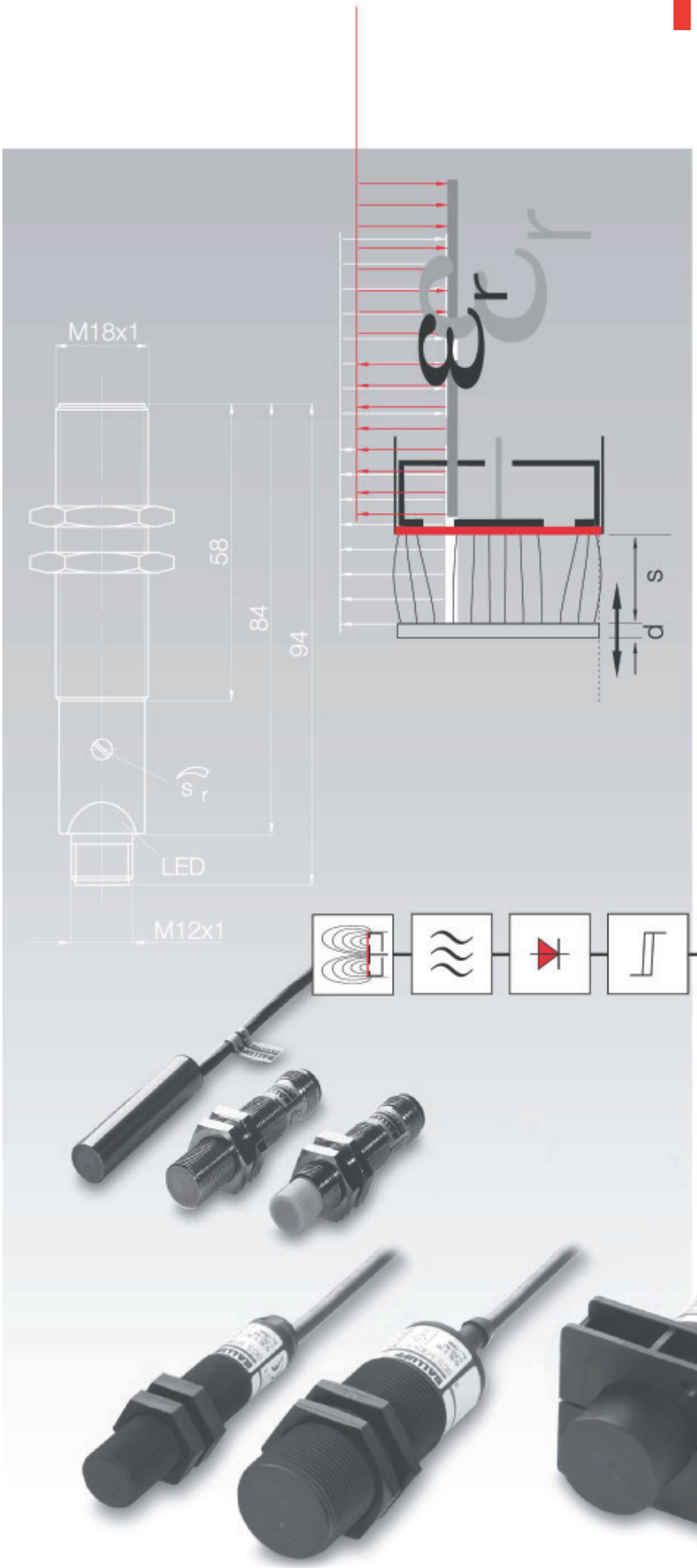
Capacitive Sensors



Capacitive sensors detect the change in capacitance caused by the approach of an object. Their advantage lies in the ability to detect virtually any material, from metals to oils.

4

- Non-contacting
- Wear-free
- Non-interfering
- LED function indicator
- Detects virtually any material
- Detects objects through many other non-metallic materials
- Detects aqueous media

A capacitor

... in its traditional form consists of two electrode plates and a dielectric, with a non- or poorly conducting medium in between. **Capacitance C** = ε **(A/d)** is determined by **surface A**, **distance d**, and the **dielectric constant ε = ($\varepsilon_0 \times \varepsilon_r$).**

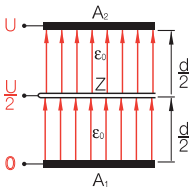
ε describes the dielectric constant of this medium.

ε_0 is the absolute dielectric constant of the empty space (vacuum).

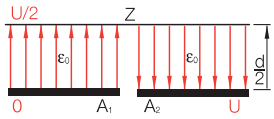
ε_r is the dielectric number, a (density dependent) material constant.

The sensor electrode

... and its effect can be explained using a step-by-step derivation of its geometric shape. The stray fields at the edges of the plates can be ignored for these purposes.
In the middle, between the two circular capacitor plates A_1 and A_2 at distance d/2,

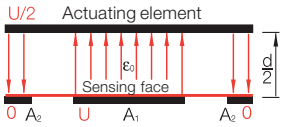


is an additional, highly conducting, folded "intermediary electrode" Z having thickness D → 0.
A voltage applied generates an electrical field between A_1 and A_2. This impresses voltage U/2 in electrode Z. The "intermediate electrode" thereby assumes the function of an additional capacitor plate. This has the effect of changing the capacitor into two geometrically and electrically series-connected capacitors. If these partial capacitors are unfolded, plates A_1 and A_2 lie next to each other in a plane and the "intermediate" electrode in a second plane at distance d/2.
This results in an "open" capacitor. The fields in the capacitor halves run in opposite directions.



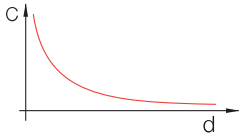
In capacitive sensors

... this „open" capacitor is used as a sensor element. The plate A_2, however, is configured as a ring electrode (housing) concentric to A_1 in order to make the electrical field symmetrical, and the „intermediate electrode" is the „actuation element". The „sensing face" of this sensor element corresponds to ring electrode A_2.



