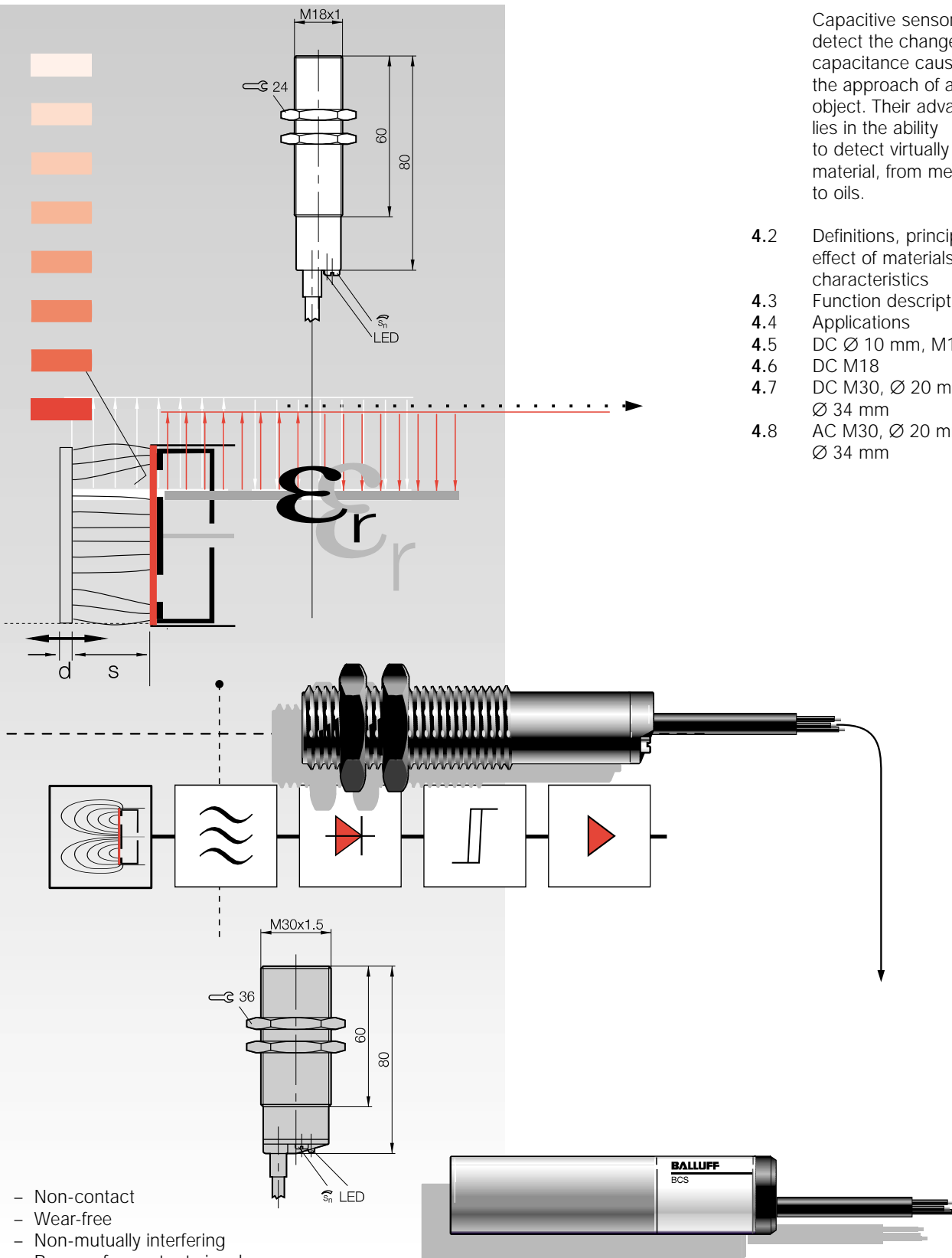


Capacitive sensors detect the change in capacitance caused by the approach of an object. Their advantage lies in the ability to detect virtually any material, from metals to oils.

