



Instruction Manual

**Press Force Sensor
Type 9340A1**

**Retrofitset
Type 9819A...**

Foreword

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1. Introduction

Please take the time to thoroughly read this instruction manual. It will help you with the installation, maintenance, and use of this product.

To the extent permitted by law Kistler does not accept any liability if this instruction manual is not followed or products other than those listed under *Accessories* are used.

Kistler offers a wide range of products for use in measuring technology:

- Piezoelectric sensors for measuring force, torque, strain, pressure, acceleration, shock, vibration and acoustic emission
- Strain gage sensor systems for measuring force and moments
- Piezoresistive pressure sensors and transmitters
- Signal conditioners, indicators and calibrators
- Electronic control and monitoring systems as well as software for specific measurement applications
- Wireless data transmission modules

Kistler also develops and produces measuring solutions for the application fields of engines, vehicles, manufacturing, plastics and biomechanics sectors.

Our product and application brochures will provide you with an overview of our product range. Detailed data sheets are available for almost all products.

If you need additional help beyond what can be found either on-line or in this manual, please contact Kistler's extensive support organization.

2. Important notes

It is essential for you to study the following notes, which are for your personal safety during work, and to ensure long term, fault-free operation of this product.

2.1 For your safety

- This product has been thoroughly tested and has left the factory in a perfectly safe condition. In order to maintain this condition and ensure safe operation, compliance is required with the instructions and warning notes in this instruction manual.
- The press force sensor must be installed, operated and maintained only by persons who are familiar with this product and who are adequately qualified for the work involved.
- If it is to be assumed that safe operation is no longer possible, the equipment must be shut down and made safe against being accidentally started up.

Safe operation must be assumed to be no longer possible when the product

- shows visible signs of damage,
- has been overloaded,
- is no longer operating,
- has been in lengthy storage under unsuitable conditions and,
- has been subjected to rough transport conditions.



Install the press force sensor in position as prescribed. Details can be found in Section 4.2.



Secure all parts mounted on the press force sensor according to anticipated moments!

2.2 Unpacking

Check all packaging for transport damage. Report any such damage to the transporters and to the authorized Kistler distributor.

Check accessories delivered (see Section 0) before first use of the equipment. Report any missing parts to the authorized Kistler distributor.

2.3 Notes on using the Press Force Sensor

- The press force sensor must be used only under the environmental and operating conditions specified.
- With piezoelectric sensors, insulation resistance is of crucial importance; it must be approx. $10^{14} \Omega$ (but not less than $5 \cdot 10^{13} \Omega$).
- In order to preserve this value, all plug-and-socket connections must be kept absolutely clean and dry. The insulation resistance can be measured with the insulation tester Type 5493.
- Protect the connector of the press force sensor against contamination and on no account touch it with your fingers (connector front). Fit the cover supplied over the connector when it is not in use.
- A high-insulation cable is used to connect the press force sensor to a charge amplifier. Once attached, it should if possible remain connected to the sensor. Use only specified connecting cables.
- Protect the press force sensor when it is not in use by storing it in its original packaging.

2.4 Hints on using this Instruction Manual

We recommend that you read the entire instruction manual carefully. However, if you are in a hurry and already have experience with Kistler press force sensors, read the specific information needed.

We have attempted to give these instructions a clear presentation to make it easier for you to gain direct access to the information you need.

Please keep these instruction manual in a safe place where you can retrieve them at any time.

If you lose this instruction manual, please contact your Kistler distributor and ask them for an immediate replacement.

3. General device description

3.1 What is the Press Force Sensor used for?

The Press Force Sensor is used for measuring dynamic and quasi-static compression forces on manual or pneumatic presses.

The most important areas of application are:

Process monitoring

- Press-fitting, punching, precision blanking, deep drawing, embossing

Product testing

- Switches, plugs, springs

Kistler Press Force Sensors are distinguished by high rigidity and a high natural frequency. The effective, useful frequency range is however determined by the natural frequency of the entire measurement setup. The high resolution capacity permits the measurement of minuscule dynamic changes, even with large forces.

The exchangeable mounting pins enable installation in manually operated or automatic presses of different force ranges from a variety of manufacturers. The Press Force Sensor is available in two versions with 10 mm and 12 mm hole diameters for the tool holder.

Kistler Press Force Sensors are shipped pre-calibrated and can be put into operation immediately.

3.2 Setup and functional principle of Press Force Sensor Type 9340A1

The Press Force Sensor is axially preloaded and is therefore particularly well suited for high linearity measurements across a wide force range of from 0,1 N to 60 kN.

The Press Force Sensor is rust-resistant, seal-welded and the plug connection of the connected cable is protected against the ingress of water spray. (Prerequisite: correctly mounted O-ring in the cable plug).

The transmission of force proceeds through the front contact surface at the top and bottom.

General device description

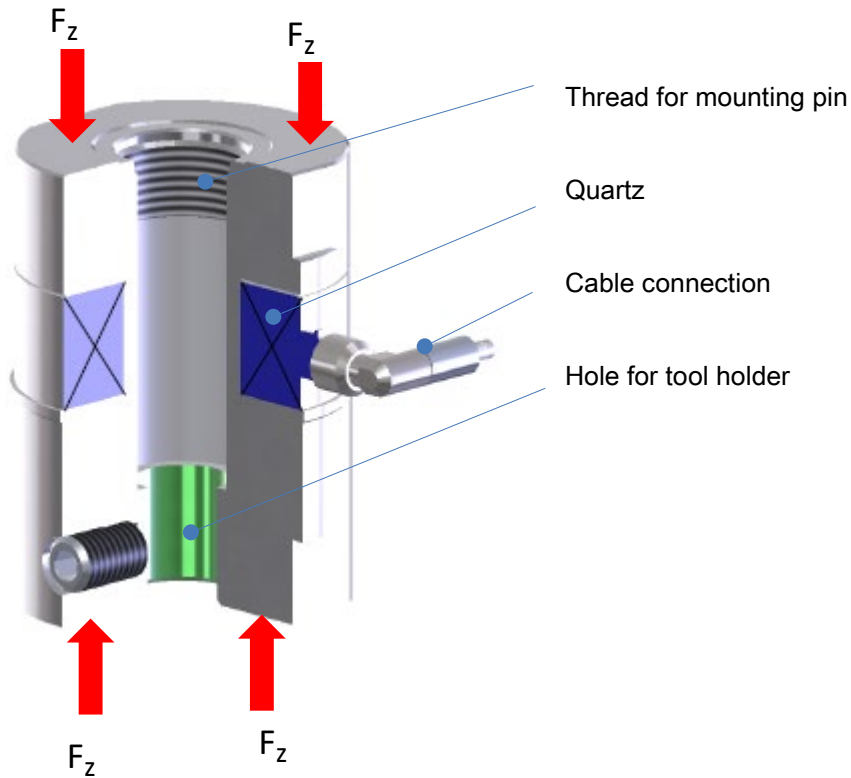


Fig. 1: Sensor setup with transmission of force

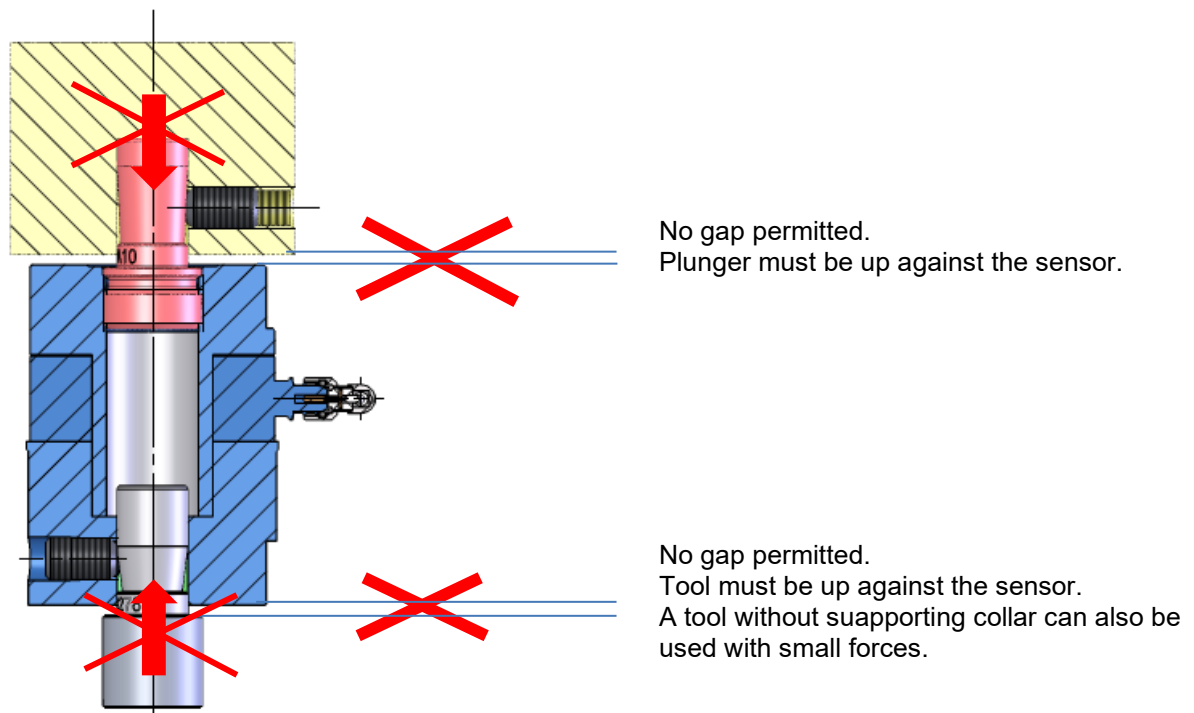
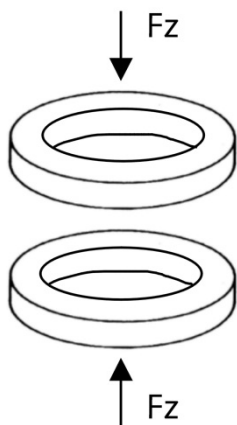


Fig. 2: Incorrect transmission of force



The transmission of force may not take place at the top through the mounting pin and at the bottom through the fastening pins of the tool.



The Press Force Sensor contains a pair of ring-shaped quartz crystal plates as an integrated sensor element that is sensitive to pressure. The pressure-sensitive direction of the quartz discs is aligned in such a way that a charge signal proportional to the force is emitted, depending on the level of the pressure force.

A negative charge results in a positive voltage at the output of the charging amplifier and vice-versa.

As a result of the piezoelectric measurement principle and the high rigidity of the Press Force Sensor, the measurement is virtually without displacement.

Fig. 3: Functional principle

4. Installation and commissioning

4.1 Important instructions

The Press Force Sensor Type 9340A1 is a precision instrument that must be utilized correctly to take full advantage of its specifications and handled carefully in order to preserve them. Please observe the following instructions:

- Ensure that the Press Force Sensor does not fall and is not subjected to severe impact! The peak force of this type of shock can cause permanent damage.
- Do not use a hammer to position the workpieces as these kinds of blows can also lead to damage!

You will find instructions regarding the installation of the Press Force Sensor and the setup of the measuring chain in the sections below.

