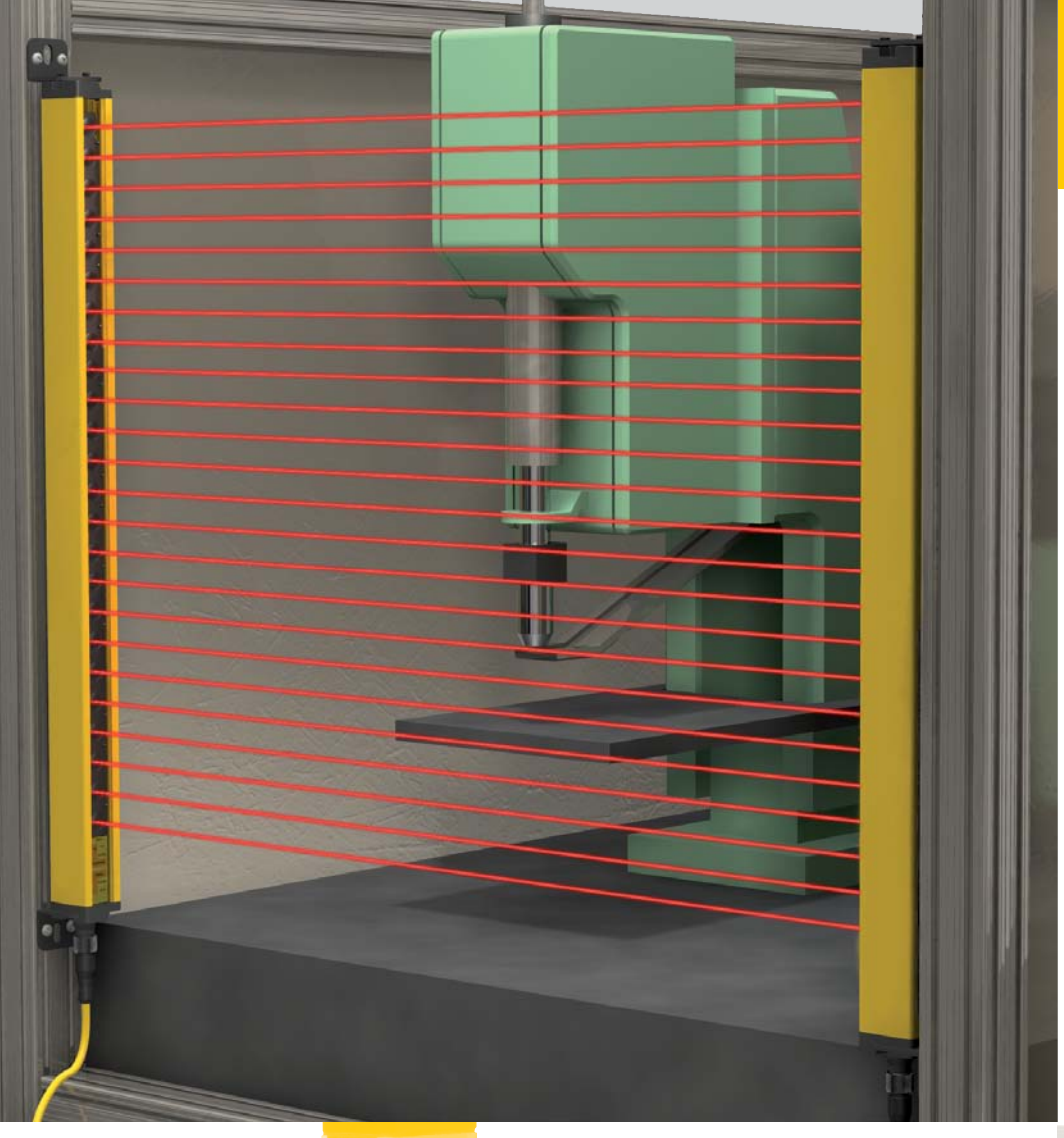

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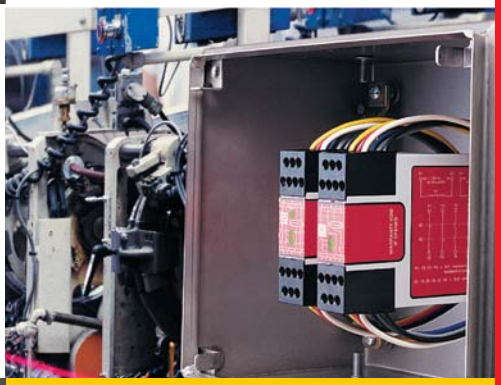
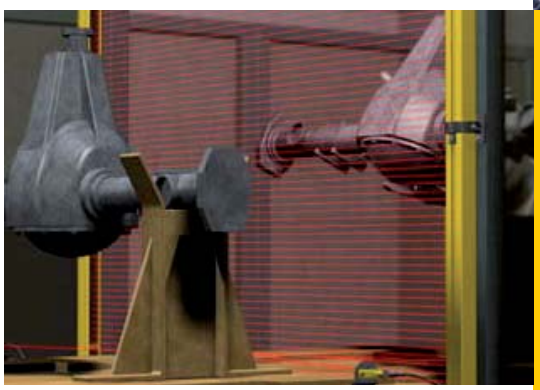
MACHINE SAFETY





Sense it! Connect it! Bus it! Solve it!

Integration of safety technology

The degree of automation is very advanced in today's manufacturing technology. At the same time, machine and system hazards have been reduced considerably. This is, in particular, owed to the high demands on the safety technology and the skilled handling of safety functions.

TURCK offers a choice of efficient, certified safety components and systems for machine and plant engineering. In addition, we also support our customers in assessing the safety requirements and present suitable solution approaches.

