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What is functional safety and why is machine safety important?



Safety is a basic need of people. And with safe machinery and systems, manufacturer and owners of machines are assured certainties with the legal requirements.

Safe machines also ensure higher productivity and prevent the loss of workers. And if accident happens due to unsafe machines, the image of the company may be damaged.

Machine owners expect to be offered only safe machinery or devices. And while operating the machines or devices, operators and maintenance personnel should be able to rely on the safety features! These expectations exist worldwide. There are also regulations on the protection of users of machinery worldwide. These regulations may vary from regions.

One of the fundamental principles of the European Community is the protection of its citizens' health both in the private and professional sphere.

The requirements for the safety of machinery as for the use of protective devices are defined in Europe by differing legislative stipulations and technical standards in the various countries.

The following directives have been published in the area of health and safety at work and machine safety:



- The Machinery Directive 2006/42/EG, which primarily addresses the **manufacturer** of machines
- The Work Equipment Directive 2009/104/EG, which primarily addresses the **operator** of machines
- Additional directives, e.g. Low Voltage Directive, EMC Directive, ATEX Directive

The **manufacturers** are obliged to construct their machines so that they comply with the fundamental requirements for safety of the Machinery Directive. The manufacturers must consider safety integration during the design process.

In practice, this means that the designer must already perform risk assessment during the development phase of the machine. The resulting measures can flow directly into the design.

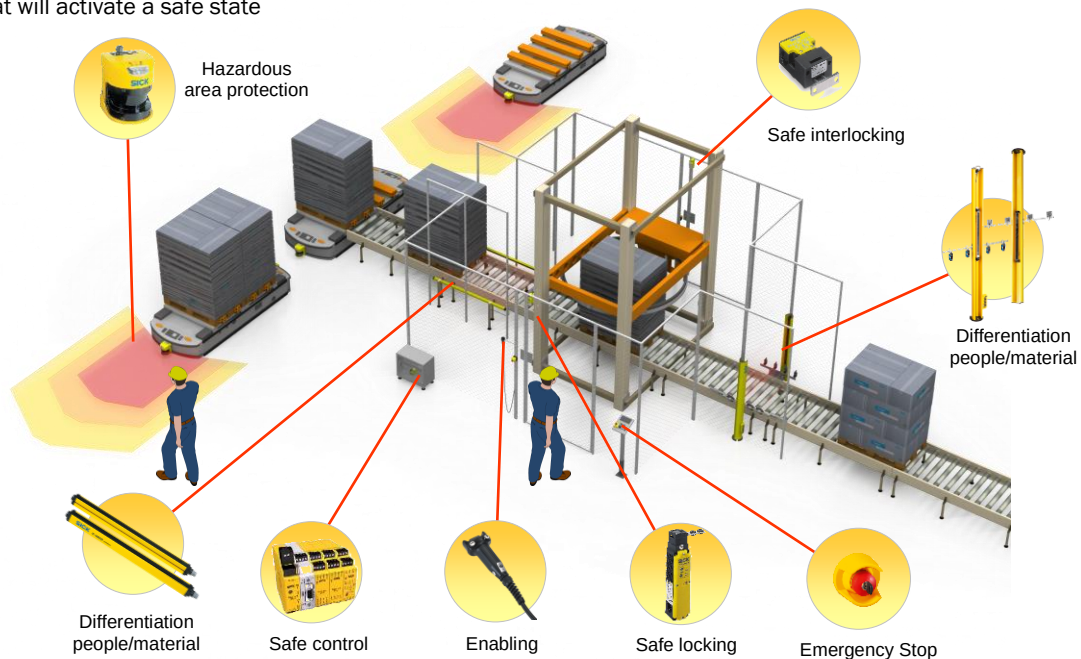
On the European level, the Work Equipment Directive applies to the **operator** of a machine:

The operator is responsible for the safety of the employees. Machines must be ergonomic and capable of being operated safely according to the qualifications of the machine operators.

Functional safety is a part of the risk reduction process. Functional safety looks into the correct functioning of the safety related (sub-) systems and the necessary external safety measures.

Not encompassed in functional safety are, electrical safety, fire protection, radiation protection, personal protective equipment, among others.

Example: A fixed hard guard protective equipment is not considered as functional safety, but the interlocked door is an instance of functional safety. Because when the interlocked door is opened, the interlock serves as an "input" to a safety system that will activate a safe state

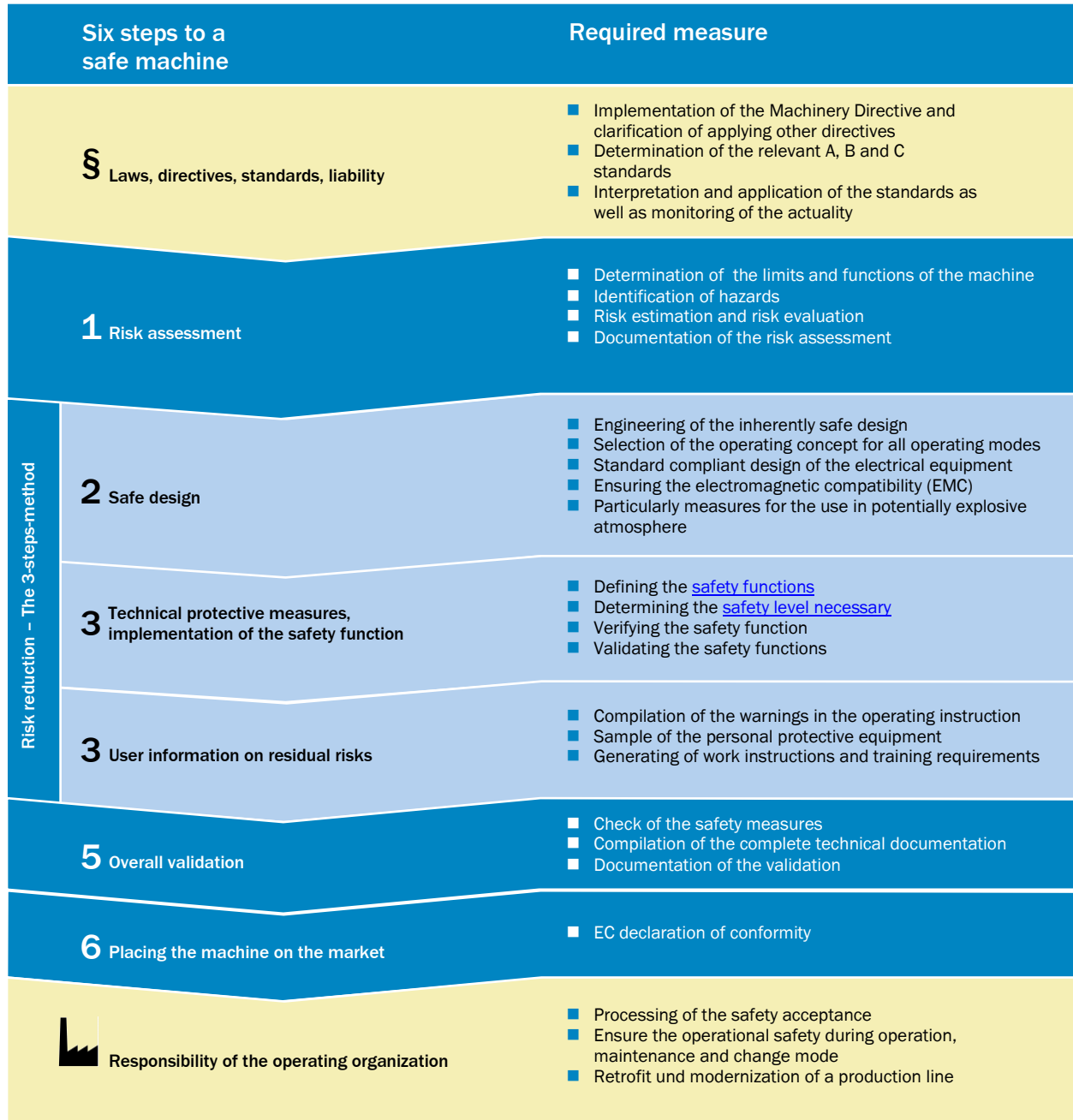


More information:

[Brochure "Guide Safe Machinery"](#)

What aspects must be considered when implementing machine safety?

In its  [brochure "Guide Safe Machinery"](#), SICK describes the complete path to a safe machine in six steps. The required measures are shown in this overview.



More information and support:

 [Brochure "Guide Safe Machinery"](#)

 [Service Solutions and Training for "Consulting, Design and Support"](#)

What hazards can exist at machines/systems?

After the definition of the function of the machine comes the most important step in the risk assessment on the machine.

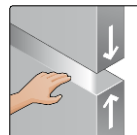
This step comprises the systematic identification of foreseeable hazards, hazardous situations and/or hazardous events. In particular the machine manufacturer should take into account the hazards in all phases of the service life of the machine.

