Installation Manual

Installation Manual
for KSM Compact Series

Installation manual for devices
- KSM 10/10A (/4x)
- KSM 11 (/4x)
- KSM 11-2 (/4x)
- KSM 12/12A (/4x)
- KSM 12-2 (/4x)
- KSM 12-2A (/4x)

of the series KSM 10/11/12 and their extension modules
- KSM 31
- KSM 31R
- KSM 5x (see section 3).

Options:
/5x   - Standard field bus
/4x   - Standard field bus and safety protocol
A   - Secure, analog inputs
R   - Relay

Note: The German version if the original version of the installation manual

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Subject to change without prior notification
The contents of this documentation are collated with greatest care and corresponds with our present status of information.

However, we would like to point out, that this document cannot always be updated at the same time as the technical further development of the products.

Information and specifications can be changed at any time. Please keep yourself informed about the current version under www.kollmorgen.com.

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Contents

1 Important Notes

Definition of individual target groups

Project engineers for safe drive systems:
Engineers and technicians

Assembly, electric installation, maintenance and replacement of devices:
Maintenance electricians and service technicians

Commissioning, operation and configuration:
Technicians and engineers

1.1 Definitions

The designation KSM is used as generic term for all derivatives from the KSM product range. Wherever this description refers to a certain derivative, the complete designation is used.

The term "safe" used in the following text in any case refers to the classification as a safe function for application up to PI e acc. to EN ISO 13849-1 or SIL3 acc. to IEC 61508.

The system software "SafePLC", "Safe PLC2" serves the purpose of configuring and programming KSM modules.

The modules of the KSM series are internally built up of two independent processing units. In the following these are referred to as system A and system B.

1.2 Co-valid Documents

Description	Reference
Configuration of the KSM module for stand-alone applications without field-bus interfacing with the program "SafePLC"	SafePLC programming manual (System CD)
Validation report for implemented parameterization and PLC-program	Safety inspection with acceptance protocol
Acceptance for general safety relevant applications	Certificate for type approval test as safety control acc. to machine guideline 2006/42/EG for the product groups KSM10 (/4x) KSM10A (/4x) KSM11 (/4x) KSM11-2 (/4x) KSM12 (/4x) KSM12-2 (/4x) KSM12-2A (/4x) KSM12A (/4x) KSM31 KSM31R
Acceptance for applications in the elevator technology (validity range EN 81)	Certificate for type approval test as PESSRAL acc. to EN 81-20/-50 resp. EN 81-1/-2 for the product groups KSM10P KSM11P

Options:
/5x   - Standard field bus
/4x   - Standard field bus and safety protocol
A   - Secure, analog inputs
R   - Relays

Note:
- Thoroughly read the manuals before you start the installation and the commissioning of the KSM module.
- Paying attention to the documentation is a prerequisite for trouble-free operation and fulfilment of possible warranty claims.

1.3 Abbreviations Used

Abbreviation	Meaning
AC	Alternating voltage
AWL	Instruction list
ELIA	Employer's liability insurance association
CLK	Clock (cycle)
CPU	Central Processing Unit
DC	Direct voltage
I1..I14	Digital Input
DIN	Deutsches Institut für Normung (German Institut for Standardization)
DO	Digital Output
EMU	Emergency Monitoring Unit
EMC	Electromagnetic compatibility
ELC	Emergency Limit Control
EN	European Standard
HISIDE	Output with 24VDC nominal level switching to plus
IP20	Protection type for housing
ISO	International Organisation for Standardisation
LED	Light Emitting Diode
LOSIDE	Output switching to reference potential
OLC	Operational Limit Control
PIA	Process image of outputs
PII	Process image of inputs
PESSRAL	Programmable electronic system in safety related applications for elevators
P1,P2	Pulse-/ Cycle outputs
PLC	Programmable Logic Controller
POR	Power on Reset
PSC	Position Supervision Control
SDDC	Safe Device-Device Communication
SELV	Safety Extra Low Voltage
SSI	Synchronous Serial Interface
VDE	Verband der Elektrotechnik, Elektronik und Informationstechnik e. V. (association for electrical engineering, electronics and information technology)
DOx.y[1]	Auxiliary Output

(1) Module address   x = 0 2
      Channel address   y = 1 40

2 Safety Regulations

2.1 Intended Use

Devices of the KSM10/11/12 are programmable fail-safe control system intended for the establishment of emergency shut-down features and functions. The devices are intended for use in
- EMERGENCY STOP facilities,
- as safety component as defined by the EC machine directive 2006/42/EG,
- as PES for risk reduction as defined by IEC 61508,
- in safety circuits acc. to EN 60204-1 u. EN 60204-32,
- as PES for functional safety as defined by EN 62061,
- as SRP/CS as defined by EN ISO 13849-1,
- as device for establishing the safety functions acc. to EN 61800-5-2,
- as logic unit for converting and processing signals in two-hand control acc. to EN 574.

The devices KSM10/P and KSM11/P are suitable for use as PESSRAL (programmable electronic system in safety related applications for elevators) in elevator technology, i.e. in the validity range of EN 81-20/-50 resp. EN 81-1/-2. Devices of the basic series without the extension "/P" cannot be used in this field of application of EN 81-20/-50 resp. EN 81-1/-2!

Warning:
Devices of the basis series without additive "/P "are not applicable in the range of application of the EN 81-20/-50 resp. EN 81-1/-2!

CE	The devices of 10/11/12 series including expansion module KSM3x are safety components as specified in appendix IV of the EC machine directive 2006/42/EC. They were developed, designed and manufactured in compliance with the above-mentioned directive as well as the EC-directive EC-EMC directive 2014/30/EU

See appendix "EC Declaration of Conformity"

2.2 Use in Regions with UL/CSA Requirements

In case of modules of KSM series, which do not have UL/CSA approval, these modules can be used in USA and Canada under the following conditions:
- the switching voltage of the output relays must be limited to max. 24 V.
- a power supply unit meeting the requirement SELV/PELV must be used for supplying electric power to the KSM modules and their inputs and outputs

Under these prerequisites no UL/CSA approval is required, and the KSM-series can be used in switchgear in accordance with IEC 61010.

2.3   General Safety Regulations

⚠ **Safety Note:**

- In order to avoid damage to persons and property only qualified personnel is entitled to work on the device. The term qualified personnel refer to persons who have successfully completed electrotechnical training and are fully familiar with the applicable rules and standards of electrical engineering.

  The qualified person must become familiar with the operating instructions (see IEC 364, DIN VDE 0100).

- The qualified must have profound knowledge of the national accident prevention regulations

- The use of the device must be strictly limited to the intended use as specified in the following list. The values of data listed under section "3.2 Characteristic device data" must also be observed.

- The contents of this installation manual are restricted to the basic function of the device or its installation. The "Programming instructions KSM10/11/ 12 contains a more detailed description of the programming and re-parameterization of the devices. Exact knowledge and understanding of these instructions is mandatory for a new installation or modification of device functions or device parameters.

- Commissioning (i.e. starting up the intended operation) is only permitted in strict compliance with the EMC-directive. The EMC-testing regulations EN 55011:2009 + A2:2010 and EN 61000-6-2:2005 are used as basis.

- Compliance with the conditions acc. to IEC 60068-2-6 related to the values specified under "Technical characteristics" is mandatory for storage and transport

- The wiring and connecting instructions in chapter "Installation" must be strictly followed.

- The applicable VDE-regulations and other special safety regulations of relevance for the application must be strictly followed.

- Evidence of the configured monitoring functions as well as their parameters and links must be issued by means of a validation report.

- The implementation of the module must be coordinated with the demands of the responsible acceptance testing authority (e.g. TÜV or ELIA).

- Do not install or operate damaged products. Report damages immediately to the responsible forwarding agent.

- Never open the housing and/or make unauthorized conversions.

- Inputs and outputs for standard functions or digital and analog data transmitted via communication modules must not be used for safety relevant applications.

WARNING:
Using our devices contrary to the rules and conditions specified hereunder can lead to injuries or fatalities as well as damage to connected devices and machines!
This will also cause the loss of all warranty and compensation claims against Kollmorgen.

2.4 Operation and Service

The module must always be de-energized before installation and removal, or before disconnecting signal lines. For this purpose, all live supply lines to the device must be checked for safe isolation from supply.

When installing or removing the module appropriate measures must be applied to prevent electrostatic discharge to the externally arranged terminal and plug connections. Contact with such terminals should be reduced to a minimum and earthing should by means of e.g. an earthing strap should take place before and during these procedures.

2.5 Transport and Storage

Information concerning transport, storage and proper handling must be strictly followed.
The climate related specifications in chapter "Technical data" must be complied with.

3 Device Types

The series KSM10/11/12 consists of
- Basic devices KSM10/11/12
- Extension modules KSM3x
- Communication modules with standard field bus KSM5x
- Integrated communication modules with safe field bus KSMxx-x(/4x)

Basic Devices

Series KSM10/11/12 is a compact fail-safe control system with optionally integrated drive monitoring for one (KSM11/11-2) or two (KSM12/12-2) axes.
The device is freely programmable for safe processing of EMERGENCY OFF buttons, two-handed controls, light barriers, operating mode selection switches etc. as well as drive-related safety functions.
Pre-configured modules for safety relevant signal pre-processing are available for a vast number of input devices. The same applies for safety functions serving the purpose of drive monitoring. Detailed information can be found in the programming manual.

The basic version of the device has 14 safe inputs and up to 3 safe cut-off channels.

Single encoder solutions as well as two encoder solutions are supported for reliable speed and/or position detection. See "Encoder specifications".

Extension Modules

Central or decentralized I/O expansion modules for KSM10/11/12 series.
A maximum of 2 expansion modules can be used.

Communications - Modules and Integrated Interface

The communication interface has a bi-directional data transfer from and to a subordinate control via standard field bus or secure standard field bus.

3.1 Module Overview

Basic Units				Extension Units	
Designation	**KSM 10/10A(4x)**	**KSM 11/11-2(/4x)**	**KSM12/12A/ 12-2/12-2A(/4x)**	**KSM31/31R**	**KSM5x**
General data					
Max. no. of expansion modules	2*	2*	2*	-	-
Safe digital inputs	14	14	14	12	-
Safe digital I/O	-	-	-	10/2	-
Safe digital outputs pn-switching / pp-switching	2/4	2/4	2/4	-/-	-
Safe analogue inputs	-/2/-/2	-	-/2/-/2-	-	-
Relay outputs	2/2/6/6	2	2	-/8	-
Auxiliary outputs	2	2	2	-/2	-
Pulse outputs	2	2	2	-/2	-
Integrated communication interface	Optional(5x) CAN 2.0, Profibus, Profinet, CANopen, EtherCAT, Devicenet			-	-
Extended Communication interface	Optional(5x) CAN 2.0, Profibus, Profinet, CANopen, EtherCAT, Devicenet			-	CAN 2.0, Profibus, Profinet, CANopen, EtherCAT, Devicenet
Axis monitoring	-	1	2	-	-
Encoder technology	-	SSI SIN/COS Inkr. TTL Proxi-SW/+Resolver Inkr. HTL	SSI SIN/COS Inkr. TTL Proxi-SW/+Resolver Inkr. HTL	-	-
Technical data					
See technical characteristic data of the respective module					

[(1)] Specification see: "Optional universal communication interface"

3.2 Characteristic Data of Device

3.2.1 Basic Modules

3.2.1.1   KSM10/10A (/4x)

Type Designation	Device Design
	Design of module with the following periphery: 14 Digital inputs 2 Pulse outputs 2 Relay outputs 2 pn-switching outputs 2 Auxiliary outputs 2 Analog inputs (KSM10A) 1 Diagnostic- and configuration interface 1 Function button 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 Optional: Communication interface (/4x, 5x)

Characteristics of the module:

- Extendable to:
  - max. 38 safe digital inputs,
  - max. 2 safe digital outputs,
  - max. 20 sichere digitale I/O's,
  - max. 12 safe relay outputs,
  - max. 6 auxiliary outputs
- Logic processing up to Pl e acc. to EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Freely programmable Modular controller for up to 800 IL instructions
- Logic diagram oriented programming
- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Monitored relay outputs for safety relevant functions
- Complete speed and position-based safety functions for drive monitoring in accordance with IEC 61800-5-2 are integrated in firmware
  - Spatial functions for safe speed and are monitoring are possible
- Parameter management for expansion modules in base device
- Comprehensive diagnostics functions integrated
- Coded status display via front-side 7 segment display and status LEDs
- Multifunction buttons (quit, start, reset) can be operated from the front side

- CAN communication in connection with the KSM5x for diagnosis via rear wall bus assembly on profile rail (see communication module)
- Assembly on top hat rail
- KSM 10A (Analog) –with 2 secure analog inputs
- The mechanical construction of the KSM10A deviates from the figure. (see mechanical data)

Technical Characteristic Data KSM10/A (/4x)

Safety related characteristic data			
	PI acc. to EN ISO 13849-1		PL e
	PFH / architecture		12,6 FIT /Cat 4
	MTTF$_d$	KSM10 KSM10A	49 years
	SIL acc. to IEC 61508		SIL 3
	Proof test interval		20 years = max. operating period
General data			
	Max. no. of expansion modules		2
	Interface for expansion modules		T-bus connector, pluggable in top-hat rail
	Number of safe digital inputs		14 (OSSD capable)
	Number of safe digital outputs		
	pn-switching	KSM10x	2
	Number of safe digital I/O		-
	Number of relay outputs		2
	Number of safe analogue inputs		-
		KSM10A/x	2 *
	Number of auxiliary outputs		2
	Number of pulse outputs (pulse outputs)		2
	Type of connection		Plug-in terminals with spring or screw connection
	Axis monitoring		-
	Encoder interfaces (D-Sub / screw terminal)		-
	Encoder technology (See table encoder specifications)		-
Electrical data			
	Supply voltage (tolerance)		24 VDC; 3,15A (-15%, +20%)
	Fuse	X11.1	min. 30 VDC; max. 3,15A
	Max. Power consumption (logic)		2,4W
	Rated data digital inputs		24 VDC; 20 mA, Typ1 acc. to EN 61131-2
	Rated data digital outputs		
		pn-switching	24 VDC; 250mA
		Auxiliary outputs	24 VDC; 250mA
		pulse outputs (pulse outputs)	24 VDC; 250mA
	Rated data relays	Normally open DC13 AC15	24 VDC; 2A 230 VAC; 2A
		Normally closed DC13 (Read back contact)	24 VDC; 2A
	Rated data analogue inputs		
		KSM10A/x	-10 … +10V
Environmental data			
	Temperature		0°C … +50°C operation -25C° … +70C° storage and transport
	Class of protection		IP 20
	Climatic category		3k3 acc. to DIN 60 721-3
	Min-, 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
	Operating altitude		2000m
	Overvoltage category		III
	Degree of pollution		2

Mechanical data			
	Dimensions (HxDxW [mm])	KSM10 KSM10A KSM10/4x KSM10A/4x	= 100x115x45 = 100x115x67,5 = 100x115x67,5 = 100x115x90
	Weight (g)	KSM10 KSM10A KSM10/4x KSM10A/4x	= 300 = 380 = 400 = 480
	Mounting	To snap on top-hat rail	
	Number of T-bus		
		KSM10	2
		KSM10A	3
		KSM10/10A/4x)	KSM10x + 1
	Min. terminal cross-section / AWG	0,2 mm² / 24	
	Max. terminal cross-section / AWG	2,5 mm² / 12	

(*)   Analogue electricity, voltage inputs are available as options
          For example: KSM10A-U   Voltage inputs
                                    KSM10A-I   Electricity inputs
                                    KSM10A   Voltage and electricity inputs

3.2.1.2   KSM11(/4x)

Type Designation	Device Design
	Design of module with the following periphery: 1 Axis 3 Encoder interfaces 14 Digital inputs 2 Pulse outputs 2 Relay outputs 2 pn-switching outputs 2 Auxiliary outputs 1 Diagnostic- and configuration interface 1 Function button 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 Optional: Communication interface (/4x, 5x)

Characteristics of the module:

- Extendable to:
    - max. 38 safe digital inputs,
    - max.   2 safe digital outputs,
    - max. 20 safe digital I/O's,
    - max.   9 safe relay outputs,
    - max.   6 auxiliary outputs
    - max.   1 safe axis
- Logic processing up to PL e acc. to EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Movement monitoring of one axis up to Pl e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Speed monitoring:
- RPM-monitoring
- Standstill monitoring
- Sense of rotation monitoring
- Safe incremental dimension
- Emergency Stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Freely programmable Modular controller for up to 800 IL instructions
- Logic diagram oriented programming
- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Monitored relay outputs for safety relevant functions

- Complete speed and position-based safety functions for drive monitoring in accordance with IEC 61800-5-2 are integrated in firmware
  - Spatial functions for safe speed and are monitoring are possible
- Parameter management for expansion modules in base device
- Comprehensive diagnostics functions integrated
- Coded status display via front-side 7 segment display and status LEDs
- Multifunction buttons (quit, start, reset) can be operated from the front side
- CAN-communication in connection with the KSM5x for diagnosis via backplane bus system mounted on top-hat rail (see communication module)
- Assembly on top hat rail
- The mechanical structure of KSM11(4x) differs from the figure. (see mechanical data)

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Technical Characteristic Data KSM11(/4x)

Safety related characteristic data		
	PI acc. to EN ISO 13849-1	PL e
	PFH / architecture	12,6 FIT / Cat 4
	MTTF$_d$	49 years
	SIL acc. to IEC 61508	SIL 3
	Proof test interval	20 years = max. operating period
General data		
	Max. no. of expansion modules	2
	Interface for expansion modules	T-bus connector, pluggable in top-hat rail
	Number of safe digital inputs	14 (OSSD capable)
	Number of safe digital outputs	
	pn-switching	2
	Number of safe digital I/O	-
	Number of relay outputs	2
	Number of safe analogue inputs	-
	Number of auxiliary outputs	2
	Number of pulse outputs (pulse outputs)	2
	Type of connection	Plug-in terminals with spring or screw connection
	Axis monitoring	1 / 3*
	Encoder interfaces (D-Sub / screw terminal)	**D-SUB X31:** SSI, SinCos, Incremental-TTL **Terminal X23:** Incremental-HTL (10kHz)
Electrical data		
	Supply voltage (tolerance)	24 VDC; 3,15A (-15%, +20%)
	Fuse X11.1	min. 30 VDC; max. 3,15A
	Max. power consumption (logic)	2,4W
	Rated data digital inputs	24 VDC; 20 mA, Typ1 acc. to EN 61131-2
	Rated data digital outputs	
	pn-switching	24 VDC; 250mA
	Auxiliary outputs	24 VDC; 250mA
	Pulse outputs (pulse outputs)	24 VDC; 250mA
	Rated data relays Normally open DC13 AC15	24 VDC; 2A 230 VAC; 2A
	Rated data analogue inputs	-
Environmental data		
	Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
	Class of protection	IP 20
	Climatic category	3k3 acc. to DIN 60 721-3
	Min-, 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
	Operating altitude	2000m
	Overvoltage category	III
	Degree of pollution	2
Mechanical data		
	Dimensions (HxDxW [mm])	KSM11 = 100x115x45 KSM11/4x = 100x115x67,5
	Weight (g)	KSM11 = 310 KSM11/4x = 410
	Mounting	To snap on top-hat rail
	Number of T-bus	
	KSM11	2
	KSM11/4x	3
	Min. terminal cross-section / AWG	0,2 mm² / 24
	Max. terminal cross-section / AWG	2,5 mm² / 12

(*)   maximum 2 encoder / axis

3.2.1.3   KSM11-2(/4x)

Type Designation	Device Design
	Design of module with the following periphery: 1 Axes 5 Encoder interfaces 14 Digital Inputs 2 Pulse outputs 2 Relay outputs 2 pn-switching outputs 2 Auxiliary outputs 1 Diagnostic and configuration interface 1 Function button 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 Optional: Communication interface (/4x, 5x)

Characteristics of the module:

- Extendable to:
  - max. 38 safe digital inputs,
  - max.   2 safe digital outputs,
  - max. 20 safe digital I/O's,
  - max.   9 safe relay outputs,
  - max.   6 auxiliary outputs
  - max.   1 safe axis
- Logic processing up to PL e acc. to with EN ISO 13849-1 or SIL 3 acc. to with IEC 61508
- Movement monitoring of one or two axes up to Pl e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Speed monitoring:
- RPM-monitoring
- Standstill monitoring
- Sense of rotation monitoring
- Safe incremental dimension
- Emergency Stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Freely programmable Modular controller for up to 800 IL instructions
- Logic diagram oriented programming
- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)

- Monitored relay outputs for safety relevant functions
- Complete speed and position-based safety functions for drive monitoring in accordance with IEC 61800-5-2 are integrated in firmware
    - Spatial functions for safe speed and are monitoring are possible
- Parameter management for expansion modules in base device
- Comprehensive diagnostics functions integrated
- Coded status display via front-side 7 segment display and status LEDs
- Multifunction buttons (quit, start, reset) can be operated from the front side
- CAN-communication in connection with the KSM5x for diagnosis via backplane bus system mounted on top-hat rail (see communication module)
- Assembly on top hat rail
- Extended functionality:
    - Allows the connection of 2 rotary encoders per axis (SSI, Sin/Cos, TTL, Proxi)
    - 2. encoder interface also supports HTL (200 kHz), Sin/Cos High-Resolution and Resolver
- The mechanical structure of KSM11-2/4x differs from the figure. (see mechanical data)

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Technical Characteristic Data KSM11-2(/4x)

Safety related characteristic data	
PI acc. to EN ISO 13849-1	PL e
PFH / architecture	12,6 FIT /CaT 4
MTTF$_d$	44 years
SIL acc. to IEC 61508	SIL 3
Proof test interval	20 years = max. operation period

General data		
Max. no. of expansion modules		2
Interface for expansion modules		T-bus connector, pluggable in top-hat rail
Number of safe digital inputs		14 (OSSD capable)
Number of safe digital outputs		
	pn-switching	2
Number of safe digital I/O		-
Number of relay outputs		2
Number of safe analogue inputs		-
Number of auxiliary outputs		2
Number of pulse outputs (pulse outputs)		2
Type of connection		Plug-in terminals with spring or screw connection
Axis monitoring		1 / 5 *
Encoder interfaces (D-Sub / screw terminal)		**D-SUB X31:** SSI, SinCos, Incremental-TTL **D-SUB X33:** SSI, SinCos, SinCos (HighRes), Incremental-TTL, Resolver **Terminal X23:** Inkremental-HTL (10kHz) **Terminals X27, X28:** Incremental-HTL (200kHz)

Electrical data		
Supply voltage (tolerance)		24 VDC; 3,15A (-15%, +20%)
Fuse	X11.1	min. 30 VDC; max. 3,15A
Max. power consumption (logic)		2,4W
Rated data digital inputs		24 VDC; 20 mA, Typ1 acc. to EN 61131-2
Rated data digital outputs		
	pn-switching	24 VDC; 250mA
	Auxiliary outputs	24 VDC, 250mA
	Pulse outputs	24 VDC, 250mA
Rated data relays	Normally open	24 VDC; 2A 120 VAC; 2A
Rated data analogue inputs		-

Environmental data	
Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
Class of protection	IP 20
Climatic category	3k3 acc. to DIN 60 721-3
Min-, 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
Operating altitude	2000m
Overvoltage category	III
Degree of pollution	2

Mechanical data		
Dimensions (HxDxW [mm])		KSM11-2 = 100x115x67,5 KSM11-2/4x = 100x115x90
Weight (g)		KSM11-2 = 390 KSM11-2/4x = 490
Mounting		To snap on top-hat rail
Number of T-bus		
	KSM11-2	3
	KSM11-2/4x	4
Min. terminal cross-section / AWG		0,2 mm² / 24
Max. terminal cross-section / AWG		2,5 mm² / 12

(*)   maximum 2 encoder / axis

3.2.1.4 KSM12/12A(/4x)

Type Designation	Device Design
	Design of module with the following periphery: 2 Axes 4 Encoder interfaces 14 Digital inputs 2 Pulse outputs 2 Relay outputs 2 pn-switching outputs 2 Auxiliary outputs 2 Analogue inputs (KSM12A) 1 Diagnostic- and configuration interface 1 Function button 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 Optional: Communication interface (/4x, 5x)

Characteristics of the module:

- Extendable to:
    - max. 38 safe digital inputs,
    - max. 2 safe digital outputs,
    - max. 20 safe digital I/O,
    - max. 9 safe relay outputs,
    - max. 6 auxiliary outputs,
    - max. 2 safe axes
- Logic processing up to PL e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Movement monitoring of one or two axes up to Pl e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Speed monitoring
- RPM-monitoring
- Standstill monitoring
- Sense of rotation monitoring
- Safe incremental dimension
- Emergency Stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Freely programmable Modular controller for up to 800 IL instructions
- Logic diagram oriented programming
- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Monitored relay outputs for safety relevant functions

- Parameter management for expansion modules in base device
- Comprehensive diagnostics functions integrated
- Coded status display via front-side 7 segment display and status LEDs
- Multifunction buttons (quit, start, reset) can be operated from the front side
- CAN-communication in connection with the KSM5x for diagnosis via backplane bus system mounted on top-hat rail (see communication module)
- Assembly on top hat rail
- Extended functionality:
  o allows the connection of 2 rotary encoders per axis (SSI, Sin/Cos, TTL, Proxi)
- The mechanical structure of KSM12/12A(/4x) differs from the figure. (see mechanical data)
- KSM 12A – Variant (analogue) – with 2 analogue inputs

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Technical Characteristic Data KSM12/12A(/4x)

Safety related characteristic data		
	PI acc. to EN ISO 13849-1	PL e
	PFH / architecture	12,6 FIT / Cat 4
	MTTF$_d$	49 years
	SIL acc. to IEC 61508	SIL 3
	Proof test interval	20 years = max. operation period
General data		
	Max. no. of expansion modules	2
	Interface for expansion modules	T-bus connector, pluggable in top-hat rail
	Number of safe digital inputs	14 (OSSD capable)
	Number of safe digital outputs	
	pn-switching	2
	Number of safe digital I/O	-
	Number of relay outputs	2
	Number of safe analogue inputs	-
	KSM12A	2 ****
	Number of auxiliary outputs	2
	Number of pulse outputs (pulse outputs)	2
	Type of connection	Plug-in terminals with spring or screw connection
	Axis monitoring	2 / 4 *
	Encoder interfaces (D-Sub / screw terminal)	**D-SUB X31, X32:** SSI-Absolut, SinCos, Incremental-TTL **Terminal X23:** Incremental-HTL (10kHz)
Electrical data		
	Supply voltage (tolerance)	24 VDC; 3,15A (-15%, +20%)
	Fuse X11.1	min. 30 VDC; max. 3,15A
	Max. power consumption (logic)	2,4W
	Rated data digital inputs	24 VDC; 20 mA, Typ1 acc. to EN 61131-2
	Rated data digital outputs	
	pn-switching	24 VDC; 250mA
	Auxiliary outputs	24 VDC; 250mA
	Pulse outputs (pulse outputs)	24 VDC; 250mA
	Rated data relays Normally open DC13	24 VDC; 2A
	AC15	230 VAC; 2A
	Rated data analogue inputs	-
	KSM12A/x ****	-10 … +10V 4 … 20 mA
Environmental data		
	Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
	Class of protection	IP 20
	Climatic category	3k3 acc. to DIN 60 721-3
	Min-, 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
	Operating altitude	2000m
	Overvoltage category	III
	Degree of pollution	2
Mechanical data		
	Dimensions (HxDxW [mm])	KSM12/12A = 100x115x67,5 KSM12/12A(/4x) = 100x115x90
	Weight (g)	KSM12/12A = 390 KSM12/12A(/4x) = 490
	Mounting	To snap on top-hat rail
	KSM12/12A	3
	KSM12/12A(/4x)	4
	Min. terminal cross-section / AWG	0,2 mm² / 24
	Max. terminal cross-section / AWG	2,5 mm² / 12

(*)   maximum 2 encoder / axis
(****)   Analogue electricity, voltage inputs are available as options
        For example: KSM12A-U   Voltage inputs
                KSM12A-I   Electricity inputs
                KSM12A Voltage and electricity inputs

3.2.1.5   KSM12-2/12-2A(/4x)

Type Designation	Device Design
	Design of module with the following periphery: 2 Axes 8 Encoder interfaces 14 Digital inputs 2 Pulse outputs 2 Relay outputs 2 pn-switching outputs 2 Auxiliary outputs 2 Analogue inputs 1 Diagnostic- and configuration interface 1 Function button 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 Optional: Communication interface (/4x, 5x)

Characteristics of the module:

Extendable to:
- o max. 38 safe digital inputs,
- o max. 2 safe digital outputs,
- o max. 20 safe digital I/O,
- o max. 9 safe relay outputs,
- o max. 6 auxiliary outputs,
- o max. 2 safe axes
- Logic processing up to PL e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Movement monitoring of one or two axes up to Pl e EN ISO 13849-1 or SIL 3 acc. to IEC 61508
- Speed monitoring
- RPM-monitoring
- Standstill monitoring
- Sense of rotation monitoring
- Safe incremental dimension
- Emergency Stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Freely programmable Modular controller for up to 800 IL instructions
- Logic diagram oriented programming
- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Monitored relay outputs for safety relevant functions

- Parameter management for expansion modules in base device
- Comprehensive diagnostics functions integrated
- Coded status display via front-side 7 segment display and status LEDs
- Multifunction buttons (quit, start, reset) can be operated from the front side
- CAN-communication in connection with the KSM5x for diagnosis via backplane bus system mounted on top-hat rail (see communication module)
- Assembly on top hat rail
- Extended functionality:
    - allows the connection of 2 rotary encoders per axis (SSI, Sin/Cos, TTL, Proxi)
    - 2. encoder interface also supports HTL (200 kHz), Sin/Cos High-Resolution and Resolver
- The mechanical structure of KSM12-2/12-2A(/4x) differs from the figure.
- (see mechanical data)
- KSM 12-2A – Variant (analogue) – with 2 analogue inputs

Technical Characteristic Data 12-2/12-2A(/4x)

Safety related characteristic data		
	PI acc. to EN ISO 13849-1	PL e
	PFH / architecture	12,6 FIT /Cat 4
	MTTF$_d$	44 years
	SIL acc. to IEC 61508	SIL 3
	Proof test interval	20 years = max. operation period
General data		
	Max. no. of expansion modules	2
	Interface for expansion modules	T-bus connector, pluggable in top-hat rail
	Number of safe digital inputs	14 (OSSD capable)
	Number of safe digital outputs	
	pn-switching	2
	Number of safe digital I/O	-
	Number of relay outputs	2
	Number of safe analogue inputs	-
	KSM12-2A/x	2 ****
	Number of auxiliary outputs	2
	Number of pulse outputs (pulse outputs)	2
	Type of connection	Plug-in terminals with spring or screw connection
	Axis monitoring (axis / encoder interfaces)	2 / 8 *
	Encoder technology (D-Sub /screw terminals)	**D-SUB X31, 32:** SSI, SinCos, Incremental-TTL **D-SUB X33, 34:** SSI, SinCos, SinCos (HighRes), Incremental-TTL, Resolver **Terminal X23:** Incremental-HTL (10kHz) **Terminals X27, X28, X29, X30:** Incremental-HTL (200kHz)
Electrical data		
	Supply voltage (tolerance)	24 VDC; 3,15A (-15%, +20%)
	Fuse X11.1	min. 30 VDC; max. 3,15A
	Max. power consumption (logic)	2,4W
	Rated data digital inputs	24 VDC; 20 mA, Typ1 acc. to EN 61131-2
	Rated data digital outputs	
	pn-switching	24 VDC; 250mA
	Auxiliary outputs	24 VDC; 250mA
	Pulse outputs (pulse outputs)	24 VDC; 250mA
	Rated data relays — Normally open DC13 / AC15	24 VDC; 2A / 230 VAC; 2A
	Rated data analogue inputs	-
	KSM12-2A/x ****	-10 … +10V / 4 … 20 mA
Environmental data		
	Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
	Class of protection	IP 20
	Climatic category	3k3 acc. to DIN 60 721-3
	Min-, 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
	Operating altitude	2000m
	Overvoltage category	III
	Degree of pollution	2

Mechanical data			
	Dimensions (HxDxW [mm])	KSM12-2/12-2A KSM12-2/12-2A(/4x)	= 100x115x112,5 = 100x115x90
	Weight (g)	KSM12-2/12-2A KSM12-2/12-2A(/4x)	= 520 = 620
	Mounting	To snap on top-hat rail	
	Number of T-bus		
	KSM12-2/KSM12-2A	5	
	KSM12-2/12-2A(/4x)	6	
	Min. terminal cross-section / AWG	0,2 mm² / 24	
	Max. terminal cross-section / AWG	2,5 mm² / 12	

(*)   maximum 2 encoder / axis
(****) Analogue electricity, voltage inputs are available as options
        For example: KSM12-2A-U   Voltage inputs
                        KSM12-2A-I   Electricity inputs
                        KSM12-2A   Voltage and electricity inputs

3.2.2 Central expansion modules

3.2.2.1   KSM31/31R

Type Designation	Device Design
	Design of module with the following periphery: 12 Digital inputs 10 Digital I/Os 2 Pulse outputs 2 Auxiliary outputs 8 Relay outputs (KSM31R) 12 status LEDs for inputs 10 Status-LEDs für I/O

Characteristics of the module:

- Pulse outputs for cross-shorting detection of digital input signals
- External contact monitoring of connected switchgear (EMU)
- Comprehensive diagnostics functions integrated
- Assembly on top hat rail
- KSM 31 – with a total of 10 I/O's
- KSM 31R – with a total of 8 relay outputs and only 2 I/Os.
- The mechanical structure of KSM31R differs from the figure. (see mechanical data)

Technical Characteristic Data KSM31/31R

Safety related characteristic data			
	PI acc. to EN ISO 13849-1		PL e
	PFH / architecture		9,2 FIT /Cat 4 [1] plus in KSM31R/31R-4 1-channel per Rel 20 FIT (max. 8) 2-channel per Rel 1,0 FIT (max. 4)
	$MTTF_d$		
		KSM31	213 years
		KSM31R	On request
	SIL acc. to IEC 61508		SIL 3
	Proof test interval		20 years = max. operating period
General data			
	Max. no. of expansion modules		-
	Interface for expansion modules		T-bus connector, pluggable in top-hat rail
	Number of safe digital inputs		12 (OSSD capable)
	Number of safe digital outputs		-
	Number of safe digital I/O		
		KSM31	10
		KSM31R	2
	Number of relay outputs		
		KSM31R	8
	Number of safe analogue inputs		-
	Number of auxiliary outputs		2
	Number of pulse outputs (pulse outputs)		2
	Type of connection		Plug-in terminals with spring or screw connection
	Axis monitoring		-
	Encoder interfaces (D-Sub / screw terminal)		-
	Encoder technology (See table encoder specifications)		-
Electrical data			
	Fuse	X11.1	min. 30 VDC; max. 3,15A
	Max. power consumption (logic)		2,4W
	Rated data digital inputs		24 VDC; 20 mA, Typ1 acc. to EN 61131-2
	Rated data digital outputs		
		Auxiliary outputs	24 VDC; 250mA
		Pulse outputs (pulse outputs)	24 VDC; 250mA
		Digital I/O	24 VDC; 250mA
	Rated data relays	Normally open — DC13 / AC15	24 VDC; 2A / 230 VAC; 2A
		Normally closed — DC13 (Read back contact)	24 VDC; 2A
	Rated data analogue inputs		-
Environmental data			
	Temperature		0°C … +50°C operation -25C° … +70C° storage and transport
	Class of protection		IP 20
	Climatic category		3k3 acc. to DIN 60 721-3
	Min-, 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
	Operating altitude		2000m
	Overvoltage category		III
	Degree of pollution		2
Mechanical data			
	Dimensions (HxDxW [mm])	KSM31 KSM31R	= 100x115x45 = 100x115x90
	Weight (g)	KSM31 KSM31R	= 300 = 680
	Mounting		To snap on top-hat rail
		KSM31	2
		KSM31R	4
	Min. terminal cross-section / AWG		0,2 mm² / 24
	Max. terminal cross-section / AWG		2,5 mm² / 12

[1] Value applies only for extension module. For a total assessment in accordance with EN ISO 13849-1 one must use a series connection with the corresponding basic device
=> $PFH_{logic} = PFH_{Basic} + PFH_{Extension}$

3.2.3 Communication Interface

3.2.3.1   KSM5x

Type Designation	Device Design
	Designs of the module with following peripherals: 1 KSM53 Profinet or KSM54 CANopen or KSM55 EtherCAT 1 backplane bus interface 1 status LED for operating status 1 status LED CAN- communication

Characteristics of the module:

- Communication modules CAN or PROFINET or CANopen or EtherCAT
- 2x 8 Byte PAA with free allocation
- 32 Bit PAE
- You can take detailed information from the installation manuals of the respective field bus modules.

Technical Characteristic Data KSM5x

Safety related characteristic data	
Pl acc. to EN ISO 13849-1	n.a.
PFH / architecture	n.a.
SIL acc. to IEC 61508	n.a.
Proof test interval	n.a.
General data	
Fieldbus interface	1
Type of connection	Standard acc. to field bus type
Max. size PAA	2x64 Bit
Max. size PAE	32 Bit
Type Update time for data	16 ms
Electrical data	
Power consumption	Max. 2,4W
Field bus ratings	Standard acc. to field bus type
Environmental data	
Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
Class of protection	IP 20
Climatic category	3k3 acc. to DIN 60 721-3
Min-, 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
Operating altitude	2000m
Overvoltage category	III
Degree of pollution	2
Mechanical data	
Dimensions (HxDxW [mm])	100x115x22,5
Weight (g)	110
Mounting	To snap on top-hat rail

3.2.3.2   KSM1x/4x

Type Designation	Device Design

KSM1x/43
KSM1x/45
 	
	Designs of the module with following peripherals:
	
	1 KSM1x/43 PROFISAFE over Profinet
	    or
	    KSM1x/45 FSoE FailSafe over EtherCAT
	1 status LED for operating status
	1 status LED internal SPI communication
	1 status LED field bus

Characteristics of the module:

- Communication modules PROFISAFE over PROFINET or FSoE FailSafe over EtherCAT
- You can take detailed information from the installation manuals of the respective field bus modules.

Note: This must be specified when ordering a base module!

Technical Characteristic Data KSM1x/4x

Safety related characteristic data	
Pl acc. to EN ISO 13849-1	n.a.
PFH / architecture	n.a.
SIL acc. to IEC 61508	n.a.
Proof test interval	n.a.
General data	
Fieldbus interface	1
Type of connection	Standard acc. to field bus type
Max. size PAA (standard)	2x64 Bit
Max. size PAE (standard)	32 Bit
Max. size PAA PAE (safe)	12 Byte
Type Update time for data	16 ms
Electrical data	
Power consumption	Max. 2,4W
Field bus ratings	Standard acc. to field bus type
Environmental data	
Temperature	0°C … +50°C operation -25C° … +70C° storage and transport
Class of protection	IP 20
Climatic category	3k3 acc. to DIN 60 721-3
Min-, 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
Operating altitude	2000m
Overvoltage category	III
Degree of pollution	2
Mechanical data	
Dimensions (HxDxW [mm])	100x115x22,5
Weight (g)	110
Mountion	To snap on top-hat rail

3.2.4 Encoder Specifications

Incremental TTL		
	Physical Layer	RS-422 compatible
	Measuring signal A/B	Track with 90-degree phase difference
	Max. frequency of input cycles (X31, X32 / X33, X34)	200 kHz / 500 kHz
	Type of connection	D-SUB 9pol
Sin / Cos		
	Physical Layer	RS-422 compatible
	Measuring signal A/B	Track with 90-degree phase difference
	Standard mode	
	Max. frequency of input cycles (X31, X32 / X33, X34)	200 kHz / 500 kHz
	High Resolution Mode	
	Max. frequency of input cycles (X33, X34)	15 kHz
	Type of connection	D-SUB 9pol
SSI-Absolut		
	Data interface	Serial Synchronous Interface (SSI) (SSI) with variable data length of 12 – 28 Bit
	Data format	Binary, grey code
	Physical Layer	RS-422 compatible
	SSI-Master operation:	
	Clock rate	150 kHz
	SSI-Listener- operation (slave mode)	
	Clock rate (X31, X32 / X33, X34)	250 kHz / 350 kHz
	Min. clock pause time	150 µsec
	Max. clock pause time	1 msec
	Type of connection	D-SUB 9pole
Resolver		
	Measuring signal	Sin/Cos – track with 90° phase difference
	Signal frequency	max. 600 Hz (900Hz Deep pass)
	Input voltage	max. 8 Vss (an 16 kΩ)
	Resolution:	9 Bit / pole
	Supported pole number	2 - 16
	Reference frequency (Listener)	4 kHz – 16 kHz
	Reference frequency (Master)	8 kHz
	Reference amplitude	8 Vss – 28 Vss
	Reference signal form	Sinusoidal, triangle
	Transformation ratio	2:1; 3:1; 4:1
	Phase fault	max. 8°
	Type of connection (X33, X34)	D-SUB 9pole
HTL		
	Signal level	24V / 0V
	Physical Layer	PUSH / PULL
	Type of connection (X27, X28, X29, X30)	Plug-in terminals with spring or screw connection
Proxi		
	Signal level	24V / 0V
	Max. counting pulse frequency (switching logic debounced)	10 kHz
	Pulse width	50 µsec
	Type of connection (X23)	Plug-in terminals with spring or screw connection
Proxi – Extended monitoring		
	Signal level	24V / 0V
	Max. counting pulse frequency (switching logic debounced)	4 kHz
	Physical Layer	PUSH / PULL
	Measuring signal A/B	Track with 90-degree phase difference
	Type of connection (X23)	Plug-in terminals with spring or screw connection

3.3 Identification

The type plate is located on the left side wall of the module and contains the following information:

3.3.1 Type Plate

Type designation
Part number
Serial number
Identification of hardware release
Identification of software release
Safety category
Input characteristics
Output characteristics
Date of manufacture (week/year)

Type plate KSM12-2 (image enlarged)

3.3.2 Scope of Delivery

The scope of delivery contains:

KSM module:
- Plug for all signal terminals without encoder connection

Not included in the scope of delivery:

- SafePLC configuration software CD with
  - Installation manual
  - Programming manual
  - Driver for programming adapter
- Programming adapter KSM91
- License key (USB-Dongle) for SafePLC/SafePLC2
- System CD with manuals
- Backplane bus plug SX0000-9 (KSM3x and and use of communication interfaces KSM5x)

4 Safety Related Characteristics

4.1 General Design, Safety Related Architecture and Characteristic Data

The inner structure of KSM series consist of two separate channels with reciprocal comparison of results.
High quality diagnoses for fault detection are made in each of the two channels.

