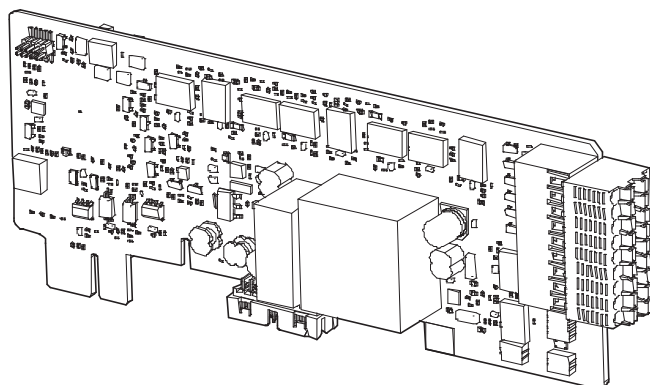


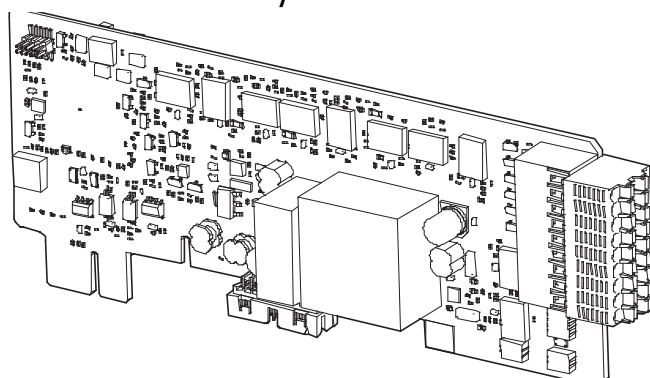
PowerXL™

Safety Option Cards for DX1 Variable Frequency Drives
(Original instructions)

DXX-EXT-SABZ
Safety ABZ Encoder Card



DXX-EXT-FS
Functional Safety Card



Powering Business Worldwide

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Service

For service and support, please contact your local sales organization.

Contact data: [Eaton.com/contacts](https://www.eaton.com/contacts)

For customers in US/Canada contact:

EatonCare Customer Support Center

Call the EatonCare Support Center if you need assistance with placing an order, stock availability or proof of shipment, expediting an existing order, emergency shipments, product price information, returns other than warranty returns, and information on local distributors or sales offices.

Voice: 877-ETN-CARE (386-2273) (8:00 a.m. – 6:00 p.m. EST)

After-hours emergency: 800-543-7038 (6:00 p.m. – 8:00 a. m. EST)

Drives Technical Resource Center

Voice: 877-ETN-CARE (386-2273) option 2, option 6

(8:00 a.m. – 5:00 p.m. Central Time U.S. [UTC-6])

Email: TRCDrives@Eaton.com

[Eaton.com/drives](https://www.eaton.com/drives)

Original Operating Instructions

The English-language edition of this document is the original operating manual.

Translation of the original operating manual.

All editions of this document other than those in German language are translations of the original operating manual.

1. 2025 edition, publication date 09/25

2. 2026 edition, publication date 01/26

See revision protocol in the „About this manual“ chapter.

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Subject to alteration.



Danger! **Dangerous electrical voltage!**

Before commencing the installation

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally retriggered.
- Verify isolation from the supply.
- Ground and short-circuit.
- Cover or enclose neighbouring units that are live.
- Follow the engineering instructions (IL) of the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE) must be connected to the protective earth (PE) or to the potential equalizing. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines must be installed so that inductive or capacitive interference do not impair the automation functions.
- Install automation devices and related operating elements in such a way that they are well protected against unintentional operation.
- Suitable safety hardware and software measures must be implemented for the I/O connection so that a cable or wire breakage on the signal side does not result in undefined states in the automation device.
- Ensure a reliable electrical isolation of the low voltage for the 24 V supply. Only use power supply units complying with IEC 60364-4-41 or HD 384.4.41 S2 (VDE 0100 part 410).
- Deviations of the mains voltage from the nominal value must not exceed the tolerance limits given in the technical data, otherwise this may cause malfunction and dangerous operation.
- Emergency-Stop devices complying with IEC/EN 60204-1 must be effective in all operating modes of the automation devices. Unlatching the emergency switching off devices must not cause restart.
- Built-in devices for enclosures or cabinets must only be run and operated in an installed state, desk-top devices or portable devices only when the housing is closed.
- Measures must be taken to ensure the proper restart of programs interrupted after a voltage dip or failure. This must not cause dangerous operating states even for a short time. If necessary, emergency switching off devices must be implemented.
- Wherever faults in the automation system may cause damage to persons or property, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (for example, by means of separate limit switches, mechanical interlocks, etc.).
- During operation, and depending on their degree of protection, variable frequency drives may have live, uninsulated, moving, and/or rotating parts, as well as hot surfaces.
- The impermissible removal of the required cover, improper installation or incorrect operation of the motor or variable frequency drive can cause the failure of the device and serious injury and/or material damage.
- Comply with all applicable national accident prevention regulations (e.g. BGV A3) when working with energized variable frequency drives.
- The electrical installation must be carried out in accordance with the relevant regulations (e.g. with regard to cable cross sections, fuses, PE).
- All transport, installation, commissioning and maintenance work must only be carried out by trained personnel (observe IEC 60364, HD 384 or DIN VDE 0100 and national accident prevention regulations).
- If applicable, systems in which variable frequency drives are installed must be equipped with additional monitoring and protective devices in accordance with the applicable safety regulations, e.g., the German Equipment and Product Safety Act, accident prevention regulations, etc. Making changes to the variable frequency drives by using the operating software is allowed.
- Keep all covers and doors closed during operation.
- When designing the machine, the user must incorporate mechanisms and measures that limit the consequences of a drive controller malfunction or failure (an increase in motor speed or the motor's sudden stop) so as to prevent hazards to people and property, e.g.:
 - Additional stand-alone devices for monitoring parameters that are relevant to safety (speed, travel, end positions, etc.)
 - Electrical and non-electrical safety devices (interlocks or mechanical locks) for mechanisms that protect the entire system
 - Due to the possibility of there being capacitors that are still holding a charge, do not touch live device parts or terminals immediately after disconnecting the variable frequency drives from the supply voltage. Heed the corresponding labels on the variable frequency drives

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0 About this manual

0.1 Subject

This manual is the original operating manual and describes functionality of FS card.

This document provides information about the safety module and the supported safety functions. The manual explains the installation of FS and S-ABZ cards and also describes their configuration and commissioning in addition to supported safety functions.

It defines how the requirements for the safety life cycle of FS and S-ABZ cards can be met and maintained to ensure the necessary performance and specified safety standards.

For drive-specific technical, configuration, and installation details, please refer to the Drive Application Manual (MN040069EN) and Installation Manual (MN040068EN).

The following chapters describe special information for project planning, installation, and operation of FS and S-ABZ cards in addition to safety functions.

0 About this manual

0.2 Target audience



0.2 Target audience

This manual is intended for engineers, electricians, and automation technicians. A thorough knowledge of the Power Drive System and the programming of a Safety PLC is required. In addition, knowledge of commissioning the DX1 variable frequency drive is required. Please read this manual carefully before running FS card or S-ABZ card. We assume that you have a good knowledge of engineering fundamentals, and that you are familiar with handling electrical systems and machines, as well as with reading technical drawings.

The manual is specifically designed for qualified individuals responsible for designing, planning, installing, and commissioning safety applications. Prior to commencing work on the safety application, it is essential to thoroughly read this manual. Proficiency in safety technology, electricity, wiring, electrical components, and electrical circuit symbols is imperative.

Authorization to work on and with this product is granted exclusively to adequately trained individuals who possess a comprehensive understanding of the contents of this manual and all other pertinent product documentation. Furthermore, these individuals must have practiced the safety training to identify and mitigate associated hazards.

Moreover, these individuals must have attained sufficient technical training, knowledge, and experience to anticipate and recognize potential hazards. They must be adept at foreseeing and identifying potential risks stemming from the use of the product, adjustments to settings, and the mechanical, electrical, and electronic components of the overall system in which the product is integrated. It is imperative that all individuals involved in working with the product are well-acquainted with all relevant documentation. Extensive knowledge of safety standards such as EN ISO 12100, EN 61800-5-2, EN ISO 13849-1, EN ISO 13849-2, EN 61508, EN 60204-1 and EN IEC 62061 are mandatory.

 	CAUTION Installation requires a qualified electrician
---	---

0.3 List of revisions

The following significant amendments have been introduced since previous issues:

Publication date	Page	Keyword	new	modified	deleted
01/26	29	→ Figure 11		✓	
01/25		First edition	✓		

0.4 Writing conventions

Symbols with the following meaning are used in this manual:

NOTICE

Indicates a potentially hazardous situation that may result in property damage.



CAUTION

Warns of hazardous situations that may cause slight injury.



WARNING

Warns of hazardous situations that could result in serious injury or death.



DANGER

Warns of hazardous situations that result in serious injury or death.



Draws your attention to interesting tips and supplementary information

0 About this manual

0.5 Safety warning concerning property damage

0.5 Safety warning concerning property damage

Ensure that the service life of each individual component employed in your application is sufficient for the intended overall service life of your application.

After an emergency stop, the shutdown must align with Stop Category 0 (e.g. STO), Stop Category 1 (e.g. SS1) or Stop Category 2 (e.g. SS2) according to EN 60204-1.

To prevent the risk of injury resulting from unintended movements of the motor, automatic restart following an emergency stop must be avoided.

Conduct thorough commissioning tests for all potential error situations to verify the effectiveness of safety-related functions and monitoring mechanisms implemented. This covers, but is not limited to, speed monitoring using encoders, short-circuit monitoring for all connected equipments, and the proper functioning of brakes and guards.

0.6 Safety warning concerning personal injury hazards**CAUTION**

Warns of hazardous situations that may cause slight injury.

**WARNING**

Warns of hazardous situations that could result in serious injury or death.

**DANGER**

Warns of hazardous situations that result in serious injury or death.



Indicates useful tips.

Risk of injury or fatality exists when safety instructions and residual risks are disregarded. Failing to comply with the safety instructions and residual risks specified in the associated hardware documentation can lead to accidents causing severe injuries or death. It is crucial to rigorously adhere to the safety instructions provided in the hardware documentation and to consider residual risks during the risk assessment.

Motors can generate voltage during shaft rotation. Before undertaking any work on the drive system, secure the motor shaft to prevent rotation. Avoid contact with unshielded components or terminals with active voltage. Disconnect all power sources, including external control power, and be aware that the circuit breaker or main switch may not de-energize all circuits.

Adhere to all accident prevention regulations and local safety guidelines. Each product implementation must undergo thorough individual testing for proper operation before being put into service. Do not operate the product with unknown or inappropriate settings or data.

The application comprises various interconnected mechanical, electrical, and electronic components, with the drive being just one component. The drive alone is neither intended nor capable of providing the entire functionality to meet all safety-related requirements applicable to the application.

0.7 Exemption of liability

We have provided all the information in this manual to the best of our knowledge and in accordance with the latest state of the art safety technology. This statement emphasizes the commitment to delivering accurate and up-to-date information, aligning with industry standards and practices. However, this does not exclude the possibility of inaccuracies so that we cannot accept any liability for the accuracy and completeness of the information. Here, the acknowledgment of the potential for inaccuracies reinforces transparency. It also clarifies that the company cannot be held responsible for any discrepancies or omissions. In particular, this information does not guarantee any particular properties. This phrase underscores that the information provided serves as a guide and reference but does not imply a warranty for specific features or outcomes.

The devices described must only be installed and operated in accordance with the content of documentation (this manual and the installation instructions) provided with the device. This highlights the importance of strictly adhering to the provided documentation to ensure proper installation and operation of the devices.

Installation, commissioning, operation, maintenance, and refitting of the devices must only be carried out by qualified persons. The emphasis on qualified personnel underlines the need for expertise in handling various aspects of the devices' lifecycle, promoting safety and optimal performance.

The devices must only be used in the areas recommended and only in conjunction with third-party devices and components that have been approved by us. This emphasizes the importance of following specified guidelines and using approved components to maintain the integrity of the system.

Only use in a technically faultless condition is permitted. Fault-free and safe operation of the system requires proper transport, storage, installation, as well as careful operation and maintenance. If these safety instructions are not observed, particularly with regard to commissioning and maintenance of the devices by insufficiently qualified personnel and/or in the event of improper use of the devices, any hazards caused by the devices cannot be excluded. This warning underscores the potential risks associated with non-compliance, particularly when tasks are performed by inadequately qualified personnel or when devices are used improperly. We cannot accept any liability for any resulting injury or damage.

0.8 Documents with additional information



More information on the devices described here can be found online at:

eaton.com/powerxl

as well as

eaton.com/documentation

In the Search field, enter the document name (for example "MN040070EN" for this manual).

Before starting the implementation of safety-related systems, it is highly recommended to read and understand the following documents, which will also be referred to in the later chapters.

Type	Description	Document
Manual	Safety Manual	MN040070EN
Manual	PowerXL™ DX1 Series VFD Installation manual	MN040068EN
Manual	Safety Tool for PowerXL™ Series DX1 VFD manual	MN040074EN
Instruction Leaflet	PowerXL™ DX1 Series S-ABZ card Instruction Leaflet	IL040093EN
Instruction Leaflet	PowerXL™ DX1 Series FS card Instruction Leaflet	IL040090EN
Product notification	Safety-relevant characteristic values for Eaton components	MZ027051EN



WARNING

The housing, as well as other safety-relevant parts, has been left out in some of the figures in this manual in order to make the figures easier to understand. However, it is important to note that the components described in this manual must always be operated with their housing installed properly, as well as with all required safety-relevant parts.



DANGER

In cases like active components are controlled, such as motors or pressurized cylinders, incorrect connection or configuration of FS or S-ABZ cards may damage plant and endanger persons



DANGER

The power up of the PowerXL™ DX1 Drive must not cause any hazards arising from activated devices, such as unexpected motor startups or power ups.



Functionality of the security application must be verified under the System Security Inspection Plan after modification or configuration of parameters subsequent to initial commissioning of FS card or S-ABZ card.

0 About this manual

0.8 Documents with additional information

WARNING

During phases of the product lifespan in which FS card and S-ABZ card option may not provide protection, such as during commissioning, equipment maintenance, troubleshooting, and decommissioning, user safety must be ensured through alternative means.



WARNING

Intentional misuse: Operate FS card or S-ABZ card in compliance with the guidelines provided in the user manual. Eaton is not responsible for damages resulting from the misuse of the cards. FS card and S-ABZ card are not designed to protect a machine against intentional misuse.



All the specifications in this manual refer to the hardware and software versions documented in it. Follow the installation instructions in the relevant instruction leaflets.

0.9 Abbreviations

The following abbreviations are used in this manual.

Table 1: Abbreviations and symbols

EMC	Electromagnetic compatibility
FS card	Functional safety card
S-ABZ card	Safety ABZ encoder card
GND	Ground (0 V potential)
CB_MCU	MCU processor on DX1 drive
CB_DSP	DSP processor on DX1 drive
SABZ_MCU	Processor on Safety ABZ encoder card
FS_MCU	Processor on functional safety card
LED	Light emitting diode (LED)
PC	Personal computer
PLC	programmable logic controller
UL	Underwriters Laboratories
SIL	Safety Integrity Level
PL	Performance Level
PFH	Average Frequency of a Dangerous Failure per hour
MTTFd	Mean time to dangerous failure
DCavg	Average diagnostic coverage
PFDavg	Average probability of dangerous failure on demand
TM	Mission time
AWG	American wire gauge
Cat.	Classification of the safety-related parts of a control system
E-stop	Emergency stop
SAR	Safe acceleration range
SBC	Safe brake control
SLS	Safely limited speed
SLS-r	Safely limited speed ramp monitor
SLS-t	Safely limited speed time monitor
SS1	Safe stop 1
SS1-r	Safe stop 1 ramp monitor
SS1-t	Safe stop 1 time monitor
SS2	Safe stop 2
SS2-r	Safe stop 2 ramp monitor
SS2-t	Safe stop 2 time monitor
SOS	Safe operating stop
SLA	Safe limited acceleration
SSR	Safe speed range
SDI	Safe direction

0 About this manual

0.10 Units of measurement

SDI-r	Safe direction ramp monitor
SDI-t	Safe direction time monitor
SSM	Safe speed monitor
STO	Safe torque off
ISO	International Organization for Standardization
EN	Europien Norm
IEC	International Electrotechnical Commission
DC	Diagnose coverage
HFT	Hardware Fault Tolerance
PDS	Power Drive System
DO	Digital Output
DI	Digital Input
NC	Normally Closed
NO	Normally Open
SELV	Safety Extra Low Voltage
PELV	Protective Extra Low Voltage
DTI	Diagnostic Test Interval
Acknowledgement	Refers to the user confirmation of remove safety functions. Through "acknowledgement", it avoids safety risks caused by accidental operations, ensuring the legitimacy and safety of the remove operation.
Reset	Refers to the user clears the current fault information and tries to restore the ready state of the device.

0.10 Units of measurement

Every physical dimension included in this manual uses international metric system units, otherwise known as SI units (International System of units). For the purpose of the equipment's UL certification, some of these dimensions are accompanied by their equivalents in imperial units.

Table 2: Unit conversion examples

Designation	US-American Designation	Anglo American value	SI value	Conversion value
Length	inch	1 in (")	25.4 mm	0.0394
Output	horsepower	1 HP = 1.014 PS	0.7457 kW	1.341
Torque	pound-force inches	1 lbf in	0.113 Nm	8.851
Temperature	Fahrenheit	1 °F (T _F)	-17.222°C (T _C)	T _F = T _C × 9/5 + 32
Speed	revolutions per minute	1 rpm	1 min ⁻¹	1
Weight	pound	1 lb	0.4536 kg	2.205
Flow rate	cubic feed per minute	1 cfm	1.698 m ³ /min	0.5889

1 Series

1.1 Checking the delivery

Before opening the package, please check the nameplate on it to make sure that you received the correct type.

FS and S-ABZ cards are carefully packed and shipped. The device must be shipped only in its original packaging and using a suitable means of transportation.

Please take note of the labels and instructions on the packaging, as well as the manual for the unpacked device.

Open the packaging with suitable tools and inspect the contents immediately after receipt in order to ensure that they are complete and undamaged.

→ FS card package must contain the following parts:

- DXX-EXT-FS: FS card
- Instruction leaflet, IL040090EN

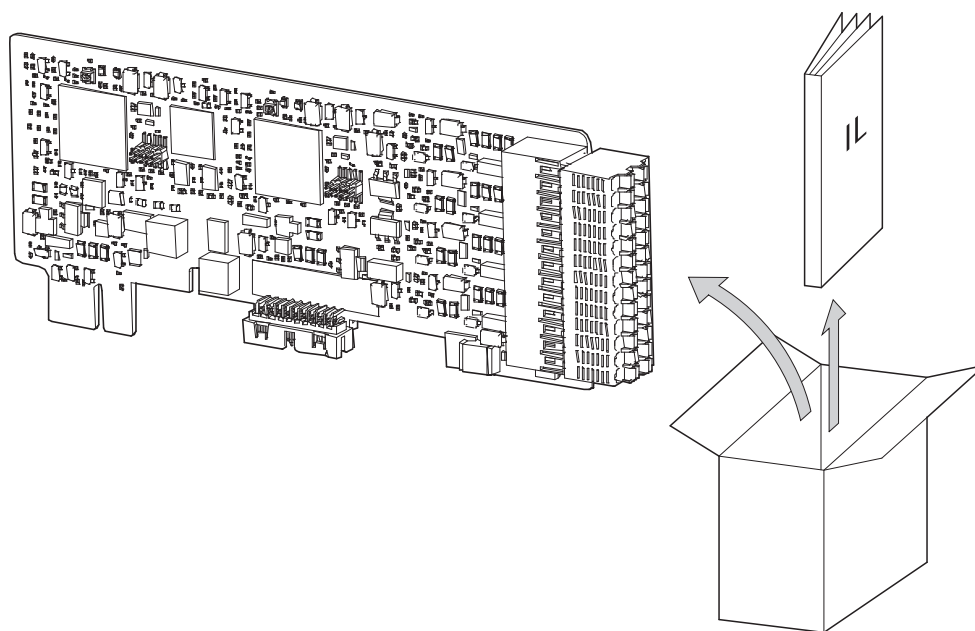


Figure 1: Scope of delivery for the DXX-EXT-FS FS card

1 Series

1.1 Checking the delivery

→ S-ABZ Card package must contain the following parts:

- DXX-EXT-SABZ: S-ABZ card
- Instructional leaflet IL040093EN

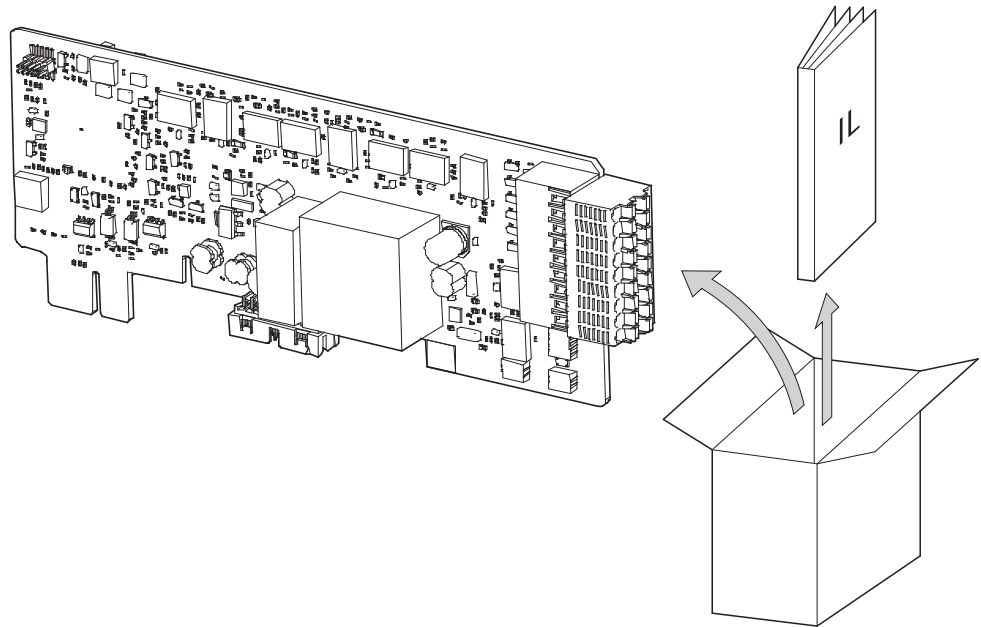


Figure 2: Scope of delivery for the DXX-EXT-SABZ S-ABZ card

→ FS and S-ABZ card must be ordered separately!

1.2 Type code

The type code and type designation of the functional safety system is described below:

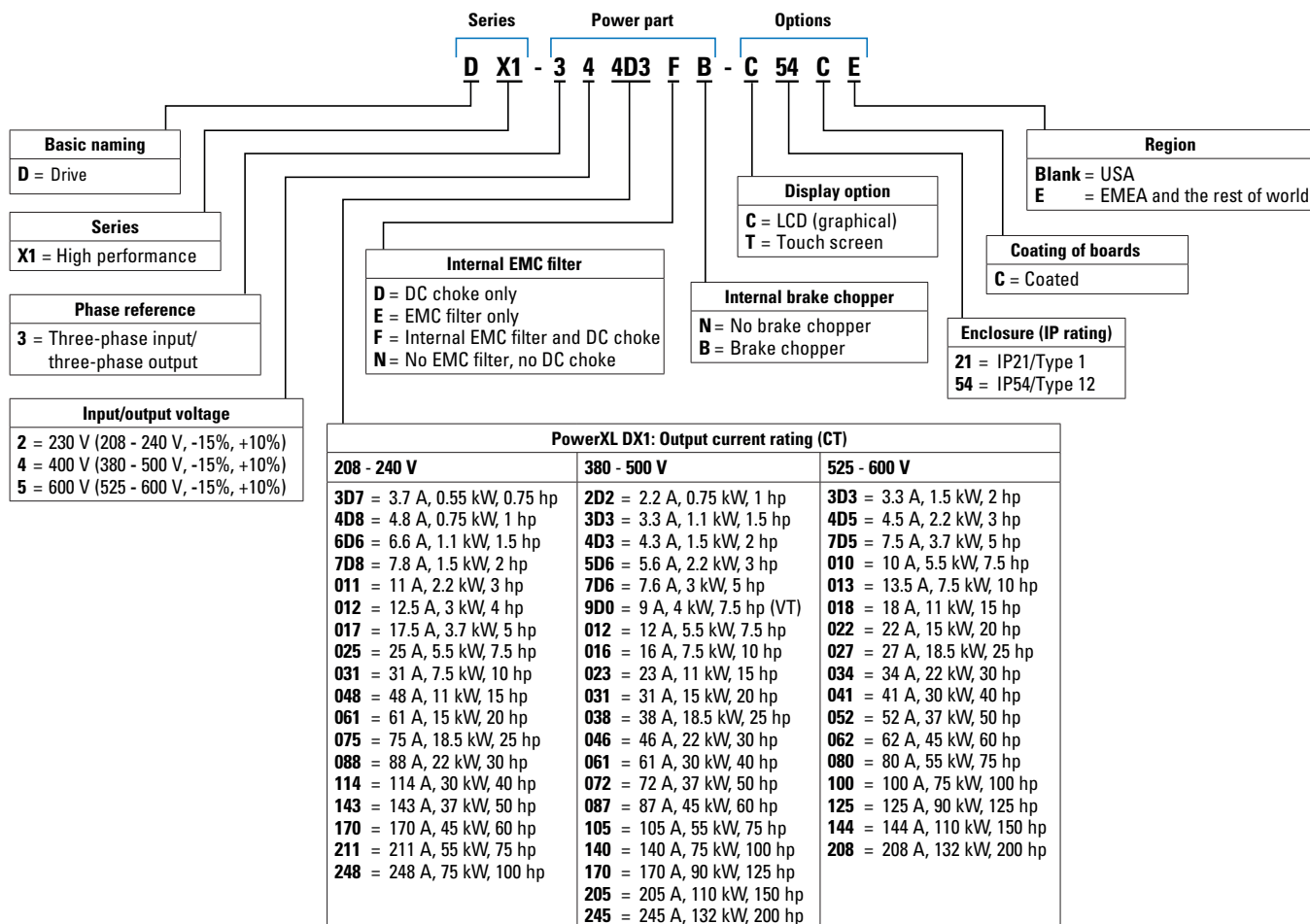


Figure 3: Type code of the PowerXL™ DX1 Series VFD

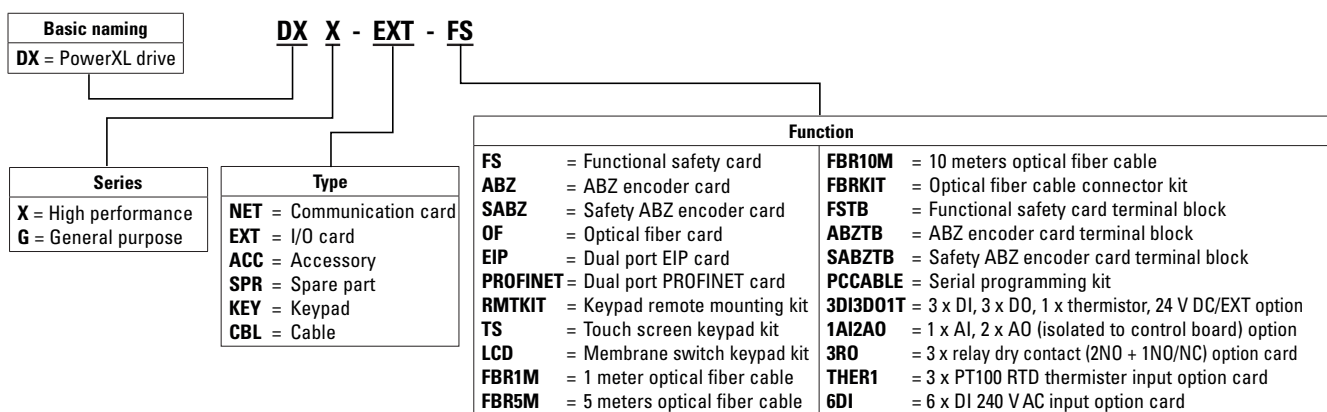


Figure 4: Type code of the DXX-EXT-FS functional safety card

1 Series

1.3 Approbations / Approvals / Certifications

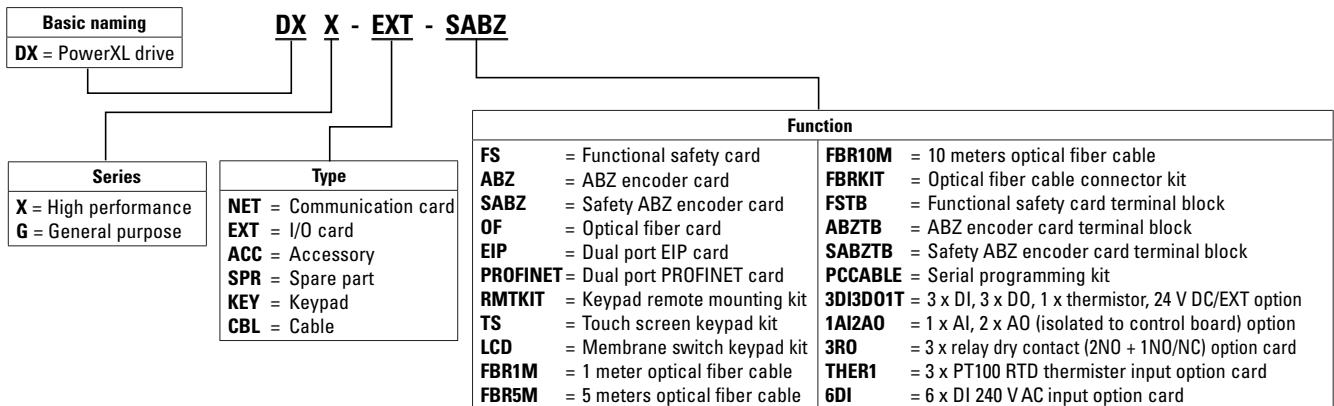


Figure 5: Type code of the DXX-EXT-SABZ safety encoder card

1.3 Approbations / Approvals / Certifications

The safety functions are compatible with and certified according to EN 61800-5-2 Adjustable speed electrical power drive systems Part 5-2: Safety requirements - Functional.

EN 61800-5-2, as a product standard, sets out safety-related considerations of Power Drive System Safety Related PDS (SR)s in terms of the framework of the EN 61508 series of standards.

Compliance with the EN 61800-5-2 standard, for the safety functions described below, facilitate incorporation of a PDS (SR) (Power Drive System suitable for use in safety-related applications) into a safety-related control system using the principles of EN 61508 or EN ISO 13849-1, as well as EN IEC 62061 for process systems and machinery.

Approbations / Approvals / Certifications

EN 61800-5-2:2007 Adjustable Speed Electrical Power Drive Systems - Part 5-2: Safety Requirements - Functional
EN 61800-5-2:2017 Adjustable Speed Electrical Power Drive Systems - Part 5-2: Safety Requirements - Functional
EN ISO 13849-1:2023 Safety of Machinery - Safety-related parts of control systems - Part 1: General Principles for Design
EN 61508 Parts 1-3:2010 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related systems
EN IEC 62061:2021 + A1:2024 Safety of machinery - Functional safety of safety related control systems
EN IEC 61800-3:2018 Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods
EN IEC 61800-3:2023 Adjustable speed electrical power drive systems-Part 3: EMC requirements and specific test methods for PDS and machine

1.4 Environmental specification

Table 3: Ambient conditions

Ambient Conditions	Description
Operating Ambient Temperature	-10 °C (no frost) to +50 °C
Storage Temperature	-40 °C to +70 °C
Relative Humidity	0 to 95% RH, non-condensing, non-corrosive
Altitude	100% load capacity (no derating) up to 1000 m; 1% derating per 100 m up to 2000 m
Enclosure Rating IEC/EN 61800-5-1 IEC/EN 60529	IP21 or IP54 rated for the whole DX1 drive's protection enclosure. All safety related (either electrical safety or functional safety related) circuits are inside and protected by this protection enclosure.
Thermal Immunity IEC/EN 61800-5-2 IEC/EN 61800-5-1	Functional thermal test and component thermal test must be performed and passed according to IEC/EN 61800-5-2 Clause 9.4 requirements.
Vibration IEC/EN 61800-5-2 IEC/EN 61800-5-1 IEC 60068-2-6 (Test Fc)	Drive mounted as normal use. Power supply connected and drive operating normally. Sinusoidal motion Vibration amplitude/acceleration: 10 Hz ≤ f ≤ 57 Hz: 0.075 mm amplitude 57 Hz < f ≤ 150 Hz: 1 g Vibration duration: 1 oct/min, 10 sweep cycles per axis on each of 3 mutually perpendicular axes
Shock IEC/EN 61800-5-2 IEC 60068-2-27	Drive mounted as normal use. Power supply connected and drive operating normally. Half sine pulse motion Peak acceleration 5 g with duration 30 ms Total 18 shocks for 3 mutually perpendicular axes and 6 directions

Table 4: EMC Directive

EMC Directive	Description
Standard	IEC/EN 61800-5-2 IEC/EN 61800-3
Environment	2nd environment
Location	Industrial location
Test Requirements For 230/480V series DX1 Drives	C2 @10m (with internal filter) C3 @50m (with internal filter)
Test Requirements For 575V series DX1 Drives	C3 @10m (with internal filter)

1.5 Power supply

DX1 must meet electrical safety requirements acc. to below table together with functional safety consideration.

Electrical safety requirements

Table 5: Electrical safety requirements

Standard	IEC/EN 61800-5-1
Mains Supply System	TN, TT and IT Systems (including corner-earthed system)
Overvoltage Category	Overvoltage Category III
Pollution Degree	Pollution Degree 2

Power supply for all DX1 safety relevant circuits is provided by drive itself.

AC input voltage

The AC input voltage rating for DX1 drives is specified as below:

Table 6: The AC input voltage rating for DX1:

Input voltage rating	Input voltage range
3 Phase, 208 VAC - 240 VAC, 50-60 Hz	-15 % to +10 %, 45-66 Hz
3 Phase, 380 VAC - 500 VAC, 50-60 Hz	-15 % to +10 %, 45-66 Hz
3 Phase, 525 VAC - 600 VAC, 50-60 Hz	-15 % to +10 %, 45-66 Hz

Encoder Voltage

S-ABZ card offers power supply for safety encoder via VPG terminal. Two power supply voltage levels (15 V, 24 V) are selectable for user based on the safety encoder requirement. The technical data for these two power supply voltage levels are defined in below table:

Table 7: Encoder Voltage

Voltage Level	Minimum Voltage	Typical Voltage	Maximum Voltage
15 V	12.75 V	15 V	17.25 V
24 V	21.6 V	24 V	26.4 V



The two-channel power supply for safety encoder combined maximum power is 4.8 W.

External 24 V DC Supply Voltage

An external power supply unit can be used to supply the DX1 variable frequency drive's control board with 24 V DC.

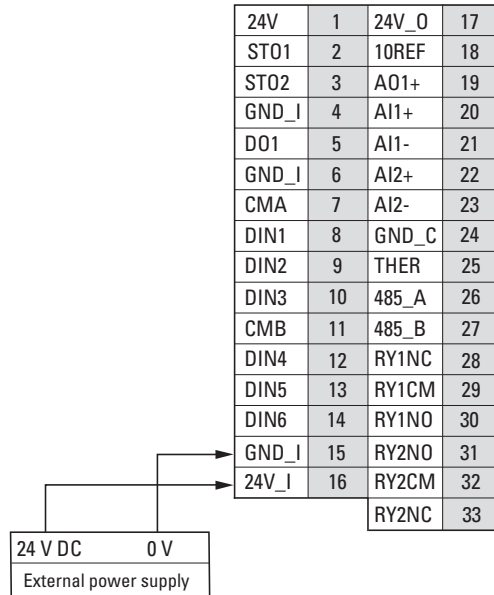


Figure 6: External power supply

DX1 can be supplied by an external 24 V power supply via user terminal block on control board of DX1 (not on FS card). The external 24 V power supply must meet SELV/PELV requirements. In case of power supply failure, the external 24 V power supply voltage must never exceed 60 V DC. The technical data is defined as below

Table 8: Technical data

24 V input voltage rating	Input voltage range	Abnormal voltage
24V_I SELV/PELV	21.6 V DC - 26.4 V DC	≤ 60 V DC Exceeding the nominal supply voltage range may definitely damage the safety related circuit (stay in safe state up to 60 V)



24V_I can handle a load of at least 100 mA. This external power supply voltage's residual ripple must be smaller than ±5%.



WARNING

For the 24V_I, it is only for debug, it must not be used during the VFD is operation.

The power supply of 24V_I must not be connected to the DC public power network during the debug phase, and the power connection line must be less than 3 meters.

Further details on 24V_I can be found in DX1 Installation Manual MN040068EN.

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1.6 Speed estimation

If the control section is powered with an external power supply unit, the control section, the control signal terminals, and the RJ45 interface will be active.

If no mains supply is available, using 24V_I you will be able to do the followings:

- Change parameters of FS card via the RJ45 interface by using Safety Tool
- Monitor parameters of FS card via the RJ45 interface by using Safety Tool
- Monitor values of Encoder with S-ABZ card via the RJ45 interface by using Safety Tool
- Read status and errors of DX1 by using Incontrol Software via Modbus TCP and Modbus RTU
- Change parameters DX1 by using Incontrol Software via ModbusTCP and ModbusRTU

1.6 Speed estimation

Speed estimation	Description
Speed range	The maximum speed can be configured by user, and its range is from (-24000 rpm/number of motor pole pairs) to (+24000 rpm/number of motor pole pairs). The motor speed is used in all safety functions.
Accuracy	The motor speed estimation error is less than 0.5%*maximum speed. Note: <ul style="list-style-type: none">• The motor speed estimation error will change with the clock frequency error. When the clock frequency error is less than 1%, the motor speed estimation error will not exceed 1.5% * maximum speed. When the clock frequency error exceeds 1%, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.• Less than the 0.5%*maximum speed only be used for non-safety functions.• All speed related safety functions must take 1.5% error into consideration
	With asynchronous motors, there can be small estimation ripples at the zero speed region (below 30 rpm).
Operational frequency	Drive output up to 400 Hz

1.7 Size and weight

1.7.1 Size of the chassis

The dimensions for DX1 series drives are shown as in below figure and table.

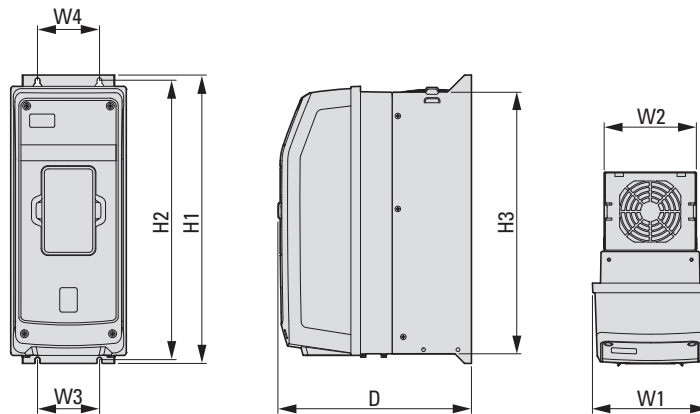


Figure 7: DX1 Series Drives Dimensions

Table 9: Series Drives Dimensions

Frame size	D	H1	H2	H3	W1	W2	W3	W4	Weight
	mm	mm	mm	mm	mm	mm	mm	mm	kg
FR1	237.4	327	312	292	153	122	100	100	7
FR2	281.2	419	406	380	168	134	90	90	11
FR3	298	558	545	518.5	205	184	125	125	23
FR4	328.5	630	617.5	590.7	238	232	205	205	36
FR5	369.1	888.5	753	707	288	282	220	220	76
FR6	399.5	1035	845	797	486	480	400	400	114

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1.7 Size and weight

1.7.2 Size of the S-ABZ card

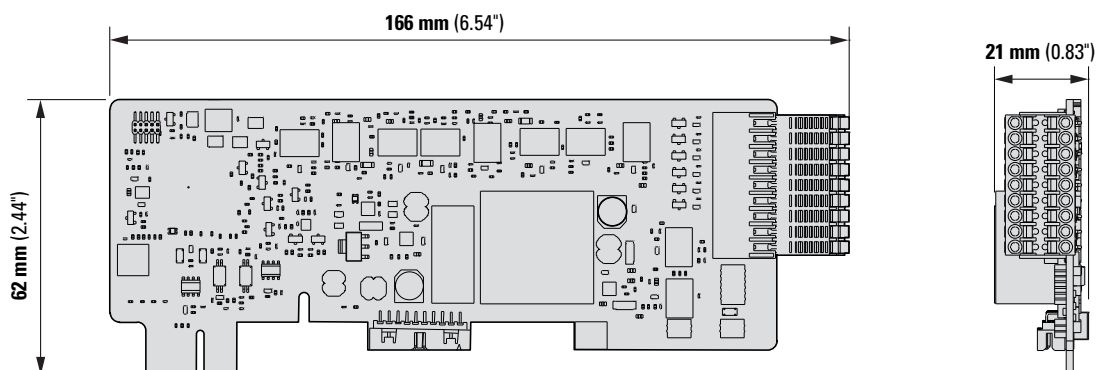


Figure 8: S-ABZ card dimensions

Table 10: S-ABZ card dimensions

	Length	Width	Depth	Weight
Optional card	mm	mm	mm	kg
S-ABZ card	166	62	21	0.068

1.7.3 Size of FS card

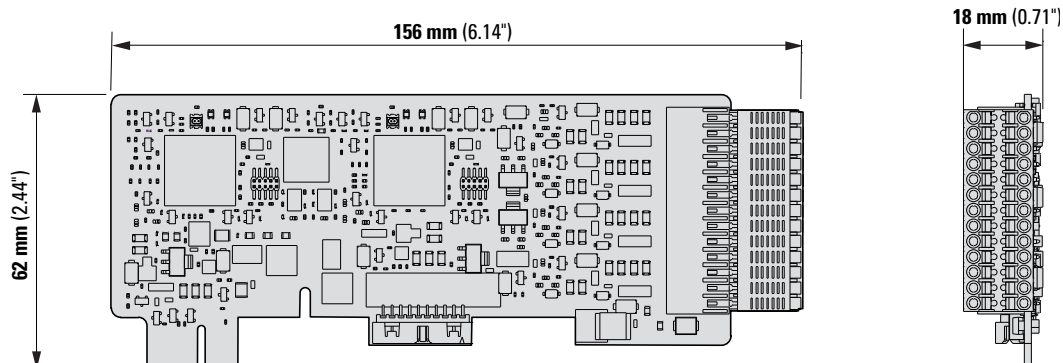


Figure 9: FS card dimensions

Table 11: FS card dimensions

	Length	Width	Depth	Weight
Optional card	mm	mm	mm	kg
FS card	156	62	18	0.049

1.7.4 Wire sizes

Wire type	Wire size	Tightening torque
STO terminal Wire (Screw Connection)	14 ~ 30AWG (0.2~1.5 mm ²)	0.2~0.3 N.m
STO terminal Wire (Push-in Design)	16 ~ 28AWG (0.2~1.5 mm ²)	NA
S-ABZ card Wire (Push-in Design)	16 ~ 28AWG (0.2~1.5 mm ²)	NA
FS card Wire (Push-in Design)	16 ~ 28AWG (0.2~1.5 mm ²)	NA

NOTICE

- For the STO signal terminal block, we have two styles for users to choose from: screw and push in.
- For the safety related signal cables, it is recommended that separate multicore shielded cable is used. The cable has an electrical enclosure which meet EN 60204-1 requirements.
- When using redundant signals, take care to avoid common cause failures in the cables. This can be done by routing the two channels through two well-apart routes, or by protecting the cabling (double shielded cables) appropriately.
- Safety related signal cables for the individual channels must be routed separately from the other channels at all positions or sufficiently shielded.
- Safety related signal and electrical energy power cables must be separated at all positions or sufficiently shielded.
- Cross-connection between the channels of the subsystem must be prevented.
- Signal paths must be physically separated.

1.8 Cooling

Cooling method: Dry clean air.

The mounting space requirements for DX1 series drives are shown as in below Figures and Tables.

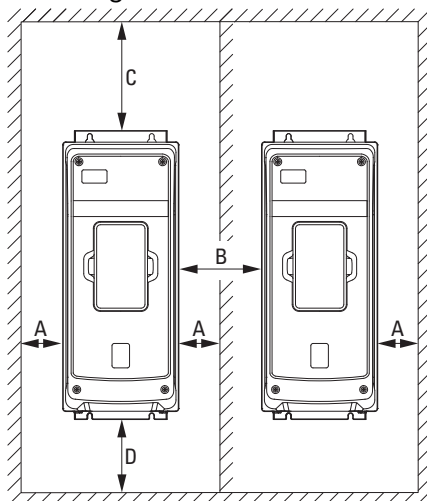


Figure 10: DX1 Mounting Space Requirement

Table 12: DX1 Mounting Space & Cooling Air Requirements

Frame size	A(mm)	B(mm)	C(mm)	D(mm)
FR1	0	0	100	50
FR2	0	0	160	60
FR3	0	0	200	80
FR4	0	0	300	100
FR5	80	160	300	200
FR6	0	0	400	330

1.9 Status LEDs

The LEDs on FS card and S-ABZ card are used for the internal investigations!
The LEDs are not user relevant!



Any error on the card will be highlighted in the PC Software or Keypad.

1.10 Proper Use

FS and S-ABZ cards are designed for the secure monitoring and halting of the drive in the event of a hazardous or unforeseen occurrence necessitating a safe response from the safety-related control system.

FS and S-ABZ cards are designed only for the PowerXL™ DX1 Drive.

FS card must be configured by Safety Tool before using.

These cards enhance the safety of applications and can function as integral parts of larger safety-related control systems, acting as subsystems within them.

FS card incorporates various safety features suitable for implementing safety functions across different applications, including emergency stops and safe speed limitations.

S-ABZ card is needed for the various safety functions. For these a compatible encoder must be used.

The safety functions of FS card are an option for the PowerXL™ DX1 drive.

The Safe Torque Of (STO) function is a standard feature on the PowerXL™ DX1 drive.

These cards form a crucial link in the functional chain of safety functions, with external components connecting to establish a comprehensive safety system. They are intended for installation within machines or integration with other components to create machines or systems.

It's important to note that FS and S-ABZ cards are not household appliances; they are exclusively designed for commercial use.

Users are responsible for ensuring that machine usage aligns with relevant EU Directives.

The CE markings on the drive and the cards signify compliance with the European Union's Low Voltage and EMC Directives (LVD 2014/35/EU, EMC 2014/30/EU, and ROHS 2011/65/EU) when utilized in their standard drive configuration.



Always observe the technical data and connection conditions!
For additional information, refer to the equipment nameplate or label at the frequency inverter and the documentation.
Another use will be considered to be an improper use of the device

The safety requirements for the application are defined in the system specific risk assessment. The system integrator must obey those requirements when implementing safety functions with FS or S-ABZ cards.

FS card does not operate the drive actively!

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1.10 Proper Use

FS and S-ABZ cards only monitor the actions of the drive and commands safety functions to be executed. The request for safety functions can come from an external safety system, for example:

- E-STOP push buttons
- Non-contact Magnetic switch
- Interlocking switch
- Light curtain devices
- Safety PLC

WARNING

Observe the technical data and connection requirements described in this manual. Another usage constitutes improper use.

WARNING

The product must adhere strictly to all relevant safety standards, local regulations, and directives, as well as the specified requirements and technical specifications. It must be installed away from hazardous ATEX zones. Before using the product, a comprehensive risk assessment must be conducted considering the intended application. Following the assessment, suitable safety measures must be put in place accordingly.

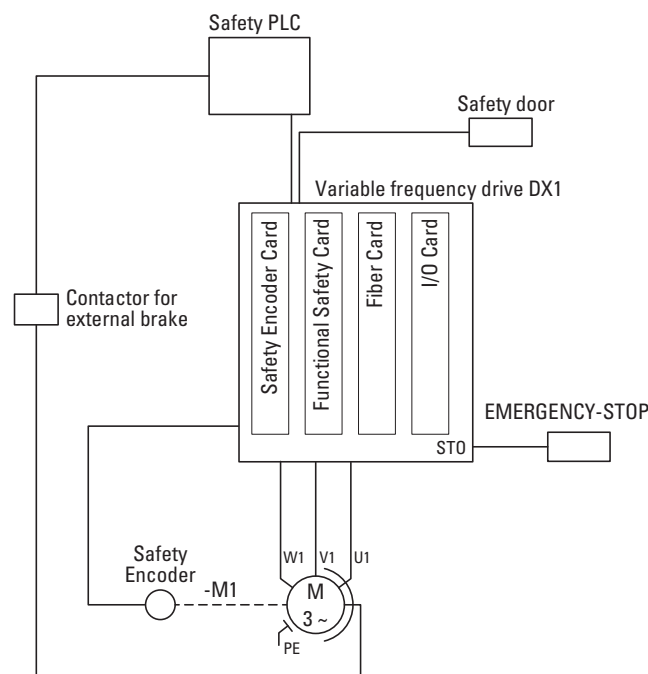


Figure 11: Integration of DXX-EXT-FS (FS card) and DXX-EXT-SABZ (S-ABZ card) in a safety application

1.11 Maintenance and Inspection

1.11.1 Safety Functions

A drive's on board STO function and Optional Safety functions must always be checked before initial commissioning, after maintenance, and at regular maintenance intervals.

The safety functions must always be included in a scheduled maintenance process (at least once a year) so that the function will be tested on a regular basis to make sure it is intact and complete – especially after changes are made to the safety system and after repair or maintenance.

During the corresponding inspection and testing, the variable frequency drive's installation and operating environment must be checked:

- The ambient temperature must fall within the admissible range.
- The heat sink and fan must be free of dust and other foreign particles.
- The fan must be able to rotate freely.
- The enclosure in which the variable frequency drive is installed must be free of dust and condensate.
- The enclosure fan and air filter must provide the required airflow.
- All electrical connections must be checked. The screw terminals must be properly tightened and the power cables must not show any signs of heat damage.

STO function proposal tests:

1. The STO inputs are de-energized and STO message is displayed. The motor coasts to stop.
2. The STO inputs are de-energized and STO message is displayed. The motor does not start when the DX1 drive receives a start command.
3. The STO inputs are powered with 24 VDC and the DX1 drive receives a start command after resetting STO function. The motor starts normally and is controlled by the DX1 drive.
4. The motor is running while being controlled by the DX1 drive and the STO inputs are de-energized. STO message is displayed and the motor coasts to stop.

Other function proposal tests:

1. The digital inputs are de-energized, activate safety functions and make them out of limit to trigger STO function. The STO message is displayed. The motor coasts to stop.
2. The digital inputs are de-energized, activate safety functions and make them out of limit to trigger STO function. The STO message is displayed. The motor does not start when the DX1 drive receives a start command.
3. The digital inputs are powered with 24 VDC and the DX1 drive receives a start command after trigger acknowledgement and resetting safety function. The motor starts normally and is controlled by the DX1 drive.

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1.11 Maintenance and Inspection

4. The motor is running while being controlled by the DX1 drive and the digital inputs are de-energized, activate safety functions and make them out of limit to trigger STO function. The STO message is displayed and the motor coasts to stop.

→ For the SSM function, safety signal is output through Digital Output (DO) to confirm whether the motor speed is within the set range. After this function is activated, you can view the SSM status output by the Digital Output (DO).

The test above must be proceeded for all other safety functions which are provided by:

DXX-EXT-FS (DX1 Functional Safety Card)

DXX-EXT-SABZ (DX1 Safety ABZ Encoder Card)



WARNING

To meet SIL 3, PL e, Cat. 3 requirements, it is necessary for user to perform SBC manually every 3 months to avoid failure of external cables and equipment.

Main device

Installation, adjustment, repair and maintenance must be performed by qualified personnel.

DX1 variable frequency drives are maintenance-free, provided that the general rating data, as well as the technical data for the specific models in use, is observed. Please note, however, those external influences may affect the operation and lifespan of a DX1 variable frequency drive.

We therefore recommend that the devices are checked regularly and the following maintenance measures are carried out at the specified intervals.

