Capacitive sensors

Introduction
Capacitive sensors can sense conducting and non-conducting materials in solid or liquid form. They have various uses including level control in tanks, as well as detection of container contents on filling and packaging machinery. Other uses include positioning and counting of materials within transportation and storage systems, for example conveyor belts, and steering mechanisms.

Typical materials which can be sensed:
Solids:
Wood, ceramic, glass, piles of paper, plastic, stone, rubber, ice, non-ferrous materials and vegetable matter.
Liquids:
Water, oil, glue and paint.
Granular:
Plastic granules, seed, feed and salt.
Powder:
Dyes, soap-powder, sand, cement, fertilizer, sugar, flour and coffee

Technical specifications
The function of a capacitive sensor is to signal a change of state based on the evaluation of the stimulus from an electrical field. Capacitive sensors detect metallic or non-metallic objects by measuring the change in capacitance, which is dependent upon the dielectric constant of the material being sensed, its mass, size and distance from the active surface of the sensor.

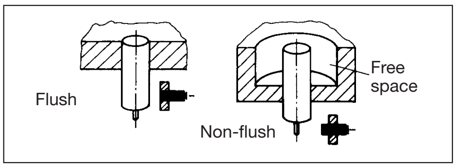
Capacitive sensors are built around an RC-oscillator. Due to the influence of the target and the change in capacitance, the amplification becomes stronger causing the oscillator to oscillate. The exact start of that function can be adjusted by means of a potentiometer, which controls the feedback to the oscillator. The sensing distance of a certain material can therefore be adjusted by the potentiometer. The output signal of the oscillator feeds another amplifier, which in turn feeds the signal to the output stage.

If a conductive target approaches the active face of the switch the target becomes a capacitor. The change in capacitance is significant resulting in a long sensing distance. If a non-conductive target approaches the switch (>1) there is only a small change in the dielectric constant and the rise in capacitance is quite small compared to conductive materials. Correction factors therefore have to be noted when comparing quoted sensing distances.

Correction factors	
Steel or other grounded metals	1.00
Surface of water	1.00
Steel 150 x 150 x 1 mm (5.9″ x 5.9″ x 0.03″) not grounded	0.85
Marble 150 x 150 x 12.5 mm (5.9″ x 5.9″ x 0.49″)	0.65
Glass 150 x 150 x 7.5 mm (5.9″ x 5.9″ x 0.29″)	0.55
Pile of paper (500 sheets)	0.55
Pressed wood 150 x 150 x 16 mm (5.9″ x 5.9″ x 0.62″)	0.45
Ceramic tile 150 x 150 x 6 mm (5.9″ x 5.9″ x 0.23″)	0.25
PVC 150 x 150 x 4 mm (5.9″ x 5.9″ x 0.15″)	0.15

The factors given are average values, as the sensing distance is influenced by individual features of the target and the environment in which the sensor is installed. In all applications, it is important to note the influence of humidity around the switch and target. High moisture content, in wood or paper for example, increases sensing distance.

Capacitive switches are available for:
– Flush mounting or shielded
– Non-flush mounting or non-shielded.



Around a non-flush mounting capacitive switch a free zone must be made available so no influencing material can affect the sensor. Because of the sensitivity control adjustment, non-flush capacitive sensors can be mounted in areas where the “Free Zone” is restricted. These sensors are less sensitive to dust or moisture in the atmosphere than flush-mounting sensors.

Flush-mounting sensors have an in-built shielding electrode, which is connected to earth. As both electrodes are very near to each other, the flush-mounting sensors are especially efficient in sensing different dielectrics. However, this makes them more prone to sensing dust or moisture in the atmosphere.

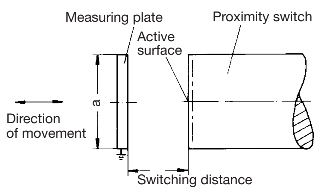
If capacitive sensors are mounted next or opposite to one another they can also influence each other. Flush mounting switches are much less sensitive in such applications than non-flush mounting. If the required sensing distance between sensors is >2 <8 times the housing diameter an application test is necessary. It is not necessary to test applications where the sensing distances between sensors is >8 times the housing diameter.

Specifications

Active-face
Active-face is the capacitive sensor's housing surface where the electrical field emerges. To ensure correct installation, cylindrical housings are mostly front sensing, while rectangular housings generally have the position marked with a line or a cross.

Actuation
To actuate means to bring the material in front of the active face of the capacitive sensor so that the output changes.

Standard targets
The standard target is square, 1 mm thick and made from steel (FE 360).



The Front face of the square target is identical to the diameter of the active face. If the sensing distance were three times greater than the diameter of the active face, the target would have to be this size. In order to ensure accurate sensing distances, the target needs to be grounded. The sensing distance of a rectangular capacitive sensor is aligned with a grounded plate the same size as the active face.

