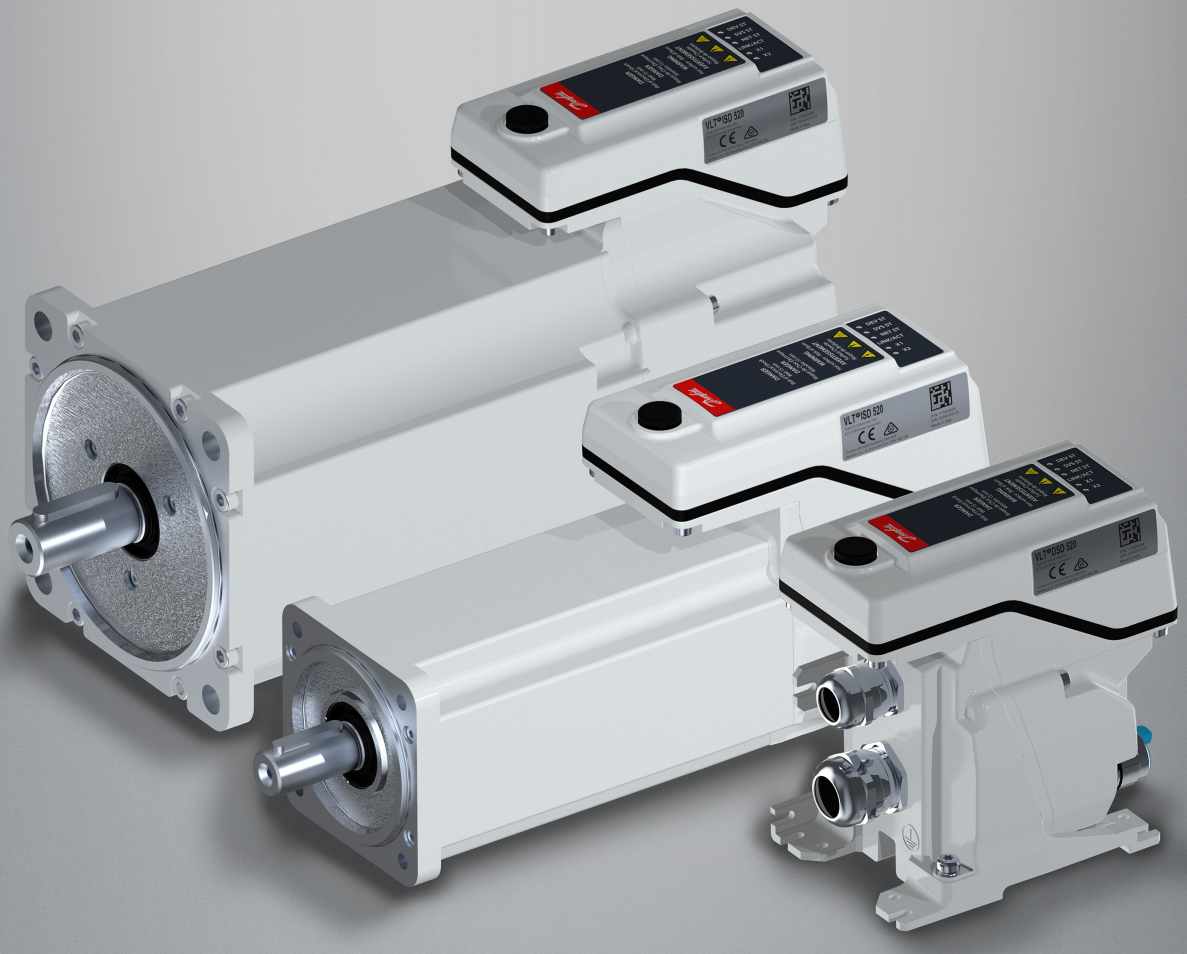
ENGINEERING
TOMORROW

Operating Guide

Advanced Functional Safety for VLT® FlexMotion™



Safety over EtherCAT®

PROFIsafe

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Contents

1 Introduction

1.1 Purpose of this Operating Guide

The purpose of this operating guide is to describe the Advanced Functional Safety option for VLT® FlexMotion™.

This operating guide contains information about:

- Installation
- Commissioning
- Programming
- Operation
- Troubleshooting
- Service and Maintenance

This operating guide is intended for use by qualified personnel. Read the operating guide in full to use the option safely and professionally, and pay particular attention to the safety instructions and general warnings.

This operating guide is an integral part of the product and also contains important service information. Therefore always keep this operating guide available with the product.

Compliance with the information in the operating guide is a prerequisite for:

- Trouble-free operation
- Recognition of product liability claims

Therefore, read this operating guide before working with the Advanced Functional Safety option for VLT® FlexMotion™.

1.2 Available Resources

Table 1: Additional Resources

Guide	Description
VLT® Servo Drive System ISD 520/DSD 520 Operating Guide.	Contains information about Installation, commissioning and operation of the ISD 520/DSD 520 servo drive system.

1.3 Copyright

1.4 Document Version

The original language of this guide is English.

Version	Remarks
AQ382061785373, version 01	First release

1.5 Approvals and Certifications

The VLT® Advanced Functional Safety option for VLT® FlexMotion™ complies with the standards and directives detailed in this section.

1.5.1 Directives and Standards

Table 2: Directives

Directive	Description
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2014/35/EU	Low Voltage Directive (LVD)
2006/42/EC	Machinery Directive (MD)
2011/65/EU, amended 2015/863/EU	Restriction of Hazardous Substances (RoHS)
CE	

Table 3: Standards

Standard	Description
EN/IEC 61800-3	Adjustable speed electrical power drive systems Part 3: EMC requirements and specific test methods
EN/IEC 61800-5-1	Adjustable speed electrical power drive systems Part 5-1: Safety requirements - Electrical, thermal, and energy
EN/IEC 61800-5-2	Adjustable speed electrical power drive systems Part 5-2: Safety requirements - Functional
EN/IEC 61508-1	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 1: General requirements
EN/IEC 61508-2	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems
EN/IEC 61508-3	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 3: Software requirements
EN ISO 13849-1	Safety of machinery - Safety-related parts of control systems Part 1: General principles for design
EN ISO 13849-2	Safety of machinery - Safety-related parts of control systems Part 2: Validation
UL 61800-5-1	Adjustable speed electrical power drive systems. Part 5-1: Safety requirements - Electrical, thermal, and energy.
CSA C22.2 No. 274	Standard specifying requirements for adjustable speed drives with regard to electrical, thermal, and energy safety considerations.

1.5.2 Fieldbuses and Technical Specifications

Table 4: Fieldbuses and Technical Specifications

Fieldbus	Description
Ethernet PROFINET®	Ethernet-based fieldbus system. PROFINET® are registered trademarks of PROFIBUS and PROFINET International (PI).
Ethernet PROFIsafe®	Safety profile for transmitting safety-critical data via PROFINET®. PROFIsafe® are registered trademarks of PROFIBUS and PROFINET International (PI).
Ethernet EtherCAT® EtherCAT®	Ethernet-based fieldbus system. EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.
Safety over EtherCAT® (FSoE) Safety over EtherCAT®	Safety profile for transmitting safety-critical data over EtherCAT®. Safety over EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

1.6 Terminology

Table 5: Terminology

Term	Description
VLT® FlexSafety™	Advanced Functional Safety for VLT®FlexMotion™
Safety boards	FS Control board and Safe I/O board
Safe Drive	Drive with FS Control board and optionally with Safe I/O board installed
Digital input/output	Safe I/O digital input/output
STO input	STO digital input (hard-wired STO digital input)

2 Safety

2.1 Legal Information

According to the Machinery Directive regulation, it is hereby stated that the original language of this operating guide is English US.

2.2 Warranty and Liability

All claims to warranty and liability are rendered invalid if:

- The product was used contrary to the purpose for which it was intended.
- Damage can be attributed to not having followed the guidelines in the guide.
- Operating personnel are not suitably qualified.
- Any type of modification has been made (for example, exchanging components on the PCB boards, soldering work, and more).

2.3 Safety Symbols

The following symbols are used in Danfoss documentation.

⚠ DANGER

Indicates a hazardous situation which, if not avoided, will result in death or serious injury.

⚠ WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

Indicates information considered important, but not hazard-related (for example, messages relating to property damage).

The guide also includes ISO warning symbols related to hot surfaces and burn hazard, high voltage and electric shock, and referring to the instructions.

	ISO warning symbol for hot surfaces and burn hazard
	ISO warning symbol for high voltage and electric shock
	ISO action symbol for referring to the instructions

2.4 Qualified Personnel

The products must only be assembled, installed, programmed, commissioned, maintained, and decommissioned by persons with proven skills. Persons with proven skills:

- Are qualified electrical engineers, or persons who have received training from qualified electrical engineers and are suitably experienced to operate devices, systems, plant, and machinery in accordance with the general standards and guidelines for safety technology.
- Are familiar with the basic regulations concerning health and safety/accident prevention.
- Have read and understood the safety guidelines given in this guide and also the instructions given in the operating guide for the drive.
- Have good knowledge of the generic and specialist standards applicable to the specific application.
- Are skilled and trained in operating the safety-related device and trained according to the action to be performed, especially for a software update, commissioning, and parameter setting.
- Have at least 3 years of professional experience in safety-related systems.

2.5 Important Safety Warnings

Compliance with the safety instructions and precautions is necessary at all times.

- Orderly and proper transport, storage, fitting, and installation, as well as careful operation and maintenance, are essential for the trouble-free and safe use of the option.
- The plant engineer or system engineer is personally responsible for checking the suitability of the supplied components and the information provided in this guide for the specific application concerned:
  - For compliance with the safety regulations and standards relevant to the specific application.
  - For implementing the necessary measures, changes, and extensions.

⚠ WARNING

HIGH VOLTAGE

The servo system contains components that operate at high voltage when connected to the electrical supply network. Not all components have indicators that indicate the presence of mains supply. Incorrect installation, commissioning, or maintenance may lead to death or serious injury.

- Installation, commissioning, and maintenance may only be performed by qualified personnel.

⚠ WARNING

DISCHARGE TIME

The servo system contains DC-link capacitors that remain charged even when the drive is not powered. High voltage can be present even when the warning indicator lights are off.

Failure to wait the specified time after power has been removed before performing service or repair work could result in death or serious injury.

- Stop the motor.
- Disconnect the AC mains and all other power supplies.
- Wait for the capacitors to discharge fully.

Minimum waiting time (minutes)
15

- Before performing any service or repair work, use a voltage measuring device to ensure that the capacitors are fully discharged.

⚠ DANGER

RISQUE DU CHOC ÉLECTRIQUE

Une tension dangereuse peut être présentée jusqu'à 15 min après avoir coupé l'alimentation.

⚠ WARNING

RISK OF ELECTRIC SHOCK

The STO safety function does not provide electrical safety. The STO function itself is not sufficient to implement the Emergency-Off function as defined by EN 60204-1. Using the STO function to implement Emergency-Off may lead to death or personal injury.

- Ensure that electrical isolation measures are taken, for example, by switching off the mains via an extra contactor.

⚠ WARNING

NO ELECTRICAL SAFETY

The VLT® FlexSafety™ option is only suitable for performing mechanical work on the drive system or affected area of a machine. It does not provide electrical safety. Using the option for starting or stopping the drive could result in death or serious injury.

- Do not use the option as a control for starting or stopping the drive.
- Refer to ISO 12100 for more information about the application requirements.

⚠ WARNING

UNINTENDED START

The system contains drives, the PSM, and DAM that are connected to the electrical supply network and can start running at any time. This may be caused by a fieldbus command, a reference signal, or clearing a fault condition. The drives and all connected devices must be in good operating condition. A deficient operating condition may lead to death, serious injury, damage to equipment, or other material damage when the unit is connected to the electrical supply network.

- Take suitable measures to prevent unintended starts.

⚠ WARNING

UNINTENDED MOVEMENT

Unintended movement may occur immediately when parameter changes are carried out, which may result in death, serious injury, or damage to equipment.

- When changing parameters, take suitable measures to ensure that unintended movement cannot pose any danger.

⚠ WARNING

LEAKAGE/GROUNDING CURRENT HAZARD

Leakage/grounding currents are >3.5 mA. Improper grounding of the drives and the system modules may result in death or serious injury.

- For reasons of operator safety, use a certified electrical installer to ground the system correctly in accordance with the applicable local and national electrical standards and directives, and the instructions in this guide.

NOTICE

- STO does not imply electrical safety of the motor and high voltage might apply to the motor. The motor might turn by half a period if an internal failure occurs while STO is applied and a cogging torque might remain.

NOTICE

- The drive has more voltage sources than the external grid or when external 24/48 V DC supply is connected.

NOTICE

- Perform a commissioning test after the initial installation, but also after each change to the installation or application involving functional safety.
- During installation and commissioning, validate the correct execution of the safety functions and the safety properties, depending on the configured functions for the whole system.
- After a software update, revalidate the safety parameters and the safety system. After downloading the software to the device, check that it is suitable for the device.

NOTICE

The operating guides for the products containing the VLT® FlexSafety™ option provide important information on how to prevent injury and damage to the system or equipment.

- Refer to the product operating guides for detailed instructions and applicable safety warnings.
- Product documentation can be downloaded at www.danfoss.com.
- Pour le instructions détaillées, lisez les guides d'utilisation des produits.
- Vous pouvez télécharger les manuels produit contenant l'ensemble des informa-tions de sécurité, avertissements et mises en garde applicables sur le site www.danfoss.com.

2.6 Risk Assessment

NOTICE

- VLT® FlexSafety™ is intended to be part of the safety-related control system of a machine. Before installation, perform a risk assessment to determine whether the specifications of VLT® FlexSafety™ are suitable for all foreseeable operational and environmental characteristics for the system in which it will be installed.

The system user is responsible for:

- Setup, safety rating, and validation of any actuators connected to the system.
- Completing a system-level risk assessment and reassessing the system anytime a change is made.
- Providing supposition (as needed for the application) that the system fulfills the requested safety rating.
- Project management and proof testing.
- Programming the application software and the VLT® FlexSafety™ configurations in accordance with the information in this guide.
- Access to the control system.
- Analyzing all configuration settings and selecting the proper setting to achieve the required safety rating.

3 Functions and Systems Overview

3.1 Systems

3.1.1 System Overview

The VLT® FlexSafety™ feature consists of 2 separate functional safety (FS) option boards:

1. FS Control board
2. Safe I/O board

The Safe I/O board is an extension of the FS Control board which enables interaction with the drive via the digital inputs/outputs. Without the Safe I/O board, interaction with the safety system via the safe fieldbus protocol is still possible without a loss in performance.

The FS Control board supports:

- Safe Fieldbus
  - Safety over EtherCAT (FSoE)
  - PROFIsafe
- Advanced safety functions (see 3.2.4 VLT® FlexSafety™ Features)
- HIPERFACE® DSL Safety encoders
- Safe Brake Control (SBC) function
  - The control of the mechanical brake (integrated in ISD 520 or external to DSD 520) in combination with the FS Control board becomes a safe control according to EN/IEC 61800-5-2. More details regarding the certification of the SBC function can be found in *Safety Characteristic Data*.
- Test pulse evaluation applied on the single channel STO input. The FS Control board increases the safety integrity level and safety performance.
- In combination with the Safe I/O board:
  - 2 double channel digital inputs (channel A and B)
  - 2 double channel digital outputs (channel A and B)

Figure 1 shows the system overview for ISD 511 and ISD 520. VLT® FlexSafety™ only applies to ISD 520/DSD 520, not to ISD 511.

Figure 2 shows the system overview for DSD 520.

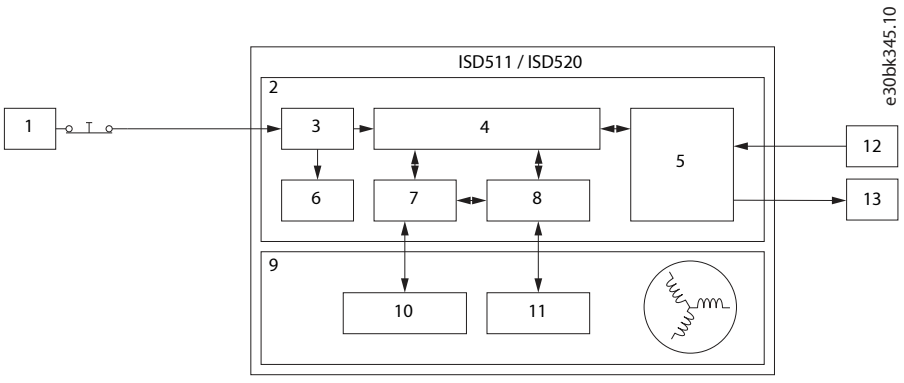

Figure 1: Overview of ISD 511/ISD 520 with VLT® FlexSafety™

1	STO digital input	**2**	Servo drive
3	STO input	**4**	FS Control board (optional)
5	Safe I/O board (optional)	**6**	Pulse inhibitor

7	Control unit	**8**	Safe brake control
9	Motor	**10**	Safety encoder (optional)
11	Safe brake (optional)	**12**	2 x dual-channel digital input
13	2 x dual-channel digital output		

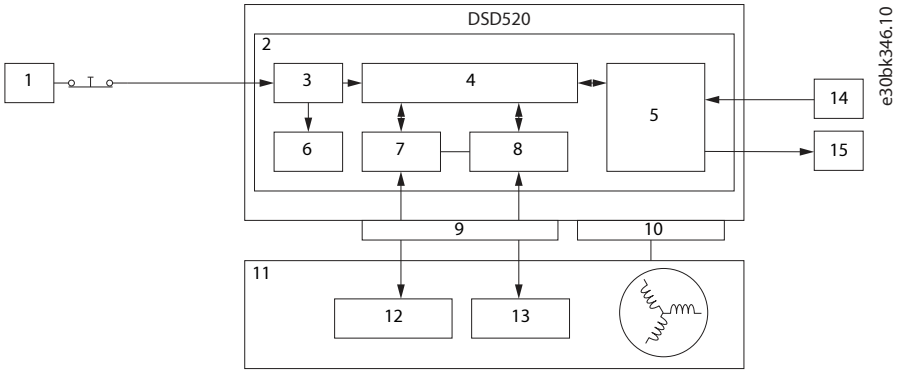

Figure 2: Overview of DSD 520 with VLT® FlexSafety™

1	STO digital input	**2**	Servo drive
3	STO input	**4**	FS Control board (optional)
5	Safe I/O board (optional)	**6**	Pulse inhibitor
7	Control unit	**8**	Safe brake control
9	Connector motor feedback	**10**	Connector motor phases
11	Motor	**12**	Safety encoder (optional)
13	Safe brake (optional)	**14**	2 x dual-channel digital input
15	2 x dual-channel digital output		

3.1.2 Behavior of Holding Brake

⚠ WARNING

UNINTENDED MOVEMENT

External forces acting on the motor and unintended movements, for example caused by gravity, may lead to death, serious injury, or damage to equipment.

- Take suitable measures to ensure that unintended movement cannot pose any danger.

Triggering the Safe Torque Off safety subfunction from STO input means that the delay time for motors with holding brake is not effective. The motor cannot generate holding torque to bridge the time to application of the holding brake. Check whether more measures have to be taken, for example, this may cause the load of vertical axes to lower.

Triggering any safety subfunction meant to stop the motor, for example Safe Torque Off, determines a delay time until the application of the holding brake can be effective. Check whether further measures are required to prevent unintended movement during the delay time.

3.1.3 Safety Certification

VLT® FlexSafety™ is certified for use in safety applications up to and including SIL 3 according to EN/IEC 61800-5-2 and EN/IEC 61508, Performance Level PL e and Cat. 3 according to EN ISO 13849-1. Safety requirements are based on the standards valid at the time of certification.

VLT® FlexSafety™ is certified for use in safety-related applications where the de-energized state is considered to be the safe state.

3.1.4 Implementation in Control Systems

Often, design measures are not sufficient and protective devices are required to minimize the risk. In this context, safety subfunctions executed by SRP/CS (safety-related part of control systems) are defined. SRP/CS includes the entire safety chain with sensor (detect), logic (process), and actuator (switch).

Safety subfunctions are defined based on the application and the hazard. They are often specified in a Type C standard (a product standard), which provides precise specifications for special machines. If a C standard is not available, the machine designer defines the safety subfunctions. Typical safety subfunctions are described in more detail in EN ISO 13849-1, section 5, Specification of Safety Functions. The safety subfunctions for drive systems are described in IEC 61800-5-2.

3.2 Functions

3.2.1 Overview

This chapter details the characteristics of the safety functions configurable on a safety drive. See 3.2.5.1 Stopping Functions for a detailed description of each safety function.

Some safety functions are available as multiple instances, however they always refer to 1 single safety drive.

3.2.2 Required Safety Functions

3.2.2.1 Specification of Required Safety Functions

The standards require the specification of safety functions used, including details about each safety function that should be executed.

The following must also be defined:

- Necessary interfaces with other control functions, such as safe fieldbus PLCs or safety I/Os.
- Required error responses.
- Performance level (PL) required or achievable safety integrity level (SIL).

3.2.2.2 Performance Level (PL) and Safety Integrity Level (SIL)

For safety-related control systems, Performance Level (PL), according to EN ISO 13849-1, and SIL levels, according to EN IEC 61508, include a rating of the system's ability to perform its safety functions.

All the safety-related components of the control system must be included in both a risk assessment and the determination of the achieved levels. Refer to EN ISO 13849-1 or EN IEC 61508 standards for complete information on requirements for PL and SIL determination.

3.2.2.3 Validation of Performance Level

Check whether the required performance level (PL), determined in the risk assessment, is achieved by the selected system for each safety function used. Check the calculation using the SISTEMA SW Tool of IFA (Institute for Occupational Safety & Health). Danfoss provides a component library that can be used for the calculation. Danfoss offers corresponding services to support the system check by calculation. The library can be downloaded from https://www.dguv.de/ifa/praxishilfen/practical-solutions-machine-safety/software-sistema/index.jsp.

If using another validation method for the performance level, use the characteristic safety values specified.

3.2.2.4 Activation of Safety Functions

The supported safety functions are detailed in Table 6.

Table 6: Supported Safety Functions

Function	Name	Request via	Instances	Comment
STO	Safe Torque Off	Safe fieldbus/Safe input/Reaction from another safety function	1	Can be activated by SS1 or if a failure occurs.
SOS	Safe operating stop	Safe fieldbus/Safe input	1	Can be activated by SS2.
SBC	Safe brake control	Safe fieldbus/Safe input	1	Activation is linked to the activation of STO.
SS1	Safe Stop 1	Safe fieldbus/Safe input/Reaction from another safety function	1	–
SS2	Safe Stop 2	Safe fieldbus/Safe input/Reaction from another safety function	1	–
SLS	Safety-limited speed	Safe fieldbus/Safe input	4	–
DLS	Dynamically limited speed	Safe fieldbus/Safe input	1	–
SMS	Safe maximum speed	Safe parameter	1	–
SLA	Safety-limited acceleration	Safe fieldbus/Safe input	1	–
SSR	Safe speed range	Safe fieldbus/Safe input	1	–
SSM	Safe speed monitor	Safe parameter	1	Can be deactivated by Safe fieldbus (only PROFIsafe)
SDI	Safe direction	Safe fieldbus/Safe input	1	–
SLP	Safety-limited position	Safe fieldbus/Safe input	4	–
SLI	Safety-limited increment	Safe fieldbus/Safe input	1	–
SCA	Safe CAM	Safe parameter	4	Can be muted by Safe fieldbus (only PROFIsafe)
SAR	Safe acceleration range	Safe fieldbus/Safe input	1	–

Table 7: Diagnostic Functions

Function	Name	Request via	Instances	Comment
SBT	Safe brake test	Safe fieldbus/Safe input	1	Not a safety function but supports safety integrity.

The safety functions are activated either via safe fieldbus or by using the safe inputs provided by the Safe I/O option board. Each safety function is configured independently. The activation logic for requesting a Safe Drive function is shown in Figure 3.

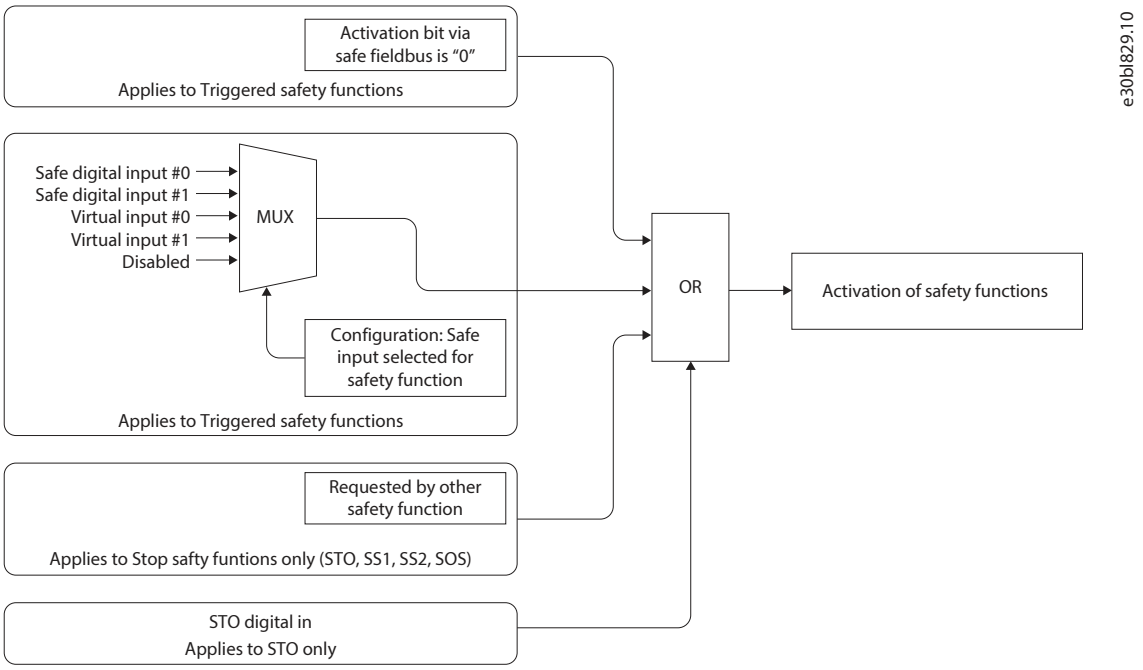

Figure 3: Safety Function Activation Sequence

The safety functions STO, SS1, and SS2 are considered as stop safety functions and can be selected to react when limits of other safety functions are violated. The safety function SOS is called by SS2 if the drive reaches the SOS zero speed window violating the SS2 limits.

The virtual inputs are safe digital inputs with the logical status derived from the status of the known "Safe digital inputs", as logical OR or logical AND, as shown in Figure 4.

If the safe digital inputs are not used and therefore no input sources are available, then the MUX defaults to the *Disabled* setting.

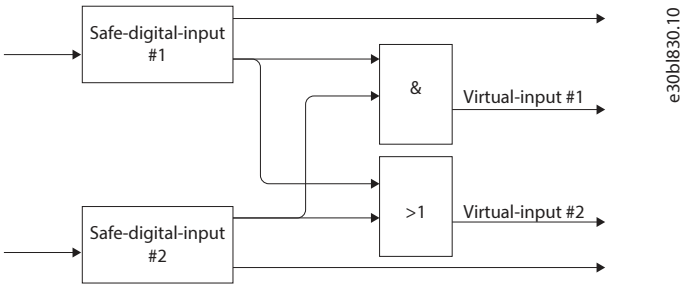

Figure 4: Overview of Virtual Safe Digital Inputs

3.2.2.5 Execution Sequence of Safety Functions

Each safety function can be activated independently at the same time. In addition, STO, SS1, and SS2 can be set as the failure reaction of other safety functions. SOS can be called by the SS2 safety function if the drive reaches the *SOS zero speed window* without violating the SS2 limits.

If a safety function can be triggered by a digital input, none or 1 digital input can be selected. A logical combination of 2 inputs is possible and mapped to virtual inputs. One input can trigger multiple safety functions.

For most safety functions, either STO or SS1/SS2 must be selected. If any safety functions failure reaction is set to SS1, then SS1 is activated.

The possible output information of a safety function includes the activation or "in range" information. A safety function, for example SS2, is activated after a configurable delay after the function is requested until the actual speed is within the *SOS zero speed window* and SOS is activated. Each safe digital output can be assigned to exactly 1 signal source or a logic (static high or low). Logical combinations of 2 states cannot be assigned to an output.

3.2.3 Safe Fieldbus

3.2.3.1 Safe Fieldbus Support

The safety drive supports several fieldbus systems:

- PROFINET with PROFIsafe
- EtherCAT with FailSafe over EtherCAT (FSoE)
- Safety operation without any PLC or fail-safe PLC connected

A different firmware binary is available for each fieldbus system.

Safe fieldbus requires a dedicated address for each device within the network topology, referred to as “Safe Address”. In the safety drive, the "Safe Address" is stored in a safety parameter and programmed into the device during parametrization.

The safe fieldbus status indicator light (LED) behaves as described by the safety protocol standard.

3.2.3.2 PROFIsafe

3.2.3.2.1 Introduction to PROFIsafe

Data about the safety functions can be transferred in 2 ways:

- Fail-safe: Using PROFIsafe telegrams 30, 31, 902, 903
- Non-fail-safe: Using supplementary telegrams 700, 701

For PROFIsafe the safe address is an FSCP 3/1 Address Type 1 (F-(Sub) Module which only checks the *destination address* as Retentive Selection of the Code name) with an allowed value from 1–999.

3.2.3.2.2 PROFIsafe Telegram 30

This telegram is used to transfer safety status word 1 (S_ZSW1) and safety control word 1 (S_STW1). The telegram is structured as follows:

Table 8: Structure of Telegram 30

Input data	Input data size (Byte)	Output data	Output data size (Byte)
S_ZSW1	2	S_STW1	2

Safety control word 1 (S_STW1)

Table 9: S_STW1 Overview

Byte	Bit	Safe drive function	Significance
0	0	STO	0: Activate the STO Safe-Drive-Function. 1: Normal operation.
0	1	SS1	0: Activate the SS1 Safe-Drive-Function. 1: Normal operation.
0	2	SS2	0 = Activate the SS2 Safe-Drive-Function. 1 = Normal operation.
0	3	SOS	0: Activate the SOS Safe-Drive-Function. 1: Normal operation.
0	4	SLS	0: Activate the SLS Safe-Drive-Function. 1: Normal operation.
0	5	Unused	Reserved (should be set to 0).

Table 9: S_STW1 Overview - (continued)

Byte	Bit	Safe drive function	Significance
0	6	SLP	0: Activate the SLP Safe-Drive-Function. 1: Normal operation.
0	7	Fault	0: Reset last error pending (INTERNAL_EVENT_ACK). Reset an *I/O Failure* if an *I/O Failure* is pending. 1: Record the next error raised (normal operation).
1	0	SLI	0: Activate the SLI Safe-Drive-Function. 1: Normal operation.
1	1	SSR	0: Activate the SSR Safe-Drive-Function. 1 = Normal operation.
1	2	SAR	0: Activate the SAR Safe-Drive-Function. 1: Normal operation.
1	3	SBC override	0: No SBC override. 1: Force SBC to release brake during STO.
1	4	Unused	Reserved (should be set to 0).
	5	Unused	Reserved (should be set to 0).
1	6	Reference SP	0: Normal operation. 1: Reset the absolute positioning after homing.
1	7	Restart acknowledge	Transition 0 to 1: Perform a restart acknowledge.

