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Laser Scanner with Monitoring Case Switching

Safety Integrated

https://support.industry.siemens.com/cs/ww/en/view/58804919

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1 Introduction

1.1 Overview

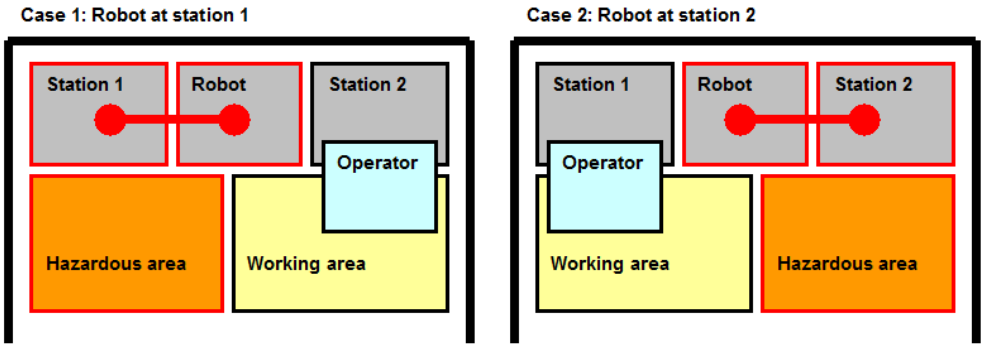
An assembly cell with a robot has two workstations that can alternately be freely accessed by an operator:

- Case 1: While the robot works at station 1, the operator can load or unload at station 2.
- Case 2: While the robot works at station 2, the operator can load or unload at station 1.

During operation, the situation changes due to the movement of the robot:
The hazardous area becomes the working area and vice versa.

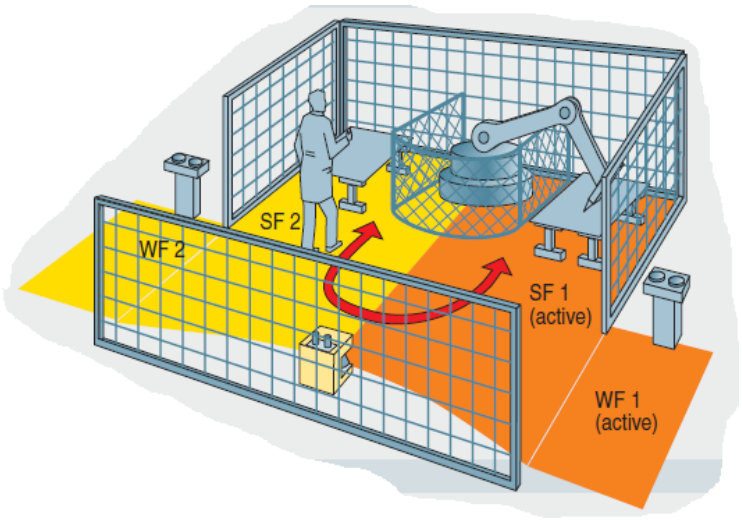
The following figure schematically shows the two cases in the assembly cell.

Figure 1-1



To monitor this assembly cell, a SICK safety laser scanner S3000 is to be used in conjunction with a fail-safe SIMATIC S7-1500 (F-CPU).

Figure 1-2



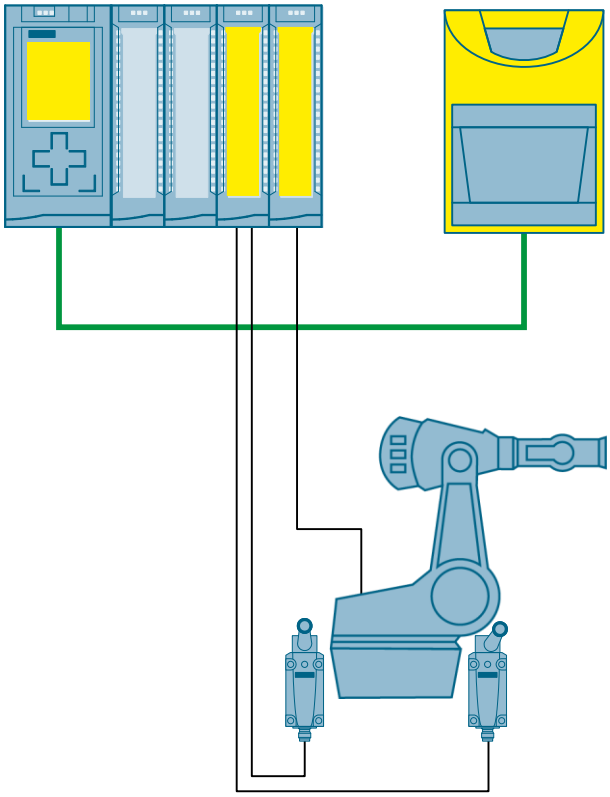
The laser scanner monitors a danger area, depending on the robot's position, and shuts down its safe OSSD output (Output Signal Switching Device) upon entering the protective field, which causes the F-CPU to shut down the robot.

The laser scanner S3000 is able to select between up to four monitoring cases, each with their own protective and warning field.

1.2 Mode of Operation

Setup

Figure 1-3 Structure



F-CPU and laser scanner communicate via PROFINET with the fail-safe "PROFIsafe" profile.

The robot's position is detected via two sensors (e.g. SIRIUS position switch).

Note This application example does not describe how to control the robot. For this, an error-secure output is set to which an indicator light is connected.

Monitoring cases

Two monitoring cases are implemented in the application example. Depending on the signals from the position switches, the F-CPU switches between the two monitoring cases. For this, the F-CPU monitors a normally-closed contact of each position switch.

- Monitoring case 1: Sensor 1 is “0“, Sensor 2 is “1“ → robot is in place 1
- Monitoring case 2: Sensor 1 is “1“, Sensor 2 is “0“ → robot is in place 2

Note In the TIA Portal project, the monitoring of up to four monitoring cases is prepared. By this, the application example can easily be expanded.

Monitoring the case switching

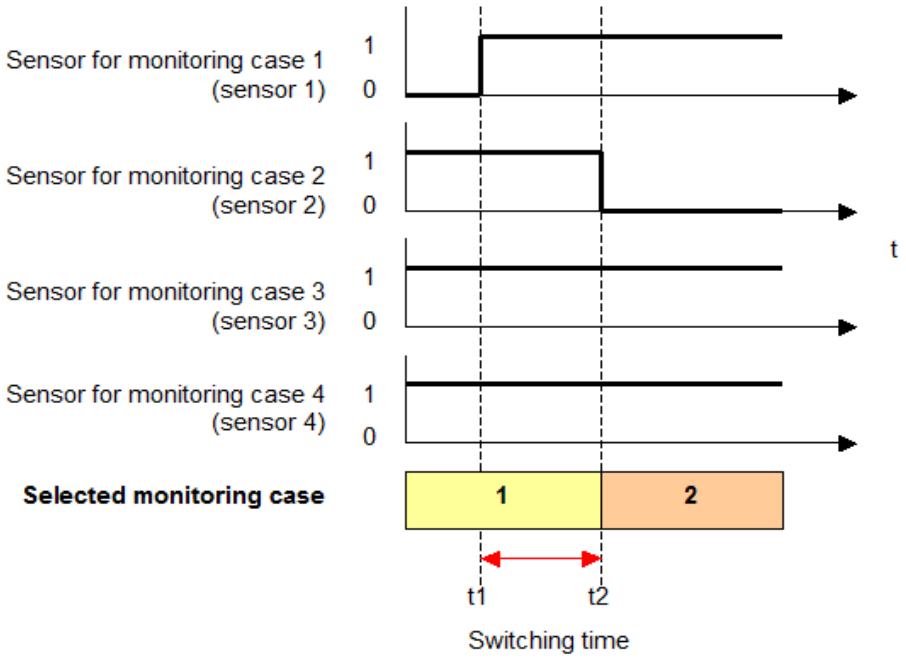
Switching from monitoring case 1 to monitoring case 2 means:

- Sensor 1 changes from “0” to “1”
- Within the switching time, sensor 2 changes from “1” to “0”

The maximum permissible time for switching between two monitoring cases is monitored by the F-CPU. The permissible switching time depends on the specific application and can be configured in the project.

Figure 1-4 shows the correlations for four sensors and switching from monitoring case 1 to monitoring case 2.

Figure 1-4 Chronological sequence of monitoring case switching



Control of laser scanner

Via four bits, the F-CPU transmits the current monitoring case to the laser scanner. Depending on the sensor signals, two of the four bits are always set.

In case of an invalid combination of these control signals, the laser scanner shuts down the OSSD output safely.

The assignment of the control signals to the monitoring cases can be found in Table 3-5.