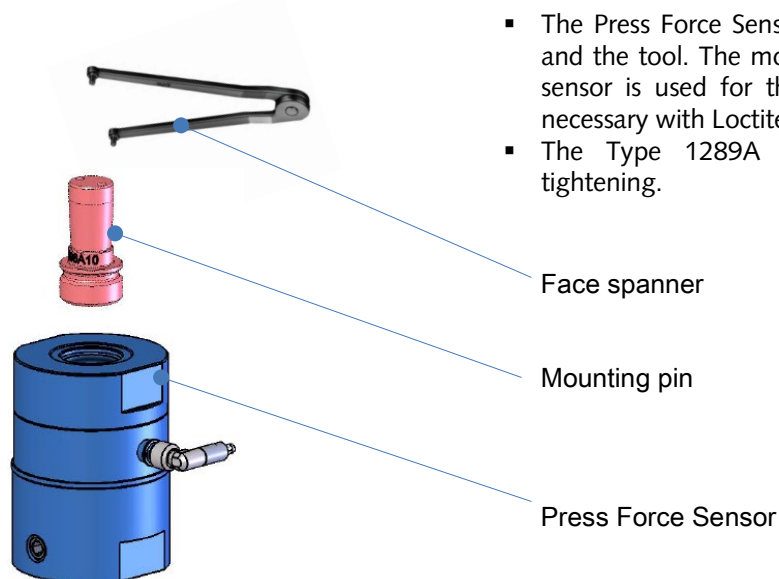
4.2 Installation of the Press Force Sensor

Please observe the following instructions for the correct assembly of the Press Force Sensor

- The Press Force Sensor may be installed only by personnel familiar with the Press Force Sensor and who are sufficiently qualified for this work.
- Tilt deviations lead to unwanted bending torques that could overload and destroy the sensor. The Press Force Sensor is designed to measure compression forces in the longitudinal axis. Even though additional **bending moments, tensile, pressure and shear forces** can be absorbed by the Press Force Sensor to a certain degree, these should be **avoided if at all possible**.



The Press Force Sensor is preloaded and calibrated at the time of delivery. Release of the preloading invalidates the guarantee and permanently alters the technical data.



- The Press Force Sensor is installed between the plunger and the tool. The mounting pin that is screwed into the sensor is used for this purpose and can be secured if necessary with Loctite 221.
- The Type 1289A face spanner can be used for tightening.

Fig. 4: Installation of the mounting pin



When tightening the mounting pin, counter-pressure must be applied with the open-end wrench on the pin near the exterior housing of the sensor!

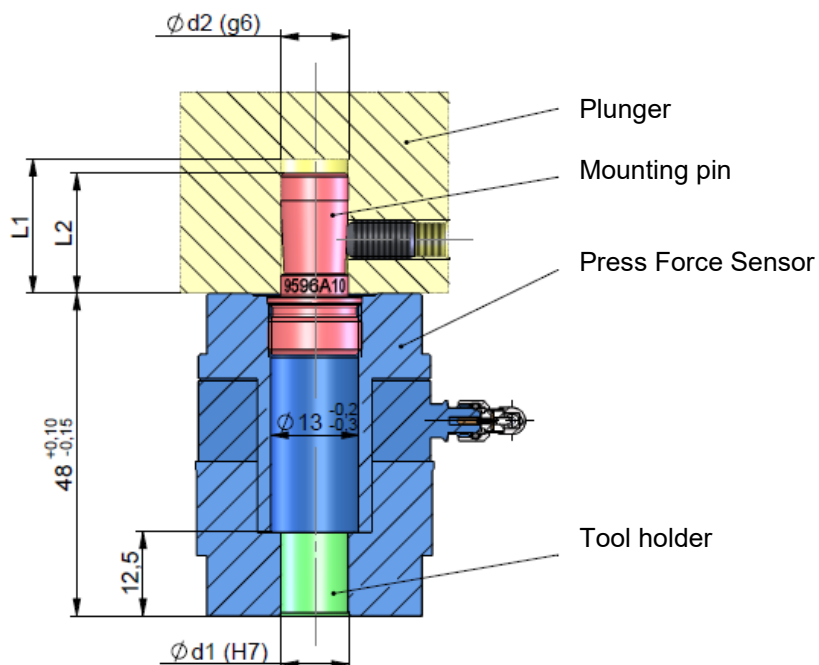


Fig. 5: Installation of the Press Force Sensor



The transmission of pressure force must be carried out exclusively through the flange surfaces on the top and bottom sides of the Press Force Sensor.

Type	Name	d1	d2	L1	L2
9340A1	Press Force Sensor	10	-	-	-
9596A10	Mounting pin	-	10	≥20	18
9596A11	Mounting pin	-	10	≥30	28
9596A20	Mounting pin	-	12	≥30	28
9596A30	Mounting pin	-	14	≥30	28
9596A40	Mounting pin	-	15	≥30	28
9596A50	Mounting pin	-	16	≥25	23
9596A60	Mounting pin	-	20	≥25	23
9596A61	Mounting pin	-	20	≥40	38
9596A70	Mounting pin	-	25	≥45	40



The connecting cable may not be connected until after completion of the installation of the Press Force Sensor. Because contaminants on the plug connections can lead to significant measurement errors (particularly with respect to drift), the plastic protective plug caps should remain screwed onto both the sensor and the cable during the entire assembly process! Maximum caution is called for, particularly in extremely dirty environments.

4.3 Tool holder

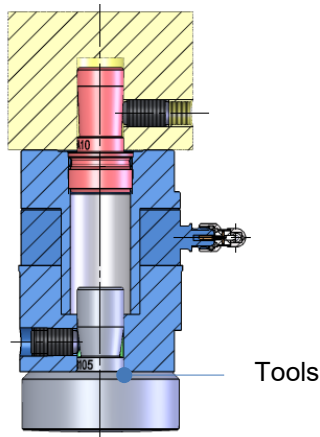


Fig. 6: Tool holder

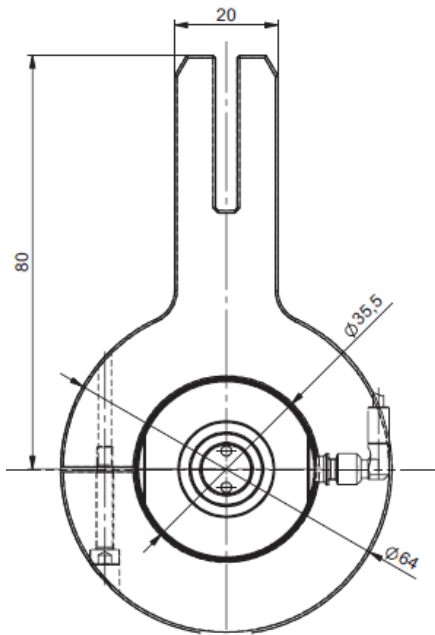
The tool is held using the hole on the bottom side of the sensor. The tool can be fixed in place with the transverse grub screw.

Multi-stage tools can be supported via the plane-machined end face of the mounting pin. Once the tool lies on top of the mounting pin, no further force can be measured, but only such things as travel distance.

Tool holder for Type

9340A1: $\varnothing d1 = 10 \text{ mm}$

4.4 Drive plate for the path sensor



The drive plate guides the path sensor. Path sensors with built-in return springs can simply be supported on the drive plate. The path sensor can be mounted rigidly to the drive plate through the slit opening, thus ensuring restricted guidance.

The drive plate is guided from below over the sensor up to the mechanical stop and firmly clamped using the integrated screw.

Fig. 7: Installation with drive plate for the path sensor.

4.5 Basic circuit and wiring of the measuring chain

When the applied compression force is changed, the Press Force Sensor emits an electrical charge. The charge signal is converted by the charge amplifier into scaled output voltage that can be detected and recorded by evaluation electronics.

4.5.1 Instructions for wiring the measuring chain



Piezoelectric sensors may only be connected to or disconnected from a charge amplifier when it is not in measuring mode. The input stage of the charge amplifier could be destroyed by voltage peaks during measurement operation!

- Only high-insulation coaxial cables with low capacity, which generate only very small amounts of static electricity when moved, may be used as connecting cables for piezoelectric sensors. We recommend using only the connecting cables listed in Data Sheet 1631C_000-346.
- We recommend cleaning both connection plugs of the connecting cable with Type 1003 cleaning and insulating spray from Kistler or with petroleum ether before connecting them. The plug on the Press Force Sensor is sealed with an O-ring. This is enclosed separately with some cables and must be placed in the plug prior to

connection. The contact surfaces for the O-ring must be clean.

- In order to avoid contamination of the plug contacts, the connecting cable should remain permanently connected to the Press Force Sensor. Do not remove the cover caps of the connections until immediately before the cable is connected.
- Lay the connecting cable in such a way that it can move as freely as required during work operations, but not so that it could be sheared off or pulled out.
- The vibration of the connecting cable can generate an electrical charge and cause noise in the charge signal (triboelectric effect).
- An aggregation of the charge and the measured variables can result from the parallel switching of several sensors. Only one charge amplifier is required.

4.6 Retrofit set Type 9819A... for manual presses

Kistler offers a complete set, comprising Press Force Sensor, XY monitor maXYmos BL, path sensor and the appropriate cables, installation aids and power supply for force-path measurement with process monitoring.

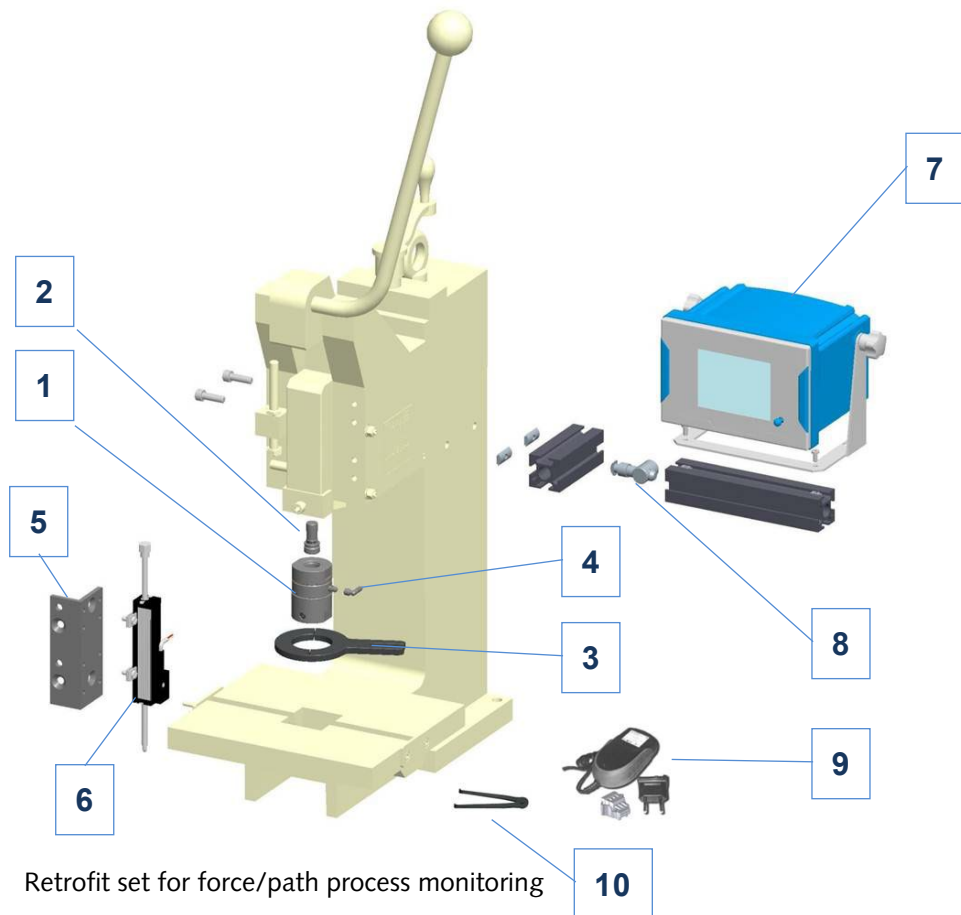


Fig. 8: Retrofit set for force/path process monitoring

No.	Type	Nomenclature
1	9340A1	Press Force Sensor
2	9596A...	Mounting pin
3	9598A	Drive plate for path sensor
4	1631C1	Connecting cable KIAG 10-32 pos.
5	55123426	Installation plate for path sensor
6	2124A..	Displacement sensor
7	5867B0010	XY monitor maXYmos BL
8	5867AZ040	Installation set for maXYmos BL
9	5781B5	Plug-in power supply max. 90 W
10	1289A	Face spanner

Additional information regarding the measuring chain components can be found in the Data Sheets in the measuring chain assembly instructions below.