Safety status word 1 (S_ZSW1)

Table 10: S_ZSW1 Overview

Byte	Bit	Safe drive function	Significance
0	0	STO	0: Normal operation. 1: STO Safe-Drive-Function is active.
0	1	SS1	0: Normal operation. 1: SS1 Safe-Drive-Function is active.
0	2	SS2	0: Normal operation. 1: SS2 Safe-Drive-Function is active.
0	3	SOS	0: Normal operation. 1: SOS Safe-Drive-Function is active.
0	4	SLS	0: Normal operation. 1: SLS Safe-Drive-Function (instance 1) is active.
0	5	Unused	Reserved.
0	6	SLP	0: Normal operation. 1: SLP Safe-Drive-Function (instance 1) is active.
0	7	Fault	0: Normal operation. 1: A fault or I/O Failure is pending (INTERNAL_EVENT).
1	0	SLI	0: Normal operation. 1: SLI Safe-Drive-Function is active.

Table 10: S_ZSW1 Overview - (continued)

Byte	Bit	Safe drive function	Significance
1	1	SSR	0: Normal operation. 1: SSR Safe-Drive-Function is active.
1	2	SAR	0: Normal operation. 1: SAR Safe-Drive-Function is active.
1	3	SBC override active	0: SBC override is not active. 1: SBC override is active.
1	4	SBC failure	0: No SBC error. 1: SBC error.
	5	SBT required	0: No SBT required. 1: SBT required.
1	6	SP referenced	0: Safe Position (SP) value is **not** referenced. (SLP is disabled and S_XIST32 values are **not** referenced). 1: Safe Position (SP) value is referenced. (SLP is possible and S_XIST32 values are referenced).
1	7	Restart acknowledge needed	0: No restart acknowledge is needed. 1: A restart acknowledge is needed to release the safety function.

3.2.3.2.3 PROFIsafe Telegram 31

This telegram is used to transfer safety status word 2 (S_ZSW2) and Safety control word 1 (S_STW2). The telegram is structured as follows:

Table 11: Structure of Telegram 31

Input data	Input data size (Byte)	Output data	Output data size (Byte)
S_ZWS2	4	S_STW2	4

Table 12: S_STW2 Overview

Byte	Bit	Safe drive function	Significance
0	0	STO	0: Activate the STO Safe-Drive-Function. 1: Normal operation.
0	1	SS1	0: Activate the SS1 Safe-Drive-Function. 1: Normal operation.
0	2	SS2	0 = Activate the SS2 Safe-Drive-Function. 1 = Normal operation.
0	3	SOS	0: Activate the SOS Safe-Drive-Function. 1: Normal operation.
0	4	SLS	0: Activate the SLS Safe-Drive-Function. 1: Normal operation.
0	5	Unused	Reserved (should be set to 0).
0	6	SLP	0: Activate the SLP Safe-Drive-Function. 1: Normal operation.

Table 12: S_STW2 Overview - (continued)

Byte	Bit	Safe drive function	Significance
0	7	Fault	0: Reset last error pending (INTERNAL_EVENT_ACK). Reset any pending I/O failure. 1: Record the next error raised (normal operation).
1	0	SLA	0: Activate the SLA Safe-Drive-Function. 1: Normal operation.
1	1	SLS_Limit	00: Use SLS instance 1. 01: Use SLS instance 2. 10: Use SLS instance 3. 11: Use SLS instance 4.
1	2		
1	3	Unused	Reserved (should be set to 0).
1	4	SDI_P	0: Activate the SDI Safe-Drive-Function (positive direction). 1: Normal operation.
	5	SDI_N	0: Activate the SDI Safe-Drive-Function (negative direction). 1: Normal operation.
1	6	Unused	Reserved (should be set to 0).
1	7		
2	0, 1	Unused	Reserved (should be set to 0).
2	2	Not applicable	Reserved for future use (should be set to 0).
2	3, 4	SLP_LIMIT	00: Use SLP instance 1. 01: Use SLP instance 2. 10: Use SLP instance 3. 11: Use SLP instance 4.
2	5, 6	Not applicable	Reserved for future use (should be set to 0).
2	7	SCA	0: Activate the SCA function (return the current state). 1: Deactivate the SCA function (indicate in range for all SCA instances).
3	0	SLI	0: Activate the SLI Safe-Drive-Function. 1: Normal operation.
3	1	SSR	0: Activate the SSR Safe-Drive-Function. 1: Normal operation.
3	2	SAR	0: Activate the SAR Safe-Drive-Function. 1: Normal operation.
3	3	SBC override	0: No SBC override. 1: Force SBC to release the brake during STO.
3	4	Unused	Reserved (should be set to 0).
3	5	Reference SP	0: Normal operation. 1: Reset the absolute position after homing.
3	6	DLS	0: Activate the DLS Safe-Drive-Function. 1: Normal operation.
3	7	Restart acknowledge	Transition 0→1: Perform a restart acknowledge.

Table 13: S_ZSW2 Overview

Byte	Bit	Safe drive function	Significance
0	0	STO	0: Normal operation. 1: STO Safe-Drive-Function is active.
0	1	SS1	0: Normal operation. 1: SS1 Safe-Drive-Function is active.
0	2	SS2	0: Normal operation. 1: SS2 Safe-Drive-Function is active.
0	3	SOS	0: Normal operation. 1: SOS Safe-Drive-Function is active.
0	4	SLS	0: Normal operation. 1: SLS Safe-Drive-Function is active.
0	5	Unused	Reserved (should be set to 0).
0	6	SLP	0: Normal operation. 1: SLP Safe-Drive-Function is active.
0	7	Fault	0: Normal operation. 1: A fault or I/O failure is pending (INTERNAL_EVENT).
1	0	SLA	0: Normal operation. 1: SLA Safe-Drive-Function is active.
1	1	SLS_LIMIT	If SLS = 0: Bits do not contain any valid information. If SLS = 1: • 00: SLS instance 1 is used. • 01: SLS instance 2 is used. • 10: SLS instance 3 is used. • 11: SLS instance 4 is used.
1	2		
1	3	Unused	Reserved (should be set to 0).
1	4	SDI_P	0: Normal operation. 1: SDI Safe-Drive-Function is active (positive direction).
	5	SDI_N	0: Normal operation. 1: SDI Safe-Drive-Function is active (negative direction).
1	6	Unused	Reserved (should be set to 0).
1	7	SSM	0: SSM Speed above threshold or SSM Safe-Drive-Function disabled. 1: SSM Speed below threshold.
2	0	Unused	Reserved (should be set to 0).
2	1		
2	2	Unused	Reserved (should be set to 0).

Table 13: S_ZSW2 Overview - (continued)

Byte	Bit	Safe drive function	Significance
2	3	SLP_LIMIT	If SLP = 0: Bits do not contain any valid information. If SLP = 1: • 00: SLP instance 1 is used. • 01: SLP instance 2 is used. • 10: SLP instance 3 is used. • 11: SLP instance 4 is used.
2	4		
2	5	Unused	Reserved (should be set to 0).
2	6	SP valid	0: Safe Position (SP) value is **invalid**. (SLP is disabled and S_XIST32 is **invalid**). 1: Safe Position (SP) value is valid. (SLP is possible and S_XIST32 is valid).
2	7	SP referenced	0: Safe Position (SP) value is **not** referenced. (SLP is disabled and S_XIST32 values are **not**referenced). 1: Safe Position (SP) value is referenced. (SLP is possible and S_XIST32 values are referenced).
3	0	SLI	0: Normal operation. 1: SLI Safe-Drive-Function is active.
3	1	SSR	0: Normal operation. 1: SSR Safe-Drive-Function is active.
3	2	SAR	0: Normal operation. 1: SAR Safe-Drive-Function is active.
3	3	SBC override active	0: SBC override is not active. 1: SBC override is active.
3	4	SBC failure	0: No SBC error. 1: SBC in error.
3	5	SBT required	0: No SBT required. 1: SBT required.
3	6	DLS	0: Normal operation. 1: The DLS Safe-Drive-Function is active.
3	7	Restart acknowledge needed	0: No restart acknowledge is pending. 1: A restart acknowledge is needed to release the safety function.

3.2.3.2.4 **PROFIsafe Telegram 902**

This telegram is used to transfer:

- Safety status word 2 (S_ZSW2)
- Safety control word 2 (S_STW2)
- SLS limit (S_SLS_LIM_A)
- Active SLS value (S_SLS_LIM_A_ACT)
- Counter value (S_CYC_COUNT)
- Safe position value in 32-bit format (S_XIST32)

Table 14: Structure of Telegram 902

Input data	Input data size (Byte)	Output data	Output data (Byte)
S_ZWS2	4	S_STW2	4
S_SLS_LIMIT_A_ACTIVE	2	SLS_LIMIT_A	2
S_CYCLE_COUNT	2	–	–
S_XIST32	4	–	–

3.2.3.2.5 PROFIdrive Telegram 903

This telegram is used to transfer:

- Safety status word 2 (S_ZSW2)
- Safety control word 2 (S_STW2)
- SLS limit (S_SLS_LIM_A)
- Active SLS value (S_SLS_LIM_A_ACT)
- Safe CAM status word (S_ZSW_CAM1)

Table 15: Structure of Telegram 903

Input data	Input data size (Byte)	Output data	Output data (Byte)
S_ZWS2	4	S_STW2	4
S_ZSW_CAM1	4	SLS_LIMIT_A	2
S_SLS_LIMIT_A_ACTIVE	2	–	–

Safe CAM Status Word S_ZSW_CAM1

Table 16: Structure of CAM Status Word S_ZSW_CAM1

Byte	Bit	Safe drive function	Significance
0	0	SCA instance 1	0: The SCA Safe-Drive-Function instance is not *inRange*. 1: The SCA Safe-Drive-Function instance is *inRange*.
0	1	SCA instance 2	0: The SCA Safe-Drive-Function instance is not *inRange*. 1: The SCA Safe-Drive-Function instance is *inRange*.
0	2	SCA instance 3	0: The SCA Safe-Drive-Function instance is not *inRange*. 1: The SCA Safe-Drive-Function instance is *inRange*.
0	3	SCA instance 4	0: The SCA Safe-Drive-Function instance is not *inRange*. 1: The SCA Safe-Drive-Function instance is *inRange*.
0	4–7	Unused	Reserved (should be set to 0).
1	0–7	Unused	Reserved (should be set to 0).
2	0–7	Unused	Reserved (should be set to 0).
3	0–5	Unused	Reserved (should be set to 0).
3	6	SCA_ACTIVE	0: The SCA Safe-Drive-Function is not active. 1: The SCA Safe-Drive-Function is active.
3	7	SCA_DATA_VALID	0: The information in Z_ZSW_CAM1 is invalid. 1: The information in Z_ZSW_CAM1 is valid.

3.2.3.2.6 Supplementary Telegram 700

This telegram is used to transfer:

- Safety status word 1B (S_ZSW1B)
- Value for the velocity limit (S_V_LIMIT_B)

Table 17: Structure of Telegram 700

Input data	Input data size (Byte)
S_ZWS1B	2
S_V_LIMIT_B	4

Safety Status Word 1B (S_ZSW1B)

Table 18: Structure of Safety Status Word 1B (S_ZSW1B)

Byte	Bit	Safe drive function	Significance
0	0	STO	0: Normal operation. 1: STO state reached.
0	1	SS1_ACTIVE	0: Normal operation. 1: SS1 function is active.
0	2	SS2_ACTIVE	0: Normal operation. 1: SS2 function is active.
0	3	SOS_ACTIVE	0: Normal operation. 1: SOS function is active.
0	4	SLS ACTIVE	0: Normal operation. 1: SLS function is active.
0	5	SOS_SELECTED	0: Normal operation. 1: SOS function is selected.
0	6	SLS_SELECTED	0: Normal operation. 1: SLS function is selected.
0	7	INTERNAL EVENT	0: Normal operation. 1: A fault is present.
1	0	Unused	Reserved (should be set to 0).
1	1–2	SLS_LIMIT	The selected SLS speed limit value. Only valid if SLS_SELECTED is true.
1	3	Unused	Reserved (should be set to 0).
1	4	SDI_P_SELECTED	0: Normal operation. 1: The SDIp Safe-Drive-Function is selected.
1	5	SDI_N_SELECTED	0: Normal operation. 1: The SDIn Safe-Drive-Function is selected.
1	6	DLS_ACTIVE	0: Normal operation. 1: The DLS Safe-Drive-Function is active.
1	7	DLS_SELECTED	0: Normal operation. 1: The DLS Safe-Drive-Function is selected.

3.2.3.2.7 Supplementary Telegram 701

This telegram is used to transfer:

- Safety status word 2B (S_ZSW2B)
- Value for the velocity limit (S_V_LIMIT_B)

Table 19: Structure of Telegram 701

Input data	Input data size (Byte)
S_ZWS2B	4
S_V_LIMIT_B	4

Safety Status Word 2B (S_ZSW2B)

Table 20: Structure of Safety Status Word 2B (S_ZSW2B)

Byte	Bit	Safe drive function	Significance
0	0–3	Unused	Reserved (set to 0).
0	4–5	SLP_LIMIT	If SLP_SELECTED = 0: Bits do not contain any valid information. If SLP_SELECTED = 1: • 0: SLP instance 1 is used. • 1: SLP instance 2 is used. • 2: SLP instance 3 is used. • 3: SLP instance 4 is used.
0	6	Unused	Reserved (set to 0).
0	7	SLP_SELECTED	0: Normal operation. 1: SLP Safe-Drive-Function is selected.
1	0	SDI_P_SELECTED	0: Normal operation. 1: SDI Safe-Drive-Function (positive direction) is selected.
1	1	SDI_N_SELECTED	0: Normal operation. 1: SDI Safe-Drive-Function (negative direction) is selected.
1	2–3	Unused	Reserved (should be set to 0).
1	4	SLI_SELECTED	0: Normal operation. 1: The SLI Safe-Drive-Function is selected.
1	5	SMS_SELECTED	0: Normal operation. 1: The SMS Safe-Drive-Function is selected.
1	6	SSR_SELECTED	0: Normal operation. 1: The SSR Safe-Drive-Function is selected.
1	7	SAR_SELECTED	0: Normal operation. 1: The SAR Safe-Drive-Function is selected.

3.2.3.3 FSoE

3.2.3.3.1 Introduction to FSoE

For FSoE (FailSafe over EtherCAT), the safe address is a system-unique 16-bit FSoE Slave Address with an allowed value of 1–999. There are 2 pre-defined fixed PDO (process data output) mappings of FSoE frames available:

- Standard

- Advanced (also features safety function DLS, the transfer of safe position and velocity).

Each device monitors that the partner device responds within the safety configured FSoE *Watchdog Time*. The minimum value is 5 ms.

3.2.3.3.2 Standard Frame RxPDO Mapping of FSoE

The RxPDO Mapping object with index 1650h contains the mapping of the FSoE Master message for the standard frame. The total size is 11 byte.

Table 21: ***RxPDO Mapping of FSoE Standard Frame Defined in RxPDO Mapping Object with Index 1650h***

Sub-index	Name	Type	Description	Object ID	Bit length
1	FSoE Master Command	uint8	FSoE command byte.	E700h:01	8
2	STO command	bool	0: Activate STO. 1: Deactivate STO.	6640h:00	1
3	SS1 command	bool	0: Activate SS1. 1: Deactivate SS1.	6650h:01	1
4	SS2 command	bool	0: Activate SS2. 1: Deactivate SS2.	6670h:01	1
5	SOS command	bool	0: Activate SOS. 1: Deactivate SOS.	6668h:01	1
6	SSR command	bool	0: Activate SSR. 1: Deactivate SSR.	6680h:01	1
7	SDI positive direction command	bool	0: Activate positive direction. 1: Deactivate positive direction.	66D0h:00	1
8	SDI negative direction command	bool	0: Activate negative direction. 1: Deactivate negative direction.	66D1h:00	1
9	Error Ack	bool	0: No acknowledge. 0 to 1: Acknowledge of an error in the drive.	6632h:00	1
10	SLP_1 command	bool	0: Activate SLP instance 1. 1: Deactivate SLP instance 1.	66A0h:01	1
11	SLP_2 command	bool	0: Activate SLP instance 2. 1: Deactivate SLP instance 2.	66A0h:02	1
12	SLP_3 command	bool	0: Activate SLP instance 3. 1: Deactivate SLP instance 3.	66A0h:03	1

Table 21: ***RxPDO Mapping of FSoE Standard Frame Defined in RxPDO Mapping Object with Index 1650h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
13	SLP_4 command	bool	0: Activate SLP instance 4. 1: Deactivate SLP instance 4.	66A0h:04	1
14	SLS_1 command	bool	0: Activate SLS instance 1. 1: Deactivate SLS instance 1.	6690h:01	1
15	SLS_2 command	bool	0: Activate SLS instance 2. 1: Deactivate SLS instance 2.	6690h:02	1
16	SLS_3 command	bool	0: Activate SLS instance 3. 1: Deactivate SLS instance 3.	6690h:03	1
17	SLS_4 command	bool	0: Activate SLS instance 4. 1: Deactivate SLS instance 4.	6690h:04	1
18	FSoE Master CRC_0	uint16	FSoE Master CRC_0 word.	E700h:03	16
19	SLI command	bool	0: Activate SLI. 1: Deactivate SLI.	66B8h:01	1
20	SLA command	bool	0: Activate SLA. 1: Deactivate SLA.	5200h:00	1
21	SAR command	bool	0: Activate SAR. 1: Deactivate SAR.	66C0h:01	1
22	Unused	bool	Not used, should be set to "0" by the safety logic.	–	1
23	Restart Ack	bool	0: No acknowledge. 0 to 1: Acknowledge restart of the drive after STO. If automatic restart is allowed, this bit has no effect.	6630h:00	1
24	Unused	bool	Not used, should be set to "0" by the safety logic.	–	1

Table 21: ***RxPDO Mapping of FSoE Standard Frame Defined in RxPDO Mapping Object with Index 1650h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
25	SP command	bool	0: Normal operation. 1: Reset the absolute position after homing.	5203h:00	1
26	SBC override command	bool	0: No SBC override. 1: Force SBC to release brake during STO.	5204h:00	1
27–34	Unused	bool	Not used, should be set to "0" by the safety logic.	–	8
35	FSoE Master CRC_1	uint16	FSoE Master CRC_1 word.	E700h:04	16
36	FSoE ConnID	uint16	FSoE Connection ID.	E700h:02	16

3.2.3.3.3 Standard Frame TxPDO Mapping of FSoE

The TxPDO Mapping object with 1A50h contains the mapping of the FSoE Slave message for the FSoE standard frame. The total size is 11 byte.

Table 22: ***TxPDO Mapping of FSoE Standard Frame Defined in TxPDO Mapping Object with Index 1A50h***

Sub-index	Name	Type	Description	Object ID	Bit length
1	FsoE Slave Command	uint8	FsoE command byte.	E600h:01h	8
2	STO command	bool	0: STO is not active. 1: STO is active.	6640h:00h	1
3	SSM command	bool	0: The drive is moving faster than the limit. 1: The drive us moving slower or equal to the limit.	66E0h:01h	1
4	Unused	–	Not used, should be set to "0" by the drive.	–	1
5	SOS	bool	0: SOS is not active. 1: SOS is active.	6668h:01	1
6	SSR	bool	0: SSR is not active. 1: SSR is active and the drive is within the safe speed range.	6680h:01h	1

Table 22: ***TxPDO Mapping of FSoE Standard Frame Defined in TxPDO Mapping Object with Index 1A50h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
7	SDIp	bool	0: Drive does not move in a positive direction. 1: Drive moves in a positive direction.	66D0h:00h	1
8	SDIn	bool	0: Drive does not move in a negative direction. 1: Drive moves in a negative direction.	66D1h:00h	1
9	Error acknowledge	bool	0: No error. 1: At least 1 safety error has occurred.	6632h:00h	1
10	SLP_1	bool	0: SLP instance 1 is not active. 1: SLP instance 1 is active.	66A0h:01h	1
11	SLP_2	bool	0: SLP instance 2 is not active. 1: SLP instance 2 is active.	66A0h:02h	1
12	SLP_3	bool	0: SLP instance 3 is not active. 1: SLP instance 3 is active.	66A0h:03h	1
13	SLP_4	bool	0: SLP instance 4 is not active. 1: SLP instance 4 is active.	66A0h:04h	1
14	SLS_1	bool	0: SLS instance 1 is not active. 1: SLS instance 1 is active.	6690h:01h	1
15	SLS_2	bool	0: SLS instance 2 is not active. 1: SLS instance 2 is active.	6690h:02h	1
16	SLS_3	bool	0: SLS instance 3 is not active. 1: SLS instance 3 is active.	6690h:03h	1
17	SLS_4	bool	0: SLS instance 4 is not active. 1: SLS instance 4 is active.	6690h:04h	1

Table 22: ***TxPDO Mapping of FSoE Standard Frame Defined in TxPDO Mapping Object with Index 1A50h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
18	FSoE Master CRC_0	uint16	FSoE Slave CRC_0 word.	E600h:03h	16
19	SLI	bool	0: SLI is not active. 1: SLI is active.	66B8h:01h	1
20	SLA	bool	0: SLA is not active. 1: SLA is active.	5200h:00h	1
21	SAR	bool	0: SAR is not active. 1: SAR is active.	66C0h:01h	1
22	Unused	bool	Not used, should be set to "0" by the drive.	–	1
23	Restart acknowledge	bool	Restart acknowledge pending.	6630h:00h	1
24	SS1	bool	0: Drive is not ramping down due to SS1. 1: Ramp down of the drive is monitored due to SS1.	6650h:01h	1
25	SS2	bool	0: Drive is not ramping down due to SS2. 1: Ramp down of the drive is monitored due to SS2.	6670h:02h	1
26	SBC override	bool	0: SBC override is not active. 1: SBC override is active.	5204h:00	1
27	SCA_1 status	bool	0: Position is not in range set by SCA instance 1. 1: Position is in range set by SCA instance 1.	66E8h:01h	1
28	SCA_2 status	bool	0: Position is not in range set by SCA instance 2. 1: Position is in range set by SCA instance 2.	66E8h:02h	1

Table 22: ***TxPDO Mapping of FSoE Standard Frame Defined in TxPDO Mapping Object with Index 1A50h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
29	SCA_3 status	bool	0: Position is not in range set by SCA instance 3. 1: Position is in range set by SCA instance 3.	66E8h:03h	1
30	SCA_4 status	bool	0: Position is not in range set by SCA instance 4. 1: Position is in range set by SCA instance 4.	66E8h:04h	1
31	SBC failure	bool	0: No SBC error. 1: SBC error.	5205h:00h	1
32	SBT required	bool	0: No SBT required. 1: SBT required.	5206h:00h	1
33	SP	bool	0: Safe Position (SP) value is **not** referenced. (SLP is disabled and the actual position is **not** referenced). 1: Safe Position (SP) value is referenced. (SLP is possible and the actual position values are referenced).	5203h:00h	1
34	Unused	–	Not used, should be set to "0" by the FS Control board.	–	1
35	FSoE Slave CRC_1	uint16	FSoE Slave CRC_1 word.	E600h:04h	16
36	FSoE ConnID	uint16	FSoE Connection ID.	E600h:02h	16

3.2.3.3.4 Advanced Frame RxPDO Mapping of FSoE

The RxPDO Mapping object with index 1651h contains the mapping of the FSoE Master message for the advanced frame. The total size is 15 byte.

Table 23: ***RxPDO Mapping of FSoE Advanced Frame Defined in RxPDO Mapping Object with Index 1651h***

Sub-index	Name	Type	Description	Object ID	Bit length
1	FSoE Master Command	uint8	FSoE command byte.	E700h:01h	8
2	STO	bool	0: Activate STO. 1: Deactivate STO.	6640h:00h	1

Table 23: ***RxPDO Mapping of FSoE Advanced Frame Defined in RxPDO Mapping Object with Index 1651h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
3	SS1	bool	0: Activate SS1. 1: Deactivate SS1.	6650h:01h	1
4	SS2	bool	0: Activate SS2. 1: Deactivate SS2.	6670h:01h	1
5	SOS	bool	0: Activate SOS. 1: Deactivate SOS.	6668h:01h	1
6	SSR	bool	0: Activate SSR. 1: Deactivate SSR.	6680h:01h	1
7	SDIp	bool	0: Activate positive direction. 1: Deactivate positive direction.	66D0h:00h	1
8	SDIn	bool	0: Activate negative direction. 1: Deactivate negative direction.	66D1h:00h	1
9	Error Ack	bool	0: No acknowledge. 0–1: Acknowledge of an error in the drive.	6632h:00h	1
10	SLP_1	bool	0: Activate SLP instance 1. 1: Deactivate SLP instance 1.	66A0h:01h	1
11	SLP_2	bool	0: Activate SLP instance 2. 1: Deactivate SLP instance 2.	66A0h:02h	1
12	SLP_3	bool	0: Activate SLP instance 3. 1: Deactivate SLP instance 3.	66A0h:03h	1
13	SLP_4	bool	0: Activate SLP instance 4. 1: Deactivate SLP instance 4.	66A0h:04h	1
14	SLS_1	bool	0: Activate SLS instance 1. 1: Deactivate SLS instance 1.	6690h:01h	1
15	SLS_2	bool	0: Activate SLS instance 2. 1: Deactivate SLS instance 2.	6690h:02h	1

Table 23: ***RxPDO Mapping of FSoE Advanced Frame Defined in RxPDO Mapping Object with Index 1651h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
16	SLS_3	bool	0: Activate SLS instance 3. 1: Deactivate SLS instance 3.	6690h:03h	1
17	SLS_4	bool	0: Activate SLS instance 4. 1: Deactivate SLS instance 4.	6690h:04h	1
18	FSoE Master CRC_0	uint16	FSoE Master CRC_0 word.	E700h:03h	16
19	SLI	bool	0: Activate SLI. 1: Deactivate SLI.	66B8h:01h	1
20	SLA	bool	0: Activate SLA. 1: Deactivate SLA.	5200h:00h	1
21	SAR	bool	0: Activate SAR. 1: Deactivate SAR.	66C0h:01h	1
22	DLS	bool	0: Activate DLS. 1: Deactivate DLS.	5201h:00h	1
23	Restart Ack	bool	0: No acknowledge. 0–1: Acknowledge restart of the drive after STO. If automatic restart is allowed, this bit has no effect.	6630h:00h	1
24	Unused	bool	Not used, should be set to "0" by the safety logic.	–	1
25	SP	bool	0: Normal operation. 1: Reset the absolute position after homing.	5203h:00h	1
26	SBC override	bool	0: No SBC override. 1: Force SBC to release brake during STO.	5204h:00h	1
27–34	Unused	bool	Not used, should be set to "0" by the safety logic.	–	8
35	FSoE Master CRC_1	uint16	FSoE Master CRC_1 word.	E700h:04h	16
36	DLS_limit	uint16	DLS limit.	5202h:00h	16

Table 23: ***RxPDO Mapping of FSoE Advanced Frame Defined in RxPDO Mapping Object with Index 1651h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
37	FSoE Master CRC_2	uint16	FSoE Master CRC_2 word.	E700h:05h	16
38	FSoE ConnID	uint16	FSoE Connection ID.	E700h:02h	16

3.2.3.3.5 Advanced Frame TxPDO Mapping of FSoE

The TxPDO Mapping object with 1A51h contains the mapping of the FSoE Slave message for the FSoE advanced frame. The total size is 31 byte.

Table 24: ***TxPDO Mapping of FSoE Advanced Frame Defined in TxPDO Mapping Object with Index 1A51h***

Sub-index	Name	Type	Description	Object ID	Bit length
1	FSoE Slave Command	uint8	FSoE command byte.	E600h:01h	8
2	STO	bool	0: STO is not active. 1: STO is active.	6640h:00h	1
3	SSM_1	bool	0: The drive is moving faster than the limit. 1: The drive is moving slower or equal to the limit.	66E0h:01h	1
4	Unused	–	Not used, should be set to "0" by the drive.	–	1
5	SOS	bool	0: SOS is not active. 1: SOS is active.	6668h:01h	1
6	SSR	bool	0: SSR is not active. 1: SSR is active and the drive is within the safe speed range.	6680h:01h	1
7	SDIp	bool	0: Drive does not move in a positive direction. 1: Drive moves in a positive direction.	66D0h:00h	1
8	SDIn	bool	0: Drive does not move in a negative direction. 1: Drive moves in the negative direction.	66D1h:00h	1
9	Error acknowledge	bool	0: No error. 1: At least 1 safety error has occurred.	6632h:00h	1

Table 24: ***TxPDO Mapping of FSoE Advanced Frame Defined in TxPDO Mapping Object with Index 1A51h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
10	SLP_1	bool	0: SLP instance 1 is not active. 1: SLP instance 1 is active.	66A0h:01h	1
11	SLP_2	bool	0: SLP instance 2 is not active. 1: SLP instance 2 is active.	66A0h:02h	1
12	SLP_3	bool	0: SLP instance 3 is not active. 1: SLP instance 3 is active.	66A0h:03h	1
13	SLP_4	bool	0: SLP instance 4 is not active. 1: SLP instance 4 is active.	66A0h:04h	1
14	SLS_1	bool	0: SLS instance 1 is not active. 1: SLS instance 1 is active.	6690h:01h	1
15	SLS_2	bool	0: SLS instance 2 is not active. 1: SLS instance 2 is active.	6690h:02h	1
16	SLS_3	bool	0: SLS instance 3 is not active. 1: SLS instance 3 is active.	6690h:03h	1
17	SLS_4	bool	0: SLS instance 4 is not active. 1: SLS instance 4 is active.	6690h:04h	1
18	FSoE Master CRC_0	uint16	FSoE Slave CRC_0 word.	E600h:03h	16
19	SLI	bool	0: SLI is not active. 1: SLI is active.	66B8h:01h	1
20	SLA	bool	0: SLA is not active. 1: SLA is active.	5200h:00h	1
21	SAR	bool	0: SAR is not active. 1: SAR is active.	66C0h:01h	1
22	DLS	bool	0: DLS is not active. 1: DLS is active.	5202h:00h	1

Table 24: ***TxPDO Mapping of FSoE Advanced Frame Defined in TxPDO Mapping Object with Index 1A51h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
23	Restart acknowledge	bool	Restart acknowledge pending.	6630h:00h	1
24	SS1	bool	0: Drive is not ramping down due to SS1. 1: Ramp down of the drive is monitored due to SS1.	6650h:01h	1
25	SS2	bool	0: Drive is not ramping down due to SS2. 1: Ramp down of the drive is monitored due to SS2.	6670h:01h	1
26	SBC override active	bool	0: SBC override is not active. 1: SBC override is active.	5204h:00	1
27	SCA_1 status	bool	0: Position is not in the range set by SCA instance 1. 1: Position is in range set by SCA instance 1.	66E8h:01h	1
28	SCA_2 status	bool	0: Position is not in range set by SCA instance 2. 1: Position is in range set by SCA instance 2.	66E8h:02h	1
29	SCA_3 status	bool	0: Position is not in range set by SCA instance 3. 1: Position is in range set by SCA instance 3.	66E8h:03h	1
30	SCA_4 status	bool	0: Position is not in range set by SCA instance 4. 1: Position is in range set by SCA instance 4.	66E8h:04h	1
31	SBC failure	bool	0: No SBC error. 1: SBC error.	5205h:00h	1

Table 24: ***TxPDO Mapping of FSoE Advanced Frame Defined in TxPDO Mapping Object with Index 1A51h*** **- (continued)**

Sub-index	Name	Type	Description	Object ID	Bit length
32	SBT required	bool	0: No SBT required. 1: SBT required.	5206h:00h	1
33	SP	bool	0: Safe Position (SP) value is **not** referenced. (SLP is disabled and the actual position is **not** referenced). 1: Safe Position (SP) value is referenced. (SLP is possible and the actual position values are referenced).	5203h:00h	1
34	Unused	–	Not used, should be set to "0" by the FS Control board.	–	1
35	FSoE Slave CRC_1	uint16	FSoE Slave CRC_1 word.	E600h:04h	16
36	DLS limit	uint16	DLS limit.	5252h:00h	16
37	FSoE Slave CRC_2	uint16	FSoE Slave CRC_2 word.	E600h:05h	16
38	Safe position	uint16	Safe position word 1.	6611h:00h	16
39	FSoE Slave CRC_3	uint16	FSoE Slave CRC_3 word.	E600h:06h	16
40	Safe position	uint16	Safe position word 2.	6611h:00h	16
41	FSoE Slave CRC_4	uint16	FSoE Slave CRC_4 word.	E600h:07h	16
42	Safe velocity	uint16	Safe velocity word 1.	6613h:00h	16
43	FSoE Slave CRC_5	uint16	FSoE Slave CRC_5 word	E600h:08h	16
44	Safe velocity	uint16	Safe velocity word 2.	6613h:00h	16
45	FSoE Slave CRC_6	uint16	FSoE Slave CRC_6 word.	E600h:09h	16
46	FSoE ConnID	uint16	FSoE connection ID.	E600h:02h	16

3.2.3.4 Encoder Feedback for Monitoring

The feedback encoder for monitoring the position requires configuration by the dedicated safety parameters. The safety device with its configured safety functions processes the encoder position. The parameters for configuring a safety feedback include all relevant settings for enabling proper feedback communication.