- mechanical hazards
- electrical hazards
- thermal hazards
- hazards due to noise
- hazards due to vibration
- hazards due to radiation
- hazards due to materials and substances
- hazards due to neglecting ergonomic principles during the design of machinery
- hazards due to slipping, tripping and falling
- hazards related to surroundings in which the machine is used
- hazards resulting from a combination of the above mentioned hazards

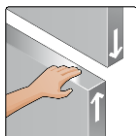
Examples of hazards at machines/systems



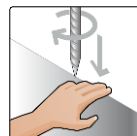
Cutting



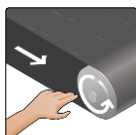
Crushing



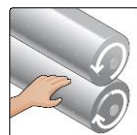
Shearing



Stabbing



Drawing in or trapping



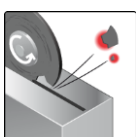
Drawing in or trapping



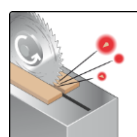
Entanglement



Impact



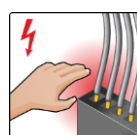
Impact from broken parts



Impact from ejected chips



Heat



Electric shock

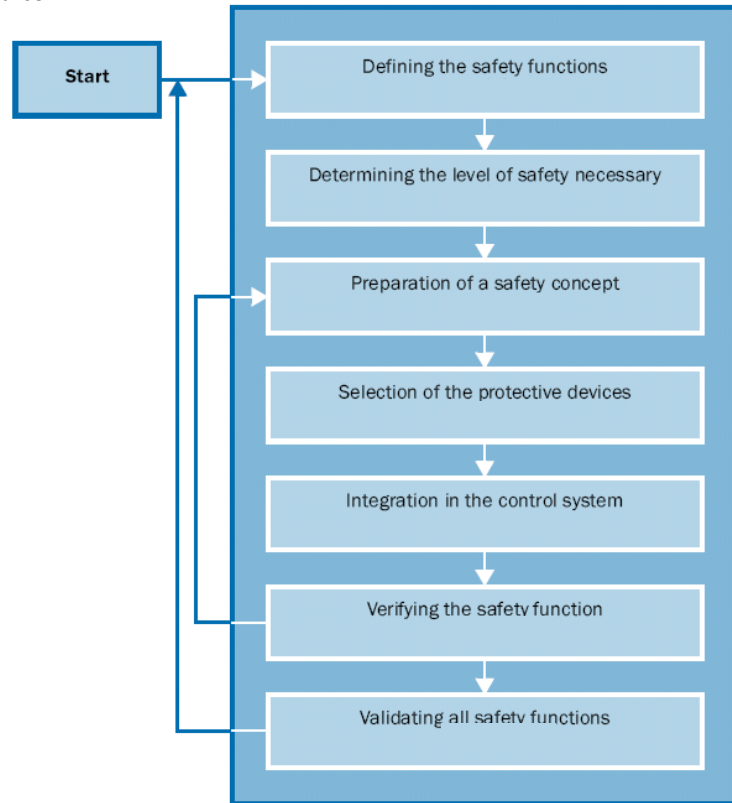


Radiation

What are technical protective measures?

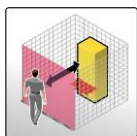
Technical protective measures are necessary when the identified risks cannot be reduced by design measures. They are implemented by using protective devices (covers, doors, light curtains, two-hand devices) or monitoring devices (for position, speed, etc.) that perform a [safety function](#) (→ on page 6).

Procedure for implementing protective measures:



The protective devices must be selected as part of the technical protective measure.

The [SICK Safety Solution Assistant](#) provides assistance when selecting the protective device and the matching product technology.



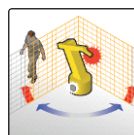
- Single-side access protection with detection of a person's body.



- Locking of physical guards (e.g. swivel doors, flaps).



- Mobile hazardous area protection to
- Detect a person (leg) approaching the hazard area in mobile applications.
- Protect persons while vehicles are moving.
- Prevent the machine from starting while persons are present in hazardous area.



- Safe monitoring of machine positions, e.g. when robots are used.

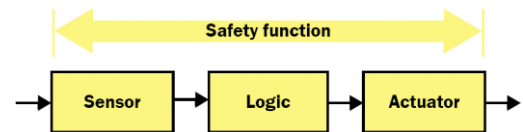
Examples for technical protective devices

More information:

[Brochure "Guide Safe Machinery"](#)

What are safety functions?

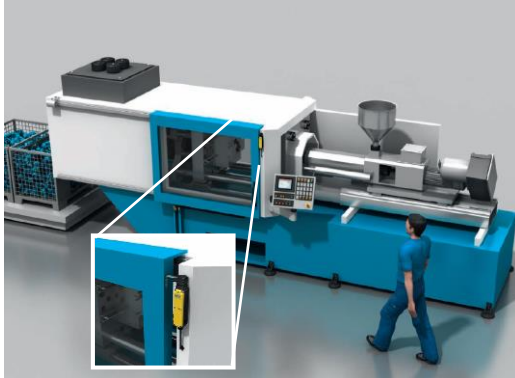
The safety function defines how safety measures will reduce the risk. A safety function must be defined for each hazard that has not been eliminated by design measures. It is necessary to provide a precise description of the safety function to achieve the required safety with reasonable effort. The type and number of components required for the function are derived from the definition of the safety function.



Examples of safety functions:

■ Temporarily preventing access

Door interlock with locking at the injection mold machine



■ Initiating a stop

Access protection at a vulcanizing for tires.



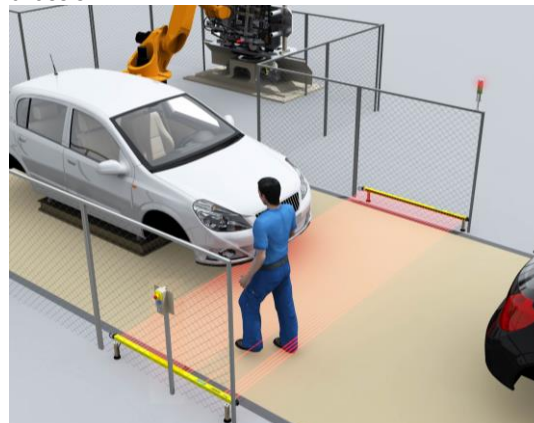
■ Initiating a stop and preventing start

Access protection and presence detection on a turntable system



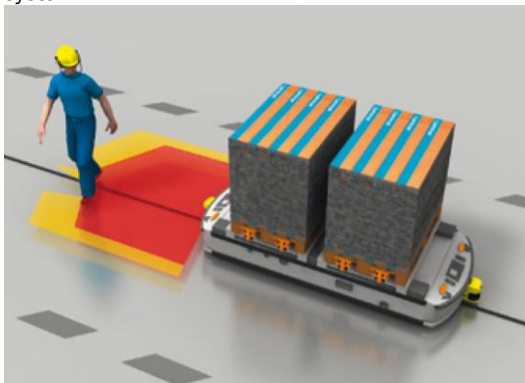
■ Differentiating people/material

Access protection in an automatic transport system for auto chassis.



■ Initiating a stop

Hazardous area protection at an automated guided system



Further safety functions

- Prevent entry/access permanently
- Retaining parts/substances/radiation
- Preventing start
- Preventing an unexpected start-up
- Monitoring machine parameters
- Disabling safety functions manually and for a limited time
- Combining or switching safety functions
- Initiating a stop if a defined speed is exceeded
- Initiating a stop if a defined moving direction is breached
- Safe brake control

More information:

[Brochure "Guide Safe Machinery"](#)

Which benefits do opto-electronic-protective devices offer, and in which applications are they used?

Opto-electronic protection

Example of a hazardous point protection using a light curtain at a press



Application:

- Continuous interactions of a person with the machine
- Unhindered, automatic material transport into/out of the machine is possible.
- Optical approach detection of persons is possible and wanted.
- Hazardous point protection, access protection and hazardous area protection
- Operator reaches directly into the machine
- Also for mobile application (AGV)

Your benefits:

- Supports high productivity
- Free access to the machine
- Free view into the machine possible
- Frequent operator/machine interaction is easily possible
- Reduces the causes of manipulation

Remarks:

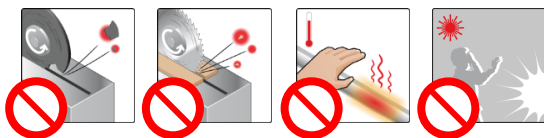
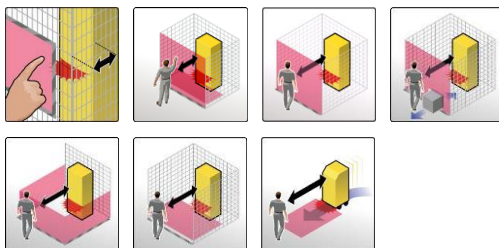
- Not applicable if the machine cannot be stopped within a reasonable period or may not be stopped before the machine cycle has been fully executed!
- In this case, [physical guards with locking function](#) (→ on page 8) may be used.
- For the [required safety level](#) (→ on page 15), refer to the existing product standards (C-standards) for the machine or determine the level!
- It is necessary to determine the [minimum distance](#) (→ on page 20)!

