Installation Manual
for
JSC-110 modules of the JSX system

Installation Manual for JSC-110, JSC-110-1-RS, JSC-110-2-RS controllers of the JSC-110 series and their JSX1-DIO22 expansion module

Note:
Translation of the German original Installation Manual.

Revision date: 04/2020

Valid as of FW release 2.0.2.46

Subject to technical modifications.
The content of our documentation is compiled with the greatest of care and corresponds to our current level of knowledge.

Please note that this document cannot always be updated concurrently with the technical further development of our products.
Information and specifications may change at any time. Please check www.jetter.de for the latest version. Jetter AG devices

Graeterstr. 2
71642 Ludwigsburg
Germany

Content

1 Important notes

Definition of the individual target groups

Designers of safe drive systems:
Engineers and technicians

Mounting, electrical installation, maintenance and equipment replacement
Industrial electricians and service technicians

Commissioning, operation and configuration:
Technicians and engineers

1.1 Definitions

The term JSC-110 is used as a generic term for all derivatives of the JSC -110 product line. Where reference is made in the description to a particular derivative, the full name shall be used.

In the following, the term "safe" refers to the classification as a safe function for application up to PL e according to EN ISO 13849-1 or SIL 3 according to IEC 61508:2010.

The "JetSafe" system software is used to configure and program the JSC-110 modules.

Internally, the modules of the JSC-110 series consist of two independent processing units. These are referred to as System A and System B in the following.

1.2 Applicable documents

Description	Referencing
Configuration of the JSC-110 modules for standalone applications without fieldbus interface with the "JetSafe" program	JetSafe programming manual (System CD)
Validation report of the implemented parameterization and the PLC program	Safety testing with acceptance report
Acceptance for general safety applications	Certificate for type testing for safety control according to Machinery Directive 2006/42/EC for the modules JSC-110 JSC-110-1-RS JSC-110-2-RS JSX1-DIO22

Note:
- Read the manuals carefully before starting to install and commission the JSC-110 modules.
- Compliance with the documentation is a prerequisite for trouble-free operation and the acceptance of any warranty claims.

1.3 Abbreviations used in this document

Abbreviation	Description
AC	Alternating current
AWL	Statement list
BG	Berufsgenossenschaft (German Employer's Liability Insurance Association)
CLK	Clock
CPU	Central processing unit
DC	Direct current
DI1..DI14	Digital input
DIN	Deutsches Institut für Normung (German Institute for Standardizing)
DO	Digital output
EMU	Emergency monitoring unit
EMC	Electromagnetic compatibility

Abbreviation	Description
ELC	Emergency limit control
EN	European standard
HISIDE	Positive switching output with DC 24 V nominal level
IP20	Degree of protection for housing
ISO	International Organization for Standardization
LED	Light Emitting Diode
LOSIDE	Output switching to reference potential
OLC	Operational limit control
PAA	Process map of the outputs
PAE	Process map of the inputs
P1, P2	Pulse outputs
PLC	Programmable logic controller
POR	Power on reset
PSC	Position supervision control
SELV	Safety extra low voltage
SSI	Synchronous-serial interface
VDE	Verband der Elektrotechnik, Elektronik und Informationstechnik e. V. (German Association of Electrical Engineering, Electronics and Information Technology e. V.)
DOx.y(1)	Auxiliary output

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

2 Safety precautions

2.1 Intended use

The devices of the JSC-110 series are programmable safety controllers for the generation of safety shutdowns and functions. The devices are intended for use

- in emergency stop equipment,
- as a safety component according to the EC Machinery Directive 2006/42/EC,
- as PES for risk reduction according to IEC 61508,
- in safety circuits according to EN 60204-1 and EN 60204-32,
- as PES for functional safety according to EN 62061,
- as SRP/CS according to EN ISO 13849-1,
- as a device for establishing the safety functions in accordance with EN 61800-5-2,
- as logic unit for signal conversion and processing in two-hand circuits according to EN 574.

CE

The devices of the JSC-110 series incl. expansion module JSX1-DIO22 are safety components according to Annex IV EC Machinery Directive 2006/42/EC.
They have been developed, designed and manufactured in accordance with the above-mentioned Directive and the EC EMC Directive 2014/30/EU.

Cf. EC Declaration of Conformity

2.2 Use in regions with UL/CSA requirements

The modules of the JSC-110 series can be used in the USA and Canada under the following conditions:

- The switching voltage of the output relays must be limited to a maximum of 24 V.
- The power supply of the JSC-110 modules and their inputs and outputs must be provided by a power supply that meets the SELV/PELV requirement.

If the above conditions are met, UL/CSA approval is not required and the JSC-110 series can be used in switchgear according to UL 61010.

2.3 General safety instructions

⚠ **Safety precaution:**

- To prevent injury and property damage, only qualified personnel are permitted to work on the device. Qualified personnel is personnel who has been trained in electrical engineering and is familiar with the applicable rules and standards of electrical engineering.
- The qualified person must be familiar with the operating instructions (cf. IEC364 DIN VDE 0100).
- The qualified person must have at least in-depth knowledge of the national accident prevention regulations.
- The use of the devices must be restricted to their intended use in accordance with the above list. The values of the data listed in section "3.2. Device Characteristics" must also be observed.
- The contents of this installation manual are limited to the basic function of the devices or their installation. The programming and reparameterization of the devices is described in more detail in the "Programming Instructions JSC-110". Their exact knowledge and understanding is a mandatory prerequisite for a new installation or modification of the device function or its parameters.
- Commissioning, i.e., the start of intended operation, is only permitted when EMC Directive is complied with.
  The EMC test regulations EN55011:2009 + A2:2010 and EN 61000- 6- 2:2005 are applied.

- For storage and transport, the conditions according to EN 60068-2-6 with regard to the values stated in the technical specifications must be observed.
- The wiring and connection instructions in chapter "Installation" must be observed.
- The applicable VDE regulations and other special safety regulations for the application in question must be observed.

- The configured monitoring functions as well as their parameters and links must be documented via a validation report.
- The implementation of the module is to be coordinated with the requirements of the responsible acceptance body (e.g. TÜV or BG).

- Never install or commission damaged products. Please report any damage immediately to the transport company.

- Never open the housing and/or carry out unauthorized modifications.
- Inputs and outputs for standard functions must not be used for safety-related applications.

WARNING:
The use of our devices in violation of the rules and conditions mentioned here can result in injury or death of persons as well as in damage to connected devices and machines!
This also leads to the loss of any warranty or compensation claims against the manufacturer.

2.4 Operation and service

Before installing or removing the module or disconnecting signal lines, the module must be disconnected from the power supply. For this purpose, switch off all live supply lines to the device and check that they are free of voltage.

During installation and removal of the module, appropriate measures must be taken to avoid electrostatic discharges on the external terminal and plug connections.
Contact with these terminals should therefore be kept to a minimum and grounding should be carried out beforehand and during this time, e.g. with a grounding wrist strap.

2.5 Transport/storage

The instructions for transport, storage and proper handling must be observed.
The climatic specifications mentioned in chapter "Technical data" must be observed.

3 Device types

The JSC-110 series consists of the following modules:

- basic modules JSC-110, JSC-110-1-RS, JSC-110-2-RS
- expansion module JSX1-DIO22

Basic modules
The JSC-110 series is a compact safety controller with optional integrated drive monitoring for one (JSC-110-1-RS) or two (JSC-110-2-RS) axes. The device is user-programmable for safe processing of EMERGENCY STOP buttons, control buttons for two-hand operation, light curtains, operating mode selector switches, etc. as well as drive-related safety functions. Preconfigured modules are available for a large number of input devices for safety-relevant signal preprocessing. The same also applies to safety functions for drive monitoring. Details can be found in the programming manual.

The basic version of the device has 14 safe inputs and up to 5 safe shutdown channels.

For safe speed and/or position detection, solutions with one, or two encoders are supported. See "Encoder specifications".

Expansion module
Central I/O expansion module for direct connection to controllers of the JSC-110 series.
A maximum of 2 IO modules can be used.

3.1 Module overview

	Basic units			Expansion module
Designation	**JSC-110**	**JSC-110-1-RS**	**JSC-110-2-RS**	**JSX1-DIO22**
Number of supported expansion modules	2			-
Safe digital inputs	14			12
Safe digital inputs/outputs (DIO)	-			10
Safe digital outputs pn-switching/pp-switching	2			-
Relay outputs	2			-
Auxiliary outputs	2			2
Pulse outputs	2			2
Axis monitoring	-	1	2	-
Encoder technology	-	SSI Sin/Cos Incr. TTL Proximity switch Incr. HTL Resolver	SSI Sin/Cos Incr. TTL Proximity switch Incr. HTL Resolver	-

3.2 Device specifications

3.2.1 Basic module

3.2.1.1 JSC-110

Type designation	Features
	The design of the module features the following: 14 digital inputs 2 pulse outputs 2 relay outputs 2 pn-switching outputs 2 auxiliary outputs 1 diagnostics 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 2 status LEDs for outputs

Characteristics of the module:

- Expandable to:
  - max. 38 safe digital inputs,
  - max. 2 safe digital outputs,
  - max. 20 safe IOs,
  - max. 6 auxiliary outputs
- Logic processing up to PL e according to EN ISO 13849-1 or SIL 3 according to EN 61508
- Programmable micro controller for up to 800 instruction list (IL) instructions
- Function chart-oriented programming
- Pulse outputs for cross-fault detection on digital input signals
- External contact monitoring of connected switching devices (EMU)
- Monitored relay outputs for safety-relevant functions
- Parameter management for expansion modules in the basic unit
- Comprehensive diagnostic functions integrated
- Coded status display via 7-segment display and status LEDs on the front
- Multi-function pushbutton (Quit, Start, Reset) can be operated from the front panel
- Installation on DIN rail

Technical specifications JSC-110

Safety specifications			
PL according to EN13849-1			PL e
PFH/architecture			12.6 FIT / Cat. 4
$MTTF_d$			49 years
SIL according to IEC 61508			SIL 3
Proof test interval			20 years = max. service life
General data			
Number of supported expansion modules			2
Interface for expansion modules			Backplane elements, pluggable into DIN rail
Number of digital inputs			14 (OSSD capable)
Number of safe digital outputs pn-switching			2
Number of safe digital IOs			-
Number of relay outputs			2
Number of auxiliary outputs			2
Number of pulse outputs			2
Connection type			Plug-in terminals with spring connection
Axis monitoring			-
Encoder interfaces (D-Sub/terminals)			-
Electrical data			
Supply voltage (tolerance)			DC 24 V; 2 A (-15 %, +20 %)
Fuse X11.1			Min. DC 30 V; max. 3.15 A
Max. power consumption (logic section)			2.4 W
Ratings - digital inputs			DC 24 V; 20 mA, type 1 according to EN 61131-2
Ratings - digital outputs			
	pn-switching		DC 24 V; 250 mA
	Auxiliary outputs		DC 24 V; 250 mA
	Pulse outputs		DC 24 V; 250 mA
Ratings - relay			
	N/O	DC13 AC15	DC 24 V; 2 A AC 230 V; 2 A
	Normally closed contact (read back contact)	DC13	DC 24 V; 2 A
Environmental data			
Temperature			0° … 50° (operation) -25° … +70° (storage, transport)
Protection class			IP 20
Climatic category			3k3 according to DIN 60 721-3
Min., max. relative humidity (no condensation)			5 % ... 85 %
EMC			EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of equipment			2000 m
Overvoltage category			III
Pollution degree			2
Mechanical specifications			

Dimensions HxDxW [mm]	100x115x45
Weight	300 g
Mounting type	Snap-on mounting to DIN rail
Number of backplane elements	2
Min. connection cross-section/AWG	0.2 mm^2/24
Max. connection cross-section/AWG	2.5 mm^2/12

3.2.1.2 JSC-110-1-RS

Type designation	Features
	The design of the module features the following: 1 axis 5 encoder interfaces 14 digital inputs 2 pulse outputs 2 relay outputs 2 pn-switching outputs 2 auxiliary outputs 1 diagnostics 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 2 status LEDs for outputs

Characteristics of the module:

- Expandable to:
  - max. 38 safe digital inputs,
  - max. 2 safe digital outputs,
  - max. 20 safe IOs,
  - max. 6 auxiliary outputs
  - Max. 1 safe axis
- Logic processing up to PL e according to EN ISO 13849-1 or SIL 3 according to IEC 61508
- Monitoring of axis motion up to PL e according to EN ISO 13849-1 or SIL 3 according to IEC 61508
- Velocity monitoring:
- Speed monitoring
- Standstill monitoring
- Direction of rotation monitoring
- Safe increment
- Emergency stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Programmable micro controller for up to 800 instruction list (IL) instructions
- Function chart-oriented programming
- Pulse outputs for cross-fault detection on digital input signals
- External contact monitoring of connected switching devices (EMU)
- Monitored relay outputs for safety-relevant functions
- Parameter management for expansion modules in the basic unit
- Complete speed- and position-related safety functions for drive monitoring according to IEC 61800-5-2 integrated in firmware
- Comprehensive diagnostic functions integrated

- Coded status display via 7-segment display and status LEDs on the front
- Multi-function pushbutton (Quit, Start, Reset) can be operated from the front panel
- Installation on DIN rail
- Advanced functionality:
    - Allows connection of 2 encoders per axis (SSI, Sin/Cos, TTL, proximity switch)
    - 2nd encoder interface supports resolver

Technical specifications JSC-110-1-RS

Safety specifications		
PL according to EN13849-1		PL e
PFH/architecture		12.6 FIT / Cat. 4
$MTTF_d$		44 years
SIL according to IEC 61508		SIL 3
Proof test interval		20 years = max. service life
General data		
Number of supported expansion modules		2
Interface for expansion modules		Backplane elements, pluggable into DIN rail
Number of digital inputs		14 (OSSD capable)
Number of safe digital outputs pn-switching		2
Number of safe digital IOs		-
Number of relay outputs		2
Number of auxiliary outputs		2
Number of pulse outputs		2
Connection type		Plug-in terminals with spring connection
Axis monitoring		1
Encoder interfaces *		
	D-Sub X31	SSI, Sin/Cos, incremental TTL
	D-Sub X33	Resolver
	Terminal X23	Incremental HTL (10 kHz)
	Terminals X27, X28	Incremental HTL (200 kHz)
Electrical data		
Supply voltage (tolerance)		DC 24 V; 2 A (-15 %, +20 %)
Fuse X11.1		Min. DC 30 V; max. 3.15 A
Max. power consumption (logic section)		2.4 W
Ratings - digital inputs		DC 24 V; 20 mA, type 1 according to EN 61131-2
Ratings - digital outputs		
	pn-switching	DC 24 V; 250 mA
	Auxiliary outputs	DC 24 V; 250 mA
	Pulse outputs	DC 24 V; 250 mA
Ratings - relay		
	N/O DC13 AC15	DC 24 V; 2 A AC 230 V; 2 A

Environmental data	
Temperature	0° … 50° (operation) -25° … +70° (storage, transport)
Protection class	IP 20
Climatic category	3k3 according to DIN 60 721-3
Min., max. relative humidity (no condensation)	5 % ... 85 %
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of equipment	2000 m
Overvoltage category	III
Pollution degree	2
Mechanical specifications	
Dimensions HxDxW [mm]	100x115x67.5
Weight	390 g
Mounting type	Snap-on mounting to DIN rail
Number of backplane elements	3
Min. connection cross-section/AWG	0.2 mm^2/24
Max. connection cross-section/AWG	2.5 mm^2/12

*) maximum 2 encoders/axis

3.2.1.3 JSC-110-2-RS

Type designation	Features
	The design of the module features the following: 2 axes 8 encoder interfaces 14 digital inputs 2 pulse outputs 2 relay outputs 2 pn-switching outputs 2 auxiliary outputs 1 diagnostics 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 2 status LEDs for outputs

Characteristics of the module:

- Expandable to:
  - max. 38 safe digital inputs,
  - max. 2 safe digital outputs,
  - max. 20 safe IOs,
  - max. 6 auxiliary outputs
  - Max. 1 safe axis
- Logic processing up to PL e according to EN ISO 13849-1 or SIL 3 according to IEC 61508
- Monitoring of axis motion up to PL e according to EN ISO 13849-1 or SIL 3 according to IEC 61508
- Velocity monitoring:
- Speed monitoring
- Standstill monitoring
- Direction of rotation monitoring
- Safe increment
- Emergency stop monitoring
- Position monitoring
- Position range monitoring
- Trend range monitoring
- Target position monitoring
- Programmable micro controller for up to 800 instruction list (IL) instructions
- Function chart-oriented programming
- Pulse outputs for cross-fault detection on digital input signals
- External contact monitoring of connected switching devices (EMU)
- Monitored relay outputs for safety-relevant functions
- Parameter management for expansion modules in the basic unit
- Complete speed- and position-related safety functions for drive monitoring according to IEC 61800-5-2 integrated in firmware
- Comprehensive diagnostic functions integrated

- Coded status display via 7-segment display and status LEDs on the front
- Multi-function pushbutton (Quit, Start, Reset) can be operated from the front panel
- Installation on DIN rail
- Advanced functionality:
    - Allows connection of 2 encoders per axis (SSI, Sin/Cos, TTL, proximity switch)
    - 2nd encoder interface supports resolver

Technical specifications JSC-110-2-RS

Safety specifications		
PL according to EN13849-1		PL e
PFH/architecture		12.6 FIT / Cat. 4
$MTTF_d$		44 years
SIL according to IEC 61508		SIL 3
Proof test interval		20 years = max. service life
General data		
Number of supported expansion modules		2
Interface for expansion modules		Backplane elements, pluggable into DIN rail
Number of digital inputs		14 (OSSD capable)
Number of safe digital outputs pn-switching		2
Number of safe digital IOs		-
Number of relay outputs		2
Number of auxiliary outputs		2
Number of pulse outputs		2
Connection type		Plug-in terminals with spring connection
Axis monitoring		2
Encoder interfaces *		
	D-Sub X31, X32	SSI, Sin/Cos, incremental TTL
	D-Sub X33, X34	Resolver
	Terminal X23	Incremental HTL (10 kHz)
	Terminals X27, X28, X29, X30	Incremental HTL (200 kHz)
Electrical data		
Supply voltage (tolerance)		DC 24 V; 2 A (-15 %, +20 %)
Fuse X11.1		Min. DC 30 V; max. 3.15 A
Max. power consumption (logic section)		2.4 W
Ratings - digital inputs		DC 24 V; 20 mA, type 1 according to EN 61131-2
Ratings - digital outputs		
	pn-switching	DC 24 V; 250 mA
	Auxiliary outputs	DC 24 V; 250 mA
	Pulse outputs	DC 24 V; 250 mA
Ratings - relay		
	N/O DC13 AC15	DC 24 V; 2 A AC 230 V; 2 A
Environmental data		
Temperature		0° … 50° (operation) -25° … +70° (storage, transport)
Protection class		IP 20
Climatic category		3k3 according to DIN 60 721-3
Min., max. relative humidity (no condensation)		5 % ... 85 %
EMC		EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of equipment		2000 m
Overvoltage category		III
Pollution degree		2

Mechanical specifications	
Dimensions HxDxW [mm]	100x115x112.5
Weight	520 g
Mounting type	Snap-on mounting to DIN rail
Number of backplane elements	5
Min. connection cross-section/AWG	0.2 mm^2/24
Max. connection cross-section/AWG	2.5 mm^2/12

*) maximum 2 encoders/axis

3.2.2 Expansion modules

3.2.2.1 JSX1-DIO22

Type designation	Features
	The design of the module features the following: 12 digital inputs 10 digital IOs 2 pulse outputs 2 auxiliary outputs 12 status LEDs for inputs 10 status LEDs for IOs

Characteristics of the module:

- Pulse outputs for cross-fault detection on digital input signals
- External contact monitoring of connected switching devices (EMU)
- Comprehensive diagnostic functions integrated
- Installation on DIN rail

Technical specifications JSX1-DIO22

Safety specifications	
PL according to EN13849-1	PL e
PFH/architecture	9.2 FIT / Cat. 4 [1)]
$MTTF_d$	213 years
SIL according to IEC 61508	SIL 3
Proof test interval	20 years = max. service life
General data	
Number of supported expansion modules	-
Interface for expansion modules	Backplane elements, pluggable into DIN rail
Number of digital inputs	12 (OSSD capable)
Number of safe digital outputs pn-switching	-
Number of safe digital IOs	10
Number of relay outputs	-
Number of auxiliary outputs	2
Number of pulse outputs	2
Connection type	Plug-in terminals with spring connection
Axis monitoring	-
Encoder interfaces (D-Sub/terminals)	-

Electrical data		
Supply voltage (tolerance)		DC 24 V; 2 A (-15 %, +20 %)
Fuse X11.1		Min. DC 30 V; max. 3.15 A
Max. power consumption (logic section)		2.4 W
Ratings - digital inputs		DC 24 V; 20 mA, type 1 according to EN 61131-2
Ratings - digital outputs		
	Digital I/Os	DC 24 V; 250 mA
	Auxiliary outputs	DC 24 V; 250 mA
	Pulse outputs	DC 24 V; 250 mA
Environmental data		
Temperature		0° … 50° (operation) -25° … +70° (storage, transport)
Protection class		IP 20
Climatic category		3k3 according to DIN 60 721-3
Min., max. relative humidity (no condensation)		5 % ... 85 %
EMC		EN 61000-6-2, EN 61000-6-4, EN 61000-6-7, EN 61800-3, EN 61326-3, EN 62061
Use of equipment		2000 m
Overvoltage category		III
Pollution degree		2
Mechanical specifications		
Dimensions HxDxW [mm]		100x115x45
Weight		300 g
Mounting type		Snap-on mounting to DIN rail
Number of backplane elements		2
Min. connection cross-section/AWG		0.2 mm^2/24
Max. connection cross-section/AWG		2.5 mm^2/12

[1)] Value applies only to expansion module. For an overall evaluation according to EN ISO 13849-1, a series connection with the respective basic module must be applied.

=> $PFH_{Logic} = PFH_{Basic\ module} + PFH_{Expansion\ module}$

3.2.3 Encoder specification

Incremental TTL	
Physical layer	RS-422 compatible
Measuring signal A/B	Track with 90 degrees phase difference
Maximum frequency of input clocks (X31, X32)	200 kHz
Connection type	D-Sub 9-pin
Sin/Cos	
Physical layer	RS-422 compatible
Measuring signal A/B	Track with 90 degrees phase difference
Maximum frequency of input clocks (X31, X32)	200 kHz
Connection type	D-Sub 9-pin
SSI absolute	
Data interface	Serial Synchron Interface (SSI) with variable data length of 12 ... 28 bit
Data Format	Binary, gray code
Physical layer	RS-422 compatible
Clock rate in SSI master mode	150 kHz
Max. clock rate in SSI listener mode (slave)	250 kHz
Min. clock pause time	150 µs
Max. clock pause time	1 ms
Connection type	D-Sub 9-pin
Resolver	
Measuring signal	Sin/Cos - track with 90° phase difference
Signal frequency	Max. 600 Hz (900 Hz low pass)
Input voltage	Max. 8 Vpp (at 16 kΩ)
Resolution	9 bit/pole
Supported number of pole pairs	1 … 8
Reference frequency (listener)	6 kHz ... 16 kHz
Reference frequency (master)	8 kHz
Reference amplitude	2.2 Vss - 4 Vss
Reference waveform	Sine, triangle
Gear ratio	2:1; 3:1; 4:1
Phase error	8° max.
Connection type	D-Sub 9-pin
Incremental HTL	
Signal level	24 V/0 V
Physical layer	PUSH/PULL
Max. counting pulse frequency	200 kHz
Type of connection (X27, X28, X29, X30)	Plug-in terminals with spring connection
Proxi	
Signal level	24 V/0 V
Max. counting pulse frequency	10 kHz
Pulse width	50 µs
Type of connection (X23)	Plug-in terminals with spring connection

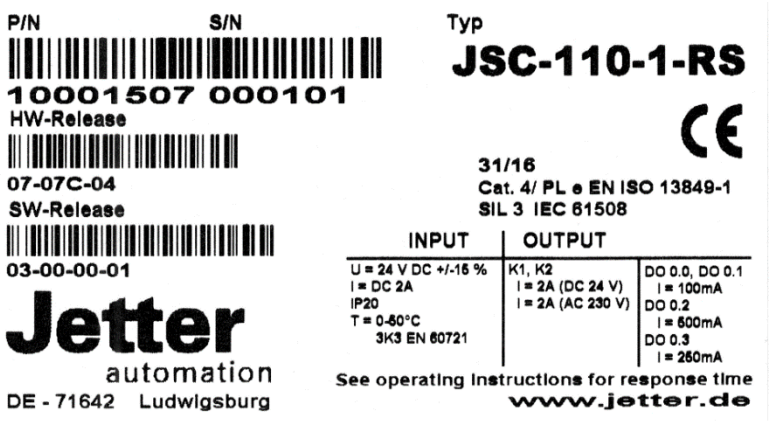
Proxi - Advanced monitoring	
Signal level	24 V/0 V
Max. counting pulse frequency	4 kHz
Physical layer	PUSH/PULL
Measuring signal A/B	Track with 90 degrees phase difference
Type of connection (X23)	Plug-in terminals with spring connection

3.3 Identification

3.3.1 Nameplate

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

- Type designation
- Item number
- Serial number
- Hardware release identification
- Software rRelease identification
- Safety category
- Characteristics of inputs
- Characteristics of outputs
- Date of manufacture (week/year)



Nameplate JSC-110-1-RS (enlarged picture)

3.3.2 Scope of delivery

The following items are included in the scope of delivery:

JSC-110 and JSX1 modules:

- Connector for all signal terminals without encoder connection

The following items are not included in the scope of delivery:

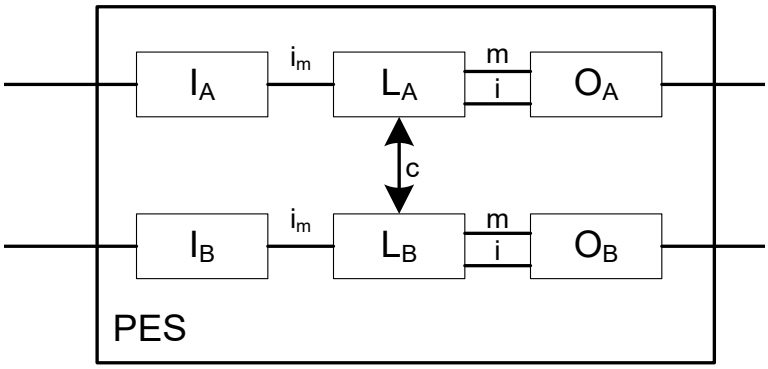
- JetSafe configuration software CD with
  - Installation Manual
  - Programming Manual
  - Driver for programming adapter
- Programming adapter JSC-PK
- License key (USB dongle) for JetSafe
- System CD with manuals
- Backplane bus connector JSC-BP (required when using JSX1-DIO22)

4 Safety features

4.1 General design, safety-related architecture and specifications

The internal structure of the JSC-110 series consists of two separate channels with reciprocal result comparison. In each of the two channels, high-quality diagnostics are carried out for error detection.

The architecture and functionality of the structure comply with category 4 of EN 13849-1.



The overall architecture thus corresponds to the following structure:

Dual reading of each input and diagnostics by cross comparison

The applicable safety specifications of the respective module can be found in the technical specifications in chapter 3.

> For the safety assessment of overall systems, the technical specifications as mentioned in chapter 3 can be used for the PES subsystem (e.g. PL e and PFH values according to table for compliance with EN ISO 13849-1).

Specifications:

Max. achievable safety class	• SIL 3 according to EN 61508 • Category 4 according to EN ISO 13849-1 • Performance level PL e according to EN ISO 13849-1	
System structure	Dual-channel with diagnostics (1002) according to IEC 61508 Architecture category 4 according to EN ISO 13849-1	
Design of the operating mode	"High demand rate" according to IEC 61508	
Probability of an endangering failure per hour (PFH value) Applicable values according to the tables on safety specifications	JSC-110	PFH = 12.6 FIT
	JSC-110-1-RS	PFH = 12.6 FIT
	JSC-110-2-RS	PFH = 12.6 FIT
	JSX1-DIO22	PFH = 9.2 FIT
Proof-test interval (IEC 61508)	20 years, after that the module must be replaced	

⚠ Safety precaution:

The applicable safety specifications of the respective module can be found in the technical specifications in chapter 3.

- When using several sensors with different functions (e.g. position indicator for access door + velocity detection) for a safety function (e.g. safely reduced speed when access door is open), these must be assumed as being connected in series for the safety assessment of the overall system. See also exemplary calculation in the appendix.
- The safety regulations and EMC guidelines must be observed.
- With regard to the applicable fault exclusions refer to the tables under D in the appendix of EN ISO 13849-2.
- For the safety assessment of overall system, the specifications given in chapter 3.2 can be used for the PES subsystem (e.g. PL e and PFH values according to table for compliance with EN ISO 13849-1)

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

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

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

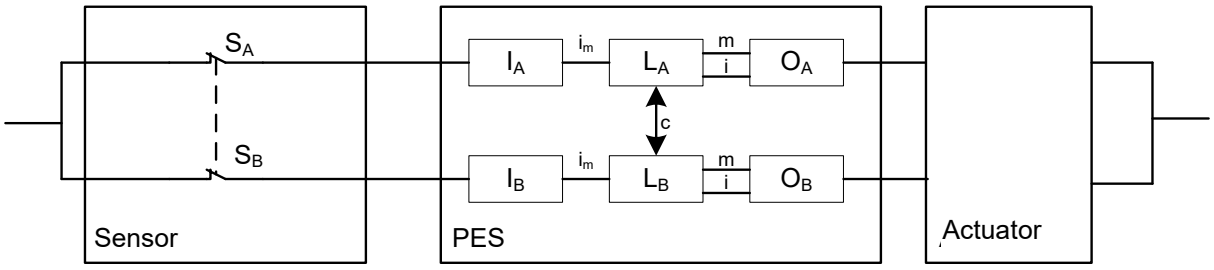
4.2 Safety specifications and circuitry for connected sensors

The JSC-110 modules have completely separate signal processing paths for each safety input. This applies to both the digital and the analog inputs. In addition, measures have been implemented to achieve the highest possible DC values.

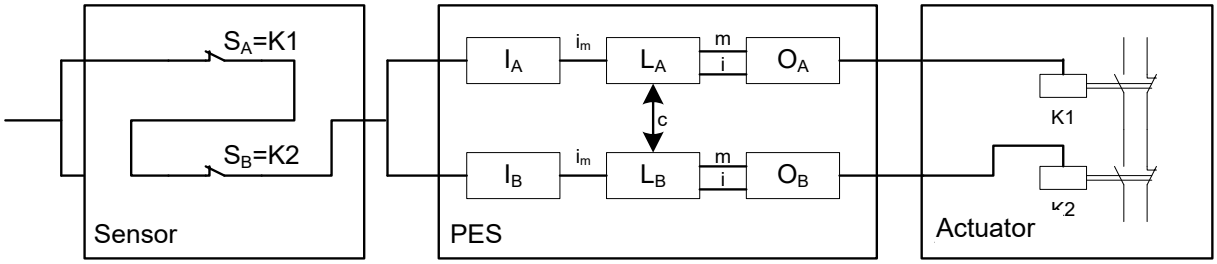
4.2.1 Digital sensors:

With the exception of the electromechanical input terminal, the digital inputs are completely redundant. Below are the details of the classification, the DC and the achievable PL or SIL.

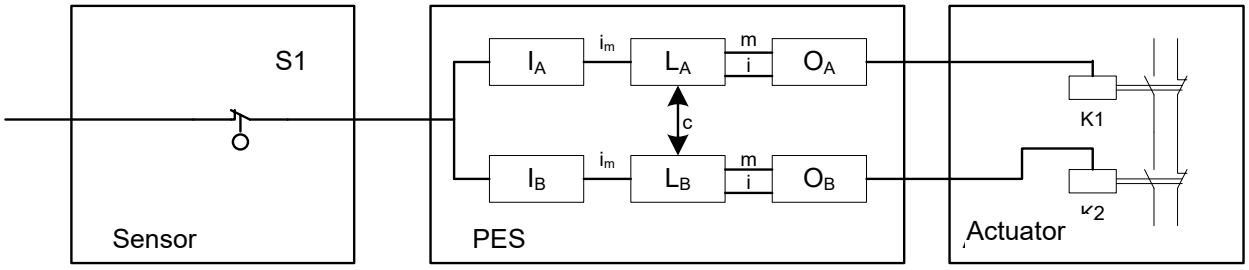
4.2.1.1 Characteristics of the sensors/input elements



Dual-channel input element in parallel connection (Cat. 4, fault tolerance 1) with high DC thanks to signal processing in two channels and diagnostics by cross-comparison in the PES.



Dual-channel input element in series connection (Cat. 4, fault tolerance 1) with low to medium DC thanks to signal processing in two channels and diagnostics by means of cyclic testing.



Single-channel input element and Dual-channel processing with low to medium DC through signal processing in two channels and diagnostics by means of cyclic testing, PL/SIL depending on permissible fault exclusions and test rate of the input element.

4.2.1.2 DC of digital sensors/inputs

The JSC-110 modules provide extensive diagnostic functions for the input subsystem. These are carried out continuously or optionally (cross-fault monitoring by means of pulse identification, cross comparison, 2-channel or multi-channel sensor with/without time monitoring, start-up test).

Constantly active diagnostic functions:

Cross comparison:

Basically, the inputs of the JSC-110 modules are designed as two internal channels. The status of the input signals is constantly compared crosswise. Only with a high signal in both input subsystems the input is set to high status; if the signal level between the two channels deviates, the input is set to low status.

Dynamic test of the switching thresholds of the input subsystem:

The switching thresholds for high level detection are tested cyclically at high rates. If the value falls below the defined threshold value, a module alarm is triggered.

Dynamic test of the switchability of the input subsystem:

The switchability of the input subsystem to low level is tested cyclically at a high rate for all inputs except DI5 ... DI8. If the value falls below the defined threshold value, a module alarm is triggered.

Diagnostic functions that can be activated by parameterization:

Check for shorts between contacts:

The JSC-110 modules have pulse signal outputs, which are imprinted with a unique signature. When using the cross-wire test, the switching elements of the digital sensors/input elements must be supplied with auxiliary voltage via the pulse signal outputs of the JSC-110 modules. The signature is thus imprinted on the high signal level of the sensors/input elements and checked by the JSC-110 modules. Short-circuits or shorts between contacts after a high signal can be detected by signature verification. In the case multiple contacts, parallel signal lines or adjacent terminal assignment, cross-connections between the corresponding input signals are detected by the alternating use of pulse signals.

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

Several contacts can be assigned to the sensors/input elements. Therefore, they correspond to at least 2-channel elements. A high level of the sensor/input element requires a logical series connection of both contacts.

Example 1:

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

Example 2:

Input element with 1 NC contact and 1 NO contact: High level if NC contact is actuated and NO is not actuated.

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

Same test as above, but with additional monitoring of the input signals for conformity with the defined level correlations within a time slot of 0.5 s. If the levels differ over a period > 0.5s, a module alarm is triggered.

Start-up test:

Each time the safety modules (=JSC-110 modules) are switched on, the input element must be tested with regard to low signal status (= defined safe status), e.g. by pressing the emergency stop button or by opening a door interlock after system start.

Operational/organizational tests:

In addition to the diagnostic measures of the JSC-110 modules mentioned above, cyclic tests can be performed in the application. These tests can also be used to assess the DC.

Thus, the JSC-110 modules provide extensive diagnostic functions for the input subsystem. These are carried out continuously or optionally (cross-fault monitoring by means of pulse identification).

