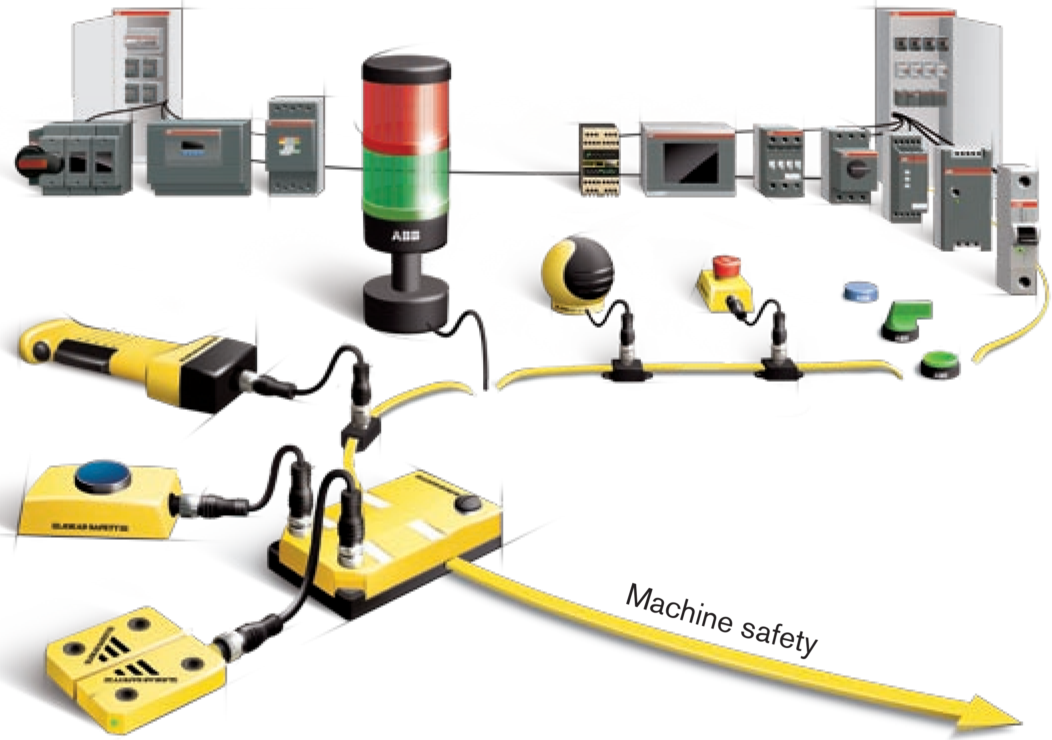
Productivity and safety go hand in hand

Jokab Safety was acquired by ABB in march 2010. This gives us extra strength and a sales network in 120 countries. Our goal is to become even better at supporting you as a customer through cooperation within ABB Jokab Safety globally and locally.

The fact that the leading power and automation technology company, ABB, and a leader in machine safety, Jokab Safety, are joining forces means a lot more than just a new organisational chart. ABB has a huge footprint in the industry - from power supply to the control of each individual motor - and has been delivering reliable solutions for decades that boost productivity in the industry. The acquisition of Jokab Safety now means the last building block is in place. We can now offer our customers tailored, turnkey solutions where machine safety is an integral and value-enhancing component.

Since its inception in 1988, Jokab Safety has been adhering to the business concept of developing innovative products and solutions for machine safety. The company has supplied everything from individual safety components to fully installed protection systems for entire production lines and works on a daily basis with the practical application of safety requirements in combination with production requirements. Jokab Safety is also represented on a variety of international standards committees concerned with the safety of machinery which means that we have now added this very valuable experience and knowledge to our offering. Similarly, ABB has always been a pioneer and a representative for its business areas and a powerful voice in professional organisations and committees. All in all, this creates an enormous bank of knowledge and experience that we look forward to sharing with our customers.

Productivity and safety are not contradictory terms. On the contrary, safety solutions that are properly executed and adapted from the beginning will increase productivity. A partner that can deliver integrated and well thought out turnkey solutions enables a production-friendly safety environment. By building up and upgrading safety solutions in existing environments in a smart way, the mode of production will not need to be adapted to meet the requirements that safety sets. Instead, this allows a system that is manufacturing-friendly and that takes into account the business and its productivity objectives.



We develop innovative products and solutions for machine safety

We make it simple to build safety systems. Developing innovative products and solutions for machine safety has been our business idea since the company Jokab Safety, now ABB AB, was founded in Sweden in 1988. Our vision is to become "Your partner for machine safety – globally and locally".

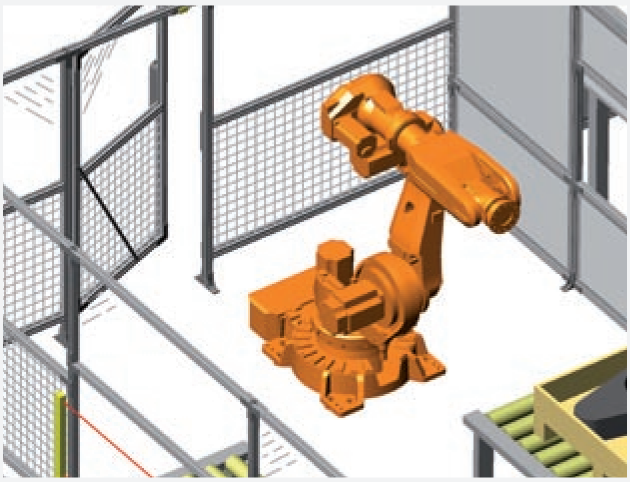
Many industries around the world, have discovered how much easier it has become to build protection and safety systems with our components and guidance.

Experience
We have great experience of practical application of safety requirements and standards from both authorities and production. We represent Sweden in standardisation organisations for machine safety and we work daily with the practical application of safety requirements in combination with production requirements. You can use our experience for training and advice.

Systems
We deliver everything from a safety solution to complete safety systems for single machines or entire production lines. We combine production demands with safety demands for production-friendly solutions.

Products
We market a complete range of safety products, which makes it easy to build safety systems. We develop these innovative products continuously, in cooperation with our customers Our extensive program of products, safety solutions and our long experience in machine safety makes us a safe partner.

Mats Linger and Torgny Olsson founded Jokab Safety AB in Sweden in 1988, together with Gunnar Widell, who remained in the company until 2001. In 2002 Jokab Safety North America was established, by means of a merger with the North American company NCC electronics, which had been founded in 1987 by Brian Sukarukoff and Scott Campbell (inset picture).

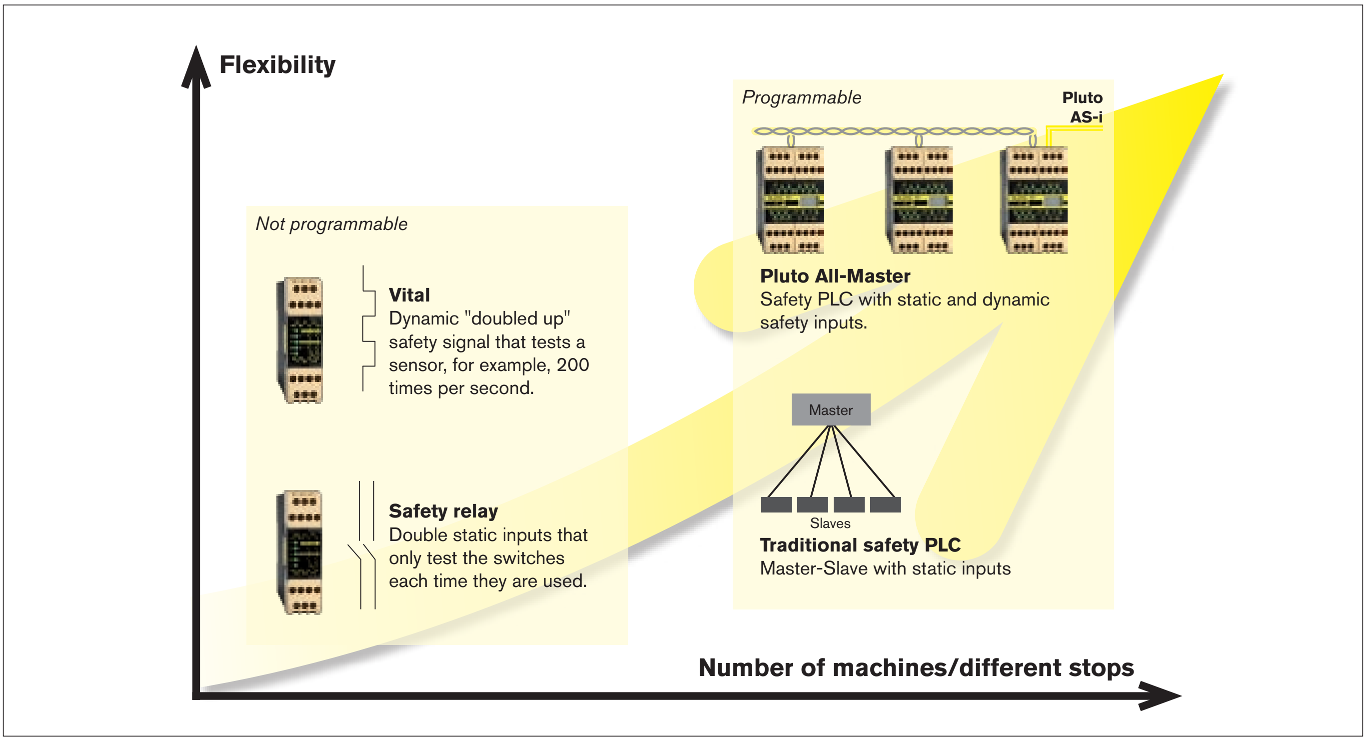


Do you need to learn about the new safety requirements for robots? If so, please contact us.

Standards and regulations

We help to develop standards
Directives and standards are very important to machinery and safety component manufacturers. We therefore participate in several international committees that develop standards, for among other things industrial robots, safety distances and control system safety features. This is experience that we absorb so that the standards will present requirements that benefit production efficiency allied to a high level of safety. We are happy to share our knowledge of standards with our customers.

Our products revolutionise the market



Our dynamic safety circuits and our comprehensive safety PLC are probably the most revolutionary ideas that have happened in the safety field in the control and supervision of protection, in many respects:

- They save on inputs: a dual safety circuit with one conductor instead of two. In addition, many protection devices can be connected to the same input while maintaining the highest level of safety.
- Reliability is better. Our electronic sensors have much longer lives than mechanical switches
- They are safer, since our dynamic safety sensors are checked 200 times per second. Traditional switches on a door can only be checked each time they are used, for example once per hour or even once a month.
- With the All-Master Safety PLC it is easy to connect and disconnect machinery from a safety viewpoint. Common emergency stop circuits and sensors can be created as soon as the buses are interconnected between our safety PLCs.

