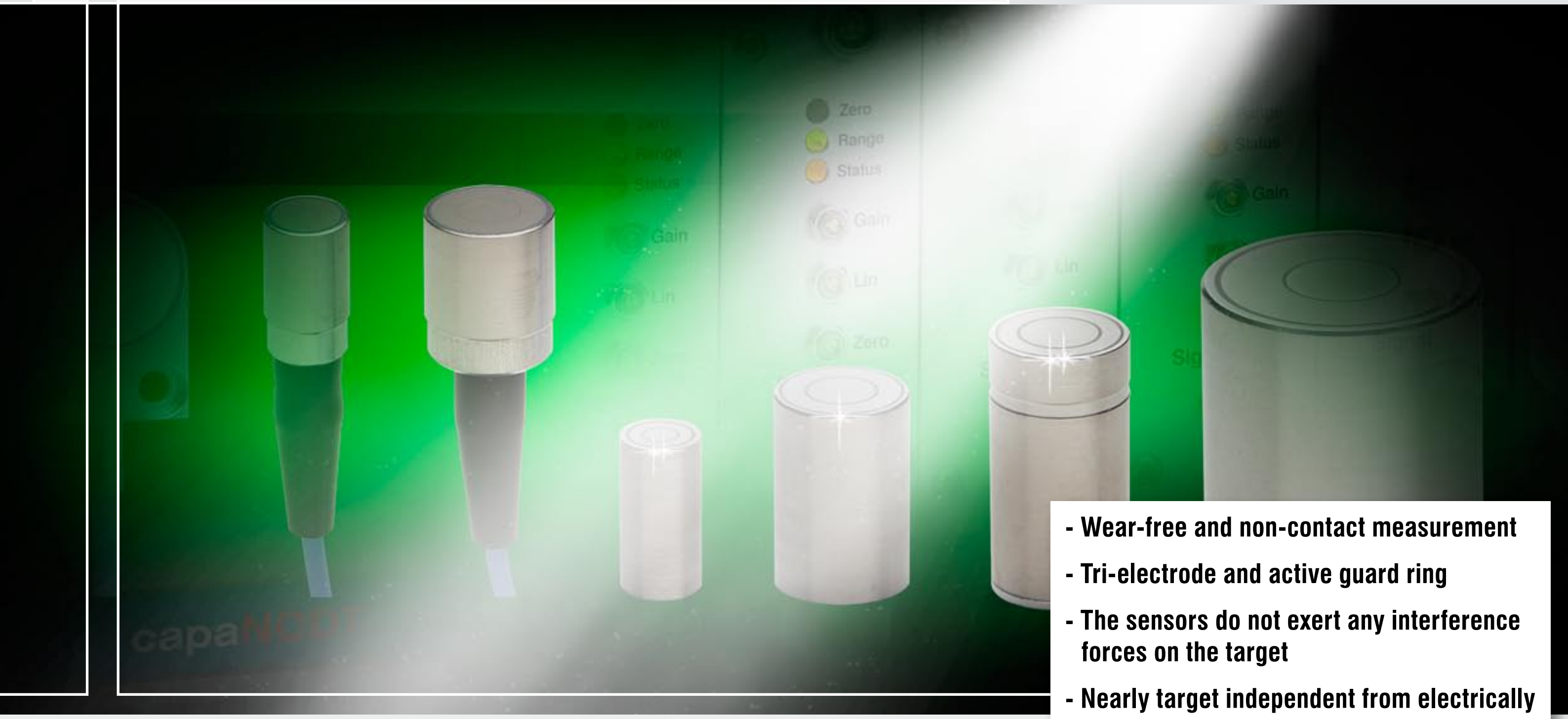
MICRO-EPSILON

More Precision.

capaNCDT

High resolution capacitive displacement sensors and systems.



- **Wear-free and non-contact measurement**
- **Tri-electrode and active guard ring**
- **The sensors do not exert any interference forces on the target**
- **Nearly target independent from electrically conductive measurement objects**

Measuring principle

The principle of capacitive displacement measurement using the capaNCDT (capacitive Non-Contact Displacement Transducer) system is based on how an ideal plate-type capacitor operates. The two plate electrodes are represented by the sensor and opposing measurement object. If a constant alternating current flows through the sensor capacitor, the amplitude of the alternating voltage on the sensor is proportional to the distance between the capacitor electrodes. The alternating current is demodulated and output as, for example, an analogue signal.

The capaNCDT system evaluates the reactance of the plate capacitor, which changes in direct proportion to the distance.

$$X_C = \frac{1}{j \cdot \omega \cdot C}$$

$$\text{Capacitance } C = \varepsilon_r \cdot \varepsilon_0 \cdot \frac{\text{area } A}{\text{distance } d}$$

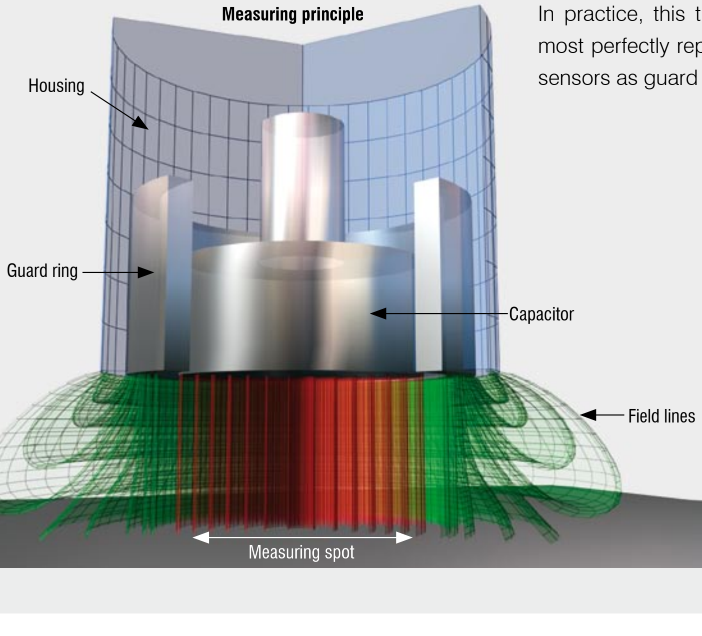
Due to the fact that $j\,\omega\,\varepsilon_r\,\varepsilon_0$ and A do not change during measurements, they are sustituted with a constant:

$$\text{constant } K = \frac{1}{j\omega\varepsilon_r\varepsilon_0 A}$$

According to that, the reactance X_C only depends from the distance:

$$X_C = \text{constant} \cdot \text{distance}$$

In practice, this theoretical relationship is almost perfectly replicated by the design of the sensors as guard ring capacitors.



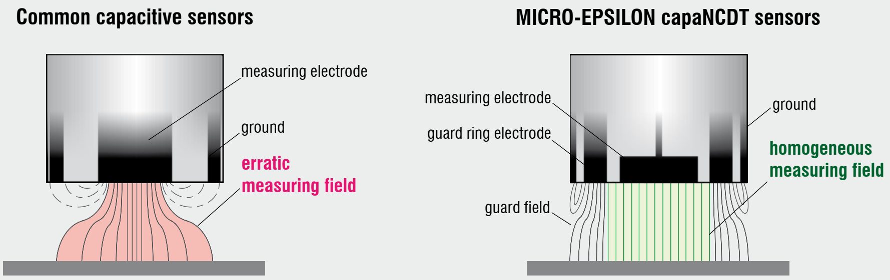
Use of capacitive sensors

Capacitive sensors are always used if very high accuracy levels are required. The capacitive measuring principle is one of the most precise measurement methods for non-contact displacement measurement.
The measurement principle requires a clean environment where a change of the dielectric ε_r affects the measurement result. The sensors measure against all electrically conductive materials.

Use in a vacuum and clean room

Sensors and sensor cables have proven themselves in clean rooms and under a vacuum. The extremely low gas release is responsible for this. capaNCDT Sensors for ultrahigh vacuum area (UHV) are available on request.

