Control of the Safety Integrated Extended Functions of the SINAMICS S110 via the fail-safe inputs of the CU305

SINAMICS S110

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SINAMICS S110
Safety Integrated

Control of the Safety Integrated Extended Functions
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of the CU305

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1 Automation task

Introduction

The following safety functions according to IEC 61800-5-2 are currently integrated in SINAMICS S110 drives:

Table 1-1: Overview of the safety functions of the SINAMICS S110

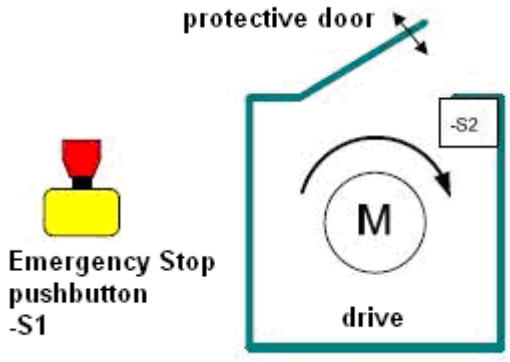
Name	Function	Description
STO	Safe Torque Off	Safe disconnection of the torque-generating power supply to the motor. The closing lockout function prevents the drive from restarting. (Stop function, Category 0 according to EN 60204-1)
SBC	Safe Brake Control	SBC is only used when there is a motor brake; the motor brake is connected to the power connector through the outputs. SBC always responds in conjunction with STO or when internal safety monitoring functions respond with safe pulse suppression.
SS1	Safe Stop 1	The drive is quickly and safely stopped along the OFF3 ramp and is safely monitored. Transition to STO after a delay time has expired or the shutdown speed has been reached. (Stop function, Category 1 according to EN 60204-1)
SS2	Safe Stop 2	The drive is quickly and safely stopped along the OFF3 ramp and is safely monitored. Transition to SOS after a delay time has expired; the drive remains in closed-loop control. (Stop function, Category 2 according to EN 60204-1) Not available for encoderless drives.
SOS	Safe Operating Stop	This function serves to safely monitor the standstill position of a drive; the drive remains in closed-loop control. Not available for encoderless drives.
SLS	Safely-Limited Speed	The drive speed is safely monitored. Parameterizable shutdown response when the limit value is violated.
SSM	Safe Speed Monitor	Safely displays when the speed falls below a speed limit (n < nx).
SDI	Safe Direction	Safe monitoring of the direction of motion (positive and negative direction). Parameterizable shutdown response when traversing in the disabled direction.

Controlling these extended safety functions can, for CU305 DP or CU305 PN, be realized via PROFIsafe with PROFIBUS or PROFINET – or using the three integrated fail-safe digital inputs (F-DI). For the CU305 CAN version, the extended safety functions can only be controlled via the integrated F-DIs.

In this example, for the CU305 DP, control via the three integrated F-DIs is shown.

Overview of the automation task

Fig. 1-1: Concept of the safety functions



The following safety functions are used as basis for further consideration.

Table 1-2: Safety functions of the application example

Safety function	Description	Reaction
SF1	Actuation of the Emergency Stop pushbutton.	Fast stopping of the drive → subsequent pulse suppression (SS1).
SF2	When the protective door is opened, the drive must not exceed a velocity/speed configured by the user.	Monitoring the speed at the drive (SLS).

Description of the automation task

This application example shows the control of safety functions SS1 and SLS via the integrated F-DIs of the CU305.

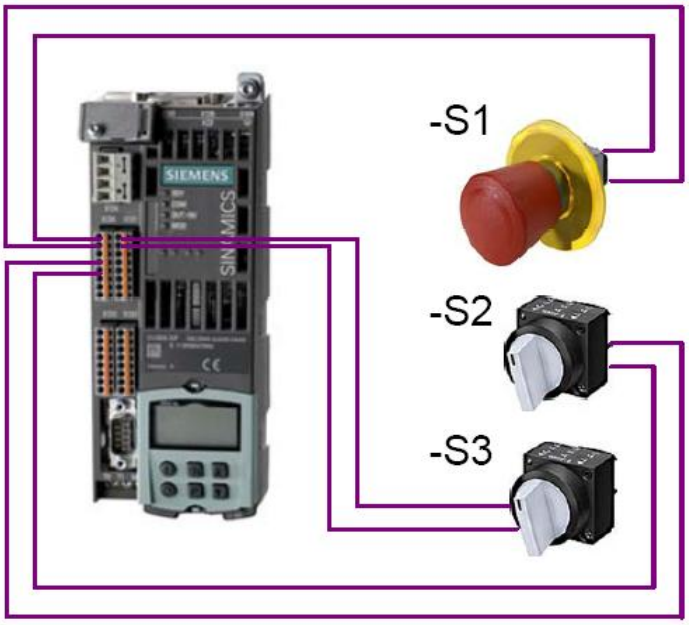
2 Automation solution

2.1 Overview of the overall solution

Schematic

The following diagram schematically shows the most important components of the solution:

Fig. 2-1: Relevant components of the safety functions



This application example shows the control of safety functions SS1 and SLS via the integrated F-DIs of the CU305. There are 3 F-DIs available, one each for SS1 and SLS, and the remaining for the fail-safe acknowledgment.
The S110 drive line-up comprises a Control Unit CU305 DP, a Power Module PM340 and an 1FK7 servomotor with incremental Drive-CLiQ encoder.

Design

This function example is based on a SINAMICS S110 training case (6AG1067-1AA18-0AA0).

Demarcation

This application does not include a description

- of the safety functions of the SINAMICS S110,
- the general drive functions of the SINAMICS S110 and
- the hardware interfaces of the CU305.

It is assumed that readers have basic knowledge about these topics.

Information on these topics can be taken from the documents in the references.

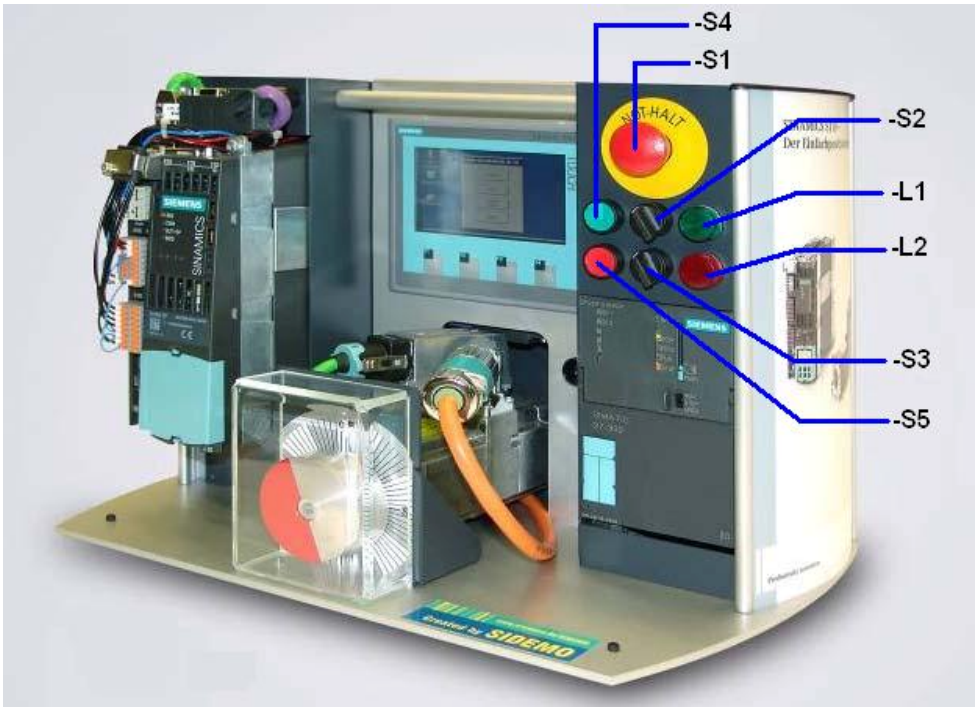
Knowledge required

It is assumed that the reader has a basic knowledge about the configuration of SINAMICS S110 drives using the engineering software STARTER or SIMOTION SCOUT.

2.2 Description of the core functions

Overview and description of the core functions

Fig. 2-2: SINAMICS S110 training case



The S110 drive line-up comprises a Control Unit CU305 DP, a Power Module PM340 and an 1FK7 servomotor with incremental Drive-CLiQ encoder.
The safety-relevant signals of the Emergency Stop pushbutton (-S1) and the two toggle switches (-S2 and -S3) are connected via the three fail-safe digital inputs (F-DIs) of the CU305. One of the two toggle switches simulates a protective door (-S2) and the other is used for the fail-safe acknowledgment (-S3).
When an Emergency Stop is issued,, the drive is stopped by the safety function SS1 integrated in the drive. The toggle switch, which simulates the protective door, activates the safety function SLS. Here, the motor speed is safely monitored against a limit configured by the user. If this limit is exceeded, the drive is stopped with stop response STOP C (corresponds to the safety function SS2). Error messages of the (extended) safety functions can only be acknowledged in a fail-safe fashion. The second toggle switch is used for this purpose.