We are continuously designing safety systems for difficult environments and also to create new safety solutions where practical solutions are missing. New technical improvements give new possibilities and therefore we continuously develope new products.

We train both machine builders and machine operators

Do you construct machinery?
We can provide the training you need to construct machinery that meets the requirements. Example subjects:

- Practical implementation of the requirements in the new Machinery Directive 2006/42/EC, which is valid for machines that was delivered/put into service from the 29th of december 2009
- Risk analysis – in theory and practice
- Control systems safety, standards EN ISO 13849-1 and EN 62061

Do you purchase and use machinery?
As a machinery user it is your responsibility to ensure that the correct requirements are complied with – regardless of whether your machinery is “new” or “old”, i.e. CE-labelled or not. Unfortunately many have purchased CE-labelled machinery that does not meet the requirements. This must not be used. Having it brought into compliance by the supplier can take a long time and be expensive in terms of loss of production, etc. We can educate you on this and help you to set the right demands when buying new or even second-hand machinery.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Safety history

Developments of the 70's

Our background in safety started in the seventies when there was a significant focus on the safety of manually operated presses, the most dangerous machine in those days. The probability of loosing a finger or hand while working with these machines was very high. New safety solutions for both safety devices as well as for the control systems for presses were developed and introduced on both old and new machines. We were directly involved in this work through the design of Two-Hand devices, control systems for presses, making safety inspections for the Health and Safety authorities and writing regulations for safety of these machines. This work provided an excellent base for our knowledge in machinery safety.

The numbers of accidents involving presses decreased significantly during these years however there is still room for new ideas to enable safety equipment become more practical and ergonomic.

We protected people from loosing fingers or/and hands in dangerous machines.

Developments of the 80's

During the eighties, industrial robots (Irb's) started to become commonplace in manufacturing industry. This meant that workers were outside of the dangerous areas during production but had at certain times to go inside the machine in order to e.g. adjust a product to the correct position, inspect the production cycle, troubleshoot and to programme the Irb. New risks were introduced and new safety methods required. It was for example hard to distinguish whether production machines had stopped safely or simply waiting for the next signal, such as a sensor giving a start signal while a product was being adjusted into the correct position. Mistakes in safety system design resulting in serious accidents were made, such as the omission of safety devices to stop the Irb, unreliable connection of safety devices and unreliable safety inputs on the Irb.

In the mid eighties the standards committee for safety in Industrial Robot Systems EN 775/ISO 775 was started. This was the first international standard for machine safety. In order to give the correct inputs to the standard, work around Irb's was closely studied in order to meet production integrated safety requirements. The introduction of a production oriented safety stop function was made, using for example, software to stop machines smoothly and then safety relays/contactors to disconnect the power to the machines actuators after the machine had stopped. This technique allows easy restart of production after a stop situation by the machine safeguards.

There were a lot of discussions as to whether one could have both safety and practical requirements in a standard, such as a safe stop function, which allowed an easy restart of the machine. Three-position enabling devices were also introduced for safety during programming, testing and trouble shooting of Irb's and other equipment. In the robot standard the three-position enabling function was first defined by only allowing for hazardous machinery functions in the mid switch position. Releasing or pressing the three-position push button in panic leading to a stop signal.

Three-position enabling devices were also introduced for safety during programming.

Developments of the 90's

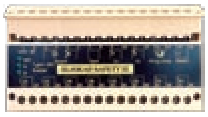
In Europe, during the nineties, the machinery directive was the start of a tremendous increase in co-operation across borders to get European standards for safety for machinery and safety devices. The experience from different European countries has led to a wide range of safety standards and this has made work in safety much easier. With the integration of Europe it is now only necessary for a safety company such as ourselves to get one approval for our components for all of Europe instead of one per country.

European standards for safety for machinery and safety devices.

Developments 2000 –

Internationally the work on safety has now been intensified within ISO. The objective is to have the same structure of safety requirements and standards within ISO as within EN. ABB Jokab Safety is active both internationally and nationally in different standard working groups. The co-operation between countries is leading to better safety solutions, making it much easier to create safe working environments around the world.

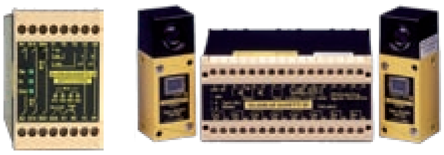
Jokab Safetys developments of the 80's



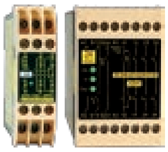
Jokab Safetys first safety relay

Jokab Safetys first steel fencing system

Jokab Safetys developments of the 90's



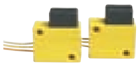
Timer reset and first light beam



Smallest safety relays JSBT5 and JSBR4

Stop time measurement

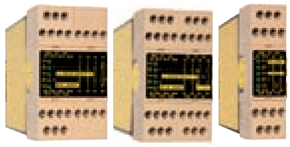
Quick-Guard aluminium fencing system



Three-position switch for robots

3-position devices

Safeball - ergonomic control device

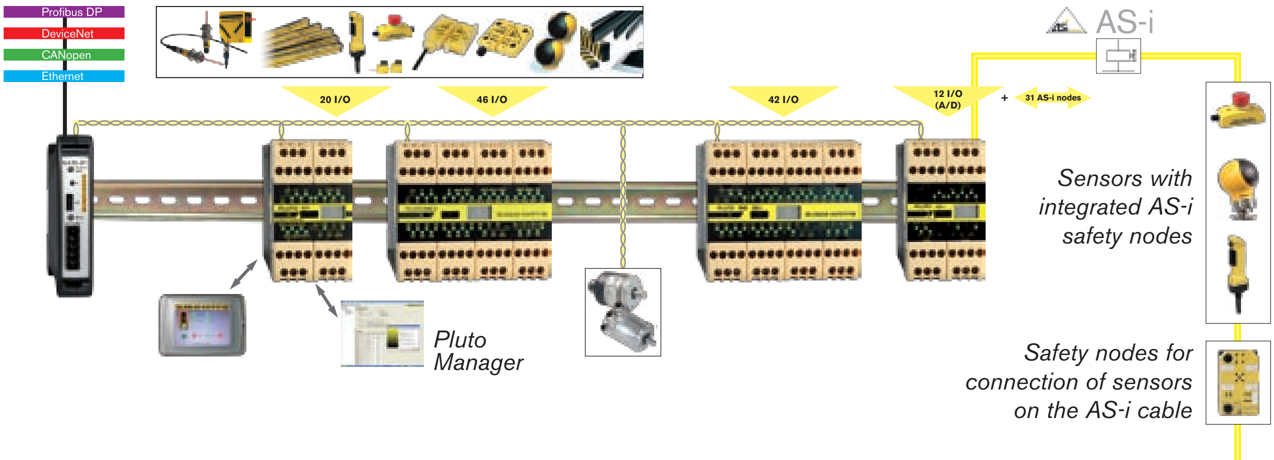


RT series universal relays

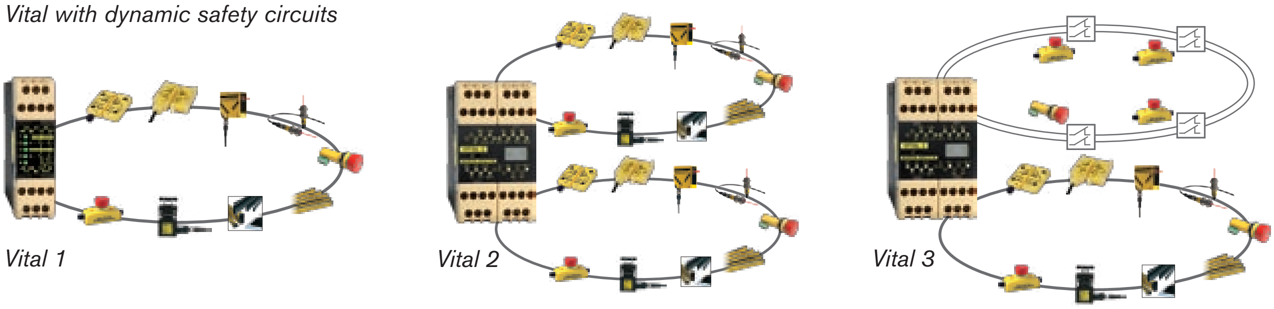
SafeCad for Quick-Guard

Jokab Safetys developments 2000 –

Pluto All-Master safety PLC



Vital with dynamic safety circuits



Non-contact sensor Eden, guard locks, Focus light beam, E-stops Inca and Smile, Smart for machine diagnosis and three-position device with hand detection

Directives and Standards

Directives and standards are of great importance for manufacturers of machines and safety components. EU Directives giving requirements for the minimum level of health and safety are mandatory for manufacturers to fulfil. In every member country the Directives are implemented in each countries legislation.
Machines which have been put on the market since december 29, 2009, must comply with the new Machinery Directive 2006/42/EC.
Before that, the old Machinery Directive 98/37/EC was valid.