				
Press Force Sensor Type 9340A1	Drive and Mounting plate Type 9598A/55123426	Cable, high insulation Type 1631C... Data sheet 000-346	Displacement sensor Type 2124A50 incl. connecting cable 2m Datasheet 003-544	maXYmos BL Type 5867B... Data sheet 003-054

Fig. 9: Measuring chain with force-path measurement for process monitoring.

5. Measurement range and determining factors

The following example for Type 9340A1 is used to show how disturbance variables that arise, e.g. shear force, bending moment and torque, influence (i.e., reduce) the normal force F_z .

- M_b = permissible bending moment (see diagram)
- M_z = permissible torque (see diagram)
- $v(ny)$ = ratio between shear force F_{shear} and absolute normal force F_{zTot}
- az_0 = distance between sensor midpoint and top side of cover plate (29 mm)
- az = lever arm from the top side of the cover plate to the point of application of force (variable)

- Shear force: $F_{Shear} = \overrightarrow{F_{x,y}} = \sqrt{F_x^2 + F_y^2}$

- Process normal force (axial force): F_z

- Absolute normal force: $F_{zTot} = F_v + F_z$

- Ratio between shear force F_{shear} and normal force F_{Tot} :

$$v = \frac{F_{Shear}}{F_v + F_z}$$

- F_v = preloading force (25 kN)

The following maximum forces apply for type 9340A1:

$$F_{zTot} = 85 \text{ kN} \quad (\text{for } F_{Shear} = 0 \text{ and } M_b, M_z = 0)$$

$$F_{Shear \max} = 4,1 \text{ kN} \quad (\text{for } az = 0 \text{ and } F_z = 38 \text{ kN})$$

- Calculation of an applied bending moment with a pure shear force, taking into account az_0 :

$$\begin{aligned} \text{Applied bending} &= \text{applied} \times (az_0 + az) \\ \text{bending} &\text{shear force} \end{aligned}$$

$$M_b = F_{Shear} \times (az_0 + az)$$

$$M_x = F_y \times (az_0 + az)$$

$$M_y = -F_x \times (az_0 + az)$$

- Calculation of an applied bending moment with any given triaxial force, taking az_0 into account:

$$M_x = F_y \times (az_0 + az) + F_z \times ay$$

$$M_y = F_x \times (az_0 + az) + F_z \times ax$$

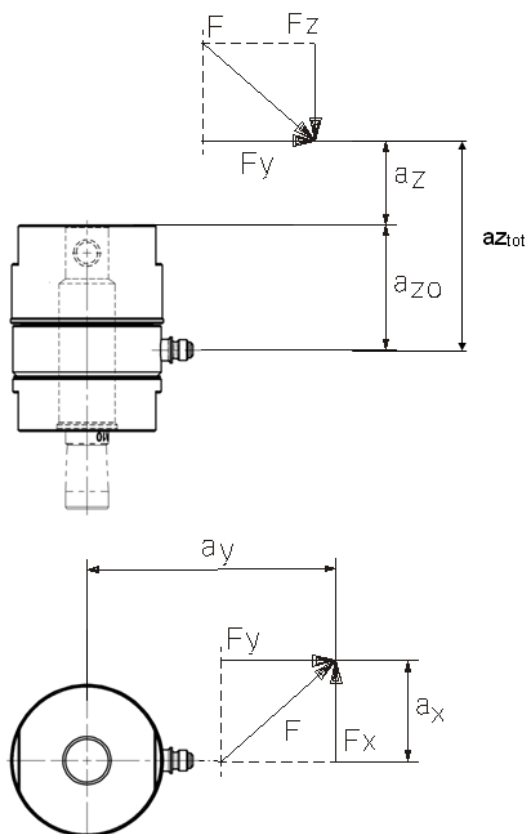


Fig. 10: Application of force

5.1 Calculation example

The point of application of force on the sensor, as well as a shear force or an additionally applied bending moment or torque, influence the permissible measurement range F_z to a considerable extent.

The following example is used to illustrate how you can determine the limits on the basis of the respective application case.

▪ **Guideline**

The Press Force Sensor Type 9340A1 is loaded with an axial force of $F_z = 50 \text{ kN}$ ($az = 0 \text{ mm}$), while at the same time a shear force $F_{\text{Shear}} = 3,1 \text{ kN}$ is to be introduced at the height of $az = 0 \text{ mm}$.

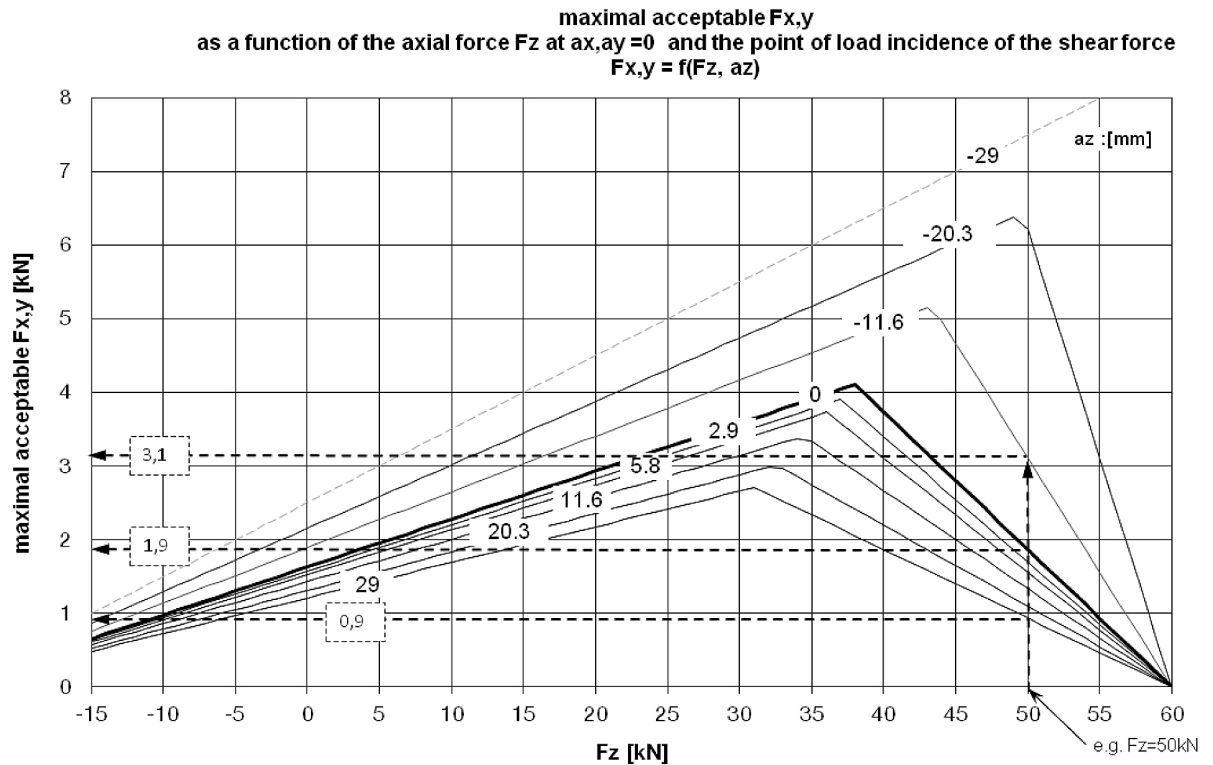


Fig. 11: Load diagram $F_{x,y} = f(F_z, az)$

Depending on the point of the application of force, the following shear forces are permissible in accordance with the load diagram $F_{x,y}$:

Case 1: $F_z = 50 \text{ kN}$; $az = 0 \text{ mm}$
The preceding load diagram results in the following:

$$F_{x,y} = 1,9 \text{ kN}$$

Case 2: $F_z = 50 \text{ kN}$; $az = 29 \text{ mm}$
The preceding load diagram results in the following:

$$F_{x,y} = 0,9 \text{ kN}$$

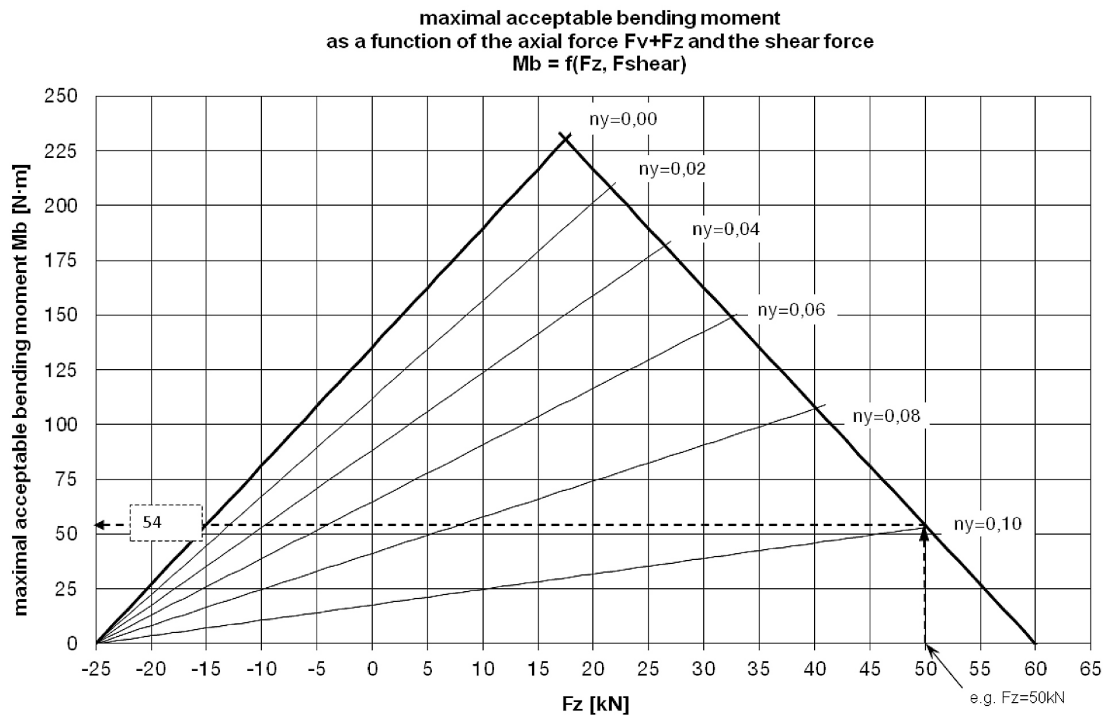


Fig. 12: Load diagram $M_b = f(F_v + F_z, F_{\text{shear}})$

- In accordance with the diagram for the determination of the maximum permissible bending moment, the presence of a given **axial force $F_z = 50 \text{ kN}$; $F_{\text{shear perm}} = 3,1 \text{ kN}$ ($a_z=0$)**

$$\Rightarrow \nu = \frac{F_{\text{shear}}}{F_v + F_z} = \frac{3,1 \text{ kN}}{25 \text{ kN} + 50 \text{ kN}} = 0,041$$

results in a bending moment of $M_{b_{\text{perm}}} = 54 \text{ N} \cdot \text{m}$

Because only the forces and free moments (moments free of lateral forces) can be determined from the load diagram, the cross-forces originating with the occurrence of a moment load (F_x, F_y with lever arm a_z) must be reduced using the following formula:

$$M_b = F_{\text{shear}} \cdot (a_{z0} + a_z) + F_z \cdot \sqrt{a_x^2 + a_y^2}$$

for $a_x = 0, a_y = 0$ and $a_z = 0$, the maximum shear load is calculated according to the formula described:

$$F_{\text{shear}} = \frac{M_b}{a_{z0}} = \frac{54 \text{ N} \cdot \text{m}}{0,029 \text{ m}} = 1,9 \text{ kN}$$

The result corresponds approximately to the value from the load diagram $F_{x,y}$, which means that when the maximum shear force F_{shear} specified in the example of $= 3,1 \text{ kN}$ is introduced at cover plate height, the maximum permissible moment will be exceeded.