Table 13: Recommended maintenance

Maintenance measures	Maintenance interval
Clean cooling vents (cooling slits)	Please enquire
Check that the fan is working properly	6 - 24 months (depending on the environment)
Check the filters in the control panel door (see manufacturer's specifications)	6 - 24 months (depending on the environment)
Check all earth connections to make sure they are intact	On a regular basis, at periodic intervals
Check the tightening torques of the terminals (control signal terminals, power terminals)	On a regular basis, at periodic intervals
Check connection terminals and all metallic surfaces for corrosion	6 - 24 months; when stored, latest on 12th month (depending on the environment)
Motor cables and shield connection (EMC)	According to manufacturer specifications, latest on 5th month

1.11.2 Replacing FS card



WARNING

Do not do maintenance work on the electrical parts of the drive or the motor before you isolate the drive system from the main supply!

If FS card malfunctions, it must be replaced with a new one as it is not repairable. Ensure to document the safety configuration during the initial setup and after successfully completing validation tests for the safety functions.

Before replacing:

- Halt the operation of the machinery and take measures to prevent any unexpected restart.
- Save safety parameters from Safety Tool by using safety file (change log)
- Deactivate the power supply using the supply disconnecting device. Refer to the PowerXL™ DX1 series VFD installation manual for safe instructions.

Replacing FS Card:

- Disconnect IO wiring, remove FS card.
- Install the new FS card and wiring according to → chapter 2, "Installation".
- Ensure the firmware revisions.
- Reconfigure safety parameters according to safety file (change log).
- Perform the validation procedure for safety function which required for user according to → chapter 5, "Verification and Validation".

NOTICE

- The STO function is the basic safety function and it has to be validated first.
- Safety Tool (PC software) is used to configure safety parameters and upgrade firmware of FS card, this tool is developed acc. to EN ISO 13849-1 clause 4.6.4 requirements.
- Only authorized user can operate the Safety Tool to do safety parameters configuration or firmware upgrading.
- Following any changes in the safety application or the safety system configuration, it is imperative to conduct acceptance tests to confirm the effectiveness of functional safety.

1.11.3 Replacing the DX1 drive

If the DX1 drive where FS card is installed malfunctions, it must be replaced with a new one. Ensure to document the safety configuration during the initial setup and after successfully completing validation tests for the safety functions.

Before replacing:

- Halt the operation of the machinery and take measures to prevent any unexpected restart.
- Save safety parameters from Safety Tool by using safety file (change log)
- Deactivate the power supply using the supply disconnecting device. Refer to the PowerXL™ DX1 series VFD installation manual for safe instructions.

Replacing drive

- Disconnect IO wiring, remove FS card.
- Install the new drive and wiring according to PowerXL™ DX1 series VFD installation manual.
- Install FS card and wiring according to → chapter 2, "Installation".
- Ensure the drive firmware revisions.
- Reconfigure safety parameters according to safety file (change log).
- Perform the validation procedure for safety function which required for user according to → chapter 5, "Verification and Validation".

NOTICE

The STO function is the basic safety function and it has to be validated first.

1.11.4 Updating the DX1 drive firmware

If the firmware of DX1 drive where FS card is installed must be updated. Ensure to document the safety configuration during the initial setup and after successfully completing validation tests for the safety functions.

Before updating:

- Halt the operation of the machinery and take measures to prevent any unexpected restart.
- Save safety parameters from Safety Tool by using safety file (change log)

Updating drive firmware:

- Update the firmware of the drive.
- Ensure the drive firmware revisions.
- Reconfigure safety parameters according to safety file (change log).
- Perform the validation procedure for safety function which required for

user according to → chapter 5, "Verification and Validation".

NOTICE

The STO function is the basic safety function and it has to be validated first.

1.11.5 Replacing the S-ABZ card

If the S-ABZ Card malfunctions, it must be replaced with a new one as it is not repairable. Ensure to document the safety configuration during the initial setup and after successfully completing validation tests for the safety functions.

Before replacing:

- Halt the operation of the machinery and take measures to prevent any unexpected restart.
- Save safety parameters from Safety Tool by using safety file (change log)
- Deactivate the power supply using the supply disconnecting device. Refer to the PowerXL™ DX1 series VFD installation manual for safe instructions.

Replacing S-ABZ card

- Disconnect IO wiring, remove the S-ABZ card.
- Install the new S-ABZ card and wiring according to → chapter 2, "Installation".
- Ensure the firmware revisions.
- Reconfigure safety parameters according to safety file (change log).
- Perform the validation procedure for safety function which required for user according to → chapter 5, "Verification and Validation".

1.12 Storage

If FS card or S-ABZ card are stored before use, the following ambient conditions must prevail at the storage location:

- Storage temperature: -40 °C to +70 °C
- Relative average air humidity: < 95 %
- No condensation allowed, non-corrosive

1.13 Service and Warranty

→ In the unlikely event that you have a problem with your FS card or S-ABZ card, please contact your local sales office.

When you call, have the following data ready:

- the exact part number (see nameplate),
- the date of purchase,
- a detailed description of the problem which has occurred with the card.

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1.14 Disposal

If some of the information printed on the rating plate is not legible, please state only the data which are clearly legible.

Information concerning the guarantee can be found in the Terms and Conditions Eaton Industries GmbH.

For service and support, please contact your local sales organization.

Contact info. [Eaton.com/contacts](https://www.eaton.com/contacts)

1.14 Disposal

FS and S-ABZ cards can be disposed of as electronic waste in accordance with the currently applicable national regulations.



Do not dispose FS card and S-ABZ card together with domestic waste.

Dispose of the device according to the applicable environmental laws and provisions for the disposal of electrical or electronic devices.

1.15 Reset Requirements

WARNING

"Reset" refers to manually clearing faults to re-enable DX1. Only users at the Installer and Eaton levels are authorized to perform fault reset operations. DX1 cannot be auto reset once it's in safe state.

When the safety function is completed and the drive goes into safe state, below steps are required to reset the safety functions:

- ▶1. Remove safety function request.
- ▶2. Trigger acknowledgement (The STO, SBC, and SSM functions are excluded).
- ▶3. Reset command via drive.

When the diagnostic function is triggered and drive goes into the safe state, below steps are required to reset fault:

- ▶1. Check and recover the diagnose fault the cause.
- ▶2. Reset command via drive.

→ Note: If an unrecoverable fault occurs, please power cycle. If error still exists, contact Eaton.

"Safe Torque Off" can be triggered by the safety functions (STO, SS1, SS2, SOS, SLA, SAR, SLS, SSR, SDI) and other diagnostics, it can be configured as fault, warning, or no indication:

1. If it is fault, the drive stops and user can see "STO" indication when it is triggered, to clear this fault, the fault condition must be removed first and a reset command from 0 to 1 is required, drive can only be manually reset after fault is cleared.
2. If it is warning, the drive stops and user can see "STO" indication when it is triggered, to clear this warning, the warning condition must be removed, drive can only be manually reset when warning condition is removed.
3. If it is no indication, the drive stops but no "STO" indication to user when it is triggered, the drive can only be manually reset when trigger condition is removed.

User can reset FS card back to factory settings over Safety Tool, a factory reset sets all safety parameters to the default value.

2 Installation

This chapter provides a description of the mounting and the electrical connection of FS card and S-ABZ card.

NOTICE

Authorization to work on and with this product is granted exclusively to adequately trained individuals who possess a comprehensive understanding of the contents of this manual and all other pertinent product documentation. They must be adept at foreseeing and identifying potential risks stemming from the use of the product, adjustments to settings, and the mechanical, electrical, and electronic components of the overall system in which the product is integrated.

Compatibility overview – hardware, software and firmware

Before installing the module, ensure that the software version of the drive is compatible with the safety cards.

The following shows the versions of the hardware and firmware with which PowerXL™ DX1 is compatible with FS card and S-ABZ card.

Product	Hardware Version	Software Version
Power Board	E3.0.1	N/A
Control Board	E1.1.0	CB_MCU V02.00.0000 CB_DSP V02.00.0000
DXX-EXT-FS	E3.1.2	FS_MCU V01.00.0000
DXX-EXT-SABZ	E3.2.3	SABZ_MCU V02.00.0000
Safety Tool	NA	V1.0.0

2.1 Safety regulations

WARNING

All handling and installation work relating to the mechanical surface mounting and installation of FS card and S-ABZ card may only be carried out in a voltage free state. In order to prevent damage to the cards, the devices must remain in their original packaging until they are installed.



Perform all installation work only with the indicated, appropriate tools and do not apply any force.



DANGER - CONTROL FAILURE

When engineering your control diagram, make sure to take all potential control path faults into account. When it comes to critical control functions, make sure that a safe state can be reached after a control path fails. Critical control function examples include:

- Emergency shutdown (emergency stop),
- Overtravel stop
- Power supply failure
- Restart

Provide separate or redundant control paths.

Make sure that system control paths include communication connections.

Take the effect of unforeseen transmission delays and connection problems into account.

Carefully and individually test every implementation of a product before putting into operation.

Observe all general accident prevention and local safety regulations.

Information for the USA:

For more information, please refer to the latest issue of NEMA ICS 1.1, „Safety Guidelines for the Application Installation, and Maintenance of Solid State Control“, and the latest issue of NEMA ICS 7.1, „Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable-Speed Drive Systems“.

In addition to property damage, failure to observe the above instructions may result in serious bodily injury or even death.

2 Installation

2.2 Installation Preparation

2.2 Installation Preparation

Before installation, the following requirements must be met:

Requirements for designers and installers

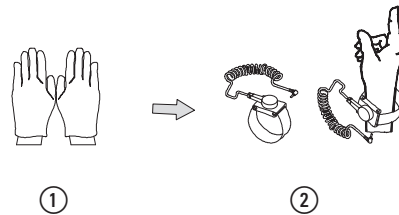
- The installer can be Eaton's professional after-sales personnel.
- If the installer and designer are users, designers and installers must be trained to understand the requirements and principles of designing and installing safety-related systems.
- Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

Requirements for installation environment

- Ensure the installation environment is clean.
- Clean the drive before installation and wipe off the dust on the drive.

Requirements for ESD protection

- The operator must wear anti-static gloves.
- The operator must wear a grounded, corded anti-static ring and connect it to a static alarm for real-time monitoring.



2.3 Installation documents

For more information on how to install FS card and S-ABZ card to PowerXL™ DX1, please refer to the instruction leaflet, IL040093EN and IL040090EN.

2.4 Mechanical setup

2.4.1 Functional safety option card slot compatibility

PowerXL™ DX1 has 4 option slots (A, B, C and D) but there is a slot compatibility matrix in place. The figure below shows the orientation of the option card slots.

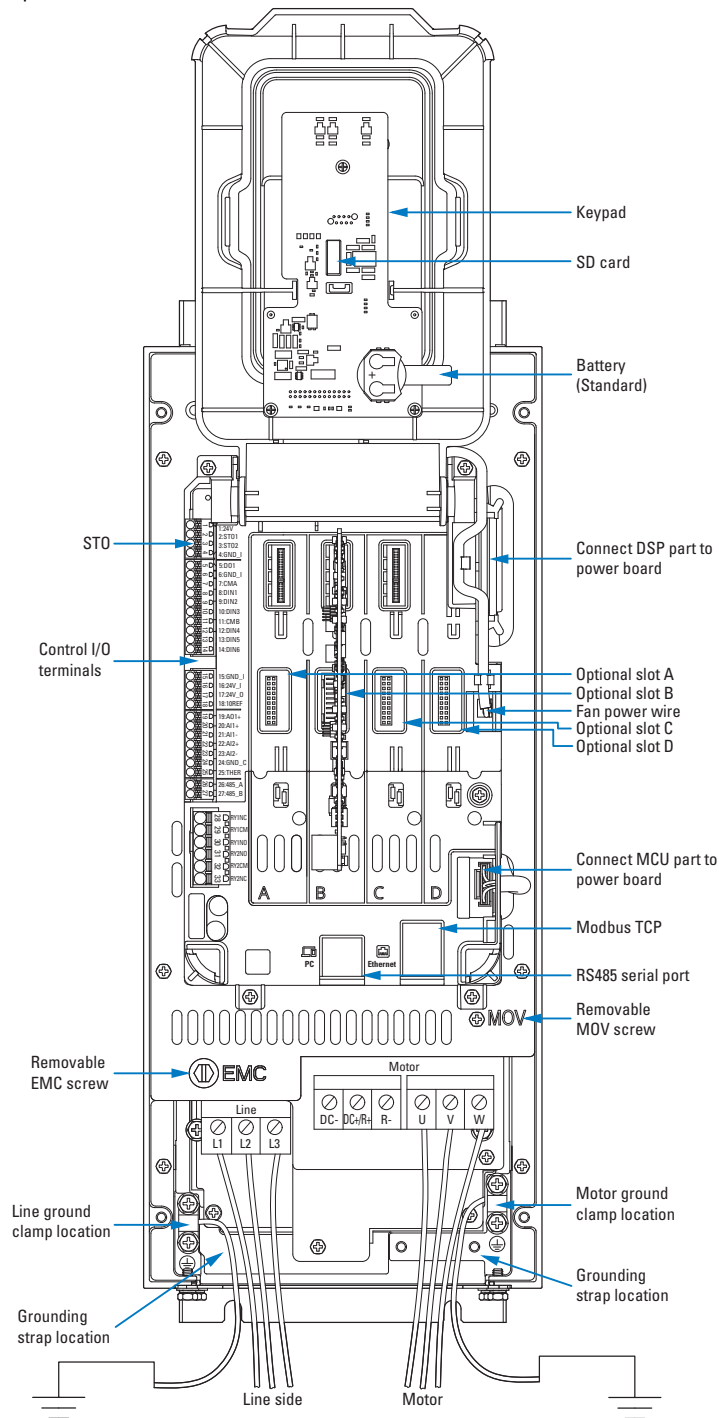


Figure 12: PowerXL™ DX1 functional safety option card slots A, B, C, D orientation

2 Installation

2.4 Mechanical setup

The DXX-EXT-FS (DX1 FS card) and DXX-EXT-SABZ (S-ABZ card) can only be installed to the Slot A and B. See the Slot reservations here:

Table 14: Option card slot compatibility

Optional card	Slots
DXX-NET-EIP (dual port EtherNet/IP card)	Slot D
DXX-NET-PROFINET (dual port Profinet card)	Slot D
DXX-EXT-3DI3DO1T, DXX-EXT-1AI2AO, DXX-EXT-3RO, DXX-EXT-THER1, DXX-EXT-6DI (I/O cards)	Slot A, B, C, D
DXX-EXT-FS (FS card)	Slot B
DXX-EXT-ABZ (dual channel standard encoder card)	Slot A
DXX-EXT-SABZ (dual channel S-ABZ card)	Slot A
DXX-EXT-OF (optical fiber card)	Slot C



WARNING

If the card is installed in a mistaken slot, then following error messages will occur on the keypad: Card Plug Slot Error.

Check the cause of the error:

If the fault code is 148, the S-ABZ card is inserted into the mistaken slot.

If the fault code is 149, FS card is inserted into the mistaken slot.

2.4.2 Functional safety option card installation

Follow the instructions to insert the card.

- ▶1. Flip the B-cover up and stop at a specific angle (120° or 150°).
- ▶2. Insert the functional safety option cards to the corresponding slots according to → Table 14. Make sure the option cards have been fixed into the slots.
- ▶3. Flip the B-cover down for snap fit with C-cover to fix the option cards firmly

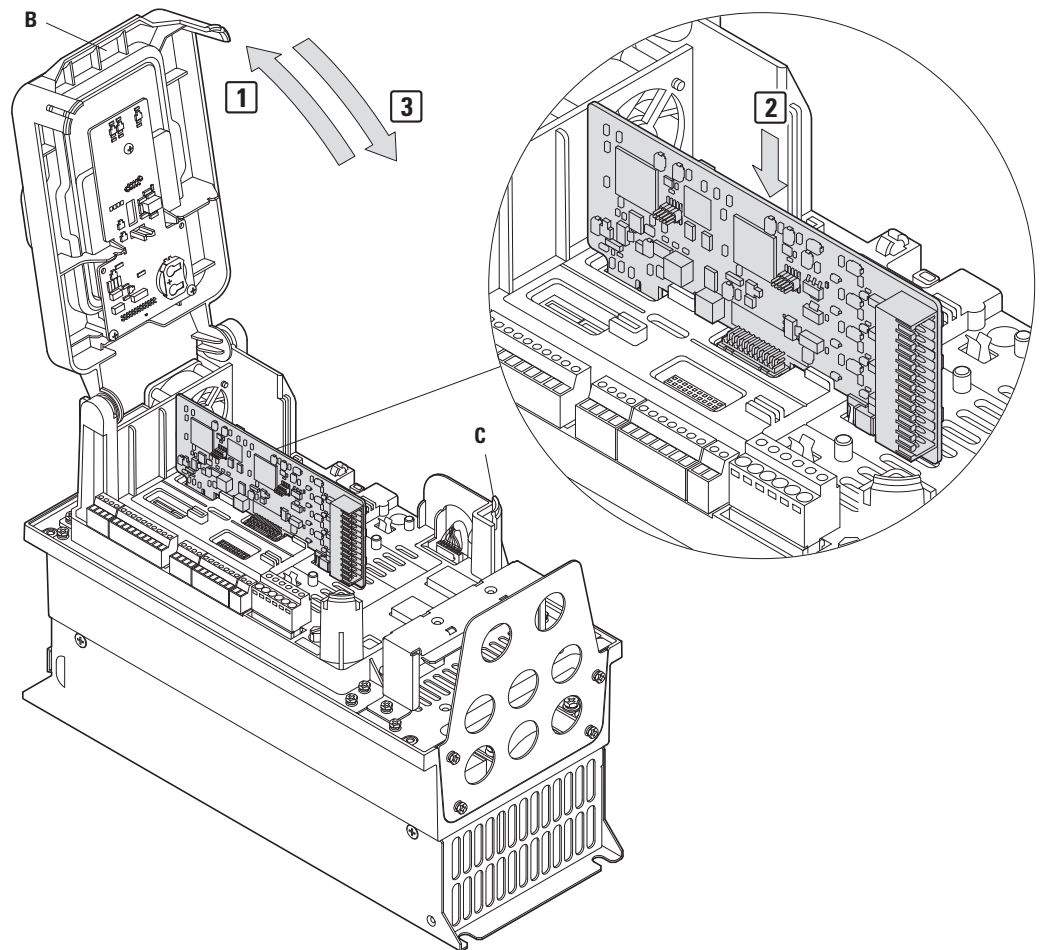


Figure 13: Access the Control Slot (new)

2 Installation

2.5 Electrical Setup

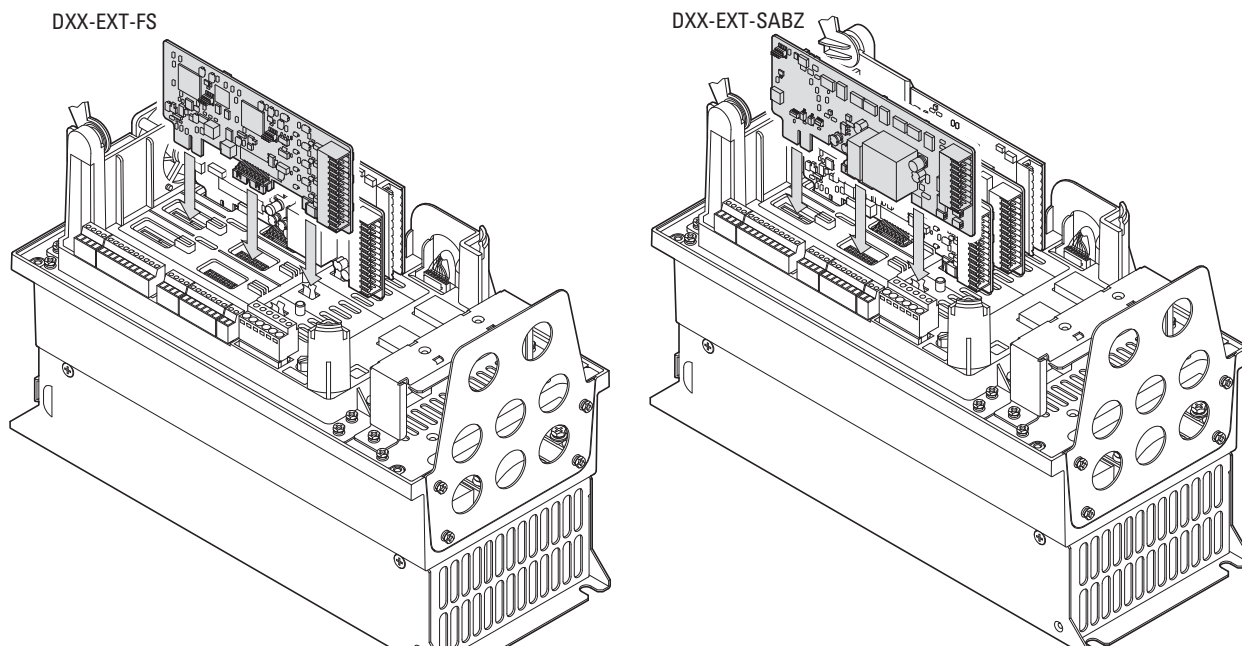


Figure 14: DXX-EXT-FS (left) and DXX-EXT-SABZ (right)

2.5 Electrical Setup

If application does not need STO function, STO terminal must be short-circuited by jumper. When application requires STO function, STO terminal block must be connected to safety switch, safety relay or safety PLC.

The diagnostic pulse width of PLC output must not be longer than 2 ms.

STO input signal must meet SELV/PELV requirements. The maximum abnormal voltage must not be more than 60 V DC.

Digital input signal of FS card must meet SELV/PELV requirements, and the maximum abnormal voltage must not be more than 60 V DC.

When PLC is used as digital input of FS card, the diagnostic pulse width of PLC output must not be longer than 2 ms.

Only authorized user can use the Safety Tool to configure FS card DI/DO.

→ Never route the cables of safety related functions directly parallel to the power cables.

When installing the card, make sure that the control, signal and encoder cables are not routed directly parallel to power cables.

With parallel cable routing, the clearances between control, signal and encoder cables ② and power cables ① must be greater than 30 cm.

All cables must always intersect at 90 degree.

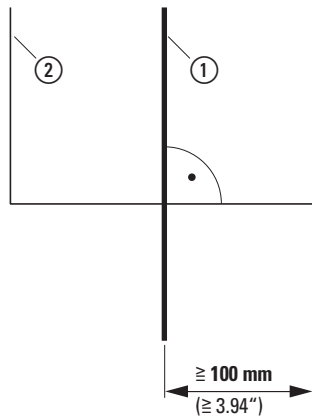


Figure 15: Routing cables for safety applications (2) and mains/motor cables (1)

If the system requires a parallel routing in cable ducts, in order to prevent electromagnetic interference with the fieldbus cable a partition must be installed between the FS/S-ABZ card signal cables (2) and the mains/motor cables (1).

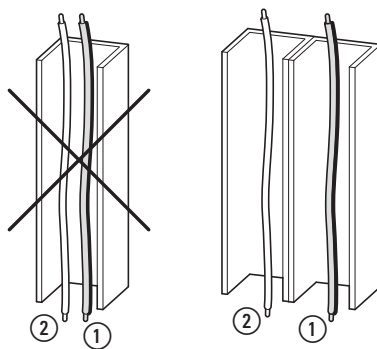


Figure 16: Separate routing in the cable duct

- ① Mains and motor connection cable
- ② Safety signal cable

2 Installation

2.6 Connection procedure

NOTICE

To avoid short circuits between conductors, follow these guidelines:

- Permanently connected (fixed) and protected against external damage, e.g. by cable ducting, armoring.
- Separate multicore cables
- Within an electrical enclosure
- Individually shielded with earth connection.
- Fault exclusion measures against short circuit fault must be implemented at application level, according to applicable requirement or standards, e.g., EN ISO 13849-2:2012.
- For the requirements of fault exclusion measures against short circuits between two adjacent tracks/pads of internal PCB according to EN ISO 13849-2:2012, some measures must be implemented at application level, i.e., this device must be installed in a cabinet with at least IP54.

2.6 Connection procedure

- ▶ 1. Stop the drive and do the steps in → Section 2.1, "Safety regulations" before you start the work.
 - ▶ 2. Make sure that the card electronics grounding screw is correctly tightened.
 - ▶ 3. Make sure that the card connectors to the drive is plugged and fixed correctly.
 - ▶ 4. Make sure that all wirings and connections to the drive are done properly and completely.
- Option cards will be inside and fully protected by the DX1 safety enclosure. The installation and operation must be done by authorized professionals (either from Eaton or user) in the field according to this manual.



First, carry out all the measures for commissioning the variable frequency drive or variable speed starter as described in the relevant manual for the device.

WARNING

Ensure that no danger will be caused by starting the motor.

2.7 STO Connection

A four-pin terminal block on control board is used for customer to connect emergency stop switch, safety relay or PLC, and so on.

For detailed wiring and usage, please refer to Appendix E of PowerXL™ DX1 Series VFD Installation manual (MN040068EN).

2.8 FS card connection

This section describes FS card safety I/O and wiring considerations.

2.8.1 FS card user interface

The figure below shows the layout of FS card.

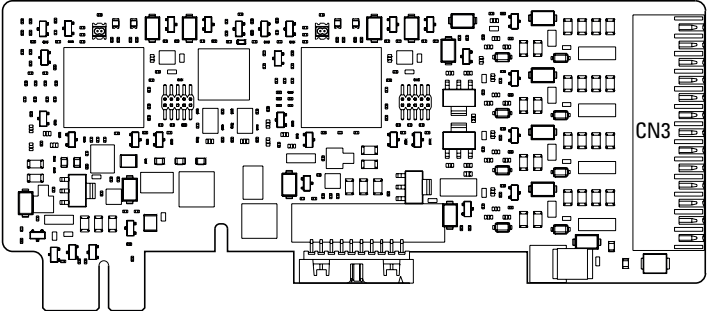


Figure 17: FS card user interface

CN3 – Connector for user input and output connections

The following figure shows the pin layout of DXX-EXT-FS (DX1 FS card)

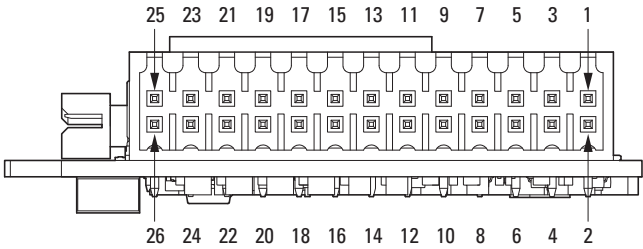


Figure 18: Pin layout of DXX-EXT-FS (FS card)

2 Installation

2.8 FS card connection

Table 15: Terminal designations

Pin	Signal name	Signal	Connection type	Description
1	NC	NC	-	No connection
2	NC	NC	-	No connection
3	GND	I/O signal ground	-	Function safety related ground
4	GND	I/O signal ground	-	Function safety related ground
5	GND	I/O signal ground	-	Function safety related ground
6	GND	I/O signal ground	-	Function safety related ground
7	DO2	Digital output signal	DO	Channel 2 digital output
8	DO1	Digital output signal	DO	Channel 1 digital output
9	GND	I/O signal ground	-	Function safety related ground
10	GND	I/O signal ground	-	Function safety related ground
11	DI42	Digital input signal	DI	Channel 2 digital input 4
12	DI41	Digital input signal	DI	Channel 1 digital input 4
13	DI32	Digital input signal	DI	Channel 2 digital input 3
14	DI31	Digital input signal	DI	Channel 1 digital input 3
15	DI22	Digital input signal	DI	Channel 2 digital input 2
16	DI21	Digital input signal	DI	Channel 1 digital input 2
17	DI12	Digital input signal	DI	Channel 2 digital input 1
18	DI11	Digital input signal	DI	Channel 1 digital input 1
19	GND	I/O signal ground	-	Function safety related ground
20	GND	I/O signal ground	-	Function safety related ground
21	24V_2	Safety power	PO	Safety 24VDC power of channel 2
22	24V_1	Safety power	PO	Safety 24VDC power of channel 1
23	24V_2	Safety power	PO	Safety 24VDC power of channel 2
24	24V_1	Safety power	PO	Safety 24VDC power of channel 1
25	PE	Chassis	-	cable shield
26	PE	Chassis	-	cable shield

2.8.2 FS card user IO specification

Digital input specification

The FS card DI can be configured as safety function enable signals.

DI Number: 4 redundant DI (2 user terminals for each redundant DI, total 8 terminals).

The FS card DI signal must meet SELV/PELV requirements. The maximum abnormal voltage must not be more than 60VDC.

Attribute	Value
De-active (logic 1)	18...27.3 V
Active (logic 0)	Max. 5 V
DI terminal input impedance	90.3 kΩ
PLC diagnostic pulse width	Max. 2 ms

Digital output specification

The FS card DO (Digital Output) can be used to perform SBC or output safety function status.

DO Number: 2 digital outputs, each output is dual channel design and achieve SIL 3, Category 3 and PL e requirement alone.

The FS card DO channel can withstand a high voltage up to 60VDC.

Attribute	Value
De-active (logic 1)	18.3...27V
Active (logic 0)	Max. 3V
Output current of High level	Each 200mA @22V
Drop voltage	Max. 2V
Leakage current of low level	Max. 100 uA
Overload current	Max. 250 mA@1s
DO diagnostic pulse	1 ms / 2 ms / 3ms configurable

2 Installation

2.8 FS card connection

2.8.3 FS card user IO wiring

Digital input terminal wiring

There are two optional methods for user to connect to DI:

- User can use redundant safety switches to activate safety functions by opening the switches.
- User can use safety PLC DOs to activate safety functions by outputting low level to FS card DI.

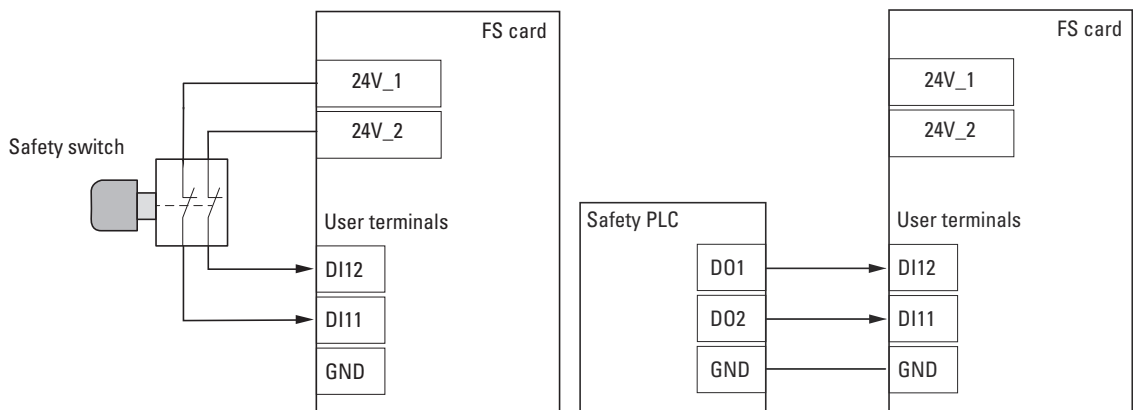


Figure 19: Digital input terminal connection

NOTICE

- Do not apply any voltage to terminal 24 V DC terminals of FS card.
- Ground must be connected to the ground of the source.
- Digital input signal of FS card must meet SELV/PELV requirements, and the maximum abnormal voltage must not be more than 60 V DC.
- When PLC is used as the input of DI, the diagnostic pulse width of PLC output does not be longer than 2ms.
- Only authorized user can operate the dedicated Safety Tool to configure FS card DI functions.

Digital output terminal wiring

There are two methods for user to realize the SBC function. See below figures for SBC function connection methods. When SBC function is active, DI4s are used as safety relay feedback signals input for diagnostic.

- Two channels use the same DO terminal.

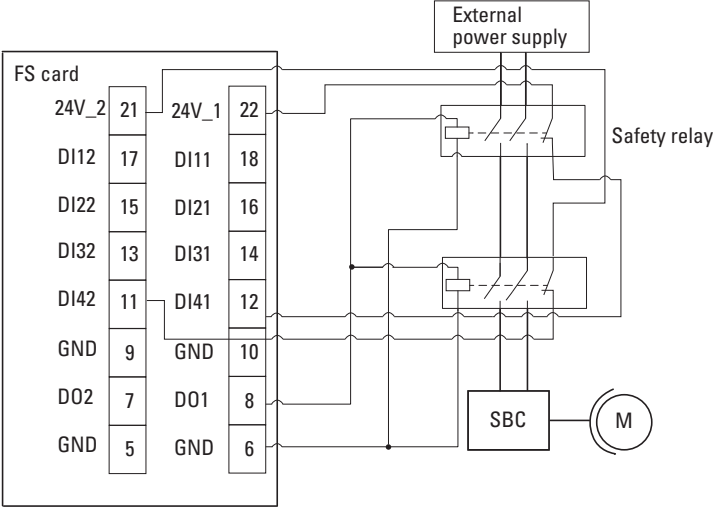


Figure 20: DO terminal connection (two channels share the same DO user terminal)

- Two channels use DO1 and DO2 terminals separately

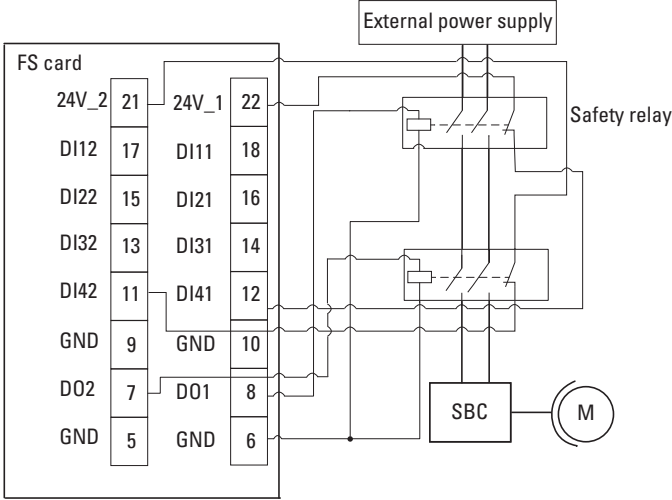


Figure 21: DO terminal connection (DO1 and DO2 work together as two channels)

2 Installation

2.8 FS card connection

NOTICE

- If single user terminal is not sufficient for user, DO1 and DO2 could work together as the two channels of one DO as well as shown in Figure 21. At this time, there will be only one Digital output on FS card.
- The DO circuit can withstand a high user input voltage up to 60 VDC.
- SBC (safe brake control) uses DO terminals to drive safety relay. The relay feedback input signal is NC type (inverted state compared with the brake relay). If SBC is enabled, DI41 and DI42 are used automatically as relay NC feedback signals input for diagnostic.
- Only authorized user can operate the dedicated Safety Tool to configure FS card digital input and digital output functions.

The working logic of the SBC function can refer to the following truth table:

Table 16: SBC function logic truth table

DO1/DO2	Safety relay (NO)	Safety relay (NC, feedback)	SBC	Motor
1	1(close)	0(open)	Release	run
0	0(open)	1(close)	Brake	stop

SBC function uses DO terminals to drive safety relay. The safety relay must meet below requirements:

- Force guided relay (meet the requirements of IEC61810-3)
- Relay outputs: at least 1 NC feedback contact
- Filter time (Response time) > 10 ms
- Voltage: 18.3...27 V
- Current: Max.200 mA

FS card also can be wired as described below:

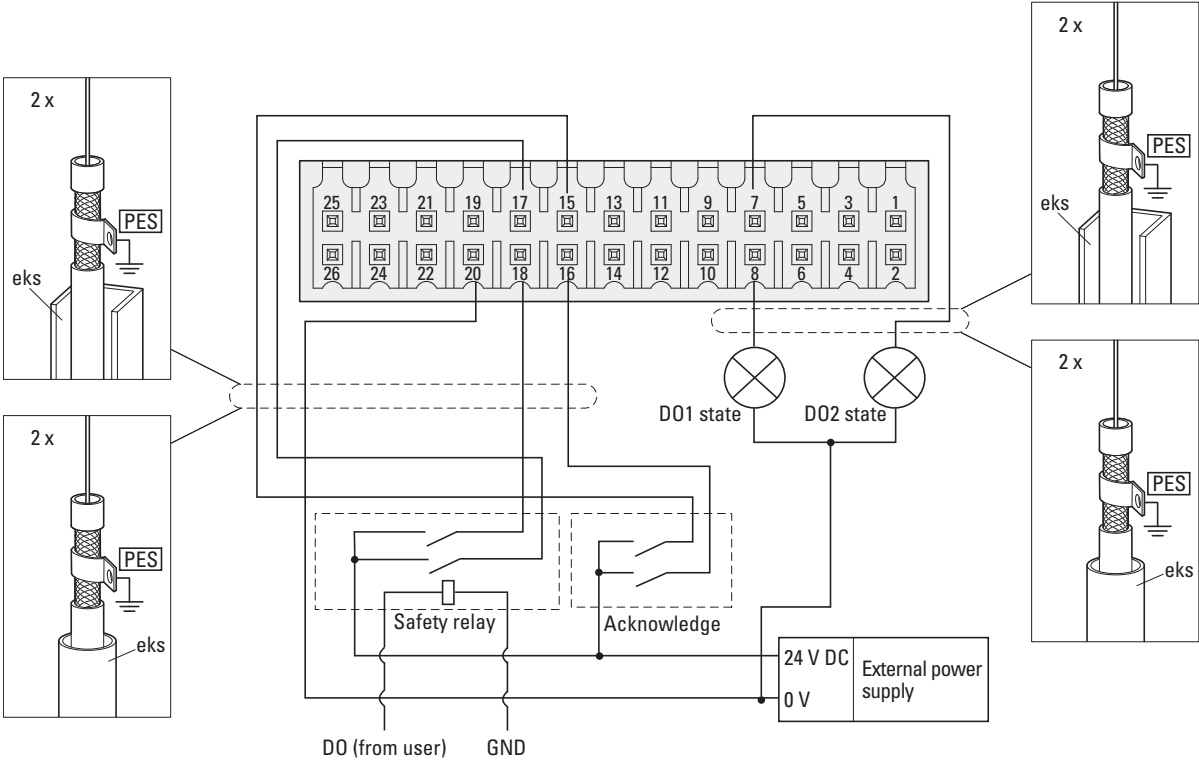


Figure 22: FS card installation wiring

The cables must be screened, and the corresponding cable screen must be earthed (PES).

The external power supply is connected to this module, output signal of the external power supply must meet SELV/PELV requirements. The maximum abnormal voltage must not be more than 60VDC.

⚠ WARNING

Do not connect capacitive external devices to DO, otherwise FS card may report a "FS DI TP Diagnosis Error" fault. The fault code is 220.

2 Installation

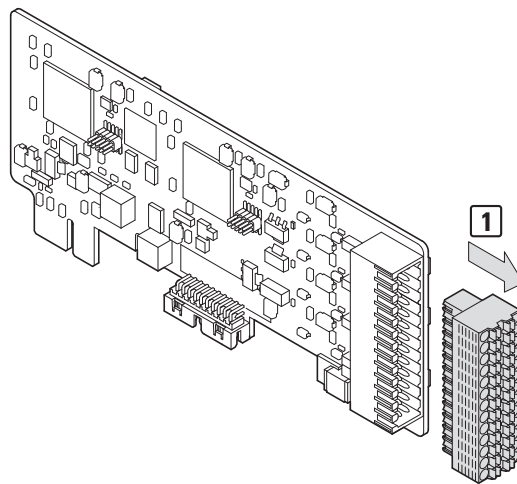
2.8 FS card connection

2.8.4 FS card user IO connection procedure

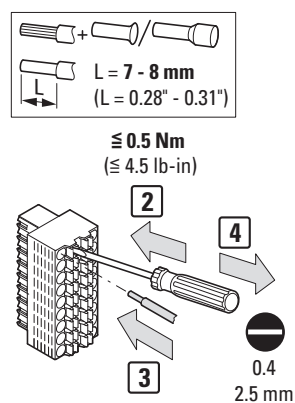
Make sure that FS card connectors to the drive is plugged and sit correctly.

Now connect the cable shield of the signal cable with the earthing terminal to the frame of the frequency inverter.

- A shielded cable must be used.
 - The connection must be made in accordance with best practice.
- ▶ Remove the removable terminal block from FS card.



- ▶ For solid wires or strand wires with ferrules, push in the wires directly. For strand wires without ferrules, use a slotted screwdriver to press the grooves on terminal block to open the corresponding wire cages, then push in the wires.

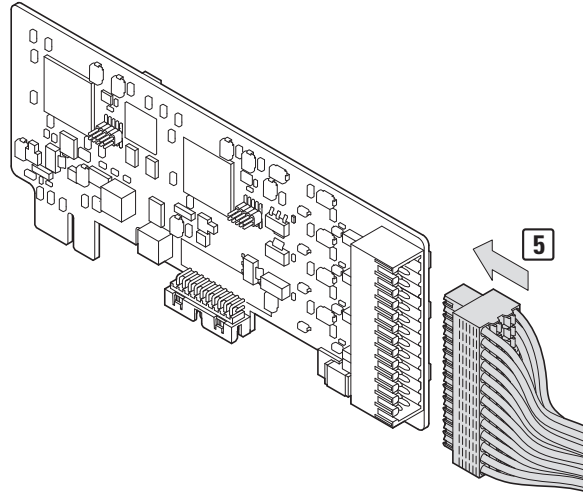


Screwdriver size: 0.4* 2.5 mm
Stripping length (mm): 7-8
Torque value: 0.5 Nm (4.5 LB.IN)

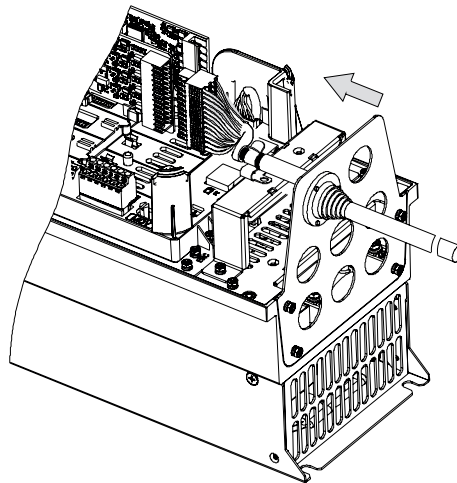
2 Installation

2.8 FS card connection

- ▶ Install the removable terminal block back to FS card after completing all wires connection.



- ▶ The cables must be screened, and the corresponding cable screen must be earthed (PES).



2 Installation

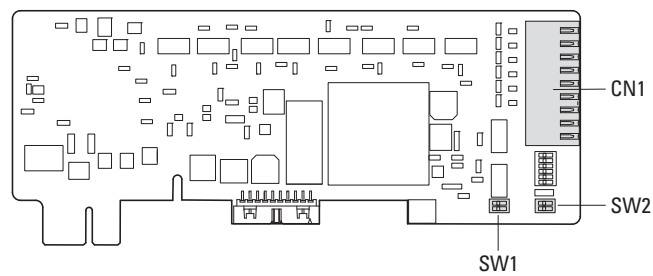
2.9 S-ABZ card connection

2.9 S-ABZ card connection

This section describes the SABZ card safety I/O and wiring considerations.

2.9.1 S-ABZ card user interface

The figure below shows the layout of the SABZ card. The following user Interface components are available:



SW1 – Set the safety encoder supply voltage.
SW2 – Set the safety encoder supply voltage.
CN1 – Connector for user input and output connections

Figure 23: S-ABZ card user interface

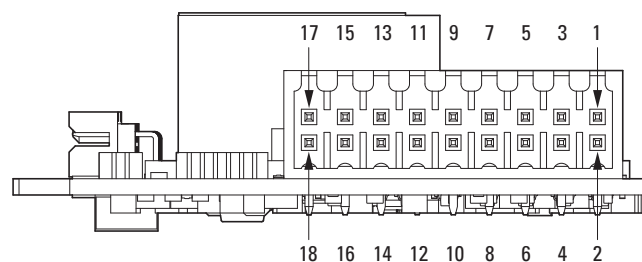


Figure 24: Pin layout of S-ABZ card

Table 17: Terminal designations

Pin	Signal name	Signal	Connection type	Description
1	A1+	Encoder1 signal A1+ input	DI	Safety encoder channel 1 signal
2	A1-	Encoder1 signal A1- input	DI	Safety encoder channel 1 signal
3	B1+	Encoder1 signal B1+ input	DI	Safety encoder channel 2 signal
4	B1-	Encoder1signal B1- input	DI	Safety encoder channel 2 signal
5	Z1+	Encoder1 signal Z1+ input	DI	Safety encoder safety unrelated signal
6	Z1-	Encoder1 signal Z1- input	DI	Safety encoder safety unrelated signal
7	GND	I/O signal ground	-	Safety encoder signal ground
8	VPG	Encoder1 power supply	PO	Safety encoder power supply
9	A2+	Encoder2 signal A2+ input	DI	Ordinary encoder signal
10	A2-	Encoder2 signal A2- input	DI	Ordinary encoder signal
11	B2+	Encoder2 signal B2+ input	DI	Ordinary encoder signal
12	B2-	Encoder2signal B2- input	DI	Ordinary encoder signal
13	Z2+	Encoder2 signal Z2+ input	DI	Ordinary encoder signal
14	Z2-	Encoder2 signal Z2- input	DI	Ordinary encoder signal
15	GND	I/O signal ground	-	Ordinary encoder signal ground
16	VPG	Encoder2 power supply	PO	Ordinary encoder power supply
17	PE	Chassis	-	cable shield
18	PE	Chassis	-	cable shield

2 Installation

2.9 S-ABZ card connection

2.9.2 S-ABZ card user IO wiring

S-ABZ card is an interface between the control board and a safety ABZ encoder. Encoder1 only supports safety encoders, and the signals are differential signals, Encoder2 supports various types of ABZ encoders.

For the wiring and use of encoder2, please refer to the PowerXL™ DX1 Series Encoder Option Cards (DXX-EXT-ABZ) user manual (MN040075EN).

General guidelines of wiring:

- Route the safety encoder cables separately from power cables (drive, motor, etc).
- The safety encoder must be attached to the motor shaft according to the instructions of the encoder manufacturer (positive lock). FS card does not detect mechanical failures outside of the encoder (for example, motor shaft slipping).

The SABZ-Encoder card can be wired as described below:

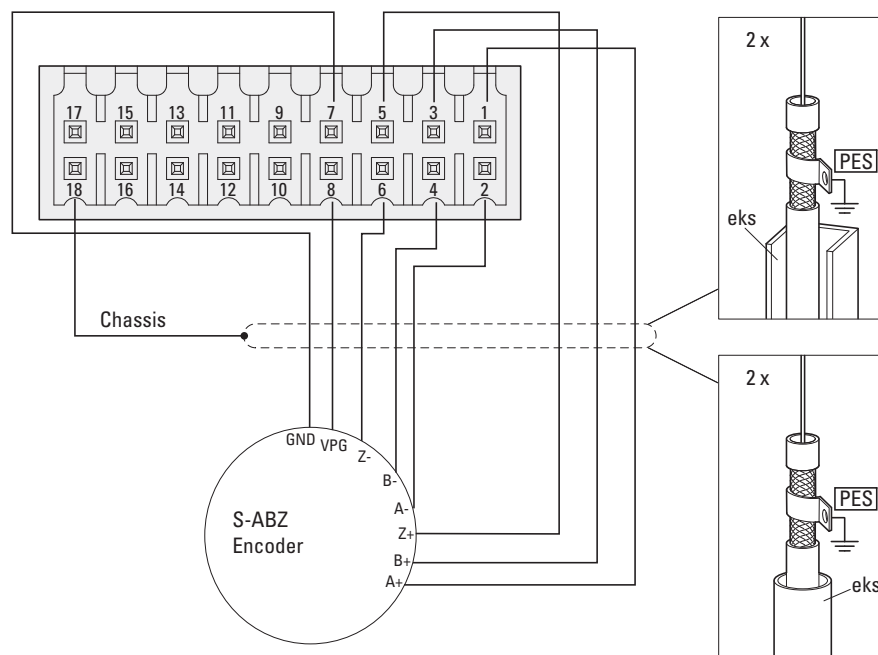


Figure 25: Encoder installation

The cables must be screened, and the corresponding cable screen must be earthed (PES).

2.9.3 Setting up encoder supply voltage



WARNING

Warns of hazardous situations that could result in serious injury or death.

Two supply voltages are available on pins 8 and 16 in connector CN1. They can power two encoders separately at the same time. The supply voltage is selected by DIP switch (SW1/ SW2).

The following supply voltages can be selected:

Encoder supply voltage	SW1 selection	SW2 selection
VPG = 5 V		
VPG = 15 V		
VPG = 24 V		

NOTICE

- S-ABZ card only support one safety certified incremental encoder1. S-ABZ card provides selectable safety power supply 15V or 24V for user’s safety encoder.
- Only when SW1 and SW2 are both set correctly, there will be a corresponding power supply voltage output. If only one is set, the output voltage is 5V.

2 Installation

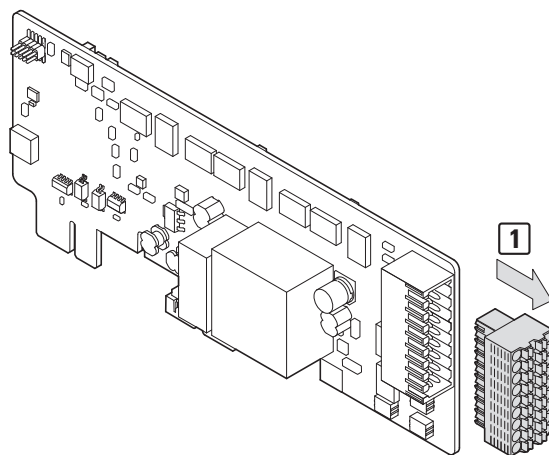
2.9 S-ABZ card connection

2.9.4 S-ABZ card user IO connection procedure

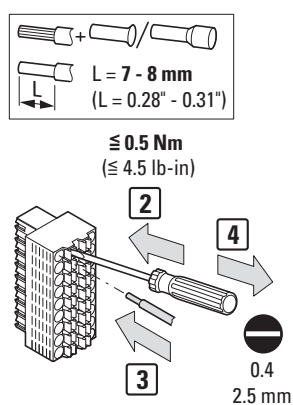
Make sure that the SABZ card connectors to the drive is plugged and sit correctly.

Now connect the cable shield of the signal cable with the earthing terminal to the frame of the frequency inverter.

- A shielded cable must be used.
 - The connection must be made in accordance with best practice.
- ▶ Remove the removable terminal block from the SABZ card.

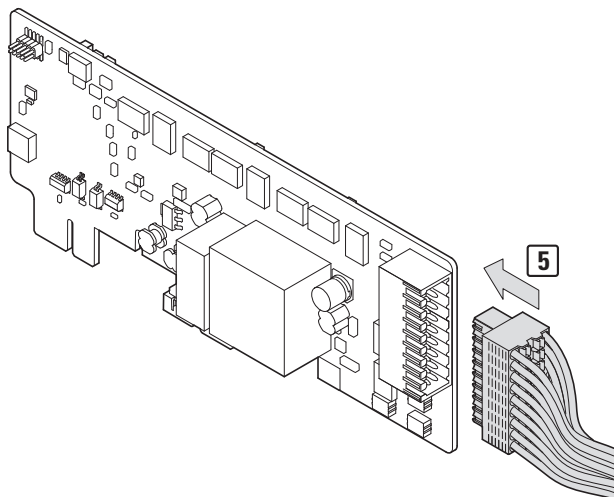


- ▶ For solid wires or strand wires with ferrules, push in the wires directly. For strand wires without ferrules, use a slotted screwdriver to press the grooves on terminal block to open the corresponding wire cages, then push in the wires.



Screwdriver size: 0.4* 2.5 mm
Striping length (mm): 7-8
Torque value: 0.5 Nm (4.5 LB.IN)

- ▶ Install the removable terminal block back to the SABZ card after completing all wires connection.



- ▶ The cables must be screened and the corresponding cable screen must be earthed (PES).