The objectives of the Machinery Directive, 2006/42/EC, are to maintain, increase and equalise the safety level of machines within the members of the European Community. Based on this, the free movement of machines/products between the countries in this market can be achieved. The Machinery Directive is developed according to "The New Approach" which is based on the following principles

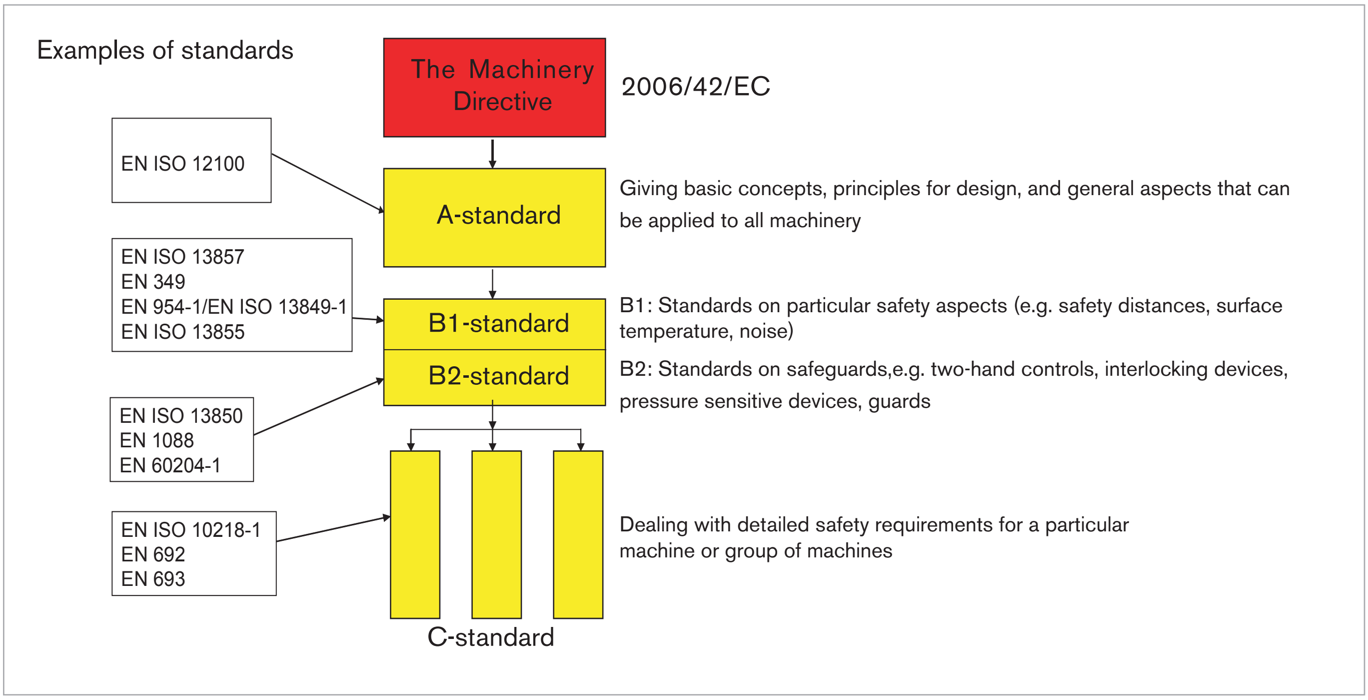
- The directives give the basic health and safety requirements, which are mandatory.
- Detailed solutions and technical specifications are found in harmonised standards.
- Standards are voluntary to apply, but products designed according to the harmonised standards will fulfil the basic safety requirements in the Machinery Directive.

Harmonised standards

Harmonised standards give support on how to fulfil the requirements of the Machinery Directive. The relationship between the Machinery Directive and the harmonised standards is illustrated by the diagram below.

Within ISO (The International Organization for Standardization) work is also going on in order to harmonise the safety standards globally in parallel with the European standardisation work. One consequence of this is that many existing EN-standards will, when revised, change number. For example, EN 954-1 will when revised change number to EN ISO 13849-1. Due to the New Machinery Directive, all harmonised standards will be reviewed and revised to some extent.

ABB Jokab Safety takes an active part in the working groups both for the ISO and EN standards.



The Machinery Directive; for machines and safety components

From 2006/42/EC

1 § This Directive applies to the following products:

a) machinery;
b) interchangeable equipment;
c) safety components;
d) lifting accessories;
e) chains, ropes and webbing;
f) removable mechanical transmission devices;
g) partly completed machinery.

The Machinery Directive gives the following definition:
a) machinery' means:

– an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application,

– an assembly referred to in the first indent, missing only the components to connect it on site or to sources of energy and motion,

– an assembly referred to in the first and second indents, ready to be installed and able to function as it stands only if mounted on a means of transport, or installed in a building or a structure,

– assemblies of machinery referred to in the first, second and third indents or partly completed machinery referred to in point (g) which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole,

– an assembly of linked parts or components, at least one of which moves and which are joined together, intended for lifting loads and whose only power source is directly applied human effort;

CE-marking and Declaration of conformity

Machines manufactured or put on the market from december 29, 2009, shall be CE-marked and fulfil the requirements according to the European Machinery Directive 2006/42/EC. This is also valid for old machines (manufactured before 1 January 1995) if they are manufactured in a country outside the EEA and imported to be used in a country in the EEA.
For mahcines manufactured and/or released to the market between january 1, 1995, and december 28, 2009, the old Machinery Directive (98/37/EC) is valid.

NOTE The point in time when the Machinery Directive was implemented in each Member Country varies.
Machines have to be accompanied by a Declaration of Conformity (according to 2006/42/EC, Annex II 1.A) that states which directive and standards the machine fulfils. It also shows if the product has gone through EC Type Examination.

Safety components have to be accompanied with a Declaration of Conformity

Requirements for the use of machinery

For a machine to be safe it is not enough that the manufacturer has been fulfilling all valid/necessary requirements. The user of the machine also has requirements to fulfil. For the use of machinery there is a Directive, 89/655/EEC (with amendment 96/63/EC and 2001/45/EC).

About CE-marked machinery the Directive gives the following requirement

From 89/655/EEC (with amendment 96/63/EC and 2001/45/EC)
1. Without prejudice to Article 3, the employer must obtain and/or use:
(a) work equipment which, if provided to workers in the undertaking and/or establishment for the first time after 31 December 1992, complies with:
(i) the provisions of any relevant Community directive which is applicable;
(ii) the minimum requirements laid down in Annex I, to the extent that no other Community directive is applicable or is so only partially;

This means that when repair/changes are made on the machine it shall still fulfil the requirements of the Machinery Directive. This doesn´t have to mean that a new CE-marking is required. (Can be required if the changes are extensive)

NOTE! This means that the buyer of a machine also has to make sure that a new machine fulfills the requirements in the directives. If the machine does not fulfill the requirements the buyer is not allowed to use it.

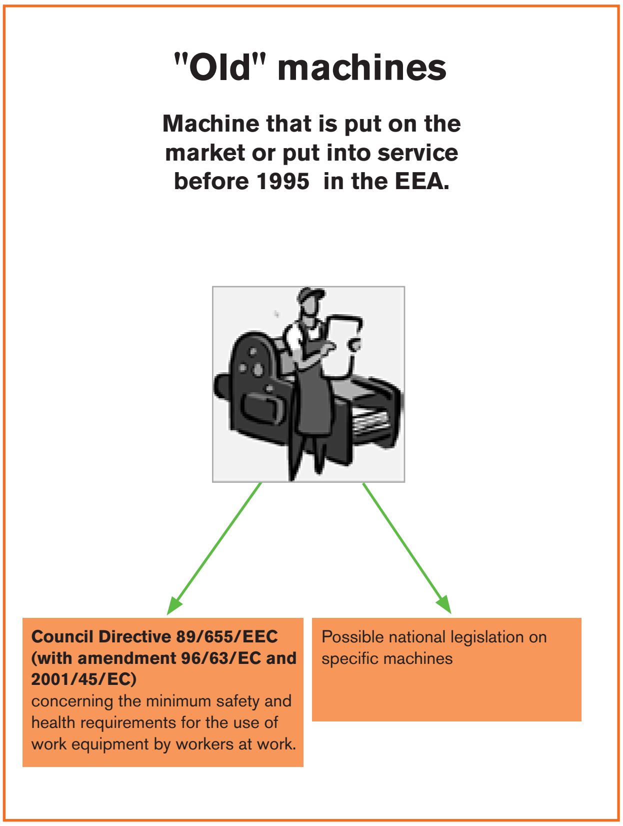
"Old" machines

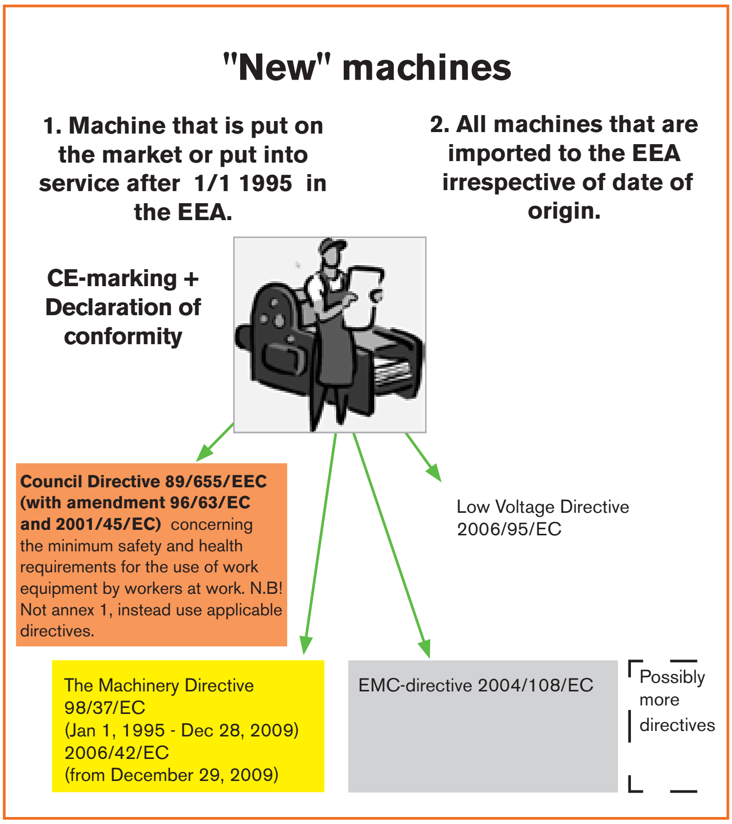
For machines delivered or manufactured in the EEA before 1 January 1995 the following is valid.

(b) work equipment which, if already provided to workers in the undertaking and/or establishment by 31 December 1992, complies with the minimum requirements laid down in Annex I no later than four years after that date.

(c) without prejudice to point (a) (i), and notwithstanding point (a) (ii) and point (b), specific work equipment subject to the requirements of point 3 of Annex I, which, if already provided to workers in the undertaking and/or establishment by 5 December 1998, complies with the minimum requirements laid down in Annex I, no later than four years after that date.

Annex I contains minimum requirements for health and safety. There can also be additional national specific requirements for certain machines. **NB** The point in time when the Machinery Directive was implemented in each Member Country varies. Therefore it is necessary to check with the national authorities in ones own country, to find out what is considered as "old" and respectively "new" machines.





Risk assessment – an important tool both when constructing a new machine and when assessing risks on older machines

A well thought-out risk assessment supports manufacturers/users of machines to develop production friendly safety solutions. One result of this is that the safety components will not be a hindrance. This minimizes the risk of the safety system being defeated.

New machines

The following requirement is given by the Machinery Directive

> The manufacturer of machinery or his authorised representative must ensure that a risk assessment is carried out in order to determine the health and safety requirements which apply to the machinery. The machinery must then be designed and constructed taking into account the results of the risk assessment.

