Understanding the Standards for Safety Guard Switches
ISO 14119 – Interlocking Devices Associated with Guards

Introduction

It is common for machine builders and end users to wire their mechanical switches in series and in many cases not realize they are reducing their safety coverage due to "fault masking". On April 30, 2015, the standard "ISO 14119 Safety of Machinery – Interlocking Devices Associated with Guards" goes into effect and it will give the machine builder and end user better guidance on switch selection and new technology.

Background

New technology and stronger worldwide harmonization of standards has led to the most significant standard change for interlocking devices since 1995. The original standard "BS EN 1088:1995 Safety of Machinery – Interlocking devices associated with guards. Principles for design and selection" is being replaced by ISO 14119.

Additional clarification of diagnostic coverage calculations to meet ISO 13849-1 will be provided in the technical report "ISO/PDTR 24119 Safety of Machinery – evaluation of the fault masking serial connection of guard interlocking devices with potential free contact" which as of March 2015 is currently in development.

Changes

Symbol

Devices with monitored locking function will have this symbol.

Locking Types

Traditionally, switches were either designed to use power-to-lock or power-to unlock. Bistable locks are now defined in the standard. Bistable allows for two stable end positions with a single actuation, thus allowing the power to be used to apply the lock and release the solenoid guard switch.

Bistable

- power-to-lock and power-to-unlock are given the same status.

Electromagnetic locking

- power-to-lock is acknowledged
- holding force is continually monitored
- measures to detect defeat by forcing

Power-to-lock

- loss of power will result in unlocking the guard

Releasing

In the case that an operator is trapped inside the safeguarded space, several methods are defined.

Auxiliary

- release manually from outside the safeguarded space
- requires a tool
- reset require use of tool or appropriate control system measure
- Not suitable for emergency or escape release of guard locking

Escape

- release manually from inside the safeguarded space to leave the area
- possible without a tool

Emergency

- release manually from outside the safeguarded space
- possible without a tool
- reset require use of tool or appropriate control system measure

Lock holding force

Holding force is the force the device can withstand without being damaged or impair use. It is has a safety coefficient of 130%, which ranges in a force value between 600 and 1,400 N. The annex has a chart shows the maximum static forces a person can exert based on:

- direction of force (horizontal, vertical)
- posture (sitting, standing)
- force application (single hand, bi-manual, shoulder)

Coding Levels

More responsibility has been placed on the machine builder to evaluate ways the switch can be bypassed over the entire life cycle of the machine and to find ways to minimize it.

"The interlocking device shall provide the minimum possible interference with activities during operation and other phases of machine life, in order to reduce any incentive to defeat it."

Coding is used to make unique combinations so the system is more difficult to bypass.

Low devices have 1 to 9 variations. Examples include magnetic reed and re-teachable RFID switches.

Medium devices use between 10 to 1,000 variations. These may include devices such as trapped key and some RFID switches.

High devices have over 1,000 variations and are currently usually found in RFID devices.

Types

Switches are categorized into 4 different types.

Type 1 - Position switch that can be operated without a specific external actuating element.

Type 2 - Position switch that can only be operated with a specific actuating element
Type 3 - interlocking devices with non-contact actuated position switch with uncoded actuator
Type 4 - interlocking devices with non-contact actuated position switch with coded actuator

Mechanical	Physical Contact	Uncoded	Rotary cam	Type 1
			Linear cam	
			Hinge	
		Coded	Tongue	Type 2
			Trapped Key	
Non-contact	Inductive	Uncoded	Ferric	Type 3
	Magnetic		Magnet, solenoid	
	Capacitive			
	Ultrasonic			
	Optic			
	Magnetic	Coded	Coded magnet	Type 4
	RFID		Coded RFID	
	Optic		Optically coded tag	

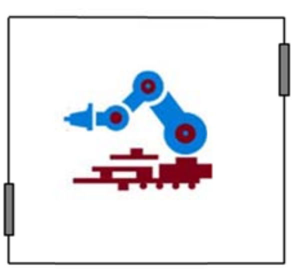
Fault Masking

Since emergency stop devices in series are an accepted practice and in many applications it does not reduce the overall PL (performance level) of their system, numerous end users believe it is also okay to apply the same concept to mechanical switches. Few understand the potential for a hazard to go undetected through "fault masking". This is even more cumbersome to explain since both types of devices can be dual channel mechanical contacts. The difference is how they are used.

