Application Example • 07/2015

Emergency Stop up to SIL 3 / PL e with a Fail-Safe S7-1500 Controller

SIMATIC Safety Integrated

https://support.industry.siemens.com/cs/ww/de/view/21064024

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1 Task

In order to be able to safely switch of a machine even in an emergency situation, an emergency stop control device shall be attached and monitored by the same controller that also controls the automation process. The actuators will be controlled via two contactors. The safety function has to be designed up to SIL 3 in accordance with IEC 62061 or PL e in accordance with EN ISO 13849-1.

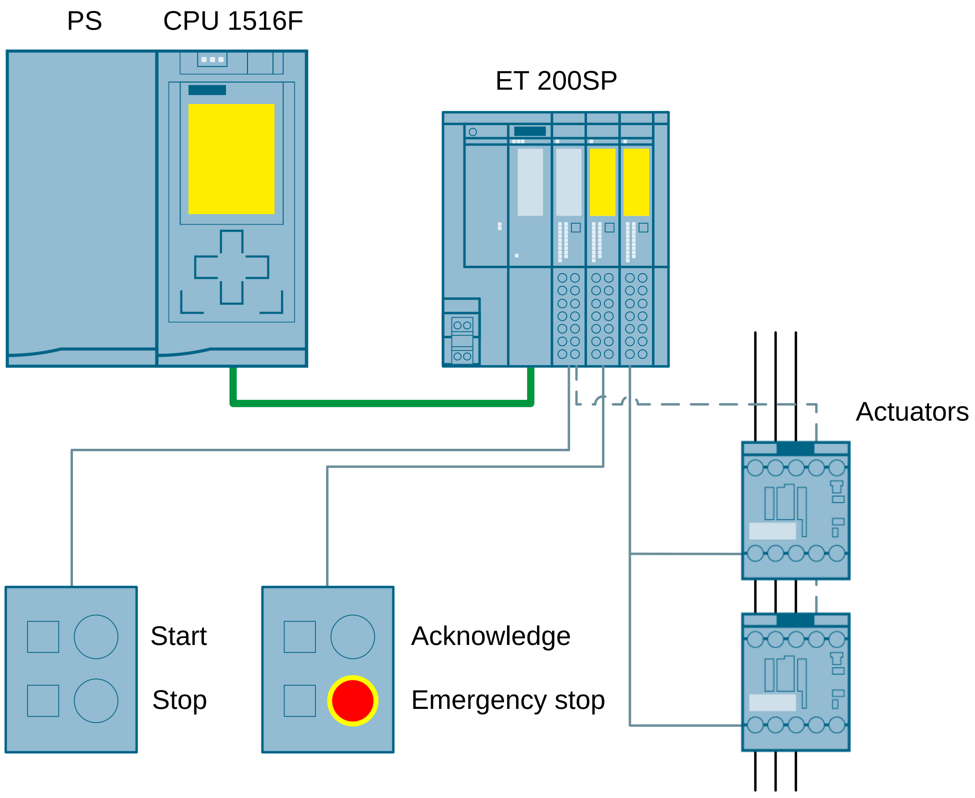
Figure 1-1

2 Solution

2.1 Overview

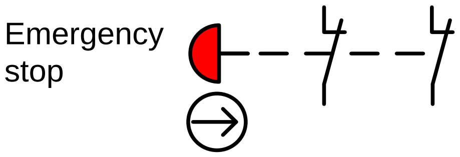
In order to guarantee the seamless integration into the automation process, the failsafe S7-1516F controller is used, in which standard user program and safety program run next to each other. The inputs and outputs are read in and output by the distributed I/O ET 200SP. The controller and the distributed I/O communicate via the fail-safe PROFINET profile PROFISafe.

Figure 2-1 Overview of the hardware configuration



In order to achieve the demanded safety level, the emergency stop is designed with two channels and monitored for discrepancy and cross-circuit by the controller

Figure 2-2



The actuators are also set up redundantly, so in case one contactor fails (e.g. welding of the contacts) the machine is still safely switched off by the second contactor.

2.2 Description of the core functionality

In this application example the following functions are realized:

- Resetting a failsafe digital output (stopping the application), after actuating the emergency stop button
- Locking against a restart of the machine until the following conditions are fulfilled:
  - Emergency stop is unlocked
  - Acknowledgement has been given (does not automatically start the application)
  - Start button is pressed (only possible with previous acknowledgement)
- Monitoring the correct function of the contactors
- Locking against a restart of the machine when a faulty contactor has been detected

2.3 Hardware and software components

The application was created with the following components:

Hardware components

Table 2-1

Component	No.	Article number	Note
Power supply	1	6EP1332-4BA00	PM 190 W
Fail-safe S7-CPU	1	6ES7516-3FN00-0AB0	CPU 1516F-3 PN/DP
SIMATIC memory card	1	6ES7954-8LF01-0AA0	SMC 24 MB
Interface module for ET 200SP	1	6ES7155-6AU00-0BN0	IM155-6PN ST
Digital input module	1	6ES7131-6BF00-0BA0	8 DI ST, DC 24 V
Fail-safe digital input module	1	6ES7136-6BA00-0CA0	8 F-DI, DC 24 V
Fail-safe digital output module	1	6ES7136-6DB00-0CA0	4 F-DQ, DC 24 V, 2 A
Server module (automatically supplied with the interface module)	1	6ES7193-6PA00-0AA0	
Base Unit for DI	1	6ES7193-6BP00-0DA0	Supply terminal separated
Base Unit for F-DI and F-DQ	2	6ES7193-6BP00-0BA0	Supply terminal bridged
Bus adapter	1	6ES7193-6AR00-0AA0	BA 2xRJ45
DIN rail S7-1500	1	6ES7590-1AE80-0AA0	Length: 482 mm
DIN rail 35mm	1	6ES5710-8MA11	Length: 483 mm
Emergency stop	1	3SU1851-0NB00-2AA2	Mushroom push 2NC
Push button	3	3SU1	2NO, 1NC
Contactor	2	3RT2015-1BB42	S00, DC 24 V, 1NC

Note The functionality was tested with the hardware components specified. Similar products that are not included in the list above can also be used. In this case, please note that changes to the example code (e.g. different addresses) may become necessary.

Software components

Table 2-2

Component	No.	Article number	Note
STEP 7 Professional	1	6ES7822-1AA03-0YA5	V13 SP1
STEP 7 Safety Advanced	1	6ES7833-1FA13-0YA5	V13 SP1

Example files and projects

The following list includes all files and projects that are used in this example.

Table 2-3

Component	Note
21064024_ESTOP_SIL3_1500F_DOC_V40_en.pdf	This document
21064024_ESTOP_SIL3_1500F_CODE_V40.zip	This zip file contains the STEP 7 project.
21064024_ESTOP_SIL3_1500F_SET_V40.zip	Evaluation of the safety functions as SET project

2.4 Advantages / customer benefits

- Integration of safety function in the complete application:
  - Status of the emergency stop is also available in the standard user program and can be processed there.
  - No complicated synchronization (extra wiring or data mapping) between standard and safety automation.
- The diagnostic is performed channel granular even for several emergency stop control devices:
  - Error localization is accelerated.
- Diagnostic messages can be displayed without the additional effort of a message configuration on
  - an HMI panel,
  - by means of web server or
  - on the display on the CPU.

3 Basics

3.1 Basic terms

Cross-circuit

The cross-circuit detection is a diagnostic function of an evaluation device, as a result of which short-circuits or cross-circuits are detected between the two input channels (sensor circuits).

A cross-circuit can occur, for example, if a light plastic-sheathed cable is crushed. Without cross-circuit detection this would lead to, for example, a 2-channel emergency stop circuit not to trigger a shut-down even if only one normally-closed contact is faulty (second error).

Feedback circuit

A feedback circuit is used for the monitoring of controlled actuators (e.g. relay or power contactors) with positively driven contacts or mirror contacts. The outputs can only be enabled when the feedback circuit is closed. When using a redundant switch off path, the feedback circuit of both actuators has to be evaluated. For this purpose, they may also be connected in series.

Positive opening operation

Positive opening switches are designed in a way that the operation of the switch inevitably leads to an opening of the contacts. Welded contacts are forced open through the operation (EN 60947-5-1).

Positively driven contacts

For a component with positively driven contacts it is guaranteed that the normally-closed and normally-open contacts are never closed at the same time (EN 60947-5-1).

3.2 Functional safety

From the view of the goods to be protected, safety is indivisible. However, since the causes of the hazards and therefore also the technical measures for avoiding them may be very different, the types of safety are also distinguished, for example, by specifying the respective cause of possible hazards. For this reason it is referred to “electrical safety” when hazards from electricity are expressed or “functional safety” when the safety depends on the correct function.