Caution!

 Cannot be used if ejection of parts, heat or radiation presents a hazard!

In this case, [physical guards \(with locking function, if necessary\)](#) (→ on page 8) or physical guards (fences, barriers, etc.) must be used.

Other protective devices

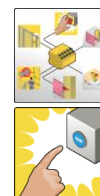


Recommended product technologies

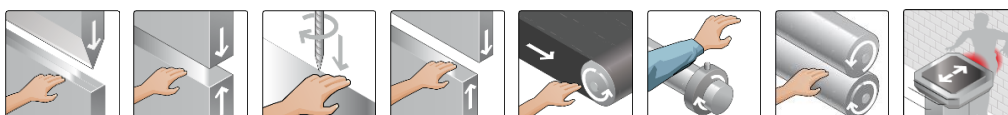


with matching → [control solution](#)

and → [safety commands](#)



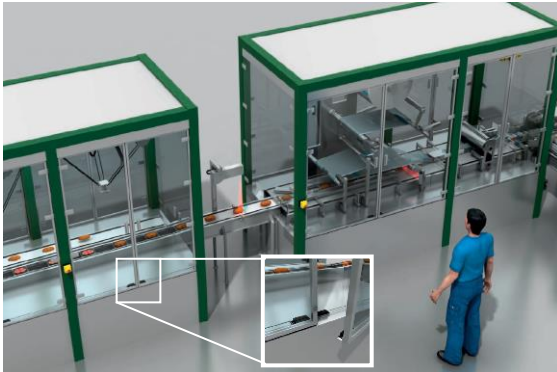
Usefull at machines with hazards like, e.g.:



Which benefits do interlocking/locking devices offer, and in which applications are they used?

Interlocking/locking of physical guards

Example for locking of a protective door using magnetic safety switches



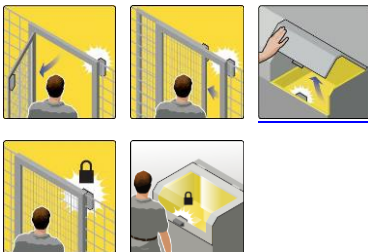
Application:

- Electrical interlocking of physical guards with and without locking
- Prevent the operator from accessing the hazardous area directly
- Protection against potential serious hazards

Your benefits:

- Achieve maximum protection
- Physical guards are the only (protective) devices that actually protect from hazards such as ejected parts, heat or radiation!
- Temporary locking to prevent access allows the machine to be stopped safely on completion of the processing cycle.

Other protective devices



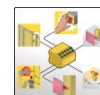
Remarks:

- Slows down direct entry/access to the machine!
- Free view into the machine compartment can be restricted.
- For the [required safety level](#) (→ on page 15), refer to the existing product standards (C-standards) for the machine or determine the level!
- It is necessary to determine the [safety distance](#) (→ on page 20)!

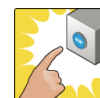
Recommended product technologies



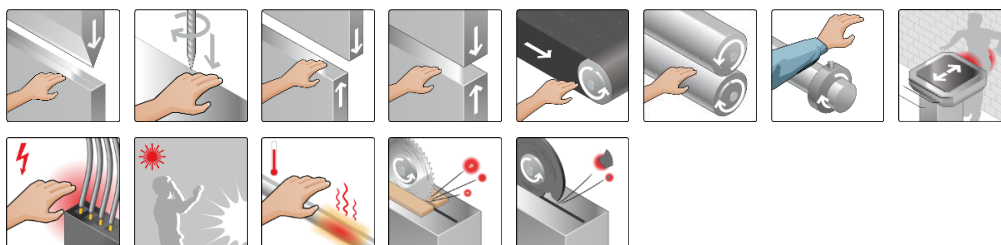
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and → [safety commands](#)



Usefull at machines with hazards like, e.g.:

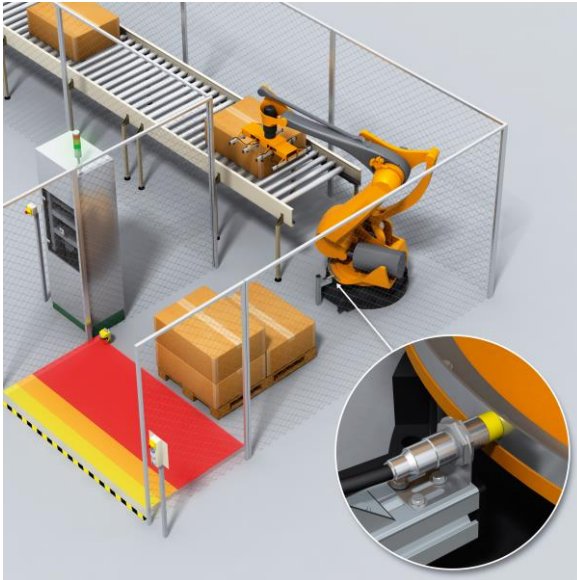


For the required safety level, please refer to the existing product standards (C-standards)!

Which benefits do safe position monitoring devices offer, and in which applications are they used?

Safe position monitoring of machine parameters

Example of safe monitoring of the working position of a robot.



Application:

- Machine parameters are monitored during operation.
- Also suitable for mobile applications (safe position monitoring for steering axes and swivel arms, e.g., to control monitoring fields of safety laser scanners on automated guided vehicles for speed shifting).

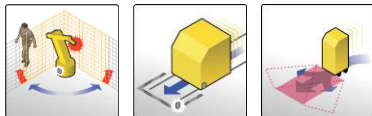
Your benefits:

- Combination of protection for machines and persons can be realized

Remark:

- For the [required safety level](#) (→ on page 15), refer to the existing product standards (C-standards) for the machine or determine the level!

Other protective devices

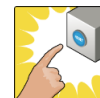
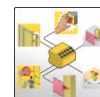


Recommended product technologies

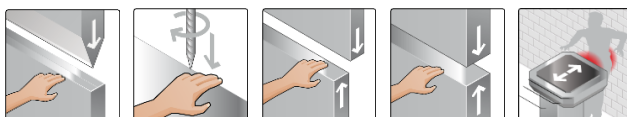


with matching → [control solution](#)

and → [safety commands](#)



Useful at machines with hazards like, e.g.:



In which applications are safe command devices used?

Safe commands

Example for use of an enabling switch in setup operation



Application:

- Emergency stop as a supplement to other protective devices and/or safety measures¹
- Dangerous movements should be stopped safely by manual operation
- Critical machine functions should be put into operation safely by manual means

Remark:

- For the [required safety level](#) (→ on page 15), refer to the existing product standards (C-standards) for the machine or determine the level!

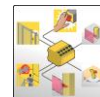
Other protective devices



Recommended product technologies



with matching → [control solution](#)

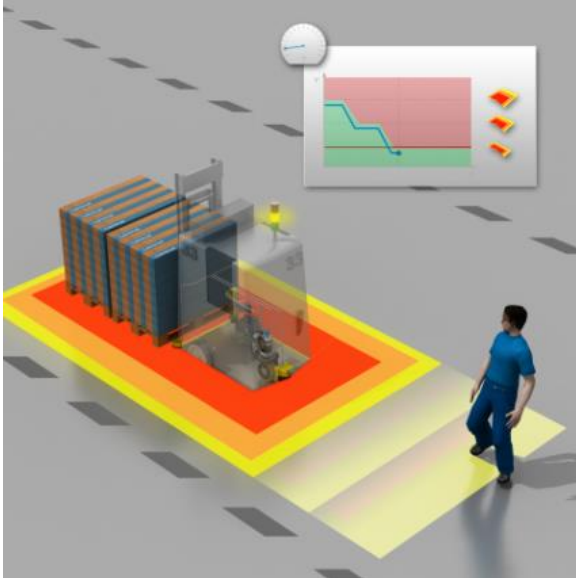


¹ Safe command devices complement the other protective devices and/or safety measures. Emergency stop is a required safety measure, but it is not a protective device

Which benefits do motion control devices offer, and in which applications are they used?

Safe motion control

Example in an application of an automated guided vehicle, safe limiting of the speed when a person is detected in the warning field of the safety laser scanner.



Applications:

- Monitoring of motor standstill, speed and/or moving direction
- Release of locked physical guards only in the absence of the hazardous movement
- Safeguarding of automated guided vehicles in combination with optical protective devices
- Service mode with limited speed

Your benefits:

- Optimization of production processes with intrusion by persons
- Convenient setup and maintenance of machines
- Optimization of processes with automated guided vehicles

Remark:

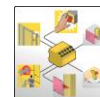
- Safe motion control is realized generally by a combination of sensors (proximity switch, encoder, motor feedback system) and monitoring device.