The formula for capacitance remains – with the above defined premises – valid even for this capacitor geometry.

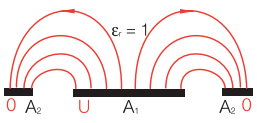
Capacitance C as a function of the distance still decreases hyperbolically (as 1/d).



Non-conducting materials

... (Plastics, glass as well as liquids) can be detected by capacitive sensors, if ε_ρ is significantly greater than ε_0; The preceding is based on the fact that for the lines of field, the path of least resistance leads across the actuation element. If the actuation element (d → ∞; ε_r = 1, C → 0) is absent, they run in an arc from the middle to the ring electrode.The path of least resistance is determined by the repelling effect of field lines oriented in the same direction.

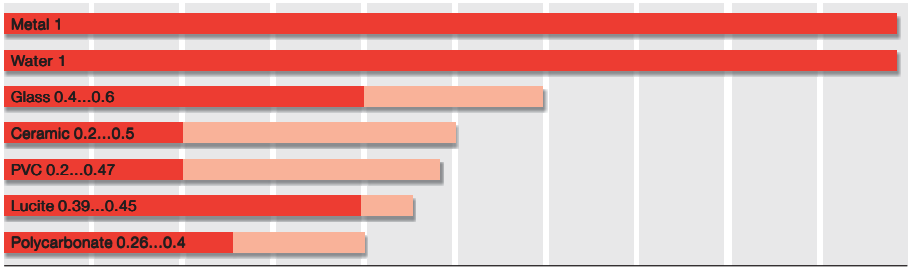
The arcs and their distances thus become larger towards the outside.



Conditions 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 face“. Since the rated switching distance s_n is based on a grounded standard target made of Fe 360, the switching distances must be corrected when using other materials.

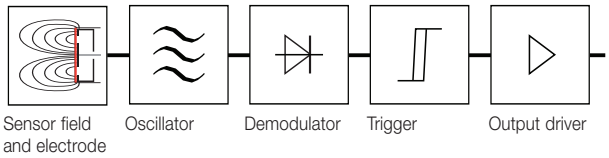
Correction factors for typical materials



Correction factors should be determined using the target material directly.

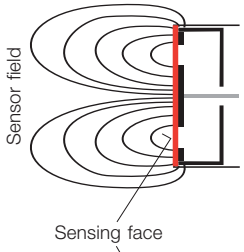
Function groups

... of a capacitive proximity sensor are:



Sensing face

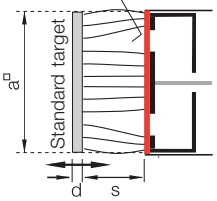
... is the area through which the high-frequency sensor field enters the air space. It is determined mainly by the area of the cover and corresponds roughly to the area of the outer sensor electrode.



Standard target

... is a grounded, square plate made of Fe 360 (ISO 630), with the switching distance determined per EN 60947-5-2.

The thickness is d = 1 mm; and the side length a corresponds to
- the diameter of the circle of the “sensing face”
- 3 s_r, if the value is greater than the respective diameter.



Rated operating distance s_n

... is a theoretical value, which does not take into account manufacturing tolerances, operating temperatures, supply voltages, etc.

Effective operating distance s_r

... is the switching distance of a single proximity switch measured under specified conditions such as flush mounting, rated operating voltage U_e, temperature T_a = +23 °C ±5 °C.

For capacitive sensors, the effective operating distance s_r can be set using a potentiometer.

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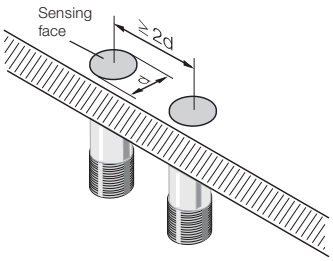
Installation in metal

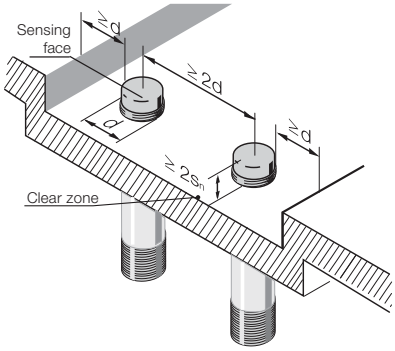
Flush mountable proximity switches

... can be installed with their sensing faces flush to the metal.
The distance between two proximity switches (in row mounting) must be ≥ 2d.



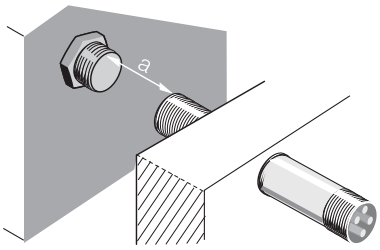
Non-flush mountable proximity switches

The sensing face must extend ≥ $2s_n$ from the metallic installation medium.
The distance between two proximity switches must be ≥ 2d.

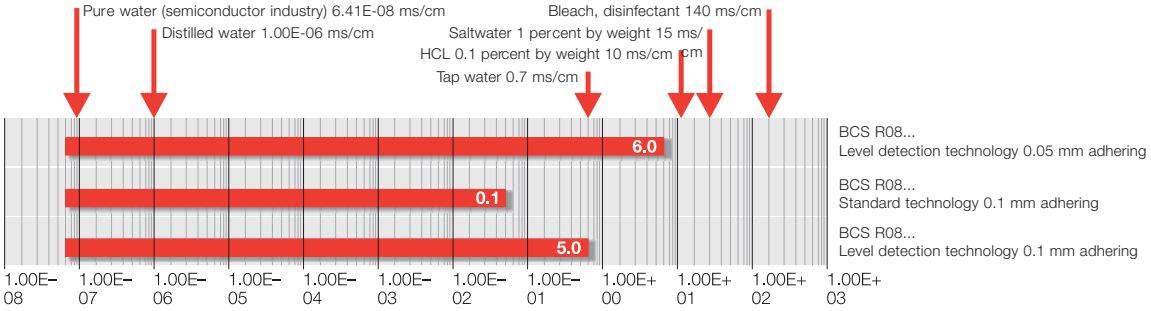


Opposing installation of 2 sensors

... requires a minimum distance of ≥ 4d between the sensing face for all inductive proximity switches.