Note

The standard wiring of the F-DIs of the S110 training case has been adapted for this application example. The changes are explained in detail in Chapter 3.

Advantages of this solution

The solution presented here offers you the following advantages

- Simple control of the safety functions integrated in the drive
- Simple design using standardized technology
- Space-saving and low-cost design using integrated safety functions – additional hardware is not required
- Complex safety concepts can be implemented on this basis.

2.3 Hardware and software components used

The application was created with the following components:

Hardware components

Table 2-1: SINAMICS S110 training case

Component	Type	Order no./Ordering data	Qty	Manufacturer
SINAMICS S110 training case	S110 CU305	6AG1067-1AA18-0AA0	1	SIEMENS

Note The application example was tested with the hardware components listed here. Alternatively, other components with the same function may be used. In such a case, a different parameter assignment and different wiring of the components may be required.

Standard software components

Table 2-2: Engineering software

Component	Type	Order no./Ordering data	Qty	Manufacturer
SIMOTION SCOUT	V4.2.1.0	6AU1 810-1BA42-1XA0	1	Siemens

Table 2-3: Runtime software used

Component	Type	Order no./Ordering data	Qty	Manufacturer
Sinamics	V4.4		1	Siemens

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Note As an alternative to the SIMOTION SCOUT software, STARTER & Drive ES Basic can also be used.

Licenses

Table 2-4: Licenses

License	MLFB/order number	Note
SINAMICS LICENSE SAFETY INTEGRATED EXTENDED FUNCTIONS	6SL3074-0AA10-0AA0	Per axis

File and project examples

Table 2-5: As-supplied state of the application example

Component	Note
MC_FE_I_012_V20.zip	Zipped project
42940007_MC_FE_I_012_V20_en.pdf	This document

3 Installation

Installing the hardware

The following diagrams show the hardware configuration of the application.

Fig. 3--1: Original wiring of the SINAMICS S110 training case

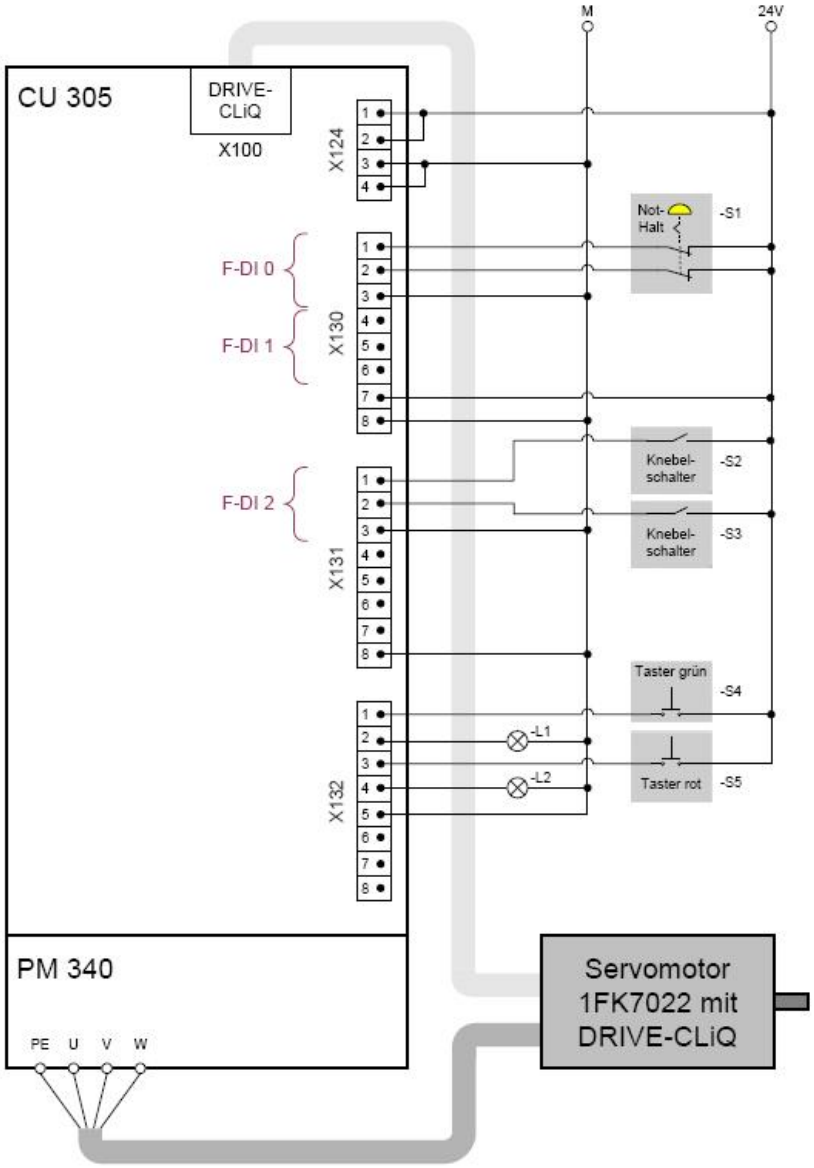
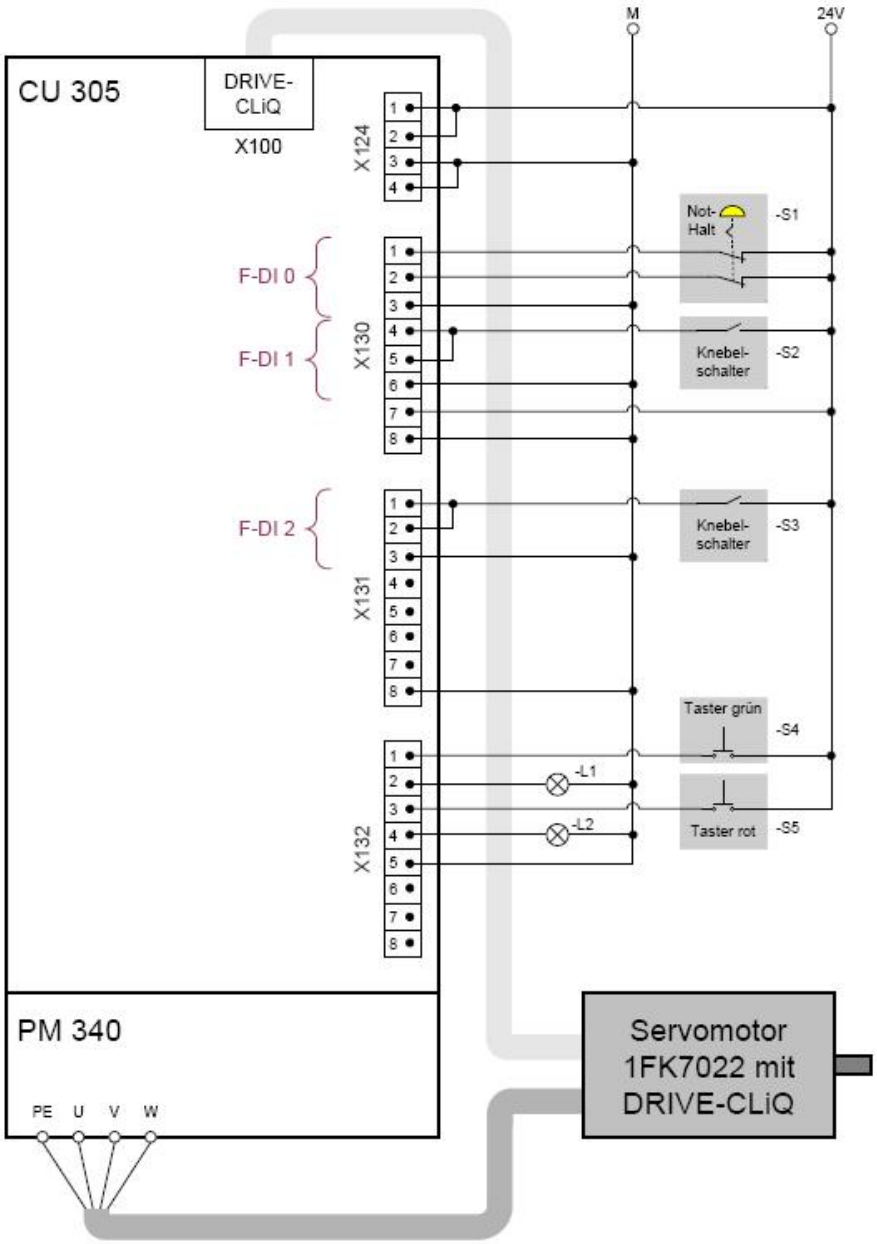


Figure 3-2: Adapted wiring of the SINAMICS S110 training case



With the original wiring of the S110 training case, F-DI 1 is not used and one channel of the F-DI 2 is switched with the toggle switches -S2 and -S3.

