Decentralised periphery PNOZmulti: PNOZ ml2p with PDP67 F 8DI ION

Product

Type:	PSEN
Name:	PSENcode, PITestop, PDP67, PNOZmulti
Manufacturer:	Pilz GmbH & Co. KG, Safe Automation

Document

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the spirit of safety

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Release	Date	Changes	Chapter
01	2013-01-17	Creation	all

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January 2013

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Abbreviations

PSEN	**P**ilz **Sen**sor
PNOZ	Pilz E-STOP Positive-guided (DE: **P**ilz **NO**T-AUS-**Z**wangsgeführt)
OSSD	**O**utput **S**ignal **S**witching **D**evice
PDP	**P**roduct Range **D**ecentralised **P**eriphery
STO	Stop Category 0 - **S**afe **T**orque **O**ff
SS1	Stop Category 1 - **S**afe **S**top **1**
SS2	Stop Category 2 - **S**afe **S**top **2**

1. Useful documentation

Reading the documentation listed below is necessary for understanding this application note. The availability of the indicated tools and safe handling are also presupposed with the user.

1.1. Documentation from Pilz GmbH & Co. KG

No.	Description	Item No.
1	Pilz international homepage, download section	www.pilz.com
2	Operating manual PDP67 F 8DI ION	1001 643-EN-xx
3	Operating manual PNOZ m3p	1001 352-EN-xx
4	Operating Manual PNOZ ml2p	1001 642-EN-xx
5	Operating instructions PSEN cs3.1n	22 172-3FR-xx
6	Operating instructions PSEN b4.1	1001 587-3FR-xx
7	Operating instructions PITes Set/1	1002 542-3FR-xx
8	Operating manual PMCprotego D.01…D.24	21 934-EN-xx
9	Operating manual PMCprotego S2	1001 432-EN-xx
10	Operating manual PMCtendo AC	21 706-EN-xx
11	User manual Motion Control Tools	21 468-EN-xx

1.2. Documentation from other sources of information

No.	Description	Item No.
1		
2		

2. Hardware configuration

2.1. Pilz products

No.	Description	Order number	Version	Number
1	PNOZ m3p	773 125	v2.1	1
2	PNOZ ml2p	773 602	v1.0	1
3	PDP67 F 8DI ION	773 600	v1.0	3
4	PSEN cs3.1n	541 003	-	1
5	PSEN b4.1	540 041	-	1
6	PIT es Set7u-5c	400 442	-	1
7	PNOZmulti Configurator	-	v8.1.1 Build 8	1
8	*Motion**	-	-	-

*** Note**
Structure, control and evaluation of the safe servo amplifier are not shown in this example. The detailed description of this functionality can be taken from the Application Note "AN_PMCprotegoDS_PSENcs_1002085-DE-xx".

2.2. Hardware configuration

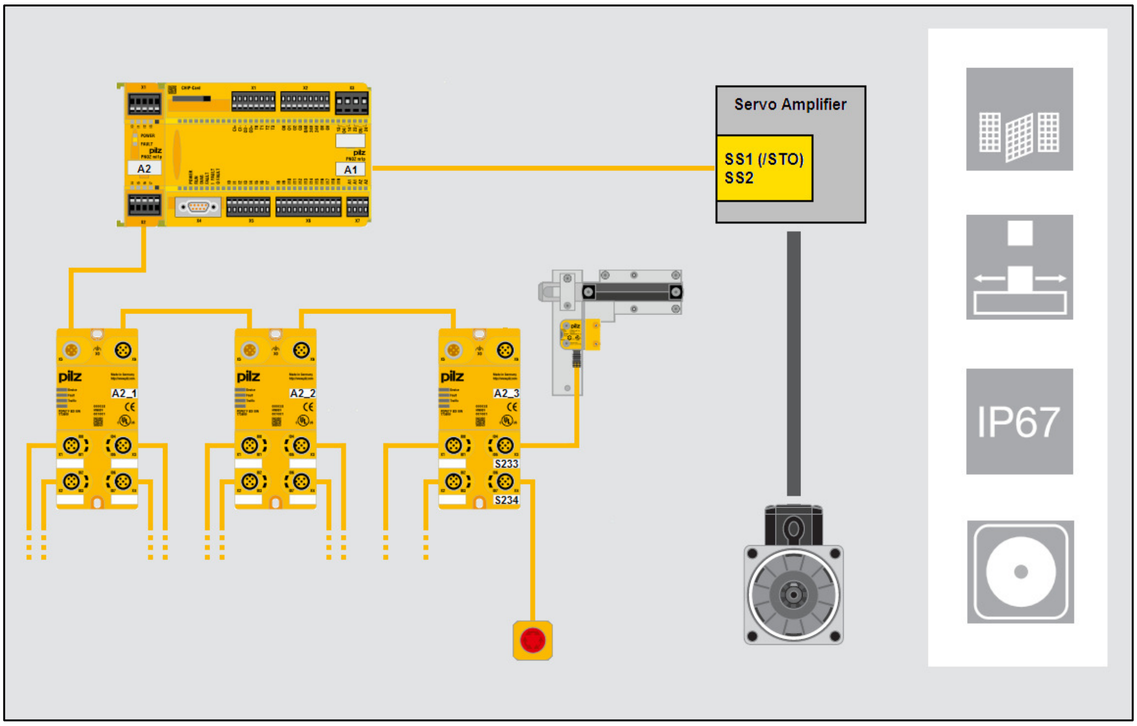


Fig. 1: Hardware configuration

3. Application Task

3.1. Description

The example shows the realisation of an emergency stop and a safety gate application at a decentralised input module PDP67 F 8DI ION (A2_3).

A machine moves inside a protective housing. Access to the danger area is possible through a safety gate installed in the housing. The door in it's closed state is locked (process protection) by a PSENbolt.
Simultaneously the bolt serves as door handle and as mounting possibility for the safety switch PSENcode. The PSENcode (S233) realise the function of the safety gate monitoring. The PITestop (S234) realises the function of the emergency stop monitoring. The decentralised input modules PDP67 F 8DI ION (A2_1, A2_2, A2_3) monitors the output signals of the connected sensors.
The signals are transmitted to the link module PNOZ ml2p via a safe data link and are monitored by the PNOZ m3p (A1).
The safe control and evaluation of the signals is performed by the Pilz function blocks "Safety Gate" and "E-STOP" from the element selection (function elements) of the PNOZmulti Configurator.
When the safety gate is opened, the drive (M1) is shut down according to the function safe stop 2 (SS2) and kept in position control.
When the emergency stop is operated, the drive (M1) is shut down according to the function safe stop 1 (SS1) and activate then the function STO.