For the safety assessment of the overall system, the following diagnostic measures can be used for the input sensors:

Specifications of input element	Parameterized/ operational tests				DC	Definition of measure	Comment
	Cross-fault detection	With time monitoring	Start-up test	Cyclic test during operation			
Single-channel			O	O	>60	Cyclic test pulse by dynamic change of the input signals	Sufficiently high test rate must be guaranteed
	X				90	Cyclic test pulse by dynamic change of the input signals	Only effective if pulse assignment active
	X		O	O	90-99	Cyclic test pulse by dynamic change of the input signals	DC depends on frequency of start-up/cyclic test DC = 90: Test only at intervals > 4 weeks DC = 99: Test at least 1 x day or 100-fold demand rate
Dual-channel					90	Cross comparison of input signals with dynamic test if short circuits cannot be detected (with multiple inputs/outputs)	With fault exclusion "short circuit" DC of up to 99 is possible
			O	O	90-99	Cyclic test pulse by dynamic change of the input signals	DC depends on frequency of start-up/cyclic test
	X				99	Cross comparison of input signals with immediate and intermediate results in logic (L) and temporal and logical program run monitoring and detection of static failures and short circuits (for multiple inputs/inputs)	Only effective if pulse assignment active
		X			99	Plausibility check, e.g. use of normally open and normally closed contacts = antivalent signal comparison of input elements	Only effective in conjunction with activated time monitoring function for input element

⚠Safety precaution:

- For a safety-related assessment of the sensor subsystem, the manufacturer's specifications (MTTFD, FIT figures, etc.) must be consulted.
- The DC values listed in the table must be conservative and the compliance with the boundary conditions (see table under "Notes") must be ensured.

- Fault exclusions are permitted according to the relevant standards. The boundary conditions mentioned there must be guaranteed on a permanent basis.
- If several sensor systems are required for the proper functioning of a single safety function, their partial values must be correctly combined according to the selected procedure.

4.2.1.3 Classification of the digital inputs

4.2.1.3.1 Digital inputs DI1 … DI14

Digital inputs	Achievable performance level	Comment
DI1 … DI4 DI9 … DI14	PL e	Suitable for all types of input elements, with/without pulses. Achievable PL depending on $MTTF_d$ of the input element, as well as fault exclusions in the external cabling
DI5 … DI8	PL e	Single-channel with pulse: • Predominantly high level required (T_{High} > 100 *T_{Low}) • At least one request/day caused by application • Error detection on request
	PL d	Single-channel without pulses: • Fault exclusion "Short circuit between the signals and after VCC" • Error detection on request
	PL e	Dual-channel: • At least one request/day caused by application • Error detection on request

4.2.1.3.2 Digital inputs IO01 … IO10

Digital inputs	Achievable performance level	Comment
IO01 … IO10		Without pulse, single-channel static signal -> Auxiliary input
	PL e	Without pulse, dual-channel static signal • At least one request/day caused by application • Fault detection only on request
	PL d	Without pulse, dual-channel static signal • Less than one request/day caused by application
	PL e	Single-channel with pulses • Predominantly high level required (T_{High} > 100 *T_{Low}) • At least one request/day caused by application • Fault detection only on request
	PL d	Single-channel with pulses • Less than one request/day
	PL e	Dual-channel with pulse 1 and pulse 2

4.2.1.4 Connection examples - Digital sensors

4.2.1.4.1 Single-channel sensor, without cross-fault detection

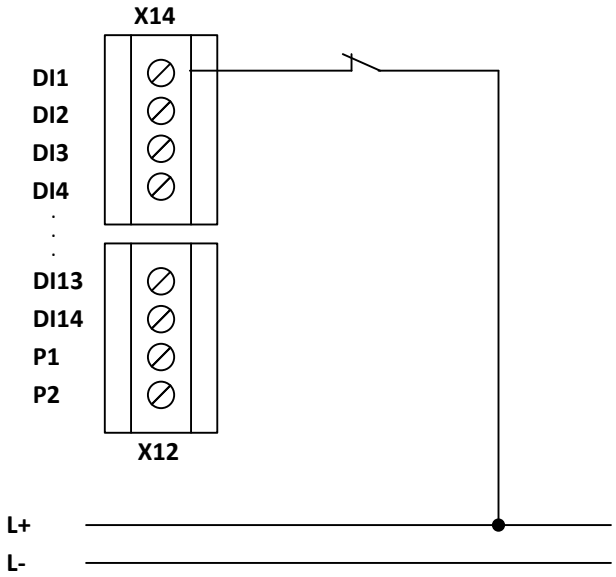


Fig.: Single-channel sensor, without cross-fault detection

The single-channel sensor is connected to the JSC-110 without pulses or without testing for short between contacts. This design is not recommended for safety applications. A maximum of PL b in accordance with EN ISO 13849-1 can be achieved.

4.2.1.4.2 Single-channel sensor with cross-fault detection

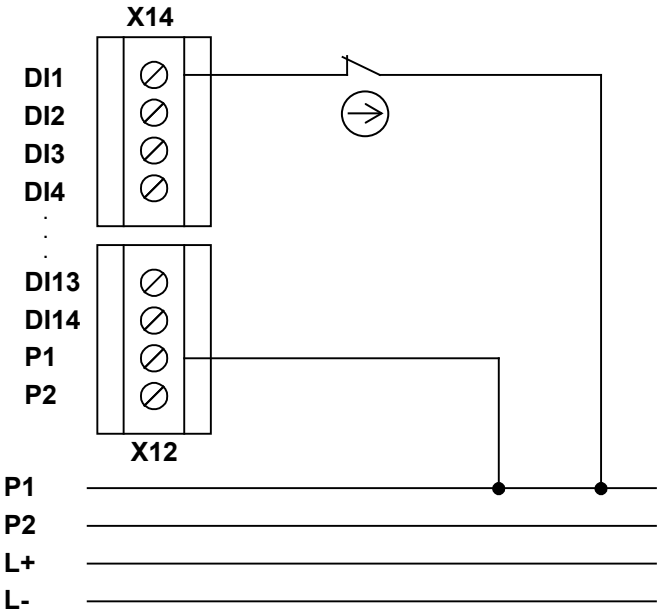


Fig.: Single-channel sensor with pulses

When using a single-channel sensor with pulses, a supply connection of the switching element is connected to the pulse output P1 or P2. Then, the pulses must be assigned on the JSC-110.

When using a single-channel sensor with pulses, the following faults are detected:

- Short circuit to supply voltage DC 24 V
- Short circuit to DC 0 V
- Broken cable (power interruption is safe condition!)

Caution is advised, however, in the event of a cable short-circuit between the two connections of the sensor, as this will not be detected! A short circuit between P1 and DI1 is also not detected.

Due to the 1-channel nature of the switching element/sensor, fault exclusion is required for its failure. This is permissible when using positive-disconnect switches with correct positive actuation.

Equivalent to this application is a series connection of 2 switching elements with corresponding fault exclusion of a double fault. These can be, for example, the safety outputs of an electronic monitoring device (light curtain, safety mat) with internal dual-channel shut-off.

If a suitable switching element is used and the sensor is carefully wired, PL d in accordance with EN ISO 13849-1 can be achieved. In special cases, i.e. in conjunction with suitable switching elements and permissible fault exclusions, PL e in accordance with EN ISO 13849-1 can also be achieved.

⚠Safety precaution:

- PL d or higher according 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. It should be noted that in the event of a fault, the switch must be positive-opening in accordance with EN 60947-5-1. In addition, the sensor must be triggered at regular intervals and the safety function requested. Fault exclusions can be achieved according to EN ISO 13849-2 Table D8. With single-channel use of the inputs, the achievable safety level is limited to SIL 2 or PL d if the safety function is not requested at regular intervals.
- A series connection of 2 switching elements with fault exclusion "Double Fault" requires a test for suitability according to the intended safety level for this element. We refer to the relevant regulations of the EC Machinery Directive 2006/42/EC.
- In the case of single-channel sensors, safety-related use of the inputs is only intended in conjunction with the pulse outputs.

4.2.1.4.3 Dual-channel sensor without time monitoring with cross-fault detection

Faults are detected at least on request. The DC is medium and can be changed to a high rating by using cyclic tests (start-up tests, operational/organizational tests) depending on the frequency of testing.

For safety applications, only NC contacts must be used for this purpose.

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

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

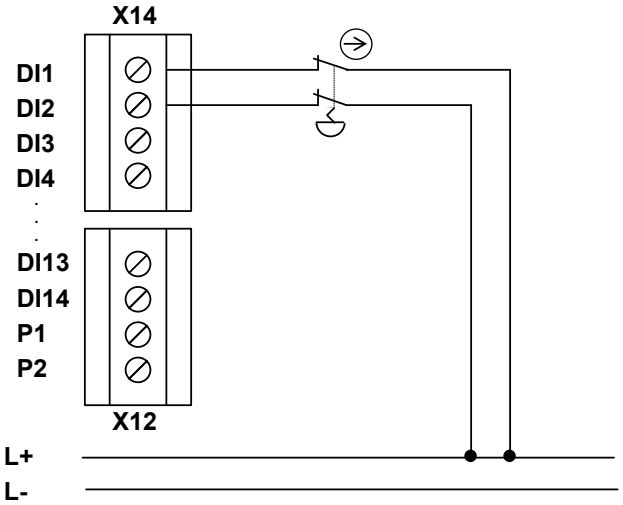


Fig.: Dual-channel sensor homogeneous without pulses, with positive opening

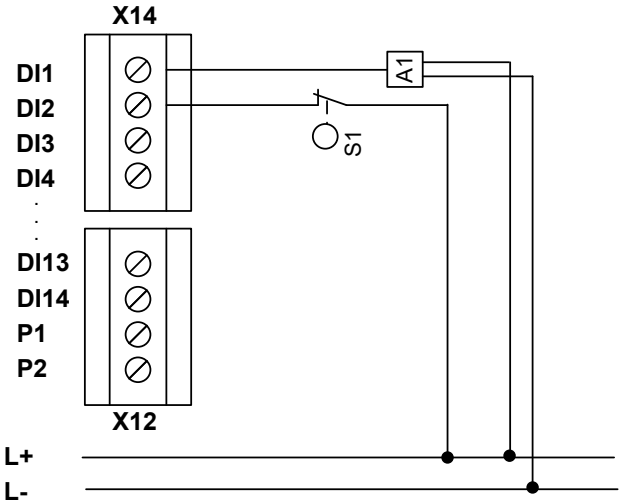


Fig.: Dual-channel input element, diverse without pulses

⚠Safety precaution:

- PL d or higher according to EN ISO 13849-1 is achieved when using switching elements/sensors with positive opening contacts or positive actuation according to EN 60947-5-1.
- It is permissible to use devices for whose switching elements the fault exclusion "Double Fault" can be made for the intended safety level. We refer to the relevant regulations of the EC Machinery Directive 2006/42/EC.

4.2.1.4.4 Dual-channel sensor with time monitoring and cross-fault detection

By using two independent clock signals on the homogeneous sensor, all shorts between contacts as well as connections to DC 24 V and DC 0 V can be detected.

For safety applications, only NC contacts must be used for this purpose.

PL d or higher according to EN ISO 13849-1 can be achieved if:
- sensors/switching elements with positive actuation are used;
- 2 sensors/switching elements with independent actuation are used.
- Ditto, but with actuation via a common actuating device in conjunction with fault exclusion for this device.

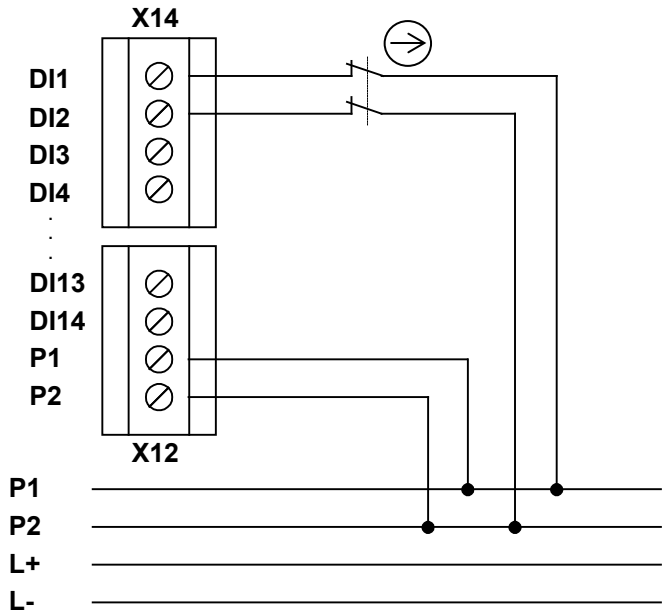


Fig.: Dual-channel sensor, homogeneous with pulses

⚠Safety precaution:
- PL d or higher according to EN ISO 13849-1 is achieved when using switching elements/sensors with positive actuation.
- When using two independent sensors with independent actuation, PL d or higher can be achieved according to EN ISO 13849-1.
- If elements are shared in the actuation chain, fault exclusion is required for this purpose. In doing so, the corresponding restrictions and criteria according to EN 13849-1 must be observed.

4.2.1.5 Overview of achievable PLs for digital safety inputs

Type of sensor/ input element	Input	Parameterized/operational tests				Achievable PL according to EN ISO 13849-1	Fault exclusion for input element	Condition for input element
		Cross-fault detection	With time monitoring	Start-up test	Cyclic test during operation			
Single-channel	DI1..D14					b		Operationally proven input element
				O	O	d	All faults on the input element Short circuit on input/signal line	$MTTF_D$ = high Connection in the control cabinet or protected installation
	DI1..D4 DI9..DI14					e	All faults on the input element Short circuit on input/signal line	Input element corresponds to at least PLr Connection in the control cabinet or protected installation
	All	X				d	Sticking contacts Short circuit on input/signal line	Predominantly high level required (T_{High} > 100 *T_{Low}) positive opening, $MTTF_D$ = high Connection in the control cabinet or protected installation
		X		O	O	e	All faults on the input element Short circuit on input/signal line	Input element corresponds to at least PLr Connection in the control cabinet or protected installation $MTTF_D$ = high
Dual-channel, parallel	All					d	Short circuit between input/signal line	Connection in the control cabinet or protected installation $MTTF_D$ = medium
		X				e		$MTTF_D$ = high
Dual-channel, parallel	All		X			e	Short circuit between input/signal line (only with same switching elements = 2xNO or 2xNC)	Connection in the control cabinet or protected installation MTTFD = high

Type of sensor/ input element	Input	Parameterized/operational tests				Achievable PL according to EN ISO 13849-1	Fault exclusion for input element	Condition for input element
		Cross-fault detection	With time monitoring	Start-up test	Cyclic test during operation			
Dual-channel, serial	DI1..D4 DI9..DI14					d	Short circuit on input/signal line Sticking contacts/positive opening	Connection in the control cabinet or protected installation $MTTF_D$ = medium
				O	O	e	Short circuit on input/signal line	Connection in the control cabinet or protected installation $MTTF_D$ = high
	All			O	O	d	Short circuit on input/signal line	Connection in the control cabinet or protected installation $MTTF_D$ = medium
		X		O	O	e		$MTTF_D$ = high

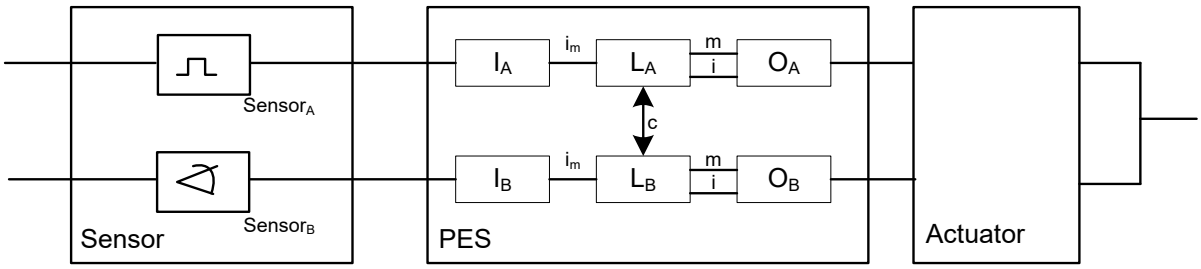
X: Diagnostic measure activated
O: at least 1 diagnostic measure activated

4.2.2 Sensors for speed and/or position detection

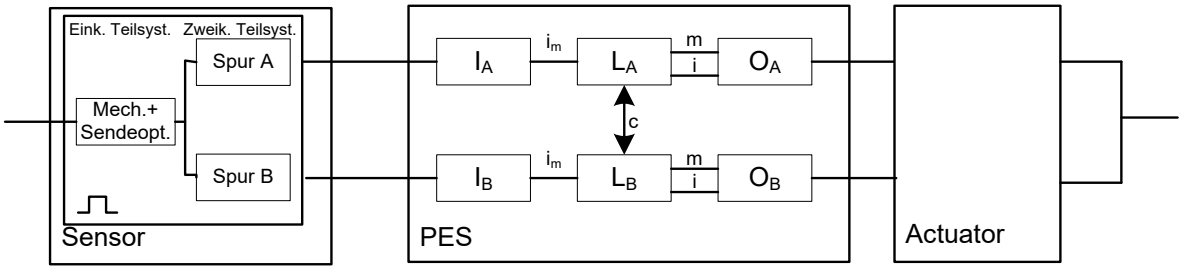
4.2.2.1 General safety-related design of interface for position and/or speed sensors

The basic modules of the JSC-110 series optionally have one encoder interface and one resolver interface per axis (JSC-110-1-RS or JSC-110-2-RS).

Depending on the encoder type and combination, different safety levels can be achieved. The following system consideration results for the corresponding subsystem:



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



Sensor system with single and dual channel subsystem (example: incremental encoder). Diagnostics by separate two channel signal processing and cross-comparison in the PES, as well as other specific diagnostics.

4.2.2.2 General diagnostic measures for encoder interface

A number of diagnostic measures are implemented in the JSC-110 series to detect errors in the sensor system depending on the selected encoder type or their combination. They are activated automatically when the encoder type is selected.

In principle, the diagnostic measures can be classified in terms of their nature and effectiveness according to the following table:

Diagnostic measures for position and/or speed sensors:

Measure	DC	Comment	Purpose
Cross comparison of input signals with immediate and intermediate results in logic (L) and time and logical program run monitoring and detection of static failures and short circuits (with multiple inputs/inputs)	99	Only applicable to: • Dual channel sensor systems (2 separate sensors) • The dual-channel subsystem of single-channel sensors (incremental encoders) • Diagnostics for the single- and dual-channel subsystem of specially suited sensor systems (SIN/COS encoders, resolvers) • Dynamic operation/no standstill monitoring	Monitoring of 2-channel subsystems 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 state, i.e. standstill or movement and on the quality of the monitoring measure (80 ... 90% for incremental encoders, 95% for Sin/Cos encoders)	Monitoring of 2-channel subsystems of sensors for non-dynamic operation. To be used especially for standstill monitoring!
Monitoring of some characteristics of the sensor (response time, the range of analog signals, e.g. electrical resistance, capacitance)	60	Diagnostics of specific characteristics of sensors. Only applicable for velocity and position sensors according to chapter 4.2.2.3	Monitoring of the single-channel subsystem of single-channel sensor systems

4.2.2.3 Encoder types and their combinations - Diagnostic specifications

Encoder A	Encoder B	Safe speed	Safe direction	Safe abs. pos.	Fault exclusion	DC		
						1-channel subsystem	2-channel subsystem, dynamic	2-channel subsystem, non-dynamic (standstill monitoring)
1 x proxi	1 x proxi	X			Actuator ***)	n.a.	99 %	80 ... 90 %
Incremental	n.c.	X			Mechanical encoder connection *) Code disc mounting **)	60 %	99 %	80 ... 90 %
Incremental	1 x proxi	X				n.a.	99 %	90 ... 95 %
Incremental	2 x counter proxi 90°	X	X			n.a.	99 %	90 ... 95 %
Incremental	HTL	X	X			n.a.	99 %	90 ... 95 %
Incremental	Resolver	X	X			n.a.	99 %	99 %
Sin/Cos	n.c.	X			Mechanical encoder connection *) Code disc mounting **)	60 %/ 90 %*) **)	99 %	90 ... 95 %
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 %
SSI	2 x counter proxi 90°	X	X	X		n.a.	99 %	90 ... 95 %
SSI	Resolver	X	X	X		n.a.	99 %	95 ... 99 %
n.c.	Resolver	X	X		Mechanical encoder connection *) Code disc mounting **)	60 %/ 90 %*) **)	99 %	90 ... 95 %

*) For the mechanical connection, a fault exclusion can be made with the note "… for the shaft-hub connection of the encoder axis only positive connections are permitted, alternatively other types of connection can be used if they meet the safety requirements.
For their reliability with regard to the targeted safety level, comprehensible proof must be provided in each case (e.g. overdimensioning in the case of positive shaft-hub connection). The corresponding information on the exclusion of faults in standard EN/IEC 61800-5-2, Appendix D.3.16 (table D.8) must be observed."

With Sin/Cos encoders suitable for safety applications (see notes on this under ...), a DC of 90 % can be applied for the single-channel transmit LED.

**) The connection between code disc and shaft, as well as the sensor embodiment must be analyzed in detail. For a possible fault exclusion, the relevant information in the standard EN/IEC 61800-5-2, Annex D.3.16 (table D.8) must be observed.

***) For speed detection by means of proxi, the actuator and the mounting of the proxi must be analyzed with regard to their reliability.
For a possible fault exclusion, the relevant information in the standard EN/IEC 61800-5-2, Annex D.3.16 (table D.8) must be applied mutatis mutandis.

Other single-channel parts to which the requirement of 60% apply:

- Power supply
- Code disk mounting
- Mechanics of the optical receivers (not Sin/Cos)
- Code disk

4.2.2.4 Specific diagnostic measures related to the type of encoder used

Encoder type	Supply voltage monitoring	Differential level monitoring	Sin/Cos plausibility monitoring	Monitoring of input signal level	Monitoring of the permitted quadrants	Monitoring of the count signal separately for track A/B	Monitoring of the transmission ratio reference signal/measuring signal	Monitoring of the reference signal frequency	Monitoring of the reference signal voltage	Analysis of the measuring signal form factor	Plausibility test of position signal versus speed	Clock frequency monitoring
Incremental	X	X				X						
Sin/Cos	X		X									
SSI	X	X										
Proxi 2 x counting input	X											
Proxi 1 x counting input	X											
HTL		X		X								
Resolver			X		X		X	X	X	X		

4.2.2.5 Safety-related shut-off thresholds in encoder systems for position and speed detection

As a basic measure, plausibility tests are performed between the two measurement channels A and B for speed and position on the JSC-110 modules. The current position and speed values are tested against parameterizable thresholds.

The ***Incremental shut-off threshold*** describes the tolerable deviation of position between the two measuring channels A and B in the unit of the measured distance.

The ***Speed shut-off threshold*** describes the tolerable deviation in speed between the two measuring channels A and B.

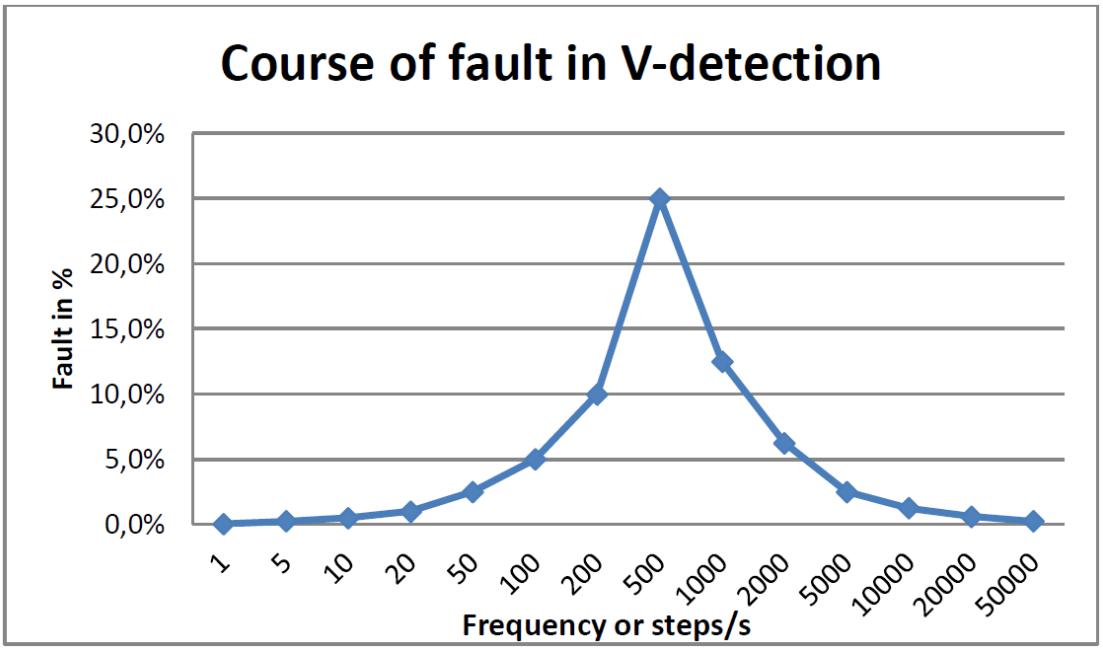
Diagnostic functions are available within the SCOPE dialog of the parameterization tool for determining the optimum parameter values for the application.

Note:

Speed and acceleration are recorded values with a minimum digital resolution.
This condition limits the smallest possible acquisition of the speed or acceleration and determines the digital increment for the input values.

Speed resolution:

The speed is recorded up to a frequency of 500 Hz or 500 steps/s using the frequency measurement method, and below that using a time measurement method.
This results in the following characteristic of the acquisition error:



Acceleration resolution:

The digital resolution of the acceleration is limited by the maximum gate time of 256 ms and the resolution of the encoders. The graphs below show the lowest measurable acceleration as a function of resolution in RPM, mm/s² and m/s².

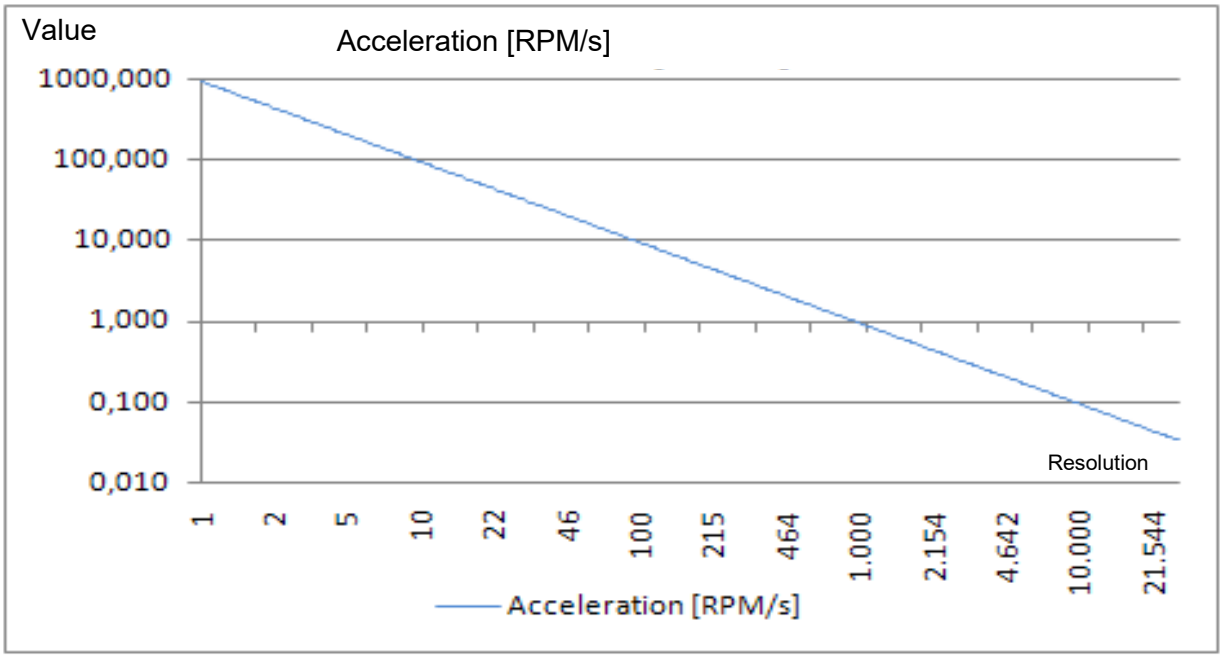


Diagram of acceleration resolution, rotary (values in RPM/s)

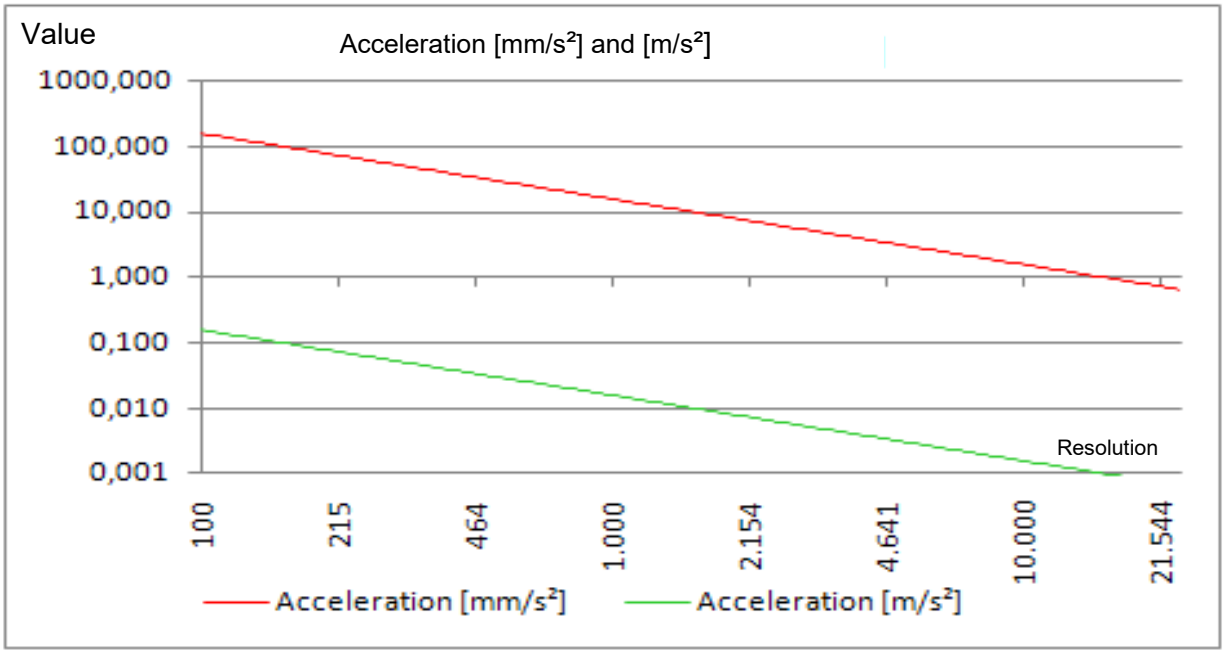


Diagram of acceleration resolution, linear (values in mm/s and m/s²)

⚠ **Safety precaution:**

- The error can be optimized for the respective application by selecting the appropriate sensor resolution.

- For applications with limited resolution and/or time variance of the sampling signal, the functionality of the monitoring functions used can be improved by using an mean value filter. The mean value filter "smoothes" the digital interference components of the sensors.

However, this is achieved at the expense of an increased response time of the overall system.

- The filter time can be set variably between 0 and 64 in increments of 8. The dimension is "msec". To determine the response time of the overall system, the filter times must be added to the specified response times of the JSC-110 system (see chapter 7 Response times of the JSC-110).

⚠ **Safety precaution:**

- For a safety-related assessment of the sensor subsystem, the manufacturer's specifications ($MTTF_D$, FIT figures, etc.) must be consulted.
- If specific diagnostics are required by the manufacturer to ensure the specified safety-related characteristic values, these must be checked in accordance with the above table "Specific diagnostic measures for position and speed sensors" with respect to the specific encoder. In case of doubt, contact the manufacturer.
- The DC values listed in the table must be conservative and the compliance with the boundary conditions (see table under "Notes") must be ensured.
- To determine the DC value for safety functions with standstill monitoring, it may be necessary to estimate how often the dynamic state exists. A DC of 90% can be assumed as a guide value here.
- Fault exclusions are permitted according to the relevant standards. The boundary conditions mentioned there must be guaranteed on a permanent basis.
- If several sensor systems are required for the proper functioning of a single safety function, their partial values must be correctly combined according to the selected procedure. This also applies to a combination of digital and analog sensors (e.g. safely reduced speed when safety door is open = door contact + encoder for speed detection).
- By appropriate selection of the resolution of the sensor system, a sufficiently low tolerance with regard to the respective shut-off thresholds for the individual safety functions must be ensured.
- When using the encoder input filter, the increase in response time must be taken into account when assessing the safety function.

4.2.2.6 Evaluation of the encoder types, resolvers or their combination in terms of safety

Thanks to the monitoring functions implemented in the JSC-110 series, applications with encoder systems do not initially place any special requirements on the internal structure of the encoder electronics, i.e. standard encoders can therefore be used.

In general, a safety evaluation of the overall arrangement must be made. To this end, refer to the manufacturer's specifications for the encoder (FIT, MTTF) and the DC from the tables in chapter "DC digital sensors/inputs".

If individual sensors are used, at least an fault exclusion must be made for the mechanical actuating chain and the single-channel part, taking into account the relevant requirements of EN ISO 13849-1. The information under 4.2.2 must be observed further.

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

The use of a compact encoder with an internal dual-channel structure of different technology is also suitable for applications up to PL e according to EN ISO 13849-1, however, taking into account the specifically required fault exclusions and if they are admitted. As a rule, use for this purpose sensors with proven safety-related properties whose safety level is at least the required level.

⚠Safety precaution:

- The use of standard encoders or a combination of standard encoders is permitted. For the overall arrangement consisting of encoder, further sensors/switching elements for triggering the safety function, the JSC-110 module and the shut-off channel, a safety-related evaluation is required. The information provided by the manufacturer (FIT, MTTF) and the DC in accordance with the specifications in chapter 4.2.2 must be used to determine the level of safety achieved.
- When using only one encoder, the fault exclusion shaft breakage/error in the mechanical encoder or resolver connection must be made. Suitable measures must be taken for this purpose, e.g. a positive-locking connection of the encoder by means of a feather key or locking pin. The relevant instructions of the manufacturer, as well as EN ISO 13849-1 regarding the requirement and admissibility of the fault exclusion must be observed.
- Preferably, only sensors with proven safety-related properties should be used as individual encoders. The safety level of these encoders must be at least equal to the target safety level of the overall arrangement. The manufacturer's instructions regarding diagnostic measures, mechanical connection and measures for the voltage supply must be observed.
- Sin/Cos encoder: The internal structure of the sensor system must be designed in such a way that the output signals of both tracks are generated independently of each other and common cause errors can be ruled out. Furthermore, the mechanical structure must be verified, e.g. fastening of the code disc to the shaft. Preferably, encoders with proven safety-related properties should be used.
- When using compact encoders with an internal dual-channel design, e.g. SSI + incremental/SinCos, the manufacturer's instructions regarding safety-related properties, diagnostics measures, mechanical connection and measures for the voltage supply must be observed. The safety level of these encoders must be at least equal to the target safety level of the overall arrangement. Preferably, encoders with proven safety-related properties should be used.

The JSC-110 modules generally detect the following errors of the external encoder system:

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

Each encoder type is assigned additional, specific diagnostics for detecting faults in the external encoder system.
The respective diagnostic measures are listed below for the individual encoder types together with the limit parameters.

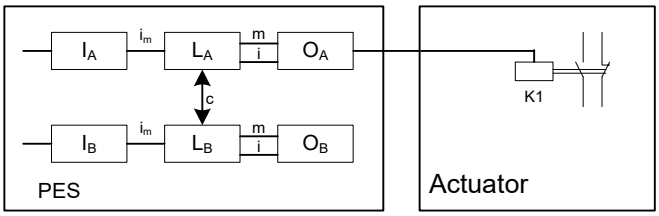
⚠**Safety precaution:**

- The diagnostic measures naturally have tolerances due to measurement inaccuracies. These tolerances must be taken into account in each case during the safety assessment.
- The limit values for the respective diagnostic measures can partly be parameterized by the user or are fixed. The resulting diagnostic coverage levels must be evaluated in relation to the application and included in the overall safety assessment.

