PUS-F161-B**-PXV/ PUS-F161-B**-WCS

Safe evaluation unit

Installation instructions

Your automation, our passion.

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1 Basic Information

1.1 Symbols Used

This document contains symbols for the identification of warning messages and of informative messages.

Warning Messages

You will find warning messages, whenever dangers may arise from your actions. It is mandatory that you observe these warning messages for your personal safety and in order to avoid property damage.

Depending on the risk level, the warning messages are displayed in descending order as follows:

Danger!

This symbol indicates an imminent danger.

Non-observance will result in personal injury or death.

Warning!

This symbol indicates a possible fault or danger.

Non-observance may cause personal injury or serious property damage.

Caution!

This symbol indicates a possible fault.

Non-observance could interrupt the device and any connected systems and plants, or result in their complete failure.

Informative Symbols

Note

This symbol brings important information to your attention.

Action

1. This symbol indicates a paragraph with instructions. You are prompted to perform an action or a sequence of actions.

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1.2 Identification

PUS evaluation unit for the linear positioning systems safeWCS/PUS and safePXV/PUS.

PUS evaluation unit

The PUS evaluation unit is available with various interfaces. These are shown in the following table

Alternative order designation	Properties
PUS-F161-B28-PXV	PROFINET with PROFIsafe protocol
PUS-F161-B31-PXV	EtherCAT with Safety-over-EtherCAT (FSoE) protocol
PUS-F161-B28-WCS	PROFINET with PROFIsafe protocol
PUS-F161-B31-WCS	EtherCAT with Safety-over-EtherCAT (FSoE) protocol

Read heads

The PUS evaluation unit can be combined with the following read heads.

PUS-F161-B*-PXV in combination with safePXV/PUS read head with RS-485 and red/blue switchable lighting.

safePXV/PUS read heads

Model number	Read window	Measurement frequency	Special features
PXV100AQS-F200-R4-V19-6011	Compact	100 Hz	Quality value output
PXV80AQS-F200-R4-V19	Standard	100 Hz	Quality value output
PXV100AQS-F200-B33-V19-6011	Compact	100 Hz	Quality value output

Note

Please observe the notes in the respective documentation for the read heads.

PUS-F161-B*-WCS in combination with 2 safeWCS/PUS read heads in forwards (U1 type) and reverse (U2 type) orientation.

safeWCS/PUS read heads

Model number	Special features
WCS3B-LS221*-U1*	Forward reading direction
WCS3B-LS221*-U2*	Reverse reading direction

Note

Please observe the notes in the respective documentation for the read heads.

Accessories

Model number	Properties
PUS-USB-LIZ	Software license (own USB dongle)
PUS-USB-COMM	Parameterization adapter
PUS-SD-CARD	SD card standard

1.3 Instructions for Use

The documentation forms part of the evaluation unit and contains important information on the integration of the evaluation unit in systems and on their operation and servicing. Programming and parameterization of the evaluation unit are described in the programming manual. Precise knowledge and understanding of these is a mandatory prerequisite for a new installation or for modification of the device function or device parameters.

Read the information in this documentation carefully and observe this information when working with the device. Failure to observe the safety information and warning messages in this documentation can lead to malfunctions of the safety devices of the machines or plants in which they are fitted.

The documentation is intended for all persons planning integration and installation and for all persons carrying out assembly, installation, commissioning, and servicing work on the product.

The documentation must be made accessible to such persons in a legible condition. Make sure that those responsible for planning and integration, plant and operations managers, and those working on the evaluation unit under their own responsibility, have fully read and understood the documentation.

If you have any questions or need more information, contact the Pepperl+Fuchs Group.

1.4 Liability Claims for Defects

Compliance with this documentation is required for trouble-free operation and the fulfillment of any liability claims for defects. Therefore, first read the documentation before planning the integration of or beginning work with the evaluation unit.

Make sure that the documentation is available in a legible condition to persons planning integration and installation, persons carrying out assembly, installation, commissioning, or servicing work on the product, to the plant and operating managers and to persons working on the devices under their own responsibility.

1.5 Exclusion of Liability

No guarantee contained herein or granted is applicable to products, which:

- have been repaired or modified or accessed internally, unless carried out or approved by Pepperl+Fuchs,
- have not been maintained in accordance with the operating and handling instructions issued by Pepperl+Fuchs,
- have been exposed to unusual physical or electrical loads, immersed in liquids, or exposed to any one of the following circumstances:
  - disruptive discharge,
  - crushing,
  - incorrect use,
  - misuse,
  - inadequate power,
  - unsuitable voltage supply,
  - incorrect polarity,
  - negligence or accident,
- or has been used for a purpose other than that described in the operating and handling instructions.

Preventive maintenance is the customer's responsibility and is not covered by this warranty.

1.6 Definitions

The term **PUS evaluation unit** is used as a generic term for all versions of the safe evaluation unit PUS-F161-B**-***. If a specific version is referred to in the description, the full identifier is used.

The term **"safe"** used in the following text refers in each case to classification as a safe function for applications up to PL e in accordance with EN ISO 13849-1 or SIL 3 in accordance with IEC 61508.

The **"safeControl Expert"** system software is used to configure and program the PUS evaluation unit.

1.7 Supporting Documents

Description	Reference
Configuration of the PUS evaluation unit for stand-alone applications without fieldbus connection with the "safeControl Expert" system software	safeControl Expert programming manual
TÜV certificate with list	TÜV certified
Safety test with acceptance log	Validation report and acceptance log
Manuals of the read heads used	safePXV/PUS manual safeWCS/PUS manual

Note

- Read this manual carefully before starting to install or commission the evaluation unit.
- Compliance with this documentation is required for trouble-free operation and the fulfillment of any warranty claims.

1.8 Acronyms

Abbreviation	Meaning
AC	Alternating current
STL	Statement list
BG	Employers' liability insurance association
Cat.	Architecture category (category acc. to EN 13849-1)
CLK	Clock
CPU	Central processing unit
CRC	Cyclic redundancy check
DC	Direct current
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DO	Digital output
ECFS	EtherCAT fail safe; EtherCAT FSoE (fail safe over EtherCAT)
EMU (EDM)	Emergency monitoring unit (External device monitoring)
EMC	Electromagnetic compatibility
EN	European standard
EtherCAT	Data log
FIT	Failures per time period, i.e., outages per 10^9 hours
FSoE	Safe data transmission via EtherCAT protocol [fail safe over EtherCAT]
GND	Ground potential [Ground]
HISIDE	High side — positive switching output with 24 V DC nominal level
I1 .. I14	Digital input
ISO	International Organization for Standardization
LED	Light-emitting diode (LED)
LOSIDE	Low side — 0 V DC output switching to reference potential (GND)
n.a.	Not applicable
OLC	Operational Limit Control
PAA	Outputs process image
PAE	Inputs process image
PELV	Protective extra low voltage
PES	Programmable electronic systems
PESSRAL	Programmable electronic systems in safety-related applications for elevators
PLC	Programmable logic controller
POR	Reset procedure [power-on reset]
PSC	Position Supervision Control
PUS	Position Unit Safe
SDDC	Safe Device-Device Communication
SELV	Safety extra low voltage
SMMC	Safe master-master communication
SSI	Synchronous serial interface

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Abbreviation	Meaning
T1, T2	Pulse/clock outputs
VDE	Association for Electrical, Electronic & Information Technologies
Yx.y [1]	Auxiliary output
G.P.	General use

1. Module address x = 0 - 2
Channel address y = 0 - 39

2 Safety Notices

The following basic safety instructions are intended to prevent personal injury and property damage. The operator must ensure that the basic safety instructions are observed and adhered to.

Make sure that those responsible for planning and integration, plant and operations managers, and those working on the device under their own responsibility, have fully read and understood the documentation. If you have any questions or need more information, please contact the Pepperl+Fuchs Group.

2.1 Intended Use

The device is only approved for appropriate use as intended. Ignoring these instructions will void any warranty and absolve the manufacturer from any liability. Only use the device in an industrial setting.

The safe evaluation unit PUS-F161-B**-*** can be used to establish safety shutoffs and safety functions.

It enables the calculation of safe position and velocity data for an axis using the data from the safePXV/PUS or safeWCS/PUS read heads.

The safe evaluation unit is used for safety-relevant evaluation and data transfer via a safe or non-safe fieldbus of:

- X-position, speed, and diagnostic data
- Diagnostic data of the read heads
- Safe input and output signals

Use the device only within the permitted ambient and operating conditions.

If you are using the device in safety-related applications, observe the information on the safety function and the safe state.

The PUS may only be operated in conjunction with approved read heads.

The PUS was developed, manufactured, tested and documented in compliance with the relevant guidelines and standards. If the described instructions and safety points are observed, the product therefore does not normally pose any risks with regard to property damage or the health of persons.

When installed in machines, commissioning of the PUS (i.e., when the machine is set up for its intended purpose) is prohibited until it has been determined that the machine complies with local laws and guidelines. Within the respective scope, the Machinery Directive 2006/42/EC and the EMC Directive 2004/108/EC must be observed in particular. The EMC test regulations EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-6, EN 61000-6-2 and EN 55011 are used as a basis. In addition, EN 60204-1 must be observed.

The PUS evaluation unit in combination with the read head is a safety component in accordance with Annex IV of the EC Machinery Directive 2006/42/EC. It has been developed, designed and manufactured in accordance with the above directive and the EC-EMC Directive 2004/108/EC.

Note

The product must not be used without other safety measures to be considered and implemented by the operator of the product. The safety instructions in this document must be followed!

Caution!
Machinery Directive

Machinery directive 2006/42/EC and EMC directive 2004/108/EC must be observed during integration and operation!

The technical data and the information on connection conditions can be found on the type plate and in the documentation. This must be observed.

2.2 General Safety Notice

- To prevent personal injury and property damage, only qualified personnel may work on the device. Qualified personnel are personnel who have electrical engineering training and are familiar with the applicable rules and standards of electrical engineering.
  The qualified person must familiarize themselves with the instructions (cf. IEC364, DIN VDE 0100).
- The qualified person must have at least in-depth knowledge of national accident prevention regulations.
- The use of the devices must be restricted to their intended use in accordance with the above list. The values of the data listed in "see chapter 3.3" must also be observed.
- The contents of this manual are limited to the basic function of the devices and their installation. The programming and reparameterization of the devices is described in more detail in the programming instructions. Precise knowledge and understanding of these is a mandatory prerequisite for a new installation or for modification of the device function or device parameters.
- Commissioning (i.e., commencement of proper operation) is only permitted if the EMC Directive is observed. The EMC test regulations EN 55011:2009 + A2:2010 and EN 61000-6-2:2005 form the basis for this.
- For storage and transport, the conditions according to EN 60068-2-6 must be adhered to with reference to the values named under "Technical Parameters."
- The wiring and connection instructions from the chapter "Installation" must be observed.
- The applicable VDE regulations and other special safety regulations for the relevant application must be observed.
- The configured monitoring functions must be verified with a validation report along with their parameters and links.
- The implementation of the module must take account of the requirements of the responsible acceptance body (e.g., TÜV or employers' liability insurance association).
- Never install or operate damaged products. Please report any damage to the transport company immediately.
- Never open the housing and/or carry out modifications without authorization.
- Neither inputs and outputs for standard functions, nor digital and analog data transmitted via communication modules may be used for safety-related applications.

Danger!
Use of the devices other than in accordance with the rules and conditions listed here may result in personal injury or death, or damage to connected devices and machines! This would also invalidate any warranty or damage claims against the manufacturer.

2.3 Personnel Requirements

Persons involved with planning the integration of the evaluation unit in systemsandwith the unit's use in applications , must be sufficiently qualified. This usually consists of university or technical training for electrical/electronic systems in combination with specific knowledge of the laws, regulations, standards and guidelines for the protection of persons and property when handling machines and equipment.

All work concerning installation, commissioning, troubleshooting and maintenance must be carried out by a qualified electrical specialist (Observing IEC 60364 or CENELEC HD 384 or DIN VDE 0100 and IEC 60664 or DIN VDE 0110 and national accident prevention regulations).

Qualified electrical specialists within the meaning of these basic safety instructions are personswho are responsible for installation, assembly,commissioning, programming, parameterization and operation of the product and who have the appropriate qualificationsfor their work. They must also be familiar with the safety regulations and laws applicable in each case, including in particular the requirements of EN ISO 13849-1 and the other standards, guidelines and laws named in this documentation.

The named persons must have been expresslygranted operational permission to commission, , program,parameterize, label and ground devices, systems and circuits in accordance, with, safety standards.

All work in the remaining areas of transport, storage, operation and disposal must be carried out by persons who have been, suitably instructed.

List of qualifications

The various tasks described in this documentation place different requirements on the qualification of the persons who are entrusted with these tasks.

Specialist	Qualifications
Project planner	The project planner has professional training or relevant experience in dealing with information technology systems and in particular with programmable logic controllers (PLCs). The project planner's tasks include the following activities: • Working on the PLC • Knowledge of safety regulations • Application • Configuring and validation of safety control systems • Configuring of EMC-compliant system structures
Electricians	The electrician has completed electrical engineering training or has relevant experience in this field. They know and understand the relevant rules and standards forelectrical components, systems and their contents. The electrician has the following knowledge: • Safety regulations for working on electrical components • Wiring guidelines for working on electrical components • Wiring diagrams • Work on live wiring

Specialist	Qualifications
Commissioning engineer	The commissioning engineer has professional training or relevant experience in dealing with the commissioning of machines and systems. The commissioning engineer has the following knowledge: • Safety regulations • Operation of the machine and system • Basic functions of the application • System diagnostics and troubleshooting • Adjustment options on the operating device • Validation of safety controls
Service technician	The service technician has appropriate professional training or relevant experience in dealing with complex machines and systems. The service technician is able toperform the repair, maintenance and servicing tasks given to them by the operator. In doing so, they are able to recognize and avoid hazards independently. The service technician has the following knowledge: • Working on the PLC • Safety regulations • Operation of the machine and system • System diagnostics • Systematic troubleshooting and fault resolution

2.4 Transport and Storage

The instructions for transport, storage, and proper handling must be observed. The climatic specifications must be observed in accordance with the "Technical Data" chapter.

2.5 Placement and Assembly

Devices must be installed in a suitable location and cooled appropriately to maintain the ambient and operating conditions in accordance with the following limits and data.

The devices must be protected against undue stress. In particular, no components may be bent and/or insulation distances changed during transport and handling. Avoid touching electronic components and contacts.

The control modules contain electrostatically sensitive components that can easily be damaged by improper handling. Electrical components must not be mechanically damaged or destroyed (potentially hazardous to health!).

Proper installation

The following areas of application are expressly forbidden for the PUS evaluation unit:

- Use in mining
- Use outdoors
- Use in wet rooms or rooms with a risk of splashing water
- Use in environments with highly polluted air
- Use in environments with harmful oils, acids, gases, vapors, dusts, radiation, etc.
- Use in non-stationary applications

For these applications, further protective measures must be taken to prevent harmful influences, such as installation in a switch cabinet or housing with a corresponding protection class, etc.

Caution!

Destruction of the PUS evaluation unit if it is not handled correctly!

The PUS evaluation unit may only be installed and removed when the supply voltage is switched off. Otherwise, the PUS evaluation unit may be destroyed or undefined signal states may lead to damage to the control system.

Note

It is requested that all potentially dangerous incidents that are related to the PUS evaluation unit be reported immediately to Pepperl+Fuchs.

Pepperl+Fuchs assumes no liability or warranty for consequential damages arising from:

- Non-compliance with standards and guidelines
- Unauthorized changes
- Improper use
- Failure to observe information in the documentation

2.6 Electrical Connection

When working on live equipment, the applicable national accident prevention regulations (e.g., BGV A3) must be observed.

The electrical installation must be carried out in accordance with the relevant regulations (e.g., cable cross-sections, fuses, protective conductor connection). Additional information is included in the documentation.

Instructions for EMC-compliant installation – such as shielding, grounding, arrangement of filters, and routing of cables – are included in the documentation. Compliance with the limits required by EMC legislation is the responsibility of the manufacturer of the system or machine.

Protective measures and protective equipment must comply with the applicable regulations (e.g., EN 60204-1).

Warning!

Risk to persons from electric shock!

Only supply the device from voltage sources providing protective extra-low voltage (e.g., SELV or PELV according to EN 61131-2). If a SELV voltage source is used, it can become PELV due to the design of the PUS evaluation unit and the connections (ground reference!). Protective extra-low voltage circuits must always be safely isolated from circuits with dangerous voltages.

Caution!

Risk of fire in case of component failure

Ensure adequate protection of the 24 V DC power supply to the control system in the final application! (Refer to the power supply section for details).

2.7 ESD Information

Electronic components are generally susceptible to (**E**lectro**S**tatic **D**ischarge) (ESD).

An electrostatic charge can be built up during any activity involving movement.

ESD can result from anycontact.

Most discharges are so small that they are imperceptible. However, they can still damage or destroy unprotected electronic components. As a result, exposed electronics may generally only be handled with effective ESD protection in place.

When handling exposed electronics, observe the following ESD measures:

- Only touch exposed electronics when absolutely necessary. Handle exposed components by the edge of the board only.
- Wear a dissipative ESD wrist strap.
- Use a dissipative work mat.
- Establish a conductive connection between device/system, mat, wrist strap and ground connection.
- Preferably wear cotton clothing for work rather than synthetic fiber materials.
- Keep working area free of highly insulating materials (e.g.,: polystyrene, plastics, nylon, etc.).
- Store the devices in their original packaging and do not remove them until immediately before installation
- Use ESD protection even if the modules are defective.

Caution!

Electrostatic discharge

Destruction of electrical components. Low health hazard – Observe the ESD instructions.

2.8 Operation and Service

Before installing and removing the PUS evaluation unit or disconnecting signal cables, the PUS evaluation unit must be de-energized. For this purpose, all live supply lines to the PUS evaluation unit must be switched off and checked to ensure no voltage is present.

The operating LED and other display elements switching off is not sufficient indication that the PUS evaluation unit is disconnected from the mains and de-energized.

During the installation and removal of the PUS evaluation unit, appropriate measures must be taken to prevent electrostatic discharges at the terminals and plug connections that are routed outward. Contact with these terminals should be kept to a minimum, and grounding should be provided beforehand and during this time, e.g., by a grounding strap.

3 Device Description

The PUS evaluation unit is a safe evaluation unit with integrated drive monitoring for one axis. The evaluation unit is freely programmable for safe operation of EMERGENCY STOP buttons, two-handed operation, light grids, operating mode selector switches, etc. and drive-related safety functions. Pre-configured modules are available for safety-relevant signal preprocessing for a wide range of input devices. The same applies to safety functions for drive monitoring. Refer to the programming manual for details.

The device has 14 safe inputs and up to 5 safe shut-off channels.

The following versions of the evaluation units are available for specific systems:

Model number	Properties
PUS-F161-B28-PXV	PROFINET with PROFIsafe protocol
PUS-F161-B31-PXV	EtherCAT with Safety-over-EtherCAT (FSoE) protocol
PUS-F161-B28-WCS	PROFINET with PROFIsafe protocol
PUS-F161-B31-WCS	EtherCAT with Safety-over-EtherCAT (FSoE) protocol

Integrated Communication Interface

The communication interface has bidirectional data transmission to and from a higher-level controller via standard fieldbus or safe standard fieldbus.

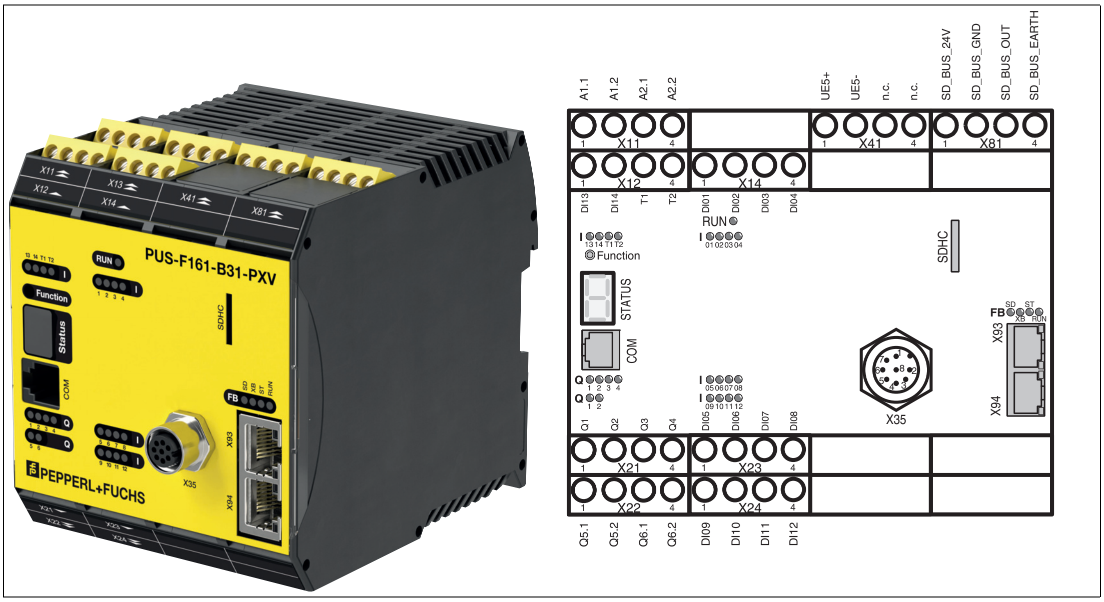
3.1 Device Overview PUS-F161-B*-PXV

The PUS evaluation unit is supplied as a complete unit and consists of the following main components:

- Read head board
- CPU and I/O board
- Communication board

The PUS evaluation unit has the following essential properties:

- Reading and evaluating the safe position of the read head
- Generation and evaluation of safe speed
- Processing of non-safe position, speed and diagnostic data of the read head



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Design of the evaluation unit

1	Axis
1	Read head interface
14	Digital inputs
2	Pulse outputs
2	Relay outputs
2/4	pn or pp switching outputs
2	Auxiliary outputs
1	Diagnostics and configuration interface
1	Function key
1	7-segment display
1	Status LED
14	Status LEDs for inputs
2	Status LEDs for pulse outputs
2	Status LEDs for relay outputs
6	Status LEDs for outputs
1	Communication interface

Properties of the evaluation unit

- Freely programmable for safe operation of EMERGENCY STOP button, two-handed operation, light grids, operating selector switches, etc.
- Complete speed and position-related safety functions for drive monitoring are integrated in the firmware
  - Spatial functions for safe speed and range monitoring are possible
- Safe position monitoring with only one read head in combination with the PXV100AQ*-F200-R4-V19* optical read head
- Logic processing up to PL e EN ISO 13849-1 or SIL 3 according to IEC 61508
- Motion monitoring of one axis up to PL e EN ISO 13849-1 or SIL 3 according to IEC 61508
- Rotation speed monitoring
- Standstill monitoring
- Direction monitoring
- Safe increment
- EMERGENCY STOP monitoring
- Position monitoring
- Position/movement area monitoring
- Target position monitoring
- Freely programmable small controller for up to 800 STL instructions
- Function diagram-oriented programming
- Pulse outputs for cross-bridging / short circuit detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Switchable safe outputs pn-, p-switching for safety-relevant functions
- Monitored relay outputs for safety-related functions
- Comprehensive integrated diagnostic functions
- Parameter management for expansion modules in the basic unit
- Coded status display via front 7-segment display and status LEDs
- Multi-function push buttons (quit, start, reset) can be operated from the front
- Configurable with safeControl Expert via USB serial adapter or Ethernet-based fieldbus
- Advanced functionality: Read head interface
- Optional: Integrated memory card
- Communication interface
  - Standard and safe fieldbus protocols for communication with a higher-level controller (PROFINET, EtherNet/IP, EtherCAT, PROFIsafe, FSoE)

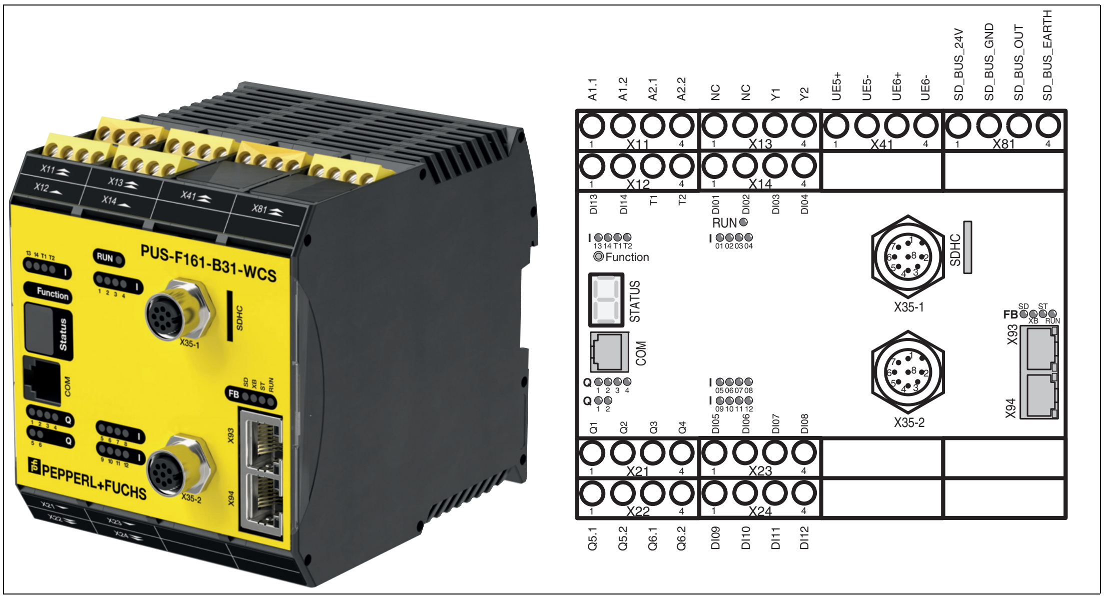
3.2 Device Overview PUS-F161-B*-WCS

The PUS evaluation unit is supplied as a complete unit and consists of the following main components:

- WCS board
- CPU and I/O board
- Communication board

The PUS evaluation unit has the following essential properties:

- Reading and evaluating the safe position of the two read heads
- Generation and evaluation of safe speed
- Processing of non-safe position, speed, and diagnostic data of the read head



Design of the evaluation unit

1	Axis
2	Read head interface
14	Digital inputs
2	Pulse outputs
2	Relay outputs
2/4	pn or pp switching outputs
2	Auxiliary outputs
1	Diagnostics and configuration interface
1	Function key
1	7-segment display
1	Status LED
14	Status LEDs for inputs
2	Status LEDs for pulse outputs
2	Status LEDs for relay outputs
6	Status LEDs for outputs
2	Communication interfaces

Properties of the evaluation unit

- Freely programmable for safe operation of EMERGENCY STOP button, two-handed operation, light grids, operating selector switches, etc.
- Complete speed and position-related safety functions for drive monitoring are integrated in the firmware
    - Spatial functions for safe speed and range monitoring are possible
- Safe position monitoring in combination with the two read heads WCS3B-LS221-U1 and WCS3B-LS221-U2
- Logic processing up to PL e EN ISO 13849-1 or SIL 3 according to IEC 61508
- Motion monitoring of one axis up to PL e EN ISO 13849-1 or SIL 3 according to IEC 61508
- Rotation speed monitoring
- Standstill monitoring
- Direction monitoring
- Safe increment
- EMERGENCY STOP monitoring
- Position monitoring
- Position/movement area monitoring
- Target position monitoring
- Freely programmable small controller for up to 800 STL instructions
- Function diagram-oriented programming
- Pulse outputs for cross-bridging / short circuit detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Switchable safe outputs pn-, p-switching for safety-relevant functions
- Monitored relay outputs for safety-related functions
- Comprehensive integrated diagnostic functions
- Parameter management for expansion modules in the basic unit
- Coded status display via front 7-segment display and status LEDs
- Multi-function push buttons (quit, start, reset) can be operated from the front
- Configurable with safeControl Expert via USB serial adapter or Ethernet-based fieldbus
- Advanced functionality: Read head interface
- Optional: Integrated memory card
- Communication interface
    - Standard and safe fieldbus protocols for communication with a higher-level controller (PROFINET, EtherNet/IP, EtherCAT, PROFIsafe, FSoE)

3.3 Technical Data PUS-F161-B*-PXV and PUS-F161-B*-WCS

Technical data PUS-F161-B*-PXV

Functional safety data

Performance level according to EN ISO 13849-1	PL e
PFH/Architecture	12.6 FIT/cat 4
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a

Characteristic data for functional safety using the read head

Max. achievable performance level in accordance with EN ISO 13849-1	PL e
PFH/Architecture	13.39 FIT/cat 4 $MTTF_d$ = 37.6 a DC = 97.0 %
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a (max. service life)

General data

Number of safe digital inputs		14 (OSSD capable)
Number of safe digital outputs		
	pn switching **	2
	pp switching **	4
Number of safe digital I/Os		-
Number of relay outputs		2
Number of safe analog inputs		-
Number of auxiliary outputs		2
Number of pulse outputs (clock outputs)		2
Connection type		Plug-in terminals with spring-loaded or screw connection
Axis monitoring (Axes/read head interfaces)		1 / 1
Read head interfaces (terminals)		RS-485, X35

Electrical data

Supply voltage (tolerance)		24 V DC; 2 A (-15 %, +20 %)
Fusing	X11.1	max. 30 V DC; 3.15 A
	X11.2	max. 30 V DC; max. 10 A
Max. power consumption (logic)		6.8 W
Nominal data for digital inputs		24 V DC; 20 mA type 1 according to IEC 61131-2
Nominal data for digital outputs		

	pn switching		24 V DC; 2 A
	pp switching		24 V DC; 2 A
	Auxiliary outputs		-
	Nominal data for pulse outputs (Clock outputs)		24 V DC; 250 mA
Nominal data for relay outputs	Normally open	DC 13	24 V DC; 2 A
		AC 15	230 V AC; 2 A
Nominal data for safe analog inputs			-

Electrical data for UL

Nominal data for digital outputs			
	pn switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	pp switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	Max. total current (pn or pp)	8 A	
	Auxiliary outputs	-	
Nominal data for relay outputs	Normally open	24 V DC; 2 A (Pilot Duty) 120 V AC; 2 A (Pilot Duty)	

Environment

Temperature	0 °C … +50 °C in operation -25 °C … +70 °C storage, transport
Degree of protection	(IP20)
Climatic class	3k3 according to DIN 60 721-3
Minimum, maximum relative humidity (No condensation)	5 % 85 %
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of operating resources	2000 m
Overvoltage category	III

Mechanical data

Housing length	115
Housing width	90
Housing height	100
Ground	490 g
Mounting	DIN mounting rail
Number of T-buses	4
Min. connector cross section/AWG	0.2 mm^2/24
Max. connector cross section/AWG	2.5 mm^2/12

Technical data PUS-F161-B*-WCS

Functional safety data

Performance level according to EN ISO 13849-1	PL e
PFH/Architecture	12.6 FIT/cat 4
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a

General data

Number of safe digital inputs		14 (OSSD capable)
Number of safe digital outputs		
	pn switching **	2
	pp switching **	4
Number of safe digital I/Os		-
Number of relay outputs		2
Number of safe analog inputs		-
Number of auxiliary outputs		2
Number of pulse outputs (clock outputs)		2
Connection type		Plug-in terminals with spring-loaded or screw connection
Axis monitoring (Axes/read head interfaces)		1 / 1
Read head interfaces (terminals)		RS-485, X35-1/35-2

Electrical data

Supply voltage (tolerance)			24 V DC; 2 A (-15 %, +20 %)
Fusing	X11.1		max. 30 V DC; 3.15 A
	X11.2		max. 30 V DC; max. 10 A
Max. power consumption (logic)			6.8 W
Nominal data for digital inputs			24 V DC; 20 mA type 1 according to IEC 61131-2
Nominal data for digital outputs			
	pn switching		24 V DC; 2 A
	pp switching		24 V DC; 2 A
	Auxiliary outputs		24 V DC; 250 mA
	Nominal data for pulse outputs (Clock outputs)		24 V DC; 250 mA
Nominal data for relay outputs	Normally open	DC 13	24 V DC; 2 A
		AC 15	230 V AC; 2 A
Nominal data for safe analog inputs			-

Electrical data for UL

Nominal data for digital outputs			
	pn switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	pp switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	Max. total current (pn or pp)	8 A	
	Auxiliary outputs	24 V DC; 250mA (G.P.)	
Nominal data for relay outputs	Normally open	24 V DC; 2 A (Pilot Duty) 120 V AC; 2 A (Pilot Duty)	

Environment

Temperature	0 °C … +50 °C in operation -25 °C … +70 °C storage, transport
Degree of protection	(IP20)
Climatic class	3k3 according to DIN 60721-3
Minimum, maximum relative humidity (No condensation)	5 % 85 %
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of operating resources	2000 m
Overvoltage category	III

Mechanical data

Housing length	115
Housing width	90
Housing height	100
Ground	490 g
Mounting	DIN mounting rail
Number of T-buses	4
Min. connector cross section/AWG	0.2 mm^2/24
Max. connector cross section/AWG	2.5 mm^2/12

3.4 Nameplate PUS-F161-B**-PXV

The nameplate is mounted on the left side panel of the evaluation unit and contains the following information:

Figure 3.1 Nameplate

Product no.	Product number
HW release	Hardware release designation
FW release	Software release designation
Date	Date of manufacture (CW/year)
Serial no.	Serial number
FBX 93/94	
FW-Rel.PXV	Firmware version
Type	Model number
Standard	Safety category

Power	Power supply characteristics
Input	Input characteristics
Output	Output characteristics
Main supply	Main supply
Power consumption	Power consumption
Digital	
Auxiliary	Auxiliary current
Relay NO (pilot duty)	

3.5 Nameplate PUS-F161-B**-WCS

The nameplate is mounted on the left side panel of the module and contains the following information:

Figure 3.2 Nameplate

Product no.	Product number
HW release	Hardware release designation
FW release	Software release designation
Date	Date of manufacture (CW/year)
Serial no.	Serial number
FBX 93/94	
FW-Rel.WCS	Firmware version
Type	Model number
Standard	Safety category

Power	Power supply characteristics
Input	Input characteristics
Output	Output characteristics
Main supply	Main supply
Power consumption	Power consumption
Digital	
Auxiliary	Auxiliary current
Relay NO (pilot duty)	

3.6 Derating Outputs

Maximum current-carrying capacity based on temperature.

The total current must not exceed **10A**.

Temperature 30 °C/50 °C	
Q1 Q4	2 A / 1.8 A

3.7 Scope of Delivery

The scope of delivery includes:

- PUS evaluation unit

Not included in the scope of delivery:

- Connectors for the signal terminals and power supply
- safePXV/PUS read heads: PXV100AQS-F200-R4-V19-6011, PXV80AQS-F200-R4-V19, PXV100AQS-F200-B33-V19-6011
- safeWCS/PUS read heads: WCS3B-LS221-U1 and WCS3B-LS221-U2
- safeControl Expert software with installation manual, programming manual
  Drivers for programming adapters
  Programming adapter PUS-USB-COMM
  License key (USB dongle) for safeControl Expert

Caution!

Condensation of humidity in the device

Destruction of electrical components.

Do not expose a device to high humidity for an extended period of time. If a cold device is moved to a much warmer environment (e.g., after being transported in a cold environment for a long period), condensation may occur in the device.
Wait until the temperature of the device has reached room temperature and the moisture has evaporated before connecting the device to the power supply.

4 Communication Interfaces

4.1 Functional Description

- The COM module with the respective communication interface is permanently integrated in each PUS evaluation unit.
- The Ethernet interface is used for non-safe communication through Ethernet-based protocols.
- Depending on the version, a safe fieldbus connection such as PROFIsafe (PUS-F161-B28-***) and FSoE (PUS-F161-B31-***) can be used.
- The COM module receives data from the application program running on the PUS evaluation unit and forwards it to a higher-level standard controller via the bus protocol selected and configured in the programming system. The data can be further processed there.
- The non-safe diagnostic data consists of logic and process data.
- The process data can include the position, speed, and other status data of the safe drive monitoring modules.
- The exact breakdown of the diagnostic data and the pre-selectable profiles can be found in the chapter Input and Output Data (see chapter 4.4).
- The PUS evaluation unit must always be configured as a node in the network.
- A corresponding device description file (EDS, GSDML, ESI, GSD) is often required for configuration in the programming system of the higher-level controller.

4.2 Fieldbus Characteristic Data

4.2.1 PROFINET

Fieldbus-specific data for PROFINET

Response time	Cycle time (input trigger) at least 1 ms, Response time depends on the host device PUS evaluation unit: 8 ms
Size of the cyclic output data	80 bytes[1]
Size of the cyclic input data	204 bytes[2]
Baud rate	100 Mbit/s
Safety I/O data (output)	12 bytes (extended format)[3]
Safety I/O data (input)	12 bytes (extended format)[4]
Supported protocols	RTC – Real time cyclic protocol (Class 1, Class 2, Class 3) RTA – Real time acyclic protocol DCP – Discover and configuration protocol LLDP – Link layer discovery protocol
Topology detection	LLDP, SNMP V1, MIB2, physical device
Duplex mode	Half-duplex, full-duplex, auto-negotiation
Data transfer layer	Ethernet II, IEEE 802.3

1. Outputs: 4 bytes; SD bus outputs: 64 bytes; safety outputs: 12 bytes
2. Diagnostic inputs: 128 bytes; SD bus inputs: 64 bytes; safety inputs: 12 bytes
3. 12 bytes of usable data + 12 bytes CRC + 2 bytes connection ID + 1 byte master command
4. 12 bytes of usable data + 12 bytes CRC + 2 bytes connection ID + 1 byte master command

4.2.2 EtherCAT

Fieldbus-specific data for EtherCAT

Response time	Cycle time (input trigger) at least 1 ms, Response time depends on the host device PUS evaluation unit: 8 ms
Size of the cyclic output data	95 bytes[1]
Size of the cyclic input data	219 bytes[2]
Safety I/O data (output)	12 bytes (extended format)[3]
Safety I/O data (input)	12 bytes (extended format)[4]
Type	Complex nodes
Number of sync managers	4 (2 acyclic, 2 cyclic)
Supported protocols	RTC – Real time cyclic protocol (Class 1, Class 2, Class 3) RTA – Real time acyclic protocol DCP – Discover and configuration protocol LLDP – Link layer discovery protocol
Topology detection	LLDP, SNMP V1, MIB2, physical device
Duplex mode	Half-duplex, full-duplex, auto-negotiation
Data transfer layer	Ethernet II, IEEE 802.3

1. Outputs: 4 bytes; SD bus outputs: 64 bytes; safety outputs: 27 bytes
2. Diagnostic inputs: 128 bytes; SD bus inputs: 64 bytes; safety inputs: 27 bytes
3. 12 bytes of usable data + 12 bytes CRC + 2 bytes connection ID + 1 byte master command
4. 12 bytes of usable data + 12 bytes CRC + 2 bytes connection ID + 1 byte master command

4.3 Equipment Configuration and Settings

4.3.1 Ethernet Interface

The front panel shows the following features:

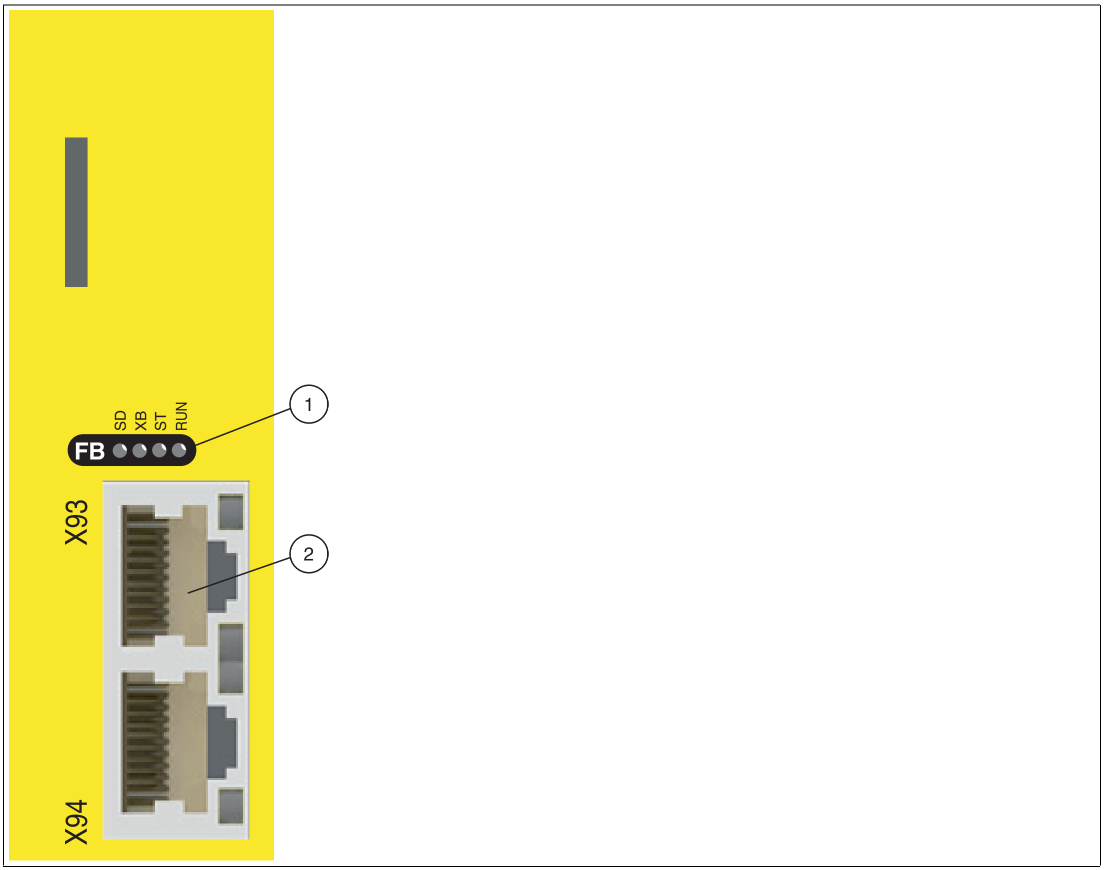


Figure 4.1 Front view

1 Diagnostic LEDs

2 Ethernet socket for Ethernet-based fieldbus

2023-06

4.3.2 Diagnostic LEDs

The communication interface has 4 bi-color LEDs, regardless of the device type.

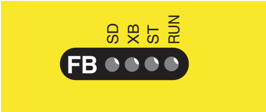


Figure 4.2 Diagnostic LEDs

Designation	Function
SD	SD bus LED
XB	Cross-link to the F-CPU
ST	Fieldbus feedback
RUN	Status of SDDC/SMMC communication

Note

The diagnostic LEDs are not reliable indicators and cannot be guaranteed to provide accurate information. They should only be used for general diagnostics during commissioning or troubleshooting. Do not attempt to use the LEDs as operational indicators.

The following table shows the functions of the display field:

Diagnostic LEDs display functions

Designation	Color	LED	Description	
RUN	Orange	Flashing	Initialize; waiting for connection and reception of device and connection parameters	
		On	Waiting for a logical connection to the main COM device	
	Green	Flashing	Waiting for the device and connection parameters to be received after the main device run timeout	
		On	Active process data exchange	
	Red	On	No connection on either port; connection timed out when starting the state or when restarting the main unit	
ST (network status)	Green	On	PROFINET:	Application relationship (AR) established; active
			EtherCAT:	Status operative
		Flashing	PROFINET:	Bus connection, but no integration
			EtherCAT:	Pre-operative status
		Short flashing	PROFINET:	Bus connection, but no integration
			EtherCAT:	Reliable operation status
	Red	On	PROFINET:	Bus error
			EtherCAT:	Application control failure
		Flashing	PROFINET:	Bus error
			EtherCAT:	Error code according to ETG.1300 EtherCAT display and labeling specification
	Orange	Flashing	PROFINET:	-
			EtherCAT:	-
	Off		PROFINET:	Inactive
			EtherCAT:	Inactivation/status initialization

Designation	Color	LED	Description
SD	Green	Flashing	SD bus scan active
		On	Data exchange active
	Red/orange	Flashing	SD bus scan error
	Red	On	SD bus error in cyclic operation
	Off	-	No fieldbus node is connected to the SD bus

4.4 Input and Output Data

The first 128 bytes of the input group are used for diagnostic data.

The following 64 bytes are used for SD bus data as described in the chapter "SD bus data."

128 bytes of diagnostic data are always sent, regardless of how much data the higher-level standard controller actually requires. Bytes that are not required are written as 0.

The diagnostic data is configured in safeControl Expert.

68 bytes of output data are available regardless of the device and the selected profile. The top 64 bytes of this are used for the SD bus.

4.4.1 Output Data

Structure of the overall frame:

Size of the diagnostic data: always 128 bytes, 16 bytes can be used for diagnostics

Logic data

Byte	Bit	"Run" mode (2, 3, 4)	Failure (A, F)
Byte 0	0 3	Device mode 1, 2, 3, 4, 5, 6 = serious fault, 7 = Alarm	
	4	0x1 (always 1)	
	5 7	Activity counter (3 bit)	
Byte 1	0 7	Logical data (bit ID: 49 56)	
Byte 2	0 7	Logical data (bit ID: 41 48)	
Byte 3	0 7	Logical data (bit ID: 33 40)	
Byte 4	0 7	Logical data (bit ID: 9 16)	
Byte 5	0 7	Logical data (bit ID: 1 8)	
Byte 6	0 6	Logical data (bit ID: 25 31)	Fault code high byte
	7	"0"	"1"
Byte 7	0 7	Logical data (bit ID: 17 24)	Fault code low byte

The device mode bits indicate the status of the controller. The statuses 1 5 are output in parallel on the 7-segment display. Status 6 indicates a fault, status 7 indicates an alarm.