Caution
The safety functions are exemplified by the shutdown of one dangerous machine movement (M1). Other hazards (machinery) in the operating area, are not shown and considered in this example. In real applications, this part must be included in the safety review.

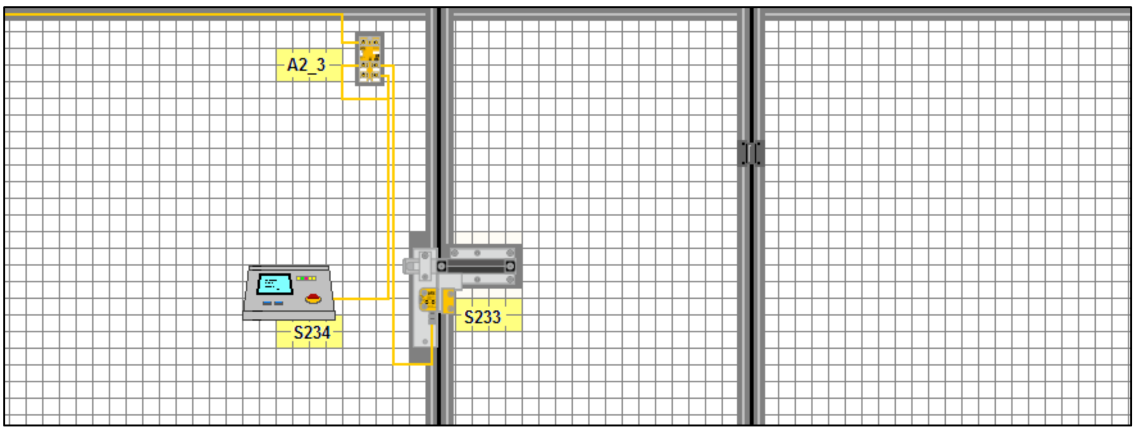


Fig. 2: Application safety gate monitoring

The process is divided into the following functions:
- Monitoring Safety Gate
- Monitoring Emergency Stop

3.1.1. Monitoring safety gate

The safety gate switch (S233) is monitored by the controller PNOZm3p (A1) via the user program.
A FS function block "Safety Gate" is assigned to the safety gate switch. This FS-FB detects whether the assigned safety gate switch has been operated, as well as detecting invalid input signals and whether the contact synchronisation time has been exceeded, etc.

If the safety gate switch is operated or an error occurs, the enable output of the FS-FB will immediately be reset. The enable output is also reset when the PNOZmulti is stopped and when the PNOZmulti is switched on.
The signal of the enable output activates the SS2 function of the safety card by means of a falling edge at the SS2 input of the PMCprotego S2 safety card. If the configured limit values of the SS2 function are violated, the drive changes to STO.
Please note that no more holding torque exists with STO and relevant additional measures must be employed to ensure that this behaviour does not lead to a hazardous situation (e.g. with suspended loads).

The way in which the error is reset will depend on the operating mode set on FS-FB.
In this application example, parameters for FS-FB have been set in such a way that:
- when cold started (PNOZ switched from off to on),
- when warm started (PNOZ transferring from STOP to RUN) or
- after closing the safety gate

it is necessary to reset (S231_0) at the FS-FB in order to reset the output parameter.

The safety gate is closed by a movable, manual bolt (process protection).

Caution
Although the safety gate functions are configured to reset themselves, a PNOZ cold start or closing the safety gate must not directly enable a machine to start up without further conditions being met.

3.1.2. Monitoring emergency stop

The emergency stop switch (S234) is monitored by the controller (A1) via the user program.
A FS function block “E-STOP” is assigned to the emergency stop switch. This FS-FB detects whether the assigned safety gate switch has been operated, as well as detecting invalid input signals and whether the contact synchronisation time has been exceeded, etc.

If the emergency stop switch is operated or an error occurs, the enable output of the FS-FB will immediately be reset. The enable output is also reset when the PNOZmulti is stopped and when the PNOZmulti is switched on.
The signal of the enable output activates the SS1 function of the safety card by means of a falling edge at the SS1 input of the PMCprotego S2 safety card.
After reached stop of the drive (M1) the function STO is released.
Please note that no more holding torque exists with STO and relevant additional measures must be employed to ensure that this behaviour does not lead to a hazardous situation (e.g. with suspended loads).

The way in which the error is reset will depend on the operating mode set on FS-FB.
In this application example, parameters for FS-FB have been set in such a way that:

- when cold started (PNOZ switched from off to on),
- when warm started (PNOZ transferring from STOP to RUN) or
- after releasing the emergency stop switch

it is necessary to reset (S231_1) at the FS-FB in order to reset the output parameter.

3.1.3. Series connection PSEN with PDP67 F 8DI ION

The decentralised input modules (PDP67 F 8DI ION) can connect by an interface to the evaluation device or to an upstream module or a downstream module.
The series connection of the modules does not represent a sensor referred series connection.
The connected sensors are detected by the inputs of the modules. Communication with the control system is via a safe data link. Data is exchanged cyclically.

INFO
The decentralised input modules PDP67 F 8DI ION (A2_1, A2_2 and A2_3) are approved in accordance with IP67.
When connecting IP67 capable sensors (e.g. PSENcode, PSENini, etc.) and using suitable connecting cables, the entire sensor part can be composed as IP67.
The emergency stop switch, used in the present case, achieves the requirement of IP69K in this configuration.

IP67

In the following some characteristics about handling the PSEN series connection at PDP67 F 8DI ION is explained in more detail.

3.1.3.1. Voltage drop of supply voltage over the input lead

For considering the fall of voltage, several factors are important:

- The power supply device (PNOZ ml2p) for the sensors must be able to provide the necessary power to supply the connected devices.
- Length, diameter and material of the used connection conductor.

General Technical Data for the calculation of the example

Condition:	Interface cable PSS SB BUSCABLE LC, Sensor cable 0.25mm^2
From "Technical Data" PNOZ ml2p:	$U_{B:}$ 24V, Max. output current decentralised module supply 4A, Maximum cable run unscreened 30 m, Maximum cable run screened 100 m
From "Technical Data" PDP67 F 8DI ION:	$U_{B:}$ 24V, Power consumption at $U_{B:}$ 1.2W, Voltage tolerance -30%/+25%, Max. output current at semiconductor output 0.50 A, Input current 3.0 mA Max. internal voltage drop 200 mV ($U_{fall\_A2\_1/A2\_2/A2\_3\_max}$),
From "Technical Data" PSEN cs3.1n (S233):	$U_{B:}$ 24V, Power consumption at $U_{B:}$ 1.0W Voltage tolerance -20%/+20%

General calculations

Current consumption at PDP67 F 8DI ION = 1.2W / 24V = 0.05A ~ 50mA (I_{PDP})

Current consumption at PSEN S233 = 1W / 24V = 0.0416A ~ 42mA (I_{S233})

Max. voltage drop ($U_{fall\_max\_PDP}$) up to the PDP = -30% (24V) = 24V * 0.3 = 7.2V = Tolerable negative voltage tolerance at module (A2_1, A2_2, A2_3).