With respect to architecture and function the internal structure corresponds with category 4 of EN 13849-1.
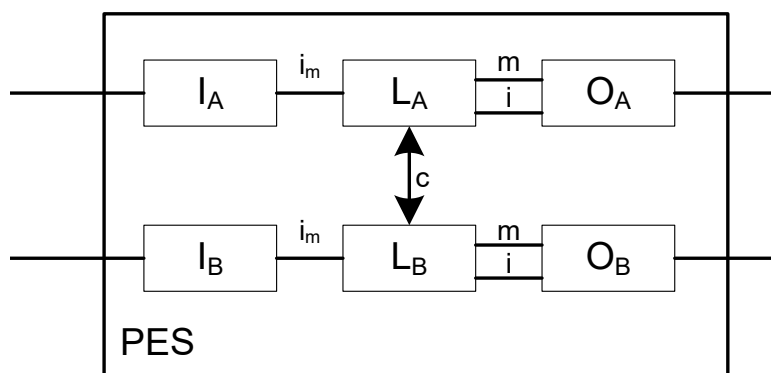
The overall architecture therefore corresponds with the following structure:
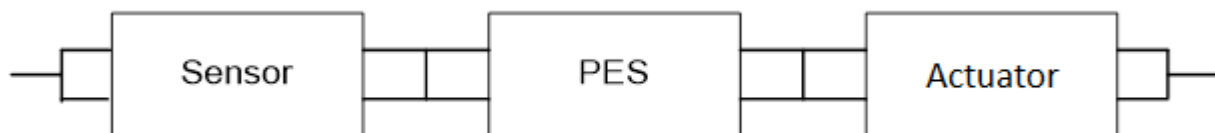
Dual reading of each input and diagnose by cross-comparison

The specific safety related characteristic data of the corresponding module can be taken from the technical characteristic data in chapter 3.

The characteristic data specified in chapter 3 (e.g. PI e and PFH-value acc. to table as evidence acc. to EN 13849) for the partial system PES can be used for the safety related assessment of the overall system.

Installation Manual

Characteristic Data:

Max. obtainable safety class	• SIL 3 acc. to IEC 61508 • Category 4 acc. to EN ISO 13849-1 • Performance-Level e acc. to EN ISO 13849-1	
System structure	System structure 2-channel with diagnose /1002) acc. to EN 61508 Architecture category 4 acc. to EN 13849	
Rating of operating mode	"high demand" acc. to EN 61508 (high demand rate)	
Probability of an endangering failure per hour (PFH-value)	KSM1x	PFH = 12,6 FIT
	KSM3x	PFH = 9,2 FIT
	KSMxR (1-channel)	PFH = 20 FIT
	KSMxR (2-channel)	PFH = 1,0 FIT
Specific values acc. to table "safety-technical characteristic data"	20 years, after this time the module must be replaced	
Proof-Test-Intervall (IEC 61508)		

⚠ **Safety Note:**
- The specific safety related characteristic data of the corresponding module can be taken from the technical characteristic data in chapter 3.
- When using several sensors with different functions (e.g. position indicator access door + speed detection) for a safety function (e.g. safe reduced speed when access door is open), these must be assumed as being connected in series for the safety related assessment of the overall system. See also exemplary calculation in appendix.
- The safety regulations and EMC-directives must be strictly followed.
- Concerning the applicable fault exclusions please refer to the tables under D in the appendix of EN ISO 13849-2.
- The characteristic data specified in chapter 3 for the partial system PES (e.g. PI e and PFH-value acc. to table as evidence acc. to EN ISO 13849-1) can be used for the safety related assessment of the overall system.

The following examples and their characteristic architecture are mainly responsible for the assignment to a category acc. to EN ISO 13849-1.

The maximum possible Performance Levels acc. to EN ISO 13849-1 resulting from this still depend on the following factors of the external components:
- Structure (simple or redundant)
- Detection of common cause faults (CCF)
- Degree of diagnostic coverage on request (DC_{avg})
- Mean time to dangerous failure of a channel ($MTTF_d$)

4.2 Safety Related Characteristic Data and Wiring for the Connected Sensors

The KSM modules have completely separated signal processing paths for each safety input. This applies for both the digital and the analog inputs. Furthermore, measures for achieving the highest possible DC-values have been implemented.

4.2.1 Digital Sensors:

Digital inputs and outputs are generally of a completely redundant design, except the electromagnetic input terminal. The following list contains details for classification, the DC and the achievable PI or SIL.

4.2.1.1 Characteristics of Sensors / Input Elements
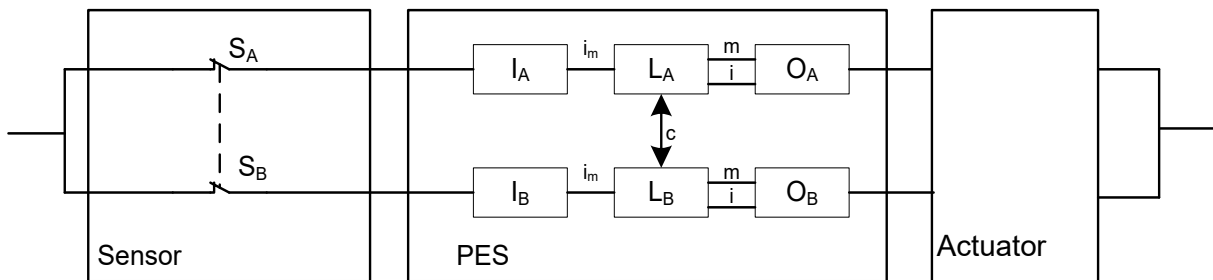
Two-channel input element in parallel connection (Cat. fault tolerance 1) with high DC caused by signal in two channels and diagnose by means of cross-comparison in the PES
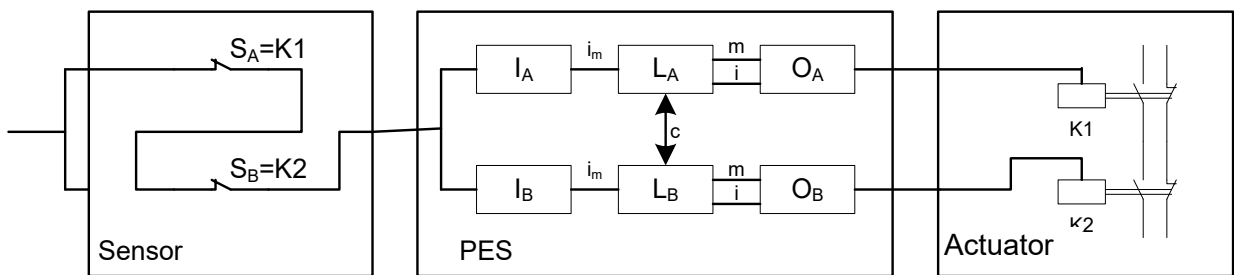
Two-channel input element in series connection (Cat. 4, fault tolerance 1) with low to medium DC caused by signal processing in two channels and diagnose by means of cyclic testing
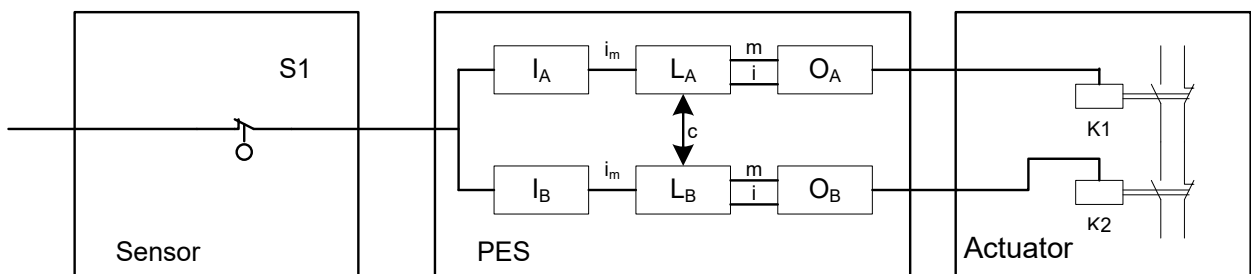
Single channel input element and dual channel processing with low to medium DC by signal processing in two channels and diagnose by means of cyclic testing, PI / SIL depending on permissible fault exclusions and test rate for input element.

4.2.1.2 DC Digital Sensors / Inputs

The KSM modules ensure far reaching diagnostics functions for the input element. These are carried out permanently, or optionally (cross-shorting monitoring by means of pulse identifier, cross-comparison, 2- or multi-channel sensor with/without time-out, start-up test).

Permanently active diagnostics functions:

Cross-comparison:
KSM module inputs are in general internally designed with two channels. The status of input signals is permanently compared crosswise. Only with High signals in both partial input systems the input is considered a High input, should the signal level deviate between both channels, the input is set to Low state.

Dynamic test of the partial input system switching threshold:
The switching thresholds for detecting the High level are tested cyclically with a high cycle rate. Falling below the defined threshold value a module triggers a module alarm.

Dynamic test of the input system's switchability:
The switchability of the input system to Low level is tested for all inputs with a high rate, except I05—I08. Falling below the defined threshold value a module triggers a module alarm.

Diagnostics functions to be activated by parameterization:

Cross-shorting test:
The KSM modules have pulse signal outputs, identified by an unambiguous signature. When performing the cross-shorting test the switching elements of the digital sensors / input elements are supplied with auxiliary voltage by the KSM-module via the pulse signal outputs. The signature is thus stamped on the High signal level of the sensors / input elements and checked by the KSM module. With the signature test short-circuits and cross-shorting to High signals can be recognized. With alternating use of the pulse signals of multi-contacts, parallel signal lines or adjacent terminal assignment, cross-shorting between the respective input elements is detected.

Sensors / input elements with 2- or multi-pole contacts without time-out.
Several contacts can be assigned to the sensors / input elements. These are therefore compatible with at least 2-channel elements. A High level of the sensor/input element requires a logic series connection of both contacts.
Example 1:
Input element with 2 normally closed contacts: High level when both contacts are closed.
Example 2:
Input element with 1 normally closed and 1 normally open contact: High level when normally open contact is actuated, and normally closed contact is not actuated.

Sensors / input elements with 2- or multi-pole contacts with time-out.
Same test as before, but additional monitoring of the input signals for compliance with the defined level connections within a time window of 0.5 seconds. Defining the levels over a time of > 0.5 seconds triggers a module alarm.

Start test:

Each time the safety module (=KSM module) is switched on, the input element must be tested in direction of the Low signal status (defined Safe State), e.g. by actuating the Emergency Stop button or a door lock after the system has been started.

Operational / organizational tests:
Apart from the previously mentioned diagnostic measures for the KSM modules, cyclic testing can be performed within the application. These tests can also be used when assessing the DC.

Note:
Operational/organizational tests can also be used for a combination of hardware inputs and functional inputs (input information transferred via standard field bus). However, an exclusive use of functional inputs is ruled out in this context (combination of two or more functional inputs).

The KSM modules therefore ensure far reaching diagnostics functions for the partial input system. These are performed permanently or optionally (cross-shorting monitoring by means of pulse identifier).

The following diagnoses for input sensors can generally be used for the safety related assessment of the entire system:

Input Element Characteristic	Parameterized / Operational Tests				DC	Definition of Measure	Note
	Cross-shorting test	With time-out	Start test	Cyclic test during operation			
Single-channel			O	O	>60	Cyclic test pulse by dynamic change of input signals	A sufficiently high-test rate must be ensured.
	X				90	Cyclic test pulse by dynamic change of input signals	Only effective if pulse assignment is active
	X		O	O	90-99	Cyclic test pulse by dynamic change of input signals	DC depending on frequency of start / cyclic test DC = 90 test only in > 4-week intervals DC = 99 test at least 1 x day / or 100-time request rate
Dual channel					90	Cross-comparison of input signals with dynamic test, if short-circuits cannot be detected (for multiple inputs/outputs)	For fault exclusion short-circuit up to DC=99 possible
			O	O	90-99	Cyclic test pulse by dynamic change of input signals	DC depending on frequency of start / cyclic test
	X				99	Cross-comparison of input signals with immediate and intermediate results in the logic (L) and temporal as well as logic program sequence monitoring and detection of static failures and short circuits (for multiple inputs/outputs).	Only effective if pulse assignment is active
		X			99	Plausibility test, e.g. use of normally open and normally closed contacts = non-equivalent signal comparison of input elements.	Only effective in connection with activated time-out function for input element

⚠️ **Safety Note:**
- The manufacturer's data (MTTFD, FIT numbers, etc.) must be used for a safety related assessment of the partial system "Sensors".
- The DC-values listed in the table must be used conservatively and compliance with the boundary conditions (see table under "Remarks") must be ensured.
- According to the applicable standards, fault exclusions are permitted. The boundary conditions mentioned in this context must permanently be met.
- If several sensor systems are required for the correct function of a single safety function, their partial values must be correctly merged by following the chosen method.

4.2.1.3 Classification of Digital Inputs

4.2.1.3.1 Digital Inputs DI01 … DI14

Digital Inputs	Achievable Performance Level	Comment
DI01 … DI04 DI09 … DI14	PL e	Suitable for any kind of input elements, with / without pulse, achievable PI depending on the MTTFd of the input element, as well as fault exclusions in the external wiring.
DI05 … DI08	PL e	Single-channel with pulse: - Mainly High level required ($T_{High} > 100 * T_{Low}$) - At least one request/day required by application - Fault detection upon request
	PL d	Single-channel without pulse: - Fault exclusion short-circuit between signals and to VCC - Fault detection upon request
	PL e	Dual channel: - At least one request/day required by application - Fault detection upon request

4.2.1.3.2 Digital Inputs I/O's (EAEx)

Digital Inputs	Achievable Performance Level	Comment
EAEx		Without pulse, single channel static signal -> auxiliary input
	PL e	Without pulse, dual channel static signal - At least one request/day required by application - Fault detection only upon request
	PL d	Without pulse, dual channel static signal - Less than one request/day required by application
	PL e	Single-channel with pulse - Mainly High level required ($T_{High} > 100 * T_{Low}$) - At least one request/day required by application - Fault detection only upon request
	PL d	Single-channel with pulse - Less than one request/day
	PL e	Dual channel with pulse1 and pulse2

Note:
The achievable PI for a combination of HW-inputs and functional inputs depends on the chosen operational/organizational tests as well as on the independence of both channels in the system structure. The determination of the PI requires an application related analysis.

4.2.1.4 Exemplary Connections of Digital Sensors

4.2.1.4.1 Single-channel sensor, without cross-shorting test
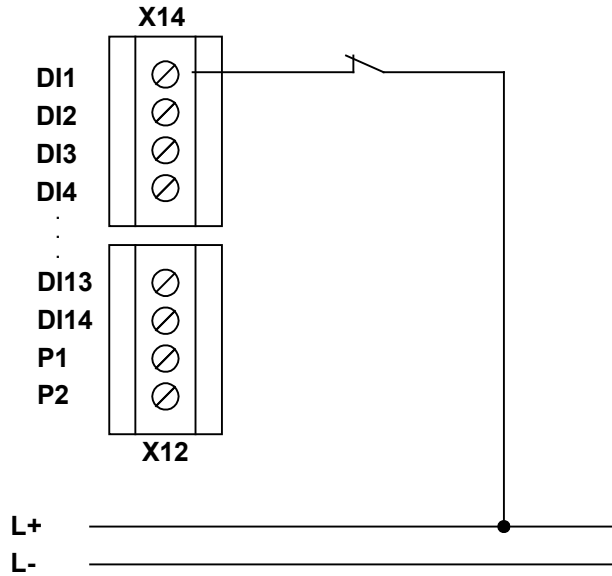

Fig.: Single-channel sensor, without cross-shorting test

The single-channel sensor is connected to the KSM without clocking or without cross-shorting test. This design is not recommended for safety applications. PI b acc. to EN ISO 13849-1 can maximally be reached.
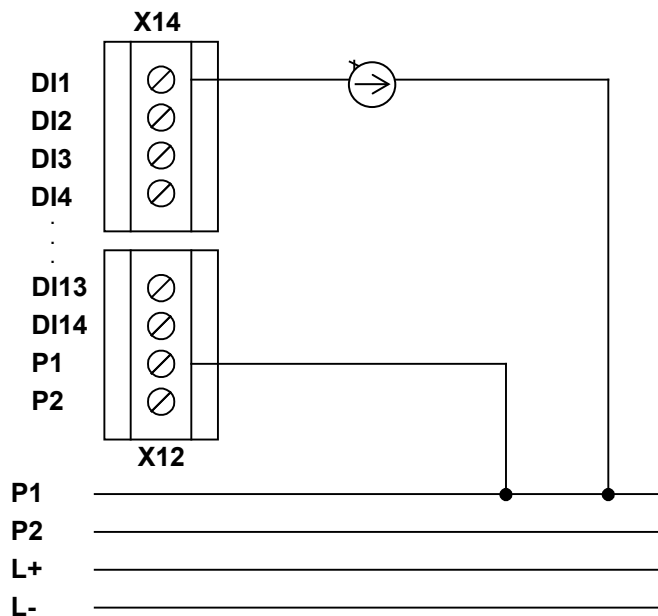
4.2.1.4.2 Single-channel sensor with cross-shorting test

Fig.: Single-channel sensor with cycling

When using a single-channel sensor with clocking, the power supply of the switching element is attached to the clock exit P1 or P2. The clock must subsequently be assigned to the KSM.

The use of a single-channel sensor with clock detects:

short-circuit to supply voltage DC 24 V
short-circuit to DC 0 V
cable interruption (current interruption is safe state!)

However, be cautious in case of a cable short between the two sensor connections, because this is not detected! A short-circuit between P1 and DI01.

Due to the single-channel character of the switching element / sensor its failure requires a fault exclusion. This is permissible when using positively disconnecting switches with correct constrained actuation.

A series connection of 2 switching elements with corresponding fault exclusion of a double fault is on equal footing with the application (Occurrence of two errors at the same time. These may be e.g. the safety outputs of an electronic monitoring device (light curtain, switching mat) with internal dual-channel switch-off.

PI d acc. to EN ISO 13849-1 can be achieved by using a suitable switching element and with cautious wiring of the sensor. In special cases, i.e. in connection with suitable switching elements and permissible fault exclusions one may also achieve PL e as per EN ISO 13849-1.

⚠ **Safety Note:**
- PI e or higher acc. to EN ISO 13849-1 is achieved if the short-circuit between input and associated pulse output as well as the short-circuit between the sensor connections can be excluded. Here one must take care that in a fault scenario the switch must be positively opening in accordance with EN 60947-5-1. The sensor must additionally be triggered in regular intervals and the safety function requested. Fault exclusions can be achieved in accordance with EN ISO 13849-2 table D8. In case of single-channel use of the inputs, the achievable safety level must be limited to SIL 2 or PL d, if the safety function is demanded at regular intervals.
- A series connection of 2 switching elements with fault exclusion for double fault requires testing of the suitability in accordance with the intended safety level of this element. We would like to draw your attention to the applicable regulations in the EC machine directive 2006/42/EC.
- For single-channel sensors a safety related use of the inputs is only intended in connection with the pulse outputs.

4.2.1.4.3 Dual-channel sensor without timeout with cross-shorting test

Faults are at least detected when requested. The DC is medium and by using cyclic tests (start test, operational/organizational tests) can be changed up to high level. depending on the test frequency.

Only normally closed contacts should be used for safety related applications.

PI d acc. to EN 13849-1 can be achieved when using sensors / switching elements with fault exclusion for not opening the switch contacts. This is permissible when using positively disconnecting switches with correct constrained actuation. The use of sensors with self-monitoring output contacts is also permitted.

PI e in accordance with EN ISO 13849-1 can be achieved when using sensors / input elements with sufficiently high MTTFd in connection with temporal plausibility monitoring and a sufficiently high change of the switching state = dynamic testing.
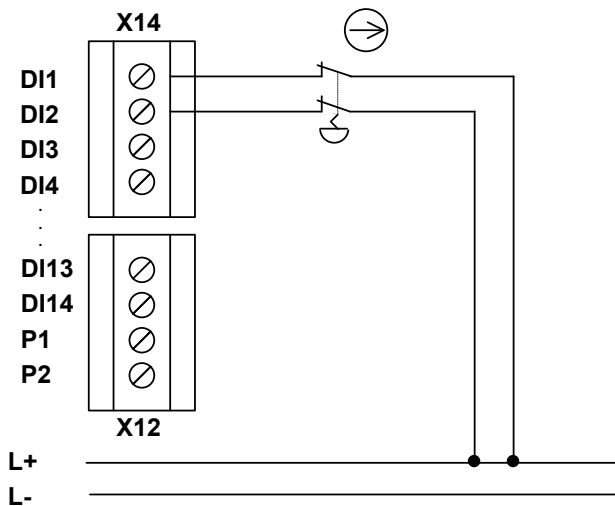

Figure: dual-channel sensor homogeneous without pulses, with positive disconnection
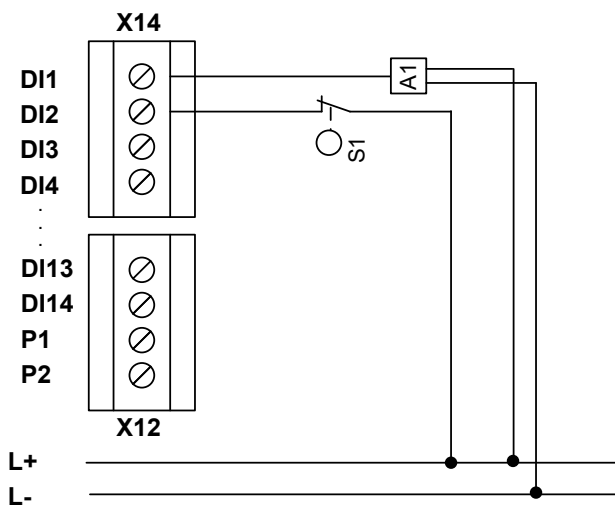
Figure: dual-channel input element heterogeneous, without pulses

⚠️ **Safety Note:**
- PI d or higher in accordance with EN ISO 13849-1 is achieved by using switching elements / sensors with positively opening contacts or positive actuation acc. to EN 60947-5-1
- Using devices for which the fault exclusion double fault for the intended safety level can be specified for the switching elements, is permitted. We would like to draw your attention to the applicable regulations in the EC machine directive 2006/42/EC.

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4.2.1.4.4 Dual-channel sensor with time-out and cross-shorting test

Cross-shorting as well as connections to DC 24 V and DC 0 V can be detected by using two independent pulse signals on the homogeneous sensor.

PI d or higher acc. to EN ISO 13849-1 can be achieved when:

- Use of sensors/switching elements with forced actuation.
- Use of 2 sensors/switching elements with independent manipulation
- dto. However, with actuation by a common actuation device in connection with an error exclusion for this device.
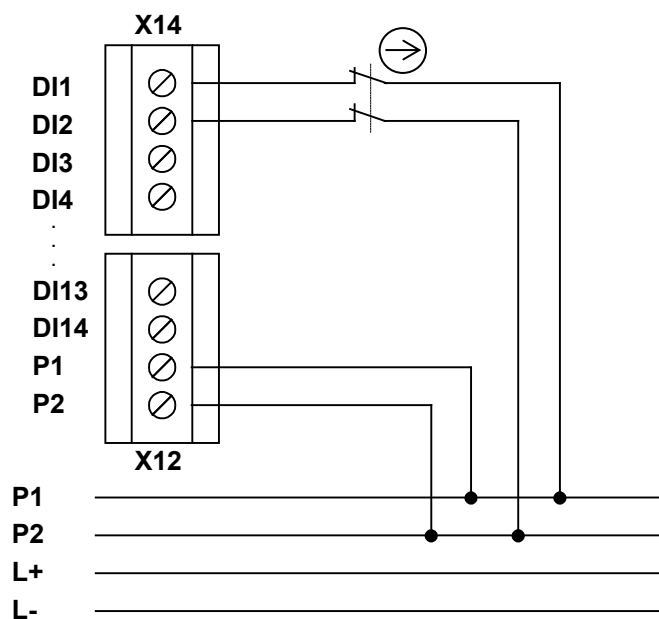
Figure: two-channel sensor, homogeneous with pulses

⚠ **Safety Note:**
- PI d or higher in accordance with EN ISO 13849-1 is achieved by using switching elements / sensors with positively actuation
- When using two independent sensors with independent actuation, PI d or higher acc. to EN ISO 13849-1 can be achieved.
- When using common elements in the actuation chain, a fault exclusion is required for this purpose. The corresponding limitations and criteria acc. to EN 13849-1 must be observed.

4.2.1.5 Overview of achievable PI for digital safety inputs

Type of Sensors / Input Element	Input	Parameterized / operational tests				Achievable PI acc. to EN ISO 13849-1	Fault exclusion for input element	Condition for input element
		Cross-shorting test	With time-out	Start test	Cyclic test during operation			
Single-channel	DI01..DI14					b		Operation proven input element
				O	O	d	All faults at the input element Short-circuit at input/signal line	$MTTF_D$ = high Connection in control cabinet or protected routing
	DI01..DI04 DI09..DI14					e	All faults at the input element Short-circuit at input/signal line	Input element does not comply with min. PIr Connection in control cabinet or protected routing
	all	X				d	Getting caught Short-circuit at input/signal line	Mainly High level required (THigh > 100 * TLow). Positively disconnecting MTTFD = high Connection in control cabinet or protected routing
		X		O	O	e	All faults at the input element Short-circuit at input/signal line	Input element does not comply with min. PIr Connection in control cabinet or protected routing $MTTF_D$ = high
Dual-channel parallel	all					d	Short-circuit between input/signal line	Connection in control cabinet or protected routing $MTTF_D$ = medium
		X				e		$MTTF_D$ = high
Dual-channel parallel	all		X			e	Short-circuit between input/signal line (only with common switching elements = 2xNO or 2xNC)	Connection in control cabinet or protected routing $MTTF_D$ = high

Type of Sensors / Input Element	Input	Parameterized / operational tests				Achievable PI acc. to EN ISO 13849-1	Fault exclusion for input element	Condition for input element
		Cross-shorting test	With time-out	Start test	Cyclic test during operation			
Two-channel serial	DI01..DI04 DI09..DI14					d	Short-circuit at input/signal line Getting caught / positively disconnecting	Connection in control cabinet or protected routing $MTTF_D$ = medium
				O	O	e	Short-circuit at input/signal line	Connection in control cabinet or protected routing $MTTF_D$ = high
	all			O	O	d	Short-circuit at input/signal line	Connection in control cabinet or protected routing $MTTF_D$ = medium
		X		O	O	e		$MTTF_D$ = high

X: Diagnostic measure activated
O: min. 1 diagnostic measure activated

### 4.2.2 Sensors for Speed and/or Position Detection

4.2.2.1 General safety related structure of the sensor interface for position and/or speed

The base modules of the KSM series can be optionally equipped with one (KSM11/12), or two encoder interfaces (KSM11-2/12-2) per axis.

Depending on encoder type and combination, different safety levels can be reached. The following system reflection results for the corresponding partial system:
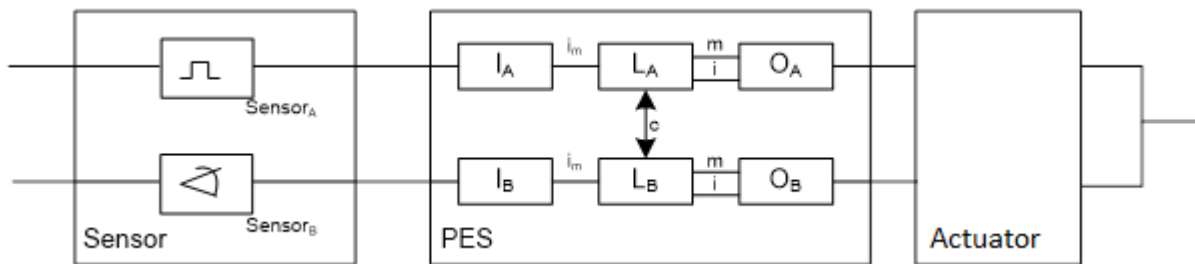
Dual sensor system with separate signal processing in two channels, diagnose by cross-comparison in the PES
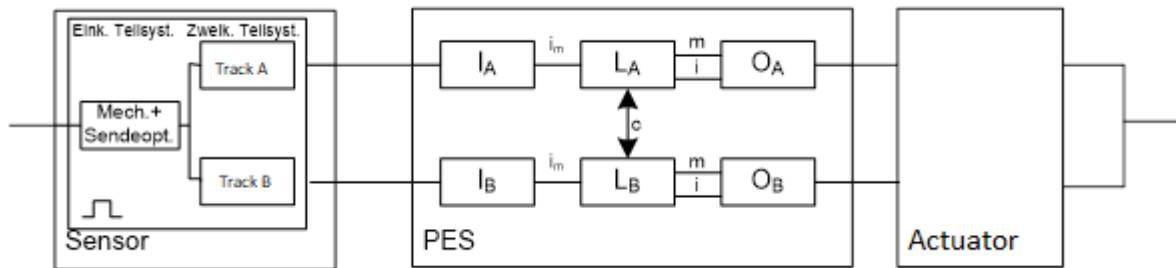
Sensor system with single and dual-channel partial system (example incremental encoder). Diagnose by separate signal processing in two channels and cross-comparison in the PES as well as further specific diagnoses.

4.2.2.2   General diagnostic measures for encoder interface

For fault detection in the sensor system the KSM series has several diagnostic measures implemented, depending on the chosen encoder type or its combination. These are automatically activated when choosing the encoder type.

With respect to their type and effectiveness diagnostic measures can generally be classified using the following table:

Diagnoses for sensors for position and/or speed detection:

Measure	DC	Note	Use
Cross-comparison of input signals with immediate and intermediate results in the logic (L) and temporal as well as logic program sequence monitoring and detection of static failures and short circuits (for multiple inputs/outputs).	99	Only to be used for: - dual-channel sensor systems (2 separate sensors), - the dual channel partial system of single channel sensors (incremental encoder) - Diagnosis for the single and dual channel partial system of specific suitable sensor systems (SIN/COS-encoder, resolver) - Dynamic operation / no standstill monitoring	Monitoring of 2-channel sensor systems or the corresponding partial system of sensors 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 condition, i.e. standstill or movement, as well as on the quality of the monitoring measure (80 – 90 % for incremental encoder, 95 % for SIN/COS-encoder)	Monitoring of 2-channel sensor systems or the corresponding partial system of sensors for non-dynamic operation To be used especially for standstill monitoring!
Monitoring of some features of the sensor (response time, the area of analog signals, e.g. electric resistance, capacity)	60	Diagnose of specific features of sensors, only to be used for speed and position sensors as per chapter 4.3.	Monitoring of the single-channel partial system in single-channel sensor systems

4.2.2.3 Encoder types and their combination, diagnostic data

Encoder A	Encoder B	Safe Speed	Safe Direction	Safe Absolute Position	Fault Exclusion	DC		
						1-Channel Partial System	2-Channel Partial System Dynamic	2-Channel Partial System Non-dynamic (standstill monitoring)
1 x Proxi	1 x Proxi	X			actuating actor ***)	n.a.	99%	80-90%
Incremental	NC	X			mechanical. encoder connection*) code disc attachment **)	60%	99%	80-90%
Incremental	Incremental	X	X			n.a.	99%	95%
Incremental	1 x Proxi	X				n.a.	99%	90-95%
Incremental	2 x counter Proxi 90°	X	X			n.a.	99%	90-95%
Incremental	SIN/COS	X	X			n.a.	99%	99%
Incremental	HTL	X	X			n.a.	99%	90-95%
Incremental	Resolver	X	X			n.a.	99%	99%
Incremental	SSI	X	X	X		n.a.	99%	90-95%
SIN/COS	NC	X	X		mechanical encoder connection *) Code disc attachment **)	90%	99%	90-95%
SIN/COS	Incremental	X	X			n.a.	99%	95-99%
SIN/COS	1 x Proxi	X	X			n.a.	99%	90-95%
SIN/COS	2 x counter Proxi 90°	X	X			n.a.	99%	95-99%
SIN/COS	HTL	X	X			n.a.	99%	95-99%
SIN/COS	Resolver	X	X			n.a.	99%	99%
SIN/COS	SSI	X	X	X		n.a.	99%	95-99%
SSI	2 x counter Proxi 90°	X	X	X		n.a.	99%	90-95%
SSI	SIN/COS	X	X	X		n.a.	99%	95-99%
SSI	Resolver	X	X	X		n.a.	99%	95-99%
SSI	SSI	X	X	X		n.a.	99%	90-95%
NC	SIN/COS	X	X		mechanical encoder connection *) Code disc attachment **)	60% /90% *) **)	99%	90-95%
NC	Resolver	X	X		mechanical encoder connection *) Code disc attachment **)	60% /90% *) **)	99%	90-95%

Encoder A	Encoder B	Safe Speed	Safe Direction	Safe Absolute Position	Fault Exclusion	DC		
						1-Channel Partial System	2-Channel Partial System Dynamic	2-Channel Partial System Non-dynamic (standstill monitoring)
NC	HTL	X			mechanical encoder connection *) Code disc attachment **)	60%	99%	80-90%
2 x counter Proxi 90°	SSI	X	X	X		n.a.	99%	90-95%

*) For the mechanical connection a fault exclusion can be made with the note „ for shaft-hub connection of the encoder axis only positive(-locking) / form-locked connections are permissible, alternatively other connection forms can be used if they meet the safety requirements. For the reliability of the connection forms in relation to the desired safety level, a comprehensible proof (e.g. oversizing in case of a positive shaft-hub connection) must be provided in any case. The corresponding notes on fault exclusion in standard EN/IEC 61800-5-2, Appendix D.3.16 (Table D.8) must be observed."

SINCOS encoders suitable for safety applications (see notes on this under ...), a DC of 90% can be applied for the single-channel transmission LED.

**) The connection code disc / shaft as well as the sensor embodiment must be analysed in detail. For a possible fault exclusion, the relevant notes in the standard EN/IEC 61800-5-2, Appendix D.3.16 (Table D.8) must be observed.

***) For speed measurement by means of proxies, the actuating actuator and the mounting of the proxi must be analysed with regard to their reliability. For a possible fault exclusion, the relevant notes in the standard EN/IEC 61800-5-2, Annex D.3.16 (Table D.8) are to be applied analogously.

Other single-channel parts to which the 60% applies:
Power supply
Code disk mounting
Mechanics of the opto-receivers (not SINCOS)
Code disk

4.2.2.4 Specific diagnostic measures with regard to the encoder type used

Interface	Encoder type	Supply voltage monitoring	Difference level monitoring	SIN/COS plausibility monitoring	Signal level input monitoring	Monitoring of the permissible quadrants	Monitoring of the counting signal separated for track A/B	Monitoring of the transfer ratio reference signal / measured signal	Frequency monitoring of the reference signal	Voltage monitoring of the reference signal	Form factor analysis of the measured signal	Plausibility test position signal versus speed	Monitoring of Clk-frequency
Interface X 31/32, X23	Incremental	X	X				X						
	SIN/COS	X		X									
	SSI	X	X										
	Proxi 2 x counting input	X											
	Proxi 2 x counting input	X											
Interface X 33/34	Incremental	X	X		X		X						
	HTL		X		X								
	Resolver			X		X		X	X	X	X		
	SIN_COS	X		X		X¹⁾							
	SSI	X	X									X	X

¹⁾ Only in High-Resolution Mode

4.2.2.5 Safety relevant cut-off thresholds encoder systems for position and speed detection

Plausibility tests with the current position and speed values are performed between both measuring channels A and B of the KSM module as a basic measure, which are then checked against parameterizable thresholds.

The *incremental shut-down threshold* describes the tolerable deviation of position between both sensing channels A and B in the unit of the measuring distance.

The *speed shut-down threshold* describes the tolerable deviation in speed between both sensing channels A and B.

Diagnostic functions for the determination of optimal parameter values for the applications are available within the SCOPE-dialog of the parameterization tool.

Note:
Speed and acceleration are detected values with a minimal digital resolution.
This fact limits the smallest possible detection of speed or acceleration and determines the digital step width for the input values.