The standard EN ISO 12100 gives guidance on the information required to allow risk assessment to be carried out. The standard does not point out a specific method to be used. It is the responsibility of the manufacturer to select a suitable method.

Machines in use

Risk assessment must be carried out on all machines that are in use; CE-marked as well as not CE-marked.

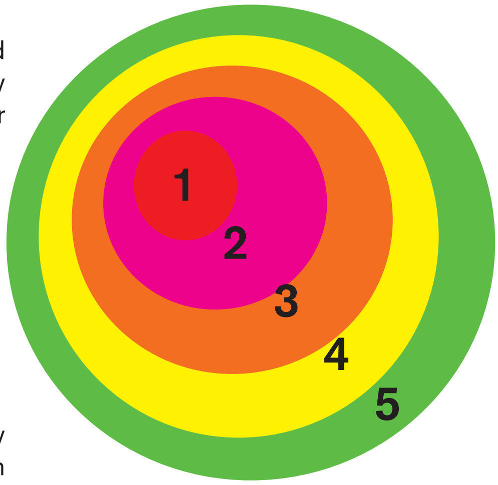
> To fullfil the requirements from Directive 89/655/EEC (concerning the minimum safety and health requirements for the use of work equipment by workers at work) risk assessment have to be made.

Documentation of risk assessment

The risk assessment shall be documented. In the assessment the actual risks shall be analysed as well as the level of seriousness.

Protection or warning?

How is it possible to choose safety measures that are production friendly and in every way well balanced? The Machinery Directive gives an order of priority for the choice of appropriate methods to remove the risks. Here it is further developed in a five step method.



Prioritize safety measures according to the five step method

1. Eliminate or reduce risks by design and construction
2. Move the work tasks outside the risk area
3. Use guards/safety devices
4. Develop safe working routines/information/education
5. Use warnings as pictograms, light, sound etc.

The further from middle of the circle, the greater the responsibility for the safety is put onto the user of the machine. If full protection is not effectively achieved in one step, one has to go to the next step and find complementary measures.

What is possible is dependant on the need for accessibility, the seriousness of the risk, appropiate safety measures etc.

Example on prioritizing according to the 5-step-method

Priority	Example of hazard and safety measure taken
1. Make machine safe by design and construction	*Hazard:* Cuts and wounds from sharp edges and corners on machinery *Safety measure:* Round off sharp edges and corners.
2. Move the work tasks outside the risk area	*Hazard:* Crushing of fingers from machine movements during inspection of the production inside the risk area *Safety measure:* Installation of a camera.
3. Use guard/safety devices	*Hazard:* Crushing injuries because of unintended start during loading of work pieces in a mechanical press *Safety measure:* Install a light curtain to detect operator and provide safe stop of the machinery.
4. Safe working routines/information	*Hazard:* Crushing injuries because the machine can tip during installation and normal use. *Safety measure:* Make instructions on how the machine is to be installed to avoid the risks. This can include requirements on the type of fastening, ground, screw retention etc.
5. Warnings	*Hazard:* Burns because of hot surfaces in reach *Safety measure:* Warning signs

The possibilities will increase to achieve a well thought-through safety system if each risk is handled according to the described prioritizing.

Combine the five step method with production friendly thinking.
This can give you e.g.

- fast and easy restart of machines after a stop from a safety device
- enough space to safely program a robot
- places outside the risk area to observe the production
- electrically interlocked doors, instead of guards attached with screws, to be able to take the necessary measures for removing production disturbances
- a safety system that is practical for all types of work tasks, even when removing production disturbances

Examples of regularly used EN/ISO standards

EN ISO 12100 (replaces EN ISO 12100-1/-2 and EN ISO 14121-1)	Safety of machinery - General principles for design - Risk assessment and risk reduction	Part 1: This standard defines basic terminology and methodology used in achieving safety of machinery. The provisions stated in this standard are intended for the designer. Part 2: This standard defines technical principles to help designers in achieving safety in the design of machinery.
EN ISO 13857	Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs	This standard establishes values for safety distances to prevent danger zones being reached by the upper limbs. The distances apply when adequate safety can be achieved by distances alone.
EN 349 (ISO 13854)	Safety of machinery – Minimum gaps to avoid crushing of parts of the human body	The object of this standard is to enable the user (e.g. standard makers, designers of machinery) to avoid hazards from crushing zones. It specifies minimum gaps relative to parts of the human body and is applicable when adequate safety can be achieved by this method.
EN ISO 13850	Safety of machinery – Emergency stop – Principles for design	This standard specifies design principles for emergency stop equipment for machinery. No account is taken of the nature of the energy source.
EN 574	Safety of machinery – Two-hand control devices – Functional aspects – Principles for design	This standard specifies the safety requirements of a two-hand control device and its logic unit. The standard describes the main characteristics of two-hand control devices for the achievement of safety and sets out combinations of functional characteristics for three types.
EN 953	Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards	This standard specifies general requirements for the design and construction of guards provided primarily to protect persons from mechanical hazards.
EN ISO 13849-1 (replaces EN 954-1)	Safety of machinery – Safety related parts of control systems – Part 1: General principles for design	This standard provides safety requirements and guidance on the principles for the design (see 3.11 of EN 292-1:1991) of safety-related parts of control systems. For these parts it specifies categories and describes the characteristics of their safety functions. This includes programmable systems for all machinery and for related protective devices. It applies to all safety-related parts of control systems, regardless of the type of energy used, e.g. electrical, hydraulic, pneumatic, mechanical. It does not specify which safety functions and which categories shall be used in a particular case.
EN ISO 13849-2	Safety of machinery. Safety-related parts of control systems. Validation	This standard specifies the procedures and conditions to be followed for the validation by analysis and testing of: • the safety functions provided, and • the category achieved of the safety-related parts of the control system in compliance with EN 954-1 (ISO 13849-1), using the design rationale provided by the designer.
EN 62061	Safety of machinery. Functional safety of safety-related electrical, electronic and programmable electronic control systems	The standard defines the safety requirements and guiding principles for the design of safety-related electrical/electronic/programmable parts of a control system.
EN ISO 13855 (replaces EN 999)	Safety of machinery - Positioning of safeguards with respect to the approach speeds of parts of the human body	This standard provides parameters based on values for hand/arm and approach speeds and the methodology to determine the minimum distances from specific sensing or actuating devices of protective equipment to a danger zone.
EN 1088 and EN 1088/A1	Safety of machinery. Interlocking devices associated with guards. Principles for design and selection	This standard specifies principles for the design and selection - independent of the nature of the energy source - of interlocking devices associated with guards. It also provides requirements specifically intended for electrical interlocking devices. The standard covers the parts of guards which actuate interlocking devices.
EN 60204-1	Safety of machinery. Electrical equipment of machines. General requirements	This part of IEC 60204 applies to the application of electrical and electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner but excluding higher level systems aspects (i.e. communications between systems).

New standards for safety in control systems

Building a protection system that works in practice and provides sufficient safety requires expertise in several areas. The design of the safety functions in the protection system in order to ensure they provide sufficient reliability is a key ingredient. As help for this there is, for example, the EN ISO 13849-1 standard. The purpose of this text is to provide an introduction to the standard and its application in conjunction with our products.

Introducing the new standard

The generation change for standards on safety in control systems involving new concepts and calculations for machine builders and machine users. The EN 954-1 standard (categories) is being phased out and replaced by EN ISO 13849-1 (PL, Performance Level) and EN 62061 (SIL, Safety Integrity Level). Although the deadline for using EN 954-1 is set to 31/12/2011, it is beneficial to start applying the new standards as soon as possible as many new standards no longer refer to EN 954-1.

PL or SIL? What should I use?

The standard you should use depends on the choice of technology, experience and customer requirements.

Choice of technology

- PL (Performance Level) is a technology-neutral concept that can be used for electrical, mechanical, pneumatic and hydraulic safety solutions.
- SIL (Safety Integrity Level) can, however, only be used for electrical, electronic or programmable safety solutions.

Experience

EN ISO 13849-1 uses categories from EN 954-1 for defining the system structure, and therefore the step to the new calculations is not so great if you have previous experience of the categories. EN 62061 defines the structures slightly differently.

Customer requirements

If the customer comes from an industry that is accustomed to using SIL (e.g. the process industry), requirements can also include safety functions for machine safety being SIL rated.

We notice that most of our customers prefer PL as it is technology-neutral and that they can use their previous knowledge in the categories. In this document we show some examples of how to build safety solutions in accordance with EN ISO 13849-1 and calculate the reliability of the safety functions to be used for a particular machine. The examples in this document are simplified in order to provide an understanding of the principles. The values used in the examples can change.

What is PL (Performance Level)?

PL is a measure of the reliability of a safety function. PL is divided into five levels (a-e). PL e gives the best reliability and is equivalent to that required at the highest level of risk.

To calculate which level the PL system achieves you need to know the following:

- The system's structure (categories B, 1-4)
- The Mean Time To dangerous Failure of the component ($MTTF_{d)}$
- The system's Diagnostic Coverage (DC)

You will also need to:

- protect the system against a failure that knocks out both channels (CCF)
- protect the system from systematic errors built into the design
- follow certain rules to ensure software can be developed and validated in the right way

The five PL-levels (a-e) correspond to certain ranges of PFH_D-values (probability of dangerous failure per hour). These indicate how likely it is that a dangerous failure could occur over a period of one hour. In the calculation, it is beneficial to use PFH_D-values directly as the PL is a simplification that does not provide equally accurate results.