Max. voltage drop ($U_{fall\_max\_Sen}$) up to the sensor = -20% (24V) = 24V * 0.2 = 4.8V = Tolerable negative voltage tolerance at sensor (S233).

Guidelines for calculating the voltage drop on various cable types:

Cable type	Voltage drop per 10 m (Cable up-and-down included) and per 100mA
PSS SB BUSCABLE LC	0.1V
Sensorkabel 0.25 mm²	0.15V
Sensorkabel 0.34 mm²	0.11V
Sensorkabel 0.5 mm²	0.07V

Calculation of voltage drop at conductor

- Length of the sensor lines W231, W233 and W234 is assumed as 5m each.
- Length of the connection line W23 is assumed as 10m.
- Length of the connection line W12 is assumed as 20m.
- Length of the connection line W01 is assumed as 30m.

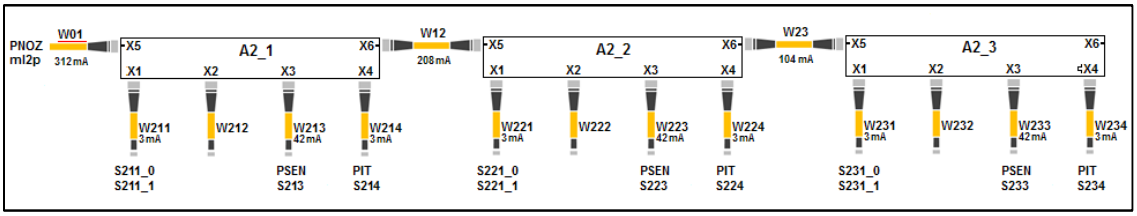


Fig. 3: Calculation of voltage drop

W231, W234

For the current calculation of mechanical wearing contacts, the input current of the used input is inserted = 3mA = I_{A2_3-I0} = I_{A2_3-I1} = I_{A2_3-I6} = I_{A2_3-I7}.

W233

The current in the conductor W233 is the same as the current of the sensor S233 (I_{S233}). It is therefore 42mA (I_{W233}).

Factor for the voltage drop = **0.15V** (per 10m and 100mA)
Factor of the cable length (W233) = **0.5** = 5m / 10m
Factor from the current = **0.42** = 42mA / 100mA

Voltage drop over the conductor resistance (U_{W233}) = Factor from the current * Factor of the cable length * Factor voltage drop

U_{W233} = 0.42 * 0.5 * 0.15V = 0.0315V ~ <u>0.04V</u>

W23

The summation of the currents $I_{A2\_3\text{-}I0}$, $I_{A2\_3\text{-}I1}$, $I_{A2\_3\text{-}I6}$, $I_{A2\_3\text{-}I7}$, I_{W233} and $I_{PDP\_A2\_3}$ results in current of line W23 = 104mA.

Factor for the voltage drop	=	**0.1V**	
Factor of the cable length (W23)	=	**1**	= 10m / 10m
Factor from the current	=	**1.04**	= 104mA / 100mA

Voltage drop over the conductor resistance (U_{W23}) = Factor from the current * Factor of the cable length * Factor voltage drop

U_{W23} = 1.04 * 1 * 0.1V = 1.04V ~ 0.11V

Note

In order to obtain realistic calculation values for the example, for the modules A2_1 and A2_2 the same allocation of the inputs is assumed, as with module A2_3.

W12

The summation of the currents $I_{A2\_2\text{-}I0}$, $I_{A2\_2\text{-}I1}$, $I_{A2\_2\text{-}I6}$, $I_{A2\_2\text{-}I7}$, I_{W223}, $I_{PDP\_A2\_2}$ and I_{W23} results in current of line W12 = 208mA.

Factor for the voltage drop	=	**0.1V**	
Factor of the cable length (W12)	=	**2**	= 20m / 10m
Factor from the current	=	**2.08**	= 208mA / 100mA

Voltage drop over the conductor resistance (U_{W12}) = Factor from the current * Factor of the cable length * Factor voltage drop

U_{W12} = 2.08 * 2 * 0.1V = 0.416V ~ 0.42V

W01

The summation of the currents $I_{A2\_1\text{-}I0}$, $I_{A2\_1\text{-}I1}$, $I_{A2\_1\text{-}I6}$, $I_{A2\_1\text{-}I7}$, I_{W213}, $I_{PDP\_A2\_1}$ and I_{W12} results in current of line W01 = 312mA.

Factor for the voltage drop	=	**0.1V**	
Factor of the cable length (W01)	=	**3**	= 30m / 10m
Factor from the current	=	**3.12**	= 312mA / 100mA

Voltage drop over the conductor resistance (U_{W01}) = Factor from the current * Factor of the cable length * Factor voltage drop

U_{W01} = 3.12 * 3 * 0.1V = 0.936V ~ 0.94V

Total voltage drop

The summation of the voltage for the highest total voltage drop at module ($U_{fall\_tot\_PDP}$) applies to the farthest connected module A2_3.

$U_{fall\_tot\_PDP}$	$= U_{W01}$	$+ U_{fall\_A2\_1\_max}$	$+ U_{W12}$	$+ U_{fallA2\_2\_max}$	$+ U_{W23}$
1.87V	= 0.94V	+ 0.2V	+ 0.42V	+ 0.2V	+ 0.11V

$U_{fall\_tot\_PDP} < U_{fall\_max\_PDP}$

The summation of the voltage for the highest total voltage drop at sensor ($U_{fall\_tot\_Sen}$) applies to the farthest connected module A2_3 and the sensor with the biggest voltage drop at the line (W233) of this module.

$U_{fall\_tot\_Sen}$	$= U_{W01}$	$+ U_{fall\_A2\_1\_max}$	$+ U_{W12}$	$+ U_{fallA2\_2\_max}$	$+ U_{W23}$	$+ U_{fall\_A2\_3\_max}$	$+ U_{W233}$
2.11V	= 0.94V	+ 0.2V	+ 0.42V	+ 0.2V	+ 0.11	+ 0.2V	+ 0.04V

$U_{fall\_tot\_Sen} < U_{fall\_max\_Sen}$

Note
The largest voltage drop (sensor) needs not to occur at the farthest connected module. By appropriate cable length and sensor performance, this also can occur at other modules.