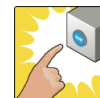
Recommended product technologies



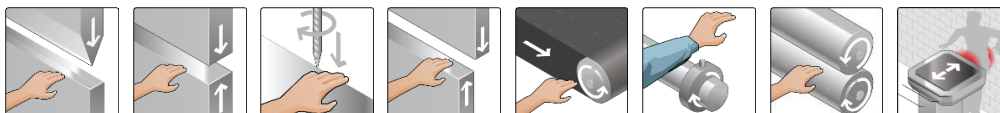
with matching → [control solution](#)



and → [safety commands](#)



Useful at machines with hazards like, e.g.:



What is the difference between safety and standard components?



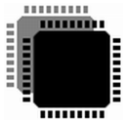
Safety components are used in safety circuits to implement safety functions to protect persons. One of the most important requirements for optoelectronic protective devices is the safe detection of persons.



Standard components are used for operating functions in machines and systems.

The additional requirements for safety components ...

... mean:



- Special dual-channel structure for detecting internal faults and faults in the wiring.
- Definition of the "safe status".
- Special device-internal safety mechanisms.

- Additional costs for hardware.
- Additional work for development and testing.



- Compliance with safety standards as a basis for development and production.

- Additional work for development and testing.
- Additional work for documentation.



- Enhanced resistance to influencing factors in the field.

- Additional effort for training the development team.
- Additional work for development and testing.



- CE type testing by an authorized body (e.g. TÜV or IFA).

- Additional costs for approval/certificate.
- Special management/qualification for the development of functional safety components.



- [Special safety data](#) (PL, SIL, PFHd, B10d, etc.), → on page 16 and the CE Declaration in compliance with the Machinery Directive.

- Additional work for development and testing.

Can standard sensors be used in safety functions?

The following can be stated as a rule:

- Generally, it is possible to use standard components in safety applications.
- However, when personal safety is involved, the user (machine manufacturer) must verify the suitability of the component (including the application conditions).
- A good (high) MTTFd value covers only a small part of the criteria and [measures required](#) (→ on page 16).
- Standard optosensors are not permissible for detecting persons (only with special conformity assessment procedures).
- It is not possible to specify further safety parameters (PL, SIL, DC, etc.) for standard components, except for the MTTF.

The machine manufacturer is on the safe side with components that were developed and tested for safety functions!

Standard component	Up to PL = „a“	Up to PL = „b“	Up to PL = „c“	Up to PL = „d“	Up to PL = „e“
Proximity sensors e.g. inductive, capacitive	Specifications from the manufacturer: - Conformity with basic safety principles²⁾ - Data sheet - Specification of MTTFd or B_{10d} Important for the user: - Conformity with basic safety principles²⁾ for implementation - Effect of ambient conditions (temperature, humidity, water, dust, electromagnetic interference, ...) on the safety function⁴⁾ - Documentation⁴⁾		Specifications from the manufacturer: - Conformity with basic safety principles²⁾ - Data sheet - Specification of MTTFd or B_{10d} Important for the user: - Conformity with basic²⁾ and well-tried³⁾ safety principles for implementation - Category requirements, e.g. dual-channel architecture with two sensors⁴⁾ - Determining/safeguarding the DC and measures to combat CCF⁴⁾ - Effect of ambient conditions (temperature, humidity, water, dust, electromagnetic interference, ...) on the safety function⁴⁾ - Documentation⁴⁾		
Single-beam photo-electric safety switches Photo-electric proximity switches Light grids Laser scanners	Not to be used for the detection of persons ⁵⁾ ; otherwise as for proximity sensors (above) with optical ambient influences taken into consideration as well. Specifications from the manufacturer: - Conformity with basic safety principles²⁾ - Data sheet - Specification of MTTFd Important for the user: - Conformity with basic safety principles²⁾ for implementation - Effect of ambient conditions (temperature, humidity, water, dust, electromagnetic interference, light ...) on the safety function⁴⁾ - Documentation⁴⁾		Specifications from the manufacturer: - Conformity with basic²⁾ and well-tried³⁾ safety principles for implementation - Data sheet - Specification of MTTFd Important for the user: - Conformity with basic²⁾ and well-tried³⁾ safety principles for implementation - Category requirements, e.g. dual-channel architecture with two sensors⁴⁾ - Determining/safeguarding the DC and measures to combat CCF⁴⁾ - Effect of ambient conditions (temperature, humidity, water, dust, electromagnetic interference, light ...) on the safety function⁴⁾ - Documentation⁴⁾		

1) In all cases, providing documented evidence of the suitability of all components used for safety functions is one of the obligations of the machine manufacturer. Authorized bodies such as the German IFA or TÜV (technical testing authority) can be consulted when evaluating the use of standard components in applications not covered by these recommendations, and in case of optimizations.

2) Basic safety principles are generally recognized sound engineering practices incorporated by the component manufacturer, such as those described in product standards (including ambient conditions, principles of operation, ...). Measures for bringing systematic errors under control have been taken during development and production. The user is also subject to obligations, such as complying with specifications and ensuring proper fastening (see EN ISO 13849-2, sections A.2, B.2, C.2, D.2).

3) Well-tried safety principles are principles which make it possible to exclude certain faults through the use or configuration of components, for example by using components with a defined (known) failure mode or with positive action/opening or by using techniques such as redundancy and diversity (EN ISO 13849-2, sections A.3 and D.3).

4) See EN ISO 13849-1, section 10 or Annex G.

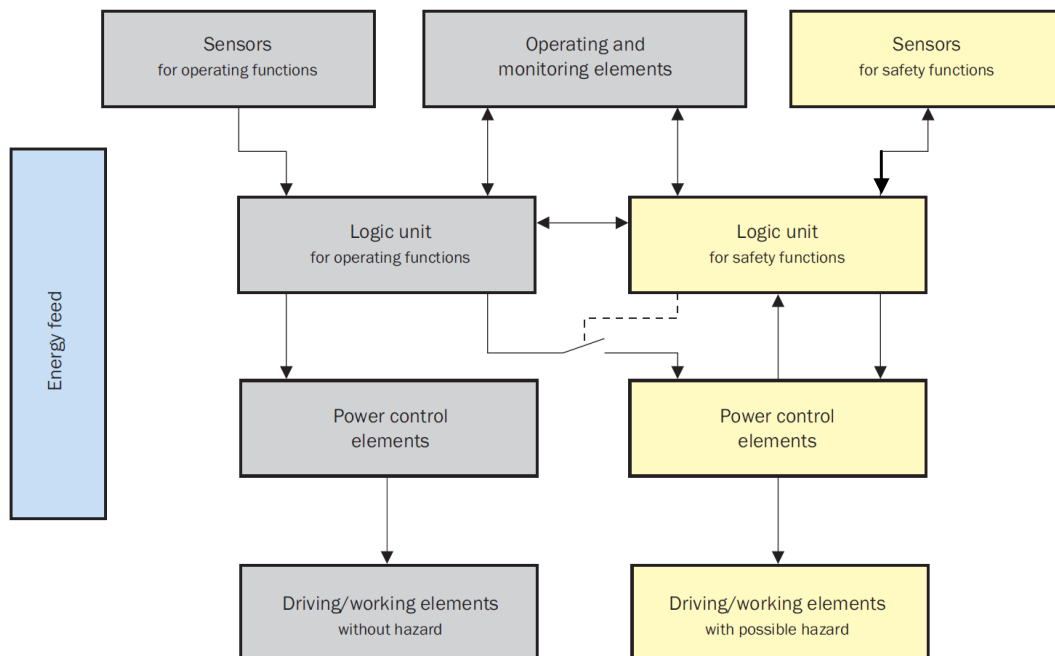
5) IEC 61496 sets out specific addition requirements for the detection of persons, including requirements for EMC and optical performance characteristics. In the EU, a special conformity assessment procedure is required in accordance with the Machinery Directive 2006/42/EC.

Recommendation for the application of standard sensors in safety functions in accordance with EN ISO 13849-1

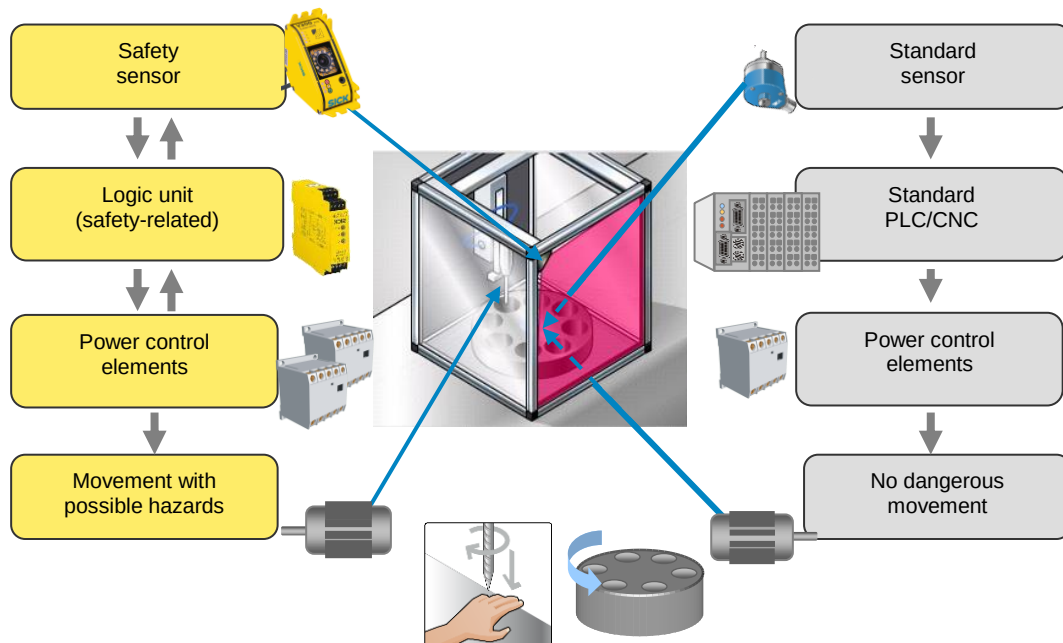
More information is provided in the [SICK-Whitepaper "Standard sensors for safety functions"](#)

How do control functions and safety functions interact at a machine?