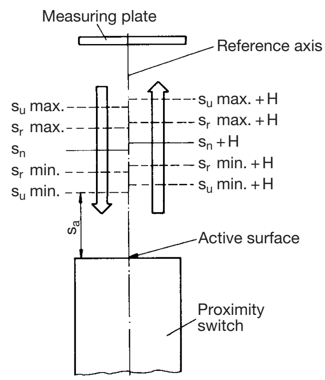
Real sensing distance
Real sensing distance is the distance between the target and the active-face when the sensor switches and gives a change in output, while mounted in a specific application.

Nominal sensing distance: s_n
Nominal sensing distance is the sensing distance shown without taking into account tolerances and influences from temperature or power supply.

Standardised sensing distance: s_r
Standardised sensing distance is the distance aligned at 23 °C +/– 5 °C. It has to be between 90% and 110% of the nominal sensing distance.

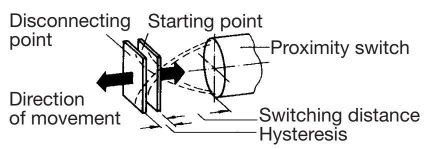
Effective sensing distance: s_n
This includes all tolerances of temperature and voltage supply. It has to be between 80% and 120% of the standardised sensing distance.

Usable sensing distance
(Working sensing distance). The usable sensing distance should be calculated for applications under the worst circumstances. This is calculated to be between 0-72% of the nominal sensing distance.

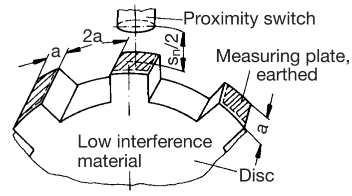


Repeatability
This is the accuracy between the first and second switching, within 8 hours of each other and with a temperature band of 18 °C to 28 °C. The maximum difference of the voltage supply may vary only by 5%. The difference between both measurements may not be more than 10% of the standardised sensing distance.

Hysteresis
This is the difference between the switch-on point when approaching the switch and the switch-off point when leaving the switch. The value is given as a percentage of the standardised sensing distance.



Switching frequency
The switching frequency is measured according to EN 60947-5-2. The standard targets with the side length "a" are mounted at intervals of 2 times "a" on a disc which does not influence the sensor when the disc starts rotating. If the on-off signal of the sensor is shorter than 50 ms the maximum switching frequency of the sensor is reached. For AC sensors the maximum switching frequency of the sensor is reached when the on-off time equals half one sine wave.



Temperature range
The temperature range for sensors is measured according to the EN-DIN at –25 °C to +75 °C. In this range the sensors will work with a tolerance of +10%.

Protection class
IP 65
IP 67

Cable
The standard cable has PVC insulation. Silicon cable, Polyurethane cable, special stabilised PVC- or PTFE-cable is available upon request.

Plug and socket
For electronic products today the plug and socket are just as important as the cable. The Bernstein capacitive proximity switch es are available with several plug and socket variations.

Standards
All sensors are in accordance with EN 60947-5,2.

CE

The way to the right sensor

Using the selection matrix

To assist the user in selecting the right capacitive sensor for their application, Bernstein developed the selection matrix below.
The colours of the individual fields match those in the product index to allow rapid selection of the most suitable sensor (by part number) starting with the most important criteria, switching distance. By not using detailed technical descriptions the selection is considerably simplified, but our engineers are always available to answer any technical questions.

Important notes

Capacitive sensors are able to sense conducting and non-conducting materials in solid, liquid, granular or powder form. In operation however, a number of criteria must be taken into account.

Switching distance
The rated switching distance is shown (according to DIN EN 6947-5-2/97) and adjusted on site. The greatest switching distance is reached with an approaching conducting target of a certain size.
With a non-conducting material, knowledge of the specific inductive capacity of the target is important as the switching distance will vary by a factor dependent on material and application (see fig. 1 and 2).

The factors indicated in the table show an expected approximation of the reacting sensitivity, since specific characteristics of the target objects (especially cross section, thickness and moisture content) and the surrounding area (earthing) have a major influence on the sensing distance.
Compensation for most applications can be made by adjustment of the built-in potentiometer.

Free zone
Non-flush mounting capacitive sensors are less sensitive to dust or condensation than flush mounting versions, but a free zone must be established around the sensor, clear of materials that could influence it.