Speed resolution:

Up to a frequency of 500 Hz or 500 steps/s speed is detected with the frequency measuring method, below this it is measured with a time measuring method. This results in the following course of the sensing fault:
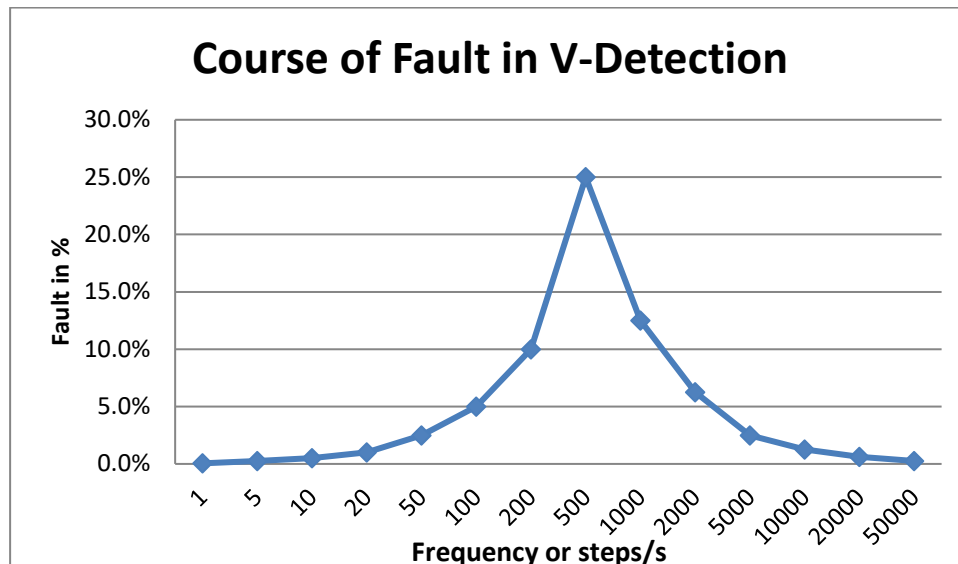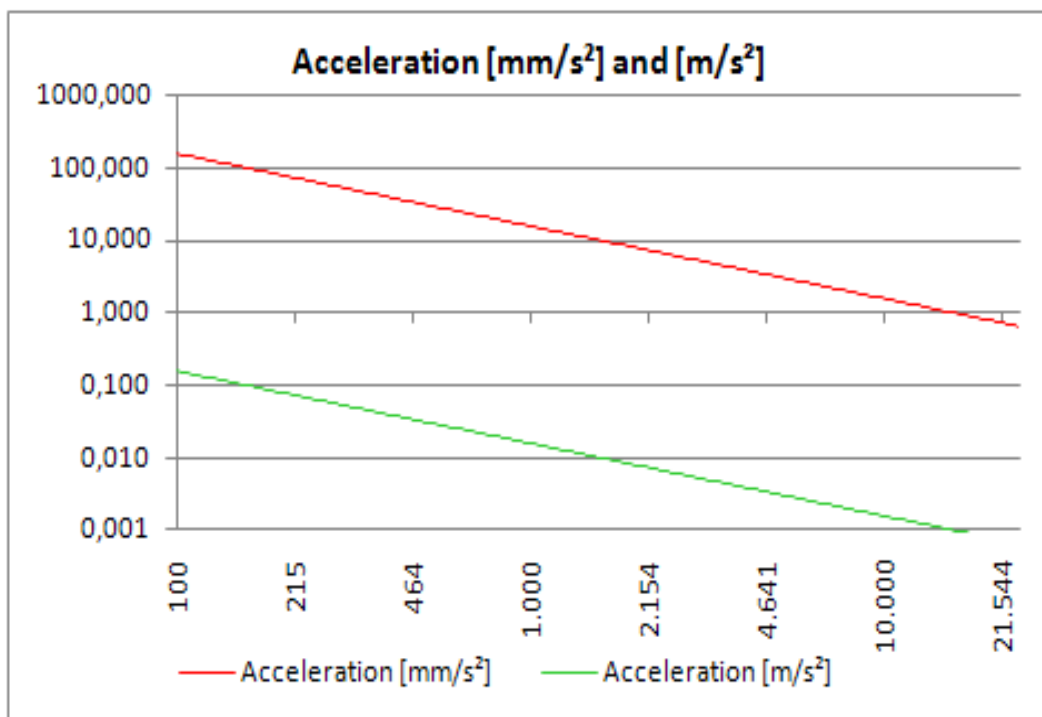

The digital acceleration resolution is limited by a maximum peak time of 256 ms and the encoder resolution. The graphs below show the lowest measurable acceleration in dependence on the resolution in revolutions/min, mm/s² and m/s².
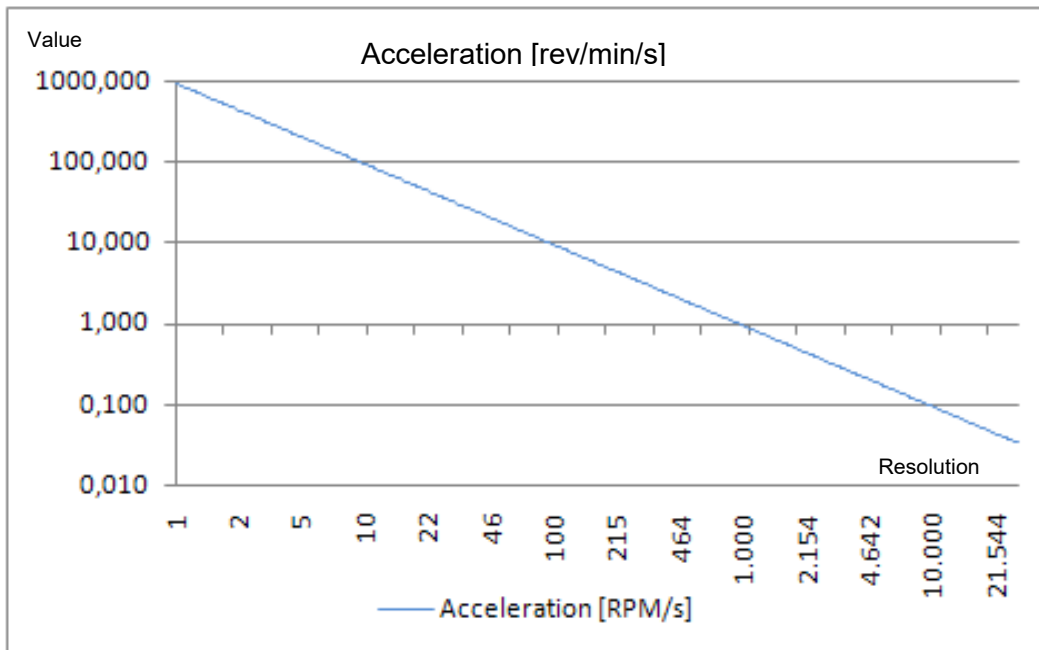
Graph acceleration, rotary (Values in rev/min/s)

Graph acceleration, linear (Values in mm/s and m/s²)

⚠ **Safety Note:**
- The fault can be optimized by choosing a suitable sensor resolution for the corresponding application.

- For applications with limited resolution and/or time variance of the sensing signal, the functional performance of the monitoring function used can be improved by using an

Auflösung

average filter. The average filter "smoothes" digital spurious components of the sensors. However, this is achieved at the cost of a longer response time of the overall system.

- The filter time can be variably set between 0 and 64 in steps of 8. The dimension is "msec". In order to determine the response time of the overall system, the filter times must be added to the specified response times of the KSM systems (see chapter 11).

⚠ **Safety Note:**
- The manufacturer's data ($MTTF_D$, FIT numbers, etc.) must be used for a safety related assessment of the partial system "Sensors".
- If the manufacturer demands specific diagnoses to be able to guarantee the specified safety related characteristic values, these must be checked with respect to the specific encoder as specified in the table "Specific diagnostic measures for position and speed sensors". If in doubt, the matter must be clarified by the manufacturer.
- The DC-values listed in the table must be used conservatively and compliance with the boundary conditions (see table under "Remarks") must be ensured.
- In order to determine the DC-value for safety functions with standstill monitoring a frequency assessment of the dynamic status may be required. A DC of 90 % may here be used a s a guide value.
- According to the applicable standards, fault exclusions are permitted. The boundary conditions mentioned in this context must permanently be met.
- If several sensor systems are required for the correct function of a single safety function, their partial values must be correctly merged by following the chosen method. This applies also for a combination of digital and analog sensors (e.g. safely reduced speed with open safety door = door contact + encoder for speed detection)
- By choosing a suitable resolution of the sensor system a sufficiently low tolerance with regard to the corresponding cut-off thresholds for the individual safety functions must be ensured.
- When using the encoder input filter, one must consider the extension of the response time when assessing the safety related function.

4.2.2.6 Safety related assessment of encoder types or their combination

Due to the monitoring functions implemented in the KSM-series, no special demands are initially made on the internal design of the encoder electronics in applications with encoder systems, i.e. standard encoders can normally be used.

A safety related assessment of the overall arrangement must generally be made. Data issued by the encoder manufacturer (FIT, MTTF) as well as the DC from the table in chapter "4.2.2.2 General diagnostic measures for encoder interface" must in this case be used.

When using individual encoders at least a fault exclusion for the mechanical actuating chain, as well as for the single-channel part of must be made under due consideration of the applicable specification in EN ISO 13849-1. Furthermore, the information in "4.2.2 Sensors for Speed and/or Position Detection" must also be observed.

PI d and higher acc. to EN ISO13849-1 is normally reached by a combination of two encoders with prioritized different technology and separated mechanical linking.

The use of compact encoders with internal 2-channel structure of different technology is also suitable for applications up to PI e acc. to EN 13849-1, however, under due consideration of the specifically required fault exclusions and their permissibility. Normally one should use encoders with proven safety related characteristics, the safety level of which meets the demanded level.

⚠ **Safety Note:**

- They use of standard encoders or a combination of standard encoders is permitted. A safety-related evaluation is strictly required for the overall arrangement consisting of encoders, sensors/switching elements for triggering the safety function, the KSM module and the shutdown channel. To determine the safety level achieved, the manufacturer's specifications (FIT, MTTF) and the DC must be used in accordance with the requirements in "4.2.2".
- If only one encoder is used, the fault exclusion "shaft breakage / fault in the mechanical encoder connection" is required. Suitable measures must be applied for this purpose, e.g. a positive connection of the encoder by means of slot shim or locking pin. The applicable information issued by the manufacturer as well as EN ISO 138549-1 with respect to requirements and permissibility of the fault exclusion must strictly be followed.
- Encoders with proven safety related characteristics must preferably be used as individual encoders. The safety level of these encoders must at least meet the intended safety level of the overall arrangement. The information of the manufacturer with respect to diagnostic measures, mechanical connection and measures for the voltage supply must be strictly followed.
- SIN/COS encoder: The internal structure of the sensor system must be designed in such a way, that output signals for both tracks can be generated independently from each other and Common-Cause faults can be ruled out. Evidence of the mechanical design, e.g. fastening of the code disc on the shaft, must also be provided. Encoders with proven safety related characteristics should preferably be used.
- When using compact encoders with internal dual-channel structure, such as e.g. SSI + incremental/SinCos, you must strictly follow the instructions of the manufacturer concerning safety related characteristics, diagnostic measures, mechanical connection and measures concerning the electric power supply. The safety level of the encoder must at least meet the intended safety level of the overall arrangement. Encoders with proven safety related characteristics should preferably be used.

The KSM module generally detects the following faults in the external encoder system:

- Short-circuits between safety relevant signal lines
- Interruptions in safety relevant signal lines
- Stuck at 0 or 1 on one or all safety relevant signal lines

Each encoder type has further specific diagnoses for fault detection in the external encoder system assigned. The following list sows the respective diagnostic measures for the individual encoders, together with the limiting parameters.

⚠ **Safety Note:**
- The diagnostic measures obviously have tolerances because of measuring inaccuracies. These tolerances must be accounted for in the safety related assessment.
- The limiting values for the corresponding diagnostic measures are partly parametrizable or fixed. The diagnostic coverages resulting from this must be assessed in relation to the application and included in the safety related overall assessment.

4.2.3   Analog Sensors

The basic modules KSM10A, KSM12A, KSM12-2A have two analog inputs with two input channels each. Only 2-channel sensors can generally be connected to this interface.

The internal signal processing takes place separately in the two channels with cross-comparison of the results.
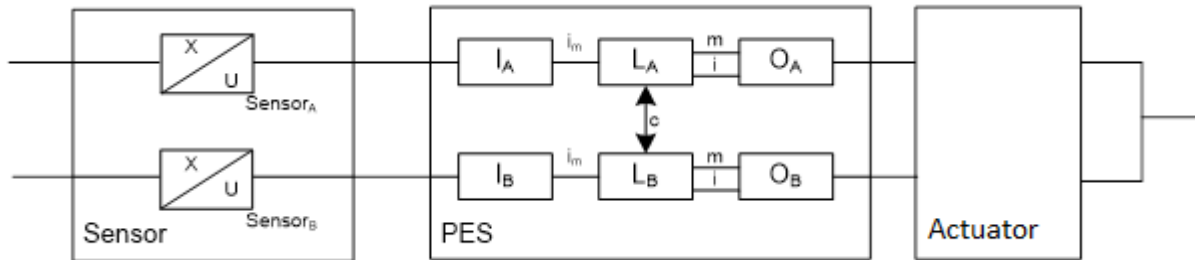
Dual-channel sensor system with separate signal processing in two channels, diagnose by cross-comparison in the PES

As with other sensor systems, a vast number of diagnostic measures has been implemented.

With respect to their type and effectiveness diagnostic measures can generally be classified using the following table:

Diagnoses for sensors for position and/or speed detection:

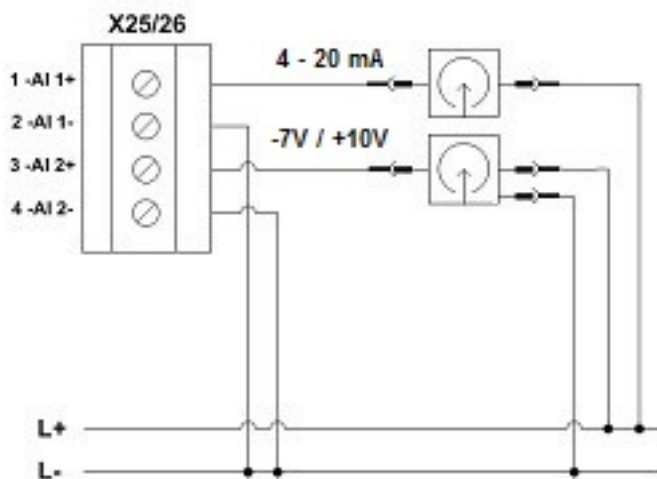| Measure	DC	Note	Use
Cross-comparison of input signals with dynamic test, if short-circuits cannot be detected (for multiple inputs/outputs)	90	Comparison of the analog input values with identical characteristics for both channels	Monitoring of dual-channel systems with identical characteristic of the input signals
Cross-comparison of input signals with immediate and intermediate results in the logic (L) and temporal as well as logic program sequence monitoring and detection of static failures and short circuits (for multiple inputs/outputs).	99	Comparison of the analog input values with diverse characteristic for both channels. E.g. inverse signal course, etc.	Monitoring of dual-channel systems with diverse characteristic of the input signals

Safety Note:

- The manufacturer's data (MTTF$_D$, FIT numbers, etc.) must be used for a safety related assessment of the partial system "Sensors".
- The DC-values listed in the table must be used conservatively and compliance with the boundary conditions (see table under "Remarks") must be ensured.
- According to the applicable standards, fault exclusions are permitted. The boundary conditions mentioned in this context must permanently be met.
- If several sensor systems are required for the correct function of a single safety function, their partial values must be correctly merged by following the chosen method. This applies also for a combination of digital and analog sensors (e.g. safely reduced speed with open safety door = door contact + encoder for speed detection)

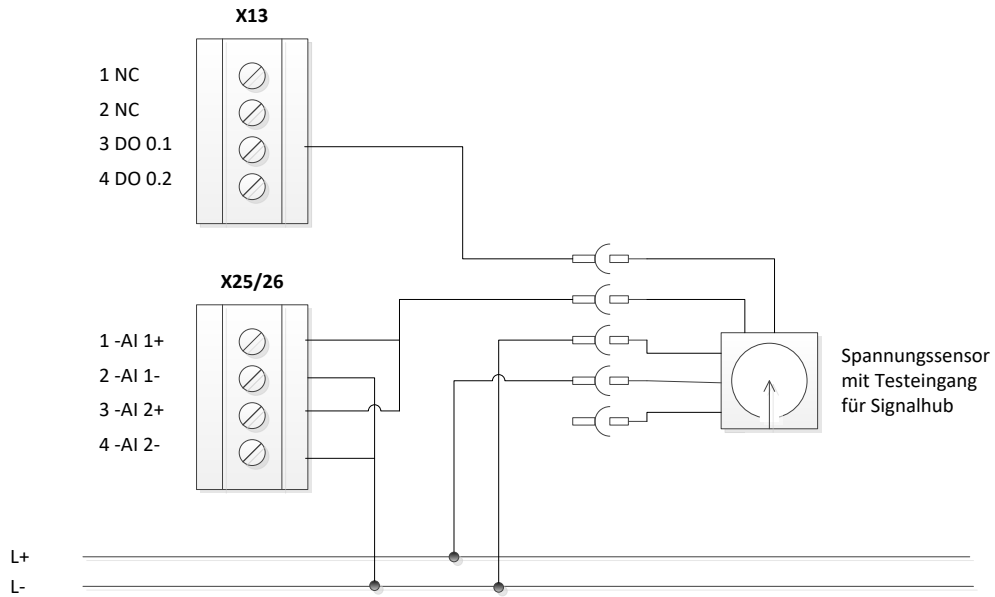### 4.2.3.1 Exemplary connection of analog sensors

By using suitable sensors and careful wiring of the sensor
OI e acc. to EN ISO 13849-1 can be achieved.

The analog current inputs are all equipped with the fixed loading resistor of 500Ohm. For analog voltage inputs this resistor is omitted.
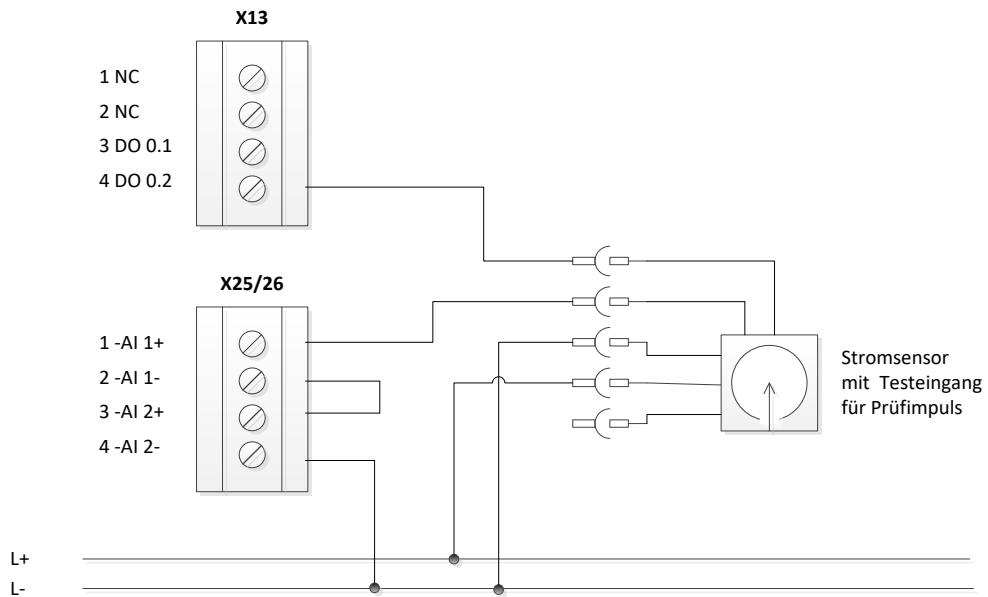
4.2.3.1.1 Voltage sensor with test pulse

X13

1 NC
2 NC
3 DO 0.1
4 DO 0.2

X25/26

1 -AI 1+
2 -AI 1-
3 -AI 2+
4 -AI 2-

Spannungssensor
mit Testeingang
für Signalhub

L+
L-

4.2.3.1.2 Current sensor with test pulse

X13

1 NC
2 NC
3 DO 0.1
4 DO 0.2

X25/26

1 -AI 1+
2 -AI 1-
3 -AI 2+
4 -AI 2-

Stromsensor
mit Testeingang
für Prüfimpuls

L+
L-

⚠ **Safety note:**
- PI e acc. to EN ISO 134849-1 is achieved when using two non-reactive sensors, for which common cause faults can be ruled out.
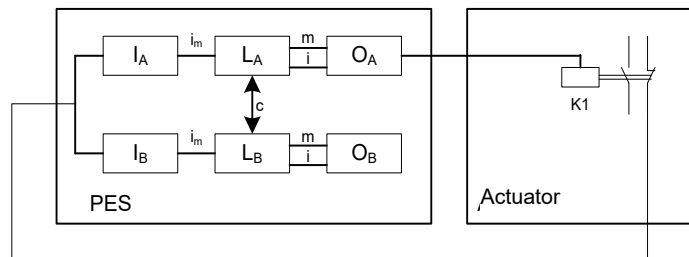
4.3 Safety Related Characteristic Data and Wiring of the Outputs

KSM modules all have safe outputs of various types. For wiring, the corresponding characteristic as specified in the following description, must be accounted for.
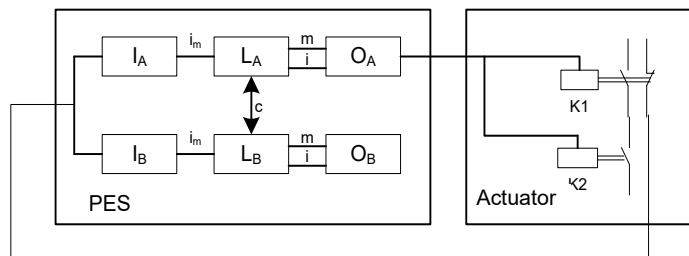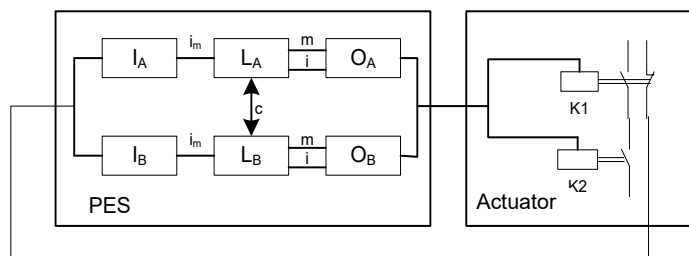
4.3.1 Characteristic of the Output Elements
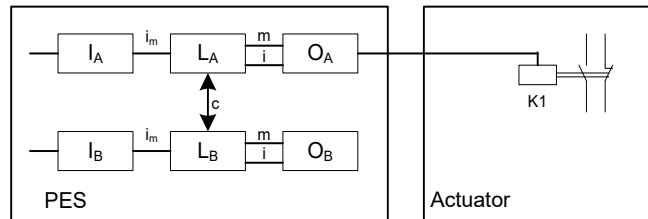
Single-channel output KSM and single-channel actuator without diagnostics

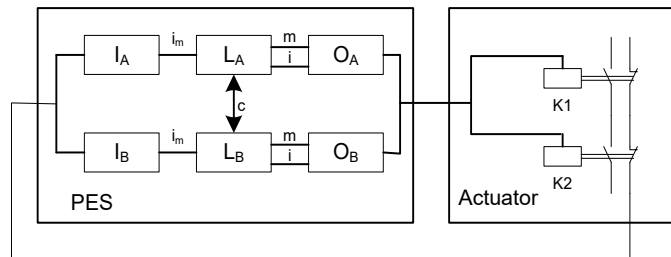Single-channel output KSM and single-channel actuator with diagnostics

Single-channel output KSM (Rel 1 / 2, DO 0/1P, DO 0/1M) and dual-channel actuator
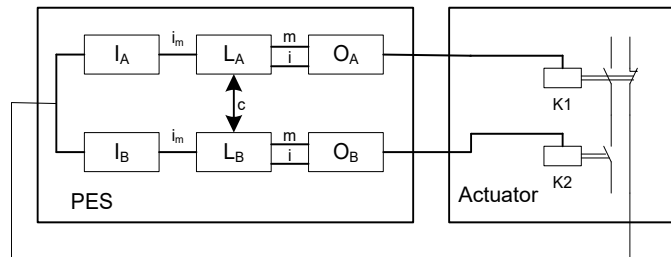with at least single-channel diagnostics.

Single-channel output KSM with internal dual-channel processing (EAAx)
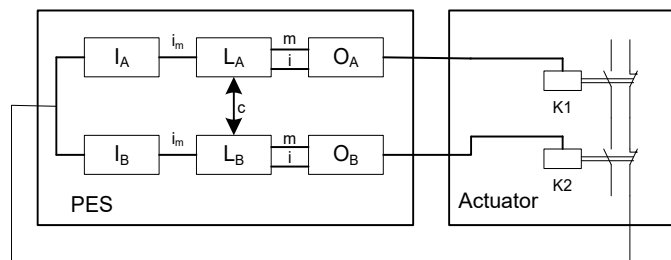and dual-channel actuator with at least single-channel diagnose

Single-channel output KSM with internal dual-channel processing (EAAx)
and dual-channel actuator with dual-channel diagnose

Dual-channel output KSM and dual-channel actuator
with single channel diagnose

Dual-channel output KSM and dual-channel actuator
with dual channel diagnose

4.3.2 Diagnoses in the Cut-off Circuit

The cut-off circuit is equipped with durably implemented and parametrizable diagnostics functions. Certain diagnostics functions also include the external part of the cut-off channel. Depending on the use of these diagnostics functions, different DC-values will arise.

4.3.2.1   Diagnostic Functions

Durably implemented diagnostics functions:

Crosswise readback of outputs:
All safety outputs are read back in the complementary channel. Faults in the internal cut-out circuit of the KSM module are thus detected with DC = High.

Test of cutout ability for K1 and K2 (only control of relay), DO 0_P, DO 0_M, DO 1_P, DO 1_M:
The cutout ability of these outputs is cyclically tested. Failure of the cutout possibility is clearly detected.

Parametrizable diagnostics functions:

Readback of the actuator status via auxiliary contacts, position indicators, etc.:
The status of the actuator is detected by correspondingly suitable auxiliary contacts or position indicators and compared with the nominal status. Any deviation is thereby clearly recognized.
Note: The DC depends on single-channel or dual-channel diagnose as well as on the switching frequency.

Testing the cutout ability for EAAx, EAA1 – EAA10:
Once this function has been activated, the cutout ability of these outputs is cyclically tested. Failure of the cutout possibility is clearly detected.

4.3.2.2 Overview DC with respect to the chosen diagnostics functions

| Measure	DC	Note	Use
Monitoring of outputs b a channel without dynamic test.	0-90%	DC depending on switching frequency When using elements for switching amplification external relays or contactors) only effective in connection with the readback function of the switching contacts	Monitoring of electro-mechanical, pneumatic or hydraulic actuators / outputs
Redundant cutout path with monitoring one of the drive elements	90%	When using elements for switching amplification external relays or contactors) only effective in connection with the readback function of the switching contacts	Monitoring of the outputs with direct functions as safety circuit or monitoring of safety circuits with elements for switching amplification of pneumatic / hydraulic control valves in connection with readback functions from their switching status
Cross-comparison of input signals with immediate and intermediate results in the logic (L) and temporal as well as logic program sequence monitoring and detection of static failures and short circuits (for multiple inputs/outputs).	99%	When using elements for switching amplification external relays or contactors) only effective in connection with the readback function of the switching contacts For applications with frequent safety shut-down requests these tests should be performed more frequently, e.g. at the beginning of the shift, 1 x per week. However, a test should at least be carried out cyclically 1 x year.	Monitoring of the outputs with direct functions as safety circuit or monitoring of safety circuits with elements for switching amplification of pneumatic / hydraulic control valves in connection with readback functions from their switching status

4.3.3 Permissible Capacitive and Inductive Load at Safe Outputs

The safe outputs of the KSM exhibit an OSSD character. That is, the outputs are cyclically switched off for the test of the switching off ability and the status is read back.

The examination of the switching off ability takes place per the following criteria/functions:

- After switching the output off, the output voltage may max. be 5.6 V
- The permissible voltage level must be achieved at the latest after 400 µs
- If the permissible voltage level is reached, the test is determined successful, the output is activated again without further delay
- If the permissible voltage level is still not reached after 400 µs, an alarm is triggered and all safe outputs (second channel with safe outputs!) are deactivated

The following diagram shows the ideal (green curve) and typical (red curve) curve.
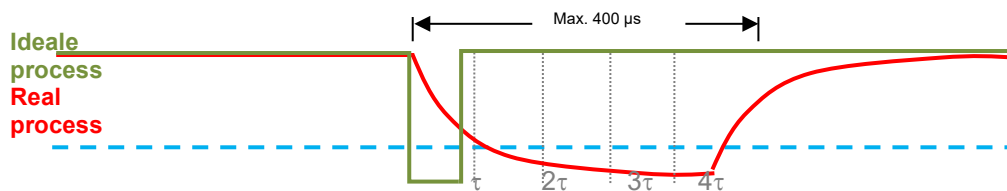
For the determination of the maximally permissible capacity or inductance, the time constant τ of the real RC or RL member at the output must be viewed.

This RC or RL member determines the real discharge curve:

The voltage level of max. 5.6 V is securely reached after $3\,\tau$.

It thus applies:

$$3\tau \leq 350\mu s$$
$$\tau \leq 100\mu s$$

With that connection:

$$\tau\ =\ RC\ =\ \frac{L}{R}$$

the max. usable capacitive or inductive load can be determined in connection its Ohm's load:

$$C_{max} = \frac{\tau}{R} = \frac{10^{-4}}{R}$$

bzw.

$$L_{max} = \tau R = 10^{-4} \cdot R$$

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

4.3.4 Digital Outputs

The modules
- KSM10/10A, KSM11, KSM11-2, KSM12/12A, KSM12-2/12-2A
- KSM31/31R

all have basic outputs of identical design.

4.3.4.1 Characteristic data of the basic outputs

The KSM series provides a total of 8 outputs, which can be interconnected individually or in groups.

Output	Architecture acc. to EN ISO 13849-1	Comment
Combination of 2 relays K1 to K2	4	Complete tripping channel in compliance with architecture category 4 acc. to EN ISO 13849-1
K1 K2	Not safe	Only functional
DO 0_P and DO 0_M	4	Complete tripping channel in compliance with architecture category 4 acc. to EN ISO 13849-1
DO 0_P	Not safe	Only functional
DO 0_M	Not safe	Only functional
DO 1_P and DO 1_M	4	Complete tripping channel in compliance with architecture category 4 acc. to EN ISO 13849-1
DO 1_P	Not safe	Only functional
DO 1_M	Not safe	Only functional
DO 0.1	Not safe	Auxiliary output
DO 0.2	Not safe	Auxiliary output

The Qx_PP, Qx_PN and Qx- outputs are subjected to a plausibility test in all operating states. In switched on state the correct function of all outputs is tested with a cyclic test pulse. For this purpose the output is switched to the corresponding inverse value for a test period TT <500µs (typically 200 µs) i.e. one pp-output is switched instantaneously to 0 VDC potential, while one pn-output is switched to 24 VDC potential.

The relay outputs are monitored for plausibility during each switching cycle. The relay outputs must be switched cyclically and thus tested to maintain the safety function. The switching/test cycle is determined in dependence on the application.

⚠️ **Safety Note:**

- For applications with frequent safety shut-down requests these tests should be performed more frequently, e.g. at the beginning of the shift, 1 x per week. However, a test should at least be carried out cyclically 1 x year.

The test function for the outputs is performed for groups and individual controls. The auxiliary outputs are not tested

- **The High-Side (DO.0_P, DO.1_P) and Low-Side (DO.0_M, DO.1_M) outputs must individually not be used for safety duties. Any use for safety duties is only permitted for High-Side / Low-Side combination**

- A mixed operation with the relay contacts is **not** permitted!
  Mixed operation: A dangerous contact voltage potential may not be mixed with a protective low voltage.

  Example:
  FALSE: *230 VAC are switched over K1.1 + K1.2 and 24V DC are switched over K2.1 + K2.2.*
  TRUE: *230 VAC are switched over K1.1 + K1.2 and over K2.1 + K2.2 respectively.*
                        Or 24 VDC are respectively switched over K1.1 + K1.2 and K2.1 + K2.2.

The outputs can be loaded as follows:

Output	Voltage	Current
Relay Qx	24 VDC	2,0 A (DC13)
Relay Qx	230 VAC	2,0 A (AC15)
DOx	24 VDC	250 mA
DO x_P	24 VDC	250 mA
DO x_M	GNDEXT	250 mA
EAAx	24 VDC	250 mA

⚠️ **Safety Note:**
- For safety relevant applications only external switching elements with a minimum withstand current of > 1.2 mA may be used.
- For the output system a vast number of diagnostic measures have been implemented. Special attention must be paid to the inclusion of elements for switching amplification, such as relays, contactors, etc. in the cutout circuit.
- With uses in the elevator technology acc. to EN 81-20/-50 resp. EN 81-1/-2, the outputs of the internal relays may not be used for switching voltages above 24V, as this does not permit the specifications of the EN 81-20/-50 resp. EN 81-1/-2. With an infringement, the guarantee expires and Kollmorgen does not pay compensation.

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

4.3.4.2 Wiring examples basic outputs

4.3.4.2.1 Single channel switching relay or semi-conductor output without test

For the connection of multi-phase applications or for higher current demands external contactors may be used. For a single-pole connection without external test please bear in mind that the KSM module will not recognize bonding of one or several external contacts. The following circuit example is only limited suitable for safety applications, PI b acc. to EN ISO 13849-1 can maximally be achieved!
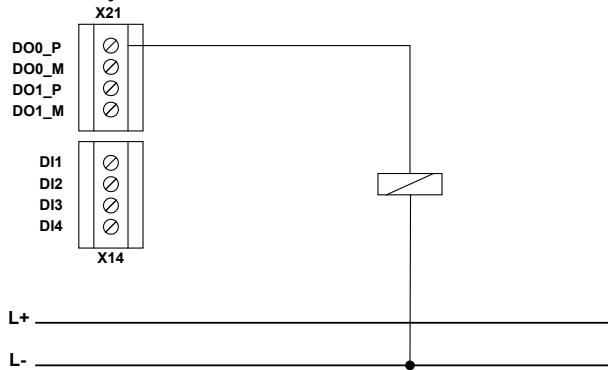

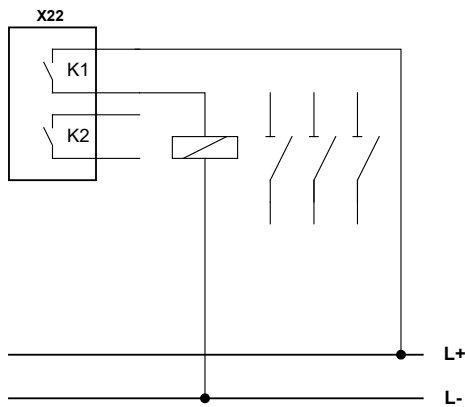*Fig.: Single-channel switching P-output.*

Fig.: Single channel switching relay output.

⚠ **Safety Note:**
- Not recommended for safety applications! In this context see also the notes in EN ISO 13849-1 concerning the application and the required fault exclusions.

4.3.4.2.2 Single channel switching relay or semi-conductor output with external switching amplifier and testing

When using external switching amplifiers or downstream electro-mechanical, pneumatic or hydraulic components, the setup for testing the complete chain and a message/warning feature for detected faults is required to achieve PI c or higher.

Positively guided auxiliary contacts are especially needed for electro-mechanical devices and message contacts for the valve position are required for hydraulic or pneumatic components.

The message/warning device must ensure that the operator recognizes the dangerous situation immediately.

The achievable PI is mainly depending on the test rate, PI d acc. to each EN ISO 13849-1 can maximally be achieved!
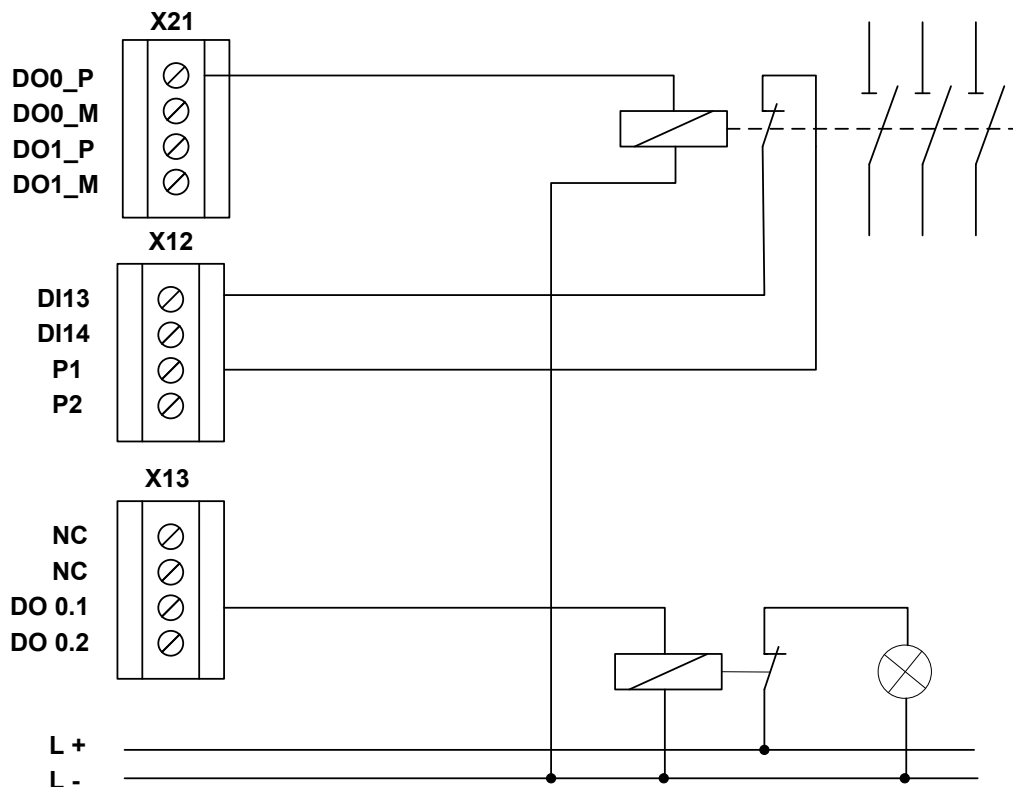

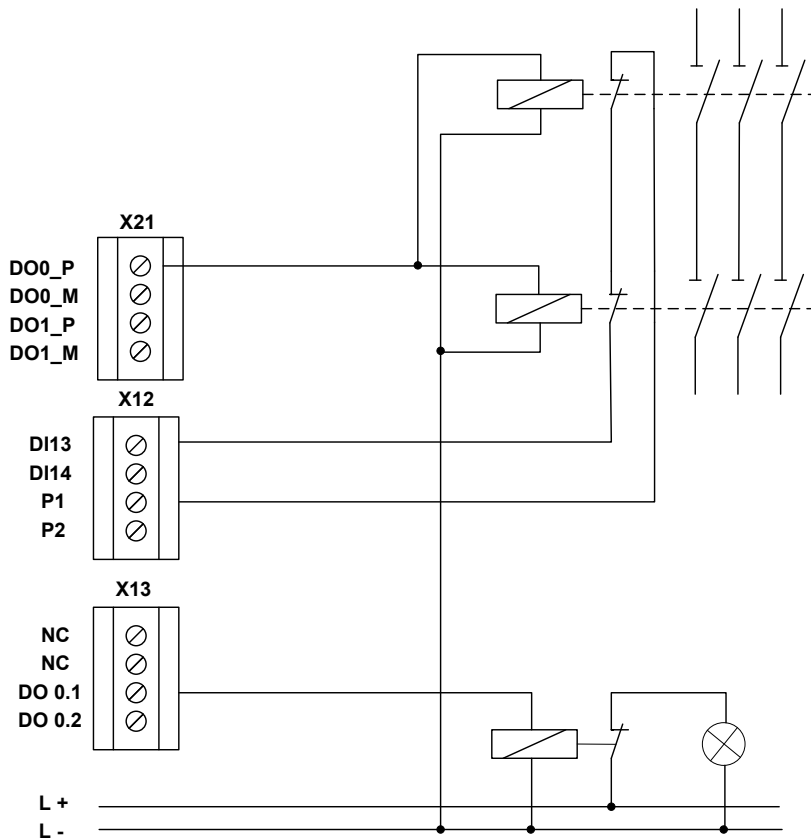*Fig.: Single-channel relay output with testing*

⚠ **Safety Note:**

- Only conditionally recommended for safety applications! In this context see also the notes in EN ISO 13849-1 concerning the application and the required fault exclusions.

- For PI c or higher a test rate of > 100 * the request rate is required.

- For PL c and higher a message/warning feature is required, which informs the operator immediately about a dangerous situation

4.3.4.2.3 Single-channel switching relay or semi-conductor output with dual-channel external circuit with testing

For safety applications from PL C after EN ISO 13849-1 it is recommended or demanded to access two external switching off elements. For reaching error of PL c or higher, a device for testing the complete chain and a notification/warning device is further required when an error is recognized - for this see notes under 0.

Fig.: Single-channel switching output DO 0_P with dual-channel external circuit and monitoring at output 13 1 as group feedback

The two external monitoring contacts are switched in series, supplied by the clock signal P1 and read via input 13. Input 13 was chosen as readback input, but any other input can be assigned for this purpose.

Installation Manual
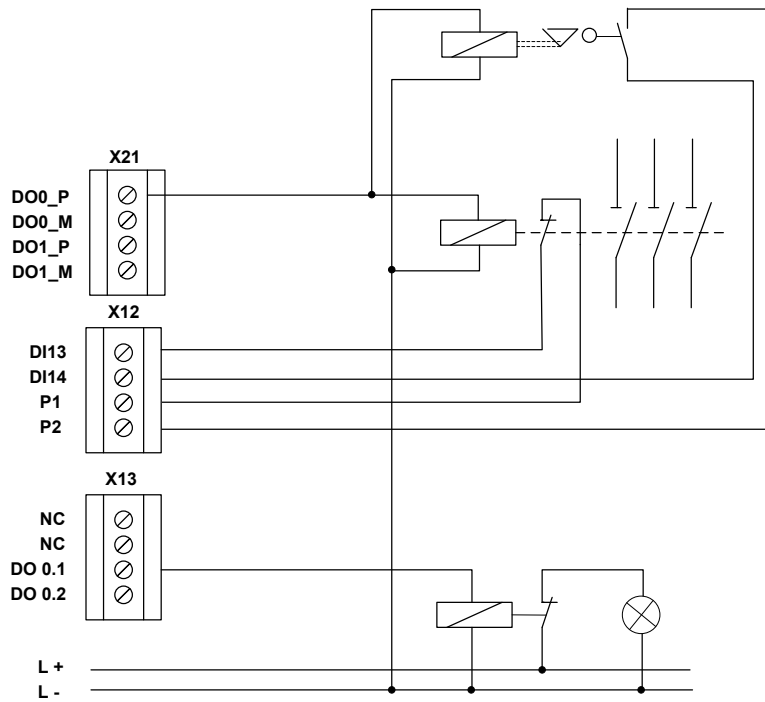
Fig.: *Single-channel switching output DO 0_P with dual-channel external circuit as combination of electro-mechanical element and hydraulic/pneumatic valve and monitoring at two inputs*

⚠ Safety Note:

- Only conditionally recommended for safety applications! In this context see also the notes in EN ISO 13849-1 concerning the application and the required fault exclusions.

- For PL c and higher a message/warning feature is required, which informs the operator immediately about a dangerous situation

- For higher requirements, make sure that at least 1 switching operation take place every 24 hours, to test the switching ability of the external power contactor.