- 4.2 Definitions, principles, effect of materials characteristics
- 4.3 Function description
- 4.4 Applications
- 4.5 DC Ø 10 mm, M12
- 4.6 DC M18
- 4.7 DC M30, Ø 20 mm, Ø 34 mm
- 4.8 AC M30, Ø 20 mm, Ø 34 mm



- Non-contact
- Wear-free
- Non-mutually interfering
- Bounce-free output signal
- LED function display
- Senses virtually any material
- Detects objects through many other non-metallic barriers

A capacitor

... in its traditional form consists of two electrode plates and a dielectric, with a non- or poorly conducting medium in between.

Capacitance $C = \epsilon (A/d)$ is determined by **surface A**,

distance d, and the **dielectric constant**

$$\epsilon = (\epsilon_0 \times \epsilon_r)$$

ϵ describes the dielectric constant of this medium.

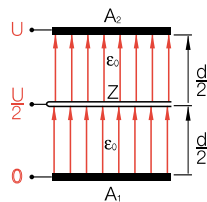
ϵ_0 is the absolute dielectric constant of empty space (vacuum).

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

The sensor electrode

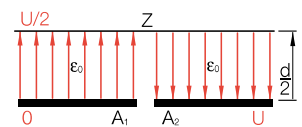
... and its effect can be explained using a step-by-step derivation of its geometric shape. The stray fields at the edges of the plates can be ignored for these purposes.

In the middle between two circular capacitor plates A_1 and A_2 there is at distance



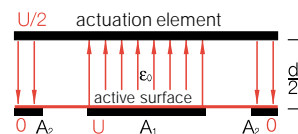
$d/2$ an additional, good conducting, folded "intermediate electrode" Z with thickness $D \rightarrow 0$. An applied voltage between A_1 and A_2 generates an electrical field. This impresses voltage $U/2$ in electrode Z. The "intermediate electrode" thereby assumes the function of an additional capacitor 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 on one level and the "intermediate capacitor" Z on a second level at distance $d/2$. The result is an "open" capacitor. The fields in the capacitor halves run in opposite directions.



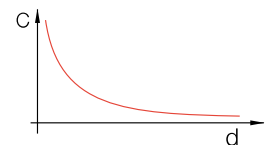
In capacitive sensors

... 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 "active surface" 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 $1/d$).

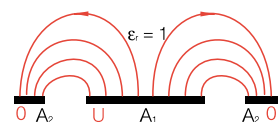


Non-conducting materials

... (plastics, glass as well as liquids) can be detected by capacitive sensors, if ϵ_r 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 ($d \rightarrow \infty$; $\epsilon_r = 1$, $C \rightarrow 0$) is absent, they run in an arc from the middle to the ring electrode. The path of least resistance is thereby also partially determined by the repelling effect of identically oriented lines of field.

The arcs and their distances become greater from inside to outside.



Conditions and correction factors

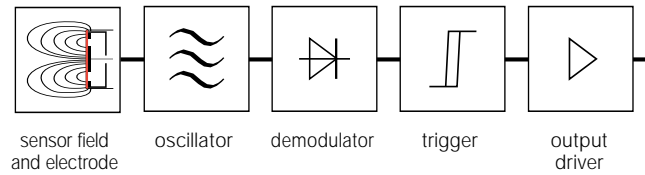
If an electrically non-conducting actuation element (target) enters the sensor field, the capacitance changes proportionally to ϵ and to the immersion depth resp. to the distance to the "active surface". However it never becomes greater than for metals.

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 are listed in the adjacent table:

Material	Correction factor
metals	1.0
wood	0.2...0.7
glass	0.5
water	1.0
PVC	0.6
oil	0.1

Function groups

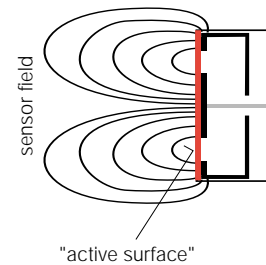
... of a capacitive sensor are:



Active surface

... is the area through which the high-frequency sensor field enters the air space.

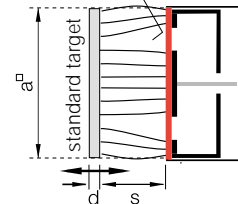
It is primarily determined by the front surface area of the cap and corresponds approximately to the surface area of the outer sensor electrode.