To realize the two safety functions (SS1 and SLS) as well as the necessary fail-safe acknowledgment, the wiring must be slightly changed. Toggle switch -S2 is now connected to both channels of the F-DI 1 and -S3 alone now supplies both channels of the F-DI 2. Thus, three fail-safe inputs are available for the application example.

Notice

In this application example, fail-safe inputs are controlled by single-channel switch. This is necessary, so that with the S110 training case the safety functions described here can be controlled without requiring any additional hardware.

For real applications, this type of control for safety categories Cat. 3 (EN954-1), SIL 2 (IEC 61508 and/or IEC62061) as well as PL d (EN13849) is **not** permissible.

4 Configuration and project engineering

In this chapter, you get to know how the individual components must be parameterized. SIMOTION SCOUT is used as the engineering software for SINAMICS S110.

How the software project belonging to this function example was created is described step-by-step in the following sections.

Note Most of the screenshots were created with the "English" language setting. For other language settings, the displays can differ slightly.

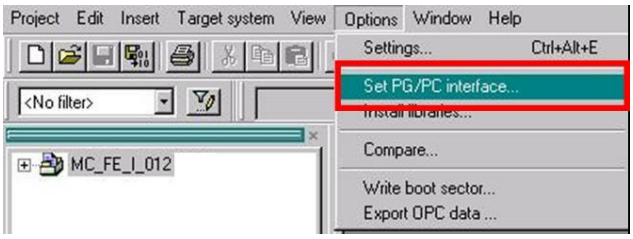
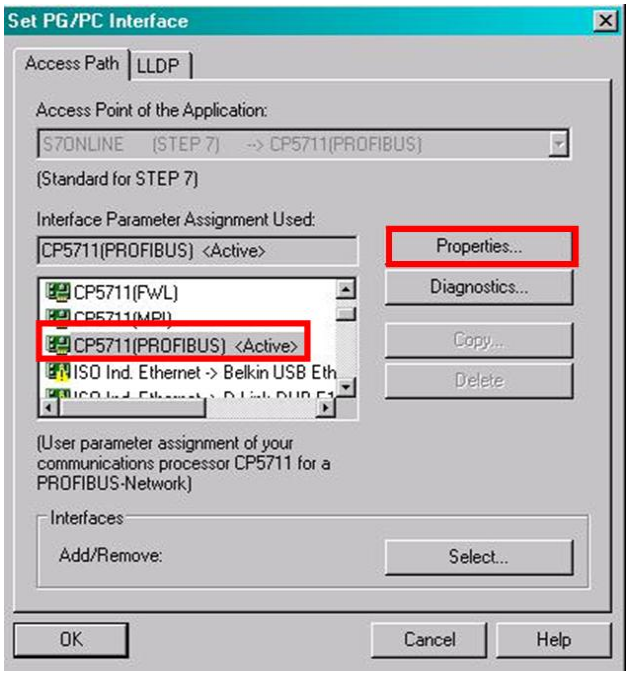
4.1 Password

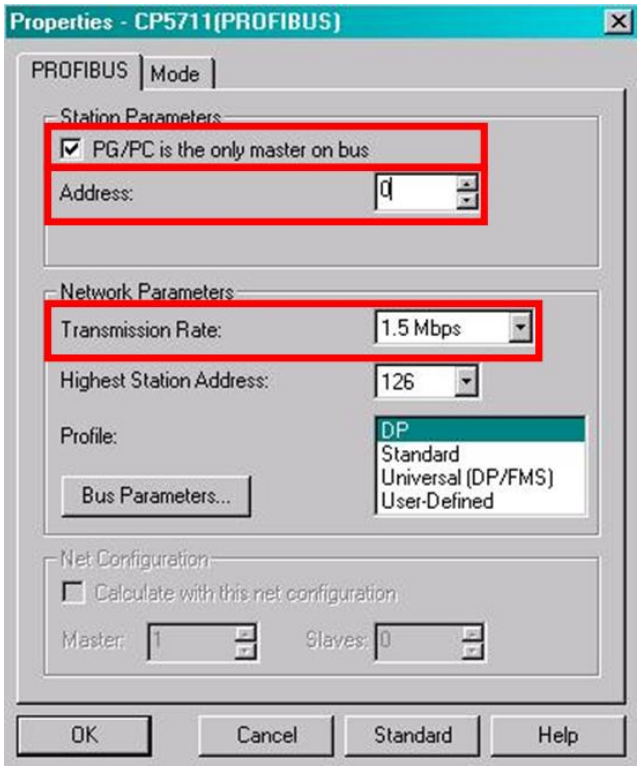
When configuring the Safety functionality of the SINAMICS components for the drive password "1" is used.

This password should not be used for real applications!

4.2 Preparation

Table 4-1: Setting the interface and assigning the PROFIBUS address

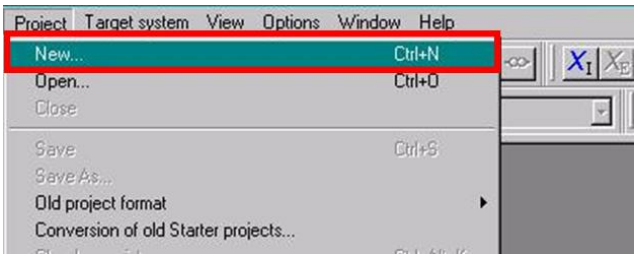
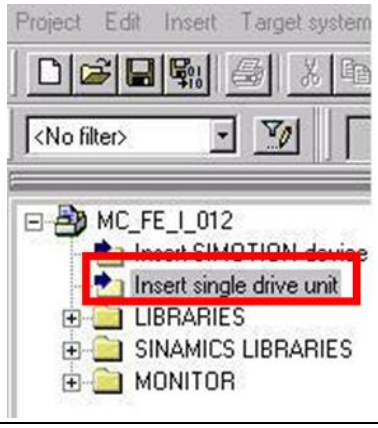
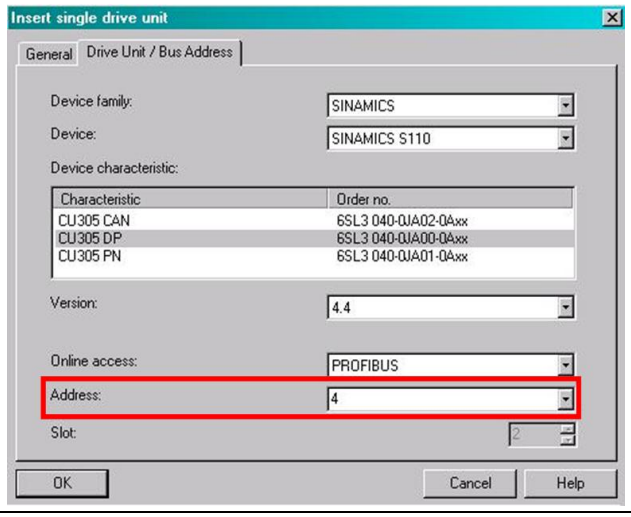
No.	Action	Note
1.	To go online with SINAMICS, open SIMOTION SCOUT. Then click on "Options" → "Set PG/PC Interface".	
2.	The adapter is now selected, via which the system goes online. Here it is the „CP5711 (PROFIBUS)“ → Now click on "Properties".	

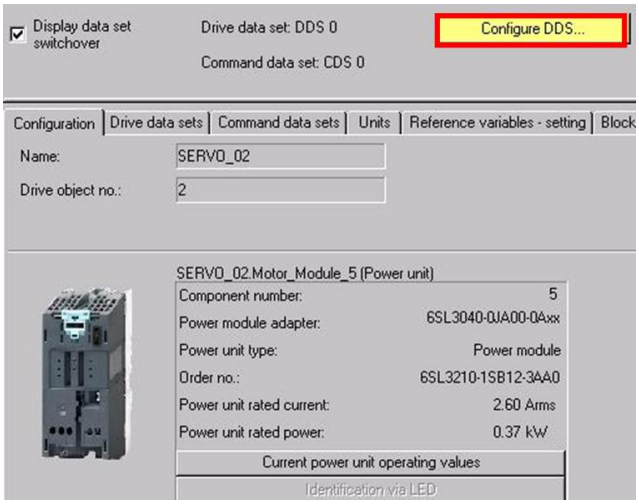
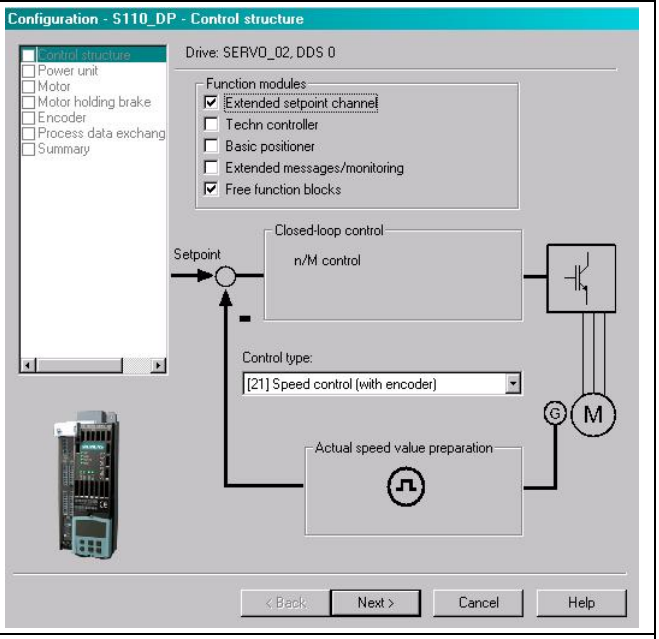
No.	Action	Note
3.	The Profibus address "0" for the PG is defined here. The data transmission rate is also set here. The PC is the only master on the bus as there is no F-CPU. → OK	
4.	The Profibus address of the Sinamics will be specified later.	

