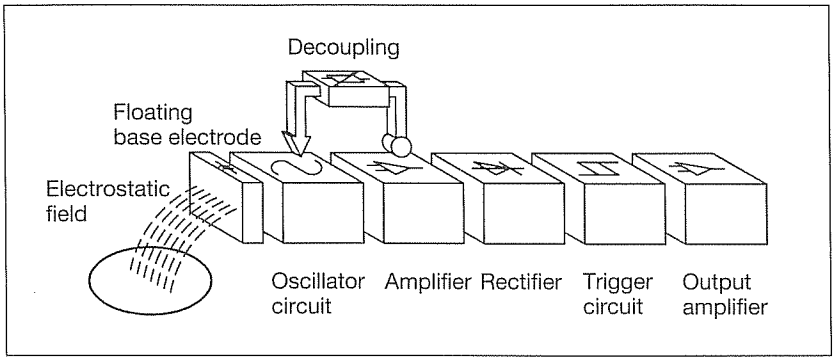
Technical Description

Proximity switches are employed in any place where fast, maintenance-free, wear-resistant detection of objects is requested. These are typical and increasingly important requirements in all automation processes.

Without physical contact and independent of form, capacitive proximity switches detect all ferrous and non-ferrous metallic objects within their active zone and give out a corresponding control signal. Furthermore, capacitive proximity switches detect non-metallic substances such as water, glass, plastics, paper, wood etc.

Block diagram



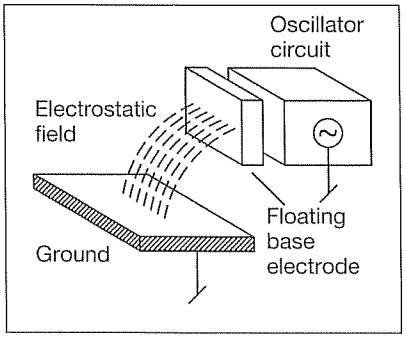
Characteristic features of proximity switches:

- Maintenance-free and wear-resistant
- No physical contact
- Contactless, hence bounce-free
- High operating frequencies
- Installable in any position
- Lifetime independent of operating frequency
- Insensitive to vibrations
- Insensitive to dirt collection
- Waterproof

Capacitive Proximity Switches

The operating principle of capacitive proximity switches is based on a damped RC oscillator with a floating base electrode (an open capacitor with only one electrode).

Physical principle



The active zone is the electrostatic field generated by the oscillator circuit in front of the base electrode. The interference by an object brought into the active zone causes oscillation to begin.

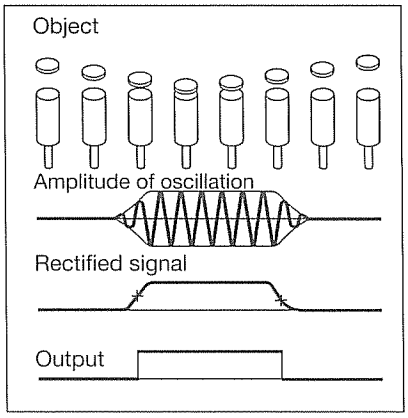
The oscillations are decoupled and rectified, and the trigger circuit subsequently detects a certain current level and drives the output stage. The decoupling stage also generates a negative feedback signal, which opposes the starting up of oscillation.

The potentiometer allows adjustment of the negative feedback and in this way determines the sensitivity of the capacitive proximity switch.

The electrostatic field can be influenced in 3 different ways:

Non-conductive materials (plastics, glass etc.) will change the dielectric characteristics of the active zone and cause oscillation to begin. Size, density and the dielectric constant of the material affect the oscillation capability/amplitude directly. The following principle is valid: The bigger the size, the higher the density

Operating principle



and dielectric constant, the better the oscillation capability, and consequently, the longer the sensing distance.

However, the effect on the electrostatic field produced by a non-conductive material is generally marginal, and consequently, the practical sensing distances are also relatively short.

Ungrounded, conductive materials change not only the dielectric characteristic of the active zone, but also cause interference in the electrostatic field. This interference has more influence on the oscillation capability than the mere change of the dielectric characteristic, thereby allowing longer sensing distances.

Grounded, conductive materials allow the longest possible sensing distances, since they have the most influence on the electrostatic field and the dielectric characteristic.

The 3 above-mentioned principles of interference of the electrostatic field usually all occur in applications simultaneously. It is therefore impossible to define the exact sensing distance of a capacitive proximity switch without knowledge of all the conditions pertaining to the application: composition of the material to be detected and ambient conditions such as temperature, humidity, dust etc.

The sensitivity adjustment potentiometer allows the adaptation to different applications in order to find the correct sensing distance. The working point should not be fixed at the highest sensitivity setting, since the noise immunity is lowest at this setting.
To define the nominal sensing distance a grounded St 37 steel plate is used whose size depends on the type of proximity switch. For other materials, the sensing distance is reduced on the basis of a reduction factor. Refer to "Reduction Factors".

Capacitive proximity switches are mainly used in automation processes for presence and level detection of fluids, powder, granules, pellets and solids. Refer to "Typical Applications".

Standards Used

Carlo Gavazzi's proximity switches are designed according to existing standards. Specifications for which no standard exists, similar or comparable methods or values are used.

IEC 60947-5-2
Low-voltage switchgear and controlgear.

EN 50 008
Euronorm for proximity switches in cylindrical housings, 3- and 4-wire DC power supply.

