

Manual

# AC500-S

## Safety User Manual

### V1.0.4

## Original Instructions

Power and productivity  
for a better world™



ABB Automation Products GmbH  
Wallstadter Str. 59  
68526 Ladenburg, Germany  
Telephone: +49 62 21 701 1444  
Fax: +49 62 21 701 1382  
E-mail: [plc.sales@de.abb.com](mailto:plc.sales@de.abb.com)  
Internet: [www.abb.com/plc](http://www.abb.com/plc)

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# **1 Introduction**

## **1.1 Purpose**

This Safety User Manual describes AC500-S Safety PLC system. It provides detailed information on how to install, run, program and maintain the system correctly in functional safety applications up to SIL3 according to IEC 61508 ed. 2, IEC 62061 and Performance Level e according to ISO 13849.

ABB's AC500 series is a PLC-based modular automation solution that makes it easy to mix and match standard and safety I/O modules to meet automation market requirements.

## Introduction

Document history

### 1.2 Document history

Rev.	Description of version / changes	Who	Date
1.0.0	First release	ABB	19.12.2012
1.0.1	Minor typos were corrected. TÜV certificate was added. The text was changed in the document: <ul style="list-style-type: none"><li>■ Safety I/O inputs and outputs are not electrically isolated from the other electronic circuitry of the module.</li><li>■ The safety values for safety outputs of DX581-S (-XC) module are only valid if the parameter "Detection" is set to "On".</li><li>■ DC (Diagnostic Coverage) for DX581-S (-XC) module shall be <math>\geq 94\%</math>.</li><li>■ The clarification was added that the boot project update on SM560-S is possible only if no boot project is loaded on SM560-S.</li><li>■ Not more than one communication error (CE_CRC or Host_CE_CRC output signals become equal to TRUE) per 100 hours is allowed to be acknowledged by the operator using OA_C input signal without consulting the responsible safety personnel.</li><li>■ SM560-S cycle time shall be included three times instead of two times in Safety Function Response Time calculation.</li><li>■ The values for input delay accuracy in Safety Function Response Time calculation were updated.</li><li>■ Update of Appendix A with system data for AC500-S-XC.</li></ul>	ABB	08.03.2013
1.0.2	Words "Original Instructions" have been added to document title	ABB	17.04.2015

Rev.	Description of version / changes	Who	Date
1.0.3	<p>Various typos were corrected. Additional abbreviations were included in the abbreviation list.</p> <p>The entire document was re-styled:</p> <ul style="list-style-type: none"> <li>■ The yellow background on notices and recommendations was replaced by a light-grey background because of document standardization.</li> <li>■ "DANGER" and "NOTICE" symbols were replaced by standard symbols from German Standard DIN 4844-2 in text boxes.</li> </ul> <p>The text was changed in the document:</p> <ul style="list-style-type: none"> <li>■ More standard terms are now used in the document.</li> <li>■ Values for storage and transport temperatures were extended.</li> <li>■ Vertical mounting option (with derating) is added for SM560-S Safety CPU and corrected for DI581-S and AI581-S Safety I/O modules.</li> <li>■ LREAL is not supported by SM560-S Safety CPUs and was removed from the document.</li> <li>■ POU SF_MAX_POWER_DIP_GET description was modified.</li> <li>■ "DANGER" text box was added for POU SF_DPRAM_PM5XX_S_SEND to explain limitations for POU usage.</li> <li>■ F_WD_Time2 and Device_WD2 term definitions in Chapter 5.3 were corrected.</li> <li>■ "F_Host_WD" was replaced with "the value set using SF_WDOG_TIME_SET" inside of "NOTICE" box in Chapter 5.3</li> </ul>	ABB	28.05.2015
1.0.4	<p>Various typos were corrected. Minor improvements in the text.</p> <p>Major changes:</p> <p>Licensing information was updated:</p> <ul style="list-style-type: none"> <li>■ Ch. 4.1: Notice Block with reference to PS501-S license installation removed.</li> <li>■ Ch. 4.2: Figure 63 updated (Programming workflow, step 2) was enhanced for the license handling of Automation Builder version V2.0.2 (or higher).</li> <li>■ Ch. 4.3.2: "Licence activation" was extended with additional licensing information for usage of Automation Builder version V2.0.2 (or higher).</li> </ul> <p>Additional information according to the new F-Host library "SAFETYBASE_PROFI-safe_AC500_V22_Ext.lib" was added:</p> <ul style="list-style-type: none"> <li>■ Ch 4.6.1: Table for library "SAFETYBASE_PROFI-safe_AC500_V22_Ext.lib" was updated.</li> <li>■ Ch. 4.6.3: The chapter was updated and renamed acc. to the new library name "SAFETYBASE_PROFI-safe_AC500_V22_Ext.lib".</li> <li>■ Ch. 6.2: Checklist item 20 was updated according to the new library name "SAFETYBASE_PROFI-safe_AC500_V22_Ext.lib".</li> </ul>	ABB	27.03.2017

## Introduction

Important user information

### 1.3 Validity

The data and illustrations found in this documentation are not binding. ABB reserves the right to modify its products in line with its policy of continuous product development.

### 1.4 Important user information

This documentation is intended for qualified personnel familiar with Functional Safety. You must read and understand the safety concepts and requirements presented in this Safety User Manual prior to operating AC500-S Safety PLC system.

The following special notices may appear throughout this documentation to warn of potential hazards or to call attention to specific information.



#### **DANGER!**

The notices referring to your personal safety are highlighted in the manual by this safety alert symbol, which indicates that death or severe personal injury may result if proper precautions are not taken.



#### **NOTICE!**

This symbol of importance identifies information that is critical for successful application and understanding of the product. It indicates that an unintended result can occur if the corresponding information is not taken into account.



## 1.5 Definitions, expressions, abbreviations

1oo2	One-out-of-Two safety architecture, which means that it includes two channels connected in parallel, such that either channel can process the safety function.
AC500-S	ABB Safety PLC for applications up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849)
AC500-S-XC	ABB Safety PLC for applications up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) suitable for Extreme Environmental Conditions
ADC	Analog to Digital Converter
CCF	Common Cause Failure
CPU	Central Processing Unit
CRC	Cyclic redundancy check. A number derived from and stored or transmitted with a block of data in order to detect data corruption.
DC	Diagnostic Coverage
DPRAM	Dual-ported Random Access Memory
IEC	International Electro-technical Commission Standard
EDM	External device monitoring signal, which reflects the state transition of an actuator
EMC	Electromagnetic Compatibility
EN	European Norm (European Standard)
EPROM	Erasable Programmable Read-only Memory
ESD	Electro Static Discharge
ESPE	Electro-sensitive protective equipment (for example a light curtain)
F-Host	Data processing unit that is able to perform a special protocol and to service the "black channel" [3]
F-Device	Passive communication peer that is able to perform the special protocol, usually triggered by the F-Host for data exchange [3]
F-Parameter	Fail-safe parameter as defined in [3]
FB	Function Block
FBD	Function Block Diagram (IEC 61131 Programming Language)
Flash memory	Non-volatile computer storage chip that can be electrically erased and reprogrammed
GSDML	Generic Station Description Markup Language
IO controller	Controller that controls the automation task in PROFINET context
IO device	Field device, monitored and controlled by an IO controller in PROFINET context
iParameter	Individual safety device parameter
LAD	Ladder Logic Diagram (IEC 61131 Programming Language)
Loop-back	The programmable routing feature of a bus device re-routes unintentionally an F-Host message back to the F-Host, which expects a message of the same length (see <a href="http://www.profi-safe.net">www.profi-safe.net</a> for further details).

## Introduction

Definitions, expressions, abbreviations

MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
Muting	Muting is the intended suppression of the safety function. This is required, e.g. when transporting the material into the danger zone.
NC	Break contact. Normally-Closed contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.
NO	Make contact. Normally-Open contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.
OEM	Original Equipment Manufacturer
Passivation	The passivation is the special state of Safety I/O modules which leads to the delivery of safe substitute values, which are '0' values in AC500-S, to the Safety CPU.
PELV	Protective Extra Low Voltage
PES	Programmable Electronic System (see IEC 61508 ed. 2)
PFD	Probability of Failure on Demand
PFH	Probability of Failure per Hour
PL	Performance Level according to ISO 13849
PLC	Programmable Logic Controller
POU	Program Organization Unit
PROFIsafe	Safety-related bus profile of PROFIBUS DP/PA and PROFINET IO for communication between the safety program and the Safety I/O in the Safety system
Proof Test Interval	The proof test is a periodic test performed to detect failures in a safety-related system so that, if necessary, the system can be restored as close as possible to its previous new state. The time period between these tests is the proof test interval.
PS	Programming System
RAM	Random Access Memory
Reintegration	It is the process of switching from substitute values "0" to the process data.
Safety variable	It is a variable used to implement a safety function in a safety-related system
SCA	Safety Code Analysis – ABB software tool to automatically check CoDeSys safety programming rules
SD card	Secure Digital Memory Card
SELV	Safety Extra Low Voltage
SFRT	Safety Function Response Time
SIL	Safety Integrity Level (IEC 61508 ed. 2)
ST	Structured Text (IEC 61131 Programming Language)
TÜV	Technischer Überwachungs-Verein (Technical Inspection Association)

TWCDT	Total Worst Case Delay Time
ULP	Unit in the Last Place, which is the spacing between floating-point numbers, i.e., the value the least significant bit represents if it is 1 (see <a href="http://en.wikipedia.org/wiki/Unit_in_the_last_place">http://en.wikipedia.org/wiki/Unit_in_the_last_place</a> for more details).

## 1.6 Functional safety certification

The AC500-S Safety Modules are safety-related up to SIL3 according to IEC 61508 ed. 2, IEC 62061 and Performance Level e according to ISO 13849, as certified by TÜV Süd Rail GmbH (Germany).

ZERTIFIKAT ♦ CERTIFICATE ♦ 認証証書 ♦ CERTIFICADO ♦ CERTIFICAT


  
Product Service

## CERTIFICATE

**No. Z10 13 01 83652 001**

**Holder of Certificate:** ABB Automation Products GmbH  
Eppelheimer Str. 82  
69123 Heidelberg  
GERMANY

**Factory(ies):** 59269

**Certification Mark:**



**Product:** Automation Equipment, Safety Referred

**Model(s):** Safety PLC AC500-S (-XC)

**Parameters:**

Process and supply voltage:	24 VDC (-25 %...+30 %)
Operating temperature	
AC500-S:	0 °C ... +60 °C
AC500-S-XC:	-40 °C ... +70 °C
Storage / Transport:	-40 °C ... +85 °C

The report and the user documentation in the currently valid revision are mandatory part of this certificate. The product complies with the below listed safety requirements only if the specifications documented in the currently valid revision of this report are met. The certified components are listed in the following report: AH84732C according to the currently valid revision.


**Tested according to:**

EN 61131-2:2003  
IEC 61508-1:2010 (SIL 3)  
IEC 61508-2:2010 (SIL 3)  
IEC 61508-3:2010 (SIL 3)  
IEC 61508-4:2010 (SIL 3)  
IEC 62061:2005 (SILCL 3)  
EN ISO 13849-1:2008 (PL e, Cat. 4)


The product was tested on a voluntary basis and complies with the essential requirements. The certification mark shown above can be affixed on the product. It is not permitted to alter the certification mark in any way. In addition the certification holder must not transfer the certificate to third parties. See also notes overleaf.

**Test report no.:** AH84732C

**Date,** 2013-02-08  
**Page** 1 of 1

  
( Jörgen Blum )





TÜV SÜD Product Service GmbH - Zertifizierstelle - Ridlerstraße 65 - 80339 München - Germany

Fig. 1: Certificate AC500-S

The AC500-S is a Safety PLC which operation reliability is significantly improved compared to a normal PLC using 1oo2 redundancy in the hardware and additional diagnostic functions in its hardware and software. The embedded safety integrity diagnostic functions are based on the safety standards current at the time of certification (↪ *TÜV Süd Rail Certification Report for AC500-S [2]*). These safety integrity tests include test routines, which are run during the whole operating phase, making the AC500-S Safety PLC suitable for the safety machinery applications up to SIL3 according to IEC 61508 ed. 2, IEC 62061 and Performance Level e according to ISO 13849.

The proof test interval for the AC500-S Safety PLC is set to 20 years.

PFH, PFD, MTTFd, Category and DC values from IEC 62061, IEC 61508 ed. 2 and ISO 13849 for AC500-S Safety Modules satisfy SIL3 and PL e requirements.

### 1.7 References/Related documents

- [1] - Creation of safety-oriented applications with CoDeSys V2.3 – Document version 1.8
- [2] - TÜV Süd Rail Certification Report for AC500-S Safety PLC, Version - 2013 (or newer).
- [3] - PROFIsafe – Profile for Safety Technology on PROFIBUS DP and PROFINET IO Profile part, related to IEC 61784-3-3, Version 2.4, March, 2007
- [4] - AC500 User Documentation, PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer)
- [5] - IEC 61131, 2003, Programmable Controllers, Part 3 – Programming Languages
- [6] - Computer Science and Engineering at University of California, Riverside, Chapter 14, Ch14\_Floating Point Calculations and its drawbacks.pdf
- [7] - User Examples with PLCopen Safety Functions, Version 1.0.1, 2008
- [8] - PROFIsafe System Description, Version – Nov. 2007
- [9] - PLCopen Safety: Concepts and Function Blocks, Version 1.0, 2006
- [10] - ISO 13849-1: Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design, 2006
- [11] - PROFIBUS Guideline: PROFIsafe – Environmental Requirements, V2.5, March 2007.

## 2 Overview of AC500-S Safety PLC

### 2.1 Overview

The AC500-S is realized as 1oo2 system (both Safety CPU and Safety I/O modules) and can be used to handle safety functions with SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) requirements in high-demand systems of safety machinery applications. 1oo2 system includes two microprocessors. Each of them executes the safety logic in its own memory area and both compare the results of the execution at the end of each cycle. If a mismatch in the execution or an error is detected, the system goes to a safe state, which is described for each of the safety modules separately.

## Overview of AC500-S Safety PLC

Overview > System

### 2.1.1 System

The AC500-S Safety PLC is an integrated part of AC500 platform with a real common Look & Feel engineering approach. Due to a tight integration in AC500 PLC platform, the generic AC500 system characteristics (mechanics, programming, configuration etc.) are also valid for AC500-S Safety modules.

All non-safety AC500 modules are considered to be interference-free modules for AC500-S Safety PLC. In contrast to Safety modules, interference-free modules are not used to perform Safety Functions. A fault in one of these modules does not influence the execution of the Safety Functions in a negative way.

The term Integrated Safety applied for AC500-S Safety PLC and AC500 platform means:

- One PROFINET IO fieldbus is used for Safety and Non-safety communication.
- The same engineering environment with real Look & Feel is used for both Safety and Non-safety programming.
- The same hardware and wiring Look & Feel is used within Safety and Non-safety modules.
- The same diagnostics concept is used for Safety and Non-safety modules.



Fig. 2: Overview on ABB's AC500 family with Safety and Non-safety modules

#### ■ Standard communication module (Fig. 2/1)

AC500 covers all common communications standards, such as Ethernet, EtherCAT, PROFINET IO, PROFIBUS DP, CANopen, DeviceNet, Modbus TCP, Modbus serial, Serial, ABB CS31 and PROFIsafe via PROFINET. Combinable to form optimally scaled network nodes, ABB's AC500 is suitable for both small-scale applications and large-scale industrial systems.

#### ■ Safety PLC (Fig. 2/2)

SM560-S Safety CPU certified up to SIL3 (IEC 62061, IEC 61508 ed. 2) and PL e (ISO 13849). An array of features such as system diagnostics provided via LEDs and onboard display of standard CPUs provides the added diagnostic concept required for integrated safety.

#### ■ Standard PLC (Fig. 2/3)

ABB's complete AC500 range of CPUs, from the PM573 to the PM592, can be used with Safety CPU to create customized solutions – even for the most challenging requirements. The programming of safety and non-safety applications is offered via a standard PLC interface.

## ■ Safety I/O module (Fig. 2/4)

Safety I/O modules certified up to SIL3 (IEC 62061, IEC 61508 ed. 2) and PL e (ISO 13849). Features such as channel-wise error diagnostics and the flexibility to choose between channel-wise or module switch-off in case of channel error make working safely easier.

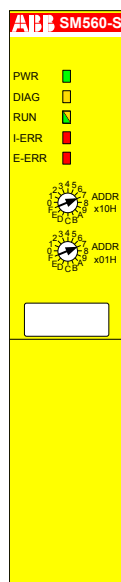
## ■ Standard I/O module (Fig. 2/5)

With ABB's standard I/O modules, the complete S500 and S500-eCo I/O module range can be connected to the standard PLC. A wealth of functions in AC500 configurable I/O modules allows getting the customized and low-priced solutions to optimize industrial applications.

## 2.1.2 Safety components

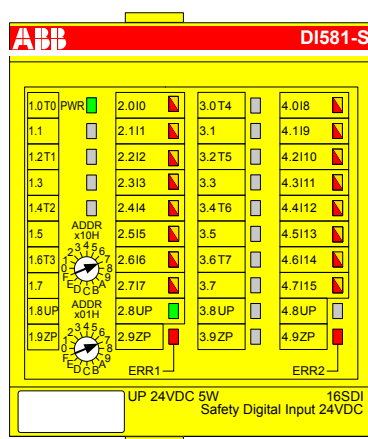
The AC500-S Safety PLC includes the following safety-related hardware components:

### SM560-S



Safety CPU (Safety Module) for up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) safety applications.

### DI581-S

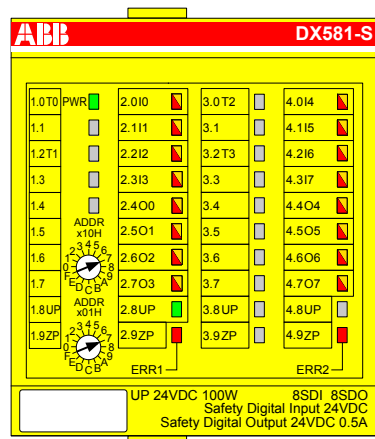


## Overview of AC500-S Safety PLC

Overview > Safety components

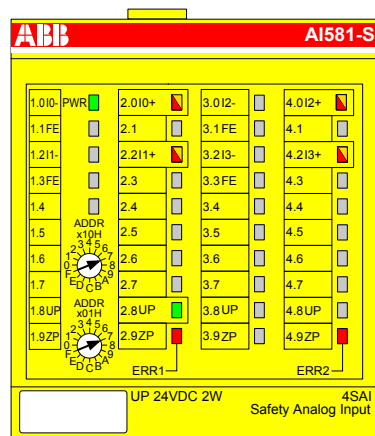
Safety binary input module DI581-S with 16 safety input channels (up to SIL2 or PL d) or 8 safety input channels (up to SIL3 or PL e) with 8 test pulse output channels.

### DX581-S



Safety binary input/output module DX581-S with 8 safety output channels (up to SIL3 or PL e) and 8 safety input channels (up to SIL2 or PL d) or 4 safety input channels (up to SIL3 or PL e) with 4 test pulse output channels.

### AI581-S

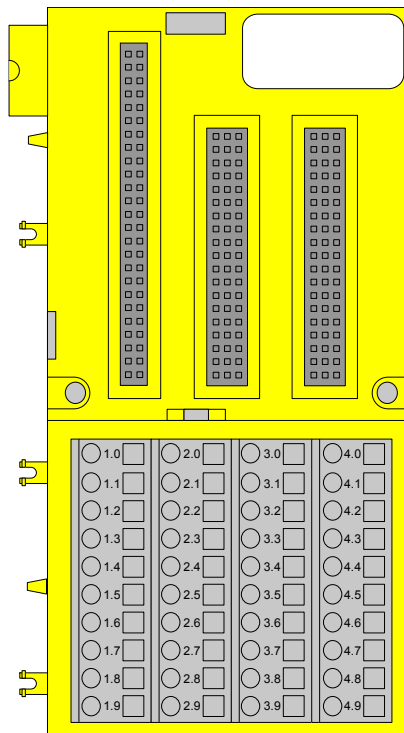


Safety analog input module AI581-S with 4 safety current input channels 0 ... 20 mA (up to SIL2 or PL d) or 2 safety current input channels (up to SIL3 or PL e).

The following interference-free component shall be used for mounting Safety I/O modules:



## TU582-S



Spring-type terminal unit TU582-S for Safety I/O modules.

## 2.2 Intended use

The user shall coordinate usage of ABB AC500-S safety components in his applications with the competent authorities and get their approval. ABB assumes no liability or responsibility for any consequences arising from the improper use:

- Non-compliance with standards and guidelines
- Unauthorized changes to equipment, connections and settings
- Use of unauthorized or improper equipment
- Failure to observe the safety instructions in this guide

## Overview of AC500-S Safety PLC

Safety values

### 2.3 Safety loop

The safety loop, to which the AC500-S Safety PLC belongs, consists of the following three parts: sensors, Safety PLC and actuators.

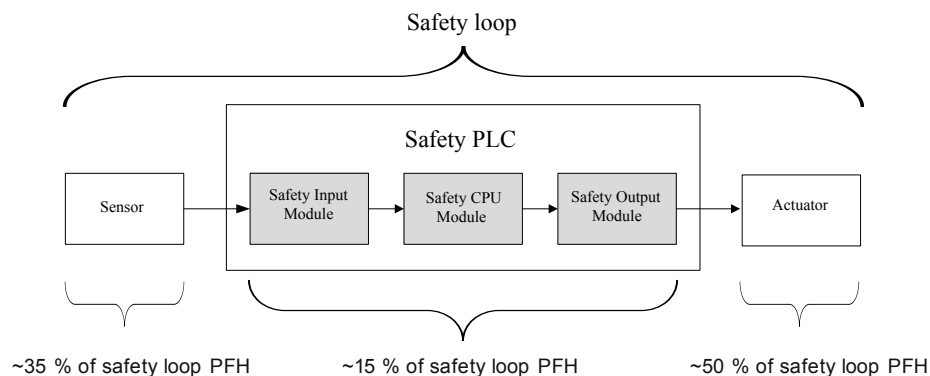


Fig. 3: Typical safety loop with AC500-S Safety PLC

For the calculation of the PFH/PFD values of an exemplary safety system, a maximum of 15 % is assumed for the Safety PLC. The detailed values of PFH for AC500-S Safety modules and PFH/PFD of the Safety PLC Loop can be obtained on request.

### 2.4 Safety values

Table 1: The following safety values can be used for AC500-S safety modules:

Type	Description	SIL <sup>(1)</sup>	PL <sup>(2)</sup>	DC <sup>(3)</sup>	PFHd <sup>(4)</sup>	MTTFd <sup>(5)</sup>	T1 <sup>(6)</sup>
SM560-S (-XC)	Safety module	3	e	≥ 95 %	< 3.0E-09	> 100 years	20
AI581-S (-XC)	Safety Analog Input Module	3	e	≥ 95 %	< 3.0E-09	> 100 years	20
DI581-S (-XC)	Safety Digital Input Module	3	e	≥ 95 %	< 3.0E-09	> 100 years	20
DX581-S (-XC) *	Safety Digital Input/ Output Module	3	e	≥ 94 %	< 3.0E-09	> 100 years	20

<sup>(1)</sup> - according to IEC 62061 and IEC 61508 ed. 2 (continuous and high demand mode)

<sup>(2)</sup> - according to ISO 13849-1

<sup>(3)</sup> - Diagnostic Coverage (see ISO 13849-1)

<sup>(4)</sup> - Probability of dangerous failure per hour according to IEC 61508 ed. 2 (Continuous and high demand mode) and IEC 62061

<sup>(5)</sup> - Mean Time To Failure (years) dangerous according to ISO 13849-1

<sup>(6)</sup> - Proof Test Interval - Mission Time - Lifetime Years

\* - See the danger note below

## **DANGER!**

The safety values for safety outputs of DX581-S (-XC) module are only valid if the parameter Detection = "On" (internal test of output transistors is active). If the parameter Detection = "Off" then contact ABB technical support to obtain proper safety values.

## **DANGER!**

The average temperature (MTBF calculation base) for both the extended temperature range (–40 °C ... +70 °C) as well as for standard temperature range (0 °C ... +60 °C) is defined to 40 °C.

Ensure that average operating temperature for used AC500-S modules does not exceed 40 °C.

The detailed safety values for AC500-S Safety modules can be obtained on request.

## 2.5 Qualified personnel

AC500-S Safety PLC may only be set up and used in conjunction with this documentation.

### **Safety application engineer of AC500-S Safety PLC**

Commissioning and operation of AC500-S Safety PLC may only be performed by the qualified personnel who is authorized to commission safety devices, systems and circuits in accordance with established functional safety practices and standards.

The following basic knowledge of AC500 system is required to correctly understand this AC500-S Safety User Manual:

- AC500 automation system
- PS501 Control Builder Plus / ABB Automation Builder Programming Environment (system configuration and programming in ST, LAD and FBD programming languages).

## 2.6 Lifecycle

All AC500-S safety modules have a maximum life of 20 years. This means that all AC500-S safety modules shall be taken out of service or replaced by new AC500-S safety modules at least one week before the expiry of 20 years (counted from the date of delivery by ABB).

## 2.7 Installation of safety modules

The following rules shall be taken into account for installing Safety Modules:

- The installation must be done according to the documentation with appropriate facilities and tools.
- The installation of the devices may be done only in de-energized condition and carried out by the qualified personnel.
- The general safety regulations and applicable national safety regulations shall be strictly observed.
- The electrical installation shall be carried out in accordance with relevant regulations.
- Take the necessary protective measures against static discharge.

## Overview of AC500-S Safety PLC

Environmentally friendly disposal

### 2.8 Exchange of modules

SM560-S Safety CPU automatically detects an exchange of Safety I/O modules during the system start-up. The overall system (SM560-S Safety CPU and PROFIsafe features of unique addresses for Safety devices [3]) provides a mechanism to automatically ensure that exchanged safety modules are operated with correct parameters and incompatible module types are rejected. No unsafe state is possible if wrong Safety I/O module type is put on the given terminal unit TU582-S.

### 2.9 AC500-S restart behaviour

When SM560-S Safety CPU is restarted using powering off/on, the previously saved error information is lost. The Safety I/O modules receive their parameter sets each time during system start-up. SM560-S is able to reintegrate Safety I/O modules using PROFIsafe start-up behaviour [3]. If your process does not allow an automatic start-up after powering off/on, you must program a restart protection in the safety program. The safety process data outputs must be blocked until manually acknowledged. These safety outputs must not be enabled until it is safe to do so and faults were corrected.

### 2.10 Replacing AC500-S Safety PLC components

When replacing software components on your programming device or PC with a newer version, you must observe the notes regarding upward and downward compatibility in the documentation and readme files for these products.

Hardware components for AC500-S (Safety CPU and Safety I/Os) are replaced in the same way as in a standard AC500 automation system.

### 2.11 Environmentally friendly disposal

All AC500-S safety components from ABB are designed with a minimal environment pollution effect. To enable environmentally friendly disposal of AC500-S safety components, they can be partially disassembled to separate various components from each other. Disposal of those materials shall be done in accordance with applicable national and international laws.

## 2.12 Safe communication

Safety data are transferred between Safety CPU and Safety I/Os using PROFI-safe profile [3]. SM560-S Safety CPU needs a Non-safety CPU, e.g., PM573, PM583, PM592 or others with the firmware version from V2.2.1, to communicate to Safety I/O modules. All safety-related communication takes place through the Non-safety CPU using a “black channel” principle of data transmission [3].

The communication of Safety CPU to remote Safety I/O modules is done using PROFINET IO field bus with a PROFI-safe profile for safe data transmission [3]. Safety and non-safety I/O modules can be mixed on a local I/O-Bus both in central and remote configuration. PROFINET IO controller Communication Module (CM579-PNIO) shall be used on Non-safety CPUs as a part of the “black channel” to transfer safety data to PROFINET IO devices. PROFINET devices CI501, CI502, CI504 and CI506 (Release date: 2013 and newer) can be used to attach Safety I/O modules in remote configurations.

Fig. 4 shows a possible system setup with PROFINET/PROFI-safe for remote Safety I/Os, sensors and actors.

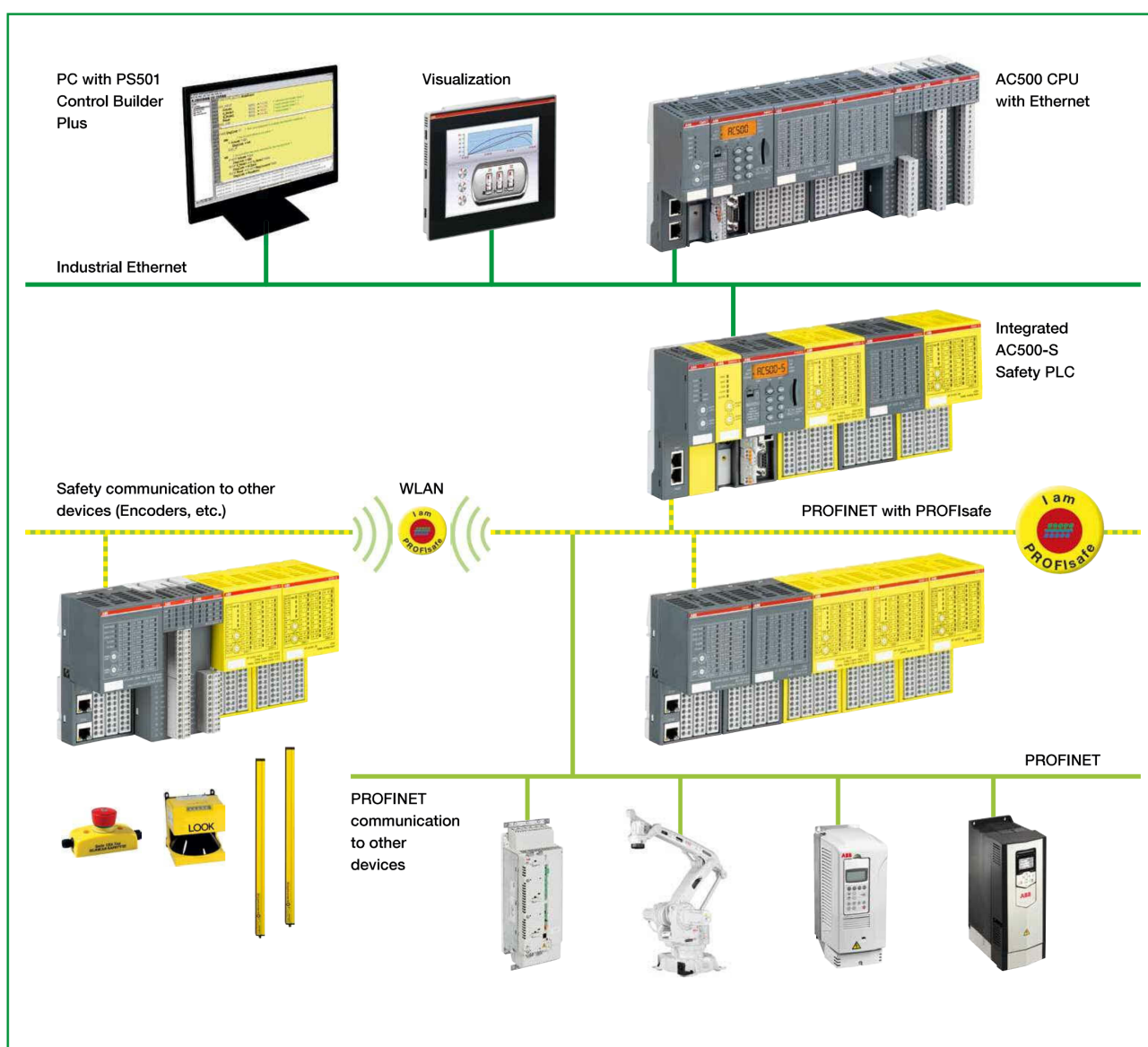


Fig. 4: AC500-S system setup with PROFINET / PROFI-safe

## Overview of AC500-S Safety PLC

Safety function and fault reaction > Safety CPU (SM560-S)

The following communication requirements shall be fulfilled for using AC500-S Safety PLC:

- Safety data cannot be transferred over public networks, e.g., Internet. If safety data is transferred across company/factory networks, ensure that sufficient protection is provided against manipulation (firewall or router for network separation).
- Equipment connected to communication devices shall feature safe electrical isolation.

### ! NOTICE!

You can use AC500-S Safety I/O modules with 3<sup>rd</sup> party F-Hosts on PROFINET. Download and install valid ABB GSDML files in your 3<sup>rd</sup> party F-Host engineering environment from <http://www.abb.com/plc>.

After this, you can configure and use AC500-S Safety I/Os with 3<sup>rd</sup> party F-Host. Use ABB PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer) to obtain F\_iPar\_CRC value for your configured iParameters or contact ABB technical support to obtain F\_iPar\_CRC values.

Validate that all iParameters (Input delay, channel configuration, etc.) for all AC500-S Safety I/Os and other F-Devices are correct with a given F\_iPar\_CRC value using appropriate functional validation tests or verification procedure ( ↪ Chapter 6.5 "Verification procedure for safe iParameter setting in AC500-S Safety I/Os" on page 412) for those parameters.

## 2.13 Safety function and fault reaction

The main safety function of AC500-S Safety PLC is to read safety digital and analog inputs to control the safety digital outputs by the safety logic module SM560-S according to a user-defined IEC 61131 application program and configuration.

The AC500-S Safety PLC can be used as a "de-energize to trip" (Normally Energized, NE) system. The safe state of the outputs is defined according to the table below:

Table 2: NE safety system behaviour

	Normally energized, NE
Mode according to IEC 61508 ed. 2	High-demand
Safety Function	De-energize to trip
Safe State	De-energized outputs

The purpose of AC500-S safety function is to enable a machine (as a system) to achieve with a given SIL (IEC 61508 ed. 2, IEC 62061) and PL (ISO 13849) a system safe state. An exemplary Safety Function on the application level, which can be executed by AC500-S in machinery applications, is the Emergency Stop.

### 2.13.1 Safety CPU (SM560-S)

The safety function of SM560-S Safety CPU is to correctly process signal information. It processes safety input signals and internal data storage to generate signals to safety output modules and set a new state of its internal data storage.

If this function cannot be correctly executed, the SM560-S Safety CPU goes to a SAFE STOP state, in which no valid safety telegrams are generated and, as a result, all safety output module channels are de-energized ('0' state) after watchdog time is expired.

Faults in the cyclic communication between the Safety CPU and Safety I/O modules are detected by the Safety CPU and, as a result, '0' values are handed to the safety application program.

The application program developer must implement a specific fault reaction, e.g., setting safety output channels to de-energized ('0' state), when required.

## 2.13.2 Safety module with safety input channels (DI581-S, DX581-S and AI581-S)

The safety function of safety modules (DI581-S, DX581-S and AI581-S) with digital and analog input channels is to correctly read external analog and/or digital signals. If this function cannot be correctly executed, the safety module or only its input channel, depending on the fault scope, has to go to a safe state. In case of a channel fault, the safe value (de-energized = '0') is transferred to the safety logic module (e.g., SM560-S) with additional information about the fault for the given channel.

In case of module fault, no valid telegrams are generated by the safety module to the safety logic module. The values of those safety input channels will be assigned to safe values (de-energized = '0') on the Safety CPU.

Faults in the cyclic communication between the Safety CPU and the safety modules are detected by the safety modules with input channels. If a communication fault occurs, all inputs of the affected safety module go to a so-called passivation state in which '0' values are sent as process values when the communication to the Safety CPU is re-established. The switch-over (reintegration) from safety values '0' to process data takes place only after user acknowledgment.

## 2.13.3 Safety module with safety output channels (DX581-S)

The safety function of safety modules (DX581-S) with safety output channels is to correctly write their output channel signals. If this function cannot be correctly executed, the safety module or its output channel group, depending on the fault scope, has to go to a safe state. In case of a channel fault, the safe value (de-energized = '0') is set for the given safety output channels. In case of module fault, no valid telegrams are generated by the safety output module to the Safety CPU. The values of all safety output channels will be assigned to safe values (de-energized = '0').

Faults in the cyclic communication between the Safety CPU and the safety output modules are detected by the safety output module DX581-S. If a communication fault occurs, all outputs of the affected safety output module are de-energized = '0'. The switch-over (reintegration) from safety values '0' to process data takes place only after user acknowledgment, when the communication is re-established.

## 2.14 Safety function test

After creating a safety program and system configuration, you must carry out a complete function test in accordance with your automation task. For changes made to a safety program which has already undergone a complete function test, only the changes need to be tested, if a proper impact analysis was done before.

Safety application program, Safety I/O configuration, etc. have to be verified, printed out and saved for project data report and archive. The system acceptance test shall follow safety function test. After you finish configuring the hardware and assigning parameters for the Safety CPU and Safety I/O modules, you can perform an acceptance test. During the system acceptance test, all relevant application-specific standards must be adhered.

## Overview of AC500-S Safety PLC

### Troubleshooting

## 2.15 Troubleshooting

Error messages in the diagnosis buffer of PM5xx Non-safety CPU include “Remedy” section, which shall help you to fix potential problems with AC500-S configuration. If some of problems persist or no error messages are available in the diagnosis buffer, contact ABB technical support for further details.

### ! NOTICE!

Make sure that Safety I/O modules are properly attached to TU582-S terminal unit with a good electrical contact to avoid unintended system state with possibly wrong LED states ( ↗ *Chapter 3.3.3 “Mounting, dimensions and electrical connection” on page 79*, ↗ *Chapter 3.4.3 “Mounting, dimensions and electrical connection” on page 112* or ↗ *Chapter 3.5.3 “Mounting, dimensions and electrical connection” on page 139*).

Below you can find a list of known issues and solutions related to AC500-S Safety PLC components:

ID	Behaviour	Potential Cause	Remedy
1.	SM560-S Safety CPU is in RUN or DEBUG RUN state, but all Safety I/O modules suddenly go to RUN (module passivation) state.	Your program may contain endless loop which prevents SM560-S Safety CPU to send valid safety telegrams to Safety I/O modules in a proper time manner (within configured watchdog time).	Check (debug) your safety application program and make sure that no endless loop(s) are in your safety application program.
2.	No Login is possible to SM560-S from CoDeSys Safety project.	CoDeSys visualization was connected directly to SM560-S Safety CPU, which blocks the connection to SM560-S.  Only one connection to SM560-S Safety CPU is allowed at a time.	Disconnect CoDeSys visualization from SM560-S Safety CPU.
3.	During closing or saving of the project, modification of CoDeSys Safety project, etc. with PS501 Control Builder Plus / ABB Automation Builder, you may see that no reaction comes from the PS501 Control Builder Plus / ABB Automation Builder and/or CoDeSys Safety project. It is as if the application hangs.	The user management of PS501 Control Builder Plus / ABB Automation Builder requires that you confirm your log-on credentials for safety components and issues a log-on message box which is not in the foreground. Your previous log-on session has expired.	Find a log-on message in the background of your Windows desktop, log-on and continue your previous actions. Set longer user log-on session time for PS501 Control Builder Plus / ABB Automation Builder ( ↗ <i>PS501 Control Builder Plus / ABB Automation Builder User Documentation</i> ) if this behavior repeats.
4.	Your safety digital input channel is occasionally passivated with an internal error diagnostic message (Err. Class: E3, Comp.: 14, Device: 1 ... 10, Module: 31, Channel: 31, ID: 43).	One of potential reasons is that your input signal frequency exceeded an allowed input channel signal frequency ( ↗ <i>Chapter 3.3.2 “Functionality” on page 76</i> for allowed frequency ranges).	Check that your input signal does not exceed the allowed digital input signal frequency.



ID	Behaviour	Potential Cause	Remedy
5.	DX581-S module is powered on, but no power supply is connected to UP clamps of DX581-S module.	Wiring error on DX581-S module when +24 V DC is connected to at least one of the safety digital output clamps of DX581-S. As a result, DX581-S is powered on through safety digital outputs.	Check the wiring of DX581-S and disconnect +24 V DC from the safety digital output clamp(s).
6.	Some channels of a Safety I/O module or a complete Safety I/O module is occasionally passivated without a reason (wiring is correct, etc.).	No proper electrical contact between a Safety I/O module and TU582-S terminal unit.	Make sure that you pressed the Safety I/O module into TU582-S terminal unit with a force of at least 100 Newton, as prescribed in AC500-S checklists.
7.	With the increased number of Safety I/O modules in the system, it takes longer to execute <i>"Create boot project"</i> command for SM560-S Safety CPU.	SM560-S Safety CPU is a single-threaded system. The more Safety I/O modules are in the system, the higher is the internal cycle time of SM560-S Safety CPU to process Safety I/O relevant data.	Currently, there is no possibility to change this behavior other than to split Safety I/Os to different SM560-S Safety CPUs, so that each SM560-S Safety CPU has less Safety I/Os to handle.
8.	After login to CoDeSys Safety, one can observe a long list of internal constants with a green font colour for PROFIsafe F-Host instances.	In CoDeSys Safety, the option <i>"Replace constants"</i> is selected.	Go in CoDeSys Safety menu to <i>"Project → Options → Build"</i> Unselect option <i>"Replace constants"</i> .
9.	No valid safety project can be generated (PROFIsafe callback functions are missing and no Safety I/O mapping is created).	A potential reason is that you selected in <i>"Object Properties... → Access rights"</i> for any of the POU's in the CoDeSys Safety project tree the following option: <ul style="list-style-type: none"> <li>■ <i>"No Access"</i> or <i>"Read Access"</i> for all <i>"User Groups"</i> with <i>"Apply to all"</i> selection.</li> </ul>	Start CoDeSys Safety project, login and go to <i>"Object Properties... → Access rights"</i> for any of the POU's in the CoDeSys Safety project tree to set <i>"Full access"</i> for any of User Groups followed by selection of <i>"Apply to all"</i> . After this, you can successfully repeat <i>"Create Safety Configuration Data"</i> command for your CoDeSys Safety project from PS501 Control Builder Plus / ABB Automation Builder.
10.	I call CurTimeEx FB and always get "0" values on the outputs.	CurTimeEx FB is not implemented in the current version of SM560-S Safety CPU and is reserved for future use.	Do not use CurTimeEx FB in your safety application program.

## Overview of AC500-S Safety PLC

### Troubleshooting

ID	Behaviour	Potential Cause	Remedy
11.	<ul style="list-style-type: none"><li>■ Set "Enable debug" parameter to "OFF" on SM560-S</li><li>■ Create boot projects for SM560-S and PM5xx</li><li>■ Execute powering off/on</li><li>■ Go to CoDeSys Safety and compare boot project CRCs on your PC and SM560-S. The comparison shows that they are the same, which is OK.</li><li>■ Try to create a boot project for SM560-S. An error message follows because of "Enable debug" set to "OFF" for SM560-S, which is OK.</li><li>■ Repeat the comparison of boot project CRCs on your PC and SM560-S. They are reported to be not equal now (boot project CRC for SM560-S is shown as CDCDCDCD), which can be misleading since the boot project on SM560-S was not changed.</li></ul>	CoDeSys Safety does not support the described use case.	After powering off/on of SM560-S Safety CPU, the correct boot project CRC shall be shown for SM560-S.
12.	The serial driver is used to connect to SM560-S Safety CPU. One executes "Login" command shortly followed by "Logout" command in CoDeSys Safety and shortly after this the "Login" command is again executed. After second login attempt, the communication error is shown in CoDeSys Safety.	The serial driver does not have enough time to be re-initialized.	Wait for at least 20 seconds before executing "Login" command after "Logout" was performed.

ID	Behaviour	Potential Cause	Remedy
13.	<ul style="list-style-type: none"> <li>One executes "Login" command in CoDeSys Safety and uses "setpwd" PLC Browser command to set a new password, e.g., "PWD1" for SM560-S Safety CPU.</li> <li>Power off/on is executed for SM560-S, but CoDeSys Safety window remains open on end-user PC.</li> <li>One executes "Login" command in CoDeSys Safety and enters the new password "PWD1", which was set in Step 1. One uses "setpwd" PLC Browser command to set a new password, e.g., PWD2, for SM560-S Safety CPU.</li> <li>Power off/on is executed for SM560-S, but CoDeSys Safety window remains open on end-user PC.</li> <li>One executes "Login" command in CoDeSys Safety and an error message is shown "You have entered a wrong PLC password!". After pressing "OK", you still have a possibility to enter a new password "PWD2" and successfully login to SM560-S Safety CPU.</li> </ul>	CoDeSys Safety instance attempts to login to SM560-S Safety CPU with an old password.	After resetting SM560-S Safety CPU password, close CoDeSys Safety instance and open it again. The error message will not appear again.
14.	After power-on, Safety I/O module goes to SAFE STOP state with both ERR LEDs = ON.	The configured F_Dest_Add value in PS501 Control Builder Plus / ABB Automation Builder project is not equal to the PROFIsafe address switch value on the Safety I/O module.	Make sure that F_Dest_Add value in PS501 Control Builder Plus / ABB Automation Builder project is equal to the PROFIsafe address switch value on the Safety I/O module.
15.	No login to SM560-S Safety CPU is possible.	Wrong "Communication parameters..." settings are used.	Check that correct settings of "Communication parameters ..." are used in CoDeSys Safety to connect to SM560-S Safety CPU.
16.	After the boot project is loaded to SM560-S Safety CPU, sometimes the PM5xx CPU seems to do nothing for about 45 seconds until its ERR-LED is switched on.	Timeout in PM5xx CPU.	Such situation can be observed very seldom. There is no remedy for this behaviour of PM5xx CPU at the moment.

## Overview of AC500-S Safety PLC

### Troubleshooting

ID	Behaviour	Potential Cause	Remedy
17.	After power-on of SM560-S Safety CPU, it may happen that SM560-S Safety CPU does not go to RUN mode. DIAG LED is ON and no boot project is loaded to SM560-S Safety CPU. If you attempt to login to SM560-S Safety CPU, then the following error message can be seen in CoDeSys Safety: "No program on the controller! Download the new program?".	SM560-S power dip function is triggered if the pause between the power-off and the following power-on phase is less than 1.5 s. The boot project is still on SM560-S Safety CPU, but not loaded due to power dip detection. Thus, there is no need to reload any boot project to SM560-S Safety CPU.	Do power-off and power-on of SM560-S Safety CPU with a pause between power-off and power-on phase $\geq 1.5$ s.
18.	If a breakpoint is reached in CoDeSys Safety during debugging and you try to force a variable, then this variable is updated with the forced value only in the next SM560-S Safety CPU cycle.	SM560-S Safety CPU is single-threaded.	This behavior is as designed.
19.	During project download to SM560-S Safety CPU, the download window stays with 0 bytes of downloaded code forever or an error message pops up.	"Enable debug" parameter was set to "OFF" for SM560-S Safety CPU and this configuration data was downloaded to PM5xx.	Set "Enable debug" parameter to "ON", generate a new configuration and download CoDeSys project to PM5xx. New project code can be now downloaded to SM560-S Safety CPU through CoDeSys Safety.
20.	Unable to login to SM560-S Safety CPU from CoDeSys Safety after logout.	Too fast login to SM560-S after logout from SM560-S in CoDeSys Safety.	Wait a few seconds ( $\sim 5 - 10$ s) after logout from SM560-S before you perform login to SM560-S in CoDeSys Safety.
21.	E3 diagnostic message with error text "Measurement underflow at the I/O module" appears in PM5xx diagnosis system despite the fact that overcurrent and not undercurrent was observed for the given AI581-S input channel.	The internal detection mechanism is not always able to differentiate between over- and undercurrent because the overcurrent is often followed by undercurrent effects in AI581-S electronics.	There is no remedy for this problem yet.

ID	Behaviour	Potential Cause	Remedy
22.	“Enable debug” parameter = “ON” was set for SM560-S Safety CPU and correctly loaded to PM5xx. However, one still cannot debug on SM560-S Safety CPU.	CoDeSys Safety projects on your PC and in SM560-S Safety CPU are not the same. You may get also the following message window with the text: “The program has changed! Download the new program?”.	Download your CoDeSys Safety project from your PC to SM560-S Safety CPU and debugging shall be possible now.
23.	After PLC browser command “reset” for SM560-S Safety CPU, SM560-S goes to DEBUG STOP state (Non-safety mode). Safety I/O modules go to module passivation state. If you login to SM560-S Safety CPU, then you can see OA_Req_S = TRUE bits in PROFIsafe instances of F-Devices. The safety application is not executed by SM560-S Safety CPU, but you still can set OA_C = TRUE for F-Devices and they will go to RUN mode. SM560-S remains in DEBUG STOP state (Non-Safety) all the time.	PROFIsafe F-Host does not run in fail-safe mode after PLC browser command “reset”.	This behaviour will be fixed in the future versions of SM560-S Safety CPU. Due to the fact that SM560-S Safety CPU is in DEBUG STOP state (Non-safety mode) all the time, this is not a safety critical case and can be easily tolerated.

### 3 AC500-S Safety Modules

#### 3.1 SM560-S Safety CPU

##### Elements of the module

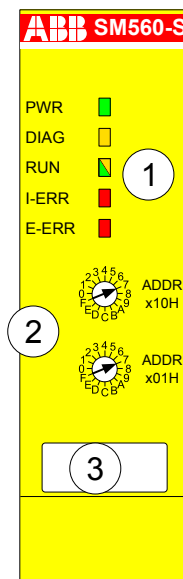


Fig. 5: SM560-S

- 1 Five LEDs for status display
- 2 Rotary switch for address/configuration setting
- 3 Label

##### 3.1.1 Purpose

SM560-S is the Safety CPU for up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) safety applications. The Safety CPU is mounted on the left side of the Non-safety CPU, e.g., PM573, PM583, PM592 or others with the firmware version from V2.2.1, on the same Terminal Base. The communication between the Non-safety CPU and the Safety CPU takes place through the internal communication bus, which is integrated in the Terminal Base. The data interchange is realized by a dual-port RAM.

Depending on the used Terminal Base, 1 ... 4 Communication Modules (e.g., CM579–PNIO, etc.) can be simultaneously employed at one Non-safety CPU. However, only one SM560-S Safety CPU can be operated simultaneously at one Non-safety CPU.

The Safety CPU is programmed and configured via the dual-port RAM using safety system configurator and CoDeSys Safety programming environment, which are a part of the PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) software.

The configuration of SM560-S is saved non-volatile in a Flash EPROM.

##### 3.1.2 Functionality

###### 3.1.2.1 Overview

SM560-S Safety CPU for AC500 PLCs is available from version V2.2.1 (or newer) of the PS501 Control Builder Plus software / version 1.0 (or newer) of the ABB Automation Builder software and can be used with Non-safety CPUs (PM573, PM583, PM592 or others with the firmware version from V2.2.1 and with suitable TB5xx units). Power supply is provided via the coupler interface of the Terminal Base.


The firmware version of the used Non-safety CPU must be V2.2.1 or above. Programming of the Safety CPU is done using CoDeSys Safety in exactly the same way as programming of AC500 CPU, but in accordance with the guidelines [1]. Programming can be done by means of routing via the AC500 CPU using the serial interface or Ethernet. The user program is composed of:

- Compiled code of all POU's called in the program
- Initialization code for variables.

### 3.1.2.2 Floating-point operations

SM560-S Safety CPU can perform floating-point operations.

#### **DANGER!**

Divisions by zero are not allowed and shall be caught latest during the formal Safety CPU code review according to CoDeSys Safety Programming Guidelines (  *Chapter 4.4 "CoDeSys Safety programming guidelines" on page 210*).

If case of exceptions during floating-point operations (e.g., due to usage of invalid arguments), SM560-S Safety CPU goes to a SAFE STOP state or delivers a return value "Infinity".

Note that the range of valid arguments in SM560-S Safety CPU for floating-point functions is:

- SIN and COS:  $[-9 \times 10^{15} \dots 9 \times 10^{15}]$
- TAN:  $[-4.5 \times 10^{15} \dots 4.5 \times 10^{15}]$
- ATAN:  $[-3.402823 \times 10^{38} \dots 3.402823 \times 10^{38}]$
- LOG, LN and SQRT: up to  $3.402823 \times 10^{38}$

The arguments outside the above-presented range will lead to a SAFE STOP state of SM560-S Safety CPU.

#### **DANGER!**

The end-result of floating-point operation has to be checked for its validity before it is further used in the safety program.

### DANGER!

It is important to take into account the following while programming with floating point arithmetic [6]:

- Round or truncate results after each floating point operation according to defined ULPs (MOD, EXPT, EXP, ABS, TAN, ASIN, ACOS, ATAN, SIN, COS, LOG and LN operations are executed with a maximum expected error of 2 ULP; ADD, SUB, MUL, DIV and SQRT are executed with a maximum error of 1 ULP in SM560-S Safety CPU). ↗ [http://en.wikipedia.org/wiki/Unit\\_in\\_the\\_last\\_place](http://en.wikipedia.org/wiki/Unit_in_the_last_place) for more details on ULPs.
- If you compute a value which is the result of a sequence of floating point operations, the error can accumulate and greatly affect the computation itself.
- Whenever subtracting two numbers with the same signs or adding two numbers with different signs, the accuracy of the result may be less than the precision available in the floating point format.
- The order of evaluation can affect the accuracy of the result.
- When performing a chain of calculations involving addition, subtraction, multiplication and division, try to perform the multiplication and division operations first.
- When multiplying and dividing sets of numbers, try to arrange the multiplications so that they multiply large and small numbers together; likewise, try to divide numbers that have the same relative magnitudes.
- When comparing two floating point numbers, always compare one value to see if it is in the range given by the second value plus or minus some small error value.

### 3.1.2.3 System functions

SM560-S Safety CPU is not equipped with a battery. Therefore, all operands are initialized once the control voltage is switched on. Data exchange between Safety and Non-safety CPUs is possible using special library POU's SF\_DPRAM\_PM5XX\_S\_SEND, SF\_DPRAM\_PM5XX\_S\_REC, DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC ( ↗ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details) on both CPUs.

### DANGER!

It is of no concern to transfer data values from Safety CPU to Non-safety CPU (e.g., for diagnosis and later visualization on the operator panels), **but it is not recommended to transfer data values from Non-safety CPU to Safety CPU**. In the latter case, end-users have to define additional process-specific validation procedures in the safety program to check the correctness of the transferred non-safety data, if they would like to use those non-safety values for safety functions.

SM560-S Safety CPU is single-threaded.

Self-tests and diagnostic functions (both start-up and runtime), like CPU and RAM tests, program flow control, etc. are implemented in SM560-S according to IEC 61508 ed. 2 SIL 3 requirements.

Selected data can be stored fail-safe and permanently in the Flash memory of SM560-S using special library POU's SF\_FLASH\_READ, SF\_FLASH\_WRITE and SF\_FLASH\_DEL ( ↗ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details).

SM560-S is a single task Safety CPU. Only one free-wheeling program task is available for safety program execution. The free-wheeling task is the task which will be processed as soon as the program is started and at the end of one run will be automatically restarted in a continuous loop. There is no cycle time defined for this task, but users can supervise the cycle time of SM560-S using a special library POU SF\_WDOG\_TIME\_SET ( ↗ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details).



The watchdog time of the Safety CPU set using `SF_WDOG_TIME_SET` is the maximum permissible time allowed for SM560-S cycle time run. If the time set in `SF_WDOG_TIME_SET` is exceeded during the program execution on SM560-S, then SM560-S goes to a SAFE STOP state (no valid telegrams are generated by the device) with I-ERR LED = ON.

**! NOTICE!**

POU `SF_WDOG_TIME_SET` must be called in the user program only one time to set some watchdog value greater than 0. If `SF_WDOG_TIME_SET` is not called in the user application program, the default watchdog time = 0 is used, which leads SM560-S Safety CPU directly to a SAFE STOP state with I-ERR LED = ON.

To avoid occasional stops of SM560-S due to cycle time overrun detected by the cycle time monitoring, one shall observe the Safety CPU load in the test run of the user application program to make sure that the selected watchdog monitoring value was correctly set.

**! NOTICE!**

The watchdog value set in POU `SF_WDOG_TIME_SET` is used for SM560-S Safety CPU cycle time monitoring only in RUN (Safety) mode. In `DEBUG RUN` and `DEBUG STOP` modes of SM560-S Safety CPU, the watchdog value is ignored.

Using a special PLC Browser command "setpwd", it is possible to set a password for SM560-S Safety CPU to prevent an unauthorized access to its data (application project, etc.). Without knowledge of this password, no connection to Safety PLC can be established.

### 3.1.2.4 Power supply supervision

The internal power supply (+3.3 V) of SM560-S is supervised for under- and overvoltage. In case of under- or overvoltage is detected, SM560-S goes to a SAFE STOP state (no valid telegrams are generated by the device) with I-ERR LED = ON. To avoid continuous automatic restart of SM560-S after power supply is back within an allowed voltage range, one can set the maximum allowed number of SM560-S restarts using POU `SF_MAX_POWER_DIP_SET` ( ↪ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details). As soon as the maximum allowed number of SM560-S restarts is exceeded, the Safety CPU does not restart automatically and remains in the SAFE STOP state until the user explicitly executes powering off/on procedure.

### 3.1.2.5 Address / configuration switch

The setting of two rotary switches for PROFI-safe address and/or system configuration (for example, these switches can be used for safety program flow control) can be read out in the safety application program using POU `SF_SM5XX_OWEN_ADR` ( ↪ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details). Switch address values 0xFF, 0xFE, 0xFD and 0xFC are used for internal SM560-S system functions described below:

- Switch address value 0xFF during the start of SM560-S prevents loading the boot project to SM560-S Safety CPU on start-up (The boot project still remains in the Flash memory of SM560-S). As a result, the user is able to log-in to SM560-S and load a new correct boot project. This can be needed if the boot project is corrupt and could lead to a SAFE STOP state of SM560-S. SM560-S goes to `DEBUG (Stop)` state after start-up and successful 0xFF command execution.
- Switch address value 0xFE during the start of SM560-S allows deleting the boot project from the Flash memory of SM560-S. The boot project is finally deleted after SM560-S powering off/on is executed. This can be needed if the boot project is corrupt and could lead to a SAFE STOP state of SM560-S. SM560-S goes to SAFE STOP state after start-up and 0xFE command execution.

## AC500-S Safety Modules

SM560-S Safety CPU > Functionality

- Switch address value 0xFD during the start of SM560-S allows deleting user data from the Flash memory of SM560-S. The user data are finally deleted after SM560-S powering off/on is executed. This can be needed if user data are corrupt and could lead to a SAFE STOP state of SM560-S. SM560-S goes to SAFE STOP state after start-up and 0xFD command execution.
- Switch address value 0xFC during the start of SM560-S allows deleting all SM560-S data, which includes, in addition to boot project and user data, also SM560-S password and defined power dip value from the Flash memory. This means that SM560-S will be brought to its original state. The data are finally deleted after SM560-S powering off/on is executed. SM560-S goes to SAFE STOP state after start-up and 0xFC command execution.

The switch address value range 0xF0 ... 0xFB is reserved for future internal system functions.

### ! NOTICE!

Usage of switch address values from the system range 0xF0 ... 0xFF can lead to the loss of important user information in the Flash memory of SM560-S, e.g., boot project, user data, password or power dip value can be lost. Therefore, it is important that users pay a special attention during the change of switch address position on SM560-S Safety CPU.

### ! NOTICE!

Despite the fact that SF\_SM5XX\_OWEN\_ADR function is a safety POU, the hardware switch address value is a non-safety value and needs additional measures to satisfy functional safety requirements.

### 3.1.2.6 Firmware, boot code and boot project update using SD card

The firmware, boot code and boot project update can be executed using standard AC500 SD card functions from PM5xx CPU. One has to do appropriate changes in the SDCARD.INI file on SD card, as it is described in AC500 User Documentation [4]. The directories and slot number, on which SM560-S Safety CPU is used, shall be taken into account.

### ! NOTICE!


From the AC500 platform definition, SM560-S Safety CPU is one of the communication modules. Thus, definitions for SD card handling in AC500 User Documentation [4] are also valid for SM560-S Safety CPU.

If FunctionOfCard=2 is going to be used for SM560-S Safety CPU, then a proper entry in SDCARD.INI file on SD card shall be made, e.g.,

#### [SM560]

TYPE=4

VERSION=1\_0\_0

If boot project update shall be carried out using SD card, then proper files SM560\_<x1>.prg and SM560\_<x1>.chk (x value is dependent on the slot number 1 ... 4 on which SM560-S is located) shall be copied to UserData\PM5xx\UserPrg\ directory on the SD card (  AC500 User Documentation [4] for more details).

**! NOTICE!**

The boot project update on SM560-S is possible only if no boot project is loaded on SM560-S. It is done to avoid any occasional overwriting of existing valid boot project on SM560-S. To delete the boot project from SM560-S Safety CPU, one can use, for example, the switch address value 0xFE during the start of SM560-S, which allows deleting the boot project from the Flash memory of SM560-S. The boot project is finally deleted after SM560-S powering off/on is executed.

**! NOTICE!**

FunctionOfCard=3 (combined boot project and firmware/boot code update) is not supported by SM560-S Safety CPU. The execution of boot project and firmware/boot code update shall be done in two steps:

- FunctionOfCard=1 with a proper boot project update shall be executed, followed by SM560-S restart.
- FunctionOfCard=2 with a proper firmware / boot code update shall be executed followed by SM560-S restart.

It means that one may need two SD cards to perform both boot project and firmware/boot code updates. One SD card with firmware/boot code update and the other SD card with boot project update.

When firmware and/or boot code update is started, SM560-S Safety CPU goes to a DEBUG STOP state and I-ERR and RUN LEDs are alternately blinking. After firmware and/or boot code update is done, no blinking of I-ERR and RUN LEDs can be observed. Do not cut power supply during firmware and/or boot code update because it can lead to an unrecoverable damage of SM560-S which would require the replacement of this device. At the end of boot code and/or firmware update, SM560-S stays in DEBUG STOP state. The updated firmware and/or boot code can be started only after powering off/on of SM560-S.

If firmware and/or boot code update was not successful, SM560-S goes to a SAFE STOP state with an I-ERR LED = ON. Restart Safety CPU and, if this error persists, replace Safety CPU.

During boot project update, only RUN LED is flashing. At the end of the boot project update, SM560-S goes to SAFE STOP state. A complete SM560-S restart, e.g., through powering off/on, is needed to activate a new boot project.

**! DANGER!**

Since firmware, boot code and boot project update is done from PM5xx CPU, **it is important that special organisational procedures (e.g., limited access to the cabinet where Safety CPU is located) on the end-customer site are defined to avoid unintended** firmware, boot code and boot project update on SM560-S Safety CPU using SD card.

It is possible to read the actual firmware version of SM560-S Safety CPU using POU SF\_RTS\_INFO ( ↗ *Chapter 4.6 "AC500-S Libraries" on page 224* for further details) and, thus, limit safety program execution only to the pre-defined firmware versions.

Each firmware and boot project update has to be followed by a complete functional safety validation procedure for a given safety process control application.

### 3.1.3 Mounting, dimensions and electrical connection

The Safety CPU is mounted on the left side of the CPU on the same Terminal Base. The electrical connection is established automatically when mounting the Safety CPU.

## **AC500-S Safety Modules**

SM560-S Safety CPU > Mounting, dimensions and electrical connection

Installation and maintenance have to be performed according to the technical rules, codes and relevant standards, e.g. EN 60204 part 1, by skilled electricians only.

## Assembly of SM560-S



### DANGER!

Hot plug and hot swap of energized modules is not permitted. All power sources (supply and process voltages) must be switched off while working on any AC500 system, including Safety Modules.

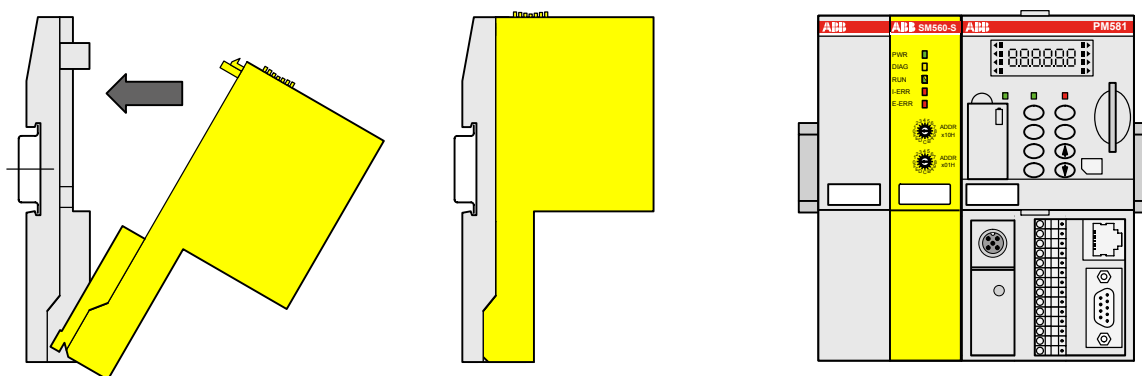


Fig. 6: Assembly instructions

➔ Insert the module below, and then click-in above.

## Disassembly of SM560-S

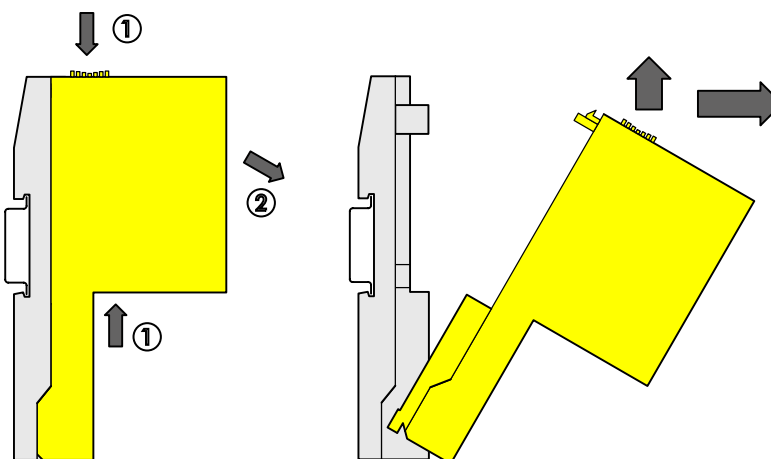


Fig. 7: Disassembly instructions

➔ Press above and below, then swing out the module and remove it.

## AC500-S Safety Modules

SM560-S Safety CPU > Diagnosis and LED status display

### Dimensions of SM560-S

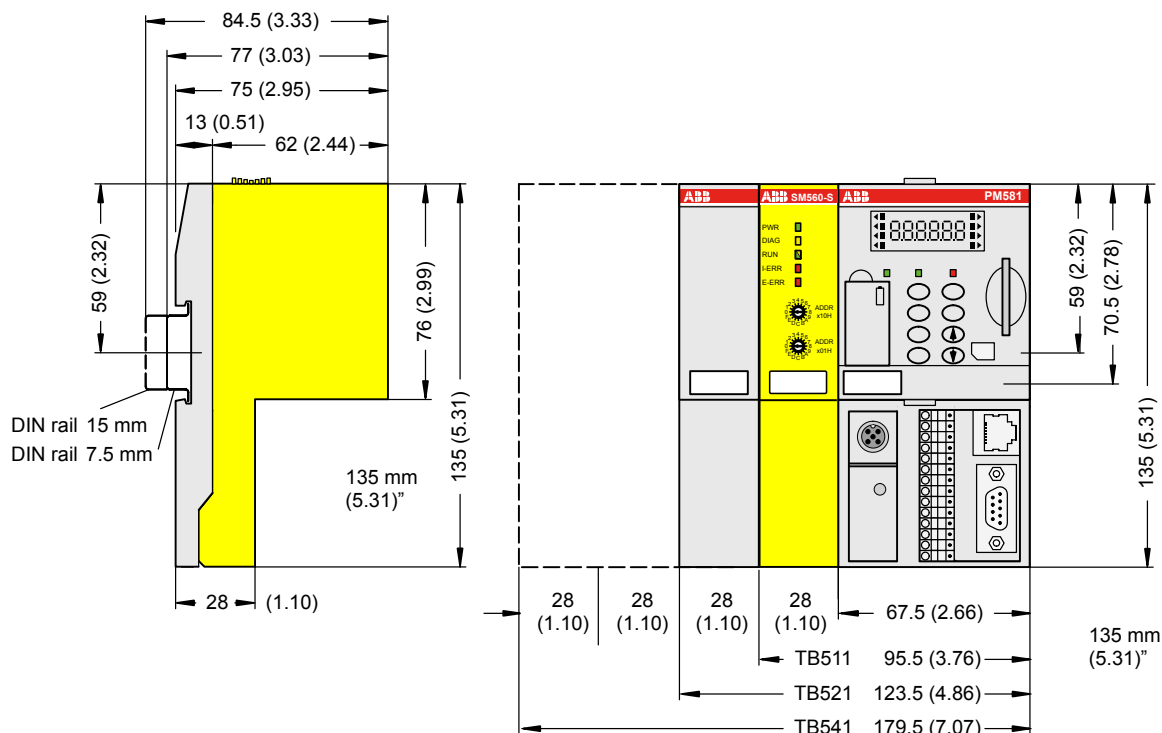


Fig. 8: Dimensions of SM560-S Safety CPU

### 3.1.4 Diagnosis and LED status display

Safety CPU status is shown by its LEDs. RUN LED is bicolored. The following figure and table show positions and functions of 5 LEDs.

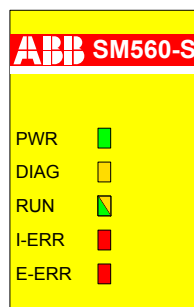


Fig. 9: LEDs for status display

Table 3: Status display and its meaning

LED	Description	Colour	Status	Meaning
PWR	Module power supply	Green	ON	+3.3V internal power supply is available
			BLINKING	Not applicable
			OFF	+3.3V internal power supply is not available

LED	Description	Colour	Status	Meaning
DIAG	Diagnostics	Yellow	ON	Configuration error
			BLINKING	Not applicable
			OFF	No configuration error
RUN	Run mode indicator	Green	ON	Safety CPU is in RUN (Safety) mode. The application program is executed.
			BLINKING	Not applicable
			OFF	Safety CPU is in DEBUG STOP mode. The application program is not executed.
		Yellow	ON	Safety CPU is in DEBUG RUN (Non-safety) mode. The application program is executed.
			BLINKING	Firmware, boot project or boot code update indication
			OFF	Safety CPU is in DEBUG STOP mode. The application program is not executed.
I-ERR	Internal device error indicator	Red	ON	Internal device error leading to a SAFE STOP state (no valid telegrams are generated by the device)
			BLINKING	Firmware or boot code update
			OFF	No internal device error leading to a safe state
E-ERR	External error indicator	Red	ON	This LED can be set only from the user application program using a special library POU SF_E_ERR_LED_SET ( ↗ Chapter 4.6 “AC500-S Libraries” on page 224 for further details). One of possible use cases is the visualization of important external device errors.
			BLINKING	This LED can be set only from the user application program using a special library POU SF_E_ERR_LED_SET ( ↗ Chapter 4.6 “AC500-S Libraries” on page 224 for further details). One of possible use cases is the visualization of light external device errors.
			OFF	No external errors were identified.



## DANGER!

The safety functionality and, as a result, safe process operation, is no more guaranteed by the SM560-S Safety CPU in the DEBUG RUN (Non-safety) mode.

In case of DEBUG RUN (Non-safety) mode activation on SM560-S Safety CPU, **the responsibility for safe process operation lies entirely with the organisation and person** responsible for the activation of DEBUG RUN (Non-safety) mode.

With the help of POU SF\_SAFETY\_MODE ( ↗ Chapter 4.6 “AC500-S Libraries” on page 224 for further details) one can retrieve the information if SM560-S is in SAFETY or DEBUG (NON-SAFETY) mode and, if required, stop or limit user application program execution.

## AC500-S Safety Modules

SM560-S Safety CPU > Diagnosis and LED status display

The next figure shows LED states of SM560-S Safety CPU, which can be observed during its start-up.

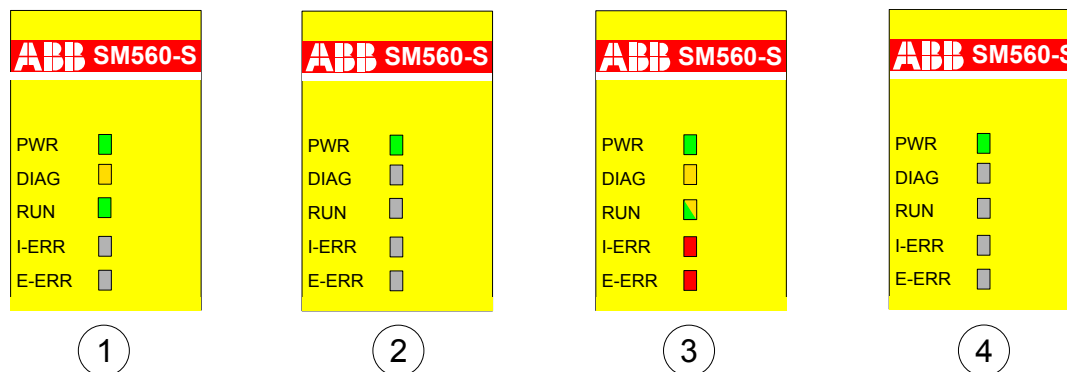


Fig. 10: LED states of SM560-S Safety CPU during start-up

- 1 State 1 – Hardware reset
- 2 State 2 – Initialisation
- 3 State 3 – LED test
- 4 State 4 – End of start-up

SM560-S error messages are aggregated together with other communication module error messages in SM560-S and PM5xx CPUs. Following Table includes a list of error messages related to SM560-S Safety CPU (all of them can be observed on PM5xx using, e.g., “diagshow all” PLC browser command).

Table 4: List of error messages for SM560-S

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E2	1 ... 4	255	30	1	2	Internal PRO-FIsafe initialization error	Restart Safety PLC. If this error persists, replace Safety PLC. Contact ABB technical support.
E2	1 ... 4	255	30	2	2	Internal PRO-FIsafe error	Restart Safety PLC. If this error persists, replace Safety PLC. Contact ABB technical support.
E2	1 ... 4	255	30	3	30	PROFIsafe configuration error	Check F-Parameter configuration of I/O module and reload boot project.
E2	1 or 9	1 ... 4	1	0	17	Access test failed	For Safety PLC: Check Safety PLC switch address setting. Restart Safety PLC. If this error persists, replace Safety PLC.



## AC500-S Safety Modules

SM560-S Safety CPU > Diagnosis and LED status display

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E2	1 or 9	1 ... 4	1	0	43	Internal error	For Safety PLC: Check Safety PLC switch address setting. Restart Safety PLC. If this error persists, replace Safety PLC
E2	1 ... 4	255	30	1	48	Overvoltage or undervoltage detected	Restart Safety PLC. Check Safety PLC setting for power supply error. If this error persists, replace Safety PLC.
E2	1 ... 4	255	30	1	43	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	1	40	Wrong firmware version	Update Safety PLC firmware. Restart Safety PLC. If this error persists, replace Safety PLC.
E2	1 ... 4	255	30	1	28	Boot project download error	Reload boot project. If this error persists, replace Safety PLC.
E2	1 ... 4	255	30	1	1	Wrong user data	Delete user data from Safety PLC. Restart Safety PLC and write user data again.
E2	1 ... 4	255	30	1	0	Operation finished.	Change Safety PLC switch address setting or remove SD-Card from non-safety PLC.  Restart Safety PLC. If this error persists, replace Safety PLC.
E2	1 ... 4	255	30	1	18	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	1	12	Flash read error	Restart Safety PLC. If this error persists, replace Safety PLC. Contact ABB technical support.
E2	1 ... 4	255	30	2	18	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	52	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	43	Internal error	Contact ABB technical support. Replace Safety PLC.

## AC500-S Safety Modules

SM560-S Safety CPU > Diagnosis and LED status display

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E2	1 ... 4	255	30	2	19	Checksum error has occurred in Safety PLC.	Restart Safety PLC. If this error persists, replace Safety PLC.
E2	1 ... 4	255	30	2	17	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	13	Flash write error	Restart Safety PLC. If this error persists, replace Safety PLC. Contact ABB technical support.
E2	1 ... 4	255	30	2	37	Cycle time error in Safety PLC	Check Safety PLC watchdog time.
E2	1 ... 4	255	30	2	10	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	25	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	42	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	1	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	3	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	54	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	38	Internal error	Contact ABB technical support. Replace Safety PLC.
E2	1 ... 4	255	30	2	52	Internal error	Contact ABB technical support. Replace Safety PLC.
E3	1 or 9	255	30	1	26	Error in configuration data, Safety PLC cannot read configuration data	Create new configuration data
E4	1 or 9	255	30	2	26	No or wrong configuration data from PM5x, run state not possible	Create correct boot project at PM5x

## AC500-S Safety Modules

SM560-S Safety CPU > Diagnosis and LED status display

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E3	1 or 9	255	30	1	27	Error in configuration data, Safety PLC cannot read configuration data	Create boot project
E4	1 or 9	255	30	2	13	Flash write error (production data)	Warning
E4	1 or 9	255	30	4	13	Flash write error (boot project)	Warning
E4	1 or 9	255	30	5	13	Flash write error (boot code)	Warning
E4	1 or 9	255	30	6	13	Flash write error (firmware)	Warning
E4	1 or 9	255	30	7	13	Flash write error (password)	Warning
E4	1 or 9	255	30	8	13	Flash write error (user data)	Warning
E4	1 or 9	255	30	9	13	Flash write error (user data)	Warning
E4	1 or 9	255	30	10	13	Flash write error (internal)	Warning
E4	1 or 9	255	30	11	13	Flash write error (internal)	Warning
E4	1 or 9	255	30	12	13	Flash write error (internal)	Warning
E4	1 or 9	255	30	1	4	Boot project not loaded, maximum power dip reached	Restart Safety PLC
E4	1 or 9	255	30	1	19	CRC error boot project	Create new boot project and restart Safety PLC
E4	1 or 9	255	30	1	0	Reserved switch address setting.	Warning

## AC500-S Safety Modules

SM560-S Safety CPU > SM560-S module states

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E4	1 or 9	255	30	2	39	More than one instance of SF_WDOG_TIME_SET or SF_MAX_POWER_DIP_SET	Warning
E4	1 or 9	255	30	1	8	Power dip data missed or corrupted. Default power dip data was flashed by Safety PLC.	Warning

The complete list of AC500 error messages can be found in AC500 User Documentation [4].

### ! NOTICE!

The error messages of not only SM560-S Safety CPU but also of Safety I/O modules ( [↗ Chapter 3.2 “Generic Safety I/O module behaviour” on page 58](#)) are aggregated in PM5xx Non-safety CPU for visualization on its LCD display.

Error messages of SM560-S Safety CPU can be acknowledged using PLC Browser commands from the CoDeSys Safety ( [↗ Chapter 4.3 “System configuration and programming” on page 168](#)). The status of error messages on SM560-S is then mirrored to PM5xx Non-safety CPU diagnosis system. However, if error message entries (copies of original error messages from SM560-S Safety CPU) are acknowledged from PM5xx Non-safety CPU, their original sources at SM560-S do not become at the same time acknowledged on SM560-S Safety CPU. As a result, error messages on SM560-S Safety CPU may exist as not acknowledged during a normal operation mode and can be used as a log if no access using CoDeSys Safety and its PLC Browser commands ( [↗ Chapter 4.3 “System configuration and programming” on page 168](#)) is available.

No error message overflow on SM560-S Safety CPU is possible. The maximum number of entries in SM560-S diagnosis system is 100. If all 100 positions in the diagnosis system are occupied, the newest entries cause the oldest ones to be deleted from the diagnosis system on SM560-S Safety CPU.

After powering off/on of SM560-S Safety CPU, error messages are deleted from the Safety CPU diagnosis system.

### 3.1.5 SM560-S module states

Fig. 11 provides an overview on possible SM560-S Safety CPU states and transitions between them.

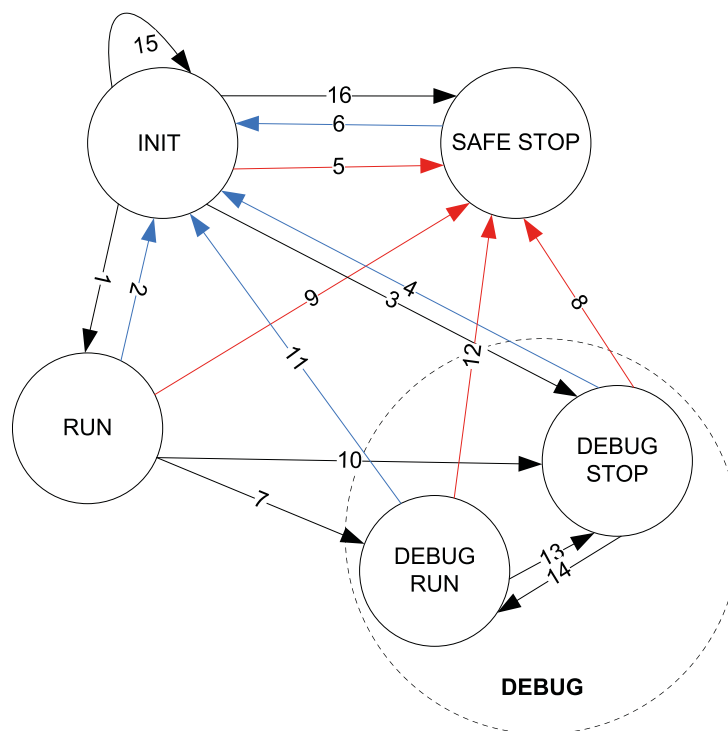


Fig. 11: SM560-S Safety CPU module states and transitions

- Powering off/on or reboot
- Fatal/serious errors
- Further transitions

SM560-S module states defined in Fig. 11 are further explained in [Chapter 3.1.5.1 "Description of SM560-S module states"](#) on page 47 and [Chapter 3.1.5.2 "Transitions between SM560-S states"](#) on page 50.

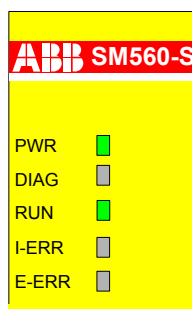
## 3.1.5.1 Description of SM560-S module states

### INIT

[Fig. 10](#)

This is a temporary system state which is left after internal safety diagnostic tests and start-up procedures are executed.

### RUN



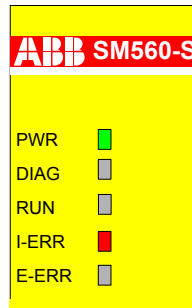
In this state, the safety application is normally executed, provided that the boot project is loaded. No fatal/serious errors are available.

## AC500-S Safety Modules

SM560-S Safety CPU > SM560-S module states

All CoDeSys online services from “Online” menu are available for users, but only three of them can be executed without leaving RUN state: “Login”, “Logout” and “Check boot project in PLC”. All other services (e.g., set a breakpoint) switch SM560-S to DEBUG states (DEBUG RUN or DEBUG STOP).

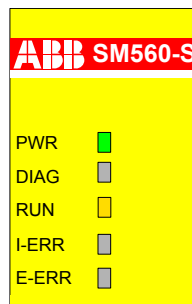
### SAFE STOP



SM560-S goes to SAFE STOP state if fatal/serious errors were identified. All PROFIsafe output telegrams are nulled (no valid PROFIsafe telegrams are generated in this state). No CoDeSys online services from “Online” menu are available for users.

This state can be left only using powering off/on or “reboot” PLC Browser command on PM5xx Non-safety CPU.

### DEBUG RUN

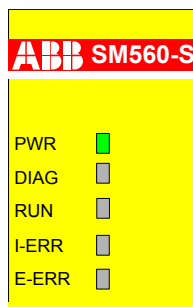
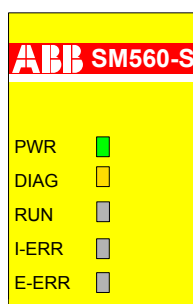


DEBUG RUN state can be reached if CoDeSys online services from “Online” menu are used (except “Login”, “Logout” and “Check boot project in PLC”) from safe RUN state. The user can set a breakpoint in the safety program, perform “Single cycle” program execution, force and write variable values and execute other debugging functions of CoDeSys Safety.

If CoDeSys online service “Stop” is called or the breakpoint is reached in the safety application program, SM560-S switches to DEBUG STOP state.

Valid PROFIsafe safety telegrams are generated in DEBUG RUN state. DEBUG RUN state is unsafe, thus, the responsibility for safe process operation lies entirely with the organisation and person responsible for the activation of DEBUG RUN (Non-safety) mode.

One can go back to a safe RUN state only using powering off/on or “reboot” PLC Browser command on PM5xx Non-safety CPU.

**DEBUG STOP****Without light error E3 or warning E4****With light error E3 or warning E4**

In this state, a user is able to intervene in safety program execution by setting breakpoints, etc., similar to DEBUG RUN state. The safety application program is not executed in DEBUG STOP state. The PROFIsafe F-Host of SM560-S sends PROFIsafe telegrams with fail-safe "0" values and sets FV\_activated for all Safety I/O modules.

If CoDeSys online service "RUN" is called in the safety application program, SM560-S switches to DEBUG RUN state.

All CoDeSys online services are available in this state.

In case of CoDeSys online commands "Step in", "Step over", "Single cycle" and when the breakpoint is reached, there is a switch between DEBUG RUN and DEBUG STOP states (↺ Fig. 11 transitions 13 and 14).

One can go back to a safe RUN state only using powering off/on or "reboot" PLC Browser command on PM5xx Non-safety CPU.

## AC500-S Safety Modules


SM560-S Safety CPU > SM560-S module states

### 3.1.5.2 Transitions between SM560-S states

ID*	From	To	Description
(1)	INIT	RUN	<ul style="list-style-type: none"> <li>Initialization was successful</li> <li>Boot project is available and there is no configuration error or any other serious or fatal error.</li> </ul>
(2)	RUN	INIT	Powering off/on or “reboot” PLC Browser command from PM5xx Non-safety CPU
(3)	INIT	DEBUG STOP	<ul style="list-style-type: none"> <li>Initialization was successful</li> <li>No boot project is available or configuration error E3</li> <li>Switch address 0xFF was set on SM560-S</li> </ul>
(4)	DEBUG STOP	INIT	Powering off/on or “reboot” PLC Browser command from PM5xx Non-safety CPU
(5)	INIT	SAFE STOP	<ul style="list-style-type: none"> <li>Fatal error E1 or serious error E2 was identified during the initialisation</li> <li>Unsuccessful firmware or boot code update</li> </ul>
(6)	SAFE STOP	INIT	Powering off/on or “reboot” PLC Browser command from PM5xx Non-safety CPU
(7)	RUN	DEBUG RUN	CoDeSys-Safety online service “Toggle breakpoint”, “Write values”, “Force values” or “Single cycle” was used.
(8)	DEBUG STOP	SAFE STOP	Fatal error E1 or serious error E2 was identified
(9)	RUN	SAFE STOP	Fatal error E1 or serious error E2 was identified
(10)	RUN	DEBUG STOP	<ul style="list-style-type: none"> <li>CoDeSys Safety online services “Stop”, “Sourcecode download” or “Reset” (various)</li> <li>“Run” button on PM5xx Non-safety CPU (Non-safety CPU was in „Run“ state)</li> <li>CoDeSys Non-safety online services “Stop” or “Reset” (various) on PM5xx</li> <li>New safety application is loaded</li> </ul>
(11)	DEBUG RUN	INIT	Powering off/on or “reboot” PLC Browser command from PM5xx Non-safety CPU
(12)	DEBUG RUN	SAFE STOP	Fatal error E1 or serious error E2 was identified
(13)	DEBUG RUN	DEBUG STOP	<ul style="list-style-type: none"> <li>CoDeSys Safety online services “Stop” or “Reset” (various)</li> <li>“Run” button on PM5xx Non-safety CPU (Non-safety CPU was in „Run“ state)</li> <li>CoDeSys Non-safety online services “Stop” or “Reset” (various) on PM5xx</li> <li>Breakpoint was reached during debugging</li> <li>At the end of the Safety CPU cycle in “Single cycle” debugging mode</li> <li>New safety application is loaded</li> </ul>



ID*	From	To	Description
(14)	DEBUG STOP	DEBUG RUN	<ul style="list-style-type: none"> <li>■ CoDeSys Safety online services “Step over”, “Step in” and “Run”</li> <li>■ CoDeSys Non-Safety online service “Run”</li> <li>■ “Run” button on PM5xx Non-safety CPU (Non-safety CPU was in “Stop” state)</li> </ul>
(15)	INIT	INIT	Powering off/on or “reboot” PLC Browser command from PM5xx Non-safety CPU
(16)	INIT	SAFE STOP	Switch address 0xFE, 0xFD or 0xFC was set on SM560-S

\* Numbers are transitions in  Fig. 11

## 3.1.6 SM560-S and PM5xx interaction

SM560-S Safety CPU and PM5xx Non-safety CPU have their own firmware, boot project and application program, which are executed separately. The only control element on PM5xx CPU hardware, which allows changing the status of both PM5xx and SM560-S is “Run” button on PM5xx. “Run” button on PM5xx simultaneously stops and starts both Safety and Non-safety CPUs. In case of SM560-S Safety CPU, even if safety application program execution is stopped, the PROFIsafe F-Host stack [3] continues running on SM560-S in so-called fail-safe mode, when all Safety I/O modules are passivated and “0” substitute values are used on SM560-S for all Safety I/Os. PROFIsafe F-Host stack execution on SM560-S can be stopped only if it goes to SAFE STOP state (no valid telegrams are generated by the device) and I-ERR LED = ON.

Online CoDeSys commands “Run” and “Stop” have the same effect on SM560-S and PM5xx as “Run” button on Non-safety CPU.



### DANGER!

It is not possible to safely start Safety CPU using “Run” button on PM5xx. SM560-S always goes to DEBUG mode (DEBUG RUN or DEBUG STOP) as soon as “Run” button is pressed on Non-safety CPU. To bring Safety CPU back into the safe RUN mode, one has to perform powering off/on of SM560-S or use “reboot” command on PM5xx CPU.

Online CoDeSys commands “Run” and “Stop” have the same effect on SM560-S and PM5xx as “Run” button on Non-safety CPU.

Depending on PM5xx parameter “Behaviour of Outputs in Stop”, “Stop on Error Class” and “Warmstart on E2 failure” setting in system configuration, one can influence the overall system behaviour of Safety and Non-safety CPUs. This, however, does not compromise on system safety. Figure 3.6 gives an overview on how PM5xx system parameter setting influences SM560-S safety telegram flow.

## AC500-S Safety Modules

SM560-S Safety CPU > SM560-S and PM5xx interaction

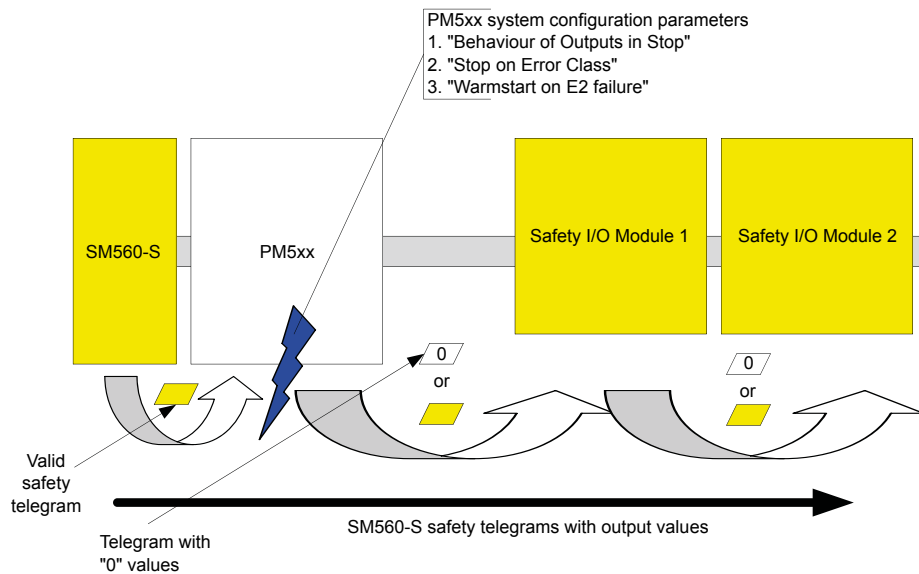


Fig. 12: Overview on how PM5xx system parameter setting influences SM560-S safety telegram flow

"Behaviour of Outputs in Stop" parameter setting of PM5xx Non-safety CPU has the following influence on the SM560-S safety telegrams:

- **"Off in hardware and online" (Default)**

The application program execution on SM560-S Safety CPU is stopped. PM5xx Non-Safety CPU is stopped. All SM560-S output values in safety telegrams will be nulled by PM5xx. No valid safety telegrams can reach Safety I/O modules and they go to a passivation state after the watchdog time runs out.

- **"Off in hardware and actual state online"**

If PM5xx is stopped then all SM560-S output values in safety telegrams will be nulled. The hardware status of SM560-S communication interface becomes "0", but online display shows the last valid values from the last safety application program cycle. As a result of "0" values in the SM560-S communication interface, no valid safety telegrams can reach Safety I/O modules and they go to a passivation state after the watchdog time runs out.

- **"Actual state hardware and online"**

If PM5xx is stopped, SM560-S continues running. SM560-S output values in safety telegrams will not be nulled by PM5xx. Both hardware status of SM560-S communication interface and online display values remain intact. As a result, Safety I/Os can receive safety telegrams from SM560-S Safety CPU and the operation of safety part is not influenced by the stop of PM5xx Non-safety CPU.

"Stop on error class" parameter setting of PM5xx Non-safety CPU has the following influence on the SM560-S:

- **"No effect" (Default)**

In case of fatal error (E1) or severe error (E2), PM5xx and all its communication modules, including SM560-S Safety CPU, will be stopped. PROFIsafe F-Host stack continues running on SM560-S in a fail-safe mode.

- **"E3"**

In case of fatal error (E1), severe error (E2) or light error (E3), PM5xx and all its communication modules, including SM560-S Safety CPU, will be stopped. PROFIsafe F-Host stack continues running on SM560-S in a fail-safe mode.

- **"E4"**

In case of fatal error (E1), severe error (E2), light error (E3) or warning (E4), PM5xx and all its communication modules, including SM560-S Safety CPU, will be stopped. PROFIsafe F-Host stack continues running on SM560-S in a fail-safe mode.

“Warmstart on E2 failure” parameter setting of PM5xx Non-safety CPU has the following influence on the SM560-S:

■ **“Off” (Default)**

In case of severe error (E2), no warm restart of PM5xx and of all its communication modules, including SM560-S Safety CPU, will be done.

■ **“On” (after E2 error and / or after short voltage dip)**

In case of severe error (E2) and or short voltage dip, the warm restart of PM5xx and of all its communication modules, including SM560-S Safety CPU, will be done. After restart of SM560-S Safety CPU, Safety I/O can be reintegrated using PROFIsafe F-Device reintegration scheme [3].

### 3.1.7 Technical data

Use SM560-S Safety CPU (up to SIL3 and PL e) with PM573, PM583, PM592 or others with the firmware version from V2.2.1 (pay attention to the required TB units). SM560-S Safety CPU shall not to be used with AC500-eCo CPUs.

**! NOTICE!**

SM560-S-XC version is available for usage in extreme environmental conditions ( ↗ *Appendix “System data for AC500-S-XC” on page 446*).

## AC500-S Safety Modules

SM560-S Safety CPU > Technical data

### Memory

Data	Value	Unit
User Program memory	1	MByte
User Data memory (thereof 120 kBytes saved)	1	MByte

### Minimum Performance

Data	Value	Unit
Cycle time Binary	0.05	µs/Instruction
Cycle time Word	0.06	µs/Instruction
Cycle time floating-point	0.50	µs/Instruction

### Voltages, according to EN 61131-2

Data	Value	Unit
Process and supply voltage (without ripple)	24 (– 15 %, +20 %)	V DC
Absolute limits (including ripple)	19.2 ... 30	V
Ripple	< 5	%
Protection against reverse polarity	10	s



#### **DANGER!**


Exceeding the maximum process or supply voltage range (< –35 V DC or > +35 V DC) could lead to unrecoverable damage of the system.

**Allowed interruptions of power supply, according to EN 61131-2**

Data	Value	Unit
DC supply interruptions	< 10	ms
Time between 2 DC supply interruptions, PS2	> 1	s

**Environmental conditions**

Data	Value	Unit
Operating temperature*	0 ... +60	°C
Storage temperature	−40 ... +85	°C
Transport temperature	−40 ... +85	°C
Humidity without condensation	max. 95	%
Operating air pressure	> 800	hPa
Storage air pressure	> 660	hPa
Operating altitude	< 2000	m above sea level
Storage altitude	< 3500	m above sea level

\* Extended temperature ranges (below 0 °C and above +60 °C) can be supported in special versions of SM560-S (  Appendix "System data for AC500-S-XC" on page 446)

**Creepage distances and clearances**

The creepage distances and clearances meet the overvoltage category II, pollution degree 2.

**Power supply units**

For the supply of modules, power supply units according to PELV/SELV specifications must be used.

**Electromagnetic compatibility**

 TÜV Report [2]

## AC500-S Safety Modules

SM560-S Safety CPU > Technical data

Data	Value	Unit
Mounting	horizontal (or vertical with derating (maximal operating temperature reduced to +40 °C))	
Degree of protection	IP 20	
Housing	according to UL 94	
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 3.5 mm	2 ... 15	Hz
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 1 g *	15 ... 150	Hz
Shock test (all three axes), 11 ms half-sinusoidal	15	g
MTBF	168	years

\* Higher values on request

### Self-test and diagnostic functions

Start-up and runtime tests: Program flow control, RAM, CPU, etc.

## Dimensions, weight

Data	Value	Unit
W x H x D	28 x 135 x 75	mm
Weight	~ 100	g

## Certifications

CE, cUL (  *further certifications at [www.abb.com/plc](http://www.abb.com/plc)* )

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Overview

### 3.1.8 Ordering data

Type	Description	Order code
SM560-S	Safety module – CPU	1SAP 280 000 R0001
SM560-S-XC	Safety module – CPU, Extreme Conditions	1SAP 380 000 R0001

## 3.2 Generic Safety I/O module behaviour

### 3.2.1 Overview

All Safety I/O modules (AI581-S, DI581-S and DX581-S) can be used in a centralized or remote configuration with PROFINET / PROFIsafe (see Figure 2.3). PROFINET devices CI501, CI502, CI504 and CI506 (Release date: 2013 and newer) can be used to attach Safety I/O modules in remote configurations. Safety I/O modules can be freely mixed with any Non-safety I/Os from AC500 and AC500 eCo product families.

#### **! NOTICE!**

Safety I/O module firmware update can be currently performed only by the qualified personnel in the ABB factory.



### 3.2.2 Safety I/O module states

Safety I/O module system states can be described using two state charts (Fig. 13 and Fig. 14). Fig. 13 provides an overview of transitions related to powering off/on and fatal errors. Fig. 14 provides an overview on the rest of transitions in Safety I/O modules.

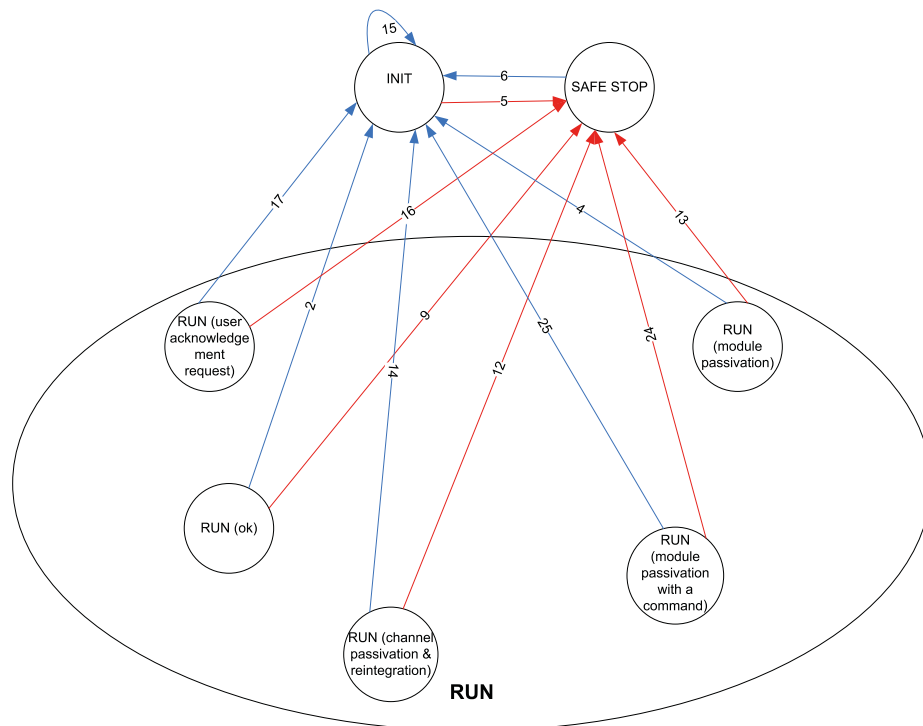


Fig. 13: Overview of transitions related to powering off/on and fatal errors in Safety I/O modules



## AC500-S Safety Modules

Generic Safety I/O module behaviour > Safety I/O module states

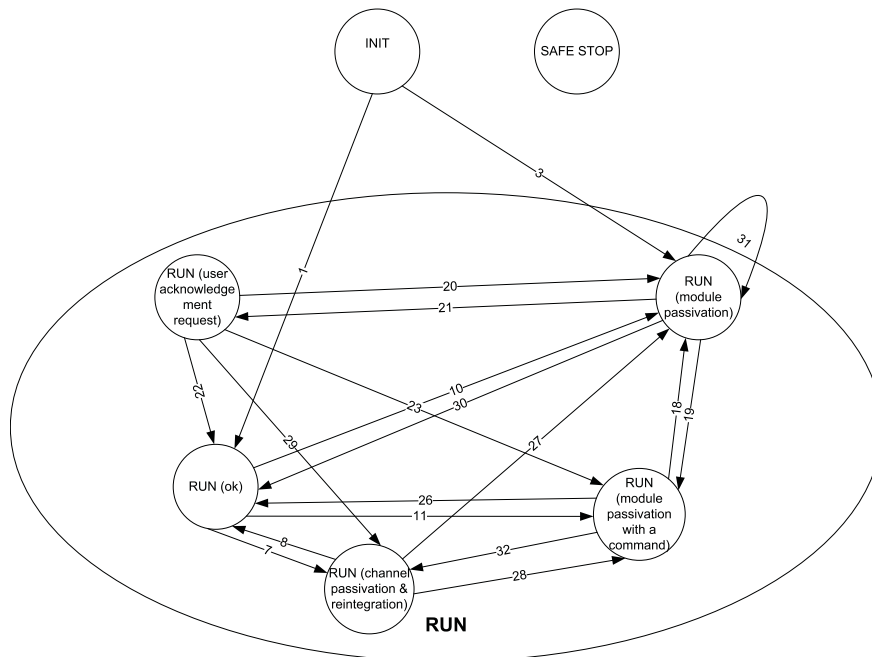


Fig. 14: Overview of transitions in Safety I/O modules (except powering off/on and fatal errors)

→ Transitions

Safety I/O module states defined in Fig. 13 and Fig. 14 are further explained in [Chapter 3.2.2.1 “Description of Safety I/O module states”](#) on page 60.

### 3.2.2.1 Description of Safety I/O module states

#### INIT

Fig. 15

The hardware is initialized and internal start-up tests of the Safety I/O module are executed. After a successful parameterization, the PROFIsafe communication is expected to be initiated by the PROFIsafe F-Host.

The Safety I/O Module will remain in this state:

- as long as the undervoltage is detected
- if the parameterization failed or pending
- if the PROFIsafe communication is pending

Users have to check that a dedicated qualifier output bit (PROFIsafe diagnostic) for at least one of the channels in the given Safety I/O module is set to “1” to verify that PROFIsafe F-Devices are initialized.

#### PROFIsafe status bits in the F-Host for Safety I/O module:

OA\_Req\_S = 0

FV\_activated\_S = 1

Device\_Fault = 0

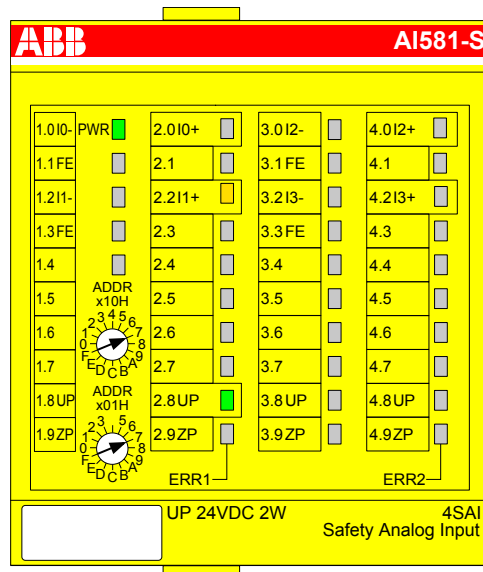
#### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

Channel process value = 0

Reintegration request bit = 0

## RUN (ok)



PROFIsafe communication is up and running. The safety application is running without any detected errors.

### PROFIsafe status bits in the F-Host for Safety I/O module:

OA\_Req\_S = 0

FV\_activated\_S = 0

Device\_Fault = 0

### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 1

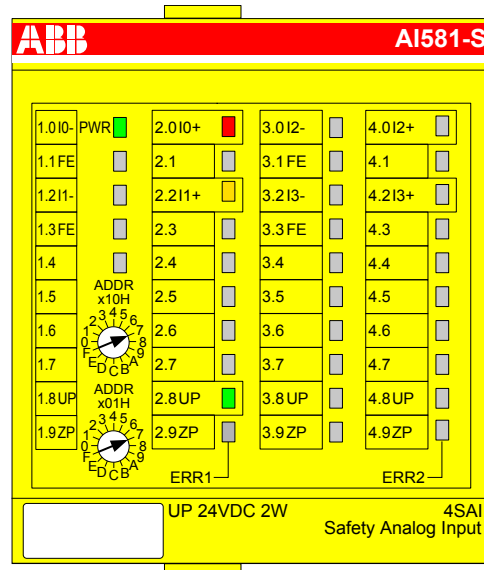
Channel process value = Process value

Reintegration request bit = 0

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Safety I/O module states

### RUN (channel passivation and reintegration)



PROFIsafe communication is up and running. The safe application is running with detected channel errors.

Channel error (e.g., no expected test pulses, discrepancy time, etc.) is identified in at least one of channels. The fail-safe value ("0") is transferred to the PROFIsafe F-Host for the passivated input channel(s). The related PROFIsafe diagnostic bit(s) are also set to "0" to indicate the usage of fail-safe values.

A passivated output channel has a state of "0" and the related PROFIsafe diagnostic bit(s) are also set to "0" to indicate the usage of fail-safe values.

As soon as the channel error is gone (e.g., wiring error was corrected; this is valid only for those errors which are acknowledgeable), the reintegration request bit for the given channel switches to "1", which indicates the safety application running on the Safety CPU that a reintegration of the channel is possible. Setting the acknowledge reintegration bit from "0" to "1" initiates a reintegration of the given channel. A positive edge from "0" to "1" is required to acknowledge channel reintegration.

As soon as all channel errors are gone and acknowledged, the RUN (ok) state is reached.

#### PROFIsafe status bits in the F-Host for Safety I/O module:

OA\_Req\_S = 0

FV\_activated\_S = 0

Device\_Fault = 0

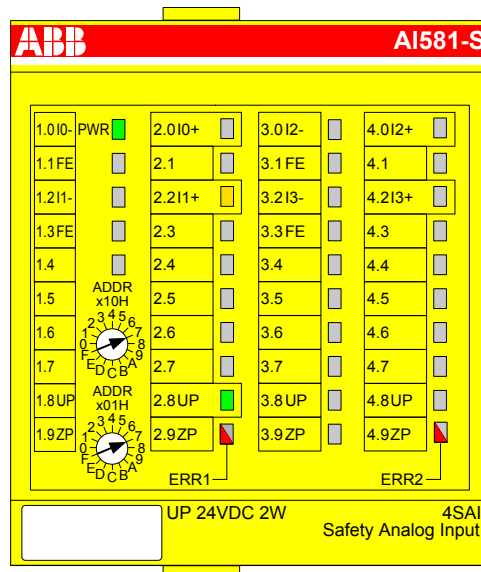
#### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

Channel process value = 0

Reintegration request bit = 0 if an error is still present; 1 if the channel can be reintegrated.