1.3 Components used

The application example has been created with the following components:

Hardware components

Table 1-1

Component	Number	Article number	Note
DIN rail	1	6ES7590-1AE80-0AA0	
Power Supply	1	6EP1333-4BA00	70 W
Fail-safe S7-CPU	1	6ES7516-3FN01-0AB0	
SIMATIC memory card	1	6ES7954-8LF02-0AA0	24 MB
Digital input module (DI)	1	6ES7521-1BL00-0AB0	
Digital output (DQ)	1	6ES7522-1BH00-0AB0	
Fail-safe digital input (F-DI)	1	6ES7526-1BH00-0AB0	
Fail-safe digital output (F-DQ)	1	6ES7526-2BF00-0AB0	
Front connector	4	6ES7592-1BM00-0XB0	Push-in, 40-pin
Position switch	2	3SE5 / 3SF1	
Button	3	3SU1	2X break contact, 1x make contact
Indicator light	3	3SU1	Robot, error lamp, acknowledgment lamp
SICK S3000 PROFINET IO safety laser scanner	1	1045652	
Plug connector with cable for S3000 PROFINET IO	1	2049575	
Configuration cable	1	6034574	Optional to load the configuration via USB instead of TCP/IP

Software components

Table 1-2

Component	Article number	Note
STEP 7 Professional V13 SP1	6ES7822-1AA03-0YA5	Update 9
STEP 7 Safety Advanced V13 SP1	6ES7833-1FA13-0YA5	Update 5
Configuration & Diagnostic Software (CDS)		V3.7.1 Supplied with laser scanner
GSDML file SICK S3000		Supplied with laser scanner

Downloads

Table 1-3

File	Content
58793869_Laserscanner_DOC_V20_de.pdf	This document
58793869_Laserscanner_PROJ_V20.zip	TIA Portal project, configuration file for CDS

2 Engineering

2.1 Hardware setup

Figure 2-1 Circuit diagram F-CPU

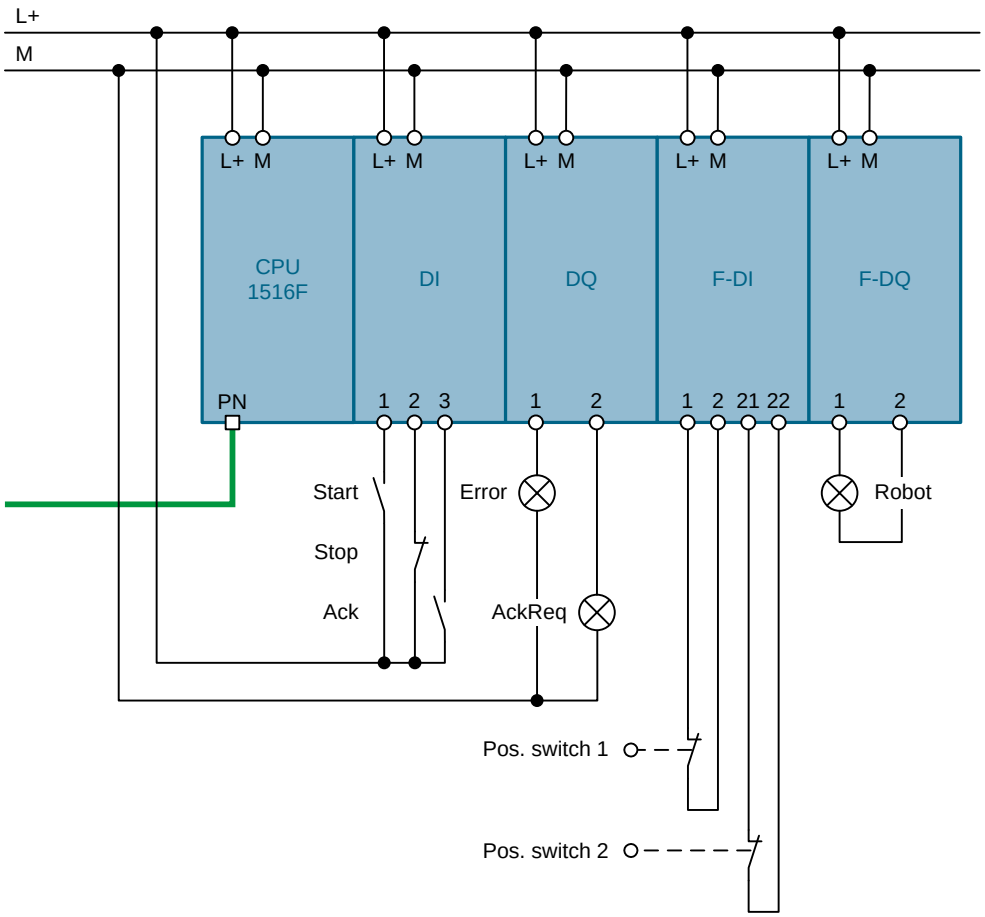


Table 2-1 Hardware assembly procedure

No.	Action
1.	Wire the F-CPU according to Figure 2-1.
2.	Connect the supply connector of the laser scanner to 24 V DC.
3.	Connect the supply connector to the laser scanner.
4.	Connect the laser scanner with your network.
5.	Connect the configuration cable with your PC/PG and the laser scanner.

2.2 Configuration

2.2.1 Configuration in the TIA Portal

The enclosed project does not require any further configuration. If you want to replicate the application example with other components, then the most important settings are shown in this chapter.

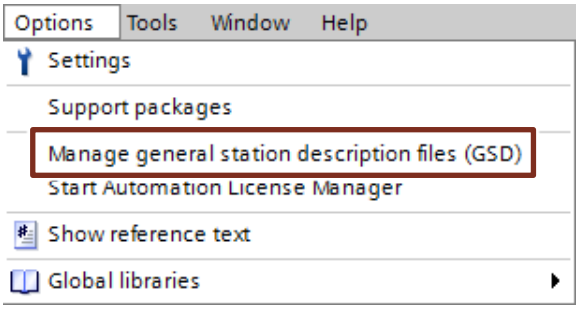
Implementing the laser scanner

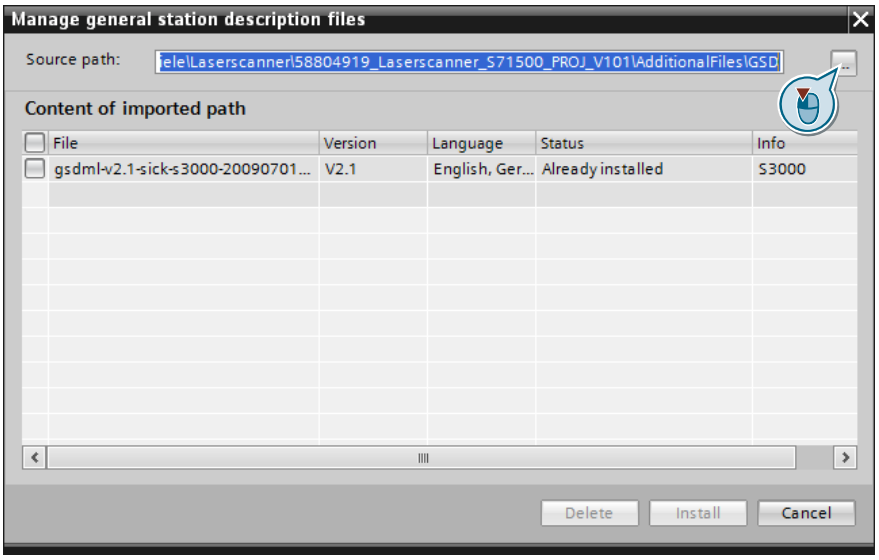
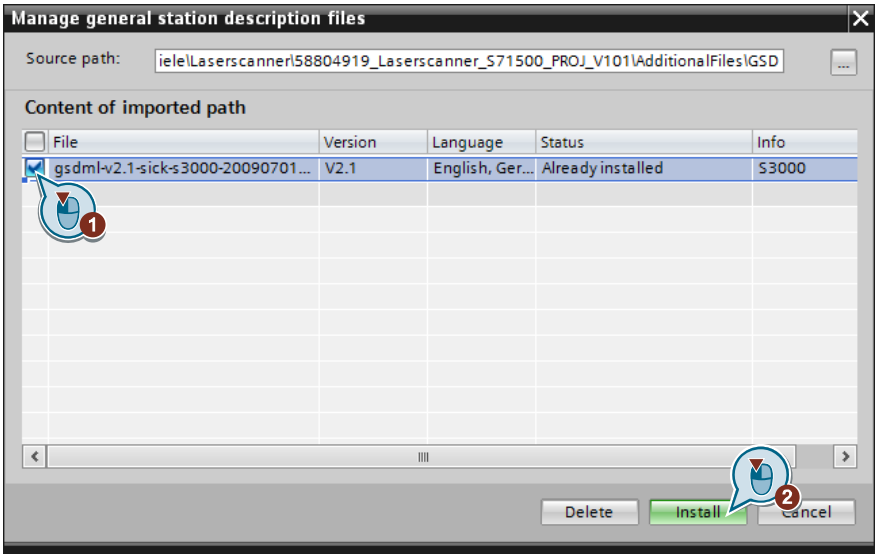
To integrate the SICK safety laser scanner into the STEP 7 hardware catalog, a device master file (GSDML file) is required. This file comes with the laser scanner or can be downloaded from the product website at \4\.