4.3.4.2.4 Two-channel switching relay output with external monitoring - group feedback

For safety related applications from PI d acc. to EN ISO 13849-1 two relays on the KSM1xx module and two external power contactors are used.
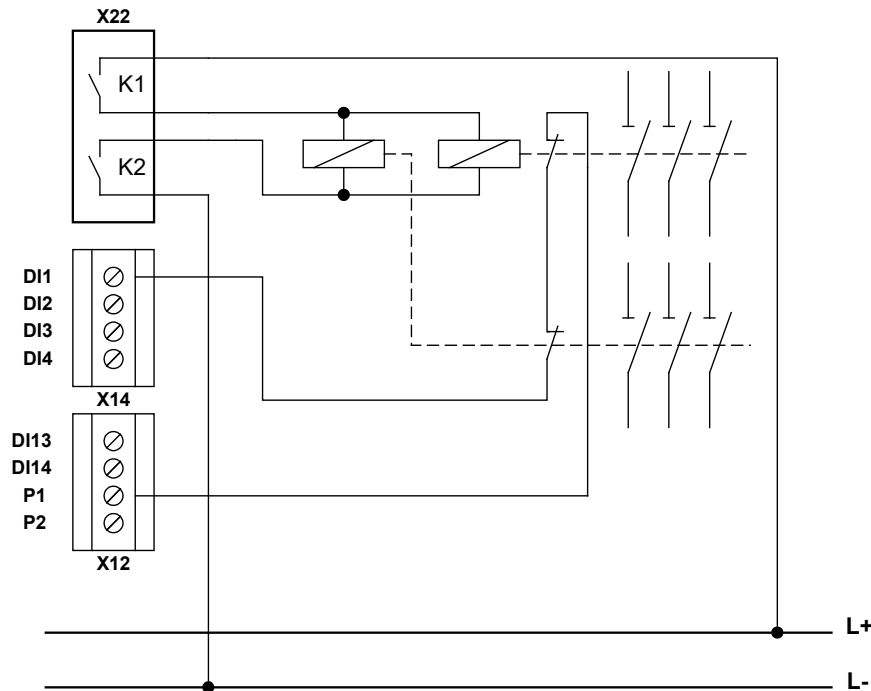

Fig.:   Two-channel switching relay output with external monitoring – group feedback

The two external monitoring contacts are switched in series, supplied by the clock signal P1 and read in from DI01 (configured as EMU-input). In case of higher demands one must consider that at least 1 switching process must take place every 24 hours.

⚠ **Safety Note:**

- For achieving PI e acc. to EN ISO 13849-1 a sufficiently high testing rate is required.

- For applications with frequent safety shut-down requests these tests should be performed more frequently, e.g. at the beginning of the shift, 1 x per week. However, a test should at least be carried out cyclically 1 x year.
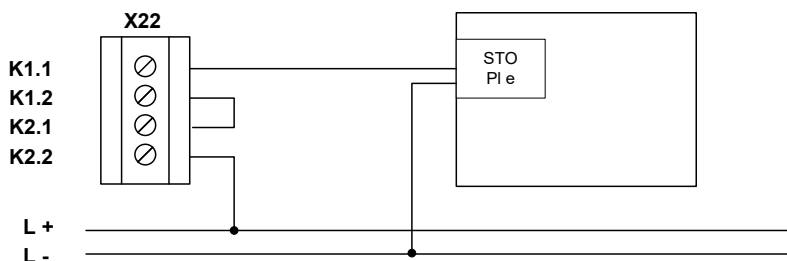
4.3.4.2.5 Dual-channel output with relay output and semi-conductor output – external control circuit with monitoring

For safety applications from PI d and higher acc. to EN ISO 13849-1. The external circuit is controlled in dual-channel mode via a relay and a semi-conductor output. Each of the two external cut-out paths is monitored. For PL e acc. to EN ISO 13849-1 a sufficiently high testing rate and $MTTF_D$ = high is demanded for the external circuit.
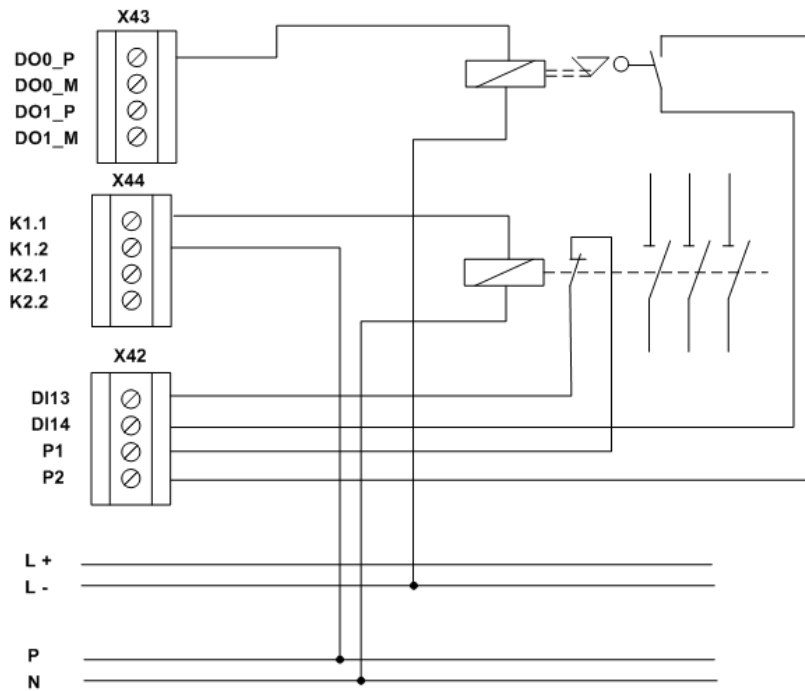
### 4.3.4.2.6 Dual-channel output with relay output and external control circuit in PI e

For safety applications from PI d and higher acc. to EN ISO 13849-1. The external circuit is controlled in dual-channel mode via the relay outputs. For PL e acc. to EN ISO 13849-1 a sufficiently high testing rate and PI e is demanded for the external circuit.

4.3.4.2.7 Dual-channel output with semi-conductor output and external control circuit in Pl e

For safety applications from PI d and higher acc. to EN ISO 13849-1. The external circuit is controlled in dual-channel mode via the semi-conductor outputs. For PL e acc. to EN ISO 13849-1 PI e is demanded for the external circuit

X21

DO0_P
DO0_M
DO1_P
DO1_M

STO
Pl e
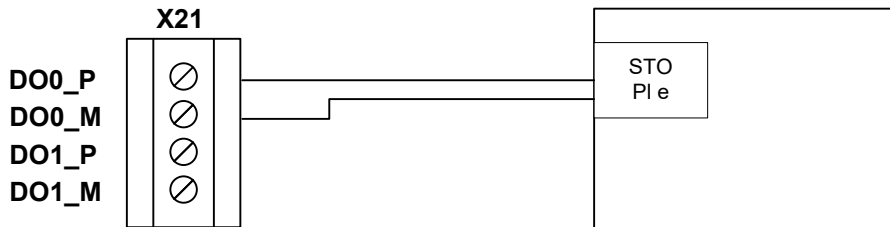
4.3.4.2.8 Wiring of a notification output

Both semi-conductor outputs implemented on the KSM1x module can be wired for functional applications. These outputs are not pulse-commutated.
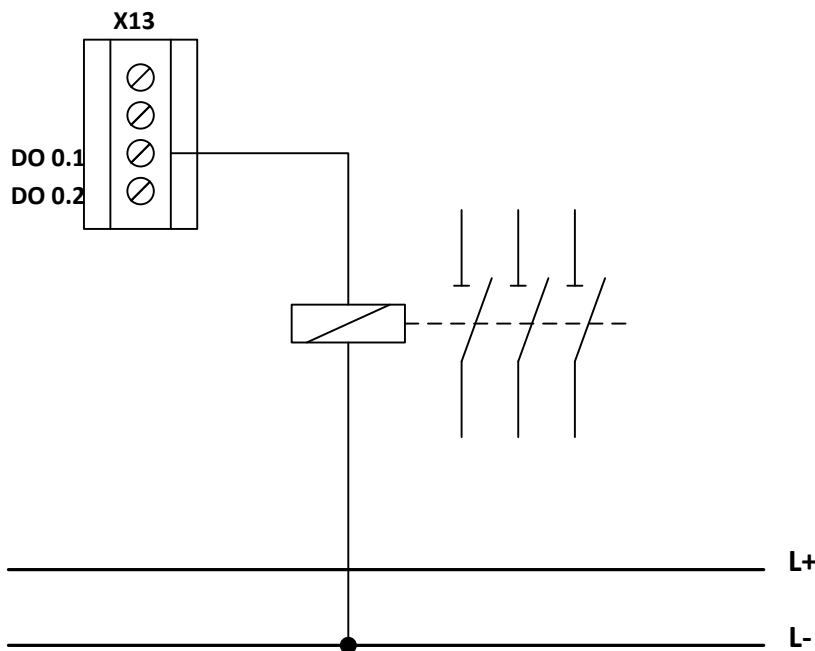
X13

DO 0.1
DO 0.2

L+
L-

Fig.: Wiring of a notification output

Applications with notification outputs are not accepted!

4.3.5 Digital Outputs I/O's (EAAx)

The expansion of modules of the KSM31/31R have configurable safe digital I/Os (see chapter 3 module overview). This connection acts as safe digital pp-switching output parameterized as output.

4.3.5.1 Classification of the I/O's (EAAx) when used as output

Classification	Achievable Pl acc. to EN ISO 13849-1	Comment
Static single-channel [2]	PL c	- Fault detection or fault reaction acc. to cat. 2
Static two-channel [2]	PL d	Same group (1): - Time-shifted triggering on PLC level - Fault approach short-circuit on both outputs Different group [1]: - Nom further requirements necessary
	PL e	Different group[1] required
Dynamically single channel [2]		
Dynamically dual channel [2]	PL e	No further requirements necessary

Note:
- 1) Group 1:   EAA1 … EAA6
  - Group 2:   EAA7 … EAA10

- 2) Static: no pulse test on output
  - Dynamic: Pulse test on output $t_{Test} \leq 500$ µs

4.3.5.2 Wiring examples for safe digital outputs I/O's (EAAx)

4.3.5.2.1 Wiring single channel without testing

When using a two-channel output (EAAx) in connection with a single-channel external wiring without external examination it must be taken into account that and adherence of one or several external contacts of the KSM1x module is not recognized. The following circuitry example is only suitable in a restrictive manner, maximally PL b according to EN ISO 13849-1 can be reached!

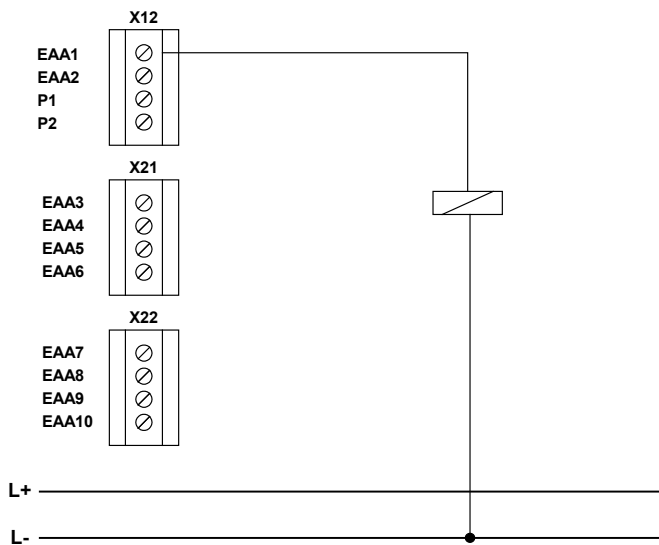*Fig.:* Two-channel output with single-channel wiring without testing

⚠ Safety Note:

- Not recommended for safety applications! In this context see also the notes in EN ISO 13849-1 concerning the application and the required fault exclusions.

4.3.5.2.2 Wiring single channel with testing

When using a two-channel output (EAAx) in connection with a single-channel external wiring with testing. Positively guided auxiliary contacts are especially needed for electro-mechanical devices and message contacts for the valve position are required for hydraulic or pneumatic components. Furthermore, a message/warning device for indicating a failure is required. The message/warning device must ensure that the operator recognizes the dangerous situation immediately. The achievable PI is mainly depending on the test rate, PI d acc. to EN ISO 13849-1 can maximally be achieved!
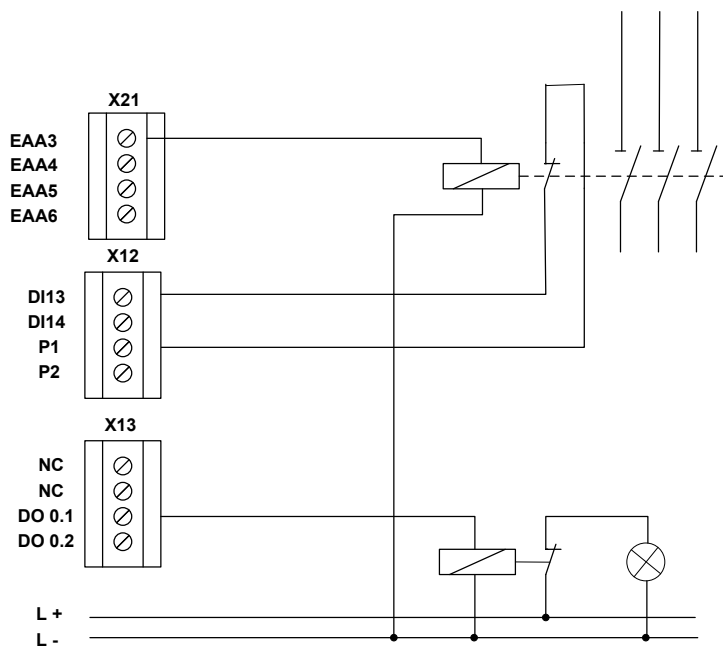
Fig.: Two-channel output with single-channel wiring with testing

⚠ Safety Note:

- Only conditionally recommended for safety applications! In this context see also the notes in EN ISO 13849-1 concerning the application and the required fault exclusions.

- For PI c or higher a test rate of > 100 * the request rate is required.

- For PL c and higher a message/warning feature is required, which informs the operator immediately about a dangerous situation

4.3.5.2.3 Wiring with safe cut-off circuit

For safety applications from PI c and higher acc. to EN ISO 13849-1. The external circuit is controlled directly via a two-channel output. The achievable PL acc. to EN ISO 13849-1 depends on the use of dynamic testing (see 4.3.2.1 DC) and the PL of the downstream device.
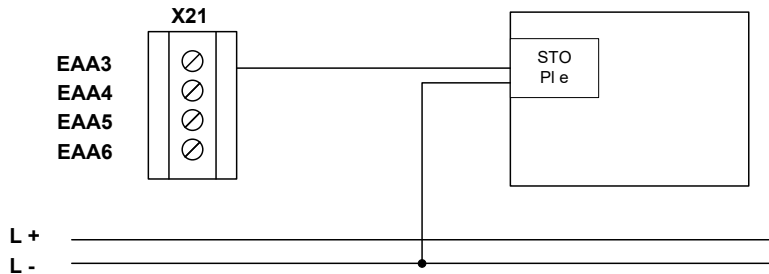
Fig.: Two-channel output in connection with a device with examined disconnection

4.3.5.2.4 Wiring in connection with two-channel switching-off circuit

Suitable for PI d and higher acc. to EN ISO 13849-1. Use of one output EAAx in conjunction with two-channel external wiring with test. Positively guided auxiliary contacts are especially needed for electro-mechanical devices and message contacts for the valve position are required for hydraulic or pneumatic components.
The achievable PI depends on the use of dynamic testing as well as $MTTF_D$-value of the external channel. PI e acc. to EN ISO 13849-1 can maximally be reached!
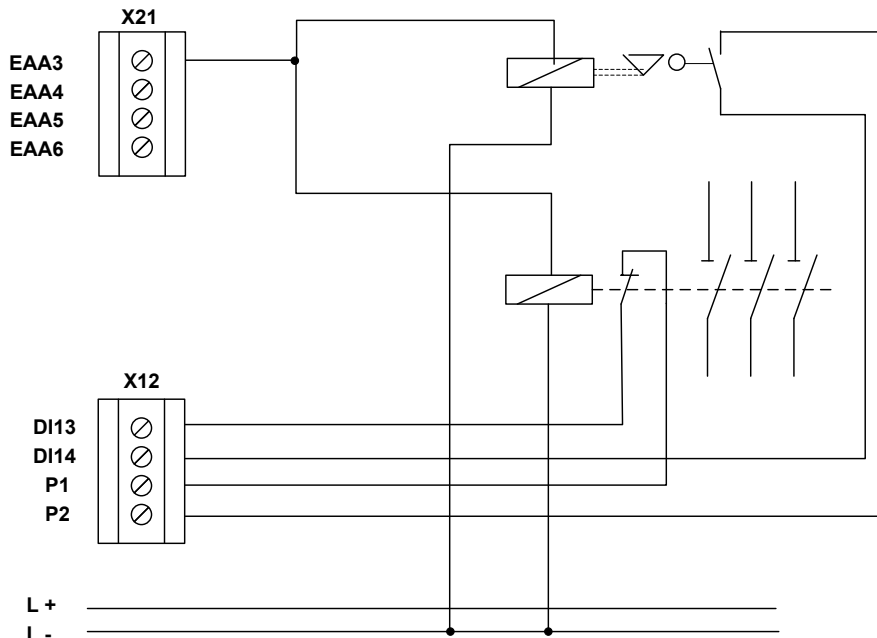
Fig.: Two-channel output in connection with two-channel switching-off circuit with testing

4.3.5.2.5 Redundant two-channel output

Suitable for PI d and higher acc. to EN ISO 13849-1. Use of two outputs EAAx in connection with a dual-channel external wiring.

4.3.5.2.5.1 Wiring dual channel in the same group

Fig.: Redundant two-channel outputs in the same group in connection with two-channel switching-off circuit

4.3.5.2.5.2 Wiring dual channel in different groups

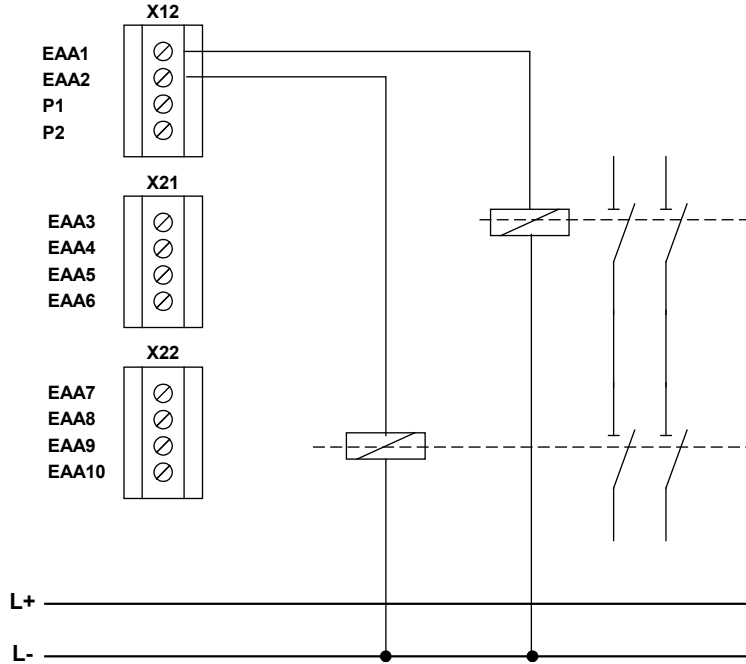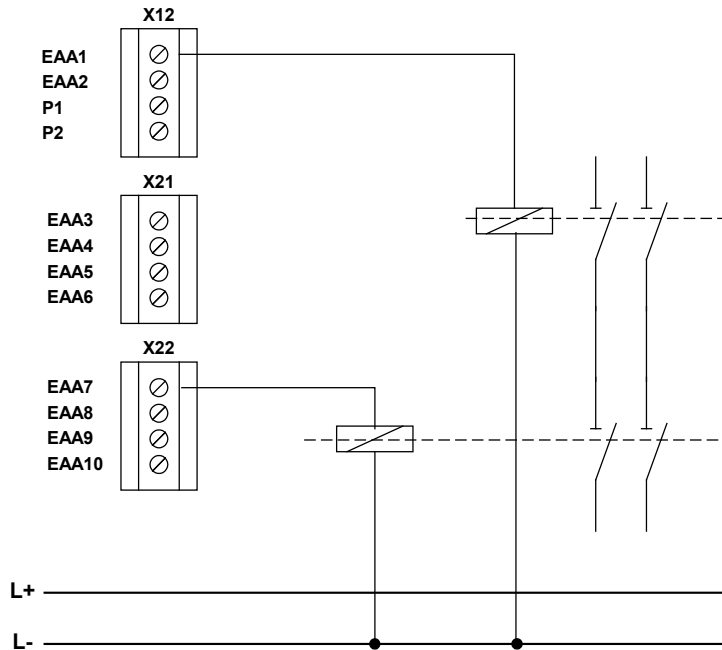Fig.: Redundant two-channel outputs in different groups in connection with two-channel switching-off circuit

⚠ **Safety Note:**

- For a safety related assessment of the partial system output the data issued by the respective manufacturer (MTTF$_D$, FIT-numbers, B10d-value, etc.) must be used when using external elements, e.g. for switching amplification, in the shut-down circuit.
- The DC-values listed in the table must be used conservatively and compliance with the boundary conditions (see table under "Remarks") must be ensured.
- According to the applicable standards, fault exclusions are permitted. The boundary conditions mentioned in this context must permanently be met.
- When using elements for switching amplification in safety circuits, their function must be monitored by means of suitable readback contacts, etc. (see circuitry examples). Suitable readback contacts are contacts which are linked with the contacts in the shut-down circuit in a positively switching way.
- The switching ability of the external switching amplifier must be cyclically tested. The time between 2 tests must be determined in accordance with the requirements of the application and ensured by suitable measures. Suitable measures may be of organizational (On and Off switching at the beginning of a shift, etc.) or technical (automatic, cyclic switching) nature.

4.3.5.3 Overview of achievable PI for digital safety outputs

Output KSM	Actuator / external shut-down circuit	Category acc. to EN13849-1	DC		MTTF$_D$ Actuator	Achievable PI acc. to EN ISO 13849-1	Boundary conditions	Fault exclusion
Single-channel without dynamic output test DOx DO 0_P, DO 0_M, DO 1_P, DO 1_M EAAx	Single-channel Contactor, valve, brake, etc. without direct feedback for diagnostics.	Cat. B	0 %		Medium	B	Contactor and downstream actuators appropriately designed for safety application	
	Single-channel Contactor, valve, brake, etc. with monitored and positively guided auxiliary contact	Cat. 2	60-90%	Depending on switching frequency	Medium	B	Auxiliary output required for warning in case of detected malfunction Contactor and downstream actuators appropriately designed for safety application	
					High	C	As before	
						D	As before DC = 90 % due to a sufficiently high test rate with reference to the application	
Single-channel without dynamic output test K1 or K2 or Single-channel DO 0_P, DO 0_M, DO 1_P, DO 1_M	Dual channel Contactor, valve, brake, etc. with direct feedback for diagnostics at least in one channel or actuator single-channel controlled with safety function cat. 3 (e.g. STO)	Cat. 2	90%	Monitoring only in an external shut-down circuit	Medium	c	Auxiliary output required for warning in case of detected malfunction Contactor and downstream actuators appropriately designed for safety application	Short circuit on external control
					High	d		
Single-channel without dynamic output test EAA01..EAA10	Dual channel Contactor, valve, brake, etc. with direct feedback for diagnostics at least in one channel or actuator single-channel controlled with safety function cat. 3 (e.g. STO)	Cat. 3	90 %	Monitoring only in an external shut-down circuit	Medium or High	d	Contactor and downstream actuators appropriately designed for safety application	Short circuit on external control
Einkanalig mit dynamischen Ausgangstest EAA01..EAA10	Dual channel Contactor, valve, brake, etc. with direct feedback for diagnostics at least in one channel or actuator with safety function cat. 4 (e.g. STO)	Cat. 4	99%	Monitoring in both external shut-down circuits	High	e	Contactor and downstream actuators appropriately designed for safety application Monitoring of electro-mechanical components by means of positively guided switches, position monitoring of control valves, etc.	

Output KSM	Actuator / external shut-down circuit	Category acc. to EN13849 -1	DC		MTTF$_D$ Actuator	Achievable Pl acc. to EN 13849-1	Boundary conditions	Fault exclusion
Dual-channel without dynamic output test K1 and K2 2 x EAA01..EAA10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics at least in one channel or actuator with safety function cat. 4 (e.g. STO)	Cat. 3	90%	Monitoring in both external shut-down circuits	Medium or High	d	Contactor and downstream actuators appropriately designed for safety application Monitoring of electro-mechanical components by means of positively guided switches, position monitoring of control valves, etc. Outputs EAA1..10 x each from different groups (groups of 6/4 EAA-Ports each, e.g. EAA..6,EAA7..10) or Time-shifted triggering on PLC level	Short circuit on external control
Dual-channel K1 and K2 or Dual-channel with dynamic output test DO 0_P and, DO 0_M, DO 1_P and DO 1_M 2 x EAA01..EAA10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics at least in one channel or actuator with safety function cat. 4 (e.g. STO)	Cat. 4	99%	Monitoring in both external shut-down circuits	High	e	Contactor and downstream actuators appropriately designed for safety application Monitoring of electro-mechanical components by means of positively guided switches, position monitoring of control valves, etc. For applications with frequent safety shut-down requests these tests should be performed more frequently, e.g. at the beginning of the shift, 1 x per week. However, a test should at least be carried out cyclically 1 x year.	Short-circuit in external control in both channels

5 Connection and Installation

5.1 General Notes on Installation

Strictly follow the safety regulations when installing!

Degree of protection IP20
Route all signal lines for the interfacing of digital inputs and contact monitoring separately.
You should in any case disconnect 230VAC voltages from low voltage power lines,
if these voltages are used in connection with the application.

The cable lengths for digital inputs and outputs and all sensors must normally not exceed **30 m**.

If the cable lengths exceed **30 m** you must apply appropriate measures for fault exclusion
concerning impermissible overvoltage. Appropriate measures include e.g. lightning protection
for outdoor lines, overvoltage protection of the indoor system, protected routing of cables.

Measures concerning the electromagnetic compatibility (EMC)

The KSM module is intended for use in the drive environment and meets the EMC-requirements
mentioned above.
It is also assumed that the electromagnetic compatibility of the overall system is ensured by
application of appropriate measures.

Use of the module as PESSRAL acc. to EN 81-20/-50 resp. EN 81-1/-2:

When using the module as PESSRAL acc. to EN 81-20/-50 resp. EN 81-1/-2 (elevator
standard), the device must be installed at a minimum distance of 200mm to the transmitting
facility with the following frequency ranges (mobile radio, etc.) 166-1000 MHz, 1710-1784 MHz,
1880-1960 MHz. The field strength of the transmitting facility must not exceed the following field
strength values:
30V/m at 166-1000 and 1710-1784 MHz, 10V/m at 1880-1960 MHz .
Installation in a closed housing with degree of protection IP5X or better is additionally required.

⚠ **Safety Note:**
- Electric power supply lines of the KSM and "discontinuous-action lines" of the power
  converter must be isolated from each other.
- Signal lines and power lines of the power converter must be routed through separate
  cable ducts. The distance between the cable ducts should be minimum 10 mm.
- Only shielded cables must be used to connect the position and speed sensors. The
  signal transmission cable must be RS-485-standard compliant (lines twisted in pairs).
- Care must be taken to ensure that the shielding is correctly connected in the 9-pin SUB-
  D plugs of the position and speed sensors. Only metal or metal coated plugs are
  permitted.
- The shielding on the sensor side must comply with appropriate methods.
- EMC-compliant installation of the power converter technology in the environment of the
  KSM module must be assured. Special attention must be paid to the routing of cables,
  the shielding of motor cables and the connection of the braking resistor. Strict
  compliance with the installation instructions of the power converter manufacturer is
  mandatory.
- All contactors in the environment of the power converter must be equipped with
  appropriate suppressor circuits.
- Suitable measures to protect against overvoltages must be applied.

Additional safety regulations when using as PESSRAL acc. to EN 81-20/-50 resp. EN 81-1/-2

- Install the device at a distance of at least 200 mm from the HF-transmitting facility (WLAN, GSM, etc.). The transmitting facilities must thereby not exceed the max. field strengths as specified above.
- The device must be installed in a closed housing, IP5X or better.

5.2 Installation and Assembly of the KSM Module

The module is <u>solely</u> to be installed in control cabinets with a degree of protection of at least IP54.

The modules must be vertically fastened on a top hat rail

The ventilation slots must be kept unobstructed, to ensure adequate air circulation inside the module.

For air vents, there must be free space of 30 mm above and below the vents. Stringing of expansion modules is permitted. As the adjacent devices can generate waste heat, a distance of 20 mm should be maintained.

Note:
When using in non-closed spaces, it must be guaranteed that the environmental conditions of the individual modules (see technical data) are adhered to.

5.3 Installation of Backplane Bus System

Mounting several KSM modules (KSM10/10A, KSM11, KSM11-2, KSM12/12A, KSM12-2/12-2A) on one top hat rail in connection with the backplane bus system is also possible. These modules can be combined with a communication extension. In this case the backplane bus system needs to be configured by Kollmorgen when placing the order and delivered in accordance with the application in question.

The backplane bus system consists of a 5-pin plug connector with snap-in contacts. In these plug connectors all 5 contacts are equipped by standard. In this case the component is not specially marked. On a second variant of the plug connector only 3 contacts are equipped.

Note:
Expansion modules have no own power supply unit and depend on a DC power supply via the backplane bus system. Base modules (KSM10/11/12) are equipped with a reinforced power supply unit and always feed in to the backplane bus.

There are two different types of backplane bus connectors:

- **TB1:** Standard design (all contacts are present)
- **TB2:** Circuit breaker design (The two live conductors are not present and are marked with a green dot.

Using the backplane bus connector TB1:
The backplane bus connector TB1 can only be installed in connection with expansion modules without their own power supply. Connection of several standalone modules is not possible.
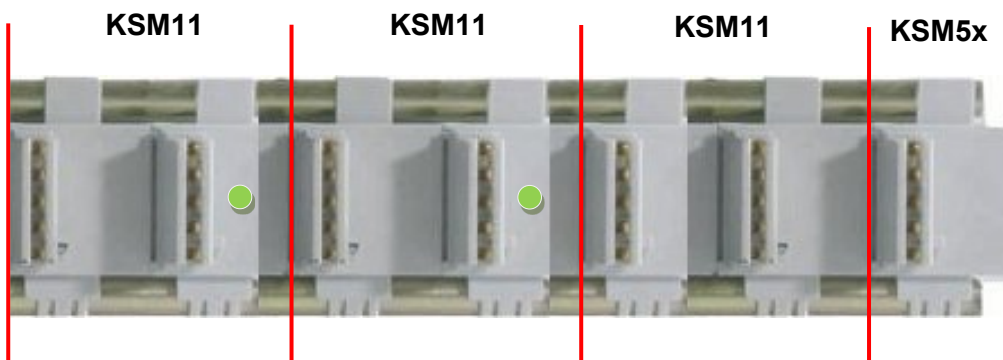
Using the backplane bus connector TB2:
The backplane bus connector TB2 is used for combining several base modules with expansion modules. A detailed description can be found under point 5.3.1.

5.3.1 Arrangement examples

5.3.1.1 KSM11 + KSM11 + KSM11 + KSM5x

There is no TB2 between the last KSM11 module and the communication module KSM5x because the power supply for the KSM5x is fed in through the backplane bus system.

5.3.1.2 KSM12 + KSM11 + KSM5x
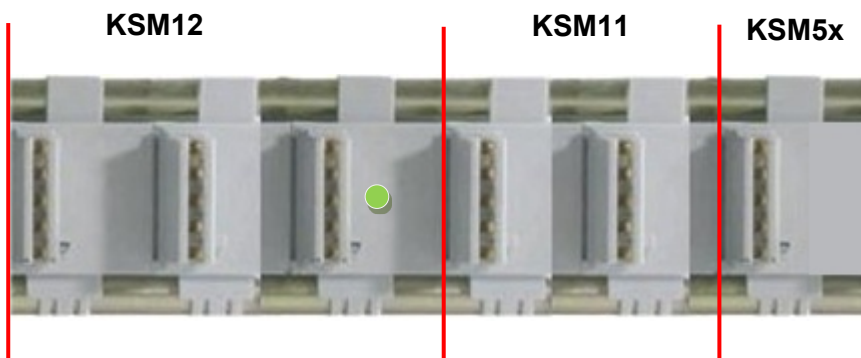
There is no TB2 between the last KSM121-2 module and the communication module KSM5x because the power supply for the KSM5x is fed in through the backplane bus system.

5.4 Assembling the Modules

The modules are mounted on C-standard rails by means of snap-on latches.

5.4.1 Assembly on C-rail

The devices are inserted into the rail under an oblique angle and then snapped on downwards. For disassembling use a screwdriver, insert it into the slot of the downwards pointing latch and then move it up.
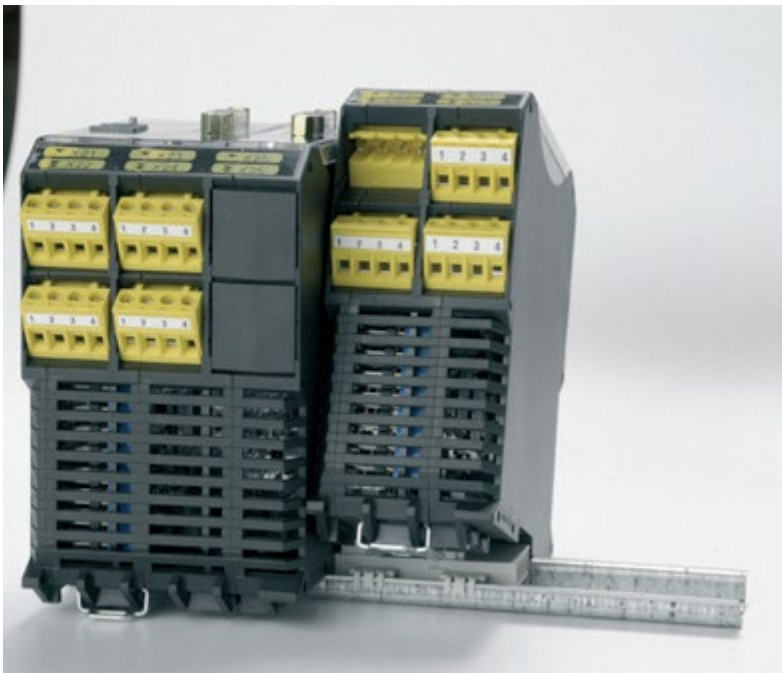
5.4.2 Assembly on Backplane Bus

After assembling the backplane bus the device can be installed. For this purpose, insert the module from above into the plug connection under an oblique angle and snap it onto the C-rail.
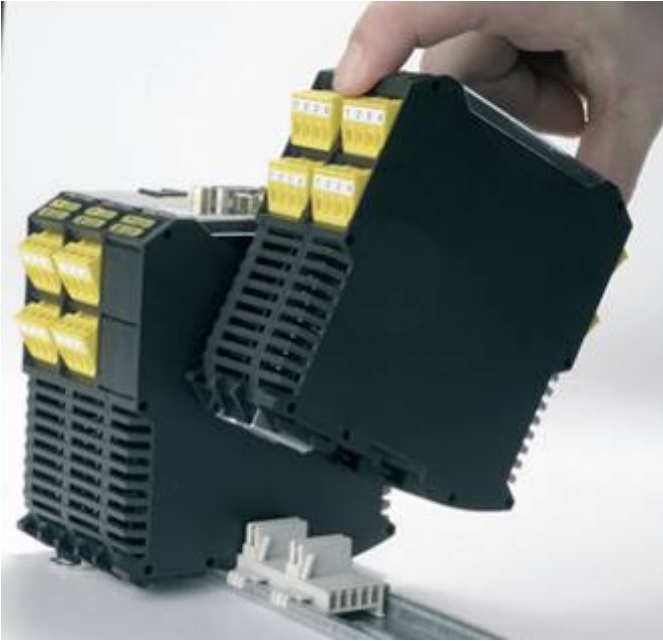
Insert the module from above under an oblique angle.

Snap-on downwards on to the C-rail.

The backplane plug connection can later be extended. The system configuration can thus be extended by additional modules.

Snap the backplane bus element into the C-rail and insert it into the counter-piece by sliding it sideways.

5.4.3 Installation I/O-Extension

Note: Max. 2 KSM3x modules can be operated with one basic unit.

3.1.1.1 Physical address configuration of the slave modules (central/decentral)

On the KSM3x module the bus address must be set with the help of the address switch.

This setting is made on the back of the module

Note:
- Address range of the KSM3x module from 1...15.
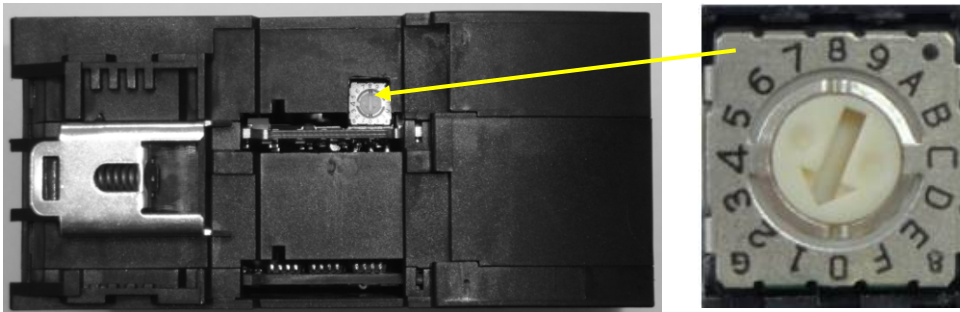- Address "0" is reserved for the basic device.

