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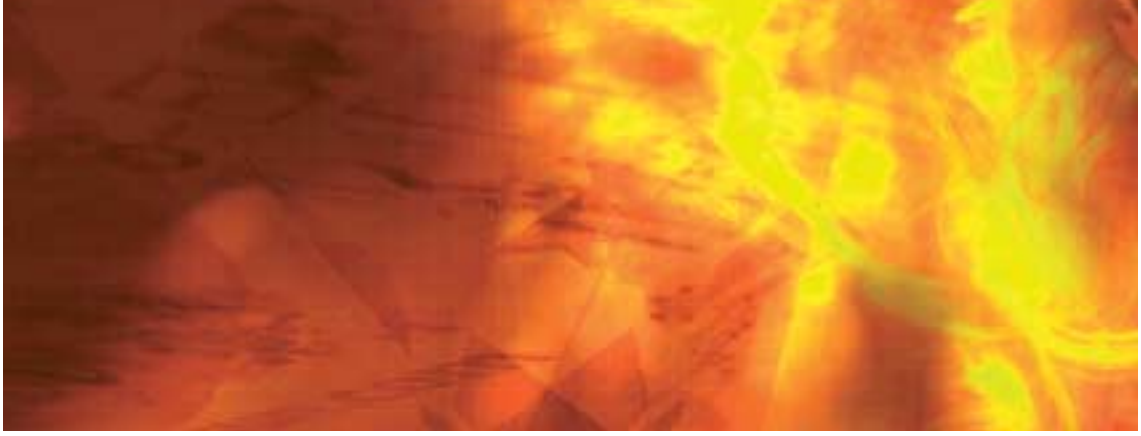

Total solutions for industrial safety

SAFETY APPLICATION HANDBOOK

Advanced Industrial Automation

OMRON

Safety Application Handbook

Disclaimer

OMRON reserve the right to alter or amend information contained in this handbook without prior notice and no responsibility can be accepted for errors or omissions. Safe installation and operation of OMRON products remains the responsibility of the user.
The contained diagrams circuits and recommendations are only general information. The user must take responsibility for his specific application according the legal obligations in the country of intended usage, and all pertaining state or Federal Bylaws that may be applicable.

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1.0 Background of this Handbook

The European Union is one of the most important industrial areas worldwide.
By doing their daily work 4,8% of workers become injured by industrial accidents (approximately 10 Million persons). Serious and lethal accidents happen to 0,17% of the workers (8000 person are killed per year).

The reasons for these accidents on one hand are human negligence and insufficient safety of machinery on the other hand.

To improve the safety level and to eliminate barriers of trade within the European Community the treaty of Maastricht initialised the harmonised EC legislation in 1992.
The Articles 100a and 118a (revised in Article 95 and 137 of the treaty of Amsterdam 1997) build the basis for a constant level of safety for machinery and place of work..

This safety handbook intends to offer a guideline how to ensure safety using the machine directive 98/37/EC.

In addition, the directive for use of work equipment by workers and their working environment, 89/655/EEC (with amendment 95/63/EC) is the minimum requirement for national labour safety legislation within the EC.

Beside this directive there are several directives that have to be considered depending on the application. Please refer to chapter 8.

1.1 Necessity of machine safety

The safety of persons, goods and animals is a target that has to be considered first if we design build or use any machinery.
The machine directive 98/37/EC specifies the essential health and safety requirements for machinery and safety components.

Beside the general ethic obligation the conformity with this essential requirements is indispensable for trade and utilisation of machinery within the EC.

Machinery designed and manufactured for internal use must also correspond to the machine directive and must be CE marked.

1.2 Targeted Audience

This safety handbook is aimed to all those who are somehow involved with machinery at some stage of its life cycle.

All persons that are in touch with design, manufacturing, use, maintenance and approval of machinery can take benefit.
Following groups of persons are mainly targeted:

Designers
Manufacturers
Panel makers
Installation companies
Maintenance and service personnel
Users , plant owners
Dealers

2.0 Safety Basics

The Member States of the European Communities (EC) – this name was changed when the Treaty establishing the "European Union" (EU) was signed in the Maastricht On 7. Febr., 1992- unanimously agreed from the very beginning that the safety requirements for numerous products in the Member States (and also in the countries belonging to the European Economic Area – EEA) have to be harmonised. This common view point resulted in Article 100a. Article 100a has been replaced by Article 95 of the Treaty of Amsterdam.
This chapter will give an overview on the legal background of safety.

2.1 European Legislation

One of the focal points of the European regulatory work, that was intensified at the end of the 1980s, was the machinery sector. The relevant EC Directive, the so-called Machinery Directive, was adopted by the Council and issued in the middle of 1989 and has since been completed by three amendments (91/368/EEC, 93/44/EEC and 93/68/EEC). Meanwhile, the consolidated version 98/37/EC has been issued. As soon as the outline of the intended Directive became apparent, CEN and CENELEC and launched a comprehensive and sophisticated programme aimed at developing standards in support of the Directive.

2.2 CE Certification

CE Mark is a passport for goods in Europe.
The free movement, putting into service and use of machinery must be guaranteed by the Member States provided that

- machinery in the sense of "single machinery", "assemblies of machines", "installations" and "interchangeable equipment" is accompanied by the EC declaration of conformity and bear the CE marking,
- "safety components" are accompanied by the EC declaration of conformity; CE Marking is not to be fixed to such components,
- "machinery which cannot function independently" and is intended to be part of an assembly of machines is accompanied by a manufacturers declaration; CE marking is not to be fixed to such machinery.
- Beside the machine directive it must be considered in addition also other directives like EMC and LVD for a valid EC declaration.

2.3 Machine Directive

Based on the definition of the term "machinery" in the Machinery Directive, the scope of this Directive is very large.
However, the Machinery Directive includes a list of machinery and technical products, such as lifts, cable ways and road vehicles, which are excluded from it, because they fall within the scope of other Community Directives or competencies.
According to the Machinery Directive the product-group machinery comprises nearly all stationary, movable, hand-guided and hand-held machinery designed for the processing, treatment, packaging and moving of material or objects in general.

2.3.1 Essential safety requirements

The essential health and safety requirements laid down in this Directive are mandatory. However, taking into account the state of the art, it may not be possible to meet the objectives set by them. In this case, the machinery must as far as possible be designed and constructed with the purpose of approaching those objectives.
The “danger zone” means any zone within and / or around machinery in which an exposed person is subject to a risk to his health or safety.
The “exposed person” means any person wholly or partially in a danger zone.
The “operator” means the person or persons given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery.

The machinery must be so constructed that it is fitted for its function, and can be adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen by the manufacturer.
The aim of measures taken must be to eliminate any risk of accident throughout the foreseeable lifetime of the machinery, including the phases of assembly and dismantling, even where risks of accident arise from foreseeable abnormal situations.

2.4 Harmonised European standards

“Directives” contain essential safety requirements or other requirements in the general interest (all referred to hereafter as “essential requirements”); these provisions are mandatory. “Harmonised standards” set out technical provisions that allow assumption of compliance of the products with the essential requirements, these safety – related rules are not mandatory.
The “technical provisions” set out in harmonised standards are not mandatory; applying them is a means a meeting the corresponding essential requirements.
A product complying with the provisions of a harmonised standard the reference of which has been published in the Official Journal of the EC is presumed to comply with the corresponding essential requirements.
A product complying with the provisions of harmonised standard the reference of which has been published in the Official Journal of the EC is presumed to comply with the corresponding essential requirement(s).
Directives in accordance with the “New Approach” describe the protective aims (essential requirements) with which the product concerned must comply before it is distributed. They also lay down the procedure(s) for the EC declaration of conformity for the product concerned, taking account of the hazards which covered by the directive.

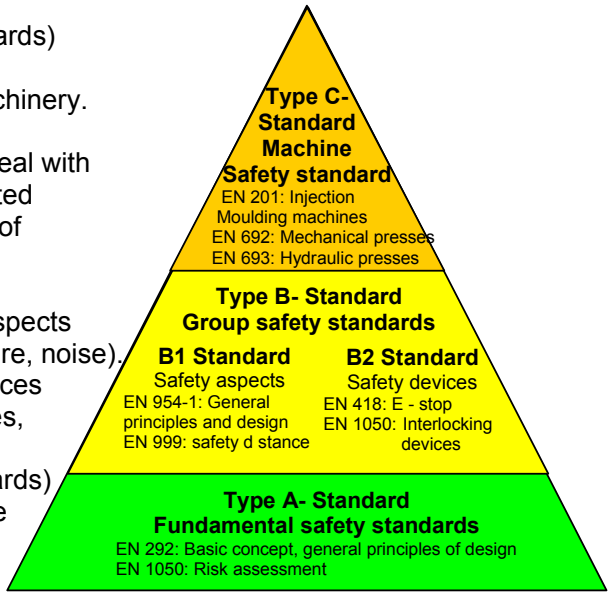
Manufacturers are responsible for deciding how their products are conceived, designed And manufactured so that they satisfy the protective aims. At any rate, manufacturers may only distribute products which comply with the essential requirements specified in the directives.
The point at which an essential requirements is complied with varies from product to product and depends on the nature of the product, its application and its concrete risks. Standards, especially product-specific standards, can serve as an indication for this. Identity as regards content exists as soon as such standards (e.g. DIN in Germany, BSI in Great Britain, AFNOR in France, UNI in Italy, SN in Switzerland).

The harmonized European safety standards have hierarchy:

- **Type A standards** (fundamental safety standards) give basic concepts, principles for design and general aspects that can be applied to all machinery.

- **Type B standards** (group safety standards) deal with one safety aspect or one type of safety – related device that can be used across a wide range of machinery. A distinction is made between:

  - **Type B1 standards** on particular safety aspects (e.g. safety distances, surfaces Temperature, noise).
  - **Type B2 standards** on safety-related devices (e.g. two-hand controls, interlocking devices, pressure sensitive devices, guards).
  - **Type C standards** (machine safety standards) give detailed safety requirements for a type C standard.



Type A:	EN 292 – 1	Safety of machinery – Basic concept, general principles for design Part 1: Basic terminology, methodology
	EN 292 – 2	Safety of machinery – Basic concept, general principles for design Part 2: Technical principles and specifications
	EN 1050	Safety of machinery – Principles of risk assessment
Type B1:	EN 999	Safety of machinery - The positioning of protective equipment in respect of approach speeds of parts of the human body.
	EN 954-1	Safety – related parts of control systems Part 1: General principles for design
	EN 60204-1	Electrical equipment of machines Part 1: Specification for general requirements
Type B2:	EN 418	Emergency stop equipment, functional aspects
	EN 574	Two-hand control devices, functional aspects
	EN 1088	Interlocking devices associated with guards
	EN 61496-1	Electro – sensitive protective equipment Part 1: General requirements and tests
	EN 60947-1	Low-voltage switchgear and controlgear Part 1: General rules
Type C:	EN 81-1/-2	Safety rules for the construction and installation of electric / hydraulic lifts
	EN 115	Safety rules for the construction and installation of escalators and passenger conveyors
	EN 201	Rubber and plastic machines – Injection Moulding machines – Safety requirements
	EN 415	Safety of packaging machines
	EN 692	Mechanical presses – Safety
	EN 693	Hydraulic presses – Safety
	EN 1010	Technical safety requirements for the design and construction of printing and paper converting machines

2.5 Product liability

The General Product Safety Directive and the Product Liability Directive are complementary regulations but their scope is not identical. For instance, the General Product Safety Directive states that even if a product does not conform to the directive and an action is taken against the manufacturer, the violation does not automatically mean the product is defective under the Product Liability Directive. However, a manufacturer could reasonable assume that a breach of the General Product Safety Directive would convince a court to include that the manufacturer was liable under the Product Liability Directive.

Another area uncertainty in the relationship between the Product Liability Directive and the General Product Safety Directive is that the former applies to virtually all products while the latter governs only new, used, or reconditioned products that are intended or likely to be used by consumers. Despite this restrictive language, experts disagree about whether the General Product Safety Directive applies only to consumer products or whether it might also apply to machines subject to the Machinery Safety Directive. This General Product Safety Directive makes clear that its provisions continue to apply to products not covered by other applicable rules of EU law. Therefore, to be especially careful, a manufacturer must be compare the individual provisions of all directives that apply to its product. Certain General Safety Directive provisions may consequently apply to machinery.

The General Product Safety Directive's effect on consumer product manufacturers can be significant. Non-complying products can be barred from some European markets or pulled off the shelves. Of course, non-compliance can be also be used, despite the language in the General Product Safety Directive, as a basic for imposing strict liability under the Product Liability Directive, at the discretion of a nation's courts.

3.0 Ensure safety

The responsible machine or process designer no longer considers the production requirements and adds safety systems later, but addresses the two issues as a whole. Legislation demands that the machine or process design meets the necessary safety standards and regulations – it is a legal requirement

Different Types of machines will have different levels of associated risk these risk levels need to addressed for the whole machine life span. In particular the requirements at the design stage, application / usage stage and destruction of the machine

Risk assessment according to EN1050 is a series of logical steps that enables designers and safety engineers to examine in a systematic way the hazards arising from the use of machinery so that appropriate safety measures can be selected.

3.1 Risk assessment

EN 1050 - Safety of Machinery – Principles for Risk Assessment

The main Objective is to describe a systematic procedure for risk assessment so that adequate and constant safety measures can be adopted. These are appropriate during the design, construction, modification, use and destruction of the machine.

The safety of machines can be determined in 5 steps. Documentation of the Risk assessment process must be kept.

Step 1 Machine Limits

- Define the limits of the machinery over all phases of the machine's life.
- Define intended use, correct operation, foreseeable miss use and malfunction.
- Define users.

Step 2 Hazard Identification

- Identify all risks for potential harm – mechanical, electrical, chemical, physical, biological, psychological, ergonomic, natural etc.
- Identify all interactive risks – access areas, loading areas etc.
- Identify hazardous events – machine failure, software failure etc.
- Methods of hazard identification include;
  - Checklists, brainstorming.
  - Hazard and Operability study (HAZOP).
  - Failure Mode and Effect Analysis (FEMA).
  - Fault tree Analysis (FTA), Accident investigations.
  - 'What if 'method.
  - Method Organised for a Systematic Analysis of Risks (MOSAR).

Step 3 Risk Estimation (see section 3.3)

- Needs to be Documented.
- All foreseeable factors must be considered.
- Combination of ;
  - Severity of injury.
  - Probability of occurrence.

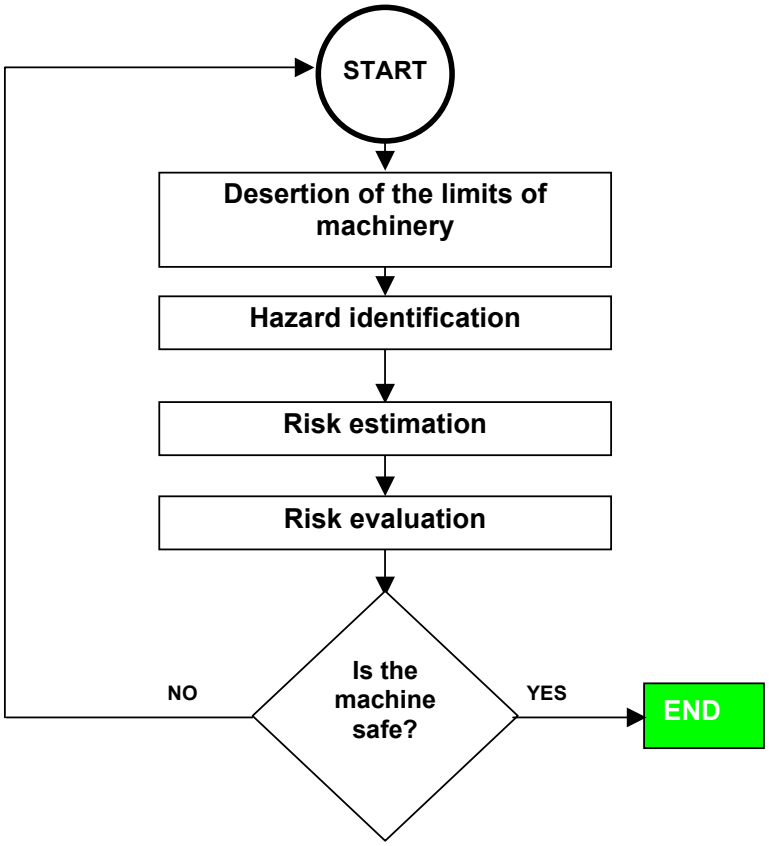
- Frequency of exposure.

Step 4 Risk Evaluation & Reduction

- Determination of whether the level of risk is acceptable.
- Prioritisation of the implementation of control measures.

Step 5 Risk Reduction

- Eliminate or reduce exposure to hazard as far as practical
- Reduce the probability and severity.
- Use safe guards and safety devices.
- Determine the performance and functional characteristics of the safety measures are suitable for the machine and its use.



3.2 Categories

EN 954 Safety of Machinery – Safety Related Parts of Control systems
Describes the risk reduction, which is necessary, when designing and constructing safety related parts of control systems and devices. The categories represent a classification of the control system with respect to their ability to withstand faults and their behaviour in the event of a fault.

Category B
Safety related parts of control systems and or their safety devices and their components must be designed, constructed, selected, assembled and combined in accordance with the relevant standards such that they can with stand expected influence.