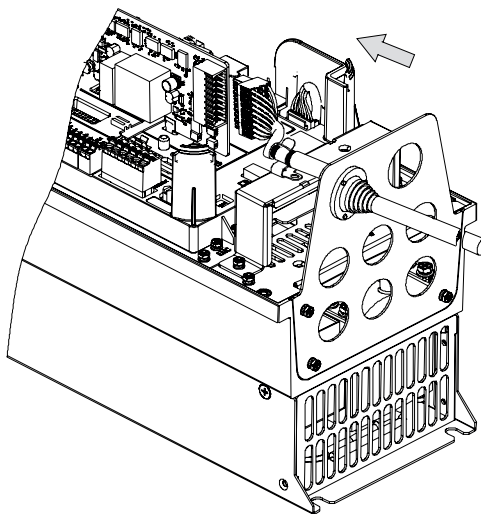


Figure 26: Screened cables and earthed cable screen

2 Installation

2.9 S-ABZ card connection

2.9.5 S-ABZ card user IO connection test procedure

When finished the installation, the SABZ card input signal must be verified.

The safety encoder signal can be verified according to following steps:

- For channel 1, write the encoder pulse count to B8.2.1 (encoder1 pulse count),
- Set P8.1.1 (motor control mode) to Freq control,
- Set P7.2.3 (frequency reference) to 10 (Hz),
- Run the motor and observe B8.1.3 (encoder1 speed).

If B8.1.3 is equal to M2.3 (motor speed), the wiring is correct. If these two values are opposite, you need to set B8.2.2 (encoder1 rotation reverse) to YES.

- For channel 2, write the encoder pulse count to B8.2.3 (encoder2 pulse count),
- set P8.1.1 (motor control mode) to frequency control,
- set P7.2.3 (frequency reference) to 10 (Hz),
- Run the motor and observe B8.1.4 (encoder2 speed).

If B8.1.4 is equal to M2.3 (Motor speed), the wiring is correct. If the two values are opposite, you need to set B8.2.4 (encoder2 rotation reverse) to YES.



WARNING

It is necessary to ensure that the motor can operate normally. If there is any discrepancy with the above description, please recheck the wiring.

2.10 Electrical Commissioning

This section provides users with a detailed guide to the electrical commissioning of the inverter to ensure that the drive can be safely and efficiently installed and put into operation.

Following diagram shows an overview of electrical architecture of safety functionality of DX1 drive.

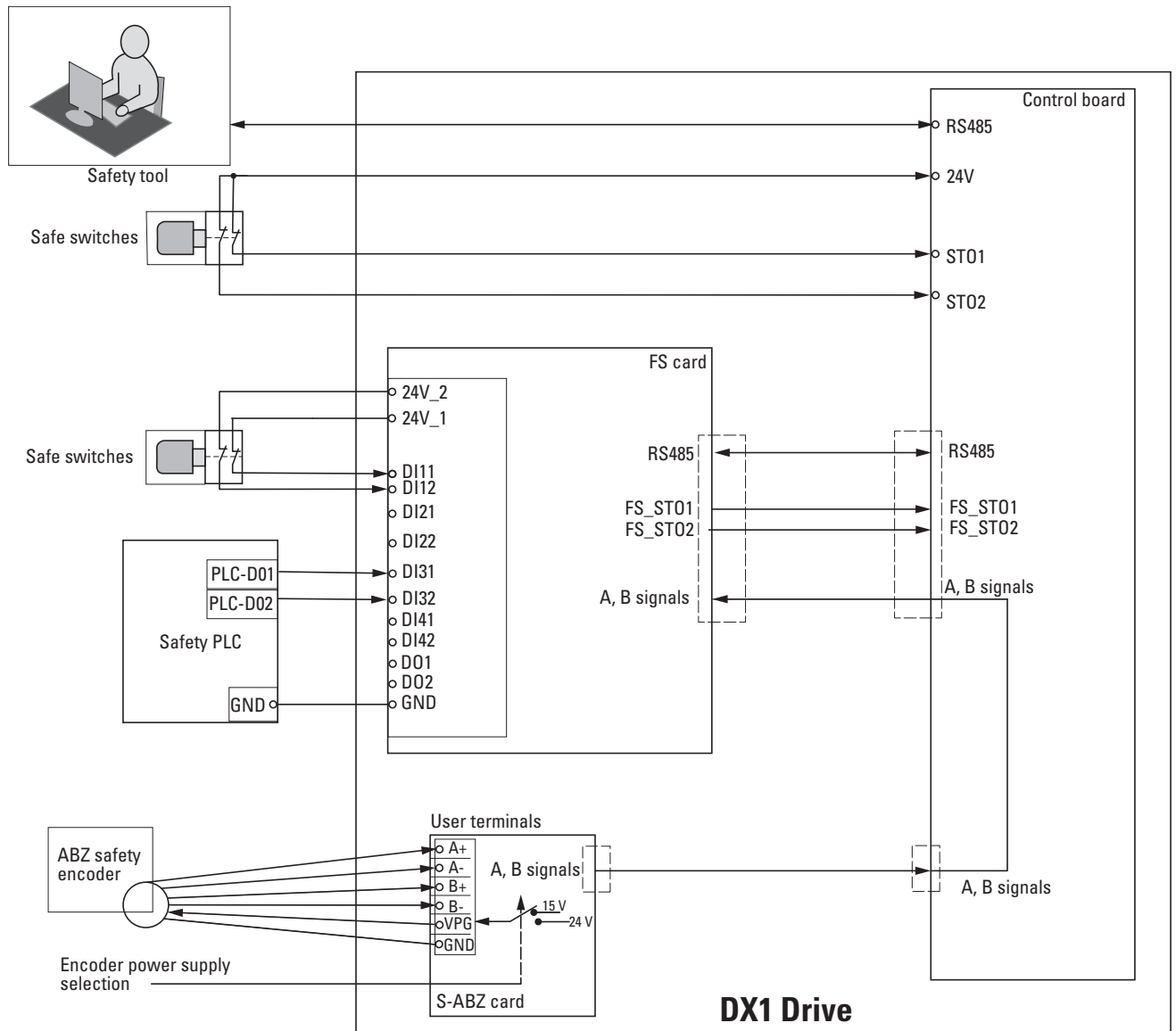


Figure 27: Inputs and outputs for DX1 functional safety system

2 Installation

2.10 Electrical Commissioning

2.10.1 Prepare for electrical commissioning

- ▶ Verify the integrity and compliance with design specifications of the drive and its associated equipments, such as motors and cables.
- ▶ Thoroughly review the user manual and technical documentation of drive to gain a comprehensive understanding of its performance. parameters, control modes, and wiring requirements.
- ▶ Gather necessary tools and devices for electrical commissioning, including multimeters, oscilloscopes, and screwdrivers.

2.10.2 Electrical debugging procedure

2.10.2.1 Power Connection

- ▶ Accurately connect the power cable and control cable according to the wiring diagram provided in the manual.
- ▶ Validate that the power supply voltage and frequency align with the rated requirements of the drive.
- ▶ Ensure a reliable grounding system that complies with safety standards.

2.10.2.2 Parameter Settings

- ▶ Configure operational parameters of the drive based on specific application needs, such as output frequency and overload protection, ensuring accurate settings.

2.10.2.3 Functional Testing

- ▶ Conduct no-load test to verify start, stop and speed regulation functionalities of the drive.
- ▶ Simulate input signals (e.g., voltage or current) and check inputs and outputs of the drive.

2.10.2.4 Troubleshooting

In case of any commissioning faults encountered:

- ▶ Refer to troubleshooting guidelines outlined in → chapter 9, "Error List". If issues persist, seek assistance from our technical support team

3 General information on safety functions

DX1 offers 11 safety functions including STO, SS1, SS2, SOS, SLA, SAR, SLS, SSR, SSM, SDI and SBC. The safety functions SS1, SS2, SOS, SLA, SAR, SLS, SSR, SSM, SDI and SBC are executed by FS card and S-ABZ card.

The control board (with STO function) is a standard for each drive, while FS card and S-ABZ card (with all other safety functions) are optional. FS card and the S-ABZ card can be plugged into the control board via the connector located inside the housing of the frequency inverter, where they are protected.

All DX1 drives have the same control board, FS card and S-ABZ card and have the same safety functions. Different frame sizes with different input voltage will have different design for power parts.

3.1 STO (Safe Torque Off)

The STO function is build-in for all DX1 series drives. It means that STO function is a standard configuration and can be achieved by standard drive without optional cards (FS card and S-ABZ card).

The STO function is available for operator to turn off the motor torque. It is certified by TÜV Rheinland and intended to be used in the safety related applications up to SIL 3 acc. to IEC/EN 61800-5-2, IEC/EN 61508 and IEC/EN 62061, and up to Cat. 4 / PL e acc. to EN ISO 13849-1.



- STO is located on control board and is a standard configuration for DX1. It can be used alone without FS card and S-ABZ card. STO can be triggered by user via control board STO input terminals directly.
- The STO function prevents force-producing power from being provided to the motor. This safety function corresponds to an uncontrolled stop in accordance with stop category 0 of EN 60204-1.
- This function meets the requirements for variable-speed drive systems defined in EN 61800-5-2 standard and ensures that torque-generating energy is no longer able to act on the motor shaft and that unintended starting is prevented

3 General information on safety functions

3.2 Other Safety Functions

3.2 Other Safety Functions



CAUTION

When the motor speed drops to the near zero speed zone (less than 30 rpm), the safe speed signal may be affected due to the dynamic characteristics of the motor system and the limitation of the control accuracy.

We can't guarantee that the motor is in a complete safe condition. Therefore, in extreme low motor speed cases which may affect the safe speed signal, users must be cautious and follow the relevant safety procedures to ensure the safety of human, equipment and reliability of the system.

The safety features provided by the safety card aim to meet safety standards or prevent potentially dangerous situations. In some scenarios, additional safety systems beyond the primary system, such as mechanical braking, may be essential to maintain safety in the absence of electrical power.

The safety card can only be configured by Safety Tool.

The inputs and outputs of the safety module can be customized to align with specific safety requirements. Requests to activate or deactivate safety functions come from external devices like push buttons, magnetic switches, or safety PLCs connected to the safety card. Thus, activation requests for safety functions can occur automatically, such as through sensor activation, or manually, like through switch activation.

Safety functions (SS1, SS2, SOS, SLA, SAR, SLS, SSR, SSM, SDI and SBC) can only be achieved by standard drives together with option cards (means FS card and S-ABZ card) and external safety encoder. FS card DI terminals can be used to activate these functions and DO terminals can be used to output these functions' status or perform some safety functions. Configuration of these safety functions must be done by Safety Tool. The function block diagram for these safety functions is shown in → figure 27. FS card functions can only be triggered by FS card DI. FS card DI cannot trigger STO function directly but can only trigger STO through other safety functions indirectly. FS card DO (Digital Output) can be configured as to output safety function status based on user application requirement.

Figure 27 shows the inputs and outputs for DX1 functional safety system including control board, FS card and S-ABZ card. FS card DI/DO configuration can be found in → Section 2.8.3, "FS card user IO wiring". Refer to → chapter 8, "List of Parameters" for the parameter configuration of each safety function.

3.3 Safe state

- For STO, SS1, SS2, SOS, SLA, SAR, SLS, SSR, SDI functions, the safe state is shutdown of motor torque. Safety functions make the drive go to a safe state if an error is detected.
- For SBC and SSM functions, the safe state is output low level of DO.

NOTICE
Reset means to enable the function again. DX1 cannot be auto reset once it's in safe state.

3.4 Response Time

The response time is the length of time from a safety-related event as input to the system until the system is in the safe state.

Safety function response time	Value
STO response time • The response time from STO terminal input to removal of motor torque	Max. 35 ms
Safety functions in FS card response time (SS1, SS2, SOS, SLA, SAR, SLS, SSR, SSM, SDI and SBC) • The response time from safety function request received to safety function start to execute	Max. 40 ms

3.5 Fault reaction Time

The fault reaction of the safety function is output safe state and report fault.

Safety function fault reaction time	Value
STO fault reaction time • Fault reaction time means the time from fault detection to shutdown of motor torque	1oo1 part: The fault reaction time \leq 35 ms 1oo2 part: The fault reaction time < 3 s
Safety functions on FS card fault reaction (SS1, SLA, SAR, SLS, SSR, SSM and SBC) • Fault reaction time means the time from fault detection to output safe state	1oo1 part: The fault reaction time \leq 40 ms 1oo2 part: The fault reaction time \leq 24 h
Safety functions on FS card fault reaction (SS2, SOS and SDI) • Fault reaction time means the time from fault detection to output safe state	1oo1 part: The fault reaction time \leq 300 ms 1oo2 part: The fault reaction time \leq 24 h

NOTICE
The demand interval time must be greater than 30 s for the safety function SS2/SOS/SDI.

3 General information on safety functions

3.6 Failure mode

3.6 Failure mode

The failure modes and diagnostics are listed in → Table 18. Relevant failure rates and other safety data are listed in → Table 3.8.

Table 18: Failure mode

Safety related part	Failure mode	Failure type	Fault reaction	DTI
STO	Safety function cannot be performed	Dangerous failure	Safe torque off	1oo1: ≤ 30 ms 1oo2: ≤ 2.8 s
	Safety function is triggered unexpectedly	Safe failure	N/A	N/A
SS1, SLS, SLA, SSR, SAR, SOS, SS2, SDI, SSM, SBC	Safety function cannot be performed	Dangerous failure	Safe torque off	1oo1: ≤ 35ms 1oo2: ≤ 24h
	Safety function is triggered unexpectedly	Safe failure	N/A	N/A
Diagnostic circuits of safety functions	Diagnostic function fail	No effect failure	N/A	N/A
	Diagnostic function is false triggered	Safe failure	N/A	N/A

3.7 Reliability diagram

To determine the safety integrity level/performance level of the 11 safety functions, the PFDavg/PFH of all components which included in the subsystems is calculated as follows RBD. For the RBD of STO function, please refer to the manual MN040068EN.

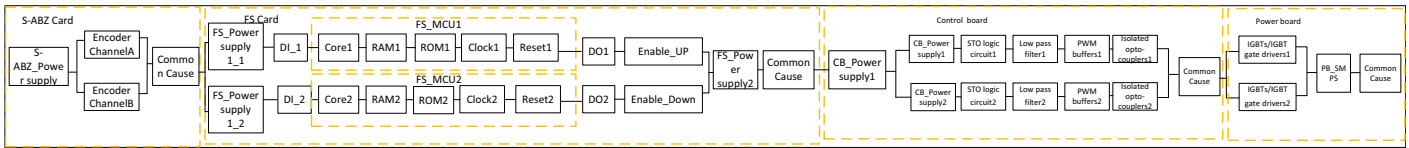


Figure 28: RBD of SS1, SLS, SLA, SSR and SAR functions

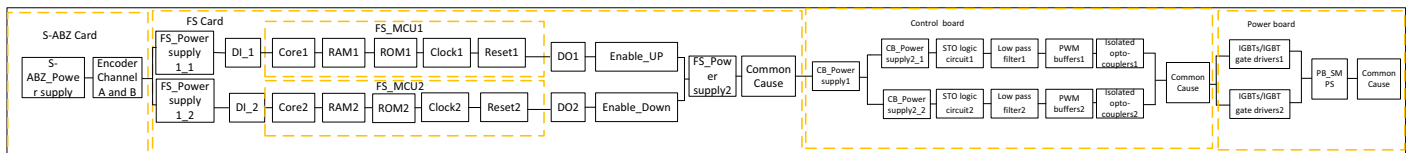


Figure 29: RBD of SOS, SS2 and SDI functions

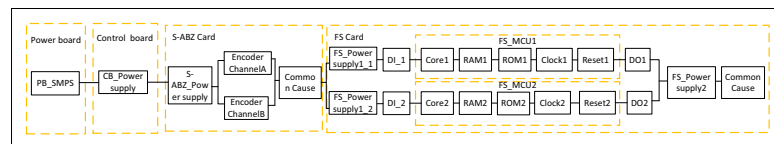


Figure 30: RBD of SSM and SBC functions

3 General information on safety functions

3.8 Safety related parameter



- SSM, SBC share the same subsystems and reliability block diagram.
- SS1, SLS, SLA, SSR, SAR, SOS, SS2 and SDI share the same subsystems. The reliability block diagrams of SS1, SLS, SLA, SSR and SAR are the same and the reliability block diagrams of SOS, SS2 and SDI are the same. Encoder signal conditioning circuit is a dual channel design for SS1, SLS, SLA, SSR and SAR, but a single channel design for SOS, SS2 and SDI.

3.8 Safety related parameter

The safety architecture diagram of all safety functions is as follows.

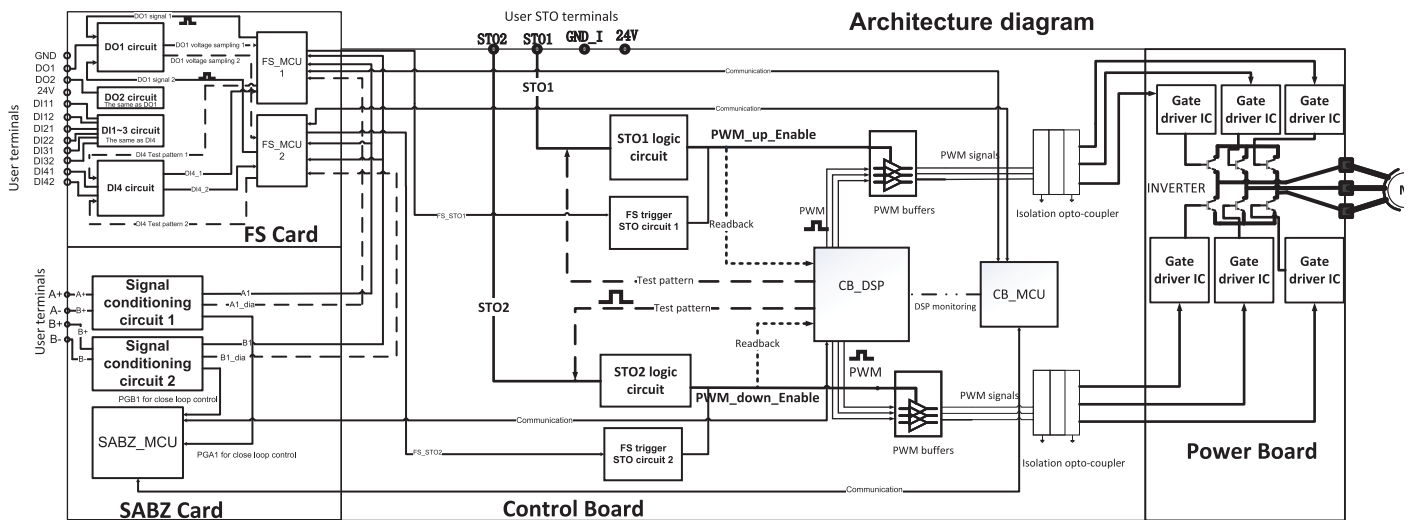


Figure 31: Architecture diagram of all safety functions

This product is a type B safety component as defined in IEC/EN 61508-2. The maximum useful mission time (T_m) is 20 years. The given safety data applies with proof test interval $T_1 = 20$ years (high demand and continuous mode of operation). Make sure the proof test is performed within this time. The data of these safety functions related to safety standards IEC/EN 61508, IEC/EN 61800-5-2, EN ISO 13849-1 and IEC/EN 62061 is listed below.

3 General information on safety functions

3.8 Safety related parameter

NOTICE

- All the safety-related parameters below are calculated without considering failure of external devices, e.g. buttons, power supply, etc.
- All the parameters are calculated based on the assumptions:
 - Failure rate of each component is based on the Siemens SN29500 database.
 - Component failure rates are constant over the life of the device.
 - Operating at a maximum ambient temperature of 50 °C.
 - The equal distribution is used for the failure modes ratio of each component.
- The failures of the diagnostic circuits have been taken into account in the calculation process of the safety parameters, and these failures will not affect the calculation results of the safety parameters.
- For the entire system including external devices (SSM and SBC), the safety parameters are calculated as follows:
 - Calculate the failure rate of the relay according to SN29500 and the MTTFd according to EN ISO 13849-1, annex C.
 - Add the failure rate to the failure rate of 1oo2 part in Table 21.
 - Calculate the DCavg according to the formula E.1 in EN ISO 13849-1.
 - Calculate the SFF, PFD, PFH according to EN 61508-6.

3.8.1 Safety Data of STO function

Please refer to Appendix E of the manual MN040068EN for the safety data of STO function.

3.8.2 Safety Data of SS1, SLS, SLA, SSR and SAR

Table 19: Safety data of SS1, SLS, SLA, SSR and SAR of different frame sizes

SS1, SLS, SLA, SSR and SAR	FR1	FR2	FR3	FR4	FR5	FR6
SIL	3	3	3	3	3	3
PL	e	e	e	e	e	e
Cat.	3	3	3	3	3	3
PFDavg	6.6E-4	7.4E-4	6.7E-4	6.5E-4	7.0E-4	7.6E-4
PFH	8.9E-9	9.8E-9	9.0E-9	8.8E-9	9.4E-9	1.0E-8
DCavg	Medium	Medium	Medium	Medium	Medium	Medium
MTTFd/years	72	68	71	72	70	67
PTI	20 years	20 years	20 years	20 years	20 years	20 years
MRT	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
MTTR	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
β	1%	1%	1%	1%	1%	1%
β_d	1%	1%	1%	1%	1%	1%
HFT=0 part						
SFF	99.61%	99.58%	99.56%	99.60%	99.62%	99.58%
λ (total failures)/FIT	841.16	993.77	766.85	787.55	1000.93	1053.09
λ_S (safe failures)/FIT	519.79	581.19	430.66	477.07	628.87	615.47
λ_{DD} (dangerous detected failures)/FIT	318.12	408.42	332.80	307.34	368.30	433.21
λ_{DU} (dangerous undetected failures)/FIT	3.25	4.16	3.40	3.14	3.76	4.41
HFT=1 part						
SFF	95.20%	94.94%	95.05%	95.36%	95.10%	95.02%
λ (total failures)/FIT	3214.27	3047.98	3113.68	3319.30	3145.77	3096.11
λ_S (safe failures)/FIT	1948.24	1781.95	1847.65	2053.27	1879.74	1830.08
λ_{DD} (dangerous detected failures)/FIT	1111.88	1111.88	1111.88	1111.88	1111.88	1111.88
λ_{DU} (dangerous undetected failures)/FIT	154.25	154.25	154.25	154.25	154.25	154.25

→ The worst case is selected for each frame size and listed in the table.

3 General information on safety functions

3.8 Safety related parameter

3.8.3 Safety Data of SOS, SS2 and SDI

Table 20: Safety data of SOS, SS2 and SDI of different frame sizes

SOS, SS2, SDI	FR1	FR2	FR3	FR4	FR5	FR6
SIL	2	2	2	2	2	2
PL	c	c	c	c	c	c
Cat.	2	2	2	2	2	2
PFDavg	3.0E-3	3.0E-3	3.0E-3	2.9E-3	3.0E-3	3.1E-3
PFH	3.5E-8	3.6E-8	3.5E-8	3.5E-8	3.5E-8	3.6E-8
DCavg	Medium	Medium	Medium	Medium	Medium	Medium
MTTFd/years	66	62	65	66	64	61
PTI	20 years	20 years	20 years	20 years	20 years	20 years
MRT	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
MTTR	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
β	1%	1%	1%	1%	1%	1%
β_d	1%	1%	1%	1%	1%	1%
HFT=0 part						
SFF	97.41%	97.64%	97.22%	97.29%	97.68%	97.72%
λ (total failures)/FIT	1158.84	1311.45	1084.53	1105.23	1318.61	1370.77
λ_s (safe failures)/FIT	528.99	590.38	439.85	486.26	638.07	624.66
λ_{DD} (dangerous detected failures)/FIT	599.81	690.11	614.49	589.03	649.99	714.90
λ_{DU} (dangerous undetected failures)/FIT	30.05	30.96	30.19	29.94	30.55	31.21
HFT=1 part						
SFF	95.39%	95.13%	95.24%	95.55%	95.29%	95.21%
λ (total failures)/FIT	3055.43	2889.14	2954.84	3160.46	2986.93	2937.27
λ_s (safe failures)/FIT	1943.64	1777.36	1843.05	2048.68	1875.14	1825.49
λ_{DD} (dangerous detected failures)/FIT	971.03	971.03	971.03	971.03	971.03	971.03
λ_{DU} (dangerous undetected failures)/FIT	140.85	140.85	140.85	140.85	140.85	140.85

→ The worst case is selected for each frame size and listed in the table.

3 General information on safety functions

3.8 Safety related parameter

3.8.4 Safety Data of SSM and SBC

For SSM and SBC, there will be an external device connected to DO, such as a relay, which have been also considered in the safety data calculation. Users use a relay that complies with the EN 61810-3 to achieve SIL 3. Since there is no restriction on the specific model of the user's external device, the following are the safety data except for the DO external device. The user can calculate the overall safety data according to the calculation guide in above notice.

Table 21: Safety data of SSM and SBC of all frame sizes

SSM, SBC	FR1	FR2	FR3	FR4	FR5	FR6
SIL	3	3	3	3	3	3
PL	e	e	e	e	e	e
Cat.	3	3	3	3	3	3
PFDavg	6.2E-4	7.0E-4	6.4E-4	6.1E-4	6.7E-4	7.2E-4
PFH	8.5E-9	9.4E-9	8.6E-9	8.3E-9	9.0E-9	9.6E-9
DCavg	Medium	Medium	Medium	Medium	Medium	Medium
MTTFd/years	80	75	79	80	77	74
PTI	20 years	20 years	20 years	20 years	20 years	20 years
MRT	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
MTTR	0 hour	0 hour	0 hour	0 hour	0 hour	0 hour
β	1%	1%	1%	1%	1%	1%
β_d	1%	1%	1%	1%	1%	1%
HFT=0 part						
SFF	99.64%	99.60%	99.58%	99.63%	99.64%	99.60%
λ (total failures)/FIT	798.39	950.99	724.07	744.78	958.15	1010.32
λ_s (safe failures)/FIT	512.28	573.67	423.14	469.56	621.36	607.95
λ_{DD} (dangerous detected failures)/FIT	283.21	373.50	297.88	272.43	333.39	398.30
λ_{DU} (dangerous undetected failures)/FIT	2.90	3.81	3.05	2.79	3.40	4.06
HFT=1 part						
SFF	94.19%	94.19%	94.19%	94.19%	94.19%	94.19%
λ (total failures)/FIT	2635.16	2635.16	2635.16	2635.16	2635.16	2635.16
λ_s (safe failures)/FIT	1486.35	1486.35	1486.35	1486.35	1486.35	1486.35
λ_{DD} (dangerous detected failures)/FIT	995.83	995.83	995.83	995.83	995.83	995.83
λ_{DU} (dangerous undetected failures)/FIT	153.08	153.08	153.08	153.08	153.08	153.08

3 General information on safety functions

3.9 Safety Encoders

3.9 Safety Encoders

If safety functions SS1, SS2, SOS, SLA, SAR, SLS, SSR, SDI, SBC or SSM required, safety encoders will be required to ensure DX1 functional safety compliance.

NOTICE

For all the safety functions which requires speed/direction/ relative position information, only asynchronization AC motor + incremental encoder is supported for DX1.

3.9.1 Supported encoders

Table below describes the supported encoder types for DX1 functional safety application.

Table 22: Safety encoders required for DX1 functional safety application

Brand / Manufacturer	Wieland Electric GmbH	BEI Sensors (Sensata Technologies)
Safety Encoder Type	SENC-58S, SENC-58H, SENC-90S, SENC-90H	DSM5-5G59, DS05-5G59, DSK5-5G59, DST5-5G59, DSM9-5G59, DSU9-5G59
Certified by	TÜV Rheinland	TÜV Rheinland
Certificate No.	01/205/5694.01/24	01/205/5356.02/20
Safety level	SIL 3, Cat.4, PL e	SIL 3, Cat.4, PL e

3.9.2 Safety Encoder Input Specification

S-ABZ card receives speed signals from safety encoder via A+, A-, B+ and B- terminals. Safety encoder must provide A+/A- and B+/B- differential signals to S-ABZ card via these terminals. The voltage of A+/A- and B+/B- differential signals is corresponding to the voltage of safety encoder power supply.

Table 23: Safety encoder input specification

Attribute	Encoder power supply	Value
Channel A/B signal threshold VIH	15 V	Min. 11 V
	24 V	Min. 18 V
Channel A/B signal threshold VIL	15 V	Max. 3 V
	24 V	Max. 3 V
Channel A/B signal threshold	15 V	Max. 200 kHz
	24 V	Max. 200 kHz
A/B signal frequency sampling error	15 V	Max. 0.5%
	24 V	Max. 0.5%

NOTICE

- The A/B signal frequency sampling error will change with the clock frequency error. When the clock frequency error is less than 1 %, the A/B signal frequency sampling error will not exceed 1.5%. When the clock frequency error exceeds 1 %, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.
- Less than 0.5% can only be used for non-safety functions.
- All speed related safety functions must take 1.5% error into consideration.

3.9.3 Encoder Diagnostics

Depending on the encoder type, DX1 drive performs several diagnostic tests on encoder signals to detect faults in the encoder.

The following encoder diagnostics are available for all supported encoder types:

Diagnostic	Description
Cable break detection	<p>Cable break detection is essential because all internally detected faults within the encoder as well as any loss of connection to the encoder will have to be detected on the external interface by this method.</p> <p>The safety encoder must indicate its internal faults by setting its outputs to the hi-Z state according to the user manual of the safety encoder.</p> <p>High-Z state diagnostic is done together with the encoder inverse signal diagnostic for cable break detection. If there is high-Z state on A, B signal wires, A+/A- and B+/B- channel are setting its complement inputs to identical states, in this case the fault will be reported.</p>
Speed comparison	<p>Speed comparison means that channel 1 (A+ or A-) and channel 2(B+ or B-) are considered as to be redundant and have the same frequency within 30 rpm tolerance.</p> <p>FS card will capture the signal from channel A/B and calculate the speed (speed _A/ speed _B). If the difference between these two speeds is greater than 30 rpm and lasts for 300 ms, then speed cross-diagnostic fault is reported, and FS card output safe state.</p>
Inverse signal monitoring	<p>In each safety digital channel, the non-inverted (A+ and B+) and inverted (A- and B-) signals must at all times, have an opposite signal level. During the transition state, a very short period of a few microseconds showing the same signal level is allowed.</p> <p>The circuit on the S-ABZ card will determine whether the differential encoder signal has opposite signal level and send the judgment result to FS card. If any failure happened in motor encoder or wiring cables, FS card will receive a wrong result. Then the fault will be detected, FS card will trigger STO, and reports speed self-diagnostic fault.</p>
Exclusive bit check	<p>The AB signal can be performed e.g. 00 -> 01 -> 11 -> 10 -> 00 (at any time, only one bit changed each step, but not two bits at each step). In case of a simultaneous bit changing, it will be considered as a phase error. If phase error lasts over 0.1 s, then direction self-diagnostic fault is reported, and FS card output safe state.</p>

3 General information on safety functions

3.10 DTI for offline test

3.10 DTI for offline test

According to the requirements of 61800-5-2, for undetected failure a suitable DTI for offline test is required.

DTI for offline test definition	Validation
STO function must be performed once per day for SIL 3, PL e / category 4 requirements.	Refer to Appendix E - STO function for Chapter "Commission and Validation" of PowerXL™ DX1 Series VFD Installation manual (MN040068EN).
SBC function must be performed once per three months for SIL 3, PL e / category 3 requirements.	Chapter "Validation of SBC"
All used digital input ports of FS card must be active once per three months for SIL 3, PL e / category 3 requirements. (When the digital input port is connected to a device that cannot be diagnosed online (such as a safety switch), this test must be performed regularly; when the digital input port is connected to a device that can complete online diagnosis by itself (such as a safety PLC), this test does not need to be performed.)	<p>Validation step:</p> <ol style="list-style-type: none"> 1. Activate safety functions with digital input ports. 2. Verify that safety functions are performed as expected. <p>Note: Users can perform the above operations according to the safety function that are used. To verify that safety functions are performed as expected, please refer to the validation of each function:</p> <ul style="list-style-type: none"> Check SS1: → Section 5.2, "Validation of SS1". Check SS2: → Section 5.3, "Validation of SS2". Check SLS: → Section 5.4, "Validation of SLS". Check SDI: → Section 5.5, "Validation of SDI". Check SOS: → Section 5.8, "Validation of SOS". Check SSM: → Section 5.9, "Validation of SSM". Check SLA: → Section 5.10, "Validation of SLA". Check SSR: → Section 5.11, "Validation of SSR".

3.11 Certificates

Certified by TÜV Rheinland for functional safety:

Safety function	Safety Level
STO (Safe Torque Off)	SIL 3, PL e, Cat. 4
SS1 (Safe Stop 1 (safe stop with following STO))	SIL 3, PL e, Cat. 3
SS2 (Safe Stop 2 (safe stop with following SOS))	SIL 2, PL c, Cat. 2
SOS (Safe operating stop (actively hold the motor in stop position))	SIL 2, PL c, Cat. 2
SLA (Safe limited acceleration)	SIL 3, PL e, Cat. 3
SAR (Safe acceleration range)	SIL 3, PL e, Cat. 3
SLS (Safe limited speed)	SIL 3, PL e, Cat. 3
SSR (Safe speed range)	SIL 3, PL e, Cat. 3
SSM (Safe Speed Monitor)	SIL 3, PL e, Cat. 3
SDI (Safe Direction)	SIL 2, PL c, Cat. 2
SBC (Safe Brake control)	SIL 3, PL e, Cat. 3

For safety-related control systems, Performance Level (PL), according to EN ISO 13849-1, and SIL levels, according to EN 61508 and EN 62061.

3 General information on safety functions

3.12 Common Requirements

3.12 Common Requirements

DX1 will offer 11 safety functions including STO, SS1, SS2, SOS, SLA, SAR, SLS, SSR, SSM, SDI and SBC. All safety functions requirements and their relationship are listed in tables below.

Table 24: Safety functions requirements and their relationship

Function	Card required
Safety function: STO	No option card required
Safety functions: SS1, SS2, SOS, SLA, SAR, SLS, SSR, SDI, SSM, SBC	FS card + S-ABZ card

NOTICE

- S-ABZ card: Safety ABZ card
 - Closed loop control with ABZ encoder.
 - Dual encoder input channels, no output.
 - Group with FS card as the input of safety functions.
- FS card: 10 safety functions.
 - S-ABZ card is required for all the safety functions except SBC.

NOTICE

Safety encoder is not a part of eaton DX1 product. It is out of the scope of this functional safety certification. Users need to prepare the right encoder themselves according to the instruction in DX1 safety manual and installation manual. S-ABZ card is necessary to get speed/direction/relative position information associate with external safety encoder

4 Safety Functions

This chapter describes the operations of each safety function, as well as the DI interface, parameter configuration, and validation.

The basic parameters can be configured by the user. DO can be configured to output safety function status based on user application requirements.

Refer → chapter 8, “List of Parameters” for the complete list of parameters.

Refer → Table 25 for safety related parameters.



WARNING

The safety functions (except STO on control board) must be implemented together with external safety encoder.

4 Safety Functions

Table 25: Parameter selection of safety functions

Parameters	Selection	Parameters	Selection
Basic Parameters	Encoder Pulse Count	SDI Function	SDI+ Enable
	Max Speed		SDI- Enable
	DO1 Mode		SDI Mode
	DO2 Mode		SDI+ Source
	Safety Card Configuration		SDI- Source
	DO Pulse Width		SDI-t delay
SS1 Function	SS1 Enable	SDI Limit degree	
	SS1 Source	SDI n = 0 Limit	
	SS1 Mode	SDI Acknowledgement Mode	
	t-delay STO@SS1	SLA Function	SLA Enable
	SS1 n = 0 Limit		SLA Source
	SS1 Acknowledgement Mode		SLA t-delay
SBC Function	STO SBC Mode		SLA+ trip limit
	STO SBC delay		SLA+ limit
	SS1 SBC speed		SLA- trip limit
	SBC feedback action	SLA delta-t	
SLS Function	SLS Enable	SLA Acknowledgement Mode	
	SLS Mode	SSR Function	SSR Enable
	SLS-t delay		SSR Source
	SLS Source		SSR upper limit
	SLS trip limit		SSR t-delay
	SLS limit		SSR Acknowledgement Mode
	SLS Acknowledgement Mode		SAR Function
SOS Function	SOS Enable		
	SOS Source	Deceleration tolerance	
	SOS n = 0 - Hysteresis	Monitor Function	Encoder speed
	SOS Acknowledgement Mode		Encoder position
SS2 Function	SS2 Enable		Encoder direction
	SS2 Source		DI status
	SS2 Mode	DO status	
	t-delay STO@SS2	STO status	
	SS2 n = 0 Limit	SSM Function	SSM Enable
	SS2 Acknowledgement Mode		SSM Source
SSM Function	SSM Limit		SSM Hysteresis
	SSM Enable		
	SSM Source		
	SSM Limit		
SSM Hysteresis			

4.1 Competence

The configuration of the system must be guaranteed by a qualified system integrator or by an application carried out by a trained, experienced, and safety-conscious authorized operator. To ensure the highest level of safety and reliability, the following good design practices must be adhered to, emphasizing the necessity of safety engineering capacity:

- Utilize comprehensive functional specifications, incorporating flow-charts, timing diagrams, sequence diagrams, and safety-related requirements.
- Conduct thorough configuration checks, incorporating safety assessments to identify and mitigate potential hazards.
- Perform rigorous configuration validation, ensuring that all safety-critical components and settings meet or exceed established safety standards and regulations.

The integration of safety engineering capacity is crucial in ensuring that the system configuration is not only safe but also designed with the utmost consideration for safety and risk management.

4.1.1 Risk analysis

STO risk analysis

Risk point: STO function fails and torque output cannot be cut off in time.

Risk Impact: The device may start unexpectedly, causing personal injury or device damage.

SS1 and SS2 risk analysis

Risk: SS1 and SS2 fail, and the device cannot be stopped in time.

Risk Impact: A safety accident may result in personal injury or device damage.

SOS Risk Analysis

Risk point: The SOS function fails and the device cannot be stopped in the safe operation stop mode.

Risk impact: The device may run in an insecure state, increasing safety risks.

SLA and SAR risk analysis

Risk point: SLA and SAR functions fail, resulting in device acceleration beyond the safe range.

Risk Impact: Equipment damage or personal injury may be caused.

SLS and SSR risk analysis

Risk point: SLS and SSR functions fail, resulting in equipment running faster than the safe range.

Risk Impact: Equipment damage or personal injury may be caused.

4 Safety Functions

4.1 Competence

SSM risk analysis

Risk point: The SSM function fails and the device speed cannot be accurately monitored.

Risk impact: The device speed may be out of control, resulting in safety accidents.

SDI risk analysis

Risk point: The SDI function fails and the device movement direction cannot be accurately controlled.

Risk impact: The device may move in the wrong direction, resulting in a safety accident.

SBC risk analysis

Risk point: SBC function failure, failure to properly control the brake system.

Risk impact: The device may fail to stop in time, resulting in a safety accident.

4.1.2 Comprehensive risk assessment

Through the risk analysis of the above safety functions, it can be seen that there are potential safety risks in many aspects of this project.

To ensure system safety and reliability, you are advised to take the following measures:

- ▶ Strengthen the testing and monitoring of various safety functions to ensure their normal operation.
- ▶ Establish a sound risk management mechanism, including risk assessment, risk monitoring, risk response, etc.
- ▶ Strengthen personnel training, improve staff safety awareness and operational skills.
- ▶ Maintain the system regularly to improve device reliability.
- ▶ Consider the use of redundant design and backup scheme to improve the overall safety and reliability of the system

4.2 General

4.2.1 Safety function request

FS card DI can be configured as safety function request signals.

For details about DI wiring, refer to → Section 2.8.3, “FS card user IO wiring”.

The digital input request signal to activate the safety function can come from the safety switch, safety plc, or other safety function. See → chapter 6, “Interaction and priority of Safety Functions”

→ For instance, to activate a safety function using a switch, the Connect DI switch must be of type “normally closed”. connect the switch to a DI that is supplied with 24 V. Here, 24 V signifies a non-request state for the safety function, whereas 0V represents a request for activation.

DI Number: 4 redundant digital inputs (2 user terminals for each redundant DI, total 8 terminals).

The Maximum allowable time delay between redundant input channels is 300 ms.

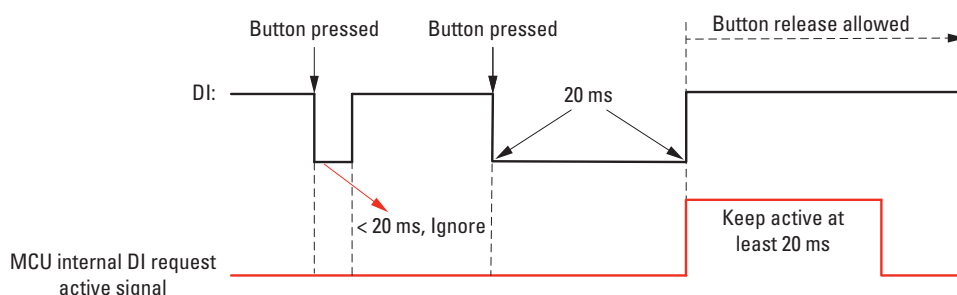


Figure 32: DI sequence diagram

The safety function request identifies whether DI is valid by monitoring the low level of the DI pin. The low level remains for at least 20 ms and is regarded as a request signal.



CAUTION

Users must ensure that the DI required to activate safety function (excluding STO and SBC) must be at least 25 ms low level signal duration. If the time threshold is lower than this value, safety functions may not be properly identified and performed, affecting the safety performance of the device.

4 Safety Functions

4.2 General

4.2.2 How to configure DI

DI can be configured as safety function request signal by user via PowerXL™ Safety Tool.

For example, user can configure DI1 as SS1 DI request, by setting parameter “SS1 source” to “DI11_DI21”.

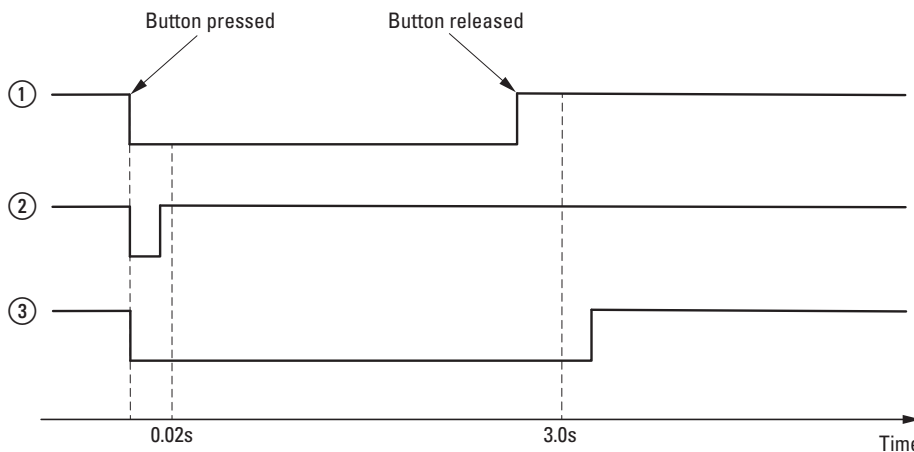
Table 26: Example of four DI set-up:

Step	PanelCode	Parameters	Set value	Description
1	P2.2	SS1 Source	DI11 & DI21	Set the DI source(DI1) to activate the SS1 function
2	P5.2	SOS Source	DI12 & DI22	Set the DI source(DI2) to activate the SOS function
3	P6.2	SS2 Source	DI13 & DI23	Set the DI source(DI3) to activate the SS2 function
4	P10.2	SSR Source	DI14 & DI24	Set the DI source(DI4) to activate the SSR function

4.2.3 Safety function acknowledgement

The safety function acknowledgement is a step that a device must perform after removing a safety function request. This step is used to acknowledge that the user understands and accepts the current safety state of the device, allowing the drive to revert to the ready state.

FS card will detect the DI signal change from rising edge to falling edge or from falling edge to rising edge within 0.02 to 3.0 s before it is considered to have successfully triggered the acknowledgement.



Step	Description	Status
①	Press and release button to acknowledge. It takes 0.02 to 3.0 seconds to complete the button operation.	Normal
②	Low signal less than 0.02s, this operation is ignored.	Abnormal
③	Low signal greater than 3.0s, this operation is ignored.	Abnormal

**WARNING**

The abnormal operation occurs during the acknowledgement, and the user needs to press the acknowledgement button again.

User can configure the acknowledgement method separately for safety functions SS1, SLS, SOS, SS2, SDI, SLA and SSR. Details can be found in the following sections for these safety functions.

4.2.3.1 Acknowledgement method

The acknowledgement method can be automatic or manual.

Manual acknowledge: The user must connect the acknowledge button to FS card. When the safety function request is removed, the action button acknowledges the safety function to allow the drive to return to the ready state.

Automatic acknowledgement: When the safety function request has been removed, FS card will automatically acknowledge the safety function, allowing the drive to return to the ready state.

NOTICE

"Acknowledge" is performed only after the user manually removes the safety function. When removing a safety function event, a acknowledge step is required to avoid mistakenly removing a safety function request.

**CAUTION**

According to EN 60204-1 automatic acknowledge is not allowed after an emergency stop.

If you decide to adopt the Automatic Acknowledge, you need to thoroughly understand its potential risks and conduct a comprehensive risk assessment. Additionally, ensure that the system configuration is accurate and has undergone thorough testing to verify the reliability and accuracy of the automatic acknowledgment function across various scenarios.

Ultimately, the decision to enable or disable this function is entirely based on your own risk assessment. We commit to providing necessary technical support and guidance, but we do not bear any responsibility for any consequences that may arise from inadequate risk assessment. Please consider carefully and ensure that your choice meets the highest safety standards.

4 Safety Functions

4.2 General

4.2.3.2 Configuring acknowledgement

Connection mode: The acknowledge button must be of type "normally closed" (NC) and connected to the digital input of FS card in the same way as the normal safety input.

Voltage state: Input 24V indicates standby state, 0V indicates acknowledge state.

Parameter configuration: By setting the Acknowledgement Mode parameter of each safety function, the acknowledgement button input port is configured for the acknowledgement function.



WARNING

When using acknowledgement, make sure that you do not create unacceptable risks by removing safety functions..

4.2.4 Configuring the safety encoder

S-ABZ card receives differential AB signals from motor encoder and converts these signals to single-end signals. The single-end AB signals will be sent to functional safety card via control board.

There are two independent channels on S-ABZ card, which are called safety encoder signal conditioning circuits. Their function is to reduce noise on the signal cables to obtain clean signals.

4.2.4.1 How to configure encoder

When using the PowerXL™ DX1 series functional safety option cards, only the safety encoder can be used.

To configure the safety encoder settings, set the FS card parameters listed below to appropriate values using the PowerXL™ Safety Tool. For example:

Table 27: Example

Step	PanelCode	Parameters	Set value	Description
1	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
2	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder

→ Here is an example, a 1024 encoder is used with a maximum speed of 1500 rpm. The user must set the correct parameters according to the encoder they are using.

For the connection of SABZ and encoder, please refer to

→ Section 2.9.4, "S-ABZ card user IO connection procedure".

**WARNING**

- The motor speed estimation error is less than $0.5\% \times \text{maximum speed}$.
- The motor speed estimation error will change with the clock frequency error. When the clock frequency error is less than 1%, the motor speed estimation error will not exceed $1.5\% \times \text{maximum speed}$. When the clock frequency error exceeds 1%, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.
- Less than the $0.5\% \times \text{maximum speed}$ only be used for non-safety functions.
- All speed related safety functions must take 1.5% error into consideration.

**WARNING**

- The motor acceleration estimation error will change with the clock frequency error. When the clock frequency error is less than 1%, the motor acceleration estimation error will not exceed $2\% \times \text{user setting acceleration}$. When the clock frequency error exceeds 1%, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.
- Less than the $1\% \times \text{user setting acceleration}$ only be used for non-safety functions.
- All acceleration related safety functions must take 2% error into consideration.

→ After connecting encoder to SABZ card, run the drive with Freq Control and check if the motor speed read by FS card is positive, if the motor speed is negative, then exchange any two phases of the drive's output.

4.2.5 Configuring the FS card

When using the FS card, you need to set parameters (P1.6 Safety Card Configuration). The FS card is configured to improve the overall safety and reliability of the product and ensure that the FS card can operate properly under the condition that the safety rules are met.

The configuration process is as follows:

- Insert the FS card and start the drive.
- Use the PowerXL™ Safety Tool to set parameters (P1.6 Safety Card Configuration) to "1".
- Configure verification. After receiving the safety configuration information, the drive is strictly verified. If the configuration information does not conform to the preset safety rules, the drive will report a "Safety card configuration fault", which will prevent further operation of the product.

4 Safety Functions

4.2 General

Table 28: Safety Card Configuration rules

Drive detection	Safety Card Configuration	
	Set to "0" - No Safety Card	Set to "1" - FS + SABZ Card
No card	OK	Fault
FS card	Fault	Fault
SABZ card	OK	Fault
FS + SABZ card	Fault	OK



WARNING

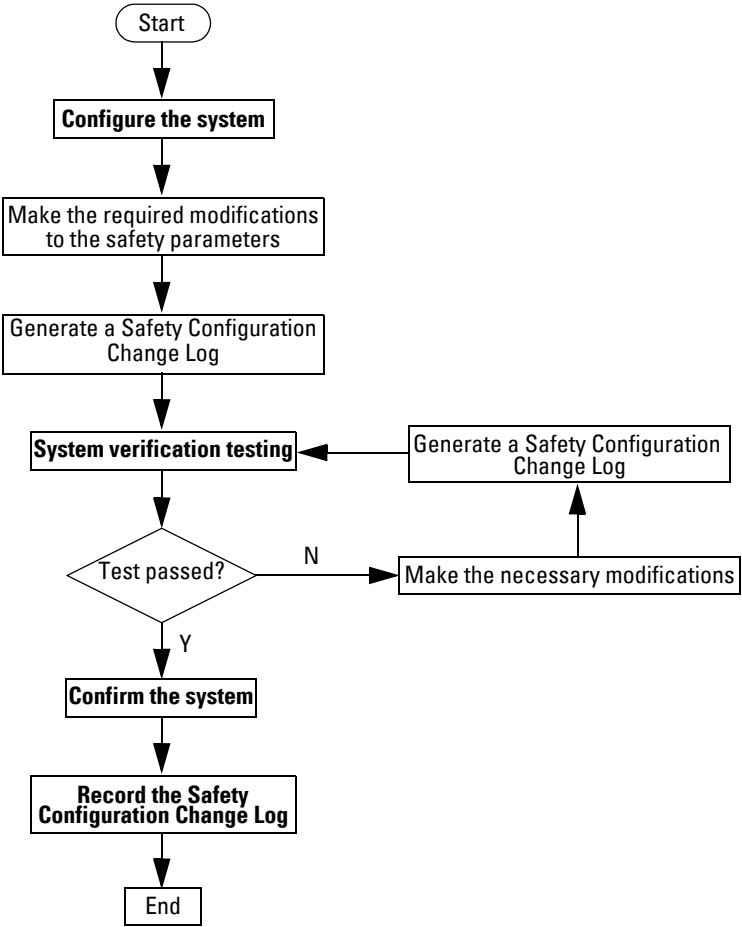
If the fault Safety Card Configuration is Incorrect occurs, check whether the configurations comply with rules and configure the safety card again.

If the problem persists, contact the product technical support team for help.

Only authorized and specially trained personnel can edit the configuration, e.g. software password protection. When edits are made by authorized and specially trained personnel, they must have the primary safety responsibility for the change process. These personnel must also ensure safe application operation. You must adequately document all edits, including the following:

- Authorization
- Impact analysis
- Execute
- Test information
- Version information

This flowchart shows the steps required to configure the system. Items in bold are described in the following sections.



4 Safety Functions

4.2 General

4.2.5.1 Configure the system

In order to ensure the safety of the system and comply with the safety standards identified in the application risk assessment, you need to develop a detailed set of system configuration specifications based on the actual use of the customer. This set of specifications will serve as a benchmark for validating that configuration choices meet the requirements of the application's functionality and safety controls. When writing your specification, make sure it's comprehensive enough to include (but is not limited to) the following key information:

- Clear operation process steps to guide users or administrators on how to configure step by step.
- Flowcharts and timing diagrams to visually show the various steps in the system configuration process and their chronological sequence.
- Sequence diagrams detailing the interaction and messaging between system components.
- A detailed description of each configuration parameter, including its purpose, value range, and recommended settings.
- Documented requirements for step execution, covering conditional branching and execution actions that need to be controlled, ensuring that each step is well documented.
- Clear input and output definitions to help users understand how the system interacts with the external environment.
- I/O wiring diagrams and reference information to guide system hardware connections.
- The working principle of the system is explained to help users deeply understand the logic and purpose behind the configuration.