Table 25: Parameters for Safety Feedback Configuration

Name	Variable	Comment
Absolute position enabled	absolutePositionEnabled	Specifies if the absolute position feature is requested.
Absolute position on reset	absolutePositionOnReset	Specifies the position the drive will return to directly after the encoder position reset has been invoked.
Encoder enabled	encoderEnabled	Specifies if the encoder can be used.
Encoder type name	encoderTypeName	The name of the encoder type.
Number of single turn bits	encoderSingleTurn	The total number of safe single-turn bits.
Number of safe single turn bits.	encoderSafeSingleTurn	The number of single-turn bits used for safety (<= number of single-turn bits).
Number of safe multi turn bits	encoderSafeMultiTurn	The number of safe multi-turn bits.
Encoder test bitmask	encoderTests	A bitmask of tests that have to be performed.
Encoder voltage range	encoderVoltageRange	The voltage range of the encoder.
Speed filter time	speedComputationTime	The filter time used for the speed filter.
Acceleration filter	timeaccelComputationTime	The filter time used for the acceleration filter.

3.2.3.5 Intended Use of the Safety Drive

The safety drive is designed for use in safety-related applications. It meets the requirements for safety functions in accordance with IEC 61800-5-2 regarding safe motion monitoring.

⚠ CAUTION

RISK OF PERSONAL INJURY AND EQUIPMENT DAMAGE

Using the safety drive for other purposes than the intended may cause personal injury and equipment damage.

- Only use the safety drive for its intended purpose.
- Do not make any modifications to the drive or its components.
- Do not use the drive outside the allowed electrical and environmental conditions specified in the technical specifications.

3.2.3.6 VLT® Toolbox Software with Functional Safety Integration

Configuration of the safety functions is required for safe motion applications.

Use the VLT® Toolbox Software to configure the safety functions supported by the safety drive, such as setting of limit values, braking ramps for the safety functions, and monitoring of motion sequences. All functions are available on VLT® Toolbox Software version 4.0 and above.

The details regarding safety drive commissioning are explained in chapter *5 Commissioning*.

Functions supporting the handling of the safety features

- Monitoring: Visualization of actual safe drive condition/status (software version, serial number, safety configuration status, and some error conditions).
- Initial commissioning phase: Safe naming of each drive via safe address assignment (pairing mechanism) and safe reset of the position (pairing mechanism).

- Configuration of safety functions and other safety relevant parameters (encoder, brake, Safe I/O board): the list of configurable parameters is shown, grouped by modules and functions. Parameters and functions are described with text and graphs.
- Download of configuration: When editing, the current state of the configuration can be saved on a PC for later reuse.
- Guided step-by-step procedure:
  - This assists by performing a download, verifying that data has been transferred correctly, and fetching the resulting configuration report from the drive.
  - To activate the configuration, the report containing the parameter values received from the drive, must be validated. The report can be saved to document the project and its settings.
- Service tools:
  - Software update of the FS Control board.
  - Factory reset of the FS Control board.
  - Backup and restore of the safety configuration parameters.
  - Access to the event log of the safe drive (errors and relevant events like software update and configuration).

3.2.4 VLT® FlexSafety™ Features

The FS Control board in combination with the Safe I/O board provides the features detailed in Table 26.

Table 26: VLT® FlexSafety™ Features

2 Dual-channel, digital inputs: DI1 and DI2	The dual-channel architecture allows the triggering/activation of the advanced safety subfunctions rated up to safety integrity level SIL 3.
2 Dual-channel, digital output: DO1 and DO2	The dual-channel architecture provides the status information about the safety subfunctions, rated up to safety integrity level about SIL 3, to the outside. The provided information on the output can be further processed by safety devices like a safe PLC.
A set of advanced safety subfunctions	Activate the safety subfunctions in accordance with EN/IEC 61800-5-2 (see Table 27).
Reset function	A safety subfunction which has triggered *Safe State* due to an error or limit violation can be reset by: • Safe fieldbus • Setting parameters to *automatic mode* If the FS Control board is used without safe fieldbus, use the automatic model to reset the safety subfunction.
Supply voltage	• 24 V DC output for safety sensors available.

Table 27: Activation of the Safety Subfunctions

Safety function	Safe digital input	Safe fieldbus	Parameterized
STO	Yes	Optional	No
SOS	Optional	Optional	No
SBC	Internal trigger	–	–
SBT (diagnostic function)	Optional	Optional	No
SS1	Optional	Optional	No
SS2	Optional	Optional	No
SLS	Optional	Optional	No

Table 27: Activation of the Safety Subfunctions - (continued)

Safety function	Safe digital input	Safe fieldbus	Parameterized
DLS	Optional	Optional	No
SMS	No	No	Yes
SLA	Optional	Optional	No
SAR	Optional	Optional	No
SSR	Optional	Optional	No
SSM	No	Optional (only PROFIsafe)	Yes
SDI	Optional	Optional	No
SLP	Optional	Optional	No
SLI	Optional	Optional	No
SCA	No	Optional (only PROFIsafe)	Yes

It is also possible to configure virtual inputs that are a logical combination of the 2 physical inputs, *DI1* and *DI2* (see Figure 5).

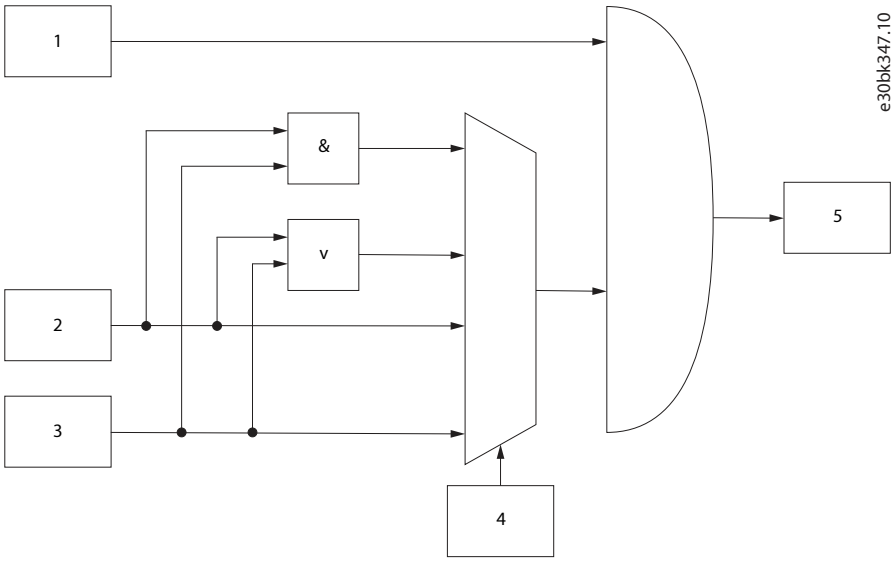

Figure 5: Overview of Safety Function Activation Mechanism

1	Activation bit via safe fieldbus	**2**	Digital input 1: DI1
3	Digital input 2: DI2	**4**	Configuration parameter
5	Activation of safety function		

The status information of the executed safety function can be propagated via *safe fieldbus* or the dual-channel digital output. Table 28 shows the possible propagation of status information in detail.

Table 28: Propagation of the Activation Status or the Limit Violation of a Safety Function

Safety function	Safe digital output	Safe fieldbus
STO	Optional	Yes
SOS		
SBC		
SBT		
SS1		
SS2		
SLS		
SMS		
SLA		
SAR		
SSR		
SSM		
SDI		
SLP		
SLI		
SCA		

3.2.5 Categories of Safe Stop

3.2.5.1 Stopping Functions

The advanced functional safety feature implements 3 stopping functions: STO, SS1, and SS2.

Refer to section 4.2.3 of EN 61800-5-2:2017 for the definitions and correspondence with the stop categories of IEC 60204-1. See EN/IEC 60204-1 for more information on stop categories.

Table 29: Stopping Functions

Function name	Description
Safe torque off (STO)	This function prevents force-producing power from being provided to the motor. This safety subfunction corresponds to an uncontrolled stop in accordance with stop category 0 of IEC 60204-1.
Safe Stop 1 time based (SS1-t)	This function initiates the motor deceleration and performs the STO function after an application specific time delay. This safety subfunction corresponds to a controlled stop in accordance with stop category 1 of IEC 60204-1.
Safe Stop 1 ramp monitored (SS1-r)	This function initiates and monitors the motor deceleration rate within selected limits to stop the motor and performs the STO function when the motor speed is below a specified limit. This safety subfunction corresponds to a controlled stop in accordance with stop category 1 of IEC 60204-1.
Safe Stop 2 ramp monitored (SS2-r)	This function initiates and monitors the motor deceleration rate within selected limits to stop the motor and performs the safe operating stop function when the motor speed is below a specified limit. This safety subfunction SS2 corresponds to a controlled stop in accordance with stop category 2 of IEC 60204-1.

An evaluation of the machine-related risks determines which of the 3 stopping methods to use.

NOTICE

- Carry out a risk assessment to select the correct stop category for each stop function in accordance with EN 60204-1.
- When designing the machine application, consider the timing and distance for a coast to stop (Stop Category 0 or Safe Torque Off). For more information regarding stop categories, refer to EN IEC 60204-1.
- If access to the machine coasting down involves a hazard (resulting from the hazard and risk analysis), take protective measures to avoid the hazard.

3.2.5.2 Operation and Requirements

The FS Control board supports digital inputs to trigger the safety subfunction and requires the position data from a safety encoder (HIPERFACE® DSL) for the calculation of velocity or acceleration needed for the rotor-motion monitoring functions.

3.2.5.3 Safe Drive Functions Overview

This section provides an overview of the Safe Drive functions available to maintain a safe condition or prevent hazardous conditions from occurring. Detailed information about the drive safety function parameters can be found in the corresponding sections.

The safety functions for drives are specified in EN IEC 61800-5-2.

The general parameter part for configuring a safe drive includes generic properties. A customer-specific drive name can be assigned to a safety drive. The safe fieldbus can generally be enabled or disabled using a dedicated parameter. This can, for example, be the case for applications where no safety PLC but a simple hard-wired safety circuit is used. See 6.2.1 General Parameters for configuration of the safe fieldbus.

Table 30: Available Safety Functions

ID	Function	Description
1	Safe Torque Off (STO)	This function prevents force-producing power form being provided to the motor.
2	Safe brake control (SBC)	When a safety mechanical brake is connected and configured, it is controlled by the safety drive, which includes proper monitoring and fault reaction.
3	Safe Stop 1 (SS1)	This function monitors the controlled stop of the axis until the STO function can be activated.
4	Safe Stop 2 (SS2)	This function monitors the controlled stop of the axis until the SOS function can be activated.
5	Safe operating stop (SOS)	The speed must remain in the SOS zero speed window and the position must re-main in a limited range.
6	Safely limited increment (SLI)	The position must remain within the specified limit of position increments.
7	Safely limited position (SLP)	The position must remain within the specified position limits.
8	Safe CAM (SCA)	The position must remain within a specified range. Only for monitoring, no reaction is issued on limit violation.
9	Safe maximum speed (SMS)	The speed must remain within the specified maximum limits.
10	Safely limited speed (SLS)	The speed must remain within the specified limits.
11	Dynamically limited speed (DLS)	The speed must remain within a dynamically adjustable limit.
12	Safe speed range (SSR)	The speed must remain within a specified upper and lower limit.
13	Safe direction (SDI)	The direction must remain positive or negative.
14	Safe speed monitor (SSM)	The speed must remain within a specified range. Only for monitoring, no reaction is issued on limit violation.

Table 30: Available Safety Functions - (continued)

ID	Function	Description
15	Safely limited acceleration (SLA)	The acceleration must remain within the specified limits.
16	Safe acceleration range (SAR)	The acceleration must remain within a specified range.

Table 31: Diagnostic Functions

Function	Description
Safe Brake Test (SBT)	This is a support or maintenance function for operators to ensure proper operation of the attached safety brake.

3.2.5.4 Safe Torque Off (STO)

Safe Torque Off (STO) turns off the drive output state that powers the motor. The safety function is implemented as specified in EN IEC 61800-5-2 and belongs to stop category 0 in EN 60204-1.

Important Note:

⚠ WARNING

SUSPENDED LOAD

Serious injury could result when a suspended load is not properly blocked. Without a mechanical brake, the drive cannot hold a vertical load when STO is active.

- Add adequate measure for fall protection (gravity loads) before operating the motor.

If the STO safety function is active as a standalone function, it is not possible to perform a controlled brake according to stop category 1 in EN 60204-1. If controlled braking is needed, use either SS1-t or SS1-r safety functions (see 3.2.5.7 Safe Stop 1 (SS1)).

One instance of the STO safety function is available. It is always active in any safety configuration, as a guaranteed and proper reaction to any safety violation.

STO can be activated by:

- A hard-wired STO input
- Safe fieldbus (PROFIsafe, FSoE)
- One of the safe digital inputs
- One of the configured safety functions

Restart can be configured as either:

- Automatic (STO is deactivated automatically when all STO requests are removed)
- Via fieldbus acknowledge (a safe fieldbus acknowledge is required)

STO timing

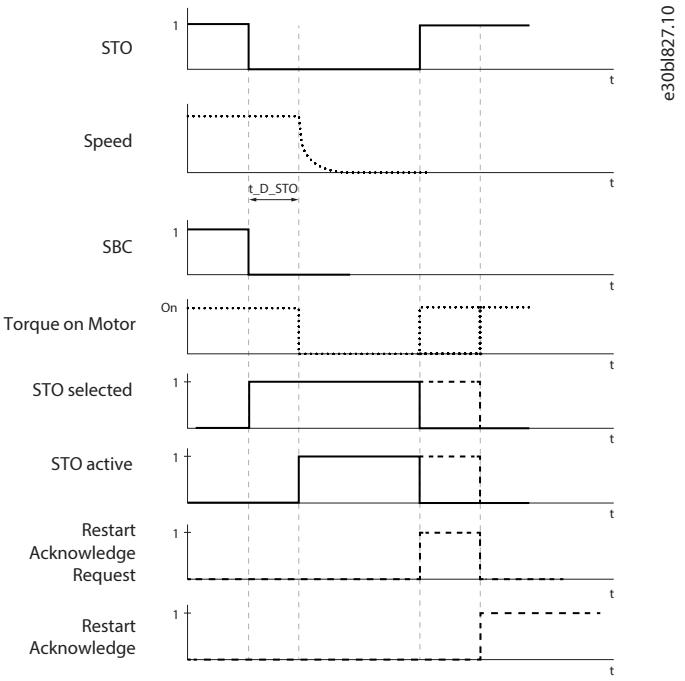

Figure 6: Functional Principle of STO and SBC

STO-Related parameters

Table 32: STO Parameters

Name	Variable	Description
STO configuration	STOConfiguredInput	Specifies the associated safe digital input used for activation of the safety function.
STO restart behavior	STORestartBehavior	Specifies if STO should be deactivated automatically when all STO requests have been removed or if a safe fieldbus acknowledge event is required.

STO fault reaction

The STO function is always active in any safety configuration, as a guaranteed final reaction to a safety violation.

When STO is activated, the drive inhibits the energy fed to the motor. The drive cannot deliver power to the motor as long as the STO is active.

If a mechanical brake is configured and the STO is active, the drive closes the brake and the STO is considered active after the maximum brake operation time, configured as *brakeTime* in Safe Brake Control (see 3.2.5.5 Safe Brake Control (SBC)).

STO is only deactivated when all STO requests from different safety functions have been removed. If the *STO restart behavior* is set to *safe fieldbus*, a safe fieldbus acknowledge event is required before the STO can be deactivated.

3.2.5.5 Safe Brake Control (SBC)

The Safe Brake Control (SBC) function is used to control a motor integrated mechanical brake or an external brake safely. One instance of the SBC function is available for safety configuration. The drive can operate without a mechanical brake, in this case disable the SBC function when commissioning the drive.

NOTICE

- The FS Control board does not verify if a brake is present or not. Ensure that the FS Control board is configured correctly. Nevertheless, the non-safety part of the drive controls the presence of the mechanical brake.

SBC Timing

The timing diagram in Figure 6 covers both the STO and the SBC function.

The SBC function is activated with either the STO function or when the drive detects a non-recoverable failure. When SBC is activated, the STO activation is delayed by the maximum brake operation time, which was configured during commissioning.

SBC Override

When STO is active, the state of SBC can be overridden using the dedicated bit of the safety control word or by using a configured safe digital input. This functionality can be used, for example, to manually move the axis during maintenance work, or for unblocking an axis in emergency situations when the drive is in STO.

⚠ WARNING

RISK OF FALLING LOAD

Falling load can cause serious injury. SBC Override allows the parking brake to be opened when the motor is in STO. Applying torque to the motor may not be sufficient to hold the vertical load when STO is active.

- Ensure that the torque applied to the motor is sufficient to hold the vertical load before opening the brake.

SBC-Related parameters

Table 33: SBC Parameters

Name	Variable	Description
Brake attached	brakeAttached	Specifies if a brake is attached, supported configurations are: • No brake • Internal brake • External brake
Maximum brake operation time	brakeTime	Specifies the maximum time that it takes for the brake to engage or release. If a brake is attached, the safety drive delays STO by this duration to ensure that the brake is engaged before STO triggers.
Brake test request interval	brakeTestRequestInterval	Time interval until a brake test should be requested.
Brake nominal torque	brakeNominalTorque	Rated torque of the brake. The brake is able to deliver at least this torque.
Motion limit in brake test	motionLimitInBrakeTest	The maximum allowed motion during the brake test. If the maximum is exceeded, a fault reaction is triggered.
Input for SBC override during STO	sbcOverrideInput	The input used for overriding SBC during STO.

SBC Fault reaction

It is not possible to detect a malfunctioning brake through SBC. Therefore, diagnosis with a safe brake test (SBT) function is necessary in regular time intervals (see 10.5.2 Mechanical Brake Considerations).

A disconnected brake or an open circuit on the brake connectors result in an STO trigger.

3.2.5.6 Safe Brake Test (SBT)

Use the safe brake test regularly to verify that the brake performances are not reduced.

NOTICE

- SBT is not a safety function and part of the test is carried out in the part of the drive that is not safety related. Ensure that the mechanical brake diagnostic is executed correctly.

SBT test steps:

1. The safe drive receives the SBT request.
2. The safe drive engages the brake.
3. The drive initiates a movement, monitors the position, and computes the deviation between the initial position and the current position for a defined time. If the deviation is 0 or the deviation exceeds a defined threshold, then the SBT has failed.
4. The safe drive repeats step 3 with a movement in the opposite direction.
5. The safe drive releases the brake.
6. On completion of the test, the safe drive indicates that either *Brake test completed successfully* or *Brake test failed* upon SBT request. If the safe brake test fails, the SBT warning of the safety status word is set to [*1*].

SBT Timing

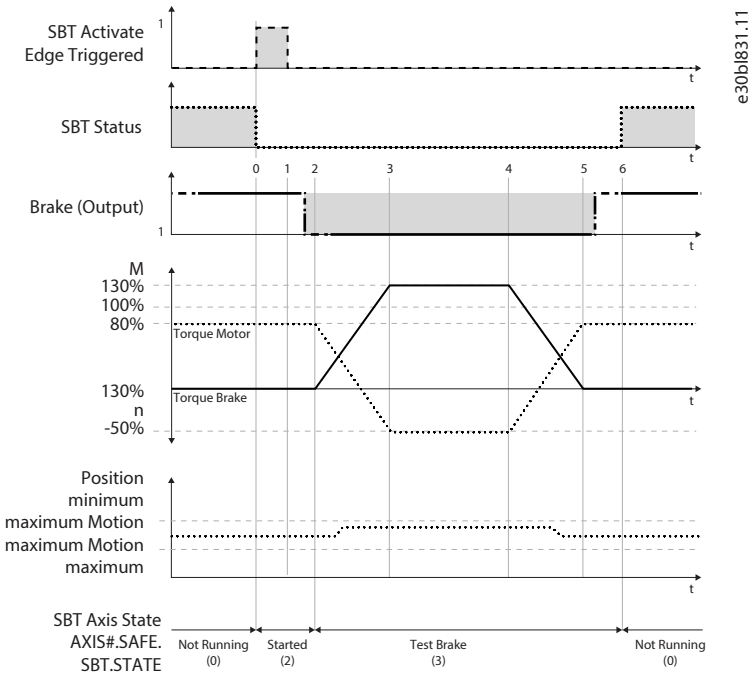

Figure 7: Functional Principle of SBT

t0	Start SBT	**t0 to t1**	Measuring actual application load on motor (maximum 200 ms)
t1 to t2	Brake engaging (maximum 300 ms)	**t2**	Brake is applied. Position monitoring is started. Drive is switched to torque mode internally.

t2 to t3	Ramp-up to apply 130% torque on the brake	**t3 to t4**	Torque duration (configurable)
t4 to t5	Ramp-down torque on the brake	**t5 to t6**	Brake released (maximum 300 ms)
t6 to t0	Maximum time interval between tests (configurable)		

SBT-Related parameters

Table 34: SBT Parameters

Name	Variable	Description
Brake test request interval	brakeTestRequestInterval	Time interval until a brake test should be requested.
Brake test nominal torque	brakeNominalTorque	Torque that should be applied to the drive in each direction.
Motion limit in brake test	motionLimitInBrakeTest	The maximum allowed motion during the brake test. If the maximum is exceeded, a fault reaction is triggered.

SBT Fault reaction

If the safe brake test procedure fails, the SBT warning bit of the safety status word is set. As this is a diagnostic function, STO is not triggered.

If SBT is not executed within the configured brake test request interval, the drive activates the SBT warning bit in the safety status word.

If the SBT function detects an anomaly in the mechanical brake, the FS Control board cannot bring the system to a safe state (single brake element). Take this into consideration by evaluating the overall risk at machine level.

3.2.5.7 Safe Stop 1 (SS1)

The Safe Stop 1 function is either time-based (SS1-t) or ramp-monitored (SS1-r) depending on the selected configuration. An SS1 request is obtained from either the configured safe input, the safe fieldbus, or a reaction to the limit violation of another safety function.

When performing a time-based Safe Stop 1 (SS1-t), the ramp is not monitored. Instead, after a configurable maximum timeout, STO is triggered.

When performing a ramp-monitored Safe Stop 1 (SS1-r), the drive performs a ramp stop towards 0 speed and then halts the motor. The safety function monitors the speed to yield a controlled ramp down and activates STO.

There is 1 instance of the SS1 safety function available for configuration. SS1 operation is finished even if the request is reset before completion. The restart behavior, as configured for STO, takes place after reaching the final state.

SS1 Timing

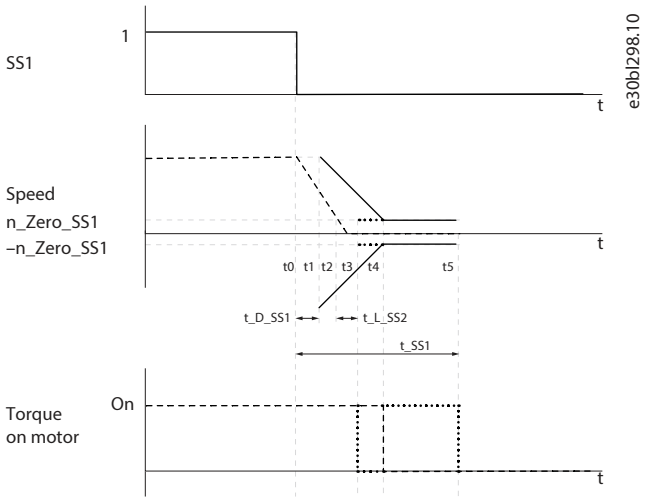

Figure 8: Functional Principle of SS1

To perform a time-based Safe Stop 1 (SS1-t), deactivate the deceleration monitoring by setting the deceleration limit a_SS1 to [*0*] so that the only remaining valid configuration parameter is the maximum timeout *t_SS1*.

While performing a ramp-monitored Safe Stop 1 (SS1-r) the speed is monitored to be within the ramp limits, then an STO is activated.

Drive behavior for SS1 with ramp-monitoring:

1. SS1 is requested.
2. After time delay *t_D_ss1*, the drive starts the deceleration monitoring.
3. When the drive reaches the zero speed according to parameter *n_Zero_SS1* and maintains it between *n_Zero_SS1* and *–n_Zero_SS1* for a time interval of *t_L_SS1*, STO is activated earlier in relation to *t_SS1* (if not yet expired).

Table 35: SS1 Timing

Time	Variable	Description
t0	SS1 is requested, reaction: start t_D_SS1	The safety function SS1 is selected.
t1	t-D_SS1 expired, reaction: start ramp monitoring	The safe drive activates the ramp monitoring. The dead time (t-D_SS1) has run out.
t2	Speed reaches the zero speed reaction: start t_L_SS1	The ramp down is complete, the speed must remain lower than n_Zero_SS1 from now on.
t3	T_L_SS1 expired, reaction: request STO	The ramp down is complete, speed is 0, and this is detected. Therefore, the safe drive requests STO early (this depends on the real deceleration and t_L_SS1).
t4	Deceleration done, reaction: request STO	Deceleration monitoring is detected reaching the n_Zero_SS1 limit. The safe drive requests STO (this point depends on the defined deceleration ramp).
t5	Maximum timeout, reaction: request STO	The maximum time (t_SS1) for the ramp down has been exceeded. The safe drive activates STO (this point depends on t_SS1).

SS1-Related parameters

Table 36: SS1 Parameters

Name	Variable	Comment
SS1 configured input	SS1ConfiguredInput	Specifies the associated safe digital input used for requesting the safety function.
Maximum delay	t_SS1	Specifies the maximum timeout for the ramp down.
Initial delay	t_D_SS1	Specifies the time between the request of SS1 and the start of speed monitoring by the safety drive.
Target speed detection delay	t_L_SS1	Specifies the duration between entering the speed window and early activation of the safety function. This value is ignored if the deceleration monitoring is deactivated (a_SS1=0).
Minimal deceleration	a_SS1	The minimal deceleration limit. If this value is 0, ramp down supervision is not performed.
Zero speed window	n_Zero_SS1	Specifies the speed window in which the speed is considered 0.

SS1 Fault reaction

SS1 can be configured as the fault reaction for other safety functions. Functions supporting this feature are:

- SLS
- SMS
- SLA
- SSR
- SDI
- SLP
- SLI
- SAR
- DLS
- SS2

If a limit violation occurs, the STO function is triggered.

3.2.5.8 Safe Stop 2 (SS2)

The Safe Stop 2 function is requested from either the configured safe input, the safe fieldbus, or a reaction to the limit violation of another safety function. In contrast to SS1, the motor is not switched off, but a monitored SOS is performed (see 3.2.5.9 Safe Operating Stop (SOS)). STO is not triggered as long as the motor position resides within the configured speed and/or position limits.

When performing a time-based Safe Stop 2 (SS2-t), the ramp is not monitored. Instead, after a configurable maximum timeout, STO is triggered.

When performing a ramp-monitored Safe Stop 2 (SS2-r), the drive performs a ramp stop towards 0 speed and then halts the motor. The safety function monitors the speed to yield a controlled ramp down and activates STO.

There is 1 instance of the SS2 safety function available for configuration. SS2 operation is finished even if the request is reset before completion.

SS2 Timing

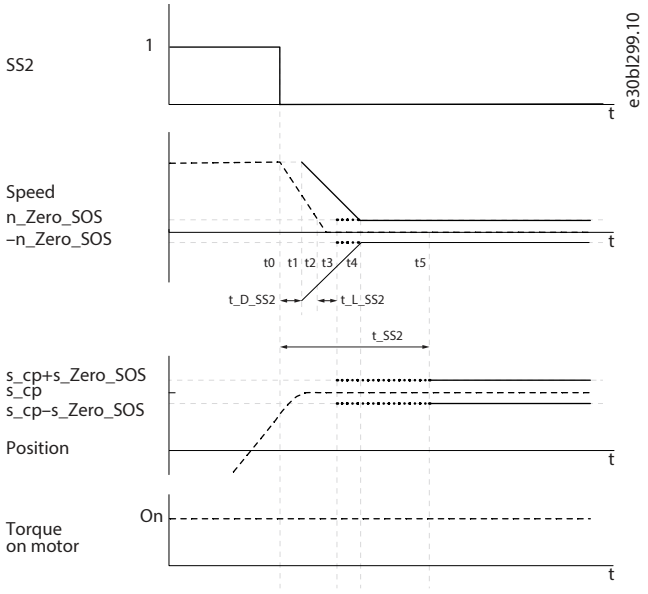

Figure 9: Functional Principle of SS2

To perform a time-based Safe Stop 2 (SS2-t), deactivate the deceleration monitoring by setting the deceleration limit a_SS2 to [*0*] so that the only remaining valid configuration parameter is the maximum timeout *t_SS2*.