Note

The meaning of the fault codes in decimal notation can be found in the "Fault list" document.

Process data follows with a byte offset of 7; byte 0 of the process data is byte 8 of the overall frame/input assignment.

Logic and process data

Byte	Assignment
Byte 0	Status
Byte 1	Logic data (bit ID: 49 56)
Byte 2	Logic data (bit ID: 41 48)
Byte 3	Logic data (bit ID: 33 40)
Byte 4	Logic data (bit ID: 9 16)
Byte 5	Logic data (bit ID: 1 8)
Byte 6	Logic data (bit ID: 25 31) / Error code
Byte 7	Logic data (bit ID: 17 24) / Error code
Byte 8	Process data (bit ID: 57 64)
Byte 9	Process data (bit ID: 49 56)
Byte 10	Process data (bit ID: 41 48)
Byte 11	Process data (bit ID: 33 40)
Byte 12	Process data (bit ID: 25 32)
Byte 13	Process data (bit ID: 17 24)
Byte 14	Process data (bit ID: 9 16)
Byte 15	Process data (bit ID: 1 8)
Byte 16	Not used
etc.	etc.
Byte 127	Not used
Byte 128	SD gateway - diagnostics
Byte 129	SD gateway - data
Byte 130	SD node 1 - data
Byte 131	SD node 1 - diagnostics
Byte 132	SD node 2 - data
Byte 133	SD node 2 - diagnostics
etc.	etc.
Byte 190	SD node 31 - data
Byte 191	SD node 31 - diagnostics

4.4.2 Input Data

Structure of the functional input data

Byte	Assignment
Byte 0	Logic data (bit ID: 1 8)
Byte 1	Logic data (bit ID: 9 16)
Byte 2	Logic data (bit ID: 17 24)
Byte 3	Logic data (bit ID: 25 31)
Byte 4	SD gateway - instruction
Byte 5	SD gateway - address
Byte 6	SD node 1 - request
Byte 7	SD node 1 - reserved
Byte 8	SD node 2 - request
Byte 9	SD node 2 - reserved
etc.	etc.
Byte 66	SD node 31 - request
Byte 67	SD node 31 - reserved

4.5 SD Bus Data

4.5.1 SD Bus Gateway Fieldbus Data

In the fieldbus protocol, 2 bytes are reserved in the request and response for gateway diagnostics and for acyclic data requests from SD nodes.

Request	Byte 00	Command byte, acyclic data request
	Byte 01	SD node address for the acyclic data request
Response	Byte 00	Gateway diagnostic byte
	Byte 01	Data byte, acyclic data request

For a detailed description of the acyclic data request from SD nodes, see

4.5.2 Fieldbus Data SD Nodes

For each SD node, 2 bytes are reserved in the request and response of the fieldbus protocol.

- SD node 01 uses bytes 02 and 03 of the fieldbus
- SD node 02 uses bytes 04 and 05 of the fieldbus
- etc.
- SD node 31 uses bytes 62 and 63 of the fieldbus

In the **request**, only the first byte of the fieldbus is required as the request byte for an SD node. The second byte is not used.

In the **response**, first the response byte and then the diagnostic byte are transmitted to the fieldbus from each SD node.

4.5.3 Structure of SD Bytes in Fieldbus Protocol

Request for all fieldbus systems (OUTPUT byte control, transmission of the request data to the SD node)

Byte no.	Byte 00	Byte 01	Byte 02	Byte 03	etc.	Byte 62	Byte 63
SD device	Gateway	Gateway	Node 01	Node 02	etc.	Node 31	Node 31
Content	Instruction byte	SD address (0, 1 31)	Request byte	-		Request byte	-

Response for all fieldbus systems (INPUT byte control, reception of the response data from the SD node)

Byte no.	Byte 00	Byte 01	Byte 02	Byte 03	etc.	Byte 62	Byte 63
SD device	Gateway	Gateway	Node 01	Node 02	etc.	Node 31	Node 31
Content	Diagnostic byte	Date byte	Response byte	Diagnostic byte		Response byte	Diagnostic byte

The content of the diagnostic byte of an SD node depends on the status of the alarm and the fault bits in the corresponding response byte (bit 6 = fault warning and bit 7 = fault).

The meaning of the individual bits of the SD bytes is explained in the installation instructions of the SD devices.

4.5.4 Reading Acyclic Data from the SD Node

In a fixed cycle, acyclic data can be requested from an individual SD node using the 2 request bytes (fieldbus request byte 00 and byte 01) and the data byte (fieldbus response byte 01).

The command byte defines which data is being requested from a node. The SD device from which the data is being requested is specified in the SD interface with the SD address byte. The SD node response data is stored in fieldbus response byte 01.

The data query cycle is defined as follows:

1. The evaluation unit deletes the data byte before or after each command. The response byte is used to generate a feedback message as to whether the data has been deleted or not.
   Hex FF: Data deleted, acyclic data service ready
2. The controller first writes the SD address to fieldbus request byte 01. The controller then writes the instruction byte to fieldbus request byte 00.
3. The response data is made available to the evaluation unit in fieldbus response byte 01. The data byte can also contain a fault message in response:
   Hex FE: Instruction fault, undefined instruction requested.
   Hex FD: Address fault, invalid node address for the selected command or node address of an unavailable SD node selected

Overview of instructions and response data

Instructions, Acyclic data retrieval	Instruction byte Fieldbus byte 00 (Request)	SD address Fieldbus byte 01 (Request)	Data byte Fieldbus byte 01 (Response)	Description of the data
Delete data byte	Hex: 00	Hex: xx	Hex: FF	Data deleted, ready for new job
Read the number of configured SD nodes	Hex: 01	Hex: 00	Hex: 01 to hex: 1F	Number of configured SD nodes 1 31
Read the device category of the SD node	Hex: 02	Hex: 01 to hex: 1F	Hex: 30 to hex: F8	SD node device category (see below)
Read the hardware revision of the SD node	Hex: 03	Hex: 01 to hex: 1F	Hex: 41 to hex: 5A	Hardware revision A–Z as ASCII characters
Read the software version of the SD node (high byte)	Hex: 04	Hex: 01 to hex: 1F	Hex: 00 to hex: 63	Software version, high byte: 0 99
Read the software version of the SD node (low byte)	Hex: 05	Hex: 01 to hex: 1F	Hex: 00 to hex: 63	Software version, low byte: 0 99

The following device categories are defined:

Hex: 30	CSS 34, safety sensor
Hex: 31	AZM 200, safety locking device "Z" version
Hex: 32	AZM 100, safety locking device "Z" version
Hex: 33	AZ 200, safety sensor
Hex: 34	CSS 30S, safety sensor
Hex: 35	MZM 100 B, safety locking device "B" version
Hex: 36	AZM 300 B, safety locking device "B" version
Hex: 37	RSS 36, safety sensor
Hex: 38	AZM 300 Z, safety locking device "Z" version
Hex: 39	RSS 16, safety sensor
Hex: 3A	RSS 260, safety sensor
Hex: 3D	MZM 120 B, safety locking device "B" version
Hex: 3E	MZM 120 BM, safety locking device "B" version
Hex: 3F	AZM 201Z, safety locking device "Z" version
Hex: 40	AZM 201B, safety locking device "B" version
Hex: 41	Operating panel BDF200-SD
Hex: 43	AZ 201, safety sensor

The individual bits in the diagnostic byte for the SD gateway have the following meaning:

Bit	Error	Description
Bit 0	Fault in SD interface	SD interface central alarm, message delayed for 1 second, invalid SD data.
Bit 1	-	-
Bit 2	-	-
Bit 3	-	-
Bit 4	SD initialization fault	SD chain must be re-initialized! Switch off the operating voltage to the gateway and SD node. Possibly no SD node connected!
Bit 5	SD teach-in fault	The structure of the SD chain has changed after switching on! If OK, press TEACH.
Bit 6	SD short circuit	Bit 6 SD short circuit in the SD interface cables. Switch off and resolve the fault.
Bit 7	SD communication fault	One or more SD nodes are not available. Invalid data from the SD nodes. If necessary, check the SD installation.

4.6 Safety-related Data

There are 12 bytes of safe data in each direction. These are already pre-defined, depending on the device description file (e.g., ESI, EDS).

The diagnostic data is configured in safeControl Expert.

4.6.1 PUS-F161-B**-***

Structure of the frame:

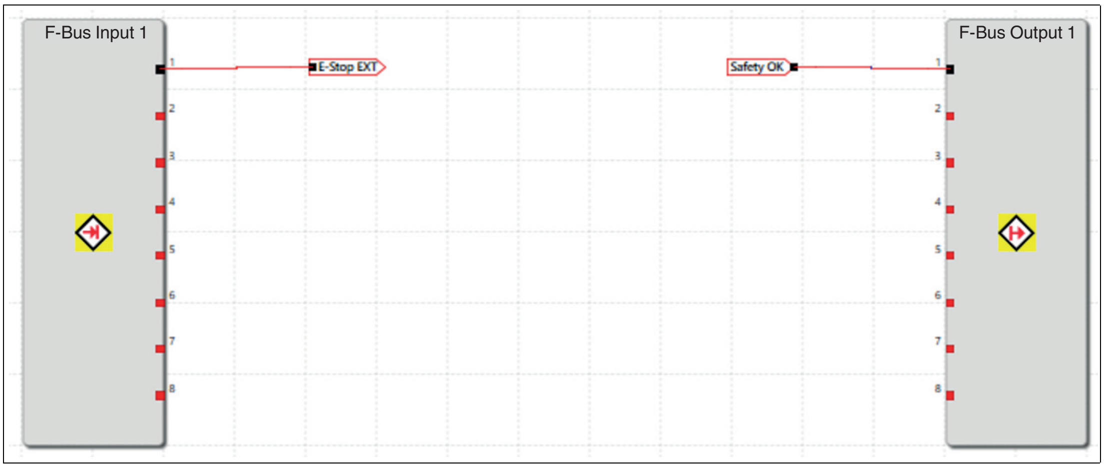
Safety data quantity: always 12 bytes

F-bus input or output

Byte	Assignment
Byte 0	Safe data bit 1 ... 8)
Byte 1	Safe data bit 18 ... 16)
Byte 2	Safe data bit 17 ... 24)
Byte 3	Safe data bit 25 ... 32)
Byte 4	Safe data bit 33 ... 40)
Byte 5	Safe data bit 41 ... 48)
Byte 6	Safe data bit 49 ... 56)
Byte 7	Safe data bit 57 ... 67)
Byte 8	Safe data bit 68 ... 72)
Byte 9	Safe data bit 73 ... 80)
Byte 10	Safe data bit 81 ... 88)
Byte 11	Safe data bit 89 ... 96)

Note

The bit names are mapped in safeControl Expert starting with bit 1.



Example

F-bus input

Byte 0: Bit 0 is mapped to bit 1 (E-Stop EXT) in safeControl Expert in the F-bus module.

F-bus output

Bit 1 (Safety OK) is mapped to byte 0 bit 0 from safeControl Expert.

5 Safety-Related Characteristics

The safety technology described below meets the following safety requirements:

- Performance level e according to EN ISO 13849-1
- SIL 3 according to EN 61508

For a complete safety concept of an entire system using the evaluation unit, additional documentation is required to be created by the user. This is not discussed in detail here.

Please refer to the underlying standards for the relevant requirements.

The following chapter describes the architecture and the basic structure of the evaluation unit.

It also describes the options for connecting the evaluation unit to sensors and actuators.

Depending on this and the diagnostics used, a safety category and a maximum achievable performance level (PL) are produced in accordance with EN ISO 13849-1.

Note

Safety function

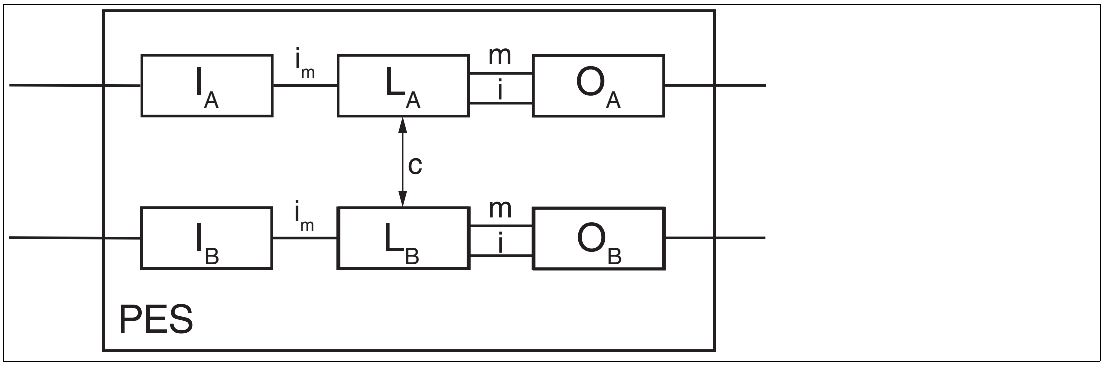
In addition to the evaluation unit, the sensor, the actuator and the type of external wiring are critical to the overall safety function.

The actual performance level achieved for the safety function must always be determined based on the underlying guideline or standard, taking into account the components used, their wiring, circuitry, and the diagnostics used!

5.1 Safety Architecture of PUS Evaluation Unit and Characteristic Data

The internal structure of the PUS evaluation unit consists of two separate channels with mutual comparison of results. High-quality diagnostics for fault detection are performed in each of the two channels.

The structure corresponds to category 4 of EN ISO 13849-1 in terms of architecture and functionality.



PES Programmable electronic system

I_A Input channel A

I_B Input channel B

L_A Logic channel A

L_B Logic channel B

O_A Output channel A

O_B Output channel B

i_m Connectors

c Cross-comparison

m Monitoring

The overall architecture therefore has the following structure:

Figure 5.1 Double reading of each input and diagnostics by cross-comparison

The specific safety characteristics can be found in the technical characteristics given in chapter 3 (or see chapter 3.2) or the respective datasheet.

For the safety assessment of complete systems, the characteristic data specified in chapter 3 can be used for the PES subsystem (e.g., PL e and PFH value according to the table for evidence in accordance with EN ISO 13849-1).

Note

For information on the fault eliminations in place, please refer to the tables under D in the annex to EN ISO 13849-2.

The examples presented in this manual and their characteristic architecture are primarily responsible for the classification into a category in accordance with EN ISO 13849-1.

The resulting maximum possible performance levels according to EN ISO 13849-1 depend on the following factors for external components:

- Structure (single or redundant)
- Measures against failures with a common cause (CCF)
  Degree of diagnostic coverage (DCavg)
  Time to dangerous channel failure (MTTFd)

Restrictions

Note

- The plant/machine manufacturer must always create a risk analysis typical of the plant/machine. In doing so, the use of the evaluation unit must be taken into account.
- The safety concept is only suitable for carrying out mechanical work on driven plant/machine components. Before carrying out any work on the electrical part of the drive system, the supply voltage must be switched off via an external maintenance switch/main switch.
- After switching off the 24 V DC power supply, voltages may still be present at inputs and from other circuits.

Safety-related key data

Max. achievable safety class	• SIL 3 according to EN 61508 • Category 4 in accordance with EN 954-1 • Performance level e according to EN ISO 13849-1
System structure	2-channel with diagnostics (1002) according to EN 61508 Architecture category 4 according to EN ISO 13849
Operating mode type	"high demand" according to EN 61508 (high demand rate)
Probability of a hazardous failure per hour (PFH value)	Specific values in accordance with the "Safety characteristics" tables
Proof test interval (EN 61508)	20 years, after which the module must be replaced

Caution!

Safety notices

The specific safety characteristics of the respective modules can be found in the technical characteristics.

When using several sensors with different functions (e.g., access door position indicator + speed detection) for one safety function (e.g., safely reduced speed when the access door is open), these must be regarded as a series connection for the safety assessment of the overall system. See the calculation example in the appendix in this respect.

The safety regulations and EMC directives must be observed.

For information on the fault eliminations in place, please refer to the tables under D in the annex to EN ISO 13849-2.

For the safety assessment of the complete system, the specified characteristic data can be used for the PES subsystem (e.g., PL e and PFH value as per the proof table according to EN ISO 13849-1)

The examples shown below and their characteristic architecture are primarily responsible for the classification into a category in accordance with EN ISO 13849-1.

The resulting maximum possible performance levels according to EN ISO 13849-1 depend furthermore on the following factors for external components:

- Structure (single or redundant)
- Detection of common cause faults (CCF)
- Degree of diagnostic coverage on request (DC_{avg})
- Time to dangerous failure of a channel ($MTTF_d$)

5.2 Safety-related Characteristics and Wiring for Connected Sensors

Each PUS evaluation unit has completely separate signal processing paths for each safety input.

Measures furthermore to achieve the highest possible DC values in each case are implemented.

5.2.1 Digital Sensors

The digital inputs are designed in principle to be fully redundant. The following list shows the details of the classification, the DC, and the achievable PL or SIL.

5.2.1.1 Characteristics of Sensors / Input Elements

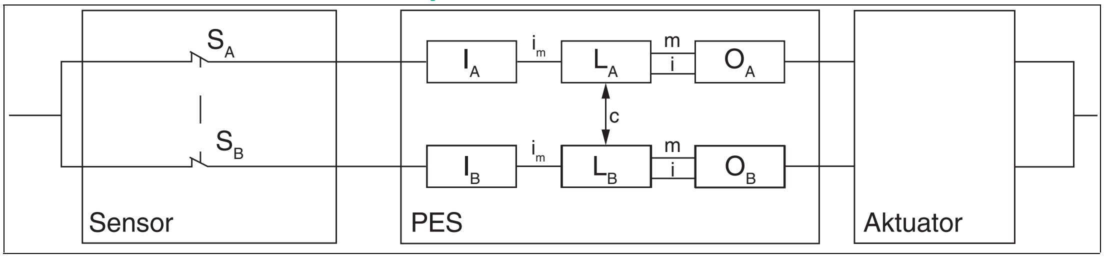


Figure 5.2 2-channel input element in parallel connection (cat. 4, fault tolerance 1) with high DC through signal processing in two channels and diagnostics by cross-comparison in the PE system

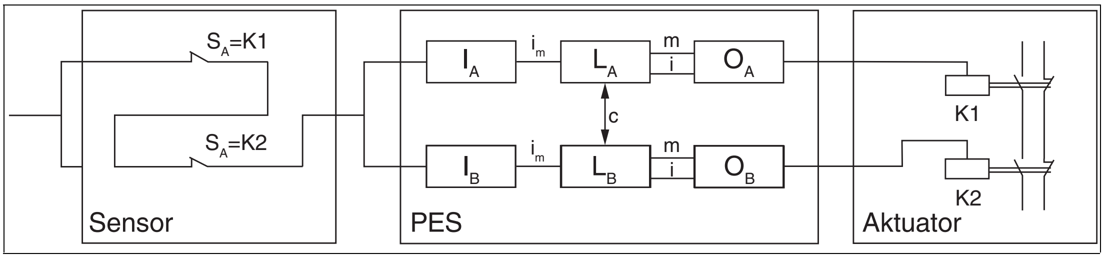


Figure 5.3 Two-channel input element in series connection (cat. 4, fault tolerance 1) with low to medium DC through signal processing in two channels and diagnostics by cyclic testing

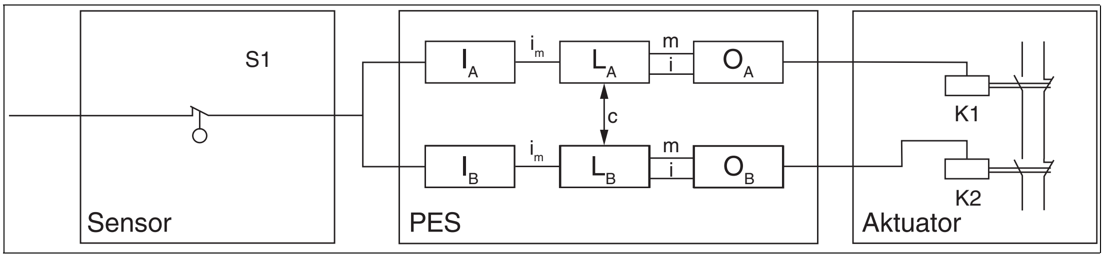


Figure 5.4 1-channel input element and 2-channel processing with low to medium DC through signal processing in two channels and diagnostics by cyclic testing, PL/SIL depending on permissible fault eliminations and test rate of the input element.

5.2.1.2 DC Digital Sensors/Inputs

The PUS evaluation unit ensures extensive diagnostic functions for the input subsystem. These are carried out continuously or optionally (cross-circuit monitoring by pulse identification, cross comparison, two- or multi-channel sensor with/without time monitoring, start-up test).

Continuously active diagnostic functions

Cross-comparison

The inputs of the PUS evaluation unit are always 2-channel internally. The status of the input signals is continuously compared crosswise. The input status is only deemed to be high in the case where a high signal is received from both input subsystems. If the signal level of the two channels differs, the input status is set low.

Dynamic test of the input subsystem switching thresholds

The switching thresholds for detecting the high level are tested cyclically, at a high rate. If the defined threshold value is not met, a module alarm is triggered.

Dynamic test of ability to switch the input subsystem

The ability to switch the input subsystem to low level is tested for all inputs except I04–I07 cyclically and at high rate. If the defined threshold value is not met, a module alarm is triggered.

Diagnostic functions that can be activated by parameterization

Cross-circuit test

The PUS evaluation units have pulse signal outputs, which are imprinted with a unique signature. When using the cross-circuit test, the switching elements of the digital sensors/input elements must be supplied with auxiliary voltage via the pulse signal outputs from the PUS evaluation unit. The signature is therefore imprinted at the high signal level of the sensors/input elements and checked by the PUS evaluation unit. The signature check allows short or cross-circuits to the high signal to be detected. Cross-circuits between the corresponding input signals are detected by alternating use of pulse signals for multiple contacts, parallel signal lines or adjacent terminal assignment.

Sensors/input elements with 2- or multi-pole contacts without time monitoring

Several contacts can be assigned to the sensors/input elements. These therefore correspond to elements with at least 2 channels. A high sensor/input element level requires a logical series connection of both contacts.

Example

Input element with 2 normally closed contacts: High level when both contacts are closed

Example

Input element with 1 normally closed contact and 1 normally open contact: High level when the normally open contact is actuated and the normally closed contact is not actuated.

Sensors/input elements with 2- or multi-pole contacts with time monitoring

The same test as before except with additional monitoring of the input signals for compliance with the defined level relationships within a time window of 3 s. A module alarm is triggered if the levels differ over a period of > 3 s.

Start-up test:

Each time the safety module (= PUS evaluation unit) is switched on, a test of the input element in the direction of the low signal status (= defined safe status) must be carried out, e.g., by pressing the EMERGENCY STOP button or actuating a door lock after the system has been started.

Operational/organizational tests

In addition to the PUS evaluation unit diagnostic measures listed above, cyclic testing can be carried out in the application. These tests can be used to evaluate the DC.

Note

The operational/organizational tests can also be applied to a combination of hardware inputs and functional inputs (input information transmitted via standard fieldbus). However, exclusive use of functional inputs is not possible in this context (combination of two or more functional inputs)

The PUS evaluation unit therefore ensures extensive diagnostic functions for the input subsystem. These can be performed continuously or optionally (cross-circuit monitoring by pulse identification).

The following diagnostics for the input sensors can therefore be used for the safety assessment of the overall system

Characteristics Input element	Parameterized/ operational tests				DC	Definition of the measure	Note
	Cross-circuit test	With time monitoring	Start-up testing	Cyclic test in operation			
1-channel			o	o	> 60	Cyclic test pulse through dynamic change of the input signals	A sufficiently high test rate must be guaranteed
	x				90	Cyclic test pulse through dynamic change of the input signals	Only effective if pulse assignment is active
	x		o	o	90 - 99	Cyclic test pulse through dynamic change of the input signals	DC depends on frequency of start/cyclic test DC = 90 test only at intervals > 4 weeks DC = 99 test at least 1 x day or 100-times request rate

Characteristics Input element	Parameterized/ operational tests				DC	Definition of the measure	Note
	Cross-circuit test	With time monitoring	Start-up testing	Cyclic test in operation			
2-channel					90	Cross-comparison of input signals with dynamic test if short circuits cannot be detected (with multiple inputs/outputs)	Short circuit to DC=99 is possible during fault elimination
			o	o	90 – 99	Cyclic test pulse through dynamic change of the input signals	DC depends on the frequency of start/cyclic test
	x				99	Cross-comparison of input signals with immediate and intermediate results in logic (L), temporal and logical program run monitoring, and detection of static failures and short circuits (with multiple inputs/outputs)	Only effective if pulse assignment is active
		x			99	Plausibility check, e.g., use of the normally open and normally closed contacts = antivalent signal comparison of input elements	Only effective in conjunction with activated time monitoring function for input element

- x: Diagnostic measure activated
- o: min. 1 diagnostic measure activated

Warning!
Safety notice

- The sensor data ($MTTF_D$, PFH numbers, etc.) must be considered in any safety assessment of the subsystem.
- The DC values listed in the table must be applied conservatively and the boundary conditions must be ensured (see table under "Notes").
- Fault eliminations are permitted in accordance with the relevant standards. The specified boundary conditions must be maintained at all times.
- If multiple sensor systems are required for the proper functioning of a single safety function, their partial values must be correctly combined according to the chosen method.

5.2.1.3 Classification of Safe Digital Inputs

Digital inputs I01–14

Digital inputs	Achievable performance level	Comment
I01–I04 I09–I14	PL e	Suitable for all types of input elements, with/without pulses, achievable PL depending on $MTTF_d$ of the input element and fault eliminations in external cabling
I05–I08	PL e	1-channel with pulses: • Mostly high level required (T_{High} > 100 * T_{Low}) • At least one request/day determined by the application • Error detection on request
	PL d	1-channel without pulses: • Fault elimination short circuit between the signals and to VCC • Error detection on request
	PL e	2-channel: • At least one request/day determined by the application • Error detection on request

Note

The achievable PL for a combination of HW inputs and functional inputs depends on the selected operational/organizational tests and the independence of each channel in the system structure. Application-specific analysis is required to determine the PL.

5.2.1.4 Example Connections for Digital Sensors

1-channel sensor, without cross-circuit test

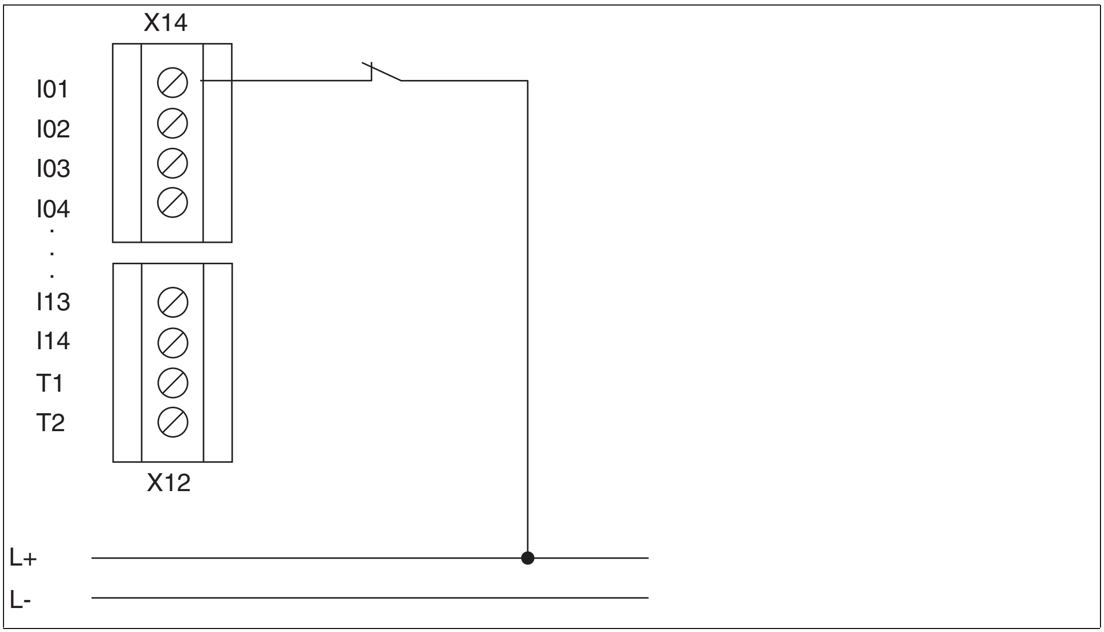


Figure 5.5 1-channel sensor, without cross-circuit test

The 1-channel sensor is connected to the evaluation unit without clock or cross-circuit testing. This design is not recommended for safety applications. A maximum of PL b can be achieved in accordance with EN ISO 13849-1.

1-channel sensor, with cross-circuit test

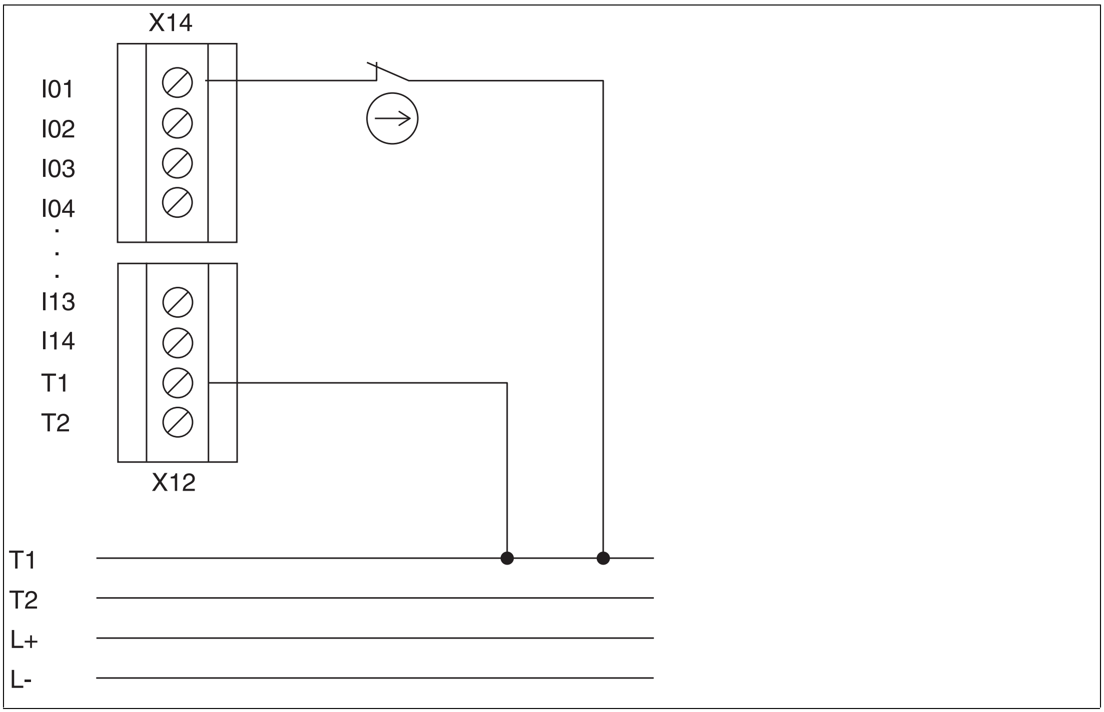


Figure 5.6 1-channel sensor with clock

If a 1-channel sensor with clock is used, a connection is made to the T0 or T1 clock output of the evaluation unit. The clock signals must then be assigned on the PUS evaluation unit.

The following can be detected by a 1-channel sensor with clock:

- Short circuit to 24 V DC supply voltage
- Short circuit to 0 V DC
- Cable break (power interruption is a safe state!)

Caution should be exercised if the cable is short-circuited between the two sensor connections since this is not detected! A short circuit between T1 and I01 is also not detected.

As the switching element/sensor is 1-channel, fault elimination is required to prevent failure. This is permissible when using forced disconnect switches with correct forced actuation.

The same applies to a series connection of 2 switching elements with appropriate elimination of a double fault condition (occurrence of two faults at the same time). This can be represented by e.g., the safety outputs of an electronic monitoring device (light curtain, switching mat) with internal 2-channel shutdown.

By using a suitable switching element and carefully wiring the sensor, PL d can be achieved in accordance with EN ISO 13849-1. In special cases, i.e., in conjunction with suitable switching elements and permissible fault eliminations, PL e according to EN ISO 13849-1 can also be achieved.

Warning!
Safety notice

- PL d or higher according to EN ISO 13849-1 is achieved if a short circuit between the input and the associated pulse output and between the sensor connections can be ruled out. It should be noted that in the event of a fault, the switch must be forced open in accordance with EN 60947-5-1. In addition, the sensor must be triggered at regular intervals and the safety function must be actuated. Fault eliminations can be achieved in accordance with EN ISO 13849-2 table D8. When using the inputs in 1-channel mode, the achievable safety level is restricted to SIL 2 or PL d if a safety function request is not made at regular intervals.
- A series connection of 2 switching elements with double fault elimination requires a test for suitability according to the desired safety level for this element. Reference is made to the relevant regulations of the EC Machinery Directive 2006/42/EC.
- In the case of 1-channel read heads, safety-related use of the inputs is intended only in conjunction with the pulse outputs.

2-channel sensor without time monitoring and without cross-circuit test

Faults are detected at least at point of request. The DC is moderate and can be raised to high classification by means of cyclic tests (start-up tests, operational/organizational tests) depending on the test frequency.

For safety applications, only normally closed contacts may be used in this respect.

PL d according to EN ISO 13849-1 can be achieved when using read heads/switching elements with fault elimination for non-opening of the switching contacts. This is permissible when using forced disconnect switches with correct forced actuation. The use of read heads with self-monitoring output contacts is also permitted.

PL e according to EN ISO 13849-1 can be achieved when using diverse read heads/input elements with sufficiently high MTTFD in conjunction with time-based plausibility monitoring and with a sufficiently high change in the switching state = dynamic testing.

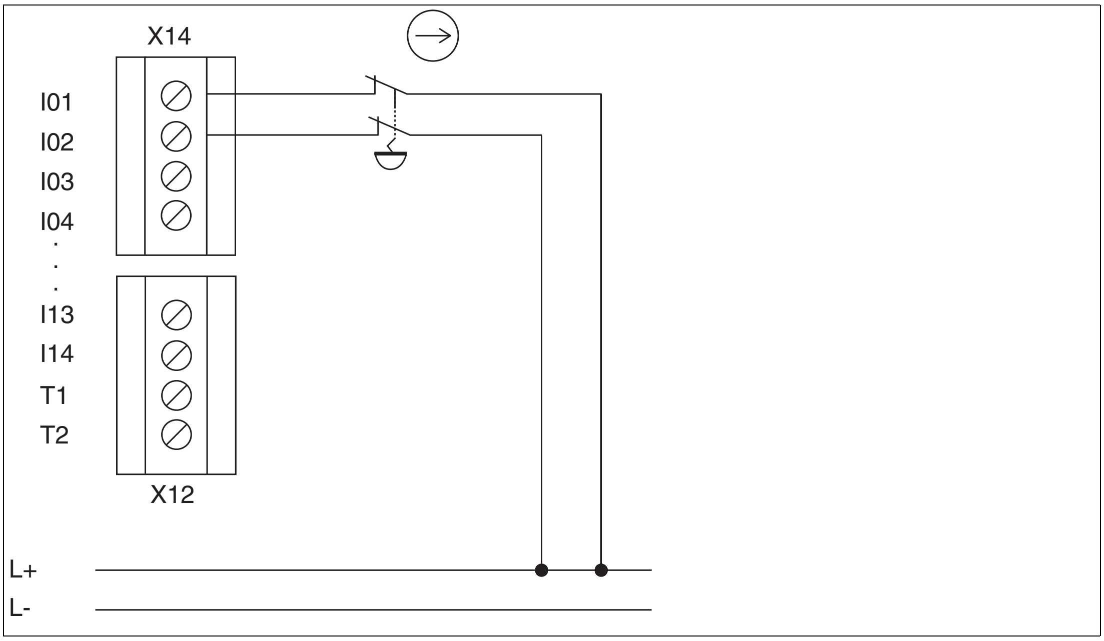


Figure 5.7 Homogeneous 2-channel sensor without clock, with forced isolation

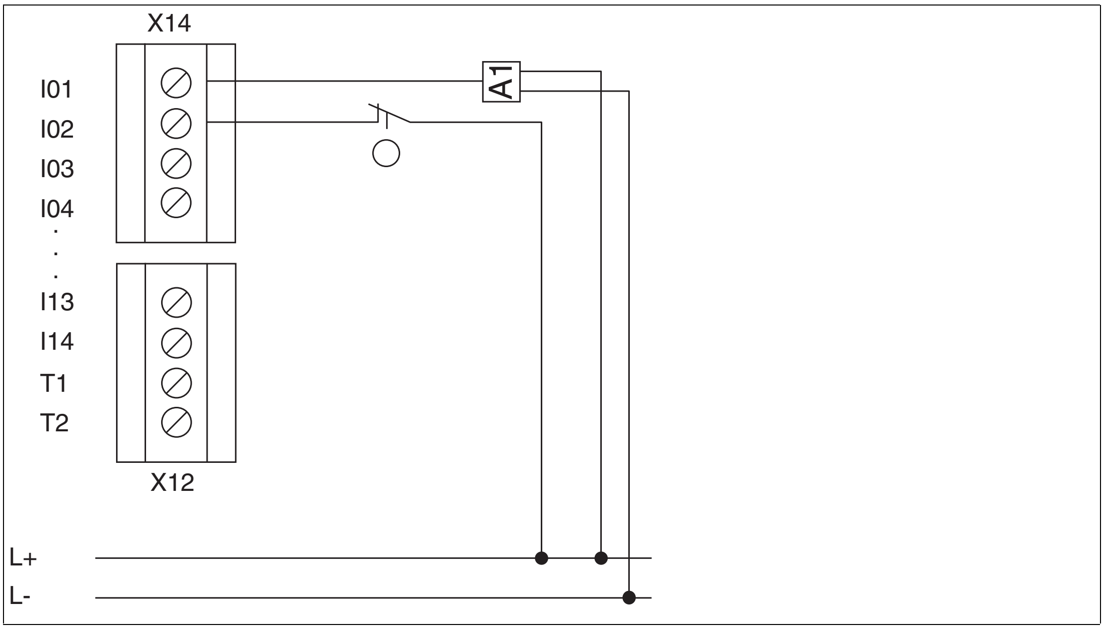


Figure 5.8 Diverse 2-channel input element, without clock

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Warning!
Safety notice

- PL d or higher according to EN ISO 13849-1 is achieved when switching elements/read heads with positive-opening contacts or forced actuation according to EN 60947-5-1 are used.
- It is permissible to use devices for whose switching elements double faults can be excluded for the desired safety level. Reference is made to the relevant regulations of the EC Machinery Directive 2006/42/EC.

2-channel sensor with time monitoring and cross-circuit test

By using two independent clock signals on the homogeneous sensor, all cross-circuits can be detected as can any connections to 24 V DC or 0 V DC.

PL d or higher according to EN ISO 13849-1 can be achieved with:

- The use of read heads/switching elements with forced actuation.
- The use of 2 read heads/switching elements with independent actuation.
- ditto But operated by a common actuation device in conjunction with a fault elimination for that device.

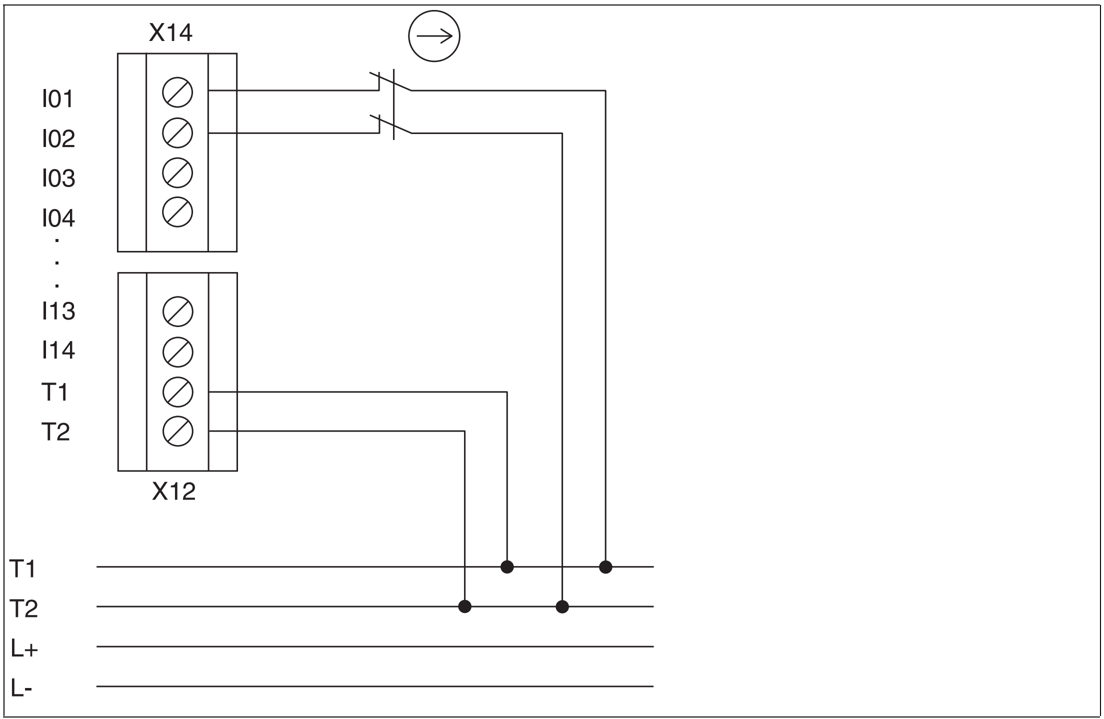

Figure 5.9 Homogeneous 2-channel sensor with clock

Warning!
Safety notice

- PL d or higher according to EN ISO 13849-1 is achieved when switching elements/read heads with forced actuation are used.
- When using read heads with non-positively opening contacts or when using two independent read heads with independent actuation, it is essential to use the macro (group) "universal input module" in the configuration software.
- When using common elements in the actuation chain, fault elimination is required for this. The corresponding restrictions and criteria in accordance with EN ISO 13849-1 must be observed for this purpose.

5.2.1.5 Overview of Achievable PL for Digital Safety Inputs

Type of sensor / input element	Input	Parameterized/ operational tests				Achievable PL in acc. with EN ISO 13849-1	Fault elimination for input element	Condition for input element
		Cross-circuit test	With time monitoring	Start-up testing	Cyclic test in operation			
1-channel						b		Proven input element
	I01 I14			O	O	d	All faults at input element Short circuit at the input/signal line	$MTTF_D$ = high Connection in the switch cabinet or protected routing
	I01 I04 I09 I14					e	All faults at input element Short circuit at the input/signal line	Input element corresponds to at least Plr Connection in the switch cabinet or protected routing
	All	X				d	Stuck Short circuit at the input/signal line	Mostly high level required (T_{High} > 100 * T_{Low}). Forced disconnect, $MTTF_D$ = high Connection in the switch cabinet or protected routing
		X		O	O	e	All faults at input element Short circuit at the input/signal line	Input element corresponds to at least Plr Connection in the switch cabinet or protected routing $MTTF_D$ = high
2-channel parallel	All					d	Short circuit between input/signal line	Connection in the switch cabinet or protected routing $MTTF_D$ = medium
		X				e		$MTTF_D$ = high
2-channel parallel	All		X			e	Short circuit between input/signal line (only for the same switching elements = 2xNO or 2xNC)	Connection in the switch cabinet or protected routing $MTTF_D$ = high

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Type of sensor / input element	Input	Parameterized/ operational tests				Achievable PL in acc. with EN ISO 13849-1	Fault elimination for input element	Condition for input element
		Cross-circuit test	With time monitoring	Start-up testing	Cyclic test in operation			
2-channel serial	I01 I04 I09 I14					d	Short circuit at the input/signal line Stuck/forced separation	Connection in the switch cabinet or protected routing $MTTF_D$ = medium
				O	O	e	Short circuit at the input/signal line	Connection in the switch cabinet or protected routing $MTTF_D$ = high
	All			O	O	d	Short circuit at the input/signal line	Connection in the switch cabinet or protected routing $MTTF_D$ = medium
		X		O	O	e		$MTTF_D$ = high

Options:

X: Diagnostic measure activated

O: min. 1 diagnostic measure activated

5.2.2 Read Heads for Speed and/or Position Detection

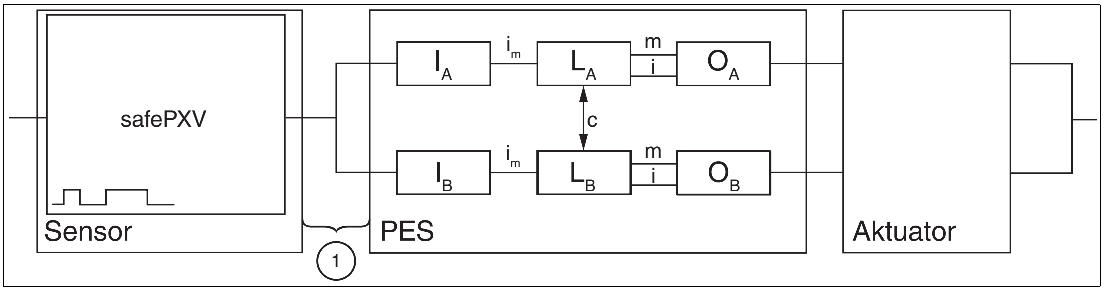
5.2.2.1 General Safety Design of Read Head Interface for Position and/or Speed

Depending on the type and combination of read head, different levels of safety can be achieved. The corresponding subsystem has been analyzed as follows:

PUS evaluation unit and safePXV/PUS read head

The PUS evaluation unit has an interface for connecting a safePXV/PUS read head.