Standard target

... is a grounded, square plate made of Fe 360 (ISO 630), with the switching distance determined per EN 60947-5-2. Thickness is $d = 1 \text{ mm}$;

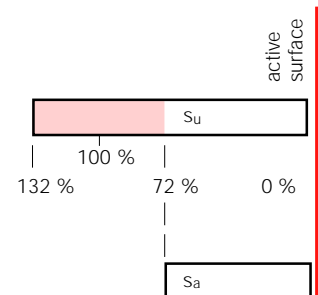
and the side length a corresponds to
 - the diameter of the inscribed circle of the active surface or
 - $3 s_n$, if the value is larger than the corresponding diameter



Useful operating distance s_u

... is the permissible switching distance of an individual proximity switch within the specified voltage

and temperature ranges ($0.72 s_n \leq s_u \leq 1.325 s_n$).



Assured operating distance s_a

... is the switching distance at which assured operation of the proximity switch is guaranteed at specified

voltage and temperature conditions ($0 \leq s_a \leq 0.72 s_n$).

Advantages

- non-contact
- rugged construction
- noise-immune

Application examples

Level monitoring of
 - liquids
 - powdered and granular materials.

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

Material comparison in constant dielectrics.

Function diagnostics

Proximity switches with function diagnostics allow virtually complete monitoring of all sensor functions including the cable connections.

Here Balluff offers the BES 113-FD-1 self diagnosis unit, which can be easily integrated in a controller.

The unit and its function is described on page 1.5.22.

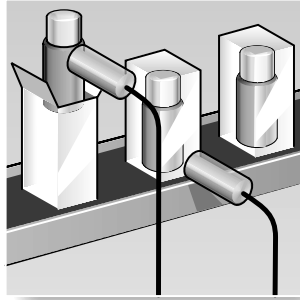
Capacitive sensors

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

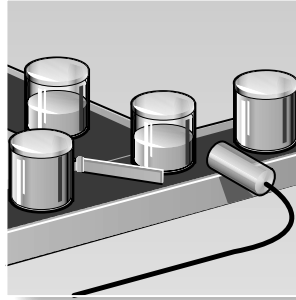
This means a capacitive sensor can detect not only metal, but even non-conductors whose dielectric constants are sufficiently large.

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.

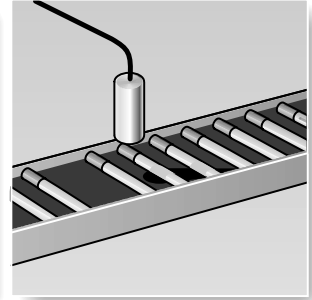
Balluff also offers the appropriate cover nuts which, once installed in the container, allow the capacitive sensor to be mounted and later replaced if necessary without un-sealing the vessel.



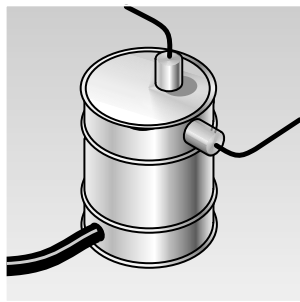
Inspection on packaging lines. Packaging, contents.



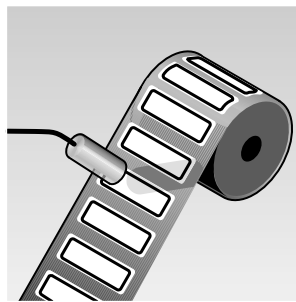
Level control in filling applications, controlling the reject station.



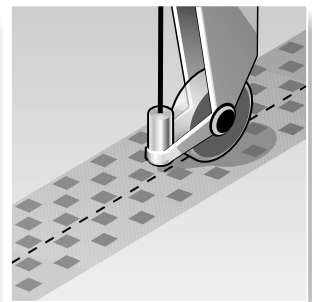
Quality and presence sensing in cigarette factory. Filter/tobacco ok?*



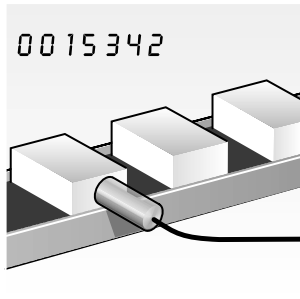
Level control in plastic or glass containers.