Result:

The voltage drop to the module A2_3 in the example (1.87V) is smaller than the maximum admissible voltage drop up to the module (A2_3) PDP67 F 8DI ION of 7.2V.
The voltage drop to the sensor S233 in the example (2.11V) is smaller than the maximum admissible voltage drop up to the sensor (S233) PSEN cs3.1n of 4.8V.

Note
The maximum admissible voltage drop across the module can lead to an unacceptable supply voltage of individual sensors.

Example:

Min. admissible input voltage at module PDP67 F 8DI ION:	24V – 7,2V (30%) =	16.8V
Min. admissible input voltage at sensor PSEN cs3.1n:	24V – 4.8V (20%) =	19.2V

➔ If the available voltage (16.8 V) at the PDP is smaller than that required voltage (19.8 V) by the sensor, the sensor can not be supplied. The circuit must not be operated.

3.1.3.2. Calculation of off-delay time

In series connection of multiple devices, the off-delay time is added by the number of intermediary devices.

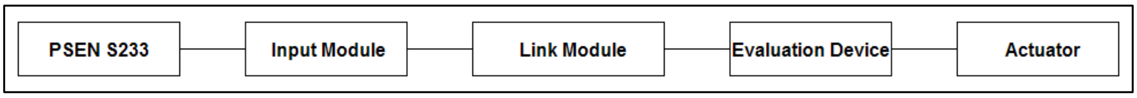


Fig. 4: Off-delay times

The calculation values can be taken from the respective Pilz operating manuals.

In the following example maximum values are used for the calculation of off-delay time.

Example: Actuation S233

Sensor	**Off-delay time$_{(max)}$**	**Activator**	**Selection of time**	**Time accumulated**
PSEN cs3.1n (S233)	**260ms**	Actuator	**260ms**	260ms
PDP67 F 8DI ION (A2_3)	**1ms**	Input	**1ms**	261ms
PNOZ ml2p (A2)	**15ms**	Maximum input delay	**15ms**	276ms
PNOZ ml2p (A2)	**35ms**	Switch-off delay	**35ms**	311ms
PNOZ m3p (A1)	**-**	Program cycle time	**-**	-
PNOZ m3p (A1)	**30ms**	Semiconductor output	**30ms**	341ms
PMCprotego S2 (A3_1)	**2ms**	Input	**2ms**	343ms

Entire off-delay time$_{(max)}$ at actuation of sensor S233 = 343ms + PNOZmulti Program cycle time

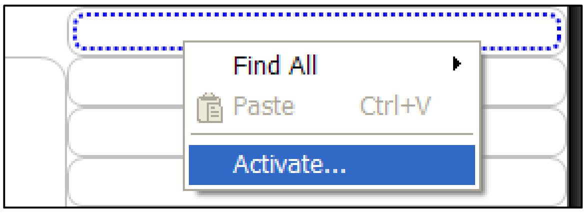
INFO
The processing time of 1.00 ms for decentralized input module PDP67 F 8DI ION applies when a signal changes from “1” to “0”.

3.1.3.3. Configuration of outputs in the PNOZmulti Configurator

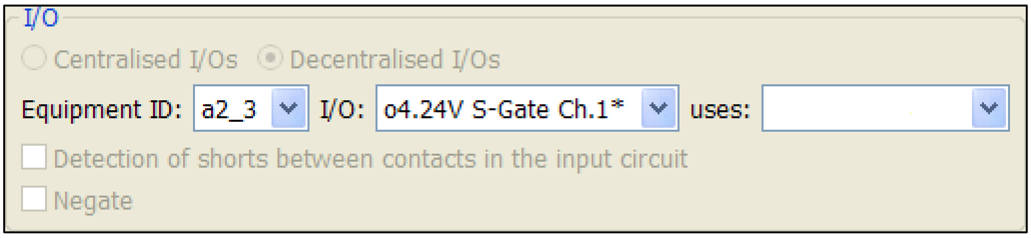
To connect sensors with OSSD outputs, the test pulse on the input circuit must be switched off. The voltage of the outputs is thereby also switched off.
To use the outputs for the supply voltage of the sensors anyway they can be configured as standard outputs or 24 VDC outputs in the system software's configurator.

Activation of 24V outputs in the Configurator

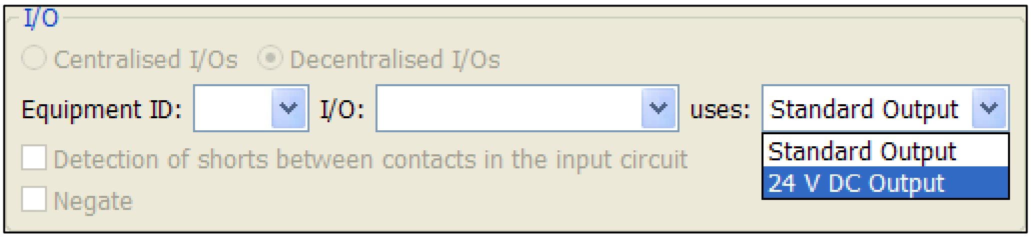
- Right click in the workspace “outputs” and choice “Activate …”.



- Choice of the (desired) output.



- Choice as a standard output or as a 24 VDC output.



Each output that is not reserved as test pulse output and which shall be used anyway, must be defined this way.

3.1.4. Safety assessment

- The circuit of PNOZ m3p (A1) is redundant with built-in self-monitoring.
- The safety function A1 remains effective in the case of a component failure.
- An fault on the PNOZmulti or the PMCprotego D and PMCprotego S2 combination does not lead to the loss of the safety function.
- The circuit of PNOZ ml2p (A2) is redundant with built-in self-monitoring.
- The safety function A2 remains effective in the case of a component failure.
- Communication of PDP67 F 8DI ION (A2_3) with the control system is via a safe data link. Data is exchanged cyclically.
- A short between the input circuits within a multicore cable is detected as an error by the PSEN cs3.1n (S233).
- As the test pulses are permanently assigned to the inputs, all short circuits will be detected, with the exception of short circuits that short out the input device.