Electrical Voltage

Automatic start-up

Entanglement hazard

Trip hazard

Hand injury

Crushing hazard

The present flyer contains a choice of safety technology solutions from TURCK The chapter "Machine safety" describes briefly how manufacturers and operators of machines can determine the required performance level through a systematic risk assessment In terms of planning, implementation and consideration of safety functions, determining the performance level is of crucial importance and cannot be done by the Hans Turck GmbH & Co. KG for legal reasons.

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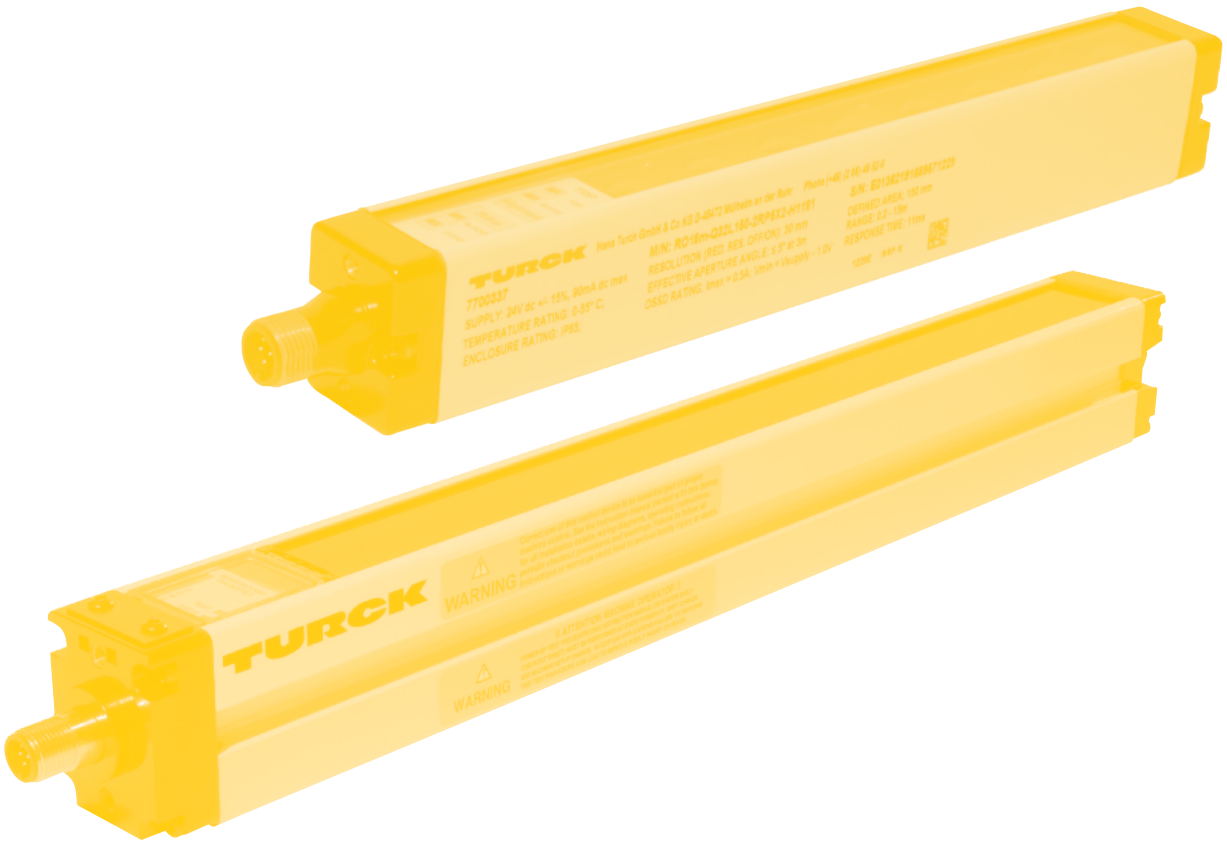
Solutions for personnel safety

