

# Safety over EtherCAT Overview

EtherCAT Technology Group



**EtherCAT**<sup>®</sup>  
Technology Group

- Requirements
- Safety over EtherCAT Technology
  - Architecture
  - Definitions
  - State Machine
  - Telegram
  - Summary
- Conformance
- Applications

## Requirements

### Safety over EtherCAT

- Architecture
- Definitions
- State machine
- Frame structure
- Summary

### Conformance

### Applications

- Functional Safety
  - Protection against malfunction of machines
  - Protection of the machine operator against dangerous movements
- Safety functions (Examples)
  - Monitoring of the workspace of a machine
    - Door guarding (with interlocking)
    - Protection with light curtain / laser scanner
  - Safe feeding of material
    - Muting
- Safe movement with manual intervention
  - Two-Hand control
  - Emergency Stop
  - Safe operating stop
  - Safely-limited speed

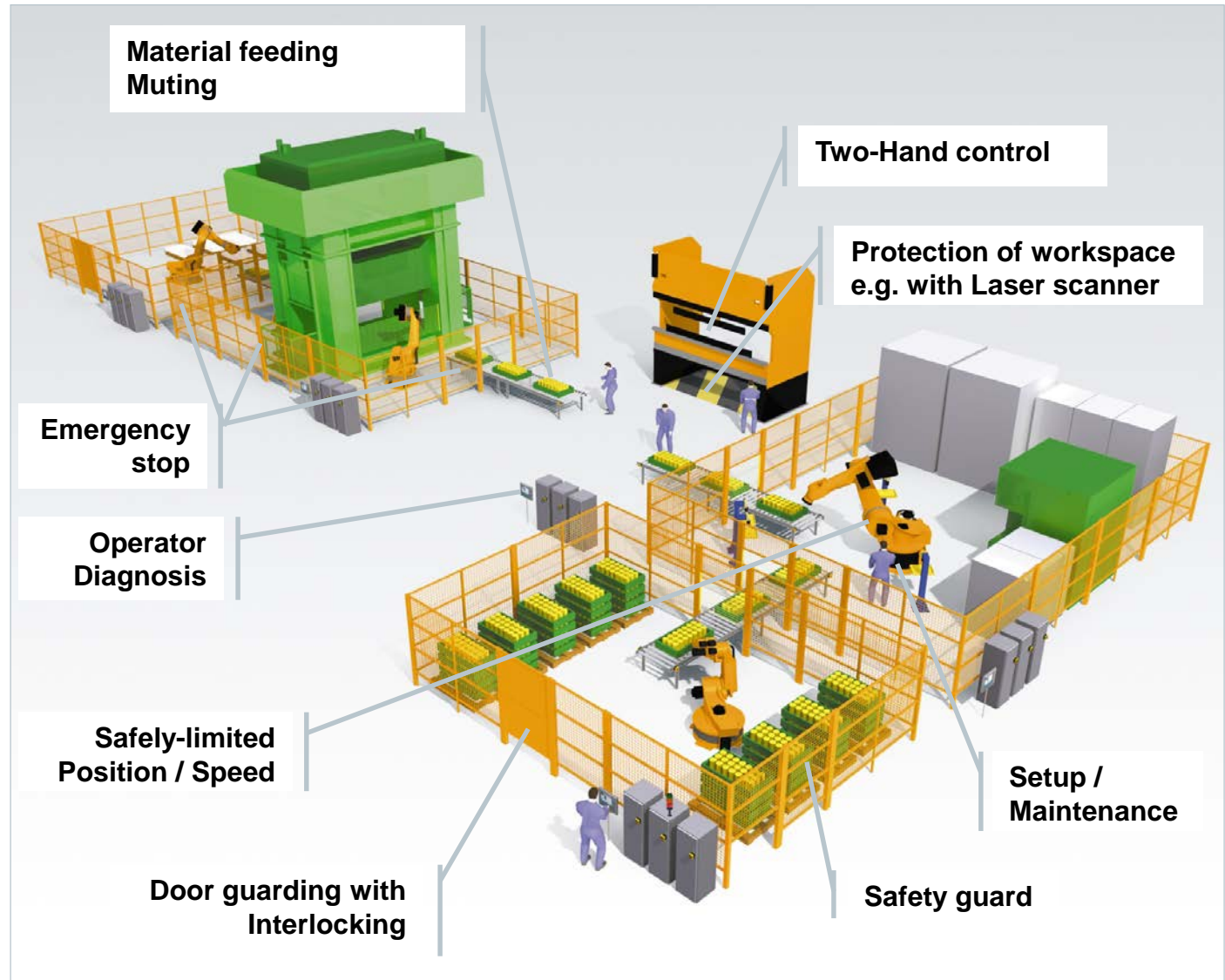
## Requirements

### Safety over EtherCAT

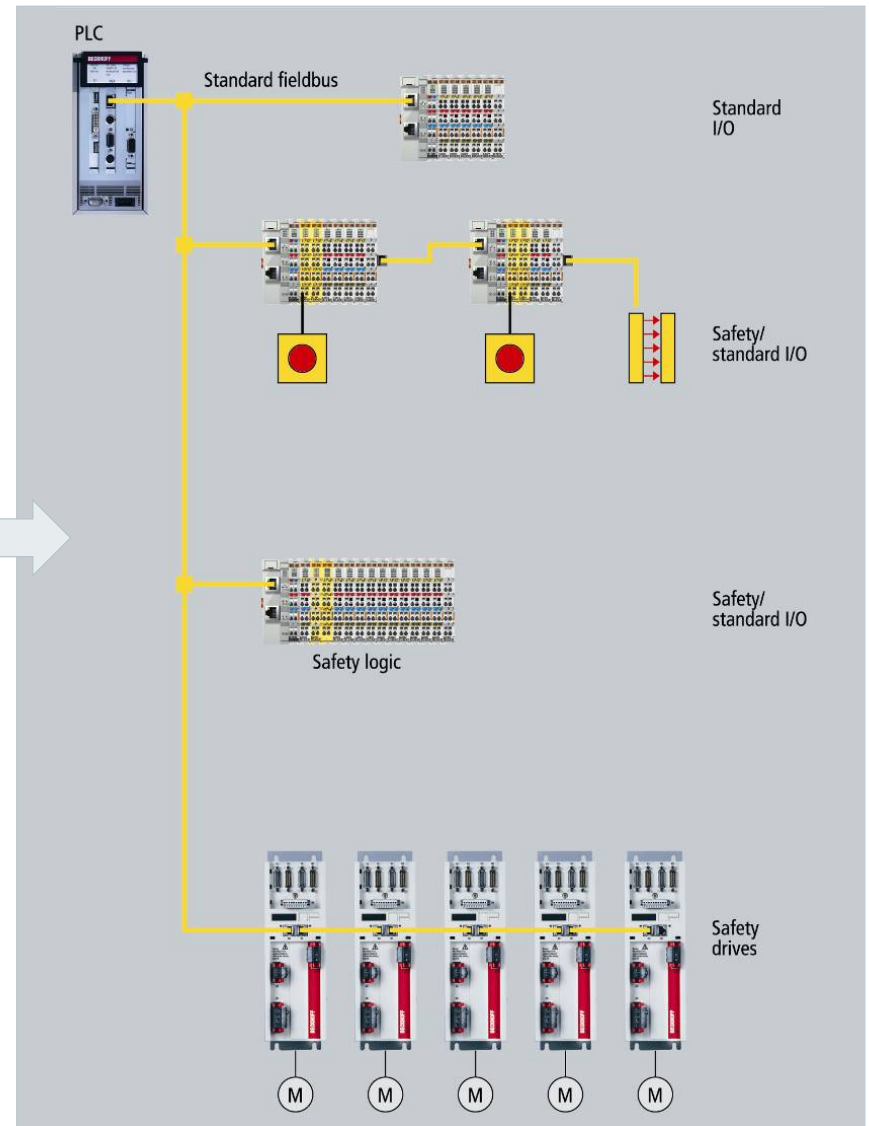
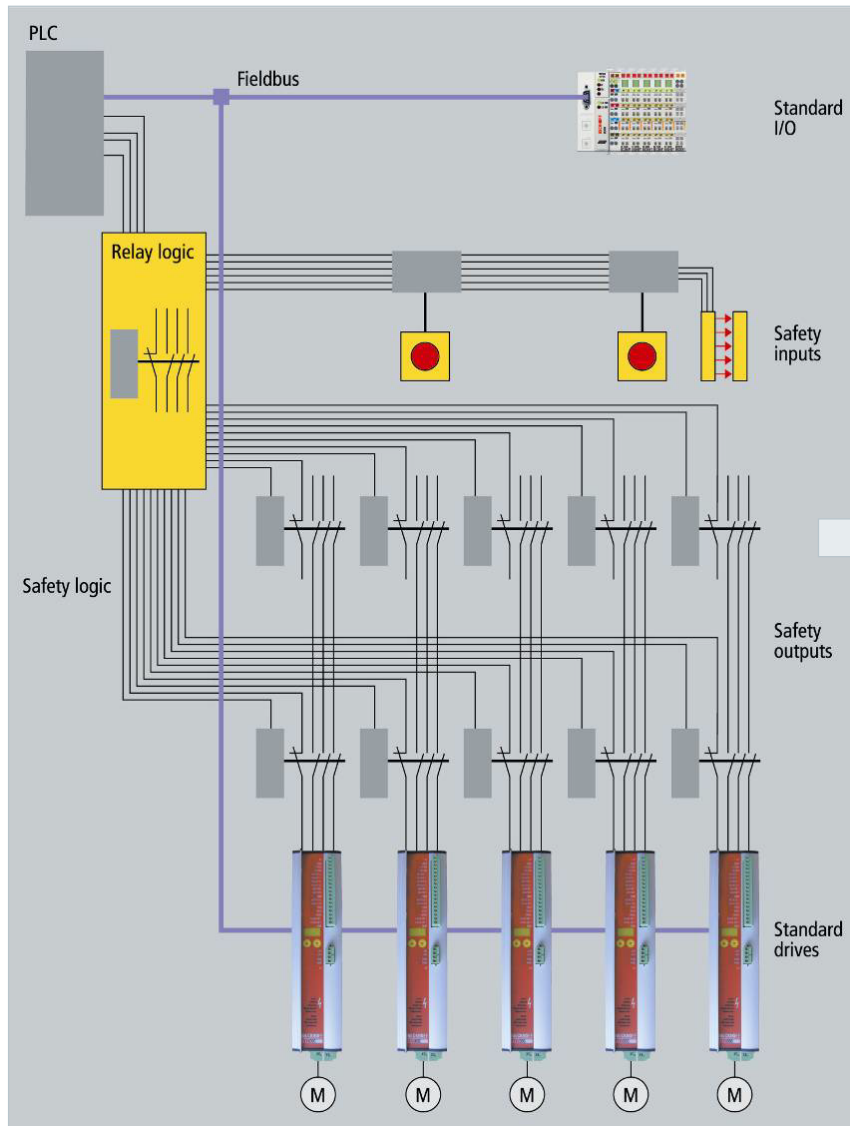
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### Conformance

### Applications



# Modern safety concepts



# Advantages of Safetybus systems

## Requirements

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### Applications

- Fast reaction
  - applicable for high dynamic drive architecture
- Simplified System
  - better clarity
  - simple cabling
  - simple extension of the system
  - better diagnosis
  - and therefore: higher safety
- Pre-tested safety functions within the devices according to the legal standards
- Lower costs

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### Applications

- German approach: BGIA Test principles GS-ET-26
  - Test principles of the German Institute for Occupational Safety and Health
  - Bus systems for the transport of safety-related messages
  - Assessment requirements of the BGIA to evaluate safety bus systems
  - Basis of the IEC 61784-3
- IEC 61784-3
  - DIGITAL DATA COMMUNICATIONS FOR MEASUREMENT AND CONTROL  
Part 3: **Profiles for functional safety communications in industrial network** - General rules and profile definitions
  - Based on Black Channel approach (see below)