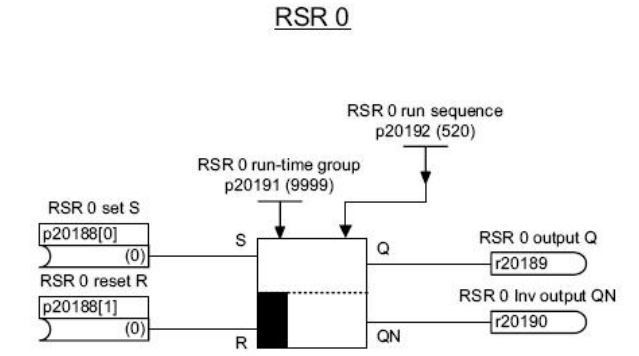
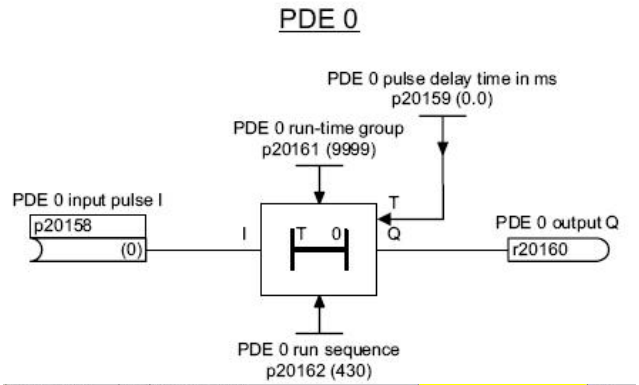
4.3 Configuration of the basic drive functions

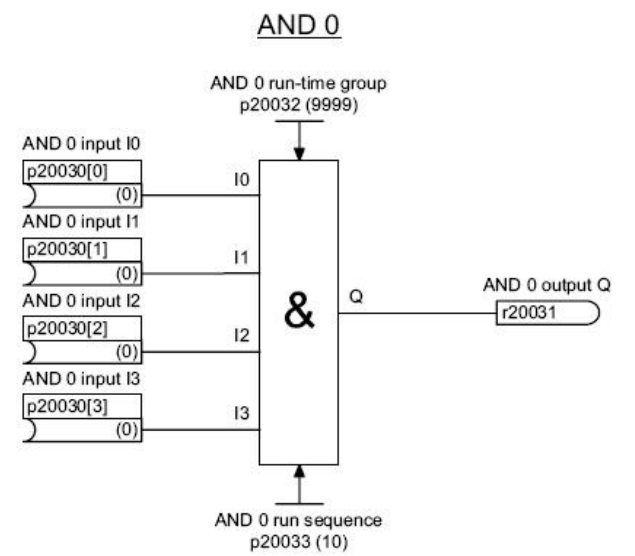
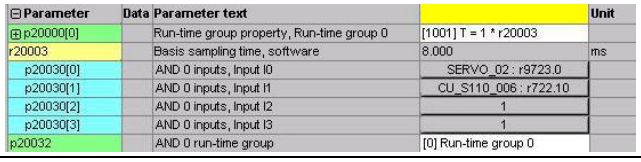
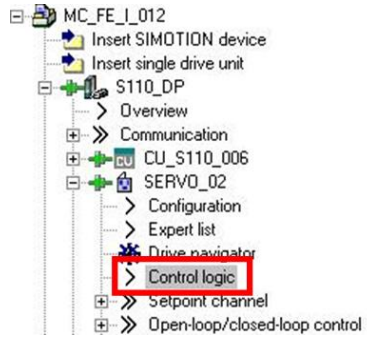
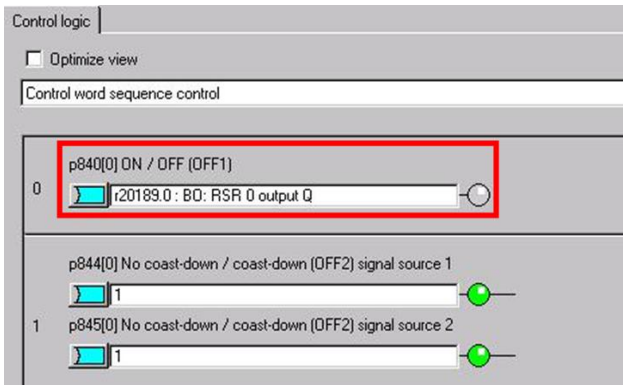
First of all, the existing hardware in the drive system must be commissioned and the desired motion functions set up.

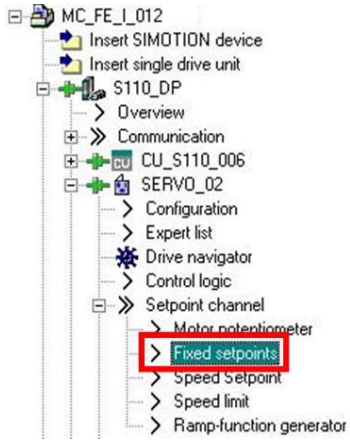
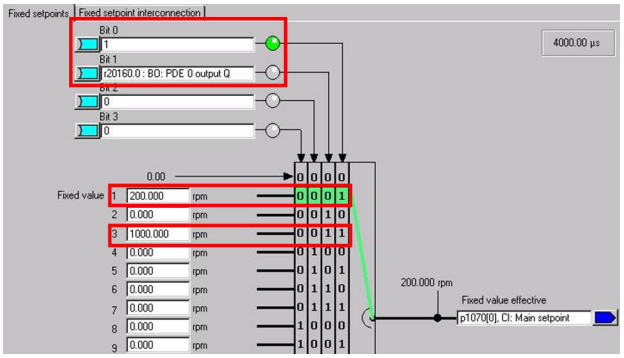
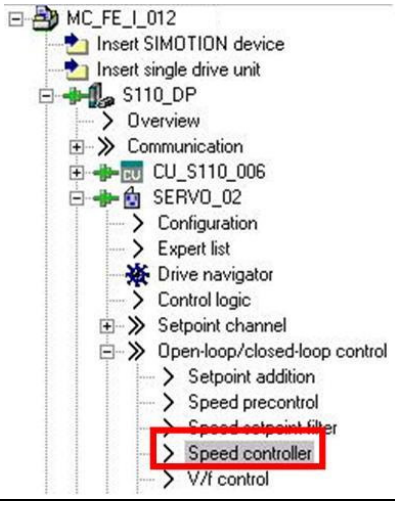
Table 4-2: Configuration of the basic functions

