NEW WITH 6 DoF

INCLINOMETERS

For static and dynamic applications

Kübler – Inclinometers

Precise and reliable – even under extreme conditions

The optimal solution for every application: Whether for static or dynamic measurement tasks, Kübler offers the right sensor technology for 1-axis and 2-axis inclination measurements as well as for rotation rate and acceleration measurements on all three axes.

Compared to alternative measuring systems, inclinometers offer more flexibility and degrees of freedom in system design, as they do not require a mechanical connection – for example, to a shaft or axis of rotation. This simplifies installation and significantly reduces potential sources of error.

A wide range of analog and digital interfaces – optionally configurable via IO-Link – enables easy integration into modern IIoT systems.

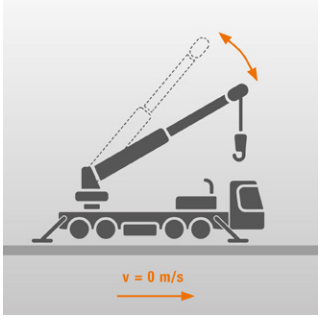
Inclinometers 6 DoF

A particular highlight are inclinometers for determining acceleration and rotation rate values for all 3 dimensions – 6 DoF (**D**egrees **o**f **F**reedom) – with the ability to determine the exact orientation of objects in space.

Further information
on inclinometers

Inclinometers for static applications / 1- and 2-axis

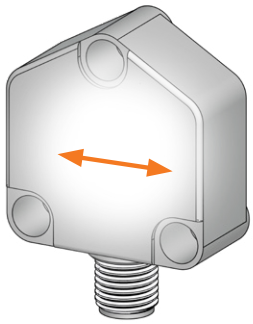
Static inclinometers measure the inclination of an object around one or two axes relative to gravity when the object is not moving or moving only slightly. The measurement is performed capacitively in acceleration measuring cells. Vibrations and shocks can be compensated for within certain limits by software filters, but this can lead to a time delay in the measurement result.
These sensors are ideal for stationary applications such as the alignment of scissor lifts, solar panels, or cranes.



Measuring principle

1-axis measurement 0 ... 360°

The sensor is mounted vertical to the earth's surface. When the sensor rotates, an integrated acceleration measuring cell detects the acceleration acting on a test mass due to gravity. This is directly related to the angle of inclination of the sensor.

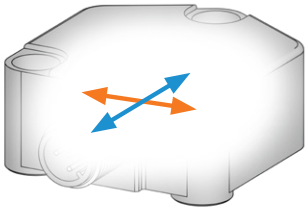


Measuring result

The result is an absolute angular position relative to the horizontal. Every change in position is recorded precisely – independently of external references or movements.

2-axis measurement ±85°

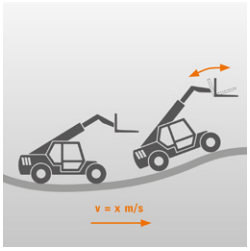
The sensor is mounted horizontally to the earth's surface. When the sensor rotates, two acceleration values are recorded, which are directly related to the tilt angles of the sensor in both axial directions.



The result is two absolute angular positions relative to the horizontal. Every change in position is detected precisely – independently of external references or movements.

Inclinometers for dynamic applications / 1- and 2-axis

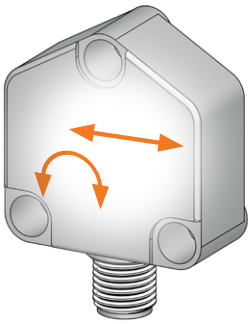
Dynamic inclinometers measure the inclination of an object around one or two axes relative to gravity – even during movement. As with static inclinometers, the inclination is determined using acceleration measuring cells. In addition, measurement data from rotation rate measuring cells (gyroscopes) is used to compensate for external interference. Intelligent sensor fusion of the acceleration and rotation rate information results in a particularly fast and precise measurement result – even in dynamic applications.
Typical areas of application are excavators, agricultural vehicles, and mobile cranes.



