Co-funded by the Erasmus+ Programme of the European Union

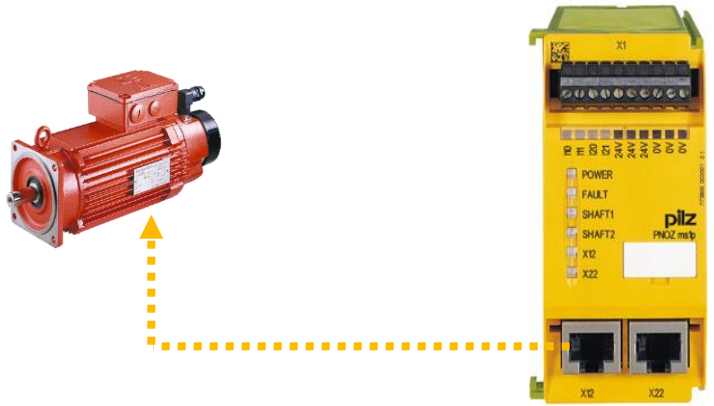
INDI 4.0

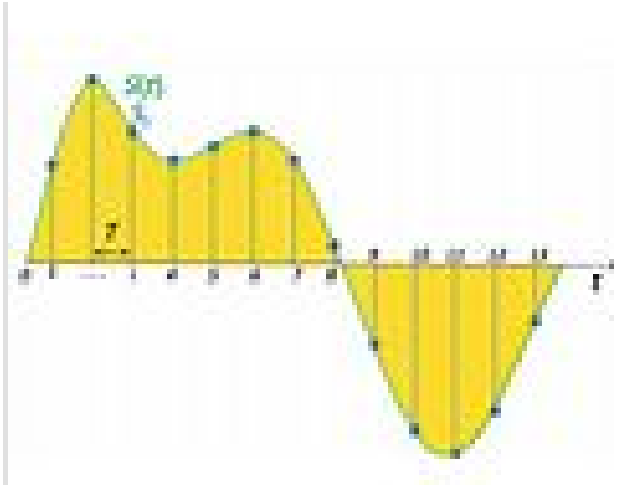
PNOZmulti - Programming and Service

PILZ
THE SPIRIT OF SAFETY

Appendix A

Speed and analogue modules





Speed Monitoring Modules
1st generation

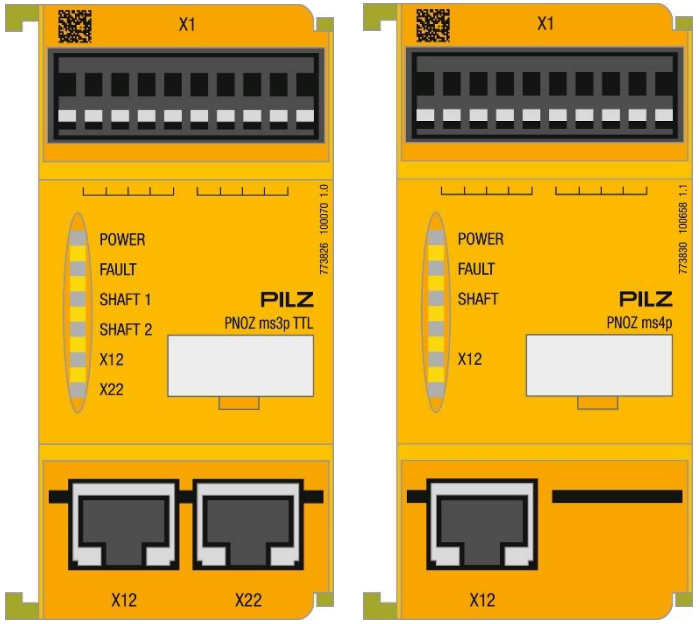
PILZ | A-2

Speed module

Programming exercise motion monitoring

Analogue module

- Safe speed/standstill monitoring
  - 2 axes PL d / SIL CL 2
  - 1 axe PL e / SIL CL 3
- Proximity detectors (ms1p ... ms2p)
  - Up to 3 kHz
- or incremental encoders (ms1p … ms4p)
  - Up to 500 kHz
- With direction recognition
- Independent monitoring of 2 axes per module
  - Maximum of 4 modules pluggable (4 modules = 8 axes)
- No external power supply required
  - Input signal of the encoder 0,5 ... 5 V, 0,5 ... 30 V or 12 … 30 V



Speed Modules
2nd generation

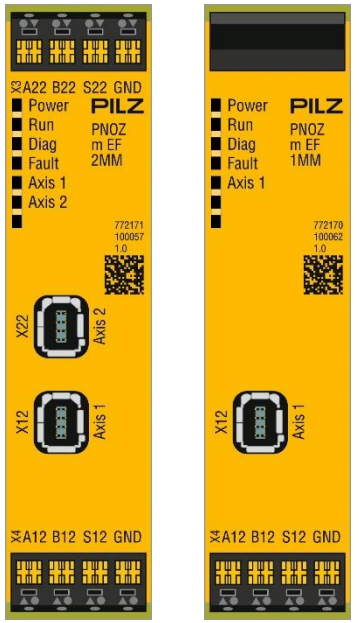
PILZ | A-2

Speed module

Programming exercise motion monitoring

Analogue module

- Safe speed/standstill monitoring
  - 2 axes PL d / SIL CL 2
  - 1 axe PL e / SIL CL 3
- Proximity detectors
  - Up to 5 kHz
- or incremental encoders
  - Up to 500 kHz
- With direction recognition
- Independent monitoring for 1 or 2 axes per module
  - Maximum of 6 modules pluggable (6 modules = 12 axes)



Speed Modules
1st generation wiring example

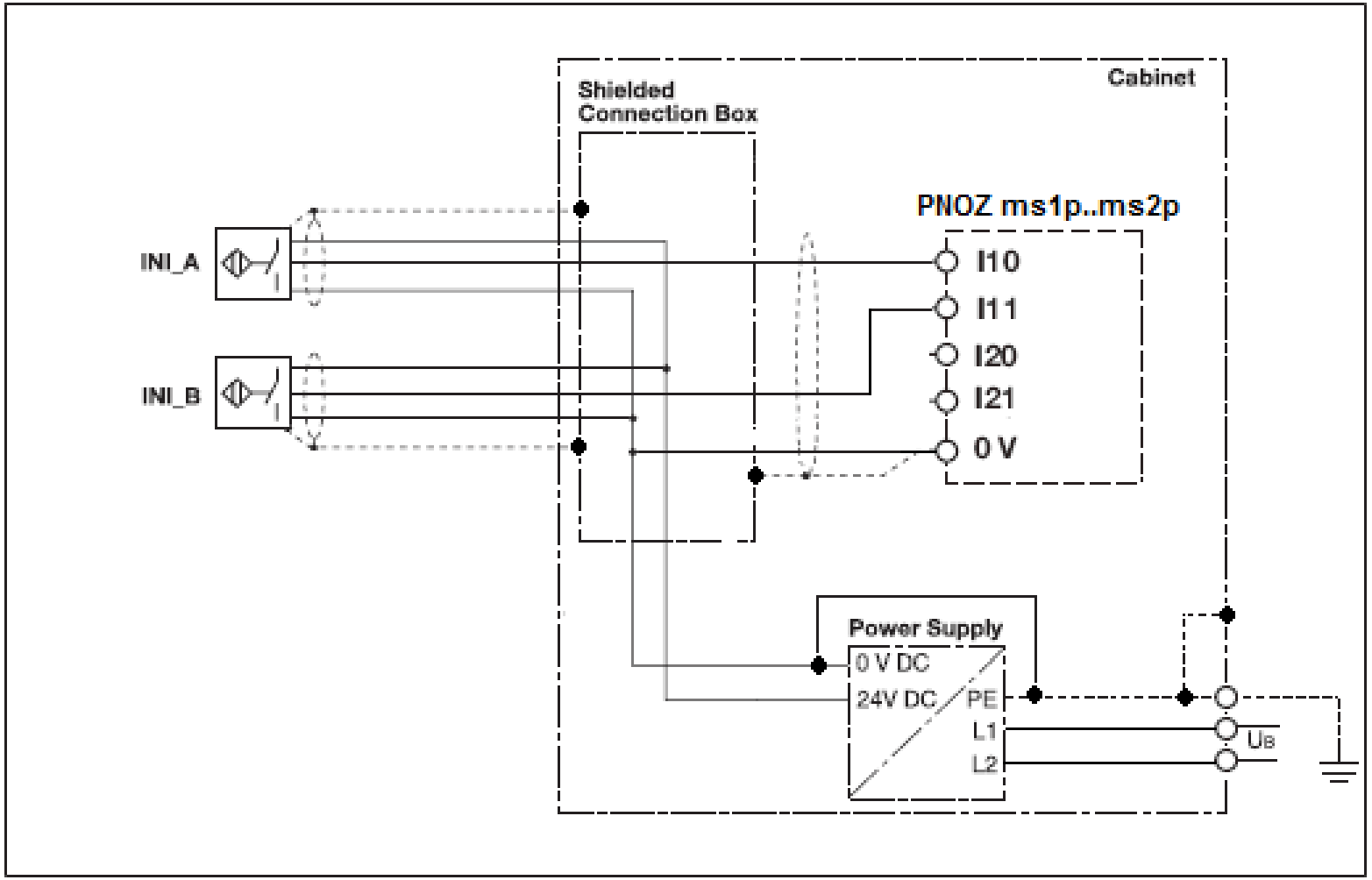
PILZ | A-5

Speed module

Programming exercise motion monitoring

Analogue module

Proximity switch with EMC-compliant wiring (PNOZ ms1p and ms2p)