When an emergency stop is activated, under most circumstances, only one (1) emergency stop device will be activated. The machine has been stopped and so there is no practical reason for a second emergency stop to be activated.

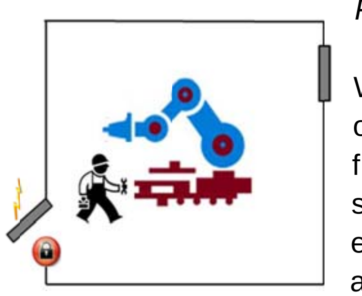
Fault masking is when there is an unknowingly or unintended resetting of faults, even with using a safety rated control system. The danger with this is when operators expect safety devices to be functional. So if a machine stopped due to a jammed part, the operator believes that opening the door will keep the machine in a safe state. The operator enters the hazard area and the machine starts unexpectedly when the jammed part is removed because the fault of the door switch was "masked" from a previous occurrence.

Over time this can lead to an accumulation of undetected faults.



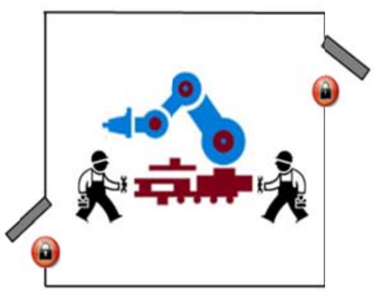
Example of a robot cell with 2 door switches

Mechanical switches have a single point of failure and these are only tested when there is a demand on the system (i.e., the door is opened). When only one switch is activated, the fault is detected when the system is reset.



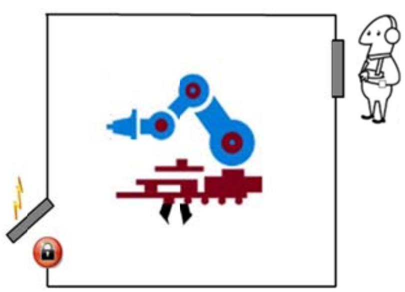
First door switch has a fault

When a gate is opened, there is a high possibility that another gate will be opened. Maintenance team members may be accessing the safeguarding area from different locations or troubleshooting different parts of the machine simultaneously. However, when multiple switches are activated, the activation of each switch resets the previous switch. So if there is a fault in the first switch, activating the second switch “masks” it.



Opening second door “masks” the fault from the safety controller

According to the ISO 14119 standard, *“Logical series connection of interlocking devices means for NC contacts wired in series or for NO contacts wired in parallel. When interlocking devices with redundant contacts are logically connected in series the detection of a single fault can be masked by the actuation of any interlocking device logically connected in series with the defective interlocking device to the safety control system.”*



Second person leaves while first person is still working in the safeguarded area. However, as soon as the reset button is pressed, it will go undetected and the system will start.

“It is foreseeable that during the fault finding (troubleshooting) by the operator one of the guards whose interlocking devices are logically connected in series with the defective interlocking device will be actuated. In that case the fault will be masked and the effect on the diagnostic coverage value shall be considered."

As more devices are connected in series, it shortens the time to a dangerous failure when doing mean time to dangerous failure calculations per ISO 13849-1.

For the following examples, assume the MTTF for all devices are 100 years. The first three examples show how the MTTFd (Mean Time To Dangerous Failure) decreases as more switches are added in series.

