≈ – 3.9	≈ – 4.2 ≈ – 2
Dimensions	D d H	mm mm mm	19 6.5 10	28 8.1 12	45 14.1 14	65 26.5 21	105 40.5 26
Rigidity	$c_{S,xy}$ $c_{A,z}$	kN/µm kN/µm	0.3 1.4	0.6 2.2	1.9 6.1	2.4 8	8.4 26
Weight		g	14	30	91	285	1 040
Operating temperature range		°C	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120	– 40 ... 120
Connector			V3 neg.	V3 neg.	V3 neg.	V3 neg.	V3 neg.
Deg. of protection to IEC/EN 60529							
screwed with cable (e.g. 1698AA)		IP65	•	•	•	•	•
screwed with cable (e.g. 1698AB)		IP68	•	•	•	•	•

Accessories							
Preloading element Thread × pitch/length Preloading force		Type Fv (kN)	**9460** M6×0.75 / 29 9.5	**9461** M8×1 / 40 20	**9465** M14×1.5 / 57 70	**9451A** M20×1.5 / 78 140	
Wrench adapter		Type	**9479**	**9475**	**9472**	**9471**	
Preloading element Thread × pitch/length Preloading force		Type Fv (kN)					**9455** M40×2 / 105 350
Wrench adapter		Type					**9473**
Preloading element Thread × pitch/length Preloading force		Type Fv (kN)				**9459** M26×0.75 / 76 140	
Wrench adapter		Type				**9477**	

3-component force links

Technical data		Type	9317C	9327C	9347C	9367C	9377C	9397C
								
Measuring ranges	F_x, F_y	kN	– 0.5 … 0.5	– 1 … 1	– 5 … 5	– 10 … 10	– 30 … 30	– 60 … 60
	F_z	kN	– 3 … 3	– 8 … 8	– 30 … 30	– 60 … 60	– 150 … 150	– 200 … 450
Calibrated meas. ranges	F_x, F_y	kN	0 … 0.05 / 0 … 0.5	0 … 0.1 / 0 … 1	0 … 0.5 / 0 … 5	0 … 1 / 0 … 10	0 … 3 / 0 … 30	0 … 4.5 / 0 … 45
	F_z	kN	0 … 0.3 / 0 … 3	0 … 0.8 / 0 … 8	0 … 3 / 0 … 30	0 … 6 / 0 … 60	0 … 15 / 0 … 150	0 … 30 / 0 … 300
Sensitivity	F_x, F_y	pC/N	≈ – 25	≈ – 7.8	≈ – 7.8	≈ – 7.6	≈ – 3.9	≈ – 3.7
	F_z	pC/N	≈ – 11	≈ – 3.8	≈ – 3.7	≈ – 3.9	≈ – 1.95	≈ – 1.95
Dimensions	L×W×H	mm	25×25×30	42×42×42	55×55×60	80×80×90	120×120×125	
Rigidity	$c_{S,xy}$ 1)	kN/µm	0.19	0.39	0.89	1.2	3.2	2.37
	$c_{A,z}$	kN/µm	0.9	1.4	2.7	3.8	8.2	11.58
Natural frequency	$f_n(x)$, $f_n(y)$	kHz	≈5.6	≈3.2	≈3.6	≈2.4	≈2	≈10.3
	$f_n(z)$	kHz	≈20	≈12	≈10	≈6	≈6	≈12.7
Weight		g	85	380	1 000	3 000	10 500	13 840
Operating temperature range		°C	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 120	– 40 … 80
Connector			V3 neg.	V3 neg.	V3 neg.	V3 neg.	V3 neg.	V3 neg.
Deg. of protection to IEC/EN 60529								
screwed with cable (e.g. 1698AA)		IP65	•	•	•	•	•	•
screwed with cable (e.g. 1698AB)		IP68	•	•	•	•	•	•
With basic insulation			•	•	•	•	•	•
Preloaded			•	•	•	•	•	•
Ready for measurement			•	•	•	•	•	•

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1) disregarding bending

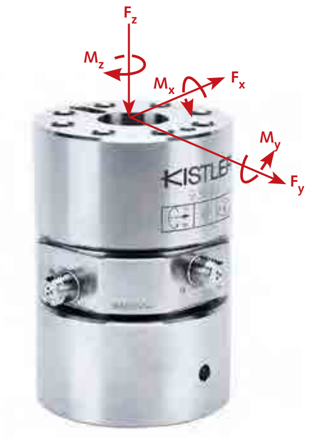
Innovative piezoelectric 6-axis force/moment sensor

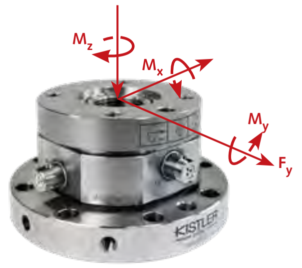
Kistler is proud to be the first sensor designer with a piezoelectric 6-axis force/torque sensor in its portfolio – specifically optimized for highly dynamic measurement with large measuring range. It is capable of measuring three forces and three moments precisely, directly and without calculation. It is also possible to set the torque range independently of the force range. Thanks to the piezoelectric measuring principle, very small moments and forces can be reliably measured at high static preloads. Based on a technological innovation of our research and development team, we have developed a truly unique measuring device and a 6 component force/moment sensor.

The Type 9306A can be used, for example:

- Testing components such as springs
- For transfer path analysis in the automotive industry
- In robotics at the joints
- For wind tunnel applications in the aerospace industry
- Micro vibration tests
- Reaction wheels measurements
- Flutter measurements

In addition, the connection technology allows a very simple cable installation with only 2 plugs. Compared to a piezoelectric dynamometer, the 6-axis force/moment sensor is much more compact. The 6-axis force/torque sensor Type 9306A ais ideally suited together with the charge amplifier LabAmp Type 5167A.





			9306A	9306A31
Measuring ranges	F_x, F_y F_z M_x, M_y, M_z	kN kN Nm	– 5 … 5 – 5 … 10 ± 200	– 1 … 1 – 2 … 2 ± 100
Calibrated meas. ranges	F_x, F_y F_z M_x, M_y, M_z	kN kN Nm	– 5 … 5 – 5 … 10 ± 200	– 1 … 1 – 2 … 2 ± 100
Natural frequency	fn(F_x, F_y, F_z) fn(M_x, M_y, M_z)	kHz kHz	>18 >11	>13 >11
Sensitivity	F_x, F_y F_z M_x, M_y M_z	pC/N pC/N pC/Nm pC/Nm	≈ – 7.3 ≈ – 3.6 ≈ – 255 ≈ – 225	≈ – 6.9 ≈ – 3.7 ≈ – 265 ≈ – 205
Dimensions	D h	mm mm	62 90	83 45
Weight	kg		1.5	0.54
Operating temprature range	°C		– 40 … 80	– 40 … 80
Connectors (2x)			V3 neg.	V3 neg.
Deg. of protection to IEC/EN 60529 (depending on cable length)			IP68	IP68
Ready for measurement			•	•

Accessories

	Type	1698ABB	1698ABB
	Type	1698ABW	1698ABW

Dynamometers and force link assembly kits

As well as classic dynamometers, Kistler also offers quartz force link assembly kits – so the right solution is available for many T&M applications.

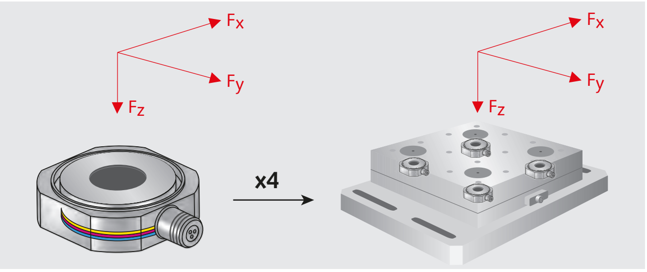
Depending on the application, one of the following two versions will be suitable:

- Dynamometers
- 3-component quartz force link assembly kits

Both versions allow 3-component-force measurements (F_x, F_y, F_z) as well as 6-component force/torque measurement (F_x, F_y, F_z, M_x, M_y, M_z); the torques are not measured in this case, but are calculated from the force components and the geometric dimensions of the dynamometer.

Dynamometers

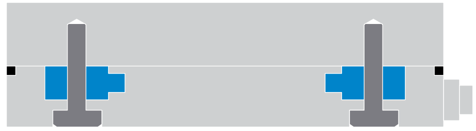
A dynamometer consists of four single 3-component force sensors which are installed with a high preload, between a baseplate and a cover plate. Dynamometers are already preloaded and calibrated for 3-component-force measurement (F_x, F_y, F_z), so it is very simple to integrate them into the application for immediate use.



Structure of a dynamometer comprising four 3-component force sensors

There are two different versions of dynamometers: they differ as regards their preloading (horizontal or vertical).

Vertical preloading is the classical method for the structure of a dynamometer. In this case, preloading screws are used to individually preload 3-component force sensors in the vertical direction, between the baseplate and cover plate.



Schematic view of a vertically preloaded dynamometer

Benefits of dynamometers with vertical preloading

- Wider measuring range
- Virtually no limits on overall dimensions

Horizontal preloading, patented by Kistler, is much less widespread. In this case, the classical setup with a baseplate and cover plate is no longer used; instead, two 3-component force sensors are preloaded in the horizontal direction between each of the two lateral and cover plates, with the help of a preloading screw.

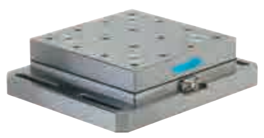
Schematic view of a horizontally preloaded dynamometer

Benefits of dynamometers with horizontal preloading

- Thermal influences on signals are significantly minimized
- Compact structural design
- Higher natural frequencies

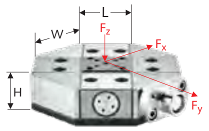
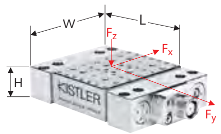
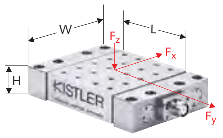
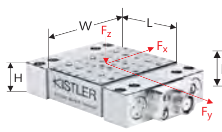
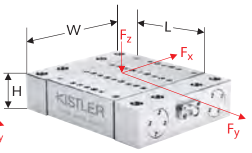
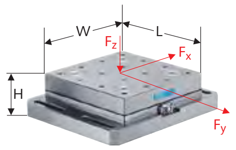
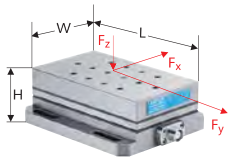
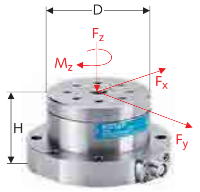
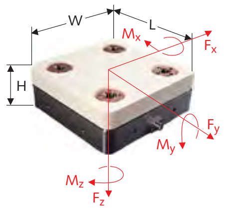
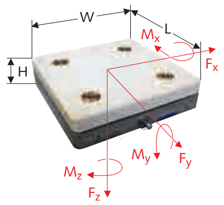
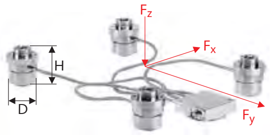
3-component force link assembly kits

A 3-component quartz force link assembly kit consists of four already preloaded 3-component quartz force links, with their outputs routed to a summing box. Assembly kits are ideal for customers who want to produce their own force plates with specific dimensions for the baseplates and cover plates. For this purpose, the assembly kits are already calibrated in the factory as force plates (F_x, F_y, F_z). Unlike dynamometers, 3-component quartz force link assembly kits are only available in the version with vertical preloading.

Dynamometers	
	+ Prefabricated standard dynamometer – ready to measure immediately + Tested specifications (in F_x, F_y, F_z) – Geometric dimensions are pre-specified and cannot be changed

3-component quartz force link assembly kits	
	+ Assembly kit for users to assemble their own application – specific force plate + Customized dimensions for baseplate and cover plate + Assembly kit is precalibrated – The customer is responsible for compliance with the specifications – Substantial effort is required before the force plate is complete and ready to measure (design and manufacture of the base-plate and cover plate, as well as mounting); this requires the relevant know-how

Multi-component dynamometers / force measurement platforms

Technical data		Type	9109	9119AA1	9119AA2	9129AA	9139AA	9255C	9257B	9272	9236A1	9236A2	9366CC...
													
Measuring range	F_x, F_y	kN	– 0.5 ... 0.5	– 4 ... 4	– 4 ... 4	– 10 ... 10	– 30 ... 30	– 30 ... 30	– 5 ... 5	– 5 ... 5	– 5 ... 5	– 5 ... 5	– 25 ... 25 1)
	F_z	kN	– 0.5 ... 0.5	– 4 ... 4	– 4 ... 4	– 10 ... 10	– 30 ... 30	– 10 ... 60	– 5 ... 10	– 5 ... 20			– 25 ... 60 1)
	M_z	N·m	– 50 ... 50							– 200 ... 200			
Calibrated meas. ranges	F_x, F_y	kN	0 ... 0.5	0 ... 0.04	0 ... 0.04	0 ... 0.1	0 ... 0.3	0 ... 3	0 ... 0.5	0 ... 0.5	0 ... 0.2	0 ... 0.1	0 ... 2.5 1)
			0 ... 0.05	0 ... 0.4	0 ... 0.4	0 ... 1	0 ... 3	0 ... 30	0 ... 5	0 ... 5			0 ... 25 1)
			0 ... 0.01	0 ... 4	0 ... 4	0 ... 10	0 ... 30						
	F_z	kN	0 ... 0.5	0 ... 0.04	0 ... 0.04	0 ... 0.1	0 ... 0.3	0 ... 6	0 ... 1	0 ... 2	0 ... 0.2	0 ... 0.1	0 ... 6 1)
			0 ... 0.05	0 ... 0.4	0 ... 0.4	0 ... 1	0 ... 3	0 ... 60	0 ... 10	0 ... 20			0 ... 60 1)
			0 ... 0.1	0 ... 4	0 ... 4	0 ... 10	0 ... 30						
	M_x	N·m									0 ... 30	0 ... 19.5	
	M_y	N·m									0 ... – 30	0 ... – 19.5	
	M_z	N·m								0 ... ±20	0 ... 30	0 ... 19.5	
		N·m								0 ... ±200			
	-M_z	N·m									0 ... – 30	0 ... 19.5	
Natural frequency	$f_n(x)$	kHz	>15	≈ 6.0	≈ 4.3	≈ 3.5	≈ 2.9	≈ 2.2	≈ 2.3	≈ 3.1	≈ 2.6	≈ 1.9	≈0.2 ... ≈1.6 2)
	$f_n(y)$	kHz	>15	≈ 6.4	≈ 4.6	≈ 4.5	≈ 2.9	≈ 2.2	≈ 2.3	≈ 3.1	≈ 2.6	≈ 1.9	≈0.2 ... ≈1.6 2)
	$f_n(z)$	kHz	>15	≈ 6.3	≈ 4.4	≈ 3.5	≈ 3.0	≈3.3	≈ 3.5	≈ 6.3	≈ 4.5	≈ 2.5	≈0.2 ... ≈1.6 2)
	$f_n(M_z)$	kHz								≈ 4.2			
Sensitivity	F_x	pC/N	≈ – 12.5	≈ – 26	≈ – 26	≈ – 8	≈ – 8.2	≈ – 7.9	≈ – 7.5	≈ – 7.8	≈ – 7.8	≈ – 7.8	≈ – 7.8
	F_y	pC/N	≈ – 12.5	≈ – 13	≈ – 13	≈ – 4.1	≈ – 4.2	≈ – 7.9	≈ – 7.5	≈ – 7.8	≈ – 7.8	≈ – 7.8	≈ – 7.8
	F_z	pC/N	≈ – 20	≈ – 26	≈ – 26	≈ – 8	≈ – 8.2	≈ – 3.9	≈ – 3.7	≈ – 3.5	≈ – 3.8	≈ – 3.8	≈ – 308
	M_z	pC/Nm								≈ – 160			
Dimensions	L	mm	30	39	55	90	140	260	170		260	400	
	W	mm	30	80	80	105	190	260	100		260	400	
	H	mm	29	26	26	32	58	95	60	70	95	95	90
	D	mm								100			72
Weight		kg	1.04	0.93	1.35	3.2	12.9	52	7.3	4.2	31.5	72	7
Operating temperature range		°C	– 20 ... 70	– 20 ... 70	– 20 ... 70	– 20 ... 70	– 20 ... 70	– 20 ... 70	0 ... 70	0 ... 70	0 ... 60	0 ... 60	– 20 ... 70
Connector			Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.	Fischer flange, 9-pole, neg.
Deg. of protection to IEC/EN 60529 with cable connected		IP67	•	•	•	•	•	•	•	•	•	•	•
Ready for measurement			•	•	•	•	•	•	•	•	•	•	•

Accessories		9109	9119AA1	9119AA2	9129AA	9139AA	9255C	9257B	9272	9236A1	9236A2	9366CC...
Connecting cable 	**Type**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**	**1687B5 (3-comp.), 1677A5 (6-comp.)**
	**Type**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**	**1689B5 (3-comp.), 1679A5 (6-comp.)**

1) depending on cover plate size and material

2) mounted on steel cover plate, 300×300×35 mm

Strain sensors

Piezoelelectric sensors from Kistler can be used for high-resolution measurements of the strains occurring on a structure.