EN 50 010
Euronorm defining methods of measuring sensing distance and operating frequency of proximity switches, AC and DC power supply.

EN 50 032
Euronorm for definitions, classifications and designations of proximity switches.

EN 50 036
Euronorm for proximity switches in cylindrical housings, AC 2-wire power supply.

EN 50 044
Euronorm defining the colour of wires/pin allocation.

IEC 60529/DIN 40050
IEC publication on degree of protection, IP.

IEC 60068-2-32

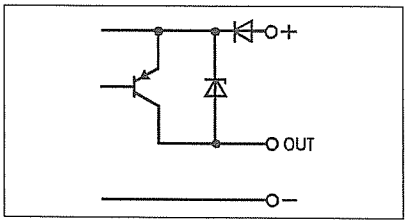
Packaging:	Separately.
Material:	Plastic bags.
Size:	Depends on sensor.
Protection during transport:	According to IEC 60068-2-32. Free fall: 1 m.

Nema
US publication on degree of protection.

Wiring Diagrams

PNP-type Proximity Switches

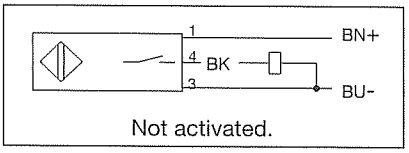
Diagram 3-wire types



Common Data

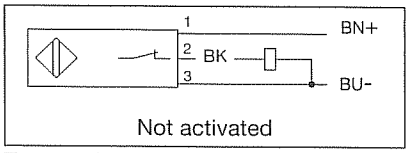
Rated operational voltage (U_B):	10 to 40 VDC, 10% ripple incl.
Rated operational current:	≤ 200 mA
Current consumption:	≤ 9 mA
Voltage drop:	≤ 2.5 VDC
Ambient temperature:	-25° to + 70°C (-13° to+158°)

DC 3-wire - normally open (NO)



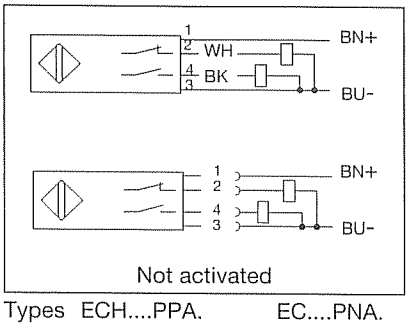
Types EC .... PPO. EC .... PNO.
ACF 10 PPO DR..PPO

DC 3-wire - normally closed (NC)



Types EC .... PNC.

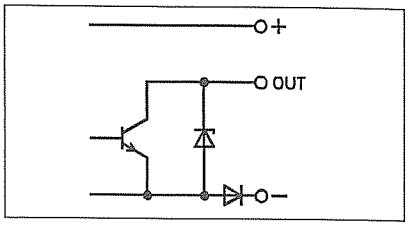
DC 4-wire - complementary output



Types ECH....PPA. EC....PNA.

NPN-type Proximity Switches

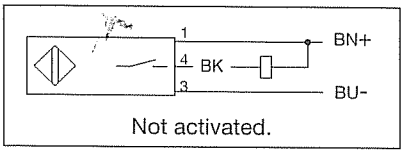
Diagram 3-wire types



Common Data

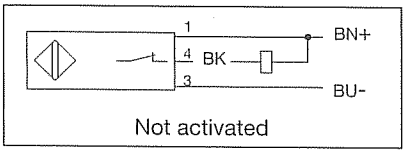
Rated operational voltage (U_B):	10 to 40 VDC, 10% ripple incl.
Rated operational current:	≤ 200 mA
No-load supply current:	≤ 9 mA
Voltage drop:	≤ 2.5 VDC
Ambient temperature:	-25° to +75°C (-13° to+158°F)

DC 3-wire - normally open (NO)



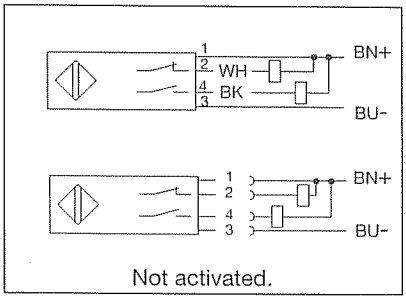
Types EC .... NPO. EC .... NNO.
ACF 10 NPO DR.E
DR.GE DR..NPO

DC 3-wire - normally closed (NC)



Types EC .... NNC.

DC 4-wire - complementary output

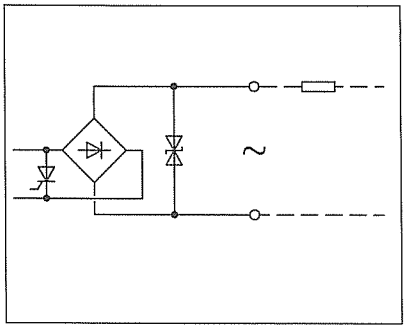


Types EC....NNA. ECH....NPA.

Wiring Diagrams (cont.)