A machine or system is made up of several components that interact and ensure the functionality of a machine or system. A distinction must be made here between components that perform pure operating tasks and ones that are responsible for safety functions.



General functional layout of a machine control



Example: representation of components of the machine controller in a drilling machine

More information:
[Brochure "Guide Safe Machinery"](#)

What is the required performance level?

As a rule, C standards (machine-specific standards) specify the required performance level.

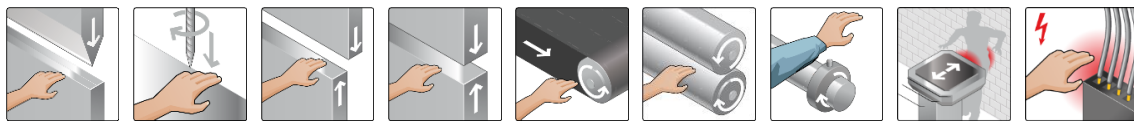
The required performance level must be defined separately for each safety function, and then applies to all devices involved, for example:

- The sensor/protective device
- The logic unit to be evaluated
- The power control element(s)

If no C standard is available for the particular machine, or no particular specifications have been made in the C standard, the required performance level can also be determined using one of the following standards:

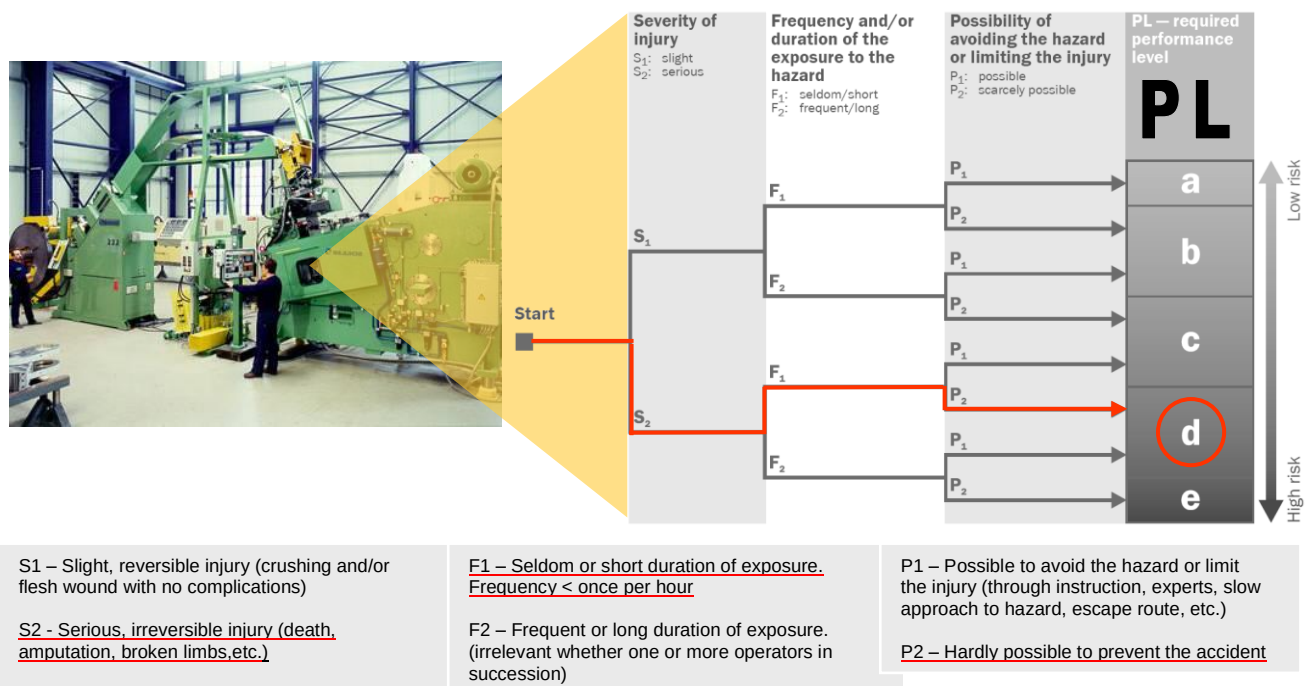
- EN ISO 13849-1
- EN 62061

The EN ISO 13849-1 standard uses risk graphs to determine the required performance level. The parameters **S** (severity of injury), **F** (frequency and/or duration of exposure) and **P** (option for avoiding the hazard or limiting the injury) are used to determine the risk level.



Examples of hazards at machines

The result of the process is a required Performance Level (PL).



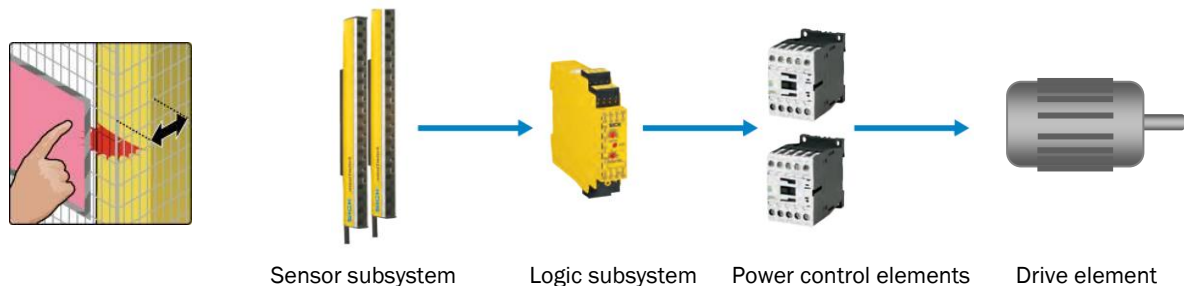
Example for determining the required performance level to protect the tool change at a punch press with risk graph according to EN ISO 13849-1.

More information: [Brochure "Guide Safe Machinery"](#)

How is the actual performance level of the safety function determined?

In accordance with the standards for functional safety (e.g. EN ISO 13849-1), the actual performance level of safety function should correspond to the [required safety level](#) (→ on page 15).

A safety function that is implemented by using control measures generally comprises a sensor, logic unit and power control element. Such a chain can include, on the one hand, discrete elements such as physical guard interlocks or valves and complex safety controllers. As a rule, it is therefore necessary to divide a safety function into subsystems.



In practice, certified subsystems are already used in many cases for certain safety functions. These subsystems can be light curtains, for example, but also safety controllers, for which "pre-calculated" PL or PFHd values are supplied by the component manufacturer.

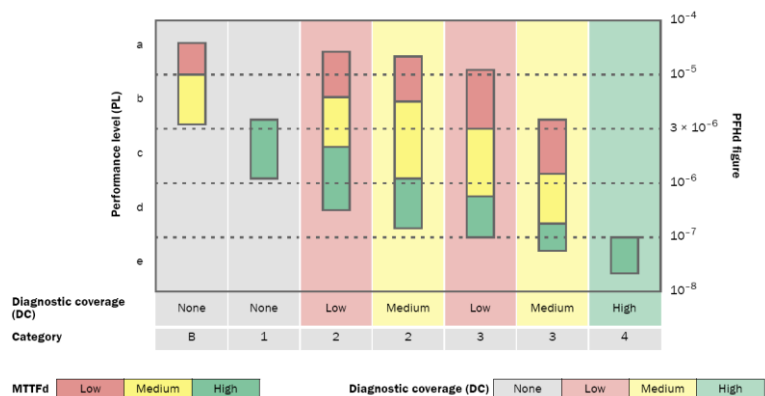
These values apply only to the mission time to be specified by the manufacturer. In addition to the quantifiable aspects, it is also necessary to verify the measures against systematic failures.

The performance level achieved per subsystem is made up of the following parameters in accordance with EN ISO 13849-1.