The originally desired shear force $F_{\text{Shear}} = 3,10 \text{ kN}$ must be reduced to the **maximum bending moment on the shear force** $F_{\text{Shear}} = 1,9 \text{ kN}$ for $az = 0$, or the **shear force** $F_{\text{Shear}} = 3,10 \text{ kN}$ can be applied at a height of $az = -11,6 \text{ mm}$ with $F_z = 50 \text{ kN}$ (see load diagram $F_{x,y}$).

The maximum bending moment of $54 \text{ N}\cdot\text{m}$ and the reduced shear force F_{Shear} , result in a maximum shear force-axial force ratio of

$$v = \frac{F_{\text{Shear}}}{F_v + F_z} = \frac{1,9 \text{ kN}}{25 \text{ kN} + 50 \text{ kN}} = 0,025$$

- The Press Force Sensor in our example is loaded with

the axial force $F_z = 50 \text{ kN}$ and the bending moment $M_{b_{\text{perm.}}} = 54 \text{ N}\cdot\text{m}$.

In accordance with the load diagram for the torque M_z , an additional

$$M_{z_{\text{permissible}}} = 81,5 \text{ N}\cdot\text{m} \text{ for } F_{\text{Shear}} = 0$$

can be introduced.

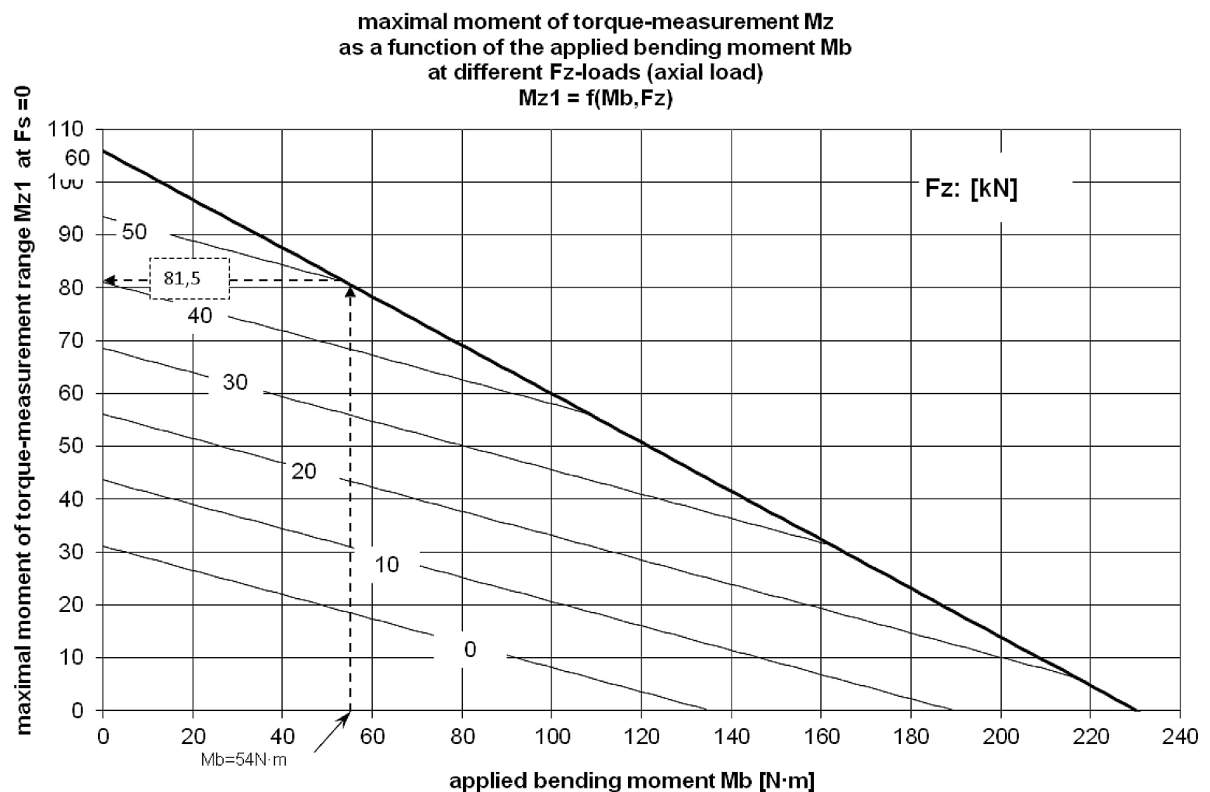


Fig. 13: Load diagram $M_{z1} = f(M_b, F_z)$

If however a shear force of $F_{\text{Shear}} = 1,9 \text{ kN}$ is in effect, as in our example, then the maximum permissible torque $M_{z_{\text{perm}}}$ must be reduced in accordance with load diagram $M_{z_{\text{max}}}$

maximal moment of torque- measuring range M_z as a function of the M_{z1} and F_{shear}
 $M_z = f(M_{z1} ; F_s)$

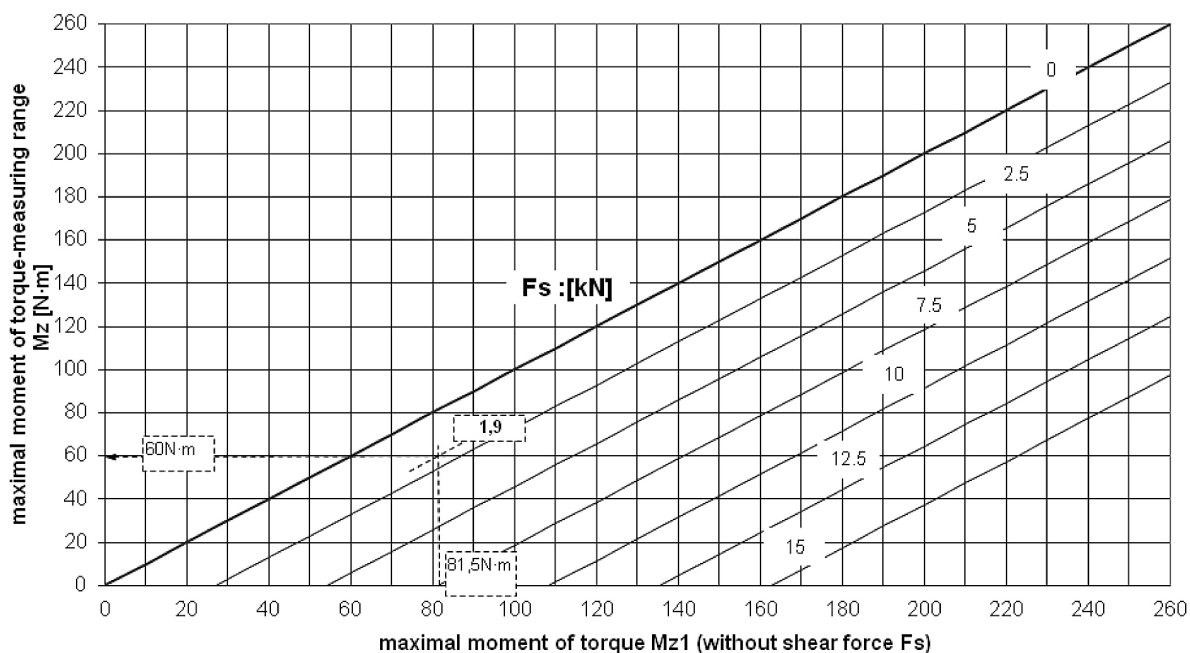
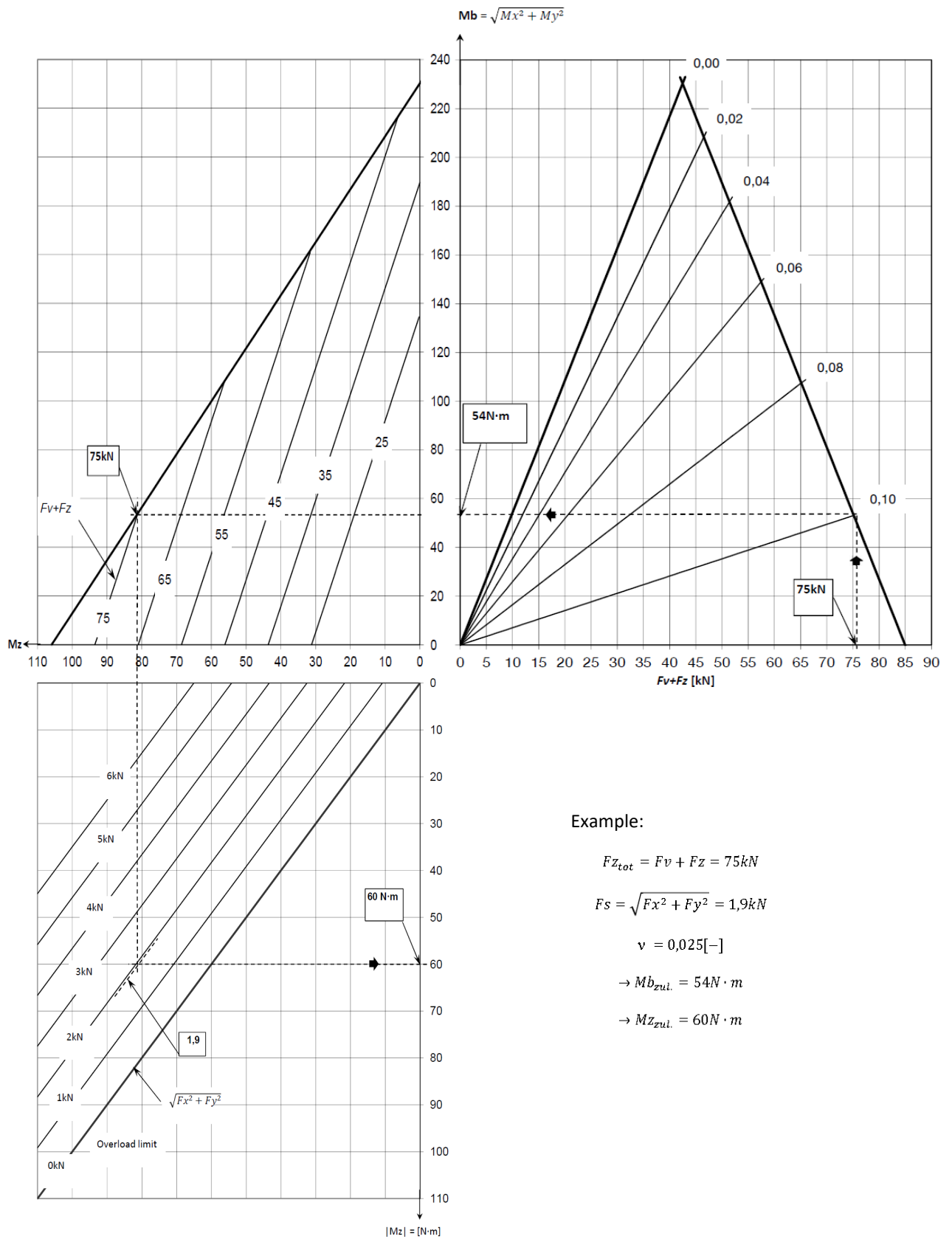


Fig. 14: Load diagram $M_z = f(M_{z1}, F_s)$

In accordance with the load diagram $M_{z_{\text{Max}}}$, the maximum torque is reduced to:

$$M_{z_{\text{Max}}} = 60 \text{ N·m}$$

If the application necessitates a larger maximum permissible torque or if a larger torque arises through a_x , a_y and the associated forces F_x , F_y , then the maximum permissible shear load must be reduced accordingly.