5.5 Terminal Assignment

5.5.1 Terminal Assignment KSM10

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU	**X13**	1 - NC	No function	
		2 - NC		
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

5.5.2 Terminal Assignment KSM10A

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU	**X13**	1 - NC	No function	
		2 - NC		
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal assignment				
Unit	*Terminal*	*Pin*	*Description*	*Note*
	X25	1 – AI 1.1+	Safe analog input	
		2 – AI 1.1-		
		3 – AI 1.2+		
		4 – AI 1.2-		
	X26	1 – AI 2.1+	Safe analog input	
		2 – AI 2.1-		
		3 – AI 2.2+		
		4 – AI 2.2-		

5.5.3 Terminal Assignment KSM11

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

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Terminal Assignment				
Unit	Terminal	Pin	Description	Note
CPU-ENC	X13	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

5.5.4 Terminal Assignment KSM11-2

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

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Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU-ENC	**X13**	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
EXT-ENC	**X17**	1 – U_ENC_3	Voltage supply encoder +24V DC X33	
		2 – GND_ENC_3	Voltage supply encoder 0V DC X33	
		3 – U_REF_3	Reference voltage encoder X33	
		4 – NC	No function	
	X18	1 – NC	No function	
		2 – NC		
		3 – NC		
		4 – NC		
	X27	1 – HTL_A_1	Encoder 24V	
		2 - HTL_A_2	Encoder A+	
		3 - HTL_A_3	Encoder Ground	
		4 – NC	No function	
	X28	1 – HTL_B_1	Encoder 24V	
		2 - HTL_B_2	Encoder B+	
		3 - HTL_B_3	Encoder Ground	
		4 - NC	No function	

HTL Geber Anschluß: A+/B+

24V ——— HTL_A_1	24V ——— HTL_B_1
A+ ——— HTL_A_2	B+ ——— HTL_B_2
GND ——— HTL_A_3	GND ——— HTL_B_3

HTL Geber Anschluß: A+,A-/B+,B-

A+ ——— HTL_A_1	B+ ——— HTL_B_1
A- ——— HTL_A_2	B- ——— HTL_B_2
——— HTL_A_3	——— HTL_B_3

5.5.5 Terminal Assignment KSM12

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Clock outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU-ENC	**X13**	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
ENC	**X15**	1 – U_ENC_2	Voltage supply encoder +24V DC X32	
		2 – GND_ENC_2	Voltage supply encoder 0V DC X32	
		3 – NC	No function	
		4 – NC		

5.5.6 Terminal Assignment KSM12A

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

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Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU-ENC	**X13**	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
ENC-ANALOG	**X15**	1 – U_ENC_2	Voltage supply encoder +24V DC X32	
		2 – GND_ENC_2	Voltage supply encoder 0V DC X32	
		3 – NC	No function	
		4 – NC		
	X25	1 – AI 1.1+	Safe analog input	
		2 – AI 1.1-		
		3 – AI 1.2+		
		4 – AI 1.2-		
	X26	1 – AI 2.1+	Safe analog input	
		2 – AI 2.1-		
		3 – AI 2.2+		
		4 – AI 2.2-		

5.5.7 Terminal Assignment KSM12-2

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Pulse outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU-ENC	**X13**	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
EXT-ENC	**X17**	1 – U_ENC_3	Voltage supply encoder +24V DC X33	
		2 – GND_ENC_3	Voltage supply encoder 0V DC X33	
		3 – U_REF_3	Reference voltage encoder X33	
		4 – NC	No function	
	X27	1 – HTL_A_1	Encoder 24V	
		2 - HTL_A_2	Encoder A+	
		3 - HTL_A_3	Encoder Ground	
		4 – NC	No function	
	X28	1 – HTL_B_1	Encoder 24V	
		2 - HTL_B_2	Encoder B+	
		3 - HTL_B_3	Encoder Ground	
		4 - NC	No function	

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Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
EXT-ENC	**X19**	1 – U_ENC_4	Voltage supply encoder +24V DC X34	
		2 – GND_ENC_4	Voltage supply encoder 0V DC X34	
		3 – U_REF_4	Reference voltage encoder X33	
		4 – NC	No function	
	X29	1 – HTL_A_1	Encoder 24V	
		2 - HTL_A_2	Encoder A+	
		3 - HTL_A_3	Encoder Ground	
		4 – NC	No function	
	X30	1 – HTL_B_1	Encoder 24V	
		2 - HTL_B_2	Encoder B+	
		3 - HTL_B_3	Encoder Ground	
		4 - NC	No function	

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
ENC	**X15**	1 – U_ENC_2	Voltage supply encoder VDC X32	
		2 – GND_ENC_2	Voltage supply encoder GND X32	
		3 – NC	No function	
		4 – NC		

HTL Geber Anschluß: A+/B+

24V	HTL_A_1		24V	HTL_B_1
A+	HTL_A_2		B+	HTL_B_2
GND	HTL_A_3		GND	HTL_B_3

HTL Geber Anschluß: A+,A-/B+,B-

A+	HTL_A_1		B+	HTL_B_1
A-	HTL_A_2		B-	HTL_B_2
	HTL_A_3			HTL_B_3
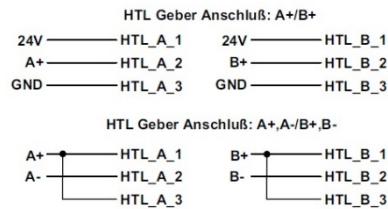
5.5.8 Terminal Assignment KSM12-2A

Terminal Assignment				
Unit	Terminal	Pin	Description	Note
REL	**X11**	1 - U24_EXT	Voltage supply device +24 VDC	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0 VDC	
		4 - GND_EXT		
	X12	1 - DI13	Safe digital inputs	
		2 - DI14		
		3 - P1	Clock outputs	
		4 - P2		
	X21	1 - DO0_P	Output pp-switching	
		2 - DO0_M	Output pn-switching	
		3 - DO1_P	Output pp-switching	
		4 - DO1_M	Output pn-switching	
	X22	1 - K1.1	Safe relay output	
		2 - K1.2		
		3 - K2.1	Safe relay output	
		4 - K2.2		

Terminal Assignment

Unit	Terminal	Pin	Description	Note
CPU-ENC	**X13**	1 – U_ENC_1	Voltage supply encoder +24V DC X31	
		2 – GNC_ENC_1	Voltage supply encoder 0V DC X31	
		3 – DO 0.1	Auxiliary outputs	
		4 – DO 0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

Terminal Assignment

Unit	Terminal	Pin	Description	Note
EXT-ENC	**X17**	1 – U_ENC_3	Voltage supply encoder +24V DC X33	
		2 – GND_ENC_3	Voltage supply encoder 0V DC X33	
		3 – U_REF_3	Reference voltage encoder X33	
		4 – NC	No function	
	X27	1 – HTL_A_1	Encoder 24V	
		2 - HTL_A_2	Encoder A+	
		3 - HTL_A_3	Encoder Ground	
		4 – NC	No function	
	X28	1 – HTL_B_1	Encoder 24V	
		2 - HTL_B_2	Encoder B+	
		3 - HTL_B_3	Encoder Ground	
		4 - NC	No function	

Installation Manual

Terminal Assignment				
Unit	Terminal	Pin	Description	Note
EXT-ENC	X19	1 – U_ENC_4	Voltage supply encoder +24V DC X34	
		2 – GND_ENC_4	Voltage supply encoder 0V DC X34	
		3 – U_REF_4	Reference voltage encoder X34	
		4 – NC	No function	
	X29	1 – HTL_A_1	Encoder 24V	
		2 - HTL_A_2	Encoder A+	
		3 - HTL_A_3	Encoder Ground	
		4 – NC	No function	
	X30	1 – HTL_B_1	Encoder 24V	
		2 - HTL_B_2	Encoder B+	
		3 - HTL_B_3	Encoder Ground	
		4 - NC	No function	

Terminal Assignment				
Unit	Terminal	Pin	Description	Note
ENC-ANALOG	X15	1 – U_ENC_2	Voltage supply encoder +24V DC X32	
		2 – GND_ENC_2	Voltage supply encoder 0V DC X32	
		3 – NC	No function	
		4 – NC		
	X25	1 – AI 1.1+	Safe analog input	
		2 – AI 1.1-		
		3 – AI 1.2+		
		4 – AI 1.2-		
	X26	1 – AI 2.1+	Safe analog input	
		2 – AI 2.1-		
		3 – AI 2.2+		
		4 – AI 2.2-		

HTL Geber Anschluß: A+/B+

24V ——— HTL_A_1	24V ——— HTL_B_1
A+ ——— HTL_A_2	B+ ——— HTL_B_2
GND ——— HTL_A_3	GND ——— HTL_B_3

HTL Geber Anschluß: A+,A-/B+,B-

A+ ——— HTL_A_1	B+ ——— HTL_B_1
A- ——— HTL_A_2	B- ——— HTL_B_2
——— HTL_A_3	——— HTL_B_3

5.5.9 Terminal Assignment KSM31

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
IO	**X11**	1 - U24_EXT	Voltage supply device +24V DC outputs	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0V DC	
		4 - GND_EXT		
	X12	1 – IO01	Safe digital inputs, outputs pp-switching	
		2 – IO02		
		3 - DO0.3	Clock outputs	
		4 - DO0.4		
	X21	1 – IO03	Safe digital inputs, outputs pp-switching	
		2 – IO04		
		3 – IO05		
		4 – IO06		
	X22	1 – IO07		
		2 – IO08		
		3 – IO09		
		4 - IO10		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU	**X13**	1 - NC	No function	
		2 - NC		
		3 - DO0.1	Auxiliary outputs	
		4 - DO0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

5.5.10 Terminal Assignment KSM31R

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
EXT-REL	**X07**	1 – K1/11	Read back contact Relais 1	
		2 – K1/12		
		3 – K2/11	Read back contact Relais 2	
		4 – K2/12		
	X08	1 – K3/11	Read back contact Relais 3	
		2 – K3/12		
		3 – K4/11	Read back contact Relais 4	
		4 – K4/12		
	X17	1 – K1.1	Safe relay output 1	
		2 – K1.2		
		3 – K2.1	Safe relay output 2	
		4 – K2.2		
	X18	1 – K3.1	Safe relay output 3	
		2 – K3.2		
		3 – K4.1	Safe relay output 4	
		4 – K4.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
EXT-REL	X09	1 – K5/11	Read back contact Relais 5	
		2 – K5/12		
		3 – K6/11	Read back contact Relais 6	
		4 – K6/12		
	X10	1 – K7/11	Read back contact Relais 7	
		2 – K7/12		
		3 – K8/11	Read back contact Relais 8	
		4 – K8/12		
	X19	1 – K5.1	Safe relay output 5	
		2 – K5.2		
		3 – K6.1	Safe relay output 6	
		4 – K6.2		
	X20	1 – K7.1	Safe relay output 7	
		2 – K7.2		
		3 – K8.1	Safe relay output 8	
		4 – K8.2		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
IO	X11	1 - U24_EXT	Voltage supply device +24V DC outputs	
		2 - U24_EXT		
		3 - GND_EXT	Voltage supply device 0V DC	
		4 - GND_EXT		
	X12	1 – IO01	Safe digital inputs, outputs pp-switching	
		2 – IO02		
		3 - DO0.3	Clock outputs	
		4 - DO0.4		
	X21	1 – IO03	Safe digital inputs, outputs pp-switching	
		2 – IO04		
		3 – IO05		
		4 – IO06		
	X22	1 – IO07		
		2 – IO08		
		3 – IO09		
		4 - IO10		

Terminal Assignment				
Unit	**Terminal**	**Pin**	**Description**	**Note**
CPU	**X13**	1 - NC	No function	
		2 - NC		
		3 - DO0.1	Auxiliary outputs	
		4 - DO0.2		
	X14	1 - DI1	Safe digital inputs	
		2 - DI2		
		3 - DI3		
		4 - DI4		
	X23	1 - DI5		
		2 - DI6		
		3 - DI7		
		4 - DI8		
	X24	1 - DI9		
		2 - DI10		
		3 - DI11		
		4 - DI12		

5.5.11 Terminal Assignment KSM5x

Please take the terminals assignments of the individual communication modules from the corresponding installation manuals.

5.5.12 Terminal Assignment KSM1x/4x

Please take the terminals assignments of the individual communication modules from the corresponding installation manuals.

5.6 External 24 VDC – Voltage Supply

The KSM module requires a 24 VDC power supply with PELV characteristic in accordance to EN50178. Please comply with the following boundary conditions when planning and installing the specified power supply unit:

Strictly comply with the minimum and maximum supply voltage tolerance.

Nominal voltage	DC 24 V
Minimum: 24 VDC – 15%	20,4 VDC
Maximum: 24 VDC + 20%	28,8 VDC

We recommend the use of a 3-phase power supply unit or an electronically controlled device to achieve an as little as possible residual ripple of the supply voltage. The power supply unit must meet the requirements acc. to EN61000-4-11 (voltage dip).
Connecting cables must comply with local regulations.
The interference voltage resistance of the KSM module is 32 VDC (protected by suppressor diodes at the input).

⚠ **Safety Note:**
- The KSM module must be individually protected by a 3,15A (min. 30 VDC) back-up fuse which must be placed near by the terminals of the modules.
  Recommended fuse type:
  3.15A circuit breaker (Class B) or safety fuse (inert).

Comments:
Reliable galvanic isolation from the 230 VAC or 400 VAC networks must be guaranteed in any case. This requires the selection of power supply units complying with the regulations DIN VDE 0551, EN 60 742 and DIN VDE 0160. Besides choosing a suitable device you must also ensure equipotent bonding between PE and 0-VDC on the secondary side.

⚠ **Safety Note:**
- All GND connections of the devices, which are connected to the inputs of the KSM module must be connected to the GND of the KSM (voltage supply).

Inputs of the KSM are:
- Digital inputs
- Digital I/Os
- Analogue inputs
- Encoder connections

Comments:
The connections GND_ENC and AIN are not internally connected to GND!

KSM12-2

KSM31

● — — — — — ● Internal connection e.g.: between UE1- -> 9-pol D-SUB X31 Pin 2
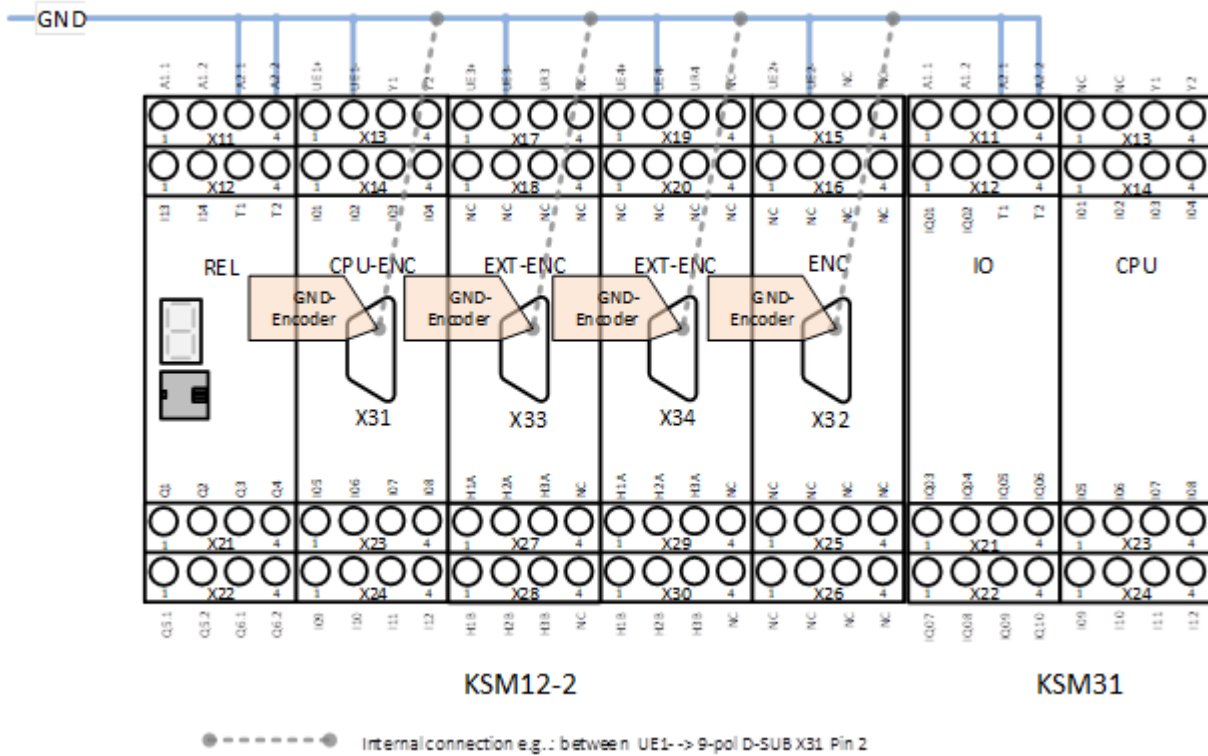
5.7 Connection of the External Encoder Supply

5.7.1 Incremental, HTL, SIN/COS, SSI
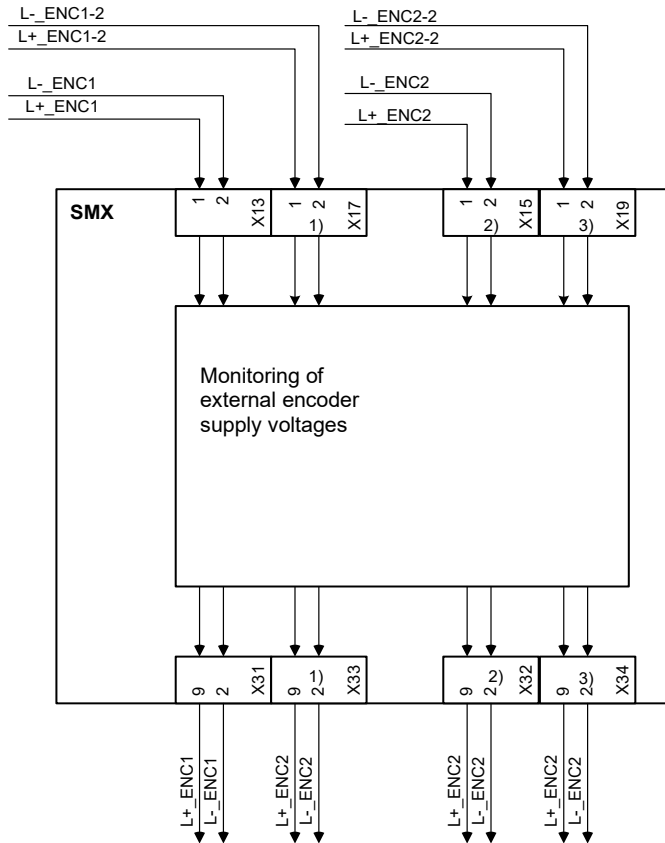
1) Only KSM 11-2 and KSM 12-2
2) Only KSM 12 and KSM 12-2
3) Only KSM 12-2

The KSM module supports encoder voltages of 5V, 8V, 10 V, 12V and 24V, which are internally monitored in accordance with the chosen configuration.
If an encoder system is not supplied through the KSM module, a supply voltage still needs to be connected to terminal X13 or X15 and configured accordingly.
The encoder supply must be protected with a fuse of max. 2A.

⚠ **Safety Note:**
- The GND connection of the encoder must be connected to the GND of the KSM

Monitoring of the supply voltage in accordance with the chosen nominal voltage:

Nominal voltage	Minimum voltage	Maximum voltage
5 VDC	4,4 VDC	5,6 VDC
8 VDC	7 VDC	9 VDC
10 VDC	8 VDC	12 VDC
12 VDC	10 VDC	14 VDC
20 VDC	16 VDC	24 VDC
24 VDC	20 VDC	29,5 VDC
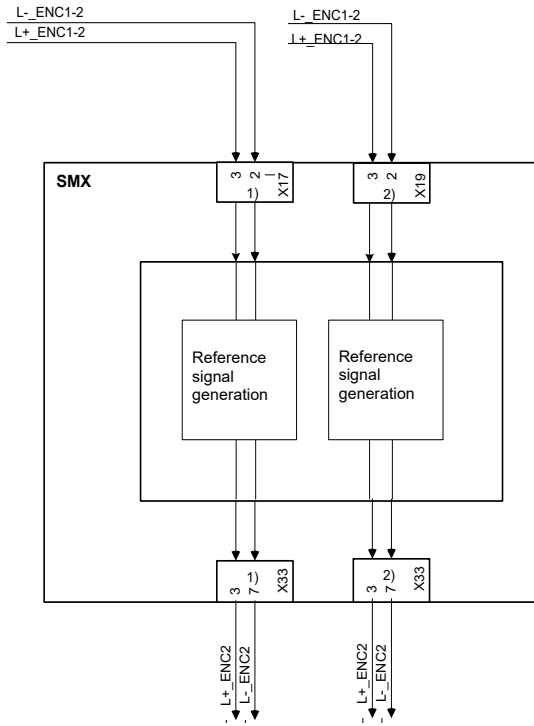
5.7.2 Resolver

1) Only KSM 11-2 and KSM 12-2
2) Only KSM 12-2

When using resolvers in Master-Mode an additional 24V DC power supply is required for generating the reference signal.

The encoder supply must be protected with a fuse of max. 2A.

Supply voltage monitoring:

Nominal voltage	Minimum voltage	Maximum voltage
24 VDC	20 VDC	29 VDC

5.8 Connection of Digital Inputs

The KSM comes with 14 (KSM10/11/12) or 12 (KSM31) safe digital inputs. These are suitable for connecting single or two-channel signals with and without cycling, or without cross-shorting test.

The connected signals must have a "High"-level of DC 24 V (DC +15 V..+ DC +30 V) and a "Low"-level of (DC -3 V... DC +5 V, Type1 acc. to IEC 61131-2). The inputs are provided with internal input filters.

A device internal diagnostic function cyclically tests the correct function of the inputs including the input filters. A detected fault will set the KSM into an alarm status. At the same time all outputs of the KSM are rendered passive.

Besides the actual signal inputs, the KSM- module holds two clock inputs P1 and P2 available. The pulse outputs are switching type 24 VDC outputs.
The pulse outputs are solely intended for monitoring the digital inputs (DI1 ... DI14) and cannot be used for any other function within the application.

The switching frequency is 125 Hz for each output. In the planning stage one must bear in mind that the outputs may only be loaded with a total current of max. 250 mA.

Furthermore, approved OSSD-outputs can be connected to the inputs I01-I14 without limitation.

In case of single-channel use of the inputs, the achievable safety level must be limited to SIL 2 or PL d, if the safety function is demanded at regular intervals.

A safety related use of the inputs is generally only intended in connection with the pulse outputs.

If pulse outputs are not used, short circuits in the external wiring between different inputs and against the supply voltage for the KSM must be ruled out by external measures, appropriate routing of cables in particular.

Each input of the KSM module can be configured individually for the following signal sources:

Input is assigned to the cycle P1
Input is assigned to the cycle P2
Input assigned to continuous voltage DC 24 V

5.9   Connection of Analog Inputs

With the executions with analog processing. max. 2 analog signals to be processed safely:

The analog inputs can be connected as follows:

	min	max
Voltage	-7VDC	+10VDC

Note:
The modules can optionally be equipped with voltage and, or current inputs.

⚠ **Safety Note:**
 • The GND connection AIN must be connected to the GND of the KSM.

5.10 Connection of Position and Speed Sensors

5.10.1 General Notes

Depending on module type the KSM module (KSM11/12) has external encoder interfaces for the connection of industrial incremental and absolute encoders. The encoder interfaces can be configured as incremental, SIN/COS, or as absolute SSI-encoders.
It is also possible to connect 2 incremental signal generating sensors (e.g. proximity switches) to the counting inputs of the KSM module. The signals must each be read in with normal and complementary track.

IMPORTANT
The voltage supply of the encoder system uses the dedicated terminals on the KSM module. This voltage is applied to the encoder plug and monitored by an internal diagnostic process. When the sensor is supplied with an external voltage, this voltage must be supplied through the encoder plug. The corresponding terminal (encoder supply voltage) on the KSM module remains unoccupied.

If an external sensor voltage supply is not recirculated through the encoder plug, any failure of this supply must be included in the fault examination of the overall system. This, in particular, requires evidence that this fault is detected or can be excluded when the specified operating voltage of the overall system is fallen short of / exceeded.

EMC - measures such as shielding etc. must be observed.
The two encoders must be non-interacting to each other. This applies for both the electrical as well as the mechanical part.
If both encoders are coupled to the facility to be monitored via common mechanical parts, the connection must be positively designed and should not have any parts that are susceptible to wear (chains, toothed belts, etc.). Should this be the case, additional monitoring features for the mechanical connection of the sensors (e.g. monitoring of a toothed belt) are required).
In case of an active position processing at least one absolute value encoder must be used.
When using two equivalent sensors one must make sure that the sensor with the higher resolution is configured as sensor 1 (process sensor) and the sensor with the lower resolution as sensor 2 (reference sensor).

⚠ **Safety Note:**
- The GND connections of the encoders must be connected to the GND of the KSM. This applies in the same way also to resolvers.

Attention:
The sensor connections must neither be plugged on nor pulled off during operation. This could cause damage to electrical components of the encoder. Always de-energize connected encoders and the KSM module **before** plugging on or pulling off encoder connections.
With externally supplied encoders, pay attention to switching off the external supply voltage (e.g. converter).

Lines twisted in pairs for signal transmission acc. to RS485 standard must be used for data and clock signals or track A and track B. The wire cross-section must in each individual case be chosen in compliance with the current consumption of the encoder and the cable length required for the installation.

The following applies when using absolute encoders:

In Slave-mode the clock signal is generated by an external process and is read in by the KSM module together with the data signal. This type of reading causes a beat which results in a reading fault of the following magnitude:

F = (reading time of encoder by external system [ms] / 8 [ms]) * 100 %

The size of the resulting reading fault F must be taken into account when determining the thresholds in the applied monitoring functions, because this fault cannot be compensated!

5.10.2 Assignment of Encoder Interface

X31/X32[1)]

Sensor assignment
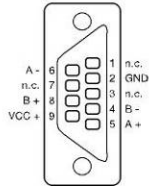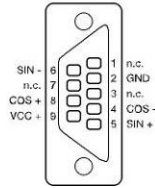
Incremental - Encoder   **SIN/COS**   **Absolute encoder**   **SSI - Listener**
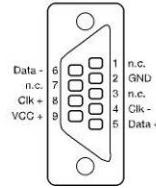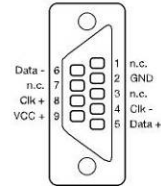
[1)] only KSM12

X33/X34[2)]

Sensor assignment
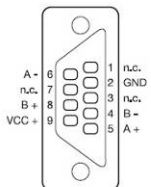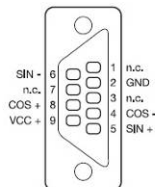
Incremental - Encoder   **SIN/COS**   **SSI - Absolut X 31/X 32**   **SSI – Absolute X 31/X 32**   **Resolver**
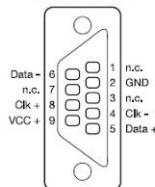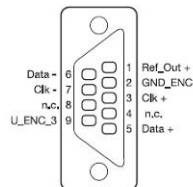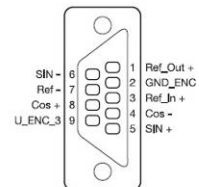
[2)]only KSM12-2

NOTE:

With the terminals X33/X34 of the modules KSM11-2 and KSM12-2, the connection is inverse to the presented and to X31/X32 with application of an incremental counting system.
With encoders not connected inversely to X33/X34, the direction of rotation is thus indicated inversely. The indicated direction of rotation can be corrected in the software. (see. programming manual S. 90 FF - "Direction UP/down")

5.10.3 Connection Variants

5.10.3.1 Connection of an absolute encoder as master

Sub-D plug (9 pin) KSM		absolute encoder (Master mode)
Pin 1	n.c.	
Pin 2	Ground	
Pin 3	n.c.	GND of the supply voltage 24 V DC
Pin 4	CLK-	→
Pin 5	DATA+	←
Pin 6	DATA-	←
Pin 7	n.c.	
Pin 8	CLK+	→
Pin 9	Supply voltage	
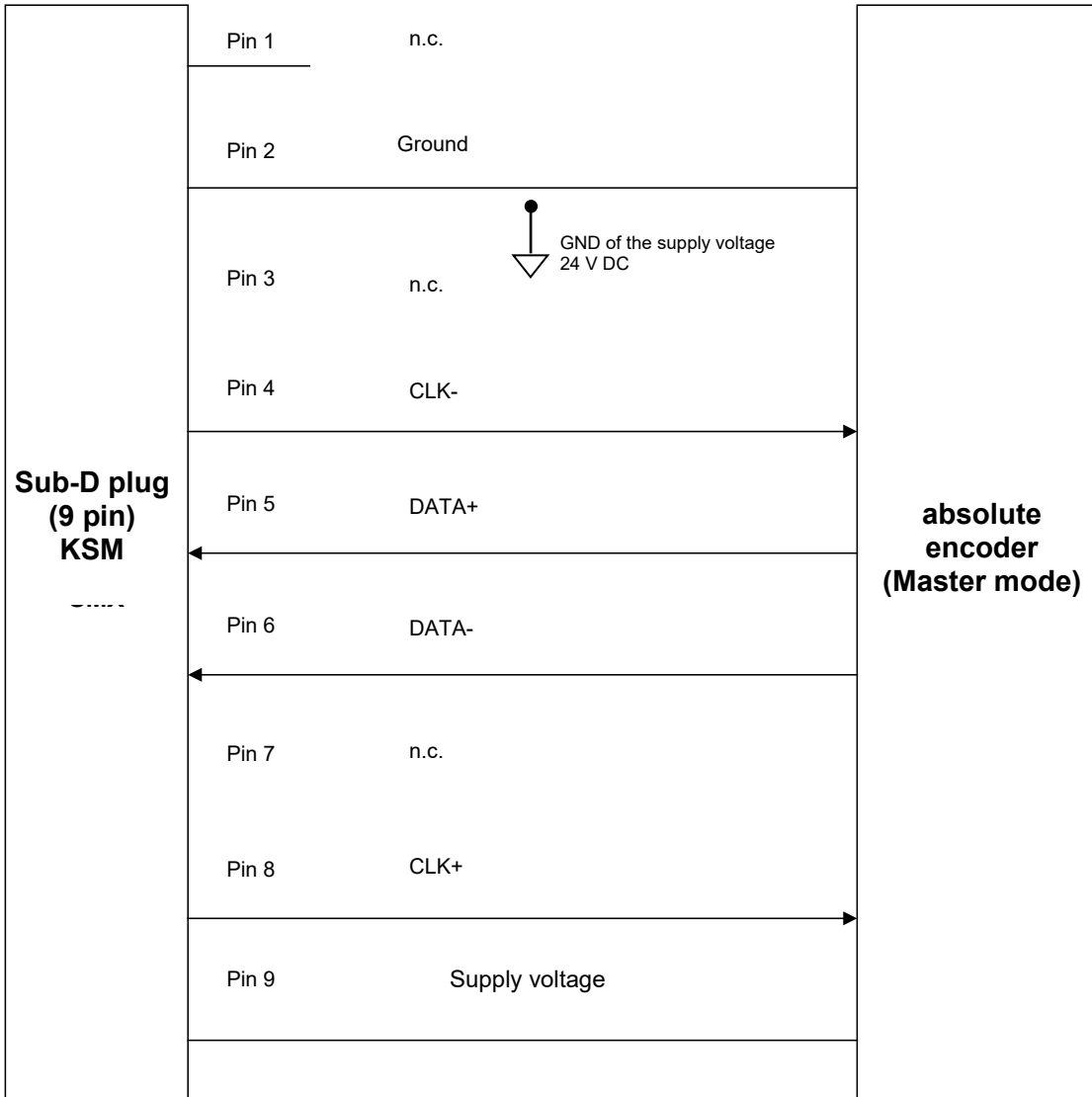
With this type of the connection the clock pulses of the module KSM run to the absolute encoder and the data from the encoder to the KSM.

5.10.3.2 Connection of an absolute encoder as slave

	Sub-D plug (9 pin) KSM		absolute encoder (Slave mode)

Pin 1 — n.c.

Pin 2 — Ground

Pin 3 — n.c.

Pin 4 — CLK-

Pin 5 — DATA+

Pin 6 — DATA-

Pin 7 — n.c.

Pin 8 — CLK+

Pin 9 — Supply voltage

GND of the supply voltage 24 V DC

external sensing system
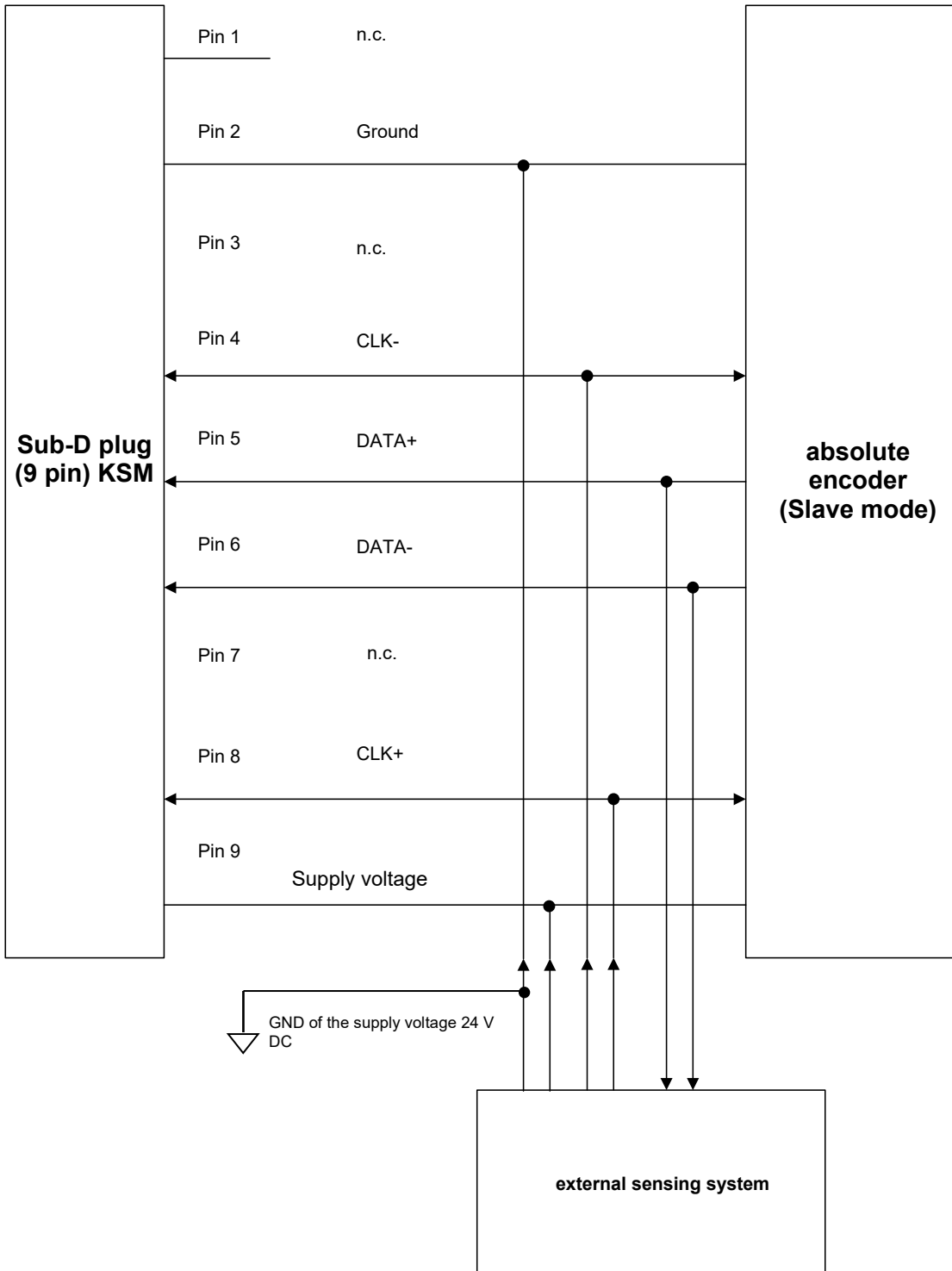
With this type of connection both clock signals and data are read in. In this example the module does not supply the encoder with voltage.

5.10.3.3 Connecting an incremental encoder with TTL-signal level
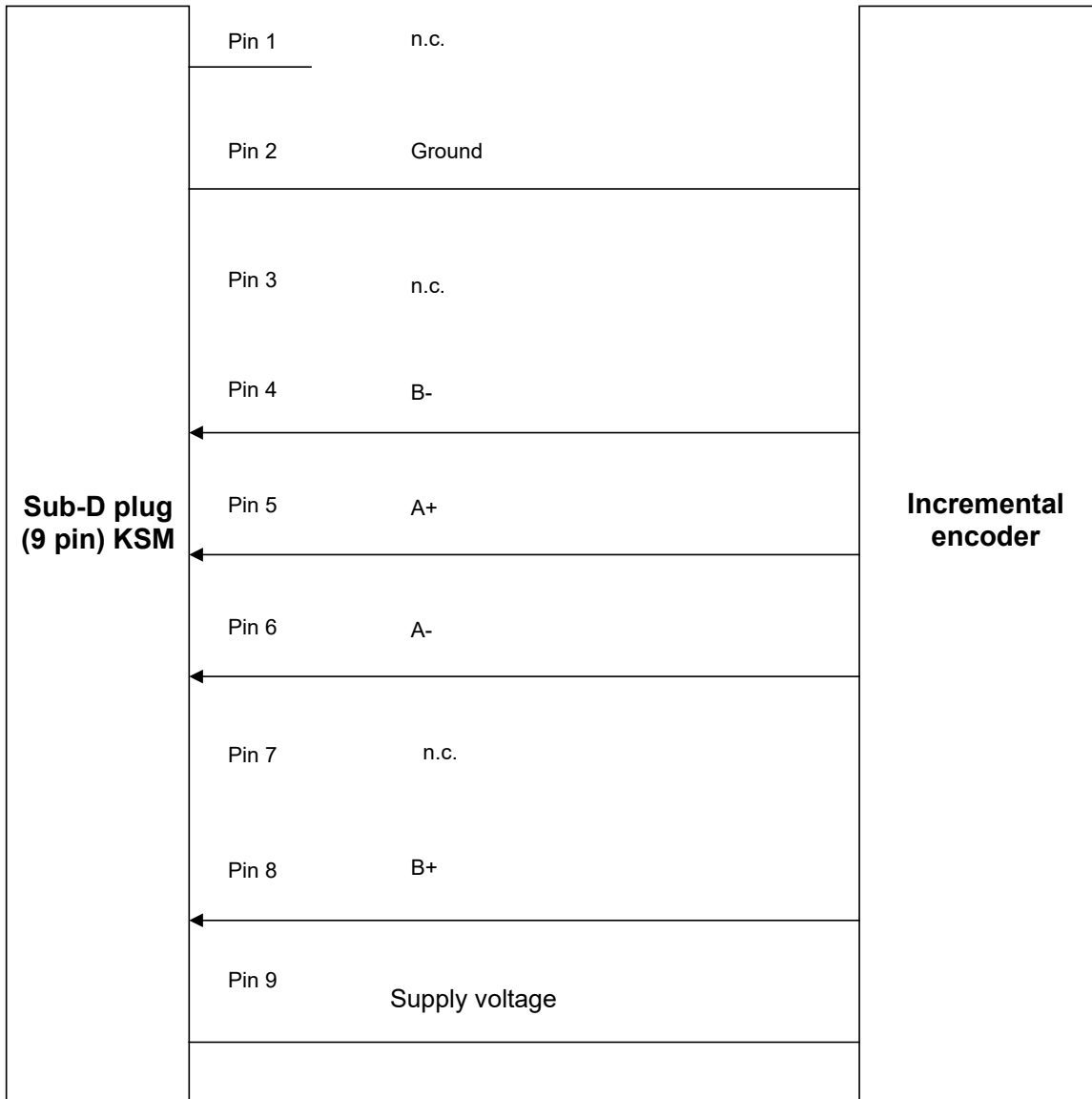
Sub-D plug (9 pin) KSM		Incremental encoder
Pin 1	n.c.	
Pin 2	Ground	
Pin 3	n.c.	
Pin 4	B-	
Pin 5	A+	
Pin 6	A-	
Pin 7	n.c.	
Pin 8	B+	
Pin 9	Supply voltage	

Pins 1, 3 and 7 stay open and are reserved for later expansions.

5.10.3.4   Connection of a SIN/COS encoder
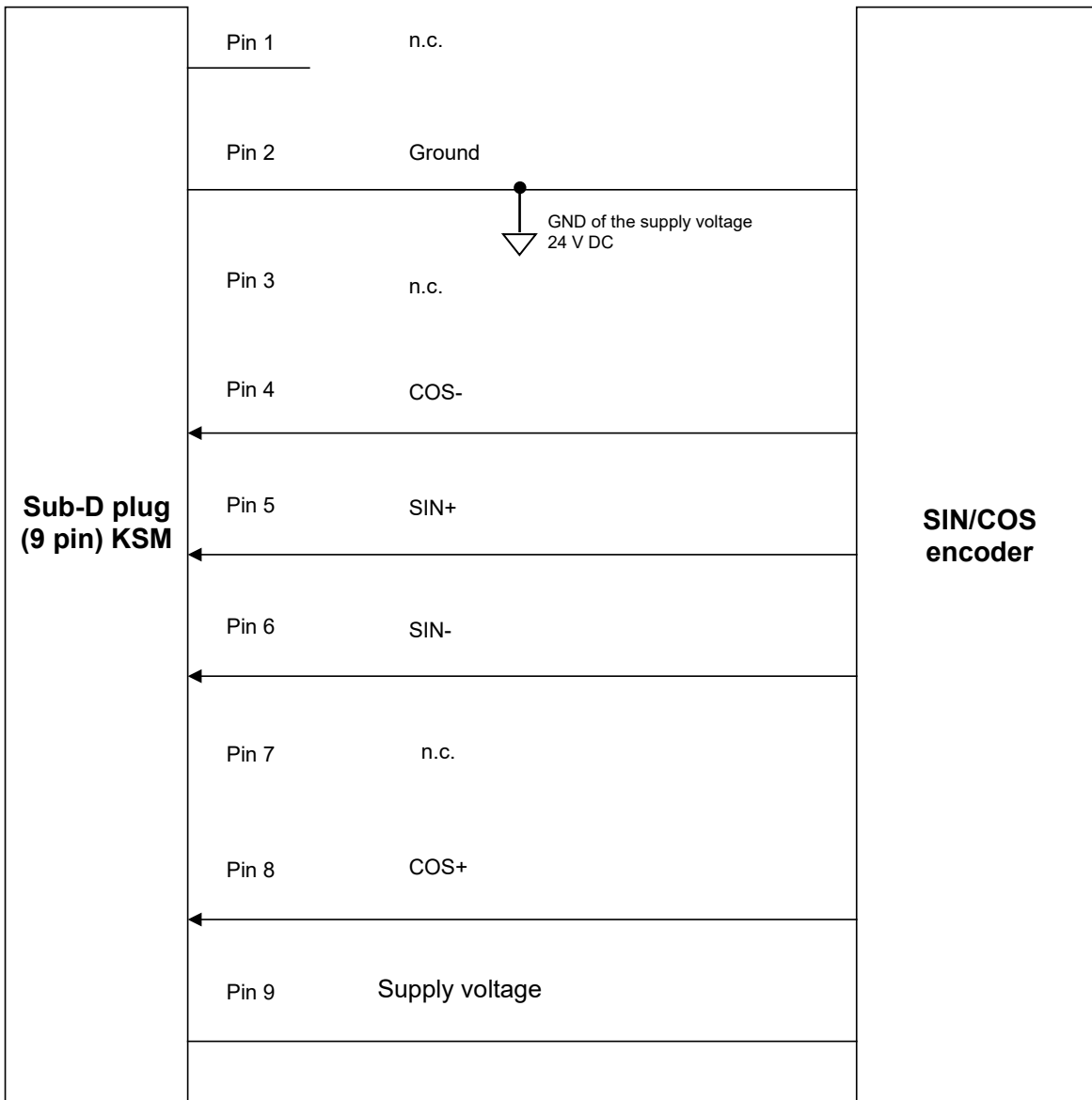
Pin 1	n.c.
Pin 2	Ground
	GND of the supply voltage 24 V DC
Pin 3	n.c.
Pin 4	COS-
Sub-D plug (9 pin) KSM Pin 5	SIN+
Pin 6	SIN-
Pin 7	n.c.
Pin 8	COS+
Pin 9	Supply voltage

SIN/COS encoder

Pins 1, 3 and 7 stay open and are reserved for later expansions.