# IEC 61784-3

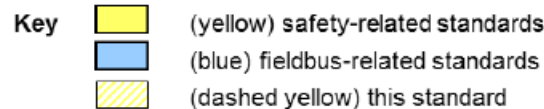
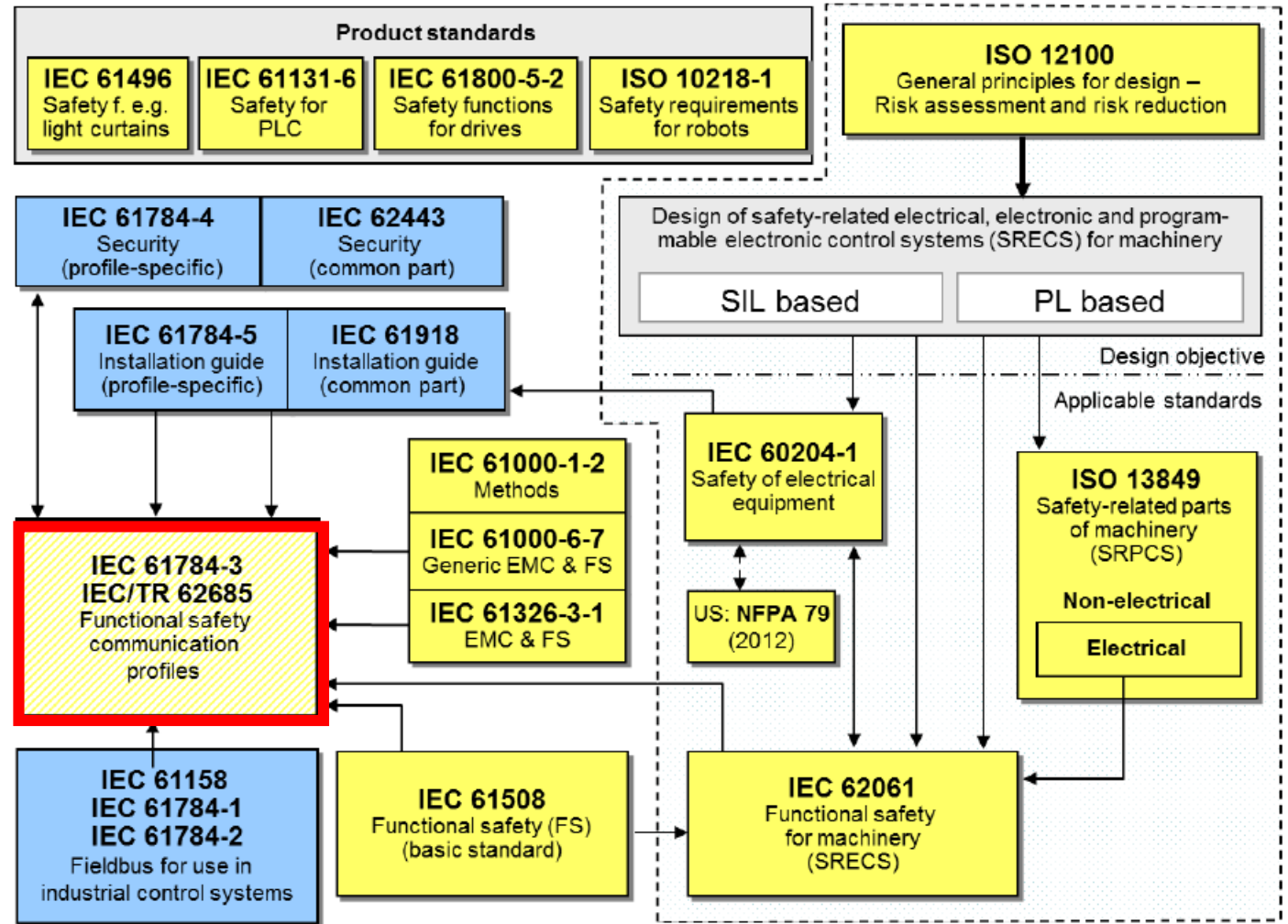
Requirements

Safety over  
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Applications





# IEC 61784-3

## Functional safety communication model

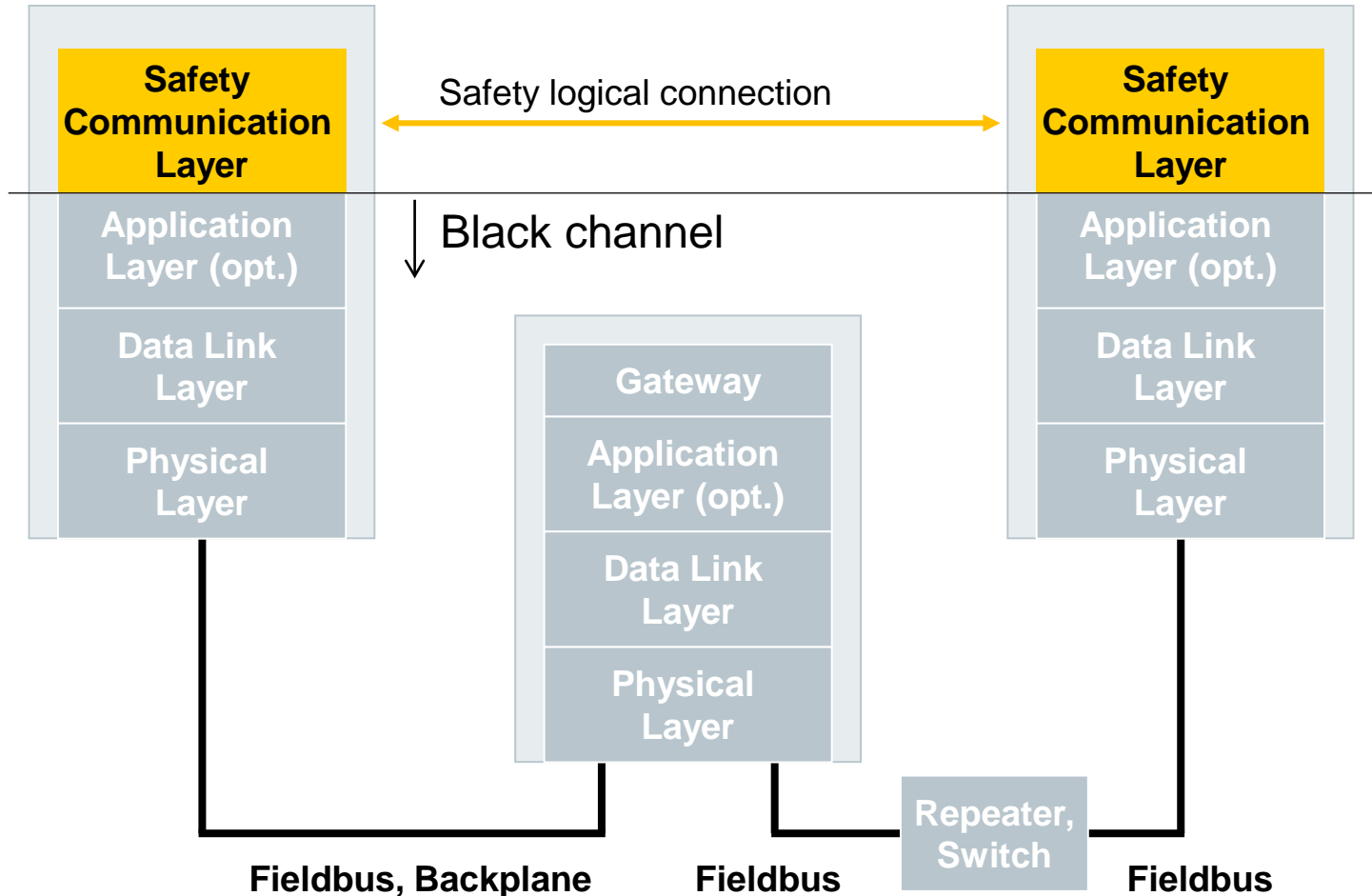
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# Safety function decomposition

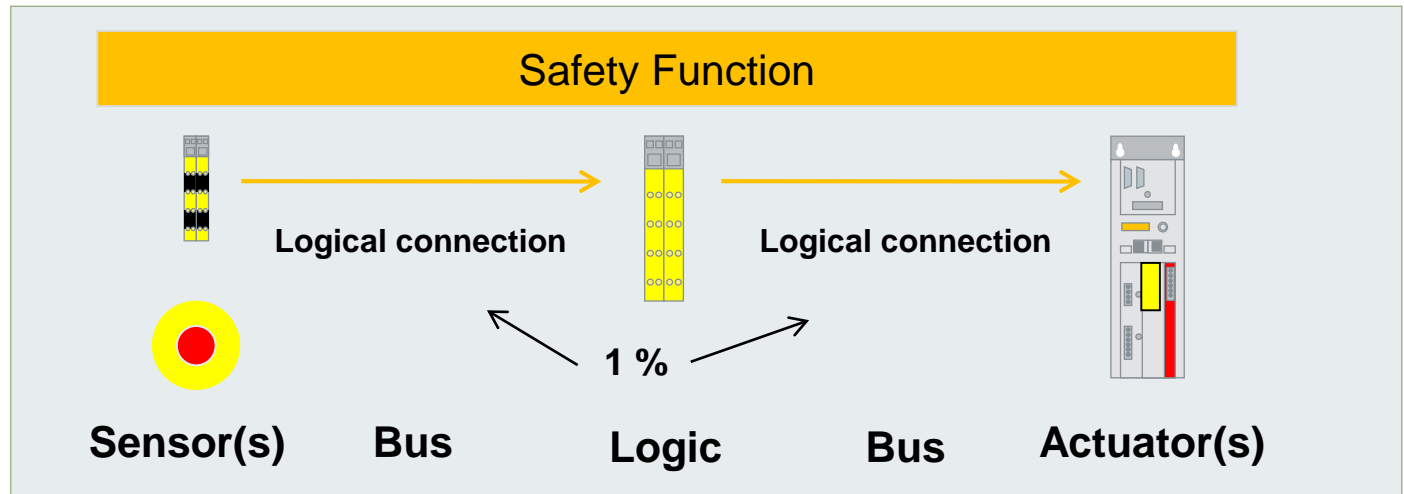
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- Probability of failure for the **safety function**, according to IEC 61508:

$$PFH_{\text{SafetyFunction}} < 10^{-8} \dots 10^{-7} / \text{h for SIL 3}$$

- The IEC 61784-3 highly recommends that the safety communication channel **does not consume more than 1 %** of the maximum PFD or PFH of the target SIL for which the functional safety communication profile is designed:

$$PFH_{\text{LogicalConnection}} < 10^{-9} / \text{h for SIL3}$$

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### Applications

- **Safety-over-EtherCAT** defines a safe communication layer, to transfer safe process data between Safety-over-EtherCAT devices.
- FSoE is an open technology
  - Supported by EtherCAT Technology Group (ETG)
  - Part of IEC 61784-3 international standard
- The protocol is approved by an independent Notified Body (TÜV Süd Rail GmbH).