AC Proximity Switches

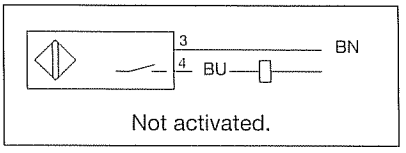
Diagram 2-wire types



Common Data

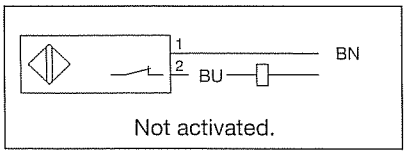
Rated operational voltage (U_B):	20 to 250 VAC
Supply frequency:	50 to 60 Hz
Rated operational current:	500 mA
Short-time current:	2.5 A@ 20 ms
OFF-state current:	≤ 3 mA
Voltage drop:	≤ 10 V
Ambient temperature:	-25° to +70°C (-13° to+158°F)

AC 2-wire - normally open (NO)



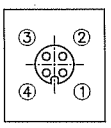
Types EC .... TBO.

AC 2-wire - normally closed (NC)

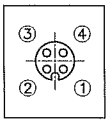


Types EC .... TBC. DR..TI

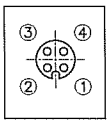
Pin configuration for connector



2-wire
Connector number
1 NC (+) (BN)
2 NC (-) (BL)
3 NO (+) (BN)
4 NO (-) (BL)
CONB1A.◊
CONB2A.◊



3-wire
Wire colours
1 + (BN)
2 Signal NC (WH)
3 - (BU)
4 Signal NO (BK)
CONL10-A◊
CONL10-S◊
CONL5A-A◊
CONL5A-S◊



4-wire
Wire colours
1 + (BN)
2 Signal NC (WH)
3 - (BU)
4 Signal NO (BK)
CONL1A-A◊
CONL1A-S◊

Reduction Factors

Reduction Factors for Capacitive Proximity Switches

The use of materials other than grounded St 37 causes a reduction of the rated operating distance.

Most important reduction factors for capacitive proximity switches:

Iron, grounded
1.0
Wheat (moisture cont. 12%)
0.8
Barley (moisture cont. 15%)
0.6
Oats (moisture cont. 15%)
0.5
Ensilage pellets
0.5

Note: When the test plate is made of materials other than St 37, this will result in deviations from the assured operating distance. Refer to "Reduction Factors".

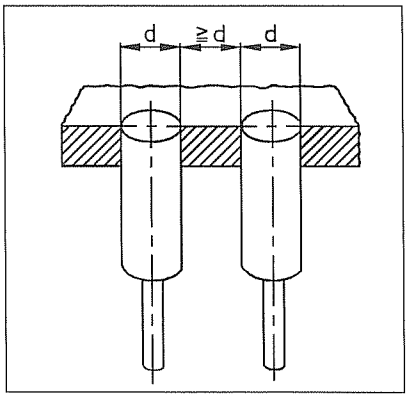
Effective operating distance (S_r):
Sensing range taking manufacturing tolerances into account.

$$0.9\ S_n \le S_r \le 1.1\ S_n$$

Flush mounting:
A proximity switch is for flush mounting if the metal surrounding the active zone does not affect the characteristic values of the switch.

In order to avoid interference a space corresponding to the diameter of the switch should be allowed between adjacent switches.

Flush mounting

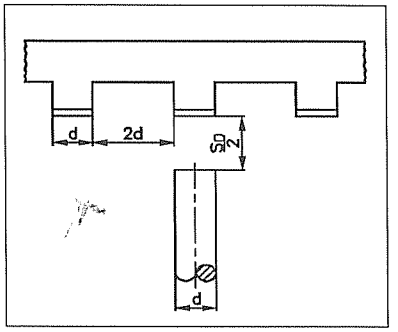


Free zone:
Area surrounding the proximity switch from which materials apt to influence the characteristics of the proximity switch must be kept out.

Frequency of operating cycles:
The highest possible number of switchings per second based on a ratio of 1:2 between operating time and idle time.

The drawing illustrates how to determine the operating frequency according to EN 50 010/IEC 60947-5-2.

Frequency measuring method



Frequency of operating cycles is found in the following way:

$$f = 1 / (t1 + t2)$$

when t1 or t2 reaches the value of 50 µs, or the signal value decreases to 90% of the initial value.

Terms Used

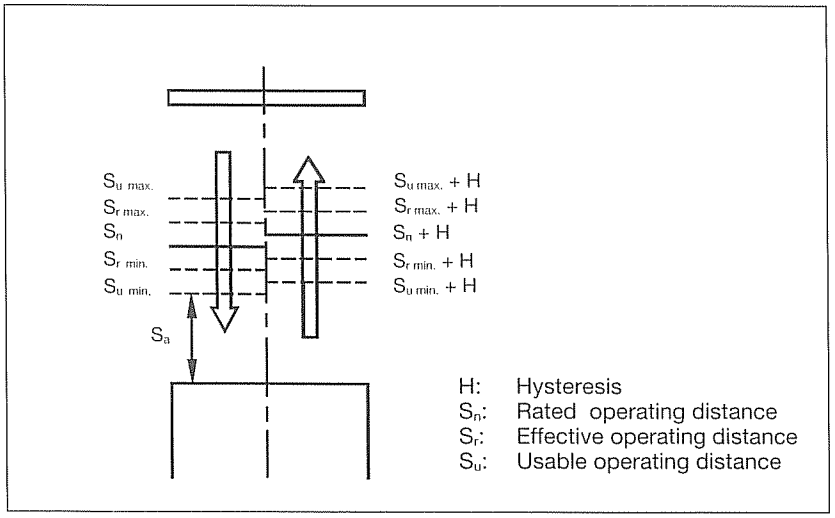
General
Use terms from norm IEC 60947-5-2

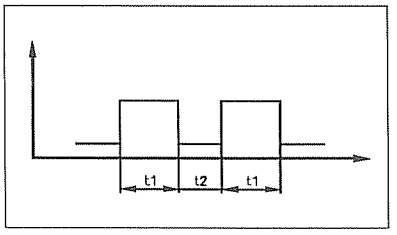
Activating switching zone
Zone in which a detectable object wil activate the proximity switch.