While performing a ramp-monitored Safe Stop 2 (SS2-r), the drive must reduce the speed towards 0 and SOS is activated at the end of the ramp.

Drive behavior for SS2 with ramp-monitoring:

1. SS2 is requested.
2. After time delay *t_D_ss2*, the drive starts the deceleration monitoring.
3. When the drive reaches the zero speed according to parameter *n_Zero_SS2* and maintains it between *n_Zero_SOS* and *–n_Zero_SOS* for a time interval of *t_L_SS2*, SOS is activated earlier in relation to *t_SS2* (if not yet expired).

Table 37: SS2 Timing

Time	Variable	Description
t0	SS2 is requested, reaction: start t_D_SS2	The safety function SS2 is selected.
t1	t-D_SS2 expired, reaction: start ramp monitoring	The safe drive activates the ramp monitoring. The dead time (t-D_SS2) has run out.
t2	Speed reaches the zero speed reaction: start t_L_SS2	The ramp down is complete, the speed remains lower than n_Zero_SS2 from now on.
t3	T_L_SS2 expired, reaction: request SOS	The ramp down is complete, speed is 0, and this is detected. Therefore, the safe drive requests SOS early (this depends on the real deceleration and t_L_SS2).

Table 37: SS2 Timing - (continued)

Time	Variable	Description
t4	Deceleration done, reaction: request SOS	Deceleration monitoring is detected reaching the n_Zero_SS2 limit. The safe drive requests SOS (this point depends on the defined deceleration ramp).
t5	Maximum timeout, reaction: request SOS	The maximum time (t_SS2) for the ramp down has been exceeded. The safe drive activates SOS (this point depends on t_SS2).

SS2-related parameters

Table 38: SS2 Parameters

Name	Variable	Comment
SS2 configured input	SS2_ConfiguredInput	Specifies the associated safe digital input used for requesting the safety function.
Maximum delay	t_SS2	Specifies the maximum timeout for the ramp down.
Initial delay	t_D_SS2	Specifies the time between the request of SS2 and the start of speed monitoring by the safety drive.
Target speed detection delay	t_L_SS2	Specifies the duration between entering the speed window and early activation of the safety function. This value is ignored if the deceleration monitoring is deactivated (a_SS2=0).
Minimal deceleration	a_SS2	The minimal deceleration limit. If this value is 0, ramp down supervision is not performed.

SS2 Fault reaction

SS2 can be configured as the fault reaction for other safety functions. Functions supporting this feature are:

- SLS
- SMS
- SLA
- SSR
- SDI
- SLP
- SLI
- SAR
- DLS

SS1 or STO functions can be configured as the reaction to a limit violation.

3.2.5.9 Safe Operating Stop (SOS)

SOS is requested either from the configured safe input, the safe fieldbus, or the SS2 safety function. The SOS function monitors both the speed and the position of the motor to ensure that the motor does not turn. It issues an STO reaction on limit violation.

There is 1 instance of the SOS safety function available for configuration.

SOS Timing

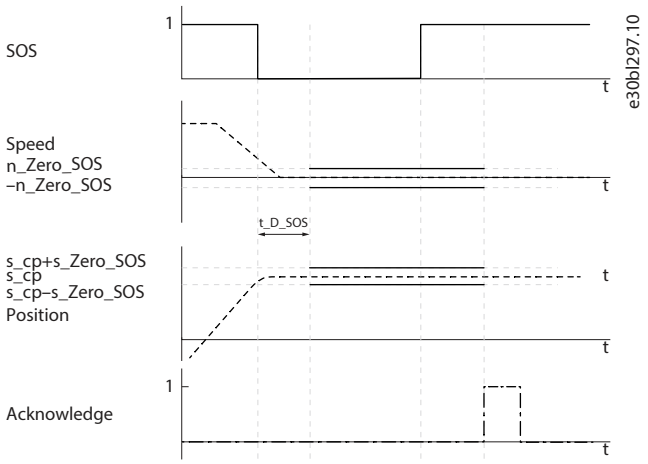

Figure 10: Functional Principle of SOS

Drive behavior for SOS:

1. SOS is requested
2. SOS activation is delayed by *t_DS_SOS*.
3. The standstill motor position is monitored using the speed window tolerance *n_Zero_SOS* and position window tolerance *s_Zero_SOS*.

SOS-related parameters

Table 39: SOS Parameters

Name	Variable	Description
SOS configured input	SOS_ConfiguredInput	Specifies the associated safe digital input used for requesting the safety function.
Initial delay	t_D_SOS	Specifies the time between the request of SOS and the start of position monitoring by the safety drive.
Zero speed window	n_Zero_SOS	Specifies the speed window in which the speed is considered to be 0, monitoring is disabled at 0.
Zero position window	s_Zero_SOS	Specifies the maximum distance the drive may move before the safety function is considered to have failed. Monitoring is disabled when set to "Max".
SOS restart behavior	SOS_RestartBehavior	Specifies if SOS should be deactivated when all SOS requests have been removed, or if a safe fieldbus acknowledge is also required.

SOS Fault reaction

SOS can be configured as an independent safety function, or as the fault reaction for the SS2 safety function.

The STO function is triggered if a limit violation occurs.

3.2.5.10 Safety-Limited Increment (SLI)

SLI is requested either from the configured safe input or the safe fieldbus. The SLI function monitors the position increments of the motor and issues an STO, SS1, or SS2 reaction on limit violation.

One instance of the SLI safety function is available for configuration.

SLI Timing

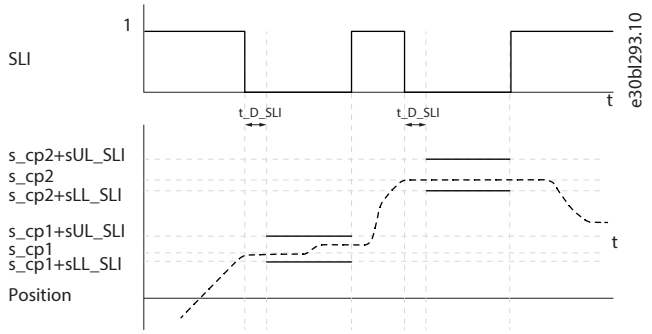

Figure 11: Functional Principle of SLI

Drive behavior for SLI:

1. SLI is requested.
2. SLI activation is delayed by *t_D_SLI*.
3. The drive stores the position immediately when SLI is activated (*s_cp1* and *s_cp2*) and starts monitoring whether the motor position exceeds the upper and lower position increments limits (*s_UL_SLI* and *s_LL_SLI*).

SLI-related parameters

Table 40: SLI Parameters

Name	Variable	Description
SLI configured input	SLI_ConfiguredInput	Specifies the associated safe digital input used to request the safety function.
Initial delay	t_D_SLI	Specifies the time between the request of SLI and the start of position monitoring by the safety drive.
Relative upper position limit	s_UL_SLI	Specifies the allowed relative upper position deviation while SLI is active.
Relative lower position limit	s_LL_SLI	Specifies the allowed relative lower position deviation while SLI is active.
Limit violation reaction	SLI_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SLI Fault reaction

SS1, SS2, or STO functions can be configured as the reaction to a limit violation.

3.2.5.11 Safety-Limited Position (SLP)

SLP is requested from either the configured safe input or the safe fieldbus. The SLP function monitors the target position of the motor and issues an STO, SS1, or SS2 reaction on limit violation. The SLP function requires a referenced safe position.

There are 4 independent instances of the SLP safety function that can be configured.

SLP Timing

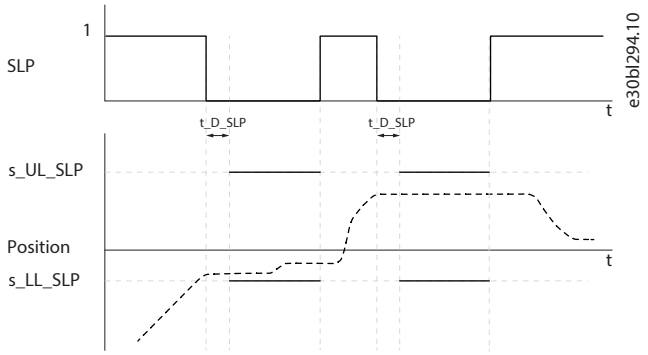

Figure 12: Functional Principle of SLP

Drive behavior for SLP:

1. SLP is requested.
2. SLP activation is delayed by *t_D_SLP*.
3. The drive starts monitoring whether the absolute motor position exceeds the upper and lower position limits (*s_UL_SLP* and *s_LL_SLP*).

SLP-related parameters

Table 41: SLP Parameters

Name	Variable	Description
SLP configured input	SLP_ConfiguredInput	Specifies the associated safe digital input used to request the safety function.
Initial delay	t_D_SLP	Specifies the time between the request of SLP and the start of position monitoring by the safety drive.
Upper position limit	s_UL_SLP	Specifies the absolute upper position limit while SLP is active.
Lower position limit	s_LL_SLP	Specifies the absolute lower position limit while SLP is active.
Limit violation reaction	SLP_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SLP Fault reaction

SS1, SS2, or STO functions can be configured as the reaction to a limit violation.

3.2.5.12 Safe CAM (SCA)

SCA is requested using safe parameters. The SCA function monitors the motor position within a given window, where *SCA in Range* is reported. The function is only for monitoring and does not issue any STO reaction. The SCA function requires a referenced safe position.

There are 4 independent instances of the SCA safety function available for configuration.

PROFINET SCA muting function

The SCA muting function is an add-on functionality to the SCA safety function. Depending on the SCA bit of the *S_STW2 PROFIsafe Safety Control Word*, the following can be overruled:

- The *SCA_ACTIVE* and *SCA_DATA_VALID*bits of the *S_ZSW_CAM1* status word.

- The safe digital outputs triggered by the SCA function.

If SCA muting is set to [*active*], the SCA_ACTIVE and SCA_DATA_VALID bits are immediately set to 0 and the configured safe digital outputs are set to inactive.

SCA Timing

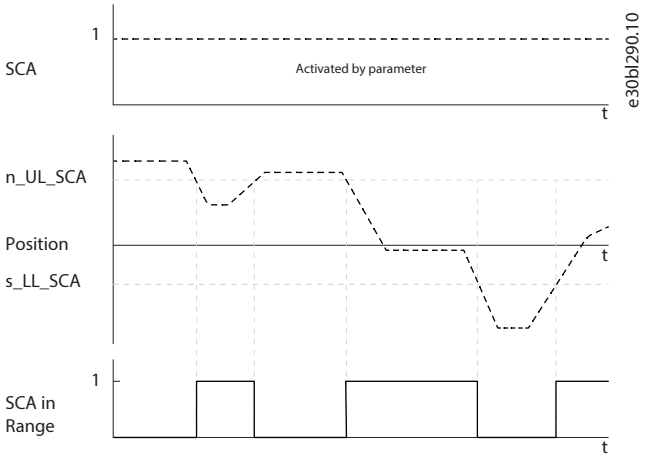

Figure 13: Functional Principle of SCA

Drive behavior for SCA:

1. SCA is activated by a parameter (at least 1 of the limits is not 0).
2. The drive starts monitoring the absolute motor position.
3. If the motor absolute position exceeds the configured upper limit *s_UL_SCA* or lower limit *s_LL_SCA*, the SCA *inRange* bit of the safety status word is set to 0, otherwise it is set to 1.

SCA-Related parameters

Table 42: SCA Parameters

Name	Variable	Description
Upper position limit	s_UL_SCA	Specifies the absolute upper position limit for SCA.
Lower position limit	s_LL_SCA	Specifies the absolute lower position limit for SCA.

SCA Fault reaction

A limit violation reaction cannot be configured because the SCA is only a monitoring function.

3.2.5.13 Safe Maximum Speed (SMS)

SMS is requested using safe parameters. The SMS function monitors the maximum speed limits in both positive and negative direction, and issues an STO, SS1, or SS2 reaction on limit violation.

There is 1 instance of the SMS safety function available for configuration.

SMS Timing

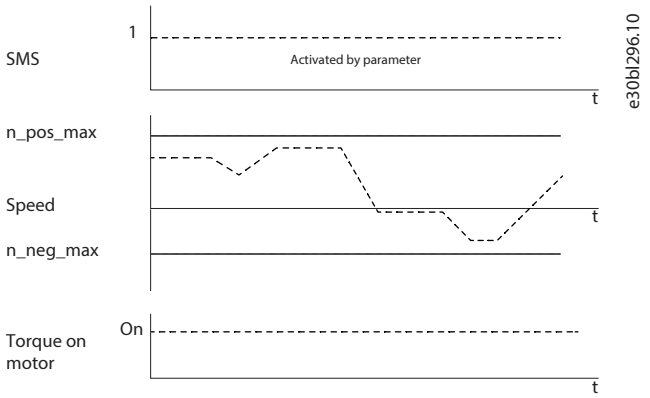

Figure 14: Functional Principle of SMS

Drive behavior for SMS:

1. SMS is activated by a parameter (at least 1 of the limits is not 0).
2. The drive starts monitoring if motor speed exceeds the configured limits (*n_neg_max* and *n_pos_max*)

SMS-related parameters

Table 43: SMS Parameters

Name	Variable	Description
Speed maximum positive value	n_pos_max_SMS	Specifies the upper positive speed limit while SMS is active.
Speed maximum negative value	n_neg_max_SMS	Specifies the upper negative speed limit while SMS is active.
Limit violation reaction	SMS_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SMS Fault reaction

The SS1, SS2, or STO safety functions can be configured as the reaction to a limit violation.

3.2.5.14 Safety-Limited Speed (SLS)

SLS is requested from either the configured safe input or the safe fieldbus. The SLS function monitors a speed limit and issues an STO, SS1, or SS2 reaction on limit violation.

When performing SLS with deceleration monitoring, the drive performs a decelerating ramp to finish within the configured target speed limits. The safety function monitors the speed to yield a controlled deceleration.

When performing SLS without deceleration monitor, the speed must be within the configured target limits after the configured timeout.

There are 4 independent instances of the SLS safety function available for configuration.

SLS Timing

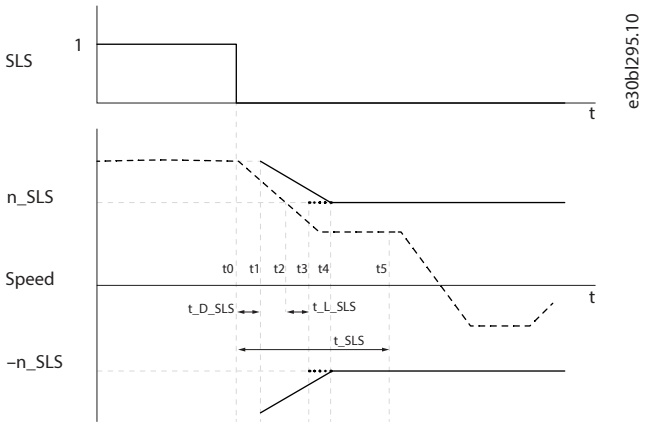

Figure 15: Functional Principle for SLS

Drive behavior for SLS with deceleration monitoring:

1. SLS is requested (time t0).
2. After time *t_D_SLS* the drive starts monitoring the speed ramp-down according to the minimal deceleration limit *a_SLS* (time t1).
3. If the drive speed is within the speed limits (*–n_SLS* and *n_SLS*) for time *t_L_SLS*, SLS is activated earlier (times t2-t3).
4. If SLS is not yet active and the configured deceleration ramp is finished, SLS is activated (time t4).

Drive behavior for SLS without deceleration monitoring:

1. SLS is requested.
2. SLS is activated after time *t_SLS* (maximum time for ramp-down) or it can be activated earlier if the drive speed is within the speed limits for time *t_L_SLS*.
3. If the configured deceleration ramp is finished and time *t_SLS* has expired, SLS is activated if it is not yet active (time t5).

SLS-related parameters

Table 44: SLS Parameters

Name	Variable	Description
SLS configured input	SLS_ConfiguredInput	Specifies the associated safe digital input used for requesting the safety function.
Maximum delay	t_SLS	Specifies the maximum time for the ramp-down.
Initial delay	t_D_SLS	Specifies the time between the request of SLS and the start of position monitoring by the safety drive.
Target speed detection delay	t_L_SLS	Specifies the duration between entering the speed window and early activation of the safety function. This value is ignored if deceleration monitoring is deactivated (*a_SLS* = 0)
Minimal deceleration	a_SLS	The minimal deceleration limit. If this value is 0, deceleration monitoring is not performed.
Speed window	n_SLS	Specifies the allowed speed window.
Limit violation reaction	SLS_limitViolationReaction	Specifies which safety function that is activated if the limits are violated.

SLS Fault reaction

SS1, SS2, or STO can be configured as the reaction to a limit violation.

3.2.5.15 Dynamically Limited Speed (DLS)

DLS is requested from either the configured safe input or the safe fieldbus. The DLS function monitors a dynamically adjustable speed limit and issues an STO, SS1, or SS2 reaction on limit violation.

While performing DLS, the speed is reduced to be within a dynamic limit. If the function is active, the safety drive compares the actual motor speed using a limit which is calculated using the value provided via the safe fieldbus. The actual limit used in speed control is shown in the status and is limited by the ramp as shown in Figure 16. The safety drive stops the motor as soon as the limit is exceeded.

DLS Timing

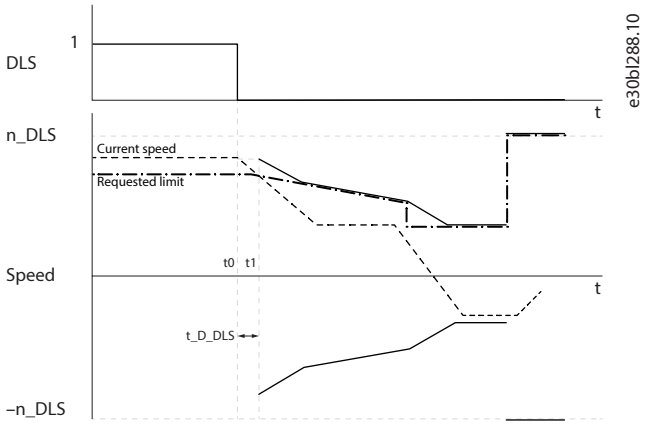

Figure 16: Functional Principle of DLS

Drive behavior for DLS:

1. DLS is requested (time t0).
2. After time *t_D_DLS* the drive starts monitoring the speed according to the requested limit and with a maximum change rate of *a_DLS* (time t1).

DLS-related parameters

Table 45: DLS Parameters

Name	Variable	Description
DLS configured input	DLS_ConfiguredInput	Specifies the associated safe digital input used for requesting the safety function.
Change rate limit	a_DLS	The maximum change rate for the dynamical speed limit.
Initial delay	t_D_DLS	Specifies the time between the request of DLS and the start of speed monitoring by the safety drive.
Maximum speed limit	n_DLS	Specifies the maximum speed limit for DLS.
Limit violation reaction	DLS_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

DLS Fault reaction

SS1, SS2, or STO can be configured as the reaction to a limit violation.

3.2.5.16 Safe Speed Range (SSR)

SSR is requested from either the configured safe input or the safe fieldbus. The SSR function monitors a speed range and issues an STO, SS1, or SS2 reaction on limit violation.

When performing SSR with deceleration monitoring, the drive must perform a decelerating ramp to finish within the configured target speed limits. The safety function monitors the speed to yield a controlled deceleration.

When performing SSR without deceleration monitor, the speed must be within the configured target limits after the configured timeout.

There is 1 instance of the SSR safety function available for configuration.

SSR Timing

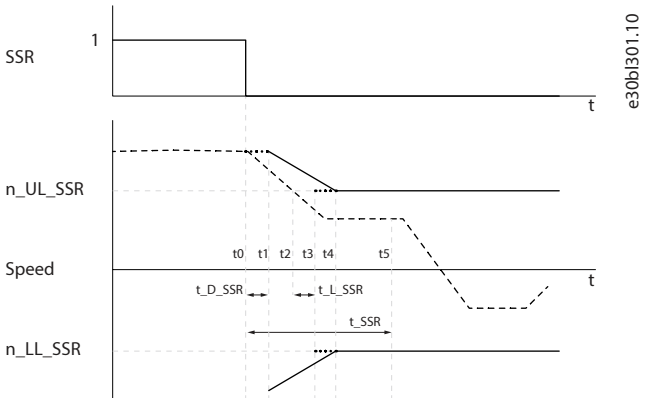

Figure 17: Functional Principle of SSR

Drive behavior for SSR with deceleration monitoring:

1. SSR is requested (time t0).
2. After time *t_D_SSR* the drive starts monitoring the speed ramp-down according to the minimal deceleration limit *a_SSR* (time t1).
3. If the drive speed is within the speed limits (*n_LL_SSR* and *n_UL_SSR*) for time *t_L_SSR*, SSR is activated earlier (times t2-t3).
4. If SSR is not yet active and the configured deceleration ramp is finished, SSR is activated (time t4).

Drive behavior for SLS without deceleration monitoring:

1. SSR is requested.
2. SSR is activated after time *t_SSR* (maximum time for ramp-down) or it can be activated earlier if the drive speed is within the speed limits for time *t_L_SSR*.

SSR-related parameters

Table 46: SSR Parameters

Name	Variable	Description
SSR configured input	SSR_ConfiguredInput	Specifies the associated safe digital input used to request the safety function.
Maximum delay	t_SSR	Specifies the maximum time for the ramp-down.
Initial delay	t_D_SSR	Specifies the time between the request of SSR and the start of position monitoring by the safety drive.

Table 46: SSR Parameters - (continued)

Name	Variable	Description
Target speed detection delay	t_L_SSR	Specifies the duration between entering the speed window and early activation of the safety function. This value is ignored if the deceleration monitoring is deactivated (*a_SSR* = 0)
Minimal deceleration	a_SSR	The minimal deceleration limit. If this value is 0, deceleration monitoring is not performed.
Upper speed limit	n_UL_SSR	Specifies the upper speed limit for SSR.
Lower speed limit	n_LL_SSR	Specifies the lower speed limit for SSR.
Limit violation reaction	SSR_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SSR Fault reaction

SS1, SS2, SOS, or STO can be configured as the reaction to a limit violation.

3.2.5.17 Safe Direction (SDI)

SDI is requested either from the configured safe input or the safe fieldbus. The SDI function supervises the direction of the motor and issues an STO, SS1, or SS2 reaction on limit violation. SDI consists of 2 subfunctions:

- SDIp for monitoring positive direction
- SDIn for monitoring negative direction

There is 1 instance of the SDI safety function available for configuration.

SDI Timing

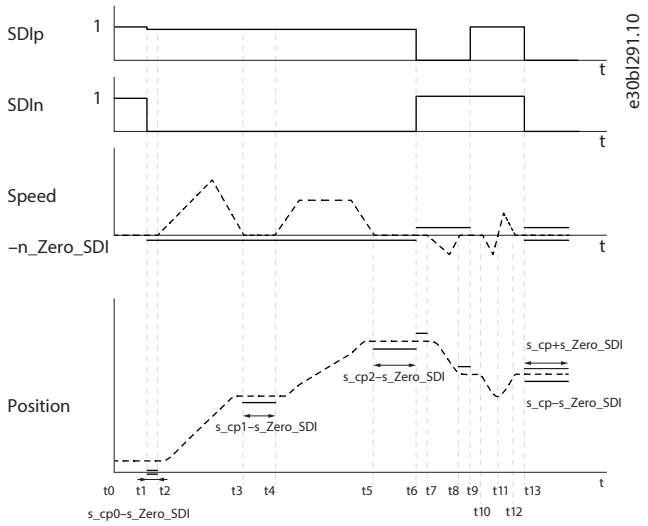

Figure 18: Functional Principle of SDI

Drive behavior for SDIn:

1. SDIn is requested (time t1)
2. SDIn limit supervision is activated after configured time t_D_SDIn (time t2). The drive starts monitoring the motor position direction compared to the stored position s_cp at time t2.
3. SDIn motion is activated if the drive moves in a negative direction for a distance longer than s_Zero_SDI.

Drive behavior for SDIp:

1. SDIp is requested (time t6)
2. SDIp limit supervision is activated after configured delay t_D_SDIp (time t7). The motor position direction is monitored compared to the stored position s_cp at time t7.
3. SDIp motion is activated if the drive moves in a positive direction for a distance longer than s_Zero_SDI.

SDI-related parameters

Table 47: SDI Parameters

Name	Variable	Description
SDI configured input for positive direction	SDI_ConfiguredInput_p	Specifies the associated safe digital input used to request the safety function.
SDI configured input for negative direction	SDI_ConfiguredInput_n	Specifies the associated safe digital input used to request the safety function.
Initial delay before SDI_p supervision	t_D_SDIp	Specifies the time between the request of SDIp and the start of monitoring by the safety drive.
Initial delay before SDI_n supervision	t_D_SDIn	Specifies the time between the request of SDIn and the start of monitoring by the safety drive.
Zero speed window	n_Zero_SDI	Specifies the speed window in which the speed is considered to be 0.
Zero position window	s_Zero_SDI	Specifies the maximum distance the drive may move before the safety function is considered to have failed.
Limit violation reaction	limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SDI Fault reaction

SS1, SS2, or STO can be configured as the reaction to a limit violation.

3.2.5.18 Safe Speed Monitor (SSM)

SSM is requested using safe parameters. The SSM function monitors the motor speed within a given window, where *SSM in Range* is reported. The function is only for monitoring and does not issue any STO reaction.

There is 1 instance of the SSR safety function available for configuration.

SSM Timing

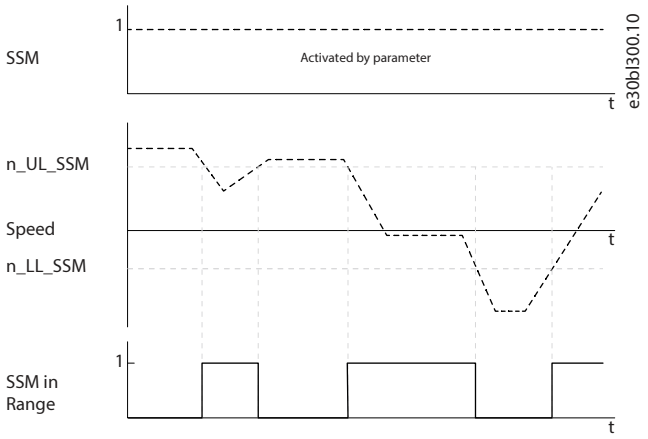

Figure 19: Functional Principle of SSM

Drive behavior for SSM:

1. SSM is activated by a parameter (1 of the limits is not 0). In PROFIsafe, SSM must be parameterized and activated/deactivated from a safe fieldbus.
2. The drive starts monitoring whether at least 1 limit is configured with a value not equal to 0 (n_neg_max, n_pos_max).
3. If the limits are not exceeded, the *SSM in Range* signal is activated. If the limits are exceeded, the *SSM in Range* signal is deactivated without any other drive reaction to the violation.

SSM-related parameters

Table 48: SSM Parameters

Name	Variable	Description
SSM speed maximum positive value	n_UL_SSM	Specifies the upper speed limit for SSM.
SSM speed maximum negative value	n_LL_SSM	Specifies the lower speed limit for SSM.

SSM Fault reaction

A reaction to a limit violation cannot be configured because SSM is only a monitoring function.

3.2.5.19 Safety-Limited Acceleration (SLA)

SLA is requested from either the configured safe input or the safe fieldbus. The SLA function supervises the acceleration or deceleration of a motor and issues an STO, SS1, or SS2 reaction on limit violation.

There is 1 instance of the SLA safety function available for configuration.

SLA Timing

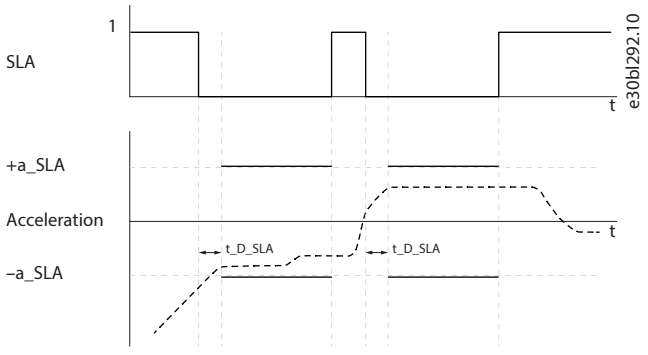

Figure 20: Functional Principle of SLA

Drive behavior for SLA:

1. SLA is requested.
2. SLA activation is delayed by the configured time t_D_SLA.
3. The drive starts monitoring motor acceleration and detects a limit violation if the acceleration is outside the configured limit (–a_SLA, a_SLA).

SLA-related parameters

Table 49: SLA Parameters

Name	Variable	Description
SLA configured input	SLA_ConfiguredInput	Specifies the associated safe digital input used to request the safety function.
Initial delay	t_D_SLA	Specifies the time between the request of SLA and the start of acceleration monitoring by the safety drive.
Upper acceleration limit	t_D_SLA	Specifies the maximum negative and positive acceleration limit.
Limit violation reaction	SLA_limitViolationReaction	Specifies which safety function will be activated if the limits have been violated.

SLA Fault reaction

SS1, SS2, or STO can be configured as the reaction to a limit violation.

3.2.5.20 Safe Acceleration Range (SAR)

SAR is requested from either the configured safe input or the safe fieldbus. The SAR function supervises the acceleration or deceleration range of a motor and issues an STO, SS1, or SS2 reaction on limit violation.

There is 1 instance of the SAR safety function available for configuration.

SAR Timing

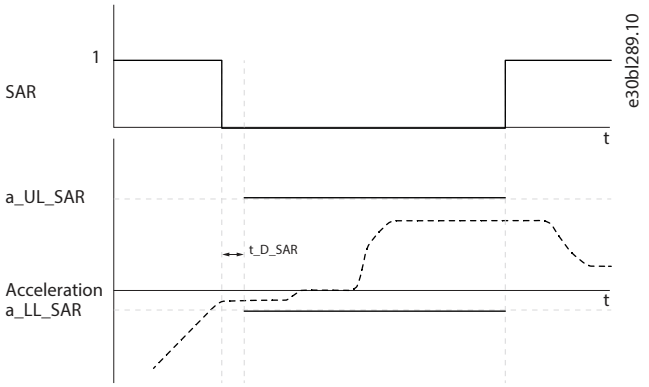

Figure 21: Functional Principle of SAR

Drive behavior for SAR:

1. SAR is requested.
2. SAR activation is delayed by the configured time t_D_SAR.
3. Drives starts monitoring motor acceleration and detects a limit violation when the acceleration is outside the configured lower and upper limits (–a_LL_SAR, a_UL_SAR).

SAR-related parameters

Table 50: SAR Parameters

Name	Variable	Description
SLA configured input	SLA_ConfiguredInput	Specifies the associated safe digital input used to request the safety function.
Initial delay	t_D_SAR	Specifies the time between the request of SAR and the start of acceleration monitoring by the safety drive.
Acceleration upper limit	a_UL_SAR	Specifies the upper acceleration limit for SAR.
Acceleration lower limit	a_LL_SAR	Specifies the lower acceleration limit for SAR.
Limit violation reaction	SLA_limitViolationReaction	Specifies which safety function will be activated if the limits are violated.