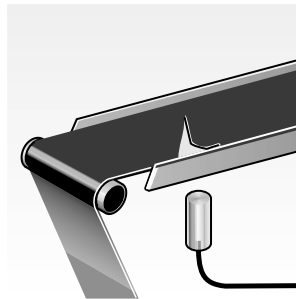
Checking for missing labels on thin backing.*



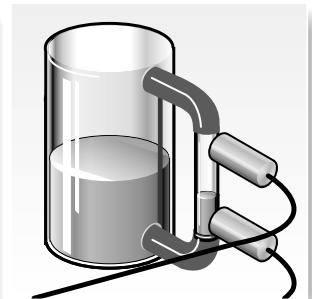
Guiding a knife through metal thread, e.g. for separating cloth.



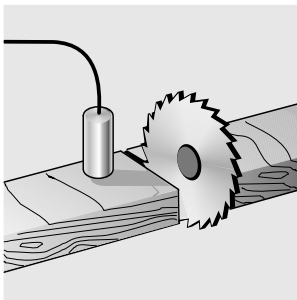
Detecting, counting objects.



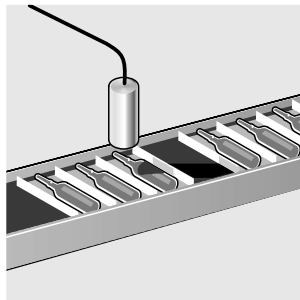
Inspecting paper, cloth or plastic strips. From above or below.*



Inflow or pumping control in water storage containers.



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.

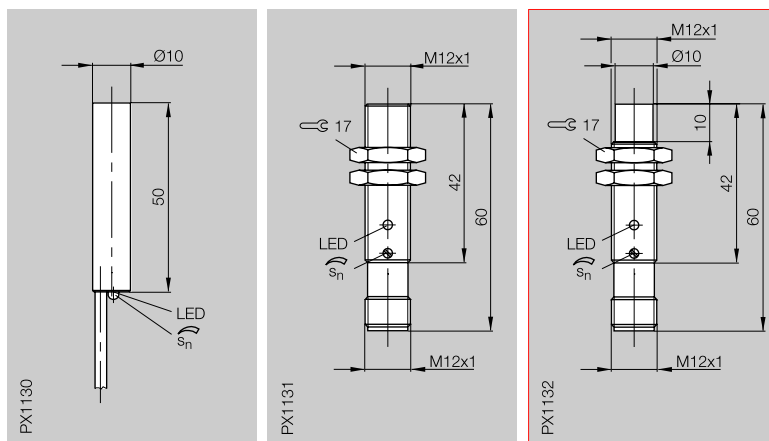
However, the potentiometers on Balluff sensors allow the switching distance to be adjusted so that even flush mounting is possible.

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

Capacitive Sensors

DC 3-Wire
 Ø 10 mm, M12
 s_r 0...4 mm, 0...8 mm

Housing size	Ø 10 mm	M12x1	M12x1
Mounting	flush	flush	non-flush
Effective operating distance s _r	0...4 mm	0...4 mm	0...8 mm
Assured operating distance s _a	0...2.9 mm	0...2.9 mm	0...5.8 mm