Category 1
The requirements of B shall apply. Well-tried components and safety principles shall be used.
The occurrence of a fault can lead to the loss of a safety function, but the probability of occurrence is lower than in category B

Category 2
The requirements of B shall apply. Well-tried components and safety principles shall apply. The safety function shall be checked at suitable intervals by the machine control system.
The occurrence of a fault can lead to the loss of a safety function between checks. The loss of the safety function is detected by the check.

Category 3
The requirements of B shall apply. Well-tried components and safety principles shall apply. Safety related parts shall be designed such that:

- A single fault in any of these parts does not lead to the loss of the safety function.
- The single fault is detected whenever reasonably practicable

Category 4
The requirements of B shall apply. Well-tried components and safety principles shall apply. Safety related parts shall be designed such that:

- A single fault in any of these parts does not lead to the loss of the safety function.
- The single fault is detected during or prior to the next demand on the safety function, or if this is not possible, an accumulation of faults does not lead to the loss of the safety function.

3.3 Failure analysis

Failure analysis can be achieved by selecting a category based on the severity of foreseeable injury, the probability of injury and the frequency of exposure to the hazard. When determining the category for the safety related control circuit of a machine there are some cases where the entire control circuit of the machine can be assessed under one category and other cases where the control circuit is assessed in sections.

The EN 954-1 is describing in the informative Annex B a guidance to select the appropriate category for the circuit of a safety function.
This simplified method bases on the EN 1050 and is working with 3 parameters to select and determine the category in the “Risk graph”

Selecting Parameter S: Severity of injury S1 and S2

In estimating the risk arising from a fault(s) in the safety-related parts of a control system only slight injuries (normally reversible) and serious injuries (normally irreversible including death) are considered.
To make a decision the usual consequences of accidents and normal healing processes should be taken into account in determining S1 and S2, e.g. bruising and/or lacerations without complications would be classified as S1 whereas an amputation or death would be classified as S2.

Selecting Parameter F: Frequency and/or exposure time to the hazard F1 and F2

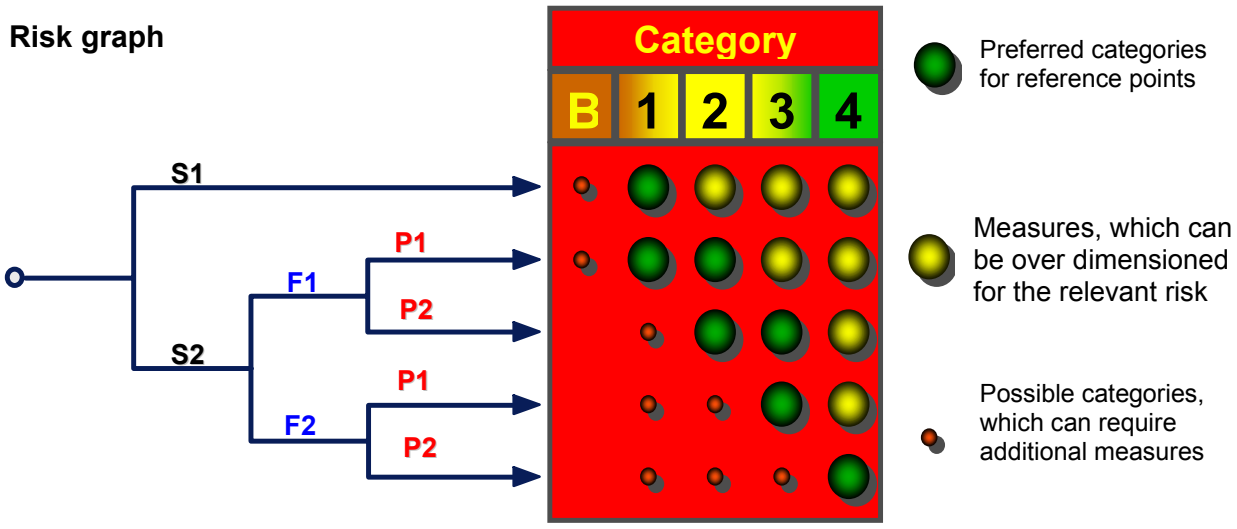
A generally valid time period when parameter F1 or when parameter F2 should be selected cannot be specified. However, the following explanation can facilitate making the right decision in cases of doubt.
F2 should be selected if a person is frequently or continuously exposed to the hazard. It is irrelevant whether the same or different persons are exposed to the hazard on successive exposures, e.g. for the use of lifts.
The period of exposure to the hazard should be evaluated on the basis of an average value which can be seen in relation to the total period of time in which the equipment is used. For example, if it is necessary to reach regularly between the tools of the machine during cyclic operation in order to feed and move work pieces, then F2 should be selected. If access is only required from time to time, then F1 can be selected.

Selecting Parameter P: Possibility of avoiding the hazard P1 and P2

When a hazard arises it is important to know if it can be recognised and whether it can be avoided before it leads to an accident. For example, an important consideration is whether the hazard can be directly identified by its physical characteristics, or whether it can only be recognised by technical means, e.g. indicators. Other important aspects which influence the selection of parameter P include, e.g.:
- operation with or without supervision;
- operation by experts or non-professionals;
- speed with which the hazard arises, e.g. quickly or slowly;
- possibilities for hazard avoidance,
- practical safety experiences relating to the process.

When a hazardous situation occurs P1 should only be selected if there is a realistic chance of avoiding an accident or of significantly reducing its effect. P2 should be selected if there is almost no chance of avoiding the hazard.

Risk graph

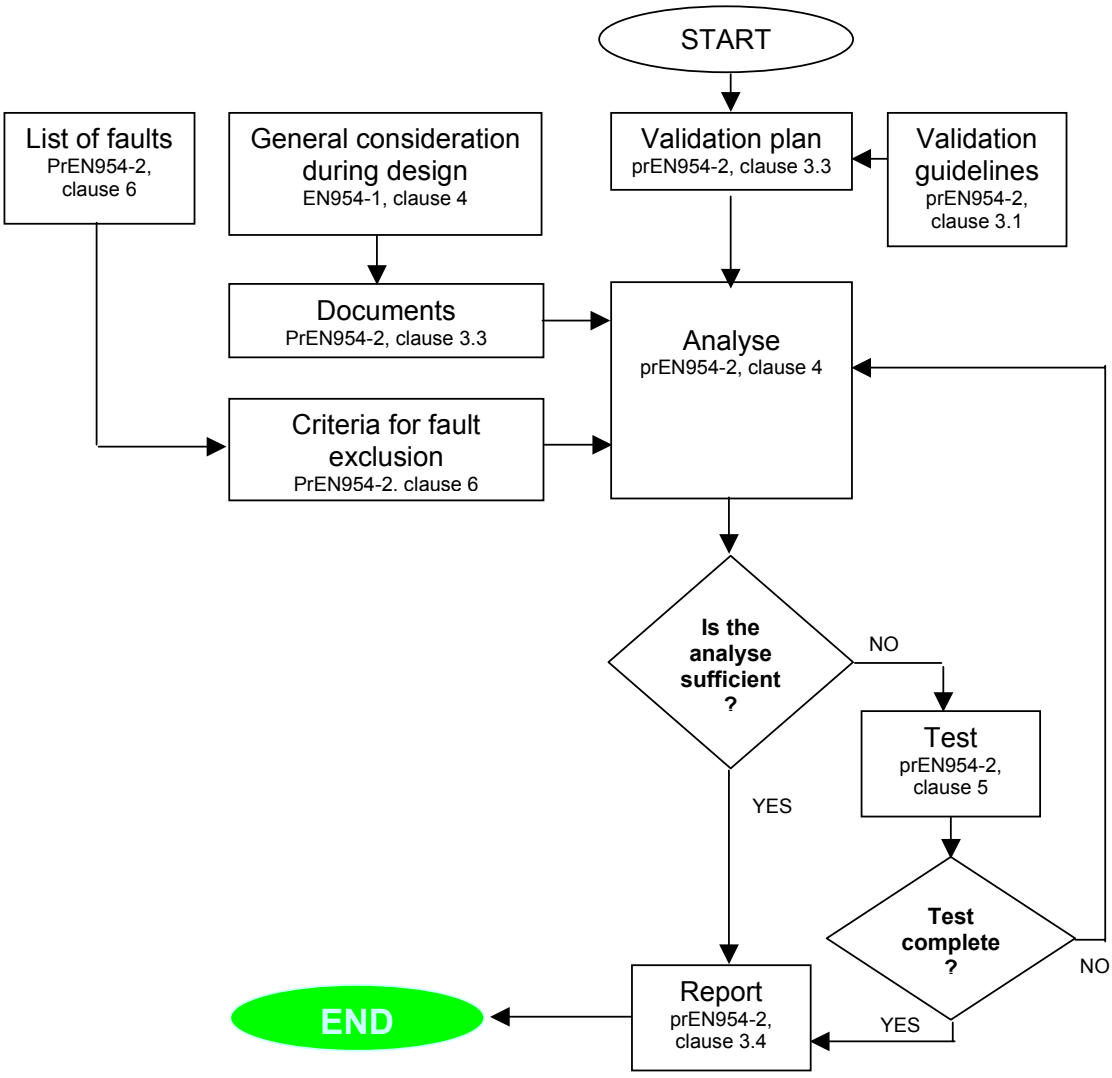


3.4 Validation

The purpose of validation is to determine the level of conformity of the safety-related parts of the control system to their specification within the overall safety requirements specification of the machinery. Validation consists of executing tests and applying analysis in accordance with the validation plan.
The design of the safety-related parts of the control system shall be validated.
The validation shall demonstrate that each safety-related part meets:
- All the requirements of the specified category
- The specified safety characteristics for that part, as set out in the design rationale.

The validation of the safety-related parts of control systems should contain the following elements:
- Selection of the validation strategy (a validation plan);
- Management and execution of validation activities (test specifications, testing procedures, analysis procedures);
- Documentation (auditable reports of all validation activities and decisions).

The prEN 954-2 (Safety of machinery – Safety related parts of control systems – Part 2: Validation) defines the procedure of Validation and contains possible validation for mechanical, pneumatic, hydraulic and electrical systems.
The principle of validation can be illustrated in a flow chart.



3.5 Documentation

A Technical file Containing the following information should be recorded:

• Drawings, control circuit drawings, calculations, test results, LVD and EMC Directives

• List of EHSRs taken into account, plus other relevant standards and technical specifications used

• Details of the methods used to eliminate hazards, risk assessment data

• A test report / certificate from a competent body if required

• A copy of the instructions

• Series manufacture details of internal measures and QA systems

• Declaration of Conformity or Declaration of Incorporation

• The CE mark represents self-certification, by fixing the CE mark the manufacturer is claiming that all relevant legal requirements have been met.

• The CE mark must be distinct, visible, legible and indelible.

4.0 E-Stop applications

Annex I of the Machine Directive states that each machine must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted. The following exceptions apply:

— machines in which an emergency stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken,
— hand-held portable machines and hand-guided machines.

This device must:

— have clearly identifiable, clearly visible and quickly accessible controls, *(EN 418: The emergency stop actuators shall be coloured red. As far as a background exists...it shall be coloured yellow.)*

— stop the dangerous process as quickly as possible, without creating additional hazards,

— where necessary, trigger or permit the triggering of certain safeguard movements.

Once active operation of the emergency stop control has ceased following a stop command, that command must be sustained by engagement of the emergency stop device until that engagement is specifically overridden; it must not be possible to engage the device without triggering a stop command; it must be possible to disengage the device only by an appropriate operation, and disengaging the device must not restart the machinery but only permit restarting.

Complex installations
In the case of machinery or parts of machinery designed to work together, the manufacturer must so design and construct the machinery that the stop controls, including the emergency stop, can stop not only the machinery itself but also all equipment upstream and/or downstream if its continued operation can be dangerous.

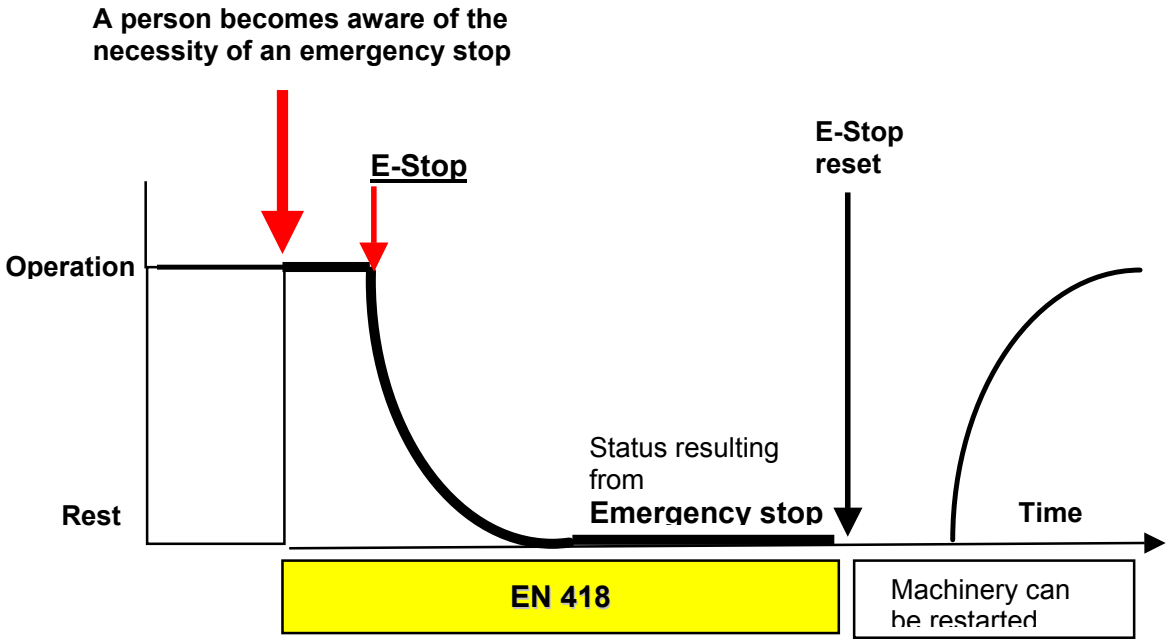
4.1 Standards for E-Stop function :EN 418, EN 60204, EN 1037

The most relevant standards for e-stop applications are EN418, EN60204 and EN1037.

EN 418 contains functional aspects and principles for design. EN 60204 is about Safety of machinery – electrical equipment of machines and EN 1037 explains prevention of unexpected start-up of machines.

4.2 Requirements for E-Stop

EN 418 defines the functional aspects and principles for design of emergency stop equipments such as e-stop push buttons, rope switches or foot-pedals. Devices constructed according to EN 418 are useful for e-stop applications. The design is illustrated by a graphic



According to EN 60204-1 the requirements for an emergency stop function are

- it shall override all other functions and operations in all modes
- power to the machine that can cause a hazardous condition(s) shall be remove as quick as possible without creating other hazards
- reset shall not initiate a restart

The standard divides applications into different stop categories. The choice of the category is depending on the risk assessment of the machine.

- Stop category 0: stopping by immediate removal of power to the machine
- Stop category 1: a controlled stop with power available to the machine actuators to achieve the stop and the removal of power when the stop is achieved
- Stop category 2: a controlled stop with power left available to the machine actuators

Especially Stop category 2 is very risky and therefore EN 1037 prevention of unexpected start-up has to be considered. Hazards other than mechanically generated by movable elements such as laser beam also need to be taken into account.

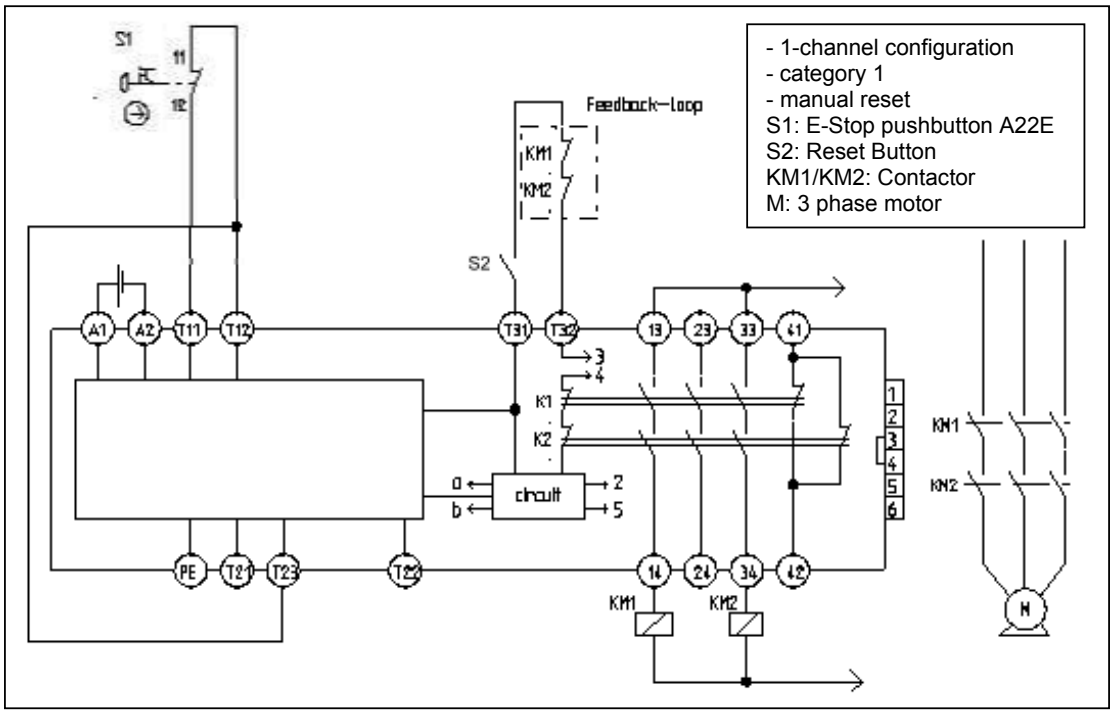
If persons are present in dangerous zones e.g. for maintenance, devices for isolation and energy dissipation have to be used. Latent energy can be stored in mechanical parts continuing to move via inertia, mechanical parts liable to move by gravity, capacitors, accumulators, pressurised fluids or springs.