Conductance values, adhering liquids

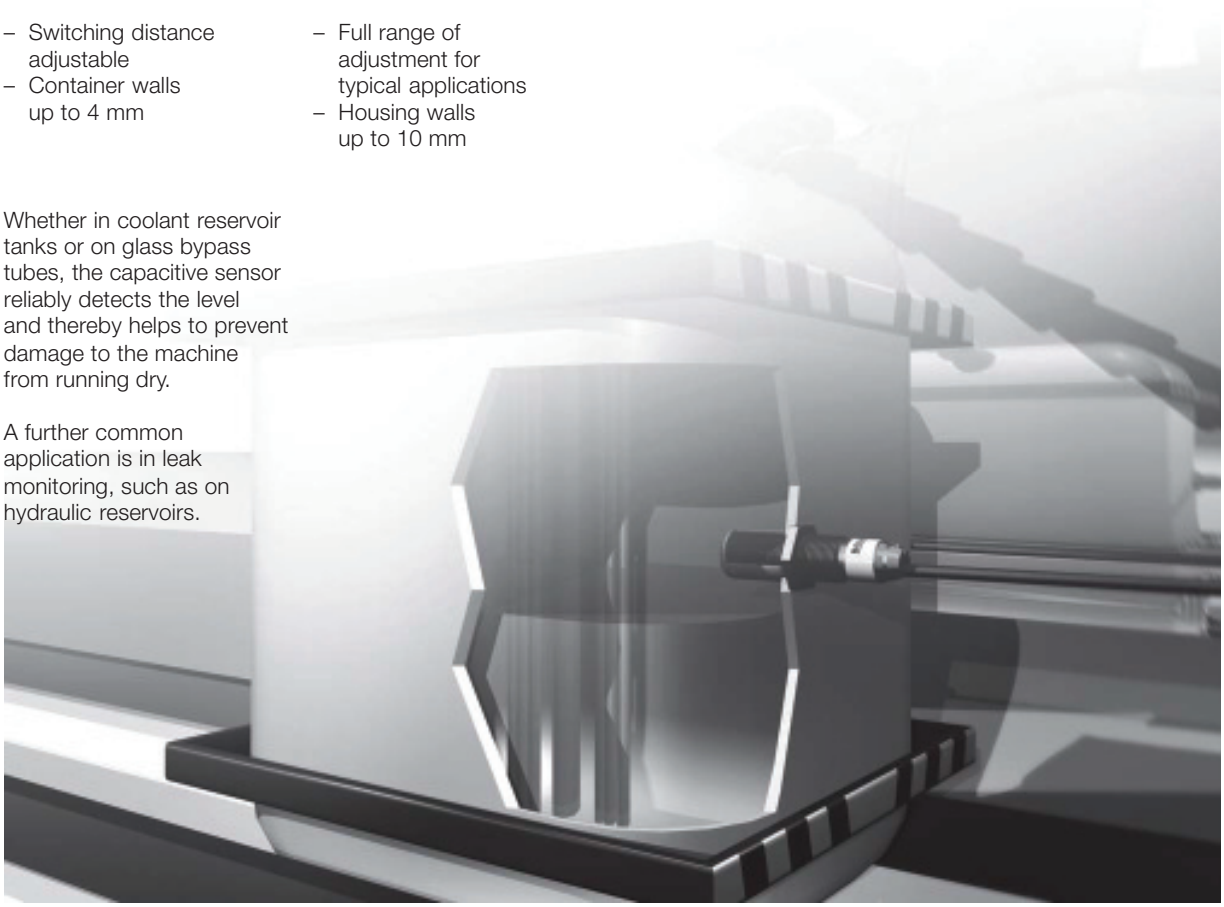


Function areas for capacitive sensors

Standard	Level Detection (Series R08)
– Metals – Plastic granulates – Hydraulic oils – Ceramics – Glass – PVC	– Aqueous media – Carbon – Graphite – Acids – Blood
– Switching distance adjustable – Container walls up to 4 mm	– Full range of adjustment for typical applications – Housing walls up to 10 mm

Whether in coolant reservoir tanks or on glass bypass tubes, the capacitive sensor reliably detects the level and thereby helps to prevent damage to the machine from running dry.

A further common application is in leak monitoring, such as on hydraulic reservoirs.



4

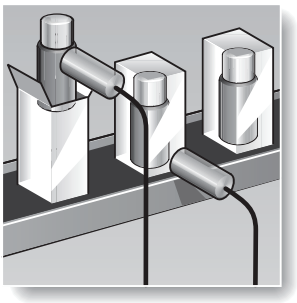
Capacitive Sensors

Capacitive sensors detect the change in capacitance of an object when it enters the sensor's electrical field.

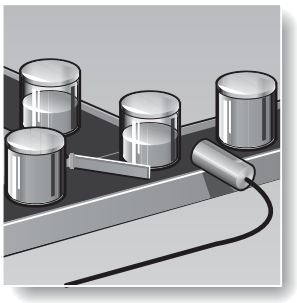
This means a capacitive sensor can detect not only metal, but even non-conductors whose dielectric constants are sufficiently large.

Properly selected, a capacitive sensor is also able to "see through" certain non-metallic materials. This makes it the classical level detector, sensing the presence or absence of liquids or granular material through the container wall.

