Application & Guidance Notes

Photoelectric Switches

Applications

Successful application of photo-electrics into systems need not involve a deep understanding of their principles of operation. Following these few simple rules will enable many of the likely pitfalls to be avoided. For more complicated applications, IMO provides a full applications advice service. In cases of uncertainty IMO will loan photoelectric switches to try out on a particular process.

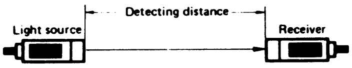
Selection Criteria

The following points must be known before the most suitable switch can be selected.

1. Detection method

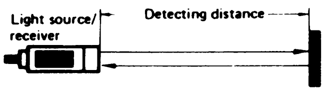
Through-beam (separate type)

This type has a separate transmitter and receiver. It will detect any object large enough to break the beam. Avoid using this style of switch to detect transparent objects, since the light beam will pass through the object without breaking the beam.



Diffuse type

This type has a transmitter and receiver in one head. It works on the principle of transmitting a beam of light and detecting reflections from the objects to be detected. Since all colours will reflect some light it can be used to detect almost all types of object, though at closer range than separate types. It is particularly suitable for detecting transparent objects, such as bottles. Avoid using this type where there is a background close to, or more reflective than the object, since this background will also be detected.

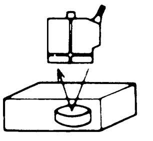


Detectable object

Fixed-focus

These are similar in operation to the Diffuse type. However, these models will ignore both background and foreground objects.

Detection of objects through a transparent cover



Typical examples:

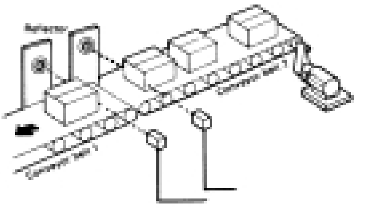
(1) Detection of the contents in a transparent case.

(2) Detection of the position of meter pointer.

Retroreflective type

This type works on the same beam-break principle as the through-beam type. However, in this case both transmitter and receiver are housed in the same body, and the light beam is bounced off a prismatic reflector which reflects light back in the direction from which it came. This is particularly important for ease of alignment.

It has the advantage that only a single head has to be mounted and wired. It can be used in the same applications as for the Separate type, though it should not be used to detect objects that will reflect light, such as polished metal, cellophane or shrink-wrapped packages, since it cannot distinguish between the two types of reflection.



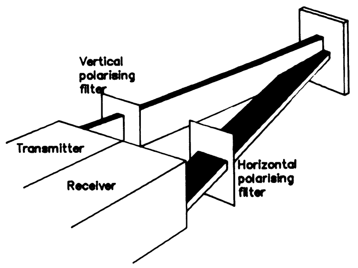
Retroreflective type - with polarised light

This is a retroreflective photoelectric switch for use in detecting shiny objects.

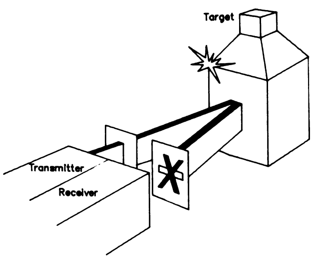
It is fitted with polarising filters in front of the transmitter and receiver lenses, one vertical and one horizontal. A prismatic reflector used with the photoelectric has the effect of turning the transmitted light through 90 degrees, thus if the filter in front of the transmitter only permits vertical light to pass through it, this vertical light is returned from the reflector as horizontal light which is allowed through the horizontal filter in front of the receiver lens. If however light is reflected from some surface other than the reflector it will be returned as vertical light and will not pass through the receiver filter.

Thus reliable operation is ensured under difficult conditions that would normally prevent the use of a retro-reflective type. Such applications include shrinkwrapping, and keg handling.

No object present – light received



Object present – no light received



Optical fibre type

This uses an optical fibre as a light guide from a remotely-mounted amplifier unit to the object to be detected. It is available as through-beam or diffuse. An optical fibre photoelectric offers several advantages over a conventional type:

Small size. The detecting head can be fitted into very confined spaces.

Sensitivity. Objects as small as 0.1 mm dia can be reliably detected.

Noise immunity. The fibre can be routed with high power cables.

