AGV Application with PNOZmulti 2 and PSENscan

PILZ
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Product

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Name:	PNOZmulti 2, PSENscan
Manufacturer:	Pilz GmbH & Co. KG, Safe Automation

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Validity of Application Note

This present Application Note is valid until a new version of the document is published.
This and other Application Notes can be downloaded in the latest version and for free from www.pilz.com. For a simple search, use our content document (1002400) or the direct search function in the download area.

The Pilz newsletter is free of charge and keeps you up to date on all the latest issues and trends in safe automation.

Exclusion of Liability

We have taken great care in compiling our application note. It contains information about our company and our products. All statements are made in accordance with the current status of technology and to the best of our knowledge and belief.
While every effort has been made to ensure the information provided is accurate, we cannot accept liability for the accuracy and entirety of the information provided, except in the case of gross negligence. In particular, all information on applicable standards, safety-related classifications and time characteristics should be viewed as provisional. In particular it should be noted that statements do not have the legal quality of assurances or assured properties.
We are grateful for any feedback on the contents.

February 2024

Industrial Security

To secure plants, systems, machines and networks against cyberthreats it is necessary to implement (and continuously maintain) an overall Industrial Security concept that is state of the art.
Perform a risk assessment in accordance with VDI/VDE 2182 or IEC 62443-3-2 and plan the security measures with care. If necessary, seek advice from Pilz Customer Support.

Abbreviations

Abbreviation / term	Description	Source
AGV	**A**utomated **G**uided **V**ehicle	
AMR	**A**utonomous **M**obile **R**obots	
AN	**A**pplication **N**ote	www.pilz.com > AN content (1002400)
ESPE	**E**lectro-**S**ensitive **P**rotective **E**quipment	
$MTTF_D$	**M**ean **T**ime **T**o **D**angerous **F**ailure	
NC	**N**ormally **C**losed	
NO	**N**ormally **O**pen	
OSSD	**O**utput **S**ignal **S**witching **D**evice	
PFH	Average Frequency Of A Dangerous **F**ailure Per **H**our	
PNOZ	Pilz E-STOP positive-guided (DE: **P**ilz **NO**T-AUS-**Z**wangsgeführt)	www.pilz.com > PNOZ
PNOZmulti 2	**PNOZ multi**functional, **2**nd generation	www.pilz.com > PNOZmulti 2
PSEN	**P**ilz **Sen**sor	www.pilz.com > PSEN
PSENscan	**PSEN Scan**ner	www.pilz.com > PSENscan
PSS	Programmable control system (DE: **P**rogrammierbares **S**teuerungs**s**ystem)	www.pilz.com > PSS
PSS u2	**PSSu**niversal, **2**nd generation	www.pilz.com > PSS u2
TTL	**T**ransistor **T**ransistor **L**ogic	

Definition of Symbols

- Information that is particularly important is identified as follows:

CAUTION!

This refers to a hazard that can lead to a less serious or minor injury plus material damage, and also provides information on preventive measures that can be taken.

NOTICE

This describes a situation in which the product or devices could be damaged and also provides information on preventive measures that can be taken.
It also highlights areas within the text that are of particular importance.

INFORMATION

This gives advice on applications and provides information on special features.

Contents

1 Useful documentation

Reading the documentation listed below is necessary for understanding this Application Note. The availability of the software used, and its safe handling are also presupposed for the user.

1.1 Documentation from Pilz GmbH & Co. KG

No.	Description	Item No. /Download
1	Pilz international homepage, download section	www.pilz.com
2	Operating Manual PSEN sc L 3.0/5.5 08-12	www.pilz.com > BA 1005056
3	Operating Manual PSEN sc ME 5.5 08-17	www.pilz.com > BA 1005388
4	Operating Manual PNOZ m B1	www.pilz.com > BA 1003790
5	Operating Manual PNOZ m EF 1MM	www.pilz.com > BA 1003108
6	Operating Manual PNOZ m EF 2MM	www.pilz.com > BA 1003107
7	Operating Manual PNOZ m EF 8DI4DO	www.pilz.com > BA 1002661

1.2 Documentation from other sources of information

No.	Description	Item No. / Download
1		
2		
3		
4		

2 Used hardware and software

2.1 Pilz products

No.	Descriptions	Order number	Version	Number
1	PSENscan Configurator	-	3.1.6.516-RTM	-
2	PNOZmulti Configurator	-	11.3.0	-
3	PSEN sc L 3.0 08-12	6D000012	-	-
4	PSEN sc L 5.5 08-12	6D000013	-	-
6	PSEN sc ME 5.5 08-17	6D000034	-	-
7	PSEN sc S 3.0 08-12	6D000020	-	-
8	PSEN sc S 5.5 08-12	6D000021	-	-
9	PNOZ m B1	772101	-	-
10	PNOZ m EF 1MM	772170	-	-
11	PNOZ m EF 2MM	772171	-	-
12	PNOZ m EF 8DI4DO	772142	-	-

2.2 Third-party products

No.	Descriptions	Order number	Version	Number
1				
2				
3				
4				

3 Preface

This guide explains how to configure the PSEN laser scanner and the PNOZmulti speed monitoring elements to be able to safely monitor the speed and direction of AGV/AMRs with directional drives and activate different protective fields on the scanner. The detection of the direction and speed of movement leads selection and control of the corresponding scanner protective zones on the AGV.

NOTICE

A detailed explanation of safety functions used in the failsafe application and its evaluation regarding functional safety are not a part of this document.

4 Application description

4.1 PSENscan Configuration

4.1.1 Overview Scanner Device Features:

First, a scanner can be, a standalone, master, or subscriber. The standalone version can't be connected to other devices, the master version can be used alone or connected to 3 devices (scanner version subscriber), and the subscriber can't be used without a master device.
A master/subscriber functionality allows one scanner to act as master and communicate with up to three other scanners. The safety controller needs to communicate only with the master, reducing the required number of input and communication channels on the controller.

Safety laser scanners of the **PSEN sc L 3.0/5.5 08-12** series constitute electrosensitive protective equipment (ESPE type: 3) in accordance with EN 61496-3 for workspaces in which machines, robots, and automated systems might pose a physical danger to their operators. Configurations are created with the PSENscan Configurator:
- With the teach-in function when creating zones.
- Support for several zone sets for a difference at exactly two points.
- Detection capability: 30 mm, 40 mm, 50 mm, 70 mm, 150 mm.

Connection:
- With 8-pin M12 connector on supply voltage and evaluation device.
- With 12-pin M12 connector on supply voltage and evaluation device.

Technical Overview PSEN sc L 3.0/5.5

Max. number	Connection to	
	8-pin male connector	12-pin male connector
OSSD pairs	1	2
Configurable inputs	2	1
Configurable inputs/outputs	1	4
Zone sets	3	10

Safety laser scanners of the **PSEN sc M 3.0/5.5 08-17** series constitute electrosensitive protective equipment (ESPE type: 3) in accordance with EN 61496-3 for workspaces in which machines, robots, and automated systems might pose a physical danger to their operators. Four safety laser scanners can be connected in series (1 master and 3 subscribers).

Configurations are created with the PSENscan Configurator:
- With teach-in function when creating zones.
- Support for several zone sets for a difference at exactly two points.

In a series connection with master and subscriber units, devices with different operating ranges and different detection capabilities can be freely combined. Their detection capability: 30 mm, 40 mm, 50 mm, 70 mm, 150 mm.

Connection:
- With 17-pin M12 connector on supply voltage, evaluation device and inputs or...
- With 17-pin M12 connector on supply voltage, evaluation device and inputs and 8-pin M12 connector on inputs.

Technical Overview PSEN sc M 3.0/5.5

Max. number	Connection to	
	17-pin male connector	8-pin male connector + 17-pin male connector
OSSD pairs	3	3
Configurable inputs	4	8
Configurable Outputs	2	2
Configurable inputs/outputs	2	2
Zone sets	20	70

4.1.2 Connection & Programming of Safety Zones:

To connect the scanner, ensure that the software PSENscan Configurator is installed on the configuration PC. We recommend that you always use the latest version (download from www.pilz.com). Finally, ensure that the safety laser scanner is switched off when creating a connection to the configuration PC (for more information consult the scanner operating manual). The first step to configure the scanner and the safety zones is to define the general properties of the project (name, IP, etc.). After that determine which signals, such as outputs and inputs are necessary for the application (see next image).