SAR Fault reaction

SS1, SS2, or STO can be configured as the reaction to a limit violation.

3.2.6 Inputs and Outputs

3.2.6.1 Introduction to Inputs and Outputs

The FS Control board in combination with the Safe I/O board offers the possibility to trigger safety subfunctions via the dual-channel digital input and to propagate the activation or in-range status of a safety subfunction to the dual-channel digital output *DO1* and *DO2*.

The correct function of the output is constantly monitored by a dedicated feedback block integrated in the option boards. A detected fault sets the FS Control board into an alarm status.

Test pulses applied to the dual channel input are evaluated by the FS Control board.

3.2.6.2 Inputs

3.2.6.2.1 Safe I/O Digital Inputs

The 2 digital inputs are galvanically isolated from the system reference (GND).

Figure 22 shows a diagram of the 2 dual-channel inputs with focus on the galvanic isolation and references for each input.

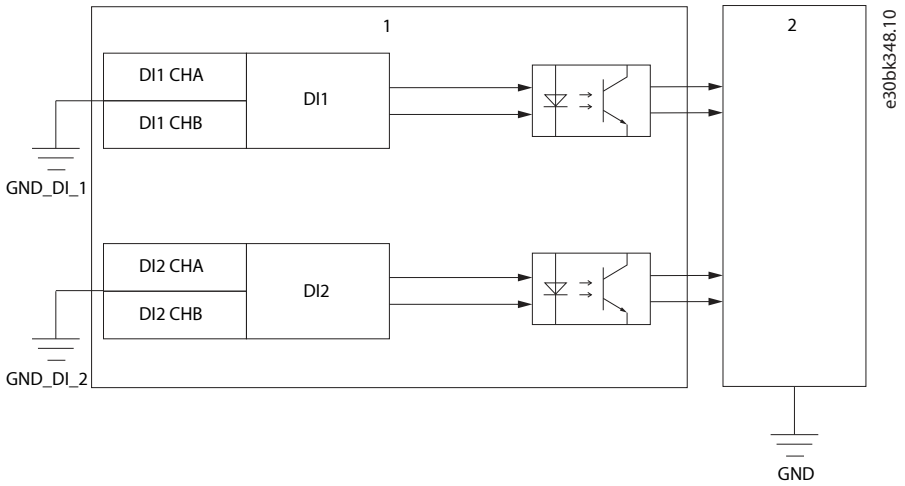

Figure 22: Block Diagram of the 2 Dual-channel Inputs

1	Safe I/O board	**2**	FS Control board

The isolation barrier between the digital input circuitry and the system reference is only low-voltage functional, which means that the applied voltage across the barrier must be ≤60 V.

The digital inputs can be configured to trigger the safety subfunctions (see 3.2.5.3 Safe Drive Functions Overview).

Without the FS Control board and Safe I/O board, the drive (ISD 520/DSD 520) offers an additional single-channel Input. The single-channel input is also called *Hard-wired STO input*. This single-channel input can only activate the safety subfunction STO and no other advanced safety functions. This input claims the safety integrity parameters as described in 10.4.4.1 Performance of the STO Function without FS Control Board.

3.2.6.2.2 Reset Input

The Safe I/O board option does not provide any physical reset input. Reset an activated safety function using the safe fieldbus or by setting the corresponding parameter from manual to automatic reset. That means that normal operation is restored when the condition for safety subfunction activation is removed.

3.2.6.3 Outputs

3.2.6.3.1 Safe Digital Outputs

The 2 dual-channel digital outputs DO1 and DO2 are implemented as multi-channel parallel output according to EN/IEC 61508-7 using a one out of two architectures (1oo2).

An external load is expected to load the output. The maximum low state output current is ≤100 µA and is consumed by the external load. The maximum load resistance is therefore ≤50 kΩ. The external loading of the digital output is therefore fundamental for the safety integrity and is under the responsibility of the application designer. The fail-safe state of the digital output is the de-energized state.

The digital outputs provided by the Safe I/O board option can be configured to propagate the status or the in-range information in a safe way. For safe digital output, the *Safe Drive Function* can be assigned for triggering.

It is also possible to activate the outputs statically (always energized or de-energized). This function can be used for driving external loads.

Each output channel provides 100 mA and is overload and short-circuit protected. For more information on the electrical data, see 10.3.1 Digital Output. The dual-channel digital output is not galvanically isolated, the output use the internal system reference.

Test pulses are applied on each output line at an interval of 1 ms each second. These parameters are not configurable by the application. Channel A and B of output 1 and 2 are guaranteed to be tested with a certain delay. This enables the check for integrity measures and diagnostic on both channels independently.

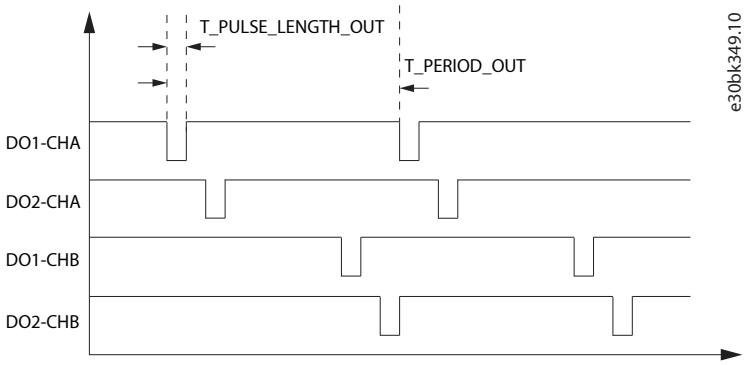

Figure 23: Test Pulses on Digital Output Lines

NOTICE

- Do not connect/disconnect the I/O connectors if the auxiliary voltage to the drive is applied (drive energized and operable). The I/O connectors must be connected when the drive is not powered/energized.

3.2.6.3.2 Brake Output

The VLT® Integrated Servo Drive ISD 520 has an integrated mechanical brake available as an option.

The VLT® Decentral Servo Drive DSD 520 provides an interface to connect a mechanical brake required for the safety subfunction *Safe Brake Control (SBC)*.

On the DSD 520 the presence of the mechanical brake is configurable within the safety parameter set. The brake control circuit is implemented in a dual-channel architecture meaning separate control over a high-side switch and a low-side switch. The safety integrity performance parameter can be found in 10.4.3.1 Performance of Safety Functions with FS Control Board. Mechanical brakes with a current rating of up to 1.2 A can be connected to the interface. All the details about the electrical characteristics can be found in 10.3.3 Brake Output.

The FS Control board applies test pulses for internal diagnosis to the high and low-side switch separately. For more information on the SBC function, see 3.2.5.5 Safe Brake Control (SBC).

3.2.6.4 Allowed Sensor Types on Digital Inputs

The 2 dual-channel digital inputs DI1 and DI2 supports the following sensor types:

- Sensor with normally closed switch NC (relay, safety switch)
- Sensor with PNP (current source) output

The safe digital inputs are configured for both directly connecting safety sensors, for example, emergency stop control devices or light curtains. They are also configured for connecting pre-processing safety relays, for example, safe controls. Ensure that the attached sensor fits the electrical characteristics detailed in 10.2.1 Digital Inputs.

3.2.6.5 Signal Filtering

VLT® FlexSafety™ activates the safety function when 1 channel of a digital input is set low for a longer period than *t_filter*. This behavior can be seen in Figure 24.

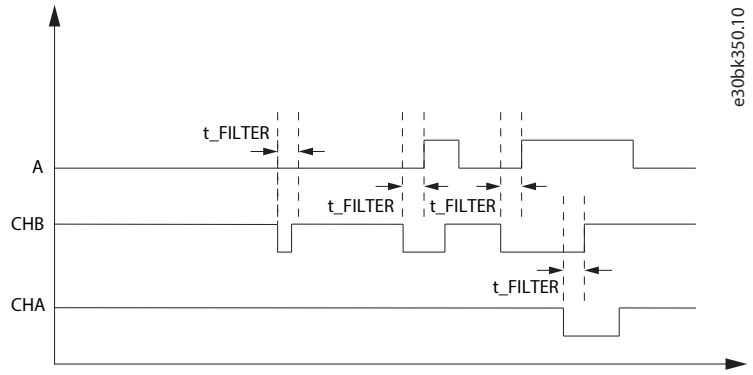

Figure 24: Timing Diagram for Digital Input: Filter Time

A	Function activation

The parameter *t_filter* is part of a larger set of parameters.

The FS Control board indicates an input error if the 2nd channel of a digital input deviates for more than the time specified in *t_discrepancy*. The discrepancy in the channels of a digital input triggers the input error.

Figure 25 shows the behavior if no test pulses are expected.

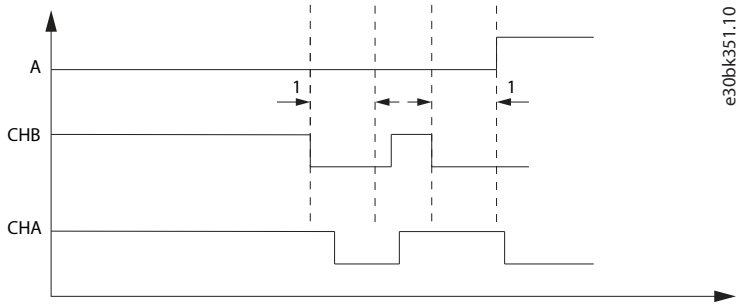

Figure 25: Timing Diagram for Digital Input: Discrepancy Time

A	Input error

3.2.6.6 Stable Signal Time from Safe Outputs

Several control modules test their safe outputs using test pulse pattern (on/off tests) to identify faults due to either short or cross-circuiting. When interconnecting the safe digital input of the option with a safe output of a control module, the option responds to these test signals.

The FS Control board supports the application of test pulses on the 2 dual-channel digital inputs and on the hard-wired STO digital input and evaluates those test pulses.

The test pulses applied to the input must have the following characteristics:

- The FS Control board considers low pulses longer than *t_filter* + 0.5 ms as request of a safety function.
- The FS Control board considers low pulses shorter than *t_filter* – 1.5 ms as a test pulse.
- The applied test pulses length is within *t_filter* – 1.5 ms and 300 µs.

Test pulses <300 µs are not guaranteed to be detected by the FS Control board. This is valid for the 2 dual-channel digital inputs and the hard-wired STO digital input.

Test pulses on the hard-wired STO digital input can only be evaluated if the FS Control board option is installed. Without FS Control board, the applied test pulses <2 ms are filtered out and ignored.

For the hard-wired STO digital input, the parameter *t_filter* is not configurable and is set to 2 ms. The maximum test pulse duration is therefore limited to 2 ms.

For the 2 dual-channel digital inputs the parameter *t_filter* is valid from 2 ms to 60 ms with a step width of 1 ms and is configurable by the application.

If no test pulse is detected within *t_period* after the last falling edge of a test pulse of the input signal, a stuck at failure is detected. The parameter *t_period* is not configurable and is set to 300 s.

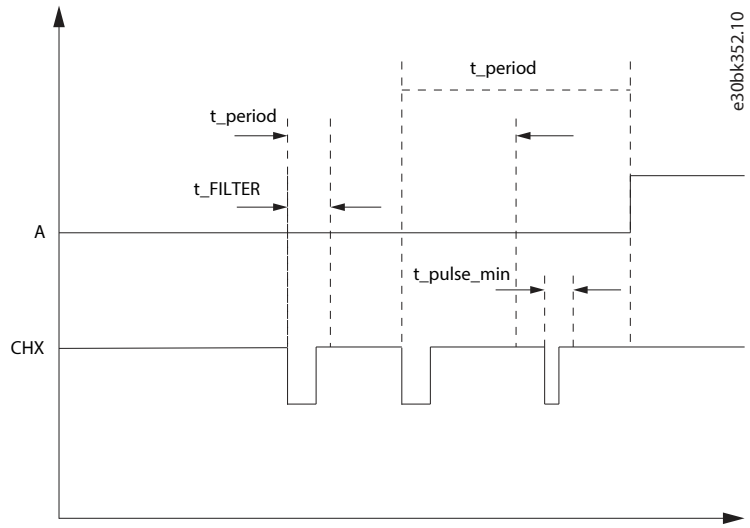

Figure 26: Timing Diagram for Digital Input: Test Pulse Period Definition

A	Input failure detected

3.2.6.7 Diagnostic Test Interval

If the FS Control board is installed, and test pulses are applied to the STO input (hard-wired or Safe I/O), no periodic test is required for the STO function. If the FS Control board is installed but test pulses are not applied to the STO input or Safe I/O digital inputs, carry out the periodic test. Perform this test at least once per year.

Without the FS Control board, the STO function must be activated and tested at least once per year.

For the SBC function, see 10.5.2 Mechanical Brake Considerations.

3.2.6.8 Safety Parameter Settings

Safety parameters for safe digital inputs and outputs are supported via the dedicated configuration settings. For safe digital inputs this comprises a function for monitoring digital input test pulses, and for monitoring the STO input test pulses. For the safe digital output, this includes a configuration parameter for specifying which safety function is mapped to the output.

A reset of the safety configuration to the factory settings can be executed via the VLT® Servo Toolbox Software.

Table 51: Parameters for Configuration of Safe Digital Inputs and Outputs

Type	Name	Variable	Comment
–	Installed I/O option	installedIoOption	Specifies the mounted I/O option board.
Safe digital input	Safe Digital Input 1 test pulse monitoring	digitalInputPulseMonitoring	Specifies if test pulses are expected on Safe Digital Input 1.
	Safe Digital Input 2 test pulse monitoring	digitalInputPulseMonitoring	Specifies if test pulses are expected on Safe Digital Input 2.
	Safe Digital Input 1 signal filter	t_filter	Maximum pulse length to be ignored on Safe Digital Input 1.
	Safe Digital Input 2 signal filter	t_filter	Maximum pulse length to be ignored on Safe Digital Input 2.
	Allowed deviation time between channels, Safe Digital Input 1	t_discrepancy	Maximum allowed time that the activation of the safety function by Safe Digital Input may deviate between the 2 channels on Safe Digital Input 1.
	Allowed deviation time between channels, Safe Digital Input 2	t_discrepancy	Maximum allowed time that the activation of the safety function by Safe Digital Input may deviate between the 2 channels on Safe Digital Input 2.
	STO Input test pulse monitoring	digitalInputPulseMonitoring_STO	Specifies if test pulses are expected on the STO Input.
	STO Input signal filter	t_filter_STO	Maximum pulse length to be ignored on the STO Input.
	Allowed deviation time between channels	t_discrepancy_STO	Maximum allowed time that the activation of STO via STO Input may deviate between the 2 channels.
Safe digital output	Safe Digital Output 1 configuration	dualOutputConfiguration	Specifies which function is assigned to Safe Digital Output 1.
	Safe Digital Output 2 configuration	dualOutputConfiguration	Specifies which function is assigned to Safe Digital Output 2

3.2.6.9 Encoder Interface

The FS Control board only supports the safety encoder protocol Safe HIPERFACE® DSL (from SICK).

In ISD 520 the safety encoder is integrated in the motor. The safety performance parameters can be found in *Safety Characteristic Data*.

3.2.6.10 HIPERFACE® DSL Encoder

The encoder protocol supported by the safety drive is HIPERFACE® DSL.

Configure the encoder together with the advanced safety functions that need safe position, velocity, and acceleration. The firmware marks the encoder as not available if safety encoder properties cannot be read or are invalid. Position information of the encoder is obtained using a double dedicated safe communication channel. The position information is compared against each other to ensure consistency.

Supported series:

- SICK EES37-2, EEM37-2
- SICK EKS36-2, EKM36-2
- SICK EDS35-2, EDM35-2

NOTICE

- Take the safety manual of the encoder into account. Follow the instructions for its mechanical mounting (DSD 520).

3.2.7 Limitations

3.2.7.1 Exceeded Limit Value and Internal Faults

If the limit values of safety functions are exceeded and violations occur, the configured drive stop reaction STO, SS1, or SS2 is executed.

If a limit violation occurs on the SS2 safety stop function, the configured stop reaction STO or SS1 is executed. If a limit violation occurs on the SS1 safety stop function, STO is triggered as the stop reaction. If a limit violation occurs on the SS2 safety stop function, SOS is activated.

Any internal fault on the safety drive activates the STO function and the drive coasts the motor. Carry out a power cycle to reset the fault state.

For PROFIsafe, the internal fault results in the *Device_Fault* bit in the status byte being set to TRUE. It is only possible to leave this error state by eliminating the error and carrying out a power cycle. The host application program does not need to prevent an unintentional restart.

3.2.7.2 Limitations when Using Safe Speed Monitoring Functions

The 2 speed monitoring functions, SCA and SSM, do not have a stop reaction when the limit values are exceeded. Instead, only the activation state is reported via fieldbus or safe digital output.

⚠ WARNING

UNEXPECTED LOAD ACCELERATION WITH PULLING LOADS

SCA and SSM are pure monitoring functions without the ability to configure a stop reaction. Therefore, a pulling load can unintentionally accelerate the motor.

- Never use SCA and SSM safety functions alone for drives with pulling loads.
- Only use SCA and SSM together with other safety functions where a stop reaction on limit violation can be configured.

3.2.7.3 Compatibility between Safety and Drive Function

The VLT® FlexSafety feature is compatible with these products:

- VLT® Integrated Servo Drive ISD 520
- VLT® Decentral Drive DSD 520
- VLT® Servo Drive Modules SDM 521/522

4 Installation

4.1 Requirements for Safe Use

⚠ CAUTION

EMC-COMPLIANT INSTALLATION

An installation that is not EMC-compliant can cause personal injury and equipment damage.

- Ensure that the installation and the wiring are EMC-compliant.

Refer to the guidelines in this guide. Also ensure compliance with:

- *VLT® Servo Drive System ISD 520/DSD 520 Operating Guide*.

4.2 Protected Cable Installation

If short circuits and cross circuits are expected with safety-related signals and are not detected by upstream devices, a protected cable installation is required. The protected cable must comply with EN ISO 13849-2.

4.3 Connecting Cables

4.3.1 Connecting Hybrid Cables

Procedure

1. Align the female connector of the M23 feed-in cable to the male input connector (X1) of the 1st ISD 520/DSD 520 servo drive.
2. Fully rotate the threaded ring of the cable connector counterclockwise. Use the marking OPEN as a reference for the cable connector.
3. Ensure the marking OPEN on the cable connector is facing the servo drive.
4. Press the connector towards the electronic housing on the servo drive until the sealing on the connector is entirely covered.
5. Tighten the M23 feed-in cable connector by rotating the threaded ring clockwise out of the flat area around the OPEN marking.

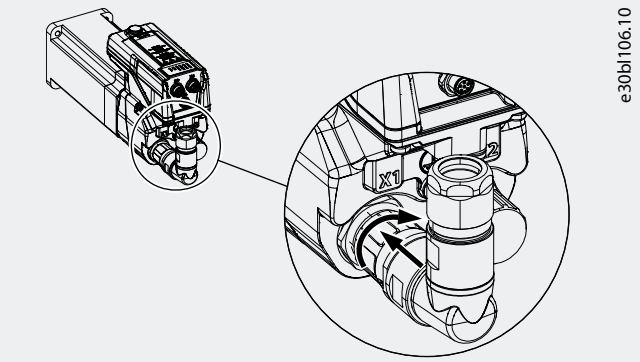

Figure 27: Connecting the M23 Feed-In Cable

6. To add more servo drives in daisy-chain format, connect the male connector of the loop cable to the female connector (X2) of the 1st servo drive.
7. Connect the female connector of the loop cable to the male connector (X1) of the next servo drive, and so on.
8. Tighten the threaded rings by hand as described in step 5.
9. Ensure that there is no mechanical tension on the cables.

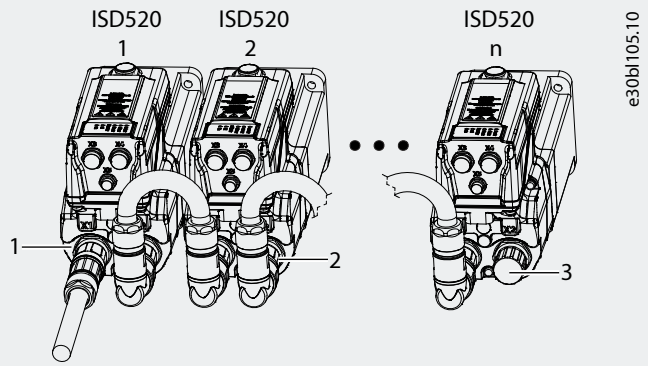

Figure 28: Adding ISD 520 Servo Drives in Daisy-Chain Format

1	X1 Male connector	**2**	X2 Female connector
3	M23 Metal blind cap		

10. Screw the M23 metal blind cap onto the unused M23 female output connector (X2) on the last servo drive in the servo system.

11. Tighten the metal blind cap until the sealing on the connector is covered.

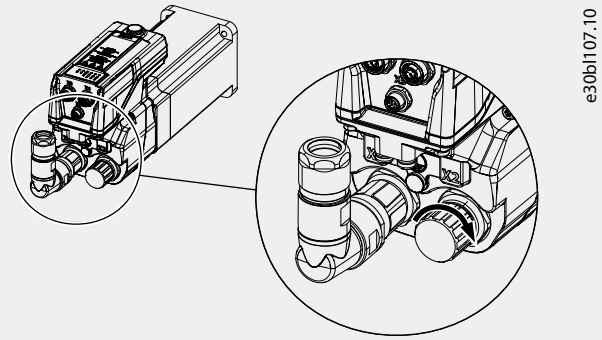

Figure 29: Mounting the M23 Blind Cap

⚠ CAUTION

RISK OF INJURY AND/OR EQUIPMENT DAMAGE

Failure to use the M23 metal blind cap may result in injury to the operator and/or damage to the ISD 520/DSD 520 servo drive.

- Always fit the M23 metal blind cap as described in steps 10 and 11.

NOTICE

- A straight version of the M23 connector is also available. The procedure for connecting the straight M23 connector is the same as for the angled connector.

4.3.2 Connecting Cables to Ports X3, X4, and X5

4.3.2.1 Cable Routing Recommendations

Avoid mechanical tension for all cables, especially regarding the range of motion of the installed servo drive.

Secure all cables in accordance with regulations and depending on conditions on site. Ensure that cables cannot come loose, even after prolonged operation.

4.3.2.2 Connecting I/O Cables to Ports X3 and X4

Procedure

1. Align the connector on the cable (not supplied) with the connector marked X3 or X4 on the servo drive.
2. Press the connector towards the electronic housing of the servo drive and tighten the threaded ring of the connector by turning it clockwise. The maximum tightening torque is 0.4 Nm (3.54 in-lbs).

4.3.2.3 Connecting the LCP Cable to Port X5

Procedure

1. Align the connector on the LCP cable (not supplied) with the LCP connector marked X5 on the ISD 520/DSD 520 servo drive.
2. Press the connector towards the electronic housing of the servo drive and tighten the threaded ring of the connector by turning it clockwise. The maximum tightening torque is 0.2 Nm (1.77 in-lbs).

The LCP cable can be ordered as an accessory.

4.3.3 General Wiring Guidelines

NOTICE

All signals to the Safe I/O board must be PELV supplied and comply with EN IEC 60204.

- Route sensitive control cables - such as encoder and active safety component cables - without any interruption and with optimum shield support at both ends.
- Connect shields at both ends to the grounded enclosures through a good electrical connection and through a large surface area.
- Connect cable shields as close as possible to the cabinet cable entry.
- If possible, intermediate terminals should not interrupt cable shields.
- Retain cable shields for both power cables and for signal and data cables using the appropriate EMC clamps. The shield clamps must connect the shield to the EMC shield bar of the shield support element for control cables through a low inductive connection through a large surface area.
- The safety channels inside a cable connected to the Safe I/O option board cannot be shorted by failure. Separately shielded lines are sufficient.

4.4 Connector Pin Assignment

See the *VLT® Servo Drive System ISD 520/DSD 520 Operating Guide* for the pin assignment of the connectors:

- X3: I/O Connector for Channel A (M12, 8 pole)
- X4: I/O Connector for Channel B (M12, 8 pole)
- X5: LCP Connector (M8, 6 pole)

4.5 External Encoder

4.5.1 Motor and Feedback Connectors on DSD 520

See the *VLT® Servo Drive System ISD 520/DSD 520 Operating Guide* for the pin assignment of the motor and motor feedback connectors on DSD 520.

4.6 Application Examples

4.6.1 Application Example 1

This example shows a 2-channel emergency stop between dual-channel output 1 and dual-channel input 1 of the Safe I/O board.

The digital outputs are fed back to the digital input passing a 2-channel emergency push-button or other equivalent safety switch. The Safe I/O board makes it possible to activate the advanced safety functions without the use of a safe PLC.

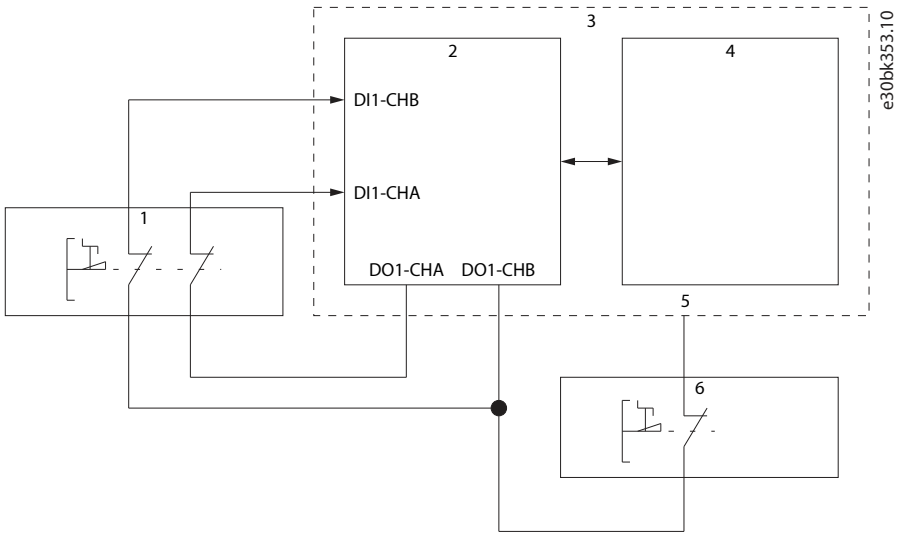

Figure 30: Application Example 1

1	2-channel emergency stop switch	**2**	Safe I/O board
3	ISD 520/DSD 520	**4**	FS Control board
5	Hard-wired STO digital input	**6**	1 channel emergency stop switch

4.6.2 Application Example 2

This example shows how safe PLC communicates via safe fieldbus to the FS Control board and controls the inputs signals of the Safe I/O board.

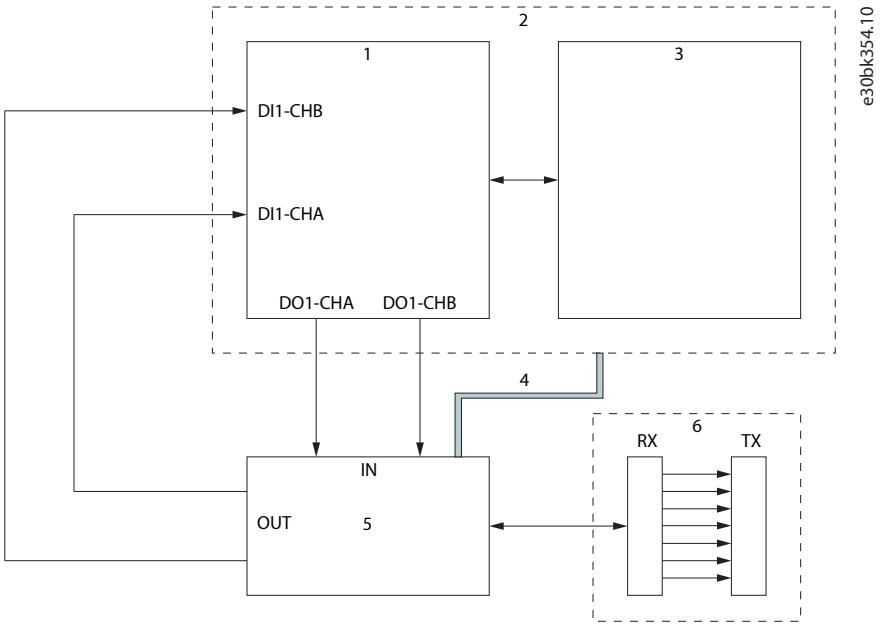

Figure 31: Application Example 2

1	Safe I/O board	**2**	ISD 520/DSD 520
3	FS Control board	**4**	Safe fieldbus communication (FSoE or PROFIsafe)
5	Safe PLC	**6**	External safety devices, for example the Safety Light Curtain, communicating to PLC

4.6.3 Application Example 3

This example shows a simplified setup that implements a safety PLC without the Safe I/O board. The advanced safety functions can only be triggered via the safe fieldbus.

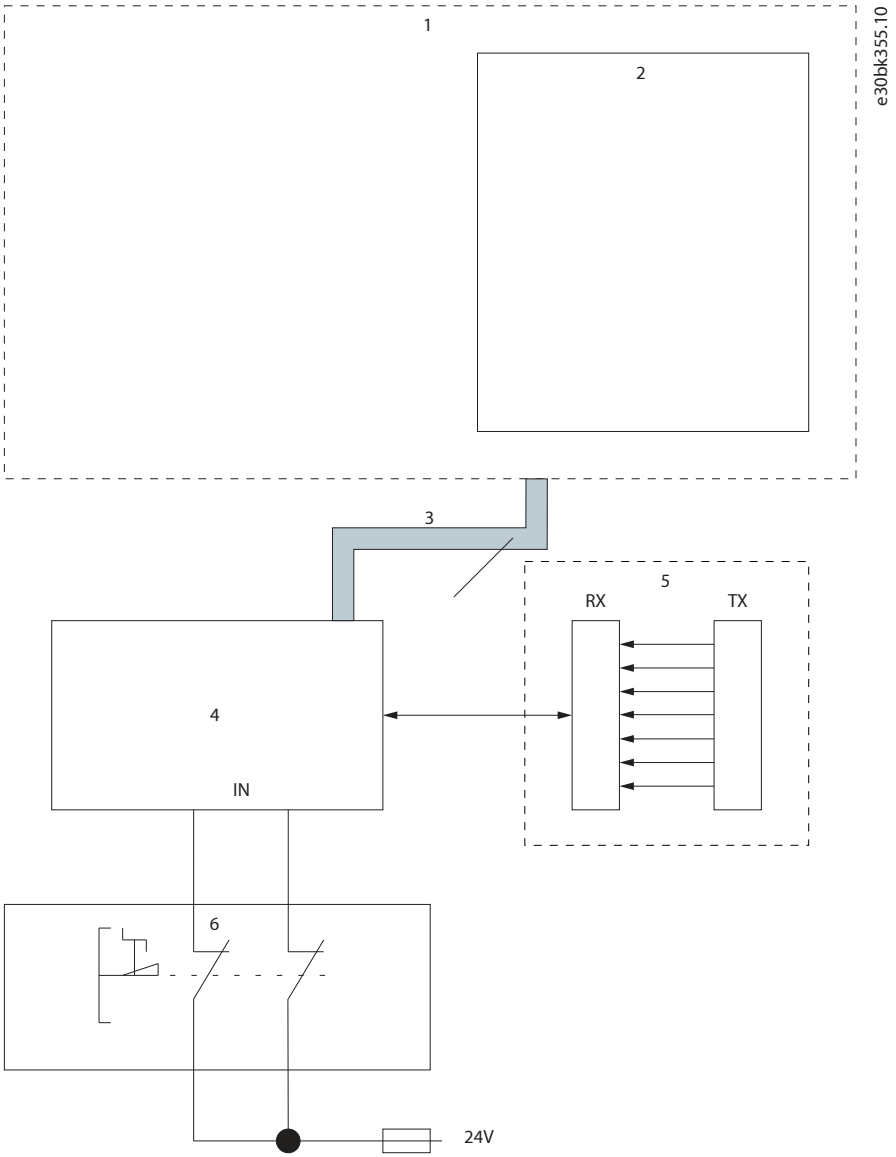

Figure 32: Application Example 3

1	ISD 520/DSD 520	**2**	FS Control board
3	Safe fieldbus communication (FSoE or PROFIsafe)	**4**	Safe PLC
5	External safety devices, for example, the Safety Light Curtain, communicating to PLC	**6**	2-channel emergency stop switch

5 Commissioning

5.1 Before Commissioning

When commissioning/decommissioning:

- Secure the site in accordance with regulations (barrier, warnings, signs, and more). Only qualified personnel are allowed to commission/recommission the system.
- Refer to the guidelines, information, and specifications stated in the operating guide of the relevant programmable control system.
- Make sure that no personal injury and/or material damage can occur, even if the plant/machine moves unintentionally.