To achieve this, the sensor is mounted in a suitable position. If an indirect force measurement is required, the sensor is calibrated. The relevant factors here are the geometry of the structure, the material's modulus of elasticity and the mechanical stress.

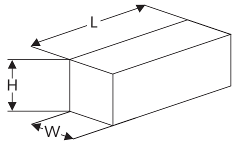
$\sigma = \frac{F}{A}$ and strain $\varepsilon = \frac{\Delta l}{l_0}$

Surface strain sensors are attached to the structure with the mounting screw. The structure's strain is transmitted to the measuring element through static friction.

Strain measuring pins need a cylindrical mounting bore in which the sensor is then inserted and preloaded. Kistler offers strain measurement sensors with axial and radial alignment to the axis of the bore hole.

Benefits
- Durable, no creep
- Protected against overload
- Cost-to-benefit ratio
- High loading capacity
- Simple to install
- Fault-resistant
- Straightforward retrofitting

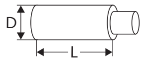
Surface strain sensor

Technical data		Type	9232A...	9237B...	9238B...
					
Measuring range		με	– 600 ... 600	– 800 ... 800	– 20 ... 20 to – 800 ... 800
Calibrated meas. ranges*		με	0 ... – 300 0 ... 300	0 ... 500	0 ... 50 0 ... 500
Sensitivity*		pC/με	≈ – 80	≈ – 34	
Output signal		V			±10 (programmable ±1 ... 10)
Dimensions	L W H	mm mm mm	40 17 15	51.5 25.4 26.7	68.1 26.9 27.5
Natural frequency	f_n	kHz	≥12	≥6	
Weight		g	50	165/190	190
Operating temperature range		°C	0 ... 70	– 30 ... 120	– 10 ... 70
Connector			KIAG 10-32 neg.	KIAG 10-32 neg.	M12×1 8-pole, shielded
Serial interface					RS-232C
Deg. of protection to IEC/EN 60529					
screwed with cable (e.g. 1631C...)		IP65	•	•	
welded with cable (e.g. 1983C...)		IP67	•		
screwed with cable (e.g. 1787A...)		IP67			•
Ready for measurement			•	•	•

* Data valid only for the test setup used at Kistler.
For precise force measurements, the sensor must be recalibrated after it is mounted.

Surface strain sensor for indirect measurement of process forces Load washer

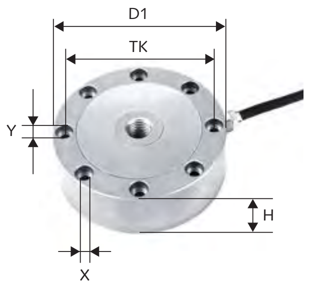
Strain measuring pin

Technical data		Type	9240A...	9241C...	9243B...	9245B..., 9245B3	9247A...
							
Measuring range		με	0 ... 500	0 ... 500	– 1 500 ... 1 500 (with nominal preload)	– 1 500 ... 1 500 (with nominal preload)	– 1 400 ... 1 400 (with nominal preload)
Calibrated meas. ranges*		με	0 ... 200	0 ... 200	0 ... 350	0 ... 350	not calibrated
Sensitivity*		pC/με	≈ – 9.5	≈ – 15	≈ – 15	≈ 15	≈ 8.6
Dimensions	D	mm	8	10	8	M10×1	M5×0.5
	L	mm	14.5	18	13	29	23.7
Hollow preloading bolt					M10×1		
Natural frequency	f_n	kHz			>110	>50	
Weight		g	34	38	4.8 (without cable and preloading screw)	36	2.5
Operating temperature range		°C	– 40 ... 200	– 40 ... 200	– 40 ... 200	– 40 ... 350	– 40 ... 200
Connector			M3 pos. KIAG 10-32 pos.	Mini-Coax neg. KIAG 10-32 pos.	M4×0.35 neg.	Fischer KE 102 neg.	M4×0.35 neg.
Deg. of protection to IEC/EN 60529 with connected cable		IP64	•	•	•		•
with cable Type 1983AB... and welded-on plug		IP67			•	•	•

Accessories						
Mounting tool	**Type**	**1300A161A100**	**1393B**	**1385B200**		**1300A9**
	Type	**1300A163A300**	**1393Bsp100-300**	**1385Bsp100-800 / 1387sp100-800**		
Force distributing cap	**Type**			**9841**		
Ground isolation set	**Type**			**9487A**		
Reamer	**Type**			**1300A21**	**1300A21**	**1300A79 / 1300A79Q01**
Screw tap	**Type**					**1357A**

* Data valid only for the test setup used at Kistler.
For precise force measurements, the sensor must be recalibrated after it is mounted.

1-component strain gauge force sensors



Type 4576A...

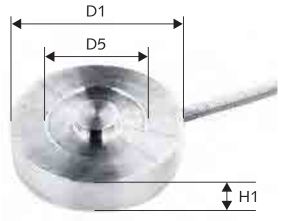
Technical data		Type	4576A0,5...	4576A1...	4576A2...
Measuring range	F_z	kN	– 0.5 ... 0.5	– 1 ... 1	– 2 ... 2
Dimensions	H	mm	16	16	16
	D1	mm	54.5	54.5	54.5
	TK	mm	45	45	45
	X	mm	4.5	4.5	4.5
	Y	mm	8	8	8

Technical data		Type	4576A5...	4576A10...	4576A20...
Measuring range	F_z	kN	– 5 ... 5	– 10 ... 10	– 20 ... 20
Dimensions	H	mm	16	16	25
	D1	mm	54.5	54.5	79
	TK	mm	45	45	68
	X	mm	4.5	4.5	4.5
	Y	mm	8	8	8

Technical data		Type	4576A50...	4576A100...	4576A200...
Measuring range	F_z	kN	– 50 ... 50	– 100 ... 100	– 200 ... 200
Dimensions	H	mm	35	50	50
	D1	mm	119	155	155
	TK	mm	105	129	129
	X	mm	6.6	13.5	13.5
	Y	mm	11	20	20

General technical data		
Nominal sensitivity	mV/V	1.5 (optional: 1.0)
Weight	Kg	0.25 ... 5.0
Operating temperature range	°C	15 ... 70
Service temperature range	°C	– 30 ... 80
Bridge resistance	Ω	350
Connector for maXYmos family		D-Sub 9-pole plug
Deg. of protection to IEC/EN 60529		IP52 (0 ... 10 kN) IP67 (20 ... 200 kN)

Accessories		
Connecting cable, 5 m, 6-pole/6-pole 	**Type**	**KSM071860-5**
Connecting cable, 5 m, 6-pole/free 	**Type**	**KSM103820-5**



Type 4577A...

Technical data		Type	4577A0,1	4577A0,2	4577A0,5	4577A1
Measuring range	F_z	kN	0.1	0.2	0.5	1
Bridge resistance		Ω	350	350	350	350
Dimensions	H1	mm	9.9	9.9	9.9	9.9
	D1	mm	31.8	31.8	31.8	31.8
	D5	mm	19	19	19	19

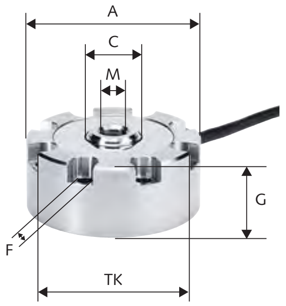
Technical data		Type	4577A2	4577A5	4577A10	4577A20
Measuring range	F_z	kN	2	5	10	20
Bridge resistance		Ω	350	700	700	700
Dimensions	H1	mm	9.9	9.9	9.9	16
	D1	mm	31.8	31.2	31.2	37.6
	D5	mm	19	19.5	19.5	25.7

Technical data		Type	4577A50	4577A100	4577A200
Measuring range	F_z	kN	50	100	200
Bridge resistance		Ω	700	700	350
Dimensions	H1	mm	16	25.4	38.1
	D1	mm	37.6	50.3	76.2
	D5	mm	25.7	34.7	45

General technical data		
Nominal sensitivity	mV/V	1
Weight	Kg	0.04 ... 1.2
Operating temperature range	°C	15 ... 70
Service temperature range	°C	– 20 ... 100
Connector for maXYmos family		D-Sub 9-pole plug
Deg. of protection to IEC/EN 60529		IP64

Accessories		
Connecting cable, 5 m, 6-pole/6-pole 	**Type**	**KSM071860-5**
Connecting cable, 5 m, 6-pole/free 	**Type**	**KSM103820-5**

1-component strain gauge force sensors



Type 4578A...

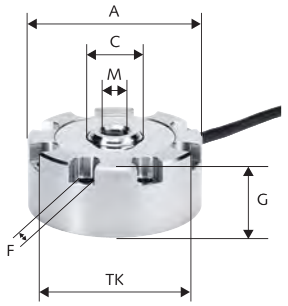
Technical data		Type	4578A0,1	4578A0,2	4578A0,5
Measuring range	F_z	kN	– 0.1 ... 0.1	– 0.2 ... 0.2	– 0.5 ... 0.5
Dimensions	A	mm	70	70	70
	C	mm	20	20	20
	F	mm	6.4	6.4	6.4
	M	mm	M12	M12	M12
	G	mm	28	28	28
	TK	mm	60	60	60

Technical data		Type	4578A1	4578A2	4578A5
Measuring range	F_z	kN	– 1 ... 1	– 2 ... 2	– 5 ... 5
Dimensions	A	mm	70	70	70
	C	mm	20	20	20
	F	mm	6.4	6.4	6.4
	M	mm	M12	M12	M12
	G	mm	28	28	28
	TK	mm	60	60	60

Technical data		Type	4578A10
Measuring range	F_z	kN	– 10 ... 10
Dimensions	A	mm	70
	C	mm	20
	F	mm	6.4
	M	mm	M12
	G	mm	28
	TK	mm	60

General technical data		
Nominal sensitivity	mV/V	2.0±0.005
Weight (without cable)	Kg	≤0.5
Operating temperature range	°C	15 ... 50
Service temperature range	°C	– 20 ... 50
Bridge resistance	Ω	350
Connector for maXYmos family		D-Sub 9-pole plug
Deg. of protection to IEC/EN 60529		IP42

Accessories		
Force distributing cap	**Type**	**4578AZ01**



Type 4579A...

Technical data		Type	4579A20	4579A50	4579A100
Measuring range	F_z	kN	– 20 ... 20	– 50 ... 50	– 100 ... 100
Dimensions	A	mm	150	150	165
	C	mm	40	40	50
	F	mm	11	11	13
	M	mm	M24×2	M24×2	M36×3
	G	mm	40	40	42
	TK	mm	130	130	145

Technical data		Type	4579A200	4579A300	4579A500
Measuring range	F_z	kN	– 200 ... 200	– 300 ... 300	– 500 ... 500
Dimensions	A	mm	165	203	203
	C	mm	50	94	94
	F	mm	13	13	13
	M	mm	M36×3	M45×3	M45×3
	G	mm	42	64	64
	TK	mm	145	165	165

General technical data		
Nominal sensitivity	mV/V	2.0±0.005
Weight (without cable)	Kg	3.7 ... 14.4
Operating temperature range	°C	15 ... 50
Service temperature range	°C	– 20 ... 50
Bridge resistance	Ω	350
Connector for maXYmos family		D-Sub 9-pole plug
Deg. of protection to IEC/EN 60529		IP67

Accessories		
Force distributing cap, measuring range 20/50 kN	**Type**	**4579AZ20/50**
Force distributing cap, measuring range 100/200 kN	**Type**	**4579AZ100/200**
Force distributing cap, measuring range 300/500 kN	**Type**	**4579AZ300/500**

Cables

As a mandatory requirement, piezoelectric force sensors and charge amplifiers must be connected with a high-insulation cable (insulation resistance $>10^{13}\ \Omega$).

In contrast to standard coaxial cables, the innermost wire of high-insulation cables is insulated with PTFE. This reduces the drift effect to the absolute minimum. In addition, a special graphite sheathing minimizes the triboelectric effect. There are various versions (with corresponding properties) for the outermost insulation casing (see: cable versions).

Cable types

Single-wire

PFA cable (ø2 mm/ø0.08 in)
The outer insulation of high-insulation PFA cable consists of a material similar to PTFE, so it exhibits excellent thermal stability and outstanding resistance to chemicals. PFA cable is suitable for most applications with temperatures up to 200°C (392°F).

PFA cable

FKM cable (ø2 mm/ø0.08 in)
FKM cable also features high thermal and chemical resistance, and can be used at temperatures of up to 200°C (392°F).
In contrast to PFA cable, however, the cable connectors are vulcanized. Tight solutions to IP68 can be achieved by welding the cable connector and the sensor connector.

FKM cable

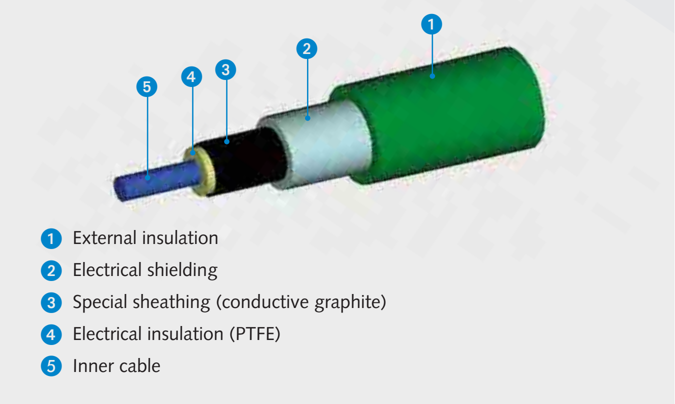
Multiple-wire

TPE cable (ø3.6 mm/ø0.14 in)
TPE cable is a high-insulation 3-wire cable with sheathing made of TPE, a thermoplastic elastomer. This cable is suitable for applications with temperatures up to 120°C (248°F) in harsh environments (e.g. dust and splash water).