By following this detailed set of specifications, you will be able to ensure the correctness, integrity, and safety of your system's configuration to meet the functional requirements and safety control requirements of your application.

4.2.5.2 System verification testing

To ensure that the configuration of the safety option card adheres to the standards and requirements of the application, a series of test cases that are closely related to the application need to be carefully designed and executed. These test cases must be formally documented and archived as test specifications for subsequent reference and auditing. In addition, a specific set of tests must be included to verify the actual effect and effectiveness of the safety configuration parameters. Thorough functional testing is an essential step before the system goes live to ensure that all functions of the safety-related system are working as intended.

For details on function configurations, refer to the following sections.

4.2.5.3 Confirm the system

When configuring the system, you must review each parameter individually to ensure that they have been set to be appropriate and accurate values in accordance with the system configuration specifications to ensure the stable operation and performance of the system.

4.2.5.4 Record the Safety Configuration Change Log

The "Safety Log" function is designed to provide a detailed record of the current system's parameter configuration status and to detect any changes in the safety parameters in real time. The change log (in CSV file format) will be stored in the PowerXL™ Safety Tool to ensure data safety and traceability. Details of the following changes will be automatically recorded in the change log:

- Operation timestamp: Accurately record the date and time of each parameter change.
- Operator Information: Identifies the identity of the person who performed the change operation in detail.
- Parameter change details: Clearly list which parameters were modified and what specific changes those parameters have experienced.
- Drive SN: Records the unique identification of the drive at the time of the change operation.
- Firmware version: records the firmware version information of the system or device when the parameters are changed.

Such a logging mechanism not only helps system administrators track and monitor parameter change history, but also provides critical information support in the event of a safety incident to ensure the safety and stability of the system

4.3 STO (Safe Torque Off)

For detailed function introduction and usage, please refer to "Appendix E - STO function" of PowerXL™ DX1 Series VFD Installation manual (MN040068EN).

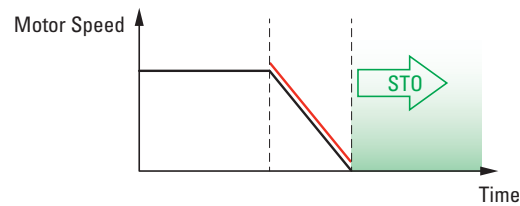
4 Safety Functions

4.4 SS1 (Safe Stop 1)

4.4 SS1 (Safe Stop 1)

4.4.1 Function Description

The SS1 (Safe Stop 1) function stops the motor safely by ramping down the motor speed, it will activate the drive's STO function below a user-defined zero speed limit. This safety function corresponds to a controlled stop in accordance with stop category 1 of IEC 60204-1.



The SS1 function uses SAR parameters to define and/or monitor the deceleration ramp.

The SS1 function utilizes the time (SS1-t) or ramp (SS1-r) monitoring method to respectively monitor the deceleration ramp.

The SS1-t uses SAR parameter to define the deceleration ramp.

The SS1-r uses SAR parameters to define and monitoring deceleration ramp.

See → Section 4.4.3, "Timing Diagram" and → Section 4.4.8, "Configuration" for more information.

4.4.2 Safety parameters

→ section , "SS1 Parameters (P2)", page 200

4.4.3 Timing Diagram

4.4.3.1 SS1-t

FS card monitors the motor speed which is expected to ramp to zero within defined delay time. If the motor speed is greater than defined zero speed after defined delay time, FS card activates the STO function and motor coasts down to stop.

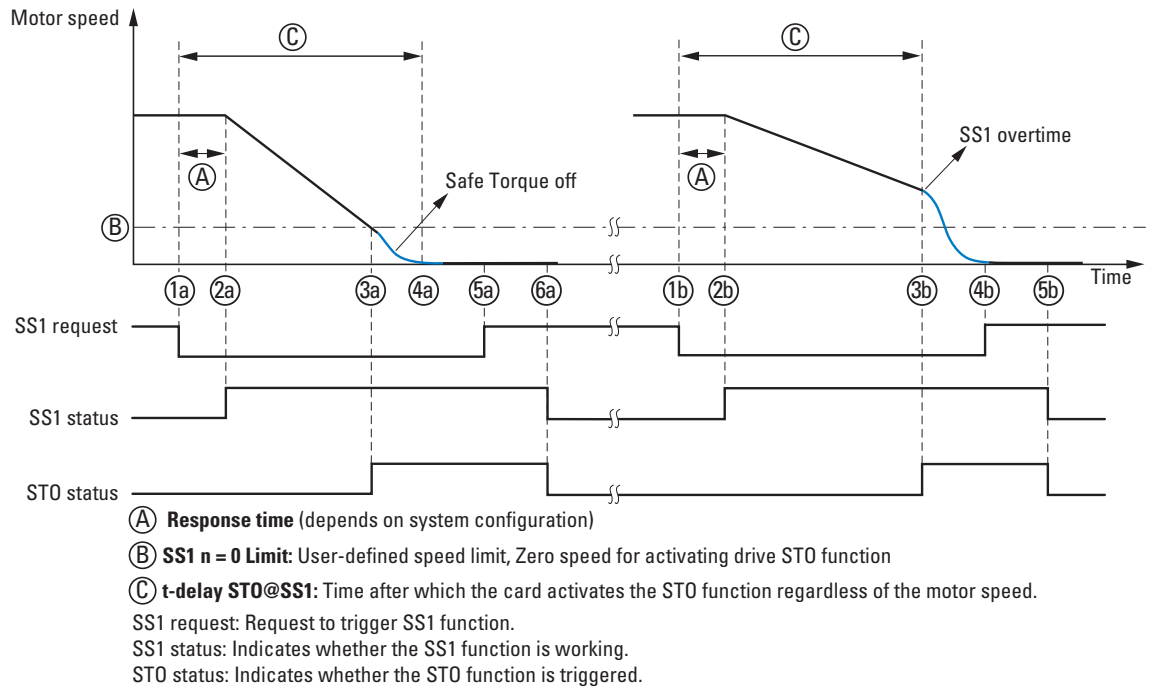


Figure 33: SS1-t function

4 Safety Functions

4.4 SS1 (Safe Stop 1)

Table 29: Timing diagram

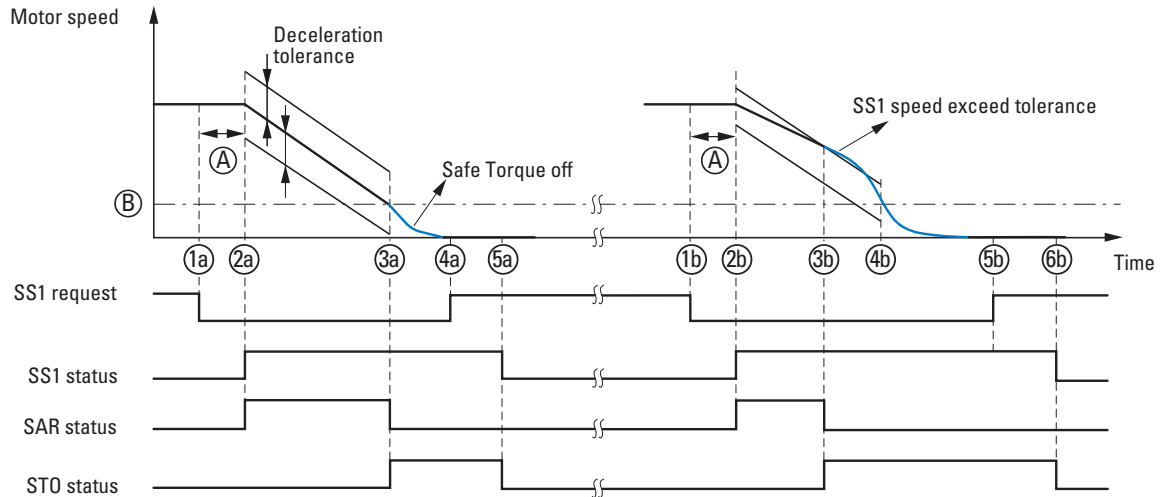
Step	Description
1a	FS card DI triggers SS1 and FS card starts a counter for delay time (C).
2a	After response time (A) has elapsed, the drive decreases the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters).
3a	Motor speed goes below the user-defined zero speed limit (B) and FS card activates STO function.
4a	End of delay time (C). The motor is reduced to zero speed (B) here at the latest.
5a	The SS1 request is removed from FS card DI.
6a	The SS1 & STO function are acknowledged from FS card DI (manual acknowledgement), and the SS1 & STO status indication goes off.
1b	Receives the SS1 request from FS card DI. Start a counter for delay time (C).
2b	After response time (A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters).
3b	When delay time (C) ends, and the motor speed has not yet reduced to zero speed (B), FS card reports over time and activates the STO function.
4b	The SS1 request is removed.
5b	The SS1 & STO function are acknowledged (manual acknowledgement), and the SS1 & STO status indication goes off.

→ User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4.4.3.2 SS1-r

FS card monitors the motor speed which is expected to ramp to zero within defined deceleration tolerance. If the motor speed exceeds defined deceleration tolerance, FS card activates the STO function and motor coasts down to stop.



- (A) **Response time** (depends on system configuration)
- (B) **SS1 n = 0 Limit:** User-defined speed limit, Zero speed limit for activating drive STO function
- SS1 request: Request to trigger SS1 function.
- SS1 status: Indicates whether the SS1 function is working.
- SAR status: Indicates whether the SAR function is working.
- STO status: Indicates whether the STO function is triggered.

Figure 34: SS1-r function

4 Safety Functions

4.4 SS1 (Safe Stop 1)

Table 30: Timing diagram

Step	Description
1a	Receives the SS1 request from FS card DI.
2a	After response time(A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters). FS card starts SAR monitoring.
3a	Motor speed goes below the user-defined zero speed (B) and activates the drive STO function. FS card stops SAR monitoring.
4a	The SS1 request is removed.
5a	The SS1 & STO function are acknowledged (manual acknowledgement), and the SS1 & STO status indication goes off.
1b	Receives the SS1 request from FS card DI.
2b	After response time(A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters). FS card starts SAR monitoring.
3b	The motor speed deceleration rate exceeds a tolerance threshold, the card activates the STO function. FS card stops SAR monitoring.
4b	The motor speed ramp down to zero speed (B).
5b	The SS1 request is removed.
6b	The SS1 & STO function are acknowledged (manual acknowledgement), and the SS1 & STO status indication goes off.

→ User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time

4.4.4 State diagram

4.4.4.1 SS1-t

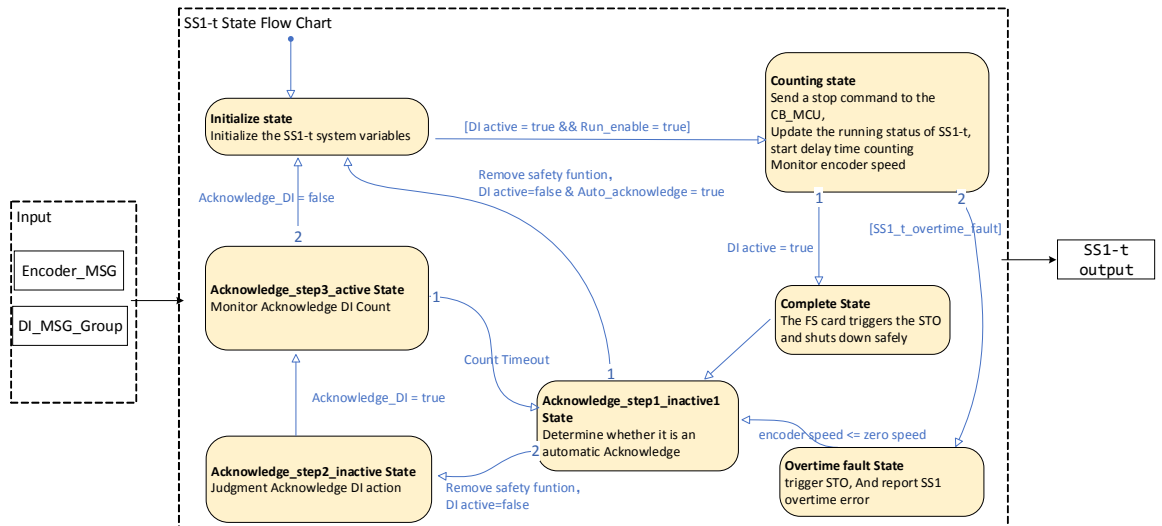


Figure 35: The SS1-t status flow chart is as follows

Table 31: The transition among states

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SS1-t function	The function is ready.	Initialize->Counting	Request DI is active
Counting	Delay the start of SS1 monitoring. Updated the status output of SS1-t.	SS1 status is high. Motor deceleration.	Counting->Complete	Motor speed \leq zero speed
			Counting->Overtime_fault	Exceeding the delay time
Complete	The motor speed is below the user-defined zero speed limit, and FS card triggers the STO and shuts down safely.	shuts down safely.	Complete->Acknowledge_step1_inactive1	Request DI is inactive
Overtime_fault	When delay time ends, and the motor speed has not yet reduced to zero speed	trigger STO(STO status is high), and report SS1 overtime error.	Overtime_fault->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method. If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledgement, SS1 and STO status is low.	Acknowledge_step1_inactive1->Initialize	select automatic acknowledgement
			Acknowledge_step1_inactive1->Acknowledge_step2_inactive	select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SS1 and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SS1 and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4 Safety Functions

4.4 SS1 (Safe Stop 1)

4.4.4.2 SS1-r

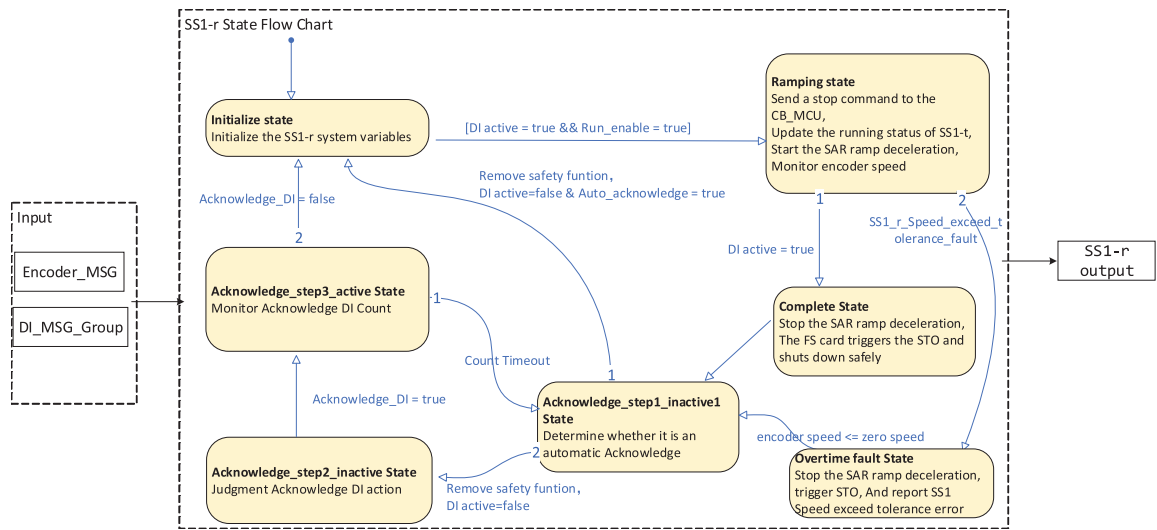


Figure 36: The SS1-r status flow

Table 32: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SS1-r variables	The function is ready.	Initialize->Ramping	Request DI is active
Ramping	Start of SAR monitoring. Updated the status of SS1-r. start SAR monitoring.	SS1 and SAR status is high. Motor deceleration.	Ramping->Complete	Motor speed \leq zero speed
			Ramping->Speed_exceed_tolerance	Exceeding the deceleration slope
Complete	The motor speed is below the user-defined zero speed limit, and FS card triggers the STO and shuts down safely.	shuts down safely	Complete->Acknowledge_step1_inactive1	Request DI is inactive
Speed_exceed_tolerance	Monitor the deceleration slope of the motor during the deceleration process, and activate the STO function if the preset limit is exceeded.	trigger STO, and report SS1 Speed exceed tolerance error	Speed_exceed_tolerance->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SS1 and STO status is low.	Acknowledge_step1_inactive1->Initialize	select automatic acknowledgement
			Acknowledge_step1_inactive1->Acknowledge_step2_inactive	select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SS1 and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SS1 and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4.4.5 Response time

SS1 response time is from the demand effected on FS card DI terminal to the stop demand be sent to drive.

SS1 response time = Delay time of DI circuit + DI filter time + 3*Safety Function execution cycle time ≤ 40 ms

- T1: Delay time of DI circuit ≤ 10 ms
- T2: DI filter time = 20 ms
- T3: 3*Safety Function execution cycle time ≤ 3 ms
- Safety function response: FS card sends stop demand to drive

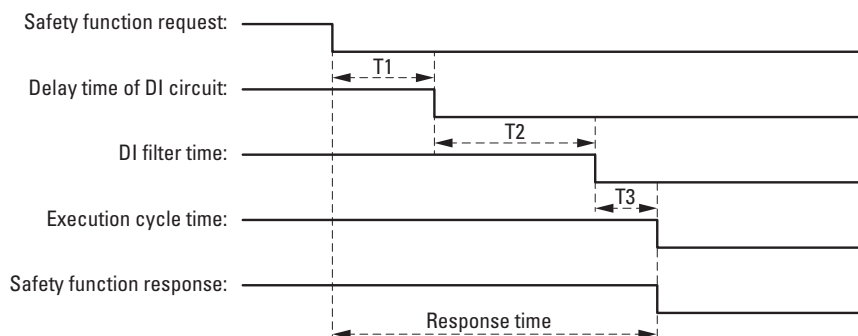


Figure 37: Timing diagram

4.4.6 Assignment of control signal terminals

Assignment of digital inputs to SS1 are user dependent and any input FS card DI can be assigned as a SS1 Source.

SS1 Source and SS1 Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring"

4 Safety Functions

4.4 SS1 (Safe Stop 1)

4.4.7 Application

This section gives an application example of SS1 function of FS card.

- Safe switch1: Connect DI1 using a button switch as an SS1 function request.
- Use the lamp to connect DO1 to indicate SS1 status.

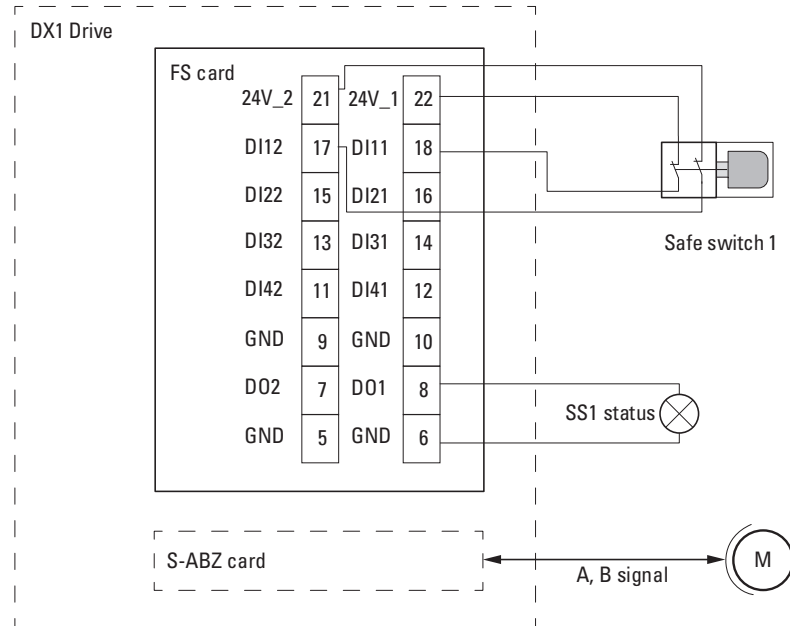


Figure 38: Wiring for SS1 application

For the implementation of this application, refer to → Section 4.4.8, "Configuration" and → Section 4.4.9, "Validation of the SS1 function".

For wiring the DX1 functional safety system, refer to → Section 2.5, "Electrical Setup".

4.4.8 Configuration

To configure the SS1 function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.4.8.1 How to configure SS1-t

Table 33: Example of an SS1-t set-up:

Step	PanelCode	Parameters	Set value	Description
1	P2.1	SS1 Enable	Enable	Set enable SS1 Function
2	P2.2	SS1 Source	DI11 & DI12	Set the DI source(DI1) to activate the SS1 function
3	P2.3	SS1 Mode	SS1 time	Set SS1 with time monitor
4	P2.4	t-delay STO@SS1	30 s	Set safe delay for activating the drive STO: 30 s
5	P2.5	SS1 n=0 Limit	20 rpm	Set zero speed limit for activating the drive STO: 20 rpm
6	P2.6	SS1 Acknowledgement Mode	Automatic	Set automatic acknowledgement
7	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
8	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
9	P1.3	DO1 Mode	SS1 Status	Set the DO output safety function status
10	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
11	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate

4.4.8.2 How to configure SS1-r

Table 34: Example of an SS1-r set-up:

Step	PanelCode	Parameters	Set value	Description
1	P2.1	SS1 Enable	Enable	Set enable SS1 Function
2	P2.2	SS1 Source	DI11 & DI12	Set the DI source(DI1) to activate the SS1 function
3	P2.3	SS1 Mode	SS1 ramp	Set SS1 with ramp monitor
4	P2.5	SS1 n=0 Limit	20 rpm	Set zero speed limit for activating the drive STO: 20 rpm
5	P2.6	SS1 Acknowledgement Mode	Automatic	Set automatic acknowledgement
6	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
7	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
8	P1.3	DO1 Mode	SS1 Status	Set the DO output safety function status
9	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
10	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
11	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

4.4.9 Validation of the SS1 function

See → chapter 5, “Verification and Validation”.

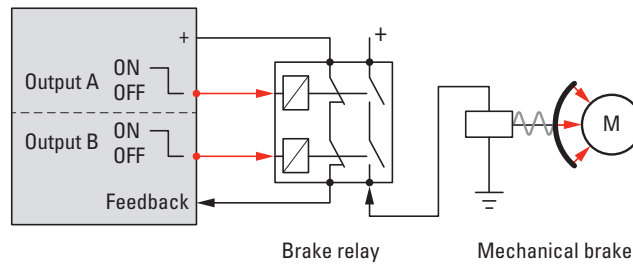
4 Safety Functions

4.5 SBC (Safe Brake Control)

4.5 SBC (Safe Brake Control)

4.5.1 Function description

The SBC (Safe Brake Control) function provides a safe output signal to control an external safe brake device via force guided safety relay.



SBC requests come from the output of other safety functions (except STO and SSM). It means SBC safety function could be triggered by the output of any other safety functions (except STO and SSM).

SBC could be combined with STO function. SBC and STO safety functions could be triggered by any other safety functions (except SSM) from FS card DI. SBC function can be activated before, at the same time with, or after STO function. Relationship between STO and SBC:

- STO SBC delay > 0 (STO before SBC)
- STO SBC delay < 0 (STO after SBC)
- STO SBC delay = 0 (STO and SBC at the same time)

SBC could be combined with SS1 function. The user-defined speed limit below which FS card activates the SBC and STO functions while ramping. Once "STO SBC delay" is set as negative, it means SBC has higher priority than STO. If there is request from other safety functions, SBC function will be activated first and then STO.

4.5.2 Safety parameters

→ section , "SBC Parameters (P3)", page 201

4.5.3 Timing Diagram

4.5.3.1 STO SBC delay > 0 (STO before SBC)

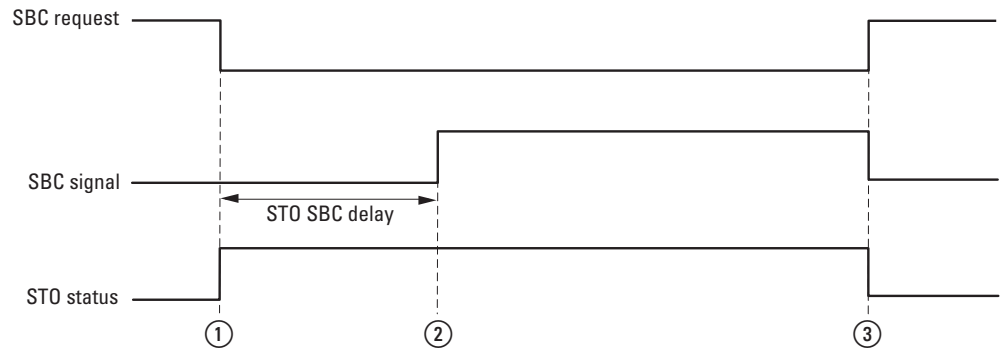


Figure: STO SBC delay > 0 (STO before SBC)

Table 35: Timing diagram

Step	Description
1	Receives the SBC request from the output of other safety functions. The value of STO SBC delay is positive, FS card triggers STO function firstly once receive an SBC request. STO status turns to high level. STO function is performed.
2	After the time of STO SBC delay, FS card activates the SBC function immediately. SBC signal turns to high level. SBC function is performed.
3	The SBC request is removed.

4 Safety Functions
 4.5 SBC (Safe Brake Control)

4.5.3.2 STO SBC delay < 0 (STO after SBC)

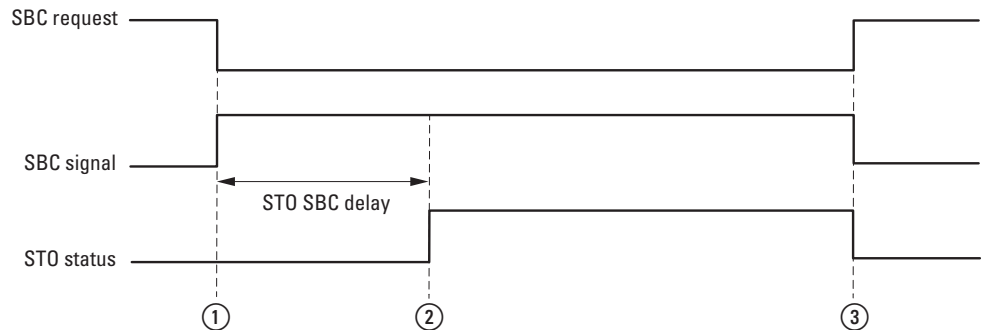


Figure 39: STO SBC delay < 0 (STO after SBC)

Table 36: Timing diagram

Step	Description
1	Receives the SBC request (from other safety functions). The value of STO SBC delay is negative, FS card triggers SBC function firstly once receive an SBC request. SBC signal turns to high level. SBC function is performed.
2	After the time of STO SBC delay, FS card activates the STO function immediately. STO status turns to high level. STO function is performed.
3	The SBC request is removed. The STO and SBC functions are stopped.

4.5.3.3 STO SBC delay = 0 (STO and SBC at the same time)

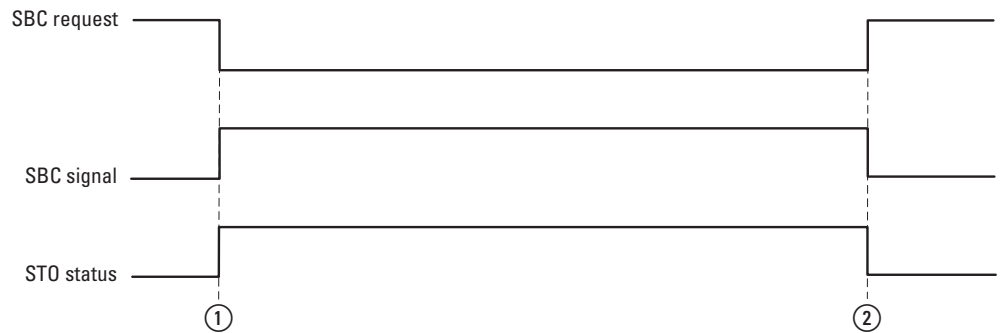


Figure 40: STO SBC delay = 0 (STO and SBC at the same time)

Table 37: Timing diagram

Step	Description
1	Receives the SBC request (from other safety functions). The value of STO SBC delay is zero, FS card triggers SBC and STO function at the same time. SBC signal and STO Status are turn to high level at the same time. SBC and STO function are all performed.
2	The SBC request is removed. The STO and SBC functions are stopped.

WARNING

The SBC and STO lack the "acknowledgement" feature. Once the requests for other safety functions have been removed and acknowledged, the drive will be allowed to return to the ready state.



CAUTION

It must be noted that without the "acknowledgement" feature, this could lead to unsafe conditions and potential dangers. Therefore, it is absolutely necessary to use external devices to maintain a safe state before the user has a chance to confirm the safety of the system. Always ensure that all safety procedures are strictly followed to prevent any accidents or injuries.

4 Safety Functions

4.5 SBC (Safe Brake Control)

4.5.3.4 SBC Activated by SS1 with Speed Limit

With a safety encoder, SBC (or STO) function can be activated by user-defined speed limit. Take SS1 time (SS1-t) monitoring as an example. The following timing diagram and table describe the operation of SBC activated by SS1-t function with speed limit.

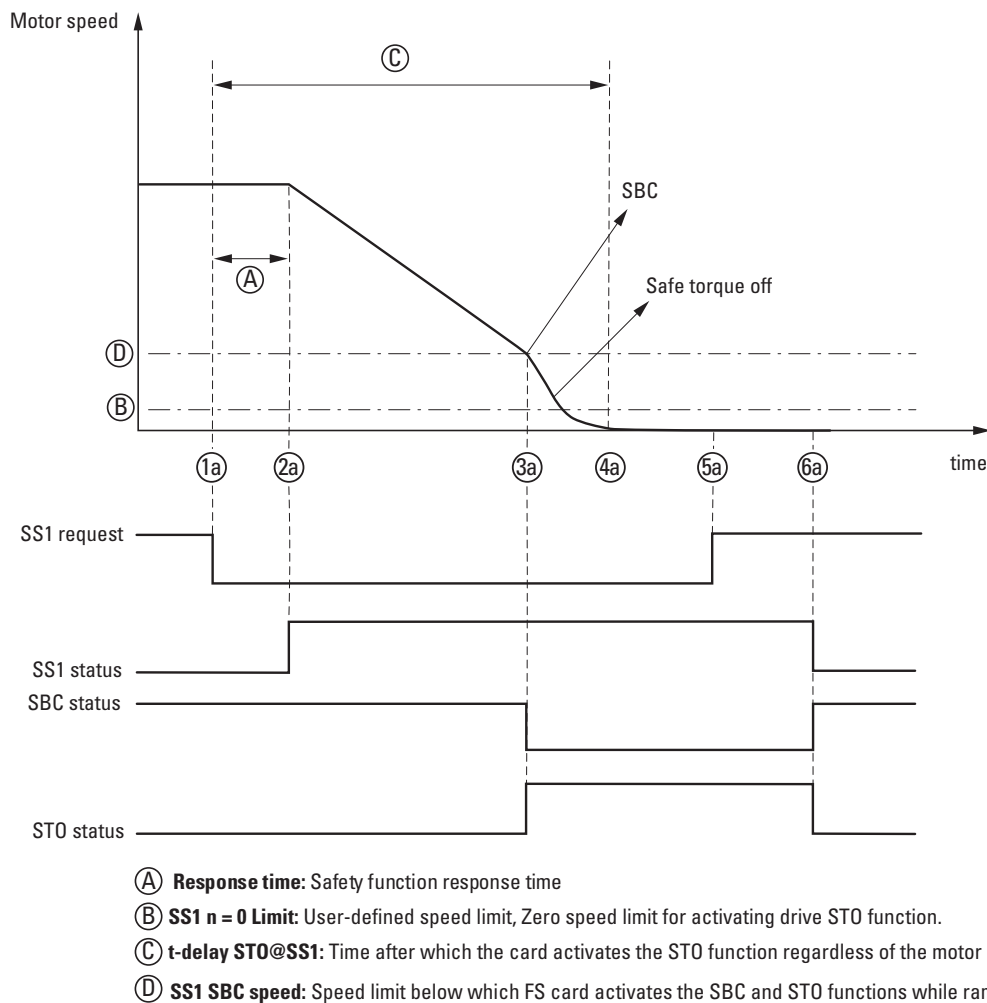


Figure 41: SBC activated by SS1 with speed limit

Table 38: Timing Diagram

Step	Description
1a	Receives the SS1 request from FS card DI. FS card start a counter for delay time (C).
2a	After response time (A) has elapsed. The drive starts to reduce the motor speed according to the user-set deceleration time. Deceleration is set at SAR Parameter.
3a	Motor speed goes below the SBC speed limit (D). FS card activates SBC and STO function. The SBC status indication goes off.
4a	End of delay time (C). The motor is reduced to zero speed (B) here at the latest.
5a	The SS1 request is removed from FS card DI.
6a	The SS1, SBC and STO function are acknowledged (manual acknowledgement), and the SS1 & STO status indication goes off. The SBC status indication goes on.

4.5.4 State Diagram

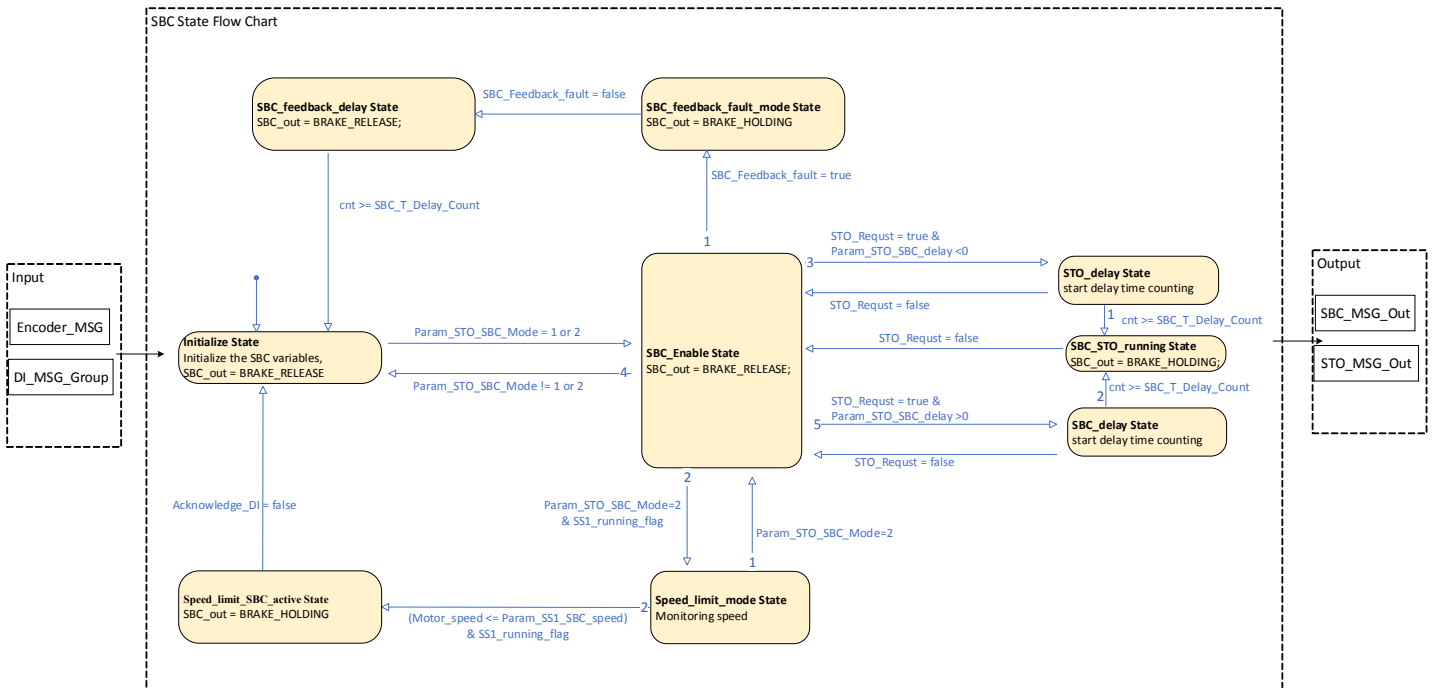


Figure 42: The SBC status flow chart

4 Safety Functions

4.5 SBC (Safe Brake Control)

Table 39: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SBC variables	The function is ready.	Initialize-> SBC_Enable	parameter "STO SBC Mode" set to "Delayed brake" or "Speed limit"
SBC_Enable	Check if the SBC is used	SBC status is high.	SBC_Enable-> SBC_feedback_fault_mode	SBC relay error
			SBC_Enable-> Speed_limit_mode	parameter "STO SBC Mode" set to "Speed limit"
			SBC_Enable-> STO_delay	occurred STO request, parameter "STO SBC Mode" set to "Delayed brake" mode and "STO SBC delay"<0
			SBC_Enable-> SBC_delay	occurred STO request, parameter "STO SBC Mode" set to "Delayed brake" mode and "STO SBC delay">=0
			SBC_Enable-> Initialize	parameter "STO SBC Mode" not set
SBC_feedback_fault_mode	Check if there is a feedback fault, and if so, it will pull down the DO and enter a safe state.	SBC status is low, and report SBC relay feedback error.	SBC_feedback_fault_mode-> SBC_feedback_delay	SBC relay feedback not error
SBC_feedback_delay	When there is no feedback error, the delay time is increased to avoid voltage jitter.	Count of SBC feedback delay time.	SBC_feedback_delay-> Initialize	Cumulative delay time count
Speed_limit_mode	Monitor the encoder speed, and when the encoder speed reaches the speed limit, it will pull down the DO and enter a safe state.	SBC status is low.	Speed_limit_mode-> Speed_limit_SBC_active	Motor speed \leq SS1 SBC speed
Speed_limit_SBC_active	Check whether the SS1 function has been removed. If yes, initialize the SBC at the same time.	SBC status is low.	Speed_limit_SBC_active-> Initialize	remove SS1 function
STO_delay	Delay count for STO	Count of STO delay time.	STO_delay-> SBC_STO_running	Cumulative STO delay time reached
			STO_delay-> SBC_Enable	No STO request
SBC_delay	Delay count for SBC	Count of SBC delay time.	SBC_delay-> SBC_STO_running	Cumulative SBC delay time reached
			SBC_delay-> SBC_Enable	No STO request
SBC_STO_running	Based on the delay time set by the user, implement the sequential operations of SBC and STO.	SBC status is low, and trigger STO(STO status is high)	SBC_STO_running-> SBC_Enable	No STO request

4.5.5 Response time

SBC response time is from the demand effected by other safety functions to Switch-off DO.

To select delayed brake mode, SBC response time = 2 * Safety Function execution cycle time + delay time of user setting + delay time of DO circuit \leq 40ms.

- T1: 2 * Safety Function execution cycle time \leq 2 ms (according to clock accuracy, max. 2.02 ms)
- T2: Delay time of user setting = User setting parameter
- T3: Delay time of DO circuit \leq 10 ms
- Safety function response: The FS card to switch-off DO

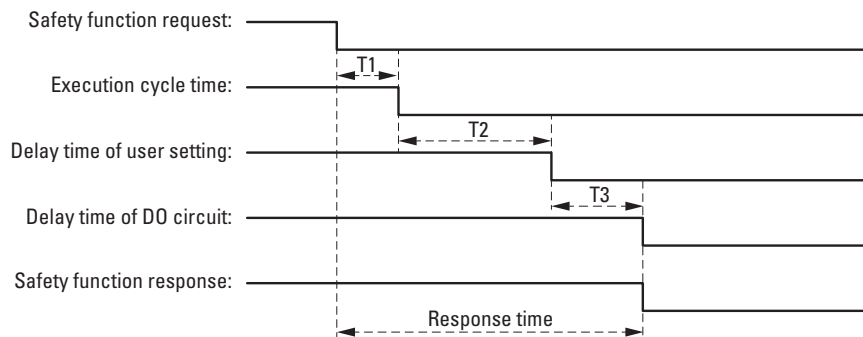


Figure 43: Timing diagram

To select speed limit mode, SBC response time = delay time of encoder signal circuit + 2 * speed sampling and calculation time + 2 * Safety Function execution cycle time + delay time of DO circuit \leq 40 ms.

- T1: Delay time of Encoder signal circuit \leq 5 ms
- T2: 2 * Speed sampling and calculation time \leq 2 ms (according to clock accuracy, max. 2.02 ms)
- T3: 2 * Safety Function execution cycle time \leq 2 ms (according to clock accuracy, max. 2.02 ms)
- T4: Delay time of DO circuit \leq 10 ms
- Safety function response: The FS card to switch off DO

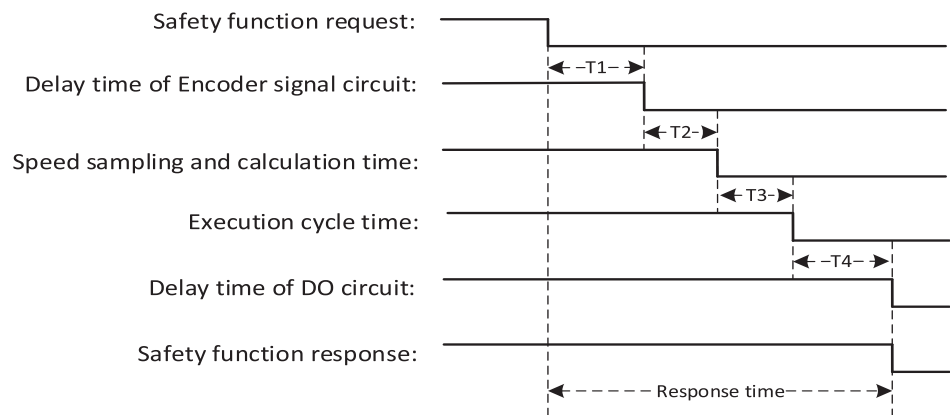


Figure 44: Timing diagram

4 Safety Functions

4.5 SBC (Safe Brake Control)

4.5.6 SBC Assignment of control signal terminals

For SBC function, DX1 uses one or two DO terminals on FS card to drive safety relay to control the safe brake device. The safety relay must be Force Guided Safety Relay. The feedback contact of safety relay is normal close type which is inverted from the NO action contacts of safety relay.

There are two methods for user to realize the SBC function. See below figures for SBC function connection methods. When SBC function is active, DIs must be used as safety relay feedback signals input for diagnostic.

WARNING

The Motor brake used must be safety brakes!

If single DO terminal is not sufficient for user, DO1 and DO2 could be used as two channels of SBC function. In this case, there will be only one digital output on FS card.

4.5.7 Application

This section gives an application example of SBC function of FS card.

Application 1: Two channels use the same DO terminal

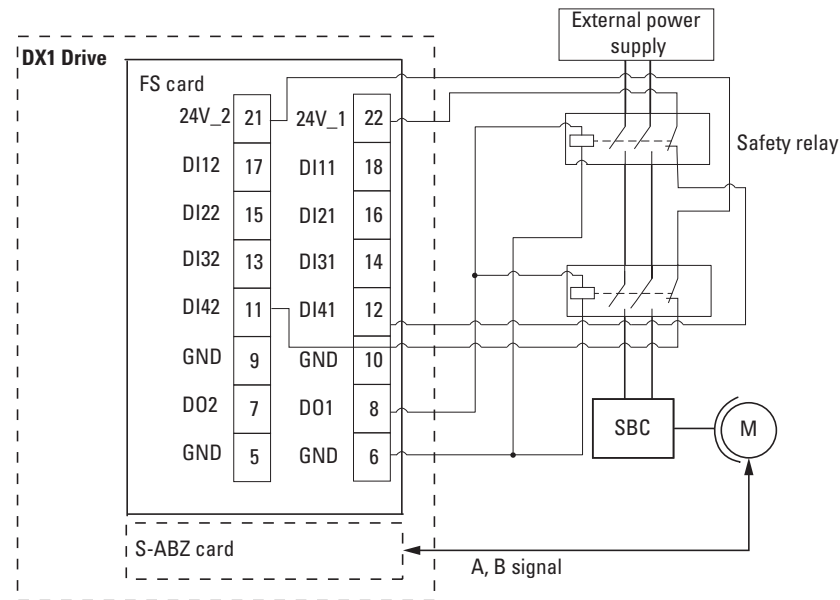


Figure 45: Application 1 for SBC function

Each DO terminal can be used as dual channel output of SBC. DO circuits on FS card are dual channel design with dynamic diagnostics. These two channels will share the same user terminal and +24V_ISO_S power supply.

→ DO circuit is dual channel design except DO user terminal.

Application 2: Two channels use DO1 and DO2 terminals separately.

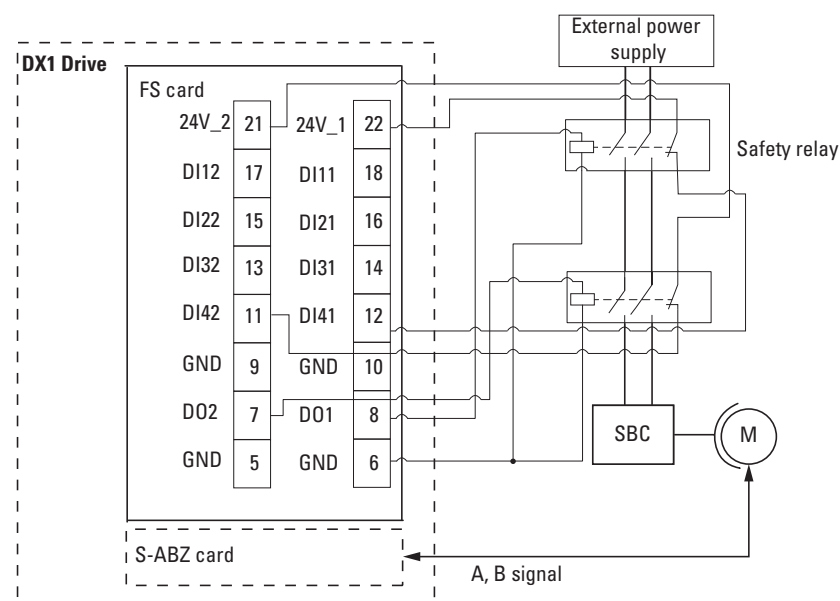


Figure 46: Application 2 for SBC function

4 Safety Functions

4.5 SBC (Safe Brake Control)

If single DO terminal is not sufficient, DO1 and DO2 could be used as two channels of SBC function. In this case, there will be only one digital output on FS card.

If single DO terminal is not sufficient for user, DO1 and DO2 could be used as two channels of SBC function. In this case, there will be only one digital output on FS card.

Table 40: SBC function logic truth table

DO1/DO2	Safety relay action contact (NO)	Safety relay feedback contact (NC)	SBC	Motor
1	1 (close)	0 (open)	SBC releases the brake	run
0	0 (open)	1 (close)	SBC holds the brake	stop

To meet the system SIL requirements, below following failure modes will be diagnosed by DX1 drive: overvoltage, undervoltage, overload, and short-circuit on the digital output.

Fault exclusion for wiring:

Fault exclusion has been considered for the DO external cables and wirings.

- The DO external cables and wirings on FS card meet the requirements of EN_ISO_13849-2: table D.4:
 - External wiring on FS card DO user terminal short circuit between any two cables.
 - Fault exclusion: separate multicore cables, permanently connected (fixed) and protected against external damage (cable ducting), and within an electrical enclosure (both conductors and enclosure meet IEC 60204-1 requirements).
 - External wiring on FS card DO user terminal open.
 - None fault exclusion. Safe failure, safety relay feedback input signal must detect the fault; drive goes into safe state.
 - External wiring on FS card DO user terminal shorted to earth.
 - None fault exclusion. Safe failure, monitors the DO user terminal readback signal with diagnostic pulse, drive goes into safe state.

Fault exclusion has been considered for the DO external wiring terminal block.

- The DO external encoder wiring terminal block meet the requirements of EN_ISO_13849-2: table D.6:
 - Short circuit between adjacent terminals:
 - Fault exclusion: the terminal block used are in accordance with IEC 60947-7-1 or IEC 60947-7-2, and the requirements of IEC 60204-1:2006 13.1.1 are satisfied.
 - Open circuit of individual terminals:
 - None fault exclusion. Safe failure, safety relay feedback input signal must detect the fault; drive goes into safe state.

4.5.8 Configuration

To configure the SBC function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

Users can customize DO pulse width (parameter P1.6) of FS card according to their selected safety relay characteristics. To ensure compatibility and coordination with the safety relays used.

4.5.8.1 How to configure STO SBC delay > 0 (STO before SBC)

Table 41: Example of an STO before SBC set-up

Step	PanelCode	Parameters	Set value	Description
1	P3.1	STO SBC Mode	Delayed brake	Set the how the brake is used with parameter.
2	P3.2	STO SBC delay	20 s	Set the correct delay with parameter.
3	P1.3	DO1 Mode	SBC Status	Set the DO output safety function status.
4	P1.6	DO Pulse Width	1 ms	Set the DO output pulse width.

After configuring these parameters, the SBC will delay the braking for 20 s when STO occurs.

4.5.8.2 How to configure STO SBC delay < 0 (STO after SBC)

Table 42: Example of an STO after SBC set-up:

Step	PanelCode	Parameters	Set value	Description
1	P3.1	STO SBC Mode	Delayed brake	Set the how the brake is used with parameter.
2	P3.2	STO SBC delay	-5 s	Set the correct delay with parameter.
3	P1.3	DO1 Mode	SBC Status	Set the DO output safety function status.
4	P1.6	DO Pulse Width	1 ms	Set the DO output pulse width.

After configuring these parameters, STO will be activated with a delay of 5s when the SBC is braked.

4.5.8.3 How to configure STO SBC delay = 0 (STO and SBC at the same time)

Table 43: Example of an STO and SBC at the same time set-up:

Step	PanelCode	Parameters	Set value	Description
1	P3.1	STO SBC Mode	Delayed brake	Set the how the brake is used with parameter.
2	P3.2	STO SBC delay	0 s	Set the correct delay with parameter.
3	P1.3	DO1 Mode	SBC Status	Set the DO output safety function status.
4	P1.6	DO Pulse Width	1 ms	Set the DO output pulse width.

After configuring these parameters, STO and SBC are activated at the same time.

4 Safety Functions

4.5 SBC (Safe Brake Control)

4.5.8.4 How to configure SBC Activated by SS1 with Speed Limit

Table 44: Example of an SBC Activated by SS1 with Speed Limit set-up

Step	PanelCode	Parameters	Set value	Description
1	P3.1	STO SBC Mode	Speed limit	Set the how the brake is used with parameter.
2	P3.2	SS1 SBC speed	10 rpm	This parameter is to allow the user to set the speed limit of FS card to activate the brake (SBC) while ramping SS1 function. If the value is 0.0 rpm, this feature is not in use.
3	P1.3	DO1 Mode	SBC Status	Set the DO output safety function status.
4	P1.6	DO Pulse Width	1 ms	Set the DO output pulse width.

After configuring these parameters, the SBC function can be activated at a user-defined speed limit

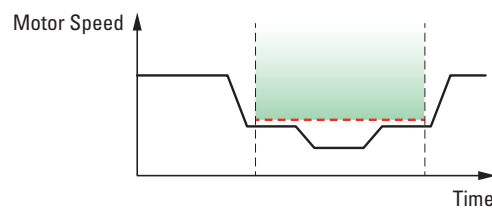
4.5.9 Validation of the SBC function

→ Section 5.6, "Validation of SBC"

4.6 SLS (Safely Limited Speed)

4.6.1 Function description

The SLS (Safely Limited Speed) prevents the motor from exceeding user-defined speed limits. The drive limits the motor speed so that it stays between the SLS speed limits.



If the user activates the SLS function when the motor speed is higher than the SLS limit, the SLS function will decelerate using a predefined SAR ramp.

The SLS function utilizes the time (SLS-t) or ramp (SLS-r) monitoring method to respectively monitor the deceleration ramp.

The SLS-t uses SAR parameter to define the deceleration ramp.

The SLS-r uses SAR parameters to define and monitoring deceleration ramp.

See function timing description → Section 4.6.3, "Timing diagram" and configuration → Section 4.6.8, "Configuration" for more information.