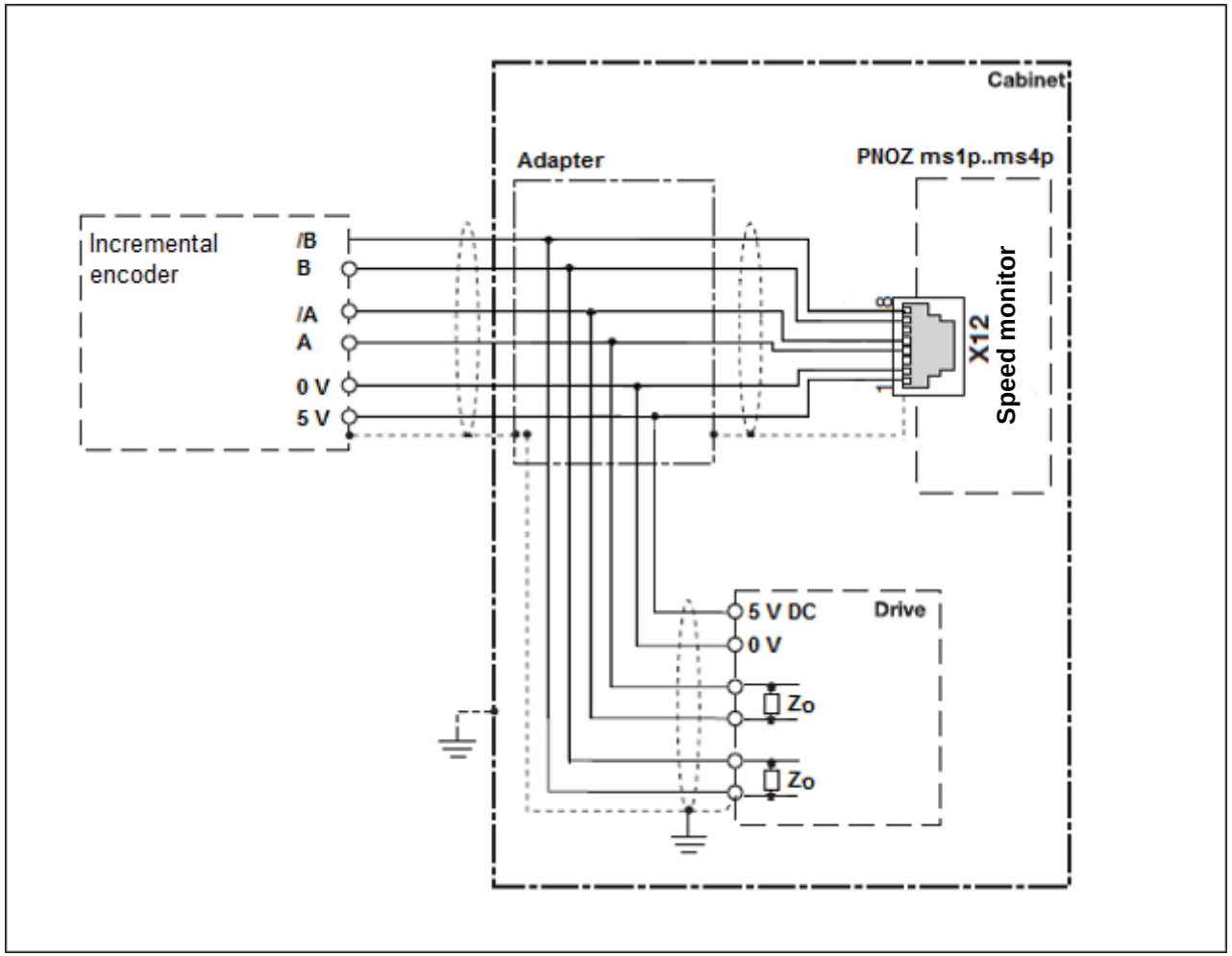
Speed Modules
1st generation wiring example

PILZ | A-5

Speed module

- Programming exercise motion monitoring
- Analogue module

Incremental encoder and drive with EMC-compliant wiring



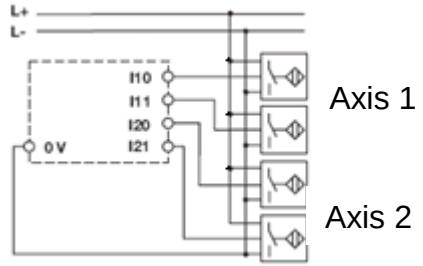
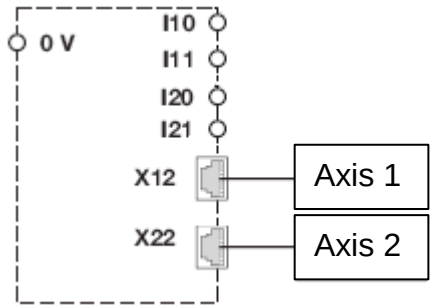
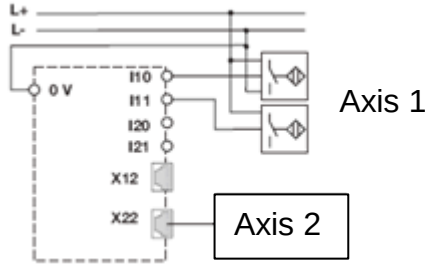
Speed Modules
1st generation encoder configuration

PILZ | A-6

Speed module

Programming exercise motion monitoring

Analogue module

Axis 1 with two proximity switches to: - I10/I11. Axis 2 with two proximity switches to: - I20/I 21.	
Axis 1 with one incremental encoder to: - X12. Axis 2 with one incremental encoder to: - X22.	
Axis 1 with two proximity switches to: - I10/I11. Axis 2 with one incremental encoder to: - X22.	

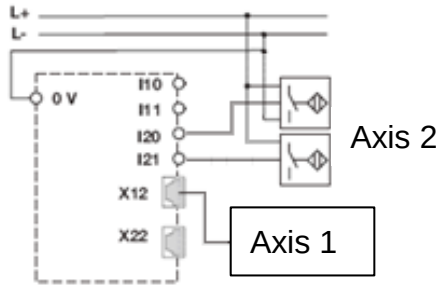
Speed Modules
1st generation encoder configuration

PILZ | A-6

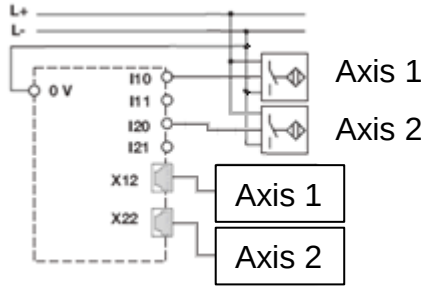
Speed module

Programming exercise motion monitoring

Analogue module

Axis 1 with one incremental encoder to: - X12 Axis 2 with two proximity switches to: - I20/I21	

Special configuration:

Axis 1 with one incremental encoder and one proximity switch to: - X12 and - I10 (I11 remains open). Axis 2 with one incremental encoder and one proximity switch to: - X22 and - I20 (I21 remains open).	

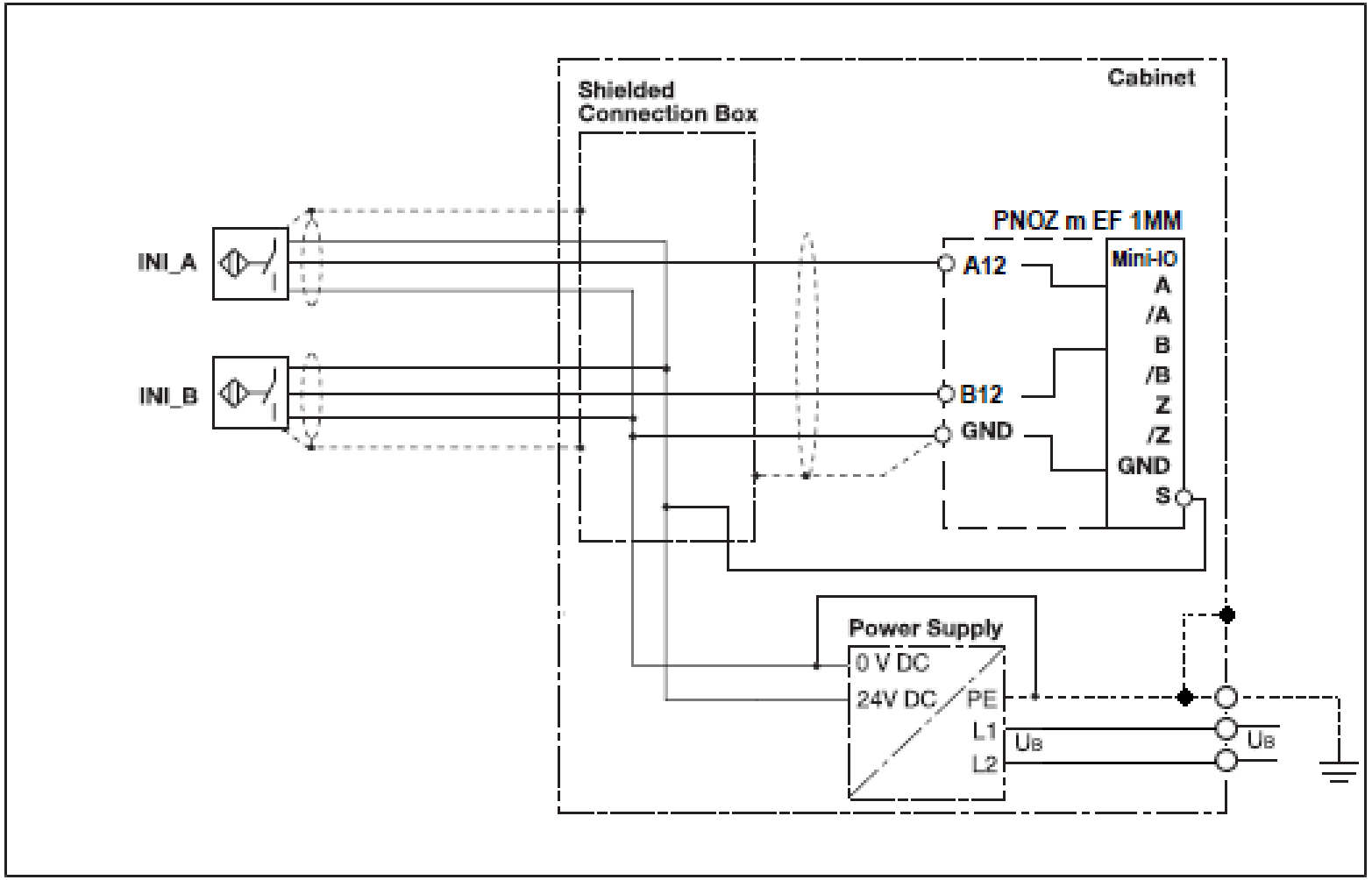
Speed Modules
2nd generation wiring example