TPE Cable

Special PI cable

The use of PI cables is only recommended for applications with high temperatures up to 260°C (500°F). Since the use of PI cables is quite rare and requires special know-how, the corresponding products are not listed in this catalog. If you have a requirement, please contact your local Kistler Sales Center.



Structure of a Kistler high-insulation cable

Cable variants

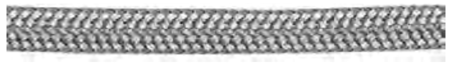
Plastic braiding

Single-wire cables (mostly PFA) that are joined together to a multi-wire harness have to be surrounded by plastic braiding which holds them together. The braiding does not change any properties of the consisting cable.

PFA cable with plastic braiding

Stainless steel braiding

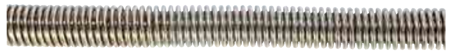
The stainless steel braiding protects against mechanical stress in a rougher environment (e.g. vibration-induced friction, sharp edges, etc). The robust structure withstands high temperatures and can achieve IP68 protection level, depending on cable and connector.



Stainless steel braiding

Flexible stainless steel hose

The flexible steel hose is used for multi-wire dynamometer cables and contains up to 8 cables. Thanks to their rugged structure they reach IP67 protection (depending on connected equipment) and can also be used in harsh environments.



Stainless steel hose

Cable lenghts

All Kistler cables are available in standard and custom lengths. Standard lengths are kept in stock, so they offer the advantage of shorter delivery times.

Connections

Following an explanation of Kistler's connectors and connector variations on their high insulating cable portfolio.

Connector types
The different connector types are not compatible between each other without an adapter. Kistler covers the following connector types in the force measuring chain:

• 1-component:	**KIAG 10-32** **M4x0.35** **BNC** **TNC**
• 2-/3-component:	**V3 (3-pin)**
• multi-component:	**Fischer (7-/9-pin)**

The single pin connectors **KIAG 10-32 pos. int.** and **M4x0.35 pos. int.** with integrated thread are firmly attached to the cable, so the cable rotates at the same time when the connector is screwed and unscrewed. This is particularly advantageous for harsh environments and one-time installations. For laboratory and test stand applications, where the test setup is changing often, the standard connectors (with swivel or hex nuts) are more convenient.

Connector types

BNC

The BNC cable connector is the most commonly used connector for the charge amplifiers. Most cables are available in this version. However, they are not suitable for certain applications where it has to be routed through small openings.

TNC

The TNC connector is a special variation of the BNC connection that is required for certain specific applications. but not widely used for piezoelectric sensors.

KIAG 10-32

KIAG 10-32 is the standard connection for most single measurand sensors. It is a slim and effective coaxial connector based on the imperial metering system.

M4x0.35

M4x0.35 is an alternative to the KIAG 10-32, but based on the metric metering system.

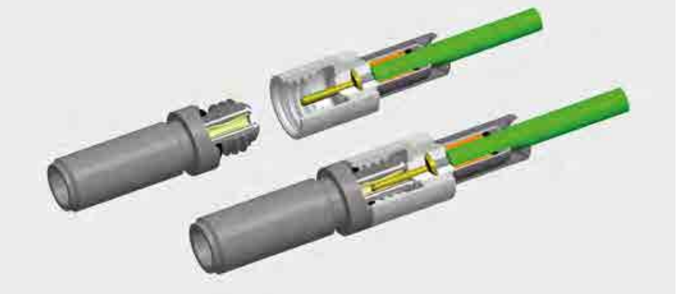
V3

V3 is a design protected 3-component connector for triaxial sensors from Kistler. It is twist protected and prevents mistakes at the cable routing.

Fischer

Fischer connectors integrate multiple wires at the same connector. They are mostly used for dynamometers and might contain a 1-to-1 routing or a summation of some of the signals. Fischer connectors come with different amount of pins.

KIAG 10-32 pos. – connector with rotatable swivel nut



KIAG 10-32 pos. int. – connector with integrated thread

Connector variants

pos./neg.

In order to get a matching pair of sensor and cable, every "neg."connector has to be combined with a "pos." connector. Precondition of course is an identical connector type.

int. (weldable)

The int. connector variant has an integrated thread and is the only cable connector, that can be welded to the sensor. Welding provides a higher IP-protection level and the best prevention of detachment of the cable, if the measuring chain is subject to strong vibrations. The possibility to weld depends on sensor counterpart as well.

hex/6kt

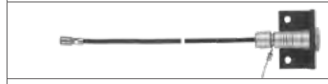
The hex/6kt variant was especially designed for single signal connectors that reach IP68 protection level without welding. They are detachable and can be tightened with a wrench.

90°

The 90° variant is an angled version of the respective connector. If the connector type has more than one pin (V3, Fischer), the horizontal/vertical direction has to be considered.

1-component sensors

Overview of cables

												Industrial amplifier					Laboratory amplifier					
											Type	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
Sensor family	Cable		Cable properties	Length [m]	Temp. range [°C]	IEC/EN 60529		Connector sensor	Connector amplifier	IEC/EN 60529		IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
90x1C 90x1B 910xC 917xC 93x1C 9313AA… 93xA…		1631C…	PFA	0.1 … 100	– 55 … 200	Plug screwed	IP65	KIAG 10-32 pos.	BNC pos.	IP40	Plug screwed	–	■	■	–	■	■	■	■	■	■	■
		1641B…	PFA	0.1 … 100				KIAG 10-32 90° pos.	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.			■	–	–	■	–	–	–	–	–	–	–
		1945A	PFA	0.1 … 5				KIAG 10-32 pos. int.	Mini-Coax neg.			–	–	–	–	–	–	–	–	–	–	–
		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		IP67	KIAG 10-32 pos. hex	BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
		1900A23A11..		0.3 … 20				KIAG 10-32 pos. hex	KIAG 10-32 pos. hex	IP67		■	–	–	■	–	–	–	–	–	–	–
		1900A21A12x	FPM flexible steel tube	0.4 … 20	– 20 … 200			KIAG 10-32 pos. hex	BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
		1900A21A11x	FPM flexible steel tube	0.4 … 20				KIAG 10-32 pos. hex	KIAG 10-32 pos. hex	IP67		■	–	–	■	–	–	–	–	–	–	–
		1983AD…	FPM	0.1 … 5			IP68	KIAG 10-32 pos. int.	BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
		1939A…	PFA	0.1 … 20	– 55 … 200	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	Plug screwed	–	■	■	–	–	–	–	–	–	–	–
		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			KIAG 10-32 pos. int.	Fischer 9-pol. neg.			–	–	–	–	–	–	–	■	–	■	–
		1983AC…	FPM	0.1 … 5			IP68	KIAG 10-32 pos. int.	KIAG 10-32 pos. int.[2]			■	–	–	■	–	–	–	–	–	–	–
		1937A…	Extension cable, PFA, Ø 2 mm	0.3 … 100	– 55 … 200	Plug screwed	IP65	Mini-Coax neg.	BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
		1637C…	Extension cable, PFA, Ø 2 mm	0.1 … 5				KIAG 10-32 neg.	KIAG 10-32 pos.	IP65	screwed	■	–	–	■	–	–	–	–	–	–	–
		1721	Adapter for cables with KIAG 10-32 pos. int.					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		–	–	–	–	–	–	–	–	–	–	–

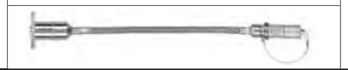
Sensor family	Cable		Cable properties	Length [m]	Temp. range [°C]	IEC/EN 60529		Connector sensor	Connector amplifier	IEC/EN 60529		IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
9215A 9243B 9247A		1651C…	PFA	0.3 … 10	– 55 … 200	Screwed	IP65	M4x0.35 pos.	BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
		1655C…	PFA	0.3 … 10				M4x0.35 pos.	KIAG 10-32 pos.	IP65	Plug screwed	■	–	–	■	–	–	–	–	–	–	–
		1645C…	PFA	0.1 … 5	– 55 … 200	Plug welded [1]	IP67	M4x0.35 pos. int.	Fischer coax neg.	IP65		–	–	–	–	–	–	–	–	–	–	–
		1926A…	PFA	0.1 …10				M4x0.35 pos. int.	M4x0.35 pos. int.			■	–	–	■	–	–	–	–	–	–	–
		1923A…	PFA	0.1 … 5				M4x0.35 pos. int.	KIAG 10-32 pos. int.[2]			■	–	–	■	–	–	–	–	–	–	–
		1983AB…	FPM	0.5 … 5				M4x0.35 pos. int.	KIAG 10-32 pos. int.[2]			■	–	–	■	–	–	–	–	–	–	–
		1951A…	Kapton steel braiding	0.1 … 5	– 55 … 300			M4x0.35 pos. int.	KIAG 10-32 pos. int.[2]			■	–	–	■	–	–	–	–	–	–	–

[1] screwed: IP65

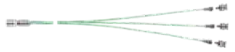
[2] welded: IP67

1-component sensor sets

Overview of cables

													Industrial amplifier					Laboratory amplifier					
												Type	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
Sensor family	**Cable/adapter**	**Output signal**		**Cable/adapter**	**Cable properties**	**Length [m]**	**Temp. range [°C]**	**IEC/EN 60529**		**Connector sensor**	**Connector amplifier**	**IEC/EN 60529**	IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
913xCA… 914xBA…		**sum**	**1**	1971A1x	PFA	0.1 … 20	– 55 … 200	Plug screwed	**IP65**	Fischer 7-pol pos.	BNC pos.	IP40	–	■	■	–	■	■	■	■	■	■	■
				1971A3x							Fischer KE102A014-14	IP65	add. cable needed										
				1971A4x							TNC pos.		–	■	■	–	–	–	–	–	–	–	–
				1971A5x							KIAG 10-32 pos. int.		■	–	–	■	–	–	–	–	–	–	–
		**separate**	**2**	1973A21x	PFA, PUR protection tube	0.1 … 20	– 55 … 200		**IP65**	Fischer 7-pol pos.	KIAG 10-32 pos. int.	IP65	■	–	–	■	–	–	–	–	–	–	–
			3	1973A31x									■	–	–	■	–	–	–	–	–	–	–
			4	1973A41x									■	–	–	■	–	–	–	–	–	–	–
			4	1973A419Q01	PFA steel braiding	0.6 … 5	– 55 … 200						■	–	–	■	–	–	–	–	–	–	–
			**4**	1692A…		0.1 … 5	– 5 … 70				Fischer 9-pole pos.		–	–	–	–	–	–	–	■	–	■	–
				1721	Adapter for cables with KIAG 10-32 pos. int.		– 55 … 200		**IP65**	KIAG 10-32 neg.	BNC pos.	IP40	–	■	■	–	■	■	■	■	■	■	■
				1729A	Cable gland with KIAG 10-32 pos. int.						KIAG 10-32 neg.	IP65	■	–	–	■	–	–	–	–	–	–	–

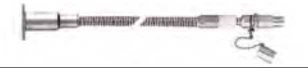
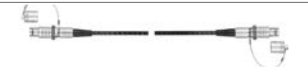
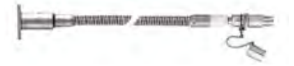
Multi-axis force sensors

														Industrial amplifier					Laboratory amplifier					
													Type	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
Sensor family	**Cable/adapter**	**Output signal**		**Cable/adapter**	**Cable properties**	**Length [m]**	**Temp. range [°C]**	**IEC/EN 60529**		**Connector sensor**	**Connector amplifier**	**IEC/EN 60529**		IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
93x5B		**separate**	**2**	1698AD…	PFA synthetic braiding	0.2 … 20	– 40 … 120		**IP65**	V3 pos.	2x BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
				1698AP...	PFA with plastic braiding						2x KIAG10-32 pos.	IP65		■	–	–	■	–	–	–	–	–	–	–
(93x5B) 90x6C 90x7C 90x8C 93x7C (9306A)		**separate**	**3**	1698AA…	PFA synthetic braiding	0.2 … 20	– 40 … 120	Plug screwed	**IP65**	V3 pos.	3x BNC pos.	IP40	Plug screwed	–	■	■	–	■	■	■	■	■	■	■
				1698AH…		0.2 … 20					3x SMC neg.			–	–	–	–	–	–	–	–	–	–	–
				1698AE…	PFA synthetic braiding	0.2 … 20					3x KIAG 10-32 pos.	IP65		■	–	–	■	–	–	–	–	–	–	–
				1698AV...	PFA without synthetic braiding	0.2 … 20					3x KIAG 10-32 pos. (3x BNC with included adapters)	IP40		■	■	■	■	■	■	■	■	■	■	■
				1698AN...	TPC black Ø3.6mm	0.5 … 20				V3 pos. 90°	3x KIAG10-32 pos.	IP65		■	–	–	■	–	–	–	–	–	–	–
				1698AK…							Fischer 9-pole pos.			–	–	–	–	–	–	–	■	–	■	–
				1698AF...					**IP68**	V3 pos.	3x Mini Coax neg.	IP40		–	–	–	–	–	–	–	–	–	–	–
				1698AL…							3x KIAG 10-32 pos.	IP65		■	–	–	■	–	–	–	–	–	–	–
				1698AM...	PFA with steel braiding	0.3 … 10								■	–	–	■	–	–	–	–	–	–	–
				1698AB…	TPC black Ø3.6 mm	0.5 … 20					Fischer 9-pole pos.			–	–	–	–	–	–	–	■	–	■	–
				1698AI…	PFA, steel braiding	0.3 … 20								–	–	–	–	–	–	–	■	–	■	–
		**separate**	**3**	1698AG…[1]	PFA, steel braiding	2 … 5	– 40 … 120	welded	**IP67**	V3 pos.	3x mini coax neg.	IP40		–	–	–	–	–	–	–	–	–	–	–
				1698AC…[1]							Fischer 9-pole pos.	IP65		–	–	–	–	–	–	–	■	–	■	–
9306A		**separate**	**6**	1698ABW…	TPC, Ø3.6 mm, Y-Cable	0.5 … 20	– 40 … 120	screwed	**IP65**	2x V3 pos. 90°	Fischer 9-pole pos.	IP65		–	–	–	–	–	–	–	■	–	■	–
				1698ABB…					**IP68**	2x V3 pos.				–	–	–	–	–	–	–	■	–	■	–

[1] not suitable with 9306A (Sensor not weldable)

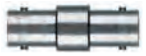
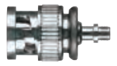
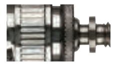
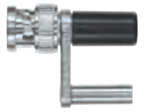
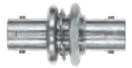
Dynamometer and force plates