4.6.2 Safety parameters

→ section , "SLS Parameters (P4)", page 202

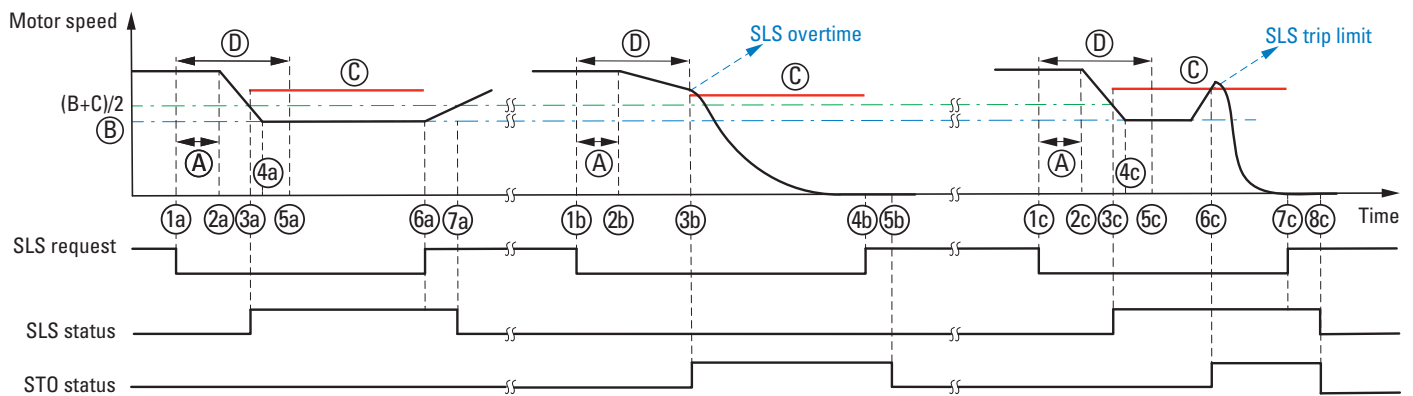
4 Safety Functions

4.6 SLS (Safely Limited Speed)

4.6.3 Timing diagram

4.6.3.1 SLS-t

When SLS function is activated at a speed higher than SLS limit, motor starts to decelerate according to deceleration ramp time defined by drive parameters. The motor speed must reach SLS limit within monitoring time limit, otherwise STO is activated.



(A) DI filtering time: 20 ms

(B) SLS limit: SLS limit speed

(C) SLS trip limit: SLS trip limit speed

(D) SLS-t delay: SLS time delay

SLS request: Request to trigger SLS function

SLS status: Indicates whether the SLS function is working.

STO status: Indicates whether the STO function is triggered.

Figure 47: SLS function with time monitoring

Table 45: Timing diagram

Step	Description
1a	Receives the SLS request from FS card DI. The motor speed is above the SLS limit (B). FS card starts to monitor the SLS time delay (D).
2a	After time(A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp(The Deceleration Ramp is defined by SAR parameters). Until the speed reaches the SLS limit (B).
3a	FS card starts the SLS monitoring when the motor speed is in the middle of the SLS limit and the SLS trip limit ((B+C)/2).
4a	The motor speed reaches the SLS limit (B).
5a	FS card starts the SLS monitoring at the latest here, that is, after the SLS time delay (D) has elapsed.
3a-6a	The drive limits the motor speed, and the motor speed does not reach the SLS trip limit. FS card continues to monitor.
6a	The SLS request is removed, but the SLS monitoring is still on.
7a	The SLS function is acknowledged (manual acknowledgement) and stops the SLS monitoring. The SLS status indication goes off.
1b	Receives the SLS request from FS card DI. The motor speed is above the SLS limit (B). FS card starts to monitor the SLS delay time (D).
2b	After time (A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters). Until the speed reaches the SLS limit (B).
3b	The drive has not ramped down fast enough when delay time (D) has elapsed, FS card activates the STO function.
4b	The SLS request is removed.
5b	The SLS & STO function are acknowledged (manual acknowledgement) and stops the SLS monitoring. The SLS & STO status indication goes off.
1c	Receives the SLS request from FS card DI. The motor speed is above the SLS limit (B). FS card starts to monitor the SLS time delay (D).
2c	After time (A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp (The Deceleration Ramp is defined by SAR parameters). Until the speed reaches the SLS limit (B).
3c	FS card starts the SLS monitoring when the motor speed is in the middle of the SLS limit and the SLS trip limit ((B+C)/2).
4c	The motor speed reaches the SLS limit (B).
5c	FS card starts the SLS monitoring at the latest here, that is, after the SLS time delay (D) has elapsed.
6c	the motor speed reaches the SLS trip limit, FS card activates the STO function.
7c	The SLS request is removed.
8c	The SLS & STO function are acknowledged and stops the SLS monitoring. The SLS & STO status indication goes off.

→ User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4 Safety Functions

4.6 SLS (Safely Limited Speed)

4.6.3.2 SLS-r

When SLS function is activated at a speed higher than SLS limit, motor starts to decelerate according to deceleration ramp slope defined by SLS SAR1 function. The motor speed must decelerate within SAR1 minimum and maximum limits, otherwise STO function must be activated.

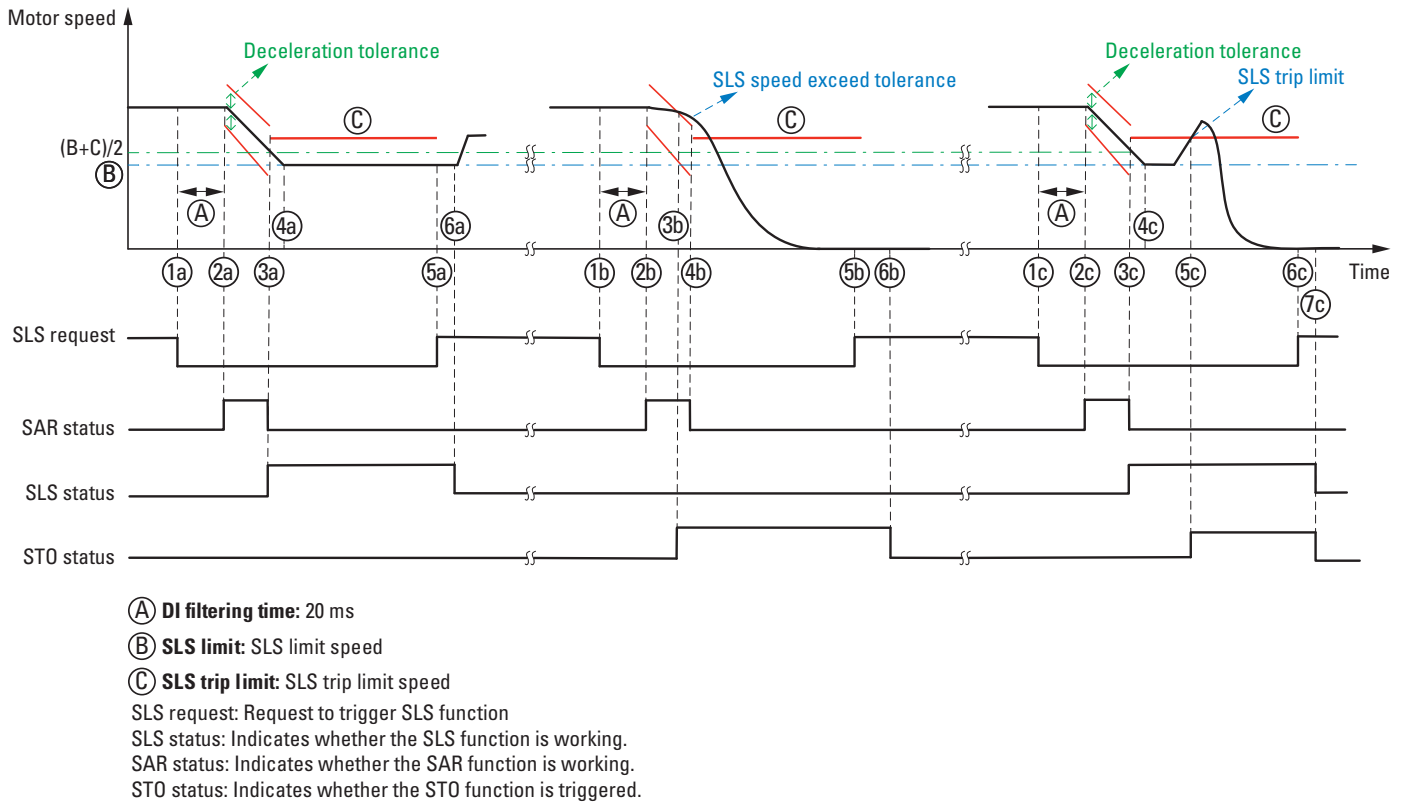


Figure 48: SLS function with ramp monitoring

4 Safety Functions

4.6 SLS (Safely Limited Speed)

Step	Description
1a	Receives the SLS request from FS card DI. The motor speed is above the SLS limit (B).
2a	After time(A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp(The Deceleration Ramp is defined by SAR parameters).Until the speed reaches the SLS limit (B). FS card starts the SAR monitoring.
3a	FS card starts the SLS monitoring when the motor speed is in the middle of the SLS limit and the SLS trip limit((B+C)/2) and stops the SAR monitoring.
4a	The motor speed reaches the SLS limit (B).
3a-5a	The drive limits the motor speed, and the motor speed does not reach the SLS trip limit. FS card continues to monitor.
5a	The SLS request is removed, but the SLS monitoring is still on.
6a	The SLS function is acknowledged (manual acknowledgement) and stops the SLS monitoring. The SLS status indication goes off.
1b	Receives the SLS request (from FS card DI). The motor speed is above the SLS limit (B).
2b	After time(A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp(The Deceleration Ramp is defined by SAR parameters).Until the speed reaches the SLS limit (B). FS card starts the SAR monitoring.
3b	The motor speed does not follow the ramp monitoring limits; FS card activates the STO function. FS card stop SAR monitoring.
4b	The SLS request is removed.
5b	The SLS & STO function are acknowledged (manual acknowledgement) and stops the SLS monitoring. The SLS & STO status indication goes off.
1c	Receives the SLS request (from FS_DI). The motor speed is above the SLS limit (B).
2c	After time (A) has elapsed. The drive starts to ramp down the motor speed according to the Deceleration Ramp(The Deceleration Ramp is defined by SAR parameters).Until the speed reaches the SLS limit (B). FS card starts the SAR monitoring.
3c	FS card starts the SLS monitoring when the motor speed is in the middle of the SLS limit and the SLS trip limit ((B+C)/2) and stops the SAR monitoring.
4c	The motor speed reaches the SLS limit (B).
5c	The motor speed reaches the SLS trip limit. FS card activates the STO function.
6c	The SLS request is removed.
7c	The SLS function is acknowledged (manual acknowledgement) and stops the SLS monitoring. The SLS status indication goes off.

→ User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4 Safety Functions

4.6 SLS (Safely Limited Speed)

4.6.4 State diagram

4.6.4.1 SLS-t

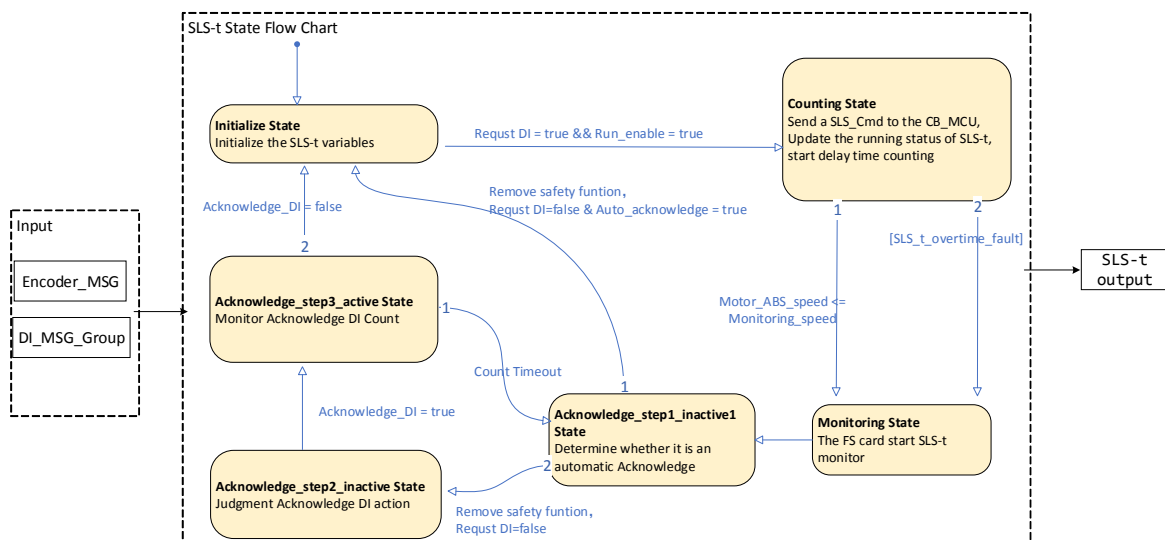


Figure 49: The SLS-t status flow chart

Table 46: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SLS-t function	The function is ready.	Initialize->Counting	Request DI is active
Counting	Delay the start of SLS monitoring. Updated the status output of SLS-t.	Count of delay time. Motor deceleration.	Counting->Monitoring	Motor speed \leq monitor speed Exceeding the delay time
Monitoring	Start SLS monitoring. The motor speed encoder data is read in real time and compared to the SLS trip limit. If the SLS trip limit is not reached within the monitoring time, FS card is trigger STO.	SLS status is high. (if trigger STO, STO status is high.)	Monitoring-> Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_ste p1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SLS and STO status is low.	Acknowledge_step1_inactive1-> Initialize	select automatic acknowledgement
			Acknowledge_step1_inactive1-> Acknowledge_step2_inactive	select manual acknowledgement
Acknowledge_ste p2_inactive	Judgment Acknowledge DI action	Time count. SLS and STO status is high.	Acknowledge_step2_inactive-> Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_ste p3_active	Monitor Acknowledge DI Count	SLS and STO status is low.	Acknowledge_step3_active-> Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active-> Initialize	Acknowledge DI is inactive within 3s

4.6.4.2 SLS-r

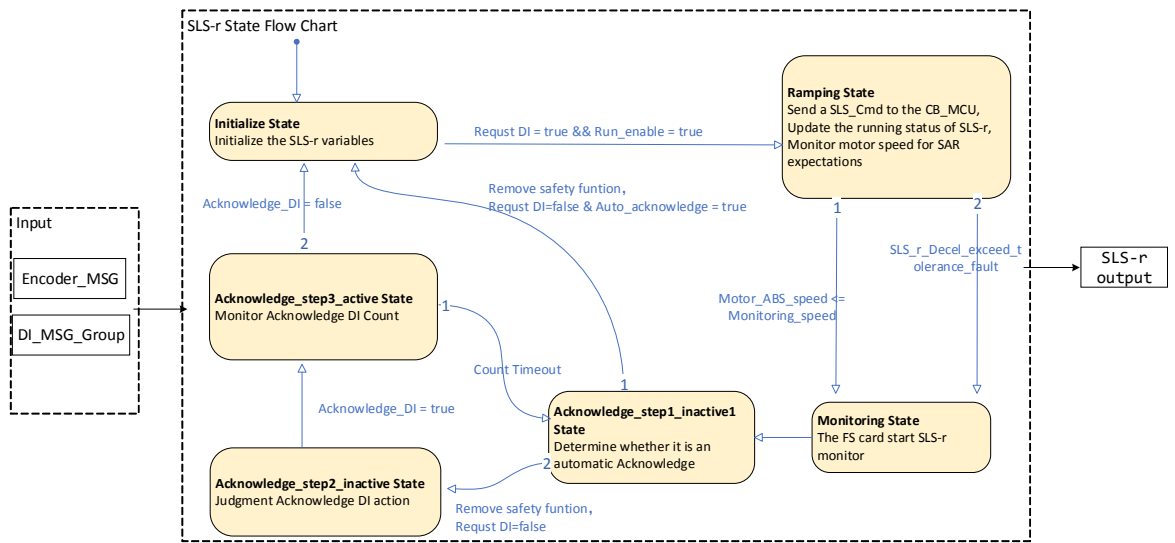


Figure 50: The SLS-r status flow chart

Table 47: The transition among states

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SLS-r variables	The function is ready.	Initialize->Ramping	Request DI is active
Ramping	start SAR ramp deceleration monitoring. Updated the status of SLS-r and SAR.	Motor deceleration. SAR status is high.	Ramping->Monitoring	Motor speed \leq monitor speed
Monitoring	Start SLS monitoring. The motor speed encoder data is read in real time and compared to the SLS trip limit. If the SLS trip limit is not reached within the monitoring time, FS card is trigger STO.	SLS status is high. (if trigger STO, STO status is high.)	Monitoring->Acknowledge_step1_inactive1	Exceeding the deceleration slope
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledgement, SLS and STO status is low.	Acknowledge_step1_inactive1 -> Initialize	Request DI is inactive
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SLS and STO status is high.	Acknowledge_step1_inactive1 -> Acknowledge_step2_inactive	select automatic acknowledgement
Acknowledge_step3_active	Monitor Acknowledge DI Count	SLS and STO status is low.	Acknowledge_step2_inactive -> Acknowledge_step3_active	select manual acknowledgement
			Acknowledge_step3_active -> Acknowledge_step1_inactive1	Acknowledge DI is active
			Acknowledge_step3_active -> Initialize	Acknowledge DI is inactive more than 3s
				Acknowledge DI is inactive within 3s

4 Safety Functions

4.6 SLS (Safely Limited Speed)

4.6.5 Response time

SLS response time is from the safety function range exceeded to the shut-down of PWM buffers.

SLS response time = delay time of Encoder signal circuit + speed sampling and calculation time + 10 * Safety Function execution cycle time + delay time of STO trigger circuit + delay time of PWM buffers ≤ 40 ms

- T1: Delay time of Encoder signal circuit ≤ 5 ms
- T2: Speed sampling and calculation time ≤ 2 ms
- T3: 10 * Safety Function execution cycle time ≤ 10 ms
- T4: Delay time of STO trigger circuit ≤ 5 ms
- T5: Delay time of PWM buffers ≤ 5 ms
- Safety function response: FS card to shutdown of PWM buffers

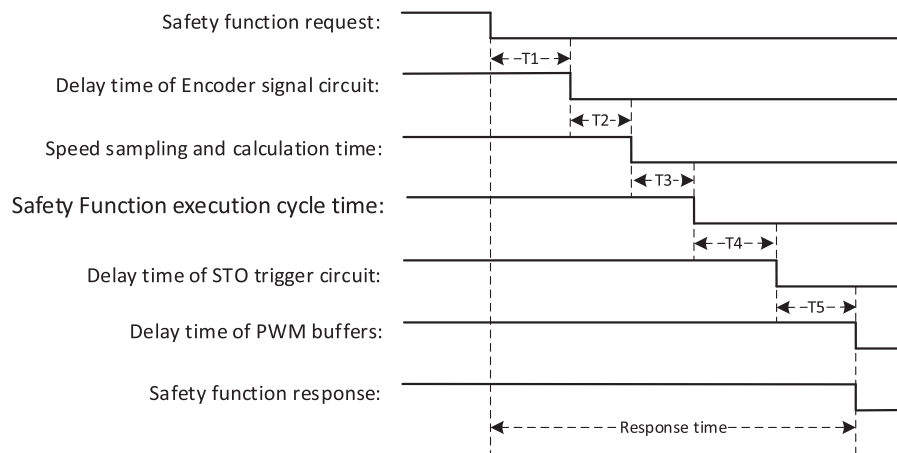


Figure 51: The timing diagram

4.6.6 Assignment of control signal terminals

Assignment of digital inputs to SLS are user dependent and any input DI of FS card can be assigned as a SLS Source.

SLS Source and SLS Manual Acknowledgement Mode must be assigned to DI of FS card.

Connection usage for digital inputs → Section 2.8.3, "FS card user IO wiring".

4.6.7 Application

This section gives an application example of SLS function of FS card.

- Safe switch1: Connect DI2 using a button switch as an SLS function request.
- Use the lamp to connect DO1 to indicate SLS status.

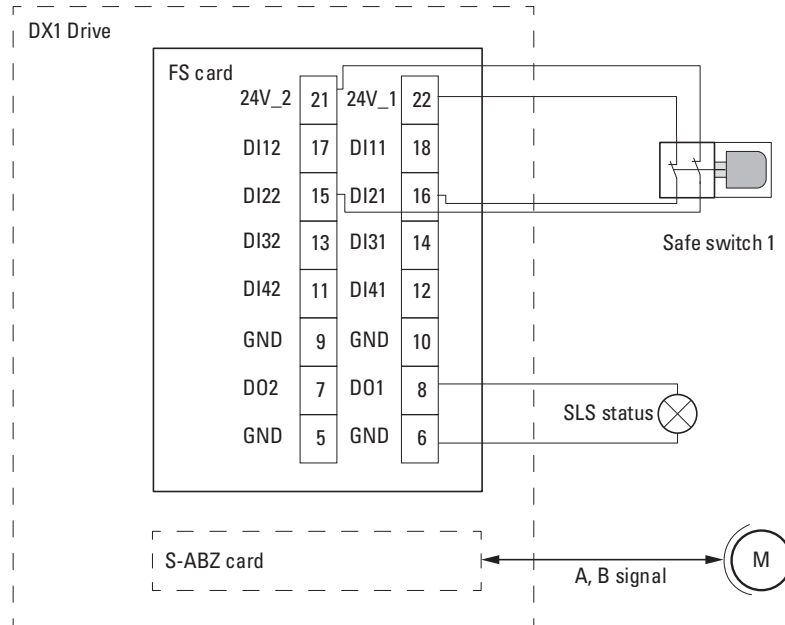


Figure 52: Wiring for SLS application

For the implementation of this application, refer to → Section 4.6.8, “Configuration” and → Section “Validation of SLS”.

For wiring the DX1 functional safety system, refer to → Section 2.5, “Electrical Setup”.

4 Safety Functions

4.6 SLS (Safely Limited Speed)

4.6.8 Configuration

To configure the SLS function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.6.8.1 How to configure SLS-t

Table 48: Example of an SLS-t set-up:

Step	PanelCode	Parameters	Set value	Description
1	P4.1	SLS Enable	Enable	Set enable SS1 Function
2	P4.2	SLS Mode	SLS time	Set SLS with time monitoring
3	P4.3	SLS-t delay	30 s	Set a safety delay after which SLS monitoring is activated: 30 s
4	P4.4	SLS Source	DI21 & DI22	Set the DI source(DI2) to activate the SLS function
5	P4.5	SLS trip limit	800 rpm	Set the SLS positive speed limit that trips the drive: 800 rpm
6	P4.6	SLS limit	600 rpm	Set the SLS positive speed limit for the drive: 600 rpm
7	P4.7	SLS Acknowledgement Mode	Automatic	Set automatic acknowledgement
8	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
9	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
10	P1.3	DO1 Mode	SLS Status	Set the DO output safety function status
11	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
12	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate

4.6.8.2 How to configure SLS-r

Table 49: Example of an SLS-r set-up:

Step	PanelCode	Parameters	Set value	Description
1	P4.1	SLS Enable	Enable	Set enable SS1 Function
2	P4.2	SLS Mode	SLS ramp	Set SLS with ramp monitoring
3	P4.4	SLS Source	DI21 & DI22	Set the DI source(DI2) to activate the SLS function
4	P4.5	SLS trip limit	800 rpm	Set the SLS positive speed limit that trips the drive: 800 rpm
5	P4.6	SLS limit	600 rpm	Set the SLS positive speed limit for the drive: 600 rpm
6	P4.7	SLS Acknowledgement Mode	Automatic	Set automatic acknowledgement
7	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
8	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
9	P1.3	DO1 Mode	SLS Status	Set the DO output safety function status
10	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
11	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
12	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

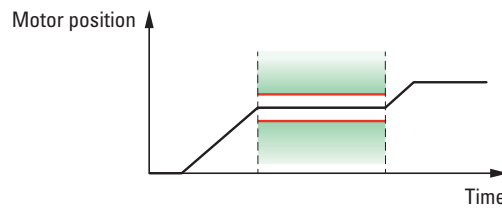
4.6.9 Validation of the SLS function

→ Section 5.4, "Validation of SLS"

4.7 SOS (Safe Operating Stop)

4.7.1 Function description

The SOS (Safe Operating Stop) function prevents the motor from deviating more than a defined amount from the stopped position. The drive provides energy to the motor to enable it to resist external forces.



4.7.2 Safety parameters

→ section , "SOS Parameters (P5)" , page 203

4 Safety Functions

4.7 SOS (Safe Operating Stop)

4.7.3 Timing diagram

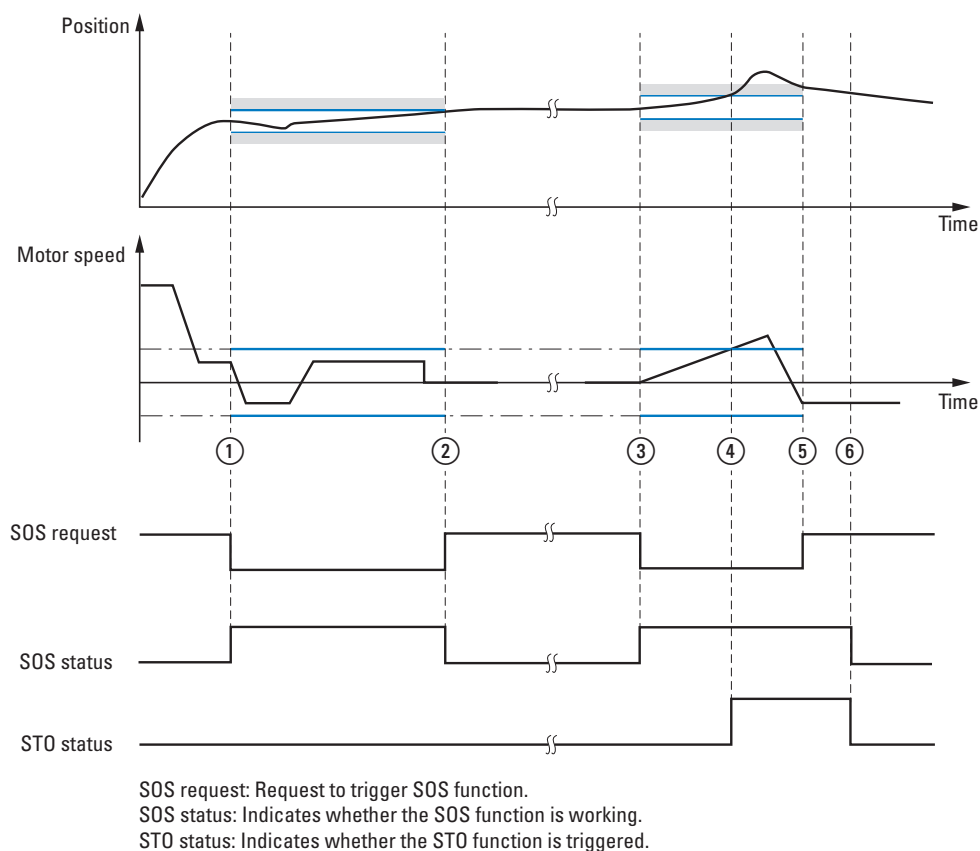


Figure 53: SOS function

Step	Description
1	The drive is at a standstill, receives the SOS request (from FS_DI), and starts SOS monitoring at the same time.
1-2	During SOS monitoring, the standstill position deviation does not exceed the defined standstill tolerance(A).
2	The SOS request is removed, and FS card stops SOS monitoring. The SOS function is acknowledged (automatic acknowledgement) and the SOS indication goes off.
3	Receives the SOS request (from FS_DI), starts SOS monitoring.
4	During SOS monitoring, the standstill position deviation does not exceed the defined standstill tolerance(A). The STO function is activated
5	The SOS request is removed and FS card stops the SOS monitoring.
6	The SOS & STO function are acknowledged, and the SOS & STO status indication goes off.

→ Set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is negative, STO after SBC.
- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4.7.4 State Diagram

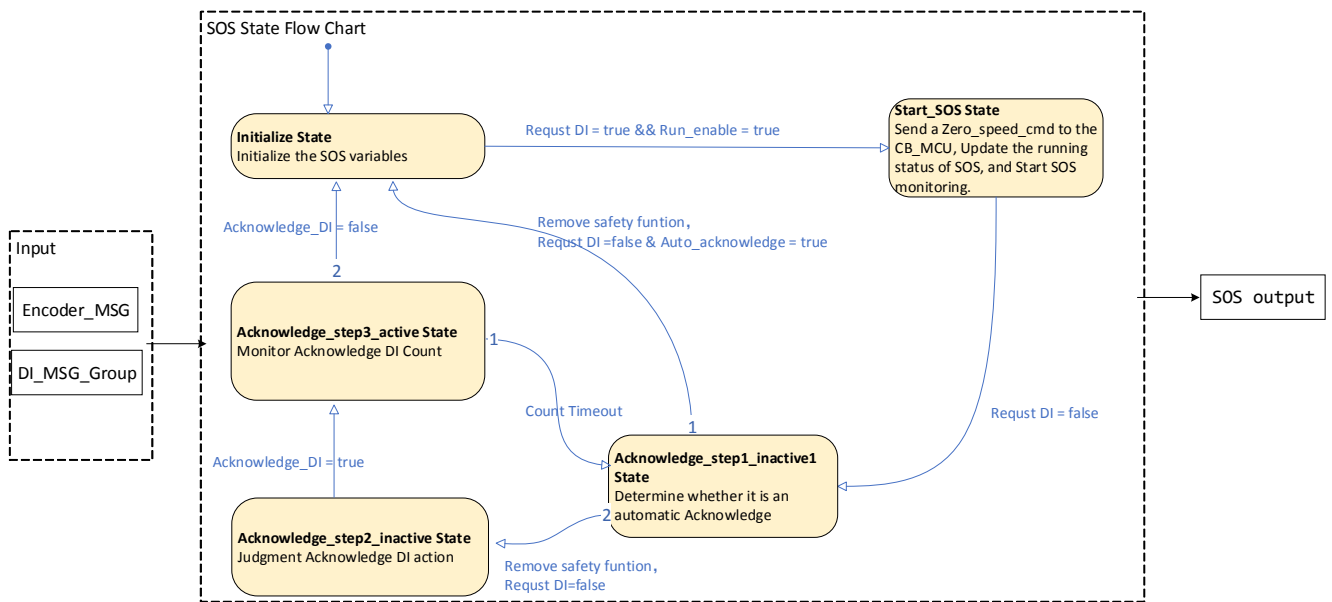


Figure 54: The SOS status flow chart

Table 50: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SOS function	The function is ready.	Initialize->Start_SOS	Request DI is active
Start_SOS	Start SOS monitoring. Check whether the motor standstill position deviation exceeds the defined standstill tolerance. If it is exceeded, FS card is trigger STO.	SOS status is high. (if trigger STO, STO status is high.)	Start_SOS-> Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SOS and STO status is low.	Acknowledge_step1_inactive1-> Initialize Acknowledge_step1_inactive1-> Acknowledge_step2_inactive	select automatic acknowledgement select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SOS and STO status is high.	Acknowledge_step2_inactive-> Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SOS and STO status is low.	Acknowledge_step3_active-> Acknowledge_step1_inactive1 Acknowledge_step3_active-> Initialize	Acknowledge DI is inactive more than 3s Acknowledge DI is inactive within 3s

4 Safety Functions

4.7 SOS (Safe Operating Stop)

4.7.5 Response time

SOS response time is from the safety function range exceeded to the shutdown of PWM buffers.

SOS response time = delay time of Encoder signal circuit + speed sampling and calculation time + 10 * Safety Function execution cycle time + delay time of STO trigger circuit + delay time of PWM buffers ≤ 40 ms

- T1: Delay time of Encoder signal circuit ≤ 5 ms
- T2: Speed sampling and calculation time ≤ 2 ms
- T3: 10 * Safety Function execution cycle time ≤ 10 ms
- T4: Delay time of STO trigger circuit ≤ 5 ms
- T5: Delay time of PWM buffers ≤ 5 ms
- Safety function response: FS card to shutdown of PWM buffers

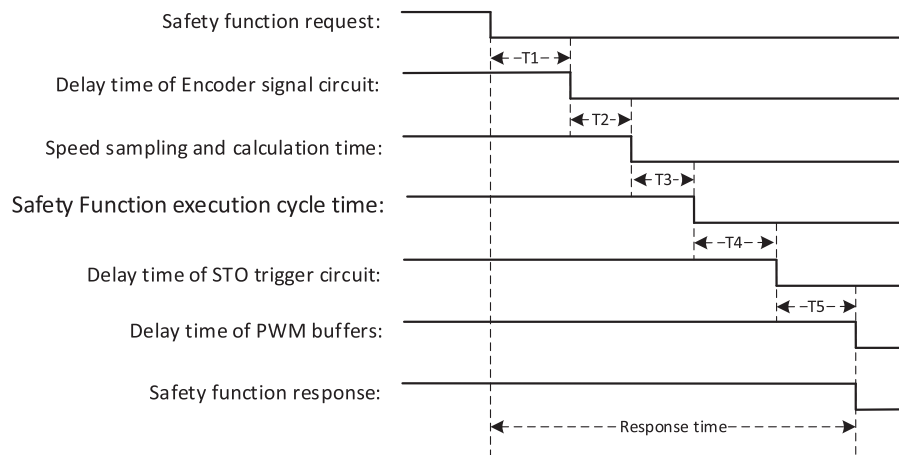


Figure 55: The timing diagram

4.7.6 Assignment of control signal terminals

Assignment of digital inputs to SOS are user dependent and any DI of FS card can be assigned as a SOS Source.

SOS Source and SOS Manual Acknowledgement Mode must be assigned to DI of FS card.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring".

4.7.7 Application

This section gives an application example of SOS function of FS card.

- Safe switch1: Connect DI2 using a button switch as an SOS function request.
- Use the lamp to connect DO1 to indicate SOS status.

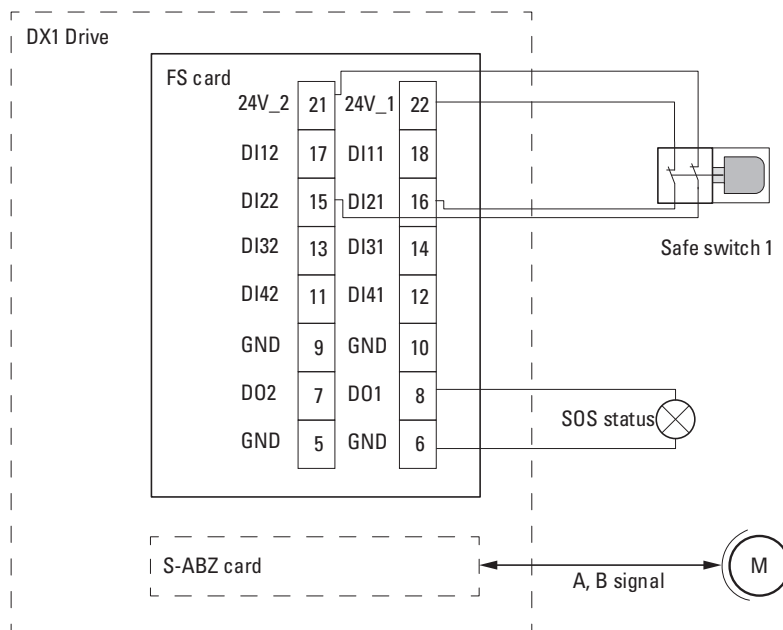


Figure 56: Wiring for SOS application

For the implementation of this application, refer to → Section 4.7.8, “Configuration” and → Section 4.7.9, “Validation of the SOS function”.

For wiring the DX1 functional safety system, refer to → Section 2.5, “Electrical Setup”.

4 Safety Functions

4.7 SOS (Safe Operating Stop)

4.7.8 Configuration

To configure the SOS function, set FS card parameters listed below to appropriate values using the PowerXL™ Safety Tool. See parameter group SOS on → section , “SOS Parameters (P5)”, page 203.

4.7.8.1 How to configure SOS

Table 51: Example of an SOS set-up

Step	PanelCode	Parameters	Set value	Description
1	P5.1	SOS Enable	Enable	Set enable SOS Function
2	P5.2	SOS Source	DI31 & DI32	Set the DI source(DI3) to activate the SOS function
3	P5.3	SOS n=0-Hysteresis	1080 deg	Set the position tolerance for the SOS function
4	P5.4	SOS Acknowledgement Mode	Automatic	Set automatic acknowledgement
5	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
6	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
7	P1.3	DO1 Mode	SOS Status	Set the DO output safety function status

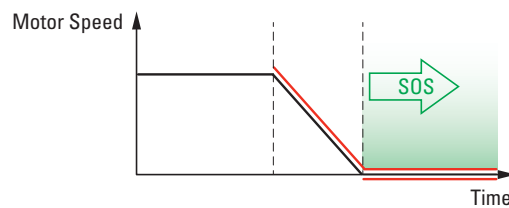
4.7.9 Validation of the SOS function

→ Section 5.8, “Validation of SOS”

4.8 SS2 (Safe Stop 2)

4.8.1 Function description

The SS2 (Safe Stop 2) function monitors the motor deceleration rate within set limits during motor stopping and initiates the Safe Operating Stop (SOS) function when the motor speed is below the specified limit. This safety function corresponds to a controlled stop in accordance with stop category 2 of IEC 60204-1.



The SS2 function uses SAR parameters to define and/or monitor the deceleration ramp.

The SS2 function utilizes the time (SS2-t) or ramp(SS2-r) monitoring method to respectively monitor the deceleration ramp.

The SS2-t uses SAR parameter to define the deceleration ramp.

The SS2-r uses SAR parameters to define and monitoring deceleration ramp.

See function timing description → Section 4.8.3, "Timing diagram" and configuration → Section 4.8.8, "Configuration" for more information.

4.8.2 Safety Parameters

→ section , "SS2 Parameters (P6)", page 204

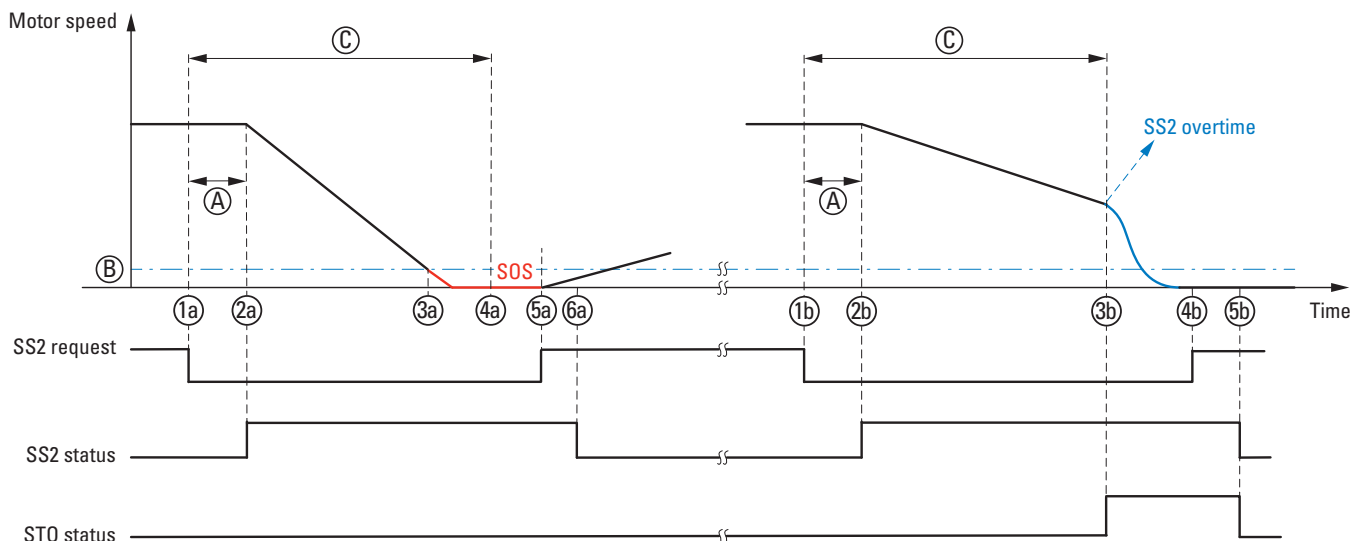
4 Safety Functions

4.8 SS2 (Safe Stop 2)

4.8.3 Timing diagram

4.8.3.1 SS2-t

The SS2-t monitors the motor deceleration and performs the safe operating stop function after an application specific time delay.



- (A) **Response time:** Safety function response time
 - (B) **SS2 n=0 limit:** Zore speed limit for activating SOS function.
 - (C) **t-delay STO@SS2:** Time after which the FS card activates the SOS function.
- SS2 request: Request to trigger SS2 function.
 SS2 status: Indicates whether the SS2 function is working.
 STO status: Indicates whether the STO function is triggered.

Figure 57: SS2-t function

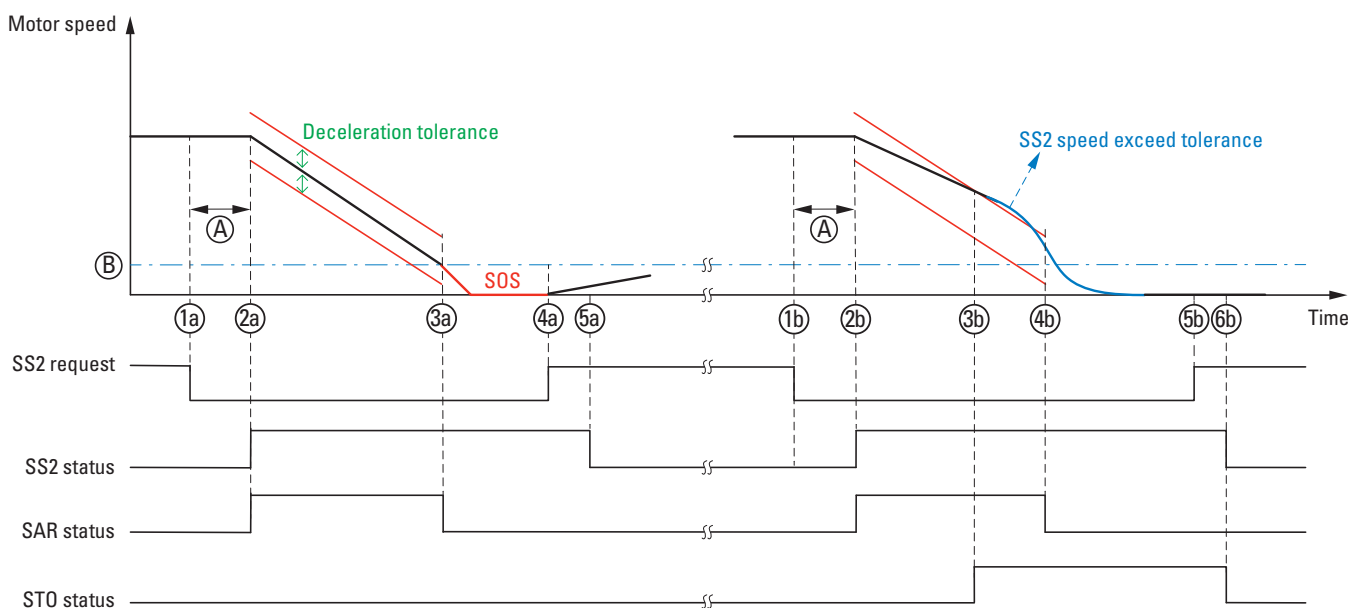
Step	Description
1a	Receives the SS2 request from FS card DI. FS card start a counter for delay time (C).
2a	After response time (A) has elapsed. The drive brakes over a ramp until the motor comes to a standstill.
3a	The motor speed is at standstill tolerance (B) and activates the SOS function.
4a	End of delay time (C).
3a-5a	During SOS monitoring, if the deviation of the stop position exceeds the defined standstill tolerance and activates the drive STO function.
5a	The SS2 request is removed.
6a	The SS2 function is acknowledged (manual acknowledgement) and FS card stops the SS2 monitoring. The SS2 status indication goes off.
1b	Receives the SS2 request from FS card DI. FS card Start a counter for delay time (C).
2b	After response time (A) has elapsed. The drive brakes over a ramp until the motor comes to a standstill. Deceleration is defined by SAR parameters.
3b	The drive has not ramped down fast enough when delay time (C) has elapsed, FS card activates the STO function.
4b	The SS2 request is removed.
5b	The SS2 & STO function are acknowledged and FS card stops the SS2 monitoring. The SS2 & STO status indication goes off.

→ Set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC
- If the STO SBC delay is zero, STO and SBC at the same time.

4.8.3.2 SS2-r

The SS2-r function 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.



- Ⓐ **Response time:** Safety function response time
 - Ⓑ **SS2 n=0 limit:** Zero speed limit for activating SOS function.
- SS2 request: Request to trigger SS2 function.
 SS2 status: Indicates whether the SS2 function is working.
 SAR status: Indicates whether the SAR function is working.
 STO status: Indicates whether the STO function is triggered.

Figure 58: SS2-r function

4 Safety Functions

4.8 SS2 (Safe Stop 2)

Step	Description
1a	Receives the SS2 request from FS card DI.
2a	After response time(A) has elapsed. The drive brakes over a ramp until the motor comes to a standstill. FS card start SAR monitoring. Deceleration is defined by SAR Parameters.
3a	The motor speed is at standstill tolerance(B) and activates the SOS function. FS card stop SAR monitoring.
3a-4a	During SOS monitoring, if the deviation of the stop position exceeds the defined standstill tolerance and activates the drive STO function.
4a	The SS2 request is removed.
5a	The SS2 function is acknowledged (manual acknowledgement) and FS card stops the SS2 monitoring. The SS2 status indication goes off.
1b	Receives the SS2 request from FS card DI.
2b	After response time(A) has elapsed. The drive brakes over a ramp until the motor comes to a standstill. FS card start SAR monitoring.
3b	The motor speed deceleration rate exceeds a tolerance threshold, FS card activates the STO function. FS card stop SAR monitoring.
4b	The motor speed ramp down to zore speed(B).
5b	The SS2 request is removed.
6b	The SS2 & STO function are acknowledged and FS card stops the SS2 monitoring. The SS2 & STO status indication goes off.

→ Set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4.8.4 State diagram

4.8.4.1 SS2-t

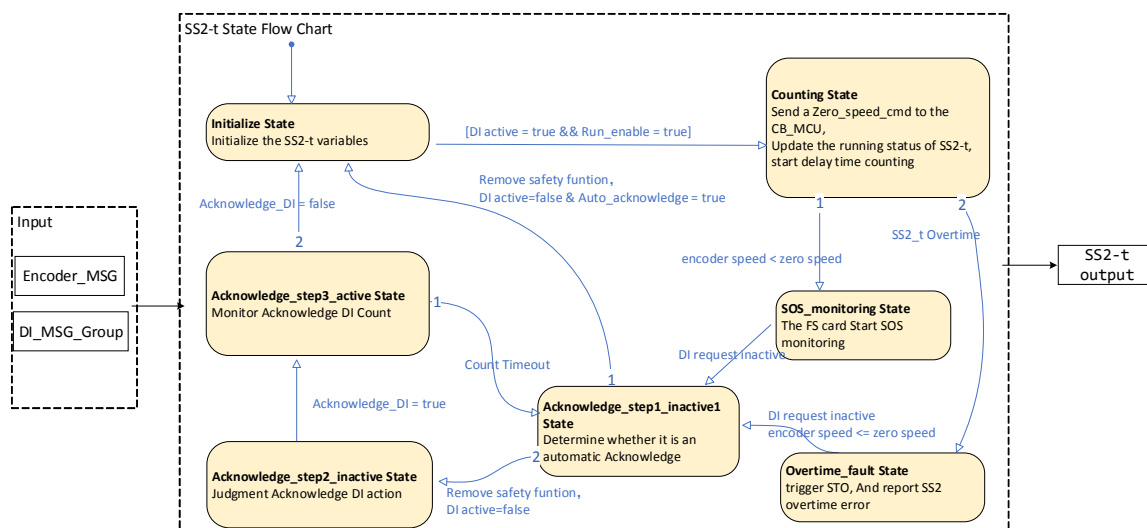


Figure 59: The SS2-t status flow chart

Table 52: The transition among states

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SS2-t function.	The function is ready.	Initialize->Counting	Request DI is active
Counting	Delay the start of SOS monitoring. Updated the status output of SS2-t.	Count of delay time. Motor deceleration. SS2 status is high.	Counting->SOS_monitoring	Motor speed \leq zero speed
			Counting->Overtime_fault	Exceeding the delay time
SOS_monitoring	Start SOS monitoring. Check whether the motor standstill position deviation exceeds the defined standstill tolerance. If it is exceeded, FS card is trigger STO.	If trigger STO, STO status is high.	SOS_monitoring->Acknowledge_step1_inactive1	Request DI is inactive
Overtime_fault	When delay time ends, and the motor speed has not yet reduced to zero speed	trigger STO(STO status is high), and report SS2 overtime error.	Overtime_fault->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SS2 and STO status is low.	Acknowledge_step1_inactive 1 -> Initialize	select automatic acknowledgement
			Acknowledge_step1_inactive 1 -> Acknowledge_step2_inactive	select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SS2 and STO status is high.	Acknowledge_step2_inactive -> Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SS2 and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4.8.4.2 SS2-r

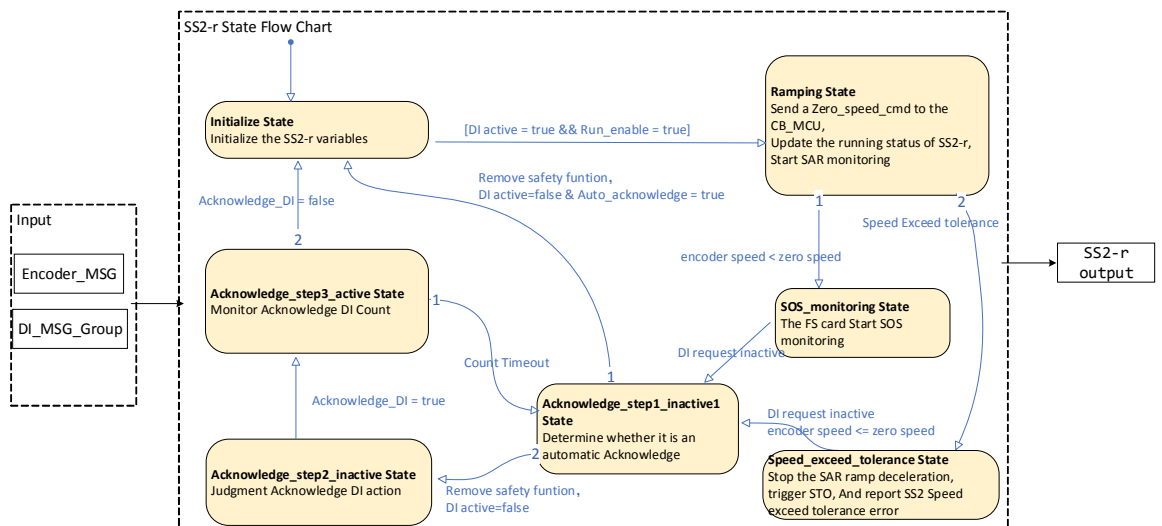


Figure 60: The SS2-r status flow chart

4 Safety Functions

4.8 SS2 (Safe Stop 2)

Table 53: The transition among states

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SS2-r function	The function is ready.	Initialize->Ramping	Request DI is active
Ramping	Start SAR monitoring. Updated the status of SS2-r.	Motor deceleration. SS2 and SAR status is high.	Ramping->SOS_monitoring	Motor speed \leq zero speed
			Ramping->Speed_exceed_tolerance	Exceeding the deceleration slope
SOS_monitoring	Start SOS monitoring. Check whether the motor standstill position deviation exceeds the defined standstill tolerance. If it is exceeded, FS card is trigger STO.	If trigger STO, STO status is high.	SOS_monitoring->Acknowledge_step1_inactive1	Request DI is inactive
Speed_exceed_tolerance	Monitor the deceleration slope of the motor during the deceleration process, and activate the STO function if the preset limit is exceeded.	trigger STO(STO status is high), and report SS2 Speed exceed tolerance error	Speed_exceed_tolerance->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method. If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SS2 and STO status is low.	Acknowledge_step1_inactive1->Initialize	select automatic acknowledgement
			Acknowledge_step1_inactive1->Acknowledge_step2_inactive	select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SS2 and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SS2 and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4.8.5 Response time

SS2 response time is from the demand effected on FS card, DI terminal to the deceleration demand be sent to drive.