## RUN (module passivation): Alternating blinking of ERR1 and ERR2 LEDs



PROFIsafe communication is up and running. The safety application is running with a present module error. The module and, as a result, all its channels are passivated. Possible reasons for module passivation are:

- PROFIsafe communication failure (CRC error)
- PROFIsafe watchdog timeout exceeded
- Undervoltage/overvoltage detected (Device\_Fault status bit = 1)

The fail-safe value “0” is transferred to the Safety PLC for all passivated input channels, if the connection to the PROFIsafe F-Host is possible. The safety application continuously attempts to establish a communication to the Safety CPU, if the communication is broken. All passivated output channels have a state of “0”.

A state transition to another RUN mode is only possible if the detected error is gone.

### PROFIsafe status bits in the F-Host for Safety I/O module (if communication is possible!):

OA\_Req\_S = 0

FV\_activated\_S = 1

Device\_Fault = 1 (in case of undervoltage/overvoltage detected) and/or CE\_CRC = 1 (in case of communication error) and/or WD\_timeout = 1 (in case of watchdog timeout)

### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

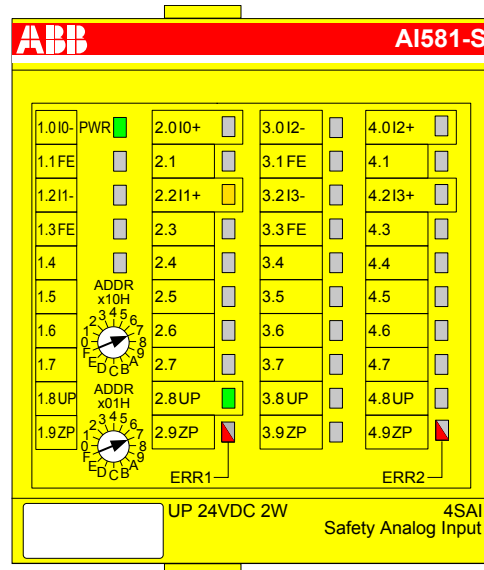
Channel process value = 0

Reintegration request bit = 0

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Safety I/O module states

### RUN (module passivation with a command): Alternating blinking of ERR1 & ERR2 LEDs



PROFIsafe communication is up and running. The safety application is running without any detected errors.

The module and all its channels are passivated because the safety application on the Safety CPU requested a module passivation (activate\_FV\_C = 1 was set).

The fail-safe value "0" is transferred to the Safety CPU for all passivated input channels. All passivated output channels have a state of "0". The PROFIsafe diagnostic bit(s) for all channels have the state of "0" to indicate that fail-safe values are transferred.

#### PROFIsafe status bits in the F-Host for Safety I/O module:

FV\_activated\_S = 1

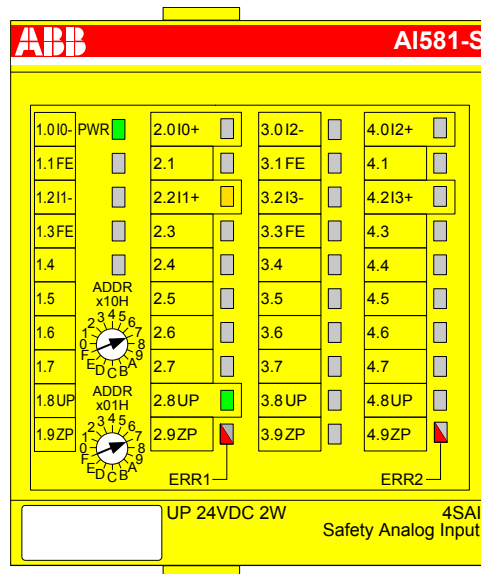
#### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

Channel process value = 0

Reintegration request bit = 0

## RUN (user acknowledgement request): Alternating blinking of ERR1 & ERR2 LEDs



PROFIsafe communication is up and running. The safety application is running without any errors but waits for the acknowledgment of a module reintegration (module error is gone).

The fail-safe value “0” is still transferred to the Safety CPU for all passivated input channels. All passivated output channels have a state of “0”. The PROFIsafe diagnostic bits for all channels have the state of “0” to indicate that fail-safe values are transferred.

The OA\_Req\_S bit is reported as “1”.

As soon as the safety application of the Safety CPU sets OA\_C (positive edge), the Safety I/O module goes to RUN (ok) state if no further errors are detected. One has to send the positive edge to the Safety I/O module until OA\_Req\_S starts delivering “0”.

### PROFIsafe status bits in the F-Host for Safety I/O module:

OA\_Req\_S = 1

FV\_activated\_S = 1

Device\_Fault = 0

### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

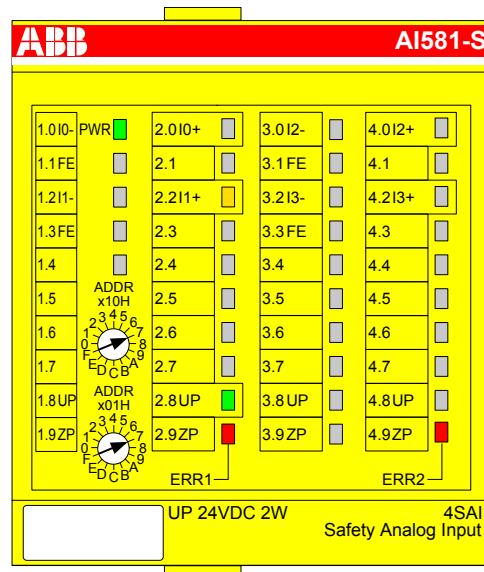
Channel process value = 0

Reintegration request bit = 0

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Safety I/O module states

### SAFE STOP



The safety application execution was stopped. No PROFIsafe communication is possible.

This state is reached if one of the fatal errors (e.g., CPU test, RAM test, etc. failed) took place.

This state can be left only through powering off/on of the process power supply (24 V) or reboot command from PM5xx or CI5xx modules.

#### PROFIsafe status bits in the F-Host for Safety I/O module:

OA\_Req\_S = 0

FV\_activated\_S = 1

Device\_Fault = 0

#### Process data bits in the Safety I/O module process image:

PROFIsafe diagnostic bit = 0

Channel process value = 0

Reintegration request bit = 0



## 3.2.2.2 Transitions between Safety I/O module states



ID*	From	To	Description
(1)	INIT	RUN (ok)	Safety I/O module comes to this state directly after INIT during a normal start-up
(2)	RUN (ok)	INIT	Powering off/on
(3)	INIT	RUN (module passivation)	<p>PROFIsafe watchdog, PROFIsafe communication error or undervoltage/overvoltage was detected directly after INIT.</p> <p>The Safety I/O module can reach this state also after powering off/on the Safety I/O module if Safety CPU with PROFIsafe F-Host continues running and brings Safety I/O module to a fail-safe RUN (module passivation) state after powering off/on</p>
(4)	RUN (module passivation)	INIT	Powering off/on
(5)	INIT	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place
(6)	SAFE STOP	INIT	Powering off/on
(7)	RUN (ok)	RUN (channel passivation and reintegration)	Channel error was identified by the Safety I/O module. The tests (whenever it is possible) are continued for the given channel to be able to see if the error is gone (e.g., wiring error was corrected). As soon as the error is gone, the module sets "Reintegration request" bit = "1" for the given channel.
(8)	RUN (channel passivation & reintegration)	RUN (ok)	<ul style="list-style-type: none"> <li>■ The channel error is gone.</li> <li>■ "Reintegration request" bit = 1 is set for the given channel by the Safety I/O module.</li> <li>■ "Acknowledge reintegration" bit (positive edge) is set by PROFIsafe F-Host for the given channel</li> </ul>
(9)	RUN (ok)	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place
(10)	RUN (ok)	RUN (module passivation)	PROFIsafe watchdog, PROFIsafe communication error or undervoltage/overvoltage was detected.
(11)	RUN (ok)	RUN (module passivation with a command)	"activate_FV_C = 1" command was sent from the Safety CPU
(12)	RUN (channel passivation & reintegration)	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place
(13)	RUN (module passivation)	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Safety I/O module states

ID*	From	To	Description
(14)	RUN (channel passivation & reintegration)	INIT	Powering off/on
(15)	INIT	INIT	Powering off/on
(16)	RUN (user acknowledge-ment request)	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place
(17)	RUN (user acknowledge-ment request)	INIT	Powering off/on
(18)	RUN (module passivation with a command)	RUN (module passivation)	PROFIsafe watchdog, PROFIsafe communication error or undervoltage/overvoltage was identified.  <b>Note:</b> In this transition, it is possible that WD_timeout bit of PROFIsafe F-Host instance toggles if watchdog timeout is periodically recognized by the Safety I/O module.
(19)	RUN (module passivation)	RUN (module passivation with a command)	If the threshold shut-down value was not reached during process undervoltage or overvoltage phase and the process voltage is back in the normal range, the Safety I/O module reintegrates and would go to RUN (ok) state automatically, but short time before the "activate_FV_C = 1" command was sent from the PROFIsafe F-Host stack, which leads the Safety I/O module to RUN (module passivation with a command) state.
(20)	RUN (user acknowledge-ment request)	RUN (module passivation)	Process undervoltage/overvoltage was identified.
(21)	RUN (module passivation)	RUN (user acknowledge-ment request)	<ul style="list-style-type: none"> <li>■ Module error (watchdog or communication error (CRC)) is gone.</li> <li><b>and</b></li> <li>■ Command activate_FV_C = 0</li> <li><b>then</b></li> <li>■ Safety I/O module sets OA_Req_S = 1</li> </ul>
(22)	RUN (user acknowledge-ment request)	RUN (ok)	<ul style="list-style-type: none"> <li>■ OA_Req_S = 1 was set by the Safety I/O module after the module error is gone.</li> <li>■ OA_C (positive edge) was set by the PROFIsafe F-Host for the given Safety I/O module</li> </ul>
(23)	RUN (user acknowledge-ment request)	RUN (module passivation with a command)	"activate_FV_C = 1" command was sent from the PROFIsafe F-Host
(24)	RUN (module passivation with a command)	SAFE STOP	Fatal error(s) (CPU test, RAM test, etc. failed) took place

ID*	From	To	Description
(25)	RUN (module passivation with a command)	INIT	Powering off/on
(26)	RUN (module passivation with a command)	RUN (ok)	<ul style="list-style-type: none"> <li>■ No module error</li> <li>■ Command activate_FV_C = 0</li> </ul>
(27)	RUN (channel passivation & reintegration)	RUN (module passivation)	<p>PROFIsafe watchdog, PROFIsafe communication error or undervoltage/overvoltage was detected.</p> <p><b>Note:</b> In this transition, it is possible that WD_timeout bit of PROFIsafe F-Host instance toggles if watchdog timeout is periodically recognized by the Safety I/O module.</p>
(28)	RUN (channel passivation & reintegration)	RUN (module passivation with a command)	"activate_FV_C = 1" command was sent from the PROFIsafe F-Host stack
(29)	RUN (user acknowledgement request)	RUN (channel passivation and reintegration)	This transition is possible only if channel error was identified before or during module passivation. As a result, after module reintegration one of the channel tests directly brings Safety I/O module to RUN (channel passivation & reintegration state).
(30)	RUN (module passivation)	RUN (ok)	<p>If the threshold shut-down value was not reached during undervoltage phase and the process voltage is back in the normal range, the Safety I/O module reintegrates and goes to RUN (ok) state automatically.</p> <p>If the threshold fuse value was not reached during overvoltage phase and the process voltage is back in the normal range, the Safety I/O module reintegrates and goes to RUN (ok) state automatically.</p>
(31)	RUN (module passivation)	RUN (module passivation)	If process undervoltage event was detected two times within 1 second, then the Safety I/O module remains in RUN (module passivation) state.
(32)	RUN (module passivation with a command)	RUN (channel passivation and reintegration)	This transition is possible only if channel error was identified during RUN (module passivation with a command) state. As a result, after command activate_FV_C = 0, Safety I/O module goes to RUN (channel passivation & reintegration state).

\* Numbers are transitions in  Fig. 13 and  Fig. 14

### 3.2.3 Undervoltage/Overvoltage

If undervoltage ( $< 18\text{ V}$ ) is detected in the Safety I/O module, the module goes to RUN (module passivation) state, until the process voltage did not reach the threshold shut-down value ( $16\text{ V}$ ), when no further communication to PROFIsafe F-Host is possible. If the threshold shut-down value ( $16\text{ V}$ ) was not reached during undervoltage phase and the process voltage is back in the normal range ( $\geq \sim 18\text{ V}$ ), the Safety I/O module reintegrates and goes to RUN (ok) state automatically.

To avoid unintended permanent module passivation and reintegration, the following feature is available for undervoltage case:

- The user has to continuously supervise Device\_Fault bit of the Safety I/O module and if Device\_Fault = 1 is detected, he passivates the module with activate\_FV\_C = 1.

If overvoltage ( $> 31.2\text{ V}$ ) is detected in the Safety I/O module, the module goes to RUN (module passivation) state, until the process voltage did not reach the threshold fuse value ( $> 35\text{ V}$ ) when the Safety I/O module is damaged and has to be replaced. If the threshold fuse value was not reached during overvoltage phase and the process voltage is back in the normal range, the Safety I/O module reintegrates and goes to RUN (ok) state automatically. To avoid unintended permanent module passivation and reintegration, the same feature (supervision of Device\_Fault bit) as for undervoltage is available.

## 3.2.4 Diagnosis



### DANGER!

The diagnosis data is not safety-relevant and, thus, shall not be used in safety application program for execution of safety functions.

Fig. 15 shows LED states of Safety I/O modules (AI581-S is used as an example), which can be observed during the start-up of Safety I/O modules.

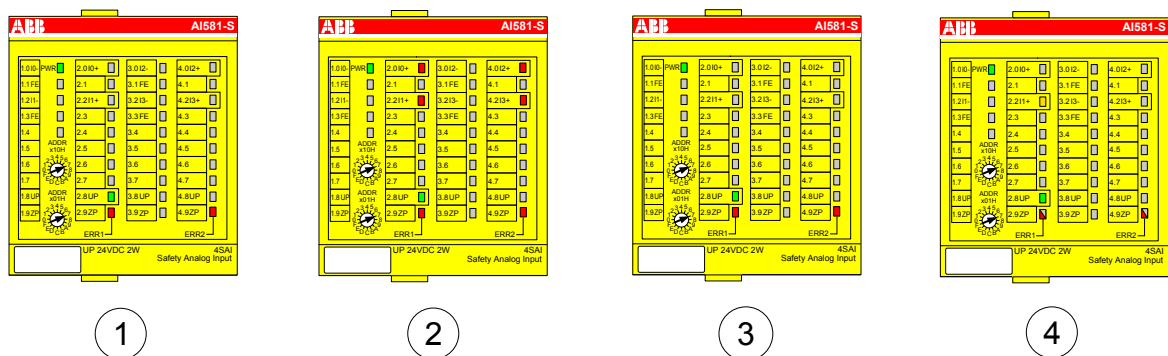


Fig. 15: LED states of Safety I/O modules during start-up (example with AI581-S module)

- 1 State 1 – Hardware reset and initialisation
- 2 State 2 – LED test
- 3 State 3 – End state of initialization
- 4 State 4 – Parameterisation is complete, but no PROFIsafe communication yet



### NOTICE!

External errors (wiring or sensor errors) in Safety I/O modules lead to the channel passivation ("0" values are delivered). As soon as an external error is fixed and this is recognized by internal Safety I/O module tests, Safety I/O module channels request an acknowledgement for their reintegration to the normal safety process control mode. The user can acknowledge such channels using dedicated channel bits ( ↪ Chapter 4.3.5 "Instantiation and configuration of safety modules/Definition of variable names" on page 177).

Safety I/O module error messages are aggregated together with other module error messages in PM5xx CPU. The following two tables include a list of error messages related to Safety I/O modules.

## AC500-S Safety Modules

Generic Safety I/O module behaviour > Diagnosis

Table 5: List of error messages for Safety I/O modules (channel or module reintegration is possible)

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E3	14	1..10	31	31	20	PROFIsafe communication error	Restart I/O module. If this error persists, contact ABB technical support.
E3	14	1..10	31	31	25	PROFIsafe watchdog timed out.	Restart I/O module. If this error persists, increase PROFIsafe watchdog time.
E3	14	1..10	31	31	10	Process voltage too high	Check process voltage
E3	14	1..10	31	31	11	Process voltage too low	Check process voltage
E3	14	1..10	31	31	43	Internal error in the device	Replace I/O module
E3	14	1..10	1	0..3	4	Measurement overflow at the I/O module	Check channel wiring and sensor power supply.
E3	14	1..10	1	0..3	7	Measurement underflow at the I/O module	Check channel wiring and sensor power supply.
E3	14	1..10	1	0..3	55	Channel value difference too high	Adjust tolerance window for channels. Check channel wiring and sensor configuration.
E3	14	1..10	0	0..15	3	Discrepancy time expired	Check discrepancy time value, channel wiring and sensor.
E3	14	1..10	0	0..15	25	Channel stuck-at error	Check I/O module wiring. Restart I/O module, if needed. If this error persists, replace I/O module.
E3	14	1..10	0	0..15	12	Test pulse error	Check wiring and sensor.
E3	14	1..10	0	0..15	13	Module 0: Channel test pulse cross-talk error  Module 2: Channel read-back error	Check wiring and sensor. If this error persists, replace I/O module. Contact ABB technical support.

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E3	14	1..10	0	0..15	28	Channel cross-talk error	Check I/O module wiring. Restart I/O module, if needed. If this error persists, replace I/O module.
E3	14	1..10	2	0..7	13	Module 0: Channel test pulse cross-talk error  Module 2: Channel read-back error	Check I/O module wiring. Restart I/O module, if needed. If this error persists, replace I/O module.
E3	14	1..10	2	0..7	18	Channel cross-talk error	Check I/O module wiring. Restart I/O module, if needed. If this error persists, replace I/O module.

Table 6: List of error messages for Safety I/O modules (channel or module reintegration is not possible)

Error class	Component or Interface	Device	Module	Channel	Error	Error text	Remedy
E3	14	1..10	31	31	28	F-Parameter configuration and address switch value do not match.	Check I/O module F-Parameter configuration and module address switch value.
E3	14	1..10	31	31	26	Parameter value	Check master or configuration
E3	14	1..10	31	31	19	Checksum error in the I/O module	Non-safety I/O: Replace I/O module  Safety I/O: Check safety configuration and CRCs for I- and F-Parameters.
E3	14	1..10	31	31	18	Plausibility check failed (iParameter)	Check configuration

The complete list of AC500 error messages [↗ AC500 User Documentation \[4\]](#).

## AC500-S Safety Modules

DI581-S digital safety input module > Purpose

### 3.3 DI581-S digital safety input module

#### Elements of the module

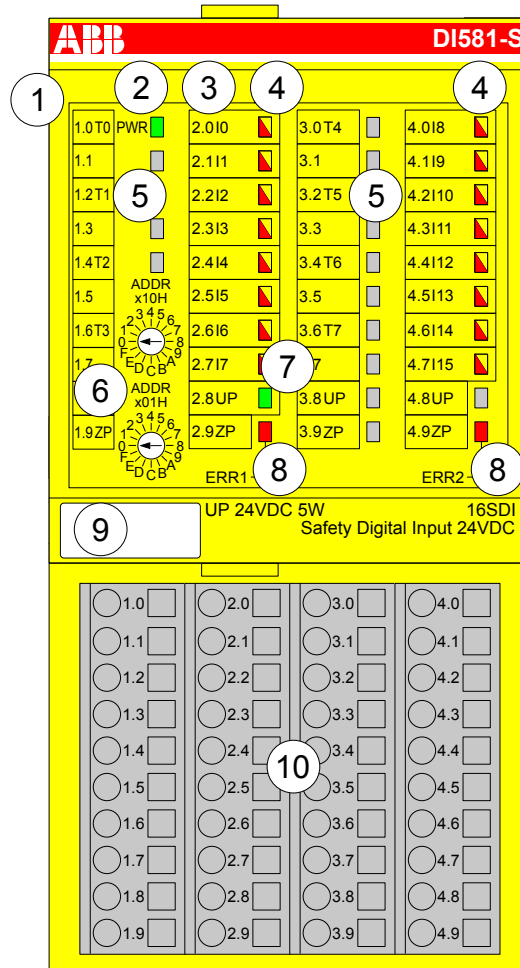


Fig. 16: Safety digital input module DI581-S, plugged on Terminal Unit TU582-S

- 1 I/O-Bus
- 2 System LED
- 3 Allocation terminal No. – signal name
- 4 16 yellow/red LEDs signal status I0 ... I7/I8 ... I15
- 5 8 unique phase-shifted test pulse outputs T0 ... T3/T4 ... T7
- 6 2 rotary switches for PROFIsafe address
- 7 Green LED process voltage UP
- 8 Red LEDs to display errors
- 9 Label (TA525)
- 10 I/O Terminal Unit (TU582-S)

#### 3.3.1 Purpose

Safety digital input module DI581-S can be used as a remote expansion module at CI501-PNIO, CI502-PNIO, CI504-PNIO and CI506-PNIO PROFINET modules (Release date: 2013 and newer) or locally at AC500 CPUs for up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) safety applications.



### **! NOTICE!**

SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849) reachable in your safety application depend on the wiring of your sensors to DI581-S module ↗ *Chapter 3.3.7 "Circuit examples" on page 85.*

DI581-S contains 16 safety digital inputs 24 V DC separated in two groups (2.0 ... 2.7 and 4.0 ... 4.7) with no potential separation between the channels.

The inputs are not electrically isolated from the other electronic circuitry of the module.

### 3.3.2 Functionality

Digital inputs	16 (24 V DC)
LED displays	for signal status, module errors, channel errors and supply voltage
Internal power supply	through the expansion bus interface (I/O-Bus)
External power supply	via the terminals ZP and UP (process voltage 24 V DC)

Self-tests and diagnostic functions (both start-up and runtime), like CPU and RAM tests, program flow control, cross-talk and stuck-at-1 tests, etc. are implemented in DI581-S according to IEC 61508 ed. 2 SIL 3 requirements.

DI581-S contains 16 safety digital input channels with the following features:

- Phase-shifted (unique) test pulses T0 ... T7 can be used for connection of mechanical sensors. Test pulse outputs T0 ... T7 provide 24 V signal with a short phase-shifted unique pulses (0 V) of 1 ms. Since the test pulses on each of the test pulse output channels are unique (due to the phase shift), they can be used to monitor the cross-talk between the given input channel with connected test pulse output and another wire, e.g. with 24 V DC, another test pulse output, etc. Test pulse outputs are dedicated ones:
  - T0 can be used only with input channels I0 and I1
  - T1 can be used only with input channels I2 and I3
  - T2 can be used only with input channels I4 and I5
  - T3 can be used only with input channels I6 and I7
  - T4 can be used only with input channels I8 and I9
  - T5 can be used only with input channels I10 and I11
  - T6 can be used only with input channels I12 and I13
  - T7 can be used only with input channels I14 and I15
- Input delay with the following values: 1 ms, 2 ms, 5 ms, 10 ms, 15 ms, 30 ms, 50 ms, 100 ms, 200 ms, 500 ms. Input delay value of 1 ms is the minimum one.

#### **! NOTICE!**

The allowed signal frequency on safety digital inputs is dependent on the input delay value for the given channel:

- For channel input delay values of 1 ... 10 ms, the pulse length of input signal shall be  $\geq 15$  ms ( $\sim 65$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 15 ms, the pulse length of input signal shall be  $\geq 20$  ms ( $\sim 50$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 30 ms, the pulse length of input signal shall be  $\geq 40$  ms ( $\sim 25$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 50 ms, the pulse length of input signal shall be  $\geq 60$  ms ( $\sim 15$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 100 ms, the pulse length of input signal shall be  $\geq 120$  ms ( $\sim 8$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 200 ms, the pulse length of input signal shall be  $\geq 250$  ms ( $\sim 4$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 500 ms, the pulse length of input signal shall be  $\geq 600$  ms ( $\sim 1.5$  Hz) to avoid occasional input channel passivation.

**⚠ DANGER!**

The input delay parameter means that signals with the duration shorter than input delay value are always not captured by the safety module.

The signals with the duration of equal to or longer than “input delay parameter” + “input delay accuracy” are always captured by the safety module, provided that the allowed frequency (see previous Notice) of the safety input signal is not exceeded.

The “input delay accuracy” can be estimated based on the following assumptions:

- If no test pulses are configured for the given digital safety input, then input delay accuracy can be calculated as 1 % of set input delay value (however, input delay accuracy value must be at least 0.5 ms!).
- If test pulses are configured for the given digital safety input of DI581-S module, then the input delay accuracy values can be estimated based on the input delay parameter value in the table below.

Input delay (ms)	Input delay accuracy (ms)
1	2
2	2
5	3
10	4
15	5
30	6
50	7
100	10
200	15
500	25

- Checking of process power supply (Diagnostic message is sent from the Safety I/O module to the CPU informing about the lack of process power supply for the given Safety I/O module). This function is a non-safety one and is not related to the internal safety-relevant over- and undervoltage detection.
- 2 channel equivalent and 2 channel antivalent mode with discrepancy time monitoring (configurable 10 ms ... 30 s).

**! NOTICE!**

In a 2 channel mode, the lower channel (channels 0/8 → Channel 0, channels 1/9 → Channel 1 etc.) transports the aggregated process value, PROFIsafe diagnostic bit, acknowledgement request and acknowledge reintegration information. The higher channel always provides the passivated value “0”.

## AC500-S Safety Modules

DI581-S digital safety input module > Functionality

### DANGER!

After discrepancy time error, the relevant channels are passivated. As soon as a valid sensor state is observed (equivalent or antivalent, depending on the selected mode), reintegration request status bit for the given channel becomes TRUE. You can acknowledge an error using acknowledge reintegration command bit for the given channel. This can directly lead to the machine start, because both TRUE – TRUE and FALSE – FALSE are valid states for equivalence and TRUE – FALSE and FALSE – TRUE are valid states for antivalence.

Make sure that such behaviour is acceptable in your safety application. If no, then you can use either included PLCopen Safety POU's for 2 channel evaluation in your safety programm or write your own POU's for 2 channel evaluation on SM560-S Safety CPU.

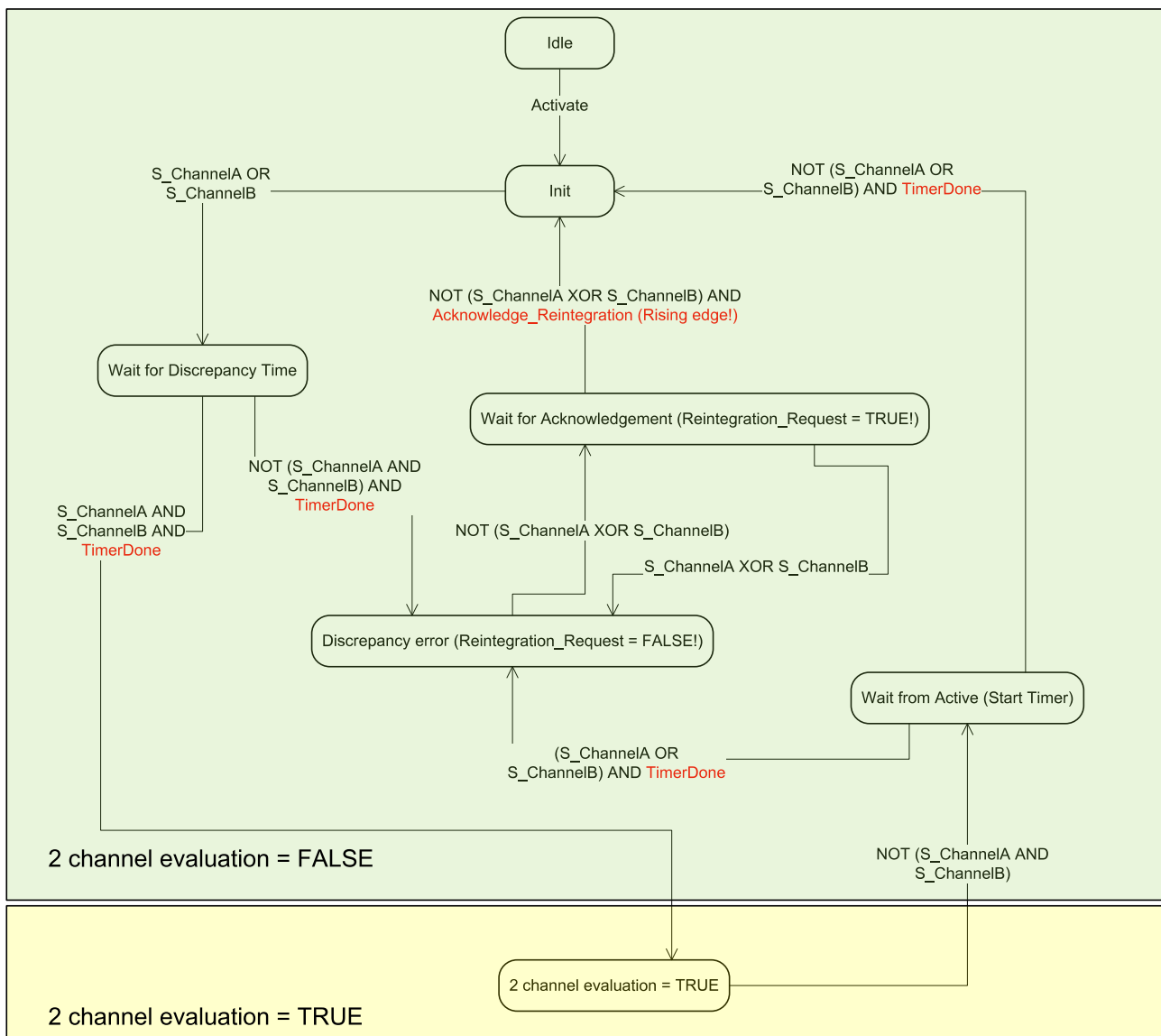


Fig. 17: 2 channel equivalent mode implemented in DI581-S

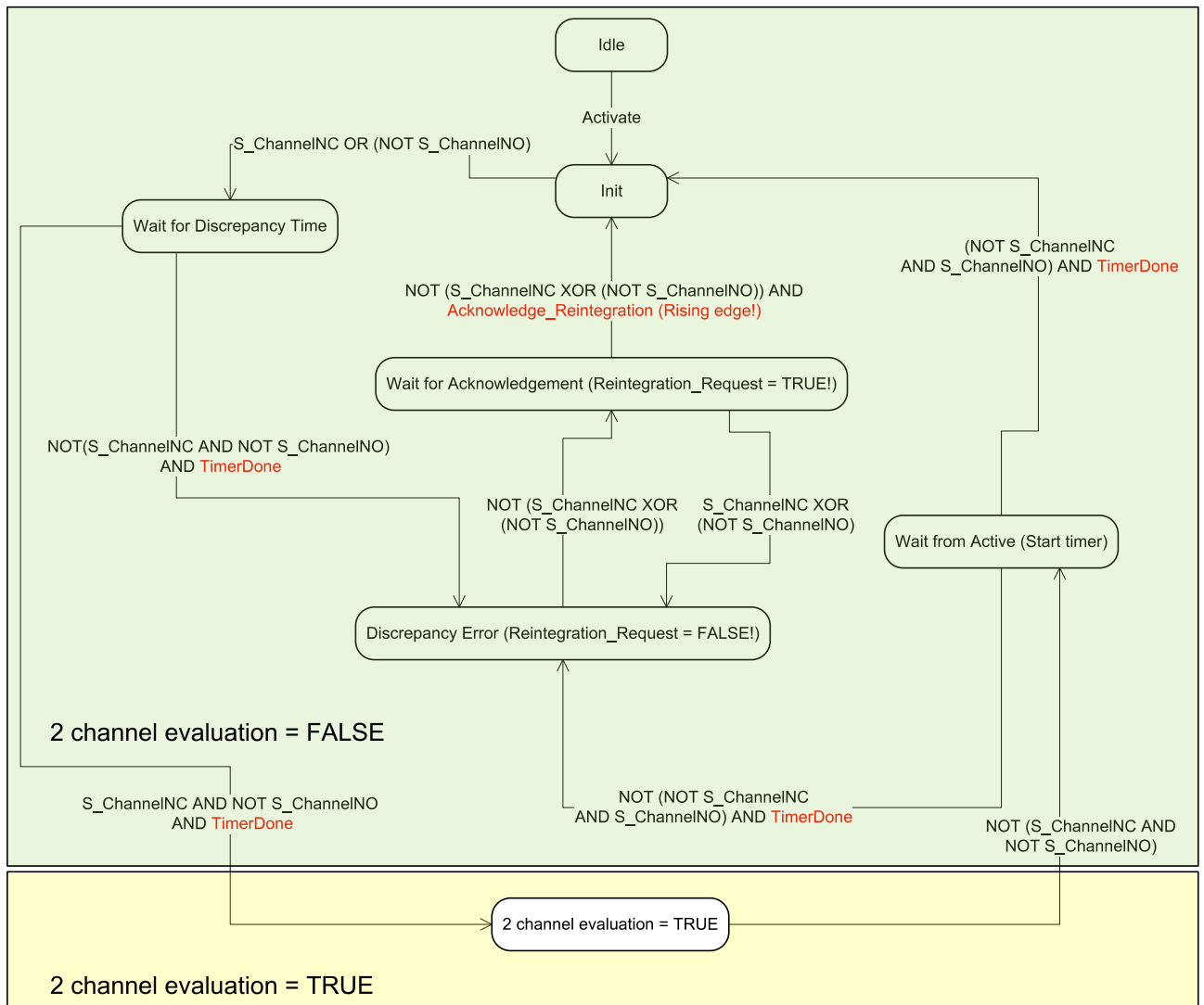


Fig. 18: 2 channel antivalent mode implemented in DI581-S

## ! NOTICE!

2 channel equivalent and 2 channel antivalent modes are implemented in DI581-S and DX581-S module to handle relatively static safety signals, e.g., those for emergency stop devices.

If frequently changing signals, like those from light curtains, laser scanners, door switches, etc. must be handled by DI581-S and DX581-S, then it is highly recommended to configure related channels in 1 channel mode and do 2 channel equivalent and 2 channel antivalent evaluation at SM560-S Safety CPU using PLCopen Safety FBs SF\_Equivalent and SF\_Antivalent ( ↗ Chapter 4.6.6.2 “SF\_Equivalent” on page 269 and ↗ Chapter 4.6.6.3 “SF\_Antivalent” on page 274).

### 3.3.3 Mounting, dimensions and electrical connection

The input modules can be plugged only on spring-type TU582-S I/O Terminal Unit. The unique mechanical coding on I/O Terminal Units prevents a potential mistake of placing the Non-safety I/O module on Safety I/O Terminal Unit and the other way around.

## AC500-S Safety Modules

DI581-S digital safety input module > Mounting, dimensions and electrical connection

Installation and maintenance have to be performed according to the technical rules, codes and relevant standards, e.g. EN 60204 part 1, by skilled electricians only.

### Assembly of DI581-S

#### **DANGER!**

Hot plug and hot swap of energized modules is not permitted. All power sources (supply and process voltages) must be switched off while working on any AC500 system, including Safety Modules.

Properly seat the module and press until it locks in place with a force of about 100 Newton. The terminal unit is mounted on a DIN rail or with 2 screws plus the additional accessory for wall mounting (TA526).

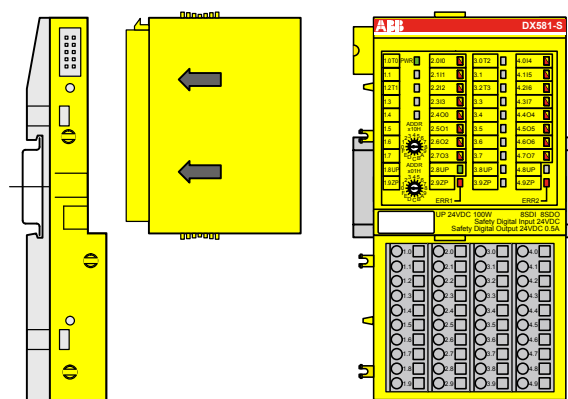




Fig. 19: Assembly instructions

1.  Put the module on the terminal unit.  
⇒ The module clicks in.
2.  Then press the module with a force of at about 100 Newton in the arrow direction.

## Disassembly of DI581-S

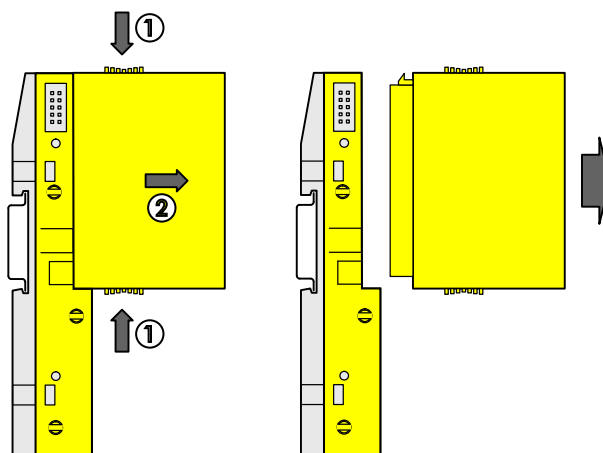


Fig. 20: Disassembly instructions

➡ Press above and below, then remove the module.

## AC500-S Safety Modules

DI581-S digital safety input module > Mounting, dimensions and electrical connection

### Dimensions

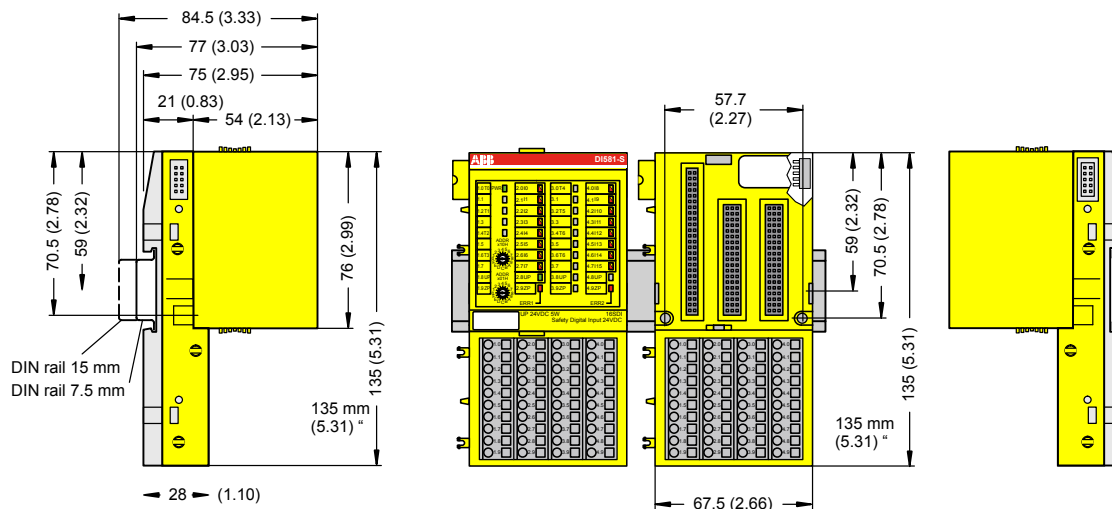


Fig. 21: Dimensions of DI581-S Safety I/O module

### Electrical connection

#### ! NOTICE!

The same TU582-S is used by all AC500-S Safety I/O modules. If TU582-S is wired for DX581-S module with Safety digital outputs and DI581-S or AI581-S modules are occasionally placed on this Terminal Unit, under no circumstances it is possible that Safety digital output clamps on TU582-S become energized due to a wrongly placed DI581-S or AI581-S Safety I/O modules.

The electrical connection of the I/O channels is carried out using 40 terminals of the I/O Terminal Unit. I/O modules can be replaced without re-wiring the Terminal Units.

The terminals 1.8, 2.8, 3.8 and 4.8 as well as 1.9, 2.9, 3.9 and 4.9 are electrically interconnected within the I/O Terminal Unit and have always the same assignment, independent of the inserted module:

- Terminals 1.8, 2.8, 3.8 and 4.8: Process voltage UP = +24 V DC
- Terminals 1.9, 2.9, 3.9 and 4.9: Process voltage ZP = 0 V

The assignment of the other terminals:

Terminals	Signal	Meaning
1.0, 1.2, 1.4, 1.6, 3.0, 3.2, 3.4, 3.6	T0, T1, T2, T3, T4, T5, T6, T7	Connectors of 8 test pulse outputs T0, T1, T2, T3, T4, T5, T6, T7
2.0 ... 2.7, 4.0 ... 4.7	I0, I1, I2, I3, I4, I5, I6, I7, I8, I9, I10, I11, I12, I13, I14, I15	16 safety digital inputs
1.8, 2.8, 3.8, 4.8	UP	Process power supply +24 V DC



Terminals	Signal	Meaning
1.9, 2.9, 3.9, 4.9	ZP	Central process earth
1.1, 1.3, 1.5, 1.7, 3.1, 3.3, 3.5, 3.7	Free	Not used

## ! NOTICE!

The process voltage must be included in the earthing concept of the control system (e.g., earthing the minus pole).

## Examples of connections

Examples of electrical connections with DI581-S module and single channel Ix.

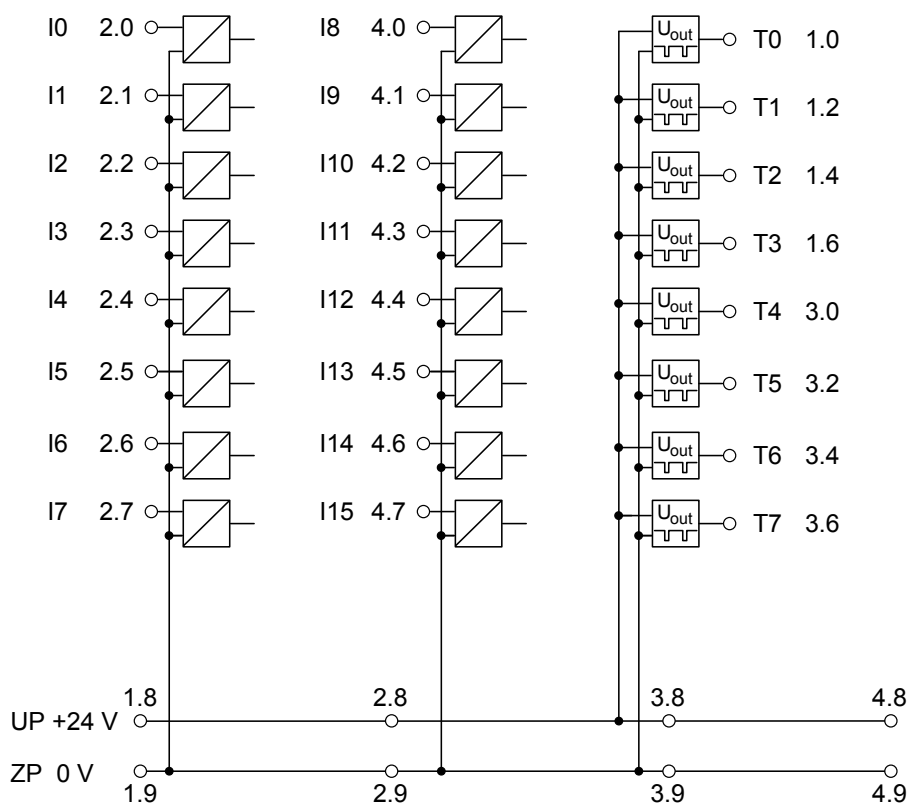


Fig. 22: Example of electrical connections with DI581-S

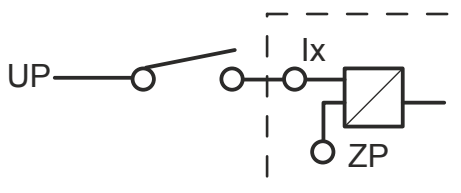


Fig. 23: Example of single channel with DI581-S

## AC500-S Safety Modules

DI581-S digital safety input module > I/O configuration

### 3.3.4 Internal data exchange

Inputs (words)	3
Outputs (words)	1

### 3.3.5 I/O configuration

The safety digital input module DI581-S does not store configuration data itself. The configuration data is stored on SM560-S and PM5xx CPUs.

### 3.3.6 Parameterization

The arrangement of the parameter data is performed by your system configuration software PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer). ABB GSDML file for PROFINET devices can be used to configure DI581-S parameters in 3<sup>rd</sup> party PROFINET F-Host systems.

The parameter setting directly influences the functionality of modules and reachable SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849).

No.	Name	Values	Default
1	Check supply	"On", "Off"	"On"
2	Configuration	"Not used", "1 channel", "2 channel equivalent", "2 channel antivalent"	"Not used"
3	Test pulse	"Disabled", "Enabled"	"Disabled"
4	Input delay	"1 ms", "2 ms", "5 ms", "10 ms", "15 ms", "30 ms", "50 ms", "100 ms", "200 ms", "500 ms"	"5 ms"
5	Discrepancy time*	"10 ms", "20 ms", "30 ms", "40 ms", "50 ms", "60 ms", "70 ms", "80 ms", "90 ms", "100 ms", "150 ms", "200 ms", "250 ms", "300 ms", "400 ms", "500 ms", "750 ms", "1 s", "2 s", "3 s", "4 s", "5 s", "10 s", "20 s", "30 s"	"50 ms"

\* Available only for "2 channel equivalent" and "2 channel antivalent" configuration

### 3.3.7 Circuit examples

Examples of electrical connections and reachable SIL (IEC 61508 ed. 2 and IEC 62061), Category (EN 954) and PL (ISO 13849) with DI581-S module are presented below.

#### ! NOTICE!

Whenever DC = High is used in the circuit examples for safety digital inputs, the following measure from ISO 13849-1 [10] is used in DI581-S module: Cross monitoring of input signals and intermediate results within the logic (L), and temporal and logical software monitor of the program flow and detection of static faults and short circuits (for multiple I/O).

Whenever DC = Medium is used in the circuit examples for safety digital inputs, any of the measures for input devices with  $DC \geq 90\%$  can be used from ISO 13849-1 [10].

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 1-channel sensor, 24 V DC

Sensor power supply on channel 1 (I0)	External 24 V DC
SIL/Cat./PL <sup>1), 2)</sup>	SIL 1/Cat. 1/PL c
SIL <sup>3)</sup>	SIL 2

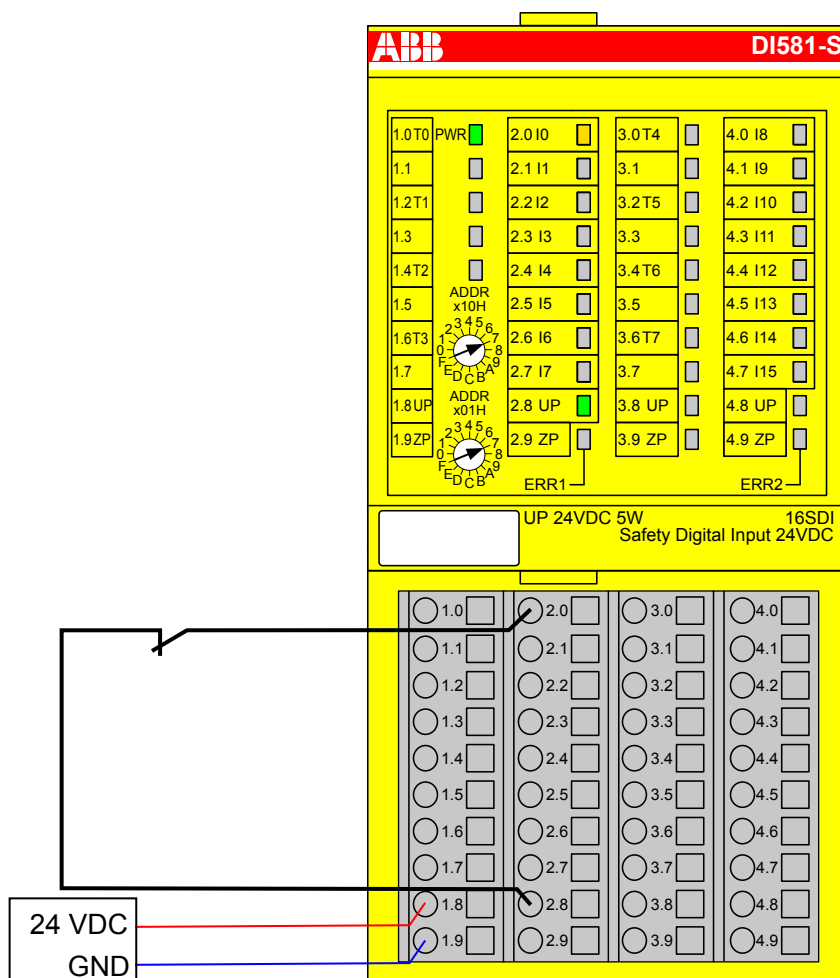


Fig. 24: Circuit example DI581-S, 1-channel sensor, 24 V DC

- 1) - MTTFd = High, DC = 0
- 2) - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- 3) - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## 1-channel OSSD output (with internal tests), external sensor power supply

Sensor power supply on channel 1 (I0)	External 24 V DC (OSSD)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 1/Cat.1/PL c
SIL <sup>3)</sup>	SIL 2

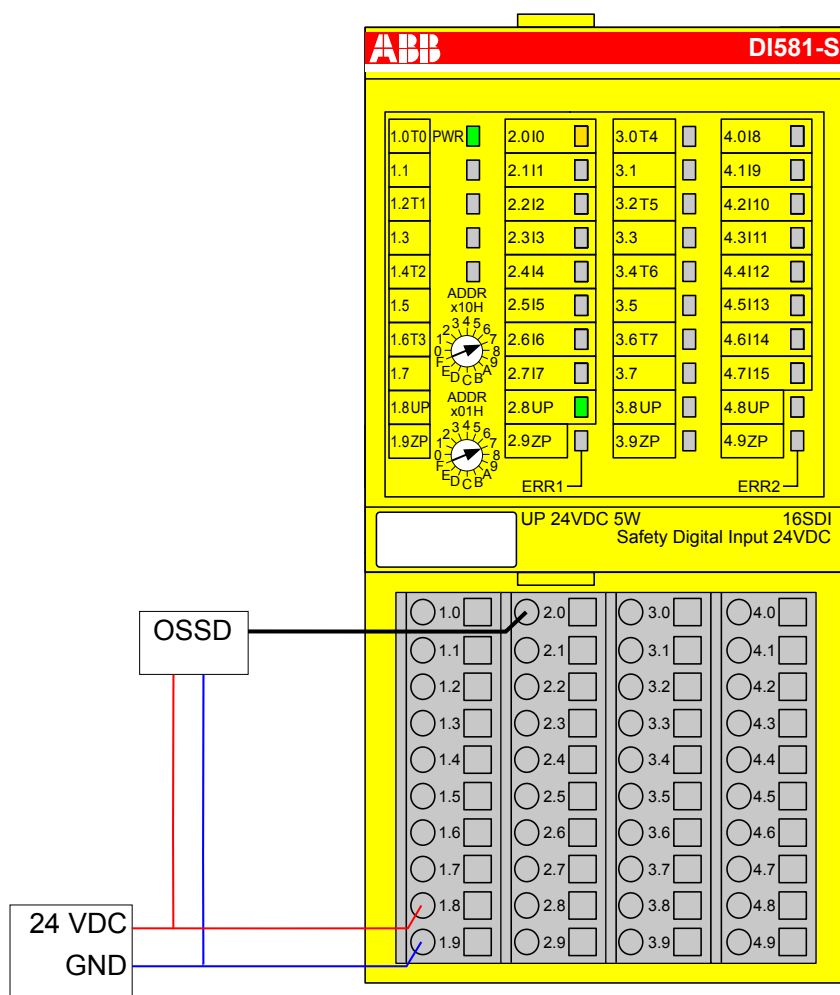


Fig. 25: Circuit example DI581-S, 1-channel OSSD output (with internal tests), external sensor power supply

- <sup>1)</sup> - MTTFd = High, DC = 0
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 2-channel sensor (equivalent), 24 V DC

2-channel evaluation	In DI581-S module
Sensor power supply on channel 1 (I0)	24 V DC
Sensor power supply on channel 2 (I8)	24 V DC
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat.3/PL d
SIL <sup>3)</sup>	SIL 3

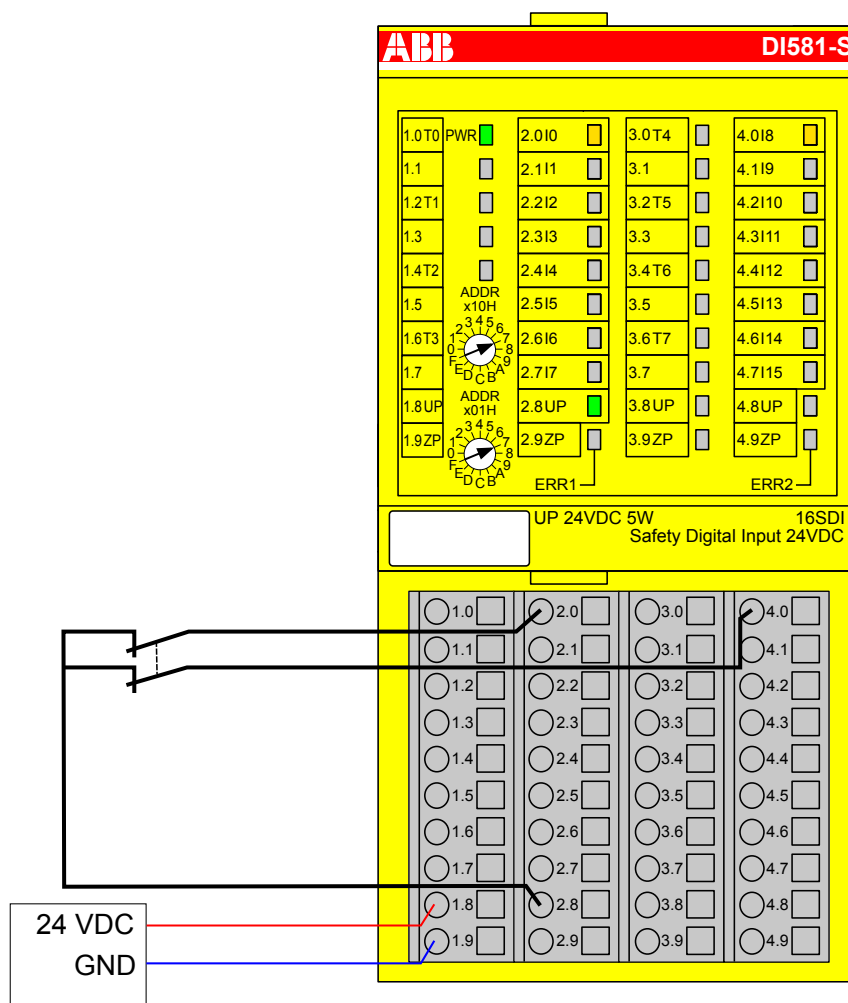


Fig. 26: Circuit example DI581-S, 2-channel sensor (equivalent), 24 V DC

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

**2-channel sensor (antivalent), 24 V DC**

2-channel evaluation	In DI581-S module
Sensor power supply on channel 1 <b>(I0)</b>	24 V DC
Sensor power supply on channel 2 <b>(I8)</b>	24 V DC
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat.3/PL d
SIL <sup>3)</sup>	SIL 3

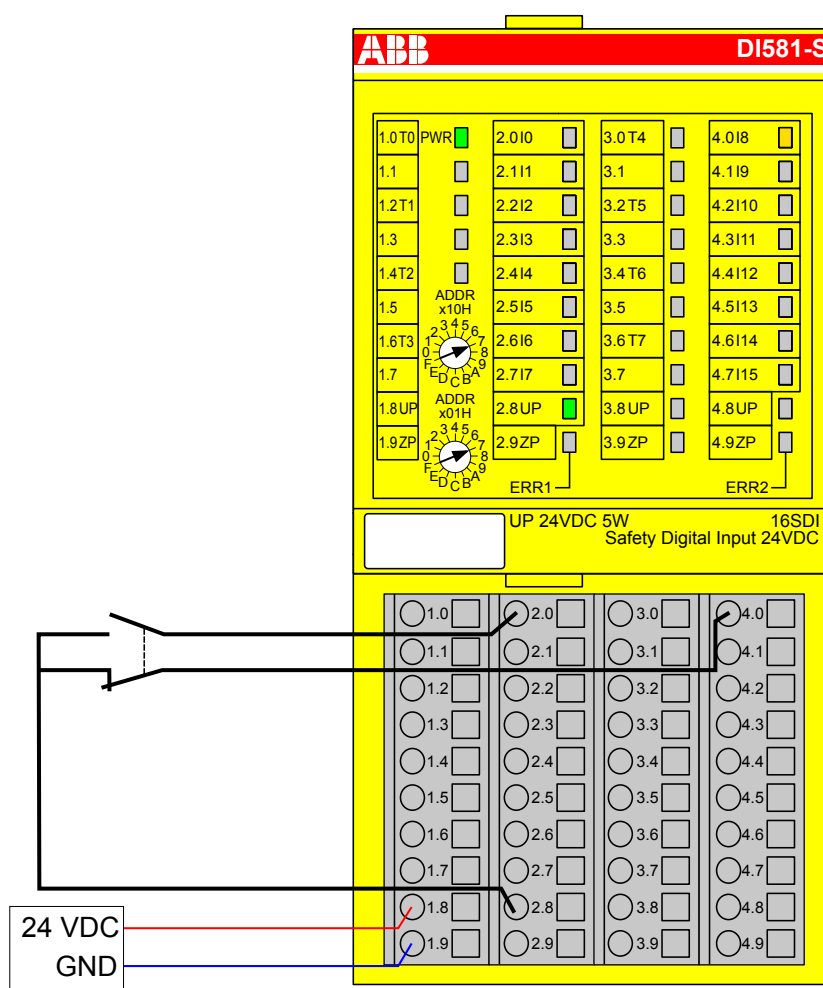


Fig. 27: Circuit example DI581-S, 2-channel sensor (antivalent), 24 V DC

- 1) - MTTFd = High, DC = Medium
- 2) - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- 3) - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 2-channel OSSD output (with internal tests), external sensor power supply

2-channel evaluation	In DI581-S module
Sensor power supply on channel 1 (I0)	External 24VDC (OSSD)
Sensor power supply on channel 2 (I8)	External 24VDC (OSSD)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 3/Cat. 4/PL e
SIL <sup>3)</sup>	SIL 3

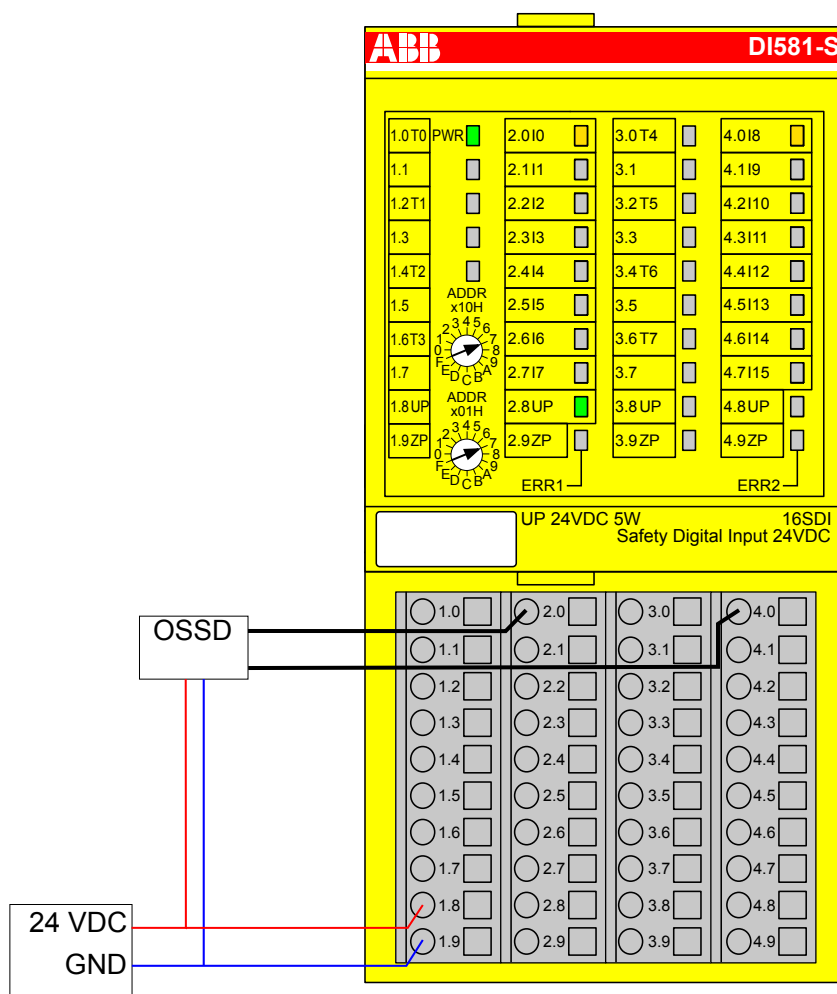


Fig. 28: Circuit example DI581-S, 2-channel OSSD output (with internal tests), external sensor power supply

- <sup>1)</sup> - MTTFd = High, DC = High
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)



## 1-channel sensor with test pulses

Sensor power supply on channel 1 (I0)	Internal using test pulse T0
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat. 2/PL d
SIL <sup>3)</sup>	SIL 3

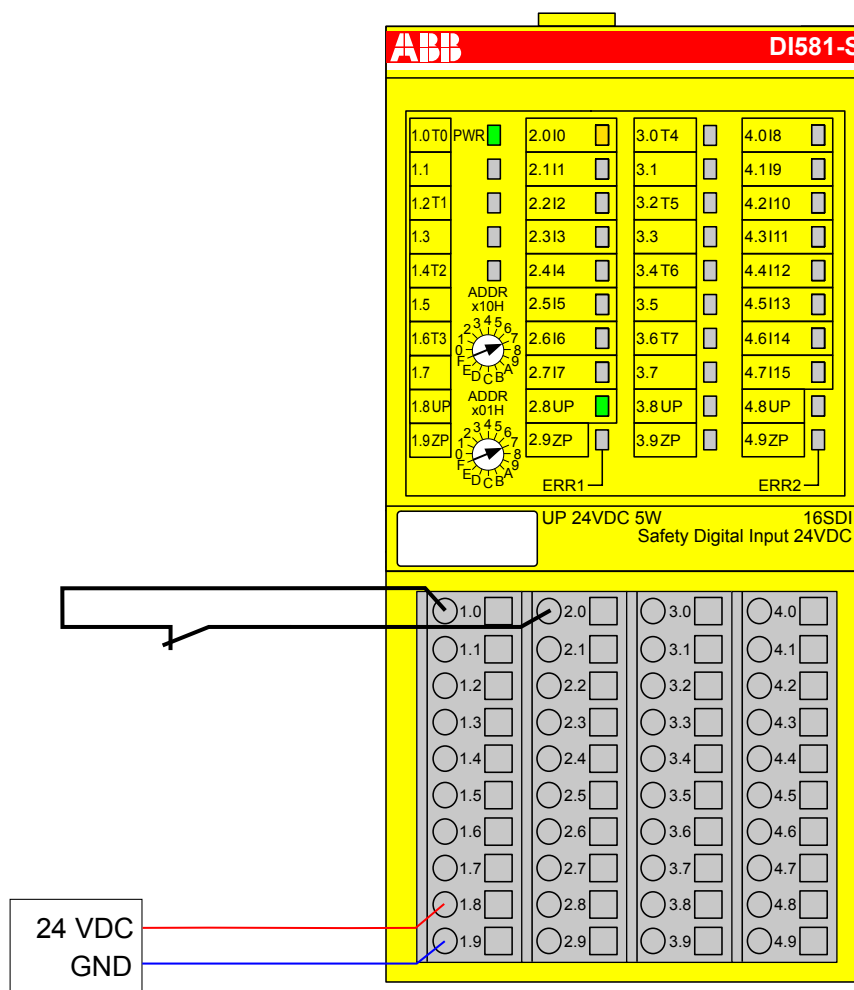


Fig. 29: Circuit example DI581-S, 1-channel sensor with test pulses

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 2-channel sensor (equivalent) with test pulses

2-channel evaluation	In SM560-S Safety CPU
Sensor power supply on channel 1 (I0)	Internal using test pulse T0
Sensor power supply on channel 2 (I1)	Internal using test pulse T0
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat. 3/PL d
SIL <sup>3)</sup>	SIL 3

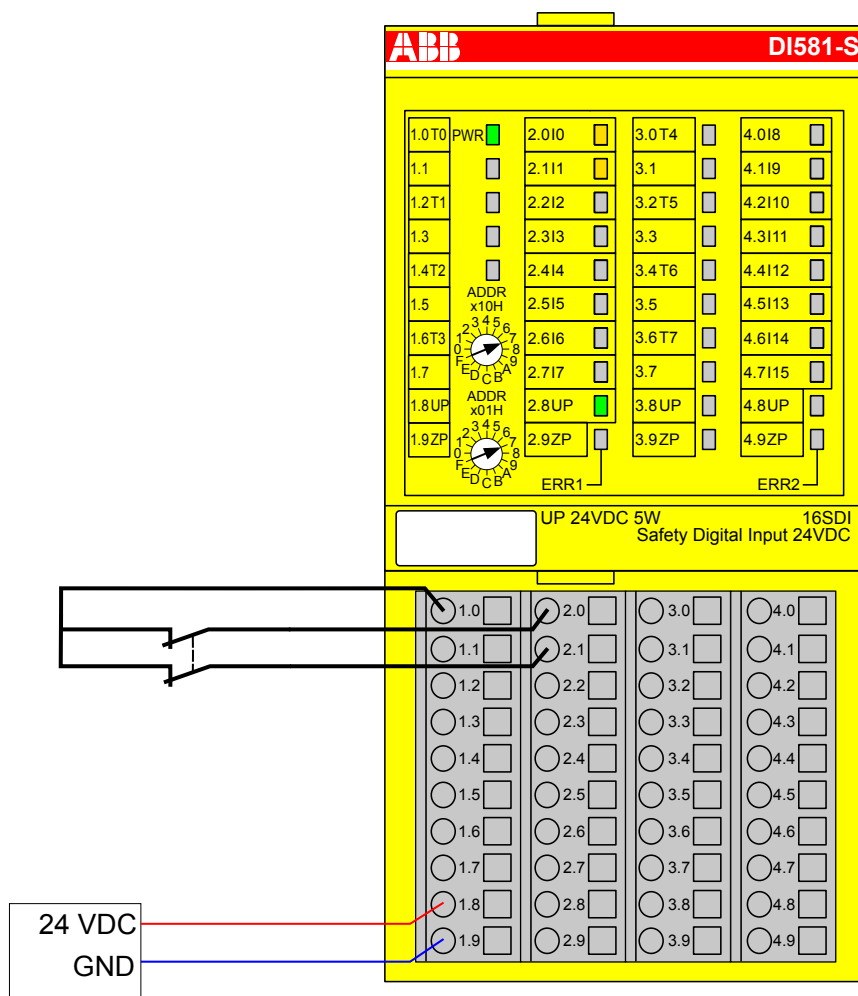


Fig. 30: Circuit example DI581-S, 2-channel sensor (equivalent) with test pulses

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## 2-channel sensor (equivalent) with test pulses

2-channel evaluation	In DI581-S module
Sensor power supply on channel 1 (I0)	Internal using test pulse T0
Sensor power supply on channel 2 (I8)	Internal using test pulse T4
SIL/Cat./PL <sup>1), 2)</sup>	SIL 3/Cat. 4/PL e
SIL <sup>3)</sup>	SIL 3

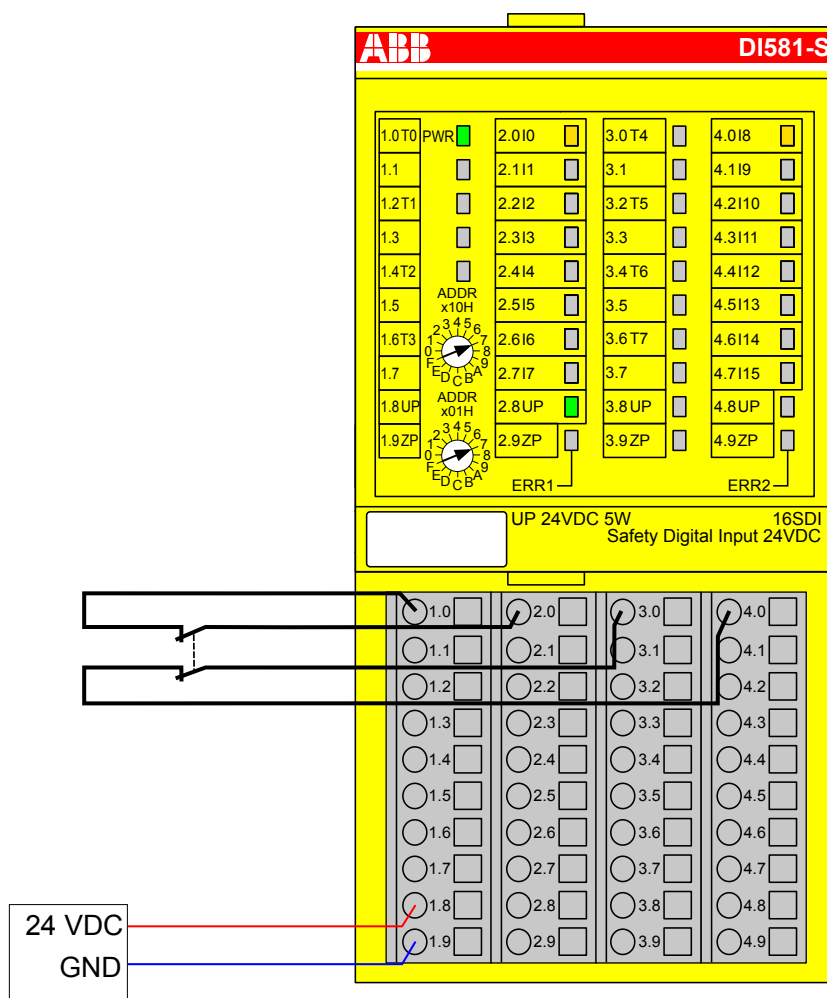


Fig. 31: Circuit example DI581-S, 2-channel sensor (equivalent) with test pulses

- <sup>1)</sup> - MTTFd = High, DC = High
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 2 x OSSD output (with internal tests), external sensor power supply

2-channel evaluation	In DI581-S module
Sensor power supply on channel 1 (I0)	External 24VDC (OSSD)
Sensor power supply on channel 2 (I8)	External 24VDC (OSSD)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 3/Cat. 4/PL e
SIL <sup>3)</sup>	SIL 3

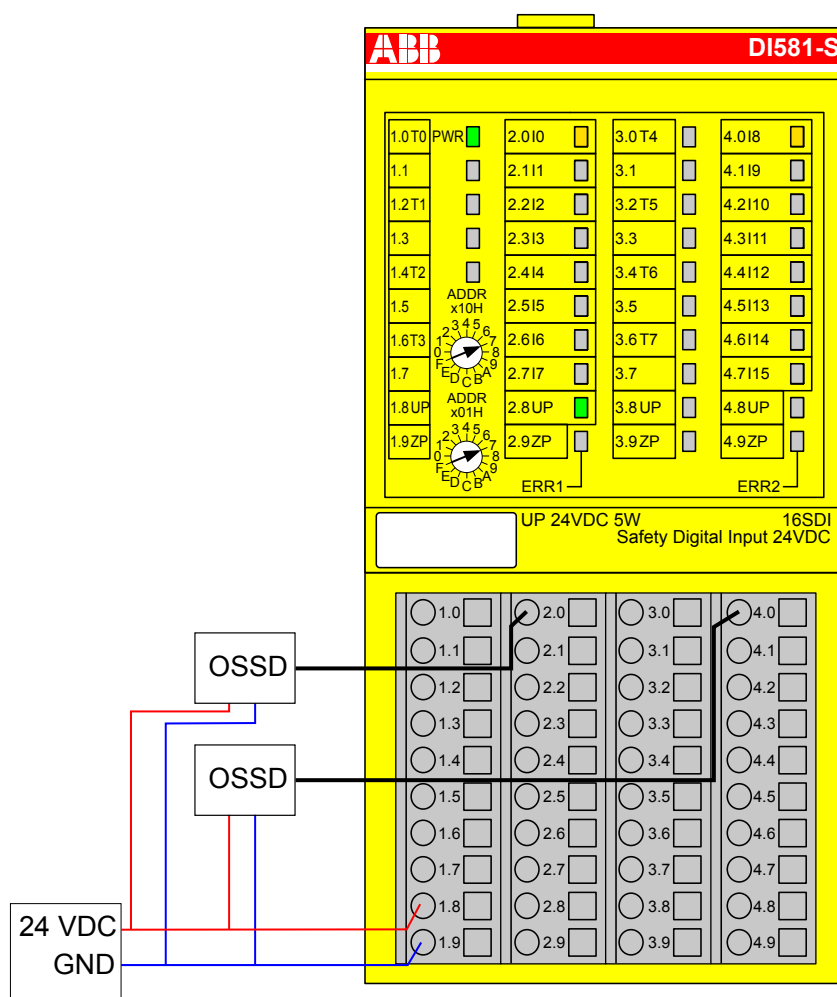


Fig. 32: Circuit example DI581-S, 2 x OSSD output (with internal tests), external sensor power supply

- <sup>1)</sup> - MTTFd = High, DC = High
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## 2 separate sensors with test pulses

2-channel evaluation	In SM560-S Safety CPU
Sensor power supply on channel 1 (I0)	Internal using test pulse T0
Sensor power supply on channel 2 (I1)	Internal using test pulse T0
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat. 3/PL d
SIL <sup>3)</sup>	SIL 3

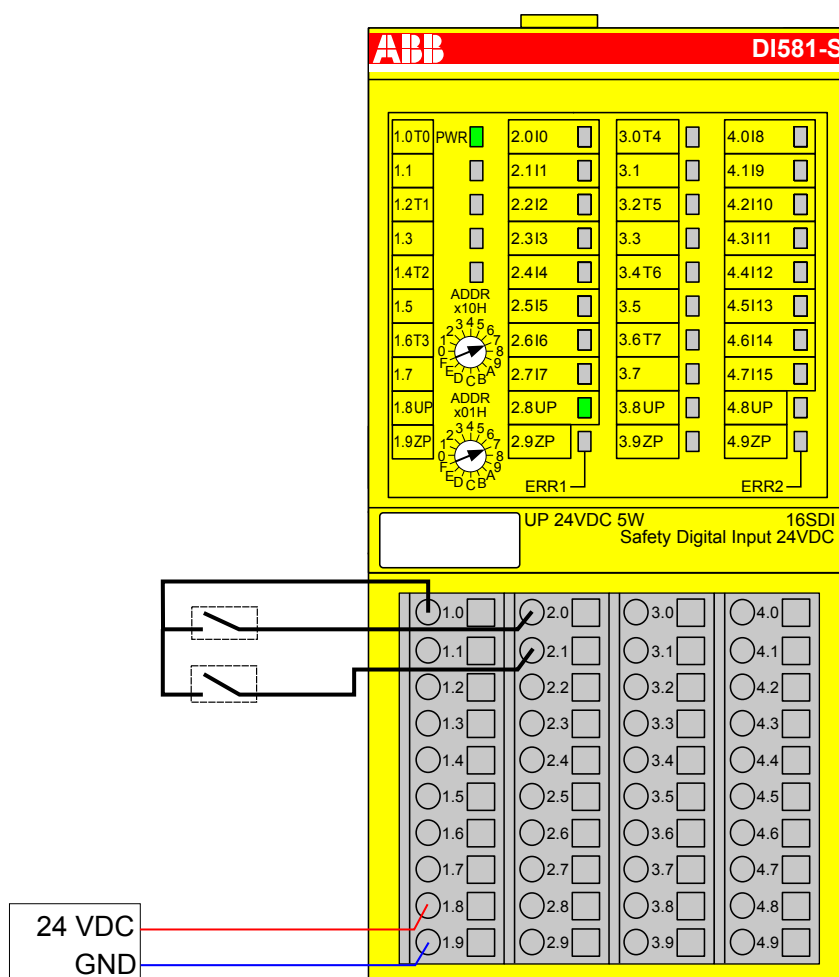


Fig. 33: Circuit example DI581-S, 2 separate sensors with test pulses

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Circuit examples

### 2 x 2-channel sensor (antivalent) with test pulses

2-channel evaluation	First in DI581-S module and then in SM560-S
Sensor power supply on channel 1 (I0)	Internal using test pulse T0
Sensor power supply on channel 2 (I8)	Internal using test pulse T4
Sensor power supply on channel 3 (I4)	Internal using test pulse T2
Sensor power supply on channel 4 (I12)	Internal using test pulse T6
SIL/Cat./PL <sup>1), 2)</sup>	SIL 3/Cat. 4/PL e
SIL <sup>3)</sup>	SIL 3

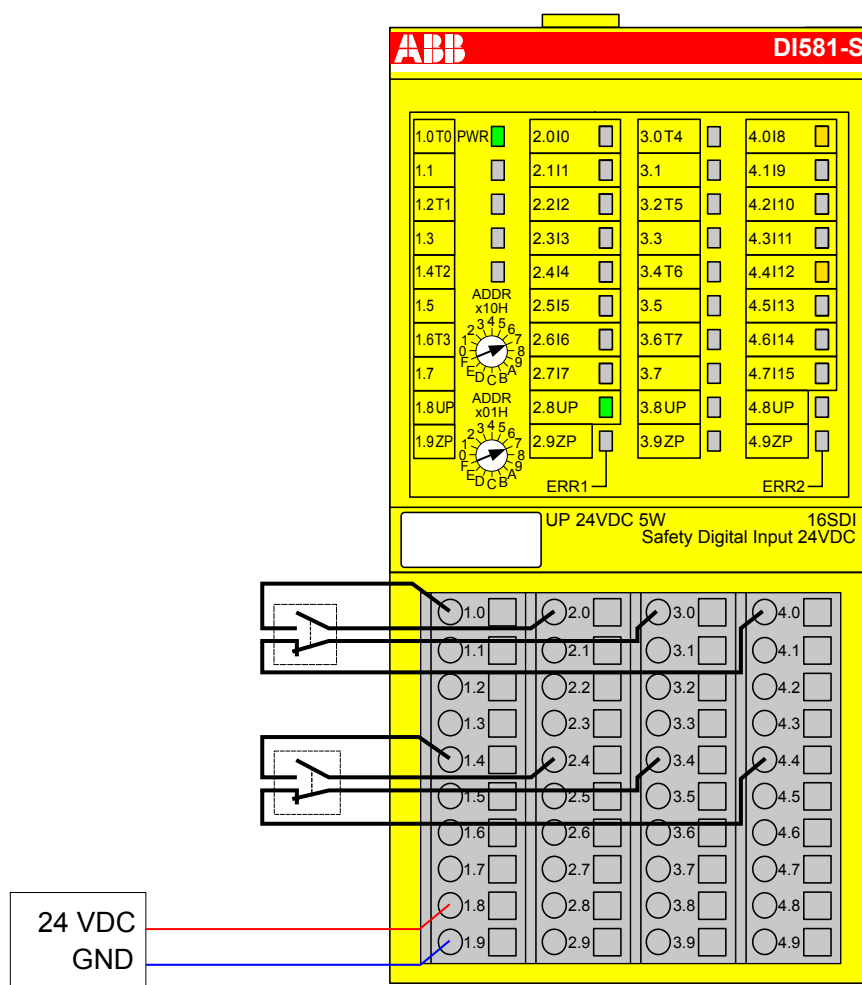


Fig. 34: Circuit example DI581-S, 2 x 2-channel sensor (antivalent) with test pulses

- <sup>1)</sup> - MTTFd = High, DC = High
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## Mode switch 1 from 4, 24 V DC

Mode switch evaluation	In SM560-S Safety CPU
Sensor power supply (I0 ... I3)	24 V DC
SIL/Cat./PL <sup>1), 2)</sup>	SIL 1/Cat. 2/PL c
SIL <sup>3)</sup>	SIL 2

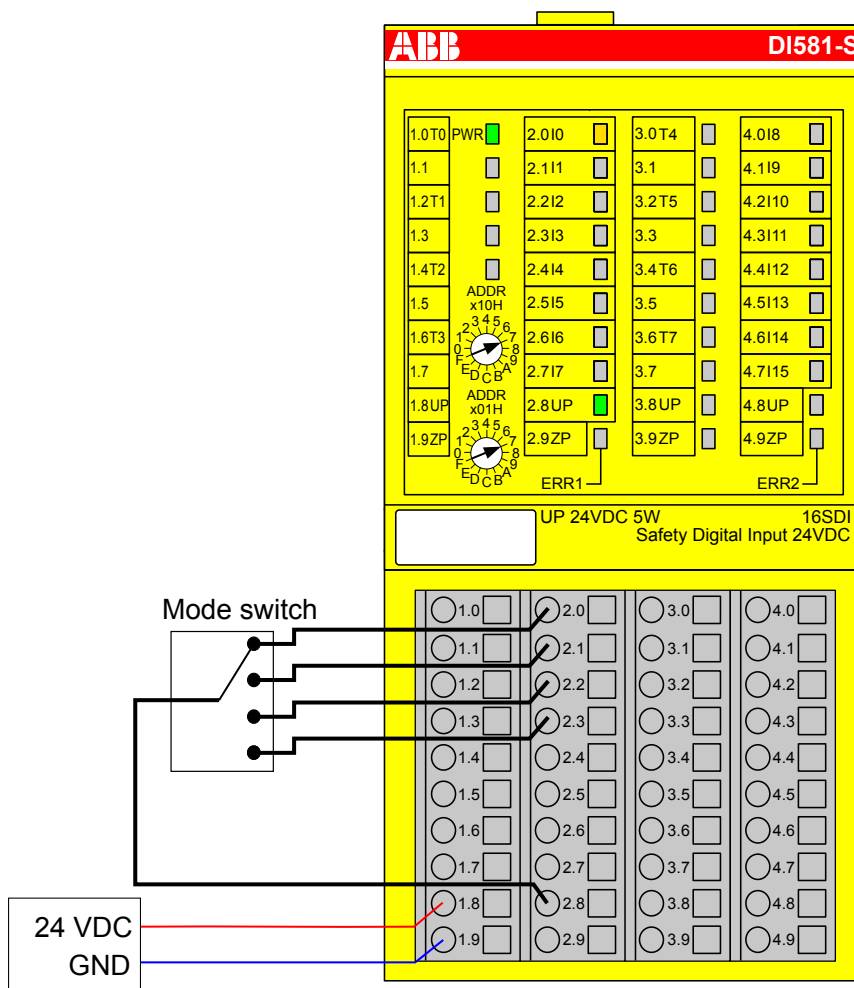


Fig. 35: Circuit example DI581-S, mode switch 1 from 4, 24 V DC

- <sup>1)</sup> - MTTFd = High, DC = Low
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DI581-S digital safety input module > Technical data

### 3.3.8 LED status display

Table 7: Status display and its meaning

LED	Description	Colour	LED = OFF	LED = ON	LED flashes
Inputs 0 ... 15	Digital input	Yellow	Input = OFF	Input = ON (the input voltage is displayed even if the supply voltage is OFF).	--
	Channel error	Red	No channel error	Channel error	--
UP	Process voltage +24 V DC via terminal	Green	Process supply voltage is missing	Process supply voltage OK	--
PWR	+3.3 V voltage from IO-Bus	Green	+3.3 V IO-Bus voltage is not available	+3.3 V IO-Bus voltage is available	--
ERR1	Module error indicator 1	Red	No module error	Module error which leads to a SAFE STOP state	Module passivation and/or acknowledgement request (alternating blinking)
ERR2	Module error indicator 2	Red			

### 3.3.9 Technical data

#### ! NOTICE!

DI581-S-XC version is available for usage in extreme environmental conditions ( ↗ Appendix "System data for AC500-S-XC" on page 446).



## Process supply voltage UP

Data	Value	Unit
Connections Terminals 1.8 ... 4.8 (UP)	+24	V
Connections Terminals 1.9 ... 4.9 (ZP)	0	V
Rated value (– 15 %, +20 %, without ripple)	24	V DC
Max. ripple	5	%
Protection against reversed voltage	Yes	
Rated protection fuse for UP (fast)	10	A
Electrical isolation	per module	
Mechanisms in which I/Os are processed	periodically refreshed	
Current consumption from UP at normal operation with + 24 V DC (for module electronics)	0.18	A
Inrush current from UP at 30 V (at power up)	0.1	A <sup>2</sup> s
Inrush current from UP at 24 V (at power up)	0.06	A <sup>2</sup> s

### ! NOTICE!

All DI581-S channels (including test pulse outputs) are protected against reverse polarity, reverse supply, short circuit and continuous overvoltage up to 30 V DC.

## Mounting position

Horizontal or vertical with derating (maximal operating temperature reduced to +40 °C)

## Cooling

The natural convection cooling must not be hindered by cable ducts or other parts in the switchgear cabinet.

## AC500-S Safety Modules


DI581-S digital safety input module > Technical data

### Allowed interruptions of power supply, according to EN 61131-2

Data	Value	Unit
DC supply interruptions	< 10	ms
Time between 2 DC supply interruptions, PS2	> 1	s

### Environmental conditions

Data	Value	Unit
Operating temperature*	0 ... +60	°C
Storage temperature	−40 ... +85	°C
Transport temperature	−40 ... +85	°C
Humidity without condensation	max. 95	%
Operating air pressure	> 800	hPa
Storage air pressure	> 660	hPa
Operating altitude	< 2000	m above sea level
Storage altitude	< 3500	m above sea level

\* Extended temperature ranges (below 0 °C and above +60 °C) can be supported in special versions of DI581-S (  Appendix “System data for AC500-S-XC” on page 446)

### Creepage distances and clearances

The creepage distances and clearances meet the overvoltage category II, pollution degree 2.

### Power supply units

For the supply of modules, power supply units according to PELV/SELV specifications must be used.

### Electromagnetic compatibility

 TÜV Report [2]

Data	Value	Unit
Degree of protection	IP 20	
Housing	according to UL 94	
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 3.5 mm	2 ... 15	Hz
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 1 g *	15 ...150	Hz
Shock test (all three axes), 11 ms half-sinusoidal	15	g
MTBF	102	years

\* Higher values on request

## Self-test and diagnostic functions

Start-up and runtime tests: Program flow control, RAM, CPU, cross-talk, stuck-at-1, etc.

## AC500-S Safety Modules

DI581-S digital safety input module > Technical data

### Dimensions, weight

Data	Value	Unit
W x H x D	67.5 x 76 x 62	mm
Weight	~ 130	g

### Certifications

CE, cUL (↗ further certifications at [www.abb.com/plc](http://www.abb.com/plc))

**3.3.9.1 Technical data of safety digital inputs**

Data	Value	Unit
Number of input channels per module	16	
Terminals of the channels I0 to I7	2.0 ... 2.7	
Terminals of the channels I8 to I15	4.0 ... 4.7	
Terminals of reference potential for all inputs (minus pole of the process supply voltage, signal name ZP)	1.9 ... 4.9	
Electrical isolation from the rest of the module (I/O-Bus)	Yes	
Input type acc. to EN 61131-2	Type 1	
Input delay (0 → 1 or 1 → 0), configurable	1 ... 500	ms

**Input signal indication**

One yellow LED per channel, the LED is ON when the input signal is high (signal 1).

## AC500-S Safety Modules

DI581-S digital safety input module > Technical data

### Signal voltage

Data	Value	Unit
Input signal voltage	24	V DC
Signal 0	-3 ... +5	V
Undefined signal	> +5 ... < +15	V
Signal 1	+15 ... +30	V

### Input current per channel

Data	Value	Unit
Input voltage +24 V, typically	7	mA
Input voltage +5 V	< 1	mA
Input voltage +15 V	> 4	mA
Input voltage +30 V	< 8	mA

### Cable length

Data	Value	Unit
Max. cable length, shielded	1000	m
Max. cable length, unshielded	600	m

### 3.3.9.2 Technical data of non-safety test pulse outputs



#### **DANGER!**

Exceeding the maximum process or supply voltage range (< -35 V DC or > +35 V DC) could lead to unrecoverable damage of the system.

Data	Value	Unit
Number of test pulse channels per module (transistor test pulse outputs)	8	
Terminals of the channels T0 to T3	1.0, 1.2, 1.4, 1.6	
Terminals of the channels T4 to T7	3.0, 3.2, 3.4, 3.6	
Terminals of reference potential for all test pulse outputs (minus pole of the process supply voltage, signal name ZP)	1.9 ... 4.9	
Terminals of common power supply voltage for all outputs (plus pole of the process supply voltage, signal name UP)	1.8 ... 4.8	
Output voltage for signal 1	UP – 0.8	V
Length of test pulse 0 phase	1	ms

## Output current

Data	Value	Unit
Rated value, per channel	10	mA
Maximum value (all channels together)	80	mA
Short-circuit proof / overload proof	yes	
Output current limitation	65	mA
Resistance to feedback against 24V signals	yes	

## Cable length

Data	Value	Unit
Max. cable length, shielded	1000	m
Max. cable length, unshielded	600	m

## 3.3.10 Ordering data

Type	Description	Order code
DI581-S	DI581-S:S500, Safety Digital Input Module 16SDI	1SAP 284 000 R0001
DI581-S-XC	DI581-S-XC:S500, Safety Digital Input Module 16SDI, Extreme Conditions	1SAP 484 000 R0001

## AC500-S Safety Modules

DX581-S digital safety input/output module > Purpose

### 3.4 DX581-S digital safety input/output module

#### Elements of the module

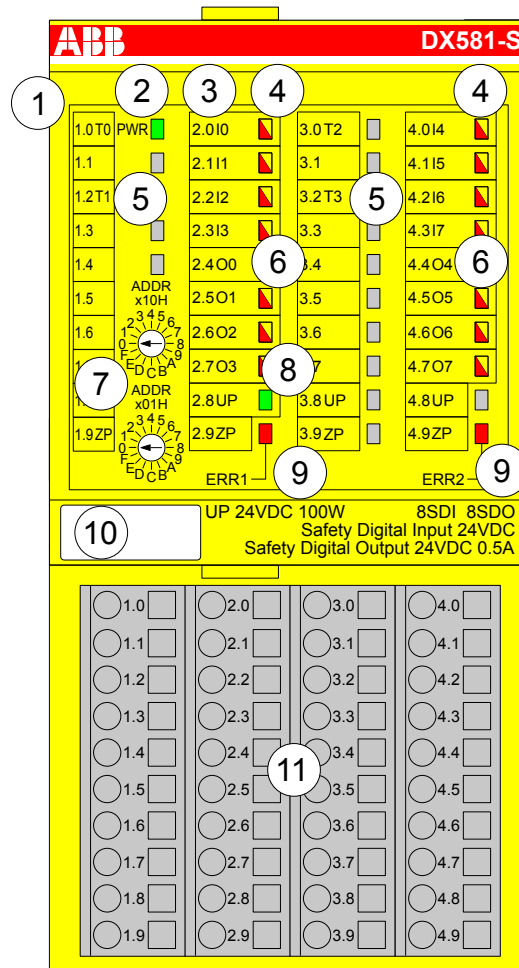


Fig. 36: Safety digital input/output module DX581-S, plugged on Terminal Unit TU582-S

- 1 I/O-Bus
- 2 System LED
- 3 Allocation terminal No. – signal name
- 4 8 yellow/red LEDs signal status I0 ... I3/I4 ... I7
- 5 4 Test pulse outputs T0 ... T1/T2 ... T3
- 6 8 yellow/red LEDs signal status O0 ... O3 / O4 ... O7
- 7 2 rotary switches for PROFIsafe address
- 8 Green LED process voltage UP
- 9 Red LEDs to display errors
- 10 Label (TA525)
- 11 I/O Terminal Unit (TU582-S)

#### 3.4.1 Purpose

Safety digital input/output module DX581-S can be used as a remote expansion module at CI501-PNIO, CI502-PNIO, CI504-PNIO and CI506-PNIO PROFINET modules (Release date: 2013 and newer) or locally at AC500 CPUs for up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) safety applications.



### ! NOTICE!

SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849) reachable in your safety application depend on the wiring of your sensors and actors to DX581-S module ↗ *Chapter 3.4.7 “Circuit examples” on page 117.*

DX581-S contains 8 safety digital inputs 24 V DC separated in two groups (2.0 ... 2.3 and 4.0 ... 4.3) and 8 safety digital transistor outputs with no potential separation between the channels.

The inputs/outputs are not electrically isolated from the other electronic circuitry of the module.

## AC500-S Safety Modules

DX581-S digital safety input/output module > Functionality

### 3.4.2 Functionality

Digital inputs	8 (24 V DC)
Digital outputs	8 (24 V DC)
LED displays	for signal status, module errors, channel errors and supply voltage
Internal power supply	through the expansion bus interface (I/O-Bus)
External power supply	via the terminals ZP and UP (process voltage 24 V DC)

Self-tests and diagnostic functions (both start-up and runtime), like CPU and RAM tests, program flow control, cross-talk and stuck-at-1 tests, etc. are implemented in DX581-S according to IEC 61508 ed. 2 SIL 3 requirements.

DX581-S contains 8 safety digital input channels with the following features:

- Phase-shifted (unique) test pulses T0 ... T3 can be used for connection of mechanical sensors. Test pulse outputs T0 ... T3 provide 24 V signal with a short phase-shifted unique pulses (0 V) of 1 ms. Since the test pulses on each of the test pulse output channels are unique (due to the phase shift), they can be used to monitor the cross-talk between the given input channel with connected test pulse output and another wire, e.g. with 24 V DC, another test pulse output, etc. Test pulse outputs are dedicated ones:
  - T0 can be used only with input channels I0 and I1
  - T1 can be used only with input channels I2 and I3
  - T2 can be used only with input channels I4 and I5
  - T3 can be used only with input channels I6 and I7
- Input delay with the following values: 1 ms, 2 ms, 5 ms, 10 ms, 15 ms, 30 ms, 50 ms, 100 ms, 200 ms, 500 ms. Input delay value of 1 ms is the minimum one.

#### **! NOTICE!**

The allowed signal frequency on safety digital inputs is dependent on the input delay value for the given channel:

- For channel input delay values of 1 ... 10 ms, the pulse length of input signal shall be  $\geq 15$  ms ( $\sim 65$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 15 ms, the pulse length of input signal shall be  $\geq 20$  ms ( $\sim 50$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 30 ms, the pulse length of input signal shall be  $\geq 40$  ms ( $\sim 25$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 50 ms, the pulse length of input signal shall be  $\geq 60$  ms ( $\sim 15$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 100 ms, the pulse length of input signal shall be  $\geq 120$  ms ( $\sim 8$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 200 ms, the pulse length of input signal shall be  $\geq 250$  ms ( $\sim 4$  Hz) to avoid occasional input channel passivation.
- For channel input delay of 500 ms, the pulse length of input signal shall be  $\geq 600$  ms ( $\sim 1.5$  Hz) to avoid occasional input channel passivation.

**⚠ DANGER!**

The input delay parameter means that signals with the duration shorter than input delay value are always not captured by the safety module.

The signals with the duration of equal to or longer than "input delay parameter" + "input delay accuracy" are always captured by the safety module, provided that the allowed frequency (see previous Notice) of the safety input signal is not exceeded.

The "input delay accuracy" can be estimated based on the following assumptions:

- If no test pulses are configured for the given digital safety input, then input delay accuracy can be calculated as 1 % of set input delay value (however, input delay accuracy value must be at least 0.5 ms!).
- If test pulses are configured for the given digital safety input of DX581-S module, then the following input delay accuracy values can be estimated based on the input delay parameter value:

Input delay (ms)	Input delay accuracy (ms)
1	2
2	2
5	3
10	4
15	5
30	6
50	10
100	15
200	25
500	50

- Checking of process power supply (Diagnostic message is sent from the Safety I/O module to the CPU informing about the lack of process power supply for the given Safety I/O module). This function is a non-safety one and is not related to the internal safety-relevant over- and undervoltage detection.
- 2 channel equivalent and 2 channel antivalent mode with discrepancy time monitoring (configurable 10 ms ... 30 s).

**! NOTICE!**

In a 2 channel mode, the lower channel (channels 0/4 → Channel 0, channels 1/5 → Channel 1, etc.) transports the aggregated process value, PROFIsafe diagnostic bit, acknowledgement request and acknowledge reintegration information. The higher channel always provides the passivated value "0".

## AC500-S Safety Modules

DX581-S digital safety input/output module > Functionality

### DANGER!

After discrepancy time error, the relevant channels are passivated. As soon as a valid sensor state is observed (equivalent or antivalent, depending on the selected mode), reintegration request status bit for the given channel becomes TRUE. You can acknowledge an error using acknowledge reintegration command bit for the given channel. This can directly lead to the machine start, because both TRUE – TRUE and FALSE – FALSE are valid states for equivalence and TRUE – FALSE and FALSE – TRUE are valid states for antivalence.

Make sure that such behaviour is acceptable in your safety application. If no, then you can use either included PLCopen Safety POU's for 2 channel evaluation in your safety programm or write your own POU's for 2 channel evaluation on SM560-S Safety CPU.

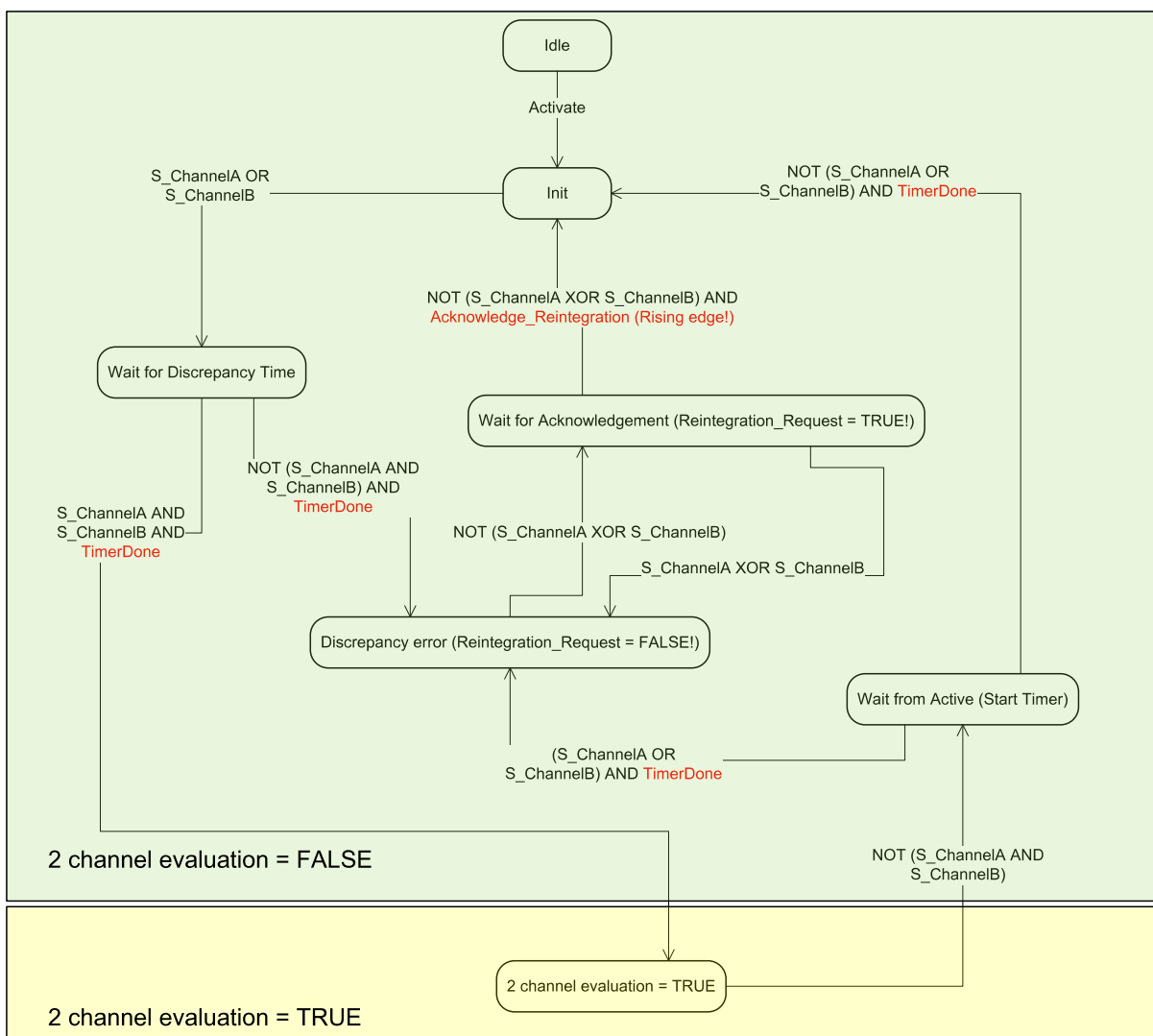


Fig. 37: 2 channel equivalent mode implemented in DX581-S

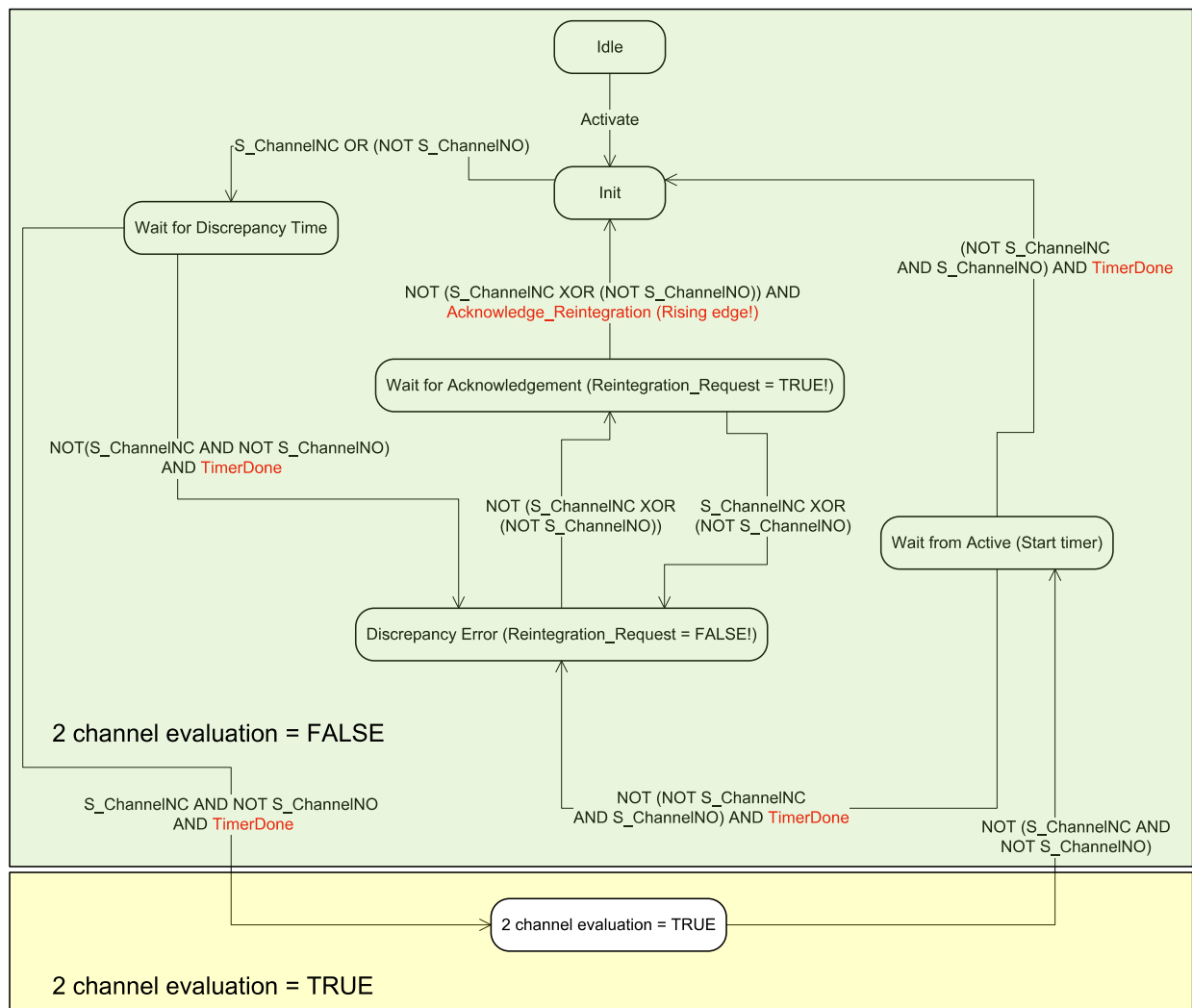


Fig. 38: 2 channel antivalent mode implemented in DX581-S

## ! NOTICE!

2 channel equivalent and 2 channel antivalent modes are implemented in DI581-S and DX581-S module to handle relatively static safety signals, e.g., those for emergency stop devices.

If frequently changing signals, like those from light curtains, laser scanners, door switches, etc. must be handled by DI581-S and DX581-S, then it is highly recommended to configure related channels in 1 channel mode and do 2 channel equivalent and 2 channel antivalent evaluation at SM560-S Safety CPU using PLCopen Safety FBs SF\_Equivalent and SF\_Antivalent ( [Chapter 4.6.6.2 “SF\\_Equivalent” on page 269](#) and [Chapter 4.6.6.3 “SF\\_Antivalent” on page 274](#)).

DX581-S contains 8 safety digital output channels with the following features:

- Internal output channel tests can be switched off.

## AC500-S Safety Modules

DX581-S digital safety input/output module > Mounting, dimensions and electrical connection

### **DANGER!**

If for one of the output channels you set Detection = OFF, the warning appears that the output channel does not satisfy SIL3 (IEC 62061) and PL e (EN ISO 13849) requirements in such condition. Two safety output channels may have to be used to satisfy required SIL or PL level.

The parameter "Detection" was created for customers who want to use safety outputs of DX581-S for SIL1 (or maximum SIL2 under special conditions) or PL c (or maximum PL d under special conditions) safety functions and have less internal DX581-S pulses visible on the safety output line. Such internal pulses could be detected as LOW signal by, for example, drive inputs, which would lead to unintended machine stop.

### **DANGER!**

Short-circuit to the ground for output channels in DX581-S module is monitored. However, short-circuit to 24 V DC on the output wire is not monitored. End-users have to take appropriate actions (e.g., on the application side by defining appropriate test periods for safety function or by reading back the status of the output wire using one of available safety digital inputs) to satisfy their respective IEC 62061 and EN ISO 13849 requirements, if short-circuit to 24V DC cannot be excluded.

### **DANGER!**

If an error is detected for the given safety output channel, it is directly passivated by DX581-S module.

Note that for some errors, the reintegration request bit for passivated output channels is automatically set to HIGH as soon as the channel is passivated and the expected LOW state ("0" value) was reached by the output channel. Such behavior can be seen for some errors because DX581-S module is not able in the LOW ("0" value) output channel state to check if previously detected errors which lead to the channel passivation still exist or not.

If the user attempts to reintegrate such output channels using relevant acknowledge reintegration bits, he will succeed but if the error is still present, the relevant channels will be passivated in the next DX581-S error detection cycle.

In the case of internal output module errors, the complete module will be passivated.

### 3.4.3 Mounting, dimensions and electrical connection

The input/output modules can be plugged only on spring-type TU582-S I/O Terminal Unit. The unique mechanical coding on I/O Terminal Units prevents a potential mistake of placing the Non-safety I/O module on Safety I/O Terminal Unit and the other way around.

Installation and maintenance have to be performed according to the technical rules, codes and relevant standards, e.g. EN 60204 part 1, by skilled electricians only.

## Assembly of DX581-S



### DANGER!

Hot plug and hot swap of energized modules is not permitted. All power sources (supply and process voltages) must be switched off while working on any AC500 system, including Safety Modules.