Overview of cables

														Industrial amplifier	Industrial amplifier	Industrial amplifier	Industrial amplifier	Industrial amplifier	Laboratory amplifier	Laboratory amplifier	Laboratory amplifier	Laboratory amplifier	Laboratory amplifier	DAQ
													Type	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
Sensor family	Cable/adapter	Output signal		Cable/adapter	Cable properties	Length [m]	Temp. range [°C]		IEC/EN 60529	Connector sensor	Connector amplifier	IEC/EN 60529		IP65	IP65	IP60	IP67	IP53	IP20	IP40	IP40	IP20	IP20	IP20
9109 9119AA… 9129AA 9139AA 9255A 9257B 9272 9366C		sum	3	Z15141sp	PFA	1 … 20	– 5…70	plugged	IP40	9-pole pos.	3x BNC pos.	IP40	plugged	–	■	■	–	■	■	■	■	■	■	■
				1683Asp	PFA with flexible steel hose	2 … 20			IP65	9-pole pos. 90°	Fischer 9-pole pos.	IP65		–	–	–	–	–	–	–	■	–	■	–
				1687BQ01…	TPC black Ø3.6 mm	1 … 20		boltable	IP65	Flange 9-pole pos.				–	–	–	–	–	–	–	■	–	■	–
				1687BQ02…	PFA, steel braiding	1 … 5			IP67	Flange 9-pole pos.				–	–	–	–	–	–	–	■	–	■	–
				1687B…	PFA with flexible steel hose	2 … 20								–	–	–	–	–	–	–	■	–	■	–
				1689B…		1 … 20				Flange 9-pole pos. 90°				–	–	–	–	–	–	–	■	–	■	–
		separate	8	Z16620sp	PFA	1 … 20	– 5…70	plugged	IP40	9-pole pos.	8x BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
				1685B…	TPC black Ø5.6 mm	1 … 20			IP65	9-pole pos.	Fischer 9-pole pos.	IP65		–	–	–	–	–	–	–	■	–	■	–
				1686A…	TPC black Ø5.6 mm	1 … 20				9-pole pos. 90°				–	–	–	–	–	–	–	■	–	■	–
				1681B…	PFA with flexible steel hose	1 … 20				9-pole pos.				–	–	–	–	–	–	–	■	–	■	–
				1677AQ01..	TPC black Ø5.6 mm	1 … 20		boltable	IP65	Flange 9-pole pos.				–	–	–	–	–	–	–	■	–	■	–
				1677AQ02..	TPC, steel braiding	1 … 20			IP67	Flange 9-pole pos.				–	–	–	–	–	–	–	■	–	■	–
				1677A…	PFA with flexible steel hose	1 … 20								–	–	–	–	–	–	–	■	–	■	–
				1679A…		2 … 20				Flange 9-pole pos. 90°				–	–	–	–	–	–	–	■	–	■	–
		extension	3	Z13705sp…	PFA	1 … 20	– 5…70	plugged	IP40	9-pole neg.	3x BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
				1688B…	TPC black Ø3.6 mm	1 … 20			IP65	9-pole neg.	Fischer 9-pole pos.	IP65		–	–	–	–	–	–	–	■	–	■	–
			8	Z16634sp..	PFA	1 … 20	– 5…70		IP40	9-pole neg.	8x BNC pos.	IP40		–	■	■	–	■	■	■	■	■	■	■
				1656Asp	PFA	1 … 20					8x KIAG 10-32 neg.	IP65		■	–	–	■	–	–	–	–	–	–	–
				1678A…	TPC black Ø5.6 mm	1 … 20			IP65	9-pole neg.	Fischer 9-pole pos.			–	–	–	–	–	–	–	■	–	■	–

Accessories – cables

Couplings

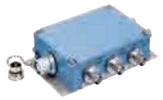
Type		Connector	
		Left	Right
1701		BNC neg.	BNC neg.
1705		BNC pos.	M4x0.35 neg.
1721		BNC pos.	KIAG 10-32 neg.
1729A		KIAG 10-32 neg.	KIAG 10-32 neg.
1733		BNC pos.	Banana jacks
1743		BNC pos.	2 x BNC neg.
1749		KIAG 10-32 pos.	2 x KIAG 10-32 neg.
1700A29		KIAG 10-32 neg.	KIAG 10-32 pos. int.
1703		BNC neg.	BNC neg.

Plastic protective caps

Type		To be used for
1851		BNC neg.
1861A		BNC pos.
1891		KIAG 10-32 neg.

The plastic protective caps reliably protect the connectors and sockets against contamination. If sensors or charge amplifiers are not being used or are in storage, it is always advisable to protect the connectors with protective caps.

Distribution box (high-insulation)

Type		Input	Output	Comments
5405A		Fischer 9-pole neg.	8 x BNC neg.	8 single channels
5407A		Fischer 9-pole neg.	3 x BNC neg.	3 channels summed: F_x, F_y, F_z

Distribution boxes can be used to assign the channels of sensors with Fischer 9-pole pos. cable connectors to individual BNC sockets:

- Type 5405A runs all 8 individual channels to separate BNC sockets
- Type 5407A runs the 8 channels (summed) to 3 BNC sockets (F_x, F_y, F_z)

BNC Cable, High-Insulation

Type	Connector		Length (standard) [m, ft] [1]	Length (custom) [m, ft] [1]		Cable sheath material	Operating temperature range [°C, °F]		Deg. of protection to IEC/EN 60529	
	Left	Right		min.	max.		min.	max.	Left	Right
1601B... 	BNC pos.	BNC pos.	0.5/1/2/5/10/20/1.6/ 3.3/6.6/16.4/32.8/65.6	0.1 0.3	50 164	PVC	– 25 – 13	70 158	IP40	IP40

---

[1] Cable ordering is in meters

Accessories – electronics

Charge attenuators

Technical data	Type	5361A...
		
Attenuation ratio	n	choice: 2:1/5:1/10:1/20:1/100:1/200:1/1000:1
Insulation resistance	Ω	$>10^{14}$
Charge input		BNC neg.
Charge output		BNC pos.
Dimensions (WxHxD)	mm in	57x29x35 (without connector) 2.24x1.14x1.38 (without connector)

In force sensors with a very wide force range, the charge produced by the sensor may exceed the maximum charge permitted by the charge amplifier input. In such cases, a charge attenuator can be connected between the sensor and the charge amplifier so the charge present on the amplifier is reduced. The charge is reduced by the attenuation ration.

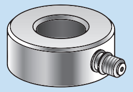
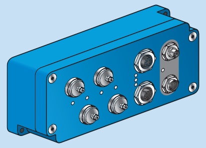
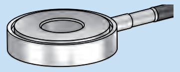
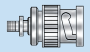
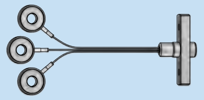
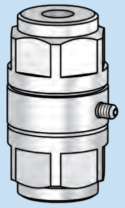
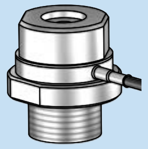
Insulation tester

Technical data	Type	5493
		
Number of channels		1
Signal input		BNC neg.
Measuring range	Ω	10^{11} … $4\cdot10^{13}$
Measurement voltage	V	5
Max. parallel capacity	nF	10 (corresponds to cable length ≈ 100 m/ ≈ 328 ft)
Power supply		9 V battery
Operation		Display and membrane keyboard
Housing		Handheld unit
Deg. of protection to IEC/EN 60529		IP50
Dimensions (WxHxD)	mm in	80x150x35 (without connector) 3.15x5.91x1.38 (without connector)

Insulation tester to check the insulation of piezoelectric measuring chains. Measures the insulation of sensors, charge amplifiers and cables.

1-component sensors

Measuring chains

	Measure	Connect	Amplify
1-component force sensors	90x1C 90x1B 910xC 	1631C… 1641B… 1939A… 1983AD… etc. 	Charge amplifiers **without** integrated data acquisition 5074… 
	913xC2 914xB2… 	Cable integrated in the sensor –> Connection to the charge amplifier with coupling 1721 	
	913xCA 914xBA… 	1971A1… 1973Ax1… 	
1-component quartz force links	9203 9205 9207 9217A 93x1C 9313AA… 93x3A… 	1631C… 1641B… 1939A… 1983AD… etc. 	Charge amplifiers **with** integrated data acquisition 5867… 
	917xC 	Cable integrated in the sensor -> Connection to the charge amplifier with cable 1631C… 1641B… etc. 	

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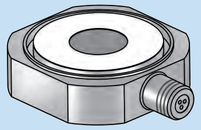
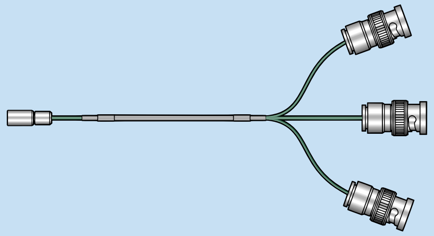
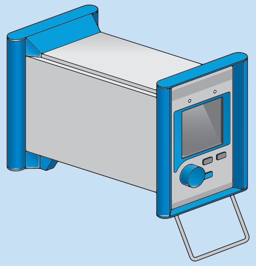
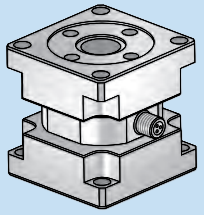
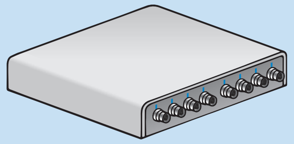
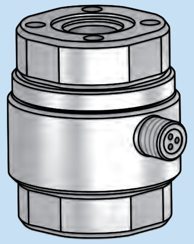
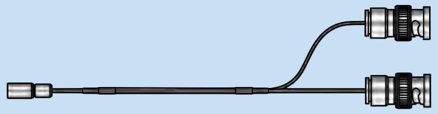
[1] Sensor 9215A can only be used with cables 1651C…

2-component and 3-component sensors

Measuring chains

	Measure	Connect	Amplify
3-component force sensors	90x7C, 90x8C[1] 	1698AA… 1698AB… 1698ACsp 	Charge amplifiers **without** integrated data acquisition 5015A… 5018A… 
3-component quartz force links	93x7C 		Charge amplifiers **with** integrated data acquisition 5167A… 5165A… 
2-component force/reaction torque links	93x5B 	1698AD… 1698AB… 1698ACsp  	

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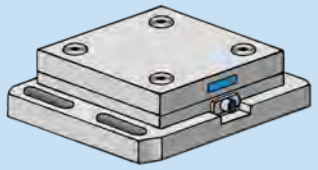
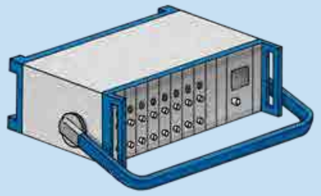
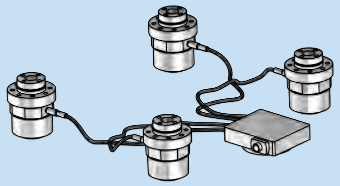
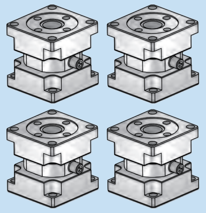
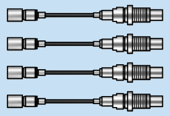
[1] Type 90x8C sensors are technically identical to Types 90x7C, but they have a rotated coordinate system (see the data sheet)

Dynamometers and quartz force link assembly kits

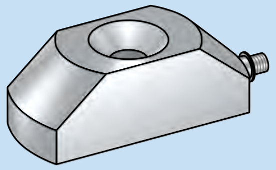
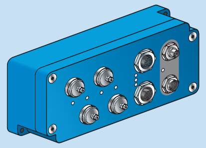
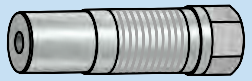
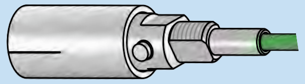
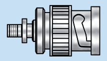
Measuring chains

	Measure	Connect	Amplify
Dynamometers	9119AA2 9139AA 9255C 9257B 	3-component force measurement 1687B... 1689B...  6-component force/torque measurement 1677A... 1679A... 	5080A... 5167A...  
Dynamometer assembly kit	9366CC... 	3-component force measurement 1687B... 1689B...  6-component force/torque measurement 1677A... 1679A... 	

	Measure	Connect			Amplify
Triaxial load cell assembly	4x 93x7C/93x8C 	6-component force/torque measurement 4x 1698AB... 	sum box 5417C 	1677A... 1679A... 	

Strain sensors

Measuring chains

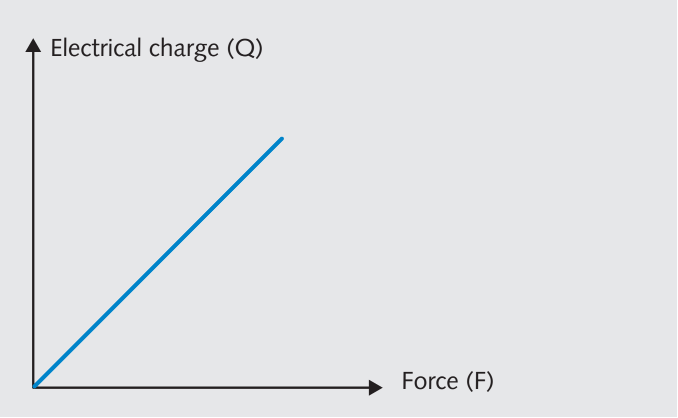
		Measure	Connect	Amplify
Surface strain sensors		9232A... 9237B... 	1631C... 1641B... 1939A... 1983AD... etc. 	Charge amplifiers **without** integrated data acquisition 5074... 
Strain measuring pins	**Longitudinal measuring pins**	9243B 9247A 	1651C... 1923A... 1983AB... 	Charge amplifiers **with** integrated data acquisition 5867... 
	Transverse measuring pins	9240AA3 	Cable integrated in the sensor -> Connection to the charge amplifier with coupling 1721 	

PiezoStar crystals and crystal disks as measuring elements

Focus on force measurement technology

Various measurement principles are used in force measurement technology. However, two principles have become established in practice: piezoelectric sensors and force sensors based on strain gauges. This catalog only covers piezoelectric force sensors for T&M applications, and it highlights their main advantages.

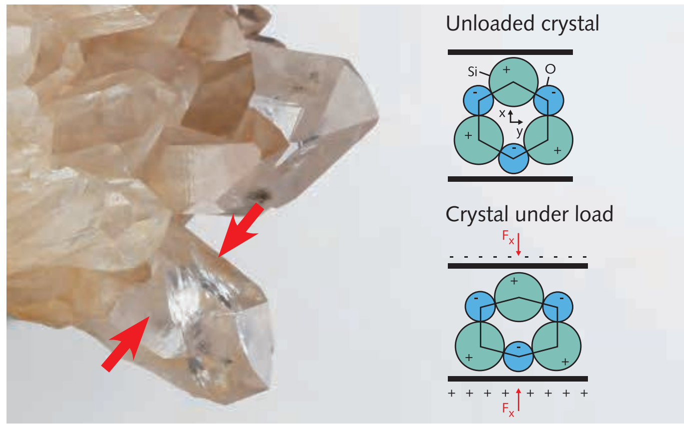
In piezoelectric force sensors, the measuring element is based on a crystal that produces an electrical charge proportional to the force when a load is applied. In strain gauge technology, the measuring element consists of a strain gauge that extends minimally under the action of force, so it changes the electrical resistance.



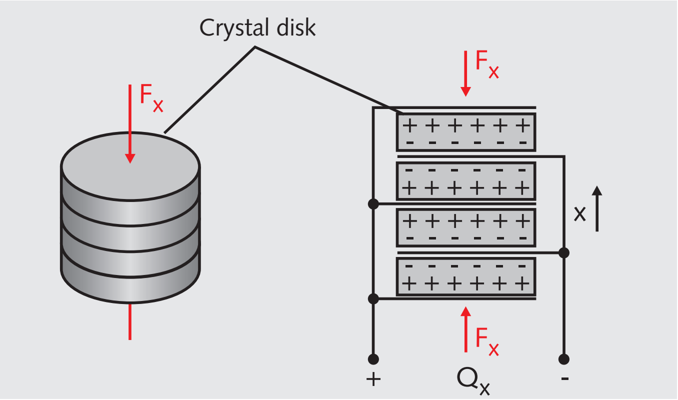
The electrical charge (Q) is proportional for the force (F).

Fundamentals of piezoelectric measuring technology

The piezoelectric effect is exhibited by piezoelectric materials (such as quartz) that produce positive or negative electrical charges when a mechanical load is applied to their outer surfaces. The charge is generated because the positive and negative crystal lattice elements are displaced relative to one another, thereby forming an electric dipole. The charge generated as this happens is proportional to the force acting on the crystal.



