

Capacitive Sensors

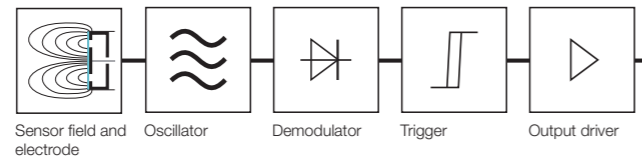
BASICS AND INSTALLATION



CAPACITIVE SENSORS

Principle of operation

The non-contacting capacitive sensor converts a variable of interest in technical production terms (e.g. object or level detection) into a signal which can be processed further. The function is based on the alteration in the electrical field around its active zone. The sensor consists essentially of an electrode system, oscillator, demodulator, trigger stage, output driver/switching amplifier. The electrode systems together with an active measuring electrode (sensing face) form an open plate capacitor. This is part of an RC oscillator.



When metallic or non-metallic objects approach the sensing surface of the capacitive sensor, the capacitance of the open plate capacitor changes and the oscillator begins to oscillate. This causes the trigger stage downstream of the oscillator to trip, and the switching amplifier to change its output state. The function of the capacitive sensor can be explained using the equation for capacitance of a plate capacitor:

$$C = \epsilon_0 \times \epsilon_r \times F \times (1/S)$$

ϵ_r : As a relative dielectric constant (property of the target medium)

ϵ_0 : As an absolute dielectric constant (natural constant)

F: As electrode surface

S: As distance

From the above formula it follows that objects which have a sufficiently large relative dielectric constant (ϵ_r) as well as area (as a ratio with the sensing surface) and sufficiently close distance are detected by the capacitive sensor. In addition to the described universal technology in which the sensor is a component of an oscillator circuit, there are also more modern technologies which satisfy the special application requirements.

Sensor for object detection (flush)

Sensors with a straight line electrical field (no side sensitivity). These detect solid bodies, e.g. cartons, paper stacks, plastic blocks and plates as well as glass. They also detect media levels through a wall made of plastic or glass. The wall thickness may not exceed 4 mm.

Sensor for level detection (non-flush)

Sensors with a spherical electrical field. These units are designed to detect the product, bulk goods or liquids (e.g. granulate, sugar, flour, corn, sand, or oil and water) with their sensing surface, preferably by contacting the medium or through a glass or plastic wall.

Foam and residue compensation (smart level technology)

Patented technology which enables optimal detection of levels of electrically conductive (polar) media (water, lyes, acids, ...). This is accomplished with direct contact (immersion probes) and through a maximum 10 mm thick wall of plastic, glass or ceramic. The sensors which are based on this technology compensate for the dielectric effect of the container wall and enable reliable distinguishing between the target medium and its build-up, films and foaming.

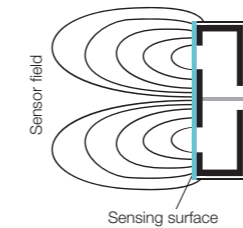
Setting the sensitivity on capacitive sensors

In most cases adjusting the sensor sensitivity (capacitance value which when exceeded causes the sensor to switch) to the environment is required (pre-loading by other objects in the capture area, e.g. a container wall). The setting is done depending on the device generation using a potentiometer, a key, a separate line or IO-Link.

Definitions and Characteristic Values

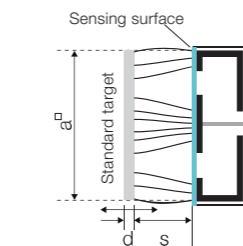
Sensing surface

Actively measuring area and thereby the externally sensitive electrode/plate of the electrode system. It is generally somewhat smaller than the surface of the cover.



Standard target

A square plate made of Fe 360 (ISO 630), used to define sensing distances per EN 60947-5-2. Thickness is 1 mm; the side length "a" corresponds to the diameter of the inscribed circle of the active surface or $3 s_n$, if the value is larger than the named diameter.

Rated operating distance S_n

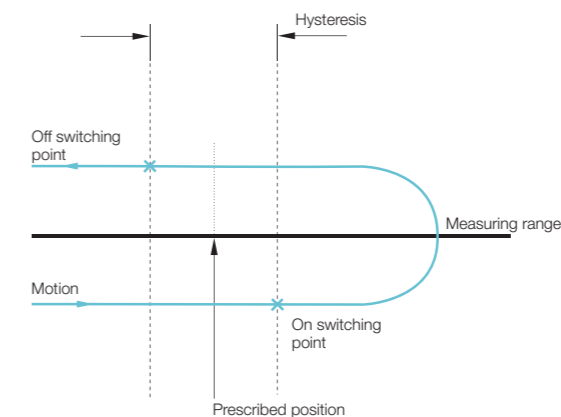
Maximum achievable switching distance from the standard target under device specification (generally with s_n as shipped from the factory).