- Structure and behavior of the safety function under fault conditions (category)
- MTTFd values of individual components (measure of safety reliability)
- Diagnostic coverage (DC) for the effectiveness of the fault detection mechanisms
- Common cause failure (CCF) and preventive measures
- Safety-relevant software aspects (software design process)
- Application conditions
- Systematic failures (due to faults caused by particular states, loads, initial conditions) These are the results of errors made during development, manufacture, operation, or maintenance.

EN ISO 13849-1 provides a guide to determining whether the technical protective measure would result in the [required performance level](#) (PLr), → on page 15).

As a basic overview, the standard also provides bar charts that summarize the above mentioned necessary criteria. The bar charts do not take account of the design process, application conditions and measures to prevent systematic failures.



More information: [Brochure "Guide Safe Machinery"](#)

What is the difference between Performance Level (PL) and Safety Integrity Level (SIL)?

1. Required safety level

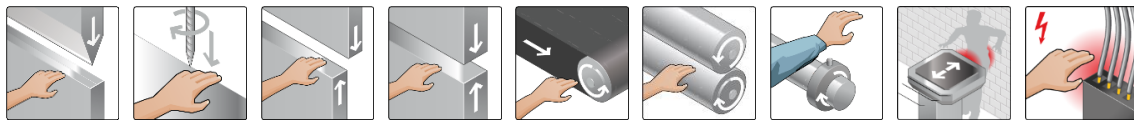
The [required performance level](#) (→ on page 15), is determined in accordance with the risk level. Standard EN ISO 13849-1 uses a risk graph to determine **PLr**², EN 62061 adopts a numerical procedure to determine the **SIL**³.

When determining the required performance level, both standards take account of

- The severity of injury
- The frequency and/or the duration of the hazard
- The options for avoiding the hazard or limiting the injury

EN 62061 (SIL) also considers the probability of occurrence of a hazardous event.

The result of EN ISO 13849 is a required performance level PLr a, b, c, d or e, where e corresponds to the highest risk level. The results of EN 62061 are classified in three risk levels SIL 1, 2 or 3, where 3 represents the highest risk.



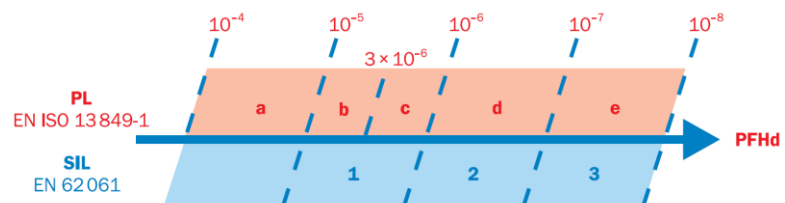
Examples of hazards at machines

2. Actual safety level

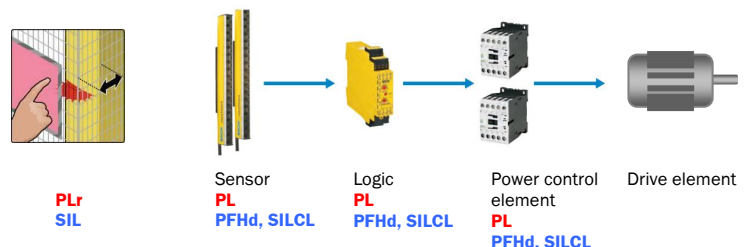
In accordance with both standards, the [actual safety level](#) with PL/SILCL (→ on page 16) should correspond to the specified performance level (PLr/SIL). Two different methods are used in this case.

- Determination of the performance level (PL) achieved⁴ according to EN ISO 13849-1
- Determination of the safety integrity level achieved (SILCL)⁵ according to EN 62061

Both methods check whether the remaining residual risk is acceptable. The a PFHd value⁶ is determined here as the quantitative measure.



Relationship between PL and SIL:



Safety subsystems of a safety function:

The application of EN ISO 13849-1 is recommended by SICK because it is easy to handle and offers greater scope.

More information: [Brochure "Guide Safe Machinery"](#)

² PLr: Performance Level required

³ SIL: Safety Integrity Level of the safety function

⁴ PL: Performance Level = capability of safety-related components to perform a safety function under the foreseeable conditions to achieve the expected risk reduction

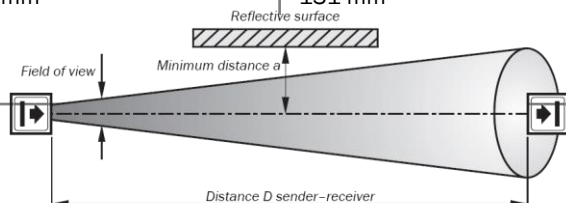
⁵ SILCL: SIL claim limit. Discrete level for defining the integrity of the safety function.

⁶ PFHd: Means probability of dangerous failure per hour: (1/h)

What does the "Type" of opto-electronic protective devices mean?



The safety parameters for opto-electronic protective devices are classified in types (Type 2, Type 3, Type 4 - refer to the IEC 61496 series of standards).
In addition to the structural aspects (similar to the familiar categories), the Type classification defines the requirements that must be satisfied for electromagnetic compatibility (EMC), environmental conditions and optical systems. These include reaction to interference sources (sun, lamps, similar types of devices, etc.) in particular and also the opening angle of lenses in safety light curtains and safety light barriers.

	Type 2	Type 4	Advantage Type 4
Functional safety	Between the test intervals, the protective function may be lost during the occurrence of a failure.	The protective function is retained even during several failures.	Higher risk reduction
EMC (electromagnetic compatibility)	Basic requirements	Increased requirements	Higher reliability of the detection capability. Higher system availability in difficult ambient conditions.
Maximum field of view of the optics	10°	5°	
Minimum distance a to reflective surfaces over a distance of D < 3 m	262 mm	131 mm	
Minimum distance a to reflective surfaces over a distance of D > 3 m			
	= distance x tan (10° / 2)	= distance x tan (5° / 2)	
Several senders of the same design in a system	No special requirements (Beam coding is recommended)	No effect; however, if affected, OSSDs switch off.	

Main differences ESPE⁷ Type 2 and Type 4 acc. to IEC 61496.

Note: Type 3 determines the requirements for safety laser scanners

More information:
[Brochure "Guide Safe Machinery"](#)

How do PL/SIL and Type relate to each other with regard to opto-electronic protective devices?

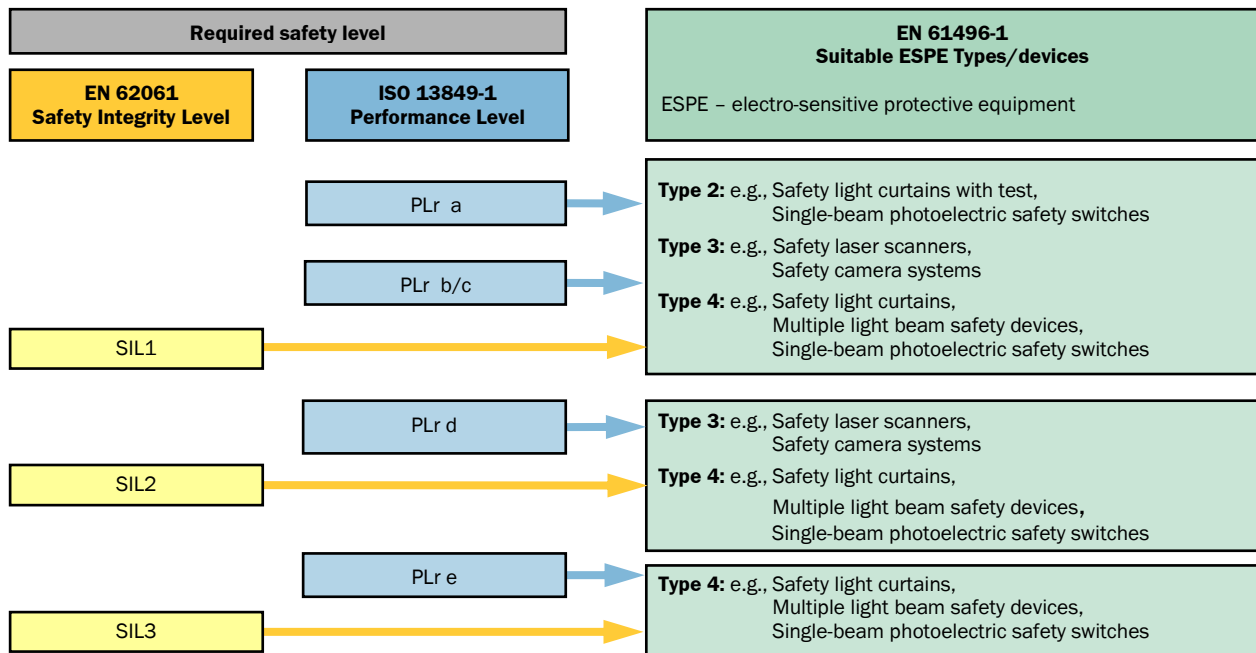
In contrast to simple control systems, such as electronic safety switches, additional criteria defined according to the Type must be taken into account for opto-electronic protective devices.