The use of the read head ensures that the maximum level of safety, as listed in the technical specifications, is achieved. The corresponding subsystem has been analyzed as follows:



1 Gray channel

Read head system with 2-channel subsystem. Diagnostics by separate signal processing in two channels and cross-comparison in the PE system plus other specific diagnostics.

Note

The parameters from the "Technical Data" table (see chapter 3.3) can be used to make a safety-related assessment of the overall configuration, since these already represent the combination of the evaluation unit with the safePXV/PUS read head.

Caution!

Standards for electromagnetic compatibility (EMC)

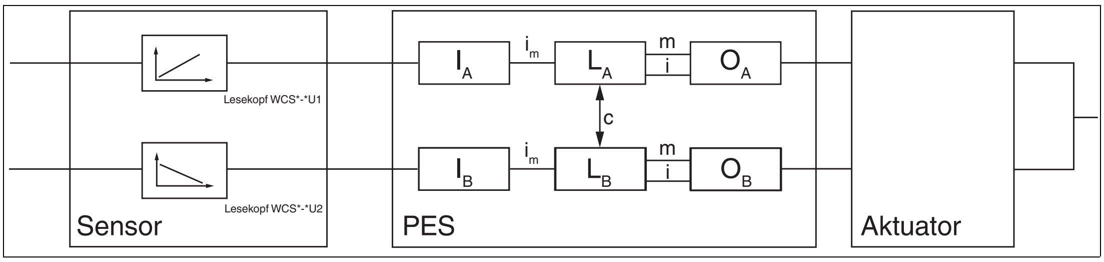
An EMC-compliant installation should be ensured. Particular attention should be paid to the cable routing and the processing of the shielding.

A further prerequisite is that the electromagnetic compatibility of the overall system is ensured by proven, applicable measures.

PUS evaluation unit and safeWCS/PUS read heads

The evaluation unit has interfaces for connecting the safeWCS/PUS read heads WCS3B-LS221-U1 and WCS3B-LS221-U2.

The use of both read heads ensures that the maximum level of safety, as listed in the technical specifications, is achieved. The corresponding subsystem has been analyzed as follows:



2-channel sensor system with separate signal processing in two channels, diagnostics by cross-comparison in the PE system.

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5.2.2.2 General Diagnostic Measures for the Read Head Interface

A number of diagnostic measures are implemented in the PUS evaluation unit for fault detection in the read head system, depending on the selected read head type or combination thereof. They are activated automatically on selection of the read head type.

In principle, the diagnostic measures can be classified in terms of their type and effectiveness using the following table:

Diagnostics for read heads for position and/or speed detection:

Action	DC	Note	Use
Cross-comparison of input signals with immediate and intermediate results in logic (L), temporal and logical program run monitoring, and detection of static failures and short circuits (with multiple inputs/outputs)	99 %	Only for use on: • 2-channel read head systems (2 separate read heads), • The 2-channel subsystem of 1-channel read heads • Diagnostics for the 1- and 2-channel subsystem of specifically suited read heads Dynamic operation / no standstill monitoring	Monitoring of 2-channel read head systems or the corresponding read head subsystem for dynamic operation. Not to be used for standstill monitoring!
Cross-comparison of input signals without dynamic test	80 ... 95 %	DC depends on the frequency of the dynamic state, i.e., stopped or moving and the quality of the monitoring measure (80–90 % for read heads, 95 % for SIN/COS read heads)	Monitoring of 2-channel read head systems or the corresponding read head subsystem for non-dynamic operation. To be used in particular for standstill monitoring!
Monitoring certain features of the read head (response time, range of analog signals, e.g., electrical resistance, capacitance)	60 %	Diagnosis of specific read head characteristics, only for speed and position read heads	Monitoring of the 1-channel subsystem of 1-channel read head systems

5.2.2.3 Read Head Combinations and Diagnostic Characteristics

Read head A	Read head B	Safe speed	Safe direction	Safe absolute	Fault elimination	DC		
						One-channel subsystem	Two-channel subsystem Dynamic	Two-channel subsystem Non-dynamic (Standstill monitoring)
safePXV/PUS	NC	X	X	X	****)	n.a.	99 %	97 %
safeWCS/PUS	safeWCS/PUS	X	X	X		n.a.	99 %	90 95 %

Note

****) For possible fault elimination, the relevant information in standard EN ISO 13849-2, tables under Annex D, must be observed accordingly. The parameters from the "Technical Data" table (see chapter 3.3) can be used to make a safety-related assessment of the overall configuration since these already represent the combination of an evaluation unit with a safePXV/PUS read head.

5.2.2.4 Specific Diagnostic Measures

Interface	Read head	Supply voltage monitoring	Plausibility test position signal versus speed	Read head interfaces specific diagnostics
Interface X35-x	safePXV/PUS	X 1)	X	X 1)
	safeWCS/PUS	X 2)	X	X 2)

1) Diagnostic measures for safePXV/PUS read head interface:

- Verify safe position transfer using CRC32
- Analysis and evaluation of read head fault bits
- Plausibility check of Data Matrix code tape by dynamic color switching

2) The safeWCS/PUS read head has the following diagnostic options:

- Verify position transfer using CRC
- Analysis and evaluation of read head fault bits
- Monitoring of addressing and data length

5.2.2.5 Safety-Related Switch-off Thresholds for Read Head Systems for Position and Speed Detection

As a basic measure, speed and position plausibility tests are carried out on the PUS evaluation unit between the two measuring channels A and B using the current position and speed values. These are tested against parameterizable thresholds.

The **incremental cut-off threshold** describes the tolerable position deviation between the two measurement channels A and B within the unit of the measuring section.

The **speed cut-off threshold** describes the tolerable speed deviation between the two measurement channels A and B.

Diagnostic functions are available within the SCOPE dialog of the parameterization tool to determine the optimal parameter values for the application.

Note

Speed and acceleration values are captured at a minimum digital resolution. This places a lower limit on the amount of speed or acceleration that can be detected and determines the digital increment for input values.

Speed resolution

Speed is recorded up to a frequency of 500 Hz or 500 steps/s using the frequency measurement method, including a time measurement method. This results in the following acquisition fault behavior:

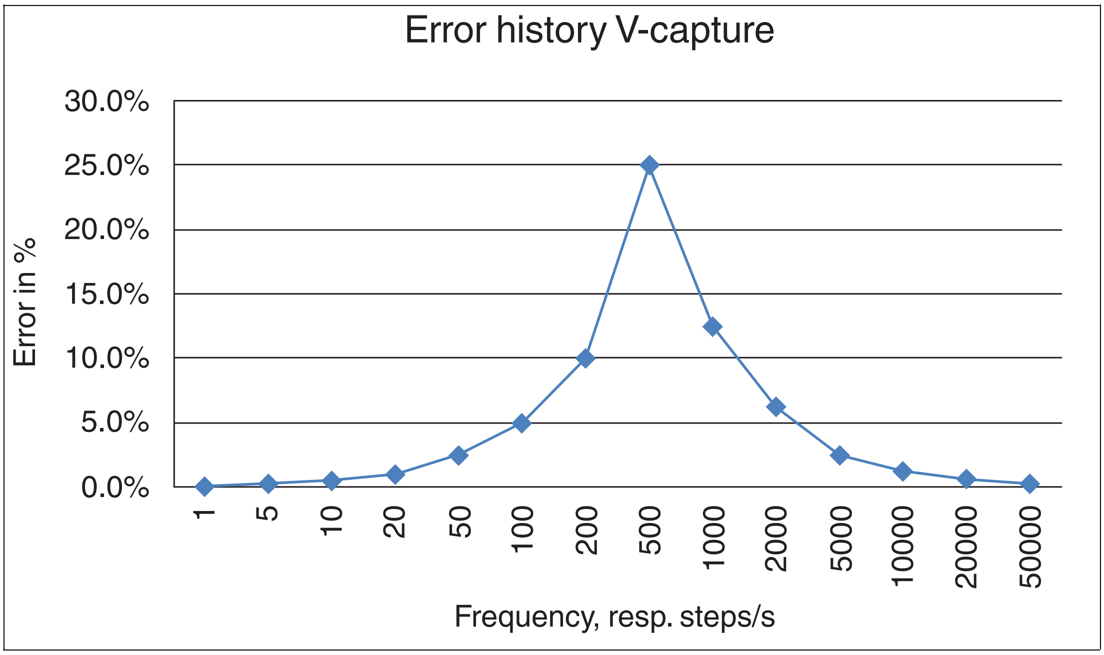

Figure 5.10

Acceleration resolution

The digital resolution of acceleration is limited by the maximum gate time of 256 ms and the resolution of the read heads. The graphs below show the lowest measurable acceleration depending on the resolution in revolutions/min, mm/s², and m/s².

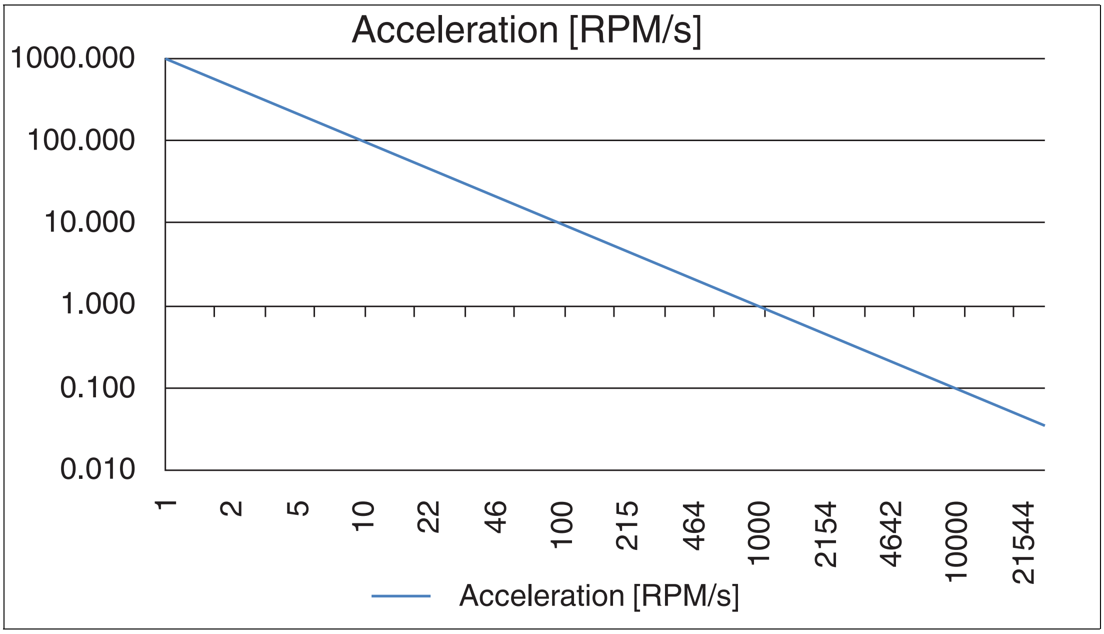

Figure 5.11

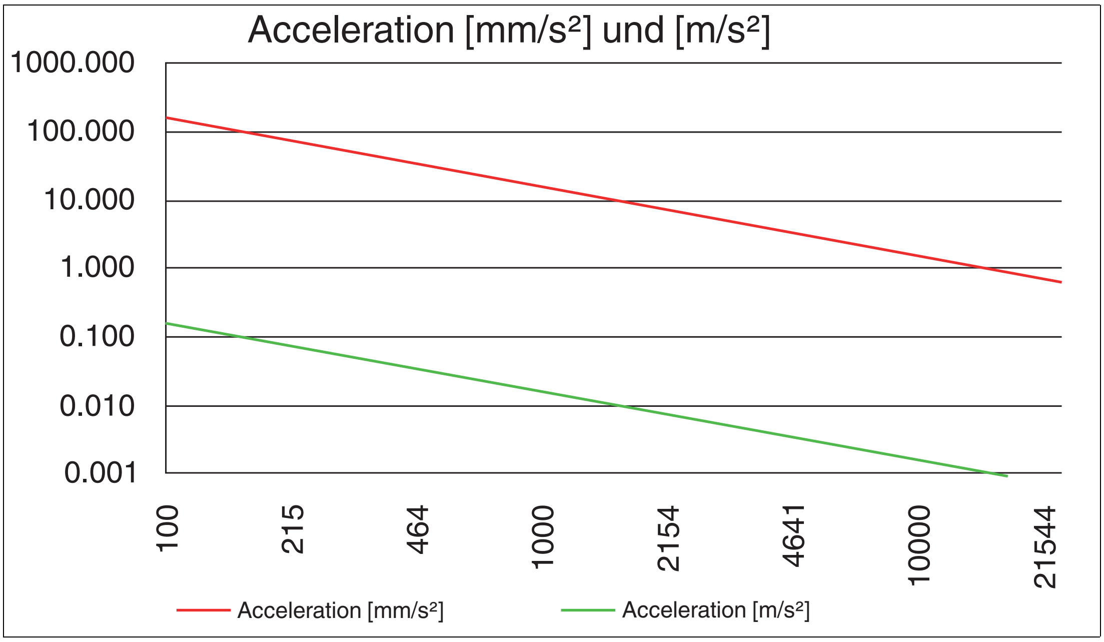

Figure 5.12

Caution!
Safety notice

- The error rate can be optimized by selecting the appropriate read head resolution for the respective application.
- For applications with limited resolution and/or time variance of the sampling signal, the functionality of the monitoring functions used can be improved by using a mean value filter. The mean value filter "smooths" the digital interference components of the read heads. However, this is achieved at the expense of an increased response time of the overall system.
- The filter time can be set between 0 and 64 in increments of 8. The dimension is "ms." To determine the response time of the overall system, the filter times must be added to the specified response times of the evaluation unit.

Caution!
Safety notice

- The read heads ($MTTF_D$, PFH numbers, etc.) must be considered in any safety assessment of the subsystem.
- If specific diagnostics are required by the manufacturer to ensure the specified safety characteristics, these must be checked in accordance with the above table "Specific diagnostic measures for position and speed read heads" with respect to the specific read head. In case of doubt, clarification from the manufacturer is required.
- The DC values listed in the table must be applied conservatively and the boundary conditions must be ensured.
- To determine the DC value for safety functions with standstill monitoring, it may be necessary to estimate the frequency of the dynamic state. A DC of 90 % can be assumed as a guideline.
- Fault eliminations are permitted in accordance with the relevant standards. The specified boundary conditions must be maintained at all times.
- If multiple read head systems are required for the proper functioning of a single safety function, their partial values must be correctly combined according to the chosen method. This also applies to a combination of digital and analog read heads (e.g., safely reduced speed when the protective door is open = door contact + read head for speed detection)
- Appropriate selection of the read head system resolution ensures sufficiently low tolerance with regard to the respective shutdown thresholds of the individual safety functions.
- When using the read head input filter, the increased response time must be taken into account when assessing the safety-related function.

5.2.2.6 Safety-related Evaluation of Read Head Types and/or their Combination

The monitoring functions implemented in the PUS evaluation unit mean that there are initially no special requirements for the internal design of the read head electronics in applications with read head systems, i.e., standard read heads can generally be used.

In general, a safety assessment of the overall configuration must be made. The details of the read head (PFH, MTTF) and the DC from the tables see chapter 5.2.2.2 must be consulted.

When using individual read heads, at least one fault elimination must be instituted for the mechanical actuation chain and the 1-channel part, taking into account the relevant specifications from EN ISO 13849-1. The information in see chapter 5.2.2 must be followed.

PL d and higher according to EN ISO 13849-1 is usually achieved by a combination of two read heads with primarily different technology and separate mechanical connection.

The use of a compact read head with an internal 2-channel design of differing technologies is also suitable for applications up to PL e according to EN ISO 13849-1, but taking into account the specific fault eliminations required and their permissibility. Read heads with proven safety properties and whose safety level is at least the required level should generally be used for this purpose.

Caution!
Safety notice

- The use of standard read heads or a combination of standard read heads is permitted. A safety assessment is required for the overall configuration consisting of read heads, further read heads/switching elements for triggering the safety function, the PUS evaluation unit and the switch-off channel. To determine the safety level achieved, details from the manufacturer (PFH, MTTF) and the DC according to the specifications under see chapter 5.2.2 should be consulted, among other things.
- If only one read head is used, the shaft breakage/fault in mechanical read head connection fault elimination must be instituted. Appropriate measures must be taken for this purpose, e.g., a positive connection of the read head by a keyway or locking pin. The relevant instructions from the manufacturer and EN ISO 13849-1 regarding the requirement and permissibility of the fault elimination must be observed.
- Where single read heads are used, these should preferably be read heads with proven safety properties. The safety level of these read heads must at least correspond to the desired safety level of the overall configuration. The manufacturer's instructions regarding diagnostic measures, mechanical connection and power supply measures must be observed.

The PUS evaluation unit generally detects the following faults in the external read head system

- Short circuits between the safety-relevant signal cables
- Interruptions on the safety-relevant signal cables
- Stuck 0 or 1 on one or all safety-relevant signal cables

Additional, specific diagnostics are assigned to each read head type for detecting faults in the external read head system. The relevant diagnostic procedures together with the limit parameters are listed below for each read head type

Caution!
Safety notice

- The diagnostic measures naturally show tolerances due to measurement inaccuracies. These tolerances must be taken into account in the safety assessment.
- The limit values for the respective diagnostic measures can in part be parameterized or fixed. The resulting levels of diagnostic coverage must be assessed on an application-specific basis and included in the overall safety assessment.

5.3 Safety-related Characteristics and Connection of Outputs

The evaluation units each have safe outputs of different types. The respective characteristics as described below must be taken into account when wiring.

5.3.1 Characteristics of the Output Elements

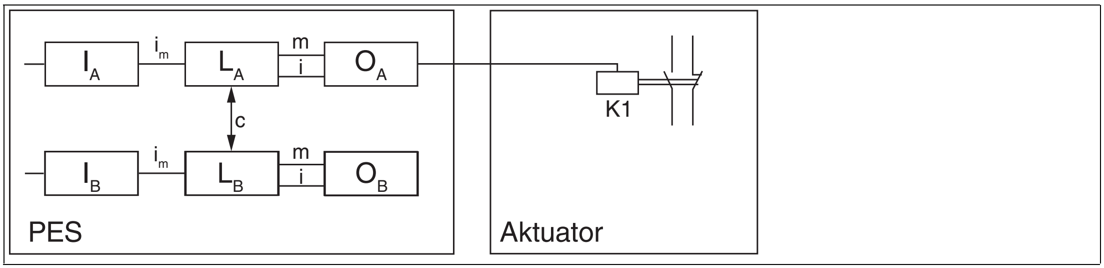

Figure 5.13 1-channel output PUS evaluation unit and 1-channel actuator without diagnostics

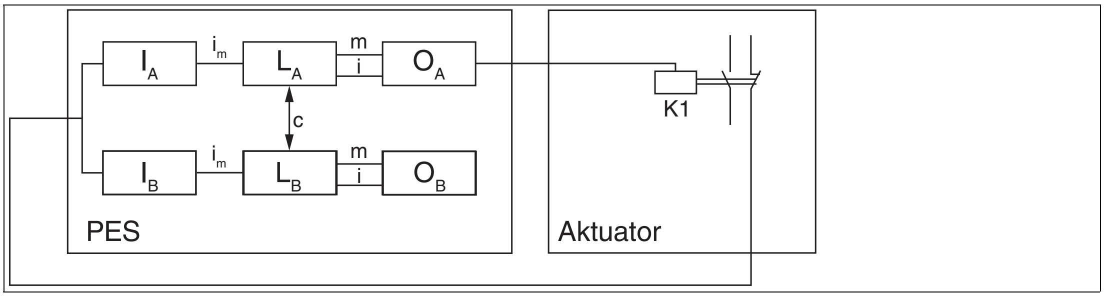

Figure 5.14 1-channel output PUS evaluation unit and 1-channel actuator with diagnostics

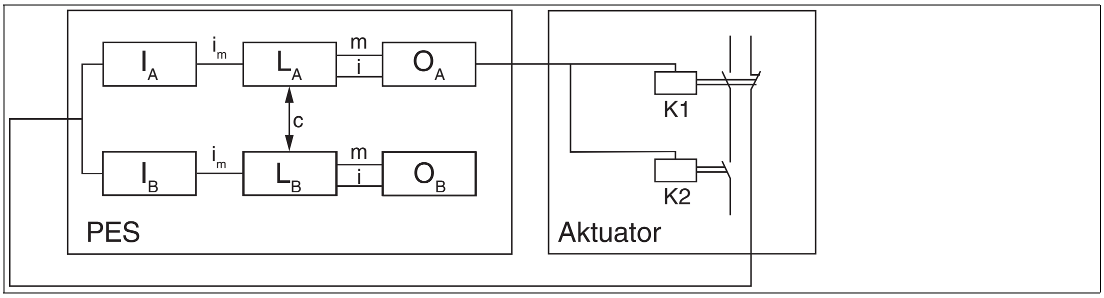

Figure 5.15 1-channel output PUS evaluation unit (Rel 1/2, DO 0/1P, DO 0/1M) and 2-channel actuator

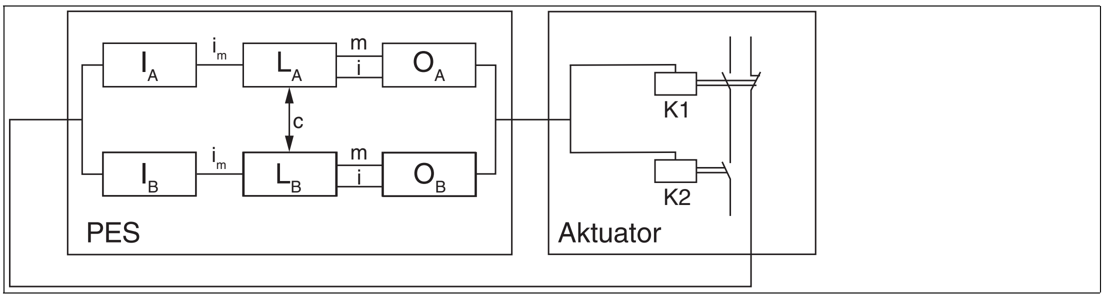

Figure 5.16 1-channel output PUS evaluation unit with internal 2-channel processing (IQQx) and 2-channel actuator with at least 1-channel diagnostics

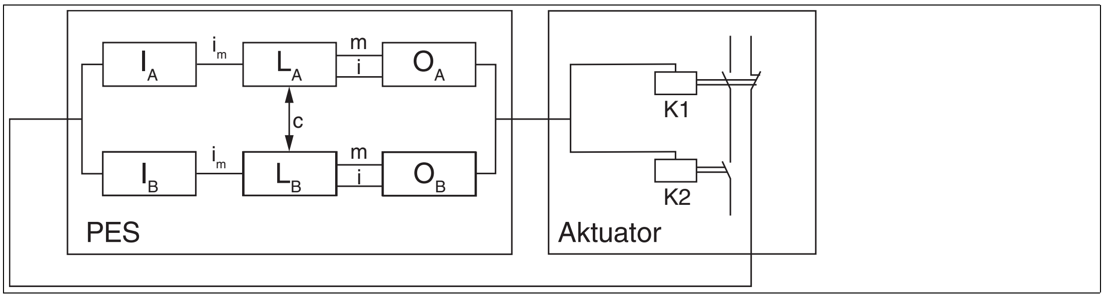

Figure 5.17 1-channel output PUS evaluation unit with internal 2-channel processing (IQQx) and 2-channel actuator with 2-channel diagnostics

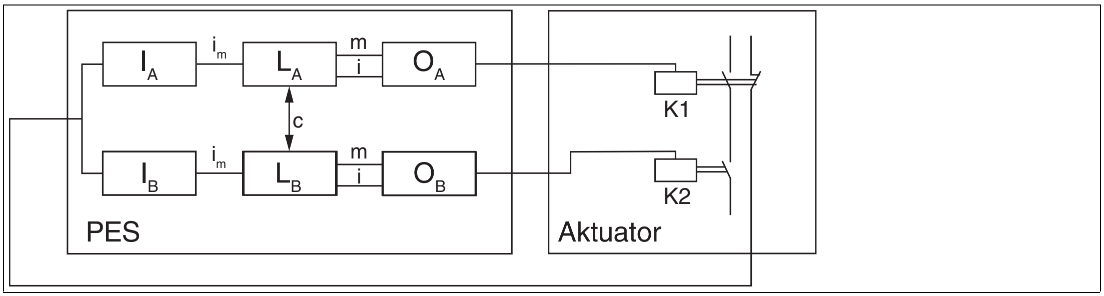

Figure 5.18 2-channel output PUS evaluation unit and 2-channel actuator with 1-channel diagnostics

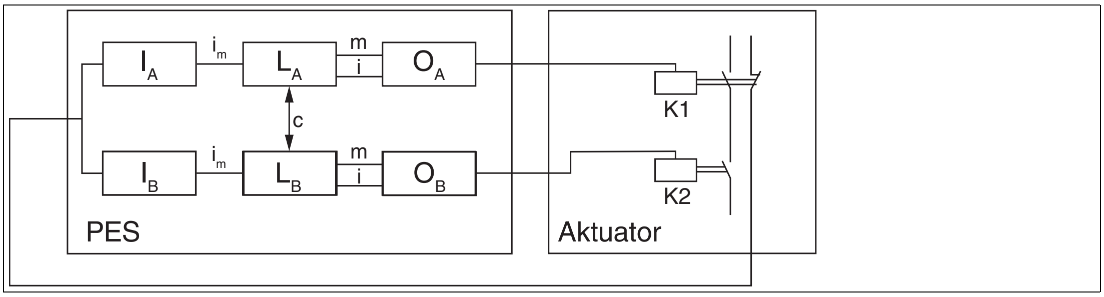

Figure 5.19 2-channel output PUS evaluation unit and 2-channel actuator with 2-channel diagnostics

5.3.2 Diagnostics in De-energizing Circuit

There are parameterizable diagnostic functions permanently implemented in the de-energizing circuits. Certain diagnostic functions also include the external part of the shutdown channel. Different DC values result depending on the use of these diagnostic functions.

5.3.2.1 Diagnostic Functions

Permanently Implemented Diagnostic Functions

Crosswise Output Readback

All safety outputs are read back in the complementary channel. Faults in the internal de-energizing circuit of the PUS evaluation unit are detected with DC = High.

Testing Shutdown Capability for Q4 and Q5 (Relay Activation Only), Q0, Q1, Q2, Q3

The shutdown capability of these outputs is tested cyclically. Any shutdown fault is clearly detected.

Programmable Diagnostic Functions

Actuator Status Readback via Auxiliary Contacts, Position Indicators, etc.

The current status of the actuator is captured by reading back the relevant auxiliary contacts or position indicators and compared with the target status. This means any deviations are clearly detected.

Note

The DC depends on whether diagnostics are 1-channel or 2-channel and on the switching frequency.

Test of Shutdown Capability for IQQx, Q0–Q3

The shutdown capability of these outputs is tested cyclically after the function is activated. Any shutdown fault is clearly detected.

5.3.2.2 Overview of DC with Respect to Selected Diagnostic Functions

Action	DC	Note	Use
Monitoring of outputs through a channel without dynamic test	0 ... 90 %	DC depends on the switching frequency When using elements for switching amplification (external relays or contactors), only effective in conjunction with the readback function of the switching contacts	Monitoring of electromechanical, pneumatic, or hydraulic actuators/outputs
Redundant shutdown path with monitoring of one of the drive elements	90 %	When using elements for switching amplification (external relays or contactors), only effective in conjunction with the readback function of the switching contacts	Monitoring of outputs with direct function as safety circuit or monitoring of safety circuits with elements for switching amplification or pneumatic/hydraulic control valves in conjunction with the readback function of their switching status
Cross-comparison of output signals with immediate and intermediate results in logistics (L), timely and logical program run monitoring, and detection of static failures and short circuits (with multiple inputs/outputs)	99 %	When using elements for switching amplification (external relays or contactors), only effective in conjunction with the readback function of the switching contacts For applications with frequent safety shutdown requirements, tests should be carried out at short intervals, e.g., once per week at the start of the shift. However, a test should be carried out cyclically at least once a year.	Monitoring of outputs with direct function as safety circuit or monitoring of safety circuits with elements for switching amplification or pneumatic/hydraulic control valves in conjunction with the readback function of their switching status

5.3.3 Permissible Capacitive and Inductive Loads at Safe Outputs

The safe outputs of the PUS evaluation unit have OSSD characteristics. This means that the outputs are cyclically switched off and the status read back to test the shutdown capability.

The shutdown capability is checked according to the following criteria/functions

- After the output is switched off, the output voltage must not exceed 5.6 V
- The permissible voltage level must be reached after 400 µs at the latest
- If the permissible voltage level is reached, the test is considered successful and the output is reactivated without further delay
- If the permissible voltage level is not reached even after 400 µs, an alarm is triggered and all safe outputs (second channel for safe outputs!) are disabled

The diagram below shows the ideal (green curve) and typical (red curve) behavior.

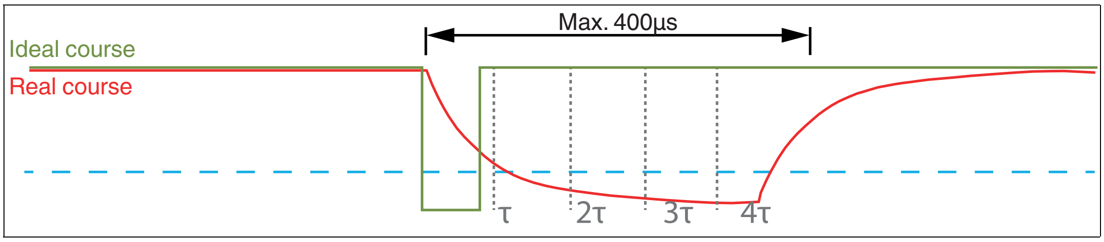

Figure 5.20

To determine the maximum permissible capacitance or inductance, observe the time constant τ on the real RC or RL link at the output.

This RC or RL link determines the real discharge curve:

The voltage level of max. 5.6 V is safely reached after 3τ.

The following therefore applies:

3τ < 350µs

τ < 100µs

With the relationship

τ = RC = L/R

the maximum usable capacitive or inductive load can be determined in conjunction with its resistive load:

$\mathbf{C_{max}} = \tau/R = 10^{-4}\mathbf{/R}$ and $\mathbf{L_{max}} = \tau R = 10^{-4}\mathbf{R}$

Typical values for capacitance C are C = 20 nF and for longitudinal inductance L = 100 mH

5.3.4 Digital Outputs

5.3.4.1 Characteristics of Basic Outputs

The PUS evaluation unit provides various types of outputs that can be connected either individually or in groups.

Output	Architecture in accordance with EN ISO 13849-1	Comment
Combination of 2 relays Q4 – Q5	4	Complete shut-off channel according to architecture category 4 as per EN ISO 13849-1
Q4 – Q13	Not safe	Functional only
Q1 _PP and Q2_PN	4	Complete shut-off channel according to architecture category 4 as per EN ISO 13849-1
Q1_PP	Not safe	Functional only
Q2_PN	Not safe	Functional only
Q3_PP and Q4_PN	4	Complete shut-off channel according to architecture category 4 as per EN ISO 13849-1
Q3_PP	Not safe	Functional only
Q4_PN	Not safe	Functional only
Q1 – Q4	4	Complete shut-off channel according to architecture category 4 as per EN ISO 13849-1
Y1	Not safe	Auxiliary output
Y2	Not safe	Auxiliary output

The Qx_PP, Qx_PN and Qx outputs are subjected to a plausibility test in all operating states. When switched on, all outputs are checked for correct function with a cyclical test pulse. For this purpose, the output is switched to the respective inverse value for a maximum test duration of TT < 500 µs (typically 200 µs), i.e., a pp output is switched briefly to 0 V DC potential and a pn output is switched briefly to 24 V DC potential.

The relay outputs are monitored for plausibility on each switching cycle. To maintain the safety function, the relay outputs must be cyclically switched and therefore tested. The switching/test cycle must be defined depending on the application.

Warning!
Safety notice

- For applications with frequent safety shutdown requirements, tests should be carried out at short intervals, e.g., once per week at the start of the shift. However, a test should be carried out cyclically at least once a year.
- The output test function is carried out for both group and individual activation. The auxiliary outputs are not tested.
- **The high side (Qx_PP) and low side (Qx_PN) outputs must not be used individually for safety tasks. Use for safety tasks is only permitted with a combination of high side/low side (note: not relevant from FW release 05-00-00-01 onward)**
- Mixed operation of the relay contacts is **not** permitted!
  Mixed operation: A hazardous touch voltage potential must not be mixed with a protective extra-low voltage.
  For example:
  INCORRECT: 230 V AC (120 V AC cULus) is switched via Q1.1 + Q1.2 and 24 V DC is switched via Q2.1 + Q2.2.
  CORRECT: 230 V AC (120 V AC cULus) is switched via each of Q1.1 + Q1.2 and Q2.1 + Q2.2.
  Or 24 V DC is switched via Q1.1 + Q1.2 and Q2.1 + Q2.2.

The outputs can be loaded as follows

Output	Voltage	Voltage
Relay Qx	24 V DC	2.0 A (DC13, Pilot Duty)
Relay Qx	230 V AC	2.0 A (AC15)
	120 V DC	2.0 A (Pilot Duty)
Yx	24 V DC	250 mA
Qx_P(P)	24 V DC	2 A
Qx_N	GNDEXT	2 A
Qx	24 V DC	0.5 A / 2 A

Warning!
Safety notice

- Only external switching elements with a minimum holding current of > 1.2 mA may be used for safety-related applications.
- For safety-related applications, only external switching elements as follows may be used in conjunction with the combination of p/n switching outputs:
  - For a load resistance ≥ 100 Ω with a minimum holding current of > 2 mA or
  - For a load resistance < 100 Ω with a holding current > 0.4 mW

  .
  Only relevant for PUS evaluation unit up to HW release 11-xx-xx…
- A number of diagnostic measures have been implemented for the output system. In particular, the inclusion of elements for switching amplification such as relays, contactors, etc. in the shutdown circuit must be taken into account.
- For applications in elevator technology according to EN 81-20/-50 or EN 81-1/-2, the outputs of the internal relay may not be used to switch voltages above 24 V because this is not permitted by the specifications of EN 81-20/-50 or EN 81-1/-2. Failure to observe this condition will void the warranty and Pepperl+Fuchs shall not be liable for any compensation.

Note

If the auxiliary outputs are used for control purposes, it must be noted that the outputs will be in an undefined state during the start-up phase following a controller POR.

5.3.4.2 Wiring Examples for Basic Outputs

5.3.4.3 1-Channel Switching Relay or Semiconductor Output without Testing

External contactors can be used to connect multi-phase applications or when there is an increased current requirement. In the case of a 1-channel connection without an external test, it must be noted that bonding of one or more external contacts is not detected by the PUS evaluation unit. The following example circuit is only suitable to a limited extent for safety applications; a maximum of PL b can be achieved according to EN ISO 13849-1!

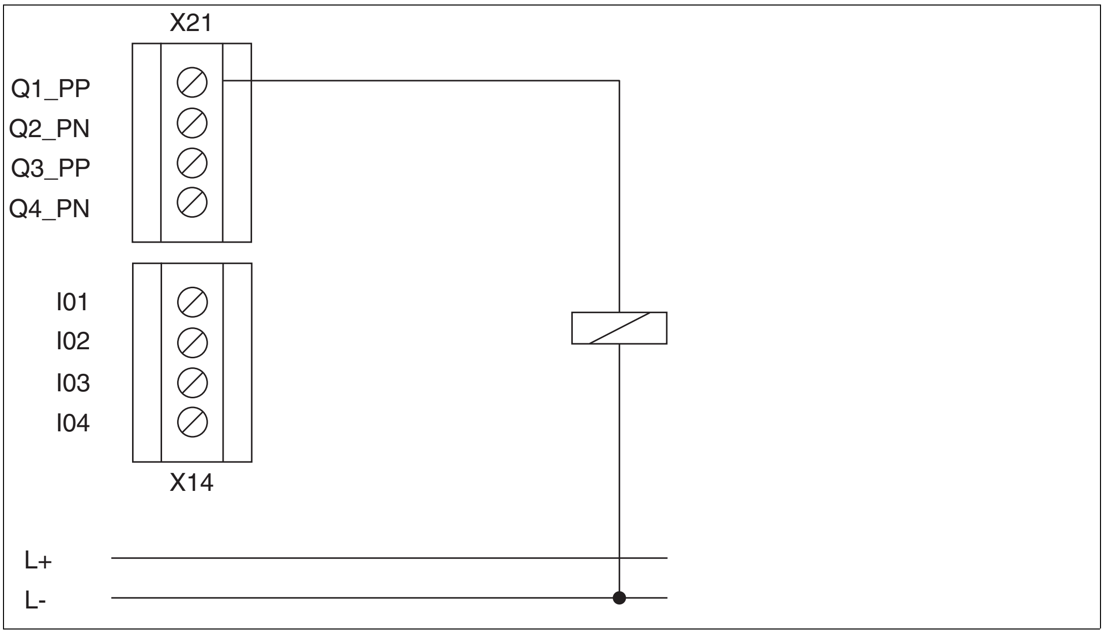

Figure 5.21 1-channel switching P-output

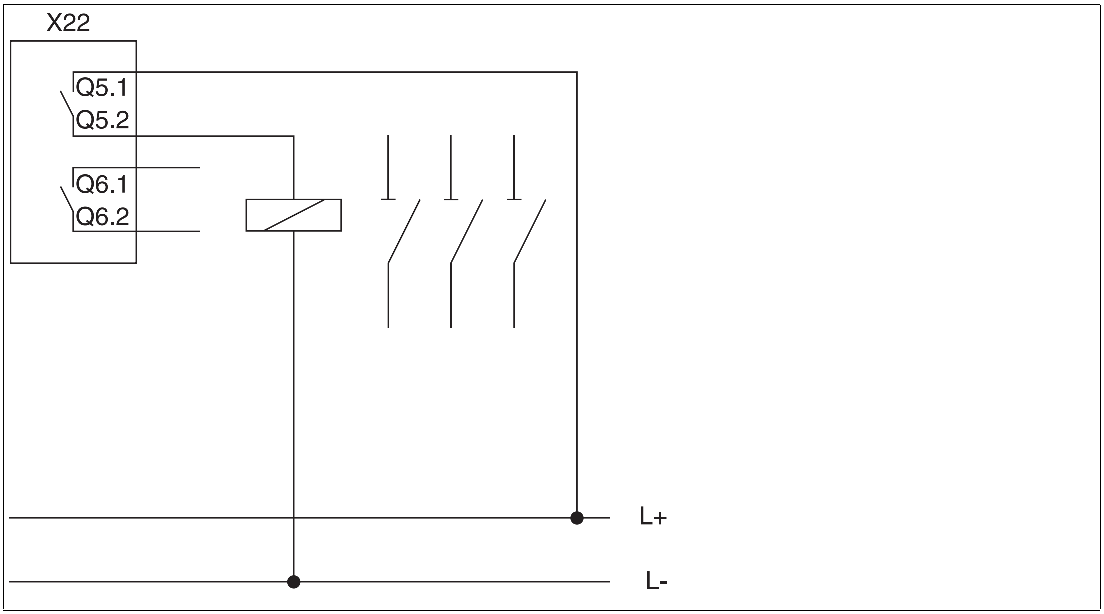

Figure 5.22 1-channel switching relay output

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Warning!
Safety notice

- Not recommended for safety applications! See also the information in EN ISO 13849-1 for application and the necessary fault eliminations.

5.3.4.4 1-Channel Switching Relay or Semiconductor Output with External Switch Amplifier and Testing

If external switch amplifiers or downstream electromechanical, pneumatic, or hydraulic components are used, equipment is required to test the entire chain and a signal/warning device is required to indicate any fault detected if PL c or higher must be achieved.

In particular, positively guided auxiliary contacts are required for electromechanical devices and signaling contacts indicating valve position are required for hydraulic or pneumatic components. The signal/warning device must immediately notify the operator of the hazardous situation.

The achievable PL depends heavily on the test rate; a **maximum of PL d** according to EN ISO 13849-1 can be achieved!

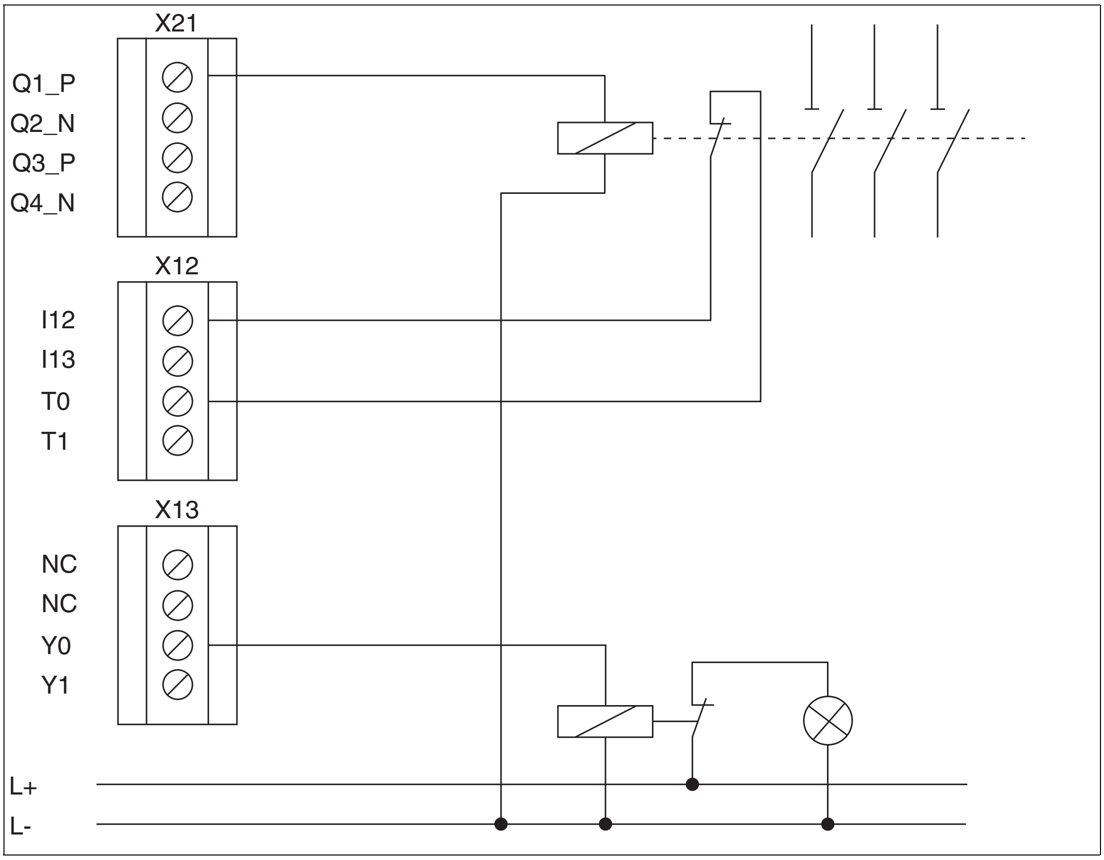

Figure 5.23 1-channel switching relay output with testing

Warning!
Safety notice

- Only conditionally recommended for safety applications! See also the information in EN ISO 13849-1 for application and the necessary fault eliminations.
- Category 2 requires a test rate > 100 * demand rate
- If a hazardous situation is detected during a safety function test, appropriate control measures must be initiated.
  For PL d, a safe state must be initiated that must not be cleared until the fault is eliminated.
- For PL up to and including PL c, it is also possible to indicate the fault by a warning or signaling device if a safe state cannot be initiated.

5.3.4.5 1-Channel Switching Relay or Semiconductor Output with 2-Channel External Circuit with Testing

For safety applications from PL c and above according to EN ISO 13849-1, it is recommended or required to control two external shut-off elements. To achieve PL c or higher, equipment is required to test the entire chain and a signal/warning device is required to indicate any fault detected – see chapter 5.3.4.4.