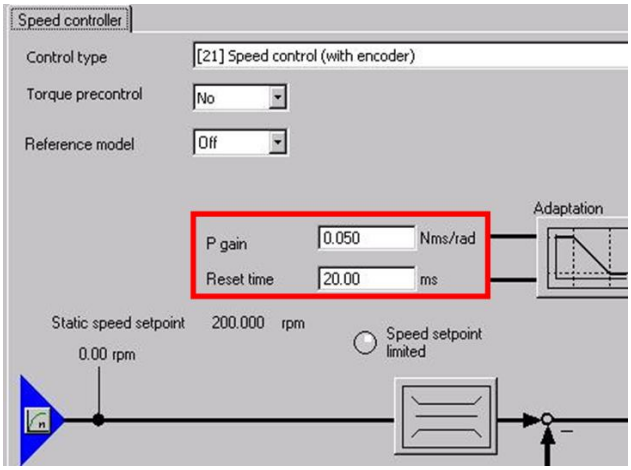
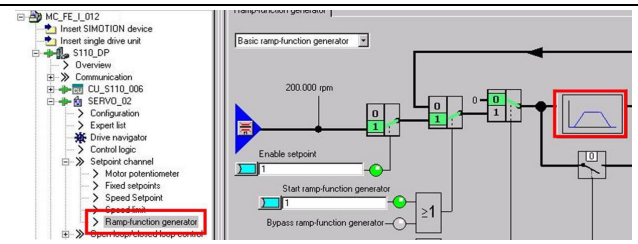
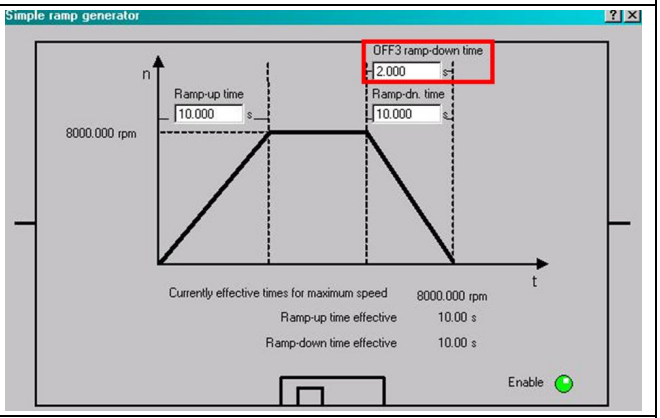
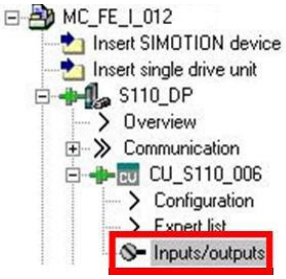
No.	Action	Note
1.	First open the SIMOTION SCOUT program.	
2.	A new project is then created. To do this, click on "Project" →"New".	
3.	An individual drive object is now created. To do this, click on "Insert single drive unit".	
4.	The SINAMICS S110 is selected here. Then select CU305 DP with Version 4.4 and specify PROFIBUS address "4". **Note** The address must match the setting of the PROFIBUS address switch at the CU305.	
5.	Go online.	
6.	No online configuration is required for the S110, and is also not possible; instead, an upload is performed.	

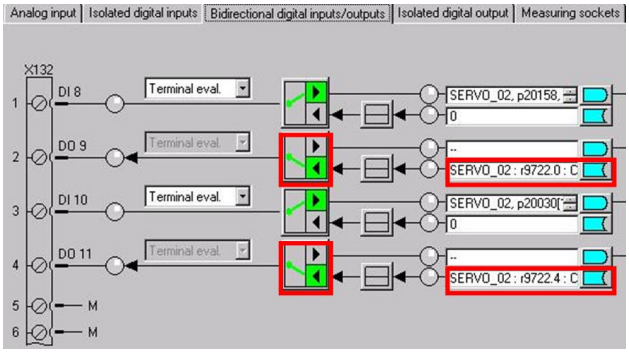
No.	Action	Note
7.	Go offline.	
8.	**Post configuration of the drive** In the project navigator, for the drive (SERVO_02) open the „Configuration“ window. "Configure DDS" starts the navigated post configuration. **Note** In the following, only those screen forms are described in which a change is required.	
9.	**Post configuration of the drive** "Extended setpoint channel" and "Free function blocks" are selected here.	
10.	Save and compile.	
11.	Go online.	
12.	Load the configuration into the drive.	

No.	Action	Note
13.	**Configuring the drive** Configuring an RS flip-flop to switch the drive on and off. The flip-flop is set using -S4 (green pushbutton, signal at r722.8 of the CU305). The flip-flop is reset using-S5 (red pushbutton; signal at r722.10 of the CU305). p20000[0] = 1001 p20188[0] = r722.8 (CU) p20188[1] = r722.10 (CU) p20191 = 0 **Remark** The flip-flop is needed to generate a signal to switch on the drive from the signal of the -S4 pushbutton without having to keep the pushbutton pressed all the time. Insert runtime group 0 in timeslice 1001.	 Parameter / Data / Parameter text / Unit p20000[0] — Run-time group property, Run-time group 0 — [1001] T = 1 * r20003 r20003 — Basis sampling time, software — 8.000 — ms p20188[0] — RSR 0 inputs, Set S — CU_S110_006 : r722.8 p20188[1] — RSR 0 inputs, Reset R — CU_S110_006 : r722.10 p20191 — RSR 0 run-time group — [0] Run-time group 0
14.	**Configuring the drive** Configuring a switch-on delay function to be able to switch between 2 fixed speed setpoints. The output only has the value "1", if -S4 (green pushbutton) is pressed for longer than 1 second. p20158 = r722.8 (CU) p20159 = 1000msec p20161 = 0 **Remark** Since the S110 training only has a few switches, a possibility is created here to be able to switch over between 2 speed setpoints.	 Parameter / Data / Parameter text / Unit p20000[0] — Run-time group property, Run-time group 0 — [1001] T = 1 * r20003 r20003 — Basis sampling time, software — 8.000 — ms p20158 — BI: PDE 0 input pulse I — CU_S110_006 : r722.8 p20159 — PDE 0 pulse delay time in ms — 1000.00 p20161 — PDE 0 run-time group — [0] Run-time group 0

No.	Action	Note
15.	**Configuring the drive** Configuring an AND logic element, to start the cyclic test stop of the Safety functions as a function of the expiration of the test stop timer. If the test stop timer has expired and -S5 (red pushbutton) is pressed at the same time, the output assumes the value "1". p20030[0] = r9723.0 p20030[1] = r722.10 (CU305) p20030[2] = 1 p20030[3] = 1 p20032 = 0	 
16.	**Configuring the drive** The "Control logic" screen form is then opened.	
17.	**Configuring the drive** The output Q of the RS flip-flop is now interconnected with ON/OFF1. p840[0] = r20189	

No.	Action	Note
18.	**Configuring the drive** In order to be able to enter some speed setpoints, under "Setpoint channel" open the "Fixed setpoints" screen form.	
19.	**Configuring the drive** Bits 0 to 1 are used to select the various speed setpoints. The following interconnections were established: Bit0: 1 Bit1: r20160 Bit2: 0 Bit3: 0 The following fixed values were entered: Fixed value 1: 200 rpm Fixed value 3: 1000 rpm The output of the switch-on delay element is used to switch over between fixed setpoints 1 and 3.	
20.	**Configuring the drive** The speed controller is set in the next step. To do this, under „Open-loop/closed-loop control“, click on the „Speed controller“ screen form.	

No.	Action	Note
21.	**Configuring the drive** Following values were set for the speed controller: P gain (p1460[0]) = 0.05 Nms/rad Reset time (p1462[0]) = 20 ms	
22.	**Configuring the drive** Under "Setpoint channel" and then "Ramp-function generator", click on the button with a red frame.	
23.	**Configuring the drive** The OFF3 ramp-down time (p1135[0]) is used for braking in the case of SS1. This parameter is set to 2 s.	
24.	**Configuring the drive** The (non-safety-related) feedback signals of the Safety functions STO and SLS are interconnected with the digital outputs DO 9 (green lamp -L1) and DO 11 (red lamp -L2). To do this, first open "Inputs/outputs" under the Control Unit.	

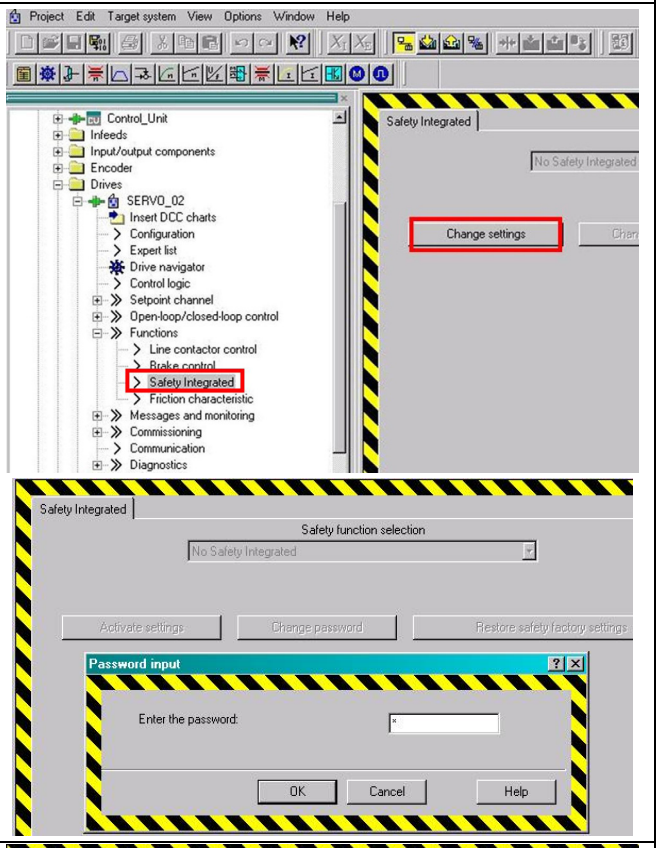
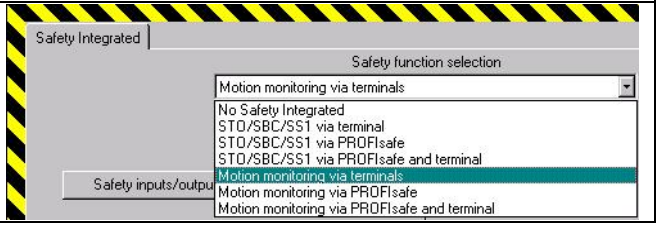
No.	Action	Note
25.	**Configuring the drive** It must be configured as to whether it involves outputs or inputs. Further, the following parameters were interconnected: p728.9 = 1 p728.11 = 1 p739=r9722.0 (Servo_02) p741=r9722.4 (Servo_02)	
26..	Copy from RAM to ROM.	
27.	Perform an upload.	
28.	Save the project.	