Properly seat the module and press until it locks in place with a force of about 100 Newton. The Terminal Unit is mounted on a DIN rail or with 2 screws plus the additional accessory for wall mounting (TA526).

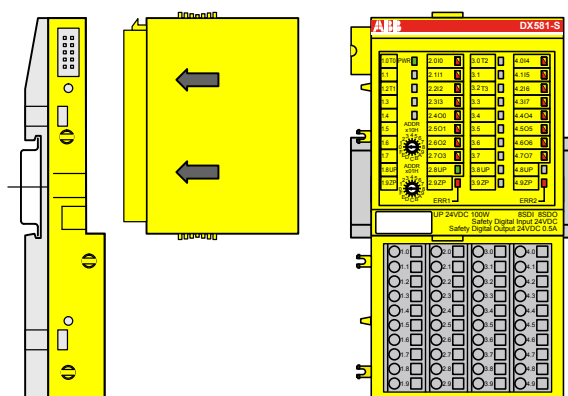


Fig. 39: Assembly instructions

1. ➡ Put the module on the terminal unit.  
⇒ The module clicks in.
2. ➡ Then press the module with a force of at about 100 Newton in the arrow direction.

## Disassembly of DX581-S

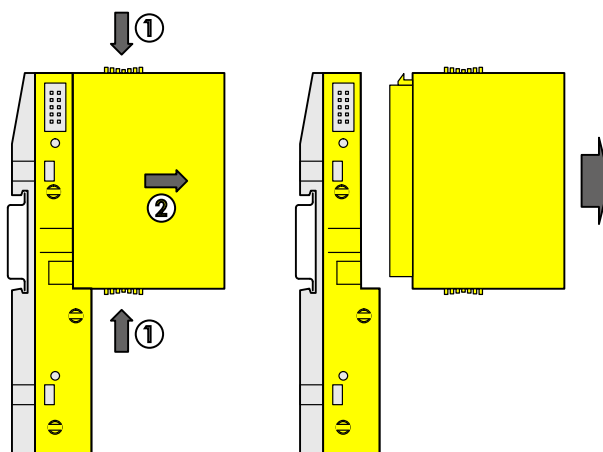


Fig. 40: Disassembly instructions

- ➡ Press above and below, then remove the module.

## AC500-S Safety Modules

DX581-S digital safety input/output module > Mounting, dimensions and electrical connection

### Dimensions

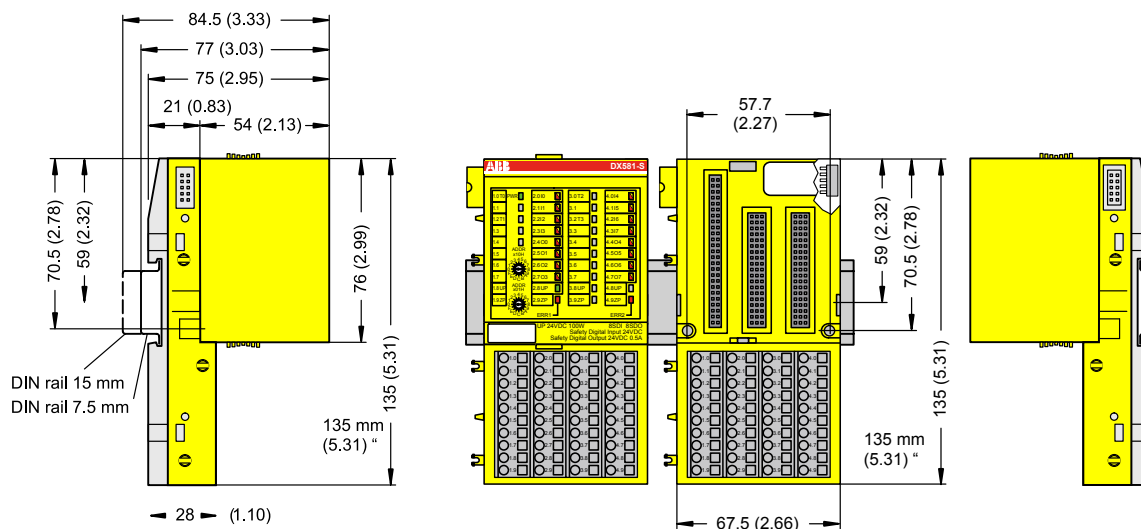


Fig. 41: Dimensions of DX581-S Safety I/O module

### Electrical connection

#### ! NOTICE!

The same TU582-S is used by all AC500-S Safety I/O modules. If TU582-S is wired for DX581-S module with Safety digital outputs and DI581-S or AI581-S modules are occasionally placed on this terminal unit, under no circumstances it is possible that Safety digital output clamps on TU582-S become energized due to a wrongly placed DI581-S and AI581-S Safety I/O modules.

The electrical connection of the I/O channels is carried out using 40 terminals of the I/O Terminal Unit. I/O modules can be replaced without re-wiring the Terminal Units.

The terminals 1.8, 2.8, 3.8 and 4.8 as well as 1.9, 2.9, 3.9 and 4.9 are electrically interconnected within the I/O Terminal Unit and have always the same assignment, independent of the inserted module:

- Terminals 1.8, 2.8, 3.8 and 4.8: Process voltage UP = +24 V DC
- Terminals 1.9, 2.9, 3.9 and 4.9: Process voltage ZP = 0 V

The assignment of the other terminals:

Terminals	Signal	Meaning
1.0, 1.2, 3.0, 3.2	T0, T1, T2, T3	Connectors of 4 test pulse outputs T0, T1, T2, T3
2.0 ... 2.3, 4.0 ... 4.3	I0, I1, I2, I3, I4, I5, I6, I7	8 safety digital inputs
2.4 ... 2.7, 4.4 ... 4.7	O0, O1, O2, O3, O4, O5, O6, O7	8 safety digital outputs
1.8, 2.8, 3.8, 4.8	UP	Process power supply +24 V DC



Terminals	Signal	Meaning
1.9, 2.9, 3.9, 4.9	ZP	Central process earth
1.1, 1.3, 1.4, 1.5, 1.6, 1.7, 3.1, 3.3, 3.4, 3.5, 3.6, 3.7	Free	Not used

## ! NOTICE!

The process voltage must be included in the earthing concept of the control system (e.g., earthing the minus pole).

### Examples of connections

Examples of electrical connections with DX581-S module, single channels Ix and Ox.

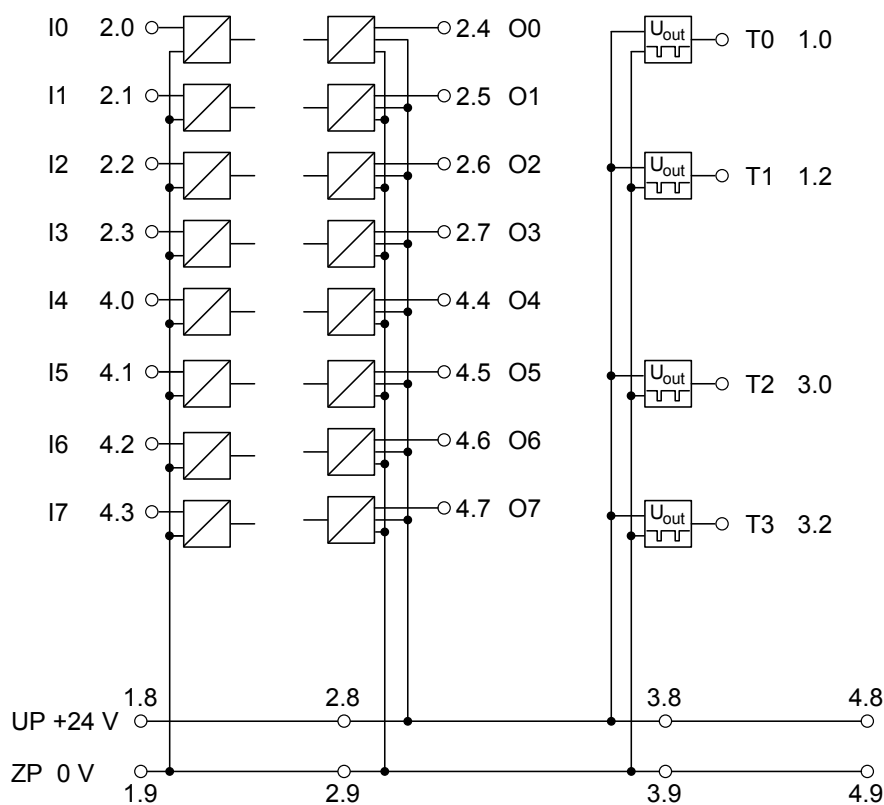


Fig. 42: Example of electrical connections with DX581-S

## AC500-S Safety Modules

DX581-S digital safety input/output module > I/O configuration

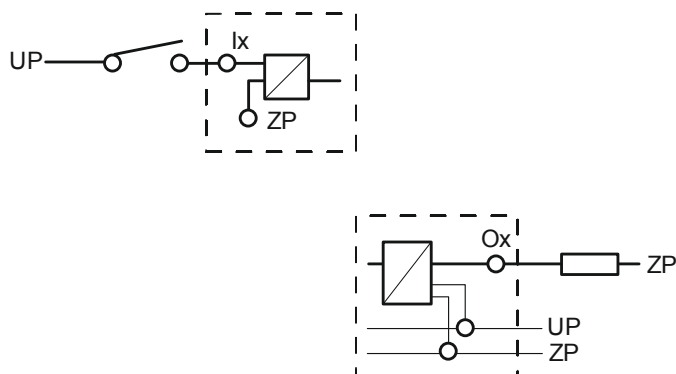


Fig. 43: Example of single channels with DX581-S

### 3.4.4 Internal data exchange

Inputs (bytes)	5
Outputs (bytes)	3

### 3.4.5 I/O configuration

The safety digital input/output module DX581-S does not store configuration data itself. The configuration data is stored on SM560-S and PM5xx CPUs.

## 3.4.6 Parameterization

The arrangement of the parameter data is performed by your system configuration software PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer). ABB GSDML file for PROFINET devices can be used to configure DX581-S parameters in 3<sup>rd</sup> party PROFINET F-Host systems.

The parameter setting directly influences the functionality of modules and reachable SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849).

No.	Name	Values	Default
1	Check supply	"On", "Off"	"On"
<b>Inputs</b>			
2	Input channel Configuration	"Not used", "1 channel", "2 channel equivalent", "2 channel antivalent"	"Not used"
3	Test pulse	"Disabled", "Enabled"	"Disabled"
4	Input delay	"1 ms", "2 ms", "5 ms", "10 ms", "15 ms", "30 ms", "50 ms", "100 ms", "200 ms", "500 ms"	"5 ms"
5	Discrepancy time*	"10 ms", "20 ms", "30 ms", "40 ms", "50 ms", "60 ms", "70 ms", "80 ms", "90 ms", "100 ms", "150 ms", "200 ms", "250 ms", "300 ms", "400 ms", "500 ms", "750 ms", "1 s", "2 s", "3 s", "4 s", "5 s", "10 s", "20 s", "30 s"	"50 ms"
<b>Outputs</b>			
6	Output channel configuration	"Not used", "Used"	"Not used"
7	Detection (internal output channel test)	"Off", "On"	"On"

\* Available only for "2 channel equivalent" and "2 channel antivalent" configuration

## 3.4.7 Circuit examples

Examples of electrical connections and reachable SIL (CL) (IEC 61508 ed. 2 and IEC 62061), PL (ISO 13849) and Category (EN 954) with DX581-S module are presented below. Note, that electrical connections presented for DI581-S safety input channels are also valid for DX581-S safety input channels.

### ! NOTICE!

Whenever DC = High is used in the circuit examples for safety digital inputs, the following measure from ISO 13849-1 [10] is used in DX581-S module: Cross monitoring of input signals and intermediate results within the logic (L), and temporal and logical software monitor of the program flow and detection of static faults and short circuits (for multiple I/O).

Whenever DC = Medium is used in the circuit examples for safety digital inputs, any of the measures for input devices with DC ≥ 90 % can be used from ISO 13849-1 [10].

## AC500-S Safety Modules

DX581-S digital safety input/output module > Circuit examples

### NOTICE!

Whenever DC = High is used in the circuit examples for safety digital outputs, the following measure from ISO 13849-1 [10] is used in the DX581-S module: Cross monitoring of output signals and intermediate results within the logic (L) and temporal and logical software monitor of the program flow and detection of static faults and short circuits (for multiple I/O).

Whenever DC = Medium is used in the circuit examples for safety digital outputs, any of the measures for output devices with  $DC \geq 90\%$  can be used from ISO 13849-1 [10].

### DANGER!

The reachable SIL CL (IEC 62061), SIL (IEC 61508 ed. 2) and PL (ISO 13849) levels for safety outputs of DX581-S module are only valid if the parameter Detection = "On". If the parameter Detection = "Off" then contact ABB technical support to obtain proper reachable SIL CL, SIL and PL levels.

## Relay

Sensor power supply on channel 1 (I4)	Internal using test pulse T2
Internal output channel test	Yes
SIL/Cat./PL <sup>1)</sup>	SIL 1/Cat.1/PL c
SIL <sup>2)</sup>	SIL 2
SIL/Cat./PL <sup>3)</sup>	SIL 2/Cat.2/PL d
SIL <sup>4)</sup>	SIL 3

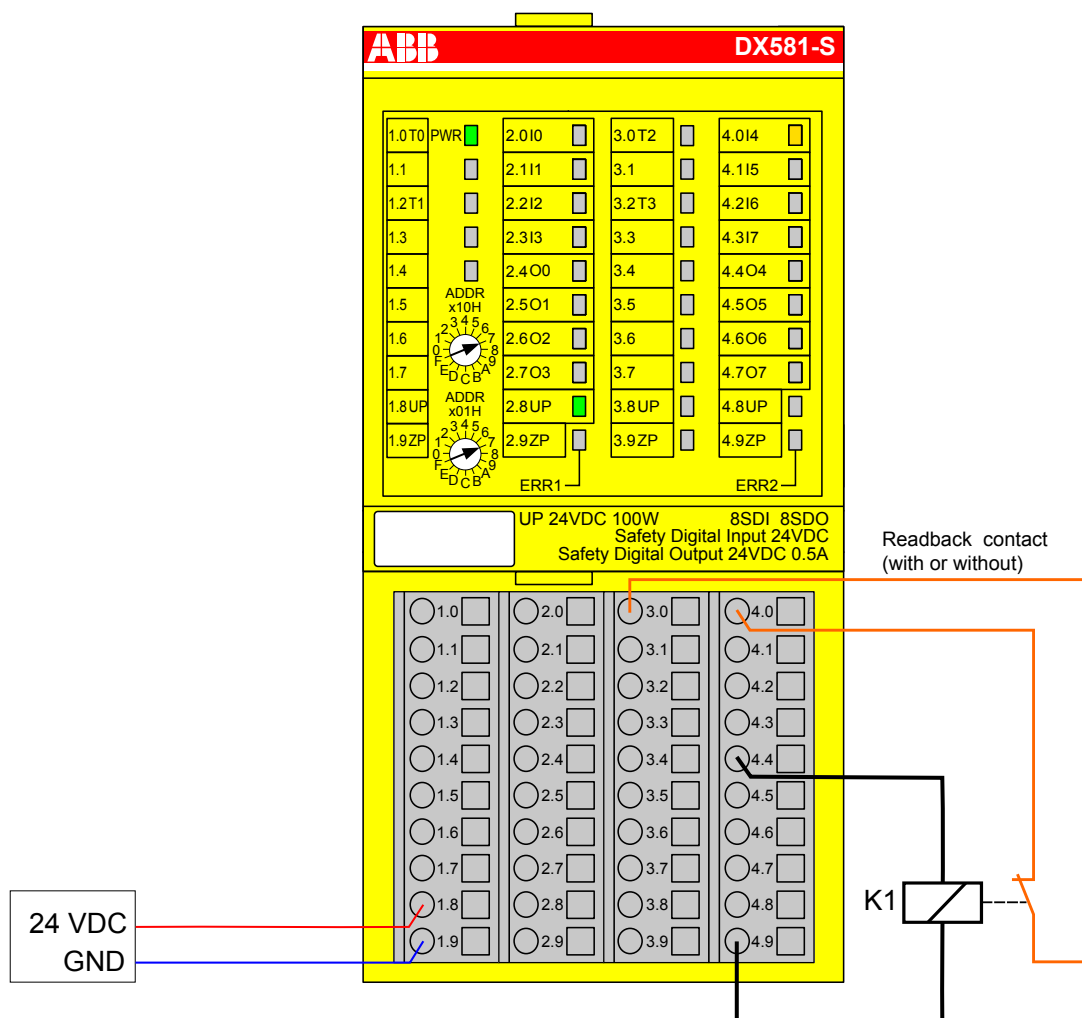


Fig. 44: Circuit example DX581-S, Relay

- <sup>1)</sup> - Without readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4, with error exclusion) MTTFd = High; DC = 0
- <sup>2)</sup> - Without readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL3 with error exclusion)

## AC500-S Safety Modules

DX581-S digital safety input/output module > Circuit examples

- <sup>3)</sup> - With readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = Medium
- <sup>4)</sup> - With readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)

## Relay (2-channel redundant)

2-channel evaluation	In SM560-S Safety CPU
Sensor power supply on channel 1 (I4)	Internal using test pulse T2
Internal output channel test	Yes
SIL/Cat./PL <sup>1)</sup>	SIL 1/Cat.1/PL c
SIL <sup>2)</sup>	SIL 3
SIL/Cat./PL <sup>3)</sup>	SIL 3/Cat.4/PL e
SIL <sup>4)</sup>	SIL 3

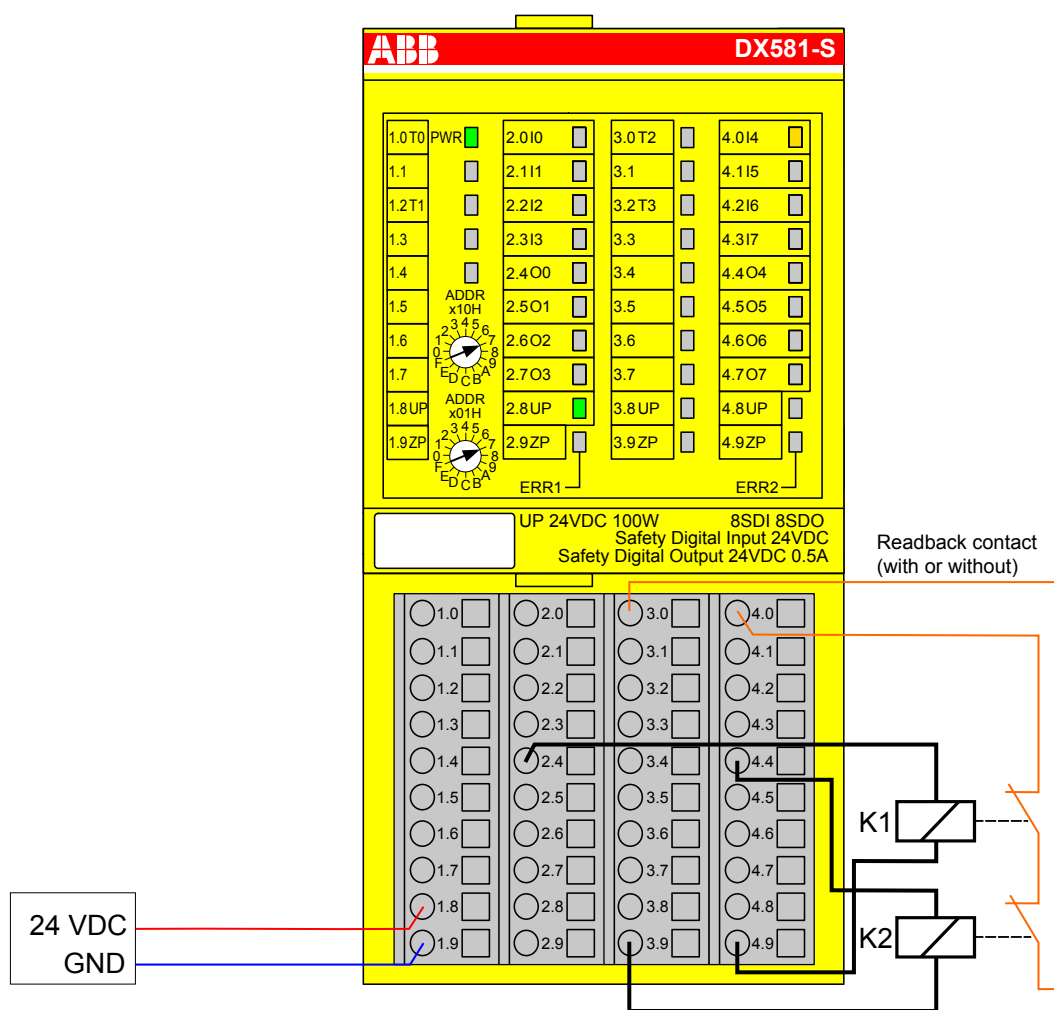


Fig. 45: Circuit example DX581-S, Relay (2-channel redundant)

- 1) - Without readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = 0
- 2) - Without readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)

## AC500-S Safety Modules

DX581-S digital safety input/output module > Circuit examples

- <sup>3)</sup> - With readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = High
- <sup>4)</sup> - With readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)



## Transistor input (1-channel)

Sensor power supply on channel 1 (I4)	Internal using test pulse T2
Internal output channel test	Yes
SIL/Cat./PL <sup>1)</sup>	SIL 1/Cat. 1/PL c
SIL <sup>2)</sup>	SIL 2
SIL/Cat./PL <sup>3)</sup>	SIL 2/Cat. 2/PL d
SIL <sup>4)</sup>	SIL 3

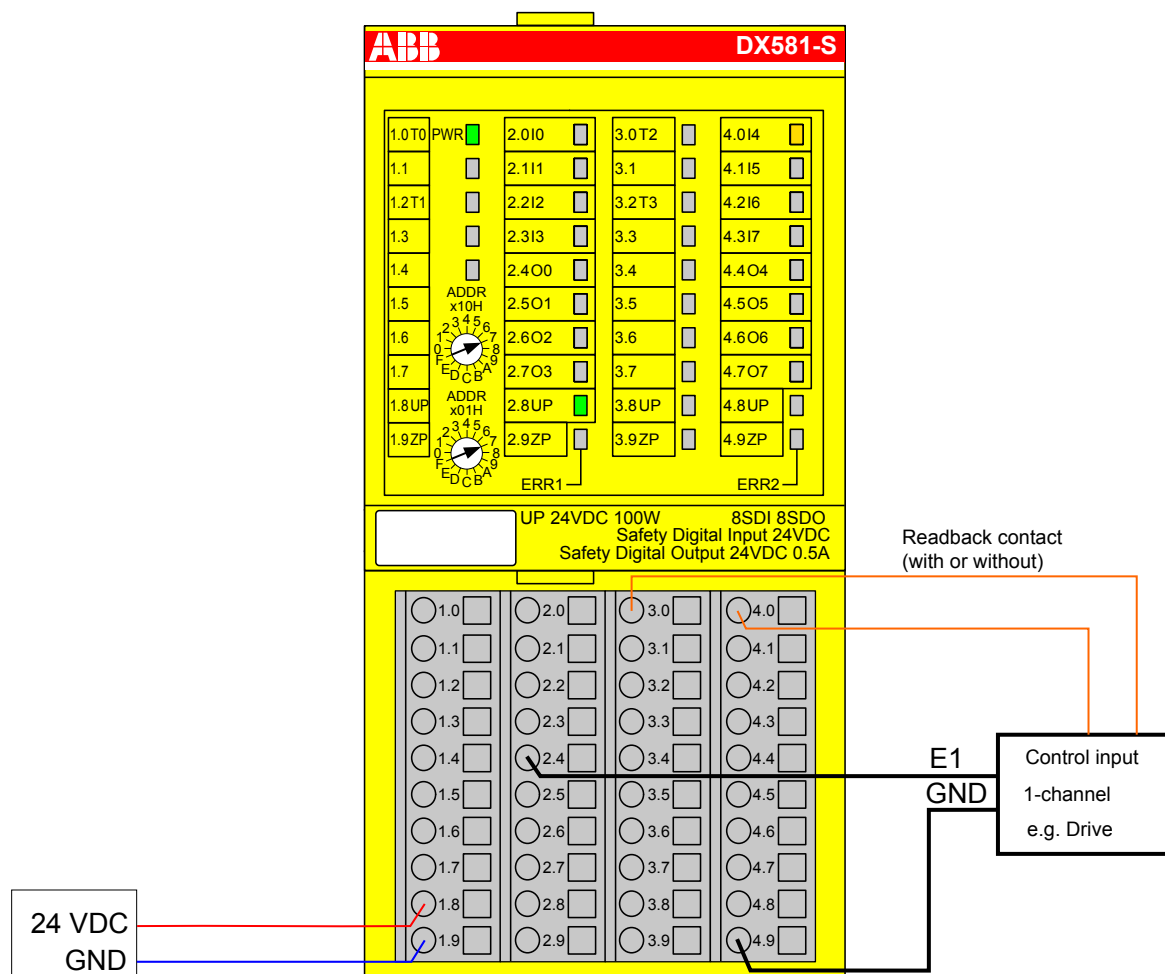


Fig. 46: Circuit example DX581-S, Transistor input (1-channel)

- 1) - Without readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = 0
- 2) - Without readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)
- 3) - With readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = Medium

## AC500-S Safety Modules

DX581-S digital safety input/output module > Circuit examples

- <sup>4)</sup> - With readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)

## Transistor input (2-channel)

2-channel evaluation	In SM560-S Safety CPU
Sensor power supply on channel 1 (I4)	Internal using test pulse T2
Internal output channel test	Yes
SIL/Cat./PL <sup>1)</sup>	SIL 1/Cat.1/PL c
SIL <sup>2)</sup>	SIL 3
SIL/Cat./PL <sup>3)</sup>	SIL 3/Cat.4/PL e
SIL <sup>4)</sup>	SIL 3

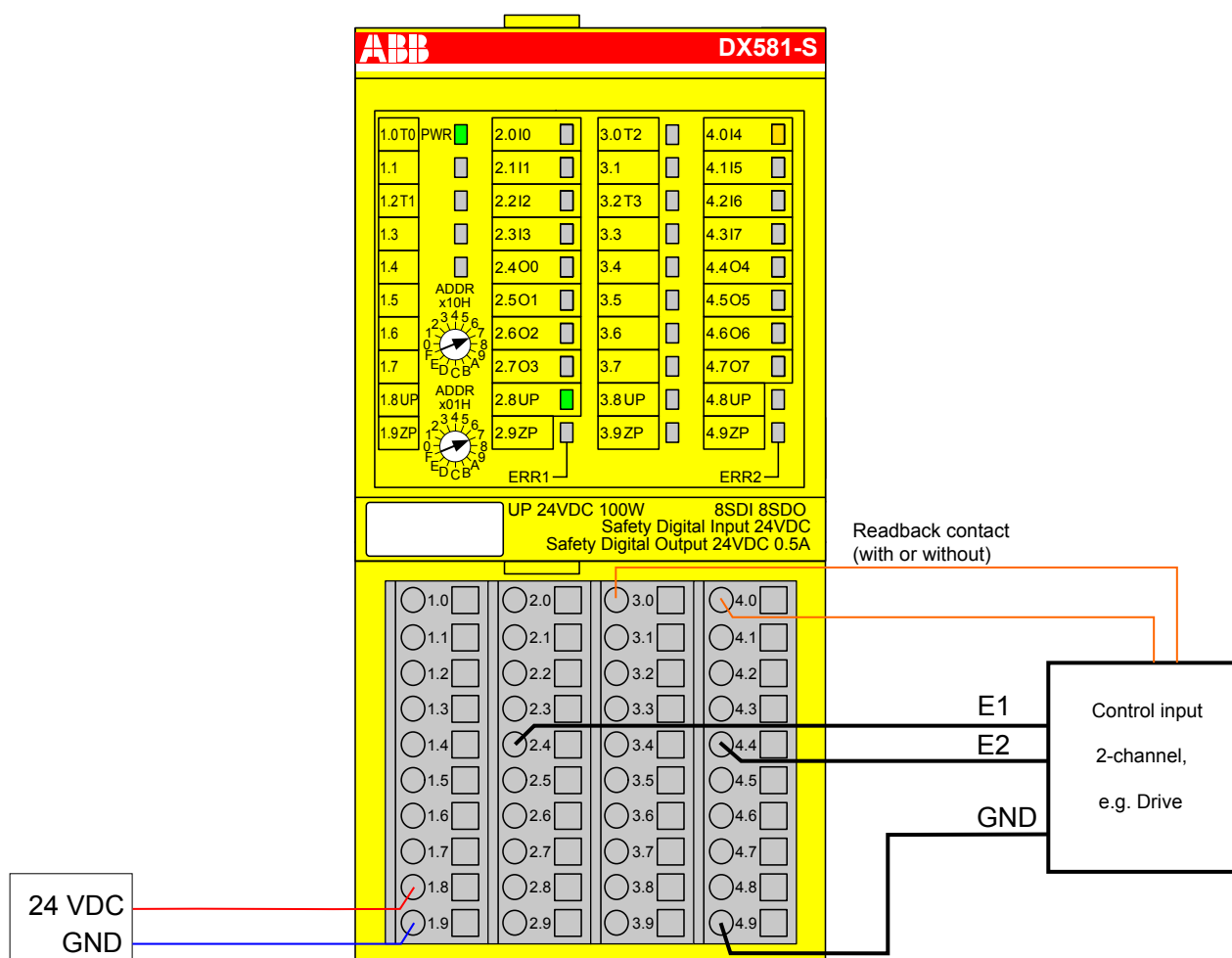


Fig. 47: Circuit example DX581-S, Transistor input (2-channel)

- 1) - Without readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = 0
- 2) - Without readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)
- 3) - With readback contact: Max reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion) MTTFd = High; DC = Medium

## AC500-S Safety Modules

DX581-S digital safety input/output module > LED status display

- 4) - With readback contact: Max reachable SIL acc. IEC 61508 (Typ A components are required) → without error exclusion (you can reach higher level up to SIL 3 with error exclusion)

### Application example

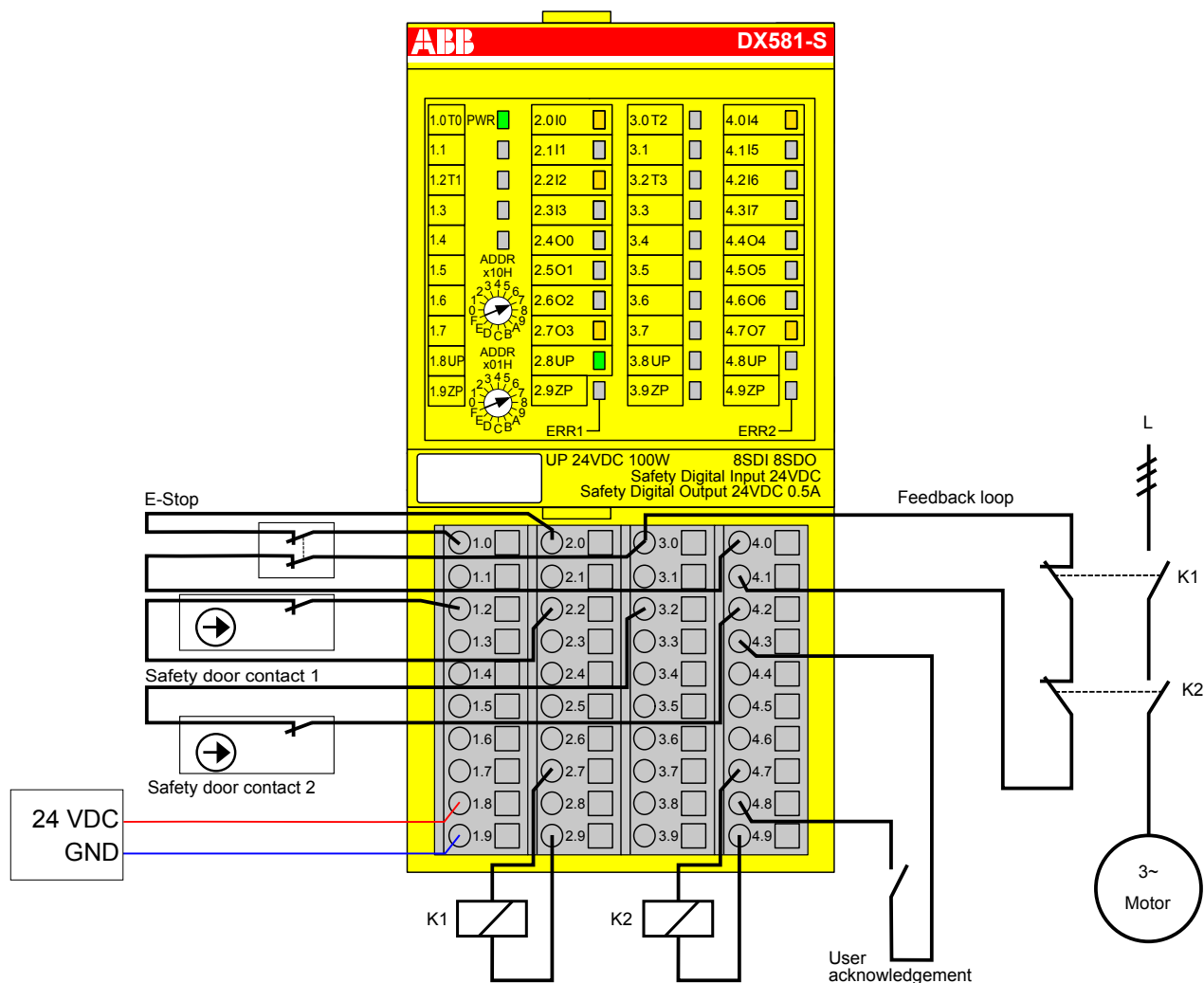


Fig. 48: Application example with DX581-S

### 3.4.8 LED status display

Table 8: Status display and its meaning

LED	Description	Colour	LED = OFF	LED = ON	LED flashes
Inputs 0 ... 7	Digital input	Yellow	Input = OFF	Input = ON (the input voltage is displayed even if the supply voltage is OFF).	--
	Channel error	Red	No channel error	Channel error	--

LED	Description	Colour	LED = OFF	LED = ON	LED flashes
Outputs 0 ... 7	Digital output	Yellow	Output = OFF	Output = ON	--
	Channel error	Red	No channel error	Channel error	--
UP	Process voltage +24 V DC via terminal	Green	Process supply voltage is missing	Process supply voltage OK	--
PWR	+3.3 V voltage from IO-Bus	Green	+3.3 V IO-Bus voltage is not avail- able	+3.3 V IO-Bus voltage is available	--
ERR1	Module error indicator 1	Red	No module error	Module error which leads to a SAFE STOP state	Module passivation and/or acknowl- edgement request (alternating blinking)
ERR2	Module error indicator 2	Red			

## 3.4.9 Technical data

### ! NOTICE!

DX581-S-XC version is available for usage in extreme environmental conditions ( ↗ *Appendix "System data for AC500-S-XC" on page 446*).

## AC500-S Safety Modules

DX581-S digital safety input/output module > Technical data

### Process supply voltage UP

Data	Value	Unit
Connections Terminals 1.8 ... 4.8 (UP)	+24	V
Connections Terminals 1.9 ... 4.9 (ZP)	0	V
Rated value (– 15 %, +20 %, without ripple)	24	V DC
Max. ripple	5	%
Protection against reversed voltage	yes	
Rated protection fuse for UP (fast)	10	A
Electrical isolation	per module	
Mechanisms in which I/Os are processed	periodically refreshed	
Current consumption from UP at normal operation with + 24 V DC (for module electronics)	0.18	A
Inrush current from UP at 30 V (at power up)	0.1	A <sup>2</sup> s
Inrush current from UP at 24 V (at power up)	0.06	A <sup>2</sup> s

#### **! NOTICE!**

All DX581-S channels (including test pulse outputs) are protected against reverse polarity, reverse supply, short circuit and continuous overvoltage up to 30 V DC.

### Mounting position

Horizontal or vertical with derating (output load reduced to 50 % at +40 °C per group and with maximal operating temperature reduced to +40 °C).

### Cooling

The natural convection cooling must not be hindered by cable ducts or other parts in the switchgear cabinet.

**Allowed interruptions of power supply, according to EN 61131-2**

Data	Value	Unit
DC supply interruptions	< 10	ms
Time between 2 DC supply interruptions, PS2	> 1	s

**Environmental conditions**

Data	Value	Unit
Operating temperature*	0 ... +60	°C
Storage temperature	−40 ... +85	°C
Transport temperature	−40 ... +85	°C
Humidity without condensation	max. 95	%
Operating air pressure	> 800	hPa
Storage air pressure	> 660	hPa
Operating altitude	< 2000	m above sea level
Storage altitude	< 3500	m above sea level

\* Extended temperature ranges (below 0 °C and above +60 °C) can be supported in special versions of DX581-S ( ↪ *Appendix "System data for AC500-S-XC" on page 446*)

**Creepage distances and clearances**

The creepage distances and clearances meet the overvoltage category II, pollution degree 2.

**Power supply units**

For the supply of modules, power supply units according to PELV/SELV specifications must be used.

**Electromagnetic compatibility**

↪ *TÜV Report [2]*

## AC500-S Safety Modules

DX581-S digital safety input/output module > Technical data

Data	Value	Unit
Degree of protection	IP 20	
Housing	according to UL 94	
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 3.5 mm	2 ... 15	Hz
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 1 g *	15 ... 150	Hz
Shock test (all three axes), 11 ms half-sinusoidal	15	g
MTBF	73	years

\* Higher values on request

### Self-test and diagnostic functions

Start-up and runtime tests: Program flow control, RAM, CPU, cross-talk, stuck-at-1, etc.



### Dimensions, weight

Data	Value	Unit
W x H x D	67.5 x 76 x 62	mm
Weight	~ 130	g

### Certifications

CE, cUL (↗ further certifications at [www.abb.com/plc](http://www.abb.com/plc))

## AC500-S Safety Modules

DX581-S digital safety input/output module > Technical data

### 3.4.9.1 Technical data of safety digital inputs

Data	Value	Unit
Number of input channels per module	8	
Terminals of the channels I0 to I3	2.0 ... 2.3	
Terminals of the channels I4 to I7	4.0 ... 4.3	
Terminals of reference potential for all inputs (minus pole of the process supply voltage, signal name ZP)	1.9 ... 4.9	
Electrical isolation from the rest of the module (I/O-Bus)	Yes	
Input type acc. to EN 61131-2	Type 1	
Input delay (0 → 1 or 1 → 0), configurable	1 ... 500	ms

#### Input signal indication

One yellow LED per channel, the LED is ON when the input signal is high (signal 1).

## Signal voltage

Data	Value	Unit
Input signal voltage	24	V DC
Signal 0	-3 ... +5	V
Undefined signal	> +5 ... < +15	V
Signal 1	+15 ... +30	V

## Input current per channel

Data	Value	Unit
Input voltage +24 V, typically	7	mA
Input voltage +5 V	< 1	mA
Input voltage +15 V	> 4	mA
Input voltage +30 V	< 8	mA

## Cable length

Data	Value	Unit
Max. cable length, shielded	1000	m
Max. cable length, unshielded	600	m

### 3.4.9.2 Technical data of safety digital outputs



#### **DANGER!**

Exceeding the maximum process or supply voltage range (< -35 V DC or > +35 V DC) could lead to unrecoverable damage of the system.

## AC500-S Safety Modules

DX581-S digital safety input/output module > Technical data

Data	Value	Unit
Number of channels per module (transistor outputs)	8	
Terminals of reference potential for all outputs (minus pole of the process supply voltage, signal name ZP)	1.9 ... 4.9	
Terminals of common power supply voltage for all outputs (plus pole of the process supply voltage, signal name UP)	1.8 ... 4.8	
Output voltage for signal 1	UP – 3	V
Output delay (0 → 1 or 1 → 0)	on request	

### Output current

Data	Value	Unit
Rated value, per channel at UP = 24 V	500	mA
Maximum value (all channels together)	4	A
Leakage current with signal 0	< 0.5	mA
Short-circuit proof/overload proof	yes	
Overload message (channel passivation), $I > 0.7$ A	yes	
Output current limitation (automatic reactivation after short-circuit/overload)	yes	
Resistance to feedback against 24 V signals	yes	
Demagnetization by internal suppressor diodes when switching off inductive loads	yes	
Rated protection fuse on UP	4.5	A

### Switching frequency

Data	Value
With resistive load	on request
With inductive loads	on request

### Cable length

Data	Value	Unit
Max. cable length, shielded	1000	m
Max. cable length, unshielded	600	m

## 3.4.9.3 Technical data of non-safety test pulse outputs

Data	Value	Unit
Number of test pulse channels per module (transistor test pulse outputs)	4	
Terminals of the channels T0, T1	1.0, 1.2	
Terminals of the channels T2 to T3	3.0, 3.2	
Terminals of reference potential for all test pulse outputs (minus pole of the process supply voltage, signal name ZP)	1.9 ... 4.9	
Terminals of common power supply voltage for all outputs (plus pole of the process supply voltage, signal name UP)	1.8 ... 4.8	
Output voltage for signal 1	UP – 0.8	V
Length of test pulse 0 phase	1	ms

## Output current

Data	Value	Unit
Rated value, per channel	10	mA
Maximum value (all channels together)	40	mA
Short-circuit proof / overload proof	yes	
Output current limitation	65	mA
Resistance to feedback against 24V signals	yes	

## Cable length

Data	Value	Unit
Max. cable length, shielded	1000	m
Max. cable length, unshielded	600	m

## 3.4.10 Ordering data

Type	Description	Order code
DX581-S	DX581-S:S500, Safety Digital I/O Module 8SDI/SDO	1SAP 284 100 R0001
DX581-S-XC	DX581-S-XC:S500, Safety Digital I/O Module 8SDI/SDO, Extreme Conditions	1SAP 484 100 R0001

## AC500-S Safety Modules

AI581-S analog safety input module > Purpose

### 3.5 AI581-S analog safety input module

#### Elements of the module

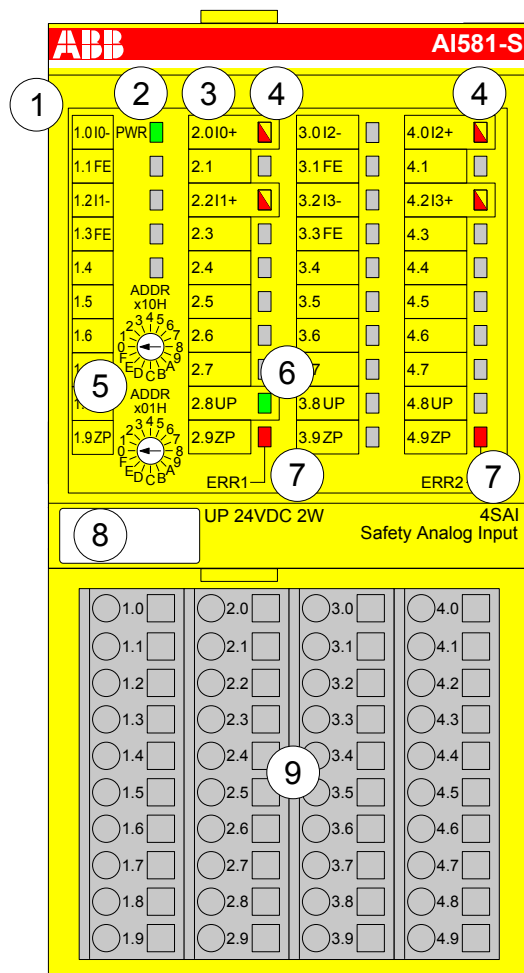


Fig. 49: Safety analog input module AI581-S, plugged on Terminal Unit TU582-S

- 1 I/O-Bus
- 2 System LED
- 3 Allocation terminal No. – signal name
- 4 4 yellow/red LEDs signal status I0 ... I1/I2 ... I3
- 5 2 rotary switches for PROFIsafe address
- 6 Green LED process voltage UP
- 7 Red LEDs to display errors
- 8 Label (TA525)
- 9 I/O Terminal Unit (TU582-S)

#### 3.5.1 Purpose

Safety analog input module AI581-S can be used as a remote expansion module at CI501-PNIO, CI502-PNIO, CI504-PNIO and CI506-PNIO PROFINET modules (Release date: 2013 and newer) or locally at AC500 CPUs for up to SIL3 (IEC 61508 ed. 2 and IEC 62061) and PL e (ISO 13849) safety applications.

### **! NOTICE!**

SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849) reachable in your safety application depend on the wiring of your sensors to AI581-S module ( ↗ *Chapter 3.5.7 “Circuit examples” on page 144*).

AI581-S contains 4 safety current analog inputs separated in two groups (2.0 ... 2.2 and 4.0 ... 4.2) with no potential separation between the channels.

The inputs are not electrically isolated from the other electronic circuitry of the module.

## AC500-S Safety Modules

AI581-S analog safety input module > Functionality

### 3.5.2 Functionality

Analog inputs	4 (0 ... 20 mA or 4 ... 20 mA)
LED displays	for signal status, module errors, channel errors and supply voltage
Internal power supply	through the expansion bus interface (I/O-Bus)
External power supply	via the terminals ZP and UP (process voltage 24 V DC)

Self-tests and diagnostic functions (both start-up and runtime), like CPU and RAM tests, program flow control and cross-talk tests, etc. are implemented in AI581-S according to IEC 61508 ed. 2 SIL 3 requirements.

AI581-S contains 4 safety analog input channels with the following features:

- 14 bit resolution
- Checking of process power supply (Diagnostic message is sent from the Safety I/O module to the CPU informing about the lack of process power supply for the given Safety I/O module). This function is a non-safety one and is not related to the internal safety-relevant over- and undervoltage detection.
- Noise rejection 50 Hz or 60 Hz
- 1 channel (0 ... 20 mA), 1 channel (4 ... 20 mA) or 2 channel (4 ... 20 mA) modes (minimum or maximum value can be selected for transfer to Safety CPU in 2 channel (4 ... 20 mA) mode; Tolerance range 4 % ... 12 % can be set for 2 channel mode)

#### ! NOTICE!

In a 2 channel mode, the lower channel (channels 0/2 → Channel 0, channels 1/3 → Channel 1, etc.) transports the aggregated process value, PROFIsafe diagnostic bit, acknowledgement request and acknowledge reintegration information. The higher channel always provides the passivated value "0".

#### ! NOTICE!

The maximal internal discrepancy time between two channel values in AI581-S module is 67.5 ms, which is also an internal worst-case input delay value.

#### ! NOTICE!

The analog input channels have built-in hardware low-pass filter of 100 Hz.

#### ! NOTICE!

In case of the overcurrent/undercurrent detected at the safety analog input channel, the channel passivation takes place latest after 200 ms. The channel remains passivated for 30 seconds and then the check is performed if the overcurrent/undercurrent still present or not. If the overcurrent/undercurrent has gone, then reintegration request signal for the given channel is set to TRUE to allow channel reintegration.

The following table shows the mapping of Safety CPU process values to the values in mA from AI581-S module. Two modes are defined for an analog input 0 ... 20 mA and 4 ... 20 mA.



Range	0 ... 20 mA	4 ... 20 mA	Digital value (dec)		Digital value (hex)	
Overflow	:	:	32767*		7FFF*	
	> 23.519	> 22.81	32512*		7F00*	
Overrange	23.519	22.81	32511		7EFF	
	:	:	:		:	
	20.000723	20.000578	27649		6C01	
Nominal range	20	20	27648		6C00	
	:	:	:		:	
	:	16	20736		5100	
	:	:	:		:	
	0	4	0		0000	
Underrange	-0.000723 : -1.481	3.999421 : 1.185	0 ... 20 mA	4 ... 20 mA	0 ... 20 mA	4 ... 20 mA
			-1	-1	FFFF	FFFF
			:	:	:	:
			-2048	-4864	F800	ED00
Underflow	< -1.481	< 1.185	0 ... 20 mA	4 ... 20 mA	0 ... 20 mA	4 ... 20 mA
			-2049*	-4865*	F7FF*	ECFF*
			:	:	:	:
			-32768*	-32678*	8000*	8000*

\* In these cases, the analog channels are passivated and "0" process values are delivered to the Safety CPU.

## 3.5.3 Mounting, dimensions and electrical connection

The input modules can be plugged only on spring-type TU582-S I/O Terminal Unit. The unique mechanical coding on I/O Terminal Units prevents a potential mistake of placing the Non-safety I/O module on Safety I/O Terminal Unit and the other way around.

Installation and maintenance have to be performed according to the technical rules, codes and relevant standards, e.g. EN 60204 part 1, by skilled electricians only.

## AC500-S Safety Modules

AI581-S analog safety input module > Mounting, dimensions and electrical connection

### Assembly of AI581-S

#### DANGER!

Hot plug and hot swap of energized modules is not permitted. All power sources (supply and process voltages) must be switched off while working on any AC500 system, including Safety Modules.

Properly seat the module and press until it locks in place with a force of about 100 Newton. The Terminal Unit is mounted on a DIN rail or with 2 screws plus the additional accessory for wall mounting (TA526).

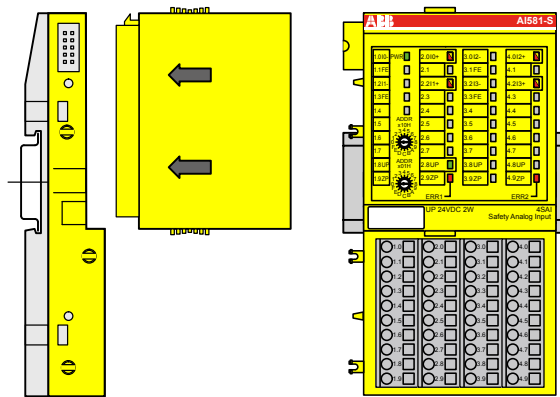




Fig. 50: Assembly instructions

1.  Put the module on the terminal unit.  
⇒ The module clicks in.
2.  Then press the module with a force of at about 100 Newton in the arrow direction.

### Disassembly of AI581-S

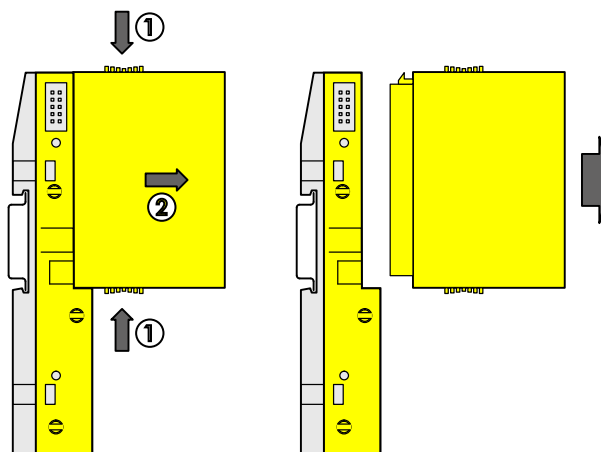


Fig. 51: Disassembly instructions

-  Press above and below, then remove the module.

## Dimensions

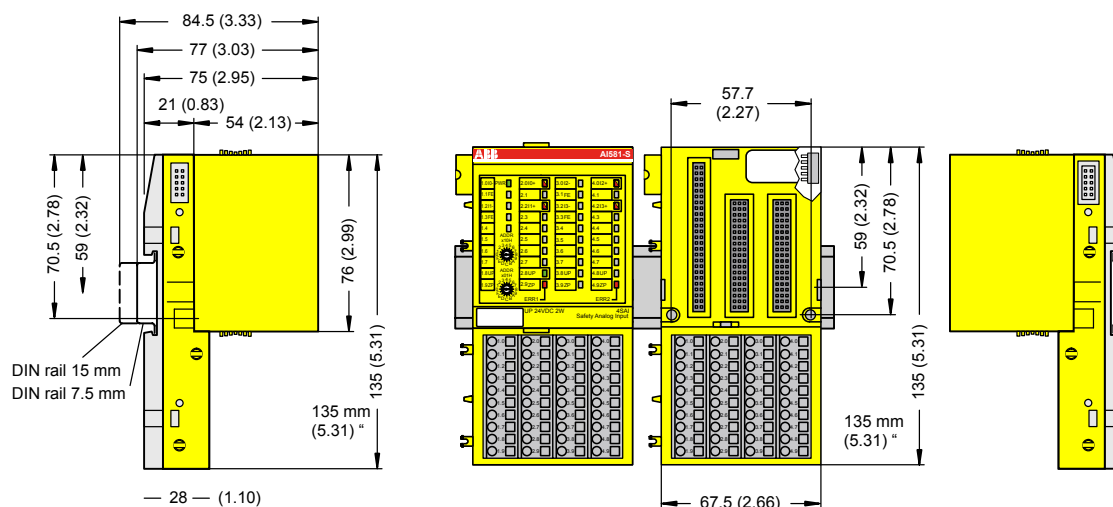


Fig. 52: Dimensions of AI581-S Safety I/O module

## Electrical connection

### ! NOTICE!

The same TU582-S is used by all AC500-S Safety I/O modules. If TU582-S is wired for DX581-S module with Safety digital outputs and DI581-S or AI581-S modules are occasionally placed on this terminal unit, under no circumstances it is possible that Safety digital output clamps on TU582-S become energized due to a wrongly placed DI581-S and AI581-S Safety I/O modules.

The electrical connection of the I/O channels is carried out using 40 terminals of the I/O Terminal Unit. I/O modules can be replaced without re-wiring the Terminal Units.

The terminals 1.8, 2.8, 3.8 and 4.8 as well as 1.9, 2.9, 3.9 and 4.9 are electrically interconnected within the I/O Terminal Unit and have always the same assignment, independent of the inserted module:

- Terminals 1.8, 2.8, 3.8 and 4.8: Process voltage UP = +24 V DC
- Terminals 1.9, 2.9, 3.9 and 4.9: Process voltage ZP = 0 V

The assignment of the other terminals:

Terminals	Signal	Meaning
1.0, 1.2, 3.0, 3.2	I0-, I1-, I2-, I3-	Negative connectors of 4 analog inputs
2.0, 2.2, 4.0, 4.2	I0+, I1+, I2+, I3+	Positive connectors of 4 analog inputs
1.1, 1.3, 3.1, 3.3	FE	Functional Earth
1.8, 2.8, 3.8, 4.8	UP	Process power supply +24 V DC

## AC500-S Safety Modules

AI581-S analog safety input module > Mounting, dimensions and electrical connection

Terminals	Signal	Meaning
1.9, 2.9, 3.9, 4.9	ZP	Central process earth
1.4 ... 1.7, 2.1, 2.3 ... 2.7, 3.4 ... 3.7, 4.1, 4.3 ... 4.7	Free	Not used

### **! NOTICE!**

The process voltage must be included in the earthing concept of the control system (e.g., earthing the minus pole).

### **! NOTICE!**

The minus poles of the analog inputs are electrically connected to each other. They form an "Analog Ground" signal for the module.

Because of their common reference potential, analog current inputs cannot be circuited in series, neither within the module nor with channels of other modules.

### **! NOTICE!**

There is no electrical isolation between the analog circuitry and ZP/UP. Therefore, analog sensors must be electrically isolated in order to avoid loops via the earth potential or supply voltage.

### **! NOTICE!**

Analog signals are always laid in shielded cables. The cable shields are earthed at both ends of the cables. In order to avoid unacceptable potential differences between different parts of the installation, low resistance equipotential bonding conductors must be laid.

For simple applications (low disturbances, no high requirement on precision), the shielding can also be omitted.

## Examples of connections

Examples of electrical connections with AI581-S module and single channels Ix.

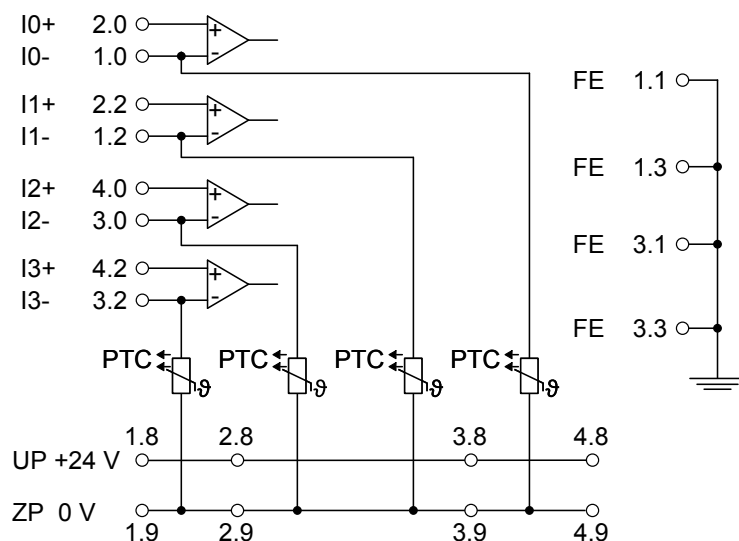


Fig. 53: Example of electrical connections with AI581-S

## ! NOTICE!

The PTC shown in the connection diagram is built-in in AI581-S module.

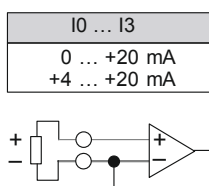


Fig. 54: Example of single channels with AI581-S

## 3.5.4 Internal data exchange

Inputs (bytes)	9
Outputs (bytes)	1

## 3.5.5 I/O configuration

The safety analog input module AI581-S does not store configuration data itself. The configuration data is stored on SM560-S and PM5xx CPUs.

## AC500-S Safety Modules

AI581-S analog safety input module > Circuit examples

### 3.5.6 Parameterization

The arrangement of the parameter data is performed by your system configuration software PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer). ABB GSDML file for PROFINET devices can be used to configure AI581-S parameters in 3<sup>rd</sup> party PROFINET F-Host systems.

The parameter setting directly influences the functionality of modules and reachable SIL (IEC 61508 ed. 2 and IEC 62061) and PL (ISO 13849).

No.	Name	Values	Default
1	Check supply	"On", "Off"	"On"
2	Configuration	"Not used", "1 channel (0 ... 20 mA)", "1 channel (4 ... 20 mA)", "2 channel (4 ... 20 mA)"	"Not used"
3	Noise rejection	"50 Hz", "60 Hz", "None"	"50 Hz"
4	Tolerance range (used only for "2 channel (4 ... 20 mA)" mode)	"4 %", "5 %", "6 %", "7 %", "8 %", "9 %", "10 %", "11 %", "12 %"	"4 %"
5	Used value (Min / Max) (used only for "2 channel (4 ... 20 mA)" mode)	"Minimum", "Maximum"	"Minimum"

### 3.5.7 Circuit examples

Examples of electrical connections and reachable SIL (CL) (IEC 61508 ed. 2 and IEC 62061), Category (EN 954) and PL (ISO 13849) with AI581-S module are presented below.

#### **! NOTICE!**

Whenever DC = High is used in the circuit examples for safety analog inputs, the following measure from ISO 13849-1 [10] is used in AI581-S module: Cross monitoring of input signals and intermediate results within the logic (L), and temporal and logical software monitor of the program flow and detection of static faults and short circuits (for multiple I/O).

Whenever DC = Medium is used in the circuit examples for safety analog inputs, any of the measures for input devices with  $DC \geq 90\%$  can be used from ISO 13849-1 [10].

## Analog sensor (0 ... 20 mA), external sensor power supply

Sensor power supply on channel 1 (I0)	External 24 V DC (Sensor)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 1/Cat.2/PL c
SIL <sup>3)</sup>	SIL 1

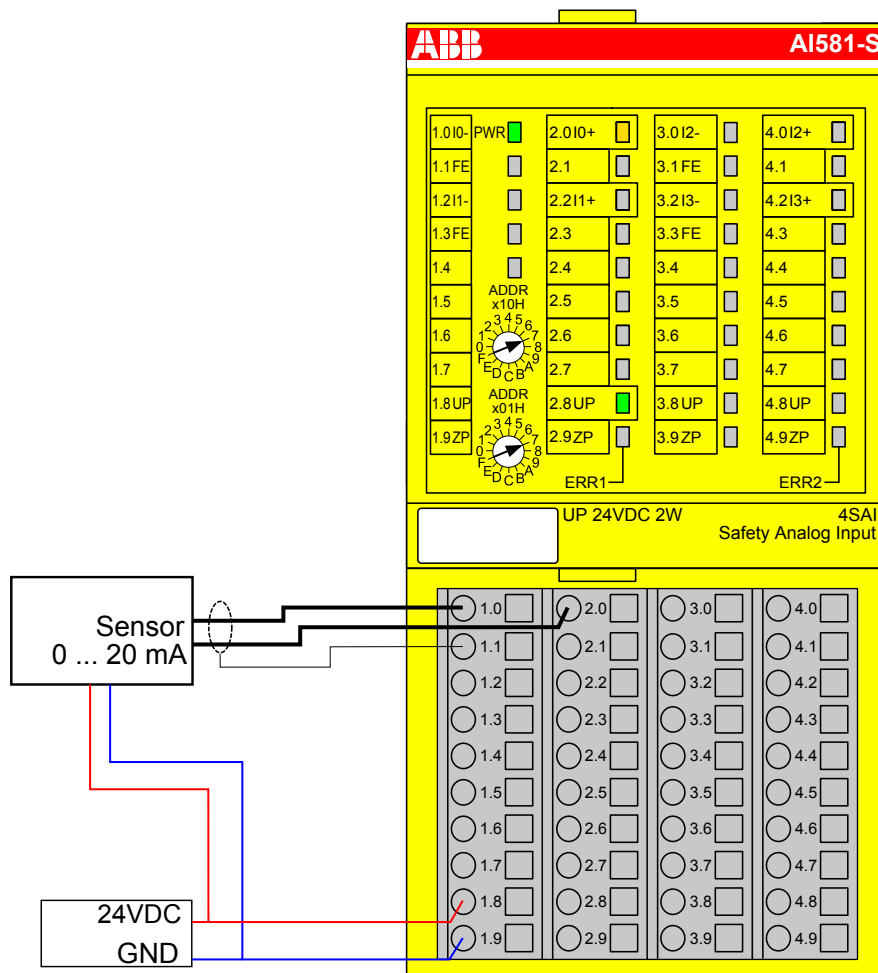


Fig. 55: Circuit example AI581-S, analog sensor (0 ... 20 mA)

- 1) - MTTFd = High, DC = Low
- 2) - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- 3) - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

AI581-S analog safety input module > Circuit examples

### 2 analog sensors (0 ... 20 mA), external sensor power supply

2-channel evaluation	In AI581-S module
Sensor power supply on channel 1 (I0)	External 24 V DC (Sensor)
Sensor power supply on channel 2 (I2)	External 24 V DC (Sensor)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat.3/PL d
SIL <sup>3)</sup>	SIL 3

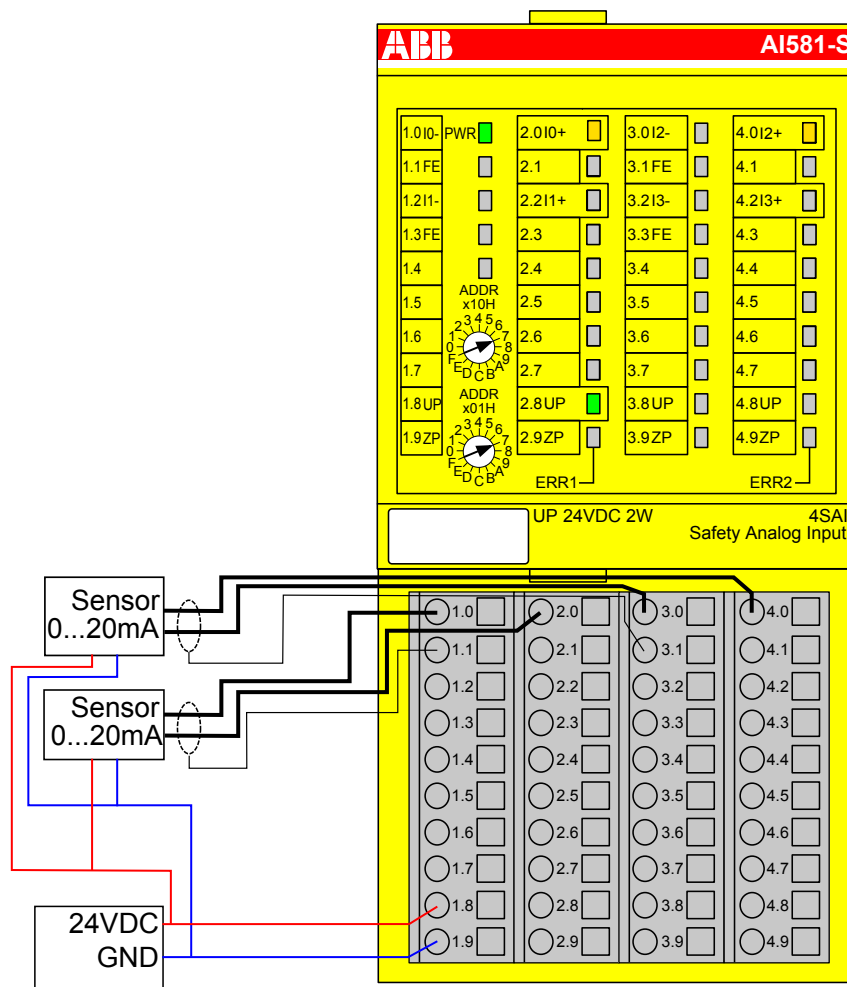


Fig. 56: Circuit example AI581-S, 2 analog sensors (0 ... 20 mA)

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)



## Analog sensor (4 ... 20 mA), external sensor power supply

Sensor power supply on channel 1 (I0)	External 24 V DC (Sensor)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 2/Cat.2/PL d
SIL <sup>3)</sup>	SIL 2

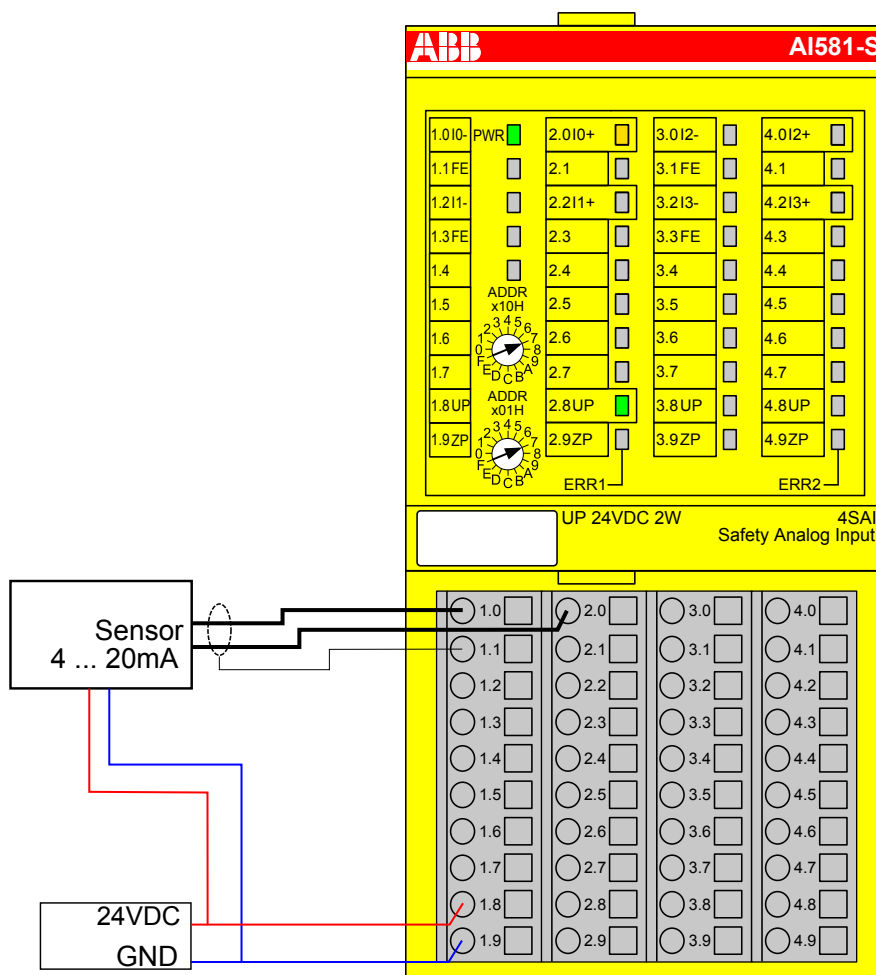


Fig. 57: Circuit example AI581-S, analog sensor (4 ... 20 mA)

- <sup>1)</sup> - MTTFd = High, DC = Medium
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)

## AC500-S Safety Modules

AI581-S analog safety input module > Circuit examples

### 2 analog sensors (4 ... 20 mA), external sensor power supply

2-channel evaluation	In AI581-S module
Sensor power supply on channel 1 (I0)	External 24 V DC (Sensor)
Sensor power supply on channel 2 (I2)	External 24 V DC (Sensor)
SIL/Cat./PL <sup>1), 2)</sup>	SIL 3/Cat.4/PL e
SIL <sup>3)</sup>	SIL 3

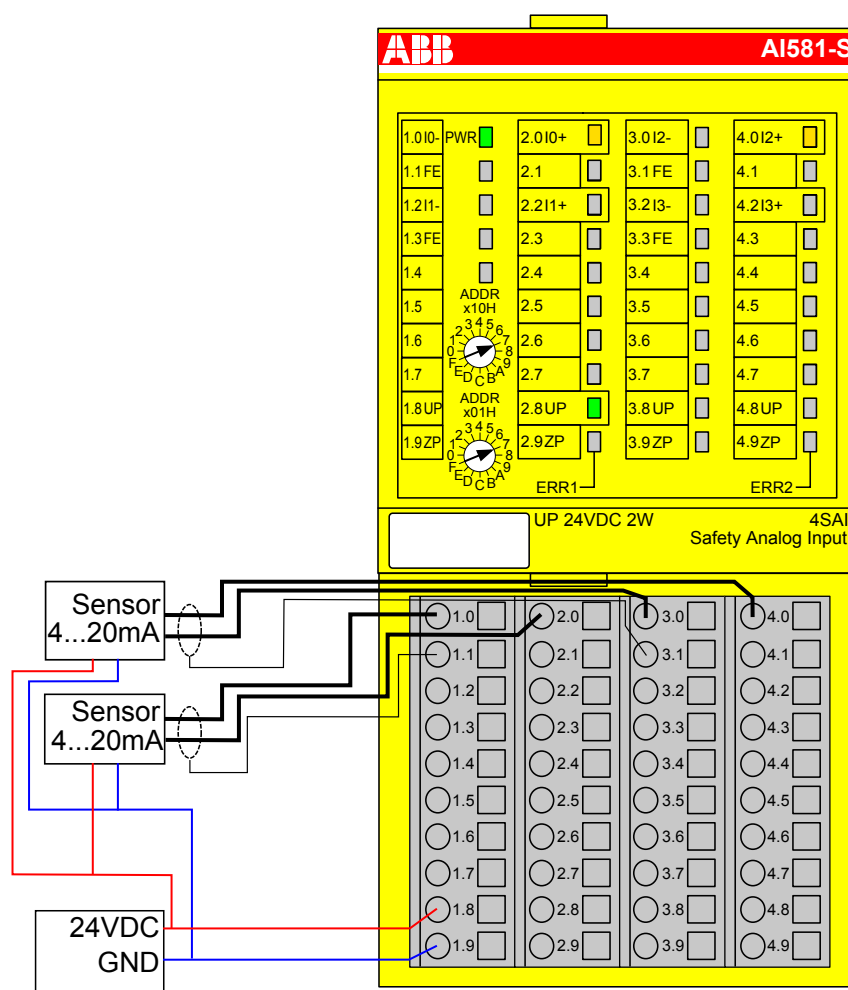


Fig. 58: Circuit example AI581-S, 2 analog sensors (4 ... 20 mA)

- <sup>1)</sup> - MTTFd = High, DC = High
- <sup>2)</sup> - Max. reachable (ISO 13849, IEC 62061, EN 954) → without error exclusion (you can reach higher levels up to PL e, SIL 3, Cat. 4 with error exclusion)
- <sup>3)</sup> - Max. reachable SIL acc. IEC 61508 (Type A components are required) → without error exclusion (you can reach higher levels up to SIL 3 with error exclusion)


### 3.5.8 LED status display

Table 9: Status display and its meaning

LED	Description	Colour	LED = OFF	LED = ON	LED flashes
Inputs 0 ... 3	Analog input	Yellow	Analog input = ca. 0 mA	Input = ON (LED light intensity depends on the input value)	--
	Channel error	Red	No channel error	Channel error	--
UP	Process voltage +24 V DC via terminal	Green	Process supply voltage is missing	Process supply voltage OK	--
PWR	+3.3 V voltage from IO-Bus	Green	+3.3 V IO-Bus voltage is not avail- able	+3.3 V IO-Bus voltage is available	--
ERR1	Module error indicator 1	Red	No module error	Module error which leads to a SAFE STOP state	Module passivation and/or acknowl- edgement request (alternating blinking)
ERR2	Module error indicator 2	Red			

### 3.5.9 Technical data

#### ! NOTICE!

AI581-S-XC version is available for usage in extreme environmental conditions (  Appendix "System data for AC500-S-XC" on page 446).

## AC500-S Safety Modules

AI581-S analog safety input module > Technical data

### Process supply voltage UP

Data	Value	Unit
Connections Terminals 1.8 ... 4.8 (UP)	+24	V
Connections Terminals 1.9 ... 4.9 (ZP)	0	V
Rated value (– 15 %, +20 %, without ripple)	24	V DC
Max. ripple	5	%
Protection against reversed voltage	yes	
Rated protection fuse for UP (fast)	10	A
Electrical isolation	per module	
Mechanisms in which I/Os are processed	periodically refreshed	
Conversion error of the analog values caused by non-linearity, adjustment error at factory and resolution within the normal range, typically	±1	%
Conversion error of the analog values caused by non-linearity, adjustment error at factory and resolution within the normal range, max.	±1.5	%
Maximum signal frequency	70	Hz
Current consumption from UP at normal operation with + 24 V DC (for module electronics)	0.18	A
Inrush current from UP at 30 V (at power up)	0.1	A²s
Inrush current from UP at 24 V (at power up)	0.06	A²s

### Mounting position

Horizontal or vertical with derating (maximal operating temperature reduced to +40 °C).

**Cable length**

Data	Value	Unit
Conductor cross section of analog cables	> 0.14	mm <sup>2</sup>
Max. analog cable length, shielded	100	m

**Cooling**

The natural convection cooling must not be hindered by cable ducts or other parts in the switchgear cabinet.

## AC500-S Safety Modules

AI581-S analog safety input module > Technical data

### Allowed interruptions of power supply, according to EN 61131-2

Data	Value	Unit
DC supply interruptions	< 10	ms
Time between 2 DC supply interruptions, PS2	> 1	s

### Environmental conditions

Data	Value	Unit
Operating temperature*	0 ... +60	°C
Storage temperature	−40 ... +85	°C
Transport temperature	−40 ... +85	°C
Humidity without condensation	max. 95	%
Operating air pressure	> 800	hPa
Storage air pressure	> 660	hPa
Operating altitude	< 2000	m above sea level
Storage altitude	< 3500	m above sea level

\* Extended temperature ranges (below 0 °C and above +60 °C) can be supported in special versions of AI581-S ( ↗ Appendix "System data for AC500-S-XC" on page 446)

### Creepage distances and clearances

The creepage distances and clearances meet the overvoltage category II, pollution degree 2.

### Power supply units

For the supply of modules, power supply units according to PELV/SELV specifications must be used.

### Electromagnetic compatibility

↗ TÜV Report [2]

Data	Value	Unit
Degree of protection	IP 20	
Housing	according to UL 94	
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 3.5 mm	2 ... 15	Hz
Vibration resistance acc. to EN 61131-2 (all three axes), continuous 1 g *	15 ... 150	Hz
Shock test (all three axes), 11 ms half-sinusoidal	15	g
MTBF	102	years

\* Higher values on request

## Self-test and diagnostic functions

Start-up and runtime tests: Program flow control, RAM, CPU, ADC, etc.

## AC500-S Safety Modules

AI581-S analog safety input module > Technical data

### Dimensions, weight

Data	Value	Unit
W x H x D	67.5 x 76 x 62	mm
Weight (without Terminal Unit)	~ 130	g

### Certifications

CE, cUL (↗ further certifications at [www.abb.com/plc](http://www.abb.com/plc))



## 3.5.9.1 Technical data of safety analog inputs



### DANGER!

Exceeding the maximum process or supply voltage range ( $< -35 \text{ V DC}$  or  $> +35 \text{ V DC}$ ) could lead to unrecoverable damage of the system.

Data	Value	Unit
Number of channels per module	4	
Configurability, 1 channel mode	0 ... 20	mA
Configurability, 1 channel mode	4 ... 20	mA
Configurability, 2 channel mode	4 ... 20	mA
Channel input resistance, in active mode	$\sim 125$	$\Omega$
Channel input resistance, in inactive mode	$\sim 15$	k $\Omega$

### Distribution of channels into groups

2 groups of 2 channels each.

## AC500-S Safety Modules

AI581-S analog safety input module > Technical data

Data	Value	Unit
Time constant of the input filter	1	ms
Conversion cycle	0.33	ms
Resolution	14	bits
Temperature coefficient $\pm$ % of full scale (0 ... 20 mA)	$\pm 0.005$	%/K
Maximum error at 25 °C $\pm$ % of full scale (0 ... 20 mA)	$\pm 0.25$	%
Maximum error over full temperature range $\pm$ % of full scale (0 ... 20 mA)	$\pm 0.25$	%
Value of a LSB (least significant bit)	2.03	$\mu$ A
Maximum permanent allowed overload (no damage) (self-protected), voltage	32	V DC
Maximum permanent allowed overload (no damage) (self-protected), current	24	mA
Non-linearity (of full scale)	$\pm 0.05$	%
Sample repetition time	3.3	ms
Input filter characteristics - first order, filter time constant	1	ms
Transition frequency	160	Hz
Overvoltage protection	Yes	

### Electrical isolation

Against internal supply and other modules.

### Input signal indication

One LED per channel.

## Maximum temporary deviation during specified electrical interference test $\pm$ % of full scale

Data	Value	Unit
Deviation during radiated and conducted disturbance	< 0.1	%
Deviation during burst test	max. 0.33	%
Deviation during surge test	up to 50	%
Deviation during electrostatic discharge	no deviation	

## Analog input protection

Data	Value
Type of analog input protection	supressor diode

## Cable length

Data	Value	Unit
Max. cable length, shielded	100	m

## 3.5.10 Ordering data

Type	Description	Order code
AI581-S	AI581-S:S500, Safety Analog Input Module 4SAI	1SAP 282 000 R0001
AI581-S-XC	AI581-S-XC:S500, Safety Analog Input Module 4SAI, Extreme Conditions	1SAP 482 000 R0001

### 3.6 TU582-S Safety I/O Terminal Unit

#### Elements of the module

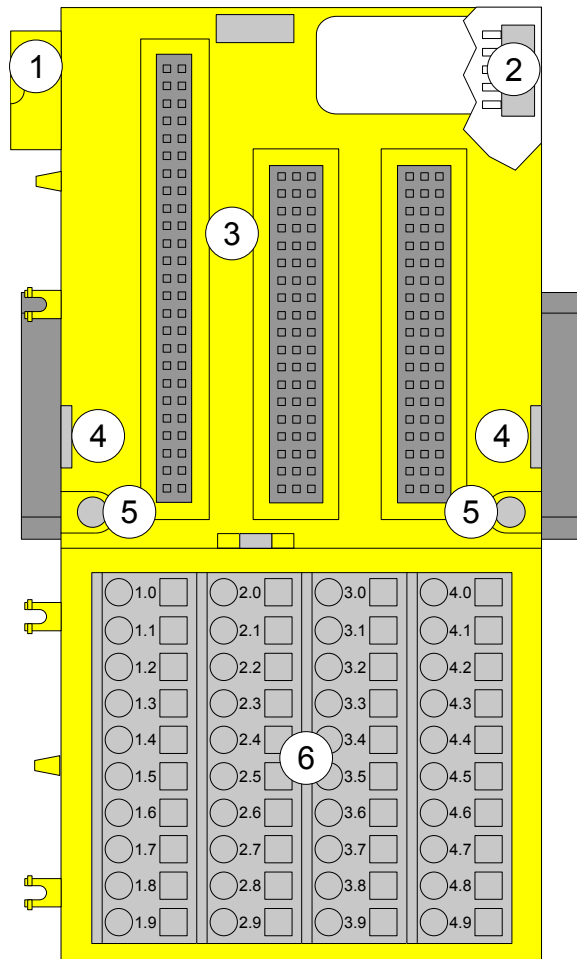


Fig. 59: Safety I/O Terminal Unit TU582-S (spring-type) for Safety I/O expansion modules

- 1 I/O-Bus (10 pole, male)
- 2 I/O-Bus (10 pole, female)
- 3 Slot for I/O module
- 4 With a screwdriver, inserted in this place, adjacent Terminal Units can be shoved from each other.
- 5 Holes for wall mounting
- 6 40 spring terminals (signals and process voltage)

#### 3.6.1 Functionality

The I/O Terminal Units TU582-S (with spring-type terminals) is specifically designed for use with AC500-S Safety I/O modules AI581-S, DI581-S and DX581-S.

The safety input/output modules (I/O expansion modules) plug into the I/O Terminal Unit. When properly seated, they are secured with two mechanical locks. All the electrical connections are made through the Terminal Unit, which allows removal and replacement of the I/O modules without disturbing the wiring at the Terminal Unit.

The terminals 1.8 to 4.8 and 1.9 to 4.9 are electrically interconnected within the I/O Terminal Unit and have always the same assignment, independent of the inserted module:

- Terminals 1.8 to 4.8: Process voltage UP = +24 V DC
- Terminals 1.9 to 4.9: Process voltage ZP = 0 V

The assignment of the other terminals is dependent on the inserted expansion module (see the description of used expansion modules).

### 3.6.2 Mounting, dimensions and electrical connection

The Safety I/O modules can be plugged only on spring-type TU582-S I/O Terminal Unit. The unique mechanical coding on I/O Terminal Units prevents a potential mistake of placing the Non-safety I/O module on Safety I/O Terminal Unit and the other way around.

Installation and maintenance have to be performed according to the technical rules, codes and relevant standards, e.g. EN 60204 part 1, by skilled electricians only.

#### Assembly of TU582-S on DIN rail

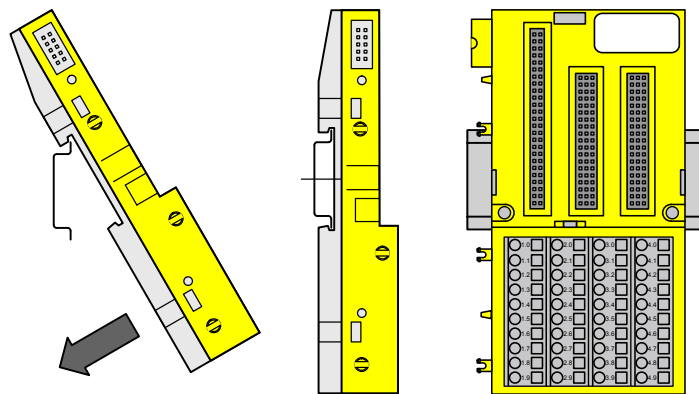


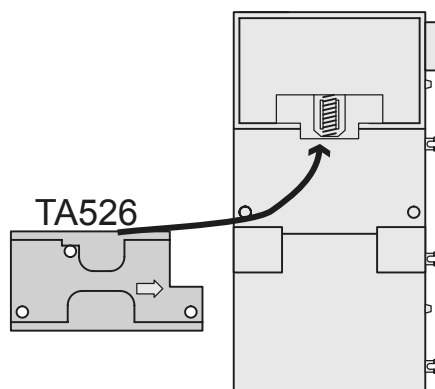
Fig. 60: Assembly instruction for mounting on a DIN rail

➡ Put the Terminal Unit on the DIN rail above and then snap-in below.

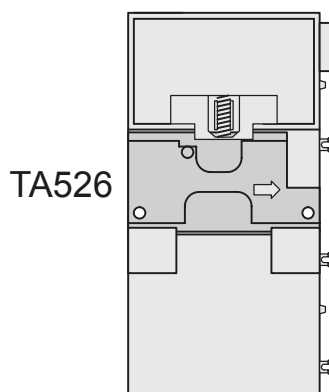
## AC500-S Safety Modules

TU582-S Safety I/O Terminal Unit > Mounting, dimensions and electrical connection

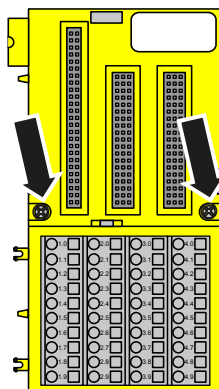
### Assembly of TU582-S with screws



The insertion of the accessories TA526 for wall mounting is essential.

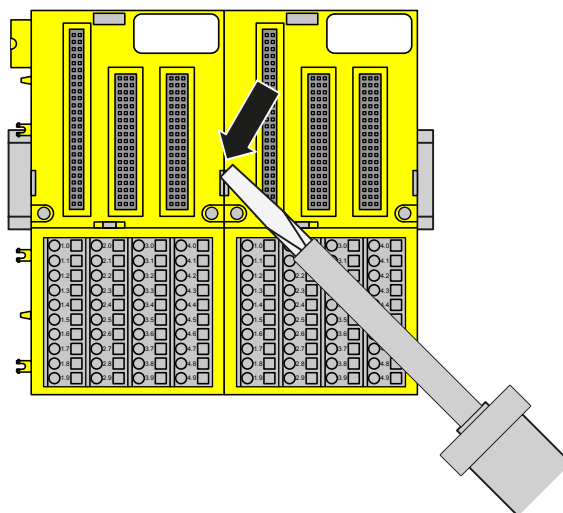


1. Snap TA526 on the rear side of the Terminal Unit like DIN rails.

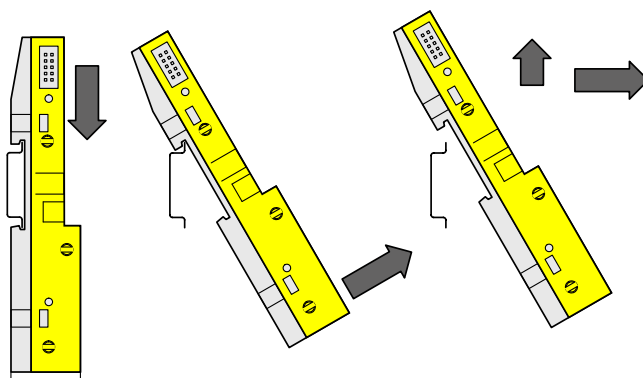


2. Fasten Terminal Unit with 2 M4 screws (max. 1.2 Nm).

## Disassembly of TU582-S



1. ➤ Shove the Terminal Units from each other,



2. ➤ Pull down the Terminal Unit and remove it.

## AC500-S Safety Modules

TU582-S Safety I/O Terminal Unit > Technical data

### Dimensions

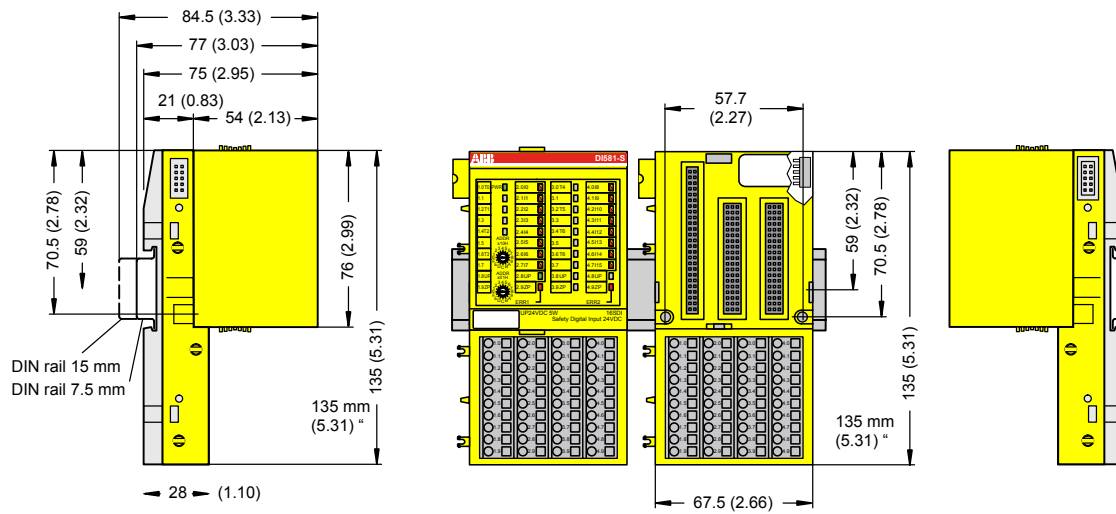


Fig. 61: Dimensions of TU582-S Safety I/O Terminal Unit

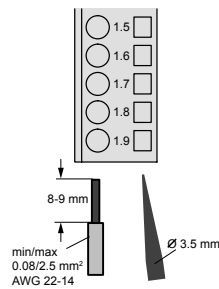


Fig. 62: Spring terminal (screw-driver opens terminal)

### 3.6.3 Technical data

#### ! NOTICE!

TU582-S-XC version is available for usage in extreme environmental conditions ( ↗ Appendix "System data for AC500-S-XC" on page 446).

#### Type

Front terminal, conductor connection vertically with respect to the printed circuit board.



Data	Value	Unit
Number of channels per module	32	
Rated voltage	24	V DC
Max. permitted total current (between the terminals 1.8 ... 4.8 and 1.9 ... 4.9)	10	A

**Distribution of channels into groups**

4 groups of 8 channels each (1.0 ... 1.7, 2.0 ... 2.7, 3.0 ... 3.7, 4.0 ... 4.7), the allocation of the channels is given by the inserted I/O expansion module.

**Mounting position**

Horizontal or vertical.

**Earthing**

Direct connection to the earthed DIN rail or via the screws with wall mounting.

## AC500-S Safety Modules

TU582-S Safety I/O Terminal Unit > Ordering data

### Conductor

Data	Value	Unit
Conductor cross section, solid	0.08 ... 2.5	mm <sup>2</sup>
Conductor cross section, flexible	0.08 ... 2.5	mm <sup>2</sup>
Conductor cross section, with wire-end ferrule	0.25 ... 1.5	mm <sup>2</sup>
Stripped conductor end, minimum	5	mm
Stripped conductor end	7	mm

Data	Value	Unit
Degree of protection	IP 20	
MTBF	2757	years
Weight	~ 200	g

### 3.6.4 Ordering data

Type	Description	Order code
TU582-S	TU582-S:S500, Safety I/O Terminal Unit, 24V DC	1SAP 281 200 R0001
TU582-S-XC	TU582-S-XC:S500, Safety I/O Terminal Unit, 24V DC, Extreme Conditions	1SAP 481 200 R0001

## 4 Configuration and programming

### 4.1 Overview

You must use PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) software with Safety features (CoDeSys Safety and Safety Configurator) to program AC500-S Safety PLCs.

A complete check of program logic and configuration must be performed to verify that logic correctly and fully addresses the functional and safety requirements in your safety application specification. Each time you make a modification, re-check project data.

The safety concept for Safety features in PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) software assures that the programming system works correctly for implementing safety functions in AC500-S, meaning that programming system errors can be detected. The communication between CoDeSys Safety and SM560-S Safety CPU is not a part of the safety loop, but is still subject to checks, for example, a CRC is used during the download of a project in order to verify that the data are transferred correctly and that there is no communication error. The user is responsible to additionally check the version and functionality of his project as well as the proper configuration of Safety and Non-safety modules.



#### **DANGER!**

For the initial start-up of a Safety CPU or after a modification of the application program or configuration, the safety of the entire system must be checked by a complete functional test, which includes also the check of the correct coding of the safety application based on the functional specification.

The safety application program must be identified using the following properties: project name, file name, change date, title, author, version, description and CRC. Using CoDeSys Safety menu item "Online/Check boot project in PLC", one can check that offline CoDeSys safety project and the boot project on the Safety CPU are identical.

Forcing of variables is supported by SM560-S Safety CPU, but only in DEBUG mode (Non-safety), which means that user takes over a complete responsibility for potential damages due to wrong system behaviour in the DEBUG mode (Non-safety).



#### **DANGER!**

Forcing of variables in SM560-S Safety CPU is only allowed after consulting the approving board responsible for site approval. During forcing, the user in charge must ensure sufficient safety technical monitoring of the process by other technical, organisational and structural measures.

Protection mechanisms are integrated in SM560-S Safety CPU and in PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) with Safety features to prevent unintentional or unauthorized modifications to the safety system:

- A modification of the safety application program generates a new project CRC version number.
- The user must be logged in to the Safety CPU to access its operating options.
- Requirements of safety and other relevant application standards regarding protection against manipulations must be observed. The authorization of employees and the necessary protection measures are the responsibility of the operator in charge.

An unauthorized access to Safety CPU and safety program is protected by three passwords:

- Password for SM560-S Safety CPU;
- Password for the safety program in CoDeSys Safety V2.3;
- Password for Safety modules and their configuration data in PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) with Safety features.

## Configuration and programming

### Overview

You can transfer your Safety Program to the Safety CPU from a PC or using SD card.




#### **DANGER!**

If you transfer your safety program to Safety CPU using SD card, you have to make sure that the inserted SD card contains the correct safety program. You can check this through program identification (e.g., CRC) or other measures, such as a unique identifier on the SD card.

#### **NOTICE!**

The boot project update on SM560-S is possible only if no boot project is loaded on SM560-S. It is done to avoid any occasional overwriting of existing valid boot project on SM560-S. To delete the boot project from SM560-S Safety CPU, one can use, for example, the switch address value 0xFE during the start of SM560-S, which allows deleting the boot project from the Flash memory of SM560-S. The boot project is finally deleted after SM560-S powering off/on is executed.

When transferring a safety application program to SD card, you must adhere to the following procedure:

1.  Transfer the safety program to the SD card.
2.  Perform a program identification – check if SD card and offline (e.g., on PC) safety program CRCs match.
3.  Attach an appropriate label to the SD card.

The procedure outlined must be ensured through organizational measures.

For safety applications developed with AC500-S, CoDeSys visualisations using CoDeSys Safety V2.3 are allowed for displaying purposes only.

#### **DANGER!**

Changing values via controls (e.g., “Write values”) would cause the SM560-S Safety CPU to switch to a DEBUG RUN mode, which is non-safe.

In case of an activation of DEBUG RUN (Non-safety) mode on SM560-S Safety CPU, the responsibility for safe process operation lies entirely with the organisation and person responsible for the activation of DEBUG RUN (Non-safety) mode.

### 4.2 Workflow

The engineering workflow presented in this chapter describes only the steps needed to instantiate, configure and program safety modules and those non-safety modules which are a part of the “black channel” [3] in the safe communication part. All other non-safety modules are separately covered in PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer) and AC500 User Documentation.

Fig. 63 provides an overview of steps which have to be carried out to successfully configure and program AC500-S Safety PLC.

## Configuration and programming

### System configuration and programming

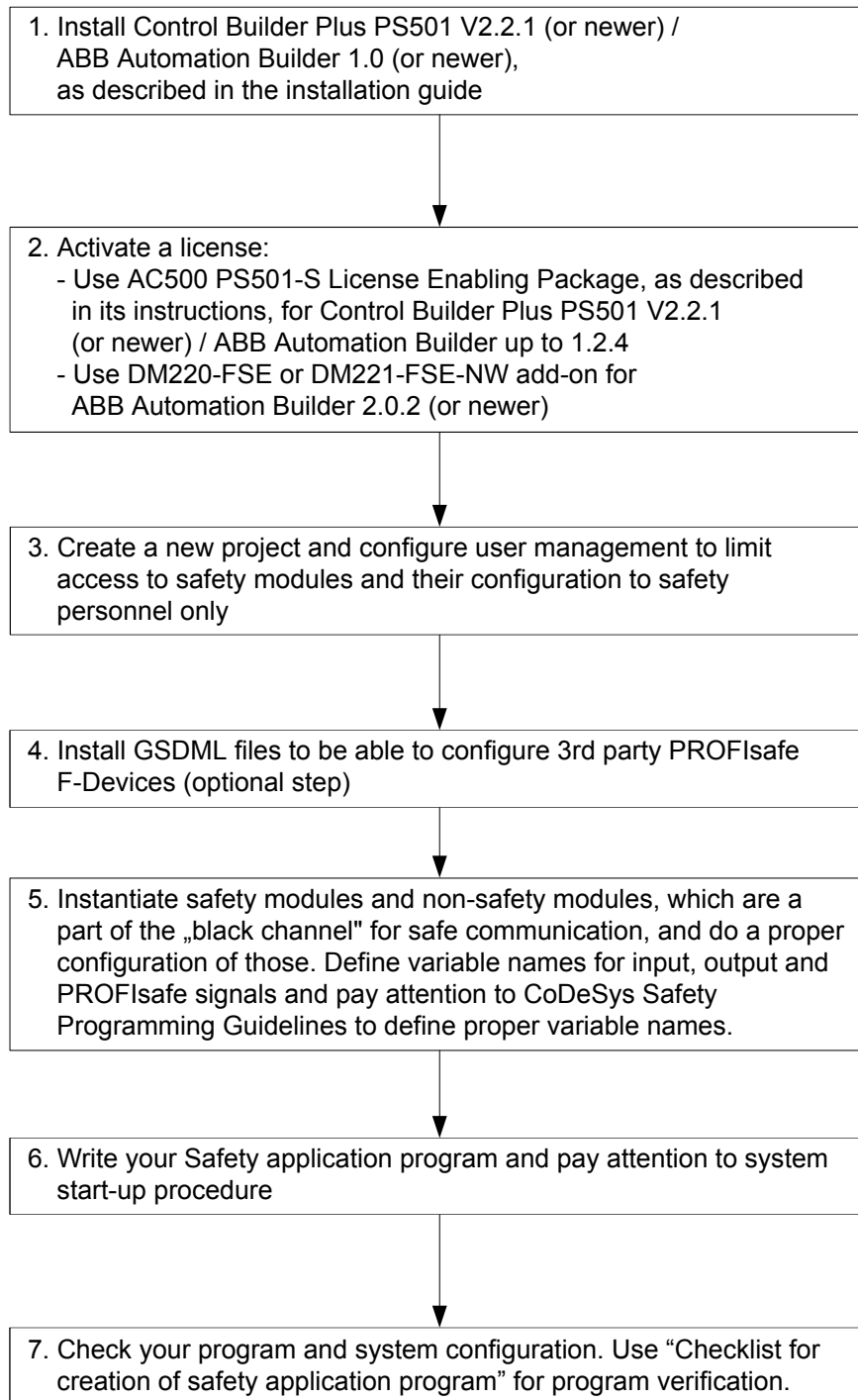


Fig. 63: AC500-S system configuration and programming workflow

### 4.3 System configuration and programming

In this chapter, we provide a step-by-step explanation on how to configure and program AC500-S Safety PLC.

### 4.3.1 Installation

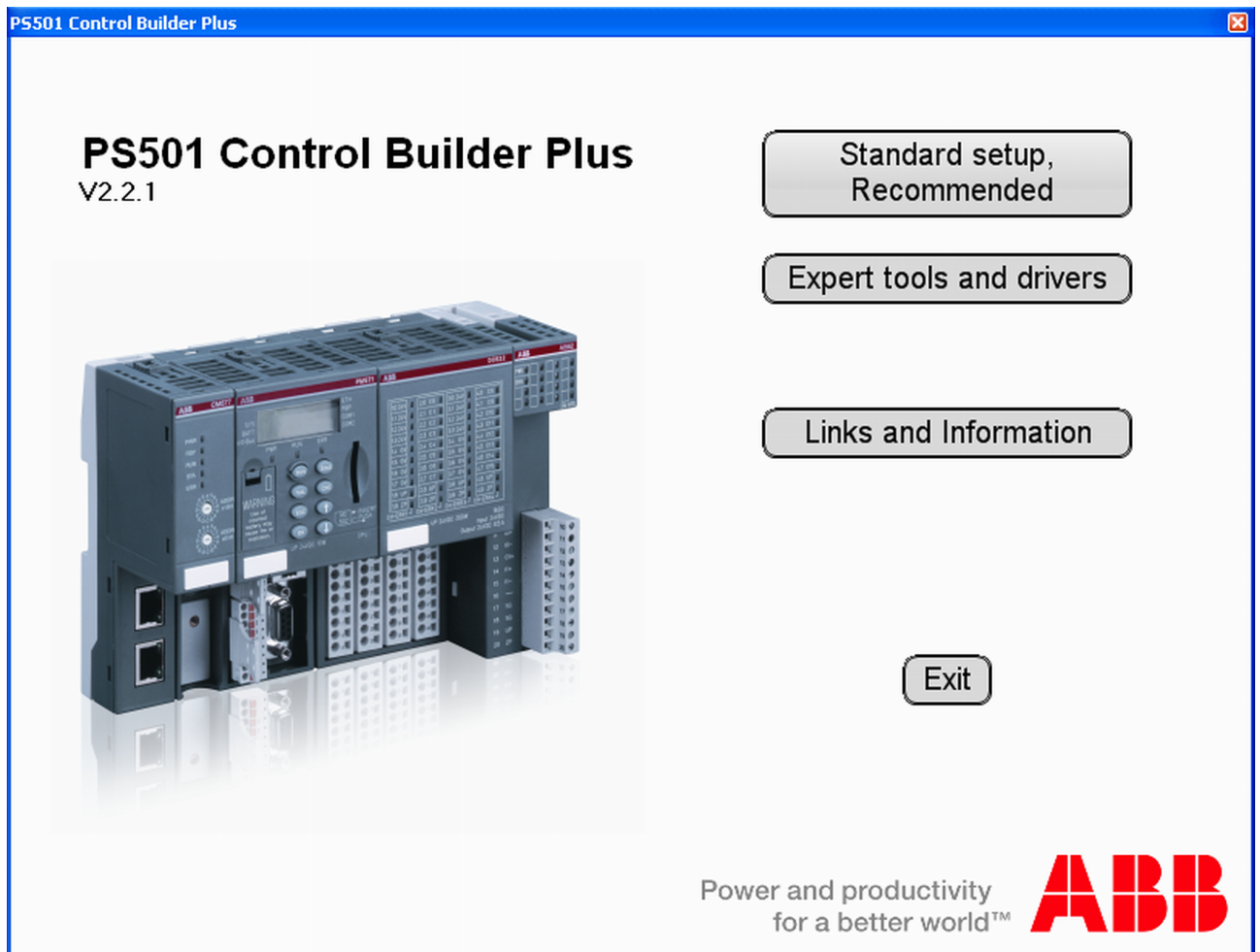


Fig. 64: Installation PS501

- ➔ Install PS501 Control Builder Plus V2.2.1 (or newer) / ABB Automation Builder 1.0 (or newer), as described in the installation guide.

### 4.3.2 License activation

For Control Builder Plus PS501 V2.2.1 (or newer) / ABB Automation Builder up to 1.2.4:

Activate a license from AC500 PS501-S License Enabling Package as follows:

1. ➔ Order PS501-S license with order number 1SAP198000R0001.
2. ➔ Activate license on your PC following license activation instructions.

For ABB Automation Builder 2.0.2 (or newer):

1. ➔ Order DM220-FSE or DM221-FSE-NW add-on with order numbers 1SAS010020R0102 and 1SAS010021R0102, respectively.
2. ➔ Activate license on your PC following license activation instructions.

## Configuration and programming

System configuration and programming > Creation of new project and user management

### 4.3.3 Creation of new project and user management

Create a new project and configure user management to limit access to safety modules and their configuration to safety personnel only as follows:

1. Use "New project ..." menu item in PS501 Control Builder Plus / ABB Automation Builder to create a new project.  
⇒ New project window opens.

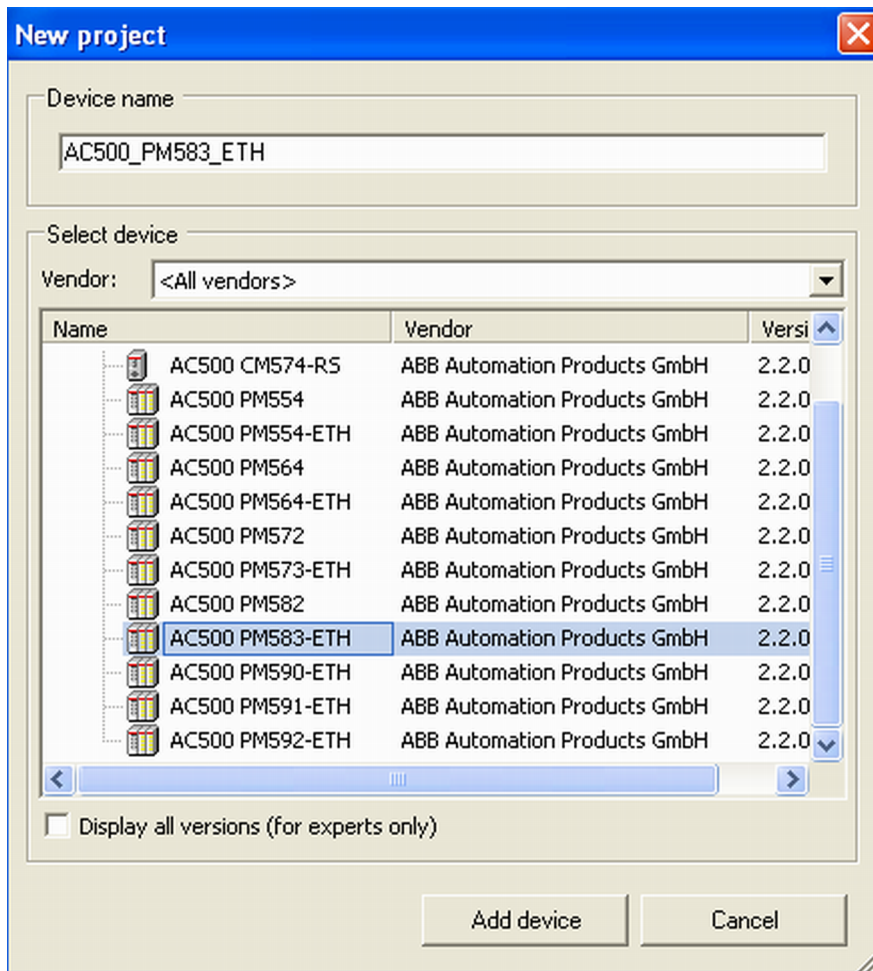


Fig. 65: New project window

2. Select, for example, AC500 PM583-ETH in the menu to instantiate a Non-safety CPU (make sure that you select the right ones supporting SM560-S Safety CPU, e.g., PM573-ETH, PM583-ETH, PM592-ETH and others).



- ⇒ As a result, you can see the following system structure which represents AC500 communication channels (↪ AC500 User Documentation for details on various non-safety hardware settings).

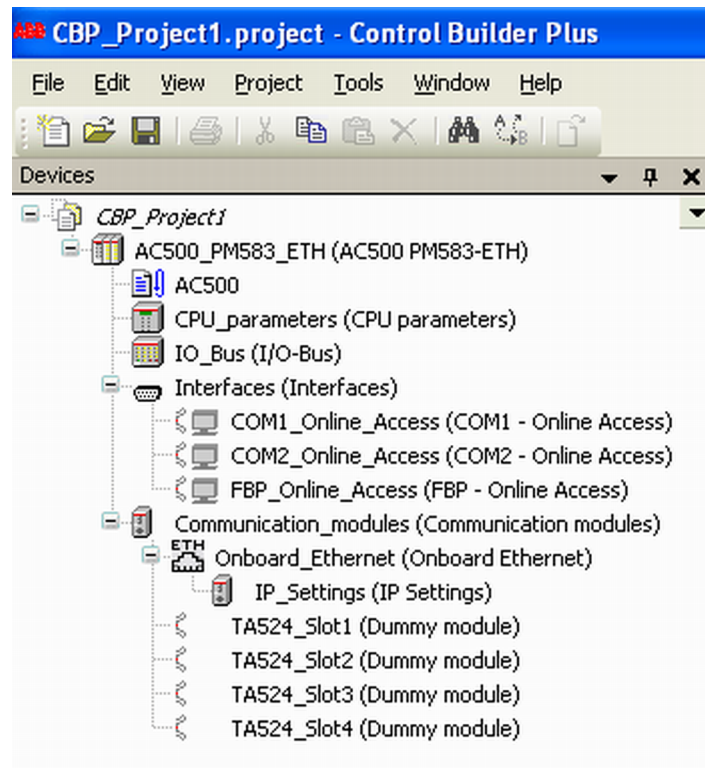


Fig. 66: AC500 communication channels

### ! NOTICE!

Pay attention to PM5xx Non-safety CPU settings ("Behaviour of Outputs in Stop", "Stop on Error Class" and "Warmstart" ↪ Chapter 3.1.6 "SM560-S and PM5xx interaction" on page 51).