PILZ | A-7

Speed module

- Programming exercise motion monitoring
- Analogue module

Proximity switch with EMC-compliant wiring



Speed Modules
2nd generation wiring example

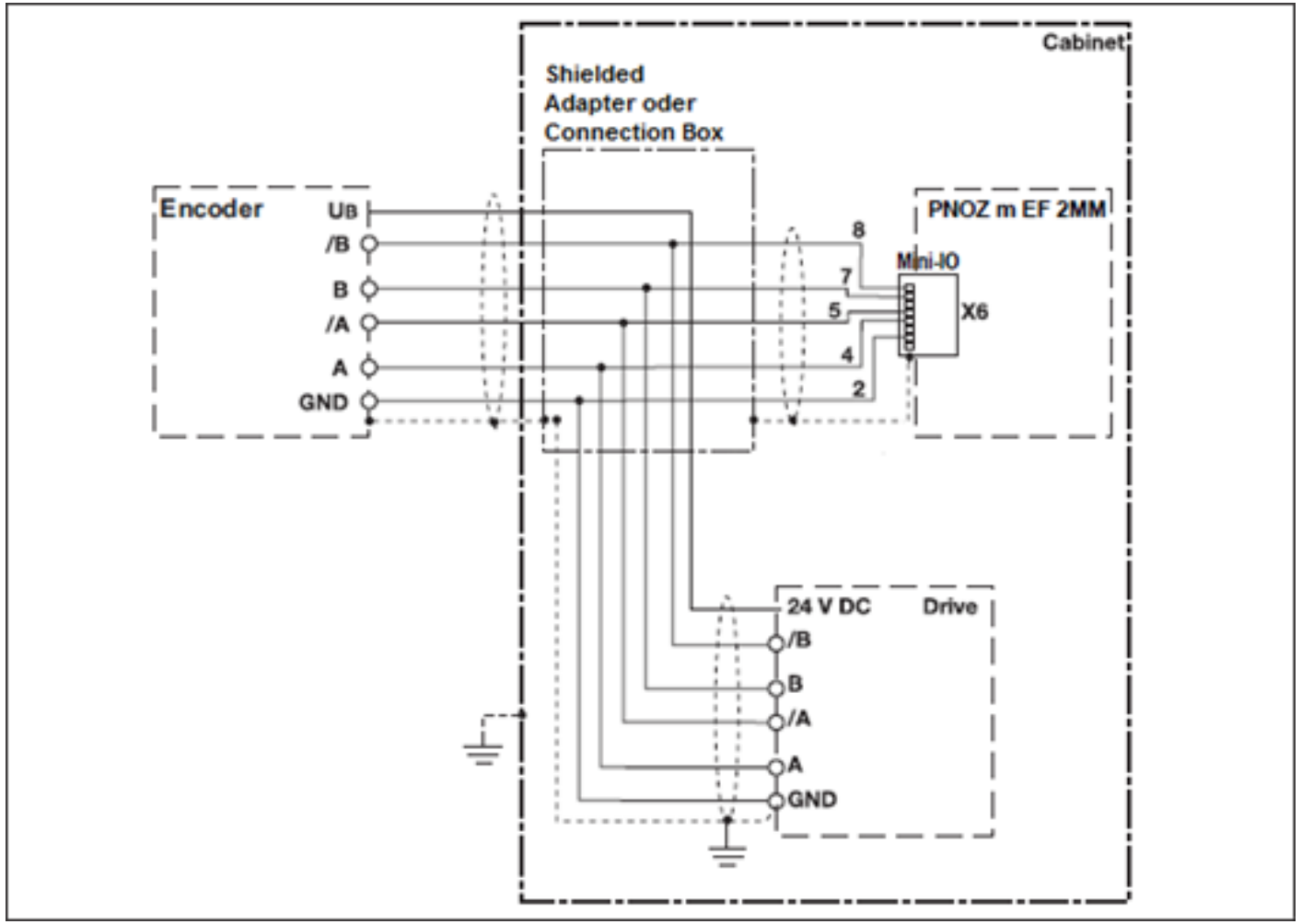
PILZ | A-7

Speed module

Programming exercise motion monitoring

Analogue module

Encoder and drive with EMC-compliant wiring



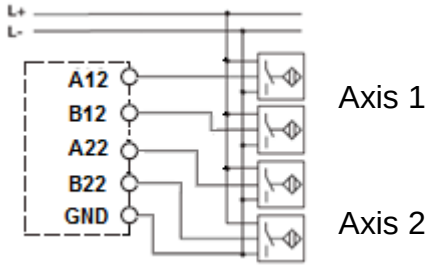
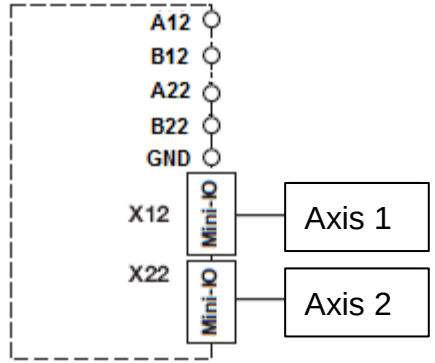
Speed Modules
2nd generation encoder configuration

PILZ | A-8

Speed module

Programming exercise motion monitoring

Analogue module

PNOZ m EF 2MM: Axis 1 with two proximity switches to: - A12/B12 Axis 2 with two proximity switches to: - A22/B22	
PNOZ m EF 2MM: Axis 1 with one encoder to: - X12 Axis 2 with one encoder to: - X22.	

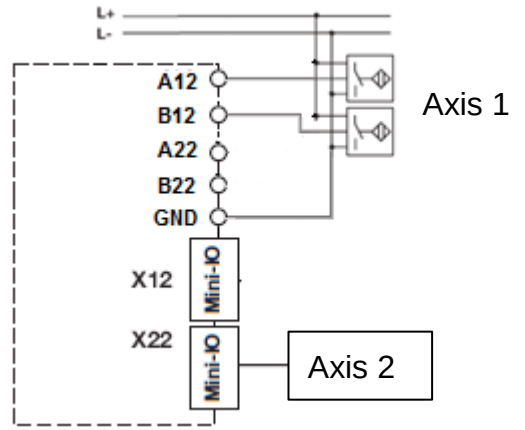
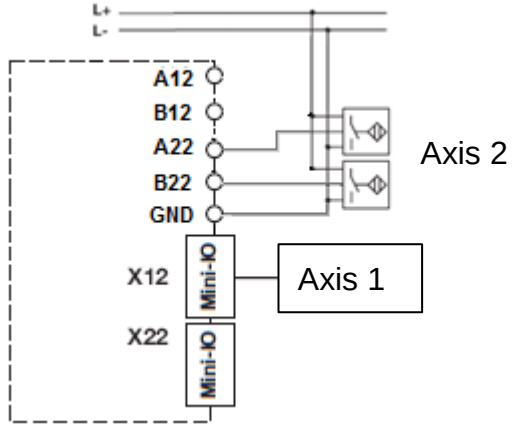
Speed Modules
2nd generation encoder configuration

PILZ | A-8

Speed module

Programming exercise motion monitoring

Analogue module

PNOZ m EF 2MM: Axis 1 with two proximity switches to: - A12/B12 Axis 2 with one encoder to: - X22	
PNOZ m EF 2MM: Axis 1 with one encoder to: - X12 Axis 2 with two proximity switches to: - A22/B22	

Speed Modules
Special configuration

PILZ | A-9

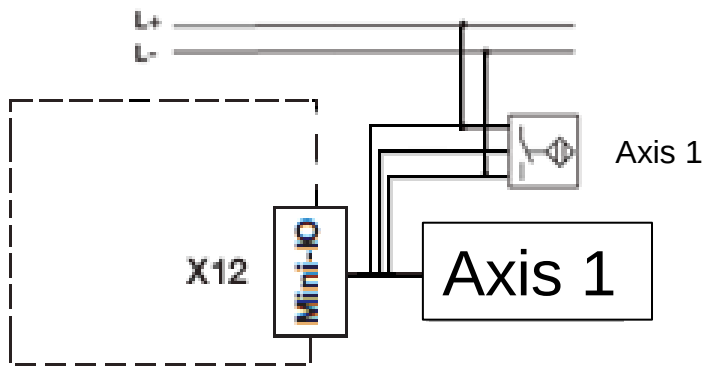
Speed module

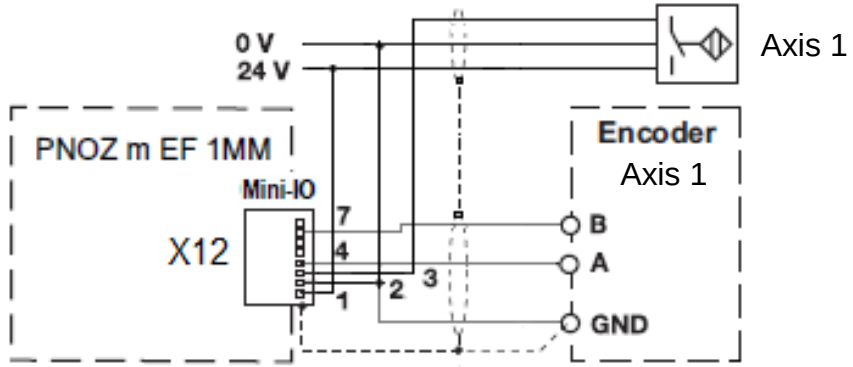
Programming exercise motion monitoring

Analogue module

PNOZ m EF 1MM..2MM:
Axis 1 with one encoder and one proximity switch to:
- X12.

PNOZ m EF 2MM:
Axis 2 with one encoder and one proximity switch to:
- X22.





Speed Modules
Proximity switch

PILZ | A-9

Speed module

Programming exercise motion monitoring

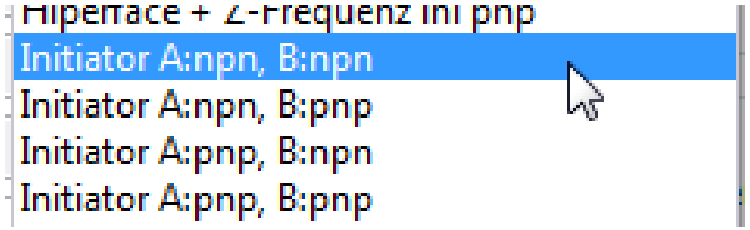
Analogue module

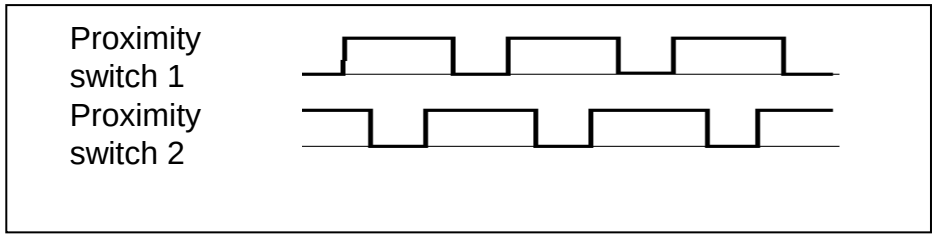
PNOZ ms1p..ms4p (*1st gen.*)

- PNP technology

PNOZ m EF 1MM..2MM (*2nd gen.)*

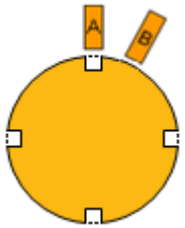
- PNP/NPN technology *(be freely selected)*





One of the proximity switch must be damped

Proximity switch: NO (normally open)



Proximity switch: NC (normally closed)

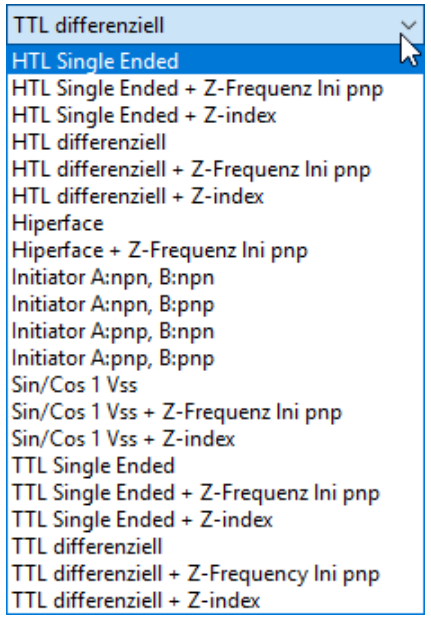
Speed Modules
Incremental encoder / absolute encoder

PILZ | A-11

Speed module

- Programming exercise motion monitoring
- Analogue module

Encoder	1st generation	2nd generation
Sin/Cos 1 V_{ss} 500 kHz	PNOZ ms1p..ms4p	PNOZ m EF 1MM..2MM
TTL (RS 422) 500 kHz	PNOZ ms1p..ms4p	PNOZ m EF 1MM..2MM
HTL (24 V) 200 kHz	PNOZ ms2p..ms3p	-
HTL (24 V) 500 kHz	PNOZ ms4p	PNOZ m EF 1MM..2MM
Hiperface® (Absolutwertgeber)	-	PNOZ m EF 1MM..2MM