4.3 Schematics

Below you will find some e-stop application examples sorted by safety category according EN 954-1 starting by category 1. OMRON offers different series of safety relay units as G9SA and G9SB.

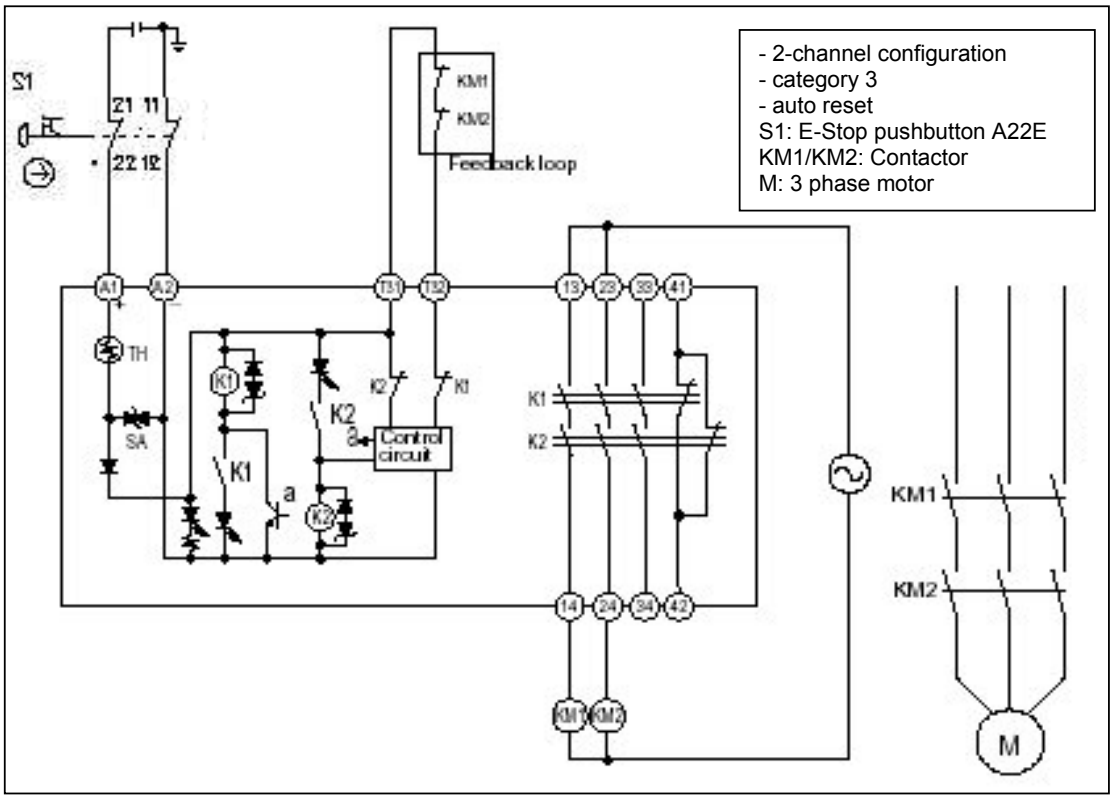
4.3.1 Single channel input, category 1

Products: G9SA-301, A22E



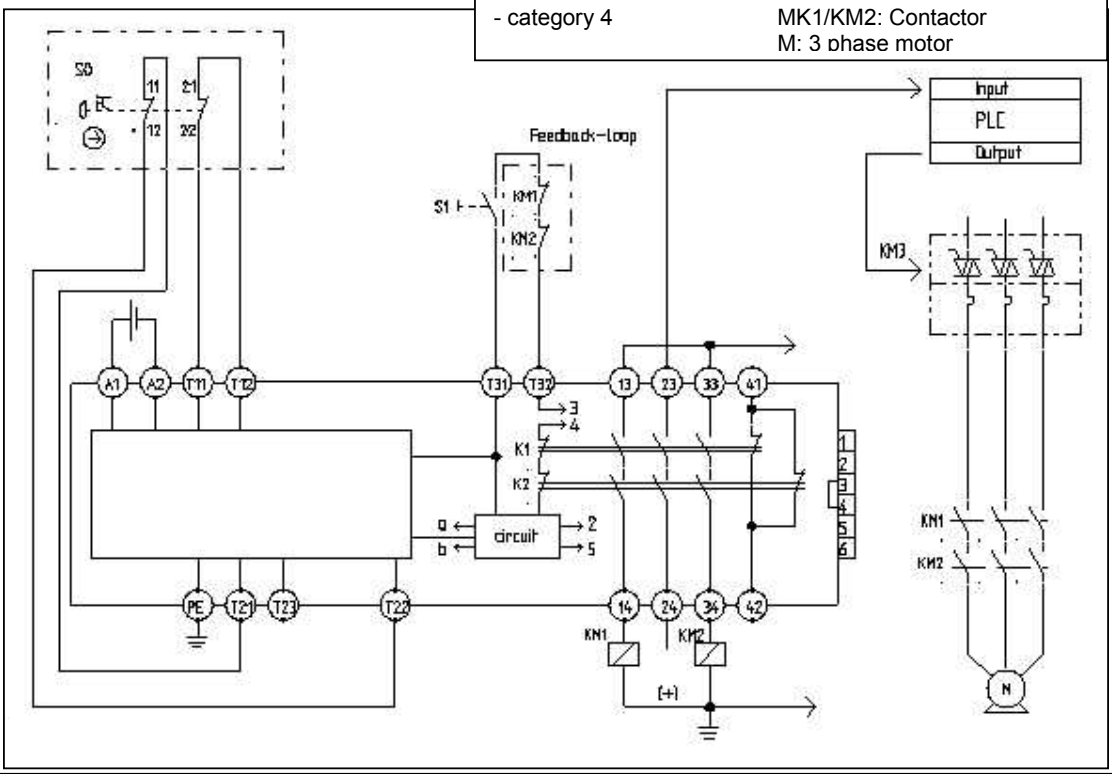
4.3.2 Two-channel input, category 3

Products: G9SB-3010, A22E



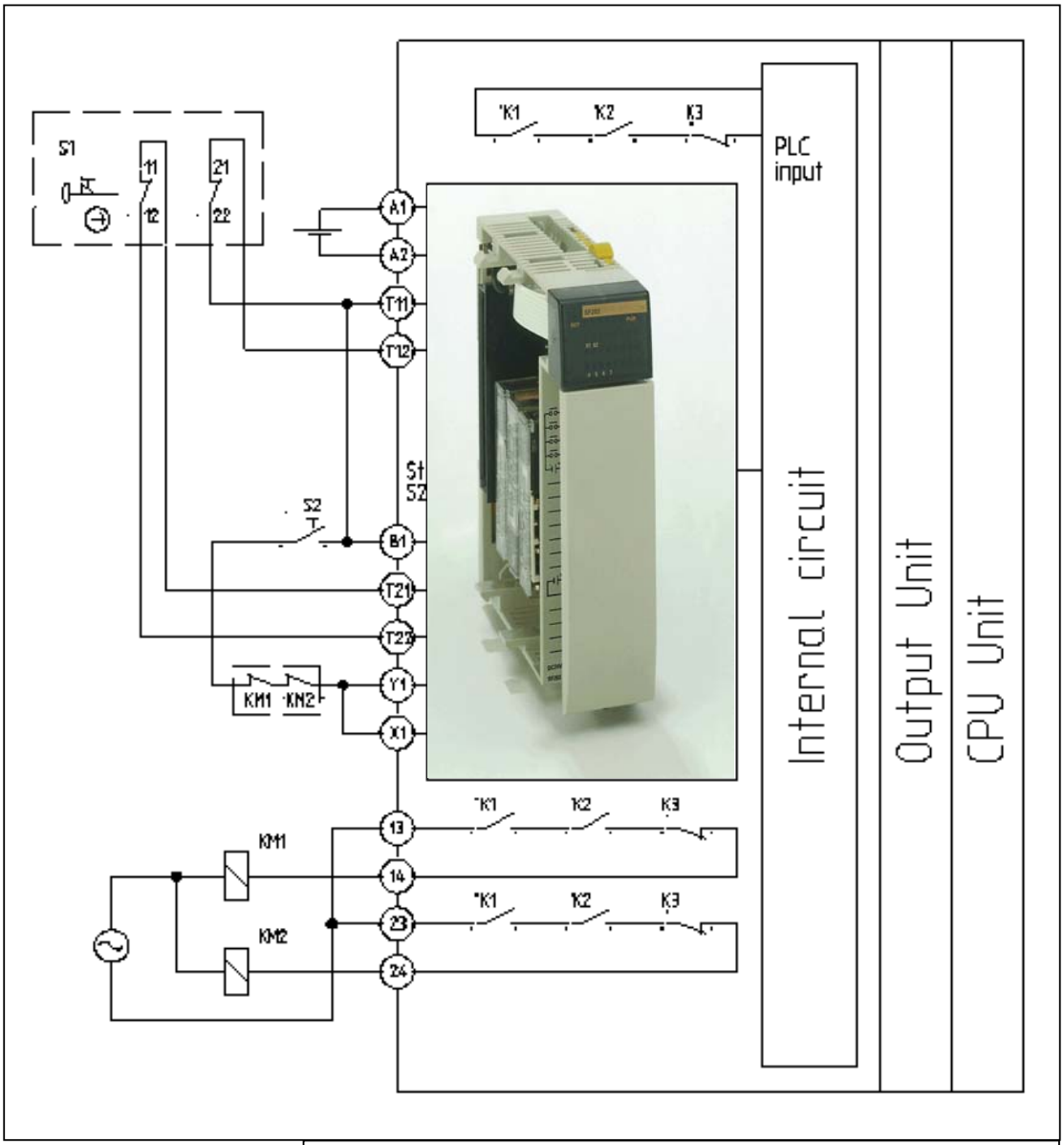
4.3.3 Two-channel input, category 4

Products: G9SA-301, A22E



4.3.4 PLC integrated E-Stop with two-channel input, category 4,

For compact system there is a possibility to have the safety circuit integrated in the PLC. The safety circuit itself is realized in hardwired technology.
The benefit is that the PLC is able to monitor the status of all safety related signals and outputs directly without any additional effort. The module is able to ensure safety in systems up to category 4 (EN954-1).
The integrated safety function can be realised in combination the OMRON CQM1 medium level PLC and the high performance PLC system CS1.

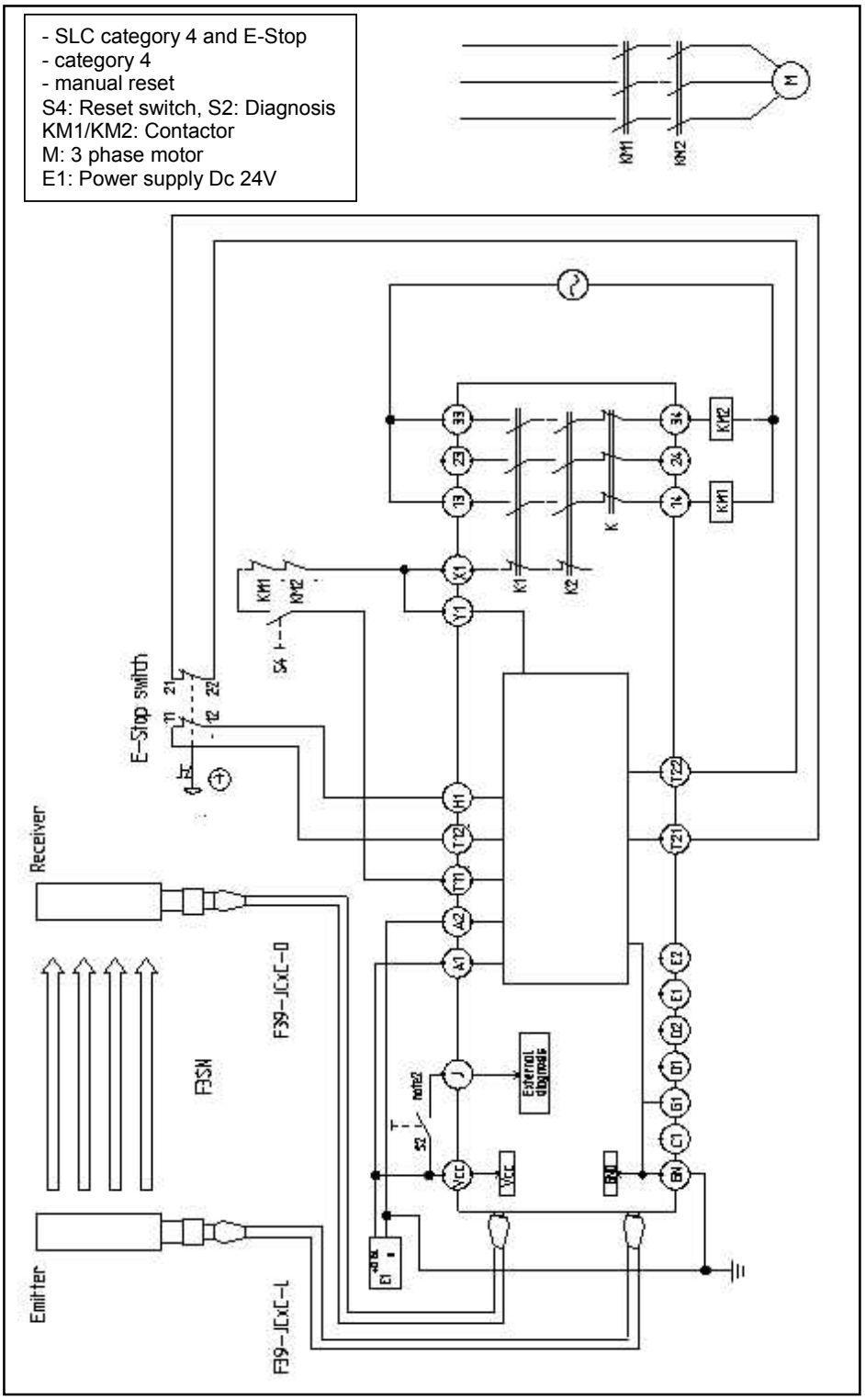


- 2-channel configuration
- Short circuit detection
- category 4
- manual reset

S1: E-Stop pushbutton A22E
S2: Reset Button
MK1/KM2: Contactor

4.4 E-Stop and SLC configuration

If the application requires same function for e-stop as in case of interruption of safety light curtain beams, you can use below circuit. The monitoring unit is able to monitor the OSSD outputs of the SLC and the E-Stop function.



Note: 1. External relay monitoring and auxiliary output function are disabled
2. Normal operation is performed if S2 is open, External diagnostics is performed with closed S2
3. Don't connect terminals C1, D2, E1 and E2

4.5 Products for E-Stop

Pushbuttons:

OMRON can supply two series of e-stop pushbuttons, with 16mm (A165E) and 22mm (A22E) diameter panel cut-out. The A165E series is the one with the world shortest mounting depth of only 28.5mm below panel.

A165E Series

The A22E series advantages are

- Easy mounting and removal
- Wide variety of buttons are available
- Up to IP65 protection

Both received UL /CSA approvals and are in accordance with EN 60947-5-1 (positive opening contacts) and EN 418. Also illuminated types are available to see at a glance the operated switch.

A22E Series

Safety relay units:

To reach category 3 or 4 in accordance to EN 954-1 you need a monitoring device for e-stop applications. OMRON offers two product families for this purpose.

G9SA is a basic series that can be extended by dedicated modules.

- 3 or 5 output contacts (SPST-NO) + 1 aux. SPST-NC
- models with delayed contacts (SPST-NO) for basic and extension models
- delay time can be adjusted in 15 steps 0.5 to 7.5s; 1 to 15s; 2 to 30s
- 2-hand-control-unit
- width only 45mm (17.5mm for extension modules)
- approvals: UL / CSA, BG
- safety category 4 according EN 954-1 (category 3 for delayed contacts)

G9SA Series

G9SB can be used for monitoring of e-stop-, guard and light curtain applications. With its width of only 17.5mm or 22.5mm it is the world most slim safety module.

- 2 contacts (SPST-NO) with only 17.5mm width
- 3 contacts (SPST-NO) + 1 aux. SPST-NC with only 22.5mm width
- automatic or manual Reset
- inverse or common mode
- approvals: UL / CSA, TUEV
- safety category 4 according EN 954-1 (category 3 for G9SB-3010)

G9SB Series

5.0 Door monitoring and interlocking

Door monitoring and interlocking switches are one of the most important types of protective devices to prevent dangerous situations by taking power off from the machine.

When it is decided to protect the machine with protective fences, we must be sure that, only way inside the dangerous area is through the guard. If the guard is opened, mechanically actuated position detector stops the machine. In every guard in the fence must have mechanically actuated position detectors (safety limit switches) to ensure the safety of personnel. Basic requirement is that if the door is opened, machine must stop before anyone can reach the hazardous moving parts of the machine.