Selection matrix – capacitive sensors

Rated sensing distance	Housing metal/plastic	Mounting	Supply	Output	Switching	Connection
2 mm 4 mm	M12 M M12 K	flush mounted non-flush mounted	10 - 36 V DC	NPN 3L, PNP 3L	N.C., N.O.	plug M8, cable 2 m
5 mm 8 mm	M18 M M18 K	flush mounted non-flush mounted	10 - 60 V DC 10 - 60 V DC, 20 - 250 V AC	NPN 3L, PNP 3L NPN 3L, PNP 3L, AC 2L	N.C., N.O.	plug M8 M12, cable 2 m
10 mm 20 mm	M30 M M30 K	flush mounted non-flush mounted	10 - 60 V DC 10 - 60 V DC, 20 - 250 V AC	NPN 3L, PNP 3L NPN 3L, PNP 3L, AC 2L	N.C., N.O.	plug M12, cable 2 m
15 mm 30 mm	M32 M M32 K	flush mounted non-flush mounted	10 - 60 V DC	NPN/PNP prog. 3L NPN/PNP prog. 3L, AC 2L	Complementary prog., N.O./N.C. prog.	plug M12, cable 2 m
15 mm	Ø 20 K	non-flush mounted	10 - 60 V DC, 20 - 250 V AC	NPN 3L, PNP 3L, AC 2L	N.C., N.O.	plug M12, cable 2 m
20 mm 30 mm	Ø 34 M Ø 34 K	flush mounted non-flush mounted	10 - 36 V DC 10 - 60 V DC, 20 - 250 V AC	PNP 3L NPN 3L, PNP 3L, AC 2L	N.C., N.O.	plug M12, cable 2 m
8 mm	E 50 50 x 25 x 10 mm P	flush mounted	10 - 36 V DC	NPN 3L, PNP 3L	N.C. on request, N.O.	cable 2 m
10 mm	E 68 68 x 30 x 15 mm P	flush mounted	10 - 36 V DC	PNP 3L, PNP 3L	N.C. on request, N.O.	cable 2 m
15 mm 30 mm	N 44 40 x 40 x 120 mm P	flush mounted non-flush mounted	10 - 60 V DC	NPN/PNP prog. 3L	N.C./N.O. prog.	Terminal chamber

Flush mounting capacitive sensors have, by design, higher sensitivity to a variety of materials, so care must be taken to ensure the sensing face is kept free of contamination by dust or moisture.
If capacitive sensors are mounted within a distance of 2 - 8 housing diameters of one another, they can influence each other and testing under real conditions is strongly recommended. The aforementioned adjustment capability however, allows a solution to be found for virtually every application.

Glass	3…14
Rubber	2.5…3
Hard paper	3.5…6
Wood	2.5…6.8
Marble	8.4…14
Mineral oil	2.15
Epoxy resin	3.3…3.6
Petroleum	2.2
Plexiglas	3.6
Polyamid	3…8
PVC	3.3…4.1
China	4.2…6.5
Teflon PTFE	2
Air	1
Water	80.8
Paper (dry)	2

Fig. 1 Dielectric Factor

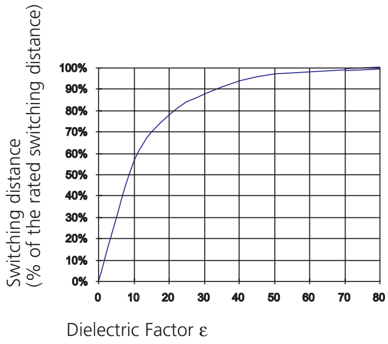
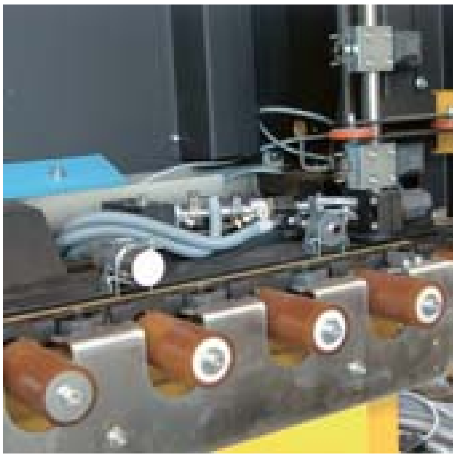


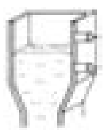
Fig. 2 Variation of the switching distance depending on Dielectric Factor ε

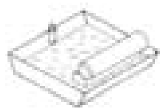
Applications

Capacitive proximity sensors are particularly useful for sensing fill levels through non-metallic container walls.
Advantage:
The container wall does not have to be breached and the sensed material will not come in contact with the sensor. A requirement for this application is that the Dielectric Factor of the target material is higher than that of the container. Using the potentiometer the sensitivity of the sensor is reduced until it responds to the target medium but not the container wall.
See below for further applications.

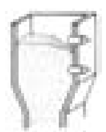



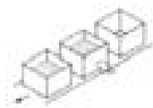
Top: insulating glass-production line fitted with Bernstein capacitive sensors

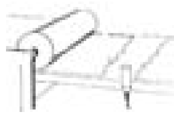

Level monitoring through non-metallic containers

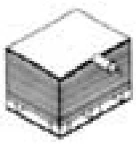

Level control in paint and glue containers

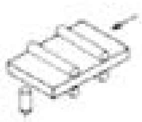

Detection at wood processing


Level control for granulate or feed hoppers


Registration, counting, sorting or control of conveyor belt systems


Tear sensing


Pallet height sensing e.g. paper


Position sensing in continuous processing


Level control in cardboard packaging