In order to achieve functional safety of a machine or plant, it is necessary for the safety-relevant parts of the protective equipment and control devices to function correctly and that they behave in a way that the plant stays in a safe state or is brought to a safe state in the event of an error.

A very high-quality technology is necessary to achieve this, where the requirements described in the appropriate standards are met. The requirements to achieve functional safety are based on the following basic targets:

- avoidance of systematic faults
- control of systematic faults
- managing accidental errors or failures

The measure for the functional safety achieved, is the probability of dangerous failures, the error tolerance and the quality through which the freedom from systematic errors is to be guaranteed. This expressed in the standards through different terms:

- In IEC 62061: “Safety Integrity Level” (SIL)
- In ISO 13849-1: “Performance Level” (PL)

More information on function safety can be found in \8\.

3.3 Emergency stop

The emergency stop control device is a widely used component to protect personnel, plants and the environment from hazards and to initiate a standstill in the event of an emergency. This chapter describes applications with safety functions from exactly this range of application.

Facilities, functional aspects and general principles for design of the emergency stop are documented in EN ISO 13850. Additionally, the standard EN 60204-1 must also be observed.

Typical applications

The emergency stop control device with its positive opening contacts is monitored by an evaluation unit. If the emergency stop is pressed, the evaluation unit safely switches off the actuators according to stop category 0 in accordance with EN 60204-1. Before switching back on or acknowledging the emergency stop, it is checked whether the contacts of emergency stop control device are closed and the actuators are switched off.

Note Emergency stop is not a means of risk reduction. Emergency stop is an “additional safety function” (if the “emergency stop” has to be pressed, the motor must be switched off).

Unintentional actuation

It is often required that an emergency stop control device has to be protected from unintentional actuation and therefore to increase plant availability. The first step is the correct placement of the emergency stop control device on the machine. The emergency stop control device has to be easily accessible, easily reachable and safe to press.

In addition, there is the option to use a protective collar to protect from unintentional actuation. It also has to be made sure that easy accessibility is guaranteed.

Note

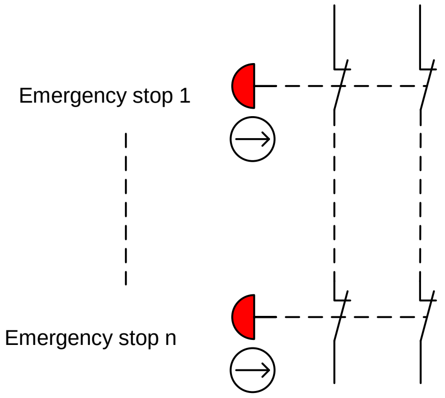
SIEMENS SIRIUS emergency stop control devices with protective collar correspond to the requirements of EN ISO 13850 "Safety of machinery - Emergency stop - Principles for design".

So far, no particular requirements exist for the protective collar, since they are not mentioned explicitly in any standard on functional safety. It is often at the discretion of the third-party expert to accept them for a certain machine.

Conditions for series connection

Up to PL e (according to ISO 13849-1) or SIL 3 (according to IEC 62061) emergency stop control devices may only be connected in series if the failure and the simultaneous pressing of the emergency stop control devices can be excluded. For further information please refer to \9\.

Figure 3-1



If several emergency stop control devices are electrically connected in series, each fail-safe switch off via an emergency stop control device represents an individual supplementary safety function. If identical emergency stop control devices are used, it is sufficient to look at one additional safety function, as an example and representative for all additional safety functions. For further information please refer to \6\.

4 Mode of Operation

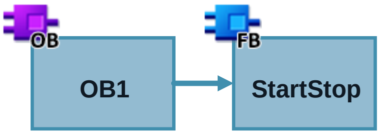
4.1 Overview

The setup for realizing the emergency stop functionality consists of a configuration with PROFINET (PN) with PROFIsafe profile. A fail-safe S7-CPU (F-CPU) is used as IO controller and an ET 200SP is used as IO device. Two contactors are used as actuators.

NOTICE	**SIL 3 / PL e can only be achieved, if the function of the contactors is monitored in the feedback circuit.** For more information regarding the “Feedback circuit” topic, please refer to \3\.

4.2 Standard user program functionality

Figure 4-1



StartStop function block

This block is used to evaluate start and stop button. With a positive edge at the input of the start button, a start signal is written into the global data block “DataToSafety”. The start signal is then evaluated in the safety program where the machine is switched on and off.

The block evaluates:

- Start button
- Stop button
- Error message “fault” from the safety program via the “DataFromSafety” data block, see chapter 4.4.

If the stop button is pushed or an error is detected by the “DataFromSafety” global data block via the “fault” signal, the start signal is reset.

Figure 4-2

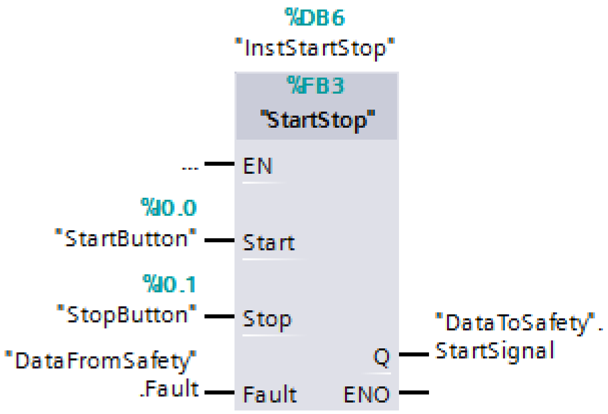
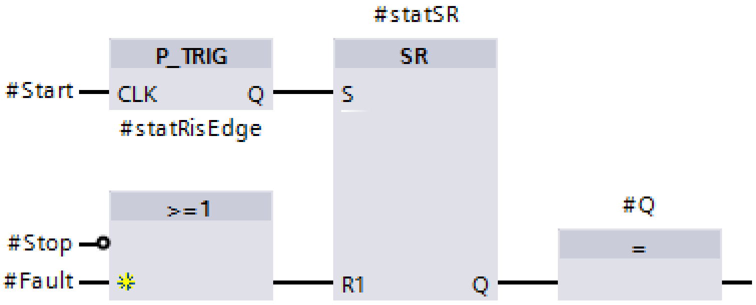
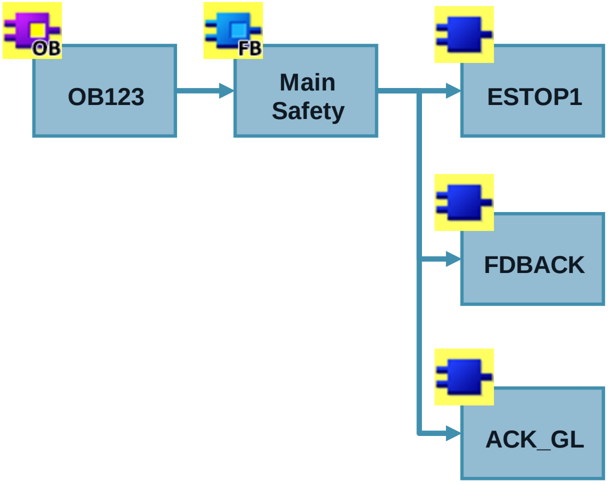


Figure 4-3



4.3 Functionality of the safety program

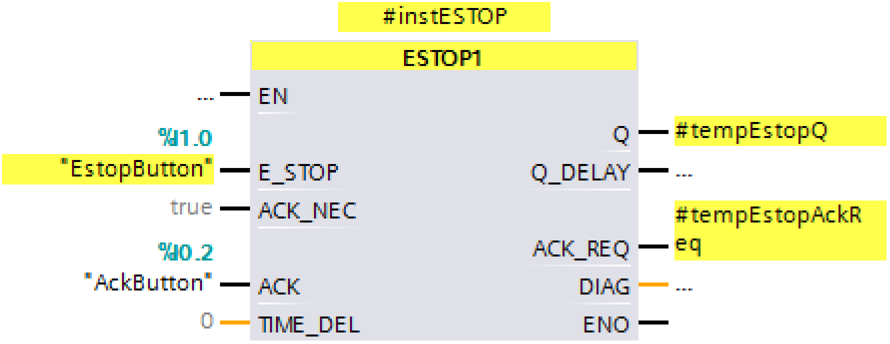
Figure 4-4



ESTOP1 instruction

The ESTOP1 instruction is included in STEP 7 Safety Advanced. If the emergency stop is not actuated, the instruction sets the output Q to TRUE. After pushing the emergency stop, it has to be unlocked and acknowledged via the ACK input. It is output via ACK_REQ that an acknowledgement is required. The Q output is intermediately saved in the temporary #tempEstopQ tag, in order to simplify access in the next instruction.