Assured operating distance (S_a):
Sensing range at which the safe operation of the proximity switch is guaranteed under specified temperature and voltage conditions.

$$0 \le S_a \le 0.81\ S_n$$

Sensing distance for proximity switches

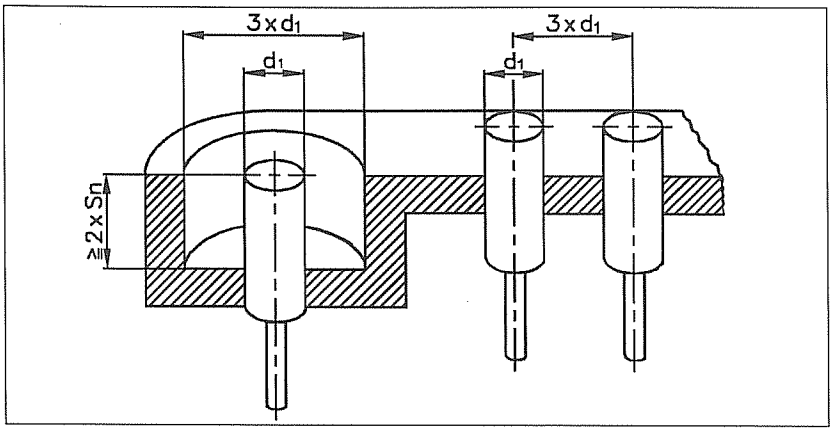




Hysteresis (H)
(differential travel):
The difference between the switching points when the test plate approaches and moves away from the active zone.

Terms Used (cont.)

Non-flush mounting



Non-flush mounting:
A proximity switch is for non-flush mounting when a free zone is needed in order to maintain the characteristic values of the switch. For switches installed opposite each other a minimum space of 6 x the nominal sensing distance must be observed.

Rated operating distance (S_n):
Type-specific characteristic disregarding manufacturing tolerances and influence by external factors such as temperature and voltage.

Repeat accuracy (R):
The percentage with which the effective sensing distance may vary. Measured on one sensor with all conditions kept constant.

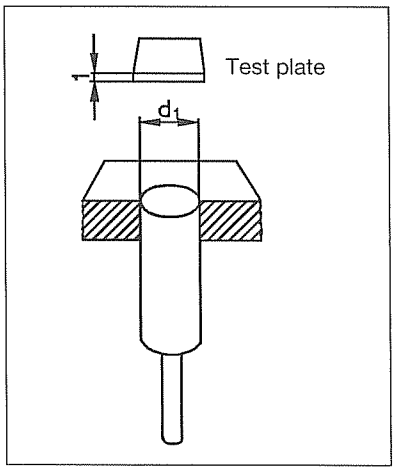
Standard test plate/
Measuring of sensing distance:
A standard test plate made of St 37 mild steel is used for measuring sensing distances. The characteristic values of the standard test plate are defined in EN 50 010/IEC 60947-5-2.

Temperature drift:
Deviation from the effective sensing distance caused by variations in ambient temperature within the range of -25° to +70 °C, all other factors being kept constant.

Usable operating distance (S_u):
Sensing range measured under different temperature and voltage conditions.

$$0.9\ S_r \leq S_u \leq 1.1\ S_r$$

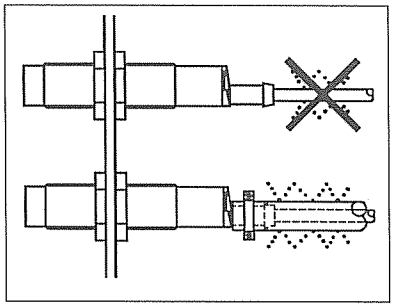
Distance measuring method



Mechanical

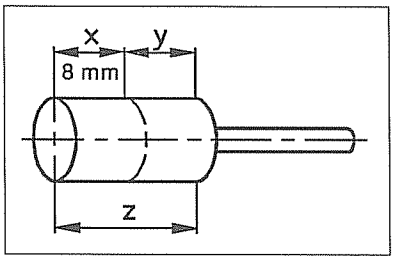
Protection tube:
In extreme environments the cable of the proximity switch should be protected against mechanical damage:

Protection of cables

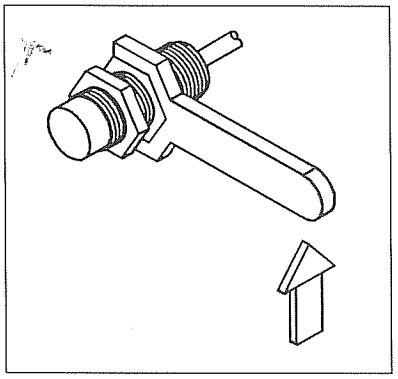


Tightening torque:

	Plastic	Metal	
M 5	-	z:	2.5 Nm
M 8	-	x:	3.0 Nm
		y:	7.0 Nm
M 12	1.8 Nm	x:	7.5 Nm
		y:	17.5 Nm
M 18	2.6 Nm	z:	27.5 Nm
M30	7.5 Nm	z:	120.0 Nm



Tightening of proximity switches



In order to prevent damage the stated tightening torques must be observed.