Speed Modules
Adapter cable

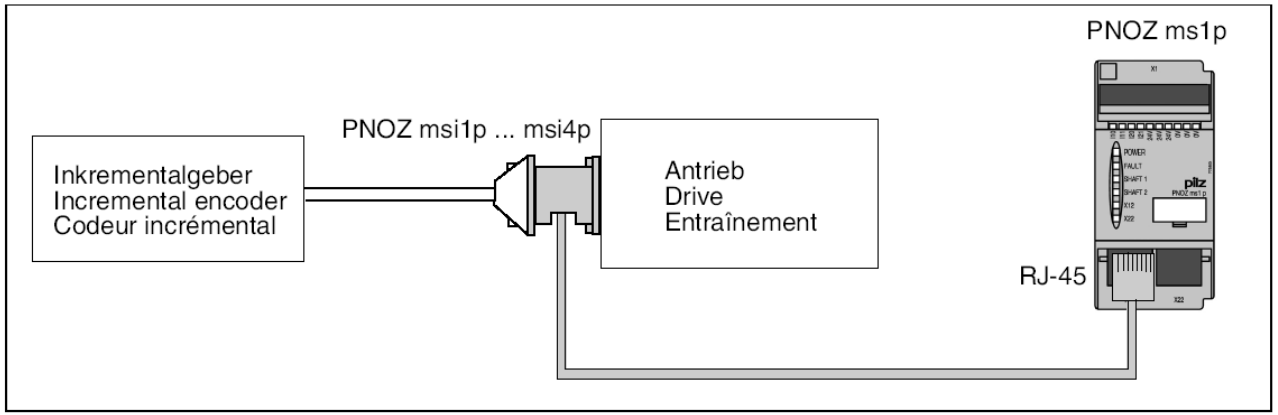
PILZ | A-11

Speed module

Programming exercise motion monitoring

Analogue module

- For connection of encoders:
  - to-PNOZ ms1p … ms4p and PNOZ m EF 1MM..2MM
- Use of available donor
- Various adapters are available for commonly used:
  - Servo amplifier
  - Incremental encoder
  - Absolute encoder
- Variable cable lengths



Speed Modules
Adapter cable

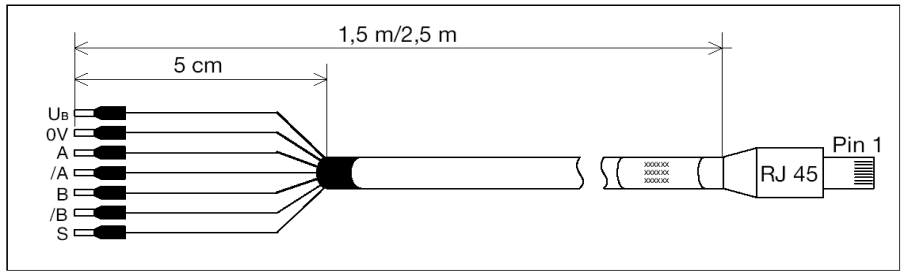
PILZ | A-12

Speed module

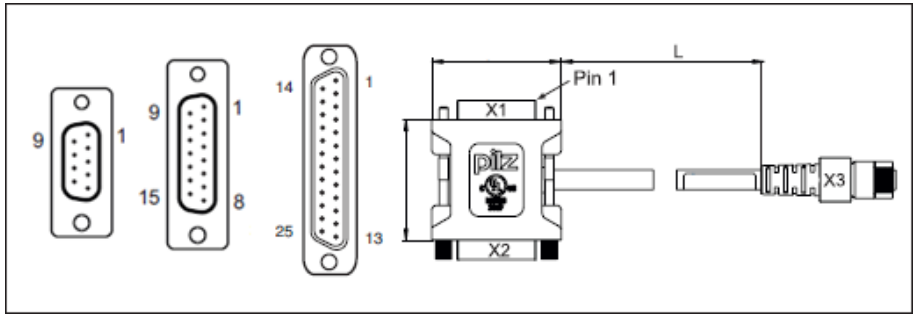
Programming exercise motion monitoring

Analogue module

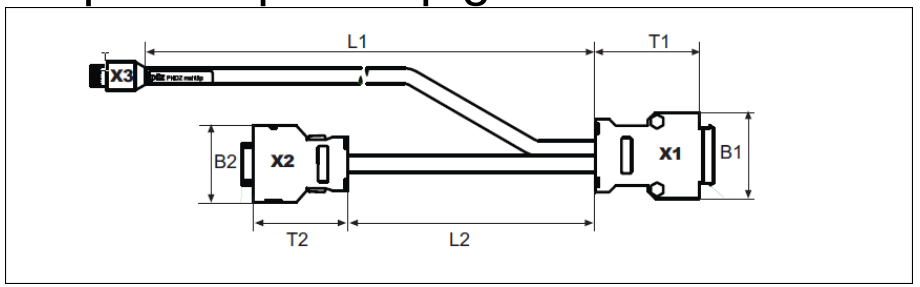
Universal adapter:



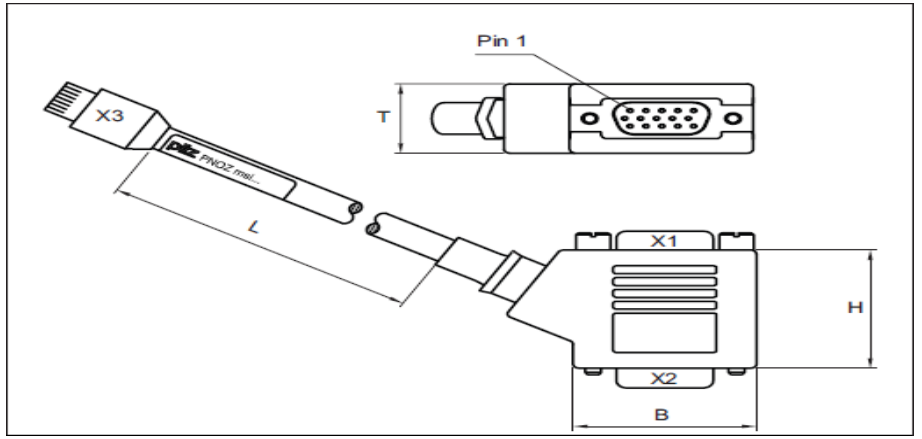
9-, 15- or 25-pin adapter:



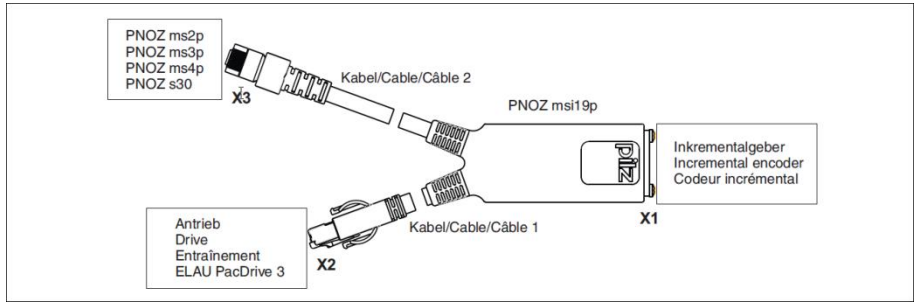
20-pin adapter in pigtail version:



25-pin adapter



RJ-45 adapter in pigtail version



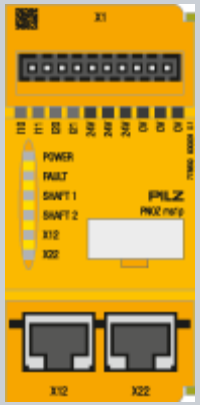
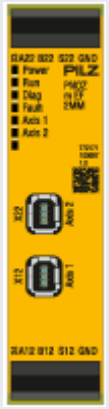
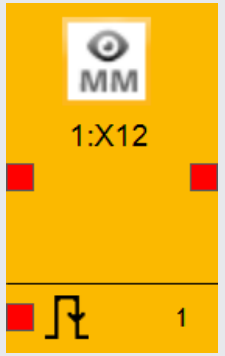
Overview of the Motion Monitor Elements

PILZ | A-15

Speed module

Programming exercise motion monitoring

Analogue module

Motion module	Title	Elements
	PNOZ ms1p PNOZ ms2p PNOZ ms3p PNOZ ms4p PNOZ ms2p HTL PNOZ ms3p HTL PNOZ ms2p TTL PNOZ ms3p TTL	
	PNOZ m EF 1MM (up to V 1.1) PNOZ m EF 2MM (up to V 1.1)	 

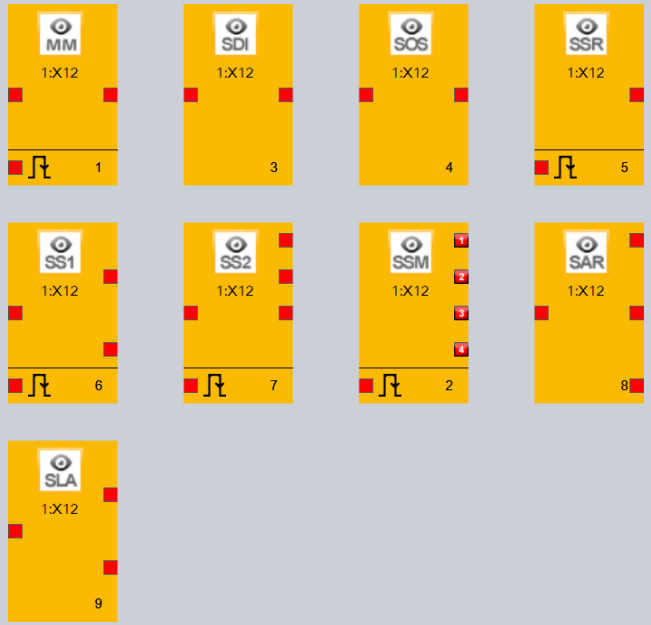
Overview of the Motion Monitor Elements

PILZ | A-15

Speed module

Programming exercise motion monitoring

Analogue module

Motion Module	Title	Elements
	PNOZ m EF 1MM (from V 2.0) PNOZ m EF 2MM (from V 2.0)	In the module program: 

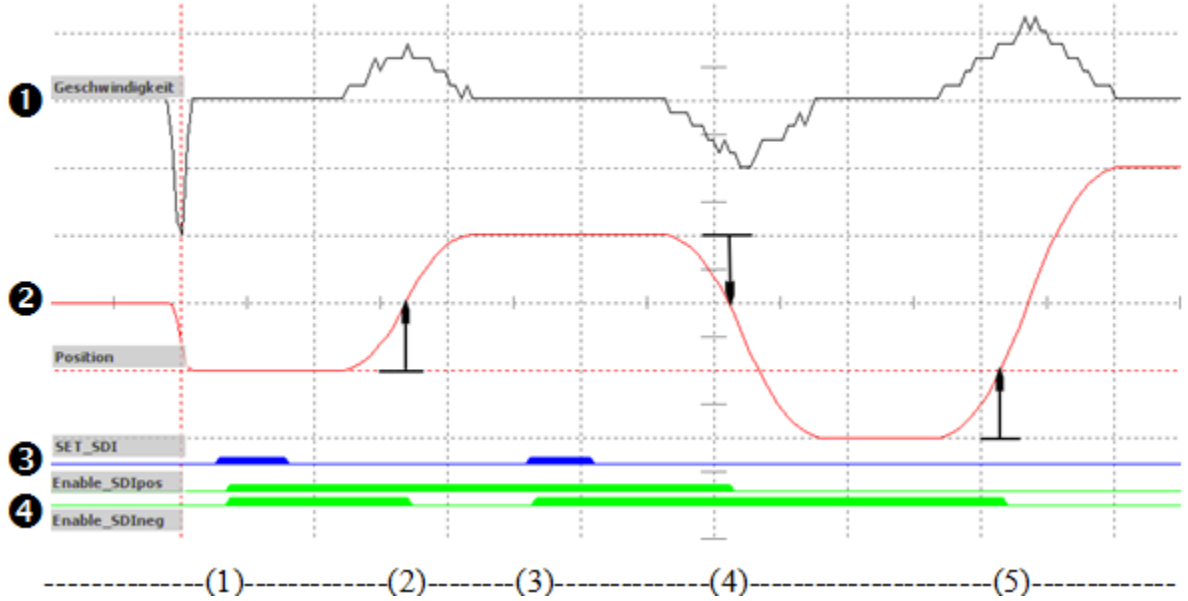
PNOZ m EF 1MM..2MM (2nd Generation)
„SDI-M (Safe Direction Monitoring)“

PILZ | A-24

Speed module

- Programming exercise motion monitoring
- Analogue module

The SDI-M function prevents the motor shaft moving in the unintended direction (EN 61800-5-2).