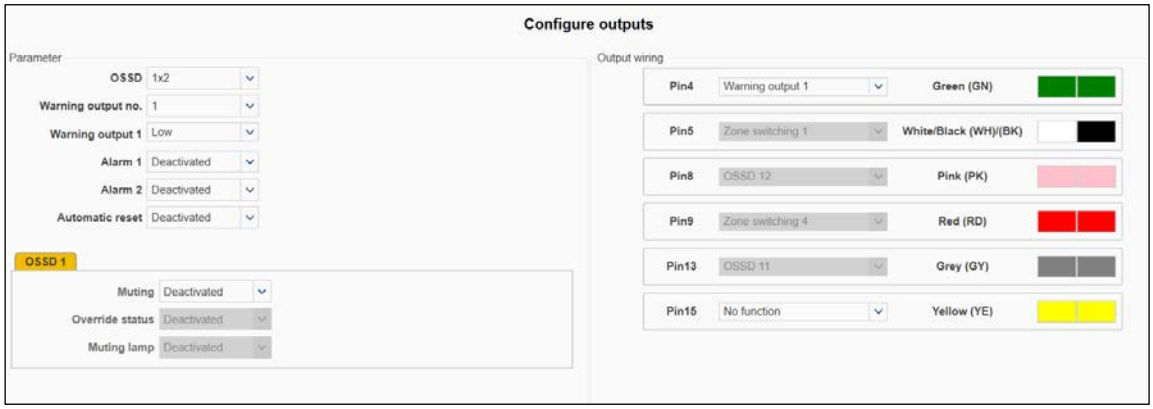


Figure 1: Configuration with PSENscan Configurator

The second step is to configure and define how many zone sets are necessary for the AGV. The number of zone sets that can be configured depends on the connection used and the number of warning outputs configured. The following table details the limits for each connection.

Connection			
8-pin	12-pin	17-pin	17+8-pin
3	10	10	70
2	6	10	70
-	6	6	70

Figure 2: Scanner Connections Options

In the following image, there's an example of different zone sets and the input signal necessary to change each one of them. On the right are the colours of the cable connection corresponding to their respective input.

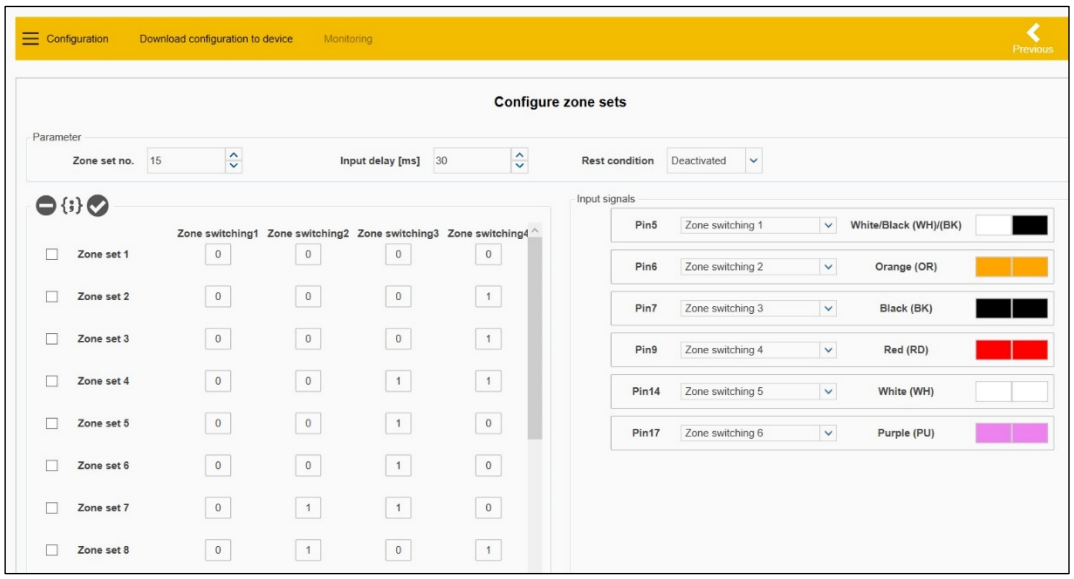


Figure 3: SW Zone Sets

Finally, the last step is the configuration of the safety and warning zones for the different zone sets created before. In the following images, there are examples of different zones depending on the application and characteristics of the AGV. After creating them, they are available to be selected (left side of the software) and checked zone by zone of the configuration.

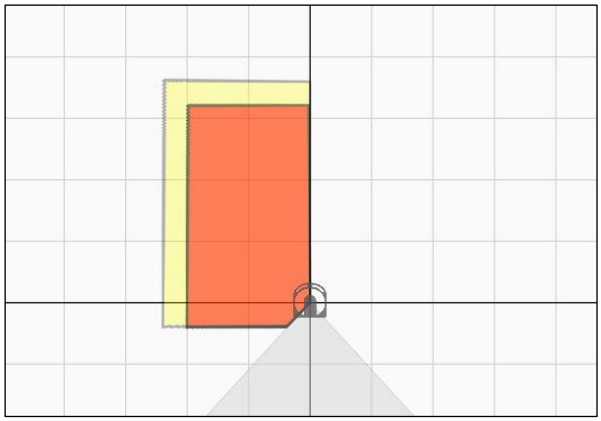


Figure 4: Zone Example 1

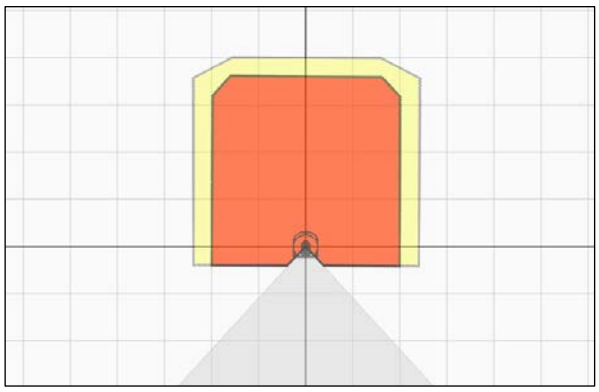


Figure 5: Zone Example 2

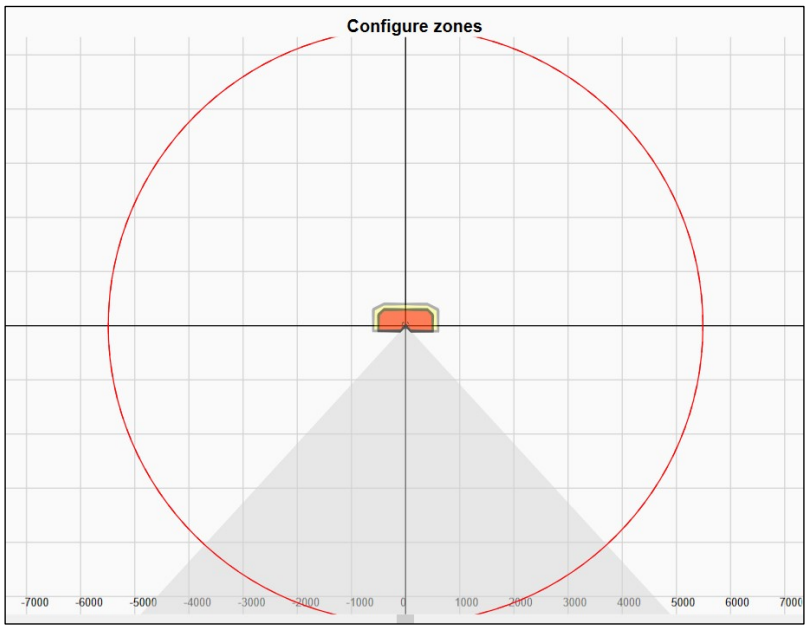


Figure 6: Zone Example 3

INFORMATION

More information about creating zones can be seen on the software “HELP” or in the Operating manuals of the respective PSENscan.

4.2 PNOZmulti Configuration

INFORMATION

PNOZ Multi AGV Configuration (Scanner):
This manual isn't an introduction to the PNOZmulti Configurator. The purpose is to introduce the Motion Monitoring Elements for AGV models.

To use the PNOZmulti for AGV applications we need to configure the hardware and program the logic, inputs and outputs necessary.