These include the required [detection capability](#) (→ on page 18), which results from the optical working principles and is defined in the IEC 61496 series of standards.

Functional safety	Resistance to environmental influences	Electro-magnetic compatibility	Detection capability
Requirements for functional safety in safety-related control components: ■ Structure (categories) ■ Probability of a hazardous failure ■ Measure for avoiding errors and detecting errors ■ Prevention and mastering of systematic faults ■ Quality of the design process ■ Documentation		opto-electronic protective devices ■ Design of the ESPE ■ optical performance features ■ Detection capability ■ Reliability of the detection capability ■ EMC ■ Structure (categories) 	
PL / SIL EN ISO 13849-1 / EN 62061		Type IEC 61496	

Supplements to the requirements of EN ISO 13849-1 / EN 62061 and IEC 61496

SICK recommends the following assignment of opto-electronic protective devices according to the required performance level:



More information:

 [Brochure "Guide Safe Machinery"](#)

Why is the minimum distance (safety distance) required and which factors play a role here?

The minimum distance (safety distance) describes the minimum distance between the protective device and the hazardous area.

One essential aspect for the selection of an optimal protective device is the space available and the minimum distance necessary.

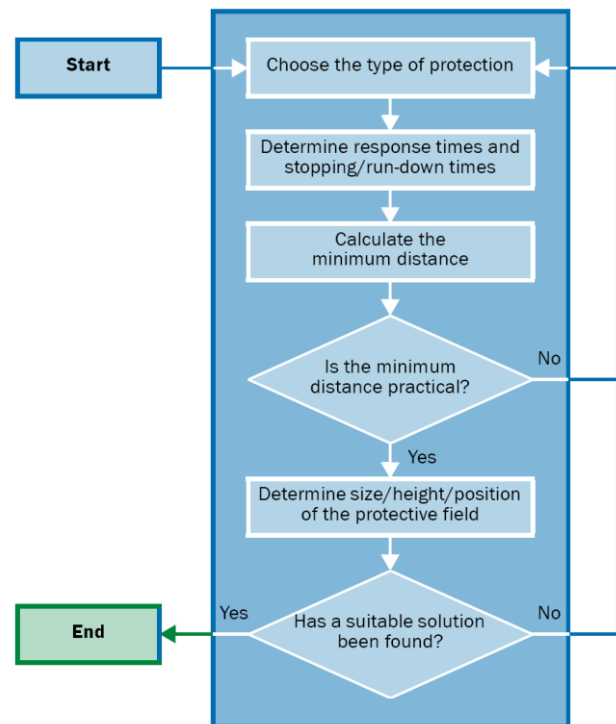
It must be ensured that the dangerous state can be eliminated in good time before the hazardous point is reached. The required minimum distance (safety distance) is calculated according to the standard EN ISO 13 855.

The consideration of the minimum distance applies to ESPE⁸ with two-dimensional protective field, for example light curtains (AOPD), laser scanners (AOPDDR) or two-dimensional camera systems.

For locked physical guards that initiate a stop, a safety distance must also be observed in analogy to the procedure for ESPE. Alternatively, locks with locking mechanisms may be used to prevent access until the hazard is no longer present.

If they have openings, physical guards must have a sufficient safety distance to the hazardous area (refer to standard EN ISO 13 857).

If the minimum distance to the hazardous area is too large and unacceptable from an ergonomic viewpoint, either the overall stop time of the machine must be reduced or an ESPE with finer resolution used. The possibility of someone standing behind must be ruled out.



The general formula for calculating the minimum distance (safety distance) is:

$$S = (K \times T) + C$$

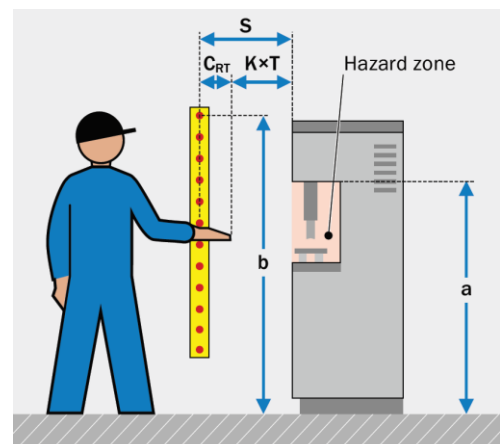
Where

- **S** is the minimum distance in millimeters, measured at the next hazardous point to the detection point and/or detection line or detection plane of the protective device.
- **K** is a parameter in millimeters per second, derived from the data for the approach speeds of the body or parts of the body.
- **T** is the stopping/run-down time of the overall system in seconds.
- **C** is an additional distance in millimeters. The distance C depends on the application (see Table 1 in the standard EN ISO 13 855).

The adjacent figure shows how the minimum distance (safety distance) is made up. The parameter C_{RO} describes reaching over the protective device and a maximum path traveled before the user is detected by the protective device. The calculation for reaching into a protective device is analogous to the one using C_{RT} . Factors that decisively influence the minimum distance (safety distance) are the additional distance C (C_{RT} or C_{RO}) and T, the stopping/run-down time of the overall system. These can be influenced actively.

For **T**, the following parameters must be taken into account

- Stopping time of the machine
- Response time of the safety-related control
- Response time of the protective device (ESPE)
- Additions according to the resolution capability of the ESPE, the protective field and/or the type of approach



The additional distance **C** is dependent on the resolution (d) for an ESPE and rectangular approach, and on the height of the protective field above the reference level (H) for parallel approach.

C is omitted when calculating the safety distance for locked physical guards. The formula for calculation is then $S = (K \times T)$.

More information: [Brochure "Guide Safe Machinery"](#)

⁸ ESPE – electro-sensitive protective equipment

Why and when should the effectiveness of opto-electronic protective devices be checked?

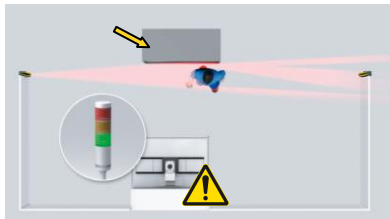
The correct functions and effectiveness of opto-electronic protective devices cannot be ensured by the manufacturer of the protective device or the machine manufacturer alone.

Changes to the machine or to the ambient conditions while the machine is in use may render the protective measures ineffective. The machine operator must carry out thorough checks in order to identify this ineffectiveness.

Causes of ineffectiveness in opto-electronic protective devices while the machine is in use (examples):

Protective devices are inadvertently rendered ineffective:

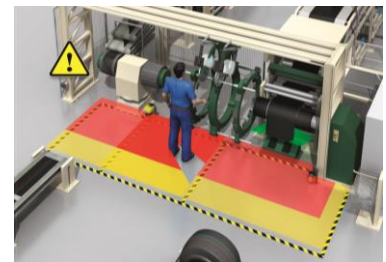
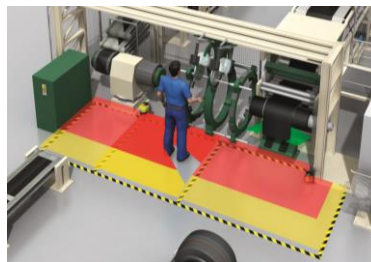
Covers that are removed during normal operational processes are not put back in the correct position after maintenance work or tool changes. This means that someone may be able to reach over, under, or around a protective device or stand behind it without realizing.



Beams from a safety light curtain are diverted by **reflective objects or reflective environments**.

In the example, a tote with a very reflective surface has been placed in the field of vision of the light curtain. The safety light curtain cannot detect the approaching person and the machine will not be switched off.

In the example, the control cabinet has been moved during **conversion work** but the protective field of the safety laser scanner and the markings showing the protective field boundaries have not been adjusted. Someone may stand in a hazardous point without realizing because the protective device is no longer covering all angles of approach.



How often should the effectiveness of the opto-electronic protective device be checked?

According to European Work Equipment Directive 2009/104/EC, work equipment (machines) must be inspected and, where appropriate, tested in the event of **exceptional circumstances** in order to prevent hazardous situations.

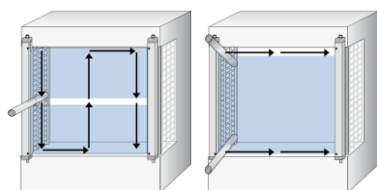
The inspection frequency should correspond to the **foreseeable frequency of exceptional circumstances** which could have a damaging effect. Exceptional circumstances can include mounting, initial commissioning, accidents, tool changes, or modifications. The degree of risk, type of mounting, mechanical influences, ambient conditions, and product-specific properties of the protective device must also be considered.

Once all of these factors have been taken into account, the effectiveness of opto-electronic protective devices may even need to be **inspected on a daily basis**.

The product standards for the machines (e.g., ISO 3691-4 Industrial trucks - Safety requirements and verification) and the operating instructions for the opto-electronic protective devices also contain regulations regarding the inspection process and frequency.

How is the effectiveness of the opto-electronic protective device checked?