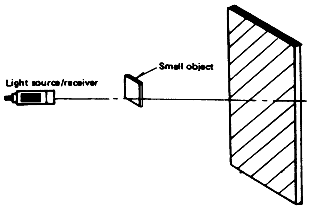
Optical fibres can also often be taken into areas where ordinary photoelectrics cannot normally be used, such as aerosol filling machines and areas containing paint fumes. The amplifier can be mounted remotely from the hazardous area, and only the fibre is taken into the danger zone.

2. Sensing Range

The detecting ranges shown against each photoelectric on the data pages are the maximum operating distance over which the device will work.

As a general rule, the shorter the range, the more precise is the detection.

So, first decide how close the device can be to the object to be detected, then select a photoelectric with a range just beyond this distance.



Power

Try to select a photoswitch with a sensing range to suit the application.

If an object can be detected with reliability at a range of say, 10mm, with no risk of the object touching the photocell at any time, choose a suitable low power photocell.

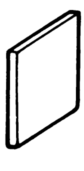
Too much power will sometimes see right through an object, or in the case of a Diffuse type, can reduce effective resolution or cause spurious background reflections.

3. Object size and speed

Minimum object size is shown on the data with each photoelectric. In high speed applications pay attention to the time that the object will be in front of the photoelectric. The minimum object size should be present for the duration of the response time otherwise the object may not be detected.

With through-beam and Retro-reflective switches, the “standard detectable object” is one which completely interrupts the light beam.

With Diffuse-reflection types, a white matt paper is used, of a size defined by individual switch data.



White matt paper
Square shaped

GENERAL

Interference

All of the photoelectrics in this catalogue use either infrared or visible light. As an additional protection, it is pulse-modulated at a high frequency and the receiver is tuned to this.

IMO photoelectrics are protected from interference against all but the most extreme sources of external light interference. Advanced circuitry ensures the highest level of immunity against electrical noise.

Stability

The increasing application of photoelectrics in inspection processes has led to the development of some very sensitive devices, able to

Application & Guidance Notes

Photoelectric Switches (continued)

discriminate small differences in the colour or size of an object.

When trying to resolve a small difference, there is a temptation to set the sensitivity of the photoelectric too close to the switching point. This can lead to "nuisance" tripping under environmental changes, or as the system ages.

To avoid this problem, the more sensitive switches incorporate, a green stability indicator LED to aid setting up. This lights when the object to be detected is within the reliable operating range of the photoelectric switch, and should always be illuminated when operating.

The stability indicator can also be useful where the photoelectric is being used in a dusty environment, since, as the dust builds up on the lens, the stability indicator will extinguish, indicating that it is time to clean the lens.

Glossary of terms

Operating principle

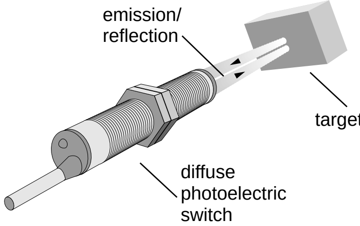
A photoelectric system consists of one or more transmitters emitting a lightbeam which is directed to one or more detectors (receiver).

An electrical signal is given when this light emission is blocked. The emission operates from an infrared (or red) light source which is generated by high efficiency, low consumption and long life semiconductors.

The emission is modulated (pulse emission and detection) for a higher instant operating power, i.e. higher distances and high immunity to the ambient light.

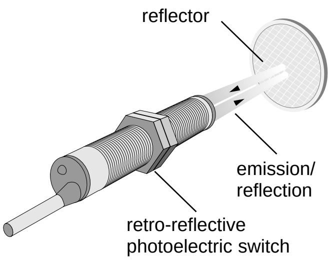
Diffuse photoelectric switch

Transmitter and receiver are housed in the same unit. The presence of a target within the sensing range cause the lightbeam to be reflected back to the receiver, thus allowing the target detection.



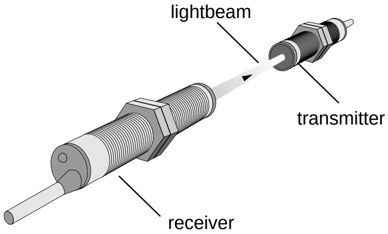
Retro-reflective photoelectric switch

Transmitter and receiver are housed in the same unit. The lightbeam emitted by the transmitter is returned to the receiver via a reflector. Detection occurs when the return lightbeam from the reflector is blocked.