The most important selection criteria of an interlocking device are:

- the conditions of use and intended use (EN292-1)
- the hazard present at the machine (EN292-1)
- the severity of the possible injury
- the probability of failure of the interlocking device
- stopping time and access time considerations
- the frequency of access
- the duration of person exposure to the hazard
- performance considerations

The position switch shall be actuated in the positive mode. The break contact of the position switch shall be of the “positive opening operation” type. (EN 60947-5-1)

The security of an interlock switch is dependent on its ability to withstand attempts to “cheat” of defeat the mechanism. An interlock switch should be designed so that it cannot be defeated in a simple manner. This means that intended operation achieved manually or with a readily available abject. Readily available objects may be:

- screws, needles, sheet-metal pieces;
- objects in daily use such as keys, coins, tools required by the intended use of the machine

5.1 Standards EN 1088, EN 1037

The European standard EN1088 “Interlocking devices associated with guards” gives a guidance of interlocking devices and it is intended to be used together with EN60947-5-1 for electromechanical switches and EN1037 “Prevention of unexpected start-up“.

5.2 Requirements for Door monitoring

Door monitoring must ensure that the safety door is protecting the hazardous area as defined in the risk assessment (EN1050).

The sensors and the signal processing must comply with
all required norms and directives.

- Switches must be designed to withstand all expected and foreseeable stresses
- Switches must comply with safety standards especially direct opening contacts and safety door switches must be used.
- The principles of redundancy and diversity must be considered in the mechanical design of switches and signal processing.
- The signal processing must be designed to be in accordance to the categories of EN954-1 defined in the risk assessment.

5.3 Requirements for Door interlocking

An interlocking device with guard locking shall be used when the stopping time is greater than the access time taken by a person to reach the danger zone.

Device intended to lock a guard in the closed position and linked to a control system so that:

- the machine cannot operate until the guard is closed and locked;
- the guard remains locked until the risk has passed.

For applications requiring frequent access, the interlocking device shall be chosen to provide the least possible hindrance to the operation of the guard. In that case also requirements of intended use, conditions of use, risk assessment and stopping time and access time must be taken in to account.

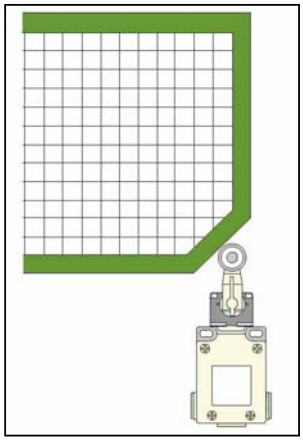
Mechanically actuated devices:

There are three types of mechanical actuation. These are:

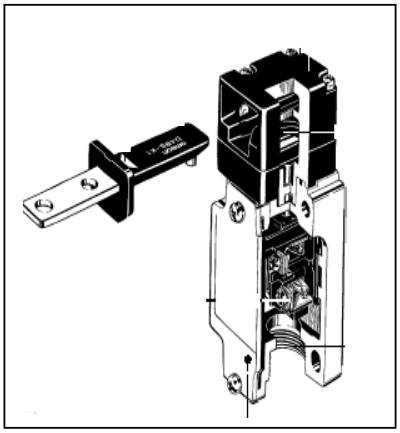
Cam operated actuation

When one single detector is used it shall be actuated in the positive mode since, among other characteristics, this mode of actuation prevents the detector from being defeated in a simple manner.

A higher level of protection against defeat can be achieved, e.g., by enclosing the cam and detector in the same housing.



Operation key operated actuation



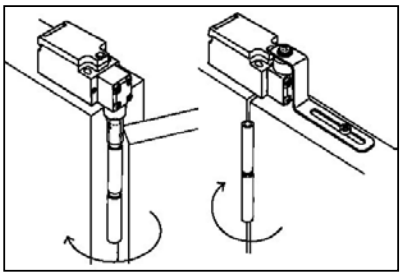
The operation key operated switch is designed to prevent easy cheating of the switch.
Dedicated operation key is needed every time.

These switches can be used on sliding, hinged and lift-off guards. Mainly they are used in interlocking switches.
Disadvantage in these switches is that it can be defeated by using a operation key which is not attached to the guard.

Preventing this kind of defeat is possible and it can be achieved by:

- Physical obstruction or shielding preventing introduction of spare actuators
- Permanent assembly (by welding, riveting, “one way” screw”) of the operating key with the guard to render dismantling more difficult.

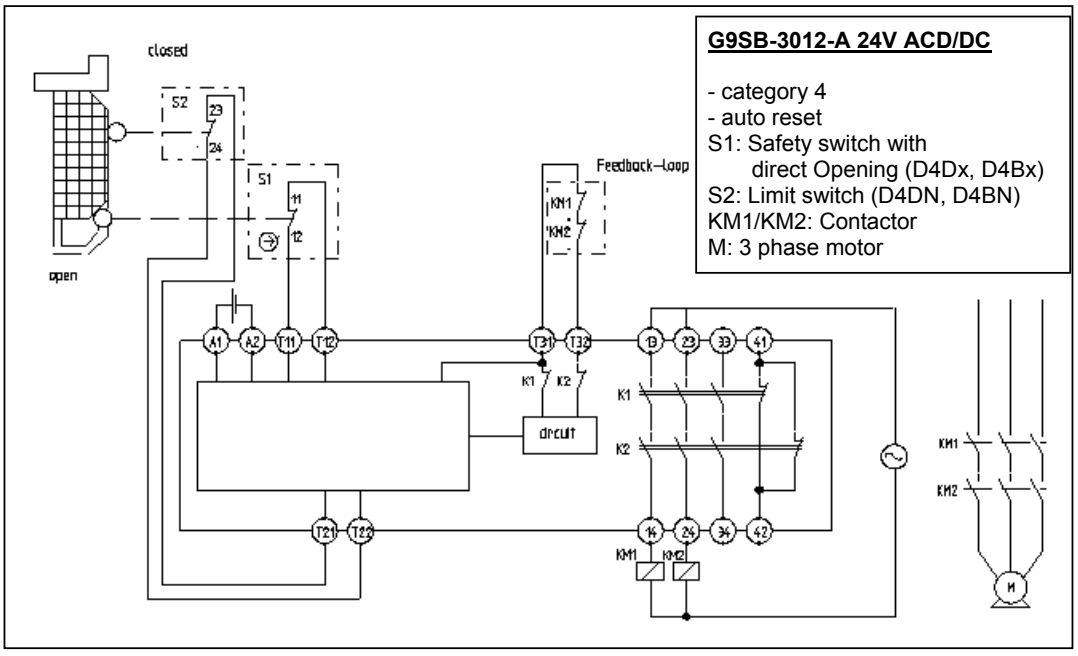
Hinge operated actuation

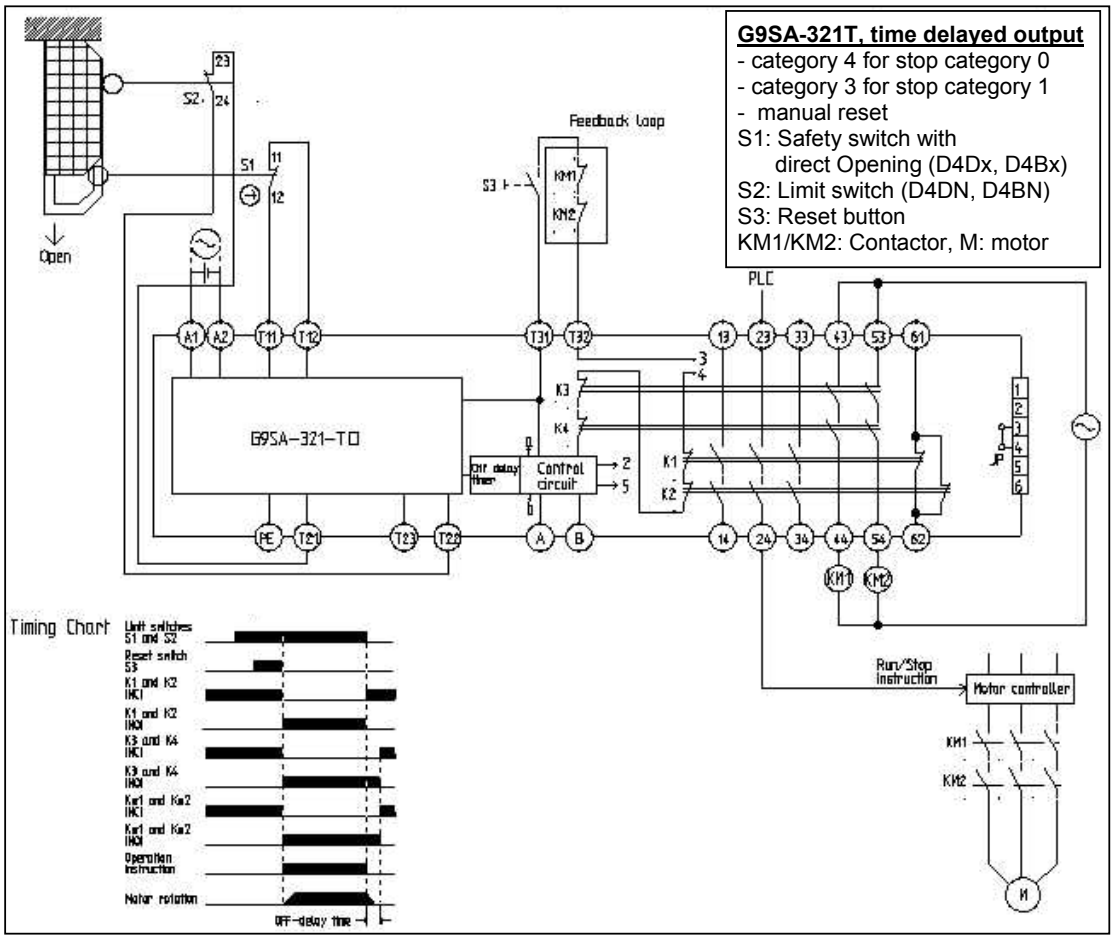


In hinged door switches it is very difficult to defeat the switch. That is very good features of hinged door switches. Another feature is easy use in small size guards, where key operated switches can not be used due to operation key radius. Care must be taken for large wide guard doors because of opening angle is resulting in a bigger movement of the door. That can result a significant gap in the opening edge on very wide guard doors.

5.4 Schematics

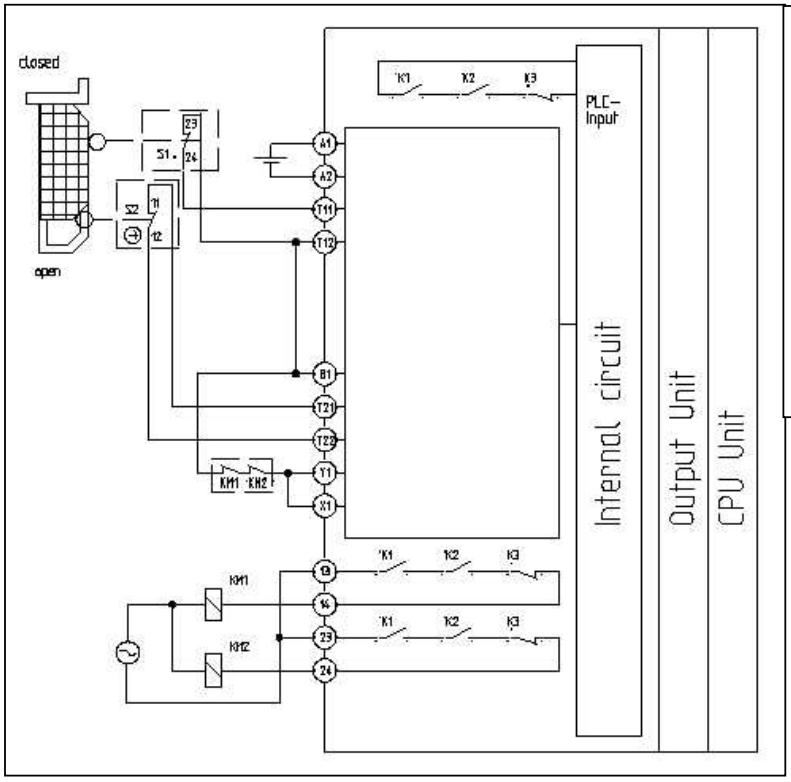
Below you will find some door monitoring application examples.





G9SA-321T, time delayed output
- category 4 for stop category 0
- category 3 for stop category 1
- manual reset

S1: Safety switch with direct Opening (D4Dx, D4Bx)
S2: Limit switch (D4DN, D4BN)
S3: Reset button
KM1/KM2: Contactor, M: motor



Safety units for PLC integration CQM1-SF200, CS1W-SF200

- category 4
- 2 channel input
- automatic reset
- cross circuit detection

S1: Limit switch (D4DN, D4BN)
S2: Safety limit switch, safety door switch with direct Opening (D4Dx, D4Bx)
KM1/KM2: Contactor,

(PLC units see chapter 4.3.4)

5.5 Products for door monitoring and interlocking

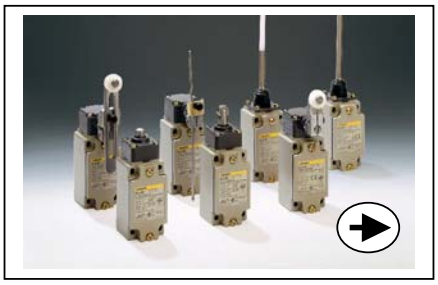
OMRON can supply a wide range of safety limit switches and safety door switches for monitoring and interlocking with of without locking function.

Safety limit switches:

D4D-N Safety Limit Switch (EN 50047)

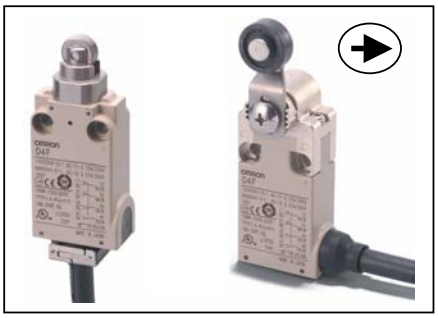
- Small economical switch with direct opening mechanism,
- Plastic body with double insulation, IP 65
- Wide temperature range –30 to 70°C
- 1 or 2 conduit models (PG13,5, M20, G1/2)
- Conforms to EN standards corresponding CE mark

D4B-N Safety limit switch (EN 50041)



- Metal body with IP67 degree of protection
- Wide temperature range –40 to 80°C
- 1 or 3 conduit models (PG13,5, M20, G1/2)
- Conforms to EN standards corresponding to the CE marking

D4F small metal body safety limit switch



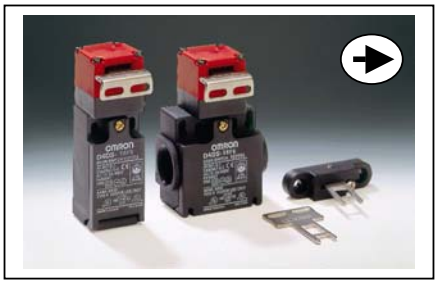
- Metal body with IP67 degree of protection
- Up to 4 NC safety contacts available
- Confectioned cable with 1m, 3m, 5m
- Conforms to EN standards corresponding to the CE marking

D4DH Door Hinge Switch

- Plastic body with double insulation , IP 65
- Wide temperature range –30 to 70°C
- Two actuator types are available:
  - Shaft
  - Arm level

Safety door switches without locking function:

D4DS Safety-door Switch

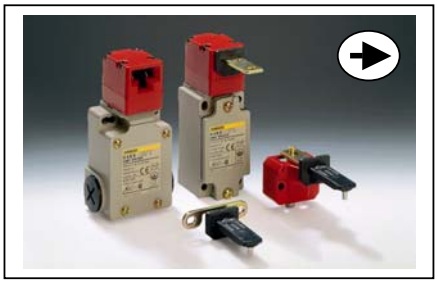


- Plastic body with double-insulation structure
- Fife-direction operation key entry
- 4 different operation keys
- Wide temperature range –30 to 70°C
- Approved UL, CSA, BIA and SUVA
- Conforms to EN standards corresponding CE mark

Note: Positive opening mechanism is indicated by arrow mark on the switch.

D4BS Safety-door Switch

- Metal body with IP67 degree of protection
- 1- conduit or 3 conduit versions
- Approved UL, CSA, BIA and SUVA
- Conforms to EN standards corresponding to the CE marking
- 3 different operation keys available



Safety door switches with locking function:

Keeps the protective guards locked until machine completely stops operation.

D4DL and D4NL Guard Lock Safety-door Switch

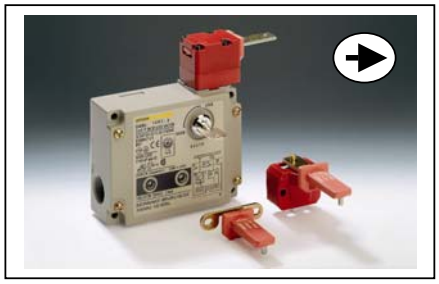
- Plastic body with double insulation
- Rotatable operation head provides for possible key
- High interlocking force , 1300 N at D4NL
- Two types of operation
  - Mechanical lock – Solenoid release
  - Solenoid lock – Mechanical release
- Conforms to EN standards corresponding to the CE marking

D4GL slim size Guard Lock Safety-door Switch

- Plastic body with double insulation
- Rotatable operation head provides for possible key entry
- High interlocking force , 1000 N
- Two types of operation
  - Mechanical lock – Solenoid release
  - Solenoid lock – Mechanical release
- Conforms to EN standards corresponding to the CE marking

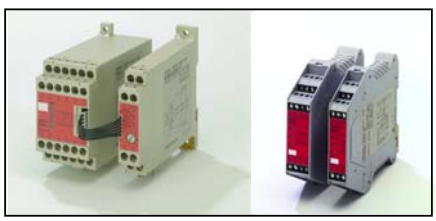
D4BL Guard Lock Safety-door Switch

- Tough aluminium die-cast unit with IP67 degree of protection
- Conforms to EN standards corresponding to the CE marking
- 3 different operation keys available
- Two types of operation
  - Mechanical lock – Solenoid release
  - Solenoid lock – Mechanical release
- Approved UL, CSA, BIA and SUVA



Safety relay units:

To monitor the safety door and to reach category 3 or 4 in accordance to EN 954-1 you need a monitoring device. OMRON offers different ranges of safety relay units. Please refer to chapter 4.5 for details.