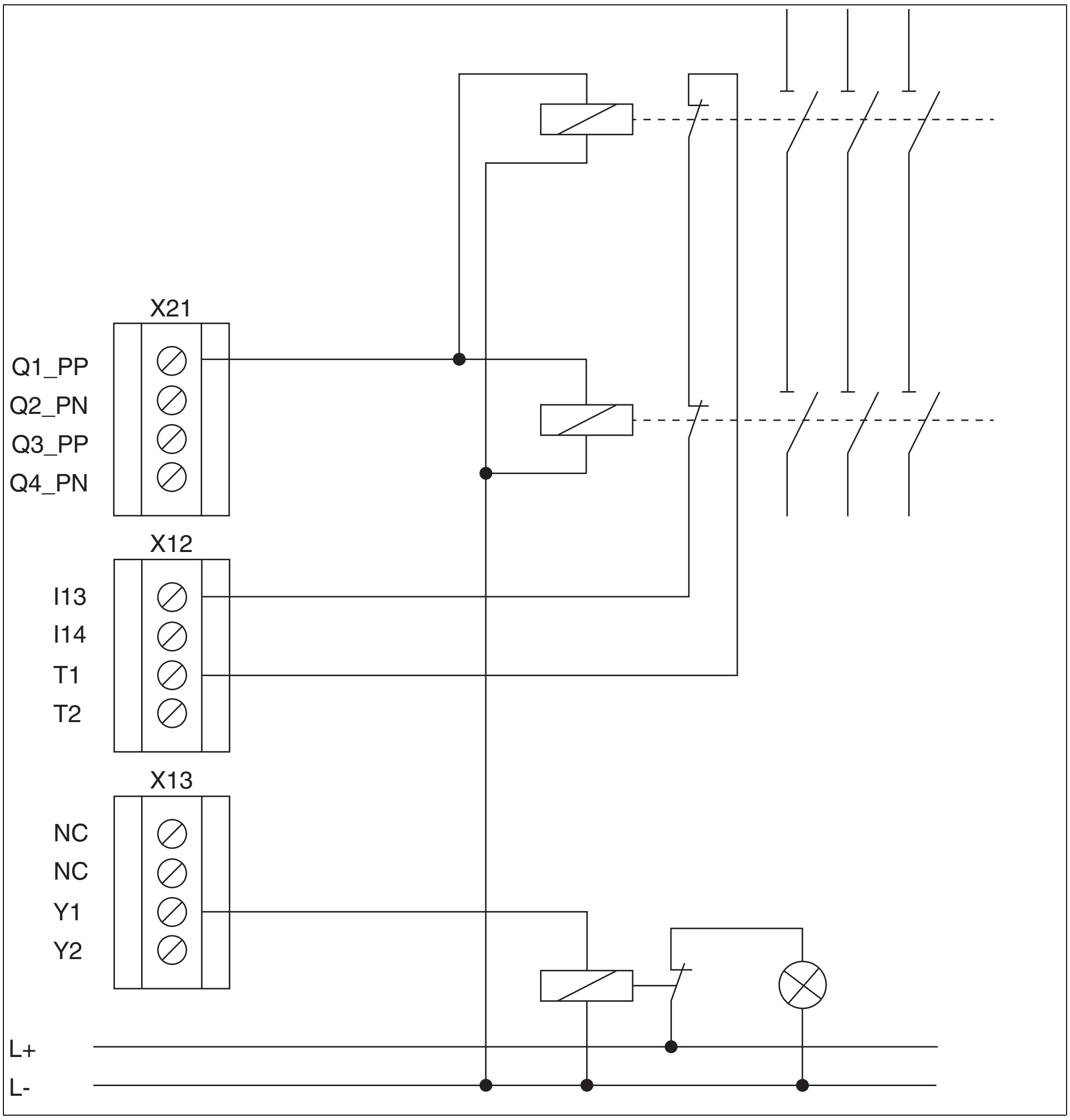

Figure 5.24 1-channel switching output Q0_P with 2-channel external circuit and monitoring at input 12 as collective feedback

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The two external monitoring contacts are connected in series, fed by the clock signal T0 and read in via input 12. Input 12 was used as the read-back input, but any other input can also be assigned.

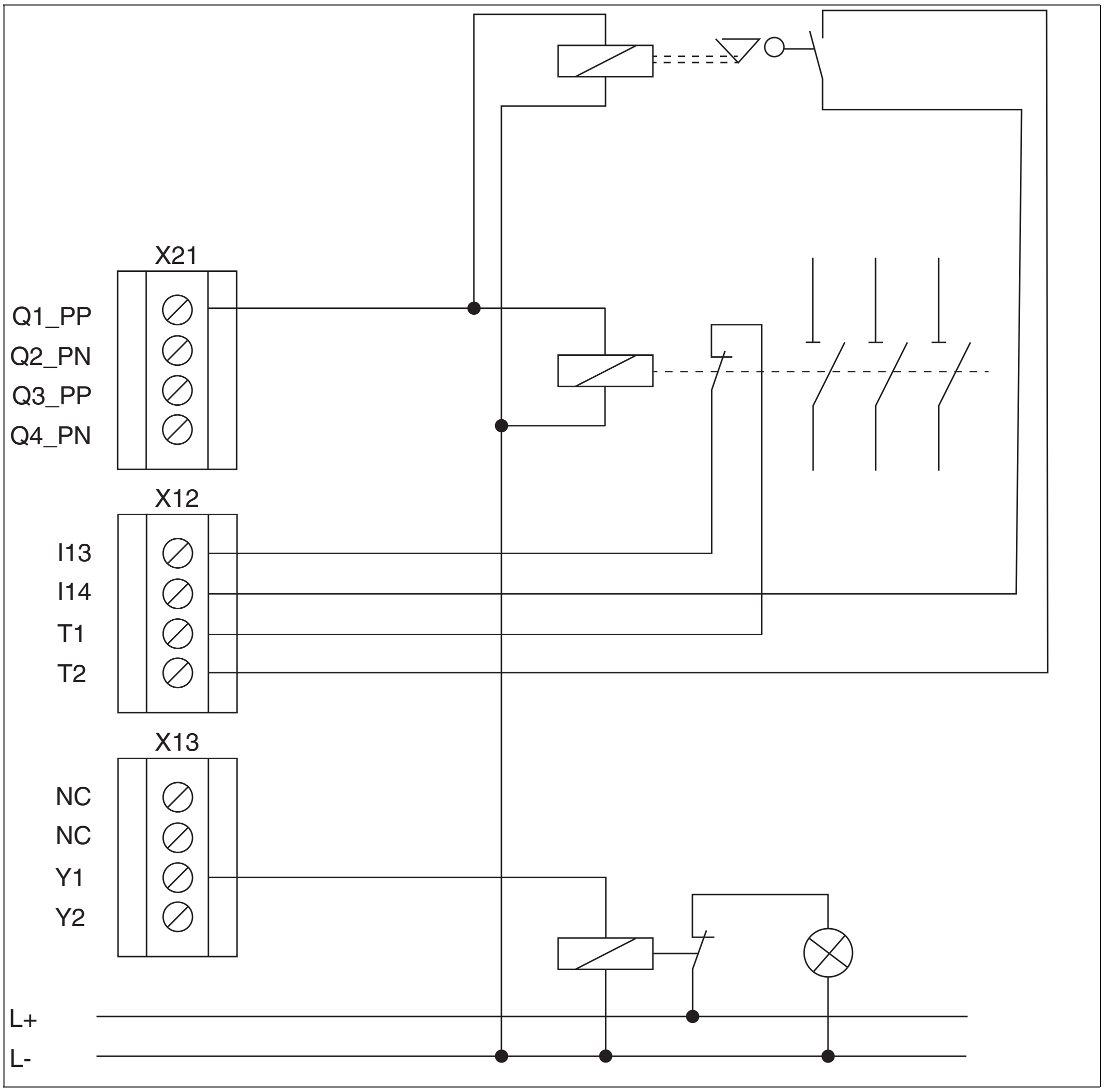


Figure 5.25 1-channel switching output Q1_PP with 2-channel external circuit as a combination of electromechanical element and hydraulic/pneumatic valve and monitoring at two inputs

Warning!
Safety notice

- Only conditionally recommended for safety applications! See also the information in EN ISO 13849-1 for application and the necessary fault eliminations.
- For PL c and higher, a signal/warning device is required that immediately notifies the operator of the dangerous situation.
- Where requirements are higher, it must be noted that at least 1 switching operation must take place every 24 hours to test the switching capability of the external power contactor.

5.3.4.6 2-Channel Switching Relay Output with External Monitoring – Collective Feedback

Two relays on the PUS evaluation unit and two external power contactors are used for safety applications from PL d according to EN ISO 13849-1.

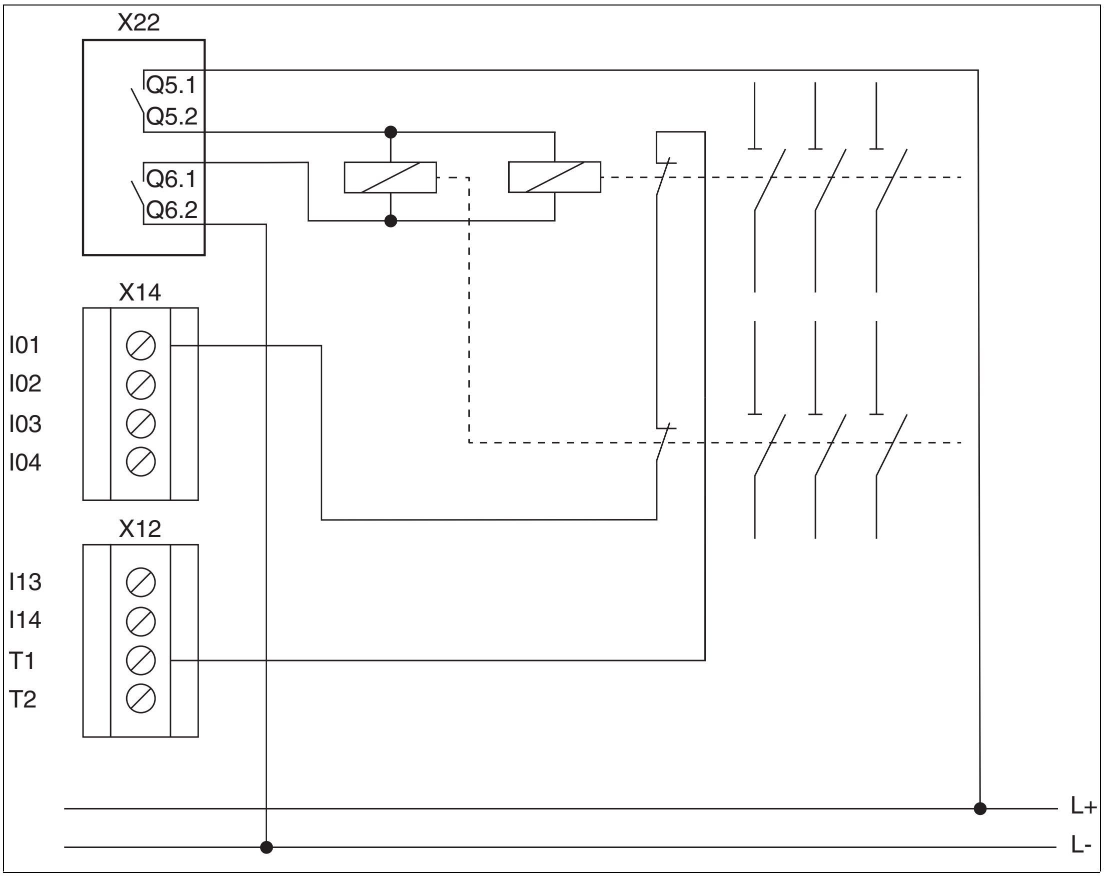


Figure 5.26 2-channel switching relay output with external monitoring – collective feedback

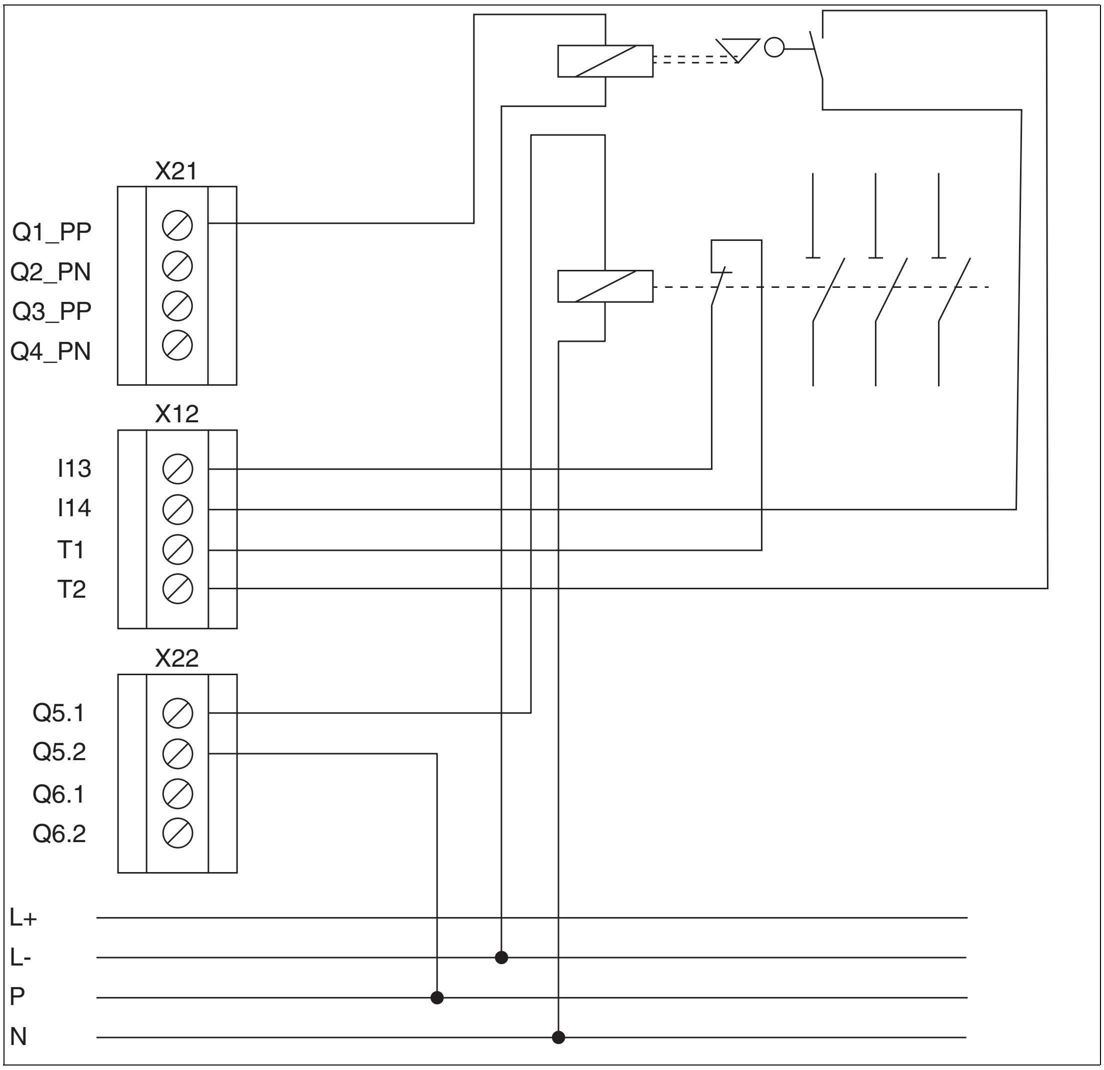
The two external monitoring contacts are connected in series, fed by clock signal T1 and read in from I01 (configured as EMU input). In the event of increased requirements, it must be noted that at least 1 switching operation must take place every 24 hours.

Warning!
Safety notice

- A sufficiently high test rate is required to achieve PL e in accordance with EN ISO 13849-1.
- For applications with frequent safety shutdown requirements, tests should be carried out at short intervals, e.g., once per week at the start of the shift. However, a test should be carried out cyclically at least once a year.

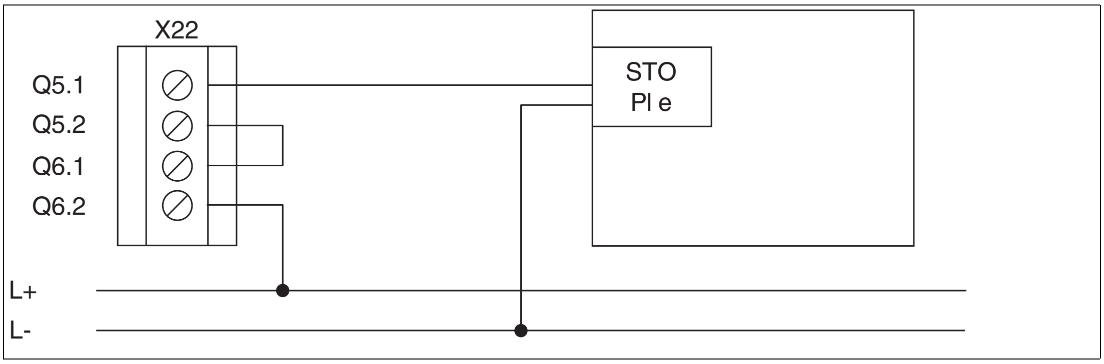
5.3.4.7 2-Channel Output with Relay Output and Semiconductor Output – External Control Circuit with Monitoring

For safety applications from PL d and higher according to EN ISO 13849-1. The external circuit is controlled via two channels via a relay and a semiconductor output. Each of the two external shutdown paths is monitored. For PL e according to EN ISO 13849-1, $MTTF_D$ = high and a sufficiently high test rate are required for the external circuit.



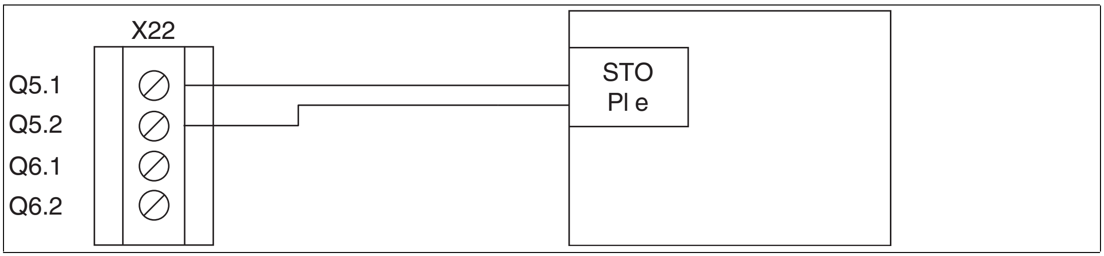
5.3.4.8 2-Channel Output with Relay Output – External Control Circuit in PL e

For safety applications from PL d and higher according to EN ISO 13849-1. The external circuit is controlled via the relay outputs using two channels. For PL e according to EN ISO 13849-1, PL e and a sufficiently high test rate are required for the external circuit.



5.3.4.9 2-Channel Output with Semiconductor Output and External Control Circuit in PL e

For safety applications from PL d and higher according to EN ISO 13849-1. The external circuit is controlled via semiconductor outputs using two channels. For PL e according to EN ISO 13849-1, PL e is required for the external circuit.



5.3.4.10 Connection of Auxiliary Output

Both semiconductor outputs implemented on the PUS evaluation unit can be connected for functional applications. The outputs are not pulsed.

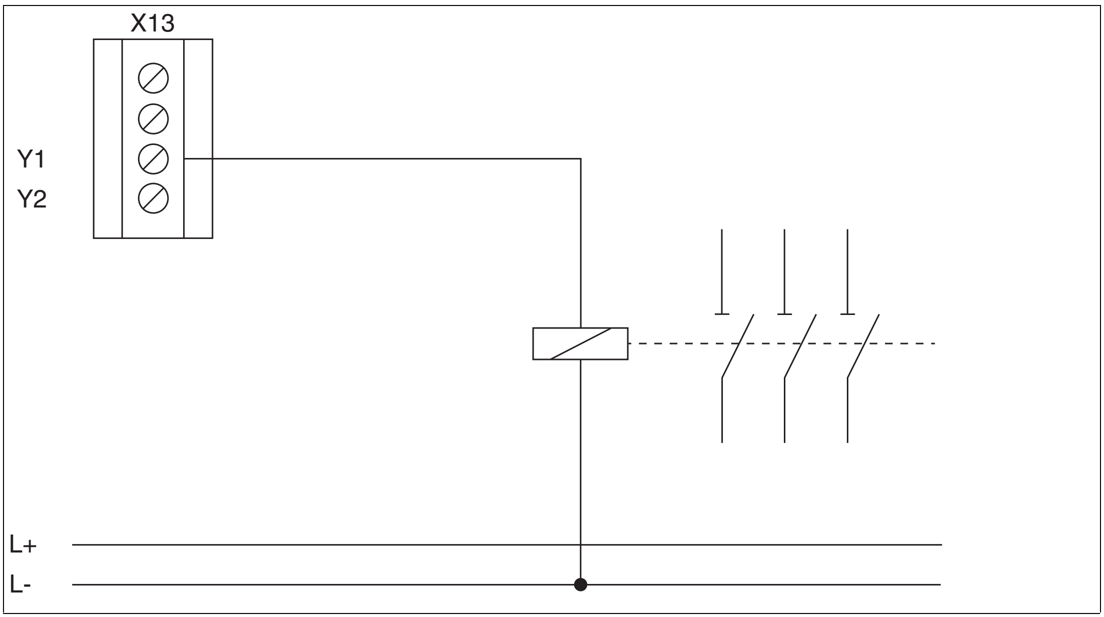


Figure 5.27 Connection of auxiliary output

Applications with auxiliary outputs are not permitted for safety applications!

5.3.4.11 Overview of Achievable PL for Digital Safety Outputs

Caution!

Unconditionally recommended for safety applications!

When using external elements in the shutdown circuit, e.g., for switching amplification, the specifications from the manufacturer of those elements ($MTTF_D$, FIT numbers, B10d value, etc.) must be considered in any safety assessment of the output subsystem.

The DC values listed in the table must be applied conservatively and the boundary conditions must be ensured (see table under "Notes").

Fault eliminations are permitted in accordance with the relevant standards. The specified boundary conditions must be maintained at all times.

When switching amplification elements are used in safety circuits, their function must be monitored using suitable readback contacts, etc. (see circuit examples). Suitable readback contacts are contacts that are connected to the contacts in the shutdown circuit in a positive-switching manner.

The switching capability of the external switch amplifiers must be checked cyclically. The period between 2 tests must be defined as required by the application and ensured using appropriate measures. Suitable measures can be of an organizational (switching off and on at the start of a shift, etc.) or technical nature (automatic, cyclic switching).

Overview of achievable PL for digital safety outputs

Output Evaluation unit	Actuator/ external shutdown circuit	Category according to EN ISO 13849-1	DC		$MTTF_D$ Actuator	Achievable PL in accordance with EN ISO 13849-1	Boundary condition	Fault elimination
1-channel without dynamic output test Q5 or Q6 Q1_PP, Q2_PN, Q3_PP, Q4_PN	1-channel contactor, valve, brake, etc. without direct feed-back for diag-nostics	Cat. B	0 %		Medium	b	Contactor and downstream actua-tors are suitable for safety applications	
	1-channel contactor, valve, brake, etc. with moni-tored positive-guided auxil-iary contact	Cat. 2	60 ... 90 %	Depends on switching frequency	Medium	b	Auxiliary output required for warning of detected malfunction Contactor and downstream actuators suitable for safety applica-tions	
					High	c	As before	
						d	As before DC = 90 % due to a sufficiently high test rate with respect to the application	
One-chan-nel without dynamic output test Q5 or Q6 or one-chan-nel Q1_PP, Q2_PN, Q3_PP, Q4_PN	2-channel contactor, valve, brake, etc. with direct feedback for diagnostics in at least one channel or actuator, 1-channel controlled with safety func-tion cat. 3 (e.g., STO)	Cat. 2	90 %	Monitor-ing only in an external shutdown circuit	Medium	c	Auxiliary output required for warn-ing of detected malfunction Contactor and downstream actuators suitable for safety applications	Short circuit at external control
					High	d		

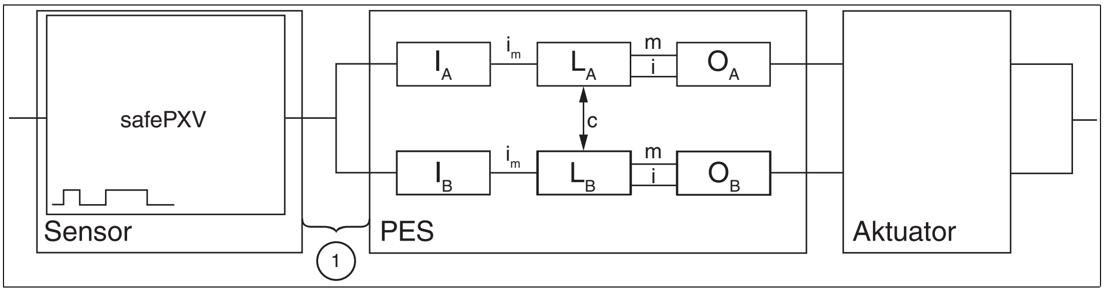
Output Evaluation unit	Actuator/ external shutdown circuit	Category according to EN ISO 13849-1	DC		$MTTF_D$ Actuator	Achievable PL in accordance with EN ISO 13849-1	Boundary condition	Fault elimination
2-channel without dynamic output tests Q1 and Q2 2 x	2-channel contactor, valve, brake, etc. with direct feedback for diagnostics in at least one channel or actuator with safety function cat. 4 (e.g., STO)	Cat. 3	90 %	Monitoring in both external shutdown circuits	Medium or high	d	Contactor and downstream actuators suitable for safety applications Monitoring of electromechanical components by positively guided switches, position monitoring of switching valves, etc. Outputs IQQ1 – 40 each 1 x from different groups (each group of 6/4 connected IQQ ports, e.g., IQQ1 – 6, IQQ7 – 10) or actuation with a time delay at the control level	Short circuit at external control
2-channel Q1 and Q2 or 2-channel with dynamic output test Q1_PP and Q2_PN, Q3_PP and Q4_PN 2 x	2-channel contactor, valve, brake, etc. with direct feedback for diagnostics in both channels or actuator with safety function cat. 4 (e.g., STO)	Cat. 4	99 %	Monitoring in both external shutdown circuits	High	e	Contactors and downstream actuators suitable for safety applications Monitoring of electromechanical components by positively guided switches, position monitoring of switching valves, etc. For applications with frequent safety shutdown requirements, tests should be carried out at short intervals, e.g., at the start of shift once a week. However, a test should be carried out cyclically at least once a year.	Short circuit at external control in both channels

5.4 Safety Characteristics and Wiring of safePXV/PUS Read Heads with PUS-F161-**-PXV Evaluation Unit

5.4.1 General Safety Design

The PUS evaluation unit has interfaces for connecting a safePXV/PUS read head.

The use of the read head ensures that the maximum level of safety, as listed in the technical specifications, is achieved. The corresponding subsystem has been analyzed as follows:



1 Gray channel

Read head with 2-channel subsystem. Diagnostics by separate signal processing in two channels and cross-comparison in the PE system plus other specific diagnostics.

Note

The parameters from the "Technical Data" table (see chapter 3.3) can be used to make a safety-related assessment of the overall configuration, since these already represent the combination of the evaluation unit with the read head.

Caution!

Standards for electromagnetic compatibility (EMC)

An EMC-compliant installation should be ensured. Particular attention should be paid to the cable routing and the processing of the shielding.

A further prerequisite is that the electromagnetic compatibility of the overall system is ensured by proven, applicable measures.

5.4.2 General Diagnostic Measures

A number of diagnostic measures are implemented in the PUS evaluation unit for fault detection in the read head. The diagnostic measures are activated automatically on selection of the read head type.

5.4.3 Read Head Type and Diagnostic Characteristics

Read head	Safe direction	Safe speed	Safe position	Properties
safePXV/PUS	x	x	x	SIL 3 (EN 61508), PL e cat. 4 (EN ISO 13849) PFHD: $13.39 * 10^{-9}$ MTTFD: 37.6 a DC: 97.0 % These characteristics refer to the use of the safePXV/PUS read head together with the implemented diagnostic measures of the PUS evaluation unit.

Note

Safety notices

- The above characteristic data can be used for a safety assessment of the subsystems (safePXV/PUS read head) and PE system (PUS evaluation unit).
- The values listed in the table must be applied conservatively and the boundary conditions must be ensured.
- Moving the axis allows faults that are not detected at standstill to be revealed.
- Fault eliminations are permitted in accordance with the relevant standards. The specified boundary conditions must be maintained at all times.

5.4.4 Diagnostic Measures for Read Head Interface

safePXV/PUS-specific diagnostic measures and general read head diagnostics:

- Validation of the checksum (CRC32) used to secure the safe position
- Forced dynamization by changing read head color and checking expectations
- Forced dynamization by offsetting position of 2-channel code tape and checking expectations
- Time expectation through color switching mentioned above based on a defined color pattern
- Logical expectation through color switching mentioned above based on a defined color pattern
- Eliminate misaddressing of the read head by using only one read head
- Monitor for maximum limits of the application
- Plausibility test for MPUA/MPUB position data
- Plausibility test for MPUA/MPUB speed data

5.4.5 Fault Model according to DIN EN 61800-5-2 and IEC 61784

A general fault model for motion and position feedback sensors is defined in the DIN EN 61800-5-2 standard table D.8. The IEC 61784 standard lists additional fault models for the communication interfaces. The diagnostics and measures listed in the table below make reference to this fault model, providing an overview of the options for detection available in the evaluation unit.

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
Position feedback sensors					
+Ub	Undervoltage	No supply, no function	-	Yes	Time expectation, data backup, logical expectation
	Overvoltage	Failure, damage to DSP/RS-485, no data transfer	-	Yes	Time expectation, data backup, logical expectation
	Drift	Failure of DSP or RS-485, therefore no position transfer	-	Yes	Time expectation, data backup, logical expectation
RS-485	Stuck-at +Ub	Faulty data transfer	-	Yes	Data backup, logical expectation
	Stuck-at GND	Faulty data transfer	-	Yes	Data backup, logical expectation
	Interruption	Faulty data transfer	-	Yes	Data backup, logical expectation
	Short circuit	Faulty data transfer	-	Yes	Data backup, logical expectation
	Drift	Faulty data transfer	-	Yes	Data backup, logical expectation
I1	Stuck-at +Ub	Continuous blue lighting	-	Yes	Logical expectation of color switching
	Stuck-at GND	Failure of blue lighting	-	Yes	Logical expectation of color switching
	Interruption	Failure of blue lighting	-	Yes	Logical expectation of color switching
	Short circuit	Incorrect blue lighting	-	Yes	Logical expectation of color switching
	Drift	Incorrect blue lighting	-	Yes	Logical expectation of color switching
I12	Stuck-at +Ub	Continuous red lighting	-	Yes	Logical expectation of color switching
	Stuck-at GND	Failure of red lighting	-	Yes	Logical expectation of color switching
	Interruption	Failure of red lighting	-	Yes	Logical expectation of color switching
	Short circuit	Incorrect red lighting	-	Yes	Logical expectation of color switching
	Drift	Incorrect red lighting	-	Yes	Logical expectation of color switching

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
SYNC	Stuck-at +Ub	Continuously active, no scanning of read head	-	Yes	No update of the SPI data, time expectation
	Stuck-at GND	No scanning of the read head and no position data	-	Yes	No update of the SPI data, time expectation
	Interruption	No scanning of the read head and no position data	-	Yes	No update of the SPI data, time expectation
	Short circuit	Incorrect scanning of the read head and data therefore not current	-	Yes	Logical expectation
	Drift	Incorrect or no scanning of the read head and data therefore not current	-	Yes	Logical expectation
SPI AI	Stuck-at +Ub	Invalid data	-	Yes	Data backup
	Stuck-at GND	Invalid data	-	Yes	Data backup
	Interruption	No data	-	Yes	Data backup
	Short circuit	Invalid data	-	Yes	Data backup
	Drift	Invalid data	-	Yes	Data backup
Mounting	Loosening	Incorrect sampling of the Data Matrix code tape, no/incorrect position	-	Yes	Monitoring for maximum limits, Data backup, logical expectation
	Incorrect assembly	Incorrect sampling of the Data Matrix code tape, no/incorrect position	Instructions for correct assembly in read head manual	Yes	Monitoring for maximum limits, Data backup, logical expectation

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
Material measure	Loosening	Incorrect sampling of the Data Matrix code tape, no/incorrect position, position jump	Instructions for correct assembly in read head manual	Yes	Monitoring for maximum limits, Data backup, logical expectation
	Contamination	Incorrect sampling of the Data Matrix code tape, no/incorrect position, position jump	Instructions for maintenance and operation in read head manual	Yes	Monitoring for maximum limits, Data backup, logical expectation
	Coverage	Incorrect sampling of the Data Matrix code tape, no/incorrect position, position jump	Instructions for correct assembly in read head manual	Yes	Monitoring for maximum limits, Data backup, logical expectation
	Incorrect dimensioning	Position outside of measuring range	Instructions for correct operation in read head manual	Yes	Monitoring for maximum limits
Camera	Contamination	Incorrect/no position	Instructions for maintenance and operation in read head manual	Yes	Data backup, monitoring maximum limits, expectation
	Damage	Incorrect/no position	-	Yes	Data backup, monitoring maximum limits, expectation Data backup, monitoring maximum limits, expectation
	No function	Incorrect/no position; frozen position	-	Yes	Data backup, monitoring maximum limits, expectation

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
Flash	Contamination	Incorrect/no position	Instructions for maintenance and operation in read head manual	Yes	Data backup, monitoring maximum limits, expectation
	Damage	Incorrect/no position	-	Yes	Data backup, monitoring maximum limits, expectation
	No function	Incorrect/no position	-	Yes	Data backup, monitoring maximum limits, expectation
DSP	Incorrect/no position	Incorrect/no position, no data transfer	-	Yes	Data backup, monitoring maximum limits, logical expectation
	Freeze	No position update	-	Yes	Time dynamization, Dynamization of exposure, logical expectation
	Incorrect time base	Outdated position	-	Yes	Time dynamization, Dynamization of exposure, logical expectation
	Data corruption	Incorrect position, invalid data	-	Yes	Data backup, monitoring maximum limits, logical expectation
Read head with computer interface					

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
Data transfer	Repetition	Outdated position	-	Yes	Data backup, dynamization through color switching and expectation
	Loss	Outdated or no position	-	Yes	Data backup, dynamization through color switching and expectation
	Insertion	Invalid data, incorrect position	-	Yes	Data backup, dynamization and color switching expectation
	Incorrect sequence	Invalid data, incorrect position	-	Yes	Data backup, expectation for, Color change
	Incorrect data	Incorrect position	-	Yes	Data backup, dynamization and color switching expectation
	Delay	Outdated position	-	Yes	Dynamization through color switching and expectation
	Masquerade/addressing	Incorrect position	Use of only one PXV read head	Yes	Data backup, only exclusive data connection
Read head with synthetically generated output signals					
SYNC	Freeze	Incorrect scanning of the read head and data therefore not current	-	Yes	Logical expectation
	Time offset	Incorrect scanning of the read head and data therefore not current	-	Yes	Logical expectation
RS-485	Incorrect level	Incorrect or no communication	-	Yes	Data backup, Time expectation
	Freeze	No communication	-	Yes	Time expectation, logical expectation
	Continuous transmission	Invalid data	-	Yes	Time expectation, logical expectation
	Failure	No data	-	Yes	Data backup, expectation
SPI AI	Incorrect level	Invalid position	-	Yes	Data backup, expectation
	Freeze	Invalid or outdated position	-	Yes	Time expectation, logical expectation
	Continuous transmission	Invalid or outdated position	-	Yes	Time expectation, logical expectation
	Failure	No position	-	Yes	Data backup, expectation

Unit Block	Type of failure Error presumption	Error effect/ influence	Avoiding errors	Revealed through diagnostics	Error detection Diagnostic option
I1/I2	Freeze	Incorrect lighting	-	Yes	Logical expectation of color switching
	Incorrect signal	Incorrect lighting	-	Yes	Logical expectation of color switching
Camera + DSP	Freeze	Outdated position	-	Yes	Time expectation, logical expectation
	Failure	Outdated or no position	-	Yes	Data backup, dynamization through color switching and expectation
	Data error / corruption	Incorrect position	-	Yes	Time expectation, logical expectation
Linear read head					
Data Matrix code tape	Offset	Unreadable, invalid position	Instructions for correct assembly in read head manual	Yes	Data backup, expectation Check for maximum range
	Damage	Invalid or no position	Instructions for maintenance and operation in read head manual	Yes	Data backup, expectation Check for maximum range

5.4.6 Safe Position

The safe position of the safePXV/PUS read head is accurate with a margin of 20 mm. This is indicated by the spacing of the code markers on the Data Matrix code tape. The accuracy of the safe position of the safePXV/PUS read head is also reduced by the field of view of the read head. The safe position must therefore be considered as follows:

$X = X_{safe} \pm \Delta X = X_{safe} \pm 1/2\ X_{FOV}$

The read window depends on the distance between the read head and the Data Matrix code tape and can be found in the relevant manual.

Read distance read head to the Data Matrix code tape [mm]	Read window dimensions [mm]
76	40
100	53
140	77

5.4.7 Safe Speed

The safe speed is not supplied by the read head itself, but is determined within the PUS evaluation unit based on the safe position. Various filters are available to improve the speed determination based on the safe position with a general resolution of 20 mm. Three filters are available:

- Mean value filter with adjustable filter window
- Modified mean value filter with adjustable filter window, where the modification refers to the safe position before using the filter, which can reduce the measurement noise
- Alpha-beta filter with the parameters alpha and beta.

General application notes for the filters can be found in the following table.

Filter	Description
Mean value filter, modified mean value filter	The mean value filter is easy to configure because it has only one filter parameter, the filter window. The average response time corresponds to the filter window. **Recommendations for use of the mean value filters:** • The modified mean value filter reduces the measurement noise. • The mean value filter is suitable for applications where a minimum response time is not necessary. • A smaller filter window should be selected for a faster response time. This has the disadvantage of higher measurement noise. • To reduce the measurement noise, select a larger filter window.
Alpha-beta filter	The alpha-beta filter has the following selection of parameter pairs: • $\alpha = 0.200$; $\beta = 0.060$ (fast with high measurement noise) • $\alpha = 0.248$; $\beta = 0.032$ (compromise between fast/short response time and slow/high response time) • $\alpha = 0.378$; $\beta = 0.022$ (slow with low measurement noise) **Recommendations for using the alpha-beta filter:** • The alpha-beta filter should be used when a fast response to speed changes is desired. The above parameter combinations are faster than those of the mean value filter. • If a fast response time is desired, the first parameter combination above can be used. However, this has the disadvantage of higher measurement noise. • If low measurement noise is required to set a lower speed limit, the third parameter combination must be used. This has a slower response time.

An overview of the filtered speeds is shown in the figure below.

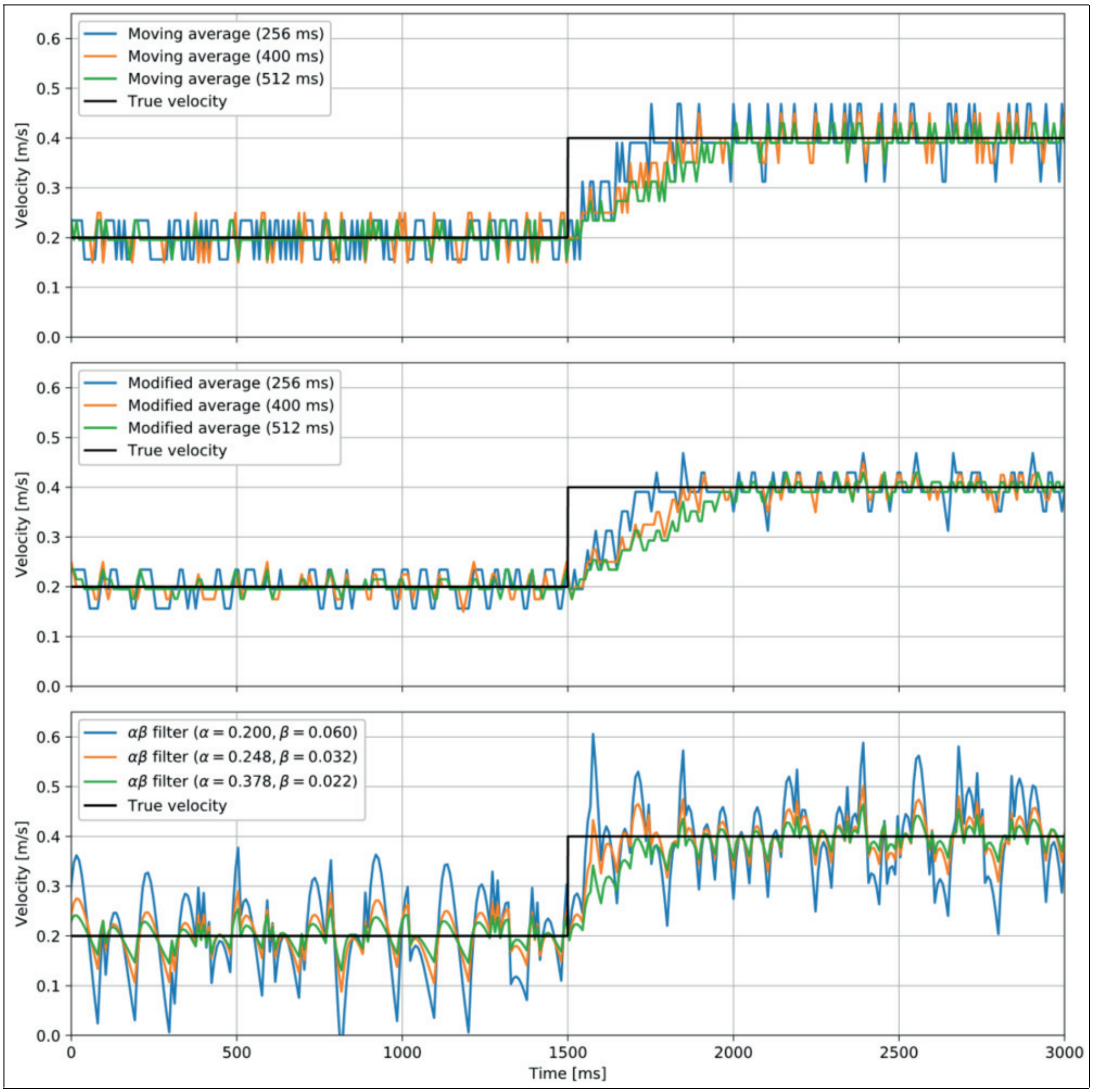


Figure 5.28

Top view	Mean value filter with filter windows of 32, 50, and 64 cycles
Middle view	Modified mean value filter with filter windows of 32, 50, and 64 cycles
Lower view	Alpha-beta filter with the three given parameter combinations

Note

- Refer to the programming manual for the correct filter configuration.
- When monitoring a speed limit value, it is recommended that "overspeed distance monitoring" (an option in the safety function SLS) be used in combination with the mean value filter.
- The safety-relevant characteristics with regard to speed, response time, and fault distance can be found in the corresponding chapter. These characteristics must be observed.
- When using the SOS safety function, monitoring by relative position is recommended.

5.4.8 Safety Assessment of the Read Head

The safety-related characteristic data can be used directly due to the monitoring functions implemented within the evaluation unit in conjunction with the safePXV/PUS read head. Use of the evaluation unit is suitable for PL e according to EN ISO 13849-1. If additional devices are used, a further assessment of the overall configuration must be carried out. For this purpose, relevant information from the manufacturer must be used.

Caution!

Safety notices

EMC measures such as shielding must be observed.

The above-mentioned PL is only valid if a PUS evaluation unit is used with the safe safePXV/PUS read head.

The PUS evaluation unit detects faults in the safe safePXV/PUS read head. The previous chapters provide information on the corresponding diagnostics and the faults that can be detected by them.

Caution!

Safety notices

The diagnostic measures naturally show tolerances due to measurement inaccuracies. These tolerances must be taken into account in the safety assessment.

The limit values for the respective diagnostic measures can in part be parameterized or fixed. The resulting levels of diagnostic coverage must be assessed on an application-specific basis and included in the overall safety assessment.

Caution!

Safety notices

The read head connections must not be plugged in or disconnected during operation. Electrical components on the read head connection may be destroyed.

Disconnect the connected read heads and the PUS evaluation unit from the power supply before plugging in or removing the read head connections.

5.4.9 Read Head Configuration

The most important input variables for the monitoring functions of the module are safe position and speed. These are generated on two channels from the connected safePXV/PUS read heads. The use of the PUS evaluation unit with a safePXV/PUS read head is suitable for PL e according to EN ISO 13849-1.

Safe configuration of the PUS evaluation unit is carried out via the safeControl Expert software and with subsequent verification of the configuration for plausibility. For more information on configuration, refer to the configuration tool documentation.

Note

For Data Matrix code readers as position read heads, e.g., for the safePXV/PUS read head considered in this respect, the measuring length must be at least the maximum value of the Data Matrix code tape used. If the input is too low, an incorrect position may be reported or a false position jump may occur. At least the part of the measuring section with the highest position value on the Data Matrix code tape must be checked for correct position.

6 Connection and Installation

6.1 Integration of the PUS Evaluation Unit

The PUS evaluation unit is intended for installation in the field.

Furthermore, the installation location and the properties of the surrounding electronic modules must ensure compliance with the specified environmental and EMC characteristics with regard to the evaluation unit and the environment. The overall configuration must be checked both with regard to the influences on the properties of the evaluation unit and on the environment.

Observe the following information before you start installing or removing the evaluation unit:

Caution!

Electrostatic discharge

Destruction of electrical components.

Observe the ESD instructions in the chapter "Safety instructions" (see chapter 2.7).

Warning!

Condensation of humidity in the device

Destruction of electrical components.

Do not expose a device to high humidity for an extended period of time. If a cold device is moved to a much warmer environment (e.g., after being transported in a cold environment for a long period), condensation may occur in the device. Wait until the temperature of the device has reached room temperature and the moisture has evaporated before connecting the device to the power supply.

6.2 General Installation Instructions

Always observe the safety instructions when installing!

Degree of protection (IP20)

All signal lines for connecting the digital inputs and contact monitoring must be routed separately.

Always separate 230 V AC (120 V AC cULus) voltages from low-voltage lines if these voltages are used in conjunction with the application.

The cable lengths for the digital inputs and outputs and for all read heads must not generally exceed **30 m**.

If the cable lengths exceed **30 m**, appropriate measures must be taken to rule out the possibility of impermissibly high voltage. Suitable measures are, for example, lightning protection for outside lines, overvoltage protection of the system indoors, protected cable routing.

cULus only

The cable length of 30 m must not be exceeded.

Standards for electromagnetic compatibility (EMC)

The PUS evaluation unit is intended for use in the drive environment and meets the EMC requirements mentioned above. A further prerequisite is that the electromagnetic compatibility of the overall system is ensured by proven, applicable measures.