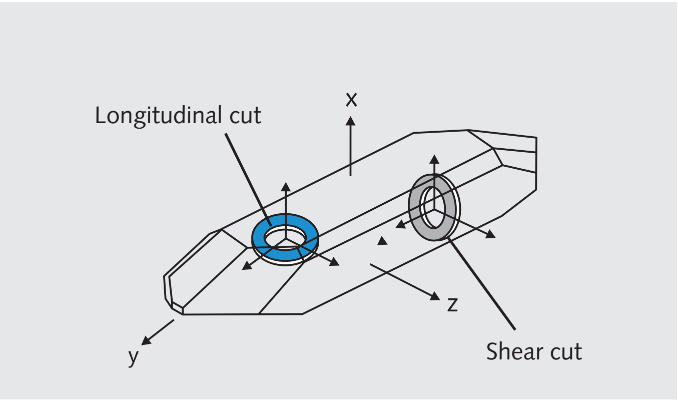
The mechanical load on a crystal produces an electrical charge



Possibility of increasing the charge yielded

Crystal disks as measuring elements
Most piezoelectric force sensors operate with a measuring element that consists of thin crystal disks. Depending on whether the sensor is to measure compression or shear forces, the disks are cut from the crystal with different cutting angles. A longitudinal cut produces crystal disks that are used in sensors to measure compression forces, whereas a shear cut is used for elements to measure shear forces.

Piezoelectric measuring chain
A piezoelectric measuring chain consists of the sensor, a high-insulation connecting cable to transport the small charges, and a charge amplifier to convert the charge signal into a voltage signal.



Possible cutting angles in the crystal

Piezoelectric crystals – PiezoStar versus Quartz
The electrical charge generated by a single crystal disk depends only on the piezoelectric material, but not on its geometric dimensions. To produce sensors with higher sensitivity, several crystal disks can be stacked on top of one another and connected electrically in parallel. Alternatively, a piezoelectric material with higher sensitivity can be used (e.g. PiezoStar crystals).
Kistler grows its own PiezoStar crystals which offer higher sensitivity and better temperature stability than quartz. PiezoStar crystals are typically installed in sensors for measuring very small forces, so they extend the application range for commonly used quartz-based force sensors. Kistler offers piezoelectric force sensors based on both quartz and PiezoStar.

Piezoelectric or strain gauge force sensors?

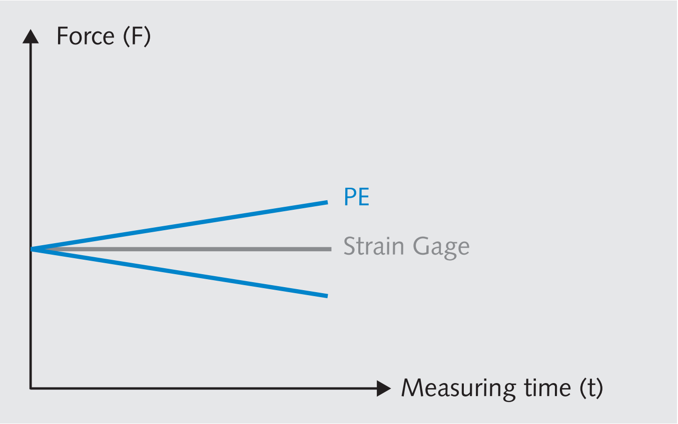
Piezoelectric and strain gauge sensors have both become established as technologies for measuring forces. These two technologies complement one another. Preference should be given either to a piezoelectric sensor or a strain gauge force sensor depending on the application concerned.

The following sections show the main differences between the two technologies, so as to simplify your decision-making process.

Static force measurements
Due to their principle of operation, piezoelectric force sensors display a small drift when a static load is applied. By contrast, sensors based on the strain gauge principle operate largely free of drift.

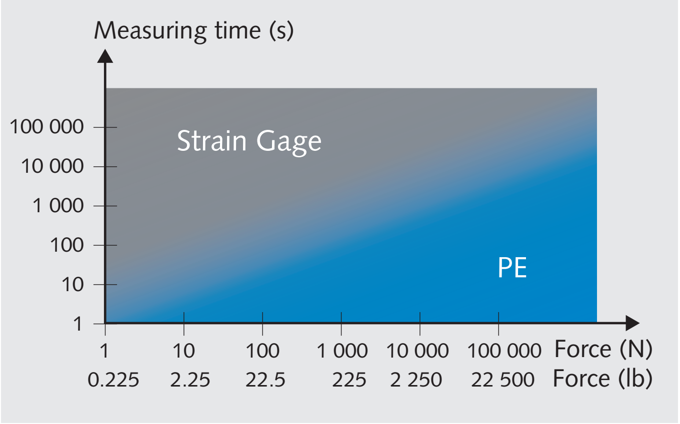
In piezoelectric force sensors, the drift value always remains the same when a static load is applied, regardless of the measured force; therefore, the relative measurement error caused by the drift is always particularly unfavorable when small forces are to be measured over a long period. However, measurements of large static forces over lengthy measuring periods pose no problem. With piezoelectric force sensors, the measuring time therefore depends on the requirements for accuracy and the force to be measured.

The next graphic is intended to help you reach your decisions. It shows whether a piezoelectric force sensor can be used for your static measurement, or whether it is only appropriate to use a strain gauge sensor. The graphic very clearly shows that long measurement times pose no problems for piezoelectric force sensors if the forces are sufficiently large. However, strain gauge force sensors are clearly preferable for long-term monitoring tasks.



Static force measurement: piezoelectric (PE) versus strain gauge

Dynamic force measurements



Measuring times and force ranges: piezoelectric (PE) versus strain gauge (basis: drift ±0.05 pC/s and measurement error of 1 %)

Piezoelectric force sensors are clearly preferable for dynamic applications because – thanks to their rigidity – they exhibit very little deformation under load. This results in a high resonance frequency which is generally very favorable for dynamic applications.

Overview of piezoelectric and strain gauge force sensors
The main criterion is whether the force to be measured is static or dynamic, but there are also other aspects that should be considered when selecting the measurement principle.
The following overview table shows various criteria according to which one measurement technology is preferable to the other; this provides further assistance with reaching a decision.

If you are not sure whether piezoelectric measurement technology is suitable for your application, we shall be happy to take the time to give you neutral advice without obligation.
Our T&M sales team will be glad to hear from you.

Criterion	**Piezoelectric technology**	**Strain gauge technology**
True static measurement*		✓
Dynamic measurement** (high rigidity)	✓	
Wide measuring range	✓	
Measurement of very small force changes with high static preloading	✓	
Compact sensor dimensions for multi-component force sensors	✓	
Lifetime with cyclical loading	✓	
Overload capability	✓	
High temperature suitability	✓	
Suitability on temperature variation		✓
Cable handling (cleanliness, low noise)		✓
Linearity		✓
Repeatability	✓	
Calibration interval	✓	

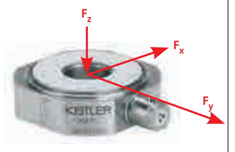
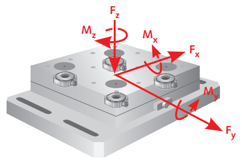
* see diagram on page 59
** see diagram on page 60

Selection criteria

Piezoelectric force sensors

Kistler offers various versions of piezoelectric force sensors for different T&M applications. They differ mainly in the number of force components and torques that can be captured with one single sensor.

The following overview describes the various categories of force sensors. The explanations are intended to assist you with the choice of the right category of force sensors for the specific application.

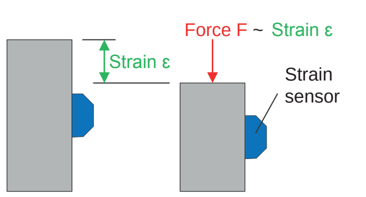
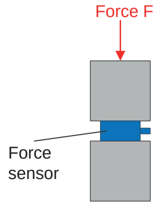
1-component sensors	
	Measure one single force component. The category of 1-component sensors includes the following versions: • Force sensors for compression and tensile forces (±F_z) • Force sensors for shear forces (±F_y) You will find more information about 1-component sensors starting on page 7.
2-Component sensors	
	Measure compression and tensile forces (±F_z) and – at the same time – the corresponding positive and negative reaction torques (±M_z). You will find more information about 2-component sensors starting on page 27.
3-component sensors	
	Measure all three orthogonal force components (F_x, F_y and F_z) at the same time. The sensors capture compression and tensile forces (±F_z) as well as positive and negative shear forces in both shear directions (±F_x and ±F_y). You will find more information about 3-component sensors starting on page 28.
Dynamometers (3-component)	
	Dynamometers are essentially based on four 3-component sensors that are mounted between a baseplate and a cover plate. A dynamometer can therefore capture the three orthogonal force components (F_x, F_y and F_z) at the same time. Based on the three force components captured by the individual 3-component sensors and the known geometric positioning of the four sensors, the corresponding torques (M_x, M_y and M_z) can be calculated. You will find more information about dynamometers starting on page 33.

Piezoelectric strain sensors

Kistler's portfolio also includes piezoelectric strain sensors that are suitable for indirect force measurements in T&M applications.

Every force results in a deformation of the structure. Piezoelectric strain sensors can measure this deformation. Since the deformation is proportional to the force, the force can be determined from the deformation.

The following table shows the advantages and limitations of indirect force measurements with a strain sensor as compared to direct force measurements with a force sensor.

Indirect force measurement	Direct force measurement
	
✓ • Least effort required for mounting • Can easily be retrofitted to the existing application • Overload protection • Since the structure absorbs the entire force, very large forces can be measured	✓ • High sensitivity • High measuring accuracy • High repeatability • Good linearity and low hysteresis
✗ • Ambient influences: Strains due to vibration forces and temperature influences are included in the measurement • For absolute values, calibration by means of a force sensor in the application is a mandatory requirement	✗ • Installation requires major effort • Force range for very large forces is limited

You will find more information about strain sensors starting on page 36.

1-component sensors

When measuring force with piezoelectric 1-component sensors, the method of installation in the structure is critically important. Kistler offers the right sensor to meet every requirement.

Depending on how the sensor is to be installed in the structure, the following two versions are available from Kistler:

- 1-component force sensors
- 1-component quartz force links

Depending on the application, one of the two categories will be more suitable. The following pages indicates potential advantages and limitations:

1-component force sensors		
	✓ • Low overall height – ideal for confined installation conditions and larger bending moments • Low-cost option for customers with experience of force sensor integration	✗ • Complex installation required with preloading, using a preloading screw or preloading element • Recalibration after installation is needed to ensure accurate measurements
1-component quartz force links		
	✓ • Already preloaded, so installation is simple • No need for time-consuming recalibration after installation, so the device is immediately ready to measure • Suitable for customers with limited experience of force sensor integration • High-sensitivity versions to capture the very smallest forces	✗ • Large overall height

1-component force sensors

1-Component force sensors essentially consist of two crystal disks which are integrated into a tightly welded housing with slight preloading.

Because of their compact structural design, 1-component force sensors are very well suited to applications where the space for installation is confined. Two versions of the sensors are available: either to capture compression forces ($+F_z$) – depending on the installation variant and the preload, tensile forces ($–F_z$) can also be measured – or to measure positive and negative shear forces ($\pm F_y$).

Installation with preloading

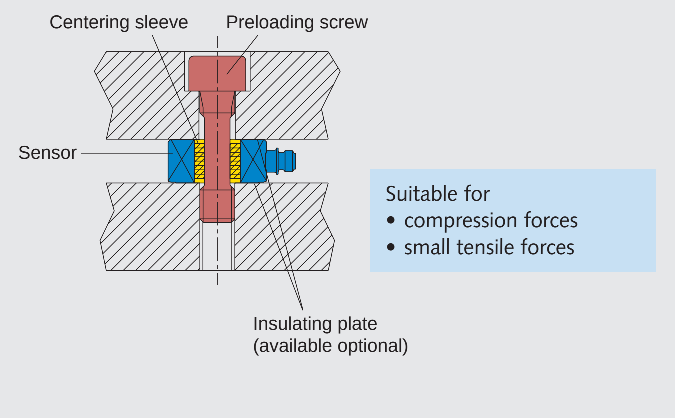
When 1-component force sensors are installed in the application, they must always be mechanically preloaded. There are several reasons for this:

- Bending moments and lateral loads are captured but not measured
- Micro-gaps are closed: this ensures high rigidity and, consequently, a wide frequency range
- Adequate static friction to transmit the shear forces from the structure to the force sensor for shear forces

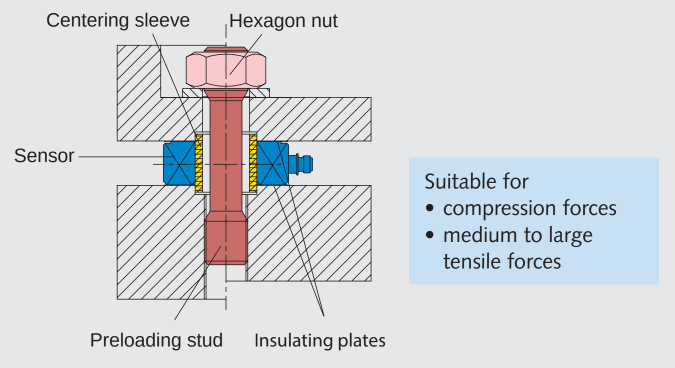
Cross-section of a 1-component force sensor

The sensor is preloaded in the application with the help of a preloading screw or a preloading element. In principle, both variants operate in the same way; they differ only as regards the type of mechanical design. Depending on the sensor type, one or possibly both variants are available.

The following illustrations show examples of the installation of a 1-component force sensor in the structure, with the help of a preloading screw or preloading element. If both mounting options are available, the variant to be preferred is also shown, depending on the application:



Installation with preloading screw



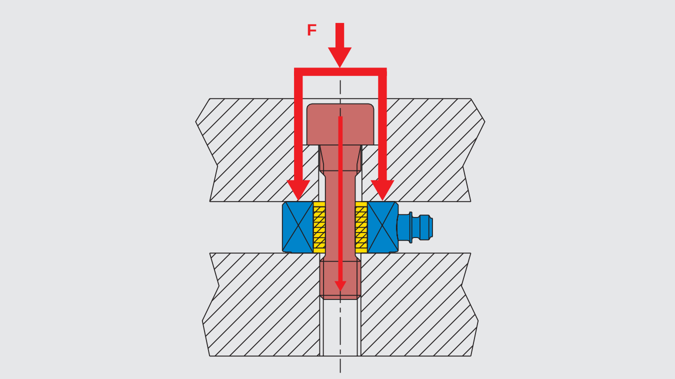
Installation with preloading element

Usable measuring range

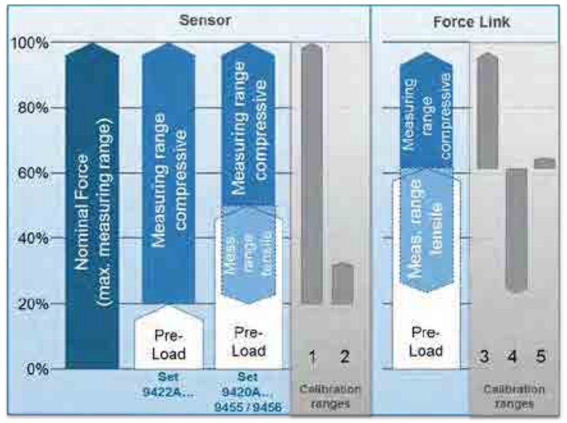
Preloading limits the sensor's usable measuring range. The actual measuring range that is obtained therefore corresponds to the measuring range shown on the data sheet less the preload; this amounts to between 20% and 70% of the total measuring range, depending on the application and installation variant.