Example:

$$Fz_{tot} = Fv + Fz = 75 \text{ kN}$$

$$Fs = \sqrt{Fx^2 + Fy^2} = 1,9 \text{ kN}$$

$$v = 0,025[-]$$

$$\rightarrow Mb_{zul.} = 54 \text{ N} \cdot \text{m}$$

$$\rightarrow Mz_{zul.} = 60 \text{ N} \cdot \text{m}$$

Fig. 15: Nomograph for determining the maximum possible moment load

6. Operation

6.1 Setting the charge amplifier

In conjunction with the Press Force Sensors Types 9323AA ... 9393A we recommend the use of a charge amplifier with sensitivity selection such as Type 5073A... or a ControlMonitor Type 5867... . Details for equipment set up are given in the relevant instruction manuals.

Sensitivity

Set the sensitivity (–pC/N) according to the calibration certificate for the Press Force Sensor. The indication appears directly in N.

Measuring range

Set the measuring range required (N). Depending on the instrument, the output voltage range ($\pm V$ FSO) and the scaling for the output voltage (N/V) can also be selected.

6.2 Polarity of the measuring signal

Compressive forces produce a negative charge signal at the sensor and a positive display value or positive voltage at the analog output of the charge amplifier.

6.3 Resolution of the measuring signal

The resolution is the smallest possible change in the measurand able to be measured by the system. It is determined by the signal-to-noise ratio at the signal output of the charge amplifier. In the case of Control Monitor maXYmos BL, the resolution with the highest gain is typically.

$$\pm 2 \text{ pC}$$

In combination with the sensitivity of the Press Force Sensor from –9,6 pC/N, the resolution amounts to:

$$\frac{\pm 2 \text{ pC}}{-4 \text{ pC/N}} = \pm 0,5 \text{ N}$$

6.4 Quasistatic measurements

With the piezoelectric measuring principle, purely static measurements over any length in time are not possible. Because the charge amplifier is not an ideal component, the charge stored in the range capacitor is not retained for an unlimited time. Leakage currents produce a drift in the order of magnitude of $\pm 0,05 \text{ pC/s}$. During measurement, the zero point of the output signal as a function of time drifts in a positive or negative direction. This can be measured with the charge amplifier in the <Operate> or <Measure> position with the sensor unloaded or constantly loaded.

Strong drift can be due to inadequate insulation resistance of the measuring chain. It is therefore important to keep the cable and connector clean and dry at all times.

The duration during which the so-called quasi-static measurements can be carried out is determined by the accuracy required. With $-4,005 \text{ pC/N}$ as the value for the sensitivity of the sensor and with a specified drift of $0,05 \text{ pC/s}$ for the maXYmos BL, the drift can be calculated in mechanical units.

$$\frac{\pm 0,05 \text{ pC/s}}{-4,005 \text{ pC/N}} = \pm 12,5 \text{ mN/s}$$

This means that, for a measurement lasting 10 minutes, a drift results in the amount of:

$$\pm 0,0125 \text{ N/s} \cdot 600 \text{ s} = \pm 7,49 \text{ N}$$

This absolute error is in relation to the measured value and equals $\pm 0,30 \%$, for example, with a force of $2\,500 \text{ N}$. Conversely, if one does not wish to suffer more than a 2% loss of accuracy due to drift, for example, then the measurement should not be permitted to take place for longer than:

$$\frac{50 \text{ N}}{0,0125 \text{ N/s}} \approx 66 \text{ Min.}$$

Therefore, depending on the sensitivity of the sensor, measured value and required accuracy, measurements ranging from minutes to several hours are possible.

6.5 Tips for good measurands

- Always store the measuring instruments in the same room in which measurements are to be carried out.
- Keep the connecting cable connected to both the sensor and the measuring instrument. If this is not possible, install the protective caps on the connectors.
- Mount the sensor exactly as specified.
- Turn on the measuring instrument for about one hour before the first measurement.
- Set the sensitivity of the sensor according to the details in the calibration certificate.
- Select the measuring range or the scaling of the output voltage so that the maximum measurand is in the range of 50 ... 100 %.
- Avoid temperature changes during the measurement.
- Actuate measurement (Operate) only shortly before the actual measurement.

7. Calibration and maintenance

The Press Force Sensor Type 9340A1 is a reliable instrument, which requires practically no maintenance. Please study the following two sections in order to maintain long and reliable operation.

7.1 In-situ calibration of force sensors

Absolute measurement results can only be made if the complete measurement assembly, e.g. the press force sensor and its mounting fixtures, has been calibrated.

If it is possible to remove the force measurement assembly, without influencing the pretension and load distributing of the force sensor, the assembly can be sent to a Kistler Calibration Centre for recalibration. If, however, the sensor is integrated into the machine structure, it normally is not possible to remove the force measurement assembly for recalibration. In this case an in-situ calibration must be performed.

7.1.1 Working point calibration by peak value comparison

The test system is calibrated by comparing its output with that of a reference measurement chain at loads around a specific working point. An average sensitivity is calculated from the peak values of both the reference and test systems recorded over multiple load cycles.

It is important to note the calculated sensitivity, S^* , is valid for a specific measurement chain, i.e. sensor, charge amplifier and display unit. Exchanging sensors or amplifiers will make the calibration invalid.

Furthermore, the sensitivity S^* is calculated around a specific working point and will invariably differ slightly from any works calibration results, which would have been derived using a standard continuous calibration procedure. It is generally also recommended to check the distribution of the average sensitivity by calculating the standard deviation of the sensitivity S^* .

7.1.1.1 Test system requirements

Reference measurement chain:

The reference measurement chain consists of a calibrated pre-loaded force sensor and charge amplifier.

Signal conditioning:

The signal readout devices for both the reference and test systems must be equipped with peak-hold functionality.

Load application:

The calibration force must be ramped from zero to the required working point and back. An external actuator, e.g. a hydraulic cylinder, should be used if the calibration loads can not be applied with the test system's internal actuation mechanism.

7.1.1.2 Reference press force sensor (pfs) installation

Place the reference press force sensor directly in the force path of the test system as shown in Fig. 16. Always make use of force distribution caps or spherical washers and ensure that the test force is applied centrally through the reference PFS.

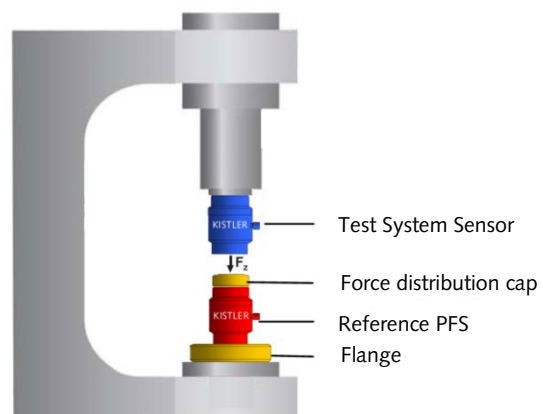


Fig. 16: Typical in-situ calibration setup

7.1.1.3 Load application

A typical load cycle is shown in Fig. 17.

1. The system must be in an unloaded condition to define the zero force bias;
2. Reset the charge amplifiers and, if necessary, the peak hold functions for both the reference and test system measurement channels.
3. Apply the load to the required working point and then back to the unloaded condition.
4. Record the peak values from the reference as well as the test-system read-outs.

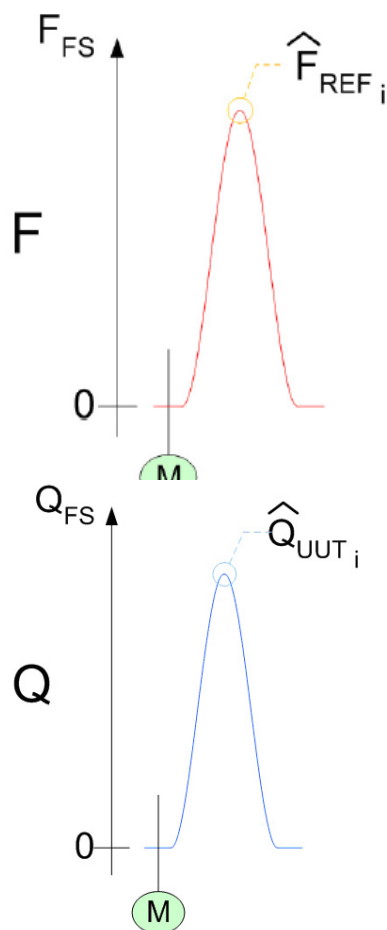


Fig. 17: Load cycle definition

Reference system

- F [MU] Force signal
 F_{PS} [MU] Measurement range (Full Scale) for reference system charge amplifier
 F_{REFi} [MU] Reference system output for load cycle i
 $\hat{F}_{REFi}$ [MU] Peak value measured by the reference measurement chain (for cycle i)

Test system

- Q [pC] Charge signal
 Q_{PS} [pC] Measurement range (Full Scale) for test system charge amplifier
 Q_{UUTi} [pC] Test system output for load cycle i
 $\hat{Q}_{UUTi}$ [pC] Peak value displayed on the test system readout (for cycle i)

 Reset charge amplifiers, start of measurement

Detailed Steps for the in-situ calibration of a typical test system is shown in Fig. 35 and the Calibration Process Worksheet on the following page.

7.1.1.4 Calibration process worksheet

1. Set up the charge amplifier for the maximum range of the reference sensor and the corresponding sensitivity as shown on the calibration certificate.

Range:		F_{nom}		[MU]
Sensitivity:	Cal. Cert.	$S_{REF(F_{nom})}$		[pC/MU]

2. Set up the test system amplifier to approximately determine the charge output of the test sensor. For the first iteration, use the maximum range of the charge amplifier. If the charge signal is very small and can not be measured properly, reduce the amplifier's charge range.

Range:		Q_{max}		[pC]
Sensitivity:		S_{UUT}	1	[pC/pC]

3. Pre-load the system at least three times.
4. Calculate and set the range of the reference channel. If required, change the sensitivity from the reference sensor's calibration certificate to closely match this range.

