Basics of Safety Applications
THE INFORMATION PROVIDED HEREIN IS PROVIDED AS A GENERAL REFERENCE REGARDING THE USE OF THE APPLICABLE PRODUCTS IN GENERIC APPLICATIONS. THIS INFORMATION IS PROVIDED WITHOUT WARRANTY. IT IS YOUR RESPONSIBILITY TO ENSURE THAT YOU ARE USING ALL SIEMENS PRODUCTS PROPERLY IN YOUR SPECIFIC APPLICATION. ALTHOUGH THIS SITE STRIVES TO MAINTAIN ACCURATE AND RELEVANT INFORMATION, THERE IS NO OFFICIAL GUARANTEE THAT THE INFORMATION PROVIDED HEREIN IS ACCURATE. IF YOU USE THE INFORMATION PROVIDED HEREIN IN YOUR SPECIFIC APPLICATION, PLEASE DOUBLE CHECK ITS APPLICABILITY AND BE ADVISED THAT YOU ARE USING THIS INFORMATION AT YOUR OWN RISK. THE PURCHASER OF THE PRODUCT MUST CONFIRM THE SUITABILITY OF THE PRODUCT FOR THE INTENDED USE, AND ASSUME ALL RISK AND LIABILITY IN CONNECTION WITH THE USE.
Why Safety Technology?

Protection of...
- People
- Environment
Why safety technology?

ISO – International Standards
IEC, ISO.
E.g. IEC 61508, IEC 62061, IEC 61511

USA:
UL, ANSI, NFPA

Europe:
IEC, EN
E.g. IEC 62061, EN ISO 13849

Japan:
JIS

The regulations and standards applicable at the installation location of the system or machine are decisive. All countries follow the same basic principles for application. The European standards and regulations are recognized worldwide.
What aspects do the safety standards cover

<table>
<thead>
<tr>
<th>Feature</th>
<th>EN 954-1</th>
<th>EN ISO 13849-1</th>
<th>IEC 61508</th>
<th>IEC 62061</th>
</tr>
</thead>
<tbody>
<tr>
<td>For manufacturers of</td>
<td>Machinery</td>
<td>Machinery</td>
<td>Components</td>
<td>Machinery</td>
</tr>
<tr>
<td>Technology</td>
<td>Also non-electrical</td>
<td>Also non-electrical</td>
<td>Electrical</td>
<td>Electrical</td>
</tr>
<tr>
<td>Concept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety function</td>
<td></td>
<td>Parts Categories</td>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>Required safety level</td>
<td></td>
<td>---</td>
<td>PL&lt;sub&gt;r&lt;/sub&gt;</td>
<td>SIL</td>
</tr>
<tr>
<td>Probability of failure</td>
<td></td>
<td></td>
<td>PFH&lt;sub&gt;D&lt;/sub&gt;</td>
<td>PFH&lt;sub&gt;D&lt;/sub&gt;</td>
</tr>
<tr>
<td>Use of programmable electronics</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(PLC, ...)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presumption of conformity, if applied</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The necessary steps towards a safe machine can be illustrated with a process chain.

**Risk Assessment**
- Cutting disc > Cutting off
- Chips > Cutting, penetrating
- Clamping plates > Crushing

**Risk Reduction**
- Cutting disc > Cutting off
- Transport rollers > Crushing and shearing

**Proof**
The necessary steps towards a safe machine can be illustrated with a process chain.

**Risk Assessment**
- Describe the machine
- Identify the hazards
- Evaluate the risks

**Risk Reduction**
- Define and evaluate the safety measures
- Design the architecture of the safety functions
- Implement a safety concept and put it into operation

**Proof**
- Document the measures
- Carry out a validation
- Document results
The measure for achieved functional safety is the probability of dangerous failures, the fault tolerance and the quality that is to be guaranteed as a result of freedom from systematic faults. It is expressed in the standards using different terms:

- In IEC 62061: “Safety Integrity Level” (SIL)
- In ISO 13849-1: “Performance Level” (PL)
Risk Reduction

