D-015 · D-050 · D-100

Sub-Nanometer-Resolution Capacitive Position Sensors

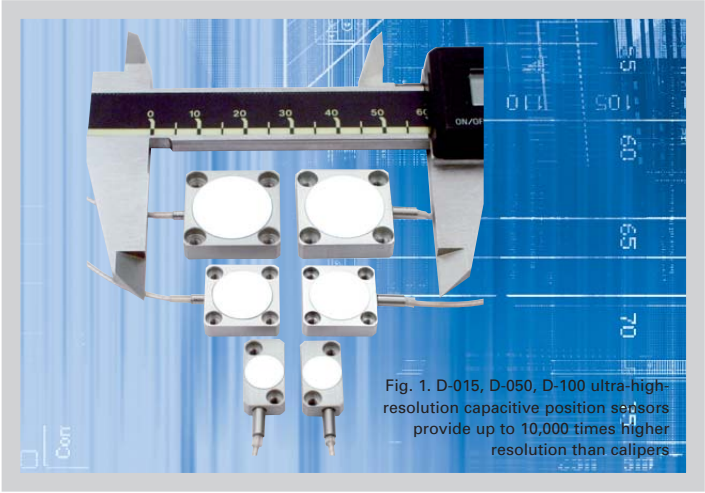

Fig. 1. D-015, D-050, D-100 ultra-high-resolution capacitive position sensors provide up to 10,000 times higher resolution than calipers

- **Measuring Range to 1000 µm**
- **Resolution <0.01 nm**
- **Linearity to 0.003 %**
- **Bandwidth to 10 kHz**
- **Integrated Linearization System (ILS)**
- **Custom Designs**

Measurement Method

Capacitive position sensors are analog non-contact devices. A two-electrode capacitive position sensor consists of two RF-driven plates that are part of a capacitive bridge. The high-frequency AC excitation provides better long term stability than DC excited sensors (see p. 5-6, Fig. 4). One plate (probe) is fixed, the other plate (target) is connected to the object to be positioned. Since the plate size and the dielectric medium (air) remains unchanged, capacitance is directly related to the distance between the plates. Ultra-precise electronics convert the capacitance information into a signal proportional to distance.

Direct Metrology, Parallel Metrology

The sensors offered by PI are the most accurate measuring systems for nanopositioning applications currently on the market. In contrast to high-resolution sensors measuring deformation in the drive train (see p. 2-5 *ff.*), like strain gauge or piezoresistive sensors, capacitive sensors are non-contact, direct-metrology devices—a fact which gives them many advantages:

- Better Phase Fidelity
- Higher Bandwidth
- No Periodic Error
- Non-Contacting
- Ideal for Parallel Metrology
- Higher Linearity
- Better Reproducibility
- Higher Long-Term Stability

Capacitive sensors are especially well-suited for parallel metrology configurations. In multi-axis nanopositioning systems, parallel metrology means that the controller monitors all controlled degrees of freedom relative to "ground" (the fixed frame) and uses each actuator to compensate the undesired off-axis motion of the others automatically (active trajectory control). As a result, it is possible to keep deviations in the sub-nanometer and sub-microradian range (see p. 4-44 *ff.* in the "Tutorial" section).

Resolution

Resolution on the order of picometers is achievable with short-range, two-electrode capacitive position sensors (single-electrode capacitive position sensors provide less resolution, linearity and accuracy than two-electrode sensors). Theoretical measurement resolution is limited only by quantum noise. In practical applications, stray radiation, electronics-induced noise and geometric effects are the limiting factors. For example, with the 100 µm range, a D-100.00 sensor and E-509.C1A electronics, the effective noise factor is 0.02 nm/$\sqrt{\text{Hz}}$. This translates to 0.2 nm at 100 Hz bandwidth. The maximum standard bandwidth (jumper selectable) is 3 kHz.

Figure 2 shows a D-015, 15 µm capacitive position sensor and an interferometer, both measuring nanometer-range actuator cycles. The graphs clearly show the superior resolution of the capacitive position sensing technique.

Ordering Information

D-015.00
Capacitive Position Sensor, 15 µm, Aluminum

D-050.00
Capacitive Position Sensor, 50 µm, Aluminum

D-100.00
Capacitive Position Sensor, 100 µm, Aluminum

Ask about custom designs!

Notes

In addition to the standard sensors listed here, PI offers a variety of custom versions along with custom electronics for different measuring ranges, material match etc. If you don't find what you are looking for, please call your local PI Sales Engineer.