Line ❶: Actual speed [5000 incr/div.]
Line ❷: Actual position [1000 incr/div.]
Line ❸: SET_SDI
Line ❹: Enable SDIpos/SDImeg
Time axis: 1000 ms/div.

(1): With a rising edge SET_SDI, the enables SDIpos and SDIneg are switched on.
(2): Tolerance is exited in the positive direction, SDIneg is reset.
(3): Post-triggering with SET_SDI is possible at any time.
(4): Tolerance is exited in the negative direction, SDIpos is reset.
(5): Tolerance is exited in the positive direction, SDIneg is also reset.

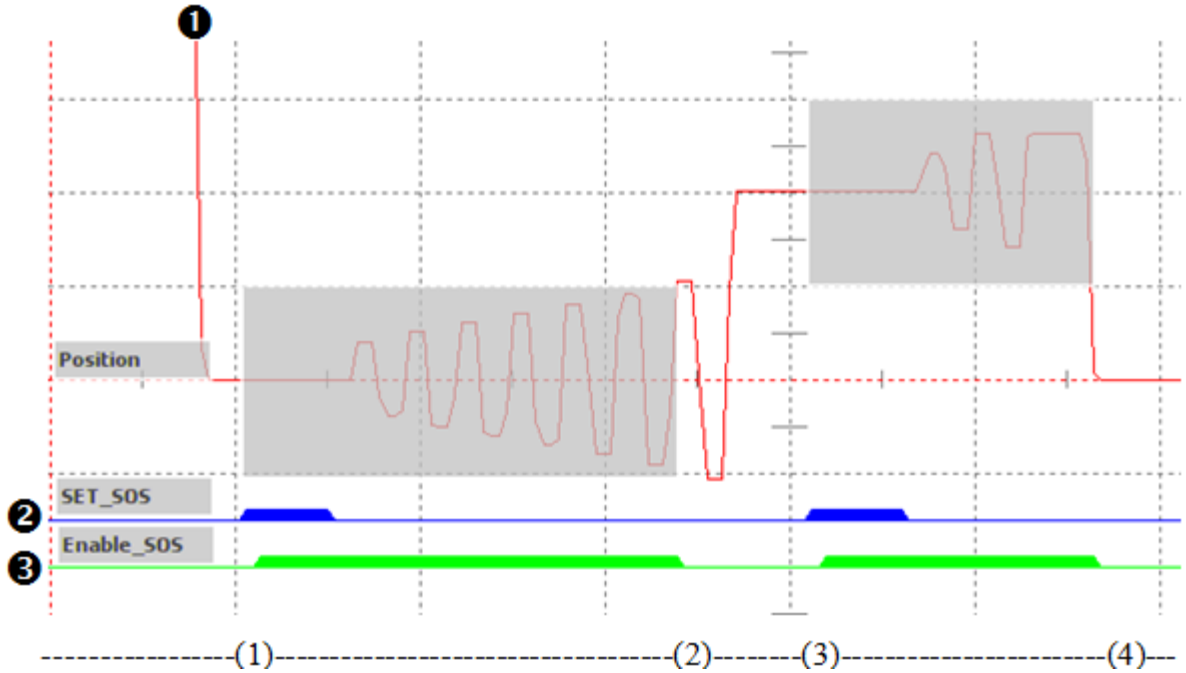
PNOZ m EF 1MM..2MM (2nd Generation)
„SOS-M (Safe Operating Stop Monitoring)“

PILZ | A-25

Speed module

- Programming exercise motion monitoring
- Analogue module

The SOS-M function prevents the motor deviating by more that a defined amount from the stop position (EN 61800-5-2).

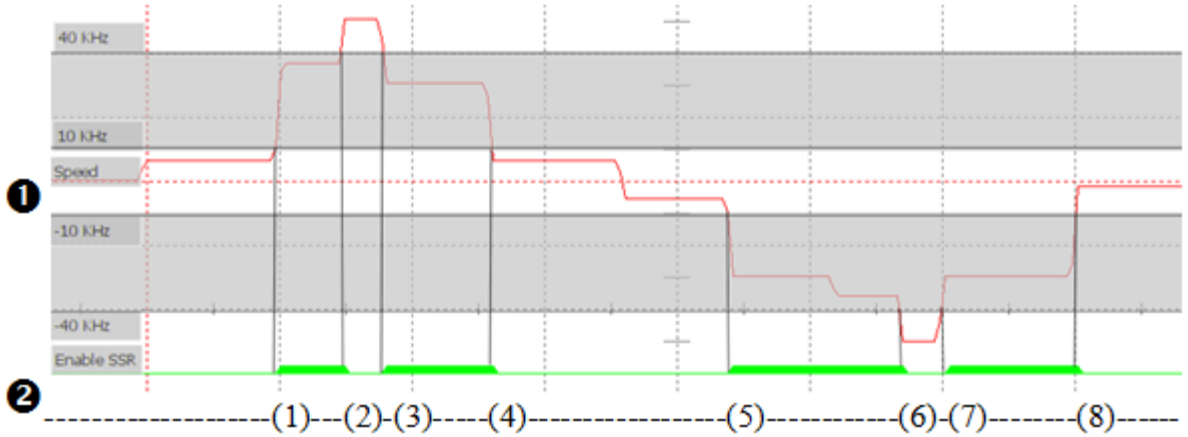


Line ❶:	Actual position [50 incr/div.]	(1):	The tolerance band is set with SET_SOS
Line ❷:	SET_SOS	(2):	The actual position leaves the tolerance band
Line ❸:	Enable SOS	(3):	The tolerance band is set again
Time axis:	1000 ms/div	(4):	The actual position leaves the tolerance band

PNOZ m EF 1MM..2MM (2nd Generation)
„SSR-M, Safe Speed Range Monitoring)“

The SSR-M function keeps the motor speed within the defined limits (EN 61800-5-2).

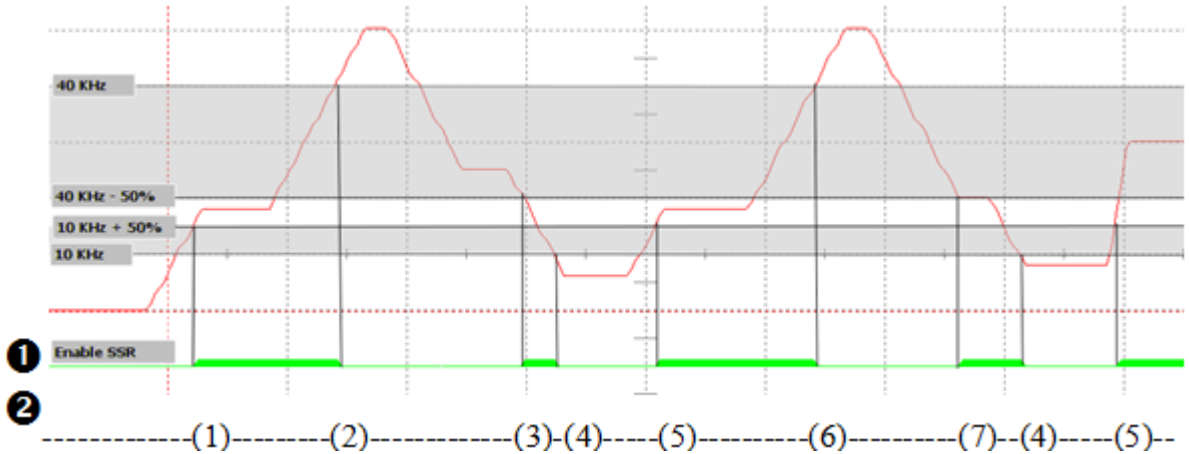
Example 1: Hysteresis = 0 %



Line ❶: Speed [10 kHz/div.]
Line ❷: Enable SSR-M
Time axis: 1000 ms/div

(1): Speed in the positive range
(2): Speed above the upper positive limit
(3): Speed in the positive range
(4): Speed below the lower positive limit
(5): Speed in the negative range
(6): Speed below the lower negative limit
(7): Speed in the negative range
(8): Speed above the upper negative limit

Example 2: Hysteresis = 50 %

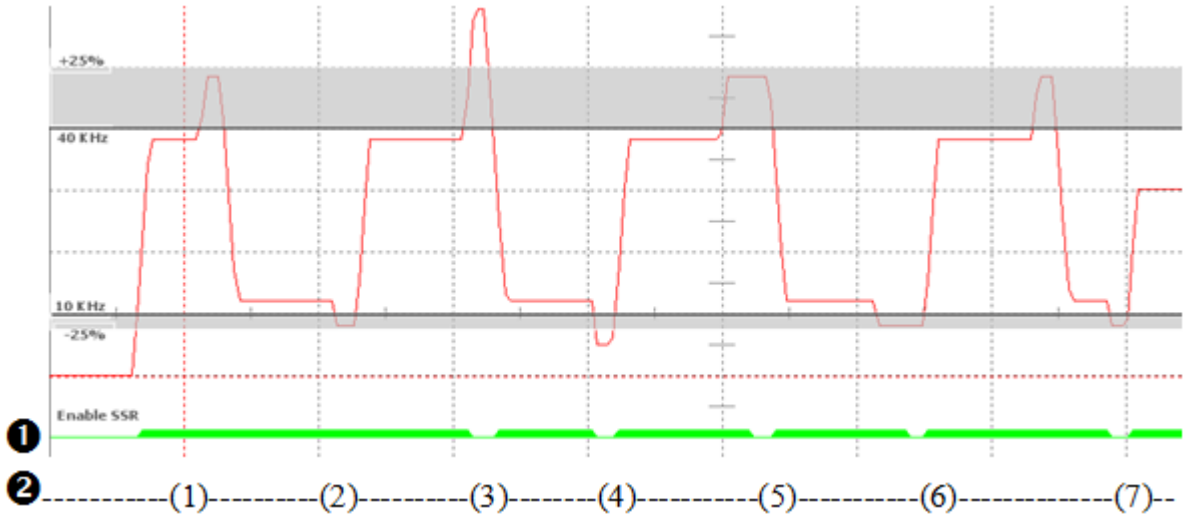


Line ❶: Speed [10 kHz/div.]
Line ❷: Enable SSR-M
Time axis: 1000 ms/div

(1): Speed > lower limit + 50%
(2): Speed > upper limit
(3): Speed < upper limit - 50%
(4): Speed < lower limit
(5): Speed > lower limit + 50%
(6): Speed > upper limit
(7): Speed < upper limit - 50%

PNOZ m EF 1MM..2MM (2nd Generation)
„SSR-M, Safe Speed Range Monitoring)“

Example 3: Activated tolerance range



Line ❶: Speed [10 kHz/div.]
Line ❷: Enable SSR-M
Time axis: 1000 ms/div

(1): Overshoots within the tolerance time t1 and the tolerance amount
(2): Overshoots within the tolerance time t1 and the tolerance amount
(3): Tolerance amount exceeded
(4): Tolerance amount exceeded
(5): Tolerance time t1 exceeded
(6): Tolerance time t1 exceeded
(7): Two overshoots within the tolerance period t2.