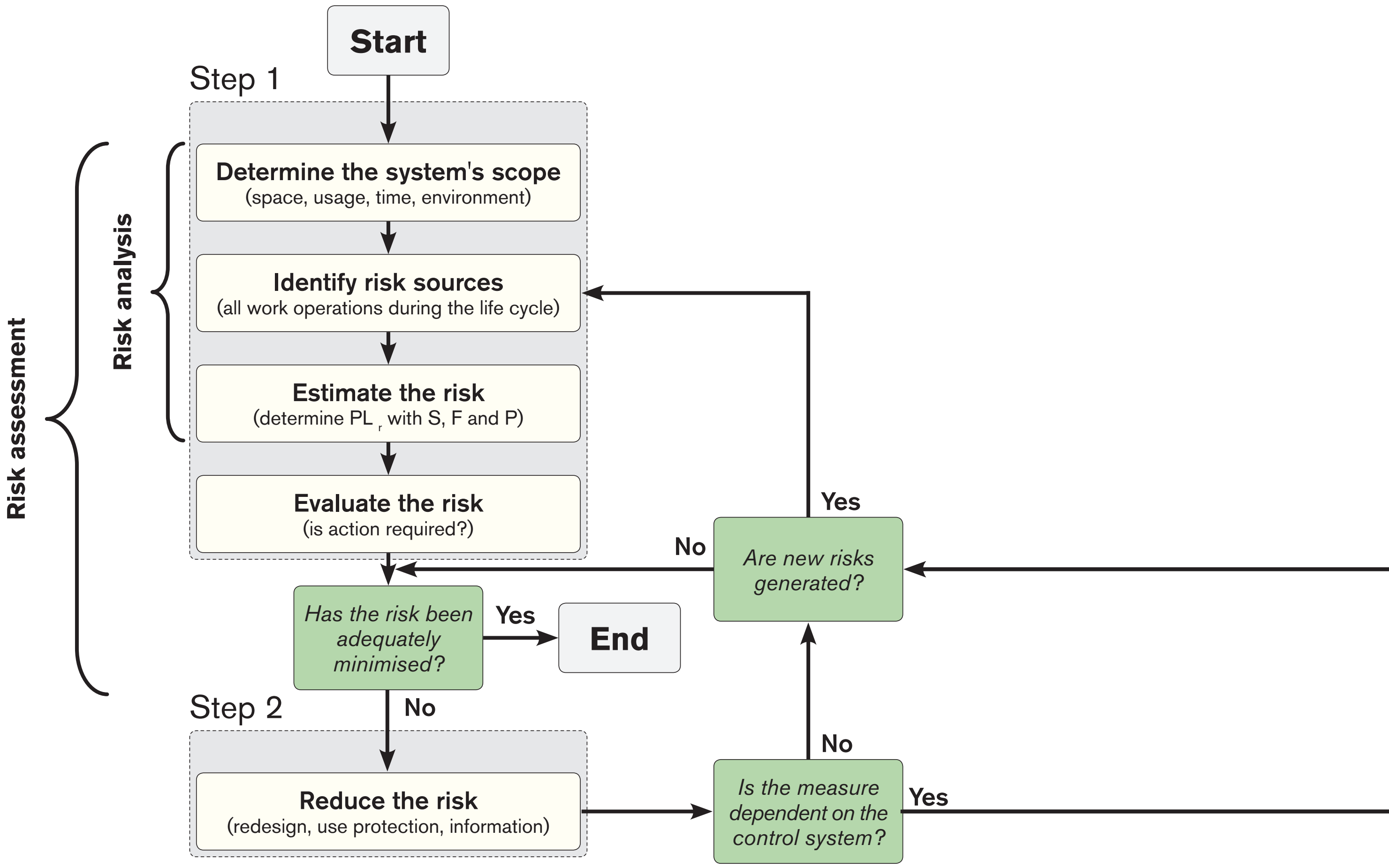
What is the easiest way of complying with the standard?

1. *Use pre-calculated components.*
As far as it is possible, use the components with pre-calculated PL and PFH_D-values. You then minimise the number of calculations to be performed. All ABB Jokab Safety products have pre-calculated PFH_D-values.

2. *Use the calculation tool.*
With the freeware application SISTEMA (see page 16) you avoid making calculations by hand. You also get help to structure your safety solutions and provide the necessary documentation.

3. *Use Pluto or Vital*
Use the Pluto safety PLC or Vital safety controller. Not only is it easier to make calculations, but above all it is easier to ensure a higher level of safety.

Working method as specified in EN ISO 13849-1



Risk assessment and risk minimisation

According to the Machinery Directive, the machine builder (anyone who builds or modifies a machine) is required to perform a risk assessment for the machine design and also include an assessment of all the work operations that need to be performed. The EN ISO 12100 standard (combination of EN ISO 14121-1 and EN ISO 12100-1/-2) stipulates the requirements for the risk assessment of a machine. It is this that EN ISO 13849-1 is based on, and a completed risk assessment is a prerequisite for being able to work with the standard.

Step 1 – Risk assessment

A risk assessment begins with determining the scope of the machine. This includes the space that the machine and its operators need for all of its intended applications, and all operational stages throughout the machine's life cycle.

All risk sources must then be identified for all work operations throughout the machine's life cycle.

A risk estimation is made for each risk source, i.e. indication of the degree of risk. According to EN ISO 13849-1 the risk is estimated using three factors: injury severity (S, severity), frequency of exposure to the risk (F, frequency) and the possibility you have of avoiding or limiting the injury (P possibility). For each factor two options are given.Where the boundary between the two options lies is not specified in the standard, but the following are common interpretations:

S1 *bruises, abrasions, puncture wounds and minor crushing injuries*
S2 *skeletal injuries, amputations and death*

F1 *less frequently than every two weeks*
F2 *more often than every two weeks*

P1 *slow machine movements, plenty of space, low power*
P2 *quick machine movements, crowded, high power*

By setting S, F and P for the risk, you will get the PL_r Performance Level (required) that is necessary for the risk source.

Finally, the risk assessment includes a risk evaluation where you determine if the risk needs to be reduced or if sufficient safety is ensured.

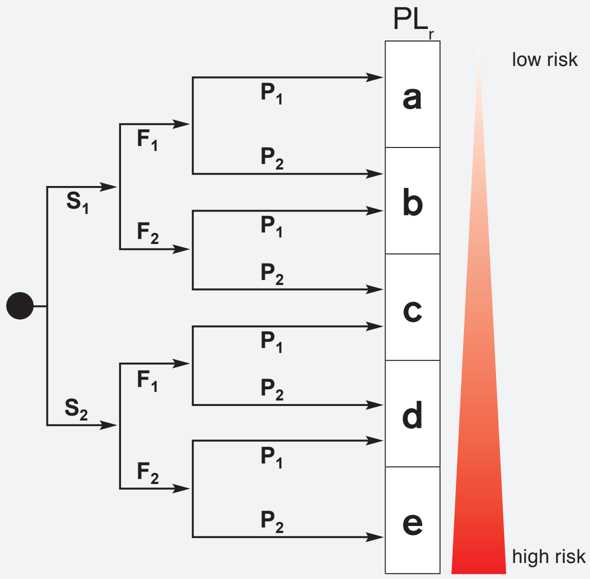
Risk estimation

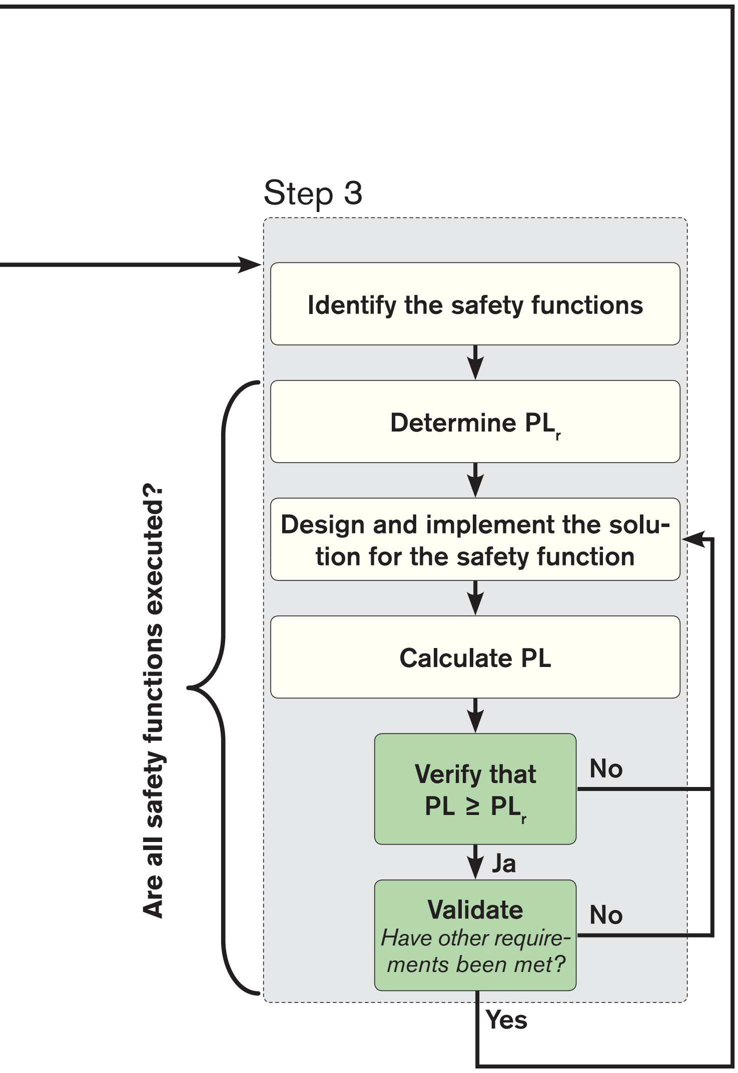
To calculate the performance level required (PL_r).

S **Severity of injury**
S1 *slight (usually transient injury)*
S2 *severe (usually permanent injury or death)*

F **Frequency and/or exposure time to risk source**
F1 *rarely less often and/or short exposure time*
F2 *often to continuous and/or extended exposure time*

P **Possibility of avoiding the risk source or minimising the injury**
P1 *possible under certain circumstances*
P2 *hardly possible*