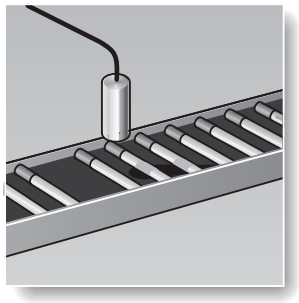
Balluff also offers the appropriate cover nuts which, once installed in the container, allow the capacitive sensor to be mounted and later replaced if necessary without unsealing the vessel.



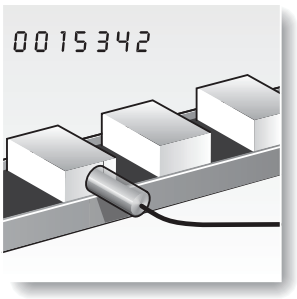
Inspection on packaging lines.
Packaging, contents.



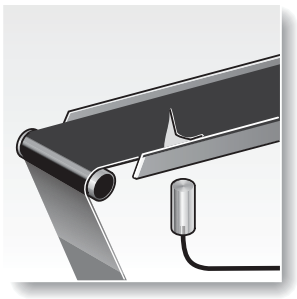
Level control in filling applications, controlling the reject station.



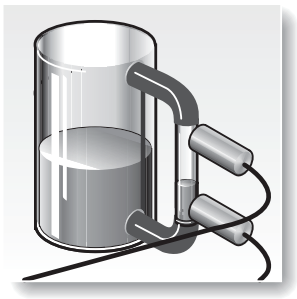
Quality and presence sensing in cigarette factory.
Filter/tobacco ok?*



Detecting, counting objects.

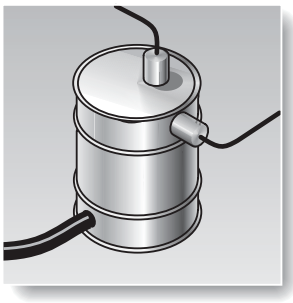


Inspecting paper, cloth or plastic strips.
From above or below.*

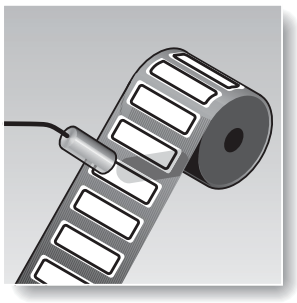


Inflow or pumping control in water storage containers.

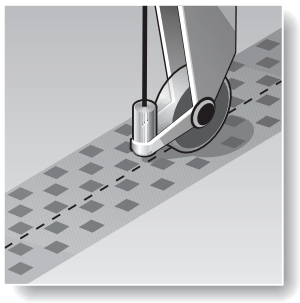
*No metal permitted underneath the desired object within the sensor field.



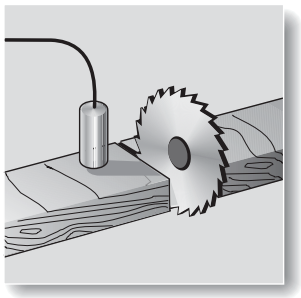
Level control in plastic or glass containers.



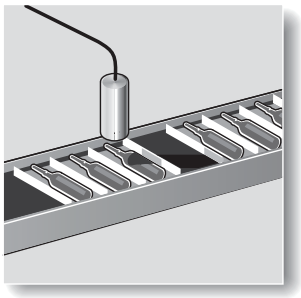
Checking for missing labels on thin backing.*



Guiding a knife through metal thread, e.g. for separating cloth.



Sensing and thickness detection of wood in secondary processing.



Packaging.
Are all the ampules there?*

Most capacitive sensors are not designed for flush mounting in metal.

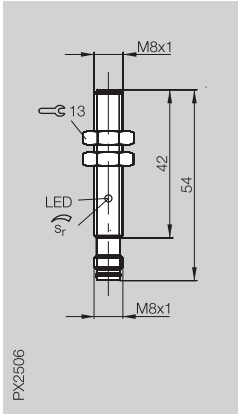
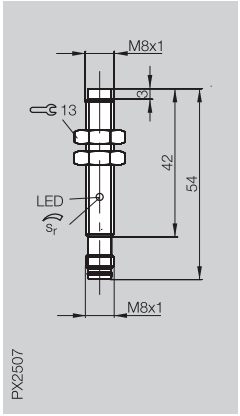
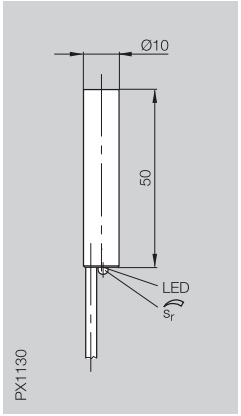
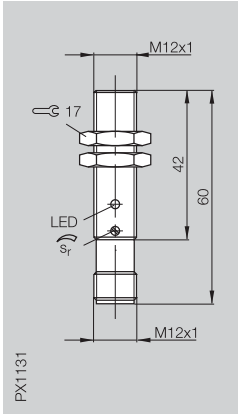
However, the potentiometers on Balluff sensors allow the switching distance to be adjusted so that even flush mounting is possible.

Typical applications

Level monitoring of
- liquids
- powdered and granular materials.

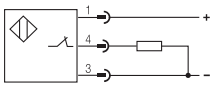
Detecting and counting parts made of
- metals
- plastics
- glass.