Measuring principle

1-axis measurement 0 ... 360°

The sensor is mounted vertical to the earth's surface. When the sensor rotates, an integrated acceleration measuring cell detects the acceleration acting on a test mass due to gravity. This is directly related to the angle of inclination of the sensor. At the same time, the relative rotation of the movement is determined by a rotation rate measuring cell (gyroscope).

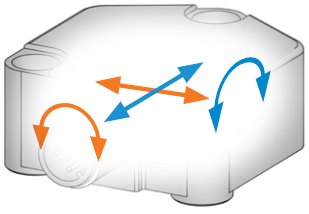


Measuring result

The intelligent combination of both measured values (sensor fusion) results in an absolute angular position relative to the horizontal – even under disruptive influences or during movement..

2-axis measurement ±85°

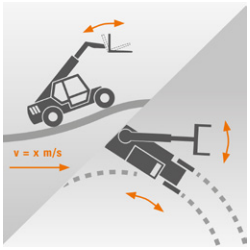
The sensor is mounted horizontally to the earth's surface. When the sensor rotates, two acceleration values are recorded, each of which is directly related to the angles of inclination of the two axes. At the same time, two rotation rate measuring cells record the relative rotational movements in the corresponding directions.



The intelligent combination of acceleration and rotation rate measurements (sensor fusion) provides an absolute angular position relative to the horizontal for each axis – even under disruptive influences or during dynamic movements.

Inclinometers for dynamic applications / 3-axis / 6 DoF

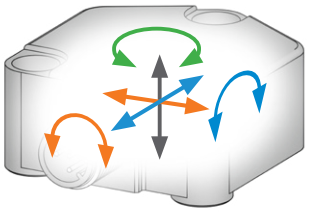
In dynamic inclinometers for 3-axis measurements, data is collected from three acceleration measurement cells and three rotation rate measurement cells – for the x, y, and z axes respectively (6 **D**egrees **o**f **F**reedom, 6 DoF). This allows the exact spatial orientation of an object to be determined – even under dynamic conditions. In addition to the calculated angle values, all six raw data sets can be output individually and processed further. In the context of condition monitoring, the data from the acceleration measurement cells in particular allow conclusions to be drawn about undesirable vibrations or mechanical influences.



Measuring principle

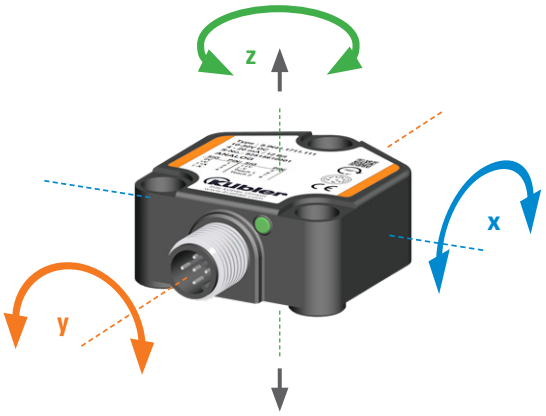
3-axis measurement, 6 DoF

The measurement is based on three acceleration measurement cells and three rotation rate measurement cells (gyroscopes), each of which records the movements and accelerations in the three spatial directions.



Measuring result

The results are the absolute angles of inclination of the sensor around the x and y axes (perpendicular to gravitational acceleration) and the relative angle of rotation around the z axis (parallel to gravitational acceleration).
In parallel with the calculated angle values, all six measurement data can be output individually and evaluated for various analysis purposes, for example in condition monitoring.



Product portfolio – Performance classes

Inclinometers **BASE-LINE**

- Maximum compactness
- Cost-effective solution
- Focus on sensor functionalities

- Ideal for applications with limited installation space
- Flexible adaptation to different applications thanks to optionally selectable and adjustable measuring ranges and filter functions
- Various analog and digital interfaces
- Protection level IP68/IP69k for use in demanding environments
- Accuracy up to ±0.15°
- Dimensions – 44.5 x 42.5 x 20 mm

Inclinometers **INDUSTRIAL-LINE**

- High flexibility in terms of interfaces / data output
- Wide range of parameterization options
- Variant with switching outputs