5.10.3.5 Connection of a resolver as master

Sub-D plug (9 pin) KSM		Resolver (Master mode)
Pin 1	Reference Out +	
Pin 2	Reference Out -	
Pin 3	Reference In +	
Pin 4	COS -	
Pin 5	SIN +	GND of the supply voltage 24 V DC
Pin 6	SIN -	
Pin 7	Reference In -	GND of the supply voltage 24 V DC
Pin 8	COS +	
Pin 9	Monitor Reference Voltage	
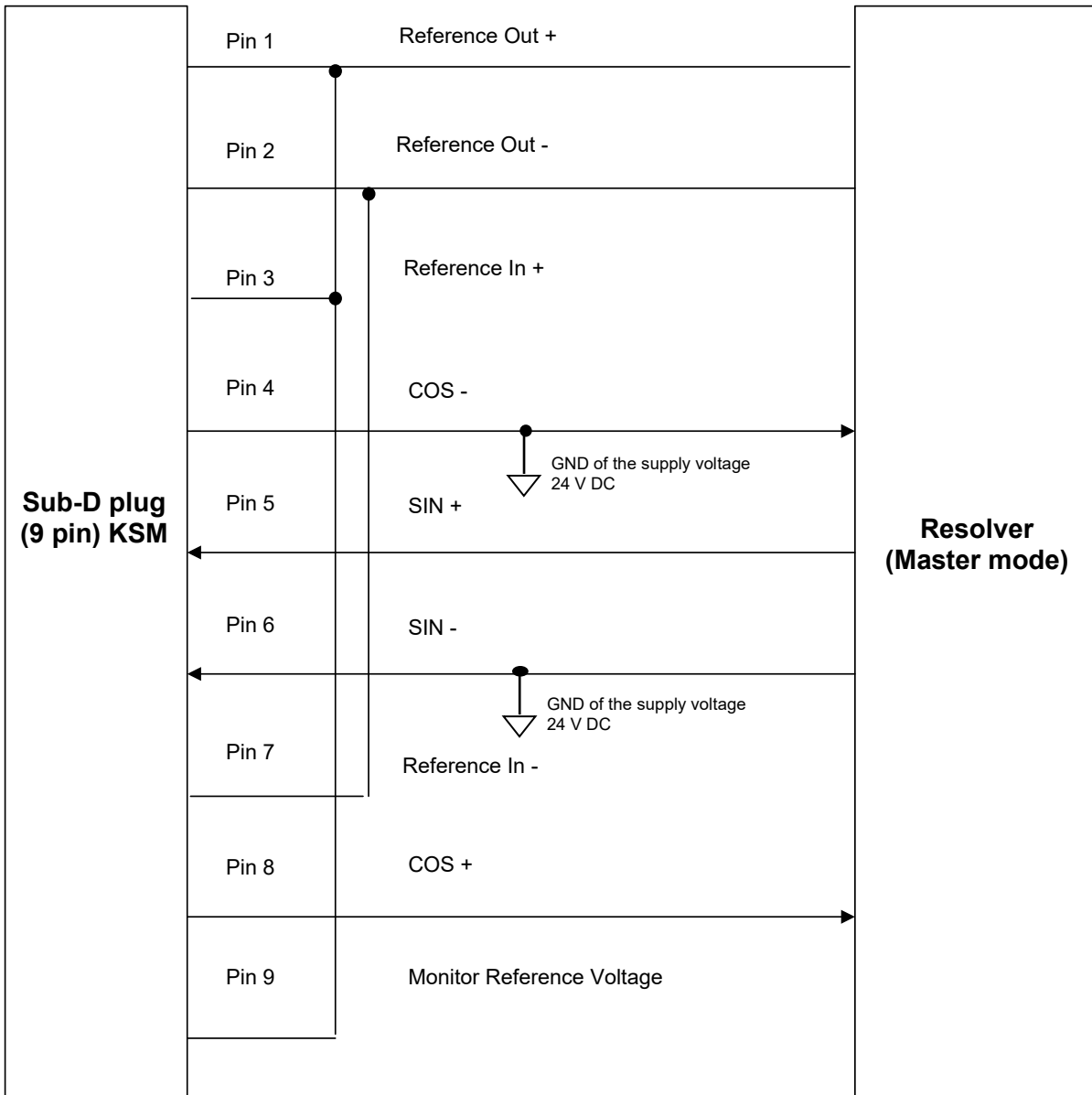
With this type of connection, the clock signals are submitted from the KSM module to the absolute encoder and the data from the encoder to the KSM.

5.10.3.6   Connection of a resolver as slave

Sub-D plug (9 pin) KSM		Resolver (Slave mode)
Pin 1	nc	
Pin 2	Monitor Reference Voltage GND	
Pin 3	Reference In +	
Pin 4	COS -	
Pin 5	SIN +	
Pin 6	SIN -	
Pin 7	Reference In -	
Pin 8	COS +	
Pin 9	Monitor Reference Voltage	

GND of the supply voltage 24 V DC

external sensing system

GND Ref- Ref+ COS- COS+ SIN- SIN+
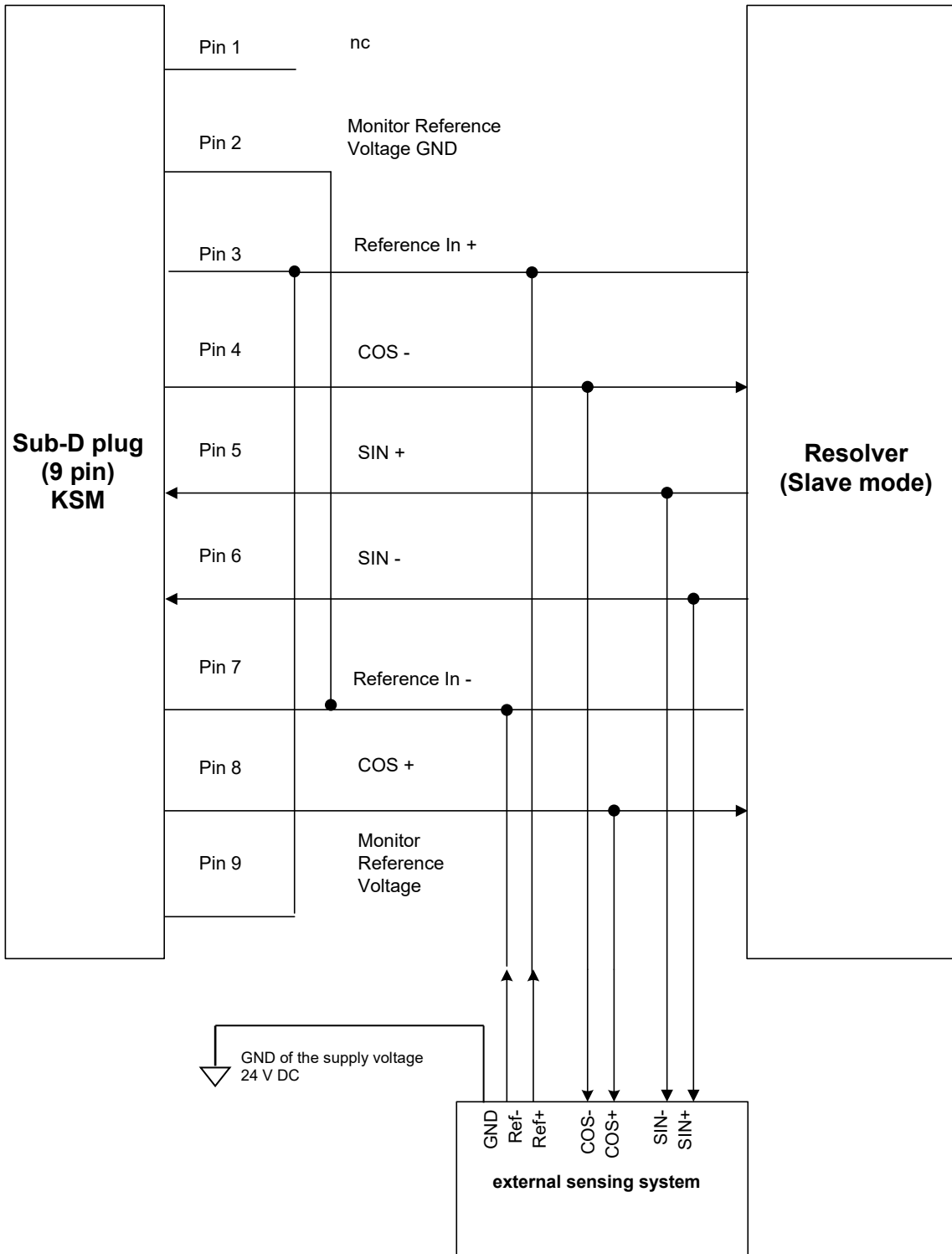
5.10.3.7 Connection of proximity switch KSM1x

The connection is made via plug connector X23 on the digital inputs DI05 …DI08.
The exact pin assignment depends on the encoder type and is shown in the connecting plan of the programming interface.

Note: When using HTL-encoders please bear in mind that the tracks A+ and B+ or A- and B- must be combined accordingly.

5.10.3.8 Connection of HTL/proximity switch KSM11-2/KSM12-2

The connection is made via plug connectors X27 and X28, or X29 and X30

5.10.3.8.1 HTL-encoder with A+/A- or B+/B- signal
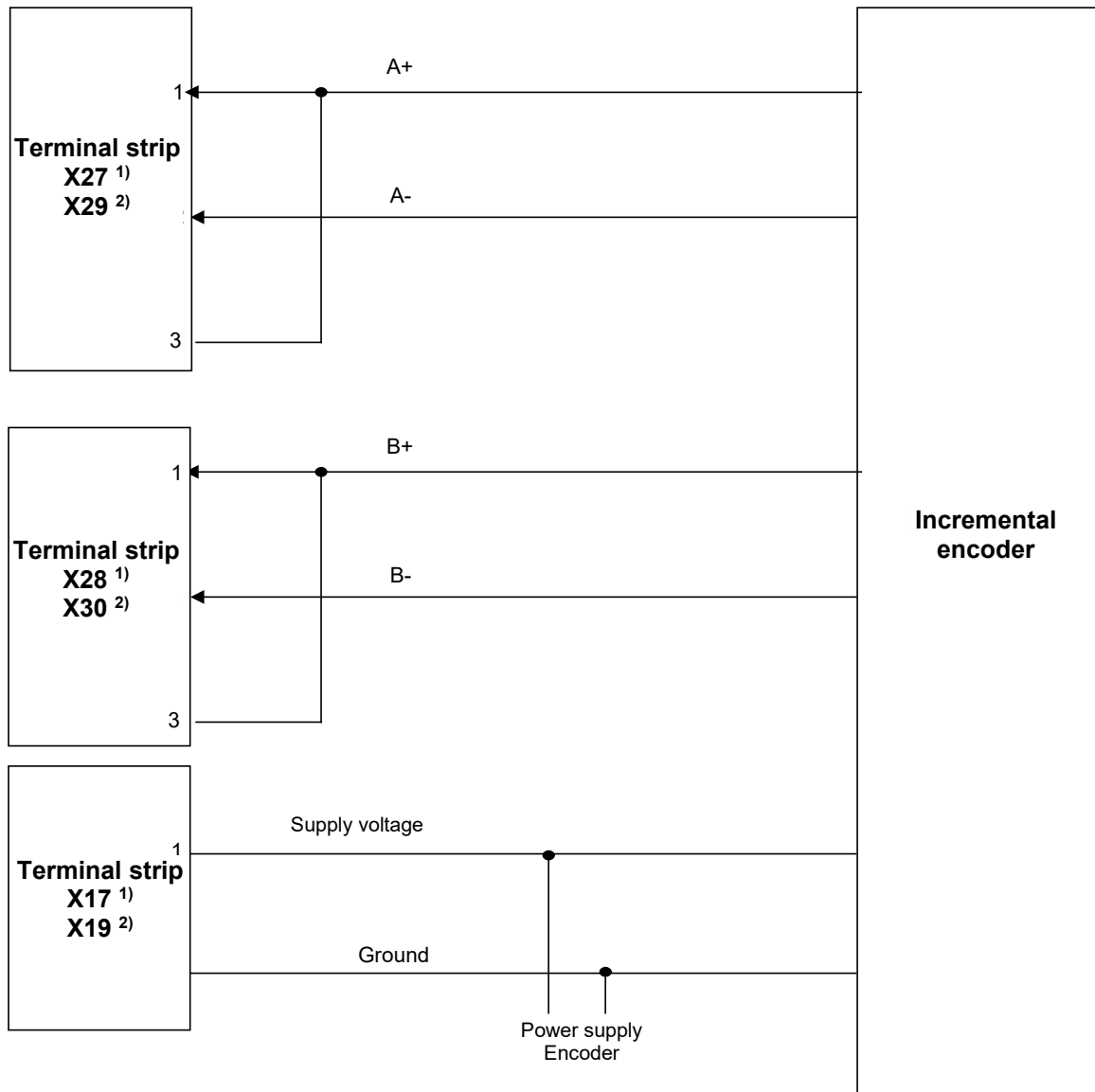
[1])KSM11-2 Encoder 3
[2])KSM12-2 Encoder 4

5.10.3.8.2 HTL-encoder with A+ or B+- signal
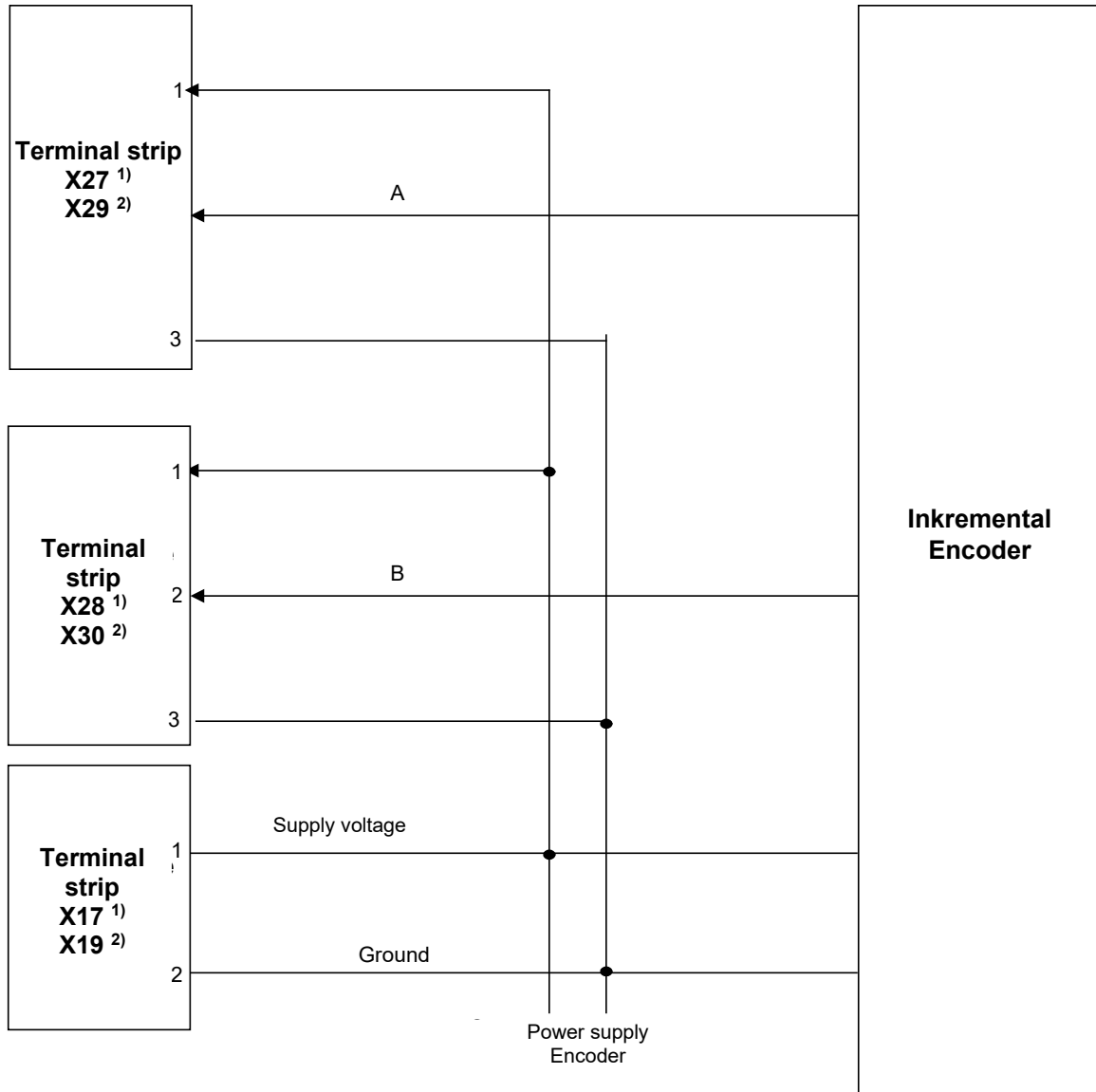
[1]KSM11-2 Encoder 3
[2]KSM12-2 Encoder 4

5.11 Configuration of Measuring Distances

5.11.1 General description of encoder configuration

The most important input variables for the monitoring functions of the module are safe position, speed and acceleration. These are obtained by dual-channel generation from the connected sensor system. A category 4 compliant architecture, i.e. continuous dual channel recording with high degree of diagnostic coverage, is required for Pl e acc. to EN ISO 13849-1. For possible single-channel components (e.g. mechanical connection of the sensors/encoders with only one shaft/fastening) fault exclusions acc. to EN ISO 13849-2 may be used, if this should be necessary. For Pl d acc. to EN ISO 13849-1 one may work with a reduced degree or diagnostic coverage. Simple design sensor systems (speed monitoring only) may under certain circumstances be sufficient under due consideration of the permissible fault exclusions acc. to EN ISO 13849-2.
See also APPENDIX 1

Further configuration is described in the programming manual:
37420-820-01-xxF-KSM Programierhandbuch.pdf

6 Sensor type

Absolute encoder and incremental measuring systems are possible, as well as counting pulse generating proximity switches.

6.1 Absolute encoder:

Data interface: Serial Synchronous Interface (SSI) with variable data length from 12 to 28 bit.
Data format: Binary or Gray code,
Physical Layer: RS-422 compatible

SSI-Master operation:
Clock rate: 150kHz

SSI-Listener operation (slave mode):
Max. external clock rate 250 KHz [1] or 350 kHz [2].
Min. clock pause time 150 μsec
Max. clock pause time 1 msec

Diagnoses:

Diagnose	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 5 V, 8V, 10V, 12V, 20V, 24V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of differential level on input	Fixed value RS 485-level	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of Clk-frequency	Fixed value	100 kHz < f < 350 kHz
Plausibility of speed versus position	Fixed value	$DP < 2 * V * T$ with T = 8 ms

Parameterization of SSI-format:

Clk   ClkN ← Number Clk = Framelength

| Start | Clk 0 | Clk 1 | Clk 2 | ... | N-4 | N-3 | N-2 | N-1 | N-0 |

Index Data

Index Status

K Data

O Status

Status information

| Status 1 | Status 2 | Status 3 | .... | Status 0 |

Fault mask

0 = don't care
1 = active

| Mask 1 | Mask 2 | Mask 3 | .... | Mask 0 |

Result mask
for error = 0
(evaluation active)

| Result 1 | Result 2 | Result 3 | .... | Result 0 |
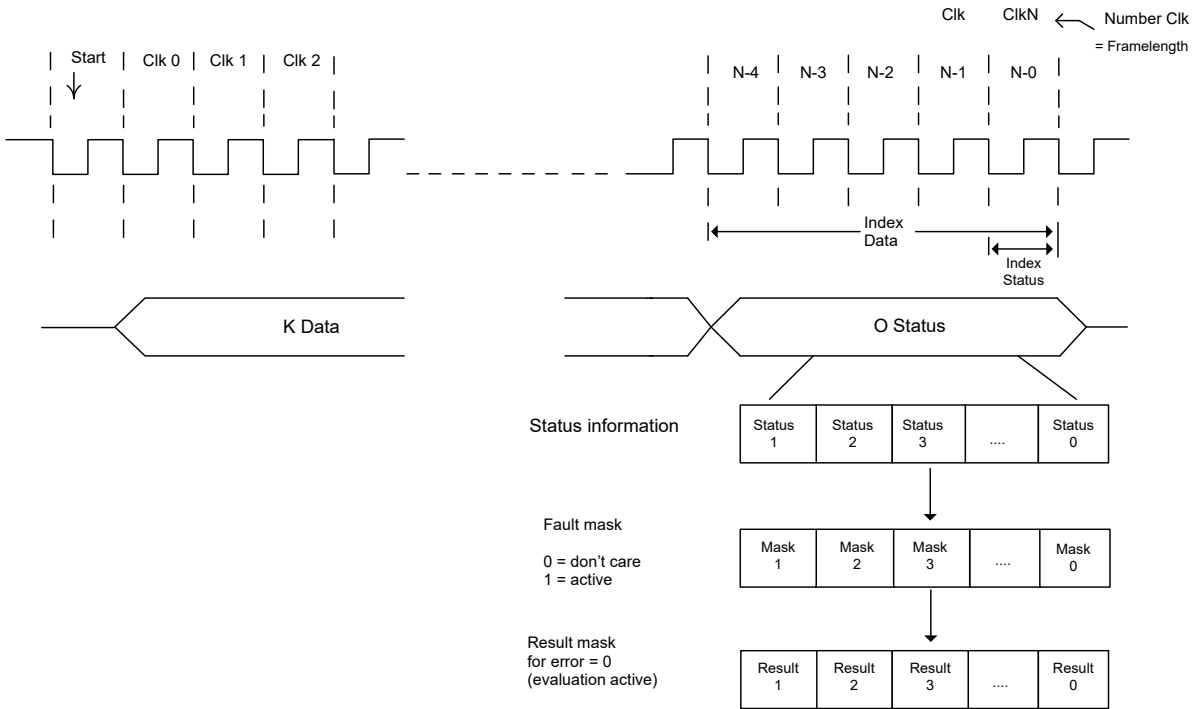
Example:

SSI-Frame length:	28 cycles
Data-Length:	22 bit
Status:	5 bit, 3 bit Fault + 2 bit Warning/ready for operation

Clk   ClkN ← Number Clk = Framelength

| Start | Clk 0 | Clk 1 | Clk 2 | ... | Clk 24 | Clk 25 | Clk 26 | Clk 27 | Clk 28 |

6 Clk

1Clk

K Data

O Status

Status information

| Temperature 1 = Error | Intensity 1 = Error | HW 1 = Error | Warning: Contamination 1 = Error | Operating mode 1 = OK | t |

Fault mask

0 = don't care
1 = active

| 1 | 1 | 1 | 0 | 0 |

Result mask
for error = false
(evaluation active)

| 0 | 0 | 0 | 0 | 0 |
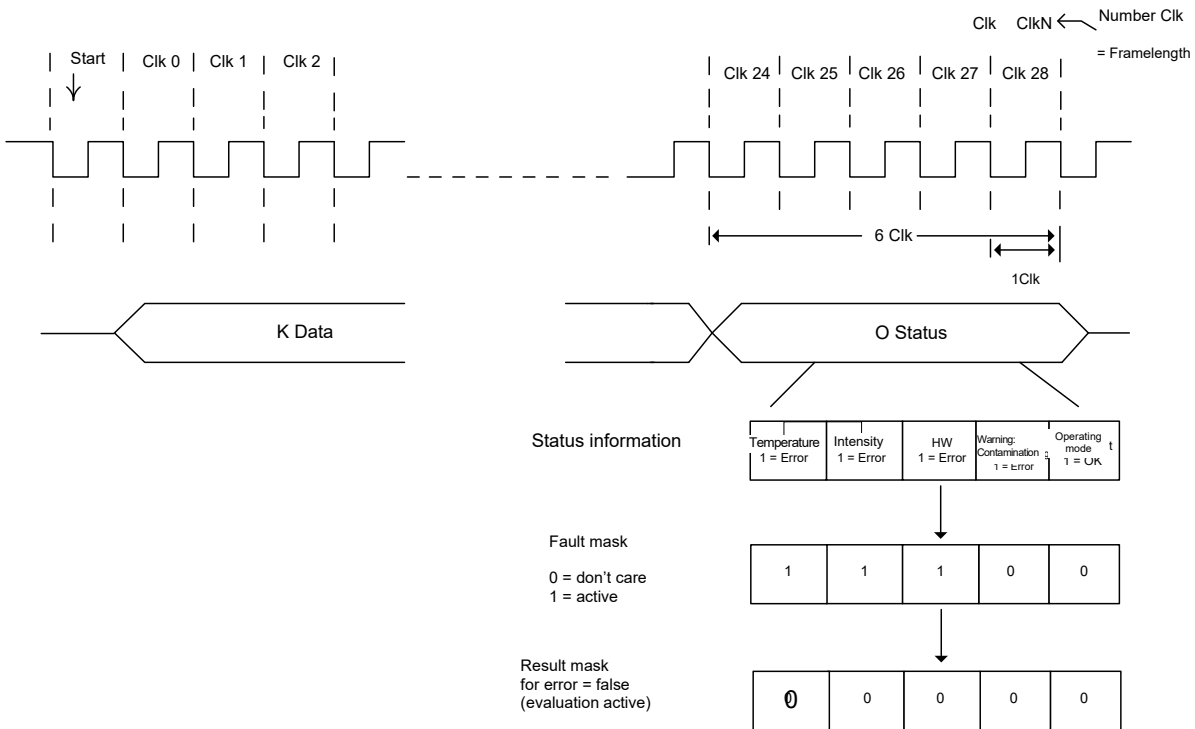
6.2 Incremental encoder:

Physical Layer: RS-422 compatible
Measuring signal A/B.   Track with 90 degree phase difference
maximum frequency of input cycles   200 KHz [1] or 500 kHz [2]

Diagnoses:

Diagnose	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 5 V, 8V, 10V, 12V, 20V, 24V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of differential level on input	Fixed value RS 485-level	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of the counting signal separated for each track A/B	Fixed value	ΔP > 4 increments

6.3 Sine/Cosine encoder – standard mode

Physical Layer: +/- 0.5 Vss (without voltage offset)
Measuring signal A/B.   Track with 90 degree phase difference
Maximum frequency of input clock pulses. 200 KHz [1] or 500 kHz [2]

Diagnoses:

Diagnose	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 5 V, 8V, 10V, 12V, 20V, 24V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of amplitude SIN^2+COS^2	Fixed value $1V_{SS}$	65 % of $1 V_{SS}$ +/- 2.5 %(measuring tolerance)
Monitoring of phases A/B	Fixed value 90°	+/- 30° +/-5° measuring tolerance

6.3.1 Sine/Cosine encoder – high resolution mode:

Physical Layer: +/- 0.5 Vss (without voltage offset)
Measuring signal A/B.   Track with 90 degree phase difference
Maximum frequency of input clock pulses. 15 kHz [2]

Diagnoses:

Diagnose	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 5 V, 8V, 10V, 12V, 20V, 24V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of amplitude SIN^2+COS^2	Fixed value $1V_{SS}$	65 % of $1 V_{SS}$ +/- 2.5 %(measuring tolerance)
Monitoring of phases A/B	Fixed value 90°	+/- 30° +/-5° measuring tolerance)
Monitoring of counting signal / signal phase quadrant	Fixed value	+/- 45°

6.4 Proxy - switch

Signal level.   24V/0V
Max. counting frequency.   10kHz
Circuit logic de-bounced

Diagnoses:

Diagnose	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 24V	+/- 20 % +/-2 %(measuring tolerance)

6.5 Extended monitoring proximity switch / proximity switch

The extended monitoring uncovers the following faults:
   a) Supply voltage failure
   b) Failure of output signal in driver direction
   c) Malfunction of High signal proximity switch
   d) Interruption of signal path
   e) Mechanical de-adjustment of proximity switch / excessive switching distance of proximity switch

For diagnostic purposes both status conditions of the counting signal are additionally recorded synchronously and compared logically. A damping of at least one of the two signals must be guaranteed for each shifting gate. The logic will evaluate this instruction.

Design of switching gate with radial sensor arrangement
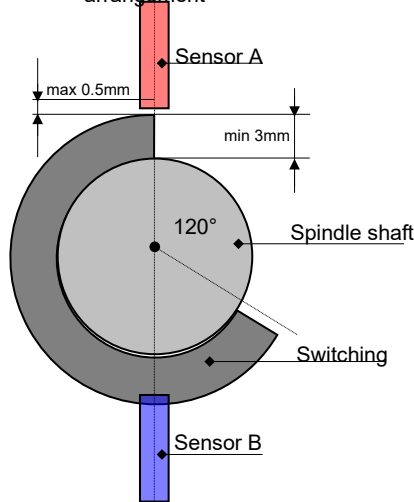
Intended theoretic signal form
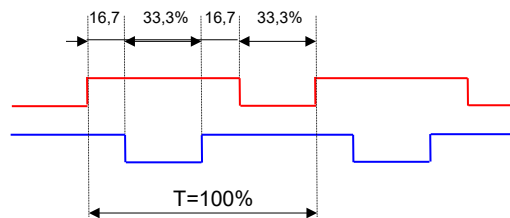
The diagnose must be designed for at least the following limiting values:

Max. counting frequency: 4 kHz
Max. blanking 0-signal: 50 %
Min. coverage: 10 %

Reading in counting signals:
The two counting signals are both separately assigned to the two channels. In each of the channels the status is read in synchronously. In order to ensure synchronization this must be carried out directly after the channel synchronization. Sampling must take place at least 1x per cycle. The max. deviation in synchronization is 20 µs.
The status conditions must be exchanged crosswise through the SPI.

Logic processing:
The following evaluation must be made in both channels:

Signal A	Signal B	Result
Low	Low	False
High	Low	True
Low	High	True
High	High	True

6.6 HTL – Sensor

Signal level.	24V/0V
Physical Layer:	Push/Pull
Measuring signal A/B	track with 90° phase difference
Max. counting pulse frequency:	200 kHz on X27/28 or X29/30 (only KSM11-2/12-2)

Diagnoses:

Diagnosis	Parameters	Fault threshold
Supply voltage monitoring	Fixed values 5 V, 8V, 10V, 12V, 20V, 24V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of differential level on input	Fixed value 24 V	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of the counting signal separated for each track A/B	Fixed value	DP > 4 increments

6.6.1 Resolver

Measuring signal:	SIN/COS – track with 90° phase difference
Max. counting pulse frequency	2 kHz/pole
Resolution:	9 bit / pole
Master-Mode:	
Frequency reference signal	8 kHz
Slave-Mode	
Frequency reference signal	6 - 16 kHz
Reference signal form:	Sinusoidal, triangle

[1])on X31/32
[2])on X33/34

Diagnoses:

Diagnosis	Parameters	Fault threshold
Monitoring of ratio	Fixed values 2:1, 3:2, 4:1	+/- 20 % +/-2 %(measuring tolerance)
Monitoring of signal amplitude SIN²+COS²	Fixed value	<2.8 V +/-5 % (measuring tolerance)
Monitoring of phases A/B	Fixed value 90°	+/- 7° +/-2°(measuring tolerance)
Monitoring of reference frequency	Fixed values 6 .. 12 kHz in steps of 1 kHz, 14 kHz, 16 kHz	+/- 20 % +/-5 %(measuring tolerance)
Form of reference signal	Sinusoidal, triangle, no monitoring	40 % form deviation
Monitoring of counting signal / signal phase quadrant	Fixed value	+/- 45°

7 KSM Response Times

The response time is a very important safety related characteristic and must be strictly observed for each application / application related safety function. The following chapter lists the response times for individual functions, probably also in dependence on further parameters. If these data are insufficient for a specific application, you should validate the actual time behaviour against the nominal behaviour by means of separate measurements. This applies also for the use of filter functions in particular.

⚠ Safety Note:
- The response times must be determined for each application related safety function in nominal behaviour and must then be compared with the actual value by using the following data.
- Special care must be taken when using filter functions. Depending on the filter length / time the response time may be extended, which must be taken into account in the safety related design.
- In case of particularly critical problem formulations the temporal behaviour must be validated by means of measurements.
- During start-up of the device / alarm or fault reset the outputs may (depending on the application program) become active over the response time period. This must be taken into consideration when planning the safety function.
- When using safe field bus connections (e.g. PROFIsafe, FSoE), the system run-time (watchdog) must also be included in the calculation.

7.1 Response Times in Standard Operation

The cycle time of the KSM system serves as basis for calculating the response times. Diese ist in 3 Stufen wählbar und beträgt im Betrieb **T_ Cycle = 8 ms**. The specified response times comply with the corresponding maximum running time for the actual application <u>within the KSM module.</u> Depending on the application, further, <u>application dependent response times</u> of the sensors and actuators used must be added, in order to obtain the total running time.

Function	Response time [ms]	Explanation
Activation of a monitoring function by means of ENABLE with subsequent shut-down via digital output	24 *)	Activation of a monitoring function by means of the ENABLE signal.
Activation of a monitoring function by means of ENABLE with subsequent shut-down via safety relay	47 *)	Activation of a monitoring function by means of the ENABLE signal.
Response of an already activated **monitoring function** including PLC editing in case of position and speed processing via digital output	16 *)	With a monitoring function that has already been activated via ENABLE, the module requires <u>one</u> cycle to calculate the current speed value. During the next cycle after calculation of the monitoring function the information is further processed and output by the PLC, i.e. according to the implemented logic this will lead to e.g. switching of an output.

Function	Response time [ms]	Explanation
Response of an already activated **monitoring function** including PLC editing in case of position and speed processing via safety relays	39 *)*	With a monitoring function that has already been activated via ENABLE, the module requires one cycle to calculate the current speed value. During the next cycle after calculation of the monitoring function the information is further processed and output by the PLC, i.e. according to the implemented logic this will lead to e.g. switching of an output.
Activation of digital output via digital input	16	Activation of an input and switching of the output
Activation output relay via digital input	26	Activation of an input and switching of the output
Deactivation of digital output via digital input	16	Deactivation of an input and thus deactivation of the output
Deactivation output relay via digital input	47	Deactivation of an input and thus deactivation of the output
Average filter (setting see encoder dialog SafePLC)	0 - 64	Group running time of the averager. This running time only effects the monitoring function in connection with position / speed / acceleration, but not the logic processing.
Analog filter • 1 (2Hz) • 2 (2Hz) • 3 (2Hz) • 4 (4Hz) • 5 (6Hz) • 6 (8Hz) • 7 (10Hz) • 8 (20Hz)	 760 760 760 512 268 143 86 56	The analog filter only affects the safe analog inputs of all modules with analog variants Response times of the analog input filters in relation to the input frequency

Note:

*) : When using an average filter the response time of this filter must also be added

7.2 Response Time for FAST_CHANNEL

FAST_CHANNEL describes a characteristic of KSM to respond quicker to speed requirements than this would be possible with the execution of the safety programs in normal cycle (= 8 msec) The sampling time of FAST_CHANNEL is 2 msec.

The following response times can be specified:

- 4 msec (Worst Case Condition)

⚠️ **Safety Note:**
- When using FAST_CHANNEL you should bear in mind that shutting down within the time specified above for a given speed threshold is only possible, if the sensor information has enough resolution. The smallest resolvable switching threshold of the FAST_CHANNEL requires at least 2 edge changes on the corresponding sensor system within a period of 2 msec.
- This function can only be used in connection with semi-conductor outputs.
- The FAST_CHANNEL may not act on SSI Listeners

7.3 Response Times for Fault Distance Monitoring

The following calculation schematic applies for calculating the Worst Case condition.

System speed to the sampling instant	$V(t)$
System speed in case of KSM response:	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
Deceleration after shut-down:	a_V = constant for all t
Sampling instant for occurrence of the Worst Case event:	T_{Fault}
Response time of the KSM systems:	$t_{Response}$

For the Worst Case assessment, it is assumed that the drive will initially move exactly to the parameterized threshold with a speed v(k) and then will accelerate to the maximum possible value a0.
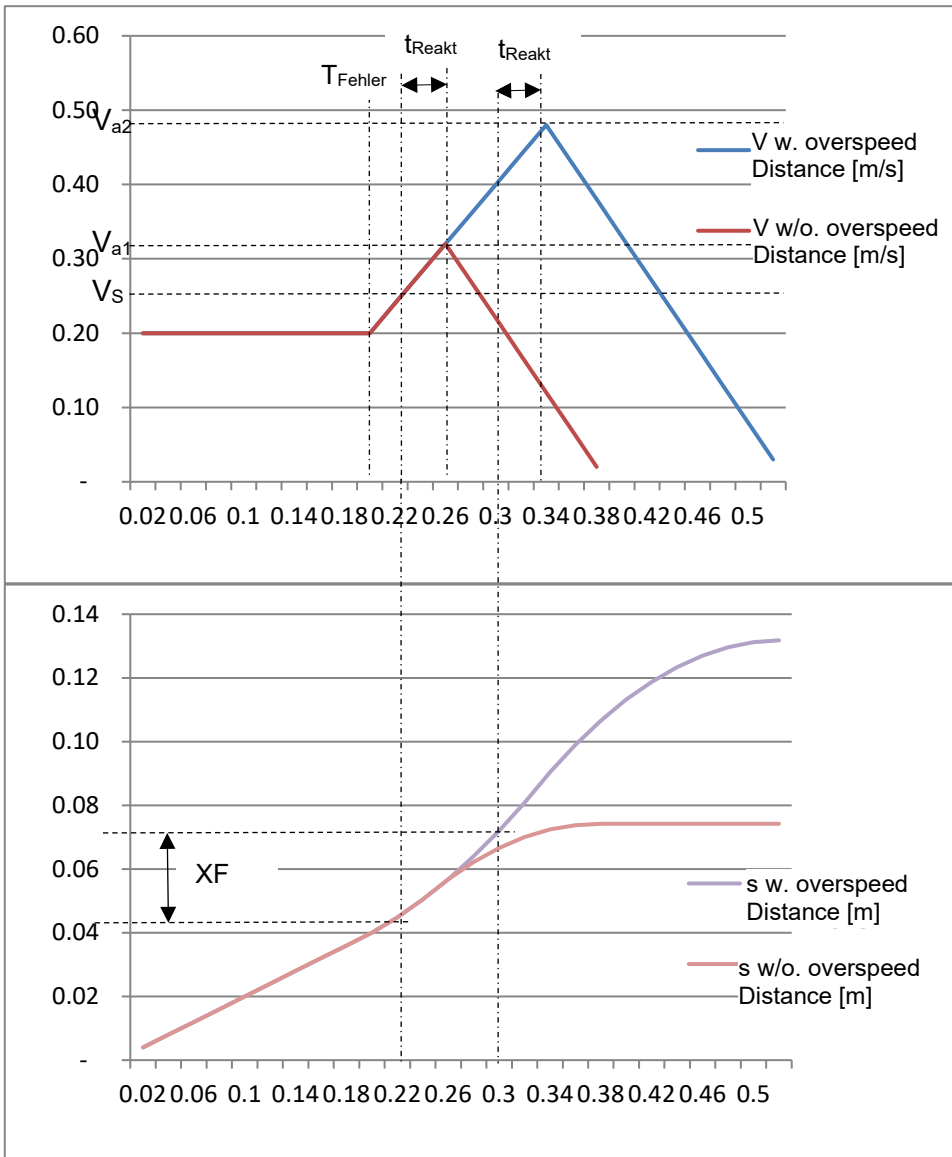
Diagram: Behavior of the drive with / without overspeed distance

<u>Without</u> overspeed distance the following connections result for the course of V and s.

Parameters	Calculation methods	Comment
$t_{Response}$	Value from the specified response time KSM + deceleration time in external shut-down chain	Deceleration time in external shut-off chain derived from relay/contactor and brake data, etc. issued by the manufacturer
a_F, a_V	n.a.	Estimation of the application
V_{a1}	$= V_S + a_F * t_{Response}$	

With overspeed distance the following connections result for the course of V and s.

