Instruction Manual

Reaction Torque Sensors
Type 9329A, 9339A, 9349A, 9369A, 9389A

9329A_002-267e-02.09

measure. analyze. innovate.

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Foreword

We thank you for choosing a Kistler quality product distinguished by technical innovation, precision and long life.

Information in this document is subject to change without notice. Kistler reserves the right to change or improve its products and make changes in the content without obligation to notify any person or organization of such changes or improvements.

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Content

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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.

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 moment
- Piezoresistive pressure sensors and transmitters
- Signal conditioners, indicators and calibrators
- Electronic control and monitoring systems as well as application-specific software for measuring technology
- Data transmission modules (telemetry)

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

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 in this manual or on www.kistler.com, please contact your Kistler distributor who will also assist you for application specific questions.

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 these Operating Instructions.
- The reaction torque 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.

NOTE

Fix the reaction torque sensor in position as prescribed. Details can be found in Section 5.2 "Installing the reaction torque sensor".

NOTE

Secure all parts mounted on the reaction torque 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 9.3) before first use of the equipment. Report any missing parts to the authorized Kistler distributor.

2.3 Notes on using the Reaction Torque Sensor

- The reaction torque 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} Ω (but not less than 10^{13} Ω). 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 Reaction Torque 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 reaction torque sensor to a charge amplifier. Once fitted, it should if possible remain connected to the sensor. Use only specified connecting cables .
- We recommend you to protect the cable connector at the sensor against damage by screwing on the connector cover provided.
- Protect the reaction torque sensor when it is not in use by storing it in its original packaging.

2.4 Hints on using these Operating Instructions

We recommend you to read the entire operating instructions carefully. However, if you are in a hurry and already have experience with Kistler Reaction Torque Sensors, you can confine yourself to reading 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 operating instructions in a safe place where you can retrieve them at any time.

If you lose these operating instructions, please contact your Kistler distributor and ask them for an immediate replacement.

3. General Description

3.1 What is the Purpose of the Reaction Torque Sensor?

Reaction torque sensors are used to measure dynamic and quasistatic torques.

The main areas of application are:

Calibration
- Calibration of manual torque wrenches
- Torque setting of pneumatic screwdrivers

Research and Development
- Measurement of irregular motion and torsional vibrations on small servo and stepper motors
- Measurements of starting torques on electric motors
- Measurements on fluid and slipping clutches
- Viscosity measurements
- Measuring the coefficient of friction of bearings
- Designing torsion springs and damping elements
- Development of locks and rotary switches
- Lubricant development
- Biomechanics and ergonomic measurements

Production Engineering
- Monitoring automated screwing processes
- Monitoring boring and cutting processes

Quality Control
- Testing screw connections
- Torsion testing of springs
- Testing the torque characteristics of hinges
- Testing rotary switches
- Testing of screw caps

The hole pattern of the bilaterally integrated flange and the optional accessories enable Kistler reaction torque sensors to be adapted to almost any task. Bilateral centering seats and the included centering rings assist in the precise axial application of torque. A centric bore can be used for shaft bushing.

Kistler reaction torque 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 test arrangement. The high resolution enables the tiniest dynamic changes to be measured, even where large torques are involved.

Kistler reaction torque sensors are calibrated prior to delivery and can be used immediately.

3.2 Construction and Functional Principle of the Reaction Torque Sensor

The special, patented construction of Kistler reaction torque sensors is distinguished by the fact that the sensor is integrated under high axial preload between a preload screw and a nut. The torque is thus transferred by friction onto the shear-sensitive quartz disks. This sensor preload is the prerequisite for good output signal linearity, particularly for small torques.

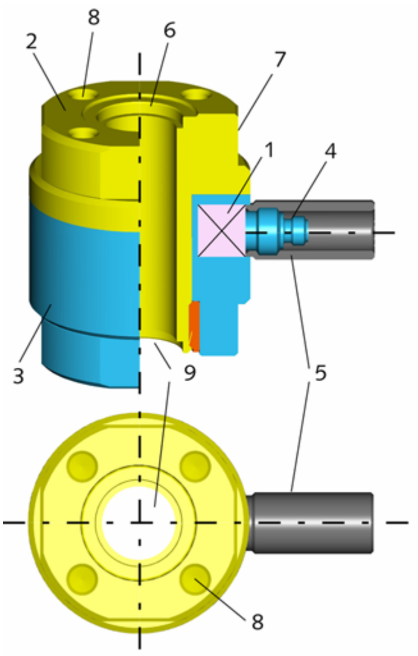


Fig. 1: Construction

The reaction torque sensor is seal welded and rust-resistant. With cable connected and O-ring correctly fitted in the cable connector, the plug connection is protected against the ingress of spray water. The cable connection is protected against mechanical damage by a screw-on connector cover.

Matching centering rings on the centering seats (6) are provided for precise coaxial application of torque.

1 Sensor
2 Preload screw
3 Nut
4 Plug connection
5 Screw-on connector cover
6 Inner centering seat
7 Outer centering seat
8 Mounting thread
9 Free passage

For dimensions see page 39.

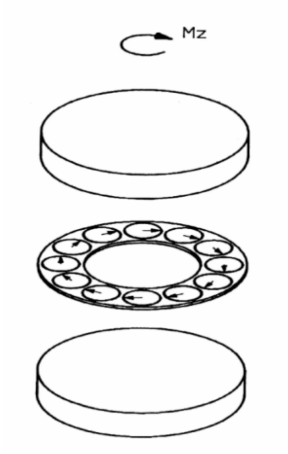


Fig. 2: Functional principle

The reaction torque sensor uses quartz disks in a circular arrangement. The shear-sensitive direction of the quartz disks is tangential, so that a charge signal proportional to the torque is fed out in a parallel circuit.

Clockwise torques produce a negative charge signal at the sensor, and a positive display value or voltage at the analog output of the charge amplifier.

As a result of the piezoelectric measuring principle and due to the high rigidity of the reaction torque sensor, the measurement is made with practically no displacement.

4. Examples of Applications

4.1 Calibration of a Stationary Torque Measuring Screwdriver

A pneumatic screwdriver with integrated torque sensor is calibrated with a reaction torque sensor.

Two Measuring Chains Consisting of

- Torque sensor Type 9039A (to be calibrated)
- Reaction torque sensor Type 9349A (Reference)
- 2 x charge amplifiers Type 5015A

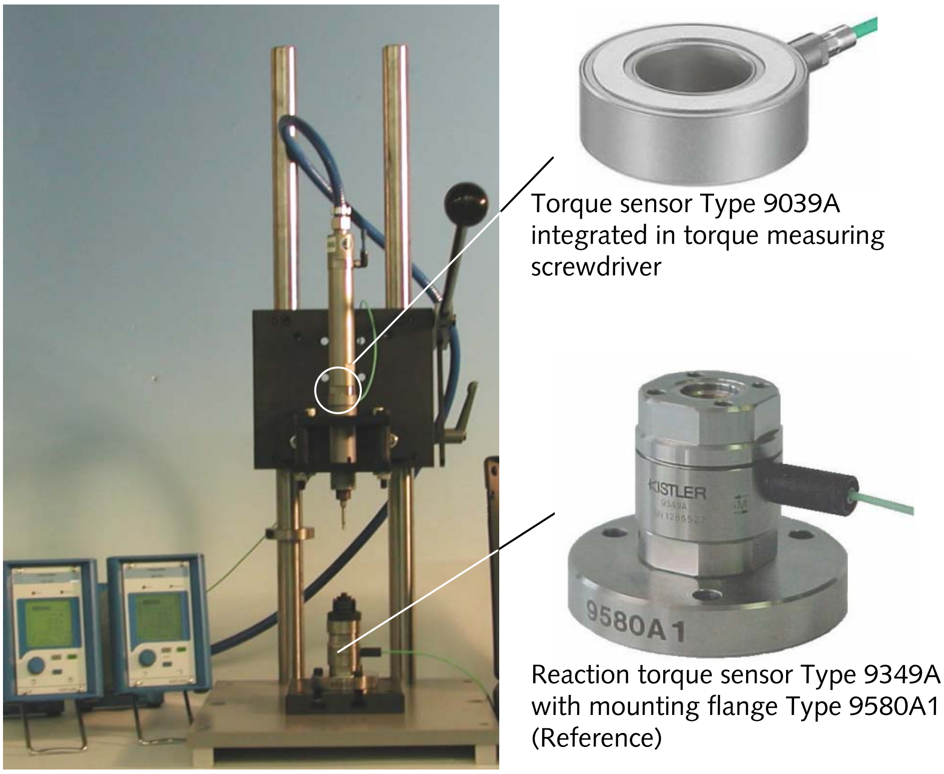


Fig. 3: Calibration of a torque measuring screwdriver

For this application, the reaction torque sensor is equipped with a screw plate with spring assembly, see Section 5.3.5. Various screwing arrangements can be represented with this structure, depending on the number and hardness of the cup springs.