Influence of preloading on sensitivity

Preloading the sensors with the help of a preloading screw or a preloading element results in a force shunt. Part of the force that acts from the application on the preloaded sensor (typically 7% to 10%, depending on the preload) passes through the preloading screw or the preloading bolt. This reduces the sensor's sensitivity in the installed state. For accurate measurements, it is therefore advisable to calibrate the preloaded sensor in the application.



Force shunt with a preloaded 1-component force sensor



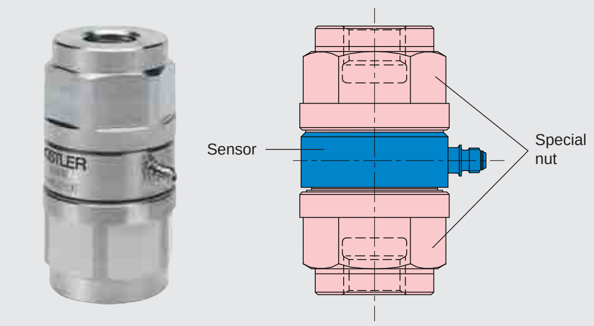
Limitation of the measuring range by preloading

1-component quartz force links

1-component quartz force links consist of a 1-component force sensor that is preloaded between two special nuts, with basic insulation.

In contrast to the 1-component force sensor, this structure substantially simplifies installation in the application: because the measuring elements are already preloaded and calibrated, they are ready to measure immediately. 1-component quartz force links can be used to measure compression forces ($+F_z$), and certain measuring elements are also designed to measure compression and tensile forces ($\pm F_z$).

Special 1-component quartz force links are available to measure extremely low forces. Thanks to their internal structure, these low-force measuring elements are substantially more sensitive, so even the smallest forces can be measured reliably.



1-component quartz force link, consisting of a 1-component-force sensor preloaded between two special nuts

1-component quartz force link for low forces

2-component and 3-component sensors

When measuring force and torque with piezoelectric 2- and 3-component sensors, the method of installation in the structure is critically important. Kistler offers the right sensor to meet every requirement.

Depending on how the sensor is to be installed in the structure, the following two versions are available from Kistler:
- 3-component force sensors
- 3-component quartz force links and 2-component force/reaction torque links

Depending on the application, one of the two categories will be more suitable. The following table indicates the advantages and limitations:

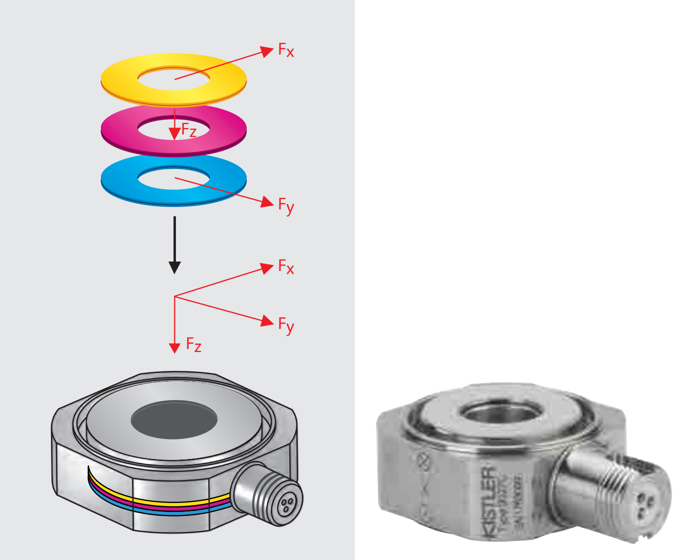
3-component force sensors		
	✓ Low overall height – ideal for confined installation conditions and larger bending moments ✓ Low-cost option for customers with experience of force sensor integration	✗ Time-consuming installation requires the use of a preloading element ✗ Recalibration after installation is needed to ensure accurate measurements
3-component quartz force links **2-component force/reaction torque links**		
	✓ Already preloaded, so installation is simple ✓ No need for time-consuming recalibration after installation, so the device is immediately ready to measure ✓ Suitable for customers with limited experience of force sensor integration	✗ Large overall height

3-component force sensors

3-Component force sensors essentially consist of three pairs of crystal disks (one for each orthogonal force component) which are integrated into a tightly welded housing with slight preloading.

Because of their compact structural design, 3-component force sensors are excellently suited to applications where the space for installation is confined. The sensors simultaneously capture compression and tensile forces ($\pm F_z$) as well as positive and negative shear forces in both shear directions ($\pm F_x$ and $\pm F_y$).

Installation with Preloading
When 3-component force sensors are installed in the application, they must always be mechanically preloaded. There are several reasons for this:
- Bending moments and lateral loads are captured but not measured
- Micro-gaps are closed: this ensures high rigidity and, consequently, a wide frequency range
- Adequate static friction to transmit the shear forces from the structure to the force sensor

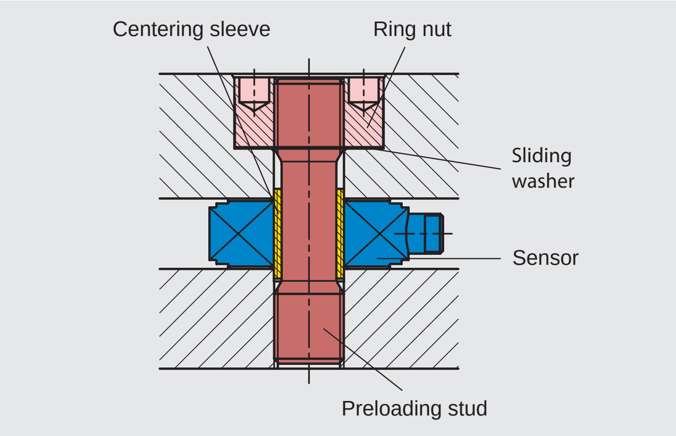


Structure of a 3-component force sensor

With 3-component force sensors, the static friction is used to transmit the shear forces from the structure to the sensor, so relatively high preloading of the sensors is required in the z-direction (approx. 70% of the total measuring range).

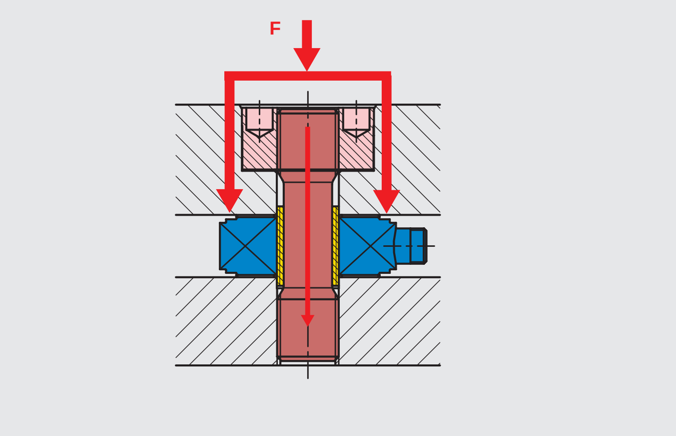
To improve transmission of the shear forces from the structure to the sensor, the two contact surfaces of all 3-component force sensors are coated with a ceramic layer: this substantially increases the static friction.

The sensor is preloaded in the application with the help of a preloading element. The following illustration shows an example of the installation of a 3-component force sensor with the help of a preloading element.



Installation with preloading element

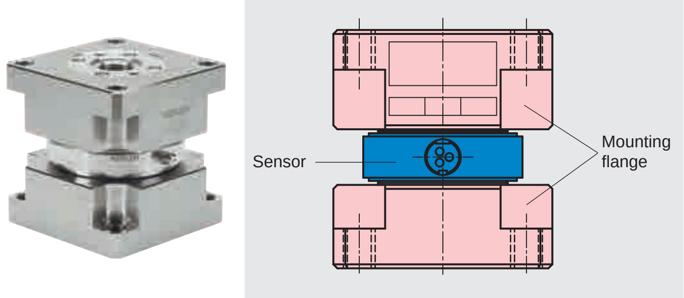
Influence of preloading on sensitivity
Preloading the sensors with the help of a preloading element results in a force shunt. Part of the force in the z-direction that acts from the application on the preloaded sensor (typically 7% to 10%) passes through the preloading bolt. In the installed state, this reduces the sensor's sensitivity in the z-direction. For accurate measurements, it is therefore advisable to calibrate the preloaded sensor in the application.



Force shunt with a preloaded 3-component force sensor

3-component quartz force links

3-component quartz force links consist of a 3-component force sensor that is preloaded between two mounting flanges, with basic insulation.



3-component quartz force link, consisting of a 3-component force sensor preloaded between two mounting flanges

In contrast to the 3-component force sensor, this structure substantially simplifies installation in the application, because the measuring elements are already preloaded and calibrated – so they are ready to measure immediately. 3-component force links can simultaneously capture compression and tensile forces ($\pm F_z$) as well as positive and negative shear forces in both shear directions ($\pm F_x$ and $\pm F_y$).

2-component force/reaction torque links

2-component-force/reaction torque links consist of a sensor that is preloaded between two special nuts. This structure makes installation in the application very simple, because the sensor is already preloaded and calibrated – so it is immediately ready to measure.

2-component force/reaction torque Link ($\pm F_z$, $\pm M_z$)

2-component-force/reaction torque links capture compression and tensile forces ($\pm F_z$) and – at the same time – the corresponding positive and negative reaction torques ($\pm M_z$).

Dynamometers and quartz force link assembly kits

Cable versions

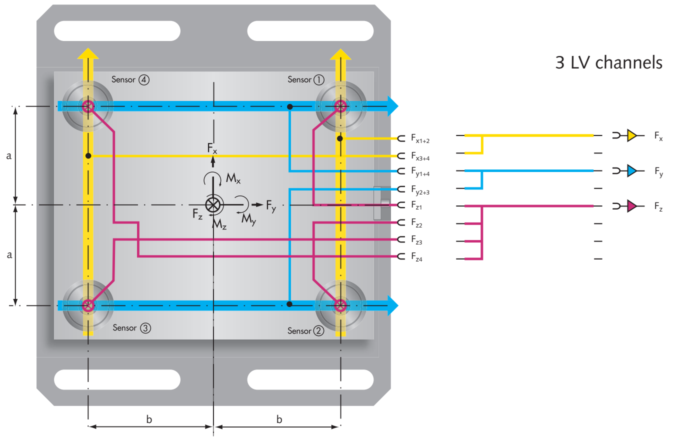
A dynamometer cable must be used to connect the dynamometers or summing boxes in the 3-component quartz force link assembly kits with the charge amplifier.

Dynamometer cables are high-insulation, ground-isolated multi-wire cables protected by a flexible stainless steel hose. They are designed for applications with temperatures of up to 70°C (158°F). Thanks to their rugged structure and IP67 protection on the dynamometer/summing box side, they can also be used in harsh environments.

Dynamometer cables with stainless steel hose

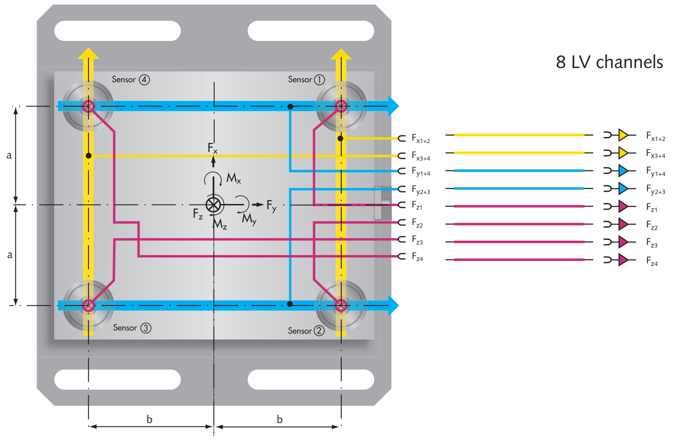
Dynamometer cables are available in two versions: 3-wire and 8-wire cables. The cable version is selected according to the requirements of the application in question. For 3-component force measurement (F_x, F_y, F_z), a 3-wire dynamometer cable should be used; for 6-component force/torque measurement, (F_x, F_y, F_z, M_x, M_y, M_z) an 8-wire dynamometer cable should be chosen.

For **3-component force measurement**, the eight output signals from the dynamometer are summed in a **3-wire dynamometer cable** and are routed to three charge amplifier channels, as shown in the illustration below. This means that the three forces (F_x, F_y and F_z) are available directly with no need for any further calculations.



3-component force measurement with a 3-wire dynamometer cable

For **6-component force-torque measurement**, the eight output signals from the dynamometer are fed directly to eight charge amplifier channels with one **8-wire dynamometer cable**. Analog calculation of the forces and torques is then performed by the 6-component summing processor in the charge amplifier. The distance from the sensors must be taken into account when calculating the torques.



6-component force measurement with an 8-wire dynamometer cable

Cable lengths

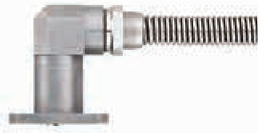
All Kistler cables are available in standard and custom lengths. Standard lengths are kept in stock, so they offer the advantage of shorter delivery times.

Cable connections

Cable connectors: dynamometer side

Two connector variants are available to connect the cable to the dynamometer or the summing box.
The standard version is the **Fischer flange, 9-pole pos.** with a straight connector outlet. If space is confined in the area where the cable is connected to the dynamometer, the **Fischer flange, angle 9-pole pos.** version is available; it features a right-angled connector outlet. Both versions are fixed to the dynamometer with two M4 screws; an O-ring seal provides good protection against dust and splash water.

Connector: Fischer flange, 9-pole pos.



Fischer flange, angle, 9-pole pos.

Cable connectors: charge amplifier side

The dynamometer cables are connected to the charge amplifier with the **Fischer 9-pole pos.** connector. This rugged connector is also suitable for applications in somewhat harsher environments where protection against dust is required.

Connector: Fischer 9-pole pos.

Strain sensors

Within its range of strain sensors, Kistler offers two versions that differ as regards the type of mounting. The correct strain sensor is therefore available for many T&M applications.

The following two versions are available:

- Surface strain sensors
- Strain measuring pins

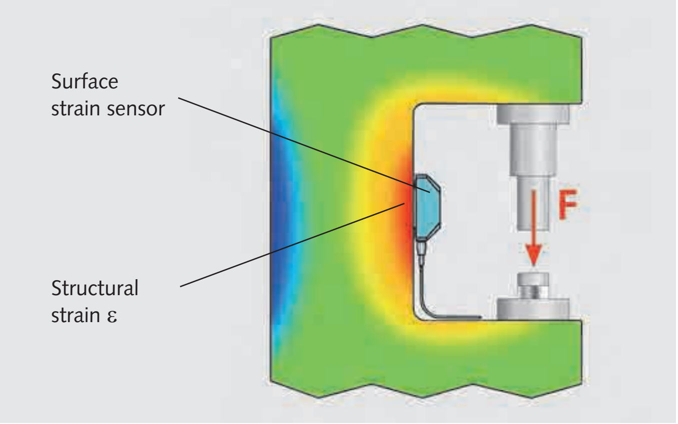
Depending on the application, one of the two categories will be more suitable. The following table indicates the advantages and limitations:

Surface strain sensors		
	✓ • Suitable for strain measurements on the surface of a structure • Easiest installation: the sensor is affixed to the surface of the structure with a screw • Can easily be retrofitted to the existing application	✗ • The sensor is remote from the structure, so free space is needed outside the structure to install the sensor
Strain measuring pins		
	✓ • Suitable for strain measurements inside a structure • The structure's outer contour is not changed because the sensor is mounted inside the structure	✗ • Blind holes must be drilled accurately for mounting • High stresses in the vicinity of the blind hole (pin must be preloaded) –> caution with cyclical loading!