Active guard field for high precision measurement



Triaxial sensor design

The completely triaxial sensor design is unique for capaNCDT sensors, where the guard ring electrode and the grounding are also located on the front edge of the sensor as well as the measurement electrode.
This means capaNCDT sensors can also be installed completely flush in conductive materials. The sensors can also come into contact with each other in the case of multi-channel measurements. Interference of the measuring field is reliably prevented by the triaxial design of the sensor.

Active guard triaxial cable

Capacitive measurement systems from Micro-Epsilon operate with a unique, active, low noise cable in combination with an active guard ring capacitor. A particularly high quality signal is achieved due to the double shielding of the field. The system has an almost perfect impermeable electrical shield, which ensures precise measurements. In addition, the guard ring electrode provides a protected, completely homogeneous measuring field for extremely high stability and interference-free, accurate measurements.

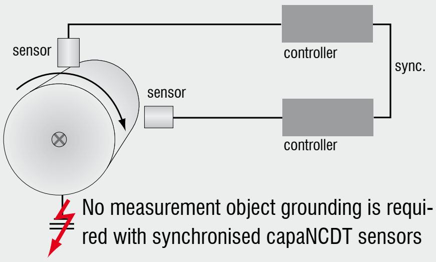
Rapid sensor replacement without calibration

The capacitive measuring principle specially developed by Micro-Epsilon enables the simple change of a sensor in just a few seconds. This simplified replacement of sensors with different measuring ranges and the interchange of different capaNCDT controllers can be easily carried out without any re-calibration. A sensor replacement normally takes around 5 seconds, unlike conventional systems, which have to be subjected to time-consuming calibration and linearisation.

Fast sensor replacement in just 5 seconds!
The interchange of various controllers and sensors in the capaNCDT series is performed rapidly without any time-consuming calibration.

Non-contact target grounding

In many applications, grounding of the target is very difficult or even impossible. Unlike conventional systems, the target for synchronisation of two capaNCDT devices does not necessarily have to be grounded. However, maximum signal quality is only achieved when the measurement object is correctly grounded. All measurement objects must be grounded for applications that use DT6019.

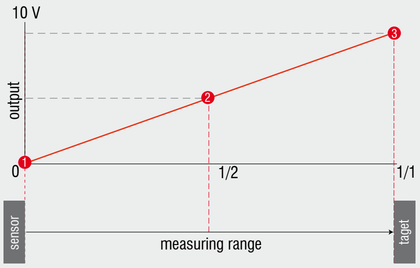


No measurement object grounding is required with synchronised capaNCDT sensors

The schematic diagram shows two synchronised capaNCDT sensors that are measuring against a roller. As the sensors are connected via Micro-Epsilon's unique synchronisation technology, grounding of the target is unnecessary in most cases.

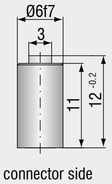
Linearisation and calibration

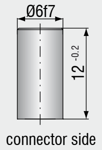
capaNCDT systems are calibrated at the factory for metallic targets (output 0 – 10V). The nominal output characteristic can be optimised by the user for special target materials or difficult installation conditions using the "Zero Point" potentiometer. Three-point linearisation is necessary for insulators as target. The adjustment is made using three distance points (1 = zero point, 2 = measuring range centre, 3 = measuring range end), which are defined as comparison standard.

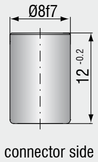


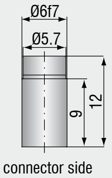
This calibration can be performed for the capaNCDT 6300 and 6500 models.

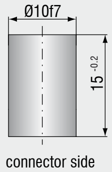
Cylindrical sensors with female connector











Sensor Type	**CS005**	**CS02**	**CS05**	**CSE05**	**CS08**
Article number	6610083	6610051	6610053	6610102	6610080
Measuring range	0.05mm	0.2mm	0.5mm	0.5mm	0.8mm
Linearity [1]	±0.2 % FSO	±0.2 % FSO	±0.05 FSO	±0.05 FSO	±0.05 FSO
Resolution [1] (static, 2Hz)	0.0375nm	0.15nm	0.375nm	0.375nm	0.6nm
Resolution [1] (dynamic, 8.5kHz)	1nm	4nm	10nm	10nm	16nm
Temperature stability zero [4]	60nm/°C	60nm/°C	60nm/°C	60nm/°C	60nm/°C
Temperature stability sensitivity	-10ppm/°C	-10ppm/°C	-10ppm/°C	-10ppm/°C	-10ppm/°C
Temperature range (operation)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Temperature range (storage)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Air humidity [2]	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.
Sensor dimensions	Ø6 × 12mm	Ø6 × 12mm	Ø8 × 12mm	Ø6 × 12mm	Ø10 × 15mm
Active measuring area	Ø1.3mm	Ø2.3mm	Ø3.9mm	Ø3.9mm	Ø4.9mm
Guard ring width	0.8mm	1mm	1.4mm	0.8mm	1.6mm
Minimum target diameter	Ø3mm	Ø5mm	Ø7mm	Ø6mm	Ø9mm
Weight	2g	2g	4g	2g	7g
Material (housing)	NiFe [3] (magn.)	NiFe (magn.)	NiFe (magn.)	NiFe (magn.)	NiFe (magn.)
Connector type	type C	type C	type C	type C	type C
Mounting	radial clamp	radial clamp	radial clamp	radial clamp	radial clamp

Sensors suitable for controller	DT 6019	-	●	●	●	●
	DT 6100	-	●	●	●	●
	DT 6300/6310	●	●	●	●	●
	DT 6350	-	●	●	●	-
	DT 6500	●	●	●	●	●

FSO = Full Scale Output

[1] With controller DT6500

[2] Non condensing

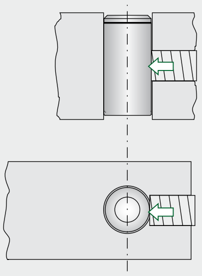
[3] Titanium version available

[4] Sensor mounted in the mid of clamping area

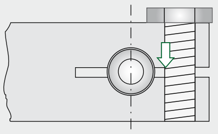
Mounting cylindrical sensors

All sensors can be installed as either freestanding or flush mounted.
Fastening is carried out using a clamp or collet.

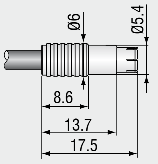
Mounting with grub screw (plastic)



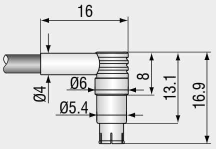
Mounting with collet



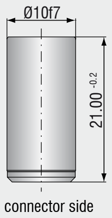
Connector type C

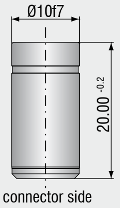


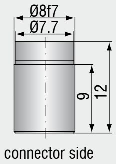
Connector type C/90

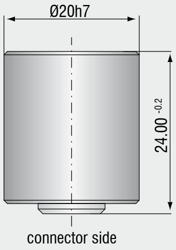


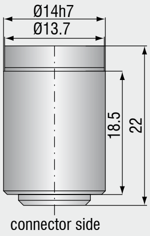
Cylindrical sensors with female connector