- The safety system (A1) should be installed in a control cabinet with a protection type of at least IP54.
- The PNOZmulti Mini and the PMCprotego D and PMCprotego S2 combination must be installed in the same mounting area in order to exclude a short circuit between 24 VDC and a safety input of the card.
- The safety system A2 should be installed in a control cabinet with a protection type of at least IP54.
- The expansion module PNOZ ml2p (A2) may only be connected to a base unit from the PNOZmulti modular safety system.
- A maximum of 4 link modules (PNOZ ml2p) can be connected to a PNOZmulti base unit.
- Do not connect terminators to the last expansion module (A2).
- A maximum of 4 decentralised modules (PDP67 F 8DI IOP) can be connected to a link module PNOZ ml2p.
- In order to guarantee protection type IP67, unused connectors at A2_3 (A2_1, A2_2) should be sealed using the blind plugs supplied.
- The safety outputs of PSEN cs3.1n (S233) must use 2-channel processing.
- It must not be possible to defeat the E-STOP pushbuttons (S234), otherwise material damage and severe injuries may result, depending on the application. The E-STOP pushbutton may not be used in place of other safety measures.
- PSENbolt must not be used on its own as a safety component to prevent hazardous conditions on a plant or machine.
- If an operator completely (or even maybe partly) is able to access the dangerous area, a risk analysis should clarify whether an additional, separate “manual reset function” is required.

Caution
Structure, control and evaluation of the safe servo amplifier are not shown in this example. The detailed description of this functionality can be taken from the Application Note "AN_PMCprotegoDS_PSENcs_1002085-DE-xx".

3.2. Functional safety

The safety functions are exemplified by the shutdown of one dangerous machine movement (M1). Other hazards (machinery) in the operating area are not shown and considered in this example. In real applications, this part must be included in the safety review

3.2.1. Safety-related characteristics in accordance with EN ISO 13849-1

No.	Safety function	Achieved Performance Level	Safety-related parts of the control system
1	Machine shut down when a safety gate (S233) is opened.	PL d	Sensor (PSEN cs3.1n S233) Input (PDP67 F 8DI ION A2_3) Logic (PNOZ ml2p A2) Logic (PNOZ m3p A1) Output (PNOZ m3p A1) Actuator (PMCprotego S2 A3_1) {SS2}
2	Machine shut down via E-STOP (S234).	PL d	Sensor (PIT es Set7u-5c S234) Input (PDP67 F 8DI ION A2_3) Logic (PNOZ ml2p A2) Logic (PNOZ m3p A1) Output (PNOZ m3p A1) Actuator (PMCprotego S2 A3_1) {SS1}

Prerequisites:

No.	Description		Identification
1	Common cause failure (CCF):		Requirements are considered to be met (must be tested on implementation)
2	Mission time:		20 years
3	Operating interval (electromechanical components):	Sensor (S234)	one operation per week

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

3.2.2. Safety-related characteristics in accordance with EN 62061

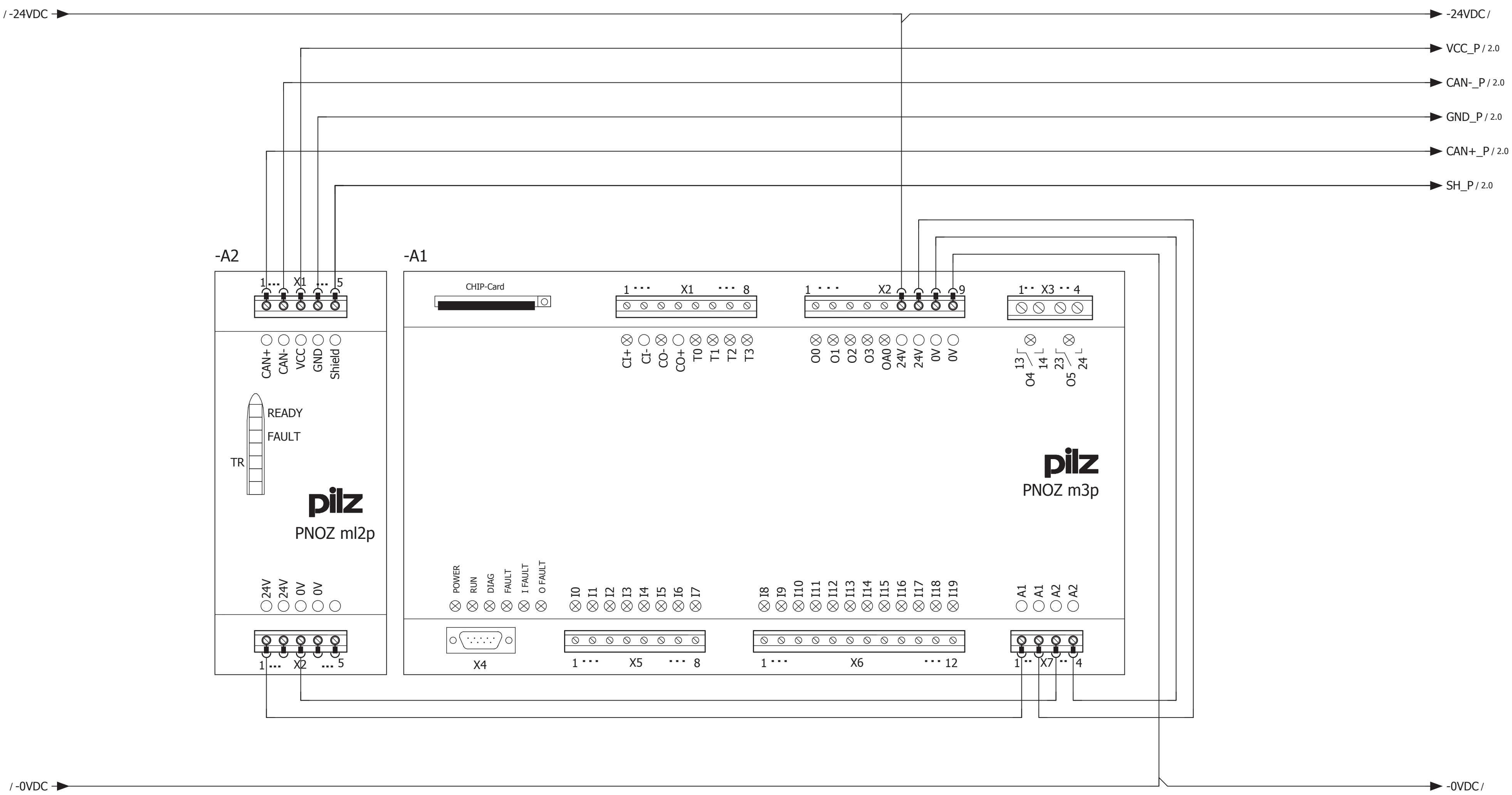
No.	Safety-related control function (SRCF):	Achieved Safety Integrity Level	Subsystems
1	Machine shut down when a safety gate (S233) is opened.	SIL 2	Sensor (PSEN cs3.1n S233) Input (PDP67 F 8DI ION A2_3) Logic (PNOZ ml2p A2) Logic (PNOZ m3p A1) Output (PNOZ m3p A1) Actuator (PMCprotego S2 A3_1) {SS2}
2	Machine shut down via E-STOP (S234).	SIL 2	Sensor (PIT es Set7u-5c S234) Input (PDP67 F 8DI ION A2_3) Logic (PNOZ ml2p A2) Logic (PNOZ m3p A1) Output (PNOZ m3p A1) Actuator (PMCprotego S2 A3_1) {SS1}