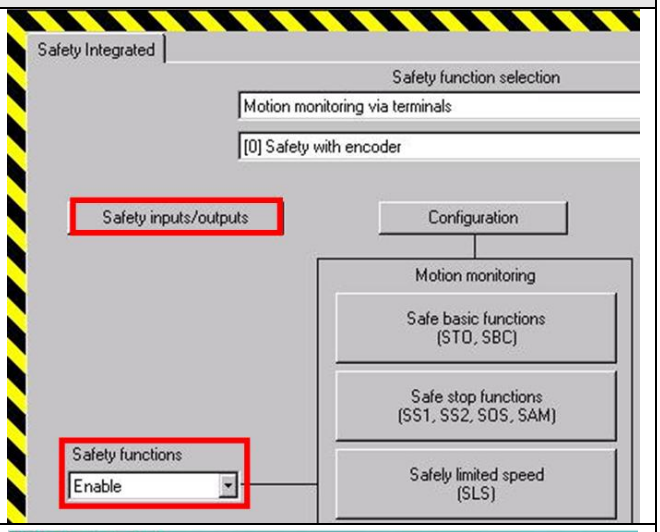
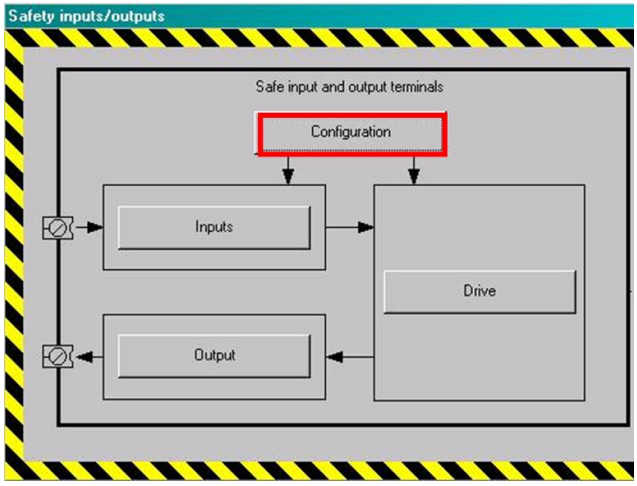
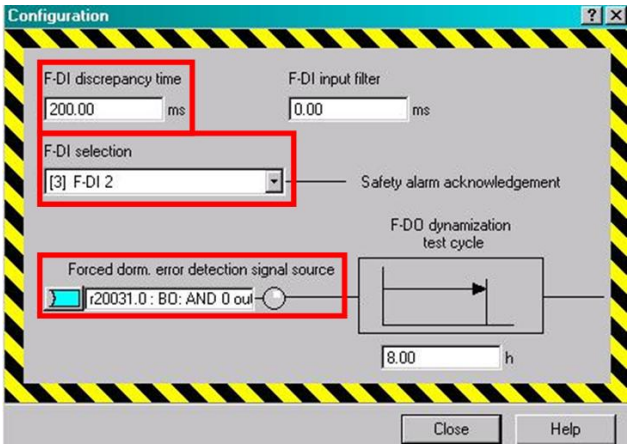
4.4 Parameterizing the safety functions integrated in the drive

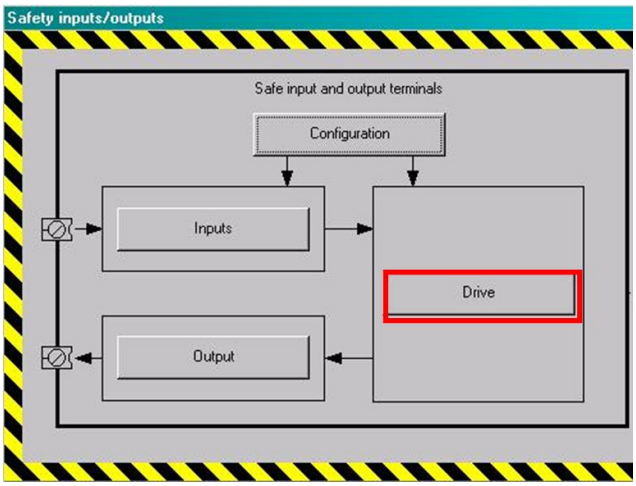
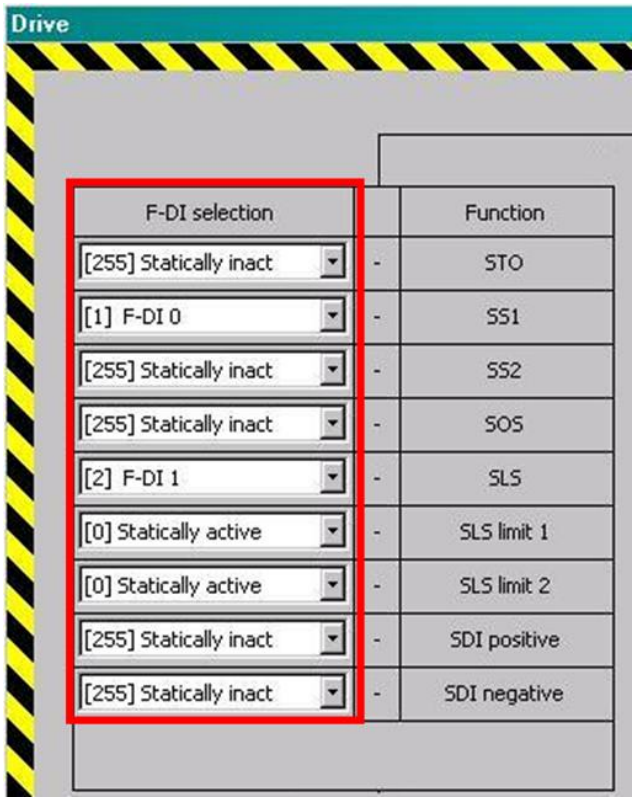
Notes

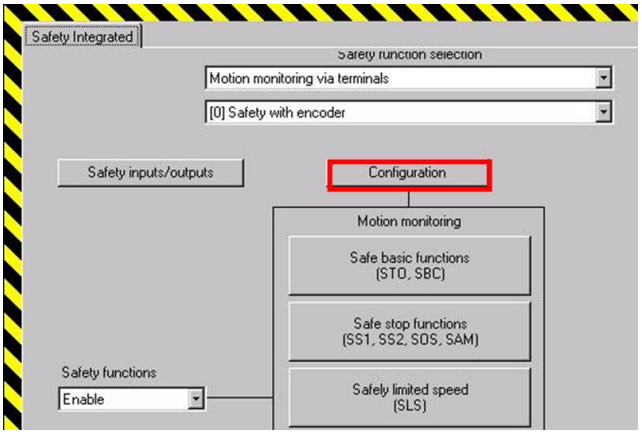
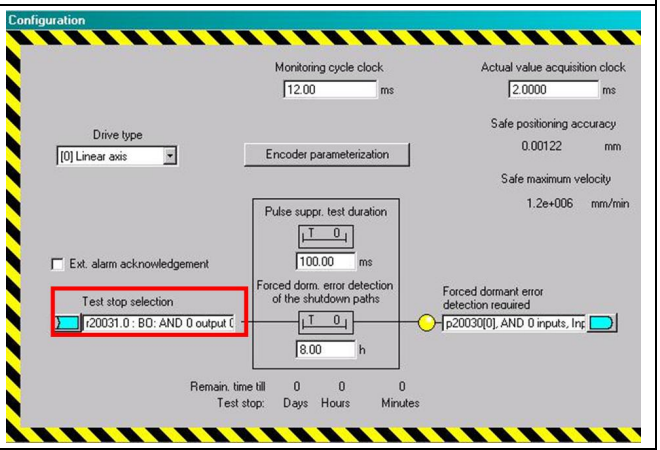
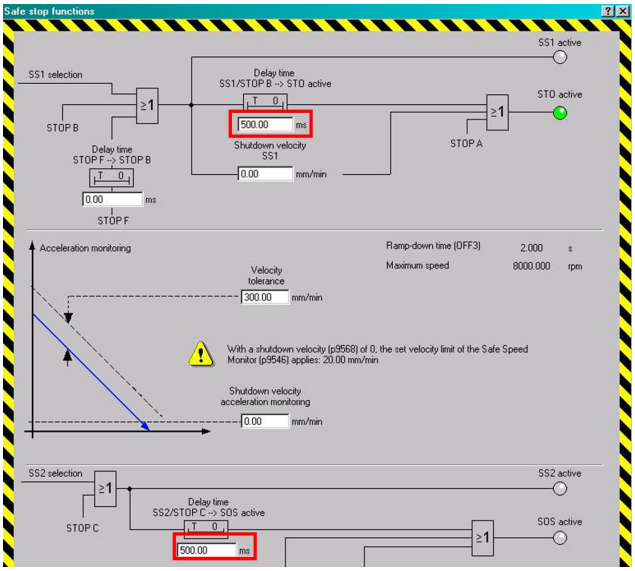
- The safety functions in the drives are configured online.
- Only the windows are described in which parameter changes are required.
- In this example, the following safety functions are used: SS1 and SLS.