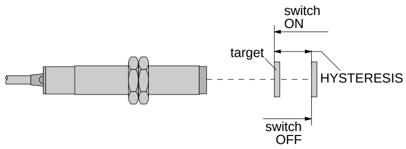
Through-beam photoelectric switch

Transmitter and receiver are mounted in separate units opposite each other. Detection occurs when the lightbeam between the transmitter and receiver is broken.



Hysteresis

Photoelectric switch hysteresis is the max. difference between the switch-ON point (non detection‘detection) and the switch-OFF point (detection‘non detection) when the target approaches and recedes from the sensing head of the photoelectric switch (or from its axis). It is quoted as a percentage of the value of the switch-ON point. The difference between the two switch-distances is intentionally introduced to avoid undesired switching when the target is just on the limit of the sensing range.



Repeatability

This is the max. variation within the different values of the switch-ON distance (non detection➔detection) in the same operating conditions and in short succession. It is quoted as a percentage of the average value computed for the different switch-ON distances.

Tolerance of the sensing range

This is quoted as a percentage of the nominal value. The real sensing range is the centre of this range.

Ripple

This is the amplitude of the max. admissible ripple in the DC supply voltage. It is quoted as a percentage of the standard DC supply voltage.

Consumption

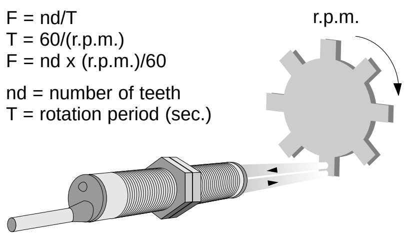
This is the maximum current required at the max. rate of nominal voltage.

Switching frequency

This is the max. ON➔OFF changes in switching state performed by the photoelectric switch. With higher switching frequency the photoelectric switch is subject to an inevitable distortion and the ON➔OFF switching may not reproduce the target state correctly.

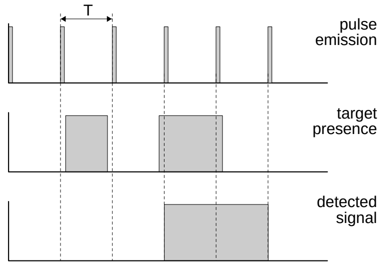
F = nd/T
T = 60/(r.p.m.)
F = nd x (r.p.m.)/60

nd = number of teeth
T = rotation period (sec.)



Response time

Time interval between two consecutive pulsed emissions. For correct switching the target should be present within the sensing range for at least this period of time. The switching frequency (f) is related to the emission range (T) by the formula: $f \leq 1/2T$.



Output type

NPN: due to the output transistor type, the load is placed between the positive and output leads.

PNP: due to the output transistor type, the load is placed between the negative and output leads.

DECOUT®: De-coupled output (fully isolated from the supply voltage) and NPN/ PNP/NO/NC user-selectable on the single unit.

TRIAC: a solid-state output to switch AC voltage loads directly.

RELAY: with output relay.

Output state

The standard terms for microswitches and inductive sensors are used to describe the output state at rest.

- NO (normally open)
- NC (normally closed)

NO: when detecting a target the output switches to the ON state (conduction).

NC: when detecting a target the output switches to the OFF state (isolation).

If the terminology light on/dark on is used, see the table below.

Detection mode	dark on	light on
DIFFUSE	NC	NO
RETRO-REFLECTIVE	NO	NC
THROUGH-BEAM	NO	NC

Residual output voltage

This is the voltage drop in the switch circuit when the output transistor is ON. It is defined as the potential drop between ground and output terminals for NPN sensors and between positive and output terminals for PNP sensors with nominal load current.

Leakage current

This is the load current when the output transistor is OFF with supply voltage at the max. nominal value.

Non-repeating current peak

The non-repeating current peak of AC photoelectric switches is the maximum current which may flow in the output circuit for a time interval of 10ms (half a full cycle) and should not be repeated within the lifetime of the sensor, e.g. a current surge due to a fault. Lower value surges, e.g. inrush currents of contactors, can be tolerated without problem, i.e. 2A max.