4

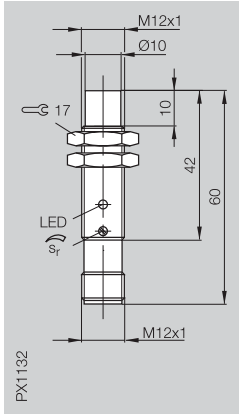
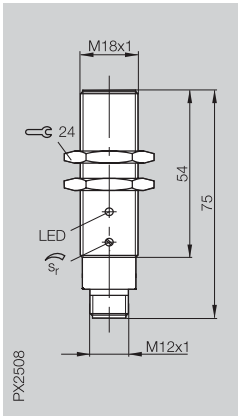
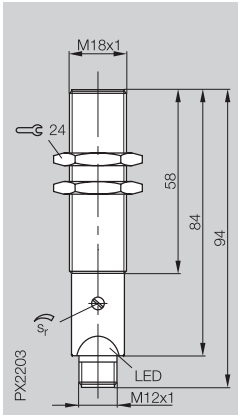
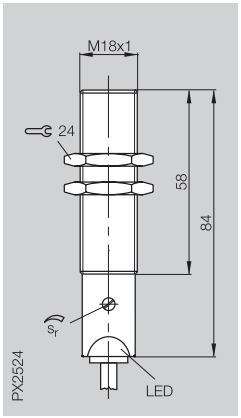
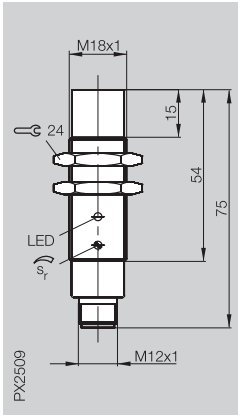
Housing size			**M8×1**	**M8×1**	**∅ 10 mm**	**M12×1**	
Mounting			flush	non-flush	flush	flush	
Rated operating distance s_n			**1.5 mm**	**3 mm**	**4 mm**	**4 mm**	
							
PNP	NO	①	BCS M08EG1-PSC15C-S49G	BCS M08EG-PSC30G-S49G	BCS 010-PSB-1-L-PU-02 BCS 010-POB-1-L-PU-02	BCS 012-PSB-1-L-S4	
	NC	②					
NPN	NO	④					
	NC	⑤					
Supply voltage U_B			11...30 V DC	11...30 V DC	12...35 V DC	12...35 V DC	
Voltage drop U_d at I_e			≤ 2 V	≤ 2 V	≤ 0.8 V	≤ 0.8 V	
Rated insulation voltage U_i			75 V DC	75 V DC	75 V DC	75 V DC	
Rated operational current I_e			50 mA	50 mA	200 mA	200 mA	
No-load supply current I_0 max.			10 mA	10 mA	10 mA	10 mA	
Polarity reversal protected			yes	yes	yes	yes	
Short circuit protected			yes	yes	yes	yes	
Repeat accuracy R			≤ 2 %	≤ 2 %	≤ 2 %	≤ 2 %	
Ambient temperature range T_a			–10...+70 °C	–10...+70 °C	–30...+70 °C	–30...+70 °C	
Switching frequency f			100 Hz	100 Hz	100 Hz	100 Hz	
Utilization category			DC 13	DC 13	DC 13	DC 13	
Function indicator			yes	yes	yes	yes	
Degree of protection per IEC 60529			IP 65	IP 65	IP 65	IP 65	
Housing material			Stainless steel	Stainless steel	Stainless steel	Stainless steel	
Material of sensing face			PTFE	PTFE	PTFE	PTFE	
Connection			Connector	Connector	2 m Cable PUR	Connector	
No. of wires × cross-section					3×0.14 mm²		
Recommended connector			BKS-_ 48/BKS-_ 49	BKS-_ 48/BKS-_ 49		BKS-_ 19/BKS-_ 20	

① Wiring diagrams see page **1.0.**6
Exception: BCS M18KM3-POC80G-S04G-001
For this sensor the pinout does not conform to the standard.

BCS M18KM3-POC80G-S04G-001



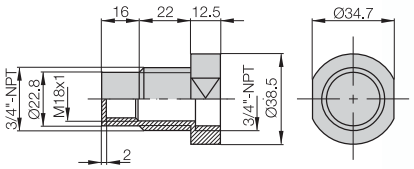
Reducing sleeve
BMS AD-P-001-12/10
for sensors with ∅ 10 mm
for installing in clamps
and holders with ∅ 12 mm,
see page **5.**65.

	M12×1 non-flush **8 mm**	M18×1 flush **8 mm**	M18×1 non-flush **8 mm**	M18×1 non-flush **8 mm**	M18×1 non-flush **15 mm**
					
	BCS 012-PS-1-L-S4	BCS M18EM1-PSC80C-S04G BCS M18EM1-POC80C-S04G	BCS M18KM3-PSC80G-S04G BCS M18KM3-POC80G-S04G-001	BCS M18KM3-PSC80G-BV02 BCS M18KM3-POC80G-BV02	BCS M18EM-PSC15G-S04G BCS M18EM-POC15G-S04G
				BCS M18KM3-NSC80G-BV02 BCS M18KM3-NOC80G-BV02	
	12...35 V DC	10...35 V DC	10...36 V DC	10...36 V DC	10...35 V DC
	≤ 0.8 V	≤ 1.5 V	≤ 2.5 V	≤ 2.5 V	≤ 1.5 V
	75 V DC	75 V DC	250 V AC	250 V AC	75 V DC
	200 mA	300 mA	250 mA	250 mA	300 mA
	10 mA	10 mA	15 mA	15 mA	10 mA
	yes	yes	yes	yes	yes
	yes	yes	yes	yes	yes
	≤ 2 %	≤ 2 %	≤ 10 %	≤ 10 %	≤ 2 %
	–30...+70 °C	–30...+70 °C	–25...+80 °C	–25...+80 °C	–30...+70 °C
	100 Hz	100 Hz	50 Hz	50 Hz	100 Hz
	DC 13	DC 13	DC 13	DC 13	DC 13
	yes	yes	yes	yes	yes
	IP 65	IP 67	IP 67	IP 67	IP 67
			⧈	⧈	
	Stainless steel	Stainless steel	PBT	PBT	Stainless steel
	PTFE	PBT	PBT	PBT	PTFE
	Connector	Connector	Connector	2 m cable, PVC 3×0.34 mm²	Connector
	BKS-_ 19/BKS-_ 20	BKS-_ 19/BKS-_ 20	BKS-_ 19/BKS-_ 20		BKS-_ 19/BKS-_ 20