Sensor Type	**CS1**	**CS1HP**	**CSE1**	**CS2**	**CSE2**
Article number	6610054	6610074	6610103	6610052	6610104
Measuring range	1mm	1mm	1mm	2mm	2mm
Linearity 1)	±0.05 FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO
Resolution 1) (static, 2Hz)	0.75nm	0.75nm	0.75nm	1.5nm	1.5nm
Resolution 1) (dynamic, 8.5kHz)	20nm	20nm	20nm	40nm	40nm
Temperature stability zero 4)	170nm/°C	60nm/°C	60nm/°C	170nm/°C	170nm/°C
Temperature stability sensitivity	-32ppm/°C	-10ppm/°C	-10ppm/°C	-32ppm/°C	-32ppm/°C
Temperature range (operation)	-50 … +200°C	-50 … +200°C	-50 … +200 °C	-50 … +200°C	-50 … +200 °C
Temperature range (storage)	-50 … +200°C	-50 … +200°C	-50 … +200 °C	-50 … +200°C	-50 … +200 °C
Air humidity 2)	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.
Sensor dimensions	Ø10 × 21mm	Ø10 × 20mm	Ø8 × 12mm	Ø20 × 24mm	Ø14 × 22mm
Active measuring area	Ø5.7mm	Ø5.7mm	Ø5.7mm	Ø7.9mm	Ø8.0mm
Guard ring width	1.5mm	1.5mm	0.9mm	4.4mm	2.7mm
Minimum target diameter	Ø9mm	Ø9mm	Ø8mm	Ø17mm	Ø14mm
Weight	8g	8g	3.5g	50g	20g
Material (housing)	1.4404 3) (non-magn.)	NiFe (magn.)	NiFe (magn.)	1.4404 3) (non-magn.)	1.4404 (non-magn.)
Connector type	type B	type B	type C	type B	type B
Mounting	radial clamp	radial clamp	radial clamp	radial clamp	radial clamp

		CS1	CS1HP	CSE1	CS2	CSE2
Sensors suitable for controller	DT 6019	●	●	●	●	●
	DT 6100	●	●	●	●	●
	DT 6300/6310	●	●	●	●	●
	DT 6350	●	●	●	●	●
	DT 6500	●	●	●	●	●

FSO = Full Scale Output

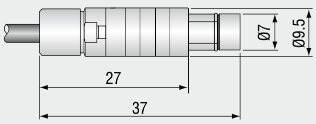
1) With controller DT6500

2) Non condensing

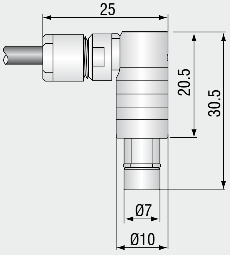
3) Titanium version available

4) Sensor mounted in the mid of clamping area

Connector type B



Connector type B/90



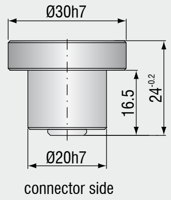
Sensors

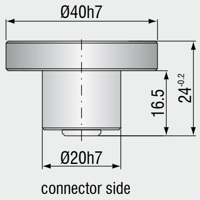
The sensors are designed as guard ring capacitors. They are connected to the signal conditioning electronics with a triaxial cable. The sensor cable is connected to the sensor using a high quality connector. All standard sensors can be used within a maximum deviation of 0.3% without recalibration. Individually matched special sensors are produced on request.

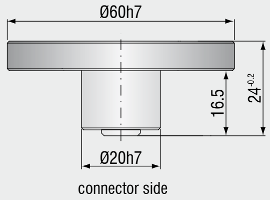
Measuring range expansion / reduction

The capaNCDT controller (except the series DT6019) can optionally be configured so that the standard measuring ranges of the sensors are reduced by half or expanded by the factor of 2. The reduction increases the accuracy while the measuring range expansion reduces the accuracy.

Cylindrical sensors with female connector







Sensor Type	**CS3**	**CS5**	**CS10**
Article number	6610055	6610056	6610057
Measuring range	3mm	5mm	10mm
Linearity 1)	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO
Resolution 1) (static, 2Hz)	2.25nm	3.75nm	7.5nm
Resolution 1) (dynamic, 8.5kHz)	60nm	100nm	200nm
Temperature stability zero 4)	170nm/°C	170nm/°C	170nm/°C
Temperature stability sensitivity	-32ppm/°C	-32ppm/°C	-32ppm/°C
Temperature range (operation)	-50 … +200°C	-50 … +200°C	-50 … +200°C
Temperature range (storage)	-50 … +200°C	-50 … +200°C	-50 … +200°C
Air humidity 2)	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.
Sensor dimensions	Ø30 × 24mm	Ø40 × 24mm	Ø60 × 24mm
Active measuring area	Ø9.8mm	Ø12.6mm	Ø17.8mm
Guard ring width	8mm	11.6mm	19mm
Minimum target diameter	Ø27mm	Ø37mm	Ø57mm
Weight	70g	95g	180g
Material (housing)	1.4404 (non-magn.)	1.4404 3) (non-magn.)	1.4404 3) (non-magn.)
Connector type	type B	type B	type B
Mounting	radial clamp	radial clamp	radial clamp

Sensors suitable for controller	DT 6019	●	●	●
	DT 6100	●	●	●
	DT 6300/6310	●	●	●
	DT 6350	●	●	●
	DT 6500	●	●	●

FSO = Full Scale Output

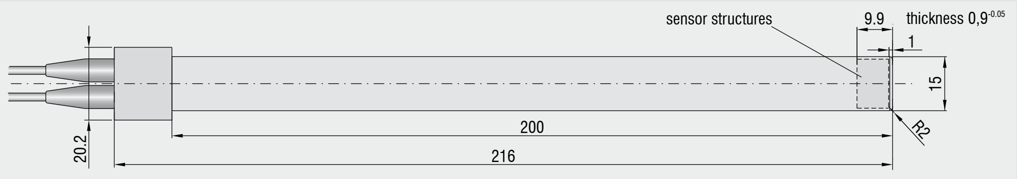
1) With controller DT6500

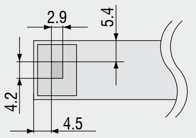
2) Non condensing

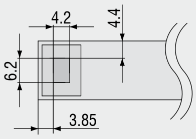
3) Titanium version available

4) Sensor mounted in the mid of clamping area

Flat sensors with connector





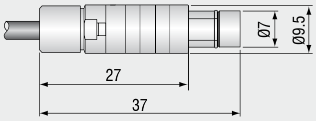


Sensor Type	**CSG0,50-CAm2,0**	**CSG1,00-CAm2,0**
Article number	6610112	6610111
Measuring range	0.5mm	1mm
Gap width [1]	0.9 - 1.9mm	0.9 - 2.9mm
Linearity [1]	±0.1% FSO	±0.1% FSO
Resolution [1] (static, 2Hz)	4nm	8nm
Resolution [1] (dynamic, 8.5kHz)	90nm	180nm
Temperature stability zero	50nm/°C	50nm/°C
Temperature stability sensitivity	-40ppm/°C	-40ppm/°C
Temperature range (operation)	-50…+100°C	-50 …+100°C
Temperature range (storage)	-50…+100°C	-50…+100°C
Air humidity [2]	0…95%	0…95%
Sensor dimensions	200 x 15 x 0.9mm	200 x 15 x 0.9mm
Active measuring area	3 x 4.3mm	4.2 x 5.1mm
Guard ring width	2.7mm	2.2mm
Minimum target diameter	approx. 7 x 8mm	approx. 8 x 9mm
Weight	77g	77g
Material (housing)	1.4301	1.4301
Material (sensor)	FR4	FR4
Integrated cable	2m	2m

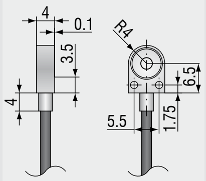
Sensors suitable for controller	DT 6019	-	-
	DT 6100	●	●
	DT 6300/6310	●	●
	DT 6350	●	●
	DT 6500	●	●

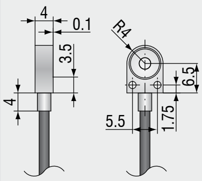
[1] Sensor width + measuring range on both sides
[2] With controller DT6500
[3] Non condensing