4.2 Calibration of Torque Wrenches

Measuring Chain Consisting of

- Reaction torque sensor Types 9329A ... 9389A on mounting flange Types 9580A0 ... 9580A9
- Connecting cable Type 1631C…
- Charge amplifier Type 5015A

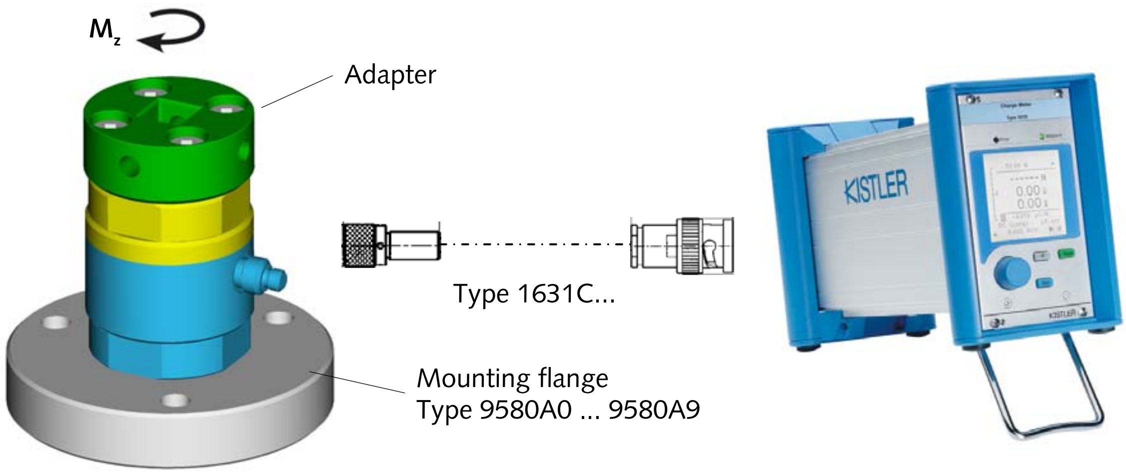


Fig. 4: Calibrating torque wrenches

4.3 Torque Testing of Potentiometers

Automated testing of the torque as a function of rotary angle of potentiometers at an automobile suppliers.

Measuring Chain Consisting of

- Reaction torque sensor Type 9339A
- ControlMonitor CoMo II-S Type 5859A…

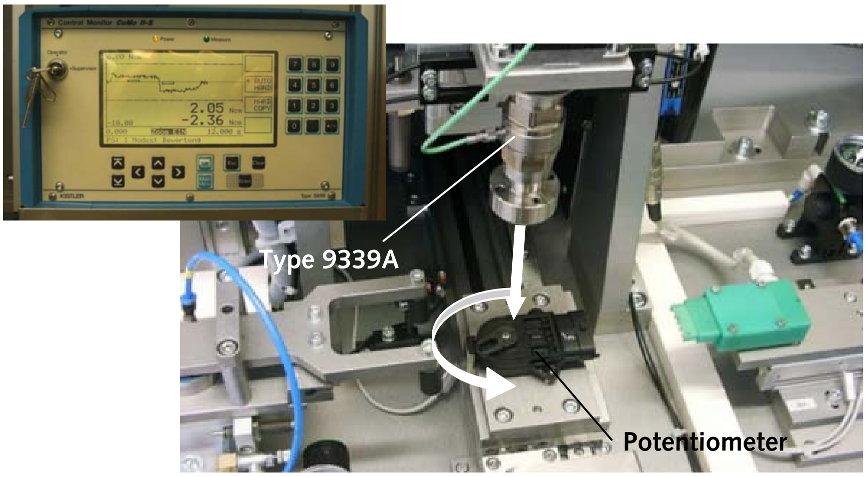


Fig. 5: Testing potentiometers

The ControlMonitor CoMo II-S is used for monitoring production processes, where there is a characteristic relationship between a measurand as a function of time y(t) or of a second measurand y(x) (displacement, rotary angle). A large number of functions such as thresholds, boxes, limit position or tolerance band is available for evaluation.

4.4 Torque Testing of Ignition Switches

Reaction torque sensor in a system for testing the torque characteristics of ignition switches over the entire rotary angle range.

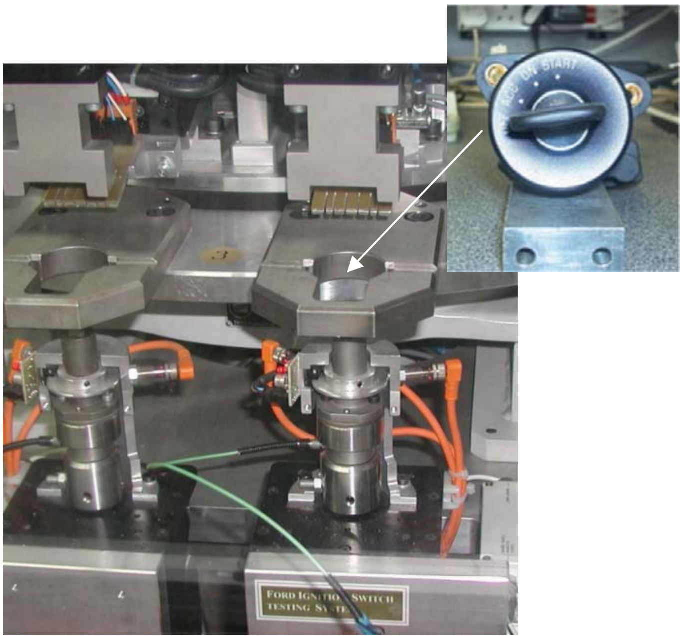


Fig. 6: Testing ignition switches

5. Installation and Startup

5.1 Important Notes

The reaction torque sensors Type 9329A … 9389A are precision instruments whose specifications can be fully utilized only when they are correctly used, and remain so only when handled carefully. Ensure that you comply with the following directions:

- Do not drop the reaction torque sensor and do not subject it to hard impacts! The peak force of this kind of shock can cause permanent damage.
- Do not use a hammer to position the workpieces, since hammer blows can also cause damage!

The following sections describe the installation of the reaction torque sensor and the setting up of the measuring chain.

5.2 Installing the Reaction Torque Sensor

Please comply with the following instructions for correct installation of the reaction torque sensor

- The reaction torque sensor must be installed only by persons who are familiar with this instrument and are adequately qualified for this work.
- When installation takes place in a shaft, the coaxial deviation must be not more than 0,02 mm. Deviations from coaxial straightness result in unwanted bending moments, which can overload and permanently damage the sensor. The contact surfaces of adapter flanges must be machined perfectly flat. If the reaction torque sensor is used as a calibration element, the adjoining surfaces must have a roughness of Ra ≤0,8 μm (N6), otherwise a roughness of Ra ≤6,3 μm (N9) will suffice. The contact surfaces must be thoroughly cleaned before installation.
- The reaction torque sensor is designed for measuring torques in the longitudinal axis. Although additional **bending moments, tensile**, **pressure and shear forces** can be absorbed to a certain extent by the reaction torque sensor, these must be **avoided as far as possible**.

The torque must be applied exclusively via the flange surfaces at the upper and lower sides of the reaction torque sensor. The torque is thereby transferred via socket head screws (minimum property class 12.9) or mounting parts with corresponding external threads. Select the length of the screws so that the depth of the threaded blind bore in the flange of the reaction torque sensor is utilized to the fullest extent possible. However, the screws must not come into contact with the base of the threaded blind bore.

Fig. 7: Reaction torque sensor with mounting flange

When firmly tightening the screw connections, the fork wrench must only be used to hold the flange on that side where the screw connections are being tightened! If the opposite side is held, there is a risk that the screw connection in the reaction torque sensor will loosen causing the latter to turn within itself. This will alter the internal preload resulting in the calibration being lost, and possibly rendering the reaction torque sensor unusable for precise torque measurement! In this event, the reaction torque sensor must again be properly preloaded and recalibrated!

Fig. 8: Installing reaction torque sensor

- Tightening torques M_A for cap screws
  Type 9329A M3x8 M_A = 1 N·m
  Type 9339A M4x10 M_A = 2 N·m
  Type 9349A M5x12 M_A = 4 N·m
  Type 9369A M8x20 M_A = 21 N·m
  Type 9389A M12x30 M_A = 100 N·m
  We advise using screws of at least property class 12.9.

The connecting cable must be connected only after installation of the reaction torque sensor has been completed. As contamination of the plug connections can result in considerable measuring inaccuracies (primarily drift), the plastic connector covers should remain screwed on during installation, both on the sensor and on the cable! Great care should be taken in particular in very dirty environments.