6.0 Two hand controlling

To protect workers that are directly exposed to dangerous areas and need to access a hazardous zone, the usage of Two-hand control devices is an appropriate solution.
Compared to a safety door that builds a barrier between user and hazard, the Two-hand control forces the operator to keep both hands on the control actuating device while the machine is executing a potentially dangerous movement.

Definition, EN 574 (1996) 3.1:
“A device that requires at least simultaneous actuation by the use of both hands in order to initiate and to maintain, whilst a hazardous condition exists, any operation of a machine thus affording a measure of protection only for the person who actuates it”

The use of Two-hand control devices is common in machinery for example, hydraulic presses (EN 692) , mechanical presses (EN692) and pneumatic presses (prEN 13736).

A Two-Hand control device has to be designed carefully, taking account of EN 574 specifications. The main concern is to prevent any possible means of defeating the built in safety function.

6.1 EN574 and EN999, relevant standards

6.1.1 EN 574, Basic Requirements for Two hand control devices

The EN 574 specifies the requirements for Two-Hand control devices.
The norm defines “Types” of devices and explains the requirements in Table 6.1.

Requirements according EN 574	Type I	Type II	Type III		
			A	B	C
Use of both hands (simultaneous actuation)	X	X	X	X	X
Relationship between input signals and output signals	X	X	X	X	X
Cessation of the output signal	X	X	X	X	X
Prevention of accidental operation	X	X	X	X	X
Prevention of defeat	X	X	X	X	X
Reinitialisation of the output signal (after the release of both control actuating devices)		X	X	X	X
Synchronous actuation (within 0,5 s)			X	X	X
Use of Category 1 (EN 954-1)	X		X		
Use of Category 3 (EN 954-1)		X		X	
Use of Category 4 (EN 954-1)					X

Table 6. 1 List of types of two-hand control devices and minimum safety requirements

One of the main requirements for electrical Two – Hand control units is the synchronous actuation. illustration 6.1 describes this function.

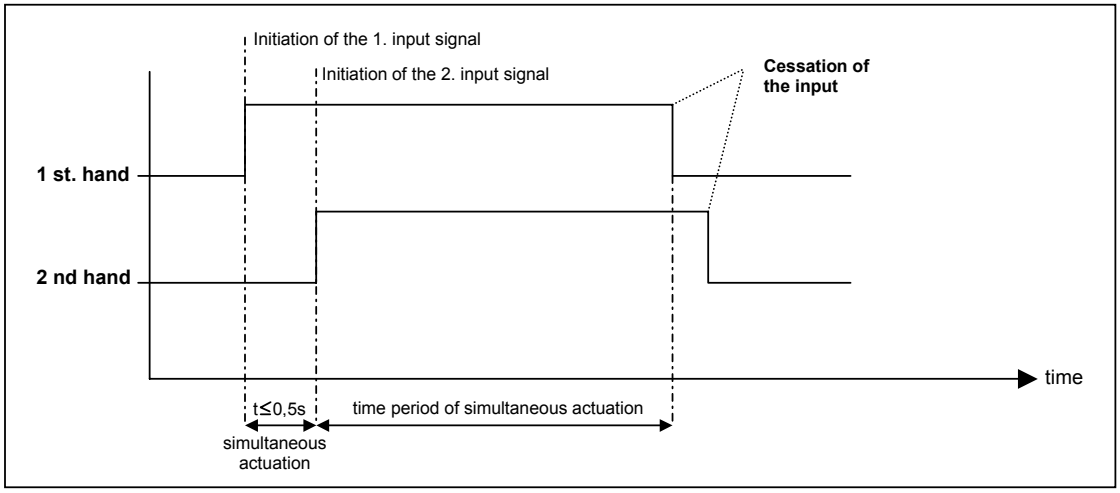
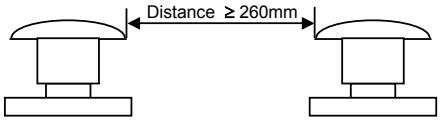


illustration 6. 1 Simultaneous actuation for two-hand type IIIa - IIIc

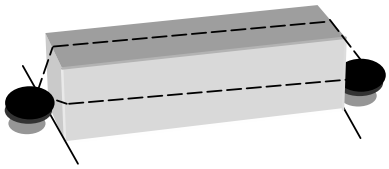
The EN 574 describes in detail that a two hand control station must be designed to prohibit several kinds of defeat.
EN 574, Clause 8 describes the prevention of accidental actuation and of defeat.
The normative Annex A shows measurement tests for the prevention of defeat.

Prevention of defeat using one arm:

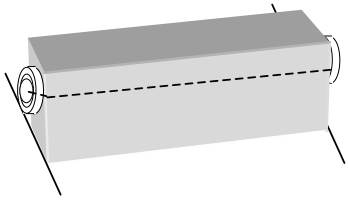
- Separation of the control actuating devices (inside dimensions) by at least 260mm



- Separation of the control actuating devices by one or more shields in an elevated area designed, in such a way that the control actuating device cannot be touched with the ends of a 260 mm cord representing the finger span.

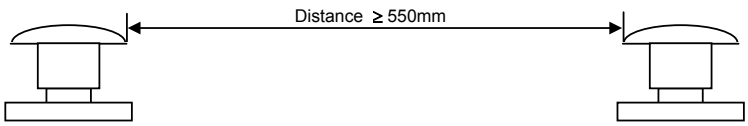


- Separation of the control actuating devices by collars and by orientation in such a way that the control actuating device cannot be touched with the ends of a 260 mm cord.

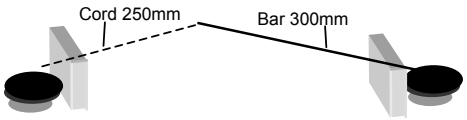


Prevention of defeat using hand and elbow of the same arm :

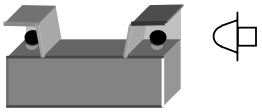
- Separation of the control actuating devices by a distance equal to or more than 550mm



- Separation of the control actuating devices by the provision of one or more shields or an elevated area designed in such a way that the control actuating devices cannot be touched at the same time with both ends of measuring equipment consisting of a 300mm rigid bar not exceeding 5mm diameter and a 250mm cord attached to it. The bar that represents the forearm and the cord the hand and it shall be applied in all possible operating positions.

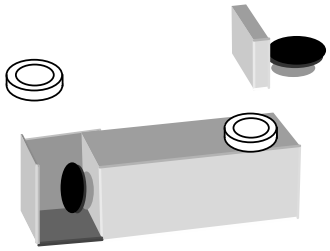


- Separation of the control actuating devices by shields that are designed to limit access from the operating side and also at the rear in such a way that the control actuating device cannot be operated from the operating side with the tip of a test cone representing the elbow. The dimensions of this test cone shall be in accordance with figure A7 of EN 574, 1996.



- Control actuating devices with different types and/or directions of operation.

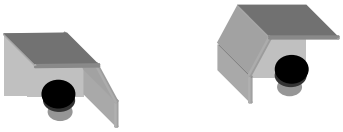
For this configuration usage of cord , bar and test cone for collar



Prevention of defeat using the forearm(s) or elbow(s)

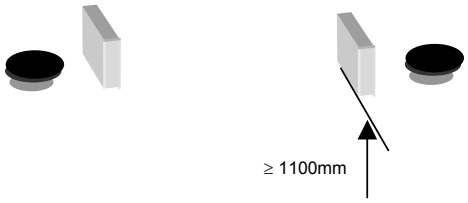
- Shields designed in such a way that the control actuating devices cannot be operated by the forearms and/or the elbows.

For the configuration use the test cone



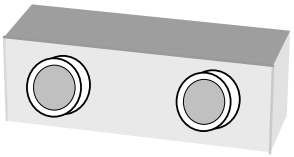
Prevention of defeat using the hand and other parts of the body:

- Arrangement of the control actuating devices on a horizontal or nearly horizontal surface at least 1100mm above floor or level of access.



- Arrangement of the control actuating devices on a vertical or nearly vertical surface with protective collar(s) around the control actuating devices and/or shield(s).
-

For this configuration
use the test cone



6.1.2 EN 999, Calculation of the required safety distance

Because an operator may be able to access the dangerous zone before the hazardous movement of the machine is stopped, a safety distance must be determined.
The calculation of this distance is described in EN 999(1998) , clause 8.

The minimum distance of the nearest actuator to the danger zone shall be calculated using this formula:

S = (K x T) + C

S = minimum safety distance in millimetres

K = approach speed in mm per second

where:

T = overall system stopping performance in seconds

K = 1600 mm/s

C = additional distance in mm

C = 250 mm

Note: If the risk of encroachment by the hands or part of the hands towards the danger zone is eliminated while the actuator is being operated, e.g. by adequate shrouding, then C may be zero, with a minimum allowable distance for S of 100mm.

Example:

Identify the off time of all components in the system (Control unit, Contactors, valves… .
It is recommended to verify this time with an additional stop time measuring.

Then you can calculate the safety distance using e.g. T = 60 ms (0,06 s) to:

S = (1600mm/s x 0,06s) + 250 mm = **346 mm**

6.2 Requirement for 2-Hd controller

A two hand control device complying to the machine directive 98/37/EC and EN 574 and is not a integral part of a machine, shall be labelled clearly and durably with the following details:

- The name of the manufacturer and/or responsible supplier.
- Manufacturer's model or type reference.
- Manufacturer's serial number and year of manufacture.
- Type of the two-hand control device according to clause 4, table 1 of EN 574.
- The response time of the two hand control device

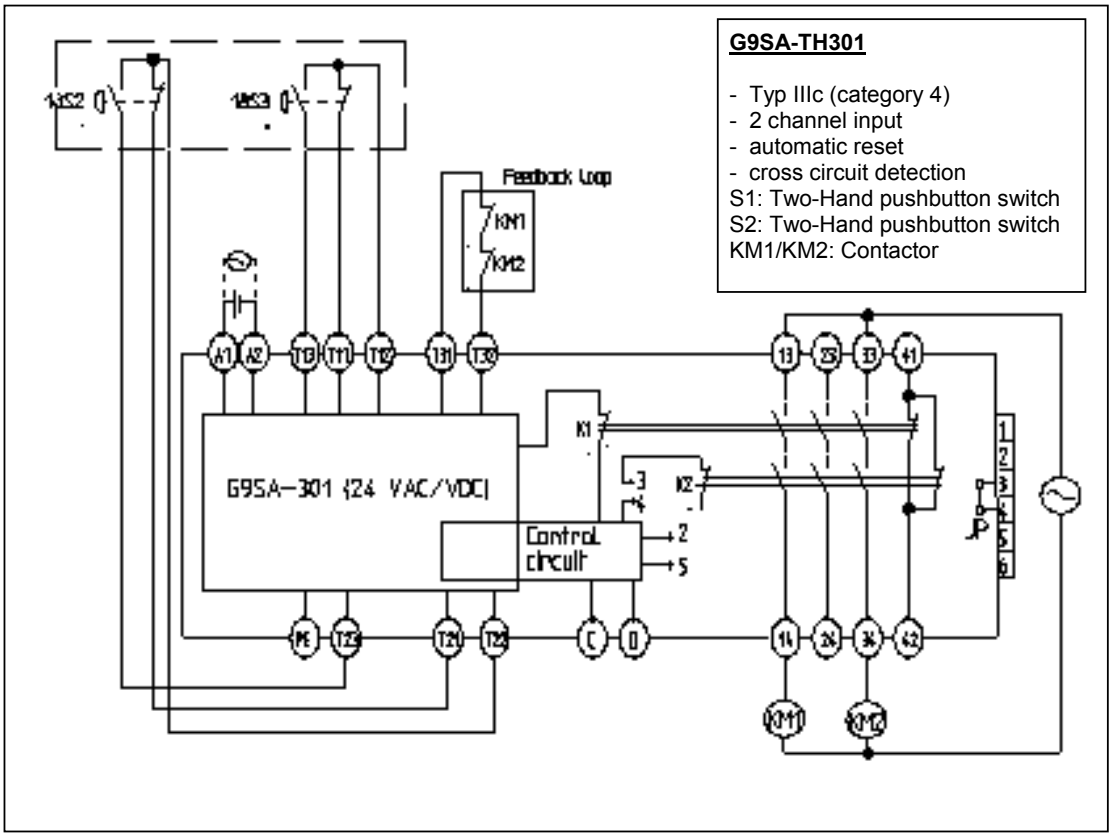
If the two-hand control device consists of one or more separate units at least one unit shall be marked as required. These units shall each be marked in such a way that they can be identified as parts of the same two-hand control device.

A two-hand control device complying with this standard, and is a integral part of a machine shall be marked on the machine, with at least the type of two-hand control device and the number of EN 574. Other instructions and technical data for the two-hand control device shall be available in the machine instruction handbook and operator handbook.

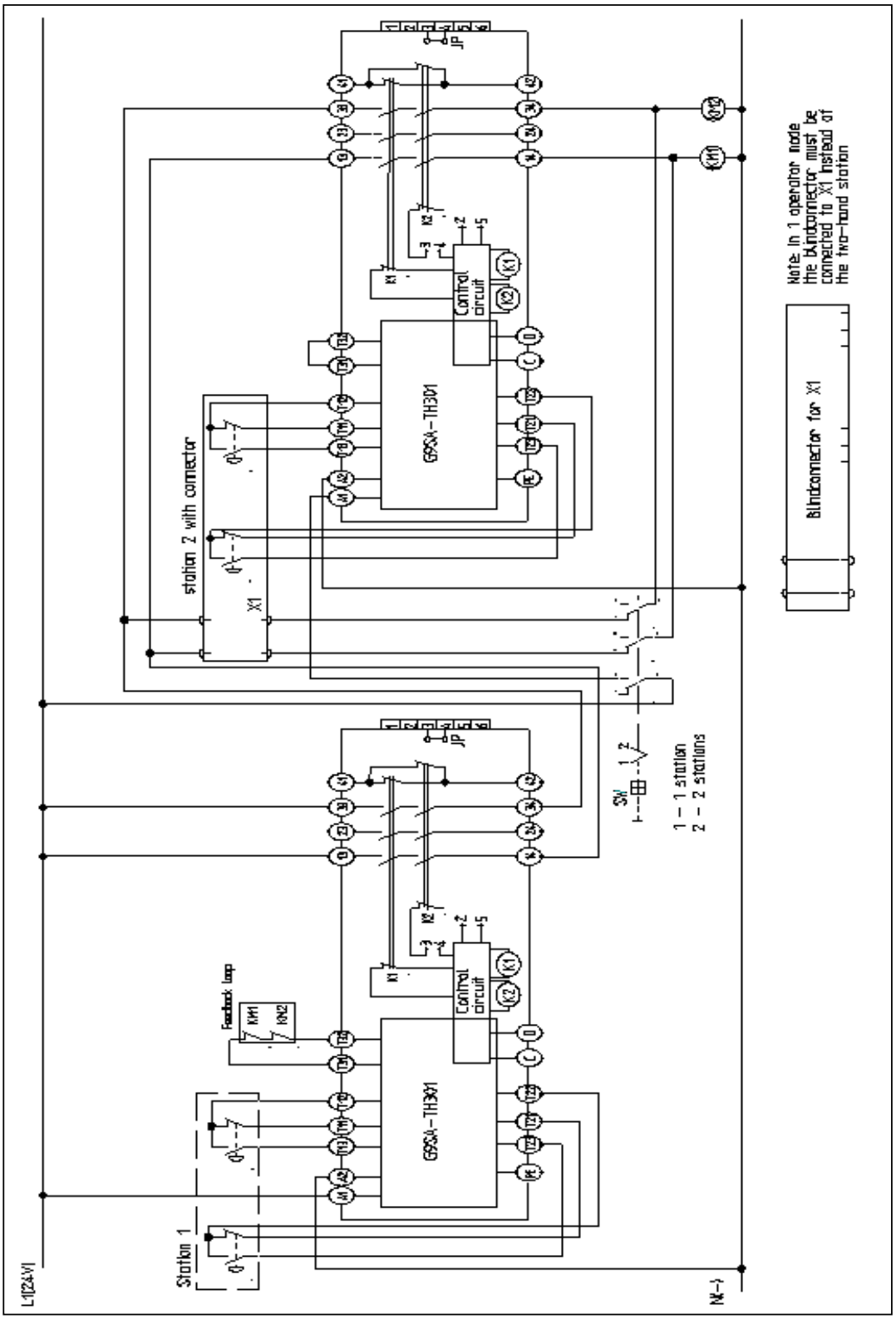
Components of a two-hand control device shall be identifiable, if necessary, for the purpose of maintenance and/or repair.