Risk Assessment  Risk Reduction  Proof

Mechanical Guarding

Education

Technology solutions consist of three main components

Detection  Evaluation  Reaction
Detection
Emergency stop and protective area monitoring

Initiates stop
Prevents unauthorized access
Detects dangerous machine functions
Positive opening contacts

Positive opening switches are designed in such a way that actuation of the switch always results in opening the contacts. Welded contacts are opened by actuation (EN 60947-5-5)
Detection

Standard position switches

Safety switch with separate actuator

Safety switch hinge switch

Safety switches with separate actuator and interlocking
Detection

Panel Mounted

Configurable Enclosures

Distributed Safety
<table>
<thead>
<tr>
<th>Achievable safety level with ONE Position switches</th>
<th>Evaluation units</th>
<th>Position switches</th>
<th>Safety switches, hinge switches</th>
<th>Safety switches with separate actuator</th>
<th>Safety switches with optional tumbler function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring an NC contact</td>
<td>SIL 1 / PL c</td>
<td>SIL 1 / PL c</td>
<td>SIL 1 / PL c</td>
<td>SIL 1 / PL c</td>
<td></td>
</tr>
<tr>
<td>Monitoring of 2 NC contacts or 1 NC contact + 1 NO contact</td>
<td>SIL 1 / PL c</td>
<td>SIL 2 / PL d</td>
<td>SIL 2 / PL d</td>
<td>SIL 2 / PL d</td>
<td></td>
</tr>
<tr>
<td>Achievable safety level with TWO position switches</td>
<td>Position switches</td>
<td>SIL 3 / PL e</td>
<td>SIL 3 / PL e</td>
<td>SIL 3 / PL e</td>
<td></td>
</tr>
</tbody>
</table>
Detection

<table>
<thead>
<tr>
<th>Safe evaluation units</th>
<th>Detection units Non-contact safety switches</th>
</tr>
</thead>
<tbody>
<tr>
<td>3SK1 safety relay</td>
<td>Solenoid-operated switches 3SE66 / 3SE67</td>
</tr>
<tr>
<td>3RK3 Modular Safety System</td>
<td>RFID safety switches 3SE63</td>
</tr>
<tr>
<td></td>
<td>Sil 3 / Pl e</td>
</tr>
<tr>
<td></td>
<td>Sil 3 / Pl e</td>
</tr>
<tr>
<td></td>
<td>Sil 3 / Pl e</td>
</tr>
</tbody>
</table>
Safety-rated contactors **must include** positively driven (mirror) contacts

A component with positive-driven contacts guarantees that the NC and NO contacts are never closed simultaneously (EN 60947-5-1)

A mirror contact is an NC contact that is guaranteed not to be closed at the same time as a main contact (EN60947-4-1)

Siemens 3RT contactors comply with this requirement
Evaluation
Monitors Inputs / Initiates Reaction

Safety Relays
- Limited inputs and outputs
- Simple logic
- Single Zone

Programmable Safety Relays
- Moderate inputs and outputs
- Simple to semi-complex logic
- Multiple Zone

Distributed Safety Systems
- Distributed multiple inputs and outputs
- Complex Logic
- Multiple Zone
Siemens Safety Integrated
Machine safety solution selection

3 Safety Functions
Without PC

8 Safety Functions
Graphical Editor

25 Safety Functions
Programming Language e.g., LAD/F-LAD

>25 Safety Functions

3 Safety Functions

8 Safety Functions

25 Safety Functions

>25 Safety Functions

Without PC

Graphical Editor

Programming Language e.g., LAD/F-LAD

Safety Relays

ASI-Safe

Modular Safety System

Fail-Safe Controllers

Fail-Safe Controllers

Cabinet-Free (IP 65/67)

In-Cabinet (IP 20)

In-Cabinet (IP 20)

Cabinet-Free (IP 65/67)
Functionality of a Safety Circuit
A review

- **Sensors**
  - Initiate machine shut down

- **Positive Opening**
  - Guarantees that all NC contacts are in the open position when actuated

- **Redundancy**
  - Ensures safety functionality even if a failure disables one channel

- **Evaluation**
  - Fault detection and evaluation; opens the circuit in case of a failure.