PNP	Normally-open ①	BCS 010-PSB-1-L-	BCS 012-PSB-1-L-S 4	BCS 012-PS-1-L-S 4
Rated operational voltage U _e		24 V DC	24 V DC	24 V DC
Supply voltage U _B		10...30 V DC	10...30 V DC	10...30 V DC
Voltage drop U _d at I _e		≤ 1 V	≤ 1 V	≤ 1 V
Rated insulation voltage U _i		75 V DC	75 V DC	75 V DC
Rated operational current I _e		200 mA	200 mA	200 mA
Minimum operational current I _m		0 mA	0 mA	0 mA
No-load supply current I ₀ max.		≤ 10 mA	≤ 10 mA	≤ 10 mA
Off-state current I _r		≤ 0.8 µA	≤ 0.8 µA	≤ 0.8 µA
Protected against polarity reversal		yes	yes	yes
Short circuit protected		yes	yes	yes
Load capacity		≤ 1 µF	≤ 1 µF	≤ 1 µF
Repeat accuracy R		≤ 5 %	≤ 5 %	≤ 5 %
Ambient temperature range T _a		-30...+70 °C	-30...+70 °C	-30...+70 °C
Frequency of operating cycles f		100 Hz	100 Hz	100 Hz
Utilization category		DC 13	DC 13	DC 13
Function indication		yes	yes	yes
Degree of protection per IEC 60529		IP 65	IP 65	IP 65
Housing material		stainless steel	CuZn	CuZn
Material of sensing face		PTFE	PTFE	PTFE
Connection		cable	connector	connector
No. of wires × conductor cross section		3 × 0.14 mm ²		
Recommended connector			BKS-B 19/BKS-B 20	BKS-B 19/BKS-B 20

① Wiring diagrams see page 1.0.12

Please add the cable length to ordering code for sensors with **cable!**
 PU-03, PU-05 = PUR, length 3 m or 5 m



4

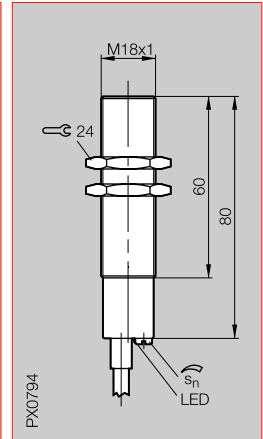
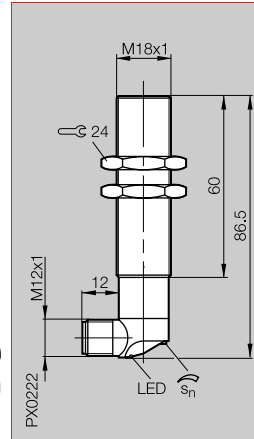
6

Connectors,
 clamps ...
 page 6.2 ...

Capacitive Sensors

DC 3-Wire
M18
s_r 1...10 mm

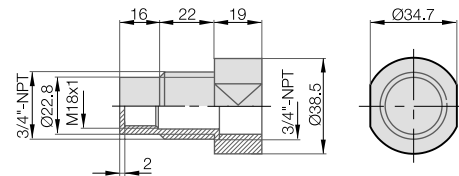
Housing size	M18x1	M18x1
Mounting	non-flush	non-flush
Effective operating distance s _r	1...10 mm	1...10 mm
Assured operating distance s _a	0.8...8.1 mm	0.8...8.1 mm



Protective cap nuts for installing in containers for level detection

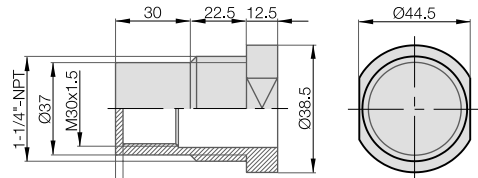
Material: PTFE
Pressure rated up to 13 bar when correctly installed.

BES 18-SM-3



PX1047a

BES 30-SM-3



PX1046a

Please add the cable length to ordering code for sensors with **cable!**
03, 05 = PVC, length 3 m or 5 m
PU-03, PU-05 = PUR, length 3 m or 5 m

PNP	Normally-open ①	BCS 018-PS-1-C-S 4	BCS 018-PS-1-C-
	Normally-closed ②		BCS 018-PO-1-C-
	Complementary ③		
NPN	Normally-open ④		BCS 018-NS-1-C-
	Normally-closed ⑤		BCS 018-NO-1-C-