4.2.1 PNOZmulti Elements

The first element needed is the "Laser Scanner":

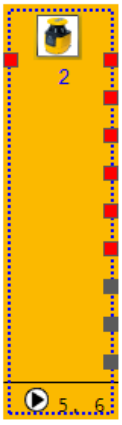
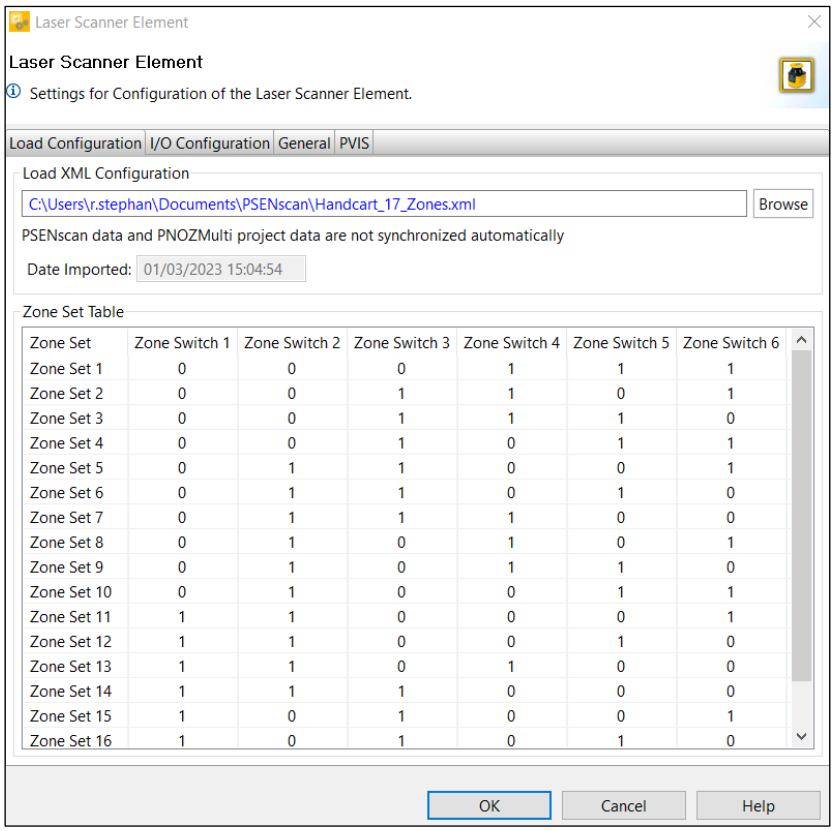


Figure 7: Laser Scanner Element

With this element, the first thing to do is import the scanner configuration developed earlier (there's a preview of that in the next image).
The I/O configuration for this element is simple, the only input indicates if the outputs of the scanner are active or not (so if the zone of the scanner is obstructed or not). The outputs of the scanner represent the "Zone Switch" signals to indicate which Zone Set is active or not, there's a preview of that in the next image as well.
After the import of the scanner configuration is important to note that these zone sets are the same configured in the scanner software, so what is configured there related to zones, dimensions, signals, etc, are imported to the element, influencing the output behavior.



Zone Set	Zone Switch 1	Zone Switch 2	Zone Switch 3	Zone Switch 4	Zone Switch 5	Zone Switch 6
Zone Set 1	0	0	0	1	1	1
Zone Set 2	0	0	1	1	0	1
Zone Set 3	0	0	1	1	1	0
Zone Set 4	0	0	1	0	1	1
Zone Set 5	0	1	1	0	0	1
Zone Set 6	0	1	1	0	1	0
Zone Set 7	0	1	1	1	0	0
Zone Set 8	0	1	0	1	0	1
Zone Set 9	0	1	0	1	1	0
Zone Set 10	0	1	0	0	1	1
Zone Set 11	1	1	0	0	0	1
Zone Set 12	1	1	0	0	1	0
Zone Set 13	1	1	0	1	0	0
Zone Set 14	1	1	1	0	0	0
Zone Set 15	1	0	1	0	0	1
Zone Set 16	1	0	1	0	1	0

Figure 8: Configuration Laser Scanner Element

With that, becomes available on the software a list and signal to change from one zone set to another. From the "Zone Set" element it's possible to select the scanner and which zone set is triggered.

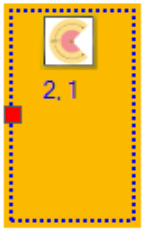


Figure 9: Zone Set Element

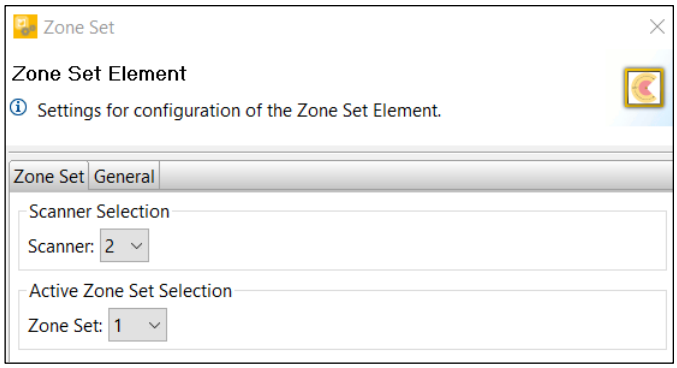


Figure 10: Configuration Zone Set Element

4.2.2 PNOZ Multi AGV Configuration (Motion Encoder):

To safely monitor the speed and direction of the AGV and enable the correct safety zone, the first element that we need to configure is the “Motion Monitoring Element”. It’s necessary one for each encoder used on the AGV. The Motion Monitoring element is used for configuration of the motion monitoring modules PNOZ m EF 1MM and PNOZ m EF 2MM.

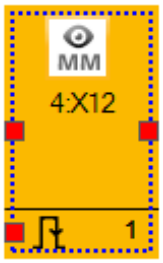


Figure 11: Motion Monitoring Element

One Motion Monitoring element is needed for each axis. The sensor data and user-defined units are configured in the element. In addition, the diagnostic configuration can be activated. Bellow there’s a representation of the schematic:

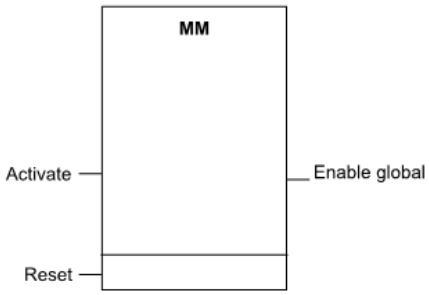


Figure 12: Schematic Motion Monitoring Element

After selecting this element, the settings pop up. The following step is to configure the axis and all the variables associated with that. One motion monitoring element is needed for each axis. If an axis has already been configured, it will no longer be available for selection. Figure 14 illustrates the settings window for this element.

The settings of this element are:

- Sensor Axis: selection of the axis connected to the module.
- Sensor Type: Type of sensor connected (HTL, TTL, etc).
- Increments per revolution: Increments per revolution at tracks A and B
- Max. Frequency AB: Maximum frequency of the sensors at tracks A and B. (A maximum permitted frequency must be entered to protect the sensors. The value must be greater than or equal to the configured limit values.).
- Hysteresis: A hysteresis can be configured to prevent the outputs from bouncing if there are fluctuations around the response value. The stated percentage refers to the values for the monitoring functions with threshold monitoring. When 0 % is configured, no hysteresis is set.
- Invert Motion Direction: Reversal of direction of movement. The internal direction of movement can be reversed. It affects the direction monitoring SDI-M.
- Advanced Settings: A tolerance time can be configured for tracks AB, Z and S respectively. The tolerance time influences the sensitivity towards invalid signal levels (e.g. in the event of EMC interference). The greater the configured tolerance time, the less sensitive the system will be towards invalid signal levels. The tolerance time can be deactivated for individual tracks by setting 0 ms.
- AB Tolerance Time: Tolerance time for tracks A and B. If a sensor is configured with Z-Index, then the AB tolerance time will also apply to track Z.

- Z Tolerance Time: Tolerance time for track Z. Can only be configured if a sensor type with Z initiator is used.
- S Tolerance Time: Tolerance time for track S. Can only be configured if a sensor type with S initiator is used.