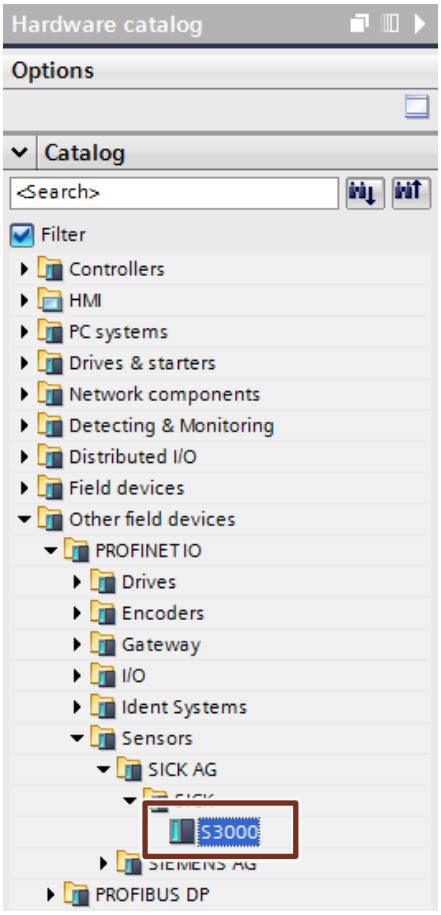
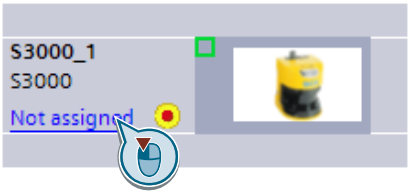
Note When opening the project, the GSDML file is automatically installed.

To implement the laser scanner into a new project, proceed as follows.

Table 2-2

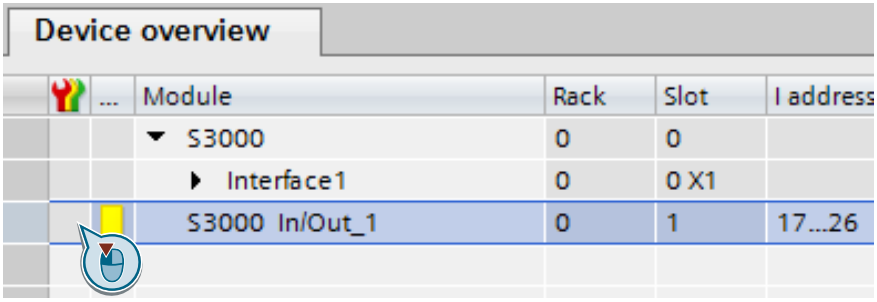
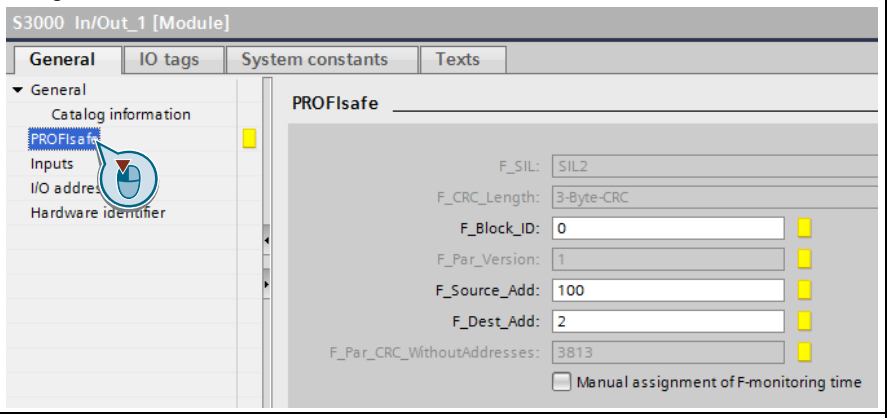
	Action
1.	In the TIA Portal in the menu list, click on “Options > Manage general station description files (GSD)”. 

	Action
2.	Click on the "..." button and select the file path to the GSDML file. 
3.	Select the GSDML file to be installed and click "Install". 
4.	Open "Devices & networks" from the project navigation.

	Action
5.	Per Drag&Drop, drag the “S3000” laser scanner from the hardware catalogue into the work area. You can find it under “Other field devices”. 
6.	Click on “Not assigned” and assign the laser scanner to the F-CPU. 

Assigning the PROFIsafe address

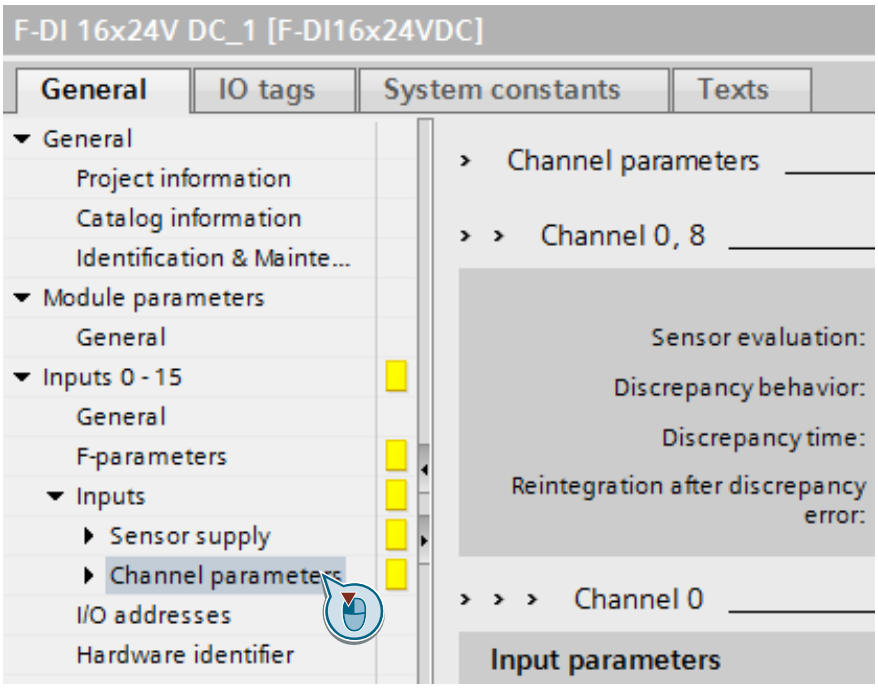
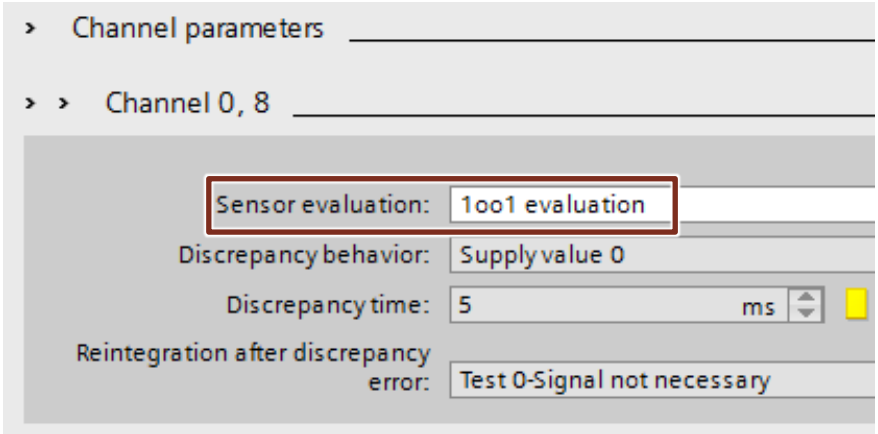
Table 2-3

	Action
1.	Open “Devices & networks” from the project navigation in the TIA Portal.
2.	Double-click on the laser scanner.
3.	In the device overview, select the line “S3000 In/Out_1“. 
4.	Open the properties in the inspector window and select “PROFIsafe“ in the area navigation. 
5.	In “F_Dest_Add“, enter a clear PROFIsafe or destination address. The same address also needs to be configured in the CDS.

Configuring F-DI

Both position switches are connected to an F-DI. Since the function block „MonitoringCaseSwitching“ checks the plausibility of the signals, the sensor evaluation in the F-DI is set to „1oo1 evaluation“. Proceed as follows.

Table 2-4

	Action
6.	Open “Devices & networks” from the project navigation in the TIA Portal.
7.	Double-click on the F-CPU.
8.	Double-click on the F-DI to open the properties.
9.	Select “Inputs 0 -15 > Inputs > Channel parameters” in the area navigation. 
10.	Under “Sensor evaluation“, select “1oo1 evaluation“. 