Protective cap nuts for installing in containers for level detection

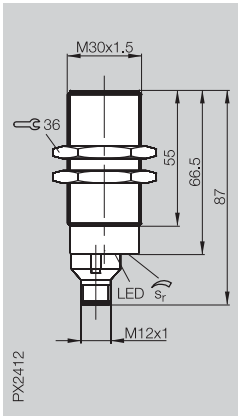
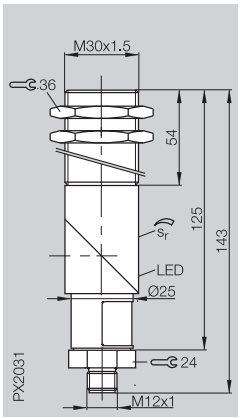
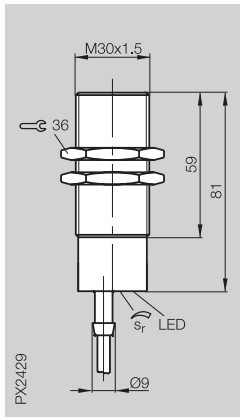
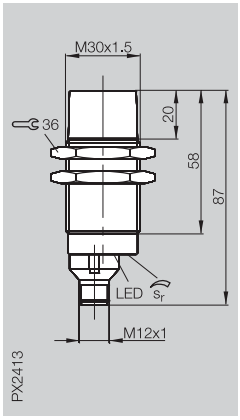
Material: PTFE
Pressure rated up to 13 bar when correctly installed.

BES 18-SM-3



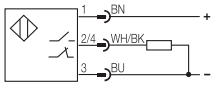
PX1047a

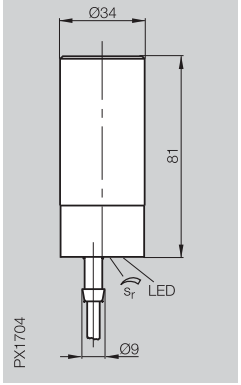
4
5
Connectors, holders ... page 5.2 ...

Housing size			**M30×1.5**	**M30×1.5**	**M30×1.5**	**M30×1.5**
Mounting			flush	non-flush	non-flush	non-flush
Rated operating distance s_n			**20 mm**	**15 mm**	**15 mm**	**30 mm**
						
PNP	NO	①	BCS M30EM2-PSC20C-S04K		BCS M30KN2-PSC18G-AV02	BCS M30EG2-PSC30G-S04K
	NC	②			BCS M30KN2-POC15G-AV02	
	NO/NC			BCS M30KM7-PPH15G-S04U		
NPN	NO	④			BCS M30KN2-NSC18G-AV02	
	NC	⑤			BCS M30KN2-NOC15G-AV02	
Supply voltage U_B			10...35 V DC	10...36 V DC	10...36 V DC	10...35 V DC
Voltage drop U_d at I_e			≤ 1.8 V	≤ 2.5 V	≤ 2.5 V	≤ 1.8 V
Rated insulation voltage U_i			75 V DC	250 V AC	250 V AC	75 V DC
Rated operational current I_e			300 mA	250 mA	250 mA	300 mA
No-load supply current I_0 max.			15 mA	16 mA	15 mA	15 mA
Polarity reversal protected			yes	yes	yes	yes
Short circuit protected			yes	yes	yes	yes
Repeat accuracy R			≤ 5 %	≤ 10 %	≤ 10 %	≤ 5 %
Ambient temperature range T_a			–30...+70 °C	–25...+70 °C	–25...+70 °C	–30...+70 °C
Switching frequency f			100 Hz	40 Hz	40 Hz	100 Hz
Utilization category			DC 13	DC 13	DC 13	DC 13
Function indicator			yes	yes	yes	yes
Degree of protection per IEC 60529			IP 67	IP 65	IP 65	IP 67
Insulation class				⧈	⧈	
Housing material			Stainless steel	PBT/PC	PBT	Stainless steel
Material of sensing face			PBT	PBT	PBT	PTFE
Connection			Connector	Connector	2 m cable, PVC	Connector
No. of wires × cross-section					3×0.5 mm²	
Recommended connector			BKS-_ 19/BKS-_ 20	BKS-_ 19/BKS-_ 20 Connector orientation rotatable by 90°		BKS-_ 19/BKS-_ 20

① Wiring diagrams see page **1.0.**6
Exception: BCS M30KM7-PPH15G-S04U
Factory setting: Normally open. The sensor can be converted to normally closed. Once done, however, this cannot be reversed.

BCS M30KM7-PPH15G-S04U

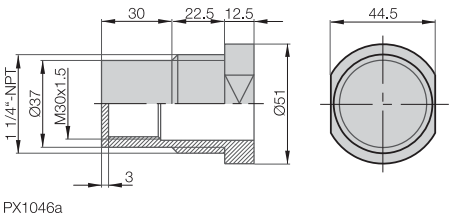


	∅ 34 mm				
	non-flush				
	20 mm				
					
	BCS G34KN2-PSC24G-AV02 BCS G34KN2-POC20G-AV02				
	BCS G34KN2-NSC24G-AV02 BCS G34KN2-NOC20G-AV02				
	10...36 V DC				
	≤ 2.5 V				
	250 V AC				
	250 mA				
	13 mA				
	yes				
	yes				
	≤ 10 %				
	–25...+70 °C				
	40 Hz				
	DC 13				
	yes				
	IP 65				
	⧈				
	PBT				
	PBT				
	2 m cable, PVC				
	3×0.5 mm²				
	Mounting cuff included in scope of delivery!				