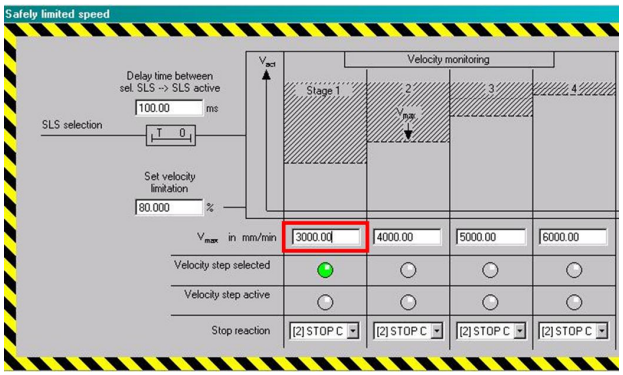
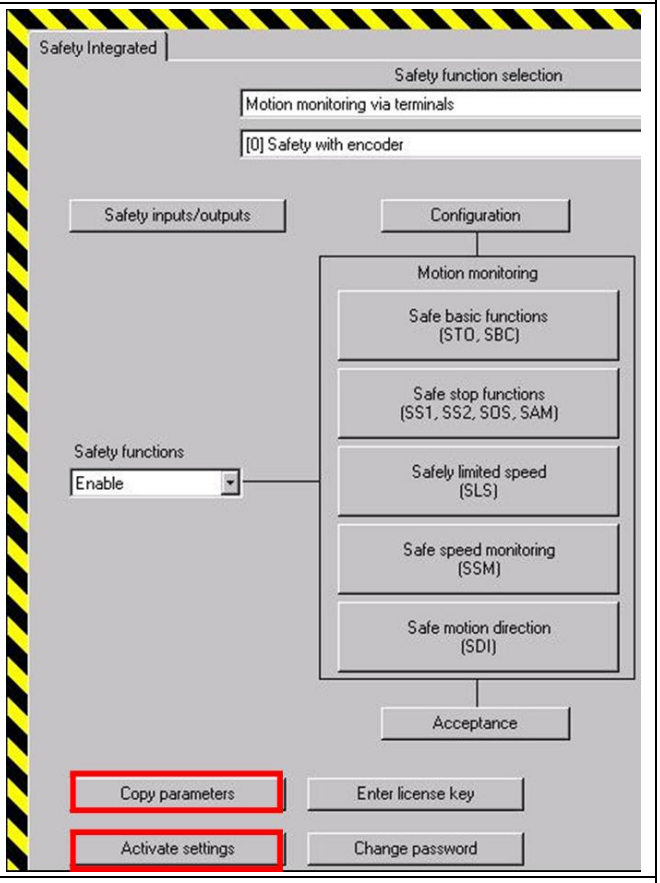
Table 4--3: Parameterizing the safety functions integrated in the drive

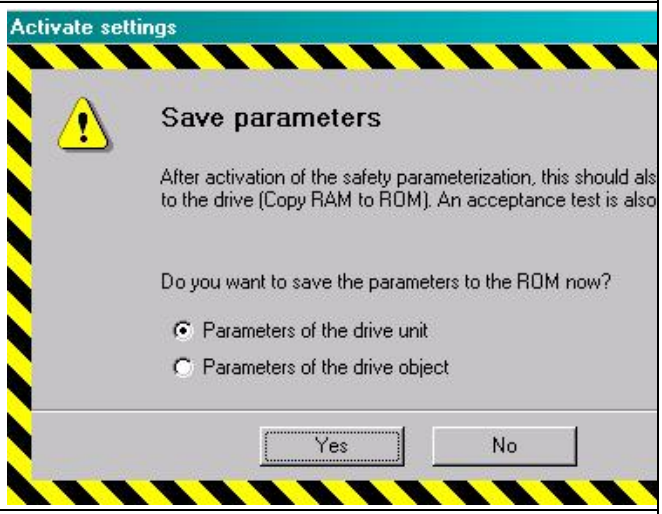
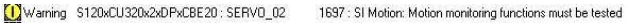
No.	Action	Note
1.	Go online with SCOUT.	
2.	**Configuring the drive** For the drive, open the "Safety Integrated" window under "Functions". In order to change the settings in the Safety screen form, click on "Change settings". A password is now required. The default password for the first commissioning is "0".	
3.	**Configuration of both drives** Change the control selection to „Motion monitoring via terminals“.	

No.	Action	Note
4.	**Configuring the drive** In the example, the following is configured: Select control with "Motion Monitoring via terminals" and "Safety with encoder" Set "Safety functions" to "Enable" and the press the "Safety inputs/outputs" button.	
5.	**Configuring the drive** Press the "Configuration" button. The screen form shown below opens.	
6.	**Configuring the drive** In this window, the discrepancy time, an F-DI for acknowledging Safety alarms and the signal for initiating the forced checking procedure are configured. p10002 = 200msec p10006 = 3 (F-DI 2) p10007 = r20031.0	

No.	Action	Note
7.	**Configuring the drive** The screen form for assigning the Safety functions to the fail-safe inputs is opened using the "Drive" button.	
8.	**Configuring the drive** The following values are set here: - SS1 is interconnected with F-DI 0. - SLS is interconnected with F-DI 1. - SLS limits 1 and 2 are interconnected with a low-signal ("Statically active") in order that velocity level 1 can be selected. All other safety functions are deselected with a high signal (statically inact).	

No.	Action	Note
9.	**Configuring the drive** After configuring the safety inputs/outputs, the Safety functions themselves still have to be configured. First, using the "Configuration" button, the following screen form is opened.	
10.	**Configuring the drive** Here, only the output of the AND element "AND 0" as signal source for selecting the test stop has to be interconnected. p9705 = r20031.0	
11.	**Configuring the drive** In the „Safe stops“ screen form, the SS1/STOP B timer (p9556) is set to 500 msec. The timer for SS2/STOP C (p9552) is also set to 500msec. This stop response is used when the SLS limit is exceeded.	

No.	Action	Note
12.	**Configuring the drive** The value for SLS level 1 (p9531[0]) is set to 3000mm/min, which corresponds to a speed of 300 rpm. **Note** The other velocity limits are set to a value greater than 3000mm/min. This is done because, for a wire break SLS level 1 is selected, for example. This means that the velocity is monitored against the lowest velocity that has been parameterized.	
13.	**Configuring the drive** You must now copy the parameters. To do this, click on the "Copy parameter" button. Then click on "Activate settings".	
14.	**Configuring the drive** You are now prompted to assign a new password. To do this, for example set the password to „1“.	

No.	Action	Note
15.	**Configuring the drive** The parameters of the drive unit are now copied to ROM. Confirm with "Yes".	
16.	Go offline.	
17.	Then perform a Power-On reset on the Control Unit.	POWER OFF/ON
18.	Go online.	
19.	Download the configuration into the PG.	
20.	Save the project.	
21.	This message indicates that a test stop of the safety functions in the drive is required. This involves an alarm, i.e. the drive can be switched-on and operated. In this example, the test stop can be initiated using switch -S5.	

4.5 Acceptance test

To verify safety-oriented parameters, an acceptance test must be performed after the machine has been commissioned for the first time and also after changes are made to safety-related parameters. The acceptance test must be appropriately documented. The acceptance reports must be adequately stored and archived.

The acceptance test must be carried out after parameterization has been completed and a power on reset.

Information about the acceptance test, the acceptance report and an example of an appropriate acceptance report is provided in the "Function Manual SINAMICS S110" (FH) in the Chapter "Acceptance test and acceptance report".

To simplify the handling of the acceptance test, an application was generated (SINAMICS S110/120 Safety Acceptance Test). This application is free, but it is only available through your local Siemens sales partner.

5 Commissioning the application

Up until now, the configuration of the application example was described step-by-step. The following steps should now be followed if the sample project is to be directly downloaded to the hardware.