Warning!
Safety notice

- It must be ensured that the power supply lines of the PUS evaluation unit and the "switching lines" of the current transformer are routed separately from each other.
- Signal cables and current transformer power cables must be routed in separate cable ducts. The distance between the cable ducts must be at least 10 mm.
- Only shielded cables may be used to connect the read heads. The cable for transmitting the signals must be suitable for the RS-485 standard (twisted pair lines).
- The shielding on the read head side must be designed according to appropriate and proven methods.
- Ensure that the current transformer is installed in accordance with EMC requirements in the vicinity of the PUS evaluation unit. Particular attention must be paid to the cable routing and the processing of the shielding for the motor supply cable and the connection of the braking resistor. The installation guidelines of the current transformer manufacturer must be observed in this respect.
- All contactors in the vicinity of the transformer must be equipped with appropriate protective circuitry.
- All contactors or comparable switch amplifiers must be equipped with appropriate protective circuitry (e.g., flyback diodes).
- Appropriate measures must be taken to protect against overvoltage.
- Symbols used according to UL 61010-1
    - The temperature at the terminals can be above 60 °C. Cable types must be used that are suitable for this temperature and above.

6.3 EMC Protective Measures

The installation location, suitable protective measures, and the properties of the surrounding electronic modules must ensure compliance with the specified environmental and EMC properties with respect to the module and the environment.

In particular, the following notes and specifications must be observed: The evaluation unit is intended for industrial use, based on EMC test regulations EN 61800-3 and EN 61326-3-1. The prerequisite is that the electromagnetic compatibility of the overall system is ensured by proven, applicable measures. The following measures ensure proper operation:

- Route the power supply cables of the evaluation unit and the "switching cables" of the non-safe and the power unit of the overall configuration separately from each other.
- Run signal cables and converter power cables in separate cable ducts. The distance between the cable ducts must be at least 10 mm.
- Only shielded motor supply cables may be used in the vicinity of the module. Ensure that converters are installed in an EMC-compliant manner in the vicinity of the evaluation unit.
- Pay particular attention to the cable routing and the processing of the shielding for the motor supply cable and the connection of the braking resistor.
- Connect the shielding of the motor, read head, and signal cables on both sides (motor and converter). The control cables between the converter and the evaluation unit must be shielded. The shield must be connected to the converter.
- All contactors in the vicinity of the evaluation unit must be equipped with appropriate suppressor elements.
- 24 V unshielded power supply

Note

The function of the evaluation unit must be verified by suitable tests as part of the certification of the overall configuration, taking into account the EMC influences of the surrounding components of the overall configuration.

6.4 Installation and Assembly

Note

Installation location

The evaluation unit must be installed exclusively in switch cabinets whose degree of protection is at least IP54.

The modules must be mounted vertically on a DIN rail.

When used in non-enclosed areas, it must be ensured that the environmental conditions of the individual modules (see technical data) are observed.

Note

Air circulation

Clearance of 30 mm must be maintained above and below the ventilation slots. A series of expansion modules is permitted. A distance of 20 mm must be maintained for adjacent devices that can generate waste heat.

Note

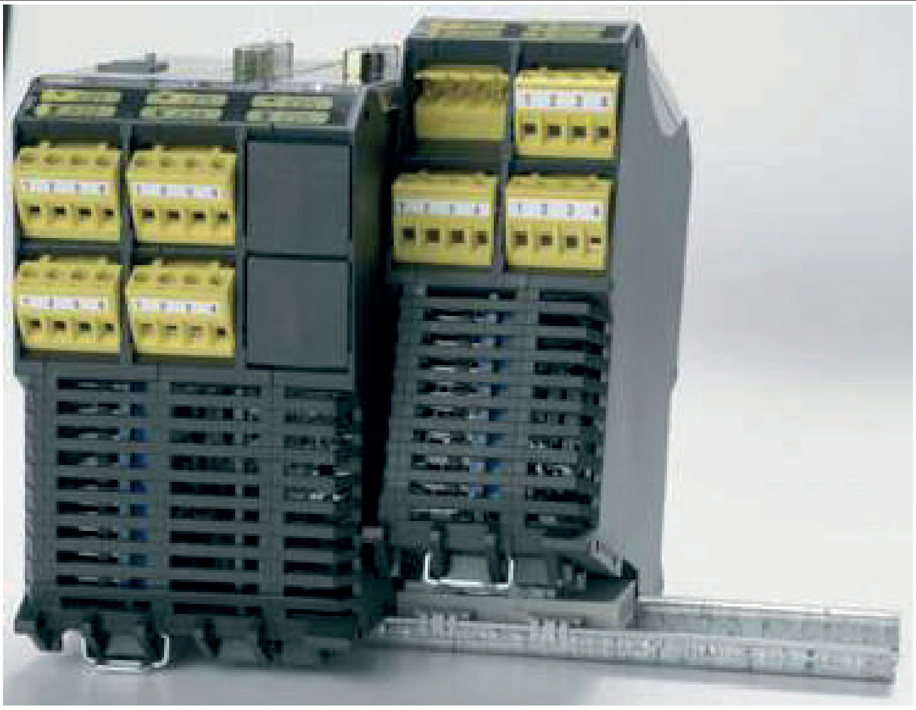
For cULus

Installation is only permitted indoors (indoor use only).

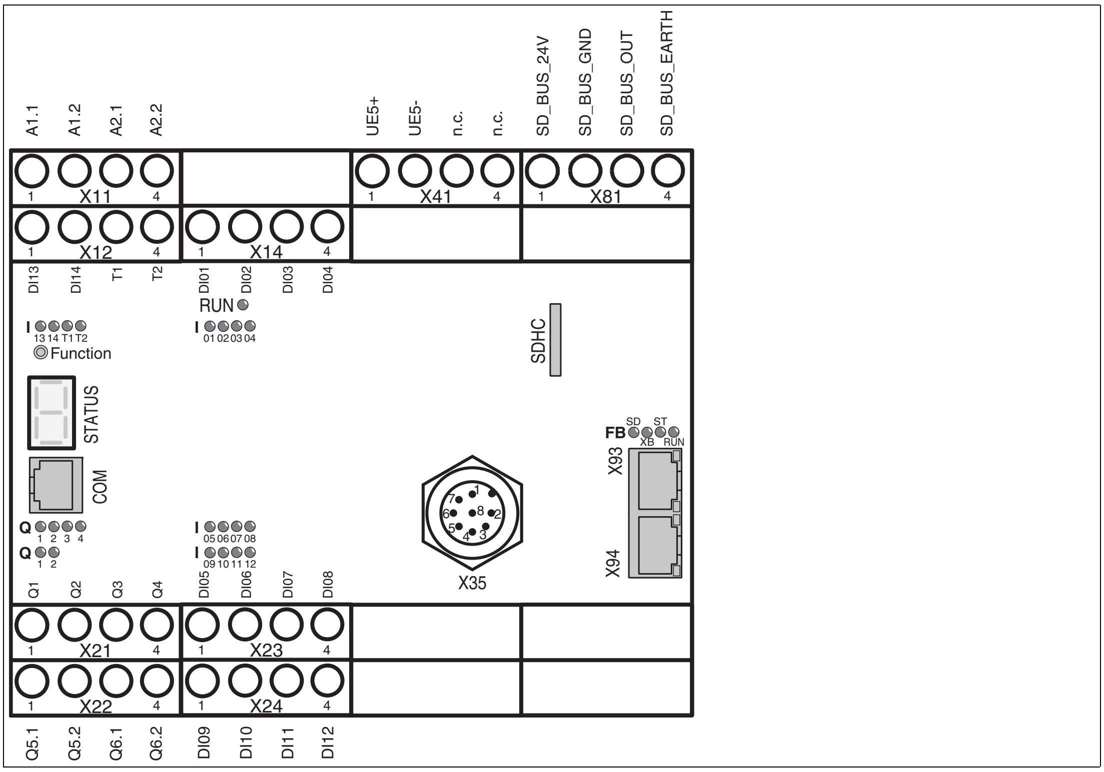
6.5 Mounting the PUS evaluation unit on the DIN rail

The PUS evaluation unit is mounted on a DIN rail using a snap-on latch.

The PUS evaluation units are inserted into the rail at an angle from above and snapped downward. To disassemble, a screwdriver is inserted into the slot in the tab protruding downward. Pushing the tab upward releases the unit.



6.6 Terminal Assignment PUS-F161-B*-PXV



Interface for voltage supply and I/O

Terminal assignment		
Terminal	**Pin**	**Description**
X11	1 - A1.1	Voltage supply Device +24 V DC
	2 - A1.2	Voltage supply Device +24 V DC outputs
	3 - A2.1	Voltage supply Device 0 V DC
	4 - A2.2	
X12	1 - I13	Safe digital inputs
	2 - I14	
	3 - T1	Clock outputs
	4 - T2	
X13	1 - NC	No function
	2 - NC	
	3 - NC	
	4 - NC	
X14	1 - I01	Safe digital inputs
	2 - I02	
	3 - I03	
	4 - I04	

Terminal assignment		
Terminal	**Pin**	**Description**
X21	1 - Q1	Output pn-switching Q1_PP / pp-switching Q1
	2 - Q2	Output pn-switching Q2_PN / pp-switching Q2
	3 - Q3	Output pn-switching Q3_PP / pp-switching Q3
	4 - Q4	Output pn-switching Q4_PN / pp-switching Q4
X22	1 - Q5.1	Safe relay output
	2 - Q5.2	
	3 - Q6.1	Safe relay output
	4 - Q6.2	
X23	1 - I05	Safe digital inputs
	2 - I06	
	3 - I07	
	4 - I08	
X24	1 - I09	Safe digital inputs
	2 - I10	
	3 - I11	
	4 - I12	
X41	1 - UE5+	Read head voltage supply +24 V DC, X35
	2 - UE5-	Read head voltage supply 0 V DC, X35
	3 - NC	No function
	4 - NC	
X81	1 - SD_BUS_24V	SD-BUS voltage supply +24 V DC
	2 - SD_BUS_GND	SD-BUS voltage supply 0 V DC
	3 - SD_BUS_OUT	SD-BUS output
	4 - FUNC_EARTH	Functional earth

Diagnostics and configuration interface

RJ10 socket, 4-pin		
Interface	**Pin**	**Designation**
COM	1	GND
	2	RS-485-
	3	RS-485+
	4	VCCH

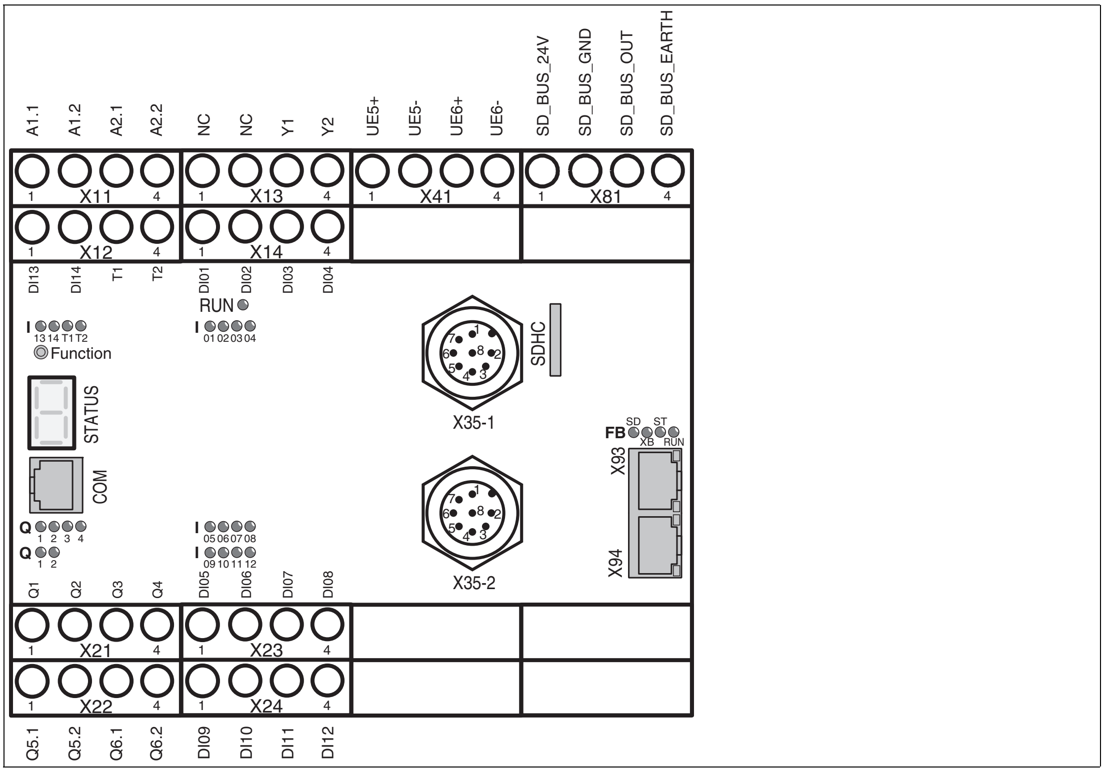
Fieldbus Interface

RJ45 socket fieldbus interface				
Interface	**Pin**	**Designation**	**Description**	**Color**
X93 / X94	1	TX+	Transmit data +	White-orange
	2	TX-	Transmit data -	Orange
	3	RX+	Receive data +	White-green
	4	nc	Not used	Blue
	5	nc	Not used	White-blue
	6	RX-	Receive data -	Green
	7	nc	Not used	White-brown
	8	nc	Not used	Brown

Read head interface

RS-485 interface for read head		
Interface	**Pin**	**Designation**
X35 M12 socket, 8-pin	1	I/O2 (enable blue)
	2	UB+
	3	Data + / TX / 485+
	4	Data - / RX / 485-
	5	O1 (sync. out)
	6	I1 (enable red)
	7	GND
	8	I/O3

6.7 Terminal Assignment PUS-F161-B*-WCS



Interface for Voltage Supply and I/O

Terminal assignment		
Terminal	**Pin**	**Description**
X11	1 - A1.1	Voltage supply Device +24 V DC
	2 - A1.2	Voltage supply Device +24 V DC outputs
	3 - A2.1	Voltage supply Device 0 V DC
	4 - A2.2	
X12	1 - I13	Safe digital inputs
	2 - I14	
	3 - T1	Clock outputs
	4 - T2	
X13	1 - NC	No function
	2 - NC	
	3 - Y1	Auxiliary outputs
	4 - Y2	
X14	1 - I01	Safe digital inputs
	2 - I02	
	3 - I03	
	4 - I04	

Terminal assignment		
Terminal	**Pin**	**Description**
X21	1 - Q1	Output pn-switching Q1_PP / pp-switching Q1
	2 - Q2	Output pn-switching Q2_PN / pp-switching Q2
	3 - Q3	Output pn-switching Q3_PP / pp-switching Q3
	4 - Q4	Output pn-switching Q4_PN / pp-switching Q4
X22	1 - Q5.1	Safe relay output
	2 - Q5.2	
	3 - Q6.1	Safe relay output
	4 - Q6.2	
X23	1 - I05	Safe digital inputs
	2 - I06	
	3 - I07	
	4 - I08	
X24	1 - I09	Safe digital inputs
	2 - I10	
	3 - I11	
	4 - I12	
X41	1 - UE5+	Read head voltage supply +24 V DC, X35-1
	2 - UE5-	Read head voltage supply 0 V DC, X35-1
	3 - UE6+	Read head voltage supply +24 V DC, X35-2
	4 - UE6-	Read head voltage supply 0 V DC, X35-2
X81	1 - SD_BUS_24V	SD-BUS voltage supply +24 V DC
	2 - SD_BUS_GND	SD-BUS voltage supply 0 V DC
	3 - SD_BUS_OUT	SD-BUS output
	4 - FUNC_EARTH	Functional earth

Diagnostics and configuration interface

RJ10 socket, 4-pin		
Interface	**Pin**	**Designation**
COM	1	GND
	2	RS-485-
	3	RS-485+
	4	VCCH

Fieldbus Interface

RJ45 socket fieldbus interface				
Interface	**Pin**	**Designation**	**Description**	**Color**
X93 / X94	1	TX+	Transmit data +	White-orange
	2	TX-	Transmit data -	Orange
	3	RX+	Receive data +	White-green
	4	nc	Not used	Blue
	5	nc	Not used	White-blue
	6	RX-	Receive data -	Green
	7	nc	Not used	White-brown
	8	nc	Not used	Brown

Read head interface

RS-485 interface for read head		
Interface	**Pin**	**Designation**
X35-1 / X35-2 2x M12 socket, 8-pin	1	NC
	2	UB+
	3	Data +
	4	Data -
	5	nc
	6	nc
	7	GND
	8	nc

6.8 External 24 V DC – Power Supply

The PUS evaluation unit requires a power supply of 24 V DC (see SELV or PELV, EN 50178). The following boundary conditions must be observed when configuring and installing the intended power supply unit:

The minimum and maximum tolerance of the supply voltage must be observed.

Nominal voltage	24 V DC
Minimum: 24 V DC - 15 %	20.4 V DC
Maximum: 24 V DC + 20 %	28.8 V DC

When configuring and installing the intended power supply unit, observe the following boundary conditions:

- Always observe the minimum and maximum tolerance of the supply voltage.
- To achieve the smallest possible residual ripple in the supply voltage, the use of a 3-phase power supply unit or an electronically controlled device is recommended. The power supply unit must comply with the requirements of EN 61000-4-11 (voltage drop).
- Safe galvanic isolation from the power supply network (e.g., 230 V AC) must always be ensured. To achieve this, select power supply units that comply with EN 60950. In addition to selecting an appropriate device, ensure that there is equipotential bonding between PE and 0 V DC on the secondary side.
- Protect the evaluation unit externally with a fuse if current is outside the permitted range. Observe the local regulations when designing the connecting cables. The minimum and maximum tolerance of the supply voltage must be observed.
- The external voltage resistance of the evaluation unit is 32 V DC (protected by suppressor diodes at the input).

Warning!

Risk to persons from electric shock!

Only supply the evaluation unit from voltage sources providing protective extra-low voltage (e.g., SELV or PELV according to EN 61131-2). If a SELV voltage source is used, it can become PELV due to the design of the module and the connections (ground reference!). Protective extra-low voltage circuits must always be safely isolated from circuits with dangerous voltages.

Caution!

Risk of fire in case of component failure!

Appropriate external fuses based on the cable and connector specifications must be used in the final application.

Caution!

Use of external power supply units

When using external power supply units, ensure that in the event of a fault, no voltage higher than 60 V can occur. The actual behavior of the power supply unit used must be requested from the respective manufacturer since the EN 60950 standard permits up to 120 V in the event of a fault.

Caution!

Back-up fuse

Each evaluation unit must be protected by an external back-up fuse of 3.15 A (min. 30 V DC). The fuse must be located near the terminals.

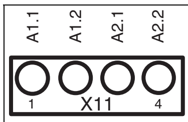
Recommended fuse type: 3.15 A circuit breaker (class B) or safety fuse (delayed action).

Caution!

GND connections

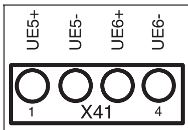
All GND connections of devices connected to the inputs of the evaluation unit must be connected to the GND of the evaluation unit (power supply).

Terminal assignment of the PUS evaluation unit (X11)



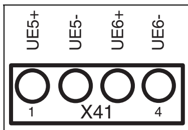
Terminal	Pin	Description
X11	1 - A1.1	Voltage supply Device +24 V DC
	2 - A1.2	Voltage supply Device +24 V DC outputs
	3 - A2.1	Voltage supply Device 0 V DC
	4 - A2.2	

Terminal assignment safePXV/PUS read head (X41)



Terminal	Pin	Description
X41	1 - UE5+	Read head voltage supply +24 V DC, X35-1
	2 - UE5-	Read head voltage supply 0 V DC, X35-1
	3 - NC	No function
	4 - NC	

Terminal assignment safeWCS/PUS read heads (X41)



Terminal	Pin	Description
X41	1 - UE5+	Read head voltage supply +24 V DC, X35-1
	2 - UE5-	Read head voltage supply 0 V DC, X35-1
	3 - UE6+	Read head voltage supply +24 V DC, X35-2
	4 - UE6-	Read head voltage supply 0 V DC, X35-2

The inputs of the evaluation unit are:

- Digital inputs
- Digital I/Os
- Read head connections

Note (safePXV/PUS read head)

The GND_ENC connections are <u>not</u> internally connected to GND!

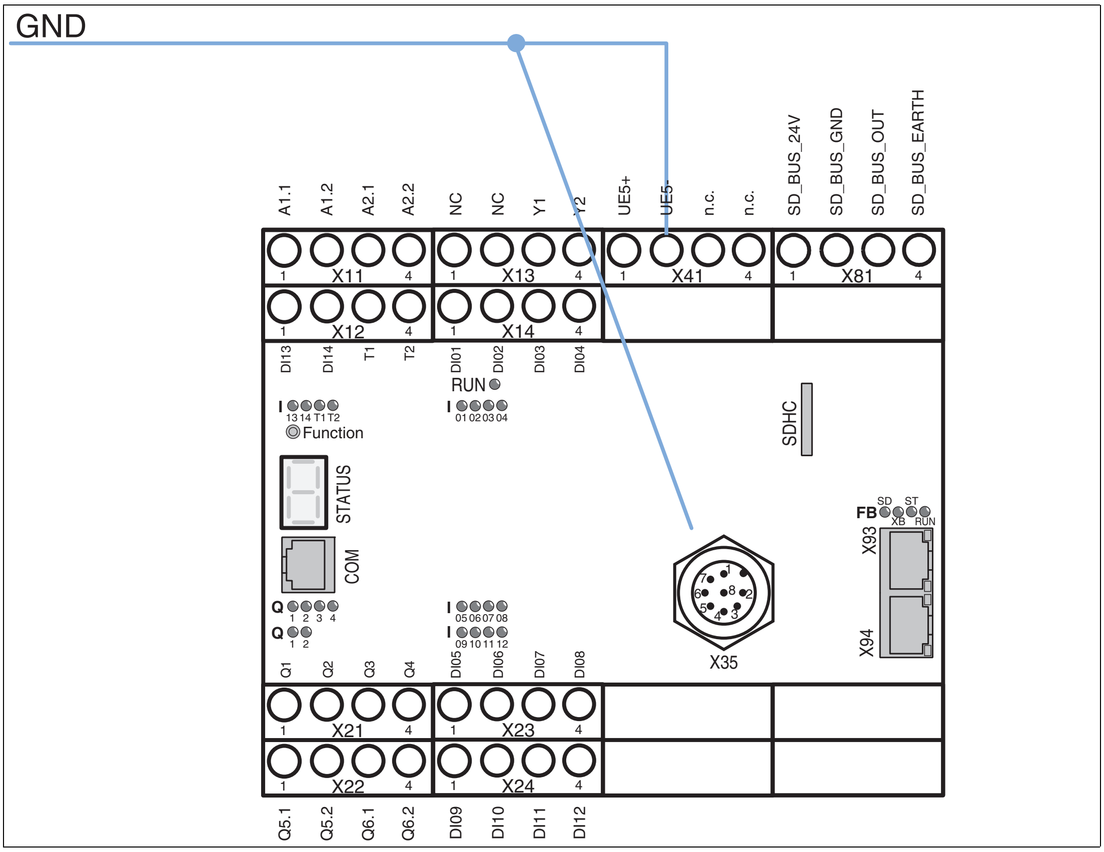


Figure 6.1

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Note (safeWCS/PUS read heads)

The GND_ENC connections are not internally connected to GND!

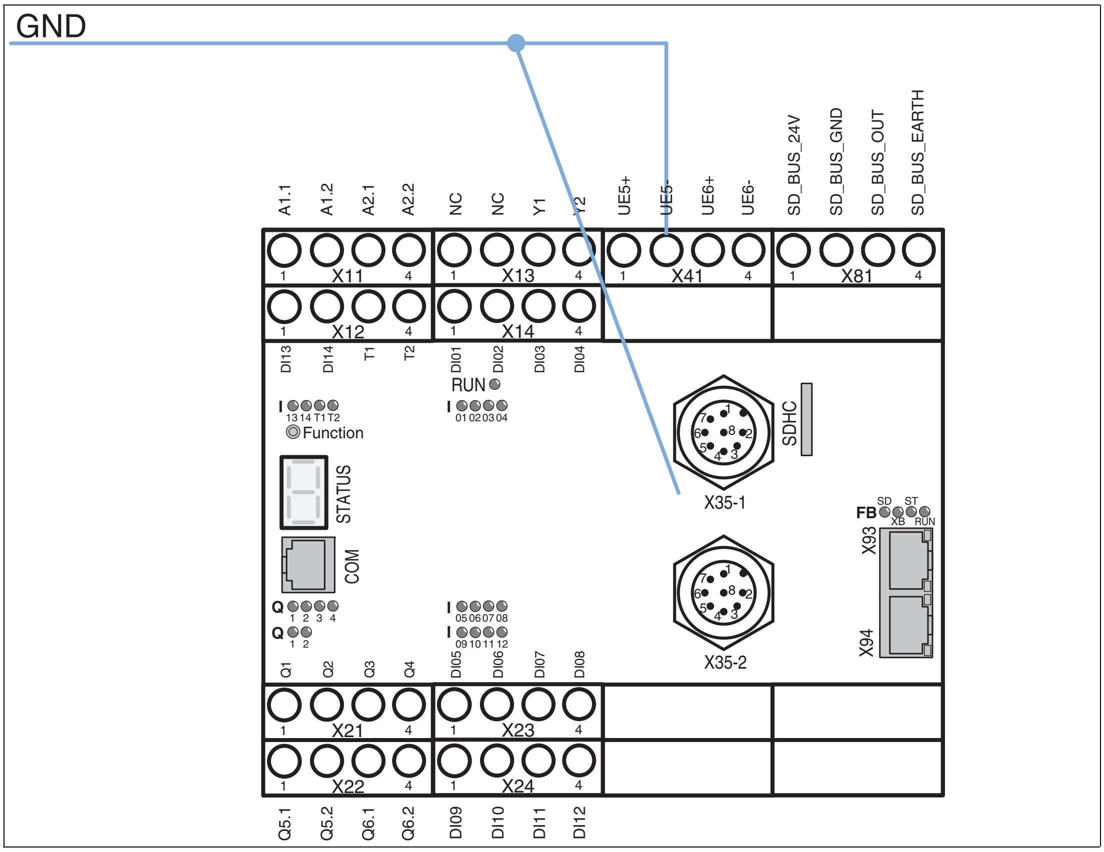

Figure 6.2

6.9 Connection of external voltage supply for safePXV/PUS and safeWCS/PUS read heads

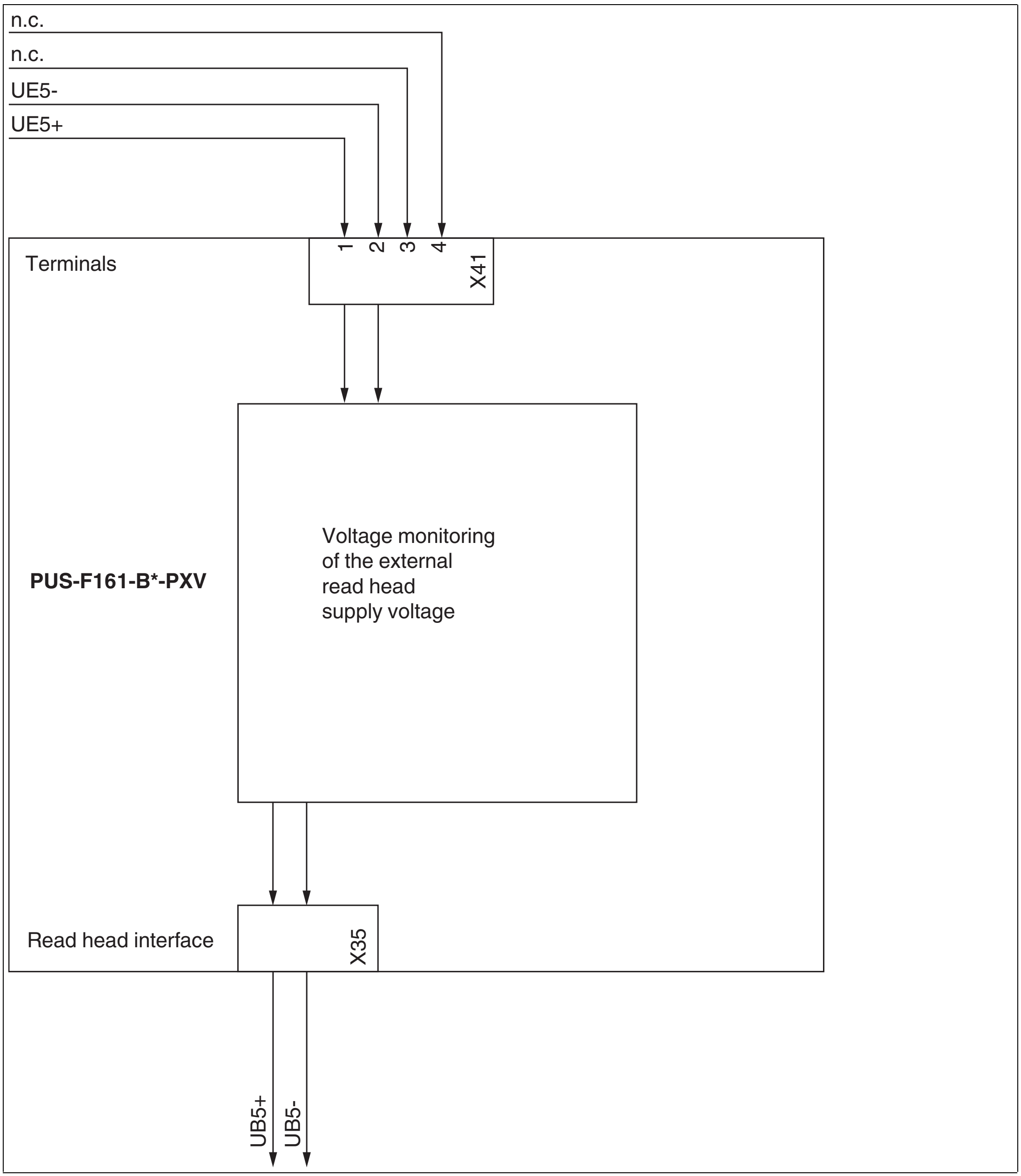

Figure 6.3 Connection of the external supply voltage to safePXV/PUS read heads

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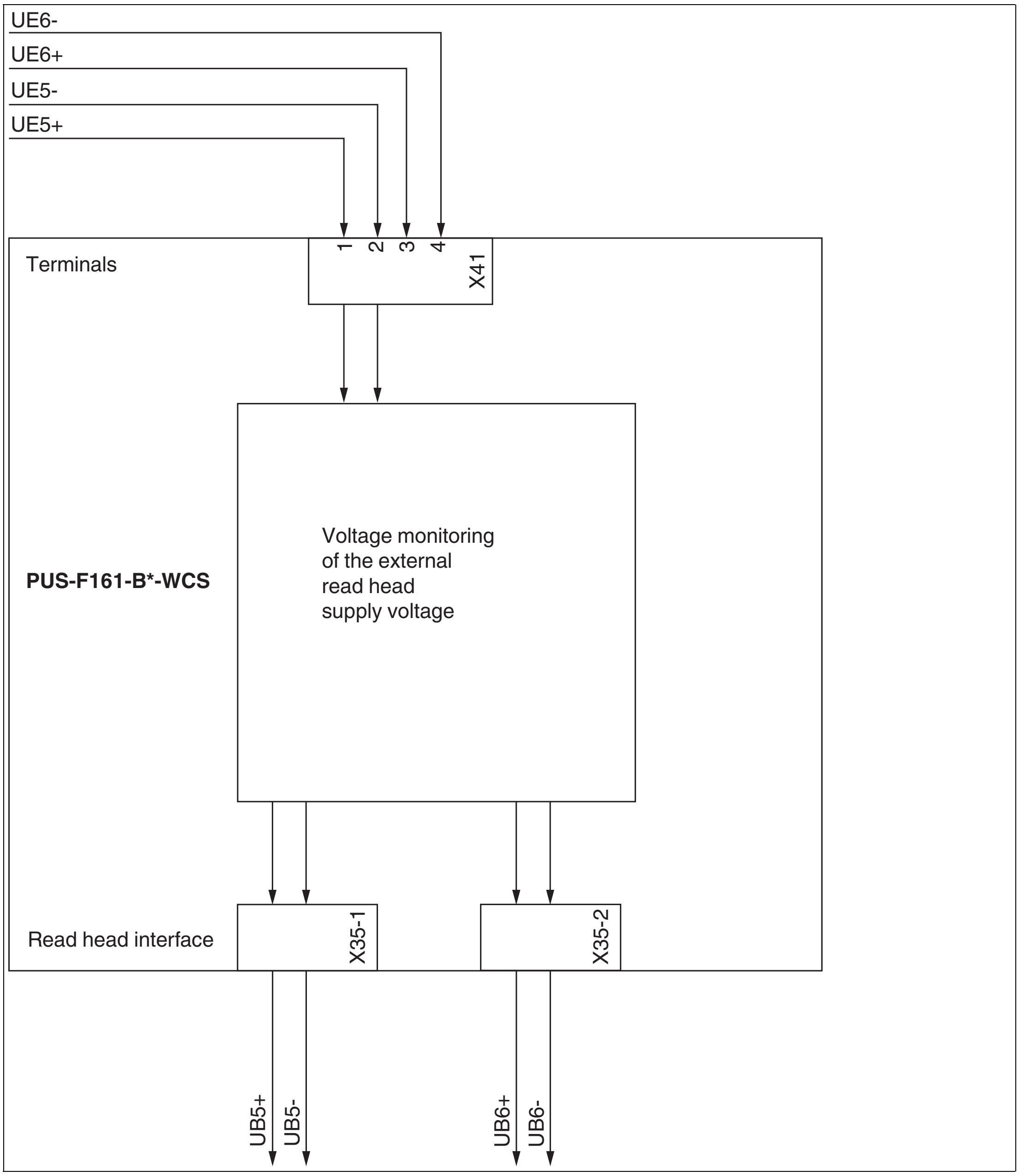


Figure 6.4 Connection of the external supply voltage to safeWCS/PUS read heads

The PUS evaluation unit supports read head voltages of 5 V, 8 V, 10 V, 12 V, 20 V, and 24 V. These are monitored internally according to the selected configuration.

If a read head system is not supplied via the PUS evaluation unit, a supply voltage must nevertheless be connected to terminal X41 and configured accordingly.

Note

The voltage at the safeWCS/PUS read heads must be 10–30 V.

The voltage at the safePXV/PUS read heads must be 14.5–30 V.

The read head supply must be protected with a maximum 2 A fuse.

Caution!

GND connection

The GND connection of the read head must be connected to the GND of the evaluation unit.

Monitoring of the supply voltage according to the selected nominal voltage:

Nominal voltage	Minimum voltage	Maximum voltage
5 V DC	4.4 V DC	5.6 V DC
8 V DC	7 V DC	9 V DC
10 V DC	8 V DC	12 V DC
12 V DC	10 V DC	14 V DC
20 V DC	16 V DC	24 V DC
24 V DC	20 V DC	29.5 V DC

6.10 Connection of Digital Inputs

- The evaluation unit has 14 safe digital inputs. These are suitable for the connection of 1- or 2-channel signals with and without a clock, or without cross-circuit test.
- The connected signals must have a "high" level of 24 V DC (+15 V DC ... + 30 V DC) and a "low" level of (-3 V DC ... +5 V DC, type 1 according to EN 61131-2). The inputs are internally equipped with input filters.
- A device-internal diagnostic function cyclically checks the correct function of the inputs including the input filters. The PUS evaluation unit is put into an alarm state if a fault is detected. At the same time, all outputs of the evaluation unit are switched to passive.
- In addition to the actual signal inputs, the evaluation unit provides two clock outputs T1 and T2. The clock outputs are switching 24 V DC outputs.

  The clock outputs are exclusively used for monitoring the digital inputs (DI01 DI14) and cannot be used for any other functions within the application.
- The switching frequency is 125 Hz for each output. When configuring, it must be noted that the outputs may be loaded with a maximum total current of 250 mA.
- Furthermore, approved OSSD outputs can be connected to the inputs I01 ... I14 with no limitations.
- When using the inputs in 1-channel mode, the achievable safety level is restricted to SIL 2 or PL d if a safety function request is made at regular intervals.

  In principle, safety-related use of the inputs is intended only in conjunction with the pulse outputs.
- If the clock outputs are not used, external measures, in particular suitable cable routing, must be taken to prevent a short circuit in the external wiring between different inputs and against the supply voltage of the evaluation unit.
- Each input of the evaluation unit can be individually configured for the following signal sources:
  - Input is assigned to clock T1
  - Input is assigned to clock T2
  - Input is assigned to 24 V DC continuous voltage

6.11 Connection of Position and Speed Read Heads

6.11.1 General Information

The PUS evaluation unit has an external read head interface for connecting a safePXV/PUS read head or two external read head interfaces for connecting the two safeWCS/PUS read heads.

Important

The read head system is supplied with power via the terminals present on the evaluation unit. This voltage is routed to the read head connector and monitored by an internal diagnostic process.

- If the read head is supplied with an external voltage, this must be fed via the read head connector. The corresponding terminal (read head supply voltage) on the PUS evaluation unit remains free.
- If an external read head supply voltage is not fed back via the read head connector, the failure of this supply must be included in the fault analysis of the overall system. In particular, it must therefore be demonstrated that if the read head system operating voltage falls below or exceeds the specified value, this fault is detected and/or can be excluded.

EMC measures such as shielding etc. must be observed.

The two read heads must not interfere with one another. This applies to both the electrical and mechanical parts.

If both read heads are coupled to the device to be monitored via common mechanical parts, the connection must have a positive fit and must not contain any parts that are subject to wear (chains, toothed belts, etc.). If this is nevertheless the case, additional monitoring devices are required for the mechanical connection of the read heads (e.g., toothed belt monitoring).

At least one read head must be used when position processing is active.

If two equivalent read heads are used, ensure that the read head with the higher resolution is configured as read head 1 (process) and the read head with the lower resolution is configured as read head 2 (reference).

Caution!

GND connections

The GND connections of the read heads must be connected to the GND of the evaluation unit. This also applies to resolvers in the same way.

Caution!

Read head connections

The read head connections must not be plugged in or disconnected during operation. Electrical components on the read head may be destroyed.

- Disconnect the connected read heads and the PUS evaluation unit from the power supply before plugging in or removing the read head connections. For externally supplied read heads, ensure that the external supply voltage (e.g., transformer) is switched off.
- For the data and clock signals and for track A and track B, twisted-pair cables must be used for signal transmission according to the RS-485 standard. When selecting the wire cross-section, the power consumption of the read head and the cable length of the installation must be taken into account in each case.

When using read heads, the following also applies:

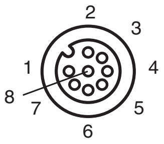
In slave mode, the clock signal is generated by an external process and is read in with the data signal from the evaluation unit. This type of sampling results in hovering followed by a sampling error of the following magnitude:

F = (sampling time of the read head by external system [ms] / 8 [ms]) * 100 %

The magnitude of the resulting sampling error **F** must be taken into account when defining the thresholds in the monitoring functions used since this error cannot be compensated!

6.11.2 Read Head Interface X35

The PUS-F161-B*-PXV evaluation unit has 1 read head input to evaluate a read head.



Read head interface

RS-485 interface for read head			
Interface	**Pin**	**Designation**	**Description**
X35 M12 socket, 8-pin	1	I/O2 (enable blue)	Activation of blue lighting
	2	UB+	Supply voltage
	3	Data + / TX / 485+	Data transfer
	4	Data - / RX / 485-	Data reception
	5	O1 (sync. out)	SYNC signal of the read head
	6	I1 (enable red)	Activation of red lighting
	7	GND	Ground
	8	I/O3	Not used

Grounding

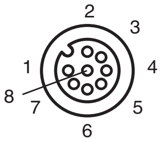
The shielding of cables is required to suppress electromagnetic interference. Please use only braided connecting cables. Avoid connecting cables with foil shielding.

Note

The shielding is connected at both ends, i.e., at the evaluation unit and at the read head. The grounding terminal available as an accessory (PCV-SC12) allows easy integration in the equipotential bonding circuit.

6.11.3 Read Head Interface X35-1/X35-2

The evaluation unit PUS-F161-B*-WCS has 2 read head inputs for evaluating WCS read heads WCS3B-LS221-U1 and WCS3B-LS221-U2.



Read head interface

RS-485 interface for read head			
Interface	**Pin**	**Designation**	**Description**
X35-1 / X35-2 2x M12 socket, 8-pin	1	NC	Not used
	2	UB+	Supply voltage
	3	Data +	Data transfer
	4	Data -	Data reception
	5	NC	Not used
	6	NC	Not used
	7	GND	Ground
	8	NC	Not used

Grounding

The shielding of cables is required to suppress electromagnetic interference. Please use only braided connecting cables. Avoid connecting cables with foil shielding.

Note

The shielding is connected at both ends, i.e., at the evaluation unit and at the read head. The grounding terminal available as an accessory (PCV-SC12) allows easy integration in the equipotential bonding circuit.

6.12 Configuration of Measuring Sections

6.12.1 General Description of Read Head Configuration

The most important input variables for the monitoring functions of the module are safe position, speed, and acceleration.

These are generated on two channels from the connected read heads. For PL e in accordance with EN ISO 13849-1, an architecture corresponding to category 4 is required, i.e., continuous 2-channel acquisition with a high degree of diagnostic coverage. For any 1-channel components (e.g., mechanical connection of the read head with only one shaft/attachment), fault eliminations can be used in accordance with EN ISO 13849-2 if necessary. For PL d according to EN ISO 13849-1, a reduced degree of diagnostic coverage can be used. Taking into account the permissible fault eliminations according to EN ISO 13849-2, single read heads may also be sufficient (speed monitoring only). Further information on the monitoring functions see chapter 5.4.9.

The further configuration is described in the **safeControl Expert programming manual**.

7 Response Time of the Evaluation Unit

The response time is an important safety characteristic and must be considered for each application / application safety function. The following chapter lists response times for individual functions, some of which depend on other parameters. If this information is not sufficient for a specific application, separate measurements must be taken to validate the actual time behavior against the target behavior. This applies in particular to the use of filter functions.

Caution!
Safety notice:

- The response times for each application safety function must be specified in the target behavior and compared against the actual value using the following information.
- Take special care when using filter functions. Depending on the filter length/time, a significant increase in the response time can occur, which must be considered in the safety design.
- For especially critical tasks, the time behavior must be validated by measurements.
- Under certain conditions (depending on the application program), outputs can become active for the duration of the response time on device startup/in the case of an alarm or fault reset. This must be taken into account when planning the safety functions
- When using safe fieldbus connections (e.g., PROFIsafe, FSoE), the system runtime (watchdog) must also be included in calculations.

7.1 Response Times in Standard Mode

The basis for calculating response times is the cycle time of the evaluation unit. In **T_cycle mode, this is 8 ms**. The specified response times correspond to the respective maximum runtime for the specific application within the evaluation unit. Depending on the application, additional, application-dependent response times of the read heads and actuators used may need to be considered to obtain the total cycle time.

Function	Response time [ms]	Description
Activation of a monitoring function by ENABLE with subsequent shutdown via digital output	24 *)	Activation of a monitoring function by the ENABLE signal.
Activation of a monitoring function by ENABLE with subsequent shutdown via safety relay	47 *)	Activation of a monitoring function by the ENABLE signal.
Response of an already activated **monitoring function** including PLC processing for position and speed processing via digital output	16 *)	If the monitoring function is already activated via ENABLE, the module requires a cycle to calculate the current speed value. In the next cycle, after calculating the monitoring function, the information is further processed and output by the controller, i.e., depending on the implemented logic, this may lead e.g., to the switching of an output.
Response from an already activated monitoring function including PLC processing for position and speed processing via safety relay	39 *)	If the monitoring function is already activated via ENABLE, the module requires a cycle to calculate the current speed value. In the next cycle, after calculating the monitoring function, the information is further processed and output by the controller, i.e., depending on the implemented logic, this may lead e.g., to the switching of an output.
Activation of digital output via digital input	16	Activation of an input and switching the output

Function	Response time [ms]	Description
Activation of an output relay via digital input	26	Activation of an input and switching the output
Deactivation of a digital output via digital input	16	Deactivation of an input and therefore deactivation of the output
Deactivation of an output relay via digital input	47	Deactivation of an input and therefore deactivation of the output
Mean value filter (for setting, see safeControl Expert read head dialog)	0 64	Group runtime of mean value former. This runtime only affects monitoring functions in connection with position/speed/acceleration, but not logic processing.

***):** If a mean value filter is used, its response time must be added up.

7.2 Response Times for FAST_CHANNEL

FAST_CHANNEL refers to a special property of the evaluation unit to react to speed requirements faster than is possible when running the safety program in the normal cycle (= 8 msec). The sampling time of the FAST_CHANNEL is 2 msec.

The following response times can be specified:

- 4 msec (worst-case condition)

Caution!

Safety notice

When using the FAST_CHANNEL, it should be noted that a shutdown can only take place within the time specified above for a specified speed threshold if the resolution of the read head information is sufficiently high. The smallest resolvable FAST_CHANNEL switching threshold requires at least two edge changes on the selected read heads within a time of 2 msec.