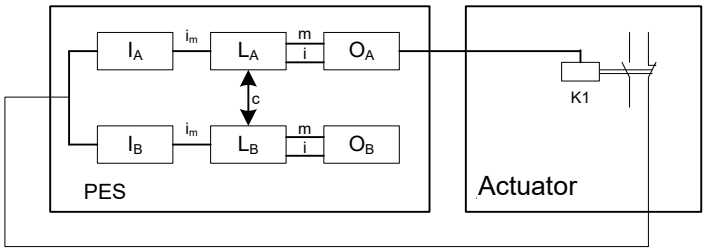
4.3 Safety specifications and wiring of the outputs

The JSC-110 modules each have safe outputs of different types. The respective characteristic according to the following description must be taken into account for the wiring.

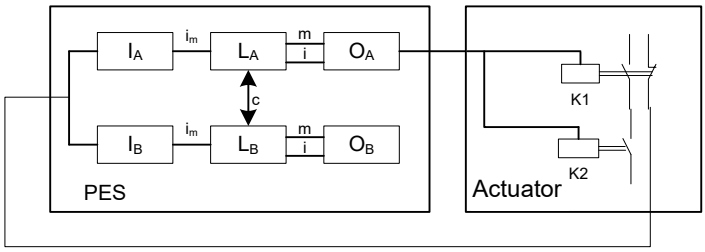
4.3.1 Characteristics of the output elements



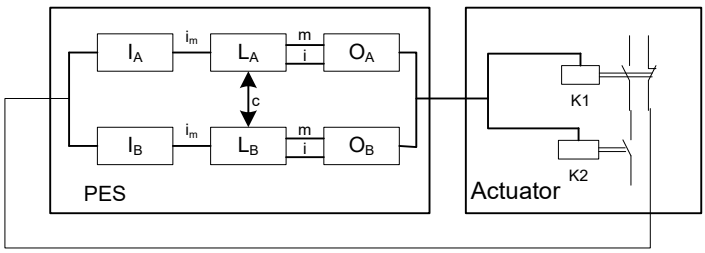
Single-channel output JSC-110 and single-channel actuator without diagnostics



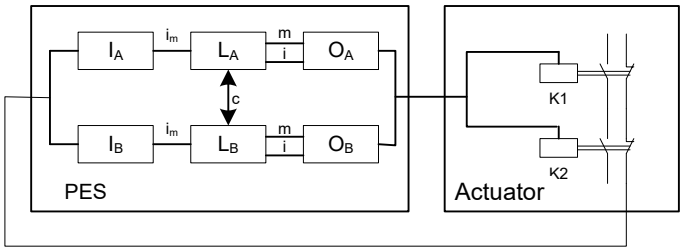
Single-channel output JSC-110 and single-channel actuator with diagnostics



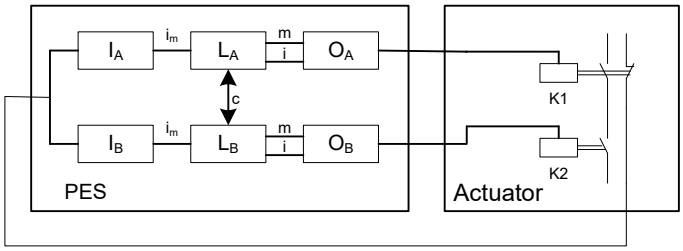
Single-channel output JSC-110 (rel 1/2, DO0/1_H, DO0/1_L) and dual-channel actuator with at least single-channel diagnostics



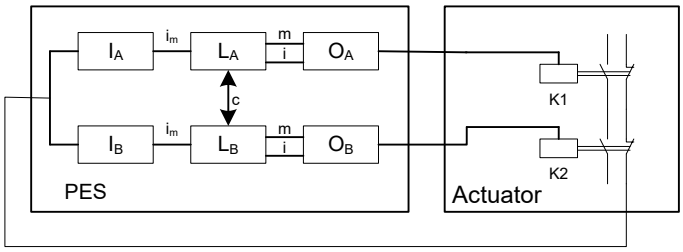
Single-channel output JSC-110 with internal dual-channel processing (IO01 ... IO10) and dual-channel actuator with at least single-channel diagnostics



Single-channel output JSC-110 with internal dual-channel processing (IO01 ... IO10) and dual-channel actuator with dual-channel diagnostics



Dual-channel output JSC-110 and dual-channel actuator with single-channel diagnostics



Dual-channel output JSC-110 and dual-channel actuator with dual-channel diagnostics

4.3.2 Diagnostics in the shut-off circuit

The shut-off circuits have permanently implemented and parameterizable diagnostic functions. Certain diagnostic functions also include the external part of the shut-off channel. Depending on the use of these diagnostic functions, different DC values result.

4.3.2.1 Diagnostic Features

<u>Permanently implemented diagnostic functions</u>

Cross read back of the outputs:

All safety outputs are read back in the complementary channel. Errors in the internal shut-off circuit of the JSC module are thus detected with DC = High.

Testing the shut-off capability for Rel 1 and Rel 2 (relay control only), DO0_P, DO0_M, DO1_P, DO1_M:

The shut-off capability of these outputs is tested cyclically. A failure of the shut-off capability is clearly detected.

Parameterizable diagnostic functions

Readback of actuator status via auxiliary contacts, position indicators, etc.:

The current status of the actuator is detected by reading back from correspondingly suitable auxiliary contacts or position indicators and compared with the setpoint status. A deviation is thus clearly detected.

Note:

The DC depends on a single-channel or dual-channel diagnostics as well as on the switching frequency.

Testing the shut-off capability for IO01 ... IO10 of the JSX1-DIO22:

The shut-off capability of these outputs is tested cyclically after activation of the function. A failure of the shut-off capability is clearly detected.

4.3.2.2 Overview of DC in relation to selected diagnostic functions

Measure	DC	Comment	Purpose
Monitoring of the outputs by one channel without dynamic test	0 ... 90 %	DC depending on the switching frequency When using elements for switching amplification (external relays or contactors) only effective in connection with read-back function of the switching contacts	Monitoring of electromechanical, pneumatic or hydraulic actuators/outputs
Redundant shut-off path with monitoring of one of the drive elements	90 %	When using elements for switching amplification (external relays or contactors) only effective in connection with read-back function of the switching contacts	Monitoring of outputs with direct function as safety circuit or Monitoring of safety circuits with elements for switching amplification or pneumatic/hydraulic control valves in connection with read-back function of their switching status
Cross-comparison of output signals with immediate and intermediate results in logic (L) and temporal and logical program run monitoring and detection of static failures and short circuits (for multiple inputs/inputs)	99 %	When using elements for switching amplification (external relays or contactors) only effective in connection with read-back function of the switching contacts For applications with frequent safety shut-off requirements, testing should be carried out once a week at short intervals, e.g. at the start of a shift. However, a test should be carried out at least cyclically once per year.	Monitoring of outputs with direct function as safety circuit or Monitoring of safety circuits with elements for switching amplification or pneumatic/hydraulic control valves in connection with read-back function of their switching status

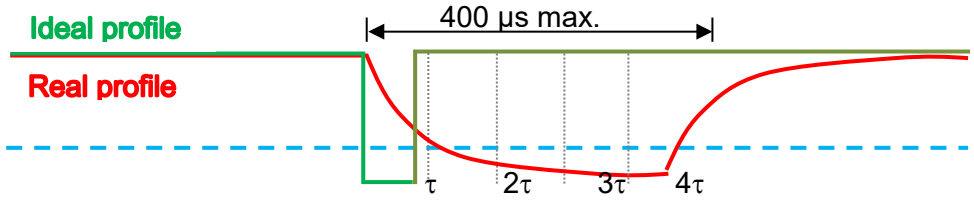
4.3.3 Permissible capacitive and inductive load at safe outputs

The safe outputs of the JSC-110 have OSSD character. This means that the outputs are switched off cyclically to test their shut-off capability and the status is read back.

The test of the shut-off capability is carried out according to the following criteria/functions:

- After switching off the output, the output voltage must not exceed 5.6 V.
- The permissible voltage level must be reached after 400 µs at the latest.
- If the permissible voltage level is reached, the test is considered successful. The output is reactivated 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 for safe outputs!) are deactivated.

The following diagram shows the ideal (green curve) and typical (red curve) profile.



To determine the maximum permissible capacitance or inductance, the time constant τ of the real RC or RL element at the output must be considered.

This RC or RL element determines the real discharge curve:

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

It thus applies:

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

With that connection

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

the max. usable capacitive or inductive load can be determined in connection with its ohmic load:

$$C_{max} = \frac{\tau}{\mathrm{R}} = \frac{10^{-4}}{\mathrm{R}} \quad \text{resp.} \quad L_{max} = \tau\mathrm{R} = 10^{-4}R$$

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

4.3.4 Digital outputs

The JSC-110, JSC-110-1-RS, JSC-110-2-RS JSX1-DIO22 modules have identical outputs.

4.3.4.1 Specifications of the basic outputs

The JSC-110 provides various types of outputs which can be interconnected either individually or in groups.

Output	**Architecture according to EN ISO 13849-1**	**Comment**
Combination of 2 relays K1 and K2	4	Complete shut-off channel conforming to architecture category 4 according to EN ISO 13849-1
K1 K2	Not safe	Functional only
DO0_P and DO0_M	4	Complete shut-off channel conforming to architecture category 4 according to EN ISO 13849-1
DO0_P	Not safe	Functional only
DO0_M	Not safe	Functional only
DO1_P and DO1_M	4	Complete shut-off channel conforming to architecture category 4 according to EN ISO 13849-1
DO1_P	Not safe	Functional only
DO1_M	Not safe	Functional only
DOo.1	Not safe	Signaling/auxiliary output
DOo.2	Not safe	Signaling/auxiliary output

The pn-switching outputs are subjected to a plausibility check in all operating states. When switched on, all outputs are tested for correct function with a cyclic test pulse. For this purpose, the output is switched to the respective inverse value for a maximum test duration TT <300µs, i.e. a pp output is briefly switched to 0 VDC potential and a pn output is briefly switched to 24 VDC potential.
The relay outputs are monitored for plausibility at each switching cycle. To maintain the safety function, the relay outputs must be switched cyclically and thus tested. The switching/test cycle must be defined depending on the application.

⚠**Safety precaution:**

- For applications with frequent safety shut-off requirements, testing should be carried out once a week at short intervals, e.g. at the start of a shift. However, a test should be carried out at least cyclically once per year.
- The test function of the outputs is executed for group and individual control. The auxiliary outputs are not tested.
- **The high-side (DO0_P, DO1_P) and low-side outputs (DO0_M, DO1_M) must not be used individually for safety tasks. The use for safety tasks is only permitted in combination of High-Side/Low-Side**.

- Mixed operation of the relay contacts is not permitted!
  Mixed operation: A dangerous touch voltage potential must not be mixed with a protective extra-low voltage.
  Example:
  WRONG: AC 230 V is switched via K1.1 + K1.2 and DC 24 V is switched via K2.1 + K2.2.
  CORRECT: AC 230 V are switched via K1.1 + K1.2 and K2.1 + K2.2 respectively. Or DC 24 V are switched via K1.1 + K1.2 and K2.1 + K2.2 respectively.

The outputs can be loaded as follows:

Output	Voltage	Current
Relay Kx	DC 24 V	2.0 A (DC13)
Relay Kx	AC 230 V	2.0 A (AC15)
DOo.x	DC 24 V	250 mA
DOxH	DC 24 V	250 mA
DOxL	GNDEXT	250 mA
IOx	DC 24 V	250 mA

⚠**Safety precaution:**

- For safety-related applications, only external switching elements with a minimum holding current of > 1.2 mA may be used.
- A number of diagnostic measures are implemented for the initial system. Special attention must be paid here to the inclusion of elements for switching amplification such as relays, contactors etc. in the shut-off circuit.

Note:

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

4.3.4.2 Wiring examples - Basic outputs

4.3.4.2.1 Single-pole switching relay or semiconductor output without testing

External contactors can be used to connect multiphase applications or for increased current requirements. In case of a single-pole connection without external testing, please note that a sticking of one or more external contacts will not be detected by the JSC-110 module. The following switching example is only suitable to a limited extent for safety applications, a maximum of PL b in accordance with EN 13849-1 can be achieved!

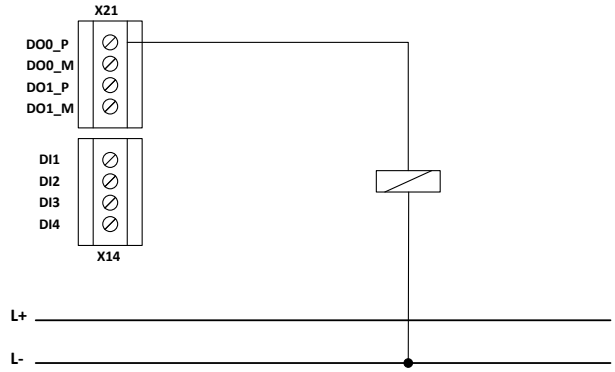


Fig.: Single-pole switching P output.

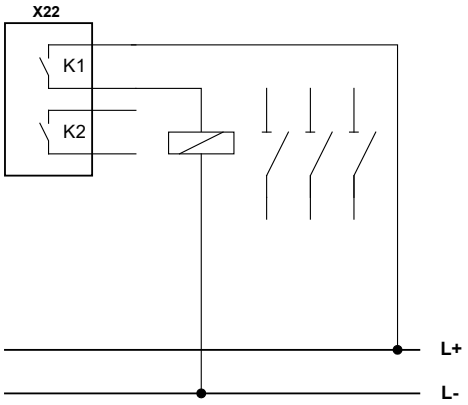


Fig.: Single-pole switching relay output.

⚠Safety precaution:

- Not recommended for safety applications! See also notes in EN ISO 13849-1 on the application and required fault exclusions.

4.3.4.2.2 Single-pole switching relay or semiconductor output with external switching amplifier and testing

If external switching amplifiers or downstream electromechanical, pneumatic or hydraulic components are used, a device for testing the complete chain and a signaling/warning device in the event of a detected fault are required to achieve PL c or higher.
In particular, positively driven auxiliary contacts are required for electromechanical devices or signal contacts of the valve position for hydraulic or pneumatic components.
The signaling/warning device must immediately inform the operator of the hazardous situation.
The achievable PL is strongly dependent on the test rate, a maximum of PL d according to EN ISO 13849-1 can be achieved!

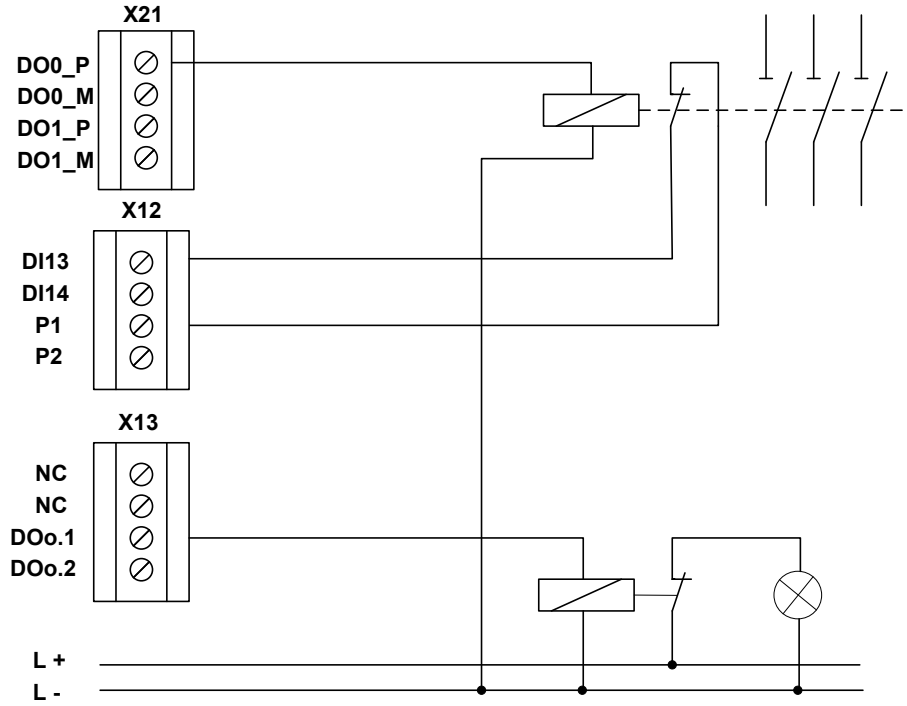


Fig.: Single-pole switching relay output with testing

⚠Safety precaution:

- Only conditionally recommended for safety applications! See also notes in EN ISO 13849-1 on the application and required fault exclusions.
- For PL c or higher, a test rate > 100 * requirement rate is required.
- For PL c and higher, a signaling/warning device is required which immediately informs the operator of the hazardous situation.

4.3.4.2.3 Single-pole switching relay or solid state output with dual channel external circuit with testing

For safety applications from PL c in accordance with EN ISO 13849-1, it is recommended or required to control two external shut-off elements. Furthermore, to achieve PL c or higher, a device for testing the complete chain and a signaling/warning device in the event of a detected fault is required - see comments under 4.3.4.1.2.

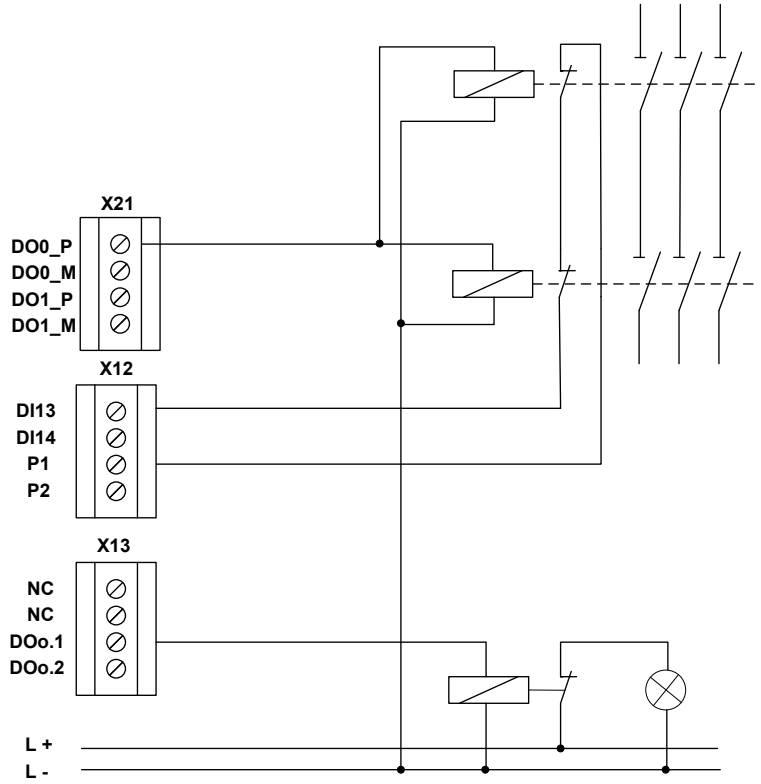


Fig.: Single-channel switching output DO0_P with dual-channel external circuit and monitoring at input 13 as collective feedback signal

The two external monitoring contacts are connected in series, fed by the pulse signal P1 and read in via input 13. Input 13 has been used as the readback input, but any other input can be used.

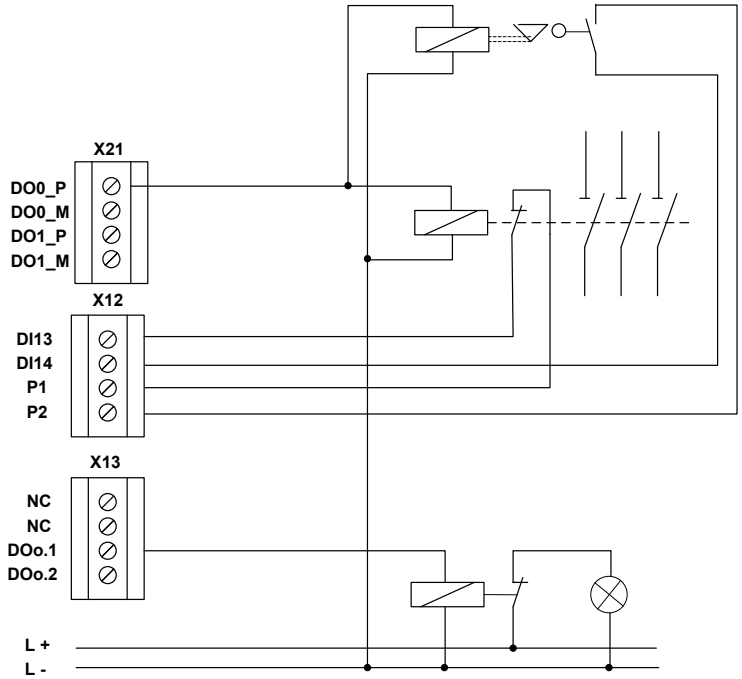


Fig.: Single-channel switching output DO0_P with dual-channel external circuit as a combination of electromechanical element and hydraulic/pneumatic valve and monitoring on two inputs

⚠Safety precaution:

- Only conditionally recommended for safety applications! See also notes in EN ISO 13849-1 on the application and required fault exclusions.
- For PL c and higher, a signaling/warning device is required which immediately informs the operator of the hazardous situation.
- In the case of increased requirements, it should be noted that at least 1 switching operation must take place every 24 hours in order to test the switching capability of the external power contactor.

4.3.4.2.4 Dual-channel switching relay output with external monitoring - Collective feedback signal

For safety applications from PL d according to EN ISO 13849-1, two relays on the JSC-110 module and two external power contactors are used.

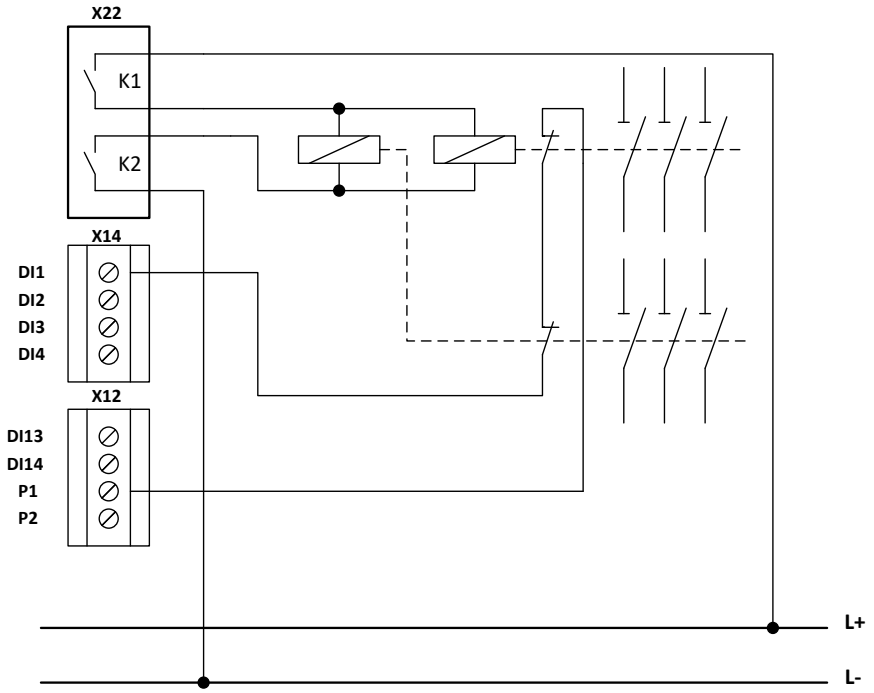


Fig.: Dual-channel switching relay output with external monitoring - Collective feedback signal

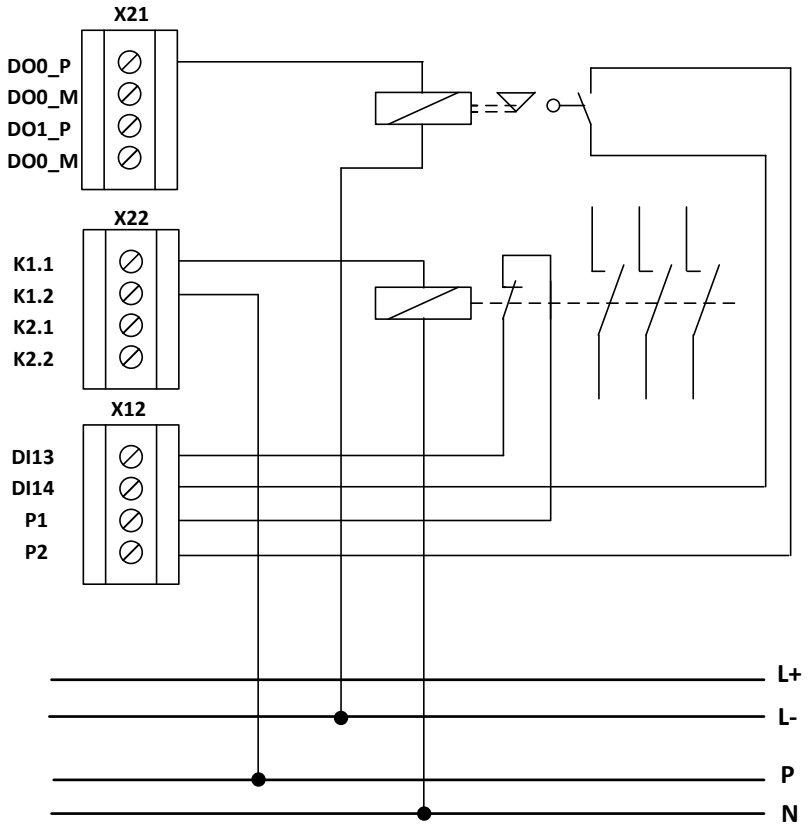
The two external monitoring contacts are connected in series, fed by pulse signal P1 and read in by DI1 (configured as EMU input). In the case of increased requirements, it must be ensured that at least 1 switching operation takes place every 24 hours.

⚠Safety precaution:

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

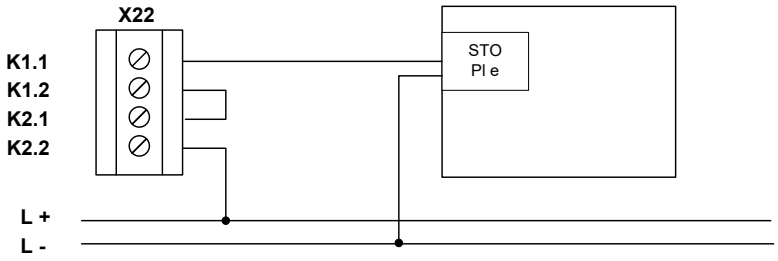
4.3.4.2.5 Dual-channel output with relay output and semiconductor output - External control circuit with monitoring

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



4.3.4.2.6 Dual-channel output with relay output and external control circuit in PL e

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



4.3.4.2.7 Dual-channel output with semiconductor output and external control circuit in PL e

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

4.3.4.2.8 Wiring of an auxiliary output

Both semiconductor outputs implemented on the JSC-110 can be wired for functional applications. The outputs are not pulsed.

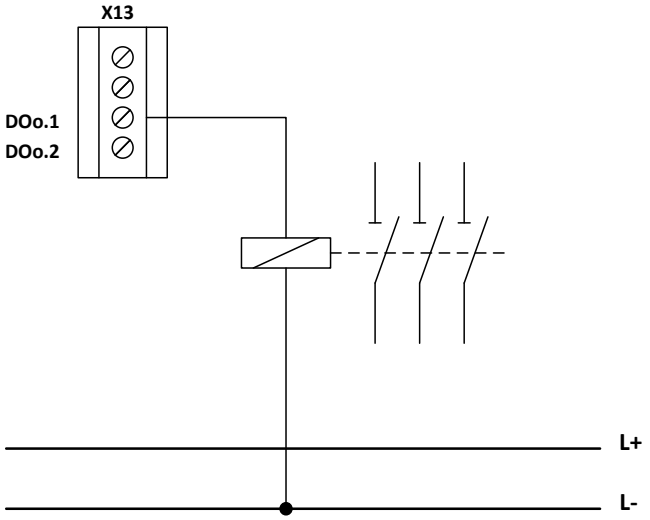


Fig.: Wiring of an auxiliary output

Applications with auxiliary outputs are not permitted for safety applications!

4.3.5 Digital outputs I/Os

The JSX1-DIO22 expansion module has configurable safe digital I/Os (see chapter 3.1 Module overview). Parameterized as an output, this connection acts as a safe digital pp-switching output (IO01 ... IO10).

4.3.5.1 Classification of the I/Os when used as output

Architecture	Achievable PL according to EN ISO 13849-1	Comment
Static single-channel[2)]	PL c	Fault detection or fault response according to Cat. 2
Static dual-channel[2)]	PL e	Different group[1)]
Static dual-channel[2)]	PL d	Same group[1)]: • Control with time delay on PLC level • Fault approach: Short circuit at both outputs Different group[1)]: • No further requirement necessary
Dynamic single-channel[2)]	PL e	No further requirement necessary
Dynamic dual-channel[2)]		

Note:

1) Group 1: IO01 … IO06
   Group 2: IO07 … IO10

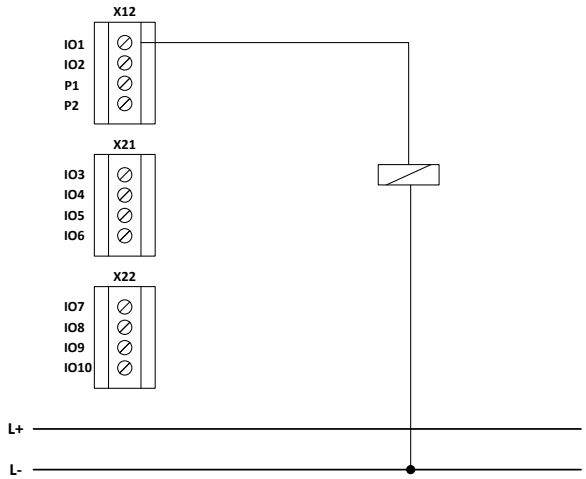
2) Static: No pulse test at the output
   Dynamic: Pulse test at output with $t_{Test} \leq 500$ µs

4.3.5.2 Wiring examples for safe digital outputs I/Os

4.3.5.2.1 Single-channel wiring without testing

When using a dual-channel output (IO01 ... IO10) in conjunction with a single-channel external circuit without external testing, please note that sticking of one or more external contacts will not be detected by the JSC-110 module.

The following switching example is only suitable for safety applications to a limited extent; a maximum of PL b in accordance with EN ISO 13849-1 can be achieved!



⚠Safety precaution:

- Not recommended for safety applications! See also notes in EN ISO 13849-1 on the application and required fault exclusions.

4.3.5.2.2 Single-channel wiring with testing

Here, a dual-channel output (IO01 ... IO10) in conjunction with a single-channel external circuit with testing is used. In particular, positively driven auxiliary contacts are required for electromechanical devices or signal contacts of the valve position for hydraulic or pneumatic components. In addition, a signaling/warning device is required to indicate the failure if necessary. The signaling/warning device must immediately inform the operator of the hazardous situation.
The achievable PL is strongly dependent on the test rate, a maximum of PL d according to EN ISO 13849-1 can be achieved!

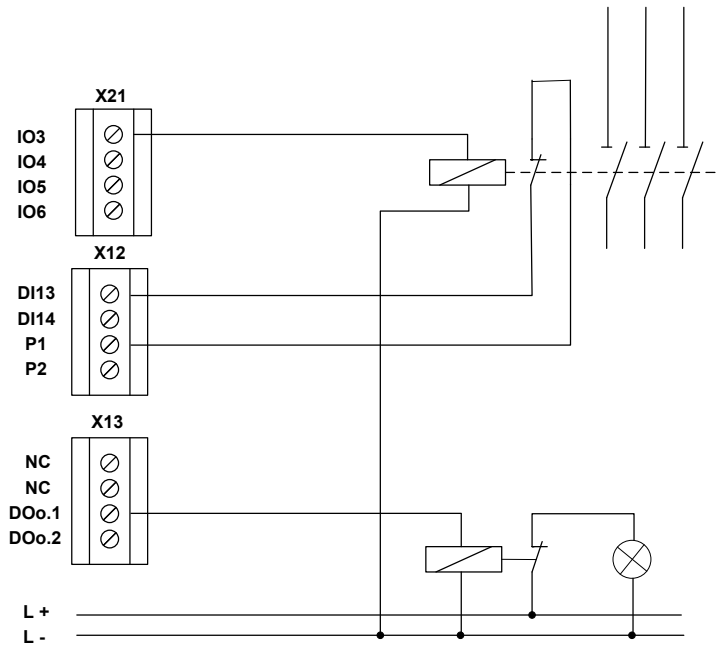


Fig.: Single-pole switching relay output with testing

⚠Safety precaution:

- Only conditionally recommended for safety applications! See also notes in EN ISO 13849-1 on the application and required fault exclusions.
- For PL c or higher, a test rate > 100 * requirement rate is required.
- For PL c and higher, a signaling/warning device is required which immediately informs the operator of the hazardous situation.

4.3.5.2.3 Circuitry with safe shutdown circuit

For safety applications from PL c and higher according to EN ISO 13849-1. The external circuit is controlled directly via a dual-channel output. The achievable PL according to EN ISO 13849-1 depends on the use of dynamic testing (see 4.3.2.1 Diagnostic Features) and the PL of the downstream device.

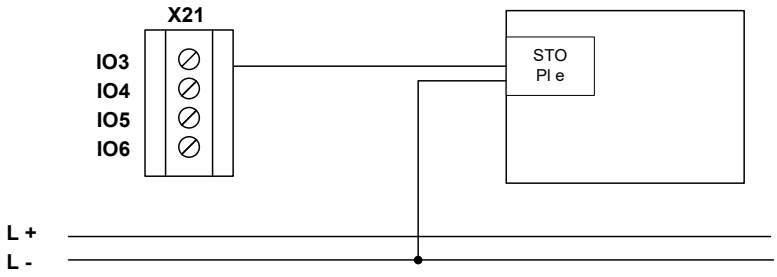


Fig.: Dual-channel output in connection with device with tested shut-off function

4.3.5.2.4 Single-channel output in conjunction with dual-channel shut-off circuit

Suitable for PL d or higher according to EN ISO 13849-1. Here, an output IO01 ... IO10 in conjunction with a dual-channel external circuit with testing is used. In particular, positively driven auxiliary contacts are required for electromechanical devices or signal contacts of the valve position for hydraulic or pneumatic components.
The achievable PL depends on the use of dynamic testing as well as the $MTTF_D$ value of the external circuit. A maximum of PL e in accordance with EN ISO 13849-1 can be achieved!

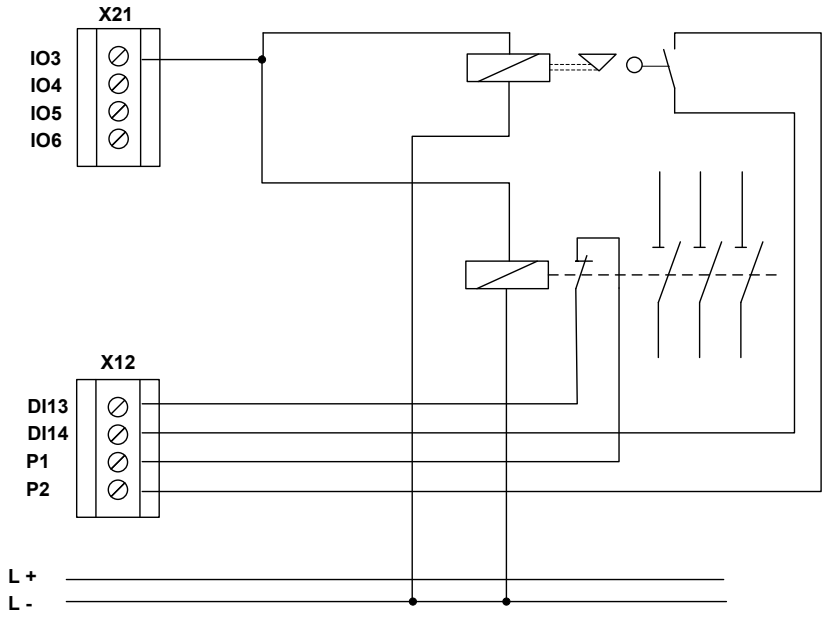


Fig.: Dual-channel output in conjunction with dual-channel shut-off circuit with testing

4.3.5.2.5 Redundant dual-channel output

Suitable for PL d or higher according to EN ISO 13849-1. Here, two outputs IO01 ... IO10 in conjunction with a dual-channel external circuit are used.