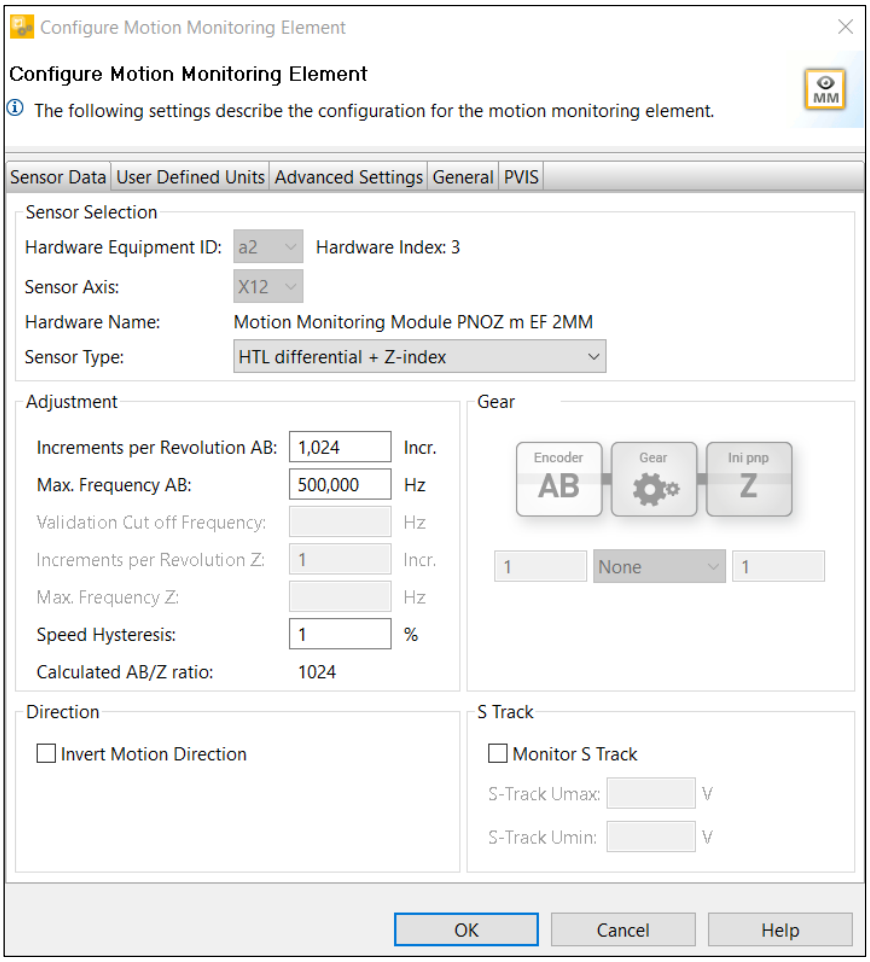


Figure 13: Configuration Motion Monitoring

After configuring the axis, there are multiple function options available. The following safe monitoring functions are available:

- Safe speed monitoring (SSM).
- Safe speed range monitoring (SSR-M).
- Safe direction monitoring (SDI-M).
- Safe operating stop monitoring (SOS-M).
- Safe stop 1 monitoring (SS1-M).
- Safe stop 2 monitoring (SS2-M).
- Safely limited acceleration monitoring (SLA-M).
- Safely acceleration range monitoring (SAR-M).

4.2.2.1 SSC Element

Let's start with one important function for an AGV application, the "Safe Speed Comparison".

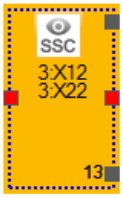


Figure 14: SSC Element

This element is used to compare the speed from Axis 1 with Axis 2 (selected on the next window). Here it's possible to enable 3 outputs depending on if it's necessary to compare if the speed is above, below, equal, or all 3 options.

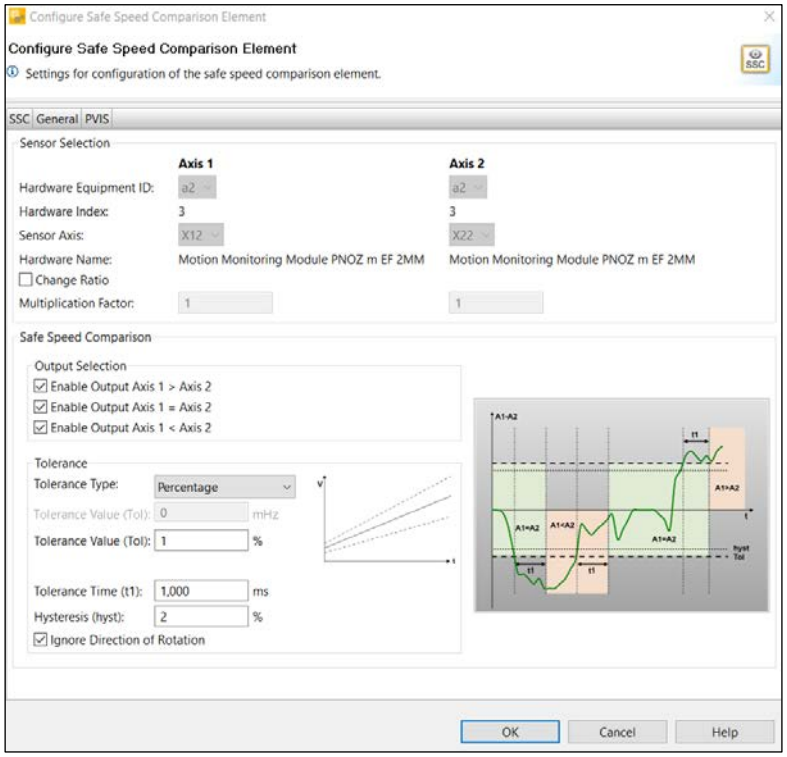


Figure 15: Configuration SSC Element

The outputs from this element activate depending on the velocity of the axis, so the first one is activated if A1 > A2, the middle one if the velocity is equal and the last one if A1 < A2. Later it explains how this influences the logic of the AGV, with this information we can detail if the vehicle is moving forward, left, or right.

4.2.2.2 SSM Element

To understand which speed is the AGV moving and if it's passing the limits established, it's necessary to use the Safe Speed Monitoring Element" (SSM).

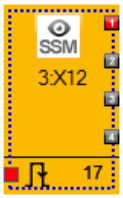


Figure 16: SSM Element

Bellow, there's a representation of the schematic:

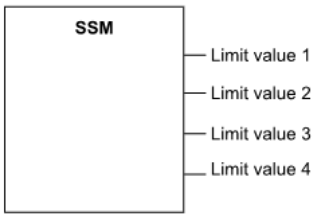


Figure 17: Schematic SSM Element

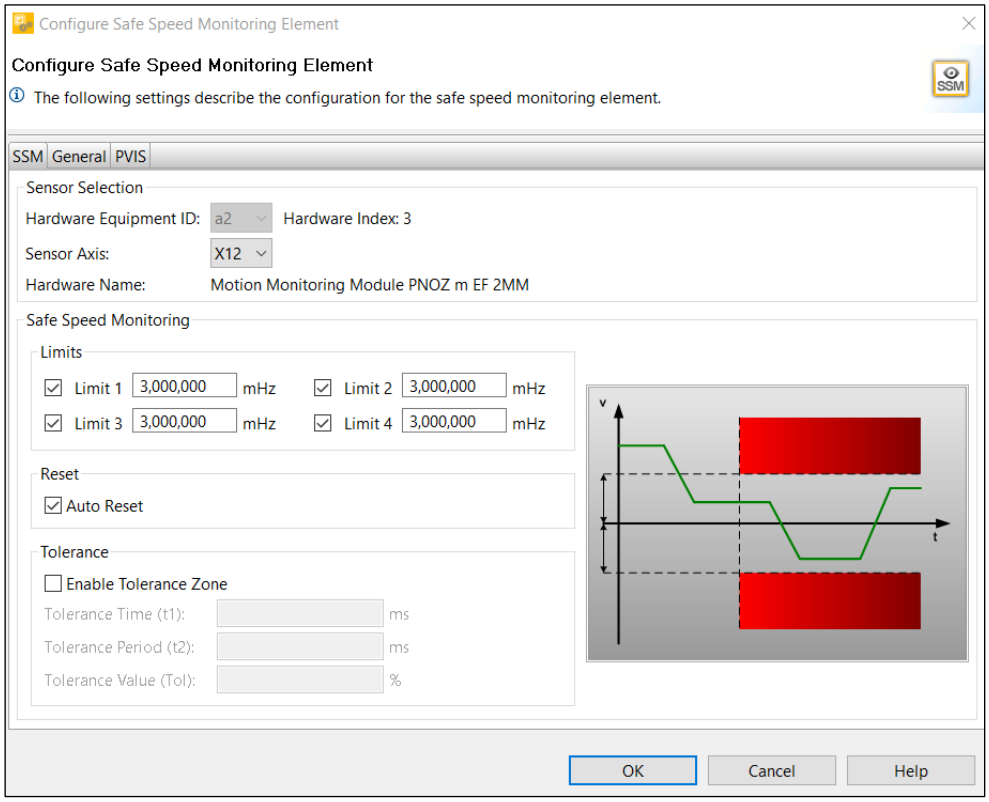


Figure 18: Configuration SSM Element

At least 3 Safe speed monitoring elements can be configured on each axis of a motion monitoring module. Up to 4 limit values for safe speed monitoring (SSM) can be configured in a Safe speed monitoring element. This means that up to 12 limit values can be monitored per axis. The output is activated when the limit is exceeded.