Effective operating distance S_e

The switching distance of a single proximity switch measured under specified conditions, e.g. flush mountable, rated operating voltage U_n , temperature T_a .

Hysteresis

The hysteresis is the difference in distance between the switch-on point (for an object that is approaching) and the switch-off point (for an object that is receding).



Repeat accuracy Variance in the output values when approaching a mechanically prescribed position repeatedly from the same direction.

Switching frequency The maximum speed at which the sensor can reliably detect an object under standardized conditions. This corresponds to the maximum number of switching operations (ON/OFF) per second. The value is dependent on the size and speed of the object and its distance from the sensing face.

Temperature drift The temperature drift indicates by what percentage amount of S_r the switching distance may change (maximum) within a defined temperature range.

Ambient temperature T_a The maximum permissible temperature range at which a sensor may be operated while ensuring reliable functioning of the sensor.

Degree of protection Indicates the suitability of electrical components for various ambient conditions and protection of persons from potential hazard in their use. The degrees of protection are specified according to IEC 60529. Code letters IP (International Protection Marking) designate protection against shock hazard, ingress of solid foreign bodies, and water, for electrical equipment. Example IP69K: Protection against ingress of water at high pressure and steam cleaning per DIN 40050 Part 9.

Output functions, connections and electric characteristic values

Normally closed (NC) Also "normally closed" – sensor principle/output function in which the switching output is inactive (not energized) when the sensor detects an object. The switching output is energized when no object is present.



Normally open (NO) Also "normally open" – sensor principle/output function in which the switching output is active (energized) when the sensor detects an object. The switching output is not energized when no object is present. This principle is the most commonly used in automation technology.



PNP Switched positive – the load is connected to negative and the positive is switched.

NPN Switched negative – the load is connected to the positive and the negative is switched.

PNP/NPN (push/pull) The sensor can be used both as PNP or NPN, depending on the wiring of the load. (The outputs from multiple devices cannot be wired in parallel)

PNP/NPN NO/NC codable The sensor can be used both as PNP or NPN, depending on the wiring of the load. By reversing the supply voltage (brown to –, blue to +) the switching function can be set from NO to NC.

IO-Link

The capacitive sensor can with an appropriate counterpart (master) enter into data communication (com2, 30Kbit) through its switching output. On one hand it can transmit much data (e.g. the continuous degree of damping by an object or fill medium as a numerical value), and on the other hand be configured remotely from the counterpart. If there is no master the sensor automatically goes into its normal switching mode (SIO): e.g. PNP/NC

Analog output

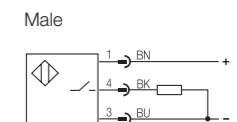
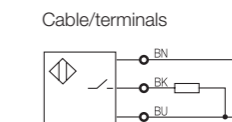
Output switches between $+U_B$ and $-U_B$. By reversing the supply voltage (brown to –, blue to +) the switching function can be set from NO to NC.

Connection diagrams

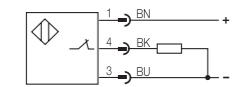
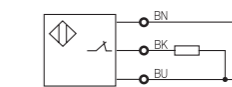
DC 3-/4-wire

NO

PNP (+) sourcing

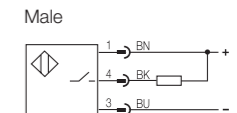
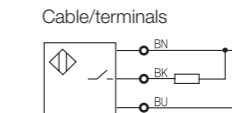


NC

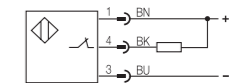
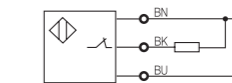


NO

NPN (-) sinking

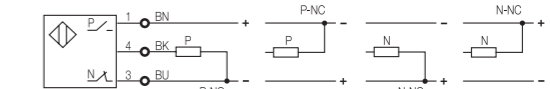


NC



PNP/NPN selectable

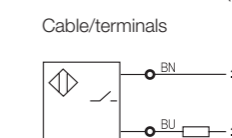
NO/NC user selectable



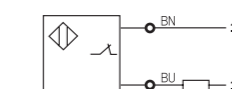
AC/DC 2-wire

Protection isolated (Protection Class II)