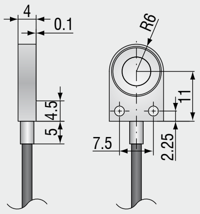
Connector type B

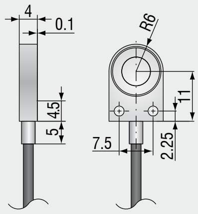


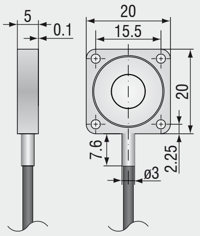
Flat sensors with integrated cable











Sensor Type	**CSH02FL-CRm1,4**	**CSH05FL-CRm1,4**	**CSH1FL-CRm1,4**	**CSH1,2FL-CRm1,4**	**CSH2FL-CRm1,4**
Article number	6610075	6610085	6610072	6610077	6610094
Measuring range	0.2mm	0.5mm	1mm	1.2mm	2mm
Linearity [1]	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO
Resolution [1] (static, 2Hz)	0.15nm	0.38nm	0.75nm	0.9nm	1.5nm
Resolution [1] (dynamic. 8.5kHz)	4nm	10nm	20nm	24nm	40nm
Temperature stability zero [4]	-37.6 / 2.4nm/°C	-37.6 / 2.4nm/°C	-37.6 / 2.4nm/°C	-37.6 / 2.4nm/°C	-47 / 4nm/°C
Temperature stability sensitivity	-12 ppm/°C	-12 ppm/°C	-12 ppm/°C	-12 ppm/°C	-12 ppm/°C
Temperature range (operation)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Temperature range (storage)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Air humidity [2]	0 … 95% r.H.	0 … 95% r.H	0 … 95% r.H	0 … 95% r.H	0 … 95% r.H
Sensor dimensions	10.5 × 8 × 4mm	10.5 × 8 × 4mm	17 × 12 × 4mm	17 × 12 × 4mm	20 × 20 × 5mm
Active measuring area	Ø2.6mm	Ø4.1mm	Ø5.7mm	Ø6.3mm	Ø8.1mm
Guard ring width	Ø1.9mm	Ø1.2mm	Ø2.4mm	Ø2.1mm	Ø4.4mm
Minimum target diameter	Ø7mm	Ø7mm	Ø11mm	Ø11mm	Ø17mm
Weight (incl. cable and connector)	28g	28g	30g	30g	36g
Material (housing)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)
Integrated cable	Ø2.1mm×1.4m radial	Ø2.1mm×1.4m radial	Ø2.1mm×1.4m radial	Ø2.1mm×1.4m radial	Ø2.1mm×1,4m radial
Mounting	2x thread M2	2x thread M2	2x screw M2 DIN 84A	2x screw M2 DIN 84A	4x screw M2 DIN 84A

Sensors suitable for controller [5]	DT 6019	-	-	-	-	-
	DT 6100	●	●	●	●	●
	DT 6300/6310	●	●	●	●	●
	DT 6350	●	●	●	●	●
	DT 6500	●	●	●	●	●

FSO = Full Scale Output

[1] With controller DT6500

[2] Non condensing

[3] Without cable, bend protection and crimp

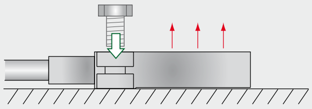
[4] In the case of a sensor mounting on the top and underside

[5] CSH Sensors are matched to controller with standard cable length 1m

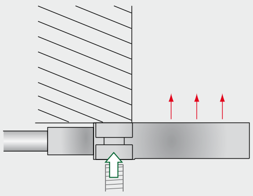
Mounting flat sensors

The flat sensors are attached using a threaded bore for M2 (for the sensors CSH02FL and CSH05FL) or using a through-hole for M2 bolts. The sensors can be bolted from above or below.

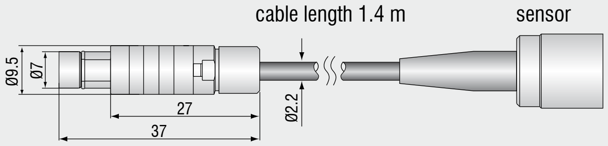
Screw connection from above on the underside



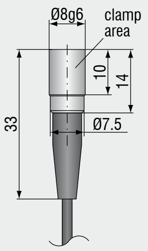
Screw connection from below on the sensor top side

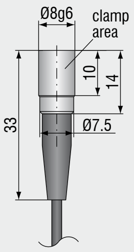


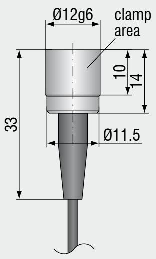
Connector for integrated cables

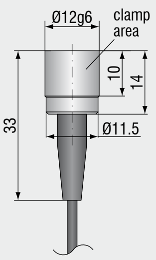


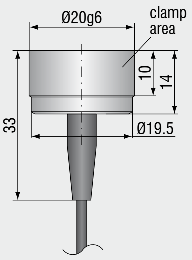
Cylindrical sensors with integrated cable











Sensor Type	CSH02-CAm1,4	CSH05-CAm1,4	CSH1-CAm1,4	CSH1,2-CAm1,4	CSH2-CAm1,4
Article number	6610086	6610087	6610088	6610089	6610107
Measuring range	0.2mm	0.5mm	1mm	1.2mm	2mm
Linearity 1)	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO	±0.05 % FSO
Resolution 1) (static, 2Hz)	0.15nm	0.38nm	0.75nm	0.9nm	1.5nm
Resolution 1) (dynamic. 8.5kHz)	4nm	10nm	20nm	24nm	40nm
Temperature stability zero 4)	-19nm/°C	-19nm/°C	-19nm/°C	-19nm/°C	-19nm/°C
Temperature stability sensitivity	-12ppm/°C	-12ppm/°C	-12ppm/°C	-12ppm/°C	-12ppm/°C
Temperature range (operation)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Temperature range (storage)	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C	-50 … +200°C
Air humidity 2)	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.	0 … 95% r.H.
Sensor dimensions	Ø8 × 14mm	Ø8 × 14mm	Ø12 × 14mm	Ø12 × 14mm	Ø20 × 14mm
Active measuring area	Ø2.6mm	Ø4.1mm	Ø5.7mm	Ø6.3mm	Ø8.1mm
Guard ring width	1.9mm	1.2mm	2.4mm	2.1mm	4.4mm
Minimum target diameter	Ø7mm	Ø7mm	Ø11mm	Ø11mm	Ø17mm
Weight (incl. cable and connector)	30g	30g	33g	33g	38g
Material (housing)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)	1.4104 (magn.)
Integrated cable	Ø2.1mm×1.4m axial	Ø2.1mm×1.4m axial	Ø2.1mm×1.4m axial	Ø2.1mm×1.4m axial	Ø2.1mm×1.4m axial
Mounting	radial clamp	radial clamp	radial clamp	radial clamp	radial clamp

Sensors suitable for controller 5)	DT 6019	-	-	-	-	-
	DT 6100	●	●	●	●	●
	DT 6300/6310	●	●	●	●	●
	DT 6350	●	●	●	●	●
	DT 6500	●	●	●	●	●

FSO = Full Scale Output

1) With controller DT6500

2) Non condensing

3) Without cable, bend protection and crimp

4) Sensor mounted 2mm behind front surface

5) CSH Sensors are matched to controller with standard cable length 1m

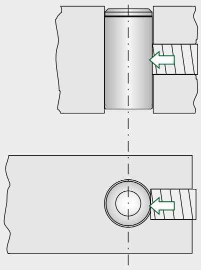
Mounting cylindrical sensors

All sensors can be installed as both freestanding and flush units. Fastening is carried out by using a clamp or collet.

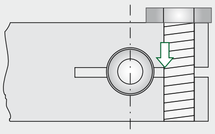
Important!