2.2.2 Configuration in the Configuration & Diagnose Software (CDS)

This chapter describes the most important settings that were made in the application example for the SICK safety laser scanner:

Note It is not necessary to make the settings in the application example, since they are already included in the supplied configuration file. The present chapter is only for your information.

Prerequisites

For the configuration, the laser scanner must be connected to the PG/PC. The software “Configuration & Diagnose Software (CDS)” from the SICK company must be installed on the PG/PC.

The CDS can be used to configure all available parameters of the S3000 and define the field geometries of the protective fields and warning fields.

The result of the configuration is stored in a configuration file (.skp). The configuration file is downloaded to the laser scanner.

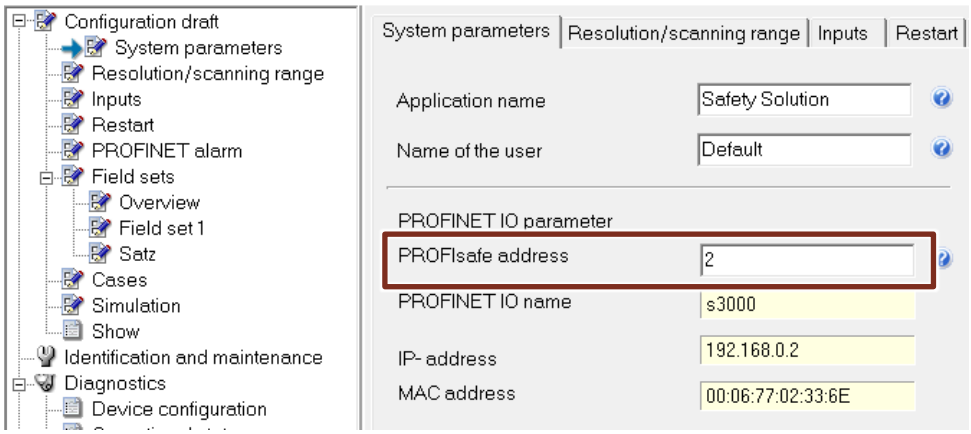
Connection establishment

For the application example, the configuration was performed via the local serial interface of the laser scanner.

PROFIsafe address

To ensure that the laser scanner can be operated as a PROFIsafe node, it must have its own PROFIsafe address. The PROFIsafe address of the laser scanner was taken from the TIA Portal project (see chapter 2.2.1) and entered in the CDS.

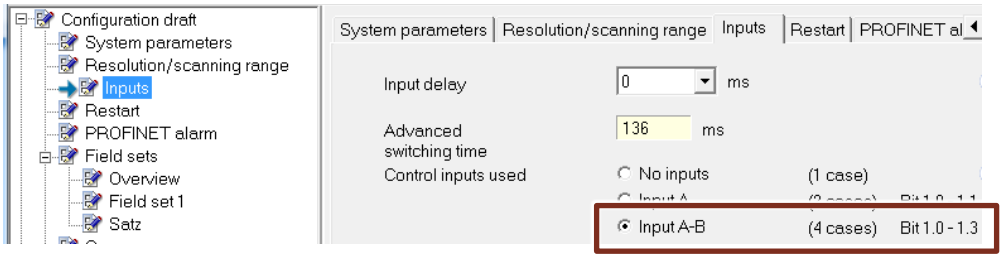
Figure 2-2



Control inputs

Two monitoring cases are implemented in the application example, four monitoring cases are prepared. Therefore, the “Input A-B” case is configured.

Figure 2-3

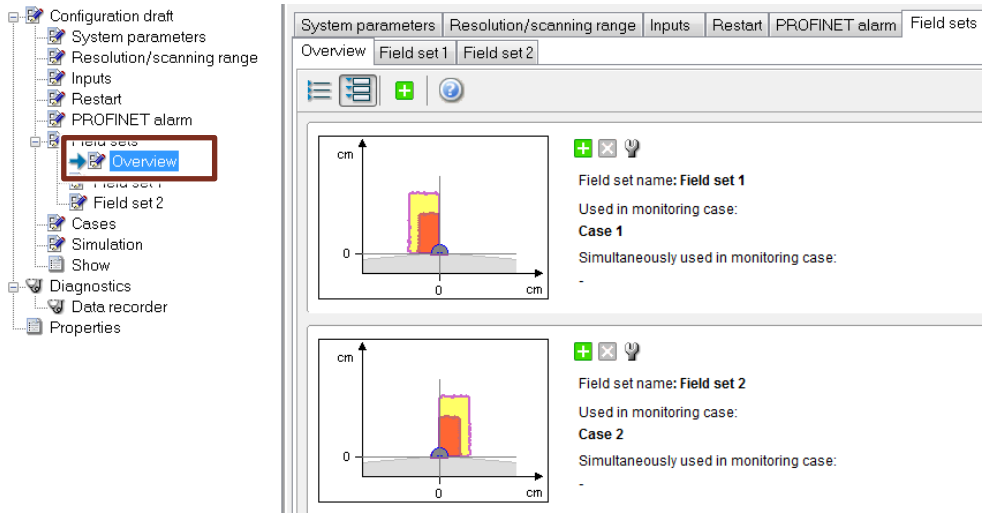


Field sets

Two field sets are configured:

- Field set 1 (protective field 1, warning field 1)
- Field set 2 (protective field 2, warning field 2)

Figure 2-4

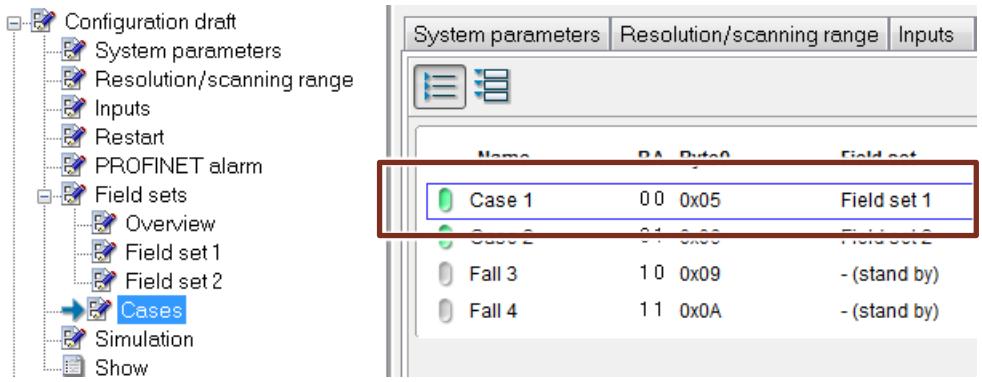


Monitoring cases

Two monitoring cases are configured:

- Monitoring case 1 with field set 1
- Monitoring case 2 with field set 2

Figure 2-5



Restart

The “without restart interlock” case is configured. A restart interlock is already implemented in the STEP 7 program.

2.2.3 Loading the configuration into the laser scanner

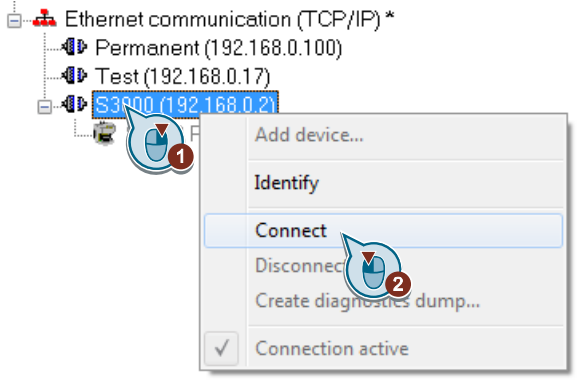
This chapter shows you how to load the configuration into the laster scanner via TCP/IP.

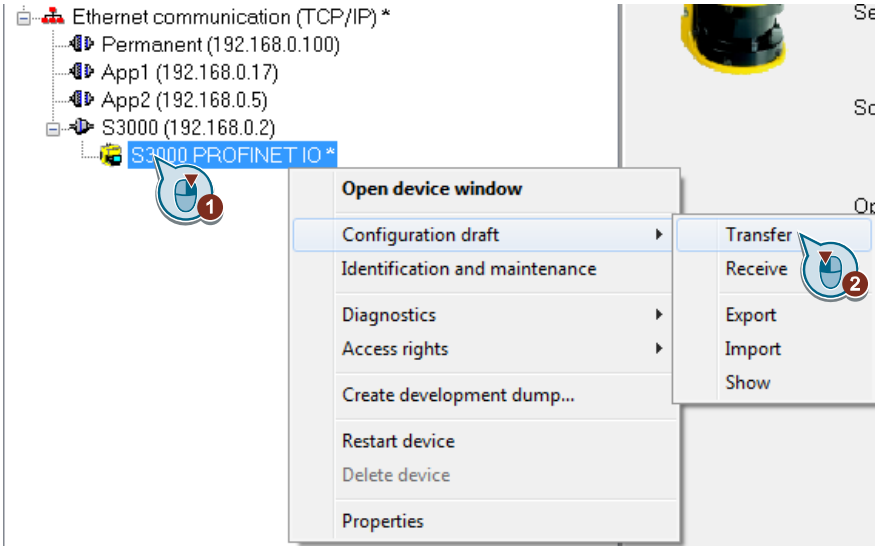
NOTE You must assign an IP address to the laser scanner before you can load the configuration into it. This happens automatically when you download the TIA Portal project to the F-CPU.