5.1 Preconditions

Preconditions for operation

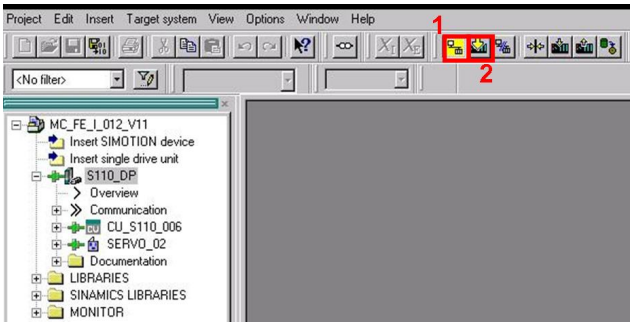
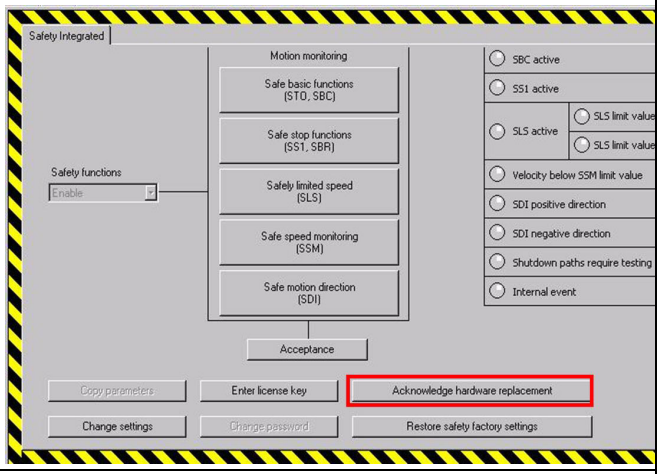
- The motor is connected to the PM340 Power Module using the power cable and the Drive-CliQ cable of the encoder is inserted into the CU305.
- The wiring of the F-DIs of the training case has been modified in accordance with Chapter 0.
- The Motor Module is correctly connected with the infeed (DC link and 24 V DC control voltage).
- The infeed is connected to the line supply.
- The components are supplied with 24 V DC.

5.2 Preparation

(see chapter 4.2 Preparation)

5.3 Commissioning

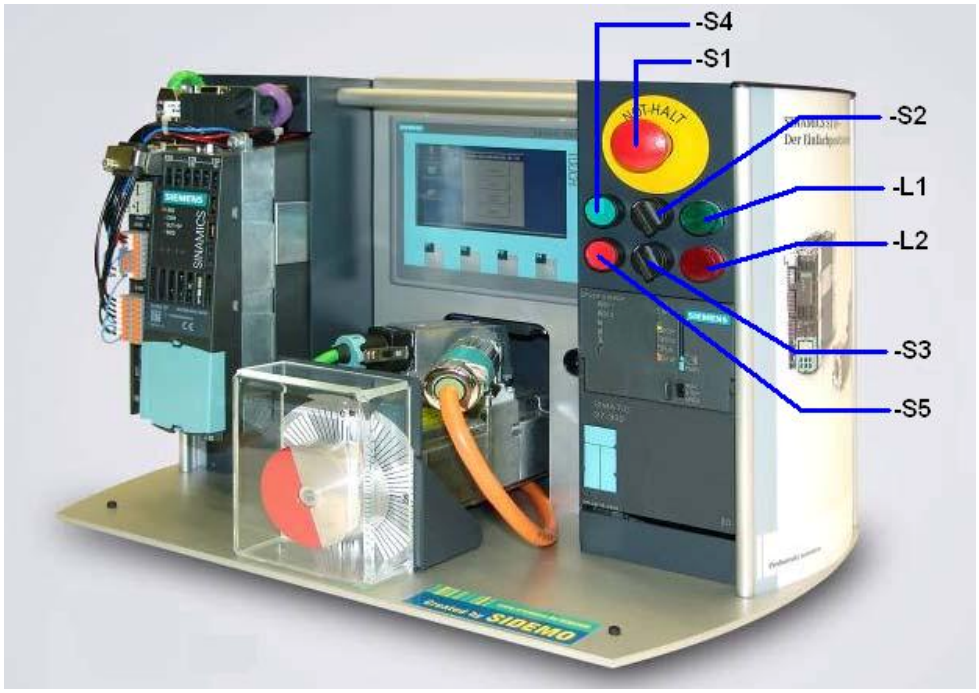
Table 5-1: Commissioning the application example

No.	Action	Note
1.	**Downloading the SINAMICS S110 configuration** You can download the configuration directly to the SINAMICS S110. To do so, first go online and then perform a download.	
2.	Now, for each series commissioning, the new serial numbers must be transferred to the Safety configuration. This is performed using "Acknowledge hardware replacement" in the Safety screen form of the drive.	
3.	The backup procedure from RAM to ROM must then be initiated for SINAMICS and a restart carried out (power on reset).	

6 Using the application

6.1 Overview

Fig. 6--1: Operator control elements of the application example



This description relates to the modified wiring according to Chapter 3.

Using switches -S1 (mushroom pushbutton) and -S2 (toggle switch), the configured safety functions SS1 and SLS are controlled. Safety-relevant errors are acknowledged using -S3 (toggle switch). The drive is switched on using the green pushbutton (-S4) and is switched off using the red pushbutton (-S5). You can switch over between to speed setpoints using -S4. The green lamp -L1 lights up when safety function STO is active. The red lamp (-L2) indicates whether SLS is active or not. The test stop (also called forced checking procedure) of the safety functions can be initiated using -S5 (red pushbutton) as soon as the test stop alarm (A1697) is present.

6.2 Description

Switching-on/switching-off

The Emergency Stop button -S1 must be released in order to be able to operate the drive. The drive is switched-on using switch -S4 (OFF1).

Speed steps

The drive is switched-on by pressing the green button (-S4), and operates with a speed of 200 rpm. If this pushbutton is pressed for longer than 1 second, then a speed setpoint of 1000 rpm is selected. The setpoint of 200 rpm becomes effective again when the pushbutton is released.

Acknowledging alarms

The Safety alarms are acknowledged in a fail-safe fashion using -S3. Cyclic test stop for the safety functions is activated using -S5.

Emergency Stop

Safety function SS1 becomes active when the Emergency Stop pushbutton (-S1) is pressed while the drive is rotating. The drive is braked along the OFF3 ramp and then STO is activated. The green signal lamp lights -L1 now lights up.

Protective door

The toggle switch -S2 simulates a protective door. If the switch is turned to the right than this corresponds to a closed protective door. In this case, the drive can be operated with any speed. If the switch is turned to the left (corresponds to an open protective door), then safety function SLS is selected. After a configurable time has expired, the speed is safely monitored against a limit value (in this case 300 rpm). The red signal lamp (-L2) is now controlled.

Fault simulation

When the limit is exceeded (this can be simulated by continually pressing -S4 (green pushbutton)), the drive is stopped and an appropriate fault is output. In this example, stop response STOP C is configured, this means that the drive is braked along the OFF3 ramp and after a configured delay time has expired, standstill is monitored using the SOS safety function. In this case, the drive remains in closed-loop control.

6.3 Summary of input signals

Table 6-1: Digital inputs/outputs of the SINAMICS

Digital input	Switch/ lamp	Component	Description
DI 8	-S4	Drive	Switching on; switching between speed setpoints
DI 10	-S5	Drive	Switching off; selecting test stop (forced checking procedure)
DO 9	-L1	lamp	Feedback, STO active
DO 11	-L2	lamp	Feedback, SLS active

Figure 6-2: Fail-safe inputs

Digital input	Switch	Component	Description
F-DI 0	-S1	Emergency Stop pushbutton	SS1
F-DI 1	-S2	Protective door	SLS
F-DI 2	-S3	Toggle switch	Fail-safe acknowledgment and depassivation

Note The drive can only be operated when the load power supply is switched on (400V).

7 References

7.1 Related documents

This list does not claim to be complete and only provides a selection of suitable references.

Table 7-1: References

	Topic	Title
/1/	SINAMICS S110	Function Manual, Edition 01/2011
/2/	SINAMICS S110	Manual, Edition 01/2011
/3/	SINAMICS S110	List Manual, edition 01/2011
/4/	SINAMICS / SIMOTION	Function manual *Description of the DCC standard blocks* Edition 11/2010

7.2 Internet links

This list does not claim to be complete and only provides a selection of suitable information.

Table 7-2: Internet link reference

	Topic	Title
\1\	Reference to the entry	http://support.automation.siemens.com/WW/view/en/42940007
\2\	Siemens I IA/DT Customer Support	http://support.automation.siemens.com

8 History

Table 8-1: History

Version	Date	Change
V1.0	06/2010	First edition
V2.0	11/2011	Revised with SINAMICS Version 4.4 and SIMOTION SCOUT 4.2.1.0