Prerequisites:

No.	Description		Identification
1	Common cause failure (CCF):		ß = 2 % (must be tested on implementation)
2	Proof test interval:		20 years
3	Operating interval (electromechanical components):	Sensor (S234)	one operation per week

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

0	1	2	3	4	5	6	7	8	9



Revision	17.01.2013	Date	06.12.2011	EN ISO 13849-1:2006	PL d	pilz	Pilz GmbH & Co.KG Felix-Wankel-Str.2 73760 Ostfildern	PDP67 F 8DI ION	Mounting place + AN_1002460_01
Name	RDS	Name	RDS						
				EN 62061:2005	SIL 2			Control	Page: 1 / 5
		Dep.	CS						

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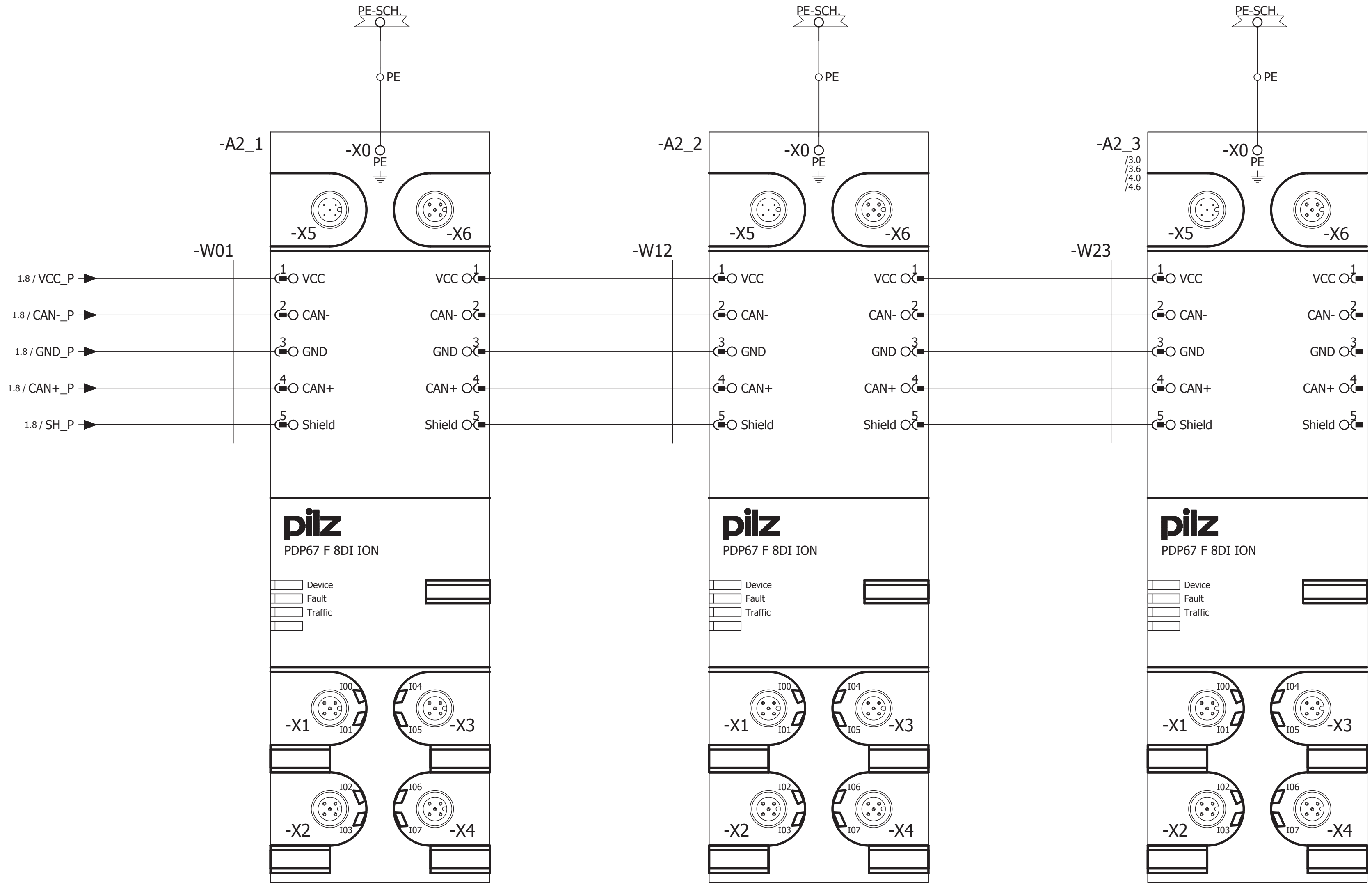