Range:	$F_{FS} = 1,25 \cdot \hat{F}_{REF_0}$	F_{nom}		[MU]
Sensitivity:	Cal. Cert.	$S_{REF(F_{FS})}$		[pC/MU]

5. Calculate and set the range of the test system charge amplifier.

Range:	$Q_{FS} = 1,25 \cdot \hat{Q}_{UUT_0}$	Q_{FS}		[MU]
Sensitivity:	Cal. Cert.	S_{UUT}	1	[pC/MU]

6. Apply load at the working point at least 5 times, note the peak values from both the reference and test systems for each cycle.

i	1	2	3	4	5	
$\hat{F}_{REF_i}$						[MU]
$\hat{Q}_{UUT_i}$						[pC]

7. Calculate the peak sensitivity for each cycle.

$$S_i^* = \frac{\hat{Q}_{UUT_i}}{\hat{F}_{REF_i}}$$

i	1	2	3	4	5	
S_i^*						[pC/MU]

8. Calculate the average sensitivity:

$$S^* = \frac{\sum_{i=1}^5 S_i^*}{5}$$

S^*		[pC/.....MU]
-------	--	--------------

9. Enter the new sensitivity S^* into the test system charge amplifier.

10. Apply load at the working point to confirm results.

$\hat{F}_{REF}$		[MU]
$\hat{F}_{UUT}$		[MU]

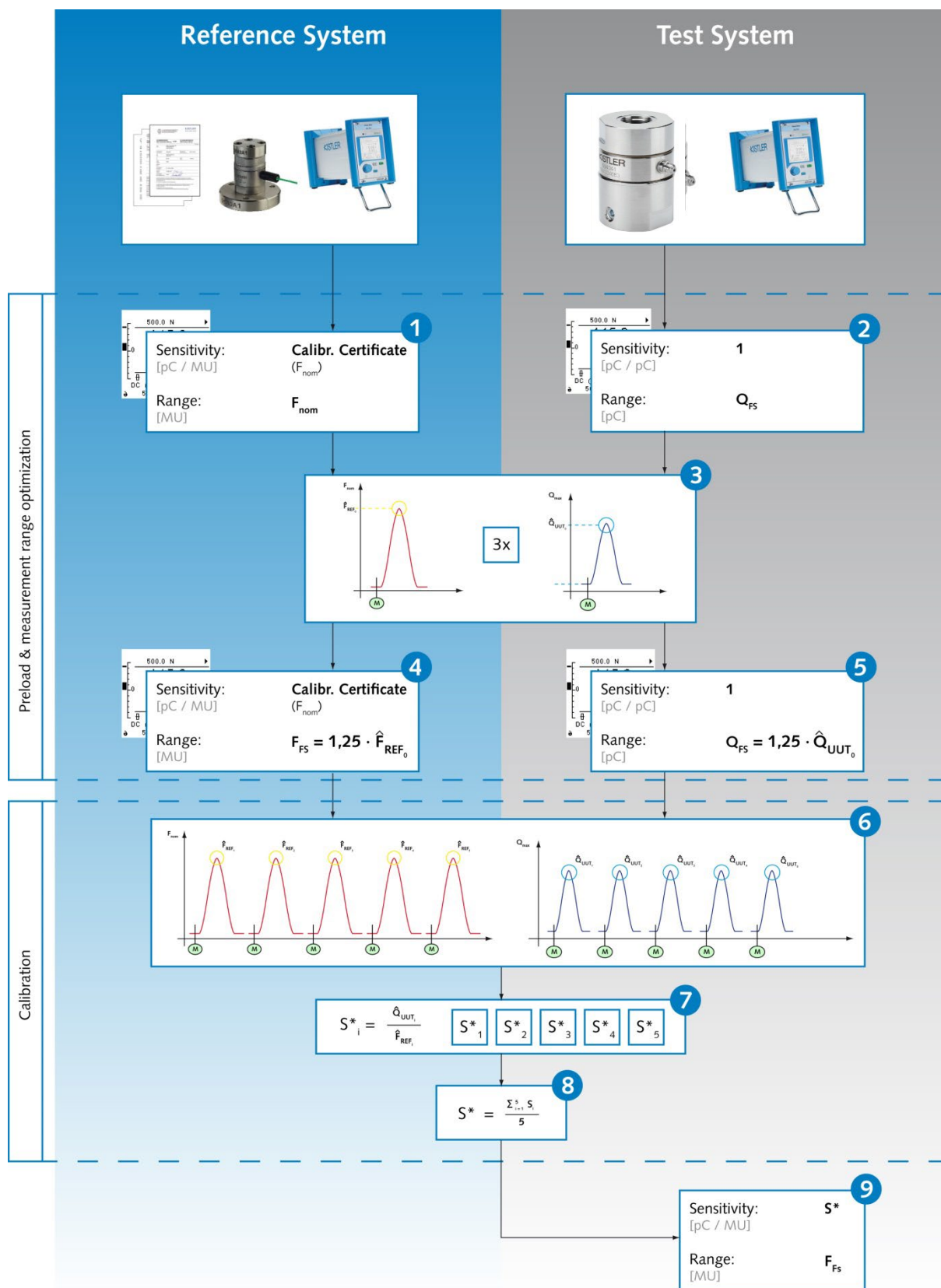


Fig. 18: In-situ calibration procedure

7.2 Kistler calibration service

To maintain their position on the world market products have to meet extremely stringent quality requirements. ISO 9001 requires test equipment to stand in a known and valid relationship to nationally recognized standards. Traceability must be ensured. Kistler offers the following calibration services:

Swiss Calibration Service (SCS)

Kistler is accredited as SCS Calibration Center No. 049 for equipment measuring pressure, force, acceleration and electrical charge. To ensure traceability and specified measurement uncertainties, calibration equipment and methods are regularly monitored and audited.

In-situ calibration

Kistler offers an in-situ calibration services for cases in which the instruments and equipment to be calibrated cannot be transported.

Calibration in one of the calibration centers

In addition to in-situ calibration Kistler offers a service that allows customers to have transportable instruments and equipment calibrated in one of the calibration centers.

7.3 Maintenance work

Please comply with the following information for maintaining your press force sensor

- Before every period of use, check the Press Force Sensor for obvious damage. Do not put a damaged sensor into operation!
- Have all repairs to the sensor such as replacement of carried out by the factory. Information can be found in section 8.2.
- The base and cover surfaces of the Press Force Sensors are machined parallel and flat to within very close tolerances. These surfaces must not be further machined! Visible scratches and notches can be restored with a whetstone.
- Clean the connectors of the Press Force Sensor or connecting cable regularly with a very clean detergent, such as the cleaning and insulation spray Type 1003 from Kistler or with white spirit.

8. Troubleshooting

8.1 Fault-finding and remedy

Below is a list of the frequent causes of malfunction and instructions on how to remedy these. If a fault occurs which you cannot correct, please contact your Kistler distributor.

Fault	Cause	Remedy
No measuring signal at the output of the charge amplifier	Signal cable open circuit	Check measuring arrangement (connections and cables).
	Charge amplifier defective	Proceed according to the instruction manual for the charge amplifier.
	Charge amplifier not in measurement mode	Proceed according to the instruction manual for the charge amplifier.
	Press Force Sensor defective	Repair at factory; proceed according to section 8.2.
Quasistatic measurements not possible (signal affected by strong drift)	Poor insulation resistance in the measuring chain	Determine the error source in stages; check the drift with open or shielded sensor input at the measuring instrument; same measurement with cable connected without sensor; check insulation resistance of sensor and cable with Kistler insulation tester Type 5493. Clean connectors.
Charge amplifier reaches the limit during measurement	The force to be measured is too high for the measuring range selected	Select a wider measuring range on the charge amplifier.
	Input stage of the measuring instrument defective	Exchange MOS-FET or operational amplifier in the charge amplifier input stage.

8.2 Repairing the press force sensor

The Press Force Sensor **cannot** be repaired in the following cases:

- No output signal.
- Wrong measurand because of reduced sensitivity (Note: possible reason due to overload).
- Strong drift not remediable by cleaning the connector.

9. Technical data

Please note that all technical data and all further information in this section can be changed at any time without prior notice.

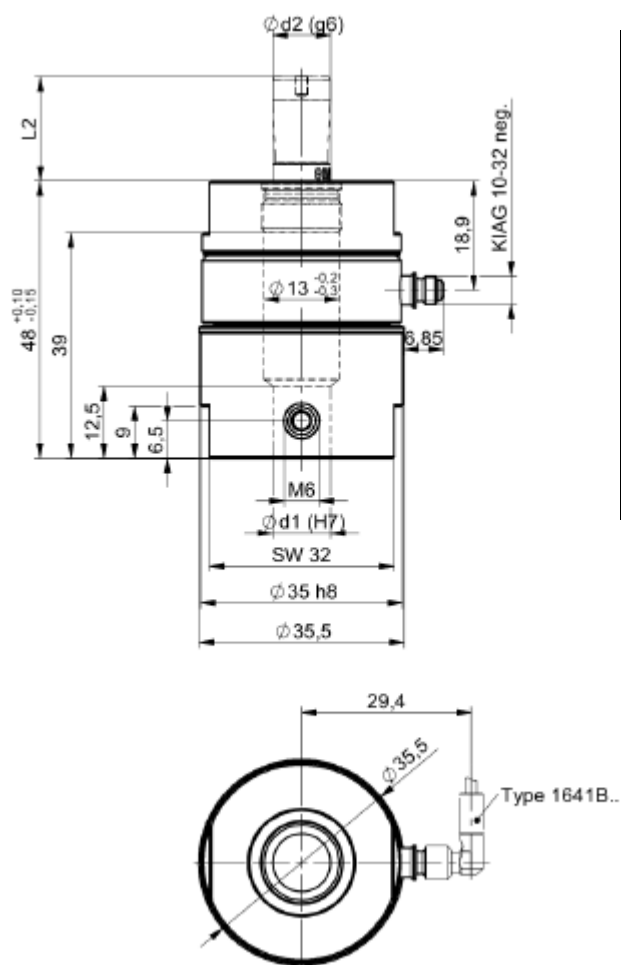
9.1 Press Force Sensor Type 9340A1

	Type	9340A1
Measuring range F_z	kN	-10 ... 60
Calibrated measuring ranges, F_z		
100 %	kN	0 ... 60
10 %	kN	0 ... 6
1 %	kN	0 ... 0,6
Overload $F_{z \max}$, tensile force/pressure	kN	-14/84
Sensitivity, F_z , nominal	pC/N	-4
Threshold, F_z	N	0,02
Linearity ¹⁾ incl. Hysteresis	%FSO	$\leq \pm 0,5$
Shear force $F_{x,y \max}$, ($F_z=0$)	kN	1,6
Bending moment ²⁾ $M_{x,y \max}$, ($F_z=100\%$ ($F_z=0$))	N·m N·m	0 135
Torque ²⁾ $M_{z \max}$, ($F_{x,y}=0$, $F_z=0$)	N·m	28
Rigidity, c_z	kN/ μ m	2,6
Natural frequency, f_n	kHz	>40,5
Operating temperature	°C	-40...120
Temperature coefficient of sensitivity, F_z	%/°C	-0,02
Insulation resistance at 20 °C	Ω	$\geq 5 \cdot 10^{13}$
Weight	g	280
Connection	KIAG	10-32 neg.
Degree of protection (with cable connected)	EN60529	IP65

¹⁾ Relative to FSO of the calibrated (!) measuring range

²⁾ expected values

9.2 Dimensions



Type	Name	d1	d2	L2
9596A10	Mounting pin	-	10	18
9596A11	Mounting pin	-	10	28
9596A20	Mounting pin	-	12	28
9596A30	Mounting pin	-	14	28
9596A40	Mounting pin	-	15	28
9596A50	Mounting pin	-	16	23
9596A60	Mounting pin	-	20	23
9596A61	Mounting pin	-	20	38
9596A70	Mounting pin	-	25	40

Fig. 19: Dimensional drawing Press Force Sensor Type 9340A1

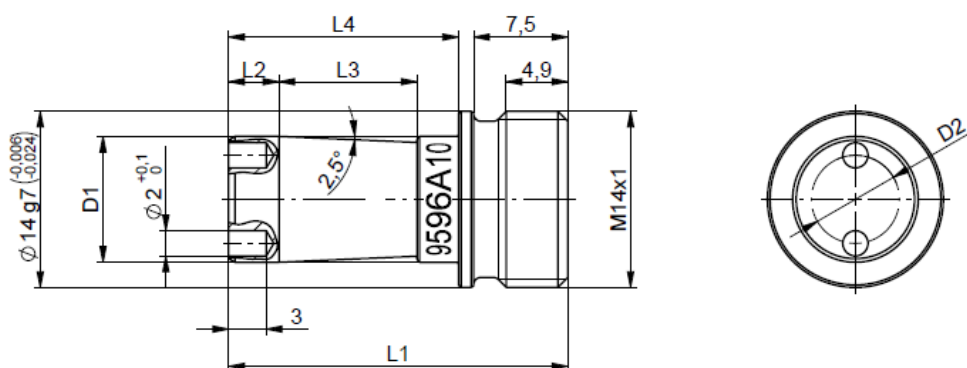


Fig. 20: Dimensional drawing mounting pin Type 9596A10...20 (See Table 1)