5.3 Overview of Installation Variants

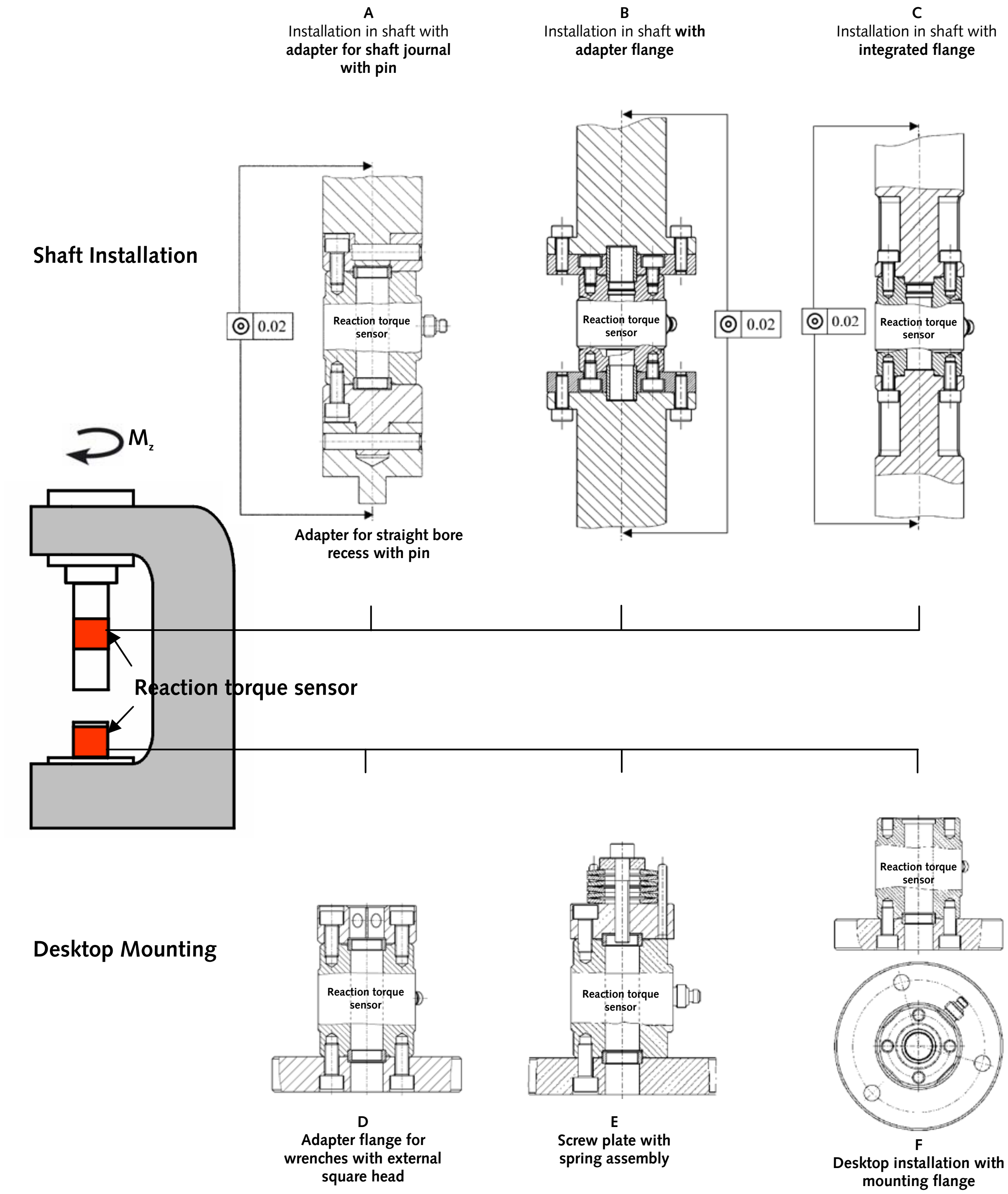


Fig. 9: Installation variants for reaction torque sensors

5.3.1 Adaptation A: Installation in Shaft with Adapter for Shaft Journal with Pin

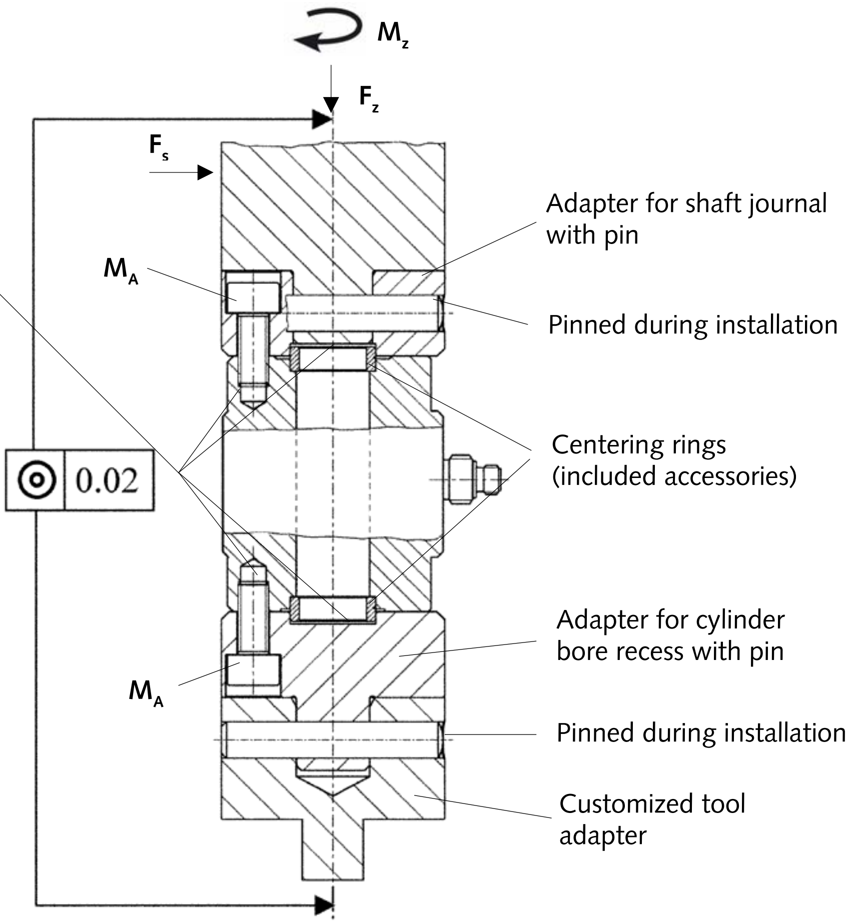


Fig. 10: Installation example A

M_z = Torque [N·m]
Applied via shaft with tool shank or cylinder bore and flange adapter with pin (pinned during installation).

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on Page 38.

- **Centering rings** (Art.-No. 3.420.196/179/180/181/197) press into the centering bores on the reaction torque sensor up to the mechanical limit stop.

- **Tightening torques M_A** for socket head screws

Type 9329A	M3x8	M_A = 1 N·m
Type 9339A	M4x10	M_A = 2 N·m
Type 9349A	M5x12	M_A = 4 N·m
Type 9369A	M8x20	M_A = 21 N·m
Type 9389A	M12x30	M_A = 100 N·m

  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the depth of the seating for the centering rings recess in the adapter must also have a clearance of at least approx. 0,5 mm.

5.3.2 Adaptation B: Installation in Shaft with Adapter Flange

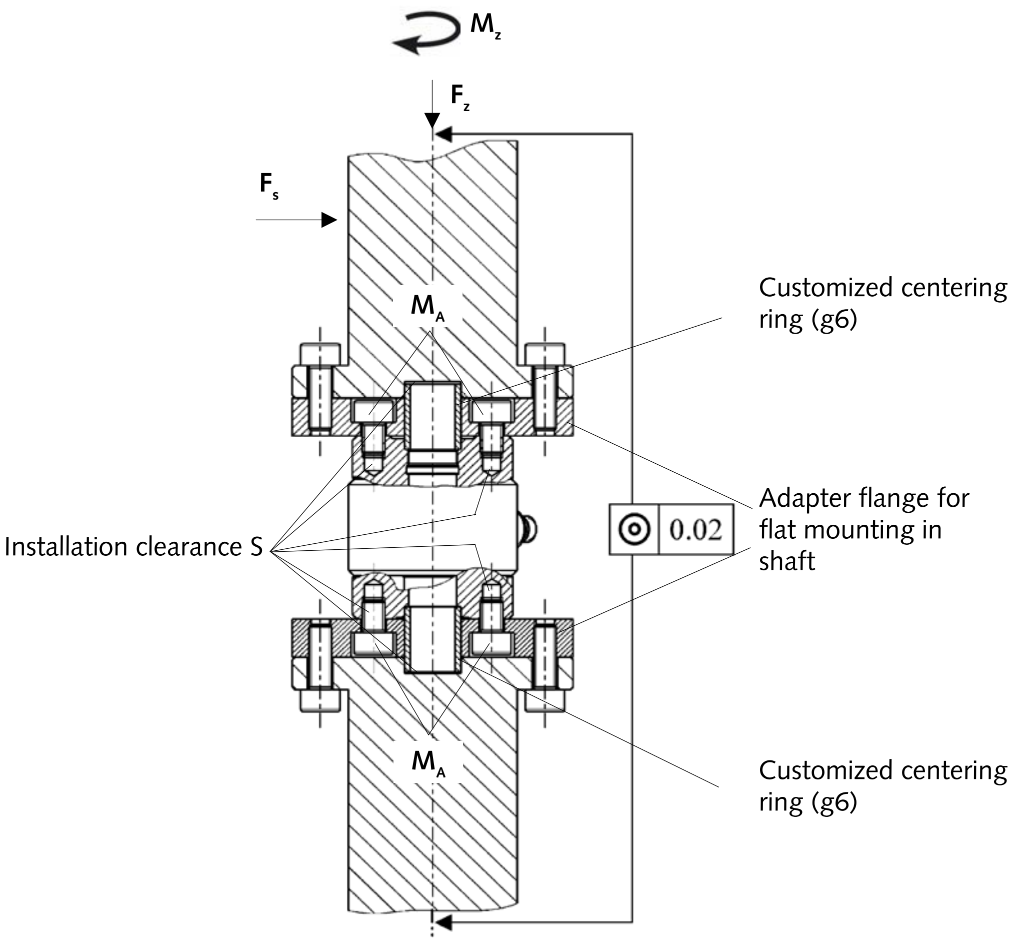


Fig. 11: Installation example B

M_z = Torque [N·m]
Applied via adapter flange for flat mounting in a shaft.

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on page 38.

- **Centering rings** (customized, fit g6) press into the centering bores on the reaction torque sensor up to the mechanical limit stop. Centering bore in shaft, fit H7.