Safety over  
EtherCAT®

# FSoE – Typical Hardware Architecture

## Requirements

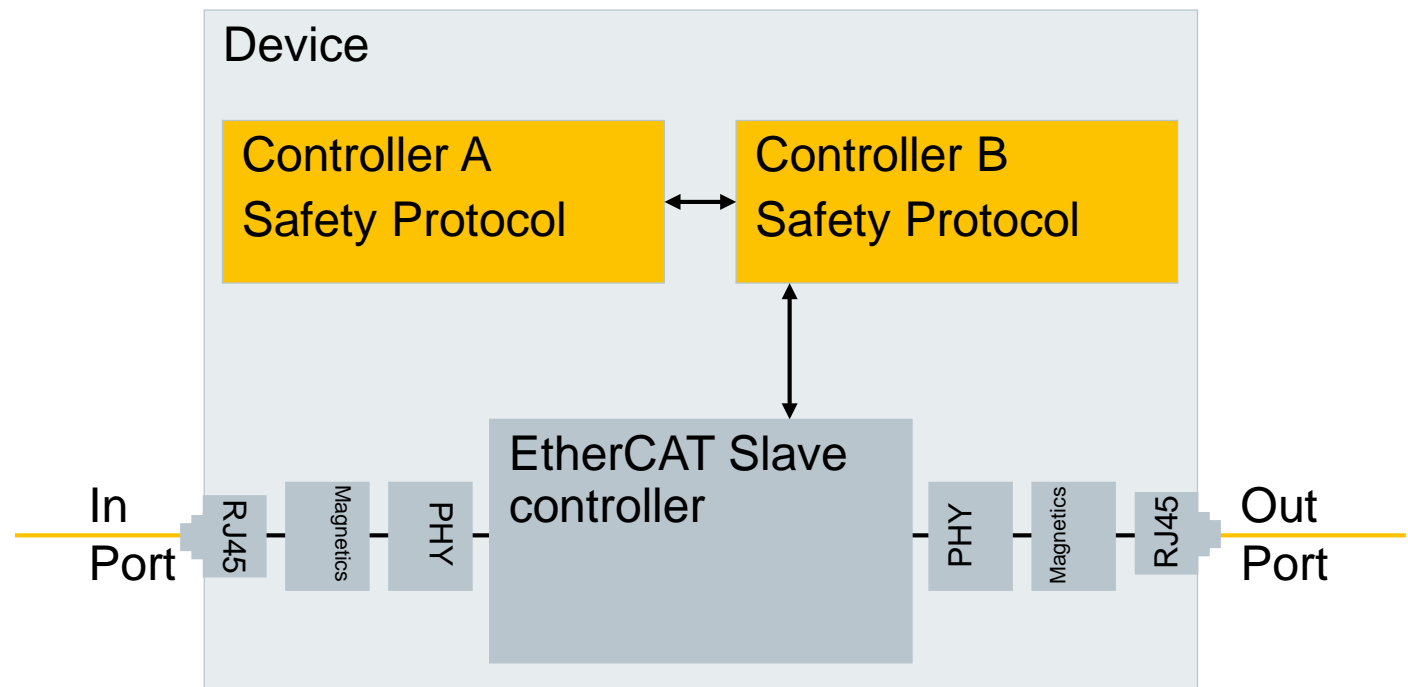
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### Applications

- 1-channel standard communication system
- Redundant hardware for safety protocol and safety-related application



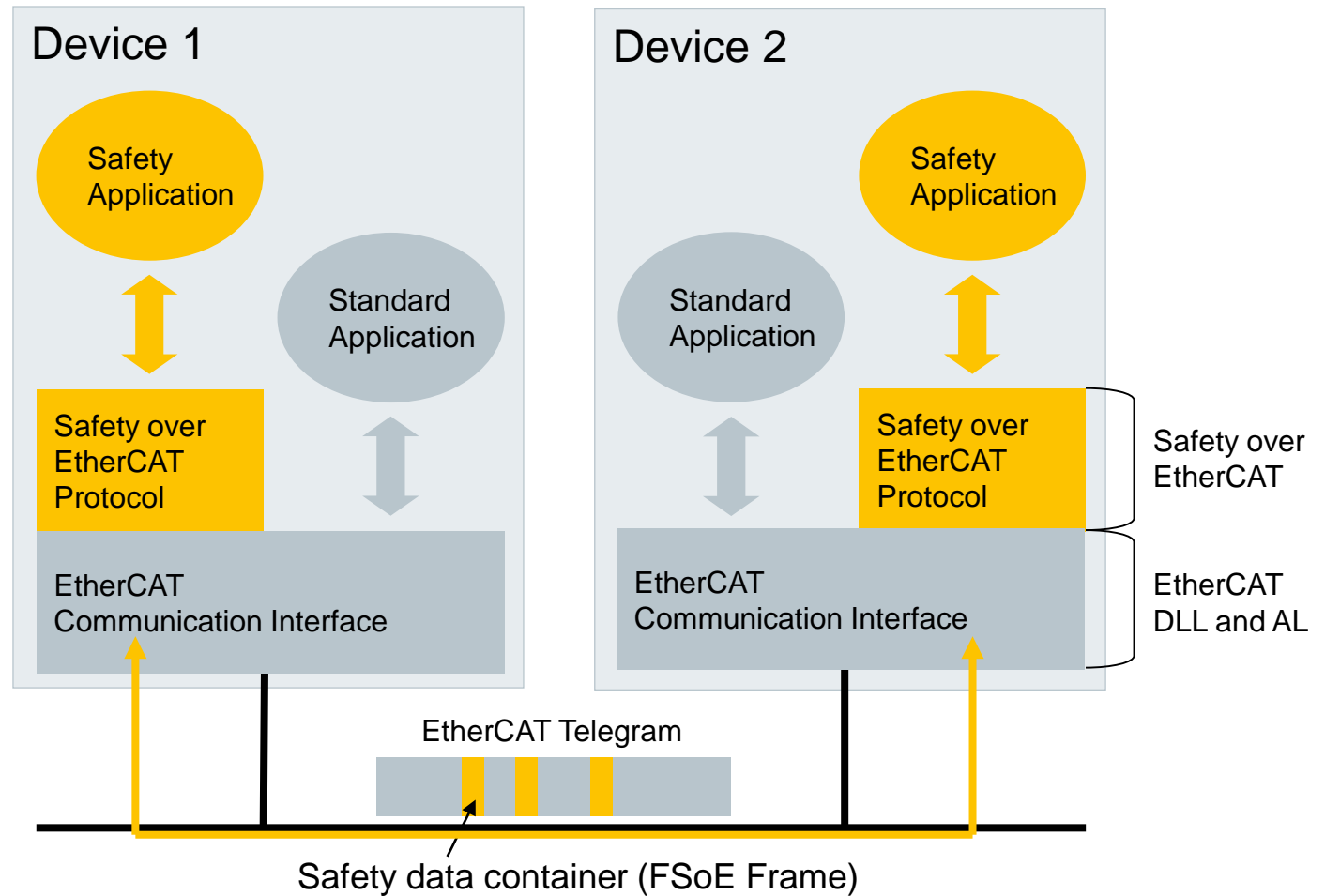
## Requirements

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**EtherCAT is used as a “black channel”.**  
**It contains safety and standard information.**

## Requirements

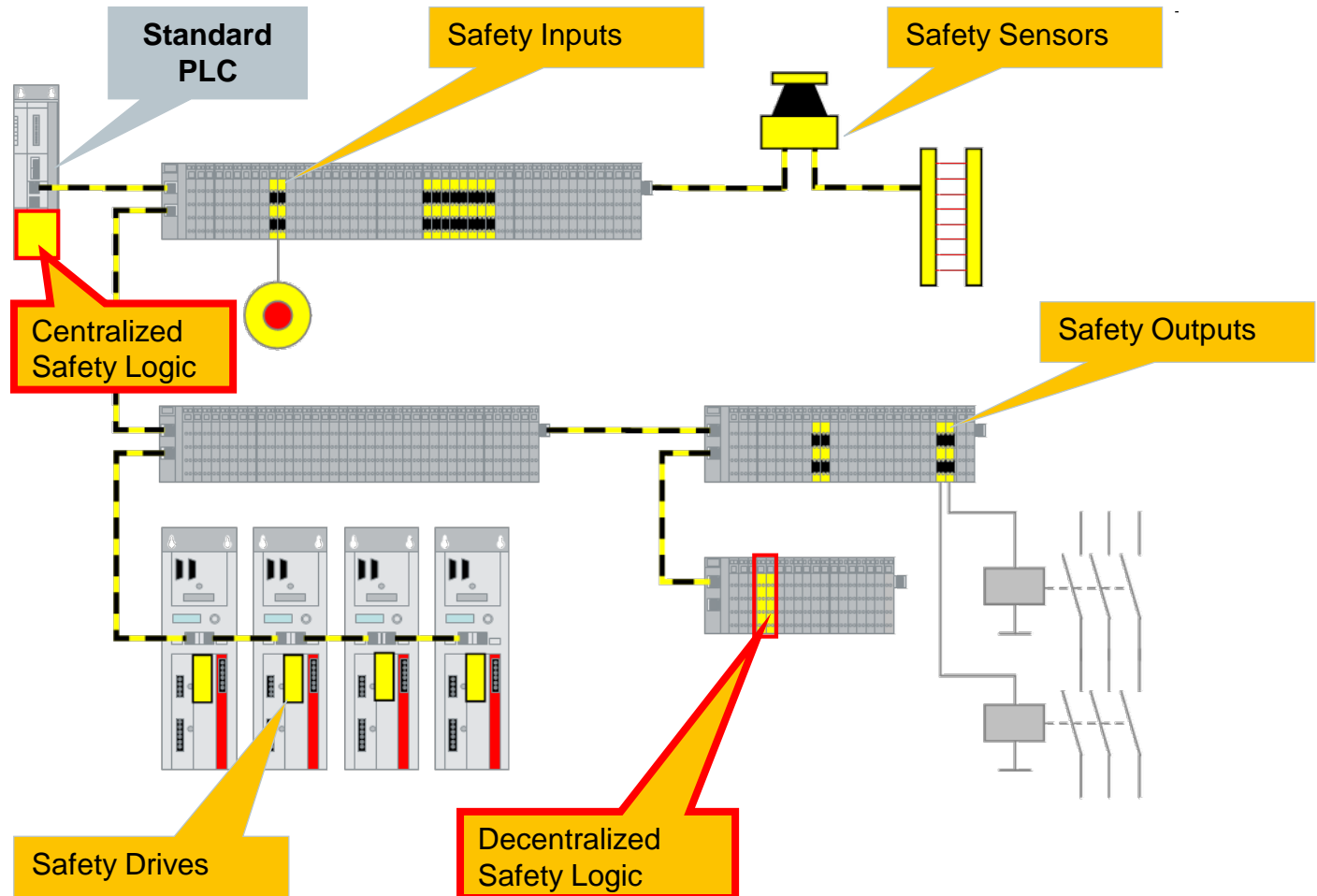
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### Applications

- Centralized or decentralized Safety-Logic
- Standard PLC routes the safety messages



# FSoE – Master / Slave Connection

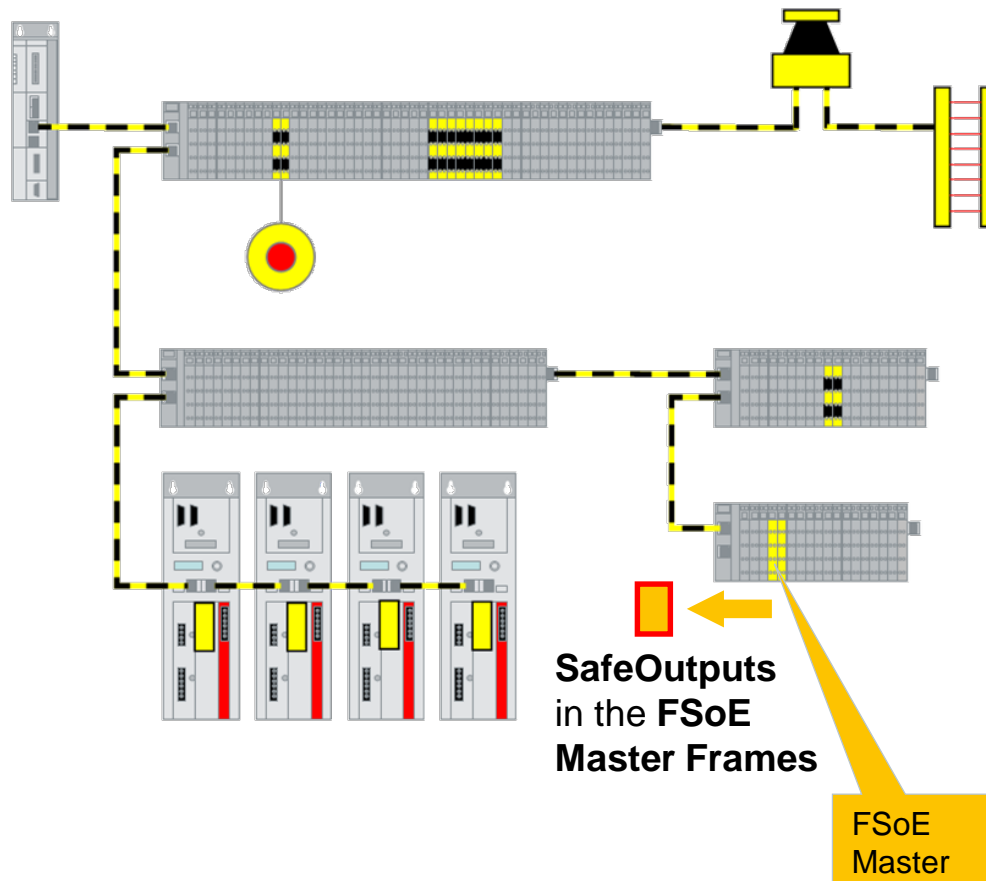
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## FSoE Master

Master of an FSoE Connection. The FSoE Master initiates the safety communication.