3. ➤ To create new users and maintain existing ones, go to "Project Settings...".

## Configuration and programming

System configuration and programming > Creation of new project and user management

### ! NOTICE!

In all newly created PS501 Control Builder Plus / ABB Automation Builder projects, there is a Default user "Owner" with an empty password. This is a project administrator. The project administrator is responsible to create a new password for user "Owner" and, in addition, create dedicated safety and non-safety users based on your project organization demands.

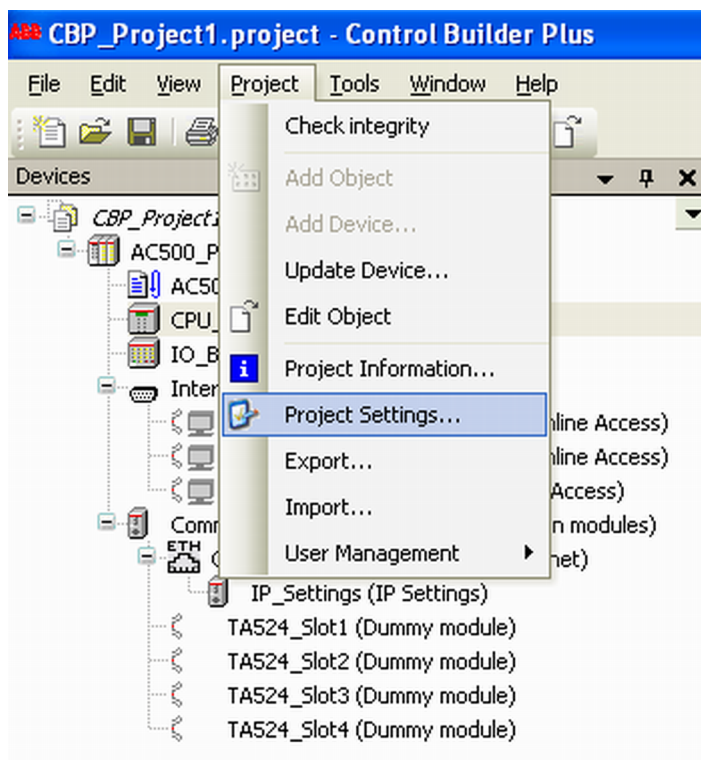


Fig. 67: Selection of project settings

Only members of Safety group are allowed to modify Safety modules, change their configuration, etc. By default, no users without proper log-in and access rights can access safety modules.

Project administrator is allowed to use all available User Management features to find the best suitable user setup with appropriate rights (🔗 *AC500 User Documentation*).

### DANGER!

It is the responsibility of project administrator to setup a proper user management for the given safety application project to avoid unauthorized access to Safety modules.

Passwords for users with Safety group membership shall be properly selected (at least 8 symbols are recommended with a combination of numbers and letters). An access to passwords must be strictly controlled.

Make sure that you set “Deny” permission for proper users and groups (e.g., Everyone) through menu “Project → User Management → Permissions ...” to avoid unauthorized creation of new users in the Safety group (Fig. 68 and Fig. 69).

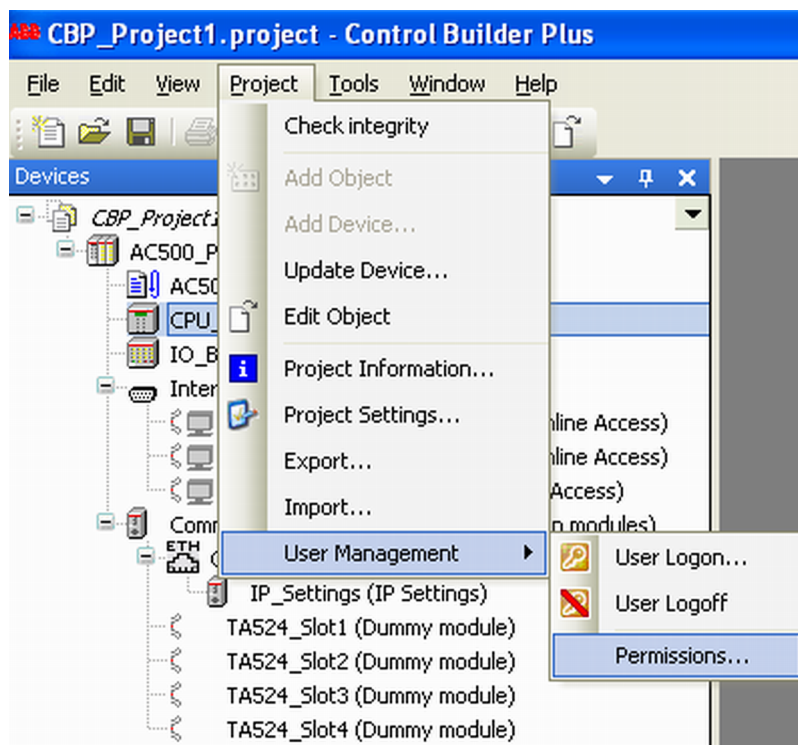


Fig. 68: Selection of user management

## Configuration and programming

System configuration and programming > Working with PROFINET / PROFIsafe F-Devices

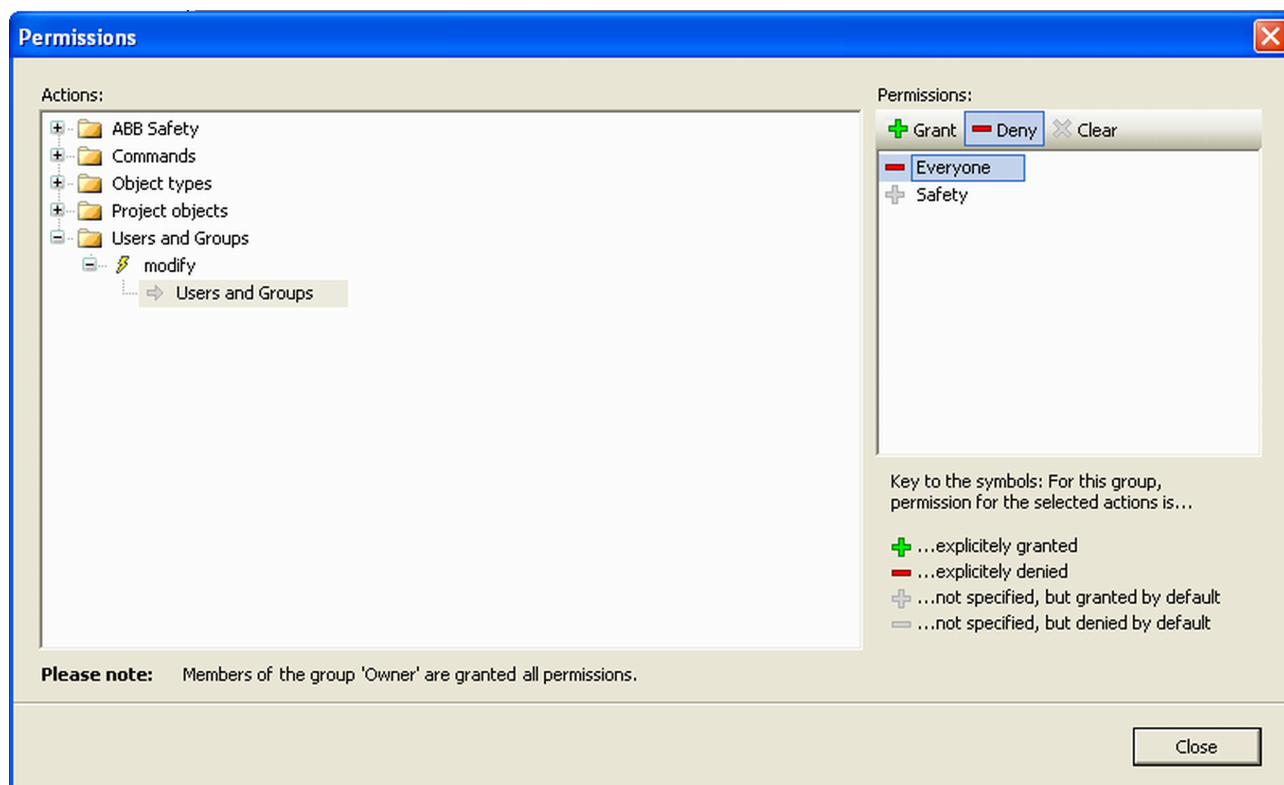


Fig. 69: Permissions for user and user groups

### 4.3.4 Working with PROFINET / PROFIsafe F-Devices

Install GSDML files to be able to configure 3<sup>rd</sup> party PROFIsafe F-Devices as follows:

In order to use 3<sup>rd</sup> party F-Devices with AC500-S Safety PLC, the safety devices must be on the PROFINET IO and support the PROFIsafe bus profile in V2 mode [3]. The basis for configuring all (Safety and Non-Safety) PROFINET devices is the specification of the device in the GSDML file (Generic Station Description Markup Language).

I/O device properties are saved in the GSDML file. For Safety PROFINET devices, portions of the specification are protected by a CRC [3]. GSDML files are supplied by the device manufacturers.

### ! NOTICE!

Only GSDML files with version 2.1 are fully supported by PS501 Control Builder Plus / ABB Automation Builder. GSDML files with version 2.2 and higher are only partially supported.

1. ➡ To install GSDML file go to “Device Repository...” menu.

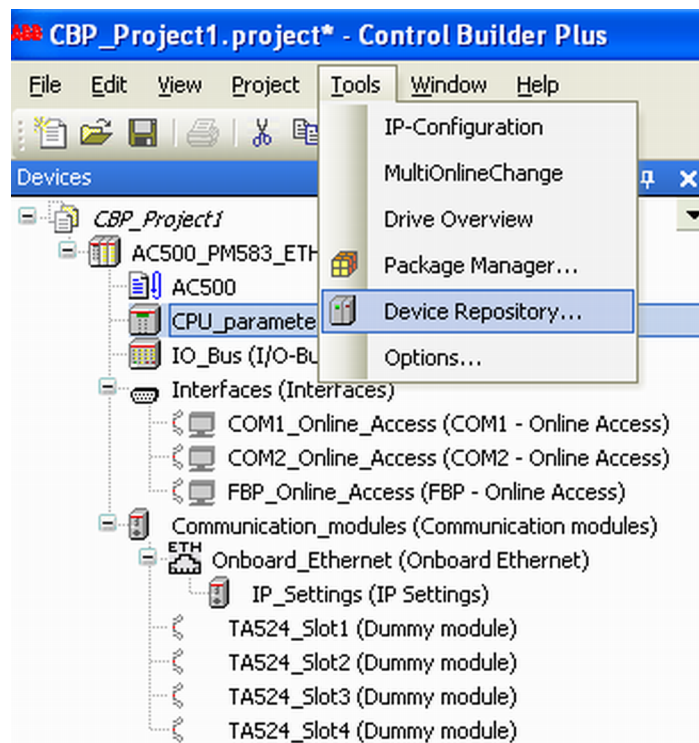


Fig. 70: Device repository

2. ➡ Then press “Install...” button to pick-up a GSDML file and install it.
  - ⇒ After successful installation, new devices can be found in Device Repository under “PROFINET” object (Fig. 72)

## Configuration and programming

System configuration and programming > Working with PROFINET / PROFIsafe F-Devices

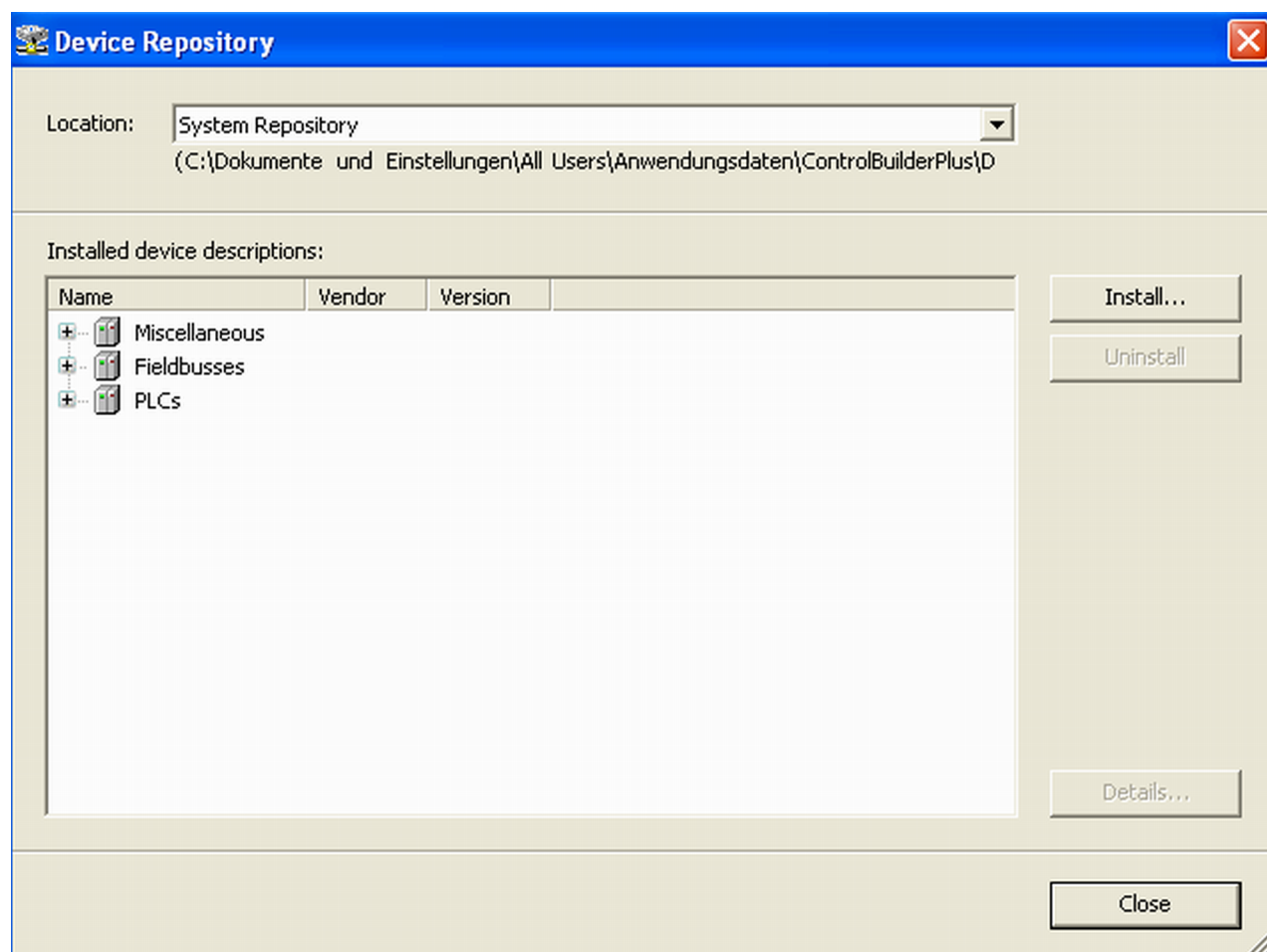


Fig. 71: Install GSDML file

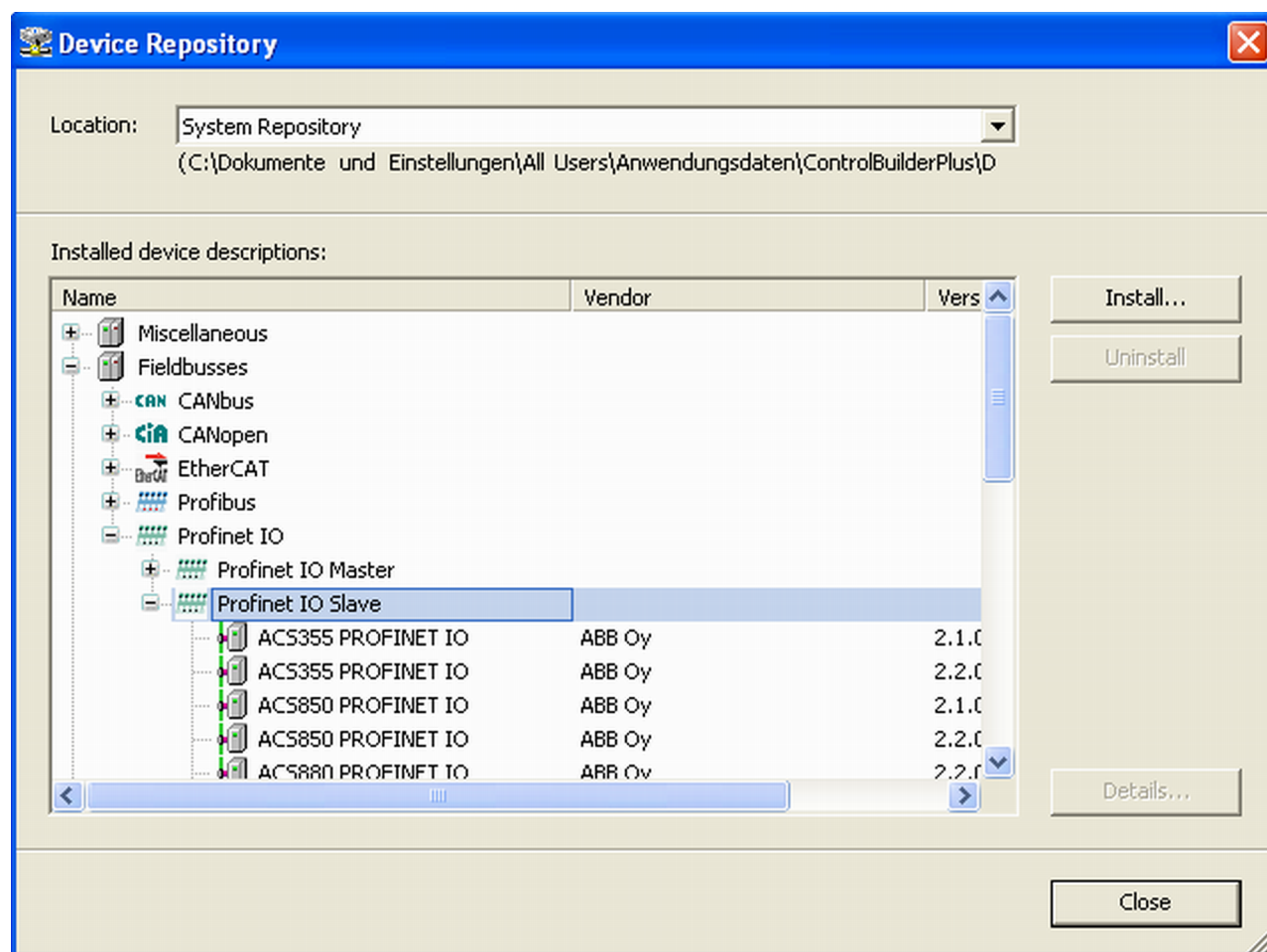


Fig. 72: New device shown in Device Repository

### 4.3.5 Instantiation and configuration of safety modules/Definition of variable names

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

Instantiate safety modules and non-safety modules, which are a part of the „black channel“ for safe communication and do a proper configuration of those. Define variable names for input, output and PROFIsafe signals and pay attention to CoDeSys Safety Programming Guidelines to define proper variable names.

1. ➤ Select one of four slots available for communication modules and Safety CPU and instantiate a Safety CPU on it using „Plug Device...“ menu. Note, that the slot number shall be the same as the physical slot number on which Safety CPU is attached.

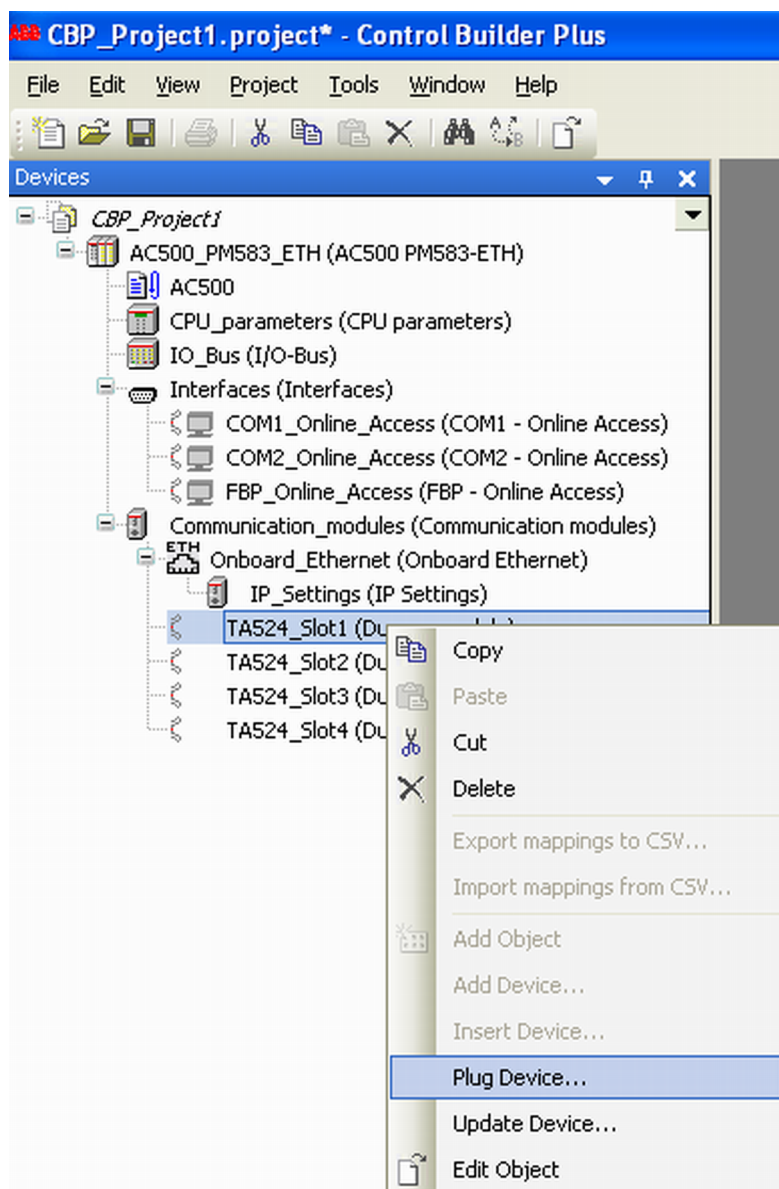


Fig. 73: Select Plug Device



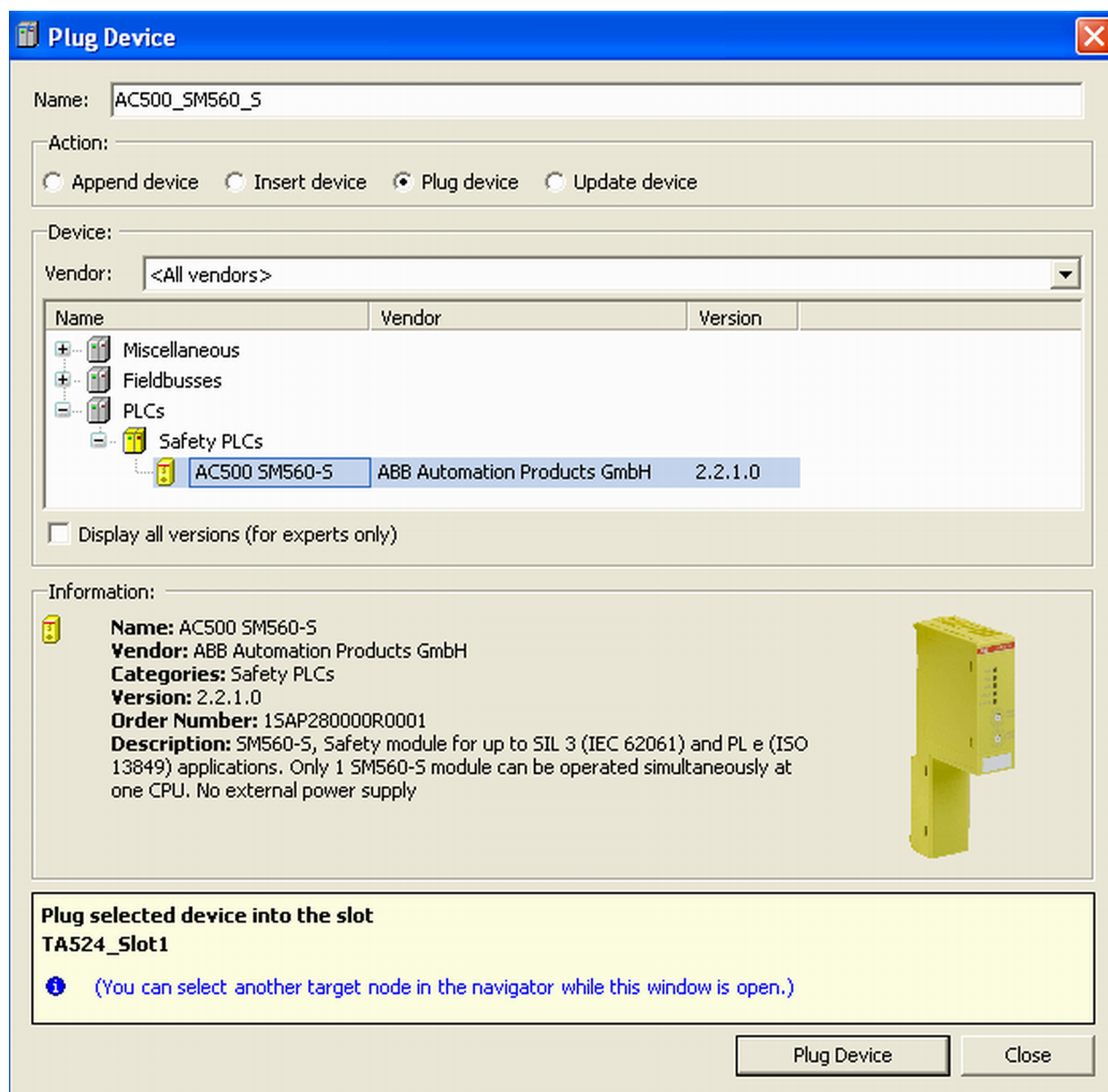


Fig. 74: Select SM560-S Safety CPU

2. ➡ Double-click on SM560-S Safety CPU and set "Min update time" and "Enable debug" parameters, as needed.

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

### ! NOTICE!

Pay attention to SM560-S Safety CPU parameter “Enable debug”. If this parameter is set to “OFF”, then no new boot project can be loaded to SM560-S.

If a new boot project has to be loaded to SM560-S Safety CPU, then, in advance, a new boot project with “Enable debug” parameter set to “ON” for SM560-S shall be loaded to PM5xx Non-safety CPU. After the reboot of PM5xx Non-safety CPU, a new boot project can be loaded to SM560-S Safety CPU.

Note that the following PLC Browser commands are allowed only if “Enable debug” parameter is set to “ON” ( *“The following PLC Browser commands (these commands can be called from CoDeSys Safety V2.3) are supported by SM560-S Safety CPU:” on page 200 for a list of all PLC Browser commands*):

- resetprg – Reset PLC program
- resetprgorg – Reset PLC program original
- setpwd – set login password
- delpwd – delete login password
- delappl – delete user program
- deluserdat – delete user data segments

Note, that “Min update time” influences the “black channel” performance for SM560-S. The smaller the value is the higher Safety Function Response Time ( *Chapter 5.1 “Overview” on page 395*) can be reached. However, at the same time, the load on Non-safety CPU increases with smaller values of “Min update time”.

### ! DANGER!

Big values (e.g., > 10 ms) of “Min update time” parameter increase the chance of not delivering input pulse signals with a length < “Min update time” value to SM560-S Safety CPU.

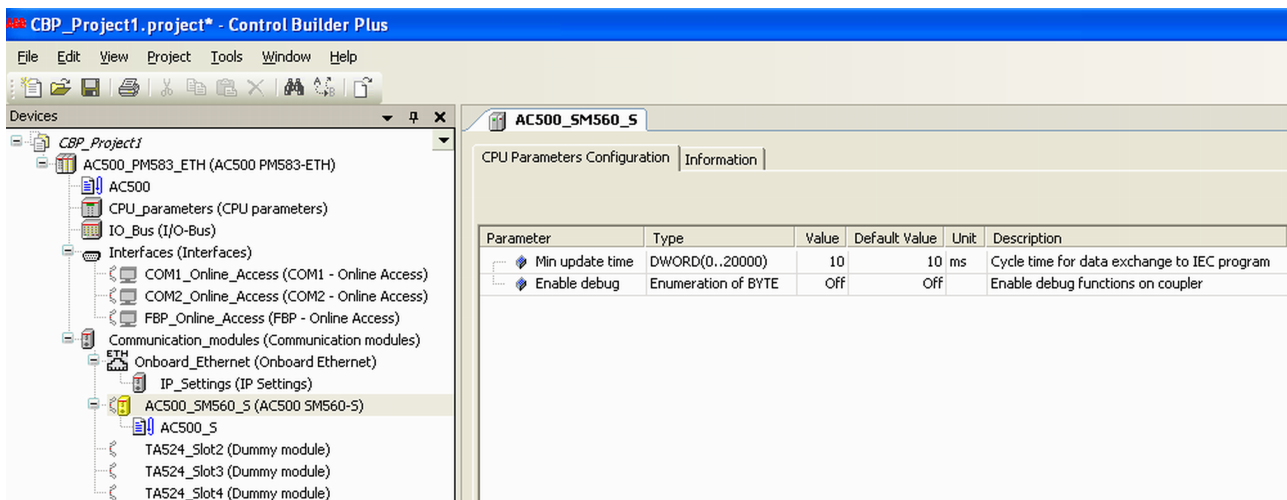


Fig. 75: CPU parameter configuration

### ! NOTICE!

Starting from Automation Builder 1.0.1, there is an additional tab "Data Exchange Configuration" available for SM560-S Safety CPU to configure cyclic non-safe data exchange functionality. It enables data exchange between SM560-S Safety CPU and PM5xx Non-Safety CPU for a fast communication and/or big data amount (up to 2 kBytes for both directions) transfer via DPRAM. In most safety applications, this functionality is not needed and, thus, shall not be used (default value for "Cyclic non-safe data exchange" is unselected). However, if you still need it, please refer to ABB technical support and request document 3ADR025195M\*, which describes in details how to use cyclic non-safe data exchange functionality.

3. To have remote stations in the system, we can instantiate PROFINET IO controller communication module CM579-PNIO in Slot 2. Note that PROFINET is the only bus which is supported for PROFIsafe communication in AC500-S Safety PLC.

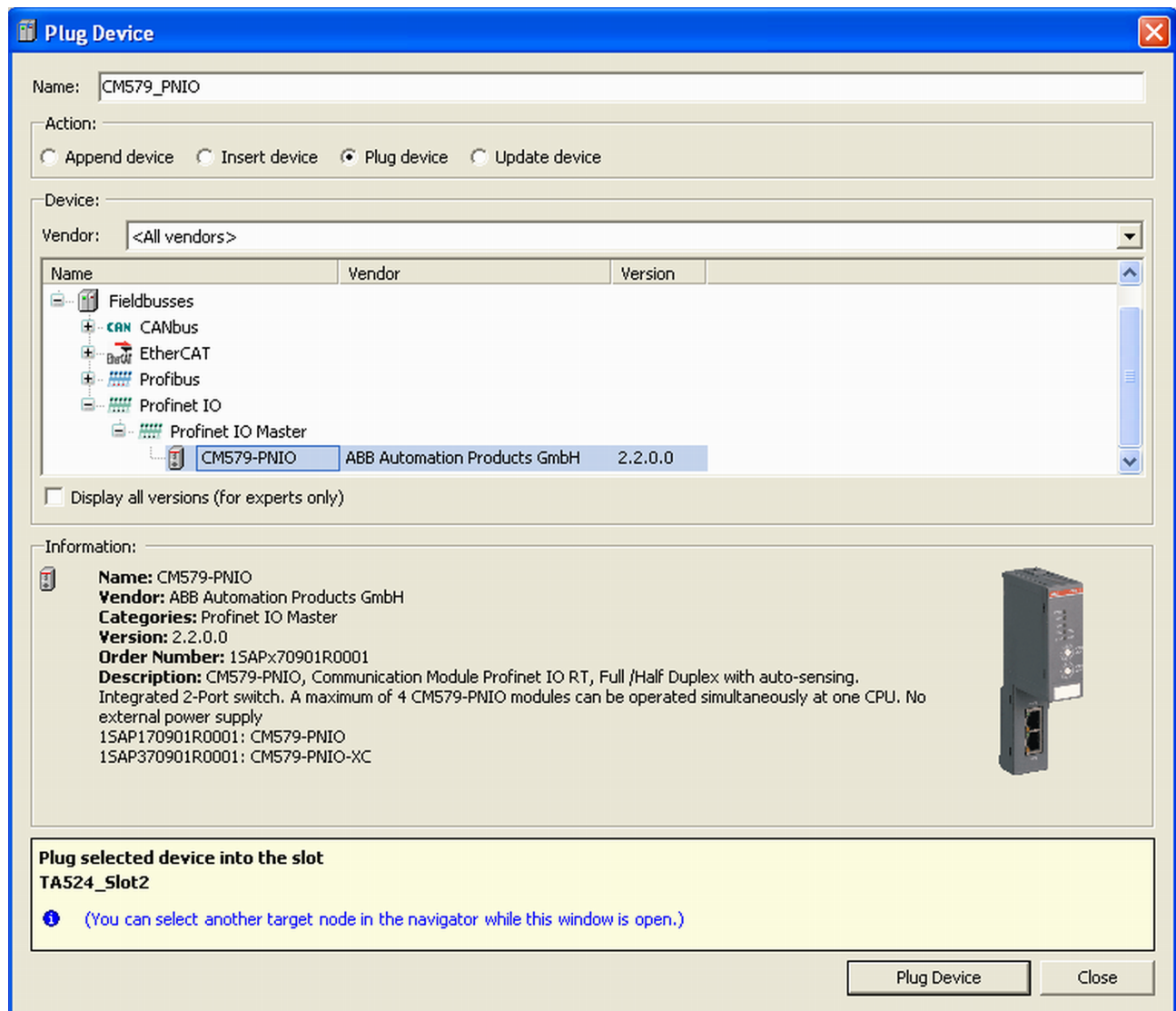


Fig. 76: Add device

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

- Now, select newly created CM579-PNIO module and using “Add Device...” command instantiate the required number of PROFINET modules, e.g., CI501-PNIO, CI502-PNIO, etc. (Release date: 2013 and newer) or any 3<sup>rd</sup> party PROFINET modules previously imported in the Device Repository using GSDML files.

Details on how to set proper PROFINET device names and IP addresses can be found in AC500 User Documentation.

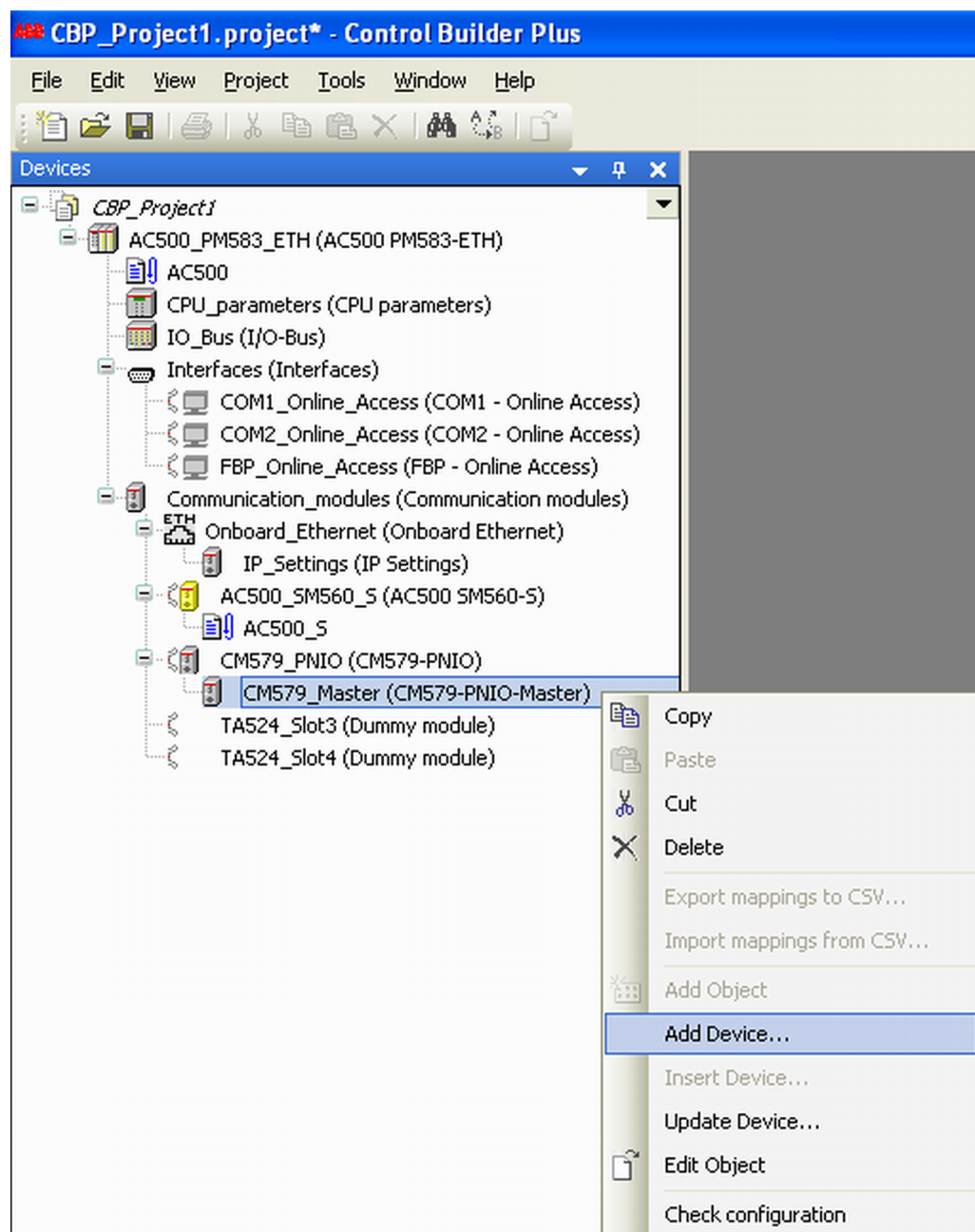


Fig. 77: Select module and open “Add Device menu ...”

5. ➤ Using “Add Device ...” menu on the context menu of IO\_Bus object (see below), one can instantiate up to 10 I/O modules (Safety or Non-safety ones) located centrally on the Non-Safety CPU.

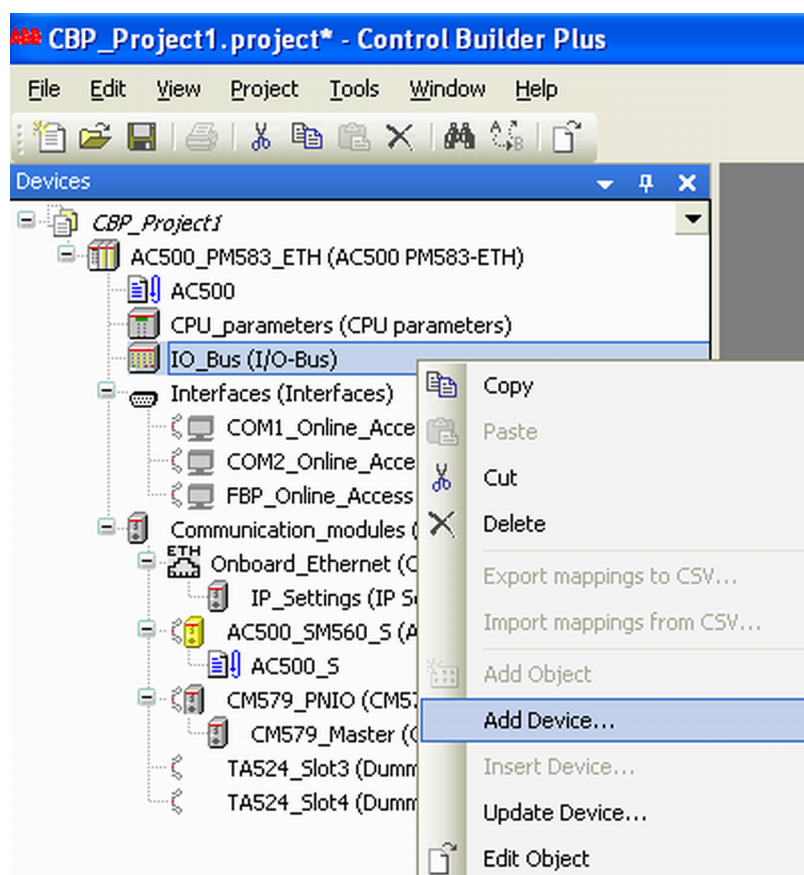


Fig. 78: Open “Add Device...” menu

6. ➤ Similarly, up to 10 I/O modules (Safety and Non-safety) can be instantiated on any ABB PROFINET IO device.

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

GSDML file defines the maximum number of supported modules on 3<sup>rd</sup> party PROFINET IO devices.

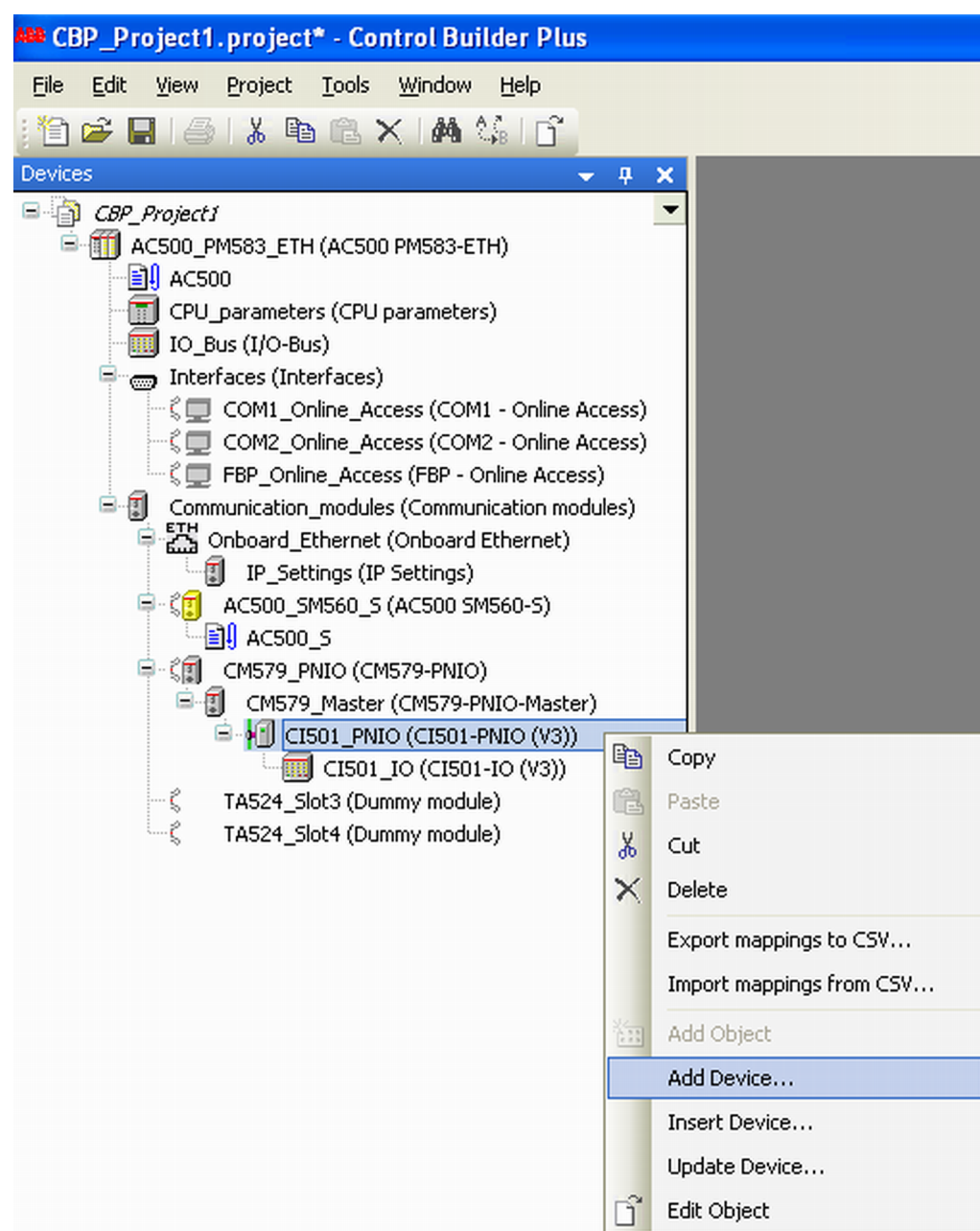


Fig. 79: Using “Add Device ...”



Parameters of Safety I/O modules can be set using double-click on those modules. Each module has two types of parameters: F-Parameters and iParameters.

F-Parameters are parameters which were specially defined by PROFIsafe group [3] to realize safe device communication and parameterisation. F-Parameter names are the same for all F-Devices (ABB and 3<sup>rd</sup> party devices). The most important of them for end-users are F\_SIL, F\_Dest\_Add, F\_Source\_Add, F\_WD\_Time and F\_iPar\_CRC. F\_WD\_Time parameter is further used in Safety Function Response Time calculations (Chapter 5.3 “Safety function response time” on page 396). F\_Dest\_Add shall be the same address as the one set on the physical Safety I/O device.

## ! NOTICE!

Make sure that F\_Dest\_Add is set unique for all F-Devices, otherwise no valid safety configuration can be generated.

Decimal or hexadecimal number with a prefix 16# or 0x can be used to set F\_Dest\_Add.

F\_iPar\_CRC is a special parameter which is used for a safe transfer of iParameters to F-Devices.

F\_iPar\_CRC is calculated outside F-Parameter editor and, thus, has to be manually copied from “Checksum iParameter” field and pasted to F\_iPar\_CRC field after pressing “Calculate” button for the given F-Device.

Note, that F\_iPar\_CRC has to be recalculated also if F\_Dest\_Add is changed, because F\_Dest\_Add is also invisibly transported as iParameter to AC500-S Safety I/O modules. It is needed in AC500-S Safety PLC for further comparison of the physical PROFIsafe address value on the Safety I/O device and one configured in the engineering environment.

Name	Value	Symbolic-Value	Description	Unit
F_Check_SeqNr	1	Check	Consecutive number check in the CRC signature	
F_Check_iPar	0	No Check	Check of manufacturer specific iParameters within safety parameters	
F_SIL	2	SIL3	Employed SIL of the safety device	
F_CRC_Length	0	3 octet CRC	Cyclic redundancy check length	
F_Block_ID	1	F_iPar_CRC in F-P...	Parameter block type identification	
F_Par_Version	1	Valid for V2 mode	Version of safety parameters	
F_Source_Add	1	1	Safety device source address (1-239)	
F_Dest_Add	2	2	Safety device destination address (1-255)	
F_WD_Time	100	100	Watchdog time in the safety device (10-10000)	ms
F_iPar_CRC	2002495418	2002495418	Value of the iParameter CRC calculation	
F_Par_CRC	17494	17494	Value of the safety parameter CRC calculation	

Fig. 80: Setting F-Parameters

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

F_Parameter	Definition	Allowed values	Default value
F_Check_SeqNr	This parameter defines whether the consecutive number shall be included in the CRC2. PROFI-safe V2-mode [3]: consecutive number has to be always included in CRC2 generation	"No Check" = 0 "Check" = 1	"Check" = 1
F_Check_iPar	Manufacturer specific use within homogeneous systems	"No Check" = 0 "Check" = 1	"No Check" = 0
F_SIL	The different safety functions using safety-relevant communication may require different safety integrity levels. The F-Devices are able to compare their own assigned SIL with the configured SIL (F_SIL). If it is higher than the SIL of the connected F-Device, the "device failure" Status Bit is set and a safe state reaction is triggered [3].	"SIL1" = 0 "SIL2" = 1 "SIL3" = 2 "NoSIL" = 3	"SIL3" = 2
F_CRC_Length	Depending on the length of the F I/O data (12 or 123 octets) and the SIL level, a CRC of 2, 3, or 4 octets is required	"3 octet CRC" = 0 "2 octet CRC" = 1 Not supported by SM560-S: "4 octet CRC" = 2	"3 octet CRC" = 0 (AC500-S Safety I/O modules can work only with „3 octet CRC“)
F_Block_ID	Type identification of parameters	"No F_iPar_CRC within F-Parameter block" = 0 "F_iPar_CRC within F-Parameter block" = 1	"F_iPar_CRC within F-Parameter block" = 1 (AC500-S Safety I/O modules can work only with this default value)
F_Par_Version	Version number of the F-Parameter set	"Valid for V1-mode" = 0 "Valid for V2-mode" = 1	"Valid for V2-mode" = 1 (AC500-S Safety I/O modules can work only with this default value)
F_Source_Add	F-Host Source Address. The F_Source_Add parameter is a logical address designation that can be assigned freely but unambiguously.  <b>F_Source_Add shall not be equal to F_Dest_Add for the given F-Device.</b>	[1 – 239] Addresses [240 - 255] are reserved for system functions. 0 is not allowed.	1 (F_Source_Add <> F_Dest_Add for the given F-Device)



F_Parameter	Definition	Allowed values	Default value
F_Dest_Add	The unique F-Device address which will be compared with the set hardware switch address in F-Device. The F_Dest_Add parameter is a logic address designation that can be assigned freely but unambiguously.	[1 – 255] for AC500-S Safety I/O modules.	2
F_WD_Time	Watchdog time in ms for receipt of the new valid telegram	[10 – 10000]	100
F_iPar_CRC	CRC over iParameters (manufacturer specific) of F-Devices (Safety I/Os).	[0 - 4294967295] Hex [0 - FFFFFFFF]	Dependent on the module type
F_Par_CRC	CRC1 signature calculation across the F-Parameters	[0 - 65535] Hex [0 - FFFF]	Dependent on the module type

iParameters are individual F-Device parameters which are transferred to F-Devices with a proper F\_iPar\_CRC parameter.

### ! NOTICE!

After changing iParameters, you have to go to F-Parameter tab, re-calculate iParameter CRC and paste it to F\_iPar\_CRC F-Parameter row. Otherwise, the new parameter set will not be accepted by the F-Device because F\_iPar\_CRC will not be a valid one for a given iParameter set.

As for 3<sup>rd</sup> party F-Devices coming from GSDML files, **one has no “Checksum iParameter” feature**, because PS501 Control Builder Plus / ABB Automation Builder does not know a specific algorithm used for F\_iPar\_CRC calculation in 3<sup>rd</sup> party devices. One has to calculate F\_iPar\_CRC using a special tool delivered by the F-Device manufacturer for engineering its F-Devices.

Another option is to contact the vendor of the F-Device and ask for F\_iPar\_CRC value for the given F-Device iParameter. As soon as F\_iPar\_CRC is available for the given 3<sup>rd</sup> party F-Device, one can paste it to the F\_iPar\_CRC row in F-Parameter editor.

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

AI581\_5 DI581\_5 DX581\_5

F-Parameter DI581-5 DI581-5 Safety I/O Mapping DI581-5 I/O Mapping Information

Parameters

Check supply On

Input channel 0

Configuration 2 channel equivalent

Test pulse Disabled

Input delay 5 ms

Input channel 8

Configuration 2 channel equivalent

Test pulse Disabled

Input delay 5 ms

2 channel configuration 0/8

Discrepancy time 50 ms

Input channel 1

Configuration 1 channel

Test pulse Enabled

Input delay 50 ms

Input channel 9

Configuration 1 channel

Test pulse Disabled

Input delay 5 ms

Input channel 2

Configuration 2 channel antivalent

Test pulse Disabled

Input delay 5 ms

Input channel 10

Configuration 2 channel antivalent

Test pulse Disabled

Input delay 5 ms

2 channel configuration 2/10

Discrepancy time 200 ms

Input channel 3

Configuration Not used

Test pulse Disabled

Input delay 5 ms

Input channel 11

Configuration Not used

Test pulse Disabled

Input delay 5 ms

Fig. 81: Examples of iParameter settings for DI581-S Safety module; all input channels are paired as "Channel X with Channel X + 8"

AI581\_S DI581\_S **DX581\_S**

F-Parameter DX581-S DX581-S Safety I/O Mapping DX581-S I/O Mapping Information

Input channel 1  
 Configuration: 2 channel antivalent  
 Test pulse: Disabled  
 Input delay: 5 ms

Input channel 5  
 Configuration: 2 channel antivalent  
 Test pulse: Disabled  
 Input delay: 5 ms

2 channel configuration 1/5  
 Discrepancy time: 1 s

Input channel 2  
 Configuration: 1 channel  
 Test pulse: Disabled  
 Input delay: 15 ms

Input channel 6  
 Configuration: Not used  
 Test pulse: Disabled  
 Input delay: 5 ms

Input channel 3  
 Configuration: 1 channel  
 Test pulse: Disabled  
 Input delay: 30 ms

Input channel 7  
 Configuration: 1 channel  
 Test pulse: Enabled  
 Input delay: 200 ms

Output channel 0  
 Output channel: Used  
 Detection: On

Output channel 4  
 Output channel: Used  
 Detection: Off

Output channel 1  
 Output channel: Not used  
 Detection: On

Output channel 5  
 Output channel: Not used  
 Detection: On

**Important**  
 The output channel 4 does not satisfy SIL 3 (IEC 62061) and PL e (EN ISO 13849) requirements in such configuration.

Fig. 82: Examples of iParameter settings for DX581-S Safety module; input channels are paired as "Channel X with Channel X + 4"

## DANGER!

If for one of the output channels you set Detection = OFF, the warning appears that the output channel does not satisfy SIL3 (IEC 62061) and PL e (EN ISO 13849) requirements in such condition. Two safety output channels may have to be used to satisfy required SIL or PL level.

The parameter "Detection" was created for customers who want to use safety outputs of DX581-S for SIL1 (or maximum SIL2 under special conditions) or PL c (or maximum PL d under special conditions) safety functions and have less internal DX581-S pulses visible on the safety output line. Such internal pulses could be detected as LOW signal by, for example, drive inputs, which would lead to unintended machine stop.

## Configuration and programming

System configuration and programming > Instantiation and configuration of safety modules/Definition of variable names

AI581\_S DI581\_S DX581\_S

F-Parameter AI581-S AI581-S Safety I/O Mapping AI581-S I/O Mapping Information

Parameters

Check supply On

Input channel 0

Configuration 1 channel (0...20 mA)

Noise rejection 50 Hz

Input channel 2

Configuration 1 channel (0...20 mA)

Noise rejection 60 Hz

Input channel 1

Configuration 2 channel (4...20 mA)

Noise rejection None

Input channel 3

Configuration 2 channel (4...20 mA)

Noise rejection None

2 channel configuration 1/3

Tolerance range 9 %

Used value (Min / Max) Maximum

Fig. 83: Examples of *iParameter* settings for AI581-S Safety module; input channels are paired as “Channel X with Channel X + 2”



### DANGER!

One can also use generic device configuration view from “DI581-S Configuration”, “DX581-S Configuration” or “AI581-S Configuration” tab to edit module and channel parameters. **However, change of Safety I/O parameters using generic device configuration view is not recommended** due to potential user mistakes during the parameter setting using integer numbers.

Furthermore, each F-Device has a special “Safety I/O Mapping” and “I/O Mapping” tab in which variable names for input and output signals, PROFIsafe diagnostic bits, etc. can be defined.

AI581_S DI581_S DX581_S					
F-Parameter AI581-S AI581-S Safety I/O Mapping AI581-S I/O Mapping Information					
Channels					
Variable	Mapping	Channel	Type	Unit	Description
		Inputs			Safety inputs
		Input 0	INT		Safety analog input 0
		Input 1	INT		Safety analog input 1
		Input 2	INT		Safety analog input 2
		Input 3	INT		Safety analog input 3
		Safe diagnostic / Reintegration request	BYTE		Safe diagnostic / Reintegration request
		Safe_Diag - Input 0	BOOL		Safe diagnostic for input 0
		Safe_Diag - Input 1	BOOL		Safe diagnostic for input 1
		Safe_Diag - Input 2	BOOL		Safe diagnostic for input 2
		Safe_Diag - Input 3	BOOL		Safe diagnostic for input 3
		Rei_Req - Input 0	BOOL		Reintegration request for input 0
		Rei_Req - Input 1	BOOL		Reintegration request for input 1
		Rei_Req - Input 2	BOOL		Reintegration request for input 2
		Rei_Req - Input 3	BOOL		Reintegration request for input 3
		Outputs			Safety outputs
		Acknowledge reintegration	BYTE		Acknowledge reintegration for inputs
		Ack_Rei - Input 0	BOOL		Acknowledge reintegration for input 0
		Ack_Rei - Input 1	BOOL		Acknowledge reintegration for input 1
		Ack_Rei - Input 2	BOOL		Acknowledge reintegration for input 2
		Ack_Rei - Input 3	BOOL		Acknowledge reintegration for input 3

Fig. 84: Example with AI581-S module for variable mapping

It is also valid for DX581-S and DI581-S safety modules; the only difference is the number of input and output channels. Each process channel (Input 0 – Input 3 for AI581-S) has additionally the following bits:

- one bit for safe diagnostic (Safe\_Diag bit) to be able to differentiate if the process value is the real process state or “0” value due to channel or module passivation.
- one bit Rei\_Req for channel reintegration request, which can be used in the safety application program as a signal that external error (e.g., sensor wiring error) was fixed and the channel can be reintegrated in the safety control. Higher overall system availability can be expected for end-customers, because they can selectively decide which channels have to be acknowledged and which not.
- one bit Ack\_Rei for channel reintegration if the error was fixed (e.g., external sensor wiring was corrected). One can also define one variable as a BYTE for all Ack\_Rei bits and use 0xFF value to acknowledge all errors at once.

## ! NOTICE!

When you define variable names for input signal, output signal and other safety signals, pay attention to CoDeSys Safety Programming Guidelines ( [Chapter 4.4 “CoDeSys Safety programming guidelines” on page 210](#) ).

### 4.3.6 Programming of AC500-S Safety CPU

Write your Safety application program and pay attention to system start-up procedure.

## Configuration and programming

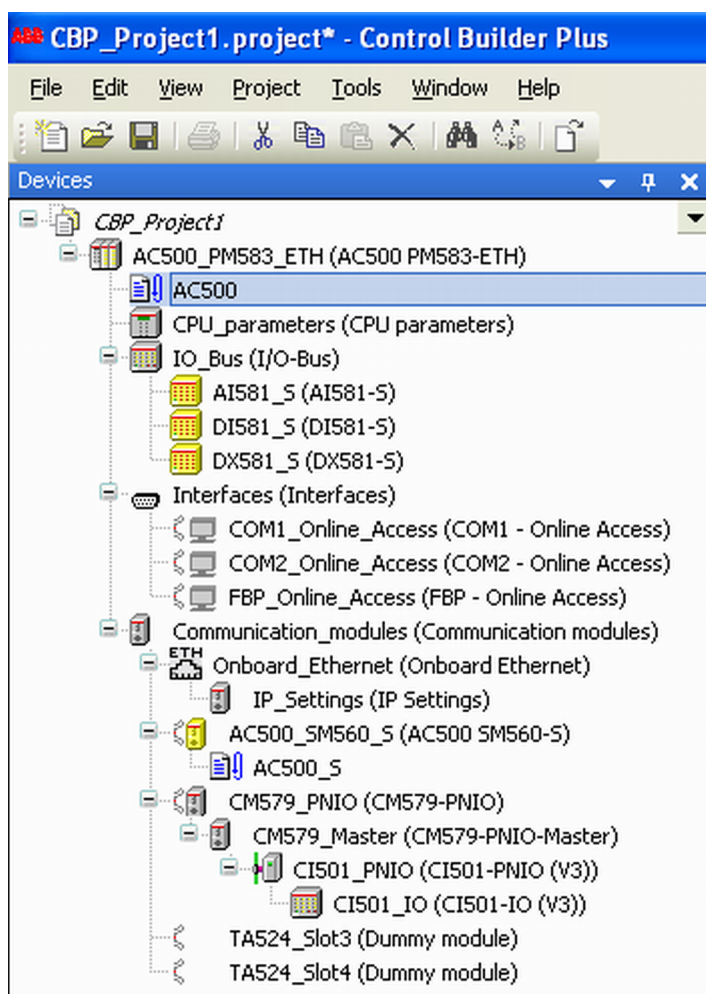
System configuration and programming > Programming of AC500-S Safety CPU

### ! NOTICE!

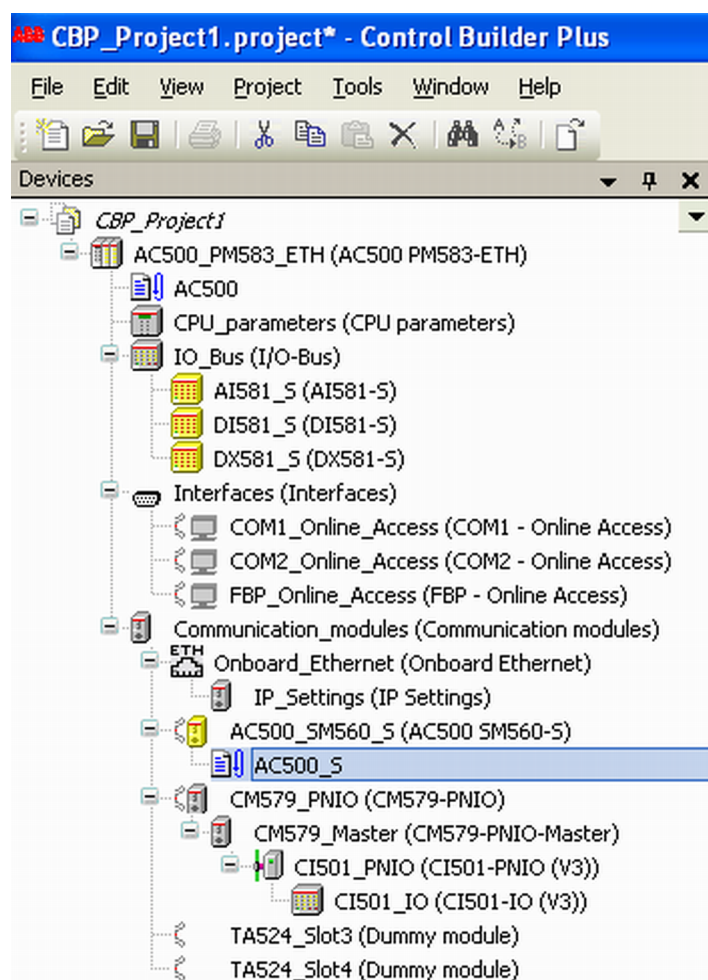
Follow AC500 Online User Documentation on how to create, configure, modify and download a valid CoDeSys Non-safety boot project.

To avoid unexpected configuration errors, make sure that you download first a valid CoDeSys Non-safety PLC project to PM5xx CPU and after this CoDeSys Safety PLC project is downloaded to SM560-S Safety CPU.

1. Start programming CoDeSys Non-Safety by double-click on AC500 object.



2. Start CoDeSys Safety by double-clicking AC500\_S object in the tree.



- ⇒ Before CoDeSys Safety or Non-Safety is started, you may be asked to update your CoDeSys V2.3 configuration. It is needed to transfer the updated configuration data (e.g., variable names, etc.) to CoDeSys V2.3.



## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

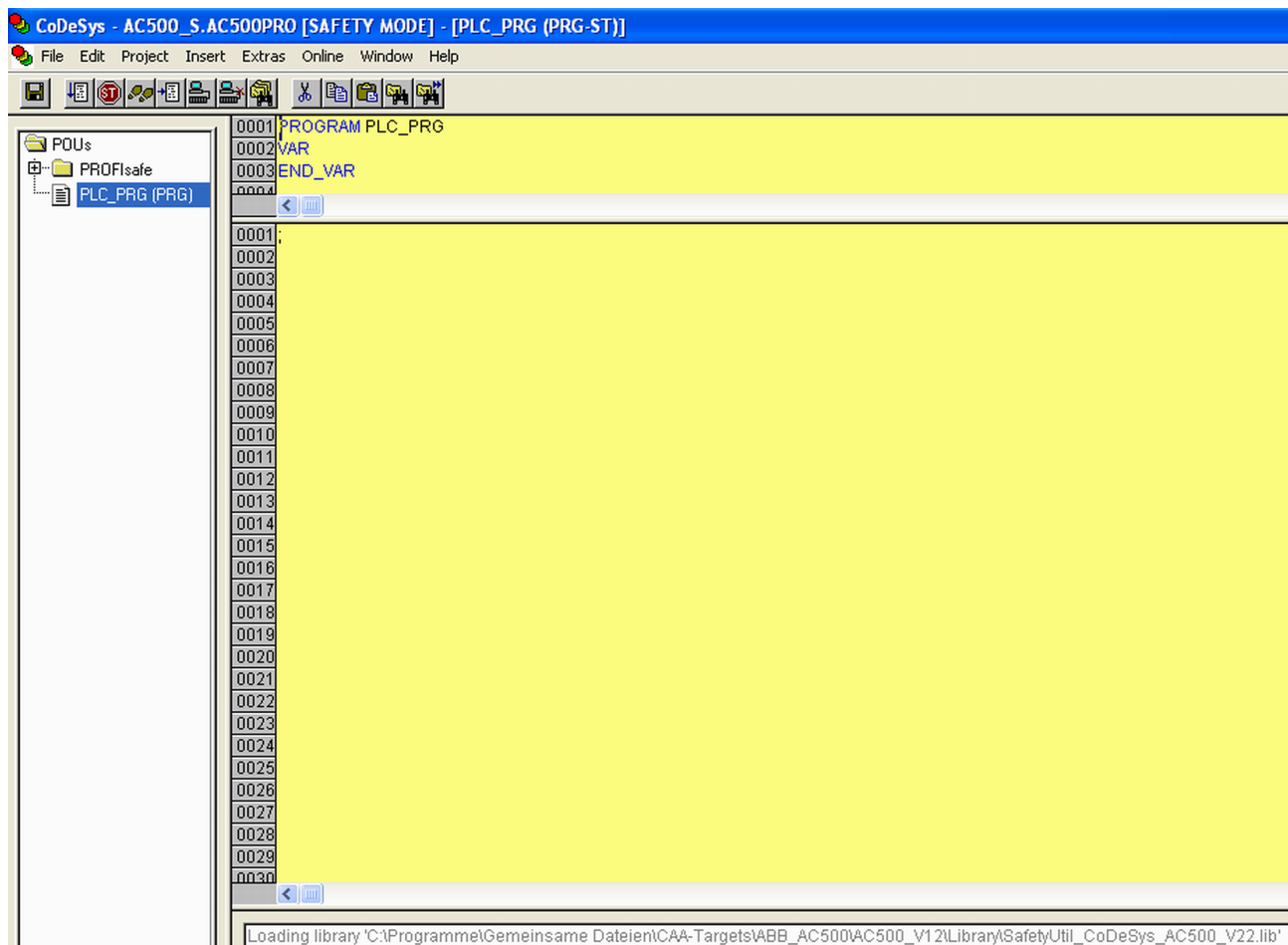


Fig. 85: CoDeSys Safety

### DANGER!

Make sure that when CoDeSys Safety is started, the following properties can be observed:

- Yellow background
- SAFETY MODE is visible in the title bar.



## ! NOTICE!

When CoDeSys Safety is started for the first time in the ABB Automation Builder project, you will be asked to manually confirm included safety library identification data (version number and CRC). After this, safety library identification data are saved in the project.

If you change the safety library content and replace it on your hard disk, then the next time you start CoDeSys Safety you will be informed that one of safety libraries changed. **In the properties window for safety libraries you will still observe an initially saved CRC value.** However, when you compile the project, you will get a CRC error message for the changed library and the project will not be compiled, as a result.

To compile the project successfully, you will have to manually delete the selected safety library, save the CoDeSys Safety project, open it again and add a new safety library with a new CRC. In the latter case, the new safety library with a new CRC will be accepted and no compilation error will be observed.

3. If your configuration of F-Devices is final, you have to check that F-Parameter values from F-Parameter tab are the same as those imported to CoDeSys Safety V2.3 (Go to "Resources" tab in CoDeSys Safety V2.3 project and navigate to "Global Variables → PROFIsafe → F-Device instance").

## ! DANGER!

You have to formally confirm that F-Parameter values from F-Parameter tab are the same as those imported to CoDeSys Safety V2.3 ( Chapter 6.2 "Checklist for creation of safety application program" on page 406 (Item 3)).

Name	Value	Symbolic-Value	Description	Unit
F_Check_SeqNr	1	Check	Consecutive number check in the CRC signature	
F_Check_IPar	0	No Check	Check of manufacturer specific IParameters within safety parameters	
F_SIL	2	SIL3	Employed SIL of the safety device	
F_CRC_Length	0	3 octet CRC	Cyclic redundancy check length	
F_Block_ID	1	F_Par_CRC in F-P...	Parameter block type identification	
F_Par_Version	1	Valid for V2 mode	Version of safety parameters	
F_Source_Add	1	1	Safety device source address (1-239)	
F_Dest_Add	3	1	Safety device destination address (1-255)	
F_WD_Time	100	100	Watchdog time in the safety device (10-10000)	ms
F_IPar_CRC	1957619468	1957619468	Value of the IParameter CRC calculation	
F_Par_CRC	55798	55798	Value of the safety parameter CRC calculation	

Fig. 86: F-Parameter values

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

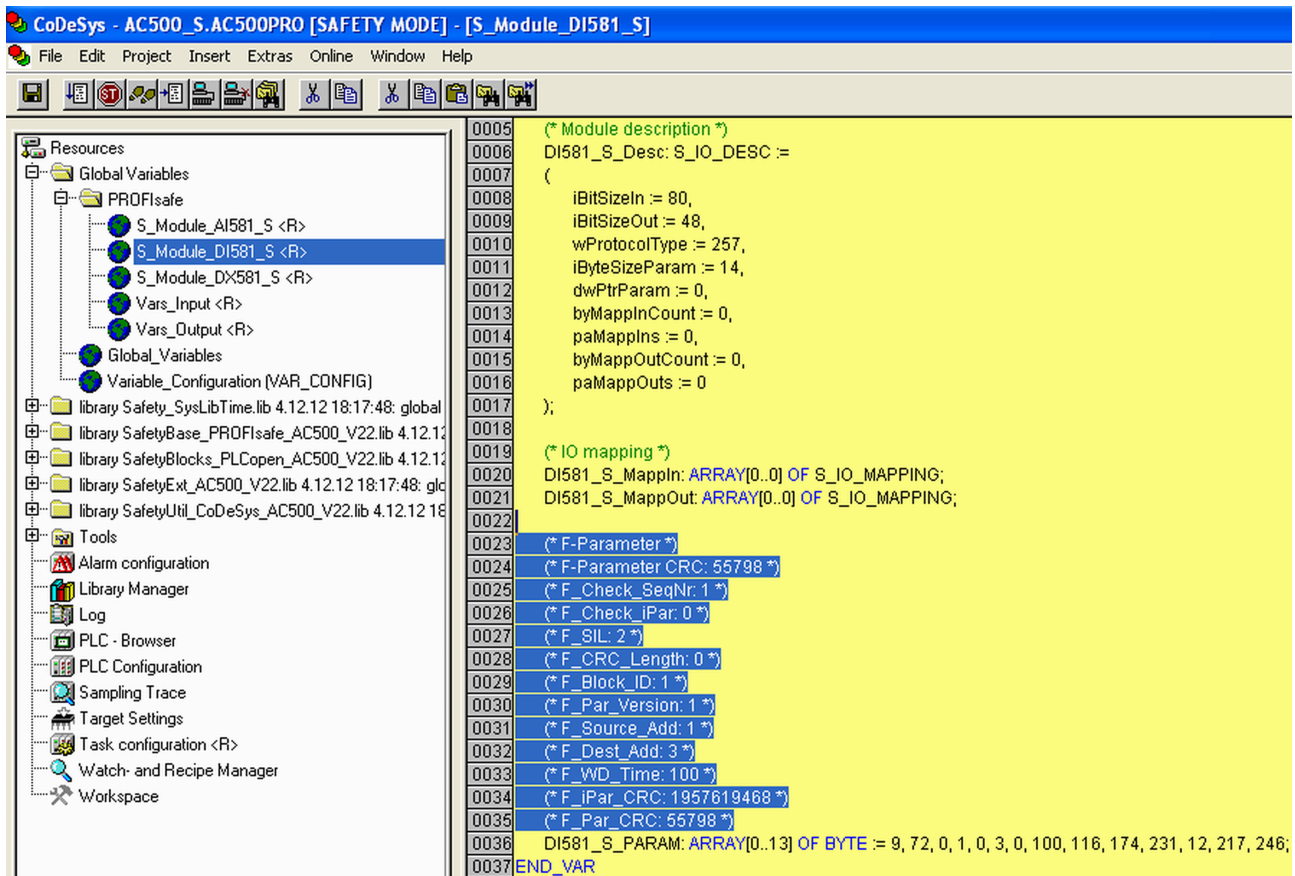


Fig. 87: F-Parameter values in CoDeSys Safety V2.3

4. All previously configured Input and Output variables can be found in separate Global Variable lists.

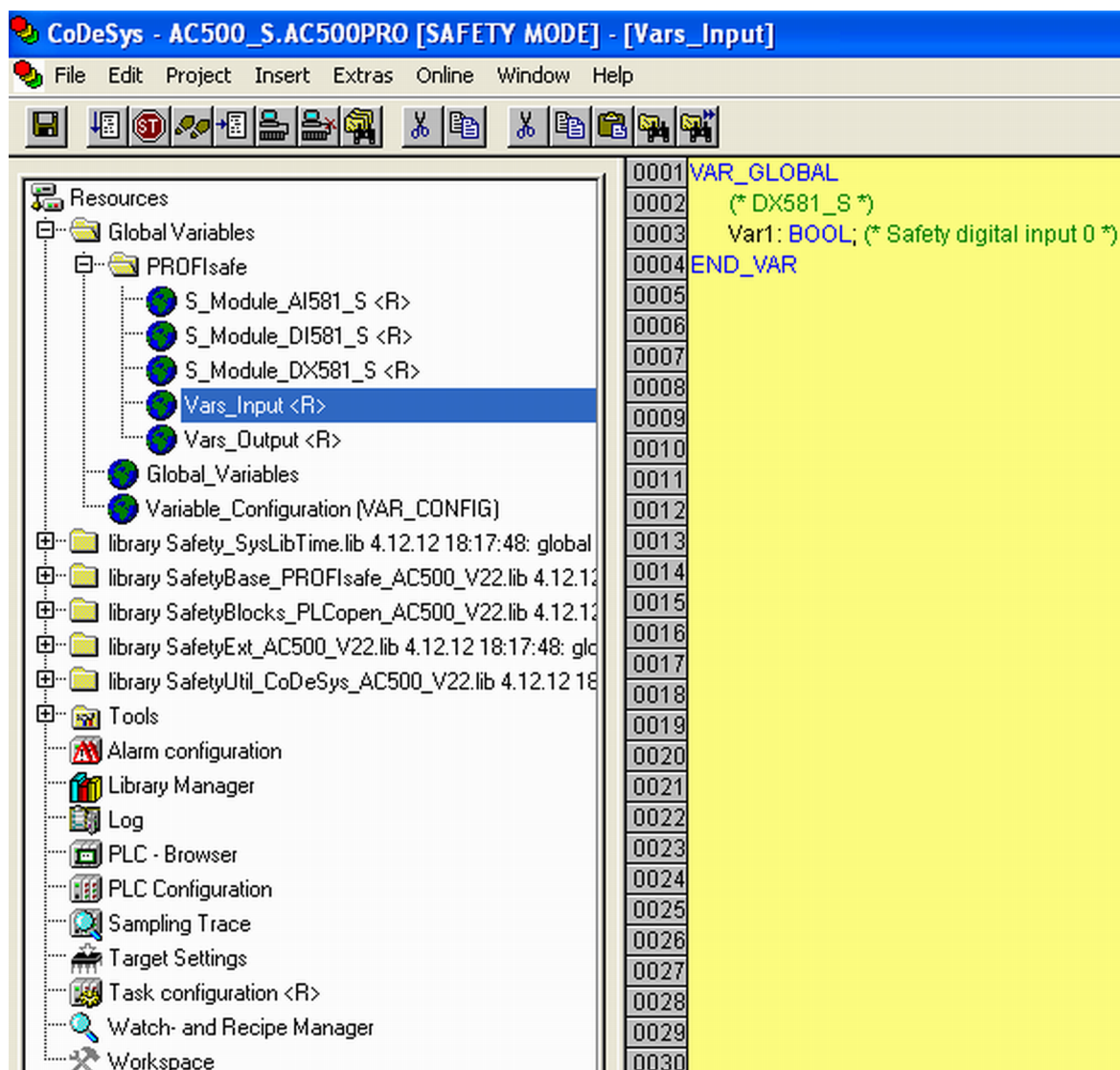


Fig. 88: Global variable list in CoDeSys Safety V2.3



## DANGER!

It is not allowed to change read-only (see <R> sign) resources or Task configuration in CoDeSys Safety V2.3.

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

### ! NOTICE!

All previously configured Safety Input and Output variables can be also automatically seen in CoDeSys Non-safety project (e.g., for their visualisation in Operator Panels, data logging, etc.).

The difference comparing to CoDeSys Safety project is that end-user is not able to modify the values of those safety variables from CoDeSys Non-safety project. It is prohibited by proper design.

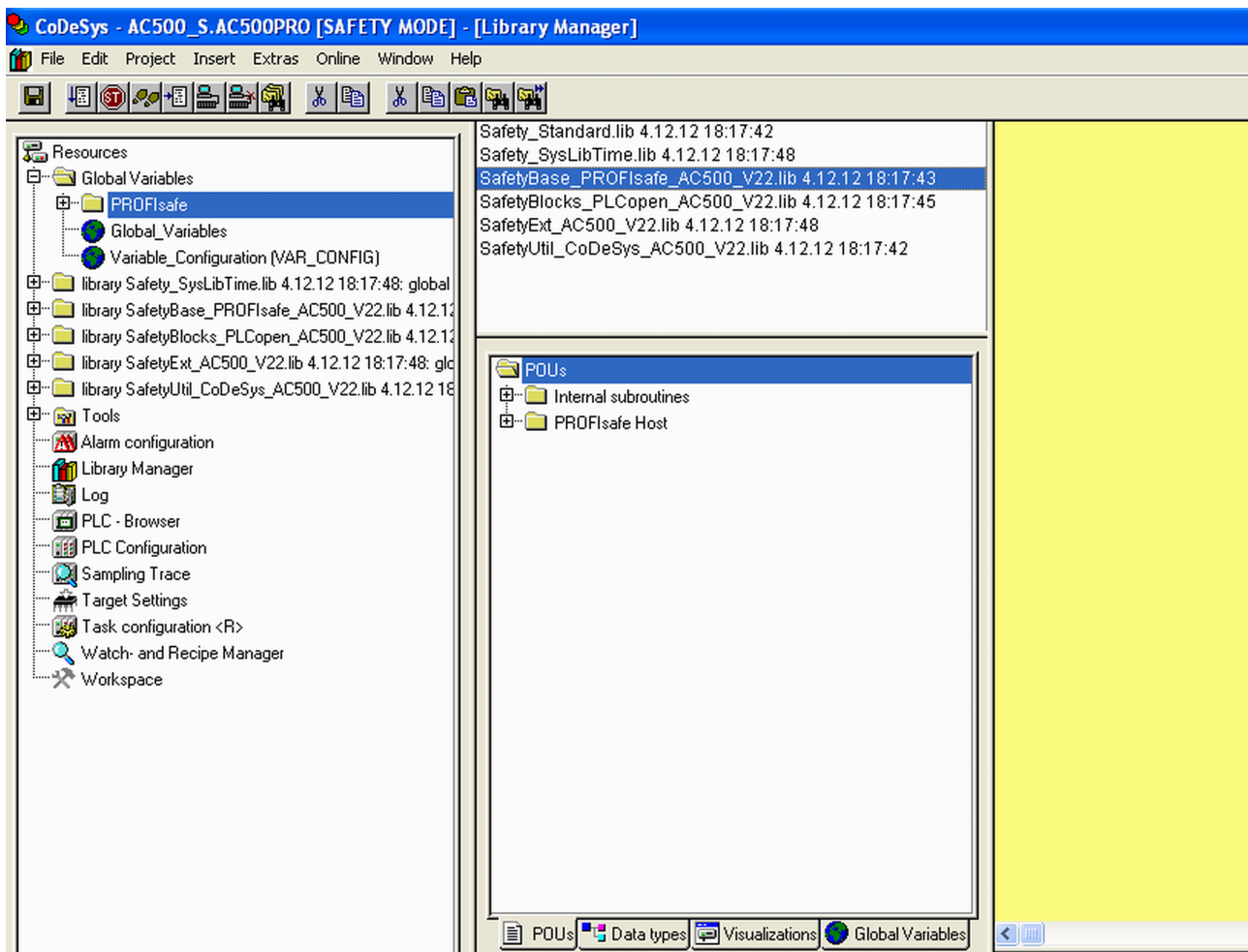


Fig. 89: All available Safety libraries can be found in the Library Manager



### **DANGER!**

The user is responsible to check that only certified Safety Libraries are used in his project. Certified safety libraries and CRCs: ↗ *Chapter 4.6.1 “Overview” on page 224.*

The user alone is responsible for all libraries which are created by him and referenced in the project for use in safety applications.

You have to formally confirm in the “Checklist for creation of safety application program” that no Non-safety libraries are used in your safety application.



### **NOTICE!**

SM560-S is a single-task machine, thus, no task configuration is needed.

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

5. The project administrator has to set a user password for newly created CoDeSys Safety V2.3 project. Go to "Project → User Group Passwords ..." and set the password for Level 0 User Group, which shall represent users from Safety User Group in PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer).

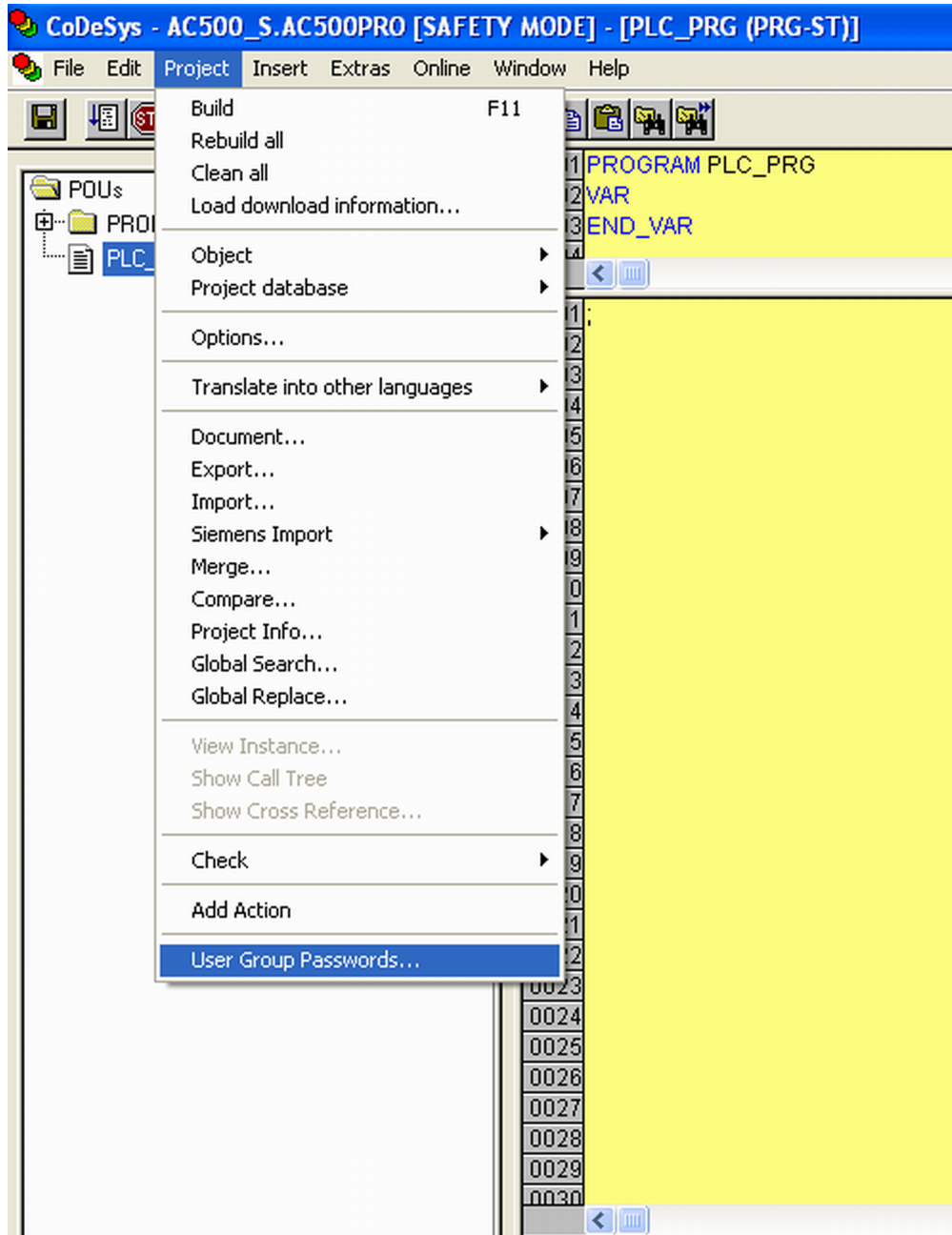


Fig. 90: Set passwords

6. All User Management features of CoDeSys Safety V2.3 are available for project administrator (☞ *AC500 User Documentation* for further details).

The following PLC Browser commands (these commands can be called from CoDeSys Safety V2.3) are supported by SM560-S Safety CPU:

- ? - List of available browser commands

reflect	- Output of browser commands (for test purposes)
pid	- It shows the project ID
pinf	- It shows project information in AC500 format
getprgprop	- It shows program properties in AC500 format
getprgstat	- It shows program status in AC500 format
setpwd	- It sets PLC password (it is needed during logging-on). This command is active only if SM560-S "Enable debug" parameter was set to "ON".
delpwd	- It deletes PLC password. This command is active only if SM560-S "Enable debug" parameter was set to "ON".
rtsinfo	- It shows firmware and boot project information in AC500 format
proddata	- It shows SM560-S production data in AC500 format
diagreset	- It resets diagnosis system of SM560-S Safety CPU
diagack all	- It acknowledges all errors
diagack x	- It acknowledges all errors of class x (x= 1 .. 4)
diagshow all	- It shows all errors in AC500 format
diagshow x	- It shows all errors of class x
delappl	- It deletes boot project in the Flash memory. This command is executed only in DEBUG STOP state of SM560-S Safety CPU. After SM560-S restart, one shall check that no boot project is available in SM560-S Safety CPU. This command is active only if SM560-S "Enable debug" parameter was set to "ON".
deluserdat:	- It deletes user data in the Flash memory. This command is executed only in DEBUG STOP state of SM560-S Safety CPU. It is executed immediately and is active only if SM560-S "Enable debug" parameter was set to "ON".
applinfo	- It shows the application information, e.g., results of time profiling using functions SF_APPL_MEASURE_BEGIN and SF_APPL_MEASURE_END.
applinfo reset	- It resets all application information, e.g., time measurement values.

None of the above-mentioned SM560-S PLC browser commands changes the state (e.g., from RUN to DEBUG RUN or DEBUG STOP, etc.) of SM560-S Safety CPU.

### **! NOTICE!**

The following PLC Browser commands from Safety CPU can influence SM560-S state:

#### **resetprg:**

It prepares SM560-S restart with initial variable values. SM560-S changes its state, e.g., from RUN to DEBUG STOP. *This command is active only if SM560-S "Enable debug" parameter was set to "ON".*

#### **resetprgorg:**

It restores SM560-S original state (all variables, Flash memory sections, etc. get original values). SM560-S changes its state, e.g., from RUN to DEBUG STOP. *This command is active only if SM560-S "Enable debug" parameter was set to "ON".*



## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU



### DANGER!

The results of “*delappl*”, “*setpwd*” and “*delpwd*” command execution shall be checked by the end-user through a log-on with CoDeSys Safety after powering off/on of SM560-S Safety CPU.

The following PLC Browser commands (these commands can be called from CoDeSys V2.3) from PM5xx are related to SM560-S Safety CPU:

- sdappl** - It saves the boot project of Non-Safety CPU and the configuration data of all attached communication modules as well as Safety CPU to SD card. The user data, SM560-S online password and power dip value of the Safety CPU are not saved. To update Non-safety CPU content with previously saved data using sdappl, one has to do appropriate modifications in sdcard.ini file (mode = ..., etc.) on SD card, [AC500 User Documentation and SD card handling](#) for more details.
- sdclone** - It saves the boot project of Non-Safety CPU and the configuration data of all attached communication modules including SM560-S Safety CPU to SD card. The user data, boot project, SM560-S online password, power dip value and user data of the Safety CPU are also saved on the SD card. After successful sdclone command execution, the “sdcard.ini” file on SD card is automatically updated so that when SD card is inserted to the other AC500 PLC with Safety CPU, the content of SD card is copied to that system to create a so-called “clone” of the previous system.
- sdcoupler <x>** - The communication module firmware (e.g., SM560-S Safety CPU firmware) will be copied from SD card to the communication module at slot <x> and the firmware update will be executed.



### NOTICE!

The following PLC Browser commands from Non-safety CPU PM5xx can influence SM560-S state:

#### **reboot**

It reboots Non-safety CPU and, as a result, SM560-S will be restarted as well.

#### **resetprgorg**

It restores PM5xx and SM560-S Safety CPU original state (all variables, Flash memory sections, etc. get original values). SM560-S changes its state from RUN to SAFE STOP.

**startprg**, **stopprg**, **resetprg** and **resetprgcold** lead to the transition of SM560-S Safety CPU to DEBUG RUN or DEBUG STOP states respectively.



## ! NOTICE!

The error messages of SM560-S Safety CPU are aggregated in the diagnosis stack on PM5xx Non-Safety CPU.

One can use `diagreset`, `diagack all`, `diagack x`, `diagshow all` and `diagshow x` commands in CoDeSys Non-safety PLC Browser to list and process various error messages in AC500 system, including those in SM560-S Safety CPU ( [↗ AC500 User Documentation](#) for more details on those commands).

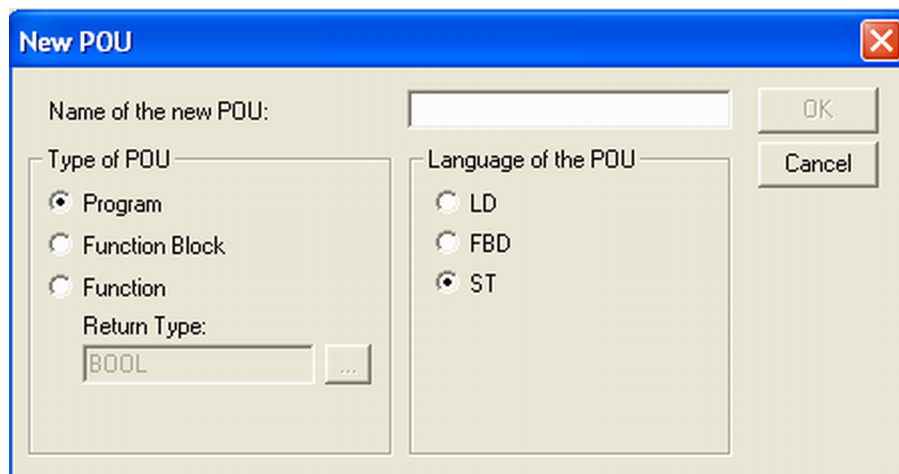


Fig. 91: The user can start programming using documented CoDeSys 2.3 features



## ! NOTICE!

ST, FBD and LAD are the only IEC 61131 languages supported by SM560-S for safety programming. Pay attention to CoDeSys Safety Programming Guidelines ( [↗ Chapter 4.4.1 "Overview" on page 210](#)). ST with a subset defined in [↗ Chapter 4.4.1 "Overview" on page 210](#) is equivalent to the Limited Variability Language, as defined in IEC 61508 ed. 2.

## ! NOTICE!

Do not create global variable lists using names beginning with the prefix "S\_Module\_". Global variable lists starting with "S\_Module\_" will be automatically updated by the CoDeSys Safety and may lead to the loss of the user information.

For SM560-S Safety PLC, it is important that all F-Devices are successfully initialized before program logic execution starts. It is also possible that some F-Devices start in FV\_activated mode ( [↗ Chapter 4.6.3 "SafetyBase\\_PROFIsafe\\_AC500\\_V22\\_Ext.lib" on page 231](#) for more details on PROFIsafe F-Host stack). To realize a simultaneous start, we recommend using a special POU, similar to SF\_Startup explained below, which could handle various possible start-up scenarios in PROFIsafe specification [3] and then give "Ready" output as a trigger for further normal safety program logic execution. As you can see from the implementation below, it is enough if at least one of the channels in DI581-S module has PROFIsafe diagnostic bit set to 1, meaning that normal process values can be delivered.

### Declaration part

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

```
FUNCTION_BLOCK SF_Startup

VAR_OUTPUT
    Ready: BOOL; (* Set to TRUE if all safety modules are initialized *)
END_VAR

VAR
    bTempReady: BOOL; (* Set if DI581-S safety module is ready *)
END_VAR

VAR CONSTANT
    _TRUE: BOOL := TRUE; (* Constant because TRUE is a literal *)
    _FALSE: BOOL := FALSE; (* Constant because FALSE is a literal *)
    wdNull: WORD := 16#0000; (* Constant for Safety I/O initialization *)
END_VAR

VAR_EXTERNAL
    DI581_S: PROFIsafeStack; (* External declaration *)
END_VAR
```

### Implementation part

```
(* Check if Operator Acknowledge is required for F-Device *)
IF DI581_S.OA_Req_S THEN (* The module requests an acknowledgement? *)
    DI581_S.OA_C := DI581_S.OA_Req_S; (* Acknowledge it, if requested *)
    (* We check here that DI581_S.OA_C did not passivate the given F-Device
    and no Operator Acknowledge Request is available from this module *)

    (* GS_DI581_Started is the variable for all channel PROFIsafe diagnostic
    bits set in Control Builder Plus / Automation Builder Plus for DI581-S
    module *)
    ELSIF GS_DI581_Started > wdNull THEN (* Is this module initialized? *)
        bTempReady := _TRUE; (* Yes, the module is initialized *)
    ELSE
        bTempReady := _FALSE; (* No, the module is not initialized yet *)
    END_IF;

    IF bTempReady THEN (* Set proper POU output signals *)
        Ready := _TRUE;
    ELSE
        Ready := _FALSE;
    END_IF;
```

### ! NOTICE!

To acknowledge the F-Device after a module passivation, OA\_C command bit has to be toggled from '0' to '1' until OA\_Req\_S status bit becomes "0".

7. To download the safety project to SM560-S Safety CPU, you have to set correct communication parameters

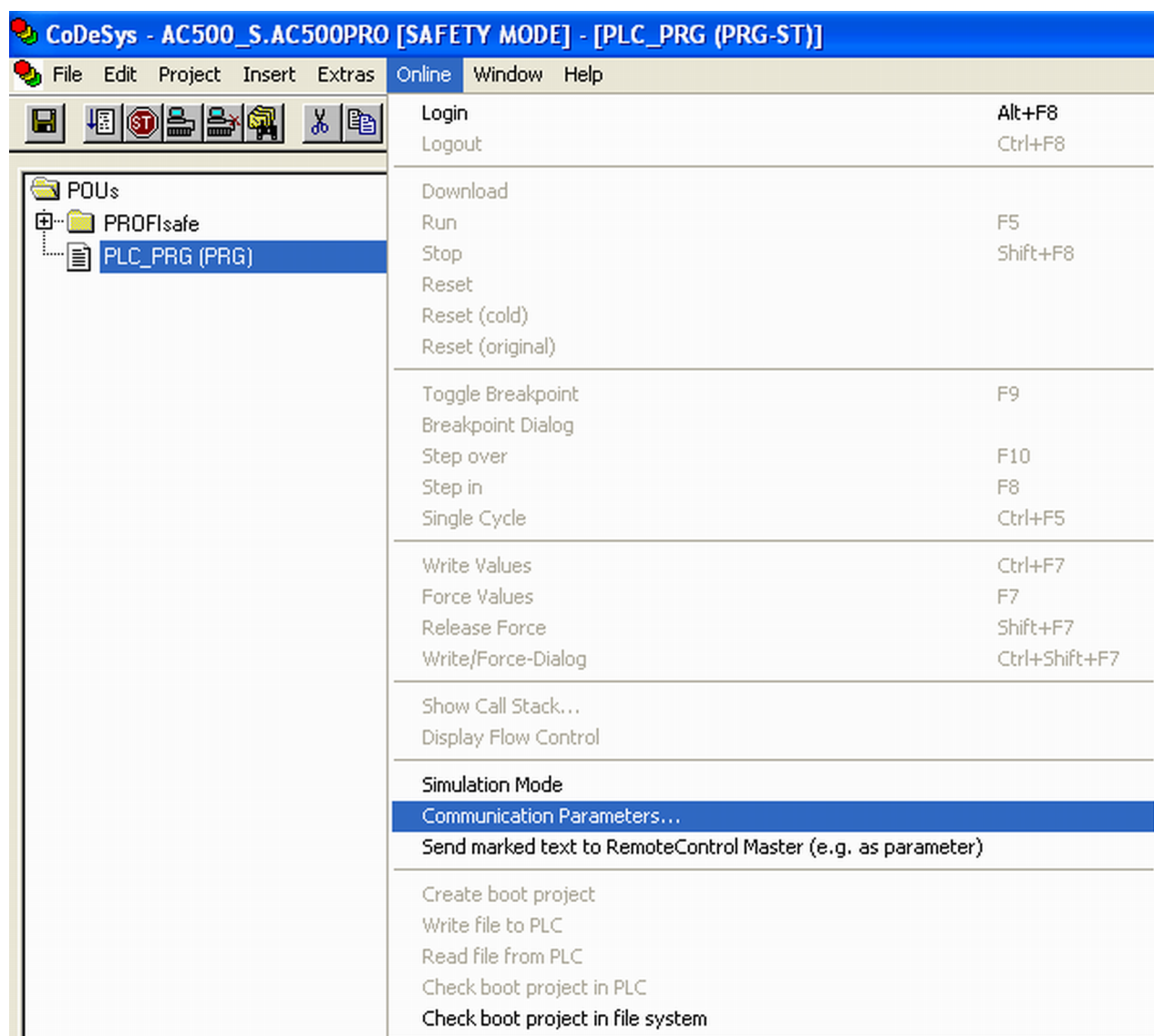


Fig. 92: Set communication parameters

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU



### ! NOTICE!

Make sure that to download CoDeSys Non-safety project either “*Tcp/Ip*” or “*Serial(RS232)*” communication channels were selected and, respectively, to download CoDeSys Safety project, either “*ABB Tcp/Ip Level 2 AC*” or “*ABB RS232 AC*” communication channels were selected.

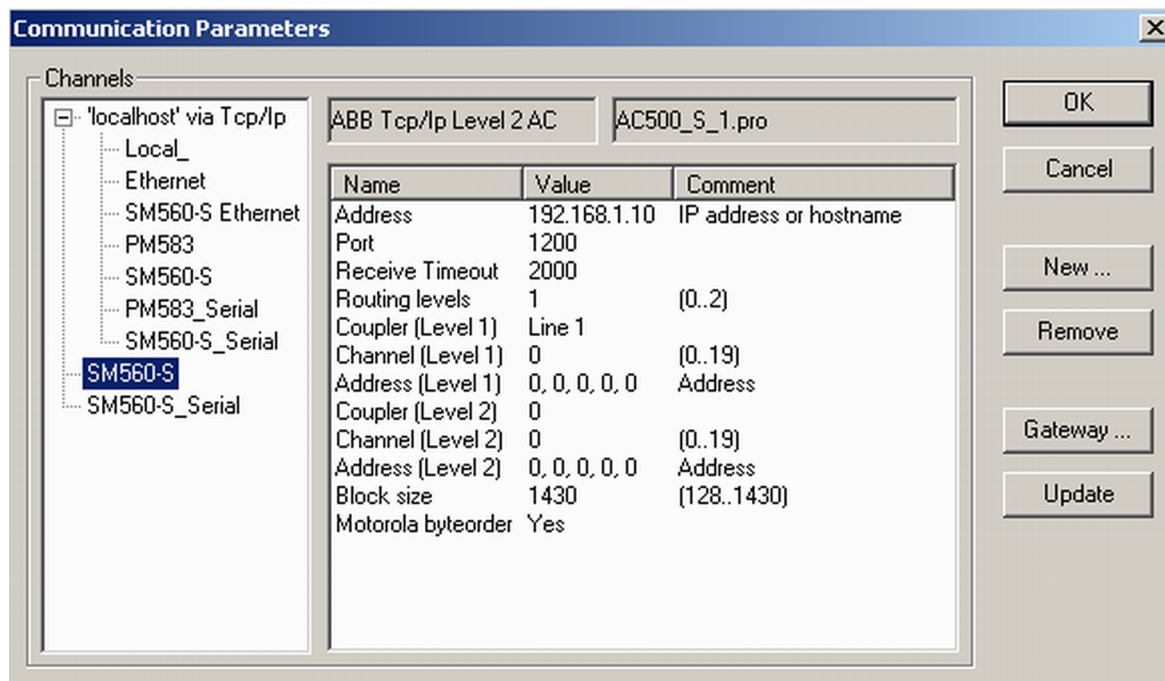


Fig. 93: Example with Ethernet connection

Note that “Address” is the IP address of your Non-safety CPU (you can also use COM port for program download using serial connection). Coupler (Level 1) defines the position of SM560-S Safety CPU (Line 1 – Position 1, Line 2 – Position 2 and so on).

➤ AC500 User Documentation for more details on “Communication Parameters”.

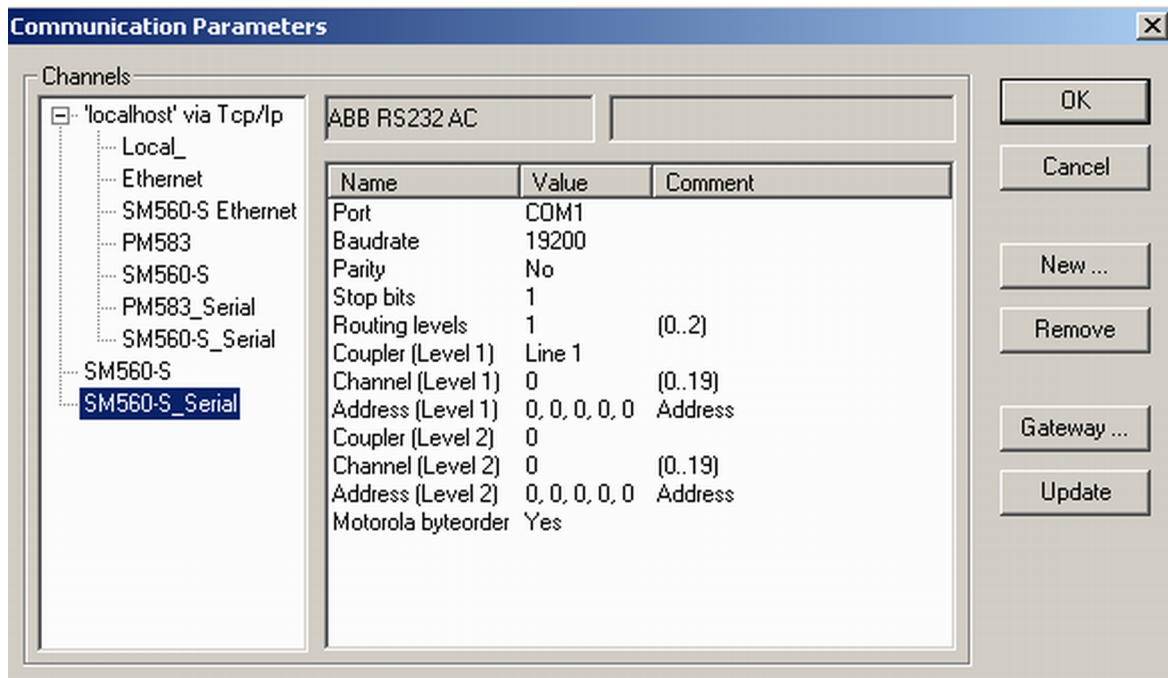


Fig. 94: Example with a serial connection

Now, you shall be able to login to your Safety CPU, download your safety application and create a boot project so that your Safety CPU can start safety program execution after powering off/on.

### ! NOTICE!

The “Online Change” service of CoDeSys is not supported by SM560-S Safety CPU for safety reasons. It means that each program change of CoDeSys Safety project requires stopping SM560-S, downloading a new boot project and then powering off/on or rebooting through PM5xx to see the safety program change(s) become active.

## Configuration and programming

System configuration and programming > Programming of AC500-S Safety CPU

### ! NOTICE!

Only one user can be logged-on to the given SM560-S Safety CPU at a time. It is needed to avoid multiple changes on the SM560-S Safety CPU from different users working at the same time.

The limitation on the number of open connections is valid only for SM560-S Safety CPU, which means that it is still possible to simultaneously connect to PM5xx Non-safety CPU using web and OPC server functionality.