Protective cap nuts for installing in containers for level detection

Material: PTFE
Pressure rated up to 13 bar when correctly installed.

BES 30-SM-3



PX1046a

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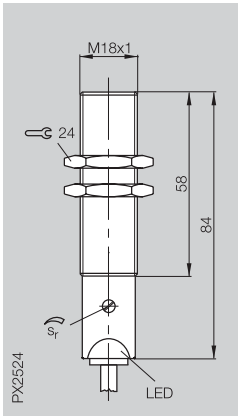
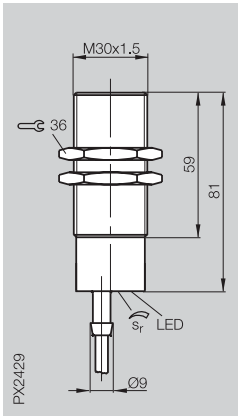
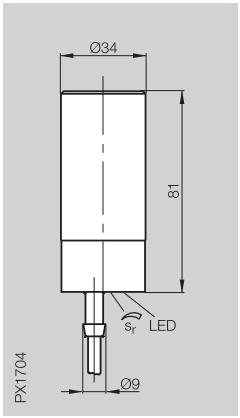
Connectors, holders ...
page 5.2 ...

Housing size	**M18×1**	**M30×1.5**	**∅ 34 mm**
Mounting	non-flush	non-flush	non-flush
Rated operating distance s_n	**8 mm**	**15 mm**	**20 mm**



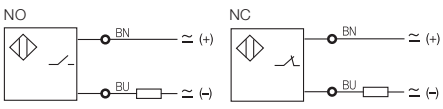




NO	BCS M18KM3-UST80G-BV02	BCS M30KN2-UST15G-AV02	BCS G34KN2-UST20G-AV02
NC	BCS M18KM3-UOT80G-BV02	BCS M30KN2-UOT15G-AV02	BCS G34KN2-UOT20G-AV02
Rated operational voltage U_e	110 V AC	110 V AC	110 V AC
Supply voltage U_B	20...250 V AC/DC	20...250 V AC/DC	20...250 V AC/DC
Voltage drop U_d at I_e	≤ 6 V	≤ 6 V	≤ 6 V
Rated insulation voltage U_i	250 V AC	250 V AC	250 V AC
Rated operational current I_e	350 mA (AC)/100 mA (DC)	250 mA (AC)	250 mA (AC)
Minimum operating current I_m	4 mA	5 mA	5 mA
Off-state current I_r	≤ 2.5 mA at 250 V AC	≤ 2.5 mA at 250 V AC	≤ 2.5 mA at 250 V AC
Inrush current I_k t ≤ 20 ms	≤ 2.1 A/≤ 0.5 Hz	≤ 1.5 A/≤ 0.5 Hz	≤ 1.5 A/≤ 0.5 Hz
Polarity reversal protected	no	no	no
Short circuit/overload protected	no/no	no/no	no/no
Repeat accuracy R	≤ 10 %	≤ 10 %	≤ 10 %
Ambient temperature range T_a	–25...+80 °C	–25...+70 °C	–25...+70 °C
Switching frequency f	25 Hz (AC)/50 Hz (DC)	25 Hz (AC)/50 Hz (DC)	25 Hz (AC)/50 Hz (DC)
Utilization category	AC 140/DC 13	AC 140/DC 13	AC 140/DC 13
Function indicator	yes	yes	yes
Degree of protection per IEC 60529	IP 67	IP 65	IP 65
Insulation class	⧈	⧈	⧈
Housing material	PBT	PBT	PBT
Material of sensing face	PBT	PBT	PBT
Connection	2 m cable, PVC	2 m cable, PVC	2 m cable, PVC
No. of wires × cross-section	2×0.34 mm²	2×0.34 mm²	2×0.5 mm²

Other cable lengths on request.

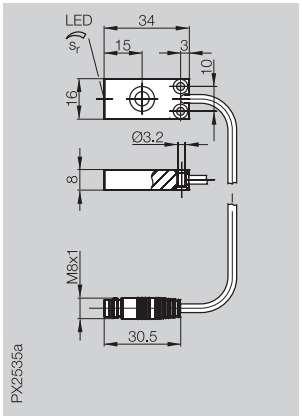
Wiring diagrams

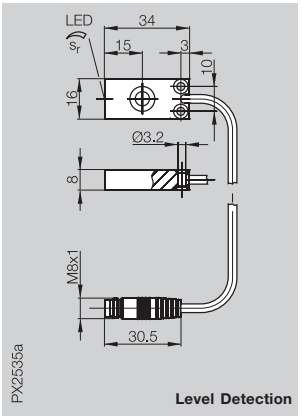


Note

With these AC/DC sensors use a miniature fuse as per the technical data sheet. Recommendation: After a short circuit, check the device for proper function.

Housing size	**16×34×8 mm** R08	**16×34×8 mm** R08
Mounting	flush	flush
Rated operating distance s_n	**8 mm**	**Self-adjusting**





PNP	NO	①	BCS R08KE-PSC80C-EP00,2-GS49	BCS R08KE-PSCFAC-EP00,2-GS49
	NC	②	BCS R08KE-POC80C-EP00,2-GS49	BCS R08KE-POCFAC-EP00,2-GS49

Supply voltage U_B	12...30 V DC	12...30 V DC
Voltage drop U_d at I_e	≤ 1.5 V	≤ 1.5 V
Rated insulation voltage U_i	75 V DC	75 V DC
Rated operational current I_e	50 mA	50 mA
No-load supply current I_0 max.	≤ 10 mA	≤ 10 mA
Polarity reversal protected	yes	yes
Short circuit protected	yes	yes
Repeat accuracy R	≤ 5 %	≤ 5 %
Ambient temperature range T_a	–30...+70 °C	–30...+70 °C
Switching frequency f	100 Hz	2 Hz
Utilization category	DC 13	DC 13
Function indicator	yes	yes
Degree of protection per IEC 60529	IP 67	IP 67
Housing material	PP	PP
Material of sensing face	PP	PP
Connection	0.2 m cable (PUR) with connector	0.2 m cable (PUR) with connector
Recommended connector	BKS-_ 48	BKS-_ 48

① Wiring diagrams see page **1.0.**6

Other cable lengths on request.