Parameters	Calculation Methods	Comment
$t_{Response}$	Value for response time data KSM + deceleration time in external shut-down chain	Deceleration time in external shut-off chain derived from relay/contactor and brake data, etc. issued by the manufacturer
a_F, a_V	n.a.	Estimation of the application
V_{a2}	= $a_F * t_{Response} + (V_S^2 + 2 * a_F * XF)^{1/2}$	

With its effect the filter displaces the set speed threshold V_a upwards by the amount **delta_v_filter**. For the application one must consider the new response time values (Treact = TKSM + Tfilter), as well as the speed at shutdown by KSM resulting from this.

7.4 Reaction Times When Using KSM 31x

The cycle time of the KSM system serves as basis for calculating the response times. In operation this is **T_zyklus = 8 ms.** The specified response times comply with the corresponding maximum running time for the actual application <u>within the KSM module.</u> Depending on the application, further, <u>application dependent response times</u> of the sensors and actuators used must be added, in order to obtain the total running time.

Function	Designation	Response time [ms]	Explanation
Worst Case deceleration time inlet in basic module to PAE	T_{IN_BASE}	10	e.g. activation of a monitoring function by an input signal in the basic module
Worst Case deceleration time input KSM31 to PAE in basic module	T_{IN_31}	18	e.g. activation of a monitoring function by an input signal in the extension module KSM31
Processing time PAE to PAA in basic module	T_{PLC}	8	Shut-down by a monitoring function or an input in PAE
Activation / deactivation digital output in basic module from PAA	T_{OUT_BASE}	-	Activation or deactivation of an output in the basic module after changes to the PAA.
Activation / deactivation digital output in extension module via PAA in basic module	T_{OUT_31}	8	Activation or deactivation of an output in the extension module KSM31 after changes to the PAA in the basic module.

Determination of the total response time

$T_{TOTAL} = T_{IN} + T_{PLC} + T_{OUT}$

Example 1:
Input to extension module, activation of SLS and processing in PLC, output to basic module.

$T_{TOTAL} = T_{IN\_31} + T_{PLC} + T_{OUT\_Base} = 18\ ms + 8\ ms + 0\ ms = 24\ ms;$

Example 2:
Input to basic module, activation of SLS and processing in PLC, output to extension module.

$T_{TOTAL} = T_{IN\_Base} + T_{PLC} + T_{OUT\_31} = 10\ ms + 8\ ms + 8\ ms = 26\ ms;$

Example 3:
Input to extension module, activation of SLS and processing in PLC, output to extension module.

$T_{TOTAL} = T_{IN\_31} + T_{PLC} + T_{OUT\_31} = 18\ ms + 8\ ms + 8\ ms = 34\ ms;$

8 Start-up

8.1 Procedure

Start-up must only be performed by qualified personnel!
Strictly follow the safety regulations when commissioning!

8.2 Making Sequences

The following phases are passed through and displayed by the front side seven segment display after each new start and fault-free running of the module:
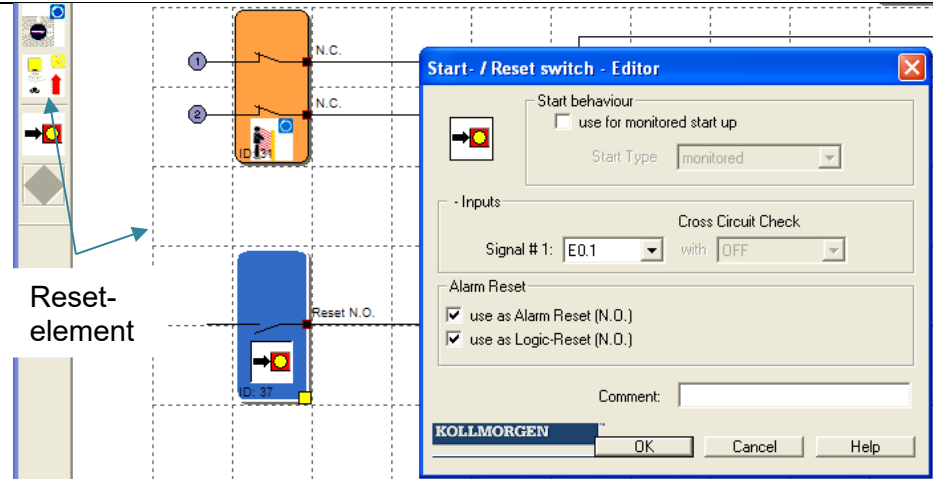
7 Segment Display	Mode	Description
"1"	STARTUP	Synchronization between both processor systems and checking of configuration/firmware data
"2"	SENDCONFIG	Distribution of configuration/firmware data and renewed checking of these data. Subsequent area checking of configuration data.
"3"	STARTUP BUS	If available, initialization of a bus system
"4"	RUN	Normal system operation. All outputs are switched according to the current logic status.
"5"	STOP	In stop mode parameter and program data can be loaded externally.
"A"	ALARM	The alarm can be reset via the digital input or the front side reset button.
"E"	ECS-Alarm ICS-Alarm ACS-Alarm	The ECS alarm can be reset via the digital inputs or the front side reset button.
"F"	Fault	Fault can only be reset via ON/OFF of the module.
"."	FBus Status	Slave F-Bus (PROFIsafe/FSoE): Out: F bus does not use slow Flashing: F bus configured, no connection to the master Fast flashing: connection to the master, F bus activation pending On: F bus connected

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8.3 Reset-Function

The reset-function is divided into a startup-function after a power cycle (power off / on) and a status-/alarm-reset = internal reset-function. The internal reset is called by pushing the "Reset"-button on the KSM front panel or by a input port, configured as "Reset-Element" with active "Alarmreset". The table below show an overview of those reset-functions:

8.3.1 Type of Reset-Functions

Reset-Type	Triggering Element	Comment
General Reset	Voltage return/equipment start-up	Reset-function after a complete power off / on
Internal Reset	Reset-Button	Internal reset called by pushing the Reset-Button on the KSM front panel
	Reset-element	Configuration of a reset-element

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8.3.2 Reset-Timing

The reset-input for an internal reset is time monitored in "RUN"-mode. A internal reset is called by a falling edge of the reset-input under the pre-condition of T<3sec between raising / falling edge.
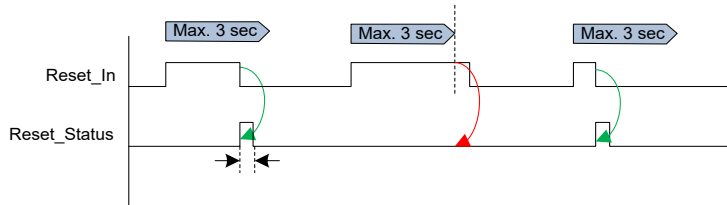
8.3.3 Reset-Function

Function block	General Reset	Internal Reset	Function
Fatal Error	X		Failure reset
Alarm	X	X	Alarm reset
Safe monitor function	X	X	Reset of triggered safe monitoring functions
Flip-Flop	X	X	Status = Reset
Timer	X	X	Timer = 0

After a reset the status of the safe monitoring functions is rebuild
- ⇨ If process values are beyond the parameterized trigger points, the status of the safe monitoring functions is kept unchanged.
- ⇨ On time based functions, the timer value is reset and therefore the output status of the relates function too. The function is triggered again if the time value versus monitored status exceeds again the parameterized limits.
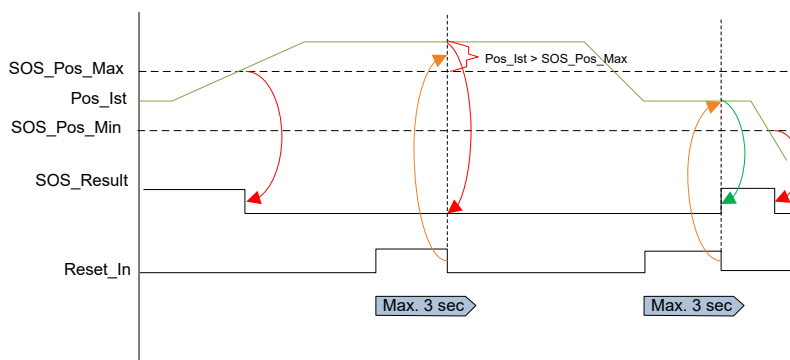
Process value (position) => no change of the output status with reset in the alarm condition
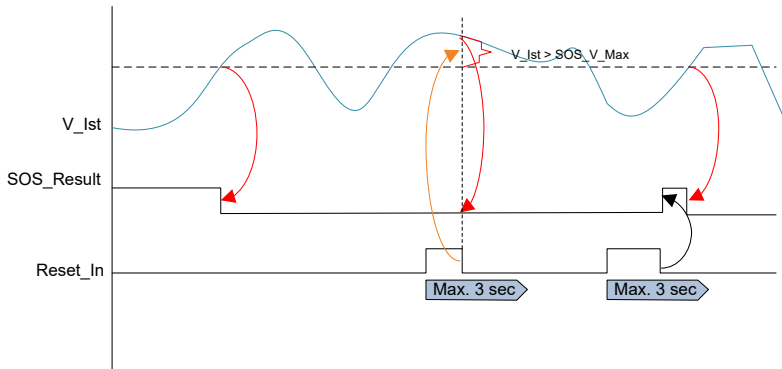
Process value (speed) => no change of the output status with reset in the alarm condition
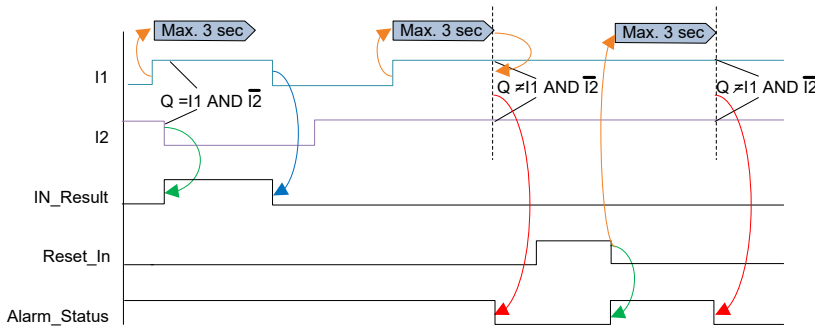
Time based function => reset of the starting state, addressing when newly exceeding the limit

⚠ Safety Note:

- On time based functions, i.e. time based monitoring of complementary input signals, the reset-function cause a reset of a possible alarm status. Only if the time versus input status exceeds again the parameterized limits, the alarm status is recalled.
- For safeguarding of false utilization of the reset-function, i.e. reiterated call of the reset-function to bypass the alarm status, adequate measures in the application program (PLC-program) must be implemented.

8.3.3.1   Example Reset-Function with safeguarding against false utilization

Function: On a machine for normal operation mode, the hazardous area shell be protected by a mechanical guard system. If in setup mode, the safety level is kept by a release button in conjunction with standstill monitoring respective safe limited speed.

The guard closed position is monitored by a sensor. With the guard in open position movement is only possible with the released button pressed.

On the application program this function is implemented by use of the function "door monitoring" (2 cannel mode with time monitoring) and the function "enabling switch".

The logic signal "door monitoring" is produced by computing of the input signals versus time monitoring. The time monitoring with an allowed difference on the expected input signals is fixed for 3 sec.

On the status "door open" (Signal "LOW" on output X23.1 and X23.2 (ID 369)) the axis can be moved with reduced speed if the enable button is on active status.

Task:

If a faulty cross connection is detected, the KSM device will show the alarm 6701.

The alarm can be quit, in result the Signal "Dorr monitoring" is kept correctly on "LOW" status.

After a reset the alarm 6701 will come back after 3 sec. if the wrong status is still applied.

If within this time frame the enable button is activated, the axis can be moved – on reduced speed only, but moved – for max. 3 sec.

The task is now to prevent a movement of the axis if the alarm will come potentially back after a reset.

Applicative measure:

By logic combination within the PLC-program the activation of the outputs by false utilization of the reset-function is prevented.
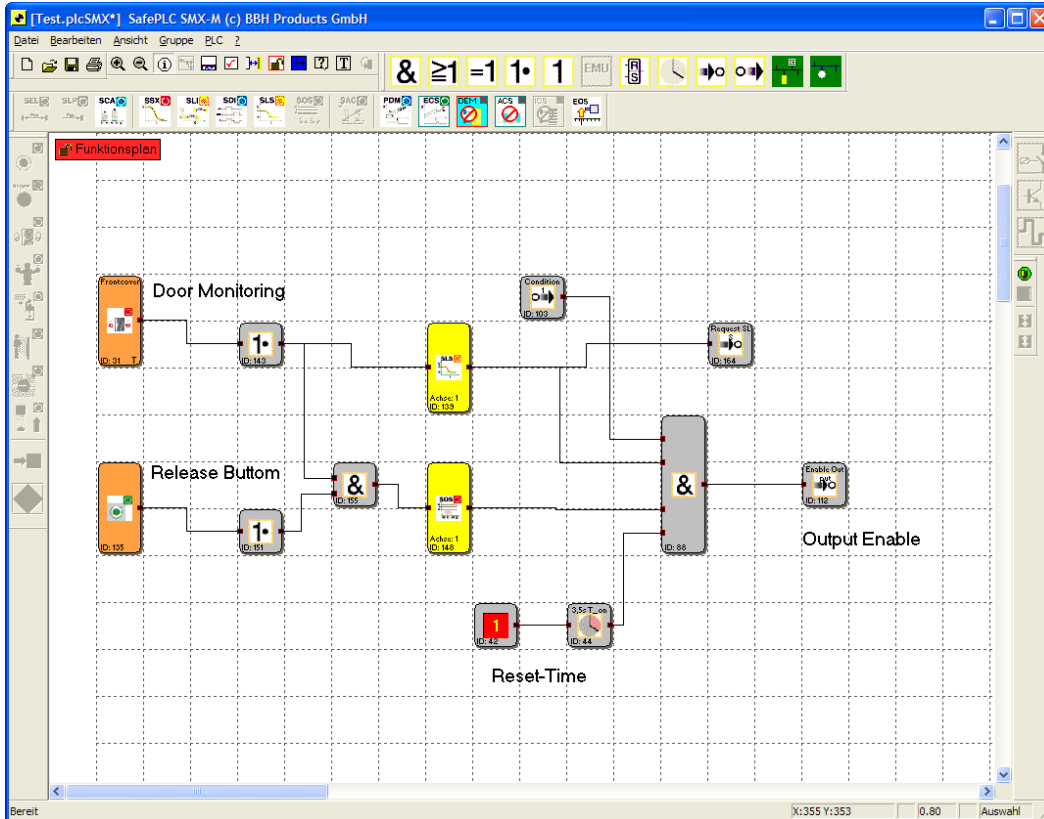
Example 1: The release function of the outputs (ID 88) is additionally AND combined with a "Reset-Timer". This timer prevents activation of the outputs for T> 3sec after a call of the reset-function.
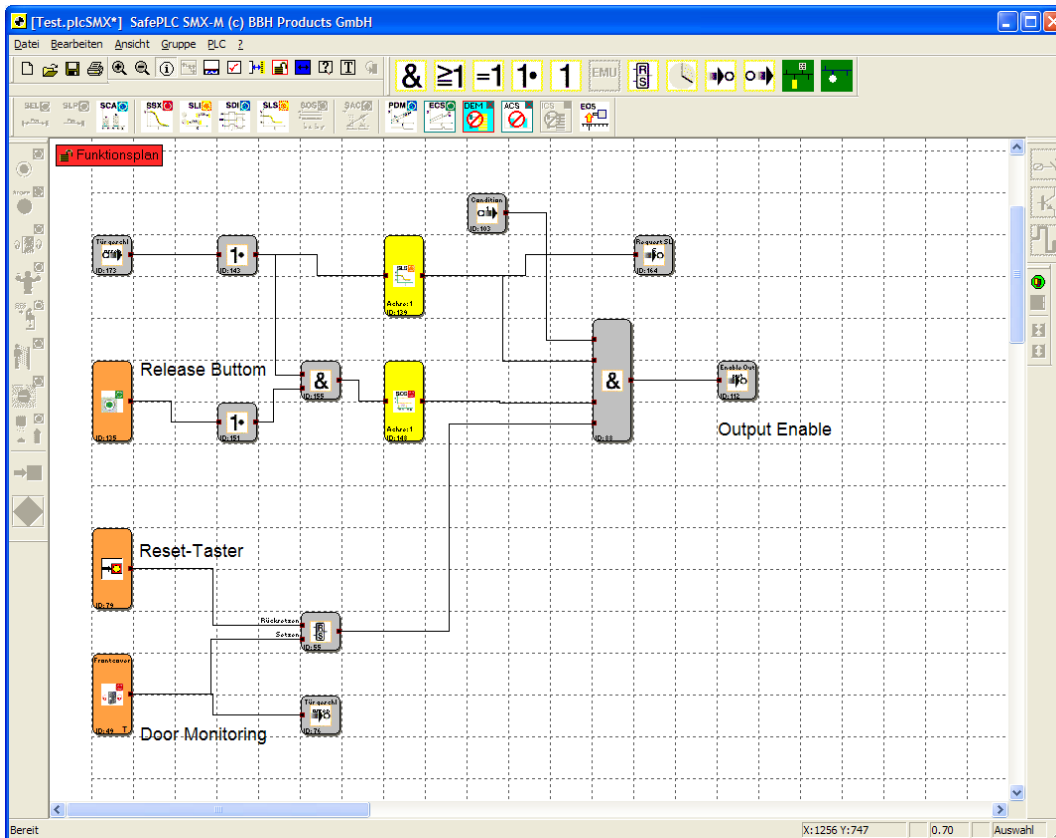
Example 2: The release function of the outputs (ID 88) is additionally AND combined with a FF. This FF-element prevents activation of the outputs after a reset with still applied failures on the inputs. Just after a first correct detection of the input signals – both input lines on "HIGH" within 3 sec. – the outputs are released.

8.4 LED Display

Color	Mode	Description
green	"flashing"	System OK, configuration validated
yellow	"flashing"	System OK, configuration not yet validated
red	"flashing"	Alarm
red	"permanent"	Fatal Fault
yellow - red	"flashing"	System OK, configuration not yet validated, SMMC configured however participant is missing
green - red	"flashing"	System OK, configuration validated, SMMC configured however participant is missing

Note:
For all operating states except RUN the outputs are rendered passive by the firmware, i.e. safely switched off. In status RUN the state of the outputs depend on the implemented PLC-program.

8.5   Parameterization

Parameterization takes place via the program SafePLC KSM. The transmission of these data to the module requires a programming adapter, the drivers of which must first be installed by the user. Parameterization is described in the programming manual.

8.6   Function Test

In order to guarantee safety of the module, the user must carry out a functional test of the safety functions at least once in a year. For this purpose, the modules used in the parameterization (inputs, outputs, monitoring functions and logic modules) must be checked with respect to function or shut-down. See programming manual.

8.7   Validation

In order to assure the reliability of the implemented safety functions the user must check and document the parameters and links after the start-up and parameterization has taken place. This is supported by a validation assistant in the programming desktop (see chapter "Safety related examination").

9 Safety Related Examination

In order to assure the reliability of the implemented safety functions the user must check and document the parameters and links after the start-up and parameterization has taken place. This is supported by the parameterization software SafePLC KSM (see programming manual).

On the first page one can enter general system data.
On the following pages of the validation report, all used functions with their parameters are printed as single verification of the safety-technological examination.

After the transmission of the configuration and program data to the KSM module the status LED flashes yellow. This indicates that the configuration data have not yet been validated. Pressing the button "LOCK CONFIGURATION" at the end of the validation dialog highlights the data as "Validated" and the LED flashes in green.

10 Maintenance

10.1 Modification / Handling Changes to the Device

Maintenance work must solely be carried out by qualified personnel.
Regular maintenance work is not required.

Repair
The devices must always be replaced as whole units
Repair work on the device can only be performed in the factory.

Warranty
By opening the module without permission, the warranty will become null and void.

Note:
By modifying the module, the safety approval will become null and void!

10.2 Exchanging a Module

The following should be noted when exchanging a module:

- Disconnect the electric power converter from the main supply.
- Switch off the electric power supply for the device and disconnect.
- Pull off the encoder plug.
- Disconnect any other pluggable connections.
- Take the module off the top hat rail and pack up EMC-compliant.
- Mount the new module on the top hat rail.
- Reconnect all connections.
- Switch on the electric power converter.
- Switch on the supply voltage.
- Configure the device

Note:
Pluggable connections of the KSM module must generally not be disconnected or connected in live condition. There is a danger of sensor damage, particularly with connected position or speed sensors.

10.3 Maintenance Intervals

Module replacement	See technical data
Function test	See chapter "Start-up"

11 Technical Data

11.1 Environmental conditions
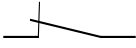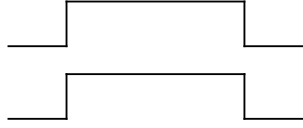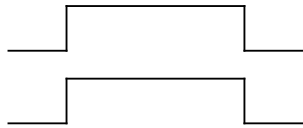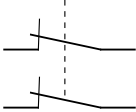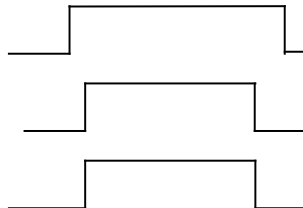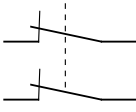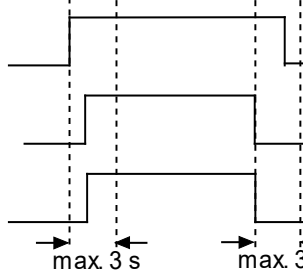
Class of protection	IP 20
Ambient temperature	0°C* ... 50°C
Climatic category	3k3 acc. to DIN 60 721
Min-, Maximum relative humidity (no condensation)	5% - 85%
Overvoltage category	III
Degree of contamination	2
Operating materials	2000m

11.2 Safety Related Characteristic Data
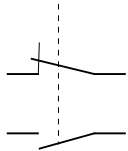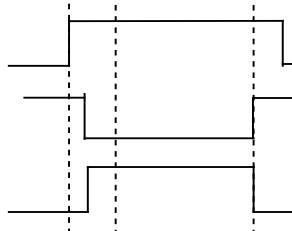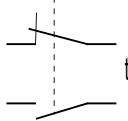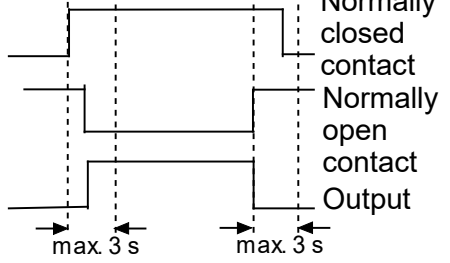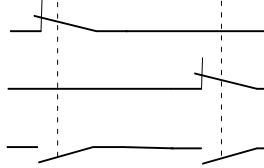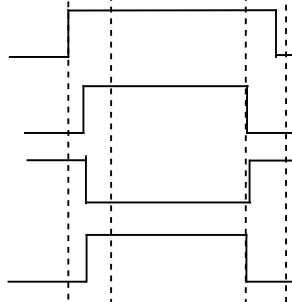
Max. obtainable safety class	• SIL 3 according to IEC 61508 • Category 4 according to EN ISO 13849-1 • Performance-Level e according to EN ISO 13849-1	
System structure	2-channel with diagnose (1002) acc. to IEC 61508 Architecture category 4 acc. to EN ISO 13849-1	
Rating of operating mode	"high demand" acc. to IEC 61508 (high demand rate)	
Probability of an endangering failure per hour (PFH-value)	KSM1x	PFH = 12,6 FIT
	KSM3x	PFH = 9,2 FIT
	KSMxR (1- channel)	PFH = 20 FIT
	KSMxR (2- channel)	PFH = 1,0 FIT
Specific values acc. to table "Safety related characteristic data"	20 years, after this time the module must be replaced	
Proof-Test-Intervall (IEC 61508)	20 years, after this time the module must be replaced	
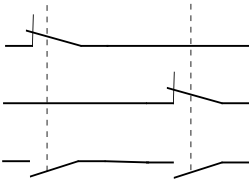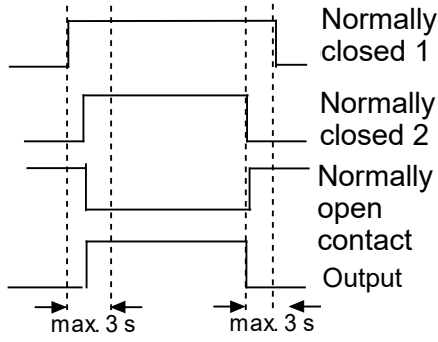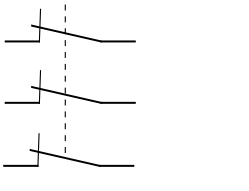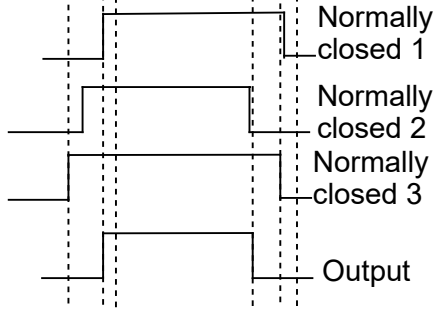
12 Switch Types

Type	Graphic symbols	Truth table			Logic function	Function block	Function	
1	eSwitch_1o	Ö	A		LD E.1 ST IE.X		Closing contact (S), only in display opening contact (O)	Normally closed contact Output
		0	0					
		1	1					
2	sSwitch_1s	S	A		LD E.1 ST IE.X		Normally open, as type 1	Normally closed contact Output
		0	0					
		1	1					
3	eSwitch_2o	Ö1	Ö2	A	LD E.1 AND E.2 ST IE.X		AND operation of both inputs	Normally closed 1 Normally closed 2 Output
		0	0	0				
		1	0	0				
		0	1	0				
		1	1	1				
4	eSwitch_2oT	Ö1	Ö2	A	LD E.1 OR E.2 ST METExA_EN.1 LD E.1 AND E.2 ST METB_EN.1 LD MET.1 ST IE.X	Time monitoring MET1..MET4	Like 3, but with time monitoring of state changes. In case of signal changes at S or Ö a complementary signal must follow within a period of t=3 s. If not, detect fault and A=0	Normally closed 1 Normally closed 2 Output max. 3 s max. 3 s
		0	0	0				
		1	0	0				
		0	1	0				
		1	1	1				
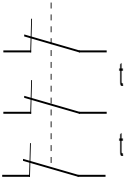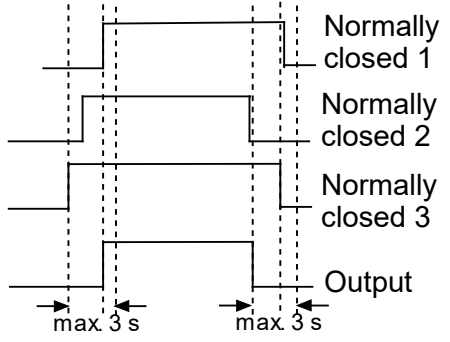
Type	Graphic symbols	Truth table					Function	
5	eSwitch_1s1o	S	Ö	A	LD E.1 AND NOT E.2 ST IE.X		Monitoring for S=inactive and Ö=active	Normally closed contact Normally open contact Output
		0	0	0				
		1	0	0				
		0	1	1				
		1	1	0				

Type	Graphic symbols	Truth table					Function	
6	eSwitch_1s1oT	S	Ö	A	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	Time monitoring MET1..MET4	Like 5, but with time monitoring of state changes. In case of signal changes at S or Ö a complementary signal must follow within a period of t=3 s. If not, detect fault and A=0	Normally closed contact Normally open contact Output max. 3 s max. 3 s
		0	0	0				
		1	0	0				
		0	1	1				
		1	1	0				

Type	Graphic symbols	Truth table						Function	
7	eSwitch_2s2o	S1	Ö1	S2	Ö2	A	LD E.1 AND E.2 AND NOT E.3 ST IE.X	Monitoring for S1*S2=inactive and Ö1*Ö2=active	Normally closed 1 Normally closed 2 Normally open contact Output
		1	0	1	0	0			
		0	1	1	0	0			
		0	1	0	1	1			
		1	0	0	1	0			

KOLLMORGEN

Because Motion Matters™
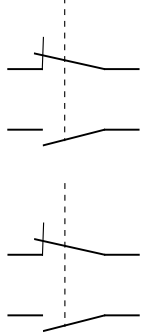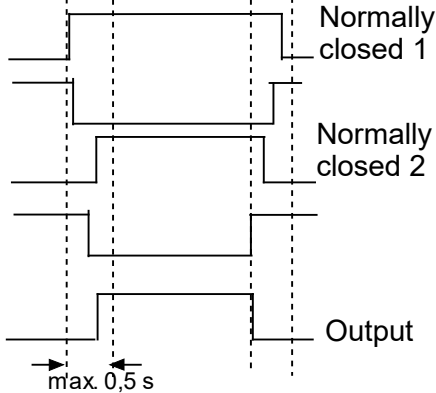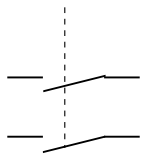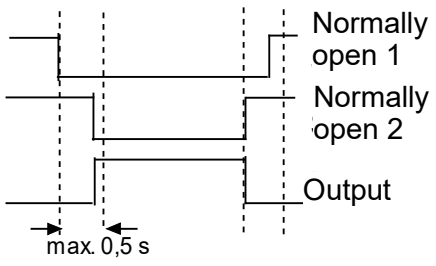
Type	Graphic symbols	Truth table							Function	
8	eSwitch_2s2oT	S1	Ö1	S2	Ö2	A	LD E.1 OR E.2 OR NOT E.3 ST META_EN.1 LD E.1 AND E.2 AND NOT E.3 ST METB_EN.1 LD MET.1 ST IE.X	Time monitoring MET1..MET4	Like 6, but with time monitoring of state changes. In case of signal changes at S (Attention: Bus line) or Ö a complementary signal must follow within a period of t=3 s. If not, detect fault and A=0	Normally closed 1 / Normally closed 2 / Normally open contact / Output / max. 3 s / max. 3 s
		1	0	1	0	0				
		0	1	1	0	0				
		0	1	0	1	1				
		1	0	0	1	0				
9	eSwitch_3o	Ö1	Ö2	Ö3	A		LD E.1 AND E.2 AND E.3 ST IE.X		AND operation of both inputs	Normally closed 1 / Normally closed 2 / Normally closed 3 / Output
		0	0	0	0					
		1	0	0	0					
		0	1	0	0					
		1	1	0	0					
		1	1	1	1					
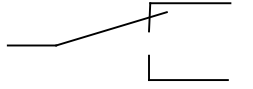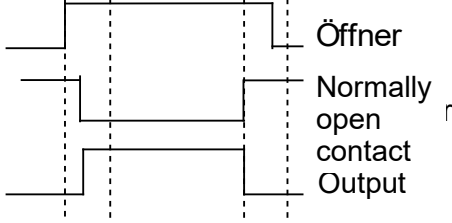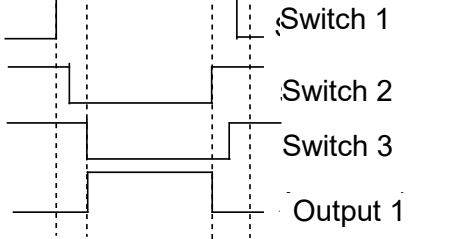
Type	Graphic symbols	Truth table						Function	
10	eSwitch_3oT	Ö1	Ö2	Ö3	A	LD E.1 OR E.2 OR E.3 ST META_EN.1 LD E.1 AND E.2 AND E.3 ST METB_EN.1 LD MET.1 ST IE.X	Time monitoring MET1..MET4	Like 8, but with time monitoring of state changes. In case of signal change on one of the Ö-inputs the other inputs must follow within a period of t=3 s. If not, detect fault and A=0	
		0	0	0	0				
		1	0	0	0				
		0	1	0	0				
		1	1	0	0				
		1	1	1	1				

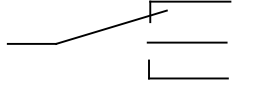| Type	Graphic symbols	Truth table					Function	
11	(graphic) eTwoHand_2o	<table><tr><th>Ö1</th><th>S1</th><th>Ö2</th><th>S2</th><th>A</th></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr></table>	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	Two-hand operation MEZ		Monitoring for S1*S2=inactive and Ö1*Ö2=active + temporal monitoring <u>of this</u> status. This means that in case of a signal change of an S from 1->0 or Ö from 0->1, the other signals (i.e. further S=0 or Ö=1) must follow within a period of 0.5 s. If not, the output = 0. No interference evaluation! No temporal monitoring when changing to inactive state.	(timing diagram) Normally closed 1 / Normally closed 2 / Output / max. 0,5 s
12	(graphic) eTwoHand_2s	<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>	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	Two-hand operation MEZ		Monitoring for S1*S2=inactive + temporal monitoring <u>of this</u> status. This means that in case of a signal change of one S from 1->0 the other signal (i.e. another S=0) must follow within a period of 0.5 s. If not, the output = 0. No interference evaluation! No temporal monitoring when changing to inactive state.	(timing diagram) Normally open 1 / Normally open 2 / Output / max. 0,5 s

13	eMode_1s1o	S1	S2	A1	A2			LD E.1 AND NOT E.2 ST IE.X1 LD NOT E.1 AND E.2 ST IE.X2	Selector switch	Clear linkage of permissible switch positions	Öffner Normally open contact Output
		1	0	1	0						
		0	1	0	1						
		0	0	0	0						
		1	1	0	0						
14	eMode_3switch	S1	S2	S3	A1	A2	A3	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	Selector switch	Clear linkage of permissible switch positions	Switch 1 Switch 2 Switch 3 Output 1
		1	0	0	1	0	0				
		0	1	0	0	1	0				
		0	0	1	0	0	1				
		1	1	0	0	0	0				
		1	0	1	0	0	0				
		0	1	1	0	0	0				
		1	1	1	0	0	0				
		0	0	0	0	0	0				

13 Notes on Designing, Programming, Validating and Testing Safety Related Applications

The following notes describe the procedure for designing, programming, validating and testing safety related applications.
The information should help the user to classify, to easily understand and to use all steps from risk assessment all the way to the system test. For better understanding the respective subjects, the individual steps are explained by means of examples.

13.1 Risk Assessment

The manufacturer of a machine must generally guarantee the safety of any machine designed or delivered by him. The assessment of safety must be based on the applicable and appropriate regulations and standards. Objective of the safety assessment and the measures derived from this must be the reduction of risks for persons down to an acceptable minimum.
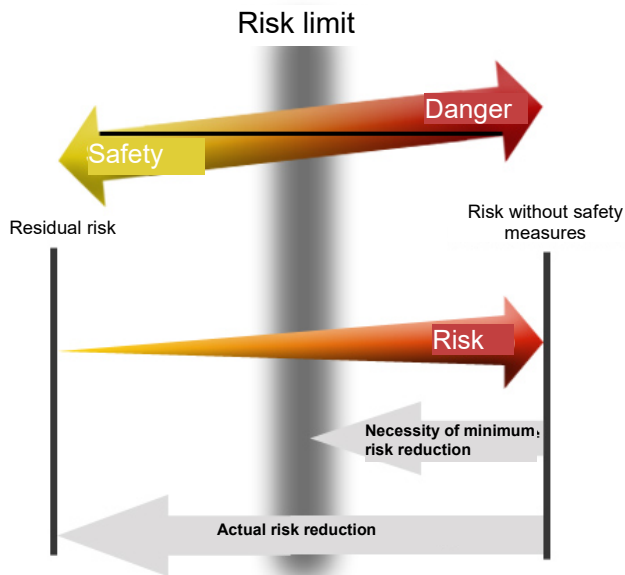
The risk analysis must account for all operating conditions of the machine, such as operation, setup work and maintenance or installation and decommissioning as well as predictable erroneous operation.

The procedure required for the risk analysis and the measures for reducing such risks can be found in the applicable standards:

- EN ISO 13849-1 Safety of machines
- IEC 61508 Functional safety of safety related e/e/p e systems.

Risk assessment as per EN ISO 13849-1
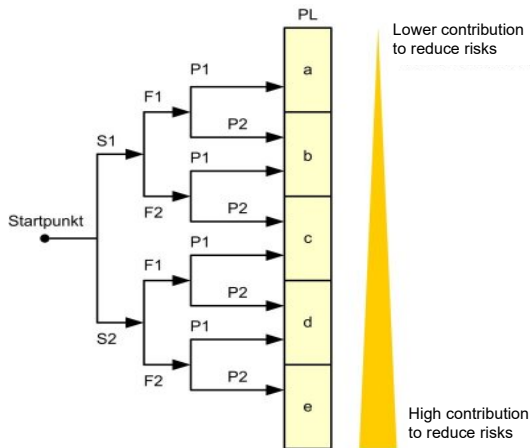
S – Severe physical injury
S1 = minor, reversible injury
S2 = severe, irreversible injury

F – Frequency and/or duration of exposure to danger
F1= rarely, not cyclic
F2 = frequently up to permanent and/or long duration, cyclic operation

P – Possibility to avoid the danger
P1 = possible, slow movement / acceleration
P2 = hardly possible, high acceleration in case of a fault

Risk assessment as per IEC 61508
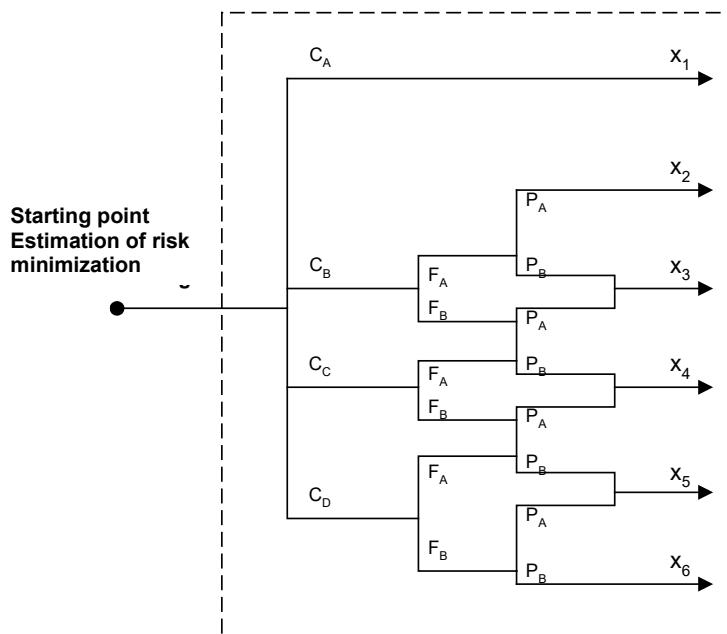
	W$_3$	W$_2$	W$_1$
a	a	---	---
	1	a	---
	2	1	a
	3	2	1
	4	3	2
b	b	4	3

- = no safety requirement
a = No special safety requirements
b = a single E /E /P E S is not sufficient
1,2,3,4 = Safety integrity level

C = Risk parameters of the effect
F = Risk parameters of the frequency of the dwell time
P = Risk parameters of the possibility to avoid the dangerous incident
W = Probability of the undesired event

The risks to be examined can also be found in applicable regulations and standards or must be considered separately by the manufacturer based on his specific knowledge of the machine.
For machines sold within the EU the minimum risks to be examined are specified in the EU machine directive 2006/42/EU or in the latest version of this directive.

Further information concerning the risk assessment and the safe design of machines can be found in the standards:

- EN 14121 Safety of machines - risk assessment
- EN 12100 Safety of machines - basic terms, general design guidelines

Measures to be applied in order to reduce identified risks must at least be of the same level as the danger itself. The regulations and standards specified above contain examples of such measures and the associated requirements.

13.2 Required Technical Documents

The manufacturer is obliged to supply various technical documents. The minimum extent is also contained in the applicable regulations and standards.
The EU machine directive, for example, requires the delivery of the following documents:

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 easy to understand and should be written in the language of the corresponding country.

13.3 Necessary Steps for Draft, Realization and Testing

The realization of plant sections with safety related function requires special attention in planning, realization and testing. Also, for this the standards (see ISO 13849-2 or EN ISO 61508) contain specific guidelines. The effort thereby is orientated on the complexity of the task for system components with safety related function.

For the realization of such functions the KSM-series offers safety relevant control and monitoring functions to support the system architecture (architecture Cat. 4 acc. to EN ISO 13849-1) and, above all, also the programming language and tested safety functions. Programming uses the form FUP (function plan-oriented programming) recommended by the safety standards. It fully meets the requirements on the programming language with limited scope of languages (LVM) for the essential simplifications in documentation and testing.

The individual steps in any case require careful planning and analysis of the methods and systems used. Furthermore, the individual steps must be documented in an understandable way.