The FSoE Master sends an **FSoE Master Frame**, that contains the **SafeOutputs**.

An FSoE Master can handle one or more FSoE Slaves.



# FSoE – Master / Slave Connection

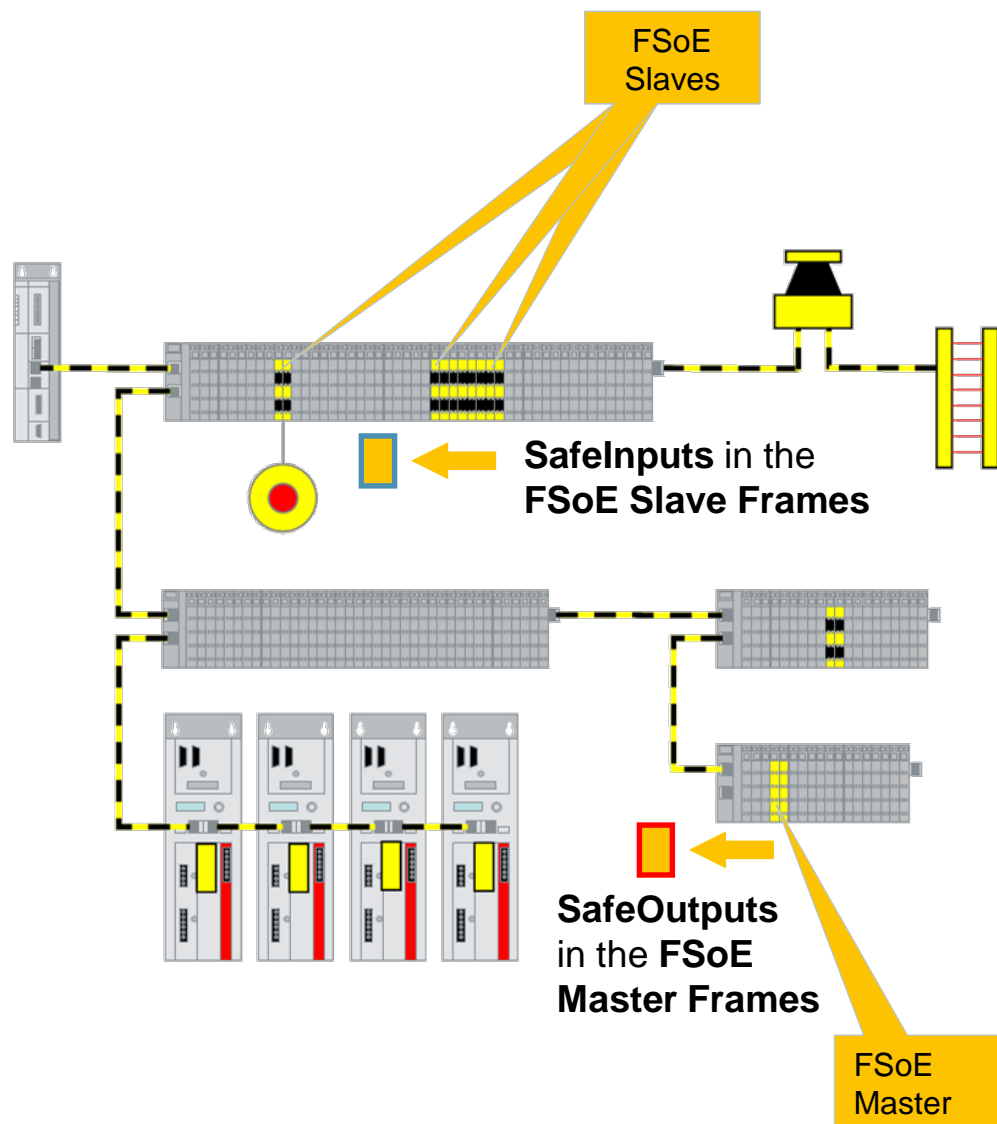
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## FSoE Slave

Slave of an FSoE Connection.

The FSoE Slave sends the **FSoE Slave Frame**, after receiving a valid FSoE Master Frame.

The FSoE Slave Frame contains the **SafeInputs**.

An FSoE Slave is assigned to one FSoE Master.

# FSoE – Communication Cycle

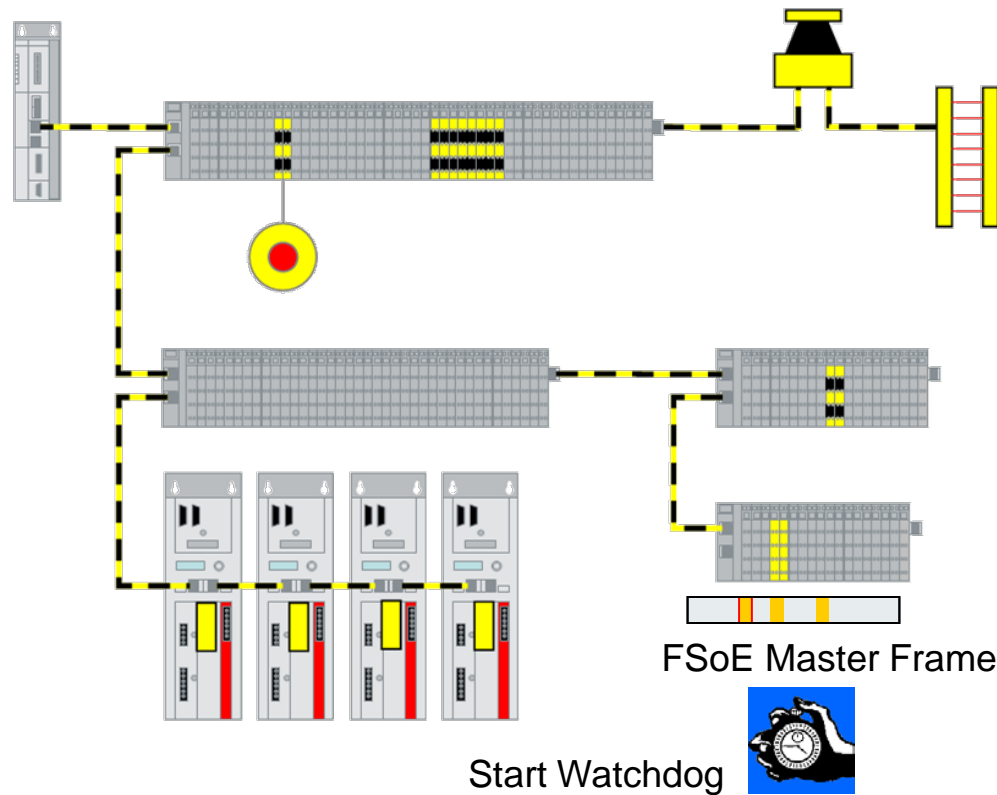
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## FSoE Cycle

The FSoE Cycle consists of an FSoE Master Frame, that is confirmed by the FSoE Slave Frame.

The FSoE Master sends the FSoE Master Frame to the FSoE Slave.

With sending the frame the FSoE Master starts a Watchdog-Timer.

# FSoE – Communication Cycle

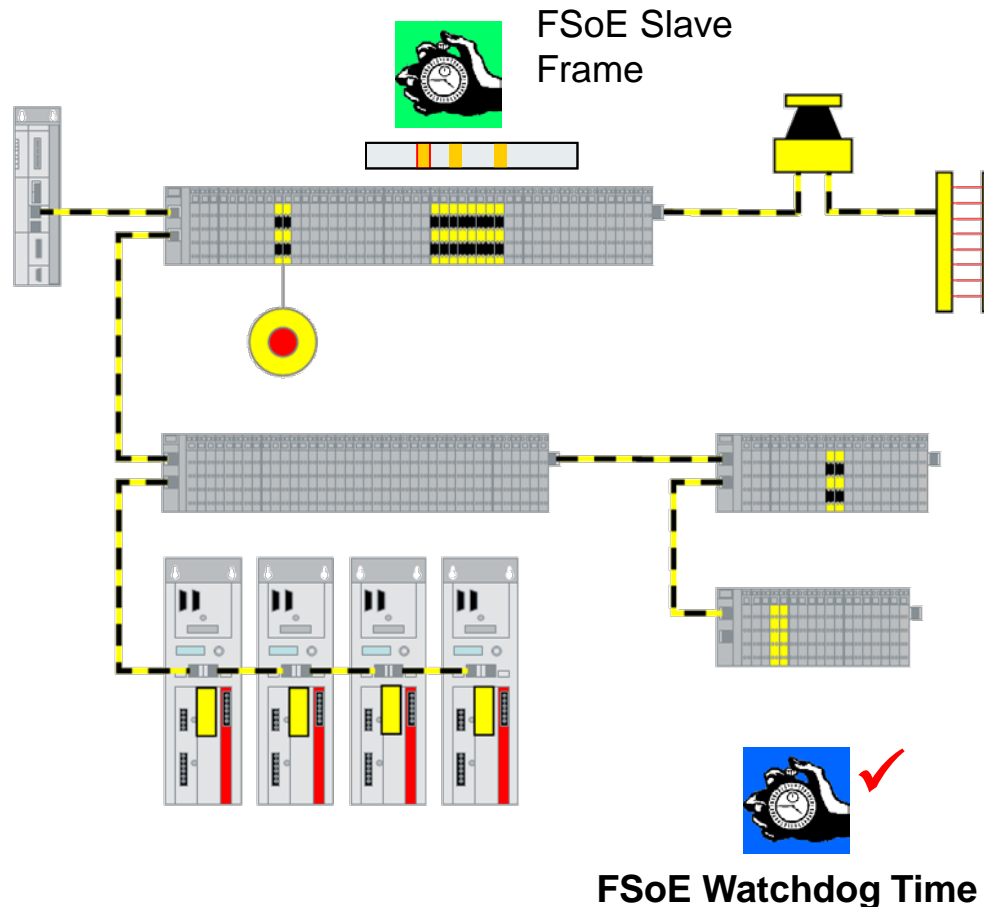
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## FSoE Cycle

The FSoE Cycle consists of an FSoE Master Frame, that is confirmed by the FSoE Slave Frame.

The FSoE Master sends the FSoE Master Frame to the FSoE Slave.

With sending the frame the FSoE Master starts a **Watchdog-Timer**.

Only after receiving a valid FSoE Slave Frame, the FSoE Master generates the next FSoE Master Frame and starts a new FSoE Cycle.