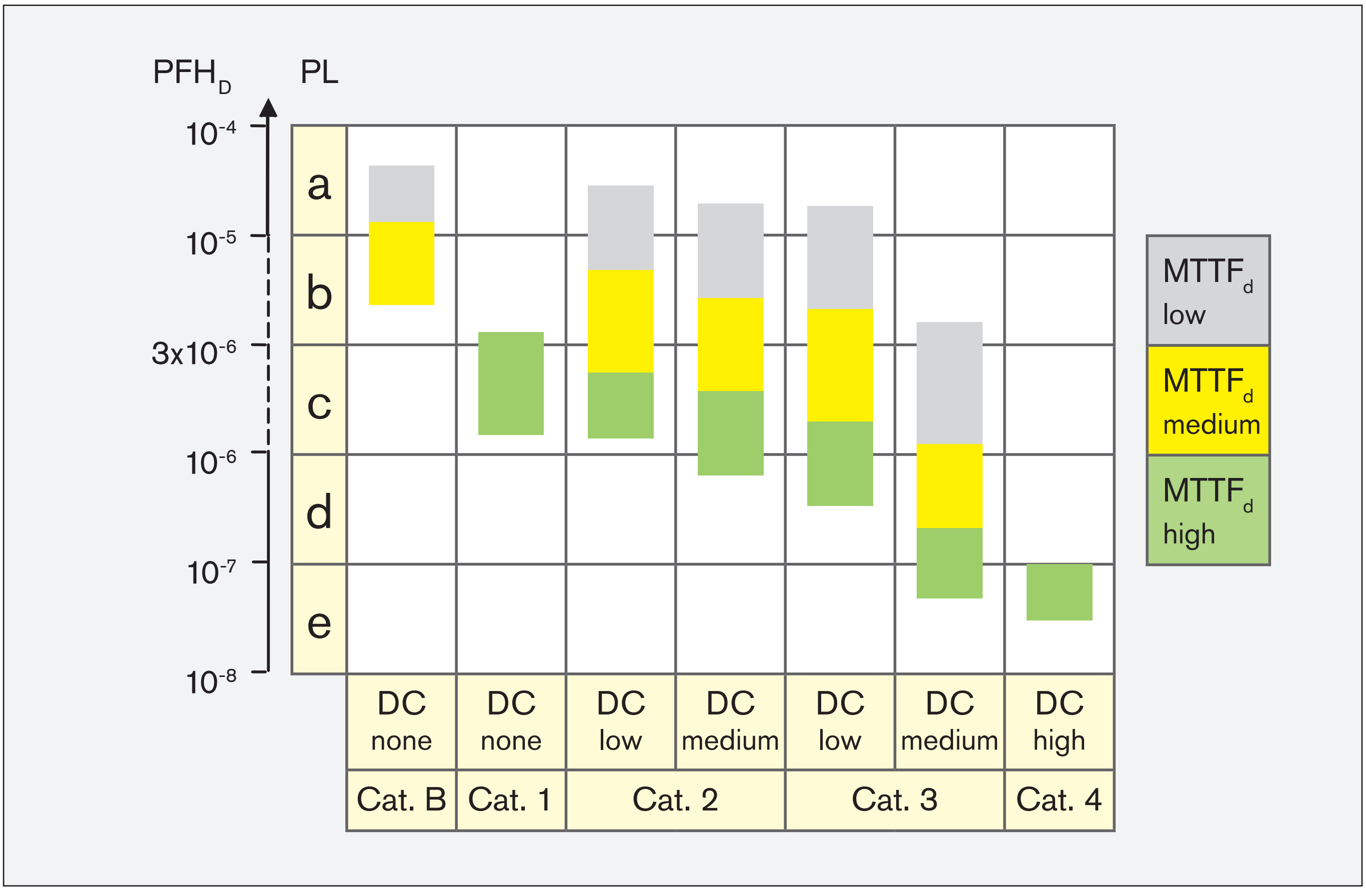
Step 2 – Reduce the risk
If you determine that risk reduction is required, you must comply with the priority in the Machinery Directive in the selection of measures:

1. *Avoid the risk already at the design stage. (For example, reduce power, avoid interference in the danger zone.)*
2. *Use protection and/or safety devices. (For example, fences, light grids or control devices.)*
3. *Provide information about how the machine can be used safely. (For example, in manuals and on signs.)*

If risk reduction is performed using safety devices, the control system that monitors these needs to be designed as specified in EN ISO 13849-1.

Step 3 - Design and calculate the safety functions
To begin with you need to identify the safety functions on the machine. (Examples of safety functions are emergency stop and monitoring of gate.)

For each safety function, a PL_r should be established (which has often already been made in the risk assessment). The solution for the safety function is then designed and implemented. Once the design is complete, you can calculate the PL the safety function achieves. Check that the calculated PL is at least as high as PL_r and then validate the system as per the validation plan. The validation checks that the specification of the system is carried out correctly and that the design complies with the specification.You will also need to verify that the requirements that are not included in the calculation of the PL are satisfied, that is, ensure that the software is properly developed and validated, and that you have taken adequate steps to protect the technical approach from systematic errors.

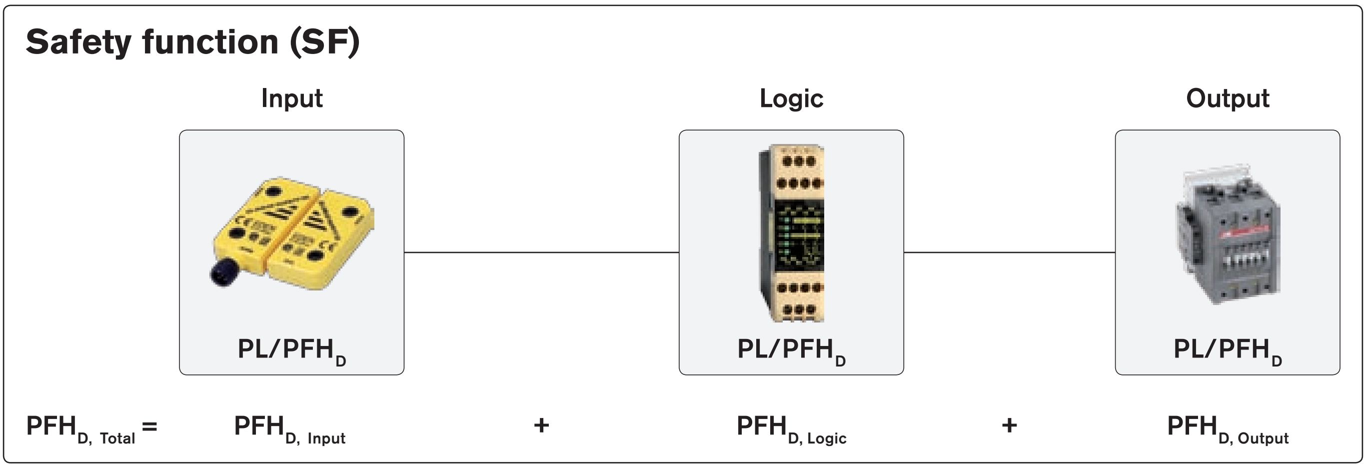


The relationship between categories, the DC_{avg}, $MTTF_d$ for each channel and PL. The table also shows the PFH_D-range that corresponds to each PL.

PL calculation in Step 3
When you calculate the PL for a safety function, it is easiest to split it into separate, well defined blocks (also called subsystems). It is often logical to make the breakdown according to input, logic and output (e.g. switch - safety relay - contactors), but there may be more than three blocks depending on the connection and the number of components used (an expansion relay could for example create an additional logic block) .

For each block, you calculate a PL or PFH_D-value. It is easiest if you obtain these values from the component manufacturer, so you do not have to calculate yourself. The manufacturer of switches, sensors and logic devices often have PL and PFH_D-values for their components, but for output devices (such as contactors and valves) you do not usually specify a value as it depends on how often the component will be used. You can then either calculate yourself according to EN ISO 13849-1 or use the pre-calculated example solutions such as those from ABB Jokab Safety.

To calculate PL or PFH_D for a block, you need to know its category, DC and $MTTF_d$. In addition, you need to protect yourself against systematic errors and ensure that an error does not knock out both channels, and generate and validate any software used correctly. The following text gives a brief explanation of what to do.



Category

The structure for the component(s) in the block is assessed to determine the category (B, 1-4) it corresponds to. For category 4, for example, individual failures do not result in any loss of the safety function.

In order to achieve category 4 with contactors, you need to have two channels - *i.e., two contactors* - that can cut the power to the machine individually. The contactors need to be monitored by connecting opening contacts to a test input on, for example a safety relay. For monitoring of this type to work, the contactors need to have contacts with positive opening operation.

Diagnostic Coverage (DC)

A simple method to determine DC is explained in Appendix E in EN ISO 13849-1. It lists various measures and what they correspond to in terms of DC. For example, DC=99 % (which corresponds to DC high) is achieved for a pair of contactors by monitoring the contactors with the logic device.

Mean Time To dangerous Failure ($MTTF_d$)

In calculating the $MTTF_d$ for the block your starting point is the B_{10d}-value (average number of cycles until 10 % of the components have a dangerous failure). To calculate the $MTTF_{d,}$ you also need to know the average number of cycles per year that the component will execute.

Calculation of the average number of cycles is as follows:

$$MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}}$$

där

$$n_{op} = \frac{d_{op} \cdot h_{op} \cdot 3600}{t_{cycle}}$$

n_{op} = Number of cycles per year
d_{op} = Operation days per year
h_{op} = Operation hours per day
t_{cycle} = Cycle time (seconds)

Example: d_{op}= 365 days, h_{op}= 24 hours and t_{cycle}= 1,800 seconds (2 times/hour) which gives n_{op}= 17,520 cycles.

With a $B_{10d}=2\cdot10^6$ this gives a $MTTF_d$=1,141 year which corresponds to $MTTF_d$=high.

Note that when you calculate $MTTF_d$ you have to calculate according to the total number of cycles the component will be working. A typical example of this is the contactors that frequently work for several safety functions simultaneously. This means that you must add the number of estimated cycles per year from all the safety functions that use the contactors.

For electromechanical, mechanical and pneumatic components whose $MTTF_d$ is calculated from a B_{10d}-value, the following applies.

Also consider that if the $MTTF_d$-value is less than 200 years, the component needs to be replaced after 10 % of the $MTTF_d$-value (due to the T_{10d}-value). That is, a component with $MTTF_d$ = 160 years needs to be replaced after 16 years in order for the conditions for achieving PL to continue to be valid. This is because EN ISO 13849-1 is based on a “mission time” of 20 years.

Common Cause Failure (CCF)

In Appendix F of EN ISO 13849-1 there is a table of actions to be taken to protect against CCF, to ensure a failure does not knock out both channels.

Systematic errors

Appendix G of EN ISO 13849-1 describes a range of actions that need to be taken to protect against incorporating faults into your design.

PL for safety functions

PL is given in the table on the facing page. If you want to use an exact PFH_D-value instead,this can be produced using a table in Appendix K in EN ISO 13849-1.

Once you have produced the PL for each block, you can generate a total PL for the safety function in Table 11 of EN ISO 13849-1. This gives a rough estimate of the PL. If you have calculated PFH_D for each block instead, you can get a total of PFH_D for the safety function by adding together all the values of the blocks. The safety function’s total PFH_D corresponds to a particular PL in Table 3 of EN ISO 13849-1.

Requirements for safety-related software

If you use a safety PLC for implementing safety functions, this places demands on how the software is developed and validated. To avoid error conditions, the software should be readable, understandable and be possible to test and maintain.

A software specification must be prepared to ensure that you can check the functionality of the program. It is also important to divide the program into modules that can be tested individually. Paragraph 4.6 and Appendix J of EN ISO 13849-1 specify requirements for safety related software.