NOTE Alternatively you can load the configuration with a USB configuration cable by dragging the laser scanner to the COM port in CDS.

To load the configuration via TCP/IP, proceed as follows.

Table 2-5

	Action
1.	Connect the laser scanner with your computer via a network.
2.	Open the CDS.
3.	Open the configuration file “58804919_Laserscanner_S71500_CONFIG_V20.skp” from the supplied archive.
4.	With the right mouse button click “S3000 (192.168.0.2)” and select “Connect”. 

	Action
5.	With the right mouse button, click on the device “S3000 PROFINET IO“ and select “Configuration draft > Transfer”. 
6.	Log in as “Authorized client” with the factory set password “**SICKSAFE**“. **Note: Change this password for security reasons before commissioning your machine.**
7.	Confirm the dialog with “Continue”.
8.	Check the protocol and release the configuration by clicking on the “Release” button. 

2.3 Operation

Test of monitoring case 1:

Table 2-6

No.	Action	Explanation	Indicator light		Laser scanner
			Robot	Error	Display[1)]
1	Press the acknowledgment pushbutton	Acknowledgment necessary after power on	off	off	No error
2	Press the start pushbutton	---	on	off	No error
3	Press the stop pushbutton	---	off	off	No error
4	Press the start pushbutton	---	on	off	No error
5	Set object in warning field 2	Non-active monitoring case	on	off	No error
6	Set object in protective field 2	Non-active monitoring case	on	off	No error
7	Set object in warning field 1	Active monitoring case	on	off	Warning field violated
8	Set object in protective field 1	Active monitoring case	off	on	Protective field violated
9	Press the start pushbutton	---	off	on	Protective field violated
10	Remove object from field set 1	Restart lock, acknowledgment lamp flashes	off	on	No error
11	Press the start pushbutton	Restart interlock	off	on	No error
12	Press the acknowledgement pushbutton	---	off	off	No error
13	Press the start pushbutton	---	on	off	No error

[1)] See chapter 2.4.2.

Setting monitoring case 2

Table 2-7

No.	Action	Explanation	Indicator light		Laser scanner
			Robot	Error	Display[1)]
1	Switch ... ...from monitoring case 1: Sensor 1 = “0” Sensor 2 = “1” ...to monitoring case 2: Sensor 1 = “1” Sensor 2 = “0”	Switching must be performed within the time “maxSwitchingTime“, which is parameterized in the “Laserscanner” block.	on	off	No error

[1)] See chapter 2.4.2.

Test of monitoring case 2:

Table 2-8

No.	Action	Explanation	Indicator light		Laser scanner
			Robot	Error	Display[1)]
2	Set object in warning field 1	Non-active monitoring case	on	off	No error
3	Set object in protective field 1	Non-active monitoring case	on	off	No error
4	Set object in warning field 2	Active monitoring case	on	off	Warning field violated
5	Set object in protective field 2	Active monitoring case	off	on	Protective field violated
6	Press the start pushbutton		off	on	Protective field violated
7	Remove object from field set 2	Restart lock, acknowledgment lamp flashes	off	on	No error
8	Press the start pushbutton	Restart interlock	off	on	No error
9	Press the acknowledgement pushbutton		off	off	No error
10	Press the start pushbutton		on	off	No error

[1)] See chapter 2.4.2.

Simulation of an error during monitoring case switching

Table 2-9

No.	Action	Explanation	Indicator light		Laser scanner
			Robot	Error	Display[1)]
1	Sensor 1: unchanged "1" Sensor 2: from "0" to "1"	Non-permissible switching state of the sensors	off	on	Incorrect operation of the control inputs
2	Press the start pushbutton		off	on	Incorrect operation of the control inputs
3	Press the acknowledgment pushbutton		off	on	Incorrect operation of the control inputs
4	Press the start pushbutton		off	on	Incorrect operation of the control inputs
5	Sensor 1: unchanged "1" Sensor 2: from "1" to "0"	After the error removal, the laser scanner is automatically reinitialized and reintegrated.	off	on	Initialization
8	Press the acknowledgment pushbutton	Acknowledgment lamp flashes as soon as laser scanner is ready	off	off	No error

[1)] See chapter 2.4.2.

2.4 Error handling

2.4.1 LEDs of F-CPU

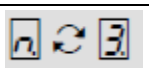
Table 2-10 LEDs of F-CPU

LED			Explanation
Robot	**Error**	**Acknowledgment**	
off	off	off	No start command
on	off	off	Robot is active
off	on	off	Error detected
off	on	flashes	Error fixed, user acknowledgment required

2.4.2 Indications on the laser scanner

The display of the laser scanner shows the laser scanner states. The following table shows the most important states for this application example.

Table 2-11 Information on the laser scanner

State	Laser scanner display		Explanation
	LED	**Segment**	
No error	Green: on		---
Warning field violated	Green: on Yellow: on		Object in the warning field
Protective field violated	Green: on Yellow: on		Object in the protective field
Incorrect operation of the control inputs	Green: on		Incorrect operation of the control inputs for switching the monitoring cases during operation
Incorrect operation of the control inputs	Green: on		Incorrect operation of the control inputs for switching the monitoring cases during initialization

3 Useful information

3.1 SICK S3000 PROFINET IO basics

The application example focuses on the use of a safety laser scanner for SIMATIC Safety Integrated for Factory Automation.

A safety laser scanner from SICK is used as an example.

This chapter describes the basics of the SICK S3000 PROFINET IO safety laser scanner.

Field of Application

The S3000 PROFINET IO safety laser scanner is used for personnel and plant protection. The laser scanner allows monitoring of hazardous areas on machines or vehicles.

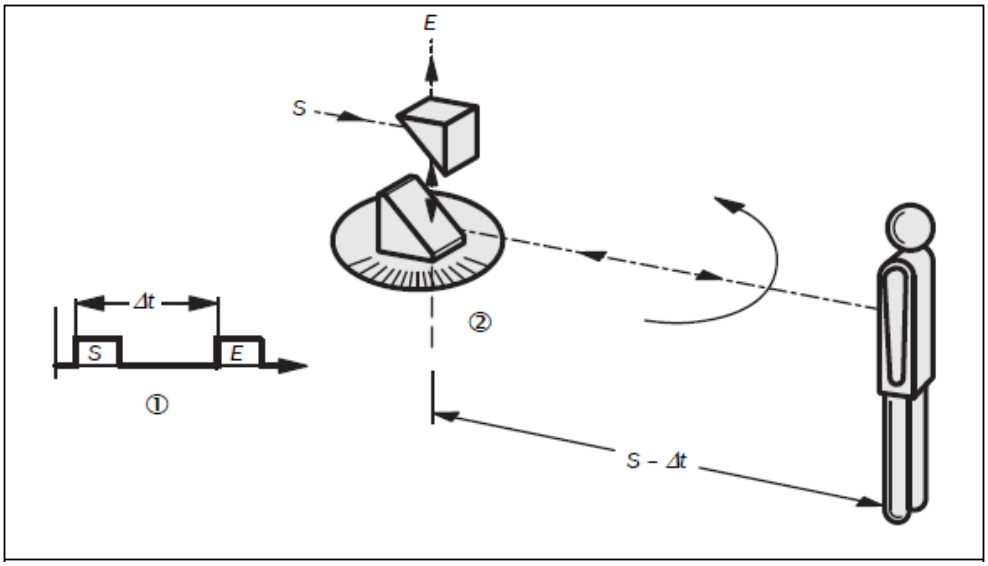
Examples of applications:

- Protection of machines with changing hazardous areas
- Hazardous area protection in robot cells and production systems

Mode of Operation

The S3000 is an optical sensor that scans its surroundings in two dimensions using infrared laser beams. The S3000 works on the principle of time of flight measurement. The figure below shows the principle of operation.