# FSoE – Watchdog Time

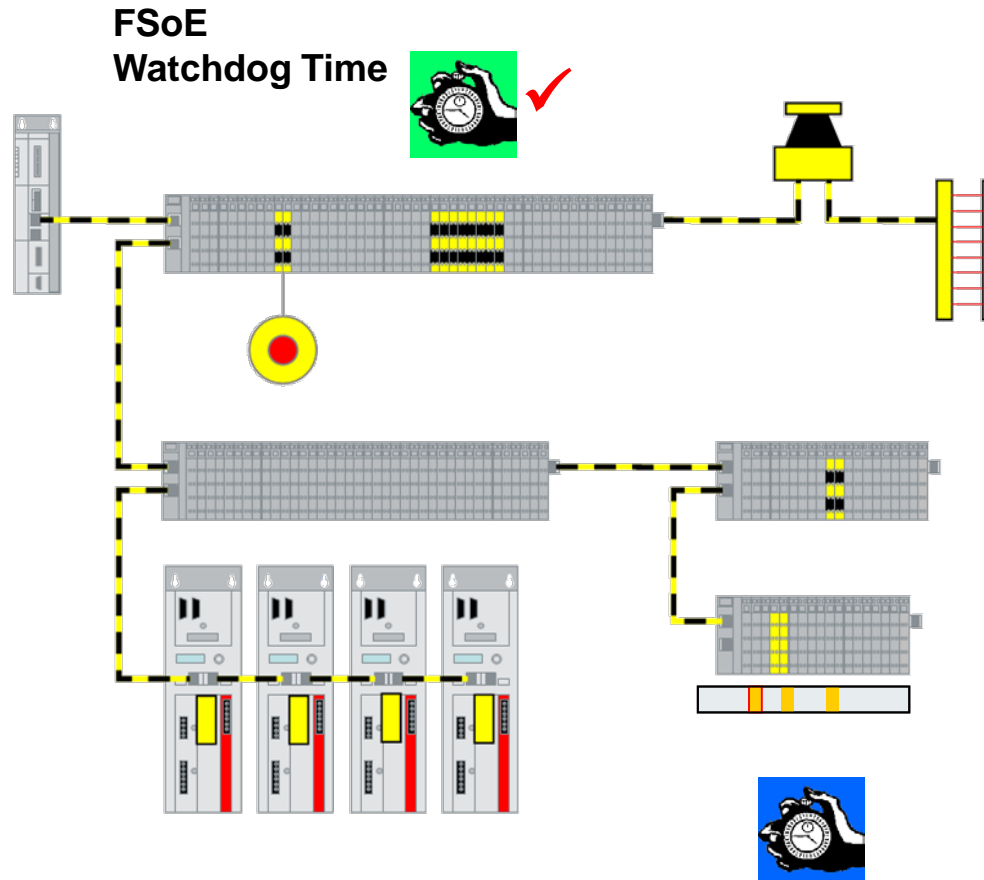
## Requirements

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## FSoE Watchdog Time

Each device monitors that the partner device responds within the safety configured **FSoE Watchdog Time**.

If the Watchdog Time exceeds, the device switches to the state "Reset".

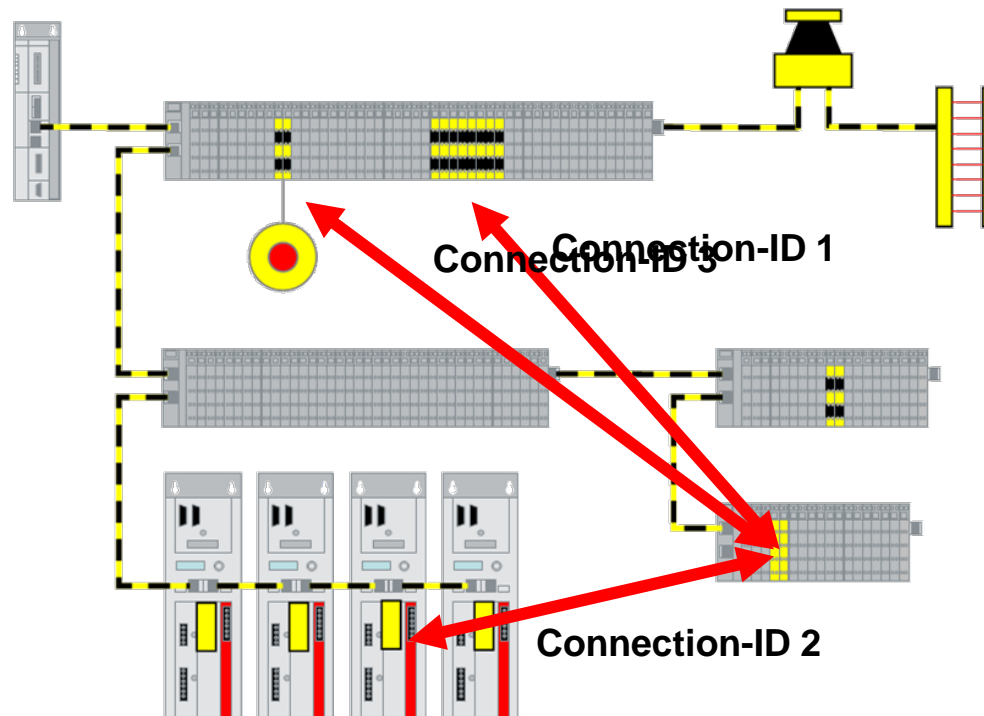
## Requirements

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### Applications



## FSoE Connection

The **FSoE Connection** is a logically connection between one FSoE Master and one FSoE Slave.

It is a system-unique **Connection-ID**.

The uniqueness has to be checked by a safe configurator.

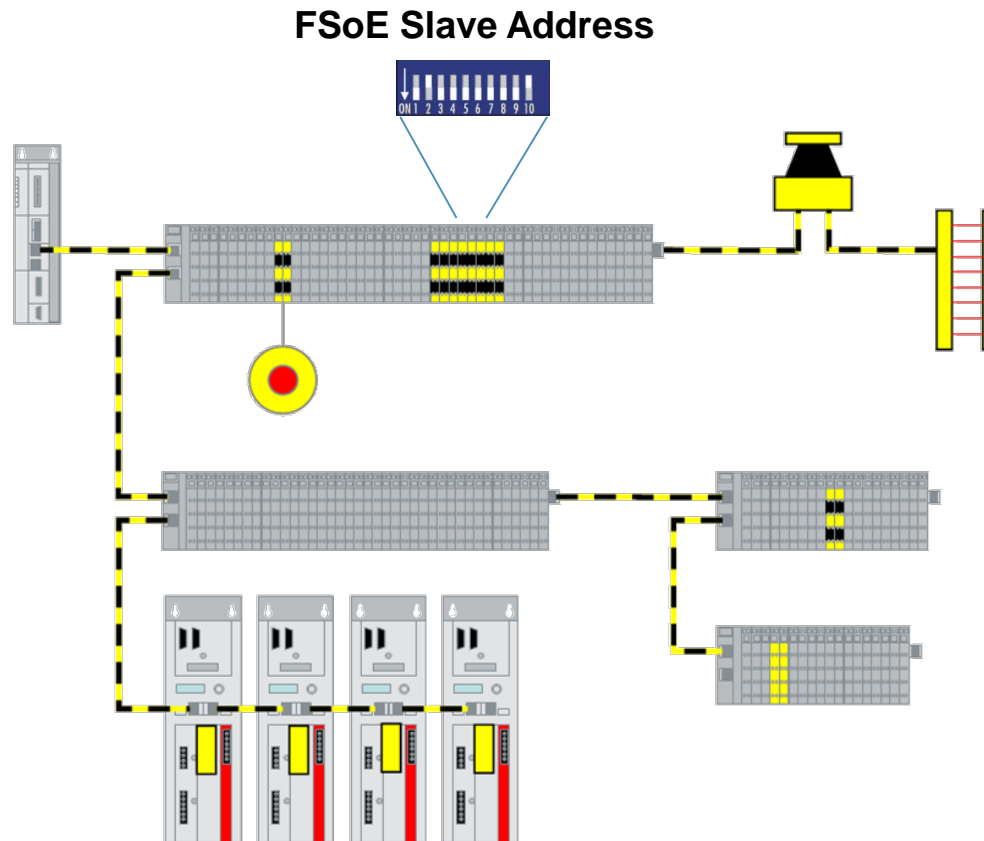
## Requirements

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## FSoE Slave Address

Next to the Connection-ID each FSoE Slave has a system-unique 16-Bit **FSoE Slave Address**.

This address can be adjusted for the device, e.g. with a DIP-Switch.

The FSoE Slave Address is used for the unique addressing of the device.

Up to 65,535 devices can be addressed.

# FSoE State Machine per Connection

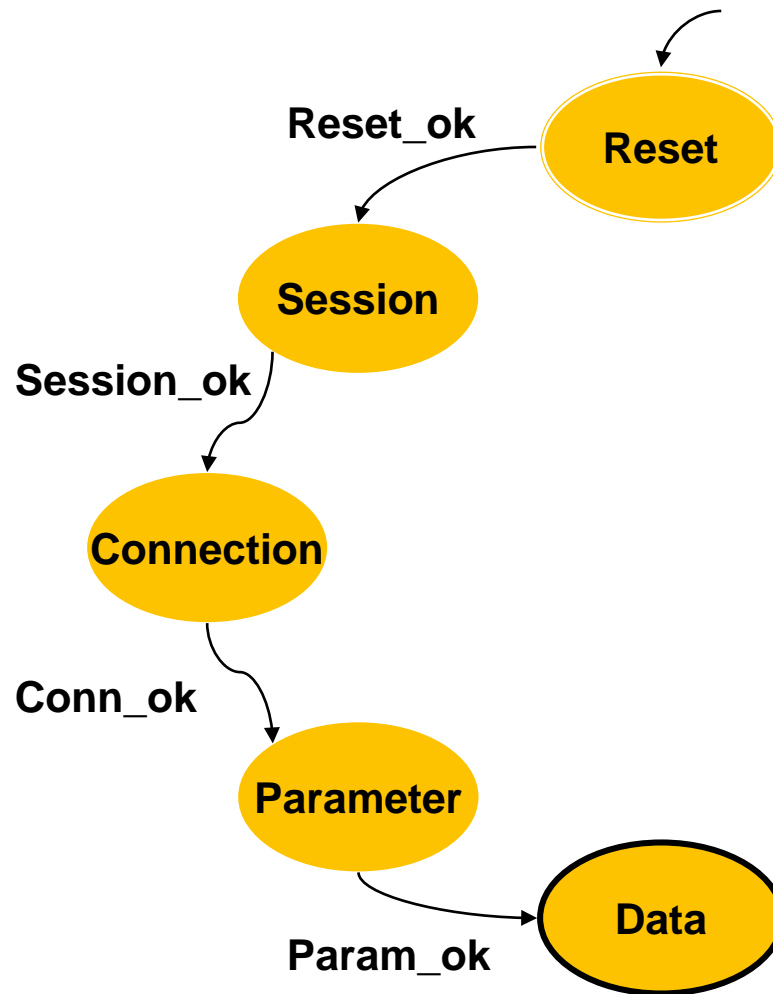
## Requirements

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For each FSoE Connection an FSoE State Machine exists in the FSoE Master and in the FSoE Slave.

The FSoE Master handles one State Machine per FSoE Slave.

After Power-On the FSoE Master and the FSoE Slave are in state **Reset**.

Only in state **Data** the safe State of the Outputs can be left.