Revision	17.01.2013	Date	06.12.2011	EN ISO 13849-1:2006 PL d	pilz Pilz GmbH & Co.KG Felix-Wankel-Str.2 73760 Ostfildern	PDP67 F 8DI ION	Mounting place + AN_1002460_01
Name	RDS	Name	RDS				
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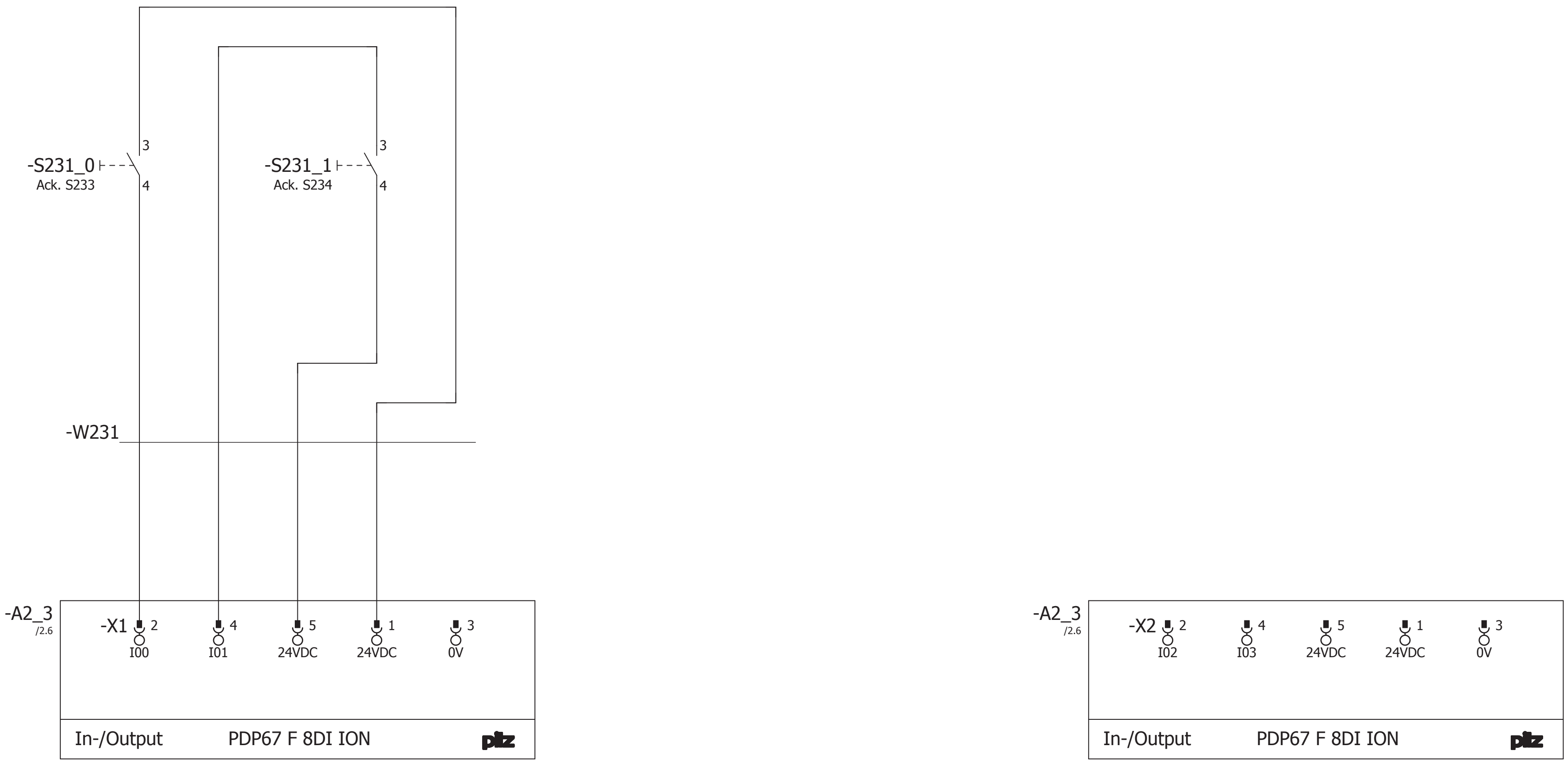

Acknowledge Safety Gate/ Acknowledge Emergency Stop

Spare

Revision	17.01.2013	Date	06.12.2011	EN ISO 13849-1:2006	PL d	Pilz GmbH & Co.KG Felix-Wankel-Str.2 73760 Ostfildern	PDP67 F 8DI ION	Mounting place + AN_1002460_01
Name	RDS	Name	RDS					
				EN 62061:2005	SIL 2		Input	Page: 3 / 5
		Dep.	CS					

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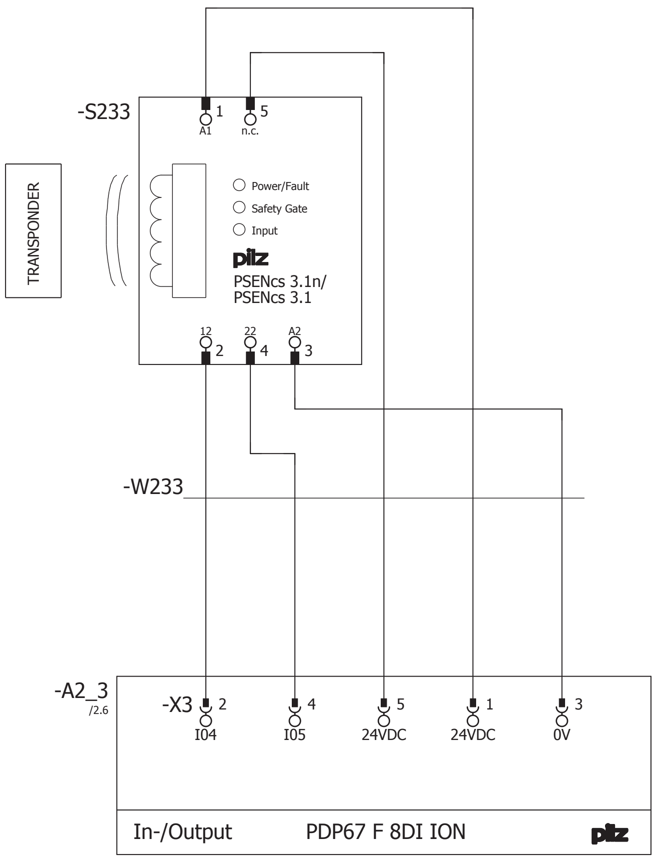
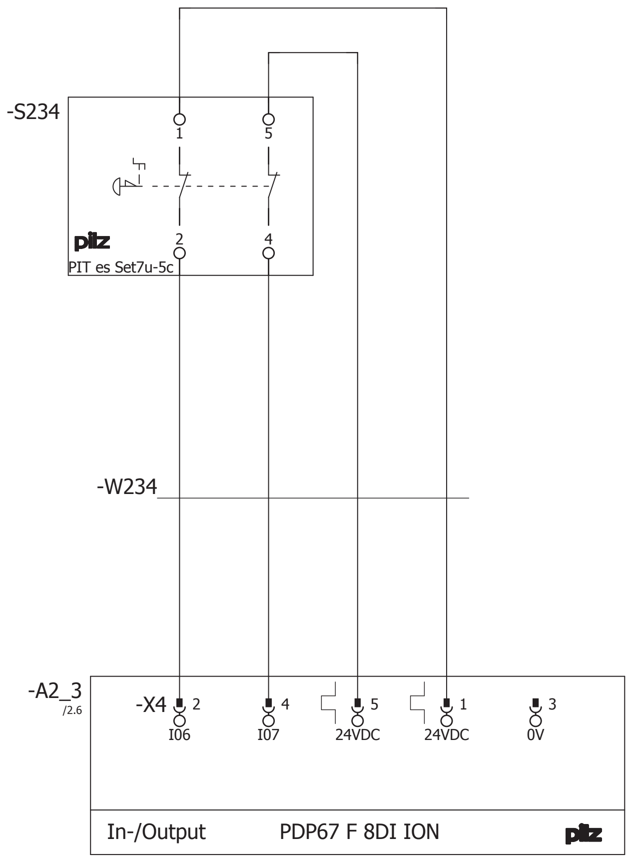