Enable Tolerance Zone: A tolerance range may be configured to modify the set limit values. As a result, one-off or periodic overshoots that exceed the limit values can be tolerated.

4.2.2.3 SDI Element

With AGV applications it's important to verify if the vehicle is moving forward or backwards. To do that it's available the "Safe Direction of Movement Monitoring Element" (SDI-M).

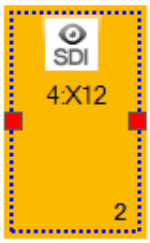


Figure 19: SDI Element

Below, there's a representation of the schematic:

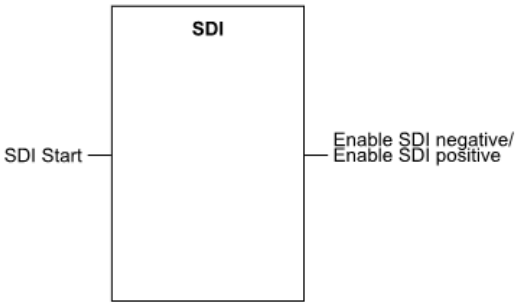


Figure 20: Schematic SDI Element

The following table details the properties and settings to configure the SDI element:

Properties	Description
Hardware equipment identifiers	Equipment ID of the motion monitoring module to be configured
Sensor axis	2 ***safe direction monitoring*** elements can be configured for each axis. Selection: ▸ X12 ▸ X22 The only axes displayed for selection are those for which a ***Motion monitoring*** element is already configured.
Enable "Negative" direction	Activation of the direction of movement monitoring for the negative direction
Enable "Positive" direction	Activation of the direction of movement monitoring for the positive direction
Tolerance amount	Tolerance amount for the wrong direction of movement

Figure 21: Configuration Parameters SDI Element

The Outputs available are:
Enable SDI positive: direction of movement monitoring positive direction:
- "0" signal: The tolerance band has been exceeded in negative direction.
- "1" signal: Positive direction of movement or standstill.

Enable SDI negative: direction of movement monitoring negative direction:
- "0" signal: The tolerance band has been exceeded in positive direction.
- "1" signal: Negative direction of movement or standstill.

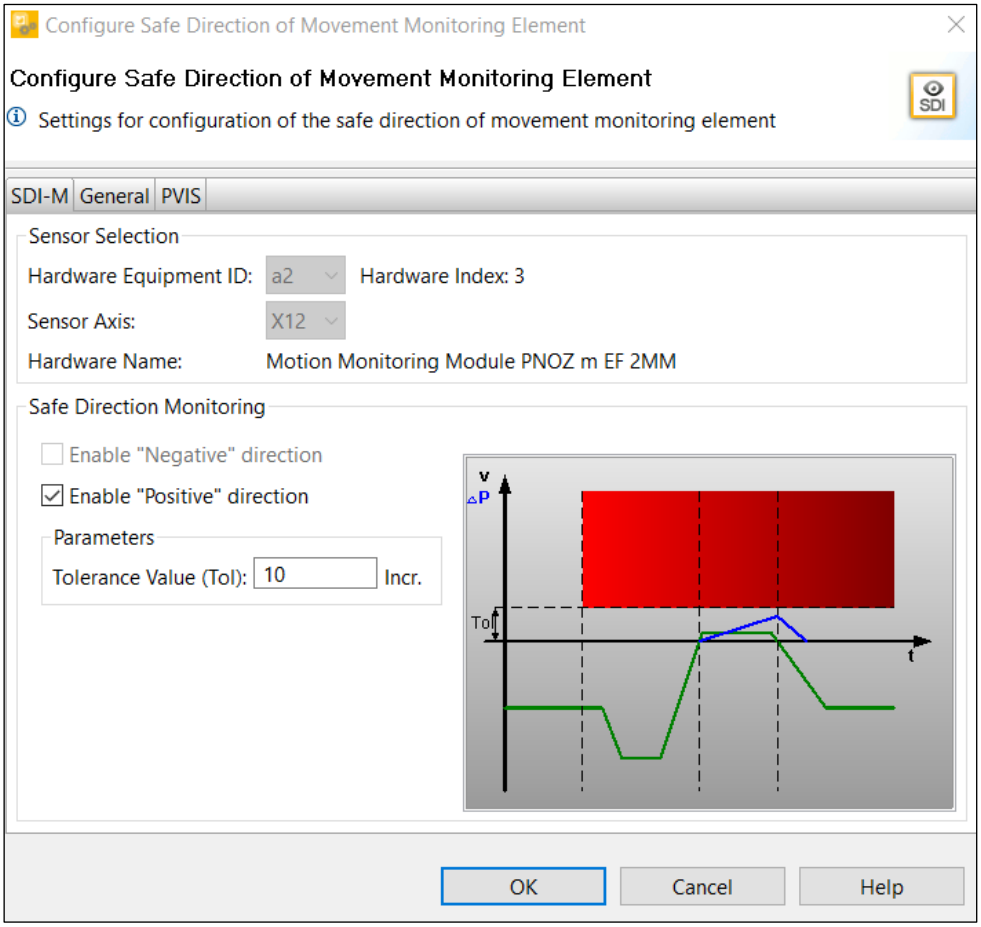


Figure 22: Configuration SDI Element

4.2.2.4 SS1 Element

The Safe Stop 1 function causes a rapid and safe stopping of a drive. It controls the drive to decelerate autonomously and finally activates the drive-internal Safe Torque Off (STO) safety-related function. As a result, the drive remains torque-free and the motor is no longer supplied with power. (In contrast, the Safe Stop 2 function finally monitors the stand-still (similar to the SOS function) instead of STO.) The "Safe Stop 1 Element" (SS1) permits the function described above:

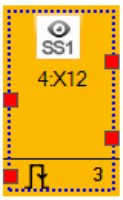


Figure 23: SS1 Element

Below, there's a representation of the schematic:

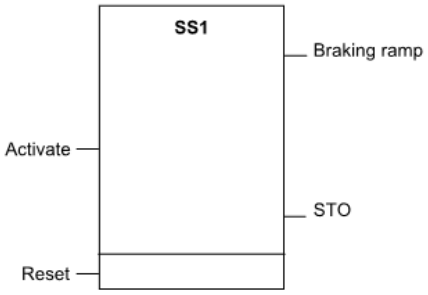


Figure 24: Schematic SS1 Element

To configure this element, it's important to define a Delay time (delay time for controlled braking of the motor after the monitoring function is triggered) and an Automatic STO (standstill limit value can be entered for activating the safety function STO). There's an overview of this element on the following figure.