6.3 Schematics

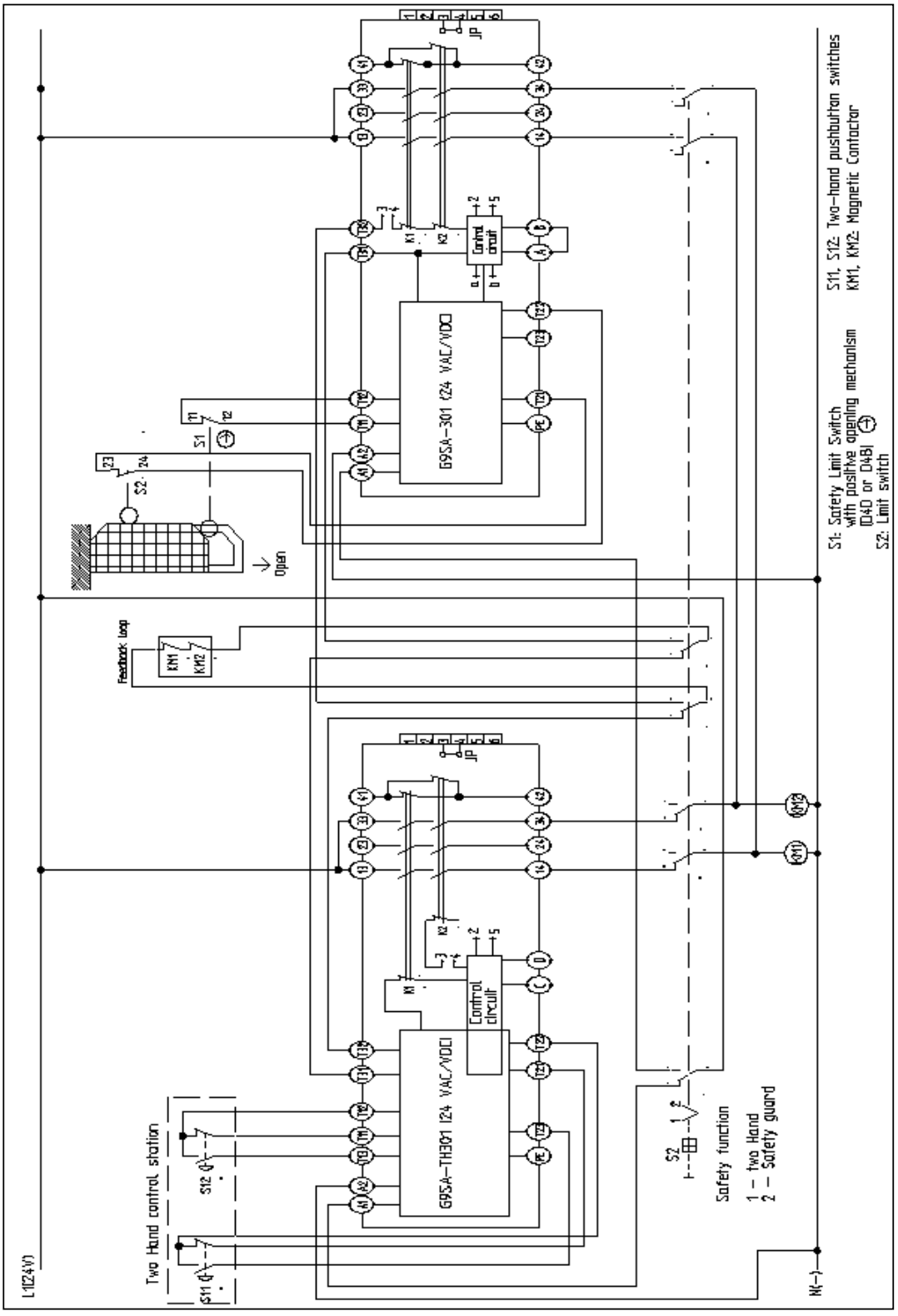
6.3.1 Standard Two-Hand control circuit



6.3.2 Two-Hand control circuit with the possibility to add a second two-hand station



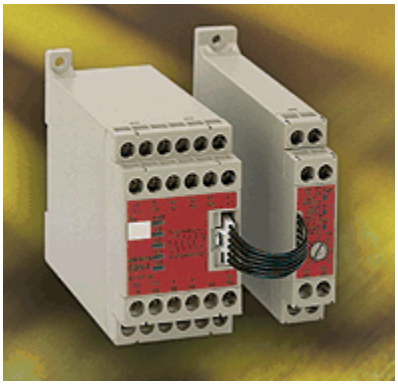
6.3.3 Two-Hand control circuit with the possibility to switch to a alternative safety door



6.4 OMRON Products for 2 Hand applications

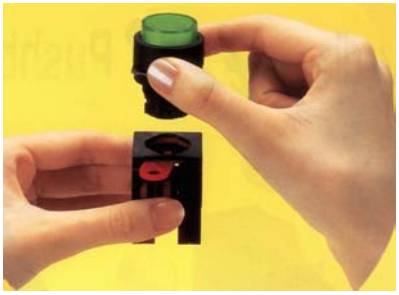
OMRON offers a wide range of safety products to realise a save and efficient solution.
These products we recommend for usage in Two-hand control.

G9SA-TH 301 control unit



- Type III C (EN574)
- 3 safety output contacts (PST-NO)
- 1 auxiliary output contact (non safety SPST-NC)
- 24V AC/DC and 100 to 240VAC models are available
- Easy expandable up to 6 safety and 2 auxiliary outputs
- 45mm size
- 5 A contact load (resistive load)

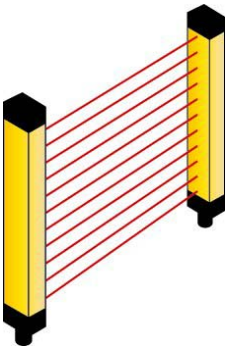
A22 Pushbutton switches



- Easy mounting and removal
- 22mm diameter
- Wide variety of buttons are available
- Up to IP65 protection

7. Light curtains

Light curtains are a part of the electrical equipment used in machines which present risk of personal injury. It provides protection by causing the machine to go to a safe condition before a person can be placed in a hazardous situation.



7.1 EN 61496, EN 999

Light curtains or barriers are named ESPE (Electro Sensitive Protective Equipment) and AOPD (Active Opto-electronic Protective Device) due to using sensing function with emitter and receiver based on optical system in the relevant norms EN 61496-1 and EN 61496-2.

ESPE are assemblies of

- a sensing device
- controlling/monitoring devices
- output signal switching device (OSSD)

The OSSD is the component of the light curtain that is connected to the control system of the machine. When the sensing device is actuated by interruption of the beams in normal operation it responds by going to the OFF-state. OSSD can be safety relays with mechanical contacts or solid state outputs such as PNP-transistors.
The overall system stopping performance is the time occurring from actuating the sensor to the cessation of a hazardous motion. This time T consists of min. two parts where t_1 is the response time of the sensor and t_2 is the max. response time of the machine: $T = t_1 + t_2$
Because of this delay the distance between the sensor and the dangerous zone has to be wide enough that personal injury is prevented.
EN 999 defines the minimum distance from the dangerous zone being calculated by a general formula

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

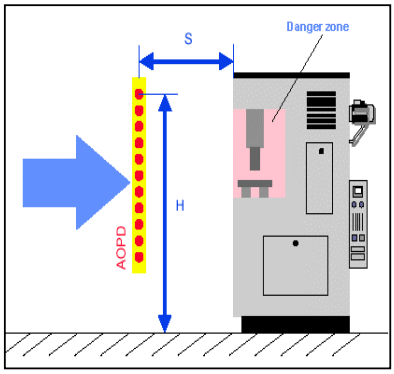
Where:

S is the minimum distance in *mm*
K is a parameter in *mm/s* , derived from data on approach speed of the body or parts of the body
T the overall system stopping performance in *s*
C is an additional distance in mm, based on intrusion towards the danger zone prior to actuation of the protective equipment

EN 999 further on divides into three main applications based on the direction of approach to the detection zone:

- Normal approach

S = (2000mm/s x T) + 8 (d-14mm) (1)



d: detection capability of the sensor in mm ≤ 40mm

This formula applies for all minimum distances of S ≤ 500mm. The minimum value of S shall not be < 100mm. If S is calculated > 500mm then formula (2) can be used. In this case the minimum value of S shall not be < 500mm.

S = (1600mm/s x T) + 8 (d-14mm) (2)

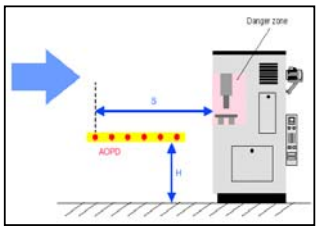
If the sensor is used for applications like single or double break, the detection capability has to be ≤ 30mm and the minimum distance S shall be > 150mm.

Sensors with **detection capability > 40mm and ≤ 70mm** shall only be used where the risk assessment indicates that detection of hands or fingers is not necessary. Then formula (3) can be used.

S = (1600mm/s x T) + 850mm (3)

If using single beams where risk assessment allows formula (4) shall be used.

S = (1600mm/s x T) + 1200mm (4)

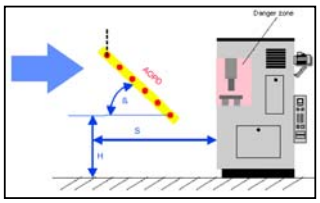


- Parallel approach

S = (1600mm/s x T) + (1200mm – 0.4 H) (5)

H is height of the detection zone above the floor in mm and shall not be > 1000mm. The lowest allowable height shall be calculated by formula (6)

H = 15 x (d – 50mm) (6)



- Angled approach

If the sensor has been installed so that the angle of approach β to the detection zone is within ± 5° the relevant formula (2)/(3) or (5) will apply.
If angle is β > 30° use formula for normal and β < 30° for parallel approach.

Summary

general formula		S = K x T +C
d ≤ 40mm	100mm ≤ S ≤ 500mm	S = (2000mm/s x T) + 8 (d -14mm)
	S > 500mm	S = (1600mm/s x T) + 8 (d -14mm)
40mm < d ≤ 70mm		S = (1600mm/s x T) + 850mm
single beams		S = (1600mm/s x T) + 1200mm

7.1.1 Examples safety distance

Before calculating the safety distance S be sure that appropriate Type-C standard or the risk assessment for the relevant machine will allow the chosen sensor.

Example 1:
Approach to detection zone: normal (vertical)
Stopping time of the machine: 60ms (t_2)
Response time AOPD: 12.5ms (t_1) typical value for F3SN-A
Detection capability: 14mm (d) finger protection

S = (2000mm/s x T) + 8 (d - 14mm)
S = (2000mm/s x (0,06s + 0,0125s)) + 8 (14mm-14mm)
S = 145mm

Example 2: The same machine but using AOPD with detection capability d = 30mm (hand protection):

S = (2000mm/s x (0,06s+0,0125s) + 8 (30mm-14mm)
S = 273mm

Example 3: AOPD with 4 beams
Stopping time of the machine: 300ms (t_2)
Response time AOPD: 10ms (t_1) max. value for F3SH-A
Beam height from floor: 300mm, 600mm, 900mm, 1200mm (table 1)

S = (1600mm/s x T) + 850mm
S = (1600mm/s x (0,3s + 0,01s)) + 850mm
S = 1346mm

7.2 Finger and hand protection systems

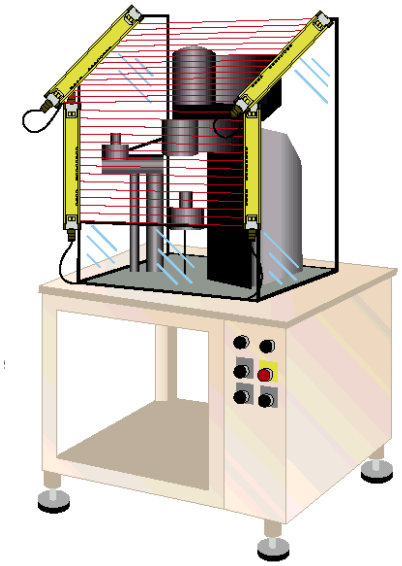
How to choose the right AOPD for my application. EN 999 helps with a strategy:

1. Identify hazards and assess the risk (see EN 292-1 and EN 1050)
2. Type-C standard exists for the machine ?
   if yes: apply the C-standard
   if no: Select appropriate AOPD using Type-A and Type-B standards
3. Calculation of safety distance according EN 999
4. Incorporate the distance into machine design
5. Access to the danger zone without detection by AOPD possible ?

Protection function:

finger- and hand protection:

body protection:



Finger protection system with two F3SN-A_P14 connected in series.

Operator is close to the danger zone

1. access protection: presence of operator in danger zone visible all the time

2. presence detection: operator has to be detected all the time

A finger or hand protection system is generally composed of a type 4, more frequently, or a type 2 safety light curtain (basing on the risk assessment result), and fixed guards. That allow to forcing the access to the dangerous zone through the detection zone of the barrier.

The typical values of resolution are 14mm for finger protection (this value allow to eliminate the static factor on the safety distance formula), and 25 to 40mm for hand protection.

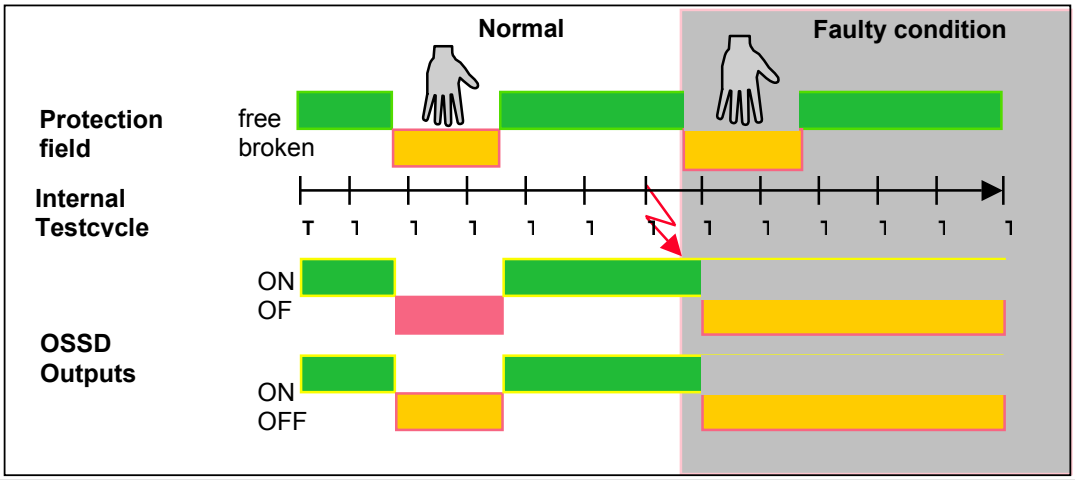
The installation of the barrier is also influenced by the dimension of the emitter/receiver components and the flexibility of connection: a protective height equal or similar to the sensor height and the possibility of a series connection could be fundamental.

7.2.1 Type 4

The norm EN 61496-2 requires a self-testing function for type 4 AOPDs.

- In case of a faulty condition the systems remains to be safe.
- If the first fault is not detected the second and third fault must not cause a loss of safety.
- The internal test cycle must be less than the response time of the system.
- The safety level of Type 4 is equal to category 4 (EN954-1).

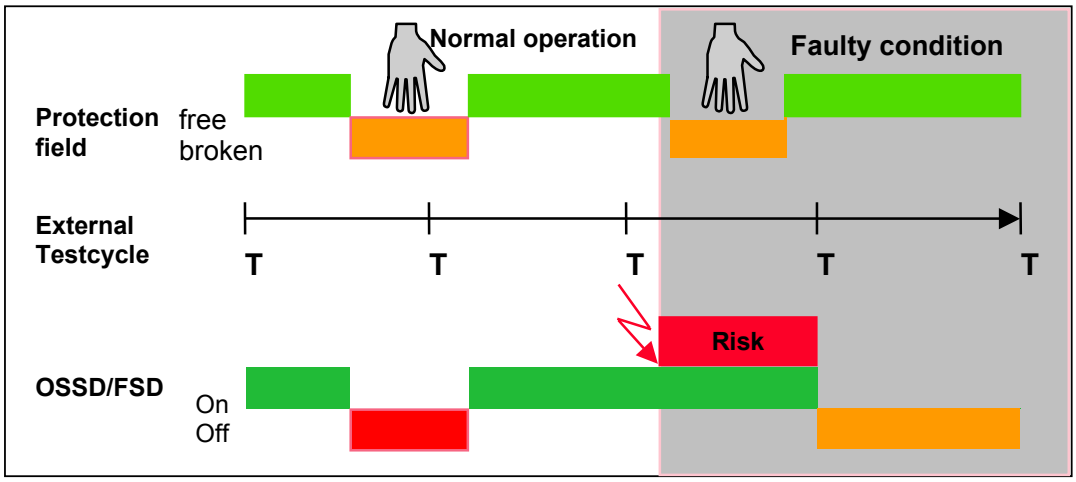
Further on the EAA effective aperture angle is specified to ± 2.5° from the beam-centre line.



7.2.2 Type 2

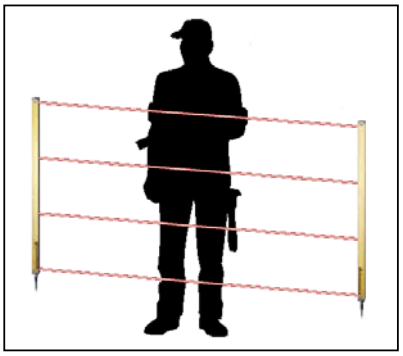
The norm EN 61496-2 requires a self-testing function for type 2 AOPDs.