- **Tightening torques M_A** for socket head screws

Type 9329A	M3x8	M_A = 1 N·m
Type 9339A	M4x10	M_A = 2 N·m
Type 9349A	M5x12	M_A = 4 N·m
Type 9369A	M8x20	M_A = 21 N·m
Type 9389A	M12x30	M_A = 100 N·m

  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the depth of the seating for the centering rings recess in the adapter must also have a clearance of at least approx. 0,5 mm.

5.3.3 Adaptation C: Installation in Shaft with Integrated Flange

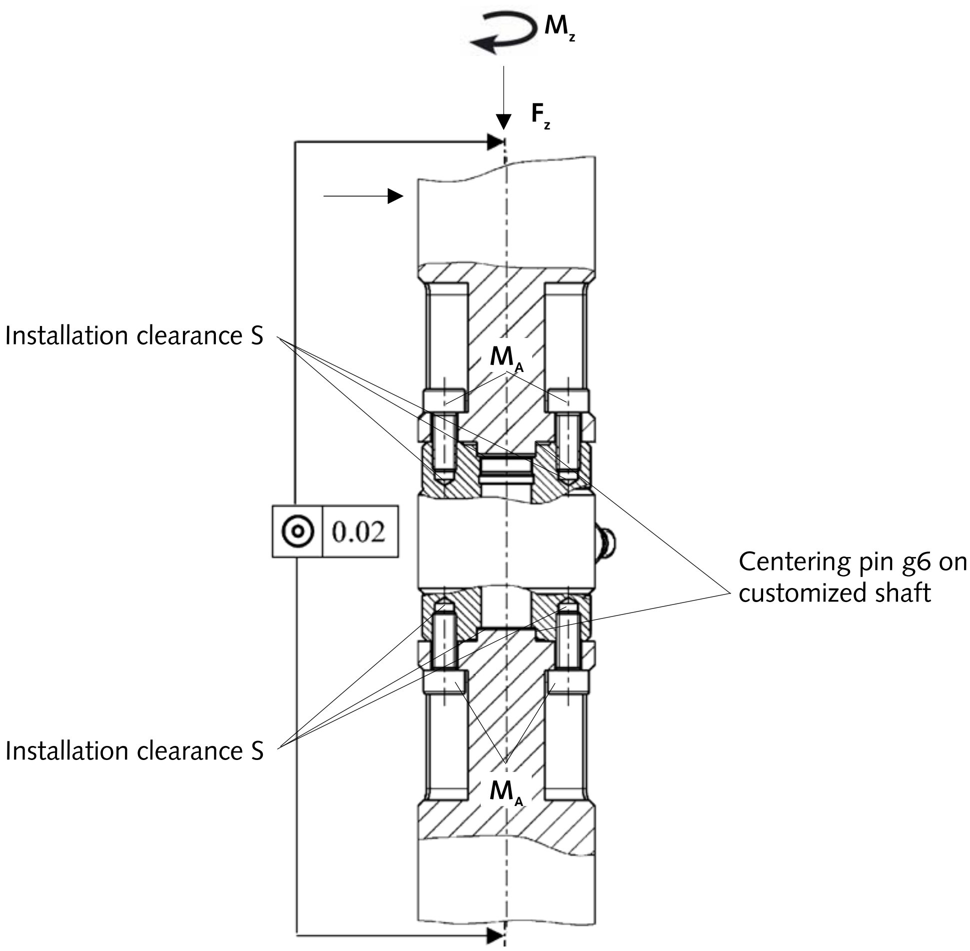


Fig. 12: Installation example C

M_z = Torque [N·m]
Applied via shaft with integrated flange and centering pin.

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on Page 38.

- **Tightening torques M_A** for socket head screws
  Type 9329A M3x8 M_A = 1 N·m
  Type 9339A M4x10 M_A = 2 N·m
  Type 9349A M5x12 M_A = 4 N·m
  Type 9369A M8x20 M_A = 21 N·m
  Type 9389A M12x30 M_A = 100 N·m
  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the length of the shaft pin (fit g6) must also be designed for a clearance of at least approx. 0,5 mm.

5.3.4 Adaptation D: Adapter Flange for Wrenches with External Square Head

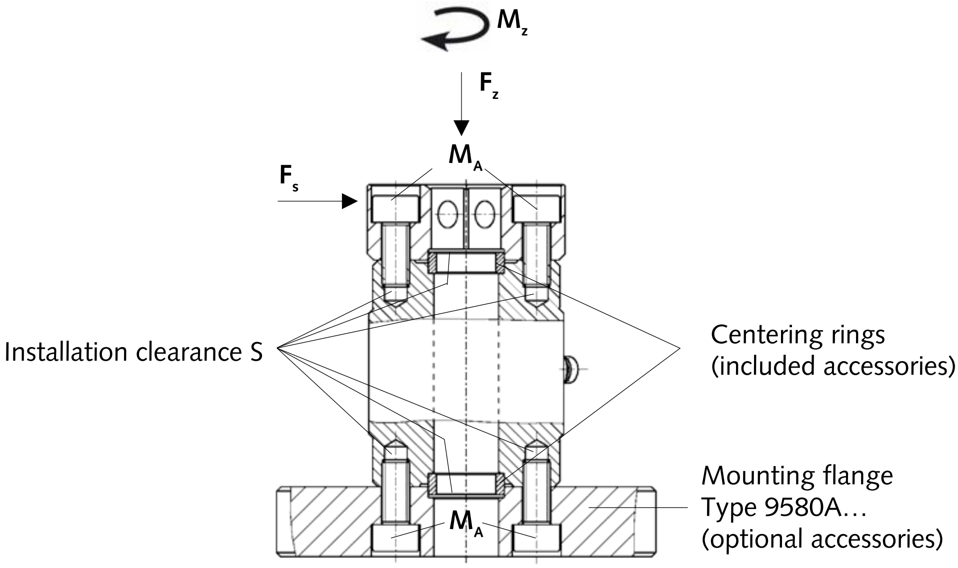


Fig. 13: Installation example D

M_z = Torque [N·m]
Applied via an internal square adapter for wrenches, e.g. for external square head DIN3120/3121

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on Page 38.

- **Centering rings** (Art.-No.3.420.196/179/180/181/197) press into the centering bores on the reaction torque sensor up to the mechanical limit stop.

- **Tightening torques M_A** for socket head screws

Type 9329A	M3x8	M_A = 1 N·m
Type 9339A	M4x10	M_A = 2 N·m
Type 9349A	M5x12	M_A = 4 N·m
Type 9369A	M8x20	M_A = 21 N·m
Type 9389A	M12x30	M_A = 100 N·m

  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the depth of the seating for the centering rings recess in the adapter must also be designed for a clearance of at least approx. 0,5 mm.

5.3.5 Adaptation E: Screw Plate with Spring Assembly

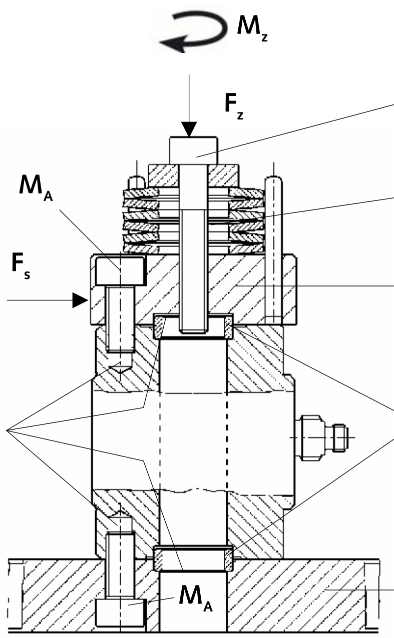


Fig. 14: Installation example E

M_z = Torque [N·m]
Applied via test screw onto spring assembly.

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on Page 38.

- **Centering rings** (Art.-No. 3.420.196/179/180/181/197) press into the centering bores on the reaction torque sensor up to the mechanical limit stop.

- **Tightening torques M_A** for socket head screws
  Type 9329A M3x8 M_A = 1 N·m
  Type 9339A M4x10 M_A = 2 N·m
  Type 9349A M5x12 M_A = 4 N·m
  Type 9369A M8x20 M_A = 21 N·m
  Type 9389A M12x30 M_A = 100 N·m
  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the depth of the seating for the centering rings recess in the adapter must also be designed for a clearance of at least approx. 0,5 mm.