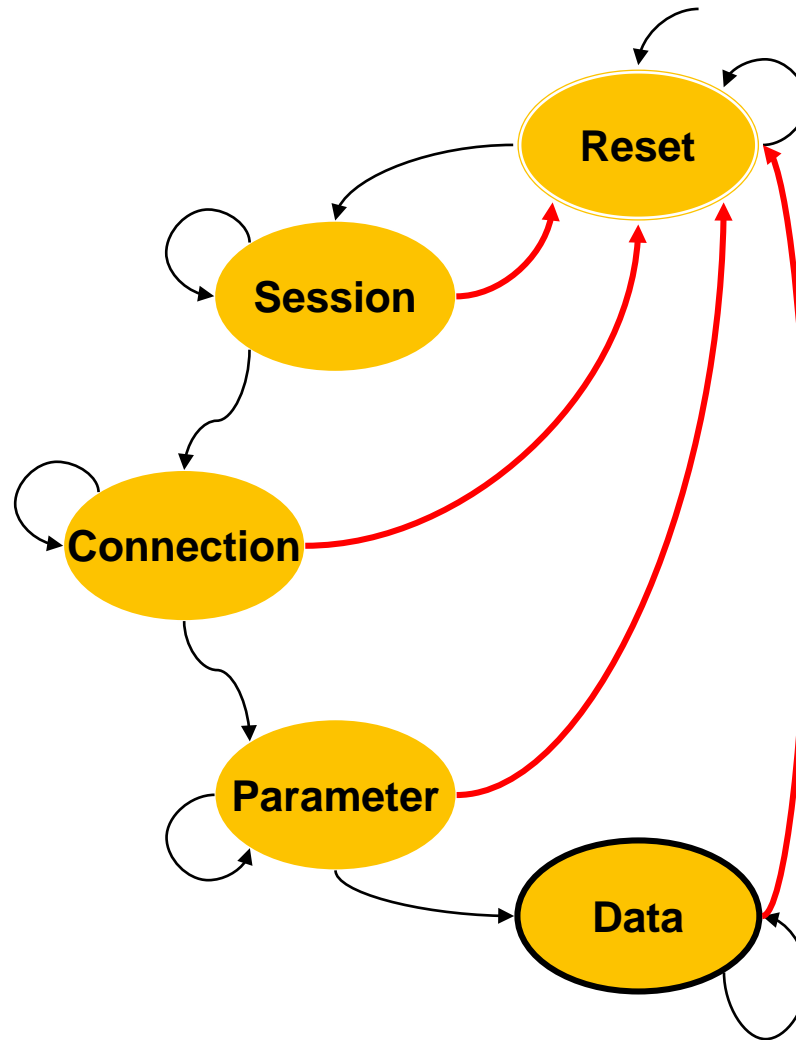
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### Applications



In case of an FSoE Connection error the devices change to the **Reset** state.

## Examples

- FSoE Watchdog expires
- CRC checks fails
- FSoE Reset telegram received

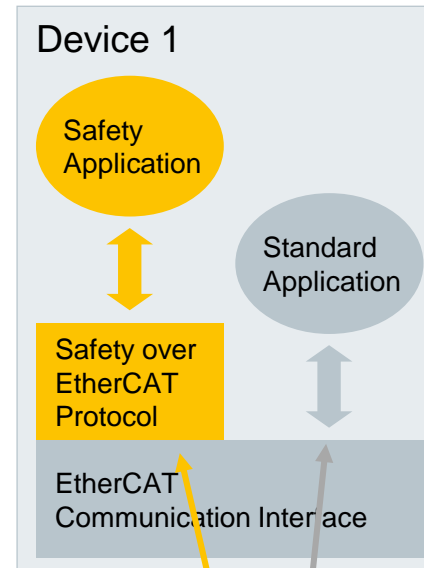
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### FSoE Frame

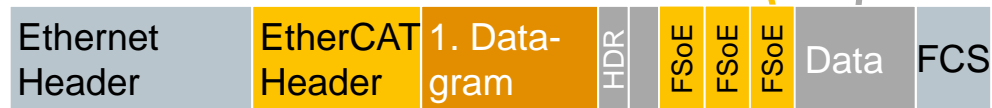
The FSoE Frame is embedded as a Container in the process data of the device.

Each device detects a new FSoE Frame, if at least one Bit in the FSoE Frame is changed.

Every 2 Byte SafeData are checked by a 2 Byte CRC.

The maximum number of SafeData is therefore not restricted by the protocol.

## EtherCAT Frame



## FSoE Frame



# Safety measures for Safety over EtherCAT

## Requirements

### Safety over EtherCAT

- Architecture
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### Conformance

### Applications

Measure	Sequence Number	Watchdog	Connection ID	CRC Calculation
<b>Unintended repetition</b>	☑			☑
<b>Loss</b>	☑	☑		☑
<b>Insertion</b>	☑			☑
<b>Incorrect sequence</b>	☑			☑
<b>Corruption</b>				☑
<b>Unacceptable delay</b>		☑		
<b>Masquerade</b>		☑		☑
<b>Repeating memory errors in Switches</b>	☑			☑
<b>Incorrect forwarding between segments</b>			☑	

# Safety over EtherCAT – Features

## Requirements

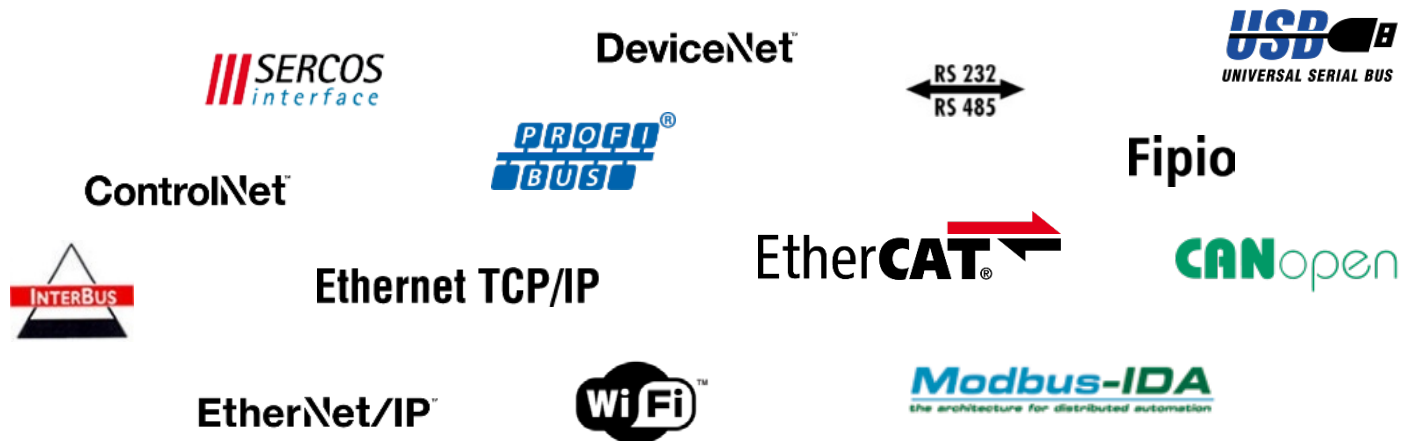
### Safety over EtherCAT

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### Conformance

### Applications

- The FSoE specification has no restrictions according to:
  - Communication layer and interface
  - Transmission speed
  - Length of safe process data
- Routing via unsafe gateways, fieldbuses or backbones is possible, even wireless.



## Requirements

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## Conformance

## Applications

- FSoE Frame is mapped in the cyclic PDOs
  - Minimum FSoE Frame-Length: **6 Byte**
  - Maximum FSoE Frame-Length: Depending on the number of safe process data of the Slave Device
  - Therefore the protocol is suitable for safe I/O as well as for functional safe motion control
- Confirmed transfer from the **FSoE Master to the FSoE Slave** and vice versa.
- **Safety-related Device Parameter** can be downloaded from the Master to the Slave at Boot-Up of the FSoE Connection.
  - Watchdog time
  - Device specific safety-related Parameter for Slave application

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## Conformance

## Applications

- Probability of failure PFH  $< 10^{-9}/h$ 
    - Based on Bit Error Probability of  $10^{-2}$  of underlying communication channel
- no restrictions for device manufacturers and end user
- The protocol is developed according to IEC 61508  
**Safety Integrity Level (SIL) 3**
  - The protocol is **approved by TÜV Süd Rail GmbH**  
(Notified body)
  - Certified products with Safety-over-EtherCAT are  
available **since 2005**.
  - Safety-over-EtherCAT is **part of IEC 61784-3** Functional  
safety fieldbuses

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## Applications

- FSoE is disclosed within the ETG.5100 and part of IEC 61784-3 Functional Safety Fieldbuses
  - FSoE is recommended Chinese Standard GB/T 36006-2018
- Safety over EtherCAT Implementation Support
  - Support for planning, implementation and certification
- FSoE Conformance Test
  - Test cases to approve conformance for FSoE Master and FSoE Slave devices are available and approved
  - FSoE Conformance Test Tool for FSoE Slave devices approved by TUV
- Implementations of several vendors already exist



\*as of 12/2019

## Safety over EtherCAT®



## Requirements

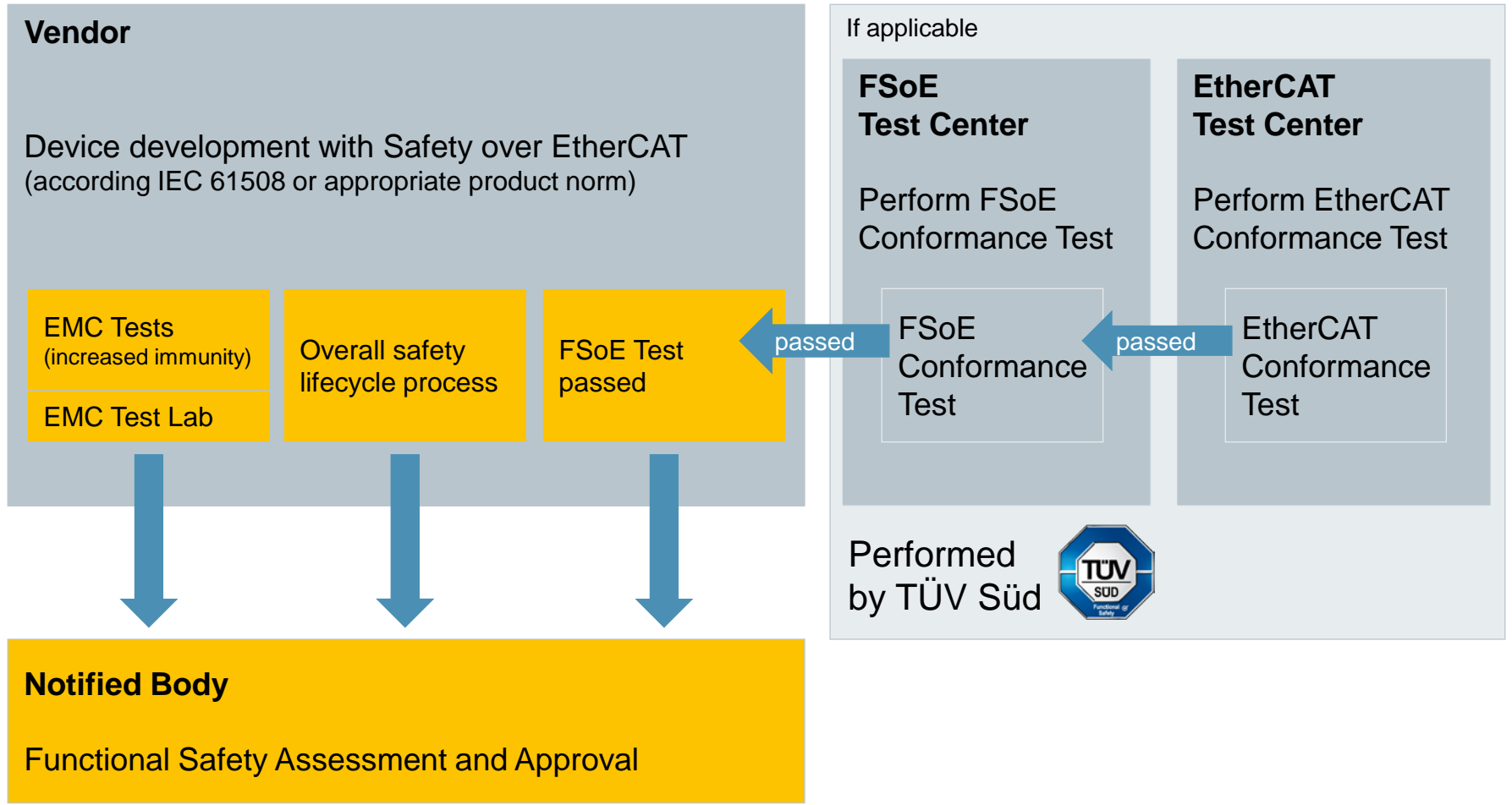
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## Applications