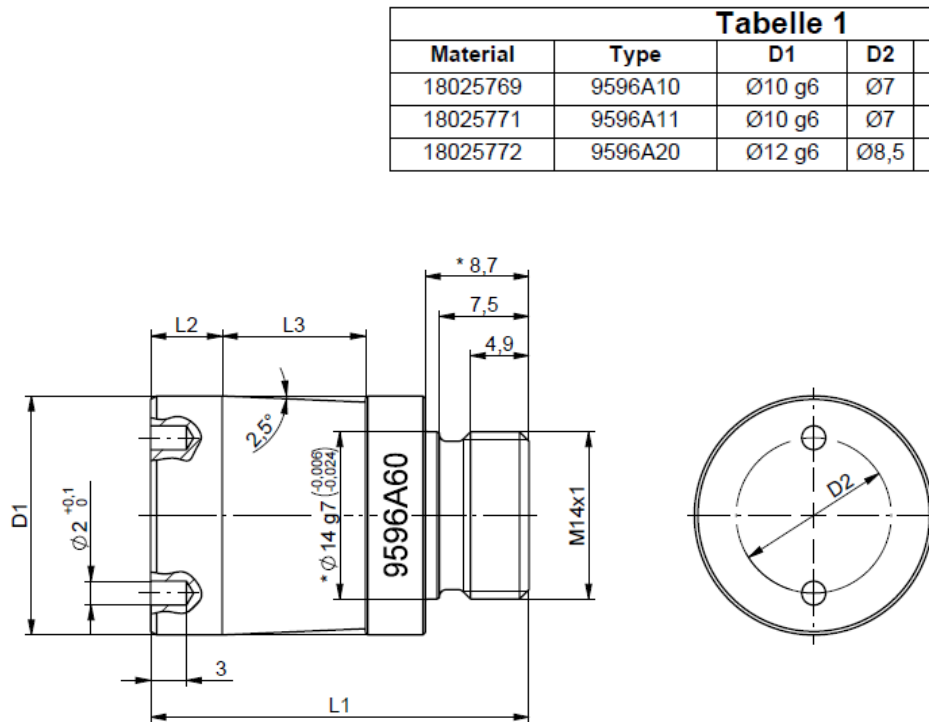


Fig. 21: Dimensional drawing mounting pin Type 9596A30...70 (See Table 2)

Tabelle 2							
Material	Type	D1	D2	L1	L2	L3	Bemerkung
18026781	9596A30	Ø14 g6	Ø10	37	8	17	* entfällt, Ø14 g7 = D1
18026782	9596A40	Ø15 g6	Ø11	37	8	17	
18026783	9596A50	Ø16 g6	Ø11,5	31,7	6	12	
18025774	9596A60	Ø20 g6	Ø13	31,7	6	12	
18026281	9596A61	Ø20 g6	Ø13	46,7	8	23	
18025775	9596A70	Ø25 g6	Ø18	48,7	9	24	

9.3 Accessories (optional)

- | | |
|--|-----------------------|
| <ul style="list-style-type: none"> Plug-mains, 90 - 264 VAC/24 VDC, ready for connection, max. 90 W (3.75 A), configurable country cable | Type
5781B5 |
| <ul style="list-style-type: none"> Connecting cable KIAG 10-32 pos. int. – BNC pos. Fluororubber connecting cable KIAG 10-32 pos. int. BNC pos. int. oil-tight | 1939A...
1983AD |
| <ul style="list-style-type: none"> Cleaning and insulation spray 250 ml Insulation testing device | 1003
5493 |

For additional connecting, extension and connection cables, see Data Sheet for Force, Torque and Expansion Sensors (1631C_000-346).

10. Annex

10.1 Glossary

Best straight line	see Annex 10.3.
Cable capacitance	The cable capacitance, and thus the length of the connecting cable, has no noteworthy influence on the measuring result when Kistler special cables and Kistler charge amplifiers are used.
Calibrated range	Measuring range or part of the measuring range for which the sensor has been calibrated. Note: Because of the high linearity of quartz crystal sensors, the sensitivity of a measuring range can usually also be used for smaller measuring ranges.
Calibration certificate	Document for sensors and devices stating the results of the factory calibration.
Charge amplifier	Part of a measuring chain which converts the charge signal from the sensor into a proportional voltage signal or current signal. Note: The linearity of charge amplifiers is typically within the range of $\pm 0,01$ % of the measuring range selected. For the accuracy of the measurement, this is usually negligible compared with other influence quantities.
Charge signal	Physical quantity which a piezoelectric sensor yields on its mechanical load.
Coulomb	Unit of electric charge. 1 coulomb corresponds to 1 Ampere-second (1 C = 1 As).
Crosstalk	Signal at the output of a sensor, produced by a measurand acting on the sensor, which is different from the measurand assigned to this output. For example, when a load in the F_y direction produces an F_z signal in a three-component sensor. In terms of electrical devices, it is a measure for the signal impact acting from a channel to the neighbouring ones.
Degree of protection	Protection of electrical equipment by suitable enclosures, covers etc. according to EN60529. The protection class is stated by IP (International Protection) followed by two digits. The first digit stands for protection against touching and the ingress of solid bodies, the second for the degree of protection against the ingress of water. Example: IP65 indicates a complete protection against touching, as well as against the ingress of dust and spray water from all directions.

Disturbance

Quantity that is not the measurand but that affects the result of the measurement. The contributions are expressed in terms of the measurand related to the acting quantity.

Examples:

- additional bending moment acts on a force sensor:
 $M_{x,y} \rightarrow F_z$
- additional axial force acts on a torque sensor:
 $F_z \rightarrow M_z$
- additional shear force acts on a force/torque sensor:
 $F_{x,y} \rightarrow F_z$ and $F_{x,y} \rightarrow M_z$

Drift

Unwanted changes in the output signal independent of the measurand as a function of time.

Frequency range

see Annex 10.4.

FSO

Full Scale Output. Range of measurement signal of a sensor, corresponding to the full scale of the measurand. It is the algebraic difference of the upper and lower limit of the measurement signal range.

Example: A pressure sensor having the measuring range from 0 bar to 2 bar and the corresponding range of measurement signal from -5 ... +5 V presents the FSO: 10 V. An electrical monitoring system having an input range from 0 ... 10 V and the corresponding output range from 4 ... 20 mA shows the FSO: 16 mA

Ground insulation

High electrical resistance of a sensor between signal line and ground, or of a charge amplifier between connector screen and ground.

Hysteresis

see Annex 10.3.

Insulation resistance

Electric resistance of a sensor, cable or the input of a charge amplifier measured between the signal line and the connection ground (sensor body), while the test voltage is stated accordingly. The insulation resistance applies for piezoelectric sensor, strain gauge sensors and semi-conductor sensors

Linearity

see Annex 10.3.

Measurand

Physical quantity, state or characteristic which is measured, e.g. force, torque, pressure etc.

Measuring chain

Interconnection of several individual components to meet measuring requirements. Measuring chains usually consist of sensors and amplifiers in conjunction with data acquisition, display, evaluation and recording equipment (e.g. PC, printer).

Measuring range, charge amplifier

Charge, voltage or current range of the signal input. Entry in units of the measurand is also possible depending on the type of charge amplifier.

Measuring range, sensor	Range in which the quality of the measurement within the stated tolerances is guaranteed. This range must be regarded as a binding maximum range.
Natural frequency	Frequency of free (not forced) oscillations of the entire sensor. In practice the (usually lower) natural frequency of the entire mounting structure governs the frequency behaviour.
Operating temperature range	Range of ambient temperatures in which the sensor is to be operated. The temperature-dependent tolerances stated apply only within this range.
Output signal	see "Charge signal"
Overload	Maximum value of the measurand with which a sensor can be loaded without sustaining damage. This refers to a safety margin and is not an extended measuring range. The characteristics specified in the calibration certificate are no longer guaranteed in the event of an overload. Nevertheless, measurements made during an overload in most cases provide useful results
pC (picocoulomb)	1 picocoulomb = 10^{-12} coulomb. See "Coulomb".
piezoelectric	Characteristic of crystals (e.g. quartz) in which mechanical loading produces a proportional electrical charge
Pretension	Continuous force loading of a measuring element resulting from the application of tension sleeves or tension bolts so that an applied force (force or pressure sensors) is acting on the measuring element as well as on the tension element (force shunt).
Preload	Loading of a calibration object prior to the calibration cycles for realization of a well-defined load at the beginning and end of the calibration cycles.
Prestress	Repeated loading (1 ... 3 times) of a calibration object prior to the calibration cycles applied for eliminating stresses within the object and/or for ensuring a rigid force application.
quasistatic	Describes the ability of Kistler sensors and charge amplifiers to undertake short-term measurements or DC-similar measurements.
Range	see "Measuring range"
Scaling	Output voltage per unit of the measurand at the analogue or monitor output of a charge amplifier..
Sensitivity	Nominal value or calibrated value stated in the calibration certificate of the change in the response of a sensor divided

by the corresponding change in the value of the measurand.

Note: sensitivity of piezoresistive and strain gauge sensors is additionally dependent on the excitation current or voltage.

Sensor

System which produces a definite change in the output signal as a function of the change of the measurand acting on it.

Note: The term "Sensor" is equivalent to "Transducer"

Temperature influence

see Annex 10.5.

Threshold

Largest change in the measurand that produces a measurable change in the sensor output, while the change of the measurand takes place slowly and monotonically.

Note: In practice, the rule of thumb applies that the threshold is about two to three times as large as the typical noise signal of a charge amplifier. This value can, however, only be achieved in dynamic measurements, whereas with quasi-static measurements, drift and environmental influences are limiting factors

Time constant

The time constant describes the behaviour of a high-pass filter and represents the time after which the signal is reduced to $1/e$ of the 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

10.2 Measurement uncertainty

Systematic errors, accuracy

Accuracy is the extent of the conformity between a measured value and a true value of the measurand. In a piezoelectric measuring chain it is determined by many systematic errors, such as

- Sensor linearity
- Sensor hysteresis
- Crosstalk from other measurands
- Charge amplifier linearity
- Disturbance (forces, moments)
- Disturbance (environmental influences, like temperature)
- Duration of the measurement
- etc.

Experience with a measuring chain consisting of sensor, cable and charge amplifier shows that an accuracy in the range of 1 ... 2 % of the measuring range is achieved. This value does not include errors due to influences from external sources acting on the measuring chain, due to mechanical adaptation of the sensor and environmental influences. For the highest accuracy requirements, we recommend calibration of measuring ranges specific to the application.

Measurement uncertainty of charge amplifiers

When random and systematic errors together are quantified as variance, measurement uncertainty can be derived. With charge amplifiers, this mainly depends on type. The following typical values apply:

Laboratory charge amplifier	$\pm 0,2 \dots 0,5 \text{ \% FSO}$
Industrial charge amplifier	$\pm 1 \text{ \% FSO}$

Higher accuracy can be achieved with the following procedures:

- Calibration in the Kistler factory
- Calibration with charge amplifier Type 5395A
- Restriction of the temperature range

Random errors, precision, reproducibility

Precision or reproducibility is the extent of conformity between independent data measured under specified conditions.

Repeatability

Repeatability is understood as "serial precision" for example conformity between several measurements in sequence under largely unchanged conditions.

This requirement is found mainly in repetitive measurements in production processes, where good repeatability is usually sufficient for process monitoring. Accuracy primarily plays only a subordinate role, when measurements can be directly related to conforming/nonconforming parts.

For good repeatability, piezoelectric measuring technology offers the particular advantage that the charge can be discharged with <Reset> before every measurement, enabling the zero point to be re-determined. Errors due to zero drift caused by influences changing with time, such as the temperature, are thus basically excluded.

With Kistler piezoelectric measuring chains, a typical repeatability within 0,1 % FSO can be assumed.