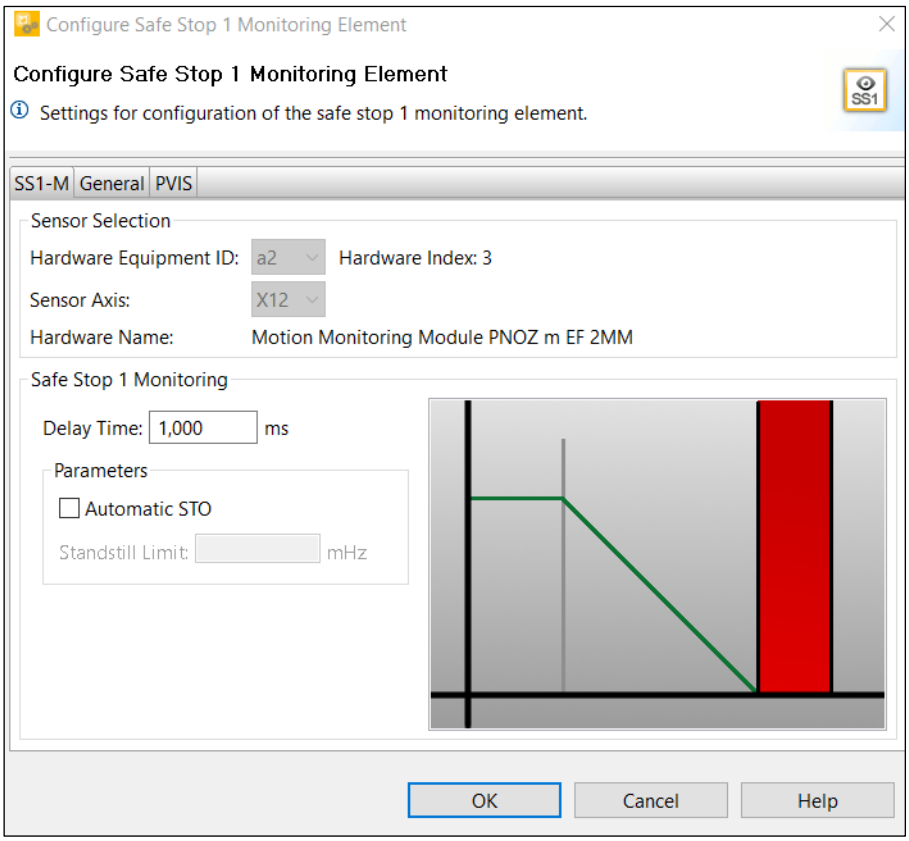


Figure 25: Configuration SS1 Element

4.2.2.5 SOS Element

Finally, the last element that can be used for an AGV application is the "Safe Operating Stop Monitoring" Element (SOS). The SOS function monitors the drive at a standstill with active position control (performed by the standard (non-safety-related) controller) and position monitoring (performed by the Safety Module).

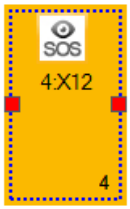


Figure 26: SOS Element

Below, there's a representation of the schematic:

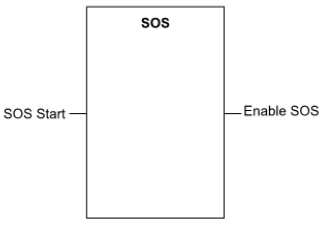


Figure 27: Schematic SOS Element

The important setting for this element is the tolerance amount by which the stop position may be exceeded. There's an overview of this element in the following figure.

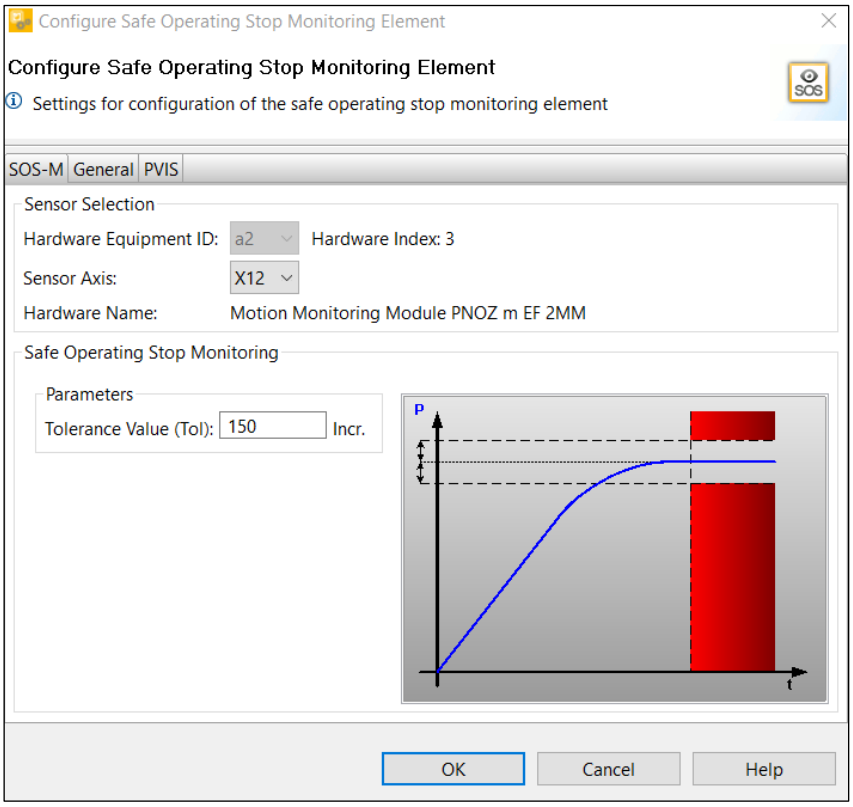


Figure 28: Configuration SOS Element

4.2.3 How to Safely Turn (Left or Right):

The first thing to do is configure the axis with the “MM” element, already explained before:

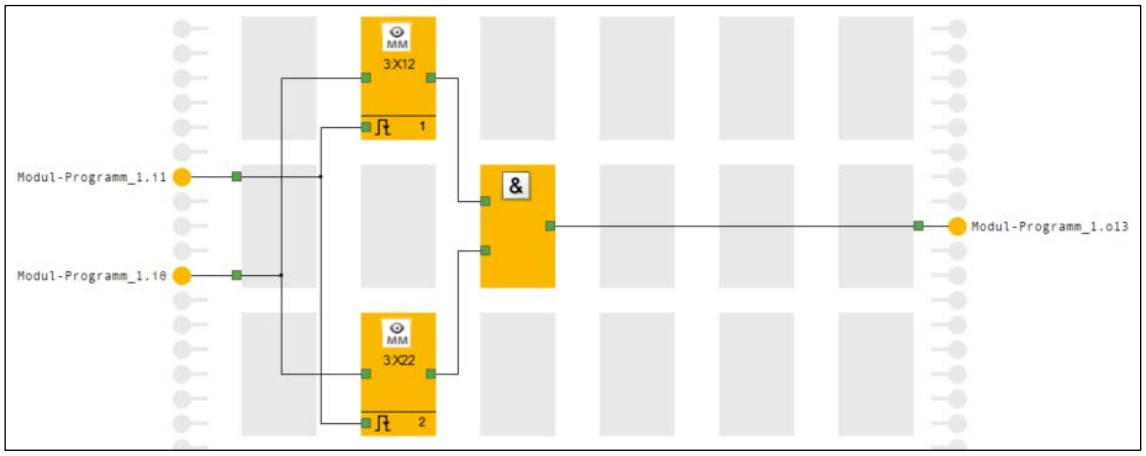


Figure 29: Initiating the motion monitoring elements

The output “Module Program O13” is being used to activate the Laser Scanner Element.

Then, with the SSC the “Safe Speed Comparison” is possible to compare the velocity for each axis. Depending on the configuration it’s determined when for example X12 > X22, the AGV is moving to the right. The outputs of this element are going to be used for the zone sets changing depending on the velocity and the route of the AGV:

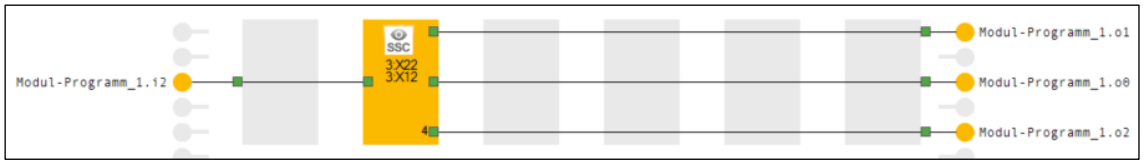


Figure 30: Application of the SSC element

So, with these outputs, it’s possible to activate (for example) the zone “1.4” or another one. This changes for each AGV, the important aspect is to understand how can the zone be changed with different signals.

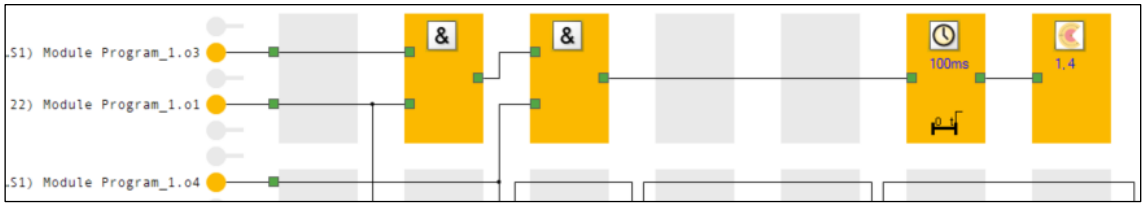


Figure 31: Selection of a zone setting

Zone 1.4 was configured in the scanner software and imported via the Laser Scanner Element. As said before, from the "Zone Set Element" block it's possible to select the scanner and which zone set is triggered.

Figure 32: Zone Set Element

4.2.4 How to Know If the AGV is Backward/Forward:

To know If the vehicle is moving forward or backward it's necessary to use the SDI element to configure the direction of moving, it's possible to match the block with the axis of the wheel we want to monitor. So, If the "Enable Negative Direction" is active, the output will be active when the AGV is moving backward, otherwise is moving forward.
This setting is detailed in the next image.