SS2 response time= Delay time of DI circuit + DI filter time + 3* Safety Function execution cycle time ≤ 40 ms

- T1: Delay time of DI circuit ≤ 10 ms
- T2: DI filter time = 20 ms
- T3: 3* Safety Function execution cycle time ≤ 3 ms
- Safety function response: FS card send deceleration demand to drive

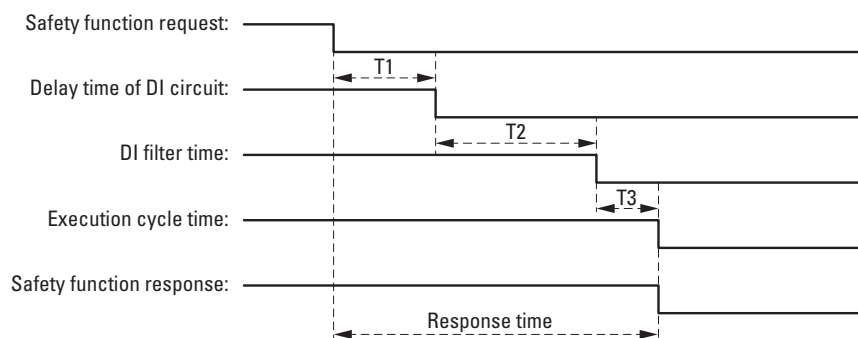


Figure 61: The timing diagram

4.8.6 Assignment of control signal terminals

Assignment of digital inputs to SS2 are user dependent and any input DI of FS card can be assigned as a SS2 Source.

SS2 Source and SS2 Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer → Section 2.8.3, "FS card user IO wiring".

4 Safety Functions

4.8 SS2 (Safe Stop 2)

4.8.7 Application

This section gives an application example of SS2 function of FS card.

- Safe switch1: Connect DI1 using a button switch as an SS2 function request.
- Use the lamp to connect DO1 to indicate SS2 status.

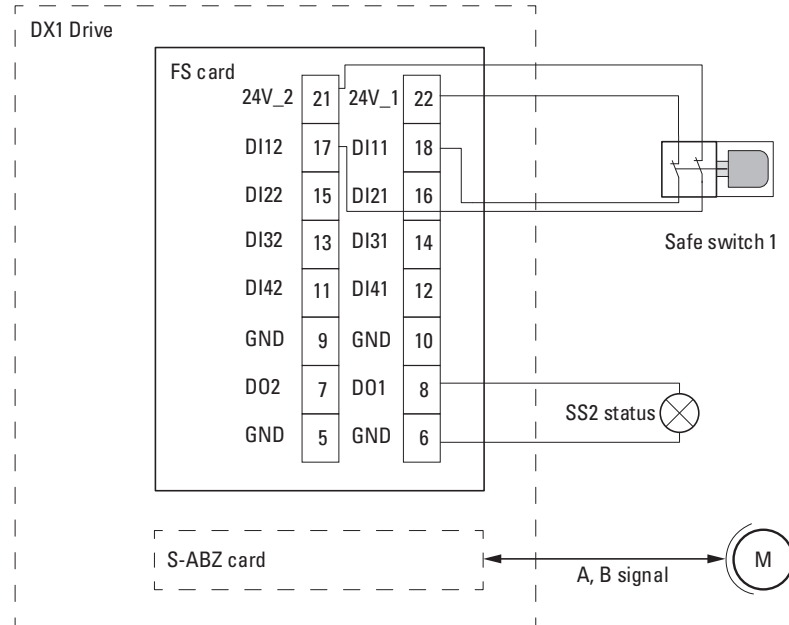


Figure 62: Wiring for SS2 application

For the implementation of this application, refer to → Section 4.8.8, “Configuration” and → Section 4.8.9, “Validation of the SS2 function”.

For wiring the DX1 functional safety system, refer to → Section 2.5, “Electrical Setup”.

4.8.8 Configuration

To configure the SS2 function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.8.8.1 How to configure SS2-t

Table 54: Example of an SS2-t set-up:

Step	PanelCode	Parameters	Set value	Description
1	P6.1	SS2 Enable	Enable	Set enable SS2 Function
2	P6.2	SS2 Source	DI11 & DI12	Set the DI source(DI1) to activate the SS2 function
3	P6.3	SS2 Mode	SS2 time	Set SS2 with time monitor
4	P6.4	t-delay STO@SS2	30 s	Set the safety delay after which FS card activates the SOS function after the SS2 request
5	P6.5	SS2 n=0 Limit	20 rpm	User-defined Zero Speed.Speed limit for activating the SOS function: 20 rpm
6	P6.6	SS2 Acknowledgement Mode	Automatic	Set automatic acknowledgement
7	P5.3	SOS n=0-Hysteresis	1080 deg	Set the position tolerance for the SOS function
8	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
9	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
10	P1.3	DO1 Mode	SS2 Status	Set the DO output safety function status
11	P11.1	Speed scaling	1500 rpm	Set reference speed value
12	P11.2	Ramp time to zero	20 s	Set the target time for the ramp decelerate

4.8.8.2 How to configure SS2-r

Table 55: Example of an SS2-r set-up:

Step	PanelCode	Parameters	Set value	Description
1	P6.1	SS2 Enable	Enable	Set enable SS2 Function
2	P6.2	SS2 Source	DI11 & DI12	Set the DI source(DI1) to activate the SS2 function
3	P6.3	SS2 Mode	SS2 ramp	Set SS2 with ramp monitor
4	P6.5	SS2 n=0 Limit	20 rpm	User-defined Zero Speed.Speed limit for activating the SOS function: 20 rpm
5	P6.6	SS2 Acknowledgement Mode	Automatic	Set automatic acknowledgement
6	P5.3	SOS n=0-Hysteresis	1080 deg	Set the position tolerance for the SOS function
7	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
8	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
9	P1.3	DO1 Mode	SS2 Status	Set the DO output safety function status
10	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
11	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
12	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

4.8.9 Validation of the SS2 function

→ Section 5.3, "Validation of SS2"

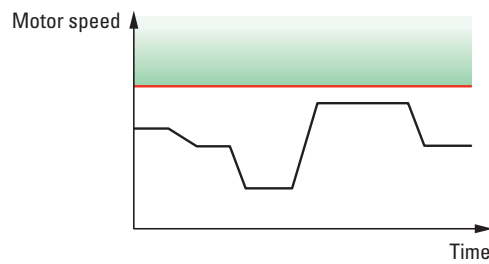
4 Safety Functions

4.9 SSM (Safe Speed Monitor)

4.9 SSM (Safe Speed Monitor)

4.9.1 Function description

The SSM (Safe Speed Monitor) function provides a safe output signal to indicate whether the motor speed is below a specified limit. FS card monitors motor speed and output a safe DO signal to indicate whether the motor speed is below a specified limit.



WARNING

SSM is only a monitor safety function. The output DO signal is only for indication purpose and will not trigger any other safety functions such as STO or SBC.

4.9.2 Safety parameters

Refer to → section , “SSM Parameters (P7)”, page 205.

4.9.3 Timing diagram

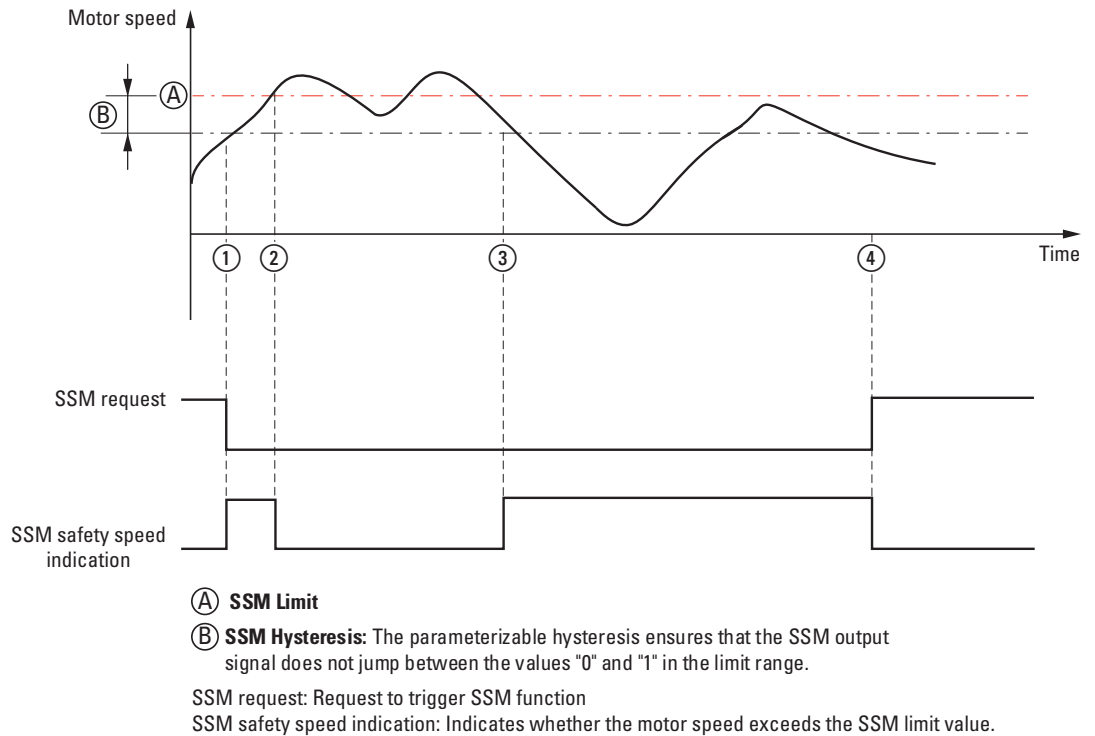


Figure 63: SSM function

Step	Description
1	Receives the SSM request from FS card DI. And FS card starts the SSM monitoring. Motor speed is below SSM limit (A). The SSM safety speed indication goes on.
2	The motor speed goes above the SSM limit (A), the SSM safety speed indication goes off.
2-3	If the Speed is within the defined hysteresis(B), the SSM safety speed indication does not go on.
3	Motor speed is under the hysteresis limit (B), the SSM safety speed indication goes on.
4	The SSM request is removed, and FS card stop SSM monitoring

4 Safety Functions

4.9 SSM (Safe Speed Monitor)

4.9.4 State diagram

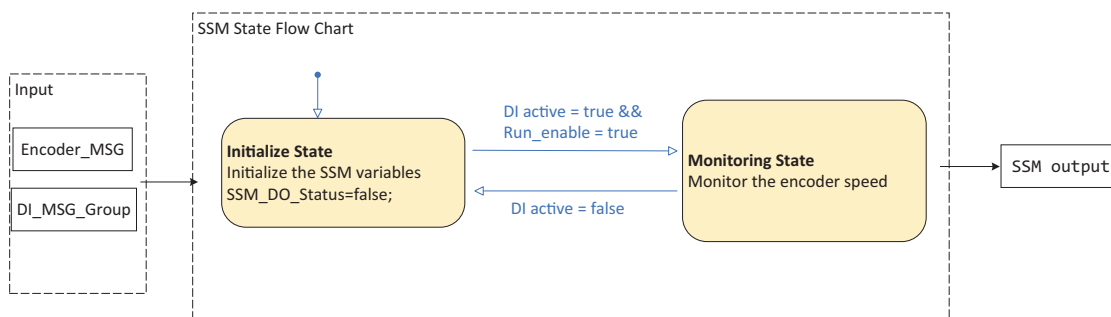


Figure 64: The SSM status flow chart

Table 56: The transition among states

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SSM variables	The function is ready.	Initialize->Monitoring	Request DI is active
Monitoring	Monitor encoder speed. The speed goes above the SSM limit, the SSM safety speed indication goes off(DO outputs low).	update DO status.	Monitoring->Initialize	Request DI is inactive

4.9.5 Response time

SSM response time is from the safety function range exceeded until the DO output is high.

SSM response time= delay time of Encoder signal circuit + speed sampling and calculation time + 10*Safety Function execution cycle time + delay time of DO circuit ≤ 40 ms

- T1: Delay time of Encoder signal circuit ≤ 5 ms
- T2: speed sampling and calculation time ≤ 2 ms
- T3: 10*Safety Function execution cycle time ≤ 10 ms
- T4: Delay time of DO circuit ≤ 5 ms
- Safety function response: FS card DO output is low.

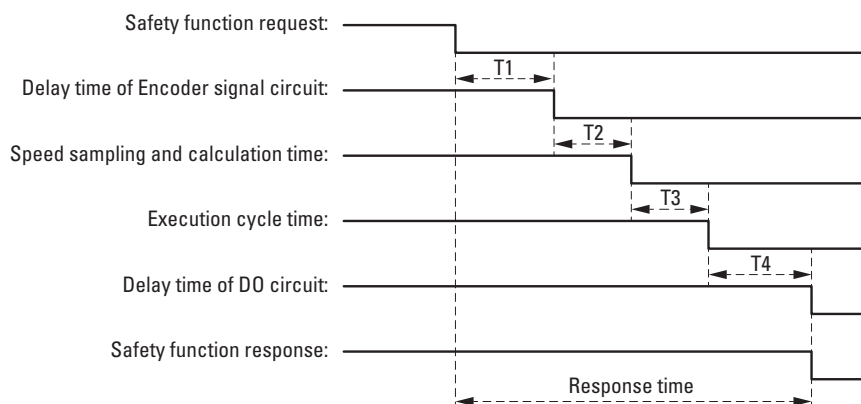


Figure 65: The timing diagram

4.9.6 Assignment of control signal terminals

Assignment of digital inputs to SSM are user dependent and FS card DI can be assigned as a SSM Source.

SSM Source and SSM Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring".

4.9.7 Application

This section gives an application example of SSM function of FS card.

- Safe switch1: Connect DI3 using a button switch as an SSM function request.
- Use the lamp to connect DO1 to indicate SSM status.

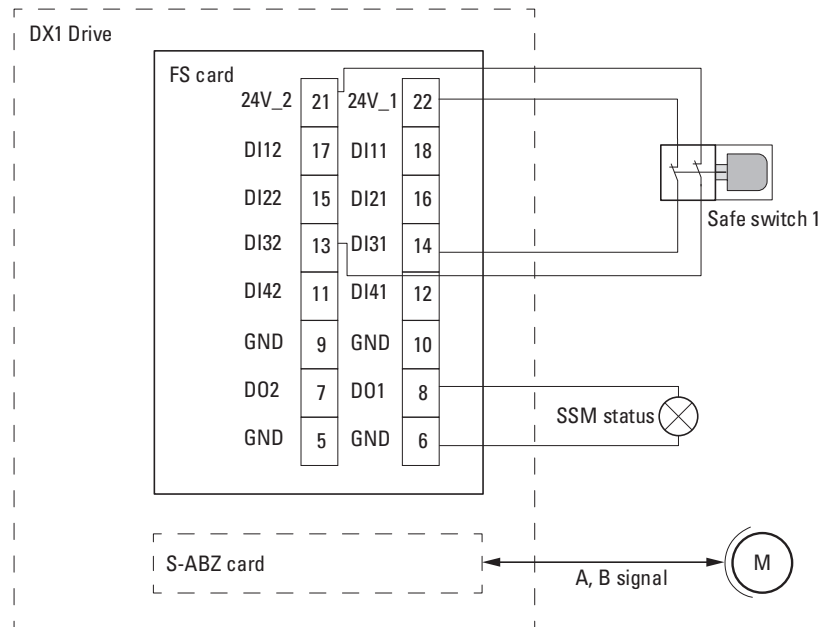


Figure 66: Wiring for SSM application

For the implementation of this application, refer to → Section 4.9.8, "Configuration" and → Section 4.9.9, "Validation of the SSM function".

For wiring the DX1 functional safety system, refer to → Section 2.5, "Electrical Setup".

4 Safety Functions

4.9 SSM (Safe Speed Monitor)

4.9.8 Configuration

To configure the SSM function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.9.8.1 How to configure SSM

Table 57: Example of an SSM set-up:

Step	Panel Code	Parameters	Set value	Description
1	P7.1	SSM Enable	Enable	Set enable SSM Function
2	P7.2	SSM Source	DI31 & DI32	Set the DI source(DI3) to activate the SSM function
3	P7.3	SSM Limit	1000 rpm	Set the speed limit for the SSM function
4	P7.4	SSM Hysteresis	30 rpm	Set the parametric hysteresis
5	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
6	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
7	P1.3	DO1 Mode	SSM Status	Set the DO output safety function status

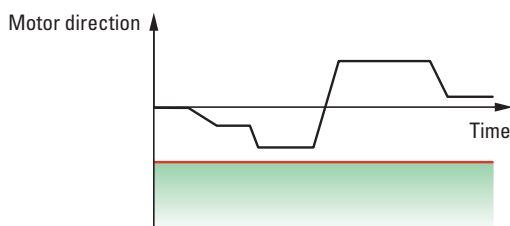
4.9.9 Validation of the SSM function

Refer to → Section 5.9, "Validation of SSM"

4.10 SDI (Safe Direction)

4.10.1 Function description

The SDI (Safe Direction) function prevents the motor shaft from moving more than a defined amount in the unintended direction.



This function monitors the direction of feedback.

- If the SDI function is activated in the forbidden direction, FS card will cause the drive to stop safely.
- If the motion direction error is detected when the SDI function is activated in the safe direction, FS card activates the STO function.

If the user activates the SDI function in the forbidden direction, the SDI function will decelerate using a predefined SAR ramp.

The SDI function utilizes the time (SDI-t) or ramp (SDI-r) monitoring method to respectively monitor the deceleration ramp.

The SDI-t uses SAR parameter to define the deceleration ramp.

The SDI-r uses SAR parameters to define and monitoring deceleration ramp.

See function timing description(→ Section 4.10.3, "Timing diagram") and configuration (→ Section 4.10.8, "Configuration") for more information.

4.10.2 Safety parameters

Refer to → section , "SDI Parameters (P8)", page 206.

4 Safety Functions

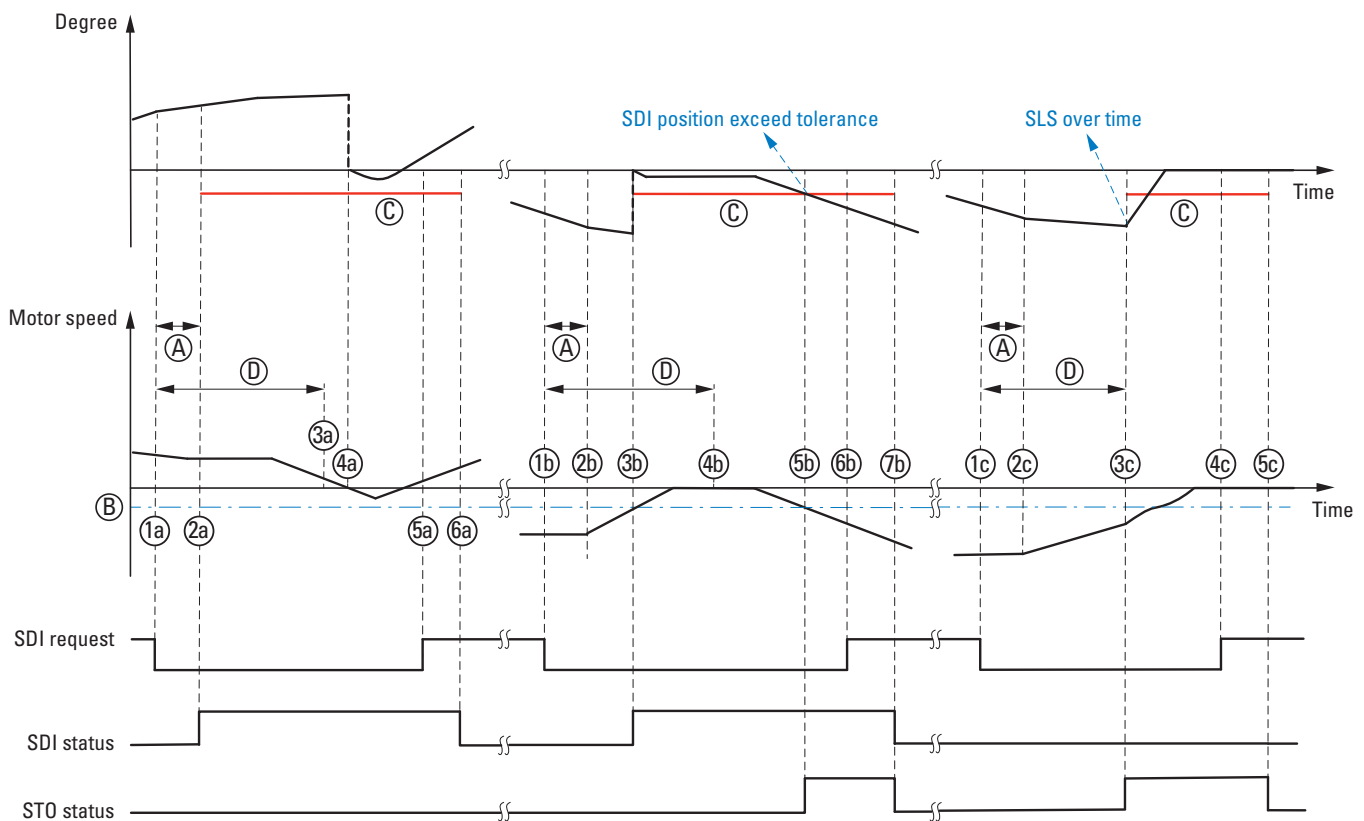
4.10 SDI (Safe Direction)

4.10.3 Timing diagram

4.10.3.1 SDI-t

This applies when the motor rotates into the forbidden direction when the SDI function is activated, and the time monitoring method is used.

→ In this case, Enable SDI+, the negative direction is set as the forbidden direction.



(A) DI filtering time: 20 ms

(B) SDI n=0 Limit: User-defined Zero Speed. Speed limit to define the motor as stopped.

(C) SDI Limit degree: Sets the position tolerance for the SDI function. The position of the motor axle cannot move into the forbidden direction more than defined with this parameter.

(D) SDI-t delay: Delay for forcing to start the SDI monitoring.

SDI request: Request to trigger SDI function.

SDI status: Indicates whether the SDI function is working.

STO status: Indicates whether the STO function is triggered.

Figure 67: SDI-t function

Step	Description
1a	Receives the SDI request from FS card DI. FS card Start a counter for delay time (D).
2a	After time (A) has elapsed. The motor is rotating in the positive direction. FS card starts the SDI monitoring.
3a	End of delay time (D). FS card starts SDI monitoring here at the latest.
4a	The rotation direction of the motor changes to the forbidden (negative) direction. The motor shaft rotation degrees did not deviate by more than defined SDI tolerance limit degrees (C).
5a	The SDI request is removed.
6a	The SDI function is acknowledged (manual acknowledgement) and FS card stops the SDI monitoring. The SDI status indication goes off.
1b	Receives the SDI request from FS card DI. The motor rotates in the forbidden direction (in this case, negative). FS card starts a counter for delay time (D).
2b	After time (A) has elapsed. The drive starts to ramp down the motor speed. Deceleration is defined by SAR Parameters.
3b	During the delay time (D), the motor speed reaches zero speed (B). FS card starts SDI monitoring.
4b	End of delay time (D). FS card starts SDI monitoring here at the latest.
3b-5b	The motor rotates to the extent allowed by the SDI tolerance limit (B) in the forbidden direction.
5b	The motor rotates to the forbidden direction exceeds the allowable degree of the SDI tolerance limit (C), FS card activate STO function.
6b	The SDI request is removed.
7b	The SDI & STO function are acknowledged and FS card stops the SDI monitoring. The SDI & STO status indication goes off.
1c	Receives the SDI request from FS card DI. The motor rotates in the forbidden direction (in this case, negative). FS card starts a counter for delay time (D).
2c	After time (A) has elapsed. The drive starts to ramp down the motor speed.
3c	FS card starts the SDI monitoring at the latest here, that is, after the delay time (D) has elapsed, the rotation direction of the motor is not correct, the motor rotates to the extent that the forbidden direction exceeds the SDI tolerance limit (C), FS card activates STO function. The motor coasts to a stop.
4c	The SDI request is removed.
5c	The SDI & STO function are acknowledged and FS card stops the SDI monitoring. The SDI & STO status indication goes off.

→ Note: User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time

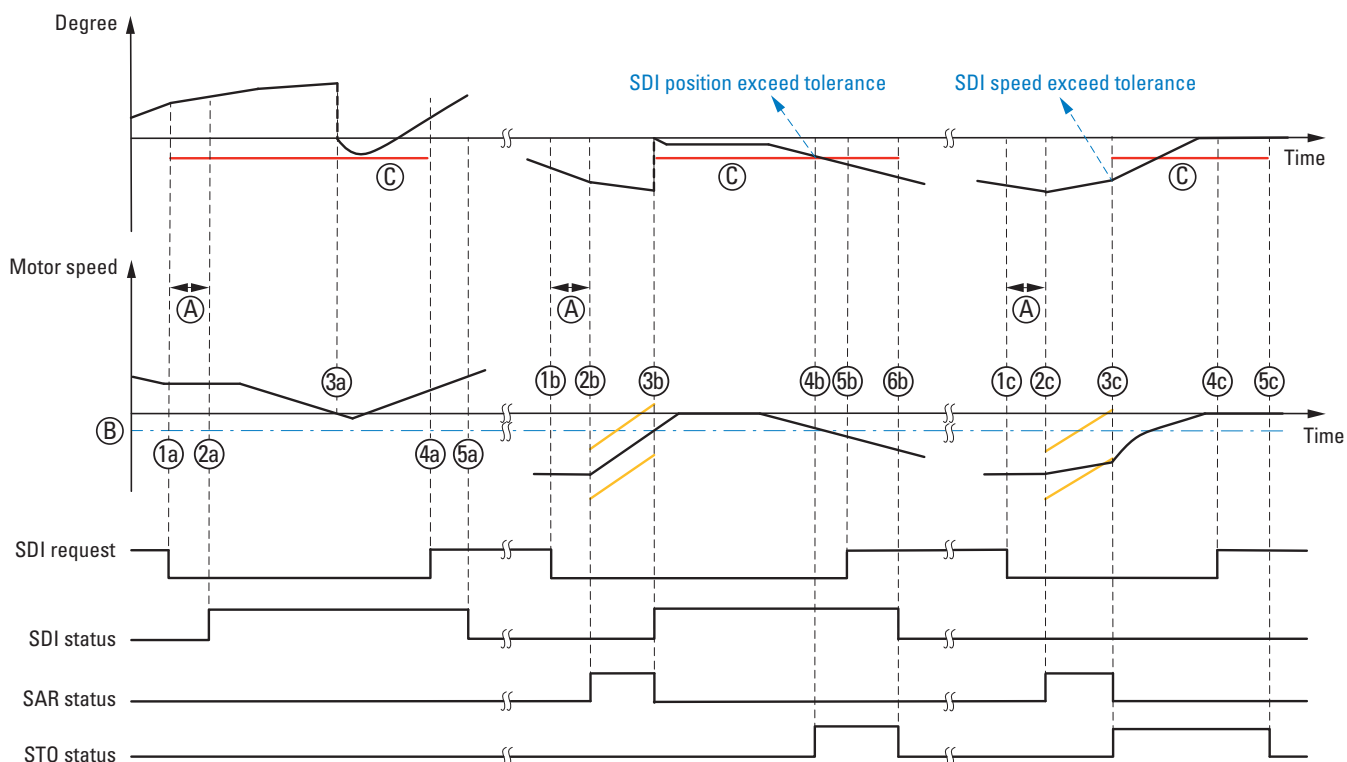
4 Safety Functions

4.10 SDI (Safe Direction)

4.10.3.2 SDI-r

This applies when the motor rotates into the forbidden direction when the SDI function is activated, and the ramp monitoring method is used.

→ In this case, Enable SDI+, the negative direction is set as the forbidden direction.



Ⓐ DI filtering time: 20 ms

Ⓑ SDI n=0 Limit: User-defined Zero Speed. Speed limit to define the motor as stopped.

Ⓒ SDI Limit degree: Sets the position tolerance for the SDI function. The position of the motor axle cannot move into the forbidden direction more than defined with this parameter.

— Ramp monitoring limits

SDI request: Request to trigger SDI function.

SDI status: Indicates whether the SDI function is working.

SAR status: Indicates whether the SAR function is working.

STO status: Indicates whether the STO function is triggered.

Figure 68: SDI-r function

4 Safety Functions

4.10 SDI (Safe Direction)

Step	Description
1a	Receives the SDI request from FS card DI. The motor is rotating in the positive direction (in this case, the negative direction is set as the forbidden direction).
2a	After time (A) has elapsed. The motor is rotating in the positive direction. FS card starts the SDI monitoring.
3a	The rotation direction of the motor changes to the forbidden (negative) direction. The motor shaft rotation degrees did not deviate by more than defined SDI tolerance limit degrees (C).
4a	The SDI request is removed.
5a	The SDI function is acknowledged (manual acknowledgement) and FS card stops the SDI monitoring. The SDI status indication goes off.
1b	Receives the SDI request (from FS card DI). The motor rotates in the forbidden direction (in this case, negative).
2b	After time (A) has elapsed. The drive starts to ramp down the motor speed. FS card start SAR monitoring. Deceleration is defined by SAR parameters.
3b	During the SAR monitoring, the motor speed reaches zero speed (B). FS card stops SAR monitoring and starts SDI monitoring.
3b-4b	The motor rotates to the extent allowed by the SDI tolerance limit (C) in the forbidden direction.
4b	The motor rotates to the forbidden direction exceeds the allowable degree of the SDI tolerance limit (C), FS card activates STO function.
5b	The SDI request is removed.
6b	The SDI & STO function are acknowledged and FS card stops the SDI monitoring. The SDI & STO status indication goes off.
1c	Receives the SDI request (from FS card DI). The motor rotates in the forbidden direction (in this case, negative).
2c	After time (A) has elapsed. The drive starts to ramp down the motor speed. FS card starts SAR monitoring.
3c	During the SAR monitoring, the motor deceleration exceeds ramp monitoring limits. FS card activates the STO function and stop SAR monitoring. The motor coasts to a stop.
4c	The SDI request is removed.
5c	The SDI & STO function are acknowledged and FS card stops the SDI monitoring. The SDI & STO status indication goes off.

→ Note: User can set the execute order between STO and SBC (not shown in the figure).

- If the STO SBC delay is positive, STO before SBC.
- If the STO SBC delay is zero, STO and SBC at the same time.

4 Safety Functions
 4.10 SDI (Safe Direction)

4.10.4 State diagram

4.10.4.1 SDI-t positive

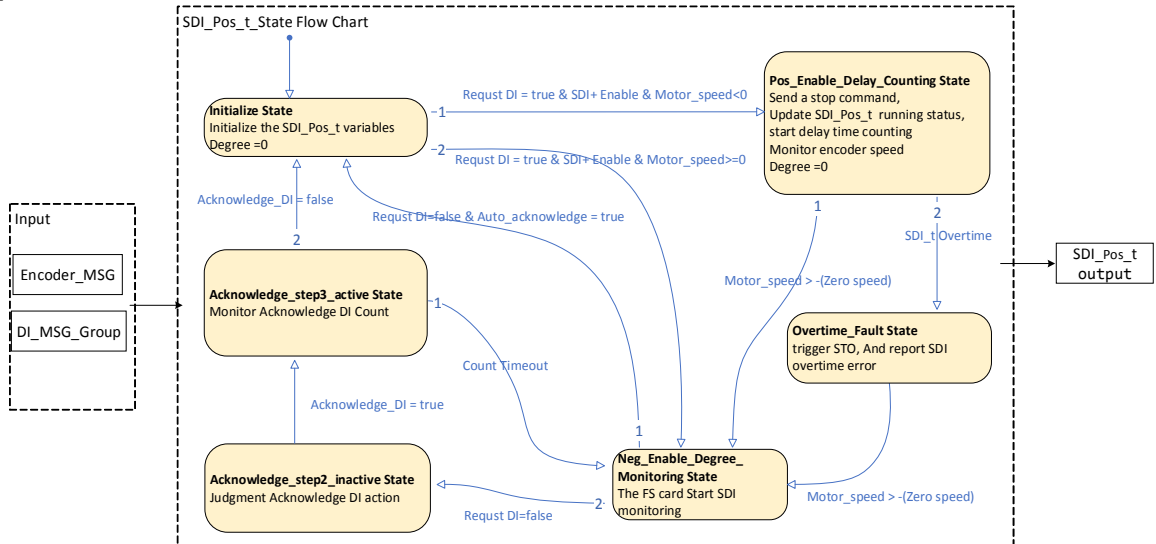


Figure 69: The SDI-t positive status flow chart

4 Safety Functions

4.10 SDI (Safe Direction)

Table 58: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SDI-t function.	The function is ready.	Initialize-> Pos_Enable_Delay_Counting	Request DI is active, Enable SDI+, and Motor speed < 0
			Initialize-> Pos_Enable_Degree_Monitoring	Request DI is active, Enable SDI+, and Motor speed >= 0
Pos_Enable_Delay_Counting	when Enable SDI+, the negative direction is set as the forbidden direction. The motor start deceleration.	Count of delay time. Motor deceleration.	Pos_Enable_Delay_Counting-> Pos_Enable_Degree_Monitoring	Motor speed > -(zero speed)
			Pos_Enable_Delay_Counting-> Overtime_Fault	Exceeding the delay time
Overtime_Fault	When delay time ends, and the motor direction has not yet reduced to zero speed	trigger STO, and report SDI overtime error.	Overtime_Fault-> Pos_Enable_Degree_Monitoring	Motor speed > -(zero speed)
Pos_Enable_Degree_Monitoring	The motor direction is below the user-defined zero speed limit, and FS card starts monitoring the motor is run direction. If the angle of rotation exceeds the tolerance, the STO function is activated. Determine function Acknowledge method. If set to automatic, the function will be automatically acknowledged when the request DI is removed.	SDI+ status is high. (When remove SDI+ function and select automatic acknowledge, SDI+ and STO (If trigger STO) status is low.)	Pos_Enable_Degree_Monitoring-> Acknowledge_step2_inactive	Request DI is inactive, select manual acknowledgement
			Pos_Enable_Degree_Monitoring-> Initialize	Request DI is inactive, select automatic acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SDI+ and STO status is high.	Acknowledge_step2_inactive-> Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SDI+ and STO status is low.	Acknowledge_step3_active-> Pos_Enable_Degree_Monitoring	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active-> Initialize	Acknowledge DI is inactive within 3s

4 Safety Functions

4.10 SDI (Safe Direction)

4.10.4.2 SDI-t negative

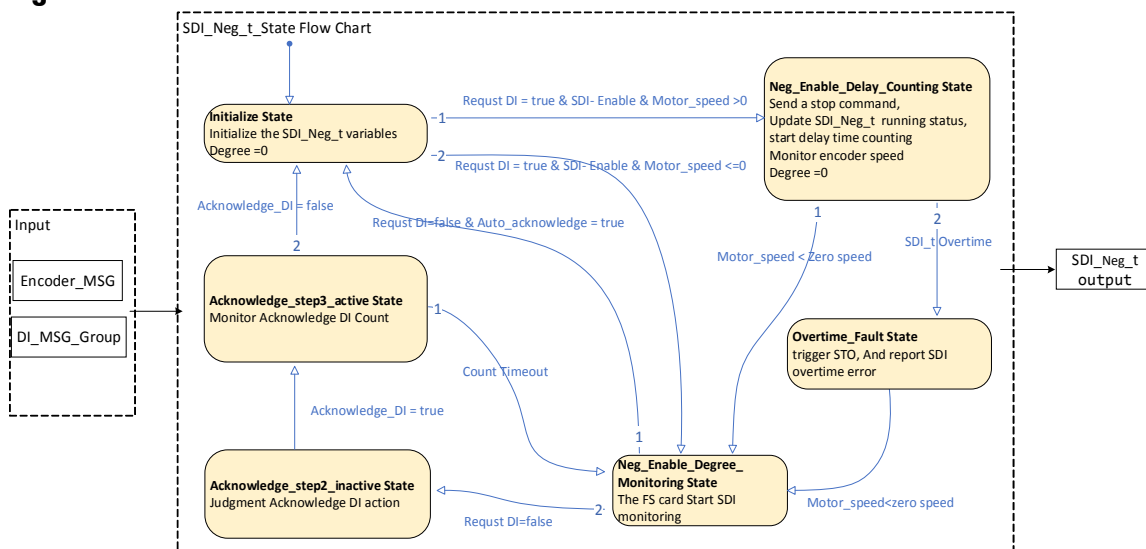


Figure 70: The SDI-t negative status flow chart

Table 59: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SDI-t function	The function is ready.	Initialize-> Neg_Enable_Delay_Counting	Request DI is active, Enable SDI-, and Motor speed < 0
			Initialize-> Neg_Enable_Degree_Monitoring	Request DI is active, Enable SDI-, and Motor speed >= 0
Neg_Enable_Delay_Counting	when Enable SDI-, the negative direction is set as the forbidden direction. The motor start deceleration.	Count of delay time. Motor deceleration.	Neg_Enable_Delay_Counting-> Neg_Enable_Degree_Monitoring	Motor speed < zero speed
Overtime_Fault	When delay time ends, and the motor direction has not yet reduced to zero speed	trigger STO, and report SDI overtime error.	Pos_Enable_Delay_Counting-> Overtime_Fault	Exceeding the delay time
			Overtime_Fault-> Neg_Enable_Degree_Monitoring	Motor speed < zero speed
Neg_Enable_Degree_Monitoring	The motor direction is below the user-defined zero speed limit, and FS card starts monitoring the motor is run direction. If the angle of rotation exceeds the tolerance, the STO function is activated. Determine function Acknowledge method. If set to automatic, the function will be automatically acknowledged when the request DI is removed.	SDI- status is high. (When remove SDI- function and select automatic acknowledge, SDI- and STO (If trigger STO) status is low.)	Neg_Enable_Degree_Monitoring-> Acknowledge_step2_inactive	Request DI is inactive, select manual acknowledgement
			Neg_Enable_Degree_Monitoring-> Initialize	Request DI is inactive, select automatic acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SDI- and STO status is high.	Acknowledge_step2_inactive-> Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SDI- and STO status is low.	Acknowledge_step3_active-> Pos_Enable_Degree_Monitoring	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active-> Initialize	Acknowledge DI is inactive within 3s

4.10.4.3 SDI-r positive

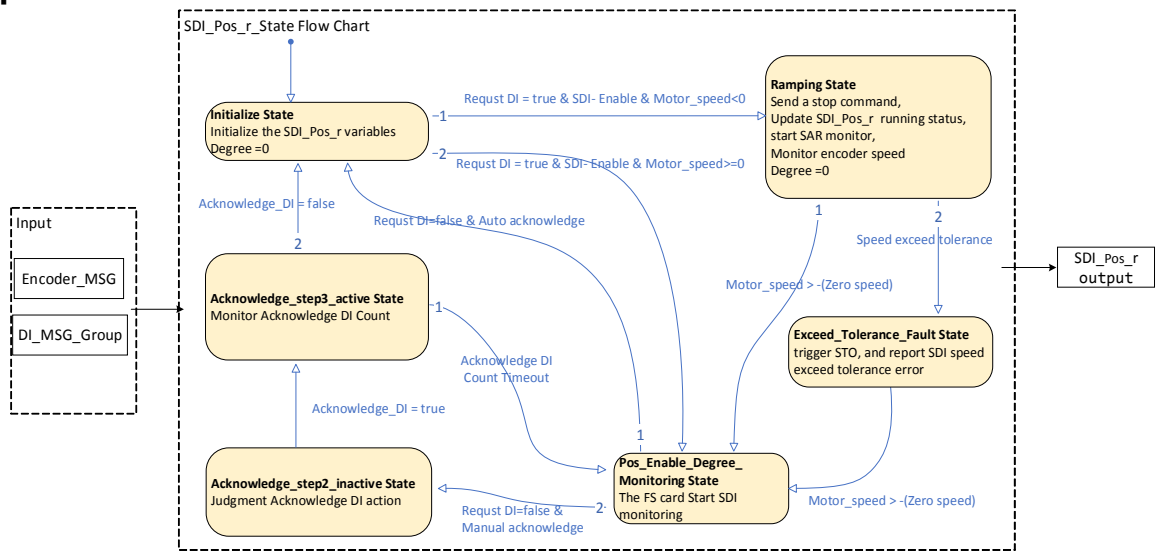


Figure 71: The SDI-r positive status flow chart

4 Safety Functions

4.10 SDI (Safe Direction)

Table 60: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SDI-r function	The function is ready.	Initialize->Ramping	Request DI is active, Enable SDI+, and Motor speed < 0
			Initialize->Pos_Enable_Degree_Monitoring	Request DI is active, Enable SDI+, and Motor speed >= 0
Ramping	when Enable SDI+, the negative direction is set as the forbidden direction. The motor start deceleration.	Motor deceleration. SDI+ and SAR status is high. (If trigger STO, STO status is high.)	Ramping -> Pos_Enable_Degree_Monitoring	Motor speed > -(zero speed)
			Ramping -> Exceed_Tolerance_Fault	Exceeding the deceleration slope
Exceed_Tolerance_Fault	When delay time ends, and the motor direction has not yet reduced to zero speed	trigger STO(STO status is high), and report SDI speed exceed tolerance error.	Exceed_Tolerance_Fault->Pos_Enable_Degree_Monitoring	Motor speed > -(zero speed)
Pos_Enable_Degree_Monitoring	The motor direction is below the user-defined zero speed limit, and FS card starts monitoring the motor is run direction. If the angle of rotation exceeds the tolerance, the STO function is activated. Determine function Acknowledge method. If set to automatic, the function will be automatically acknowledged when the request DI is removed.	SDI+ status is high. (When remove SDI+ function and select automatic acknowledge, SDI+ and STO(If trigger STO) status is low.)	Pos_Enable_Degree_Monitoring->Acknowledge_step2_inactive	Request DI is inactive, select manual acknowledgement
			Pos_Enable_Degree_Monitoring->Initialize	Request DI is inactive, select automatic acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SDI+ and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SDI+ and STO status is low.	Acknowledge_step3_active->Pos_Enable_Degree_Monitoring	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4.10.4.4 SDI-r negative

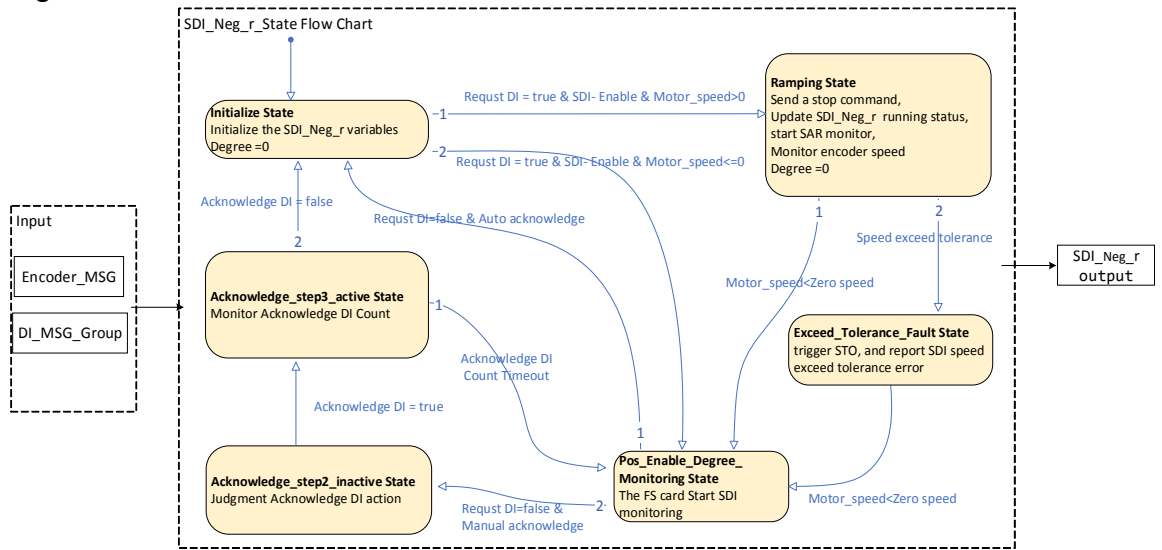


Figure 72: The SDI-r negative status flow chart

Table 61: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SDI-r variables	The function is ready.	Initialize->Ramping	Request DI is active, Enable SDI-, and Motor speed < 0
			Initialize->Neg_Enable_Degree_Monitoring	Request DI is active, Enable SDI-, and Motor speed >= 0
Ramping	when Enable SDI+, the negative direction is set as the forbidden direction. The motor start deceleration.	Motor deceleration. SDI- and SAR status is high. (If trigger STO, STO status is high.)	Neg_Enable_Delay_Counting->Neg_Enable_Degree_Monitoring	Motor speed > -(zero speed)
			Neg_Enable_Delay_Counting->Exceed_Tolerance_Fault	Exceeding the deceleration slope
Exceed_Tolerance_Fault	When delay time ends, and the motor direction has not yet reduced to zero speed	trigger STO(STO status is high), and report SDI speed exceed tolerance error.	Exceed_Tolerance_Fault->Neg_Enable_Degree_Monitoring	Motor speed > -(zero speed)
Neg_Enable_Degree_Monitoring	The motor direction is below the user-defined zero speed limit, and FS card starts monitoring the motor is run direction.If the angle of rotation exceeds the tolerance, the STO function is activated. Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	SDI- status is high. (When remove SDI- function and select automatic acknowledge, SDI- and STO(if trigger STO) status is low.)	Neg_Enable_Degree_Monitoring->Acknowledge_step2_inactive	Request DI is inactive, select manual acknowledgement
			Pos_Enable_Degree_Monitoring->Initialize	Request DI is inactive, select automatic acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SDI- and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SDI- and STO status is low.	Acknowledge_step3_active->Pos_Enable_Degree_Monitoring	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4 Safety Functions

4.10 SDI (Safe Direction)

4.10.5 Response Time

SDI response time is from the safety function range exceeded to the shutdown of PWM buffers.

SDI response time = delay time of Encoder signal circuit + speed sampling and calculation time + 2 * Safety Function execution cycle time + delay time of STO trigger circuit + delay time of PWM buffers ≤ 40 ms

- T1: Delay time of Encoder signal circuit ≤ 5 ms
- T2: Speed sampling and calculation time ≤ 2 ms
- T3: 10 * Safety Function execution cycle time ≤ 10 ms
- T4: Delay time of STO trigger circuit ≤ 5 ms
- T5: Delay time of PWM buffers ≤ 5 ms
- Safety function response: FS card to shutdown of PWM buffers

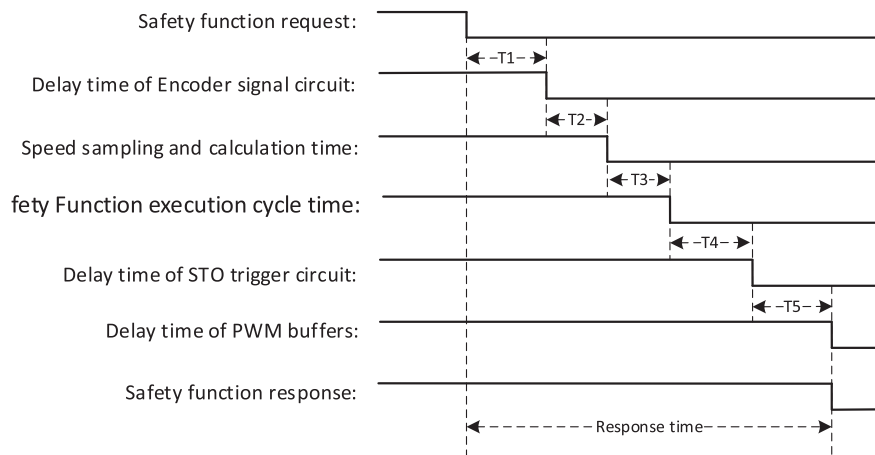


Figure 73: The timing diagram

4.10.6 Assignment of control signal terminals

Assignment of digital inputs to SDI are user dependent and any input DI of FS card can be assigned as a SDI Source.

SDI Source and SDI Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring".

4.10.7 Application

This section gives an application example of SDI function of FS card.

- Safe switch1: Connect DI1 using a button switch as an SDI function request.
- Safe switch2: Set manual acknowledgement, and connect DI3 using a button switch as an SDI function acknowledge.
- Use the lamp to connect DO2 to indicate SDI+ or SDI- status

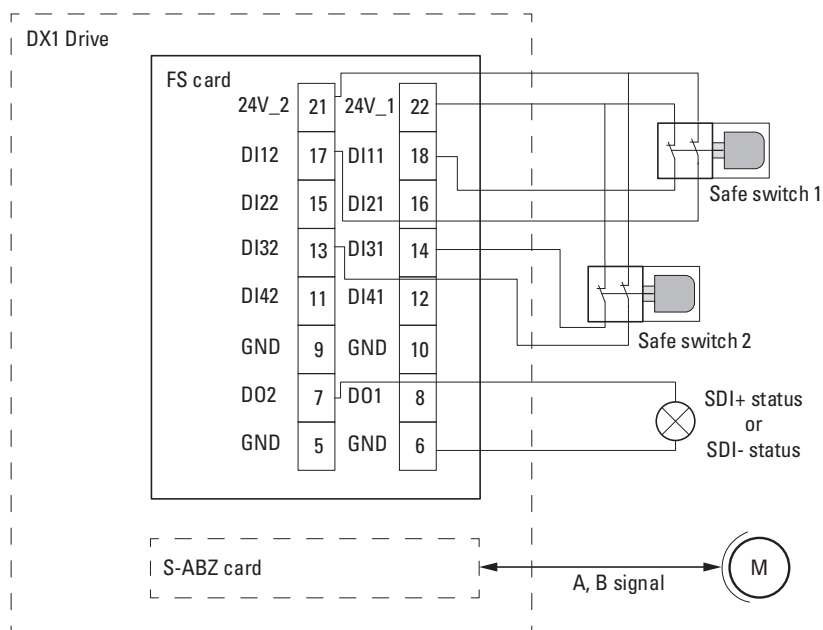


Figure 74: Wiring for SDI application

For the implementation of this application, refer to the following sections
 → Section 4.10.8, "Configuration" and → Section 4.10.9, "Validation of the SDI function".

For wiring the DX1 functional safety system, refer to → Section 2.5, "Electrical Setup".

4 Safety Functions

4.10 SDI (Safe Direction)

4.10.8 Configuration

To configure the SDI function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.10.8.1 How to configure SDI-t

Table 62: Example of an SDI-t positive(SDI+) set-up

Step	PanelCode	Parameters	Set value	Description
1	P8.1	SDI+ Enable	Enable	Set enable SDI Function
2	P8.3	SDI Mode	SDI time	Set SDI with time monitor
3	P8.4	SDI+ Source	DI11 & DI12	Set the DI source(DI1) to activate the SDI function
4	P8.6	SDI-t delay	30 s	Set the delay for starting SDI monitoring
5	P8.7	SDI Limit degree	3600 deg	Set the maximum allowed movement of the motor axle
6	P8.8	SDI n=0 Limit	5 rpm	Set the encoder Zero speed
7	P8.9	SDI Acknowledgement Mode	DI31 & DI32	Set manual(DI3) acknowledgement
8	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
9	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
10	P1.4	DO2 Mode	SDI+ Status	Set the DO output safety function status
11	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
12	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate

Table 63: Example of an SDI-t negative(SDI-) set-up

Step	PanelCode	Parameters	Set value	Description
1	P8.2	SDI- Enable	Enable	Set enable SDI Function
2	P8.3	SDI Mode	SDI time	Set SDI with time monitor
3	P8.5	SDI- Source	DI11 & DI12	Set the DI source(DI1) to activate the SDI function
4	P8.6	SDI-t delay	30 s	Set the delay for starting SDI monitoring
5	P8.7	SDI Limit degree	3600 deg	Set the maximum allowed movement of the motor axle
6	P8.8	SDI n=0 Limit	5 rpm	Set the encoder Zero speed
7	P8.9	SDI Acknowledgement Mode	DI31 & DI32	Set manual(DI3) acknowledgement
8	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
9	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
10	P1.4	DO2 Mode	SDI- Status	Set the DO output safety function status
11	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
12	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate

4.10.8.2 How to configure SDI-r

Table 64: Example of an SDI-r positive(SDI+) set-up

Step	PanelCode	Parameters	Set value	Description
1	P8.1	SDI+ Enable	Enable	Set enable SDI Function
2	P8.3	SDI Mode	SDI ramp	Set SDI with time monitor
3	P8.4	SDI+ Source	DI11_DI21	Set the DI source(DI1) to activate the SDI function
4	P8.7	SDI Limit degree	3600 deg	Set the maximum allowed movement of the motor axle
5	P8.8	SDI n=0 Limit	5 rpm	Set the encoder Zero speed
6	P8.9	SDI Acknowledgement Mode	DI13_DI23	Set manual(DI3) acknowledgement
7	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
8	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
9	P1.4	DO2 Mode	SDI+ Status	Set the DO output safety function status
10	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
11	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
12	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

Table 65: Example of an SDI negative(SDI-) set-up.