The following are examples of requirements for software from EN ISO 13849-1:

- A development life cycle must be produced with validation measures that indicate how and when the program should be validated, for example, following a change.
- The specification and design must be documented.
- Function tests must be performed.
- Validated functional blocks must be used whenever possible.
- Data and control flow are to be described using, for example, a condition diagram or software flow chart.

What defines a safety function?

Calculating that you have achieved the PL_r that is required is not difficult, especially if you use “pre-calculated” safety devices and logic units. But what parts should then be included in each safety function? This must be resolved before you start calculating phase. To summarise in simple terms you can say that each safety device gives rise to a safety function for each machine that is affected by the safety device in question. Three safety devices that all cut the power to three machines in a cell is therefore equal to nine safety functions. In the section that follows, we explain the background.

Multiple safety functions for a machine

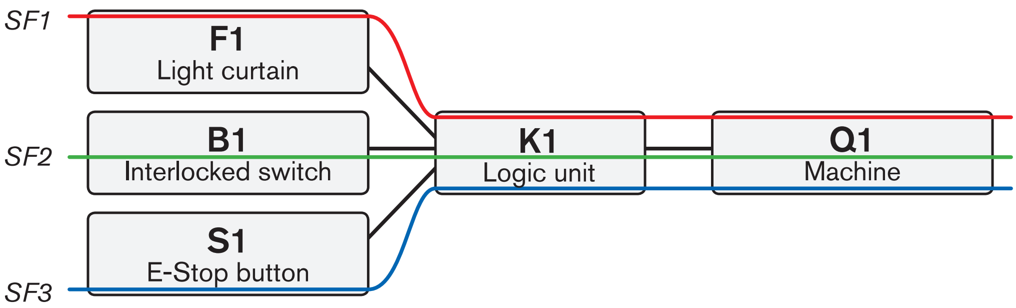
Multiple safety devices are often used on a machine in order to provide satisfactory and practical protection for the operators. In the following example, the machine is protected by three safety devices connected to a logic device. The following figure illustrates this interconnection schematically.

Three safety functions (SF) are defined for the machine and are calculated as:

SF1: $PFH_{D,\ F1} + PFH_{D,\ K1} + PFH_{D,\ Q1} = PFH_{D,\ SF1}$

SF2: $PFH_{D,\ B1} + PFH_{D,\ K1} + PFH_{D,\ Q1} = PFH_{D,\ SF2}$

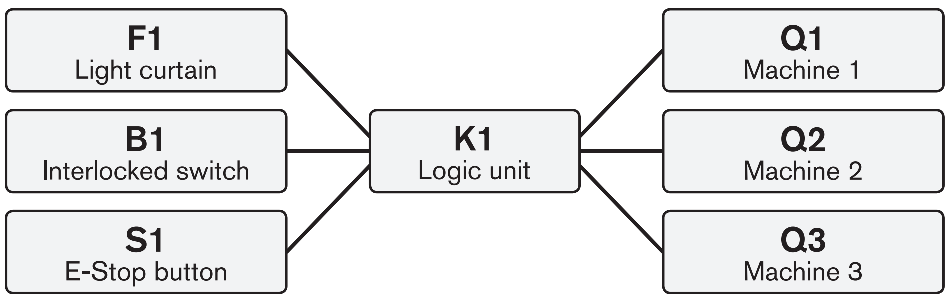
SF3: $PFH_{D,\ S1} + PFH_{D,\ K1} + PFH_{D,\ Q1} = PFH_{D,\ SF3}$



Multiple safety functions for multiple machines in a cell

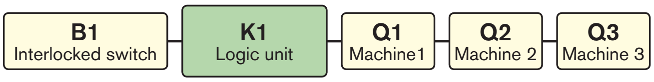
More commonly, several machines in a single cell/zone are to be protected by multiple safety devices. The following figure illustrates the interconnection schematically for an example. Each of the machines Q1 – Q3 is shut down separately and independently of K1.

If the operator enters the cell, he is exposed in this case to the same type of risk from all three machines. The power to all three machines must be cut when the operator enters the cell through the door interlocked by B1.



Theoretical approach for multiple machines

The theoretical approach to calculate the safety function is as follows:

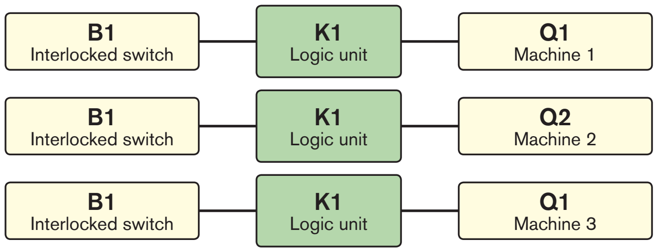


For the full safety function to be performed you require all the components to be working. Note that if B1 or K1 has a dangerous malfunction, the entire safety function is disabled. However, if for example machine Q1 has a dangerous malfunction, and is not shut down, machines Q2 and Q3 will still be shut down. One disadvantage in considering the safety function in this way is that you may have trouble achieving the PL_r required. But if you achieve the PL_r required, you can use the theoretical approach.

Sources:
www.dguv.de/ifa/de/pub/grl/pdf/2009_249.pdf
www.bg-metall.de/praevention/fachausschuesse/infoblatt/deutsch.html
(No 047, Date 05/2010)

Practical approach for multiple machines

A more practical approach is to divide the safety function into three parts, one for each of the three machines.



This is an approach that can provide a more accurate way of looking at the safety functions, especially where a different PL_r is required for the safety functions above. If machine Q1 is a robot and machine Q2 is a conveyor which is designed to have negligible risks, the different PL_r required to protect against risks from Q1 and Q2 will also be different. This practical approach is therefore the one recommended. The interpretation is based on information provided by IFA (Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung). For more information on this and other issues, see Sources.

Example of safety functions for multiple machines in a cell

For a cell with three machines (one robot, one hydraulic press and one pneumatic machining tool) a risk assessment is made resulting in different PL_r for the individual machines. The robot and the hydraulic press requires PL_r = e, while the pneumatic machining tool requires PL_r = d.

One of the safety functions is that a non-contact sensor (Eden) supervised by a safety PLC (Pluto) shall disconnect the energy to all three machines in the hazard zone:

- Eden B1 ($PFH_{D,\,B1} = 4{,}5 \cdot 10^{-9}$)
- Pluto K1 ($PFH_{D,\,K1} = 2 \cdot 10^{-9}$)
- Robot Q1 ($PFH_{D,\,Q1} = 5{,}79 \cdot 10^{-8}$)
- Hydraulic press Q2 ($PFH_{D,\,Q2} = 8 \cdot 10^{-8}$)
- Pneumatic machining tool Q3 ($PFH_{D,\,Q3} = 2 \cdot 10^{-7}$).

Practical approach

If you use the practical approach the safety functions are as follows:

Robot:

$PFH_{D,\,B1} + PFH_{D,\,K1} + PFH_{D,\,Q1} = 4{,}5 \cdot 10^{-9} + 2 \cdot 10^{-9} + 5.79 \cdot 10^{-8} = 6.44 \cdot 10^{-8} \longrightarrow$ PL e

Hydraulic press:

$PFH_{D,\,B1} + PFH_{D,\,K1} + PFH_{D,\,Q2} = 4.5 \cdot 10^{-9} + 2 \cdot 10^{-9} + 8 \cdot 10^{-8} = 8.65 \cdot 10^{-8} \longrightarrow$ PL e

Pneumatic machining tool:

$PFH_{D,\,B1} + PFH_{D,\,K1} + PFH_{D,\,Q3} = 4.5 \cdot 10^{-9} + 2 \cdot 10^{-9} + 2 \cdot 10^{-7} = 2.07 \cdot 10^{-7} \longrightarrow$ PL d

This is to be done in a similar way with other safety functions for the cell. For each safety device, you define the machines it affects, and establish the various safety functions according to this.

Theoretical approach

How would it have worked if you had used the theoretical approach? Would the safety function have achieved PL e?

All machines:

$PFH_{D,\,B1} + PFH_{D,\,K1} + PFH_{D,\,Q1} + PFH_{D,\,Q2} + PFH_{D,\,Q3}$
$= 4{,}5 \cdot 10^{-9} + 2 \cdot 10^{-9} + 5.79 \cdot 10^{-8} + 8 \cdot 10^{-8} + 2 \cdot 10^{-7} = 3.44 \cdot 10^{-7} \longrightarrow$ PL d

In this case, the safety function would therefore have not achieved a total PL e, which was required for the risks associated with a robot and hydraulic press.

Conclusions

- Use the practical approach.
- Use safety devices/logic units with high reliability (low PFH_D) to make it easy to achieve the PL_r required.
- With Vital or Pluto, it is easier to achieve the PL_r required.

Please note that the examples on these pages are simplified in order to explain the principles. Values of products can also change.

Applying EN 62061

If one chooses to design a safety function in accordance with EN 62061, the level of reliability is expressed as the Safety Integrity Level, SIL. There are a total of 4 levels, but in the EN 62061 standard SIL 3 is the highest level. SIL also (similar to the Performance Level PL), is expressed as the Probability of Dangerous Failure Per Hour.

Safety Integrity Level, SIL	Probability of dangerous Failure per Hour (PFH_D)
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-5}$

There is a method in EN 62061 for assigning the Safety Integrity Level.

Severity (Se)	Class (Cl)				
	3-4	5-7	8-10	11-13	14-15
4	SIL2	SIL2	SIL2	SIL3	SIL3
3		(OM)	SIL1	SIL2	SIL3
2			(OM)	SIL1	SIL2
1				(OM)	SIL1

Cl=Fr+Pr+Av OM=Other Measures

The seriousness of injury that can occur is defined at one of four levels. Class is the addition of the values of frequency (Fr, stated as a value between 1 and 5, where 5 represents the highest frequency), probability that a dangerous event will occur (Pr, stated as a value between 1 and 5, where 5 represents the highest proability) and the possibility of avoiding or limiting injury (Av, sated as a value of 1, 3 or 5, where 5 represents the least chance of avoiding or limiting an injury).

The safety function that is to be designed must at least fulfil the SIL that has been assigned to it in the analysis. The safety function consists of a number of sub-elements. Example: a door is interlocked by a non-contact sensor which is in turn monitored by a Pluto safety PLC, with outputs that break the power to two supervised contactors. The sensor is sub-element 1, Pluto is sub-element 2 and the two supervised contactors are sub-element 3. If in the analysis it has been established that SIL2 shall be used, every individual sub-element in the safety function must fulfil the SIL2 requirements. The safety function must then in its entirety fulfil the SIL2 requirements.