Figure 3-1

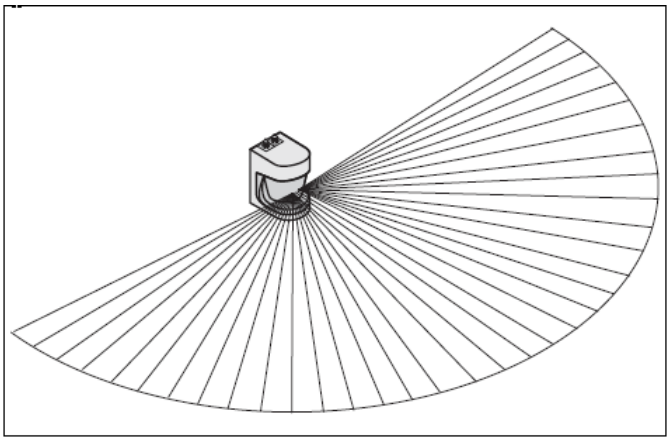


The S3000 sends out very short light pulses (S). When the light is incident on an object, it is reflected and received by the safety laser scanner (E). From the time between sending and receiving (Δt), the S3000 calculates the distance to the object.

In the S3000, there is also a mirror rotating at a constant speed that deflects the light pulses so that they cover an arc of 190° (Figure 3-2). By determining the angle of rotation of the mirror, the S3000 determines the direction of the object.

From the measured distance and the direction of the object, the safety laser scanner determines the exact position of the object.

Figure 3-2

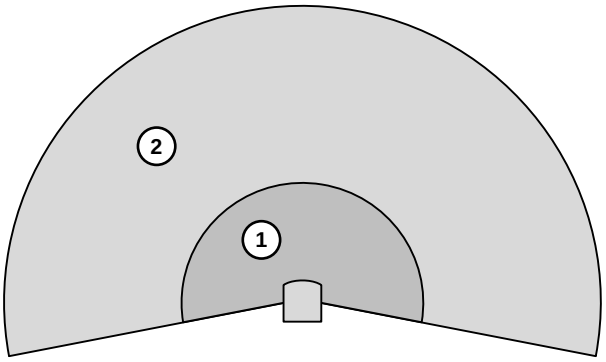


Protective field and warning field

The protective field (Figure 3-3 (1)) secures the hazardous area on a machine or vehicle. As soon as the safety laser scanner detects an object in the protective field, the S3000 switches the OSSD[1)] signal output to the off status (“0” signal) and thus initiates the shutdown of the machine or stop of the vehicle.

The warning field (Figure 3-3 (2)) can be defined so that the safety laser scanner detects an object before the actual hazardous area and, for example, triggers a warning signal.

Figure 3-3



[1)] OSSD (output signal switching device): Signal output of the protective device that is used to stop the dangerous movement.

Field set

Protective field and warning field form a pair, the so-called field set. With the aid of the Configuration & Diagnostic Software, these field sets are configured and transferred to the S3000. Up to eight field sets can be defined and saved in the S3000 PROFINET IO.

Monitoring case

With the S3000 safety laser scanner, you can define different monitoring cases to match the protective fields and warning fields to the situation on the machine. This allows situation-specific monitoring of changing hazardous areas, for example during the different production phases of a machine.

When configuring using the Configuration & Diagnostic Software, a monitoring case x is assigned a field set y (protective field y, warning field y).

Example

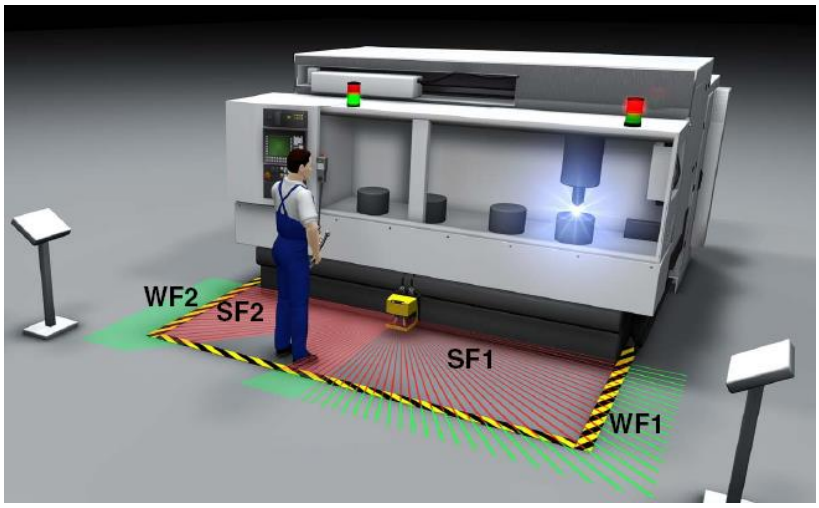
Figure 3-4 shows an example of hazardous area protection with two areas to be monitored. Two monitoring cases are defined in the robot cell shown in this figure:

- Monitoring case 1: Warning field 1 (WF1) and protective field 1 (SF1)
- Monitoring case 2: Warning field 2 (WF2) and protective field 2 (SF2)

Depending on where the robot is located in the robot cell, the respective monitoring case is active:

- The robot is located on the left: Monitoring case 2 is active
- The robot is located on the right: Monitoring case 1 is active

Figure 3-4



In the figure, the robot is located on the right of the robot cell, i.e. monitoring case 1 is active. This means:

- When the operator enters protective field 1, the robot will stop.
- The operator may enter protective field 2 and warning field 2.

Communication via PROFINET

The S3000 PROFINET IO is operated as an IO device on PROFINET. All input signals and output signals of the laser scanner are exchanged with the IO controller via the PROFINET interface.

Secure Communication

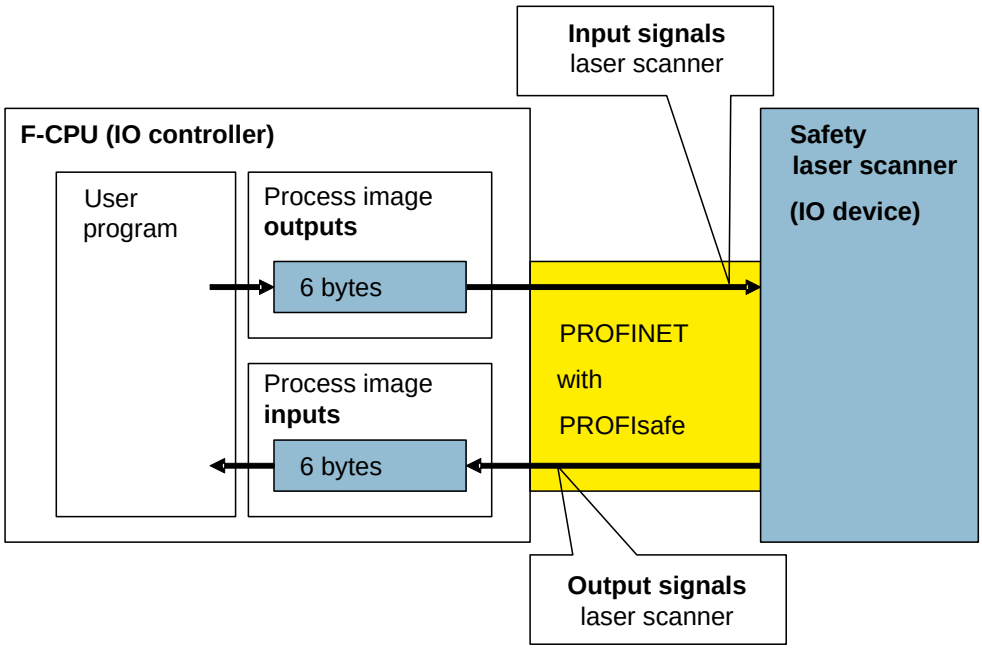
Safety-related components and standard components can be operated together on PROFINET. This is enabled by PROFIsafe, an extension of PROFINET.

PROFIsafe defines how safety-related IO devices (e.g., a SICK safety laser scanner) securely communicate with safety-related IO controllers (e.g., a SIMATIC F-CPU) via a network.

Process image of the SIMATIC F-CPU

F-CPU and safety laser scanner cyclically exchange signals via the process image.