Application & Guidance Notes

Photoelectric Switches (continued)

Protection against polarity reversal

No damage will occur to photoelectric switches if the supply wires are reversed.

Protection against short circuit/ current limit

Short circuit and over-voltage protection operates by identifying a max. current peak or current limit. When the current peak or limit is exceeded the photoelectric switch opens the output circuit.

Reset of the operating system is performed in different ways according to the type of protection:

a) autoreset. The reset occurs automatically some time after the overload has been removed.

b) disconnect power to reset. Power must be disconnected from the switch and re-applied before it will function correctly.

Protection against inductive loads

Photoelectric switch output with inductive loads (over-voltage) protection is achieved with a diode or a Zener diode.

Time before switch operation

Time interval required by the photoelectric switch output to become ready after power has been applied. During this time the output state is open.

This time is necessary to avoid the photoelectric switch output being in an undefined state, when the system is switched on.

Insulation resistance

This is the resistance, expressed in Ω, between the photoelectric circuit and the metal housing or between the photoelectric circuit and the insulator in which the photoelectric switch is encapsulated when the housing is made of plastic, when a direct voltage of specified value is applied.

Dielectric strength

This is the max. value of sinusoidal voltage (freq.=50/60 Hz) which can be applied for 1 min. between the photoelectric circuit and the housing (metal) or the insulator in which the photoelectric switch is encapsulated (plastic) without breakdown of the dielectric used for the circuit insulation.

Noise immunity

For DC devices: the maximum noise rate asymmetrically applied on the power supply, before any errant switching.

For AC devices: the maximum noise rate applied on the power supply in a common way through the two phases, before any errant switching.

The immunity rate is computed according to the standard IEC 801. The test is carried out by applying pulse trains to the power supply during a time interval of 1 min.

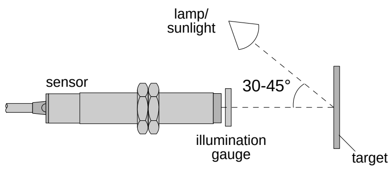
Every pulse has a rise time of 5ns and a duration of 150ns. Several pulses with a frequency of 2.5-5kHz form a train of 15ms duration. Several trains are applied with a repetition time of 300ms. 4 levels are provided according to the different pulse amplitude of 500, 1000, 2000, 4000V (I, II, III, IV).

Operating temperature

Temperature range at which nominal operating conditions are guaranteed.

Interference by external light/sunlight

This refers to the radiance (quantified in lux) falling on the receiver surface, due to any target's illumination by lamp or sunlight. The external illumination causes a variation in the reception signal of ±20% of the standard value when the illumination range is 200 lux. However, this value should not be considered to be the limit for the device's correct operating.

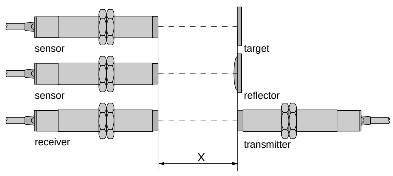


Ambient humidity

Relative humidity range at which nominal operating conditions are guaranteed.

Excess gain graph

This represents the ratio between the signal on the receiver when the target, reflector or transmitter are placed at a distance X and the minimum signal necessary to detect the target. Expressed as a function of the distance X.



Parallel displacement graph

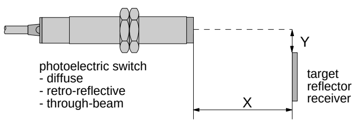
This gives the limit of approach distance Y (non detection→detection) at which the detection occurs. This is the position of:

the target (diffuse)

the reflector (retro-reflective)

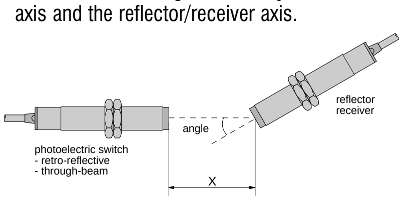
the receiver (through-beam)

as a function of the distance X between the two devices.