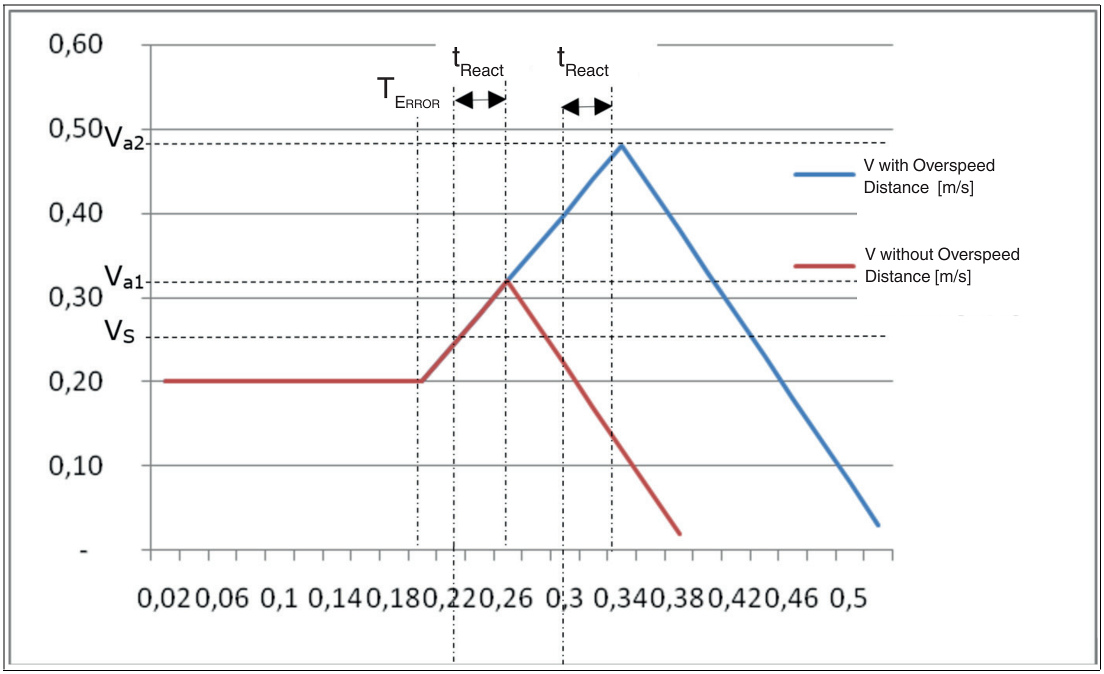
- This function is only possible when used with safe semiconductor outputs.
- The FAST_CHANNEL must not affect SSI listeners

7.3 Response Times for Fault Distance Monitoring

The following calculation schema is used to calculate the worst-case condition:

System speed at sampling time:	V(t)
System speed on response from evaluation unit:	V_A
Threshold value for monitoring (SLS or SCA):	V_S = constant for all t
Parameterized filter value:	XF = constant for all t
Maximum possible acceleration of the application:	a_F = constant for all t
Delay after shutdown:	a_V = constant for all t
Sampling time for occurrence of a worst-case event:	T_{Fault}
Response time of the evaluation unit:	t_{Resp}

For the worst-case analysis, it is assumed that the drive initially moves at speed V(k) to precisely the parameterized threshold V0 and then accelerates at a maximum possible value a0.



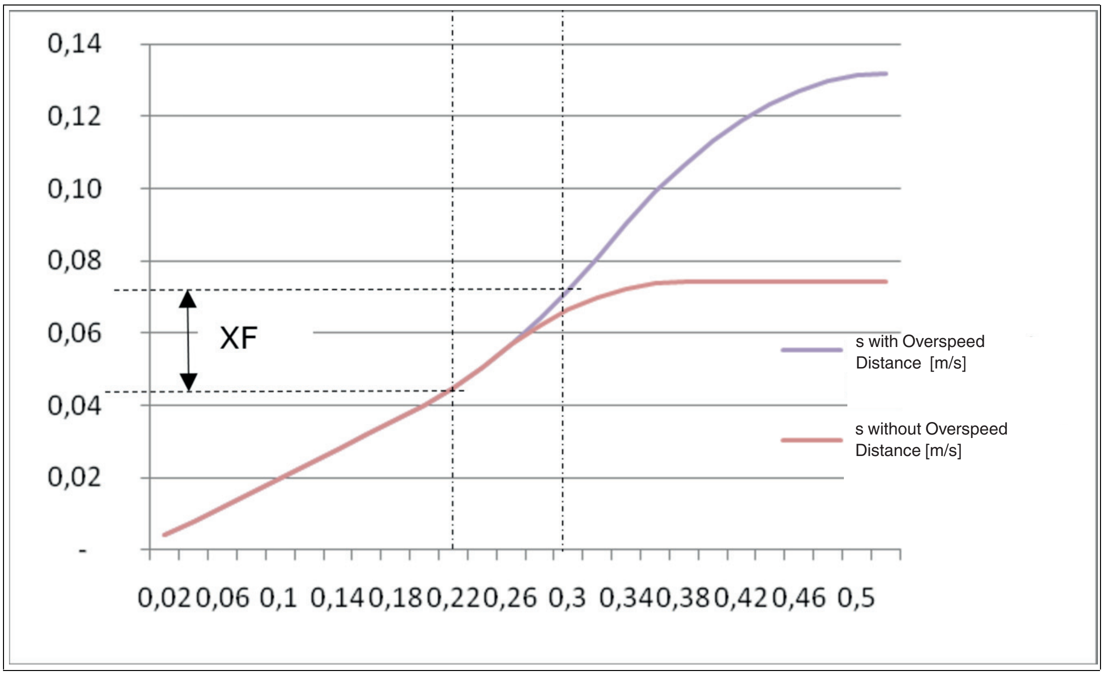


Chart: Behavior of the drive with and without overspeed distance

The V and s trends have the following relationships without overspeed distance:

Parameter	Calculation method	Comment
t_{Resp}	Value from specified response time of evaluation unit + delay time in external shutdown chain	Delay time in the external shutdown chain from manufacturer specifications for relay/contactor, brake, etc.
a_F, a_V	n.a.	Estimation from application
V_{a1}	$= V_S + a_F * t_{Resp}$	

The following applies to V and s trends <u>with</u> overspeed distance:

Parameter	Calculation method	Comment
t_{Resp}	Value from specified response time of evaluation unit + delay time in external shutdown chain	Delay time in the external shutdown chain from manufacturer specifications for relay/contactor, brake, etc.
a_F, a_V	n.a.	Estimation from application
V_{a2}	$= a_F * t_{Resp} + (V_S^2+2*XF)½$	

The effect of the filter shifts the set velocity threshold V_a upward by an amount **delta_v_filter**. The new values for the response time ($T_{resp} = T_{PSU} + T_{filter}$) and the resulting speed on shutdown must be considered by the evaluation unit for the application.

7.4 Response Times for Safe Position Determination with safePXV/PUS

Determination and verification of response times and fault distances

The response time and fault distance are important safety-related properties and must be considered for each application and application safety function. The following chapter lists response times and fault distances for individual functions, some of which depend on other parameters. If this information is not sufficient for a specific application, separate measurements must be taken to validate the actual time behavior against the target behavior. This applies in particular to the use of filter functions.

Danger!

Significant impairment of safety in the event of incorrectly determined response times/fault distances

The response times and fault distances for each application safety function must be specified in the target behavior and compared against the actual value using the following information.

For especially critical tasks, the behavior must be validated by measurements.
Under certain conditions (depending on the application program), outputs can become active for the duration of the response time on device startup/in the case of an alarm or fault reset. This must be taken into account when planning the safety functions (e.g., time-monitored input element triggers an alarm after 3 seconds).

7.4.1 Response Times in Standard Mode

The basis for calculating response times is the worst case response time of the evaluation unit when used with a safe safePXV/PUS read head. This response time is:

T_worstcase = 263 ms

and is constituted by data acquisition, processing and diagnostics.

Additional response times that affect only the evaluation unit can be found in the corresponding chapter. These are based on the evaluation unit cycle time of:

T_cycle = 8 ms

Depending on the application, additional, application-dependent response times of the read heads and actuators used may need to be considered to obtain the total cycle time.

Note

- The response time specified in this respect must be used to evaluate the safe position.
- If no Data Matrix code is seen on the Data Matrix code tape, the response time increases by the number of permitted zero positions multiplied by the cycle time of the evaluation unit.
- If the safe speed is used for safety functions, the response time may increase or the fault distance must be considered a safety parameter.

7.4.2 Fault Distances for Speed Considerations

Note

- When using the safe speed for safety functions, the use of "overspeed distance monitoring" is recommended. The safety characteristic is therefore the fault distance.
- Fault distances vary depending on the speed filter used.
- It is recommended to use exclusively the two mean value filters for the use of "overspeed distance monitoring."
- The exact configuration of "overspeed distance monitoring" can be found in the programming manual.
- The following considerations are based on the assumption of a speed limit of 15 % above the functional speed and a speed due to a malfunction of 5 % above the limit speed.
- Worst case fault distances occur when the speed limit is slightly exceeded. When the speed change increases, the fault distance decreases. For safety-relevant considerations, the worst case must be assumed.
- The response time of the filtered speed can also be no less than the worst case response time of the overall system at this point (T_worstcase = 263 ms).

The basis for determining the fault distance is the setting of the "permitted distance" within "overspeed distance monitoring." First of all, the result of the two mean value filters must be shown. The subsequent analysis of the fault distance assumes the following settings:

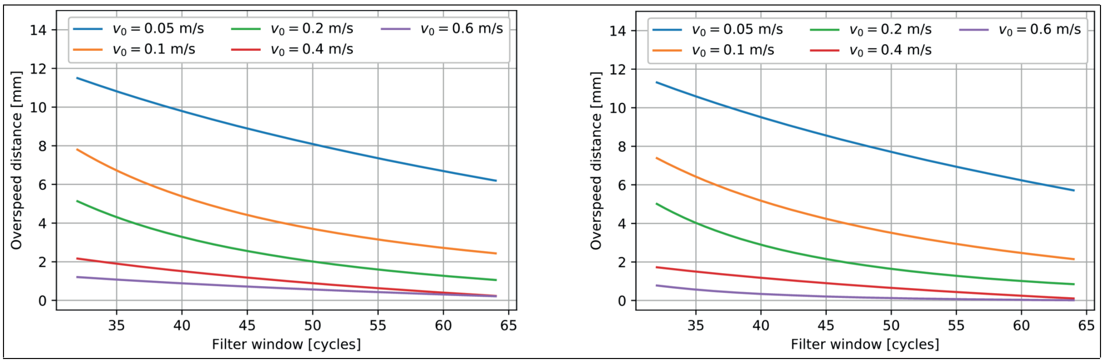


Figure 7.1 Setting of the "permitted distance" for the mean value filter (left) and the modified mean value filter (right) as a function of the filter window for various functional speeds.

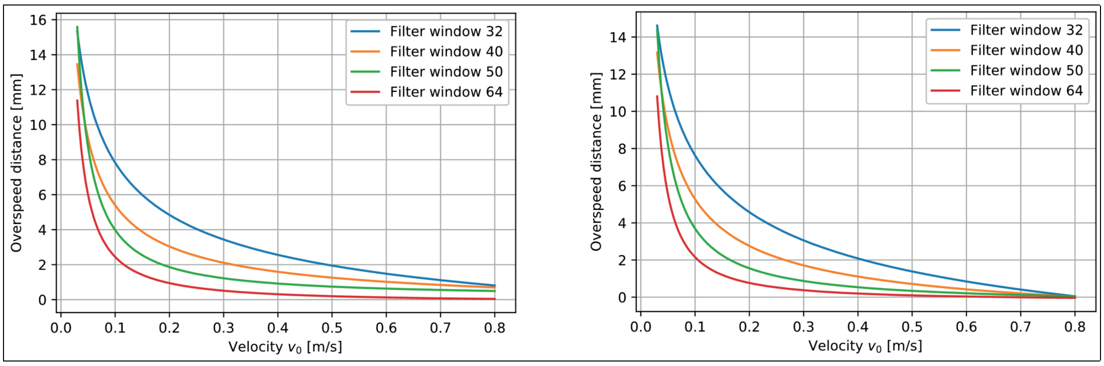


Figure 7.2 Setting of the "permitted distance" for the mean value filter (left) and the modified mean value filter (right) as a function of the functional speed for various filter windows.

Caution!

For mean value filters, it is recommended to use the standard mean value filter with a filter window of 400 ms (50 cycles) or less (minimum possible is 256 ms or 32 cycles). This results in a minimized fault distance and a minimized response time.

When using the above-mentioned "permitted distances," the corresponding fault distances are as shown in the figure below. Here, neither the filter window nor the reduced noise behavior of the modified filter have any effect, as shown subsequently in the response times. The fault distances can be calculated as follows:

- Moving mean value: 0.39 s v_0 + 0.16 m
- Modified mean value: 0.40 s v_0 + 0.15 m

Influence of the initial speed v_0 on the fault distance of the moving and modified mean value:

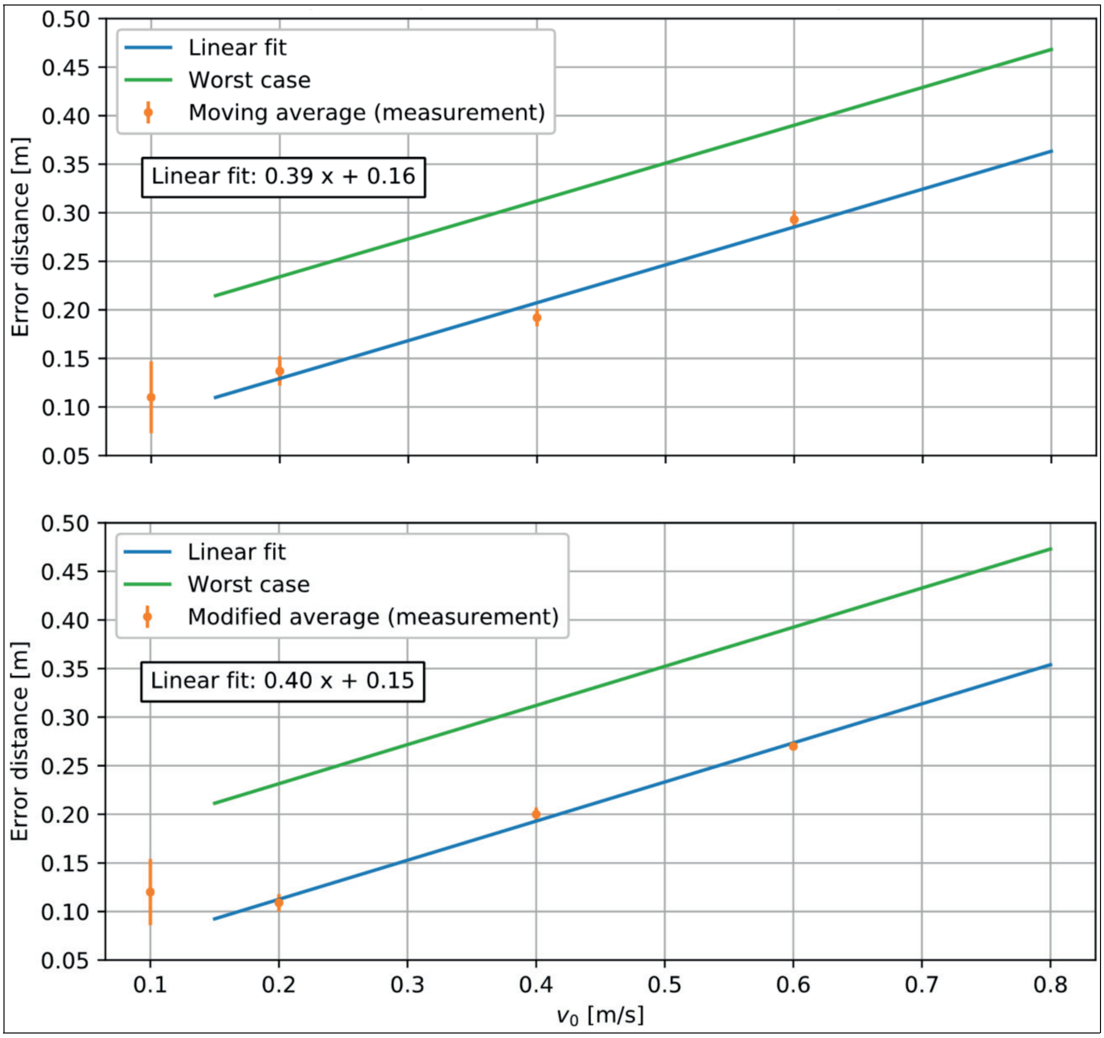


Figure 7.3 Fault distances for the mean value filter (top) and the modified mean value filter (bottom). The safety parameters are shown as a function of the functional speed. The blue line corresponds to the mean fault distance, the green line to the worst case fault distance. The text box shows the function of the worst case fault distance. This can be used to calculate the values for the worst case fault distance.

Note

- Fault distances can only be used for functional speeds at the interval shown since the values may change outside the interval.
- When using "permitted distances" that deviate from the above value, the fault distances must be corrected.

The correction of the worst case fault distance for deviating "permitted distances" can be calculated as follows:

$$d_{worst\ case}^{new} = d_{worst\ case}^{old} + \frac{v_1}{v_1 - v_{lim}} \cdot \Delta d_{lim}$$

The following applies:

$d_{worst\ case}^{new}$: new fault distance

$d_{worst\ case}^{old}$: the fault distance determined from the above diagram

Δd_{lim}: Increase in "permitted distance" compared to the above recommendation

v_1 : the final speed due to a malfunction (the worst case must be assumed to be 5 % above the speed limit)

v_{lim}: the speed limit

When using the alpha-beta filter, analog observations must be performed. The "permitted distance" is shown in the figure below.

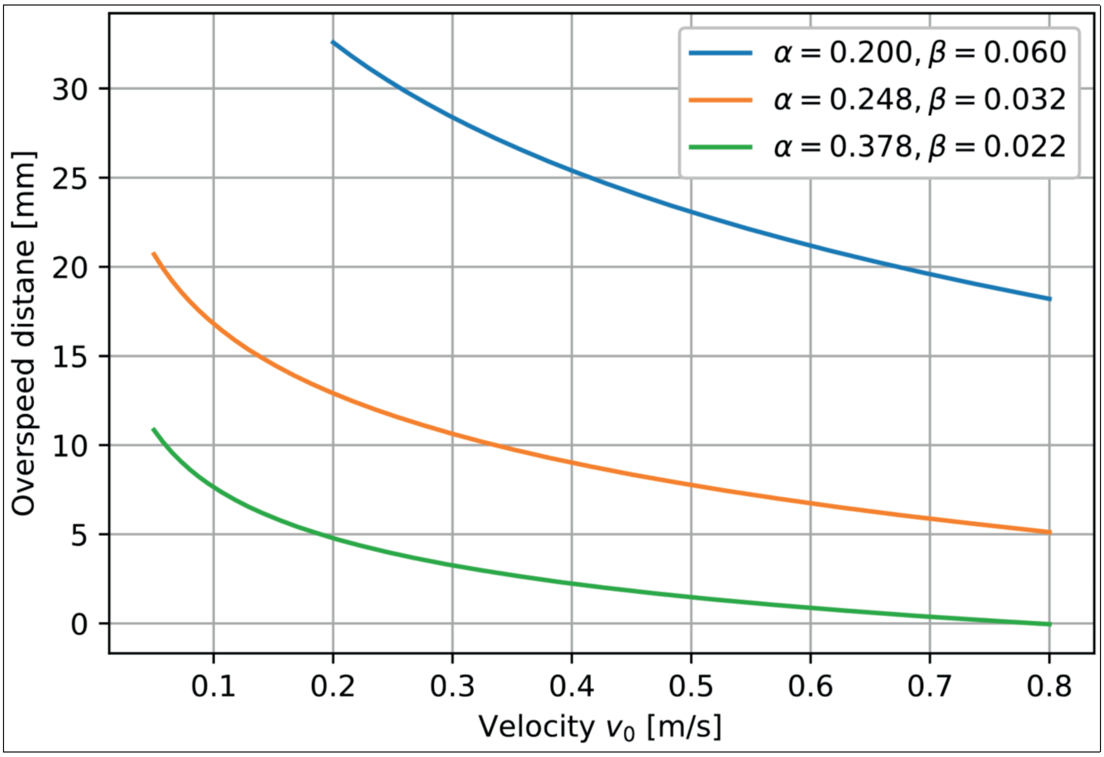


Figure 7.4 Setting of the "permitted distance" for the alpha-beta filter as a function of functional speed for 3 different parameter combinations

Note

- When using the alpha-beta filter, the indicated parameter combinations must be used. No other combinations have been examined for their safety parameters.
- The use of alpha = 0.378 and beta = 0.022 only are recommended for using "overspeed distance monitoring."
- In general, the use of mean value filters for "overspeed distance monitoring" is recommended.

The worst case fault distances for the alpha-beta filter with alpha = 0.378 and beta = 0.022 are shown in the diagram below. The fault distances can be calculated as follows:

- a = 0.378, b = 0.022: 0.25 s?v_0 + 0.21 m

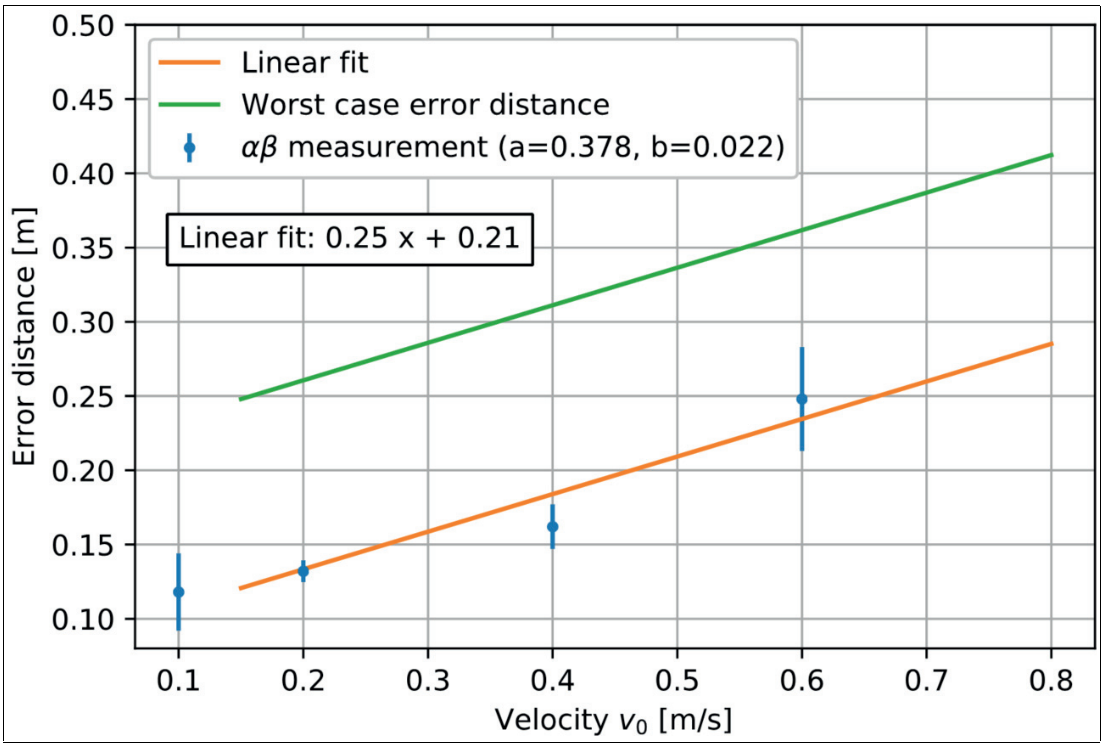


Figure 7.5 Fault distances for the alpha-beta filter as a function of functional speed. The safety parameters are shown as a function of the functional speed. The orange line corresponds to the mean fault distance, the green line to the worst case fault distance. The text box shows the function of the worst case fault distance. This can be used to calculate the values for the worst case fault distance.

Note

- Fault distances can only be used for functional speeds at the interval shown since the values may change outside the interval.
- When using "permitted distances" that deviate from the above value, the fault distances must be corrected as shown above.

7.4.3 Response Times for Speed Considerations

Note

The response times of the filtered speed cannot be less than the worst case response time of the overall system as listed above (T_worstcase = 263 ms).

If "overspeed distance monitoring" cannot be used as shown above, the response times of the filters must be considered. The setting for the monitored limit speed must be selected in this respect based on the expected measurement noise, so that the safety function is not accidentally triggered at the functional speed. The expected measurement noise is shown in the figure below.

Note

It is recommended to set limit speeds that are approximately 5 times the measurement noise above the functional speed.

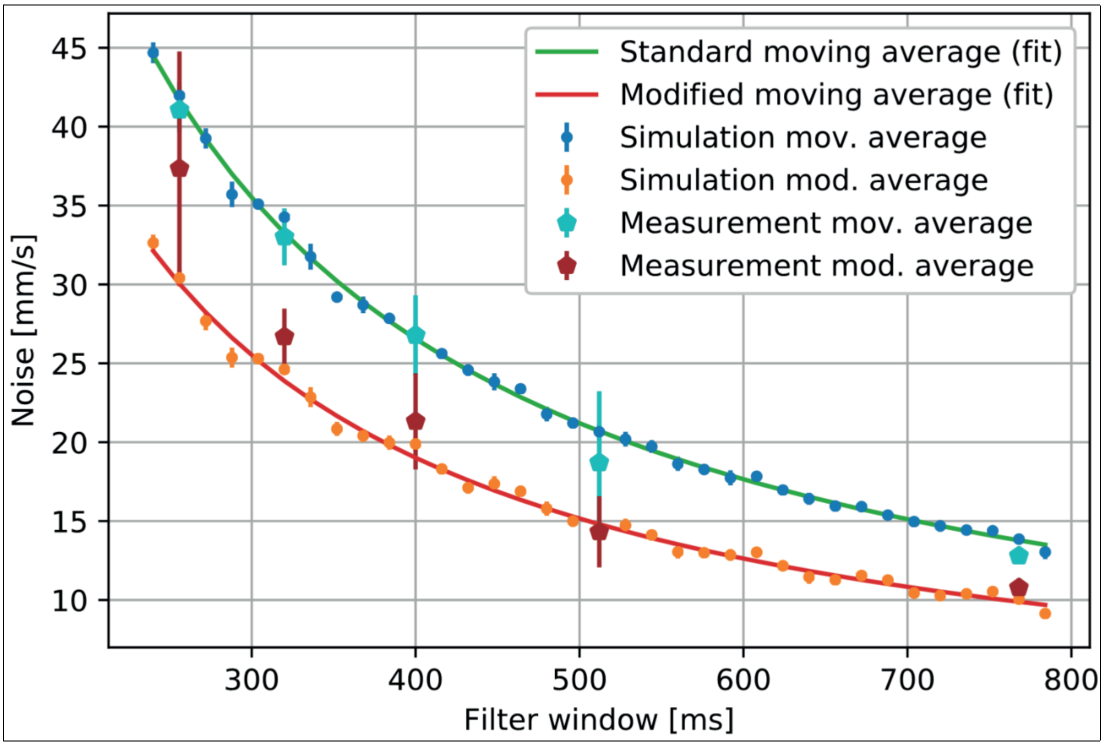


Figure 7.6 Expected measurement noise for the mean value filter and the modified mean value filter. The measurement noise shown in this respect can be used to set the speed threshold value. The green curve corresponds to the measurement noise of the mean value filter, the red curve corresponds to the measurement noise of the modified mean value filter. A limit value of 5 times the shown measurement noise is recommended.

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The worst case response times for the mean value filters are shown in the figure below.

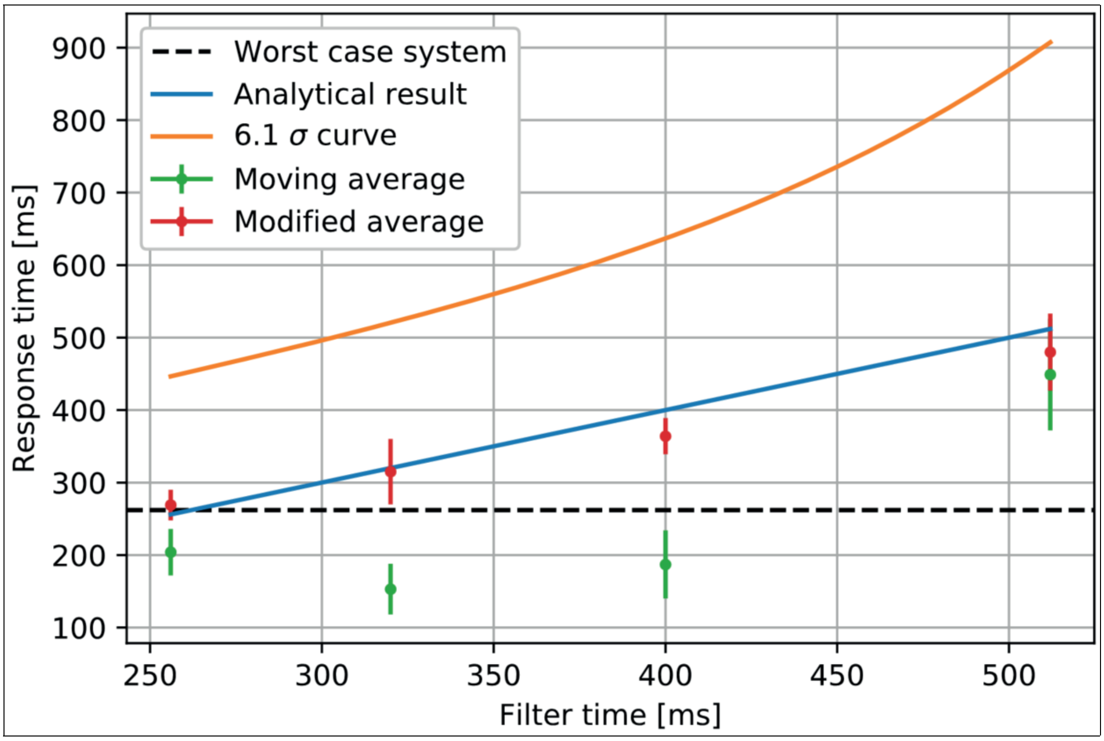


Figure 7.7 Response times of the mean value filter and the modified mean value filter as a function of the set filter time. The orange curve corresponds to the worst case response time for both mean value filters and is independent of the set speed threshold value.

Note

- The response times of the mean value filter and the modified mean value filter do not differ in worst case considerations.
- Due to the lower measurement noise, it is recommended to use the modified mean value filter.

The alpha-beta filter, in contrast to mean value filters, has a faster response time but higher measurement noise. The mean measurement noise can be estimated from the following table.

Alpha-beta	Noise [mm/s]
a = 0.248; b = 0.032	67
a = 0.200; b = 0.060	126
a = 0.378; b = 0.022	34

Note

It is recommended to set limit speeds that are approximately 5 times the measurement noise above the functional speed.

The worst case response times are shown in the figure and the table below.

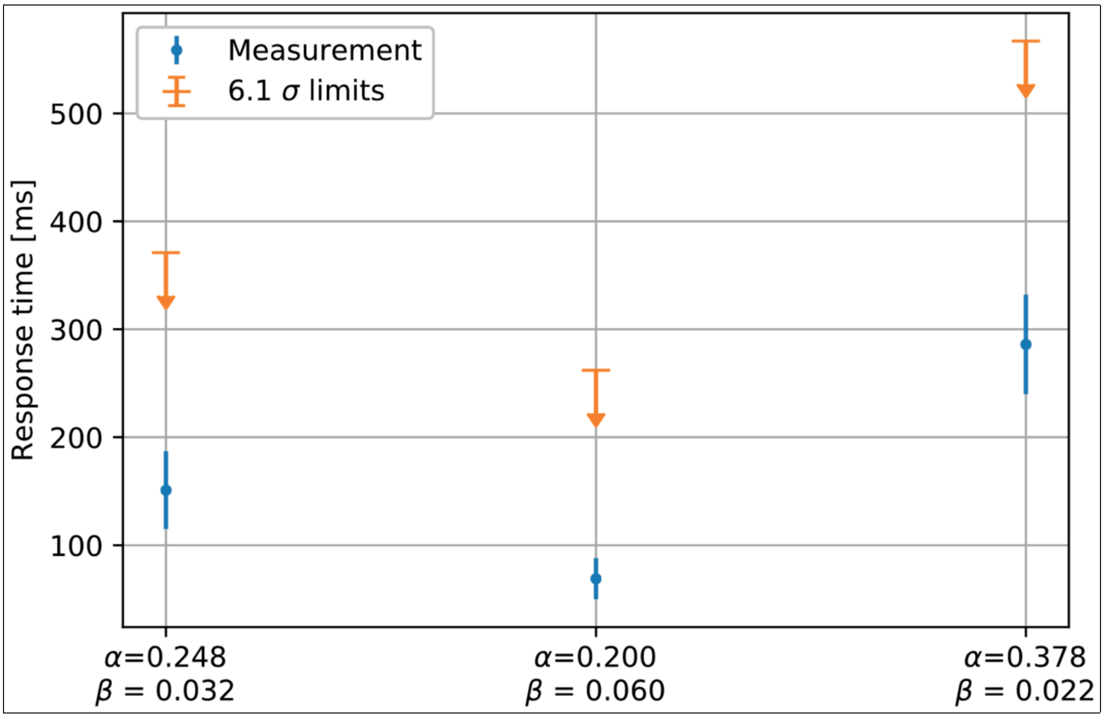


Figure 7.8 Worst case response times (orange arrows) for the alpha-beta filter for 3 different parameter combinations

Alpha	Beta	Response time [ms]
0.248	0.032	371
0.200	0.060	263
0.378	0.022	568

8 Commissioning

8.1 Procedure

Commissioning may only be carried out by qualified personnel! Please observe the safety instructions during commissioning!

8.2 General Information

Prerequisites for successful commissioning are:

- Correct configuration of the system
- Correct and complete assembly of all components
- Correct and complete wiring of all components
- Installation and all components used

Caution!

Work on electrical components

Destruction of electrical components. Risk of injury from electrical voltage.

Wiring may only be carried out by those with appropriate qualifications and in compliance with the safety regulations.
Check the wiring and insulation before switching on the supply voltage.

8.3 Commissioning Steps

- Ensure that the following items have been completed correctly and according to the application:
  - The installation of the evaluation unit
  - The wiring
  - The terminal assignment and cable routing
- Take appropriate measures to prevent the motor from starting unintentionally. Depending on the application, take additional safety precautions to avoid danger to people or the machine.
- Switch on the mains voltage and, if necessary, the 24 V DC supply voltage
- Parameterize the devices according to the application
- Configure the fieldbus connection according to the application

Caution!

Validation must be carried out before the commissioned system goes into regular operation.

Further steps must be observed for commissioning the safePXV/PUS read head. These must be carried out in addition to the points mentioned above.

Refer to the manual of the respective read head.

Note

- The read head may only be operated within the technical specification as described in the documentation of the read head.
- The read head distance affects the read head's field of view and therefore the accuracy of the safe position.
- When using an evaluation unit with a communication interface, the available diagnostic data (warning and code quality) can be used to check that the safePXV/PUS read head has been correctly installed and is stable. A description of this diagnostic data can be found in the manual of the read head.
- Loosening, shifting, twisting of the read head or the influence of ambient light can lead to a malfunction of the read head.
- For more stable operation, a certain number of zero positions (no code marker in the field of view) can be allowed. This makes the evaluation of the read head less sensitive to contaminated code markers or short-term exiting of the viewing area. However, this increases the response time.
- Read the manual of the safePXV/PUS read head for more information on commissioning the read head.

Warning!

Misuse

Misuse of the safePXV/PUS positioning system can lead to dangerous situations.

Note

Typical problems that can occur when commissioning the read head:

- Distance to the Data Matrix code tape in the z or y direction being too large. This means that no additional position can be read as recognized by the evaluation unit. The correct distance must be maintained throughout the measuring section.
- EMC influences caused by unshielded cables can interfere with communication. This is indicated by differing diagnostics from the evaluation unit, see the fault list of the evaluation unit. Correct shielding of all cables in the application must be ensured.
- Excessively bright sources of ambient light can prevent correct readout of the position. The influence of ambient light must be kept low.
- The temperature range must be maintained in accordance with the specifications of the read head and the modules.

8.4 Power-on Sequences

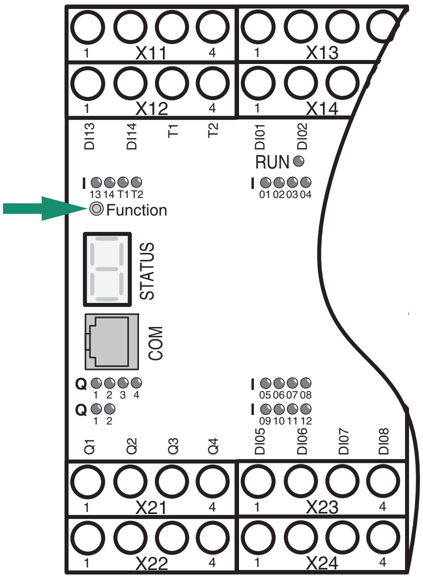
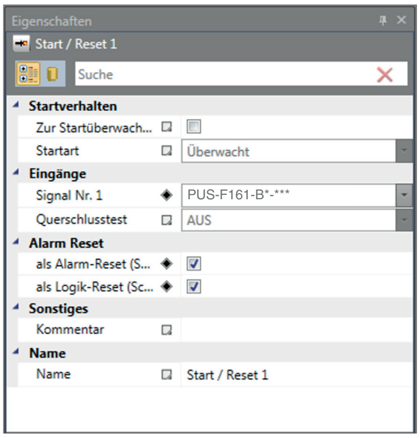
Each time the module is restarted, the following phases are run through and displayed on the front seven-segment display when the module is running correctly:

Seven-segment display	Mode	Description	
"1"	STARTUP	Synchronization between both processor systems and verification of configuration/firmware data	
"2"	SENDCONFIG	Distribution of configuration/firmware data and repeated checking of this data. Followed by range check of the configuration data.	
"3"	STARTUP BUS	Initialization of bus system if present	
"4"	RUN	Normal operation of the system. All outputs are switched according to the current logic state.	
"5"	STOP	In stop mode, parameters and program data can be loaded externally.	
"A"	ALARM	Alarm can be reset via digital input or front acknowledgment button.	
"E"	ECS alarm ICS alarm ACS alarm	ECS alarm can be reset via digital inputs or front acknowledgment button.	
"F"	Error	Error can only be reset via evaluation unit ON/OFF.	
"."	FBus Status	**F-Bus node (PROFIsafe/FSoE):**	
		Off:	F-Bus not used
		Slow flashing:	F-bus configured, no connection to the main unit
		Rapid flashing:	Connection to the main unit, F-bus activation pending
		On:	F-bus connected

8.5 Reset Behavior

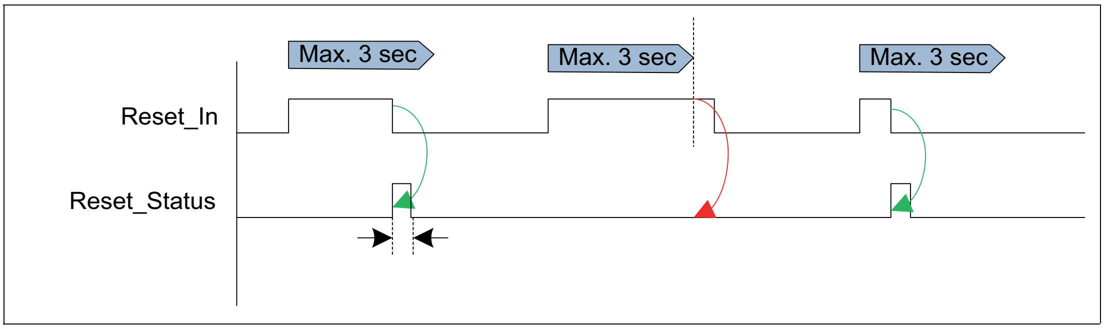
The reset function is differentiated into start-up after voltage recovery = general reset and a status/alarm reset = internal reset. The latter is triggered via the front button or a suitably configured input = reset element with the "alarm reset" function activated. The following table provides an overview of the reset functions and their effect.

8.5.1 Reset Types and Triggering Element

<table>
<tr><th>Reset types</th><th>Triggering element</th><th>Comment</th></tr>
<tr><td>General reset</td><td>Voltage recovery/device start-up</td><td>Reset function after a complete switch-off and switch-on of the evaluation unit</td></tr>
<tr><td>Internal reset</td><td>
</td><td>Initiation of internal reset using the reset button on the front</td></tr>
<tr><td></td><td>

</td><td>Configuring a reset input</td></tr>
</table>

8.5.2 Reset Timing Behavior

The reset input for the internal reset is time-monitored in "RUN" mode. An internal reset is triggered on the falling edge of the reset input subject to the condition T < 3 sec between rising/falling edge.



8.5.3 Reset Function

Functional unit	General reset	Internal reset	Function
Serious fault	X		Reset fault
Alarm	X	X	Reset alarm
Monitoring functions	X	X	Resets an activated monitoring function
Flip-flop	X	X	Status = Reset
Timer	X	X	Timer = 0

The status of the monitoring functions is regenerated after a reset.

- Process values do not change the output status of the monitoring function if the parameterized limits are exceeded.
- Time-based functions – timers reset the output status of the monitoring function. Response only occurs if the parameterized limit values are exceeded again.

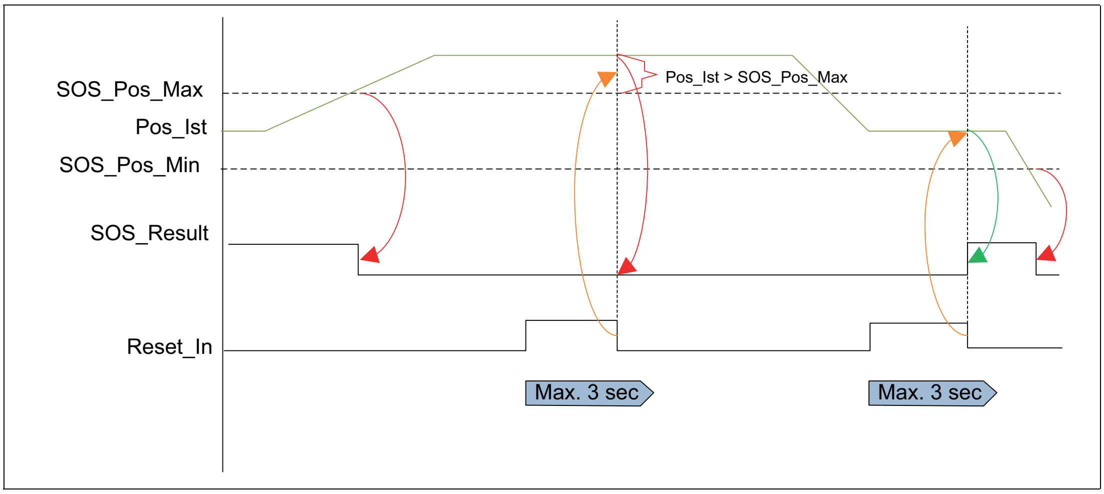


Figure 8.1 Process value (position) —> no change in the output status when reset in alarm state

2023-06

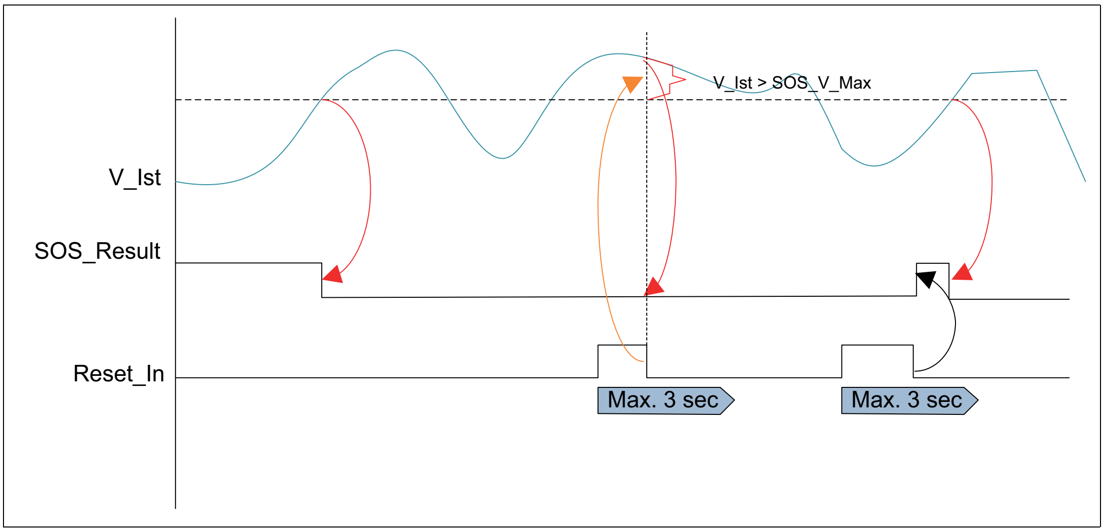


Figure 8.2 Process value (speed) —> no change in the output status when reset in alarm state

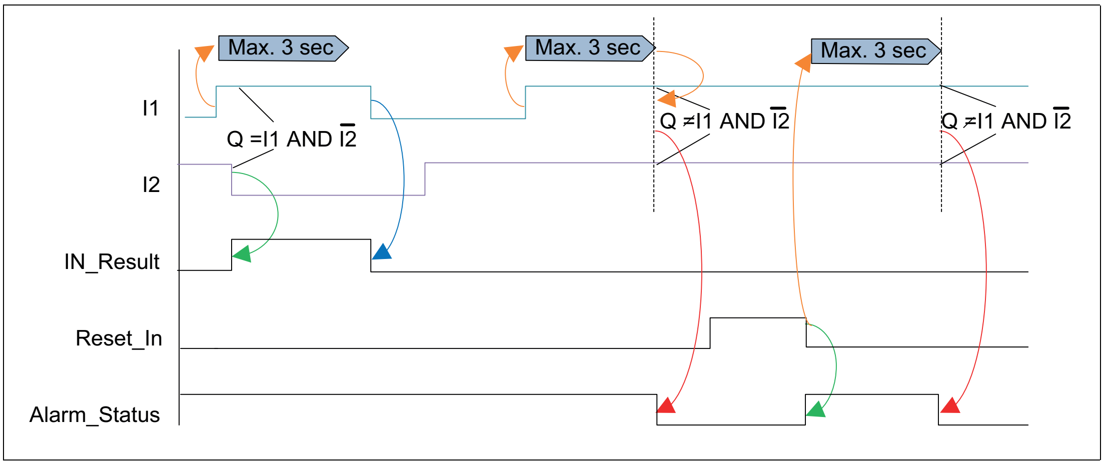


Figure 8.3 Time-based function —> resets output state, responds when the limit is exceeded again

Caution!