5.3.6 Adaptation F: Desktop Installation with Mounting Flange

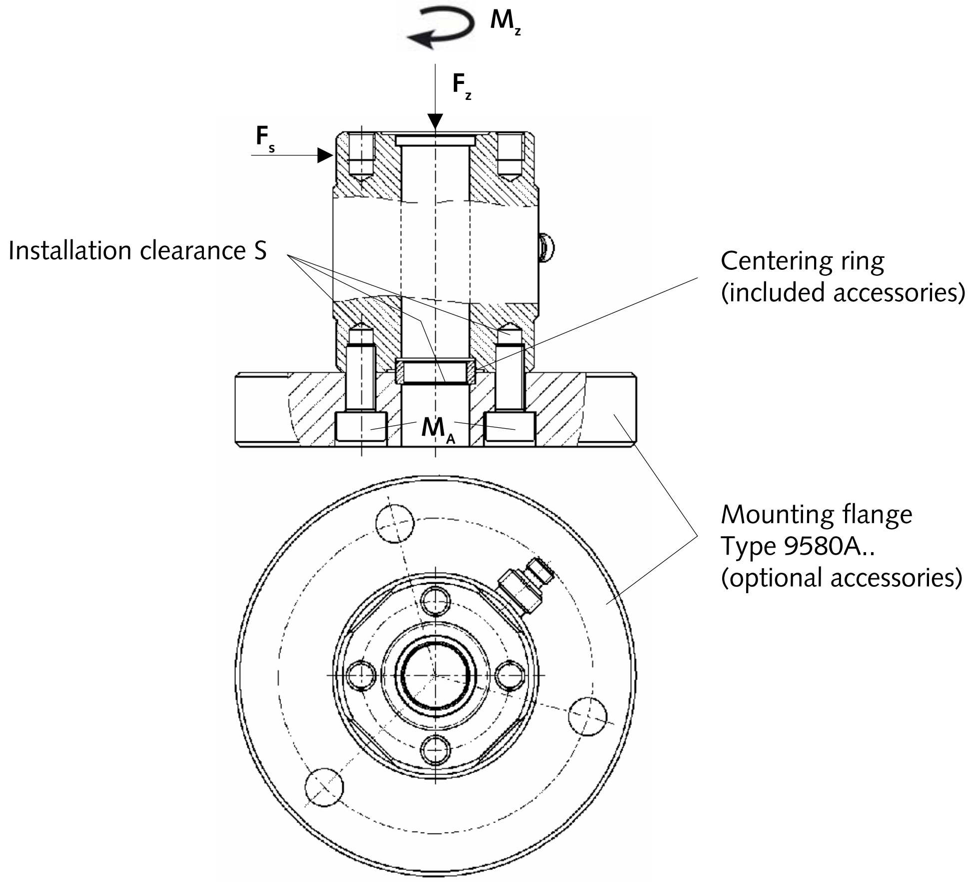


Fig. 15: Installation example F

M_z = Torque [N·m]
Applied via standard flange adaptation

F_z = Compression force [N]

F_s = Transverse force [N]
This "disturbance force" represents the shear forces and bending moments acting on the reaction torque sensor. The maximum permissible values are listed in the table in the "Technical data" on Page 38.

- **Centering rings** (Art.-No. 3.420.196/179/180/181/197) press into the centering bores on the reaction torque sensor up to the mechanical limit stop.

- **Tightening torques M_A** for socket head screws

Type 9329A	M3x8	M_A = 1 N·m
Type 9339A	M4x10	M_A = 2 N·m
Type 9349A	M5x12	M_A = 4 N·m
Type 9369A	M8x20	M_A = 21 N·m
Type 9389A	M12x30	M_A = 100 N·m

  We recommend using screws with at least property class 12.9, see also Section 5.2.

- **Clearance S** between the end of the mounting screw and the base of the threaded blind bore in the flange of the reaction torque sensor. The installation clearance should not be less than 0,5 mm or half a screw turn. Similarly, the depth of the seating for the centering rings recess in the adapter must also be designed for a clearance of at least approx. 0,5 mm.

5.4 Basic Circuitry and Connections for the Measuring Chain

When the applied torque changes, the reaction torque sensor produces an electric charge. The charge signal is converted into a proportional output voltage by the charge amplifier, which can then be measured and recorded by an electronic evaluation system.

Notes on the Measuring Chain Connections

Piezoelectric sensors must be connected to or disconnected from a charge amplifier only when the latter is in the <Reset> mode. The input stage of the charge amplifier may be damaged beyond repair by voltage spikes in the <Operate> or <Measure> mode!

- Only high-insulation coaxial cables with low capacitance may be used as connecting cables for piezoelectric sensors. They produce only very low frictional electricity as a result of movement. We advise you to use only connecting cables listed in data sheet 1631C_000-346.
- Prior to connection, we recommend to clean the two cable connectors with cleaning and insulation spray Type 1003 or white spirit. The connector is sealed at the reaction torque sensor with an O-ring. With some cables, this O-ring is included separately and must be fitted into the connector before making the connection. The contact surfaces for the O-ring must be clean.
- To protect the connector contacts against contamination, the connecting cable should remain permanently connected to the reaction torque sensor. Remove the connection covers only immediately before connecting the cable.
- Fit the connecting cable so that it can move freely as necessary, but cannot be sheared off or ripped out.
- Connecting cable vibrations can generate an electric charge and produce noise on the charge signal (triboelectric effect).
- A summation of the charge and the measurands can be obtained by connecting several sensors in parallel. Only one charge amplifier is required.
- Standard cables can be used to connect indicator or evaluation units to charge amplifiers.

6. Operation

6.1 Charge Amplifier Settings

For reaction torque sensors Type 9329A ... 9389A, we recommend that you use a charge amplifier with sensitivity adjustment (e.g. Type 5015A...). Please consult the relevant operating instructions for details concerning the settings for the charge amplifier.

Sensitivity
Set the sensitivity (pC/N·m) as specified in the calibration certificate for the reaction torque sensor. The display will then show the value directly in N·m.

Measuring Range
Set the desired measuring range (N·m). In addition, depending on the charge amplifier, the output voltage range (± V FSO) and scaling for the output voltage (N·m/V) can also be set.

Time Constant
The time constant describes the behavior of a high-pass filter (RC element) and represents the time after which the signal has fallen to 1/e of the output value. 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 quasistatic measurements. The time constant enables the measuring error in relation to the measuring time to be estimated. You will find detailed information on time constants and sensitivity ranges in the operating instructions for your charge amplifier.

6.2 Measuring Signal Polarity

Clockwise torques produce a negative charge signal at the sensor, and a positive indicated value or positive voltage at the analog output of the charge amplifier and vice versa.

6.3 Measuring Signal Resolution

Resolution is the smallest possible change to the measurand which can be measured by the system. It is determined by the signal/noise ratio at the signal output of the charge amplifier. For laboratory charge amplifiers, the resolution at the highest gain is typically.

$$\pm 0{,}01 \text{ pC}$$

Together with the sensitivity of the sensor (e.g. reaction torque sensor Type 9369A: –130 pC/N·m), the result for the resolution is:

$$\frac{0{,}01 \text{ pC}}{130 \text{ pC/N·m}} = 7{,}7 \cdot 10^{-5} \text{ N·m}$$

6.4 Quasistatic Measurements

Piezoelectric charge amplifiers have an inherent electric input current (drift current) of approximately

$$\pm 0{,}05 \text{ pC/s}$$

For this reason, purely static measurements over any length of time are not possible based on the piezoelectric measuring principle. The drift current is determined mainly by the insulation resistance of the measuring chain (typically 10^{13} Ω) and the time constant of the charge amplifier. Over time, the zero point and thus the output signal drift in a negative or positive direction. With an unloaded or constantly loaded sensor, this can be measured with the charge amplifier in the <Operate> or <Measure> position. Extensive drift indicates inadequate insulation resistance of the measuring chain. It is therefore important to keep the cable und connector clean and dry.

The length of time during which so-called quasistatic measurements can be carried out, is determined by the accuracy required. The drift in mechanical units can be estimated using the sensitivity value of the sensor (e.g. reaction torque sensor Type 9369A: –130 pC/N·m).

$$\frac{0{,}05 \text{ pC/s}}{130 \text{ pC/N·m}} = 3{,}8 \cdot 10^{-4} \text{ N·m/s}$$

A measurement of 10 minutes duration therefore results in a drift of:

$$3{,}8 \cdot 10^{-4}\ \text{N·m/s} \cdot 600\ \text{s} = 0{,}23\ \text{N·m}$$

This absolute error is viewed in relation to the measured value; for example, with 100 N·m torque it amounts to 0,23 %. If, on the other hand, you do not want to lose more than, for example, 2 % accuracy due to drift, the measurement must not last longer than:

$$\frac{2\ \text{N·m}}{3{,}8 \cdot 10^{-4}\ \text{N·m/s}} \cong 90\ \text{Min.}$$

Depending on the sensor sensitivity, the measured value and the required accuracy, measurements lasting from minutes to several hours are therefore possible.

6.5 Sensitive Measurement under High Basic Load

The piezoelectric method of measurement allows very sensitive measurements to be made of small changes in a high basic load. The following example describes how measurements can be made with the reaction torque sensor Type 9369A of torque changes ΔM_z in the order of magnitude of only 0,01 N·m, which are superimposed on a main torque M_z of approx. 100 N·m.

a Switch the charge amplifier to <Reset> and check that the sensitivity is set as specified in the sensor calibration certificate (e.g. approx. –130 pC/N·m for 9369A). For quasistatic measurements, select the time constant <DC (Long)>.

b Select a large measuring range (e.g. 200 N·m) or an insensitive scale for the output voltage (e.g. 20 N·m/V).

c Start the measurement with <Operate> and apply the (constant) torque M_z.

d After reading off and/or recording the torque M_z, switch the charge amplifier back to <Reset>, so that the charge corresponding to M_z is discharged.

e Now switch the charge amplifier to a more sensitive measuring range of 0,01 N·m for example, or scale the output voltage accordingly (e.g. 1 mN·m/V).

f Start the measurement with <Operate>. The fluctuations of M_z can now be measured with high resolution, since the dynamic threshold is ≈0,6 mN·m. This means that a ΔM_z of 0,6 mN·m will produce an output voltage of ≈600 mV (scaling 1 mN·m/V).