Terms Used (cont.)

Electrical

Activated proximity switch:
When a detectable object is in the active zone.

Complementary output function:
Incorporates both NO and NC functions.

Current consumption 2-wire AC types (leakage current):
The current consumption when the proximity switch output is open. In 2-wire AC types the current consumption is equal to the leakage current.

Degree of protection according to DIN 40 050 (IEC 529):
IP 67: Degree of protection IP 67 means that the proximity switch is dust- and watertight. The test implies immersion in water having the same temperature as the test unit with the unit remaining 1m below the water surface for 30 min. The corresponding Nema degrees are: 1, 3, 4, 6, 13.

Lamp load:
Standard output stages may be exposed to a lamp load. The starting current of the lamp when it is cold can lead to activation of the short circuit protection.

LED-indication:
The LED is ON when the proximity switch output is ON.

Max. rated operational current ($I_{e\ max}$):
The max. allowable current which the proximity switch can withstand under continuous operation.

Min. rated operational current ($I_{e\ min}$): 2-wire:
The smallest current which must flow when the proximity switch is activated in order to ensure reliable operation.

No-load supply current (I_o): 2-wire:
The current consumption measured when the output is open.

OFF-state current (I_r): 2-wire:
Current flowing in the semiconductor output when the output is open.

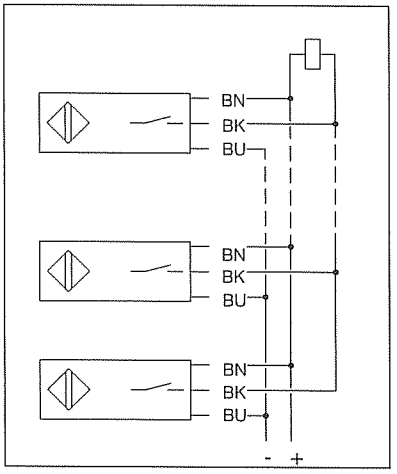
Output function break switching (NC):
The circuit is closed in the non-activated state and open in the activated state.

Output function make switching (NO):
The circuit is closed in the activated state and open in the non-activated state.

Output resistance:
The internal resistance of the sensor seen from the output.

Parallel connection of DC 3-wire:
Depending upon the load, up to approx. 25 DC proximity switches can be connected in parallel.

NPN parallel connection



Peak voltage:
I.e. the peak value of the sinus curve, is the maximum voltage which may be applied without the risk of damaging the proximity switch.

Power ON delay:
The time delay between connection of supply voltage and the ready-for-operation condition of the proximity switch.

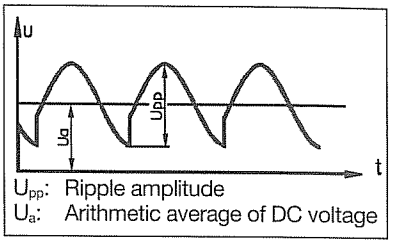
Rated operational voltage (U_B):
The voltage range within which function of the proximity switch is guaranteed.

Rated operational voltage (U_e):
The voltage range for which the proximity switch is intended.

Reverse polarity protection:
This feature ensures that the proximity switch is not damaged by reverse connection of the supply.

Ripple:
The peak-to-peak value of an AC-voltage (U_{pp}) on top of the DC-voltage (U_a).

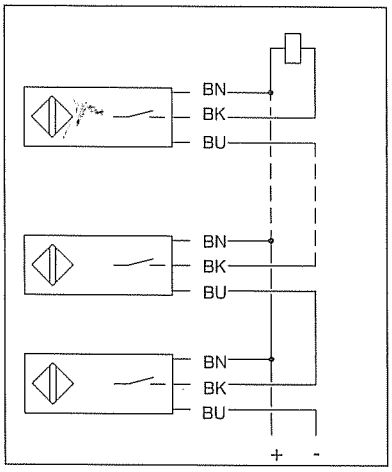
Ripple amplitude (U_{pp})



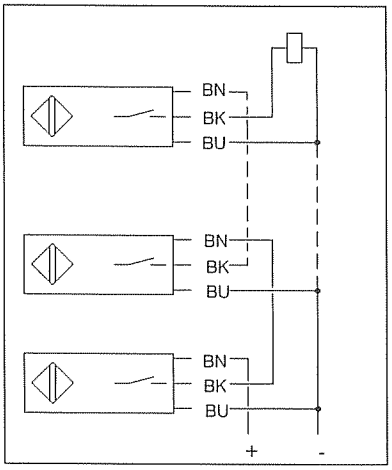
U_{pp}: Ripple amplitude
U_a: Arithmetic average of DC voltage

Series connection of DC 3-wire:
The type-specific delay before availability can result in a delayed reaction time. It is possible to connect proximity switches and mechanical contacts. The maximum number of proximity switches to be connected in this way is determined by the voltage drop and the required supply voltage.

NPN series connection



PNP series connection



Terms Used (cont.)

Short-circuit protection (= switching mode short-circuit):
Prevents damage to the proximity switch through short-circuit of load.

Protection of the proximity switch is ensured by an electronic circuit which in the case of short-circuit causes the output transistor to rapidly switch off/on by measuring either current or temperature.

Short-time current:
The max. current allowed to flow for a limited period at a specific operating frequency.