PNOZ m EF 1MM..2MM (2nd Generation)
„SSM (Safe Speed Monitoring)“

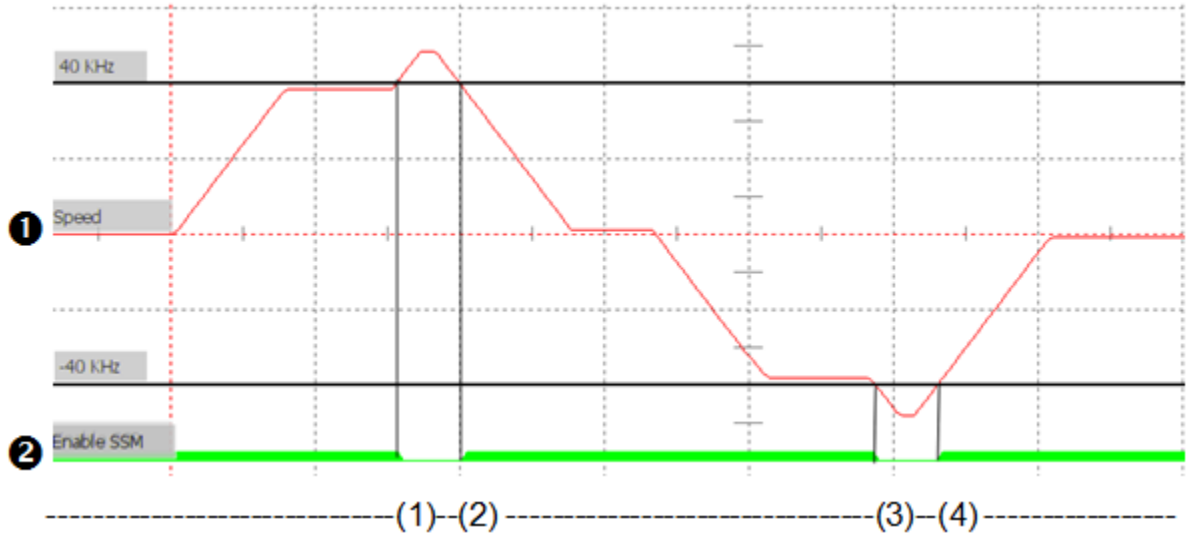
PILZ | A-29

Speed module

- Programming exercise motion monitoring
- Analogue module

The SSM function delivers a safe signal to indicate whether the motor speed lies below or above a defined limit (EN 61800-5-2).

Example 1: Hysteresis = 0 %



Line ❶: Speed [20 kHz/div.]
Line ❷: Enable SSM
Time axis: 1000 ms/div

(1): Speed exceeds the positive limit
(2): Speed falls below the positive limit
(3): Speed falls below the negative limit
(4): Speed exceeds the negative limit

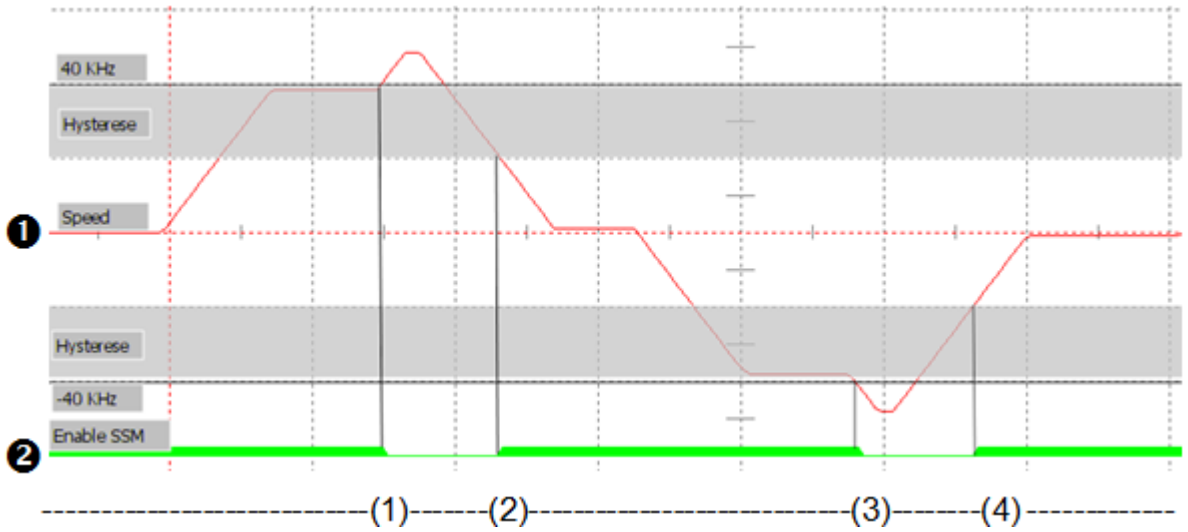
PNOZ m EF 1MM..2MM (2nd Generation)
„SSM (Safe Speed Monitoring)“

PILZ | A-30

Speed module

- Programming exercise motion monitoring
- Analogue module

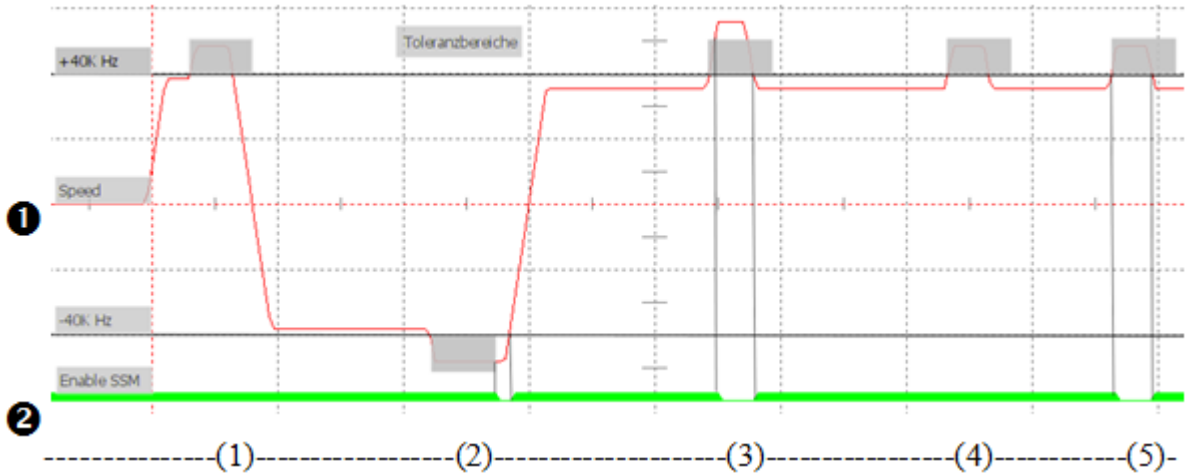
Example 1: Hysteresis = 50 %



Line ❶: Speed [20 kHz/div.]
Line ❷: Enable SSM
Time axis: 1000 ms/div

(1): Speed exceeds the positive limit
(2): Speed falls below the positive limit minus hysteresis
(3): Speed falls below the negative limit
(4): Speed exceeds the negative limit plus hysteresis

Example 2: Activated tolerance range



Line ❶: Speed [20 kHz/div.]
Line ❷: Enable SSM
Time axis: 1000 ms/div.

(1): The speed remains within the defined tolerance range.
(2): The tolerance time t1 is exceeded.
(3): The tolerance amount Tol is exceeded.
(4): The speed remains within the defined tolerance range.
(5): The tolerance period t2 has not been observed

Programming Exercise Speed Modules
Spezification

PILZ | A-34

Speed module

Programming exercise motion monitoring

Analogue module

No.	Description	PLr	Max. Reac-tion time	Priority
SF1	E-STOP (-4S1) (as in programming exercise no. 2)	d	100 ms	High
SF2	E-STOP (-6S1) (as in programming exercise no. 2)	d	100 ms	High
SF3	Safety gate (as in programming exercise no. 2)	d	100 ms	Med.
SF4	Light curtain (as in programming exercise no. 2)	d	40 ms	Med.
SF5	**Operating mode selector switch:** **OFF: No operating selected (as E-STOP)** **Automatic mode: Motor speed is not monitored** **Manual mode: Motor speed is monitored**	d	100 ms	High
SF6	**Motion monitoring:** **If the motor speed in “Manual mode” exceeds the maximum permitted speed, the motor is switched off.** **Hysteresis 50 %.** **Reset with neg. edge is required.**	d	100 ms	Med.