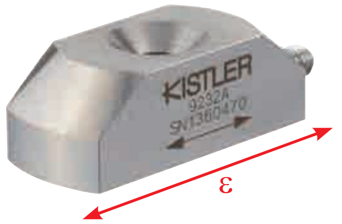
Surface strain sensors

Surface strain sensors measure the strain (extension and deflection) on the outer surface of a structure. They are very easy to mount on the structure with the help of a mounting screw. The structure's strain is transmitted as shear force to the measuring element, through static friction. Surface strain sensors are suitable for most application cases involving indirect force measurements. For this reason, they are the standard strain sensors for indirect measurement of forces on structures which do not allow direct force measurements with a force sensor, due to the requirements of the application.

The C-frame press is a typical application case for indirect force measurement using the surface strain sensor. Thanks to the surface strain sensor, force monitoring can be implemented for the pressing process in this application, at low cost and with minimum outlay on installation. If the absolute values are of interest, the strain sensor must be calibrated in the application with the help of a reference force sensor.



Indirect force measurement on a C-frame press, using a surface strain sensor

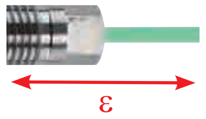


Surface strain sensor to measure strain on the outer surface of a structure

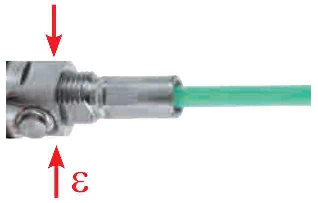
Strain measuring pins

Strain measuring pins measure the strain inside a structure. To mount the pins, it is necessary to drill a cylindrical bore into which the sensor is then inserted and preloaded. The following two categories of strain measuring pins are differentiated:

- Longitudinal strain measuring pins measure strain (extension and deflection) lengthwise along the pin

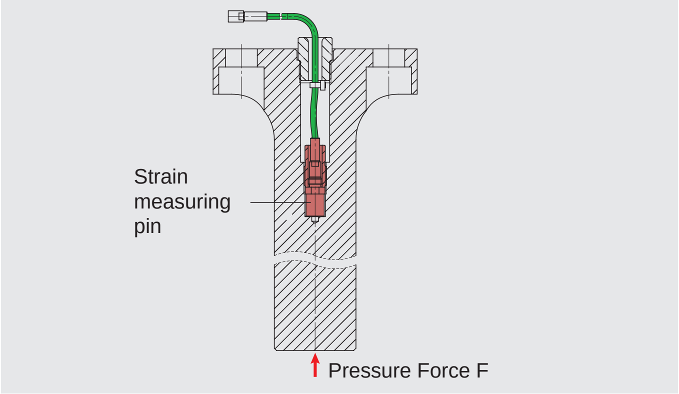


- Transverse strain measuring pins measure the strain (deflection only) transversely in relation to the pin



Like surface strain sensors, strain measuring pins are mostly used for indirect force measurements. Strain measuring pins are mainly used for special application cases where the surface of the structure does not offer optimal conditions for measuring strain.

In the example of the pressure bolt, a strain measuring pin is preferred over a surface strain sensor because the pin can be mounted so that it is centered on the pressure bolt and, therefore, the acting moments of bending cannot influence the measurement results. Furthermore, for reasons of space, this example does not allow any change to the outer contour of the pressure bolt.



Indirect force measurement on a pressure bolt, using a strain measuring pin

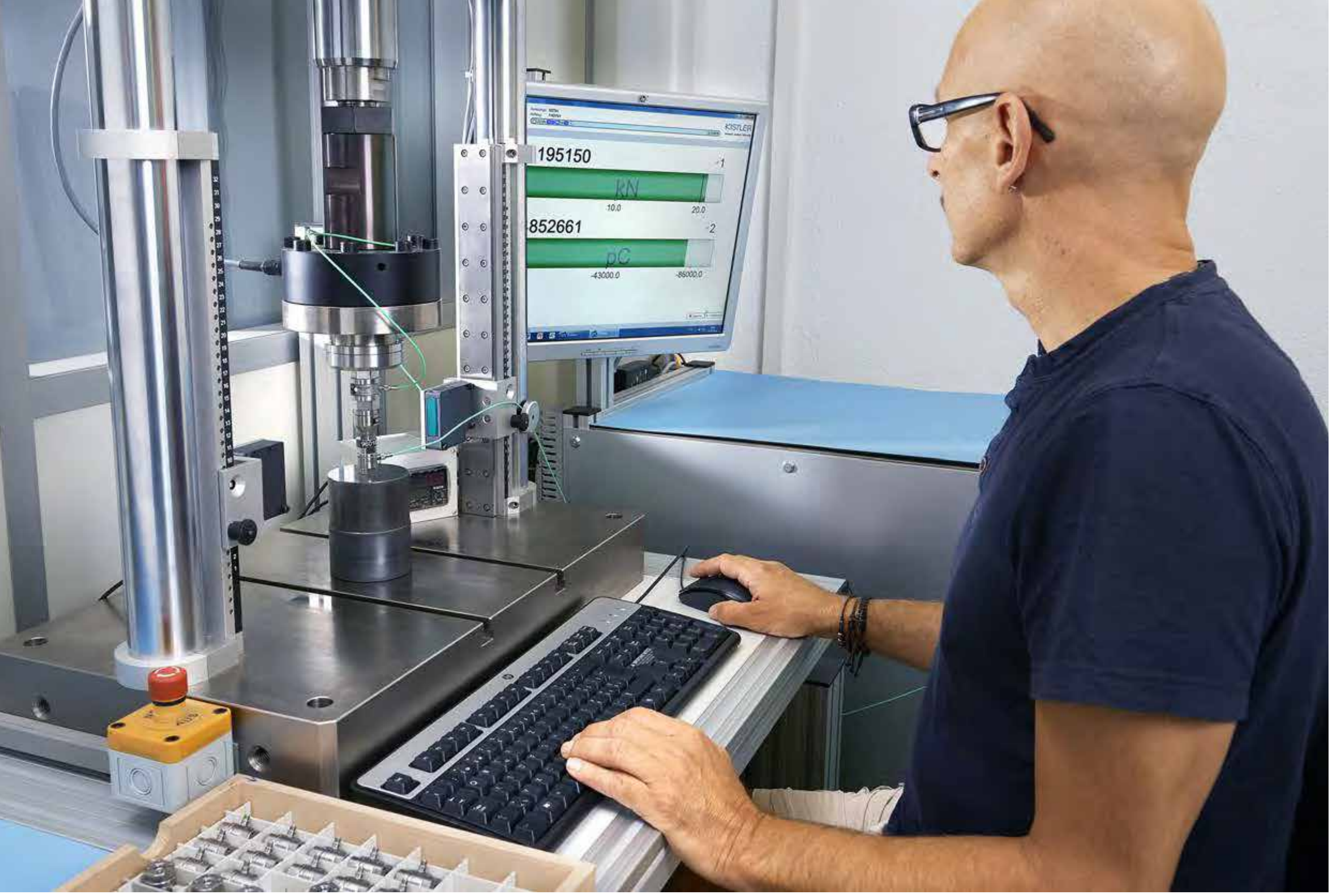
Signal conditioning

A high-grade signal conditioning solution ensures the sensor signals are available with the best possible quality and this is the key to producing the desired high-precision measurement results.

Kistler offers the matching signal conditioning solution for each sensor. A charge amplifier is required for piezoelectric sensors (PE), whereas piezoelectric sensors with integrated electronics (IEPE) are fed by Piezotron couplers.

In addition to analog amplifier solutions, Kistler also offers devices with integrated data acquisition. High-precision calibration equipment rounds off the offer.

Charge amplifiers	
 	• Charge ranges from 2 to 2,200,000 pC • Frequency ranges from ≈ 0 to 200,000 Hz • Devices with integrated data acquisition • Dual-mode amplifiers (compatible with PE and IEPE sensors) • Single- and multi-channel solutions
Piezotron couplers (IEPE)	
	• From battery-operated single channel devices to line-powered multi-channel systems • IEPE solutions with TEDS support
Amplifier for piezoresistive pressure sensors	
	• PiezoSmart sensor identification • Support of digital compensation for maximum measuring accuracy
Power supplies for MEMS capacitive accelerometers	
	• Powering up to 15 single axis and up to five triaxial K-Beam accelerometers
Calibration devices	
	• Fully automated calibration of charge amplifiers and other signal conditioning devices • Portable signal conditioning system for the calibration of piezoelectric sensors



Sensors must be meticulously calibrated in order to guarantee reliable measurement results

Calibration

Sensors and measuring instruments must be calibrated at regular intervals, as their characteristics and hence the measurement uncertainties can change over time as a result of frequent use, aging and environmental factors. Instruments used for calibration are traceable to national standards and subject to a uniform international quality control. Calibration certificates document calibration values and conditions.

Safe and reliable measurements

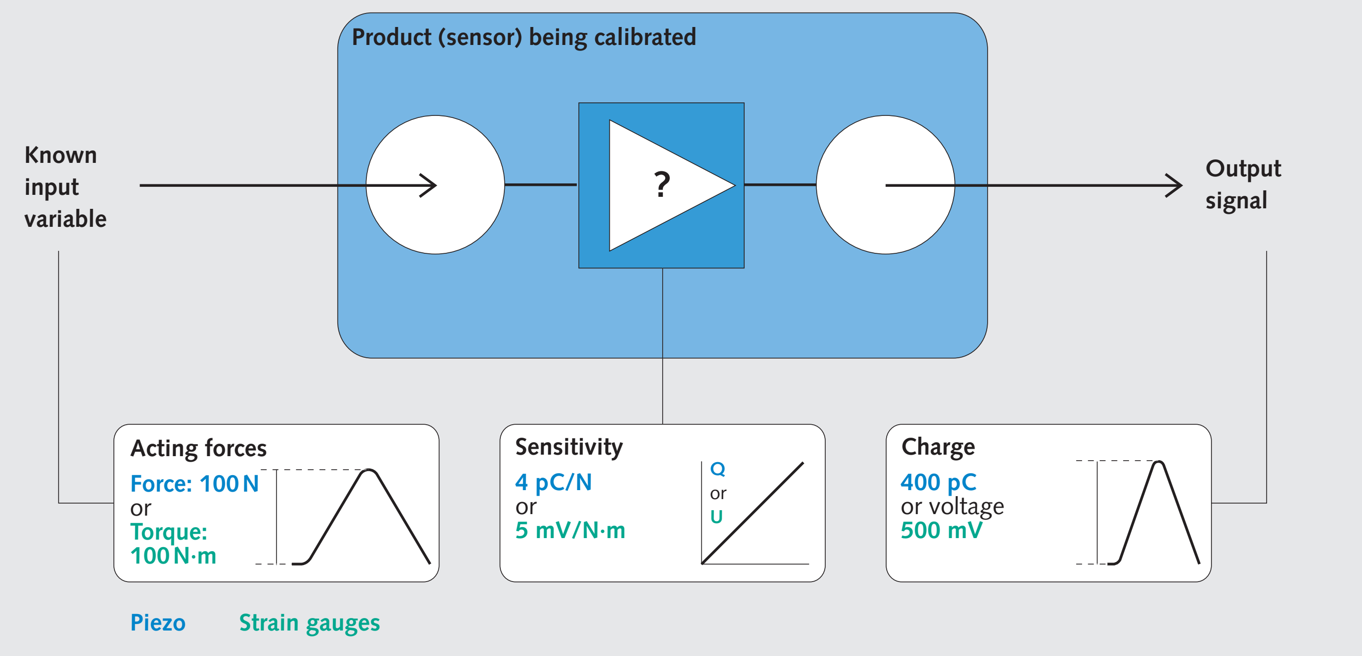
Quality assurance systems and product liability laws call for systematic monitoring of all test equipment needed for measuring quality characteristics. This is the only way to ensure that measurement and test results provide a reliable and dependable benchmark for quality control.

All sensors and electronic measuring devices are subject to some degree of measurement uncertainty. As the deviations involved can change over time, the test equipment must be calibrated at regular intervals.

This involves determining the deviation of the measured value from an agreed reference value, which is also referred to as the calibration standard. The result of a calibration can either be used to assign the actual values of the measurand to the readings or to determine correction factors for them. The required information is documented on the calibration certificate.

Definition: Calibration is the use of a defined method under specified conditions to determine the relationship between a known input variable and a measured output variable.

Principle of sensor calibration

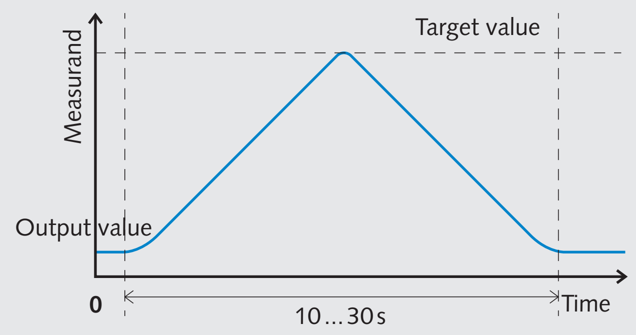


Calibration process

During calibration, sensors are subjected to known quantities of a physical measurand (such as force) and the corresponding values of the output variable are recorded. The magnitude of this load is accurately known, as it is measured with a traceably calibrated "factory standard" at the same time. Depending on the method, sensors are calibrated either across the entire measuring range or in a partial range:

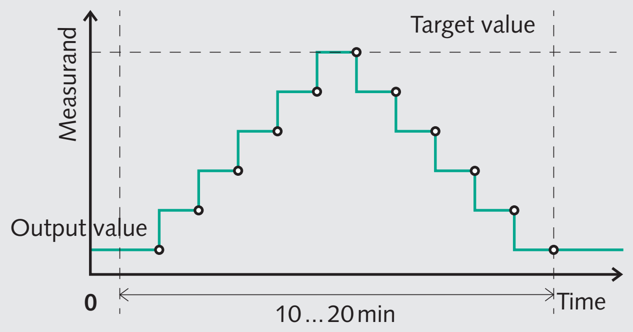
- at a single point,
- continuously, or
- stepwise at several different points.

Piezo calibration



During **continuous calibration**, the load is continuously increased to the required value within a defined time and then reduced to zero within the same time. A "best straight line" passing through the origin is defined for the resultant characteristic, which is never exactly linear. The gradient of this line corresponds to the sensitivity of the sensor within the calibrated measuring range.

Strain gauge calibration



Step-by-step calibration involves the application of a load with or without unloading between successive increases or decreases, depending on the calibration method used. The process is halted after each increment until the measurement stabilizes.

Linearity is determined by the deviation of the characteristic from the best straight line. Hysteresis corresponds to the maximum difference between the rising and falling characteristics. Most Kistler single- or multiaxial force and torque sensors are factory calibrated.

The continuous approach is the most suitable calibration method for piezoelectric sensors. Strain gauge sensors are preferably calibrated step-by-step.