4.3.5.2.5.1 Dual-channel wiring in the same group

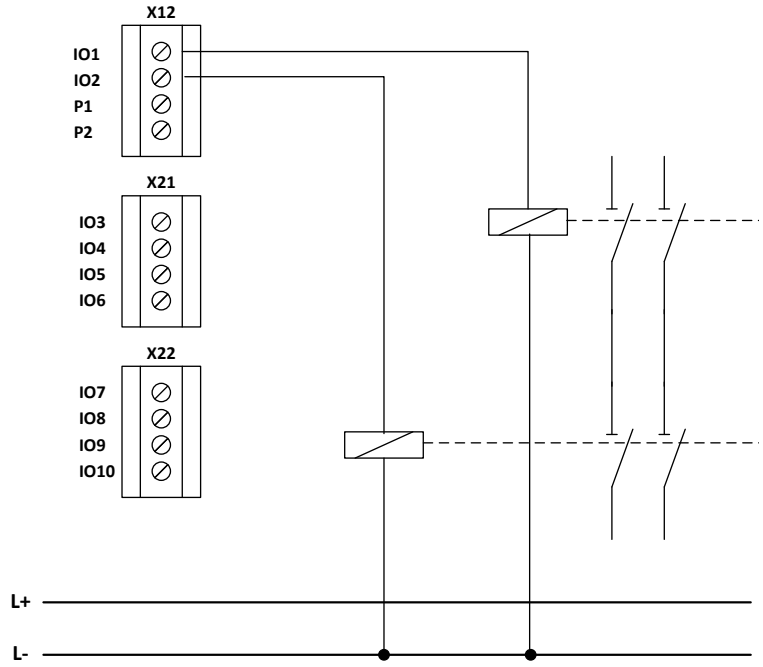


Fig.: Redundant dual-channel outputs in the same group in connection with dual-channel shutdown circuit

4.3.5.2.5.2 Dual-channel wiring in different groups

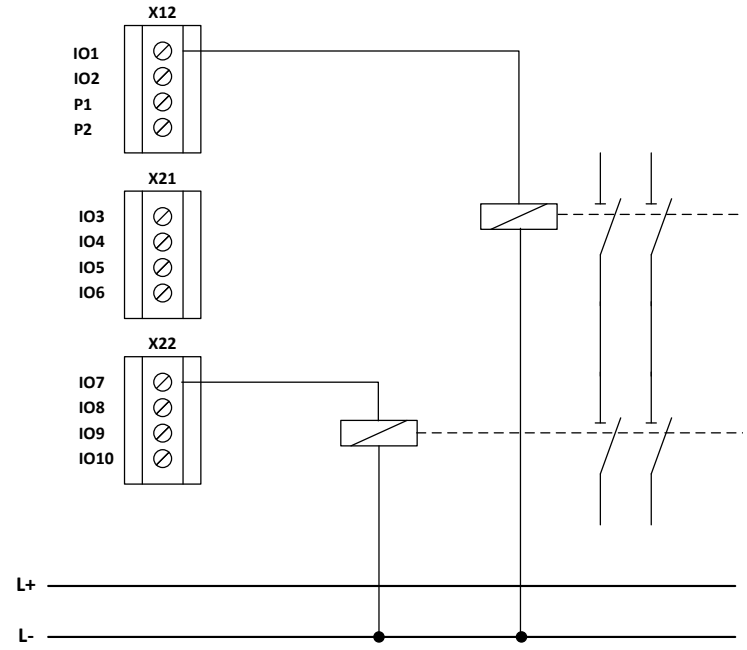


Fig.: Redundant dual-channel outputs in different groups in connection with dual-channel shutdown circuit

⚠ Safety precaution:

- For a safety-related assessment of the output subsystem, the manufacturer's specifications ($MTTF_D$, FIT numbers, B10d value, etc.) must be used when using external elements in the shut-off circuit, e.g. for switching amplification.
- The DC values listed in the table must be conservative and the compliance with the boundary conditions (see table under "Notes") must be ensured.
- Fault exclusions are permitted according to the relevant standards. The boundary conditions mentioned there must be guaranteed on a permanent basis.
- When using elements for switching amplification in safety circuits, their function must be monitored by means of suitable read-back contacts etc. (see switching examples). Suitable read-back contacts are contacts which are positively connected to the contacts in the shut-off circuit.
- The switching capability of the external switching amplifiers must be checked cyclically. The period between 2 tests shall be determined by the application as required and shall be ensured by suitable measures. Suitable measures can be of an organizational (switching off and on at the start of a shift, etc.) or technical (automatic, cyclical switching) nature.

4.3.5.3 Overview of achievable PLs for digital safety outputs

Output JSC-110	Actuator/ external shutdown circuit	Category according to EN ISO 13849-1	DC		$MTTF_D$ actuator	Achievable PL according to EN 13849-1	Boundary condition	Fault exclusion
Single-channel without dynamic output test K1, K2 DO0_P, DO0_M, DO1_P, DO1_M IO01..IO10	Single-channel Contactor, valve, brake, etc. without direct feedback for diagnostics	Cat. B	0 %		Medium	b	Contactor and downstream actuators suitably designed for safety application	
	Single-channel Contactor, valve, brake, etc. with monitored positively driven auxiliary contact	Cat. 2	60 ... 90 %	Depending on switching frequency	Medium	b	Signal output required for warning in case of detected malfunction Contactor and downstream actuators suitably designed for safety application	
					High	c	As above	
						d	As above DC = 90% due to sufficiently high test rate in relation to the application	
Single-channel without dynamic output test K1 or K2 or Single-channel DO0_P, DO0_M, DO1_P, DO1_M	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics in at least one channel or Actuator with single-channel control with safety function cat. 3 (e.g. STO)	Cat. 2	90 %	Monitoring only in an external shutdown circuit	Medium	c	Signal output required for warning in case of detected malfunction Contactor and downstream actuators suitably designed for safety application	Short-circuit in external control
					High	d		
Single-channel without dynamic output test IO01..IO10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics in at least one channel or Actuator with single-channel control with safety function cat. 3 (e.g. STO)	Cat. 3	90 %	Monitoring only in an external shutdown circuit	Medium or high	d	Contactor and downstream actuators suitably designed for safety application	Short-circuit in external control
Single-channel with dynamic output test IO01..IO10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics in both channels or Actuator with safety function cat. 4 (e.g. STO)	Cat. 4	99 %	Monitoring in both external shutdown circuits	High	e	Contactor and downstream actuators suitably designed for safety application Monitoring of electro-mechanical components by positively driven switches, position monitoring of switching valves etc.	

Output JSC-110	Actuator/ external shutdown circuit	Category according to EN ISO 13849-1	DC		$MTTF_D$ actuator	Achievable PL according to EN 13849-1	Boundary condition	Fault exclusion
Dual-channel without dynamic output test K1 and K2 2 x IO01 … IO10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics in at least one channel or Actuator with safety function cat. 4 (e.g. STO)	Cat. 3	90 %	Monitoring in both external shutdown circuits	Medium or high	d	Contactor and downstream actuators suitably designed for safety application Monitoring of electro-mechanical components by positively driven switches, position monitoring of switching valves etc. Outputs IO01 ... 10 each 1 x from different groups (groups of 6/4 consecutive IO ports each, e.g. IO01 ... 06, IO07 ... 10) or Control with time delay on PLC level	Short-circuit in external control
Dual-channel K1 and K2 or Dual-channel with dynamic output test DO0_P and DO0_M, DO1_P and DO0_M 2 x IO1 ... IO10	Dual-channel Contactor, valve, brake, etc. with direct feedback for diagnostics in both channels or Actuator with safety function cat. 4 (e.g. STO)	Cat. 4	99 %	Monitoring in both external shutdown circuits	High	e	Contactor and downstream actuators suitably designed for safety application Monitoring of electro-mechanical components by positively driven switches, position monitoring of switching valves etc. For applications with frequent safety shut-off requirements, testing should be carried out once a week at short intervals, e.g. at the start of a shift. However, a test should be carried out at least cyclically once per year.	Short-circuit in external control on both channels

5 Connection and Installation

5.1 General Installation Instructions

Strictly observe the safety advices during installation!

Degree of protection: IP20
Route all signal lines for connecting the digital inputs and contact monitoring separately.
In any case, route all AC 230 V separately from low voltage lines if these voltages are used in your application.

The cable lengths for the digital inputs and outputs must not exceed **30 m** as a rule.

If the cable lengths exceed a value of **30 m** , suitable measures must be taken to exclude faults caused by impermissible overvoltage. Suitable measures are, for example, lightning protection for outdoor lines, overvoltage protection of the system indoors, protected cable routing.

Measures for Electromagnetic Compatibility (EMC)
The JSC-110 is intended for use in the drive environment and meets the above EMC requirements.
Furthermore, it is assumed that the electromagnetic compatibility of the overall system is ensured by relevant known measures.

⚠ **Safety precaution:**

- Ensure that the power supply lines of the JSC-110 and "switching lines" of the power converter are routed separately.
- Signal lines and power lines of the power converters must be routed in separate cable ducts. The distance between the cable ducts should be at least 10 mm.
- Only shielded cables must be used to connect the position and speed sensors. The cable for transmitting the signals must be suitable for RS-485 standard (twisted pair cables).
- The shield in the 9-pin SUB-D connectors of the position and speed sensors must be connected correctly. Only metallic or metalized connectors must be used.
- The shielding at the sensor end must be designed according to relevant known methods.
- Ensure EMC-compliant installation of the power converters in the vicinity of the JSC-110 module. Special attention should be paid to the cable routing and the processing of the shielding for the motor cable and the connection of the braking resistor. It is imperative that the installation guidelines of the power converter manufacturer are observed here.
- All contactors in the vicinity of inverters must be equipped with appropriate suppressor circuitry.
- Suitable measures must be taken to protect against overvoltages.

5.2 Mechanical and electrical installation of the JSC-110

The module is installed exclusively in control cabinets that meet at least the IP54 degree of protection.

The modules must be mounted vertically on a DIN rail.

A clearance of 30 mm must be maintained at the top and bottom of the ventilation slots. Butt mounting of several expansion modules is allowed. A distance of 20 mm must be maintained between adjacent devices that can generate waste heat.

Note:
When used in non-enclosed rooms, it must be ensured that the environmental conditions of the individual assemblies (see technical data) are complied with.

5.3 Mounting the Backplane Bus

It is possible to mount several JSC-110 modules on a DIN rail in by means of the backplane bus.

The backplane bus consists of a 5-pole connector with spring contacts. All 5 contacts of the connectors are assigned as standard.

Note:
Expansion modules do not have their own power supply and depend on a DC supply via the backplane bus. JSC-110 basic modules have a high-performance power supply unit and always feed into the backplane bus.

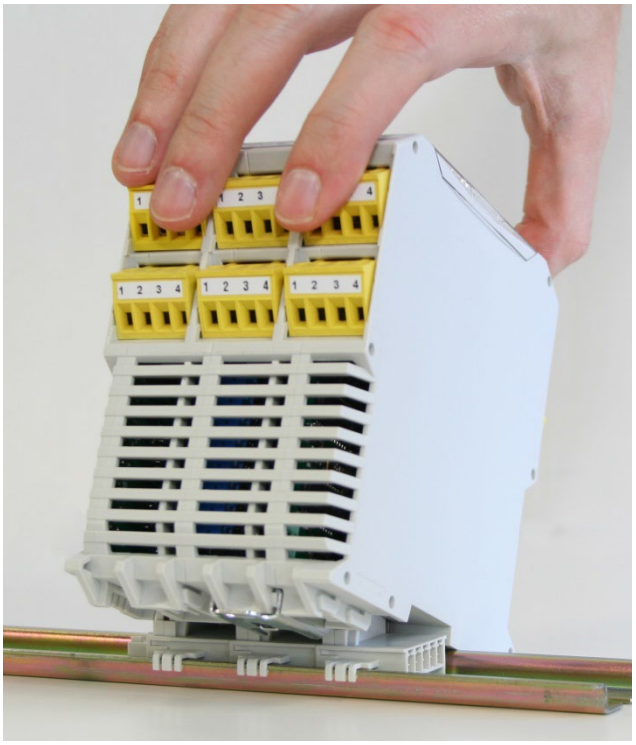
The backplane connector can only be installed in conjunction with expansion modules without their own power supply. A connection of several basic modules is not possible.

5.4 Mounting the modules

The modules are just snapped into place on standard C-rails (DIN rail).

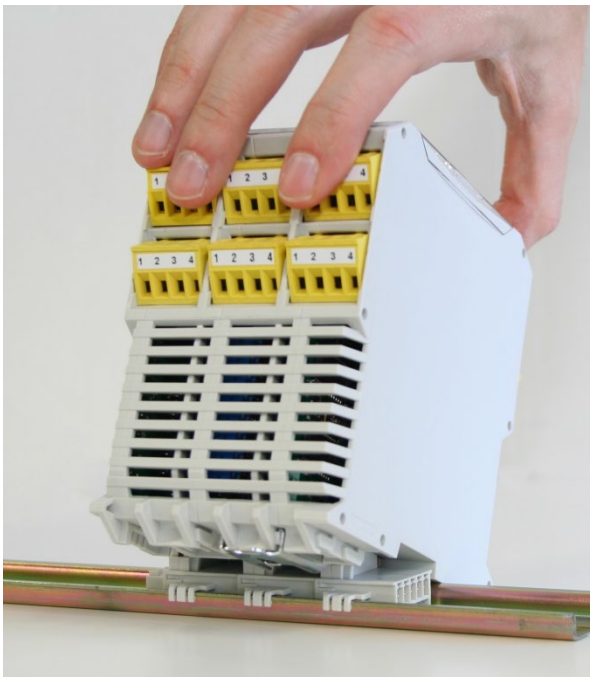
5.4.1 Mounting on a C-rail

The devices are inserted into the rail at an angle from above and snapped into place.
To remove a module insert a flat-bladed screwdriver into the slot of the pawl leading out downwards. Then move the screwdriver upwards.



5.4.2 Mounting on the Backplane Bus

After mounting the backplane bus, the device can be mounted. To do this, insert the module into the plug connection from above at an angle and snap it onto the C-rail



Insert module from above at an angle.

Snap the module into place on the C-rail.

Backplane connectors can be added at a later date. The system configuration can thus be extended by additional modules.

Snap the backplane bus element into the C-rail and slide it to the side to insert it into its counterpart.

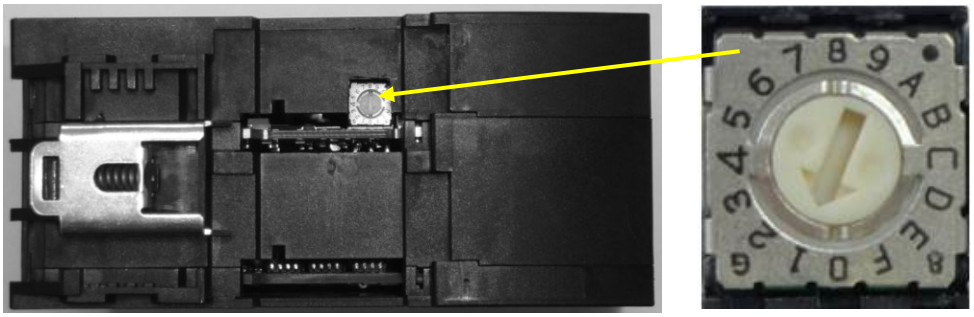
5.4.3 Installing the I/O extension JSX1-DIO22

Note:
A maximum of two JSX1-DIO22 modules can be operated with one basic module.

5.4.3.1 Physical address configuration - JSX1-DIO22

On the JSX1-DIO22 module, the bus address must be set using the address switch.

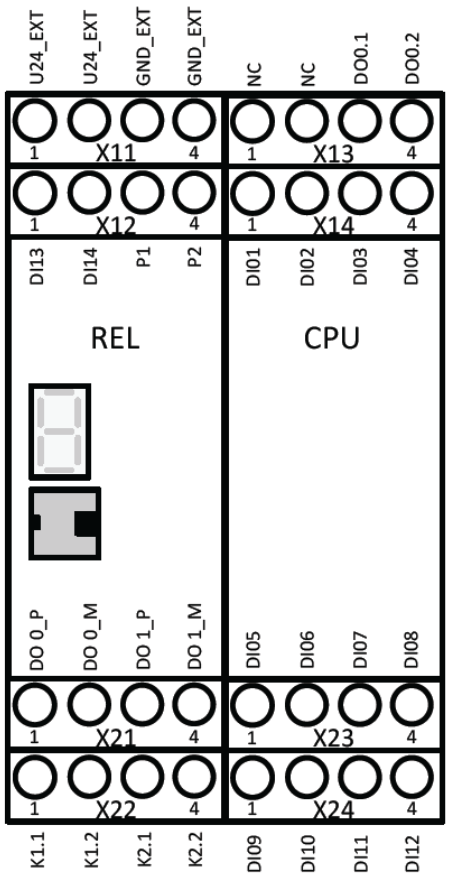
The address switch is on the back of the module.



Note:
The valid address range of the JSX1-DIO22 module is 1 ... 2
Address "0" is reserved for the basic module.

5.5 Terminal assignment

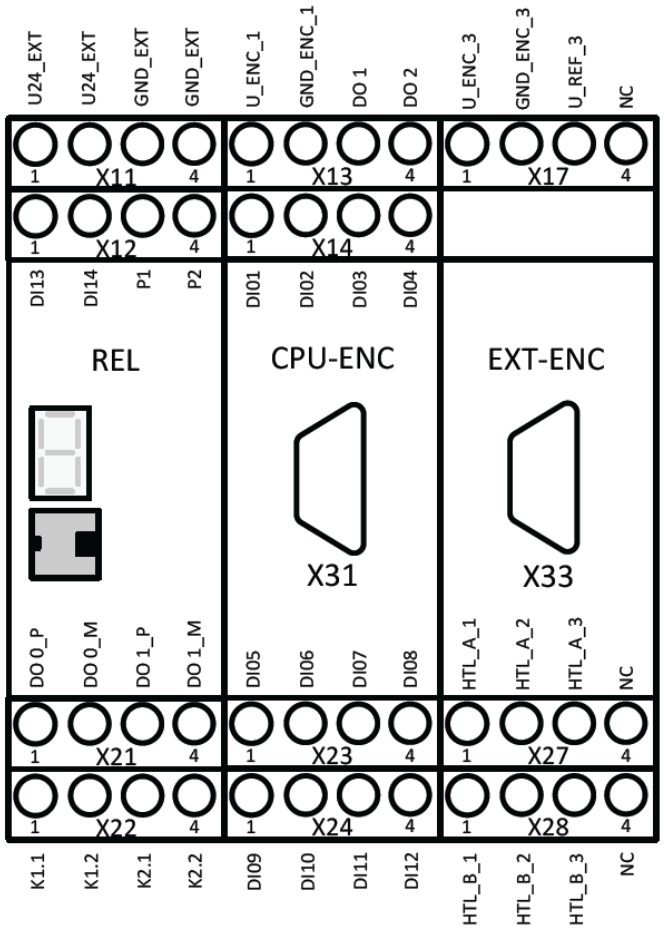
5.5.1 Terminal assignmentJSC-110



Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
REL	X11	1 – U24_EXT	DC +24 V power supply of the device
		2 – U24_EXT	
		3 – GND_EXT	DC 0 V power supply of the device
		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	
CPU	X13	1 – NC	No function
		2 – NC	

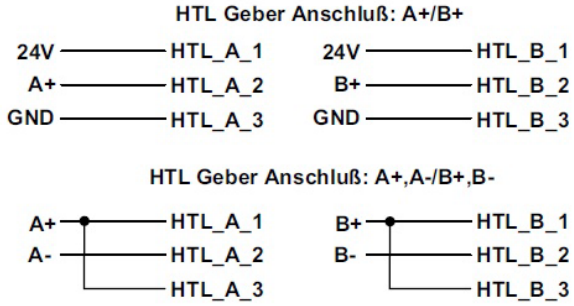
Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
		3 – DOo.1	Auxiliary outputs
		4 – DOo.2	
	X14	1 – DI1	Safe digital inputs
		2 – DI2	
		3 – DI3	
		4 – DI4	
	X23	1 – DI5	
		2 – DI6	
		3 – DI7	
		4 – DI8	
	X24	1 – DI9	
		2 – DI10	
		3 – DI11	
		4 – DI12	

5.5.2 Terminal assignment JSC-110-1-RS

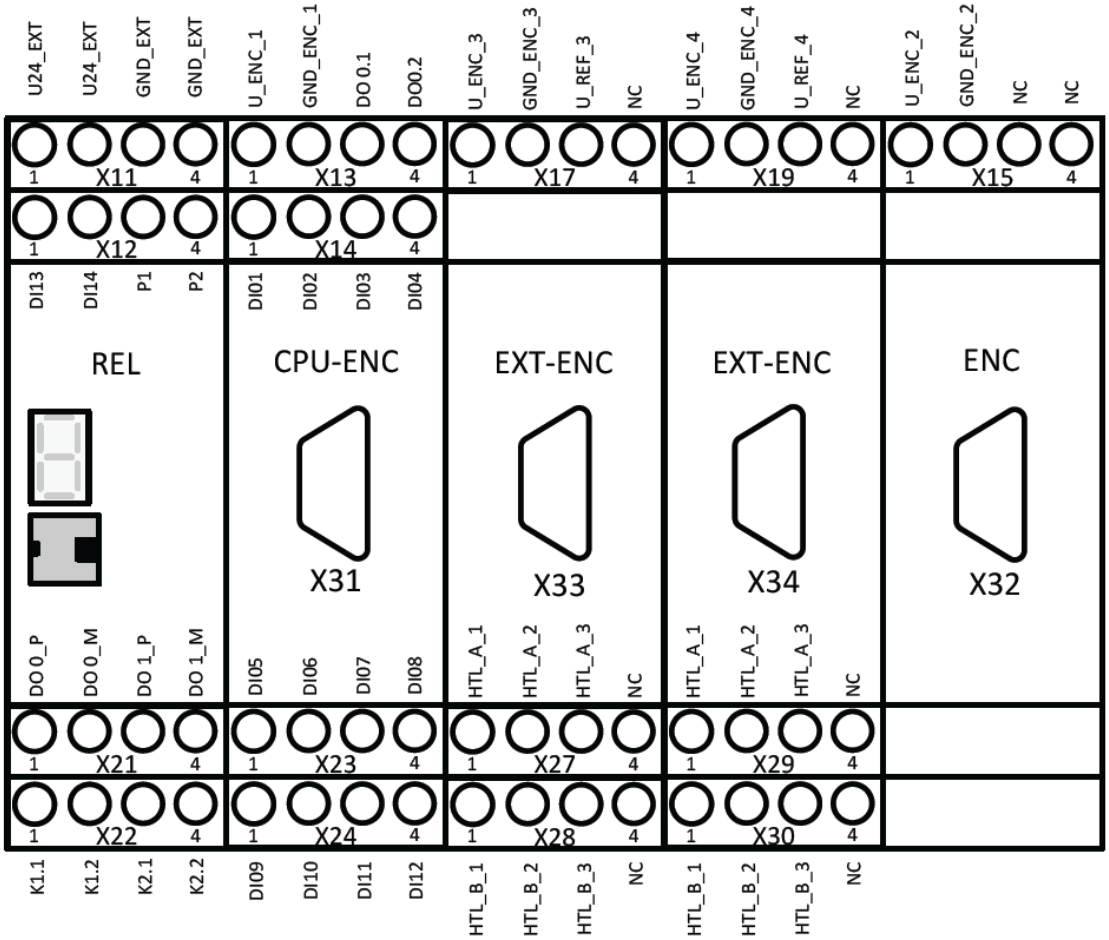


Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
REL	X11	1 – U24_EXT	DC +24 V power supply of the device
		2 – U24_EXT	
		3 – GND_EXT	DC 0 V power supply of the device
		4 – GND_EXT	
	X12	1 – DI13	Safe digital inputs
		2 – DI14	
		3 – P1	Pulse outputs
		4 – P2	
	X21	1 – DO0_P	Output 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	
CPU-ENC	X13	1 – U_ENC_1	Encoder power supply DC +24 V X31
		2 – GND_ENC_1	Encoder power supply DC 0 V X31
		3 – DOo.1	Auxiliary outputs
		4 – DOo.2	

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



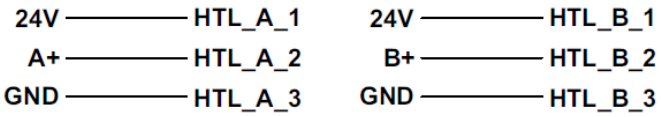
5.5.3 Terminal assignment JSC-110-2-RS



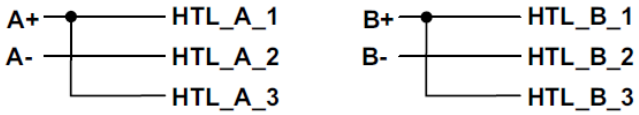
Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
REL	X11	1 – U24_EXT	DC +24 V power supply of the device
		2 – U24_EXT	
		3 – GND_EXT	DC 0 V power supply of the device
		4 – GND_EXT	
	X12	1 – DI13	Safe digital inputs
		2 – DI14	
		3 – P1	Pulse outputs
		4 – P2	
	X21	1 – DO0_P	Output 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	
CPU-ENC	X13	1 – U_ENC_1	Encoder power supply DC +24 V X31
		2 – GND_ENC_1	Encoder power supply DC 0 V X31
		3 – DOo.1	Auxiliary outputs

Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
		4 – DOo.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	
EXT-ENC	X17	1 – U_ENC_3	Encoder power supply DC +24 V X33
		2 – GND_ENC_3	Encoder power supply DC 0 V X33
		3 – U_REF_3	Encoder reference voltage X33
		4 – NC	No function
	X27	1 – HTL_A_1	Encoder 24 V
		2 – HTL_A_2	Encoder A+
		3 – HTL_A_3	Encoder ground
		4 – NC	
	X28	1 – HTL_B_1	Encoder 24 V
		2 – HTL_B_2	Encoder B+
		3 – HTL_B_3	Encoder ground
		4 – NC	
EXT-ENC	X19	1 – U_ENC_4	Encoder power supply DC +24 V X34
		2 – GND_ENC_4	Encoder power supply DC 0 V X34
		3 – U_REF_4	Encoder reference voltage X34
		4 – NC	No function
	X29	1 – HTL_A_1	Encoder 24 V
		2 – HTL_A_2	Encoder A+
		3 – HTL_A_3	Encoder ground
		4 – NC	
	X30	1 – HTL_B_1	Encoder 24 V
		2 – HTL_B_2	Encoder B+
		3 – HTL_B_3	Encoder ground
		4 – NC	
ENC	X15	1 – U_ENC_2	Encoder power supply DC +24 V X32
		2 – GND_ENC_4	Encoder power supply DC 0 V X32
		3 – NC	No function
		4 – NC	

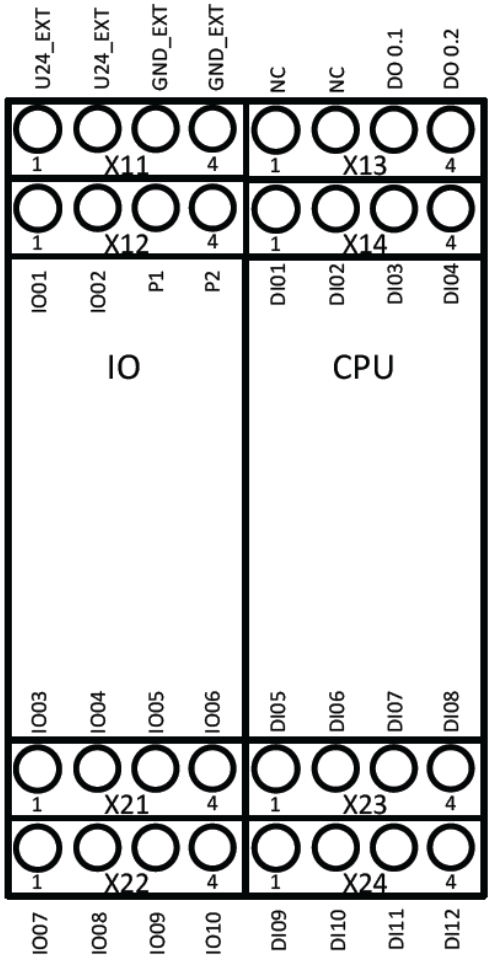
HTL Encoder Connection: A+/B+



HTL Encoder Connection: A+, A-/B+, B-



5.5.4 Terminal assignment JSX1-DIO22



Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
IO	X11	1 – U24_EXT	Power supply of device DC +24 V Outputs
		2 – U24_EXT	
		3 – GND_EXT	DC 0 V power supply of the device
		4 – GND_EXT	
	X12	1 – IO01	Safe digital inputs/outputs, pp-switching
		2 – IO02	
		3 – P1	Pulse outputs
		4 – P2	
	X21	1 – IO03	Safe digital inputs/outputs, pp-switching
		2 – IO04	
		3 – IO05	
		4 – IO06	
	X22	1 – IO07	
		2 – IO08	
		3 – IO09	
		4 – IO10	
CPU	X13	1 – NC	No function
		2 – NC	

Terminal assignment			
Unit	***Terminal***	***Pin***	***Description***
		3 – DOo.1	Auxiliary outputs
		4 – DOo.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	

5.6 External DC 24 V power supply

The JSC-110 module requires a power supply of DC 24 V (see SELV or PELV, EN50178). The following boundary conditions must be observed during project planning and installation of the intended power supply unit:

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

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

In order to achieve the lowest possible residual ripple of the supply voltage, we recommend using a 3-phase power supply unit or an electronically controlled PSU. The power supply unit must meet the requirements of EN 61000-4-11 (voltage dip).
The connecting cables must be designed in accordance with the local regulations.
The external voltage resistance of the JSC-110 module is DC 32 V (protection by suppressor diodes at the input).

⚠ **Safety precaution:**

- Each JSC-110 module must be individually fused externally with a line fuse of 3.15 A (min. DC 30 V). The fuse must be located near the terminals.
  Recommended type: single-pole thermal magnetic circuit breaker, characteristic: fast.

Note:
In any case, safe galvanic isolation from the AC 230 V or AC 400 V mains must be ensured. For this purpose, power supply units must be selected which comply with the standards DIN VDE 0551, EN 60 742 and DIN VDE 0160. In addition to the selection of a suitable device, care must be taken to ensure equipotential bonding between PE and DC 0 V on the secondary side.

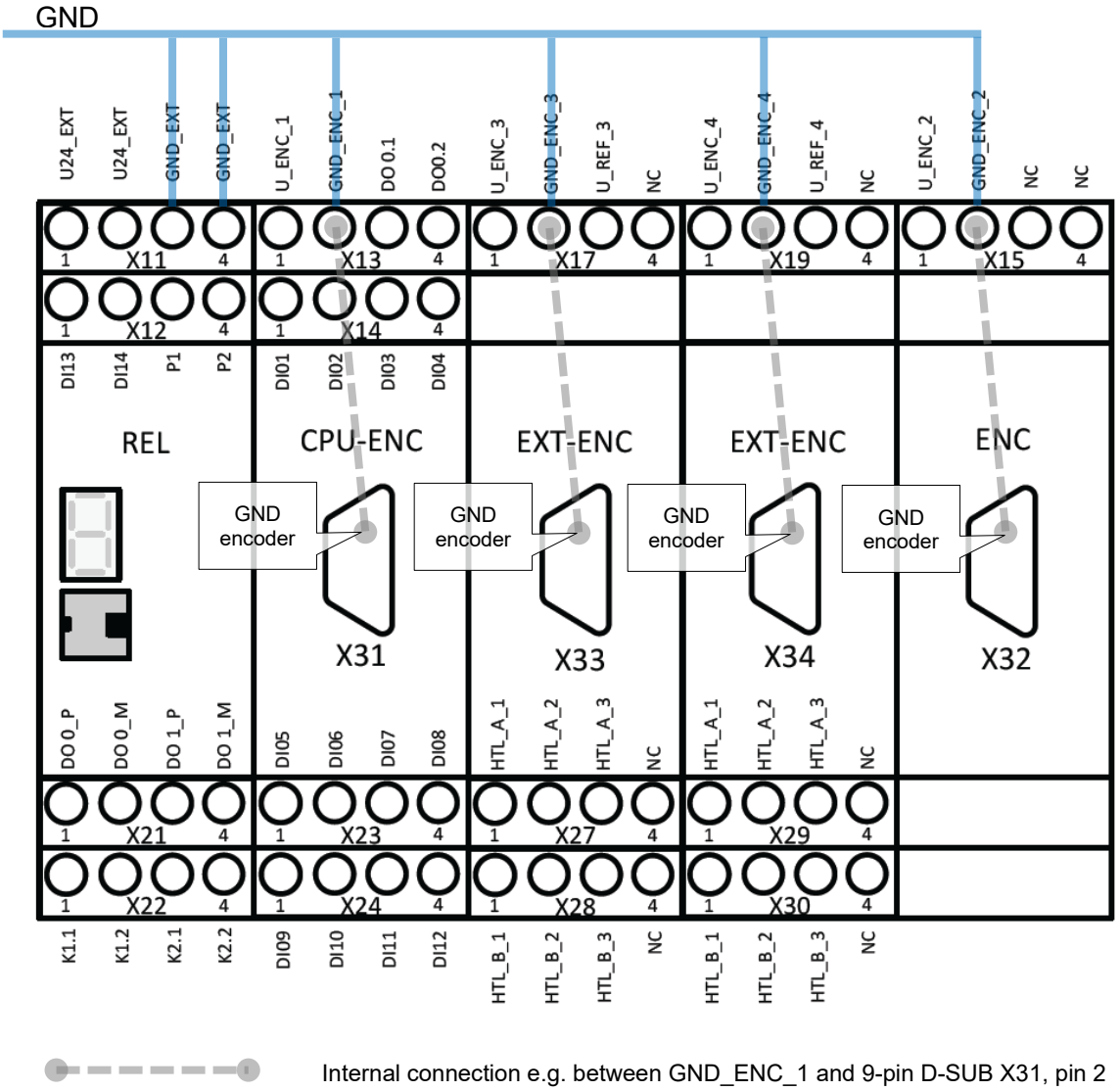
⚠ **Safety precaution:**

- All GND terminals of the devices connected to the inputs of the JSC-110 module must be connected to the GND of the JSC-110 module (power supply).

JSC-110 modules have the following inputs:

- Digital Inputs
- Digital I/Os
- Encoder connections

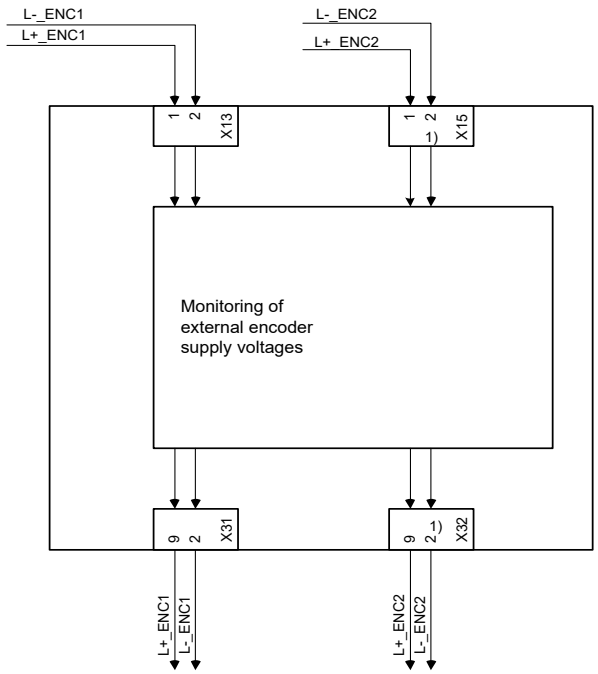
Note:
Terminals GND_ENC are not internally connected to GND!