- In case of a faulty condition the systems will detect this condition after the next test cycle
- The internal test cycle must be obtained in an appropriate time (max. 150ms), depending on the safety requirement
- The effective aperture angle is specified to ± 5° from the beam-centre line.
- The safety level of Type 2 is equal to category 2 (EN954-1).



7.3 Body protection devices

Multiple separate beams are often used to detect intrusion of the whole body rather than parts of the body. During risk assessment bypassing of the sensor such as



- crawling below the lowest beam
- reaching over the top beam
- reaching between two of the beams and
- bodily access by passing between two beams

have to been taken into account.

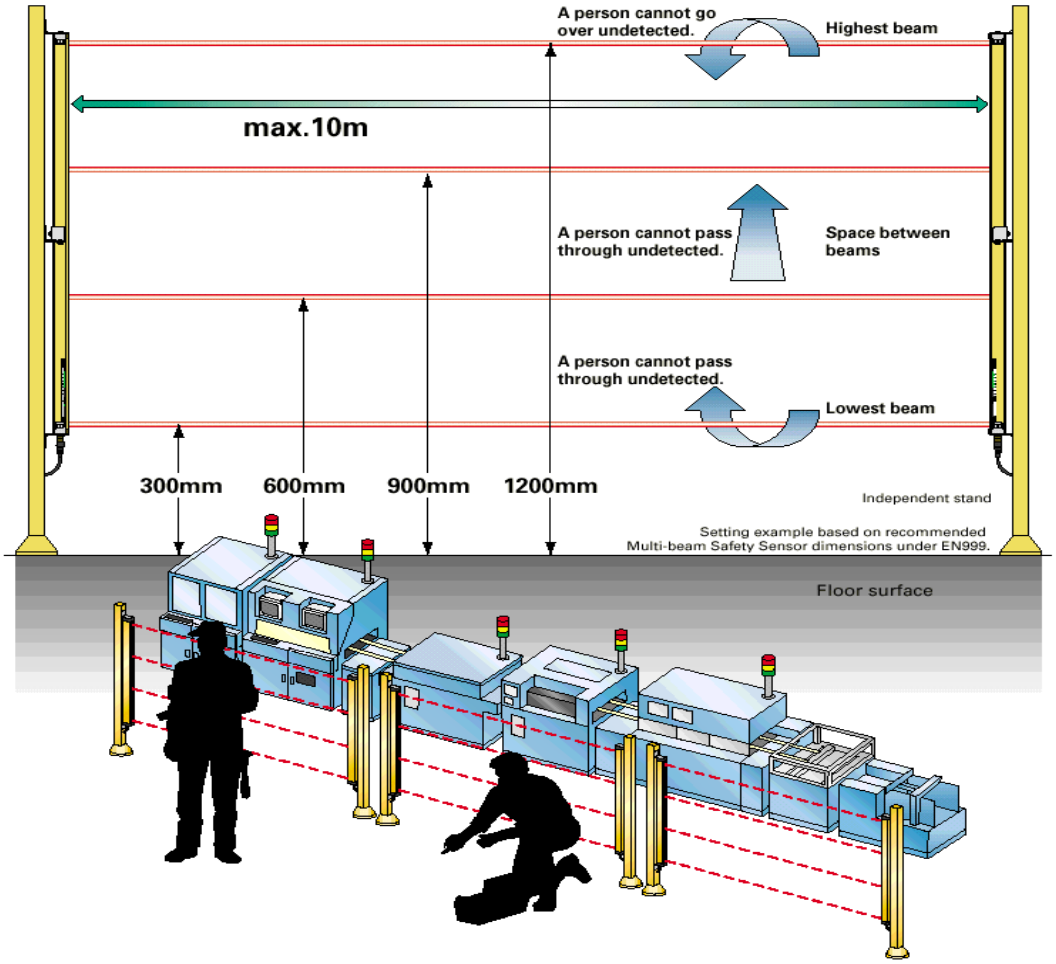
The heights for 2, 3 or 4 beams given in the table below have been found to be the most practical in application.
Clause 6.1.4 of EN 999 specifies this heights and distances. The appropriate number of beams has to be analysed and decided by risk assessment.

No. of beams	Heights above floor in mm
2	400, 900
3	300, 700, 1100
4	300, 600, 900, 1200

Note: Only 0ne beam is not sufficient for safety applications

7.3.1 Type 4, multi beam

To meet the requirements of EN 999 you can install single beams in the shown heights above floor. You can make it more simple by using multibeam sensors like Omron's F3SH 4-beam safety sensor where the beam gap is already according to EN 999.



7.3.2 type 2, single beam

For type 2 applications it is common to use single photoelectric sensors.
This sensor can be combined with as much beams as required from the risk assessment. For palletisers and depalletisers (EN 415-4) where only sporadic access is necessary this is a often used application.

To maintain safety the sensors must be tested by a dedicated and approved controller. The requirements for design to prevent bypassing and defeat must be in accordance to EN999.

To obtain a good assembly the M18 sensors with ranges up to 10 m are a appropriate solution. Depending on the solution it is necessary to chose between metal or plastic body as well as between prewired and connector types.

7.4 Muting application

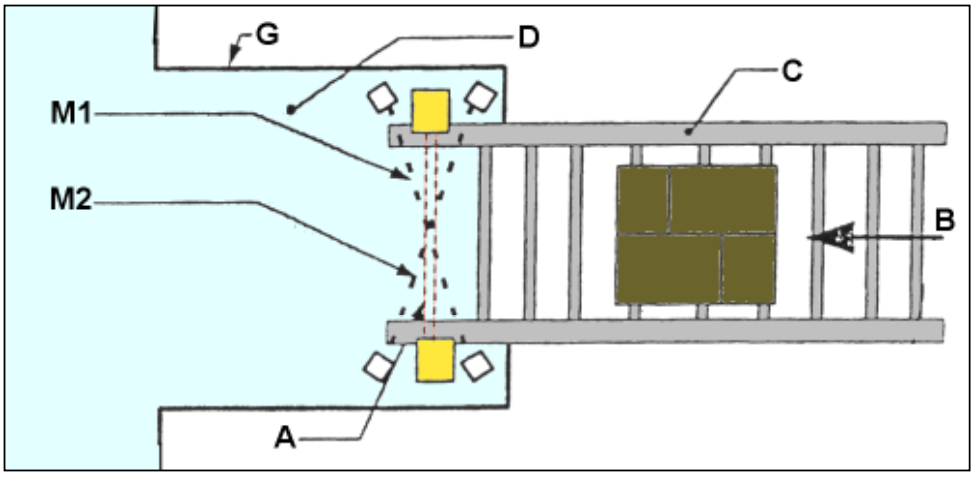
The muting function is a *temporary automatic suspension of a safety function(s) by safety-related parts of the control system*, as described on the EN954-1 (Safety-related parts of control system).

Muting application is very often used in combination with safety photoelectric sensors (ESPE, like safety light curtains). The general requirements for this kind of device are listed below, basing on the EN61496-1:

- When the muting function is activated the safety outputs are in the ON state, also when the ESPE is activated.
- The muting function is active when a predefined sequence of at least two signals reaches the muting control unit. The signals shall be generated from two or more muting sensors (e.g. photoelectric sensors, limit switches or proximity sensors) located near the ESPE device and activated with the object passage.
- At least one indicator shall illuminate when the ESPE is in muted condition. The indicator should be visible from any position near the dangerous zone.
- Any fault condition in the muting inputs or in the indicator or a wrong signals sequence is revealed and the muted condition is prevented.

More specific requirements are included in type C norms (see below).
The muting function is essential in an automatic cycle of a plant where a crossing of the light barrier is requested from machine tools or other objects (e.g. pallets) without stopping of the plant.

A typical application is the palletiser / depalletiser machine. The pallet must go through the light barrier monitored zone freely while the access of a person must stop the plant immediately.



Application example for palletiser

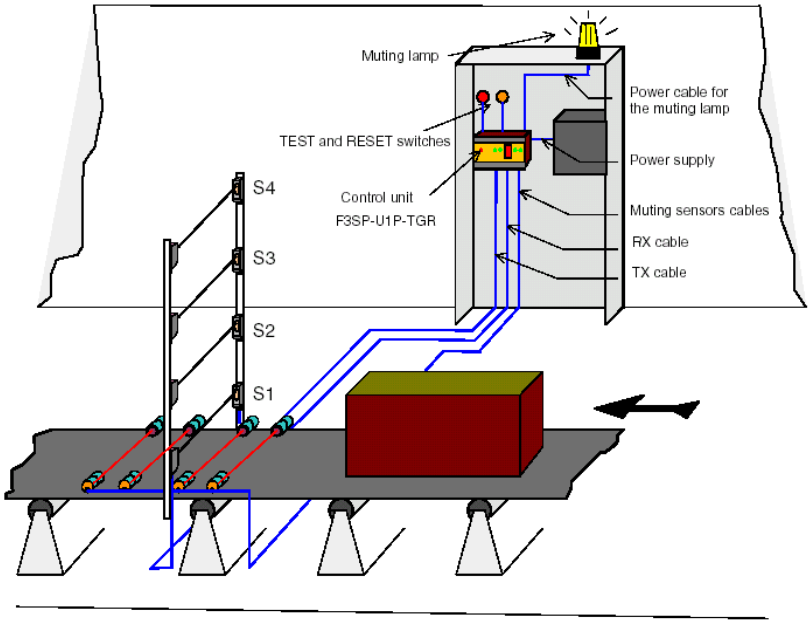
A: Main ESPE device
B: Pallet movement direction
C: Pallet conveyor
D: Danger zone
G: Fixed guards
M1, **M2**: Muting beam sensors

It's necessary to realize a system that is able to discriminate between:
- authorized objects to go trough the light barrier freely and
- non authorized objects (e.g. person).

The muting function is possible for both type 2 and type 4 ESPE.
The essential requirements for a particular application are described in type C norms. For example the essential requirements for palletiser are listed below, basing on the EN415-4:

- Muting shall only occur during a **limited time** when the access to the dangerous zone is obstructed by the pallet.
- Muting should be completely automatic, in other words shall not depend from a manual operation of the operator.
- Mute initiation shall not be activated on a single electrical signal. At least **two different signals** are necessary.
- Mute initiation shall not rely entirely on software signals. Is possible to use a software signal in combination with hardware signal.
- Mute signals shall allow a muted condition only if a correct **sequence** is respected, otherwise an incorrect sequence causes the machine to stop.
- The safety function of the light barrier shall be re-established immediately after the passage of the recognized pallet.
- In case of some material is blocked inside the detection area (for example some box fallen down from a pallet), the muting will be disabled and the machine shall stop. A manual action it is required for removing the box from the area. Restart of the machine shall only be possible by voluntary action. This function is called **override**.

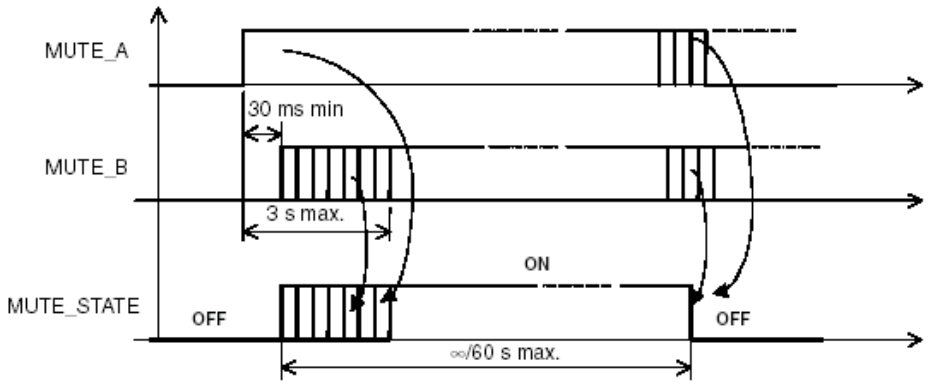
Next figure illustrate a typical installation of the mute sensors, the mute control device, the indicator and the command pushbuttons.



Wiring of a muting system

Four external 'mute sensors' provide inputs to the 'mute control relay'. Only a specific sequential activation of the mute sensors will allow operation of the 'mute sequence'.
In this case, when the first two sensors are activated in sequence, the mute state starts indicated by the yellow mute blinking lamp. The pallet goes through each sensor and through the light curtain in one direction. The mute function will remain until the first of the last two mute sensors are de-activated. The light curtain is then re-enabled.

The mute sequence of the Omron F3SP-U_P-TGR control units is composed of two mute signals within bond times. The picture 3 illustrates graphically this concept: the delay between the second and the first mute signal, respectively B and A, must not exceed 3 seconds. Moreover, cause of the response time of the control unit, the delay between A and B can't be lower than 30ms.



Mute signals timing chart

The duration of the mute state has a limit of 60 seconds, as requested by the norm. However, this default setting can be changed to infinite.
The mute sensors are physically positioned so that any person trying to gain access cannot activate the mute sensors in sequence and permanently. Therefore, the mute sequence will not be activated causing the machine to stop as the light curtain is broken.

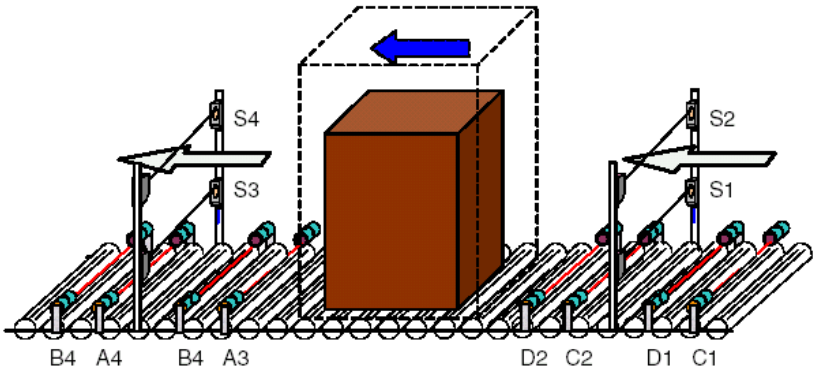
The muting function is generally managed with an external control device, as seen in the previous figure. Omron mute control units comes in two different versions:

- F3SP-U1P-TGR for single beam type sensors E3FS,
- F3SP-U2P-TGR for multi-beams type sensors, like F3SB and F3SN/H-A.

The F3SP-U1P-TGR is necessary for the management of the diagnostic of the E3FS safety sensor. Is possible to link 1 to 4 pairs of sensor.

The F3SP-U2P-TGR complete a type 2 (F3SB) or type 4 (F3SN/H-A) ESPE with the muting function.
Both control units are supplied with two muting function. Each function is independent and activated with dedicated inputs (A-B and C-D) for the mute sensors.

Following picture illustrate an application where a component go through a dangerous zone where the input and the output of this zone are monitored by two pairs of E3FS (S1-S2 and S3-S4) and four pairs of mute sensors for each couple of safety sensors.



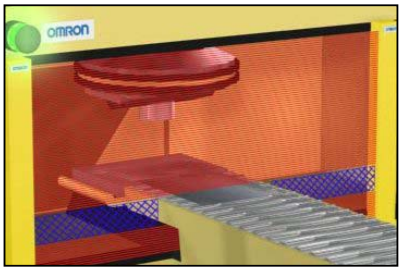
Example with two barriers composed of two single beam ESPE, four mute sensors and one F3SP-U1P-TGR control unit.

Others characteritics of the F3SP control unit are the indicator, that is necessary for the correct working of the system, and the override function, that is activated by the pression of two pushbutton during the start-up of the unit.

7.5 Blanking application

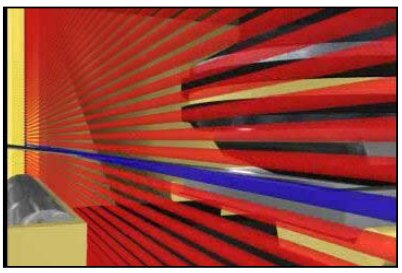
Fixed Blanking:

Some applications have problems with mounting of the light curtain. Therefore it is helpful to take out zones from the protection field. With the function blanking it is possible to specify beams that will not interpreted by the light curtain. This is called fixed blanking.
The remaining field or zone has to be protected by mechanical guards.



Floating blanking:

Floating blanking function allows the output to remain ON when beams of the sensor are interrupted anywhere in the protection field. In contrast with fixed blanking function, which invalids fixed detection area, floating blanking function ignores object smaller than specified radius. This reduces the optical resolution.



For calculating the safety distance this reduced resolution has to be taken in account (see table below).

floating beam gap (mm)	Resolution (mm)				undetectable diameter (mm)		
	0	1	2	3	1	2	3
9	14	23	32	41	4	13	22
15	25	40	55	70	5	20	35
30	40	70	100	130	20	50	80
60	70	130	190	250	50	110	170

7.6 Single / double break application (EN 61496 Annex A, A8)

If parts have to be put in and removed from a press machine manually then the safety light curtain is used not only for protection purpose but for initiation of the machine cycle as well. This will optimise the process and makes it safe. The control can be realised either in single break or double break mode.

Single break: Actuation and de-actuation of the light curtain initiates machine movement.
Double break: Two consecutive actuations and de-actuations of the light curtain initiates machine movement.

The start and restart interlock function has to be used.