Step	PanelCode	Parameters	Set value	Description
1	P8.2	SDI- Enable	Enable	Set enable SDI Function
2	P8.3	SDI Mode	SDI ramp	Set SDI with time monitor
3	P8.5	SDI- Source	DI11_DI21	Set the DI source(DI1) to activate the SDI function
4	P8.7	SDI Limit degree	3600 deg	Set the maximum allowed movement of the motor axle
5	P8.8	SDI n=0 Limit	5 rpm	Set the encoder Zero speed
6	P8.9	SDI Acknowledgement Mode	DI13_DI23	Set manual(DI3) acknowledgement
7	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
8	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
9	P1.4	DO2 Mode	SDI- Status	Set the DO output safety function status
10	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
11	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
12	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

4.10.9 Validation of the SDI function

Refer to → Section 5.5, “Validation of SDI”.

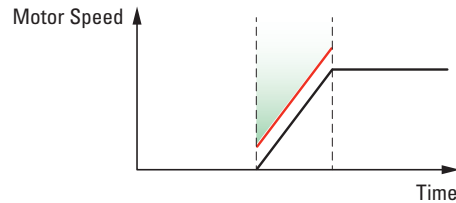
4 Safety Functions

4.11 SLA (Safe Limit Acceleration)

4.11 SLA (Safe Limit Acceleration)

4.11.1 Function description

The SLA (Safety limit acceleration) function prevents the motor from exceeding the specified acceleration or deceleration limit. FS card monitors motor acceleration/ deceleration and activates STO if the motor acceleration exceeds the specified limit.

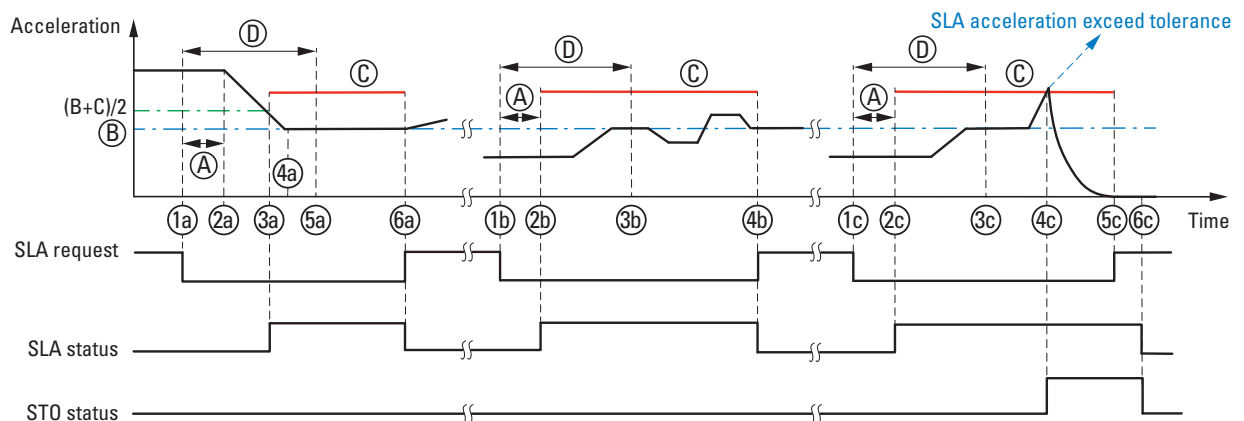


4.11.2 Safety parameters

Refer to → section , “SLA Parameters (P9)”, page 208

4.11.3 Timing diagram

→ Note: In this case, Enable SLA+, FS card monitors motor acceleration.



- (A) DI filtering time: 20 ms
- (B) SLA+ limit: SLA limit positive
- (C) SLA+ trip limit: SLA trip limit positive
- (D) SLA t-delay: SLA time delay

SLA request: Request to trigger SLA function.

SLA status: Indicates whether the SLA function is working.

STO status: Indicates whether the STO function is triggered.

Figure 75: SLA function timing diagram

Step	Description
1a	Receives the SLA request from FS card DI. The motor acceleration is above the SLA+ limit (B). FS card Start a counter for delay time (C).
2a	After time(A) has elapsed. The drive begins to reduce the acceleration until the acceleration reaches the SLA+ limit (B).
3a	When the motor acceleration is halfway between the SLA+ limit (B) and the SLA+ trip limit (C) ((B+C)/2), FS card starts the SLA monitoring.
4a	Motor acceleration reaches SLA+ limit (B).
5a	End of delay time (D). FS card starts the SLA monitoring here at the latest.
3a-6a	The drive limits the acceleration of the motor, and the acceleration does not exceed the SLA+ trip limit (C).
6a	The SLA request is removed. The SLA function is acknowledged (automatic acknowledgement) and stops the SLA monitoring. The SLA status indication goes off.
1b	Receives the SLA request from FS card DI. The motor acceleration of the motor is lower than the SLA+ limit (B).
2b	After time (A) has elapsed. FS card starts SLA monitoring.
3b	End of delay time (D). FS card starts the SLA monitoring here at the latest.
2b-4b	The drive limits the acceleration of the motor, and the acceleration does not exceed the SLA+ trip limit (A).
4b	The SLA request is removed. The SLA function monitoring is off. The SLA function is acknowledged (automatic acknowledgement) and the SLA indication goes off.
1c	Receives the SLA request from FS card DI. The motor acceleration of the motor is lower than the SLA+ limit (B).
2c	After time (A) has elapsed. FS card starts SLA monitoring.
3c	End of delay time (D). FS card starts the SLA monitoring here at the latest.
4c	The acceleration exceeds the SLA+ trip limit (A), and FS card activates the STO function. The motor coasts to a stop. Note: User can set the execute order between STO and SBC (not shown in the figure). • If the STO SBC delay is positive, STO before SBC. • If the STO SBC delay is zero, STO and SBC at the same time.
5c	The SLA request is removed.
6c	The SLA & STO function are acknowledged and FS card stops the SLA monitoring. The SLA & STO status indication goes off.

Acceleration calculation:

Acceleration is calculated by encoder counts and expressed in encoder counts per second squared. FS card calculates acceleration every 1 ms.

If speed averaging is disabled, the acceleration is calculated directly from raw speed measured in that 1 ms interval.

When speed averaging is used, acceleration is calculated from filtered speed over time window (Setting via parameter "SLA t-window ").

$$acc = \frac{v_{t2} - v_{t1}}{dt}$$

dt : acceleration time window ($dt=t2-t1$)

$t2$: is current sample time

$t1$: is past sample time

$v_{t n}$: is averaging speed sample at time window $t n$

4 Safety Functions

4.11 SLA (Safe Limit Acceleration)

4.11.4 State diagram

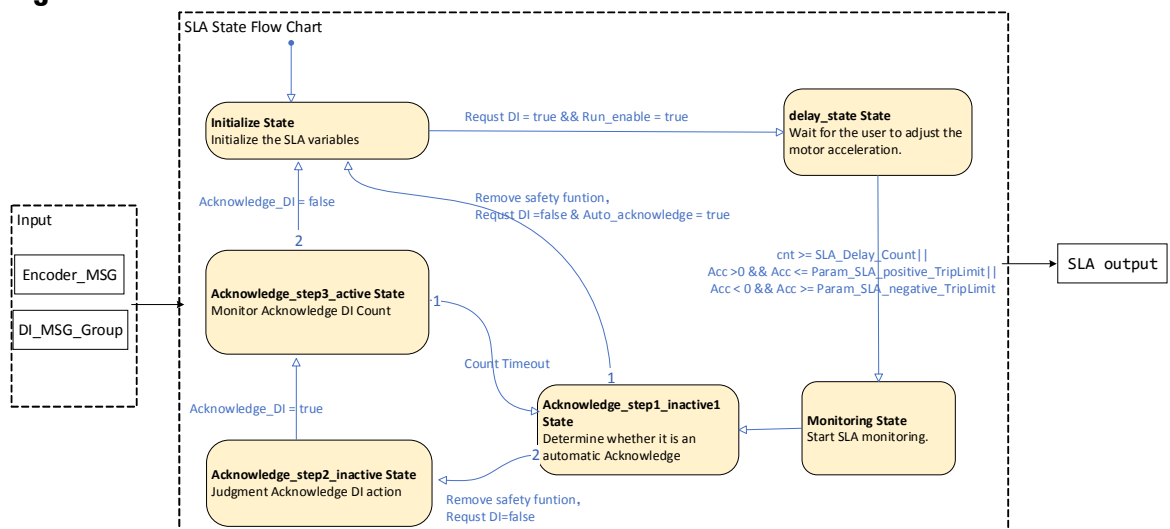


Figure 76: The SLA status flow chart

Table 66: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SLA variables, Calculate acceleration middle limit	The function is ready.	Initialize->Delay	Request DI is active & Motor acceleration > acceleration middle limit
			Initialize->Monitoring	Request DI is active & Motor acceleration \leq acceleration middle limit
Delay	Delay the start of SLA monitoring.	Count of delay time.	Delay->Monitoring	Cumulative delay time count
Monitoring	Start SLA monitoring. Monitor motor acceleration and activate the STO if the motor acceleration exceeds the specified limit.	SLA status is high. (If trigger STO, STO status is high.)	Monitoring->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SLA and STO status is low.	Acknowledge_step1_inactive1->Initialize	select automatic acknowledgment
			Acknowledge_step1_inactive1->Acknowledge_step2_inactive	select manual acknowledgment
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SLA and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SLA and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1	Acknowledge DI is inactive more than 3s
			Acknowledge_step3_active->Initialize	Acknowledge DI is inactive within 3s

4.11.5 Response time

SLA response time is from the safety function range exceeded to the shut-down of PWM buffers.

SLA response time = delay time of Encoder signal circuit + speed sampling and calculation time + 10* Safety Function execution cycle time + delay time of STO trigger circuit + delay time of PWM buffers + delay time of user setting $\leq 40\text{ms}$ + delay time of user setting

- T1: Delay time of Encoder signal circuit $\leq 5\text{ ms}$
- T2: Speed sampling and calculation time $\leq 2\text{ ms}$
- T3: 10* Safety Function execution cycle time $\leq 10\text{ ms}$
- T4: Delay time of STO trigger circuit $\leq 5\text{ ms}$
- T5: Delay time of PWM buffers $\leq 5\text{ ms}$
- T6: Delay time of user setting = User setting parameter
- Safety function response: FS card to shutdown of PWM buffers

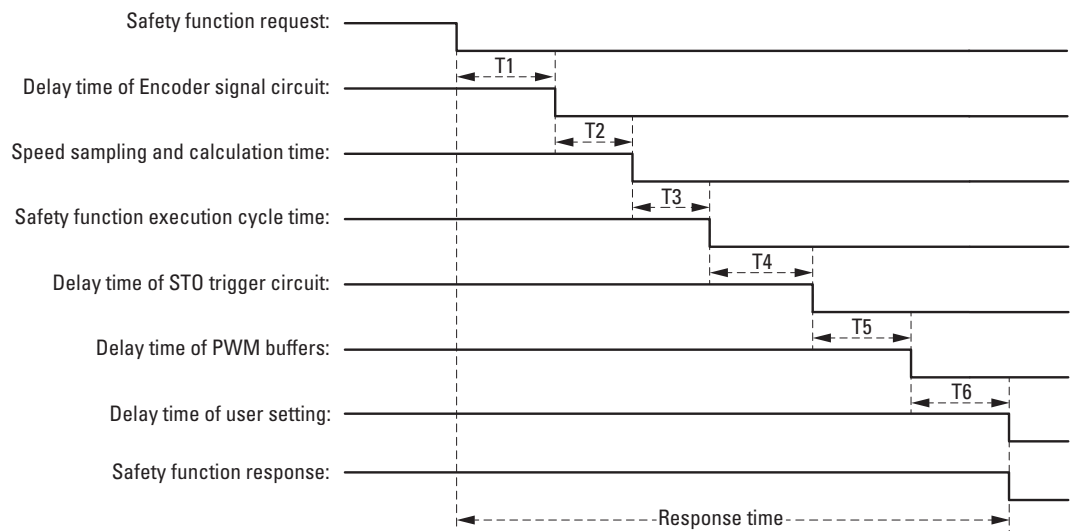


Figure 77: Timing diagram

4.11.6 Assignment of control signal terminals

Assignment of digital inputs to SLA are user dependent and any input DI of FS card can be assigned as a SLA Source.

SLA Source and SLA Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring".

4 Safety Functions

4.11 SLA (Safe Limit Acceleration)

4.11.7 Application

This section gives an application example of SLA function of FS card.

- Safe switch1: Connect DI1 using a button switch as an SLA function request.
- Safe switch2: Set manual acknowledgement, and connect DI4 using a button switch as an SLA function acknowledge.
- Use the lamp to connect DO2 to indicate SLA status.

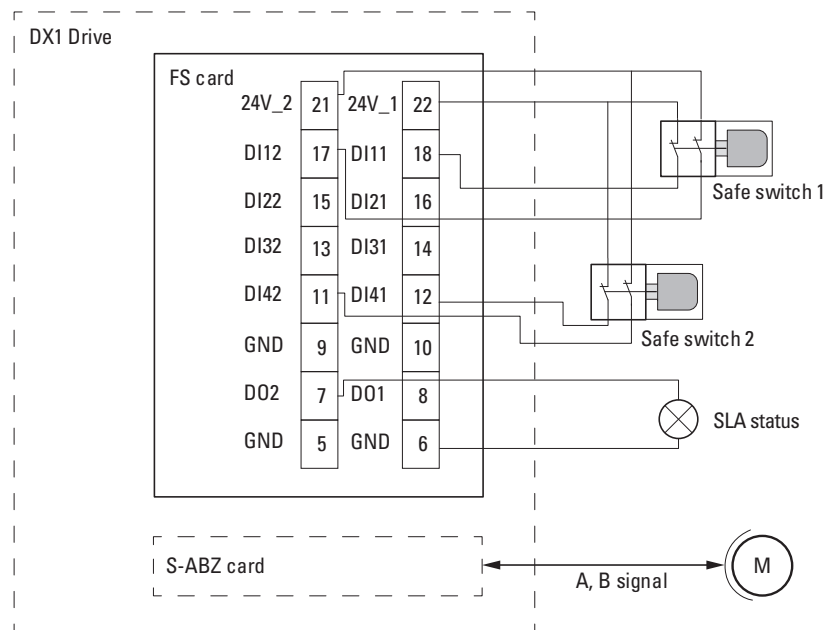


Figure 78: Wiring for SLA application

For the implementation of this application, refer to the following sections
→ Section 4.11.8, "Configuration" and → Section 4.11.9, "Validation of the SLA function".

For wiring the DX1 functional safety system, refer to → Section 2.5, "Electrical Setup".

4.11.8 Configuration

To configure the SLA function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.11.8.1 How to configure SLA

Table 67: Example of an SLA set-up:

Step	PanelCode	Parameters	Set value	Description
1	P9.1	SLA Enable	Enable	Set enable SLA Function
2	P9.2	SLA Source	DI11 & DI12	Set the DI source(DI1) to activate the SLA function
3	P9.3	SLA-t delay	30 s	Set a safety delay time to activate SLA monitoring
4	P9.4	SLA+ trip limit	30 rpm/s	Set the SLA positive safe acceleration limit that trips the drive
5	P9.5	SLA+ limit	5 rpm/s	Set the SLA positive safe acceleration limit for the drive
6	P9.6	SLA- trip limit	-30 rpm/s	Set the SLA negative safe deceleration limit that trips the drive
7	P9.7	SLA- limit	-5 rpm/s	Set the SLA negative safe deceleration limit for the drive
8	P9.8	SLA delta-t	2000 ms	Set the time to calculate the change of acceleration
9	P9.9	SLA Acknowledgement Mode	DI41 & DI42	Set manual(DI4) acknowledgement
10	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
11	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
12	P1.4	DO2 Mode	SLA Status	Set the DO output safety function status

4.11.9 Validation of the SLA function

Refer to → Section 5.10, “Validation of SLA”

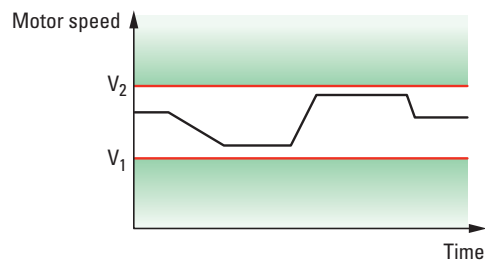
4 Safety Functions

4.12 SSR (Safe Speed Range)

4.12 SSR (Safe Speed Range)

4.12.1 Function description

The SSR (Safe Speed Range) function keeps the motor speed within specified limits. FS card monitors motor speed range and activates STO if the motor speed exceeds the specified limits.



4.12.2 Safety parameters

Refer to → section , "SSR Parameters (P10)" , page 209.

4.12.3 Timing diagram

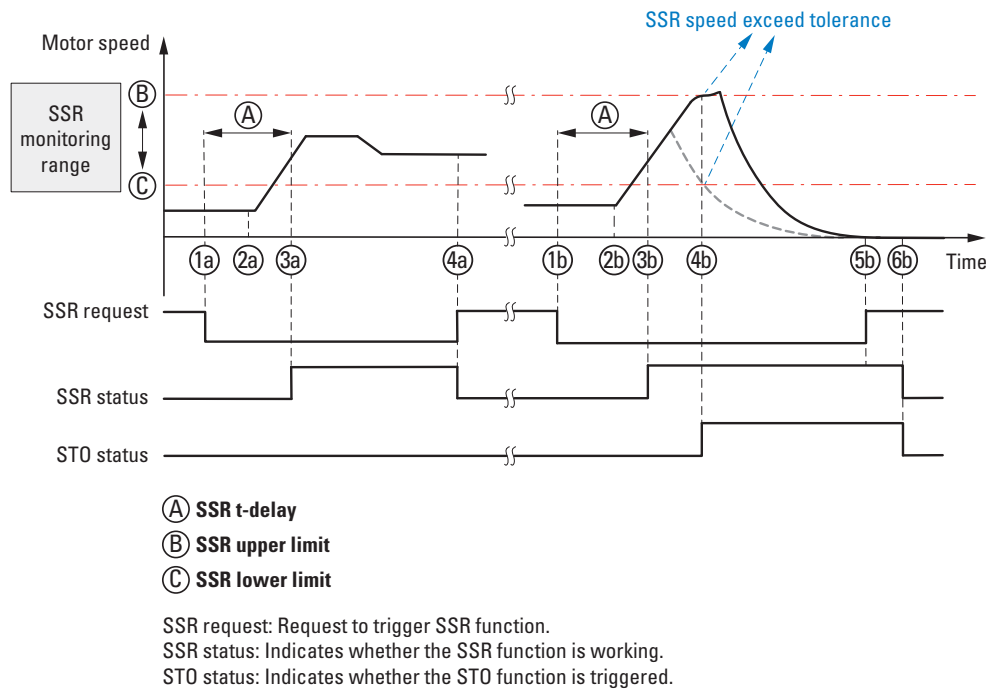


Figure 79: SSR function

Step	Description
1a	Receives the SSR request from FS card DI. Start a counter for delay time (A).
2a	The speed is not within the monitoring range. User adjusts speed.
3a	End of delay time (A). The user sets the speed within the monitoring range here at the latest. FS card start SSR Monitoring.
3a-4a	The motor speed is within the defined SSR Monitoring Range and has not exceeded the SSR speed limit. The status is normal.
4a	The SSR request is removed. The SSR function is acknowledged (automatic acknowledgement) and stops the SSR monitoring. The SSR status indication goes off.
1b	Receives the SSR request from FS card DI. Start a counter for delay time (A).
2b	The speed is not within the monitoring range. User adjusts speed.
3b	End of delay time (A). The user sets the speed within the monitoring range here at the latest. FS card start SSR Monitoring.
4b	The motor speed exceeds the SSR Monitoring Range (Exceed the upper limit (B) or lower limit (C)), and FS card activates the STO function. The motor coasts to a stop. Note: User can set the execute order between STO and SBC (not shown in the figure). <ul style="list-style-type: none"> • If the STO SBC delay is positive, STO before SBC. • If the STO SBC delay is zero, STO and SBC at the same time.
5b	The SSR request is removed.
6b	The SSR & STO function are acknowledged (manual acknowledgement) and FS card stops the SSR monitoring. The SSR & STO status indication goes off.

4 Safety Functions

4.12 SSR (Safe Speed Range)

4.12.4 State diagram

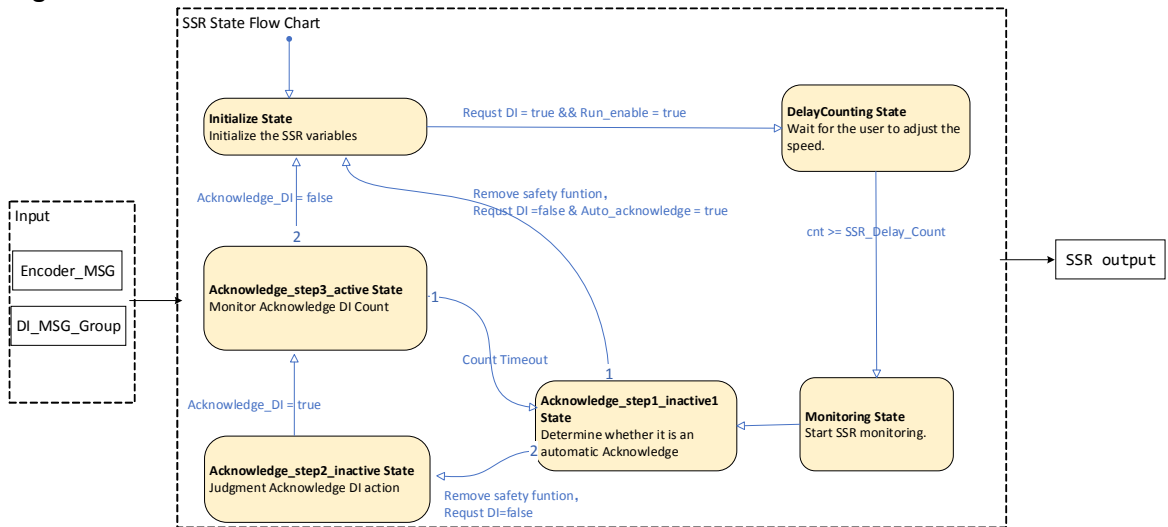


Figure 80: The SSR status flow chart

Table 68: The transition among states is as following:

State name	State description	Output	State Transition	Transition condition
Initialize	Initialize the SSR variables	The function is ready	Initialize->DelayCounting	Request DI is active
DelayCounting	Delay the start of SSR monitoring.	Count of delay time.	DelayCounting->Monitoring	Cumulative arrival time
Monitoring	Start SSR monitoring. As soon as the monitoring speed is out of range, the STO function is triggered immediately. Otherwise, the speed will continue to be monitored.	SSR status is high. (If trigger STO, STO status is high.)	Monitoring->Acknowledge_step1_inactive1	Request DI is inactive
Acknowledge_step1_inactive1	Determine function Acknowledge method.If set to automatic, the function will be automatically acknowledged when the request DI is removed.	If select automatic acknowledge, SSR and STO status is low.	Acknowledge_step1_inactive1->Initialize Acknowledge_step1_inactive1->Acknowledge_step2_inactive	select automatic acknowledgement select manual acknowledgement
Acknowledge_step2_inactive	Judgment Acknowledge DI action	Time count. SSR and STO status is high.	Acknowledge_step2_inactive->Acknowledge_step3_active	Acknowledge DI is active
Acknowledge_step3_active	Monitor Acknowledge DI Count	SSR and STO status is low.	Acknowledge_step3_active->Acknowledge_step1_inactive1 Acknowledge_step3_active->Initialize	Acknowledge DI is inactive more than 3s Acknowledge DI is inactive within 3s

4.12.5 Response time

SSR response time is from the safety function range exceeded to the shut-down of PWM buffers.

SSR response time = delay time of Encoder signal circuit + speed sampling and calculation time + 10 * Safety Function execution cycle time + delay time of STO trigger circuit + delay time of PWM buffers ≤ 40 ms

- T1: Delay time of Encoder signal circuit ≤ 5 ms
- T2: Speed sampling and calculation time ≤ 2 ms
- T3: 10 * Safety Function execution cycle time ≤ 10 ms
- T4: Delay time of STO trigger circuit ≤ 5 ms
- T5: Delay time of PWM buffers ≤ 5 ms
- Safety function response: FS card to shutdown of PWM buffer

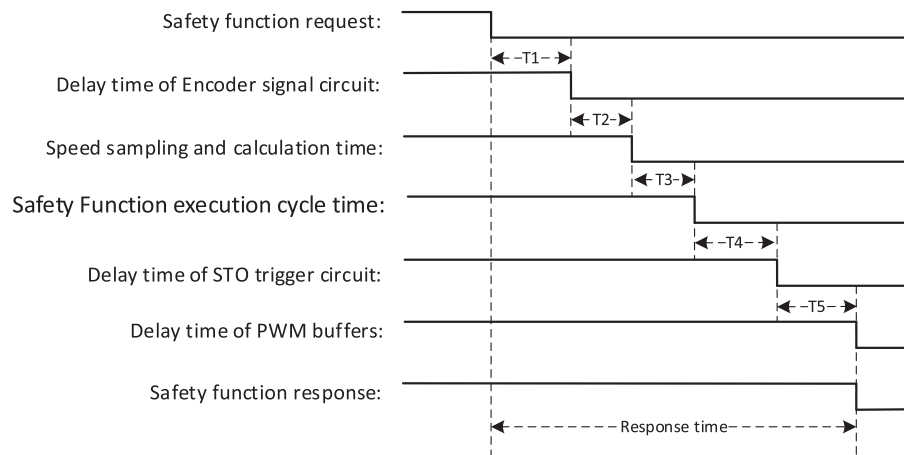


Figure 81: Timing diagram

4.12.6 Assignment of control signal terminals

Assignment of digital inputs to SSR are user dependent and any input DI of FS card can be assigned as a SSR Source.

SSR Source and SSR Manual Acknowledgement Mode must be assigned to FS card DI.

Connection usage for digital inputs. Refer to → Section 2.8.3, "FS card user IO wiring".

4 Safety Functions

4.12 SSR (Safe Speed Range)

4.12.7 Application

This section gives an application example of SLA function of FS card.

- Safe switch1: Connect DI1 using a button switch as an SSR function request.
- Safe switch2: Set manual acknowledgement, and connect DI4 using a button switch as an SSR function acknowledge.
- Use the lamp to connect DO1 to indicate SSR status.

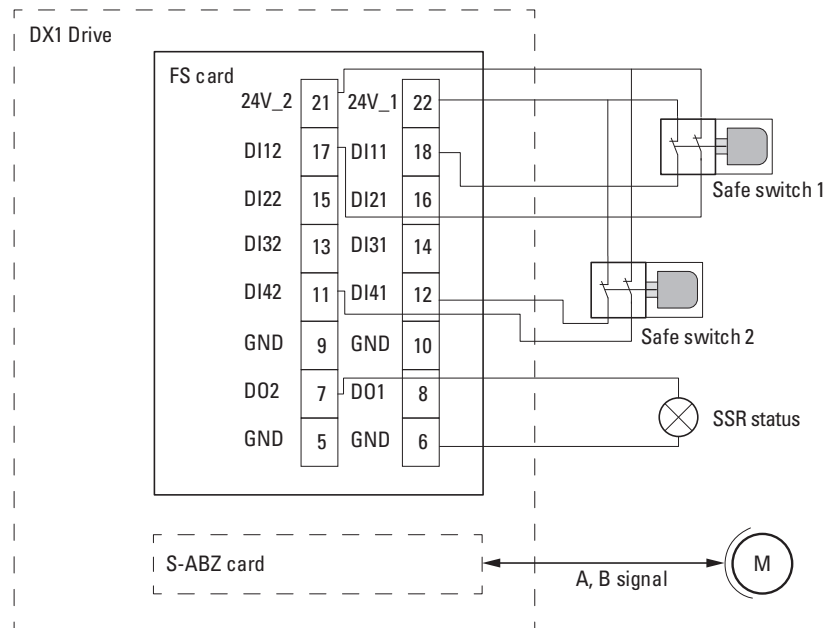


Figure 82: Wiring for SSR function

For the implementation of this application, refer to the following sections
 → Section 4.12.8, “Configuration” and → Section 4.12.9, “Validation of the SSR function”.

For wiring the DX1 functional safety system, refer to → Section 2.5, “Electrical Setup”.

4.12.8 Configuration

To configure the SSR function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.12.8.1 How to configure SSR

Table 69: Example of an SSR set-up:

Step	PanelCode	Parameters	Set value	Description
1	P10.1	SSR Enable	Enable	Set enable SSR Function
2	P10.2	SSR Source	DI11 & DI12	Set the DI source(DI1) to activate the SSR function
3	P10.3	SSR upper limit	1000 rpm	Set the motor speed upper limit for the SSR function. Requirement: SSR upper limit > SSR lower limit.
4	P10.4	SSR lower limit	0 rpm	Set the motor speed lower limit for the SSR function.
5	P10.5	SSR t-delay	20 s	Set a safety delay time to activate SSR monitoring
6	P10.6	SSR Acknowledgement Mode	DI41 & DI42	Set manual(DI4) acknowledgement
10	P1.1	Encoder Pulse Count	1024 ppr	Set the number of pulses for encoder
11	P1.2	Max Speed	1500 rpm	Set the maximum speed of the encoder
12	P1.3	DO1 Mode	SSR Status	Set the DO output safety function status

4.12.9 Validation of the SSR function

Refer to → Section 5.11, “Validation of SSR”.

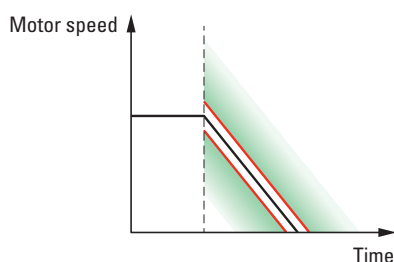
4 Safety Functions

4.13 SAR (Safe Acceleration Range)

4.13 SAR (Safe Acceleration Range)

4.13.1 Function description

The SAR(Safe Acceleration Range) function is used to define and/or monitor deceleration ramps in the safety function. This function can decelerate the motor within the specified range. If the motor decelerates exceeds the specified limit, FS card will activate STO function.



- SAR is used only for ramp deceleration with Safety functions SS1, SS2, SDI and SLS. When these functions are enabled, the ramp defined by the SAR parameter is automatically obtained for deceleration. The function does ramp monitoring from each safety functions deceleration request, decelerating the scaling speed to zero according to the target time(B). If the speed exceeds the deceleration tolerance (P11.3), the STO function is triggered.

Table 70: Interactions of Safety functions with SAR

Function	Effect of SAR
SS1-t	Define deceleration ramp
SS1-r	Define and monitor deceleration ramp
SS2-t	Define deceleration ramp
SS2-r	Define and monitor deceleration ramp
SLS-t	Define deceleration ramp
SLS-r	Define and monitor deceleration ramp
SDI-t	Define deceleration ramp
SDI-r	Define and monitor deceleration ramp

If ramp deceleration is activated due to SAR activation by SS1, SS2, SDI or SLS, the drive will preferentially use the deceleration time defined by SAR, regardless of the motor deceleration time.

Deceleration time of the drive is not relevant if SAR is active due to activation of SS1, SS2, SDI, or SLS. During all deceleration through safety function, FS card has priority and activate the SAR deceleration.

The gradient of ramp from SAR deceleration is set through the Division of "Speed scaling" and "Ramp time to zero".

The Deceleration tolerance is the range of the ramp, if the deceleration exceeds the tolerance these borders, SAR monitoring will stop and STO will be activated

So for example, if the drive must decelerate with the factor 150 rpm/s, set "Speed scaling" to 1500 rpm and the "Ramp time to zero" to 10 s.

4.13.2 Safety parameters

Refer to → section , "SAR Parameters (P11)", page 210

4.13.3 Timing diagram

The ramp monitoring is configured as described below.

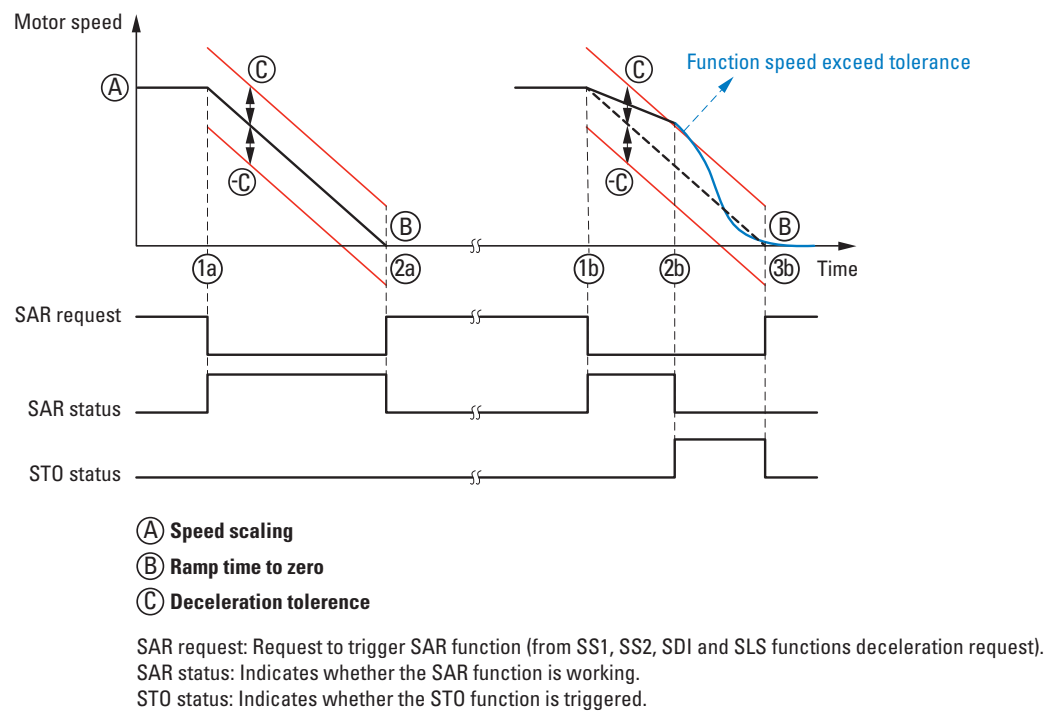


Figure 83: SAR function

Step	Description
1a	Receives the SAR request from each SS1, SS2, SDI and SLS functions deceleration request. The drive starts to ramp down the motor speed to zero speed. SAR parameter(A/B) defines the deceleration ramp. FS card start SAR monitoring.
2a	The motor speed is reduced to zero speed. FS card stop SAR monitoring.
1b	Receives the SAR request from each SS1, SS2, SDI or SLS functions deceleration request. The drive starts to ramp down the motor speed to zero speed. SAR parameter(A/B) defines the deceleration ramp. FS card start SAR monitoring.
2b	The motor speed deceleration rate exceeds a tolerance threshold. FS card stop SAR monitoring and activates the STO function. Note: Acknowledgment is not required at the end of SAR. Because after the SAR is executed, other safety functions will be monitored, so Acknowledgment is performed in other safety functions. For example, refer to the working process of SS1 → Section 4.4.3, "Timing Diagram".
3b	The request(from SS1, SS2, SDI and SLS functions deceleration request) is removed. The STO function is acknowledged (automatic acknowledgment) and the STO indication goes off.

4 Safety Functions

4.13 SAR (Safe Acceleration Range)

4.13.4 Configuration

To configure the SAR function, set FS card parameters below to appropriate values using the PowerXL™ Safety Tool.

4.13.4.1 How to configure SAR

Table 71: Example of an SAR set-up

Step	PanelCode	Parameters	Set value	Description
1	P11.1	Speed scaling	1500 rpm	Set SAR reference speed value
2	P11.2	Ramp time to zero	20 s	Set the target time for the SAR ramp decelerate
3	P11.3	Deceleration tolerance	30 rpm	Set SAR allowed deceleration tolerance

- SAR is required to work in conjunction with deceleration ramp for SS1, SLS, SS2 and SDI. Refer to following sections for more info.
- SS1 → Section 4.4.8, "Configuration"
 - SLS → Section 4.6.8, "Configuration"
 - SS2 → Section 4.8.8, "Configuration"
 - SDI → Section 4.10.8, "Configuration"

4.13.5 Validation of the SAR function

Refer to → Section 5.7, "Validation of SAR"

5 Verification and Validation

After the safety system is installed and configured correctly or any changed, the implemented safety function must be verified and validated according to the validation procedure in the corresponding chapter of each safety function.

The validation testing is to verify that the used safety functions operate as required in the safety system.



WARNING

A system can only be considered safe if all safety functions necessary for the safe use of applications based on risk assessment have been verified. Before an application can be put into use, every safety function must be rigorously verified.

The validation procedure of safety functions can be found in corresponding chapters:

Safety Function	Validation test
STO	→ Chapter 5 "Verification and Validation"
SS1	
SBC	
SLS	
SOS	
SS2	
SSM	
SDI	
SLA	
SSR	
SAR	

The checklist below can be printed out to validate safety functions

NOTICE

The checklist in Appendix A can be printed out to record the validation result.

5 Verification and Validation

5.1 Validation of STO

5.1 Validation of STO

For detailed STO validation introduction, please refer to Appendix E - STO function for Chapter "Commission and Validation" of PowerXL™ DX1 Series VFD Installation manual(MN040068EN).

5.2 Validation of SS1

1. Check the wiring for SS1 function.
2. Follow steps below if SS1-t mode is used:
 - SS1-t Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.4.8.1 How to configure SS1-t".
 2. Set a proper time of P2.4 t-delay STO@SS1 to make sure that the motor speed is lower than P2.5 SS1 n=0 Limit when SS1 function is activated and the time of P2.4 t-delay STO@SS1 elapsed.
 3. Start the drive to run the motor at the desired speed.,
 4. Activate the SS1 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P2.5 SS1 n=0 Limit, the drive shuts down the output and reports a Safe Torque Off fault.
 6. Deactivate the SS1 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P2.5 SS1 n=0 Limit (It is necessary to wait until the motor speed is less than P2.5 SS1 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 - SS1-t Validation - Abnormal Operation:
 1. Set the related parameters according to → Section "4.4.8.1 How to configure SS1-t".
 2. Set a proper time of P2.4 t-delay STO@SS1 to make sure that the motor speed is still higher than P2.5 SS1 n=0 Limit when SS1 function is activated and the time of P2.4 t-delay STO@SS1 elapsed.
 3. Start the drive to run the motor at the desired speed again.
 4. Activate the SS1 function by turning off the safe switch which is connected to FS card.
 5. Wait the time of P2.4 t-delay STO@SS1, Drive shuts down the output and reports a SS1 Overtime warning and a Safe Torque Off fault.
 6. Deactivate the SS1 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P2.5 SS1 n=0 Limit(It is necessary to wait until the motor speed is less than P2.5 SS1 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed again.
 10. Stop the drive and the motor will stop running as required.

3. Follow steps below if SS1-r mode is used:
 - SS1-r Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.4.8.2 How to configure SS1-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed won't exceed the tolerance in P11.3 Deceleration tolerance when SS1 function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS1 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P2.5 SS1 n=0 Limit, the drive shuts down the output and reports a Safe Torque Off fault.
 6. Deactivate the SS1 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P2.5 SS1 n=0 Limit(It is necessary to wait until the motor speed is less than P2.5 SS1 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 - SS1-r Validation- Abnormal Operation:
 1. Set the related parameters according to → Section "4.4.8.2 How to configure SS1-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed must exceed the tolerance in P11.3 Deceleration tolerance when SS1 function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS1 function by turning off the safe switch which is connected to FS card.
 5. During deceleration, Drive shuts down the output and reports a SS1 Speed exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SS1 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P2.5 SS1 n=0 Limit(It is necessary to wait until the motor speed is less than P2.5 SS1 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed again.
 10. Stop the drive and the motor will stop running as required.

5 Verification and Validation

5.3 Validation of SS2

5.3 Validation of SS2

1. Check the wiring for SS2 function.
2. Follow steps below if SS2-t mode is used:
 - SS2 Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.8.8.1 How to configure SS2-t".
 2. Set a proper time of P6.4 t-delay STO@SS2 to make sure that the motor speed is lower than P6.5 SS2 n=0 Limit when SS2 function is activated and the time of P6.4 t-delay STO@SS2 elapsed.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS2 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P6.5 SS2 n=0 Limit, the drive continues decelerating to 0Hz.
 6. Wait 1 or 2 minutes, the motor is at a standstill.
 7. Deactivate the SS2 function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P6.5 SS2 n=0 Limit (It is necessary to wait until the motor speed is less than P6.5 SS2 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 9. Give a stop command, then the motor stops running.
 - SS2 Validation - Abnormal Operation 1:
 1. Set the related parameters according to → Section "4.8.8.1 How to configure SS2-t".
 2. Set a proper time of P6.4 t-delay STO@SS2 to make sure that the motor speed is still higher than P6.5 SS2 n=0 Limit when SS2 function is activated and the time of P6.4 t-delay STO@SS2 elapsed.
 3. Start the drive to run the motor at the desired speed again.
 4. Activate the SS2 function by turning off the safe switch which is connected to FS card.
 5. Wait the time of P6.4 t-delay STO@SS2, the drive shuts down the output and reports a SS2 Overtime warning and a Safe Torque Off fault.
 6. Deactivate the SS2 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P6.5 SS2 n=0 Limit. No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed again.
 10. Stop the drive and the motor will stop running as required.

- SS2 Validation - Abnormal Operation 2:
 1. Set the related parameters according to → Section "4.8.8.1 How to configure SS2-t".
 2. Set a proper time of P6.4 t-delay STO@SS2 to make sure that the motor speed is lower than P6.5 SS2 n=0 Limit when SS2 function is activated and the time of P6.4 t-delay STO@SS2 elapsed.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS2 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P6.5 SS2 n=0 Limit, the drive continues decelerating to 0Hz.
 6. Try to run the motor at the minimum speed allowed.
 7. Wait until the position tolerance reaches P5.3 SOS n=0-Hysteresis, the drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault.
 8. Deactivate the SS2 function by turning on the safe switch.
 9. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P6.5 SS2 n=0 Limit(It is necessary to wait until the motor speed is less than P6.5 SS2 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 10. Try to reset all faults.
 11. Start the drive to run the motor at the desired speed again.
 12. Stop the drive and the motor will stop running as required.
- 3. Follow steps below if SS2-r mode is used:
 - SS2-r Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.8.8.2 How to configure SS2-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed won't exceed the tolerance in P11.3 Deceleration tolerance when SS2 function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS2 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P6.5 SS2 n=0 Limit, the drive continues decelerating to 0Hz.
 6. Wait 1 or 2 minutes, the motor is at a standstill.
 7. Deactivate the SS2 function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P6.5 SS2 n=0 Limit(It is necessary to wait until the motor speed is less than P6.5 SS2 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 9. Give a stop command and make sure that the drive is stopped.

5 Verification and Validation

5.3 Validation of SS2

- SS2-r Validation - Abnormal Operation:
 1. Set the related parameters according to → Section "4.8.8.2 How to configure SS2-r".
 - 2: Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed must exceed the tolerance in P11.3 Deceleration tolerance when SS2 function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS2 function by turning off the safe switch which is connected to FS card.
 5. During deceleration, Drive shuts down the output and reports a SS2 Speed exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SS2 function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P6.5 SS2 n=0 Limit(It is necessary to wait until the motor speed is less than P6.5 SS2 n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed again.
 10. Stop the drive and the motor will stop running as required

5.4 Validation of SLS

1. Check the wiring for SLS function.
2. Follow steps below if SLS-t mode is used:
 - SLS-t Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.6.8.1 How to configure SLS-t".
 2. Set a proper time of P4.3 SLS-t delay to make sure that the motor speed is lower than P4.5 SLS trip limit when SLS function is activated and the time of P4.3 SLS-t delay elapsed.
 3. Start the drive to run the motor at the desired speed which is higher than P4.5 SLS trip limit.
 4. Activate the SLS function by turning off the safe switch which is connected to FS card.
 5. The motor speed decelerates to the speed of P4.6 SLS limit.
 6. Deactivate the SLS function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. The motor accelerates to the desired speed following the Speed Reference.
 9. Give a stop command and the motor will stop running.
 - SLS-t Validation - Abnormal Operation 1:
 1. Set the related parameters according to → Section "4.6.8.1 How to configure SLS-t".
 2. Set a proper time of P4.3 SLS-t delay to make sure that the motor speed is lower than P4.5 SLS trip limit when SLS function is activated and the time of P4.3 SLS-t delay elapsed.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SLS function by turning off the safe switch which is connected to FS card.
 5. The motor speed decelerates to the speed of P4.6 SLS limit.
 6. Try to increase the motor speed.
 7. When the motor speed is higher than the speed of P4.5 SLS trip limit, the drive shuts down the output and reports a SLS trip limit warning and a Safe Torque Off fault.
 8. Deactivate the SLS function by turning on the safe switch.
 9. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 10. Try to reset all faults.
 - SLS-t Validation - Abnormal Operation 2:
 1. Set the related parameters according to → Section "4.6.8.1 How to configure SLS-t".
 2. Set a proper time of P4.3 SLS-t delay to make sure that the motor speed is still higher than P4.5 SLS trip limit when SLS function is activated and the time of P4.3 SLS-t delay elapsed.
 3. Start the drive to run the motor at the desired speed.

5 Verification and Validation

5.4 Validation of SLS

4. Activate the SLS function by turning off the safe switch which is connected to FS card.
 5. Wait the time of P4.3 SLS-t delay, the drive shuts down the output and reports a SLS over time warning and a Safe Torque Off fault.
 6. Deactivate the SLS function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed.
 10. Stop the drive and the motor will stop running as required.
3. Follow steps below if SLS-r mode is used:
- SLS-r Validation - Normal Operation:
 1. Set the related parameters according to → Section "4.6.8.2 How to configure SLS-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed won't exceed the tolerance in P11.3 Deceleration tolerance when SLS function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SLS function by turning off the safe switch which is connected to FS card.
 5. The motor speed decelerates to the speed of P4.6 SLS limit.
 6. Deactivate the SLS function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. Give a stop command and the motor will stop running.
 - SLS-r Validation - Abnormal Operation:
 1. Set the related parameters according to → Section "4.6.8.2 How to configure SLS-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed must exceed the tolerance in P11.3 Deceleration tolerance when SLS function is activated.
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SLS function by turning off the safe switch which is connected to FS card.
 5. During deceleration, the drive shuts down the output and reports a SLS speed exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SLS function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed.
 10. Stop the drive and the motor will stop running as required.

5.5 Validation of SDI

1. Check the wiring for SDI function.
2. Follow steps below if SDI-t mode is used:
 - SDI-t Validation - Normal Operation:
 1. Refer to → Section "4.10.8.1 How to configure SDI-t" to configure SDI-t.
 2. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the intended direction. The intended direction must be positive if SDI+ is enabled and negative if SDI- is enabled.
 3. Activate the SDI function by turning off the safe switch which is connected to FS card.
 4. Wait the time of P8.6 SDI-t delay, the drive keeps running the motor in the intended direction.
 5. Set Speed Reference of the drive to 0 rpm and the motor is at a standstill. No warning or fault is triggered.
 6. Deactivate the SDI function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P8.8 SDI n=0 Limit (It is necessary to wait until the motor speed is less than P8.8 SDI n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Give a stop command, then the drive stops running.
 - SDI-t Validation - Abnormal Operation 1:
 1. Refer to → Section "4.10.8.1 How to configure SDI-t" to configure SDI-t.
 2. Set a proper time of P8.6 SDI-t delay to make sure that the motor speed is lower than P8.8 SDI n=0 Limit when SDI function is activated and the time of P8.6 SDI-t delay elapsed.
 3. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the unintended direction.
 4. Activate the SDI function by turning off the safe switch which is connected to FS card.
 5. The drive ramps down the motor speed. When the time of P8.6 SDI-t delay elapsed:
 - If the motor is stopped, no warning or fault will be triggered.
 - If the motor is still running in the unintended direction and the position tolerance exceeds the degree of P8.7 SDI Limit degree, the drive will stop running and report an SDI Position exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SDI function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P8.8 SDI n=0 Limit (It is necessary to wait until the motor speed is less than P8.8 SDI n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.

5 Verification and Validation

5.5 Validation of SDI

- SDI-t Validation - Abnormal Operation 2:
 1. Set the related parameters according to → Section "4.10.8.1 How to configure SDI-t".
 2. Set a proper time of P8.6 SDI-t delay to make sure that the motor speed is still higher than P8.8 SDI n=0 Limit when SDI function is enabled and the time of P8.6 SDI-t delay elapsed.
 3. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the unintended direction.
 4. Activate the SDI function by turning off the safe switch which is connected to FS card.
 5. The drive ramps down the motor speed. When the time of P8.6 SDI-t delay elapsed, the drive stops running and reports an SDI over time warning and a Safe Torque Off fault.
 6. Start the drive to run the motor at the desired speed in the intended direction.
 7. Stop the drive and the motor will stop running as required.
- 3. Follow steps below if SDI-r mode is used:
 - SDI-r Validation - Normal Operation 1:
 1. Set the related parameters according to → Section "4.10.8.2 How to configure SDI-r".
 2. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the intended direction.
 3. Activate the SDI function by turning off the safe switch which is connected to FS card.
 4. The drive keeps running the motor in the intended direction.
 5. Set Speed Reference of the drive to 0 rpm and the motor is at a standstill. No warning or fault is triggered.
 6. Deactivate the SDI function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P8.8 SDI n=0 Limit (It is necessary to wait until the motor speed is less than P8.8 SDI n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 8. Give a stop command, then the drive stops running.
 - SDI-r Validation - Normal Operation 2:
 1. Set the related parameters according to → Section "4.10.8.2 How to configure SDI-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed won't exceed the tolerance in P11.3 Deceleration tolerance when SDI function is activated.
 3. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the unintended direction.
 4. Activate the SDI function by turning off the safe switch which is connected to FS card.
 5. The drive ramps down the motor speed and the motor is at a standstill finally.

6. Deactivate the SDI function by turning on the safe switch.
7. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P8.8 SDI n=0 Limit (It is necessary to wait until the motor speed is less than P8.8 SDI n=0 Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.

- SDI-r Validation - Abnormal Operation:
 1. Set the related parameters according to → Section "4.10.8.2 How to configure SDI-r".
 2. Set a proper value for P11.1 Speed scaling, P11.2 Ramp time to zero and P11.3 Deceleration tolerance to make sure that the deceleration rate of the motor speed must exceed the tolerance in P11.3 Deceleration tolerance when SDI function is activated.
 3. Start the drive to run the motor at a speed which is higher than P8.8 SDI n=0 Limit in the unintended direction.
 4. Activate the SDI function by turning off the safe switch which is connected to FS card.
 5. During deceleration, the drive is running and reports an SDI speed exceed tolerance warning and a Safe Torque Off fault.
 6. Try to reset all faults.
 7. Start the drive to run the motor at the desired speed in the positive direction.
 8. Stop the drive and the motor will stop running as required.