- Individual adjustment options for sensors with analog interface and switching outputs via IO-Link communication
- LED display for operating status and FDT/IODD communication as well as integrated spirit level function
- Various analog and digital interfaces
- Protection level IP68/IP69k for use in demanding environments
- Accuracy up to ±0.1°
- Dimensions – 71.6 x 62.6 x 20 mm

Inclinometers **PERFORMANCE-LINE**

- Robust design in metal housing
- High-performance 6 DoF technology
- Maximum accuracy

- The robust metal housing reliably protects the electronics from extreme mechanical influences
- Optimal integration into bus networks thanks to 2x M12 connector option
- Option for redundant measurement using stackable sensors
- Various analog and digital interfaces
- Accuracy up to ±0.1°
- Dimensions – 80 x 60 x 23 mm

For static applications **IN41, IN48**
1- and 2-axis measurement

For dynamic applications **IN51, IN58**
1- and 2-axis measurement

For dynamic applications **IN58.6DOF**
3-axis measurement (6 DoF)

Analog Output · CANopen · SAE J1939 · Modbus

For static applications **IN61, IN62, IN68**
1- and 2-axis measurement

For dynamic applications **IN71, IN72, IN78**
1- and 2-axis measurement

Analog Output · PNP NPN · IO-Link · CANopen

For static applications **IN81, IN88**
1- and 2-axis measurement

For dynamic applications **IN91, IN98**
1- and 2-axis measurement

For dynamic applications **IN98.6DOF**
3-axis measurement (6 DoF)

Analog Output · CANopen · SAE J1939 · Modbus

Our know-how directly in your application – integrable solutions

Sometimes small isn't small enough. In certain applications, the required sensor technology cannot be integrated as a separate component. In such cases, the sensor technology can be integrated directly without its own housing – either as a separate circuit board or as an integrated component on the application controller.

- Extremely space-saving
- Reduced installation effort
- Reduction in overall costs

Contact us – we will develop the right solution for your application.

Customized adaptations of existing sensors

Not every application can be covered by standard solutions. Our specific designs enable individual adaptation of the sensor technology—from housing shape and dimensions to interfaces, mounting variants, or special functional requirements. This results in tailor-made solutions that integrate perfectly into your application and offer maximum precision, reliability, and efficiency.

- Even better integration into the application
- Fully configured plug & play solution
- Reduction in overall costs

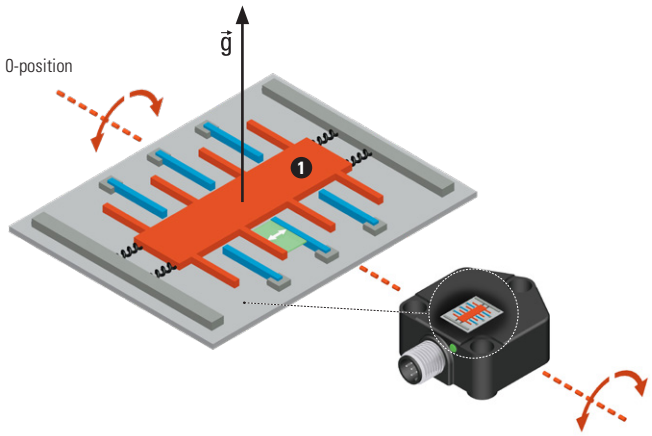
Functional principles of static/dynamic inclinometers

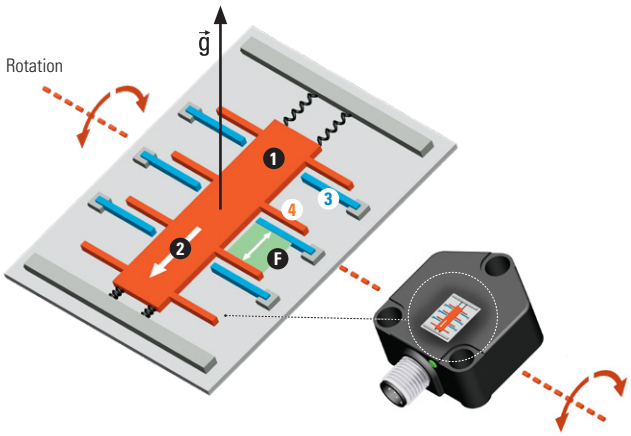
Precise angular position via acceleration measurement in static inclinometers

Acceleration measurement

In the acceleration measuring cell, the absolute angular position is determined capacitively in relation to the gravity acceleration $\vec{g}$.