Programming Exercise Speed Modules
Spezification

PILZ | A-34

Speed module

Programming exercise motion monitoring

Analogue module

No.	Description	PLr	Max. Reac-tion time	Priority
SF7	**Enabling switch:** **In manual mode, the drive can run with the enabling switch when the safety gate is open and/or the light curtain is actuated. Motor speed is monitored.**	-	100 ms	High
ZF1	Plant stop (as in programming exercise no. 1)	-	100 ms	Low_2
ZF2	Plant stop (as in programming exercise no. 1)	-	100 ms	Low_2
ZF3	Light in the start button (as in programming exercise no. 1)	-	100 ms	Low_3

Programming Exercise Speed Modules
Cause and Effect-Matrix

PILZ | A-35

Speed module

Programming exercise motion monitoring

Analogue module

				Cause													Effect					
				Involved Inputs										Safety function			Outputs				Verification	Validation
Operating mode AUTO (SF5)	Operatin mode manual (SF5)	Previous state no. during test	State no.	4S1.E-STOP_Ch1 (SF1)	4S1.E-STOP_Ch2 (SF1)	6S1.E-STOP_Ch1 (SF2)	6S1.E-STOP_Ch2 (SF2)	Safety_gate_Ch1 (SF3)	Safety_gate_Ch2 (SF3)	Light_Curtain_Ch1 (SF4)	Light_Curtain_Ch1 (SF4)	Motion-Monitoring (SF6)	Enable Button (SF7)		Reset (Reset plant)	Reset (Reset Safety gate)	Contactor K1	Contactor K2	Lamp in the start button		Checked (ok / not ok)	Checked (ok / not ok)
1	0	-	1	1	1	1	1	1	1	1	1	1	0	ALL_OK: All safety devices are in order. The system has started. Automatic mode is selected.			ON	ON	ON			
1	0	1	2	0	0	1	1	1	1	1	1	1	0	E-STOP (SF1) operated at the control panel	YES	NO	OFF	OFF	OFF			
1	0	1	3	1	1	0	0	1	1	1	1	1	0	E-STOP (SF2) actuated at the danger point	YES	NO	OFF	OFF	OFF			
1	0	1	4	1	1	1	1	0	0	1	1	1	0	ALL_OK not available. Safety gate (SF3) is open.	NO	YES	OFF	OFF	OFF			
1	0	1	5	1	1	1	1	1	1	0	0	1	0	ALL_OK not available. Light curtain (SF4) is interrupted	NO	NO	OFF	OFF	OFF			
1	0	1	6	1	1	1	1	1	1	1	1	0	0	Maximum speed is exceeded	YES	NO	ON	ON	ON			
0	1	1	7	1	1	1	1	1	1	1	1	1	0	ALL_OK: All safety devices are in order. The system has started. Manual operation is selected.			ON	ON	ON			
0	1	7	8	0	0	1	1	1	1	1	1	1	0	E-STOP (SF1) operated at the control panel	YES	NO	OFF	OFF	OFF			
0	1	7	9	1	1	0	0	1	1	1	1	1	0	NE-STOP (SF2) actuated at the danger point	YES	NO	OFF	OFF	OFF			
0	1	7	10	1	1	1	1	0	0	1	1	0	0	ALL_OK not available. Safety gate(SF3) is open and the maximum speed (SF6) is exceeded.	NO	YES	OFF	OFF	OFF			
0	1	7	11	1	1	1	1	1	1	0	0	0	0	ALL_OK not available. Light grid (SF4) is interrupted and the maximum speed (SF6) is exceeded.	NO	NO	OFF	OFF	OFF			
0	1	7	12	1	1	1	1	0	0	1	1	0	1	ALL_OK not available. Safety gate (SF3) is open, the maximum speed (SF6) is exceeded and the enabling switch (SF7) is actuated.	NO	YES	ON	ON	ON			
0	1	7	13	1	1	1	1	1	1	0	0	0	1	ALL_OK not available. Light curtain (SF4) is interrupted, the maximum speed (SF6) is exceeded and the enabling switch (SF7) is activated.	NO	NO	OFF	OFF	OFF			

V1	Date:
	Name:
D1	Validation performed (ok / not ok):
	Date:
	Name:

Programming Exercise Speed Modules
Cause and Effect-Matrix

PILZ | A-36

Speed module

Programming exercise motion monitoring

Analogue module

Main program	Function description	Graphic
Page 1 (SF)	Safety function: If one of the E-STOP devices is operated or the safety gate is opened or the light curtain is actuated, the enable for power to the drive contactors is removed. **NEW:** **Operating mode selector switch with the operating modes:** **- OFF (as E-STOP)** **- MANUAL** **- AUTOMATIC** **and the enabling switch.** **In MANUAL mode, the enabling switch can be used to run the drive at max. 200 1/min even if the safety gate is open and/or the light curtain is actuated.**	

Programming Exercise Speed Modules
Cause and Effect-Matrix

PILZ | A-36

Speed module

Programming exercise motion monitoring

Analogue module

Main program	Function description	Graphic
Page 2 (Start-Stop)	The machine drive can be switched on using the start button and switched off using the stop button. The enable for the safety functions must be present. The drive contactors are monitored using a feedback loop (EDM).	
Module program_1	**Function description**	**Graphic**
Page 1 (SSM)	**The speed is to be monitored at 200 revolutions per minute (1/min) with the SSM element. This is only monitored in “Manual” mode.**	

Analogue Module 1st Generation
General

PILZ | A-37

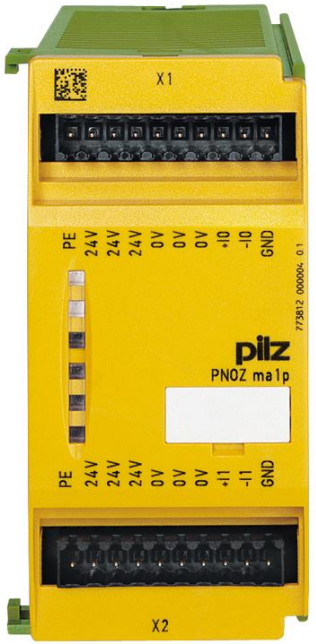
Speed module

Programming exercise motion monitoring

Analogue module

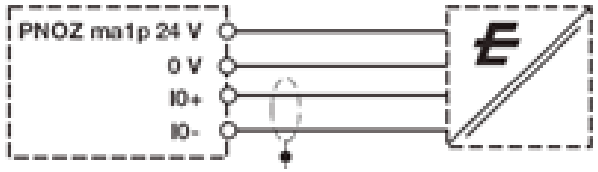
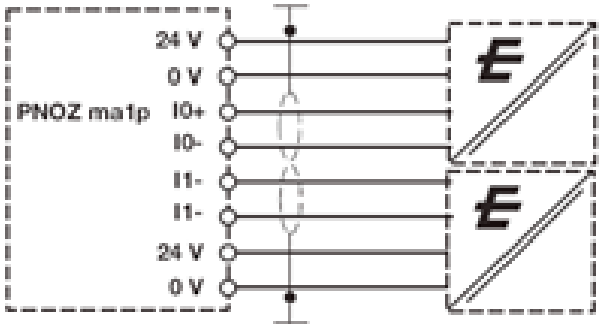
Features

- Module is connected to the left page
- 2 safety analog inputs
  - IEC 62061: SIL CL 2
  - ISO 13849-1: PL d
- Monitoring of current or voltage
- Up to 4 modules can be connected to the base unit left = 8, analog inputs
- Condition
  - Hardware: PNOZmulti base unit up to V 5.6
  - Software: PNOZmulti Configurator up to V 5.3.0



Analogue Module 1st Generation
Wiring

- Current measurement

Application in accordance with: - PL d - SIL 2	
Application in accordance with: - PL e - SIL 3	

- Voltage measurement
  - No examples for voltage measurement
  - The signal to be measured must be connected to the analogue input
  - Pay attention to shielding

Analogue Module 1st Generation
Software elements

PILZ | A-39

- Speed module
- Programming exercise motion monitoring
- **Analogue module**

Illustration	Name	Description and setting options
	Analogue	Input element for processing the analog signals of the PNOZ m a1p module. This element has the following functions: - Tolerance and current equivalent - Area monitoring - Threshold monitoring - Restart behavior

Analogue Module 1st Generation
Software elements

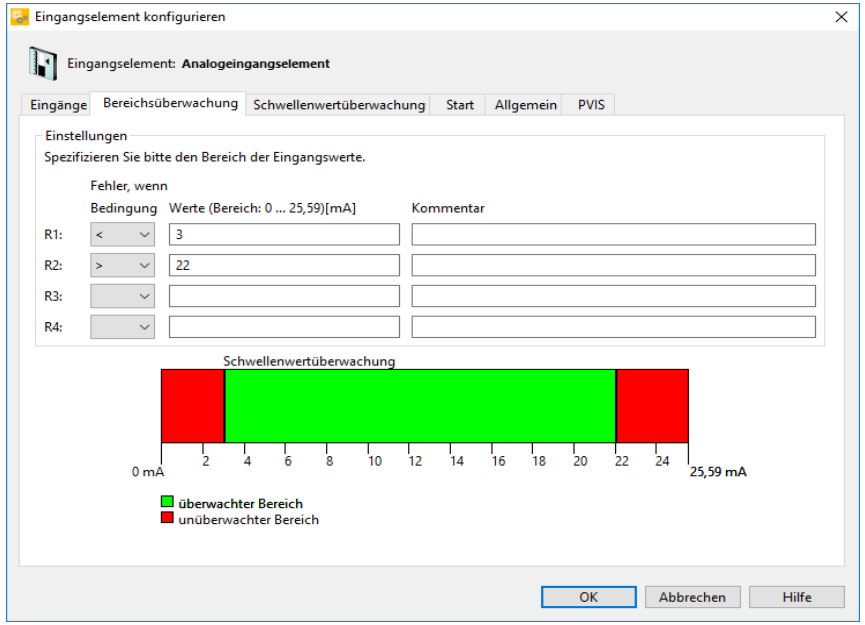
PILZ | A-41

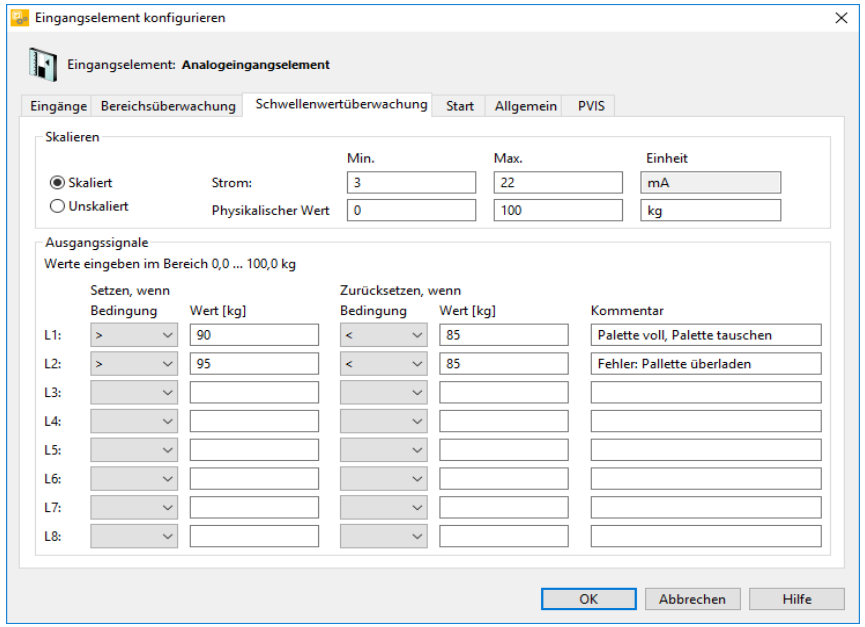
Speed module

Programming exercise motion monitoring

Analogue module

- Only one element: analogue element
- Placement in the left column in the main program
- All settings are made in the module
  - Range monitoring to configure the expected input signal
  - Threshold value monitoring for configuring the switching thresholds





Analogue Module 2nd Generation
General

Features

- Module is connected to the right page
- 4 safety analog inputs
  - IEC 62061: SIL CL 2
  - ISO 13849-1: PL d
- Monitoring of current
- Up to 6 (PNOZ m B0 = 24 analog inputs) or 12 (PNOZ m B1 = 48 analog inputs) modules can be connected to the base unit
- Condition
  - Hardware: PNOZmulti base unit up to V 2.5 (PNOZ m B0)
  - Software: PNOZmulti Configurator up to V 10.8.0