All Micro-Epsilon sensors are short circuit proof. Unlike other systems the pre-amplifier will not get damaged, if the front face of the sensor gets shorted by touching the conductive target

Mounting with grub screw (plastic)



Mounting with collet



Accessories

	DT 6019	DT 6100	DT 6300/6310	DT 6350	DT 6500
MC2.5 Micrometer for sensor calibration, range 0 - 2.5mm, Resolution 0.1μm. Suitable for sensors CS005 to CS2		●	●	●	●
MC25D Digital micrometer for sensor calibration, range 0 - 25mm, adjustable offset (zero). Suitable for all sensors.	●	●	●	●	●
SWH.0S.650.CTMSV Vacuum feed through		●	●	●	●
UHV Vacuum feed through		●	●	●	●
PC3/8 Power- and output cable, 3m, 8-pin		●	●	●	
ESC30 Synchronisation cable, 0.3m, necessary for multi channel applications				●	
SC30 Synchronisation cable, 0.3m		●			
PSCC30 Power-/synchronisation cable, necessary for multi channel applications			●		
PS2010 Power supply for DIN rail mounting Input 230 VAC (115 VAC) Output 24 VDC / 2.5 A; L/W/H 120x120x40 mm		●		●	
PS300/15 Power supply; output ±15 V / 1 A Input 90 - 264 VAC			●		
CSP 301 Digital signal processing unit with display for synchronous processing of 2 channels		●	●	●	
SCAC3/4 Signal output cable, necessary for multi channel applications			●		

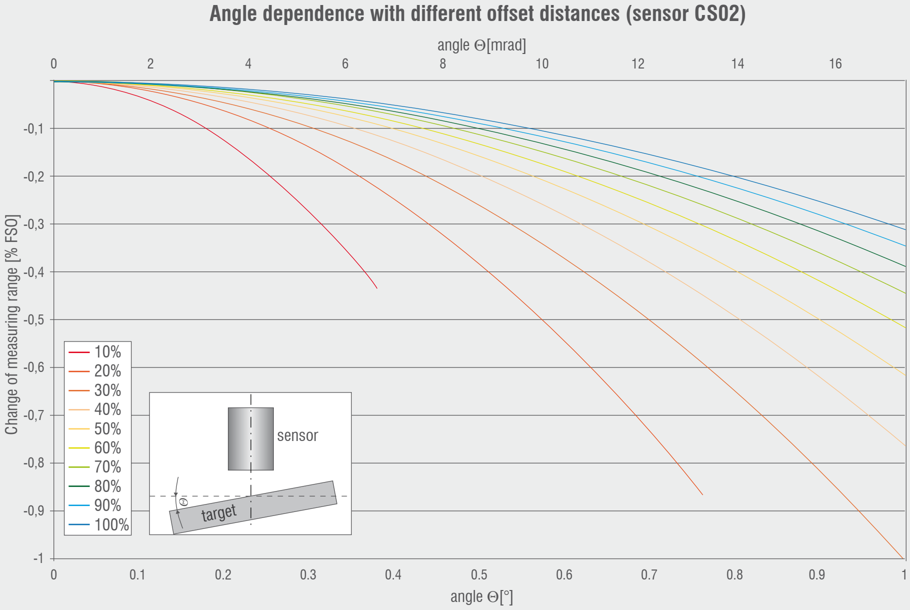
Influence of tilting the capacitive sensor

In the case of tilting of the capacitive sensor, a measurement error must be assumed as the geometric conditions of the field for the target change. In fact, the average distance of the sensor remains constant; however, the edge areas move closer or further away from the target. This results in field distortions, which affect the capacity C according to the following model:

$$C_d(\Theta)=C_d(0)*[1+(\frac{1}{4})*(\frac{R^2}{d^2})*\tan^2\Theta]$$

$$\Delta_x=100*(\frac{d}{d_{MAX}})*\{\frac{1}{[1+(\frac{R^2}{4d^2})*\tan^2\Theta]}-1\}$$

C	*capacity*
Θ	*tilt angle*
R	*measurment area radius*
d	*working distance sensor-target*
d_{MAX}	*sensor measuring range*
Δx	*signal change*



Example illustration of the influence using the CS02 sensor as an example, consideration of a tilt angle of max. 1° for different sensor distances.

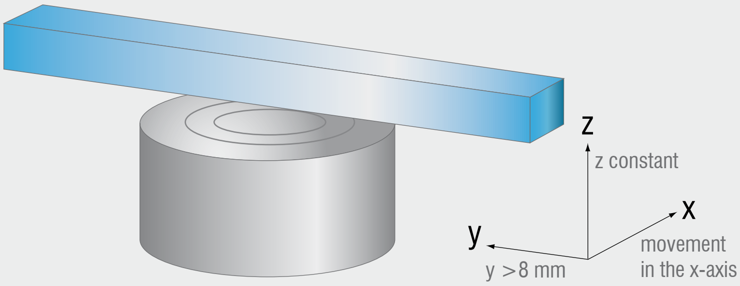
In the case of 10% distance in the sensor axis, there is already contact between sensor housing and target at 0.38°; in the case of 20% distance, the contact is at 0.76°. The simulation can be performed for all sensors and installation conditions; tilt angles around a decentralised tilt point can also be calculated.

Measurement on narrow targets

The influence of the target width on the measurement signal is shown using the example of a CS05 sensor.

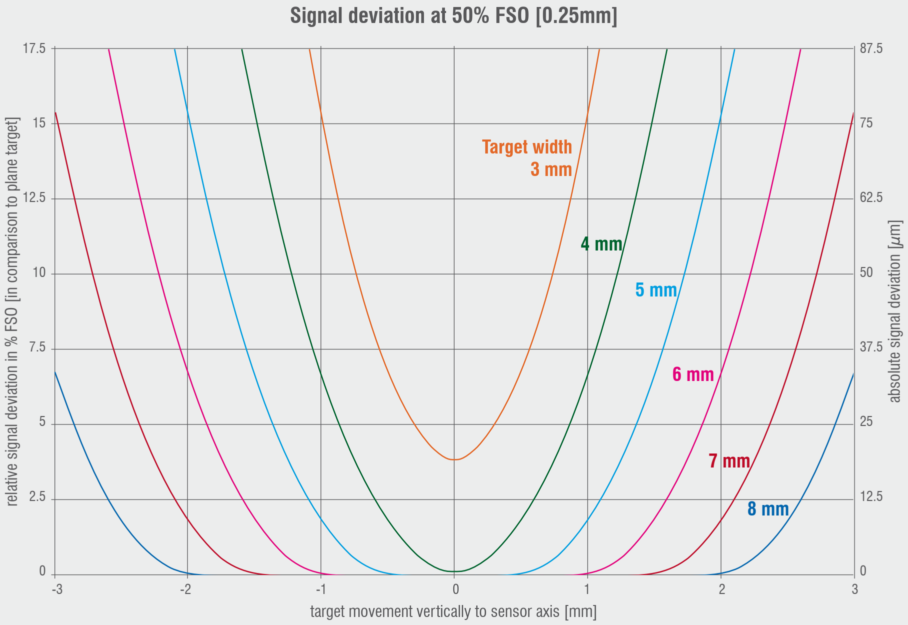
A target extended in the y-axis, narrowed in the x-axis has been varied in different parameters:

- target-sensor distance (z-axis): 0.25mm (measuring range centre)
- width of the target in the x-axis: 3 ... 8mm (21 values)
- displacement of the target in the x-axis (vertical to the sensor axis): 0 ... 3mm (13 values)



In each case, the capacity between electrode and target and its reciprocal (this is proportional to the sensor signal of the controller) were calculated. The diagram shows the deviations from the capacity values for a flat target (large opposite sensor in x and y axes) depending on the target width and displacement.

The smaller the distance between sensor and target, the narrower the target can be. In the example, a centrally placed target with a width of 5mm is sufficient to achieve a stable signal in the centre of the measuring range. This proves that the field does not spread beyond the sensor diameter.