Industrial Automation



Machine safety

Functional safety of machines and plants is described in the current directive EN ISO 13849-1 (formerly EN 954-1) This directive not only comprises a deterministic approach, hence the risk assessment based on predetermined machine properties (approved methods are described in the directive), it also contains a probabilistic approach, assessing the likelihood and the dangers of a failure, regardless of the type of machine and thus enabling direct comparison with EN 6206 1. The resulting risk analysis requires a redefinition of terms, which is shortly outlined below.

EN ISO 13849-1

The EN ISO 13849-1 is applicable to safety-related parts of control systems (SRP/CS) and machines of all kinds, regardless of the technology deployed (electrical, electronic, programmable electronic, hydraulic, pneumatic, mechanical systems). The performance level (PL) is used to assess the safety functions comprehensively.

Performance level: From the nominal value to the actual value

Step 1:

A performance level PLr must be determined for each intended safety function. The EN ISO 13849-1 contains a hazard graph with different risk parameters, similar to EN-954-1. (Fig. 1). One out of five performance levels "a" to "e" results from the risk analysis. This PLr value is the nominal value on the basis of which the design engineer implements the safety functions.

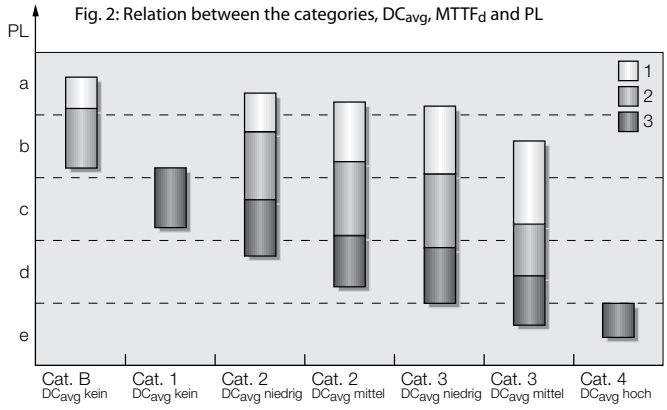
Step 2:

Once the safety function and the required risk mitigation in form of the PLr value is determined, the actual design of the safety related parts follows next. The starting point is the envisaged structure or architecture of the safety control. Following the EN 954-1, the EN ISO 13849-1 defines five structures as categories (Cat. B, 1, 2, 3, 4). These categories are the guideline along which the probability of failure and the achieved PL can be determined in a simple way, in combination with the following cause variables (Fig. 2):

– $MTTF_d$ (Mean Time To Failure) and
– DC_{avg} (Average Diagnostic Coverage).