Figure 4-5



Note

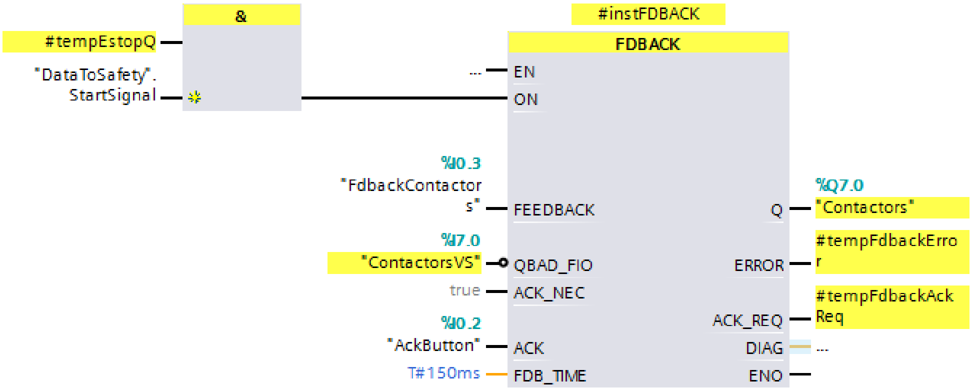
Both channels of the emergency stop are monitored for discrepancy and cross-circuit by the F-DI module. There will then be one processed signal available in the user program for both channels. The individual channels cannot be accessed.

FDBACK instruction

The FDBACK instruction is included in STEP 7 Safety Advanced. It switches the actuators (in this example the two contactors) and monitors their correct function via the feedback circuit.

When the enable signal #tempEstopQ and the start signal #StartSignal from the standard user program (see chapter 4.4) are present, the contactors are switched on. The signal on the FEEDBACK input has to switch inverse to the Q output signal within the configured FDB_TIME time. If this is not the case, the contactors are switched off again. Afterwards it has to be acknowledged via the ACK input. It is output via ACK_REQ that an acknowledgement is required.

Figure 4-6



Note

In the newer controllers S7-1200 and S7-1500, the channel granular QBAD bit is replaced by the value status. The following rules apply for the value status:

FALSE: Substitute values are output.

TRUE: Process values are output.

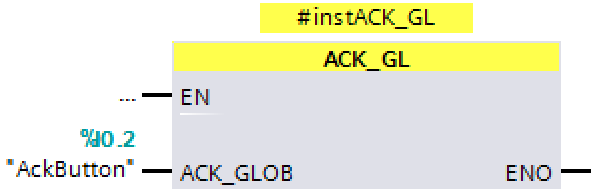
The value status behaves inversely to the QBAD bit and is entered into the process image of the inputs (PII).

For more information on the value status, please refer to \5\.

ACK_GL instruction

The ACK_GL instruction is included in STEP 7 Safety Advanced. It generates an acknowledgement for the simultaneous reintegration of all F-I/Os/channels of the F I/Os of an F-runtime group after communication errors or F-I/O/channel errors.

Figure 4-7



Examples of events that cause passivation:

- Wire break on the F-DQ
- Missing power supply on the F-DI

Note

If an error occurs on the hardware, it may take a couple of seconds until the module detects that the error has been removed (e.g. detected wire break). Only then is there an effect from pressing the acknowledgement button.

4.4 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 standard user program and read by the safety program.

The processed “StartSignal” is transferred from the standard user program to the safety program. The safety program reports a fail-safe shutdown or errors in the safety program via the “fault” tag to the standard user program.

Note For more information about the data exchange between the standard user program and the safety program, please refer to \5\.

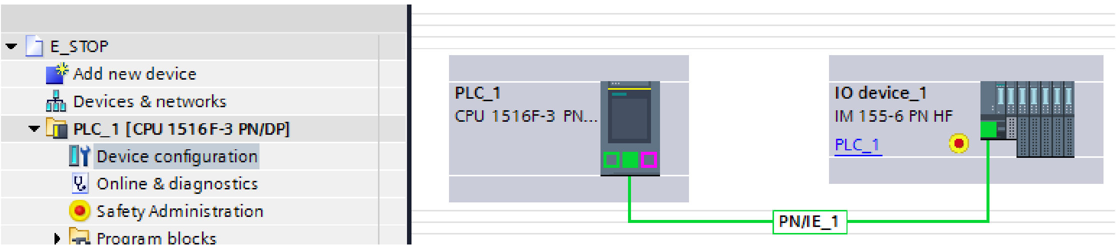
5 Configuration and Settings

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.

NOTICE	**The settings displayed below help to meet PL e / SIL 3. Changes on the settings may cause loss of the safety function.**

NOTICE	**The default values used in the example projects may also differ from your individual requirements.**

Figure 5-1 Network view in the device configuration

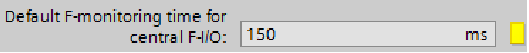


5.1 Configuration of S7-1500 F-CPU

F-monitoring time

The F-monitoring time is set to 150 ms.

Figure 5-2 F-monitoring time



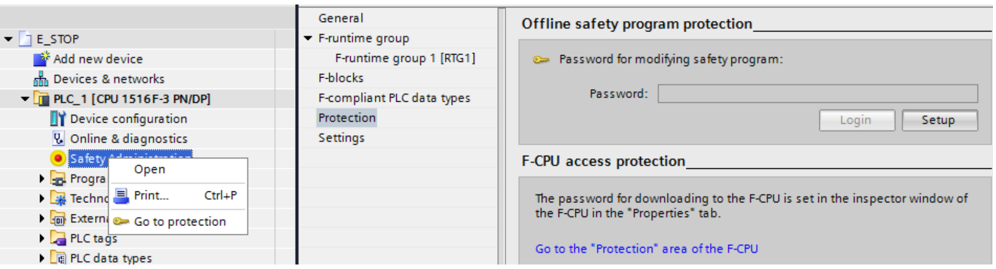
Default F-monitoring time for central F-I/O: 150 ms

Password and access protection

No access protection is configured in the project presented.

In order to create, change or cancel the access rights for the safety program, double-click “Safety Administration” in the project tree and click on “Protection”.

Figure 5-3 Password and access protection



Offline safety program protection

Password for modifying safety program:

Password:

F-CPU access protection

The password for downloading to the F-CPU is set in the inspector window of the F-CPU in the "Properties" tab.

Go to the "Protection" area of the F-CPU

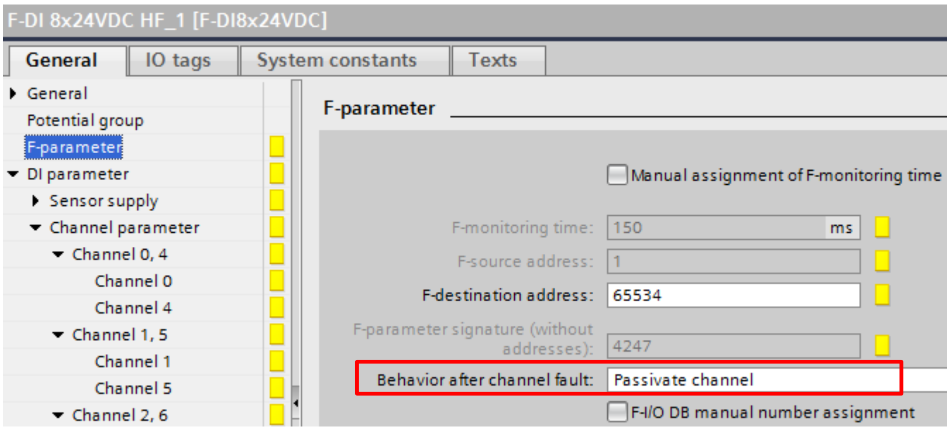
5.2 Configuration of the distributed I/O

5.2.1 Settings of the F-DI

Behavior after channel fault

In the event of channel errors, only the affected channel is passivated and not the entire module.

Figure 5-4 F-monitoring time and behavior in the event of channel error



F-parameter

□ Manual assignment of F-monitoring time

F-monitoring time: 150 ms

F-source address: 1

F-destination address: 65534

F-parameter signature (without addresses): 4247

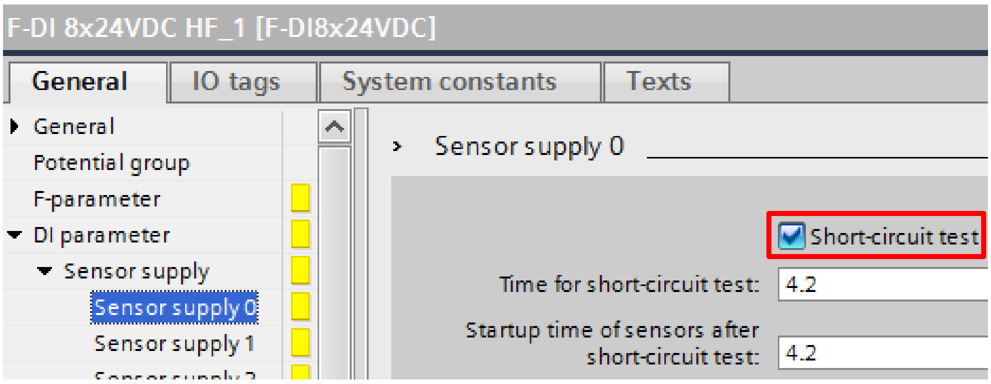
Behavior after channel fault: Passivate channel

□ F-I/O DB manual number assignment

Short circuit test

The short circuit test for the channels 0 and 4 is activated.