Figure 3-5



Examples of input signals of the laser scanner (F-CPU outputs):

- Number of the monitoring case
- Reset protective field
- Initialize

Examples of output signals of the laser scanner (F-CPU inputs):

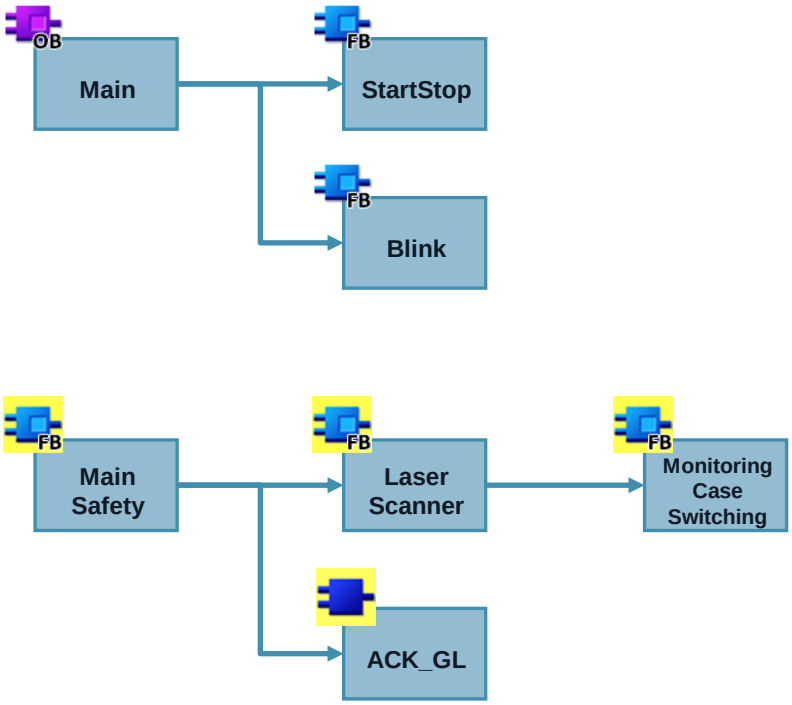
- Protective field unoccupied
- Warning field unoccupied
- Contamination

3.2 Mode of operation details

3.2.1 User program structure

Overview

Figure 3-6



Program blocks of the standard user program

Table 3-1

Program block	Function
StartStop	Represents the standard user program for controlling the robot
Blink	Generates a blinking signal for the acknowledgment lamp

Program blocks of the safety program

Table 3-2

Program block	Function
MainSafety	• Calls the block “LaserScanner” • Switches the actuator • Re-integrates passivated F-I/O
LaserScanner	• Calls the block “MonitoringCaseSwitching“ • Evaluates and controls the laser scanner
MonitoringCaseSwitching	Monitoring case switching
ACK_GL	Re-integrates passivated F-I/O

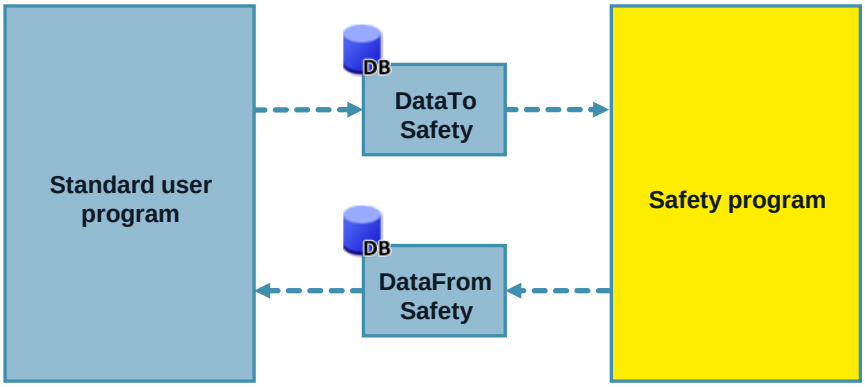
Data exchange between standard user program and safety program

In order to exchange data between the standard user program and the safety program, two global data blocks are used:

- DataToSafety
- DataFromSafety

The DataToSafety data block is written by the standard user program and read by the safety program. The DataFromSafety data block is written by the safety program and read by the standard user program.

Figure 3-7 Data exchange



The standard user program transmits the control signal “condition” to safety program.

The safety program transmits the following signals to the standard user program:

- Release signal “release”
- “ackReq“: Acknowledgment required by the user

Note More information on the exchange of data between the standard user program and the safety program can be found under \3\.

3.2.2 Program block LaserScanner

Function

The program block has the following functions:

- Evaluating the OSSD signals
- Calling up MonitoringCaseSwitching to switch the monitoring case
- Evaluating errors and restart lock
- Automatically re-initializing the laser scanner after an invalid control signal to switch the monitoring case
- Automatically re-integrating the laser scanner
- Outputting the release signal

Parameters of the function block

Figure 3-8 Function block “LaserScanner“

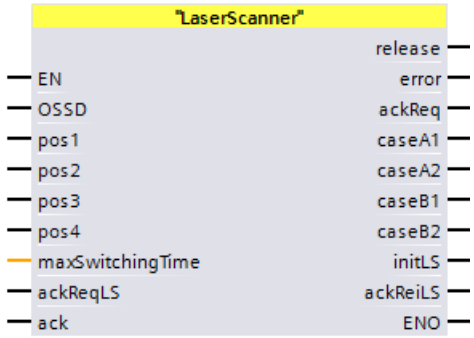


Table 3-3 Parameter “LaserScanner“

Parameter	Declaration	Type	Description
OSSD	IN	Bool	OSSD signal of laser scanner
pos1	IN	Bool	Sensor for monitoring case 1[1)]
pos2	IN	Bool	Sensor for monitoring case 2[1)]
pos3	IN	Bool	Sensor for monitoring case 3[1)]
pos4	IN	Bool	Sensor for monitoring case 4[1)]
maxSwitchingTime	IN	Time	Maximum permissible switching time
ackReqLS	IN	Bool	Bit “ACK_REQ“ of the F-I/O data block of the laser scanner
ack	IN	Bool	Acknowledgment by the user

Parameter	Declaration	Type	Description
release	OUT	Bool	Release signal of the safety function
error	OUT	Bool	An error has occurred
ackReq	OUT	Bool	Acknowledgment required by the user
caseA1	OUT	Bool	Control signals for switching the monitoring cases[2)]
caseA2	OUT	Bool	
caseB1	OUT	Bool	
caseB2	OUT	Bool	
initLS	OUT	Bool	Signal for re-initializing the laser scanner after an invalid control signal
ackReiLS	OUT	BOOL	Bit “ACK_REI“ of the F-I/O data block of the laser scanner

[1)] Non-existent sensors must be interconnected with a “1” signal.

[2)] Table 3-5 shows the assignment of the control signals

Re-initialization of laser scanner

When receiving invalid control signals (e.g. no sensor is “0”), the laser scanner switches to an error state that can only be exited via a restart or re-initialization.

A re-initialization is triggered automatically by the “Laserscanner” block as soon as the position switches output valid signals again. The re-initialization of the laser scanner takes a few seconds. The re-integration is carried out automatically. After that, the error, which has been caused by the invalid signals of the position switches, must be acknowledged by the user.

Figure 3-9

Re-integration of laser scanner

During a passivation of the laser scanner (e.g. communication error or re-initialization due to invalid control signals), this is recognized as an error in the “Laserscanner” function block and requires an acknowledgment by the user.

To prevent the user from having to press the acknowledgment button twice in a row (re-integration of laser scanner and acknowledgment of error), the laser scanner is always re-integrated automatically.

Figure 3-10

3.2.3 Program block: MonitoringCaseSwitching

Function

Monitoring case switching

This block implements monitoring case switching of max. four monitoring cases.

For this purpose, the F-CPU reads in the status of max. 4 sensors, derives the monitoring case number from this information and writes the respective control signals (A1, A2, B1, B2) to the laser scanner. The laser scanner activates the field set that is allocated to the monitoring case number.

One sensor (break contact) is allocated to each monitoring case:

- Monitoring case 1: Sensor 1
- Monitoring case 2: Sensor 2
- Monitoring case 3: Sensor 3
- Monitoring case 4: Sensor 4

Monitoring case x is selected when the following conditions apply:

- The sensor for monitoring case x is active (“0” signal)
- All other sensors are not active (“1” signal)

Switching time monitoring

The time that is required to switch between two monitoring cases (switching time) is monitored. The switching time can be parameterized on the block.

The following conditions are monitored:

- After switching a sensor from “0” to “1”, another sensor must switch from “1” to “0” within the monitoring time.
- After switching, exactly one of the following cases must be present:
  - Sensor 1 has “0” signal and all other sensors have “1” signal
  - Sensor 2 has “0” signal and all other sensors have “1” signal
  - Sensor 3 has “0” signal and all other sensors have “1” signal
  - Sensor 4 has “0” signal and all other sensors have “1” signal

If the above conditions are not met, an error has occurred.

Response in the event of an error

The control signals (from the F-CPU to the laser scanner) for switching the monitoring cases (A1, A2, B1, B2) are deleted (“0”).

In the laser scanner, the deletion of the control signals (“0”) causes the following actions:

- Reset of the OSSD output, which causes the F-CPU to shut down the robot.
- Error display on the laser scanner: “Incorrect operation of the control inputs”.