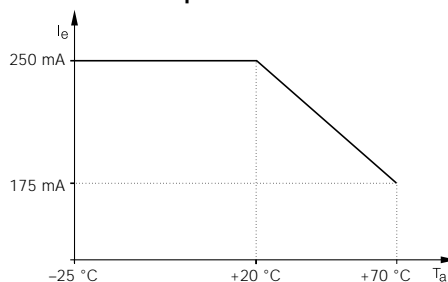
Rated operational voltage U _e	24 V DC	24 V DC
Supply voltage U _B	10...30 V DC	10...30 V DC
Voltage drop U _d at I _e	≤ 3.5 V	≤ 3.5 V
Rated insulation voltage U _i	75 V DC	250 V AC
Rated operational current I _e	250 mA	250 mA
Minimum operational current I _m	100 μA	100 μA
No-load supply current I ₀ max.	≤ 8 mA	≤ 8 mA
Off-state current I _r	≤ 50 μA	≤ 50 μA
Protected against polarity reversal	yes	yes
Short circuit protected	yes	yes
Load capacity	≤ 1 μF	≤ 1 μF

Repeat accuracy R	≤ 5 %	≤ 5 %
Ambient temperature range T _a	-25...+70 °C	-25...+70 °C
Frequency of operating cycles f	≤ 200 Hz	≤ 200 Hz
Utilization category	DC 13	DC 13
Function indication	yes	yes

Degree of protection per IEC 60529	IP 67	IP 67
Insulation class		□
Housing material	PBT	PBT
Material of sensing face	PBT	PBT
Connection	connector	cable
No. of wires × conductor cross section		3 × 0.34 mm ²
Recommended connector	BKS-B 19/BKS-B 20	

① Wiring diagrams see page 1.0.12

Current reduction as a function of ambient temperature



Capacitive Sensors

DC 3-/4-Wire
M30, Ø 20 mm, Ø 34 mm
s_r 2...20, 1...12, 3...40 mm

M30×1.5 non-flush 2...20 mm 1.6...16.2 mm	M30×1.5 non-flush 2...20 mm 1.6...16.2 mm	Ø 20 mm non-flush 1...12 mm 0.8...9.7 mm	Ø 20 mm non-flush 1...12 mm 0.8...9.7 mm	Ø 34 mm non-flush 3...40 mm 2.4...32.4 mm
BCS 030-PS-1-C-S 4 BCS 030-GA-1-C-S 4	BCS 030-PS-1-C- BCS 030-PO-1-C-	BCS 020-PS-1-C-S 4	BCS 020-PS-1-C-	BCS 034-PS-1-C- BCS 034-PO-1-C-
	BCS 030-NS-1-C- BCS 030-NO-1-C-	BCS 020-NS-1-C-S 4	BCS 020-NS-1-C-	BCS 034-NS-1-C- BCS 034-NO-1-C-
24 V DC 10...30 V DC ≤ 3.5 V 75 V DC 250 mA 100 µA ≤ 8 mA ≤ 50 µA yes yes ≤ 1 µF	24 V DC 10...30 V DC ≤ 3.5 V 250 V AC 250 mA 100 µA ≤ 8 mA ≤ 50 µA yes yes ≤ 1 µF	10...30 V DC 30 V DC ≤ 3.5 V 250 V AC 250 mA ≤ 0,1 mA ≤ 11 mA ≤ 10 µA yes yes ≤ 0.33 µF	10...30 V DC 30 V DC ≤ 3.5 V 250 V AC 250 mA ≤ 0,1 mA ≤ 11 mA ≤ 10 µA yes yes ≤ 0.33 µF	24 V DC 10...30 V DC ≤ 3.5 V 250 V AC 250 mA 100 µA ≤ 8 mA ≤ 50 µA yes yes ≤ 1 µF
≤ 10 % -25...+70 °C ≤ 100 Hz DC 13 yes	≤ 10 % -25...+70 °C ≤ 100 Hz DC 13 yes	≤ 10 % -25...+70 °C 150 Hz DC 13 yes	≤ 10 % -25...+70 °C 150 Hz DC 13 yes	≤ 10 % -25...+70 °C ≤ 100 Hz DC 13 yes
IP 67	IP 67	IP 67	IP 67	IP 67
PBT	PBT	PBT	PBT	PBT
PBT	PBT	PBT	PBT	PBT
connector	cable 3 × 0.34 mm ²	connector	cable 3 × 0.34 mm ²	cable 3 × 0.34 mm ²
BKS-B 19/BKS-B 20		BKS-B 19/BKS-B 20 Clamp cuff included!	Clamp cuff included!	Clamp cuff included!