Internal connection e.g. between GND_ENC_1 and 9-pin D-SUB X31, pin 2

5.7 Connecting the external encoder supply

5.7.1 Incremental, HTL, SIN/COS, SSI



1) Only JSC-110-2-RS

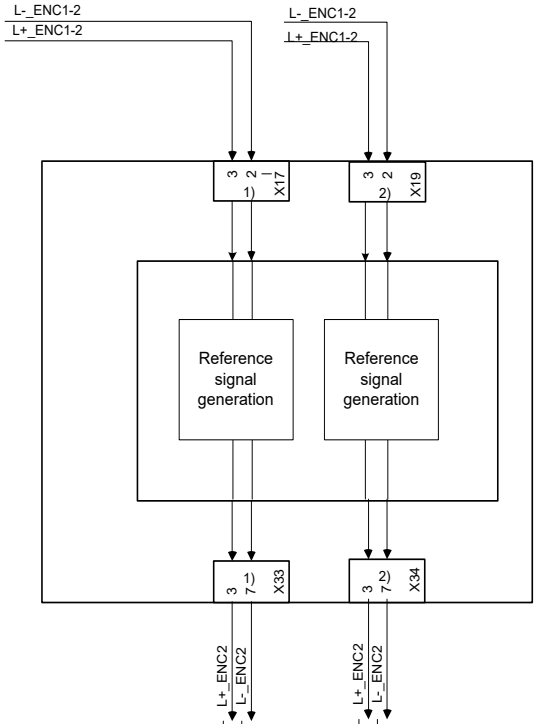
The JSC-110 module supports encoder voltages of 5 V, 8 V, 10 V, 12 V, 20 V and 24 V, which are monitored internally according to the selected configuration.
If an encoder system is not supplied via the JSC-110 module, a supply voltage must still be connected to terminal X13 or X15 and configured accordingly.
The sensor supply must be protected with a maximum of 2 A.

⚠ **Safety Notice:**
The GND connection of the encoder must be connected to the GND of the JSC-110.

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

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

5.7.2 Resolver



1) JSC-110-1-RS and JSC-110-2-RS only
2) Only JSC-110-2-RS

When using a resolver in master mode, an additional DC 24 V power supply is required to generate the reference signal.

Note:

- Make sure that no voltage supply is connected to PIN 1 at the voltage supply terminals X17 and X19.
- The sensor supply must be protected with a maximum of 2 A.

Monitoring of the supply voltage:

Rated voltage	Minimum voltage	Maximum voltage
DC 24 V	DC 20 V	DC 29 V

5.8 Connecting Digital Inputs

The JSC-110 modules have 14 safe digital inputs, the JSX1-DIO22 has 12 safe digital inputs. These are suitable for the connection of single- or dual-channel signals with or without clocking, or without cross-fault detection.

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, type 1, according to EN 61131-2. The inputs are internally provided with input filters.

A device-internal diagnostic function cyclically checks the correct function of the inputs including the input filters. A detected fault will put the JSC-110 into alarm mode. At the same time all outputs are passivated.

In addition to the actual signal inputs, the JSC-110 modules provide two pulse outputs P1 and P2. The pulse outputs are switching DC 24 V outputs.
The pulse outputs are exclusively intended for monitoring the digital inputs (DI1 ... DI14) and cannot be used for any other functions in an application.

The switching frequency is 125 Hz for each output. During project planning, take into account that the outputs may be loaded with a maximum total current of 250 mA.

Furthermore, approved OSSD outputs can be connected to inputs DI1 ... DI14 without restriction.

With single-channel use of the inputs, the achievable safety level is limited to SIL 2 or PL d if the safety function is requested at regular intervals.

Basically, a safety-related use of the inputs is only intended in connection with the pulse outputs.

If the pulse outputs are not used, external measures, in particular suitable cable routing, must be taken to prevent short circuits in the external wiring between different inputs and with regard to the supply voltage of the JSC-110 modules.

Each input of the JSC-110 modules can be individually configured for the following signal sources:

- Input is assigned to pulse P1
- Input is assigned to pulse P2
- Input is assigned to DC 24 V continuous voltage

5.9 Connecting Position and Speed Sensors

5.9.1 General remarks

Depending on the module type, the JSC-110 module has external encoder interfaces for connecting industry-standard incremental and absolute encoders. The encoder interfaces can be configured as incremental, SIN/COS, or as absolute SSI encoders.
Furthermore, it is possible to connect two sensors generating incremental signals (such as proximity switches) to the counting inputs of the JSC-110 module. The signals must be read in each with normal and complementary track.

NOTICE!
The encoder system is supplied with power via the terminals specified on the JSC-110 module. This voltage is fed to the encoder connector and monitored by an internal diagnostic process.
If the sensor is supplied with an external voltage, this must be fed via the encoder connector. The corresponding terminal (encoder supply voltage) on the JSC-110 module remains free.

If an external sensor supply voltage is not fed back via the encoder connector, a failure of this supply voltage must be included in the fault analysis of the overall system. In particular, it must therefore be demonstrated that if the specified operating voltage of the encoder system is undershot/overshot, this fault is detected or can be ruled out.

EMC measures such as shielding etc. must be observed.
The two encoders must be free of interaction between each other. This applies to both the electrical and the mechanical part.
If both encoders are coupled to the device to be monitored via common mechanical parts, the connection must have a positive fit and must not have any parts subject to wear (chains, toothed belts, etc.). If this is nevertheless the case, additional monitoring devices are required for the mechanical connection of the sensors (e.g. monitoring of a toothed belt).
At least one absolute encoder must be used for active position processing.
When using two equivalent sensors, note that the sensor with the higher resolution is configured as Sensor1 (process sensor) and the sensor with the lower resolution is configured as Sensor 2 (reference sensor).

⚠ **Safety precaution:**
- The GND connections of the encoders must be connected to the GND of the JSC-110 module. This also applies to resolvers in the same way.

Warning!
The encoder connections must not be plugged or unplugged during operation. Failure to do so could destroy electrical components on the encoder. Disconnect connected encoders and the JSC-110 module from the power supply before plugging or unplugging the encoder connections. For externally supplied encoders, make sure that the external supply voltage (e.g. inverter) is switched off.

For the data and clock signals or track A and track B, twisted pair cables must be used for signal transmission according to the RS485 standard. When selecting the wire cross-section, the current consumption of the encoder and the cable length of the installation must be taken into account in each individual case.

When using absolute encoders, the following also applies:

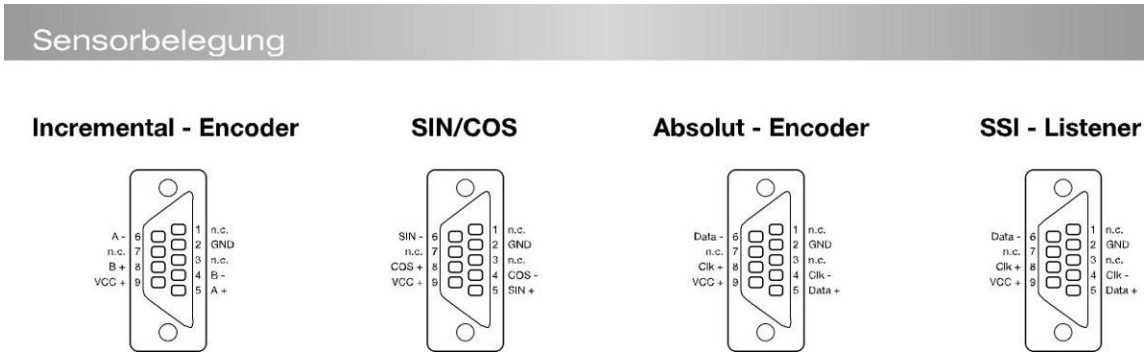
In slave mode, the clock signal is generated by an external process and is read in via data signal from the JSC-110 module. This type of sampling causes a beat frequency and consequently a sampling error of the following magnitude:

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

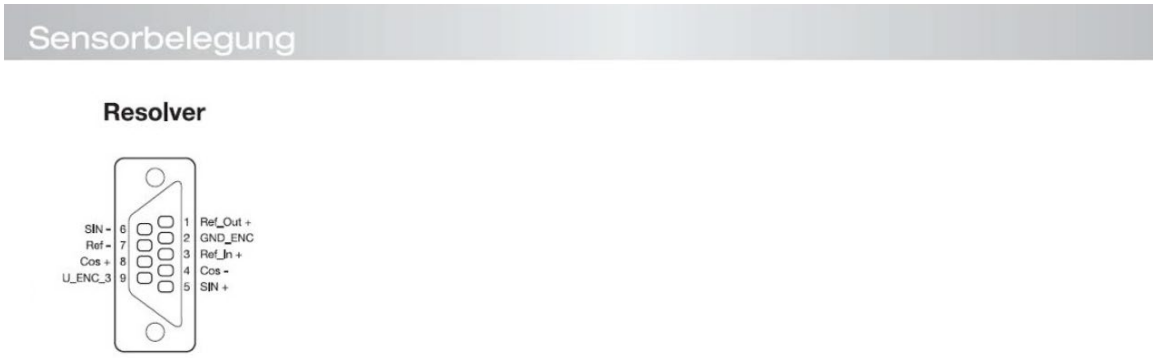
The size of the resulting sampling error F must be taken into account when defining the thresholds in the monitoring functions used since this error cannot be compensated!

5.9.2 Assignment of the encoder interfaces

X31/X32[1)]



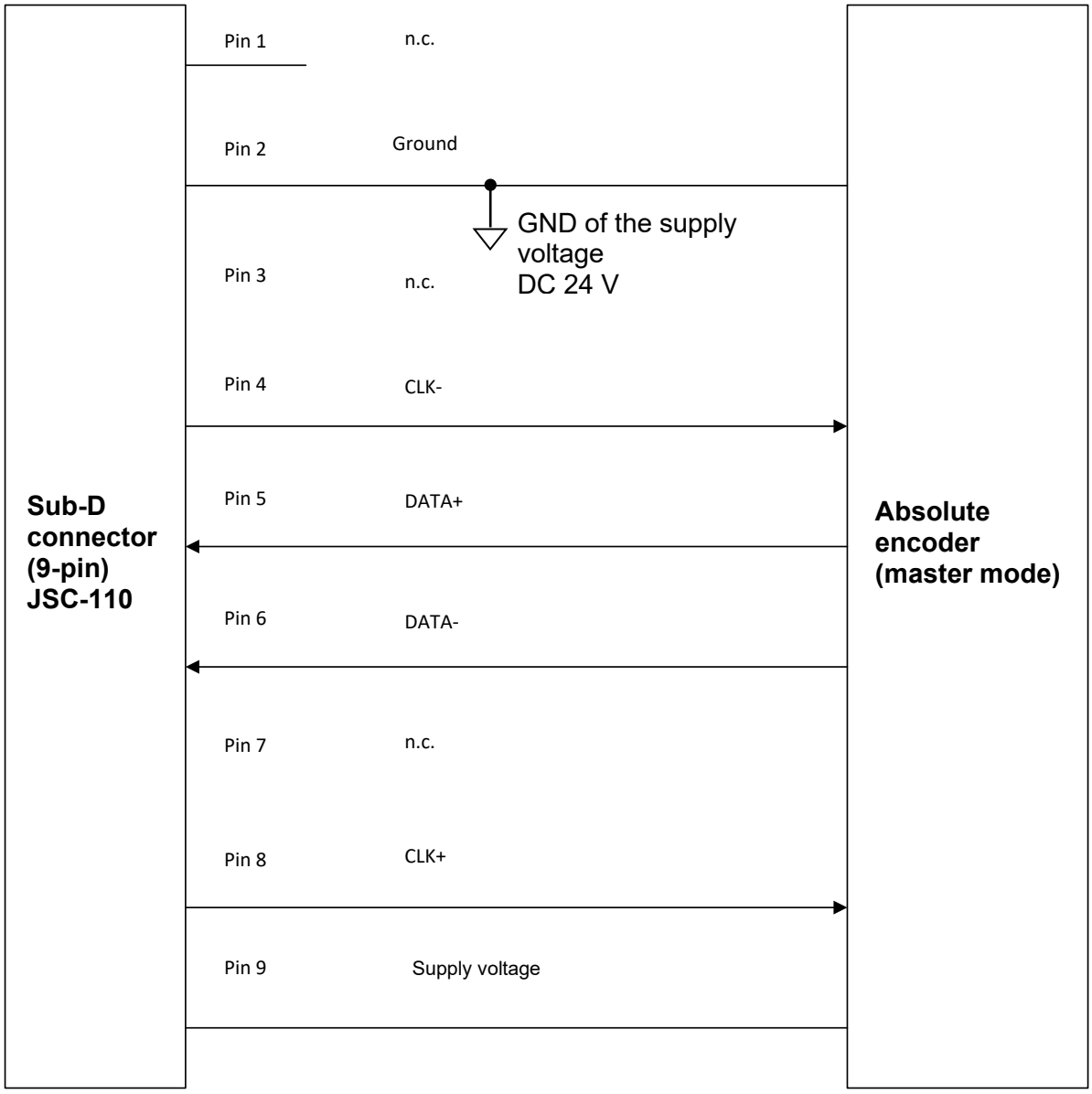
X33/X34[1)]



[1)] JSC-110-2-RS only

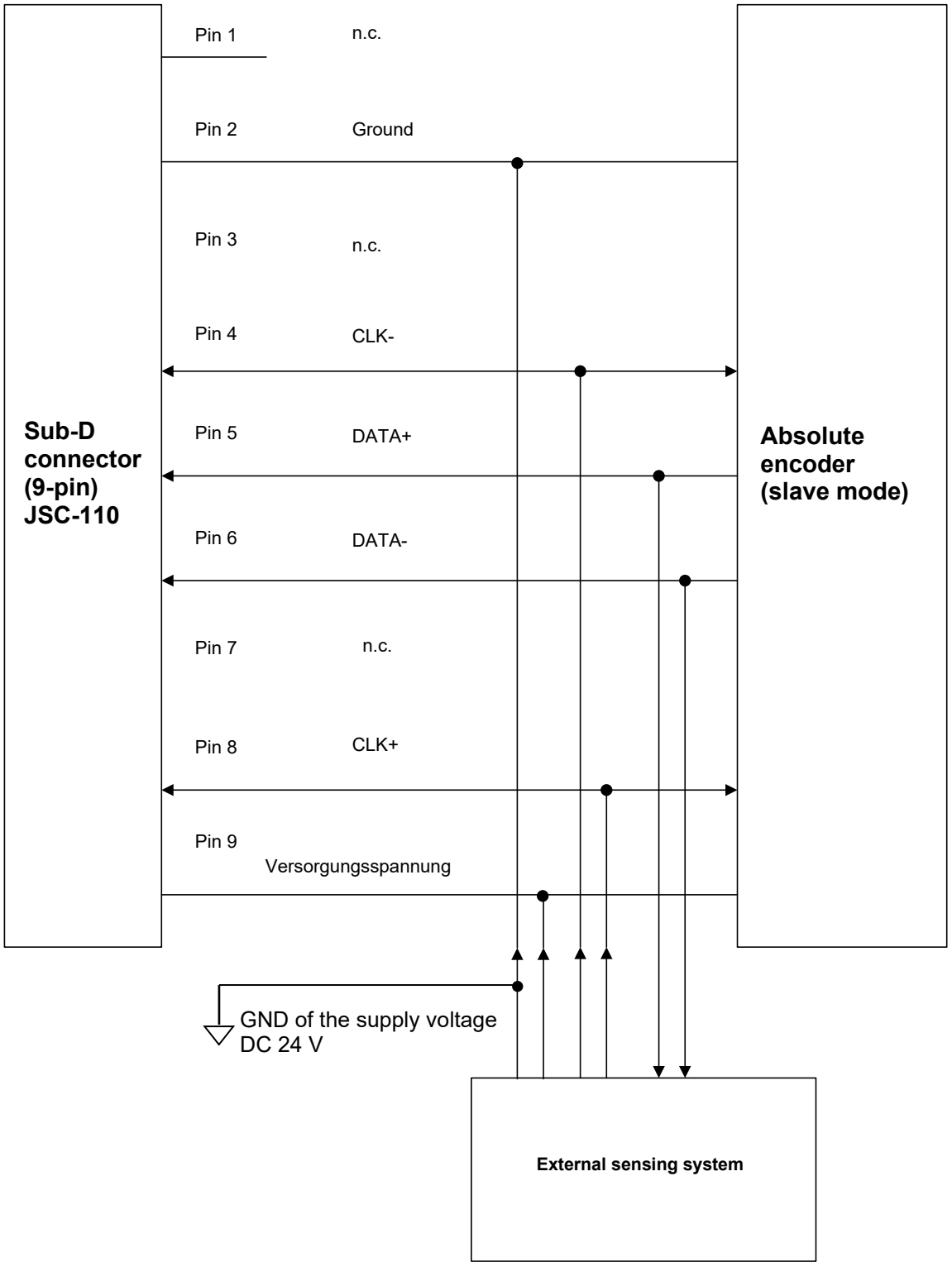
5.9.3 Connection Variants

5.9.3.1 Connection of an absolute encoder as master



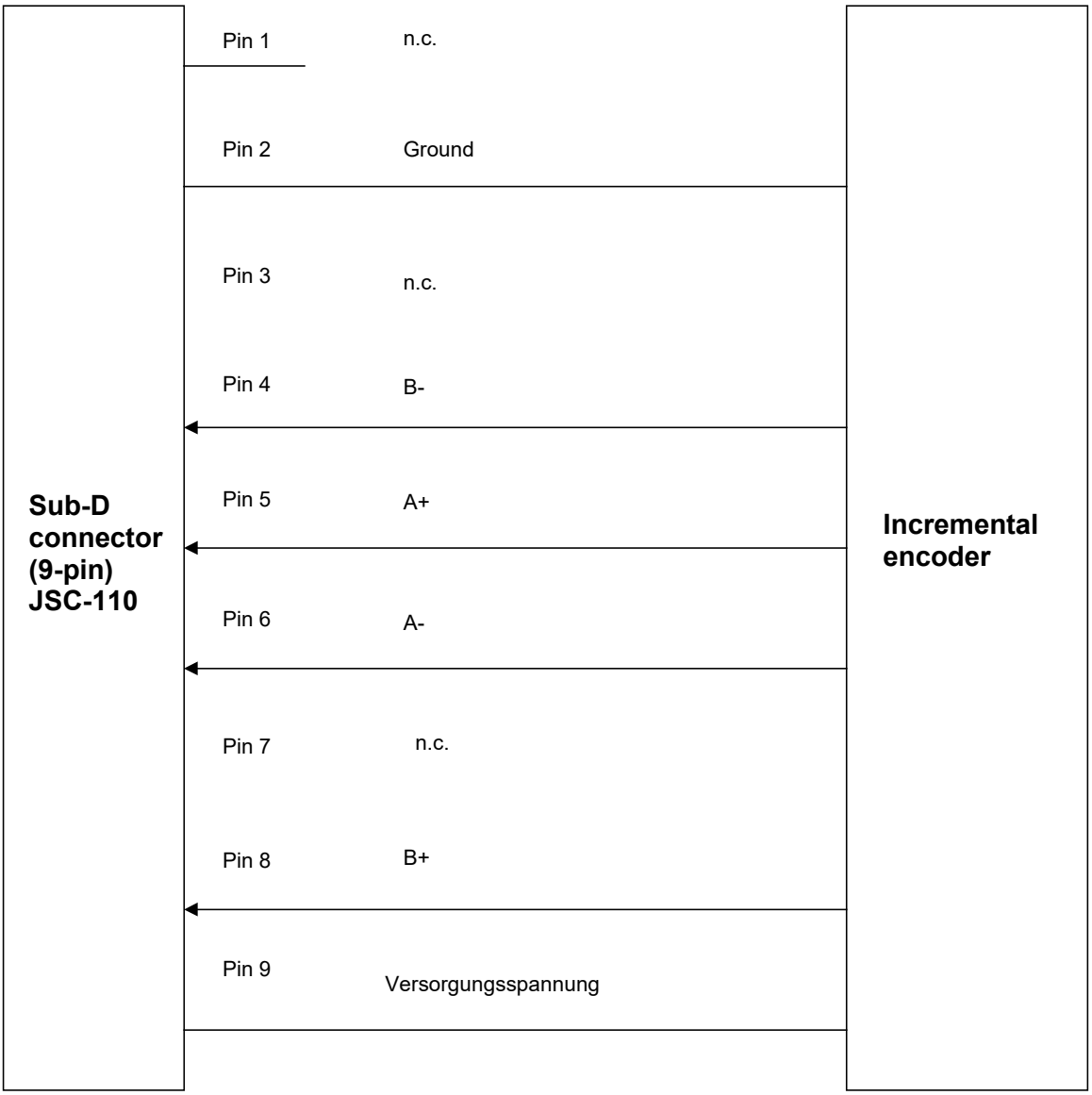
With this type of connection, the clock signals run from the JSC-110 module to the absolute encoder and the data from the encoder to the JSC-110 module.

5.9.3.2 Connection of an absolute encoder as slave



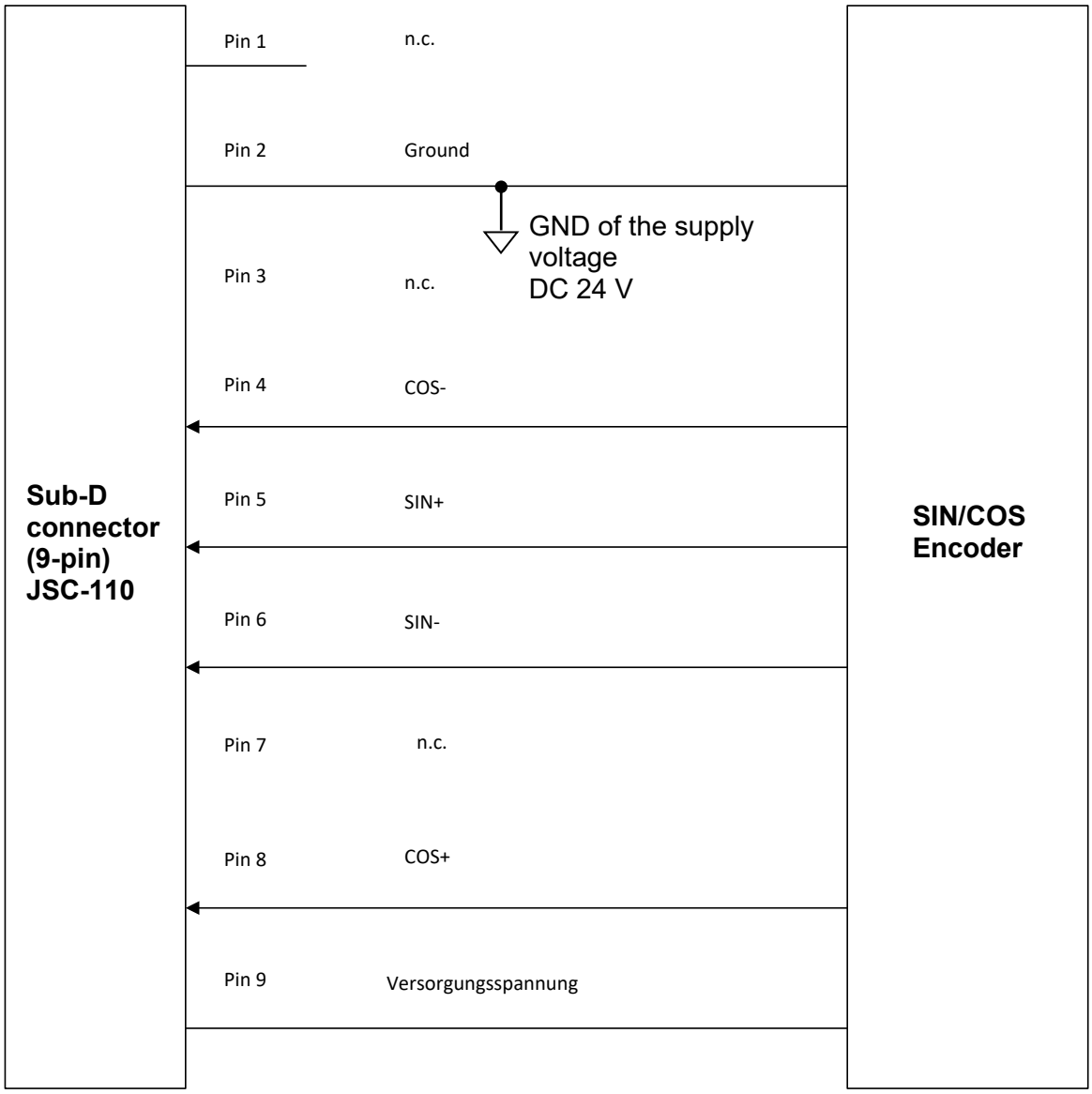
With this type of connection, the clock signals and the data are also read. In this example, the encoder is not supplied with voltage from the module.

5.9.3.3 Connection of an incremental encoder with TTL signal level



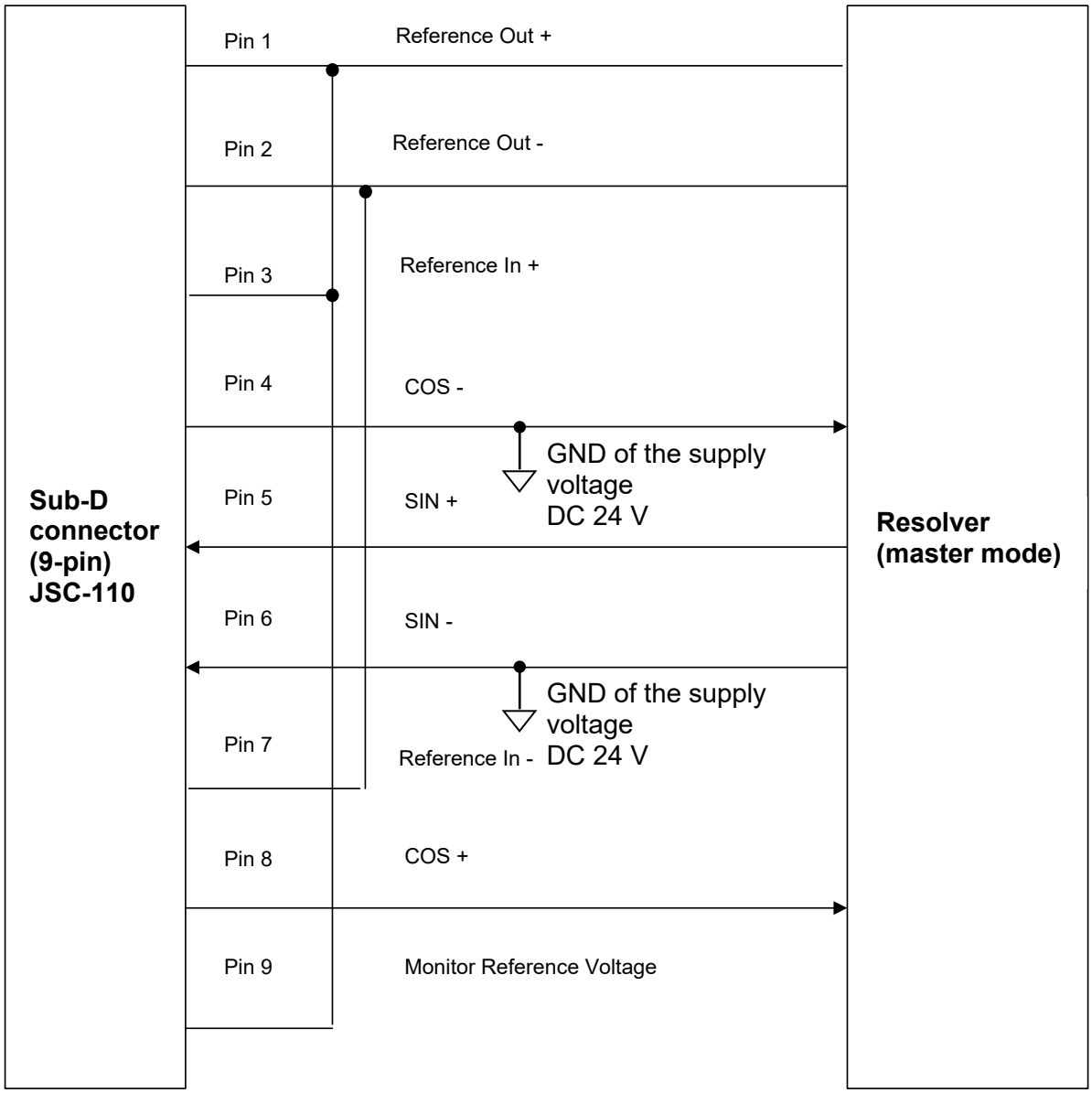
Pins 1, 3 and 7 remain open and are reserved for later extensions.

5.9.3.4 Connection of a SIN/COS encoder

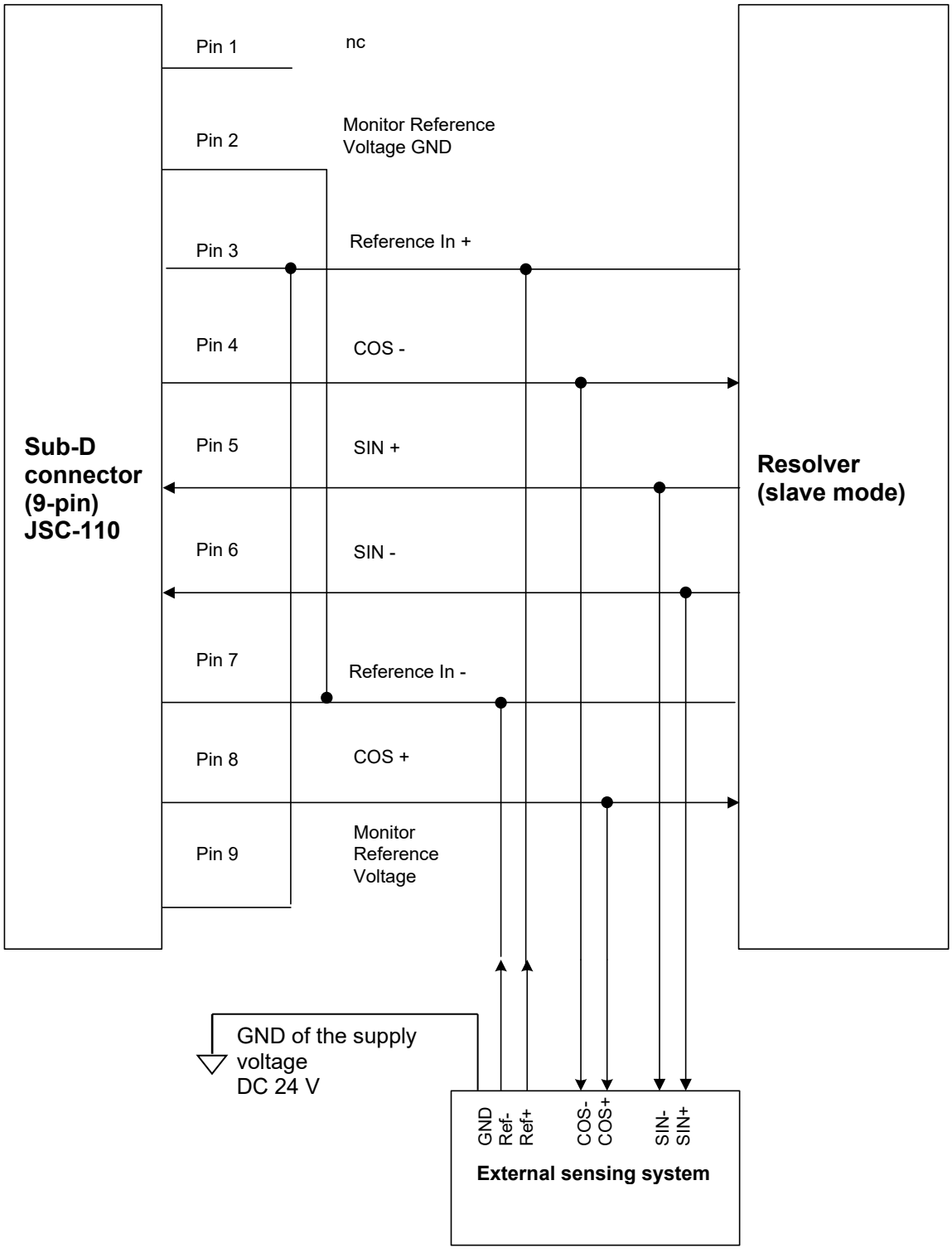


Pins 1, 3 and 7 remain open and are reserved for later extensions.

5.9.3.5 Connection of a resolver as master



5.9.3.6 Connection of a resolver as slave



5.9.3.7 Connecting a proximity switch to a JSC-110-x-RS

Connection is made via connector X23 to the digital inputs DI5 ... DI8.
The exact pin assignment depends on which encoder type is used and is displayed in the connection diagram in the programming interface.

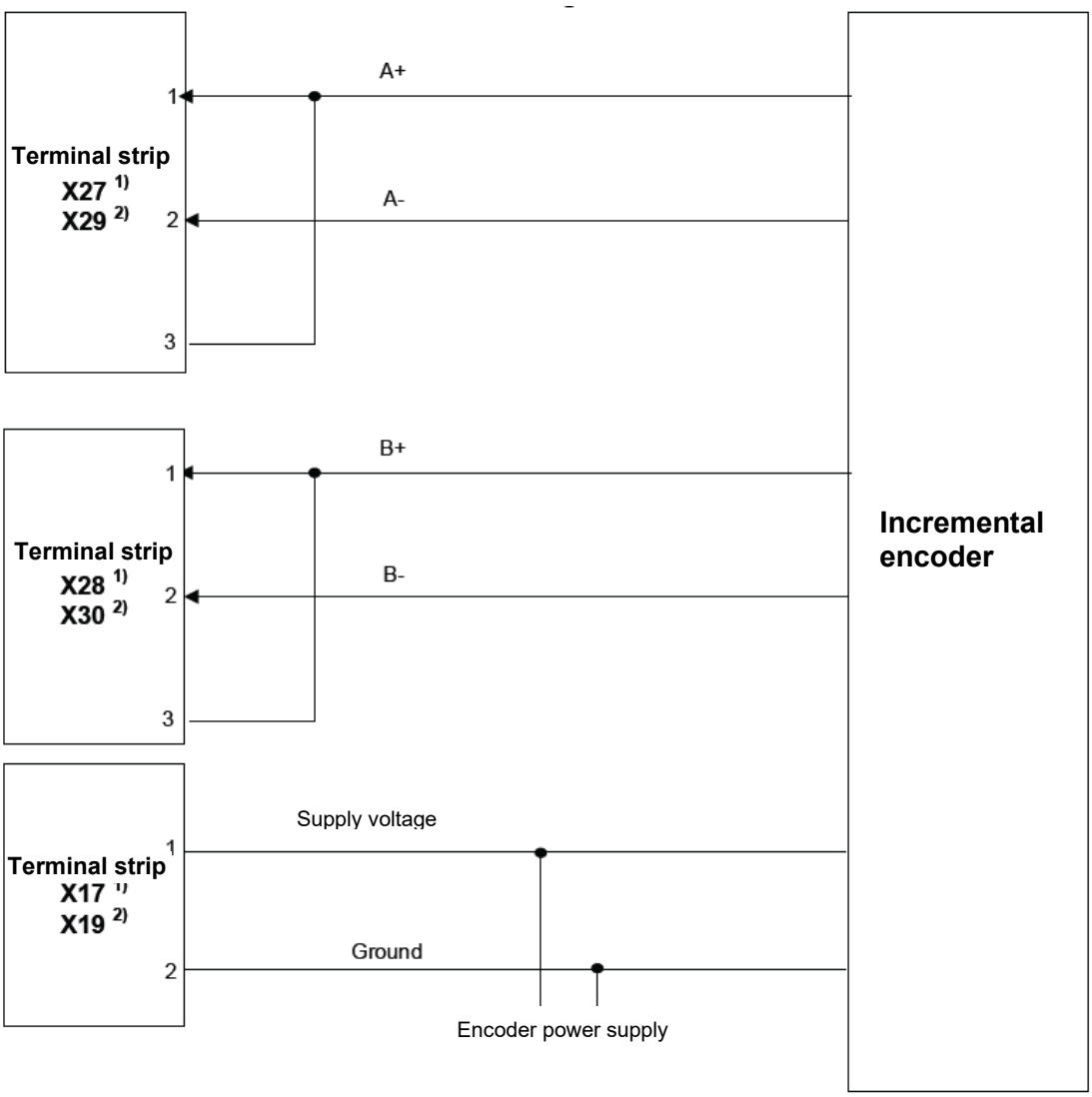
Note:

When using HTL encoders, make sure that the tracks A+ and B+ or A- and B- must be combined accordingly.