Force effects on the target

Alternating forces between the two electrodes are produced by the electrical field:

$$F=\frac{C*U^2}{(2*d)}=constant$$

$$F=\frac{\epsilon_0*\epsilon_R*A*E^2}{2}=constant$$

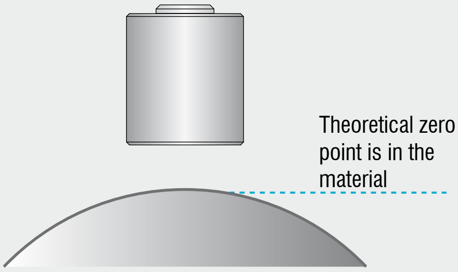
$$F=\frac{1}{2}*E*Q=constant$$

Using the example of a CS1 sensor, which is operated using the DT6300/DT6500 system, a force of approx. 0.23µN is produced. The force however is dependent on the selection of sensor and electronics, not on the sensor's position over the measuring range. The DT6019/6100 systems operate using lower measuring currents, whereby the electrical field and the electrical voltage are lower so that the force is only 0.01µN and so measurement without feedback is assumed.

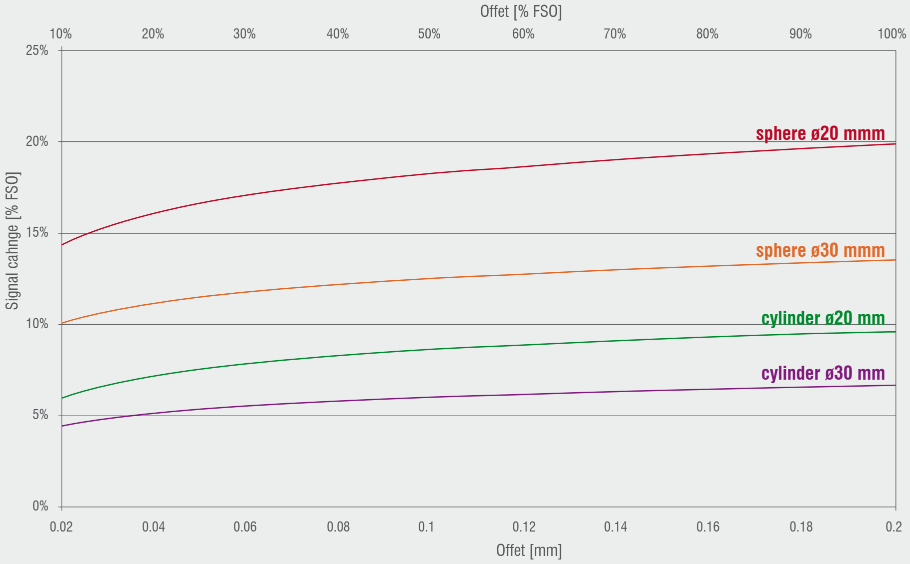
Measurements on spheres and shafts

In practice, it is often necessary to measure curved surfaces. A classic example is shaft runout measurements, where a cylindrical target is measured. Compared to a flat target, there are either more or less significant measured value deviations depending on the bending radius in doing so. This is caused by various effects, e.g. concentration of the field lines at the highest point or a capacity increase due to a larger measuring spot.

In reality, it can be assumed that the bending radius results in a virtual zero point, i.e., the sensor value 0 can no longer be achieved. Due to the integrating function of the capacitive senor over the measurement surface, the virtual, average measuring plane lies behind the surface line. For example, this means that with a 200µm sensor and a roller with an external diameter of 30mm and a gap clearance of 20µm, almost 5% more is indicated, i.e. approx 30µm. As this effect can be calculated, corresponding characteristics can be calibrated in the evaluation electronics.



Signal change: various target geometries (sensor CS02)



Consideration of the conductivity requirements

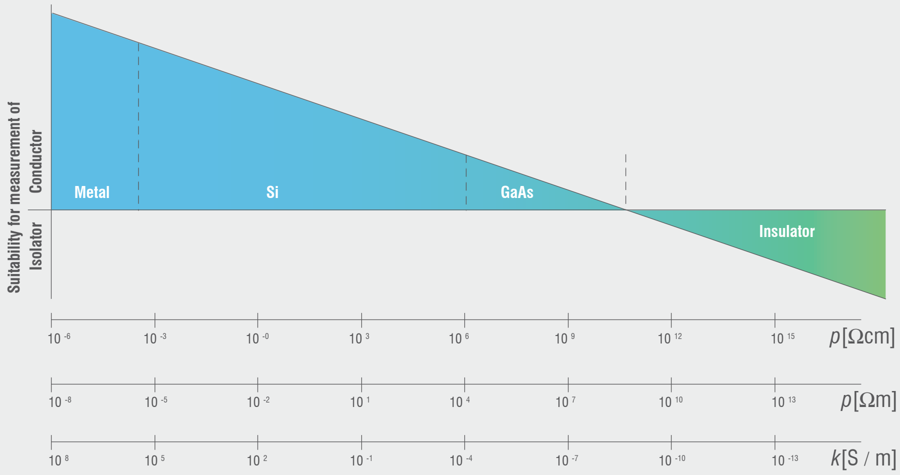
In order to achieve a linear output signal across the complete measuring range, certain requirements for the target or the counter electrode must be complied with.

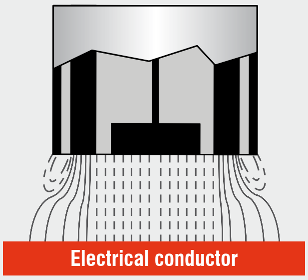
The impedance in the ideal plate capacitor can be shown in the equivalent circuit diagram by a capacitor and a resistor connected in parallel. For measurement against metals, the Ohm part can be disregarded; the impedance is only determined by the capacitive part.

Conversely, only the Ohm part is considered for measurements against insulators. In between, there is the large range of semiconductors. Most semiconductors can be measured very well as electrical conductors. The requirement is that the capacitive part of the total impedance is still significantly larger (>10x) than the ohmic part. This is almost always the case for silicon wafers irrespective of the endowment.

Nevertheless, semiconductors with poor conductivity (e.g. GaAs) can also be measured as conductors under certain circumstances. However, various adjustments are required for this, e.g. reduction of the operating frequency or a temporary, partial increase of the conductivity.

Relation between conductivity and suitability of materials





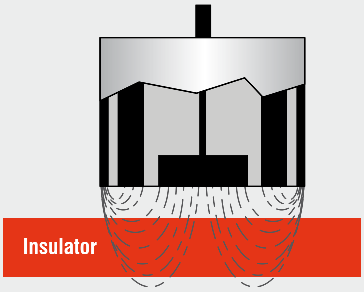
Electrical conductor as target

The capaNCDT system measures the reactance Xc of the capacitor, which changes proportionally with distance. The high linearity of the signal is achieved without further electronic circuitry. This particularly applies to measurements against electrically conductive materials (metals). Changes of the conductivity have no influence on linearity or sensitivity. All conductive or semi-conductive targets are measured without any loss in measurement performance.

No penetration of the fields for electric conductors

As the measurement principle operates without penetration of the fields in the target, even the thinnest targets, e.g. 10µm electrically conductive paint, can be measured.

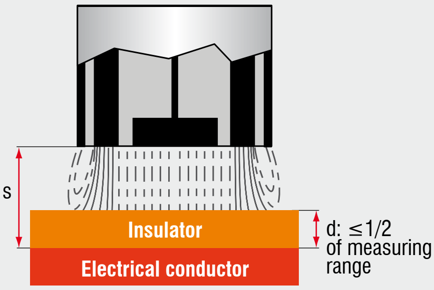
The capacitive measuring process operates with currents in the µA range. This means even the smallest electrical charges are sufficient to make measurements possible. Even very thin metallic objects can guarantee the charge carrier displacement. A target thickness of a few micrometres is sufficient here. The electrical field develops between sensor electrode and target surface; the distance determines the reactance.



Insulators as target

Some capaNCDT systems can also measure insulating materials. In this case resolution and accuracy are reduced.

The field lines penetrate the insulator and join with the electrical sensor housing. The reactance Xc depends on the distance between sensor and insulator. Therefore a constant thickness and permittivity of the insulator is necessary. Factory calibration/compensation is strongly recommended.