⚠ WARNING

RISK OF ELECTROCUTION

Wiring the electrical connections on the drive while voltage is applied can result in death or serious injury.

- Switch the power off
- Make sure that the control cabinet is provided with an access lock or warning signs.
- Do not switch on the voltage until the system is commissioned.

NOTICE

- Change the default password before commissioning (see 5.7.5 Password Change).

Refer to the relevant operating guide for further information on the drive.

5.2 Commissioning Requirements

Meet the following requirements to commission the safety drive:

- Installation of VLT® Servo Toolbox Software (minimum version 4.0).
- Successful connection to VLT® FlexMotion™ drive with FS Control board.
- Ethernet fieldbus connection for connecting the safety drive with the PC.

Procedure

1. Configure the safety drive in the VLT® Servo Toolbox using the *Safety Configuration* subtool.
2. Ensure that the serial number on the drive matches the device number in the VLT® Servo Toolbox *Safety Configuration* subtool.
3. Ensure that the safety drive is ready for commissioning (see the relevant operating guide for the drive).

5.3 Initial Commissioning

1. Switch on all the supply voltages for the safety drive or motion control system.

   The display elements on the drive and on the safety option show when they are ready for operation.

2. Connect the configuration PC to the network topology of the safety drive.

   Connect with the *Safety Configuration* subtool of the VLT® Servo Toolbox (for a general description of the VLT® Servo Toolbox refer to the corresponding operating guide for the drive and the *Tool-Tip* indications).

3. Set the Safe Address of the safety drive, for details refer to 5.4 Safe Address Setting.

   The safe address is a unique identifier of a safety drive within a network topology. Every safety drive must have the safe address set to be operated properly within the network as part of the motion control system.

A dedicated pairing mechanism is provided by the VLT® Servo Toolbox. The pairing mechanism ensures that the safe address is configured on the correct physical drive with the corresponding device from the network topology. As an alternative, the safe address can also be programmed directly using a connected LCP display.

4. Prepare the safety configuration, for details refer to 5.5 Safe Position Reset.

   The safety configuration comprises setup of all used safety functions, safe digital I/Os, safety encoder, and the safe fieldbus selection.

   Safety parameter configurations can be generated, modified, and stored as backup on the PC.

5. Download and validate the safety configuration on the safety drive, for details refer to 6.1 Safety Parameter Configuration.
   a. Apply the user login and password to the safety drive to start writing a safety configuration from the PC to the drive.
   b. Select *Download to drive* in the Safety Configuration Subtool.
   c. The drive verifies the consistency of the received parameter configuration and creates a text report.
   d. Validate the obtained report to finally confirm the programmed configuration and activate the safety functions.
6. Reset the Safe Absolute Position of the drive, for details refer to 5.5 Safe Position Reset.

   The safe absolute position allows a user to reset the safe absolute position directly using the VLT® Servo Toolbox.

   A dedicated pairing mechanism is provided by the VLT® Servo Toolbox to ensure that the selected drive is the correct one.

   The safe position can also be reset directly using a connected LCP.

5.4 Safe Address Setting

The safe address is a unique identifier of a safety drive within a network topology. Every safety drive must use a safe address to be operated properly within a motion control network. The safe address can also be used for an automated safety parameter backup when a drive is replaced.

Therefore, set up the safe address by a fail-safe mechanism and assign it manually by an instructed operator. VLT® FlexSafety™ drives support 2 different procedures to set up the safe address.

Safe address setting using direct connection to the LCP

The **Safe Address** object is visible on index 0x5074 but the parameter cannot be written to using normal write access. This prevents incorrectly selecting and programming the wrong safety drive inside a network topology where multiple devices are present.

Instead, the LCP is used to modify the safe address of a drive using index 15–63. This procedure guarantees a direct connection between the physical drive and the LCP as a human machine interface, where the user can select the correct safe address. A power cycle is not needed when the safe address is modified via LCP.

NOTICE

- Remove the LCP after completing the procedure.

Safe address setting via the pairing mechanism in VLT® Servo Toolbox software

Pairing via the VLT® Servo Toolbox software guarantees that the desired safe address is programmed on the correct physical drive.

Procedure:

1. Open the Safety Configuration subtool and enter the safe address setting mode in the **Commissioning** section.

2. Start the guided step-by-step procedure.
3. Set the desired safe address.
4. The indicator lights (LEDs) of the safety device start to blink with a repeated pattern where a random number of blinks can be counted by the user.
5. The observed number must be inserted as a numeric code in the VLT® Servo Toolbox software. The pre-defined timeout is 10 minutes.
6. If the correct number is inserted, the pairing is successfully established and the desired safe address is accepted by the device.
7. To activate the new safe address, restart the functional safety board or power cycle the safety drive.

5.5 Safe Position Reset

A safe position must always be referenced correctly via a dedicated reset mechanism for advanced safety functions operating on drive positions.

VLT® FlexSafety drives support 2 different procedures to reset a safe position.

Safe position reset using direct connection to the LCP

The safe position of a drive can be reset via the LCP using index 15–69. The **Safe position actual value** object is visible on index 0x507E but the parameter cannot be written to using normal write access. This prevents incorrectly selecting and programming the wrong safety drive inside a network topology where multiple devices are present.

Instead, the LCP is used to modify the safe position of a drive using index 15–69. This procedure guarantees a direct connection between the physical drive and the LCP as a human machine interface, where the user can trigger the safe position reset. A power cycle is not needed when the safe position reference is modified via LCP. The safe position actual value can be read on the LCP using index 15–64.

Check the safe position after a safe absolute position reset is performed, reading the safe position parameter actual (0x507E).

NOTICE

- Remove the LCP after completing the procedure.

Safe position reset via pairing mechanism in VLT® Servo Toolbox software

Pairing via the VLT® Servo Toolbox software guarantees that the desired safe position reset is carried out on the correct physical drive.

Procedure:

1. Open the Safety Configuration subtool and enter the *Safe Position Reset* mode in the *Commissioning* section.
2. Start the guided step-by-step procedure.
3. The indicator lights (LEDs) of the safety device start to blink with a repeated pattern where a random number of blinks can be counted by the user.
4. The observed number must be inserted as a numeric code in the VLT® Servo Toolbox software. The pre-defined timeout is 10 minutes.
5. If the correct number is inserted, the pairing is successfully established and the absolute position is reset.
6. Check the safe position after a safe absolute position reset is performed, reading the safe position parameter actual (0x507E).

5.6 User Login and Parameter Download

5.6.1 User Login and Password

To download a safety configuration, the users must be logged in with username and password. There are 2 types of users with corresponding access rights: *admin* and *service*.

Table 52: User Types

User type	Description	Rights
Service	Intended for machine operators and service technicians. Covers maintenance actions such as the field replacement of a safety drive.	• Download/upload of safety parameter configurations to a drive. • Modifications to safety configurations are not allowed.
Admin	Intended for machine builders.	Same rights as service user plus: • Create and modify safety configurations • Change admin and service level passwords.

The default passwords for *admin* and *service* are the same and can be modified as desired. Passwords can be reset to the factory default passwords via the reset functionality, however any programmed safety configurations or safe addresses will be lost.

5.6.2 Safety Parameter Download and Validation

A prepared configuration can be programmed onto a safety drive using the safety configuration subtool of the VLT® Servo Toolbox. After login, the configuration download can be started and the progress is reported. The safety drive automatically verifies the consistency of the received parameter configuration.

Once the download is complete, a report is returned from the drive in Ascii text format. Validate the report for it to become active.

A safety configuration can be uploaded from a configured drive to the VLT® Servo Toolbox to save, visualize, and modify it using the safety configuration subtool.

5.7 Utility Functions

5.7.1 Logbook

The safety drive registers errors or fault conditions related to safety (*Error Log*), and validated accesses when updating FS Control board firmware or validating parameters (*Login Log*). The last 8 entries for each log are permanently stored and can be read from the drive and saved using the safety configuration subtool of the VLT® Servo Toolbox.

Procedure:

1. Open the *Safety Configuration* subtool and enter the *Log Book Read* function in the *Tools* section.
2. Start the guided step-by-step procedure.
3. Select the log book type.
4. The desired log book is retrieved from the drive and shown.
5. Select the local file path and save the log book content as text.

5.7.2 Software Update

The safety firmware of the safety drive can be updated using the safety configuration subtool of the VLT® Servo Toolbox.

Procedure:

1. Open the *Safety Configuration* subtool and enter the *SW Update function* in the *Tools* section.
2. Start the guided step-by-step procedure.
3. Enter the credentials.

4. Select the binary file (.bin extension) from the local file system.
   a. A consistency check takes place on the header of the selected file to prove that the user has selected a valid safety software package.
   b. The user interface shows both software versions: the current one (running on the device) and the one of the selected file.
   c. If everything is fine, the user is able to proceed and download the selected firmware package to the device.
5. New firmware package download (long-lasting operation).
6. (Optional) After successful completion, the safety software can be restarted immediately or done at a later date.

5.7.3 Backup

The current configuration of the drive can be backed up for future reuse (for example, for device replacement, configuration replication.) using the safety configuration subtool of the VLT® Servo Toolbox.

Procedure:

1. Open the *Safety Configuration* subtool and enter the *Backup* function in the *Tools* section.
2. Start the guided step-by-step procedure.
3. Backup data is retrieved from the drive.
4. Select the local file system path.
5. The backup is saved to the selected path as a unique binary file.

5.7.4 Restore

A successfully backed up configuration can be restored to a safe drive for device replacement or configuration replication. This is done via the safety configuration subtool of the VLT® Toolbox.

Procedure:

1. Open the *Safety Configuration* subtool and enter the *Restore* function in the *Tools* section.
2. Start the guided step-by-step procedure.
3. Enter valid credentials to proceed.
4. Select a valid backup file. The binary file is downloaded to the safe drive.
5. The VLT® Toolbox requests and retrieve the report (text format) that corresponds to the downloaded configuration.
6. The retrieved report is shown. Check the configuration parameters.
7. If everything is like intended, validate the report and activate the configuration.

5.7.5 Password Change

Admin or Service passwords can be changed using the *Safety Configuration* subtool. If a password is lost and cannot be recovered, a factory reset will reset the password to the default settings but the safety configuration and safe address will be lost.

5.7.6 Factory Reset

A factory reset can be carried out. This deletes any safety configuration, sets the safe address to 0, and resets both admin and service passwords. Power cycle the device after a factory reset.

6 Parameter Setup

6.1 Safety Parameter Configuration

The safety configuration tool of the VLT® Servo Toolbox software allows the safety configurations to be created, modified, and downloaded to a drive. Safety configuration data can also be stored to and loaded from files in the local file system, enabling work to be saved and completed later. The same configuration can be reused and downloaded to several drives.

Select the *Safety Function* section of the *Safety Configuration* subtool to view the list of safety functions and other configuration sets for brake, encoder, safe I/O, user units, and general parameters.

Each set contains a group of parameters with adjustable values. For the selected set, the parameters are shown as a table at the right of the window along with a graphical representation of the function.

If a configuration is invalid, the incorrect parameter is highlighted and the command for downloading is disabled.

If all the checks are passed, start the programming process:

1. Open the *Safety Configuration* subtool and enter the *Safety Functions* section.
2. Start the guided step-by-step procedure (Download button).
3. Enter valid values/settings to proceed.
4. Download step: current values of parameters are downloaded as a binary package.
5. Verification step: the VLT® Servo Toolbox verifies that the drives have correctly received the parameter values.
6. Validation step: the VLT® Servo Toolbox requests and fetches the report (text format) that corresponds to the downloaded configuration.
7. The retrieved report is shown.
8. Check all the configuration parameters in the report.
9. If everything is like intended, validate the report and activate the configuration.

6.2 Parameter List

6.2.1 General Parameters

Table 53: General Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Drive name	p12800	0x3200	char[24]	–	–	–	The user-specific name of the drive.
Safe fieldbus activation	p12801	0x3201	uint8	0	1	0	Configures the safe fieldbus use. • 0 = safe fieldbus is not used. • 1 = safe fieldbus is used.

NOTICE

- Safe fieldbus data is ignored, if the safe fieldbus is deactivated.

6.2.2 User Units Parameters

The safe position value in user units is calculated using the following formula:

$$Safepositionvalue = \frac{internalpositionvalue}{positionencoderresolution} \times SafeGearratio \times SafeFeedconstant$$

The gear ratio is calculated using the following formula:

$$Safegearratio = \frac{Safegearrationumerator}{Safegearratiodivisor}$$

The feed constant is the measurement distance per 1 revolution of the driving shaft of the gearbox. The feed constant is calculated using the following formula:

$$Safefeedconstant = \frac{Safefeed}{Safeshaftrevolutions}$$

Table 54: User Units Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Position unit name	p12810	0x320A	char[24]	–	–	–	The name of the position user unit configuration. It can be used as identifier of the current configuration.
Safe gear ratio numerator	p12811	0x320B	uint32	1	2^{32}–1	1	The numerator of the safe gear ratio.
Safe gear ratio denominator	p12812	0x320C	uint32	1	2^{32}–1	1	The denominator of the safe gear ratio.
Safe feed	p12813	0x320D	uint32	1	2^{32}–1	1	The safe feed is used as numerator for the safe feed constant calculation.
Safe shaft revolutions	p12814	0x320E	uint32	1	2^{32}–1	1	The safe shaft revolutions are used as denominator for the safe feed constant calculation.

6.2.3 Safe I/O Parameters

Table 55: Safe I/O Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Installed I/O option	p12820	0x3214	Uint8	0	1	0	Configures if the safe I/O option board is mounted. • 0 = safe I/O option board is not mounted. • 1 = safe I/O option board is mounted.
Safe digital input 1 test pulse monitoring	p12821	0x3215	Uint8	0	1	0	Configures if test pulses are expected on Safe Digital Input 1. • 0 = test pulses are not expected. • 1 = test pulses are expected.

Table 55: Safe I/O Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Safe digital input 2 test pulse monitoring	p12822	0x3216	Uint8	0	1	0	Configures if test pulses are expected on Safe Digital Input 2. • 0 = test pulses are not expected. • 1 = test pulses are expected.
Safe digital input 1 signal filter	p12823	0x3217	Uint8	2 ms	60 ms	2 ms	The maximum pulse duration to be ignored on *Safe Digital Input 1*.
Safe digital input 2 signal filter	p12824	0x3218	Uint8	2 ms	60 ms	2 ms	The maximum pulse duration to be ignored on *Safe Digital Input 2*.
Safe Digital Input 1 allowed deviation time between channels	p12825	0x3219	Uint8	1 ms	200 ms	50 ms	The maximum allowed time that the activation of the safety function by *Safe Digital Input 1* may deviate between the 2 channels.
Safe Digital Input 2 allowed deviation time between channels	p12826	0x321A	Uint	1 ms	200 ms	50 ms	The maximum allowed time that the activation of the safety function by *Safe Digital Input 2* may deviate between the 2 channels.
STO input test pulse monitoring	p12827	0x321B	Uint8	0	1	0	Configures if test pulses are expected on the STO output. • 0 = test pulses are not expected. • 1 = test pulses are expected.
STO input signal filter	p12828	0x321C	Uint8	2 ms	60 ms	2 ms	The maximum pulse duration to be ignored on STO input.
STO Input allowed deviation time between channels	p12829	0x321D	Uint8	1 ms	200 ms	50 ms	The maximum allowed time that the activation of STO via STO Input may deviate between the 2 channels.

Table 55: Safe I/O Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Safe Digital Output 1 configuration	p12830	0x321E	Uint8	0x00	0x1C	0x00	Configures which function is assigned to *Safe Digital Output 1*. If the assigned function has a limit violation reaction, its value cannot be *0*. The assigned function must have a digital input configured or the safe fieldbus must be enabled. • 0x00: Permanent low • 0x01: Permanent high • 0x02: STO • 0x03: STO selected • 0x04: SOS • 0x05: SCB • 0x06: SCB selected • 0x07: SBT • 0x08: SS1 • 0x09: SS2 • 0x0A: SLS1 • 0x0B: SLS2 • 0x0C: SLS3 • 0x0D: SLS4 • 0x0E: SMS • 0x0F: SLA • 0x10: SSR • 0x11: SSM
Safe Digital Output 1 configuration (continued)	p12830	0x321E	Uint8	0x00	0x1C	0x00	• 0x12: SDIp • 0x13: SDIn • 0x14: SLP1 • 0x15: SLP2 • 0x16: SLP3 • 0x17: SLP4 • 0x18: SLI • 0x19: SCA1 • 0x1A: SCA2 • 0x1B: SCA3 • 0x1C: SCA4

Table 55: Safe I/O Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Safe Digital Output 2 configuration	p12831	0x321F	Uint8	0x00	0x1C	0x00	Configures which function is assigned to *Safe Digital Output 1*. If the assigned function has a limit violation reaction, its value cannot be *0*. The assigned function must have a digital input configured or the safe fieldbus must be enabled. • 0x00: Permanent low • 0x01: Permanent high • 0x02: STO • 0x03: STO selected • 0x04: SOS • 0x05: SCB • 0x06: SCB selected • 0x07: SBT • 0x08: SS1 • 0x09: SS2 • 0x0A: SLS1 • 0x0B: SLS2 • 0x0C: SLS3 • 0x0D: SLS4 • 0x0E: SMS • 0x0F: SLA • 0x10: SSR • 0x11: SSM
Safe Digital Output 2 configuration (continued)	p12831	0x321F	Uint8	0x00	0x1C	0x00	• 0x12: SDIp • 0x13: SDIn • 0x14: SLP1 • 0x15: SLP2 • 0x16: SLP3 • 0x17: SLP4 • 0x18: SLI • 0x19: SCA1 • 0x1A: SCA2 • 0x1B: SCA3 • 0x1C: SCA4

6.2.4 Safe Brake Parameters

Table 56: Safe Brake Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Brake attached	p12840	0x3228	Uint8	0	1	0	Configures if the brake is mounted. • 0 = brake is not mounted. • 1 = brake is mounted.
Maximum brake operation time	p12841	0x3229	Uint16	0 ms	2^{16}–1 ms	0 ms	Configures the maximum time that is required for engaging or releasing the brake. If a brake is mounted, STO activation is delayed by this duration to ensure that the brake is engaged before STO.
Brake test request interval	p12842	0x322A	uint32	3600 s	31536000 s	28800 s	Configures the time interval in seconds that a brake test should be requested.
Brake nominal torque	p12843	0x322B	uint32	0 Nm	2^{31}–1 ms	0 Nm	Configures the torque that should be applied by the drive to the motor in each direction when SBT is activated.
Motion limit in brake test	p12844	0x322C	Uint32	0 (user position unit)	2^{31}–1 Nm (user position unit)	0 (user position unit)	Configures the maximum allowed movement during the safe brake test in a user-defined position unit. If the maximum is exceeded, a fault reaction is triggered.
Input for SBC override during STO	p12845	0x322D	Uint8	0	4	0	Configures the input used for overriding SBC during STO. • 0 = Not used • 1 = Dual input 1 • 2 = Dual input 2 • 3 = Virtual input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*

6.2.5 Encoder Parameters

Table 57: Encoder Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Absolute position enabled	p12850	0x3232	Uint8	0	1	0	Configures if the absolute position feature is requested. It can only be enabled if the encoder is enabled. • 0 = absolute position disabled • 1 = absolute position enabled
Absolute position on reset	p12851	0x3233	Int32	2^{31}+1 (user position unit)	2^{31}–1 (user position unit)	0 (user position unit)	Configures the position that the drive will return to after the encoder position reset has been invoked.
Absolute position reset input	p12852	0x3234	Uint8	0	4	0	Configures the associated safe digital input used for resetting the safe absolute position. • 0 = Not used • 1 = *Safe Digital Input 1* • 2 = *Safe Digital Input 2* • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
Encoder enabled	p12853	0x3235	Uint8	0	1	0	Configures if the encoder is used. • 0 = use of encoder is disabled • 1 = use of encoder is enabled
Encoder type name	p12854	0x3236	Char[24]	–	–	–	The name of the encoder type. The value cannot be empty if the encoder is enabled.
Number of single-turn bits	p12855	0x3237	Uint8	0	255	0	The number of single-turn bits of the used encoder, including safe and non-safe bits.

Table 57: Encoder Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Number of safe single-turn bits	p12856	0x3238	Uint8	0	255	0	The number of safe single-turn bits of the used encoder. The configured values must be higher than the number of single-turn bits.
Number of safe multi-turn bits	p12857	0x3239	Uint8	0	255	0	The number of multi-turn bits of the used encoder.
Encoder test bitmask	p12858	0x323A	Uint8	0	255	0	The bitmask of tests that must be performed. This parameter depends on the encoder type used. • 0x01 = Encoder test message 6 required. • 0x02 = Encoder test message 8 required. • 0x80 = This encoder behaves like the EEx37 series.
Encoder voltage range	p12859	0x323B	Uint8	0	255	0	The power supply voltage range of the encoder in volts. • 0 = 7–12 V.
Speed filter time	p12860	0x323C	Uint8	1	100	1	The filter time used by the filter for the speed computation. • 1 = no filtering is applied. • 100 = the maximum filtering level is applied.
Acceleration filter time	p12861	0x323D	Uint8	1	100	1	The filter time used by the filter for the acceleration computation. • 1 = no filtering is applied. • 100 = the maximum filtering level is applied.

6.2.6 STO Parameters

Table 58: STO Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
STO Restart Behavior	p12870	0x3246	Uint8	0	1	0	Configures if STO will be deactivated when all STO requests have been removed or if a safe fieldbus "Acknowledge" is required. • 0 = automatic restart is allowed. • 85 = acknowledge is required to restart.
							Configures the associated safe digital input used for the SOS request. • 0 = not used. • 1 = Safe Digital Input 1. • 2 = Safe Digital Input 2. • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2*. • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*.
SOS initial delay	p12881	0x3251	Uint16	0 ms	60000 ms	0 ms	Configures the time between the SOS request and the start of position monitoring.
SOS zero speed window	p12882	0x3252	int32	0 (user position units)	2^{31}–1 (user position units)	0 (user position units)	Configures the speed window for SOS. If the drive speed falls within it, the drive speed is considered *0*. The supervision of zero-speed is disabled when it is set to *0*.

Table 58: STO Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SOS zero position window	p12883	0x3253	Uint32	1 (safe encoder digits)	2^{31}–1 (user position units)	1 (safe encoder digits)	Configures the maximum drive movement allowed before an SOS limit violation is detected. The supervision is disabled when it is set to its maximum value.
SOS restart behavior	p12884	0x3254	Uint8	0	1	0	Configures if SOS will be deactivated when all SOS requests have been removed, or if a safe fieldbus "Acknowledge" is required. • 0 = automatic restart is allowed. • 85 = acknowledge is required to restart.

6.2.7 SS1 Parameters

Table 59: SS1 Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SS1 configured input	p12890	0x325A	Uint8	0	4	0	Configures the associated safe digital input used for the SS1 request. • 0 = not used • 1 = Safe Digital Input 12 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SS1 maximum delay	p12891	0x325B	Uint16	2 ms	60000 ms	2 ms	The maximum time for the ramp-down when SS1 is activated.
SS1 initial delay	p12892	0x325C	Uint16	1 ms	60000 ms	1 ms	The time between the SS1 request and the start of position monitoring.

Table 59: SS1 Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SS1 target speed detection delay	p12893	0x325D	Uint16	1 ms	60000 ms	1 ms	The time interval between entering the speed window and the early activation of SS1. The parameter value must be lower than the SS1 initial delay time.
SS1 minimal deceleration	p12894	0x325E	Int32	0 (speed change/ms)	2^{31}–1 (speed change/ms)	0 (speed change/ms)	The minimal deceleration limit for SS1. If the encoder is not used, the parameter must be set to *0* (deceleration monitoring disabled).
SS1 zero speed window	p12895	0x325F	Int32	1 (user position unit/s)	2^{31}–1 (user position unit/s)	1 (user position unit/s)	Configures the speed window for SS1. If the drive speed falls within it, the drive speed is considered *0*.

6.2.8 SS2 Parameters

Table 60: SS2 Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SS2 configured input	p12900	0x3264	Uint8	0	4	0	Configures the associated safe digital input used for the SS2 request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SS2 maximum delay	p12901	0x3265	Uint16	2 ms	60000 ms	2 ms	The maximum time for the ramp-down when SS2 is activated.
SS2 initial delay	p12902	0x3266	Uint16	1 ms	60000 ms	2 ms	The time between the SS2 request and the start of position monitoring.

Table 60: SS2 Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SS2 target speed detection delay	p12903	0x3267	Uint16	1 ms	60000 ms	1 ms	The time interval between entering the speed window and the early activation of SS2. The parameter value must be lower than the SS2 initial delay time.
SS2 minimal deceleration	p12904	0x3268	Int32	0 (speed change/ms)	2^{31}–1 (speed change/ms)	0 (speed change/ms)	The minimal deceleration limit for SS2. If the encoder is not used, the parameter must be set to *0* (deceleration monitoring disabled).
SS2 limit violation reaction	p12905	0x3269	Uint8	1	3	1	Configures which safety function will be activated if the SS2 limits are violated. • 1 = none • 2 = STO • 3 = SS1

6.2.9 SLI Parameters

Table 61: SLI Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLI configured input	p12910	0x326E	Uint8	0	4	0	Configures the associated safe digital input used for the SLI request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLI initial delay	p12911	0x326F	Uint16	1 ms	60000 ms	1 ms	The time between the SLI request and the start of position monitoring.
SLI relative upper position limit	p12912	0x3270	Uint32	0 (safe encoder digits)	2^{31}–1 (safe encoder digits)	1 (safe encoder digits)	Configures the relative upper position limit for SLI in safe encoder digits.

Table 61: SLI Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLI relative lower position limit	p12913	0x3271	Uint32	0 (safe encoder digits)	2^{31}–1 (safe encoder digits)	1 (safe encoder digits)	Configures the relative lower position limit for SLI in safe encoder digits.
SLI limit violation reaction	p12914	0x3272	Uint8	1	4	1	Configures which safety function will be activated if the SS2 limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.10 SLP Parameters

Table 62: SLP Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLP1 configured input	p12920	0x3278	Uint8	0	4	0	Configures the associated safe digital input used for SLP request instance 1. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLP1 initial delay	p12921	0x3279	Uint16	1 ms	60000 ms	1 ms	The time between SLP request instance 1 and the start of position monitoring.
SLP1 upper position limit	p12922	0x327A	Uint32	–(2^{31})+1 (safe encoder digits)	2^{31}–1 (safe encoder digits)	1 (safe encoder digits)	Configures the absolute upper position limit for SLP instance 1.
SLP1 lower position limit	p12923	0x327B	Uint32	–(2^{31})+1 (safe encoder digits)	2^{31}–1 (safe encoder digits)	1 (safe encoder digits)	Configures the absolute lower position limit for SLP instance 1.

Table 62: SLP Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLP1 limit violation reaction	p12924	0x327C	Uint8	1	4	1	Configures which safety function will be activated if the SLP instance 1 limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2
SLP2 configured input	p12925	0x327D	Uint8	0	4	0	Configures the associated safe digital input used for SLP request instance 2. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLP2 initial delay	p12926	0x327E	Uint16	1 ms	60000 ms	1 ms	The time between SLP request instance 2 and the start of position monitoring.
SLP2 upper position limit	p12927	0x327F	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute upper position limit for SLP instance 2.
SLP2 lower position limit	p12928	0x3280	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute lower position limit for SLP instance 2.
SLP2 limit violation reaction	p12929	0x3281	Uint8	1	4	1	Configures which safety function will be activated if the SPL instance 2 limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

Table 62: SLP Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLP3 configured input	p12930	0x3282	Uint8	0	4	0	Configures the associated safe digital input used for SLP request instance 3. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLP3 initial delay	p12931	0x3283	Uint16	1 ms	60000 ms	1 ms	The time between SLP request instance 3 and the start of position monitoring.
SLP3 upper position limit	p12932	0x3284	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute upper position limit for SLP instance 3.
SLP3 lower position limit	p12933	0x3285	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute lower position limit for SLP instance 3.
SLP3 limit violation reaction	p12934	0x3286	Uint8	1	4	1	Configures which safety function will be activated if the SPL instance 3 limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

Table 62: SLP Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLP4 configured input	p12935	0x3287	Uint8	0	4	0	Configures the associated safe digital input used for SLP request instance 4. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLP4 initial delay	p12936	0x3288	Uint16	1 ms	60000 ms	1 ms	The time between SLP request instance 4 and the start of position monitoring.
SLP4 upper position limit	p12937	0x3289	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute upper position limit for SLP instance 4.
SLP4 lower position limit	p12938	0x328A	Uint32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (safe encoder digits)	1 (safe encoder digits)	Configures the absolute lower position limit for SLP instance 4.
SLP4 limit violation reaction	p12939	0x328B	Uint8	1	4	1	Configures which safety function will be activated if the SPL instance 4 limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.11 SCA Parameters

Table 63: SCA Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SCA1 upper position limit	p12950	0x3296	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	1 (safe encoder digits)	Configures the absolute upper position limit for SCA instance 1.
SCA1 lower position limit	p12951	0x3297	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	1 (safe encoder digits)	Configures the absolute lower position limit for SCA instance 1.

Table 63: SCA Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SCA2 upper position limit	p12952	0x3298	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute upper position limit for SCA instance 2.
SCA2 lower position limit	p12953	0x3299	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute lower position limit for SCA instance 2.
SCA3 upper position limit	p12954	0x329A	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute upper position limit for SCA instance 3.
SCA3 lower position limit	p12955	0x329B	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute lower position limit for SCA instance 3.
SCA4 upper position limit	p12956	0x329C	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute upper position limit for SCA instance 4.
SCA4 lower position limit	p12957	0x329D	int32	$-(2^{31})+1$ (safe encoder digits)	$2^{31}-1$ (speed change/ms)	0 (safe encoder digits)	Configures the absolute lower position limit for SCA instance 4.