NO



NC



Smallest bending radius for standard PUR and standard PVC cables

Bending radius at rest: min. 5 × cable diameter
Bending radius in motion: min. 10 × cable diameter

Operating voltage U_B	Voltage range (V) in which flawless functioning of the sensor is assured. It includes all voltage tolerances and ripple.
Voltage drop U_d	The maximum voltage loss of the switching final stage between switching output and $+U_B$ (PNP) or $-U_B$ (NPN) at the maximum specified load current.
Ripple	The maximum permissible AC voltage (peak-to-peak of U_a) which may be superimposed on the operating voltage U_S without affecting the function of the sensor.
Output current I_o	The maximum current with which the output of the sensor may be loaded in continuous operation. Also referred to as operating current.
No-load current	The maximum internal current consumption with no load connected to the switching output (in general at $U_{B\ max}$ and actuated).
Short-circuit protection	Protective device for overload and short-circuit. Present in all our DC sensors. In the event of overload or short-circuit at the output, the output transistor is automatically switched off. As soon as the malfunction has been corrected, the output stage is reset to normal functioning.
Reverse polarity protection	Also called polarity reversal protection. This sensor technology protects against reversal of the supply voltage (plus and minus) and reversal of the connection wires (brown and blue).
Reverse protected	The sensor electronics is protected against any possible reversal combination of all the leads.
Mechanical features	
General tolerances	In general, the variances in external dimensions, form, and position tolerances of Balluff products fall within the general tolerance in accordance with DIN ISO 2768-cK. Important functional dimensions are indicated with specific tolerances in the product view. For all other dimensions without a specific tolerance specified, the general tolerance per DIN ISO 2768-cK applies.

Limit deviations for linear dimensions: Tolerance class c

Tolerance class	From 0.5 until 3	Over 3 until 6	Over 6 until 30	Over 30 until 120	Over 120 until 400	Over 400 until 1000	Over 1000 until 2000	Over 2000 until 4000
c (coarse)	±0.2	±0.3	±0.5	±0.8	±1.2	±2	±3	±4

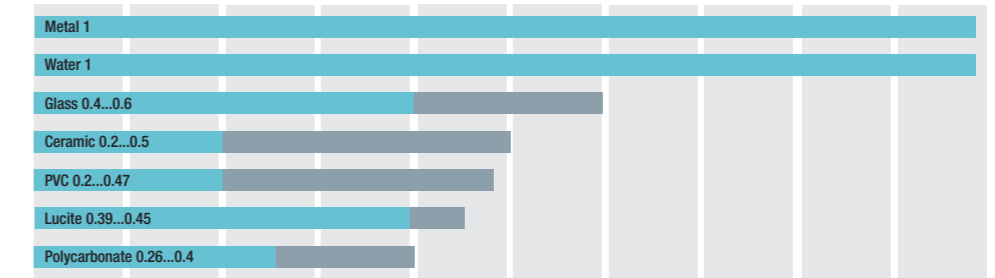
Straightness and flatness: Tolerance class K

Tolerance class	Until 10	Over 10 until 30	Over 30 until 100	Over 100 until 300	Over 300 until 1000	Over 1000 until 3000		
K	0.05 mm	0.1 mm	0.2 mm	0.4 mm	0.6 mm	0.8 mm		

Correction factors and guide values for smart level technology

Conditions of operation and correction factors

If an electrically non-conducting actuation element (target) enters the sensor field, the capacitance changes proportionally to ϵ_r and to the immersion depth or to the distance to the sensing surface. Since the rated switching distance s_n is based on a grounded standard target made of Fe, the switching distances must be corrected when using other materials:



These data depend among other things on the sensor type and the object dimensions and should be used for reference only.

Application area for foam and residue compensation (smart level technology) with guide values

The media and conductivity values given here are only guide values and are for general orientation only. Basically all the media listed can be reliably detected. The differences are in the compensation ability for buildup, foaming and films when the level is falling. When in doubt, testing should be carried out, since factors such as temperature and media concentration can affect the conductivity values. Please contact us. Conductivity values for other media on request.