Optical axis angle graph

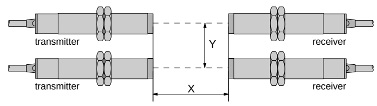
Graph for retro-reflective and through-beam photoelectric switches giving the sensing range as a function of the angle formed by the transmitter axis and the reflector/receiver axis.



Mutual interference graph

This indicates the possible interference when installing several through-beam photoelectric switches side by side. Within the interference area the lightbeam emitted by one transmitter may affect the non-corresponding receiver.

For a correct application it is necessary to avoid the possibility of interference with a certain safety degree. This can be helped by alternating the positions of the transmitters and receivers.



Distance/target size graph

This graph is suitable only for diffuse photoelectric switches. It gives the sensing range as a function of the target dimension for a white matt paper square.

DECOUT® NPN PNP NO NC multifunction isolated output

DECOUT® output advantages

The DECOUT® output is an exclusive innovation developed for photoelectric and inductive DC sensors to provice a more flexible alternative to traditional fixed output types (i.e. NPN or PNP, normally closed or normally open).

Using an opto-isolator, which isolates the DECOUT® output (DECoupled OUTput) from supply and detector circuits, the single unit is able to:

– perform the 4 possible output configurations, i.e. NPN-NO, NPN-NC, PNP-NO, PNP-NC

(this multifunction output allows for a large reduction of operating and stocking costs, permitting 1/4 reduction of the number of models employed.)

– perform series/parallel connections of different sensors without restriction

(for applications with PLC programmable logic this feature can reduce the number of inputs employed with a consequent reduction of costs, i.e. by using several sensors in a logic configuration, (AND, OR, AND/OR, etc.) on one PLC input, the possibility of requiring an expansion unit may be saved. Also, the use of several DECOUT® sensors in a logic circuit can simplify the control electronics and save relays.)

Description

Fig. 1 shows the block diagram of a DECOUT® sensor.

The output stage is electronically isolated from the rest of the circuit by an opto-isolator. Therefore, the output stage may be seen as a simple electric switch driven by detector circuitry, but isolated from it (fig 2).

In this way, the output is released from the strict logic configurations NPN or PNP.

Application & Guidance Notes

IMO

Photoelectric Switches (continued)

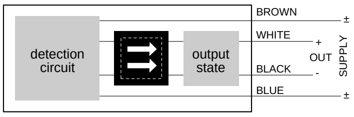


fig. 1

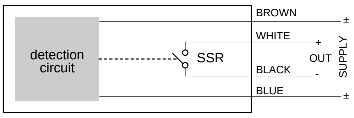


fig. 2

The DECOUT® output is also able to switch the output state at rest from NO to NC and vice versa simply by reversing the polarity of the power supply cables (BROWN - BLUE). Therefore, it is possible to perform all the output configurations, as shown in fig. 3.

■ **NPN/NO**

■ **NPN/NC**

■ **PNP/NO**

■ **PNP/NC**

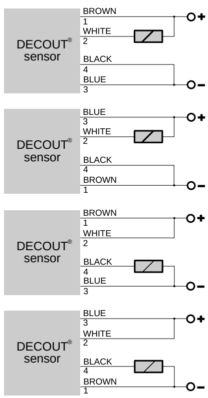


fig. 3

Output stage

Fig. 4 shows the output stage diagram. It consists of a power transistor driven by an opto-isolator. The Zener diode gives protection against inductive loads. Short circuit protection is ensured through a check of the load current. When overload or short circuit occur the output transistor is inhibited (see diagram shown in fig. 5).

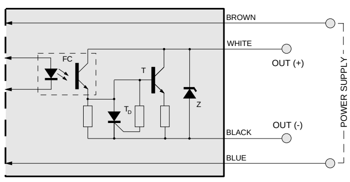


fig. 4

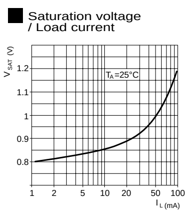


fig. 5

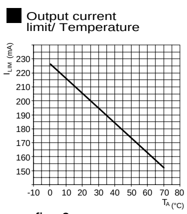


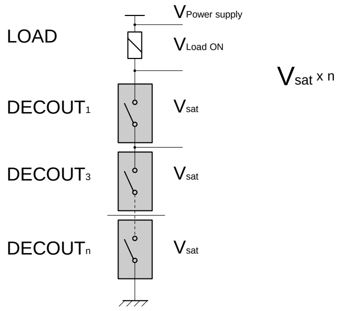
fig. 6

Series connection

The figure shows a simplified diagram of series connection of a number of DECOUT® sensors.