- **Feedback Loop**
  - Monitors the correct operation of the contactor coils

- **Positive Driven (Mirror)**
  - Guarantees that NC contacts are not to be closed at the same time as the main contact

- **Reset**
  - Reactivates the safety circuit
Safety Levels
PL a

PL a allows
• NO contacts for
• Enabling
• Two-hand control
• Restart
Safety Levels
PL b

PL b requires
• Sensors with positive opening contacts
Safety Levels
PL c / SIL 1

- Sensors with positive opening contacts
- Safety evaluation unit rated to SIL 1
- Feedback loop from contactor’s NC contacts

PL c / SIL 1 requires:
- Safety evaluation unit rated to SIL 1
- Feedback loop from contactor’s NC contacts
Safety Levels
PL d / SIL 2

- Sensors with positive opening contacts
- Safety evaluation unit rated to SIL 2
- Feedback loop from contactor’s NC contacts
- Redundancy in sensor contacts
- Redundancy in contactors

PL d / SIL 2 requires
Safety Levels
PL e / SIL 3

PL e / SIL 3 requires
• Sensors with positive opening contacts
• Safety evaluation unit rated to SIL 3
• Feedback loop from contactor’s NC contacts
• Redundancy in sensor contacts
• Redundancy in contactors
• Separate channels of evaluation for sensors
## Siemens Safety Evaluation Portfolio

<table>
<thead>
<tr>
<th></th>
<th>3SK1</th>
<th>3SK2</th>
<th>MSS ASIsafe</th>
<th>MSS 3RK3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety device</strong></td>
<td>Safety Relays</td>
<td>Safety Relays</td>
<td>Modular Safety System</td>
<td>Failsafe SIMATIC PLCs and distributed I/O</td>
</tr>
<tr>
<td></td>
<td>SIRIUS 3SK</td>
<td>SIRIUS 3SK</td>
<td>SIRIUS 3RK3</td>
<td></td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
<td>Hardware-parameterized</td>
<td>Software-parameterized</td>
<td>Software-parameterized</td>
<td>Software-programed</td>
</tr>
<tr>
<td><strong>Number of safety functions</strong></td>
<td>Up to 3*</td>
<td>Up to 6</td>
<td>Up to 20</td>
<td>From 10</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>None</td>
<td>AS-i and PROFIBUS</td>
<td>AS-i, PROFIBUS, PROFINET, PROFIsafe, I-WLAN</td>
<td></td>
</tr>
</tbody>
</table>
Online Configurator

Industrial Controls

www.siemens.com/industrymall

Safety Relays 3SK

The new 3SK safety relays offer outstanding simplicity, flexibility and efficiency. Their modular design facilitates system engineering, commissioning and expansion. Selecting the optimum motor starter is child's play with the 3SK Configurator. In just a few steps, you can add simple safety functions, such as emergency stop or protective door monitoring systems. Simply select the number of sensors and actuators you require, and the program will determine your optimum system configuration, consisting of basic units and input and output expansions. This means you are able to quickly and easily implement a safe and productive system.
Evaluation - Safety Relay

3SK1 Standard

Output Expansion

4 RO
5 Amp

3 RO
10 Amp
3SK1 Advanced

Power Supply

Input Expansion

Output Expansion

Device Connector
New 3SK1 Safety Relay
Safety Relay Application Example
Evaluation – Programmable Safety Relay

Power Supply

3SK2

Output Expansion

Device Connector
Evaluation – Programmable Safety Relay

Area Estop

Zone Estop

Zone Estop
SIRIUS Innovations
Motor starter 3RM1 Failsafe

Direct / reversing start
Same Size Enclosure

With Safety functionality
• Suitable for safety applications up to PL e / SIL 3

With overload protection
• ATEX certified up to SIL 2
**Evaluation**

SIL 3 application with a safety relay

6 Wires / starter
- 4 wires for 2 coils
- 2 wires for feedback
SIRIUS 3SK1 and 3RM1 Failsafe Application
Distributed Safety

