

## Safety Circuit Integrity and ISO 13849-1 Safety Circuit Principles

Safety circuits involve the safety-related functions of a machine that minimize the level of risk of harm. These safety-related functions can prevent initiation, or they can stop or remove a hazard. The failure of a safety-related function or its associated safety circuit usually results in an increased risk of harm.

The integrity of a safety circuit depends on several factors, including fault tolerance, risk reduction, reliable and well-tried components, well-tried safety principles, and other design considerations.

Depending on the level of risk associated with the machine or its operation, an appropriate level of safety circuit integrity (performance) must be incorporated into its design. Standards that detail safety performance levels include ANSI B11.19 Performance Criteria for Safeguarding and ISO 13849-1 Safety-Related Parts of a Control System.

### Safety Circuit Integrity Levels

Safety circuits in International and European standards have been segmented into Categories and Performance Levels, depending on their ability to maintain their integrity in the event of a failure and the statistical likelihood of that failure. ISO 13849-1 details safety circuit integrity by describing circuit architecture/structure (Categories) and the required performance level (PL) of safety functions under foreseeable conditions.

In the United States, the typical level of safety circuit integrity has been called "Control Reliability". Control Reliability typically incorporates redundant control and self-checking circuitry and has been loosely equated to ISO 13849-1 Category 3 or 4 and/or Performance Level "d" or "e" (see ANSI B11.19).

Perform a risk assessment to ensure appropriate application, interfacing/hookup, and risk reduction (see ANSI B11.0 or ISO 12100). The risk assessment must be performed to determine the appropriate safety circuit integrity in order to ensure that the expected risk reduction is achieved. This risk assessment must take into account all local regulations and relevant standards, such as U.S. Control Reliability or European "C" level standards.

### Fault Exclusion

An important concept within the requirements of ISO 13849-1 is the probability of the occurrence of a failure, which can be reduced using a technique termed "fault exclusion." The rationale assumes that the possibility of certain well-defined failure(s) can be reduced via design, installation, or technical improbability to a point where the resulting fault(s) can be, for the most part, disregarded—that is, "excluded" in the evaluation.

Fault exclusion is a tool a designer can use during the development of the safety-related part of the control system and the risk assessment process. Fault exclusion allows the designer to design out the possibility of various failures and justify it through the risk assessment process to meet the requirements of ISO 13849-1/-2.

## Safety Mat Requirements



### WARNING: Risk Assessment

The level of safety circuit integrity can be greatly affected by the design and installation of the safety devices and the means of interfacing of those devices. A risk assessment must be performed to determine the appropriate level of safety circuit integrity to ensure the expected risk reduction is achieved and all relevant regulations and standards are complied with.

The following are minimum requirements for the design, construction, and installation of four-wire safety mat sensor(s) to be interfaced with the SM-xA-5A Module. These requirements are a summary of standards ISO 13856-1 and ANSI/B11.19. Review all relevant applicable regulations and standards and apply the Module and any sensors in full compliance.

### Design and Constructions

The safety mat system [Safety Module, sensor(s), and any additional devices] must have a response time that is fast enough (less than 100 to 200 ms, depending on the relevant standard) to reduce the possibility of an individual stepping lightly and quickly over the mat's sensing surface, without being detected.

For a safety mat system, the minimum object sensitivity of the sensor must detect, at a minimum, a 30 kg (66 lb.) weight on an 80 mm (3.125 in) diameter circular disk test piece, anywhere on the mat's sensing surface, including at joints and junctions. The effective sensing surface or area must be identifiable and can comprise one or more sensors. The safety mat supplier should state this minimum weight and diameter as the minimum object sensitivity of the sensor.

User adjustments to actuating force and response time are not allowed (ISO 13856-1). The sensor should be manufactured to prevent any reasonably foreseeable failures (for example, oxidation of the contact elements) which could cause a loss in sensitivity.

The sensor must meet a minimum environmental rating of IP54. When the sensor is specified for immersion in water, the sensor's minimum environmental rating must be IP67. Special attention may be required to the interconnect cabling; wicking action may result in the ingress of liquid into the mat, possibly causing loss of sensor sensitivity. The termination of the interconnect cabling may need to be located in an enclosure that has an appropriate environmental rating.

The sensor must not be adversely affected by the environmental conditions for which the system is intended. The effects on the sensor of liquids and other substances which can be expected must be taken into account. For example, long-term exposure to some liquids can cause degradation or swelling of the sensor's housing material, resulting in an unsafe condition.

The sensor's top surface should be a lifetime non-slip design, or otherwise minimize the possibility of slipping, under the expected operating conditions.

The four-wire connection between the Module interconnect cables and the sensor must withstand dragging or carrying the sensor by its cable without failing in an unsafe manner (for example, broken connections due to sharp pulls, steady pulls, or continuous flexing). If not, an alternate means must be employed to avoid such a failure, for example, a cable which disconnects without damage and results in a safe situation.

## Installation

The mounting surface quality and preparation for the sensor must meet the requirements stated by the sensor's manufacturer. Irregularities in the floor (or other mounting surfaces) may impair the function of the sensor and therefore should be reduced to an acceptable minimum.

The mounting surface should be level and clean. Avoid the collection of fluids under or around the sensor. Prevent the risk of failure due to build-up of dirt, turning-chips, or other material under the sensor(s) or the associated hardware. Give special consideration to joints between sensors to ensure that foreign material does not migrate under or into the sensor.

Immediately repair or replace any damage (for example, cuts, tears, wear, or punctures) to the outer insulating jacket of the interconnect cable (in the presence of fluids) or to any part of the exterior of the sensor. Ingress of material (including dirt particles, insects, fluid, moisture, or turning-chips) which may be present near the mat can cause the sensor to corrode or to lose its sensitivity.

Routinely inspect and test the sensor(s) per the manufacturer's recommendations. Care must be taken not to exceed operational specifications (for example, the maximum number of switching operations).

Securely mount the sensor(s) to prevent inadvertent movement (creeping) or unauthorized removal. Methods include (but are not limited to) secured edging or trim, tamper-resistant or one-way fasteners, and recessed flooring or mounting surface, in addition to the size and weight of large mats.

Install the sensor(s) to minimize tripping hazards (particularly towards the hazard). A tripping hazard may exist when the difference in height of an adjacent horizontal surface is 4 mm (1/8 in) or more. Minimize tripping hazards at joints, junctions, edges, and when additional coverings are used. Methods include a ground-flush installation of the sensor, or a ramp that does not exceed 20° from horizontal. Use contrasting colors or markings to identify ramps and edges.

Size and position the safety mat system so that persons cannot enter the hazardous area without being detected, and can not reach the hazard before the hazardous conditions have ceased. Additional guards or safeguarding devices may be required to ensure that exposure to the hazard(s) is not possible by reaching over, under or around the device's sensing surface.

Take into account the possibility of easily stepping over the sensing surface without being detected. ANSI and international standards require a minimum depth of field of the sensor surface (the smallest distance between the edge of the mat and hazard) to be between 750 mm to 1200 mm (30 in to 48 in), depending on the application and the relevant standard. Prevent the possibility of stepping on machine supports or other physical objects to bypass or climb over the sensor.