Figure 5-5 Activate the short circuit test



Sensor supply 0

☑ Short-circuit test

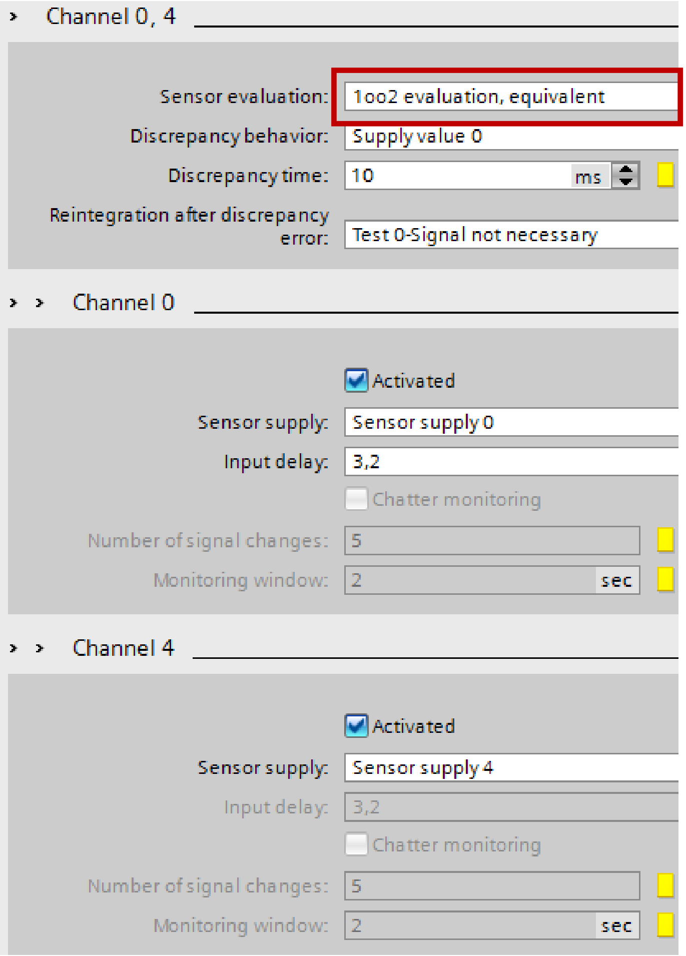
Time for short-circuit test: 4.2

Startup time of sensors after short-circuit test: 4.2

Channel parameters

The monitoring of the emergency stop is via the channel pair 0, 4. The evaluation of the sensor has to be set to “1oo2 evaluation, equivalent” in order to detect discrepancies between the two channels and to therefore achieve the demanded safety level.

Figure 5-6 Enabling channels



Channel 0, 4

Sensor evaluation: 1oo2 evaluation, equivalent
Discrepancy behavior: Supply value 0
Discrepancy time: 10 ms
Reintegration after discrepancy error: Test 0-Signal not necessary

Channel 0

☑ Activated
Sensor supply: Sensor supply 0
Input delay: 3,2
□ Chatter monitoring
Number of signal changes: 5
Monitoring window: 2 sec

Channel 4

☑ Activated
Sensor supply: Sensor supply 4
Input delay: 3,2
□ Chatter monitoring
Number of signal changes: 5
Monitoring window: 2 sec

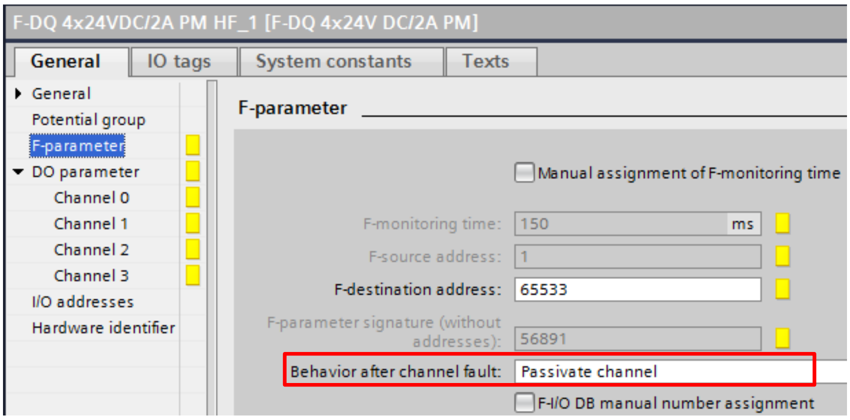
Note Channels which are not used must be deactivated manually.

5.2.2 Setting the F-DQ

Behavior after channel fault

In the event of channel errors, only the affected channel is passivated and not the entire module.

Figure 5-7 F-monitoring time and behavior in the event of channel error



F-DQ 4x24VDC/2A PM HF_1 [F-DQ 4x24V DC/2A PM]

F-parameter

□ Manual assignment of F-monitoring time

F-monitoring time: 150 ms

F-source address: 1

F-destination address: 65533

F-parameter signature (without addresses): 56891

Behavior after channel fault: Passivate channel

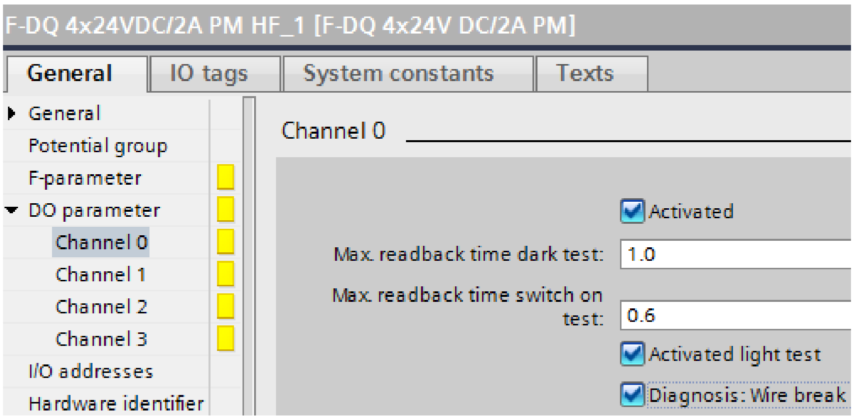
□ F-I/O DB manual number assignment

Channel settings

For each channel you can

- specify the readback time for the dark test and the switch on test
- activate the light test
- enable the diagnostic for wire break

Figure 5-8 Channel settings



F-DQ 4x24VDC/2A PM HF_1 [F-DQ 4x24V DC/2A PM]