- ETG.9001 Safety over EtherCAT Policy
  - defines FSoE conformance testing rules and policies
- FSoE Devices shall fulfil following requirements:
  - Compliance to
    - IEC 61508 and / or relevant sector / product standards
    - IEC 61784-3 general part
    - ETG.5100 Safety over EtherCAT Specification
    - EtherCAT Conformance Test Policy (if applicable)
  - Passing Functional Safety Assessment and approval of the FSoE Device by a Notified Body



Process according to ETG.9100 FSoE Policy

# FSoE Conformance Test Tool

## Requirements

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## Conformance

## Applications

Approved  
FSoE Test  
cases (XML)



EtherCAT Slave  
Information ESI  
(XML-File)



EtherCAT  
Conformance  
Test Tool  
(CTT)



EtherCAT



EtherCAT Master

Device under Test  
EtherCAT Slave  
FSoE Slave

FSoE Test  
Results



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### Applications

## Machine A

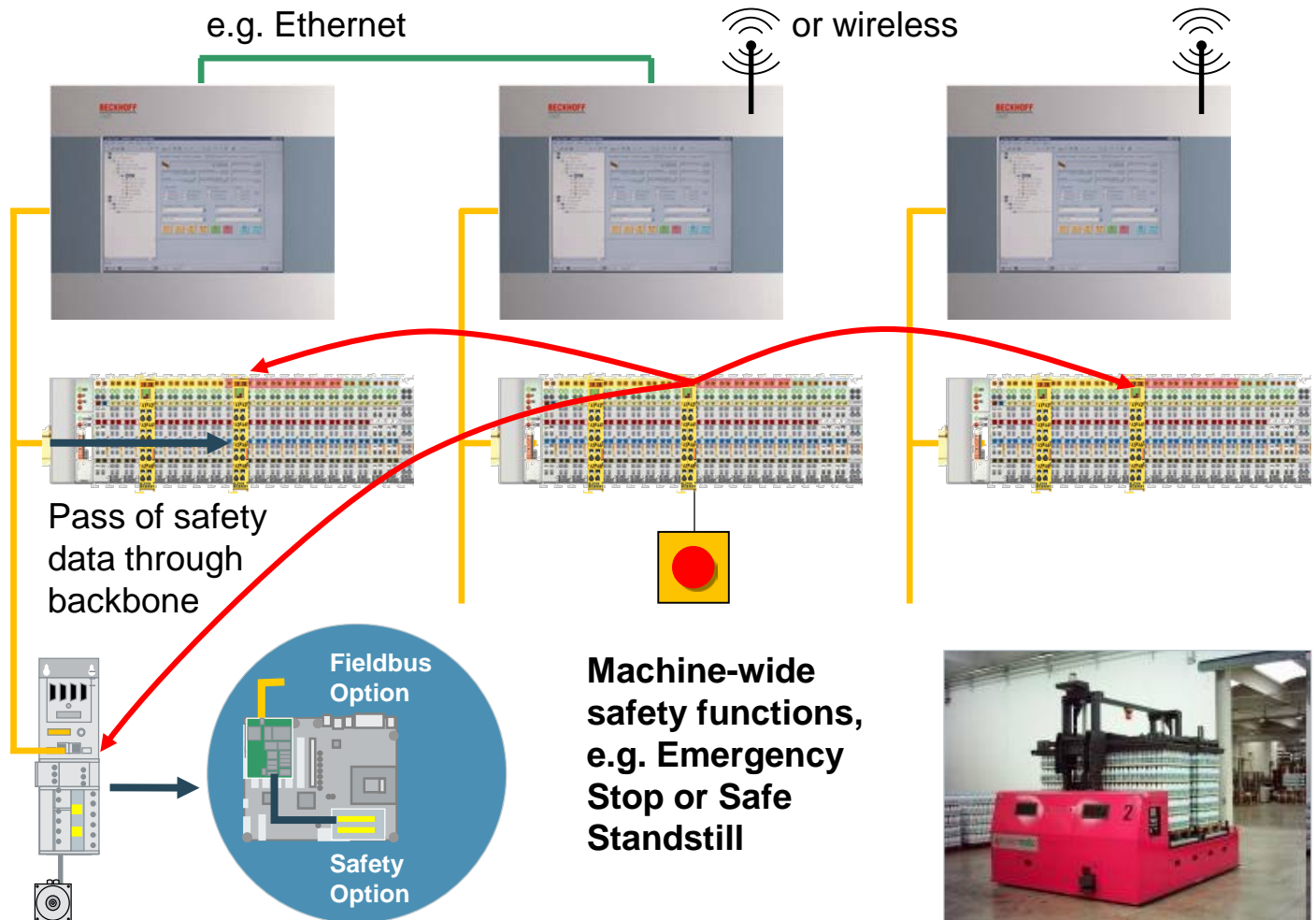
## Machine B

## Machine C

Safety-related communication via standard communication systems

e.g. Ethernet

or wireless



# Safety for modern automation

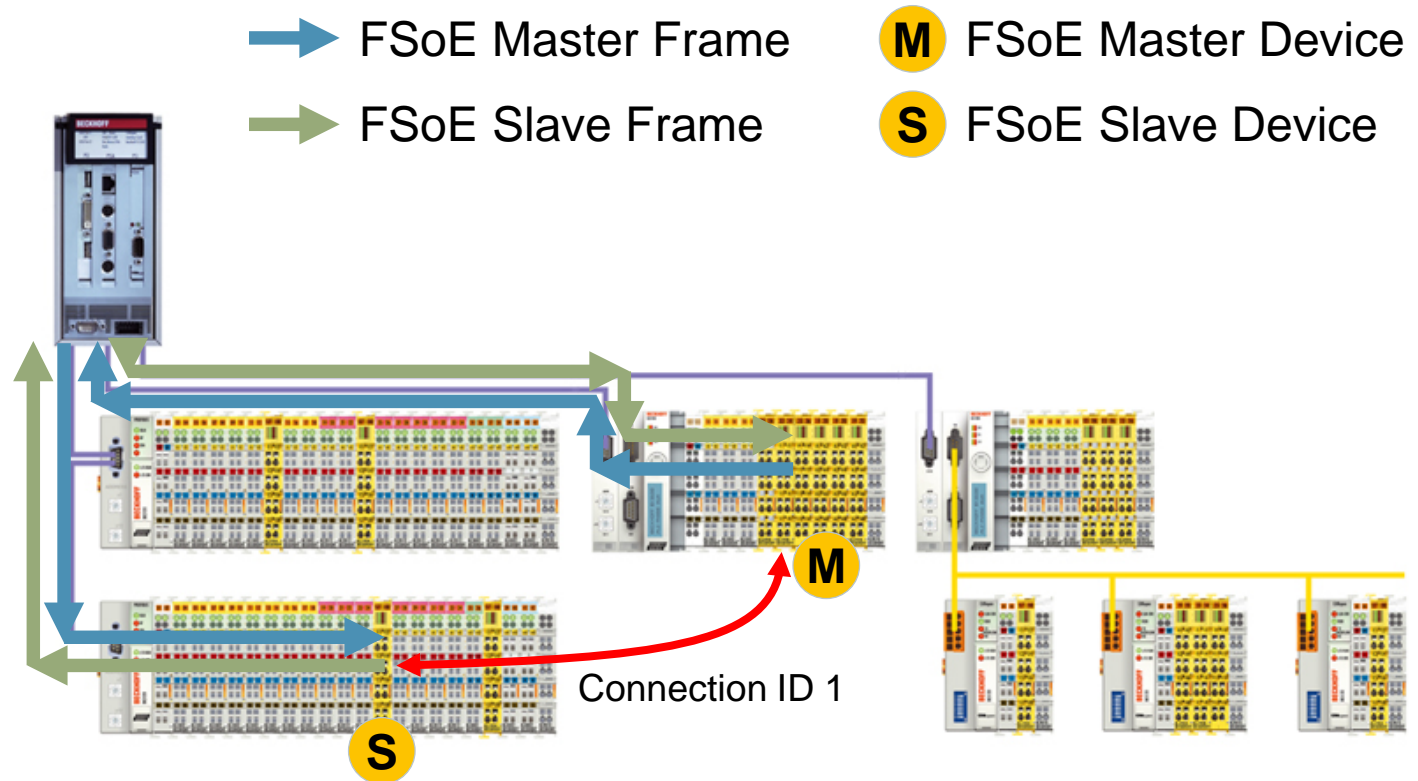
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- Configured Master-Slave Connections
- Communication is routed via standard PLC