5 Verification and Validation

5.6 Validation of SBC

5.6 Validation of SBC

SBC and STO safety functions could be triggered by any other safety functions (except SSM). Here gives an example of using SOS function to trigger STO and SBC:

1. Check the wiring for SBC function and SOS function.
2. Follow the steps below if delayed brake is selected for STO SBC mode.
 - SBC Validation - Delayed Brake Mode:
 1. Set SOS function related parameters according to → Section "4.7.8.1 How to configure SOS".
 2. Set SBC function related parameters according to → Section "4.5.8.1 How to configure STO SBC delay > 0 (STO before SBC)".
 3. Start the drive to run the motor at the minimum speed allowed.
 4. Activate the SOS function by turning off the safe switch which is connected to FS card.
 5. Wait until the position tolerance reaches the degrees of P5.3 SOS n=0-Hysteresis, the drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault.
 6. The SBC function is activated when the time of P3.2 STO SBC Delay elapsed.
 7. Deactivate the SOS function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 9. Try to reset all faults.
 10. Set SBC function related parameters according to → Section "4.5.8.2 How to configure STO SBC delay < 0(STO after SBC)".
 11. Start the drive to run the motor at the minimum speed allowed.
 12. Activate the SOS function by turning off the safe switch which is connected to FS card.
 13. Wait until the position tolerance reaches the degrees of P5.3 SOS n=0-Hysteresis, the SBC function is activated.
 14. The drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault when the time of P3.2 STO SBC Delay elapsed.
 15. Deactivate the SOS function by turning on the safe switch.
 16. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 17. Try to reset all faults.
 18. Set SBC function related parameters according to → Section "4.5.8.3 How to configure STO SBC delay = 0 (STO and SBC at the same time)".
 19. Start the drive to run the motor at the minimum speed allowed.
 20. Activate the SOS function by turning off the safe switch which is connected to FS card.
 21. Wait until the position tolerance reaches the degrees of P5.3 SOS n=0-Hysteresis, the drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault. The SBC

function is also activated at the same time.

22. Deactivate the SOS function by turning on the safe switch.

23. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.

24. Start the drive to run the motor at the desired speed.

25. Stop the drive and the motor will stop running as required.

SBC could be combined with SS1 function. The user-defined speed limit activates the SBC and STO functions while ramping.

3. Follow the steps below if speed limit is selected for STO SBC mode.

- SBC Validation - Speed Limit Mode:
 1. Set SS1 function related parameters according to → Section "4.4.8.1 How to configure SS1-t".
 2. Set SBC function related parameters according to → Section "4.5.8.4 How to configure SBC Activated by SS1 with Speed Limit".
 3. Start the drive to run the motor at the desired speed.
 4. Activate the SS1 function by turning off the safe switch which is connected to FS card.
 5. Wait until the motor speed reaches P3.2 SS1 SBC speed, the SBC function is activated.
 6. Wait until the motor speed reaches P2.5 SS1 n=0 Limit, the drive shuts down the output and reports a Safe Torque Off fault.
 7. Deactivate the SS1 function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor speed is higher than P2.5 SS1 n=0 Limit. No action is needed if automatic acknowledgement is selected.
 9. Start the drive to run the motor at the desired speed.
 10. Stop the drive and the motor will stop running as required.

5.7 Validation of SAR

SAR Function is used in combination of other Safety Functions (SS1, SS2, SDI and SLS). For validation of the SAR function, refer to the validation of SS1-r, SS2-r, SDI-r, and SLS-r. Note that any changes of SAR parameter settings will impact SS1, SS2, SDI and SLS functions simultaneously.

5.8 Validation of SOS

1. Check the wiring for SOS function.
2. Follow the steps below to validate SOS function:
 - SOS Validation - Normal Operation:
 1. Set SOS function related parameters according to → Section "4.7.8.1 How to configure SOS".
 2. Start the drive to run the motor at zero speed.
 3. Activate the SOS function by turning off the safe switch which is connected to FS card.
 4. Monitor the position tolerance. No warning or fault will be triggered if the position tolerance is not exceeding the degrees of P5.3 SOS n=0-Hysteresis.
 5. Try to increase the motor speed to the minimum speed allowed.
 6. Wait until the position tolerance reaches P5.3 SOS n=0-Hysteresis, the drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault.
 7. Deactivate the SOS function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 9. Try to reset all faults.
 10. Start the drive to run the motor at the desired speed.
 11. Stop the drive and the motor will stop running as required.
 - SOS Validation - Abnormal Operation:
 1. Set SOS function related parameters according to → Section "4.7.8.1 How to configure SOS".
 2. Start the drive to run the motor at zero speed.
 3. Activate the SOS function by turning off the safe switch which is connected to FS card.
 4. Monitor the position tolerance. No warning or fault will be triggered if the position tolerance is not exceeding the degrees of P5.3 SOS n=0-Hysteresis.
 5. Try to increase the motor speed to the minimum speed allowed.
 6. Wait until the position tolerance reaches P5.3 SOS n=0-Hysteresis, the drive shuts down the output and reports a SOS Position exceed tolerance warning and a Safe Torque Off fault.
 7. Deactivate the SOS function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 9. Try to reset all faults.
 10. Start the drive to run the motor at the desired speed.
 11. Stop the drive and the motor will stop running as required.

5.9 Validation of SSM

1. Check the wiring for SSM function.
2. Follow the steps below to validate SSM function:
 1. Set SSM function related parameters according to → Section "4.9.8.1 How to configure SSM".
 2. Start the drive to run the motor at the desired speed and make sure that the motor speed is lower than P7.3 SSM Limit.
 3. Activate the SSM function by turning off the safe switch which is connected to FS card.
 4. The digital output for SSM status is on.
 5. Try to increase the motor speed to higher than P7.3 SSM Limit. The digital output for SSM status is changed to off.
 6. Try to decrease motor speed to lower than (P7.3 SSM Limit-P7.4SSM Hysteresis). Digital output for SSM status is changed back to on.
 7. Deactivate the SSM function by turning on the safe switch.
 8. Give a stop command, then the drive stops running.
 9. Start the drive to run the motor at the desired speed.
 10. Stop the drive and the motor will stop running as required.

5 Verification and Validation

5.10 Validation of SLA

5.10 Validation of SLA

1. Check the wiring for SLA function.
2. Follow steps below to validate SLA function:
 - SLA Validation - Normal Operation 1:
 1. Set the related parameters according to → Section "4.11.8.1 How to configure SLA".
 2. Set a proper time of P9.3 SLA-t delay to make sure that the motor acceleration is lower than P9.4 SLA+ trip limit when SLA function is activated and the time of P9.3 SLA-t delay elapsed.
 3. Start the drive to run the motor with an acceleration which is higher than P9.4 SLA+ trip limit.
 4. Activate the SLA function by turning off the safe switch which is connected to FS card.
 5. The motor accelerates to the maximum speed allowed with the acceleration of P9.5 SLA+ Limit.
 6. Give a stop command and the motor decelerates to zero speed with the deceleration of P9.7 SLA- Limit.
 7. Deactivate the SLA function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor acceleration is higher than P9.4 SLA+ trip limit or the motor deceleration is higher than P9.6 SLA- trip limit (It is necessary to wait until the motor speed is less than SLA trip Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 - SLA Validation - Normal Operation 2:
 1. Set the related parameters according to → Section "4.11.8.1 How to configure SLA".
 2. Set a proper Accel Time to make sure that the motor acceleration is lower than P9.5 SLA+ Limit. Set a proper Decel Time to make sure that the motor deceleration is lower than P9.7 SLA- Limit.
 3. Start the drive to run the motor with the desired acceleration.
 4. Activate the SLA function by turning off the safe switch which is connected to FS card.
 5. The motor accelerates to the maximum speed allowed with the desired acceleration (lower than P9.5 SLA+ Limit).
 6. Give a stop command and the motor decelerates to zero speed with the deceleration (Lower than P9.7 SLA- Limit).
 7. Deactivate the SLA function by turning on the safe switch.
 8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor acceleration is higher than P9.4 SLA+ trip limit or the motor deceleration is higher than P9.6 SLA- trip limit (It is necessary to wait until the motor speed is less than SLA trip Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.
 - SLA Validation - Abnormal Operation 1:
 1. Set the related parameters according to → Section "4.11.8.1 How to

configure SLA".

2. Set a proper Accel Time to make sure that the motor acceleration is lower than P9.5 SLA+ Limit. Set a proper Decel Time to make sure that the motor deceleration is lower than P9.7 SLA- Limit.

3. Start the drive to run the motor with the desired acceleration.

4. Activate the SLA function by turning off the safe switch which is connected to FS card.

5. When the time of P9.3 SLA-t delay elapsed, try to increase the motor acceleration to higher than P9.4 SLA+ trip limit.

6. The drive stops running and reports an SLA acceleration exceed tolerance warning and a Safe Torque Off fault.

7. Deactivate the SLA function by turning on the safe switch.

8. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor acceleration is higher than P9.4 SLA+ trip limit or the motor deceleration is higher than P9.6 SLA- trip limit (It is necessary to wait until the motor speed is less than SLA trip Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.

9. Try to reset all faults.

- SLA Validation - Abnormal Operation 2:

1. Set the related parameters according to → Section "4.11.8.1 How to configure SLA".

2. Set a proper Accel Time to make sure that the motor acceleration is lower than P9.5 SLA+ Limit. Set a proper Decel Time to make sure that the motor deceleration is lower than P9.7 SLA- Limit.

3. Start the drive to run the motor with the desired acceleration.

4. Activate the SLA function by turning off the safe switch which is connected to FS card.

5. The motor accelerates to the maximum speed allowed with the desired acceleration (lower than P9.5 SLA+ Limit).

6. Give a stop command and the motor decelerates with the deceleration (Lower than P9.7 SLA- Limit).

7. When the time of P9.3 SLA-t delay elapsed, try to increase the motor deceleration to higher than P9.6 SLA- trip limit.

8. The drive stops running and reports an SLA acceleration exceed tolerance warning and a Safe Torque Off fault.

9. Deactivate the SLA function by turning on the safe switch.

10. Execute the Acknowledgement if manual acknowledgement is selected. Note that the Acknowledgement cannot be executed if the motor acceleration is higher than P9.4 SLA+ trip limit or the motor deceleration is higher than P9.6 SLA- trip limit (It is necessary to wait until the motor speed is less than SLA trip Limit, and then manually operate the switch again). No action is needed if automatic acknowledgement is selected.

11. Try to reset all faults.

12. Start the drive to run the motor at the desired speed.

13. Stop the drive and the motor will stop running as required.

5 Verification and Validation

5.11 Validation of SSR

5.11 Validation of SSR

1. Check the wiring for SSR function.
2. Follow steps below to validate SSR function:
 - SSR Validation - Normal Operation
 1. Set the related parameters according to → Section "4.12.8.1 How to configure SSR".
 2. Start the drive to run the motor at the desired speed which is within SSR monitor range.
 3. Activate the SSR function by turning off the safe switch which is connected to FS card.
 4. Wait the time of P10.5 SSR t-delay, the drive keeps running at the desired speed and no warning or fault is triggered.
 5. Deactivate the SSR function by turning on the safe switch.
 6. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 7. Give a stop command, then the motor stops running.
 - SSR Validation - Abnormal Operation 1:
 1. Set the related parameters according to → Section "4.12.8.1 How to configure SSR".
 2. Start the drive to run the motor at the desired speed which is within SSR monitor range.
 3. Activate the SSR function by turning off the safe switch which is connected to FS card.
 4. When the time of P10.5 SSR t-delay elapsed, try to run the motor at a speed which is higher than P10.3 SSR upper limit.
 5. The drive stops running and reports a SSR speed exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SSR function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.

- SSR Validation - Abnormal Operation 2:
 1. Set the related parameters according to → Section "4.12.8.1 How to configure SSR".
 2. Start the drive to run the motor at the desired speed which is within SSR monitor range.
 3. Activate the SSR function by turning off the safe switch which is connected to FS card
 4. When the time of P10.5 SSR t-delay elapsed, try to run the motor at a speed which is lower than P10.4 SSR lower limit.
 5. The drive stops running and reports a SSR speed exceed tolerance warning and a Safe Torque Off fault.
 6. Deactivate the SSR function by turning on the safe switch.
 7. Execute the Acknowledgement if manual acknowledgement is selected. No action is needed if automatic acknowledgement is selected.
 8. Try to reset all faults.
 9. Start the drive to run the motor at the desired speed.
 10. Stop the drive and the motor will stop running as required.

6 Interaction and priority of Safety Functions

Each safety functionality must be configured according to the corresponding application requirement.

Safety applications are prioritized below:

Table 72: DX1 safety functions priority:

Priority	Safety Function
1	STO
2	SBC
3	SS1
4	SS2, SLS, SLA, SAR, SOS
5	SDI, SSR, SSM

Safety functions are triggering STO or SBC if their limits are exceeded. See below the table for STO and SBC which are triggered by safety functions.


	<p>WARNING</p> <p>Users are not authorized to configure the priority of safety functions.</p>
--	--

Table 73: Safety functions trigger relationship:

Safety Function	Trigger STO	Trigger SBC	Note
SOS	Yes	Yes	SBC can be triggered before, at the same time as, or after STO
SS1, SS2, SLS, SDI, SSR, SLA, SAR	Yes	Yes	SBC can only be triggered at the same time as or after STO
SSM	No	No	Only output DO indicate status, no other safety functions will be triggered

7 Safety Tool

The tool is designed to ensure the integrity of parameter configuration, prevent unauthorized access, and guarantee operational safety through a series of safety measures.

With the use of Safety tool software, users must take appropriate caution as unintentional device connection or access can occur which increases the risk of personnel and equipment safety issues.

All systems must be tested in a controlled environment prior to usage in an active production or service environment as to make the user aware of the tools functionality and control abilities.

User roles have been defined within this tool and can be activated to restrict certain user's configuration and control abilities, reducing the risk of those users unintentionally connecting devices through Safety Tool.

7.1 System Requirements

Hardware Requirements

- 32 bit or 64-bit compatible PC.
- 1 GB RAM
- At least 50 MB free hard disk.

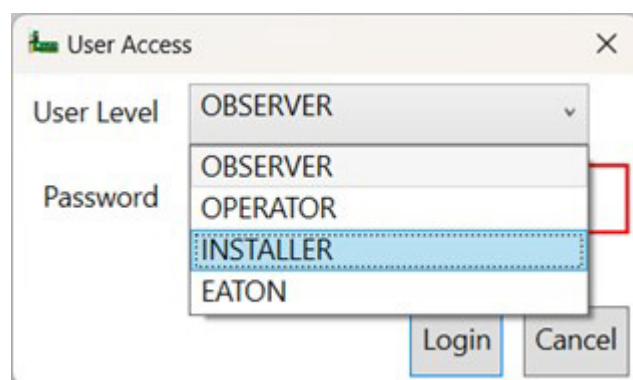
Software Requirements

- Operating system Windows 8 and higher.
- Microsoft .NET Framework 4.0.
- Microsoft Office 2007 or above.

7.2 User Access Level

Our User Access Level is designed to ensure safe and controlled access to the parameter configuration of safety functions. The design incorporates multiple layers of safety to prevent unauthorized access and maintain the integrity of the system configuration. User access level are categorized as follows:

- Observer: can only view parameters, but cannot change them.
- Operator: can only view parameters, but cannot change them.
- Installer: with full access to all parameters and configuration settings.
- Eaton: with full access to all parameters and configuration settings.



CAUTION

Users must select their corresponding access level and enter the correct password. The system will verify the correctness of the user's access level and login password.

By implementing these measures, our rights management design ensures that only authorized personnel can access and modify the parameter configuration of safety functions, thereby maintaining the safety and integrity of the system.

7.3 Password

Parameter configuration of safety functions requires a password.

The default password set at the factory is "12345678" and it must comprise 8 digits. Upon changing the password, kindly ensure to remember the new one; failure to do so will necessitate a factory reset of the FS card, resulting in the erasure of the configuration and restoration of the parameters to their factory defaults. This will also reset the password back to the default "12345678".

WARNING

The default password must be modified during configuration.

7.4 Configuration Parameters

To ensure the safety of data transmission, the drive now exclusively supports serial communication between the safety tool and the FS card, and has established a dedicated serial configuration page for users to adjust settings as needed. Users must select the correct COM port through the settings options. After configuration is complete, by clicking the connect button, the application will establish communication with the FS card via serial connection.

- Update Parameters: Users can view all safety parameters on the safety tool.
- Set Parameters: Before setting parameters, the system will validate the actual value against predefined minimum and maximum values. If the value falls outside the range, the system will display an invalid value message and reject the setting.
- Confirm Parameters: Users will be prompted with a verification window to confirm or reject the parameter settings.



WARNING

The user need to confirm whether the parameters are set by themselves. User will get confirmation or verification dialog box where user can select OK and Cancel to confirm parameter write operation. In the parameter validation window, when user click on OK button, tool sends Confirm OK command or if user click on Cancel button, then tool sends Confirm Cancel button.

7.5 Factory reset

This section is intended to guide users on how to use safety tools to factory reset FS cards. Factory reset is a method to restore all safety parameters on the FS card to their default values. Before performing this operation, please ensure that important data is backed up, as this action will erase all custom settings.

The steps to factory reset are as follows:

- Log in to the safety tool and enter the configurable parameter mode (requires the installer or Eaton user level).
- In the main interface of the software, find and click the "Factory Reset" button. After clicking the button, a success or failure message will appear on the screen.



CAUTION

Factory reset will erase all safety parameters and user data. Please ensure a backup is made in advance.

7 Safety Tool

7.6 Safety Considerations

7.6 Safety Considerations

- Login Connection Timeout. If there is no user activity for 1 hour, the system will automatically lock, requiring re-entry of the password for re-login. This measure aims to prevent unauthorized access and mitigate potential safety risks.
- Password Management. Users must regularly change their passwords, kept safe and not disclosed to others.
- Data Backup. Regularly export parameter data files to prevent data loss or damage. Files must be stored in a safe location, and recovery tests must be conducted periodically.



WARNING

In the event of data loss or damage, use the latest backup data for recovery. During the recovery process, follow the guidance of technical support personnel to ensure the accuracy and completeness of data restoration.



WARNING

In case of system abnormalities or error messages, immediately cease operations and contact technical support personnel. Do not attempt to repair or bypass safety mechanisms independently.

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description
Basic Parameters (P1)							
Encoder Pulse Count	P1.1	1	60000	ppr	1024	–	Sets the number of pulses for motor revolution of encoder.
Max Speed	P1.2	–	–	rpm	1500.00	–	Set the maximum speed according to the specifications on the encoder. Divide the captured encoder signal. Make speed calculations more accurate
DO1 Mode	P1.3	–	–	–	0	0 = NOT USED 1 = SS1 Status 2 = SBC Status 3 = SBC test OK signal 4 = SLS Status 5 = SOS Status 6 = SS2 Status 7 = SSM safety speed indication 8 = SDI+ Status 9 = SDI- Status 10 = SLA Status 11 = SSR Status 12 = SAR Status 13 = STO Status 14 = Output High 15 = Output Low	Setting Value Signal Content 0: No Action. 1: SS1 function is activated. 2: SBC output is activated. 3: SBC test OK signal is activated. Active when the SBC feedback indicates that the SBC works correctly. 4: SLS function is activated. 5: SOS function is activated. 6: SS2 function is activated. 7: SSM function safety speed indication is activated. 8: SDI+ function is activated. 9: SDI- function is activated. 10: SLA function is activated. 11: SSR function is activated. 12: SAR function is activated. 13: FS card STO function is activated. 14: DO keeps high. 15: DO keeps low.
DO2 Mode	P1.4	–	–	–	0	0 = NOT USED 1 = SS1 Status 2 = SBC Status 3 = SBC test OK signal 4 = SLS Status 5 = SOS Status 6 = SS2 Status 7 = SSM safety speed indication 8 = SDI+ Status 9 = SDI- Status 10 = SLA Status 11 = SSR Status 12 = SAR Status 13 = STO Status 14 = Output High 15 = Output Low	Setting Value Signal Content 0: No Action. 1: SS1 function is activated. 2: SBC output is activated. 3: SBC test OK signal is activated. Active when the SBC feedback indicates that the SBC works correctly. 4: SLS function is activated. 5: SOS function is activated. 6: SS2 function is activated. 7: SSM function safety speed indication is activated. 8: SDI+ function is activated. 9: SDI- function is activated. 10: SLA function is activated. 11: SSR function is activated. 12: SAR function is activated. 13: FS card STO function is activated. 14: DO keeps high. 15: DO keeps low.
Safety Card Configuration	P1.5	–	–	–	0	0 = No Safety Card 1 = FS + SABZ Card	This parameter configures whether to use the functional safety module. 0: Configure not use safety card. 1: Configure use FS and SABZ Card.

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description
DO Pulse Width	P1.6	–	–	–	0	0 = 1 ms 1 = 2 ms 2 = 3 ms	This parameter configures the pulse width of the DO output. 0: DO output pulse width is 1ms 1: DO output pulse width is 2ms 2: DO output pulse width is 3ms

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SS1 Parameters (P2)																									
SS1 Enable	P2.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SS1 function.																		
SS1 Source	P2.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 This parameter sets the digital input that is connected to the input of the SS1 function. The truth table is as follows: <table border="1" data-bbox="1061 734 1455 1014"> <thead> <tr> <th>Options in "Note"</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options in "Note"	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options in "Note"	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SS1 Mode	P2.3	–	–	–	0	0= SS1 time 1= SS1 ramp	Sets the SS1 type, that is, the method used for the SS1 monitoring. SS1 time is Time monitoring. SS1 ramp is Ramp monitoring.																		
t-delay STO@SS1	P2.4	0	3600.0	s	20.0	–	Sets the safe delay after which FS card activates the STO function after the SS1 request. This parameter is relevant only if time monitoring is used and the motor speed does not follow the ramp. See parameter SS1 type.																		
SS1 n = 0 Limit	P2.5	0	600.00	rpm	40.00	–	User-defined Zero Speed. Speed limit for activating the drive STO function. The safety function is completed and the SS1 completed indication goes on.																		
SS1 Acknowledgement Mode	P2.6	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge																		

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description
SBC Parameters (P3)							
STO SBC Mode	P3.1	–	–	–	0	0 = None 1 = Delayed brake 2 = Speed limit	Sets how the mechanical brake (SBC) is used together with the STO function. 0: No brake 1: Time controlled brake. Parameter STO SBC delay defines the delay. 2: The brake is activated below a user-defined speed limit.
STO SBC delay	P3.2	-5.0	3600.0	s	20.0	–	Sets the time after which FS card activates the SBC after it has activated the drive STO function. A negative value means that FS card activates the SBC before the drive STO function. If the value is 0 s, FS card activates the drive STO and SBC functions at the same time.
SS1 SBC speed	P3.3	0.00	1000.00	rpm	0.00	–	This parameter is to allow the user to set the speed limit of FS card to activate the brake (SBC) while ramping SS1 function. The STO SBC usage is set up to the Speed limit value defined in this parameter. If the value is 0.0 rpm, this feature is not in use.
SBC feedback action	P3.4	–	–	–	1	0 = STO 1 = No STO	Sets the action that FS card takes when there is a problem with the SBC feedback. 0: FS card activates the drive STO function. 1: FS card sends a warning to the drive.

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SLS Parameters (P4)																									
SLS Enable	P4.1	–	–	–	0	0 = Disabled 1 = Enable	0: Deactivates the SLS function 1: Activates the SLS function Activates or deactivates the SLS function and shows the version of the SLS function.																		
SLS Mode	P4.2	–	–	–	0	0 = SLS time 1 = SLS ramp	Sets the monitoring method that is used in SLS activation. 0: Select SLS time monitoring 1: Select SLS ramp monitoring																		
SLS-t delay	P4.3	0	3600.0	s	20.0	–	Sets the security delay after which FS card activates the SLS monitoring after the SLS request. This parameter is relevant only if time monitoring is used.																		
SLS Source	P4.4	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 This parameter the digital input that is connected to the primary input of the SLS function with limits. The truth table is as follows: <table border="1" data-bbox="1082 1025 1455 1283"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SLS trip limit	P4.5	0	30000.00	rpm	1000.00	–	Sets the SLS positive speed limit that trips the drive.																		
SLS limit	P4.6	0	30000.00	rpm	500.00	–	Sets the SLS positive speed limit for the drive.																		
SLS Acknowledgement Mode	P4.7	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge																		

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SOS Parameters (P5)																									
SOS Enable	P5.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SOS function.																		
SOS Source	P5.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	<p>0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 5: The SOS function is always on.</p> <p>This parameter sets the digital input that is connected to the input of the SOS function. The truth table is as follows:</p> <table border="1"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SOS n = 0 Hysteresis	P5.3	0	3600000	deg	1080	–	Sets the position tolerance for the SOS function. The deviation of the position must within in this value. Otherwise, will trigger STO function.																		
SOS Acknowledgement Mode	P5.4	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	<p>Safety functions acknowledgement methods.</p> <p>0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge</p>																		

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SS2 Parameters (P6)																									
SS2 Enable	P6.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SS2 function.																		
SS2 Source	P6.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 This parameter sets the digital input that is connected to the input of the SS2 function. The truth table is as follows: <table border="1" data-bbox="1066 734 1441 987"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SS2 Mode	P6.3	–	–	–	0	0= SS2 time 1= SS2 ramp	Sets the SS2 type, that is, the method used for the SS2 monitoring. SS2-r is Ramp monitoring. SS2-t is Time monitoring.																		
t-delay STO@SS2	P6.4	0	3600.0	s	20.0	–	Sets the security delay after which FS card activates the STO function after the SS2 request. This parameter is relevant only if time monitoring is used and the motor speed does not follow the ramp. See parameter SS2 type.																		
SS2 n = 0 Limit	P6.5	0	600.00	rpm	40.00	–	Speed limit for activating the drive STO function. The safety function is completed and the SS2 completed indication goes on. The acknowledgment becomes allowed.																		
SS2 Acknowledgement Mode	P6.6	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge																		

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																					
SSM Parameters (P7)																												
SSM Enable	P7.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SSM function.																					
SSM Source	P7.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	<p>0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 5: The SSM function is always on.</p> <p>This parameter sets the digital input that is connected to the input of the SSM function. The truth table is as follows:</p> <table border="1"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> <tr> <td>5</td> <td>Always on</td> <td>Always on</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42	5	Always on	Always on
Options	FS_MCU1	FS_MCU2																										
0	NOT_USED	NOT_USED																										
1	Select DIN11	Select DIN12																										
2	Select DIN21	Select DIN22																										
3	Select DIN31	Select DIN32																										
4	Select DIN41	Select DIN42																										
5	Always on	Always on																										
SSM Limit	P7.3	0.0	30000.00	rpm	0.00	–	Sets the speed limit for the SSM function.																					
SSM Hysteresis	P7.4	0.0	30000.00	rpm	0.00	–	The parameterization hysteresis ensures that the SSM output signal does not jump between the values 0 and 1 in the limit range.																					

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SDI Parameters (P8)																									
SDI+ Enable	P8.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SDI positive activity function.																		
SDI- Enable	P8.2	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SDI negative activity function.																		
SDI Mode	P8.3	–	–	–	0	0 = SDI time 1 = SDI ramp	0: Ramp monitoring. 1: Time monitoring Sets the monitoring method that is used in SDI activation.																		
SDI+ Source	P8.4	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 This parameter sets the digital input that is connected to the input of the SDI positive function. The truth table is as follows: <table border="1" data-bbox="1082 925 1453 1178"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SDI- Source	P8.5	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 This parameter sets the digital input that is connected to the input of the SDI negative function. The truth table is as follows: <table border="1" data-bbox="1075 1462 1447 1715"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
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1	Select DIN11	Select DIN12																							
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3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SDI-t delay	P8.6	0	3600.0	s	20.0	–	Sets the delay for starting SDI monitoring. This parameter is relevant only when parameter SDI activation monitoring method is set to Time.																		
SDI Limit degree	P8.7	0	3600000	deg	100	–	Sets the position tolerance for the SDI function. The position of the motor axle cannot move into the forbidden direction more than defined with this parameter. Note: This is the absolute value. The same value is used in both positive and negative directions.																		

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description
SDI n = 0 Limit	P8.8	0	600.00	rpm	40.00	–	Speed limit for activating the drive STO function. The safety function is completed, and the SDI completed indication goes on. The acknowledgment becomes allowed.
SDI Acknowledgement Mode	P8.9	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SLA Parameters (P9)																									
SLA Enable	P9.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SLA function.																		
SLA Source	P9.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	<p>0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4 5: The SAR function is always on.</p> <p>This parameter sets the digital input that is connected to the input of the SLA function. The truth table is as follows:</p> <table border="1"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SLA t-delay	P9.3	0	3600.0	s	20.0	–	Sets the security delay after which FS card activates the SLA monitoring after the SLA request.																		
SLA+ trip limit	P9.4	0	60000.0	rpm/s	30.00	–	Sets the SLA positive safe acceleration limit that trips the drive. Requirement: SLA+ trip limit > SLA+ limit																		
SLA+ limit	P9.5	0	60000.0	rpm/s	5.00	–	Sets the SLA positive safe acceleration limit for the drive.																		
SLA- trip limit	P9.6	-60000.0	0	rpm/s	-30.00	–	Sets the SLA negative safe acceleration limit that trips the drive. Requirement: SLA- trip limit < SLA- limit																		
SLA- limit	P9.7	-60000.00	0	rpm/s	-5.00	–	Sets the SLA negative safe acceleration limit for the drive.																		
SLA delta-t	P9.8	500.0	10000.0	ms	1000.0	–	Set the time to calculate the change of acceleration.																		
SLA Acknowledgement Mode	P9.9	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge																		

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																		
SSR Parameters (P10)																									
SSR Enable	P10.1	–	–	–	0	0 = Disabled 1 = Enable	This parameter allows the user to activate or deactivate the SSR function.																		
SSR Source	P10.2	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42	<p>0: No select input connected. 1: select input DI 1:1 & DI 2:1 2: select input DI 1:2 & DI 2:2 3: select input DI 1:3 & DI 2:3 4: select input DI 1:4 & DI 2:4</p> <p>This parameter sets the digital input that is connected to the input of the SSR function. The truth table is as follows:</p> <table border="1"> <thead> <tr> <th>Options</th> <th>FS_MCU1</th> <th>FS_MCU2</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>NOT_USED</td> <td>NOT_USED</td> </tr> <tr> <td>1</td> <td>Select DIN11</td> <td>Select DIN12</td> </tr> <tr> <td>2</td> <td>Select DIN21</td> <td>Select DIN22</td> </tr> <tr> <td>3</td> <td>Select DIN31</td> <td>Select DIN32</td> </tr> <tr> <td>4</td> <td>Select DIN41</td> <td>Select DIN42</td> </tr> </tbody> </table>	Options	FS_MCU1	FS_MCU2	0	NOT_USED	NOT_USED	1	Select DIN11	Select DIN12	2	Select DIN21	Select DIN22	3	Select DIN31	Select DIN32	4	Select DIN41	Select DIN42
Options	FS_MCU1	FS_MCU2																							
0	NOT_USED	NOT_USED																							
1	Select DIN11	Select DIN12																							
2	Select DIN21	Select DIN22																							
3	Select DIN31	Select DIN32																							
4	Select DIN41	Select DIN42																							
SSR upper limit	P10.3	-60000.00	60000.00	rpm	1000.00	–	Sets the motor speed upper limit for the SSR function. Requirement: SSR upper limit > SSR lower limit																		
SSR lower limit	P10.4	-60000.00	60000.00	rpm	0	–	Sets the motor speed lower limit for the SSR function.																		
SSR t-delay	P10.5	0	3600.0	s	20.0	–	Sets the safety delay, the latest time at which FS card activates SSR monitoring after an SSR request.																		
SSR Acknowledgement Mode	P10.6	–	–	–	0	0 = None 1 = DIN11 & DIN12 2 = DIN21 & DIN22 3 = DIN31 & DIN32 4 = DIN41 & DIN42 5 = Automatic	Safety functions acknowledgement methods. 0: No select Acknowledge. 1: select dual channel DI1 to manual acknowledge 2: select dual channel DI2 to manual acknowledge 3: select dual channel DI3 to manual acknowledge 4: select dual channel DI4 to manual acknowledge 5: Automatic acknowledge																		

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description
SAR Parameters (P11)							
Speed scaling	P11.1	0	30000.00	rpm	1500.00	–	Sets a speed value that FS card uses as a reference point in ramp time calculations.
Ramp time to zero	P11.2	0	3600.0	s	10.0	–	Sets the target time for the ramp decelerate. Target time = Time in which the drive decelerates the motor from speed scaling to zero.
Deceleration tolerance	P11.3	0	30000.00	rpm	30.00	–	The permitted decelerate tolerance during the ramp deceleration.
Monitoring Parameters							
Encoder speed	P12.1	–	–	rpm	0	Monitor encoder speed	The encoder speed calculated by FS card.
Encoder position	P12.2	–	–	deg	0	Monitor encoder position	The encoder position calculated by FS card.
Encoder direction	P12.3	–	–	rpm	0	Monitor encoder direction	The encoder direction calculated by FS card.

8 List of Parameters

Parameter	Parameter Number	Min	Max	Unit	Default	Note	Description																																																																																					
DI status	P12.4	–	–	–	0	Monitor DI status. 1: DI1 active 2: DI2 active 4: DI3 active 8: DI4 active	<p>Monitor the status of 4 DI activity. DI is low, DI status is true (activity). The truth table of parameter values is as follows:</p> <table border="1"> <thead> <tr> <th>DI4 Status</th> <th>DI4 Status</th> <th>DI4 Status</th> <th>DI4 Status</th> <th>Parameter value</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>0</td><td>2</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>0</td><td>3</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>0</td><td>4</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>0</td><td>5</td></tr> <tr><td>0</td><td>1</td><td>1</td><td>0</td><td>6</td></tr> <tr><td>1</td><td>1</td><td>1</td><td>0</td><td>7</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>1</td><td>8</td></tr> <tr><td>1</td><td>0</td><td>0</td><td>1</td><td>9</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>1</td><td>10</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>1</td><td>11</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>1</td><td>12</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>1</td><td>13</td></tr> <tr><td>0</td><td>1</td><td>1</td><td>1</td><td>14</td></tr> <tr><td>1</td><td>1</td><td>1</td><td>1</td><td>15</td></tr> </tbody> </table> <p>1: indicates that DI is disconnected(active status). 0: indicates that DI is connected(deactive status).</p>	DI4 Status	DI4 Status	DI4 Status	DI4 Status	Parameter value	0	0	0	0	0	1	0	0	0	1	0	1	0	0	2	1	1	0	0	3	0	0	1	0	4	1	0	1	0	5	0	1	1	0	6	1	1	1	0	7	0	0	0	1	8	1	0	0	1	9	0	1	0	1	10	1	1	0	1	11	0	0	1	1	12	1	0	1	1	13	0	1	1	1	14	1	1	1	1	15
DI4 Status	DI4 Status	DI4 Status	DI4 Status	Parameter value																																																																																								
0	0	0	0	0																																																																																								
1	0	0	0	1																																																																																								
0	1	0	0	2																																																																																								
1	1	0	0	3																																																																																								
0	0	1	0	4																																																																																								
1	0	1	0	5																																																																																								
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1	1	1	0	7																																																																																								
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1	0	1	1	13																																																																																								
0	1	1	1	14																																																																																								
1	1	1	1	15																																																																																								
DO status	P12.5	–	–	–	0	Monitor DO status. 1: DO1 output high 2: DO2 output high	<p>Monitor the status of 2 DO activity. DO is high, DO status is true. The truth table of parameter values is as follows:</p> <table border="1"> <thead> <tr> <th>DO1 status</th> <th>DO2 status</th> <th>Parameter Value</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td><td>0</td></tr> <tr><td>1</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>1</td><td>2</td></tr> <tr><td>1</td><td>1</td><td>3</td></tr> </tbody> </table> <p>1: indicates that DO is output high status. 0: indicates that DO is output low status.</p>	DO1 status	DO2 status	Parameter Value	0	0	0	1	0	1	0	1	2	1	1	3																																																																						
DO1 status	DO2 status	Parameter Value																																																																																										
0	0	0																																																																																										
1	0	1																																																																																										
0	1	2																																																																																										
1	1	3																																																																																										
STO status	P12.6	–	–	–	0	Monitor STO status. 0: No STO 1: Trigger STO	<p>Monitor the status of STO activity. STO is high, STO status is true (activity). The truth table of parameter values is as follows:</p> <table border="1"> <thead> <tr> <th>STO status</th> <th>Parameter Value</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td></tr> <tr><td>1</td><td>1</td></tr> </tbody> </table> <p>1: indicates that STO is active status. 0: indicates that STO is deactive status.</p>	STO status	Parameter Value	0	0	1	1																																																																															
STO status	Parameter Value																																																																																											
0	0																																																																																											
1	1																																																																																											

9 Error List

Motor speed estimation error

The motor speed estimation error is less than $0.5\% \times$ maximum speed.

The maximum speed can be configured by user, and its range is from (-24000 rpm/number of motor pole pairs) to (+24000 rpm/number of motor pole pairs).

The motor speed is used in all safety functions.

NOTICE

- The motor speed estimation error will change with the clock frequency error. When the clock frequency error is less than 1%, the motor speed estimation error will not exceed $1.5\% \times$ maximum speed. When the clock frequency error exceeds 1%, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.
- Less than the $0.5\% \times$ maximum speed only be used for non-safety functions.
- All speed related safety functions must take 1.5% error into consideration

Acceleration estimation error

The acceleration estimation error is less than $1\% \times$ user setting acceleration.

The user setting acceleration can be configured by user, and its range is from 0 to 60000 rpm/s.

The acceleration is used in safety functions SLA and SAR.

NOTICE

- The motor acceleration estimation error will change with the clock frequency error. When the clock frequency error is less than 1%, the motor acceleration estimation error will not exceed $2\% \times$ user setting acceleration. When the clock frequency error exceeds 1%, "FS Clock Diagnosis Error" will be reported, and the drive enter safe state.
- Less than the $1\% \times$ user setting acceleration only be used for non-safety functions.
- All acceleration related safety functions must take 2% error into consideration

9 Error List

Table 74: Error list

Fault code	Fault Name	Type	Description	Possible Cause	Remedy
153	MCU STO 5V Power Fault	Fault	CB_MCU detects 5V power is out of range	<ul style="list-style-type: none"> • Circuit fault, 5V power > 5.2V • Circuit fault, 5V power < 4.8 	Power cycle, if fault still exists, contact the distributor near you
154	DSP STO 5V Power Fault	Fault	CB_DSP detects 5V power is out of range	<ul style="list-style-type: none"> • Circuit fault, 5V power > 5.2V • Circuit fault, 5V power < 4.8V 	Power cycle, if fault still exists, contact the distributor near you
23	STO Fault	Fault	Safety related diagnostic functions failure	<ul style="list-style-type: none"> • STO1 or STO2 is open • STO1 disconnect time and STO2 disconnect time is more than 300 ms 	Check STO1 and STO2 connection, ensure STO1 and STO2 are disconnect within 300 ms.
				Circuit fault, control board STO1 or STO2 diagnostic failure	Power cycle, if fault still exists, contact the distributor near you
				FS card STO1 or STO2 diagnostic failure	
				Circuit fault, STO over voltage	
				PWM buffer diagnostic failure	
				Software error, logical monitor failure	
				NTC cross diagnostic failure	
200	FS CPU Diagnostic Error	Fault	The CPU logic test failure	The CPU logic failure in the system.	Power cycle, if fault still exists, contact the distributor near you
201	FS RAM Diagnostic Error	Fault	The ECC SRAM test failure or meet uncorrectable error	<ul style="list-style-type: none"> • The SRAM uncorrectable error occur • SRAM test fail via MARCH13 algorithm 	Power cycle, if fault still exists, contact the distributor near you
202	FS FLASH Diagnosis Error	Fault	Flash CRC check failure or ECC test failure	<ul style="list-style-type: none"> • The flash uncorrectable error occur • CRC check fail due to program data incorrect 	Power cycle, if fault still exists, contact the distributor near you
203	FS BUS Diagnosis Error	Fault	Program sequence is incorrect, or stack is out of range	<ul style="list-style-type: none"> • Program sequence error • Stack is over flow or under flow 	Power cycle, if fault still exists, contact the distributor near you
205	FS Clock Diagnosis Error	Fault	FS_MCU clock frequency or another FS_MCU clock frequency is out of limit	<ul style="list-style-type: none"> • External crystal oscillator is broken • Clock configuration is incorrect. 	Power cycle, if fault still exists, contact the distributor near you
206	FS EEPROM Diagnosis Error	Fault	Write or read parameter fail	<ul style="list-style-type: none"> • Parameter CRC is incorrect • Read data from EEPROM failure • Write data to EEPROM failure 	Power cycle, if fault still exists, contact the distributor near you
207	FS SCI Diagnosis Error	Fault	Communication is lost between CB_MCU and FS_MCU	<ul style="list-style-type: none"> • Connection is not stable • Communication circle broken 	Power off, make sure the connection is stable, power on again, if fault still exists, contact the distributor near you
208	FS FSI Diagnosis Error	Fault	Communication is lost between two FS_MCU	<ul style="list-style-type: none"> • Receive data is incorrect • Communication circle broken 	Power cycle, if fault still exists, contact the distributor near you
209	FS MCU ID Diagnosis Error	Warning	MCU identification pins error	<ul style="list-style-type: none"> • MCU identification circle broken during run time 	Power cycle, if fault still exists, contact the distributor near you
210	FS Watchdog Diagnosis Error	Fault	The execution time of interrupt or main task is out of limit	Software error, the execution time is out of limit	Power cycle, if fault still exists, contact the distributor near you
211	FS Reset Circuit Diagnosis Error	Fault	FS_MCU reset unintendedly	<ul style="list-style-type: none"> • Software error cause watchdog timeout reset • Reset pin is force to low 	Power cycle, if fault still exists, contact the distributor near you

Fault code	Fault Name	Type	Description	Possible Cause	Remedy
212	FS MCU1 Power Diagnosis Error1	Fault	The 1.2V power supply for FS_MCU1 is under-voltage or overvoltage	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
213	FS MCU1 Power Diagnosis Error2	Fault	The 3.3V power supply for FS_MCU1 is under-voltage or overvoltage	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
214	FS MCU2 Power Diagnosis Error1	Fault	The 1.2V power supply for FS_MCU1 is under-voltage or overvoltage	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
215	FS MCU2 Power Diagnosis Error2	Fault	The 3.3V power supply for FS_MCU1 is under-voltage or overvoltage	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
216	FS SABZ 24V Diagnosis Error	Fault	The 24V power supply for S-ABZ is out of range	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
217	FS SABZ 6V Diagnosis Error	Fault	The 6V reference voltage for S-ABZ is out of range	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
218	FS SABZ 5V Diagnosis Error	Fault	The 5V reference voltage for S-ABZ is out of range	Power supply circuit fault	Power cycle, if fault still exists, contact the distributor near you
219	FS SABZ Power Diagnosis Error	Fault	S-ABZ card encoder power configuration is incorrect, or power is out of range	<ul style="list-style-type: none"> SW1 and SW2 of ABZ card configuration are not match SW1 and SW2 are configure invalid power Power supply circuit fault 	<p>SW1 and SW2 configuration must match, encoder power only supports 15 V and 24 V, the valid configuration is below,</p> <p>Correct the configuration and power cycle, if fault still exists, contact the distributor near you</p>
220	FS DI TP Diagnosis Error	Fault	DI self-diagnostic failure	Digital input circuit fault	Power cycle, if fault still exists, contact the distributor near you
221	FS DI Crossing Diagnosis Error	Fault	DI status are not match	<ul style="list-style-type: none"> The two digital inputs are the same The time difference between two digital inputs is more than 300 ms Digital input circuit fault 	Ensure the two digital inputs are closed/open within 300 ms, power cycle, if fault still exists, contact the distributor near you
222	FS DO Diagnosis Error	Fault	DO self-diagnostic failure	Digital Output circuit fault	Power cycle, if fault still exists, contact the distributor near you
223	FS DO Crossing Diagnosis Error	Fault	DO status are not match between two MCUs	<ul style="list-style-type: none"> Software error Digital Output circuit fault 	Power cycle, if fault still exists, contact the distributor near you
224	FS Speed Self Diagnosis Error	Fault	Speed self-diagnostic failure	<ul style="list-style-type: none"> AB signal duty cycle is out of range AB signal is missing 	Check A/B signals

9 Error List

Fault code	Fault Name	Type	Description	Possible Cause	Remedy
225	FS Speed Crossing Diagnosis Error	Fault	Speed cross-diagnostic failure	The frequency of A signal and B signal are not the same	Check A/B signals
226	FS Direction Self Diagnosis Error	Fault	Direction self-diagnostic failure	AB signal phase error	Check A/B signals
227	FS Direction Crossing Diagnosis Error	Fault	Direction cross-diagnostic failure	The direction on FS_MCU1 and FS_MCU2 is not the same	Check A/B signals
228	FS Position Diagnosis Error	Fault	Relative position diagnostic failure	The relative position on FS_MCU1 and FS_MCU2 is not the same	Check A/B signals
229	FS Parameter Diagnosis Error	Fault	The parameters value is not the same between FS_MCU1 and FS_MCU2	Setting parameter failure on one MCU	Use safety tool and check which parameter is not the same between FS_MCU1 and FS_MCU2, then rewrite that parameter, or do factory reset to reset all parameters to default value
230	SS1 Over Time	Fault	Use SS1-t, motor deceleration time is too long	The motor does not reduce to zero speed within the activation SS1-t function delay time	<ul style="list-style-type: none"> • Check the FS card parameter settings • Required parameter "t-delay STO@SS1" > Motor deceleration time • Motor deceleration time is calculated based on the parameters "Speed scaling" and "Ramp time to zero"
231	SS1 Speed Exceed Tolerance	Fault	Use SS1-r, the speed changes greatly during deceleration	After activating the SS1-r function, the speed change during motor deceleration is greater than the parameter "Deceleration tolerance"	<ul style="list-style-type: none"> • Monitor motor speed change • According to the actual deceleration of the motor, set the parameter "Deceleration tolerance"
232	SBC Relay Feedback Error	Warning	SBC relay feedback failure	<ul style="list-style-type: none"> • Relay is broken • Connection is lost between relay and the card 	Check SBC safety relay and connection
233	SBC Relay Feedback Warning	Fault	SBC relay feedback failure	<ul style="list-style-type: none"> • Relay is broken • Connection is lost between relay and the card 	Check SBC safety relay and connection
234	SLS Over Time	Fault	Use SLS-t, motor deceleration time is too long	The motor does not reduce to zero speed within the activation SLS-t function delay time	<ul style="list-style-type: none"> • Check the FS card parameter settings • Required parameter "SLS-t delay" > Motor deceleration time. • Motor deceleration time is calculated based on the parameters "Speed scaling" and "Ramp time to zero".
235	SLS Speed Exceed Tolerance	Fault	Use SLS-r, the speed changes greatly during deceleration	After activating the SLS-r function, the speed change during motor deceleration is greater than the parameter "Deceleration tolerance"	<ul style="list-style-type: none"> • Monitor motor speed change • According to the actual deceleration of the motor, set the parameter "Deceleration tolerance"
236	SLS Trip Limit	Fault	Use SLS, the motor speed is not limited and exceeds the trip limit value.	After activating the SLS function, the motor speed is uncontrolled and exceeds the trip limit value.	<ul style="list-style-type: none"> • Check the cause of motor speed change • Check the FS card parameter settings. Required parameter "SLS trip limit" > "SLS limit".

Fault code	Fault Name	Type	Description	Possible Cause	Remedy
237	SOS Position Exceed Tolerance	Fault	Use SOS, displacement occurs when the motor is stationary	After activating the SOS function, the motor deviation of the stop position exceeds the defined standstill tolerance	<ul style="list-style-type: none"> Check the cause of motor stop position change Required stop position change < parameter "SOS n=0-Hysteresis"
238	SS2 Over Time	Fault	Use SS2-t, motor deceleration time is too long	The motor does not reduce to zero speed within the activation SS2-t function delay time	<ul style="list-style-type: none"> Check the FS card parameter settings Required parameter "t-delay STO@SS2" > Motor deceleration time Motor deceleration time is calculated based on the parameters "Speed scaling" and "Ramp time to zero"
239	SS2 Speed Exceed Tolerance	Fault	Use SS2-r, the speed changes greatly during deceleration	After activating the SS2-r function, the speed change during motor deceleration is greater than the parameter "Deceleration tolerance"	<ul style="list-style-type: none"> Monitor motor speed change According to the actual deceleration of the motor, set the parameter "Deceleration tolerance"
240	SS2 Position Exceed Tolerance	Fault	Use SS2, displacement occurs when the motor is stationary	After activating the SS2 function, the motor deviation of the stop position exceeds the defined standstill tolerance	<ul style="list-style-type: none"> Check the cause of motor stop position change Required stop position change < parameter "SOS n=0-Hysteresis"
241	SDI Over Time	Fault	Use SDI-t, motor deceleration time is too long	The motor does not reduce to zero speed within the activation SDI-t function delay time	<ul style="list-style-type: none"> Check the FS card parameter settings Required parameter "t-delay STO@SS2" > Motor deceleration time
242	SDI Speed Exceed Tolerance	Fault	Use SDI-r, the speed changes greatly during deceleration	After activating the SDI-r function, the speed change during motor deceleration is greater than the parameter "Deceleration tolerance"	<ul style="list-style-type: none"> Monitor motor speed change According to the actual deceleration of the motor, set the parameter "Deceleration tolerance"
243	SDI Position Exceed Tolerance	Fault	Use SDI, displacement occurs when the motor is stationary	After activating the SDI function, the motor rotates to the forbidden direction exceeds the allowable degree of the SDI tolerance limit	<ul style="list-style-type: none"> Check the cause of motor rotates to the forbidden direction change Required rotates to the forbidden direction change < parameter "SDI Limit degree"
244	SLA Acceleration Exceed Tolerance	Fault	Use SLA, the motor accelerates/deceleration too fast	After activating the SLA function, the motor acceleration/deceleration exceeds the trip limit	<ul style="list-style-type: none"> Check acceleration/deceleration time According to the actual acceleration/deceleration of the motor, set the parameter "SLA+ trip limit"/"SLA- trip limit"
245	SSR Speed Exceed Tolerance	Fault	Use SSR, the motor speed exceeds the monitoring range	After activating the SSR function, the motor speed exceeds the monitoring range	Check whether the motor speed is between the parameters "SSR upper limit" and "SSR lower limit"
246	FS MCU ID Diagnosis Error	Fault	MCU identification pins error	<ul style="list-style-type: none"> MCU identification circle broken during power on 	Power cycle, if fault still exists, contact the distributor near you
249	Safety Card Configuration Error	Fault	Safety card configuration is error	<ol style="list-style-type: none"> The drive is configured as no safety card, but safety card is on board. The drive is configured as safety card and SABZ card, but safety card or SABZ is not on board. 	<ul style="list-style-type: none"> Check the Settings of "safety card Configuration" parameter Power cycle, if fault still exists, contact the distributor near you
250	FS card Over Temp	Fault	The temperature of the FS card chip is too high	FS card chip temperature greater than 120°	<ul style="list-style-type: none"> Stop run drive and wait for the temperature to drop. Power cycle, if fault still exists, contact the distributor near you

10 Appendix

Table 75: Safety Function Validation Checklist

Safety Function	Validation Test	Test Result	Test Personnel	Test Date
STO	STO Validation - STO1 or STO2			
	STO Validation - STO1 and STO2			
SS1	SS1-t Validation - Normal Operation			
	SS1-t Validation - Abnormal Operation			
	SS1-r Validation - Normal Operation			
	SS1-r Validation - Abnormal Operation			
SBC	SBC Validation - Delayed Brake Mode			
	SBC Validation - Speed Limit Mode			
SLS	SLS-t Validation - Normal Operation			
	SLS-t Validation - Abnormal Operation 1			
	SLS-t Validation - Abnormal Operation 2			
	SLS-r Validation - Normal Operation			
	SLS-r Validation - Abnormal Operation			
SOS	SOS Validation - Normal Operation			
	SOS Validation - Abnormal Operation			
SS2	SS2-t Validation - Normal Operation			
	SS2-t Validation - Abnormal Operation 1			
	SS2-t Validation - Abnormal Operation 2			
	SS2-r Validation - Normal Operation			
	SS2-r Validation - Abnormal Operation			
SSM	SSM Validation			
SDI	SDI-t Validation - Normal Operation			
	SDI-t Validation - Abnormal Operation 1			
	SDI-t Validation - Abnormal Operation 2			
	SDI-r Validation - Normal Operation 1			
	SDI-r Validation - Normal Operation 2			
	SDI-r Validation - Abnormal Operation			
SLA	SLA Validation - Normal Operation 1			
	SLA Validation - Normal Operation 2			
	SLA Validation - Abnormal Operation 1			
	SLA Validation - Abnormal Operation 2			
SSR	SSR Validation - Normal Operation			
	SSR Validation - Abnormal Operation 1			
	SSR Validation - Abnormal Operation 2			
SAR	See SS1-r Validation, SLS-r Validation, SS2-r Validation and SDI-r Validation			

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By capitalizing on the global growth trends of electrification and digitalization, we're accelerating the planet's transition to renewable energy sources, helping to solve the world's most urgent power management challenges, and building a more sustainable society for people today and generations to come.

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