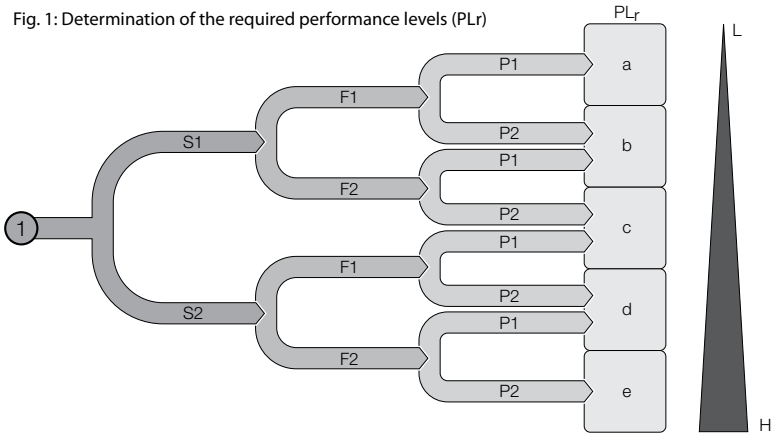
However, a basic precondition is that the duration of use is at least 20 years and that the failure rate is constant during this period.

Fig. 2: Relation between the categories, DC_{avg}, $MTTF_d$ and PL



Key
PL Performance Level
1 $MTTF_d$ of each channel = low
2 $MTTF_d$ of each channel = middle
3 $MTTF_d$ of each channel = high

Fig. 1: Determination of the required performance levels (PLr)



Key
1 Start point for evaluation of the effects of risk mitigation
L low effect on risk mitigation
H high effect risk mitigation
PLr required Performance Level

Risk parameters
S severity of injury
S1 minor (normally reversible injury)
S2 serious (normally irreversible injury including death)
F frequency and/or duration of exposure to hazards
F1 seldom to less often and/or short period of exposure to hazards
F2 frequent to continuous and/or long period of exposure to hazards dungsexposition
P possibility to avoid hazard or to minimize damage
P1 possible under certain conditions
P2 hardly possible

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Step 3:
Via the determined values $MTTF_d$ and DC_{avg} this procedure results in a performance level (PL) and, when complying with the required PLr value, it can be gradually approached to the required result (PLr ≤ PL)

Determining the $MTTF_d$ value
Unlike the EN 61508 (to which EN 62061 is subordinated) the EN ISO 13849 only covers those components which are relevant for the safety function. The directive provides default values for some standard components; however, it makes more sense to refer to the values state on the technical data sheets or the generally accepted values of the Siemens norm SN29500. It is generally assumed that the probability of dangerous failure is equal to the probability of safe failure, with the $MTTF_d$ calculated as twice the value of MTTF. The grouping is done as follows:

Designation	Value range $MTTF_d$
low	3 years ≤ $MTTF_d$ < 10 years
middle	10 years ≤ $MTTF_d$ < 30 years
high	30 years ≤ $MTTF_d$ < 100 years

Multichannel systems are first evaluated separately and then symmetrized with a formula. Fault exclusions are defined as infinite $MTTF_d$ values.

Determining the DC_{avg} value
The degree of diagnostic coverage DC indicates the effect of test routines in % error recognition. Tables with typical test measures and DC values are contained in the appendix E of EN ISO 13849-1. The averaging of DCavg is achieved with an approximation formula. DC is defined as the ratio of dangerous undetected failure rate to the rate of all dangerous failures.

Designation	Value range DC
n.a.	DC < 60 %
low	60 % ≤ DC < 90 %
middle	90 % ≤ DC < 99 %
high	99 % ≤ DC

Step 4:
Common Cause Failures (CCF)
Multichannel systems additionally require a safety evaluation in the event of common cause failures. At least 65 out of 100 points of a list of measures must be scored to obtain the go-ahead for construction.

Measures	Points
Separation signal paths	15
Diversity	20
Design (e.g. surge protection/ overpressure protection)	15
Proven components	5
FMEA	5
Competence/training of developers	5
Electromagnetic compatibility (EMC), filtration etc.	25
Other environmental influences (e.g. temperature)	10

Functional safety acc. to EN 62061

EN 62061 is applicable to safety related electrical, electronic and programmable systems.
In machine safety, the highest level of risk mitigation to be achieved is SIL3. With the new directive EN ISO 13849-1 the probability of dangerous failure was introduced. This means that the safety function and the related components of the safety chain need differentiated and extended evaluation (Fig. 3). Interconnecting several safety parts to a chain may increase the probability of failure of the safety function, depending on the type of connection.