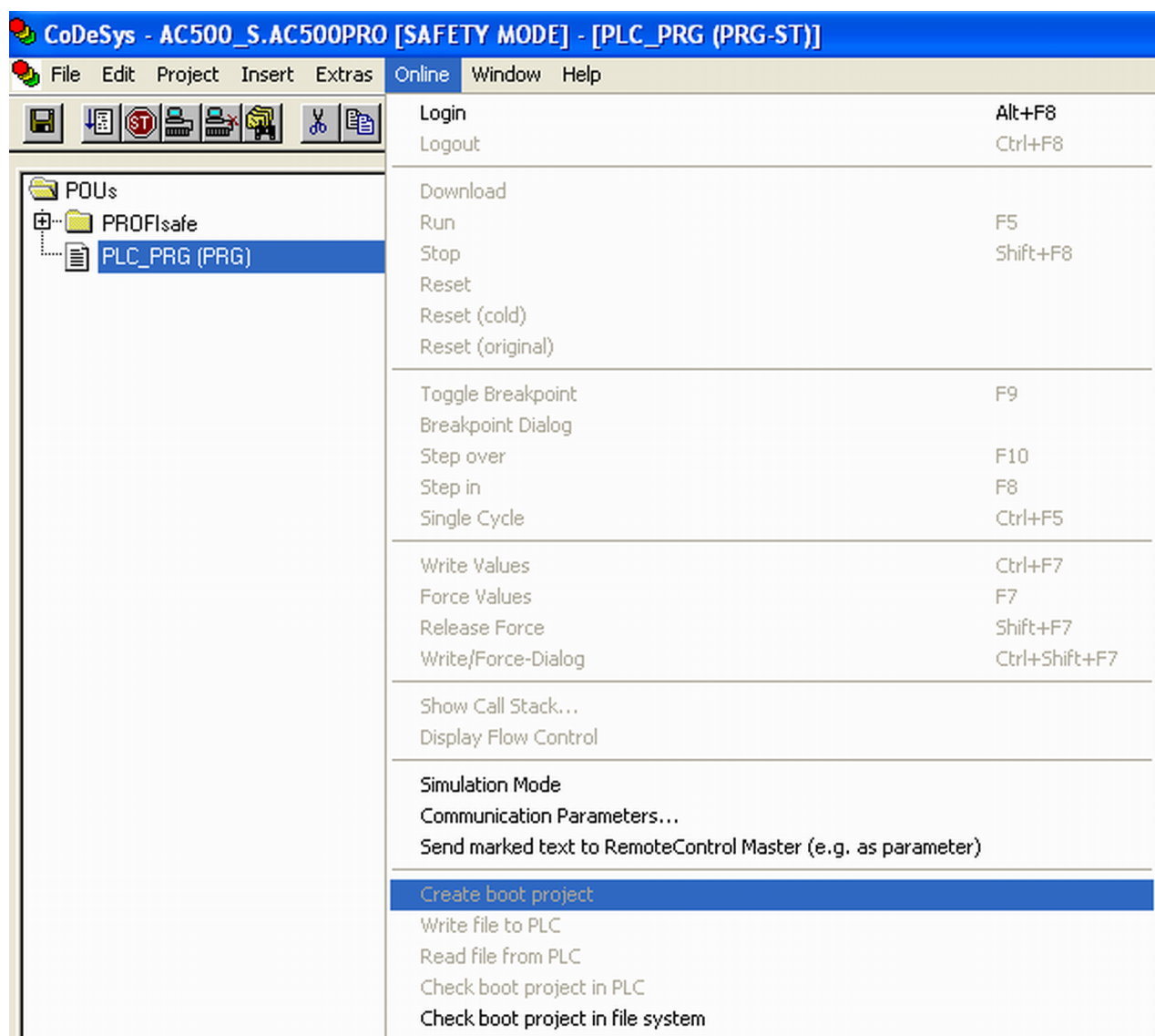


Fig. 95: Create boot project for SM560-S Safety CPU



### DANGER!

If “*Update Device ...*” function was used on Safety modules, then a full functional testing of all parts of the safety-oriented application has to be performed. This test must be carried out with the machine in its final configuration including mechanical, electrical and electronic components, sensors, actuators and software.



### NOTICE!

The user can later on verify using CoDeSys Safety menu item “*Online* → *Check boot project in PLC*” that offline CoDeSys safety project and the boot project on the Safety CPU are identical (File name, Change date, Title, Author, Version, Description and CRC).

The same comparison can be done with another boot project saved on the PC using “*Online* → *Check boot project in file system*” menu item.

**Note that before the boot project is created offline on the PC for a backup and later usage, the boot project has to be loaded at least once to the SM560-S Safety CPU.**

**It is highly recommended to execute “*Clean All*”, “*Rebuild All*” commands from CoDeSys Safety “*Project*” menu before downloading the safety program to SM560-S Safety CPU.**



### NOTICE!

Remember that Non-safety CPU takes part in iParameter transfer to F-Devices, thus, you shall not only download your safety application program to Safety CPU, but also in a similar way (☞ *AC500 User Documentation* for details) download Non-safety program from CoDeSys Non-Safety to Non-Safety CPU and create a boot project for PM5xx Non-Safety CPU.

If you do not follow the recommendation above, you may face configuration error or passivation of some F-Devices.



### DANGER!

Do not use “*Write file to PLC*” command for SM560-S because it may lead to the loss of important user information or load of corrupted data on SM560-S Safety CPU.

### 4.3.7 Checking of program and system configuration

**Check your program and system configuration. Use “Checklist for creation of safety application program” for program verification.**

It is important that you are able to successfully fill out “Checklist for creation of safety application program” (☞ *Chapter 6.2 “Checklist for creation of safety application program” on page 406*) and sign it. No safety program shall be approved without a positively completed “Checklist for creation of safety application program”. If some items from the “Checklist for creation of safety application program” cannot be fulfilled, then a proper explanation shall be provided in the Comment section.

### 4.4 CoDeSys Safety programming guidelines

This chapter and sub-chapters present an extract of SM560-S relevant rules from CoDeSys V2.3.x Safety Guidelines [1].

#### 4.4.1 Overview

CoDeSys V2.3 is usually used for creating non-safety-oriented applications. CoDeSys V2.3 is also suitable for creating safety-oriented applications of certain classes if it is used in a suitable environment in conjunction with controllers like AC500-S, specially approved for this purpose. However, this requires certain guidelines to be followed, which are described in this document.

##### 4.4.1.1 Target group

This document is aimed at users who wish to create safety-oriented applications with CoDeSys V2.3.

It also serves as a basis for testers who approve safety-oriented applications.

##### 4.4.1.2 Requirements

To understand this document knowledge of IEC 61131-3 [5], particularly the CoDeSys V2.3 programming system, is required.

Experience with the creation of safety-oriented applications is helpful.

##### 4.4.1.3 Terms

- Output - Variable that is mapped to an IEC output address (%Q)
- Output parameter - VAR\_OUTPUT of a program or function block
- Inputs - Variable that is mapped to an IEC input address (%I)
- Input parameter - VAR\_INPUT of a program, function or function block

#### 4.4.2 Framework

##### 4.4.2.1 Safety Integrity Level (SIL)

CoDeSys V2.3 is suitable for creating applications up to SIL 3. The use of CoDeSys 2.3 is not permitted for higher levels.



### 4.4.2.2 Approved CoDeSys version

The following product component versions are approved for creating safety-oriented applications:

Type of product component	Name of product component	Version (date)
Programming system	CoDeSys	2.3.9.9 or higher

The CoDeSys version can be checked via "Help" – "About". The correct version of the runtime system is indicated by SIL 3 approval of the control system through the German Technical Inspection Association (TÜV).

### 4.4.2.3 Control-specific application notes

Safety controllers require a special procedure for loading safety-oriented applications. In CoDeSys, the download of the bootproject is considered as safe, as it is secured by the appropriate mechanisms.

The procedure using CoDeSys is:

- Compile the user application
- Connect to the controller. This is secured by password protection. It causes automatic compile of user application, if needed.
- Execute menu item "/Online/Create Boot Project"
- Reboot the controller, causes loading and starting of the application.

All online commands like the following disable the safe operation:

- Download
- Online change
- Set breakpoint
- Write values
- Force values
- Trace
- Single cycle
- Start/Stop
- Flow control

The variable monitoring in online mode does not disable the safe operation.

### 4.4.2.4 Application creation procedure

Application creation must follow the guidelines of relevant safety standards, e.g., IEC 61508 ed. 2 for functional safety and DIN ISO 13849 for machinery. In addition to comprehensive documentation of requirements, architecture and module interfaces, this also includes full functional testing of all parts of the safety-oriented application. This test must be carried out with the machine in its final configuration including mechanical, electrical and electronic components, sensors, actuators, and software. Testing in a special test environment, for example using a debugger, may facilitate passing the final test, but cannot be used as a substitute.

## Configuration and programming

CoDeSys Safety programming guidelines > Language-specific programming guidelines

### 4.4.2.5 Settings

Table 10: The following system settings are required:

Setting	Value
Replace constants	Selected in Project/Options/Build
Actions hide programs	Selected in Project/Options/Build


### 4.4.2.6 Classification

In principle most language constructs can be used in safety-oriented applications. However, for some constructs that are associated with an increased fault potential during application creation this is only possible to a limited extent and compliance with additional fault prevention measures is strongly recommended. These measures are listed with the respective construct.

## 4.4.3 Language-specific programming guidelines

### 4.4.3.1 Safety-related restrictions for developers

There are some restrictions to developing safety applications with CoDeSys V2.3.x which have to be secured by organisational means. These are as follows:

- For Safety Applications, CoDeSys visualisations are allowed for Displaying purposes only. Changing values via controls (  Chapter 4.4.2.3 “Control-specific application notes” on page 211 “Write values”) would cause the run-time system to switch into non-safe mode without necessarily telling the user.

### 4.4.3.2 Language

Of the five IEC 61131-3 languages implemented in CoDeSys V2.3, “Structured Text” (ST), “Function Block Diagram” (FBD) and “Ladder Logic” (LD) are approved for creating safety-oriented applications.

### 4.4.3.3 Task system

Due to poor testability it is only advisable to a limited extend to use multitasking for safety-oriented applications. For application with CoDeSys this means:

- The complete application consisting of safety-oriented parts and non-safety-oriented parts should be called from program “PLC\_PRG”. To achieve a well arranged structure of the program, no logic processing should be programmed in “PLC\_PRG”. Assignments, calls to programs, function blocks or functions are allowed.
- The controller-specific options for monitoring total execution time must be activated and set significantly below the fault tolerance time.

## 4.4.3.4 Variable declarations

Of the variable types and attributes defined in IEC 61131-3 the following are suitable for creating safety-oriented applications:

Keyword	Description	Suitable (Yes / To a limited extent / No) (comment)
VAR	Local block variable	Yes
VAR_INPUT	Block input parameter	Yes
VAR_OUTPUT	Block output parameter	Yes
VAR_IN_OUT	Block reference parameter	To a limited extent (To illustrate the side effect the parameter should be identified with a prefix. Even better would be to use an input and output parameter instead.)
VAR_GLOBAL	Global variable	Yes (We strongly recommend identifying global variables with a prefix such as "G_" or "GS_" (for safety-oriented variables).)
VAR_EXTERNAL	Declaration of global variables used in the block	Yes/optional (not required in CoDeSys)
AT	Variable address allocation	Yes (see next chapter)
CONSTANT	Declaration as constant (no write access possible)	Yes (We recommend to declare each constant explicitly.)
RETAIN	Variable value is preserved after switch-off	No, not supported
PERSISTENT	Variable value is preserved after reloading	No, not supported

In the interest of better readability the following rules should be followed for the declaration of variables:

- Only one block of declaration type (e.g., VAR, VAR\_INPUT, VAR\_OUTPUT, VAR\_IN\_OUT, VAR\_GLOBAL and combinations with CONSTANT) per component
- Only one variable declaration per line with informative comment  
 Bad:
 

```
VAR
    A, B, C: BOOL; (* several variables *)
END_VAR
```

 Good:
 

```
VAR
    A: BOOL; (* first variable *)
    B: BOOL; (* second variable *)
    C: BOOL; (* third variable *)
END_VAR
```
- Local variables (VAR) should always have a different name. Obscuring of global variables through local variables must be avoided.

### 4.4.3.5 Direct addresses

The following rules must be followed when using addresses for creating safety-oriented applications:

- No application of addresses directly in the program code. Each used address must be assigned to a variable with "AT" in the declaration. In addition, we recommend identifying input/output variables through a prefix and defining them together in a single variable list.
- The application of marker addresses (%M) should be limited to a minimum due to the error-proneness of the allocation and the lack of purpose (memory for variables is allocated automatically).
- Multiple address allocation should be avoided due to obscure side effects. For word- and bit-wise access a variable is defined for the word and accessed via bit access <variable>.<bit number>.
- No address declarations within programs, function blocks, functions and data structures

## 4.4.3.6 Data types

Of the data types defined in CoDeSys the following are approved for creating safety-oriented applications:

Table 11: Simple data type

Keyword	Suitable (Yes / To a limited extent / No) (comment)
BOOL	Yes
BYTE, SINT, USINT	Yes
WORD, INT, UINT	Yes
DWORD, DINT, UDINT	Yes
TIME, TOD, DATE, DT	Yes
STRING	To a limited extent (technically possible, although it makes little sense due to the lack of safety-oriented input/output devices)
REAL	To a limited extent (prone to error through rounding errors, therefore no query with EQ operator, note invalid operations such as division by zero, square root of a negative number, logarithm of a negative number)

Table 12: Complex data types

Keyword	Suitable (Yes / To a limited extent / No) (comment)
ARRAY	To a limited extent (Only with explicit range check, otherwise too prone to errors)
STRUCT	Yes
Listing types	Yes
Subrange types	Yes
POINTER	To a limited extent (Recommended measures: no pointer arithmetic, range check, new allocation of pointer value at the start of each cycle)

The following rules must be followed when complex data types are used:

- For complex data types we recommend using type declarations
- Before each access to an array an explicit range check of the index should be carried out. In the event of a violation that cannot be explained through the application, the control system should be switched to safe state.

### DANGER!

The memory access using POINTERS (e.g., ADR function) is error-prone and is generally NOT recommended. If used in safety applications, then the responsibility for correct usage of these and related functions lies entirely with the organization and persons who use those functions in AC500-S safety PLC.

### 4.4.3.7 Blocks

All IEC 61131-3 block types are suitable for creating safety-oriented applications:

- PROGRAM
- FUNCTION
- FUNCTION\_BLOCK

If blocks are used the following programming guidelines should be followed:

- Functions and function blocks must not affect global application states. This can be achieved through write access to global data and by calling system components.
- Explicit parameter transfer is preferable for calling programs and function blocks.

Bad:

```
Inst.Param1 := 7;  
Inst.Param2 := 3;  
Inst();  
X := (Inst.Out1 AND A) OR B;
```

Good:

```
Inst(Param1 := 7, Param2 := 3, Out => Result);  
X := (Result AND A) OR B;
```

- All input parameters should be assigned for a call.

## 4.4.3.8 Libraries

External libraries approved by the manufacturer of the control system (i.e. implemented in the firmware of the control system) may be used for safety-oriented applications.

Of the standard CoDeSys libraries only the following are approved:

Library	Description	Version (date)
Safety_Standard.lib (former Standard.lib)	Standard IEC 61131-3 functions: <ul style="list-style-type: none"> <li>■ Timer</li> <li>■ Counter</li> <li>■ Trigger</li> <li>■ Flip-flops</li> <li>■ String processing</li> </ul>	2.3 (04.10.2005) or higher

User libraries, created by the manufacturer of the control system or the end user, may be used. On insert of a library, it has to be checked whether the selected library was actually inserted. The respective information is shown when the library is inserted.

## 4.4.3.9 Expressions

### 4.4.3.9.1 General

The following general rules must be followed for programming of expressions in safety-oriented applications:

- Mixing of different data types in an expression should be avoided. If mixing is unavoidable explicit type conversion should be used instead.
- The complexity of expressions should be minimised through the following measures:
  - Limitation of nesting depth (e.g., no more than 3 nesting levels) per expression
  - No more than 10 operators and 10 operands per expression
  - No application of expressions or array access in array indices
  - No application of expressions in function parameters, function block parameters or program parameters.

### 4.4.3.9.2 Constants

In the interest of more transparent semantics constants should either be declared explicitly or associated with explicit typification.

Bad:

```
VAR
    size: REAL;
    diameter: REAL;
END_VAR
size:= diameter * 3.14;
```

Good:

```
VAR CONSTANT
    PI: REAL := 3.14;
END_VAR
VAR
```

## Configuration and programming

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```
    size: REAL;
    diameter: REAL;
END_VAR
size:= diameter * PI;
```

Also good:

```
VAR
    size: REAL;
    diameter: REAL;
END_VAR
size:= diameter * REAL#3.14;
```

### 4.4.3.9.3 Assignments

If assignments are used, the following programming guidelines should be followed:

- For each instruction only one assignment is permitted. The expression assignments possible in CoDeSys must not be used for safety-oriented applications.

Bad:

```
Res1 := Res2 := FunCall(1, C := D, 3);
```

Good:

```
C := D;
Res2 := FunCall(1, C, 3);
Res1 := Res2;
```

- The implicit conversion between unsigned, signed and bit string types realised in CoDeSys and the extension of smaller types to larger types during assignment should not be used. Explicit conversion should be used instead.

### 4.4.3.9.4 Parentheses

Through definition of priorities for operators each expression is uniquely defined even without parentheses. However, in order to avoid mistakes and improve readability the use of parenthesis is highly recommended except in very familiar cases (multiplication/division before addition/subtraction).

Bad:

```
X := A < B AND NOT A > C + D OR E;
```

Good:

```
X := (A < B) AND NOT(A > (C + D)) OR E;
```

### 4.4.3.9.5 Bit access

Bit access (<variable>.<bit number>) is approved for creating safety-oriented applications and should also be used instead of the regularly used multiple address allocation.

Bad:

```
VAR_GLOBAL
    Flags AT %QW12: WORD;
    Enable AT %QX12.0: BOOL;
END_VAR
```



```
Flags := 0;  
Enable := TRUE;
```

**Good:**

```
VAR CONSTANT  
    EnableBit: INT := 0;  
END_VAR  
VAR  
    Flags AT %QW12: WORD;  
END_VAR  
Flags := 0;  
Flags.EnableBit := TRUE;
```

#### 4.4.3.9.6 Conversions

No implicit type conversions should be used for assignation and mixed types, i.e., only explicit conversions should be used.

**Bad:**

```
VAR  
    A: BYTE;  
    B: INT;  
    C: DWORD;  
END_VAR  
C := A + B;
```

**Good:**

```
VAR  
    A: BYTE;  
    B: INT;  
    C: DWORD;  
END_VAR  
C := INT_TO_DWORD(B + BYTE_TO_INT(A));
```

An even better solution in such cases is to reflect on type allocation.

## Configuration and programming

CoDeSys Safety programming guidelines > Language-specific programming guidelines

### 4.4.3.10 Operators

The following table indicates the suitability of operators for creating safety-oriented applications.

Keyword	Suitable (Yes / To a limited extent / No) (comment)
AND, OR, NOT, XOR	Yes
+, -, *, /, MOD	Yes (Division should include an explicit test for divisor <> 0)
=, <>, >, >=, <, <=	Yes
SQRT, SIN, COS, TAN, ASIN, ACOS, ATAN, LOG, LN, EXPT, EXP	To a limited extent (Prone to error through rounding errors)
MIN, MAX, LIMIT	Yes
MUX, SEL	Yes (Please note: branches that are not selected are not executed. This can lead to problems if functions calling system libraries are used.)
TIME	Yes
ADR	To a limited extent (Required for POINTERS that may be used to a limited extent.)
INDEXOF	To a limited extent (Only used as parameter for runtime system functions. The function used should be treated like an independent task.)
SIZEOF	Yes
ROL, ROR, SHR, SHL	Yes

### 4.4.3.11 Language constructs

The following ST language control elements are suitable for creating safety-oriented applications:

Keyword	Suitable (Yes / To a limited extent / No) (comment)
IF	Yes
CASE	Yes
FOR	Yes
WHILE	To a limited extent (Proof of avoidance of an infinite loop is required)
REPEAT	To a limited extent (Proof of avoidance of an infinite loop is required)
EXIT	To a limited extent (Exits a loop immediately. A loop should only be exited through its end condition leave.)
RETURN	To a limited extent (Exits a subroutine immediately. A subroutine should only be exited once all instructions have been processed.)

### 4.4.4 General programming guidelines

In addition to language-specific guidelines, errors should be avoided through compliance with additional general guidelines. These guidelines are listed here in no particular order:

- Few states  
States in the form of variables that retain their value beyond a control cycle hamper the testability of an application. This can be avoided with the following measures:
  - Avoidance of states wherever possible
  - A state variable should only be described once per cycle. This facilitates tracing of errors if a state has an invalid value.
  - If a state consists of several variables it should be encapsulated in a function block. State transitions should only be affected by calling the block.
- No warnings  
A safety-oriented application must not generate compiler warnings!
- Limited number of rows (500) per block  
In the interest of transparency, a block should have no more than 500 rows.
- Limited number of characters per row (150)  
In the interest of transparency, a row should have no more than 150 characters
- No reuse of variables  
Each variable should only be used for one purpose. Application in another context, even if the previous purpose is no longer important, involves a significant fault potential, particularly for modifications.
- Variables as local as necessary  
Variables that are only described in one block must be declared locally. The only exception is variables that are linked with addresses. These should be declared globally in order to avoid multiple assignments.
- Only one access to output  
As for states, outputs should only be described at one point in the program.
- No access to global variables from functions and function blocks  
A function should have no side effects, a function block should only change the state of its own instance. Functions and function blocks should therefore not access global variables.

### 4.4.5 Safety-oriented and non-safety-oriented parts of the application

For very complex applications, it is advisable to transfer all safety-oriented application parts to a separate control system. If this is not possible, the application parts should be separated through the following measures:

- Blocks (programs, function blocks and functions) are either safety-oriented or not. All safety-oriented blocks should be identified through a prefix (e.g., "S\_").
- Calls of non-safety-oriented blocks in safety-oriented blocks are not permitted. This must be checked with the "Show project call tree" function.
- Calls of safety-oriented blocks in non-safety-oriented blocks are limited to standard functions. This must be checked with the "Show project call tree" function.
- Global variables are either safety-oriented or not. All safety-oriented variables should be identified through a prefix (e.g., "S\_"). All safety-oriented variables are defined in separate variable lists that are also identified through a prefix.
- Write access to safety-oriented variables from non-safety-oriented blocks is not permitted. This must be checked with the "Show project cross-reference list" function.
- Write access to non-safety-oriented variables from safety-oriented blocks is not permitted. This must be checked with the "Show project cross-reference list" function.

## Configuration and programming

CoDeSys Safety programming guidelines > Safety-oriented and non-safety-oriented parts of the application

- The I/O addresses for safety-oriented application parts and non-safety-oriented application parts are separated into different ranges, while the safety-oriented parts coming first (lower addresses) in the memory.
- The following measures should also be adhered to in the non-safety-oriented part:
  - Limited application of pointers
  - Range check of indices before write access to fields (ARRAY)
  - No multiple address allocation

## 4.5 Safety code analysis tool

Instead of manually checking CoDeSys safety programming guidelines, one can use ABB software tool "AC500-S Safety Code Analysis" (SCA) to automatically check most of the safety rules defined by CoDeSys V2.3 (A list of rules which still have to be checked manually can be found in [Table 13 "CoDeSys safety programming rules which have to be checked manually \(ABB SCA tool is not able to detect them in the safety application program\)" on page 224](#)).

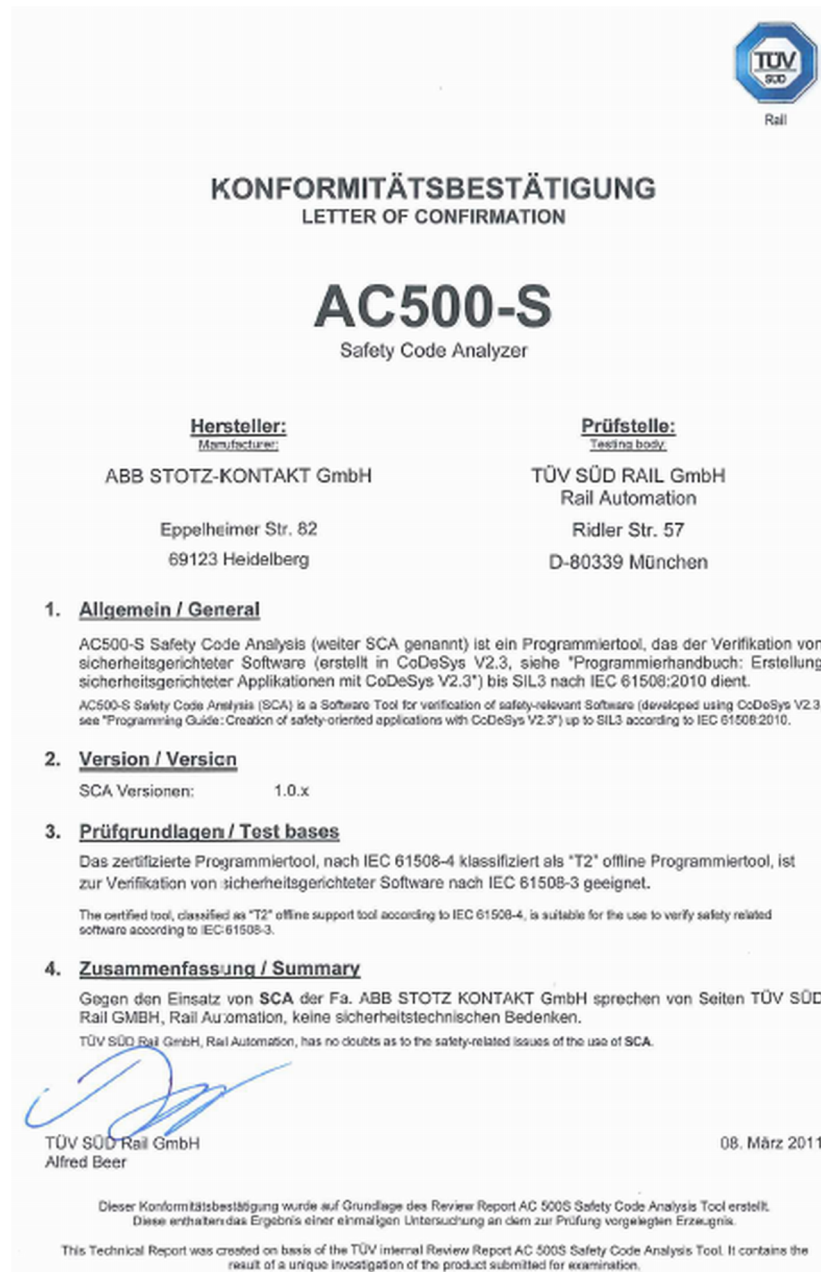


Fig. 96: TÜV letter of confirmation

The detailed description on how to use ABB SCA tool can be found in its Help system. Contact ABB technical support to obtain ABB SCA tool.

## Configuration and programming

AC500-S Libraries > Overview


Table 13: CoDeSys safety programming rules which have to be checked manually (ABB SCA tool is not able to detect them in the safety application program)

Rule for manual check in CoDeSys Safety	Comments (Relevance for AC500-S)
Verify that the watchdog is activated. Verify that the watchdog time is set sufficiently shorter than the process failure response time.	Use a special library POU SF_WDOG_TIME_SET ( ↗ Chapter 4.6.1 “Overview” on page 224 for further details)
Verify that there is only one task.	AC500-S supports only one task, thus, there is no need for this check.
Verify that, other than standard libraries, only libraries certified for safety applications are used.	These rules are included in AC500-S “Checklist for Creation of Safety Application Program”
For each POU, verify that there are no unnecessary state variables.	
Verify that the following holds for all function blocks: If more than one variable is used to store state information, encapsulate these variables into their own function block and only use calls on this function block to change the state.	
Verify that the compiler reports neither errors nor warnings when compiling the application.	
For each POU, verify that variables are not re-used later on with a different meaning.	
Verify that the names of safety POUs start with “S_”. Verify that the names of non-safety POUs do not start with “S_”.	These rules have to be checked only if you plan to implement not only safety but also non-safety functions on SM560-S Safety CPU. In typical applications with AC500-S it is not the case, because non-safety functions are realized on PM5xx Non-safety CPUs.
Verify that names of safety-related local variables start with “S_”.	
Verify that names of global safety variables start with “GS_”.	
Verify that names of safety inputs start with “IS_”.	
Verify that names of safety outputs start with “OS_”.	
Verify that names of non-safety variables do not start with either “S_”, “GS_”, “IS_” or “OS_”.	
Verify that names of global variable lists containing non-safety variables do not start with S_.	
Verify that names of global variable lists containing safety variables start with S_.	
For each non-safety POU, verify that it does not write to any safety variable.	


## 4.6 AC500-S Libraries

### 4.6.1 Overview

The following safety libraries are certified by TÜV and are allowed to be used with AC500-S Safety PLC:

Library Name / Version	Library CRC	Description
Safety_Standard.lib Version 2.3, which is an exact copy of the proven-in-use CoDeSys standard.lib (Version 2.3)	fd5d3581	Standard functions of CoDeSys  <i>AC500 User Documentation [4]</i> for further details
SafetyBase_PROFI-safe_AC500_V22_Ext.lib Version 1.0.1	f34d9a48	PROFIsafe F-Host and Safety I/O base functions Old versions: <ul style="list-style-type: none"> <li>■ SafetyBase_PROFI-safe_AC500_V22.lib, Version 1.0.0, library CRC: 7f64e267, license activation with PS501-S License Enabling Package;</li> <li>■ SafetyBase_PROFI-safe_AC500_V22.lib, Version 1.0.0, library CRC: c688eb23, special OEM version of PROFIsafe library.</li> </ul> <b>Note:</b> Old versions are NOT for use in new AC500-S customer projects.
SafetyExt_AC500_V22.lib Version 1.0.0	72a88162	Safety functions for Safety CPU cycle monitoring, under- and overvoltage supervision, data exchange with Non-safety CPU, user data storage in the Flash memory, etc.
Safety-Blocks_PLCOpen_AC500_v22.lib Version 1.0.0	b6e0bc60	PLCOpen Safety Libraries
SafetyUtil_CoDeSys_AC500_V22.lib Version 1.0.0	6b29c54	Internal SM560-S safety utilities <b>(Internal use only!)</b>
Safety_SysLibTime.lib Version 2.4.0.6	672b8325	Time system library <b>(Internal use only!)</b>
SysLibCallback.lib Version 2.4.0.6	6b29c54 or 62ad210d	Internal CoDeSys library (not shown in Library Manager) <b>(Internal use only!)</b>
Target_AC500_V22.lib Version 3.4.0.6	8daa436	Internal AC500 library (not shown in Library Manager) <b>(Internal use only!)</b>

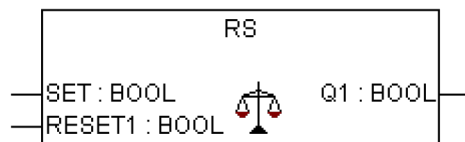
Non-safety POU's DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC are included in the existing PM5xx Non-safety CPU SysInt\_AC500\_V10.lib library for data exchange with SM560-S Safety CPU.

Note, that a list of operators, data types, etc., mentioned in  *Chapter 4.4 "CoDeSys Safety programming guidelines" on page 210*, according to IEC 61131-3 is supported with appropriate limitations in CoDeSys Safety programming environment.

### 4.6.2 Safety\_Standard.lib

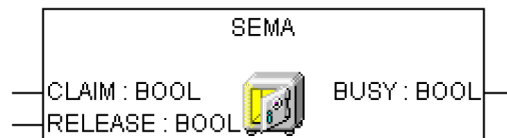
Only a short description is provided for standard CoDeSys POU's from Safety\_Standard.lib. For more detailed information about CoDeSys Standard Functions ↗ *AC500 User Documentation*.

#### RS



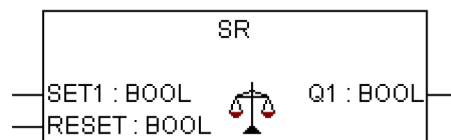
Bistable function, reset dominant  
 $Q1 = \text{NOT RESET1 AND (SET OR Q1)}$

#### SEMA



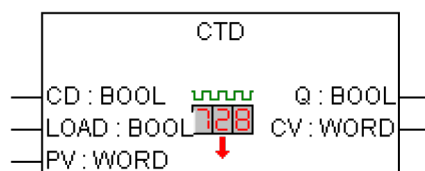
Software semaphore. Interruptable!  
BUSY is TRUE, if there was a call with CLAIM = TRUE,  
but no call with RELEASE = TRUE.  
CLAIM = TRUE sets BUSY = TRUE;  
RELEASE = TRUE sets BUSY = FALSE;

#### SR



Bistable function, set dominant  
 $Q1 = \text{SET1 OR (NOT RESET AND Q1)}$

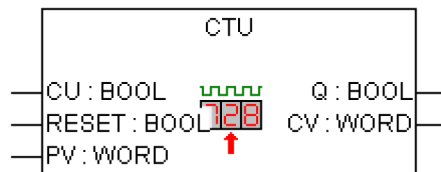
#### CTD



Counter Down.  
CV is decremented by 1 if CD has a rising edge.  
Q is TRUE, if CV reached 0.

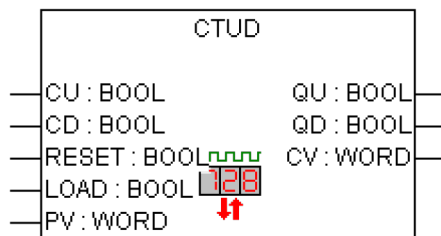


## CTU



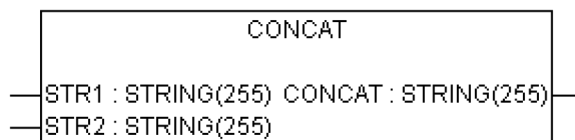
Counter Up.  
CV is incremented by 1 if CU has a rising edge.  
Q is TRUE, if CV is reached PV.

## CTUD



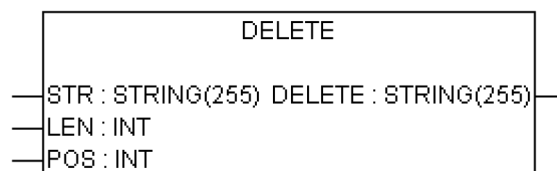
Counter Up Down  
CV is incremented by 1 if CU has a rising edge.  
CV is decremented by 1 if CD has a rising edge.  
QU is TRUE, if counter is PV.  
QD is TRUE, if counter is 0.

## CONCAT



Concatenation of two strings.

## DELETE

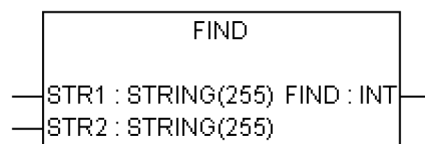


Delete LEN characters of STR, beginning at the POS-th character position.  
POS = 1 is the first character.

## Configuration and programming

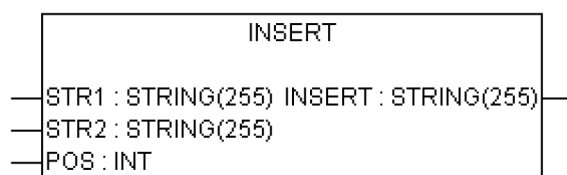
AC500-S Libraries > Safety\_Standard.lib

### FIND



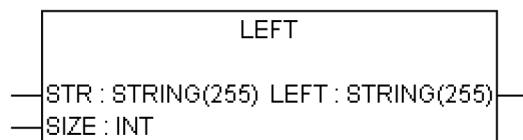
Find the character position of the beginning of the first occurrence of STR2 in STR1.  
If no occurrence of STR1 is found, then the result is 0.

### INSERT



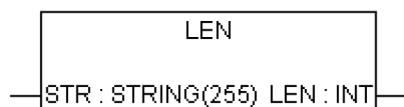
Insert STR2 into STR1 after the POS-th character position.  
POS = 0 inserts before the first character.  
POS = 1 inserts after the first character.

### LEFT



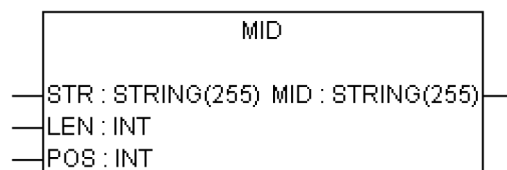
Return leftmost SIZE characters of STR.

### LEN



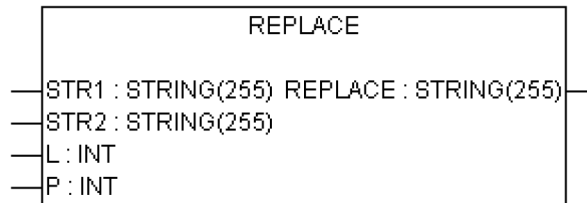
String length function.  
Returns the number of characters in STR.

### MID



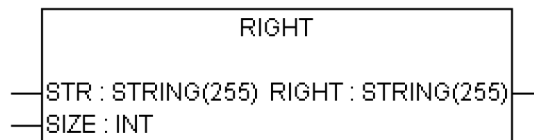
Return LEN characters of STR, beginning at the POS-th character position.  
POS = 1 is the first character.

## REPLACE



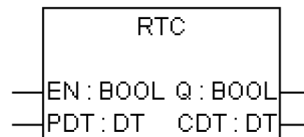
Replaces L characters of STR1 by STR2,  
starting at the POS-th character position and returns the new string.  
POS = 1 is the first character.

## RIGHT



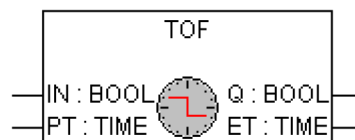
Returns rightmost SIZE characters of STR.

## RTC



Sets CDT to PDT when rising edge in EN and starts increasing CDT.  
With EN = FALSE, CDT set to DT#1970-01-01-00-00:00

## TOF

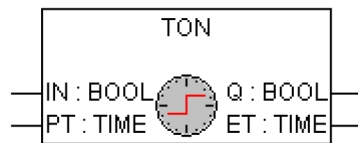


Timer of delay.  
Q is FALSE, PT milliseconds after IN had a falling edge.

## Configuration and programming

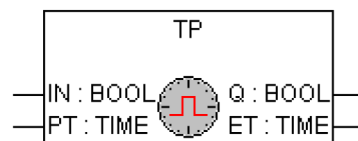
AC500-S Libraries > Safety\_Standard.lib

### TON



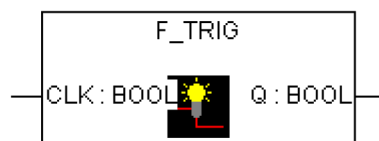
Timer on delay.  
Q is TRUE, PT milliseconds after IN had a rising edge.

### TP



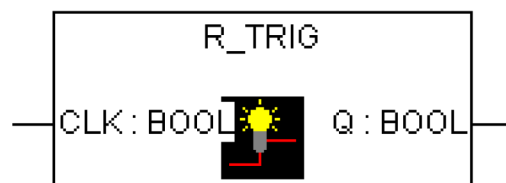
Timer Pulse.  
Q produces a High-Signal with the length of PT on every rising edge on IN.

### F\_TRIG



Falling Edge detection.

### R\_TRIG



Rising Edge detection.

## 4.6.3 SafetyBase\_PROFIsafe\_AC500\_V22\_Ext.lib

This library includes a PROFIsafe Stack implementation (PROFISAFESTACK POU), which is a key F-Host component.

### ! NOTICE!

Old versions

- SafetyBase\_PROFIsafe\_AC500\_V22.lib, Version 1.0.0, library CRC: 7f64e267, license activation with PS501-S License Enabling Package
- SafetyBase\_PROFIsafe\_AC500\_V22.lib, Version 1.0.0, library CRC: c688eb23, special OEM version of PROFIsafe library

are NOT for use in new AC500-S customer projects.

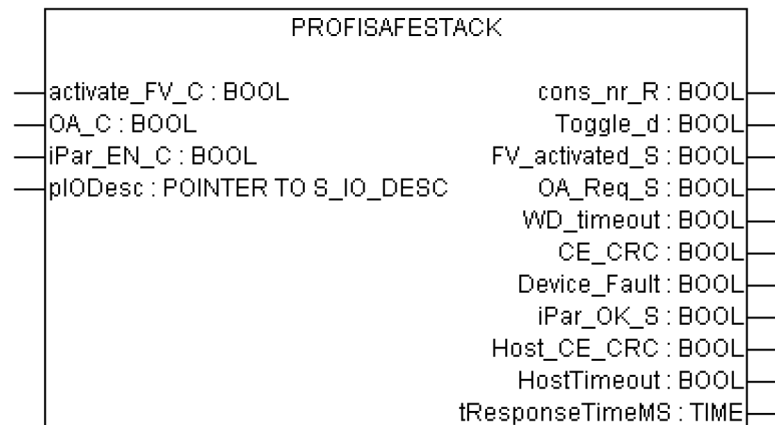
### ! NOTICE!

Loop-back check via Bit 7 in Status / Control Byte of PROFIsafe telegram is implemented, which means that no further considerations against systematic loop-back configuration errors shall be performed by end-users (☞ [www.profisafe.net](http://www.profisafe.net) for further details).



### DANGER!

Not more than one communication error (CE\_CRC or Host\_CE\_CRC output signals become equal to TRUE) per 100 hours is allowed to be acknowledged by the operator using OA\_C input signal without consulting the responsible safety personnel (☞ [www.profisafe.net](http://www.profisafe.net) for further details).



This function block represents PROFIsafe F-Device instance in the PROFIsafe F-Host to control and monitor the status of the given F-Device [3].

## Configuration and programming

AC500-S Libraries > SafetyBase\_PROFIsafe\_AC500\_V22\_Ext.lib

Table 14: FB Name: PROFISAFESTACK

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
activate_FV_C	BOOL	FALSE	Command (= TRUE) to activate fail-safe values in F-Device or (= FALSE) for normal F-Device operation
OA_C	BOOL	FALSE	Command (= TRUE) for operator acknowledgement and resume of safety function by F-Device
iPar_EN_C	BOOL	FALSE	This variable TRUE allows a safety control program to switch the F-Device into a mode during which it will accept iParameters. This mode is not supported by AC500-S Safety I/O modules (DI581-S, DX581-S and AI581-S)
plODesc	POINTER	NULL	Internal input parameter ( <b>Internal use only!</b> )
<b>VAR_OUTPUT</b>			
cons_nr_R	BOOL	FALSE	<b>This parameter is for debugging purposes only.</b> It is set when the F-Device has reset its consecutive number counter in PROFIsafe communication [3].
Toggle_d	BOOL	FALSE	<b>This parameter is for debugging purposes only.</b> It is a device-based Toggle Bit indicating a trigger to increment the virtual consecutive number within the F-Host [3].
FV_activated_S	BOOL	FALSE	With input devices this variable indicates if TRUE that the driver is delivering fail-safe values "0" to the F-Host program for every input value.  With output devices this variable indicates if TRUE that every output is set to fail-safe values "0" (default behavior) or F-Output device specific value controlled by the "activate_FV" signal [3].
OA_Req_S	BOOL	FALSE	This variable indicates a request for acknowledgement prior to the resumption of a safety function. In case the F-Host driver or F-Device detects a communication error or F-Device fault, fail-safe values will be activated. F-Device driver then sets the variable OA_Req_S (= TRUE) as soon as the fault/error has been eliminated and operator acknowledgement is possible. Once the acknowledgement occurred (OA_C = TRUE) the F-Device driver will reset the request variable OA_Req_S (= FALSE) [3].

Name	Data Type	Initial Value	Description, Parameter Values
WD_timeout	BOOL	FALSE	<p><b>This parameter is for debugging purposes only.</b></p> <p>It is set to TRUE if the F-Device is recognizing a communication failure, i.e. if the watchdog time in the F-Device is exceeded [3].</p>
CE_CRC	BOOL	FALSE	<p><b>This parameter is for debugging purposes only.</b></p> <p>It is set if the F-Device is recognizing a communication failure, i.e. if the consecutive number is wrong (detected via CRC2 error in V2-mode) or the data integrity is violated (CRC error) [3].</p>
Device_Fault	BOOL	FALSE	<p>This parameter is set to TRUE if there is a malfunction in the F-Device (e.g., under- or over-voltage) [3].</p>
iPar_OK_S	BOOL	FALSE	<p>This parameter is set to TRUE when F-Device has new parameter values assigned [3].</p>
Host_CE_CRC	BOOL	FALSE	<p><b>This parameter is for debugging purposes only.</b></p> <p>This parameter is set to TRUE if communication fault (CRC error on F-Host side) occurred.</p>
HostTimeout	BOOL	FALSE	<p><b>This parameter is for debugging purposes only.</b></p> <p>This parameter is set to TRUE if communication fault (Timeout on F-Host side) occurred.</p>
tResponseTimeMS	TIME	16#0000	<p><b>This parameter is for debugging purposes only.</b></p> <p>It represents the current response time for F-Device in ms. This value shall be smaller than the defined F_WD_Time parameter for the given F-Device. If not, then the passivation of the given F-Device will happen.</p>

The FB instances for all F-Devices are automatically generated and can be found in CoDeSys Safety project in Resources/Global Variables/PROFIsafe/ directory, as shown below. Those FB-Instances, as normal Global Variables, can be accessed by end-users from their safety application programs.

## Configuration and programming

AC500-S Libraries > SafetyBase\_PROFIsafe\_AC500\_V22\_Ext.lib

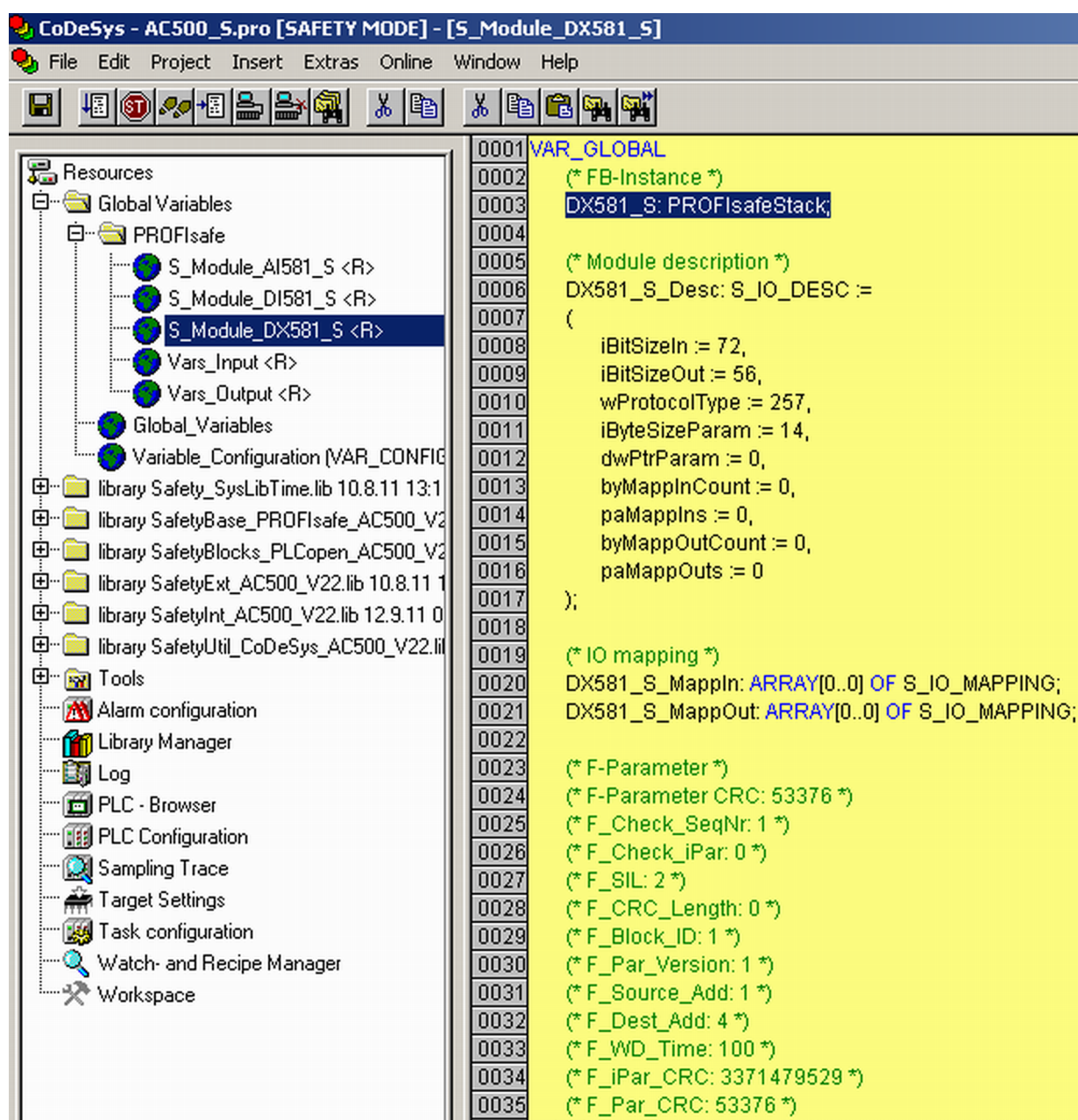


Fig. 97: FB instances for F-Devices

Note, that SafetyBase\_PROFIsafe\_AC500\_V22\_Ext.lib library also includes a number of internal POU's (GetWord, MappingIn, MappingOut and SMemCpy) related to Safety I/O handling. **These POU's are for internal use only!**



## 4.6.4 SafetyExt\_AC500\_V22.lib

SafetyExt\_AC500\_V22.lib library includes the following POUs:

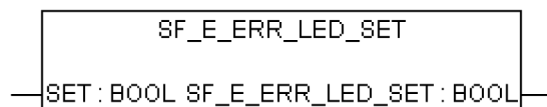
- System commands
  - SF\_E\_ERR\_LED\_SET (Setting E-ERR LED state (ON or OFF))
  - SF\_MAX\_POWER\_DIP\_SET (Setting the maximum number of restarts after power dip in SM560-S Safety CPU)
  - SF\_WDOG\_TIME\_SET (Setting the maximum allowed cycle time of SM560-S Safety CPU)
  - SF\_APPL\_MEASURE\_BEGIN (This function defines the start point of time profiling)
  - SF\_APPL\_MEASURE\_END (This function defines the end point of time profiling)
- System information
  - SF\_MAX\_POWER\_DIP\_GET (Getting the current number of restarts after power dip in SM560-S Safety CPU)
  - SF\_SAFETY\_MODE (Reading out if SM560-S Safety CPU is in DEBUG or SAFETY mode)
  - SF\_SM5XX\_OWEN\_ADR (Getting the value of the hardware switch address on SM560-S Safety CPU)
  - SF\_RTS\_INFO (It provides the firmware version of the Safety CPU. The version is a binary coded decimal, e.g., 16#10 means version 1.0)
- Data storage
  - SF\_FLASH\_DEL (This function block deletes a data segment in the Flash memory. All data in this data segment will be deleted.)
  - SF\_FLASH\_READ (The function block reads a data set from a data segment of the Flash memory and stores the read data set beginning at the start flag defined by SM560-S Safety CPU.)
  - SF\_FLASH\_WRITE (The function block writes data to a data segment in the Flash memory.)
- DPRAM communication
  - SF\_DPRAM\_PM5XX\_S\_REC (Receiving data from Non-safety CPU PM5xx)
  - SF\_DPRAM\_PM5XX\_S\_SEND (Sending data to Non-safety CPU PM5xx)

Note, that DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC POUs shall be used respectively on the Non-safety CPU PM5xx to send and receive data to/from the SM560-S Safety CPU.

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.1 SF\_E\_ERR\_LED\_SET



#### Setting E-ERR LED state (ON = TRUE or OFF = FALSE)

E-ERR LED is set directly in the same SM560-S Safety CPU cycle. The state remains unchanged until it is not explicitly changed using SF\_E\_ERR\_LED\_SET call.

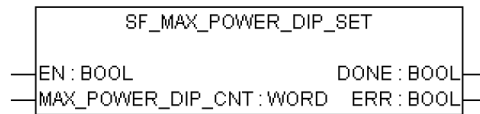
Table 15: FUN Name: SF\_E\_ERR\_LED\_SET

Name	Data Type	Initial Value	Description, Parameter Values
VAR_INPUT			
SET	BOOL	FALSE	FALSE = E-ERR LED is OFF, TRUE = E-ERR LED is ON
VAR_OUTPUT			
SF_E_ERR_LED_SET	BOOL	FALSE	FALSE = E-ERR LED is OFF, TRUE = E-ERR LED is ON

#### Call in ST

```
SF_E_ERR_LED_SET_Value := SF_E_ERR_LED_SET(SF_E_ERR_LED_SET_Set);
```

## 4.6.4.2 SF\_MAX\_POWER\_DIP\_SET



### Setting the maximum number of restarts after power dip in SM560-S Safety CPU

The SF\_MAX\_POWER\_DIP\_SET function block allows user controlling the restart of SM560-S after power dip in a power supply of PM5xx Non-safety CPU. The function block provides an input for the 'maximum number of warm starts after power dips' (input MAX\_POWER\_DIP\_CNT). The value applied at this input can be stored in the Flash memory after a rising edge on EN input.

If this function block is not available in the safety application program or not activated, then the initial value (= "0") is stored in the Flash memory instead. The number of warm starts that occurred after power dips is counted and compared to the number available prior to the start of the safety application program. If the number is higher, then the application on the SM560-S is not executed. This condition can only be terminated by switching the voltage off and then powering SM560-S on after a pause of at least 1.5 seconds.

Only one function block instance must be used in the safety program, otherwise a warning is issued.

### ! NOTICE!

Each time SF\_MAX\_POWER\_DIP\_SET FB is called, the internal power dip counter value is reset, which means that power dip counter will be started from 0 now. Thus, it makes sense to use SF\_MAX\_POWER\_DIP\_SET FB in safety program only once as a one-time parameterisation of power dip functionality.

After calling SF\_MAX\_POWER\_DIP\_SET FB in your safety application program, either uncomment SF\_MAX\_POWER\_DIP\_SET in your safety application program, recompile your project and create a new boot project or make sure that SF\_MAX\_POWER\_DIP\_SET FB is not called in your safety application after powering off/on or reboot. If you do not follow the recommendation above, each time SF\_MAX\_POWER\_DIP\_SET FB is called in the safety application program, the counter value for restarts after power dip in SM560-S Safety CPU from SF\_MAX\_POWER\_DIP\_GET FB will be reset to '0'.

Table 16: FB Name: SF\_MAX\_POWER\_DIP\_SET

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	The block is activated to store MAX_POWER_DIP_CNT value in the Flash memory using a transition of EN input from FALSE to TRUE. The block remains active and ignores any changes on EN input until DONE output is equal to TRUE.  The MAX_POWER_DIP_CNT value can be stored in the Flash memory only if the transition on EN input from FALSE to TRUE is triggered.
MAX_POWER_DIP_CNT	WORD	16#0000	Maximum number of SM560-S warm starts after power dip errors from power supply of PM5xx Non-safety CPU.

## Configuration and programming

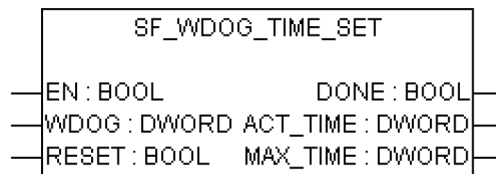
AC500-S Libraries > SafetyExt\_AC500\_V22.lib

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	Output DONE indicates that the set process is finished (see also ERR output).
ERR	BOOL	FALSE	If TRUE, then error occurred during the set process (saving of MAX_POWER_DIP_CNT value to the Flash memory).

### Call in ST

```
SF_MAX_POWER_DIP_SET (EN := SF_MAX_POWER_DIP_SET_EN,  
MAX_POWER_DIP_CNT := SF_MAX_POWER_DIP_SET_MAX_POWER_DIP_CNT,  
DONE => SF_MAX_POWER_DIP_SET_DONE, ERR => SF_MAX_POWER_DIP_SET_ERR);
```

## 4.6.4.3 SF\_WDOG\_TIME\_SET



### Setting the maximum allowed cycle time of SM560-S Safety CPU

The SF\_WDOG\_TIME\_SET function block allows the user to monitor the cycle time. The function block must be called by the user during the first cycle. In order to update the outputs ACT\_TIME and MAX\_TIME, it is necessary to call the function block in each cycle. If the function block is not available in the application, the SM560-S and the application program will enter the SAFE STOP state after the first cycle. The watchdog time is monitored prior to the output of the PROFIsafe telegrams.

If the cycle time is exceeded, an error message is an output and the Safety CPU enters the SAFE STOP state. Reasonable values are longer than the basic SM560-S run time and at least two times shorter than the F\_WD\_Time of the safety I/O module.

Only one function block instance must be used in the safety program, otherwise a warning is issued.

### ! NOTICE!

The cycle time supervision takes place only in RUN (Safety) mode.

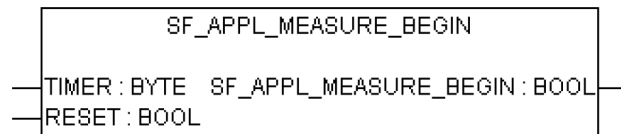
Table 17: FB Name: SF\_WDOG\_TIME\_SET

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	The function block is activated (EN = TRUE) or deactivated (EN = FALSE) via input EN. If the block is active, the current values are available at the outputs.
WDOG	DWORD	16#00000000	Watchdog time in ms. The maximum allowed value is 1000. If WDOG is > 1000, then SAFE STOP state will be entered by SM560-S Safety CPU.
RESET	BOOL	FALSE	TRUE sets MAX_TIME to 0.
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	Output DONE indicates that the set process is finished.
ACT_TIME	DWORD	16#00000000	Actual SM560-S Safety CPU cycle time in ms
MAX_TIME	DWORD	16#00000000	Maximal monitored SM560-S Safety CPU cycle time in ms

### Call in ST

```
SF_WDOG_TIME_SET (EN := SF_WDOG_TIME_SET_EN,  
WDOG := SF_WDOG_TIME_SET_WDOG,  
RESET := SF_WDOG_TIME_SET_RESET,  
DONE => SF_WDOG_TIME_SET_DONE,  
ACT_TIME => SF_WDOG_TIME_SET,  
MAX_TIME => SF_WDOG_TIME_SET_MAX_TIME);
```

## 4.6.4.4 SF\_APPL\_MEASURE\_BEGIN



### Defining the start point of time profiling

This function defines the start point of time profiling within safety application program and shall be used together with SF\_APPL\_MEASURE\_END function. The time profiling results can be seen only using “applinfo” PLC Browser command and cannot be used within safety application program.

The time between the calls of SF\_APPL\_MEASURE\_BEGIN and SF\_APPL\_MEASURE\_END functions in the safety application program is measured (including within one SM560-S cycle) and saved in the timer identified with the value set for input parameter TIMER.

### ! NOTICE!

SF\_APPL\_MEASURE\_BEGIN function was developed for measuring short time intervals only, which means that for time intervals of ~ 10 minutes and longer, it produces invalid results.

Table 18: FUN Name: SF\_APPL\_MEASURE\_BEGIN

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
TIMER	BYTE	16#00	Timer identification. The allowed range is from 0 to 31.
RESET	BOOL	FALSE	If TRUE, then MAX and MIN results of time profiling will be deleted. Otherwise, the observed values are kept.
<b>VAR_OUTPUT</b>			
SF_APPL_MEASURE_BEGIN	BOOL	FALSE	Return value is TRUE if the TIMER value is within the allowed range (0 ... 31), otherwise the return value is FALSE.

### Call in ST

```

SF_APPL_MEASURE_BEGIN_VALUE :=
SF_APPL_MEASURE_BEGIN(SF_APPL_MEASURE_BEGIN_TIMER,
SF_APPL_MEASURE_BEGIN_RESET);

```

...

...

```

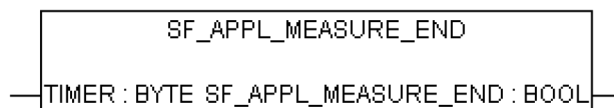
SF_APPL_MEASURE_END_VALUE := SF_APPL_MEASURE_END(SF_APPL_MEASURE_END_TIMER);

```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.5 SF\_APPL\_MEASURE\_END



#### Defining the end point of time profiling

This function defines the end point of time profiling within safety application program and shall be used together with SF\_APPL\_MEASURE\_BEGIN function. The time profiling results can be seen only using “applinfo” PLC Browser command and cannot be used within safety application program.

The time between the calls of SF\_APPL\_MEASURE\_BEGIN and SF\_APPL\_MEASURE\_END functions in the safety application program is measured and saved in the timer identified with the value set for input parameter TIMER.

#### ! NOTICE!

SF\_APPL\_MEASURE\_END function was developed for measuring short time intervals only, which means that for time intervals of ~ 10 minutes and longer, it produces invalid results.

Table 19: FUN Name: SF\_APPL\_MEASURE\_END

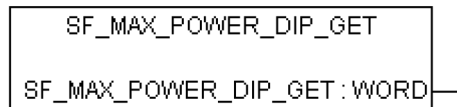
Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
TIMER	BYTE	16#00	Timer identification. The allowed range is from 0 to 31.
<b>VAR_OUTPUT</b>			
SF_APPL_MEASURE_END	BOOL	FALSE	Return value is TRUE if the TIMER value is within the allowed range (0 .. 31), otherwise the return value is FALSE.

#### Call in ST

```
SF_APPL_MEASURE_BEGIN_VALUE :=
SF_APPL_MEASURE_BEGIN(SF_APPL_MEASURE_BEGIN_TIMER,
SF_APPL_MEASURE_BEGIN_RÉSET);
...
...
SF_APPL_MEASURE_END_VALUE := SF_APPL_MEASURE_END(SF_APPL_MEASURE_END_TIMER);
```



## 4.6.4.6 SF\_MAX\_POWER\_DIP\_GET



Getting the current number of restarts after power dip in SM560-S Safety CPU

Table 20: FUN Name: SF\_MAX\_POWER\_DIP\_GET

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_OUTPUT</b>			
SF_MAX_POWER_DIP_GET	WORD	16#0000	Actual value of power dip error counter.

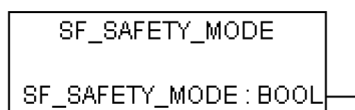
### Call in ST

```
SF_MAX_POWER_DIP_GET_Value := SF_MAX_POWER_DIP_GET();
```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.7 SF\_SAFETY\_MODE



Reading out if SM560-S Safety CPU is in **DEBUG RUN (non-safety)**, **DEBUG STOP (non-safety)** or in **RUN (safety)** mode

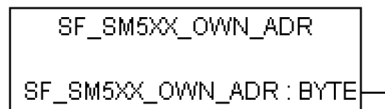
Table 21: FUN Name: SF\_SAFETY\_MODE

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_OUTPUT</b>			
SF_SAFETY_MODE	BOOL	FALSE	SM560-S Safety CPU mode: <ul style="list-style-type: none"><li>■ FALSE: DEBUG RUN (non-safety) or DEBUG STOP (non-safety) mode is active.</li><li>■ TRUE: RUN (safety) mode is active.</li></ul>

#### Call in ST

```
SF_SAFETY_MODE_Value := SF_SAFETY_MODE();
```

## 4.6.4.8 SF\_SM5XX\_OWN\_ADR



### Getting the value of the hardware switch address on SM560-S Safety CPU

Only the value set during SM560-S Safety CPU start-up is read. Further changes of the hardware switch address are ignored.

#### ! NOTICE!

Despite the fact that SF\_SM5XX\_OWN\_ADR function is a safety POU, the hardware switch address value is a non-safety value and needs additional measures to satisfy functional safety requirements.

Table 22: FUN Name: SF\_SM5XX\_OWN\_ADR

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_OUTPUT</b>			
SF_SM5XX_OWN_ADR	BYTE	16#00	Value of the hardware switch address on SM560-S Safety CPU set during its start-up.

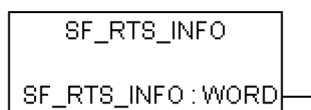
### Call in ST

```
SF_SM5XX_OWN_ADR_Value := SF_SM5XX_OWN_ADR();
```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.9 SF\_RTS\_INFO



#### Display of the firmware version of the Safety CPU

This function provides the firmware version of the Safety CPU. The version is a binary coded decimal, e.g., 16#10 means version 1.0.

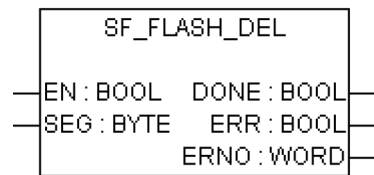
Table 23: FUN Name: SF\_RTS\_INFO

Name	Data Type	Initial Value	Description, Parameter Values
VAR_OUTPUT			
SF_RTS_INFO	WORD	16#0000	Firmware version of the Safety CPU. The upper BYTE of the entry represents the main version; the lower BYTE represents the subversion of the runtime system. Example: RTS_VERSION = 16#0110 → V01.1.0

#### Call in ST

```
SF_RTS_INFO_Value := SF_RTS_INFO();
```

## 4.6.4.10 SF\_FLASH\_DEL



### Delete a selected segment from the flash memory

This function block deletes a selected segment with user data from the Flash memory.

Input SEG defines the data segment within the Flash memory. In the SM560-S controller, two segments numbered 1 and 2 (each providing 64 kBytes incl. CRC, flag and alignment) are reserved for the user. Deleting a data segment within the Flash memory may take several PLC cycles.

Deletion of the data segment is triggered once by a FALSE/TRUE edge at input EN. Input EN will not be evaluated again until the delete operation is completed (DONE = TRUE).

After the deletion procedure is finished, all function block outputs are updated. The deletion was successful if DONE = TRUE and ERR = FALSE. If the outputs show DONE = TRUE and ERR = TRUE, the data segment could not be deleted.

Table 24: FB Name: SF\_FLASH\_DEL

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	<p>Activation of the FB using a positive edge</p> <p>Deletion of the data segment is started once. Input EN will not be evaluated again until the delete operation is finished (DONE = TRUE).</p> <p>EN = TRUE:</p> <p>The function block is not processed, i.e. it does not change its outputs anymore. This is not valid during a delete operation.</p>
SEG	BYTE	16#00	ID number of the data segment (16#01 or 16#02)
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	<p>Delete procedure is completed (DONE = TRUE)</p> <p>Output DONE indicates that deletion of the data segment is completed. This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <p>DONE = TRUE and ERR = FALSE:</p> <p>Deletion completed. The data segment has been deleted successfully.</p> <p>DONE = TRUE and ERR = TRUE:</p> <p>An error occurred while deleting the data segment. The data segment could not be deleted successfully.</p>

## Configuration and programming

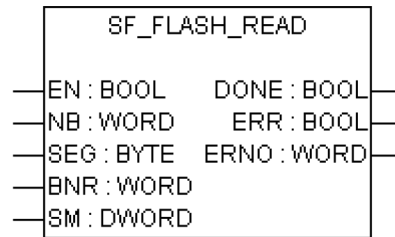
AC500-S Libraries > SafetyExt\_AC500\_V22.lib

Name	Data Type	Initial Value	Description, Parameter Values
ERR	BOOL	FALSE	<p>Error occurred (data segment could not be deleted)</p> <p>Output ERR indicates whether an error occurred during deletion. This output always has to be considered together with output DONE. The following applies if the data segment could not be deleted: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.</p>
ERNO	WORD	16#0000	<p>Error number (see [4] for more details)</p> <p>Output ERNO indicates an error number. This output always has to be considered together with the outputs DONE and ERR.</p> <p>The SF_FLASH_DEL operation may take quite a long time since the PLC user program is processed with priority. Output ERNO then indicates that the function block has started the execution (0x0FFF = BUSY).</p> <p>During this phase, the outputs ERR and DONE are set to FALSE.</p>

### Call in ST

```
DEL_FLASH(EN := EN_FLASH_DEL,  
SEG := SEG_FLASH_DEL,  
DONE => DONE_FLASH_DEL,  
ERR => ERR_FLASH_DEL,  
ERNO => ERNO_FLASH_DEL);
```

## 4.6.4.11 SF\_FLASH\_READ



### Reading of user data from the Flash memory

The function block reads a data set from a data segment in the Flash memory and stores this data set beginning at the starting flag defined at input SM. The data contained in the data set were previously stored to the Flash memory using the SF\_FLASH\_WRITE function block.

#### ! NOTICE!

Access to the Flash memory is only possible using the function blocks SF\_FLASH\_WRITE, SF\_FLASH\_DEL and SF\_FLASH\_READ.

NB blocks are read starting at block BNR within segment SEG and stored starting at address SM.

32 binary data or 16 word data or 8 double word data are read per block.

One block contains 38 bytes:

- 32 bytes of data
- 4 bytes for CRC checksum
- 1 byte as "written" identifier
- 1 byte for alignment

(see figure at the end of this block description)

Reading a data set is triggered once by a FALSE/TRUE edge at input EN. If no error occurred while reading the data, output DONE is set to TRUE and the outputs ERR and ERNO are set to FALSE. The data set is stored beginning at the defined start flag SM.

Storing the data set can take several PLC cycles.

If an error occurs during reading, DONE and ERR are set to TRUE and data from SM are equal to 0. The error type is indicated at output ERNO.

Table 25: FB Name: SF\_FLASH\_READ


Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	Activation of the FB using a positive edge The following applies: <ul style="list-style-type: none"> <li>■ EN = FALSE/TRUE edge: Reading the data set is carried out once.</li> <li>■ EN = TRUE: The function block is not processed, i.e. it does not change its outputs anymore.</li> </ul>

## Configuration and programming

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Name	Data Type	Initial Value	Description, Parameter Values
NB	WORD	16#0000	<p>Number of data set blocks (decimal 1 ... 1724)</p> <p>Input NB is used to specify the number of blocks contained in the data set. 32 binary data or 16 word data or 8 double word data are read per block.</p> <p>Valid values: 1 ... 1724</p> <p>Example:</p> <ul style="list-style-type: none"><li>■ SM = ADR(%MW0.0) and NB = 1: Data are stored at %MW0.0 to %MW0.15 (1 block = 16 word data)</li><li>■ SM = ADR(%MW0.0) and NB = 2: Data are stored at %MW0.0 to %MW0.31 (2 blocks = 32 word data)</li></ul>
SEG	BYTE	16#00	ID number of the data segment (16#01 or 16#02)
BNR	WORD	16#0000	Starting block number in the Flash memory data segment (decimal 0 ... 1723)
SM	DWORD	16#00000000	Destination address for the read data set (address of the first variable where the data are placed)
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	<p>Reading procedure is completed (DONE = TRUE)</p> <p>This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <ul style="list-style-type: none"><li>■ DONE = TRUE and ERR = FALSE: Reading completed. The data set has been stored beginning at the defined input SM.</li><li>■ DONE = TRUE and ERR = TRUE: An error occurred while reading the data set. Output ERNO indicates the error number.</li></ul>



Name	Data Type	Initial Value	Description, Parameter Values
ERR	BOOL	FALSE	Error occurred (data segment could not be read) This output always has to be considered together with output DONE. The following applies if an error occurred: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.
ERNO	WORD	16#0000	Error number (  [4] for more details). Output ERNO indicates an error number. This output always has to be considered together with the outputs DONE and ERR. The SF_FLASH_READ operation may take quite a long time since the PLC user program is processed with priority. Output ERNO then indicates that the function block has started the execution (0x0FFF = BUSY). During this phase, the outputs ERR and DONE are set to FALSE.

The structure of one of the Flash memory segments with user data is presented below.

Byte:		1   2	3   4	5   6	...	29   30	31   32	33 ... 36	37	38
Byte offset	Block no.	Word 1	Word 2	Word 3	...	Word 15	Word 16	CRC	Written identifier	Alignment
0	0									
38	1									
76	2									
...	...									
65436	1722									
65474	1723									

## Call in ST

```

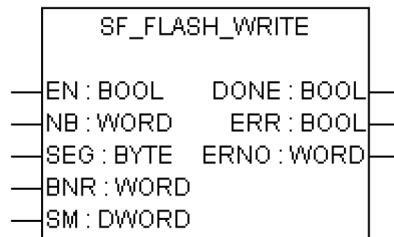
READ_FLASH(EN := EN_FLASH_READ,
NB := NB_FLASH_READ,
SEG := SEG_FLASH_READ,
BNR := BNR_FLASH_READ,
SM := SM_FLASH_READ,
DONE => DONE_FLASH_READ,
```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

```
ERR => ERR_FLASH_READ,  
ERNO => ERNO_FLASH_READ);
```

## 4.6.4.12 SF\_FLASH\_WRITE



### Writing of user data to the Flash memory

The function block writes a data set to a data segment in the Flash memory. For that purpose, two data segments are available in the SM560-S controller. The delete operation (function block SF\_FLASH\_DEL) always deletes a data segment as a whole. One data segment consists of 1724 blocks (0 ... 1723). Each block comprises 38 bytes. The maximum number of writing cycles to the Flash memory is limited. Deleting data in the Flash memory is also considered to be a "writing" cycle.

After a delete operation, data can be written only once to each of these 1724 data segment blocks. If a block containing data is to be overwritten with new data, the entire data segment has to be deleted first. In doing so, all data in this segment will be lost.

NB blocks are read starting at address SM and stored in segment SEG starting at block BNR.

32 binary data or 16 word data or 8 double word data are read per block.

One block contains 38 bytes:

- 32 bytes of data
- 4 bytes for CRC checksum
- 1 byte as "written" identifier
- 1 byte for alignment

(See figure at the end of the SF\_FLASH\_READ function block description. )

Once the write operation for a data set has been started (by a FALSE/TRUE edge at input EN), the data contained in the data set must not be changed anymore until the write operation completes (DONE = TRUE). Storing the data set in the Flash can take several PLC cycles.

With a FALSE/TRUE edge at input EN, the data set is written once. Input EN is not evaluated again until the storage procedure is finished (DONE = TRUE).

After the write operation is finished, the function block outputs DONE, ERR and ERNO are updated. Data storage was successful if DONE = TRUE and ERR = FALSE. If DONE = TRUE and ERR = TRUE, an error occurred. The error type is indicated at output ERNO.


A new FALSE/TRUE edge at input EN starts a new write operation. Input BNR must point to the next free block for the next write operation since no new data can be written to blocks that already contain data without a preceding deletion of the data segment.

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

Table 26: FB Name: SF\_FLASH\_WRITE

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	<p>Activation of the FB using a positive edge</p> <p>The following applies:</p> <ul style="list-style-type: none"> <li>■ EN = FALSE/TRUE edge: Reading the data set is carried out once.</li> <li>■ EN = TRUE: The function block is not processed, i.e. it does not change its outputs anymore.</li> </ul>
NB	WORD	16#0000	<p>Number of data set blocks (decimal 1 .. 1724)</p> <p>Input NB is used to specify the number of blocks contained in the data set. 32 binary data or 16 word data or 8 double word data are read per block.</p> <p>Valid values: 1 ... 1724</p> <p>Example:</p> <ul style="list-style-type: none"> <li>- SM = ADR(%MW0.0) and NB = 1: Data are stored at %MW0.0 to %MW0.15 (1 block = 16 word data)</li> <li>- SM = ADR(%MW0.0) and NB = 2: Data are stored at %MW0.0 to %MW0.31 (2 blocks = 32 word data)</li> </ul>
SEG	BYTE	16#00	ID number of the data segment (16#01 or 16#02)
BNR	WORD	16#0000	Starting block number in the Flash memory data segment (decimal 0 ... 1723)
SM	DWORD	16#00000000	<p>Source start address (address of the first variable from where the data will be written to the Flash memory)</p> <p>At input SM, the address of the first variable of the data set is specified using an ADR operator. Once the write operation for a data set has been started (by a FALSE/TRUE edge at input EN), the data contained in the data set must not be changed anymore until the write operation is finished (DONE = TRUE).</p>
<b>VAR_OUTPUT</b>			

Name	Data Type	Initial Value	Description, Parameter Values
DONE	BOOL	FALSE	<p>Writing procedure is completed (DONE = TRUE)</p> <p>This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <p>DONE = TRUE and ERR = FALSE: Write operation completed. The data set has been stored in the Flash.</p> <p>DONE = TRUE and ERR = TRUE: An error occurred during the write operation. Output ERNO indicates the error number.</p>
ERR	BOOL	FALSE	<p>Error occurred (data segment could not be written)</p> <p>Output ERR indicates whether an error occurred during the write operation. This output always has to be considered together with output DONE. The following applies if an error occurred: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.</p>
ERNO	WORD	16#0000	<p>Error number (  [4] for more details)</p> <p>Output ERNO indicates an error number. This output always has to be considered together with the outputs DONE and ERR.</p> <p>The SF_FLASH_WRITE operation may take quite a long time since the Safety PLC user program is processed with priority. Output ERNO then indicates that the function block has started the execution (0x0FFF = BUSY).</p> <p>During this phase, the outputs ERR and DONE are set to FALSE.</p>

## Call in ST

```

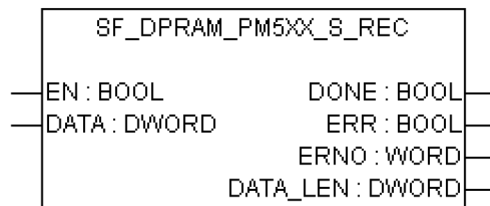
WRITE_FLASH(EN := EN_FLASH_WRITE,
NB := NB_FLASH_WRITE,
SEG := SEG_FLASH_WRITE,
BNR := BNR_FLASH_WRITE,
SM := SM_FLASH_WRITE,
DONE => DONE_FLASH_WRITE,
ERR => ERR_FLASH_WRITE,
ERNO => ERNO_FLASH_WRITE);

```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.13 SF\_DPRAM\_PM5XX\_S\_REC



#### Reading the data from PM5xx Non-safety CPU to safety application on SM560-S Safety CPU

##### DANGER!

It is of no concern to transfer data values from Safety CPU to Non-safety CPU (e.g., for diagnosis and later visualization on the operator panels), but it is not recommended to transfer data values from Non-safety CPU to Safety CPU. In the latter case, end-users have to define additional process-specific validation procedures in the safety program to check the correctness of the transferred non-safety data, if they would like to use those non-safety values for safety functions.

The SF\_DPRAM\_PM5XX\_S\_REC function block is used to receive data from the non-safety CPU PM5xx. These data are stored in the planned memory area (DATA, memory address for received data, provided via ADR operator). The function block is enabled by a TRUE signal at input EN. It remains active until input EN is set to FALSE. Output DATA\_LEN displays the length of the received data in bytes. DONE = TRUE and ERR = FALSE indicate successful reception. If an error was detected during function block processing, the error is indicated at the outputs ERR and ERNO.

##### NOTICE!

Reception using the SF\_DPRAM\_SM5XX\_S\_REC function block is not edge-triggered. Therefore, input EN has to be continuously set to TRUE during data reception.

Table 27: FB Name: SF\_DPRAM\_PM5XX\_S\_REC function

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	Processing of this function block is controlled by input EN. The function block is active if EN = TRUE. The reception of data is indicated by output DONE.
DATA	DWORD	16#00000000	Input DATA is used to specify the address of the variable the user data are to be copied to. The address specified at DATA has to belong to a variable of the type ARRAY or STRUCT.  Set the variable size to the maximum expected amount of data in order to avoid overlapping of memory areas.
<b>VAR_OUTPUT</b>			

Name	Data Type	Initial Value	Description, Parameter Values
DONE	BOOL	FALSE	<p>Output DONE indicates the reception of data. This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <p>DONE = TRUE and ERR = FALSE:</p> <p>Reception completed. A data set was received correctly.</p> <p>DONE = TRUE and ERR = TRUE:</p> <p>An error occurred during reception. The error number is indicated at output ERNO.</p>
ERR	BOOL	FALSE	<p>Output ERR indicates whether an error occurred during reception. This output always has to be considered together with output DONE. The following applies if an error occurred during reception: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.</p>
ERNO	WORD	16#0000	<p>Output ERNO provides an error identifier if an invalid value has been applied to an input or if an error occurred during job processing. ERNO always has to be considered together with the outputs DONE and ERR. The output value at ERNO is only valid if DONE = TRUE and ERR = TRUE. The error messages encoding at output ERNO is explained at the beginning of the function block description.</p>
DATA_LEN	DWORD	16#00000000	<p>Output DATA_LEN displays the length of the received data in bytes (The maximum number is 84). The output value at DATA_LEN is only valid if DONE = TRUE.</p>

## Call in ST

```

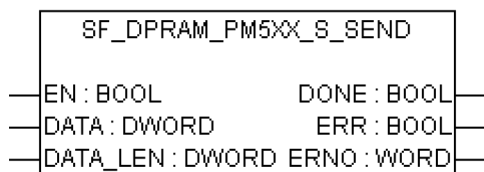
PM5xxRec (EN := PM5xxRec_EN,
DATA := ADR(PM5xxRec_DATA),
DONE => PM5xxRec_DONE,
ERR => PM5xxRec_ERR,
ERNO => PM5xxRec_ERNO,
DATA_LEN => PM5xxRec_DATA_LEN);

```

## Configuration and programming

AC500-S Libraries > SafetyExt\_AC500\_V22.lib

### 4.6.4.14 SF\_DPRAM\_PM5XX\_S\_SEND



#### Sending data from SM560-S Safety CPU to PM5xx Non-safety CPU

The SF\_DPRAM\_PM5XX\_S\_SEND function block is used to send data to the PM5xx non-safety CPU. The data to be sent are available in the planned memory area (DATA, memory address for data to be transmitted, provided via ADR operator). The function block is activated with a TRUE signal (FALSE/TRUE edge) at input EN. The length of the data to be transmitted is specified in bytes at input DATA\_LEN. DONE = TRUE and ERR = FALSE indicate that the sending process was successful. If an error was detected during function block processing, the error is indicated at the outputs ERR and ERNO.



#### DANGER!

If FB SF\_DPRAM\_PM5XX\_S\_SEND is used to send safety-critical data, then SIL3 (IEC 61508 and IEC 62061) and PL e (ISO 13849-1) safety requirements will not be fulfilled for sent data (independently on application safety communication profile used), because only one microprocessor (no 1oo2 safety architecture in the background) on SM560-S Safety CPU handles FB SF\_DPRAM\_PM5XX\_S\_SEND. Contact ABB technical support on how to reach SIL 3 and PL e with FB SF\_DPRAM\_PM5XX\_S\_SEND or use PROFIsafe Safety Output, e.g., from DX581-S to trigger safety functions.



#### NOTICE!

Sending data using the SF\_DPRAM\_PM5XX\_S\_SEND function block is edge-triggered, i.e. each sending process is initiated by a FALSE/TRUE edge at input EN.

Table 28: FB Name: SF\_DPRAM\_PM5XX\_S\_SEND function

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	Processing of this function block is controlled by input EN. The function block is active if EN = TRUE. The sending of data is indicated by output DONE.
DATA	DWORD	16#00000000	Input DATA is used to specify the address of the variable the user data are to be copied to. The address specified at DATA has to belong to a variable of the type ARRAY or STRUCT.  Set the variable size to the maximum expected amount of data in order to avoid overlapping of memory areas.



Name	Data Type	Initial Value	Description, Parameter Values
DATA_LEN	DWORD	16#00000000	The length of the data to be transmitted is specified in bytes at input DATA_LEN. The maximum number is 84.
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	Output DONE indicates the sending of data. This output always has to be considered together with output ERR.  The following applies:  DONE = TRUE and ERR = FALSE:  Sending completed. A data set was sent correctly.  DONE = TRUE and ERR = TRUE:  An error occurred during sending. The error number is indicated at output ERNO.
ERR	BOOL	FALSE	Output ERR indicates whether an error occurred during sending. This output always has to be considered together with output DONE. The following applies if an error occurred during sending: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.
ERNO	WORD	16#0000	Output ERNO provides an error identifier if an invalid value has been applied to an input or if an error occurred during job processing. ERNO always has to be considered together with the outputs DONE and ERR. The output value at ERNO is only valid if DONE = TRUE and ERR = TRUE. The error messages encoding at output ERNO is explained at the beginning of the function block descriptions ( <a href="#">AC500 User Documentation</a> ).

## Call in ST

```

PM5xxSend (EN := PM5xxSend_EN,
DATA := ADR(PM5xxSend_DATA),
DATA_LEN := PM5xxSend_DATA_LEN,
DONE => PM5xxSend_DONE,
ERR => PM5xxSend_ERR,
ERNO => PM5xxSend_ERNO);

```

## 4.6.5 DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC in SysInt\_AC500\_V10.lib

DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC POU's from SysInt\_AC500\_V10.lib can be used on PM5xx Non-safety CPU to exchange data with SM560-S Safety CPU.

## Configuration and programming

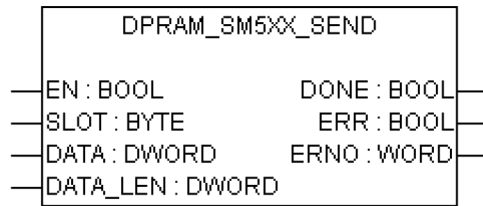
AC500-S Libraries > DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC in SysInt\_AC500\_V10.lib



### **DANGER!**

It is of no concern to transfer data values from Safety CPU to Non-safety CPU (e.g., for diagnosis and later visualization on the operator panels), but it is not recommended to transfer data values from Non-safety CPU to Safety CPU. In the latter case, end-users have to define additional process-specific validation procedures in the safety program to check the correctness of the transferred non-safety data, if they would like to use those non-safety values for safety functions.

## 4.6.5.1 DPRAM\_SM5XX\_SEND



### The DPRAM\_SM5XX\_SEND function block sends data to the SM560-S Safety CPU

The DPRAM\_SM5XX\_SEND function block is used to send data to the SM560-S Safety CPU. The data to be sent are available in the planned memory area (DATA, memory address for data to be transmitted, provided via ADR operator). The function block is activated with a TRUE signal („0“ → „1“ edge) at input EN. The slot number of the SM560-S is set at input SLOT. The length of the data to be transmitted is specified in bytes at input DATA\_LEN. DONE = TRUE and ERR = FALSE indicate that the sending process was successful. If an error was detected during function block processing, the error is indicated at the outputs ERR and ERNO.

Caution: Sending data using the DPRAM\_SM5XX\_SEND function block is edge-triggered, i.e. each sending process is initiated by a FALSE/TRUE edge at input EN.

Table 29: FB Name: DPRAM\_SM5XX\_SEND

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	Enabling of function block processing.  Processing of this function block is controlled by input EN. The function block is active if EN = TRUE. The sending of data is indicated by output DONE.
SLOT	BYTE	16#00	Slot number (module number)  Input SLOT is used to select the slot (module number) the data should be sent to.  The external slots are numbered consecutively from right to left, starting with number 1.
DATA	DWORD	16#00000000	Memory address for data to be transmitted, provided via ADR operator  Input DATA is used to specify the address of the variable the user data are to be copied to. The address specified at DATA has to belong to a variable of the type ARRAY or STRUCT.  Caution: Set the variable size to the maximum expected amount of data in order to avoid overlapping of memory areas.
DATA_LEN	WORD	16#0000	Length of data to be transmitted (in bytes) starting at address DATA, max. 84.  The length of the data to be transmitted is specified in bytes at input DATA_LEN. The maximum number is 84.

## Configuration and programming

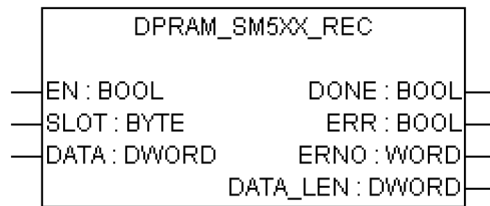
AC500-S Libraries > DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC in SysInt\_AC500\_V10.lib

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_OUTPUT</b>			
DONE	BOOL	FALSE	<p>The Data were sent.</p> <p>Output DONE indicates that data were sent. This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <p>DONE = TRUE and ERR = FALSE:</p> <p>Sending completed. A data set was sent correctly.</p> <p>DONE = TRUE and ERR = TRUE:</p> <p>An error occurred during sending. The error number is indicated at output ERNO.</p>
ERR	BOOL	FALSE	<p>Error message of the function block.</p> <p>Output ERR indicates whether an error occurred during sending. This output always has to be considered together with output DONE. The following applies if an error occurred during sending: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.</p>
ERNO	WORD	16#0000	<p>Error number</p> <p>Output ERNO provides an error identifier if an invalid value has been applied to an input or if an error occurred during job processing. ERNO always has to be considered together with the outputs DONE and ERR. The output value at ERNO is only valid if DONE = TRUE and ERR = TRUE. The error messages encoding at output ERNO is explained at the beginning of the function block description (see AC500 User Documentation).</p>

### Call in ST

```
SM5xxSend (EN := SM5xxSend_EN,  
SLOT := SM5xxSend_SLOT,  
DATA := ADR(SM5xxSend_DATA),  
DATA_LEN := SM5xxSend_DATA_LEN,  
DONE => SM5xxSend_DONE,  
ERR => SM5xxSend_ERR,  
ERNO => SM5xxSend_ERNO);
```

## 4.6.5.2 DPRAM\_SM5XX\_REC



### The DPRAM\_SM5XX\_REC function block receives data from the SM560-S safety CPU

The DPRAM\_SM5XX\_REC is used to receive data from the SM560-S Safety CPU. These data are stored in the planned memory area (DATA, memory address for received data, provided via ADR operator). The function block is enabled by a TRUE signal at input EN. It remains active until input EN is set to FALSE. The slot number of the SM560-S is set at input SLOT. Output DATA\_LEN displays the length of the received data in bytes. DONE = TRUE and ERR = FALSE indicate that the reception was successful. If an error was detected during function block processing, the error is indicated at the outputs ERR and ERNO.

Caution: Reception using the DPRAM\_SM5XX\_REC function block is not edge-triggered. Therefore, input EN has to be continuously set to TRUE during data reception.

Table 30: FB Name: DPRAM\_SM5XX\_REC

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
EN	BOOL	FALSE	Enabling of function block processing.  Processing of this function block is controlled by input EN. The function block is active if EN = TRUE. The reception of data is indicated by output DONE.
SLOT	BYTE	16#00	Slot number (module number)  Input SLOT is used to select the slot (module number) the data should be read from.  The external slots are numbered consecutively from right to left, starting with number 1.
DATA	DWORD	16#00000000	Memory address for received data, provided via ADR operator.  Input DATA is used to specify the address of the variable the user data are to be copied to. The address specified at DATA has to belong to a variable of the type ARRAY or STRUCT.  Caution: Set the variable size to the maximum expected amount of data in order to avoid overlapping of memory areas.
<b>VAR_OUTPUT</b>			

## Configuration and programming

AC500-S Libraries > DPRAM\_SM5XX\_SEND and DPRAM\_SM5XX\_REC in SysInt\_AC500\_V10.lib

Name	Data Type	Initial Value	Description, Parameter Values
DONE	BOOL	FALSE	<p>The Data were received.</p> <p>Output DONE indicates the reception of data. This output always has to be considered together with output ERR.</p> <p>The following applies:</p> <p>DONE = TRUE and ERR = FALSE:</p> <p>Reception completed. A data set was received correctly.</p> <p>DONE = TRUE and ERR = TRUE:</p> <p>An error occurred during reception. The error number is indicated at output ERNO.</p>
ERR	BOOL	FALSE	<p>Error message of the function block.</p> <p>Output ERR indicates whether an error occurred during reception. This output always has to be considered together with output DONE. The following applies if an error occurred during the processing of the function block: DONE = TRUE and ERR = TRUE. Output ERNO indicates the error number.</p>
ERNO	WORD	16#0000	<p>Error number</p> <p>Output ERNO provides an error identifier if an invalid value was applied to an input or if an error occurred during job processing. ERNO always has to be considered together with the outputs DONE and ERR. The output value at ERNO is only valid if DONE = TRUE and ERR = TRUE. The error messages encoding at output ERNO is explained at the beginning of the function block description.</p>
DATA_LEN	WORD	16#0000	<p>Data length in bytes</p> <p>Output DATA_LEN displays the length of the received data in bytes. DATA_LEN is only valid if DONE = TRUE.</p>

### Call in ST