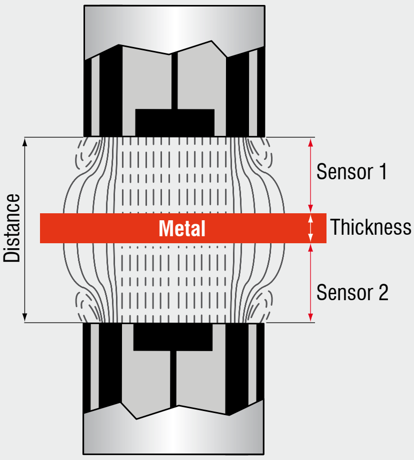
Thickness measurement of insulators

The capaNCDT system can also be used for the linear thickness measurement of insulators. The field lines penetrate the insulator and join with the electrical conductor. If the thickness of the insulator changes, this influences the reactance Xc of the sensor. The distance to the electrical conductor must therefore be constant.

$$\frac{C}{C_0}=\frac{1}{(1-(\frac{d}{s})*(1-\frac{\epsilon_1}{\epsilon_2}))}$$

$$\epsilon_1=\epsilon_0*\epsilon_{r1},\epsilon_2=\epsilon_0*\epsilon_r$$

d	*Target thickness*
s	*Measuring gap*
ε_1	*Permittivity air*
ε_2	*Permittivity insulator*



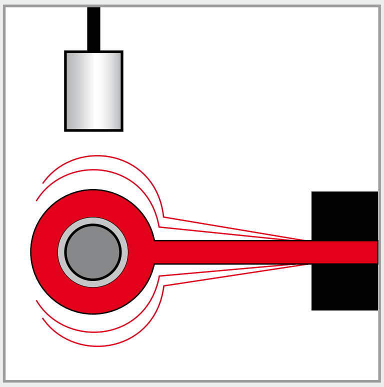
Thickness = Distance - (Sensor 1 + Sensor 2)

Thickness measurement of metals

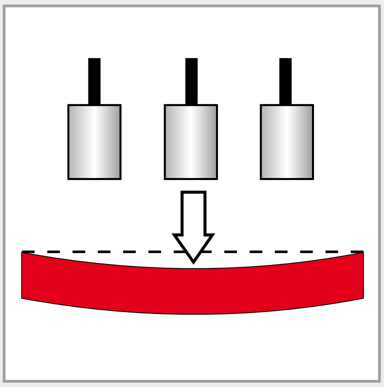
Two-sided thickness measurement of metals is made possible by installing the sensors opposite each other. Strip thicknesses in the µm range can be measured using this method. Each sensor generates a linear output signal dependent on the distance between sensor surface and target surface. If the sensor distance is known, the thickness of the target can be determined easily.

Due to the capacitive principle, the measurement is only performed against the surface without penetrating the target. If the measuring points are synchronised, measurement against non-grounded targets is possible.

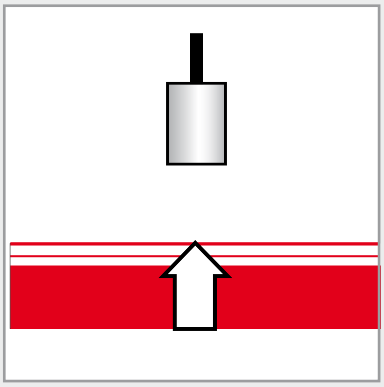
Applications



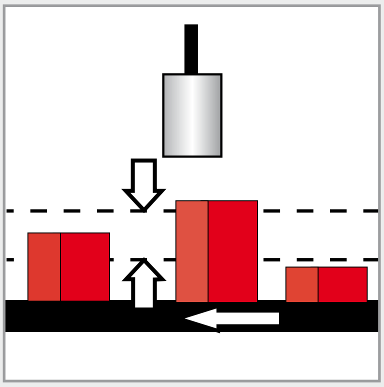
Vibration, amplitude, clearance, run-out



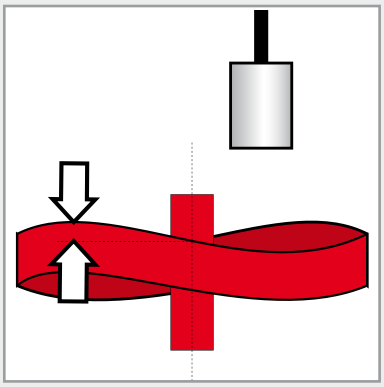
Deflection, deformation, waviness, tilt



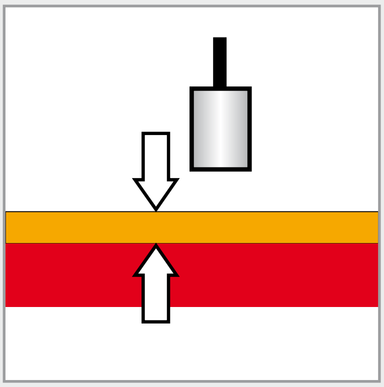
Displacement, distance, position, elongation



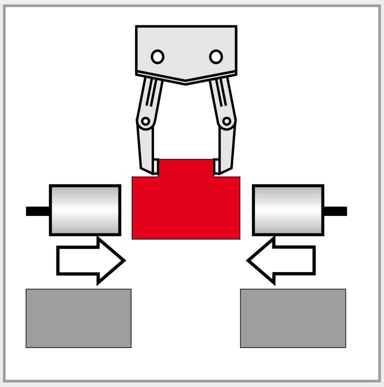
Dimensions, dimensional tolerances, sorting, parts recognition



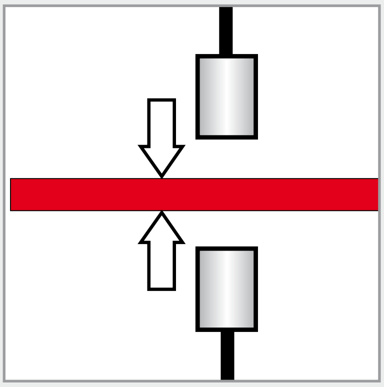
Stroke, deformation, axial shaft oscillation



Thickness measurement of insulating materials



In-process inspection,dimensional inspection

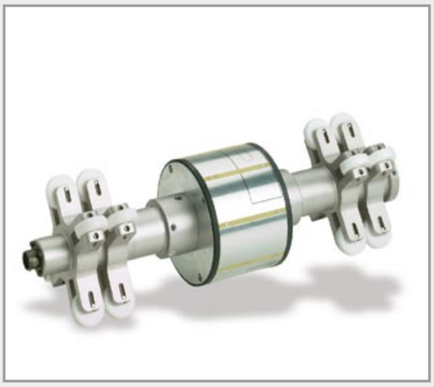


Two-sided thickness measurement

Specific sensors for OEM applications

Application examples occur again and again where the standard versions of the sensors and the controller are performing at their limits. For these special tasks, we modify the measuring systems exclusively according to your individual requirements. Changes often requested include for example modified designs, target coordination, mounting options, individual cable lengths, modified measuring ranges or sensors with integrated controller.