# Safety for modern automation

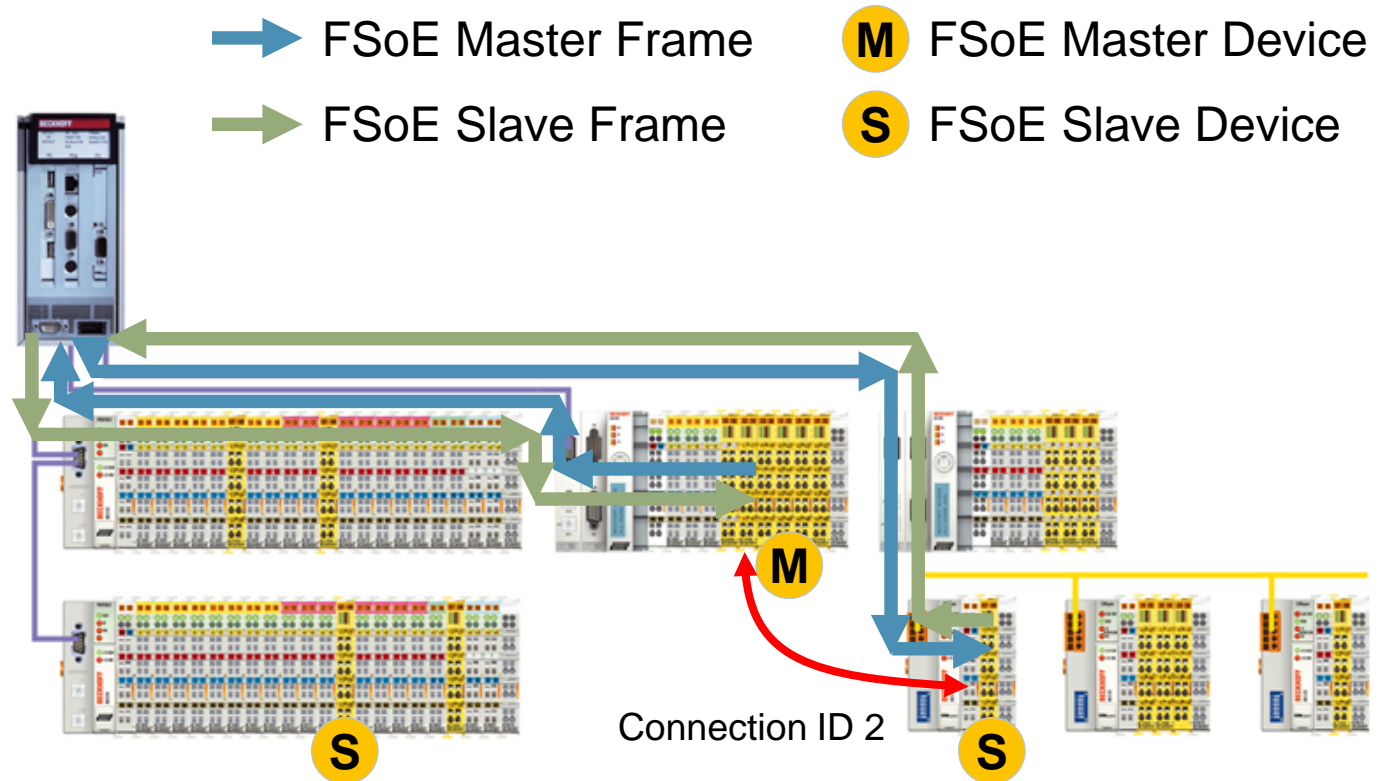
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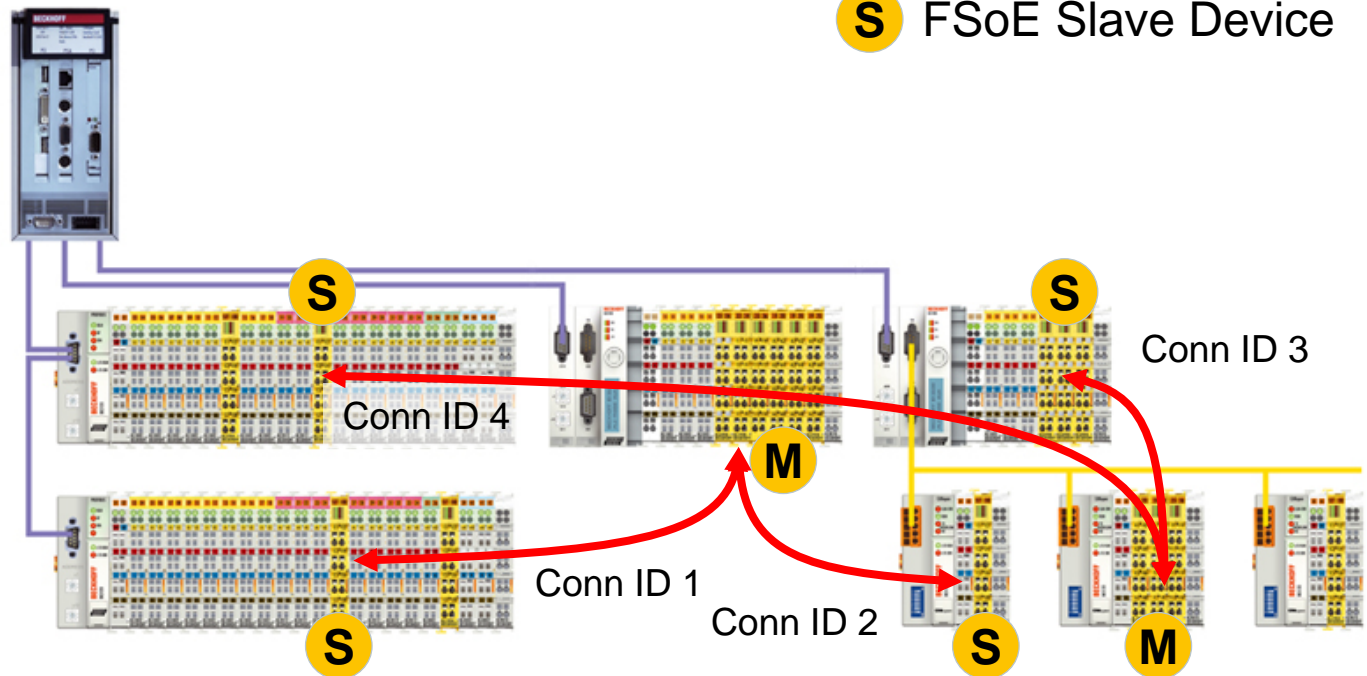
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### Applications

- M** FSoE Master Device
- S** FSoE Slave Device



- Several Master in one network
- Safety groups with group-switch-off possible



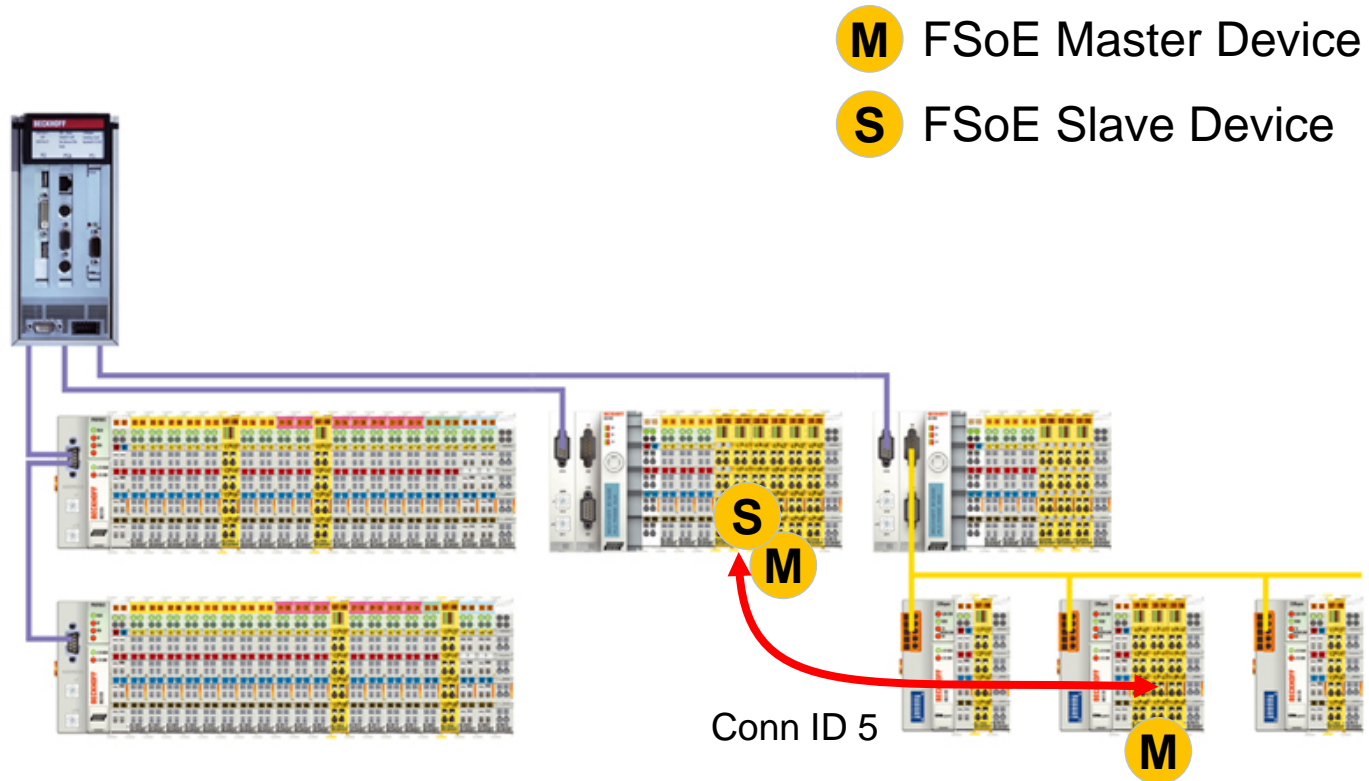
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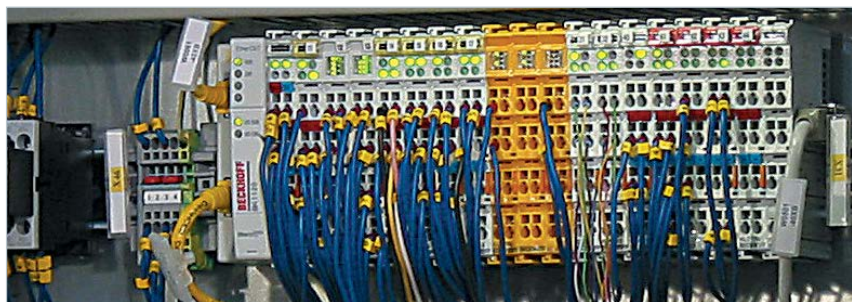
### Conformance

### Applications



- “Master–Master” communication via Master&Slave implementation in the device
- Unique Conn-ID necessary!
- Used for machine chaining

# Application | Tire and wheel testing machine



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### Applications

- Advantages for the customer:
- Integration of Safety functions in the TwinSAFE system
  - Emergency stop
  - Safety fence monitoring
- Small switch box directly at the safety fence
- Optimum interaction between standard automation and safety technology
  - Reduced engineering and hardware costs
  - Simplified wiring
  - Modifications are easy to implement
- Only one tool needed for Standard and Safety functions
  - TwinSAFE software editor conveniently integrated in the TwinCAT system



[www.ethercat.org](http://www.ethercat.org)

**EtherCAT – The Ethernet Fieldbus**

EtherCAT is the open real-time Ethernet network originally developed by Bosch. EtherCAT sets new standards for real-time performance and topology flexibility. Why use EtherCAT?

EtherCAT Technology Group  
The ETG is a global organization in which OEM, End Users and Technology Providers join forces to support and promote the further technology development. Who we are

The world's largest Industrial Ethernet organization with 6425 member companies.

**ETG News**

ETG experiences continued growth through outstanding technology and comprehensive support  
Nov 2019 | Just in time for this year's SPS exhibition in Nuremberg, Germany, the EtherCAT Technology Group (ETG) has once again taken stock of its membership growth, which is again convincing in 2019. [More...](#)

Visit us at SPS 2019: ETG Joint Booth  
Nov 2019 | From Nov 26th to Nov 28th, 2019, we will exhibit again at this year's SPS fair in Nuremberg, Germany. Together with 55 co-exhibitors, we'll show more than 500 products and solutions with EtherCAT at our ETG Joint Booth in Hall 5, Booth 310. [More...](#)

EtherCAT Seminar Korea 2019  
Nov 2019 | We cordially invite all interested parties to attend our full-day EtherCAT seminar in Seoul on Tuesday, December 11th, 2019. [More...](#)

**Latest Product Entries**

Linear Transducer LMP48 - ETC by TR-Electronic  
Dec 2019 | Non-contact linear position sensor. Absolute detection, multi magnet capable.

FS-IO OCP2101 by ACD  
Dec 2019 | The OCP2101 allows to connect actuators and sensors as FS-IO slave into a safety over EtherCAT system to provide safety functions according to EN 61800-5-2.

Safety controller FS-PLC43 by ACD  
Dec 2019 | The FS-PLC3A00500 allows to connect actuators and sensors as FS-IO-Master in a Safety over EtherCAT system to provide safety functions according to EN 61800-5-2.

FlexPro™ by ADVANCED Motion Controls  
Dec 2019 | FlexPro meets the demand for smaller, more versatile, and higher power servo drives that are designed to easily integrate into ever-tightening constraints.

AccuET Modular 400 by CTEL  
Dec 2019 | With EtherCAT compatibility, the high-end performance of AccuET position controllers can be brought to your machine with minimal integration effort and the performance improved straightaway.

**Upcoming Events**

EtherCAT Slave Evaluation Kit Workshop  
Nuremberg, Germany  
Dec 11, 2019

TWG Conference Web Conference  
Dec 12, 2019

→ All events

EtherCAT Technology Basics for Developers  
Nuremberg, Germany  
Feb 04, 2020

EtherCAT Slave Evaluation Kit Workshop  
Nuremberg, Germany  
Feb 05, 2020

EtherCAT Master Simple Code Workshop  
Nuremberg, Germany  
Feb 03, 2020

embedded world 2020: ETG Booth  
Nuremberg, Germany  
Feb 25 - Feb 27, 2020

2020 Spring European EtherCAT Plug Fest

EtherCAT Technology Group  
Dr. Guido Beckmann  
g.beckmann@ethercat.org