```
SM5xxRec (EN := SM5xxRec_EN,  
SLOT := SM5xxRec_SLOT,  
DATA := ADR(SM5xxRec_DATA),  
DONE => SM5xxRec_DONE,  
ERR => SM5xxRec_ERR,  
ERNO => SM5xxRec_ERNO,  
DATA_LEN => SM5xxRec_DATA_LEN);
```

### 4.6.6 SafetyBlocks\_PLCOpen\_AC500\_v22.lib

A list of supported PLCOpen Safety POU is presented in the following sub-chapters. The developed PLCOpen Safety POU is based on [9].

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### 4.6.6.1 Introduction

Generic parameters and diagnostic codes of PLCopen Safety POU's are presented below.

Table 31: General Input Parameters

Name	Type	Description
Activate	BOOL	<p>Variable or constant.</p> <p>Activation of the FB. Initial value is FALSE.</p> <p>This parameter can be connected to the variable, which represents the status (Active or Not Active) of the relevant safety device. This ensures no irrelevant diagnostic information is generated if a device is disabled.</p> <p>If FALSE, all output variables are set to the initial values.</p> <p>If no device is connected, a static TRUE signal must be assigned.</p>
S_StartReset	BOOL	<p>Variable or constant.</p> <p>FALSE (= initial value): Manual reset when PES is started (warm or cold).</p> <p>TRUE: Automatic reset when PES is started (warm or cold).</p> <p>This function shall only be activated if it is ensured that no hazard can occur at the start of the PES. Therefore the use of the Automatic Circuit Reset feature of the function blocks requires implementation of other system or application measures to ensure that unexpected (or unintended) start-up does not occur.</p>
S_AutoReset	BOOL	<p>Variable or constant.</p> <p>FALSE (= initial value): Manual reset when emergency stop button is released.</p> <p>TRUE: Automatic reset when emergency stop button is released.</p> <p>This function shall only be activated if it is ensured that no hazard can occur at the start of the PES. Therefore the use of the Automatic Circuit Reset feature of the function blocks requires implementation of other system or application measures to ensure that unexpected (or unintended) startup does not occur.</p>
Reset	BOOL	<p>Variable. Initial value is FALSE.</p> <p>Depending on the function, this input can be used for different purposes:</p> <ul style="list-style-type: none"><li>■ Reset of the state machine, coupled error and status messages as indicated via DiagCode, when the error cause has been removed. This reset behavior is designed as an error reset.</li><li>■ Manual reset of a "restart interlock" ("Wiederanlaufsperr" in German) by the operator ( EN 954-1). This reset behavior is designed as a functional reset.</li><li>■ Additional FB-specific reset functions.</li></ul> <p>This function is only active on a signal change from FALSE to TRUE. A static TRUE signal causes no further actions, but may be detected as an error in some FBs.</p> <p>The appropriate meaning must be described in every FB.</p>



Table 32: General Output Parameters

Name	Type	Description
Ready	BOOL	If TRUE, indicates that the FB is activated and the output results are valid (same as the "POWER" LED of a safety relay). If FALSE, the FB is not active and the program is not executed. Useful in debug mode or to activate/deactivate additional FBs, as well as for further processing in the functional program.
Error	BOOL	Error flag (same as "K1/K2" LED of a safety relay). When TRUE, indicates that an error has occurred, and the FB is in an error state. The relevant error state is mirrored at the DiagCode output.  If FALSE, there is no error and the FB is in another state. This again is mirrored by DiagCode (this means that DiagCode must be set in the same cycle as the state change).  Useful in debug mode as well as for further processing in the functional program.
DiagCode	WORD	D diagnostic register.  All states of the FB (Active, Not Active and Error) are represented by this register. This information is encoded in hexadecimal format in order to represent more than 16 codes. Only one consistent code is represented at the same time. In the event of multiple errors, the DiagCode output indicates the first detected error.  For additional information, see next tables in this sub-chapter.  Useful in debug mode as well as for further processing in the functional program.

A transparent and unique diagnostic concept forms the basis of all function blocks. Thus, it is ensured, that, regardless of the supplier's implementation, uniform diagnostic information is available to the user in the form of DiagCode. If no error is present, the internal status of the function block (state machine) is indicated. An error is indicated via a binary output (error). Detailed information about internal or external function block errors can be obtained via DiagCode. The function block must be reset via the different reset inputs.

Suppliers may add additional interfaces via function blocks with supplier-specific diagnostic information.

Table 33: General Diagnostic Code Ranges

DiagCode	Description
0000_0000_0000_0000 <sub>bin</sub>	The FB is not activated or safety CPU is halted.
10xx_xxxx_xxxx_xxxx <sub>bin</sub>	Shows that the activated FB is in an operational state without an error. X = FB-specific code.
11xx_xxxx_xxxx_xxxx <sub>bin</sub>	Shows that the activated FB is in an error state. X = FB-specific code.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

Table 34: System or Device-Specific Codes

DiagCode	Description
0xxx_xxxx_xxxx_xxxx <sub>bin</sub>	X = System or device-specific message. This information contains the diagnostic information for the system or device, and is mapped directly to the DiagCode output. (Note: 0000 <sub>hex</sub> is reserved)

Table 35: General Diagnostic Codes

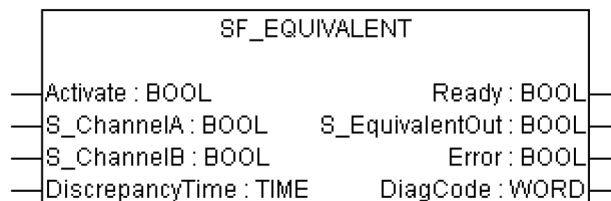
DiagCode	Description
0000_0000_0000_0000 <sub>bin</sub> 0000 <sub>hex</sub>	The FB is not activated. This code represents the Idle state. For a generic example, the I/O setting could be: Activate = FALSE S_In = FALSE or TRUE Ready = FALSE Error = FALSE S_Out = FALSE
0111_1111_1111_1111 <sub>bin</sub> 7FFF <sub>hex</sub>	Value 16#7FFF at DiagCode output of PLCopen Safety Function Blocks indicates an internal error. Contact ABB technical support. <b>Note:</b> This is a manufacturer-specific value defined by AC500-S Safety PLC.
1000_0000_0000_0000 <sub>bin</sub> 8000 <sub>hex</sub>	The FB is activated without an error or any other condition that sets the safety output to FALSE. This is the default operational state where the S_Out safety output = TRUE in normal operation. For a generic example, the I/O setting could be: Activate = TRUE S_In = TRUE Ready = TRUE Error = FALSE S_Out = TRUE
1000_0000_0000_0001 <sub>bin</sub> 8001 <sub>hex</sub>	An activation has been detected by the FB and the FB is now activated, but the S_Out safety output is set to FALSE. This code represents the Init state of the operational mode. For a generic example, the I/O setting could be: Activate = TRUE S_In = FALSE or TRUE Ready = TRUE Error = FALSE S_Out = FALSE

DiagCode	Description
1000_0000_0000_0010 <sub>bin</sub> 8002 <sub>hex</sub>	<p>The activated FB detects a safety demand ("Sicherheitsanforderung" in German), e.g., S_In = FALSE. The safety output is disabled. This is an operational state where the S_Out safety output = FALSE. For a generic example, the I/O setting could be:</p> <p>Activate = TRUE S_In = FALSE Ready = TRUE Error = FALSE S_Out = FALSE</p>
1000_0000_0000_0011 <sub>bin</sub> 8003 <sub>hex</sub>	<p>The safety output of the activated FB has been disabled by a safety demand. The safety demand is now withdrawn, but the safety output remains FALSE until a reset condition is detected. This is an operational state where the S_Out safety output = FALSE. For a generic example, the I/O setting could be:</p> <p>Activate = TRUE S_In = FALSE =&gt; TRUE (continuing with static TRUE) Ready = TRUE Error = FALSE S_Out = FALSE</p>

Note: If there are more operational states where safety output = TRUE, the next available DiagCode number will be assigned for subsequent states.

## 4.6.6.2 SF\_Equivalent

Standards	Requirements
EN 954-1: 1996	<p>6.2 General safety principles, Idle current</p> <p>6.2 Error detection for category 3 und 4</p>



This function block converts two equivalent BOOL inputs (both NO or NC) to one BOOL output, including discrepancy time monitoring. This FB should not be used stand-alone since it has no restart interlock. It is required to connect the output to other safety related functionalities.

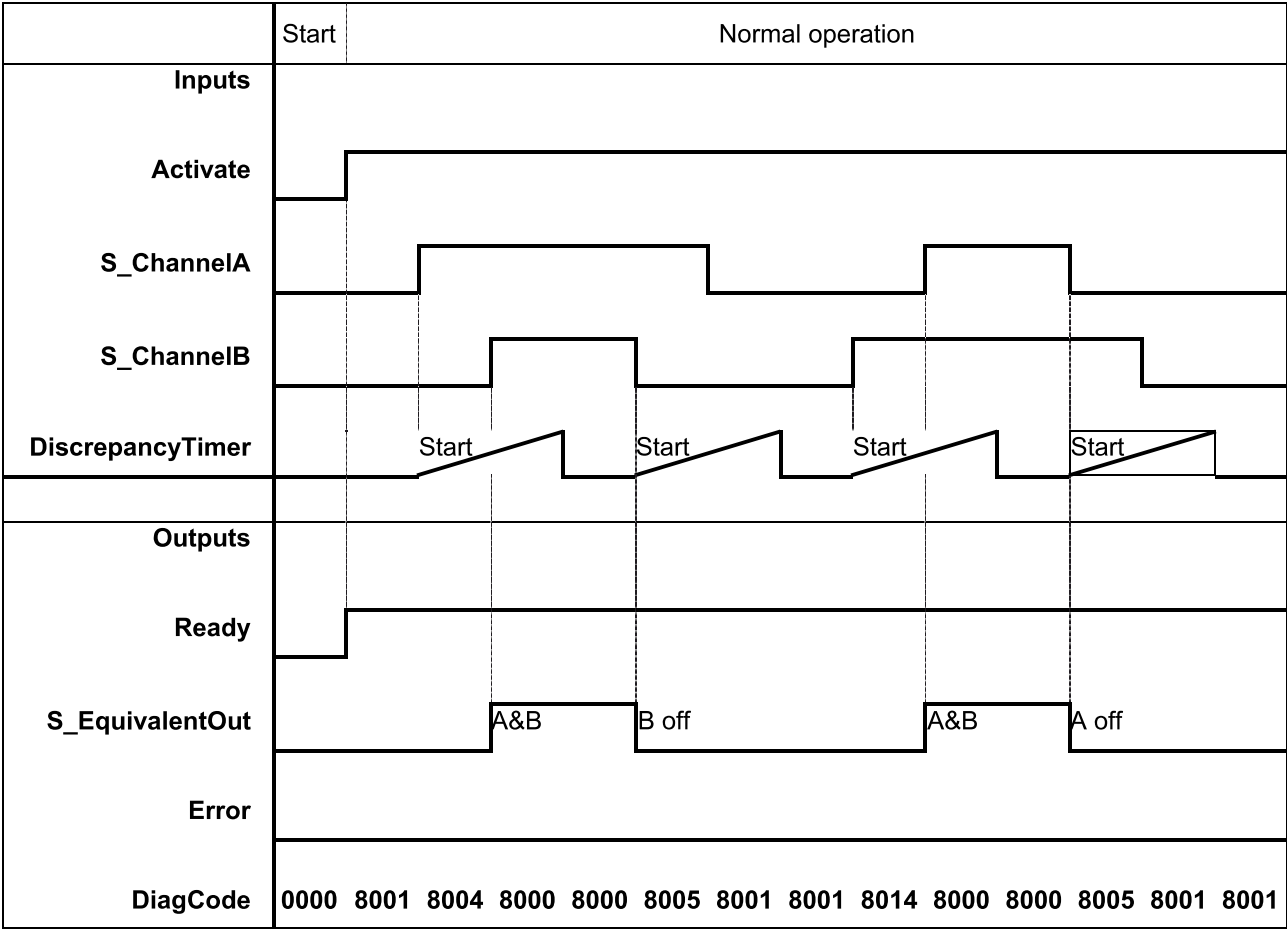
## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

Table 36: FB Name: SF\_Equivalent

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_ChannelA	BOOL	FALSE	Variable. Input A for logical connection. FALSE: Contact A open TRUE: Contact A closed.
S_ChannelB	BOOL	FALSE	Variable. Input B for logical connection. FALSE: Contact B open TRUE: Contact B closed.
DiscrepancyTime	TIME	T#0ms	Constant. Maximum monitoring time for discrepancy status of both inputs.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_EquivalentOut	BOOL	FALSE	Safety related output FALSE: Minimum of one input signal = "FALSE" or status change outside of monitoring time. TRUE: Both input signals "active" and status change within monitoring time.
Error	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	☞ Table 32 "General Output Parameters" on page 267

Typical Timing Diagrams



## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

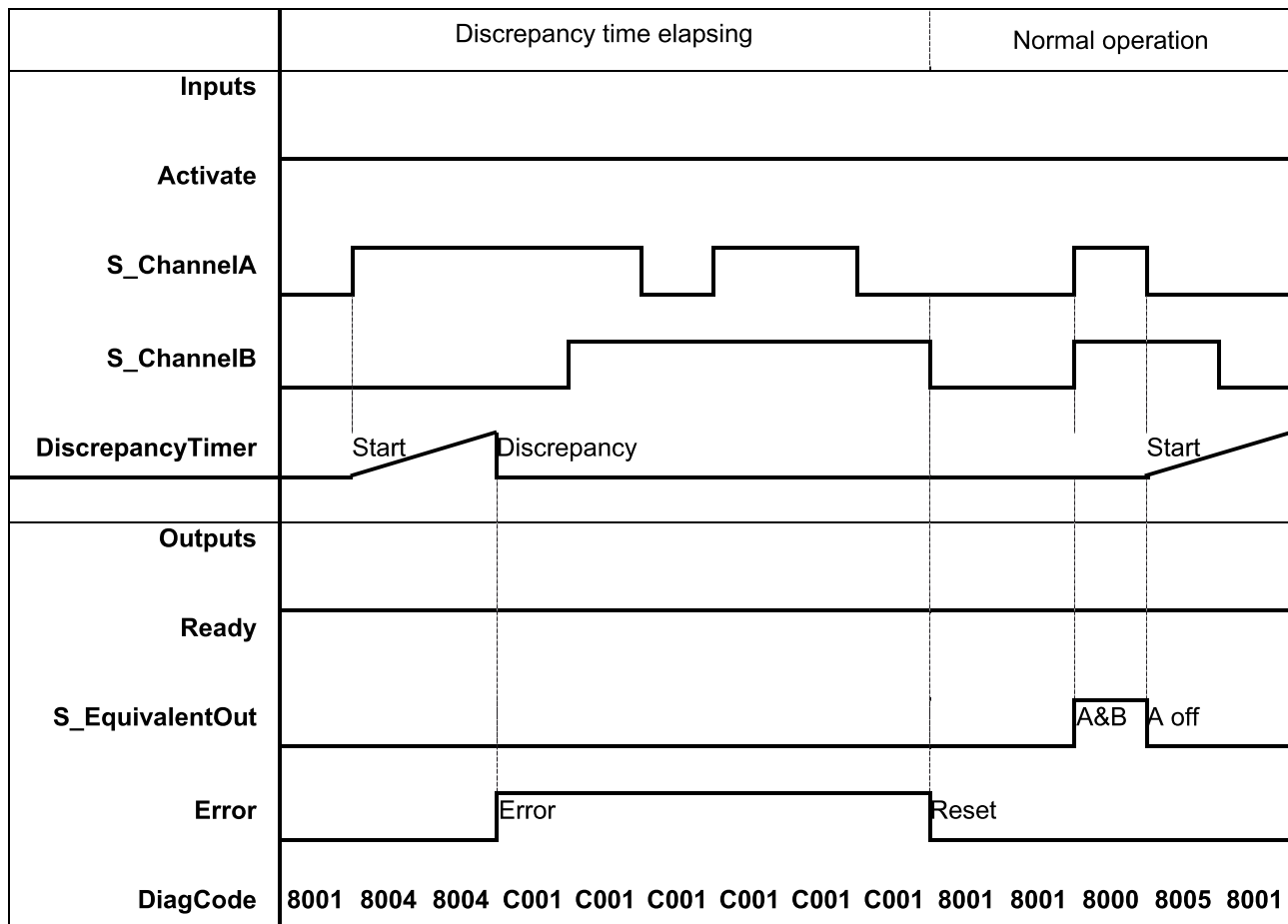


Fig. 98: Typical Timing Diagram for SF\_Equivalent

The function block monitors the discrepancy time between Channel A and B, when switching to TRUE and also when switching to FALSE.

### Error Behavior

S\_EquivalentOut is set to FALSE. Error is set to TRUE. DiagCode indicates the Error states. There is no Reset defined as an input coupled with the reset of an error. If an error occurs in the inputs, a new set of inputs with correct S\_EquivalentOut must be able to reset the error flag. (Example: if a switch is faulty and replaced, using the switch again results in a correct output.)

## Function Block-Specific Error and Status Codes

Table 37: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Error 1	Discrepancy time elapsed in state 8004. Ready = TRUE S_EquivalentOut = FALSE Error = TRUE
C002	Error 2	Discrepancy time elapsed in state 8014. Ready = TRUE S_EquivalentOut = FALSE Error = TRUE
C003	Error 3	Discrepancy time elapsed in state 8005. Ready = TRUE S_EquivalentOut = FALSE Error = TRUE

Table 38: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_EquivalentOut = FALSE Error = FALSE
8001	Init	An activation has been detected by the FB and the FB is now activated. Ready = TRUE S_EquivalentOut = FALSE Error = FALSE
8000	Safety Output Enabled	The inputs switched to TRUE in equivalent mode. Ready = TRUE S_EquivalentOut = TRUE Error = FALSE
8004	Wait for Channel B	Channel A has been switched to TRUE - waiting for Channel B; discrepancy timer started. Ready = TRUE S_EquivalentOut = FALSE Error = FALSE

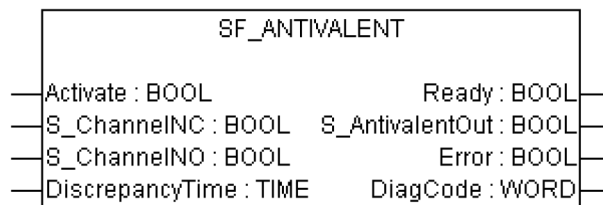
## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8014	Wait for Channel A	Channel B has been switched to TRUE - waiting for Channel A; discrepancy timer started.  Ready = TRUE S_EquivalentOut = FALSE Error = FALSE
8005	From Active Wait	One channel has been switched to FALSE; waiting for the second channel to be switched to FALSE, discrepancy timer started.  Ready = TRUE S_EquivalentOut = FALSE Error = FALSE

### 4.6.6.3 SF\_Antivalent

Standards	Requirements
EN 954-1: 1996	6.2 General safety principles, Idle current 6.2 Error detection for category 3 und 4



This function block converts two antivalent BOOL inputs (NO/NC pair) to one BOOL output with discrepancy time monitoring. This FB should not be used stand-alone since it has no restart interlock. It is required to connect the output to other safety related functionalities.



Table 39: FB Name: SF\_Antivalent

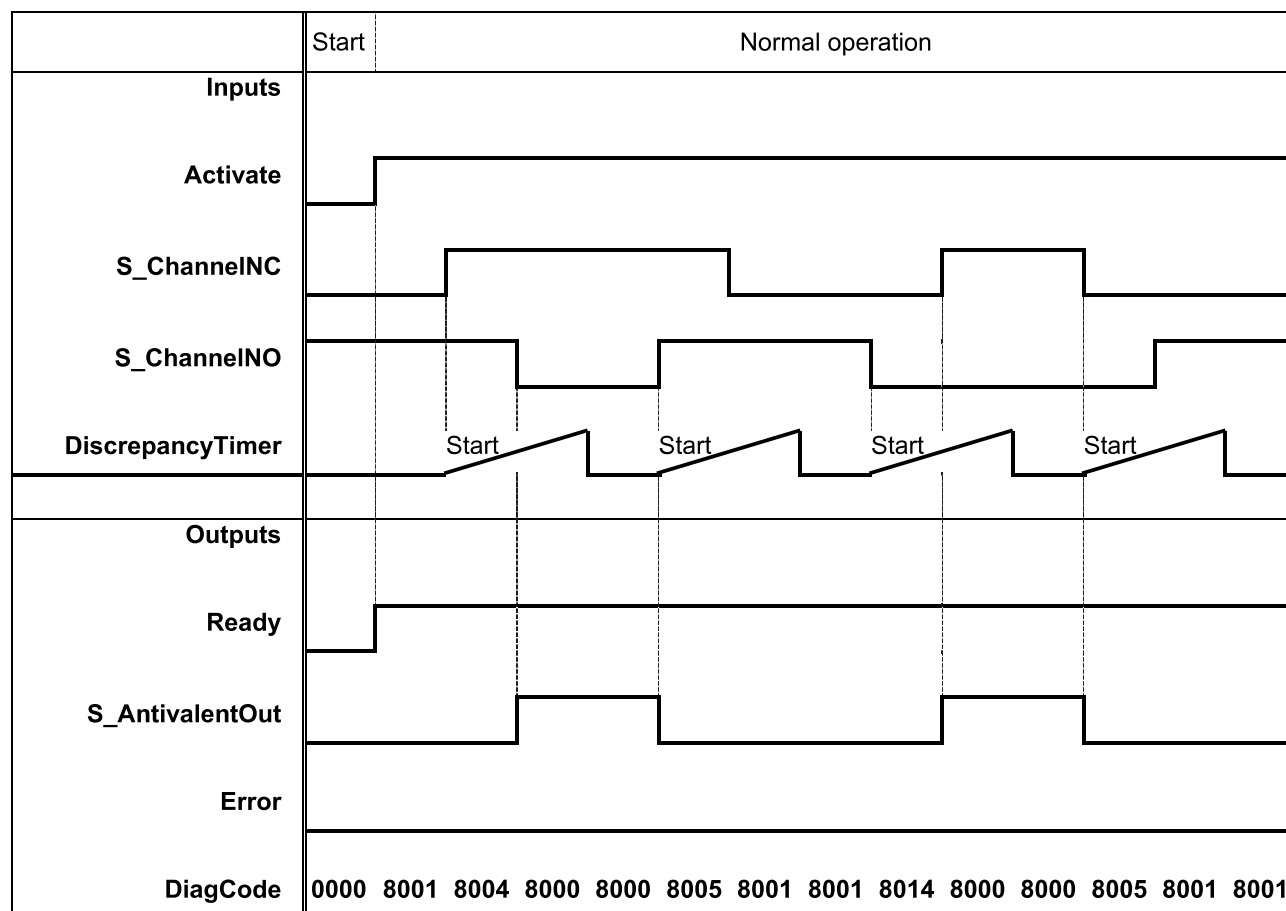
Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_ChannelNC	BOOL	FALSE	Variable. NC stands for Normally Closed. Input for NC connection. FALSE: NC contact open. TRUE: NC contact closed.
S_ChannelNO	BOOL	TRUE	Variable. NO stands for Normally Open. Input for NO connection. FALSE: NO contact open TRUE: NO contact closed
DiscrepancyTime	TIME	T#0ms	Constant. Maximum monitoring time for discrepancy status of both inputs.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
S_AntivalentOut	BOOL	FALSE	Safety related output FALSE: Minimum of one input signal "not active" or status change outside of monitoring time. TRUE: Both inputs signals "active" and status change within monitoring time.
Error	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	↗ Table 32 "General Output Parameters" on page 267

Notes: "Antivalent" means that during normal operation, the two inputs are in opposite states at the same time. This is sometimes called "complementary" or "non-equivalent".

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### Typical Timing Diagrams



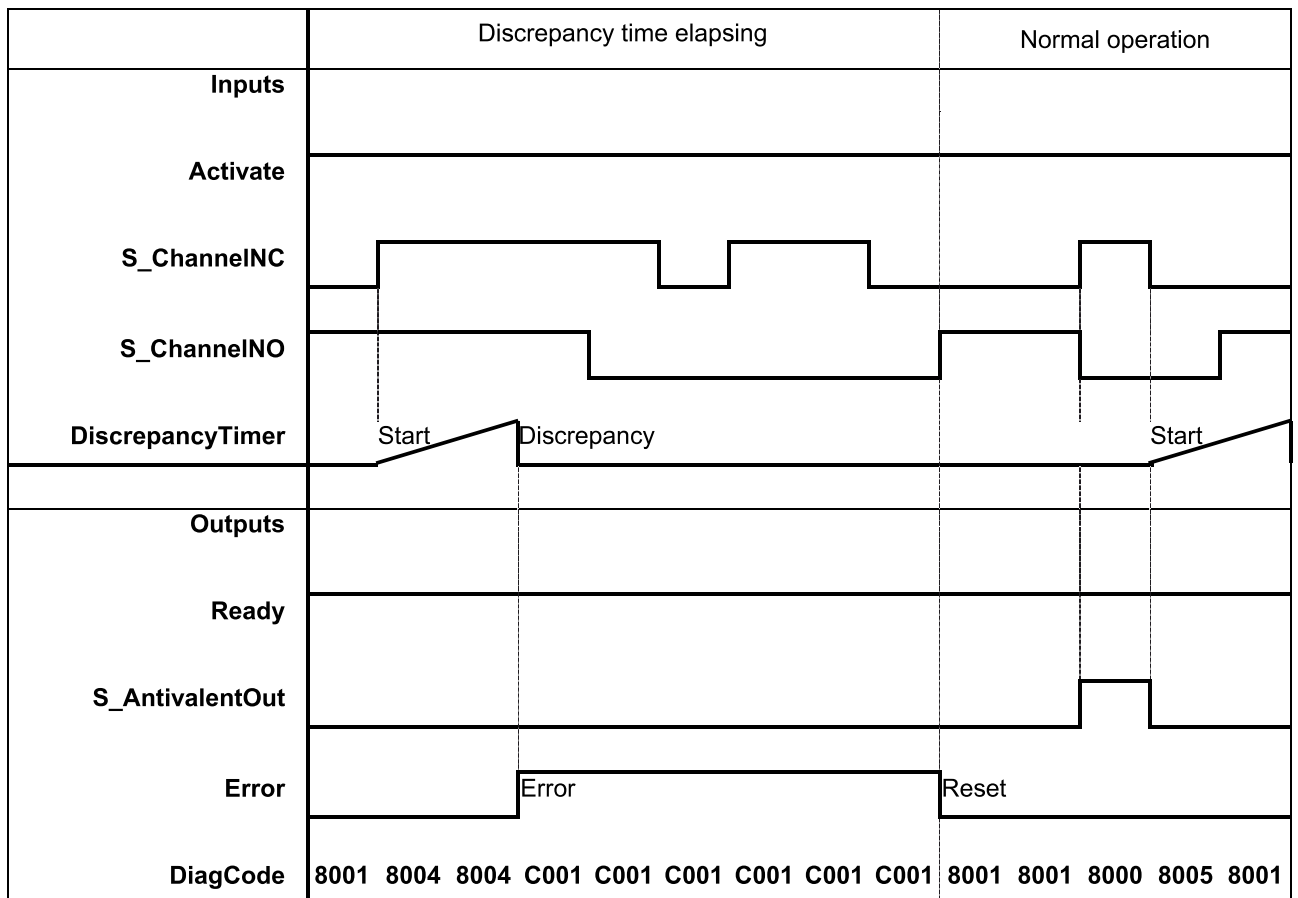


Fig. 99: Typical Timing Diagram for SF\_Antivalent

The function block monitors the discrepancy time between Channel NO and Channel NC.

## Error Behavior

The output S\_AntivalentOut is set to FALSE. Error is set to TRUE. DiagCode indicates the Error states.

There is no Reset defined as an input coupled with the reset of an error. If an error occurs in the inputs, one new set of inputs with the correct value must be able to reset the error flag. (Example: if a switch is faulty and replaced, using the switch again results in a correct output.)

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 40: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Error 1	Discrepancy time elapsed in state 8004. Ready = TRUE S_AntivalentOut = FALSE Error = TRUE
C002	Error 2	Discrepancy time elapsed in state 8014. Ready = TRUE S_AntivalentOut = FALSE Error = TRUE
C003	Error 3	Discrepancy time elapsed in state 8005. Ready = TRUE S_AntivalentOut = FALSE Error = TRUE

Table 41: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_AntivalentOut = FALSE Error = FALSE
8001	Init	An activation has been detected by the FB and the FB is now activated. Ready = TRUE S_AntivalentOut = FALSE Error = FALSE
8000	Safety Output Enabled	The inputs switched to the Active state in antivalent mode. Ready = TRUE S_AntivalentOut = TRUE Error = FALSE
8004	Wait for NO	ChannelINC has been switched to TRUE - waiting for ChannelINO to be switched to FALSE; discrepancy timer started. Ready = TRUE S_AntivalentOut = FALSE Error = FALSE

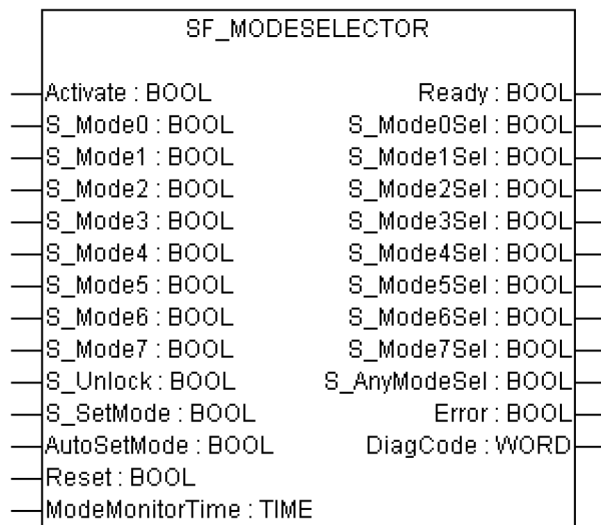
DiagCode	State Name	State Description and Output Setting
8014	Wait for NC	<p>ChannelNO has been switched to FALSE - waiting for ChannelNC to be switched to TRUE; discrepancy timer started.</p> <p>Ready = TRUE</p> <p>S_AntivalentOut = FALSE</p> <p>Error = FALSE</p>
8005	From Active Wait	<p>One channel has been switched to inactive; waiting for the second channel to be switched to inactive too.</p> <p>Ready = TRUE</p> <p>S_AntivalentOut = FALSE</p> <p>Error = FALSE</p>

## 4.6.6.4 SF\_ModeSelector

Standards	Requirements
MRL 98/37/EC, Annex I	<p>1.2.3. Starting</p> <p>... It must be possible to start machinery only by voluntary actuation of a control provided for the purpose ... The same requirement applies: ...</p> <p>- when effecting a significant change in the operating conditions ...</p> <p>1.2.5 ... mode selector which can be locked in each position. Each position of the selector must correspond to a single operating or control mode ...</p>
EN ISO 12100-2: 2003	<p>4.11.10 Selection of Control and Operating Modes</p> <p>... shall be fitted with a mode selector which can be locked in each position. Each position of the selector shall be clearly identifiable and shall exclusively enable one control or operating mode to be selected...</p>
IEC 60204-1, Ed. 5.0 : 2003	<p>9.2.3 Operating Modes</p> <p>... When a hazardous condition can result from a mode selection, unauthorized and/or inadvertent selection shall be prevented by suitable means (e.g. key operated switch, access code). Mode selection by itself shall not initiate machine operation. A separate action by the operator shall be required. ... Indication of the selected operating mode shall be provided ...</p>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib



This function block selects the system operation mode, such as manual, automatic, semi-automatic, etc.

Table 42: FB Name: SF\_ModeSelector

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	🔗 Table 31 "General Input Parameters" on page 266
S_Mode0	BOOL	FALSE	Variable or constant. Input 0 from mode selector switch FALSE: Mode 0 is not requested by operator. TRUE: Mode 0 is requested by operator.
S_Mode1	BOOL	FALSE	Variable or constant. Input 1 from mode selector switch FALSE: Mode 1 is not requested by operator. TRUE: Mode 1 is requested by operator.
S_Mode2	BOOL	FALSE	Variable or constant. Input 2 from mode selector switch FALSE: Mode 2 is not requested by operator. TRUE: Mode 2 is requested by operator.
S_Mode3	BOOL	FALSE	Variable or constant. Input 3 from mode selector switch FALSE: Mode 3 is not requested by operator. TRUE: Mode 3 is requested by operator.
S_Mode4	BOOL	FALSE	Variable or constant. Input 4 from mode selector switch FALSE: Mode 4 is not requested by operator. TRUE: Mode 4 is requested by operator.
S_Mode5	BOOL	FALSE	Variable or constant. Input 5 from mode selector switch FALSE: Mode 5 is not requested by operator. TRUE: Mode 5 is requested by operator.
S_Mode6	BOOL	FALSE	Variable or constant. Input 6 from mode selector switch FALSE: Mode 6 is not requested by operator. TRUE: Mode 6 is requested by operator.
S_Mode7	BOOL	FALSE	Variable or constant. Input 7 from mode selector switch FALSE: Mode 7 is not requested by operator. TRUE: Mode 7 is requested by operator.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

Name	Data Type	Initial Value	Description, Parameter Values
S_Unlock	BOOL	FALSE	Variable or constant. Locks the selected mode FALSE: The actual S_ModeXSel output is locked therefore a change of any S_ModeX input does not lead to a change in the S_ModeXSel output even in the event of a rising edge of SetMode. TRUE: The selected S_ModeXSel is not locked; a mode selection change is possible.
S_SetMode	BOOL	FALSE	Variable (or constant FALSE, if AutoSetMode = TRUE) Sets the selected mode Operator acknowledges the setting of a mode. Any change to new S_ModeX = TRUE leads to S_AnyModeSel/S_ModeXSel = FALSE, only a rising SetMode trigger then leads to new S_ModeXSel = TRUE.
AutoSetMode	BOOL	FALSE	Constant. Parameterizes the acknowledgement mode FALSE: A change in mode must be acknowledged by the operator via SetMode. TRUE: A valid change of the S_ModeX input to another S_ModeX automatically leads to a change in S_ModeXSel without operator acknowledgment via SetMode (as long as this is not locked by S_Unlock).
Reset	BOOL	FALSE	↪ <i>Table 31 "General Input Parameters" on page 266</i>
ModeMonitorTime	TIME	T#0	Constant. Maximum permissible time for changing the selection input.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↪ <i>Table 32 "General Output Parameters" on page 267</i>
S_Mode0Sel	BOOL	FALSE	Indicates that mode 0 is selected and acknowledged. FALSE: Mode 0 is not selected or not active. TRUE: Mode 0 is selected and active.
S_Mode1Sel	BOOL	FALSE	Indicates that mode 1 is selected and acknowledged. FALSE: Mode 1 is not selected or not active. TRUE: Mode 1 is selected and active.



Name	Data Type	Initial Value	Description, Parameter Values
S_Mode2Sel	BOOL	FALSE	Indicates that mode 2 is selected and acknowledged. FALSE: Mode 2 is not selected or not active. TRUE: Mode 2 is selected and active.
S_Mode3Sel	BOOL	FALSE	Indicates that mode 3 is selected and acknowledged. FALSE: Mode 3 is not selected or not active. TRUE: Mode 3 is selected and active.
S_Mode4Sel	BOOL	FALSE	Indicates that mode 4 is selected and acknowledged. FALSE: Mode 4 is not selected or not active. TRUE: Mode 4 is selected and active.
S_Mode5Sel	BOOL	FALSE	Indicates that mode 5 is selected and acknowledged. FALSE: Mode 5 is not selected or not active. TRUE: Mode 5 is selected and active.
S_Mode6Sel	BOOL	FALSE	Indicates that mode 6 is selected and acknowledged. FALSE: Mode 6 is not selected or not active. TRUE: Mode 6 is selected and active.
S_Mode7Sel	BOOL	FALSE	Indicates that mode 7 is selected and acknowledged. FALSE: Mode 7 is not selected or not active. TRUE: Mode 7 is selected and active.
S_AnyModeSel	BOOL	FALSE	Indicates that any of the 8 modes is selected and acknowledged. FALSE: No S_ModeX is selected. TRUE: One of the 8 S_ModeX is selected and active.
Error	BOOL	FALSE	 Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	 Table 32 "General Output Parameters" on page 267

Notes: The X in parameter names "S\_ModeX" or "S\_ModeXSel" is a placeholder for digits 0 to 7.

## Typical Timing Diagrams

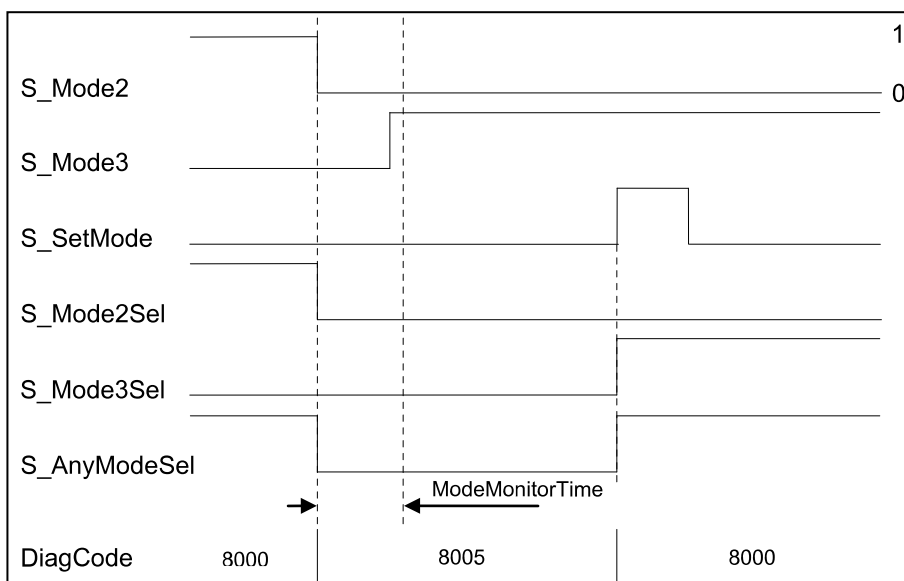


Fig. 100: Timing diagram for SF\_ModeSelector, valid change in Mode input with acknowledgment

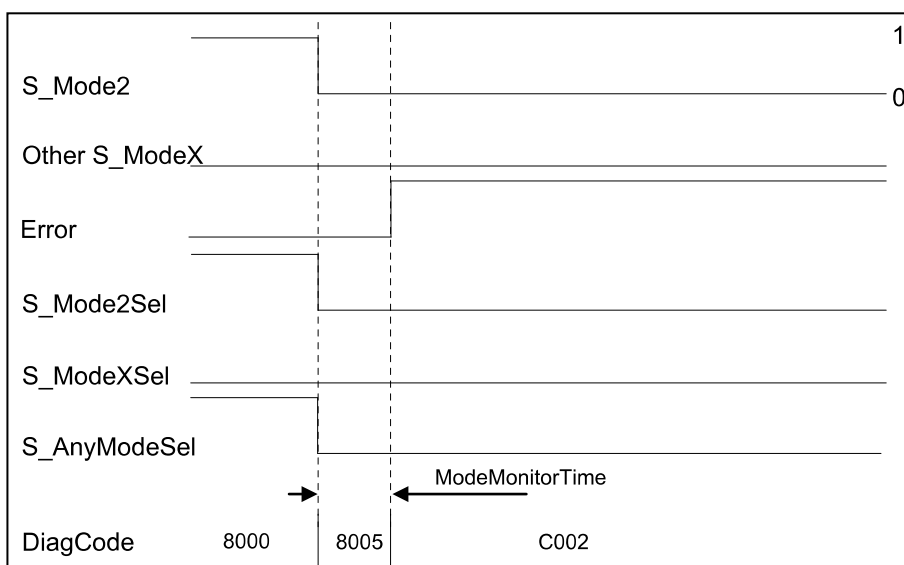


Fig. 101: Timing diagram for SF\_ModeSelector, error condition 2 at Mode inputs

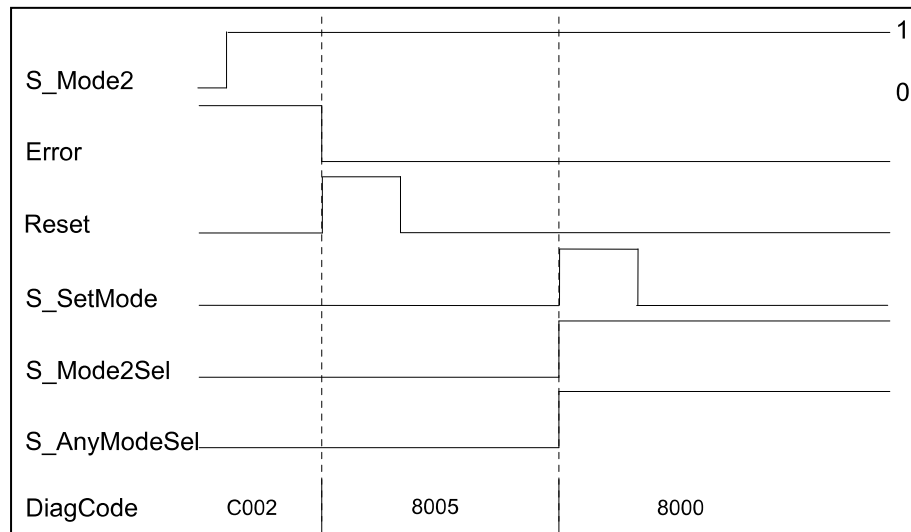


Fig. 102: Timing diagram for SF\_ModeSelector, reset of error condition

The FB detects whether none of the mode inputs is selected. This invalid condition is detected after ModeMonitorTime has elapsed:

- Which restarts with each falling trigger of an S\_ModeX switched mode input
- Which is then in the ModeChanged state following activation of the FB

In contrast, the FB directly detects whether more than one S\_ModeX mode input is selected at the same time.

A static reset condition is detected when the FB is either in Error state C001 or C002.

## Error Behavior

In the event of an error, the S\_ModeXSel and S\_AnyModeSel outputs are set to safe state = FALSE. The DiagCode output indicates the relevant error code and the Error output is set to TRUE.

An error must be acknowledged with the rising trigger of the Reset BOOL input. The FB changes from an error state to the ModeChanged state.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 43: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Error Short-circuit	The FB detected that two or more S_ModeX are TRUE, e.g., short-circuit of cables. Ready = TRUE Error = TRUE S_AnyModeSel = FALSE All S_ModeXSel = FALSE
C002	Error Open-circuit	The FB detected that all S_ModeX are FALSE: The period following a falling S_ModeX trigger exceeds ModeMonitorTime, e.g., open-circuit of cables. Ready = TRUE Error = TRUE S_AnyModeSel = FALSE All S_ModeXSel = FALSE
C003	Reset Error 1	Static Reset signal detected in state C001. Ready = TRUE Error = TRUE S_AnyModeSel = FALSE All S_ModeXSel = FALSE
C004	Reset Error 2	Static Reset signal detected in state C002. Ready = TRUE Error = TRUE S_AnyModeSel = FALSE All S_ModeXSel = FALSE

Table 44: FB-specific status codes (no error):

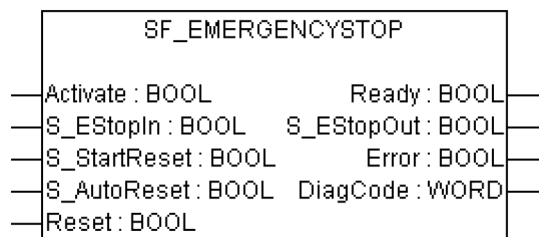
DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE Error = FALSE S_AnyModeSel = FALSE All S_ModeXSel = FALSE
8005	ModeChanged	State after activation or when S_ModeX has changed (unless locked) or after Reset of an error state. Ready = TRUE Error = FALSE S_AnyModeSel = FALSE All S_ModeXSel = FALSE
8000	ModeSelected	Valid mode selection, but not yet locked. Ready = TRUE Error = FALSE S_AnyModeSel = TRUE S_ModeXSel = Selected X is TRUE, others are FALSE.
8004	ModeLocked	Valid mode selection is locked. Ready = TRUE Error = FALSE S_AnyModeSel = TRUE S_ModeXSel = Selected X is TRUE, others are FALSE.

## 4.6.6.5 SF\_EmergencyStop

Standards	Requirements
EN 418: 1992	3. Definitions 4.1.12 ... Resetting the control device shall not by itself cause a restart command.
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4 Restart following power failure/spontaneous restart
EN 16204-1, 1997	9.2.2. Stop Functions

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib



This function block is a safety-related function block for monitoring an emergency stop button. This FB can be used for emergency switch off functionality (stop category 0), or – with additional peripheral support – as emergency stop (stop category 1 or 2).

Table 45: FB Name: SF\_EmergencyStop

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 “General Input Parameters” on page 266
S_EStopIn	BOOL	FALSE	Safety demand input. Variable. FALSE: Demand for safety-related response (e.g., emergency stop button is engaged). TRUE: No demand for safety-related response (e.g., emergency stop button not engaged).
S_StartReset	BOOL	FALSE	↗ Table 31 “General Input Parameters” on page 266
S_AutoReset	BOOL	FALSE	↗ Table 31 “General Input Parameters” on page 266
Reset	BOOL	FALSE	↗ Table 31 “General Input Parameters” on page 266
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ Table 32 “General Output Parameters” on page 267
S_EStopOut	BOOL	FALSE	Output for the safety-related response. FALSE: Safety output disabled. Demand for safety-related response (e.g., emergency stop button engaged, reset required or internal errors active) TRUE: Safety output enabled. No demand for safety-related response (e.g., emergency stop button not engaged, no internal errors active).
Error	BOOL	FALSE	↗ Table 32 “General Output Parameters” on page 267
DiagCode	WORD	16#0000	↗ Table 32 “General Output Parameters” on page 267

Notes: The following requirements as defined in EN 418: 1992 have to be fulfilled by the user:

- Ch. 4.1.4 After activation of the actuator, the emergency stop equipment shall operate in such a way that the hazard is averted or reduced automatically in the best possible manner.
- 4.1.7 The emergency stop command shall override all other commands.
- 4.1.12 Resetting the control device shall only be possible as the result of a manual action on the control device itself ... It shall not be possible to restart the machine until all control devices which have been actuated are reset manually, individually and intentionally.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Typical Timing Diagrams

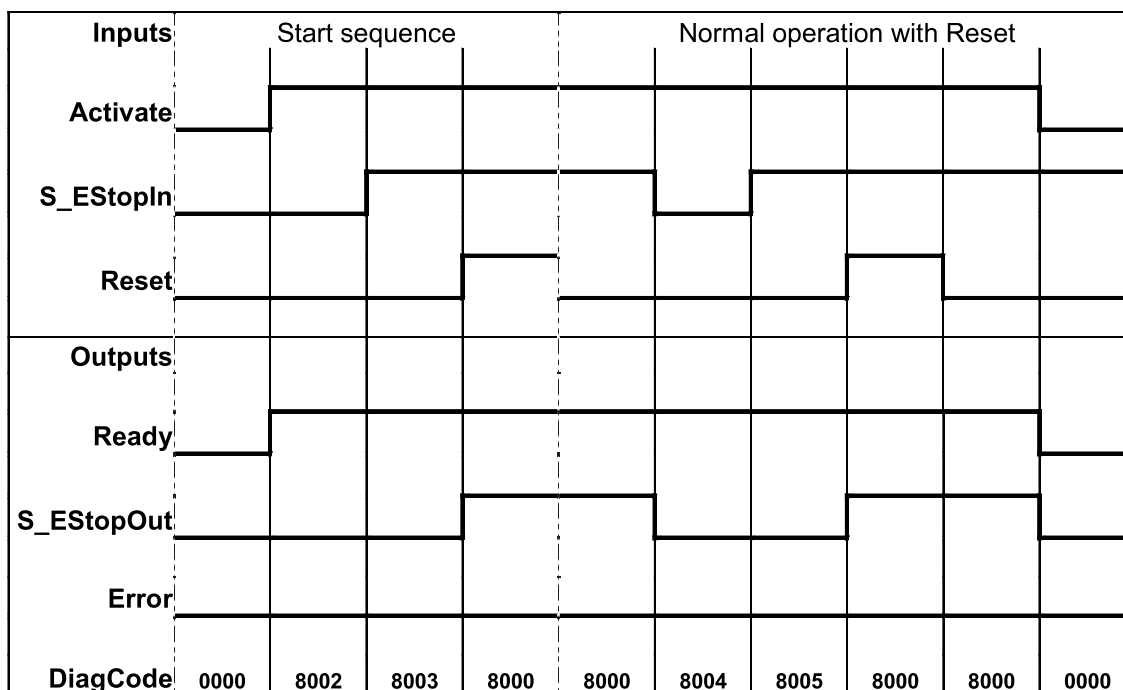


Fig. 103: Timing diagram for SF\_EmergencyStop: S\_StartReset = FALSE; S\_AutoReset = FALSE; Start, reset, normal operation, safety demand, restart

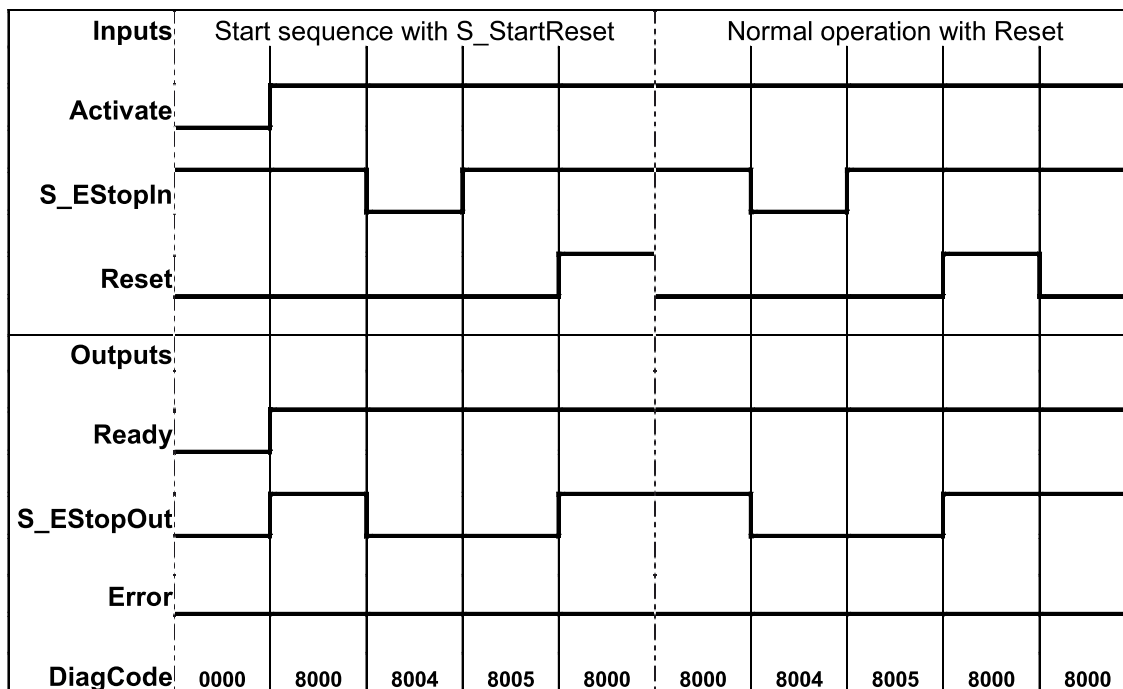


Fig. 104: Timing diagram for SF\_EmergencyStop: S\_StartReset = TRUE, S\_AutoReset = FALSE; Start, normal operation, safety demand, restart



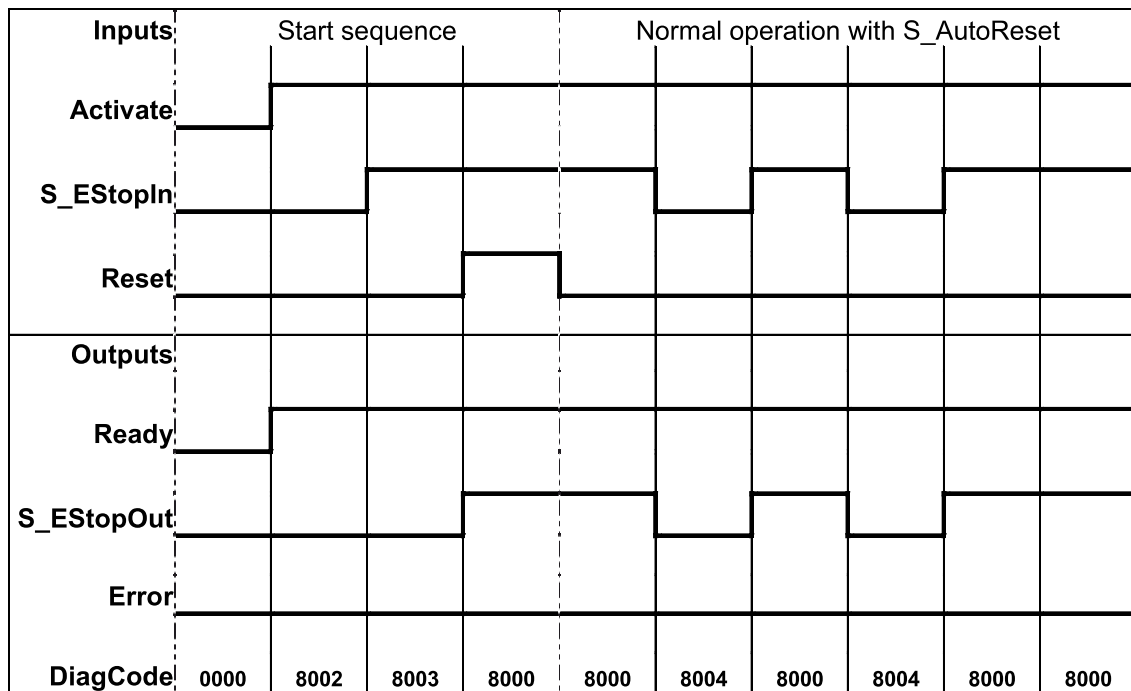


Fig. 105: Timing diagram for SF\_EmergencyStop: S\_StartReset = FALSE, S\_AutoReset = TRUE, Start, normal operation, safety demand, restart

The function block detects a static TRUE signal at Reset input.

## Error Behavior

S\_EStopOut is set to FALSE. In case of a static TRUE signal at the Reset input, the DiagCode output indicates the relevant error code and the Error output is set to TRUE.

To leave the error states, the Reset must be set to FALSE.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 46: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Reset is TRUE while waiting for S_EStopIn = TRUE. Ready = TRUE S_EStopOut = FALSE Error = TRUE
C002	Reset Error 2	Reset is TRUE while waiting for S_EStopIn = TRUE. Ready = TRUE S_EStopOut = FALSE Error = TRUE

Table 47: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_EStopOut = FALSE Error = FALSE
8001	Init	Activation is TRUE. The function block was enabled. Check if S_StartReset is required. Ready = TRUE S_EStopOut = FALSE Error = FALSE
8002	Wait for S_EstopIn 1	Activation is TRUE. Check if Reset is FALSE and wait for S_EStopIn = TRUE. Ready = TRUE S_EStopOut = FALSE Error = FALSE
8003	Wait for Reset 1	Activation is TRUE. S_EStopIn = TRUE. Wait for rising trigger of Reset. Ready = TRUE S_EStopOut = FALSE Error = FALSE
8004	Wait for S_EstopIn 2	Activation is TRUE. Safety demand detected. Check if Reset is FALSE and wait for S_EStopIn = TRUE. Ready = TRUE S_EStopOut = FALSE Error = FALSE

DiagCode	State Name	State Description and Output Setting
8005	Wait for Reset 2	Activation is TRUE. S_EStopIn = TRUE. Check for S_AutoReset or wait for rising trigger of Reset.  Ready = TRUE S_EStopOut = FALSE Error = FALSE
8000	Safety Output Enabled	Activation is TRUE. S_EStopIn = TRUE. Functional mode with S_EStopOut = TRUE.  Ready = TRUE S_EStopOut = TRUE Error = FALSE

## 4.6.6.6 SF\_ESPE

Standards	Requirements
EN IEC 61496-1: 2004	A.5.1 Start Interlock: The start interlock shall prevent the OSSD(s) going to the ON-state when the electrical supply is switched on, or is interrupted and restored.  A.5.2: A failure of the start interlock which causes it to go to, or remain in a permanent ON-state shall cause the ESPE to go to, or to remain in the lock-out condition.  A.6.1 Restart interlock: ... The interlock condition shall continue until the restart interlock is manually reset. However, it shall not be possible to reset the restart interlock whilst the sensing device is actuated.
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



This function block is a safety-related function block for monitoring electro-sensitive protective equipment (ESPE). The function is identical to SF\_EmergencyStop. The S\_ESPE\_Out output signal is set to FALSE as soon as the S\_ESPE\_In input is set to FALSE. The S\_ESPE\_Out output signal is set to TRUE only if the S\_ESPE\_In input is set to TRUE and a reset occurs. The enable reset depends on the defined S\_StartReset, S\_AutoReset, and Reset inputs.

If S\_AutoReset = TRUE, acknowledgment is automatic.

If S\_AutoReset = FALSE, a rising trigger at the Reset input must be used to acknowledge the enable.

If S\_StartReset = TRUE, acknowledgment is automatic the PES is started the first time.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

If S\_StartReset = FALSE, a rising trigger at the Reset input must be used to acknowledge the enable.

The S\_StartReset and S\_AutoReset inputs shall only be activated if it is ensured, that no hazardous situation can occur when the PES is started.

The ESPE must be selected in respect of the product standards EN IEC 61496-1, -2 and -3 and the required categories according EN 954-1.

Table 48: FB Name: SF\_ESPE

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_ESPE_In	BOOL	FALSE	Safety demand input. Variable. FALSE: ESPE actuated, demand for safety-related response. TRUE: ESPE not actuated, no demand for safety-related response. Safety control system must be able to detect a very short interruption of the sensor (which is specified in 61496-1: minimum 80 ms), when the ESPE is used in applications as a trip device
S_StartReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_AutoReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_ESPE_Out	BOOL	FALSE	Output for the safety-related response. FALSE: Safety output disabled. Demand for safety-related response (e.g., reset required or internal errors active). TRUE: Safety output enabled. No demand for safety-related response.
Error	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	☞ Table 32 "General Output Parameters" on page 267

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Typical Timing Diagrams

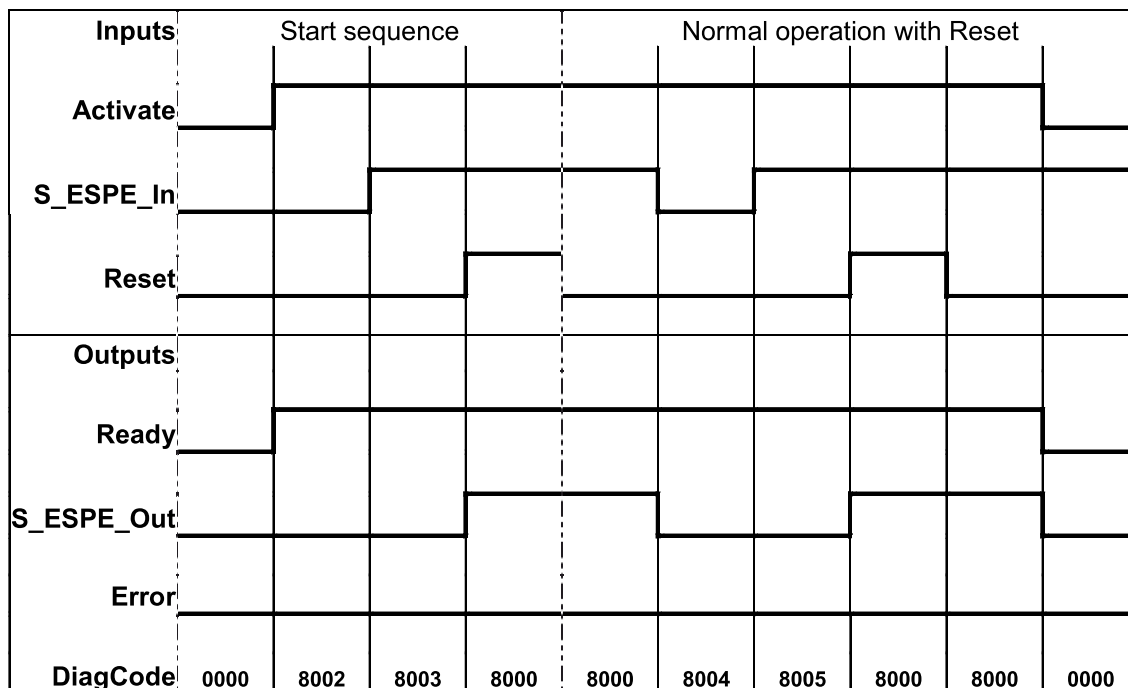


Fig. 106: Timing diagram for SF\_ESPE: S\_StartReset = FALSE; S\_AutoReset = FALSE; Start, reset, normal operation, safety demand, restart

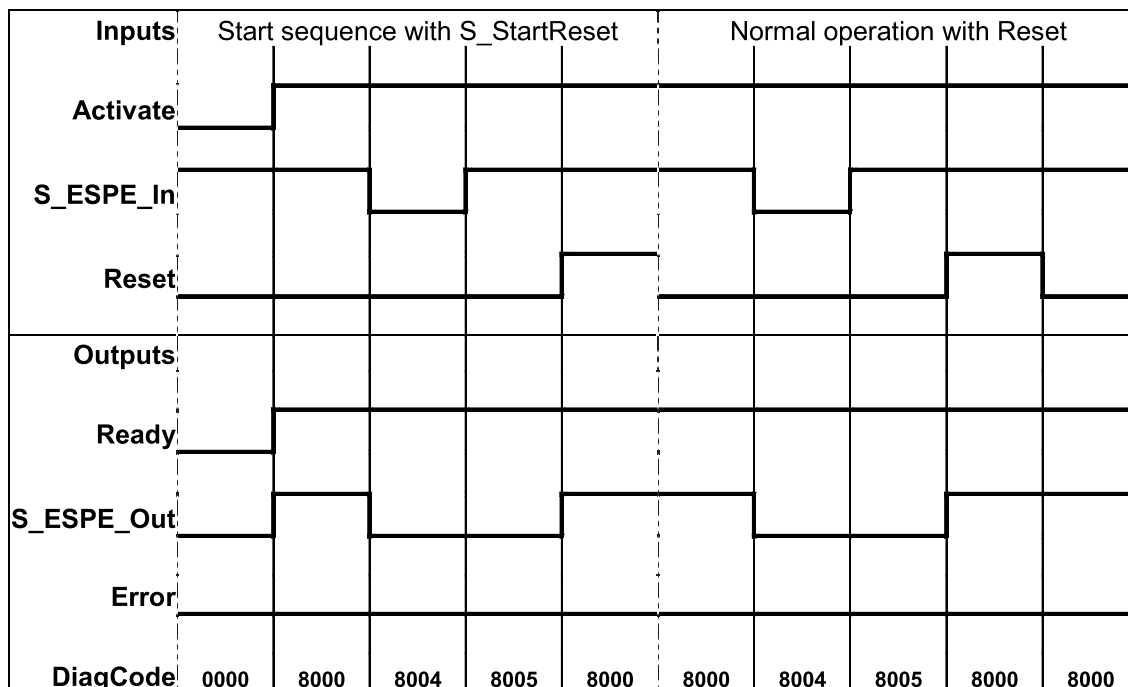


Fig. 107: Timing diagram for SF\_ESPE: S\_StartReset = TRUE, S\_AutoReset = FALSE; Start, normal operation, safety demand, restart

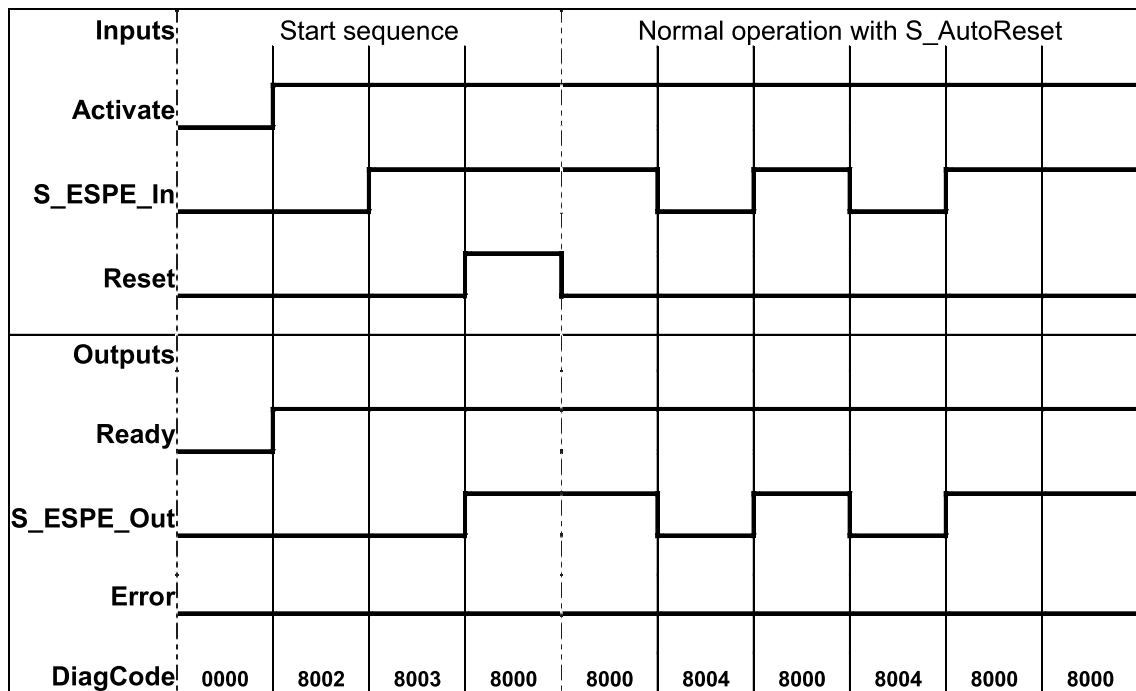


Fig. 108: Timing diagram for SF\_ESPE: S\_StartReset = FALSE, S\_AutoReset = TRUE, Start, normal operation, safety demand, restart

The function block detects a static TRUE signal at Reset input.

## Error Behavior

S\_ESPE\_Out is set to FALSE. In case of a static TRUE signal at the Reset input, the DiagCode output indicates the relevant error code and the Error output is set to TRUE.

To leave the error states, the Reset must be set to FALSE.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 49: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Reset is TRUE while waiting for S_ESPE_In = TRUE. Ready = TRUE S_ESPE_Out = FALSE Error = TRUE
C002	Reset Error 2	Reset is TRUE while waiting for S_ESPE_In = TRUE. Ready = TRUE S_ESPE_Out = FALSE Error = TRUE

Table 50: FB-specific status codes (no error):

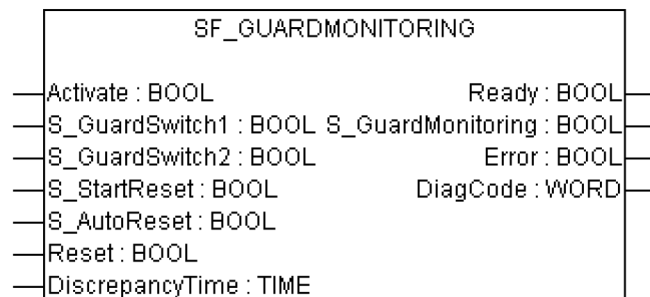
DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_ESPE_Out = FALSE Error = FALSE
8001	Init	Activation is TRUE. The function block was enabled. Check if S_StartReset is required. Ready = TRUE S_ESPE_Out = FALSE Error = FALSE
8002	Wait for S_ESPE_In 1	Activation is TRUE. Check if Reset is FALSE and wait for S_ESPE_In = TRUE. Ready = TRUE S_ESPE_Out = FALSE Error = FALSE
8003	Wait for Reset 1	Activation is TRUE. S_ESPE_In = TRUE. Wait for rising trigger of Reset. Ready = TRUE S_ESPE_Out = FALSE Error = FALSE
8004	Wait for S_ESPE_In 2	Activation is TRUE. Safety demand detected. Check if Reset is FALSE and wait for S_ESPE_In = TRUE. Ready = TRUE S_ESPE_Out = FALSE Error = FALSE



DiagCode	State Name	State Description and Output Setting
8005	Wait for Reset 2	Activation is TRUE. S_ESPE_In = TRUE. Check for S_AutoReset or wait for rising trigger of Reset.  Ready = TRUE S_ESPE_Out = FALSE Error = FALSE
8000	Safety Output Enabled	Activation is TRUE. S_ESPE_In = TRUE. Functional mode with S_ESPE_Out = TRUE.  Ready = TRUE S_ESPE_Out = TRUE Error = FALSE

## 4.6.6.7 SF\_GuardMonitoring

Standards	Requirements
EN 953: 1997	3.3.3 Control Guard <ul style="list-style-type: none"> <li>■ The hazardous machine functions "covered" by the guard cannot operate until the guard is closed;</li> <li>■ Closing the guard initiates operation of the hazardous machine function(s).</li> </ul>
EN 1088: 1995	3.2 Interlocking Guard <ul style="list-style-type: none"> <li>■ The hazardous machine functions "covered" by the guard cannot operate until the guard is closed;</li> <li>■ If the guard is opened while the hazardous machine functions are operating, a stop instruction is given;</li> <li>■ When the guard is closed, the hazardous machine functions "covered" by the guard can operate, but the closure of the guard does not by itself initiate their operation.</li> </ul>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4 Restart following power failure/spontaneous restart



## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

This function block monitors the relevant safety guard. There are two independent input parameters for two switches at the safety guard coupled with a time difference (MonitoringTime) for closing the guard.

The function block requires two inputs indicating the guard position for safety guards with two switches (according to EN 1088), a DiscrepancyTime input and Reset input. If the safety guard only has one switch, the S\_GuardSwitch1 and S\_GuardSwitch2 inputs can be bridged. The monitoring time is the maximum time required for both switches to respond when closing the safety guard. The Reset, S\_StartReset, and S\_AutoReset inputs determine how the function block is reset after the safety guard has been opened.

When opening the safety guard, both S\_GuardSwitch1 and S\_GuardSwitch2 inputs should switch to FALSE. The S\_GuardMonitoring output switches to FALSE as soon as one of the switches is set to FALSE. When closing the safety guard, both S\_GuardSwitch1 and S\_GuardSwitch2 inputs should switch to TRUE.

This FB monitors the symmetry of the switching behavior of both switches. The S\_GuardMonitoring output remains FALSE if only one of the contacts has completed an open/close process.

The behavior of the S\_GuardMonitoring output depends on the time difference between the switching inputs. The discrepancy time is monitored as soon as the value of both S\_GuardSwitch1/S\_GuardSwitch2 inputs differs. If the DiscrepancyTime has elapsed, but the inputs still differ, the S\_GuardMonitoring output remains FALSE. If the second corresponding S\_GuardSwitch1/S\_GuardSwitch2 input switches to TRUE within the value specified for the DiscrepancyTime input, the S\_GuardMonitoring output is set to TRUE following acknowledgment.

The S\_StartReset and S\_AutoReset inputs shall only be activated if it is ensured that no hazardous situation can occur when the PES is started.

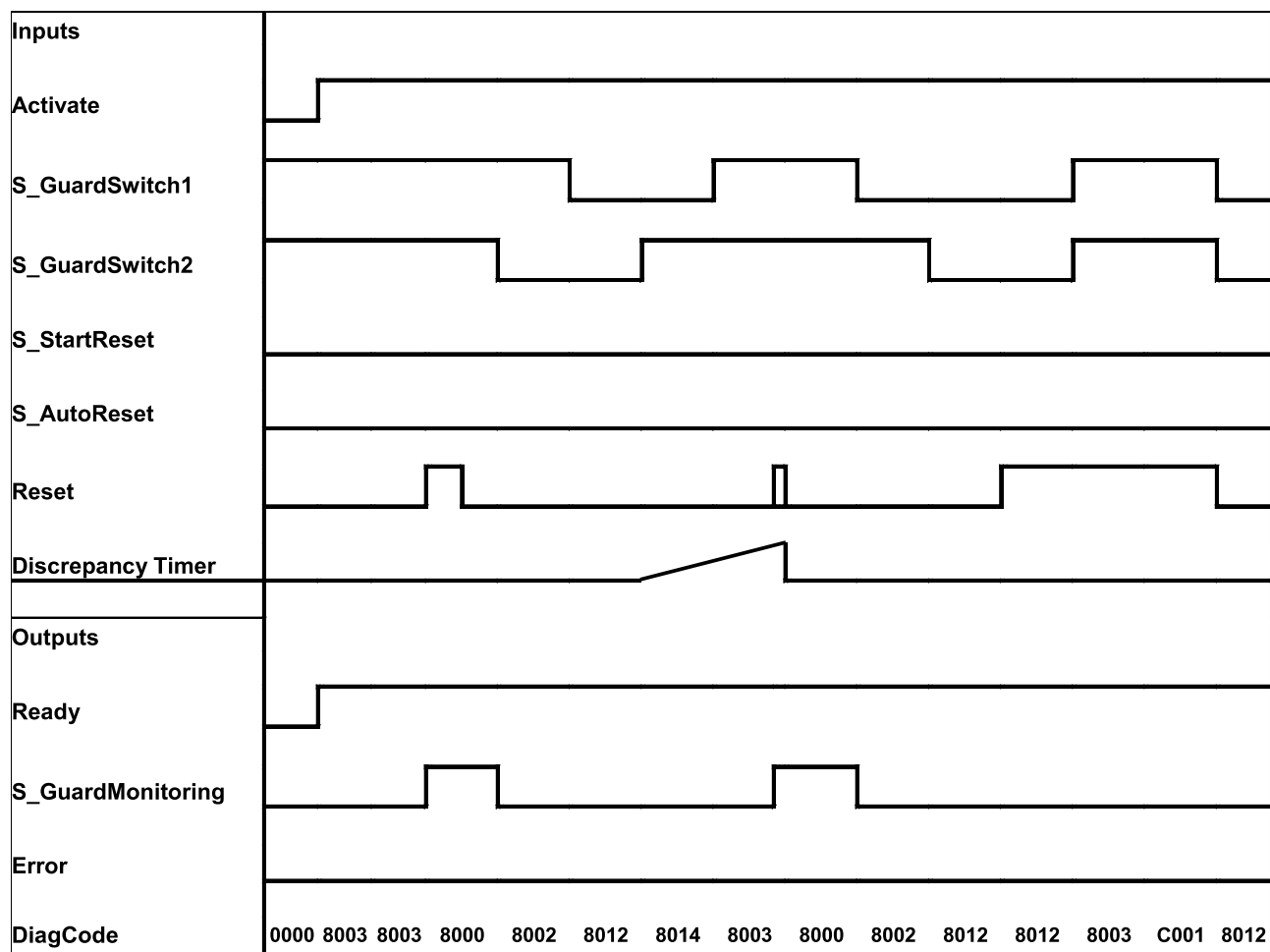
Table 51: FB Name: SF\_GuardMonitoring

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_GuardSwitch1	BOOL	FALSE	Variable. Guard switch 1 input. FALSE: Guard is open. TRUE: Guard is closed.
S_GuardSwitch2	BOOL	FALSE	Variable. Guard switch 2 input. FALSE: Guard is open. TRUE: Guard is closed.
DiscrepancyTime	TIME	T#0ms	Constant. Configures the monitored synchronous time between S_GuardSwitch1 and S_GuardSwitch2.
S_StartReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266 – Only Constant
S_AutoReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266 – Only Constant
Reset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_GuardMonitoring	BOOL	FALSE	Output indicating the status of the guard. FALSE: Guard is not active. TRUE: both S_GuardSwitches are TRUE, no error and acknowledgment. Guard is active.
Error	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	☞ Table 32 "General Output Parameters" on page 267

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### Typical Timing Diagrams



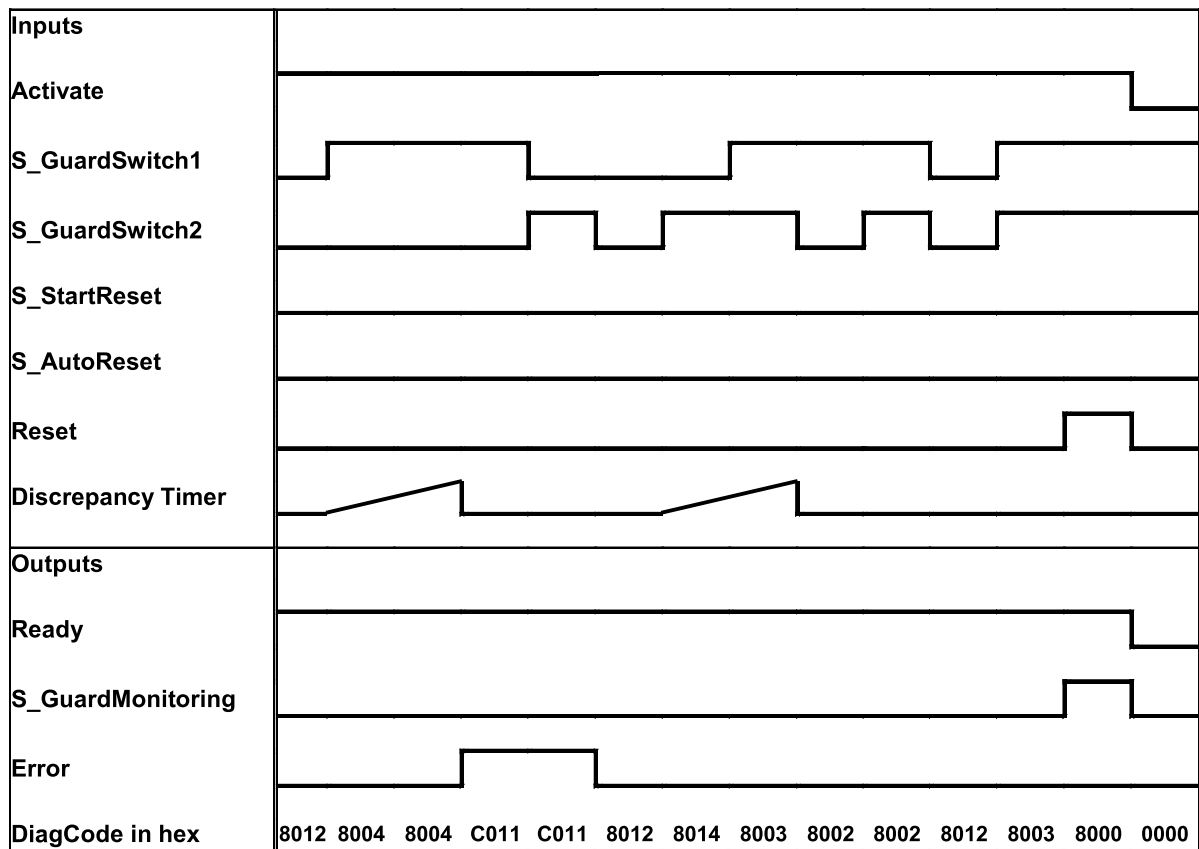


Fig. 109: Timing Diagrams for SF\_GuardMonitoring

External signals: Mechanical setup combines that of an opening and closing switch according to EN 954 (safety guard with two switches). Discrepancy time monitoring for time lag between both mechanical switches reaction, according to EN 954 (to be considered as "application error" detection, i.e., generated by the application).

An error is detected if the time lag between the first S\_GuardSwitch1/S\_GuardSwitch2 input and the second is greater than the value for the DiscrepancyTime input. The Error output is set to TRUE.

The function block detects a static TRUE signal at the RESET input.

## Error and Reset Behavior

The S\_GuardMonitoring output is set to FALSE. If the two S\_GuardSwitch1 and S\_Guardswitch2 inputs are bridged, no error is detected. To leave the Reset error state, the Reset input must be set to FALSE. To leave the discrepancy time errors, the inputs S\_GuardSwitch1 and 2 must both be set to FALSE.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 52: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error	Static reset detected in state 8003. Ready = TRUE S_GuardMonitoring = FALSE Error = TRUE
C011	Discrepancy-time Error 1	DiscrepancyTime elapsed in state 8004. Ready = TRUE S_GuardMonitoring = FALSE Error = TRUE
C012	Discrepancy-time Error 2	DiscrepancyTime elapsed in state 8014. Ready = TRUE S_GuardMonitoring = FALSE Error = TRUE

Table 53: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_GuardMonitoring = FALSE Error = FALSE
8000	Normal	Safety guard closed and Safe state acknowledged. Ready = TRUE S_GuardMonitoring = TRUE Error = FALSE
8001	Init	Function block has been activated. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE
8002	Open Guard Request	Complete switching sequence required. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE

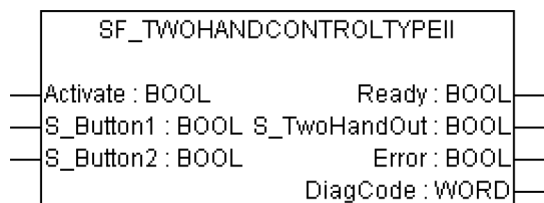
DiagCode	State Name	State Description and Output Setting
8003	Wait for Reset	Waiting for rising trigger at Reset. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE
8012	Guard Opened	Guard completely opened. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE
8004	Wait for GuardSwitch2	S_GuardSwitch1 has been switched to TRUE - waiting for S_GuardSwitch2; discrepancy timer started. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE
8014	Wait for GuardSwitch1	S_GuardSwitch2 has been switched to TRUE - waiting for S_GuardSwitch1; discrepancy timer started. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE
8005	Guard Closed	Guard closed. Waiting for Reset, if S_AutoReset = FALSE. Ready = TRUE S_GuardMonitoring = FALSE Error = FALSE

## 4.6.6.8 SF\_TwoHandControlTypell

Standards	Requirements
EN 574: 1996	Clause 4, Table 1, Type II. 5.1 Use of both hands / simultaneous actuation. 5.2 Relationship between output signal and input signals. 5.3 Completion of the output signal. 5.6 Reinitiation of the output signal. 6.3 Use of DIN EN 954-1 category 3 (Can only be realized by NO and NC switches together with antivalent processing)
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib



This function block provides the two-hand control functionality (☞ *EN 574, Section 4 Type II*).

This function block provides the two-hand control functionality according to EN 574, Section 4 Type II. If S\_Button1 and S\_Button2 are set to TRUE in a correct sequence, then the S\_TwoHandOut output will also be set to TRUE. The FB also controls the release of both buttons before setting the output S\_TwoHandOut again to TRUE.



Table 54: FB Name: SF\_TwoHandControlTypeII

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_Button1	BOOL	FALSE	Variable. Input of button 1 (for category 3 or 4: two antivalent contacts) FALSE: Button 1 released. TRUE: Button 1 actuated.
S_Button2	BOOL	FALSE	Variable. Input of button 2 (for category 3 or 4: two antivalent contacts) FALSE: Button 2 released. TRUE: Button 2 actuated.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_TwoHandOut	BOOL	FALSE	Safety related output signal. FALSE: No correct two hand operation. TRUE: S_Button1 and S_Button2 inputs are TRUE and no error occurred. Correct two hand operation.
Error	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	☞ Table 32 "General Output Parameters" on page 267

Notes: No Reset input or Error output is required, because no test can be performed on both switches.

### Typical Timing Diagram

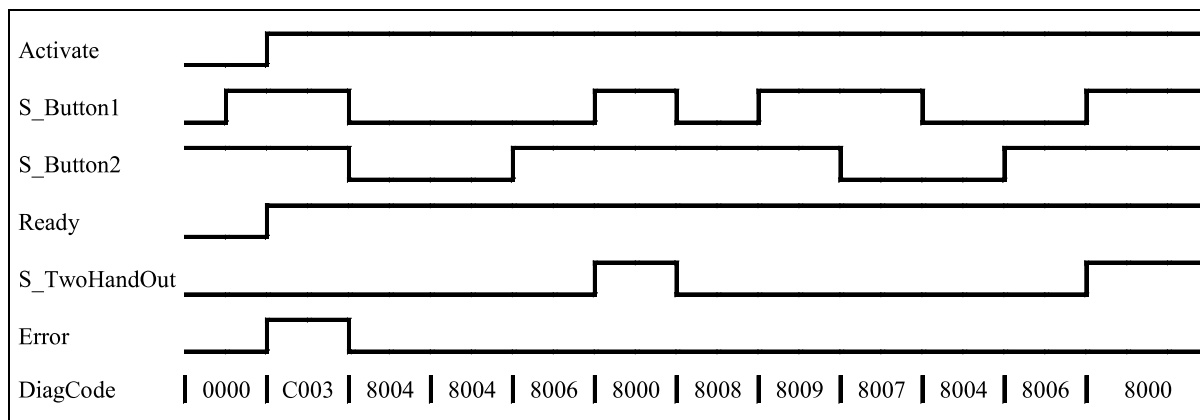


Fig. 110: Timing diagram for SF\_TwoHandControlTypell

After activation of the FB, any button set to TRUE is detected as an invalid input setting leading to an error.

### Error Behavior

In the event of an error, the S\_TwoHandOut output is set to FALSE and remains in this safe state.

The Error state is exited when both buttons are released (set to FALSE).

## Function Block-Specific Error and Status Codes

Table 55: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Error B1	S_Button1 was TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C002	Error B2	S_Button2 was TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C003	Error B1&B2	The signals at S_Button1 and S_Button2 were TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE

Table 56: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE Error = FALSE S_TwoHandOut = FALSE
8000	Buttons Actuated	Both buttons actuated correctly. The safety related output is enabled. Ready = TRUE Error = FALSE S_TwoHandOut = TRUE
8001	Init	Function block is active, but in the Init state. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8004	Buttons Released	No button is actuated. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE

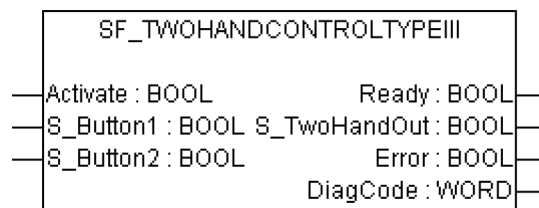
## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8005	Button 1 Actuated	Only Button 1 is actuated. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8006	Button 2 Actuated	Only Button 2 is actuated. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8007	Button 2 Released	The safety related output was enabled and is disabled again. FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output. In this state, S_Button1 is TRUE and S_Button2 is FALSE after disabling the safety related output. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8008	Button 1 Released	The safety related output was enabled and is disabled again. FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output. In this state, S_Button1 is FALSE and S_Button2 is TRUE after disabling the safety related output. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8009	Locked Off	The safety related output was enabled and is disabled again. FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output. In this state, S_Button1 is TRUE and S_Button2 is TRUE after disabling the safety related output. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8019	Locked On	Incorrect actuation of the buttons. Waiting for release of both buttons. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE

## 4.6.6.9 SF\_TwoHandControlTypeIII

Standards	Requirements
EN 574: 1996	<p>Clause 4, Table 1, Type III A; B; C.</p> <p>5.1 Use of both hands / simultaneous actuation.</p> <p>5.2 Relationship between output signal and input signals.</p> <p>5.3 Completion of the output signal.</p> <p>5.6 Reinitiation of the output signal.</p> <p>5.7 Synchronous actuation.</p> <p>6.2 Use of DIN EN 954-1 category 1.</p> <p>6.3 Use of DIN EN 954-1 category 3. (Can only be realized by NO and NC switches together with antivalent processing)</p> <p>6.4 Use of DIN EN 954-1 category 4. (Can only be realized by NO and NC switches together with antivalent processing)</p>
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



This function block provides the two-hand control functionality (see EN 574, Section 4 Type III. Fixed specified time difference is 500 ms).

This function block provides the two-hand control functionality according to EN 574, Section 4 Type III. If S\_Button1 and S\_Button2 are set to TRUE within 500 ms and in correct sequence, then the S\_TwoHandOut output is also set to TRUE. The FB also controls the release of both buttons before setting the output S\_TwoHandOut again to TRUE.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Table 57: FB Name: SF\_TwoHandControlTypeIII

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_Button1	BOOL	FALSE	Variable. Input of button 1 (for category 3 or 4: two antivalent contacts) FALSE: Button 1 released. TRUE: Button 1 actuated.
S_Button2	BOOL	FALSE	Variable. Input of button 2 (for category 3 or 4: two antivalent contacts) FALSE: Button 2 released. TRUE: Button 2 actuated.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
S_TwoHandOut	BOOL	FALSE	Safety related output signal. FALSE: No correct two hand operation. TRUE: S_Button1 and S_Button2 inputs changed from FALSE to TRUE within 500 ms and no error occurred. The two hand operation has been performed correctly.
Error	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	↗ Table 32 "General Output Parameters" on page 267

Notes: No Reset input or Error output is required, because no test can be performed on both switches.

## Typical Timing Diagram

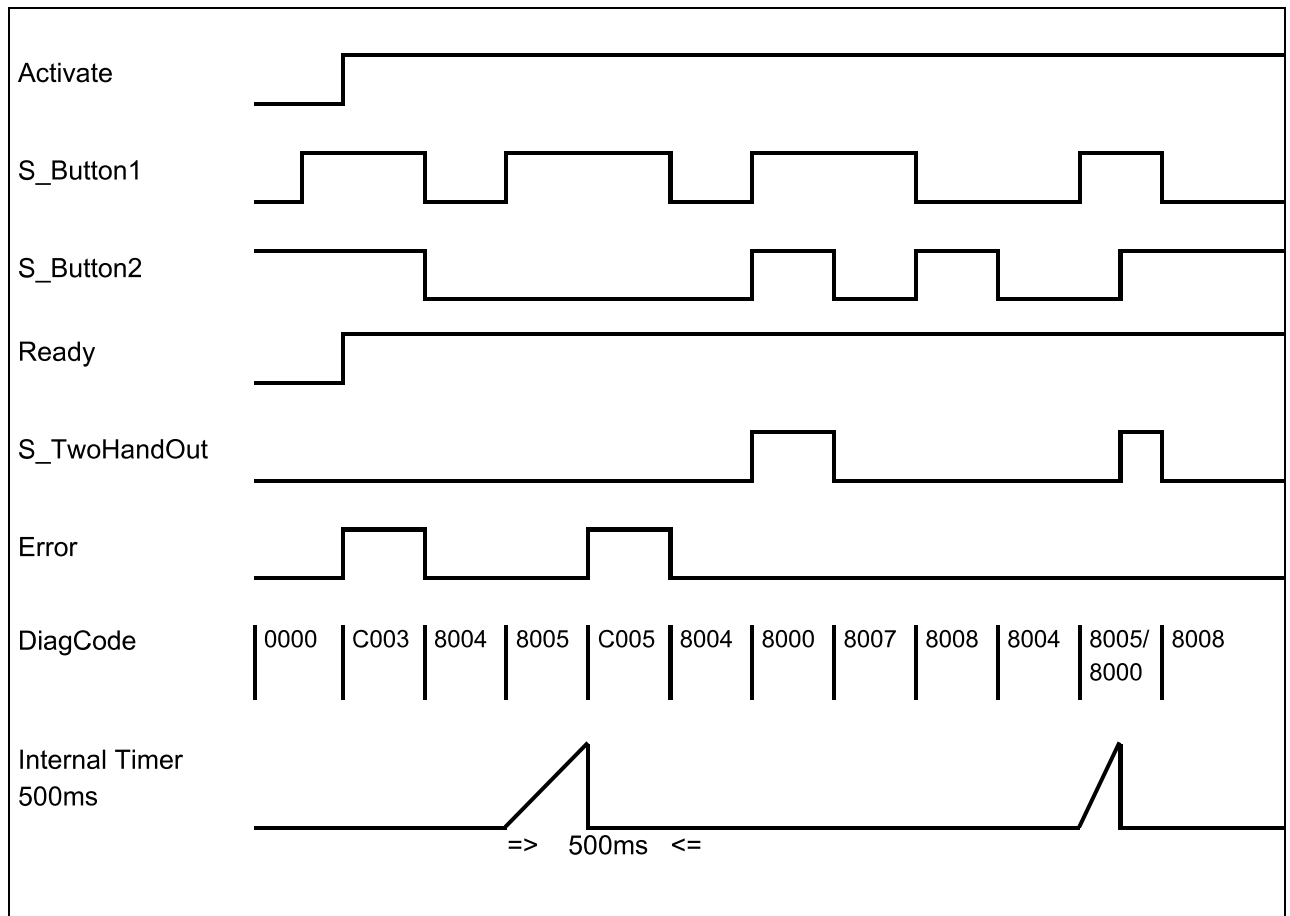


Fig. 111: Timing diagram for SF\_TwoHandControlTypeIII

After activation of the FB, any button set to TRUE is detected as an invalid input setting leading to an error. The FB detects when the divergence of the input signals exceeds 500 ms.

## Error Behavior

In the event of an error, the S\_TwoHandOut output is set to FALSE and remains in this safe state.

The Error state is exited when both buttons are released (set to FALSE).

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 58: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Error 1 B1	S_Button1 was TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C002	Error 1 B2	S_Button2 was TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C003	Error 1 B1&B2	The signals at S_Button1 and S_Button2 were TRUE on FB activation. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C004	Error 2 B1	S_Button1 was FALSE and S_Button 2 was TRUE after 500 ms in state 8005. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C005	Error 2 B2	S_Button1 was TRUE and S_Button 2 was FALSE after 500 ms in state 8005. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE
C006	Error 2 B1&B2	S_Button1 was TRUE and S_Button 2 was TRUE after 500 ms in state 8005 or 8006. This state is only possible when the states of the inputs (S_Button1 and S_Button2) change from divergent to convergent (both TRUE) simultaneously when the timer elapses (500 ms) at the same cycle. Ready = TRUE Error = TRUE S_TwoHandOut = FALSE



Table 59: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE Error = FALSE S_TwoHandOut = FALSE
8000	Buttons Actuated	Both buttons actuated correctly. The safety related output is enabled. Ready = TRUE Error = FALSE S_TwoHandOut = TRUE
8001	Init	Function block is active, but in the Init state. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8004	Buttons Released	No Button is actuated. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8005	Button 1 Actuated	Only Button 1 is actuated. Start monitoring timer. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8006	Button 2 Actuated	Only Button 2 is actuated. Start monitoring timer. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE
8007	Button 2 Released	The safety related output was enabled and is disabled again. FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output. In this state, S_Button1 is TRUE and S_Button2 is FALSE after disabling the safety related output. Ready = TRUE Error = FALSE S_TwoHandOut = FALSE

## Configuration and programming

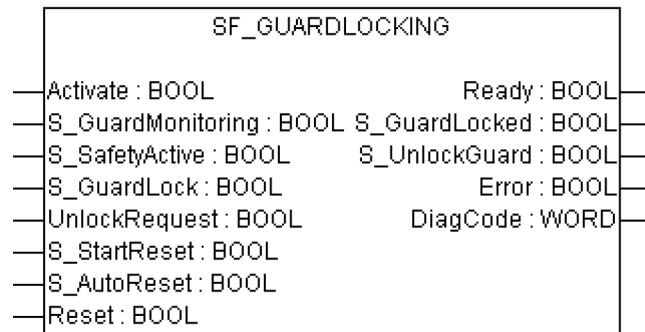
AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8008	Button 1 Released	<p>The safety related output was enabled and is disabled again.</p> <p>FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output.</p> <p>In this state, S_Button1 is FALSE and S_Button2 is TRUE after disabling the safety related output.</p> <p>Ready = TRUE</p> <p>Error = FALSE</p> <p>S_TwoHandOut = FALSE</p>
8009	Locked Off	<p>The safety related output was enabled and is disabled again.</p> <p>FALSE at both S_Button1 and S_Button2 was not achieved after disabling the safety related output.</p> <p>In this state, S_Button1 is TRUE and S_Button2 is TRUE after disabling the safety related output.</p> <p>Ready = TRUE</p> <p>Error = FALSE</p> <p>S_TwoHandOut = FALSE</p>
8019	Locked On	<p>Incorrect actuation of the buttons. Waiting for release of both buttons.</p> <p>Ready = TRUE</p> <p>Error = FALSE</p> <p>S_TwoHandOut = FALSE</p>

### 4.6.6.10 SF\_GuardLocking

Standards	Requirements
EN 953: 1997	<p>3.3.3 Control Guard</p> <ul style="list-style-type: none"> <li>■ The hazardous machine functions "covered" by the guard cannot operate until the guard is closed;</li> <li>■ Closing the guard initiates operation of the hazardous machine function(s).</li> </ul>
EN 1088: 1995	<p>3.3 Definition: Interlocking Guard With Guard Locking</p> <ul style="list-style-type: none"> <li>■ The hazardous machine functions "covered" by the guard cannot operate until the guard is closed and locked;</li> <li>■ The guard remains closed and locked until the risk of injury from the hazardous machine functions has passed;</li> <li>■ When the guard is closed and locked, the hazardous machine functions "covered" by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.</li> </ul> <p>4.2.2 – Interlocking Device With Guard Locking</p> <p>Conditional unlocking ("four-state interlocking"), see Fig. 3 b2)</p>

Standards	Requirements
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



This FB controls an entrance to a hazardous area via an interlocking guard with guard locking (“four state interlocking”).

The function controls the guard lock and monitors the position of the guard and the lock. This function block can be used with a mechanical locked switch.

The operator requests to get access to the hazardous area. The guard can only be unlocked when the hazardous area is in a safe state. The guard can be locked if the guard is closed. The machine can be started when the guard is closed and the guard is locked. An open guard or unlocked guard will be detected in the event of a safety-critical situation.

The S\_StartReset and S\_AutoReset inputs shall only be activated if it is ensured that no hazardous situation can occur when the PES is started.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

Table 60: FB Name: SF\_GuardLocking

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_GuardMonitoring	BOOL	FALSE	Variable. Monitors the guard interlocking. FALSE: Guard open. TRUE: Guard closed.
S_SafetyActive	BOOL	FALSE	Variable. Status of the hazardous area (EDM), e.g., based on speed monitoring or safe time off delay. FALSE: Machine in "non-safe" state. TRUE: Machine in safe state.
S_GuardLock	BOOL	FALSE	Variable. Status of the mechanical guard locking. FALSE: Guard is not locked. TRUE: Guard is locked.
UnlockRequest	BOOL	FALSE	Variable. Operator intervention – request to unlock the guard. FALSE: No request. TRUE: Request made.
S_StartReset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_AutoReset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266  Also used to request the guard to be locked again. The quality of the signal must conform to a manual reset device (EN954-1 Ch. 5.4)
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
S_GuardLocked	BOOL	FALSE	Interface to hazardous area which must be stopped. FALSE: No safe state. TRUE: Safe state.

Name	Data Type	Initial Value	Description, Parameter Values
S_UnlockGuard	BOOL	FALSE	Signal to unlock the guard. FALSE: Close guard. TRUE: Unlock guard.
Error	BOOL	FALSE	🔗 <i>Table 32 “General Output Parameters” on page 267</i>
DiagCode	WORD	16#0000	🔗 <i>Table 32 “General Output Parameters” on page 267</i>

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### Typical Timing Diagram

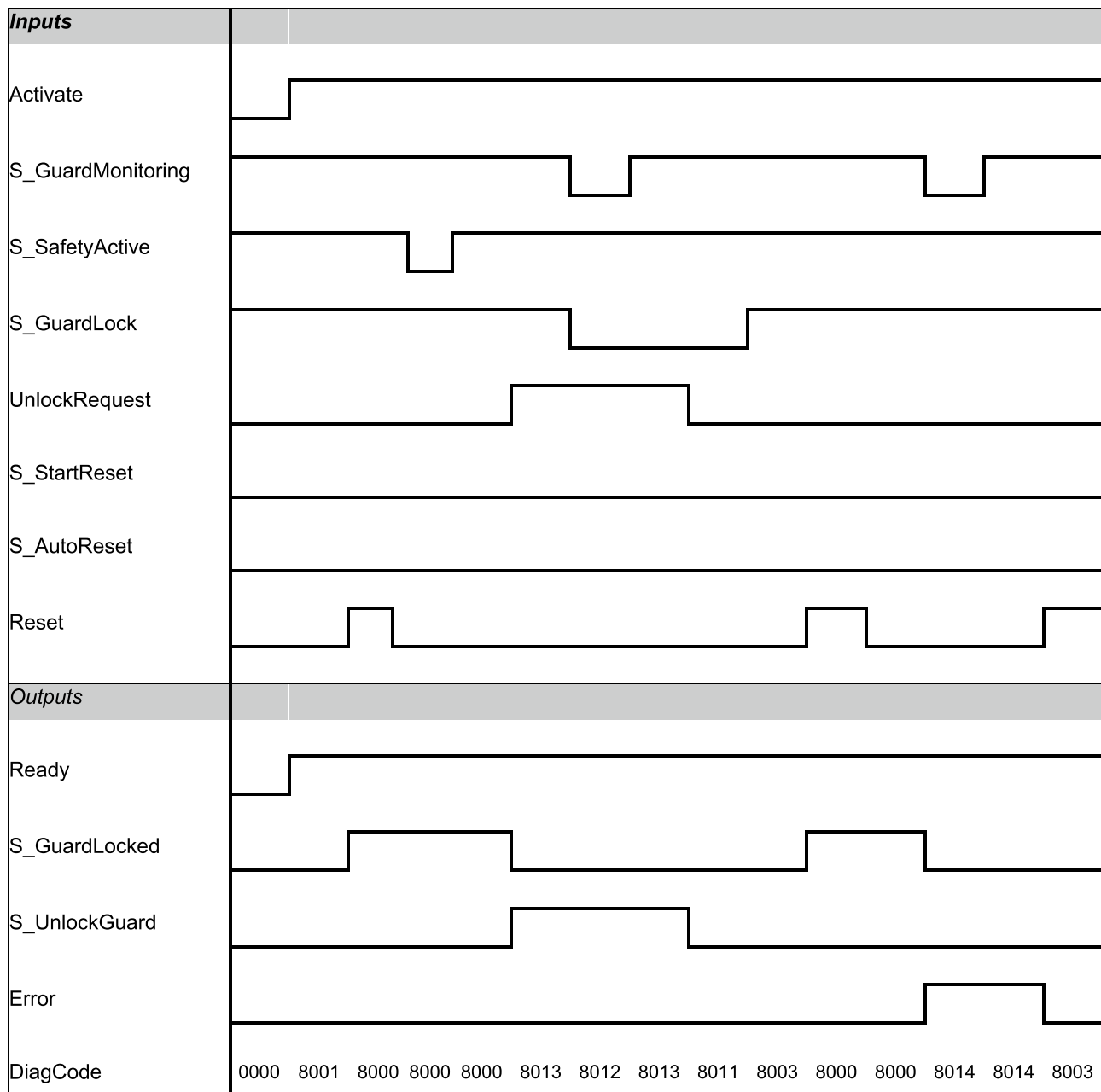


Fig. 112: Timing diagram for SF\_GuardLocking

Static signals are detected at Reset. Errors are detected at the Guard switches.

### Error Behavior

In the event of an error the S\_GuardLocked and S\_UnlockGuard outputs are set to FALSE, the DiagCode output indicates the relevant error code, and the Error output is set to TRUE.

An error must be acknowledged by a rising trigger at the Reset input.

## Function Block-Specific Error and Status Codes

Table 61: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error1	Static Reset detected in state 8001. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = TRUE
C002	Reset Error 2	Static Reset detected in state C004. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = TRUE
C003	Reset Error 3	Static Reset detected in state 8011. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = TRUE
C004	Safety Lost	Safety lost, guard opened or guard unlocked. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = TRUE

Table 62: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = FALSE
8000	Guard Closed and Locked	Guard is locked. Ready = TRUE S_GuardLocked = TRUE S_UnlockGuard = FALSE Error = FALSE

## Configuration and programming

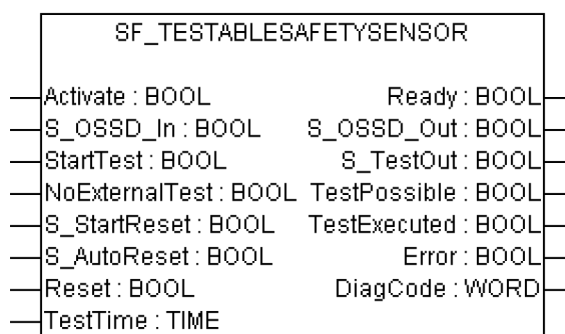
AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8001	Init	Function block was activated and initiated. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = FALSE
8003	Wait for Reset	Door is closed and locked, now waiting for operator reset Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = FALSE
8011	Wait for Operator	Waiting for operator to either unlock request or reset. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = FALSE
8012	Guard Open and Unlocked	Lock is released and guard is open. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = TRUE Error = FALSE
8013	Guard Closed but Unlocked	Lock is released but guard is closed. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = TRUE Error = FALSE
8014	Safety Return	Return of S_SafetyActive signal, now waiting for operator acknowledge. Ready = TRUE S_GuardLocked = FALSE S_UnlockGuard = FALSE Error = FALSE



## 4.6.6.11 SF\_TestableSafetySensor

Standards	Requirements
IEC 61496-1: 2004	<p>4.2.2.3 Particular requirements for a type 2 ESPE</p> <p>A type 2 ESPE shall have means of periodic test to reveal a failure to danger (for example, loss of detection capability, response time exceeding that specified).</p> <p>A single fault resulting in the loss of detection capability or the increase in response time beyond the specified time or preventing one or more of the OSSDs going to the OFF-state, shall result in a lock-out condition as a result of the next periodic test.</p> <p>Where the periodic test is intended to be initiated by an external (for example machine) safety-related control system, the ESPE shall be provided with suitable input facilities (for example terminals).</p> <p>The duration of the periodic test shall be such that the intended safety function is not impaired.</p> <p>NOTE If the type 2 ESPE is intended for use as a trip device (for example when used as a perimeter guard), and the duration of the periodic test is greater than 150 ms, it is possible for a person to pass through the detection zone without being detected. In this case, a restart interlock should be included.</p> <p>If the periodic test is automatically initiated, the correct functioning of the periodic test shall be monitored and a single fault in the parts implementing the monitoring function shall be detected. In the event of a fault, the OSSD(s) shall be signalled to go to the OFF-state.</p> <p>If one or more OSSDs do not go to the OFF-state, a lock-out condition shall be initiated.</p>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



This function block detects, for example, the loss of the sensing unit detection capability, the response time exceeding that specified, and static ON signal in single-channel sensor systems. It can be used for external testable safety sensors (ESPE: Electro-sensitive protective equipment, such as a light beam).

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Table 63: FB Name: SF\_TestableSafetySensor

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_OSSD_In	BOOL	FALSE	Variable. Status of sensor output, e.g., light curtain. FALSE: Safety sensor in test state or demand for safety-related response. TRUE: Sensor in the state for normal operating conditions.
StartTest	BOOL	FALSE	Variable. Input to start sensor test. Sets "S_TestOut" and starts the internal time monitoring function in the FB. FALSE: No test requested. TRUE: Test requested.
NoExternalTest	BOOL	FALSE	Constant. Indicates if external manual sensor test is supported. FALSE: The external manual sensor test is supported. Only after a complete manual sensor switching sequence, an automatic test is possible again after a faulty automatic sensor test. TRUE: The external manual sensor test is not supported. An automatic test is possible again without a manual sensor switching sequence after faulty automatic sensor test.
S_StartReset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_AutoReset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
TestTime	TIME	T#10ms	Constant. Range: 0 ... 150ms. Test time of safety sensor.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267

Name	Data Type	Initial Value	Description, Parameter Values
S_OSSD_Out	BOOL	FALSE	Safety related output indicating the status of the ESPE.  FALSE: The sensor has a safety-related action request or test error. TRUE: The sensor has no safety-related action request and no test error.
S_TestOut	BOOL	TRUE	Coupled with the test input of the sensor.  FALSE: Test request issued. TRUE: No test request.
TestPossible	BOOL	FALSE	Feedback signal to the process.  FALSE: An automatic sensor test is not possible. TRUE: An automatic sensor test is possible.
TestExecuted	BOOL	FALSE	A positive signal edge indicates the successful execution of the automatic sensor test.  FALSE: - An automatic sensor test was not executed yet. - An automatic sensor test is active. - An automatic sensor test was faulty. TRUE: A sensor test was executed successfully.
Error	BOOL	FALSE	🔗 <i>Table 32 "General Output Parameters" on page 267</i>
DiagCode	WORD	16#0000	🔗 <i>Table 32 "General Output Parameters" on page 267</i>

Notes: OSSD: Output Signal Switching Device.

## Typical Timing Diagram

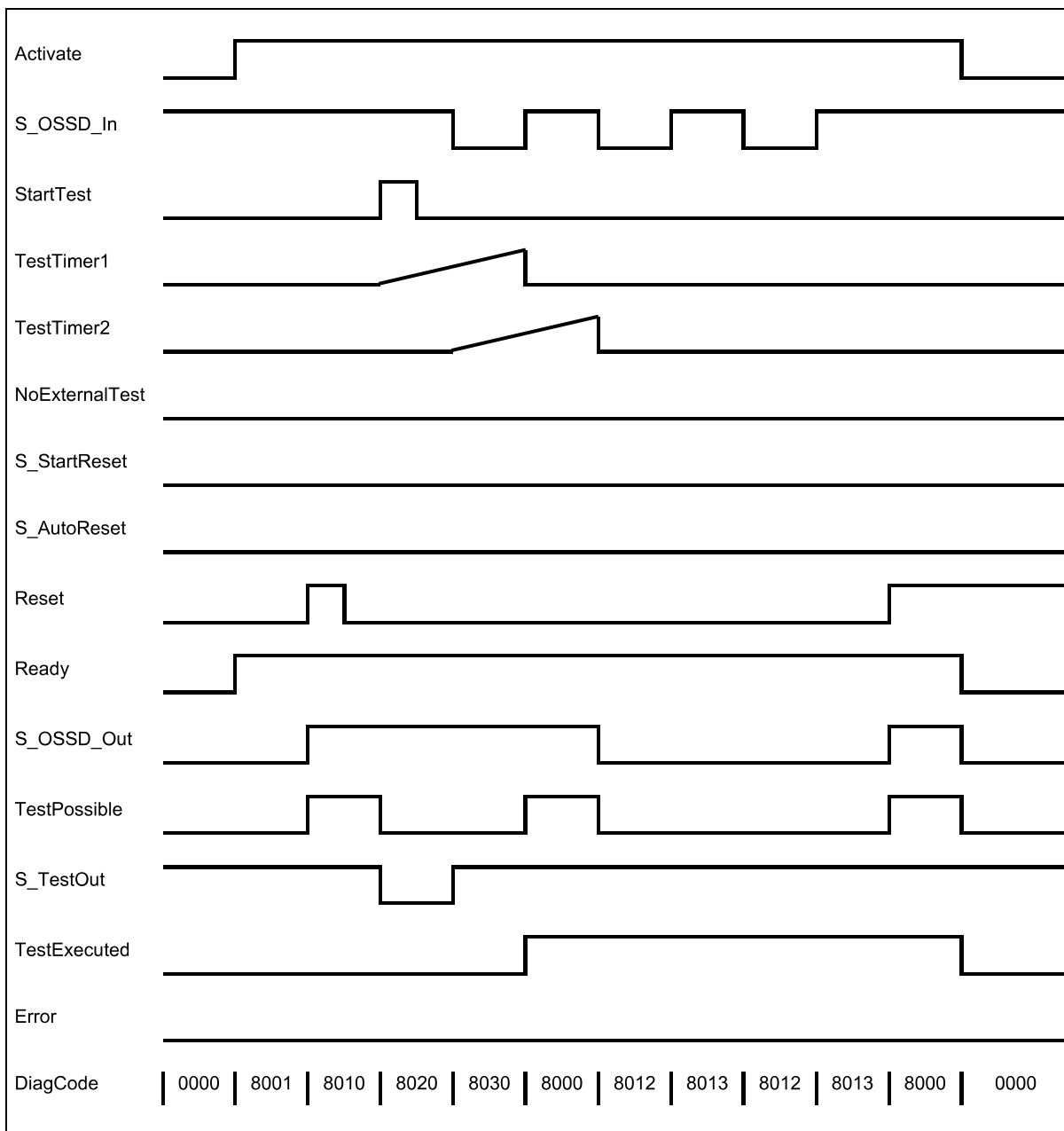


Fig. 113: Timing diagram for SF\_TestableSafetySensor

The following conditions force a transition to the Error state:

- Test time overrun without delayed sensor feedback.
- Test without sensor signal feedback.
- Invalid static reset signal in the process.
- Plausibility check of the monitoring time setting.

In the event of an error, the S\_OSSD\_Out output is set to FALSE and remains in this safe state.

Once the error has been removed and the sensor is on (S\_OSSD\_In = TRUE) – a reset removes the error state and sets the S\_OSSD\_Out output to TRUE.

If S\_AutoReset = FALSE, a rising trigger is required at Reset.

After transition of S\_OSSD\_In to TRUE, the optional startup inhibit can be reset by a rising edge at the Reset input.

After block activation, the optional startup inhibit can be reset by a rising edge at the Reset input.

## Function Block-Specific Error and Status Codes

Table 64: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C000	Parameter Error	Invalid value at the TestTime parameter. Values between 0 ms and 150 ms are possible. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C001	Reset Error 1	Static Reset condition detected after FB activation. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C002	Reset Error 2	Static Reset condition detected in state 8003. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C003	Reset Error 3	Static Reset condition detected in state C010. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE

## Configuration and programming

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DiagCode	State Name	State Description and Output Setting
C004	Reset Error 4	Static Reset condition detected in state C020. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C005	Reset Error 5	Static Reset condition detected in state 8006. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C006	Reset Error 6	Static Reset condition detected in state C000. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = FALSE Error = TRUE
C007	Reset Error 7	Static Reset condition detected in state 8013. Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = TRUE Error = TRUE

DiagCode	State Name	State Description and Output Setting
C010	Test Error 1	<p>Test time elapsed in state 8020.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = TRUE</p>
C020	Test Error 2	<p>Test time elapsed in state 8030.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = TRUE</p>

Table 65: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	<p>The function block is not active (initial state).</p> <p>Ready = FALSE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8001	Init	<p>An activation has been detected by the FB.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8002	ESPE Interrupted 1	<p>The FB has detected a safety demand.</p> <p>The switch has not been automatically tested yet.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8003	Wait for Reset 1	<p>Wait for rising trigger of Reset after state 8002.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8004	External Function Test	<p>The automatic sensor test was faulty.</p> <p>An external manual sensor test is necessary.</p> <p>The support for the necessary external manual sensor test has been activated at the FB (NoExternalTest = FALSE).</p> <p>A negative signal edge at the sensor is required.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>



DiagCode	State Name	State Description and Output Setting
8005	ESPE Interrupted External Test	<p>The automatic sensor test was faulty.</p> <p>An external manual sensor test is necessary.</p> <p>The support for the necessary external manual sensor test has been activated at the FB (NoExternalTest = FALSE).</p> <p>A TRUE signal at the sensor is required.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8006	End External Test	<p>The automatic sensor test was faulty.</p> <p>An external manual sensor test is necessary.</p> <p>The support for the necessary external manual sensor test has been activated at the FB (NoExternalTest = FALSE).</p> <p>The external manual test is complete.</p> <p>The FB detected a complete sensor switching cycle (external controlled).</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = FALSE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8010	ESPE Free No Test	<p>The FB has not detected a safety demand.</p> <p>The sensor has not been tested automatically.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = TRUE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = TRUE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8020	Test Request	<p>The automatic sensor test is active. Test Timer is started first time.</p> <p>The transmitter signal of the sensor is switched off by the FB.</p> <p>The signal of the receiver must follow the signal of the transmitter.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = TRUE</p> <p>S_TestOut = FALSE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8030	Test Active	<p>The automatic sensor test is active. Test Timer is started second time.</p> <p>The transmitter signal of the sensor is switched on by the FB.</p> <p>The signal of the receiver must follow the signal of the transmitter.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = TRUE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = FALSE</p> <p>TestExecuted = FALSE</p> <p>Error = FALSE</p>
8000	ESPE Free Test ok	<p>The FB has not detected a safety demand.</p> <p>The sensor was automatically tested.</p> <p>Ready = TRUE</p> <p>S_OSSD_Out = TRUE</p> <p>S_TestOut = TRUE</p> <p>TestPossible = TRUE</p> <p>TestExecuted = TRUE</p> <p>Error = FALSE</p>

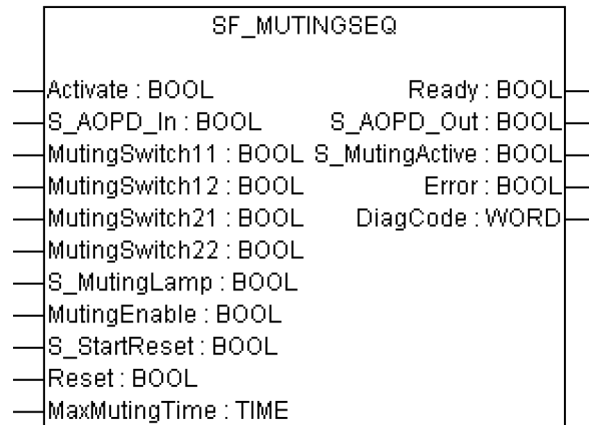
DiagCode	State Name	State Description and Output Setting
8012	ESPE Interrupted 2	<p>The FB has detected a safety demand. The switch was automatically tested.</p> <p>Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = TRUE Error = FALSE</p>
8013	Wait for Reset 2	<p>Wait for rising trigger of Reset after state 8012.</p> <p>Ready = TRUE S_OSSD_Out = FALSE S_TestOut = TRUE TestPossible = FALSE TestExecuted = TRUE Error = FALSE</p>

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### 4.6.6.12 SF\_MutingSeq

Standards	Requirements
IEC 61496-1:2004	<p>A.7 Muting</p> <p>A.7.1.2 There shall be at least two independent hard-wired muting signal sources to initiate the function. It shall not be possible to initiate muting when the OSSDs are already in the OFF-state.</p> <p>A.7.1.3 The mute function shall only be initiated by the correct sequence and/or timing of the mute signals. Should conflicting muting signals occur, the ESPE shall not allow a muted condition to occur.</p> <p>A.7.1.4 There shall be at least two independent hard-wired muting signal sources to stop the function. The muting function shall stop when the first of these muting signals changes state. The deactivation of the muting function shall not rely only on the clearance of the ESPE.</p> <p>A.7.1.5 The muting signals should be continuously present during muting. When the signals are not continuously present, an incorrect sequence and/or the expiration of a pre-set time limit shall cause either a lock-out condition or a restart interlock.</p> <p>A.7.4 Indication: A mute status signal or indicator shall be provided (in some applications, an indication signal of muting is necessary)</p>
CD IEC 62046/Ed. 1: 2005	<p>5.5.1: ... an indicator to show when the muting function is active can be necessary.</p> <p>The muting function shall be initiated and terminated automatically ... Incorrect signals, sequence, or timing of the muting sensors or signals shall not allow a mute condition. It shall not be possible to initiate the muting function when:</p> <ul style="list-style-type: none"> <li>■ the protective equipment OSSDs are in the OFF-state;</li> <li>■ the protective equipment is in the lock-out condition.</li> <li>■ initiation of the muting function by two or more independent muting sensors such that a single fault cannot cause a muted condition;</li> <li>■ termination of the muting function by two or more independent muting sensors such that deactivation of one sensor will terminate the muting function;</li> <li>■ use of timing and sequence control of the muting sensors to ensure correct muting operation;</li> </ul> <p>5.5.3: The following measures shall be considered: ...</p> <ul style="list-style-type: none"> <li>■ limiting muting to a fixed time that is only sufficient for the material to pass through the detection zone. When this time is exceeded, the muting function should be cancelled and all hazardous movements stopped;</li> </ul> <p>Annex F.3 Four beams – sequence control: (see also Fig. F.3.1 and table F.1)</p> <p>The initiation of the muting function depends on monitoring the correct sequence of activation of the muting sensors. For example, in the muted condition, if S2 [in this document MS_12] is deactivated before S3 [in this document MS_21] is activated, muting is terminated.</p> <p>Annex F.5: Methods to avoid manipulation of the muting function: ... use a muting enable command generated by the control system of the machine that will only enable the muting function when needed by the machine cycle.</p>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



Muting is the intended suppression of the safety function (e.g., light barriers). In this FB, sequential muting with four muting sensors is specified.

Muting is the intended suppression of the safety function. This is required, e.g., when transporting the material into the danger zone without causing the machine to stop. Muting is triggered by muting sensors. The use of two or four muting sensors and correct integration into the production sequence must ensure that no persons enter the danger zone while the light curtain is muted. Muting sensors can be proximity switches, photoelectric barriers, limit switches, etc. which do not have to be failsafe. Active muting mode must be indicated by indicator lights.

There are sequential and parallel muting procedures. In this FB, sequential muting with four muting sensors was used; an explanation for the forward direction of transportation is provided below. The FB can be used in both directions, forward and backward. The muting should be enabled with the MutingEnable signal by the process control to avoid manipulation. When the MutingEnable signal is not available, this input must be set to TRUE.

The FB input parameters include the signals of the four muting sensors (MutingSwitch11 ... MutingSwitch22) as well as the OSSD signal from the "active opto-electronic protective device", S\_AOPD\_In.

The S\_StartReset input shall only be activated if it is ensured that no hazardous situation can occur when the PÉS is started.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

Table 66: FB Name: SF\_MutingSeq

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	🔗 Table 31 "General Input Parameters" on page 266