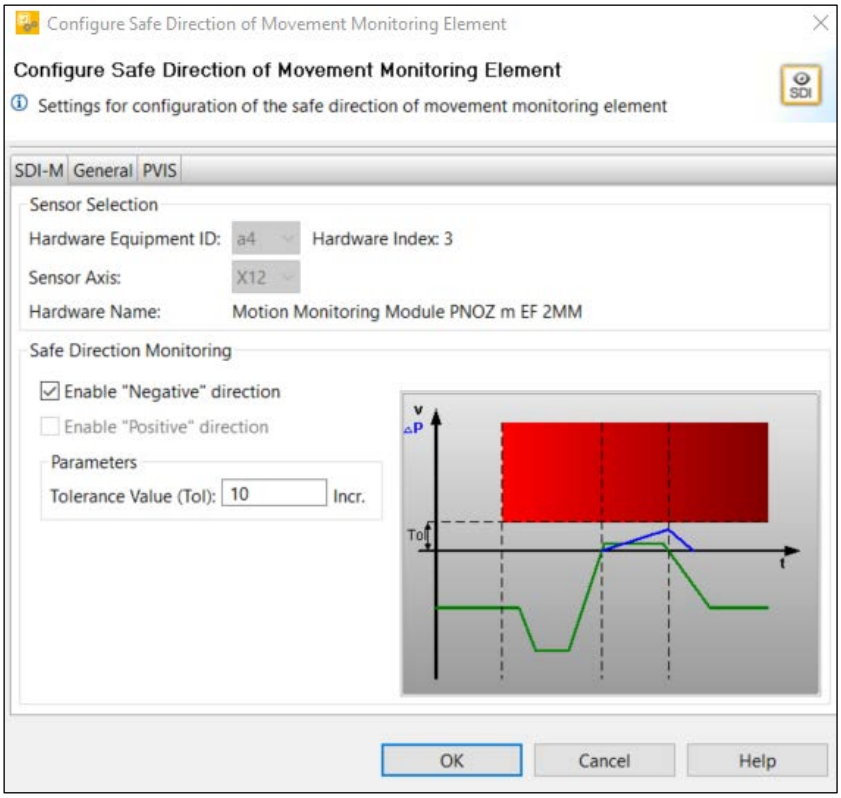


Figure 33: Configuration SDI Element

- Enable "Positive" Direction: Activation of the direction of movement monitoring for the positive direction.
- Enable "Negative" Direction: Activation of the direction of movement monitoring for the negative direction.
- Tolerance Amount: Tolerance amount for the wrong direction of movement.

4.2.5 Activating Different Zones:

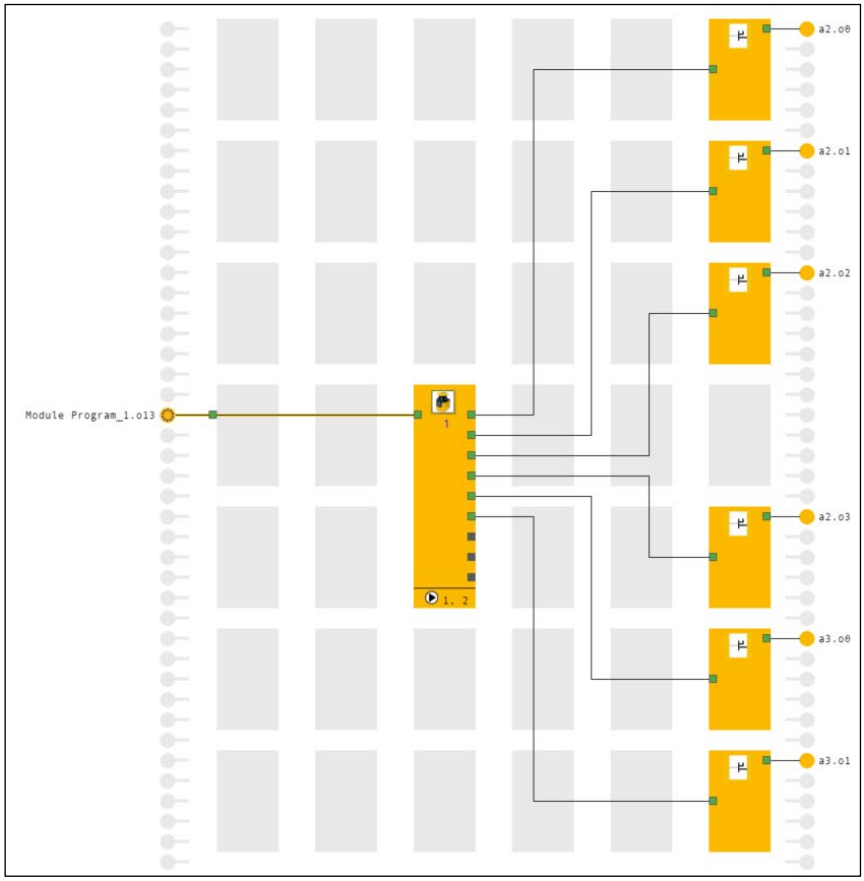


Figure 34: Laser Scanner Element - Distribution of the Zone Switch Outputs

It was explained before the Laser Scanner Element and how to configure a program to change zones depending on different signals. The previous image shows that depending on the zone the outputs will have different states.
These outputs match the outputs configured in the software which need to be connected physically according to that.

4.2.6 AGV Safe Stop:

This function stops the motor safely, using a controlled ramp stop and then activates the STO function. SS1 is typically used in applications like rolling mills where motion must be stopped in a controlled manner before switching to a no-torque state. In addition to a safe process stop, SS1 can also be used to implement an emergency stop, fulfilling stop category 1 (EN 60204-1).
With the SS1 function the power to the actuators is maintained to guarantee a controlled stop. When the motor is at a standstill, the STO function is triggered. In the following image, it's possible to view a simple configuration of a Safe Stop function for the axis (encoders):

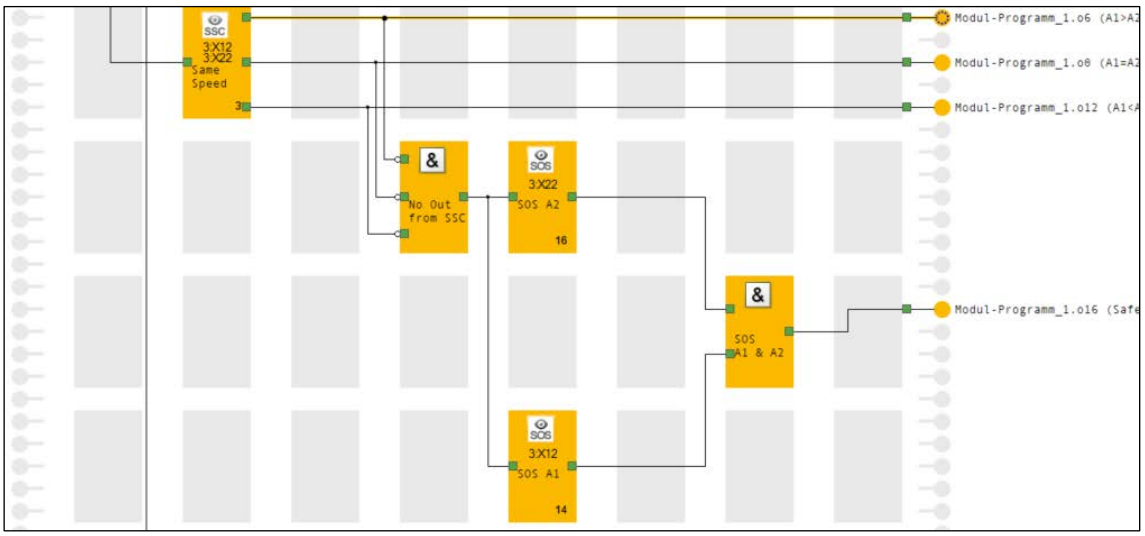


Figure 35: SOS Element handling

When the speed on both axes is less than 100 mHz, all the outputs on the SSC element are switched off even when the monitoring function is active.
The two SOS elements, one for each axis (encoder), are configured to activate a stop signal if there is no signal from the AND that monitors the outputs of the SSC element above.