Analogue Module 2nd Generation
Wiring

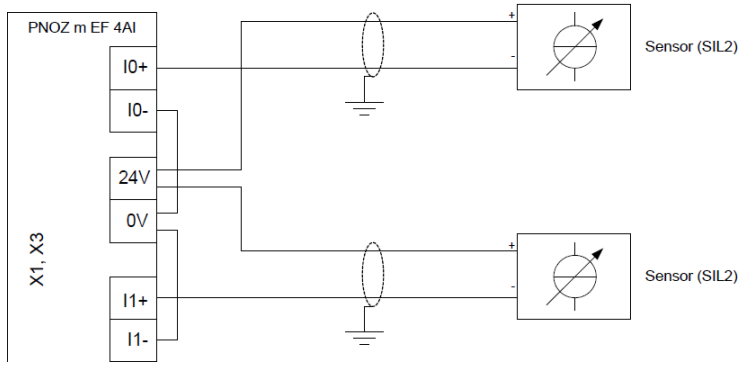
PILZ | A-44

Speed module

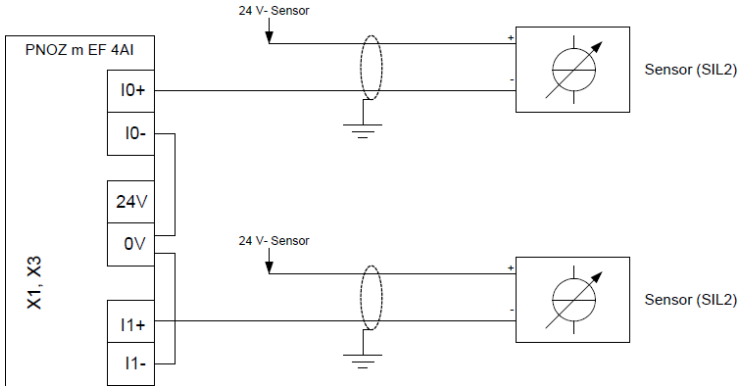
Programming exercise motion monitoring

Analogue module

2-wire connection, voltage supplied to the sensors via analogue input module



2-wire connection, voltage supplied to the sensors externally



Analogue Module 2nd Generation
Wiring

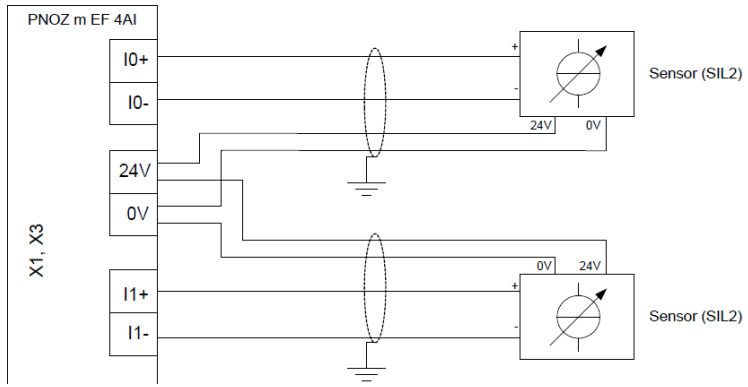
PILZ | A-45

Speed module

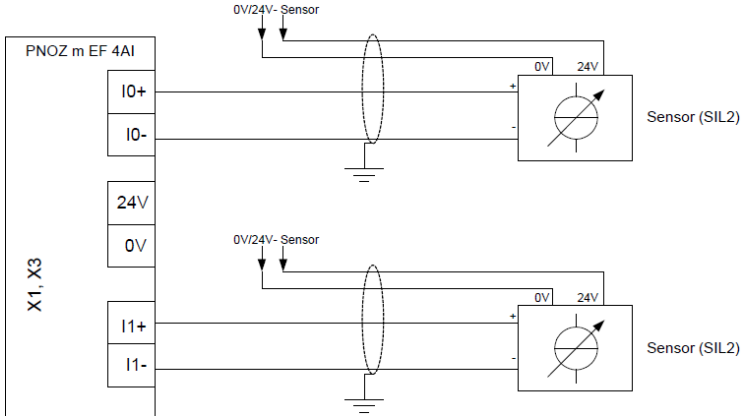
Programming exercise motion monitoring

Analogue module

- 4-wire connection, voltage supplied to the sensors via analogue input module



- 4-wire connection, voltage supplied to the sensors externally

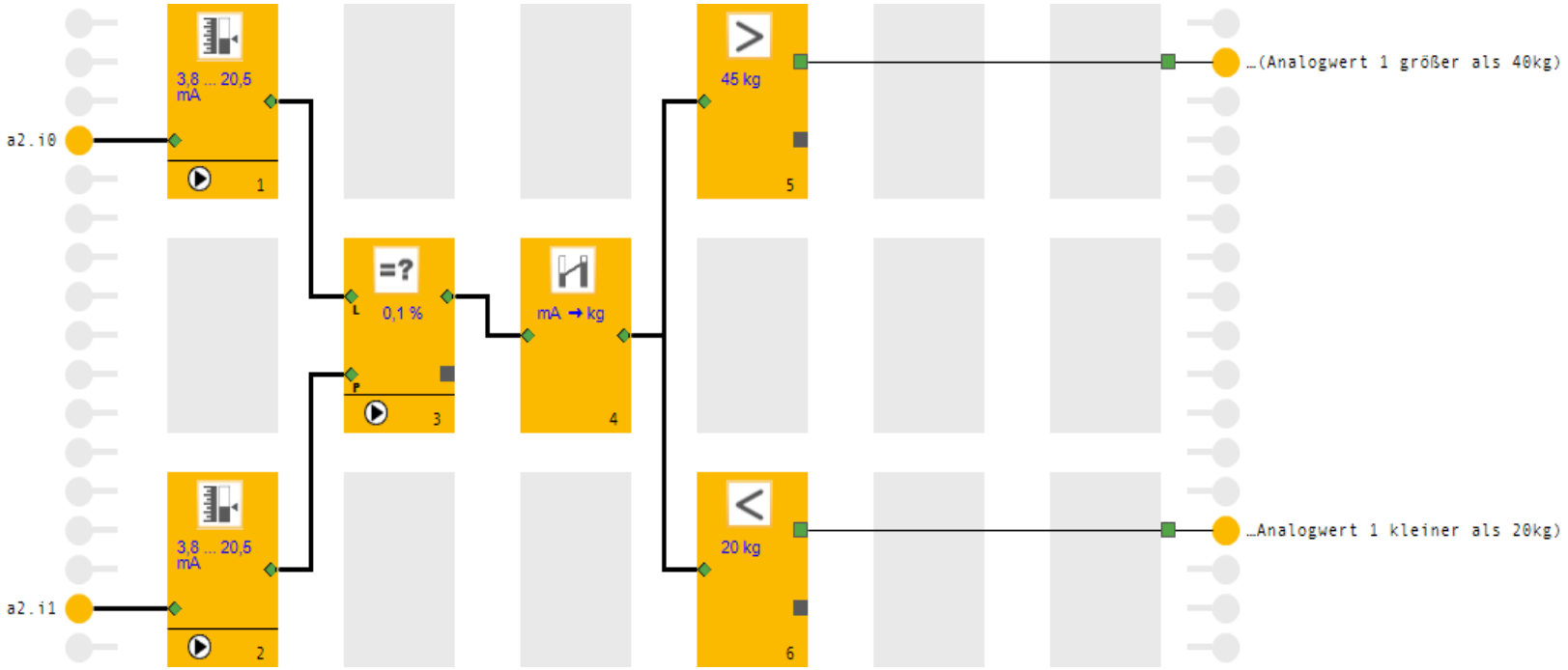


Analogue Module 2nd Generation
Software elements

PILZ | A-46

- Speed module
- Programming exercise motion monitoring
- **Analogue module**

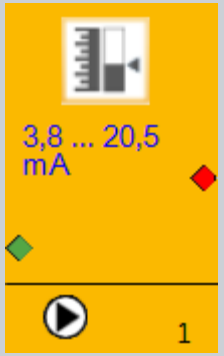
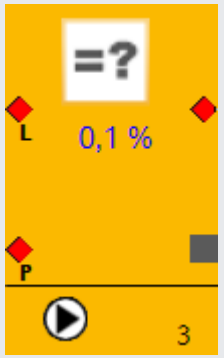
- Several elements:
  - Analog input element
  - Billing and calculation elements
  - Area monitoring elements



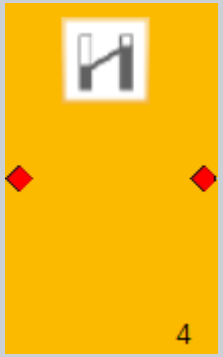
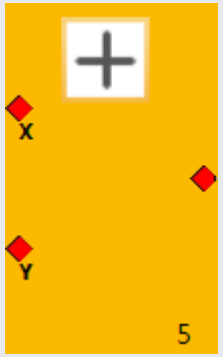
Analogue Module 2nd Generation
Software elements

PILZ | A-49

- Speed module
- Programming exercise motion monitoring
- **Analogue module**

Illustration	Name	Description and setting options
	Analogue input element	Function element for processing the analogue signals of the module PNOZ m EF 4AI. This element has the following functions: - Tolerance and current equivalent - Working range monitoring - Restart behaviour
	Plausibility	Function element for connecting two analogue input elements with integrated plausibility test. The deviation of both values is monitored. Tolerance types: -Percentage tolerance -Absolute tolerance -Absolute/percentage tolerance A temporary deviation of the value can also be set via the “Peak Tolerance” tab. A tolerance time and a tolerance period can be set.

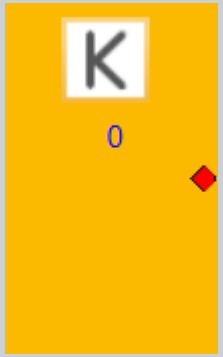
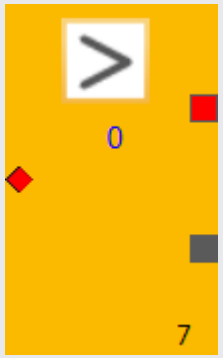
Analogue Module 2nd Generation
Software elements

Illustration	Name	Description and setting options
	Scaling	The scaling block is used to convert the input value into an output value. The current, checked for plausibility, is configured on the input side; the scaled limit values are set on the output side. The unit of the configured value is also entered. This will be set and displayed automatically in all subsequent elements.
	Mathematical operation	The input value X is offset with the input value Y via a mathematical function. The following mathematical functions are available: - Addition - Subtraction - Average

Analogue Module 2nd Generation
Software elements

PILZ | A-50

- Speed module
- Programming exercise motion monitoring
- **Analogue module**

Illustration	Name	Description and setting options
	Constant	The constant element allows a consistent variable constant to be added in mathematical operations. A constant can have a positive or negative sign.
	Range monitoring	Range monitoring is used to monitor analogue words. These may or may not have been calculated. One threshold is monitored per element via the conditions - Greater than - Less than The switch-on and switch-off threshold can be set separately. This element serves as the interface between the analogue values and the main program's binary system. Only its output can be connected to a program connector output.

Automatisierungs-
technik

COMPONENTS
SYSTEMS
SERVICES

innovativ ökologisch
sicher wirtschaftlich

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