S_AOPD_In	BOOL	FALSE	Variable. OSSD signal from AOPD. FALSE: Protection field interrupted. TRUE: Protection field not interrupted.
MutingSwitch11	BOOL	FALSE	Variable. Status of Muting sensor 11. FALSE: Muting sensor 11 not actuated. TRUE: Workpiece actuates muting sensor 11.
MutingSwitch12	BOOL	FALSE	Variable. Status of Muting sensor 12. FALSE: Muting sensor 12 not actuated. TRUE: Workpiece actuates muting sensor 12.
MutingSwitch21	BOOL	FALSE	Variable. Status of Muting sensor 21. FALSE: Muting sensor 21 not actuated. TRUE: Workpiece actuates muting sensor 21.
MutingSwitch22	BOOL	FALSE	Variable. Status of Muting sensor 22. FALSE: Muting sensor 22 not actuated. TRUE: Workpiece actuates muting sensor 22.
S_MutingLamp	BOOL	FALSE	Variable or constant. Indicates operation of the muting lamp. FALSE: Muting lamp failure. TRUE: Muting lamp no failure
MutingEnable	BOOL	FALSE	Variable or constant. Command by the control system that enables the start of the muting function when needed by the machine cycle. After the start of the muting function, this signal can be switched off. FALSE: Muting not enabled TRUE: Start of Muting function enabled
S_StartReset	BOOL	FALSE	🔗 Table 31 "General Input Parameters" on page 266

Name	Data Type	Initial Value	Description, Parameter Values
Reset	BOOL	FALSE	↗ <i>Table 31 "General Input Parameters" on page 266</i>
MaxMutingTime	TIME	T#0s	Constant 0 .. 10 min; Maximum time for complete muting sequence, timer started when first muting sensor is actuated.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↗ <i>Table 32 "General Output Parameters" on page 267</i>
S_AOPD_Out	BOOL	FALSE	Safety related output, indicates status of the muted guard.  FALSE: AOPD protection field interrupted and muting not active.  TRUE: AOPD protection field not interrupted or muting active.
S_MutingActive	BOOL	FALSE	Indicates status of Muting process.  FALSE: Muting not active.  TRUE: Muting active.
Error	BOOL	FALSE	↗ <i>Table 32 "General Output Parameters" on page 267</i>
DiagCode	WORD	16#0000	↗ <i>Table 32 "General Output Parameters" on page 267</i>

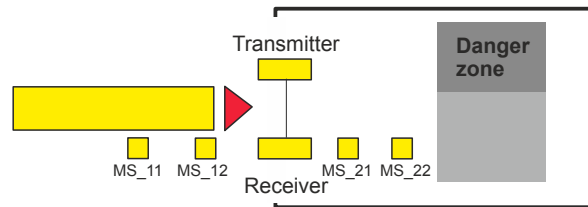
Notes: A short circuit in the muting sensor signals, or a functional application error to supply these signals, are not detected by this FB but interpreted as incorrect muting sequence. However, this condition should not lead to unwanted muting. The user should take care to include this in his risk analysis.

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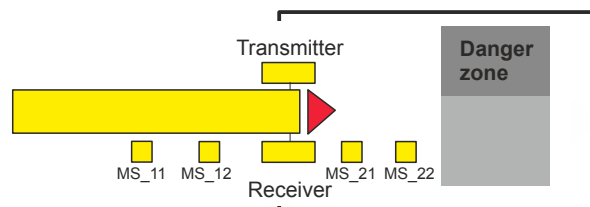
### Example for SF\_MutingSeq in forward direction with four sensors

1



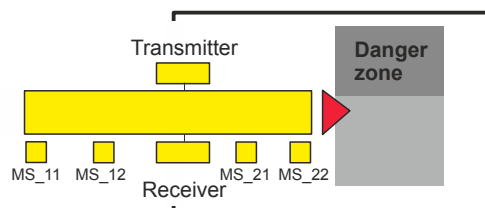
If muting sensor MutingSwitch12 (MS\_12) is activated by the product after MutingSwitch11 (MS\_11), the muting mode is activated.

2



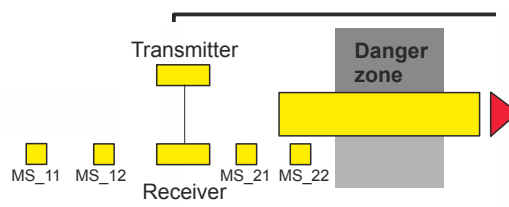
Muting mode remains active as long as MutingSwitch11 (MS\_11) and MutingSwitch12 (MS\_12) are activated by the product. The product may pass through the light curtain without causing a machine stop.

3



Before muting sensors MutingSwitch11 (MS\_11) and MutingSwitch12 (MS\_12) are disabled, muting sensors MutingSwitch21 (MS\_21) and MutingSwitch22 (MS\_22) must be activated. This ensures that muting mode remains active.

4



Muting mode is terminated if only muting sensor MutingSwitch22 (MS\_22) is activated by the product.

### Muting Conditions

#### Forward Direction

Muting condition 1 (to 8011) (MS\_11 is the first entry switch actuated). Start timer MaxMutingTime:



MutingEnable AND (R\_TRIG at MS\_11 AND NOT MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 2 (from 8011 to 8012) (MS\_12 is the second entry switch actuated):

MutingEnable AND (MS\_11 AND R\_TRIG at MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 3 (from 8012 to 8000) (MS\_21 is the first exit switch released). Stop timer MaxMutingTime:

NOT MS\_11 AND NOT MS\_12 AND F\_TRIG at MS\_21 AND MS\_22

### Backward Direction

Muting condition 11 (to 8122) (MS\_22 is the first entry switch actuated). Start timer MaxMutingTime:

MutingEnable AND (NOT MS\_11 AND NOT MS\_12 AND NOT MS\_21 AND R\_TRIG at MS\_22)

Muting condition 12 (from 8122 to 8112) (MS\_21 is the second entry switch actuated):

MutingEnable AND (NOT MS\_11 AND NOT MS\_12 AND R\_TRIG at MS\_21 AND MS\_22)

Muting condition 13 (MS\_12 is the first exit switch released). Stop timer MaxMutingTime:

MS\_11 AND F\_TRIG at MS\_12 AND NOT MS\_21 AND NOT MS\_22

### Specification of wrong MutingSequences:

In state 8000 - (NOT MutingEnable AND R\_TRIG at MS\_11) OR (NOT MutingEnable AND R\_TRIG at MS\_22) OR (MS\_12 OR MS\_21) OR (MS\_11 AND MS\_22)

In state 8011 - NOT MutingEnable OR NOT MS\_11 OR MS\_21 OR MS\_22

In state 8012 - R\_TRIG at MS\_11 OR R\_TRIG at MS\_12 OR F\_TRIG at MS\_22

In state 8122 - NOT MutingEnable OR MS\_11 OR MS\_12 OR NOT MS\_22

In state 8112 - F\_TRIG at MS\_11 OR R\_TRIG at MS\_21 OR R\_TRIG at MS\_22

### Typical Timing Diagram

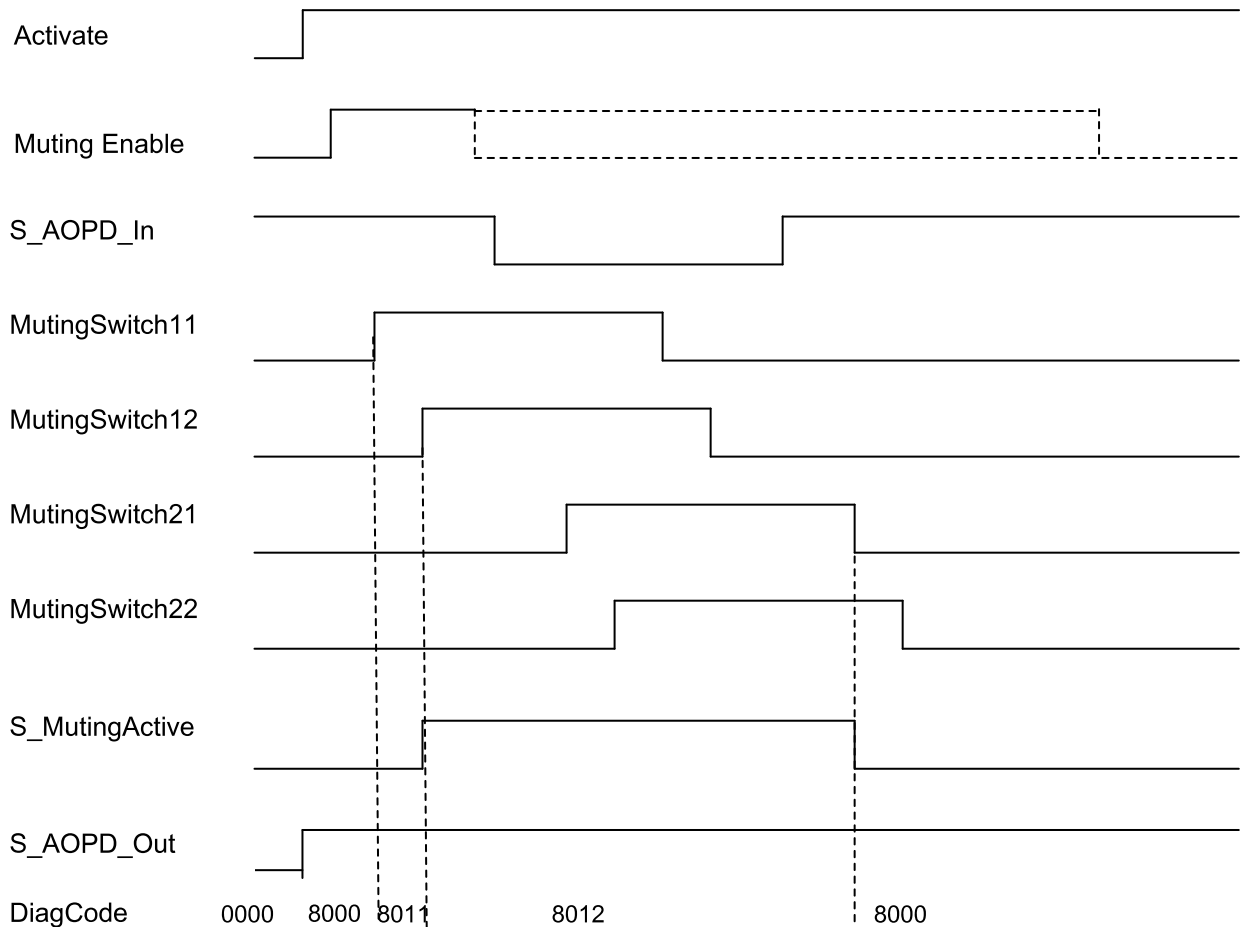


Fig. 114: Timing diagram for SF\_MutingSeq with S\_StartReset = TRUE

The FB detects the following error conditions:

- Muting sensors MutingSwitch11, MutingSwitch12, MutingSwitch21, and MutingSwitch22 are activated in the wrong order.
- Muting sequence starts without being enabled by MutingEnable
- A faulty muting lamp is indicated by S\_MutingLamp = FALSE.
- A static Reset condition.
- MaxMutingTime has been set to a value less than T#0s or greater than T#10min.
- The muting function (S\_MutingActive = TRUE) exceeds the maximum muting time MaxMutingTime.

### Error Behavior

In the event of an error, the S\_AOPD\_Out and S\_MutingActive outputs are set to FALSE. The DiagCode output indicates the relevant error code and the Error output is set to TRUE.

A restart is inhibited until the error conditions are cleared and the Safe state is acknowledged with Reset by the operator.

## Function Block-Specific Error and Status Codes

Table 67: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset condition detected after FB activation. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C002	Reset Error 2	Static Reset condition detected in state 8003. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C003	Error Muting lamp	Error detected in muting lamp. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
CYx4	Error Muting sequence	Error detected in muting sequence in states 8000, 8011, 8012, 8112 or 8122. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE  Y = Status in the sequence (2 states for forward and 2 states for backward direction). C0x4 = Error occurred in state 8000 C1x4 = Error occurred in state Forward 8011 C2x4 = Error occurred in state Forward 8012 C3x4 = Error occurred in state Backward 8122 C4x4 = Error occurred in state Backward 8112 CFx4 = Muting Enable missing  x = Status of the sensors when error occurred (4 bits: LSB = MS_11; MS_12; MS_21; MSB = MS_22).

## Configuration and programming

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DiagCode	State Name	State Description and Output Setting
C005	Parameter Error	MaxMutingTime value out of range. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C006	Error Timer MaxMuting	Timing error: Active muting time (when S_MutingActive = TRUE) exceeds MaxMutingTime. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE

Table 68: FB-specific status codes (no error):

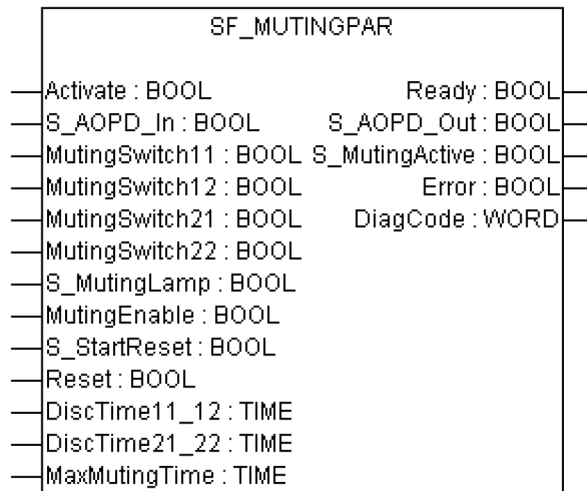
DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8000	AOPD Free	Muting not active and no safety demand from AOPD. Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8001	Init	Function block has been activated. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8002	Safety Demand AOPD	Safety demand detected by AOPD, muting not active. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE

DiagCode	State Name	State Description and Output Setting
8003	Wait for Reset	Safety demand or errors have been detected and are now cleared. Operator acknowledgment by Reset required. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8005	Safe	Safety function activated. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8011	Muting Forward Start	Muting forward, sequence is in starting phase and no safety demand. Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8012	Muting Forward Active	Muting forward, sequence is active. Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE
8112	Muting Backward Active	Muting backward, sequence is active. Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE
8122	Muting Backward Start	Muting backward, sequence is in starting phase and no safety demand. Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE

### 4.6.6.13 SF\_MutingPar

Standards	Requirements
IEC 61496-1:2004	<p>A.7 Muting</p> <p>A.7.1.2 There shall be at least two independent hard-wired muting signal sources to initiate the function. It shall not be possible to initiate muting when the OSSDs are already in the OFF-state.</p> <p>A.7.1.3 The mute function shall only be initiated by the correct sequence and/or timing of the mute signals. Should conflicting muting signals occur, the ESPE shall not allow a muted condition to occur.</p> <p>A.7.1.4 There shall be at least two independent hard-wired muting signal sources to stop the function. The muting function shall stop when the first of these muting signals changes state. The deactivation of the muting function shall not rely only on the clearance of the ESPE.</p> <p>A.7.1.5 The muting signals should be continuously present during muting. When the signals are not continuously present, an incorrect sequence and/or the expiration of a pre-set time limit shall cause either a lock-out condition or a restart interlock.</p> <p>A.7.4 Indication: A mute status signal or indicator shall be provided (in some applications, an indication signal of muting is necessary</p>
CD IEC 62046/Ed. 1: 2005	<p>5.5.1: ... an indicator to show when the muting function is active can be necessary.</p> <p>The muting function shall be initiated and terminated automatically ... Incorrect signals, sequence, or timing of the muting sensors or signals shall not allow a mute condition. It shall not be possible to initiate the muting function when:</p> <ul style="list-style-type: none"> <li>■ the protective equipment OSSDs are in the OFF-state;</li> <li>■ the protective equipment is in the lock-out condition.</li> <li>■ initiation of the muting function by two or more independent muting sensors such that a single fault cannot cause a muted condition;</li> <li>■ termination of the muting function by two or more independent muting sensors such that deactivation of one sensor will terminate the muting function;</li> <li>■ use of timing and sequence control of the muting sensors to ensure correct muting operation;</li> </ul> <p>5.5.3: The following measures shall be considered: ...</p> <ul style="list-style-type: none"> <li>■ limiting muting to a fixed time that is only sufficient for the material to pass through the detection zone. When this time is exceeded, the muting function should be cancelled and all hazardous movements stopped;</li> </ul> <p>Annex F.2 Four beams – timing control: (see also Fig. F.2.4): The monitoring of the muting function is based on time limitation between the actuation of the sensors S1 [in this document MS_11] and S2 [in this document MS_12] and between the actuation of sensors S3 [in this document MS_21] and S4 [in this document MS_22]. A maximum time limit of 4 sec. is recommended. The muting function is initiated by the two sensors S1, S2 and maintained by the two sensors S3, S4; this means that for a certain time all the four sensors are activated. The muting function is terminated when S3 or S4 is deactivated.</p> <p>Annex F.5: Methods to avoid manipulation of the muting function: ... use a muting enable command generated by the control system of the machine that will only enable the muting function when needed by the machine cycle.</p>

Standards	Requirements
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



Muting is the intended suppression of the safety function. In this FB, parallel muting with four muting sensors is specified.

Muting is the intended suppression of the safety function. This is required, e.g., when transporting the material into the danger zone without causing the machine to stop. Muting is triggered by muting sensors. The use of two or four muting sensors and correct integration into the production sequence must ensure that no persons enter the danger zone while the light curtain is muted. Muting sensors can be proximity switches, photoelectric barriers, limit switches, etc. which do not have to be failsafe. Active muting mode must be indicated by indicator lights.

There are sequential and parallel muting procedures. In this FB, parallel muting with four muting sensors was used; an explanation is provided below. The FB can be used in both directions, forward and backward. The muting should be enabled with the MutingEnable signal by the process control to avoid manipulation.

The FB input parameters include the signals of the four muting sensors (MutingSwitch11 .. MutingSwitch22), the OSSD signal from the "active opto-electronic protective device", S\_AOPD\_In, as well as three parameterizable times (DiscTime11\_12, DiscTime21\_22 and MaxMutingTime).

The S\_StartReset input shall only be activated if it is ensured that no hazardous situation can occur when the PÉS is started.

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Table 69: FB Name: SF\_MutingPar

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	🔗 Table 31 "General Input Parameters" on page 266
S_AOPD_In	BOOL	FALSE	Variable. OSSD signal from AOPD. FALSE: Protection field interrupted. TRUE: Protection field not interrupted.
MutingSwitch11	BOOL	FALSE	Variable. Status of Muting sensor 11. FALSE: Muting sensor 11 not actuated. TRUE: Workpiece actuates muting sensor 11.
MutingSwitch12	BOOL	FALSE	Variable. Status of Muting sensor 12. FALSE: Muting sensor 12 not actuated. TRUE: Workpiece actuates muting sensor 12.
MutingSwitch21	BOOL	FALSE	Variable. Status of Muting sensor 21. FALSE: Muting sensor 21 not actuated. TRUE: Workpiece actuates muting sensor 21.
MutingSwitch22	BOOL	FALSE	Variable. Status of Muting sensor 22. FALSE: Muting sensor 22 not actuated. TRUE: Workpiece actuates muting sensor 22.
S_MutingLamp	BOOL	FALSE	Variable or constant. Indicates operation of the muting lamp. FALSE: Muting lamp failure. TRUE: Muting lamp no failure.
MutingEnable	BOOL	FALSE	Variable or constant. Command by the control system that enables the start of the muting function when needed by the machine cycle. After the start of the muting function, this signal can be switched off. FALSE: Muting not enabled TRUE: Start of Muting function enabled
S_StartReset	BOOL	FALSE	🔗 Table 31 "General Input Parameters" on page 266



Name	Data Type	Initial Value	Description, Parameter Values
Reset	BOOL	FALSE	🔗 <i>Table 31 "General Input Parameters" on page 266</i>
DiscTime11_12	TIME	T#0s	Constant 0..4 s; Maximum discrepancy time for MutingSwitch11 and MutingSwitch12.
DiscTime21_22	TIME	T#0s	Constant 0..4 s; Maximum discrepancy time for MutingSwitch21 and MutingSwitch22.
MaxMutingTime	TIME	T#0s	Constant 0..10 min; Maximum time for complete muting sequence, timer started when first muting sensor is actuated.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	🔗 <i>Table 32 "General Output Parameters" on page 267</i>
S_AOPD_Out	BOOL	FALSE	Safety related output, indicates status of the muted guard.  FALSE: AOPD protection field interrupted and muting not active.  TRUE: AOPD protection field not interrupted or muting active.
S_MutingActive	BOOL	FALSE	Indicates status of Muting process.  FALSE: Muting not active.  TRUE: Muting active.
Error	BOOL	FALSE	🔗 <i>Table 32 "General Output Parameters" on page 267</i>
DiagCode	WORD	16#0000	🔗 <i>Table 32 "General Output Parameters" on page 267</i>

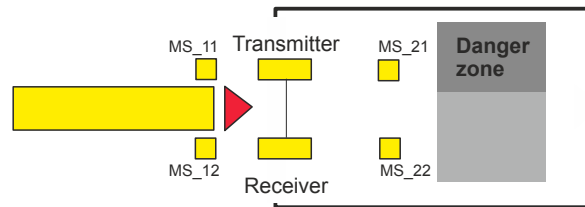
Notes: A short circuit in the muting sensor signals, or a functional application error to supply these signals, are not detected by this FB. However, this condition should not lead to unwanted muting. The user should take care to include this in his risk analysis.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

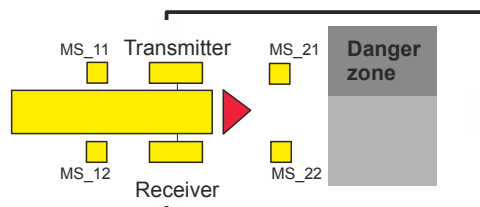
### Example for SF\_MutingPar in forward direction with four sensors

1



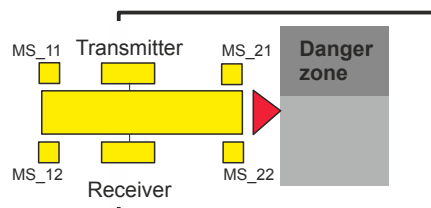
If the muting sensors MutingSwitch11 (MS\_11) and MutingSwitch12 (MS\_12) are activated by the product within the time DiscTime11\_12, muting mode is activated (S\_MutingActive = TRUE).

2



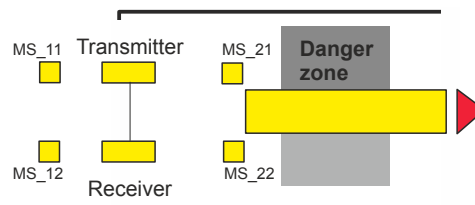
Muting mode remains active as long as MutingSwitch11 (MS\_11) and MutingSwitch12 (MS\_12) are activated by the product. The product may pass through the light curtain without causing a machine stop.

3



Before muting sensors MutingSwitch11 (MS\_11) and MutingSwitch12 (MS\_12) are disabled, muting sensors MutingSwitch21 (MS\_21) and MutingSwitch22 (MS\_22) must be activated. This ensures that muting mode remains active. The time discrepancy between switching of MutingSwitch21 and MutingSwitch22 is monitored by the time DiscTime21\_22.

4



Muting mode is terminated if either muting sensor MutingSwitch21 (MS\_21) or MutingSwitch22 (MS\_22) is disabled by the product. The maximum time for muting mode to be active is the MaxMutingTime.

### Muting Conditions

#### Forward Direction

Muting condition 1 (to 8011) (MS\_11 is the first entry switch actuated). Start timers MaxMutingTime and DiscTime11\_12:

MutingEnable AND (R\_TRIG at MS\_11 AND NOT MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 1 (to 8311) (MS\_12 is the first entry switch actuated). Start timers MaxMutingTime and DiscTime11\_12:

MutingEnable AND (NOT MS\_11 AND R\_TRIG at MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 2 (from 8011) (MS\_12 is the second entry switch actuated). Stop timer DiscTime11\_12:

MutingEnable AND (MS\_11 AND R\_TRIG at MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 2 (from 8311) (MS\_11 is the second entry switch actuated). Stop timer DiscTime11\_12:

MutingEnable AND (R\_TRIG at MS\_11 AND MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 3 (both entry switches actuated in same cycle). Start timer MaxMutingTime:

MutingEnable AND (R\_TRIG at MS\_11 AND R\_TRIG at MS\_12 AND NOT MS\_21 AND NOT MS\_22)

Muting condition 4 (all switches actuated): MS\_11 AND MS\_12 AND MS\_21 AND MS\_22

Muting condition 24 (to 8014) (MS\_21 is the first exit switch actuated). Start timer DiscTime21\_22:

MS\_11 AND MS\_12 AND R\_TRIG at MS\_21 AND NOT MS\_22

Muting condition 24 (to 8314) (MS\_22 is the first exit switch actuated). Start timer DiscTime21\_22:

MS\_11 AND MS\_12 AND NOT MS\_21 AND R\_TRIG at MS\_22

Muting condition 25 (from 8014) (MS\_22 is the second exit switch actuated). Stop timer DiscTime21\_22:

MS\_11 AND MS\_12 AND MS\_21 AND R\_TRIG at MS\_22

Muting condition 25 (from 8314) (MS\_21 is the second exit switch actuated). Stop timer DiscTime21\_22:

MS\_11 AND MS\_12 AND R\_TRIG at MS\_21 AND MS\_22

Muting condition 5 (one of the exit switches released). Stop timer MaxMutingTime:

NOT MS\_11 AND NOT MS\_12 AND (F\_TRIG at MS\_21 OR F\_TRIG at MS\_22)

### Backward Direction

Muting condition 11 (to 8122) (MS\_21 is the first entry switch actuated). Start timers MaxMutingTime and DiscTime21\_22:

MutingEnable AND (NOT MS\_22 AND R\_TRIG at MS\_21 AND NOT MS\_11 AND NOT MS\_12)

Muting condition 11 (to 8422) (MS\_22 is the first entry switch actuated). Start timers MaxMutingTime and DiscTime21\_22:

MutingEnable AND (R\_TRIG at MS\_22 AND NOT MS\_21 AND NOT MS\_11 AND NOT MS\_12)

Muting condition 12 (from 8122) (MS\_22 is the second entry switch actuated). Stop timer DiscTime21\_22:

MutingEnable AND (MS\_21 AND R\_TRIG at MS\_22 AND NOT MS\_11 AND NOT MS\_12)

Muting condition 12 (from 8422) (MS\_21 is the second entry switch actuated). Stop timer DiscTime21\_22:

MutingEnable AND (R\_TRIG at MS\_21 AND MS\_22 AND NOT MS\_11 AND NOT MS\_12)

Muting condition 13 (both entry switches actuated in same cycle). Start timer MaxMutingTime:

MutingEnable AND (R\_TRIG at MS\_21 AND R\_TRIG at MS\_22 AND NOT MS\_11 AND NOT MS\_12)

Muting condition 14 (all switches actuated): MS\_11 AND MS\_12 AND MS\_21 AND MS\_22

Muting condition 44 (to 8114) (MS\_11 is the first exit switch actuated). Start timer DiscTime11\_12:

MS\_21 AND MS\_22 AND R\_TRIG at MS\_11 AND NOT MS\_12

## Configuration and programming

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Muting condition 44 (to 8414) (MS\_12 is the first exit switch actuated). Start timer DiscTime11\_12:

MS\_21 AND MS\_22 AND NOT MS\_11 AND R\_TRIG at MS\_12

Muting condition 45 (from 8114) (MS\_12 is the second exit switch actuated). Stop timer DiscTime11\_12:

MS\_21 AND MS\_22 AND MS\_11 AND R\_TRIG at MS\_12

Muting condition 45 (from 8414) (MS\_11 is the second exit switch actuated). Stop timer DiscTime11\_12:

MS\_21 AND MS\_22 AND R\_TRIG at MS\_11 AND MS\_12

Muting condition 15 (one of the exit switches released). Stop timer MaxMutingTime:

NOT MS\_21 AND NOT MS\_22 AND (F\_TRIG at MS\_11 OR F\_TRIG at MS\_12)

### Wrong Muting Sequences:

State 8000 - (MutingEnable = FALSE when muting sequence starts) OR

((MS\_11 OR MS\_12) AND (MS\_21 OR MS\_22)) OR

(R\_TRIG at MS\_11 AND MS\_12 AND NOT R\_TRIG at MS\_12) OR

(R\_TRIG at MS\_12 AND MS\_11 AND NOT R\_TRIG at MS\_11) OR

(R\_TRIG at MS\_21 AND MS\_22 AND NOT R\_TRIG at MS\_22) OR

(R\_TRIG at MS\_22 AND MS\_21 AND NOT R\_TRIG at MS\_21) OR

((MS\_11 AND NOT R\_TRIG at MS\_11) AND (MS\_12 AND NOT R\_TRIG at MS\_12)) OR

((MS\_21 AND NOT R\_TRIG at MS\_21) AND (MS\_22 AND NOT R\_TRIG at MS\_22))

State 8011 - NOT MutingEnable OR NOT MS\_11 OR MS\_21 OR MS\_22

State 8311 - NOT MutingEnable OR NOT MS\_12 OR MS\_21 OR MS\_22

State 8012 - NOT MS\_11 OR NOT MS\_12

State 8021 - R\_TRIG at MS\_11 OR R\_TRIG at MS\_12 OR R\_TRIG at MS\_21 OR R\_TRIG at MS\_22

State 8014 - NOT MS\_11 OR NOT MS\_12 OR NOT MS\_21

State 8314 - NOT MS\_11 OR NOT MS\_12 OR NOT MS\_22

State 8122 - NOT MutingEnable OR MS\_11 OR MS\_12 OR NOT MS\_21

State 8422 - NOT MutingEnable OR MS\_11 OR MS\_12 OR NOT MS\_22

State 8121 - NOT MS\_21 OR NOT MS\_22

State 8112 - R\_TRIG at MS\_11 OR R\_TRIG at MS\_12 OR R\_TRIG at MS\_21 OR R\_TRIG at MS\_22

State 8114 - NOT MS\_21 OR NOT MS\_22 OR NOT MS\_11

State 8414 - NOT MS\_21 OR NOT MS\_22 OR NOT MS\_12

## Typical Timing Diagram

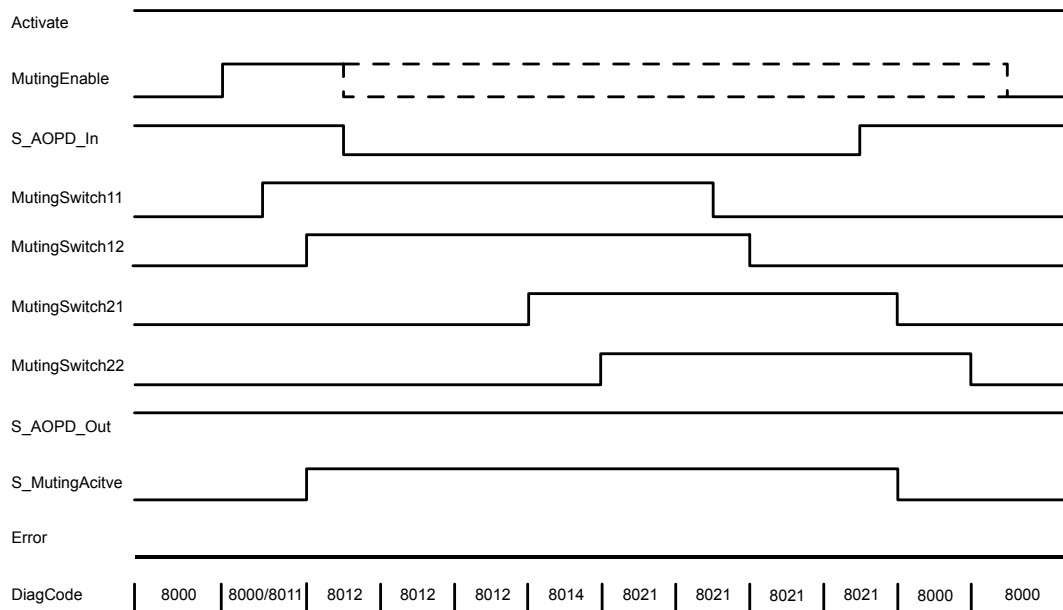


Fig. 115: Timing diagram for SF\_MutingPar

The FB detects the following error conditions:

- DiscTime11\_12 and DiscTime21\_22 have been set to values less than T#0s or greater than T#4s.
- MaxMutingTime has been set to a value less than T#0s or greater than T#10min.
- The discrepancy time for the MutingSwitch11/MutingSwitch12 or MutingSwitch21/MutingSwitch22 sensor pairs has been exceeded.
- The muting function (S\_MutingActive = TRUE) exceeds the maximum muting time MaxMutingTime.
- Muting sensors MutingSwitch11, MutingSwitch12, MutingSwitch21, and MutingSwitch22 are activated in the wrong order.
- Muting sequence starts without being enabled by MutingEnable
- A faulty muting lamp is indicated by S\_MutingLamp = FALSE.
- A static Reset condition is detected in state 8001 and 8003.

## Error Behavior

In the event of an error, the S\_AOPD\_Out and S\_MutingActive outputs are set to FALSE. The DiagCode output indicates the relevant error code and the Error output is set to TRUE.

A restart is inhibited until the error conditions are cleared and the Safe state is acknowledged with Reset by the operator.

## Configuration and programming

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### Function Block-Specific Error and Status Codes

Table 70: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset condition detected after FB activation in state 8001. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C002	Reset Error 2	Static Reset condition detected in state 8003. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C003	Error Muting Lamp	Error detected in muting lamp. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE

DiagCode	State Name	State Description and Output Setting
CYx4	Error Muting sequence	<p>Error detected in muting sequence state 8000, 8011, 8311, 8012, 8021, 8014, 8314, 8122, 8422, 8121, 8112, 8114 or 8414.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = FALSE</p> <p>S_MutingActive = FALSE</p> <p>Error = TRUE</p> <p>Y = Status in the sequence (6 states for forward and 6 states for backward direction).</p> <p>C0x4 = Error occurred in state 8000</p> <p>C1x4 = Error occurred in state Forward 8011</p> <p>C2x4 = Error occurred in state Forward 8311</p> <p>C3x4 = Error occurred in state Forward 8012</p> <p>C4x4 = Error occurred in state Forward 8014</p> <p>C5x4 = Error occurred in state Forward 8314</p> <p>C6x4 = Error occurred in state Forward 8021</p> <p>C7x4 = Error occurred in state Backward 8122</p> <p>C8x4 = Error occurred in state Backward 8422</p> <p>C9x4 = Error occurred in state Backward 8121</p> <p>Cx4 = Error occurred in state Backward 8114</p> <p>Cx4 = Error occurred in state Backward 8414</p> <p>Cx4 = Error occurred in state Backward 8112</p> <p>...</p> <p>Cx4 = Muting Enable missing</p> <p>x = Status of the sensors when error occurred (4 bits: LSB = MS_11; MS_12; MS_21; MSB = MS_22).</p>
C005	Parameter Error	<p>DiscTime11_12, DiscTime21_22 or MaxMutingTime value out of range.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = FALSE</p> <p>S_MutingActive = FALSE</p> <p>Error = TRUE</p>
C006	Error Timer MaxMuting	<p>Timing error: Active muting time (when S_MutingActive = TRUE) exceeds MaxMutingTime.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = FALSE</p> <p>S_MutingActive = FALSE</p> <p>Error = TRUE</p>

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DiagCode	State Name	State Description and Output Setting
C007	Error Timer MS11_12	Timing error: Discrepancy time for switching MutingSwitch11 and MutingSwitch12 > DiscTime11_12.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C008	Error Timer MS21_22	Timing error: Discrepancy time for switching MutingSwitch21 and MutingSwitch22 > DiscTime21_22.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE

Table 71: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state).  Ready = FALSE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8000	AOPD Free	Muting not active and no safety demand from AOPD. If timers from subsequent muting are still running, they are stopped.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8001	Init	Function block has been activated.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8002	Safety Demand AOPD	Safety demand detected by AOPD, muting not active.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE



DiagCode	State Name	State Description and Output Setting
8003	Wait for Reset	<p>Safety demand or errors have been detected and are now cleared. Operator acknowledgment by Reset required.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = FALSE</p> <p>S_MutingActive = FALSE</p> <p>Error = FALSE</p>
8005	Safe	<p>Safety function activated.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = FALSE</p> <p>S_MutingActive = FALSE</p> <p>Error = FALSE</p>
8011	Muting Forward Start 1	<p>Muting forward sequence is in starting phase after rising trigger of MutingSwitch 11. Monitoring of DiscTime11_12 is activated. Monitoring of MaxMutingTime is activated.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = TRUE</p> <p>S_MutingActive = FALSE</p> <p>Error = FALSE</p>
8311	Muting Forward Start 2	<p>Muting forward sequence is in starting phase after rising trigger of MutingSwitch 12. Monitoring of DiscTime11_12 is activated. Monitoring of MaxMutingTime is activated.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = TRUE</p> <p>S_MutingActive = FALSE</p> <p>Error = FALSE</p>
8012	Muting Forward Active 1	<p>Muting forward sequence is active either:</p> <ul style="list-style-type: none"> <li>- After rising trigger of the second entry MutingSwitch 12 or 11 has been detected.</li> <li>- When both MutingSwitch 11 and 12 have been actuated in the same cycle.</li> </ul> <p>Monitoring of DiscTime11_12 is stopped. Monitoring of MaxMutingTime is activated, when transition came directly from state 8000.</p> <p>Ready = TRUE</p> <p>S_AOPD_Out = TRUE</p> <p>S_MutingActive = TRUE</p> <p>Error = FALSE</p>

## Configuration and programming

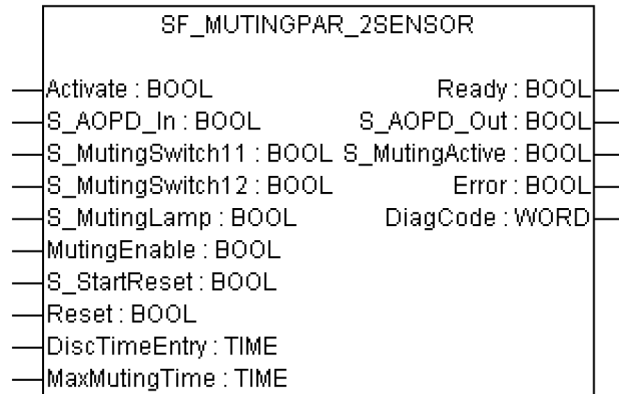
AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8014	Muting Forward Step 1	Muting forward sequence is active. MutingSwitch21 is the first exit switch actuated. Monitoring of DiscTime21_22 is started.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE
8314	Muting Forward Step 2	Muting forward sequence is active. MutingSwitch22 is the first exit switch actuated. Monitoring of DiscTime21_22 is started.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE
8021	Muting Forward Active 2	Muting forward sequence is still active. Both MutingSwitch21 and 22 are actuated, the monitoring of DiscTime21_22 is stopped.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE
8122	Muting Backward Start 1	Muting backward sequence is in starting phase after rising trigger of MutingSwitch21. Monitoring of DiscTime21_22 is activated. Monitoring of MaxMutingTime is activated.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8422	Muting Backward Start 2	Muting backward sequence is in starting phase after rising trigger of MutingSwitch22. Monitoring of DiscTime21_22 is activated. Monitoring of MaxMutingTime is activated.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE

DiagCode	State Name	State Description and Output Setting
8121	Muting Backward Active 1	<p>Muting backward sequence is active either:</p> <ul style="list-style-type: none"> <li>- After rising trigger of the second MutingSwitch 21 or 22 has been detected.</li> <li>- When both MutingSwitch 21 and 22 have been actuated in the same cycle.</li> </ul> <p>Monitoring of DiscTime21_22 is stopped. Monitoring of MaxMutingTime is activated, when transition came directly from state 8000.</p> <p>Ready = TRUE  S_AOPD_Out = TRUE  S_MutingActive = TRUE  Error = FALSE</p>
8114	Muting Backward Step 1	<p>Muting backward sequence is active. MutingSwitch11 is the first exit switch actuated. Monitoring of DiscTime11_12 is started.</p> <p>Ready = TRUE  S_AOPD_Out = TRUE  S_MutingActive = TRUE  Error = FALSE</p>
8414	Muting Backward Step 2	<p>Muting backward sequence is active. MutingSwitch12 is the first exit switch actuated. Monitoring of DiscTime11_12 is started.</p> <p>Ready = TRUE  S_AOPD_Out = TRUE  S_MutingActive = TRUE  Error = FALSE</p>
8112	Muting Backward Active 2	<p>Muting backward sequence is still active. Both exit switches MutingSwitch11 and 12 are actuated, the monitoring of DiscTime11_12 is stopped.</p> <p>Ready = TRUE  S_AOPD_Out = TRUE  S_MutingActive = TRUE  Error = FALSE</p>

### 4.6.6.14 SF\_MutingPar2Sensor

Standards	Requirements
IEC 61496-1:2004	<p>A.7 Muting</p> <p>A.7.1.2 There shall be at least two independent hard-wired muting signal sources to initiate the function. It shall not be possible to initiate muting when the OSSDs are already in the OFF-state.</p> <p>A.7.1.3 The mute function shall only be initiated by the correct sequence and/or timing of the mute signals. Should conflicting muting signals occur, the ESPE shall not allow a muted condition to occur.</p> <p>A.7.1.4 There shall be at least two independent hard-wired muting signal sources to stop the function. The muting function shall stop when the first of these muting signals changes state. The deactivation of the muting function shall not rely only on the clearance of the ESPE.</p> <p>A.7.1.5 The muting signals should be continuously present during muting. When the signals are not continuously present, an incorrect sequence and/or the expiration of a pre-set time limit shall cause either a lock-out condition or a restart interlock.</p> <p>A.7.4 Indication: A mute status signal or indicator shall be provided (in some applications, an indication signal of muting is necessary)</p>
CD IEC 62046/Ed. 1: 2005	<p>5.5.1: ... an indicator to show when the muting function is active can be necessary.</p> <p>The muting function shall be initiated and terminated automatically ... Incorrect signals, sequence or timing of the muting sensors or signals shall not allow a mute condition. It shall not be possible to initiate the muting function when:</p> <ul style="list-style-type: none"> <li>■ the protective equipment OSSDs are in the OFF-state;</li> <li>■ the protective equipment is in the lock-out condition.</li> <li>■ initiation of the muting function by two or more independent muting sensors such that a single fault cannot cause a muted condition;</li> <li>■ termination of the muting function by two or more independent muting sensors such that deactivation of one sensor will terminate the muting function;</li> <li>■ use of timing and sequence control of the muting sensors to ensure correct muting operation;</li> </ul> <p>5.5.3: The following measures shall be considered ...</p> <ul style="list-style-type: none"> <li>■ limiting muting to a fixed time that is only sufficient for the material to pass through the detection zone. When this time is exceeded, the muting function should be cancelled and all hazardous movements stopped;</li> </ul> <p>Annex F.7 Two sensors – Crossed beams (see also Fig. F.7.2 and F.7.3)</p> <p>The muting function should only be initiated when the two beams are activated within a time limit of 4 sec. The muting function should be terminated as soon as one of the two beams of the muting sensors is no longer activated. A monitored timer that limits the muting function to the minimum time practicable is required.</p> <p>Annex F.5: Methods to avoid manipulation of the muting function: ... use a muting enable command generated by the control system of the machine that will only enable the muting function when needed by the machine cycle.</p>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



Muting is the intended suppression of the safety function. In this FB, parallel muting with two muting sensors is specified.

Muting is the intended suppression of the safety function. This is required, e.g., when transporting the material into the danger zone without causing the machine to stop. Muting is triggered by muting sensors. The use of two muting sensors and correct integration into the production sequence must ensure that no persons enter the danger zone while the light curtain is muted. Muting sensors can be push buttons, proximity switches, photoelectric barriers, limit switches, etc. which do not have to be failsafe. Active muting mode must be indicated by indicator lights.

There are sequential and parallel muting procedures. In this FB, parallel muting with two muting sensors was used; an explanation is provided below. The positioning of the sensors should be as described in Annex F.7 of IEC 62046, CD 2005, as shown in Figure 48. The FB can be used in both directions, forward and backward. However, the actual direction cannot be identified. The muting should be enabled with the MutingEnable signal by the process control to avoid manipulation.

The FB input parameters include the signals of the two muting sensors (S\_MutingSwitch11 and S\_MutingSwitch12), the OSSD signal from the "active opto-electronic protective device", S\_AOPD\_In, as well as two parameterizable times (DiscTimeEntry and MaxMutingTime).

The S\_StartReset input shall only be activated if it is ensured that no hazardous situation can occur when the PÉS is started.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Table 72: FB Name: SF\_MutingPar\_2Sensor

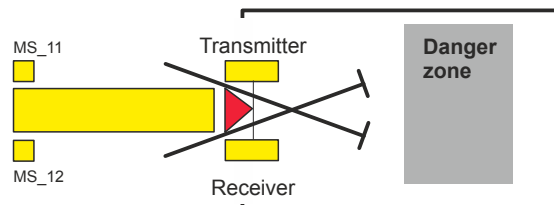
Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
S_AOPD_In	BOOL	FALSE	Variable. OSSD signal from AOPD. FALSE: Protection field interrupted. TRUE: Protection field not interrupted.
S_MutingSwitch11	BOOL	FALSE	Variable. Status of Muting sensor 11. FALSE: Muting sensor 11 not actuated. TRUE: Workpiece actuates muting sensor 11.
S_MutingSwitch12	BOOL	FALSE	Variable. Status of Muting sensor 12. FALSE: Muting sensor 12 not actuated. TRUE: Workpiece actuates muting sensor 12.
S_MutingLamp	BOOL	FALSE	Variable or constant. Indicates operation of the muting lamp. FALSE: Muting lamp failure. TRUE: Muting lamp no failure.
MutingEnable	BOOL	FALSE	Variable or constant. Command by the control system that enables the start of the muting function when needed by the machine cycle. After the start of the muting function, this signal can be switched off. FALSE: Muting not enabled TRUE: Start of Muting function enabled
S_StartReset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	↗ Table 31 "General Input Parameters" on page 266
DiscTimeEntry	TIME	T#0s	Constant 0..4 s; Max. discrepancy time for S_MutingSwitch11 and S_MutingSwitch12 entering muting gate
MaxMutingTime	TIME	T#0s	Constant 0..10 min; Maximum time for complete muting sequence, timer started when first muting sensor is actuated.
<b>VAR_OUTPUT</b>			

Name	Data Type	Initial Value	Description, Parameter Values
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_AOPD_Out	BOOL	FALSE	Safety related output, indicates status of the muted guard.  FALSE: AOPD protection field interrupted and muting not active.  TRUE: AOPD protection field not interrupted or muting active.
S_MutingActive	BOOL	FALSE	Indicates status of Muting process.  FALSE: Muting not active.  TRUE: Muting active.
Error	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	☞ Table 32 "General Output Parameters" on page 267

Notes: Line control of muting sensor signals must be active in the safety loop

## Example for SF\_MutingPar\_2Sensor with two reflecting light barriers

1



If reflection light barriers are used as muting sensors, they are generally arranged diagonally. In general, this arrangement of reflection light barriers as muting sensors requires only two light barriers, and only S\_MutingSwitch11 (MS\_11) and S\_MutingSwitch12 (MS\_12) are allocated.

### Muting conditions

Muting condition 1 (to 8011) (MS\_11 is the first entry switch actuated). Start timer DiscTimeEntry and Max-MutingTime:

MutingEnable AND R\_TRIG at MS\_11 AND NOT MS\_12

Muting condition 2 (to 8311) (MS\_12 is the first entry switch actuated). Start timer DiscTimeEntry and Max-MutingTime:

MutingEnable AND NOT MS\_11 AND R\_TRIG at MS\_12

Muting condition 3 (from 8011 to 8012) (MS\_12 is the second entry switch actuated):

Stop timer DiscTimeEntry:

MutingEnable AND MS\_11 AND R\_TRIG at MS\_12

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Muting condition 4 (from 8311 to 8012) (MS\_11 is the second entry switch actuated):

Stop timer DiscTimeEntry:

MutingEnable AND R\_TRIG at MS\_11 AND MS\_12

Muting condition 5 (from 8000 to 8012) (both switches actuated in same cycle): Start Timer MaxMutingTime:

MutingEnable AND R\_TRIG at MS\_11 AND R\_TRIG at MS\_12

Muting condition 6 (from 8012 to 8000) (both switches released in same cycle or MS\_11 and MS\_12 released consecutively). Stop timer MaxMutingTime: NOT MS\_11 OR NOT MS\_12

### Wrong Muting Sequences

State 8000 - (R\_TRIG at MS\_11 AND MS\_12 AND NOT R\_TRIG at MS\_12) OR  
(R\_TRIG at MS\_12 AND MS\_11 AND NOT R\_TRIG at MS\_11) OR  
((MS\_11 AND NOT R\_TRIG at MS\_11) AND (MS\_12 AND NOT R\_TRIG at MS\_12)) OR  
(NOT MutingEnable AND R\_TRIG at MS\_11) OR  
(NOT MutingEnable AND R\_TRIG at MS\_12)

State 8011 - NOT MutingEnable OR NOT MS\_11

State 8311 - NOT MutingEnable OR NOT MS\_12

State 8012 - all possible transitions allowed



## Typical Timing Diagram

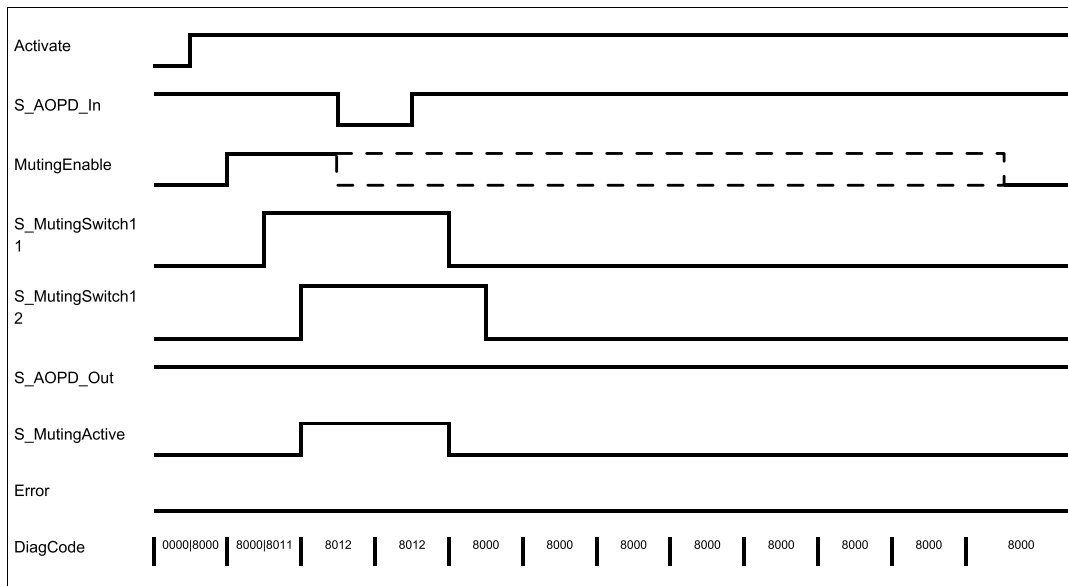


Fig. 116: Timing diagram for SF\_MutingPar\_2Sensor ( $S\_StartReset = TRUE$ ,  $Reset = FALSE$ ,  $S\_MutingLamp = TRUE$ )

The FB detects the following error conditions:

- DiscTimeEntry has been set to value less than T#0s or greater than T#4s.
- MaxMutingTime has been set to a value less than T#0s or greater than T#10min.
- The discrepancy time for the S\_MutingSwitch11/S\_MutingSwitch12 sensor pair has been exceeded.
- The muting function ( $S\_MutingActive = TRUE$ ) exceeds the maximum muting time MaxMutingTime.
- Muting sensors S\_MutingSwitch11, S\_MutingSwitch12 are activated in the wrong order.
- Muting sequence starts without being enabled by MutingEnable
- Static muting sensor signals.
- A faulty muting lamp is indicated by  $S\_MutingLamp = FALSE$ .
- A static Reset condition is detected in state 8001 and 8003.

## Error Behaviour

In the event of an error, the S\_AOPD\_Out and S\_MutingActive outputs are set to FALSE. The DiagCode output indicates the relevant error code and the Error output is set to TRUE.

A restart is inhibited until the error conditions are cleared and the Safe state is acknowledged with Reset by the operator.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 73: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset condition detected after FB activation in state 8001. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C002	Reset Error 2	Static Reset condition detected in state 8003. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C003	Error Muting Lamp	Error detected in muting lamp. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
CYx4	Error Muting sequence	Error detected in muting sequence state 8000, 8011, 8311. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE Y = Status in the sequence C0x4 = Error occurred in state 8000 C1x4 = Error occurred in state 8011 C2x4 = Error occurred in state 8311 CFx4 = Muting Enable missing x = Status of the sensors when error occurred (4 bits: LSB = MS_11; next to LSB = MS_12).
C005	Parameter Error	DiscTimeEntry or MaxMutingTime value out of range. Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE

DiagCode	State Name	State Description and Output Setting
C006	Error timer MaxMuting	Timing error: Active muting time (when S_MutingActive = TRUE) exceeds MaxMutingTime.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE
C007	Error timer Entry	Timing error: Discrepancy time for switching S_MutingSwitch11 and S_MutingSwitch12 from FALSE to TRUE > DiscTimeEntry.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = TRUE

Table 74: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state).  Ready = FALSE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8000	AOPD Free	Muting not active and no safety demand from AOPD. If timers from subsequent muting are still running, they are stopped.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8001	Init	Function block was activated.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8002	Safety Demand AOPD	Safety demand detected by AOPD, muting not active.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE

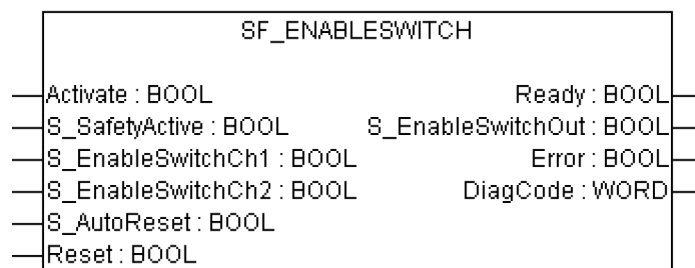
## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8003	Wait for Reset	Safety demand or errors have been detected and are now cleared. Operator acknowledgment by Reset required.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8005	Safe	Safety function activated.  Ready = TRUE S_AOPD_Out = FALSE S_MutingActive = FALSE Error = FALSE
8011	Muting Start 1	Muting sequence is in starting phase after rising trigger of S_MutingSwitch11. Monitoring of DiscTimeEntry is activated.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8311	Muting Start 2	Muting sequence is in starting phase after rising trigger of S_MutingSwitch12. Monitoring of DiscTimeEntry is activated.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = FALSE Error = FALSE
8012	Muting Active	Muting sequence is active either: <ul style="list-style-type: none"><li>- After rising trigger of the second S_MutingSwitch 12 or 11 has been detected.</li><li>- When both S_MutingSwitch 11 and 12 have been actuated in the same cycle.</li></ul> Monitoring of DiscTimeEntry is stopped. Monitoring of MaxMutingTime is activated.  Ready = TRUE S_AOPD_Out = TRUE S_MutingActive = TRUE Error = FALSE

## 4.6.6.15 SF\_EnableSwitch

Standards	Requirements
IEC 60204-1, Ed. 5.0: 2003	<p>9.2.6.3: Enabling control (see also 10.9) is a manually activated control function interlock that:</p> <ul style="list-style-type: none"> <li>■ when activated allows a machine operation to be initiated by a separate start control, and</li> <li>■ when de-activated – initiates a stop function, and – prevents initiation of machine operation.</li> </ul> <p>Enabling control shall be so arranged as to minimize the possibility of defeating, for example by requiring the de-activation of the enabling control device before machine operation may be reinitiated. It should not be possible to defeat the enabling function by simple means.</p> <p>10.9: When an enabling control device is provided as a part of a system, it shall signal the enabling control to allow operation when actuated in one position only. In any other position, operation shall be stopped or prevented.</p> <p>Enabling control devices shall be selected that have the following features: ...</p> <ul style="list-style-type: none"> <li>■ for a three-position type: <ul style="list-style-type: none"> <li>– position 1: off-function of the switch (actuator is not operated);</li> <li>– position 2: enabling function (actuator is operated in its mid position);</li> <li>– position 3: off-function (actuator is operated past its mid position);</li> </ul> </li> <li>■ when returning from position 3 to position 2, the enabling function is not activated.</li> </ul>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



The SF\_EnableSwitch FB evaluates the signals of an enable switch with three positions.

The SF\_EnableSwitch FB supports the suspension of safeguarding (DIN EN 60204 Section 9.2.4) using enable switches (DIN EN 60204 Section 9.2.5.8), if the relevant operating mode is selected and active. The relevant operating mode (limitation of the speed or the power of motion, limitation of the range of motion) must be selected outside the SF\_EnableSwitch FB.

The SF\_EnableSwitch FB evaluates the signals of an enable switch with three positions (DIN EN 60204 Section 9.2.5.8).

The S\_EnableSwitchCh1 and S\_EnableSwitchCh2 input parameters process the following signal levels of contacts E1 to E4:

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

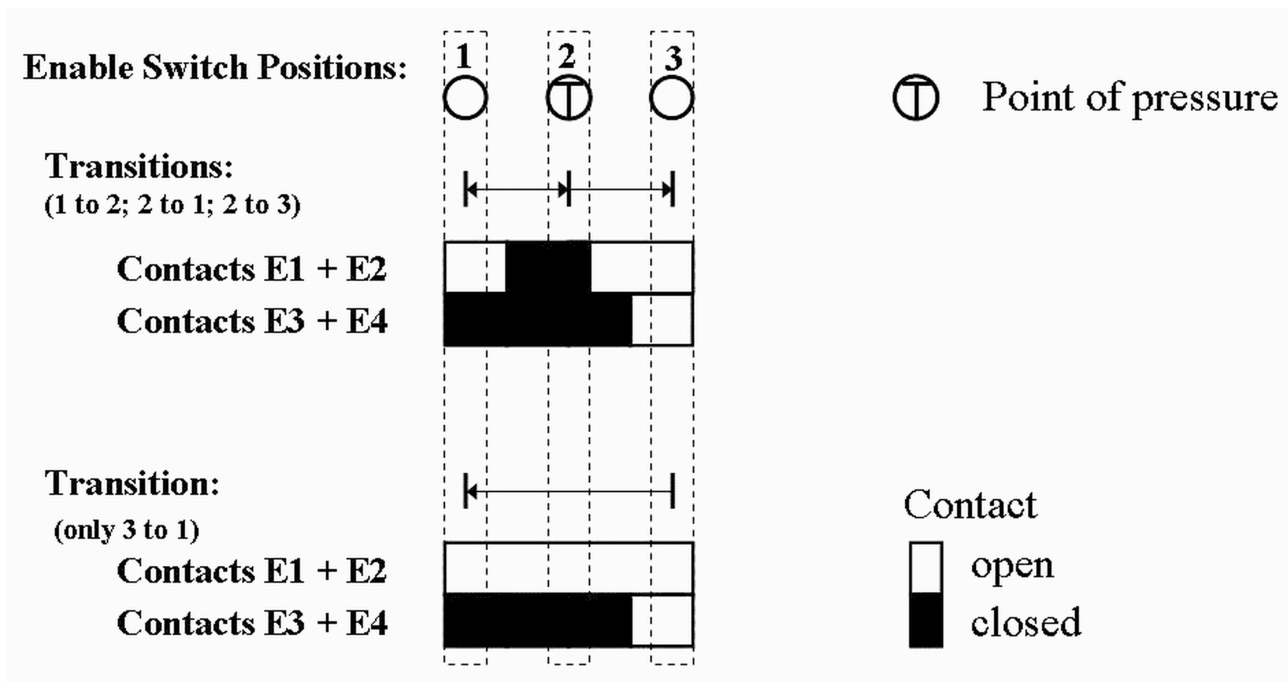


Fig. 117: Switch positions

The signal from E1+E2 must be connected to the S\_EnableSwitchCh1 parameter. The signal from E3+E4 must be connected to the S\_EnableSwitchCh2 parameter. The position of the enable switch is detected in the FB using this signal sequence.

The transition from position 2 to 3 can be different from shown here.

The switching direction (position 1 => position 2/position 3 => position 2) can be detected in the FB using the defined signal sequence of the enable switch contacts. The suspension of safeguarding can only be enabled by the FB after a move from position 1 to position 2. Other switching directions or positions may not be used to enable the suspension of safeguarding. This measure meets the requirements of EN 60204 Section 9.2.5.8.

In order to meet the requirements of DIN EN 60204 Section 9.2.4, the user shall use a suitable switching device. In addition, the user must ensure that the relevant operating mode (DIN EN 60204 Section 9.2.3) is selected in the application (automatic operation must be disabled in this operating mode using appropriate measures).

The operating mode is usually specified using an operating mode selection switch in conjunction with SF\_ModeSelector FB and SF\_SafeRequest or SF\_SafelyLimitedSpeed FB.

The SF\_EnableSwitch FB processes the confirmation of the "safe mode" state via the "S\_SafetyActive" parameter. On implementation in an application of the safe mode without confirmation, a static TRUE signal is connected to the "S\_SafetyActive" parameter.

The S\_AutoReset input shall only be activated if it is ensured that no hazardous situation can occur when the PES is started.

Table 75: FB Name: SF\_EnableSwitch

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	✎ Table 31 "General Input Parameters" on page 266
S_SafetyActive	BOOL	FALSE	Variable or constant. Confirmation of the safe mode (limitation of the speed or the power of motion, limitation of the range of motion). FALSE: Safe mode is not active. TRUE: Safe mode is active.
S_Enable-SwitchCh1	BOOL	FALSE	Variable. Signal of contacts E1 and E2 of the connected enable switch. FALSE: Connected switches are open. TRUE: Connected switches are closed.
S_Enable-SwitchCh2	BOOL	FALSE	Variable. Signal of contacts E3 and E4 of the connected enable switch. FALSE: Connected switches are open. TRUE: Connected switches are closed.
S_AutoReset	BOOL	FALSE	✎ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	✎ Table 31 "General Input Parameters" on page 266
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	✎ Table 32 "General Output Parameters" on page 267
S_Enable-SwitchOut	BOOL	FALSE	Safety related output: Indicates suspension of guard. FALSE: Disable suspension of safeguarding. TRUE: Enable suspension of safeguarding.
Error	BOOL	FALSE	✎ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	✎ Table 32 "General Output Parameters" on page 267

## Typical Timing Diagrams

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

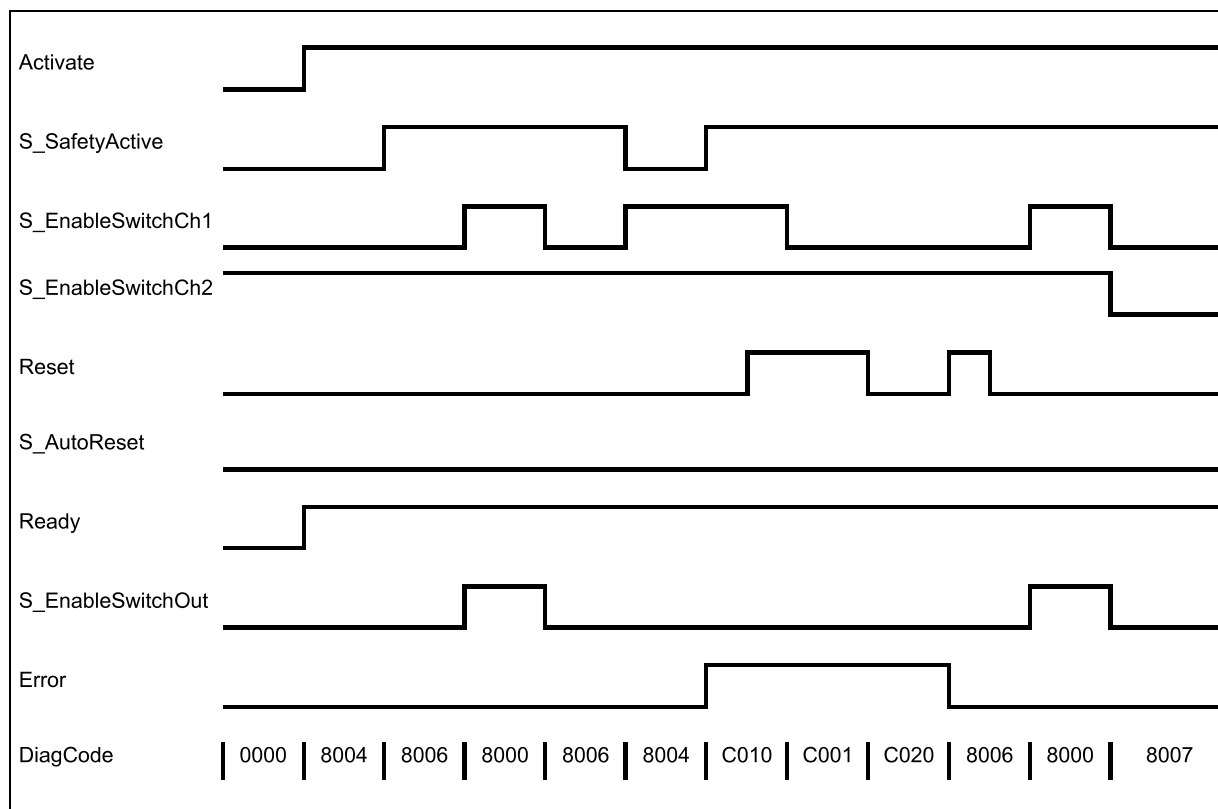


Fig. 118: Timing diagram for SF\_EnableSwitch: S\_AutoReset = FALSE



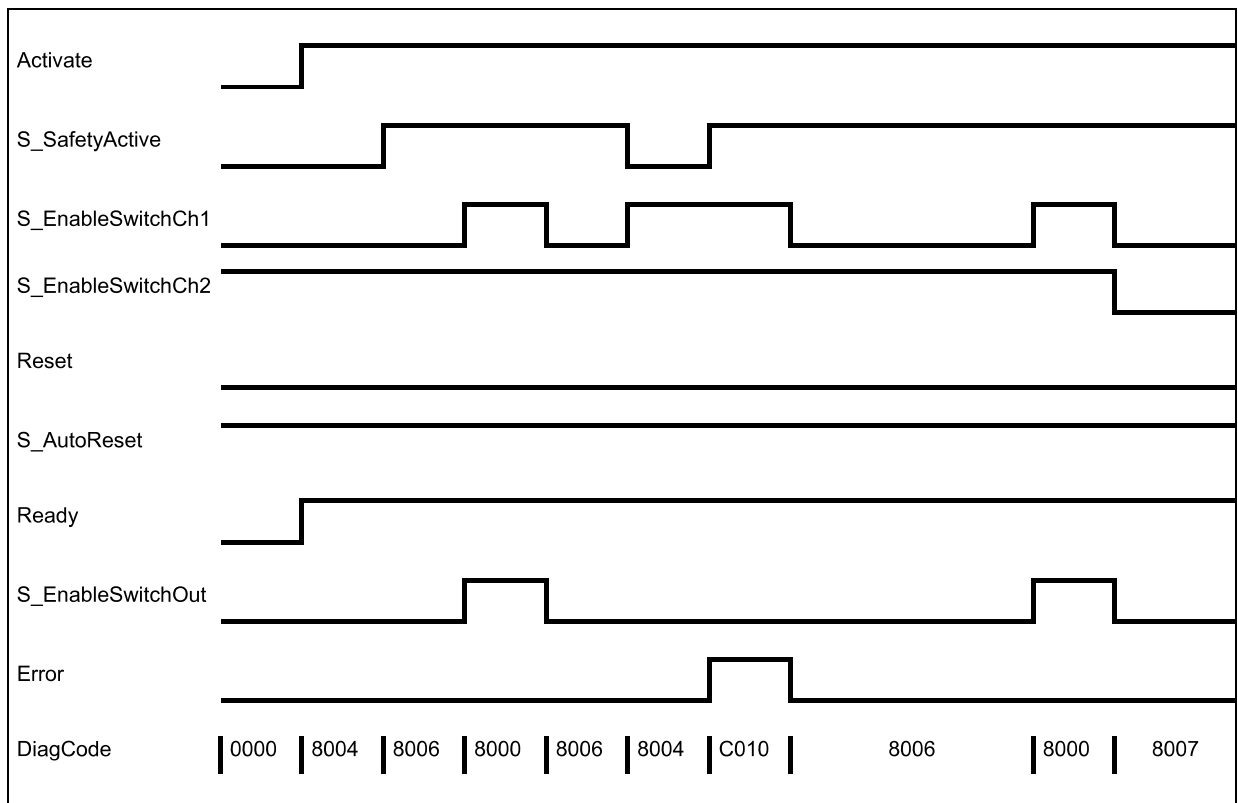


Fig. 119: Timing diagram for SF\_EnableSwitch: S\_AutoReset = TRUE

The following conditions force a transition to the Error state:

- Invalid static Reset signal in the process.
- Invalid switch positions.

## Error Behavior

In the event of an error, the S\_EnableSwitchOut safe output is set to FALSE and remains in this Safe state.

Different from other FBs, a Reset Error state can be left by the condition Reset = FALSE or, additionally, when the signal S\_SafetyActive is FALSE.

Once the error has been removed, the enable switch must be in the initial position specified in the process before the S\_EnableSwitchOut output can be set to TRUE using the enable switch. If S\_AutoReset = FALSE, a rising trigger is required at Reset.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 76: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset signal detected in state C020. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE
C002	Reset Error 2	Static Reset signal detected in state C040. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE
C010	Operation Error 1	Enable switch not in position 1 during activation of S_SafetyActive. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE
C020	Operation Error 2	Enable switch in position 1 after C010. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE
C030	Operation Error 3	Enable switch in position 2 after position 3. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE
C040	Operation Error 4	Enable switch not in position 2 after C030. Ready = TRUE S_EnableSwitchOut = FALSE Error = TRUE

Table 77: FB-specific status codes (no error):

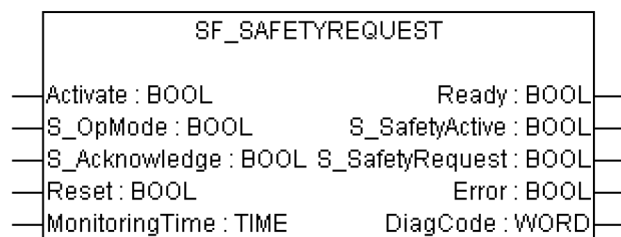
DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_EnableSwitchOut = FALSE Error = FALSE
8004	Basic Operation Mode	Safe operation mode is not active. Ready = TRUE S_EnableSwitchOut = FALSE Error = FALSE
8005	Safe Operation Mode	Safe operation mode is active. Ready = TRUE S_EnableSwitchOut = FALSE Error = FALSE
8006	Position 1	Safe operation mode is active and the enable switch is in position 1. Ready = TRUE S_EnableSwitchOut = FALSE Error = FALSE
8007	Position 3	Safe operation mode is active and the enable switch is in position 3. Ready = TRUE S_EnableSwitchOut = FALSE Error = FALSE
8000	Position 2	Safe operation mode is active and the enable switch is in position 2. Ready = TRUE S_EnableSwitchOut = TRUE Error = FALSE

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

### 4.6.6.16 SF\_SafetyRequest

Standards	Requirements
IEC 60204-1, Ed. 5.0: 2003	<p>9.2.4 Suspension of safety functions and/or protective measures</p> <p>Where it is necessary to suspend safety functions and/or protective measures (for example for setting or maintenance purposes), protection shall be ensured by:</p> <ul style="list-style-type: none"> <li>■ disabling all other operating (control) modes; and</li> <li>■ other relevant means (see 4.11.9 of ISO 12100-2:2003), that can include, for example, one or more of the following: <ul style="list-style-type: none"> <li>■ limitation of the speed or the power of motion;</li> <li>■ limitation of the range of motion.</li> </ul> </li> </ul>
EN 954-1: 1996	5.4 Manual reset
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart



The function block represents the interface between the user program and system environment.

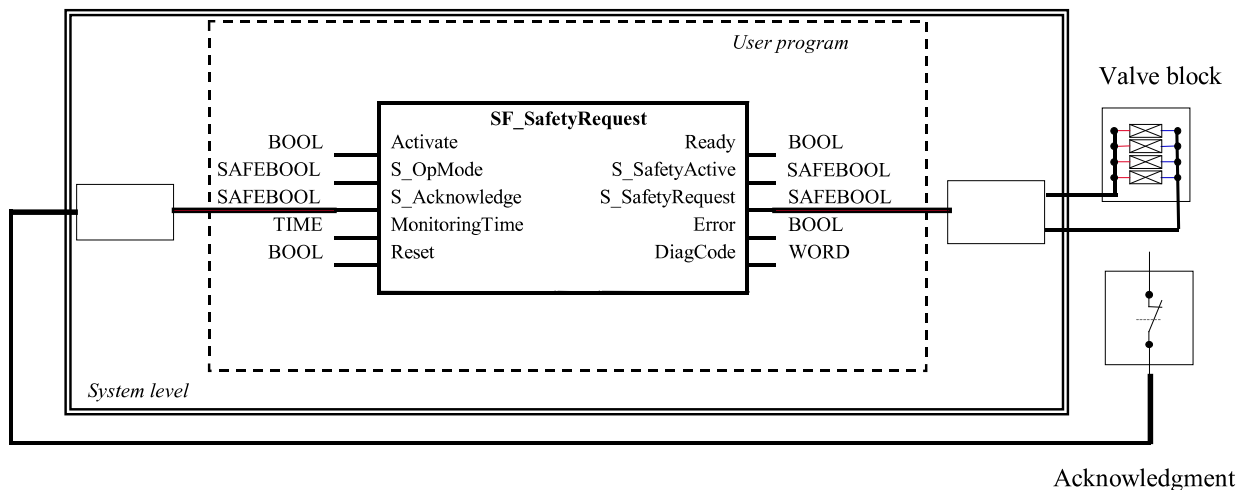


Fig. 120: Example of SF\_SafetyRequest

This function block provides the interface to a generic actuator, e.g. a safety drive or safety valve, to place the actuator in a safe state.

This FB provides the interface between the safety-related system and a generic actuator. This means that the safety-related functions of the actuator are available within the application program. However, there are only two binary signals to control the Safe state of the generic actuator, i.e., one for requesting and one for receiving the confirmation.

The safety function will be provided by the actuator itself. Therefore the FB only initiates the request, monitors it, and sets the output when the actuator acknowledges the Safe state. This will be indicated with the "S\_SafetyActive" output.

This FB does not define any generic actuator-specific parameters. They should have been specified in the generic actuator itself. It switches the generic actuator from the operation mode to a safe state.

Table 78: FB Name: SF\_SafetyRequest

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	↳ Table 31 "General Input Parameters" on page 266
S_OpMode	BOOL	FALSE	Variable. Requested mode of a generic safe actuator. FALSE: Safe mode is requested. TRUE: Operation mode is requested.
S_Acknowledge	BOOL	FALSE	Variable. Confirmation of the generic actuator, if actuator is in the Safe state. FALSE: Operation mode (non-safe). TRUE: Safe mode.
Reset	BOOL	FALSE	↳ Table 31 "General Input Parameters" on page 266
MonitoringTime	TIME	T#0s	Constant. Monitoring of the response time between the safety function request (S_OpMode set to FALSE) and the actuator acknowledgment (S_Acknowledge switches to TRUE).
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	↳ Table 32 "General Output Parameters" on page 267
S_SafetyActive	BOOL	FALSE	Confirmation of the Safe state. FALSE: Non-safe state. TRUE: Safe state.
S_SafetyRequest	BOOL	FALSE	Request to place the actuator in a safe state. FALSE: Safe state is requested. TRUE: Non-safe state.
Error	BOOL	FALSE	↳ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	↳ Table 32 "General Output Parameters" on page 267

### Typical Timing Diagram

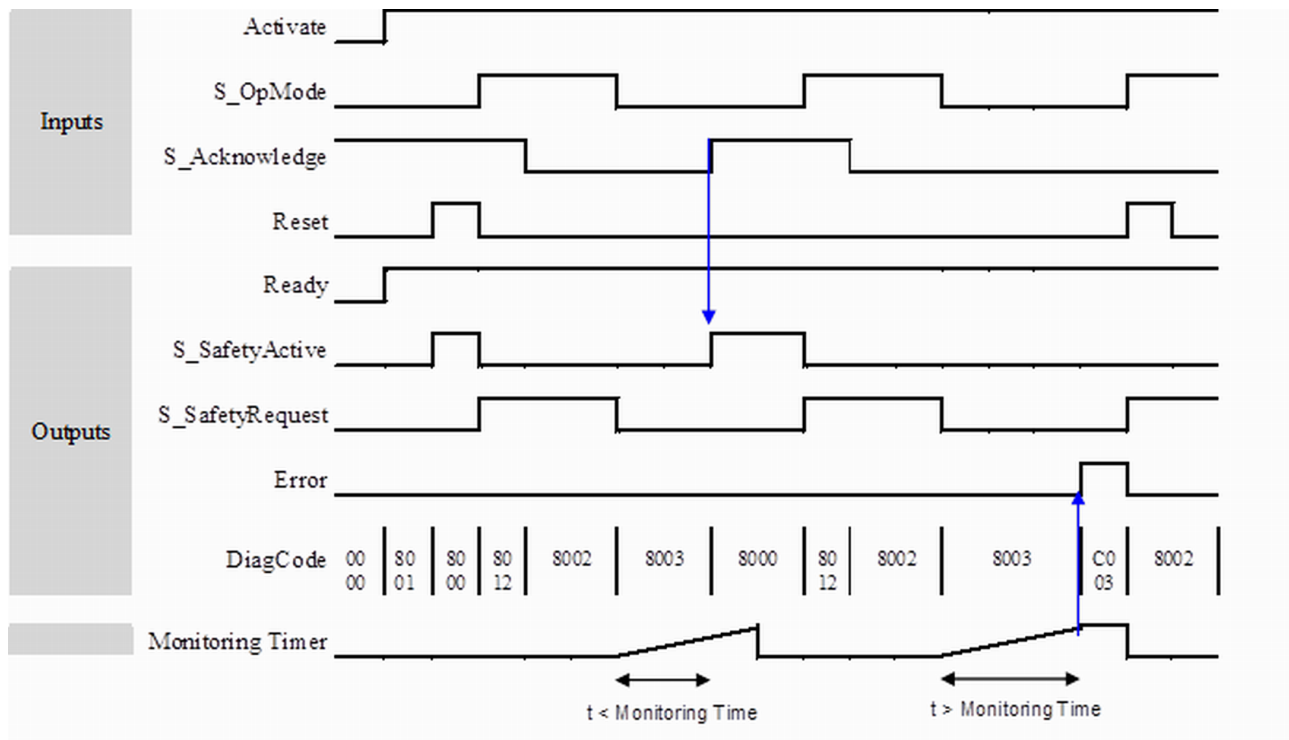


Fig. 121: Timing diagram for SF\_SafetyRequest

The FB detects whether the actuator does not enter the Safe state within the monitoring time.

The FB detects whether the acknowledge signal is lost while the request is still active.

The FB detects a static Reset signal.

External FB errors:

There are no external errors, since there is no error bits/information provided by the generic actuator.

### Error Behavior

In the event of an error, the S\_SafetyActive output is set to FALSE.

An error must be acknowledged by a rising trigger at the Reset input. To continue the function block after this reset, the S\_OpMode request must be set to TRUE.

## Function Block-Specific Error and Status Codes

Table 79: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C002	Acknowledge Lost	Acknowledgment lost while in the Safe state. Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = TRUE
C003	Monitoring-Time Elapsed	S_OpMode request could not be completed within the monitoring time. Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = TRUE
C004	Reset Error 2	Static Reset detected in state C002 (Acknowledge Lost). Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = TRUE
C005	Reset Error 3	Static Reset detected in state C003 (MonitoringTime Elapsed). Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = TRUE

Table 80: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = FALSE
8000	Safe Mode	Actuator is in a safe mode. Ready = TRUE S_SafetyActive = TRUE S_SafetyRequest = FALSE Error = FALSE

## Configuration and programming

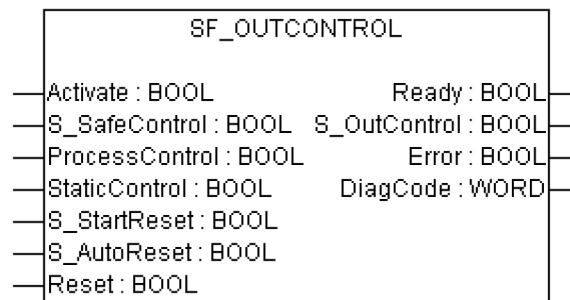
AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
8001	Init	State after Activate is set to TRUE or after a rising trigger at Reset. Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = FALSE
8002	Operation Mode	Operation mode without Acknowledge of safe mode Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = TRUE Error = FALSE
8012	Wait for Confirmation OpMode	Operation mode with Acknowledge of safe mode Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = TRUE Error = FALSE
8003	Wait for Confirmation	Waiting for confirmation from the drive (system interface). Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = FALSE
8005	Wait for OpMode	Error was cleared. However S_OpMode must be set to TRUE before the FB can be initialized. Ready = TRUE S_SafetyActive = FALSE S_SafetyRequest = FALSE Error = FALSE



## 4.6.6.17 SF\_OutControl

Standards	Requirements
IEC 60204-1, Ed. 5.0: 2003	<p>9.2.2: Stop functions: Stop function categories; Category 0 - stopping by immediate removal of power to the machine actuators (i.e. an uncontrolled stop ...)</p> <p>9.2.5.2: Start: The start of an operation shall be possible only when all of the relevant safety functions and/or protective measures are in place and are operational except for conditions as described in 9.2.4. Suitable interlocks shall be provided to secure correct sequential starting.</p>
EN 954-1: 1996	<p>5.2: Stop function; stop initiated by protective devices shall put the machine in a safe state ... and shall have priority over a stop for operational reasons</p> <p>5.5: Start and restart; automatic restart only if a hazardous situation cannot exist.</p> <p>5.11: Fluctuations in energy levels; in case of loss of energy supply, provide or initiate outputs to maintain a safe state.</p>
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart
EN 954-1: 1996	5.4 Manual reset



Control of a safety output with a signal from the functional application and a safety signal with optional startup inhibits.

The SF\_OutControl FB is an output driver for a safety output.

The safety output is controlled via S\_OutControl using a signal from the functional application (ProcessControl/BOOL to control the process) and a signal from the safety application (S\_SafeControl/BOOL to control the safety function).

Optional conditions for process control (ProcessControl):

- An additional function start (ProcessControl FALSE => TRUE) is required following block activation or feedback of the safe signal (S\_SafeControl). A static TRUE signal at ProcessControl does not set S\_OutControl to TRUE.
- An additional function start (ProcessControl FALSE => TRUE) is not required following block activation or feedback of the safe signal (S\_SafeControl). A static TRUE signal at ProcessControl sets S\_OutControl to TRUE if the other conditions have been met.

Optional startup inhibits:

- Startup inhibit after function block activation.
- Startup inhibit after interruption of the protective device.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

The StaticControl, S\_StartReset and S\_AutoReset inputs shall only be activated if it is ensured that no hazardous situation can occur when the PES is started.

Table 81: FB Name: SF\_OutControl

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_SafeControl	BOOL	FALSE	Variable. Control signal of the preceding safety FB. Typical function block signals from the library (e.g., SF_EStop, SF_GuardMonitoring, SF_Two-HandControlTypell, and/or others). FALSE: The preceding safety FB's are in safe state. TRUE: The preceding safety FB's enable safety control.
ProcessControl	BOOL	FALSE	Variable or constant. Control signal from the functional application. FALSE: Request to set S_OutControl to FALSE. TRUE: Request to set S_OutControl to TRUE.
StaticControl	BOOL	FALSE	Constant. Optional conditions for process control. FALSE: Dynamic change at ProcessControl (FALSE => TRUE) required after block activation or triggered safety function. Additional function start required. TRUE: No dynamic change at ProcessControl (FALSE => TRUE) required after block activation or triggered safety function.
S_StartReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_AutoReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267
S_OutControl	BOOL	FALSE	Controls connected actuators. FALSE: Disable connected actuators. TRUE: Enable connected actuators.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Name	Data Type	Initial Value	Description, Parameter Values
Error	BOOL	FALSE	🔗 Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	🔗 Table 32 "General Output Parameters" on page 267

### Typical Timing Diagrams

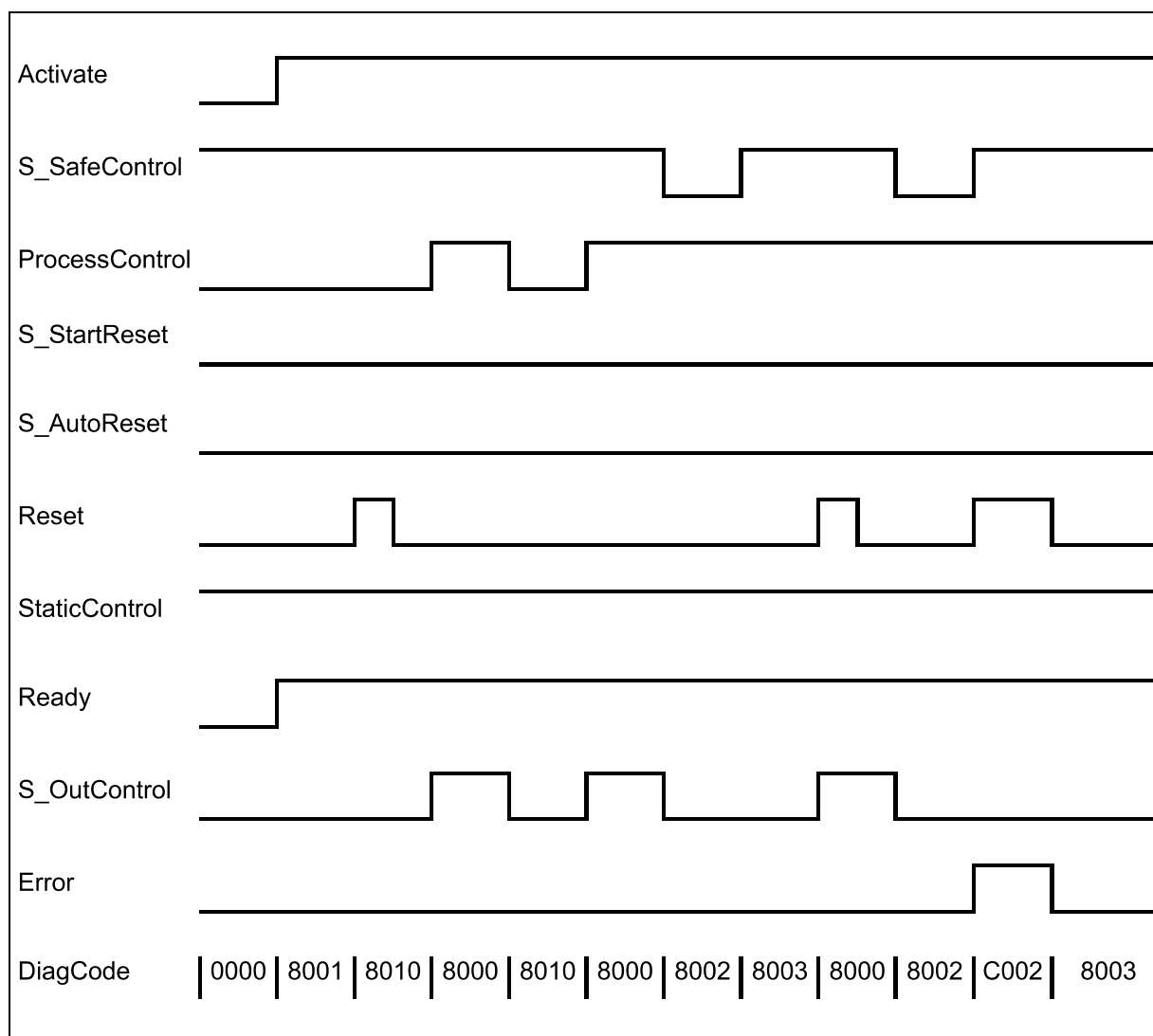


Fig. 122: Timing diagram for SF\_OutControl: S\_StartReset = FALSE

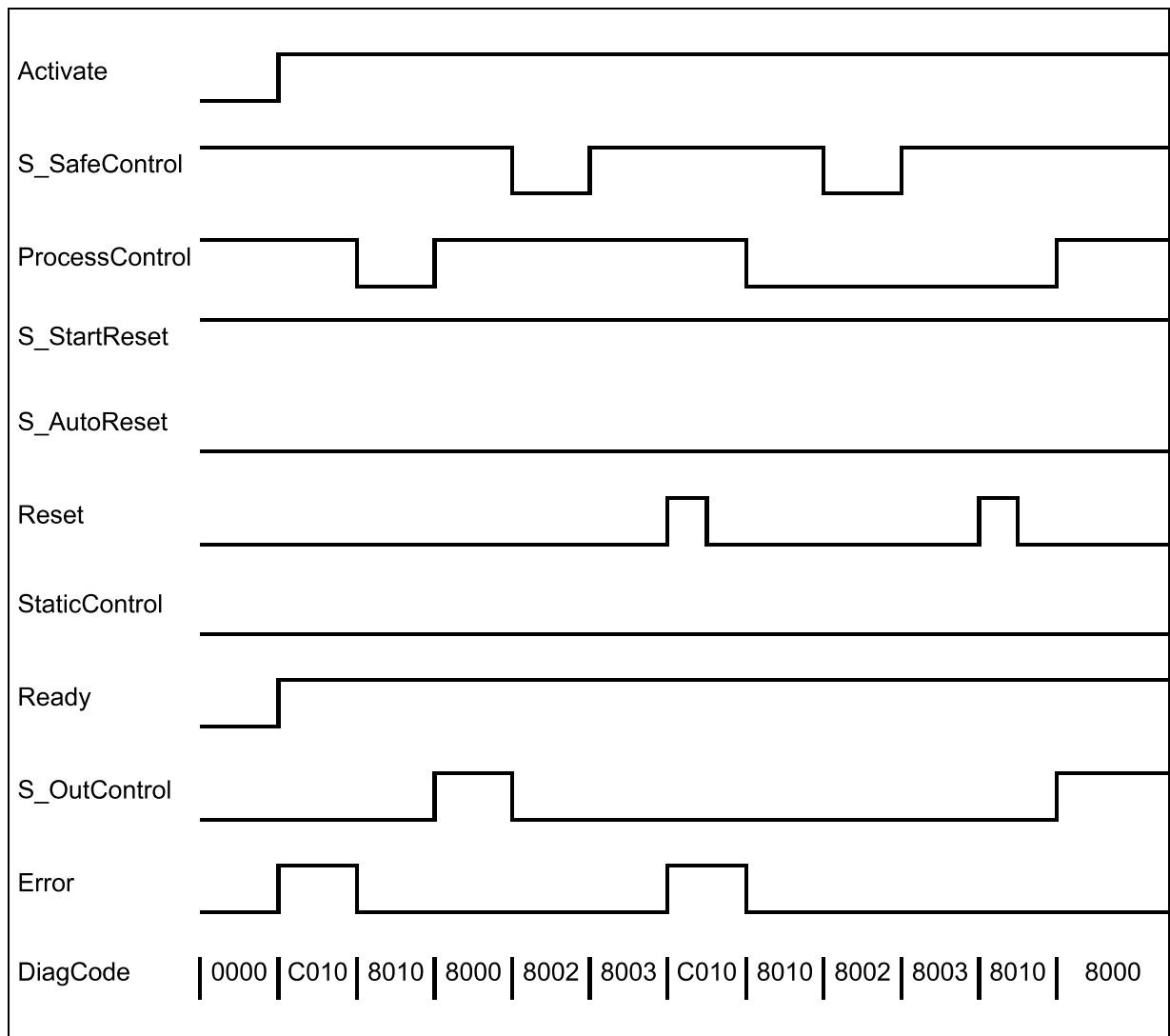


Fig. 123: Timing diagram for SF\_OutControl: S\_StartReset = TRUE

The following conditions force a transition to the Error state:

- Invalid static Reset signal in the process.
- Invalid static ProcessControl signal.
- ProcessControl and Reset are incorrectly interconnected due to programming error.

## Error Behavior

In the event of an error, the S\_OutControl output is set to FALSE and remains in this safe state.

To leave the Reset, Init or Lock error states, the Reset input must be set to FALSE. To leave the Control error state, the ProcessControl input must be set to FALSE.

After transition of S\_SafeControl to TRUE, the optional startup inhibit can be reset by a rising edge at the Reset input.

After block activation, the optional startup inhibit can be reset by a rising edge at the Reset input.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCopen\_AC500\_v22.lib

### Function Block-Specific Error and Status Codes

Table 82: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset signal in state 8001. Ready = TRUE S_OutControl = FALSE Error = TRUE
C002	Reset Error 2	Static Reset signal in state 8003. Ready = TRUE S_OutControl = FALSE Error = TRUE
C010	Control Error	Static signal at ProcessControl in state 8010. Ready = TRUE S_OutControl = FALSE Error = TRUE
C111	Init Error	Simultaneous rising trigger at Reset and ProcessControl in state 8001. Ready = TRUE S_OutControl = FALSE Error = TRUE
C211	Lock Error	Simultaneous rising trigger at Reset and ProcessControl in state 8003. Ready = TRUE S_OutControl = FALSE Error = TRUE

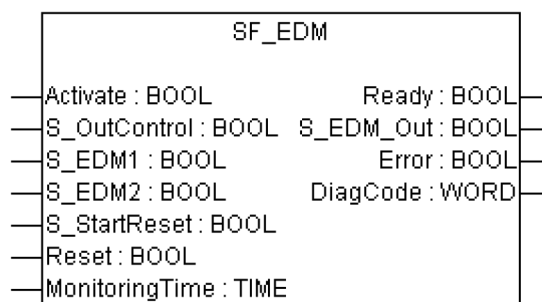
Table 83: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_OutControl = FALSE Error = FALSE
8001	Init	Block activation startup inhibit is active. Reset required. Ready = TRUE S_OutControl = FALSE Error = FALSE

DiagCode	State Name	State Description and Output Setting
8002	Safe	Triggered safety function. Ready = TRUE S_OutControl = FALSE Error = FALSE
8003	Lock	Safety function startup inhibit is active. Reset required. Ready = TRUE S_OutControl = FALSE Error = FALSE
8010	Output Disable	Process control is not active. Ready = TRUE S_OutControl = FALSE Error = FALSE
8000	Output Enable	Process control is active and safety is enabled. Ready = TRUE S_OutControl = TRUE Error = FALSE

## 4.6.6.18 SF\_EDM

Standards	Requirements
IEC 60204-1, Ed. 5.0: 2003	Section 9.2.2: Stop function categories; Category 0
EN 954-1: 1996	5.2: Stop function; stop initiated by protective devices shall put the machine in a safe state 6.2: Specification of categories: Fault detection (of the actuator, e.g. open circuits)
ISO 12100-2: 2003	4.11.4: Restart following power failure/spontaneous restart
EN 954-1: 1996	5.4 Manual reset



## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

External device monitoring – The FB controls a safety output and monitors controlled actuators, e.g. subsequent contactors

The SF\_EDM FB controls a safety output and monitors controlled actuators.

This function block monitors the initial state of the actuators via the feedback signals (S\_EDM1 and S\_EDM2) before the actuators are enabled by the FB.

The function block monitors the switching state of the actuators (MonitoringTime) after the actuators have been enabled by the FB.

Two single feedback signals must be used for an exact diagnosis of the connected actuators. A common feedback signal from the two connected actuators must be used for a restricted yet simple diagnostic function of the connected actuators. When doing so, the user must connect this common signal to both parameter S\_EDM1 and parameter S\_EDM2. S\_EDM1 and S\_EDM2 are then controlled by the same signal.

The switching devices used in the safety function should be selected from the category specified in the risk analysis (EN 954-1).

Optional startup inhibits:

- Startup inhibit in the event of block activation.

The S\_StartReset input shall only be activated if it is ensured that no hazardous situation can occur when the PÉS is started.



Table 84: FB Name: SF\_EDM

Name	Data Type	Initial Value	Description, Parameter Values
<b>VAR_INPUT</b>			
Activate	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
S_OutControl	BOOL	FALSE	Variable. Control signal of the preceeding safety FB's. Typical function block signals from the library (e.g., SF_OutControl, SF_TwoHandControlTypell, and/or others). FALSE: Disable safety output (S_EDM_Out). TRUE: Enable safety output (S_EDM_Out).
S_EDM1	BOOL	FALSE	Variable. Feedback signal of the first connected actuator. FALSE: Switching state of the first connected actuator. TRUE: Initial state of the first connected actuator.
S_EDM2	BOOL	FALSE	Variable. Feedback signal of the second connected actuator. If using only one signal in the application, the user must use a graphic connection to jumper the S_EDM1 and S_EDM2 parameters. S_EDM1 and S_EDM2 are then controlled by the same signal. FALSE: Switching state of the second connected actuator. TRUE: Initial state of the second connected actuator.
S_StartReset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
Reset	BOOL	FALSE	☞ Table 31 "General Input Parameters" on page 266
MonitoringTime	TIME	#0ms	Constant. Max. response time of the connected and monitored actuators.
<b>VAR_OUTPUT</b>			
Ready	BOOL	FALSE	☞ Table 32 "General Output Parameters" on page 267

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Name	Data Type	Initial Value	Description, Parameter Values
S_EDM_Out	BOOL	FALSE	Controls the actuator. The result is monitored by the feedback signal S_EDMx. FALSE: Disable connected actuators. TRUE: Enable connected actuators.
Error	BOOL	FALSE	↗ Table 32 "General Output Parameters" on page 267
DiagCode	WORD	16#0000	↗ Table 32 "General Output Parameters" on page 267

### Typical Timing Diagrams

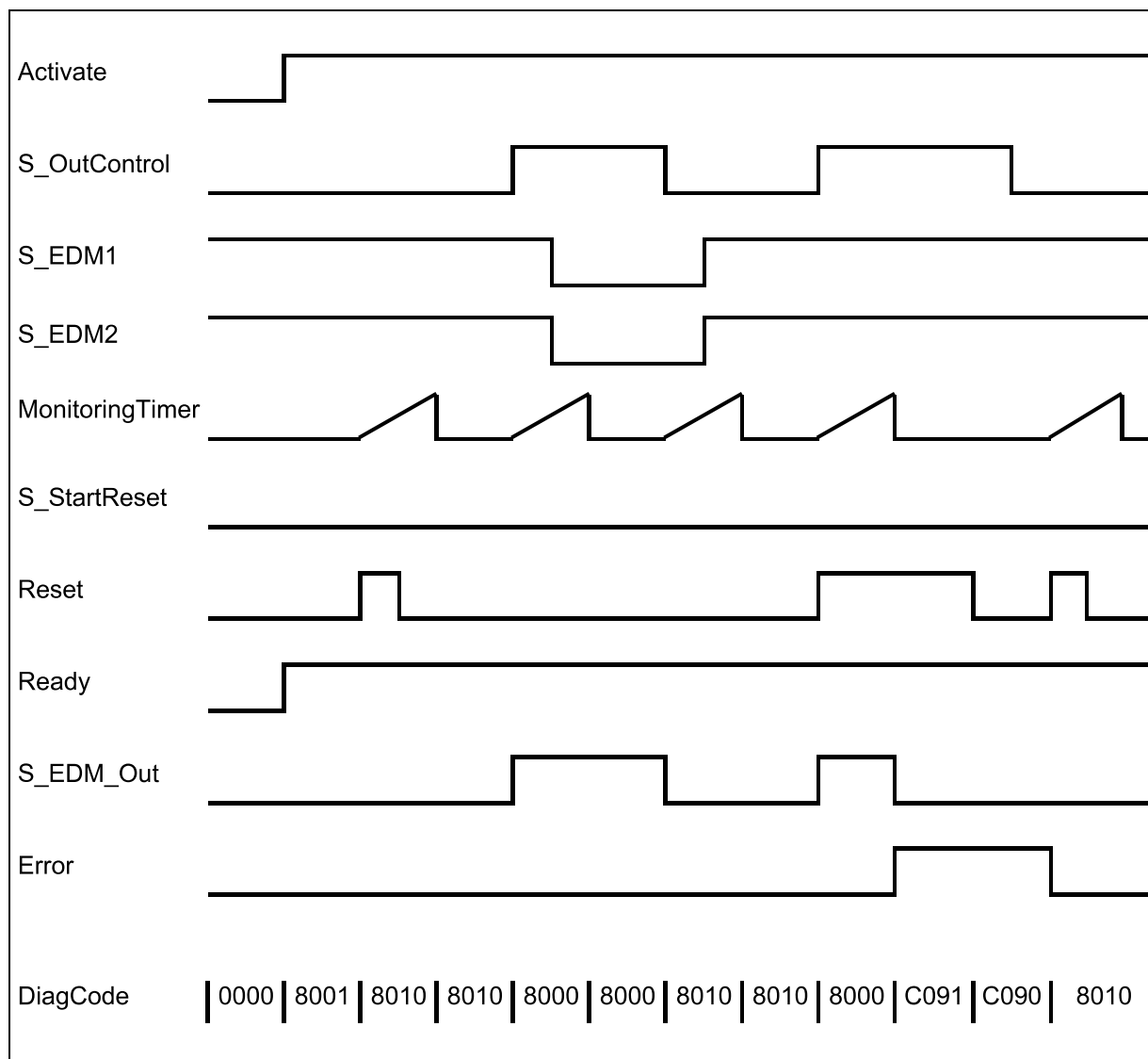


Fig. 124: Timing diagrams for SF\_EDM: S\_StartReset = FALSE

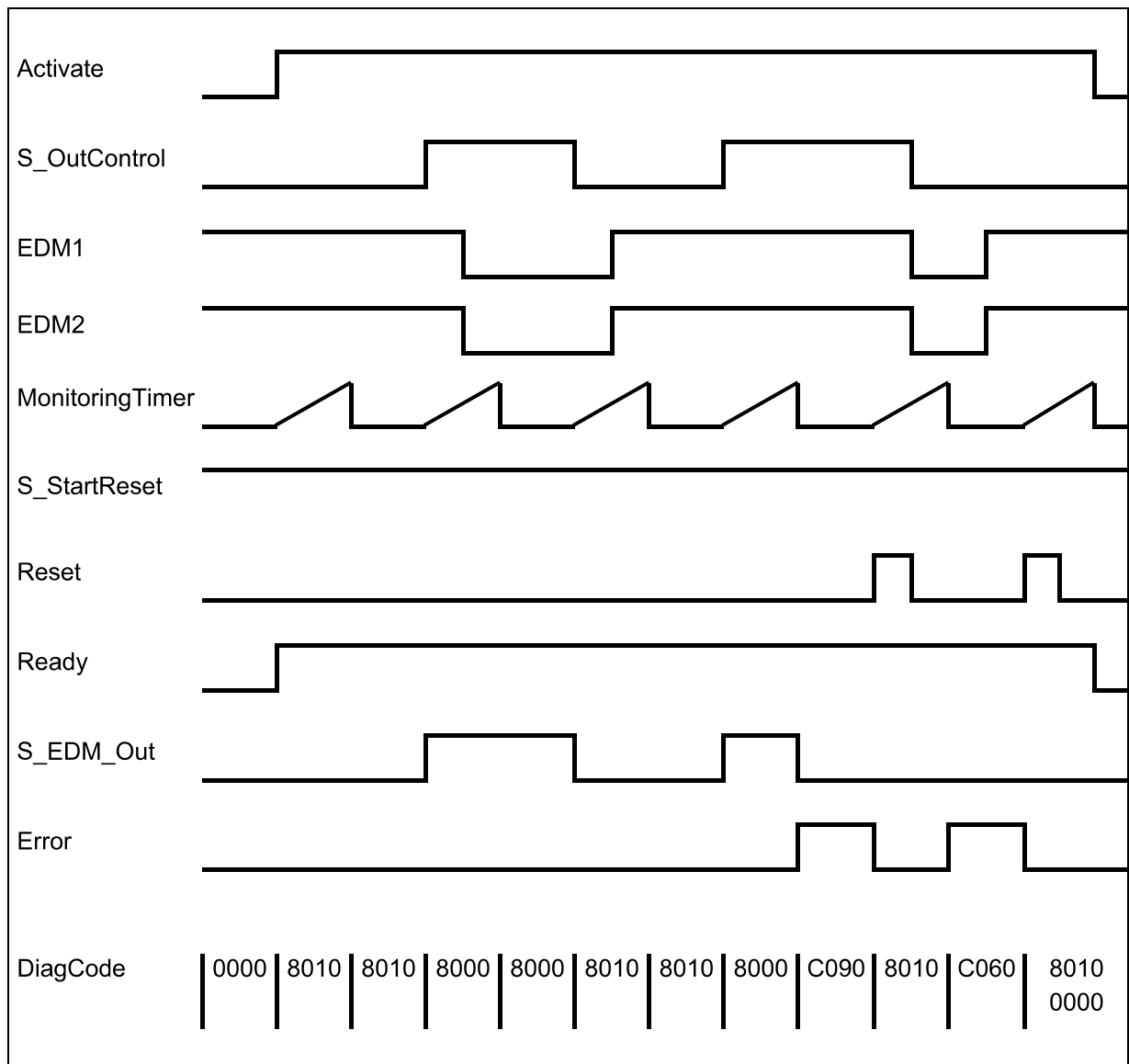


Fig. 125: Timing diagrams for SF\_EDM: S\_StartReset = TRUE

The following conditions force a transition to the Error state:

- Invalid static Reset signal in the process.
- Invalid EDM signal in the process.
- S\_OutControl and Reset are incorrectly interconnected due to programming error.

## Error Behavior

In error states, the outputs are as follows:

- In the event of an error, the S\_EDM\_Out is set to FALSE and remains in this safe state.
- An EDM error message must always be reset by a rising trigger at Reset.
- A Reset error message can be reset by setting Reset to FALSE.

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

After block activation, the optional startup inhibit can be reset by a rising edge at the Reset input.

## Function Block-Specific Error and Status Codes

Table 85: FB-specific error codes

DiagCode	State Name	State Description and Output Setting
C001	Reset Error 1	Static Reset signal in state 8001. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C011	Reset Error 21	Static Reset signal or same signals at EDM1 and Reset (rising trigger at Reset and EDM1 at the same time) in state C010. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C021	Reset Error 22	Static Reset signal or same signals at EDM2 and Reset (rising trigger at Reset and EDM2 at the same time) in state C020. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C031	Reset Error 23	Static Reset signal or same signals at EDM1, EDM2, and Reset (rising trigger at Reset, EDM1, and EDM2 at the same time) in state C030. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C041	Reset Error 31	Static Reset signal or same signals at EDM1 and Reset (rising trigger at Reset and EDM1 at the same time) in state C040. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C051	Reset Error 32	Static Reset signal or same signals at EDM2 and Reset (rising trigger at Reset and EDM2 at the same time) in state C050. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C061	Reset Error 33	Static Reset signal or same signals at EDM1, EDM2, and Reset (rising trigger at Reset, EDM1, and EDM2 at the same time) in state C060. Ready = TRUE S_EDM_Out = FALSE Error = TRUE

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

DiagCode	State Name	State Description and Output Setting
C071	Reset Error 41	Static Reset signal in state C070. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C081	Reset Error 42	Static Reset signal in state C080. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C091	Reset Error 43	Static Reset signal in state C090. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C010	EDM Error 11	The signal at EDM1 is not valid in the initial actuator state. In state 8010 the EDM1 signal is FALSE when enabling S_OutControl. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C020	EDM Error 12	The signal at EDM2 is not valid in the initial actuator state. In state 8010 the EDM2 signal is FALSE when enabling S_OutControl. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C030	EDM Error 13	The signals at EDM1 and EDM2 are not valid in the initial actuator states. In state 8010 the EDM1 and EDM2 signals are FALSE when enabling S_OutControl. Ready = TRUE S_EDM_Out = FALSE Error = TRUE
C040	EDM Error 21	The signal at EDM1 is not valid in the initial actuator state. In state 8010 the EDM1 signal is FALSE and the monitoring time has elapsed. Ready = TRUE S_EDM_Out = FALSE Error = TRUE