Channel 0

☑ Activated

Max. readback time dark test: 1.0

Max. readback time switch on test: 0.6

☑ Activated light test

☑ Diagnosis: Wire break

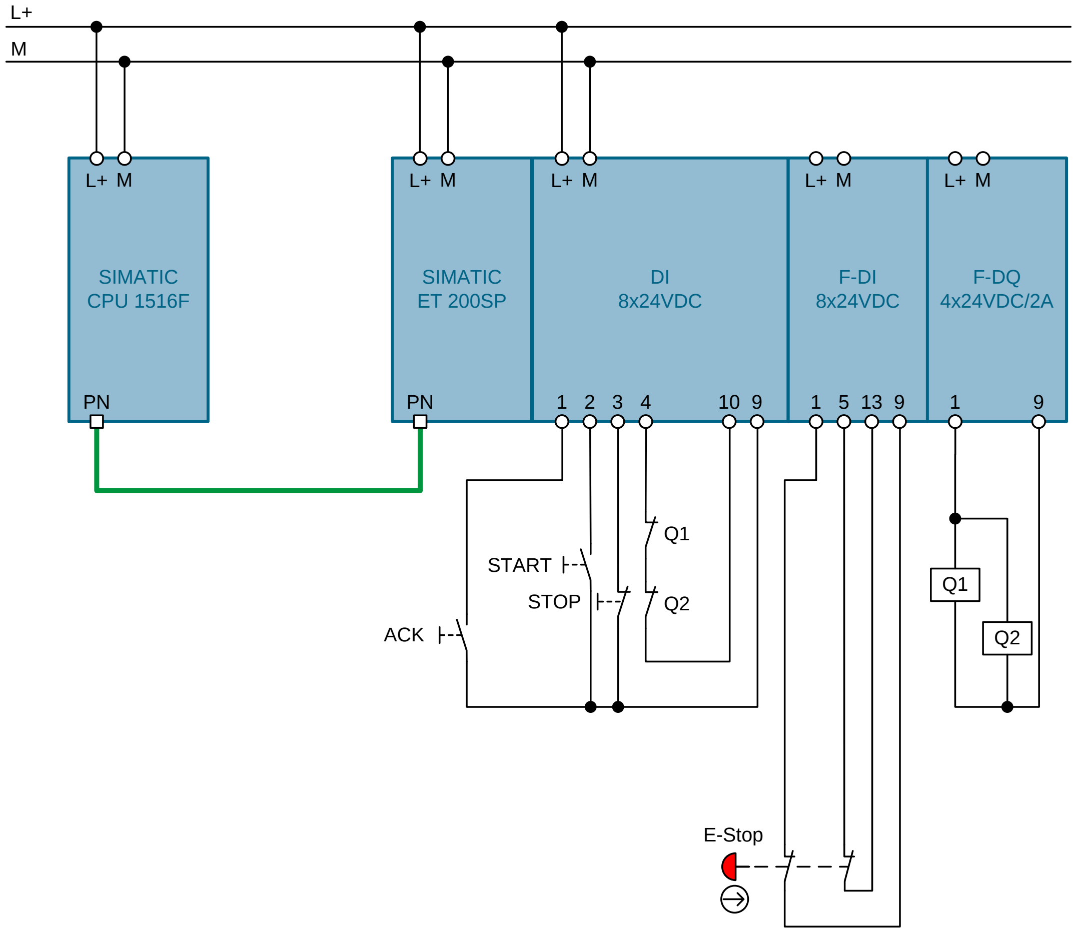
Note Channels which are not used must be deactivated manually.

6 Installation and Commissioning

6.1 Installing the hardware

In order to recreate this application example, wire the hardware components as illustrated below.

Figure 6-1 Wiring the hardware components



6.2 Commissioning

6.2.1 Preparation

1. Download the “21064024_ESTOP_SIL3_1500F_CODE_V40.zip” project file. The download can be found in \2\.
2. Save the zip file in any directory on your computer and unzip it.
3. Set the IP address of the PG/PC in a way so that the PG/PC is located in the same subnet as the CPU.
4. Use an Ethernet cable to connect the PG/PC with the Ethernet interface of CPU S7-1516F.

For this application example, the following IP addresses were used:

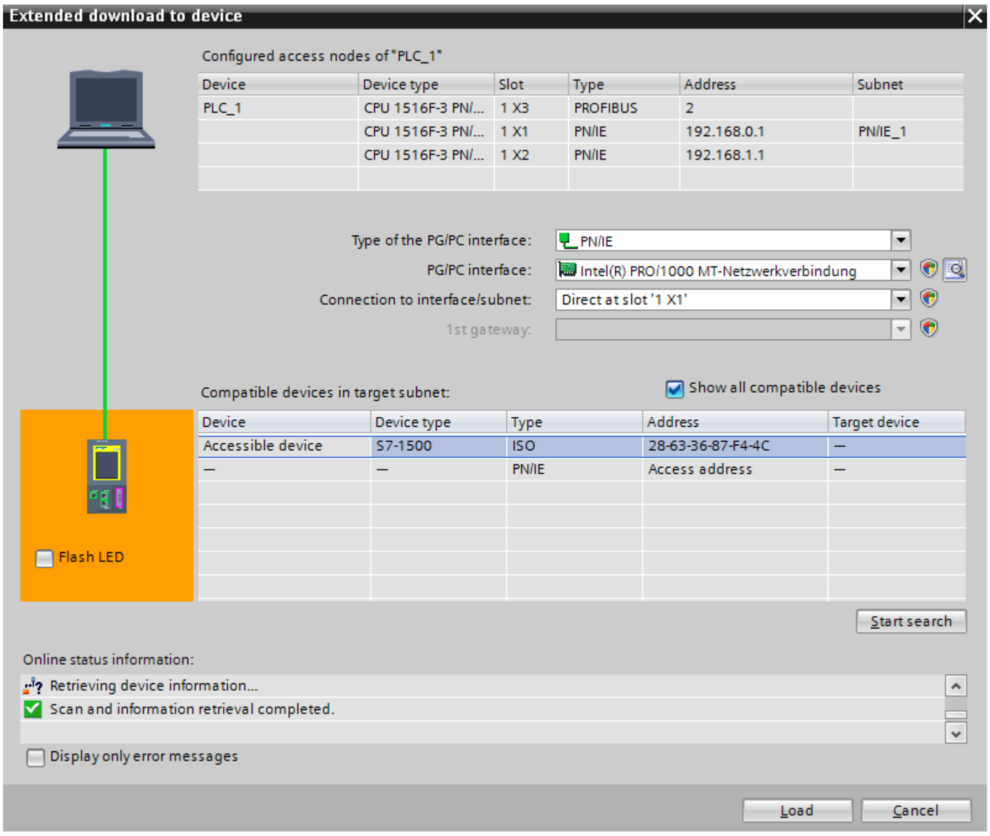
CPU S7-1516F
IP address: 192.168.0.1
Subnet mask: 255.255.255.0

IM 155-6PN
IP address: 192.168.0.2
Subnet mask: 255.255.255.0

6.2.2 Loading the S7 project into CPU S7-1516F

1. Open “TIA Portal V13”
2. Go to the project view.
3. Click “Project > Open” in the menu bar in the TIA Portal.
4. Click “Browse” and open the unzipped project.
5. Set the CPU S7-1516F to STOP.
6. Right click “PLC_1 [CPU1516F-3 PN/DP]” and then “Download to device > Hardware and Software (only changes)”).
7. Select the respective interface and click “Start search”.

Figure 6-2



Extended download to device

Configured access nodes of "PLC_1"

Device	Device type	Slot	Type	Address	Subnet
PLC_1	CPU 1516F-3 PN/...	1 X3	PROFIBUS	2	
	CPU 1516F-3 PN/...	1 X1	PN/IE	192.168.0.1	PN/IE_1
	CPU 1516F-3 PN/...	1 X2	PN/IE	192.168.1.1	

Type of the PG/PC interface: PN/IE
PG/PC interface: Intel(R) PRO/1000 MT-Netzwerkverbindung
Connection to interface/subnet: Direct at slot '1 X1'
1st gateway:

Compatible devices in target subnet:

☑ Show all compatible devices

Device	Device type	Type	Address	Target device
Accessible device	S7-1500	ISO	28-63-36-87-F4-4C	—
—	—	PN/IE	Access address	—

□ Flash LED

Start search

Online status information:

Retrieving device information...
✓ Scan and information retrieval completed.

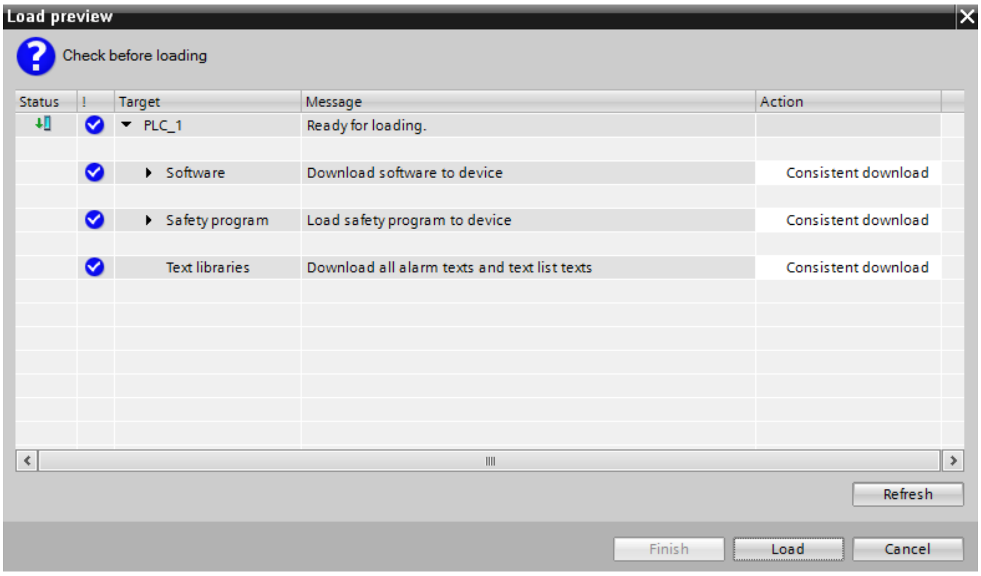
□ Display only error messages

Load Cancel

8. Select the CPU based on the address and then click “Load”.

Note The IP address and the device name are automatically assigned when downloading the project into the CPU.