5.9.3.8 Connecting an HTL/Proximity Switch to a JSC-110-x-RS

Connection is made via connector X27 and X28, or X29 and X30.

5.9.3.8.1 HTL encoder with A+/A- or B+/B- signal



[1)]JSC-110-x-RS encoder 3
[2)]JSC-110-2-RS encoder 4

5.10 Configuring the Measuring Sections

5.10.1 General description of the encoder configuration

The most important input variables for the monitoring functions of the module are safe position, velocity and acceleration. These are generated in two channels from the connected sensor systems. For PL e according to EN ISO 13849-1, an architecture corresponding to category 4 is required, i.e. continuous dual-channel detection with a high degree of diagnostic coverage. For any single-channel components (e.g. mechanical connection of the sensor/encoder with only one shaft/fixing), fault exclusions according to EN ISO 13849-2 can be used as a basis if need be. For PL d according to EN 13849-1, reduced diagnostic coverage can be used. Taking into account the permissible fault exclusions according to EN ISO 13849-2, simple sensor systems may also be sufficient (speed monitoring only).
See ANNEX 1

The further configuration is described in the programming manual.

6 Sensor type

Absolute encoders 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 of 12 ... 28 bit.
Data format: Binary or Gray code,
Physical layer: RS-422 compatible

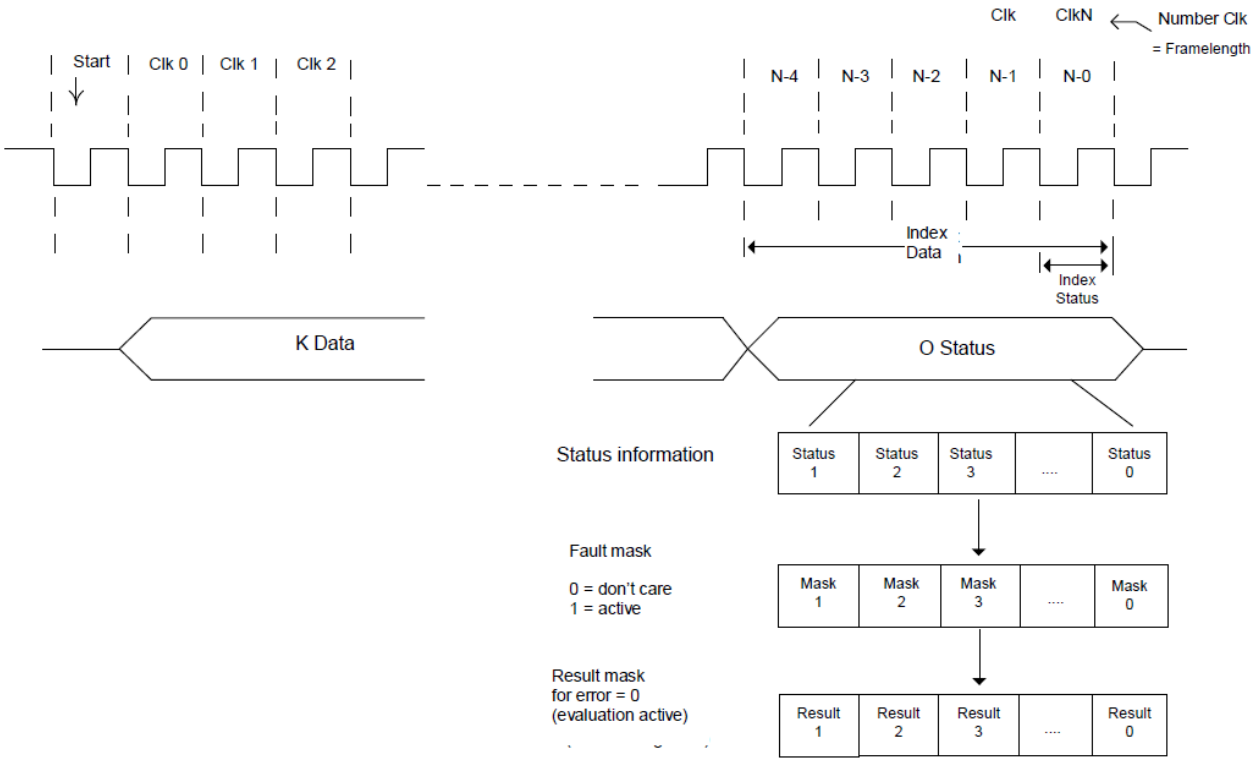
SSI master mode:
Clock speed: 150 kHz

SSI listener operation (slave mode):
Max. external clock rate: 250 kHz
Min. clock pause time: 150 µsec
Max. clock pause time: 1 msec

Diagnostic functions:

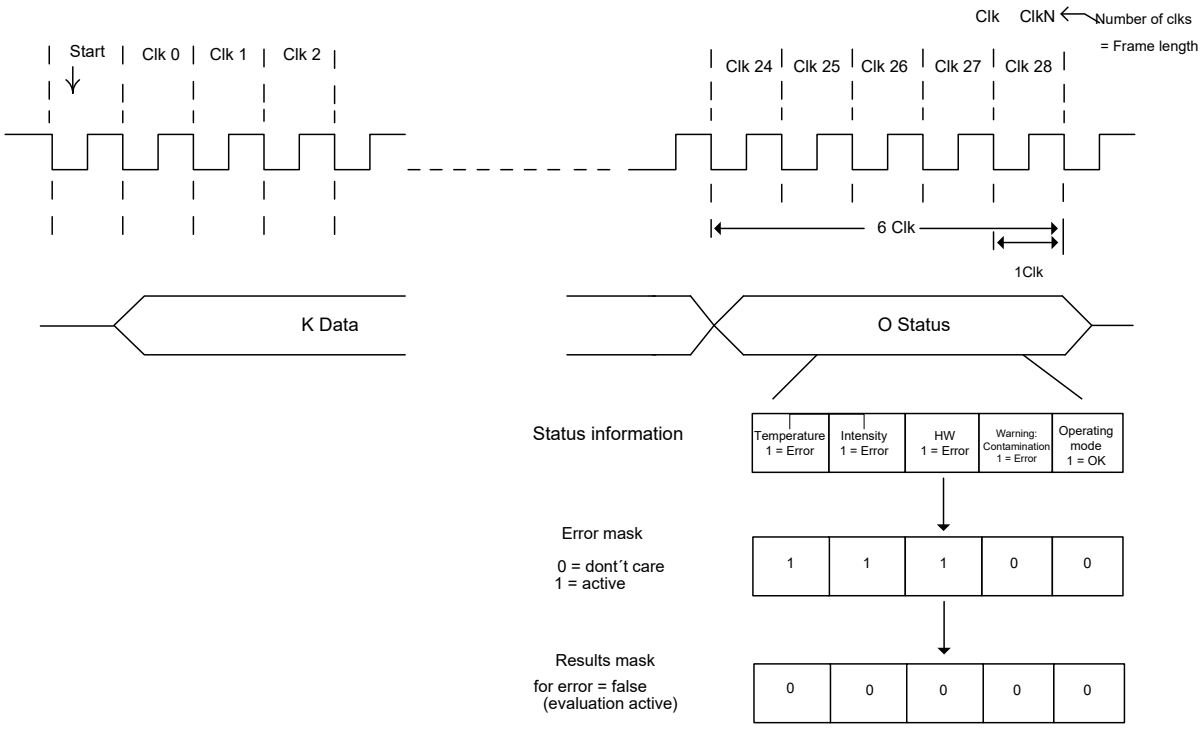
Diagnostic functions	Parameter	Fault threshold
Monitoring of the supply voltage	Fixed values 5 V, 8 V, 10 V, 12 V, 20 V, 24 V	+/-20 % +/-2 % (measuring tolerance)
Monitoring of differential level at input	Fixed value RS485 level	+/-20 % +/-2 % (measuring tolerance)
Clock frequency monitoring	Fixed value	100 kHz < f < 350 kHz
Plausibility check: velocity versus position	Fixed value	ΔP < 2 * V * T where T = 8 ms

Parameterization of the SSI format:



Example:

SSI framelength: 28 clocks
Data length: 22 bits
Status: 5 bits, 3 bits error + 2 bits warning/ready for operation



6.2 Incremental encoder:

Physical layer: RS-422 compatible
Measurement signal A/B: Track with 90 degrees phase difference
Maximum frequency of the input clocks: 200 KHz

Diagnostic functions:

Diagnostic functions	Parameter	Fault threshold
Monitoring of the supply voltage	Fixed values 5 V, 8 V, 10 V, 12 V, 20 V, 24 V	+/-20 % +/-2 % (measuring tolerance)
Monitoring of differential level at input	Fixed value RS485 level	+/-20 % +/-2 % (measuring tolerance)
Monitoring of the counting signal separately for each track A/B	Fixed value	DP > 4 increments

6.3 SinCos encoder - standard mode

Physical layer: +/-0.5 Vpp (without voltage offset)
Measurement signal A/B: Track with 90 degrees phase difference
Maximum frequency of the input clocks: 200 KHz

Diagnostic functions:

Diagnostic functions	Parameter	Fault threshold
Monitoring of the supply voltage	Fixed values 5 V, 8 V, 10 V, 12 V, 20 V, 24 V	+/-20 % +/-2 % (measuring tolerance)
Amplitude monitoring SIN^2+COS^2	Fixed value 1 V_{pp}	65 % of 1 V_{pp} +/-2.5 % (measuring tolerance)
Phase A/B monitoring	Fixed value 90°	+/-30° +/-5° (measuring tolerance)

6.4 Proxi Switch

Signal level: 24 V/0 V
Max. count pulse frequency: 10 kHz
Switching logic debounced

Diagnostic functions:

Diagnostic functions	Parameter	Fault threshold
Monitoring of the supply voltage	Fixed value 24 V	+/-20 % +/-2 % (measuring tolerance)

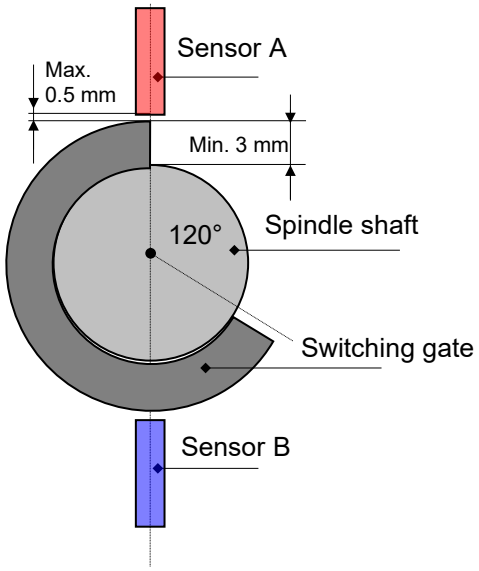
6.5 Extended monitoring proxi switch/proxi switch

Advanced monitoring detects the following faults:

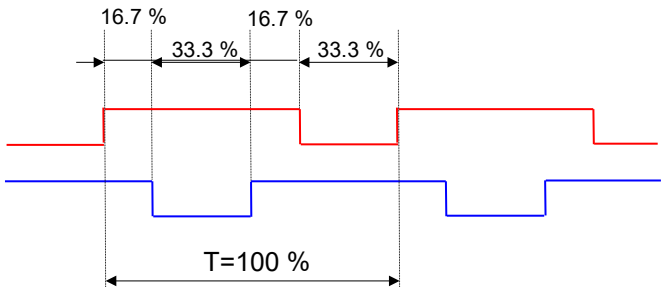
- Failure of the supply voltage
- Failure of the output signal in the driver direction
- Function failure of proxi for high signal
- Interruption of signal path
- Mechanical misalignment/excessive switching distance

For diagnostic purposes, the two status states of the counter signals are also synchronously detected and logically compared. At least one of the two signals must be attenuated by means of a switching gate. The logic evaluates this arrangement rule.

Design of the switching gate with radial sensor arrangement



Targeted theoretical signal shape



The diagnostics must be designed for at least the following limit values:

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

Reading in the counting signals:
The two counting signals are assigned separately to the two channels. In each of the two channels the status is read in synchronously. To ensure synchronization, this must be done immediately after channel synchronization. Sampling must be performed at least once per cycle.
The maximum deviation in synchronism is 20 µs.
The statuses must be exchanged crosswise via the SPI.

Logic processing:
The following evaluation is to be carried out 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: 24 V/0 V
Physical layer: Push/Pull
Measurement signal A/B: Track with 90° phase difference
Maximum counting pulse frequency: 200 kHz at X27/28 resp. X29/30

Diagnostic functions:

Diagnostic functions	Parameter	Fault threshold
Monitoring of the supply voltage	Fixed values 5 V, 8 V, 10 V, 12 V, 20 V, 24 V	+/-20 % +/-2 % (measuring tolerance)
Monitoring of differential level at input	Fixed value 24 V	+/-20 % +/-2 % (measuring tolerance)
Monitoring of the counting signal separately for each track A/B	Fixed value	DP > 4 increments

6.7 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 waveform: Sine, triangle

Diagnostic functions:

Diagnostic functions	Parameter	Fault threshold
Monitoring of ratio	Fixed values 2:1, 3:2, 4:1	+/-20 % +/-2 % (measuring tolerance)
Signal amplitude monitoring SIN^2+COS^2	Fixed value	<2.8 V +/-5 % (measuring tolerance)
Phase A/B monitoring	Fixed value 90°	+/-7° +/-2°(measuring tolerance)
Ref. frequency monitoring	Fixed values in steps of 1 ... 12 kHz, 14 kHz, 16 kHz	+/-20 % +/-5 % (measuring tolerance)
Reference signal waveform	Sine, triangle, no monitoring	40% form deviation
Quadrant monitoring counting signal/signal phase	Fixed value	+/-45°

7 Response times of the JSC-110

The response time is an important safety-related characteristic and must be considered for each application/application-related safety function. The following chapter lists the response times for individual functions, probably also depending on other parameters. If this information is not sufficient for a specific application, the actual time response must be validated against the target response by separate measurements. This applies in particular to the use of filter functions.

⚠ **Safety precaution:**

- The target response times must be defined for each application-related safety function and must then be compared with the actual values using the following information.
- Special care must be taken when using filter functions. Depending on the filter length/time, the response time may be considerably longer, which must be taken into account in the safety-related design.
- For particularly critical tasks, the time response must be validated by measurements.
- In the event of a device startup/alarm or error reset, the outputs may become active for the duration of the response time (depending on the application program). This must be taken into account when planning the safety functions.

7.1 Response Times in Standard Operation

The basis for the calculation of response times is the cycle time of the JSC-110 system. This is **T_cycle = 8 ms** in operation. The specified response times correspond to the respective maximum time for the specific application within the JSC-110 module. Depending on the application, further application-dependent response times of the sensors and actuators used must be added to obtain the total runtime.

Function	Response time [ms]	Explanation
Activation of a monitoring function by ENABLE with subsequent shut-off via digital output.	24*)	Activation of a monitoring function by the ENABLE signal.
Activation of a monitoring function by ENABLE with subsequent shut-off via safety relay.	47*)	Activation of a monitoring function by the ENABLE signal.
Response of an already activated **monitoring function** including PLC processing for position and speed processing via digital output.	16*)	With a monitoring function already activated via ENABLE, the module requires one cycle to calculate the current velocity value. In the next cycle, after the monitoring function has been calculated, the information is processed further and output by the PLC, i.e. according to the implemented logic, this leads, for example, to the switching of an output.

Function	Response time [ms]	Explanation
Response of an already activated **monitoring function** including PLC processing for position and speed processing via safety relay.	39*)	With a monitoring function already activated via ENABLE, the module requires one cycle to calculate the current velocity value. In the next cycle, after the monitoring function has been calculated, the information is processed further and output by the PLC, i.e. according to the implemented logic, this leads, for example, to the switching of an output.
Activation of digital output via digital input	16	Activation of an input and switching of the output
Activation of relay output 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 of relay output via digital input	47	Deactivation of an input and thus deactivation of the output
Averaging filter (for setting see JetSafe encoder dialog)	0 … 64	Group runtime of the averager. This runtime only affects monitoring functions related to position/speed/acceleration, but not logic processing.

Note:
*) When using an averaging filter, its response time must also be added.

7.2 Response times for FAST_CHANNEL

FAST_CHANNEL is a feature of the JSCM-110 module to react faster to speed requests than this would be possible with the processing of the safety programs in the normal cycle (= 8 msec). The FAST_CHANNEL sampling time is 2 msec.

The following response times can be specified:
4 ms (worst case condition)

⚠ **Safety precaution:**

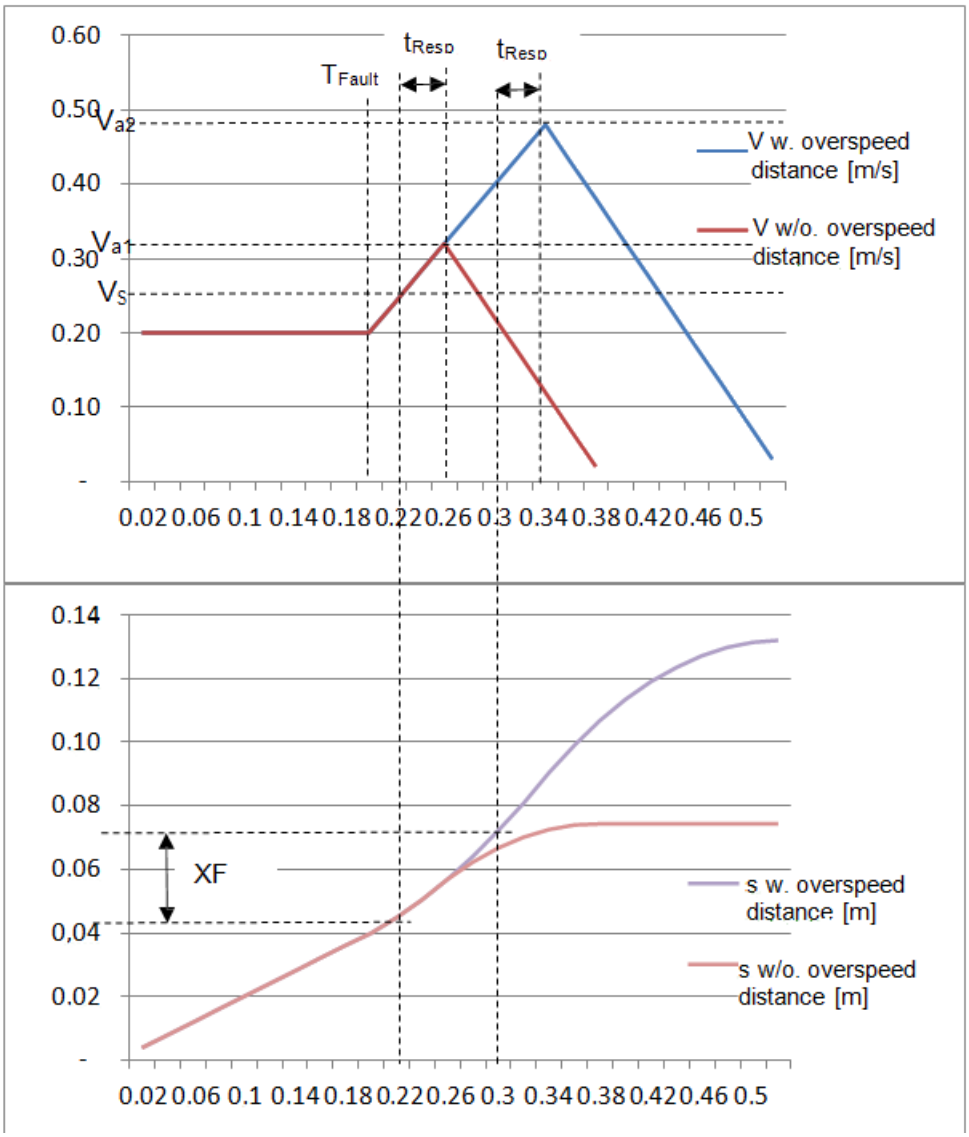
- When using the FAST_CHANNEL, please note that a shut-off in the time specified above for a specified speed threshold can only take place if the sensor information has a sufficient resolution. The smallest resolvable switching threshold of the FAST_CHANNEL requires at least 2 edge changes at the respectively selected sensor system within a time of 2 msec.
- This function is only possible when used with safe semiconductor outputs.
- The FAST_CHANNEL must not affect SSI listeners

7.3 Response Times for Fault Distance Monitoring

For calculating the worst-case condition the following calculation scheme applies:

System speed at sampling time: V(t)
System speed in case of JSC-110 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
Delay after shut-off: a_V = constant for all t
Sampling time for occurrence of a worst case event: T_{Fault}
Response time of the JSC-110 system: $t_{Response}$

For the worst-case assessment, it is assumed that the drive initially moves at a velocity v(k) exactly at the parameterized threshold v0 and then accelerates with the maximum possible value a0.



Graph: Behavior of the drive with/without overspeed distance

Without overspeed distance the following correlations result for the curves V and s:

Parameter	Calculation method	Comment
$t_{Response}$	Specified JSC-110 response time + delay time in external shutdown chain	Delay time in external shutdown chain based on specification of relay/ contactor, brake manufacturer, etc.
a_F, a_V	n.a.	Estimation for application
V_{a1}	= V_S + a_F * $t_{Response}$	

For the curves V and s with overspeed distance the following applies:

Parameter	Calculation method	Comment
$t_{Response}$	Specified JSC-110 response time + delay time in external shutdown chain	Delay time in external shutdown chain based on specification of relay/ contactor, brake manufacturer, etc.
a_F, a_V	n.a.	Estimation for application
V_{a2}	$= a_F * t_{Response} + (V_S^2 + 2 * a_F * XF)^{1/2}$	

The effect of the filter shifts the set velocity threshold V_a upwards by the amount **delta_v_filter**. For the application, the new values for the response time ($t_{Response} = T_{JSC-110} + T_{filter}$), as well as the resulting speed when switched off by the JSC-110 module must be taken into account.

7.4 Response times when using the JSX1-DIO22

The basis for the calculation of response times is the cycle time of the JSC-110 system. This is **T_cycle = 8 ms** in operation. The specified response times correspond to the respective maximum time for the specific application within the JSC-110 module. Depending on the application, further application-dependent response times of the sensors and actuators used must be added to obtain the total runtime.

Function	Designation	Response time [ms]	Explanation
Worst case delay time between input in basic module and PMI	T_{IN_BASE}	10	e.g. activation of a monitoring function by an input signal in the basic module
Worst case delay time between JSX1-DIO22 input and PMI in basic module	T_{IN_31}	18	e.g. activation of a monitoring function by an input signal in the JSX1-DIO22 expansion module
Processing time from PMI to PMO in the basic module	T_{PLC}	8	Shutdown by a monitoring function or by an input in the PMI
Activation/deactivation of a digital output in basic module by PMO	T_{OUT_BASE}	-	Activation or deactivation of an output in the basic module after changes to the PMO
Activation/deactivation of a digital output in an expansion module via PMO in the basic module	T_{OUT_31}	8	Activation or deactivation of an output in the JSX1-DIO22 expansion module after a change to the PMO of the basic module

Calculating the Total Response Time

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

Example 1:
Input on expansion module, activation of SLS and processing in PLC, output on basic module

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

Example 2:
Input on basic module, activation of SLS and processing in PLC, output on expansion module

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

Example 3:
Input on expansion module, activation of SLS and processing in PLC, output on expansion module

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

8 Commissioning

8.1 Procedure

Commissioning may only be carried out by qualified personnel!
Strictly follow the safety advices during commissioning!

8.2 Power-up Sequence

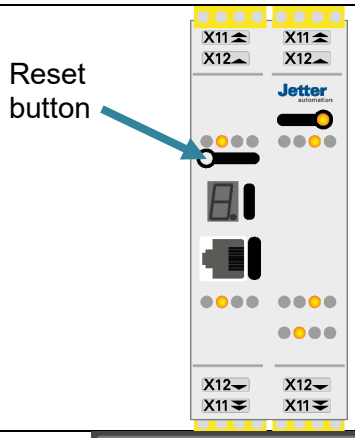
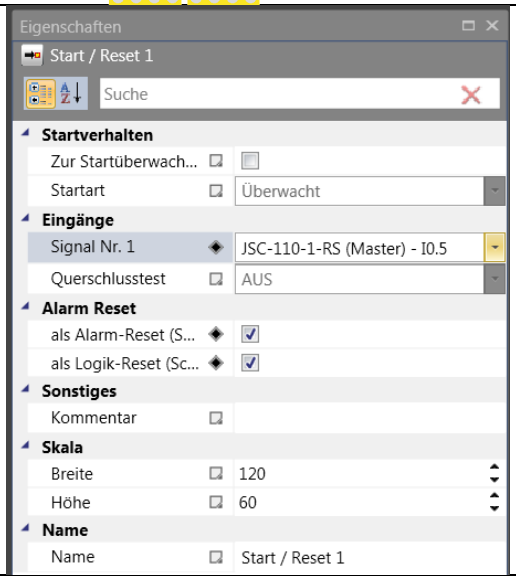
Each time the module is powered up, it goes through the following phases and displays the status on the front seven-segment display:

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 rechecking of this data. Then range check of the configuration data.
„3“	STARTUP BUS	If available, initialization of a bus system
„4“	RUN	Normal operation of the system. All outputs are switched according to the current state of the logic.
„5“	STOP	In stop mode, external parameter and program data can be loaded.
„A“	ALARM	An alarm can be reset via digital input or the Reset button.
„E“	ECS alarm	An ECS alarm can be reset via digital input or the Reset button.
„F“	Error	An error can only be reset by power-cycling (OFF/ON) the module.

8.3 Reset Behavior

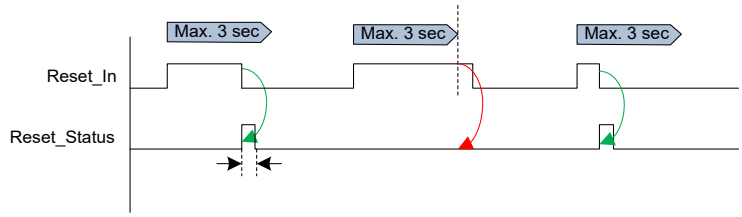
The reset function is divided into a start-up function after power-cycling = General Reset and a status/alarm reset = Internal Reset. The internal reset is triggered by pressing the pushbutton on the front or by a correspondingly configured input = reset element with activated "alarm reset" function. The table below gives an overview of the reset functions and their effect.

8.3.1 Reset types and triggering element

Reset type	Triggering element	Comment
General Reset	Voltage recovery/device start-up	Reset function after a complete power OFF/ON of the device
Internal Reset		The internal reset is triggered by pressing the reset button on the front panel
		Configuration of a reset input in the Properties window

8.3.2 Reset Timing

The reset input for the internal reset is time monitored in "RUN" mode. An internal reset is triggered with falling edge of the reset input under the condition T < 3 s between rising/falling edge.

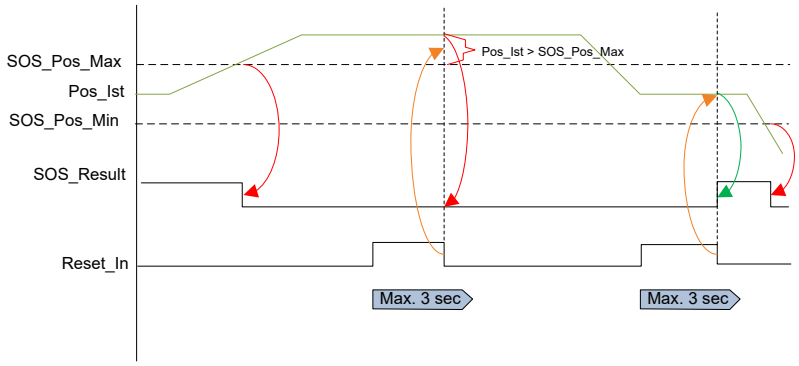


8.3.3 Reset function

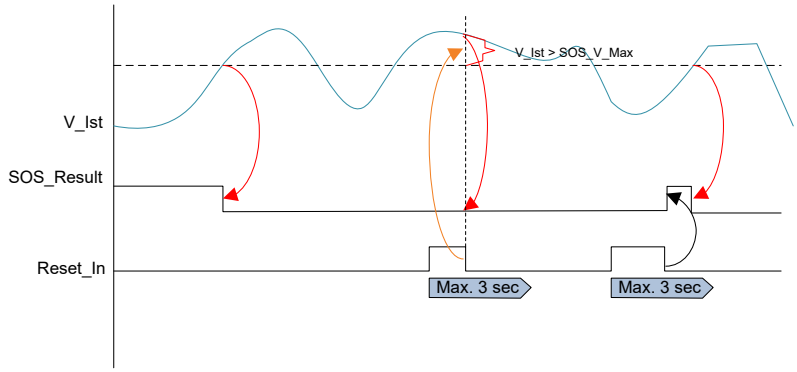
Functional Unit	General Reset	Internal Reset	Function
Fatal Error	X		Resetting the failure
Alarm	X	X	Resetting the alarm
Monitoring functions	X	X	Resetting a triggered monitoring function
Flip-flop	X	X	Status = Reset
Timer	X	X	Timer = 0

The status of the monitoring functions is formed anew after a reset

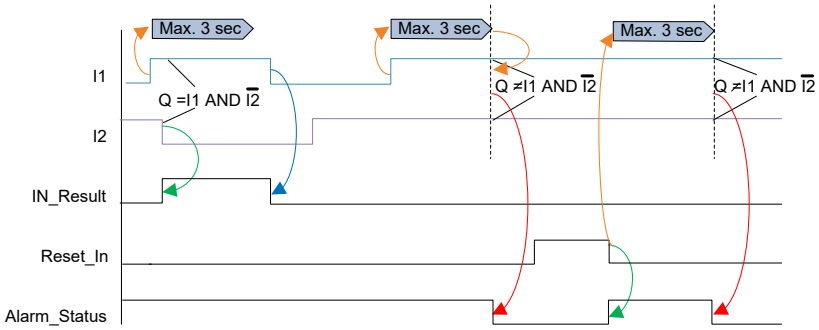
- Process values do not lead to a change in the output status of the monitoring function if their parameterized limits are exceeded.
- Time-based functions - Timers result in a reset of the output status of the monitoring function. A response only occurs if the parameterized limit values are exceeded again.



Process value (position) => no change of output status in case of reset in alarm state



Process value (speed) => no change of output status in case of reset in alarm state



Time-based function => reset of the initial state, response when the limit is exceeded again

⚠Safety precaution:

- In the case of time-based functions, e.g. time-based monitoring of complementary input signals, the initial state is reset and a state defined as faulty is only detected when the (time-based) limit value is exceeded again.
- To protect against incorrect use, such as repeated triggering of the reset function to bypass an alarm condition, adequate measures must be implemented in the application program (PLC program).

8.3.3.1 Example: Reset function with protection against incorrect use

Function:

On a machine, the hazardous area is to be protected in normal operation by a mechanical guard system and in set-up operation by an enabling switch in conjunction with standstill monitoring and safely limited speed.

An electrical sensor monitors if the guard is closed. When the safety guard is open, the axis can only be moved with the enabling switch actuated.

In the program, this is implemented by a "Safety Door" function (2-channel with time monitoring) and an "Enabling Switch" function.

The logic signal "Safety Door" is generated by means of input preprocessing with complementary inputs and time monitoring. The time monitoring of this element is fixed at 3 seconds.

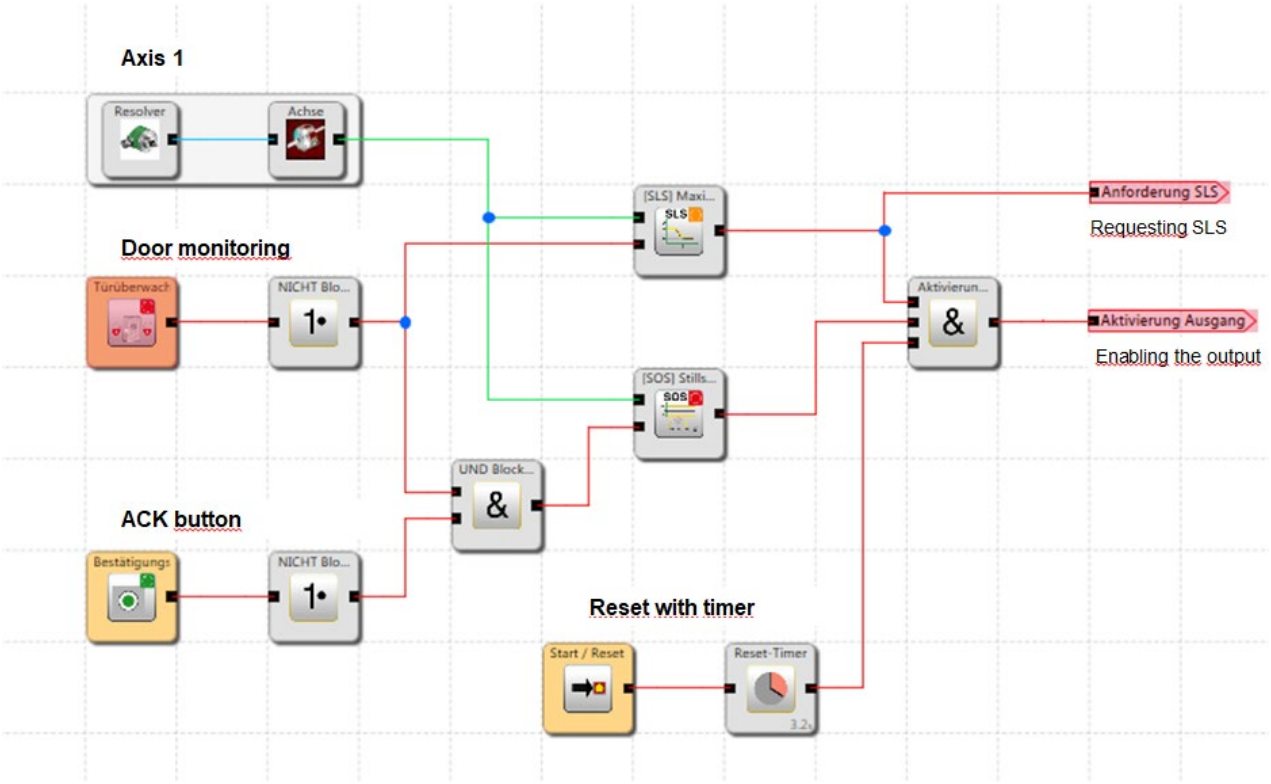
When the safety door is open (signal "LOW" at switch output X23.1 and X23.2), the axis can be moved at reduced speed if it is enabled.