V-model (simplified)

The implementation of safety related functions requires a structured approach, like the V-model that is exemplary described in applicable standards. The following shows an exemplary approach for applications with modules of the KSM-series.
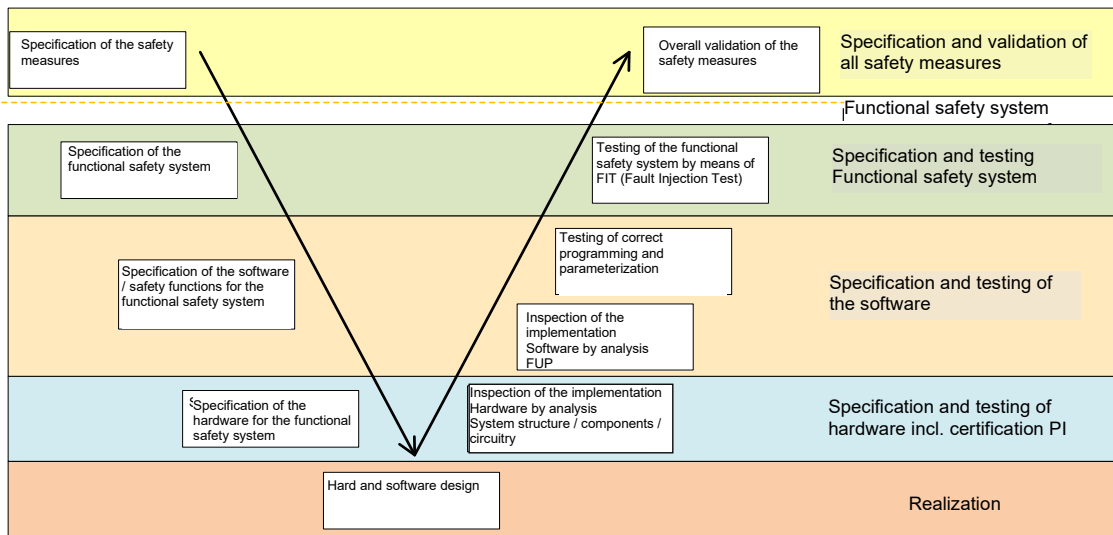
13.3.1 Phases of the V-model

Designation	Description Design phase	Validation phase
Specification and validation of all passive and active safety measures.	Specification of all safety measures to be applied, such as covers, barriers, max. machine parameters, safety related functions, etc.	Testing of all passive and active safety measures for correct implementation and effectiveness.
Specification of the functional safety systems	Specification of the active safety systems and their assignment to the risks to be reduced, such as e.g. reduced speed in setup operation, stop-mode, monitoring of access areas, etc. Specification of the PIr or the demanded SIL for each individual safety function	Testing of all active safety systems regarding effectiveness and compliance with specific parameters, such as e.g. erroneous increased speed, faulty stop, responding of monitoring facilities, etc. by means of practical tests
Specification of software / safety functions	Specification of the functionality of individual safety functions incl. the definition of the shut-down circuit, etc. Definition of parameters for individual safety functions, such as e.g. max. speed, stop ramps and - categories, etc.	Testing of correct implementation of specified functions by analysis FUP programming Validation of application programs and parameters by comparing the validation report with FUP or specifications for parameters
Specification of the hardware	Specification of the system structure and the functions of the individual sensors, command units, control components and actuators regarding their safety functions	Testing of the correct implementation of specifications. Determination of the failure probability or PI by means of analysis of the overall architecture and the characteristic data of all components involved, each related to the individual safety functions
Hard and software design	Actual planning and implementation of system structure / wiring. Actual implementation of safety functions by programming in FUP	nil

13.3.2 Specification of safety requirements (structural schematic)

The safety requirements must be individually analysed based on applicable standards, e.g. product standard.

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 from BGIA Report 2/2008 concerning EN ISO 13849-1

Example for an automatic handling machine:

Description of function:
The automatic handling machine serves the purpose of automatically picking up truck cabins of different heights. After being picked up, the height of the cabin is correctly detected, so that within the working area the cabin cannot be lowered below a certain height. Within the working area the automatic machine must not exceed a maximum speed. Once the cabin has been completely finished, it is put down at the end of the processing line and the automatic handling machine moves along a return track back to the beginning of the track to pick up the next cabin…..

Limits of the machine:
Spatial limits: The working area must provide sufficient space for the workers, so that they are able to carry out all necessary work on the cabin..... In the return pass there must be sufficient space for the empty suspension gear of the automatic handler...
Temporal limits: Description of lifetime, description of ageing processes, which could cause changes of machine parameters, (e.g. brakes). Monitoring mechanisms must be implemented for such cases.
Limits of use: The automatic machine automatically fetches new cabins and moves these through a processing area. Workers work in the processing area .... etc.
The following operating modes are intended: Setup operation, automatic operation and service operation ... etc.

Identification of dangers:
The following dangers are of relevance with the automatic handling machine:
Danger 1: Crushing by cabin / lifting beam falling down
Danger 2: Impact by moving cabin / lifting beam
Danger 3: Crushing by too fast lowering of the cabin in case of a fault
Danger 4:..............

Risk analysis:
G1: The weight of cabin and lifting beam is so high, that it will cause irreversible crushing or even fatalities.
G2: The moving cabin/lifting beam may cause impacts that can lead to irreversible injuries.
G3: ….

Risk assessment
A risk reduction is required under due consideration of all operating conditions.
Inherently (risk from the project) safe design
Movement of the cabin in direction x and y within the working area cannot be avoided. In the processing area the cabin must be moved up/down ...
The following measures can be applied:
Avoid dangers caused by too fast movements
Avoid dangers caused by too small distances
…….

Example for a risk analysis:

Risk analysis for declaration of manufacturer		ype plant customer	Order-Number 200-402								
			Created: Michael Duessel Oct. 16. 2005 Page 1 of 4								
Operating status	Endangered by		Result or protection objective	Solution	Start Cl.	St. Cat.	Standards and directives used	Notes/criteria for commissioning and testing	tested		
	Short description	Check							on	by	
			Linear units								
Automatic and manual mode	Pinching Getting caught Being pulled in		Protection against pinching, getting caught and being pulled in required for: - Linear movement in direction X - Linear movement in direction Y	Protective covering 2 m high, with spot welded grid MW 40 mm Safety door with safety door switch			EN 292-2 sect. 3.2 EN 294 sect. 4.5.1	Protective covering present? Tightly bolted to the machine? ES-function tested -Machine must stop immediately when the door is opened			
			Tensioning cylinder / sword								
Automatic and manual mode	Pinching Punching		Protection against pinching and punching required for: - pneumatic linear movement	Protective covering 2 m high, with spot welded grid MW 40 mm			EN 292-2 sect. 3.2 EN 294 sect. 4.5.1	Protective covering present? Tightly bolted to the machine?			
			Centring with pressing plate								
Automatic and manual mode	Crushing Getting caught Being pulled in		Protection against pinching, getting caught and being pulled in required for: - pneumatic slewing movement	Protective covering 2 m high, with spot welded grid MW 40 mm Safety door with safety door switch			EN 292-2 sect. 3.2 EN 294 sect. 4.5.1	Protective covering present? Tightly bolted to the machine? ES-function tested -Machine must stop immediately when the door is opened			
			Closing rollers								
Automatic and manual mode	Crushing Getting caught Being pulled in		Protection against pinching, getting caught and being pulled in required for: - pneumatic linear movement	Protective covering 2 m high, with spot welded grid MW 40 mm Protective covering made of sheet metal or perforated sheet metal. Gaps and hole size < 8 mm			EN 292-2 sect. 3.2 EN 294 sect. 4.5.1	Protective covering present? Protective covering present? Tightly bolted to the machine?			

13.3.3 Specification of the functional safety system

Derived from the general danger and risk analysis for the machine, the active safety functions must be identified and specified.
Active safety functions are, e.g. safely reduced speed under certain system conditions, monitored stop and standstill functions, area monitoring facilities, processing of monitoring facilities like light grid, switching mats, etc.
The safety functions must each be delimited and the specific requirements in function and safety level must be defined.

13.3.3.1 Definition of safety functions

definition of the safety function must:
- specify the risk to be covered,
- describe the exact function,
- list all sensors, command equipment involved,
- specify the control units and
- designate the shut-down circuit mentioned.

The definition should serve as basis for the specification of the hardware and software design.
For each of the safety functions defined this way one may need to determine parameters to be used, like e.g. max. system speed in setup operation, etc.
Examples for safety functions:
SF1: STO (safely switched off torque) to protect against safe starting
SF2: Safe speeds
SF3: Safe positions
SF4.:……

13.3.3.2 Required performance level (PLr) (additional emergency stop)

The required performance level must now be determined on basis of the safety functions SF1.... recognized above. The example below shows the decision path.
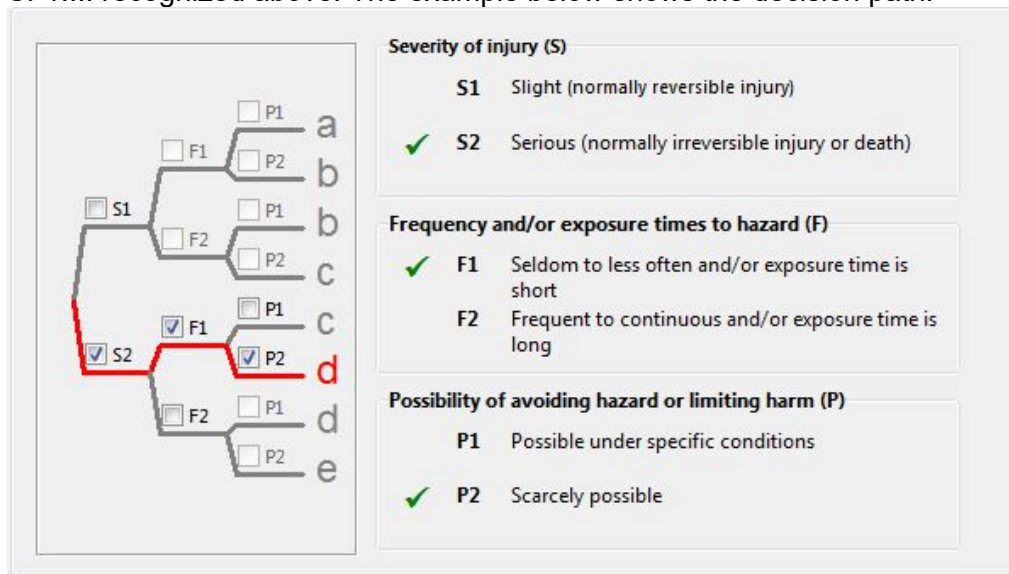
Example for SF1: Result PF = d (source Sistema)

13.3.3.3 Example – Specification of safety functions in form of a table

Cons.-No.	Safety function	Ref from GFA	PI$_r$	Measuring value /sensor	Implementation of software	Nominal parameters	Input/activation	Response/ output
1.1	Limitation of max. travel speed to limitation of the maximum speed	2.3	e	1 x WCS absolute encoder 1 x Incremental encoder on motor / drive wheel	Monitoring by means of tested safety function SLS for fixed limits	550mm/s Fault distance monitoring 200mm	**Input/activation**	Operation stop SF 1.7.1
1.2	Limitation of max. travel speed in working area of workers Monitoring of the maximum speed to < 0.33 m/s	2.4	e	1 x WCS absolute encoder 1 x Incremental encoder on motor / drive wheel	Monitoring by means of tested safety function SLS for fixed limits	60 mm/s Fault distance monitoring 200mm	Permanently Reset: Acknowledgement button	SF 1.7.1
1.3	Limitation of max. travel speed in setup operation Monitoring of the maximum speed to < 0.07 m/s	3.1	d	1 x WCS absolute encoder 1 x Incremental encoder on motor / drive wheel	Monitoring by means of tested safety function SLS for fixed limits	70mm/s Fault distance monitoring 200mm	Identification of worker's work area via position of carriage AND NOT Setup Reset: Acknowledgement button	SF 1.7.1
1.4	Collision protection of carriage Monitoring of the distances between carriages for minimum distance by means of redundant laser distance measurement	2.5	d	2 x Laser distance measuring facilities	Monitoring of distances by means of tested SAC function. The analog distance measurements are reciprocally compared for max. tolerance (diagnose of analog sensor) M´monitored for minimum value (SAC function) Min distance value 25% of the max. value of the measuring device.		Operating mode Setup AND button "Bridge safety" Reset: Acknowledgement button	SF 1.7.1
1.6.1	Monitoring of carriage sensor system * the two carriage sensors	5.1	e	1 x WCS absolute encoder 1 x Incremental encoder on motor / drive wheel	Muting of diagnoses for both carriage sensors by means of tested SCA function Muting is started before each gap, a faulty encoder value will be temporarily suppressed. Within the gap an encoder value outside 2 to 160000mm will cause muting.		Pos 1 (7626 - 7850) Pos 2 (11030-1263) Pos 3 (75134-5338) Pos 4 (145562-145622) Pos 5 (143935-143995) Pos 6 (80000-80060)	SF 1.6.2

13.3.4 Software specification

The software specification refers to the previous specification of the safety functions. It can also be replaced by a correspondingly worked out specification of the safety functions, as far as this contains all specifications (see example under 12.3.3.3).
However, it is recommended to prepare an extracted list. This list should contain the following data:

- Designation of safety function
- Description of function
- Parameters, as far as available
- Triggering event / operating status
- Response / output

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

Example of software specification

Cons.-No.	Safety function	Plr	Measuring value /sensor	Solution new	Input/ activation	Response/ output
1.4	Monitoring V_Rope to V_Nominal Monitoring of differences between speed of main drive and rope drive for maximum value	d	Digital incremental encoder, tachometer generator rope sheave	Monitoring by means of tested function SLS + SAC with comparison of speed ranges /analog value ranges = comparison for diagnose of the speed detection Shut-down dual-channel new (see below)	Permanently Reset: Acknowledgement button	Operation stop SF 1.3.1
1.6	Backstop Monitoring for reversing	d	Mechanical limit switch 22S2 Digital incremental encoder	Monitoring by means of tested function direction monitoring SDI	EMERGENCY (auxiliary contact 28K4 – reversing) Reset: Acknowledgement button	Operation stop SF 1.3.1
1.15	Step-by-step shut-down 3 Activation of the safety brake	e	-	Processing of SF in Safe PLC	SF 1.2 SF 1.3.2 SF 1.7 SF 1.8	Setting the safety brake
1.8	Standstill functional	d	Digital incremental encoder	Standstill monitoring by means of tested function SOS	Regulator lock OR Set service brake	SF 1.15/ Set safety brake
1.9	direction monitoring	e	Digital incremental encoder,	Monitoring by means of tested function direction monitoring SDI	28K1 = FORW. 28K2 = BACK = safe <signals from control "Frey"""	Operation stop SF 1.3.1

13.3.5 Hardware specification

The hardware specification should describe the entire system design and, in particular, the components used with their specific characteristic data. The hardware specification serves as basis for the determination of the achieved safety level based on the architecture and the characteristic data of all devices involved in a safety function.
Furthermore, the hardware specification should also specify the design measures applied for protecting against systematic and common cause faults.

13.3.5.1 Selection of SRP/CS and operating means

The selection of SRP/CS (Safety related parts of control system) is most suitable to achieve the intended safety level and should be made for any safety function. The components with safety relevant function must be designated in a total overview of the system structure and are to be assigned to the individual safety functions The safety related code numbers must be determined for these components.

The code numbers cover the following values:

MTTFd   = mean time to failure, the mean time until a danger imposing failure)
DC avg   = Mean diagnostic coverage
CCF   = common cause failure, a failure caused on a common cause

For an SRP/CS both the software and systematic faults must be taken into consideration.

An analysis of the SRP/CS participating in the safety function must generally be performed in accordance with the schematic Sensor / PES / Actuator.
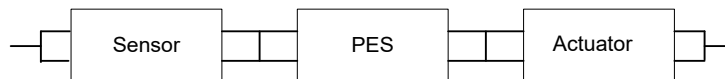
13.3.5.2 Example of default HW

Safety function		Safely reduced speed	SF 2.2	Safely monitored limited speed with door open								
Type	Designation	Function	Design	Characteristic data								Note
				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	Data sheet	99	Inst. manual op. KSM		
	Sensor 2.1	Incremental encoder – Motor feedback SIN/COS	G 1.1	4	30			Gen. specification	99	Inst. manual op. KSM		Cat. 4 in connection with selection KSM
PES	Safety PLC	Central safety PLC for control and evaluation of safety relevant functions	A 4.1			1,4 E-8		Data sheet KSM				
Actuator	STO	Safe Torque Off on inverter	A 5.1	4	150			Data sheet inverter	99	Inst. manual op. KSM		Cat. 4 in connection with dual-channel
	Mains contactor	Contactor in mains line of inverter	K 5.1	4			20 E6	Data sheet contactor	99	Inst. manual op. KSM		Cat. 4 in connection with dual-channel

13.3.5.3 Consideration of systematic failures

Within the hardware specification one must also consider systematic failures.

Examples for measures against systematic failures:
Power drop during operation. If this causes a danger, a power drop must be considered an operating status. The SRP/CD must be able to cope with this condition, so that a safe state is maintained.

Measures against systematic failures acc. to appendix G DIN EN ISO 13849-9


```
┌──────────────────────────────────────────────────────────────────────────┐
│  ┌─────────────────────────┐    ┌──────────────────────────────────────┐  │
│  │  Causes of systematic   │    │ Measures for the avoidance of failures│ │
│  │        failures         │    │ Appropriate materials and suitable manufacture │
│  │                         │    │  Correct dimensioning and design of shape │
│  │ ● Before commissioning, │    │   Correct selection, arrangement, assembly, installation │
│  │     e.g.:               │    │    Component with compatible operating characteristics │
│  │  - Manufacturing faults │ →  │     Resistance against determined environmental conditions │
│  │  - Fault in development │    │      Component in accordance with standard with defined types of failure │
│  │    (incorrect selection,│    │       Function test │
│  │    incorrect            │    │  INTEGRATION: Project management, documentation │
│  │    dimensioning, faulty │    │   additionally:  Black-Box test │
│  │    software)            │    └──────────────────────────────────────┘  │
│  │  - Fault in integration │    ┌──────────────────────────────────────┐  │
│  │    (incorrect selection,│    │ Measures for the control of failures │  │
│  │    faulty wiring)       │    │ Principle of power supply shut-down │   │
│  │                         │    │  Draft for the control of voltage related influences │
│  │ ● after commissioning,  │    │   Draft for the control of environment related influences │
│  │     e.g.:               │ →  │    Monitoring of program run (in case of software) │
│  │  - Power failure/       │    │     "Secure" data communication processes (bus systems) │
│  │    fluctuations         │    │      Automatic testing │
│  │  - environmental        │    │ additionally: Redundant hardware/hardware diversity │
│  │    influences           │    │       Desmodromic operation mode │
│  │  - Wear, overloading    │    │        Contacts with positive guidance/ with forced │
│  │  - Faulty maintenance   │    │         Directed failures │
│  │                         │    │          Over-dimensioning │
│  └─────────────────────────┘    └──────────────────────────────────────┘  │
└──────────────────────────────────────────────────────────────────────────┘
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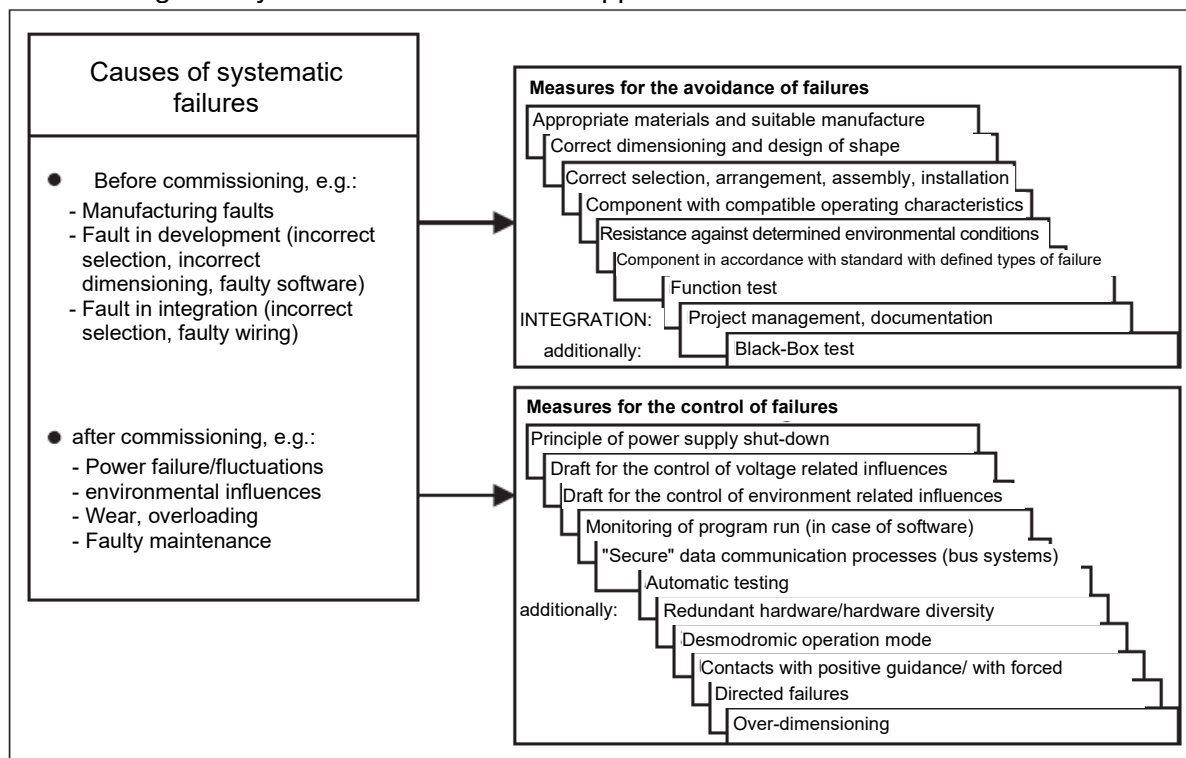
Source BGIA Report 2/2008

Fault exclusions
If fault exclusions are made for certain devices or system components, these must be individually nominated and specified.
Fault exclusions may be e.g. mech. shaft breakage, sticking of switching contacts, short-circuits in cables and lines, etc.
The permissibility of fault exclusions must be justified, e.g. by referencing to permissible fault exclusions acc. to applicable standards, e.g. EN ISO 13849-1)
If these fault exclusions require special measures, these must be mentioned.

Examples for fault exclusions and associated measures:
- Positive connection for mechanical shaft connections
- Dimensioning based on sufficient theoretical bases in case of breakage of components in the safety chain.
- Positively guided connection with forced separation in case of sticking of switching contacts.
- Protected routing within switchgear in case of short-circuit in cables and lines, as well as routing of cables in cable ducts – especially for use in elevator technology acc. to EN 81-20/-50 resp. EN 81-1/-2

13.3.6 Hard and Software design

The performance targets from the hardware and software specification are implemented in the actual system design.

The performance targets for the components to be used and their wiring from the hardware specification must also be met, the same applies for the performance targets for fault exclusions. Both must be achieved and documented with appropriate means.
In the software one must also account for and completely implement the targets from the software specification.
Furthermore, one must consider the superimposed targets placed on the software by safety related programming. These are among others:
Modular and clear program structure
Assignment of functions to the safety functions
Understandable representation functions by:
Unambiguous designations
Understandable comments
Use of tested functions / function modules, as far as this is possible
Defensive programming

13.3.7 Testing of the hardware design

After completing the planning, the hardware design must be examined for compliance with the targets from the hardware specification.
Furthermore, one must check the compliance with the specified safety level for each safety function by using suitable analyses. The analysis methods have been described in applicable standards (e.g. EN ISO 13849-1).

Analysis of wiring diagram
Compliance with the targets set under safety related aspects can be checked by means of the wiring diagram and the bill of materials. The following must be checked in particular:
the correct wiring of components as specified,
the dual-channel structure, as far as specified
the non-reactivity of parallel, redundant channels.
The use of components as specified
The checks should be made by understandable analysis.

13.3.7.1   Iterative testing of the achieved safety level

The achieved safety level must be determined by means of the circuit structure
(= architecture single-channel (dual-channel / with or without diagnose), the characteristic device data (manufacturer's data or appropriate sources) and the diagnostic coverage (manufacturer's data PES or general sources). Appropriate measures can be taken from the underlying safety standard.
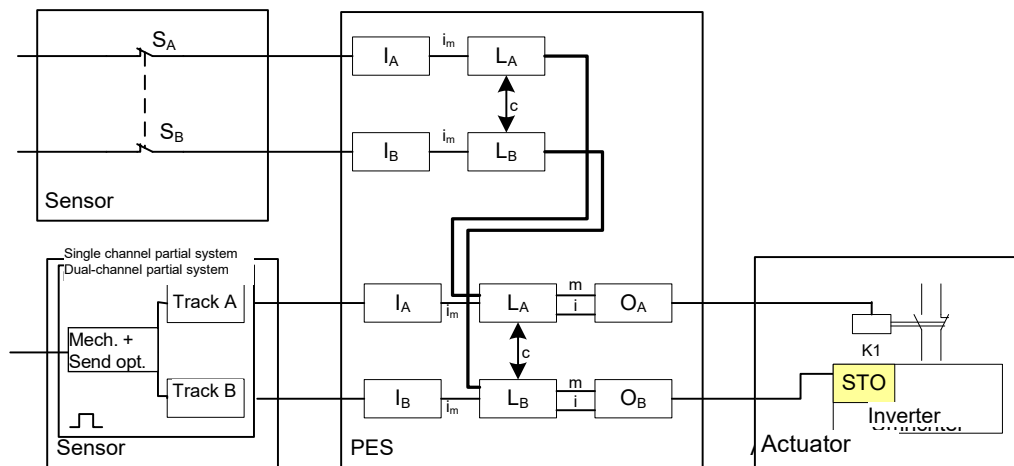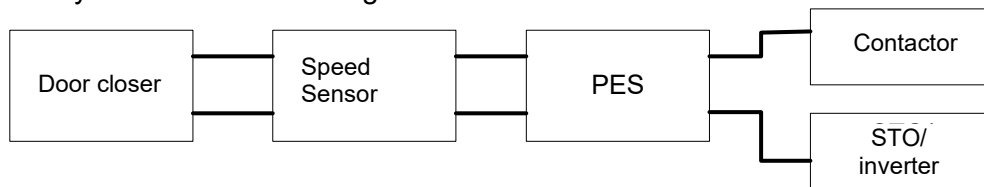
A calculation acc. to EN ISO 13849-1 shall serve as an example:

Safety function:
Safely reduced speed with access door open

Structural diagram:

Safety related structural diagram:

Calculation acc. to EN ISO 13849-1:

Channel A – shut-down via mains contactor:

C	$MTTF_d$ [years]	DC
Door closer[1]	B_{10d} = 100000 n_{op} = 30/AT = 9270/year (309 AT/year)	DC_{Switch} = 99%
	$$MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 107{,}87 \text{ years}$$	
SIN/COS-Encoder	$MTTF_d$ = 30 years	$DC_{Encoder}$ = 99%
PES[2]	$$\lambda_d = 1884{,}21 \text{ fit}$$ $$MTTF_d = \frac{10^9}{365 \cdot 24 \cdot \lambda_d} = 60{,}59 \text{ years}$$	DC_{PES} = 94,5%
Main contactor[3]	$B_{10d} = 1{,}3 \cdot 10^6$ N_{op} = 20/AT = 6180/year (309 AT/year)	$DC_{Contactor}$ = 60%
	$$MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 2103{,}56 \text{ years}$$	

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

---

[1] Value for $MTTF_{d \text{ acc. to}}$ EN ISO 13849-1, Table C.1
[2] Value from company internal HW FMEA; assumption of an SMX12-2A with relay board, CPU board, processing subsystem and output subsystem with HighSide/LowSide combination
[3] Value for MTTFd from EN ISO 13849-1, Table C.1; assumption "worst case" by "contactor with nominal load"

Channel B – shut-down via STO/inverter:

Component	$MTTF_D$ [years]	DC
Door closer (s.o.)	B_{10d} = 100000 n_{op} = 30/AT = 9270/years (309 AT/year)	DC_{Switch} = 99%

$$MTTF_d = \frac{B_{10d}}{0,1 \cdot n_{op}} = 107,87 \text{ years}$$

SIN/COS-Encoder (s.o.)	$MTTF_d$ = 30 years	$DC_{Encoder}$ = 99%
PES (s.o.)	$\lambda_d = 1884,21 \text{ fit}$ $MTTF_d = \dfrac{10^9}{365 \cdot 24 \cdot \lambda_d}$ $= 60,59 \text{ years}$	DC_{PES} = 94,5%
STO/converter[4]	$MTTF_d$ = 150 years	DC_{STO} = 90%

Resulting PI for both channels:

Symmetry of both channels	$MTTF_d = \dfrac{2}{3}\left[MTTF_d^A + MTTF_d^B - \dfrac{1}{\dfrac{1}{MTTF_d^A} + \dfrac{1}{MTTF_d^B}}\right] = 16,00 \text{ years}$
DC mean value	$DC_{avg} = \dfrac{\sum_i \dfrac{DC_i}{MTTF_i}}{\sum_i \dfrac{1}{MTTF_i}} = 97,2\ \%$
PL	MTTFD = 16 years = average DC avg = 97,4 % = average PL ="d" (from EN ISO 13849-1, tables 5,6, and 7) In this case the B10d value of the door monitoring feature is is determining for PI. If an even higher safety level is to be reached a correspondingly higher qualitative switch is to be used.

Note: The characteristic values of the individual components were chosen as examples and must be adjusted accordingly for user applications.

Note:
The PI can also be determined with the program tool "Sistema" from BGIA.

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[4] Value for $MTTF_d$ acc. to EN ISO 13849-1, table C.1

13.3.8 Verification software(program) and parameters

Verification takes place in two steps:
1. Checking the FUP with respect to the specified functionality.
2. Checking the FUP against the AWL-listing of the validation report, or the default parameters against the one listed in the validation report.

13.3.8.1   Checking FUP

The programmed FUP must be compared with the defaults in the specification.
Note:
The comparison is all the more efficient the more clearly the programming has been structured with respect to the safety functions.

Example:
Safety function:
1.1 Limitation of the max. travel speed of the carriage to 1.1 VMax
Monitoring of the maximum speed to < 1.1 VMax
FW Max Speed OK (ID 548) (is bridged by available gap):
FW Max Speed is permanently activated and responds when a speed of 550 mm/s is exceeded.
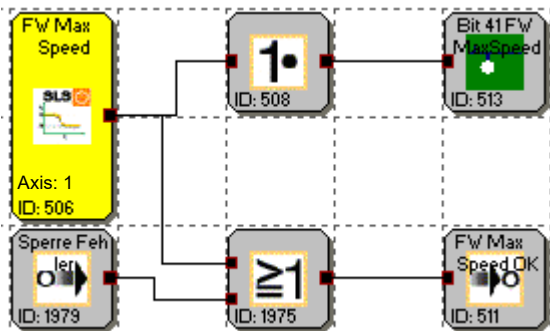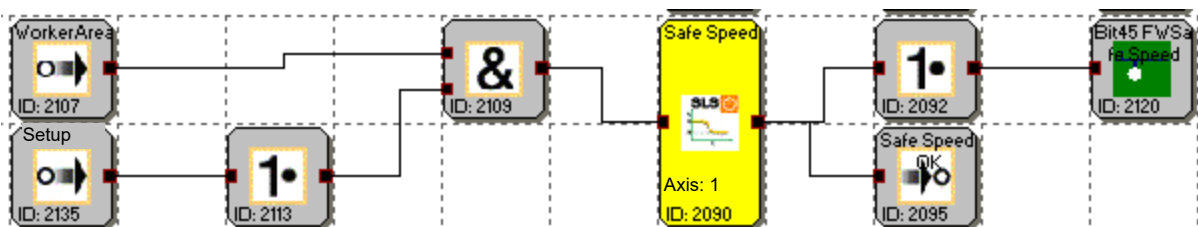

Safety function:
Limitation of max. travel speed in carriage in the worker's area:
Monitoring of the maximum speed to < 0.33 m/s
Safe Speed OK (ID 2124) (is bridged by available gap):
Safe Speed OK responds when the safe speed SLS (ID 2090) is exceeded in the worker's area and during setup work.

Parameter SLS Safe Speed:
60 mm/s, no further parameters

Safety function:
Carriage shut down
Shut down of travel system and deactivation of brakes
Shut down on carriage
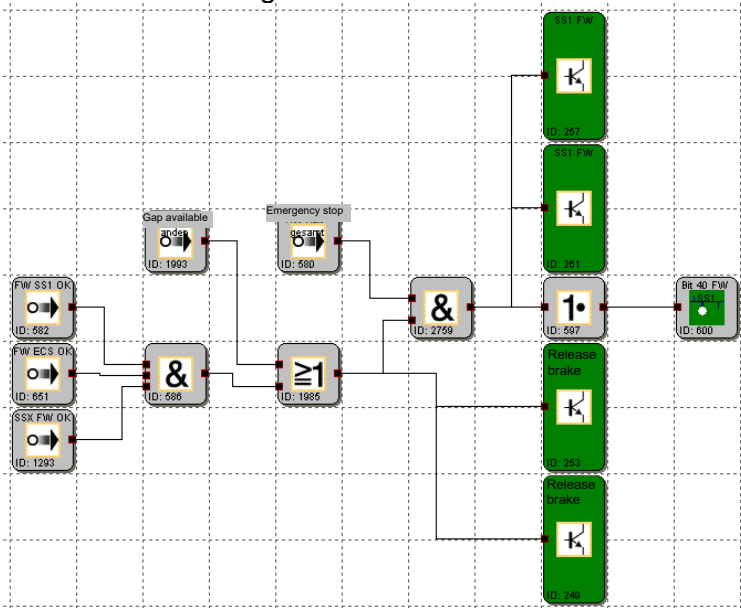
The carriage is switched off via two outputs (EAA1.5 ID 257 and 1.6 ID 261).
The brakes are released via two outputs (EAA1.3 ID 253 and 1.4 ID 249).
The PLC receives a message concerning bit 40 (ID 600).
In case of an emergency stop the shut-down takes place immediately.

Lift

Safety function
Emergency stop switch inputs and shut-down outputs.
1.1 Emergency stop head control
Dual-channel emergency stop with pulse monitoring
If an emergency stop is triggered at the imposed control, this emergency stop can be bridged
if the approval 'Bridge safety' has been issued.
Emergency stop button head control

Emergency stop contacts from emergency stop relay with pulsing from the KSM

13.3.8.2 Validation of FUP against AWL and parameters by means of validation report.

The programming that took place in the FUP must be compared with the AWL-listing of the validation report.
Example AWL-listing in 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		

Step-by-step testing is recommended. The test all the batter, the more structured the programming in FUP has been made.

After checking the program, one must also check the parameters against the targets set in the specifications by means of comparison.

Example SLS:

Validation report

Safe Limited Speed (SLS)

Index	Parameters	Value	validated
SLS - 0	Chosen axis:	1	
	Speed threshold:	2	0
SLS - 1	Chosen axis:	1	
	Speed threshold:	500	0
SLS - 2	Chosen axis:	1	
	Speed threshold:	2	0
	Acceleration threshold	2	0
SLS - 3	Chosen axis:	1	
	Speed threshold:	2	0
	Assigned SSX-ramp	0	

Example encoder configuration:

Validation report

Axis configuration / sensor interface		
Axis 1		
General parameters		
Measuring distance:	500	0
Type:	Rotational	
	No	
Position processing:	Activ	
Maximum speed:	2000	0
Incremental shut-down:	10000	0
Shut-down		
speed:	100	0

Sensors	0		0	
Type:	SSI-standard		SSI-standard	
Format:	Binary		Binary	
Direction of rotation:	Ascending		Ascending	
Supply voltage:	0		0	
Resolution:	1024	Steps//1000mm	64	Steps//1000mm
Offset:	0	Steps/	0	Steps/

General parameters correctly configured

Parameter sensor 1 correct

Parameter sensor 2 correct

13.3.9 Performance of the system test / FIT (fault injection test)

For the FIT the manufacturer must prepare a complete list of the functions to be tested. This list includes the defined safety functions as well as the fault test for checking the right response of the SRP/CS to this fault

Example test list:

No	Setup	Test	Result
1	Test SLS for max. speed in setup operation		
	Activate setup operation Travel with maximally allowed speed	- Diagnose of the actual speed versus the SLS limit - Manipulation of the setup speed beyond the permitted reduced speed	
2	Test SSX for Stop-category 2		
	Travel with max. speed Actuate the emergency stop	- Diagnose of the SSX-ramp against the actual deceleration ramp - Setting an impermissible weak deceleration - Moving the axis after standstill is reached by manipulating the drive	
3	Test of the dual-channel door monitoring		
	Select operating mode for setup operation	Diagnose of inactive monitoring with door closed (using diagnostics function FUP) Diagnose of active monitoring with door open (using diagnostics function FUP) Disconnecting one channel and opening the door Generate cross-shorting between both inputs	

Appendix A – Classification of switch types

General note:

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

Enable switch

Switch type	Comment	Classification Pl acc. to EN ISO 13849-1	Classification SIL acc. to IEC 61508
1 normally closed	Enable switch standard	PL d	SIL 2
1 normally open	Enable switch standard	PL d	SIL 2
2 normally closed	Enable switch higher requirements	PL e	SIL 3
2 normally closed time monitored	Enable switch monitored	PL e	SIL 3

Emergency Stop

Switch type	Comment	Classification category	Classification SIL
1 normally closed	Emergency Stop standard	PL d[1]	SIL 2
2 normally closed	Emergency stop higher requirements	PL e	SIL 3
2 normally closed time monitored	Emergency Stop monitored	PL e	SIL 3

[1]   Fault exclusions and boundary conditions acc. EN 13849-2 must be observed!

Door monitoring

Switch type	Comment	Classification category	Classification SIL
2 normally closed	Door monitoring higher requirements	PL e	SIL 3
2 normally closed time monitored	Door monitoring monitored	PL e	SIL 3
1 normally open + 1 normally closed	Door monitoring higher requirements	PL e	SIL 3
1 normally open + 1 normally closed time monitored	Door monitoring monitored		SIL 3
2 normally open + 2 normally closed	Door monitoring higher requirements	PL e	SIL 3
2 normally open + 2 normally closed time monitored	Door monitoring monitored	PL e	SIL 3
3 normally closed	Door monitoring higher requirements	PL e	SIL 3
3 normally closed time monitored	Door monitoring monitored	PL e	SIL 3

Two-hand button

Switch type	Comment	Classification category	Classification SIL
2 two-way switch	Two-hand button higher requirements	Type III C PL e	SIL3
2 normally open	Two-hand button monitored	Type III A PL e	SIL1

Note: With these in Port elements a fixed pulse assignment takes place, which cannot be influenced by the user!

Light curtain

Switch type	Comment	Classification category	Classification SIL
2 normally closed	Light curtain higher requirements	PL e	SIL 3
2 normally closed time monitored	Light curtain monitored	PL e	SIL 3
1 normally open + 1 normally closed	Light curtain higher requirements	PL e	SIL 3
1 normally open + 1 normally closed time monitored	Light curtain monitored	PL e	SIL 3

Mode selector switch

Switch type	Comment	Classification category	Classification SIL
2 positions	Mode selector switch monitored	PL e	SIL 3
3 positions	Mode selector switch monitored	PL e	SIL 3

Safety Note: When changing the status of the switch the SafePLC program to be created must ensure that the outputs of the module are deactivated
(Note: Standard 60204-Part1-Paragraph 9.2.3).

Sensor

Switch type	Comment	Classification category	Classification SIL
1 normally closed	Sensor input standard	PL d	SIL 2
1 normally open	Sensor input standard	PL d	SIL 2
2 normally closed	Sensor input higher requirements	PL e	SIL 3
2 normally closed time monitored	Sensor input monitored	PL e	SIL 3
1 normally open + 1 normally closed	Sensor input higher requirements	PL e	SIL 3
1 normally open + 1 normally closed time monitored	Sensor input monitored	PL e	SIL 3

Start / reset element

Switch type	Comment	Classification category	Classification SIL
1 normally open	Alarm reset standard (evaluation of edge)	--	--
1 normally open	Logic reset standard	PL d	SIL 2
1 normally open	Start monitoring standard (optional function)	--	--

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

Appendix B – Approvals

The latest Certificates for Conformity to European Directives are located on the product DVD or can be downloaded from the Kollmorgen website.

Existing documents:

- EU Declaration of Conformity according to EC Directives 2006/42/EC Appendix IV and 2004/108/EC
- Functional Safety Certificate according to EC Directive 2006/42/EC Appendix I

About KOLLMORGEN

Kollmorgen is a leading provider of motion systems and components for machine builders. Through world-class knowledge in motion, industry-leading quality and deep expertise in linking and integrating standard and custom products, Kollmorgen delivers breakthrough solutions that are unmatched in performance, reliability and ease-of-use, giving machine builders an irrefutable marketplace advantage.

Join the Kollmorgen Developer Network for product support. Ask the community questions, search the knowledge base for answers, get downloads, and suggest improvements.

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