DiagCode	State Name	State Description and Output Setting
C050	EDM Error 22	<p>The signal at EDM2 is not valid in the initial actuator state. In state 8010 the EDM2 signal is FALSE and the monitoring time has elapsed.</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>
C060	EDM Error 23	<p>The signals at EDM1 and EDM2 are not valid in the initial actuator states. In state 8010 the EDM1 and EDM2 signals are FALSE and the monitoring time has elapsed.</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>
C070	EDM Error 31	<p>The signal at EDM1 is not valid in the actuator switching state. In state 8000 the EDM1 signal is TRUE and the monitoring time has elapsed.</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>
C080	EDM Error 32	<p>The signal at EDM2 is not valid in the actuator switching state. In state 8000 the EDM2 signal is TRUE and the monitoring time has elapsed.</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>
C090	EDM Error 33	<p>The signals at EDM1 and EDM2 are not valid in the actuator switching state. In state 8000 the EDM1 and EDM2 signals are TRUE and the monitoring time has elapsed.</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>
C111	Init Error	<p>Similar signals at S_OutControl and Reset (R_TRIG at same cycle) detected (may be a programming error)</p> <p>Ready = TRUE S_EDM_Out = FALSE Error = TRUE</p>

## Configuration and programming

AC500-S Libraries > SafetyBlocks\_PLCOpen\_AC500\_v22.lib

Table 86: FB-specific status codes (no error):

DiagCode	State Name	State Description and Output Setting
0000	Idle	The function block is not active (initial state). Ready = FALSE S_EDM_Out = FALSE Error = FALSE
8001	Init	Block activation startup inhibit is active. Reset required. Ready = TRUE S_EDM_Out = FALSE Error = FALSE
8010	Output Disable	EDM control is not active. Timer starts when state is entered. Ready = TRUE S_EDM_Out = FALSE Error = FALSE
8000	Output Enable	EDM control is active. Timer starts when state is entered. Ready = TRUE S_EDM_Out = TRUE Error = FALSE



## **5 Safety times**

### **5.1 Overview**

Errors in the system may lead to dangerous operating conditions. Potential errors are detected by the safety module background self-tests, which trigger defined error reactions in safety modules to transfer faulty modules into the safe state. In this chapter, we list various safety times for AC500-S components and AC500-S Safety PLC as a system.

## Safety times

Safety function response time

### 5.2 Fault reaction time

Fault reaction time is the maximum time between the appearance of the fault in the system and the trigger of pre-defined error reactions. The table below provides an overview on the longest fault reaction times in AC500-S Safety modules.

Table 87: Fault reaction times in AC500-S Safety modules

Module	Fault reaction time	
	Internal faults (e.g., RAM cell fault)	External faults (e.g., wrong wiring)
SM560-S Safety CPU	< 24 h	Not applicable
DI581-S Safety I/O	< 24 h	< 1.9 s
DX581-S Safety I/O	< 24 h	< 0.5 s
AI581-S Safety I/O	< 24 h	< 0.8 s

Contact ABB technical support for more detailed fault reaction times of various faults, if needed.

### 5.3 Safety function response time

The safety function response time (SFRT) is the time within which the AC500-S Safety PLC in the normal RUN mode must react after an error has occurred in the system.

On the application side, SFRT is the maximum amount of time in which the safety system must respond to a change in the input signals or module failure.

SFRT is one of the most important safety times, because it is used in time-critical safety applications, like presses, to define a proper distance for a light curtain or other safety sensor from the potentially dangerous machine parts.

SFRT for PROFIsafe devices can be defined, based on [8], as :

**Equation 1:**  $SFRT = TWCDT + Longest \Delta T_{WD}$

where

- TWCDT (Total Worst Case Delay Time) is the maximal time for input signal transfer in AC500-S system until the output reaction under worst-case conditions (all components require the maximum time);
- Longest  $\Delta T_{WD}$  is the longest time difference between watchdog time for a given entity and worst case delay time. In safety context, to identify SFRT one has to take into account a potential single fault in one of the components during the signal transfer. It is enough to consider a single fault only [8].

Fig. 126 and Fig. 127 explain SFRT in more details. The model in Fig. 126 and Fig. 127 includes the stages of input signal reading, safe data transfer, safe logic processing, safe data transfer and safe signal output.

#### DANGER!

Input delay, input delay accuracy and test pulse low phase are not needed for AI581-S, however, the worst case fixed internal input delay of 67.5 ms shall be used for AI581-S instead.

## DANGER!

The input delay accuracy has to be calculated based on the following assumptions:

- Not used for safety analog inputs;
- If no test pulses are configured for the given digital safety input, then input delay accuracy can be calculated as 1 % of set input delay value (however, input delay accuracy value must be at least 0.5 ms!)
- If test pulses are configured for the given digital safety input, then depending on the type of the module (DI581-S or DX581-S) and set input delay value, the following input delay accuracy values can be used in SFRT calculations:

The following terms are defined in Fig. 126 and Fig. 127:

- Device\_WD1 is an internal input device watchdog time in ms which includes:
  - Input delay (variable as parameter; not used for safety analog inputs which have an internal input delay of 67.5 ms in the worst case);
  - Input delay accuracy (see tables below)
  - Test pulse low phase (fixed to 1 ms and optional (only if test pulses are used); not used for safety analog inputs);
  - Two times internal cycle time (fixed; AI581-S → 4.5 ms, DX581-S → 5.5 ms and DI581-S → 6.5 ms);
- F\_WD\_Time1 is the first watchdog time in ms for receipt of the new valid telegram (variable as parameter and depends on system configuration);
- F\_Host\_WD is the watchdog time in ms equal to three times of the set value using SF\_WDOG\_TIME\_SET POU (variable as parameter through SF\_WDOG\_TIME\_SET POU and depends on the number of F-Devices, safety application program and system configuration);
- F\_WD\_Time2 is the second watchdog time in ms for receipt of the new valid telegram (variable as parameter and depends on system configuration).
- Device\_WD2 is an internal output device watchdog time in ms which includes:
  - Internal safety output device cycle time (fixed; DX581-S → 5.5 ms);
  - Output processing time (fixed to 1.5 ms);
  - Hardware delay (current dependent, e.g., ~1 ms (747 µs at 5 mA) and the maximum of 4 ms under the maximum output current of 500 mA). If precise values are needed, please contact ABB technical support.

Table 88: DI581-S safety module

Input delay (ms)	Input delay accuracy (ms)
1	2
2	2
5	3
10	4
15	5
30	6
50	7
100	10

## Safety times

Safety function response time

Input delay (ms)	Input delay accuracy (ms)
200	15
500	25

Table 89: DX581-S safety module

Input delay (ms)	Input delay accuracy (ms)
1	2
2	2
5	3
10	4
15	5
30	6
50	10
100	15
200	25
500	50

Below, a few examples on how to calculate SFRT values under various AC500-S system configurations are presented. In our calculations, we use the following approach, based on [3] and [8], which allows us calculating SFRT as:

**Equation 2:**  $SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD$

## ! NOTICE!

↪ *Equation 2, page 398* is taken for SFRT calculation with the following reasoning:

- Device\_WD1 and Device\_WD2 as worst case delay times for Safety I/Os can be directly calculated as it is shown in Fig. 126 and Fig. 127.
- It is not always easy to calculate the worst case delay time of “Black channel” components (see AC500 Non-safety modules in Fig. 126 and Fig. 127). Thus, we propose to use half of F\_WD\_Time1 and F\_WD\_Time2 instead. F\_WD\_Time1 and F\_WD\_Time2 can be empirically obtained for the given AC500 system configuration by tracing the values of tResponseTimeMS for given Safety I/Os in the safety application. Use PROFIsafe instance for the given Safety I/O (↪ *Chapter 4.6.3 “SafetyBase\_PROFIsafe\_AC500\_V22\_Ext.lib” on page 231*). F\_WD\_Time1 and F\_WD\_Time2 shall be set about 30 % higher than the worst case value observed in the tResponseTimeMS for the given Safety I/O.
- We propose to take F\_Host\_WD time instead of the worst case delay time of SM560-S Safety CPU. F\_Host\_WD can be calculated as three times the value set using SF\_WDOG\_TIME\_SET POU. The correct value for SF\_WDOG\_TIME\_SET can be empirically obtained using tracing MAX\_TIME output of the same POU in a test run. SF\_WDOG\_TIME\_SET value shall be set about 30 % higher than the worst case value (MAX\_TIME) observed in the given safety application to avoid potential availability problems due to triggering of SM560-S Safety CPU watchdog.
- F\_WD\_Time1 and F\_WD\_Time2 are the only potential candidates for Longest ΔT\_WD, because F\_Host\_WD, Device\_WD1 and Device\_WD2 are already equal to their worst case delay times. Thus,

$$\text{Longest } \Delta T_{WD} = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2)$$

## ! NOTICE!

One could achieve even better SFRT values than those obtained using ↪ *Equation 2, page 398* with a more detailed technical analysis. Contact ABB technical support for further details.

## ! NOTICE!


You have to set F\_WD\_Time1 and F\_WD\_Time2 at least 2 times bigger than the value set using SF\_WDOG\_TIME\_SET time to avoid unintended system stop due to PROFIsafe watchdog expiration.

## Safety times

Safety function response time

### **DANGER!**

For safety time critical applications, one has to take into account that AC500-S Safety I/O modules satisfy the requirement of IEC 61131 (PLC standard) to bypass a potential undervoltage event with a duration of up to 10 ms. During this undervoltage effect of up to 10 ms, AC500-S Safety I/O modules deliver the last valid process value before the undervoltage was detected for safety analog input channels in AI581-S and actual safety digital input and output values for DI581-S and DX581-S modules.

If the undervoltage phase is longer than 10 ms then module passivation occurs (  *Chapter 3.2.3 "Undervoltage/Overvoltage" on page 70*).

End-users, who are not satisfied with the undervoltage detection approach described above (e.g., undervoltage events with duration of < 10 ms are frequently observed in their application), have to add 10 ms for AI581-S module in their SFRT calculation to take into account a bypass stage described above. Normally, periodic undervoltage events with duration of < 10 ms are considered to be low probability faults in the power supply of the safety system and shall not be included in the SFRT calculation.

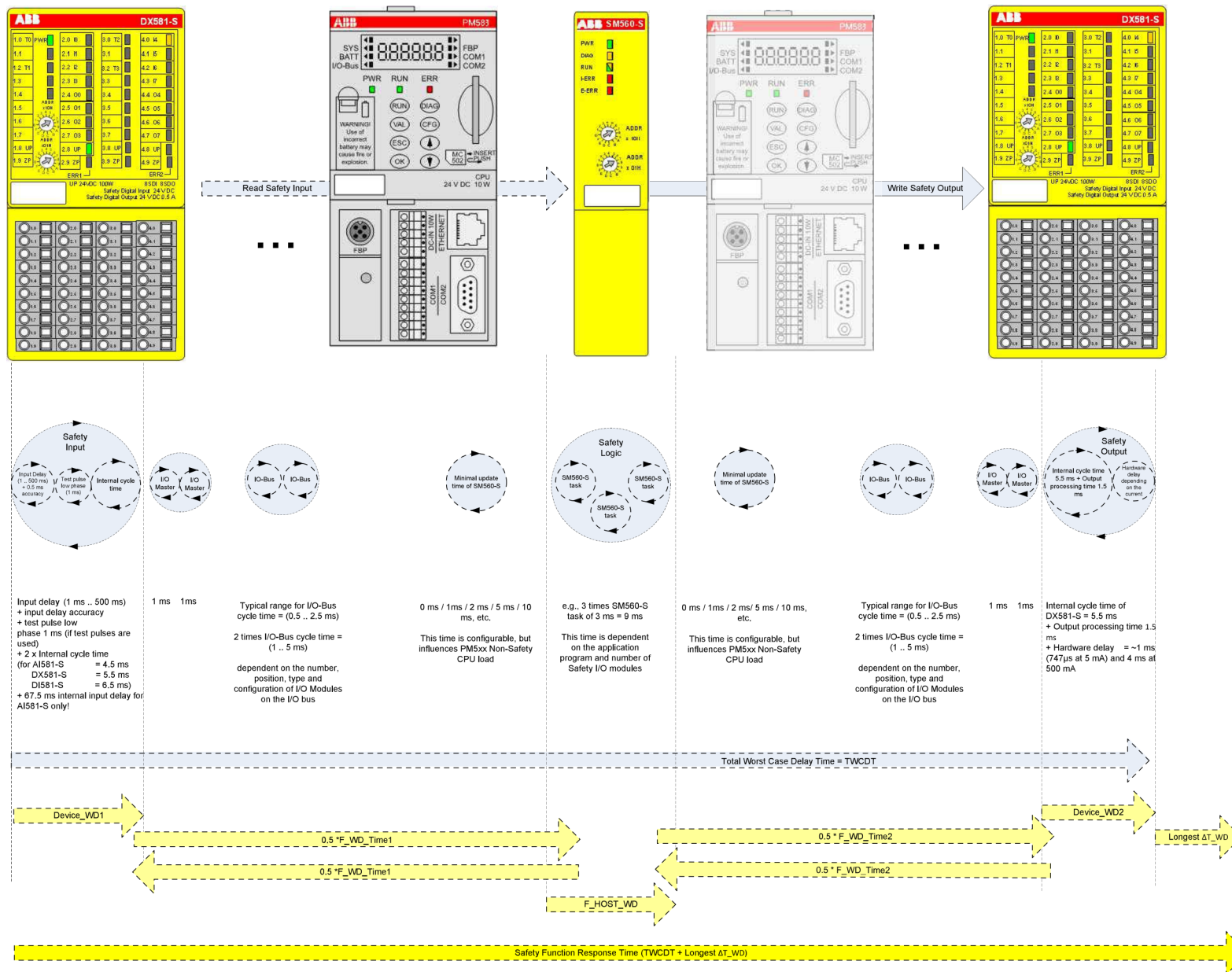


Fig. 126: SFRT in AC500-S system without PROFINET components

# Safety times

## Safety function response time

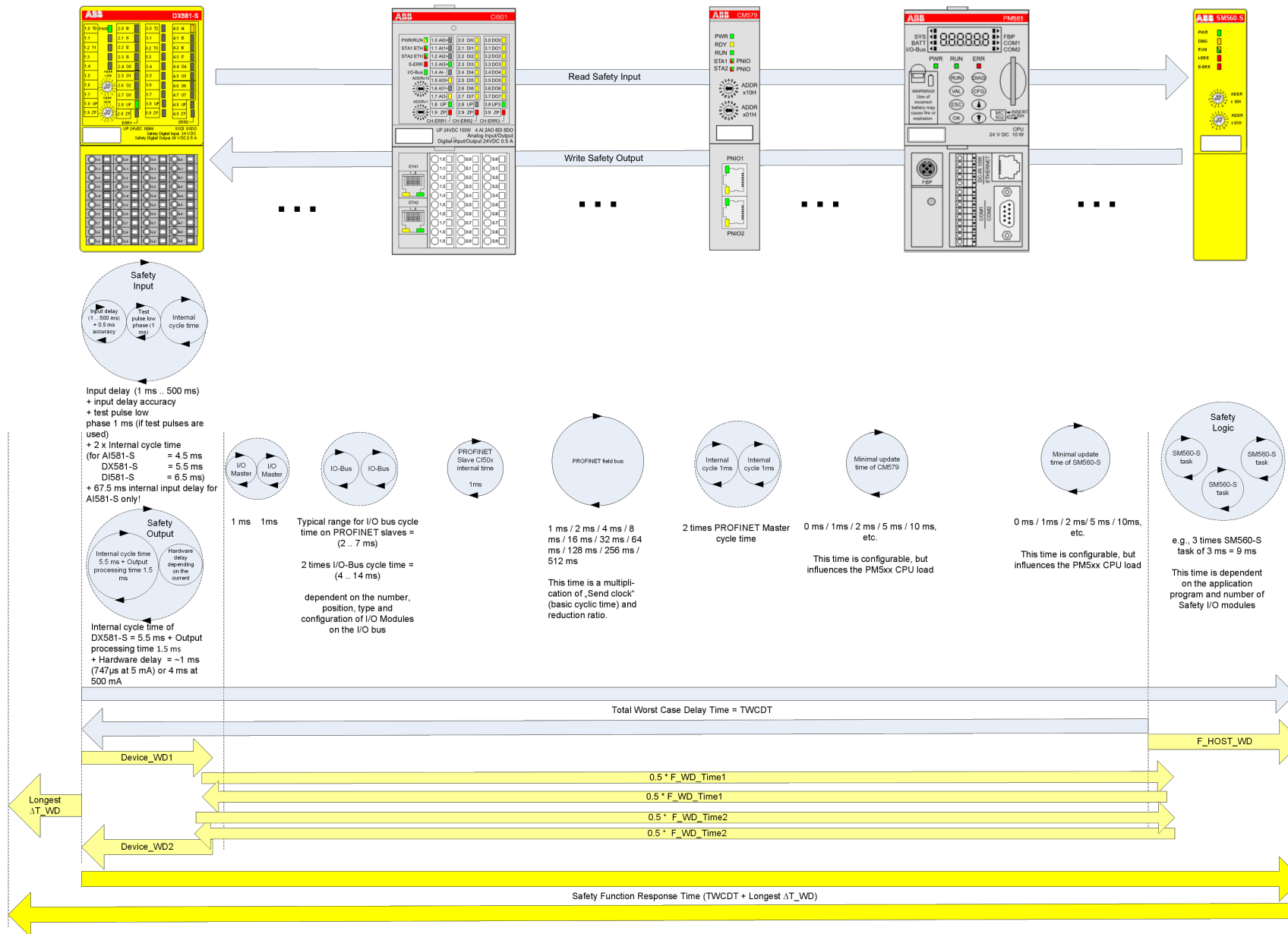


Fig. 127: SFRT in AC500-S system with PROFINET components



Based on Fig. 126 and Fig. 127, the following exemplary SFRT values can be achieved for some typical AC500-S configurations using [Equation 2, page 396](#):

## Without PROFINET (DI581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD$   
 $\Delta T\_WD = 14.5 + 10 + 6 + 10 + 8 + 10 = 58.5 \text{ ms}$

where:

- $Device\_WD1 = 1 \text{ ms} + 0.5 \text{ ms} + 2 \times 6.5 \text{ ms} = 14.5 \text{ ms}$  (no test pulses were used)
- $F\_WD\_Time1 = 20 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms
- $F\_WD\_Time2 = 20 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2) = 10 \text{ ms}$

## Without PROFINET (DX581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD$   
 $\Delta T\_WD = 12.5 + 10 + 6 + 10 + 8 + 10 = 56.5 \text{ ms}$

where:

- $Device\_WD1 = 1 \text{ ms} + 0.5 \text{ ms} + 2 \times 5.5 \text{ ms} = 12.5 \text{ ms}$  (no test pulses were used)
- $F\_WD\_Time1 = 20 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms
- $F\_WD\_Time2 = 20 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2) = 10 \text{ ms}$

## Without PROFINET (AI581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD$   
 $\Delta T\_WD = 76.5 + 10 + 6 + 10 + 8 + 10 = 120.5 \text{ ms}$

where:

- $Device\_WD1 = 2 \times 4.5 \text{ ms} + 67.5 \text{ ms} = 76.5 \text{ ms}$
- $F\_WD\_Time1 = 20 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms
- $F\_WD\_Time2 = 20 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2) = 10 \text{ ms}$

## With PROFINET (DI581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD$   
 $\Delta T\_WD = 14.5 + 15 + 6 + 15 + 8 + 15 = 73.5 \text{ ms}$

where:

- $Device\_WD1 = 1 \text{ ms} + 0.5 \text{ ms} + 2 \times 6.5 \text{ ms} = 14.5 \text{ ms}$  (no test pulses were used)
- $F\_WD\_Time1 = 30 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms

## Safety times

Safety function response time

- $F\_WD\_Time2 = 30 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2) = 15 \text{ ms}$

### With PROFINET (DX581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD = 12.5 + 15 + 6 + 15 + 8 + 15 = 71.5 \text{ ms}$

where:

- $Device\_WD1 = 1 \text{ ms} + 0.5 \text{ ms} + 2 \times 5.5 \text{ ms} = 12.5 \text{ ms}$  (no test pulses were used)
- $F\_WD\_Time1 = 30 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms
- $F\_WD\_Time2 = 30 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = (\text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2)) = 15 \text{ ms}$

### With PROFINET (AI581-S → SM560-S → DX581-S)

$SFRT = Device\_WD1 + 0.5 * F\_WD\_Time1 + F\_Host\_WD + 0.5 * F\_WD\_Time2 + Device\_WD2 + Longest \Delta T\_WD = 76.5 + 15 + 6 + 15 + 8 + 15 = 135.5 \text{ ms}$

where:

- $Device\_WD1 = 2 \times 4.5 \text{ ms} + 67.5 \text{ ms} = 76.5 \text{ ms}$
- $F\_WD\_Time1 = 30 \text{ ms}$
- $F\_Host\_WD = 3 \times 2 \text{ ms}$  (SF\_WDOG\_TIME\_SET time) = 6 ms
- $F\_WD\_Time2 = 30 \text{ ms}$
- $Device\_WD2 = 8 \text{ ms}$  (output current = ~ 5 mA)
- $Longest \Delta T\_WD = \text{Max} (0.5 * F\_WD\_Time1; 0.5 * F\_WD\_Time2) = 15 \text{ ms}$



### DANGER!

Mistakes in SFRT calculation can lead to death or severe personal injury, especially in such applications like presses, robotic cells, etc.



### NOTICE!

The high priority tasks on PM5xx Non-safety CPU ("Black channel" for safety communication) may affect SFRT for SM560-S Safety CPU and Safety I/O modules.

## 6 Checklists for AC500-S Commissioning

### 6.1 Overview

All users of AC500-S Safety PLC shall evaluate items from the checklists presented in this Chapter for AC500-S commissioning and document those in their final reports.

The items presented in the checklists include only the most important ones from AC500-S Safety PLC perspective, which means that AC500-S checklists can be also extended by users to include additional aspects important for their safety applications.

## Checklists for AC500-S Commissioning

Checklist for creation of safety application program

### 6.2 Checklist for creation of safety application program

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
1.	Verify that only safety signals are used for all safety functions.		
2.	<p>Verify that not only safety application project is loaded to SM560-S Safety CPU but also the relevant non-safety application project is loaded to PM5xx Non-safety CPU.</p> <p>Verify that programs are saved from RAM memory to the Flash memory.</p> <p>("Create boot project") is done.</p>		
3.	Verify that F-Parameters for all Safety I/Os and other F-Devices set in F-Parameter Editor are the same as those listed in CoDeSys Safety, see Global Variables / PROFIsafe ( ↗ Chapter 4 "Configuration and programming" on page 165).		
4.	<p>F_Source_Add is the virtual address (different to F_Device_Add which is also physical). F-Host can handle more than one F_Source_Add, if required, e.g., for PROFIsafe Master - Master coupling of different network islands. Verify that no ambiguous F_Source_Add settings for various F-Devices were set for the given safety application.</p> <p><i>Note:</i></p> <p><i>The rule "F_Source_Add &lt;&gt; F_Dest_Add for the given F-Device" is automatically checked by PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer).</i></p>		
5.	<p>Validate iParameters. Two options are available:</p> <p>A) Validate that all iParameters (Input delay, channel configuration, etc.) for all Safety I/Os and other F-Devices are correct with a given F_iPar_CRC value using appropriate functional validation tests for those parameters (contact ABB technical support if questions arise)</p> <p>or</p> <p>B) Use a special verification procedure defined in ↗ Chapter 6.5 "Verification procedure for safe iParameter setting in AC500-S Safety I/Os" on page 412 to validate each iParameter and then carry out only functional safety validation tests of your application (no need to check each single iParameter value). You have to provide a report confirming that all iParameters were checked as described in ↗ Chapter 6.5 "Verification procedure for safe iParameter setting in AC500-S Safety I/Os" on page 412.</p> <p>Make sure that all F_iPar_CRC are &gt; 0.</p>		

## Checklists for AC500-S Commissioning

Checklist for creation of safety application program

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
6.	Verify that CoDeSys safety programming guidelines were properly used in the safety application program.		
7.	All signals from the standard user program on PM5xx, which are evaluated in the safety program on SM560-S, have to be included when the safety application program is printed out.		
8.	Has a review of the safety application program been carried out by a person not involved in the program creation?		
9.	Has the result of the safety application program review been documented and released (date/ signature)?		
10.	<p>Was a backup of the complete Safety (see below) and Non-safety project created before loading a program in CPUs?</p> <p><i>Note:</i></p> <ul style="list-style-type: none"> <li>■ <i>Make sure that File name, Change date, Title, Author, Version, Description and CRC of the CoDeSys Safety boot project are documented as a backup.</i></li> <li>■ <i>No further changes are allowed for Safety parts in PS501 Control Builder Plus / ABB Automation Builder project and CoDeSys Safety. If any changes are still done, then they will lead to a new CoDeSys Safety boot project CRC, which will require re-doing this checklist from the beginning.</i></li> </ul>		
11.	Verify using CoDeSys Safety menu item "Online → Check boot project in PLC" that offline CoDeSys safety project and the boot project on the Safety CPU are identical (File name, Change date, Title, Author, Version, Description and CRC).		
12.	If floating-point operations and data types are used, verify that rules presented in <a href="#">Chapter 3.1.2.2 "Floating-point operations"</a> on page 33 are taken into account and do not lead to any unsafe states in the safety application program.		
13.	Verify that POU SF_WDOG_TIME_SET is called once in the safety application program and the watchdog time is correctly selected.		
14.	Verify that a password for SM560-S Safety CPU is set to prevent an unauthorized access to its data.		
15.	Verify that only authorized personnel has "Write" access for Safety module parameter settings and programs in PS501 Control Builder Plus / ABB Automation Builder and CoDeSys Safety projects.		

## Checklists for AC500-S Commissioning

Checklist for creation of safety application program

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
16.	Verify that correct value for power supply supervision using POU SF_MAX_POWER_DIP_SET was set to have a correct system behaviour in case of under- or overvoltage.		
17.	Verify that POU SF_SAFETY_MODE is correctly used in the safety application program to avoid unintended safety program execution in DEBUG (Run) non-safety mode.		
18.	<p>Verify that no “Update Device ...”, Export/Import, Copy/Paste and Archive related functions in PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer) were executed on Safety modules after the project was validated.</p> <p>If the functions mentioned above were used and this lead to a CoDeSys safety boot project with a new CRC, then a full functional testing of all parts of the safety-oriented application has to be performed. This test must be carried out with the machine in its final configuration including mechanical, electrical and electronic components, sensors, actuators, and software.</p>		
19.	Verify using library CRC, shown in CoDeSys Safety, that only TÜV certified safety libraries with correct CRCs ( ↗ Chapter 4.6.1 “Overview” on page 224) are used in the given CoDeSys Safety project to execute safety functions. All other user-defined libraries have to be separately validated by the end-user to qualify for the given safety application.		
20.	Make sure that internal POUs from SafetyUtil_CoDeSys_AC500_V22.lib and internal actions from SafetyBase_PROFIsafe_AC500_V22_Ext.lib (or older versions) are not called by end-user program, which starts from PLC_PRG as the main root.		
21.	Make sure that all three system events (“CallbackInit”, “CallbackReadInputs” and “CallbackWriteOutputs”) in “Resources → Task configuration → System Events” of CoDeSys Safety remain selected.		

## Checklists for AC500-S Commissioning

Checklist for configuration and wiring

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
22.	If the Flash memory content (SF_FLASH_READ and/or SF_FLASH_WRITE FBs are called in the safety application) is used in the safety application for safety functions, then appropriate Flash memory content validation procedures (e.g., proper safety application CRC over stored safety data) shall be implemented to ensure safety application data integrity before Flash memory data are used in safety functions.		

Reviewer(s):

Machine/Application <ID>:

Signature:

Date:

### 6.3 Checklist for configuration and wiring

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
1.	Are all safety input and output signals correctly configured and are the output signals connected to physical output channels?		
2.	Verify that SM560-S switch addresses 0xF0 ... 0xFF are not used for SM560-S identification (e.g., PROFI-safe address).		
3.	Verify that special organisational procedures (e.g., limited access to the cabinet where Safety CPU is located) on the end-customer site are defined to avoid unintended firmware and/or boot code update on SM560-S Safety CPU using SD card.		
4.	Verify that correct parameter settings <i>"Behaviour of Outputs in Stop"</i> , <i>"Stop on error class"</i> and <i>"Warmstart on E2"</i> of PM5xx Non-safety CPU are used for the given safety application.		
5.	Verify that required Safety Function Response Time of your Safety application can be satisfied with current AC500-S Safety PLC settings and your SFRT calculation is done based on chapter <a href="#">Chapter 5.3</a> <i>"Safety function response time"</i> on page 396.		
6.	Verify that none of safety output channels has a configuration with "Detection" parameter = OFF, which reduces safety diagnostics for such safety output channels. If such configuration is used, explain in the "Comment" section of this checklist your reasons and claim that the required application SIL and PL levels can be reached with such configuration.		

## Checklists for AC500-S Commissioning

Checklist for operation, maintenance and repair

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
7.	Verify that: <ul style="list-style-type: none"> <li>■ Address setting is correct</li> <li>■ Assignment of signal inputs is complete</li> <li>■ Assignment of signal outputs is complete</li> <li>■ Assignment of unused inputs is complete</li> <li>■ All terminal blocks are plugged</li> </ul>		
8.	Verify that correct firmware versions are used for dependent non-safety components, like CM579-PNIO (V2.6.5.1 or higher), CI50x (V3.2.0 or higher) and PM5xx CPUs (V2.2.1 or higher).  Contact ABB technical support if needed.		
Reviewer(s): Machine/Application <ID>: Signature: Date:			

### 6.4 Checklist for operation, maintenance and repair

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
1.	Make sure that all Safety modules are properly placed on their positions at the terminal base (Safety CPU) or terminal units (Safety I/Os) and stable contact between terminals and safety modules is assured.		
2	Check that proper temperature monitoring measures (e.g., temperature sensors could be placed in the control cabinet and connected to AI581-S safety analog input channels) are implemented in the control cabinet where AC500-S safety modules are placed, if the operating temperature range for AC500-S Safety PLC cannot be guaranteed.  <i>Note:</i>  <i>Safety digital outputs of DX581-S module have internal built-in overtemperature protection and always deliver fail-safe "0" values in case of overtemperature.</i>		



## Checklists for AC500-S Commissioning

Checklist for operation, maintenance and repair

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
3.	<p>Make sure that the following rule, as defined by PRO-FIsafe standard (refer to <a href="http://www.profisafe.net">www.profisafe.net</a> for more details), was considered in the safety application analysis:</p> <ul style="list-style-type: none"> <li>■ A maximum of 10 communication links (i.e., PRO-FIsafe connections from the given safety input to the given safety output) per safety function is permitted for an average probability of a dangerous failure of <math>10^{-9}/h</math> (SIL3). In case of more than 10 communication links per safety function, the probability of a dangerous failure increases by <math>10^{-10}/h</math> per additional communication link. Correspondingly, a maximum of 100 communication links is permitted in case of SIL2.</li> </ul>		
4.	<p>Make sure that all network devices used in conjunction with AC500-S Safety PLC meet the requirements of IEC 61010 or IEC 61131-2 (e.g., PELV). Single port routers are not permitted as borders for a safety island.</p> <p>↳ [3] for further details</p>		
5	<p>Before any deployment of a safety application with PROFIsafe, especially those using wireless components, an assessment for dangerous threats such as eavesdropping or data manipulation shall be executed ( ↳ [11] for more details). Check that adequate level of security defining security zones with security gates was established.</p> <p>In case of no threat, no security measures are necessary.</p> <p><i>Note:</i></p> <p><i>There are two possible threats identified so far mainly for applications with wireless components [3]:</i></p> <ul style="list-style-type: none"> <li>■ <i>Willful changes of parameters of F-Devices and safety programs;</i></li> <li>■ <i>Attacks on the cyclic communication, e.g., simulation of the safety communication.</i></li> </ul>		
6.	<p>The complete functional testing of all parts of the safety-oriented application has to be performed. This test must be carried out with the machine in its final configuration including mechanical, electrical and electronic components, sensors, actuators, and software.</p>		

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os

Nr.	Item to check	Fulfilled (Yes / No)?	Comment
7.	<p>Verify that clear operation, maintenance and repair procedures (organisation, responsibility, spare parts, project data backup, etc.) for safety application are defined.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>Restart of the corresponding safety control loop is only permitted, if there is no hazardous process state, and after an operator acknowledgement (OA_C).</li> </ul> <p>🔗 [3] for further details</p>		
8.	<p>Verify that proper electrical contact is available between Safety I/O modules (AI581-S, DI581-S and DX581-S) and TU582-S terminal units. To do this, after properly attaching Safety I/O modules to TU582-S terminal units, press each Safety I/O module into the TU582-S terminal unit with a force of at least 100 Newton.</p>		
9.	<p>Ensure that average operating temperature for used Safety modules (AC500-S and AC500-S-XC) does not exceed 40 °C (e.g., temperature sensors could be placed in the control cabinet and connected to AI581-S safety analog input channels for temperature monitoring).</p>		
10.	<p>Verify that no automatic reboot of PM5xx Non-safety CPU is programmed in CoDeSys Non-safety program. The automatic reboot of PM5xx would lead to automatic restart of SM560-S Safety CPU, which is directly attached to PM5xx. Such automatic restart of SM560-S Safety CPU may not be accepted in some safety applications.</p>		

Reviewer(s):

Machine/Application <ID>:

Signature:

Date:

### 6.5 Verification procedure for safe iParameter setting in AC500-S Safety I/Os

This verification procedure has to be performed before commissioning of the final safety application and relevant validation tests to confirm that F\_iPar\_CRC was calculated for a correct set of iParameters.

### 6.5.1 Verification procedure workflow

**Personnel:**

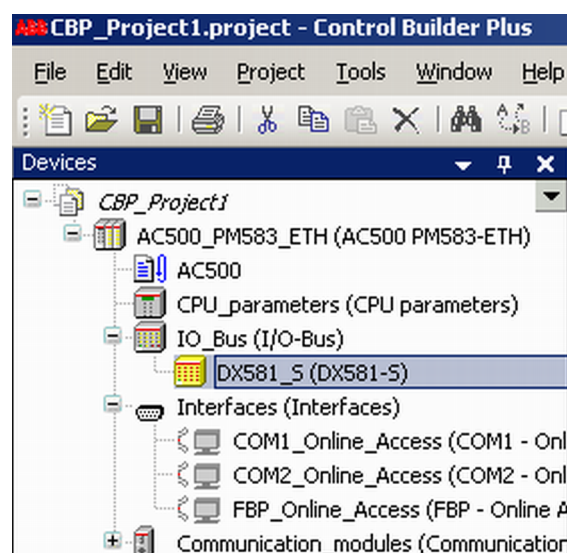
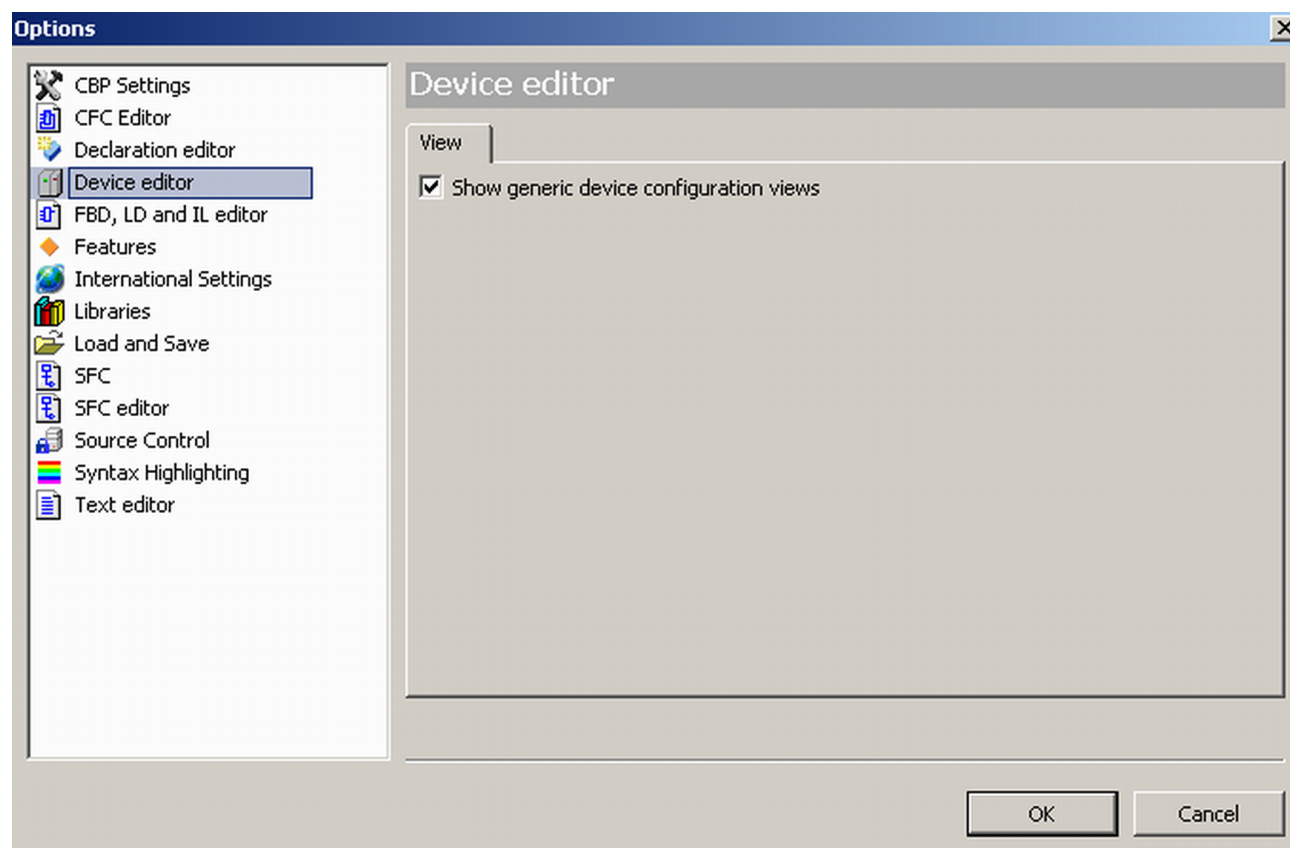
- Safety application engineer of AC500-S Safety PLC

All required steps for verification procedure are described below:

1. ➤ Go to “*Tools/Options...*” and activate “*Show generic device configuration views*” and instantiate a given type of Safety I/O module (AI581-S, DI581-S or DX581-S) in the PS501 Control Builder Plus V2.2.1 (or newer) / Automation Builder 1.0 (or newer) tree (DX581-S is used as an example):

## Checklists for AC500-S Commissioning

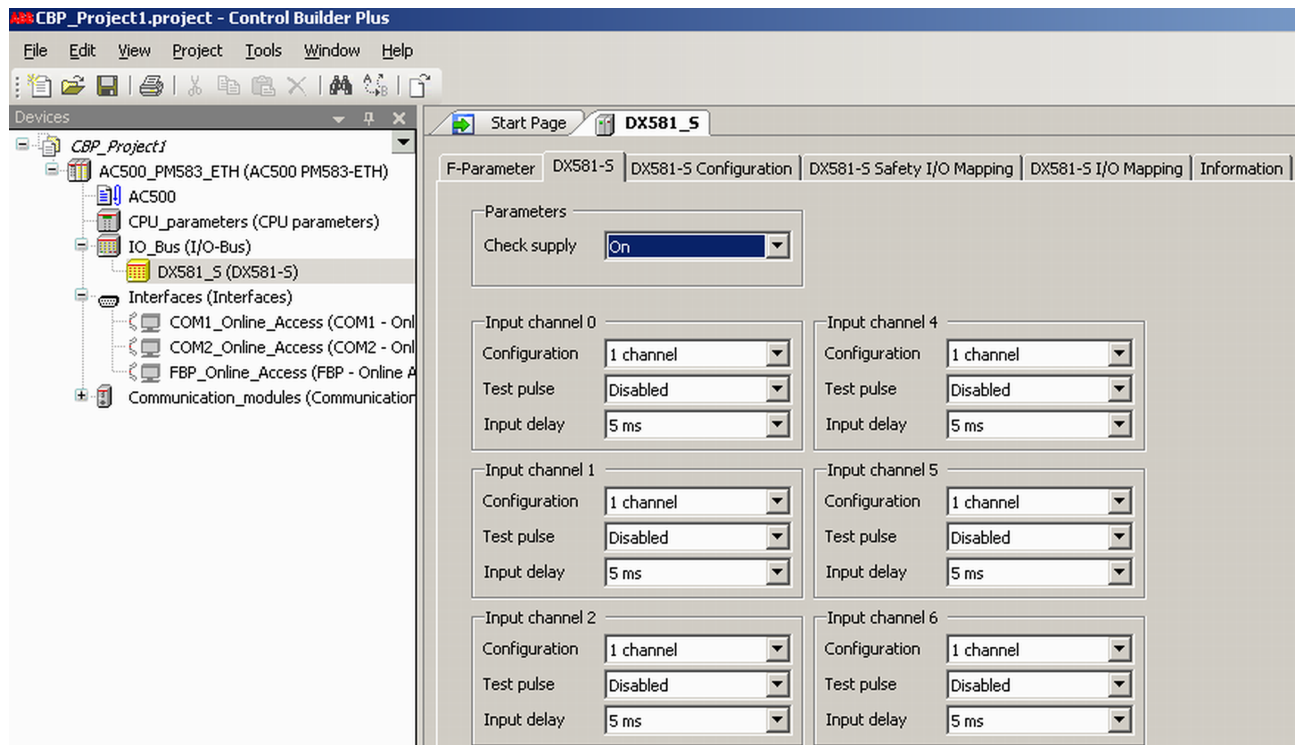
Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification procedure workflow



2. Go to the iParameter setting tab (DX581-S, DI581-S or AI581-S respectively) for the given module and set appropriate iParameter values (e.g., "Test Pulse", "Input Delay", etc.).

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification procedure workflow



3. Verify against your safety application technical specification that all iParameters for all Safety I/O channels are set correctly.
4. Go to F-Parameter tab and press “*Calculate*” button. Copy calculated F\_iPar\_CRC value from the “Checksum iParameter” field and paste it to F\_iPar\_CRC field of the F-Parameter editor (see below).

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification procedure workflow

F-Parameter DX581-S DX581-S Configuration DX581-S Safety I/O Mapping DX581-S I/O Mapping Information

F-Parameters for safety device

Checksum F-Parameter: 2893

Checksum iParameter: 1356340128

Name	Value	Symbolic-Value	Description	Unit
F_Check_SeqNr	1	Check	Consecutive numb...	
F_Check_iPar	0	No Check	Check of manufac...	
F_SIL	2	SIL3	Employed SIL of t...	
F_CRC_Length	0	3 octet CRC	Cyclic redundancy...	
F_Block_ID	1	F_iPar_CRC in F-P...	Parameter block t...	
F_Par_Version	1	Valid for V2 mode	Version of safety ...	
F_Source_Add	1	1	Safety device sou...	
F_Dest_Add	3	3	Safety device des...	
F_WD_Time	300	300	Watchdog time in ... ms	
F_iPar_CRC	1356340128	1356340128	Value of the iPara...	
F_Par_CRC	2893	2893	Value of the safet...	

**Edit Parameter**

Parameter: F\_iPar\_CRC

Maximum Value: 4294967295

Minimum Value: 0

Value:

⇒ F\_iPar\_CRC value is safely saved now.

- Go to "DX581-S Configuration", "DI581-S Configuration" or "AI581-S Configuration" tabs, respectively, and verify using a cross-check according to *Chapter 6.5.2 "Verification tables for iParameter settings in AC500-S Safety I/Os" on page 417* that iParameter settings previously set at Step 2 are the same as ones listed in the "Value" column for given channels (use *Chapter 6.5.2 "Verification tables for iParameter settings in AC500-S Safety I/Os" on page 417* to decode integer values to real parameter values).

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S

Safety I/Os

F-Parameter	DX581-S	DX581-S Configuration	DX581-S Safety I/O Mapping	DX581-S I/O Mapping	Information
Parameter	Type	Value	Default Value	Unit	Description
Check supply	Enumeration of BYTE	On	On		Check supply
Input 0, channel configuration	BYTE	49	48		Input 0, channel configuration
Input 1, channel configuration	BYTE	49	48		Input 1, channel configuration
Input 2, channel configuration	BYTE	49	48		Input 2, channel configuration
Input 3, channel configuration	BYTE	49	48		Input 3, channel configuration
Input 4, channel configuration	BYTE	49	48		Input 4, channel configuration
Input 5, channel configuration	BYTE	49	48		Input 5, channel configuration
Input 6, channel configuration	BYTE	49	48		Input 6, channel configuration
Input 7, channel configuration	BYTE	49	48		Input 7, channel configuration
Inputs 0/4, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 0/4, discrepancy time
Inputs 1/5, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 1/5, discrepancy time
Inputs 2/6, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 2/6, discrepancy time
Inputs 3/7, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 3/7, discrepancy time
Output 0, channel configuration	BYTE	193	65		Output 0, channel configuration
Output 1, channel configuration	BYTE	193	65		Output 1, channel configuration
Output 2, channel configuration	BYTE	193	65		Output 2, channel configuration
Output 3, channel configuration	BYTE	193	65		Output 3, channel configuration
Output 4, channel configuration	BYTE	193	65		Output 4, channel configuration
Output 5, channel configuration	BYTE	193	65		Output 5, channel configuration
Output 6, channel configuration	BYTE	193	65		Output 6, channel configuration
Output 7, channel configuration	BYTE	193	65		Output 7, channel configuration

6. Go to F-Parameter tab and press “Calculate” button once more, even if the previous value is still available. Compare that the value shown in “Checksum iParameter” field and the one in F\_iPar\_CRC field of the F-Parameter editor are the same.

⇒ If F\_iPar\_CRC values are the same, then the verification procedure for given iParameter settings of the given AC500-S Safety I/O module **was successfully passed**.

### Important!

- If any errors (F\_iPar\_CRC or iParameters are not equal) were identified during Steps 1 ... 6, then one has to re-do the same procedure from the beginning. If after this second repetition there is still inconsistency, contact ABB technical support for help.
- Note, if iParameters values were verified as described in Steps 1 ... 6, you can reuse this iParameter combination with the given F\_iPar\_CRC for further modules of the same type without repeating the verification procedure described above.

### 6.5.2 Verification tables for iParameter settings in AC500-S Safety I/Os

The instructions below provide a basis for cross-check of values set for iParameters in “AI581-S”, “DI581-S” and “DX581-S” tabs.

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S Safety I/Os

### 6.5.2.1 AI581-S Safety I/O tables

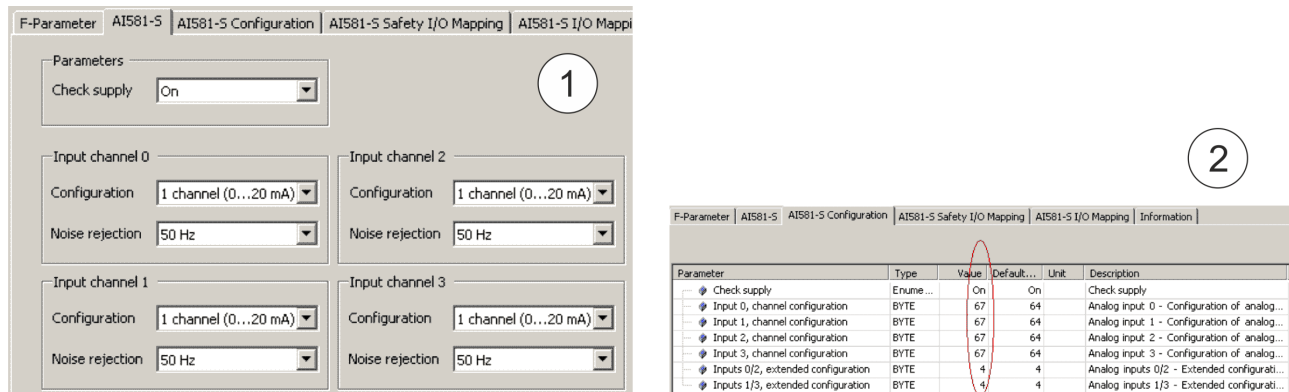


Fig. 128: The “AI581-S Configuration” Tab is a readback view for iParameters set in “AI581-S” Tab.

1 “AI581-S” Tab

2 “AI581-S Configuration” Tab

1. Compare that “Check supply” parameters have the same values “On” or “Off” (English settings) in both “AI581-S” and “AI581-S Configuration” tabs.

2. Refer to “AI581-S” tab and calculate “Input channel 0” decimal equivalent (**Dec\_InputChannel0**) as:

$$\text{Dec\_InputChannel0} = \text{Configuration\_Value} + \text{Noise\_Rejection\_Value}$$

where:

**Configuration\_Value:**

0 → Not used

3 → 1 channel (0 ... 20 mA)

4 → 1 channel (4 ... 20 mA)

5 → 2 channel (4 ... 20 mA)

**Noise\_Rejection\_Value:**

0 → None

64 → 50 Hz

128 → 60 Hz

Compare calculated **Dec\_InputChannel0** (↩ step 2) with “Input 0, channel configuration value”. They have to be equal.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

3. Repeat step 2 for the rest of analog input channels (Input 1, Input 2 and Input 3).

4. Refer to “AI581-S” tab and calculate “Analog inputs 0/2 – Extended configuration” decimal equivalent (**Dec\_ExtConf0\_2**) as:

$$\text{Dec\_ExtConf0\_2} = \text{Tolerance\_Range\_Value} + \text{Min\_Max\_Value}$$

where

**Tolerance\_Range\_Value:**

4 → 4 %



5 → 5 %

6 → 6 %

7 → 7 %

8 → 8 %

9 → 9 %

10 → 10 %

11 → 11 %

12 → 12 %

**Min\_Max\_Value:**

0 → Min

128 → Max

Compare calculated **Dec\_ExtConf0\_2** (↺ Step 5) with “**Analog inputs 0/2 – Extended configuration**”. They have to be equal.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

- 5.** ➡ Repeat step 4 for “Analog inputs 1/3 – Extended configuration” value.

# Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S Safety I/Os

## 6.5.2.2 DI581-S Safety I/O tables

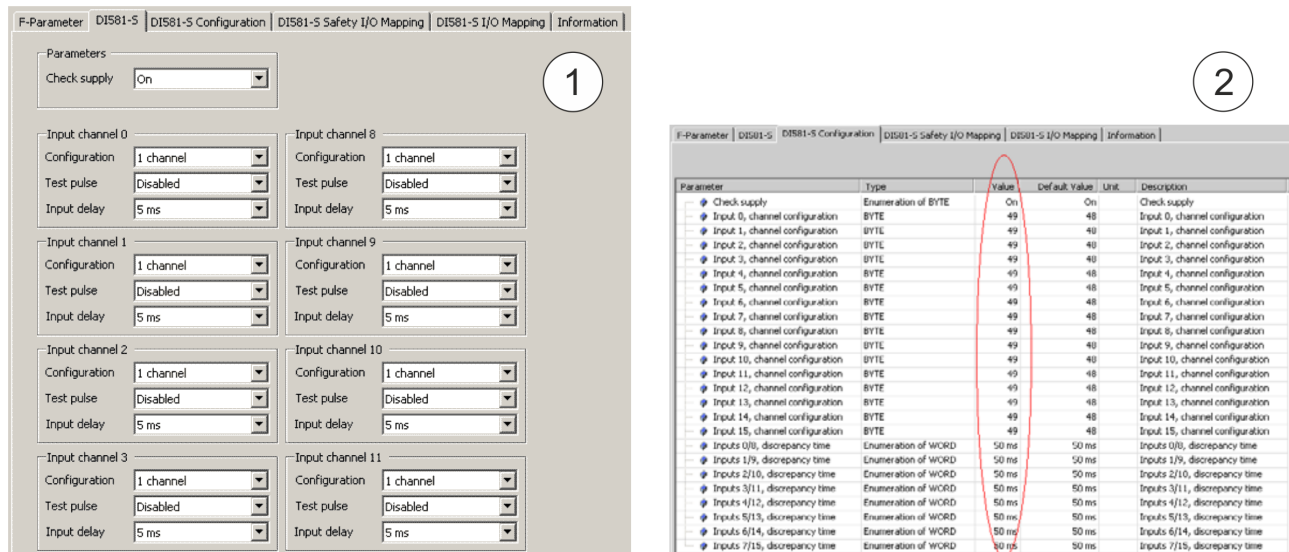


Fig. 129: The "DI581-S Configuration" Tab is a readback view for iParameters set in "DI581-S" Tab.

1 "DI581-S" Tab

2 "DI581-S Configuration" Tab

1. Compare that "Check supply" parameters have the same values "On" or "Off" (English settings) in both "DI581-S" and "DI581-S Configuration" tabs.

2. Refer to "DI581-S" tab and calculate "Input channel 0" decimal equivalent (**Dec\_InputChannel0**) as:

$$\text{Dec\_InputChannel0} = \text{Configuration\_Value} + \text{Test\_Pulse\_Value} + \text{Input\_Delay\_Value}$$

where

**Configuration\_Value:**

0 → Not used

1 → 1 channel

2 → 2 channel equivalent

3 → 2 channel antivalent

**Test\_Pulse\_Value:**

0 → Disabled

8 → Enabled

**Input\_Delay\_Value:**

16 → 1 ms

32 → 2 ms

48 → 5 ms

64 → 10 ms

80 → 15 ms

96 → 30 ms

112 → 50 ms

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S

Safety I/Os

128 → 100 ms

144 → 200 ms

160 → 500 ms

Compare calculated **Dec\_InputChannel0** (↪ step 2) with **“Input 0, channel configuration value”**. They have to be equal.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

3. Repeat step 2 for the rest of digital input channels (Input 1, Input 2, ... Input 15).

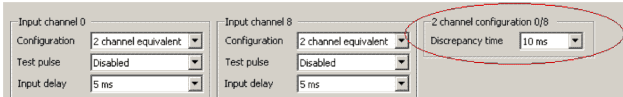
4. Compare that “2 channel configuration 0/8” parameter in “DI581-S” tab have the same value as “Inputs 0/8, discrepancy time” parameter in “DI581-S Configuration” tab.

The values have to be the same.

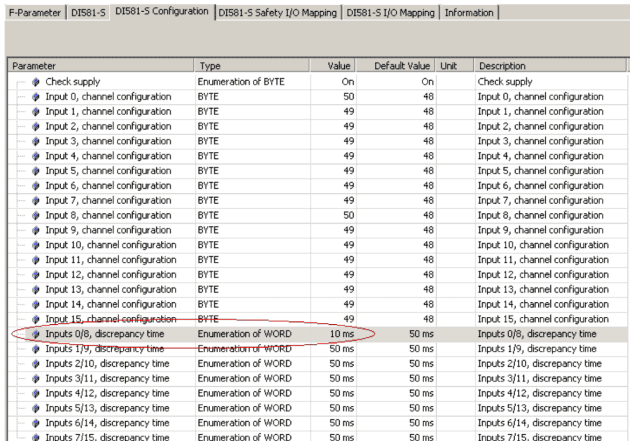
If they are not the same, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

1



2



Parameter	Type	Value	Default Value	Unit	Description
Check supply	Enumeration of BYTE	On	On		Check supply
Input 0, channel configuration	BYTE	50	48		Input 0, channel configuration
Input 1, channel configuration	BYTE	49	48		Input 1, channel configuration
Input 2, channel configuration	BYTE	49	48		Input 2, channel configuration
Input 3, channel configuration	BYTE	49	48		Input 3, channel configuration
Input 4, channel configuration	BYTE	49	48		Input 4, channel configuration
Input 5, channel configuration	BYTE	49	48		Input 5, channel configuration
Input 6, channel configuration	BYTE	49	48		Input 6, channel configuration
Input 7, channel configuration	BYTE	49	48		Input 7, channel configuration
Input 8, channel configuration	BYTE	50	48		Input 8, channel configuration
Input 9, channel configuration	BYTE	49	48		Input 9, channel configuration
Input 10, channel configuration	BYTE	49	48		Input 10, channel configuration
Input 11, channel configuration	BYTE	49	48		Input 11, channel configuration
Input 12, channel configuration	BYTE	49	48		Input 12, channel configuration
Input 13, channel configuration	BYTE	49	48		Input 13, channel configuration
Input 14, channel configuration	BYTE	49	48		Input 14, channel configuration
Input 15, channel configuration	BYTE	49	48		Input 15, channel configuration
Inputs 0/8, discrepancy time	Enumeration of WORD	10 ms	50 ms		Inputs 0/8, discrepancy time
Inputs 1/9, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 1/9, discrepancy time
Inputs 2/10, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 2/10, discrepancy time
Inputs 3/11, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 3/11, discrepancy time
Inputs 4/12, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 4/12, discrepancy time
Inputs 5/13, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 5/13, discrepancy time
Inputs 6/14, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 6/14, discrepancy time
Inputs 7/15, discrepancy time	Enumeration of WORD	50 ms	50 ms		Inputs 7/15, discrepancy time

Fig. 130: Compare “DI581-S” tab and “DI581-S Configuration” tab

1 “2 channel configuration 0/8” parameter in “DI581-S” tab

2 “Inputs 0/8, discrepancy time” parameter in “DI581-S Configuration” tab

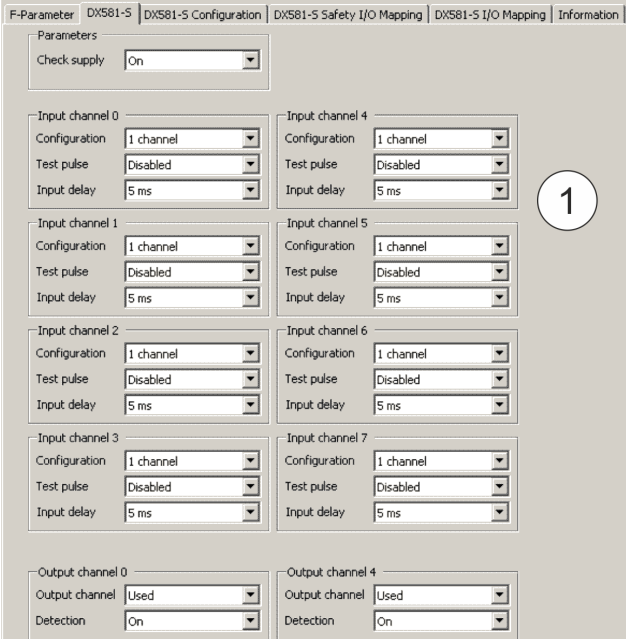
5. Repeat step 4 for the rest of channel combinations:

- Inputs 1/9, discrepancy time
- Inputs 2/10, discrepancy time
- Inputs 3/11, discrepancy time
- Inputs 4/12, discrepancy time
- Inputs 5/13, discrepancy time
- Inputs 6/14, discrepancy time
- Inputs 7/15, discrepancy time

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S Safety I/Os

### 6.5.2.3 DX581-S Safety I/O tables



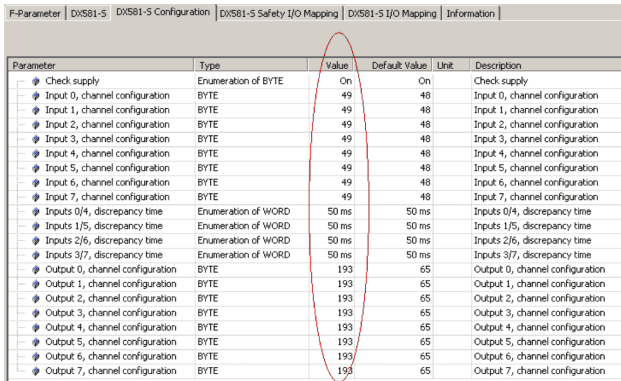


Fig. 131: The “DX581-S Configuration” Tab is a readback view for iParameters set in “DX581-S” Tab.

- 1 “DX581-S” Tab
- 2 “DX581-S Configuration” Tab

1. Compare that “Check supply” parameters have the same values “On” or “Off” (English settings) in both “DX581-S” and “DX581-S Configuration” tabs.

2. Refer to “DX581-S” tab and calculate “Input channel 0” decimal equivalent (**Dec\_InputChannel0**) as:

$$\text{Dec\_InputChannel0} = \text{Configuration\_Value} + \text{Test\_Pulse\_Value} + \text{Input\_Delay\_Value}$$

where

**Configuration\_Value:**

0 → Not used

1 → 1 channel

2 → 2 channel equivalent

3 → 2 channel antivalent

**Test\_Pulse\_Value:**

0 → Disabled

8 → Enabled

**Input\_Delay\_Value:**

16 → 1 ms

32 → 2 ms

48 → 5 ms

64 → 10 ms

80 → 15 ms

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S Safety I/Os

96 → 30 ms

112 → 50 ms

128 → 100 ms

144 → 200 ms

160 → 500 ms

Compare calculated **Dec\_InputChannel0** (↪ step 2) with **“Input 0, channel configuration value”**. They have to be equal.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

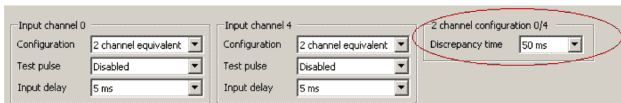
**3.** Repeat step 2 for the rest of digital input channels (Input 1, Input 2, ... Input 7).

**4.** Compare that “2 channel configuration 0/4” parameter in “DX581-S” tab have the same value as “Inputs 0/4, discrepancy time” parameter in “DX581-S Configuration” tab.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

**1**



**2**

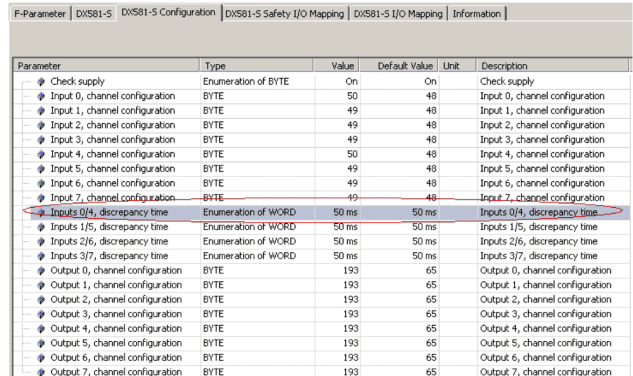


Fig. 132: Compare “DX581-S” tab and “DX581-S Configuration” tab

**1** 2 channel configuration 0/4” parameter in “DX581-S” tab

**2** “Inputs 0/4, discrepancy time” parameter in “DX581-S Configuration” tab

**5.** Repeat Step 4 for the rest of input channel combinations:

- Inputs 1/5, discrepancy time
- Inputs 2/6, discrepancy time
- Inputs 3/7, discrepancy time

**6.** Refer to “DX581-S” tab and calculate **“Output channel 0”** decimal equivalent (Dec\_OutputChannel0) as:

$$\text{Dec\_OutputChannel0} = \text{Detection\_Value} + \text{Output\_Value} + 1$$

where

**Detection\_Value:**

0 → Off

## Checklists for AC500-S Commissioning

Verification procedure for safe iParameter setting in AC500-S Safety I/Os > Verification tables for iParameter settings in AC500-S Safety I/Os

64 → On

**Output\_Value:**

0 → Not used

128 → Used

Compare calculated **Dec\_OutputChannel0** (↪ step 7) with “**Output 0, channel configuration**”. They have to be equal.

If they are not equal, stop the procedure and re-do the configuration and comparison.

If after the second iteration, there is still a difference between those values, stop verification procedure and contact ABB technical support.

**7.** ➤ Repeat step 6 for the rest of digital output channels (Channel 1, Channel 2, ... Channel 7).

## 7 Safety application examples

### 7.1 Overview

In this chapter, application examples based on PLCopen Safety POU's are presented with the main goal to give an explanation on how PLCopen Safety POU's can be used in typical safety applications. Examples are used from [7] with a permission from PLCopen organisation.

Initialization procedures for handling PROFIsafe start-up behaviour and AC500-S specific POU's are not listed in these examples, but have to be included in the final safety application programs, as it was mentioned in the chapter "Checklist for creation of safety application program" ( Chapter 6.2 "Checklist for creation of safety application program" on page 406).

As an example of the usage of safety functions, the following production line is used (Fig. 133). It is state-of-the-art to use a programmable electronic system (PES) to realize the safety functions (versus hard-wired). The PLCopen FBs described below can be used to easily realize the safety application program.

This production line includes the following:

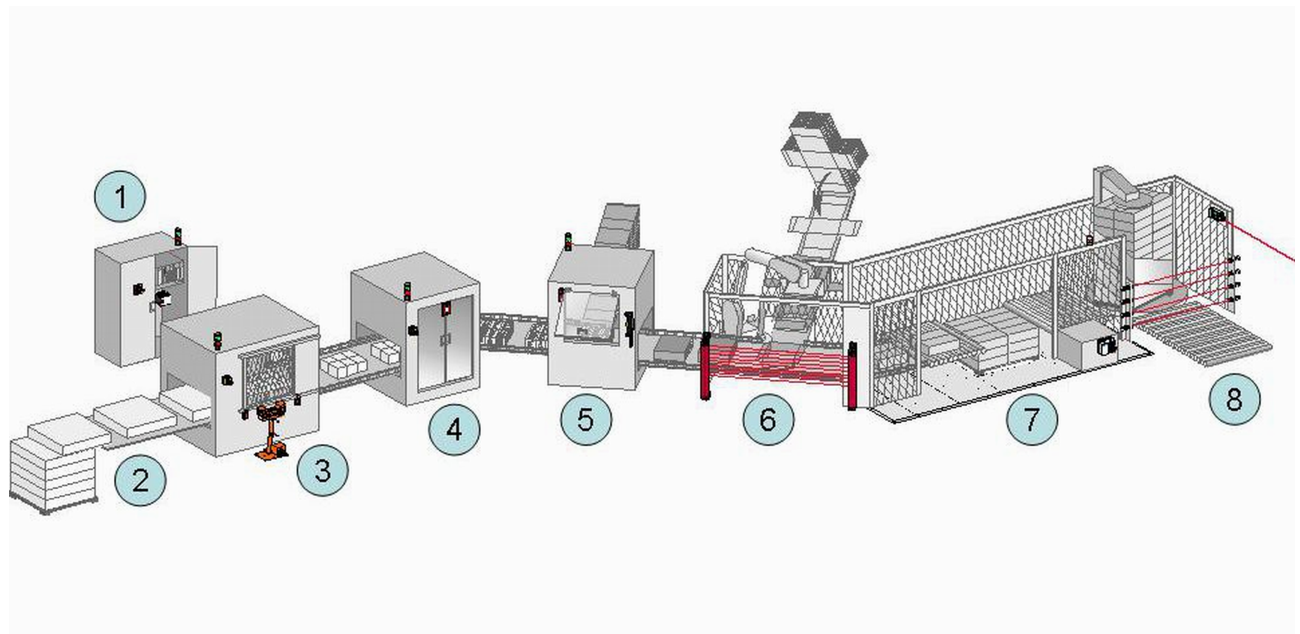


Fig. 133: Example of safety functionalities in a production line

- 1 Centralized control cabinet, including the safety related part of the control system where the safety related function blocks are running.
- 2 Infeed of material. In this example no special safety related functions are used. However, safety functionalities like muting to separate between products and persons could be used.
- 3 Cutting of the material. For manual control a two hand control safety function (unit is in front of the machine) is added combined with a 2-fold door monitoring system (attached to the door on the machine)
- 4 Automatic printing station, with door monitoring as safety function in case of service access (attached to the door on the machine)
- 5 First cartonning machine with door monitoring as safety function in case of service access (attached to the door on the machine). Sometimes, the manual operation is necessary. In this case, the operator can run the machine with a safely limited speed controlled by an enabling device which, when released, initiates a safe stop.

## Safety application examples

Example 1: Diagnostics concept > Functional description of safety functions

- |  |   |
|--|---|
| <p>6 Second cartonning machine, guarded by an electro-sensitive protective equipment, ESPE. In this case, it is a light curtain.</p> <p>7 Palletizing function, guarded by safety mats. This functionality could be coupled to the ESPE safety function.</p> | <p>8 Foil wrapping station of the palletized products, as well as exit of the production line. This area is safeguarded by several combined light beams, coupled to the ESPE safety function.</p> |
|--|---|

In addition, every station is equipped with an emergency stop.

### 7.2 Example 1: Diagnostics concept

This example shows the usage of the diagnostic concept, with a daisy chain from the FB parameters Activate and Ready (with perhaps a pre-evaluation of hardware errors), and a coupling to an HMI screen with error IDs and messages through the functional application. For clarity sake of the safety function, the other examples ( ↩ Chapter 7.3 “Example 2: Muting” on page 430 and ↩ Chapter 7.4 “Example 3: Two-hand control” on page 437) will not show the diagnostic connections.

The safety functionality is to stop a drive in accordance with stop category 1 of IEC 60204-1 initiated by an Emergency stop or by interrupting the light curtain. The equivalent monitoring of the 2 connectors of the emergency switch is done in the safety application.

In this example, both options of input evaluation are shown:

- via intelligent safety input
- via the equivalent function block.

#### 7.2.1 Functional description of safety functions

This example uses the following safety functions:

- Issuing the emergency stop (via SF\_EmergencyStop) or interrupting the light beam in the light curtain (via SF\_ESPE) stops the drive in accordance with stop category 1.
- The stop of the electrical drive within a predefined time is monitored (via SF\_SafeStop1).
- The Safe Status of the drive is indicated by the S\_Stopped variable, connected to the functional application.
- If the stop is performed by the Emergency Switch, a manual reset is required (via SF\_EmergencyStop).
- If a monitoring time violation is detected (via SF\_SafeStop1), manual error acknowledge is required to allow a reset.
- The 2 channel connectors of the emergency stop are monitored. An error is detected when both inputs do not have the same status once the discrepancy time has elapsed (via SF\_EQUIVALENT).
- The functional stop in this example is performed as a safe stop issued from the functional application. A restart interlock for this stop is not necessary.



## 7.2.2 Graphical overview of safety application interface

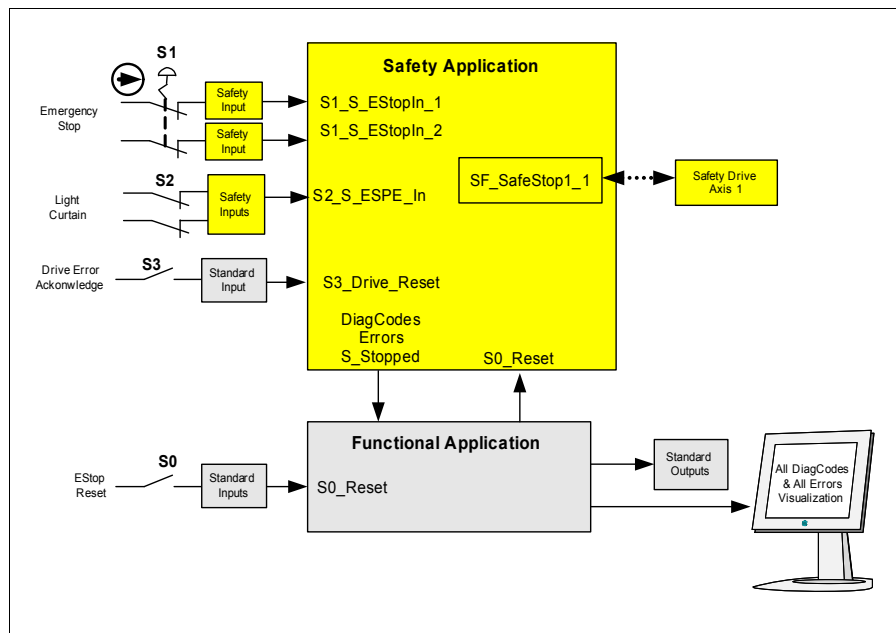


Fig. 134: Graphical overview of the example with emergency stop

- ☞ The symbol represents a direct opening action  
(☞ IEC 60947-5-1).

## 7.2.3 Declaration of used variables

Table 90: Inputs

Name	Data type	Description
S1_S_EstopIn_1	BOOL	Emergency Stop Channel 1
S1_S_EstopIn_2	BOOL	Emergency Stop Channel 2
S2_ESPE_In	BOOL	Light curtain signal
S0_Reset	BOOL	Reset Emergency Stop and ESPE
S3_Drive_Reset	BOOL	Reset Drive Error

Table 91: Outputs

Name	Data type	Description
S_Stopped	BOOL	Indication of Safe Stop of drive
All Errors	BOOL	Errors of SF_Function Blocks
All Diagcodes	BOOL	Diag codes of SF_Function Blocks

## Safety application examples

Example 1: Diagnostics concept > Additional notes

Table 92: Hidden Interface of FB instances towards drives (Vendor specific).

Name	Description
SF_SafeStop1_1	Connection to Drive 1

Table 93: Local variable

Name	Data type	Description
S_EStopOut	BOOL	Emergency stop request
InputDevice1_active	BOOL	Status of the relevant input device as provided by the system
InputDevice2_active	BOOL	Status of the relevant input device as provided by the system

### 7.2.4 Program example

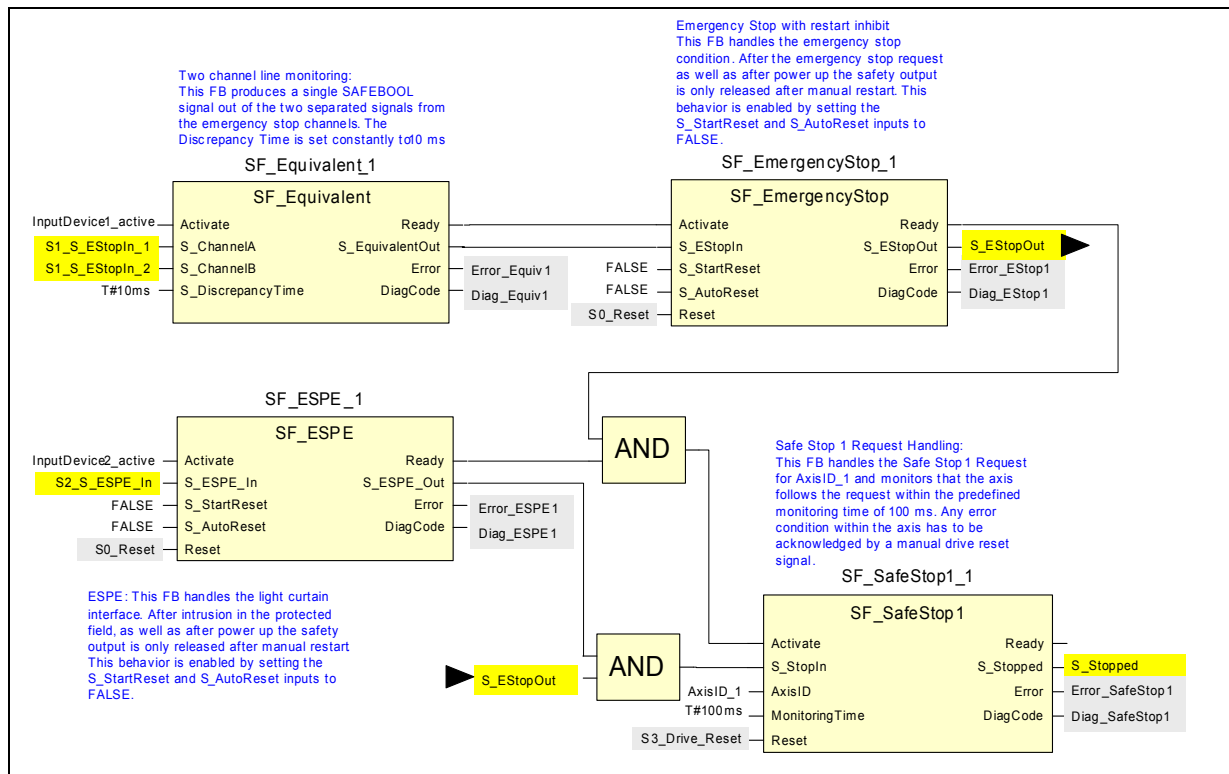


Fig. 135: Program example – Emergency stop with safe stop & equivalent monitoring

### 7.2.5 Additional notes

This example uses different reset signals to acknowledge the emergency stop situation and to acknowledge the monitoring violation situation of the drive. If the safety requirement specification of the application allows the acknowledgement of both situations with the same signalling device, the identical signal from the functional application may be used to reset the FB SF\_EmergencyStop\_1 as well as to reset the FB SF\_SafeStop1\_1.

### Information on the diagnostics concept

The representation of the diagnostics concept is for information only. For the safety functionality the dedicated safety inputs and outputs shall be used.

### Daisy chain from Activate and Ready

The connection of the Ready output to an Activate input of the following FB ensures that no irrelevant diagnostic information is generated if a device is disabled. The daisy chain from Activate and Ready avoid subsequent error messages of related function blocks.

### Pre-evaluation of Hardware errors

If the target system supports an error signal, e.g., InputDevice\_active, which represents the status (Active or Not Active) of the relevant safety device, this signal can be used to disable the safety function blocks. This ensures no irrelevant diagnostic information is generated if a device is disabled. If no such error signal is provided by the target system, a static TRUE signal must be assigned to the Activate input.

### Evaluation of the diagnostic information

The Error signals and DiagCodes of each safety function block are transferred to the standard application. Diagnosis information might be processed and displayed by an attached visualization. There are different possibilities to realize the evaluation of the diagnostic information:

- Transfer these values into the visualization and realize the diagnostic evaluation in the visualization.
- Realize the diagnostic evaluation in the standard logic and transfer the results to the visualization

Because of the various possibilities and the differences in the target system to realize diagnostic processing, there is no special example showed here. Further diagnostic processing could be:

- Display of the error status for each safety function block
- Providing an error overview which is linked to function block specific error displays
- Detection and display of the last error of the used safety function blocks in the safety application.

## Safety application examples

Example 2: Muting > Functional description of safety functions

### Information on the used function block parameters

Function Block	Input	Constant Value	Description
SF_Equivalent_1	S_Discrepancy-Time	10 ms	Maximum monitoring time for discrepancy status of both inputs.
SF_Emergency-Stop_1	S_StartReset	FALSE	Manual reset when PES is started (warm or cold).
	S_AutoReset	FALSE	Manual reset when emergency stop button is released.
SF_SafeStop1_1	AxisID	AxisID_1	Drive address, supplier specific value
	MonitoringTime	100 ms	Time until the drive shall be stopped.
SF_ESPE	S_StartReset	FALSE	Manual reset when PES is started (warm or cold).
	S_AutoReset	FALSE	Manual reset after safety demand condition is cleared.

## 7.3 Example 2: Muting

This example describes the safety functions for the safeguarding of a production cell. Objects are transferred through an entry gate, which is guarded by a light curtain. This light curtain can be muted only for material transport into the cell. The cell may be entered by the operator through a safety door. The process inside the cell is controlled by the functional application and enabled by the safety circuit. In case of a safety demand or an error, all hazardous movements are stopped in accordance with stop category 0.

### 7.3.1 Functional description of safety functions

All hazardous movements are stopped in case of:

- an opening of the door,
- an error (e.g. invalid muting sequence),
- an interruption of the unmuted light curtain (e.g., by a person),
- pushing an emergency stop button.

By pushing an emergency stop button, the operator can also stop all hazardous movements in stop category 0 (via SF\_EmergencyStop and subsequent FBs).

An infringement of the unmuted light curtain stops all hazardous movements. In this application, a light curtain type 2 is used, which requires a test by the FB SF\_TestableSafetySensor.

For the described muting function, four muting sensors are applied sequentially (via SF\_MutingSeq). Additionally, the muting phase is indicated by a lamp, which is monitored in this case (also via SF\_MutingSeq).

An additional door for maintenance purposes is monitored by a door switch (via SF\_GuardMonitoring).

By resetting buttons, the operator must acknowledge the detected demand of the safety functions and errors.

The initial state and the operational state of the connected actuator are checked by an external device monitoring. In case an error is detected, the control cannot become operational (via SF\_EDM).

The process and related movements inside the production cell are controlled by the functional application. Within the safety application, this control is enabled by the above-described safety circuit (via SF\_OutControl) and drives the actuator via a safety output.

## 7.3.2 Graphical overview of the safety application interface

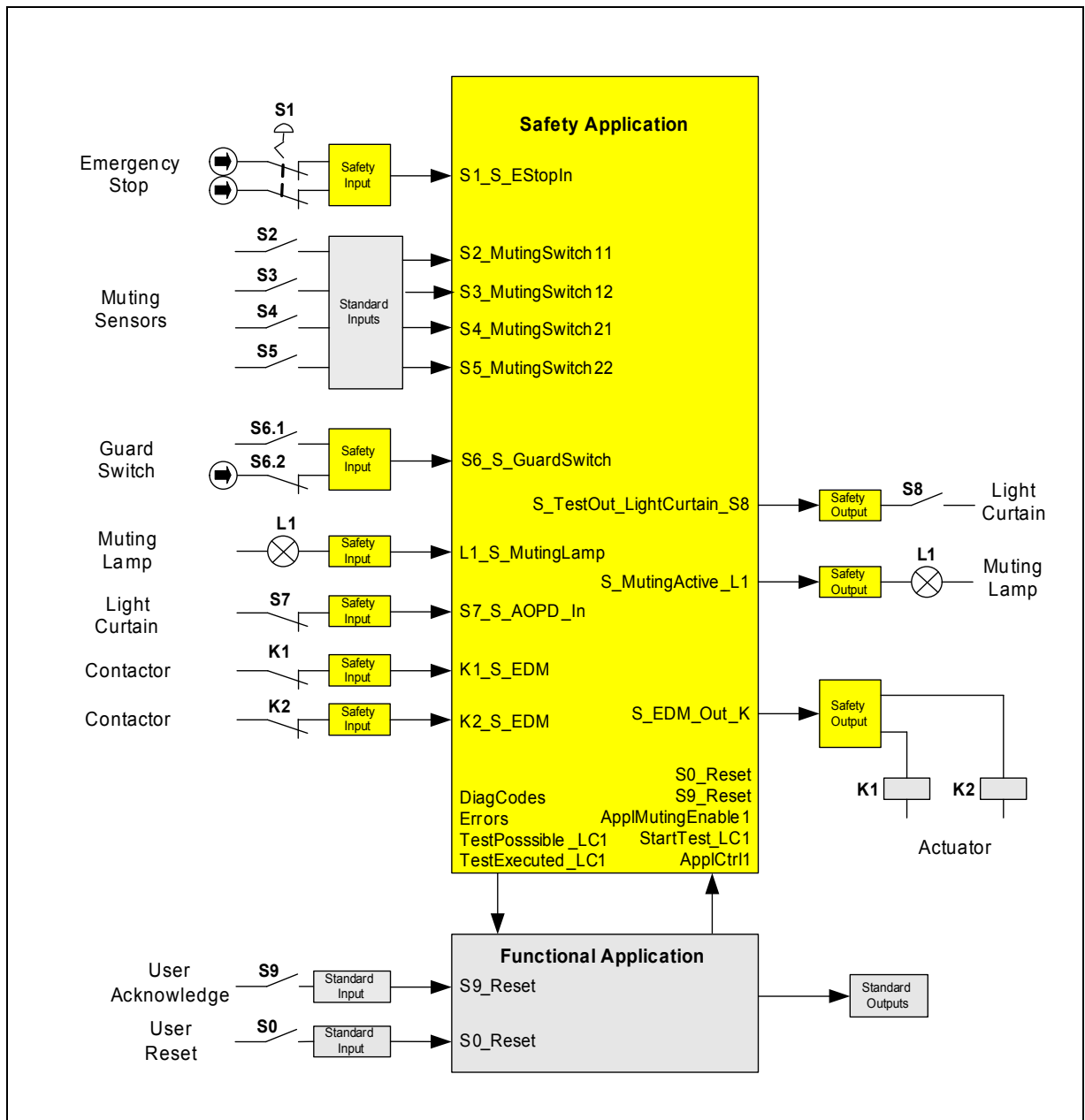


Fig. 136: Graphical overview of the example access protection at a material gate

## Safety application examples

Example 2: Muting > Declaration of used variables

### 7.3.3 Declaration of used variables

Table 94: Inputs

Name	Data type	Description
S1_S_EStopIn	BOOL	Emergency stop button S1
S2_MutingSwitch11	BOOL	Muting sensor S2
S3_MutingSwitch12	BOOL	Muting sensor S3
S4_MutingSwitch21	BOOL	Muting sensor S4
S5_MutingSwitch22	BOOL	Muting sensor S5
S6_S_GuardSwitch	BOOL	Door switch S6 with two contacts
L1_S_MutingLamp	BOOL	Muting lamp monitor signal L1
S7_S_AOPD_In	BOOL	OSSD from light curtain S7
K1_S_EDM	BOOL	Feedback external device K1
K2_S_EDM	BOOL	Feedback external device K2
S9_Reset	BOOL	Reset safety demand by user S9
S0_Reset	BOOL	Reset error by user S0 (derived from functional application)
ApplCtrl1	BOOL	Signal controlling the actuator, enabled by safety loop (derived from functional application)
StartTest_LC1	BOOL	Signal starting test of light curtain S7 (derived from functional application)
ApplMutingEnable1	BOOL	Signal enabling start of the muting sequence (derived from functional application)

Table 95: Outputs

Name	Data type	Description
S_EDM_Out_K	BOOL	Drives actuator via K1 and K2
S_MutingActive_L1	BOOL	Drives Muting lamp L1
S_TestOut_Light-Curtain_S8	BOOL	Test output for light curtain S8
All Errors	BOOL	Represents all error parameter of the used FB (connected to functional application)
All DiagCodes	WORD	Represents all diagnosis codes of the used FB (connected to functional application)
TestPossible_LC1	BOOL	Indicates to the functional application that an automatic sensor test of the light curtain is possible.
TestExecuted_LC1	BOOL	Indicates to the functional application the successful execution of an automatic sensor test of the light curtain.

Table 96: Local variables

Name	Data type	Description
S_SafeControl	BOOL	Indicates the status of the safety guards (TRUE = safety enabled)

## Safety application examples

Example 2: Muting > Program example

### 7.3.4 Program example

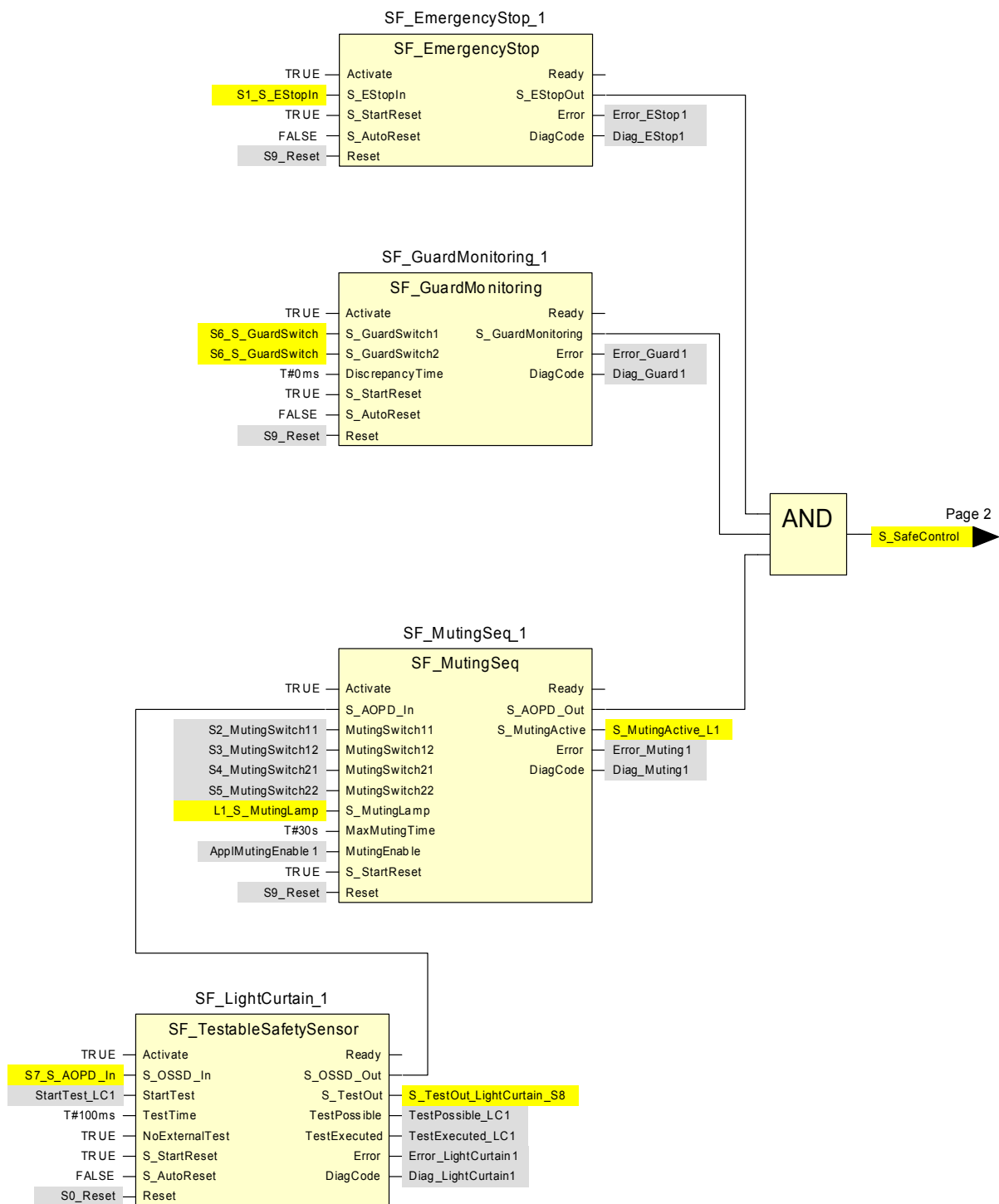


Fig. 137: Access protection at a material gate - Application Program Page 1



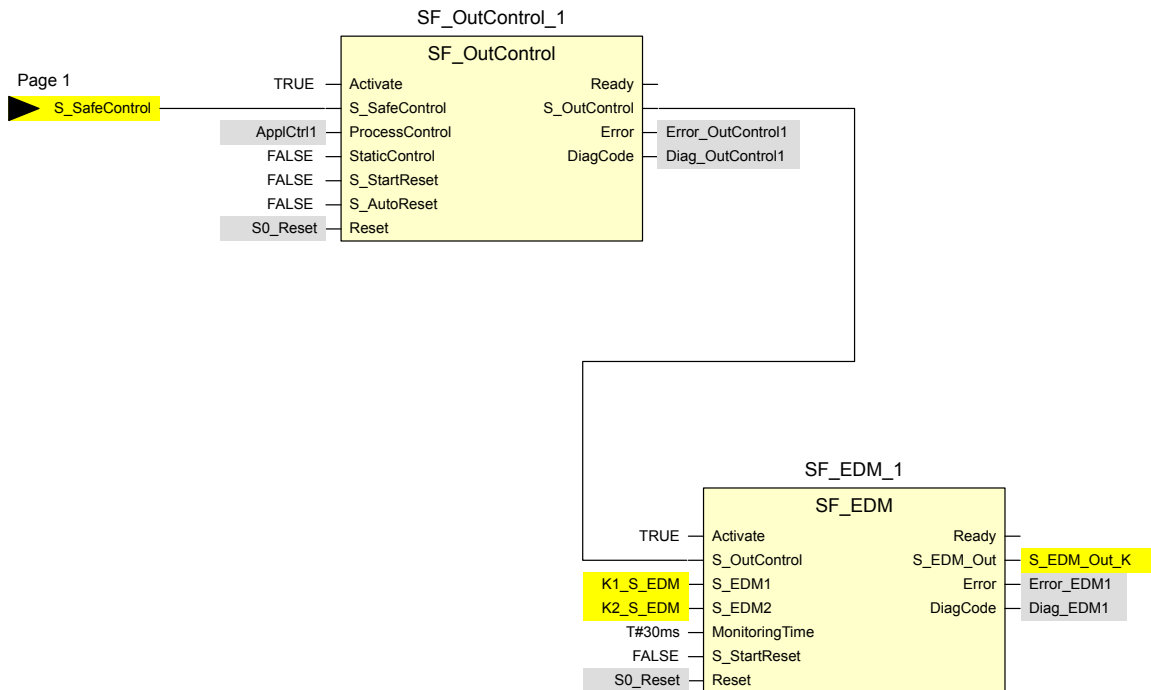


Fig. 138: Access protection at a material gate - Application Program Page 2

## 7.3.5 Additional notes

In this example, two contacts of the guard switch are connected to a safety input device, which realizes the error detection. The resulting BOOL signal is mapped to the two input channels of the SF\_GuardMonitoring\_1.

The diagnostic information retrieval has not been covered in this example. For this, refer to [Chapter 7.2.5 "Additional notes" on page 428](#). The input parameter Activate for the dynamic FB activation has been set to TRUE for clarity sake. However, in an application, this can be replaced by a variable.

## Safety application examples

Example 2: Muting > Additional notes

### Information about the used Function Block Parameters

Function Block	Input	Constant Value	Description
SF_Emergency-Stop_1	S_StartReset	TRUE	Automatic reset allowed when PES is started
	S_AutoReset	FALSE	No automatic reset, user reset/acknowledge necessary
SF_GuardMonitoring_1	S_StartReset	TRUE	Automatic reset allowed when PES is started
	S_AutoReset	FALSE	No automatic reset, user reset/acknowledge necessary
	DiscrepancyTime	T#0ms	The discrepancy time between both safety inputs S_GuardSwitchX is not monitored, because they are identical and since the input unit provides one signal of type BOOL from the contactors.
SF_MutingSeq_1	S_StartReset	TRUE	Automatic reset allowed when PES is started
	MaxMutingTime	T#30s	The maximum muting time is monitored to be within 30 sec.
SF_LightCurtain_1	S_StartReset	TRUE	Automatic reset allowed when PES is started
	S_AutoReset	FALSE	No automatic reset, user reset/acknowledge necessary
	TestTime	T#100ms	The maximum test time is monitored to be within 100 msec
	NoExternalTest	TRUE	The external manual sensor test is not supported.
SF_OutControl_1	S_StartReset	FALSE	No automatic reset allowed when PES is started
	S_AutoReset	FALSE	No automatic reset, user reset/acknowledge necessary
	StaticControl	FALSE	A dynamic change of the signal ApplCtrl1 (rising edge) is required after block activation or a triggered safety function (S_SafeControl at FALSE).
SF_EDM_Contactor_1	S_StartReset	FALSE	No automatic reset allowed when PES is started
	MonitoringTime	T#30ms	The maximum response time of both the feedback signals S_EDM1 and S_EDM2 are monitored to be within 30 msec.

### 7.4 Example 3: Two-hand control

This example describes a machine where a two-hand control initiates the dangerous movement as long as both push buttons on the two-hand control are pressed and the process provides an enabling signal.

The dangerous movement is initiated by the closing of two subsequent contactors, which are monitored via a feedback loop.

#### 7.4.1 Functional description of safety functions

This example uses the following safety functions:

- By pushing an emergency stop button all hazardous movements must be stopped (via SF\_Emergency-Stop). Emergency stop has the highest priority. After releasing the EStop push button, a reset via S0\_Reset is required.
- By pressing both push buttons of the two-hand control, the safety output is activated. The release of any of the two-hand push buttons disables the safety output and stops the dangerous motion via the contactors K1 and K2 (via SF\_TwoHandControlTypell).
- The initial state and the operational state of the connected contactors K1 and K2 are monitored and if an error is detected, the safety output cannot become operational (via SF\_EDM).
- After power on of the safety or functional application, or after an emergency stop condition, the two-hand control must be released and re-operated in order to activate the safety output again (via SF\_OutControl). In order to guarantee this for the functional application restart, the Process signal from the functional application is connected to the Activate input of the two hand control function block THC\_S2\_S3 (If the application process is restarted while the two hand control is activated, the FB goes to the state C003 signalling an error that both buttons are pressed at the activation, prohibiting a restart.).

In this example, only one operation mode exists.

## Safety application examples

Example 3: Two-hand control > Declaration of used variables

### 7.4.2 Graphical overview of the safety application interface

The safety inputs for the two-hand control (S2\_S\_Switch1 and S3\_S\_Switch2) are connected to the two-hand control type II.

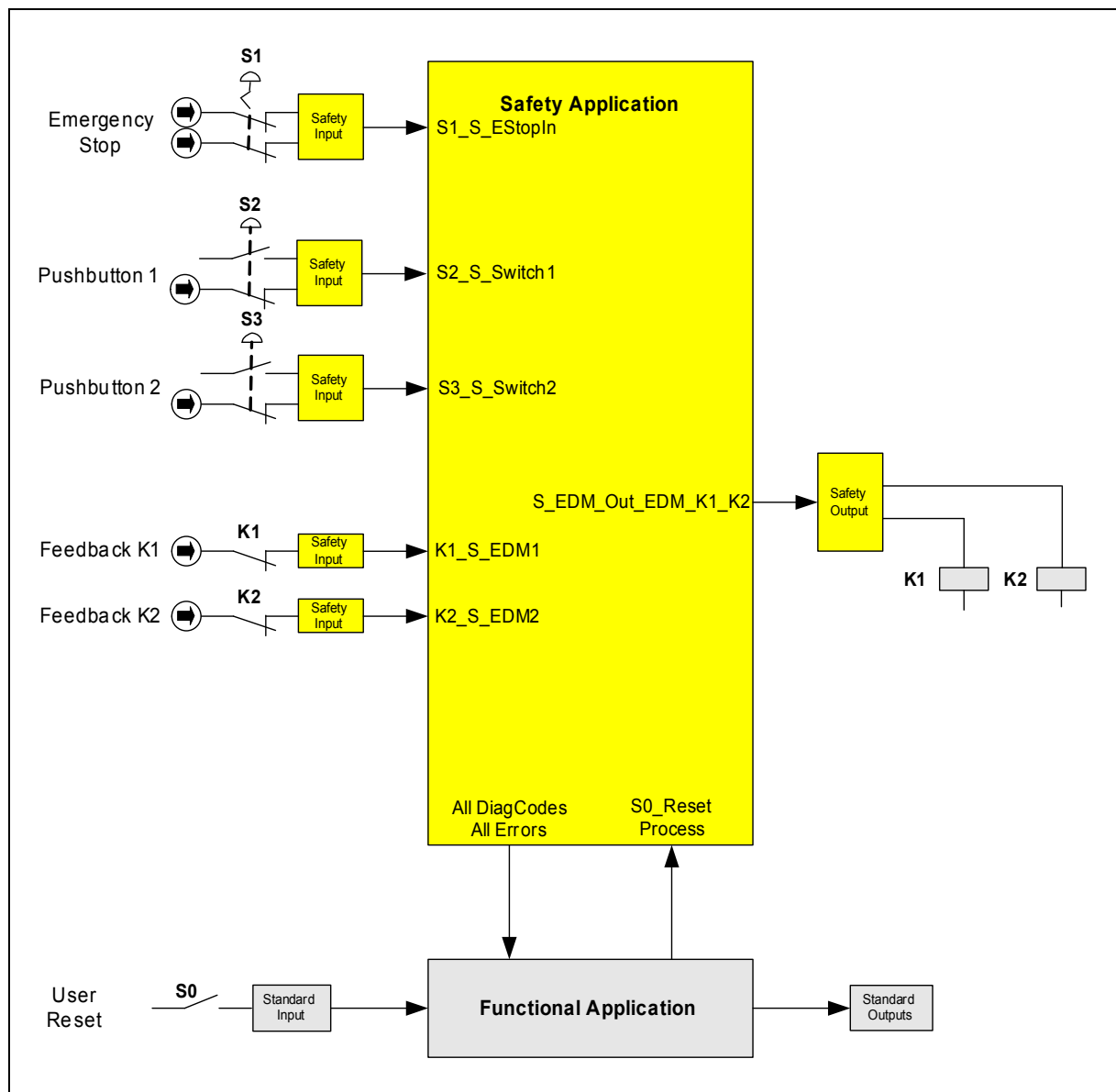


Fig. 139: Graphical overview of the example TwoHand Control with EDM

### 7.4.3 Declaration of used variables

Table 97: Inputs

Name	Data type	Description
S1_S_EStopIn	BOOL	Emergency stop button S1
S2_S_Switch1	BOOL	Switch S2 related to push button 1 of two hand control

## Safety application examples

Example 3: Two-hand control > Declaration of used variables

Name	Data type	Description
S3_S_Switch2	BOOL	Switch S3 related to push button 2 of two hand control
K1_S_EDM1	BOOL	Feedback from external device K1
K2_S_EDM2	BOOL	Feedback from external device K2
S0_Reset	BOOL	Reset by user via Switch S0 (derived from the functional application)
Process	BOOL	Enabling motion by the process (derived from functional application)

Table 98: Outputs

Name	Data type	Description
S_EDM_Out_EDM_K1_K2	BOOL	Drives actuator via K1 and K2
All Errors	BOOL	Represents all error BOOLs of the used FB (connected to the functional application)
All DiagCodes	WORD	Represents all diagnostic codes of the used FB (connected to the functional application)

## Safety application examples

Example 3: Two-hand control > Additional notes

### 7.4.4 Program example

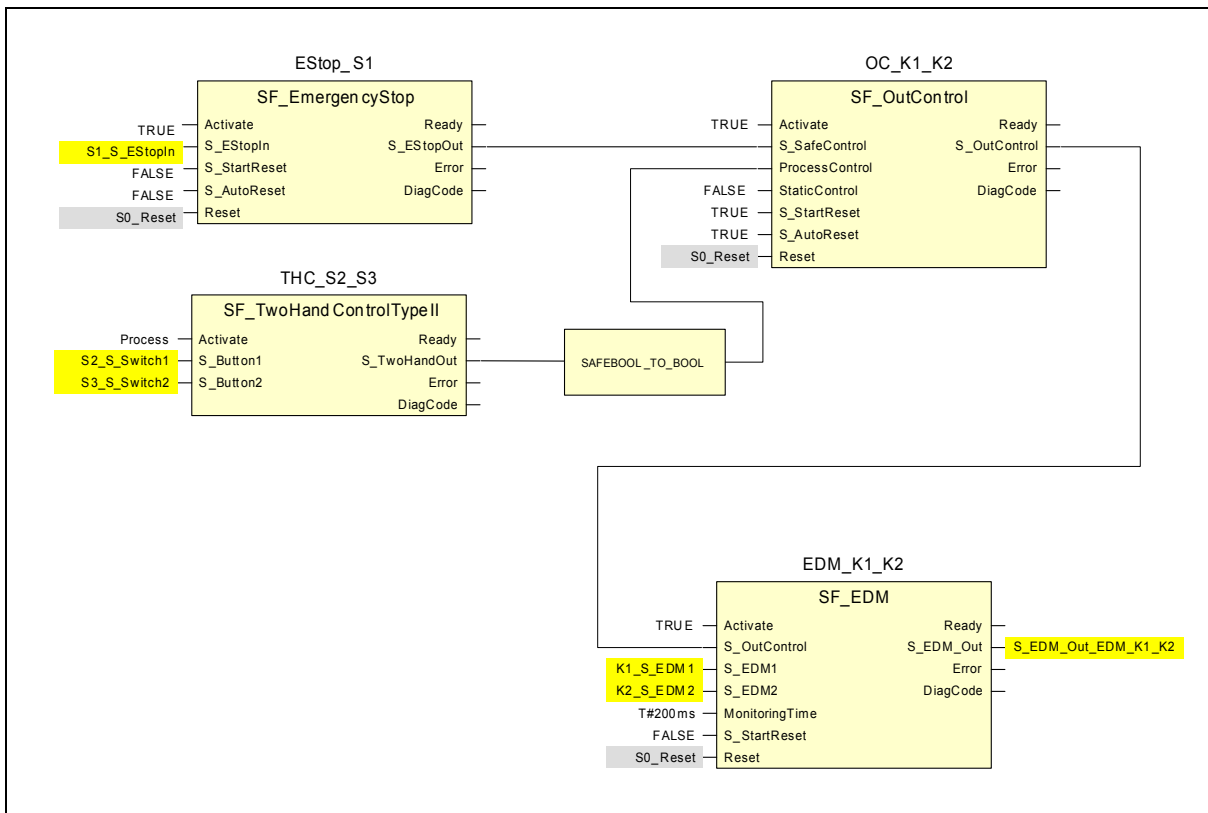


Fig. 140: Application Program TwoHand Control with EDM

### 7.4.5 Additional notes

This example can also be used with the `SF_TwoHandControlTypeIII`.

The diagnostic information retrieval has not been covered in this example. For this, refer to [Chapter 7.2.5 "Additional notes" on page 428](#). The input `Activate` has been set to `TRUE` via its input for clarity sake. However, in an application this can be replaced by a variable.

### Information about the used Function Block Parameters

Function Block	Input	Constant Value	Description
EStop_S1	S_StartReset	FALSE	No automatic reset when PES is started
	S_AutoReset	FALSE	No automatic reset, user reset/acknowledge necessary
OC_K1_K2	S_StartReset	TRUE	Automatic reset allowed when PES is started
	S_AutoReset	TRUE	Automatic reset, no user reset/acknowledge necessary
	StaticControl	FALSE	A dynamic change of the signal Appl_Control (rising edge) is required after block activation or a triggered safety function (S_SafeControl at FALSE)
EDM_K1_K2	S_StartReset	FALSE	No automatic reset when PES is started
	MonitoringTime	T#200ms	The maximum response time of both feedback signals S_EDM1 and S_EDM2 is monitored to be within 200 msec.

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## **Appendix**

## System data for AC500-S-XC

### A System data for AC500-S-XC

#### A.1 Environmental conditions

##### Process and supply voltages

Data	Value	Unit
Process and supply voltage (-25 %, +30 % inclusive ripple)	24	V DC
Absolute limits inclusive ripple	18 ... 31.2	V
Ripple	< 10	%
rotection against reverse polarity	yes	
Allowed interruptions of DC power supply	< 10	ms
Time between 2 interruptions, PS2	> 1	s

#### DANGER!

Exceeding the maximum process or supply voltage range (< –35 V DC or > +35 V DC) could lead to unrecoverable damage of the system.

#### DANGER!

For the supply of the modules, power supply units according to PELV or SELV specifications must be used.

#### NOTICE!

The creepage distances and clearances meet the requirements of the overvoltage category II, pollution degree 2.

##### Temperature

Data	Value	Unit
Operating temperature*	–40 ... +70	°C
Operating temperature (vertical mounting of module output load limited to 50 % per group)	–40 ... +40	°C
Storage temperature	–40 ... +85	°C
Transport temperature	–40 ... +85	°C

\* +60 °C ... +70 °C with the following deratings:

- Terminal Bases: max. 2 Communication Modules allowed
- Digital inputs: maximum number of simultaneously switched on input channels limited to 50 % per group (e.g. 8 channels => 4 channels)
- Digital outputs: output current maximum value (all channels together) limited to 50 % per group (e.g. 4 A => 2 A)
- Analog inputs: No limitations


**DANGER!**

The average temperature (MTBF calculation base) for both the extended temperature range (–40 °C ... +70 °C) as well as for standard temperature range (0 °C ... +60 °C) is defined to +40 °C.

Ensure that average operating temperature for used AC500-S-XC modules does not exceed +40 °C.

**Humidity**

Data	Value	Unit
Relative humidity with condensation (Operating/Storage)	100	%

**Air pressure**

Data	Value	Unit
Operating air pressure	1080 ... 620	hPa
Operating altitude	–1000 ... 4000	m
Reduction of operating temperature at an air pressure of < 795 hPa (or > 2000 m above sea level)	10 (e.g. 70 °C to 60 °C)	K

**Immunity to corrosive gases**

Data	Value
Operating: according to: ISA S71.04.1985 Harsh group A, G3/GX IEC 60721-3-3 3C2 / 3C3	yes

**Immunity to salt mist**

Data	Value
Operating: horizontal mounting only, according to: IEC 60068-2-52 severity level: 1	yes

**Electromagnetic Compatibility**

Data	Value
Radiated emission (radio disturbance) according to CISPR 16-2-3	yes
Conducted emission (radio disturbance) according to CISPR 16-2-1, CISPR 16-1-2	yes
Electrostatic discharge (ESD) according to IEC 61000-4-2, zone B, criterion B	yes
Fast transient interference voltages (burst) according to IEC 61000-4-4, zone B, criterion B	yes
High energy transient interference voltages (surge) according to IEC 61000-4-5, zone B, criterion B	yes
Influence of radiated disturbances according to IEC 61000-4-3, zone B, criterion A	yes
Influence of line-conducted interferences according to IEC 61000-4-6, zone B, criterion A	yes

## System data for AC500-S-XC

Data	Value
Influence of power frequency magnetic fields according to IEC 61000-4-8, zone B, criterion A	yes

### **! NOTICE!**

In order to prevent malfunctions, it is recommended, that the operating personnel discharge themselves prior to touching communication connectors or perform other suitable measures to reduce effects of electrostatic discharges.

### **! NOTICE!**

Unused sockets for Communication Modules on Terminal Bases must be covered with TA524 Dummy Communication Module. I/O-Bus connectors must not be touched during operation.

## Radiation

Data	Value
Radio disturbance according to IEC 55011, group 1, class A	yes

## A.2 Mechanical data

Data	Value
Wiring method	spring terminals
Degree of protection	IP 20
Vibration resistance according to: IEC 61131-2, IEC 60068-2-6, IEC 60068-2-64	yes
Shock resistance according to: IEC 60068-2-27	yes
Horizontal assembly position	yes
Vertical assembly position (no application in salt mist environment)	yes

### Assembly on DIN rail according to IEC 60715

Data	Value	Unit
DIN rail type	35	mm
DIN rail type depth	7.5 or 15	mm

### Assembly with screws

Data	Value	Unit
Screw diameter	4	mm
Fastening torque	1.2	Nm

## System data for AC500-S-XC

### A.3 Environmental tests

Storage	IEC 60068-2-1 Test Ab: cold withstand test -40 °C / 16 h IEC 60068-2-2 Test Bb: dry heat withstand test +85 °C / 16 h
Humidity	IEC 60068-2-30 Test Dd: Cyclic (12 h / 12 h) Damp-Heat Test 55 °C, 93% relative humidity / 25 °C, 95 % relative humidity, 6 cycles IEC 60068-2-78, Stationary Humidity Test: 40 °C, 93 % relative humidity, 240 h
Insulation test	IEC 61131-2
Vibration resistance	IEC 61131-2 / IEC 60068-26: 5 Hz ... 500 Hz, 2 g (with SD memory card inserted in PM5xx CPU) IEC 60068-2-64: 5 Hz ... 500 Hz, 4 g rms
Schock resistance	IEC 60068-2-27: all 3 axes 15 g, 11 ms, half-sinusoidal

#### EMC Immunity

##### Electrostatic discharge (ESD)

Data	Value	Unit
Electrostatic voltage in case of air discharge	8	kV
Electrostatic voltage in case of contact discharge	6	kV

##### Fast transient interference voltages (burst)

Data	Value	Unit
Supply voltage units (DC)	4	kV
Digital inputs/outputs (24 V DC)	2	kV
Analog inputs/outputs	2	kV
Communication lines shielded	2	kV
I/O supply (DC-out)	2	kV

##### High energy transient interference voltages (surge) - Common Mode (CM)

Data	Value	Unit
Supply voltage units (DC)	1	kV
Digital inputs/outputs (24 V DC)	1	kV
Analog inputs/outputs	1	kV
Communication lines shielded	1	kV
I/O supply (DC-out)	0.5	kV

##### High energy transient interference voltages (surge) - Differential Mode (DM)

Data	Value	Unit
Supply voltage units (DC)	0.5	kV
Digital inputs/outputs (24 V DC)	0.5	kV



Data	Value	Unit
Analog inputs/outputs	0.5	kV
I/O supply (DC-out)	0.5	kV

Data	Value	Unit
Influence of radiated disturbances: test field strength	10	V/m
Influence of line-conducted interferences: test voltage	10	V
Power frequency magnetic fields at 30 A/m	50 and 60	Hz

### ! NOTICE!

Extreme environmental conditions and relevant requirements for non-safety AC500-XC modules shall be taken into account for used Non-safety CPUs and I/O modules from AC500-XC family ( ↗ *AC500 User Documentation* for further details).

# Contact us

ABB Automation Products GmbH  
Wallstadter Str. 59  
68526 Ladenburg, Germany  
Phone: +49 62 21 701 1444  
Fax: +49 62 21 701 1382  
E-Mail: [plc.sales@de.abb.com](mailto:plc.sales@de.abb.com)

[www.abb.com/plc](http://www.abb.com/plc)

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