SIMATIC AS-i F-Link with TIA Portal

PROFINET / PROFIsafe

SIMATIC PN / AS-i F-Link
AS-i double master and F-DI module

AS-i / ASIsafe

Safety cell

Standard data

Safety cell
3 Application examples ........................................................................................................... 21

3.1 Introduction .................................................................................................................... 21

3.2 Stopping in an emergency .............................................................................................. 23

3.2.1 Introduction ................................................................................................................. 23

3.2.2 Emergency stop shutdown to SIL 1 or PL c with a 3SK1 safety relay ......................... 25

3.2.3 Emergency stop shutdown to SIL 1 or PL c with a Modular Safety System .............. 27

3.2.4 Emergency stop shutdown to SIL 3 or PL e with a 3SK1 safety relay ......................... 29

3.2.5 Emergency stop shutdown to SIL 3 or PL e with a 3SK2 safety relay ......................... 31

3.2.6 Emergency stop shutdown to SIL 3 or PL e with a modular safety system ............... 33

3.2.7 Emergency stop shutdown to SIL 3 or PL e with fail-safe motor starters and a 3SK1 safety relay ......................................................................................................................... 35

3.2.8 Emergency stop shutdown to SIL 3 or PL e with fail-safe motor starters and a modular safety system ......................................................................................................................... 37

3.2.9 Emergency stop shutdown via AS-i to SIL 3 or PL e with a Modular Safety System .... 39

3.3 Protective door monitoring ............................................................................................. 41

3.3.1 Introduction ................................................................................................................. 41

3.3.2 Terminology from the standard .................................................................................... 42

3.3.3 Protective door monitoring to SIL 1 or PL c with a 3SK1 safety relay ......................... 50

3.3.4 Protective door monitoring to SIL 1 or PL c with a Modular Safety System .............. 52

3.3.5 Protective door monitoring to SIL 3 or PL e with a 3SK1 safety relay ......................... 54

3.3.6 Protective door monitoring to SIL 3 or PL e with a 3SK2 safety relay ......................... 56

3.3.7 Protective door monitoring to SIL 3 or PL e with a Modular Safety System ............... 58

3.3.8 Protective door monitoring to SIL 3 or PL e with a fail-safe motor starter and a 3SK1 safety relay ......................................................................................................................... 60

3.3.9 Protective door monitoring to SIL 3 or PL e with a fail-safe motor starter and a modular safety system ......................................................................................................................... 62

https://support.industry.siemens.com/
Safety Application Manual

3.2.5 Emergency stop shutdown to SIL 3 or PL e with a 3SK2 safety relay

Application
Two-channel emergency stop shutdown of a motor of a 3SK1 safety relay and power contactor.

Design

Operating principle
The safety relay monitors the emergency stop command device on the switch. When the operating switch is actuated, a normally closed contact closes and actuates the emergency stop relay. The controlling circuit checks whether the emergency stop command device is selected and the feedback circuit is closed; the start button can be used to switch on again.

See also:
Circuit diagram, 3SK2 project and STC calculation
Siemens Safety Integrated
Machine Safety Life-Cycle Support — USA

Siemens provides competent support throughout the entire machine safety lifecycle

Support
- Safety Consultants
- Safety Core Team
- Safety Validation

Implementation
- Siemens Solution Partners – Safety
- Safety Functional Examples
- Safety Training
- Risk Assessment Training

Safety Education
- Machine Safety Standards
- Safety Webinars
- Newsletter
- Safety White Papers
- Siemens Safety Website

Compliance
- OSHA Website
- Consensus Standards
- Risk Assessment Standard
- Safety Evaluation Tool - SET

Products and Solutions
- Safety Products
- Safety Software
- Wireless Safety
- PC-Based Safety
- BMS
Basics of Safety Applications

John Burns
Lead Application Consultant
SII DF CP
5300 Triangle Parkway
Norcross, GA 30092
Tel.: +1 (770) 625-5726
Fax: +1 (678) 297-7250
Cell: +1 (678) 575-3086
E-mail: john.burns@siemens.com

siemens.com