6.2.12 SMS Parameters

Table 64: SMS Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
Speed maximum positive value	p12960	0x32A0	int32	0 (user position unit/s)	$2^{31}-1$ (user position unit/s)	0 (user position unit/s)	Configures the upper positive speed limit for SMS.
Speed maximum negative value	p12961	0x32A1	int32	$-(2^{31})+1$ (user position unit/s)	0 (user position unit/s)	0 (user position unit/s)	Configures the upper negative speed limit for SMS.
Limit violation reaction	p12962	0x32A2	Uint8	1	4	1	Configures which safety function will be activated if the SMS limits are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.13 SLS Parameters

Table 65: SLS Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLS1 configured input	p12970	0x32AA	Uint8	0	4	0	Configures the associated safe digital input used for SLS request instance 1. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLS1 maximum delay	p12971	0x32AB	Uint16	2 ms	60000 ms	2 ms	Configures the maximum time for the ramp-down of SLS instance 1.
SLS1 initial delay	p12972	0x32AC	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between SLS request instance 1 and the start of position monitoring.
SLS1 target speed detection delay	p12973	0x32AD	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between entering the speed window and early activation of SLS instance 1.
SLS1 minimal deceleration	p12974	0x32AE	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	Configures the minimal deceleration limit of SLS instance 1.
SLS1 speed window	p12975	0x32AF	Uint32	1 (user position unit/s)	2^{31}–1 (speed change/ms)	1 (user position unit/s)	Configures the allowed speed window of SLS instance 1.
SLS1 limit violation reaction	p12976	0x32B0	Uint8	1	4	1	Configures which safety function will be activated if the limits of SLS instance 1 are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

Table 65: SLS Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLS2 configured input	p12977	0x32B1	Uint8	0	4	0	Configures the associated safe digital input used for the request of the safety function. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLS2 maximum delay	p12978	0x32B2	Uint16	2 ms	60000 ms	2 ms	Configures the maximum time for the ramp-down of SLS instance 2.
SLS2 initial delay	p12979	0x32B3	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between SLS request instance 2 and the start of position monitoring.
SLS2 target speed detection delay	p12980	0x32B4	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between entering the speed window and early activation of SLS instance 2.
SLS2 minimal deceleration	p12981	0x32B5	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	Configures the minimal deceleration limit of SLS instance 2.
SLS2 speed window	p12982	0x32B6	Uint32	1 (user position unit/s)	2^{31}–1 (speed change/ms)	1 (user position unit/s)	Configures the allowed speed window of SLS instance 2.
SLS2 limit violation reaction	p12983	0x32B7	Uint8	1	4	1	Configures which safety function will be activated if the limits of SLS instance 2 are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

Table 65: SLS Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLS3 configured input	p12984	0x32B8	Uint8	0	4	0	Configures the associated safe digital input used for the request of the safety function. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLS3 maximum delay	p12985	0x32B9	Uint16	2 ms	60000 ms	2 ms	Configures the maximum time for the ramp-down of SLS instance 3.
SLS3 initial delay	p12986	0x32BA	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between SLS request instance 3 and the start of position monitoring.
SLS3 target speed detection delay	p12987	0x32BB	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between entering the speed window and early activation of SLS instance 3.
SLS3 minimal deceleration	p12988	0x32BC	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	Configures the minimal deceleration limit of SLS instance 3.
SLS3 speed window	p12989	0x32BD	Uint32	1 (user position unit/s)	2^{31}–1 (speed change/ms)	1 (user position unit/s)	Configures the allowed speed window of SLS instance 3.
SLS3 limit violation reaction	p12990	0x32BE	Uint8	1	4	1	Configures which safety function will be activated if the limits of SLS instance 3 are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

Table 65: SLS Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLS4 configured input	p12991	0x32BF	Uint8	0	4	0	Configures the associated safe digital input used for the request of the safety function. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLS4 maximum delay	p12992	0x32C0	Uint16	2 ms	60000 ms	2 ms	Configures the maximum time for the ramp-down of SLS instance 4.
SLS4 initial delay	p12993	0x32C1	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between SLS request instance 4 and the start of position monitoring.
SLS4 target speed detection delay	p12994	0x32C2	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between entering the speed window and early activation of SLS instance 4.
SLS4 minimal deceleration	p12995	0x32C3	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	Configures the minimal deceleration limit of SLS instance 3.
SLS4 speed window	p12996	0x32C4	Uint32	1 (user position unit/s)	2^{31}–1 (speed change/ms)	1 (user position unit/s)	Configures the allowed speed window of SLS instance 4.
SLS4 limit violation reaction	p12997	0x32C5	Uint8	1	4	1	Configures which safety function will be activated if the limits of SLS instance 4 are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.14 DLS Parameters

Table 66: DLS Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
DLS configured input	p13000	0x32C8	Uint8	0	4	0	Configures the associated safe digital input used for the DLS request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
DLS initial delay	p13001	0x32C9	Uint16	1 ms	60000 ms	1 ms	Configures the time between the DLS request and the start of speed monitoring.
DLS minimal deceleration	p13002	0x32CA	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	The minimal DLS deceleration limit.
DLS speed window	p13003	0x32CB	Uint32	1 (user position unit/s)	2^{31}–1 (speed change/ms)	1 (user position unit/s)	Configures the allowed DLS speed window.
DLS limit violation reaction	p13004	0x32CC	Uint8	1	4	1	Configures which safety function will be activated if the limits of DLS are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.15 SSR Parameters

Table 67: SSR Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SSR configured input	p13010	0x32D2	Uint8	0	4	0	Configures the associated safe digital input used for the SSR request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SSR maximum delay	p13011	0x32D3	Uint16	2 ms	60000 ms	2 ms	Configures the maximum time for the SSR ramp-down.
SSR initial delay	p13012	0x32D4	Uint16	1 ms	60000 ms	1 ms	Configures the time between the SSR request and the start of speed monitoring.
SSR target speed detection	p13013	0x32D5	Uint16	1 ms	60000 ms	1 ms	Configures the time interval between entering the speed window and early activation of SSR.
SSR minimal deceleration	p13014	0x32D6	Uint32	1 (speed change/ms)	2^{31}–1 (speed change/ms)	1 (speed change/ms)	Configures the SSR minimal deceleration limit.
SSR upper speed limit	p13015	0x32D7	int32	–(2^{31})+1 (user position unit/s)	2^{31}–1 (user position unit/s)	0 user position unit/s	Configures the SSR upper speed limit.
SSR lower speed limit	p13016	0x32D8	Uint32	–(2^{31})+1 (user position unit/s)	2^{31}–1 (user position unit/s)	0 user position unit/s	Configures the SSR lower speed limit.
SSR limit violation reaction	p13017	0x32D9	Uint8	1	4	1	Configures which safety function will be activated if the limits of SSR are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.16 SDI Parameters

Table 68: SDI Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SDI configured input for positive direction	p13020	0x32DC	Uint8	0	4	0	Configures the associated safe digital input used for the SDI request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SDI configured input for negative direction	p13021	0x32DD	Uint8	0	4	0	Configures the associated safe digital input used for the SDI request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SDI initial delay before SDI_p supervision	p13022	0x32DE	Uint16	1 ms	60000 ms	1 ms	Configures the time between the SDI_p request and the start of monitoring.
SDI initial delay before SDI_n supervision	p13023	0x32DF	Uint16	1 ms	60000 ms	1 ms	Configures the time between the SDI_n request and the start of monitoring.
SDI zero speed window	p13024	0x32E0	int32	1 (user position unit/s)	2^{31}–1 (user position unit/s)	1 (user position unit/s)	Configures the speed window in which the speed can be considered zero. The supervision of zero-speed is disabled when it is set to *0*.

Table 68: SDI Parameters - (continued)

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SDI zero position window	p13025	0x32E1	Uint32	1 (safe encoder digits)	2^{31}–1 (user position unit/s)	1 (safe encoder digits)	Configures the maximum drive movement before a safety function limit violation is detected.
SDI limit violation reaction	p13026	0x32E2	Uint8	1	4	1	Configures which safety function will be activated if the limits of SSR are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.17 SSM Parameters

Table 69: SSM Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SSM speed maximum positive value	p13030	0x32E6	int32	–(2^{31})+1 (user position unit/s)	2^{31}–1 (user position unit/s)	0 (user position unit/s)	Configures the upper speed limit for SSM.
SSM speed maximum negative value	p13031	0x32E7	int32	–(2^{31})+1 (user position unit/s)	2^{31}–1 (user position unit/s)	0 (user position unit/s)	Configures the lower speed limit for SSM.

6.2.18 SLA Parameters

Table 70: SLA Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SLA configured input	p13040	0x32F0	Uint8	0	4	0	Configures the associated safe digital input used for the SLA request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SLA initial delay	p13041	0x32F1	Uint16	1 ms	60000 ms	1 ms	Configures the time between the SLA request and the start of acceleration monitoring.
SLA upper acceleration limit	p13042	0x32F2	Int32	1 (speed change/ms)	2^{31}–1 (user position unit/s)	1 (speed change/ms)	Configures the maximum negative and positive acceleration limit of SLA.
SLA limit violation reaction	p13043	0x32F3	Uint8	1	4	1	Configures which safety function will be activated if the limits of SLA are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

6.2.19 SAR Parameters

Table 71: SAR Parameters

Parameter name	PN index	CoE index	Data type	Minimum	Maximum	Default	Description
SAR configured input	p13050	0x32FA	Uint8	0	4	0	Configures the associated safe digital input used for the SAR request. • 0 = not used • 1 = Safe Digital Input 1 • 2 = Safe Digital Input 2 • 3 = Virtual Input: logical AND between *Safe Digital Input 1* and *Safe Digital Input 2* • 4 = Virtual Input: logical OR between *Safe Digital Input 1* and *Safe Digital Input 2*
SAR initial delay	p13051	0x32FB	Uint16	0 ms	60000 ms	0 ms	Configures the time between the SAR request and the start of acceleration monitoring.
SAR upper acceleration limit	p13052	0x32FC	Int32	$-(2^{31})+1$ (speed change/ms)	$2^{31}-1$ (speed change/ms)	0 (speed change/ms)	Configures the maximum negative and positive acceleration limit of SAR.
SAR lower acceleration limit	p13053	0x32FD	Int32	$-(2^{31})+1$ (speed change/ms)	$2^{31}-1$ (speed change/ms)	0 (speed change/ms)	Configures the lower acceleration limit for SAR.
SAR limit violation reaction	p13054	0x32FE	Uint8	1	4	1	Configures which safety function will be activated if the limits of SAR are violated. • 1 = none • 2 = STO • 3 = SS1 • 4 = SS2

7 Service and Repair

7.1 Servicing and Modifications

Safety instructions for servicing, modifications, and updates.

⚠ CAUTION

FIRMWARE MODIFICATIONS

Unauthorized modifications made to the firmware can lead to injury or equipment damage, and void the warranty. Furthermore, Danfoss cannot be held liable for any consequences third-party changes may have on the functional safety.

- Only allow Danfoss to change the firmware.

⚠ CAUTION

MODIFICATIONS TO THE UNIT

Unauthorized modifications made to the unit can lead to injury or equipment damage, and void the warranty. Furthermore, Danfoss cannot be held liable for any consequences third-party changes may have on the functional safety.

- Only allow Danfoss to make hardware modifications to the product.

NOTICE

UPDATES TO FIRMWARE

Contact Danfoss to get an update of the firmware.

NOTICE

DIAGNOSTIC TEST

A diagnostic test may be required occasionally. For further information, see:

- 3.2.6.7 Diagnostic Test Interval
- 10.4.4.1 Performance of the STO Function without FS Control Board
- 10.5.2 Mechanical Brake Considerations

7.2 Repair

Do not attempt to repair the products. Defective products must be returned to Danfoss. Contact the local Danfoss sales company for information about returns.

7.3 Safety Device Replacement with ProfiSAFE

7.3.1 Introduction

Even though the iPar Server falls within the range of optional PROFINET features, it is by far one of the most significant additions when implemented on a PROFINET device.

It allows device manufacturers to dynamically load technology-specific parameters (“iParameters”) into field devices in addition to the static definitions in the GSD file. This can be done without stopping the line or having to rely on custom engineering tools.

Furthermore, the availability of an Ipar server can make the difference when a device replacement is needed, for example, due to a defect. In these cases the replacement device can be configured without using any engineering tool, thus reducing the down time of the whole line.

When an iPar Server is available, any field device or module (iPar-Clients) can automatically store (upload) and restore (download) iParameters data to/from the controller. This applies to both PROFINET or a PROFINET in combination with PROFIsafe one.

This automatic backup/restore mechanism can be provided as a function block or as a system function within the non-safety-related part of the safe PLC.

The solution described in this guide is based on a function block implementation of the iPar-Server capability, with particular focus on functional safety systems and safety parameters (F-Parameters).

A general overview of the communication between the PLC and the drive is given, as well as descriptions of the implementation details and data structures.

7.3.2 Overview

The operating principle of the iPar server mechanism is shown in Figure 33, where the commissioning phase of an F-device is demonstrated via an example:

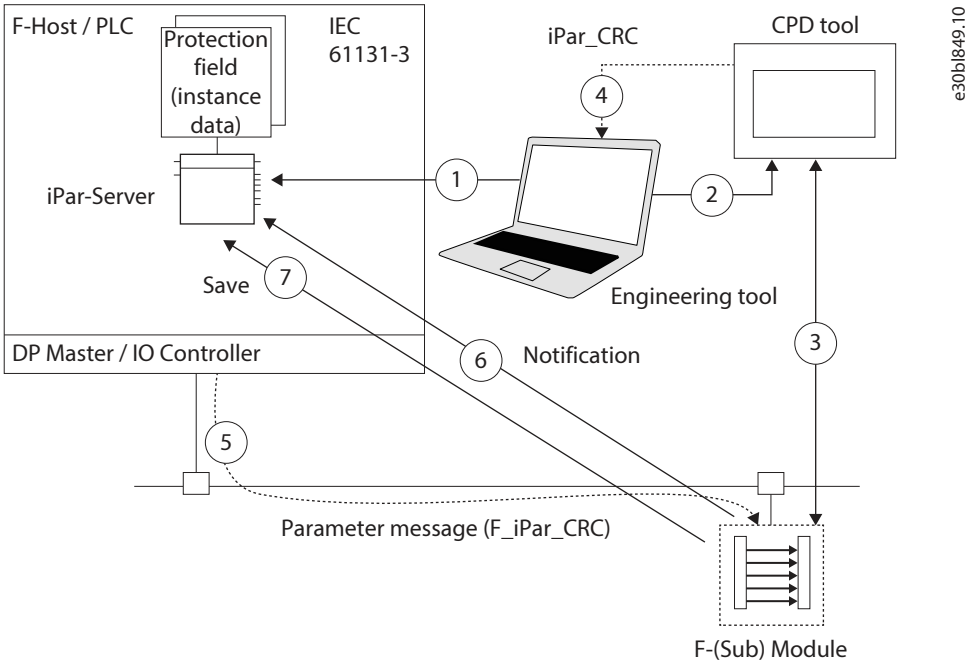

Figure 33: iPar Server Mechanism (Commissioning)

An iPar-Server function is first instantiated in the I/O Controller (step 1). The device is configured using a Configuration and Parameterization tool (CPD Tool) such as the Safety Configuration subtool in the VLT® Servo Toolbox, the official Danfoss tool for configuration and commissioning (steps 2 and 3). After successful download and validation of the safety configuration, the *iPar_CRC* signature calculated by the CPD-Tool can manually be copied to the *F_iPar_CRC* entry field in the engineering tools configuration section (step 4). This entry is part of the parameter assignment frame sent from the I/O controller to the F-device when starting (step 5).

The F-device sends a request for upload (notification) to the iPar-Server instance (step 6), which triggers the backup process (step 7) storing the iParameters as instance data.

The second part of the iPar-Server mechanism is shown in Figure 34, focusing on the common scenario of device replacement, for example, due to malfunction:

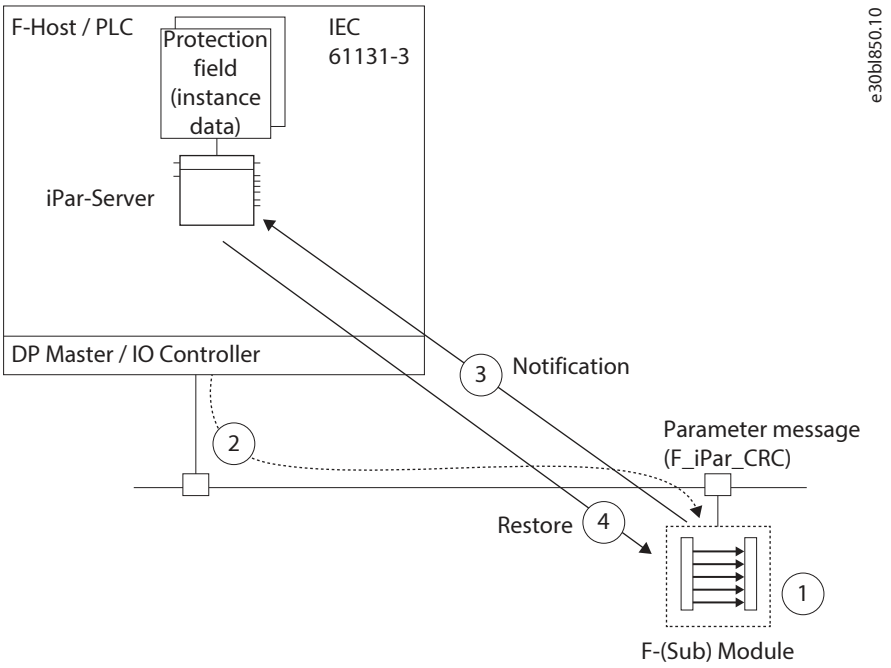

Figure 34: iPar Server Mechanism (Device Replacement)

The replacement device receives the static GSD-based F-Parameters, including the "F_iPar_CRC", at start-up (step 2). At the same time, as iParameters normally are missing in a replacement device, it starts a download notification to the iPar-Server instance (step 3). Finally, the iPar-Server establishes the download process which allows the parameters to be restored in the new device (step 4). This way the original functionality of the F-(Sub)Module can be re-established without using other engineering tools.

7.3.3 iPar Server as a Function Block

The Danfoss function block providing the iParServer functionality, named *DD_iParServer_DDS*, is implemented in the non-safety-related part of the controller. It can be triggered via the *Upload&Retrieval* mechanism, a new diagnostic alarm type explicitly introduced by PROFINET I/O for supporting the iPar-Server functionality.

Although the *Upload&Retrieval Alarm* has nothing to do with diagnostics, it contains all the information required to initiate an upload or download session. Depending on the type of request message (upload/download), the function block behaves differently:

- For an upload request (*back up request*), it reads the data record that contains the device-specific iParameters and stores them in a defined data block (unique across the project).
- For a download request (*restore request*), it reads the saved iParameters out of the data block and writes the data record to the device.

The details of this process are shown in Figure 35:

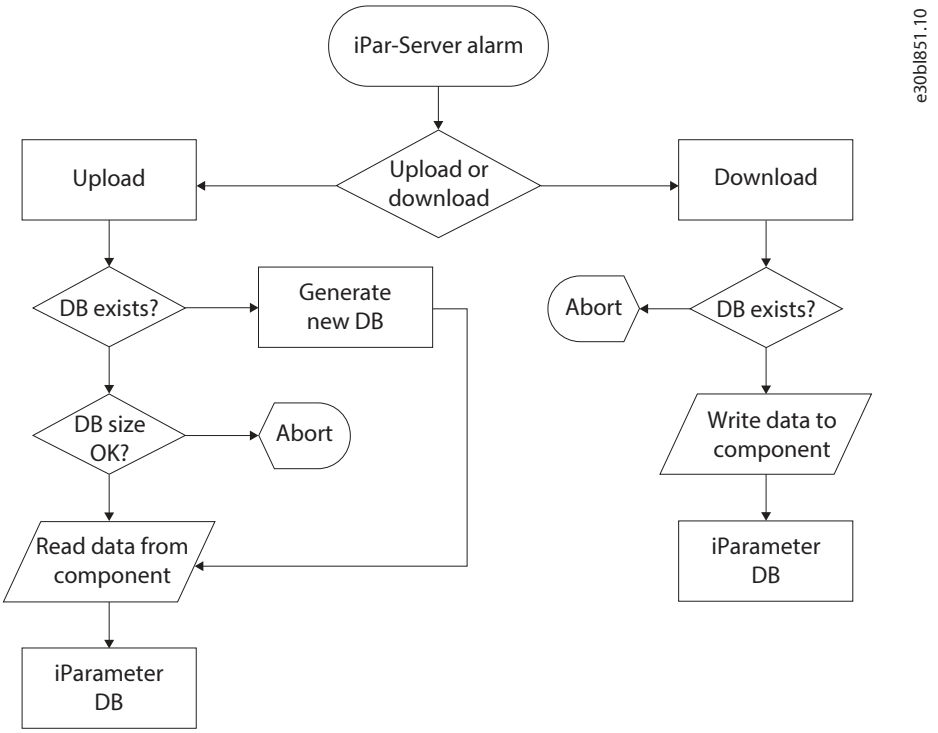

Figure 35: iPar-Server Process

Due to the large number of safety-related parameters involved, data transfer from/to the device takes place via segmented read/writes. These are based on *Pull* and *Push* services, which is an extended version of the *read record* and *write record* acyclic services.

When uploading data, each segment read from the device is stored to the right position in the data block it belongs to, and the ID is validated. If a data block is not already present in the PLC, a new data block is generated.

When downloading data, the function block first checks whether a valid data block exists in the PLC. If a data block can be found, it starts transferring data segments to the device.

7.3.4 Function Block

7.3.4.1 Function Block Description

The iPar Server function block is required not only to control the upload/download of data segments. It can also detect and analyze this new diagnostic alarm (*Upload&Retrieval*) whenever a parameters change occurs in the device.

Therefore, it is essential for it to be called in 2 different cyclic programs on the controller:

- A standard cyclic program (OB 1), where the process is handled after an alarm request has been received either for a download or an upload of iParameters.
- The *Update Alarm* OB (OB 56) that is called by the operating system of the PLC when an update interrupt occurs.

The complete function block interface is shown in Figure 36, while Table 72 provides a more detailed description of each input/output parameter:

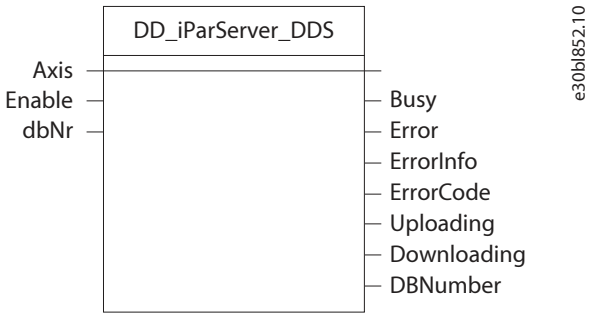

Figure 36: iPar Server Function Block

Table 72: Input and Output Variables

Parameter	Declaration	Data type	Description	Assignment
Enable	Input	BOOL	Start the iPar server functionality.	–
dbNr	Input	DB_ANY	The number must be unique for each component from which iParameters are to be saved.	Number of the data block for the iParameters
Axis	Input	DB_ANY	Reference to the axis.	–
Busy	Output	BOOL	The function block is not finished and new output values are expected.	–
Error	Output	BOOL	Signals that an error has occurred within the function block.	–
ErrorInfo	Output	DD_ERROR_DDS	Error identification and instance identifier.	–
ErrorCode	Output	INT	Return value of an application call.	–
Uploading	Output	BOOL	Signals that a backup of the iParameters is in progress	–
Downloading	Output	BOOL	Signals that a restore of the iParameters is in progress	–
DBNumber	Output	UINT	Number of the generated data block.	–

7.3.4.2 Error Codes

For proper working, the *DD_iParServer_DDS* function block relies on multiple internal system functions provided by SIEMENS® that could raise errors when something goes wrong. In such cases, the *ErrorCode* output gives feedback on the result of an alarm request.

Table 73 lists all the supported error codes along with a short description of the problem and a reference to the affected SIEMENS® system function. Possible solutions are given in the troubleshooting column:

Table 73: Error Codes

Error code	Description	System function	Troubleshooting
0xD000	No error.		
0xD001	No communication.		
0xD201	It was not possible to create the data block for the iParameter block.	CREATE_DB	Check and eliminate the error using the error information provided by *ErrorCode*.
0xD202	Data block ("dbNr") is too small for iParameter storage.	–	Check the required minimum length of your data block.
0xD203	Error while reading the alarm information.	RALRM	Check and eliminate the error using the error information provided by *ErrorCode*.
0xD204	Invalid request from the component. Possible reasons: • No request for upload or download of iParameters. • Data size too significant.	–	–
0xD205	Error while reading the iParameters from the component (upload).	RDREC	Check and eliminate the error using the error information provided by *ErrorCode*.
0xD206	Wrong segment while reading segmented iParameters.	–	–
0xD207	Error while reading/writing segment from/to the data block.	MOVE_BLK_VARIANT	Check and eliminate the error using the error information provided by *ErrorCode*.
0xD208	Error while writing the iParameters to the component (download).	WRREC	Check and eliminate the error using the error information provided by *ErrorCode*.
0xD209	Invalid data base data. The database contains not valid data to be send to the device.	–	–
0xD20A	Version ID within the data block ("dbNr") is invalid.	–	The 1st 2 bytes of the data block for the iParameters are reserved for the version ID and must not be changed.
0xD20B	Error while checking the existence of the DB with the "dbNr" number.	ATTR_DB	Check and eliminate the error using the error information provided by *ErrorCode*.

An overview of the internal function blocks with a brief description of their usage is given in Table 74. Refer to the TIA Online Help, if further information is needed.

Table 74: Internal Function Blocks

Function block	Function
MOVE_BLK_VARIANT	Move the content of a memory area (source range) to another memory area (target range).
RDREC	Read a data record from a component.
WRREC	Write a data record to a component.
ATTR_DB	Determine information via a data block.
CREATE_DB	Create a new data block with the given id.
PEEK/POKE	Read/write from/to a memory address.
RALRM	Readout the alarm information of a component.

A special call is the RALRM: It allows the system to receive an alarm from a module and needs to be called in the *Update Alarm* OB 56 program call.

A shown error code does not affect the execution of the function block. An error code is shown until it is overwritten with another one after successful transfer of the iParameters from or to the component. The request to read or write a data record is reset.

7.3.5 Data Block

7.3.5.1 Data Block for DD_iParServer_DDS

The repository used by *DD_iParServer_DDS*for iParameters storage is a globally defined data block of appropriate size, whose unique identification number is selected by the user via an input variable *dbNr*. If a data block with the given number does not exist, a new is automatically created with an ID in the range 60000–60999. This ID is available in the *DBNumber* output variable.

All data blocks created automatically by the function block are available just on the controller, but they can be downloaded to the working project for offline use.

It is also important to follow these rules for all data blocks supporting the iPar-Server functionality:

- Uncheck the *Optimized block access* checkbox.
- Add checkmark to the *Retain* checkbox.

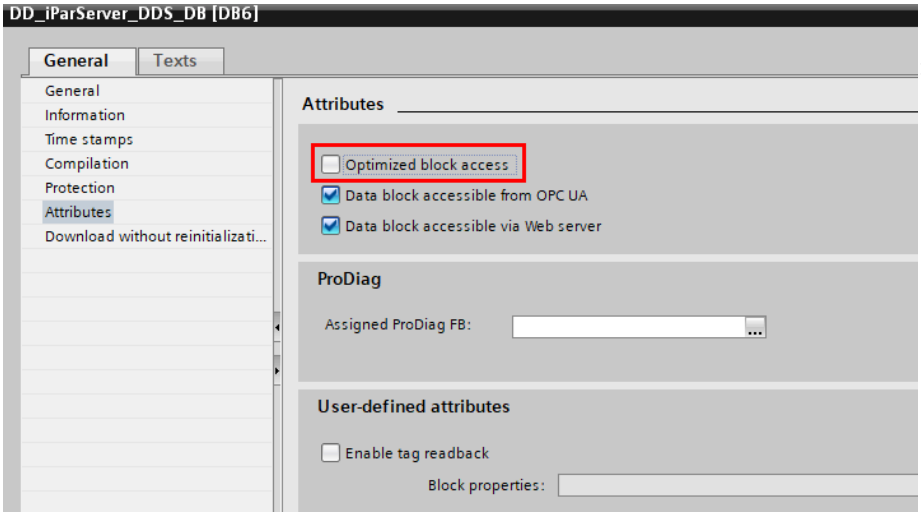

Figure 37: Optimized Block Access

8 Warnings and Alarms

8.1 Safe Alarm Codes

Table 75: Safe Alarm Codes

PN index	CoE index	Name	Severity	Description	LCP name
336	0xFF96	Safe Drive Internal Failure	Error	The drive detects an error and enters a fail-safe status. The error type is specified by the corresponding subcode.	Safe drv fail
366	0xFF97	FS Control board Internal Failure	Error	The FS Control board detects an error and enters a fail-safe status. The error type is specified by the corresponding subcode.	SIM fail

8.2 Safe Alarm Subcodes

8.2.1 Reading Safe Alarm Subcodes

The subcode related to each error can be read via object 0x4051 (Internal Alarm Subcode).

8.2.2 Safe Drive Internal Failure Subcodes

Table 76: Safe Drive Internal Failure Subcodes

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
No error	0	No error occurred.	No reaction	–
Watchdog Alarm	1	The application watchdog has expired.	Error	–
Fieldbus Mismatch Alarm	2	A mismatch between the fieldbus version of the FS Control board and the drive has been detected.	Error	–
UART Alarm	3	Hardware problems with the UART have been detected.	Error	–
RDY Alarm	4	FS Control board RDY line is low.	Error	The FS Control board RDY signal has been low for longer than the specified timeout.