The reset button has to be operated under following conditions:

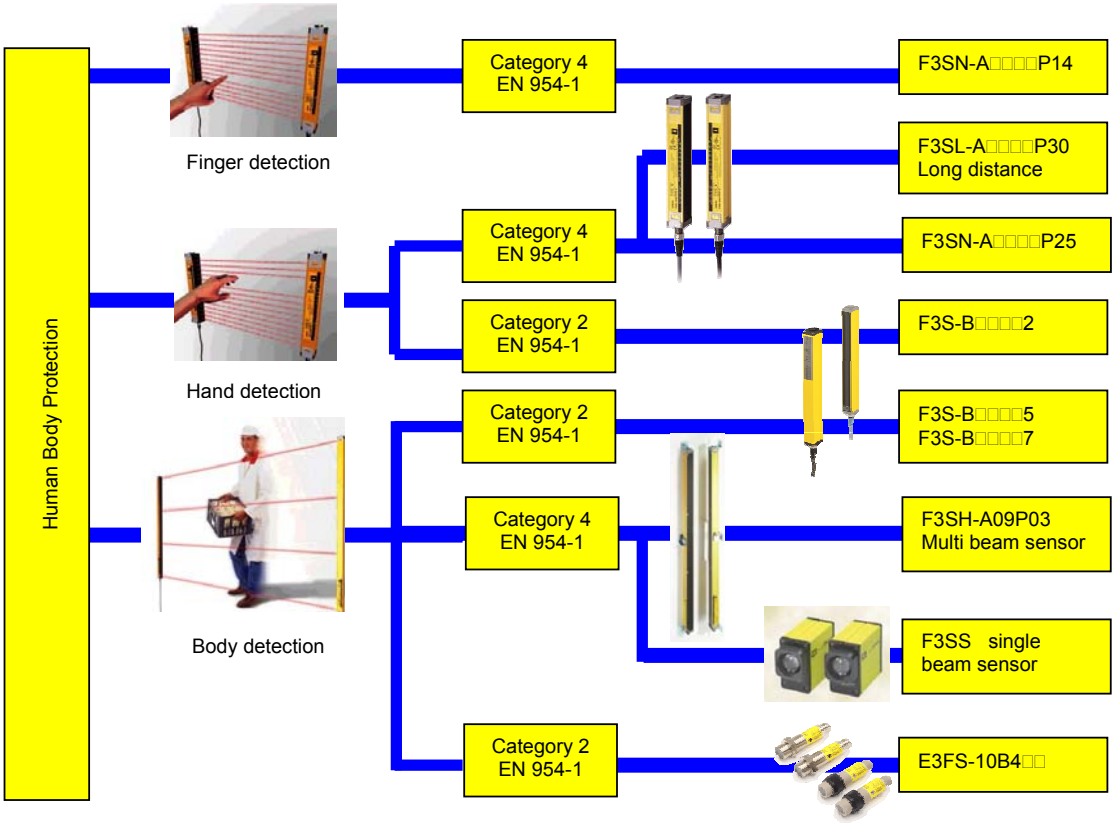
- Machine start
- Restart, after obstructing the light curtain during a hazardous movement
- Restart, after exceeding the permitted time period of 30 s for machines having a cycle time of less than 5 s.

The mode single or double break is allowed for small machines and light curtains with detection capability of less equal 30mm only.
Always check that the hazardous zone can not be entered and the light curtains can not be bypassed by operator.

7.7 Products for safety sensor applications

OMRON offers a wide variety of safety sensors to protect your application.

Selection Guide OMRON Safety Sensors



For the different possible applications there is a wide variety of accessories available.

- Mirrors for perimetrical protection
- Plug and Play controller solution F3SP-B1P
- 17,5mm and 22,5mm Small size controller G9SB
- Muting controller F3SP-U2P-TGR for safety light curtains F3S-B, F3SN-A and F3SH-A
- Controller F3SP-U1P-TGR for test and muting for singe beam sensors E3FS
- Setting console for F3SN-A and F3SH-A
- Protection covers for F3SN and F3SH

8.0 Safe networks

Due to technical progress it is possible to have safe data communication on serial networks. For standard communication Networks as DeviceNet, ASI, Ethernet etc. are established systems to have a high reliable communication.

The connection of safety related information to a network was not possible in the past. Some European and international standards still insist on “hard wired“ realisation of safety systems. The revisions of these standards will also allow to use safe data communication instead. The main requirement is that the system provides the same integrity and safety as a hard wired system.

8.1 Background of safety networks and bus systems

To ensure an appropriate level of safety, this systems must be designed to detect failures caused by several reasons to prevent an unsafe condition of the system:

- Message repetition
- Message loss
- Message insertion
- Coupling of safety and standard information
- Coupling of safety and safety information
- Incorrect sequence
- Message corruption
- Message delay

To ensure high safety special measures must be implemented in the communication protocol to reach an appropriate “ Safety Integrity Level”.

- Control of time with time stamp
- Identification of producer and consumer
- Multiple CRC checking

Safe networks are defined in several categories:

1) Proprietary systems that are owned and developed by one major company
2) Open networks that are owned and developed by multiple companies
A) Safety only networks that are only dedicated to handle safety functions
B) Mixed (hybrid) networks that allow standard (non safety) and safety communication on the same network

In the past mainly “1A” networks were released and are used in safety dominated application like press lines. Since several years the networks got more open and were designed as safety extension to the standard functions. (2A)

Safety networks offer a lot of benefits and new functionality.

- Easy design and wiring, safe time in engineering and mounting
- Additional functionality increases safety of the application
- Reduced possibility to defeat or manipulate safety measures
- Transparency , the condition of all safety device can easily be monitored
- Possibility of rooting within several safety related networks (Depend on system)

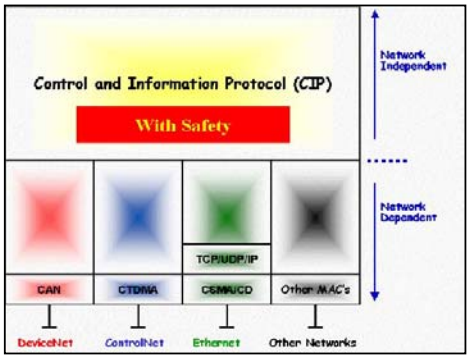
Safety networks are able to provide safety up to SIL 3 (safety integrity level, EN 61508) that represent a similar failsafe level as Category 4 (EN954-1).

8.2 CIP-safety®, DeviceNet safety ®

"CIP" represents the Control Information protocol of DeviceNet, Ethernet IP and some other bus systems. In 2002 three major automation companies (OMRON, Rockwell Automation and Sick) developed the CIP safety extension. This CIP safety provides a open hybrid network that is the first media independent safety protocol.

The network is a real open system, because the technology rights are transferred to ODVA (**O**pen **D**eviceNet **V**endor **A**ssociation). The benefit is that a huge number of independent companies offers products and services to support CIP and CIP safety.

DeviceNet safety is CIP safety on CAN (**C**ontroller **A**rea **N**etwork) media.



The features of CIP safety offer a unique combination of safety and productivity:

- Standard and safety devices can co-exist on the same wire
Standard devices must not interfere with the functions of the safety devices
Safety devices must not interfere with the functions of the standard devices
- Standard and safety connections supported on the same safety device
- Seamless routing of safety messages
Applicable to all CIP based networks
Safety protocol in end nodes only
Safety transactions between multiple networks using standard routers
- Protocol can handle small and large safety data packets
Two packet formats:
Short format - up to 2 bytes of safety data
Long format - up to 250 bytes of safety data

Communication can be performed in a lot of channels:

- Controller communication on single link
  Performs fast safety data communication between controllers and PLC
- Controller communication over multiple links
  Allows sophisticated communication between controller and PLC on several media and networks
- Peer to peer communication on a single link
  Fast direct communication from slave to slave in a isle within a complex structure
- Peer to peer communication over multiple links
  Direct communication from slave to slave using communication over several media and networks
- Peer to peer communication via controller logic
  Slave communication using a controller or PLC for processingMulticatsing communication where one "producer" addresses a multiple number of "consumers" (limited broadcast)

CIP safety and DeviceNet safety provide a hybrid safety network up to SIL3, Cat 4.

9.0 Glossary

European standards defines technical principles and specifications to help designers and manufacturers in achieving safety in the design of machinery for professional and non-professional purposes. It may also be used for other technical products having similar hazards.

9.1 Definitions

Hazard
A source of possible injury or damage to health.

Hazardous situation
Any situation in which a person is exposed to a hazard or to hazards.

Danger zone
Any zone within and/or around machinery in which a person is exposed to risk of injury or damage to health.

Design of a machine
A series of actions including:

a) The study of the machine itself, taking into account all phases of its “life”:
   1. Construction
   2. Transport and commissioning
      - assembly, installation,
      - adjustment
   3. Use
      - setting, teaching / programming or process changeover
      - operation
      - cleaning,
      - fault finding,
      - maintenance,
   4) De-commissioning, dismantling and, as far as safety is concerned, disposal.

Safety device
Device (other than a guard) which eliminates or reduces risk, alone or associated with a guard.

Enabling (control) device
Additional manually operated control device used in conjunction with a start control and which, when continuously actuated, allows a machine to function.

Safety distance
The minimum distance a protective structure shall be placed from a danger zone.

Direct contact
Contact of persons or livestock with live parts.

Indirect contact
Contact of persons or livestock with exposed conductive parts which have become live under fault conditions.

Live part:
A conductor or conductive part intended to be energised in normal use, including a neutral conductor, but, by convention, not a PEN conductor.

Interlocking guard
Guard associated with an interlocking device, so that:
- the hazardous machine functions “covered” by the guard cannot operate until the guard is closed;
- if the guard is opened while the hazardous machine functions are operating, a stop instruction is given;
- when the guard is closed, the hazardous machine functions are “covered” by the guard can operate, but the closure of the guard does not by itself initiate their operation.

Note: In English ”stop signal” and “stop command” are synonyms for “stop instruction”.

Interlocking guard with guard locking
Guard associated with an interlocking device and a guard locking device so that:
- the hazardous machine functions “covered” by the guard cannot operate until the is closed and locked;
- the guard remains closed and locked until the risk of injury from the hazardous machine functions has passed;
- when the guard is closed and locked, the hazardous machine functions “covered” by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.

Guard locking device:
Device intended to lock a guard in the closed position and linked to the control system so that:
- the machine cannot operate until the guard is closed and locked;
- the guard remains locked until the risk has passed

Direct mode actuation (positive mode actuation)
If a moving mechanical component inevitably moves another component along with it, either by direct contact or via rigid elements, the second component is said to be actuated in the positive mode (or positively) by the first one.

Direct opening operation of a contact element (positive opening)
The achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (e.g. not dependent upon springs). [“Special requirements for control switches with positive opening operations”, EN 60947-5-1: 1991, chapter 3,2.2].
Note: For fluid power, the equivalent concept may be called “positive mode interruption”.

Stopping time
time for hazard elimination
The period between the point at which the interlocking device initiates the stop command and the point at which the risk from hazardous machine functions has passed.

Category
Classification of the safety – related parts of a control system in respect of their resistance to faults and their subsequent behaviour in the fault condition, and which is achieved by the structural arrangement of the parts and/or by their reliability.

Muting
Temporary automatic suspension of a safety function(s) by safety-related parts of the control system

Manual reset
Function within the safety – related parts of the control system to manually restore Given safety functions before the re-starting of a machine.

9.2 Directives, Standards

- **Directives:**

Low Voltage Directive:	73/23/EC issue date 19. Feb., 1973
Electromagnetic Compatibility Directive:	89/336/EC issue date 03. May, 1989 89/655/EEC (95/63/EC)
Machinery Directive:	98/37/EC issue date 22. June, 1998

- **Standards:**

EN 292 – 1:	Safety of machinery – Basic concept, general principles for design, part 1: Basic terminology, methodology
EN 292 – 2	Safety of machinery – Basic concept, general principles for design, part 2: Technical principles and specifications
EN 954-1:	Safety – related parts of control systems, part 1: General principles for design
pr EN 954-2:	Safety – related parts of control systems, part 2: Validation
EN 1050:	Safety of machinery – Principles of risk assessment
EN 61508:	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 1: General requirements Part 2: Requirements for e/e/pe systems Part 3: Software requirements Part 4: Definitions and abbreviations Part 5: Examples of methods for the determination of SIL's Part 6: Guidelines on the application of IEC61508-2 and -3 Part 7: Overview of techniques and measures
IEC 62061: (draft)	Safety of machinery – Functional safety – electrical, electronic programmable electronic control systems
EN 418:	Emergency stop equipment, functional aspects – principles for design
EN 574:	Two-hand control devices, functional aspects – principles for design
EN 999:	Safety of machinery – The positioning of protective equipment In respect of approach speeds of parts of the human body
EN 1037:	Safety of machinery: Prevention of unexpected start-up

EN 1088:	Interlocking devices associated with guards – principles for design and selection
EN 60204-1:	Electrical equipment of machines, part 1: Specification for general Requirements
EN 60947-1:	Low-voltage switchgear and controlgear, part 1: General rules
EN 60947-5-1:	Low-voltage switch gear and controlgear – part 5-1: Control circuit devices and switching elements – Electromechanical circuit devices
EN 61496-1:	Electro – sensitive protective equipment, Part 1: General requirements and tests
IEC 61496-2:	Electro – sensitive protective equipment, Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)
EN 81-1 :	Safety rules for the construction and installation of electric lifts
EN 81-2	Safety rules for the construction and installation of hydraulic lifts
EN 115:	Safety rules for the construction and installation of escalators and passenger conveyors
EN 201:	Rubber and plastic machines – Injection Moulding machines – Safety requirement
EN 415:	Safety of packaging machines Part 4: Palletisers and Depalletisers
EN 692:	Mechanical presses - Safety
EN 693:	Hydraulic presses – Safety
EN 1010:	Technical safety requirements for the design and construction of printing and paper converting machines
EN 1501:	Refuse collecting vehicles and their associated lifting devices Part 1: Rear-end loaded refuse collecting vehicles Part 2: Side loaded refuse collecting vehicles
pr EN 12622:	Hydraulic press brakes

9.3 Literature, Links

This section is to give you some additional sources for safety related topics.

OMRON interactive safety guide (UK, EN,DE,IT)

Flash based guide through European legislation and standards
Contains animated explanations for muting, blanking etc

English sources:

Safety of machinery in Europe (English Version)

Beuth Verlag GmbH, Berlin. Germany

Loose paper collection (3 binders) or CD

BIA-Report 6/97e:

Categories for safety related control systems in Accordance with EN 954-1

Hauptverband der gewerblichen Berufsgenossenschaften (HVBG), Germany

ISBN 3-88383-528-5, (www.hvbg.de)

http://standards.ieee.org	IEEE , standard association
http://www.iec.ch	International Electrotechnical Commission
http://www.iso.ch/iso/en	ISO - International Organization for Standardization
http://www.cenelec.org/	CENELEC - European Committee for Electrotechnical Standardization
http://www.cenorm.be/	CEN - The European Committee for Standardization
http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/machines.html	Harmonised Standards Machinery Directive
http://europa.eu.int/comm/enterprise/newwapproach/standardization/harmstds/index.	European comission, harmionized standards
http://www.eotc.be	European Org Conformity Assessment
http://www.newapproach.org	European harmonized standards under the New Approach directives
http://www.osha.gov	OSHA HOME PAGE
http://www.tuvam.com/home.cfm	TÜV

http://www.ul.com Underwriters Laboratories Inc.

http://www.bsi-global.com/index.html British Standards Institution

German sources:

Leitfaden Maschinensicherheit in Europa (German Version)

Beuth Verlag GmbH, Berlin. Germany

Loose Blatt Sammlung (4 Ordner) oder CD (zweisprachig)

CD-ROM: Was? - Wie? – Wo?

Bestellnummer: BG-2000

Herausgeber: Süddeutsche Metall-Berufsgenossenschaft

Sichere Maschinen in Europa

Verlag Technik & Information, Bochum

ISBN 3-928535-10-2

BIA-Report 6/97:

Kategorien für sicherheitsbezogene Steuerungen nach EN 954-1

Hauptverband der gewerblichen Berufsgenossenschaften (HVBG)

ISBN 3-88383-445-9

www.beuth.de	Beuth verlag, Norms and directives
www.ce-richtlinien.de	Informationen zu EU Richtlinien
http://europa.eu.int	Europaeische Kommission
www.kan.de	Kommission Arbeitschutz und Normung
www.vde.de	Verband der Elektrotechnik in Deutschand
www.hvbg.de	Hauptverband der Berufsgenossenschaften
www.tuevit.de	TUV Informationstechnik GmbH
www.tuevs.ds	Technische Ueberwachungsvereine
www.zvei.de	Zentralverband der Elektroindustrie

Italian sorces

http://www.imq.it	IMQ (Italian mark of quality)
http://www.ceiuni.it/	CEI Comitato Elettrotecnico Italiano (Italian Electrotechnics committee)
http://www.tuv.it/	TÜV Italia
http://www.qec.it/gazzette/guce	Q&C - Ultime notizie dalla UE (European gazette italian site)
http://catalogo.uni.com/catalogo/	Il catalogo UNI On-Line (
http://www.inail.it/	INAIL Istituto Nazionale Assicurazioni contro gli Infortuni sul Lavoro (Italian insurance institute for health of workers))
http://www.ispesl.it	ISPESL Istituto Superiore per la Prevenzione e la Sicurezza del Lavoro (Italian institute for the prevention and safety of the workers)