Problem:

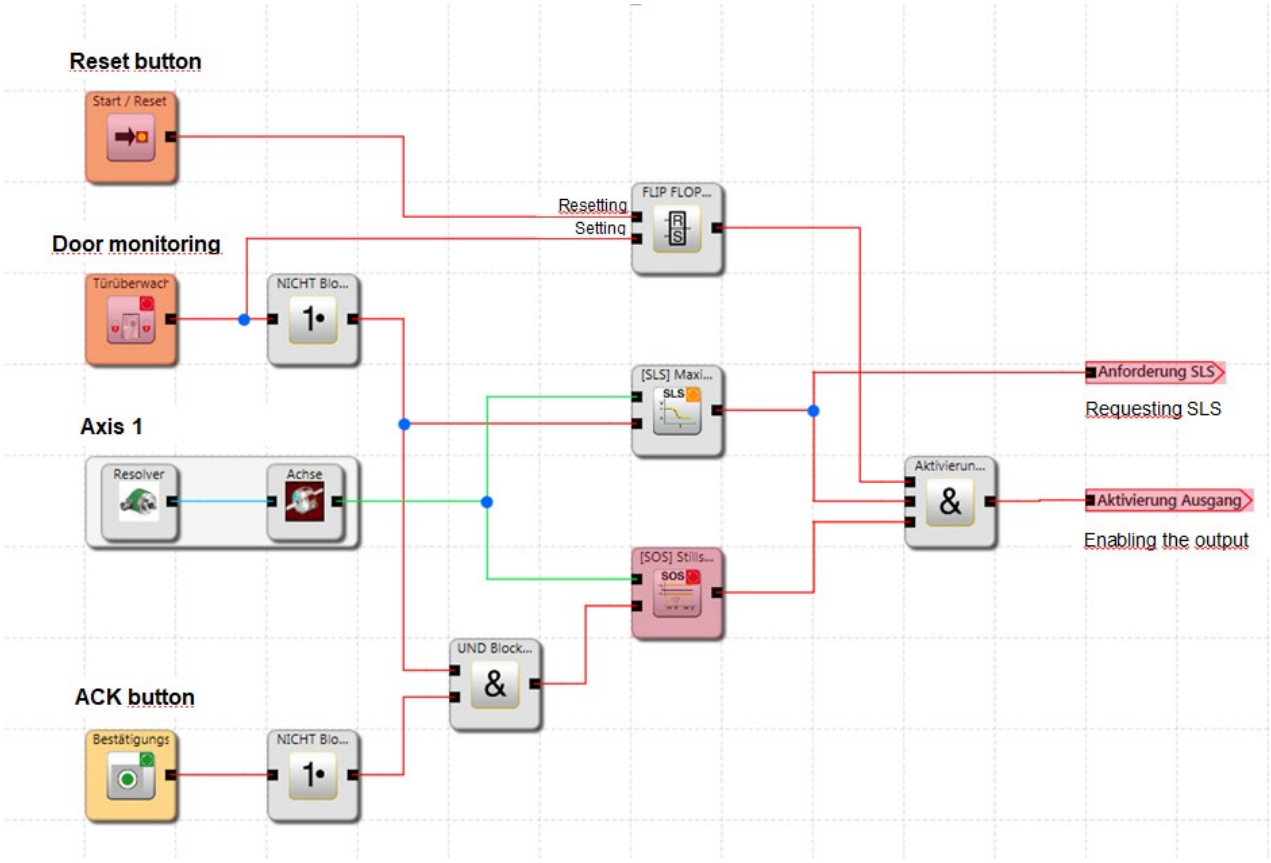
If a "Short between contacts" is simulated at the "Safety Door" input, the JSC-110 module displays alarm 6701.
This fault can be acknowledged and the "Safety Door" signal remains correctly at "0".
After the time monitoring of 3 seconds has elapsed, alarm 6701 is triggered again.
If the enabling switch is pressed during this period, the axis can be moved again for 3 seconds.

Measure in the application program:

A logic operation in the application program prevents the outputs from being activated through a time bypass.



Example 1:
The enable function of the outputs is additionally combined with a "Reset Timer". This timer prevents the activation of the outputs after a reset for t > 3 sec => the time monitoring function is not affected.



Example 2:
The enable function of the outputs (ID 88) is additionally combined with a flip-flop. This prevents the activation of the outputs after a reset and pending fault in the input circuit. The outputs are only enabled after an fault-free input signal has been applied once.

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	Permanently lit	Fatal Error

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

8.5 Parameterization

Parameterization is carried out in the JetSafe programming tool. To be able to upload the data to the module, a programming adapter is required. Before you can use the adapter, you must install its drivers first.
For a description of the parameterization, see the *Programming Manual*.

8.6 Functional Test

To ensure the safety of the module, a functional test of the safety functions must be carried out once a year. For this purpose, the blocks used in the parameterization (inputs, outputs, monitoring functions and logic blocks) must be tested for function or shut-off.
See *Programming Manual*.

8.7 Validation

To ensure the implemented safety functions, the user must check and document the parameters and logic operations after commissioning and parameterization. This is supported by the validation wizard in the programming interface (see chapter Safety-related Test).

9 Safety test

To ensure the implemented safety functions, the user must check and document the parameters and logic operations after commissioning and parameterization.

This is supported by the JetSafe parameterization software (see Programming Manual).

On the first two pages you can enter general information about the system.
On the following pages of the validation report, all functions used are printed with their parameters as an itemized proof of the safety-related test.

After the configuration and program data have been transferred to the JSC-110 module, the status LED flashes yellow. This indicates that the configuration data has not yet been validated. By pressing the "LOCK CONFIGURATION" button at the end of the validation dialog, the data are marked as "Validated" and the LED flashes in green.

10 Maintenance

10.1 Modification/Handling of Changes to the Device

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

Repairs
Devices must always be replaced as whole units.
The device can only be repaired in the manufacturer's factory.

Guarantee
Unauthorized opening of the module will void the warranty.

Note:
Any modification of the module will invalidate the safety approval!

10.2 Replacing a Module

When replacing a module, the following should be observed:

- Disconnect the power converter from the main supply.
- Switch off the power supply for the device and disconnect it.
- Disconnect the encoder plugs.
- Disconnect all other pluggable connections.
- Remove the module from the top-hat rail (DIN rail) and pack it according to EMC rules.
- Mount the new module on the DIN rail.
- Restore all connections.
- Switch on the power converter.
- Switch on the supply voltage.
- Configure the device.

Note:
As a rule, pluggable connections of the JSC-110 module must not be disconnected or reconnected while they are live. Failure to do so may destroy connected position or speed sensors.

10.3 Maintenance Intervals

Module replacement	See "Technical Data"
Functional Test	See chapter "Commissioning"

11 Technical specifications

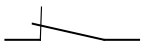
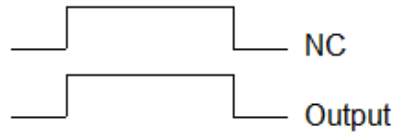
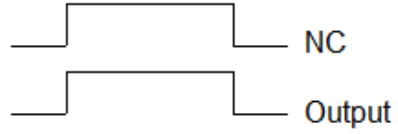
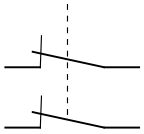
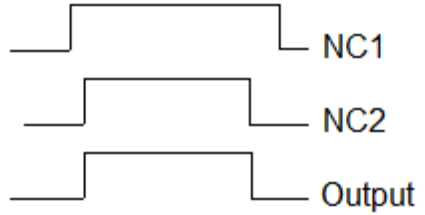
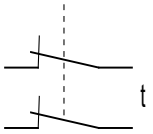
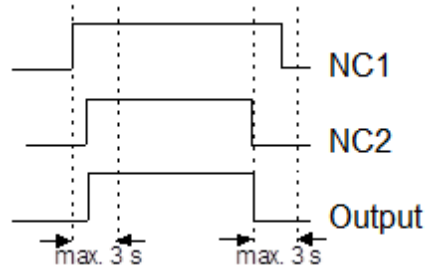
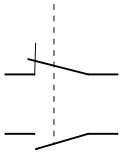
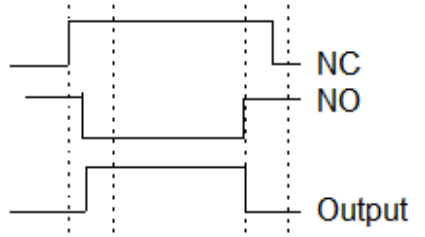
11.1 Environmental conditions

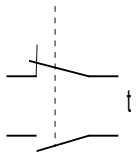
Protection class	IP 20
Ambient temperature	0 °C* ... 50 °C
Climatic category	3k3 acc. to DIN 60721
Minimum, maximum relative humidity (no condensation)	5 % ... 85 %
Overvoltage category	III
Pollution degree	2
Use of equipment	2000 m

11.2 Safety specifications

Max. achievable safety class	• SIL 3 according to EN 61508 • Category 4 according to EN ISO 13849-1 • Performance level PL e according to EN ISO 13849-1	
System structure	2-channel with diagnostics (1002) according to IEC61508 Architecture category 4 according to EN ISO 13849-1	
Design of the operating mode	"high demand" according to IEC 61508 (high demand rate)	
Probability of an endangering failure per hour (PFH value) Applicable values according to the tables on safety specifications	JSC-110	PFH = 12.6 FIT
	JSC-110-1-RS	PFH = 12.6 FIT
	JSC-110-2-RS	PFH = 12.6 FIT
	JSX1-DIO22	PFH = 9.2 FIT
Proof-test interval (IEC 61508)	20 years, after that the module must be replaced	

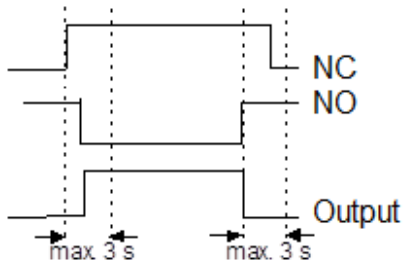
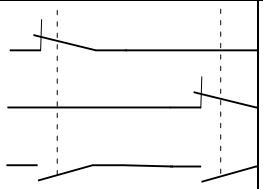
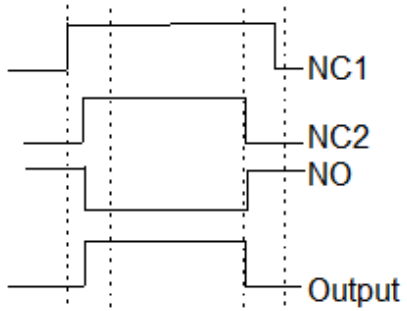
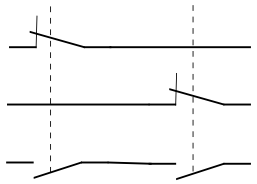
12 Switch Types

Type	Switching symbol	Truth table	Logic function	Function block	Function	
1	 eSwitch_1o	NC | A 0 | 0 1 | 1	LD E.1 ST IE.X		Normally open, in illustration only shown normally closed	
2	 sSwitch_1s	S | A 0 | 0 1 | 1	LD E.1 ST IE.X		Normally open, as type 1	
3	 eSwitch_2o	Ö1 | Ö2 | A 0 | 0 | 0 1 | 0 | 0 0 | 1 | 0 1 | 1 | 1	LD E.1 AND E.2 ST IE.X		AND operation of both inputs	
4	 eSwitch_2oT	Ö1 | Ö2 | A 0 | 0 | 0 1 | 0 | 0 0 | 1 | 0 1 | 1 | 1	LD E.1 OR E.2 ST META_EN.1 LD E.1 AND E.2 ST METB_EN.1 LD MET.1 ST IE.X	Time monitoring MET1..MET4	Same as 3, but with time monitoring of state changes. When signals change at NO or NC complementary, a complementary signal must follow within time t=3 s. If not, error is detected and Out=0	
5	 eSwitch_1s1o	S | NC | A 0 | 0 | 0 1 | 0 | 0 0 | 1 | 1 1 | 1 | 0	LD E.1 AND NOT E.2 ST IE.X		Monitoring for NO=inactive and NC=active	

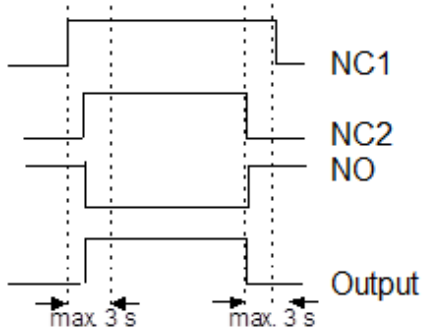
<table>
<tr>
<td>6</td>
<td> 

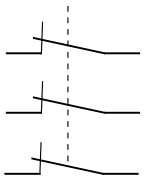
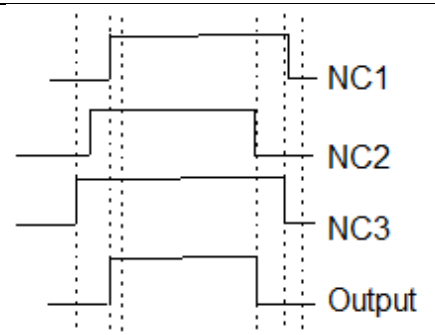
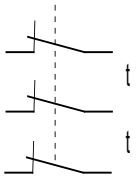
eSwitch_1s1oT</td>
<td>
<table>
<tr><th>S</th><th>NC</th><th>A</th></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
</table>
</td>
<td>LD E.1
OR NOT E.2
ST META_EN.1

LD E1
AND NOT E2
ST METB_EN.1

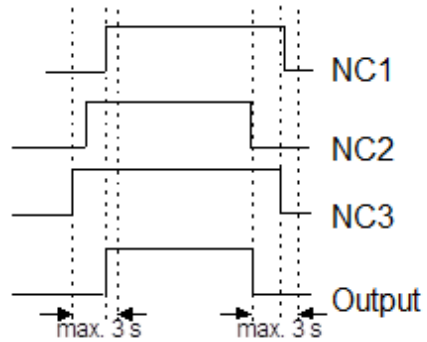
LD MET.1
ST IE.X</td>
<td>Time monitoring
MET1..MET4</td>
<td>Same as 5, but with time monitoring of state changes.
When signals change at NO or NC complementary, a complementary signal must follow within time t=3 s. If not, error is detected and Out=0</td>
<td> 
</td>
</tr>
<tr>
<td>7</td>
<td> 
eSwitch_2s2o</td>
<td>
<table>
<tr><th>S1</th><th>Ö 1</th><th>S2</th><th>Ö2</th><th>A</th></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
</table>
</td>
<td>LD E.1
AND E.2
AND NOT E.3
ST IE.X</td>
<td></td>
<td>Monitoring for NO1*NO2=inactive and NC1*NC2=active</td>
<td> 
</td>
</tr>
<tr>
<td>8</td>
<td> 
eSwitch_2s2oT</td>
<td>
<table>
<tr><th>S1</th><th>Ö 1</th><th>S2</th><th>Ö2</th><th>A</th></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
</table>
</td>
<td>LD E.1
OR E.2
OR NOT E.3
ST META_EN.1

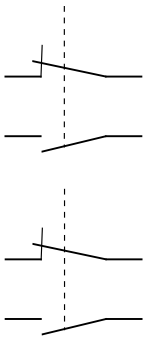
LD E.1
AND E.2
AND NOT E.3
ST METB_EN.1

LD MET.1
ST IE.X</td>
<td>Time monitoring
MET1..MET4</td>
<td>Same as 6, but with time monitoring of state changes.
When the signal changes at NO (attention: common line!) or NC, the complementary signal must follow within time t=3 s. If not, error is detected and Out=0</td>
<td> 
</td>
</tr>
</table>

<table>
<tr>
<td>9</td>
<td> 
eSwitch_3o</td>
<td>
<table>
<tr><th>Ö1</th><th>Ö2</th><th>Ö3</th><th>A</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>
</td>
<td>LD E.1
AND E.2
AND E.3
ST IE.X</td>
<td></td>
<td>AND operation of the 3 inputs</td>
<td> 
</td>
</tr>
<tr>
<td>10</td>
<td> 
eSwitch_3oT</td>
<td>
<table>
<tr><th>Ö1</th><th>Ö2</th><th>Ö3</th><th>A</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>
</td>
<td>LD E.1
OR E.2
OR E.3
ST META_EN.1

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

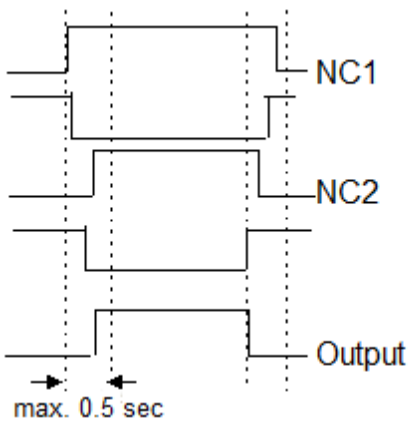
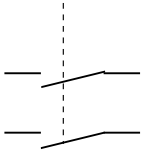
ST IE.X</td>
<td>Time monitoring MET1..MET4</td>
<td>Same as 8, but with time monitoring of state changes.
If there is a signal change at one of the NC inputs, the other inputs must follow within time t=3 s. If not, error is detected and Out=0</td>
<td> 
</td>
</tr>
</table>

<table>
<tr>
<td>11</td>
<td> 
eTwoHand_2o</td>
<td>
<table>
<tr><th>Ö 1</th><th>S 1</th><th>Ö 2</th><th>S 2</th><th>A</th></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
</table>
</td>
<td>LD NOT E.1
OR E.2
OR NOT E.3
OR E.4
ST MEZ_EN.1

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

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

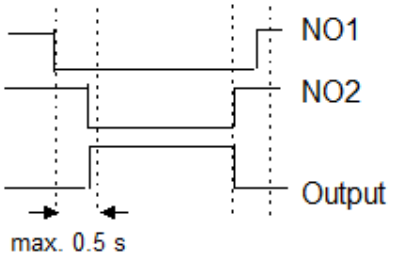
LD MEZ.1
ST IE.X</td>
<td>Two-hand operation
MEZ</td>
<td>Monitoring for NO1*NO2=inactive and NC1*NC2=active + time monitoring of this state. I.e. if the signal of an NO changes from 1->0 or NC from 0->1, then the further signals (i.e. subsequent NO=0, or NC=1) must follow within 0.5 s.
If not, the output remains 0.

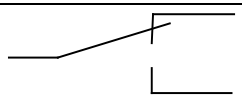
Malfunctions are not evaluated! No time monitoring when changing to inactive state.</td>
<td> 
</td>
</tr>
<tr>
<td>12</td>
<td> 
eTwoHand_2s</td>
<td>
<table>
<tr><th>S1</th><th>S2</th><th>A</th></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table>
</td>
<td>LD E.1
OR E.2
ST MEZ_EN.1

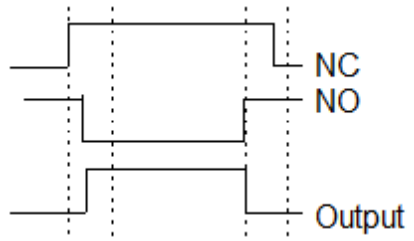
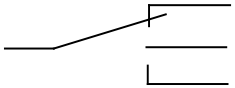
LD NOT E.1
AND NOT E.2
ST MEZ_EN.2

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

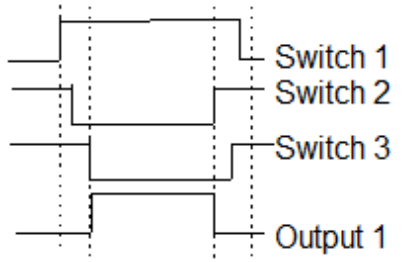
LD MEZ.1
ST IE.X</td>
<td>Two-hand operation
MEZ</td>
<td>Monitoring for NO1*NO2=inactive + time monitoring of this state. I.e. if the signal of an NO changes from 1->0, then the further signal (i.e. subsequent NO=0) must follow within 0.5 s.
If not, the output remains 0.

Malfunctions are not evaluated! No time monitoring when changing to inactive state.</td>
<td> 
</td>
</tr>
</table>

<table>
<tr>
<td>13</td>
<td> 
eMode_1s1o</td>
<td>
<table>
<tr><th>S1</th><th>S2</th><th>A 1</th><th>A 2</th></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>LD E.1
AND NOT E.2
ST IE.X1

LD NOT E.1
AND E.2
ST IE.X2</td>
<td>Selector switch</td>
<td>Clear linkage of the permissible switch positions</td>
<td> 
</td>
</tr>
<tr>
<td>14</td>
<td> 
eMode_3switch</td>
<td>
<table>
<tr><th>S1</th><th>S2</th><th>S3</th><th>A 1</th><th>A 2</th><th>A 3</th></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>LDN E.1
AND NOT E.2
AND NOT E.3
ST IE.X1

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

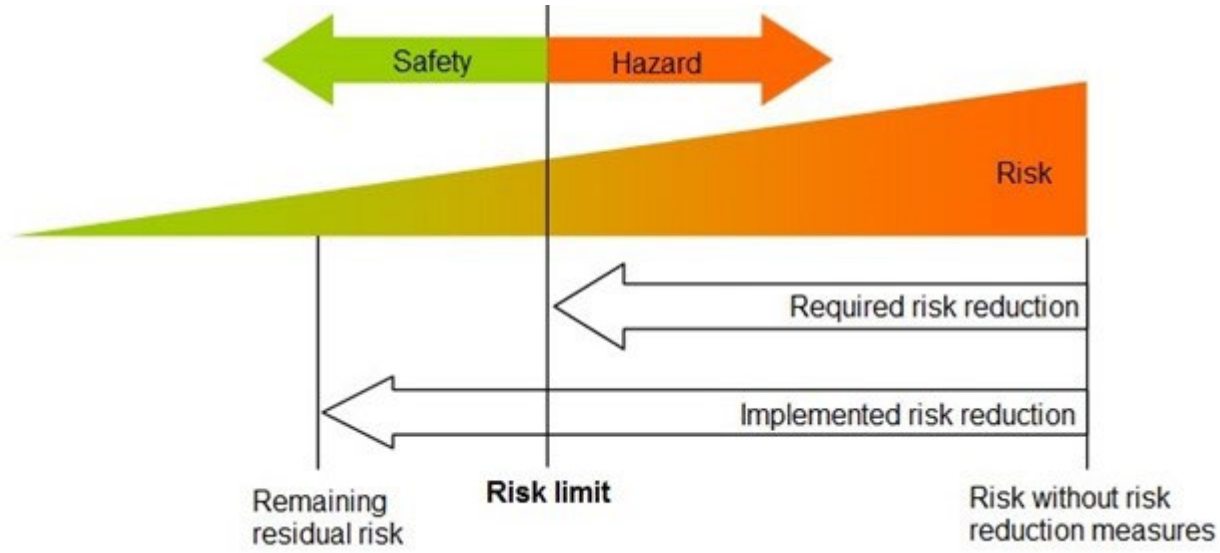
LDN E.1
AND NOT E.2
AND E.3
ST IE.X3</td>
<td>Selector switch</td>
<td>Clear linkage of the permissible switch positions</td>
<td> 
</td>
</tr>
</table>

13 Notes on designing, programming, validating and testing safety applications

The following notes describe the procedure for designing, programming, validating and testing safety applications.
The notes are intended to help the user to classify, easily understand and apply all steps from risk assessment to system testing. For a better understanding of the respective aspects, the individual steps are explained in more detail using examples.

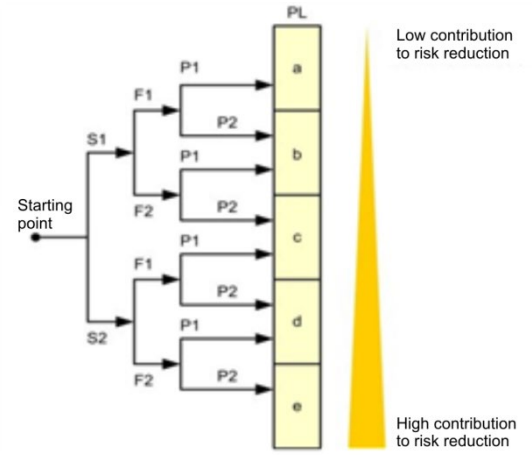
13.1 Risk assessment

In principle, the manufacturer of a machine must guarantee the safety of a machine designed or supplied by him. The assessment of safety must be based on the relevant directives and standards applicable. The objective of the safety assessment and the measures derived from it must be to reduce the risk to persons to an acceptable level.



The analysis of hazards must take account of all the operating conditions of the machinery, such as operation, setup work and maintenance or installation and decommissioning, as well as reasonably foreseeable misuse.
The procedure for risk assessment required for this purpose and the measures to reduce it can be found, for example, in the relevant standards:
EN ISO 13849-1 Safety of machinery
IEC 61508 Functional safety of electrical, electronic, programmable electronic safety-related systems

Risk assessment according to EN ISO 13849-1

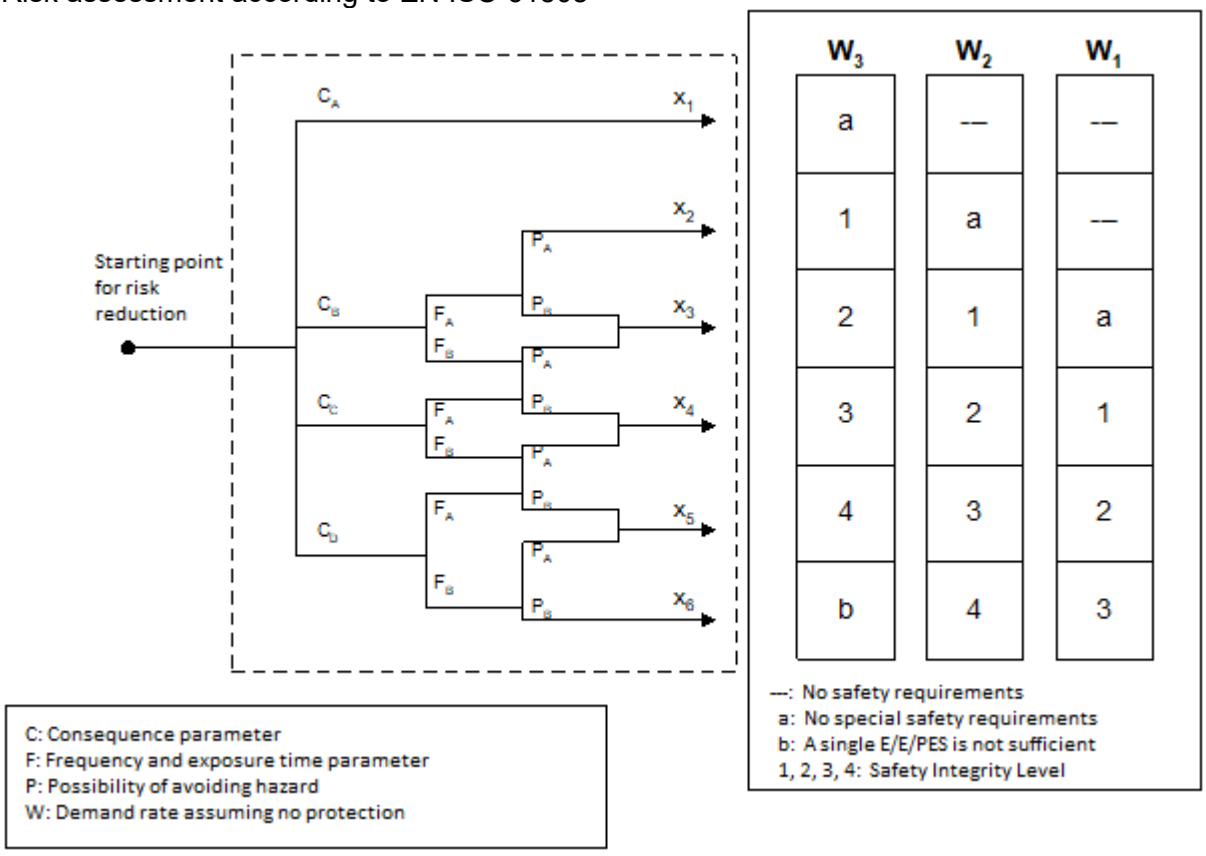


S - Severity of the injury
S1 = Minor, reversible injury
S2 = Severe, irreversible injury

F - Frequency and/or duration of exposure to the hazard
F1 = Seldom, not cyclic
F2 = Frequent to permanent and/or long duration, cyclic operation

P - Possibility of avoiding the hazard
P1 = Possible, slow movement/acceleration
P2 = Hardly possible, high acceleration in case of fault condition

Risk assessment according to EN ISO 61508



The risks to be considered can be found in relevant directives and standards, or must be considered separately by the manufacturer on the basis of his specific knowledge of the machine.
For machines placed on the market within the EU, the lowest risks to be considered are specified in the EU Machinery Directive 2006/42/EC or in the latest valid version of this directive.
Further information on risk assessment and the safe design of machinery can be found in the following standards:
EN 14121 Safety of machinery - Risk assessment
EN 12100 Safety of machinery - Basic concepts, general principles for design

.
Measures applied to reduce identified hazards must be at least of the same level as those of the hazard itself. Such measures and the associated requirements are also included as examples in the above-mentioned directives and standards.

13.2 Required Technical Documents

The manufacturer shall provide various technical documents. Their minimum scope is also specified in the relevant directives and standards.
For example, according to the EU Machinery Directive, at least the following documents must be provided:

1. The technical file shall comprise the following:

a) a construction file including:

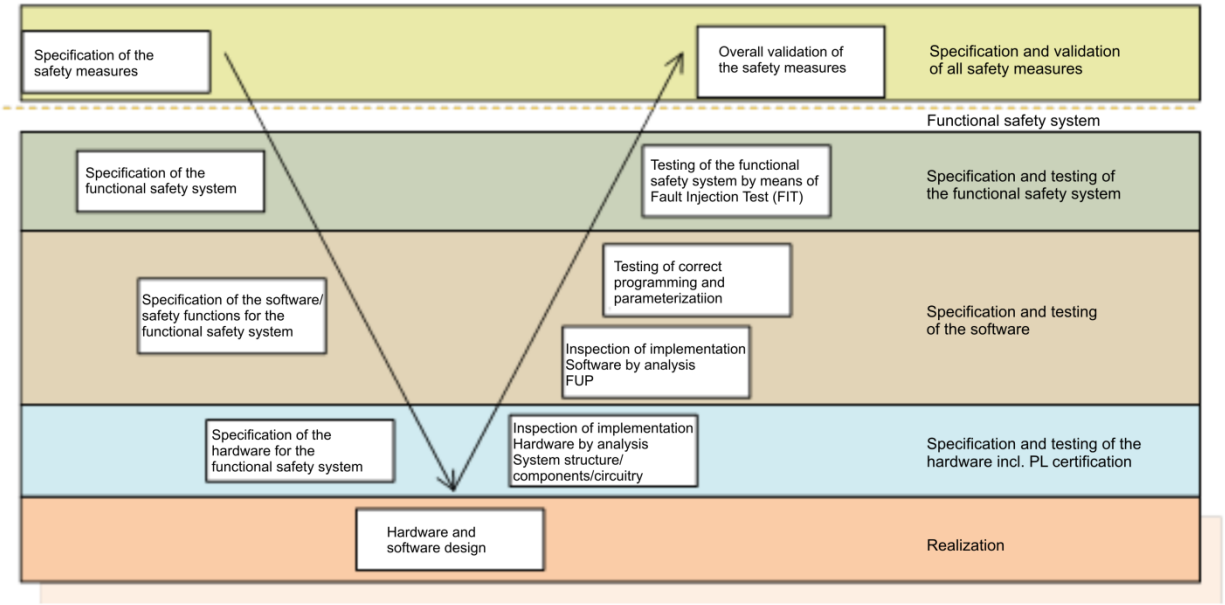
- a general description of the machinery,
- the overall drawing of the machinery and drawings of the control circuits, as well as the pertinent descriptions and explanations necessary for understanding the operation of the machinery,
- full detailed drawings, accompanied by any calculation notes, test 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 authorized 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 written in the language of the corresponding country.

13.3 Necessary steps for design, realization and testing

The realization of plant components with safety functions requires special care in planning, realization and testing. For this purpose, guidelines are also contained in the relevant standards (cf. EN ISO 13849-2, or IEC 61508). The effort required depends on the complexity of the task for plant components with safety functions.
For the implementation of such functions with the aid of safety-related control and monitoring functions, the JSC-110 series offers efficient support through its system architecture (architecture Cat. 4 according to EN ISO 13849-1) and above all through the programming language and through tested safety functions. Programming is carried out in the form SFC (Sequential function chart oriented programming) recommended by the safety standards. It further meets the requirements of a programming language with limited variability (LVL) for which significant simplifications in documentation and test scope apply.
In any case, the individual steps require careful planning and analysis of the methods and systems used. In addition, the individual steps must be documented in a way that is easy to understand.
V-Model (simplified)
The implementation of safety functions requires a structured approach, such as the V-model recommended in the relevant standards. The following is an example of the procedure for applications involving modules of the JSC-110 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 taken, such as covers, barriers, maximum machine parameters, safety functions, etc.	Checking of all passive and active safety measures for their proper implementation and effectiveness
Specification of the functional safety systems	Specification of the active safety systems and their allocation to the risks to be reduced, e.g. reduced speed in set-up mode, stop mode, monitoring of access areas, etc. Specification of the PLr or required SIL for each individual safety function.	Testing of all active safety systems for their effectiveness and compliance with the specified parameters such as incorrectly increased speed, incorrect stop, response of monitoring devices, etc. by means of practical tests
Specification of software/safety functions	Specification of the functionality of the individual safety functions, including definition of the shut-off circuit etc. Definition of the parameters for the individual safety functions, such as max. speed, deceleration ramps and stop category, etc.	Verification of the correct implementation of the functional specifications through analysis of the SFC programming. Validation of the application program and the parameters by comparison of validation report with SFC or parameter specifications.
Hardware specification	Specification of the system design and the functions of the individual sensors, control devices, control system components and actuators with regard to the safety functions.	Verification of the correct implementation of the specifications. Determination of the failure probability or PL by means of analysis of the overall architecture and the specifications of all components involved, in each case related to the individual safety functions.
Hardware and software design	Concrete planning and implementation of the plant structure/wiring. Concrete implementation of the safety functions by programming in SFC.	nil

13.3.2 Specification of safety requirements (structural schematic)

On the basis of the standards to be applied, e.g. product standards, the safety requirements must be analyzed in detail.

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)
- Behavior of the machine when the safety function is triggered
- Conditions to be observed for re-starting
- Performance criteria/performance data
- Process (timing behavior) 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 Behavior at switch-on, implementation of the required starting and restarting behavior
- 5.5 Performance data: cycle times, response times, etc.
- 5.6 Behavior of the SRP/CS in the event of component failures and faults (achieve and maintain the safe state), including timing behavior
- 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 $MTTF_a$ 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 on EN ISO 13849-1

Example: Automatic handling machine

Function description:
The automatic handling machine is used to automatically pick up truck cabins of different heights. After being picked up, the height of the cabin is reliably determined so that the cabin cannot be lowered below a certain height in the workers' area. The machine must not exceed a maximum speed in the workers' area. Once machining of the cabin is finished, it is put down at the end of the production line and the automatic handling machine returns to the beginning of the line via a return path to pick up another cabin …

Limits of the machine:
Spatial limits: In the worker's area there must be enough space for the workers to carry out all the necessary work on the cabin ... In the return path there must be enough space for the empty suspension gear of the handling machine ...
Temporal limits: Description of service life, description of aging processes that can lead to changes in machine parameters (e.g. brakes). Monitoring mechanisms must be implemented for such cases.
Limits of use: The machine automatically fetches new cabins and moves them through a machining area. There are workers in the machining area, … etc.
The following operating modes are defined: Setup mode, automatic mode, service mode, … etc.

Identification of hazards:
The following mechanical hazards are relevant for the automatic handling machine:
Hazard 1: Crushing due to departing cabin/lifting beam
Hazard 2: Impact from moving cabin/lifting beam
Hazard 3: Crushing due to the cabin being lowered too quickly in the event of a malfunction
Hazard 4:

Risk Analysis:
G1: The weight of the cabin and the lifting beam is so high that irreversible bruising or death can occur.
G2: Moving cabs/lifting beams can cause impacts that result in irreversible injuries.
G3: ….

Risk assessment:
A risk reduction is necessary taking into account all operating conditions.
Inherently (risks from the project) safe design.
Moving the cabin in x and y direction in the worker area is unavoidable. In the machining area, the cabin must be moved up/down and forward ….
The following measures can be taken:
Avoid hazards caused by movements that are too fast
Avoid hazards caused by too small distances
…….