Table 76: Safe Drive Internal Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
FS Control board Communication Timeout	5	The FS Control board communication timeout has expired.	Error	The FS Control board cyclic communication with the drive has been interrupted for longer than the specified timeout.
FS Control board Request-Response Timeout	6	The FS Control board request-response timeout has expired.	Error	The FS Control board acyclic communication with the drive has been interrupted for longer than the specified timeout

8.2.3 FS Control Board Failure Subcodes

Table 77: FS Control Board Failure Subcodes

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_NO_ERROR	0	No error occurred.	No reaction	Not applicable. Error code for internal use only.
ERROR_BUSY	1	The device is busy performing an action. This may be expected behavior.	No reaction	Not applicable. Error code for internal use only.
ERROR_NO_DATA_AVAILABLE	2	No data is available yet.	No reaction	Not applicable. Error code for internal use only.
ERROR_INVALID_CREDENTIALS	3	The username and password is invalid for this operation.	No reaction	Not applicable. Error code for internal use only.
ERROR_I2C_NAK	4	The I2C Driver reports a NAK.	No reaction	Not applicable. Error code for internal use only.
ERROR_TIMEOUT	5	A timeout has been detected.	No reaction	Not applicable. Error code for internal use only.
ERROR_INVALID_PARAMETER	6	The parameter is invalid.	No reaction	Not applicable. Error code for internal use only.
ERROR_CRC_INVALID	7	The checksum of the data block is invalid. The data has been read but is probably corrupt.	No reaction	Not applicable. Error code for internal use only.
ERROR_NO_IPARSERVER	8	No iPar server is available.	No reaction	Not applicable. Error code for internal use only.
ERROR_SAFETY_PARAMETER_INVALID	9	The safety parameters are invalid.	Invalidate safety parameters	Not applicable. Error code for internal use only.
ERROR_ACKNOWLEDGE_INPUT_FAULT	10	An acknowledge input fault occurred and acknowledge input is disabled.	No reaction	Not applicable. Error code for internal use only.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_ENCODER_INVALID_ASSOCIATION	11	The configuration of the encoder is incorrect and must be corrected.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_SAFE_FIELDBUS_CONFIG_MISMATCH	12	Safe fieldbus is disabled but black channel data is received.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_SAFE_FIELDBUS_FAULT	13	The safe fieldbus reported an error.	I/O Error (STO)	Instance = 0xFFFFFFFF, 0x80000000, 0: Internal error. Safe fieldbus is aborted. A power cycle may be required.
ERROR_MONITORING_BRAKE_OUTPUT	14	The monitoring of the brake output reported an error.	I/O Error (STO)	No details available.
ERROR_MISSING_PULSE_BRAKE_OUTPUT	15	The pulse monitoring of the brake output reported an error.	I/O Error (STO)	Instance = 1, additional value = time in ms since the last pulse started. Diagnostic operation was blocked. Instance = 2, additional value = 0: The drive did not respond to the request to enable maximum PWM. Instance = 2, additional value = 1: State before pulse does not match expectation. Instance = 2, additional value = 2: State during the pulse does not match expectation. Instance = 2, additional value = 3: Unexpected internal state.
ERROR_INPUT_DISCREPANCY	16	The calculation of the inputs differs between the 2 MCUs.	I/O Error (STO)	Instance = number of input 0 = Digital input 1, 1 = Digital input 2, 2 = STO Input
ERROR_INPUT_MISSING_PULSE	17	The expected pulse was not seen for the specified time.	I/O Error (STO)	Instance = Number of Input 0 = Digital Input 1, 1 = Digital Input 2, 2 = STO Input
ERROR_COMMUNICATION_DRIVE_FAILED	18	An error in communication with the drive occurred.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_NO_POSITION_AVAILABLE	19	A valid position is not available from the encoder.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_SPEED_BUFFER_NOT_FILLED	20	The buffer for the speed calculation is not filled.	I/O Error (STO)	Not applicable. Error code for internal use only.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_NO_SPEED_AVAILABLE	21	A valid speed is not available	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_ACCELERATION_BUFFER_NOT_FILLED	22	The buffer for the acceleration calculation is not filled.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_NO_ACCELERATION_AVAILABLE	23	No valid acceleration is available.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_INVALID_INTERFACE_VERSION	24	The protocol version of the service or safe fieldbus interface is not compatible with this FS Control board version.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_ENCODER_PARAMETER_MISMATCH	25	The received encoder configuration does not match the encoder configuration in the safety parameters.	I/O Error (STO)	Instance 0x80000000: Additional information = value found (no information given on which is the offending value). Others: Checksum mismatch. Expected = instance, received = additional information.
ERROR_ENCODER_ABSOLUTE_POSITION_INVALID	26	An absolute position for the encoder could not be retrieved. Therefore, its value is not safe.	I/O Error (STO)	Not applicable. Error code for internal use only.
ERROR_POWERSUPPLY_ENCODER_EXTERN	27	The power supply of the external encoder failed.	I/O Error (STO)	Instance = 12: Undervoltage detected Instance = 13: Overvoltage detected, additional information: measured voltage in uV.
ERROR_ENCODER_INTERNAL_ERROR	28	An internal encoder error occurred.	I/O Error (STO)	Instance = 0, additional information = 55: Speed or acceleration could not be calculated. No data position data available. Instance = 0: Internal encoder error. Additional information provides information on the internal error state. Instance > 0: Execution of the diagnostic is too slow, additional information contains the time since the last diagnostic operation was executed.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_ENCODER_INVALID_TYPE	29	The selected encoder type does not match the encoder attached to the drive.	Internal Error (STO)	Instance = 0, additional information = internal error code.
ERROR_MONITORING_STO	30	The monitoring of the STO output reported an error.	Internal Error (STO)	Instance = 0x80000000: Internal state invalid. Instance = 0: Feedback signal during startup is invalid. Instance!= 0: Feedback signal during normal operation is invalid.
ERROR_MONITORING_DUAL_DIGITAL_OUTPUT	31	The monitoring of the safe digital output reported an error.	Internal Error (STO)	Instance = Output Number (starting at 0). Additional information = 0: Error occurred during startup. Additional information!= 0: Fault occurred during cyclic testing
ERROR_MISSING_PULSE_DUAL_DIGITAL_OUTPUT	32	The pulse monitoring of the safe digital output reported an error.	Internal Error (STO)	Instance = Output Number (starting at 0). Additional information = Number of failed pulses.
ERROR_CROSS_COM_FAILED	33	Cross communication failed.	Internal Error (STO)	No details available. Sources cannot be distinguished reliably.
ERROR_CROSS_COM_CRC	34	CRC error detected in cross communication.	Internal Error (STO)	No details available.
ERROR_CROSS_COM_HEADER_CORRUPT	35	Corrupted header detected in cross-communication message.	Internal Error (STO)	No details available.
ERROR_CROSS_COM_SEND_BUFFER_OVERFLOW	36	Send buffer overflow in cross-communication.	Internal Error (STO)	No details available.
ERROR_DISCREPANCY	37	The calculation output differs between the 2 FMCUs.	Internal Error (STO)	Instance = MCUa result, additional information = MCUb result. No information on which part of the internal state is available (must be derived from previous results).
ERROR_TEMPERATURE_OUT_OF_LIMIT	38	The temperature of the device is too high or too low to continue operation.	Internal Error (STO)	Instance = Number of the temperature sensor. Additional Information = Measured value in mdeg Celsius.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_TEMPERATURE_SENSOR_BROKEN	39	The temperature sensor fails to report a value.	Internal Error (STO)	Additional value = Step of the operation that failed during startup. During normal operation, this error only occurs if communication to the sensor can not be established.
ERROR_TEMPERATURE_DISCREPANCY	40	The reported temperature sensor values are too far apart.	Internal Error (STO)	Instance = Number of the temperature sensor. Additional information = Deviation between the 2 MCUs in mdeg Celsius.
ERROR_POWERSUPPLY_OTHER_CHANNEL	41	The power supply of the other channel failed.	Internal Error (STO)	Instance = 4: Undervoltage Instance = 5: Overvoltage Additional value: Measured voltage in uV.
ERROR_POWERSUPPLY_STAGE1	42	The 1st stage power supply failed (15 V)	Internal Error (STO)	Instance = 8: Undervoltage Instance = 9: Overvoltage Additional value: Measured voltage in uV.
ERROR_POWERSUPPLY_STAGE2	43	The 2nd stage power supply failed (5 V)	Internal Error (STO)	Instance = 6: Undervoltage Instance = 7: Overvoltage Additional value: Measured voltage in uV.
ERROR_POWERSUPPLY_DIGITAL_IO	44	The power supply for the digital I/O failed (24 V).	Internal Error (STO)	Instance = 10: Undervoltage Instance = 11: Overvoltage Additional value: Measured voltage in uV.
ERROR_MANUFACTURING_PARAMETERS_INVALID	45	The manufacturing parameters are not valid or could not be read.	Internal Error (STO)	Instance = 0: Additional information = found manufacturing data version Instance!= 0, Additional information = 0: Error code for readout in instance number otherwise: Instance = Stored checksum, additional information = computed checksum.
ERROR_EXTERNAL_MEMORY_FAILED	46	A problem occurred with the external memory.	Internal Error (STO)	No details available.
ERROR_INTERNAL_FLASH	47	A problem occurred with the internal Flash memory.	Internal Error (STO)	No details available.
ERROR_INVALID_IOOPTION	48	The detected I/O option is invalid.	Internal Error (STO)	Additional information = detected pin state.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
ERROR_INITIAL_SYNC_FAILED	49	The initial sync between MCUa and MCUb failed.	Internal Error (STO)	No details available.
ERROR_SERVICECOM_COMMUNICATION_TIMEOUT	50	The ServiceCom communication timed out.	Internal Error (STO)	No details available.
ERROR_SERVICECOM_TOO_MANY_ERRORS	51	Too many ServiceCom communication errors have occurred.	Internal Error (STO)	Additional Information = last error code.
ERROR_SERVICECOM_REQUEST_TIMEOUT	52	The ServiceCom cyclic request timed out.	Internal Error (STO)	No details available.
ERROR_SERVICECOM_REQUEST_OVERFFLOW	53	The request sends queue overflowed.	Internal Error (STO)	No details available.
ERROR_RESTART_REQUIRED	54	The device requires a restart, for example after a software update.	Internal Error (STO)	No details available.
ERROR_COMPUTATION_FAILED	55	A calculation failed. Recovery is not possible.	Fatal failure	No details available.
ERROR_SAFE_FIELDBUS_INVALID_INSTANCE	56	Safe fieldbus is called with an invalid instance.	Fatal failure	No details available.
ERROR_SAFE_FIELDBUS_FATAL_ERROR	57	Safe fieldbus raises a fatal failure.	Fatal failure	No details available.
ERROR_ADC_TEST	58	Test of the ADC peripheral failed.	Fatal failure	No details available.
ERROR_INVALID_HW_REVISION	59	Invalid hardware revision read.	Fatal failure	No details available.
ERROR_INVALID_MCU_CHANNEL	60	Invalid MCU channel.	Fatal failure	No details available.
OS_ERROR_STACKPOINTER	61	The stack pointer position is invalid.	Fatal failure	No details available.
OS_ERROR_MAGICPATTERN	62	The stack has overflowed or underflowed.	Fatal failure	No details available.
OS_ERROR_CRITICAL_SECTION_USAGE	63	The critical section is used in an invalid context.	Fatal failure	No details available.
OS_ERROR_RESUME	64	The OS task resume action failed.	Fatal failure	No details available.
OS_ERROR_SLEEP	65	The OS task sleep action failed.	Fatal failure	No details available.
OS_ERROR_TASK_NOT_SLEEPING	66	The OS task is not sleeping.	Fatal failure	No details available.
OS_ERROR_ILLEGAL_TASKID	67	The OS task ID is invalid.	Fatal failure	No details available.
OS_ERROR_CYCLIC_TASK_CHECK_FAILED	68	An error occurred during a cyclic task.	Fatal failure	No details available.

Table 77: FS Control Board Failure Subcodes - (continued)

Enumeration name	Value	Description	Failure reaction	Instance/Additional information
OS_ERROR_CYCLIC_TASK_STATE_CHECK_FAILED	69	An error occurred during a cyclic task.	Fatal failure	No details available.
OS_ERROR_TASK_RETURNED	70	A task is returned.	Fatal failure	No details available.
OS_ERROR_INIT	71	An error occurred during OS initialization.	Fatal failure	No details available.
ERROR_CPU_TEST	72	The CPU test failed.	Fatal failure	No details available.
ERROR_RAM_TEST	73	The RAM test failed.	Fatal failure	No details available.
ERROR_CLOCK_SECURITY_SYSTEM_TEST	74	The clock security system test failed.	Fatal failure	No details available.
ERROR_TIMER_TEST	75	The timer test failed.	Fatal failure	No details available.
ERROR_APPLICATION_CRC_FAILED	76	The application CRC is invalid.	Fatal failure	No details available.
ERROR_INVALID_FUNCTION_CALL	77	This function may not be called at this time.	Fatal failure	No details available.
ERROR_INVALID_STATE	78	This function can not be called in this state. This is a direct mapping to an error code in the communication with the drive.	Fatal failure	No details available.
ERROR_INVALID_ACCESS	79	The value/parameter can not be accessed as requested.	Fatal failure	No details available.
ERROR_INVALID_VERSION	80	The version check result shows that this version is invalid.	Fatal failure	No details available.
ERROR_OUT_OF_RANGE	81	The values given are out of range.	Fatal failure	No details available.

9 Maintenance

9.1 Maintenance Tasks

Table 78: Maintenance Tasks

Component	Maintenance task	Maintenance interval	Instruction
Mechanical brake	Check brake friction work	Every 12 months	Check the brake and ensure it can perform sufficient friction work.

10 Specifications

10.1 Consumption

Table 79: Consumption Values

Type	Value
Power consumption FS Control board	1.2 W
Current consumption FS Control board on +5 V internal supply	<0.23 A
Current on auxiliary supply +24 V changes with FS Control board (standby) and Safe I/O board	+35% (standard configuration without safety boards)

10.2 Inputs

10.2.1 Digital Inputs

Table 80: Digital Input Characteristics Supported by the Safe I/O Board

Type	Value
Number of safe digital inputs	4 (2 x dual channel)
Nominal input voltage range	0–24 V DC
Input voltage range, logic 0	0–5 V DC
Input voltage range, logic 1	>10 V DC
Input voltage maximum	30 V
Maximum input current at low level	5 mA
Minimum input current at high level	1.5 mA
Maximum input current at high level	15 mA
Typical input current at high level (24 V)	3.5 mA
Galvanic isolation	Yes
Minimum recognition test pulse time	300 µs
Discrepancy time	Configurable 1–200 ms
Filter time	Configurable 2–60 ms
Cable length	Maximum 30 m (98 ft) (shielded)

NOTICE

- Do not connect any capacitive load >120 nF to any of the digital outputs.

10.2.2 Encoder Interface

The DSD 520 provides the encoder interface with these characteristics.

Table 81: Encoder Interface Characteristics

Characteristic	Value
Number of encoder interfaces	1
Type	HIPERFACE® DSL
Implementation according to SICK specification	Yes

Table 81: Encoder Interface Characteristics - (continued)

Characteristic	Value
Supply voltage range	7–12 V
Nominal supply voltage	11.5 V
Inrush current (for first 100 µs)	3.5 A
Maximum supply current	250 mA
Galvanic isolation	No
Cable length	Maximum 100 m (328 ft) (shielded)

10.3 Outputs

10.3.1 Digital Output

Table 82: Digital Input Characteristics Supported by the Safe I/O Board

Type	Value
Number of safe digital inputs	4 (2 x dual channel)
Nominal input voltage range	0–24 V DC
Input voltage range, logic 0	0–5 V DC
Input voltage range, logic 1	>10 V DC
Input voltage maximum	30 V
Maximum input current at low level	5 mA
Minimum input current at high level	1.5 mA
Maximum input current at high level	15 mA
Typical input current at high level (24 V)	3.5 mA
Galvanic isolation	Yes
Minimum recognition test pulse time	300 µs
Discrepancy time	Configurable 1–200 ms
Filter time	Configurable 2–60 ms
Cable length	Maximum 30 m (98 ft) (shielded)

10.3.2 24 V Supply Output

In addition to the 2 safe dual-channel outputs, the Safe I/O board also provides a 24 V output that is not safety-related (it is without the presence of test pulses in the output voltage). The 24 V output is present on pin 4 of the I/O connectors.

Table 83: 24 V Supply Output Characteristics

Characteristic	Value
Number of digital outputs	1[(1)]
Nominal output voltage high	24 V DC ±15%
Nominal output voltage low	<5 V DC
Maximum low level output current	100 µA
Maximum high level output current	100 mA

Table 83: 24 V Supply Output Characteristics - (continued)

Characteristic	Value
Galvanic isolation	No
Short-circuit protected	Yes
Cable length	Maximum 30 m (98 ft) (shielded)

1) Not safety-related

10.3.3 Brake Output

This section applies to DSD 520.

Table 84: Brake Output

Characteristic	Value
Number of brake output interfaces	1
Nominal output voltage high	Powered from auxiliary supply
Control mode	Current/voltage control mode
Maximum high-level output current	1.2 A
Galvanic isolation	No
Short-circuit protected	Yes
Overload protection	Yes
Overload trip maximum current	2.1 A
Brake control circuit architecture	Dual channel
Diagnostic test pulse time for channel A and channel B	1 ms every 30 s

NOTICE

- Mechanical brakes with an inductivity of >0.6 H are not allowed.

10.4 Safety Characteristic Data

10.4.1 Safety Functions and Features

Table 85: Safety Functions and Features

Abbreviation	Description[1]
STO	Safe torque off
SS1-t	Safe stop 1 time based
SS1-r	Safe stop 1 ramp monitored
SS2-r	Safe stop 2 ramp monitored
SOS	Safe operating stop
SLA	Safety-limited acceleration
SAR	Safe acceleration range
SLS	Safety-limited speed
DLS	Dynamically limited speed[2]
SMS	Safe maximum speed[2]

Table 85: Safety Functions and Features - (continued)

Abbreviation	Description[1]
SSR	Safe speed range
SLP	Safety-limited position
SLI	Safety-limited increment
SDI	Safe direction
SCA	Safe CAM
SSM	Safe speed monitor
SBC	Safe brake control

1) EN 61800-5-2.

2) Not described under EN 61800-5-2, added by Danfoss.

NOTICE

- In addition to the safety functions, the Advanced Functional Safety portfolio provides a diagnostic feature called SBT, which verifies the safe mechanical brake. The diagnostic feature applies torque to the motor while the brake is closed and checks that the shaft cannot rotate.

10.4.2 Available Configurations

The ISD 520 servo drive has an integrated encoder and mechanical brake.

For the DSD 520 servo drive, the safety characteristics depend on the selected safety encoder and mechanical brake. Ensure that the overall safety characteristics take the data provided by the manufacturer into consideration.

Table 86: Safety Functions Allowed by the Configuration

Configuration	Safety functions
Product without safety boards	STO (via STO input)
Product with safety boards	STO (via STO input, over fieldbus, via Safe I/O), SS1-t
Product with safety boards and safety encoder	STO (via STO input, over fieldbus, via Safe I/O), SS1-t, SS1-r, SS2-r, SOS, SLS, DLS, SMS, SLA, SSR, SDI, SLP, SLI, SAR, SSM, SCA
Product with safety boards, safety encoder, and mechanical brake	STO (via STO input, over fieldbus, via Safe I/O), SS1-t, SS1-r, SS2-r, SOS, SLS, DLS, SMS, SLA, SSR, SDI, SLP, SLI, SAR, SSM, SCA, SBC

NOTICE

- For ISD 520, the safety functions that use the encoder are limited to safety integrity level SIL 2 due to the SIL 2 encoder.
- For DSD 520, the overall SIL level of the safety functions that use the encoder is determined by the customer safety encoder.

10.4.3 Safety Functions with FS Control Board

10.4.3.1 Performance of Safety Functions with FS Control Board

NOTICE

- The safety characteristic data of the safety boards include the data of the FS Control board and the data of the Safe I/O board.
- The safety characteristic data in Table 87 with safety encoder apply to ISD 520 and DSD 520. The safety characteristic data refer to the series EES37-2, EEM37-2. Contact Danfoss for other supported safety encoders.
- The safety characteristic data in Table 87 with mechanical brake only apply to ISD 520. For DSD 520, combine the values from the table with the data provided by the 3rd party brake manufacturer.

Table 87: Performance of Safety Functions with FS Control Board

Abbreviation	Description	Value[1]
General information		
–	Reaction time for STO function activated by hard-wired STO input without mechanical brake	Maximum 15 ms
–	Reaction time for STO function activated by hard-wired STO input with mechanical brake	Maximum 30 ms + delay brake closing time
–	Reaction time for STO function activated by Safe I/O digital input without mechanical brake	Maximum 15 ms + t_FILTER
–	Reaction time for STO function activated by Safe I/O digital input with mechanical brake	Maximum 30 ms + t_FILTER + delay brake closing time
–	Reaction time for STO function activated via safety fieldbus without mechanical brake	Maximum 25 ms
–	Reaction time for STO function activated via safety fieldbus with mechanical brake	Maximum 25 ms + delay brake closing time
–	Mission time, proof test interval	20 years
EN ISO/ISO 13849-1		
PL	Performance level (safety boards only)	e (maximum 16 drives)[2]
	Performance level (with safety encoder or mechanical brake)	d[3]
Cat.	Category (without mechanical brake)	3[2]
	Category (with mechanical brake)	2[3]
DCavg.	Average diagnostic coverage (safety boards only)	99%
	Average diagnostic coverage (with safety encoder)	90%
EN/IEC 61508		

Table 87: Performance of Safety Functions with FS Control Board - (continued)

Abbreviation	Description	Value[1]
SIL	Safety Integrity Level (safety boards only)	3 (maximum 16 drives)[2]
	Safety Integrity Level (with safety encoder or mechanical brake)	2[3]
PFH (see 10.4.3.2 Calculation Example for Safety Chain PFH)	Probability of dangerous failure per hour (safety boards only[4])	5×10^{-9}/h
	Probability of dangerous failure per hour (mechanical brake only)	0×10^{-9}/h (fault exclusion)
	Probability of dangerous failure per hour (safety boards[4] with safety encoder at 60 °C and mechanical brake)	31×10^{-9}/h
	Probability of dangerous failure per hour (safety boards[4] with safety encoder at 80 °C and mechanical brake)	57×10^{-9}/h
	Probability of dangerous failure per hour (safety boards[4] with safety encoder at 100 °C and mechanical brake)	110×10^{-9}/h
SFF	Safe failure fraction (safety boards only)	99%
	Safe failure fraction (with safety encoder)	90%
–	Subsystem classification	Type B
–	Diagnostic test interval	1 year (only required for STO input or Safe I/O digital inputs, if test pulses are not used). For SBC, see 10.5.2 Mechanical Brake Considerations.

1) With FS Control board.

2) If test pulses are used, SIL 3, PL e, Cat. 3 also apply to STO via STO input or Safe I/O digital inputs.

3) The maximum number of drives depends on the PFH of the safety encoder within the safety application.

4) The residual error rate of the safety fieldbus is not included in the PFH value. Ensure that the overall PFH calculation also contains the fieldbus.

⚠ WARNING

RISK OF FALLING LOAD

If the STO is activated by an STO input, the FS Control board does not respect the time to engage the mechanical brake. STO is activated independently from the delay parameter (brakeTime), which may result in an unwanted movement leading to death or serious injury.

- Add measures to prevent unintended movement before operating the motor.

NOTICE

- For detailed information on the diagnostic test interval, see 3.2.6.7 Diagnostic Test Interval.
- Do not operate the device for more than 20 years (mission time).

10.4.3.2 Calculation Example for Safety Chain PFH

- Safety PLC
- Fieldbus cabling

- 2 drives configured for STO activation over fieldbus (FSoE or PROFIsafe)

Contribution to the safety chain of the safety PLC: PFH_{PLC} refer to manufacturer data.

Contribution to the safety chain of using FSoE or PROFIsafe is 1.0×10^{-9}/h.

Contribution to the safety chain of the 2 drives PFH refer to the relevant value in Table 87.

Total value: $PFH_{total} = PFH_{PLC} + 2 \times PFH + 1.0 \times 10^{-9}$/h.

10.4.4 STO Function without FS Control Board

10.4.4.1 Performance of the STO Function without FS Control Board

Table 88: Performance of the STO Function without the FS Control Board

Abbreviation	Description	Value[1]
General information		
–	Reaction time for STO function activated via hard-wired STO input	Maximum 100 ms
–	Mission time, proof test interval	20 years
EN ISO/ISO 13849-1		
PL	Performance Level	d (maximum 80 drives)
Cat.	Category	3
DCavg	Average diagnostic coverage	60%
EN/IEC 61508		
SIL	Safety Integrity Level	2 (maximum 80 drives)
PFH	Probability of dangerous failure per hour	3×10^{-9}/h
SFF	Safe failure fraction	82%
–	Subsystem classification	Type A
–	Diagnostic test interval	1 year (maximum)

1) Without FS Control board.

10.5 Mechanical Brake

10.5.1 Mechanical Brake Characteristic Data

There is an optional mechanical brake for the ISD 520 servo drives. The mechanical brake is an element of the safety chain and is used by the SBC function. The diagnostic function SBT is implemented to verify the integrity of the mechanical brake. Table 89 shows the characteristics of the different mechanical brakes available for the ISD 520 servo drives.

Table 89: ISD 520 Mechanical Brake Characteristics Including Release and Engage Times

Code number	Release delay [ms]	Engage delay [ms]	Brake nominal holding torque [Nm]	Brake nominal holding torque (safety limits) [Nm]
2T5	60	10	3.2	2.13
3T5	60			

Table 89: ISD 520 Mechanical Brake Characteristics Including Release and Engage Times - (continued)

Code number	Release delay [ms]	Engage delay [ms]	Brake nominal holding torque [Nm]	Brake nominal holding torque (safety limits) [Nm]
4T0	55	38	8	5.33
4T5	55			
5T0	55			
6T5	55			
9T0	75	25	17	11.33
14T0	50	30	15	10.00
19T0	110	70	33	22.00

The mechanical brake within the ISD 520 is a holding brake and only a limited number of emergency cycles can be applied to the brake.

An additional derating named *Nominal holding torque (safety limits)* is applied to the nominal holding torque.

Do not exceed the brake *Nominal holding torque (safety limits)*. The safety application ensures that the indicated torque limit on the motor shaft is not exceeded by any external load and by the motor itself.

The dynamic (emergency) brake event is limited according to Table 90.

Table 90: ISD 520 Mechanical Brake Dynamic Brake Characteristics

Code number	Emergency Stops						
	Maximum operating cycles as holding brake (on/off)	Total number of stops	Maximum stops/hour	Maximum energy for each stop [J]	Maximum safe energy for each stop [J]	Maximum speed [RPM]	Maximum inertia (motor + load) [kgcm^2]
2T5	5000000	1000	20	200	133	3000	20
3T5							
4T0				250	167		25
4T5							
5T0							
6T5							
9T0				330	220		33
14T0							
19T0				420	280		42

The parameters in Table 90 are defined in Table 91.

Table 91: Parameter Descriptions

Parameter	Description
Maximum operating cycles as holding brake (on/off)	Maximum number of complete switchings (on and off)
Emergency stop	Occasional event in which the brake is required to perform a braking operation to decelerate and stop the shaft; the torque during this phase can be higher or lower than the nominal holding torque.
Total number of emergency stops	Maximum number of total braking operations for a given energy, inertia, frequency, and speed limits; it must be strictly observed to avoid diminished brake torque and brake malfunction/damage.
Maximum energy for each stop	Maximum allowed friction work for each stop, for a given speed, and braking operations frequency; it must be strictly observed to avoid diminished brake torque and brake malfunction/damage.
Maximum speed	Maximum shaft speed during braking operation; speed values higher than this value substantially reduce the maximum allowed friction work.
Maximum inertia	Maximum allowed total (brake+motor+load) inertia during a braking operation; it must be strictly observed to avoid diminished brake torque and brake malfunction/damage.
Release time	Time for the mechanical brake to release the motor shaft (typical value).
Engage time	Time for the mechanical brake to de-energize the mechanical brake (typical value).

10.5.2 Mechanical Brake Considerations

Storage

If the brake has not been used for some time (for example, for motors kept in stock or brake not being activated/deactivated for long time), it is necessary to carry out a brake run-in process to restore the correct value of braking torque. The run-in process can be executed by executing the transition from *operation enabled* to *operation disabled* in the state machine. Execute the run-in process several times within the specified emergency brake limits. At the end of the procedure, verify the brake torque and, if necessary, repeat the process.

The torque can drop if the brake is not used for a prolonged period. Check that the brake can perform sufficient friction work once per year.

Radial and axial loads

Radial and axial loads applied on the motor shaft end must be within the prescribed limits to avoid damaging of the brake. An excessive thrust load on the shaft, for example, during installation of the motor in the machine, can lead to permanent deformation and the inability to engage the brake. For further information, refer to the *VLT® Servo Drive System ISD 520/DSD 520 Operating Guide*.

Liquids

The brake is designed to operate dry. Avoid contaminating the friction surfaces with grease, oil, or other fluids to avoid braking torque reduction. Ensure that external oil or other fluids cannot penetrate the motor shaft.

Adverse conditions

Negative effects on the brake torque (for example, brake torque variations, reduced brake torque) can occur from adverse conditions. Carry out the run-in process and torque verification for the brake.

Torque reductions

Using the brake primarily as a holding brake can lead to torque reductions over time.

Brake wear

Consider the gradual brake wear of the friction surfaces due to emergency stops. Excessive wear leads to an excessive air gap resulting in the inability to engage the brake or it can only be engaged with insufficient torque.

Diagnostics

- Danfoss recommends executing the diagnostic test on the mechanical brake (SBT) after every 8 hours of operation. The application must ensure that the load does not block the shaft during the execution, otherwise the diagnosis cannot execute correctly.
- The diagnostic measures of the mechanical brake are the responsibility of the user.
- SBT does not claim a SIL level and does not provide a safe result. The torque application to the motor is not implemented within the safety chain. Ensure that the mechanical brake diagnostic is executed correctly.
- Ensure that the attached load does not block the shaft during the SBT execution.
- Ensure that torque is applied during the test by checking that the cabling and connections are not open or damaged. Also, monitor the energy consumption to evaluate if torque is applied to the motor.
- If the diagnostic reports an issue or problem with the brake, bring the system into a safe state. This has an impact on certain applications, such as gravity loads where the safe state must be guaranteed by additional measures.
- The time interval for the execution of SBT depends on the overall machine level. If necessary, amend the interval to meet the machine process safety time.

10.6 Cables

For information on cables, refer to the operating guide and the design guide of the specific product in which the safety boards are installed.

10.7 General Specifications and Environmental Data

The VLT® FlexSafety™ environmental ratings depend on the ratings of the product in which the safety boards are installed.

Refer to the relevant product operating guide for confirmed data and values.

For DSD 520, protect the safety encoder on the motor by an enclosure rated at least IP54.

11 Appendix

11.1 Abbreviations

Table 92: Abbreviations

Abbreviation	Description
Cat	Category B, 1–4
DC	Diagnostic coverage
DLS	Dynamically limited speed
FIT	Failures in time (1E-9/hour)
HFT	Hardware fault tolerance HFT = n means that n+1 faults could cause a loss of the safety function
$MTTF_D$	Mean time to failure – dangerous
PFH	Probability of dangerous failures per hour Consider this value if the safety device is operated in high demand or continuous mode of operation, where the frequency of demands for operation made on a safety-related system is greater than 1 per year.
PL	Performance level The discrete level is used to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions. Levels divided into a-e.
SAR	Safe acceleration range
SBC	Safe brake control
SBT	Safe brake test
SCA	Safe CAM
SDI	Safe direction
SFF	Safe failure fraction
SIL	Safety integrity level
SLA	Safety-limited acceleration
SLI	Safety-limited increment
SLP	Safety-limited position
SLS	Safety-limited speed
SMS	Safe maximum speed
SOS	Safe operating stop
SP	Safe position
SS1	Safe Stop 1
SS2	Safe Stop 2
SSM	Safe speed monitor
SSR	Safe speed range
STO	Safe torque off

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