The maximum number of sensors (n) to be connected is obtained from the following formula:

$$n = (V_{Power\ supply} - V_{Load\ ON}) / V_{sat}$$



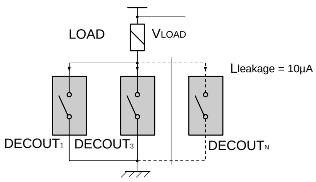
Where:

$V_{Load\ ON}$ min. load energization voltage
$V_{Power\ supply}$ supply voltage
V_{sat} saturation voltage of the sensor in ON mode (0.8-1.2V, see fig. 6).

In series connection of several sensors it is necessary to account for the voltage drop value when the load is energized (V_{sat} ranges between 0.8 and 1.2V, as shown in fig. 6), according to the available supply voltage.

Parallel connection

The figure shows the simplified diagram of parallel connection of a number of DECOUT® sensors.



The maximum number of the sensors (n) to be connected is obtained from the formula:

$$n = V_{Load\ OFF} / (R_{Load} \times L_{leakage})$$

Where:

$V_{Load\ OFF}$ max. load de-energization voltage
R_{Load} load resistance
$L_{Leakage}$ max. leakage current of the sensor (10μA).

Since the value for leakage current is very low there are no practical restrictions in the parallel connection of several sensors, provided the load current is of a few mA.

Application examples

The following examples show simple logic configurations.

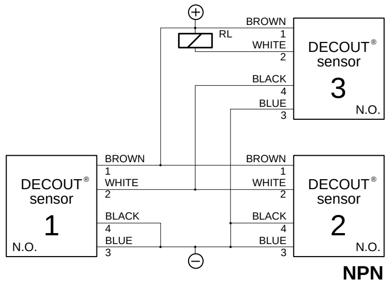
For a better understanding of these, consider that:

a) n truth-table 0 and 1 indicate the actual output configuration (0 open - 1 closed). The target presence is shown by the shaded areas.

b) a 1 in column RL indicates an energized load.

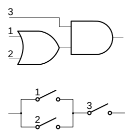
c) the equivalent logic diagrams are shown, without NPN or PNP load connection, for easy understanding.

1. Series/parallel combined connection

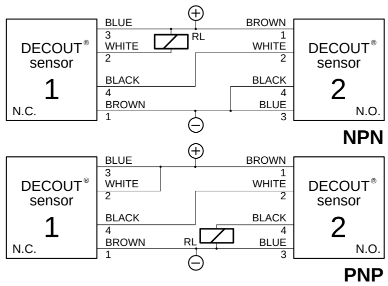


■ Parallel/series connection

DECOUT 1	DECOUT 2	DECOUT 3	RL
0	0	0	0
1	0	0	0
0	1	0	0
1	1	0	0
0	0	1	0
1	0	1	1
0	1	1	1
1	1	1	1

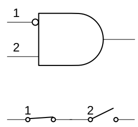


2. Series connected sensor outputs (NO NC outputs)

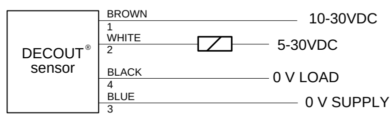


■ AND function
with inverted input

DECOUT 1	DECOUT 2	RL
1	0	0
0	0	0
1	1	1
0	1	0



Separate power supply



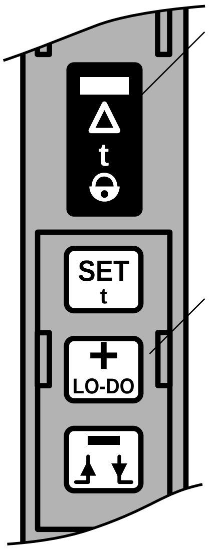
MAX. ISOLATION BETWEEN 0 V LOAD AND O V SUPPLY: 1000 VAC

The decoupled output allows different voltages from separate power sources to supply the sensor and load. This enables the user to meet all interface applications.