The displacement ❷ of a test mass ❶ changes the distance and therefore also the capacity Ⓕ between fixed ③ and moving ④ electrodes in the measuring cell. This measured capacity is directly related to the inclination of the sensor.





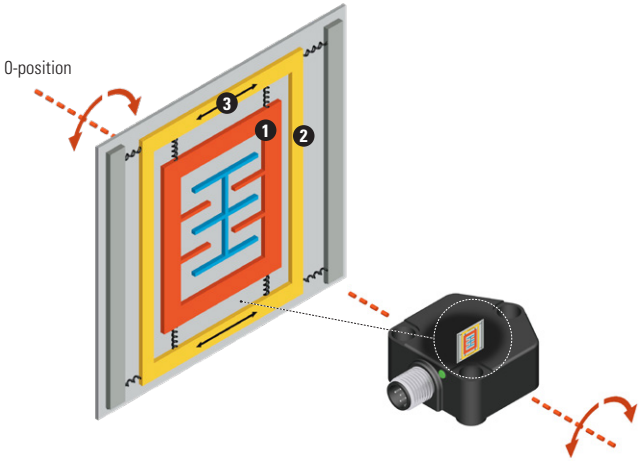
Intelligent sensor fusion of acceleration and rotation rate measurement for dynamic applications

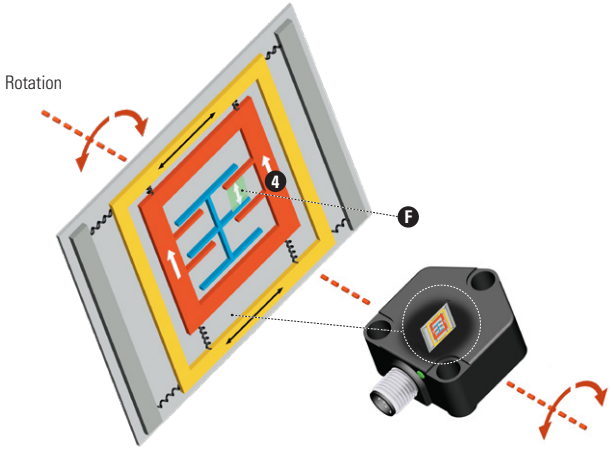
In addition to the acceleration measuring cell, a rotation rate measuring cell is used in the inclinometers for dynamic applications. This results in even faster and more accurate output results.

Rotation rate measurement

In the rotation rate measuring cell (gyroscope), the Coriolis force resulting from a rotation is evaluated in order to determine the angle of rotation in relation to the starting position. An arrangement of frame ❷ and test mass ❶ is in a permanent linear movement ❸ (oscillating). If this system is brought into rotation, this results in a force (Coriolis force) ❹ that leads to a displacement of the test mass.

This displacement is also determined by the change in capacity Ⓕ between fixed and moving electrodes and is directly related to the rotational speed (rotation rate).
The angle of rotation is determined from the speed of rotation and the duration of rotation.



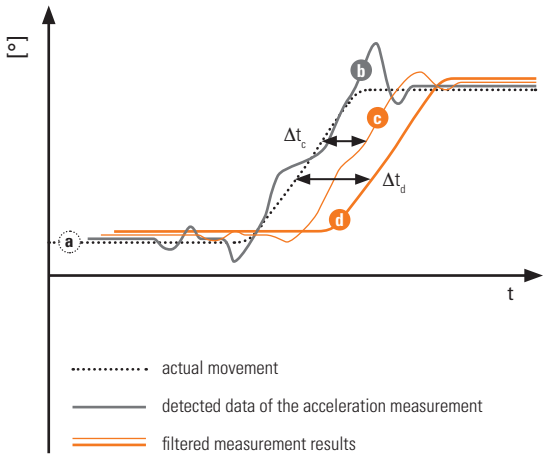


Optimization of measurement in the acceleration measuring cell through filter functions