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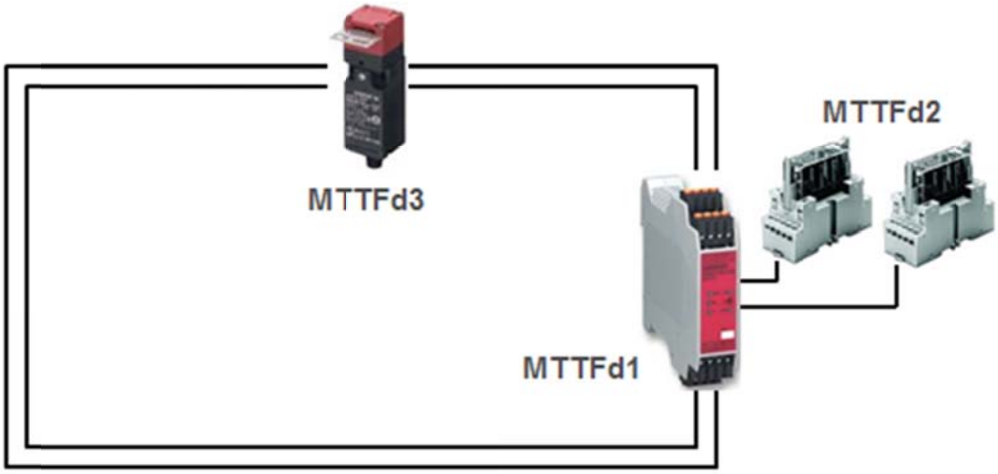
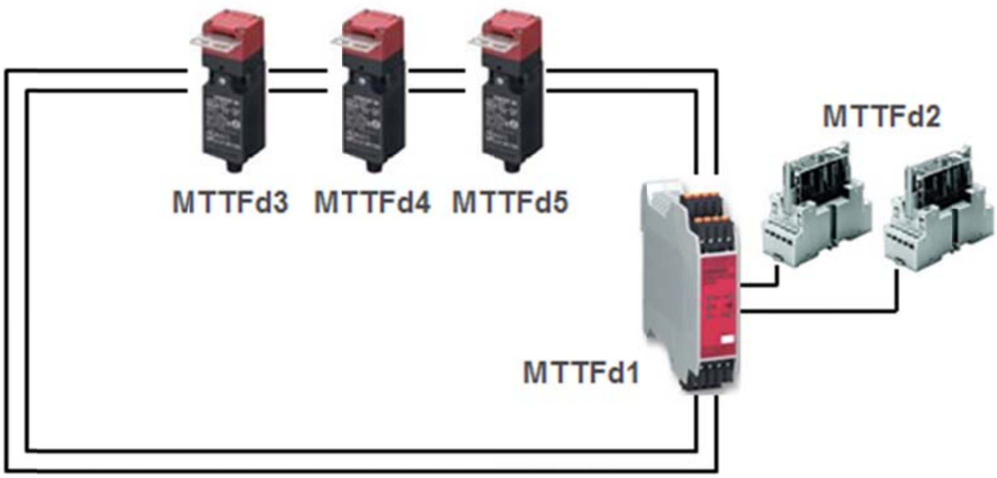
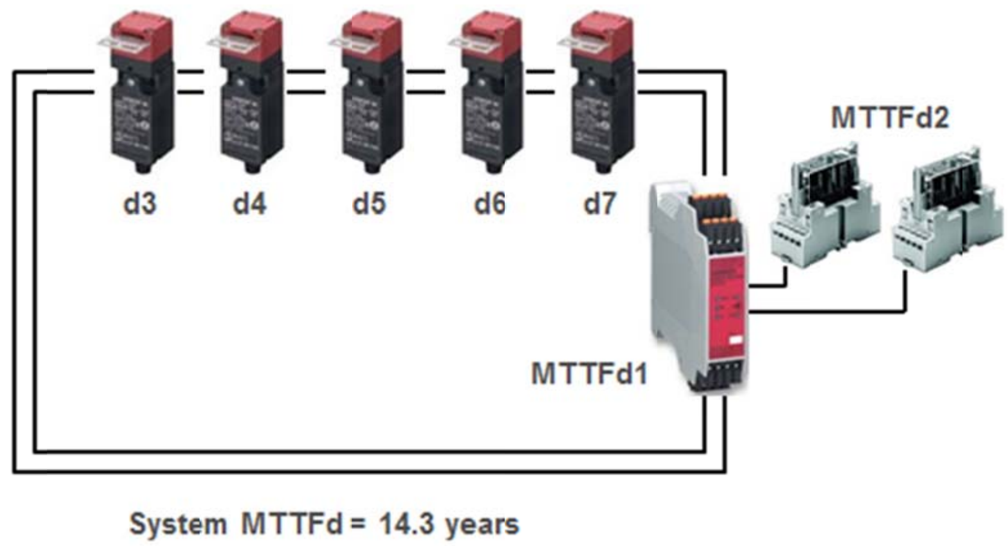