Special OEM electronic design

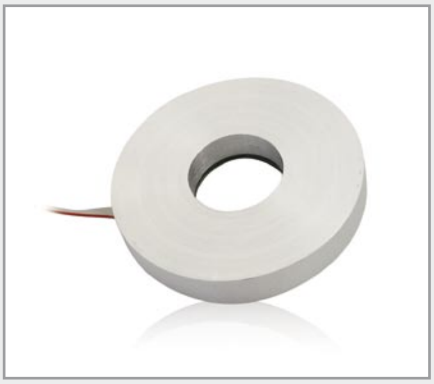


System for measuring the internal diameter of extruder bores

Dual sensor integration for ID check

Customised sensor body

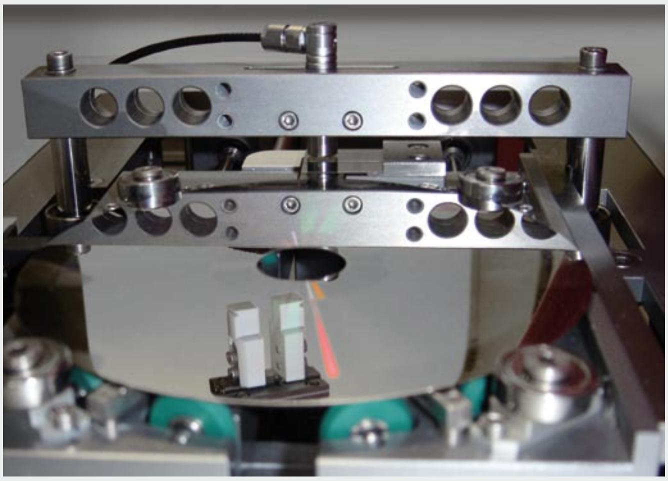
Customised modification for a specific environment



Special OEM design

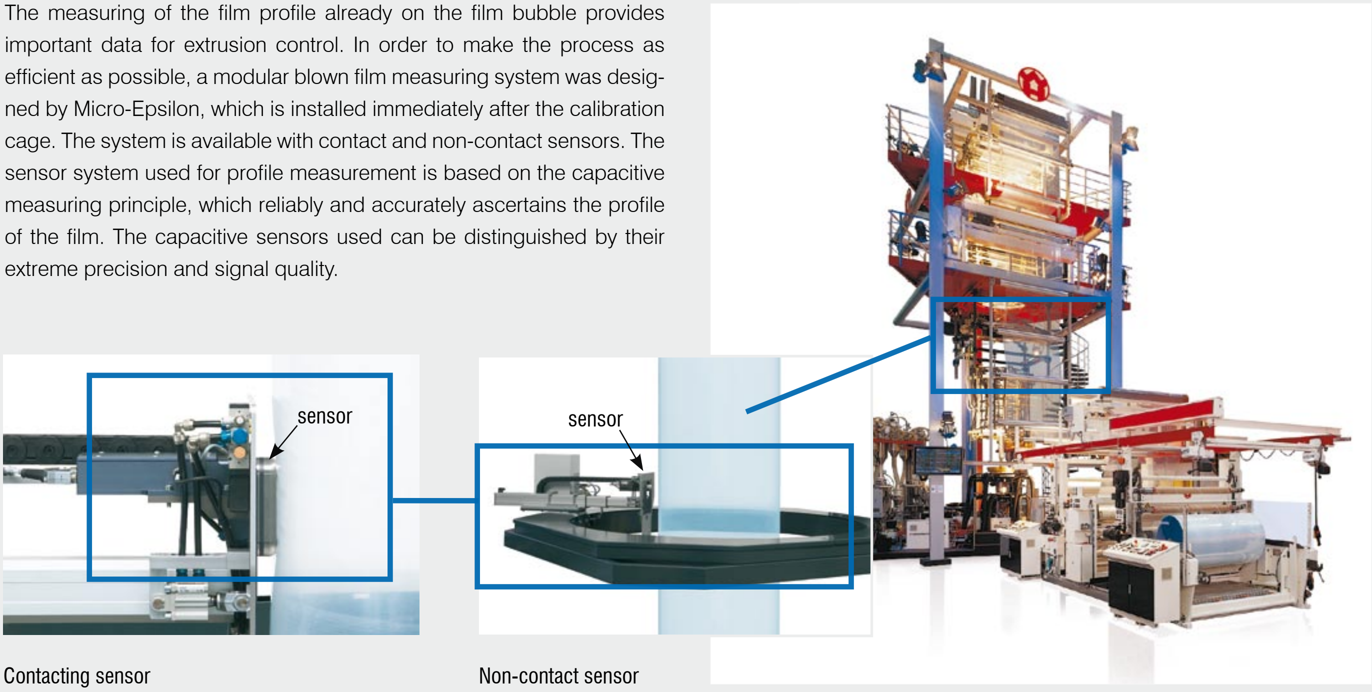
Thickness measurement of dies for optical data carriers

Previously, the data was transferred to a master system using a laser to reproduce CDs, DVDs, HD-DVDs or Blu-ray discs by pressing. A thin layer of nickel is applied using galvanisation to the silicon or glass carrier (substrate). The absolute thickness values of the nickel layer are required in order for the exact control of the galvanisation bath. Capacitive sensors from Micro-Epsilon are used to measure the thickness and profile. A sensor is positioned above and below the die, which is then moved between the sensors during measurements. Using the two units for distance information, the thickness is determined very precisely using the differential method.



Modular measuring system for the profile measurement of blown films

The measuring of the film profile already on the film bubble provides important data for extrusion control. In order to make the process as efficient as possible, a modular blown film measuring system was designed by Micro-Epsilon, which is installed immediately after the calibration cage. The system is available with contact and non-contact sensors. The sensor system used for profile measurement is based on the capacitive measuring principle, which reliably and accurately ascertains the profile of the film. The capacitive sensors used can be distinguished by their extreme precision and signal quality.



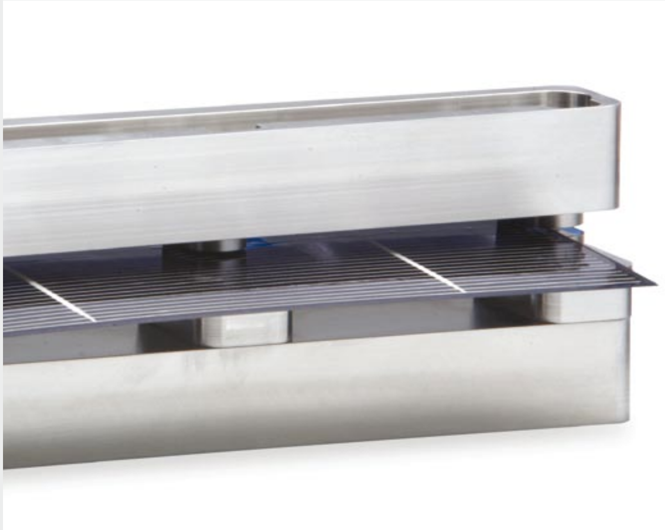
Contacting sensor

Non-contact sensor

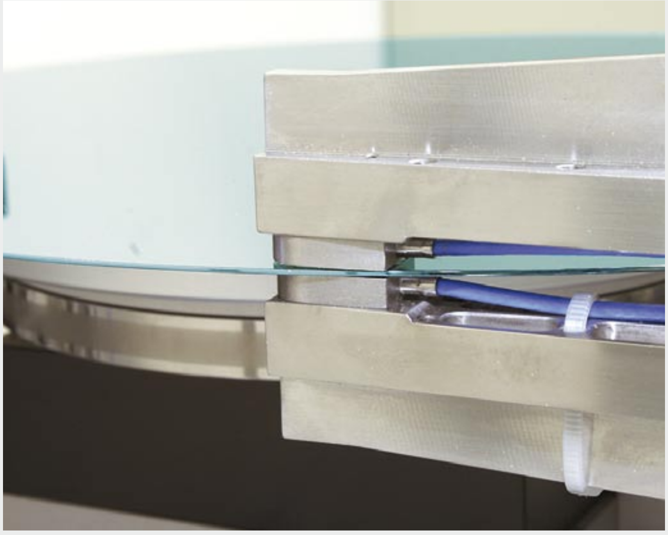
Measurements on wafers and semiconductors

Extreme accuracies are required in the semiconductor industry in order to design processes and products efficiently. Capacitive sensors from Micro-Epsilon are used, among other things, for the positioning, displacement measurement and thickness measurement in the semiconductors area.

Capacitive displacement sensors are used for adjustment with nanometre precision of lenses in optical systems for wafer exposure.



Wafer thickness measurement with 3 tracks



Wafer thickness measurement with two capacitive sensors