Switch-ON impulse suppression AC-Types:
Carlo Gavazzi's proximity switches feature suppression of a false output signal when the supply voltage is applied.

Transient voltage:
The max. voltage pulse of specified duration which the proximity switch can withstand.

Voltage drop (U_d):
Voltage measured across the active output at rated operational current. When prolonging the cable, the voltage drop is increased by the value of

$$\frac{2 \times \rho \times l \times I}{a}$$

ρ = 0.01725 for copper wire
l = Length of cable (in meters)
I = Output current (in Amps)
a = Crosssection of wire (in mm^2)

Wiring Colours

according to EN 50044

BK = black
BU = blue
BN = brown
BE = beige
WH= white
YE = yellow

Black is used to indicate output when there is only one output.
Blue indicates -
Brown indicates +

In the case of 4-wire switches, black is used to indicate the NO output and white the NC output.

Beige and yellow are used for proximity switches with relay output.

Materials

Housing:
Plastics: thermoplastic polyester - resistant to oil.

Metal: nickel-plated brass - stainless steel 1.4301 (DIN norm) or stainless steel 304 (ASTM).

Cable:
PVC - resistant to oil according to VDE 0472, part 803 B (at temperatures below - 5°C the cable must not be bent).

Min. bending radius: Min. 15 x outer diameter.

PUR - resistant to oil according to harmonised document HD 505.2.1, part 10.

Min. bending radium: Min. 10 x outer diameter.

Connector:
Thermoplastic polyester.

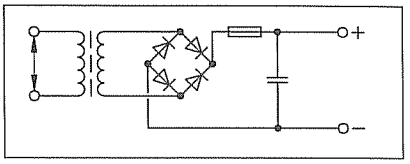
Power Supply Suggestions

Carlo Gavazzi's power supply unit SS 130 ... 24 for instance has been built in the following way:

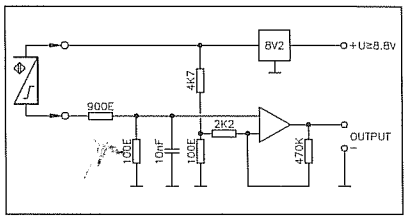
Filtered secondary voltage at no-load operation 28 V~.

Filtered secondary voltage at full-load operation (300 mA) 19 V~.

DC



Switching with OP-amplifier



N.B. When proximity switches are applied outdoors and consequently exposed to heavy rain and strong sunlight, it is recommended to mount a protective cover in order to ensure that the max. operating temperature is not exceeded.

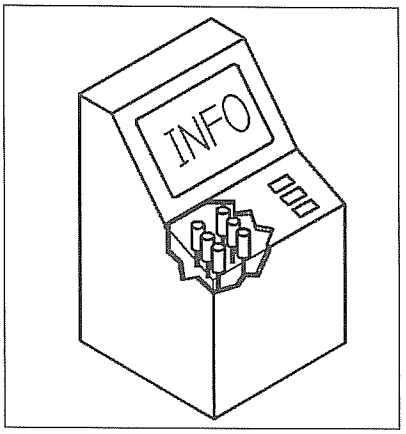
Parameters relating to application environment.

Temperature: When the specified temperature ranges are not observed, reliable operation cannot be guaranteed, and permanent damage may occur.

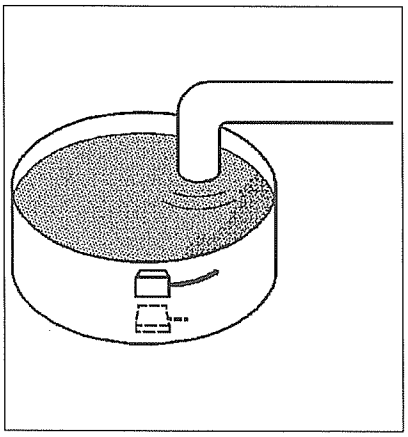
Chemical environment: Due to the wide range of chemicals used in modern industry it is very difficult to provide general guidelines for the application of switches. In cases where chemical attack could present a danger, please consult your sales office stating the model and the chemical(s) in question.

N.B.: To ensure operational reliability the switch should never be moved away from its original adjustment position fixing its sensing distance. The sensing distance should be carefully adjusted during installation. Adjustment is performed by means of a movable support bracket. By following this procedure the use of switch fixings for adjustment purposes is avoided.