4.3 Using a ST Encoder to Achieve PLd:

It is possible to achieve PLd with standard encoders depending on the $MTTF_D$ of the encoders.
As per the 2MM operations manual, the maximum achievable safety level depends, among other things, on the sensor, the wiring, and the operating mode of the PNOZ m EF 2MM.
In point 10.1.5 of the manual "Safety-related characteristic data for operation with a non-safety-related encoder with diagnostics via the drive controller," and in point 10.1.12 "Safety-related characteristic data for operation with non-safety-related encoder with diagnostics via the drive controller when two axes are compared" we can see that the detection of sensor errors (diagnostics for the sensor subsystem via the evaluation device) can be supplemented with a drive controller.
With that, it's possible to achieve Category 2. See below for the required architecture.

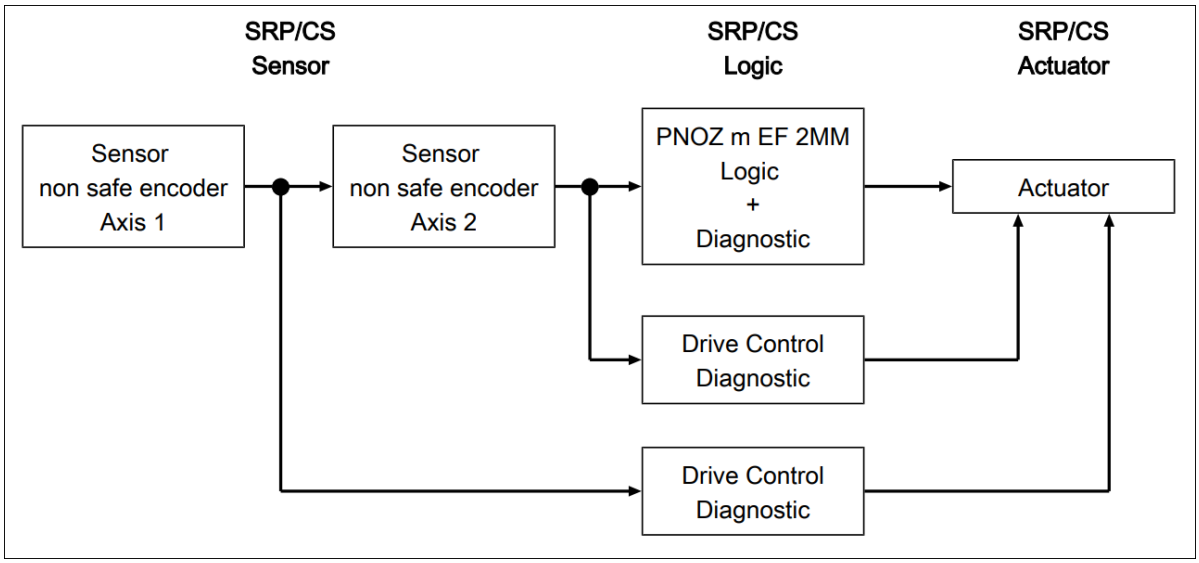


Figure 36: Safety architecture for comparison of two axes

To calculate the safety function (detection of the direction and speed of movement leads to selection and control of the corresponding scanner protective zones on the AGV), you will need the following data for the "sensor" subsystem and the subsystem "PNOZ m EF 2MM":

Sensor			**Subsystem PNOZ m EF 2MM**	
Category	**$MTTF_D$**	**DC**	**Operating mode**	**PFH (1/h)**
2	Manufacturer-specific	90%	Monitoring 1 sensor	1,83E-08

Figure 37: Safety characteristic data for one sensor on one axis

Where the values for DC refer to the standard EN/IEC 61508 and the value 3.63E-08 specified for the PNOZ m EF 2MM is composed of the values for (2x) monitoring 1 encoder (1.80E-08) and the CPU share (3.37E-10) specified in the operating manual of the PNOZ m EF 2MM under chapter 8.1 Safety characteristics.
With this in mind, the table below shows the achievable PL with the mentioned architecture for different monitoring functions.

If monitoring of one axis:

Monitoring function	PL of EN ISO 13849-1: 2015	SIL CL in accordance with EN IEC 62061
SOS-M SSR-M SDI-M SSM SS1-M SS2-M SLA-M SAR-M SPR-M SPM	PL d (Cat.2)	2

Figure 38: Achievable safety level on one axis

If comparing two axes:

Monitoring function	PL of EN ISO 13849-1: 2015	maximum SIL in accordance with EN IEC 62061
SSC SPC	PL d (Cat.2)	2

Figure 39: Achievable safety level on two axes

We also need to make sure the drive controller meets the following characteristics:

- Parameters for the control loops and motor control must be set in such a way as to guarantee stable operation. Drag error detection (speed deviation detection) must be capable of operating in accordance with the requirements of the safety function.
- The motor must be operated with a current impressing control procedure, based on the rotor position (field-oriented control). If the analogue track signals are idle, field-oriented control will brake and/or stop the rotor.
- The drive controller must be in position control or speed control operating mode.
- If a maximum error variable is exceeded (set/true comparison) the drive controller must switch to a fault condition and stop the drive (drag error detection). The error reaction to drag error detection or speed deviation should be a controlled motor stop.
- Fault detection via the error variable with subsequent shutdown must meet the requirements of the safety function, with regard to reaction times for example.
- The drive controller must evaluate the same incremental/SinCos signals from the encoder for control as are processed by the safe evaluation device (important on encoders with combined analogue/digital interface).

CAUTION!

A drive control that does not meet the required conditions cannot achieve the safety levels specified above. The user must provide a suitable drive control system according to the requirements.

5 Functional safety

Not only the speed comparison of the two axes is sufficient for the zone selection, but also the direction of rotation and speed of the respective axis is additionally queried via the element monitoring functions (e.g. SDI, SSM, etc.).
Since the same hardware subsystems are used for the evaluation of all element monitoring functions, only the consideration of the comparison of two axes (covering all subsystem elements) is necessary for the calculation of the safety level.
The programming and use of the element monitoring functions are classified as systematic faults and has no direct effect on the PFH.

Further safety functions that supplement the function of the AGV (e.g. emergency stop) are not considered in this example.

5.1 Safety-related characteristics in accordance with EN ISO 13849-1

No.	Safety function	Performance Level	Safety-related parts of the control system
1	The detection of an obstacle in the danger zone by the laser scanner leads to a controlled stop of the AGV movement at the drive.	PL d	Sensor (Standard Incremental Encoder (TTL) Axis 1) Sensor (Standard Incremental Encoder (TTL) Axis 2) Input (PNOZ m EF 2MM Axis 1) Input (PNOZ m EF 2MM Axis 2) Logic (PNOZ m EF 2MM (CPU)) Logic (PNOZ m B1) Logic (PNOZ m EF 8DI4DO (CPU)) Output (PNOZ m EF 8DI4DO) Actuator (Servo amplifier)

No.	Description		Identification
1	Common cause failure (CCF):		The requirements are met (to be checked when implemented)
2	Mission time:		20 years
3	Characteristic values of Standard Incremental Encoder Axis 1:	MTTFD Mission Time	200 years 10 years
4	Characteristic values of Standard Incremental Encoder Axis 2:	MTTFD Mission Time	200 years 10 years
5	Characteristic values of Servo amplifier:	PL e Cat.3 Mission Time	- - 20 years

Please note the further requirements of EN ISO 13849-1, e.g. requirements for avoiding systematic faults.

5.2 Safety-related characteristics in accordance with EN 62061

No.	Safety-related control function	Safety Integrity Level	Subsystems
1	The detection of an obstacle in the danger zone by the laser scanner leads to a controlled stop of the AGV movement at the drive.	SIL 2	Sensor (Standard Incremental Encoder (TTL) Axis 1) Sensor (Standard Incremental Encoder (TTL) Axis 2) Input (PNOZ m EF 2MM Axis 1) Input (PNOZ m EF 2MM Axis 2) Logic (PNOZ m EF 2MM (CPU)) Logic (PNOZ m B1) Logic (PNOZ m EF 8DI4DO (CPU)) Output (PNOZ m EF 8DI4DO) Actuator (Servo amplifier)

No.	Description		Identification
1	Common cause failure (CCF):		The requirements are met (to be checked when implemented)
2	Mission time:		20 years
3	Characteristic values of Standard Incremental Encoder Axis 1:	MTTFD Mission Time	200 years 10 years
4	Characteristic values of Standard Incremental Encoder Axis 2:	MTTFD Mission Time	200 years 10 years
5	Characteristic values of Servo amplifier:	SIL 2 Mission Time	- 20 years

Please note the further requirements of EN 62061, e.g. requirements for systematic safety integrity.

6 Table of figures

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