Example:

Hazard analysis

Safety proof for declaration of manufacturer			Machine type Packaging 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

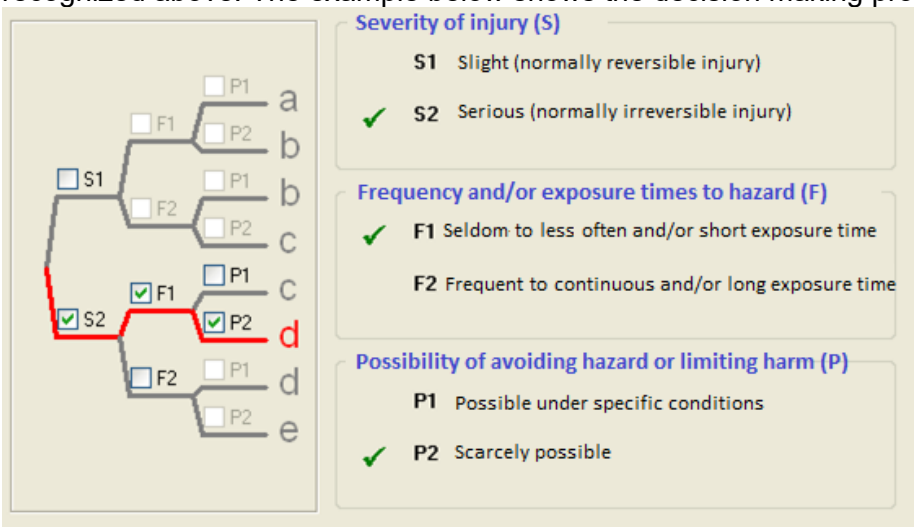
The active protective functions must be identified and specified on the basis of the general hazard and risk analysis of the machine.
Active protective functions are, for example, safely reduced speed in certain system states, monitored stop and standstill functions, area monitoring, processing of monitoring devices such as light curtain, pressure sensitive mats etc.
The safety functions must be defined in each case and the specific requirements in terms of function and safety level defined.

13.3.3.1 Definition of safety functions

The definition of the safety function must include:
specify the risk to be covered
describe the exact function
list all sensors and command devices involved
name all control units
denote the shut-off circuit triggered.
. The definition should serve as a basis for the specification of the hardware and software design.
For each of the safety functions defined in this way, any parameters to be used, such as maximum system speed in setup mode, etc., must be determined.
Examples of safety functions:
SF1: STO (safe torque-off) to protect against unintentional start-up
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 from the security functions SF1..... recognized above. The example below shows the decision making process.



Example for SF1: Result PF = d (source: Sistema)

13.3.3.3 Example – Specification of safety functions in table form

Cons. No.	Safety function	Ref from GFA	PI_r	Measured value/ sensor	Implementation in software	Target parameters	Input/activation	Response/ Output
1.1	Limitation of maximum travel speed of carriage to Monitoring the maximum speed.	2.3	e	1 x WCS absolute encoder 1 x incremental encoder on motor/drive wheel	Monitoring of fixed limits by means of tested safety function SLS:	550 mm/s Error distance monitoring: 200 mm	Permanently Reset: ACK button	Operational stop SF 1.7.1
1.2	Limitation of max. travel speed of carriage in workers' area. Monitoring of the maximum speed for < 0.33 m/s.	2.4	e	1 x WCS absolute encoder 1 x incremental encoder on motor/drive wheel	Monitoring of fixed limits by means of tested safety function SLS:	60 mm/s Error distance monitoring: 200 mm	Identification of workers' area through carriage position AND NOT setup mode. Reset: ACK button	SF 1.7.1
1.3	Limitation of maximum travel speed of carriage in setup mode. Monitoring of the maximum speed for < 0.07 m/s.	3.1	d	1 x WCS absolute encoder 1 x incremental encoder on motor/drive wheel	Monitoring of fixed limits by means of tested safety function SLS:	70 mm/s Error distance monitoring: 200 mm	Operating mode Setup AND button "Bridge safety". Reset: ACK button	SF 1.7.1
1.4	Collision protection of carriage Monitoring of the minimum distances between carriages by means of redundant laser distance measurement.	2.5	d	2 x laser distance measuring devices	Monitoring of the distances by means of tested SAC function. The analog measured values for distance are compared to each other for max. tolerance (diagnostics analog sensor). Monitored for minimum values (SAC function) Min. distance value is 25% of the max. value of measuring device		Carriage within the workers' area. Reset: ACK button	SF 1.7.1
1.6.1	Monitoring of carriage sensor system * of the two carriage sensors	5.1	e	1 x WCS absolute encoder 1 x incremental encoder on motor/drive wheel	Muting of diagnostics for both carriage sensors using tested SCA function. Muting is started before each gap, an incorrect encoder value is then briefly suppressed. In the gap, an encoder value outside 2 to 160000 mm leads to 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 elaborated specification of the security functions, provided that it includes all the specifications (see example under 13.3.3.3).
However, it is recommended to prepare an extracted list. This list should contain the following information:

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

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

Example of a software specification

Cons. No.	Safety function	PLr	Reading/sensor	Solution new	Input/ activation	Response/ output
1.4	Monitoring V_rope to V_set Monitoring of the difference between speed of main drive and rope drive for maximum value.	d	Digital incremental encoder, Tachogenerator rope pulley	Monitoring by means of tested function SLS + SAC with comparison of speed ranges/analog value ranges = comparison for diagnostics of speed detection 2-channel shut-off new (see below)	Permanently Reset: ACK button	Operational stop SF 1.3.1
1.6	Return stop Monitoring for return travel	d	Mechanical limit switch 22S2 Digital incremental encoder	Monitoring by means of tested function Direction monitoring SDI	EMERGENCY OFF (auxiliary contact 28K4 – revision run) Reset: ACK button	Operational stop SF 1.3.1
1.15	Step-by-step shut-off 3 Activation of the safety brake	e	-	Processing SF in JetSafe	SF 1.2 SF 1.3.2 SF 1.7 SF 1.8	Safety brake is set
1.8	Standstill functional	d	Digital incremental encoder	Still stand monitoring by means of tested function SOS	Motor power disable OR service brake is set	SF 1.15/ Safety brake is set
1.9	Direction monitoring	e	Digital incremental encoder	Monitoring by means of tested function Direction monitoring SDI	28K1 = NEXT 28K2 = BACK = safe signals from controller "Frey"	Operational 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 here with their applicable specifications. The hardware specification serves as the basis for determining the achieved security level on the basis of the architecture and the specifications of all devices involved in a safety function.
The hardware specification must also specify the design measures for protection against systematic and common-cause errors.

13.3.5.1 Selection of SRP/CS and equipment

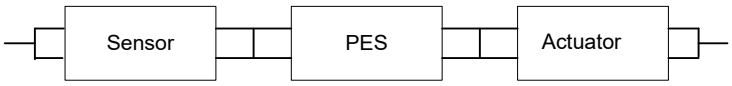
The selection of the SRP/CS (Safety-related parts of control system) shall be appropriate to achieve the desired level of safety for each safety function. In a total overview of the system design, components with safety-relevant functions shall be designated and assigned to the individual safety functions. For these components, the safety-related figures are to be determined.

These figures include the following values:

$MTTF_d$ = Mean Time To Failure - the mean time to a dangerous failure
DC_{avg} = Average diagnostic coverage
CCF = common cause failure - failure due to a common cause

In the case of SRP/CS, the software and systematic errors must also be considered.

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



13.3.5.2 Example of hardware specification

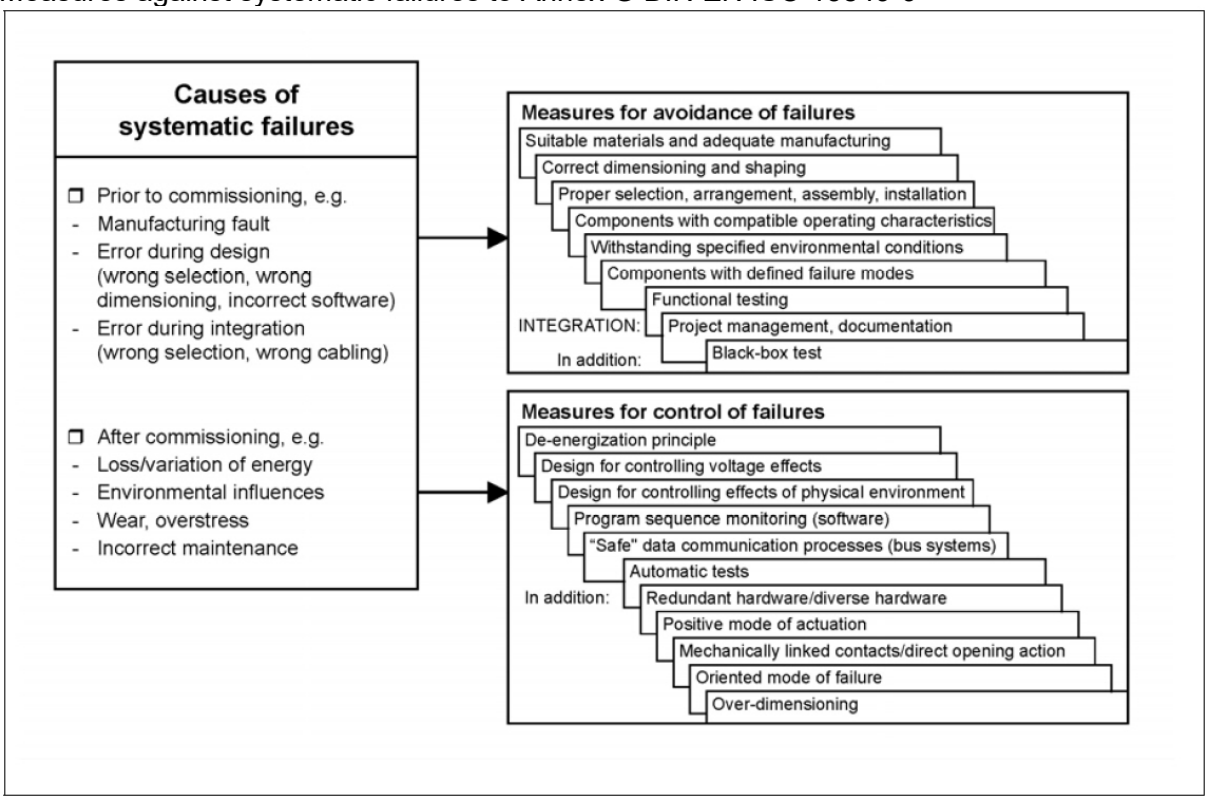
Safety function		Safely limited speed	SF 2.2	Safely monitored limited speed with door open							
Type	Designation	Function	Desig-nation	Specifications							Comment
				Archi-tecture	MTTFd [years]	PFH [1/h]	B10d	Source	DC [%]	Source	
Sensor	Sensor 1	Door lock – Monitoring of access door	A 3.1	4			100000	Data Sheet	99	Installation Instruction JSC-110	
	Sensor 2.1	Incremental encoder - Motor feedback Sin/Cos	G 1.1	4	30			General spec.	99	Installation Instruction JSC-110	Cat. 4 in combination with selection JSC-110
PES	Safety PLC	Central safety PLC for control and evaluation of safety-relevant functions	A 4.1			1.4 E-8		Data Sheet JSC-110			
Actuator	STO	Safe torque-off at inverter	A 5.1	4	150			Data sheet of inverter	99	Installation Instruction JSC-110	Cat. 4 in combination with second channel
	Line contactor	Contactor in power line of inverter	K 5.1	4			20 E6	Data sheet of contactor	99	Installation Instruction JSC-110	Cat. 4 in combination with second channel

13.3.5.3 Consideration of systematic failures

Within the HW specification, systematic failures must also be considered.

Example of measures against systematic failures:
Power drop during operation. If there is a hazard here, a power drop must be considered as an operating condition. The SRP/CD shall control this condition so that the safe condition is maintained.

Measures against systematic failures to Annex G DIN EN ISO 13849-9



Source: BGIA Report 2/2008

Fault exclusions
If fault exclusions are made for certain devices or system components, these must be named and specified in detail.
Fault exclusions can be, for example, shaft breakage, sticking of switching contacts, short circuits in cables and wires, etc.
The permissibility of the fault exclusions shall be justified, e.g. by referencing to permissible fault exclusions according to relevant standards (e.g. EN ISO 13849-1).
If separate measures are required for these exclusions of errors, they shall be specified.

Examples of fault exclusions and associated measures:

- Positive connection for mechanical shaft connections
- Dimensioning on the basis of sufficient theoretical principles in the event of breakage of components in the safety chain.
- Positively driven operation in combination with automatic disconnection in case of sticking switching contacts.
- Protected installation within the switchgear in case of short circuits in cables and lines, as well as routing of cables in cable ducts - especially for use in elevator technology according to EN81-20/-50 or EN81-1/-2

13.3.6 Hardware and software design

The performance objectives defined in the HW and SW specifications are implemented in the actual system design.

The performance objectives for the components to be used and their wiring defined in the HW specification must be complied with, as must the performance objectives for fault exclusions. Both must be ensured and documented by appropriate means.
The requirements from the SW specification must also be observed and completely implemented in the software.
Furthermore, the higher-level specifications placed on the SW of safety-related programming must be observed here. These are, among others:
Modular and clear program structure
Assignment of functions to the safety functions
Easy-to-understand presentation of the functions through:
Unique designations
Comprehensible comments
Use of tested functions/function modules as far as possible
Defensive programming

13.3.7 Hardware design test

After completion of the planning, the HW design must be checked for compliance with the objectives from the HW specification.
Furthermore, compliance with the specified safety level for each individual safety function shall be verified by appropriate analysis. The analytical procedures are described in the relevant standards (e.g. EN ISO 13849-1).

Wiring diagram analysis
The circuit diagram and parts list must be used to check compliance with the safety-related specifications. In particular, the following must be checked:
Correct wiring of the components according to specification,
Dual-channel design, if specified
Lack of feedback from parallel, redundant channels
Use of components as specified
The check shall be carried out by means of a comprehensible analysis.

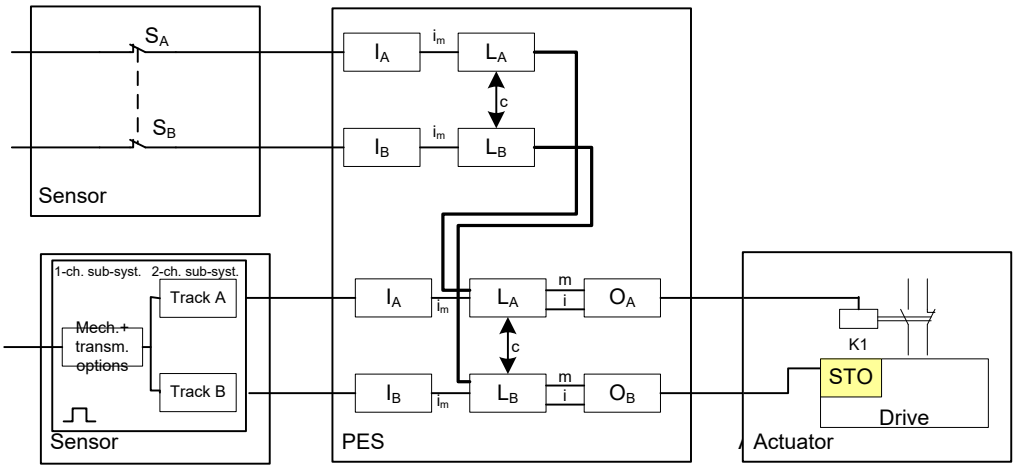
13.3.7.1 Iterative verification of the achieved safety level

The achieved safety level shall be determined on the basis of the circuit design (= single-channel/dual-channel/with or without diagnostics), the device specifications (manufacturer's information or relevant sources) and the diagnostic coverage level (specification from PES manufacturer or general sources). The relevant procedures can be found in the underlying safety standard.

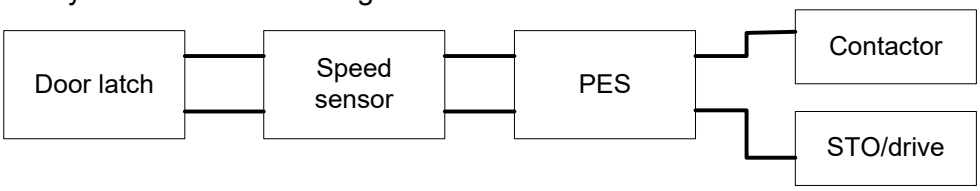
A calculation according to EN ISO 13849-1 is shown as an example:

Safety function:
Safely limited speed with access door open

Structural diagram:



Safety-related structural diagram:



Calculation according to EN ISO 13849-1:

Channel A – shut-off through mains contactor:

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

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

[1] Value for $MTTF_d$ from EN ISO 13849-1, table C.1
[2] Value from in-house HW FMEA; assumption of a JSC-110-2-RS with relay board, CPU board, processing subsystem and output subsystem with HighSide/LowSide combination
[3] Value for $MTTF_d$ from EN ISO 13849-1, table C.1; Assumption: "worst case" by "contactor with nominal load".

Channel B – Shut-off through STO/inverter

Component	$MTTF_d$ [years]	DC
Door latch (see above)	B_{10d} = 100000 n_{op} = 30/AT = 9270/year (309 AT/year) $MTTF_d = \frac{B_{10d}}{0{,}1 \cdot n_{op}} = 107{,}87\ years$	DC_{Switch} = 99%
SIN/COS encoder (see above)	$MTTF_d$ = 30 years	$DC_{Encoder}$ = 99%
PES (see above)	λ_d = 1884.21 fit $MTTF_d = \frac{10^9}{365 \cdot 24 \cdot \lambda_d} = 60{,}59\ years$	DC_{PES} = 94.5%
STO/inverter[4]	$MTTF_d$ = 150 years	DC_{STO} = 90%

$$MTTF_d^B = \frac{1}{\frac{1}{MTTF_d^{Switch}} + \frac{1}{MTTF_d^{Encoder}} + \frac{1}{MTTF_d^{PES}} + \frac{1}{MTTF_d^{STO}}} = 15{,}20 \text{ years}$$

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

Resulting PL for both channels:

Balancing of both channels:	$MTTF_d = \frac{2}{3}\left[MTTF_d^A + MTTF_d^B - \frac{1}{\frac{1}{MTTF_d^A} + \frac{1}{MTTF_d^B}}\right] = 16 \text{ years}$
DC mean value	$DC_{avg} = \frac{\sum_i \frac{DC_i}{MTTF_i}}{\sum_i \frac{1}{MTTF_i}} = 97{,}2\%$
PL	$MTTF_d$ = 16 years (average) DC $_{avg}$ = 97.4% (average) PL =“d“ (from EN ISO 13849-1, tables 5, 6 and 7) In this case, the $MTTF_d$ value of the Sin/Cos encoder determines the PL. If a higher safety level is to be achieved, an encoder of a correspondingly higher quality must be used.

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

Note:
The PL can also be determined using the BGIA's "Sistema" program tool.

13.3.8 Verification of software (program) and parameters

Verification takes place in two steps:
Checking the SFC for the specified functionality
Check the SFC against the instruction list of the validation report, or the specified parameters against those listed in the validation report.

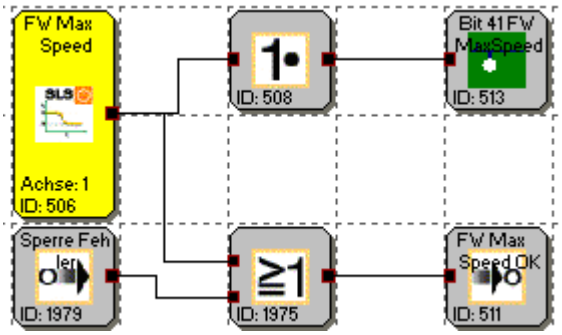
13.3.8.1 Checking the SFC

For verification purposes, the actually programmed SFC shall be compared against the specification.

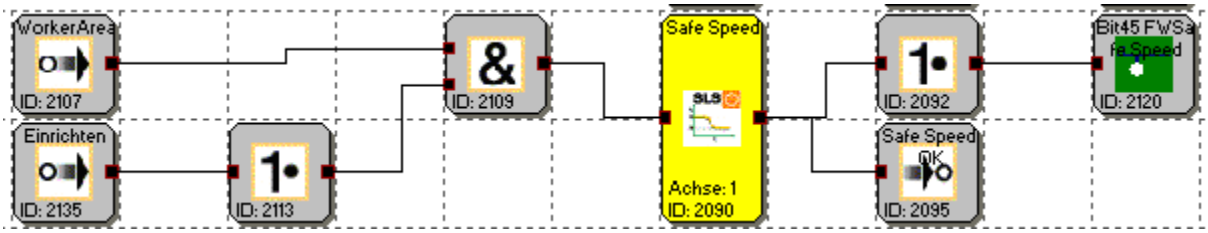
Note:

The more clearly the programming has been structured with regard to the safety functions, the more efficient the comparison is.

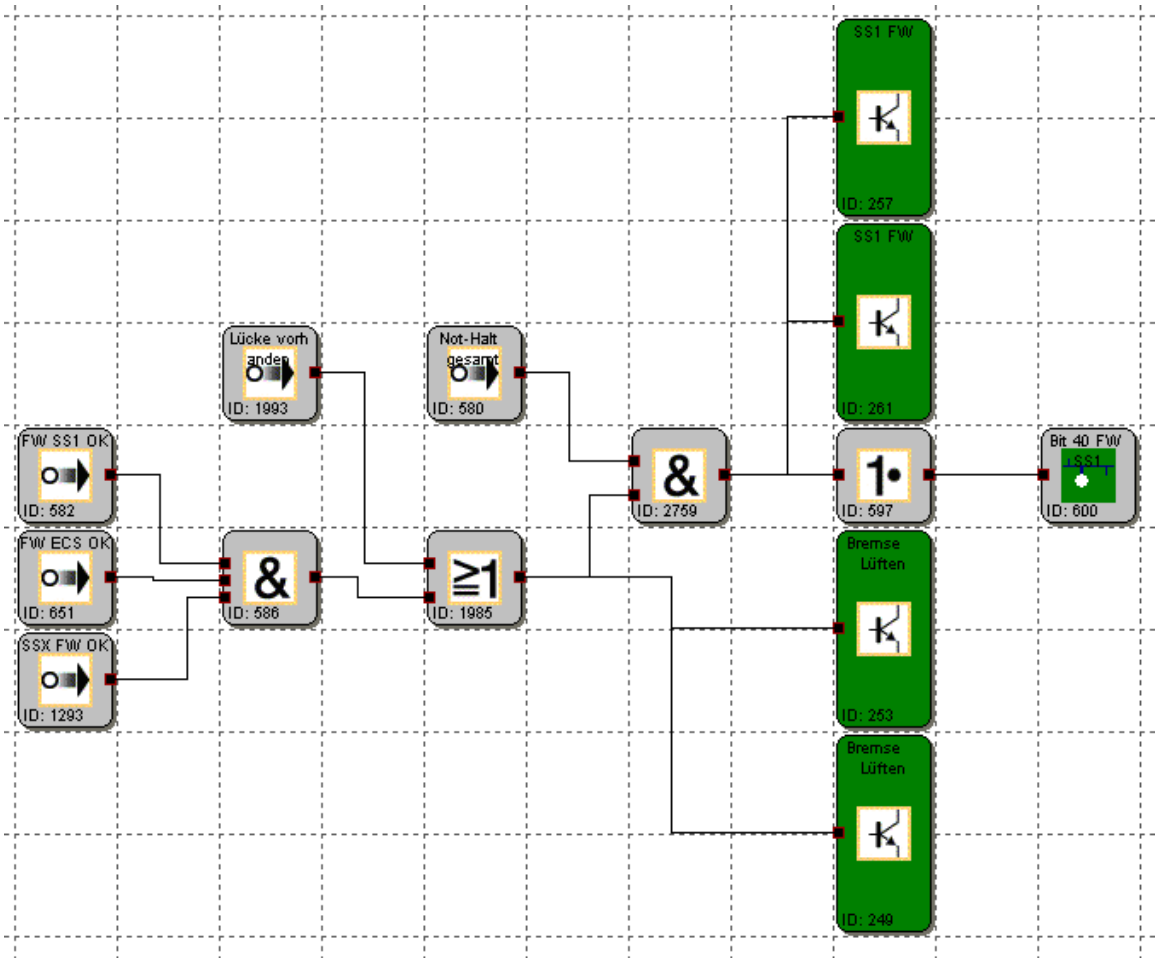
Example:
Safety function:
Limitation of maximum travel speed of the carriage to 1.1 V max.
Monitoring of the maximum speed for < 1.1 V max
FW Max Speed OK (ID 548) (is bridged through the existing gap):
FW Max Speed is permanently activated and responds when a speed of 550 mm/s is exceeded.



Safety function:
Limitation of max. travel speed of carriage in workers' area.
Monitoring of the maximum speed for < 0.33 m/s.
Safe Speed OK (ID 2124) (is bridged through existing gap):
Safe Speed Ok responds if the safe speed SLS (ID 2090) is exceeded in the operator work area and if there is no setup operation.

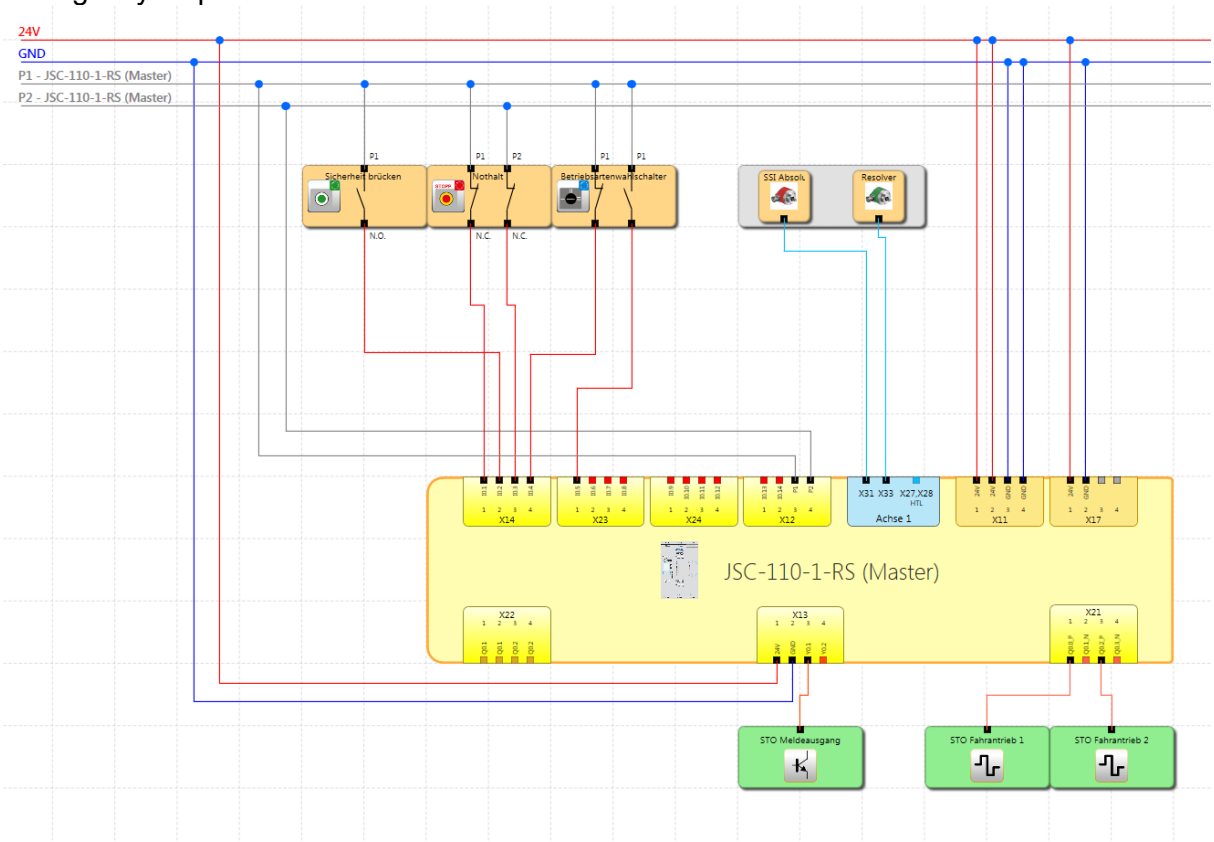


Parameter SLS Safe Speed:
60 mm/s, no other parameters
Safety function:
Carriage shut-off
Switch-off of travel drive and deactivating brakes
Switch-offs at the carriage



The carriage is switched off through two outputs (ID 257 and ID 261).
The brakes are released through two outputs (ID 253 and ID 249).
A message is sent to the PLC via bit 40 (ID 600).
In the event of an emergency stop, the shut-off is carried out immediately.
Hitch

Safety function
Emergency stop button inputs and shut-off outputs
Emergency stop master PLC
Dual-channel emergency stop with pulse monitoring.
If an emergency stop is triggered at the master PLC, this emergency stop can be overridden by pressing the acknowledgment button "Override safety function".
Emergency stop button connected to the master PLC



Emergency stop contacts from emergency stop relay with pulses from JSC-110-1-RS

13.3.8.2 Validating SFC against IL and parameters using validation report

The programming carried out in the SFC is to be compared with the instruction list of the validation report.

Example of instruction list in the validation report

Index	Command	Operand
1	SQH	3
2	LD	I0.1
3	AND	I0.3
4	ST	MX.128
5	SQC	0.1
6	S1	MX.64
7	SQH	9
8	LD	I0.4
9	AND NOT	I0.5
10	ST	MX.129
11	LD NOT	I0.4
12	AND	I0.5
13	ST	MX.130
14	SQC	0.1
15	LD	MX.129
16	XOR	MX.130
17	ST	MX.131
18	LD	MX.131
19	ST	MX.120
20	LD	PLCT.0
21	AND	MX.130
22	ST	MX.132
23	SQH	2
24	LD	I0.2
25	ST	MX.133
26	SQC	0.1

Step-by-step testing is recommended. The more structured the programming in the SFC, the more efficient the test.

After testing the program, check the parameters against the parameters in the specification by comparison.

Example: SLS

Safe Limited Speed (SLS)				
Index	**Parameter**	**Value**	**Unit**	**Validated**
SLS - 1				
	Axis	1		☐
	Permanently activated:	No		☐
	Velocity tolerance			
	Velocity threshold	550	mm/s	☐
SLS - 2				
	Axis	1		☐
	Permanently activated:	No		☐
	Velocity tolerance			
	Velocity threshold	330	mm/s	☐
SLS - 3				
	Axis	1		☐
	Permanently activated:	No		☐
	Velocity tolerance			
	Velocity threshold	2	mm/s	☐

Sample encoder configuration:

Axis Configuration

Parameter	Value	Unit	
Axis 1			
Position processing	Active		☐
Measured length	13600	mm	☐
Type	Linear		☐
Velocity filter	Off		☐
Maximum velocity	2000	mm/s	☐
Incremental shut-off	10	mm	☐
Velocity shut-off	100	mm/s	☐
Encoder A			
Sensor	SSI		☐
Resolution	1024	l/1000 mm	☐
Supply voltage	24 V		☐
Direction of rotation	Ascending		☐
Offset	0		☐
Type	Master clock		☐
Format	Binary		☐
Frame length	24		☐
Data length	24		☐
Data index	0		☐
Status length	0		☐
Status index	0		☐
Status Mask Err	0000 0000		☐
Status Mask Def	0000 0000		☐
Encoder B			
Sensor	Resolver		☐
Resolution	1024	l/1000 mm	☐
Direction of rotation	Ascending		☐
Type	Standard		☐
Resolver ratio	4:1		☐
Listener frequency	6	kHz	☐
Form factor	Sine		☐

13.3.9 Executing system tests/FIT (Fault Injection Test)

For the FIT, the manufacturer must provide a complete list of functions to be tested. This list includes the defined safety functions, as well as error tests to check the correct response of the SRP/CS to these errors.

Example of test list

No.	Setup	Test	Result
1 Testing SLS for max. speed in setup mode			
	Activate setup mode Travel at max. permitted speed	- Compare actual speed with SLS - limit - Manipulation of setup speed through allowed reduced speed	
2 Testing SSX for Stop Category 2			
	Travel at maximum speed Actuate emergency stop	- Compare the SSX ramp with the actual deceleration ramp - Set an invalid small deceleration - Move the axis after standstill by manipulation of the drive	
3 Testing the 2-channel door monitoring system			
	Select the operating mode "Setup"	- Check the monitoring system for inactivity in case of closed door (via diagnostics function SFC) - Check the monitoring system for activity in case of open door (via diagnostics function SFC) - Disconnect one channel and open the door Create cross fault between both inputs	

Appendix

Annex A – Classification of switch types

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

Enabling switch

Switch type	Comment	PL category according to EN ISO 13849-1	SIL category to IEC 61508
1 NC contact	Enabling switch, standard	PL d	SIL 2
1 NO contact	Enabling switch, standard	PL d	SIL 2
2 NC contact	Enabling switch, increased requirement	PL e	SIL 3
2 NC contacts, time monitored	Enabling switch, monitored	PL e	SIL 3

Emergency stop

Switch type	Comment	PL category	SIL category
1 NC contact	Emergency stop, standard	PL d[1)]	SIL 2
2 NC contact	Emergency stop, increased requirements	PL e	SIL 3
2 NC contacts, time monitored	Emergency stop, monitored	PL e	SIL 3

[1)] Fault exclusions and boundary conditions as per EN 13849-2 must be observed!

Door monitoring

Switch type	Comment	PL category	SIL category
2 NC contact	Door monitoring, increased requirement	PL e	SIL 3
2 NC contacts, time-monitored	Door monitoring, monitored	PL e	SIL 3
1 NO + 1 NC contact	Door monitoring, increased requirement	PL e	SIL 3
1 NO + 1 NC contact, time-monitored	Door monitoring, monitored		SIL 3
2 NO + 2 NC contact	Door monitoring, increased requirement	PL e	SIL 3
2 NO + 2 NC contact, time-monitored	Door monitoring, monitored	PL e	SIL 3
3 NC contact	Door monitoring, increased requirement	PL e	SIL 3
3 NC contacts, time-monitored	Door monitoring, monitored	PL e	SIL 3

Two-hand pushbutton

Switch type	Comment	PL category	SIL category
2 changeover contacts	Two-hand pushbutton, increased requirements	Type III C PL e	SIL3
2 NO contact	Two-hand pushbutton, monitored	Type III A PL e	SIL1

Note: In the case of these input elements, a fixed pulse assignment takes place which cannot be influenced by the user!

Light curtain

Switch type	Comment	PL category	SIL category
2 NC contact	Light curtain, increased requirements	PL e	SIL 3
2 NC contacts, time-monitored	Light curtain, monitored	PL e	SIL 3
1 NO + 1 NC contact	Light curtain, increased requirements	PL e	SIL 3
1 NO contact + 1 NC contact, time-monitored	Light curtain, monitored	PL e	SIL 3

Mode selector

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

⚠ **Safety precaution:**

- When the state of the switch changes, the JetSafe program to be created must ensure that the outputs of the module are deactivated (Note: Standard EN 60204-1, Part 1, Section 9.2.3).

Sensor

Switch type	Comment	PL category	SIL category
1 NC contact	Sensor input, standard	PL d	SIL 2
1 NO contact	Sensor input, standard	PL d	SIL 2
2 NC contact	Sensor input, increased requirements	PL e	SIL 3
2 NC contacts, time-monitored	Sensor input, monitored	PL e	SIL 3
1 NO + 1 NC contact	Sensor input, increased requirements	PL e	SIL 3
1 NO + 1 NC contact, time-monitored	Sensor input, monitored	PL e	SIL 3

Start/reset element

Switch type	Comment	PL category	SIL category
1 NO contact	Alarm reset, standard (edge evaluation)	--	--
1 NO contact	Logic reset, standard	PL d	SIL 2
1 NO contact	Start monitoring, standard (special function)	--	--

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