Safety notice

- In the case of time-based functions, e.g., time monitoring of complementary input signals, the output state is reset and a state defined as faulty is only detected once the (time) limit is exceeded again.
- To protect against incorrect use, e.g., repeated triggering of the reset function to bypass an alarm condition, appropriate measures if necessary must be taken in the PLC programming.

8.5.4 Example of Reset Function with Protection Against Incorrect Use

Function

The danger zone around a machine should be protected in normal operation by a separating protective device and during setup by an enabling switch in conjunction with standstill monitoring and safely reduced speed.

The presence of the separating protective device is monitored by an electrical read head. When the protective device is open, it is only possible to proceed when the enabling switch is pressed.

This is implemented in the program by a "protective door" function (2-channel with time monitoring) and an "enable" function.

The "protective door" logic signal is generated by input preprocessing with complementary inputs and time monitoring. The time monitoring of this item is fixed at 3 seconds.

If the protective door is open (signal "LOW" at switch outputs X23.1 and X23.2 (ID 369)), the axis can be moved at reduced speed if consent X14.1 and X14.2 (ID 318) is active.

Problem description

If a "cross-circuit" fault is simulated at the protective door input, the evaluation unit displays alarm 6701.

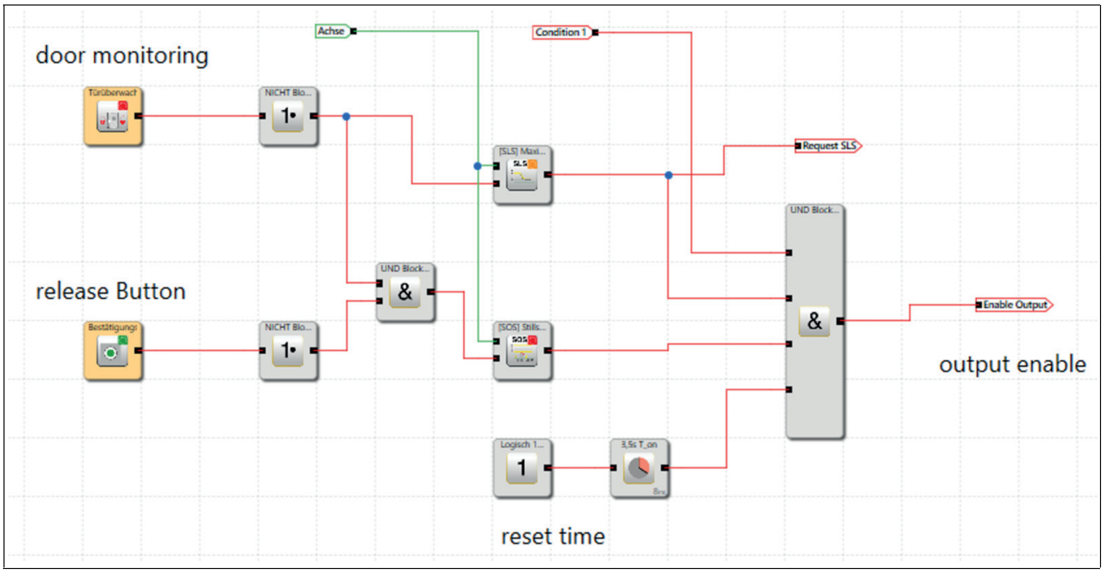
This can be acknowledged and the "protective door" signal (ID 369) correctly remains at "0."

Once the time monitoring period of 3 seconds has elapsed, alarm 6701 is triggered again.

If consent is pressed during this period, the axis can be moved again for 3 seconds.

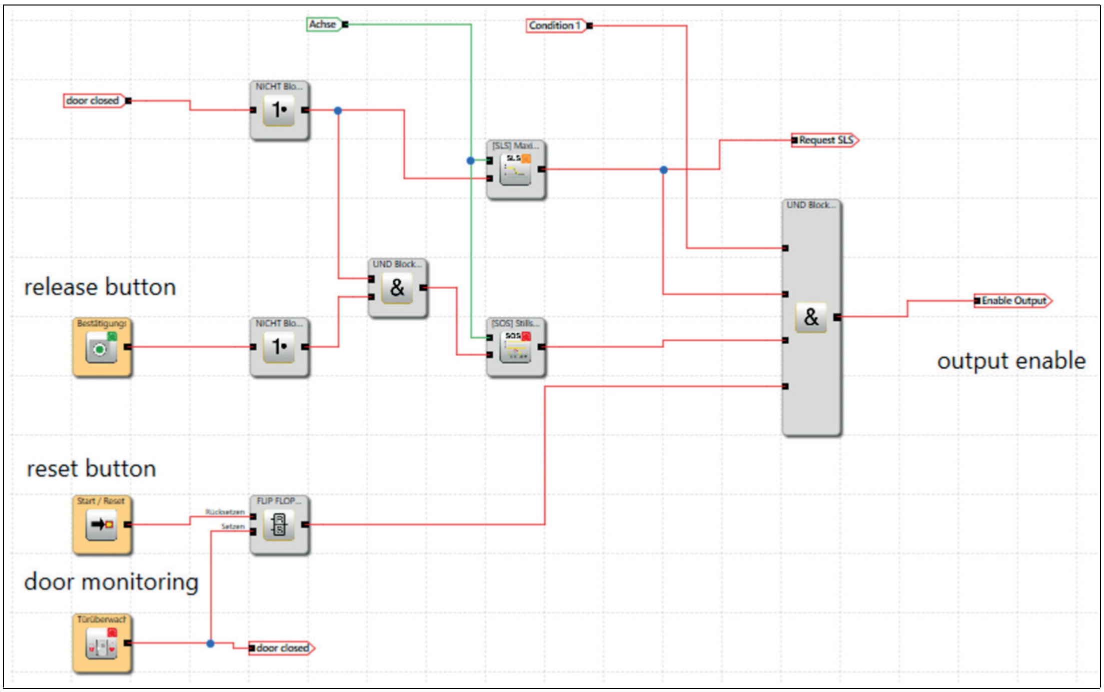
Applicative measure

A link within the PLC program prevents activation of the outputs while the alarm status is temporarily bypassed.



Example

The release function of the outputs (ID 88) is additionally linked to a "reset timer." This prevents activation of the outputs after a reset for t > 3 sec —> repeated effect of time monitoring is ensured.



Example

The release function of the outputs (ID 88) is additionally linked to a "FF." This prevents the activation of the outputs after a reset and with pending faults in the input circuit. The outputs are only enabled after a fault-free input signal has been applied once.

8.6 LED Indicator

Color	Mode	Description
Green	Flashing	System OK, configuration validated
Yellow	Flashing	System OK, configuration not yet validated
Red	Flashing	Alarm
Red	On	Serious fault
Yellow/red	Flashing	System OK, configuration not validated, SMMC configured but node missing
Green/red	Flashing	System OK, configuration validated, SMMC configured but node missing

Note

For all operating states except RUN, the outputs are made passive by the firmware, i.e., safely switched off. In the RUN state, the status of the outputs depends on the implemented PLC program.

8.7 Parameterization

Parameterization is performed via the safeControl Expert program. To send the data to the module, a programming adapter is required whose driver first must be installed before use.

A description of parameterization can be found in the safeControl Expert programming manual.

8.8 Function Testing

The safety functions must be checked for correct operation once a year to ensure the safety of the evaluation unit. To do so, the modules used in parameterization (inputs, outputs, monitoring functions, and logic modules) must be tested with regard to function and shutdown (see safe-Control Expert programming manual).

8.9 Validation

Following successful commissioning and parameterization, the user must check and document the parameters and links to ensure correct operation of the implemented safety functions. This is supported by the validation wizard in the programming interface (see chapter Safety Testing).

9 Safety-related Inspection

Following successful commissioning and parameterization, the user must check and document the parameters and links to ensure correct operation of the implemented safety functions. This is supported by the safeControl Expert parameterization software (see safeControl Expert programming manual).

The first two pages provide general information about the system. The following pages of the validation report show all of the functions used along with their parameters. This serves as a single proof of the safety inspection.

You must make the following entries in this respect:

- Serial number (identical to serial number on the type plate)
- Identity of the evaluation unit

In this regard, the person responsible for inspecting the safety module confirms that the CRC displayed in the programming interface is identical to the CRC stored in the evaluation unit.

After all header data has been entered, the validation report can be generated via the "Save" button. The parameterization tool generates a report (.PDF) with the file name of the program data record. The report contains the following information:

- The 3 pages of the header data edited above
- The configuration of the read heads
- The parameters of the available monitoring functions
- PLC program as a statement list

After the configuration and program data have been transferred to the evaluation unit, the status LED flashes "yellow". This indicates that the configuration data has not yet been validated. When the "LOCK CONFIGURATION" key is pressed at the end of the validation dialog, the data is marked as "Validated" and the LED flashes "green".

10 Servicing

10.1 Safety Information Concerning Device Maintenance

Caution!

Safety Information Concerning Device Maintenance

If the device is damaged, the device must be taken out of service and repaired or replaced by trained personnel.

The device may only be opened by trained personnel and only the maintenance work expressly permitted by Pepperl+Fuchs may be carried out. Any other manipulation of the device will result in the warranty being voided.

Firmware update

For instructions on performing a firmware update for the CPU part, please refer to the programming manual.

Repairs

Repairs to the device are not permitted. The device must always be completely replaced and the defective module must be sent to Pepperl+Fuchs.

Note

Loss of approval

Unauthorized manipulation of the evaluation unit will result in the loss of approval.

10.2 Modification / Handling of Changes to the Device

Maintenance work must be carried out by qualified personnel only.

Note

Repairs

Devices must always be replaced in their entirety.

Repairs can only be carried out by the manufacturer.

Note

Tampering

Any internal tampering by the user (e.g., replacement of components, soldering by the user) shall void any warranty.

Note

Changes to the hardware

Changes to the hardware can only be made by the manufacturer.

Note

Changes to the firmware

Changes to the firmware (firmware update) can only be made by the manufacturer.

Note

Impermissible modification

The safety approval is voided if the module is modified!

10.3 Device Replacement

Danger!

Danger to life from missing safety function

Changes to the device or a defect of the device can lead to device malfunction. The function of the device and the safety function is no longer guaranteed.

Do not repair, modify, or manipulate the device.

Caution!

Destruction of the read head

No connection may be unplugged from or plugged back into the evaluation unit while the unit is energized. In particular, there is a risk of destruction of the read head for connected position or speed read heads.

Servicing, repairing, or replacing the device

In the event of servicing, repair, or replacement of the device, proceed as follows:

1. Create appropriate maintenance plans for regular maintenance of the safety circuit.
2. The safety function will not work while the device is being serviced, repaired or replaced.
   Take appropriate measures to protect personnel and equipment while the safety function is unavailable.
   Ensure that the application cannot be inadvertently turned back on.
3. Disconnect the current transformer from the main supply.
4. Switch off the power supply to the evaluation unit and disconnect the connection.
5. Disconnect the read head connector.
6. Disconnect all plug-in connections.
7. Remove the evaluation unit from the DIN rail and package it in an EMC-safe manner.
8. Do not attempt to repair a defective device. Always have the device repaired by the manufacturer.
9. In the event of a defect, always replace the device with an original device.
10. Attach the evaluation unit to the DIN rail.
11. Restore all connections.
12. Switch on the current transformer.
13. Switch on the supply voltage.
14. When replacing the evaluation unit, the new module must be re-loaded with the corresponding project data. You can do this using the safeControl Expert configuration software.

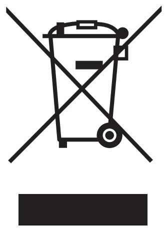
Note

The module forms an overall CRC. This must be the same after replacing the module.

10.4 Maintenance Intervals

Action	Information
Replacing the evaluation unit	See chapter 3.3
Function testing	See chapter 8

10.5 Disposal



The device, built-in components, packaging, and any batteries contained within must be disposed in compliance with the applicable laws and guidelines of the respective country.

11 Technical Data PUS-F161-B*-PXV

Functional safety data

Performance level according to EN ISO 13849-1	PL e
PFH/Architecture	12.6 FIT/cat 4
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a

Characteristic data for functional safety using the safePXV/PUS read head

Max. achievable performance level in accordance with EN ISO 13849-1	PL e
PFH/Architecture	13.39 FIT/cat 4 $MTTF_d$ = 37.6 a DC = 97.0 %
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a (max. service life)

General data

Number of safe digital inputs		14 (OSSD capable)
Number of safe digital outputs		
	pn switching **	2
	pp switching **	4
Number of safe digital I/Os		-
Number of relay outputs		2
Number of safe analog inputs		-
Number of auxiliary outputs		2
Number of pulse outputs (clock outputs)		2
Connection type		Plug-in terminals with spring-loaded or screw connection
Axis monitoring (Axes/read head interfaces)		1 / 1
Read head interfaces (terminals)		RS-485, X35

Electrical data

Supply voltage (tolerance)		24 V DC; 2 A (-15 %, +20 %)
Fusing	X11.1	max. 30 V DC; 3.15 A
	X11.2	max. 30 V DC; max. 10 A
Max. power consumption (logic)		6.8 W
Nominal data for digital inputs		24 V DC; 20 mA type 1 according to IEC 61131-2
Nominal data for digital outputs		

	pn switching		24 V DC; 2 A
	pp switching		24 V DC; 2 A
	Auxiliary outputs		-
	Nominal data for pulse outputs (Clock outputs)		24 V DC; 250 mA
Nominal data for relay outputs	Normally open contacts	DC 13	24 V DC; 2 A
		AC 15	230 V AC; 2 A
Nominal data for safe analog inputs			-

Electrical data for UL

Nominal data for digital outputs			
	pn switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	pp switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	Max. total current (pn or pp)	8 A	
	Auxiliary outputs	-	
Nominal data for relay outputs	Normally open contacts	24 V DC; 2 A (Pilot Duty) 120 V AC; 2 A (Pilot Duty)	

Environment

Temperature	0 °C … +50 °C in operation -25 °C … +70 °C storage, transport
Degree of protection	IP20
Climatic class	3k3 according to DIN 60 721-3
Minimum, maximum relative humidity (No condensation)	5 % 85 %
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of operating resources	2000 m
Overvoltage category	III

Mechanical data

Housing length	115
Housing width	90
Housing height	100
Ground	490 g
Mounting	DIN mounting rail
Number of T-buses	4

Min. connector cross section/AWG	0.2 mm^2/24
Max. connector cross section/AWG	2.5 mm^2/12

12 Technical Data PUS-F161-B*-WCS

Functional safety data

Performance level according to EN ISO 13849-1	PL e
PFH/Architecture	12.6 FIT/cat 4
Safety integrity level (SIL) according to IEC 61508	SIL 3
Useful lifetime (T_M)	20 a

General data

Number of safe digital inputs		14 (OSSD capable)
Number of safe digital outputs		
	pn switching **	2
	pp switching **	4
Number of safe digital I/Os		-
Number of relay outputs		2
Number of safe analog inputs		-
Number of auxiliary outputs		2
Number of pulse outputs (clock outputs)		2
Connection type		Plug-in terminals with spring-loaded or screw connection
Axis monitoring (Axes/read head interfaces)		1 / 1
Read head interfaces (terminals)		RS-485, X35-1/35-2

Electrical data

Supply voltage (tolerance)			24 V DC; 2 A (-15 %, +20 %)
Fusing	X11.1		max. 30 V DC; 3.15 A
	X11.2		max. 30 V DC; max. 10 A
Max. power consumption (logic)			6.8 W
Nominal data for digital inputs			24 V DC; 20 mA type 1 according to IEC 61131-2
Nominal data for digital outputs			
	pn switching		24 V DC; 2 A
	pp switching		24 V DC; 2 A
	Auxiliary outputs		24 V DC; 250 mA
	Nominal data for pulse outputs (Clock outputs)		24 V DC; 250 mA
Nominal data for relay outputs	Normally open contacts	DC 13	24 V DC; 2 A
		AC 15	230 V AC; 2 A
Nominal data for safe analog inputs			-

Electrical data for UL

Nominal data for digital outputs			
	pn switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	pp switching	Temperature Rating 30 °C	24 V DC; 2 A (G.P.)
		Temperature Rating 50 °C	24 V DC; 1.8 A (G.P.)
	Max. total current (pn or pp)	8 A	
	Auxiliary outputs	24 V DC; 250 mA (G.P.)	
Nominal data for relay outputs	Normally open contacts	24 V DC; 2 A (Pilot Duty) 120 V AC; 2 A (Pilot Duty)	

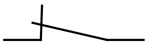
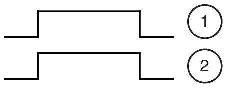
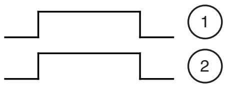
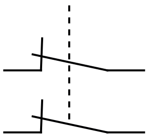
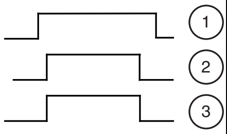
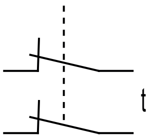
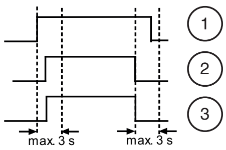
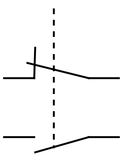
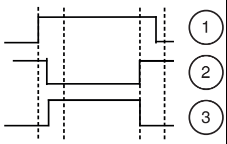
Environment

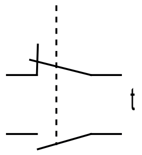
Temperature	0 °C … +50 °C in operation -25 °C ... +70 °C storage, transport
Degree of protection	IP20
Climatic class	3k3 according to DIN 60721-3
Minimum, maximum relative humidity (No condensation)	5 % 85 %
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of operating resources	2000 m
Overvoltage category	III

Mechanical data

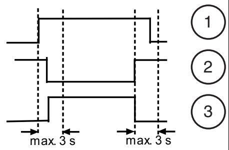
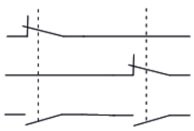
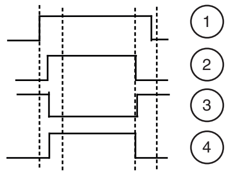
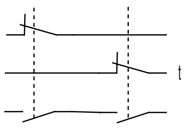
Housing length	115
Housing width	90
Housing height	100
Ground	490 g
Mounting	DIN mounting rail
Number of T-buses	4
Min. connector cross section/AWG	0.2 mm^2/24
Max. connector cross section/AWG	2.5 mm^2/12

13 Switch Types

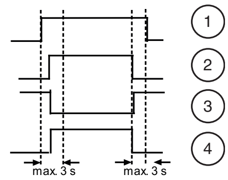
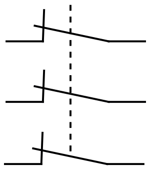
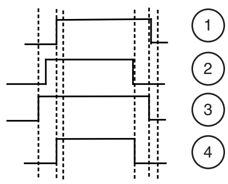
Type	Switching symbol	Truth table	Logical function	Function block	Function	
1	 eSwitch_1o	Ö, A 0, 0 1, 1	LD E.1 ST IE.X		Normally open contact, only shown here as normally closed contact	 1: Normally closed contact 2: Output
2	 sSwitch_1s	S, A 0, 0 1, 1	LD E.1 ST IE.X		Normally open, as type 1	 1: Normally closed contact 2: Output
3	 eSwitch_2o	Ö1, Ö2, A 0, 0, 0 1, 0, 0 0, 1, 0 1, 1, 1	LD E.1 AND E.2 ST IE.X		Two inputs linked with AND	 1: Normally closed contact 1 2: Normally closed contact 2 3: Output
4	 eSwitch_2oT	Ö1, Ö2, A 0, 0, 0 1, 0, 0 0, 1, 0 1, 1, 1	LD E.1 OR E.2 ST META_EN.1 LD E.1 AND E.2 ST METB_EN.1 LD MET.1 ST IE.X	Time monitoring MET1 ... MET4	As for 3, but with time monitoring of state changes. When the signal changes at the NO or NC contact, a complementary signal must follow within a time of t = 3 s. If no fault detected and A = 0	 1: Normally closed contact 1 2: Normally closed contact 2 3: Output
5	 eSwitch_1s1o	S, Ö, A 0, 0, 0 1, 0, 0 0, 1, 1 1, 1, 0	LD E.1 AND NOT E.2 ST IE.X		Monitoring for NO = inactive and NC = active	 1: Normally closed contact 2: Normally open contact 3: Output

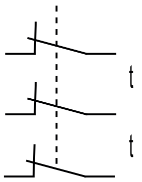
<table>
<tr><th>Type</th><th>Switching symbol</th><th>Truth table</th><th>Logical function</th><th>Function block</th><th>Function</th><th></th></tr>
<tr><td>6</td><td>
eSwitch_1s1oT</td><td><table><tr><th>S</th><th>Ö</th><th>A</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table></td><td>LD E.1
OR NOT E.2
ST META_EN.1

LD E1
AND NOT E2
ST METB_EN.1

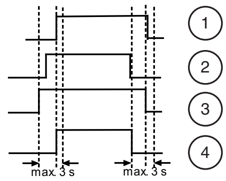
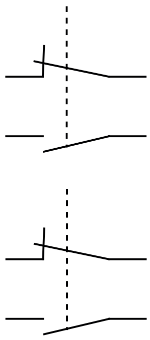
LD MET.1
ST IE.X</td><td>Time monitoring MET1 ... MET4</td><td>As for 5, but with time monitoring of state changes. When the signal changes at the NO or NC contact, a complementary signal must follow within a time of t = 3 s. If no fault detected and A = 0</td><td>
1: Normally closed contact
2: Normally open contact
3: Output</td></tr>
<tr><td>7</td><td>
eSwitch_2s2o</td><td><table><tr><th>S1</th><th>Ö1</th><th>S2</th><th>Ö2</th><th>A</th></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr></table></td><td>LD E.1
AND E.2
AND NOT E.3
ST IE.X</td><td></td><td>Monitoring for NO1*NO2 = inactive and NC1*NC2 = active</td><td>
1: Normally closed contact 1
2: Normally closed contact 2
3: Normally open contact
4: Output</td></tr>
<tr><td>8</td><td>
eSwitch_2s2oT</td><td><table><tr><th>S1</th><th>Ö1</th><th>S2</th><th>Ö2</th><th>A</th></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr></table></td><td>LD E.1
OR E.2
OR NOT E.3
ST META_EN.1

LD E.1
AND E.2
AND NOT E.3
ST METB_EN.1

LD MET.1
ST IE.X</td><td>Time monitoring MET1 ... MET4</td><td>As for 6, but with time monitoring of state changes. When the signal changes at the NO (note common wire!) or NC contact, a complementary signal must follow within a time of t = 3 s. If no fault detected and A = 0</td><td>
1: Normally closed contact 1
2: Normally closed contact 2
3: Normally open contact
4: Output</td></tr>
<tr><td>9</td><td>
eSwitch_3o</td><td><table><tr><th>Ö1</th><th>Ö2</th><th>Ö3</th><th>A</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td><td>1</td></tr></table></td><td>LD E.1
AND E.2
AND E.3
ST IE.X</td><td></td><td>Three inputs linked with AND</td><td>
1: Normally closed contact 1
2: Normally closed contact 2
3: Normally closed contact 3
4: Output</td></tr>
</table>

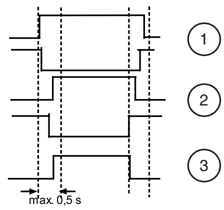
<table>
<tr><th>Type</th><th>Switching symbol</th><th>Truth table</th><th>Logical function</th><th>Function block</th><th>Function</th><th></th></tr>
<tr><td>10</td><td>
eSwitch_3oT</td><td><table><tr><th>Ö1</th><th>Ö2</th><th>Ö3</th><th>A</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td><td>1</td></tr></table></td><td>LD E.1
OR E.2
OR E.3
ST META_EN.1

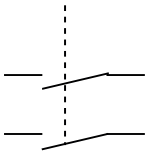
LD E.1
AND E.2
AND E.3
ST METB_EN.1
LD MET.1

ST IE.X</td><td>Time monitoring MET1 ... MET4</td><td>As for 8, but with time monitoring of state changes. When the signal changes at one of the NC inputs, the other inputs must follow within a time of t = 3 s. If no fault detected and A = 0</td><td>
1: Normally closed contact 1
2: Normally closed contact 2
3: Normally closed contact 3
4: Output</td></tr>
<tr><td>11</td><td>
eTwoHand_2o</td><td><table><tr><th>Ö1</th><th>S1</th><th>Ö2</th><th>S2</th><th>A</th></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr></table></td><td>LD NOT E.1
OR E.2
OR NOT E.3
OR E.4
ST MEZ_EN.1

LD E.1
AND NOT E2
AND E3
AND NOT E4
ST MEZ_EN.2

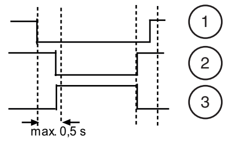
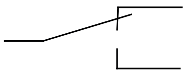
LD NOT E1
AND E.2
AND NOT E3
AND E.4
ST MEZ_EN.3

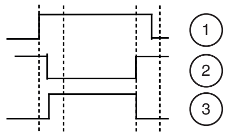
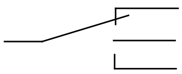
LD MEZ.1
ST IE.X</td><td>Two-handed operation MEZ</td><td>Monitoring for NO1*NO2 = inactive and NC1*NC2 = active + time monitoring of this state. This means that if a signal change occurs at a NO contact from 1->0 or at a NC contact from 0->1, the other signals (i.e., other NO = 0, NC = 1) must follow within 0.5 s. If not, output remains = 0. No fault evaluation! No time monitoring when switching to inactive state.</td><td>
1: Normally closed contact 1
2: Normally closed contact 2
3: Output</td></tr>
</table>

<table>
<tr><th>Type</th><th>Switching symbol</th><th>Truth table</th><th>Logical function</th><th>Function block</th><th>Function</th><th></th></tr>
<tr><td>12</td><td>
eTwoHand_2s</td><td><table><tr><th>S1</th><th>S2</th><th>A</th></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>LD E.1
OR E.2
ST MEZ_EN.1

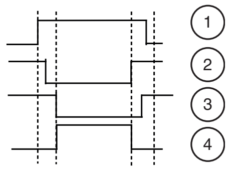
LD NOT E.1
AND NOT E.2
ST MEZ_EN.2

LD E.1
AND E.2
ST MEZ_EN.3

LD MEZ.1
ST IE.X</td><td>Two-handed operation MEZ</td><td>Monitoring for NO1*NO2 = inactive + time monitoring of this state. This means that if a signal change occurs at a NO contact from 1->0, the other signal (i.e., other NO = 0) must follow within 0.5 s. If not, output remains = 0. No fault evaluation! No time monitoring when switching to inactive state.</td><td>
1: Normally open contact 1
2: Normally open contact 2
3: Output</td></tr>
<tr><td>13</td><td>
eMode_1s1o</td><td><table><tr><th>S1</th><th>S2</th><th>A1</th><th>A2</th></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td></tr></table></td><td>LD E.1
AND NOT E.2
ST IE.X1

LD NOT E.1
AND E.2
ST IE.X2</td><td>Selector switch</td><td>Unique linking of the permissible switch positions</td><td>
1: Normally closed contact
2: Normally open contact
3: Output</td></tr>
<tr><td>14</td><td>
eMode_3switch</td><td><table><tr><th>S1</th><th>S2</th><th>S3</th><th>A1</th><th>A2</th><th>A3</th></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table></td><td>LD E.1
AND NOT E.2
AND NOT E.3
ST IE.X1

LDN E.1
AND E2
AND NOT E.3
ST IE.X2

LDN E.1
AND NOT E.2
AND E.3
ST IE.X3</td><td>Selector switch</td><td>Unique linking of the permissible switch positions</td><td>
1: Switch 1
2: Switch 2
3: Switch 3
4: Output 1</td></tr>
</table>

2023-06

PEPPERL+FUCHS

14 Information on Design, Programming, Validation, and Testing of Safety-Related Applications

The following information describes the procedure for designing, programming, validating, and testing safety-related applications. This information is intended to help the user classify, understand, and apply all steps from risk assessment to system testing. The individual steps are explained in more detail, using examples, to better understand the respective points.

14.1 Risk Assessment

The manufacturer of a machine is fundamentally responsible for ensuring the safety of any machine they design or supply. Safety must be assessed using the relevant directives and standards that are in force at the time. The objective of the safety assessment and the measures derived from it must be to reduce the risk to persons to an acceptable level.

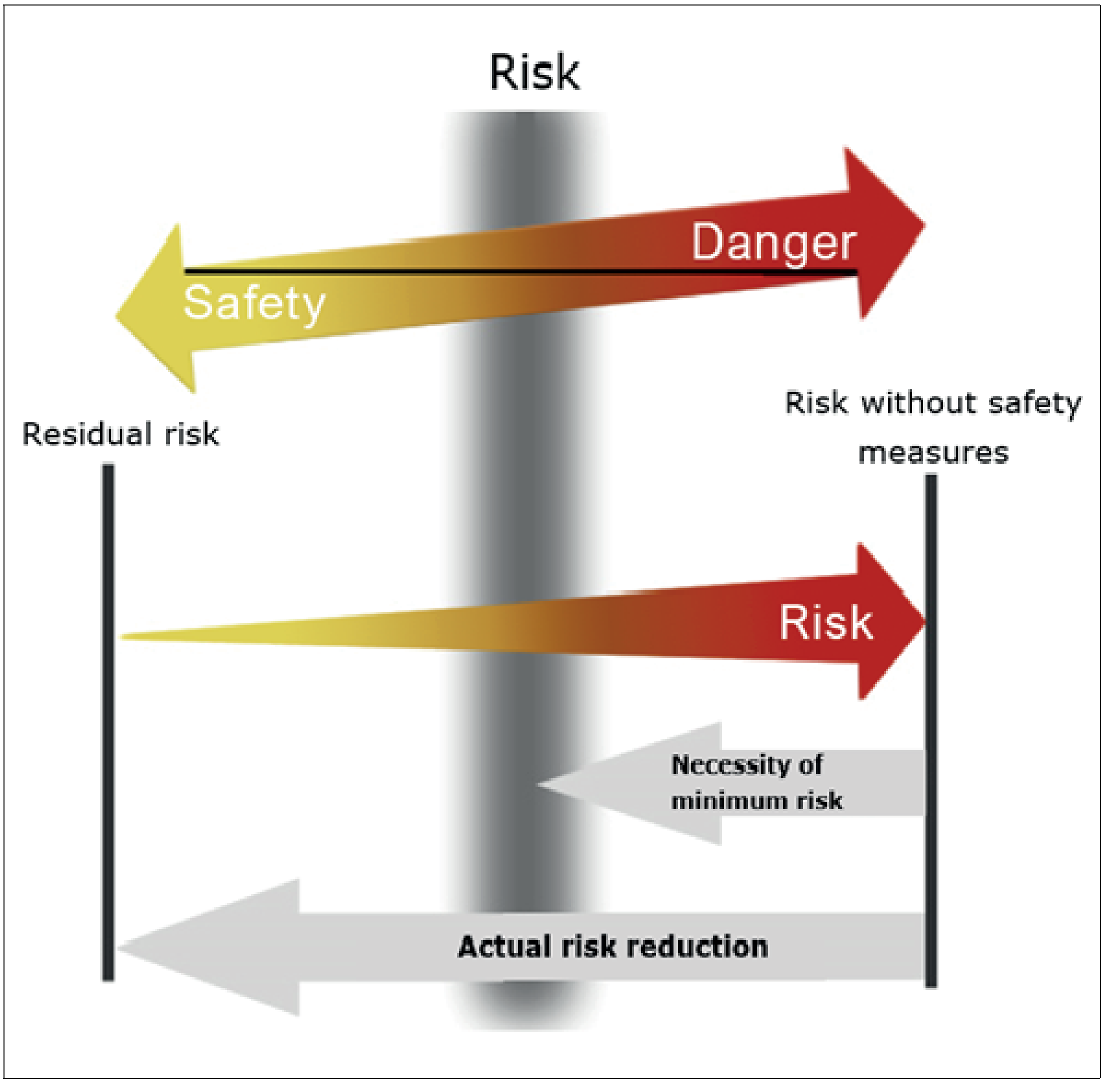
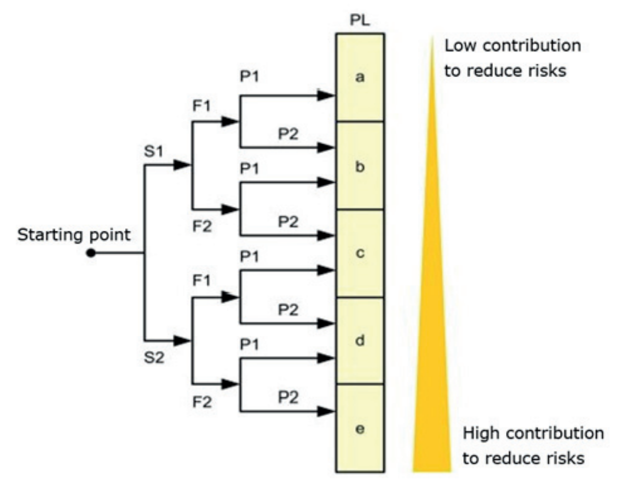


Figure 14.1

The analysis of the hazards must include all operating conditions of the machine, such as operation, setup and maintenance, installation and decommissioning as well as foreseeable incorrect usage. The procedures required in this regard for risk assessment and the measures to reduce risk are contained in the relevant standards e.g.:

- EN ISO 13849-1 Safety of machines
- IEC 61508 Functional safety of safety-related electric / electronic / programmable electronic systems.

Risk assessment in accordance with EN ISO 13849-1

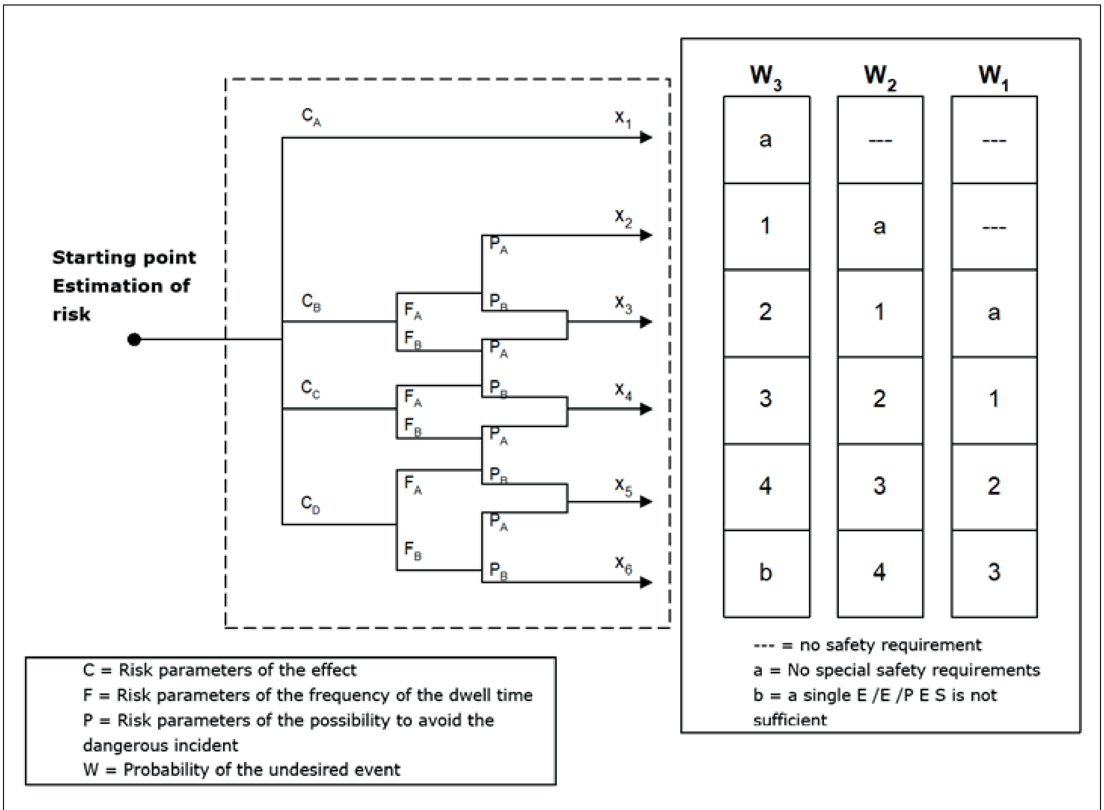


S – Schwere der Verletzung
S1 = leichte, reversible Verletzung
S2 = schwere, irreversible Verletzung

F – Häufigkeit und/oder Dauer der Gefährdungsexposition
F1=selten, nicht zyklisch
F2 = häufig bis dauernd und/oder lange Dauer, zyklischer Betrieb

P – Möglichkeit zur Vermeidung der Gefährdung
P1 = möglich, langsame Bewegung / Beschleunigung
P2 = kaum möglich, hohe Beschleunigung im Fehlerfall

Risk assessment in accordance with IEC 61508



The risks to be considered are also contained in relevant directives and standards, or must be considered separately by the manufacturer on the basis of its specific knowledge of the machine.

For machines placed on the market within the EU, the minimum risks to be considered are specified in the EU Machinery Directive 2006/42/EC or in the latest version of this Directive.

Further information on risk assessment and the safe design of machines is contained in the standards

- EN 14121 Safety of machines — risk assessment
- EN 12100 Safety of machines — basic terminology, general design principles.

The level of the measures used to reduce identified hazards must be appropriate to the severity of the hazard or better. Such measures and the requirements of them are exemplified in the guidelines and standards mentioned above.

14.2 Required Technical Documentation

The manufacturer must supply a number of technical documents. The minimum scope of such is also contained in the relevant directives and standards.

For example, in accordance with the EU Machinery Directive, at least the following documents must be supplied:

1. The technical file shall comprise the following:
   a) a construction file including:
   - a general description of the machinery,
   - the overall drawing of the machinery and drawings of the control circuits, as well as the pertinent descriptions and explanations necessary for understanding the operation of the machinery,
   - full detailed drawings, accompanied by any calculation notes, test results, certificates, etc., required to check the conformity of the machinery with the essential health and safety requirements,
   - the documentation on risk assessment demonstrating the procedure followed, including:
     i) a list of the essential health and safety requirements which apply to the machinery,
     ii) the description of the protective measures implemented to eliminate identified hazards or to reduce risks and, when appropriate, the indication of the residual risks associated with the machinery,
   - the standards and other technical specifications used, indicating the essential health and safety requirements covered by these standards,
   - any technical report giving the results of the tests carried out either by the manufacturer or by a body chosen by the manufacturer or his authorised representative,
   - a copy of the instructions for the machinery,
   - where appropriate, the declaration of incorporation for included partly completed machinery and the relevant assembly instructions for such machinery,
   - where appropriate, copies of the EC declaration of conformity of machinery or other products incorporated into the machinery,
   - a copy of the EC declaration of conformity;

   b) for series manufacture, the internal measures that will be implemented to ensure that the machinery remains in conformity with the provisions of this Directive.

Source BGIA Report 2/2008

The documents must be formulated clearly and in the respective national language.

14.3 Required Steps for Design, Implementation, and Testing

The implementation of system components with safety-related functions requires special care in planning, implementation, and testing. Guidelines are also laid down for this in the relevant standards (cf. EN ISO 13849-2 or IEC 61508). Outlay is based in this regard on the complexity of the task for system components with safety-related functions.

The PUS evaluation unit offers efficient support for implementing such functions with the help of safety-related control and monitoring functions. It does so through its system architecture (cat. 4 in accordance with EN ISO 13849-1) and above all through the programming language and tested safety functions. Programming is conducted in the form of FBD (function block diagram) recommended in accordance with safety standards. It also complies with the requirements for a low variable language (LVL) for which documentation and test scope are simplified substantially.

In all cases, the individual steps require careful planning and analysis of the methods and systems used. The individual steps must also be documented in a comprehensible manner.

V-model (simplified)

The implementation of safety-related functions requires a structured procedure as exemplified by the V-model recommended in relevant standards. The following is an example of the procedure for applications with PUS evaluation unit modules.

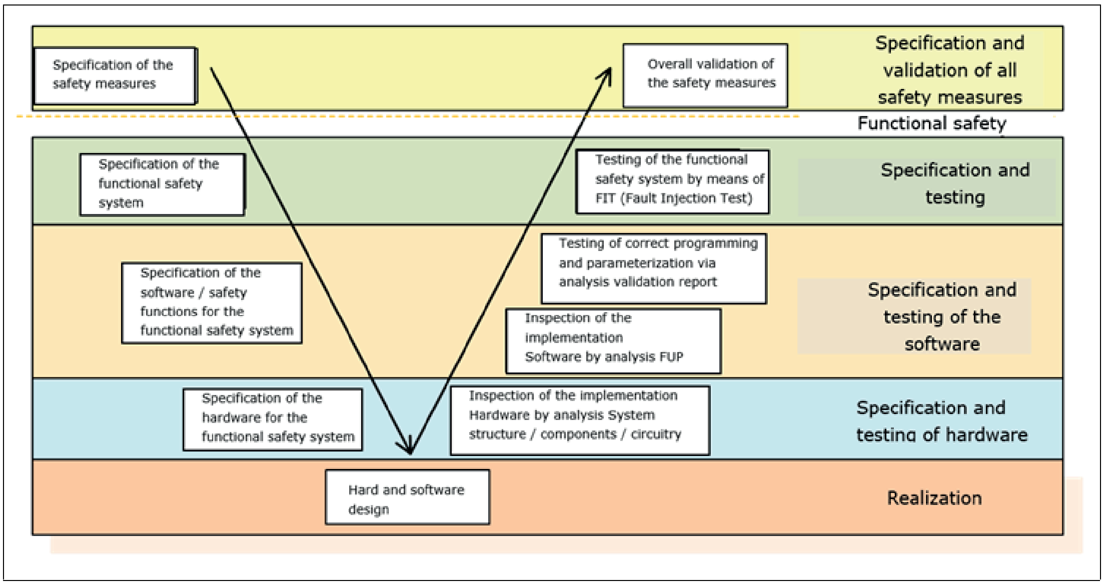


Figure 14.2

14.3.1 Phases of the V-model

Naming	Description	
	Design phase	Validation phase
Specification and validation of all passive and active safety measures	Specification of all safety measures to be taken such as covers, barriers, max. machine parameters, safety functions, etc.	Checking of all passive and active safety measures for their proper implementation and effectiveness
Specification of functional safety systems	Specification of active safety systems and their assignment to the risks to be reduced, e.g., reduced speed In setup mode, stop mode, monitoring of access areas, etc., specification of the PLr or required SIL for each individual safety function	Testing of all active safety systems for their effectiveness and adherence to the specified parameters such as erroneously increased speed, erroneous stoppage, activation of monitoring devices, etc. with practical tests
Specification of software/safety functions	Specification of the functionality of the individual safety functions incl. definition of the shutdown circuit, etc. Definition of the parameters for the individual safety function, e.g., max. speed, stopping ramps and category etc.	Checking for correct implementation of the function specifications by analyzing FBD programming, validation of the application program and the parameters by comparing the validation report with FBD and parameter specifications
Hardware specification	Specification of the plant design and functions of the individual sensors, control devices, control components, and actuators with regard to safety functions	Checking for correct implementation of the specifications. Determination of the probability of failure or PL by analyzing the overall architecture and the characteristics of all components involved, in each case with reference to the individual safety functions
Hardware and software design	Specific planning and implementation of the plant design/wiring. Specific implementation of safety functions by programming in FBD	nil

14.3.2 Specification of Safety Requirements (Outline)

Safety requirements must be analyzed individually based on the applicable standards, e.g., product standards.