Safety Gate 233



Emergency Stop 234

Revision	17.01.2013	Date	06.12.2011	EN ISO 13849-1:2006	PL d	pilz	Pilz GmbH & Co.KG Felix-Wankel-Str.2 73760 Ostfildern	PDP67 F 8DI ION	Mounting place + AN_1002460_01
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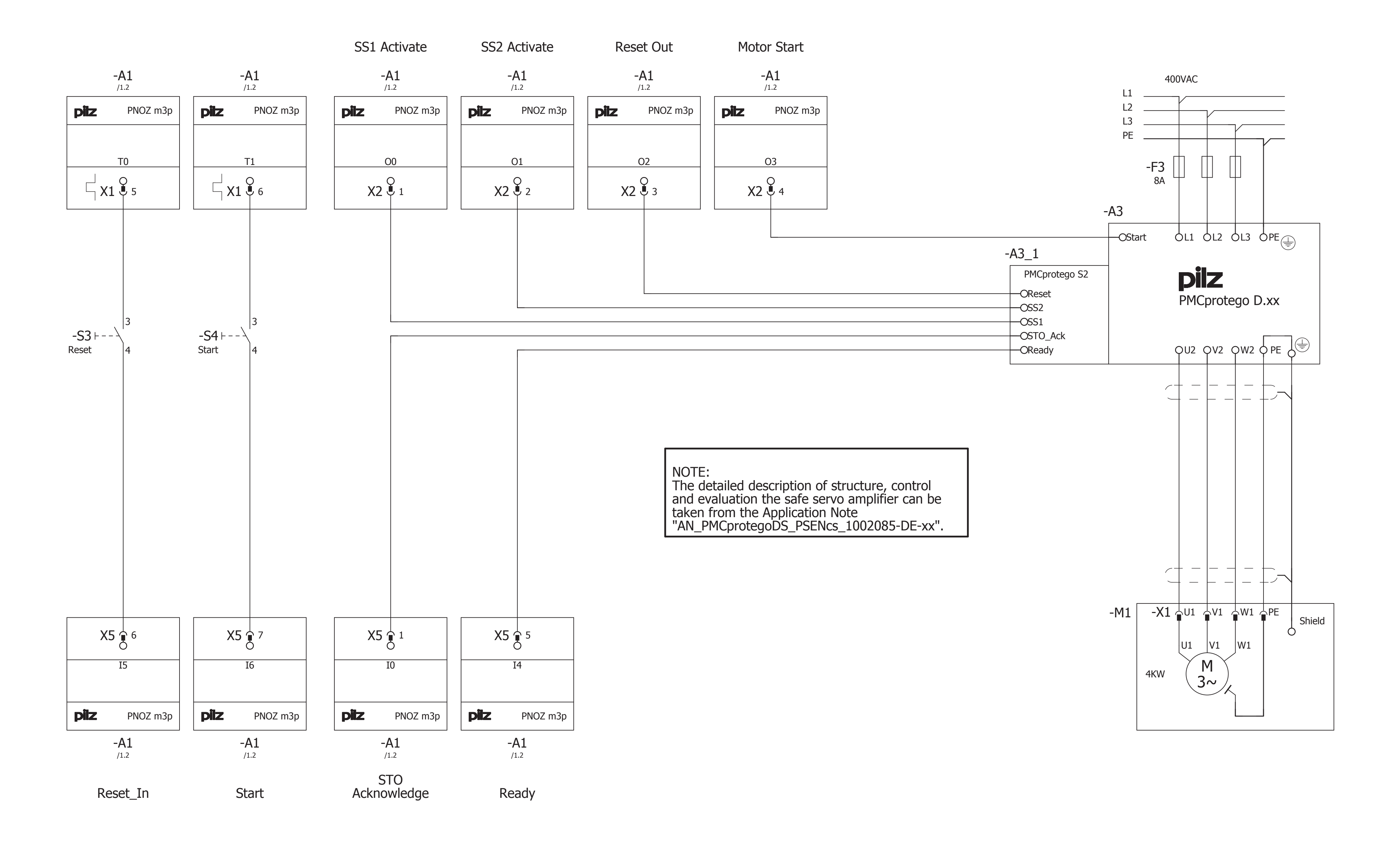
		Dep.	CS						

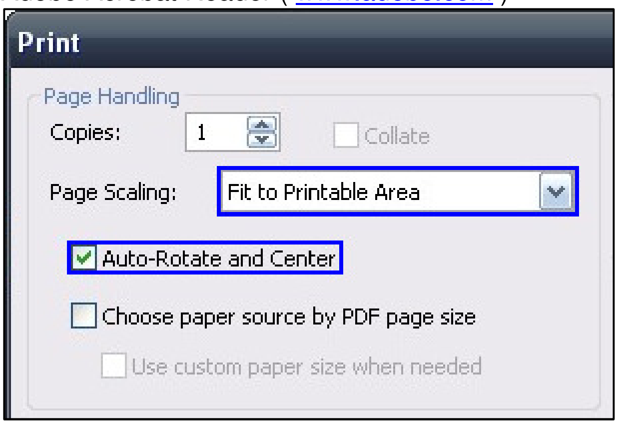


Revision	17.01.2013	Date	06.12.2011	EN ISO 13849-1:2006 PL d	Pilz GmbH & Co.KG Felix-Wankel-Str.2 73760 Ostfildern	PDP67 F 8DI ION	Mounting place + AN_1002460_01
Name	RDS	Name	RDS				
				EN 62061:2005 SIL 2		Drive Control	Page: 5 / 5
		Dep.	CS				

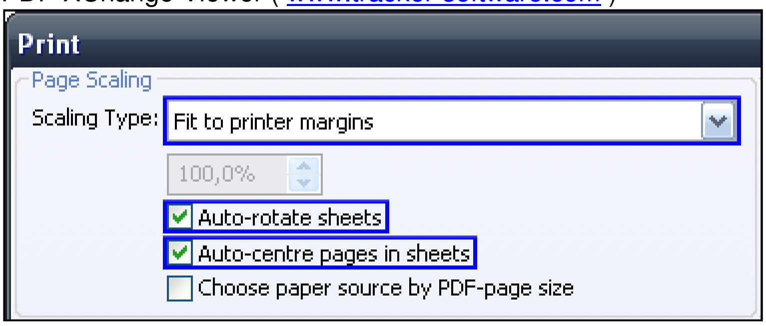
4. Table of figures

Recommended printer settings

Adobe Acrobat Reader (www.adobe.com)



PDF-XChange Viewer (www.tracker-software.com)



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In many countries we are represented by our subsidiaries and sales partners.

Please refer to our homepage for further details or contact our headquarters.

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