Effects and severity	S	Frequency and duration	F	Probability dangerous event	W	Avoidance	P	Class K = F + W + P 3-4	5-7	8-10	11-13	14-15
Death, loss of an eye or arm	4	≤ 1 hrs.	5	frequently	5			SIL 2	SIL 2	SIL 2	SIL 3	SIL 3
permanently, loss of fingers	3	> 1 hrs. – ≤ 1 day	5	probable	4				AM	SIL 1	SIL 2	SIL 3
reversible, medical treatment	2	> 1 day – ≤ 2 weeks	4	possible	3	impossible	5			AM	SIL 1	SIL 2
reversibel, first aid	1	> 2 weeks – ≤ 1 year	3	rarely	2	possible	3				AM	SIL 1
		> 1 year	2	negligible	1	probable	1	(AM = other measures recommended)				

Source: BGIA

Fig.3 Assessing the risk and determining the required Safety Integrity Level (SIL)

Safety light screen Q32L

Type 2/PL c/SIL 1

Features

- Low-priced light screen
- Resolution 30 mm, (hand detection)
- Field height 150 …1500 mm
- Range 0.2…15 m
- Synchronized, modulated infrared beams
- Switching or locking output with start/restart interlock (automatic or manual start/restart)
- Safety transistor outputs located directly at the light screen
- Immune to EMI and RFI, ambient, welding and flash light
- Clearly visible LED indicators on the emitters and receivers for system status and error code
- Rugged aluminium housing, IP65 rated
- Integrated M12 connector
- Mounting bracket included in delivery

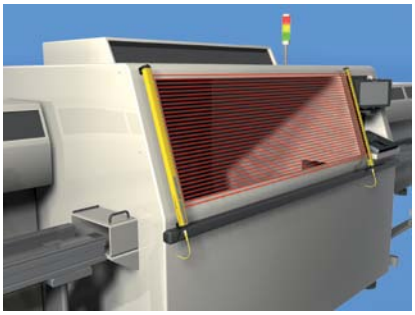
Safety Light Screen Q32L – light screen triggers start and stop of machine

The Safety Light Screens of the Q32L series are certified acc. to type 2, EN 61496, SIL 1 acc. to EN 62061 and PL c acc. to EN ISO 13849-1. These devices are rugged and a reasonably priced hand guard for industrial applications.
Two versions are available with switching or locking output.

Commissioning of the Q32L is easy. It is simply mounted and aligned, no further action is needed.

The safety light screen consists of an emitter and a receiver and operates contactless. The system is optically synchronized without wiring between emitter and receiver. The safety switching outputs of the receiver are directly connected to a load relay (e.g. IM73-23-R/24VDC) and trigger an immediate stop of the dangerous machine cycle.

Safety Light Screen Q32L – hand guard at the storage paternoster



Safety Light Screen Q32L – hand guard at the storage paternoster

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Type code

R	O	15m	–	Q32L1050	–	2RL	P	5	X2	–	H1	1	8	1

R	O	15m	Optical feature	–	Q32L1050	Housing feature	–	2	R	L	P	5	X2	Electrical feature	–

Range
15m distance in m

Function principle
O photoelectric sensors

Operating mode
E Emitter
R Receiver

Housing style
Q32 rectangular housing, size in mm
L1050 lenght of active area, size in mm

H1	1	8	1	Connection

Assignment
1 pinning acc. to standard

Number of contacts
8 number of contacts

Connector design
1 straight

Connector type
H1 M12 x 1

LEDs
X2 2 LEDs or 2-color-LED

Voltage range
5 24 VDC ± 20 %

Output
P PNP

Output function
L Latch
blank Trip

Output function
R N. C. (normally closed

Output function
2 number of outputs in case of more than one

Resolution 30 mm, range 0.2 ...15 m

Field height	Type code	Description
150 mm	EO15m-Q32L150-5X2-H1181	emitter
	RO15m-Q32L150-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L150-2RP5X2-H1181	receiver output function trip
300 mm	EO15m-Q32L300-5X2-H1181	emitter
	RO15m-Q32L300-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L300-2RP5X2-H1181	receiver output function trip
450 mm	EO15m-Q32L450-5X2-H1181	emitter
	RO15m-Q32L450-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L450-2RP5X2-H1181	receiver output function trip
600 mm	EO15m-Q32L600-5X2-H1181	emitter
	RO15m-Q32L600-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L600-2RP5X2-H1181	receiver output function trip
750 mm	EO15m-Q32L750-5X2-H1181	emitter
	RO15m-Q32L750-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L750-2RP5X2-H1181	receiver output function trip
900 mm	EO15m-Q32L900-5X2-H1181	emitter
	RO15m-Q32L900-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L900-2RP5X2-H1181	receiver output function trip