Industrial waste water (select the sensor according to conductivity of the medium)			
Disinfectants (media containing chlorine)			
Table salt solution			
Alcohol	Rinsing agents		
Marmalade	Milk/buttermilk/yogurt		
Demineralized water	Fruit juice		
Mineral oils	Coolant/lubricants	Ketchup/ mayonnaise/mustard	
Plant oils	Formic acid (30 %)	Phosphoric acid (10 %)	
Ammonia (30 %)	Vinegar	Sulfuric acid (10 %)	
Drinking water	Cola	Calcium chloride (30 %)	
Sugar solution, diluted	Honey/glue	Blood	Hydrochloric acid (40 %)
Toothpaste	Beer	Seawater	Nitric acid (12 %)

BCS Standard up to approx. 0.7 mS	Smart level technology 15 approx. 0.7...15 mS	Smart level technology 50 approx. 15...50 mS	Smart level technology 500+ approx. 50...500 mS and greater
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Application and setting examples for basic sensor types

Flush sensors

Normally, the rectilinear field of flush-mounted sensors scans objects from a distance. To ensure flawless switching of the sensor, the maximum switching distance must be checked before using the device. The following example applications show how you can do this.



Detecting solid bodies made of different materials

A flush mountable capacitive sensor will be used to detect a ceramic plate. The sensor is set to the maximum rated switching distance s_n of, for example, 4mm from metal or by approximation from your hand. With this preset distance of 4 mm, move the sensor towards the ceramic plate. The rated switching distance s_n to the ceramic plate has been reduced to approx. 2mm. The distance of 2 mm is now the maximum permissible switching distance for the ceramic plate. Only adjustment for smaller sensing distances than 2mm is permitted.

Attention! To ensure that our sensors work reliably within their technical specifications, they have a greater sensing distance than the maximum rated switching distance s_n indicated in the catalog. If the user now adjusts the switching distance for the above described ceramic plate to 4 mm, the sensor will operate outside the permitted range. This entails a risk that temperature and other environmental factors, plus electrical interference in the mains, may lead to faulty switching by the sensor.

Sensing levels through container walls

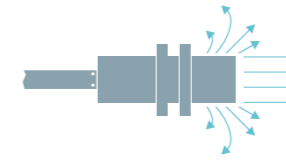
A flush mountable capacitive sensor will be used to detect a liquid, e.g. water, through the container wall. The dividing wall must be made of a non-conductive material, e.g. glass or plastic. The max. permissible wall thickness increases with the diameter of the sensing face: max. 4 mm (except SmartLevel technology).

The sensor's face (sensing surface) is now attached to the glass or plastic wall as tightly as possible. The tank is then filled with water until approx. 30 to 50% of the sensor's sensing surface is covered.

Particularly when small and ultra-small quantities of liquid are being scanned, and if the sensor has not been mounted in a form-fitting configuration (flat sensor surface on a tank wall with a small radius), 30 % should be chosen as a coverage area. Now turn the sensor's potentiometer counter-clockwise (less sensitivity) until it turns off (NO). Now turn the potentiometer clockwise again (greater sensitivity) until the LED and sensor turn on again. For modern versions with a teach function at 30-50 % coverage of the sensing face through the fill material hold down the key or placed a defined potential on the Teach line until the LED flashes (full teach).

Non-flush sensors

These capacitive sensors with their spherical electrical field are especially suited as level detectors for liquids, granulates or powders.



Sensing levels directly in the container

A non-flush mountable capacitive sensor will be used to detect a granulate in a tank. The sensor is now installed in the tank with its sensing surface (clear zone at the head as described in the catalog), in a configuration ensuring that the head is completely covered by the product.

Now turn the sensor's potentiometer counter-clockwise (lower sensitivity) until the LED, and thus the output signal, switch off. Now turn the potentiometer clockwise again (higher sensitivity) just enough until the LED, and thus the output signal, switch on again. Then turn the potentiometer another ½-turn (180°-rotation) clockwise. This compensates for possible temperature fluctuations or humidity changes in the product you are detecting. If a medium has a high ϵ_r , especially water, the sensor will react much more sensitively. Therefore the adjustment should be for around 50 % coverage or a sensor resp. immersion probe in the SmartLevel technology series should be used.

Detecting levels of conductive liquids directly in the container or through a container wall

Level sensors using SmartLevel technology detect liquid, conductive and even sticking liquids directly or indirectly through container walls. And they do it without adjustment using the factory default setting as long as the wall thickness does not exceed 6mm. For thicker walls or extremely conductive and adhering media the SmartLevel technology sensor can be adjusted.

Adjustment:

First install the sensor flush against the container wall. Bring level to 30...50 % coverage of the sensing face. Set the switching point on the potentiometer so that the sensor is just switching. For the new device generation with Teach key hold down or place a defined potential on the Teach line until the LED flashes.