The resolution which can be achieved is thus
0,6 mN·m : 100 N·m → ≈1 : 160 000 !

g Switch the amplifier to <Reset>.

h Select an insensitive measuring range on the amplifier again (e.g. 200 N·m) or an insensitive scaling of the output voltage (e.g. 20 N·m/V) and switch the amplifier to <Operate>.

i If the sensor is now relieved of the basic torque M_z, a negative measured value will occur.

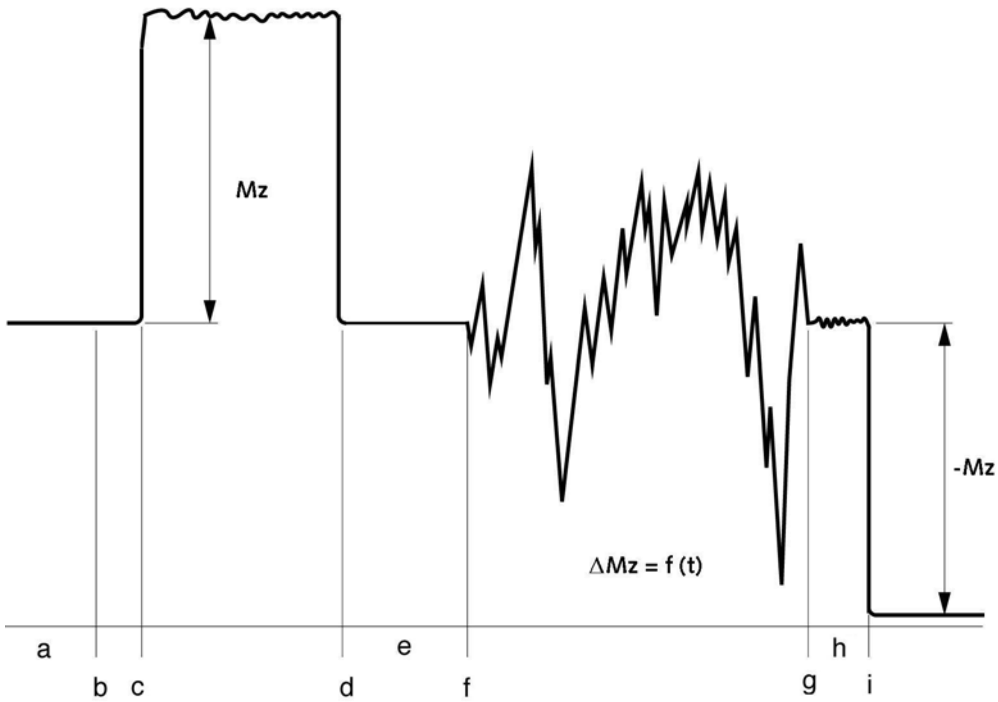


Fig. 16: Torque measurement with basic load

6.6 Hints for Obtaining good Measuring Results

- Always store the measuring instruments in the same room in which the measurements are made.
- Leave the connecting cable permanently connected to both the sensor and the charge amplifier. If this is not possible, fit the connector covers.
- Install the sensor exactly according to the instructions.
- Switch on the charge amplifier for about 1 hour before the first measurement.
- Set the sensor sensitivity as specified in the calibration certificate.
- Always work with the <DC (Long)> time constant when making torque measurements.
- Select the measuring range or scaling of the output voltage so that the maximum value measured is within the range 50 ... 100 %.
- For normal torque measurements, filter the input signal to 1/3 of the resonant frequency of the measuring arrangement.
- Only switch the charge amplifier to <Operate> immediately prior to the measurement.
- Avoid temperature changes during the measurement.

7. Maintenance

The reaction torque sensor Types 9329A … 9389A are reliable instruments requiring practically no maintenance. Please study the following two sections carefully to ensure long and reliable operation.

7.1 Recalibration

The reaction torque sensors are calibrated before delivery. Recalibration will be necessary, for example, after an uncontrolled overload.

Recalibration should be carried out in the factory of origin or in one of our sales centers, which can undertake calibration using in part the same or similar methods. For this purpose, contact your authorized Kistler distributor.

Quality management systems such as ISO 9001 require periodic recalibration of measuring instruments.

Kistler recommends recalibration every two years.

All calibrations and repairs carried out by Kistler are documented and preserved to guarantee traceability of the products at any time.

7.2 Maintenance Work

Please comply with the following instructions for maintenance of your reaction torque sensor

- Make sure to always check the reaction torque sensor before use for signs of damage. Do not use a damaged sensor!
- Have all repairs to defective sensors (e.g. replacement of damaged connectors) carried out in the factory. You will find the procedures to be followed in such cases in Section 8.2.
- The base and top surfaces of the reaction torque sensors are ground parallel and flat to within very close tolerances. These surfaces must not be re-machined! Visible scratches and notches can be leveled with a whetting stone.
- Clean the plug connection of the reaction torque sensor or connecting cable regularly with a very clean detergent, such as Kistler cleaning and insulation spray Type 1003 or white spirit.

8. Troubleshooting

8.1 Location of Faults and Remedies

Below is a list of frequently occurring problems with information on how to remedy them. If you cannot cure the fault, please contact your Kistler distributor.

Fault	Cause	Remedy
No measuring signal at the output of the charge amplifier	Signal line interrupted	Check the measuring arrangement (connections).
	Charge amplifier malfunction	Proceed according to the operating instructions for the charge amplifier.
	Reaction torque sensor malfunction	Repair in the factory. Proceed according to Section 8.2.
Quasistatic measurements not possible (large signal drift)	Poor insulation resistance of the measuring chain	Check the insulation resistance of the individual components with insulation tester Type 5493. Clean plug connections. Check charge amplifier according to operating instructions.
Charge amplifier goes into saturation during measurement	The torque to be measured is too large for the measuring range selected	Select a larger measuring range on the charge amplifier.

8.2 Repairing the Reaction Torque Sensor

If your reaction torque sensor malfunctions, comply with the directions below:

- Contact your authorized Kistler distributor and arrange the return of the faulty device.
- Send the faulty reaction torque sensor in its original packaging to the Kistler distributor.
- Include with the reaction torque sensor an accurate description of the fault and accompanying circumstances.
- Describe the measuring process during which the fault occurred.
- In the event of any necessary major repairs, you will receive a cost estimate.
- Kistler will attempt to repair your reaction torque sensor in the shortest possible time at minimal cost and return it to you in an as-new condition.
- The reaction torque sensor will be recalibrated in the factory after every repair.

9. Technical Data

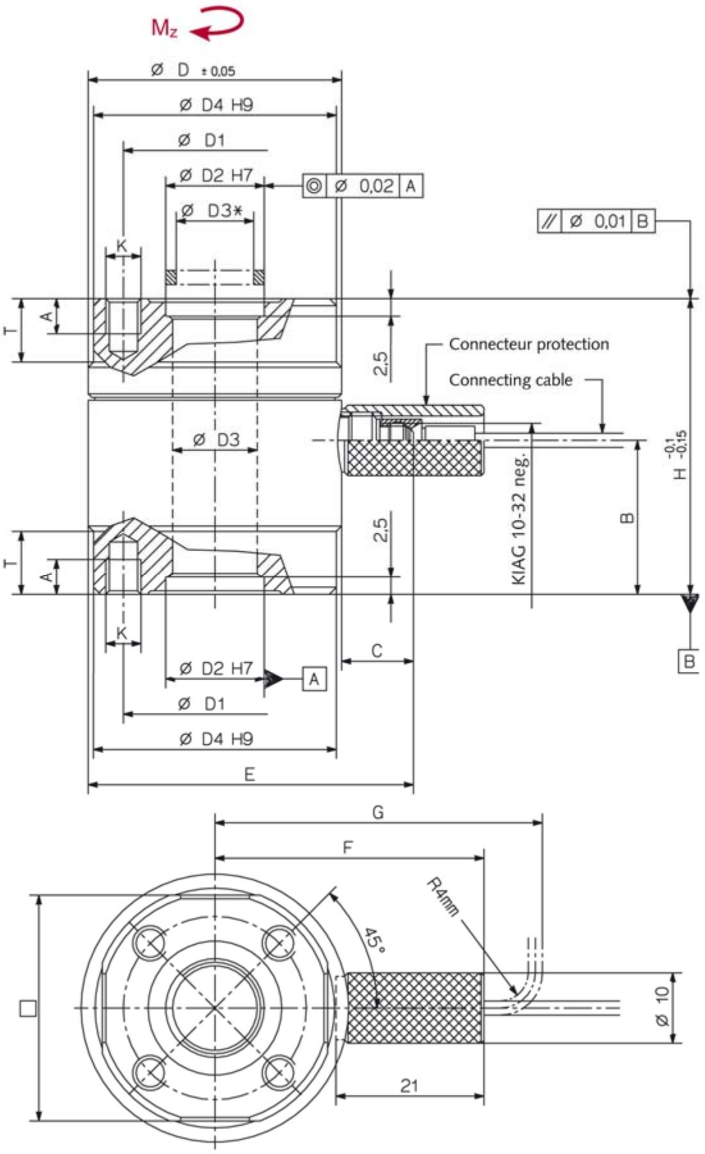
Please note that all technical data and information are subject to change at any time without prior notification.