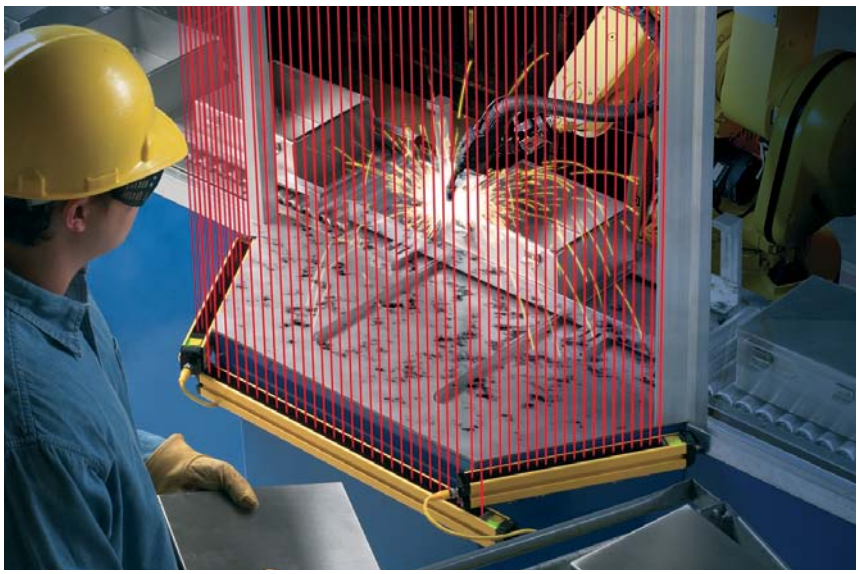
Field height	Type code	Description
1050 mm	EO15m-Q32L1050-5X2-H1181	emitter
	RO15m-Q32L1050-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1050-2RP5X2-H1181	receiver output function trip
1200 mm	EO15m-Q32L1200-5X2-H1181	emitter
	RO15m-Q32L1200-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1200-2RP5X2-H1181	receiver output function trip
1350 mm	EO15m-Q32L1350-5X2-H1181	emitter
	RO15m-Q32L1350-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1350-2RP5X2-H1181	receiver output function trip
1500 mm	EO15m-Q32L1500-5X2-H1181	emitter
	RO15m-Q32L1500-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1500-2RP5X2-H1181	receiver output function trip
1650 mm	EO15m-Q32L1650-5X2-H1181	emitter
	RO15m-Q32L1650-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1650-2RP5X2-H1181	receiver output function trip
1800 mm	EO15m-Q32L1800-5X2-H1181	emitter
	RO15m-Q32L1800-2RLP5X2-H1181	receiver output function latch
	RO15m-Q32L1800-2RP5X2-H1181	receiver output function trip

Safety light screen Q45L

Type 4/PL e/SIL 3

Features

- Versions with 14 mm resolution for finger detection:
  Scan field 150…1200 mm, range 0.1…6 m
- Versions with 30 mm resolution for hand detection:
  Scan field 150…1800 mm, range 0.1…18 m
- Coarser resolution adjustable
- DIP switch to adjust the operation mode (switching or locking function), scan code etc.
- Receiver with bargraph for optical alignment
- Optical disply o diagnostic data of system and operating status
- Blanking function
- Rugged aluminium housing, IP65 rated
- Integrated M12 connector
- Mounting bracket included in delivery



Protection area of a hazardous machine

The Safety Light Screens of the Q45L series are certified acc. to type 4 EN 61496, SIL 3 acc. to EN 62061 and PL e acc. to EN ISO 13849-1. The resolution is either 14 mm for finger detection or 30 mm for hand detection

The Safety Light Screen Q45L is easily configured via DIP switch Diagnostic data is indicated via LED display and a bargraph Thanks to many different versions and a comprehensive choice of accessories, the rugged light screen can be installed in many applications.