Adjustment can also be made with a totally filled or empty container:

Full compensation: turn the potentiometer slowly counter-clockwise until the sensor turns off. Now slowly turn the potentiometer (with the sensor switched off) clockwise until the sensor turns on again. At the turn-on point then turn the potentiometer another half-turn (approx. 180°) clockwise and the SmartLevel sensor is adjusted.

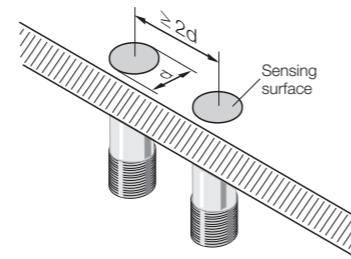
Empty compensation: Now slowly turn the potentiometer (with the sensor switched off) clockwise until the sensor turns on again. At the turn-on point the potentiometer only needs to be turned 3 times by approx. 360° counter-clockwise and the SmartLevel sensor is adjusted.

In essence the switching point for a SmartLevel sensor should be at 30-50 % coverage of the sensing face with the medium.

Installation guidelines

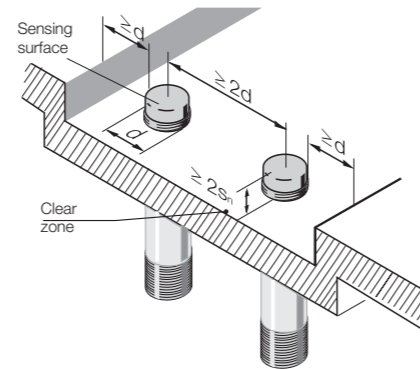
Flush-mount
Proximity switches

Flush mountable sensors can be installed with their sensing surface flush to the metal. The distance between two proximity switches (in row mounting) must be $\geq 2d$.



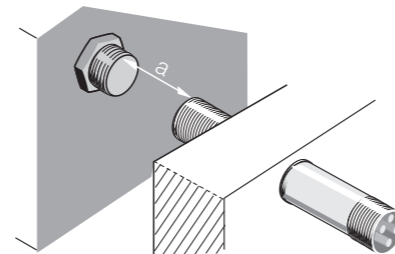
Non-flush mountable
proximity switches

The sensing surface must extend $\geq 2sn$ from the metallic installation medium. The distance between two proximity switches must be $\geq 2d$.

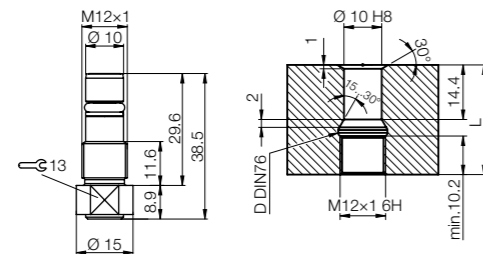


Opposing
Installation of two sensors

The opposing installation of two sensors requires a minimum distance of $a \geq 4d$ between the sensing surfaces.



Installation note for
high-temperature and
pressure-resistant
capacitive sensors



Installation and
mounting options

Mounting sensors for object detection

Central mounting in a drilled hole

- M5, M8, M12, M18, M30
- Simple, flexible fastening with two nuts
- Flexible positioning in the sensor axis



Through-holes in the sensor

- Standard mounting for cubical sensors
- Simple mounting through threaded hole
- Clear positioning when replacing



Threaded holes in the sensor

- Central hole with M3 thread
- Very easy installation
- Clear positioning when replacing



Clamping a cylindrical sensor

- Suitable for all cylindrical designs
- Simple, reliable fastening
- Very flexible positioning



Installation as a leak sensor

- Simple to install
- Clear positioning when fastening
- Use of sensors with a fixed switching distance



Installation of fill-level indicators

Flange mounting

- Pressure-tight screw connection
- Can be used in metal containers
- Installation in standard bushings is possible



Hole mounting

- Simple screw connection
- Can be used for every container material
- Not pressure-tight
- Suitable for powders and granules



Installation of cable ties

- Simple, subsequent fastening
- No contact with product necessary
- For non-metallic containers



Wall mounting

- Simple fastening
- For non-metallic containers
- No drilling of container
- No contamination of the medium



Headquarters
Balluff GmbH
Schurwaldstrasse 9
73765 Neuhausen a. d. F.
Germany



www.balluff.com/go/contact

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