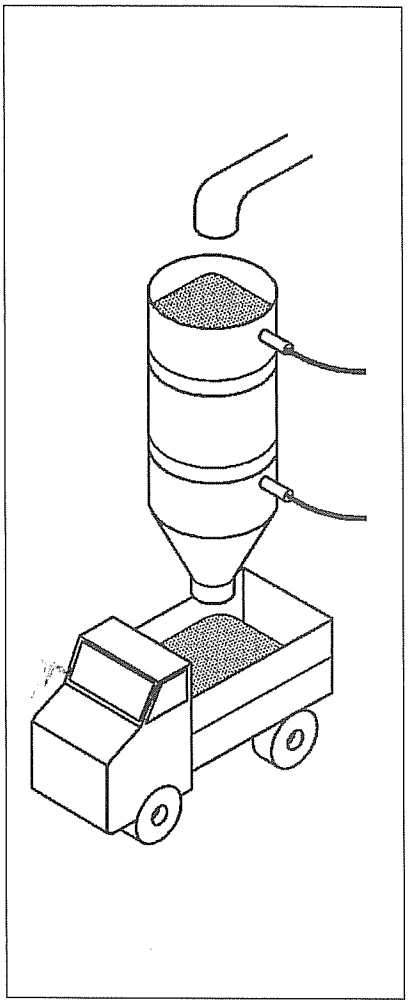
Typical Applications



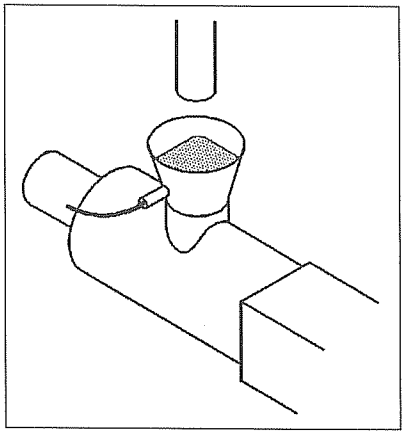
Capacitive proximity switches used as touchless push buttons.
EC/CA series.



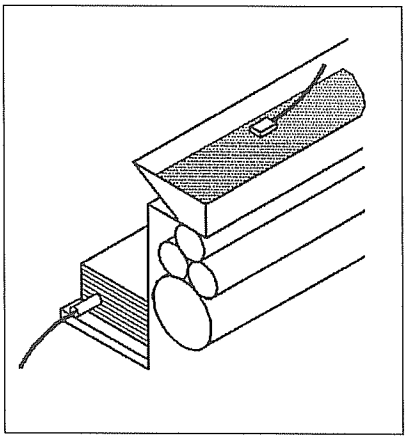
Liquid level detection through container wall with capacitive proximity switches.
EC 55 series.



Granulate level detection through silo wall with capacitive proximity switches.
EC/CA series.



Granulate level detection with capacitive proximity switches in the plastics industry.
EC/CA series.



Paper and ink detection with capacitive proximity switches in the printing industry.
EC/CA series.

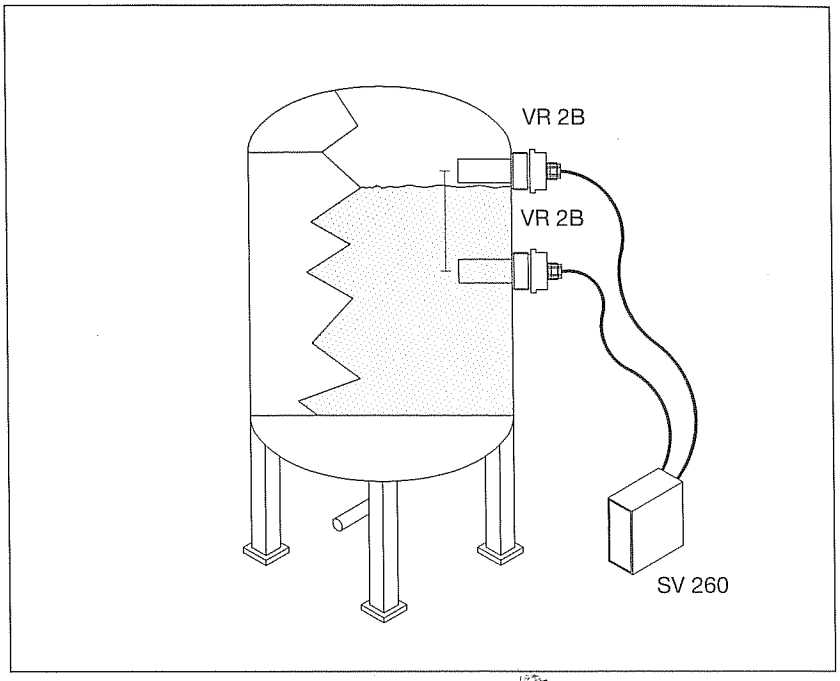
Typical Applications (cont.)

Capacitive level control

Max./min. control of non-conductive liquids, granules, solids; the chemical industry (paint), agriculture (grain), cement works (cement powder).

With capacitive sensors it does not make any difference whether the container is of conductive or non-conductive material. It should be noted that not all capacitive sensors can be flush-mounted. In the case of non-conductive containers, some sensors are able to detect the level through the container wall if the wall is thin.

The example shows detection of two levels with two **VR 2B** sensors and **SV 260** amplifier.