The Safety Light Screen consists of an emitter and a receiver and operates contactless. The system is optically synchronized without wiring between emitter and receiver. The safety switching outputs of the receiver are directly connected to a load relay (e.g. IM73-23-R/24VDC) and trigger an immediate stop of the dangerous machine cycle.

Safety Light Screen Q45L – bargraph for optical alignment

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Type code

R	O	18m	–	Q45L1050	–	2R	P	5	X2	–	H1	1	8	1
R	O	18m	Optical feature	–	Q45L1050	Housing feature	–	2R	P	5	X2	Electrical feature	–			

Range
18m distance in m

Function principle
O photoelectric sensors

Operating mode
E Emitter
R Receiver

Housing style
Q45 rectangular housing, size in mm
L1050 lenght of active area, size in mm

LEDs
X2 2LED/or 2-color-LED

Voltage range
5 special voltage ranges

Output
P PNP

Output function
2 number of outputs in cases of more than one
R N. C. (normally closed)

H1	1	8	1	Connection

Assignment
1 pinning acc. to standard

Number of contacts
8 number of contacts

Connector design
1 straight

Connector type
H1 M12 x 1

Resolution 14 mm, range 0.1…6 m

Field height	Type code	Description
150 mm	EO6m-Q45L150-5X2-H1181 RO6m-Q45L150-2RP5X2-H1181	emitter receiver
300 mm	EO6m-Q45L300-5X2-H1181 RO6m-Q45L300-2RP5X2-H1181	emitter receiver
450 mm	EO6m-Q45L450-5X2-H1181 RO6m-Q45L450-2RP5X2-H1181	emitter receiver
600 mm	EO6m-Q45L600-5X2-H1181 RO6m-Q45L600-2RP5X2-H1181	emitter receiver
750 mm	EO6m-Q45L750-5X2-H1181 RO6m-Q45L750-2RP5X2-H1181	emitter receiver
900 mm	EO6m-Q45L900-5X2-H1181 RO6m-Q45L900-2RP5X2-H1181	emitter receiver
1050 mm	EO6m-Q45L1050-5X2-H1181 RO6m-Q45L1050-2RP5X2-H1181	emitter receiver
1200 mm	EO6m-Q45L1200-5X2-H1181 RO6m-Q45L1200-2RP5X2-H1181	emitter receiver
1350 mm	EO6m-Q45L1350-5X2-H1181 RO6m-Q45L1350-2RP5X2-H1181	emitter receiver
1500 mm	EO6m-Q45L1500-5X2-H1181 RO6m-Q45L1500-2RP5X2-H1181	emitter receiver
1650 mm	EO6m-Q45L1650-5X2-H1181 RO6m-Q45L1650-2RP5X2-H1181	emitter receiver
1800 mm	EO6m-Q45L1800-5X2-H1181 RO6m-Q45L1800-2RP5X2-H1181	emitter receiver

Resolution 30 mm, range 0.1…18 m

Field height	Type code	Description
150 mm	EO18m-Q45L150-5X2-H1181 RO18m-Q45L150-2RP5X2-H1181	emitter receiver
300 mm	EO18m-Q45L300-5X2-H1181 RO18m-Q45L300-2RP5X2-H1181	emitter receiver
450 mm	EO18m-Q45L450-5X2-H1181 RO18m-Q45L450-2RP5X2-H1181	emitter receiver
600 mm	EO18m-Q45L600-5X2-H1181 RO18m-Q45L600-2RP5X2-H1181	emitter receiver
750 mm	EO18m-Q45L750-5X2-H1181 RO18m-Q45L750-2RP5X2-H1181	emitter receiver
900 mm	EO18m-Q45L900-5X2-H1181 RO18m-Q45L900-2RP5X2-H1181	emitter receiver
1050 mm	EO18m-Q45L1050-5X2-H1181 RO18m-Q45L1050-2RP5X2-H1181	emitter receiver
1200 mm	EO18m-Q45L1200-5X2-H1181 RO18m-Q45L1200-2RP5X2-H1181	emitter receiver
1350 mm	EO18m-Q45L1350-5X2-H1181 RO18m-Q45L1350-2RP5X2-H1181	emitter receiver
1500 mm	EO18m-Q45L1500-5X2-H1181 RO18m-Q45L1500-2RP5X2-H1181	emitter receiver
1650 mm	EO18m-Q45L1650-5X2-H1181 RO18m-Q45L1650-2RP5X2-H1181	emitter receiver
1800 mm	EO18m-Q45L1800-5X2-H1181 RO18m-Q45L1800-2RP5X2-H1181	emitter receiver