Figure 6-3



Load preview

Check before loading

Status	!	Target	Message	Action
↓	✓	PLC_1	Ready for loading.	
	✓	Software	Download software to device	Consistent download
	✓	Safety program	Load safety program to device	Consistent download
	✓	Text libraries	Download all alarm texts and text list texts	Consistent download

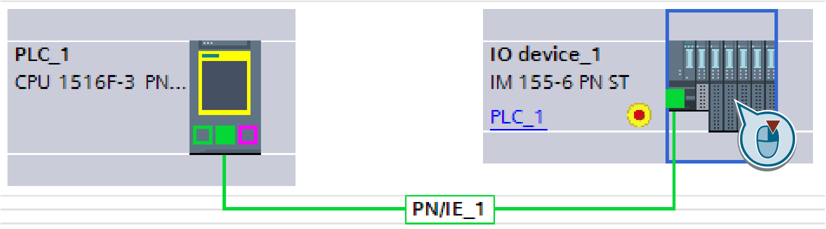
9. Confirm the dialog by clicking “Load”.
10. Click “Finish” when the loading process is completed.

6.2.3 Assigning device names

The device name of the CPU is automatically assigned during the loading process. The device name of the ET 200SP has to be assigned manually. To do this, proceed as follows:

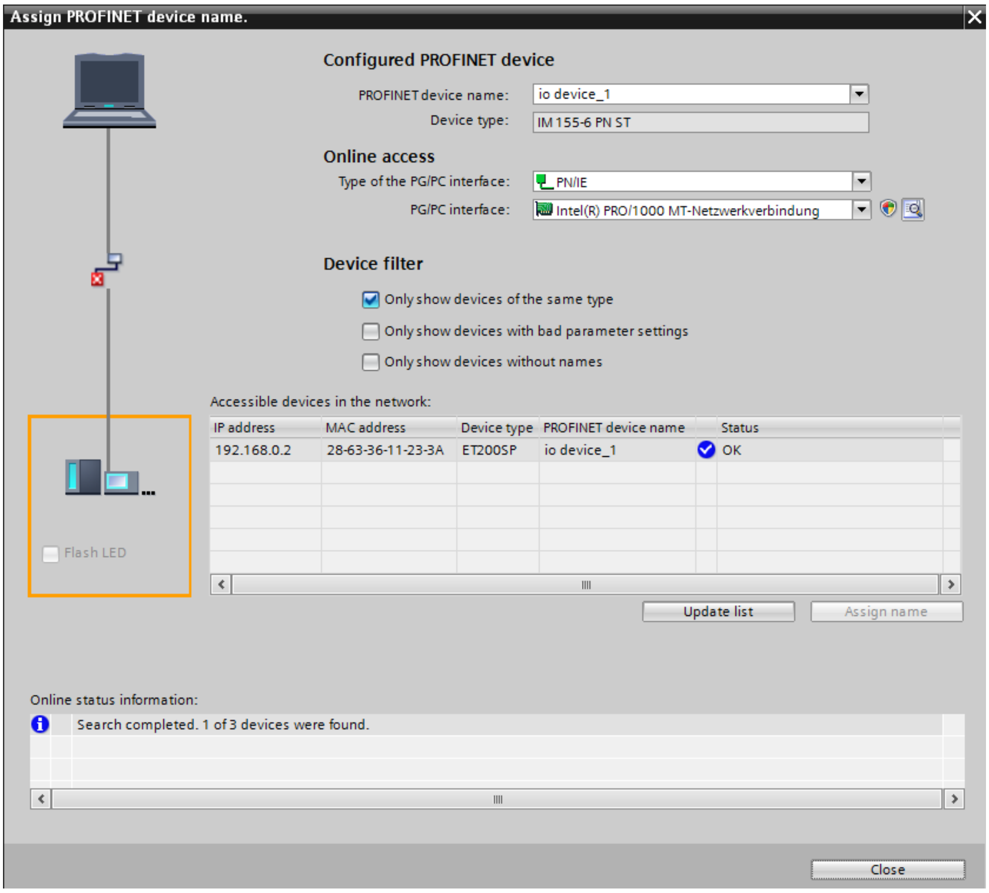
1. Open “Devices & networks” from the project tree.
2. Right click the ET 200SP and select “Assign device name”.

Figure 6-4 Devices & networks



3. Click on “Update list” and select the detected ET 200SP based on the address.
4. Now click “Assign name” and close the window when the status is marked with “OK”.

Figure 6-5 Assigning device names



Configured PROFINET device

PROFINET device name: io device_1
Device type: IM 155-6 PN ST

Online access

Type of the PG/PC interface: PN/IE
PG/PC interface: Intel(R) PRO/1000 MT-Netzwerkverbindung

Device filter

☑ Only show devices of the same type
☐ Only show devices with bad parameter settings
☐ Only show devices without names

Accessible devices in the network:

IP address	MAC address	Device type	PROFINET device name	Status
192.168.0.2	28-63-36-11-23-3A	ET200SP	io device_1	✓ OK

Online status information:

Search completed. 1 of 3 devices were found.

6.2.4 Assigning F-destination address

In order to establish a secure communication between the F-CPU and the fail-safe modules of the ET 200SP, the modules have to be assigned F-destination addresses.

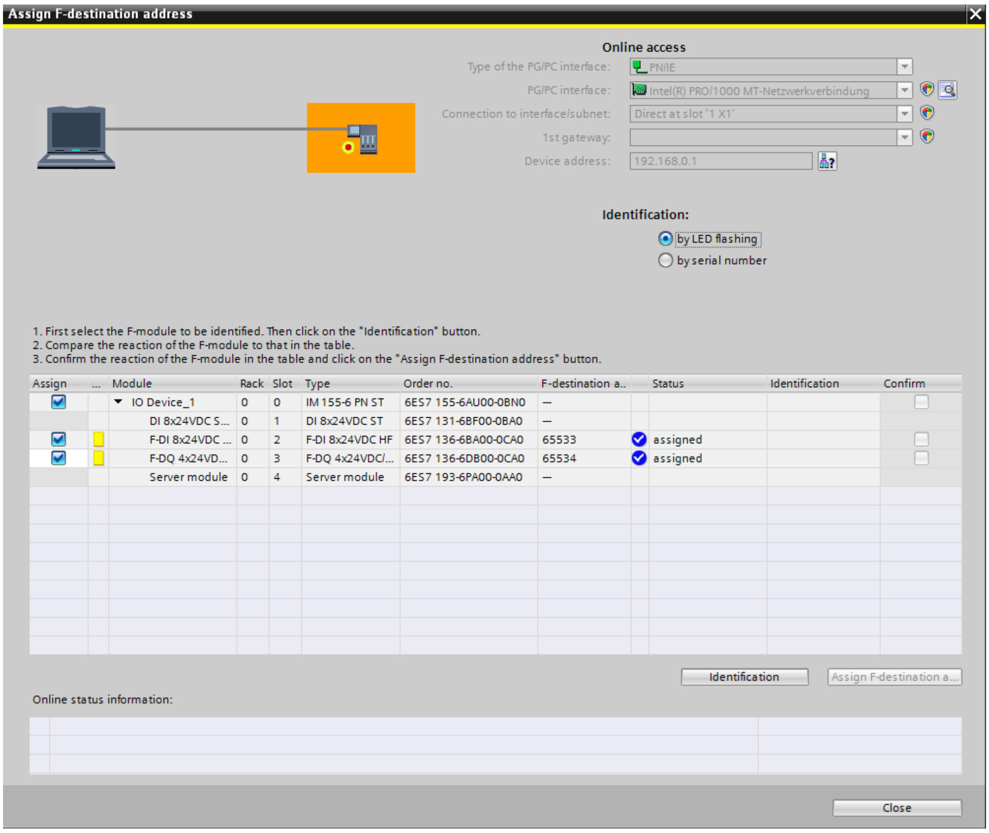
Note

> Since the F-destination address is saved in the electronic coding element, the following steps are only required if the coding element has not previously been assigned an F-destination address or has been assigned another F-destination address.

1. Open “Devices & networks” from the project tree.
2. Right click the ET 200SP station and select the “Assign F-destination address” action, see Figure 6-4.

3. Enable the checkbox of the first fail-safe module and click the “Identification” button.
4. When the LEDs of the F-DI are simultaneously flashing green, enable the “Confirm” checkbox.
5. Then click the “Assign F-destination address” button and confirm the dialog with “Yes”

Figure 6-6



Assign F-destination address

Online access

Type of the PG/PC interface: PN/IE

PG/PC interface: Intel(R) PRO/1000 MT-Netzwerkverbindung

Connection to interface/subnet: Direct at slot '1 X1'

1st gateway:

Device address: 192.168.0.1

Identification:

● by LED flashing
○ by serial number

1. First select the F-module to be identified. Then click on the "Identification" button.
2. Compare the reaction of the F-module to that in the table.
3. Confirm the reaction of the F-module in the table and click on the "Assign F-destination address" button.