Level Detection

- For aqueous media with foam compensation
- Standard application with no adjustment
- Self-compensating
- Through glass or plastic with wall thicknesses of approx. 2...10 mm
- Level detection – the new solution for critical or challenging applications with aqueous media

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Connectors, holders ... page 5.2 ...

Function principle

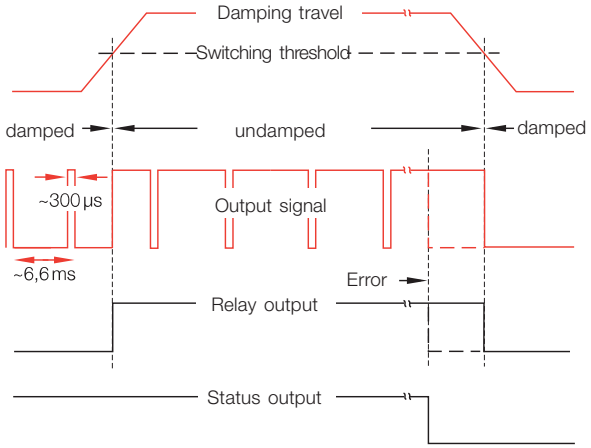
Proximity switches with dynamic diagnostics allow monitoring of the sensor functions including the cable.

The oscillator state is changed by means of a pulse generator while the switch is operating. As soon as there is any damage to the sensor head or the oscillator fails electrically, the pulse generator can no longer change the oscillator state and there are no longer pulses on the output.

The pulse frequency is f ~ 160 Hz and the pulse duration t ~ 300 µs. The pulse-pause ratio of t ~ 5 % is selected small enough that the test pulses can be filtered out by the input filter of a controller, or, for example, a relay can be directly driven.
The information “proximity switch damped or undamped” can therefore be processed in the usual fashion.

Function monitoring

The test pulses and thereby the function of the proximity switch are monitored by additional electronics which signal error-free function by means of a high level on the “Status/Output” message output.



Pulse diagram of a proximity switch with function diagnostics (NC).

For this, Balluff offers a function diagnostics unit which can be easily installed in a controller:

Function diagnostics unit
see page **1.5.**19
– BES 113-FD-1
(for 1 Sensor)

The following may be connected:

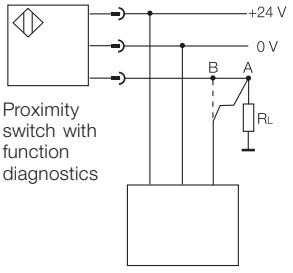
Inductive sensors
see page **1.5.**18
– BES 113-356-SA6-S4
Normally open
– BES 113-356-SA31-S4
Normally open
– BES 113-3019-SA1-S4
Normally closed

Capacitive sensor
see page **4.**15
– BCS 20MG10-XPA1Y-8B-03
Complementary.

Single faults are detected when monitoring for the entire system.

Installation notes

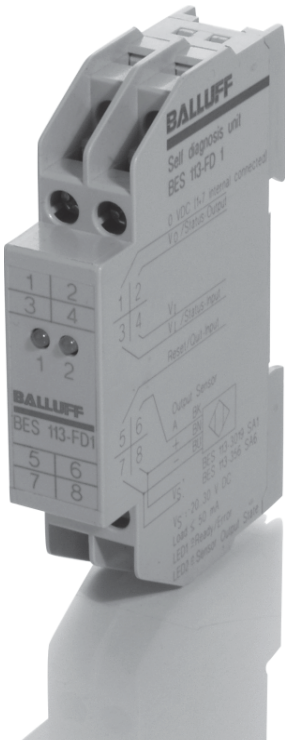
The signal line for the function diagnostics unit should be connected as close as possible to the load R_L (Point A). When Point B is connected the cable segment between B and load R_L is not monitored.



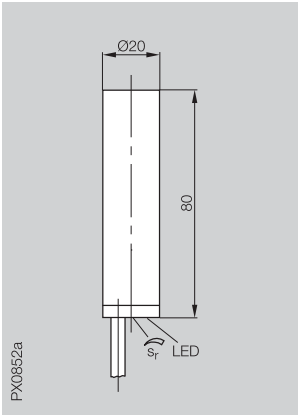
Note!

The system described here is not suitable for systems with personal protection.

For additional information please request a device description.



Housing size	∅ **20 mm**
Mounting	flush
Rated operating distance s_n	**10 mm**



PNP	complementary ③	BCS 20MG10-XPA1Y-8B-03
Supply voltage U_B		10...30 V DC
Voltage drop U_d at I_e		≤ 3.5 V
Rated insulation voltage U_i		75 V DC
Rated operational current I_e		130 mA
Minimum operating current I_m		1 mA
No-load supply current I_0 max.		10 mA
Output resistance R_a		Open collector
Polarity reversal protected		yes
Short circuit protected		yes
Repeat accuracy R		≤ 15 %
Ambient temperature range T_a		+10...+50 °C
Switching frequency f		100 Hz
Utilization category		DC 13
Function/Supply voltage indicator		yes/yes
Degree of protection per IEC 60529		IP 63
Housing material		Stainless steel
Material of sensing face		EP
Connection		3 m Cable PUR
No. of wires × cross-section		4×0.25 mm²

③ Wiring diagram see page **1.0.**6

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Connectors, holders ... page 5.2 ...