Definition of protective safety in accordance with EN 62061
"Function of a machine whose failure can result in an immediate increase of the risk(s)"

If the SIL requirements are not fulfilled in any of the sub-elements or by the safety function in its entirety, there must be a re-design.

Finally
This is just a brief introduction to the EN ISO 13849-1 and EN 62061 standards. You are welcome to contact us so that we can prepare suitable training and guide you in how to apply the standards to our products.

A mechanical switch does not give a safe function!

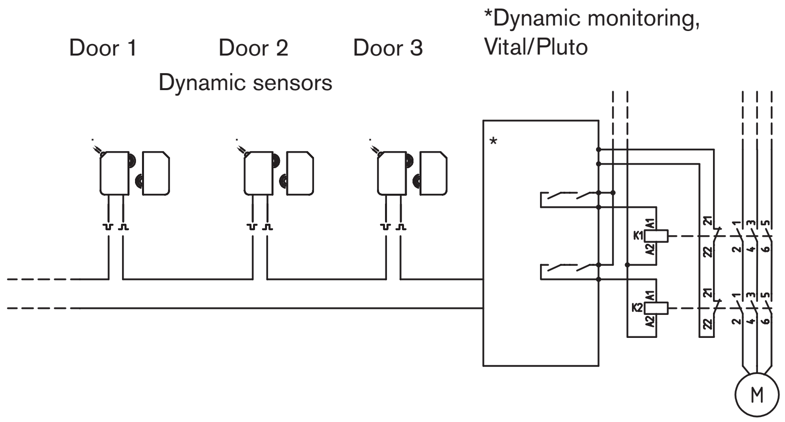
A mechanical switch does not give a safe function!
When it comes to mechanically operated interlocked switches, it has long been accepted a Category 1 switch is adequate for many installations, which is also supported by several standards. However some companies have now re-evaluated this and have instead started to demand two mechanical switches or non-contact switches/sensors, where they previously accepted single mechanical switches. Many reported incidents form the background to this. The requirements for switches to provide safe functioning are that they are mounted correctly and that their positions do not change during their life-cycle, in other words, ideal conditions. In many installations the location of hatches or doors changes over time. This has led to a switch not giving a stopping signal when an interlocked gate has opened. The reasons for this are many, but they can be summarized in mechanical deterioration or physical damage to a door/hatch. In turn this has led to an interlocked switch being affected by higher stress than the switch manufacturer's specifications. To avoid this type of malfunction it is more appropriate to use non-contact switches/sensors because mechanical deterioration does not affect the safety function, i.e. the stop signal is given directly if the position is wrong.

A non-contact switch/sensor does not have a guided function and is designed to fulfill the requirements in another way. The requirements are fulfilled either with dynamic sensors where the safety signal is monitored all the time and a fault directly leads to a stop signal or with a magnetic switch which has two independent contact elements which are monitored every time a gate opens. From the user's perspective the dynamic function is preferable because several sensors can be connected to a single safety module and still achieve PL e. Also the sensor's safety function is monitored without having to open a gate. For a magnetic switch the requirements for PL e are only fulfilled if one switch per monitoring unit is used and if the gate is opened regularly.

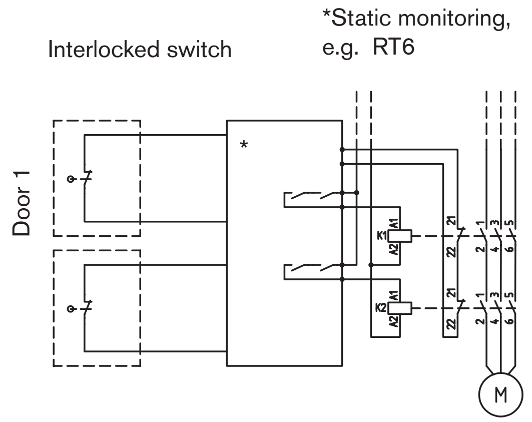
If PL e is to be achieved with electromechanical switches, maximum two switches can be connected to one safety relay. This means that it is only with Eden that several doors can be supervised with one safety module and achieve PL e.

Since the standard EN 954-1 was written, development has progressed and the costs to fulfill category 4 have dropped dramatically. Generally mechanical switches are replaced with non-contact sensors to increase the reliability of production equipment. The same goes for the safety side. With electronic non-contact switches, with a transmitter and a receiver, one avoids the problems of deterioration and excessive stress which harm the sensor. For that kind of sensor dynamic monitoring is required to enable a safe function. This means that its function is constantly being monitored, hundred of times per second. The reaction time for a safe stop will then be the same during a malfunction as during the activation of a stop (e.g. a gate opening). The monitoring frequency will also be astronomical compared to that of mechanical switches and magnetic switches, which are only monitored every time they are used. In the new EN ISO 13849-1, which will replace 954-1, probability calculations are used together with different category levels to compare different "performance levels". Even when using EN ISO 13849-1 it can be so that one achieves reasonably high theoretical reliability with an electromechanical switch, although this presumes correct installation, proper use and otherwise ideal conditions. A non-contact switch instead provides high levels of both theoretical and practical reliability.

Our conclusion, use dynamic signals!
Our conclusion is that today it is more cost effective, safer and more reliable to work with dynamic signals to achieve category 4 for sensors and monitoring units. In that case it is also possible to fulfill the Machinery Directive, 1.2.7. requirement: "A fault in the control circuit logic, or failure of or damage to the control circuit, must not lead to dangerous situations". Also one does not have to discuss whether the correct safety category has been chosen!



Up to 30 doors (Eden sensors) can be connected to the dynamic monitoring maintaining category 4.



Maximum 1 door (2 interlocked switches) can be connected to the static monitoring for category 4 to be maintained for the entire system.

We train you on safety requirements

- enhance your knowledge!

What requirements are there today?

With the incorporation of Sweden into the EU there are many new standards and regulations with which to comply. There have also been changes and revisions of existing standards and directives.

As a business and designer one is obliged to know about and to follow all the regulations. But it can be difficult for each individual company to keep track of all the new regulations and how they should be applied.

Your local ABB Jokab Safety sales office can help you with training and analysis during a build-up phase or as a continuous consulting assignment.

Our course trainers have a extensive experience in machine safety

A distinguishing feature of all the engineers at ABB Jokab Safety is that they work daily with practical applications of standards and regulations. This is true for everything from safety components for individual machines to entire deliveries of safety systems for larger production lines. Within the company there is also a very good knowledge of machine control and production. We are also represented in standardisation groups which decide on European and International standards concerning machine safety. Because ABB Jokab Safety is represented globally, we have the knowledge of safety requirements in different countries.

Training in machine safety

Are you building machines for sale or for your own use? Are you a user of machines? Are you working with automation of production plants or do you make technical evaluations of machines prior to purchase?

Regardless of the purpose, there is a need for knowledge concerning what requirements and regulations exist in respect of machine safety, and how they should be applied.

We offer company-adapted training in the following fields:

- Product liability and its consequences
- CE-labelling
- The Machine Directive and how to apply it
- Choice of certification procedure with examination of the parts which are required in order to be able to CE-label a machine

- Harmonised standards and the applications of these, e.g.
  - EN ISO 13849-1/-2
  - EN ISO 12100
  - EN 60204-1
  - EN ISO 13850
  - EN ISO 13857
  - EN ISO 13855 (previously EN 999)

- Machine safety analysis; method and cases
- Choice of safety measures/safety devices
- Requirements for manufacturer´s technical documentation
- Requirements for manuals
- Requirements for ”old machines”

- Specific interpretation cases, e.g. re-construction of machines
- Forthcoming changes in the Machine Directive

Company-adapted training in machine safety
Contact your local sales office with questions and your current training needs. Together with you, we will customize the training to your specific company requirements.

Training in risk analysis

We regularly have training courses in our offices. One of these covers risk analysis and how to choose production adapted measures.

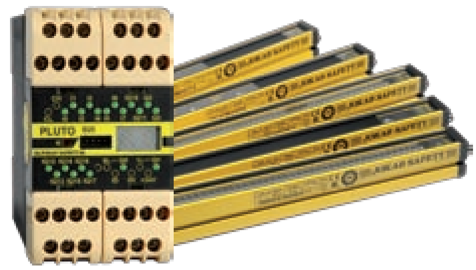
A course in risk analysis contains the following:

- Risk analysis - from theory to practice
- What durability towards errors shall the safety system have?
- Standard EN ISO 13849-1/-2
- Safety distances for fencing systems and safety components - how do you choose?
- Cases, practice and briefing of risk analysis and choice of actions

Product training

Our unique Pluto Safety PLC gives new and great possibilites to build-up a cost effective and flexible safety system. With this also comes the demands of higher knowledge. For you as a customer to be able to quickly get started using Pluto in the most effective way and to learn about its possibilities, we regularly offer trainings at our local sales offices. In the training course cost is included a Pluto, software for Pluto and full documentation. We also offer training on the other ABB/Jokab Safety products such as the Vital solution, safety relays and light beams/curtains.

Training - Pluto and other ABB Jokab Safety products
Contact your local sales office with questions and your current training needs. Together with you, we will customize the training to your specific company requirements.

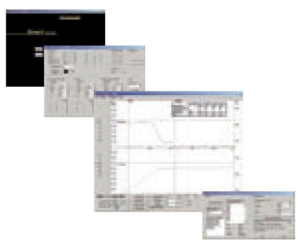


Consulting

Do you need assistance in CE-marking a machine? Do you want a third party to carry out a risk analysis on a machine line? Do you have the need of a partner to examine how various regulations effect the safety of your machines?

We can offer assistance and support in both short and longer assignments. Here are a few examples of what we can offer you:

- **Risk analysis** with proposal of measures. We do this together with the customer and it is often done as a pilot-project so that the company afterwards themselves can carry out analysis.
- Guide the customer business through a **CE-marking** of machine/ plant.
- Write/review **technical documentation/manuals**
- **Interpret** standards and regulations
- **Stopping time measurement** - We can measure the stopping time on your machines with our Stopping time and motion analyser tool. Knowledge of the stopping time is a prerequisite to be able to determine the correct safety distance. EN ISO 13855 (previously EN 999) gives the requirements.
- **Programming** of Pluto Safety-PLC.



Stopping time measurement is required in order to be able to determine the correct safety distance.

Consulting - Contact us
Come to us with your needs and we will plan with you a suitable project programme. You can also contact us with short questions which we can solve directly over the phone or via e-mail.