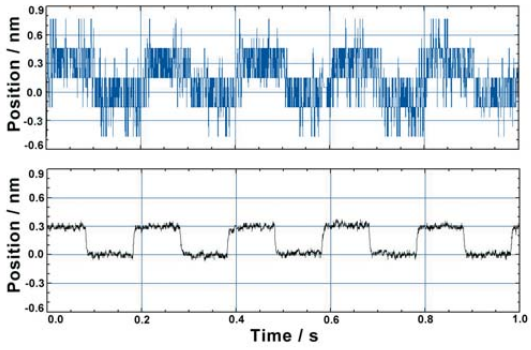

Fig. 2. Piezo nanopositioning system making 0.3 nm steps, measured with PI capacitive sensor (lower curve) and with a highly precise laser interferometer. The capacitive sensor provides significantly higher resolution than the interferometer.

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Capacitive Position Sensors
Piezo Drivers & Nanopositioning Controllers
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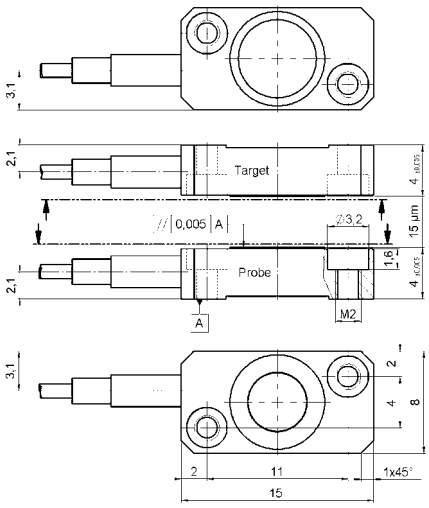
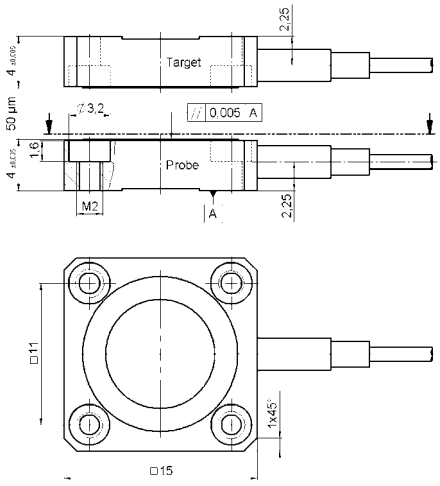
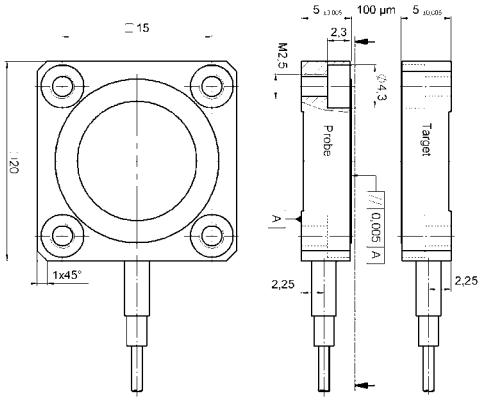


D-015.00 (dimensions in mm)



D-050.00 (dimensions in mm)



D-100.00 (dimensions in mm)

Technical Data: Capacitive Sensor Electronics

Models	E-509.CxA
Power supply	±15 V
Analog output	±5 V (0V - 10V)
Noise factor*	0.115 ppm/$\sqrt{Hz}$
Bandwidth	0.3 to 3 kHz, selectable; up to 10 kHz on request
Temperature drift*	typ. -30 ppm/K
Linearity error (before digital polynomial linearization)	<0.05 %
Operating temperature range	-20 to 80 °C

* Specifications in ppm (parts per million) refer to measuring range

Technical Data: Capacitive Sensors

Sensor Models	D-015.00	D-050.00	D-100.00	Units
Material	Aluminum*	Aluminum*	Aluminum*	
Active Surface	16.6	67.7	113.1	mm²
Nominal Measuring Distance	15	50	100	µm
Extended Measuring Distance	45	150	300	µm
Therm. Drift **	50	50	50	ppm/K
Operating temperature range	-20 to +80	-20 to +80	-20 to +80	°C

* Other materials, measuring ranges and form factors or request.
** Change of the active measuring surface in parts per million as referred to the selected measuring range