Assign	...	Module	Rack	Slot	Type	Order no.	F-destination a..		Status	Identification	Confirm
☑		IO Device_1	0	0	IM 155-6 PN ST	6ES7 155-6AU00-0BN0	—				□
		DI 8x24VDC S...	0	1	DI 8x24VDC ST	6ES7 131-6BF00-0BA0	—				
☑	🟨	F-DI 8x24VDC ...	0	2	F-DI 8x24VDC HF	6ES7 136-6BA00-0CA0	65533	✓	assigned		□
☑	🟨	F-DQ 4x24VD...	0	3	F-DQ 4x24VDC/...	6ES7 136-6DB00-0CA0	65534	✓	assigned		□
		Server module	0	4	Server module	6ES7 193-6PA00-0AA0	—				

Online status information:

6. Repeat the steps for the other fail-safe modules.
7. You can then close the window.

Note All red LEDs of the ET 200SP station should go out after assigning the F-target address. If this is not the case, there may be an error in the wiring.

8. Now set the CPU S7-1516F to RUN

7 Operating the Application

The table below demonstrates the function principle:

Table 7-1 Operating instruction

No.	Action	Result / Note
1	Press the acknowledge button	Acknowledgement
2	Press the start button	Contactors are switched on
3	Press the stop button	Contactors are switched off
4	Press the start button	Contactors are switched on
5	Press the emergency stop	Contactors are switched off
6	Unlock the emergency stop	
7	Repeat actions 1 and 2	Contactors are switched on

8 Evaluation of the Safety Function

8.1 Standards

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

Table 8-1

Version	Mentioned below
EN ISO 13849-1:2006	ISO 13849-1
EN ISO 13849-2:2012	ISO 13849-2
EN 62061:2005 + A1:2013	IEC 62061

8.2 Safety function

Preliminary remarks

- Emergency stop is not a means of risk reduction.
- Emergency stop is a “supplementary safety function”.

Supplementary safety function

For the following considerations are based on the supplementary safety function below:

Table 8-2

Safety function	Description
SF1	If the emergency stop is pressed, the machine has to safely switch off.

Below the SF1 safety function is evaluated according to the standards IEC 62061 and ISO 13849-1.

8.3 Evaluation according to IEC 62061

Below, the evaluation according to IEC 62061 is carried out with the Safety Evaluation Tool (SET). For the link to the SET, refer to the Internet in \4\.

8.3.1 Evaluation of "Detection"

The parameters relevant for the evaluation are provided by the manufacturer and specified by the user.

Table 8-3

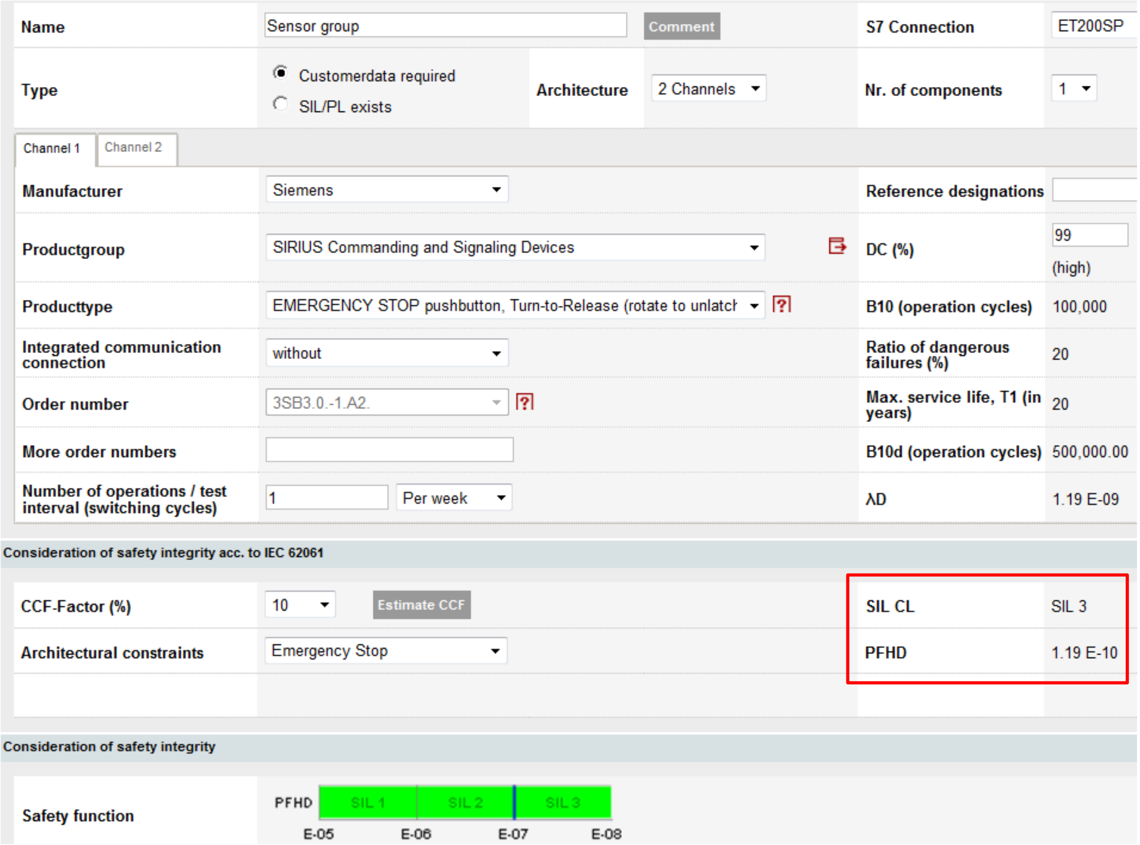
Parameter	Value	Explanation	Definition
B10 B10 value Emergency stop control device	100.000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures Emergency stop control device	0.2 (20%)	Manufacturer information	
T1 Lifetime	175,200 h (20 years)	Manufacturer information	
Subsystem architecture	D	2 channels, 1 component: Single fault tolerance with diagnostic function	User
Actuations/ test interval	1/week	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%)	Cross-comparison in F-DI	

Result "Detection"

Table 8-4

PFH_D	SILCL achieved
$1.19 \cdot 10^{-10}$	SILCL 3

Figure 8-1 Evaluating “Detection” (IEC 62061)



Name	Sensor group	Comment	S7 Connection	ET200SP
Type	● Customerdata required ○ SIL/PL exists	Architecture 2 Channels	Nr. of components	1

Channel 1 | Channel 2

Manufacturer	Siemens	Reference designations	
Productgroup	SIRIUS Commanding and Signaling Devices	DC (%)	99 (high)
Producttype	EMERGENCY STOP pushbutton, Turn-to-Release (rotate to unlatc	B10 (operation cycles)	100,000
Integrated communication connection	without	Ratio of dangerous failures (%)	20
Order number	3SB3.0.-1.A2.	Max. service life, T1 (in years)	20
More order numbers		B10d (operation cycles)	500,000.00
Number of operations / test interval (switching cycles)	1 Per week	λD	1.19 E-09

Consideration of safety integrity acc. to IEC 62061

CCF-Factor (%)	10 Estimate CCF	SIL CL	SIL 3
Architectural constraints	Emergency Stop	PFHD	1.19 E-10

Consideration of safety integrity

Safety function

8.3.2 Evaluation of "Evaluation"

The parameters relevant for the evaluation are provided by the manufacturer and are available in the SET:

Table 8-5

Component	PFH_D	SILCL	Definition
CPU 1516F-3PN/DP incl. PROFIsafe	$2.00 \cdot 10^{-9}$	SILCL 3	SIEMENS AG
F-DI of the ET 200SP	$1.00 \cdot 10^{-9}$	SILCL 3	
F-DQ of the ET 200SP	$1.00 \cdot 10^{-9}$	SILCL 3	
Total	$\mathbf{4.00 \cdot 10^{-9}}$	**SILCL 3**	

8.3.3 Evaluation of “Reacting”

The parameters relevant for the evaluation of the contactors are provided by the manufacturer and specified by the user.