The opto-electronic protective device must be used for its intended function in order to check its effectiveness. The inspection should establish whether the hazardous point in question can **only be accessed via the detection field** of the protective device and whether the device can detect someone accessing/approaching the machine. Pieces of equipment such as test rods or suitable test objects are used in the process. Details and notes are given in the product documentation for the protective devices. These should be included in the machine documentation according to how the protective device is used.



Example from the operating instructions for the deTec4 Core safety light curtain from SICK:

Checking the effectiveness of safety light curtains in two stages using a test rod.

Who is responsible for carrying out the inspection?

The **machine operator** is responsible for ensuring that work equipment is safe. The **machine manufacturer** must provide a safe machine and the accompanying documents describing measures for safe operation.

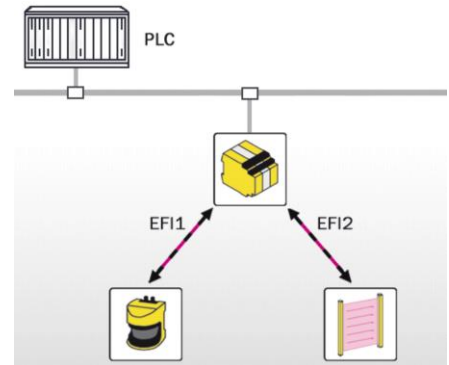
What is the SICK Enhanced Function Interface (EFI)?

The Enhanced Function Interface (EFI) is a SICK-specific interface that supports safe communication between opto-electronic protective devices, Flexi Soft, and gateways. Additional data for safety-related communication, extended functionality of sensors, and diagnostics is also transmitted via EFI.

EFI provides a means of interconnecting SICK safety devices and extending the functionality of individual protective devices. Safety-related applications, which would otherwise only be possible with complex configurations, can be implemented efficiently with protective devices connected via EFI. Examples of such applications include:

- Simultaneous monitoring of protective fields (up to four simultaneous protective fields with the S3000 safety laser scanner)
- Operating mode selection and host/guest evaluation (C4000 safety light curtain)
- Evaluation of status signals (for a contaminated scanner front screen, for example)

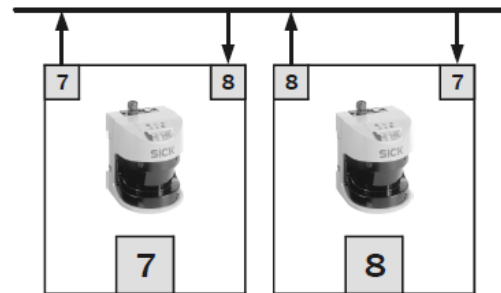
Devices exchange status and control information via the EFI. EFI gateways are used to integrate applications into higher-level bus systems. Furthermore, all devices can be configured together in a single project.



EFI is a bus system that connects up to four devices. The actual number of devices is determined by the requirements of the corresponding application or product family. Each device connected to EFI has a unique address.

Example:

The S3000 host has the address 7; the S3000 guest has the address 8. The host receives status information about the OSSDs and diagnostic messages from the guest about contamination via address 8. The guest, on the other hand, receives the values from the incremental encoder from the host via address 7.



The advantages of EFI are:

- Enhanced functionality of the safety connected devices
- Reduced wiring effort
- Increased system reliability
- Easy and flexible configuration
- Function switch-over of the opto-electronic protective device (e. g. switch-over of protective field sets at safety laser scanners) via the safety controller
- Simplified diagnostics for the host/guest system

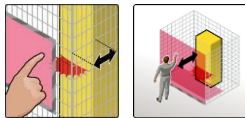
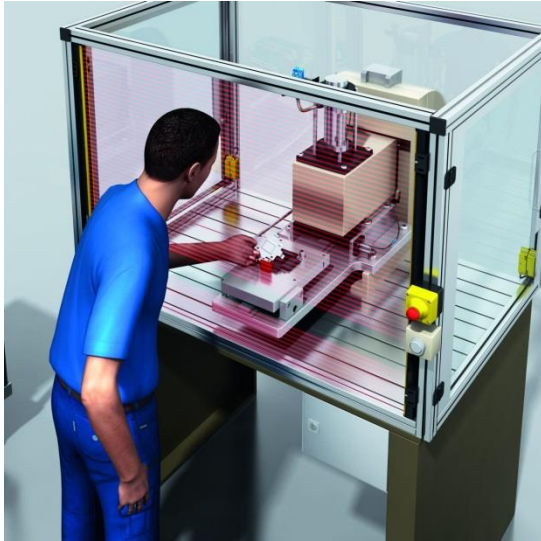
The decisive strength of EFI versus integration via OSSD inputs is its ability to provide a high volume of diagnostic information about all EFI safety devices to the higher-level control system or gateway.

More Information: [🌐 Technical Description „EFI – Enhanced Function Interface“](#)

PSDI - What is it? What are its main benefits? What machines can use it?

PSDI is an acronym for 'Presence Sensing Device Initiation'. It is a function that uses an opto-electronic sensor to provide a safe start signal to a machine, such as a press. This means that the machine will start its cycle when the operator clears the opto-electronic field. There is no need for the operator to press a start button or two-hand control buttons. This ergonomic savings leads to a significant increase in productivity for manually loaded machines.

Example of a manually loaded press that would use PSDI functionality



Application:

- Continuous loading and unloading interactions of a operator with a machine.
- Low cycle time processes for metal forming (stamping, punching, bending or drawing), part assembly, welding, gluing and cutting.
- High volume production as in the automotive and consumer electronics industries.
- Applicable press machines will generally be less than 400 tons in press force.
- Single break mode (single interruption of the opto-electronic field to initiate a start) is generally the most efficient mode.
- Double break mode (opto-electronic field must be interrupted twice) can be effective for larger parts in which the operator uses both hands to hold the part, or if two operators are working in tandem.

Your benefits:

- Increases the productivity of the machine (some cases have shown as much as 100%).
- Operator requires less movement and effort for each machine cycle. Therefore is less tired and generally healthier.
- Free access and view into the machine.
- As two-hand controls are no longer used, possible manipulation of the control buttons is eliminated.
- Dangerous foot pedal controls can be eliminated.
- Overrun monitoring of the press ram is normally included in PSDI solutions. This can provide valuable information for the maintenance of the machine and avoid future unsafe situations.

Remarks:

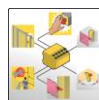
- The interaction 'window' for the operator with the machine is normally based on the required dimensions in EN 692 and EN 693. The tooling/hazardous point must be at least 750 mm from the floor, have a maximum opening height of 600 mm and a table depth of 1000 mm.
- Appropriate protective guards (i.e., fencing) must be on the other three sides of the machine as necessary to prevent unwanted access to the hazardous point.
- Not applicable if the machine cannot be stopped within a reasonable period or may not be stopped before the machine cycle has been fully executed!
- In this case, [physical guards with locking function](#) (→ on page 8) may be used.
- For the [required safety level](#) (→ on page 15), refer to the existing product standards (C-standards) for the machine or determine the level!
- It is necessary to determine the [minimum distance](#) (→ on page 20)!



Exemplary product choice



with matching → [control solution](#)



Checklist for manufacturers/installers installing protective devices (e.g., an ESPE)

The effectiveness of a protective device can be determined using the checklist below.
Example:

	Yes	No
1. Have adequate measures been taken to prevent access to the hazardous area or hazardous point and can the hazardous area or hazardous point only be accessed via secured areas (ESPE, protective doors with interlocking device)?	☐	☐
2. Have appropriate measures been taken to prevent (mechanical protection) or monitor presence (protective device) in the hazardous area when protecting a hazardous area/hazardous point and have these been secured against removal?	☐	☐
3. Does the protective device conform to the reliability level (PL or SIL) required for the safety function?	☐	☐
4. Has the maximum stopping time of the machine been measured and has it been specified and documented (at the machine and/or in the machine documentation)?	☐	☐
5. Has the protective device been mounted so that the required safety distance or minimum distance from the nearest hazardous point has been achieved?	☐	☐
6. Have effective measures been taken to prevent reaching under, reaching over, climbing under, climbing over, or reaching around the protective device?	☐	☐
7. Have the devices or switches been properly mounted and secured against manipulation after adjustment?	☐	☐
8. Are the required protective measures against electric shock in effect (protection class)?	☐	☐
9. Is the control switch for resetting the protective device or restarting the machine present and correctly installed?	☐	☐
10. Have the components used for the protective devices been integrated according to the manufacturer's instructions?	☐	☐
11. Are the given protective functions effective at every setting of the operating mode selector switch?	☐	☐
12. Are the protective devices effective for the entire duration of the dangerous state?	☐	☐
13. Once initiated, will a dangerous state be stopped when the protective devices are deactivated or switched off as well as when the operating mode is changed or switching over to another protective device takes place?	☐	☐
14. Are the notes for the operator, which were supplied with the protective device, located in a clearly visible position?	☐	☐

More information: [🌐 Brochure "Guide Safe Machinery"](#)