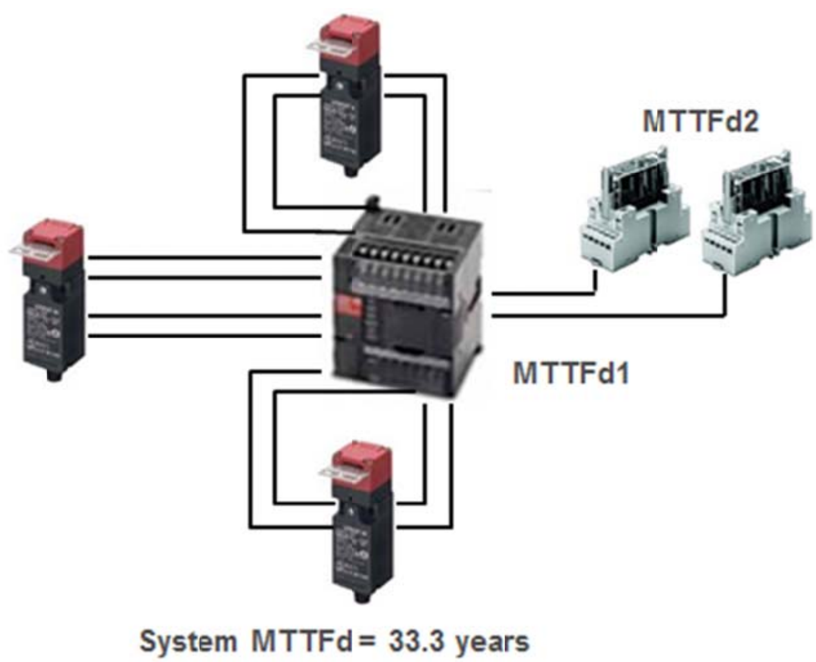
$$\text{System MTTFd} = \frac{1}{\frac{1}{MTTFd1} + \frac{1}{MTTFd2} + \frac{1}{MTTFd3}} = \text{33.3 years}$$



$$\text{System} = \frac{1}{\frac{1}{MTTFd1} + \frac{1}{MTTFd2} + \frac{1}{MTTFd3} + \frac{1}{MTTFd4} + \frac{1}{MTTFd5}} = \text{20 years}$$



Now use a safety controller, such as Omron G9SP, to monitor each device individually.



The probability of fault masking can also be influenced by the frequency of device activation, distance between devices, accessibility of moveable guards, and the number of operators.

Diagnostic coverage (DC) can be dependent on cabling, switch arrangement, and the likelihood of multiple guards being opened.

Summary

The standard has been revised to allow for the use of currently available technology and a technical report is in development to better explain safe principles when using mechanical switches in series.

Reliable methods to achieve a high level of diagnostic coverage and system PL (performance level) are:

- use a mechanical switch with individual monitoring
- add a second switch, such as a limit switch
- use non-contact switches, such as D40Z, which can maintain PLe in series.

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