Table 8-6

Parameter	Value	Explanation	Definition
B10 B10 value Contactor	1.000.000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures Contactor	0.73 (73%)	Manufacturer information	
T1 Lifetime	175,000 h (20 years)	Manufacturer information	
Subsystem architecture	D	2 channels, 2 components: Single fault tolerance with diagnostic function	User
Actuations/ test interval	1/h	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%)	Redundant switch-off path and dynamic monitoring of the contactors	

Result “Reaction”

Table 8-7

PFH_D	SILCL achieved
$7.30 \cdot 10^{-9}$	SILCL 3

8.3.4 Result of the evaluation according to IEC 62061

Table 8-8

Subsystem	PFH_D	SIL achieved
Detection	$1.19 \cdot 10^{-10}$	SILCL 3
Evaluation	$4.00 \cdot 10^{-9}$	SILCL 3
Reaction	$7.30 \cdot 10^{-9}$	SILCL 3
Total	$\mathbf{1.14 \cdot 10^{-8}}$	**SILCL 3**
	SIL 3	

8.4 Evaluation according to ISO 13849-1

Below, an evaluation according to ISO 13849-1 is carried out with the Safety Evaluation Tool (SET). For the link to the SET, refer to the Internet in \4\.

8.4.1 Evaluation of "Detection"

The parameters relevant for the evaluation are provided by the manufacturer and specified by the user.

Table 8-9

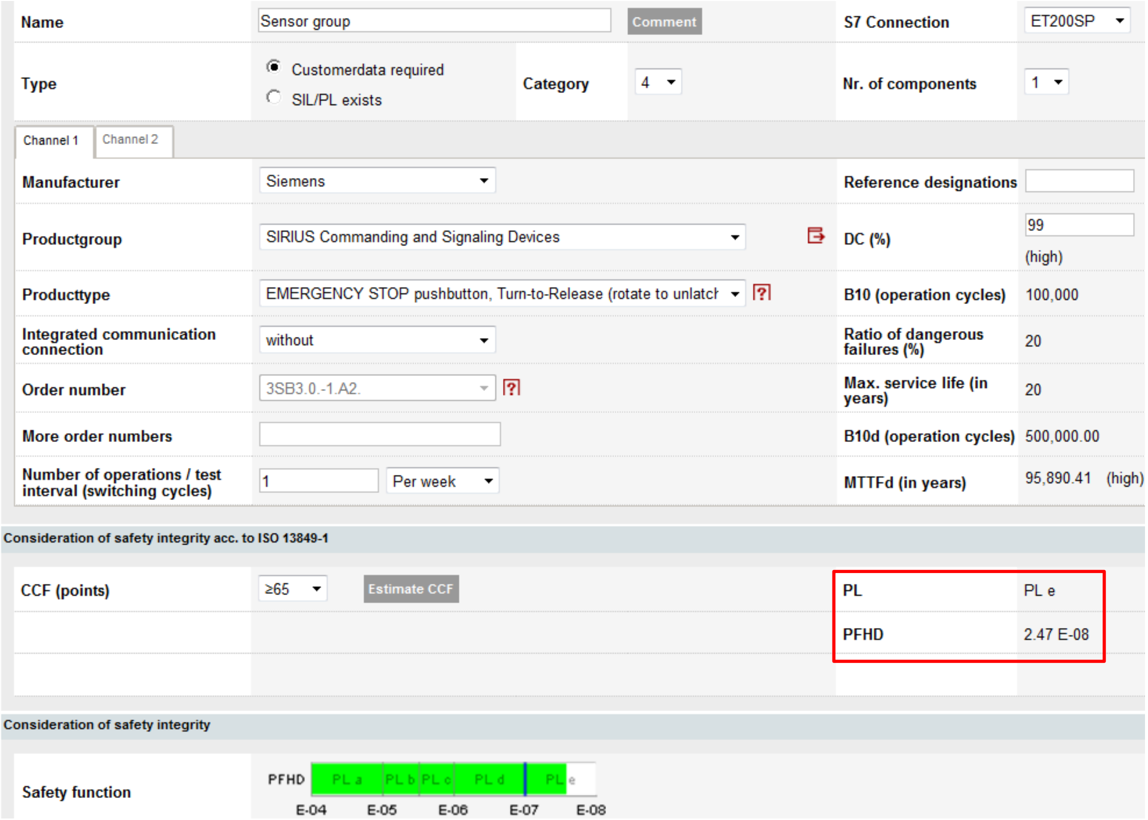
Parameter	Value	Explanation	Definition
B10 B10 value Emergency stop control device	100.000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures Emergency stop control device	0.2 (20%)	Manufacturer information	
T1 Lifetime	175,200 h (20 years)	Manufacturer information	
Architecture	Category 4	2 channels, 1 component	User
Actuations/ test interval	1/week	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%)	Cross-comparison in F-DI	

Result “Detection”

Table 8-10

PFH_D	PL achieved
$2.47 \cdot 10^{-8}$	PL e

Figure 8-2 Evaluation of "Detection" (ISO 13849)



Name	Sensor group Comment	S7 Connection	ET200SP
Type	● Customerdata required ○ SIL/PL exists Category 4	Nr. of components	1

Channel 1 | Channel 2

Manufacturer	Siemens	Reference designations	
Productgroup	SIRIUS Commanding and Signaling Devices	DC (%)	99 (high)
Producttype	EMERGENCY STOP pushbutton, Turn-to-Release (rotate to unlatcl	B10 (operation cycles)	100,000
Integrated communication connection	without	Ratio of dangerous failures (%)	20
Order number	3SB3.0.-1.A2.	Max. service life (in years)	20
More order numbers		B10d (operation cycles)	500,000.00
Number of operations / test interval (switching cycles)	1 Per week	MTTFd (in years)	95,890.41 (high)

Consideration of safety integrity acc. to ISO 13849-1

CCF (points)	≥65 Estimate CCF	PL	PL e
		PFHD	2.47 E-08

Consideration of safety integrity

Safety function

8.4.2 Evaluation of "Evaluation"

The parameters relevant for the evaluation are provided by the manufacturer and are available in the SET:

Table 8-11

Component	PFH_D	PL	Definition
CPU 1516F-3PN/DP incl. PROFIsafe	$2.00 \cdot 10^{-9}$	PL e	SIEMENS AG
F-DI of the ET 200SP	$1.00 \cdot 10^{-9}$	PL e	
F-DQ of the ET 200SP	$1.00 \cdot 10^{-9}$	PL e	
Total	$\mathbf{4.00 \cdot 10^{-9}}$	**PL e**	

8.4.3 Evaluation of “Reacting”

The parameters relevant for the evaluation of the contactors are provided by the manufacturer and specified by the user.

Table 8-12

Parameter	Value	Explanation	Definition
B10 B10 value Contactor	1.000.000	Manufacturer information	SIEMENS AG
Percentage of dangerous failures Contactor	0.73 (73%)	Manufacturer information	
T1 Lifetime	175,000 h (20 years)	Manufacturer information	
Architecture	Category 4	2 channels, 2 components	User
Actuations/ test interval	1/h	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%)	Redundant switch-off path and dynamic monitoring of the contactors	

Result “Reaction”

Table 8-13

PFH$_D$	PL achieved
$2.47 \cdot 10^{-8}$	PL e

8.4.4 Result of the evaluation according to ISO 13849-1, ISO 13849-2

Table 8-14

Subsystem	PFH$_D$	PL achieved
Detection	$2.47 \cdot 10^{-8}$	PL e
Evaluation	$4.00 \cdot 10^{-9}$	PL e
Reaction	$2.47 \cdot 10^{-8}$	PL e
Total	$\mathbf{5.34 \cdot 10^{-8}}$	**PL e**
	PL e	

9 Links & Literature

Table 9-1

	Topic	Title
\1\	Siemens Industry Online Support	https://support.industry.siemens.com
\2\	Download page of the entry	https://support.industry.siemens.com/cs/ww/en/view/21064024
\3\	Application example “feedback circuit”	https://support.industry.siemens.com/cs/ww/en/view/21331098
\4\	Safety Evaluation Tool (SET)	http://siemens.com/safety-evaluation-tool
\5\	SIMATIC Safety - Configuring and Programming	https://support.industry.siemens.com/cs/ww/en/view/54110126
\6\	Series connection of several emergency stop control devices	https://support.industry.siemens.com/cs/ww/en/view/35444028
\7\	Migrating a safety program to TIA Portal.	https://support.industry.siemens.com/cs/ww/en/view/109475826
\8\	Functional Safety at Siemens	www.siemens.de/safety-integrated
\9\	Define of Diagnostic Coverage for subsystem with electromechanical components	https://support.industry.siemens.com/cs/en/en/view/35444114

10 History

Table 10-1

Version	Date	Modifications
V1.0	02/2005	First version
V2.0	09/2007	Updating the contents regarding: • Hardware and software • Performance data • Screenshots
		New chapter: • Evaluating the function example according to the new standards EN 62061 and EN ISO 13849-1:2006.
V3.0	01/2015	Migration of STEP 7 V5.4 with Distributed Safety to TIA Portal (STEP 7 Professional V13 with STEP 7 Safety V13)
V4.0	07/2015	• Publication of migration instruction as independent application example • Replacement of the light indicator to simulate the actuators against two contactors • Supplement of the evaluation of the safety function by the “Reaction” subsystem