Implementation in the application example

Two monitoring cases are implemented in the application example. The code is prepared for max. 4 monitoring cases. To use additional monitoring cases, perform the following steps:

- Configure the additional field sets and allocate the monitoring cases using the CDS
- Interconnect the additional sensors for the monitoring cases at the call interface of the program block

Parameters of the function block

Figure 3-11 Function block “MonitoringCaseSwitching“

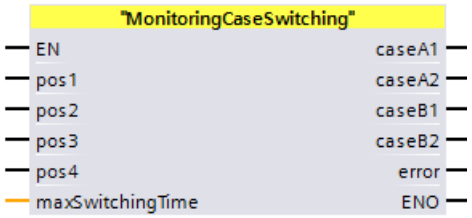


Table 3-4 Parameter “MonitoringCaseSwitching“

Parameter	Declaration	Type	Description
pos1	IN	Bool	Sensor for monitoring case 1[1)]
pos2	IN	Bool	Sensor for monitoring case 2[1)]
pos3	IN	Bool	Sensor for monitoring case 3[1)]
pos4	IN	Bool	Sensor for monitoring case 4[1)]
maxSwitchingTime	IN	Time	Maximum permissible switching time
caseA1	OUT	Bool	Control signals for switching the monitoring cases[2)]
caseA2	OUT	Bool	
caseB1	OUT	Bool	
caseB2	OUT	Bool	
error	OUT	Bool	Error when monitoring the switching time

[1)] Non-existent sensors must be interconnected with a “1” signal.

[2)] The following table shows the assignment.

Table 3-5 Control signals to control the current monitoring case

Sensor for monitoring case				Control signals from F-CPU to laser scanner				Monitoring case
Sensor 1	Sensor 2	Sensor 3	Sensor 4	Bit B2	Bit B1	Bit A2	Bit A1	
0	1	1	1	0	1	0	1	1
1	0	1	1	0	1	1	0	2
1	1	0	1	1	0	0	1	3
1	1	1	0	1	0	1	0	4

3.3 Evaluation of the Safety Function

3.3.1 Standards

For an evaluation of the safety function, the following versions of the standards were used:

Table 3-6

Version	Mentioned below
EN ISO 13849-1:2015	ISO 13849-1
EN 62061:2005 + A2:2015	IEC 62061

3.3.2 Safety function

The following safety function is important for the further considerations:

“If the laser scanner’s safety field is harmed during the current monitoring case, the robot needs to be shut down.”

Note This application example ignores the “React” subsystem. Therefore, the evaluation of the safety function is incomplete.

3.3.3 Evaluation according to IEC 62061

Detection

The subsystem “Capture” consists of the following safety-related parts:

- Safety laser scanner
- Position switch

The failure probabilities of the safety-related parts are summed up.

Both position switches are considered as a non-equivalent, two-channel system.

The following table lists possible errors of the position switches and their recognition by the safety program.

Table 3-7

Error	Recognition
Wire break	If at the time of the wire break, the robot activates the concerned position switch (”0” signal), the error is recognized at the latest when the robot changes its position (both sensors report “0”). Otherwise, the error is immediately recognized. At any point, the relevant protection field is active.
Actuator break or position switch break-off	If at the time of the break, the robot activates the unconcerned position switch (”0” signal), the error is recognized at the latest when the robot changes its position (both sensors report “1”). Otherwise, the error is immediately recognized. At any point, the relevant protection field is active.
Jamming of actuator or welding of a contact	If at the time of the error, the robot activates the concerned position switch (”0” signal), the error is recognized at the latest when the robot changes its position (both sensors report “0”). Otherwise, the error is immediately recognized. At any point, the relevant protection field is active.

Due to the evaluation of the signals in the “MonitoringCaseSwitching“ function block, a diagnostic coverage of 99 % can be assumed.

The following table shows the parameters of the evaluation of the position switches.

Table 3-8

Parameter	Value	Explanation	Definition
B10 Switching cycles	10,000,000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures	0.2 (20%)	Manufacturer information	
T1 Lifetime	20 years	Manufacturer information	
Subsystem architecture	D	2 channels, 2 components: Single fault tolerance with diagnostic function	User
Operations/ Test interval	6/hour	Assumption	
β (CCF factor) Susceptibility to common cause failures	0.1 (10%)	For installations according to IEC 62061, a CCF factor of 0.1 (10%) is achieved.	
DC Diagnostic coverage	≥ 0,99 (99%)	Plausibility check by the safety program	

Table 3-9

Component	PFH_D	SILCL	Definition
S3000 safety laser scanner	$8{,}00 \cdot 10^{-8}$	SILCL 2	SICK AG
Position switch	$1{,}20 \cdot 10^{-9}$	SILCL 3	Calculation
Total	$\mathbf{8{,}12 \cdot 10^{-8}}$	**SILCL 2**	**Calculation**

Evaluation

Table 3-10

Component	PFH_D	SILCL	Definition
CPU 1516F-3PN/DP incl. PROFIsafe	$2{,}00 \cdot 10^{-9}$	SILCL 3	SIEMENS AG
ET 200MP F-DI	$1{,}00 \cdot 10^{-9}$	SILCL 3	
ET 200MP F-DQ	$2{,}00 \cdot 10^{-9}$	SILCL 3	
Total	$\mathbf{5{,}00 \cdot 10^{-9}}$	**SILCL 3**	

Result

Table 3-11

Subsystem	PFH_D	SIL achieved
Detection	$8{,}12 \cdot 10^{-8}$	SILCL 2
Evaluation	$5{,}00 \cdot 10^{-9}$	SILCL 3
Reaction	---	---
Total	**$8{,}62 \cdot 10^{-8}$**	**SILCL 2**
	SIL 2	

Note The “React” subsystem must comply with a SILCL 2 in order for the safety function to reach SIL 2.

3.3.4 Evaluation according to ISO 13849-1

Detection

The same explanations as in chapter 3.3.3 apply.

The following table shows the parameters of the evaluation of the position switches.

Table 3-12

Parameter	Value	Explanation	Definition
B10 Switching cycles	10,000,000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures	0.2 (20%)	Manufacturer information	
T1 Lifetime	175,200 h (20 years)	Manufacturer information	
Architecture	Category 4	2 channels, 2 component	User
Operations/ Test interval	6/hour	Assumption	
CCF measures (points) Susceptibility to common cause failures	≥ 65	Sufficient measures against CCF according to ISO 13849-1 table F.1 have to be provided	
DC Diagnostic coverage	≥ 0,99 (99%)	Plausibility check by the safety program	

Table 3-13

Component	PFH_D	PL	Definition
S3000 safety laser scanner	$8{,}00 \cdot 10^{-8}$	PL d	SICK AG
Position switch	$2{,}47 \cdot 10^{-8}$	PL e	Calculation
Total	**$1{,}04 \cdot 10^{-7}$**	**PL d**	**Calculation**

Evaluation

Table 3-14

Component	PFH_D	PL	Definition
CPU 1516F-3PN/DP incl. PROFIsafe	$2{,}00 \cdot 10^{-9}$	PL e	SIEMENS AG
ET 200MP F-DI	$1{,}00 \cdot 10^{-9}$	PL e	
ET 200MP F-DQ	$2{,}00 \cdot 10^{-9}$	PL e	
Total	**$5{,}00 \cdot 10^{-9}$**	**PL e**	

Result

Table 3-15

Subsystem	PFH_D	PL achieved
Detection	$1{,}04 \cdot 10^{-7}$	PL d
Evaluation	$5{,}00 \cdot 10^{-9}$	PL e
Reaction	**---**	---
Total	**$1{,}09 \cdot 10^{-7}$**	**PL d**
	PL d	

Note The “React” subsystem must comply with a PL d in order for the safety function to reach PL d.

4 Appendix

4.1 Service and support

Industry Online Support

Do you have any questions or need assistance?

Siemens Industry Online Support offers round the clock access to our entire service and support know-how and portfolio.

The Industry Online Support is the central address for information about our products, solutions and services.

Product information, manuals, downloads, FAQs, application examples and videos – all information is accessible with just a few mouse clicks at:
https://support.industry.siemens.com/

Technical Support

The Technical Support of Siemens Industry provides you fast and competent support regarding all technical queries with numerous tailor-made offers – ranging from basic support to individual support contracts. You send queries to Technical Support via Web form:
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Service offer

Our range of services includes, inter alia, the following:

- Product trainings
- Plant data services
- Spare parts services
- Repair services
- On-site and maintenance services
- Retrofitting and modernization services
- Service programs and contracts

You can find detailed information on our range of services in the service catalog:
https://support.industry.siemens.com/cs/sc

Industry Online Support app

You will receive optimum support wherever you are with the "Siemens Industry Online Support" app. The app is available for Apple iOS, Android and Windows Phone:
https://support.industry.siemens.com/cs/ww/en/sc/2067

4.2 Links and references

Table 4-1 Links and references

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/58804919
\3\	SIMATIC Safety – Configuring and Programming https://support.industry.siemens.com/cs/ww/en/view/54110126
\4\	Product website SICK S3000 PROFINET IO https://www.sick.com/us/en/opto-electronic-protective-devices/safety-laser-scanners/s3000-profinet-io-advanced/s30a-6111cp/p/p120141

4.3 Change documentation

Table 4-2 Change documentation

Version	Date	Modifications
V1.0	03/2012	First version
V2.0	09/2016	Exchange of S7-300 for a S7-1500 Migration to TIA Portal V13 SP1