Optimization of the measurement using filter functions
The inertia of the test mass, particularly in the case of fast or rapidly changing rotations and vibrations, can lead to inaccuracies in the detected measurement data ⓑ compared to the actual movement ⓐ.
To compensate for these undesirable effects, various filters ⓒ + ⓓ can be parameterized in the inclinometer.

Restrictions due to filters
However, this leads to a time delay ($\Delta t_c + \Delta t_d$) for the output of the measurement result (the more precise the desired measurement, the greater the time delay).

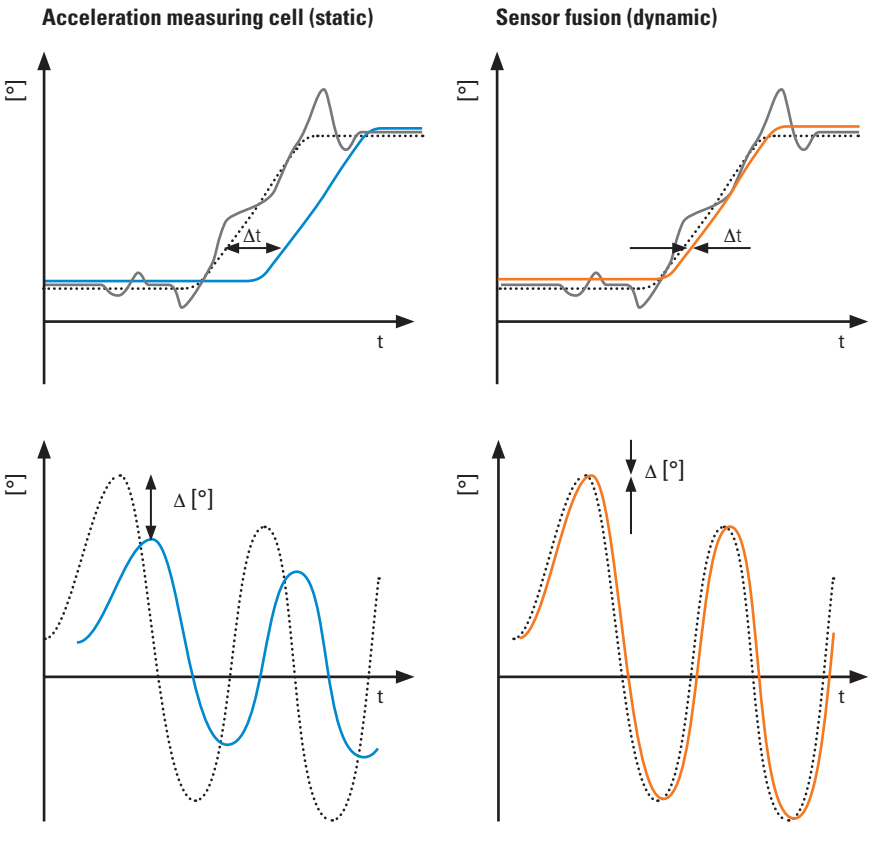
Further optimization through dynamic inclinometers
This time delay is not relevant for many static applications (such as solar panels, crane masts, etc.). In dynamic applications (e.g. vehicles in motion), however, this can lead to problems, as a reaction to the movement can only occur with a delay.
In this case we recommend using a dynamic inclination sensor with intelligent sensor fusion from Kübler to further optimize the measurement result.



Comparison static inclinometer (accelerometer only) - dynamic inclinometer (sensor fusion)

Fast measurement
Inaccuracies due to the inertia of the test mass can be compensated for in acceleration measurement via filters. However, there is a time delay Δt for the output of the measurement result. This time delay is minimized with sensor fusion.

Accurate measurement
The sensor fusion leads to more accurate measurement results when changing direction quickly.



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