9.1 Reaction Torque Sensors Type 9329A ... 9389A

Type			9329A	9339A	9349A	9369A	9389A
Measuring range	M_z	N·m	–1 ... 1	–10 ... 10	–25 ... 25	–200 ... 200	–1 000 ... 1 000
Overload	M_z	N·m	–1,2/1,2	–12/12	–30/30	–240/240	–1 200/1 200
Calibrated measuring ranges 100 %	M_z	N·m	–1 ... 1	–10 ... 10	–25 ... 25	–200 ... 200	–1 000 ... 1 000
10 %	M_z	N·m	–0,1 ... 0,1	–1 ... 1	–2,5 ... 2,5	–20 ... 20	–100 ... 100
Threshold	M_z	mN·m	<0,03	<0,18	<0,35	<0,62	<0,78
Sensitivity		pC/N·m	≈–2 170	≈–460	≈–230	≈–130	≈–100
Linearity, all measuring ranges		% FSO	≤±0,2	≤±0,2	≤±0,2	≤±0,2	≤±0,2
Hysteresis, all measuring ranges		% FSO	≤0,3	≤0,3	≤0,3	≤0,3	≤0,3
Tensile/compression force, max.	F_z	kN	–3/9	–5/14	–10/8	–10/10	–60/60
Crosstalk	$F_z \rightarrow M_z$	mN·m/N	≤±0,01	≤±0,05	≤±0,01	≤±0,02	≤±0,01
Side force, max.[1]	$F_{x,y}$ (M_z = 100 %; F_z = 0)	kN	0,47	0,38	0,44	0,27	3,66
Crosstalk (typical)	$F_{x,y} \rightarrow M_z$	mN·m/N	<0,5	<0,3	<0,3	<0,3	<0,2
Bending moment, max.	$M_{x,y}$ (M_z = 100 %; F_z = 0)	N·m	17,3	20	30	27	698
Crosstalk	$M_{x,y} \rightarrow M_z$	mN·m/N·m	<8	<8	<8	<12	<10
Rigidity	$c\varphi$	mN·m/µrad	≈17	≈96	≈189	≈924	≈1 540
Natural frequency (torsion)	f_n	kHz	>53	>36	>33	>23	>11
Operating temperature range		°C	–20 ... 80	–40 ... 120	–40 ... 120	–40 ... 120	–40 ... 120
Temperature coefficient of sensitivity		%/°C	0,02	–0,02	–0,02	–0,02	–0,02
Insulation resistance at 20 °C		Ω	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$
Capacitance		pF	≈73	≈43	≈340	≈350	≈910
Connection			KIAG 10-32 neg.				
Connector protection			no	yes	yes	yes	yes
Degree of protection (with cable connected)		EN60529	IP65				
Case material		DIN	1.4542				
Weight		g	50	137	243	800	6 720

[1] Application of force in plane of flange

9.2 Dimensions Reaction Torque Sensor Type 9329A ... 9389A



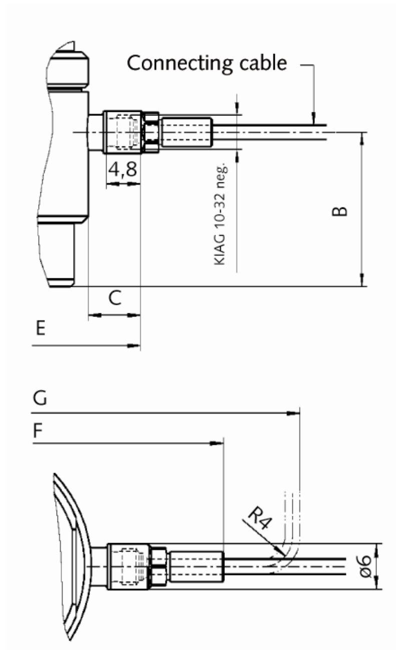


Fig. 17: Type 9329A

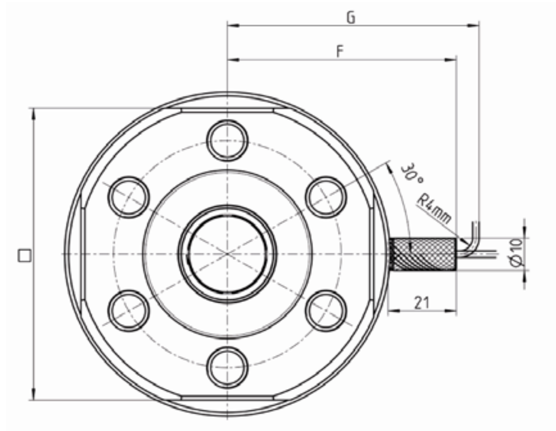


Fig. 18: Type 9339A ... 9389A with connector protection

Fig. 19: Type 9389A

Dimensions in mm

Type	D	D1	D2	D3	D3*	D4	H	A	B	C	□	E	F	G	K	T
9329A	20	14	6	4,4	4	19,5	26	3	13,2	7,4	17	27,4	–	36	M3	6
9339A	30	21	10	8,3	8	28,5	34	4	16,6	10,1	26	40,1	36	43,5	M4	8
9349A	36	26	14	11,7	11	34,5	42	5	21,7	10,2	32	46,2	39	46,5	M5	9
9369A	54	40	21	18,1	17	53	60	8	32,5	10,4	48	64,4	48	56	M8	13
9389A	100	70	30	24,5	23,5	98	130	14	69,2	10,4	90	110,4	70,4	80,5	M12	30

* Free access with mounted centering rings

9.3 Accessories Included

Ordering Key Scope of Delivery including Accessories	Type/Art. No.
Reaction Torque Sensor Type 9329A	
▪ 2 x centering ring	3.420.196
Reaction Torque Sensor Type 9339A	
▪ Connector protection	3.414.366
▪ 2 x centering ring	3.420.179
Reaction Torque Sensor Type 9349A	
▪ Connector protection	3.414.366
▪ 2 x centering ring	3.420.180
Reaction Torque Sensor Type 9369A	
▪ Connector protection	3.414.366
▪ 2 x centering ring	3.420.181
Reaction Torque Sensor Type 9389A	
▪ Connector protection	3.414.366
▪ 2 x centering ring	3.420.197

9.4 Optional Accessories

Fig. 20: Insulation tester

Ordering Key	**Type**
Connecting Cable KIAG 10-32 pos. – BNC pos.	
Length	
0,5 m	1631C
2 m	1631C2
5 m	1631C5
10 m	1631C10
20 m	1631C20
Extension Cable BNC neg. - BNC pos.	
Length	
2 m	1603B2
5 m	1603B5
10 m	1603B10
20 m	1603B20
50 m	1603B50

For further connecting and extension cables, see data sheet 1631C_000-346.

Cleaning and Insulation Spray 250 ml	1003
Insulation Tester	5493

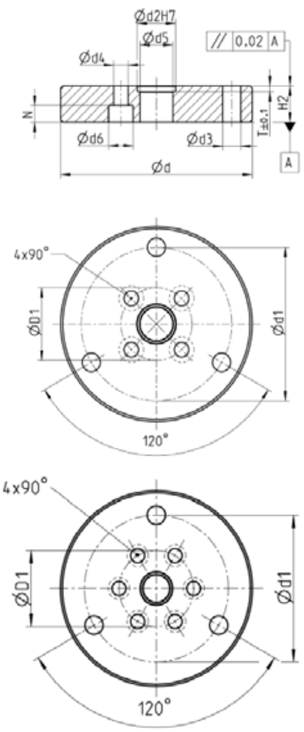


Fig. 21: Mounting flange

Mounting Flange

for Type	**Type**	D1	D	D1	D2	D3	D4	D5	D6	H	T	N
9329A	**9580A9**	14	40	30	6	4,5	3,2	4,5	5,6	8	2	3
9339A	**9580A0**	21	62	50	10	5,5	4,3	8,5	7,5	11	2	5
9349A	**9580A1**	26	70	55	14	6,6	5,3	12	9	13	2	7
9369A	**9580A2**	40	100	78	21	13,5	8,4	18	14	22	2	9
9389A	**9580A4**	70	180	135	30	17	13	25	20	30	2,5	13

10. Annex

10.1 Glossary

Best straight line
see Annex 10.3.

Cable capacitance
The capacitance, and thus the length of the connecting cable, has no influence on the measuring result when Kistler special cables and Kistler charge amplifiers are used.

Calibrated measuring range
Measuring range or part of the measuring range for which the sensor has been calibrated. 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 in the mounted condition is advisable in the case of unusual measuring arrangements and/or if the measurement must meet very high requirements for accuracy. For applications in shunt mode, calibration in the mounted condition is essential.

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.

Charge signal
Output signal in picocoulomb (pC) of a piezoelectric sensor without integrated charge amplifier.

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.

Degree of protection
Protection of electrical equipment by suitable enclosures, covers etc. according to EN60529. The degree of protection is stated by IP (International Protection) followed by two digits. The first digit stands for the level of protection against touching and the ingress of solid bodies, the second for the level of protection against the ingress of water. IP65 indicates, for example, complete protection against touching, as well as against the ingress of dust and spray water from all directions.

Disturbance Forces, moments and environmental influences acting on the sensor such as the temperature, which the sensor does not measure as a measurand and which produce an output signal (error). Example: when an additional bending moment acts on a force sensor.

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. Difference in output signal between the zero and end points of the measuring range

Ground insulation 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 Electrical resistance of a sensor, cable or the input of a charge amplifier, measured between signal line and connection ground.

Linearity see Annex 10.3.

Measurand Physical quantity, state or characteristic which is measured, e.g. force, torque 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 behavior, see also Annex 10.4.

Operating temperature Range of ambient temperatures in which the sensor is to be operated. The temperature-dependent tolerances stated apply only within this range. Higher temperatures can cause irreversible damage to the sensor.