Kistler offers diverse calibration options:

- The sensor equipment can be sent to the production plant
- Onsite calibration in the plant
- Calibration equipment for in-house calibration

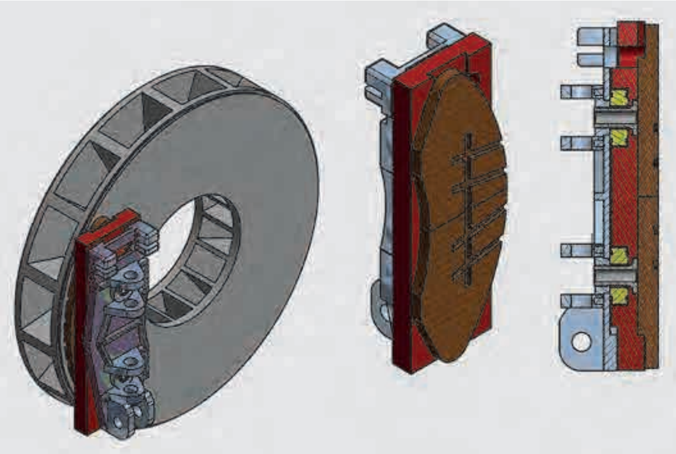
Advisory

Kistler has many years' experience of integrating force and strain sensors into customized applications. Take advantage of our experts' know-how and benefit from their advice.

During an advisory session, you will learn the best way of installing the sensor in the application so as to obtain reliable and accurate measurement results. The following examples show customer projects where Kistler provided advisory support for the integration of the sensors in the application.

Measurement of frictional force on a railway brake

On railway brakes, maximum braking forces are critical for high deceleration. Kistler force sensors were integrated into the brake lining so that the braking forces could be measured during real operation. Because of the confined space available, the Kistler Sales Center's experience was a key factor in the successful installation of the sensors.



Brake lining with force sensors

Challenge
- To measure very large forces
- Confined installation space

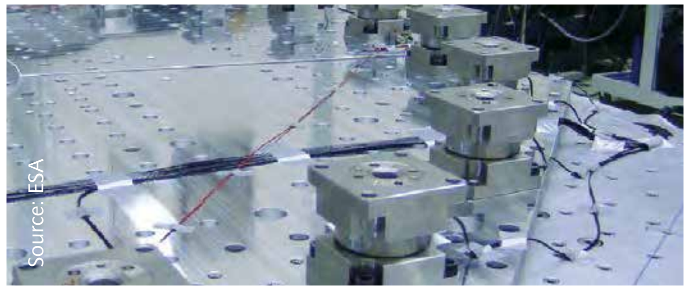
Solution
- Two 3-component force sensors with force application
- Special preloading bolts
- Onsite calibration after installation, with special equipment

Force limited vibration test (FLV)

Satellites are exposed to large vibration loads on lift-off and as they fly through the atmosphere. A vibration test is carried out prior to launching. Losses of satellites have become infrequent thanks to this test. Kistler force sensors measure the forces, thereby ensuring a reliable test procedure.

Source: ESA

Satellite on shaker



Source: ESA

Positioning of 3-component quartz force links on a shaker

Challenge
- Wide measuring range
- High rigidity
- High reliability
- Complex mechanical integration

Solution
- Multiple 3-component quartz force links
- All measuring elements machined to the same height
- Customized base plate and cover plate for the mechanical connection
- Easily operated charge amplifier (LabAmp 5165A)

If you would like advice on your application, please contact your local Kistler Sales Center.

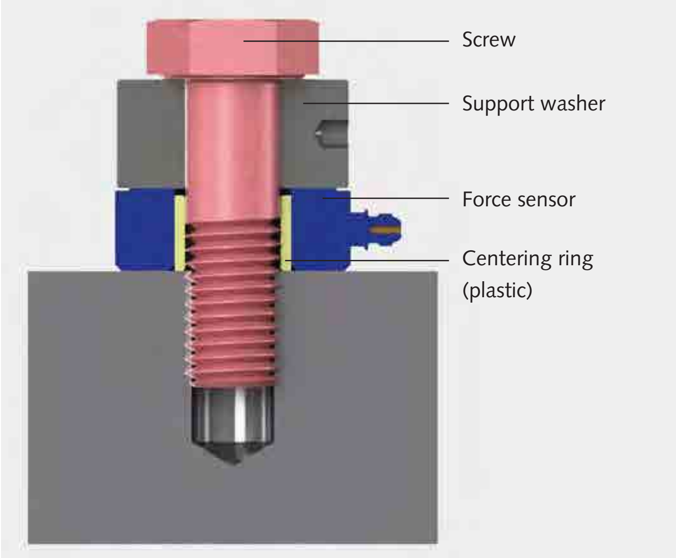
Customized sensors

Do you have an application for which you cannot find a suitable force or strain sensor in the T&M product portfolio? Take advantage of Kistler's lengthy experience in the design and development of customized sensors, and have a sensor developed entirely in line with your specifications.

The following examples show customized sensors that were realized by Kistler in close collaboration with customers – from the development, design and production phases through to calibration.

Measuring the preloading force of a screw

The relationship between the preloading force and tightening torque of screwed connections is a critical factor to ensure reliable installation and to prevent the connection from becoming loose.



Measuring setup with screw, support washer and force sensor

Challenge
- High resistance to overloading
- Simple to handle
- Long service lifetime

Solution
- Hardened support washer on 1-component-force sensor and centering with plastic ring

Dynamometers to measure grinding forces

Toothed wheels must be ground in order to ensure quiet running. The grinding process is very time-consuming. A research project is under way to optimize the large number of machining parameters so as to ensure efficient grinding.

Toothed wheel with grinding wheel

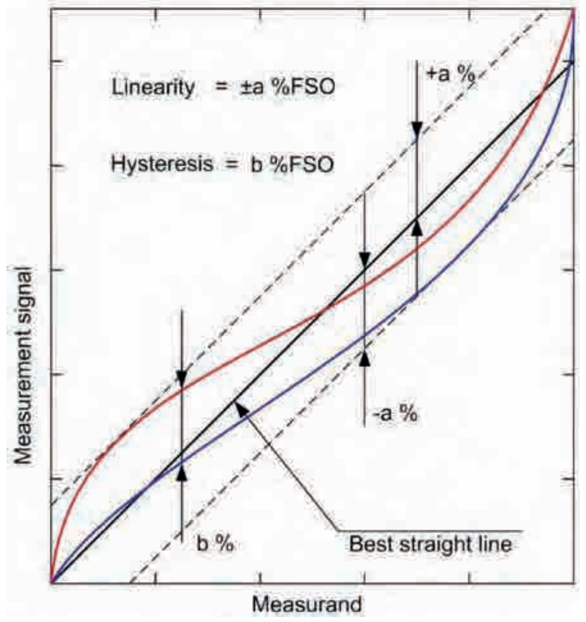
Dynamometer

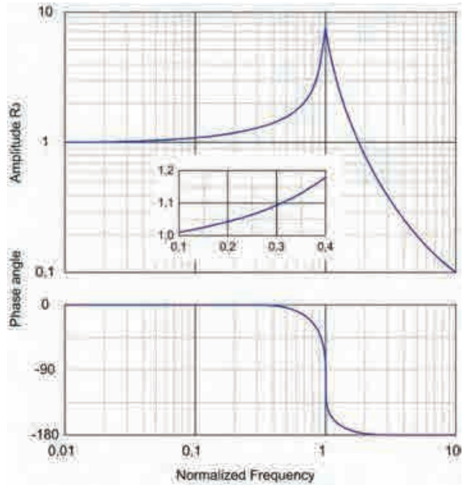
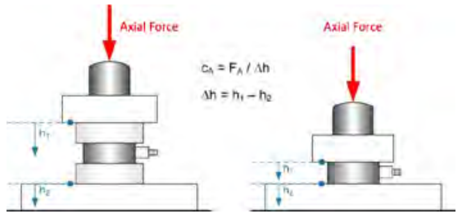
Challenge
- Very wide force measuring range
- High natural frequency
- Very aggressive media

Solution
- Four 3-component force sensors
- Compressed air cushion to prevent the penetration of dirt
- Custom calibration for wide measuring range

Please contact your local Kistler Sales Center for further information and advice on every aspect of customized sensor development.

Glossary

Terms	Symbol	Unit	Definition
Force	F	N	Force is a physical quantity in terms of vector having a center of impact, direction, and value.
Strain	ε	µm/m	Strain is a measure for relative change of dimensions (extension or contraction) of a body due to load, e.g. an applied force or a temperature change (thermal expansion). The enlargement of body dimension corresponds to a positive strain, whereas the reduction of body dimension corresponds to a negative strain.
Coulomb	Q	C	Unit of electric charge. 1 Coulomb corresponds to 1 Ampere-second (1 C = 1 As).
Dynamic	–	–	Describes the ability of Kistler sensors, charge amplifiers, and electrical devices to measure rapid and strongly time-variable measurands (e.g. motions with high frequencies).
Quasi-static	–	–	Describes the ability of Kistler sensors, charge amplifiers, and electrical devices to undertake time-variable and nearly time-constant measurements (e.g. long-term measurements or DC-similar measurements).
Time constant	τ	s	The time constant describes the behavior of a high-pass filter and represents the time after which the signal is reduced to 1/e of the initial output value. *Note: The time constant enables the measuring error to be estimated in relation to the measuring duration. You will find detailed information on time constants and sensitivity ranges in the operating instructions for your charge amplifier.* *Example: The time constant depends on the measuring range selected on the charge amplifier. Possible values vary from approx. 0.01 s in the most sensitive range to approx. 100 000 s in the least sensitive range. The largest possible time constant must be selected for quasi-static measurements.*
Linearity including hysteresis	Lin_{Hys}	%FSO	Dependent on the sensor type, the linearity is determined from data which includes the output values taken from the increasing (blue) and decreasing (red) measurand. For these cases, hysteresis (b %FSO) is included in the linearity (± a %FSO) and does not have to be taken additionally into account for estimating the measurement uncertainty of the application. *Note: The slope of this center line corresponds to the sensitivity of the sensor. Half the distance between the two parallels (measured in the ordinate direction) is the linearity.* 

Terms	Symbol	Unit	Definition
Frequency range	f_r	Hz	The useful frequency range is limited to the frequencies at which the corresponding amplitudes of transfer function do not exceed the permitted values of amplitude error. Because of their mechanical quality, piezoelectric sensors have very low damping. The useful frequency range is limited in the upwards direction by the increasing resonance rise. The following approximate values apply to the amplitude error or achievable accuracy as a function of frequency: • Genauigkeit 10 % –> $f_{max} \approx 0.3 \cdot f_n$ • Genauigkeit 5 % –> $f_{max} \approx 0.2 \cdot f_n$ • Genauigkeit 1 % –> $f_{max} \approx 0.1 \cdot f_n$ Symbols: • f = measuring frequency • f_{max} = maximum frequency of measurement • f_n = natural frequency
Frequency range (continued)	f_r	Hz	*Note: In their dynamic behavior, piezoelectric sensors are superior to all other measuring methods. Their high rigidity results in the highest possible natural frequencies. Piezoelectric sensors are thus ideal for measuring measurands which change rapidly over time. Their dynamic behavior is thereby largely determined by the surrounding structure. Therefore the frequency response of the entire measuring arrangement must be investigated for the largest possible, useful measuring range. There are two possibilities here: frequency analysis, f.e. pressure sensors in shock tube or finite-element method. Schematic presentation of frequency response and phase response.* 
Axial stiffness	$c_{A,x}$ $c_{A,y}$ $c_{A,z}$	N/µm	Mechanical resistance of a loaded sensor against its axial deformation which results from the acting force in designed axial axis of the force sensor. The stiffness value is calculated from the applied force F_A divided by the effective distance Δh between specified reference points. *Illustration of reference points for distance measurement.* 

From professional advice on installation to speedy deliveries of spare parts: Kistler's comprehensive range of services and training is at your disposal across the globe

Service: customized solutions from A to Z

Kistler offers sales and service wherever automated manufacturing processes take place.

In addition to sensors and systems, Kistler offers a host of services – from professional advice on installation to speedy worldwide deliveries of spare parts. For an overview of the services we offer, visit **www.kistler.com**. For detailed information on our training courses, please contact our local distribution partners (see page 77).

Kistler service at a glance
- Advice
- Support with system commissioning
- Process optimization
- Periodic onsite calibration of sensors
- Education and training events
- Development services

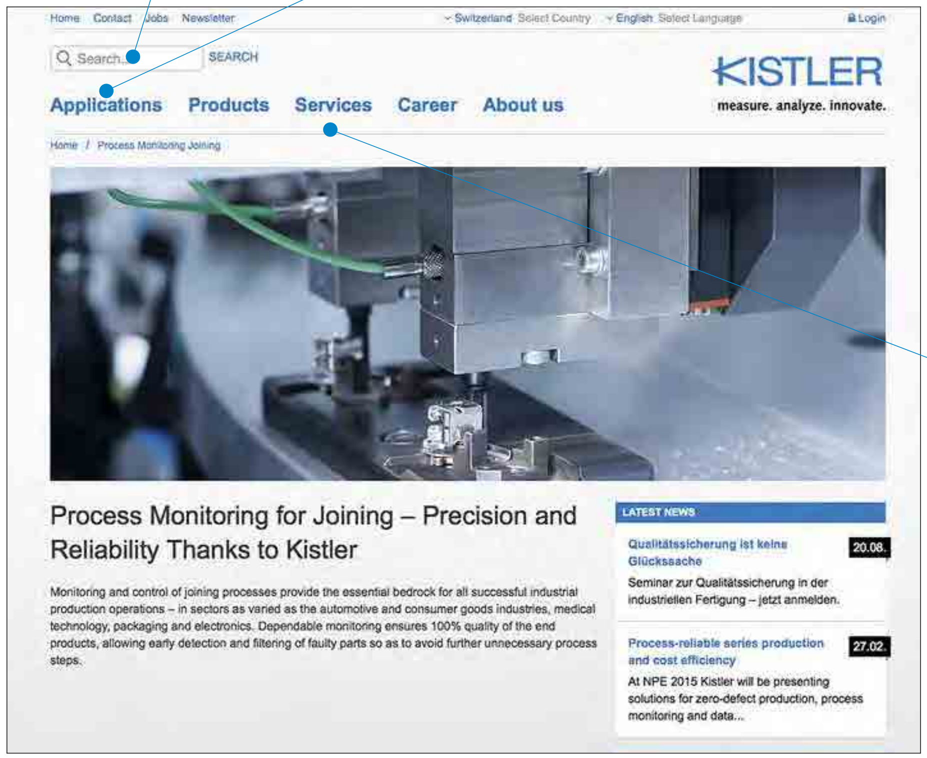
Kistler – at our customers' service across the globe

With around 1,500 employees, the Kistler Group leads the global market for dynamic measuring technology. 31 group companies and over 30 distributors ensure close contact with customers, individual application support and short delivery times.

Datasheets and documents
Use our search engine to download datasheets, brochures or CAD data.

For Clean-Cut Fracture Splitting: Monitor Cutting Processes with Kistler

Your contacts
No matter whether you come to us for advice or for support with an installation – on our website, you will find the contact details for your personal partner anywhere in the world.



Process Monitoring for Joining – Precision and Reliability Thanks to Kistler

Monitoring and control of joining processes provide the essential bedrock for all successful industrial production operations – in sectors as varied as the automotive and consumer goods industries, medical technology, packaging and electronics. Dependable monitoring ensures 100% quality of the end products, allowing early detection and filtering of faulty parts so as to avoid further unnecessary process steps.

Qualitätssicherung ist keine Glücksache 20.08.
Seminar zur Qualitätssicherung in der industriellen Fertigung – jetzt anmelden.

Process-reliable series production and cost efficiency 27.02.
At NPE 2015 Kistler will be presenting solutions for zero-defect production, process monitoring and data...

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Education and training courses – when our sensors and measuring systems are explained by experienced Kistler experts – are the most efficient way for you to acquire the expertise you need.

960-262e-01.23

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Find out more about our applications:
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