4

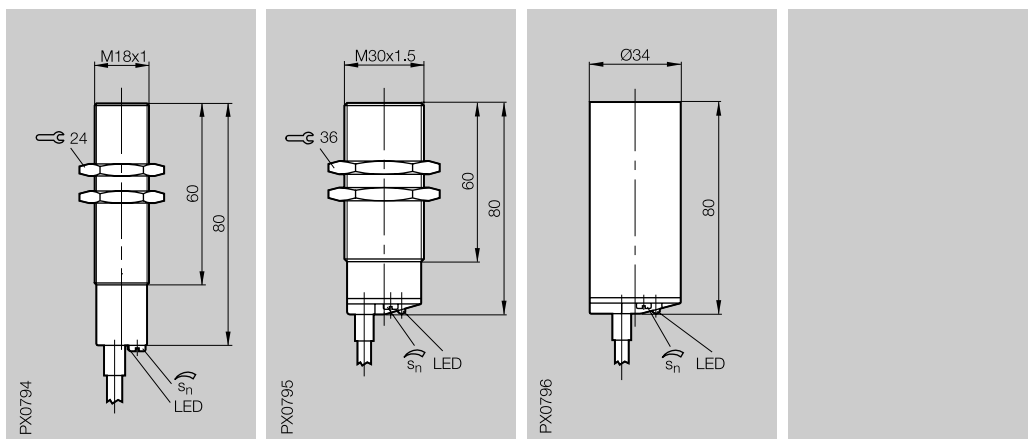
6

Connectors, clamps ...
page 6.2 ...

Capacitive Sensors

AC 2-Wire
M18, M30, Ø 34 mm
 s_r 1...10 mm, 2...20 mm, 3...40 mm

Housing size	M18x1	M30x1.5	Ø 34 mm
Mounting	non-flush	non-flush	non-flush
Effective operating distance s_r	1...10 mm	2...20 mm	3...40 mm
Assured operating distance s_a	0.8...8.1 mm	1.6...16.2 mm	2.4...32.4 mm



AC	Normally-open ①	BCS 018-WS-5-L-	BCS 030-WS-5-L-	BCS 034-WS-5-L-
	Normally-closed ②	BCS 018-WO-5-L-	BCS 030-WO-5-L-	BCS 034-WO-5-L-
Rated operational voltage U_e	110 V AC	110 V AC	110 V AC	
Supply voltage U_B	45...250 V AC	45...250 V AC	45...250 V AC	
Voltage drop U_d at I_e	≤ 21 V	≤ 21 V	≤ 21 V	
Rated insulation voltage U_i	250 V AC	250 V AC	250 V AC	
Rated operational current I_e	250 mA	250 mA	250 mA	
Minimum operational current I_m	8 mA	8 mA	8 mA	
Off-state current I_r	≤ 3 mA	≤ 3 mA	≤ 3 mA	
Inrush current I_k $t \leq 20$ ms	≤ 2 A/≤ 1 Hz	≤ 2 A/≤ 1 Hz	≤ 2 A/≤ 1 Hz	
Protected against polarity reversal	yes	yes	yes	
Short circuit protected	no	no	no	
Repeat accuracy R	≤ 5 %	≤ 10 %	≤ 10 %	
Ambient temperature range T_a	-25...+70 °C	-25...+70 °C	-25...+70 °C	
Frequency of operating cycles f	25 Hz	25 Hz	25 Hz	
Utilization category	AC 140	AC 140	AC 140	
Function indication	yes	yes	yes	
Degree of protection per IEC 60529	IP 67	IP 67	IP 67	
Insulation class	□	□	□	
Housing material	PBT	PBT	PBT	
Material of sensing face	PBT	PBT	PBT	
Connection	cable	cable	cable	
No. of wires × conductor cross section	2 × 0.34 mm ²	2 × 0.34 mm ²	2 × 0.34 mm ²	

Clamp cuff included!

① Wiring diagrams see page 1.0.12

Please add the cable length to ordering code for sensors with **cable!**
03 = PVC, length 3 m