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 quartz crystals in which mechanical loading produces a proportional electric charge.

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 analog or monitor output of a charge amplifier.

Sensitivity

Nominal value or calibrated value stated in the calibration certificate of the change in signal produced by the sensor per change in measurand.

Sensor

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

Temperature influence

see Annex 10.5.

Threshold

Smallest change in the measurand, which produces a measurable change in the sensor signal. 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 quasistatic measurements, drift and environmental influences are limiting factors.

Time constant

The time constant describes the behavior of a high-pass filter (RC element), and represents the time after which the signal has fallen to 1/e of the output value. 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 quasistatic measurements. 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.

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, e.g.

- Sensor linearity
- Sensor hysteresis
- Crosstalk from other measurands
- Charge amplifier linearity
- Disturbance (forces, moments)
- Disturbance (environmental influences, e.g. 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 influence quantities from external sources acting on the measuring chain, e.g. 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	±0,2 ... 0,5 % FSO
Industrial charge amplifier	±1 % 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", i.e. 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 influence quantities 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
Two parallel straight lines must be located which are as close as possible to one another and enclose the entire calibration curve. In addition, the center parallel must pass through the zero point (no force, no output signal). The slope of this center parallel 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 $a = res_{max} = |res_{min}|$

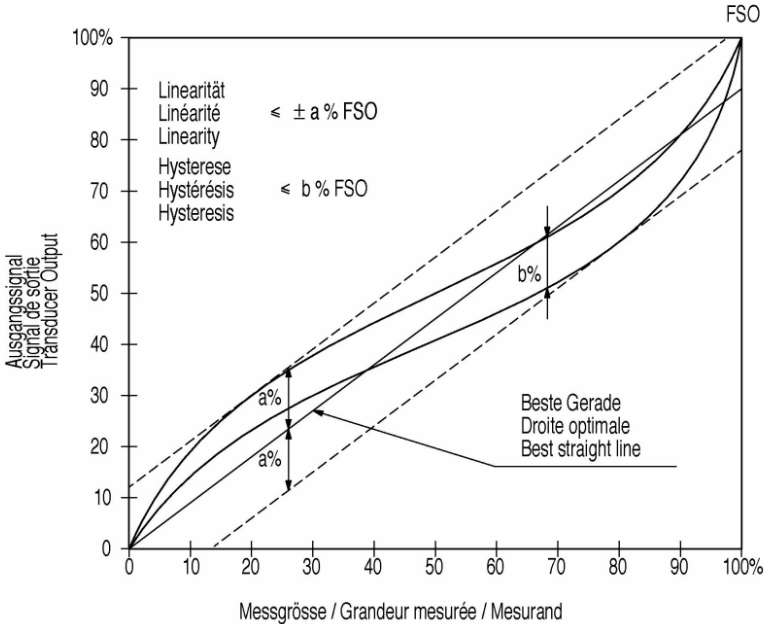


Fig. 22: Best straight line, linearity and hysteresis

Hysteresis
Quartz itself has a scarcely measurable hysteresis. However, the mechanical construction of the sensor can result in slight hysteresis, but this is below the specified value (% FSO) in every measuring range. If a greater hysteresis occurs, then the sensor has not been correctly installed.

Hysteresis (b%) is included in the linearity (±a %) and does not have to be additionally taken into account in estimating the measurement uncertainty.

Charge Amplifier Linearity
The linearity of charge amplifiers is typically within the range of ±0,05 % of the measuring range selected. For the accuracy of the measurement, this is usually negligible compared with other influence quantities.

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 %	→	f_{max}	≈	0,3 · natural frequency
	5 %	→	f_{max}	≈	0,2 · natural frequency
	1 %	→	f_{max}	≈	0,1 · natural frequency

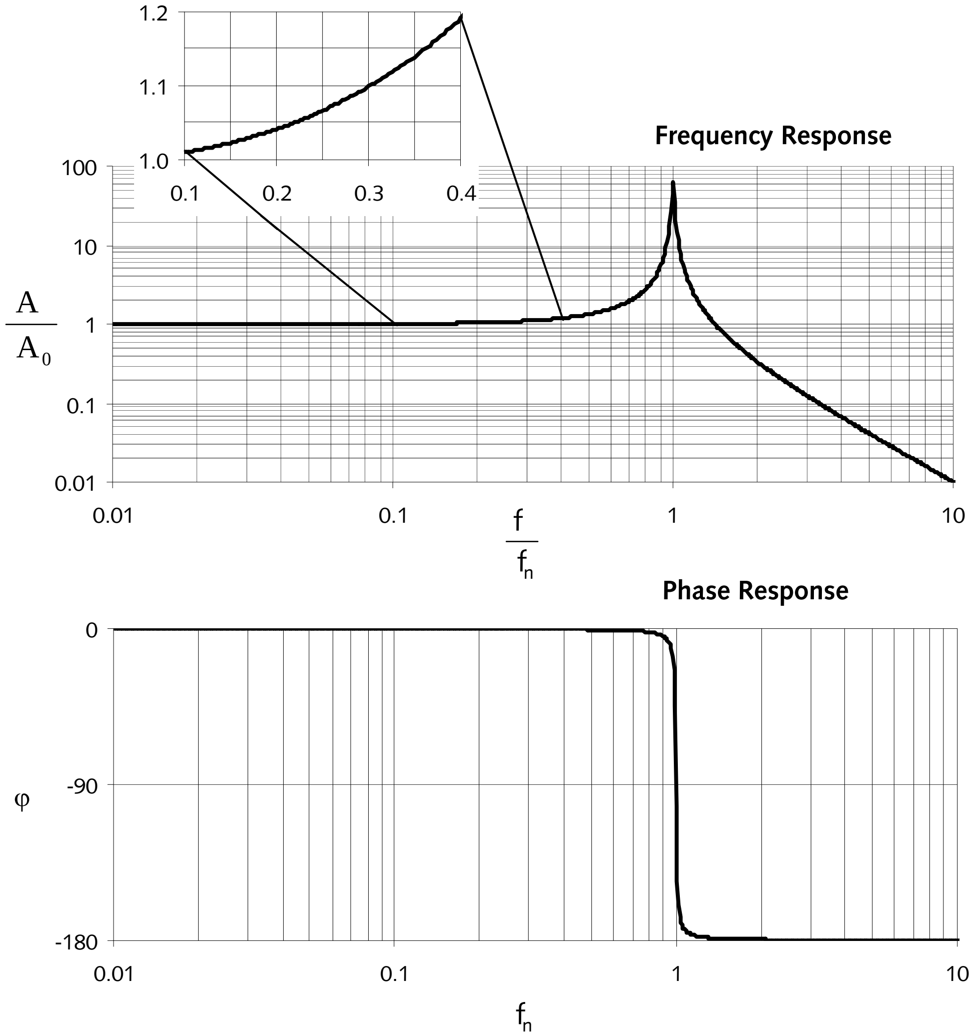


Fig. 23: Schematic representation of frequency response and phase response

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 with a pulse hammer and the sensor output signal then subjected to a frequency analysis.

FEM
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 behavior 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.

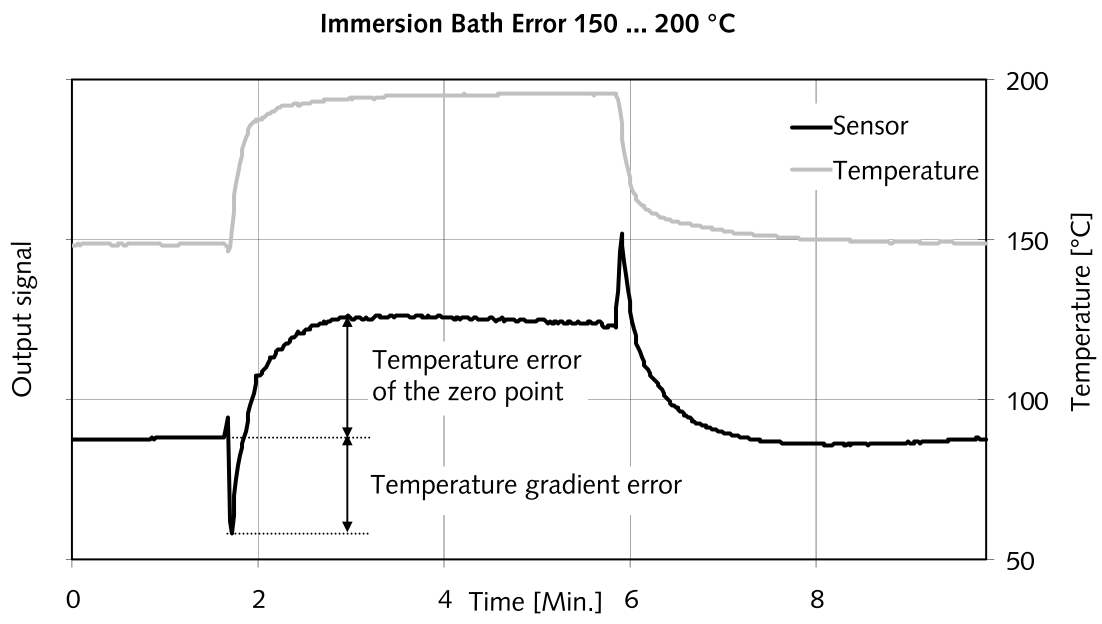


Fig. 24: Example of a temperature error of the output signal zero for a temperature rise from 150 °C to 200 °C (immersion bath).

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 influence quantities.

11. Index