Set up procedure for self teach product types RD, RP, RJ, FP2 and FG2

Adjustment at the touch of a button...

Needing no special skills, simply press to activate the self-teach function and configure sensor parameters in-situ. The lock keyboard function prevents unauthorised or accidental resetting of sensivity.



LED display

At-a-glance indication of:

- ON-OFF detection
- dirty optic
- low signal
- alignment
- timer ON
- locked keyboard
- short circuit

Keyboard

Three waterproof keys are used to adjust and set:

- threshold/sensitivity
- timing (from 0.04 to 5secs)
- sensor output state
- keyboard lock

Keyboard use

There are three methods to activate the keys:

a) short press (<1s); LED is on for the activation time of the key.

b) long press (<4s); LED is on and goes off after 4 seconds signalling

reception of input.

c) double press (when activated); LED is on for the activation time of the key (two impulses).

In the following instructions the following symbology will be used.

( ) = short press

(4s) = long press

(2x) = double press

These symbols will be put after the key number examined.

Keyboard Lock

To block the keyboard, press key and at the same time (4s); LED is on when the keyboard is locked.

Keyboard Reactivation

To reactive the keyboard, press key and at the same time (4s); LED is off when the keyboard is active.

Automatic sensitivity adjustment

Standard set-up (detection with high immunity to dust and to exteral light)

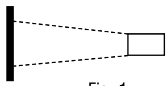


Fig. 1

Diffuse

Place the detectable object at the required reading distance (Fig. 1) and press key ( ); LED 4 illuminates signalling the self teach operation is in progress.

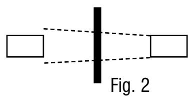


Fig. 2

Through beam

Place the detectable object between emitter and receiver of the through beam as shown in (Fig. 2) press key ( ); LED 4 illuminates signalling the self teach operation is in progress.

Fine set-up (precise detection of small objects or detection of transparent objects).

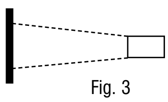


Fig. 3

Diffuse

Place the detectable object at the required reading distance (Fig. 3) and press key (2x); LED illuminates signalling the set-up complete.

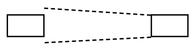


Fig. 4

Through beam

Place emitter and receiver of the through beam as in (Fig. 4) press key (2x). LED illuminates signalling the set-up complete.

To set the through beam, see paragraph "alignment help".

Manual sensitivity adjustment

After executing threshold set-up, it is possible to manually adjust the sensitivity function in the following way: press key ( ) to obtain an increase in sensitivity. The number of impulses corresponds to an equal number of sensitivity increases. Press key ( ) to obtain a decrease in sensitivity. The number of impulses corresponds to an equal number of sensitivity decreases.

N.B. In diffuse reflection configuration the maximum sensing distance is obtained when you press the key ( ) without a target.

Alignment help

The sensor is set for alignment help when you press key set (4s); LED blinks with three different speeds depending on the intensity of signal received.

For fine set-up applications, operate the alignment as follows:

Diffuse: adjust the distance of the detectable object between the limit of rapid and medium blinking of the LED.

Through beam: adjust the emitter and the receiver position as to reach the limit of rapid and medium blinking of the LED.

When the correct alignment is obtained, press key set (4s); LED turns off signalling the end of alignment help conditions.

Output selection NO/NC

To invert the output state from NO to NC and vice versa, it is sufficient to press key (4s).

Timer adjustment

To activate timer adjustment modes press key set (4s); LED starts blinking thus showing that sensor is ready for timer activation:

a) press key ( ); we obtain a timer increase reaching 40ms with the 1st impulse and reaching up to 500ms with successive impulses;

b) if we press key ( ), we obtain a timer decrease at each impulse.

c) press key ( ) if you want to switch off the timer function;

d) press key (4s) in case you need to invert from "on delay" to "off delay" timer and vice versa;

When you have finished the timer adjustment, press key set (4s); LED turns off signalling the conclusion of adjustment function.

N.B. Detection is active during timer adjustment function. LED is on only when the timer has already been set-up.