10.3 Linearity

Sensor linearity

The quartz crystal produces an electric charge, which is exactly proportional to the load. However, certain unavoidable deviations occur due to the mechanical construction of the sensor. Linearity represents the maximum deviation between ideal and actual output signal characteristics in relation to the measurand in a specific measuring range. It is expressed in percentage of the particular measuring range limit and is defined according to ANSI/ISA-S37.1 as the closeness of the calibration curve to a "best straight line" passing through the zero point:

"Best Straight Line" – A line midway between the two parallel straight lines closest together and enclosing all Output vs. Measurand values on a Calibration Curve.

The best straight line can be determined as follows:

Best straight line – geometric definition

A line midway the two parallel straight lines closest together and enclosing all output versus measurand values on a calibration curve. In addition, it must pass through the zero point based on the assumption that zero measurand results in zero output signal.

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

Best straight line – mathematical definition

The minimization of maximum deviation is known as Chebyshev's approximation. The best straight line is determined as follows:

- x = measurand (reference)
- Q = sensor charge signal or output signal from the charge amplifier
- $Q(x)$ = calibration curve, rising and falling
- s = slope of the best straight lines
- Best straight line: $y_i = s x_i$ (with starting value for slope s)
- Form residues: $res_i = Q_i - y_i$
- $\Sigma_{res} = res_{max} + res_{min}$ sum min. + max. deviation
- Recursive minimization of $\Sigma_{res} = f(s)$ by changing s until $\Sigma_{res} = 0$
- Linearity $a = res_{max} = |res_{min}|$

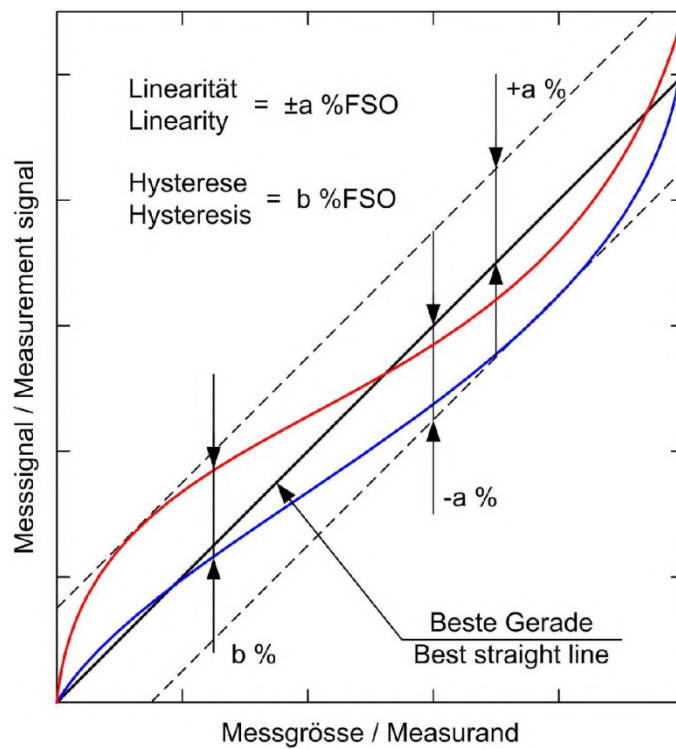


Fig. 22: Best straight line, linearity and hysteresis

Hysteresis

The maximum difference in output, at any measurand value within the specified range, when the value is approached first increasing and then decreasing measurand (source: ANSI/ISA-S37.1).

Note: The quartz crystal itself has a scarcely measurable hysteresis. However, the mechanical construction of the sensor can result in slight hysteresis. If the hysteresis is above the specified values (in %FSO), then the sensor is faulty or has not been correctly installed.

Charge amplifier linearity

The linearity of charge amplifiers is typically within the range of $\pm 0,05$ % of the measuring range selected. For the accuracy of the measurement, this is usually negligible compared with other influences.

10.4 Frequency range

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.

Key: f = Measuring frequency
 f_n = Natural frequency
 A/A_0 = Amplitude ratio

The following approximate values apply to the amplitude error or achievable accuracy as a function of frequency:

Accuracy 10 % $\rightarrow f_{\max} \approx 0,3 \cdot \text{natural frequency}$
 5 % $\rightarrow f_{\max} \approx 0,2 \cdot \text{natural frequency}$
 1 % $\rightarrow f_{\max} \approx 0,1 \cdot \text{natural frequency}$

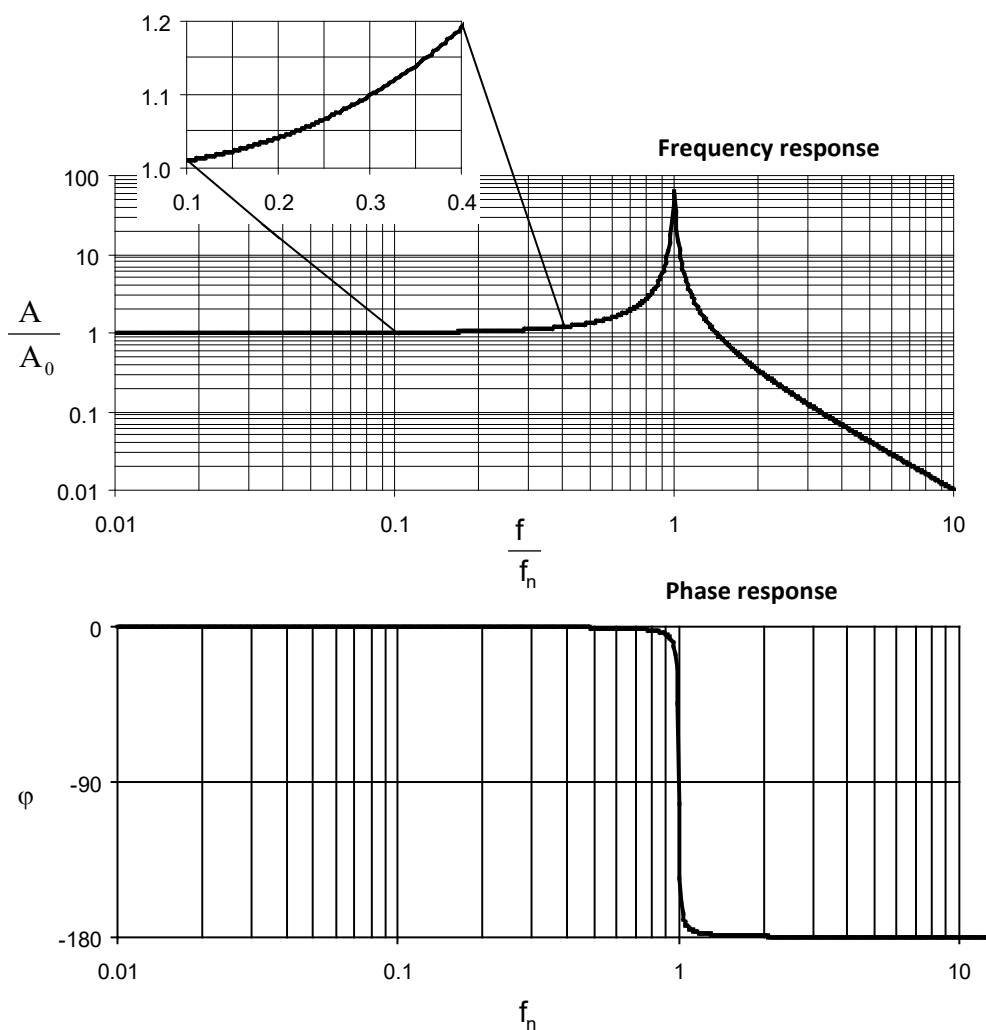


Fig. 23: Schematic representation of frequency response and phase response

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

The measuring arrangement is stimulated e.g. with an impulse hammer and the sensor output signals then subjected to a frequency analysis. The results is presented in terms of an amplitude and phase response curve

FEM

Finite Element Method: Finite Element Method (FEM) is a numerical procedure for the approximate solution of differential equations having boundary conditions. Using the FE-Method, various problems from physical areas can be calculated. A computing field obtains an arbitrary number of elements, however, being finite in size and number.

Note: In the finite element method, a homogeneous body is substituted for the sensor closely approximating to the dimensions and average density of the sensor. The average modulus of elasticity of this equivalent body is then continuously varied until its natural frequency coincides with that of the actual sensor (technical data). An equivalent body defined in this way is usually a good approximation of the sensor. The equivalent substitute body is inserted into the structure to be simulated, and by this means the natural frequency of the structure is calculated. Using this procedure, the FEM can be used to determine the frequency behaviour of a measuring arrangement with good approximation

10.5 Influence of temperature

Temperature changes during a measurement result in an error signal in the form of a zero drift. In critical applications, we recommend that protection be provided for the sensor as far as possible against changes in temperature.

Temperature error of the zero point (static error)

Temperature error [unit of the measurand/°C] is the greatest change to the output signal in a specified measuring range after a specific sensor temperature change, following which the sensor is again in thermal equilibrium with its environment. Temperature errors are

caused by changes in stress in the sensor, which in turn are influenced by the preload or installation conditions.

Temperature gradient error (dynamic error)

A temporary change in the output signal is denoted as temperature gradient error, when the temperature of the environment or surrounding medium changes with a certain rate. In this case, the sensor is not in thermal equilibrium with the environment.

The temperature gradient error is primarily determined by the installation conditions and the application, and cannot be generally specified. However, the temperature gradient error can be significant, particularly in the case of sensitive measurements and small measured values. It is therefore extremely important to keep the sensor temperature constant during the actual measuring time.

Immersion bath error 150 ... 200 °C

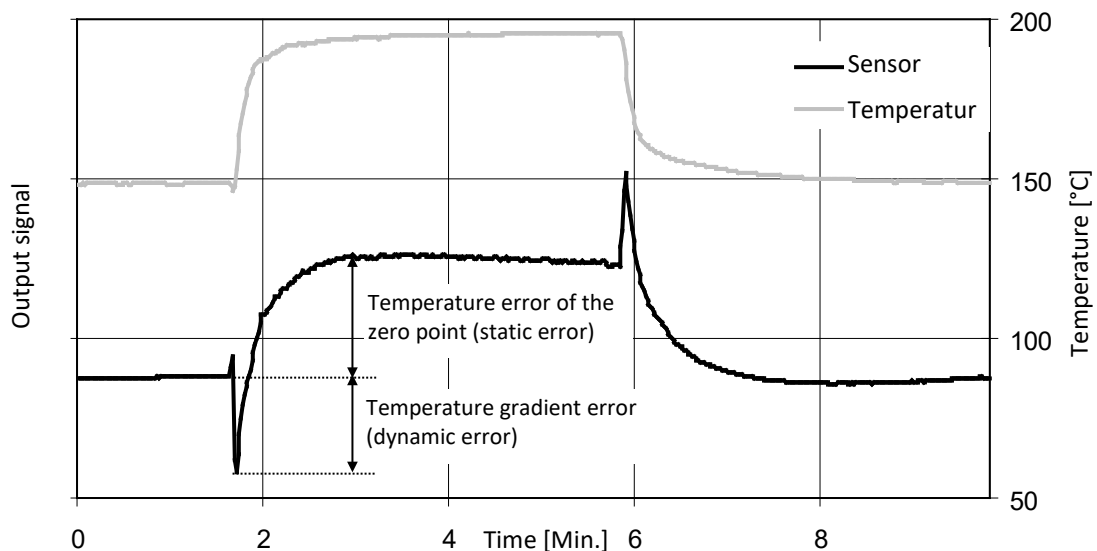


Fig. 24: Example of a temperature error of the output signal zero for a temperature rise from 150 °C to 200 °C (immersion bath).

Temperature coefficient of sensitivity

Change in the sensitivity, i.e. the slope of the best straight line, as a function of temperature. The temperature distribution in the sensor is assumed to be homogeneous, and in thermal equilibrium with the environment. The temperature coefficient of the sensitivity is typically only approx. 0,02 %/°C, and is thus mostly negligible compared with other influences.

10.6 Indexverzeichnis

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