1 General product and project information

1.1 Product identification
1.2 Author, version, date, document name, file name
1.3 Contents
1.4 Terminology, definitions, glossary
1.5 Version history and changes
1.6 Directives, standards and technical rules relevant to development

2 Functional information on the machine, where relevant to safety

2.1 Intended use and reasonably foreseeable misuse
2.2 Process description (operating functions)
2.3 Operating modes (e.g. setup mode, automatic mode, operation of localized relevance or of parts of the machine)
2.4 Characteristic data, e.g. cycle times, response times, overrun distances
2.5 Other characteristics of the machine
2.6 Safe state of the machine
2.7 Interaction between processes (see also 2.2) and manual actions (repair, setup, cleaning, troubleshooting, etc.)
2.8 Emergency operations

3 Required Performance Level(s) (PL_r)

3.1 Reference to existing documentation concerning the hazard analysis and risk assessment for the machine
3.2 Results of the risk assessment for each identified hazard or hazardous situation and specification of the safety function(s) required in each case for risk reduction

4 Safety functions (information applies to each safety function)

- Description of the function ("input – logic – output") including all functional characteristics (refer also to Tables 5.1 and 5.2)
- Activation/deactivation conditions or events (e.g. operating modes of the machine)
- Behaviour of the machine when the safety function is triggered
- Conditions to be observed for re-starting
- Performance criteria/performance data
- Process (timing behaviour) of the safety function, including response time
- Frequency of actuation (i.e. demand rate), recovery time following demand
- Other data
- Adjustable parameters (where provided)
- Classification and assignment of priorities in the event of simultaneous demand for and processing of multiple safety functions
- Functional concept for separation or independence/freedom of reciprocal action from non-safety functions and further safety functions

5 Required information for the SRP/CS design

5.1 Allocation of the SRP/CS and the form of technology by which the safety function is to be implemented; intended equipment
5.2 Selection of the Category, designated architecture (structure) in the form of a safety-related block diagram and description
5.3 Description of the interfaces (process interfaces, internal interfaces, user interfaces, control and display elements, etc.)
5.4 Behaviour at switch-on, implementation of the required starting and restarting behaviour
5.5 Performance data: cycle times, response times, etc.
5.6 Behaviour of the SRP/CS in the event of component failures and faults (achieve and maintain the safe state), including timing behaviour
5.7 Failure modes of components, modules or blocks which are to be considered; where applicable, reasoning for fault exclusions
5.8 Concept for implementation of the detection and control of random and systematic failures (self-tests, test circuits, monitoring arrangements, comparisons, plausibility tests, fault detection by the process, etc.)
5.9 Quantitative aspects
5.9.1 Target values for $MTTF_d$ and DC_{avg}
5.9.2 Switching frequency of components subject to wear
5.9.3 Frequency of measures for fault detection
5.9.4 Mission time, where different from the assumption upon which the intended architecture is based (20 years)
5.10 Operating and limit data (operating and storage temperature range, humidity class, IP degree of protection, resistance values for shock/vibration/EMC, supply data with tolerances, etc.)
5.11 Generic standards to be applied for design (for the equipment, for protection against electric shock/hazardous shock currents, for resistance to environmental conditions, etc.)
5.12 Technical and organizational measures for protected access to safety-related parameters and to SRP/CS characteristics (protection against tampering, access protection, program/data protection) and for protection against unauthorized operation (key switch, code, etc.), for example in non-standard operating modes
5.13 General technical requirements and organizational framework for commissioning, testing and acceptance, and for maintenance and repair

Source: General specification, excerpt BGIA Report 2/2008 to EN ISO 13849-1

Example of a handling machine:

Functional description:

The automatic handling machine is used to automatically pick up truck cabs of different heights. Upon pickup, the height of the cab is securely recorded so that the cab cannot be lowered below a certain height in the working area. In the working area, the machine must not exceed a maximum speed. After work on the cab is complete, it is put back down at the end of the processing line and the automatic handler travels back to the beginning of the line via a return path to pick up another cab.

Machine limits:

Spatial limits: There must be sufficient space for workers in the working area to carry out all the necessary work on the cab. There must be enough space in the return path for the machine's empty hanger. Time limits: Description of the service life, description of aging processes that can lead to changes in machine parameters (e.g., braking). Monitoring mechanisms must be provided for in such cases. Usage limits: The machine automatically fetches new cabs and moves them through a processing area. There are workers in the machining area, etc. The following operating modes are provided: Setup mode, automatic mode, service mode, etc.

Identifying hazards:

The following mechanical hazards are relevant for the handling machine:

Hazard 1: Crushing by the cab/lifting beam starting to move

Hazard 2: Impact by moving cab/lifting beam

Hazard 3: Crushing by the cab lowering too quickly in the event of a fault

Hazard 4:....

Risk analysis:

G1: The weight of the cab and lifting beam is sufficiently great to cause irreversible crushing or death.

G2: Impacts from moving cabs/lifting beams can cause permanent injuries.

G3: …

Risk assessment:

Risk mitigation is required, taking into account all operating conditions.

Inherently safe design (risks from the project)

Movement of the cab in the x and y direction in the working area is unavoidable. In the working area, the cab must be moved up/down and forwards.

The following measures can be taken:

- Avoiding hazards caused by motion that is too fast
- Avoiding hazards caused by distances that are too small

Examples of risk assessment

Risk assessment acc. to EN 12100:2010 Date: 03.08.2011

Project no. 20

Customer BBH Forming transfer press

01 Mechanical hazards

Description	Norm	solution	risk
01.07 Gravity Life cycle: II, III Category: All operation modes			R5
Squeezing; Pressing In the event of a loss of energy supply (a power failure), the force generator may stop working. If the worker is in the press at this moment, the stoppage of the force generator poses a hazard to the worker.	EN 60204-1	In the event of a loss of energy, the safety valves go into the safe state and a press movement is no longer possible.	S4/A1/E1/M2 ☑ electrical
01.13 Moving parts Life cycle: II, III Category: Insertion operation			R19
Squeezing; Pressing When the workpiece is inserted, the press pad must be moved. At this point, the hand is inside the press. The press itself is active and can move. There is a threat of closing of the press while the hand and arm are inside the tool.	EN 692 EN 61800-5-2 EN ISO 13849-1 EN ISO 13849-2 EN 574 EN ISO 11161	The press can only be moved at a safely reduced speed (SLS). A safety-oriented joystick is used for this purpose. When the joystick button is released, the standstill is monitored (SOS). The tool can only be closed after the hand is removed from the tool and two-hand operation is initiated. If the conditions for a safely reduced speed of > 10m/s or for a standstill are violated, the safety valves are triggered via the safety chain and the press goes into the safe state. In SIL3, the SMX safety controller from BBH ensures that the standstill and the safely reduced speed are enabled in a safety-oriented manner.	S4/A3/E4/M2 ☑ electrical

03 Thermal hazards

Description	Norm	solution	risk

www.Csafe.biz Life cycle I= Transport I= Assembly II= Operation IV= Disposal 1 / 2

Risk assessment acc. to EN 12100:2010 Date: 03.08.2011

Project no. 20

Customer BBH Forming transfer press

Description	Norm	solution	risk
03.03 Objects or materials of high or low temperature Life cycle: III Category: Insertion operation, Retooling, Cleaning and maintenance, Troubleshooting and fault elimination			R6
Burning The preheating tool for the foaming unit is heated to a temperature of 120 There is a risk of contact or overtemperature in the event of a fault.	EN 60204-1 EN ISO 13849-1 EN ISO 13849-2	The Temperature of preheating unit is monitored that a dangerous temperature cannot be reached. In addition, a warning sign warns against contact. Temperature in normal operation is not so high that significant danger occurs. The Temperature is monitored via safe analog inputs and a heat sensor, so that in the event of a fault the preheating unit is switched off and protected against being switched on again.	S3/A2/E2/M1 ☑ electrical

www.Csafe.biz Life cycle I= Transport I= Assembly II= Operation IV= Disposal 2 / 2

14.3.3 Specification of the Functional Safety System

The active protective functions must be identified and specified, derived from the machine's general hazard and risk analysis.

Active protection functions include, for example, safely reduced speed in certain plant states, monitored stop and standstill functions, area monitoring, processing of monitoring devices such as light grids, switching mats, etc.

The safety functions must be defined and the specific requirements given in terms of function and safety level.

14.3.3.1 Definition of Safety Functions

The definition of the safety function must:

- Identify the risk to be covered
- Describe the exact function
- List all sensors and control devices involved
- Name all control units
- Identify the triggered de-energizing circuit

.

The definition should serve as the basis for the hardware and software design specification.

For each of the safety functions defined in this way, the parameters that may be used must be defined, such as max. system speed in setup mode, etc.

Examples of safety functions include:

SF1: STO (safe torque off) to protect against restarting

SF2: Safe speeds

SF3: Safe positions

SF4.:....

14.3.3.2 Required Performance Level (PLr) (Additional Emergency Stop)

The required performance level must now be determined from the SF1 safety functions identified above. The example below shows the decision path.

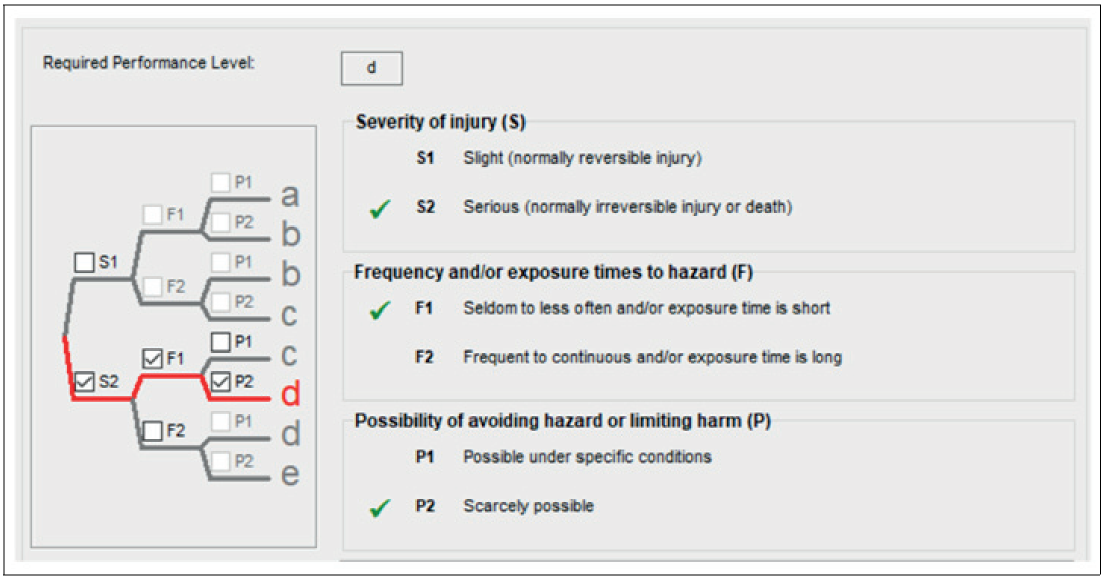


Figure 14.3 Example of SF1: Result PF = d (source Sistema)

14.3.3.3 Example - Specification of Safety Functions in Table Form

Serial no.	**Safety function**	**Ref from GFA**	**Plr**	**Measured value/read head**	**Implementation in software**	**Setpoint parameters**	**Input/ activation**	**Response /output**
1.1	Limitation of max. chassis travel speed to monitor max speed	2.3	e	1 x safePXV / PUS read head 1 x safePXV / PUS read head on motor / drive wheel	Monitoring by tested SLS safety function to fixed limits:	550 mm/s Fault distance monitoring: 200 mm	Continuous Reset: Acknowledge button	Operation stop SF 1.7.1
1.2	Limited max. chassis speed in operator's work area Monitoring of the maximum speed at < 0.33 m/s.	2.4	e	1 x safePXV / PUS read head 1 x safePXV / PUS read head on motor / drive wheel	Monitoring by tested SLS safety function to fixed limits:	60 mm/s Fault distance monitoring: 200 mm	Identification of operator's work area via chassis position AND NOT Setup Reset: Acknowledge button	SF 1.7.1
1.3	Limited max. chassis travel speed in setup mode Monitoring of the maximum speed at < 0.07 m/s.	3.1	1 x safePXV / PUS read head 1 x safePXV / PUS read head on motor / drive wheel	Monitoring by tested SLS safety function to fixed limits:	70 mm/s Fault distance monitoring: 200 mm	Setup operating mode AND "bridge safety" button Reset: Acknowledge button	Setup operating mode AND "bridge safety" button Reset: Acknowledge button	SF 1.7.1

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1.4	Chassis collision protection Monitoring of chassis distances against minimum distance by redundant laser distance measurement	2.5	d	2 x laser distance measuring devices	Monitoring of the distances using tested SAC function. The analog distance measurement values are mutually compared for max. tolerance Monitored for minimum values (SAC function) Min. distance value 25 % of max. measuring device value		Chassis within operator's work area Reset: Acknowledge button	SF 1.7.1
1.6.1		5.1	e	1 x safePXV / PUS read head 1 x safePXV / PUS read head on motor / drive wheel	Muting of diagnostics for chassis read heads using tested SCA function Muting is started before each gap and the incorrect read head value is then temporarily suppressed. In the gap, muting is triggered by a read head value outside 2 to 160,000 mm		Item 1 (7626 – 7850) Item 2 (11030 – 1263) Item 3 (75134 – 5338) Item 4 (145562 – 145622) Item 5 (143935 – 143995) Item 6 (80000 – 80060)	SF 1.6.2

14.3.3.4 Software Specification

The software specification refers to the previous specification for safety functions. It may also be replaced by an appropriately prepared safety function specification, provided that this contains all necessary guidelines.

However, it is recommended that a list be extracted. This should include the following information:

- Designation of the safety function
- Functional description
- Parameters, if any
- Triggering event/operating state
- Response/output

The details of the specification should be suitable for later validation of the programming.

Example software specification

Serial no.	Safety function	PLr	Measured value/read head	New solution	Input/ Activation	Response/ Output
1.4	Monitoring V_cable against V_set Monitoring difference between the main drive speed and cable drive at maximum value	d	Digital read head, Cable pulley tachogenerator	Monitoring by tested SLS + SAC function with comparison of speed ranges/analog value ranges = comparison for speed acquisition diagnostics New 2-channel shutdown (see below)	Continuous Reset: Acknowledge button	Operation stop SF 1.3.1
1.6	Return block Monitoring for return	d	Mechanical limit switch 22S2 Digital read head	Monitoring by tested SDI direction monitoring function	EMERGENCY (auxiliary contact 28K4 - inspection run) Reset: Acknowledge button	Operation stop SF 1.3.1
1.15	Step-by-step shutdown 3 Activating the safety brake	e	-	Processing SF in safeControl Expert	SF 1.2 SF 1.3.2 SF 1.7 SF 1.8	Set safety brake
1.8	Standstill functional	d	Digital read head	Standstill monitoring using tested SOS function	Controller lock OR Set operating brake	SF 1.15/ Set safety brake
1.9	Direction monitoring	e	Digital read head	Monitoring by tested SDI direction monitoring function	28K1 = FORWARD 28K2 = BACKWARD = safe signals from "Frey" controller	Operation stop SF 1.3.1

14.3.3.5 Hardware Specification

The hardware specification is intended to describe the entire system design and, in particular, the components used within it, including their specific characteristics. The hardware specification serves as the basis for determining the achieved safety level based on the architecture and the characteristics of all devices involved in a safety function.

The hardware specification also includes the design measures taken to protect against systematic and common cause faults.

14.3.3.6 Selection of SRP/CS and Resources

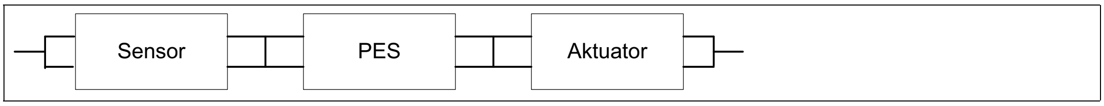
SRP/CS (safety related parts of the control system) should be selected as appropriate to achieve the desired safety level for each safety function. An overview of the system design must be produced identifying the components with a safety-relevant function and assigning them to the individual safety functions. Safety-related metrics must be determined for these components.

These metrics include the following values:

- MTTFd = mean time to failure, the average time to a dangerous failure)
- DC avg = mean diagnostic coverage
- CCF = common cause failure, failure resulting from a common cause

In an SRP/CS, the software and systematic faults must also be considered.

In principle, an analysis of the SRP/CS involved in a safety function must be carried out according to the sensor / PE system / actuator schematic.



14.3.3.7 Example of Hardware Specification

Safety function		**Safely reduced speed**	**SF 2.2**	**Safely monitored limited speed with the door open**							
				Nominal ratings							**Note**
Type	**Name**	**Function**	**Designation**	Architecture	MTTFD [years]	PFH [1/h]	B10d	Source	DC [%]	Source	
Sensor	Sensor 1	Door lock – monitoring of the access door	A 3.1	4			100000	Datasheet	99	Inst. manual PUS	
	Sensor 2.1	Sensor/motor feedback SIN/COS	G 1.1	4	30			General specification	99	Inst. manual PUS	Cat. 4 in conjunction with eval. PUS
PES	Safety PLC	Central safety PLC for controlling and evaluating safety-related functions	A 4.1			1.4 E-8		Datasheet SXM			
Actuator	STO	Safe Torque Off to the transformer	A 5.1	4	150			Datasheet transformer	99	Inst. manual PUS	Cat. 4 in conjunction with 2-channel
	mains contactor	Contactor in mains cable of transformer	K 5.1	4			20 E6	Datasheet contactor	99	Inst. manual PUS	Cat. 4 in conjunction with 2-channel

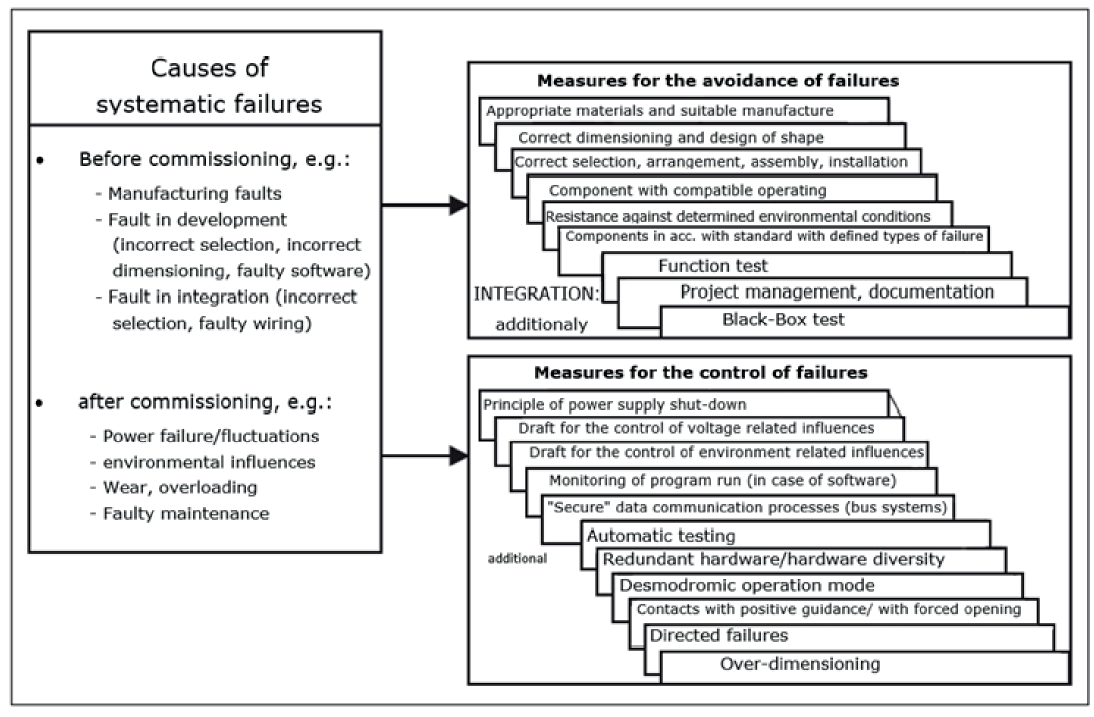
14.3.3.8 Consideration of Systematic Failures

Systematic failures must also be considered within the HW specification.

Example of measures to prevent systematic failures:

Power failure during operation. If this represents a hazard, a power failure must be viewed in the same way as an operating state. The SRP/CD must control this state so that the safe condition is maintained.

Measures to prevent systematic failures in accordance with Annex G DIN EN ISO 13849-9



Source BGIA Report 2/2008

Fault Eliminations

If fault eliminations are instituted for certain devices or system components, these must be named and specified in detail.

Fault eliminations can include e.g., mech. shaft breakage, sticking of switch contacts, short circuits in cables and wires, etc.

The admissibility of the fault eliminations should be justified, e.g., by making reference to permissible fault eliminations according to relevant standards, e.g., EN ISO 13849-1

If special measures are required for these fault eliminations, these must be specified.

Examples of fault eliminations and associated actions:

- Positive connection at mech. shaft connections
- Dimensioning based on sufficient theoretical foundations in the case of component breakage within the safety chain
- Positive guidance in conjunction with forced separation in the case of switching contacts remaining stuck
- Protected routing within switchgear in the case of short circuits in cables and lines, laying cables in cable ducts – especially for applications in elevator technology in accordance with EN 81-20/-50 and/or EN 81-1/-2

14.3.3.9 Hardware and Software Design

The provisions of the HW and SW specifications are implemented in the actual system design.

The provisions of the HW specification regarding the components to be used and their connection must be adhered to along with the specifications for fault eliminations. Both must be ensured and documented by appropriate means.

The provisions of the software specification must also be observed in the software and fully implemented.

The higher-level software specifications for safety-related programming must also be observed in this respect. These include:

- The program having a clear, modular structure
- Assignment of functions to the safety functions
- Functions being clearly represented by:
- Unique names
- Understandable comments
- Extensive use of tested functions/function blocks
- Defensive programming

14.3.3.10 Inspection of Hardware Design

Once the planning has been completed, the hardware must be checked for compliance with the provisions of the HW specification.

In addition, appropriate analysis must take place to ensure compliance with the specified safety level for each individual safety function. The analysis methods are described in the relevant standards (e.g., EN ISO 13849-1).

Analysis of Wiring Diagram

The wiring diagram and the parts list must be used to check compliance with the specifications in terms of safety. The following must be tested in particular:

- Correct connection of the components according to the specifications
- 2-channel layout where specified
- Absence of feedback from parallel, redundant channels
- That components are used as specified
- The inspection analysis should be understandable by a third party.

14.3.3.11 Iterative Review of the Safety Level Achieved

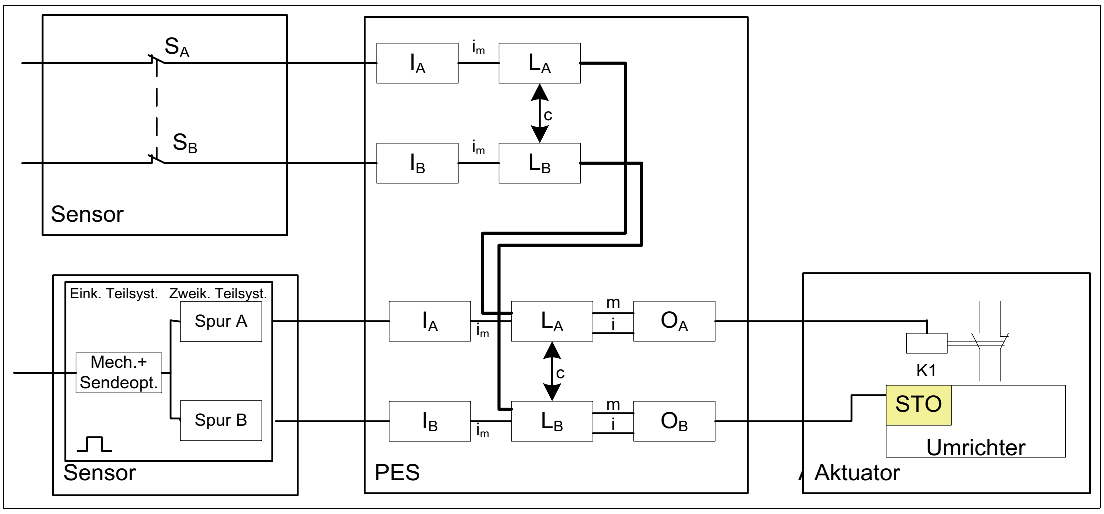
The achieved safety level must be determined based on the circuit structure (=1/2-channel architecture with or without diagnostics), the device characteristics (details from manufacturer or relevant sources) and the degree of diagnostic coverage (manufacturer PE system or general sources). The relevant procedures can be found in the safety standard used.

The following is an example calculation based on EN ISO 13849-1:

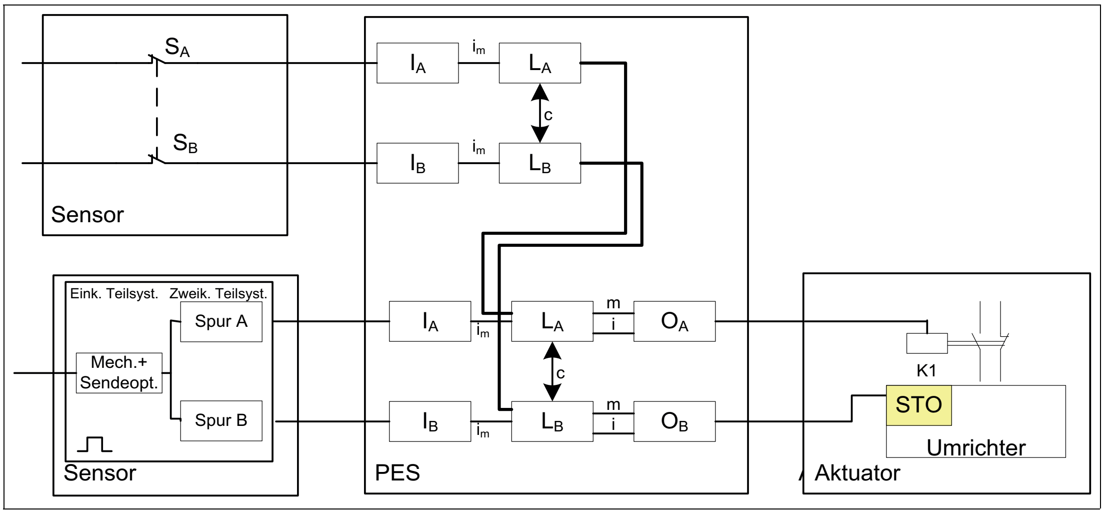
Safety function:

Safely reduced speed with opened access door

Layout diagram:



Safety layout diagram:



Calculation in accordance with EN ISO 13849-1:

Channel A – shutdown via mains protection:

Component	$MTTF_d$[years]	DC
Door protection switch[1]	B_{10d}=100000 N_{op}= 30/AT = 9270/year (309 AT/year) $MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 107{,}87\ a$	DC_{Switch}= 99 %
SIN/COS sensor	$MTTF_d$= 30 years	DC_{sensor}= 99 %
PES[2]	λ_d =1884.21 fit $MTTF_d = \frac{10^9}{365 \cdot 24 \cdot \lambda_d} = 60{,}59\ a$	DC_{PES}= 94.5 %
Mains contactor[3]	B_{10d} = 1.3 ? 10^6 N_{op} 20/AT = 6180/year (309 AT/year) $MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 2103{,}56\ a$	$DC_{Contactor}$= 96 %

$$MTTF_d^A = \frac{1}{\frac{1}{MTTF_d^{Switch}} + \frac{1}{MTTF_d^{Encoder}} + \frac{1}{MTTF_d^{PES}} + \frac{1}{MTTF_d^{Contactor}}} = 16{,}78\ a$$

1. Value for $MTTF_d$ from EN ISO 13849-1, table C.1
2. Value from internal HW FMEA; acceptance of a PUS evaluation unit with relay board, CPU board, processing subsystem and output subsystem with high side/low side combination
3. Value for $MTTF_d$ from EN ISO 13849-1, table C.1; "worst case" assumption by "contactor with nominal load"

Channel B – shutdown via STO/converter:

Component	$MTTF_d$[years]	DC
Door protection switch (See above)	B_{10d}=100000 N_{op}= 30/AT = 9270/year (309 AT/year) $MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 107{,}87\ a$	DC_{Switch}= 99 %

SIN/COS sensor (See above)	$MTTF_d$= 30 years	DC_{sensor}= 99 %
PES (See above)	λ_d =1884.21 fit $$MTTF_d = \frac{10^9}{365 \cdot 24 \cdot \lambda_d} = 60{,}59\ a$$	DC_{PES}= 94.5 %
STO/converter[1]	$MTTF_d$= 150 years	$DC_{Contactor}$= 90 %
$$MTTF_d^B = \frac{1}{\frac{1}{MTTF_d^{Switch}} + \frac{1}{MTTF_d^{Encoder}} + \frac{1}{MTTF_d^{PES}} + \frac{1}{MTTF_d^{STO}}} = 15{,}20\ a$$		

1. Value for $MTTF_d$ from EN ISO 13849-1, table C.1

Resulting PL for both channels:

Symmetrization of both channels:	$$MTTF_d = \frac{2}{3}\left[MTTF_d^A + MTTF_d^B - \frac{1}{\frac{1}{MTTF_d^A} + \frac{1}{MTTF_d^B}}\right] = 16{,}00\ a$$
DC average value	$$DC_{avg} = \frac{\sum_i \frac{DC_i}{MTTF_i}}{\sum_i \frac{1}{MTTF_i}} = 97{,}2\ \%$$
PL	$MTTF_d$= 16.00 years (average) DC_{avg}= 97.4 % (average) Pl ="d" (from EN ISO 13849-1, tables 5, 6, and 7) In this case, the PL is determined by the $MTTF_d$ value of the sin/cos sensor. If a higher level of safety must be achieved, a sensor with a correspondingly higher quality must be used.

Note:

The characteristic values of the individual components used in this respect have been selected as examples and must be adapted accordingly for user applications.

NOTE

The PL can also be determined using the program tool "Sistema" from BGIA, among other options.

14.3.3.12 Verification Software (Program) and Parameters

Verification takes place in two steps:

1. Checking of the FBD with regard to the specified functionality
2. Checking of the FBD against the STL listing of the validation report, or the specified parameters against those listed in the validation report.

14.3.3.13 Testing FBD

The FBD as programmed must be compared against the specifications for testing purposes.

NOTE

Comparison becomes more efficient the more clearly structured programming is with regard to the safety functions.

For example:

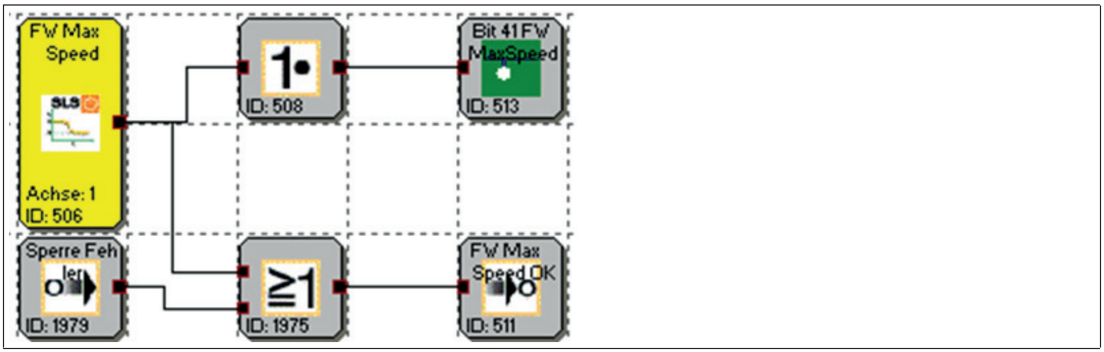
Safety function:

1.1 Limiting the max. chassis travel speed to 1.1 VMax

Monitoring maximum speed for < 1.1 VMax

FW Max Speed OK (ID 548) (gap present therefore bridged):

FW Max Speed is permanently activated and responds when a speed of 550 mm/s is exceeded.



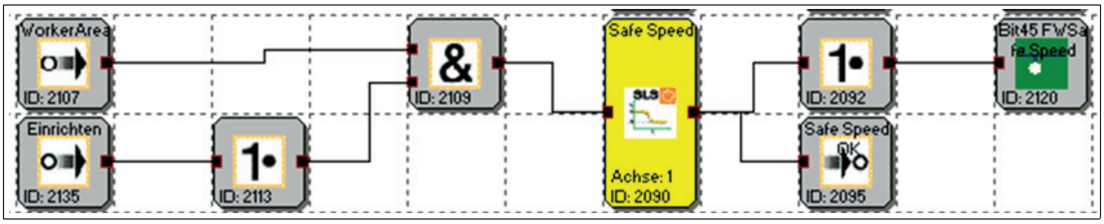
Safety function:

Limited max. chassis travel speed in operator's work area

Monitoring of the maximum speed at < 0.33 m/s.

Safe Speed OK (ID 2124) (gap present therefore bridged):

Safe Speed Ok responds if the safe speed SLS (ID 2090) is exceeded in the worker area when not in setup mode.



SLS Safe Speed parameters:

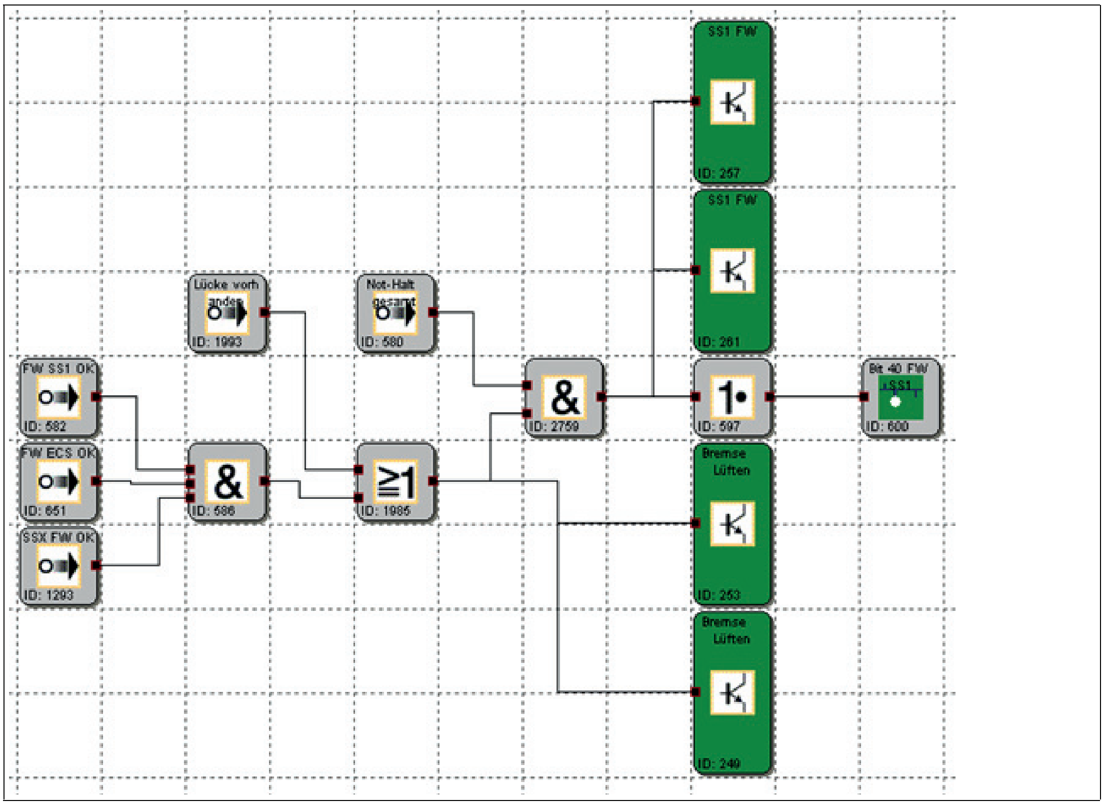
60 mm/s, no further parameters

Safety function:

Chassis shutdown

Traction drive shutdown and deactivation of brakes

Shutdowns on the chassis



The chassis is switched off via two outputs (IQQ1.5 ID 257 and 1.6 ID 261).

The brakes are released via two outputs (IQQ1.3 ID 253 and 1.4 ID 249).

A message is sent to the PLC via bit 40 (ID 600).

In the event of an emergency stop, the shutdown occurs immediately.

Lifting gear

Safety function

Emergency stop button inputs and shutdown outputs

1.1 Emergency stop head control

2-channel emergency stop with pulse monitoring.

If an emergency stop is triggered on the higher-level controller, this emergency stop can be bridged by approving "Bridge safety."

Emergency stop button, head control

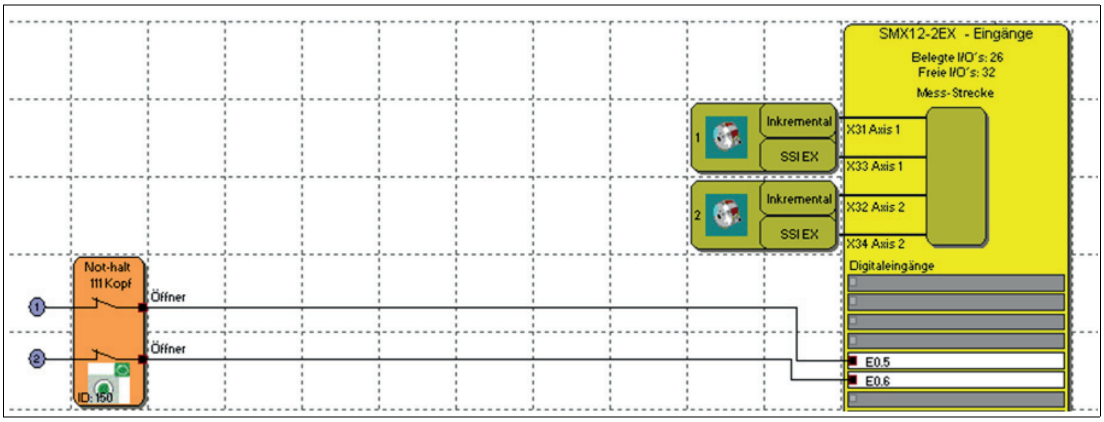


Figure 14.4 **Fig. 32: Emergency stop contacts from the emergency stop relay with pulses from the PUS evaluation unit**

14.3.3.14 Validate FBD against STL and Parameters using a Validation Report

The programming carried out in FBD must be compared with the STL listing of the validation report.

Example of STL listing in the validation report

Validation report

Validation report

PLC program			
Index	**Command**	**Operand**	**validated**
1	S1	SLI_EN.1	
2	S1	SLI_EN.2	
3	S1	SLI_EN.3	
4	S1	SCA_EN.1	
5	S1	SCA_EN.2	
6	S1	SCA_EN.3	
7	S1	SLS_EN.2	
8	S1	SCA_EN.4	
9	S1	SLS_EN.3	
10	S1	SLS_EN.4	
11	S1	SLI_EN.5	
12	SQH		
13	LD	E0.1	
14	ST	MX.2	
15	SQC		
16	SQH		
17	LD	E0.3	
18	AND	E0.4	
19	ST	MX.3	
20	SQC		

A step-by-step check is recommended. The more structured the FBD programming is, the more efficient the test will be.

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After the program has been checked, the parameters must be checked by comparing them against the specifications.

Example SLS:

Validation report

Safe Limited Speed (SLS)				
Index	**Parameter**	**Value**		**validated**
SLS-0	Selected axis:	1		
	Speed threshold:	2	0	
SLS-1	Selected axis:	1		
	Speed threshold:	500	0	
SLS-2	Selected axis:	1		
	Speed threshold:	2	0	
	Acceleration threshold:	2	0	
SLS-3	Selected axis:	1		
	Speed threshold:	2	0	
	Associated SSX ramp:	0		

Example sensor configuration

Validation report

Axis configuration/sensor interface				
Axis 1				
General parameters				
Measuring section:	500	0		
Type:	Rotational			
	No			
Position processing:	Enabled			
Maximum speed:	2000	0		
Incremental shutdown:	10,000	0		
Shutdown speed:	100	0		
Sensor				
Type:	SSI standard		SSI standard	
Format:	Binary		Binary	
Direction of rotation:	Rising		Rising	
Supply voltage:	0		0	
Resolution:	1024	Steps/1000mm	64	Steps/1000mm
Offset:	0	steps	0	steps

Axis configuration/sensor interface		
Axis 1		
	General parameters configured correctly	
	Parameter sensor 1 correct	
	Parameter sensor 2 correct	

14.3.3.15 Performing System Tests/FIT (fault injection test)

The FIT (fault injection test) requires the manufacturer to create a complete list of functions to be tested. This list includes the defined safety features and fault tests to verify that the SRP/CS is responding correctly to these faults.

Example test list:

No.	Setup	Test	Result
1 SLS test for max. speed in setup mode			
	Activate setup mode, travel at max. permissible speed	• Diagnosis of the actual speed versus SLS limit • Manipulation of the setup speed via permitted reduced speed	
2 SSX test for stop category 2			
	Movement at max. speed, emergency stop actuation	• Diagnosis of SSX ramp versus actual deceleration ramp • Setting an impermissibly weak delay • Traversing the axis following a standstill by manipulating the drive	
3 Test of 2-channel door monitoring			
	Select setup mode	Diagnosis of inactive monitoring when the door is closed (using the FBD diagnostic function) Diagnosis of active monitoring when the door is open (using the FBD diagnostic function) Disconnection of a channel and opening of door, creation of cross-circuit between both inputs	

15 Appendix

15.1 Appendix A - Classification of Switch Types

Note

The individual switches of the following input elements can be freely assigned to the digital inputs DI1 to DI8.

Enabling switches

Switch type	Comment	PL classification according to EN ISO 13849-1	SIL classification according to IEC 61508
1 normally-closed contact	Single enable switch	PL d	SIL 2
1 normally open contact	Single enable switch	PL d	SIL 2
2 normally closed contacts	Enable switch increased requirement	PL e	SIL 3
2 normally closed contacts for time monitoring	Enable switch, monitored	PL e	SIL 3

E-stop

Switch type	Comment	Category classification	SIL classification
1 normally-closed contact	Single emergency stop	PL d 1)	SIL 2
2 normally closed contacts	Emergency stop increased requirement	PL e	SIL 3
2 normally closed contacts for time monitoring	Emergency stop, monitored	PL e	SIL 3

1): Fault eliminations and boundary conditions according to EN ISO 13849-2 must be observed!

Door monitoring

Switch type	Comment	Category classification	SIL classification
2 normally closed contacts	Door monitoring increased requirement	PL e	SIL 3
2 normally closed contacts for time monitoring	Door monitoring, monitored	PL e	SIL 3
1 normally open and 1 normally closed contact	Door monitoring increased requirement	PL e	SIL 3
1 normally open + 1 normally closed contact, time monitoring	Door monitoring, monitored		SIL 3

Switch type	Comment	Category classification	SIL classification
2 normally open + 2 normally closed contacts	Door monitoring increased requirement	PL e	SIL 3
2 normally open + 2 normally closed contacts, time monitoring	Door monitoring, monitored	PL e	SIL 3
3 normally closed contacts	Door monitoring increased requirement	PL e	SIL 3
3 normally closed contacts, time monitoring	Door monitoring, monitored	PL e	SIL 3

Two-handed button

Switch type	Comment	Category classification	SIL classification
2 change-over contacts	Two-handed button increased requirement	Type III C PL e	SIL 3
2 normally open contacts	Two-handed button, monitored	Type III A PL e	SIL 1

Note

These input elements have a fixed pulse assignment that cannot be influenced by the user!

Light curtain

Switch type	Comment	Category classification	SIL classification
2 normally closed contacts	Light curtain increased requirement	PL e	SIL 3
2 normally closed contacts for time monitoring	Light curtain monitored	PL e	SIL 3
1 normally open and 1 normally closed contact	Light curtain increased requirement	PL e	SIL 3
1 normally open + 1 normally closed contact, time monitoring	Light curtain monitored	PL e	SIL 3

Operating mode selector switch

Switch type	Comment	Category classification	SIL classification
2 positions	Operating mode selector switch, monitored	PL e	SIL 3
3 positions	Operating mode selector switch, monitored	PL e	SIL 3

Caution!
Safety notice
When the switch changes state, the safeControl Expert program to be created must ensure that the outputs of the evaluation unit are deactivated (note: Standard 60204-part 1-section 9.2.3).

Sensor

Switch type	Comment	Category classification	SIL classification
1 normally-closed contact	Single sensor input	PL d	SIL 2
1 normally open contact	Single sensor input	PL d	SIL 2
2 normally closed contacts	Sensor input increased requirement	PL e	SIL 3
2 normally closed contacts for time monitoring	Sensor input monitored	PL e	SIL 3
1 normally open and 1 normally closed contact	Sensor input increased requirement	PL e	SIL 3
1 normally open + 1 normally closed contact, time monitoring	Sensor input monitored	PL e	SIL 3

Start/reset element

Switch type	Comment	Category classification	SIL classification
1 normally open contact	Single alarm reset (edge evaluation)	-	-
1 normally open contact	Single logic reset	PL d	SIL 2
1 normally open contact	Single start monitoring (special function)	-	-

Note
The alarm reset input can be operated with 24 V continuous voltage and is edge-controlled.

16 Log of Changes

The "Log of Changes" chapter lists the respective changes made to this document for each version of the installation manual documentation.

Document version	Change	See
DOCT-8116	First edition of the installation manual	-
DOCT-8116A	Cover page - PUS-F161-B**-WCS added Figure altered	
	Identification - safe evaluation unit PUS-F161-B*-WCS and WCS read heads added	See chapter 1.2
	Other applicable documents - reference to the WCS manual added	See chapter 1.7
	Intended use altered	See chapter 2.1
	Device description - safe evaluation unit PUS-F161-B*-WCS added	See chapter 3
	Chapter: Device overview PUS-F161-B*-WCS added	See chapter 3.2
	Technical data PUS-F161-B*-PXV and PUS-F161-B*-WCS	See chapter 3.3
	Chapter: Nameplate PUS-F161-B**-WCS added	See chapter 3.5
	Scope of delivery - WCS read heads added	See chapter 3.7
	Chapter heading adapted, note removed	See chapter 4.3.1
	Text alteration	See chapter 4.3.2
	General safety design - PUS evaluation unit and WCS read heads	See chapter 5.2.2.1
	Read head combinations and diagnostic characteristic data - WCS added	See chapter 5.2.2.3
	Specific diagnostic measures - WCS added	See chapter 5.2.2.4
	Chapter: PUS-F161-B*-WCS terminal assignment added	See chapter 6.7
	External 24 V DC power supply - WCS added	See chapter 6.8
	Connection of external voltage supply for safePXV/PUS and safeWCS/PUS read heads	See chapter 6.9
	Chapter: read head interface X35-1/X35-2 added	See chapter 6.11.3
	Chapter: PUS-F161-B*-WCS technical data added	See chapter 12

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