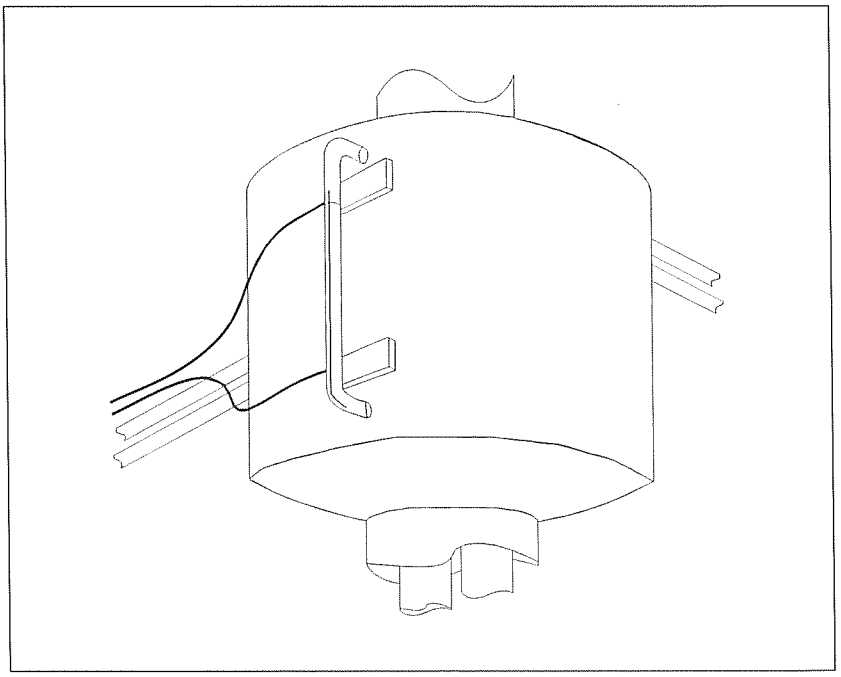


Application no. 1

Capacitive level control

In some instances, certain chemicals will attack sensor housings.

In the application shown, two **EC 55 Flat Pack** sensors detect through a sight glass and control high and low levels of a tank full of chemicals.



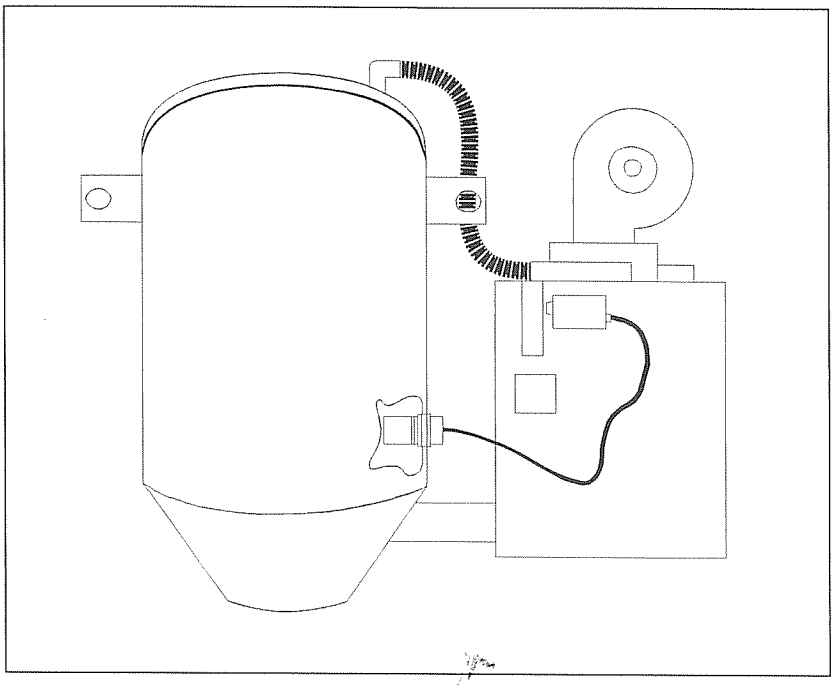
Application no. 2

Typical Applications (cont.)

Capacitive level control

The **ECH** Series can detect material as hot as 180°C (356°F) or as cold as -180°C (-292°F).

In the example shown, the sensor is monitoring a plastic pellet drying hopper, and the amplifier is located at a more "comfortable" location.

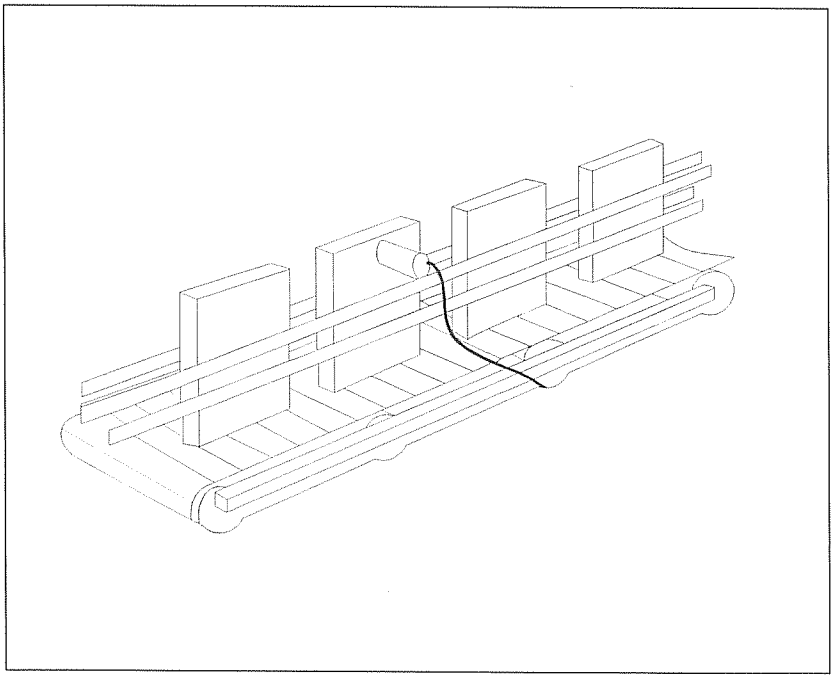


Application no. 3

Capacitive level control

For many years customers have used Carlo Gavazzi's Proximity Sensors to detect inside of a box or container, making sure that there is the proper amount of material inside.

The application shown is using the **EC 3015** for detecting powdered cake mix. Other detectable materials include: powdered milk, soup or noodle mixes, jellies and jam, spices and many more.



Application no. 4