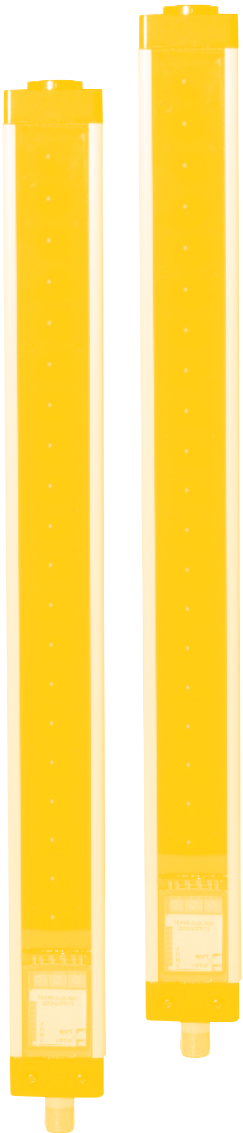
Accessories

Connection cables for – Q32L and Q45L series

Type code	Length	Description
RKC-8-5/5	5 m	Female M12 x 1, 8-pin

safety relays

Type code	Description
IM73-23-R/24VDC	3 NO, 6 A
IM73-221-R/24VDC	2 NO, 1 auxiliary NC, 6 A



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Terms, characteristic values and definitions

- **B_{10d}**
  Number of cycles, of which 10 % of components affected by wear have failed dangerously after random check

- **β**
  Beta factor also Common Cause Factor; measure for CCF; rate of failures with common cause

- **CCF**
  Common cause failure

- **Diagnostic coverage (DC)**
  Measure for diagnostic effect; the DC (degree of coverage) is defined as the ratio of the dangerous detected failure rate to the rate of all dangerous failures.

- **DC_{avg}**
  average diagnostic coverage
- **Diagnostic-Test interval**
  Time between online tests to detect failures in a safety-related system with specified diagnostic coverage
- **Diversity**
  Different means to perform one demanded function

- **Failure**
  State of a unit characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources.
- **FMEA**
  Failure Mode and Effects Analysis; preventive method for risk and failure analysis of products and processes
- **Category (CAT)**
  Classification of the safety-related parts of a control system in respect of their resistance to failures and their subsequent behaviour in the failure condition, and which is achieved by the structural arrangement of the parts, fault detection and/or reliability

- **λ** failure rate
  $\lambda = 1/MTTF$
- **λ_g** dangerous failure rate
  $\lambda_g = 1/MTTFg$
- **λ_s** safe failure rate
  $\lambda_s = 1/MTTFs$
- **$MTTF_d$**
  Mean Time To Failure dangerous

- **Performance Level (PL)**
  Specifies the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions to fulfill the expected risk mitigation.

- **Performance Level, required (PL_r)**
  Specifies the level of risk mitigation required for a safety function.
- **PFH = PFH_d**
  Probability of dangerous failure per hour at continuous use (reference value for PL and SIL).

- **Redundancy** Presence of more means than necessary for a functional unit to fulfill the intended function or for data to represent information

- **Residual risk**
  Risk still inherent after undertaking protective measures.
- **Risk**
  Combination of probability of occurrence of damage and severity of this damage
- **Risk analysis**
  Combination of specification of machine limits, identification of hazards and risk estimation
- **Risk assessment**
  Entire procedure comprising the analysis and evaluation of risk.
- **Risk evaluation**
  Evaluation based on the risk analysis, judging if the targets to minimize the risk were achieved.

- **Safety Integrity Level (SIL)**
  Discrete level for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE system, where SIL 3 (SIL 4 in the process industry) has the highest level of safety integrity and SIL 1 the lowest.

The measures described here are a simplification and provide an overview of the two standards EN ISO 13849-1 and EN 62061. The validation of control circuits requires knowledge of the correct application of relevant standards and directives. Therefore we do not take responsibility for the completeness of the information

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